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OPTIMIZATION OF THERMAL PROTECTION SYSTEMS FOR THE SPACE SHUTTLE VEHICLE

VOLUME II ✦ USER'S MANUAL

GENERAL DYNAMICS
Convair Aerospace Division

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San Diego, California

FOREWORD

This investigation was performed for the NASA Manned Spacecraft Center's Structures and Mechanics Division. Dr. Donald M. Curry was the technical monitor, and Dr. Kenton D. Whitehead was the project manager. The study was conducted by a project team consisting of Drs. K. T. Shih, A. Gay, and O. Brevig, and Mr. R. C. Day - Thermodynamics, Messrs. R. S. Wilson and P. T. Thorndyke - Stress, S. T. Hitchcock - Weights, and T. C. Johnson - Costs. Programming and computer coordination was performed by Ms. E. R. Neuharth. All work was done at the San Diego Operation of the Convair Aerospace division of General Dynamics. Results of the study are published in two volumes: the Final Report (Volume I) and the User's Manual (Volume II).

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SUMMARY

A study was performed to continue the development of the computational techniques for the design optimization of thermal protection systems for the space shuttle vehicle. The resulting computer program was then used to perform initial optimization and sensitivity studies on a typical thermal protection system (TPS) to demonstrate its application to the space shuttle TPS design. The program was developed in Fortran IV for Convair Aerospace's CDC 6400, but it was subsequently converted to the Fortran V language to be used on the MSC Univac 1108. Documentation for the study is reported in two volumes - the Final Report and the User's Manual. The latter contains input instructions and sample problems to illustrate use of the program.

The efforts of the investigation involved continued development of theoretical models describing performance of the TPS and the programming of the subsequent methodology. The program itself was effected in a modular fashion to allow continuing updating of the methods. The logic of the computer code involves subroutines which handle the following basic functions: (1) A driver link which establishes communication between the overlays of the program, (2) an overlay which handles the thermodynamic analysis (including aerodynamic heating and the temperature response of the TPS cover panel and underlying insulation) and the discrete element stress analysis of the panel, (3) an overlay which performs the finite element stress analysis for the RSI configuration, and (4) a link which predicts the weight and cost of the TPS panel and supporting structure. For metallic panels, the system weight and manufacturing cost is determined by identifying and evaluating these parameters for each of the TPS's component parts. The RSI and ablator systems are evaluated as a honeycomb panel with an additional external insulation. In addition, a system total cost is predicted based on system weight and historical cost data of similar systems.

Each of the major components of the program described above is complemented by other subroutines which provide specialized calculations for the analyses.

Two basic types of input are provided, both of which are based on trajectory data. In the first, vehicle attitude (altitude, velocity, and angles of attack and sideslip) is input and external heat and pressure loads are calculated. In the second, heating rates and pressure loads are provided to the program as a function of time. Standard program output includes heating rates, temperature, and stresses for the discrete elements of the TPS analyzed as well as dynamic stresses and the number of stress reversals for the panel and its weight and cost. A panel redesign technique is included to increase the panel thickness to transfer mechanical loads and to increase insulation thickness to protect the underlying load-bearing structure. Subsequent investigations have shown, however, that the most efficient and economical method of sizing the TPS is performed by manual iteration by the program user.

Preliminary optimization and sensitivity runs have been performed to demonstrate the sizing procedure in terms of varying panel size, material properties, and configuration. Six different metallic panel cross-section geometries are provided along with an ablative system, and reusable surface insulation (RSI), the last with or without a phase change material (PCM) embedded in the substrate.

An optimum design is then identified as the one giving either minimum weight or cost as a function of the parameters being varied for the investigation. Sensitivity studies are performed by noting the change in system weight or cost due to the variation in some independent variable such as trajectory or heating prediction method for an optimum panel configuration.

SECTION 1

INTRODUCTION

This manual describes the computer program P5490 developed for use in optimizing the design of the thermal protection system for manned spacecraft in terms of weight and cost. A brief description is given of the capabilities and limitations of the program followed by operation instructions and sample problems. Source listings, descriptive paragraphs of all subroutines, and a flow chart of the program are given in the appendices.

The program starts by calling subroutine INPUT1 to read in portions of the data necessary to perform the thermal protection system (TPS) sizing. Computations are performed for four types of cover panel: (1) metallic, (2) ablator, (3) reusable surface insulation (RSI), and (4) a carbon-carbon leading edge. Flat plate, carbon-carbon cover panels may also be simulated by simply inputting proper material properties while using the metallic cover panel option. For the case of ablative and RSI systems, a second input subroutine, INPUT2, is called to read in the thermodynamic properties of the cover panel, underlying insulation, backup structure, and backface environment. The second input routine was employed to permit use of the formats already existing in the charring ablator program which is the backbone of the ablator and RSI analyses. In this manner, the two programs were kept consistent. Program control was then returned to INPUT1 to allow input of parameters need to perform stress and acoustic fatigue analyses.

For a given trajectory, location on the spacecraft, and computational time increment, the subroutine THERMO computes local pressure and aerodynamic heating rate. The temperature response of the panels and underlying structure are computed either by subroutine CONDTN (for the metallic and carbon-carbon configurations) or by subroutine ABLATE for the ablator and RSI. Provisions are also made in the latter routine for using either cold or hot wall heat fluxes. Of course, all these routines have many auxiliaries which perform subordinate computations. Subroutine STRESS performs a discrete element stress analysis on all configurations but the carbon-carbon leading edge. For the case of the RSI panels, an additional finite element stress analysis is performed by subroutine MAIN at the trajectory design point identified by STRESS. (MAIN is the CDC 6400 version of a two-dimensional stress analysis initally developed at Convair as the independent computer program P2354.) Once the thermodynamic and structural performance of the TPS have been assessed, the acoustic fatigue analysis subroutine FATIG computes the dynamic response of the system and compares it to the lifetime requirements of the vehicle. Next, weight and cost data are read into the computer via the subroutine DRVTPS, and weight of the system is computed by subroutine WTTPS. Manufacturing costs of the system are developed from standard hour predictions by subroutine COST for a wide variety of materials, and total systems costs for a wide variety of materials, and total systems costs (again, per unit area) are determined from subroutine COSTOT. In this, the second version of the TPS sizing program, all automatic sizing procedures have been removed from the program. Experience gained in running the computer program during its development demonstrated that such procedures were both expensive and time consuming when compared with those effected by an experienced program user.

The computer program was developed simultaneously in Fortran IV for the CDC 6400 and in Fortran V for the Univac 1108 by the Convair Aerospace Division of General Dynamics. The complexity of the program required several overlays; the resulting system can be run in 130,100 words octal.

SECTION 2

PROGRAM CAPABILITIES

The program has been written in modular fashion. This will provide ease of modification. The following subsections describe the capabilities and limitations of the program.

2.1 COORDINATE SYSTEMS

In this program, a rectangular coordinate system was adopted. The plane of symmetry of the spacecraft (the pitch plane) is specified as the xz-plane of the coordinate system (Figure 2-1). The location on the spacecraft is described in the program by a characteristic length which is either the distance from the leading edge to the point of interest or the diameter of the swept cylinder configuration. The local body orientation is defined by the effect angle of attack ψ which is computed by the program as a function of body geometry (θ and ϕ in Fig. 2-1) and angle of attack α and sideslip β, α being measured in the x, z plane and β in the x, y plane.

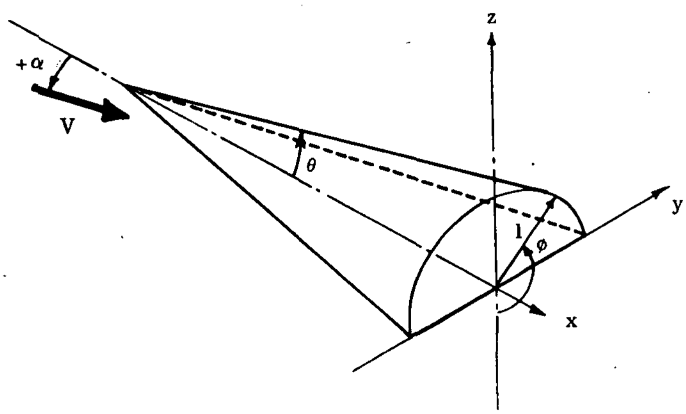


Figure 2-1. Body Orientation

2.2 AERODYNAMIC HEATING

Two methods are employed to specify the aerothermodynamic environment of the local TPS of interest. The first is to input the vehicle trajectory as a function of time (i.e., altitude, velocity, angle of attack, yaw angle). These points are tabulated data and the trajectory at a specific time is established by linear interpolation. Freestream properties of temperature, pressure, density, speed of sound, and viscosity are determined from the 1963 Patrick AFB Atmosphere (subroutine PRA63). The second technique is to input the local pressure and heat transfer rate (either steady state or as a function of time). This input provision can take two alternative forms, cold or hot wall heat fluxes. The cold wall values are input with the RSI or ablator configurations and can be corrected to hot wall values as a function of computed hot wall enthalpy and an input fictional total enthalpy.

Prediction of aerodynamic heating is performed by seven different options: (1) conical flow field with detached shock at high angle of attack, (2) laminar or turbulent swept cylinder, (3) cone, (4) wedge, (5) sphere, (6) laminar cylinder, and (7) turbulent cylinder. The first option is the technique which will be used most frequently since it embodies the techniques recommended by the NASA Thermal Panel for windward surface heating. At low angles of attack, flow field properties are predicted from a number of curve fits developed for real gases, and at high angles at which the shock detaches, the real gas flow field properties are determined by a series of calculations considering the specified shock wave angle, changes in properties across the shock, and expansion to local Newtonian. The equation of state is a curve-fitted Mollier chart for equilibrium air. From the known flow field properties, laminar heating rates are computed from the Blasius equation evaluated at the Eckert reference enthalpy and the Colburn statement of Reynolds analogy. For turbulent flow, two heating prediction techniques are available: the first is the Schultz-Grunow equation with the Eckert reference enthalpy and Colburn's Reynold analogy, and the second is the Spalding-Chi method with the von Karman statement of Reynolds analogy. Transition between laminar and turbulent flow is specified by Masek's transition criterion. The end of transition region is determined by a value of Reynolds number equal to twice the initial value. Transitional heating between the laminar and turbulent boundary layers is calculated as a linear interpolation of laminar and turbulent heating values, the degree of turbulence depending on the turbulent fraction exhibited by the boundary layer with respect to values of Reynolds number for transition onset and end. Cross flow effects are also included to modify heating rates for the effects of three dimensionality. For the cone and wedge flowfields of options (3) and (4), curve fits predict flow field properties for the attached shock flow field. No provision is made for shock detachment.

The second option of the program, laminar and turbulent swept cylinders, is valid for only high angles of attack and is applicable to geometries such as swept leading edges. The laminar swept cylinder heating rates are predicted by Fay-Riddell and the turbulent rates by the Beckwith-Gallagher method. In both techniques, flow field properties are computed for real gas shock waves. The transition criterion, suggested by the NASA Thermal Panel, starts transition at a freestream Reynolds number based on body diameter of 10^5 and ends it at a value of 2×10^5. The computer codes aeroheating options of (6) and (7) are simply the laminar and turbulent swept cylinder techniques independent of boundary layer transition. Spherical heating, is simply the method originally posed by Fay and Riddell as applied to a sphere.

2.3 STRUCTURAL TEMPERATURE RESPONSE

Two methods are now available for determining the structural temperature response of the TPS. The first, an explicit statement of the energy equation, is used in conjunction with the metallic configurations and the carbon-carbon leading edge. The second, an implicit solution technique, is used for predicting performance of the ablator and RSI structures, the latter with and without an underlying phase change material. The implicit scheme is limited to one-dimensional heat transfer. For both heat transfer prediction methods property values for heat conduction analysis (density, emissivity, heat capacity, and thermal conductivity) are fed into the program as constants or as functions of temperature. For the ablative and RSI systems, the thermal conductivity can be input as a function of both temperature and pressure, the latter dependency being especially significatnt for the RSI. These points are tabulated data, and the properties at a specific temperature are established by linear interpolation.

For the case of the explicit solution, structural temperature response is evaluated by either a one- or two-dimensional conduction program with internal radiation. The structure is divided into an arbitrary number (maximum of 9 columns x 9 segments) of nodes (Figure 2-2).

The CONDTN subroutine accommodates simulation of radiation heat exchange between nodes. There are two general expressions available for calculation of radiation heat exchange. The equation

$$Q_{ij} = \frac{\epsilon_i \epsilon_j \sigma}{1-(1-\epsilon_i)(1-\epsilon_j)} A_i F_{ij} (T_j^4 - T_i^4) \qquad 2\text{-}1$$

describes radiation heat exchange, Q_{ij}, between two parallel plates i and j, where σ is the Boltzmann's constant, ϵ is the emissivity, A is the area, F is the view factor and T is the temperature. Equation 2-1 is an approximate form. For rigorous calculations the "overall interchange factor," $\mathcal{F}_{ij}$ should be computed and supplied as part of the problem input. By substituting $\epsilon_i = \epsilon_j = 1$ and $F_{ij} = \mathcal{F}_{ij}$ into equation 2-2 we have

$$Q_{ij} = \sigma A_i \mathcal{F}_{ij} (T_j^4 - T_i^4) \qquad 2\text{-}2$$

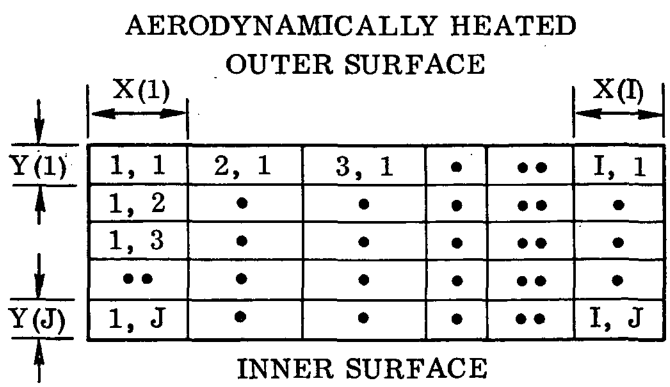


Figure 2-2. Structure Segmentation

The implicit, one-dimensional heat transfer routine is used to predict charring ablator performance or the temperature prediction of the RSI either with or without a phase change material embedded in the substrate. The RSI is simulated simply by suppressing the chemical reaction of the outermost material. The ablator or RSI material can have up to ten nodes, and up to 5 backup materials with 4 nodes each used to simulate the backup structure. A schematic of the nodal breakdown for the implicit routine is shown in Figure 2-3.

2.4 STRESS ANALYSIS

The stress analysis (subroutine STRESS) is performed for any of the six simply-supported metallic panels (Figure 2-4 and 2-5) and for the RSI system (Figure 2-8). Figure 2-4 gives overall geometrical dimensions for the panel, and geometries for individual panel configurations are given in Figure 2-5. The loadings considered are bending due to aerodynamic pressure and the internal forces induced by temperature gradients within the panel cross section.

The panels are segmented for the stress analysis; Figure 2-6 shows the panel segmentation together with the conduction matrices and Figure 2-7 gives the segmentation for the RSI system. It is essential that the conduction input obeys the matrix given in these figures.

The following property values of panel material are needed for stress analysis; they are input as tabulated data.

a. Young's modulus vs. temperature.

b. Coefficient of thermal expansion vs. temperature.

c. Yield strength vs. temperature.

d. Ultimate tensile strength vs. temperature.

e. Larson-Miller parameter for strain 1 vs. stress.

f. Larson-Miller parameter for strain 2 vs. stress.

g. Ultimate compressive strength.

h. Ultimate shear strength.

i. Shear modulus.

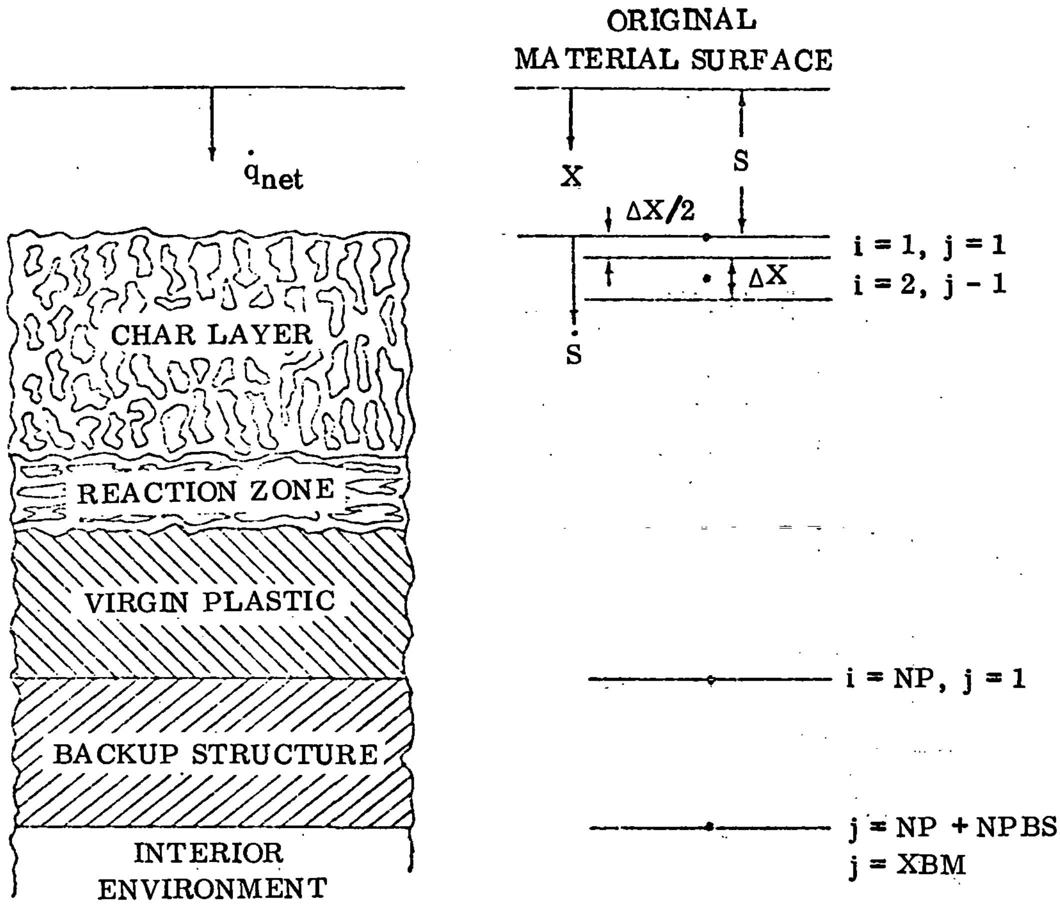


Figure 2-3 - Schematic diagram of charring ablator thermal protection system.

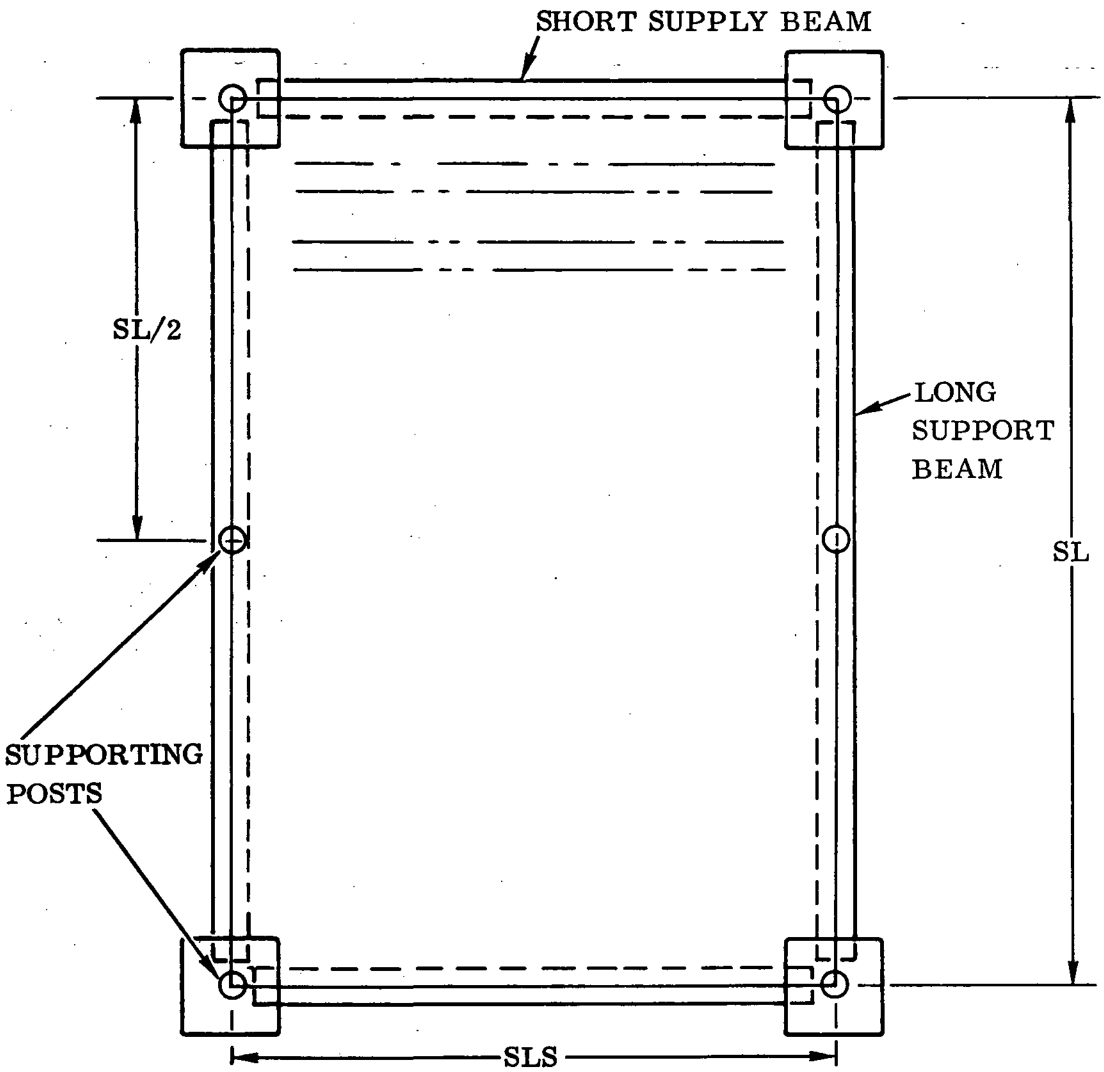


Figure 2-4. Panel Overall Geometry

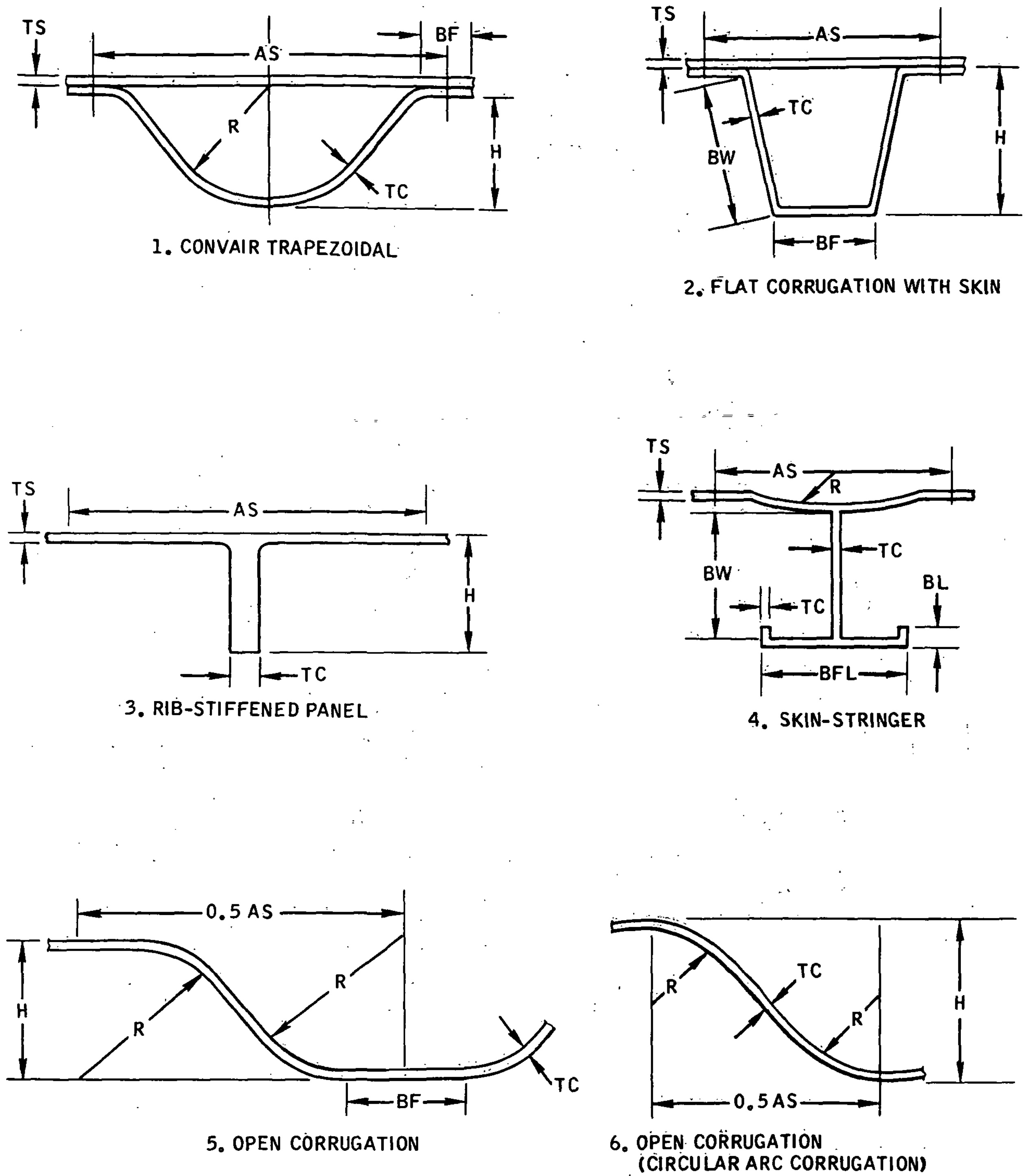


Figure 2-5. Panel Geometries

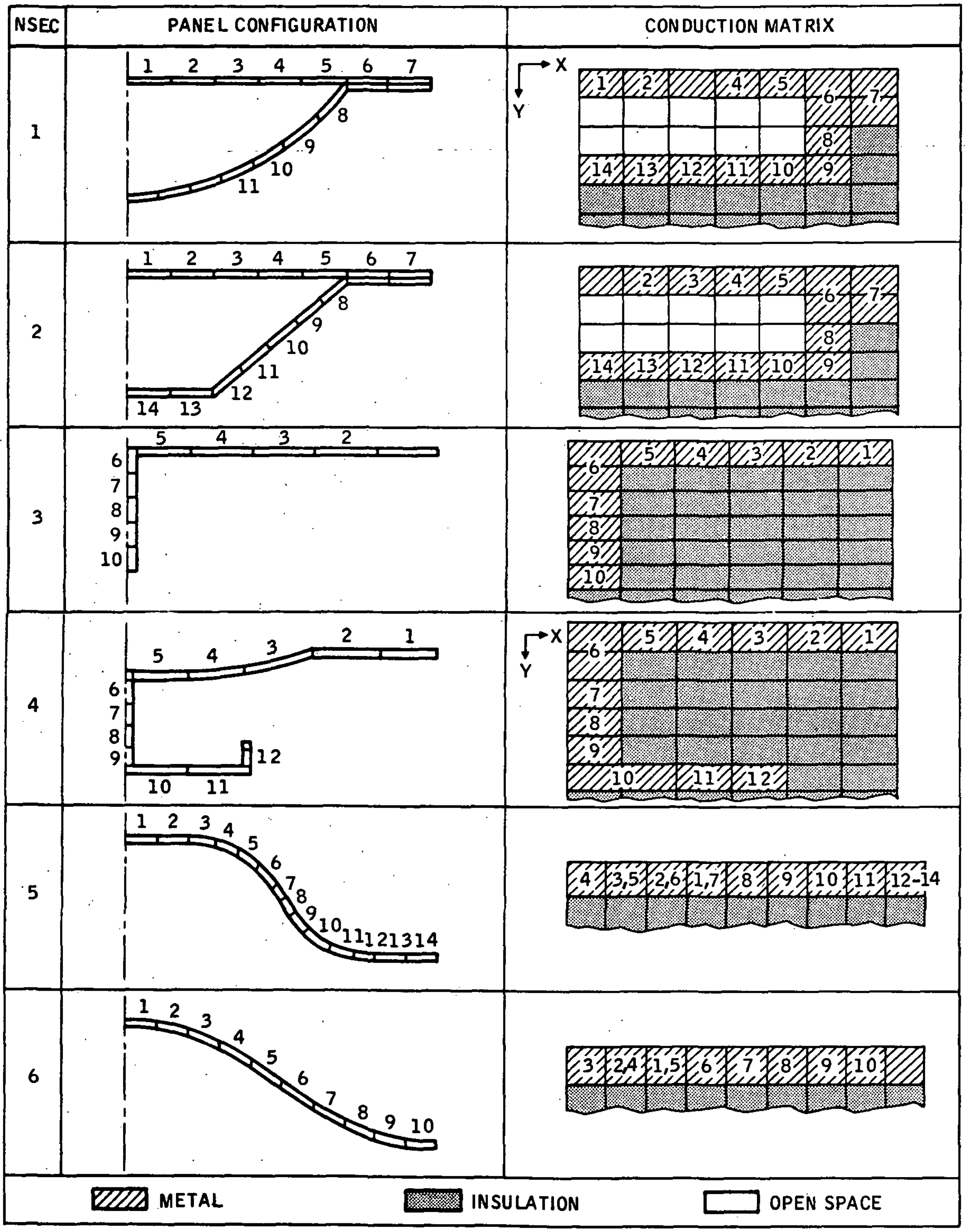
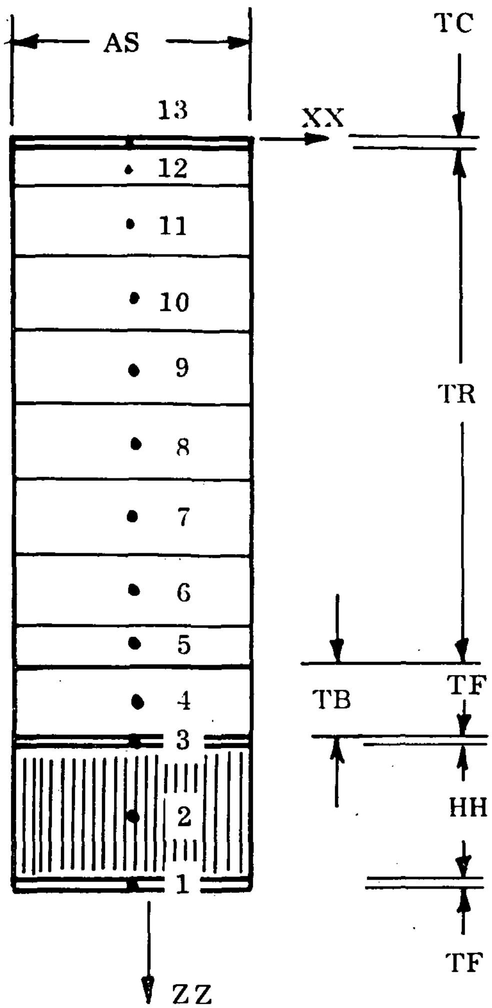


Figure 2-6. Configurations for Stress Analysis



NOTE: The honeycomb substrate is analyzed as a slab of equivalent properties. It is bonded to the RSI with a simple adhesive

Figure 2-7. Discrete Element Stress Analysis Nodal Schematic

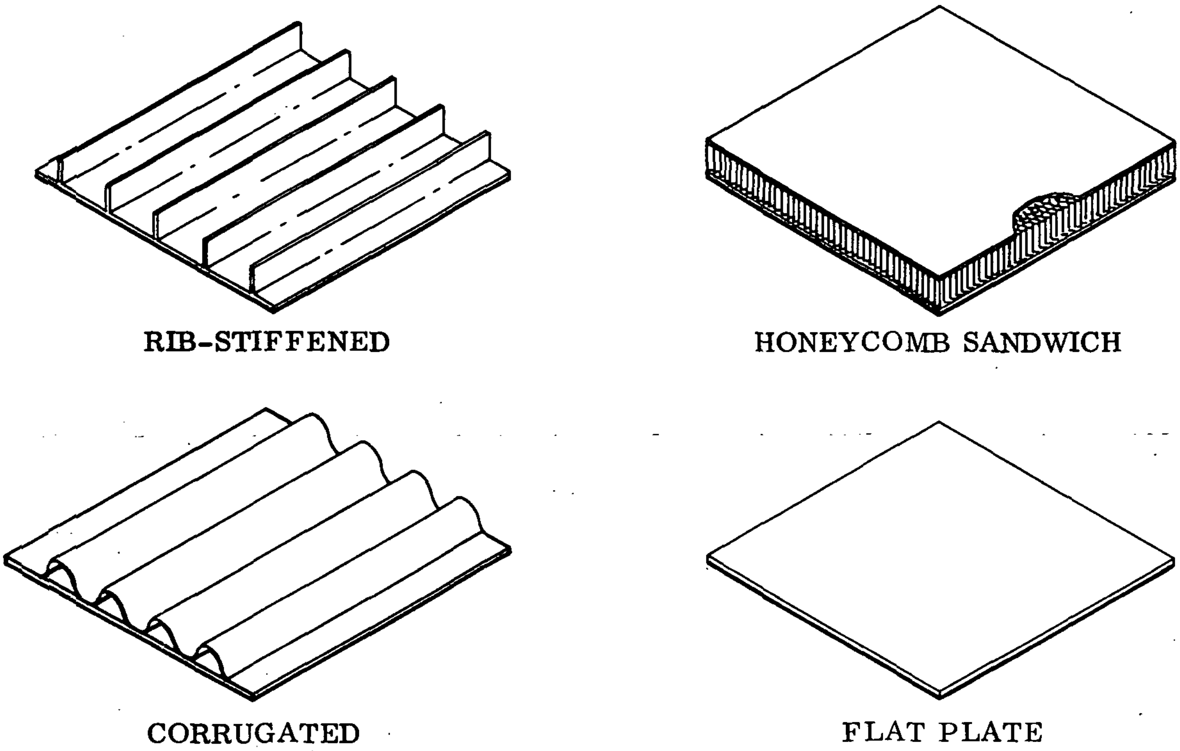


Figure 2-8 Sonic Fatigue Analysis Configurations

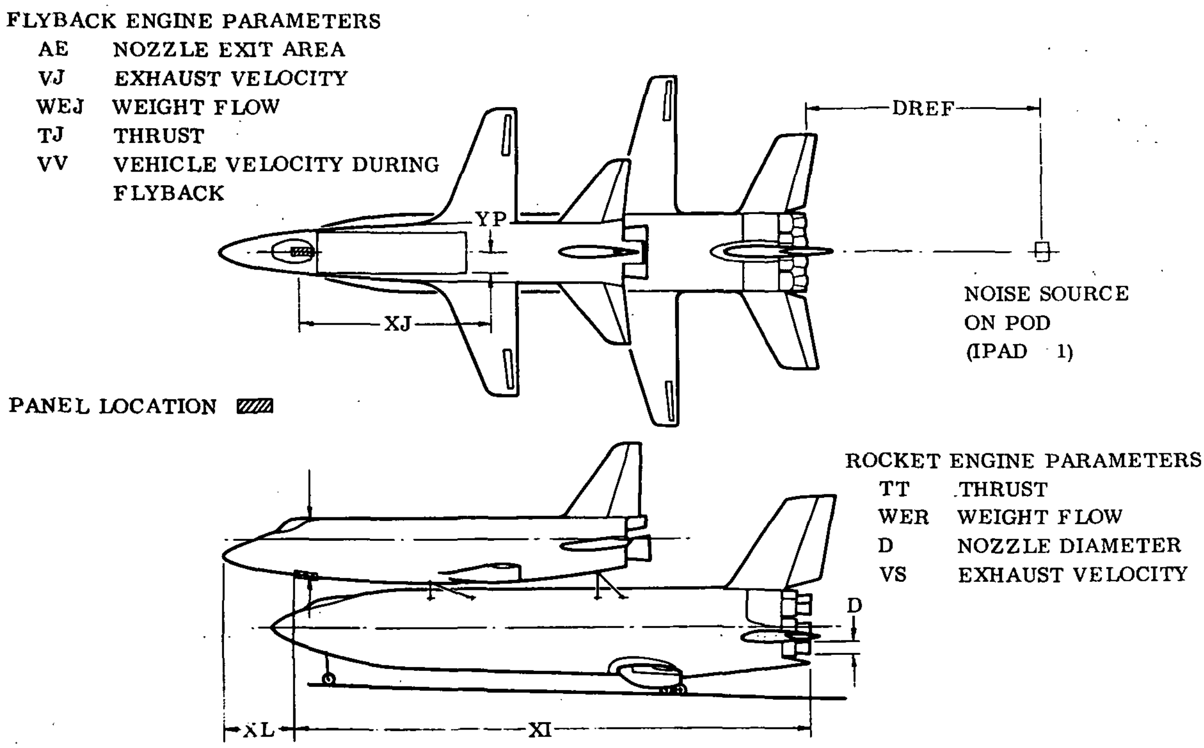


Figure 2-9. Sonic Fatigue Input Nomenclature

2.5 ACOUSTIC FATIGUE AND PANEL FLUTTER

The acoustic fatigue analysis (subroutine FATIG) computes the fundamental frequency of each of four different panel configurations (Figure 2-8). Noise computations are performed for each of four different sources (turbulent boundary layer, boost engines, jet flyback engine, or scrubbing by the exhaust of the jet flyback engines). Each sound pressure level is a function of local geometry (e.g., the distance between the source and the point of interest for the case if engine induced noise, or the run length distance for the turbulent boundary layer, Figure 2-9). The panel moment of inertia may be computed in either of two ways. In the first case, the moment of inertia may be input as part of the standard format. However, if this value is input as zero, the value will be computed for the metallic configuration, or for the honeycomb substrate used in conjunction with the RSI and the ablator. Dynamic stresses are computed for each sound pressure level; these are adjusted to account for a dynamic magnification factor due to resonance and for a local stress raiser due to edge conditions. Critical stress levels for each noise source are determined by equating the randomly applied excitation energy to the allowed levels of stress as a function of number of stress reversals determined by test. (The latter information is calculated external to the program from data of the final report and is input as a third-degree least-squares curve fit of stress in kips per square inch as a function of stress reversals.) The composite critical stress is determined as the square root of the sum of the squares, and the corresponding equivalent number of stress reversals is determined by equating the total energy absorbed by the system at the composite critical stress to the sum of all the energies absorbed by the application of random noises due to each of the four possible noise sources. The resulting critical stress and number of stress reversals are compared to the allowable values to see if they have been exceeded.

2.6 WEIGHT AND COST ANALYSIS

The weight and cost analysis predicts unit area weight and cost for six different metallic panel configurations and both ablative and RSI systems attached to a honeycomb panel. Three different concepts of heat post supports (Figure 2-10) are also considered. The type of panel and support structure are input to the program by appropriate option parameters along with the panel and supporting structure geometry (Figures 2-11 through 2-15). The total system weight per panel is computed as the summation of weights of the various components, and weight per unit area is determined by dividing panel weight by panel area. Costs per unit area are determined by calculating the material and manufacturing processes for each panel configuration and then dividing by panel size. Each individual cost is calculated by identifying the type of material purchased, the form in which it is purchased, and the operations needed to manufacture the part (clamping, drilling, inspecting, etc.) as well as the manhours required for supporting activities (sustaining engineering, tooling, and the like). At the present time these data are stored within the computer program as tabulated values.

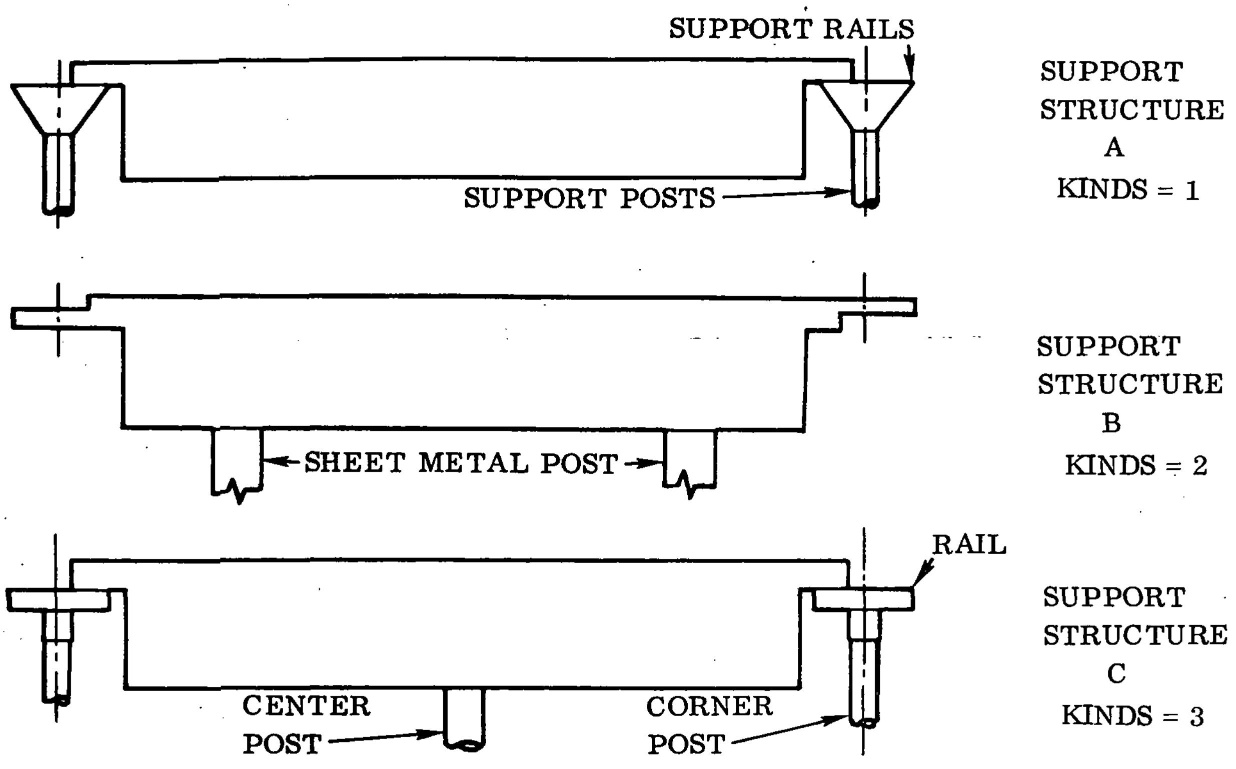


Figure 2-10. Schematic of Supporting Structures

Costs are computed by two different techniques. The first predicts the costs of manufacturing the TPS per unit area and includes materials and manufacturing costs. This is performed by summing the manufacturing costs of the systems individual component parts. Materials considered along with their complexity factors are given in Table 2-1.

The program total cost prediction techniques are based on methodologies developed for the space shuttle booster and orbiter as well as other cost models of the aerospace industry. All costs are based on a TPS area of 10000 square feet and then normalized to unit area. The total cost model is outlined in Table 2-2, and the embedded constants of the routine are given in Table 2-3. The user may override the embedded values, however, simply by supplying the proper input values to subroutine DRTPS. (See the next chapter for details.)

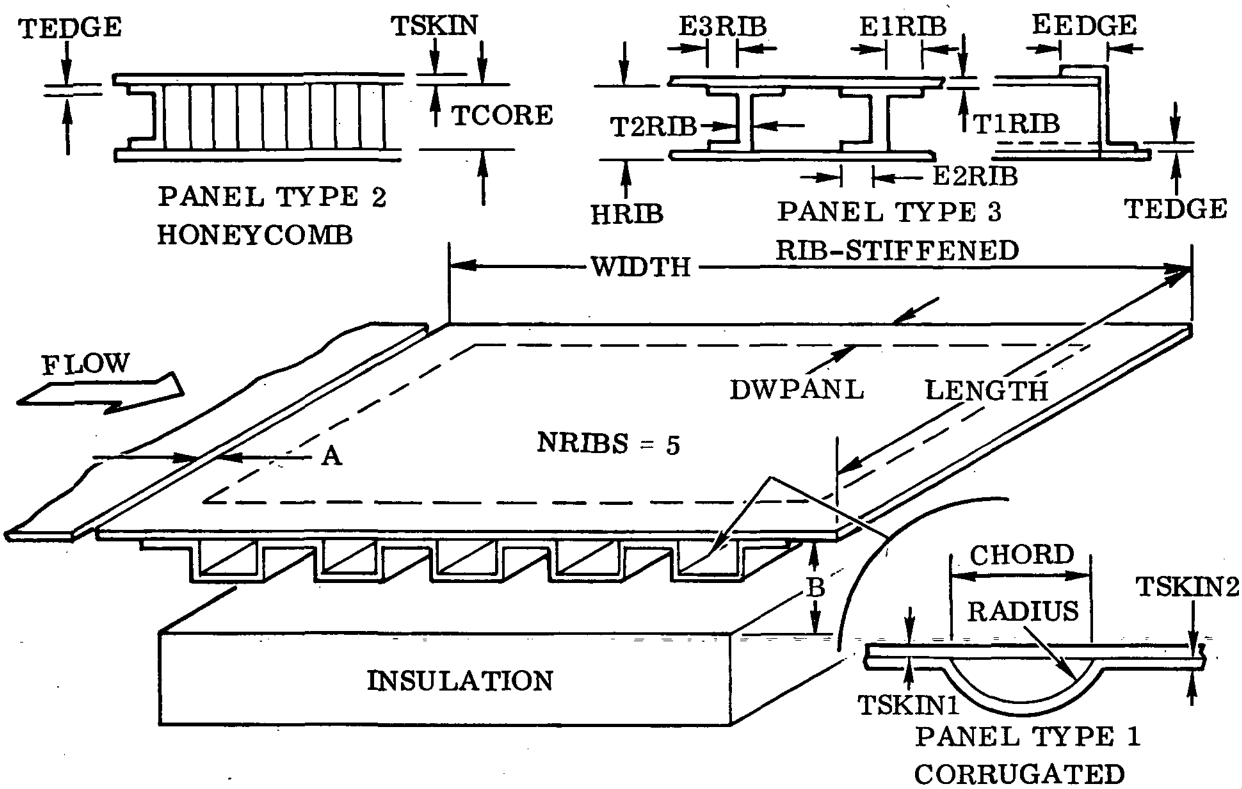


Figure 2-11. Panel Nomenclature for Weights/Cost

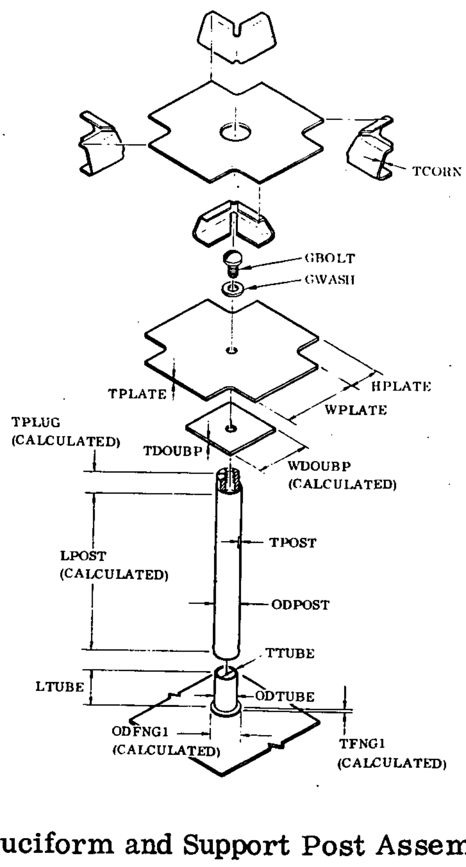


Figure 2-12. Cruciform and Support Post Assembly (Concept A)

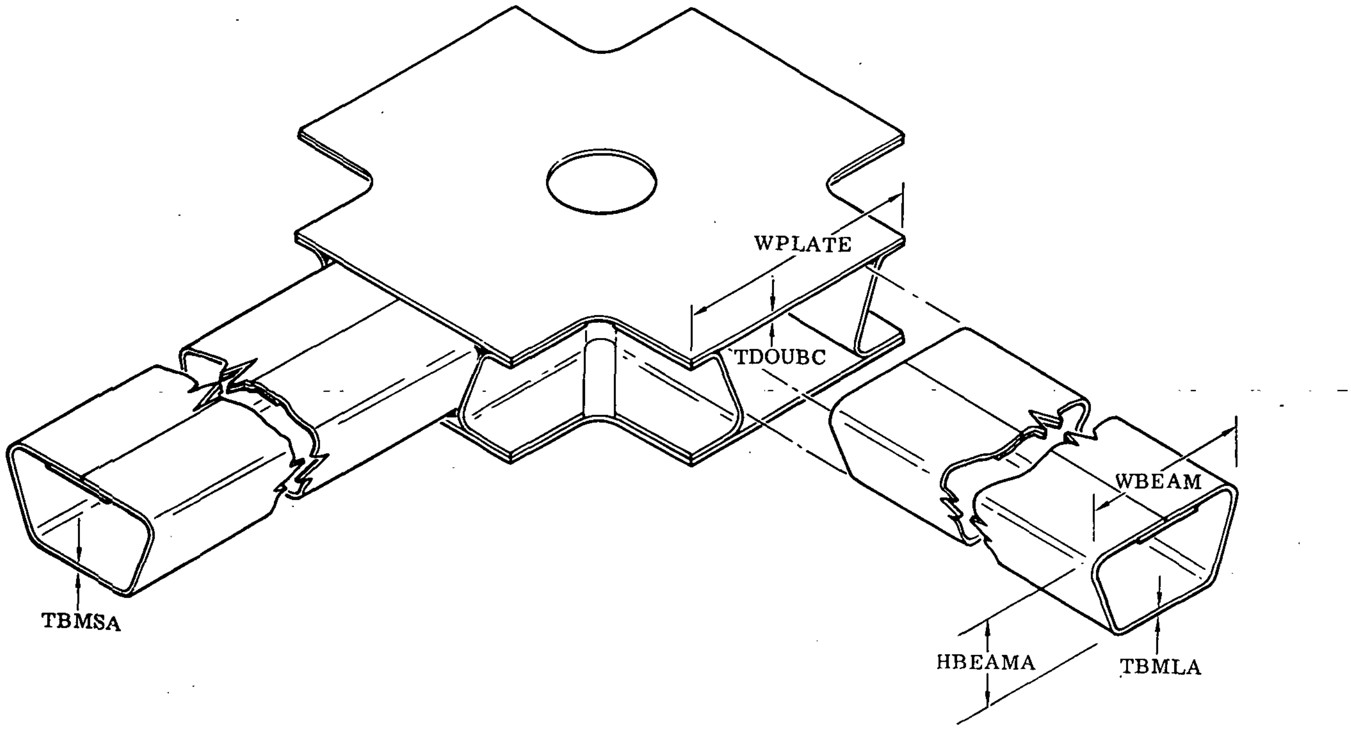


Figure 2-13. Cruciform and Support Beams (Concept A)

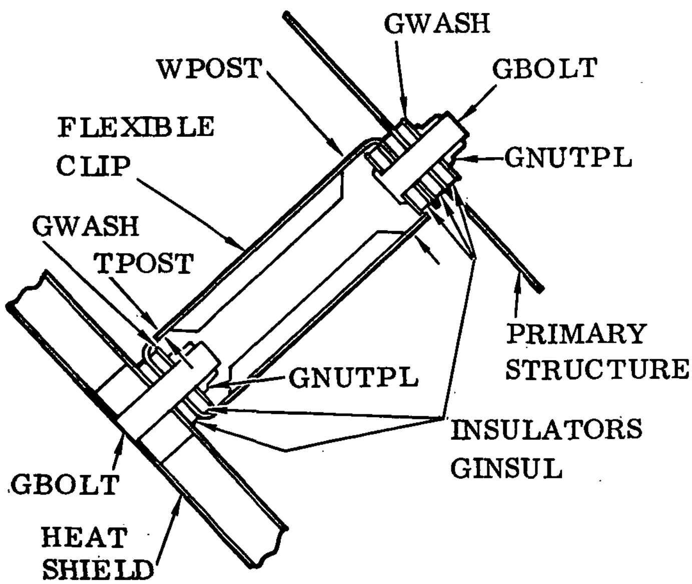


Figure 2-14. Sheet Metal Standoff Post (Concept B)

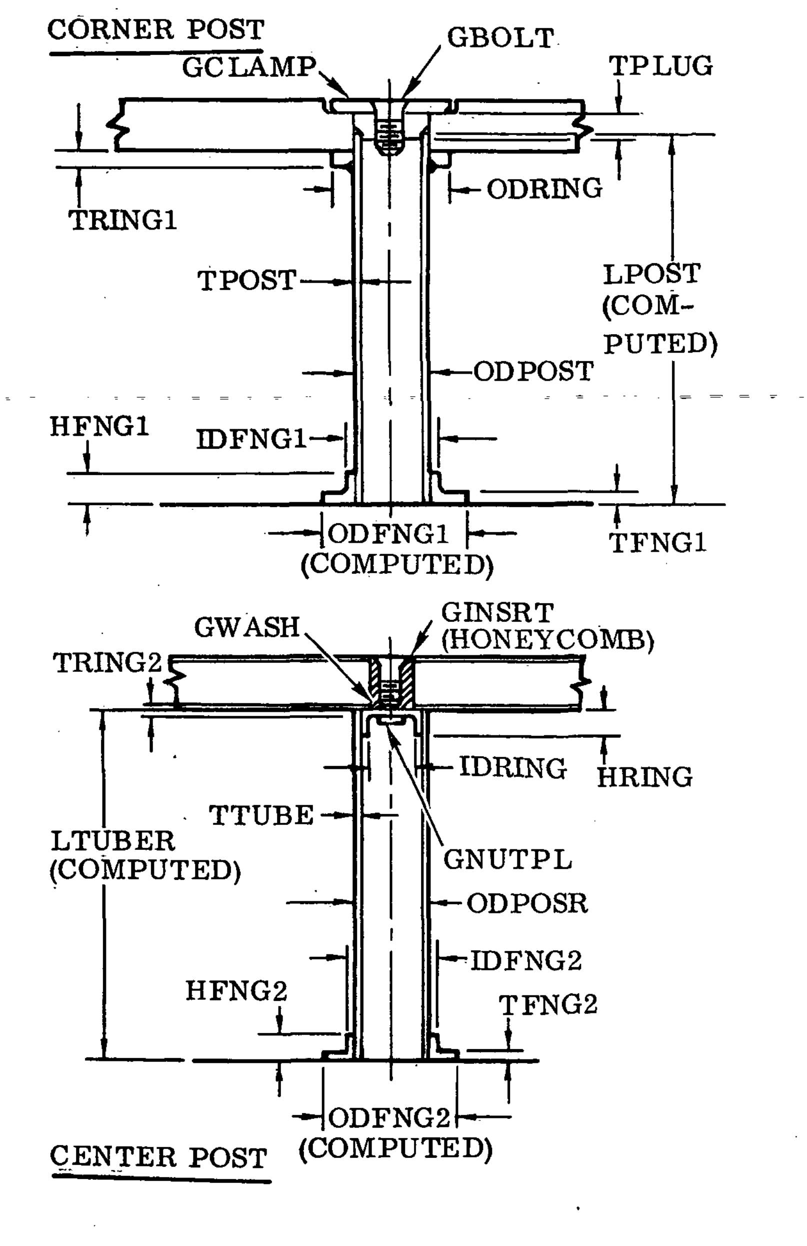


Figure 2-15. Support Post (Concept C)

Table 2-1. Material Types and Complexity Factors

Material	MATLID	Material Complexity Factor F
Aluminum	1	1.0
Titanium	2	4.2
Inconel 718	3	4.2
Hastelloy X	4	4.0
Rene 41	5	4.2
TD Nicrome	6	5.0
Columbium C-6752	7	6.0
Columbium C-129Y	8	6.0
Haynes 188	9	4.2
Tantalum	10	6.0
Alloy Steel	11	3.8
Stainless Steel	12	4.2
Magnesium	13	4.0
Beryllium	14	5.0
L-605	15	4.2

Table 2-2. Total Cost Model

Theoretical first unit cost (TFU)		non-recurring costs
$TFU = CF_1 K_1 (W)^{AT}$		
Engineering Design and Developments Costs (EDD)		
$EDD = K_2 (W)^{BT}$		
Tooling Costs (TOOL)		
$TOOL = K_3 (W)^{CT}$		
Hardware requirements		
Ground test hardware (GTH)		
GTH = EGH TFU		
Flight test articles (FTA)		
FTA = FTH TFU		
Flight test spares and replenishment parts (FTSRP)		
FTSRP = FTS TFU		
Production articles (PA)	also Sustaining Engineering, Tooling in TFU	recurring production
PA = NPA TFU		
Test article conversion (TAC)		
TAC = ETA TFU		

The total program cost (TPC) is obtained by a summation of non-recurring DDT&E(NR), recurring production (RP), and recurring operations (RO) costs.

Table 2-3. Values of Total Cost Constants

AT	.667
BT	.187
CT	0.86
K1	.00171
K2	6.58
K3	.004324
EGTH	3.75
FTH	2.0
FTS	.67
NPA	1.0
ETA	0.3
OS	1.332
STPS	22,000

SECTION 3

PROGRAM OPERATION INSTRUCTIONS

This section presents the information required for effective use of the program. The instructions for correct program input are given in Section 3.1, a description of the program output is given in Section 3.2, and error statements are shown in Section 3.3.

3.1 INPUT

The input system has been designed to allow multiple cases with the complete input data deck consisting of input packages for each case. The first case generally requires specification of all necessary parameters whereas, in subsequent cases, a namelist DATANU can be used to make changes of parameters. A complete input package is composed of 30 records; a record is simply a convenient gathering of similar terms or groups of terms. The input symbols are defined in Table 3-1, and the format records are given in Table 3-2 and illustrated in Figure 3-1.

The formats of data input are of the form nEw.o. Thus, a decimal point may appear anywhere in the field. However, if the exponential notation E xx is used, it must be right-hand justified. Any field may be left blank. The blank is interpreted as a 0 (integer) or 0.0 (floating point).

The definitions of the input symbols are given in Table 3-1.

Data for the weights and cost analyses are also read in using conventional formats, but they are read into the subroutine DRVTPS. Results of this analysis are output from this portion of the program also. The weights/cost input variables are indicated also in Table 3-1 starting with record 52.

3.2 OUTPUT

The program output consists of three distinct sections. They are illustrated in Section 4. The first includes the case identification and printout of the input data. The last line of print is the phase END OF INPUT. This section of the output is accomplished by the subroutine INPUT1.

The second section of the output consists of results. Numerical values are printed on the line below each heading. Output symbols are defined in Table 3-3.

The third section of the output is the debug results output. This section presents the values of parameters which are not normally required but which may be helpful in tracking down the source of errors. This is especially helpful when a new subroutine is added or an existing subroutine is modified. The debug output is not printed unless it is specially requested by means of input a 1 of NPRT in the input data.

3.3 ERROR STATEMENTS

a. ALTITUDE LT 0 OR GT 700000 FT - Trajectory corresponds to an altitude out of range of PRA63 subroutine.

b. LOCAL VELOCITY SQUARE IS NEGATIVE - This comment is printed when a calculated local velocity square becomes negative in subroutine THERMO.

c. ERROR IN OBSPL COMPUTATION - Function Curve F out of range.

d. SEGMENT NUMBER IJ TEMPERATURE CHANGE IS GREATER THAN 500 DEG - Conduction solution is unstable; however, the program normally readjusts the computation true interval. The computation will be stopped for a readjusted true interval less than 0.1 sec (subroutine CONDTN).

e. NO. OF TITLE CARD IS GREATER THAN 10 - Subroutine INPUT1 limits title cards to 10.

f. NO. OF TRAJECTORY IS GREATER THAN 99 - Subroutine INPUT1 limits trajectory cards to 99.

g. OX ARGUMENT ERROR IN TABLE - Error in Function Table.

Table 3-1. Input Symbols

Record	Variable Type	Symbol	Definition
1	Alpha-numeric	TITLE	Case identification and comments, maximum 10 cards.
1	Integer	JI	Indicator marking the last title card which specifies the input data form, input a non-zero value.
2	Integer	ICONF	Specifies body configuration, input a 1 through 7. 1. Conical flowfield with detached shock 2. Laminar and turbulent swept cylinders 3. Cone 4. Wedge 5. Sphere 6. Laminar cylinder 7. Turbulent cylinder
↓	↓	IQCON	Specifies variation of input heat transfer multipliers, laminar and turbulent input a 1, 2, or 3 1. QCONL(I) = QCONT(I) = 1 (no input required) 2. Input QCONL(I). QCONT(I) = QCONL(I) 3. Input both QCONL(I) and QCONT(I)
↓	↓	IQINP	Specifies variation of trajectory cards, input a 1,2,or 4 1. Input trajectory 2. Input local hot wall heat flux and pressure 4. Input local cold wall heat flux and pressure
↓	↓	ITURB	Specifies turbulent prediction method, input a 1 or 2 1. Eckert reference enthalpy 2. Spalding-Chi
↓	↓	IWALT	Specifies conditions of wall temperature, input a 1 or 2 1. Uniform 2. Nonuniform
↓	↓	NANG	Specified variation of input angle of attack, input a 1 or 2 1. α, β are function of trajectory 2. α = ALPHA(1), β = BETA(1)
↓	↓	NCOLM	Number of Columns ≤ 9 1. One-dimensional heat conduction 2-9. Two-dimensional heat conditions
↓	↓	NSEG	Number of segments ≤ 9
2	Integer	NMAT	Number of materials ≤ 9

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
2	Integer	NRSG	One-dimensional case (NCOLM=1) number of internal radiation gaps Two-dimensional case (NCOLM>1) number of internal radiation segments, for segments which have more than one face radiation interchange, count each face as one segment ≤ 18
		NCRC	Specifies coordinate systems used for conduction analysis, input a 1
		NSECT	Panel configurations (see Figure 2-5) input a 1, 2, 3, 4, 5, 6 or (see Figure 2-7) 7, 8 or 9 1. Convair trapezodial 2. Flat corrugation with skin 3. Rib stiffened panel 4. Skin stringer 5. Open corrugation 6. Circular arc corrugation 7. Reusable surface insulation (RSI) 8. Ablator 9. Carbon-carbon leading edge
		NINS	Specifies input material number of the insulation (limited to one material) to be sized. If insulation sizing option is not used, leave blank.
		NF	Number of flights.
		NPRT	Specifies output form, input a 1 if "long" print out option is used. Leave blank for "short" print out
		ISTRES	Specifies whether or not to conduct stress analysis, input 0 or 1 0. Omit stress analysis 1. Call stress analysis
		IFATIG	Specifies whether or not to conduct fatigue analysis, input 0 or 1 0. Omit fatigue analysis 1. Call fatigue analysis
2	Integer	IWTCST	Specifies whether or not to conduct weight/cost analysis, input 0 or 1 0. Omit weight/cost analysis 1. Call weight/cost analysis

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
2	Integer	IEQOS	Specifies equation of state, input 1 or 2 1. Real gas 2. Perfect gas
↓	↓	ITRAS	Specifies location of virtual origin, input 1 or 2 1. Leading edge 2. Beginning of transition
2	Integer		
3	Real	THETA PHI	Direction angles (see Figure 2-1)
↓	↓	XDST	Distance from the leading edge, ft
		DIAM	Diameter of a sphere or cylinder, ft
		AROD	Ratio of shoulder radius to body diameter
		XEMIS	Outer surface emissivity
3	Real	FACC	Factor to increase insulation thickness
4	Real	STAAT	Time to start computation, sec
↓	↓	DELTA	Computation interval, sec
		WROTE	Print interval, sec
4	Real	STOOP	Time to stop computation, sec
5	Real	AS	Pitch of corrugation or ribs, inches (see Figure 2-5)
↓	↓	R	Radius of corrugations, inches (see Figure 2-5)
		HH	Depth of section, inches (see Figure 2-5)
		TS TF	Skin thickness, inches (see Figure 2-5) or facesheet thickness of honeycomb substrate (see Figure 2-7)
		TC	Corrugation thickness, inches (see Figure 2-5)
		SL	Overall width of panel, inches (see Figure 2-4)
		SLS	Overall length of panel, inches (see Figure 2-4)
5	Real	BE	Distance of reaction from panel edge, inches (see Figure 2-5)
6	Real	F07	Secant yield stress $F_{0.7}$ (Ramberg-Osgood) lb/in^2 (Ref 2)
↓	↓	UF	Ultimate factor
		DST	Difference between two values of creep strain used for Lawson-Miller data, inches/inches

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
6	Real	EALL	Allowable creep strain, inches/inches
↓	↓	CRN	Shape parameter for stress strain curve (Ramberg-Osgood) (Ref. 2)
		BF } TB	Width of flange or flat segment (Conf. 2) inches (see Figure 2-6) or bond thickness in RSI (see Figure 2-7)
		BFL } TR	Width of inner flange (Conf. 4) in. (see Figure 2-6) or Thickness of RSI (see Figure 2-7)
		BL }	Width of lip on inner flange (Conf. 4) in. (see Figure 2-6)
6	Real	DC	or RSI coating thickness (see Figure 2-7)
7	Real	SN	Exponent of Arhennius equation describing pyrolysis gas generation
↓	↓	CA	Coefficient of Arhennius equation describing pyrolysis gas generation
		XB	Activation temperature of Arhennius equation describing pryolysis gas generation
		CPGAS	Specific heat of pyrolysis gas, Btu/lb
		XMC	Molecular weight of char
7	Real	XMP	Molecular weight of pyrolysis gas
8	Alpha-numeric	HEADING	Title card to ablation input
9	Real	TABL	Temperature at which ablator starts, °R
9	Real	TCHAR	Temperature at which ablator stops, °R
↓	↓	TREC	Temperature at which char removal starts, °R
		RHOV	Density of virgin ablation material, lb/ft^3
		RHOC	Density of charred ablation material, lb/ft^3
		TBLOW	Time of transition between laminar and turbulent blowing
		EMV	Emissivity of virgin ablation material
		EMC	Emissivity of charred ablation material
		H300	Enthalpy of air at 300K, 129.06 Btu/lbm
9	Real	VL	Initial thickness of virgin ablation material, inches

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
9	Real	HV	Heat of degradation of virgin material, Btu/lbm
		FV	View factor for external environment
		TV	Sink temperature of external environment, °R
		CHARK	Thermal conductivity of material at TCHAR, Btu/ft-hr-°R
		CHARC	Specific heat of material at TCHAR, Btu/lbm-°R
		ABLK	Thermal conductivity of material at TABL, Btu/ft-hr-°R
9	Real	ABLC	Specific heat of material at TABL, Btu/lbm-°R
10	Integer	NP	Number of node points in ablation material
		NKC	Number of points in char thermal conductivity - temperature table
		NCPC	Number of points in char specific heat - temperature table
		NKV	Number of points in virgin thermal conductivity - temperature table. If zero, program reads record 13B instead of Record 13A.
		NCPV	Number of points in virgin specific heat - temperature table
		NREC	Number of points in surface recession - temperature table
10	Integer	IBLCK	Specifies use of heating reduction due to blowing, input O or 1. 0. No blowing heat transfer reduction 1. Heat transfer reduction due to blowing
11	Real	TKC(I)	Temperature values in char thermal conductivity - temperature table, °R
11	Real	XKC(I)	Thermal conductivity values in char thermal conductivity - temperature table, Btu/ft-hr-°R
12	Real	TCPC(I)	Temperature values in char specific heat - temperature table, °R
12	Real	CPC(I)	Specific heat values in char specific heat - temperature table, Btu/lbm- °R

Record	Variable Type	Symbol	Definition
13A	Real	TKV(I)	Temperature values in virgin thermal conductivity - temperature table, °R
13A	Real	XKV(I)	Thermal conductivity values in virgin thermal conductivity - temperature table, Btu/ft-hr-°R
13B ↓	Integer	NTKV	Number of points in virgin thermal conductivity - temperature table
	Integer	NPKV	Number of different pressures in virgin thermal - conductivity table
	Real ↓	PKV(J)	Values of pressure in virgin thermal conductivity - temperature table, psf
		TKV(I)	Temperature values in virgin thermal conductivity - temperature table, °R
13B	Real	XKV(I, J)	Pressure dependent thermal conductivity values in virgin thermal conductivity - temperature table, Btu/ft-hr-°R
14	Real ↓	TCPV(I)	Temperature values in virgin specific heat - temperature table, °R
14		CPV(I)	Specific heat values in virgin specific heat temperature table, Btu/lbm-°R
15		TS(I)	Temperature values in the surface recession table, °R
15	Real	SR(I)	Surface recession values in the surface recession - temperature or time table, in./sec
16 ↓	Integer	NMB	Number of materials in backup structure
	Integer	NPBS	Total number of node points in backup structure
	Real	BL	Total thickness of backup structure, in.
16A	Integer	NIFPCM	Specifies whether PCM is to be used or not, input 0 or 1 0. No PCM 1. PCM used
16B ↓	Integer	NPC	Material number for phase - change material (PCM) in backup structure
	Integer	NFIL	Test to determine if filler material (honeycomb material) is used in PCM

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
16B	Real	TMELT	Melting temperature of PCM or temperature at which solid-solid transition takes place ~°R
↓	↓	HFUS	Latent heat of fusion of PCM or heat of transition for solid-solid transition ~ Btu/lb
↓	↓	RHØFIL	Density of filler (honeycomb) material ~ lb/ft^3
16B	Real	FIFR	Filler (honeycomb material) fraction in PCM
17	Real	XNPM(I)	Number of nodes in each individual material in backup structure
18	Integer	NKPB(I)	Number of points in each individual backup structure material thermal conductivity - temperature table
18	Integer	NCPB(I)	Number of points in each individual backup structure material specific heat - temperature table
19	Alpha-numeric	XIDNT(I)	Any 72 alphanumeric characterers used to describe each individual material in the backup structure
20	Real	TXK(J, I)	Temperature values in backup material thermal conductivity - temperature table, °R
20	Real	XK(J, I)	Thermal conductivity values in backup material thermal conductivity - temperature table, Btu/ft-hr-°R
21	Real	TCP(J, I)	Temperature values in backup material specific heat — temperature tables, °R
↓	↓	CPX(J, I)	Specific heat values in backup material specific heat — temperature tables, Btu/lbm-°R
22	Real	RHØBX(I)	Density of individual materials in backup, lb/ft^3
↓	↓	XBM(I)	Thickness of individual materials in backup, in.
↓	↓	EMFB(I)	Emissivity of front surface of each material in backup
↓	↓	EMBB(I)	Emissivity of back surface of each material in backup
23	Real	H(I)	Film coefficient between adjacent materials in backup, Btu/ft^2-hr-°R
↓	↓	GAPX(I)	Width of gap between adjacent materials in backup, in.
↓	↓	FTEST(I) BTEST(I)	Test to determine the mode of heat transfer between materials for the front and backface of each material respectively

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
23	Real	=0	Conduction only between materials
↓	↓	=+1	Convective heat transfer only
↓	↓	=-1	Radiation only or radiation and convection heat transfer
24	Alpha-numeric	HEADNG	Any 72 alphanumeric characters used to describe properties of the environment
25	Real	TENV	Temperature of interior cabin environment, °R
↓	↓	HENV	Film coefficient to interior cabin environment, Btu/ft^2-hr-°R
↓	↓	FENV	View factor and emissivity product for radiative heat transfer to cabin interior
↓	↓	QLØSS	Boundary condition between last node of the backup structure and cabin environment
↓	↓	=0	Adiabatic surfaces
↓	↓	=+1	Radiation and/or convective loss
26	Alpha-numeric	HEADNG	Any 72 alphanumeric characters used to describe the initial temperature distribution
27	Real	TEST2	Determines the proper heat shield initial temperature distribution
↓	↓	=0	Constant, uniform initial temperature distribution
↓	↓	=-1	Arbitrary initial temperature distribution
↓	↓	TEMPI	Temperature to be used when constant temperature distribution option is used, °R
28	Real	TEMDI	Arbitrary temperature distribution values, to be used only if TEST2 is negative, °R
29	Integer	NHP	Number of points in enthalpy — temperature curve fit
30	Real	HX(I)	Enthalpy values in enthalpy — temperature table, Btu/lbm
↓	↓	TW(I)	Corresponding temperature values in enthalpy — temperature table, °R
31	Integer	IPRINT	Specifies output form of RSI stress analysis, input a 1 if "long" print out option is used. Leave blank for "short" print out

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
31	Integer	NC	Number of constraints, NC = 8
↓	↓	NH	Number of vertical bars, $16 \le NH \le 40$
		PZ	Axial load lb/in
		VB	Poisson's ratio for bond
32	Real	TALLW(I)	Allowable temperature of the material, °R
33	Real	EMIS(I)	Emissivity of the material
34	Real	RHO(I)	Density of the material, lb/ft
35	Integer	ID(I, J)	Specifies input of material property tables input a 1 or 2 or leave blank to skip input 1. Read AY only (AX same as before) 2. Read both AX and AY
↓	Integer	MPT(I,J)	Number of pairs or points
36	Real	AX(I,J,K)	Independent variable
37	Real	AY(I,J,K)	Dependent variable I = 1, 2, ..., NMAT J = 1. Heat capacity (C_p) 2. Thermal conductivity (k) 3. Young's modulus (E) 4. Coefficient of thermal expansion (α) 5. Yield strength (F_{cy}) 6. Ultimate tensile strength (F_{tu}) 7. Larson Miller parameter for strain 1 (E_1) 8. Larson Miller parameter for strain 2 (E_2) 9. Ultimate compressive strength (F_{cu}) 10. Ultimate shear strength (F_{su}) 11. Shear modulus (G) K = 1, 2 ..., MPT(I,J)
38	Real	X(I)	Width of the Ith Column, ft

Record	Variable Type	Symbol	Definition
39	Real	QCONL(I)	Laminar heat transfer multiplier of the Ith column, omit if IQCON=1 or NCOLM=1
40	Real	QCONT(I)	Turbulent heat transfer multiplier for the Ith column, omit if IQCON ≠3 or NCOLM=1
41	Real	Y(J)	Thickness of the Jth segment, ft
42 ↓	Integer ↓	MAT(I,J)	Specifies materials of column I, segment J A zero denotes a void 1-9, material number negative. The segment will be grouped together with the right-hand side segment for condition computations
	Real ↓	TAMP(I,J)	Specifies initial temperature of column I, segment J, °R Omit record 18 if NCOLM=1 or NRSG=O
43 ↓	Integer ↓	NR(N)	Specifies nodes with internal radiation exchange Example: 18 means column 1, segment 8 For segments which have more than one side have radiation exchange, treat each side as a segment in the order of left-right-upper-lower
		NI(N)	Number of nodes to be interacted with node NR(N), ≤ 9
		MR(M, N)	Specifies nodes to interchange with node NR(N)
	Real	VFACT(M,N)	View factors or $\mathfrak{F}_{ij}$ with EMIS(I) = 1
44 ↓	Integer ↓	IPFI	Number of noise sources to be considered 1. Turbulent boundary layer 2. Rocket engine 3. Jet engine 4. Jet engine scrubbing
		IPF(I)	Identifies by number the noise sources
		IPAD	Specified if vehicle is on the pad Zero - not on pad Non-zero - on pad
		KFLEX	Flexural rigidity index 0. if structure symmetrical, rigid 1. if unsymmetrical and/or flexible

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
44	Integer	NPAN	Panel configuration index 1. flat plate 2. honeycomb sandwich 3. integrally stiffened 4. corrugated
45	Real	DT(1)	Period of turbulent boundary layer noise excitation, sec
		XL	Run length of turbulent boundary layer, feet
		REY	Local Reynolds number
		VU	Local velocity, ft/sec
		QL	Local dynamic pressure, psi
		AMACH	Local Mach number
46	Real	DT(2)	Period of rocket engine noise excitation, sec
		TT	Rocket engine thrust, lb
		WER	Rocket engine weight flow, lb/sec
		D	Rocket nozzle exit diameter, ft
		VS	Rocket exhaust velocity, ft/sec
		XI	Distance between point of interest and rocket engine exit, ft
		DVEH	Vehicle diameter, ft
		YCL	Buttline distance between panel and vehicle centerline, ft
		DREF	Reference distance between noise source on pad and rocket engine exhaust plane, ft
47	Real	DT(3)	Period of jet (flyback) engine noise excitation, sec
		AE	Nozzle exit area, ft
		VJ	Jet velocity, ft/sec
		WEJ	Jet engine weight flow, lb/sec
		VV	Vehicle velocity at flyback cruise, ft/sec
		TJ	Jet engine thrust, lb
		XJ	Axial distance from point of interest to jet engine exit nozzle, ft

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
47	Real	YP	Radial distance from point of interest to jet engine nozzle, ft (less than 200 ft)
48	Real	DT(4)	Period of jet (flyback) engine scrubbing noise excitation, sec
↓	↓	HPAN	Panel thickness, inches
		HC	Core thickness, inches (for honeycomb sandwich)
		AI	Panel moment of inertia, in^4
		AIY	Panel moment of inertia, in^4 (for normal direction of corrugated panel)
		AW	Panel length, ft
		BW	Panel width, ft
		EP	Modulus of elasticity for panel, psi
49	Real	C(I)	Coefficients of a least squares, 3rd order curve fit of allowable S-N data
↓	↓	RHOP	Panel material density, lb/ft^3
50	Real	TIME(I)	Time in trajectory, sec, I ≤ 99
↓	↓	ALT(I)	IQINP=1. Altitude, ft 2. Local heat flux, Btu/ft^2-sec °R 3. Temperature of first segments °R Note: QCONL(I) may be used to obtain a distribution of Q(I) or TEMP(I, 1)
		VINF(I)	If IQINP=1, free stream velocity, ft/sec If IQINP=2, 3 local pressure psia
		ALPHA(I)	Angle of attack, degrees (velocity for IQINP=4)
		BETA(I)	Yaw angle, degrees
		HINSD(I)	Convection heat transfer coefficient to internal fluid. Btu/ft^2-sec °R. (Input 1. E9 to keep last row of segments at the initial temperature)
		TINSD(I)	Bulk temperature of internal fluid, °R
50	Real	NREADT	Non-zero indicator marking the last trajectory card

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
52	Integer	KINDP	Specifies panel configuration, input a 1, 2, 3, 4, or 5 1. Corrugated (either open or closed) 2. Integrally stiffened 3. Honeycomb 4. RSI 5. Ablator
	Integer	KINDS	Specific supporting structure configuration, input a 1, 2, or 3 1. Configuration type A 2. Configuration type B 3. Configuration type C
		LENGTH	Panel length, inches
		WIDTH	Panel width, inches
		DLPANL	Panel length overlap, inches
		DWPANL	Panel width overlap, inches
		A	Distance between adjacent panels, inches
		B	Air space gap between panel and insulation, inches
	Integer	MATLID	Material identification number (see Table 2-1) for metallic panel or substrate.
		ICOS	Specifies input of total cost data, input 0 or 1 0. No additional data required 1. Additional data input at end of weight/cost input
53	Real	PINS1	Density of insulation type 1
		PINS2	Density of insulation type 2
		PINS3	Density of insulation type 3
		TINS1	Thickness of insulation type 1
		TINS2	Thickness of insulation type 2
		TINS3	Thickness of insulation type 3
54[1]	Integer	NRIBS	Number of corrugations across panel width
	Real	CHORD	Corrugation chord length, inches
	Real	RADIUS	Corrugation radius, inches
54[2]	Real	GINSRT	Weight of honeycomb inserts, lb/100 inserts
	Real	TCORE	Thickness of panel honeycomb core, in.
	Real	TEDGE	Thickness of panel edge piece, in.

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
54[3]	Integer	NRIBS	Number of panel ribs
↓	Real	HRIB	Height of panel rib, inches
	Real	TEDGE	Thickness of panel edge piece, inches
	Real	E1RIB	Width of panel rib, outside leg, inches
	Real	E2RIB	Width of panel rib, base leg, inches
	Real	E3RIB	Width of panel rib, inside leg, inches
	Real	T1RIB	Thickness of panel rib, outside leg, inches
	Real	T2RIB	Thickness of panel rib, base leg, inches
	Real	TWRIB	Thickness of panel rib, web, inches
54[4] } 54[5]	Real	GINSRT	Weight of honeycomb inserts, lb/100 inserts
↓	↓	TCORE	Thickness of panel honeycomb core, inches
		TEDGE	Thickness of panel edge piece, inches
		TEXT	Thickness of RSI or ablator, inches
		PEXT	Density of RSI or ablator, lb/in^3
55[1]	Real	GBOLT	Weight of bolts, lb/100 bolts
↓	↓	GNUTPL	Weight of nutplates, lb/100 nutplates
		GWASH	Weight of washers, lb/100 washers
		TCORN	Thickness of corner piece, inches
		TPOST	Thickness of wall of corner post, inches
		ODPOST	Outside diameter of corner post, inches
		LTUBE	Length of support tube, inches
		TTUBE	Thickness of wall of support tube, inches
		TFNG1	Thickness of support tube flange, inches
		TBMLA	Thickness of long beam, A, inches
		TBMSA	Thickness of short beam, A, inches
		TDOUBC	Thickness of long beam doubler channel, inches
		TDOUBP	Thickness of corner doubler plate, inches
55[1]	Real	TPLATE	Thickness of corner plates

Table 3-1. Input Symbols (Continued)

Record	Variable Type	Symbol	Definition
55[1]	Real	TSEAL	Thickness of seal strip, inches
↓	↓	HBEAMA	Height of long and short beams A, inches
		WBEAMA	Width of long and short beam A, inches
55[2]	Real	GBOLT	Weight of bolts, lb/100 bolts
↓	↓	GNUTPL	Weight of nutplates, lb/100 nutplates
		GWASH	Weight of washers, lb/100 washers
		GINSUL	Weight of insulators, lb/100 insulators
		TPOST	Thickness of wall of corner post, inches
		WPOST	Width of post B, inches
55[3]	Real	GBOLT	Weight of bolts, lb/100 bolts
↓	↓	GNUTPL	Weight of nutplates, lb/100 nutplates
		GWASH	Weight of washers, lb/100 washers
		GCLAMP	Weight of clamping washers, lb/100 washers
		TPOST	Thickness of wall of corner post
		ODPOST	Outside diameter of corner post, inches
		ODPOSR	Outside diameter of center post, inches
		TTUBE	Thickness of wall of support tube, inches
		TFNG1	Thickness of support tube flange, inches
		TBMLC	Thickness of long beam C, inches
		TBMSC	Thickness of short beam C, inches
		WBMLC	Width of long beam C, inches
		WBMSC	Width of short beam C, inches
		TRIBL	Thickness of long rib C, inches
		TRIBS	Thickness of short rib C, inches
		WRIBL	Width of long rib C, inches
		WRIBS	Width of short rib C, inches
		HRING	Height of the post of internal ring, center post C, inches
		ODRING	Outside diameter of beam support ring, corner post C, inches

Table 3-1. Input Symbols (Continued

Record	Variable Type	Symbol	Definition
55[3]	Real	IDFNG1	Outside diameter of support tube, corner post C, inches
↓	↓	IDFNG2	Outside diameter of support tube, center post C, inches
		HFNG1	Height of support tube flange, corner post C, inches
		HFNG2	Height of support tube flange, center post C, inches
		TRING1	Thickness of post support ring, corner post C, inches
		TRING2	Thickness of post support ring, center post C, inches
56	Real	AT	Exponent of TFU costs
↓	↓	BT	Exponent of engineering design and development costs
		CT	Exponent of tooling costs
		CF1	Complexity factor of TFU costs
		EGTH	Ground test hardware shipsets
		ETA	Test article conversion shipsets
57	Real	FTH	Flight test article shipsets
↓	↓	FTS	Flight test spares and replenishment parts shipsets
		K1	Coefficient of TFU costs
		K2	Coefficient of engineering design and development costs
		K3	Coefficient of cooling costs
		NPA	Production article shipsets
		OS	Recurring operations shipsets (refurbishment)
57	Real	STPS	Surface area of the TPS

NOTE: In Tables 3-1 and 3-2, the superscripts on record 54 denote values of the panel index KINDP whereas those on record 55 show values of the structural index KINDS.

RECORD																				
1	TITLE																			
1	TITLE																			
1	TITLE																			
2	ICØNF	IQCØN	IQINP	ITURB	IWALT	NANG	NOØLM	NSEG	NMAT	NRSG	NCRC	NSECT	NINS	NF	NPRT	ISTRES	IFATIG	IWTCST	IEQØS	ITRAS
3	THETA	PHI	XDST	DIAM	ARØD	XEMIS	FACC													
4	STAAT	DELTA	WRØTE	STØØP																
5	AS	R	HH	TS or TF	TC	SL	SLS	BE												
6	FO7	UF	DST	EALL	CRN	BF or TB	BFL or TR	BL or DC												
7	SN	CA	XB	CPGAS	XMC	XMP														
8	HEADING (Title card for ablation or RSI analysis)																			
9A	TABL	TCHAR	TREC	RHØV	RHØC	TBLØW														
9B	EMV	EMC	H300	VL	HV	FV														
9C	TV	CHARK	CHARC	ABLK	ABLC															
10	NP	NKC	NCPC	NKV	NCPV	NREC	IBLCK													
11	TKC(1)	XKC(1)	TKC(2)	. . .	TKC(NKC)	XKC(NKC)														
12	TCPC(1)	CPC (1)	TCPC(2)	. . .	TCPC(NCPC)	CPC(NCPC)														
13A	TKV(1)	XKV(1)	TKV(2)	. . .	TKV(NKV)	XKV(NKV)														
13B-1	NTKV	NPKV	PVK(1)	PVK(2)	. . .	PVK(NPKV)														
13B-2	TKV(1)	XKV(1, 1)	XKV(1, 2)	. . .	XKV(1, NPVK)															
13B-2	⋮	⋮	⋮																	
13B-2	TKV(NTKV)	XKV(NTKV, 1)	XKV(NTKV, 2)	. . .	XKV(NTKV, NPKV)															
14	TCPV(1)	CPV(1)	TCPV(2)	. . .	TCPV(NCPV)	CPV(NCPV)														
15	TS(1)	SR(1)	TS(2)	. . .	TS(NREC)	SR(NREC)														
16	NMB	NPBS	BL																	
16A	NIFPCM																			
16B	NPC	NFIL	TMELT	HFUS	RHØFIL	FIFR														
17	XNPM(1)	XNPM(2)	. . .	XNPM(NMB)	(Note: If NIFPCM = +ve: NMB = NMB+1 and record 19, 20, 21 required for filler material)															
18	NKPB(1)	NCPB(1)	NKPB(2)	NCPB(2)		NCPB(NMB)														
19	HEADING (Title for each individual backup material)																			
20	TXK(1, I)	XK(1, I)	TXK(2, I)	. . .	TXK(NKPB (I), I)	XK(NKPB(I), I)	I = 1, 2, · · ·, NMB													
21	TCP(1, I)	CPX(1, I)	TCP(2, I)	. . .	TCP(NCPB(I), I)	CPX(NCPB(I), I)														

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Figure 3-1. Sample Chart for Standard Input Formats of Program P5490B

RECORD										
22	RHØBX(1)	XBM(1)	EMFB(1)	EMBB(1)	RHØBX(2)	...				
22	RHØBX(NMB)	XBM(NMB)	EMFB(NMB)	EMBB(NMB)						
23	H(1)	GAPX(1)	FTEST(1)	BTEST(1)	H(2)	...				
23	H (NMB)	GAPX(NMB)	FTEST(NMB)	BTEST(NMB)						
24	HEADING (Title for properties of the environment)									
25	TENV	HENV	FENV	QLØSS						
26	HEADING (Title card for initial temperature distribution)									
27	TEST2	TEMPI								
28	TEMDI(1)	TEMDI(2)	.	.	.	TEMDI(NP+NPBS)				
29	NHP									
30	HX(1)	TW(1)	HX(2)	...	NX(NHP)	TW(NHP)				
31	IPRINT	NC	NH	PZ	VB					
32	TALLW(1)	TALLW(2)	...	.	.	.	TALLW(NMAT)			
33	EMIS(1)	EMIS(2)	...	.	.	.	EMIS(NMAT)			
34	RHØ(1)	RHØ(2)	...	.	.	.	RHØ(NMAT)			
35	ID(I, 1)	(MPT(I, 1)	ID(I, 2)	(MPT(I, 2)	.	.	.			
35	ID(I, 11)	MPT(I, 11)	I = 1, 2, ···, NMAT							
36	AX(I, J, 1)	AX(I, J, 2)	...						AX(I, J, MPT(I, J))	
37	AY(I, J, 1)	AY(I, J, 2)	...	J = 1, 2, ···, 11					AY(I, J, MPT(I, J))	
38	X(1)	X(2)	...					X(NCØLM)		
39	QCØNL(1)	QCØNL(2)	...					QCØNL(NCØLM)		
40	QCØNT(1)	QCØNT(2)	...					QCØNT(NCØLM)		
41	Y(1)	Y(2)	...					Y(NSEG)		
42	MAT (I, 1)	TAMP(I, 1)	MAT (I, 2)	TAMP(I, 2)	...	MAT(I, NCØLM)	TAMP(I,NCØLM)	I=1, 2, ... SEG		
43	MR (J)	NI(J)	MR (1, J)	VFACT(1, J)	MR (2, J)	VFACT(2, J)	...	MR(NI(J), J)	VFACT(NI(J), J)	J-1, 2, ··· NRSG
44	IPFI	IPF(1)	IPF(2)	IPF(3)	IPF(4)	IPAD	KFLEX	NPAN		
45	DT(1)	XL	REY	VU	QL	AMACH				
46	DT(2)	TT	WER	D	VS	XI	DVEH	YCL	DREF	
47	DT(3)	AE	VJ	WEJ	VV	TJ	XJ	YP		
48	DT(4)									

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Figure 3-1. Sample Chart for Standard Input Formats of Program P5490B (Continued)

RECORD	1–8	9–16	17–24	25–32	33–40	41–48	49–56	57–64	65–72	73–80
49	HPAN	HC	AI	AIY	AW	BW	EP	TIMEF		
50	C(1)	C(2)	C(3)	C(4)	RHØP					
51	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)	XSTG(I)	NREADT	} I = 1, 2, ···, NTRAJ
52	KINDP | KINDS	LENGTH	WIDTH	DLPANL	DWPANL	A	B	MATLID | ICØS		
53	PINS1	PINS2	PINS3	TINS1	TINS2	TINS3				
54-1	NRIBS	CHØRD	RADIUS	(KINDP = 1)						
54-2	GINSRT	TCØRE	TEDGE	(KINDP = 2)						
54-3	NRIBS	HRIB	TEDGE	E1RIB	E2RIB	E3RIB	T1RIB	T2RIB	TWRIB	(KINDP = 3)
54-4, 54-5	GINSRT	TCØRE	TEDGE	TEXT	PEXT	(KINDP = 4 or 5)				
55-1	GBØLT	GNUTPL	GWASH	TCORN	TPØST	ØDPØST	LTUBE	TTUBE	TFNG1	(KINDS = 1)
55-1	TBMLA	TBMSA	TDØUBC	TDØUBP	TPLATE	TSEAL	HBEAMA	WBEAMA		
55-2	GBØLT	GNUTPL	GWASH	GINSUL	TPØST	WPØST	(KINDS = 2)			
55-3	GBØLT	GNUTPL	GWASH	GCLAMP	TPØST	ØDPØST	ØDPØSR	TTUBE	TFNG1	(KINDS = 3)
55-3	TBMLC	TBMSC	WBMLC	WBMSC	TRIBL	TRIBS	WRIBL	WRIBS		
55-3	HRING	ØDRING	IDFNG1	IDFNG2	HFNG1	HFNG2	TRING1	TRING2		
56	AT	BT	CT	CF1	EGTH	ETA				
57	FTH	FTS	K1	K2	K3	NPA	OS	STPS	(ICØS = 1)	

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Figure 3-1. Sample Chart for Standard Input Formats of Program P5490B (Continued)

Table 3-2. Input Records Format

Record	Data	I, J, K Range	Format
1.	JI, TITLE		I1, 13A6
2.	ICONF, IQCON, IQINP, ITURB, IWALT, NANG, NCOLM, NSEG, NMAT, NRSG, NCRC, NSECT, NINS, NF, NPRT, ISTRES, IFATIG, IWTCST, IEQOS, ITRAS		20I4
3.	THETA, PHI, XDIST, DIAM, AROD, XEMIS, FACC		10F8.0
4.	STAAT, DELTA, WROTE, STOOP		10F8.0
5.	AS, R, HH, TS, TC, SL, SLS, BE		10F8.0
6.	FO7, UF, DST, EALL, CRN, BF, BFL, BL		F8.0
7.	SN, CA, XB, CPGAS, XMC, XMP		6E12.8
8.	HEADING(K)	1, 12	12A6
9A.	TABL, TCHAR, TREC, RHOV, RHOC, TBLOW		6E12.8
9B.	EMV, EMC, H300, VL, HV, FV		6E12.8
9C.	TV, CHARK, CHARC, ABLK, ABLC		6E12.8
10.	NP, NKC, NKV, NCPV, IQBLCK		7I5
11.	TKC(I), XKC(I)	1, NCPC	6E12.8
12.	TCPC(I), CPC(I)	1, NCPC	6E12.8
13A.	TKV(I), XKV(I)	1, NKV	6E12.8
13B-1.	NTKV, NPKV, PKV(I)	1, NPK	2I5, 7E10.5
13B-2.	TKV(I), XKV(IJ)	1, NTKV;1, NPKV	8E10.5
14.	TCPV, CPV(I)	1, NCPV	6E12.8
15.	TS(I), SR(I)	1, NREC	6E12.8
16.	NMB, NPBS, BL		2I5, E14.8
17.	XNPM(I)	1, NMB	6E12.8
18.	NKPB(I), NCPB(I)	1, NMB	10I5
19.	XIDNT(I, J)	1, 12;1, NMB	12A6

Table 3-2. Input Records Format (Cont.)

Record	Data	I, J, K RANGE	Format
20.	TXK(I, J), XK(I, J)	1, LK;1, NMB	6E12.8
21.	TCP(I, J), CPK(I, J)	1, LCP;1, NMB	6E12.8
22.	RHOBX(I), XBM(I), EMFB(I), EMBB(I)	1, NMB	6E12.8
23.	H(I), GAPX(I), FTEST(I), BTEST(I)	1, NMB	6E12.8
24.	HEADNG(I)	1, 12	12A6
25.	TENV, HENV, FENV, QLOSS		6E12.8
26.	HEADNG(I)	1, 12	12A6
27.	TEST2, TEMPI		6E12.8
28.	TEMDI(I)	1, NPF	6E12.8
29.	NHP		I5
30.	HX(I), TW(I)	1, NHP	6E12.8
31.	IPRINT, NC, NH, NLC, NV, PZ, VB		3I5, 2F10.0
32.	TALLW(I)	1, 9	10F8.0
33.	XEMIS(I)	1, 9	10F8.0
34.	RHO(I)	1, 9	10F8.0
35.	ID(I, J), MPT(I, J)	1, NMAT;1, 11	20I4
36.	AX(I, J, K)	1, NMAT;1, 11; 1, MPT(I, J)	10F8.0
37.	AY(I, J, K)	1, NMAT;1, 11; 1, MPT(I, J)	10F8.0
38.	X(I)	1, 9	10F8.0
39.	QCONL(I)	1, 9	10F8.0
40.	QCONT(I)	1, 9	10F8.0
41.	Y(I)	1, 9	10F8.0
42.	MAT(I, J), TAMP(I, J)	1, 9;1, NSEG	9(I2, F6.0)
43.	NR(J), NI(J), MR(I, J), VFACT(I, J)	1, 9;1, NRSG	I2, I6, 9(I2, F6.0)
44.	IPFI, IPF(I), IPAD, KFLEX, NPAN	1, 4	20I4

Table 3-2. Input Records Format (Cont.)

Record	Data	I, J, K Range	Format
45.	DT(1), XL, REY, VU, QL, AMACH		10F8.0
46.	DT(2), TT, WER, D, VS, XI, DUEH, YCL, DREF		10F8.0
47.	DT(3), AE, VJ, WEJ, VV, TJ, XJ, YP		10F8.0
48.	DT(4)		10F8.0
49.	HPAN, HC, AI, AIY, AW, BW, EP, TIMEF		10F8.0
50.	C(I), RHOP		10F8.0
51.	TIME(I), ALT(I), VINF(I), ALPHA(I), BETA(I), HINSD(I), TINSD(I), XSTG(I), NREADT	1, 99	8F8.0, I16
52.	KINDP, KINDS, LENGTH, WIDTH, DLPANL, DWPANL, A, B, MATLID, ICOS		12I4, 6E8.0, 2I4
53.	PINS1, PINS2, PINS3, TINS1, TINS2, TINS3		9E8.0
54-1.	NRIBS, CHORD, RADIUS		I8, 9E8.0
54-2.	GINSRT, TCORE, TEDGE		9E8.0
54-3.	NRIBS, HRIB, TEDGE, E1RIB, E2RIB, E3RIB, T1RIB, T2RIB, TWRIB		I8, 9E8.0
54-4. 54-5.	GINSRT, TCORE, TEDGE, TEXT, PEXT		9E8.0
55-1.	GBOLT, GNUTPL, GWASH, TCORN, TPOST, ODPOST, LTUBE, TTUBE, TFNG1, TBMLA, TBMSA, TDOUBC, TDOUBP, TPLATE, TSEAL, HBEAMA, WBEAMA		
55-2.	GBOLT, GNUTPL, GWASH, GINSUL, TPOST, WPOST		9E8.0
55-3.	GBOLT, GNUTPL, GWASH, GCLAMP, TPOST, ODPOST, ODPOSR, TTUBE, TFNG1, TBMLC, TBMSC, WBMLC, WBMSC, TRIBL, TRIBS, WRIBL, WRIBS, HRING, ODRING, IDFNG1, IDFNG2, HFNG1, HFNG2, TRING1, TRING2		9E8.0
56.	AT, BT, CT, CF1, EGTH, ETA		9E8.0
57.	FTH, FTS, K1, K2, NPA, OS, STPS		9E8.0

Table 3-3. Output Symbols

Symbol	Definition	
TAU	Time in trajectory for which output is given, sec	
AL	Altitude, ft	
VI	Free-stream velocity, ft/sec	
AOFA	Angle of attack, degrees	
PI	Free-stream static pressure, psia	
AMI	Free-stream Mach number	
AME	Local Mach number	
RYI	Free-stream Reynolds number/ft	
PE	Local static pressure, psia	
Q(I)	Boundary convective heat transfer rate at Ith Column, Btu/ft^2-sec	
QNET(I)	Net external surface heat transfer at Ith Column, Btu/ft^2-sec	
TEMP(I, J)	Temperature of Ith Column and Jth Segment at time TAU	
A	Section area of the element C stress analysis, in.^{2}	
XX	X-coordinate of the element, in.	
ZZ	Z-coordinate of the element, in.	
T	Temperature of the element, °R	
FT	Thermal stress	
FNET	Total stress	
EDOT	Creep rate	
FTU	Ultimate tensile strength, lb/in.^{2}	
FCY	Yield strength, lb/in.^{2}	
E	Youngs modules, lb/in.^{2}	Used for NSECT-1 through NSECT-6 (Metallic panels)
TIMS	Design factor for ultimate tension	
Y2MS	Design factor for yield strength	
C3MS	Design factor for ultimate compression	
C4MS	Design factor for bucking of corrugation	
F5MS	Design factor for crippling of flange	
F6MS	Design factor for crippling of flange	

Table 3-3. Output Symbols, (Cont.)

Symbol	Definition	
WBMS	Creep rate	Used for NSECT-1 through NSECT-6 (Metallic panels)
DMAX	Maximum deflection	
EMS	Minimum of margins of safety	
EMAX	Total creep strain	
TS	Corrugation thickness, in.	
TC	Skin thickness, in.	
FVFT	Maximum tensile stress in axial direction in face sheets lb/in^2	
FVFC	Maximum compression stress in axial direction in face sheets lb/in^2	
FVCT	Maximum tensile stress in coatings lb/in^2	
FVCC	Maximum compression stress in coatings lb/in^2	
FSIM	Maximum shear stress in RSI lb/in^2	
FPIT	Maximum principle stress in RSI lb/in^2	
FPIC	Minimum principle stress in RSI lb/in^2	
FSCM	Maximum shear stress in structural panel lb/in^2	
FSBM	Maximum shear stress in bond lb/in^2	
FPBT	Maximum principle stress in bond lb/in^2	
ZMAX	Maximum normal deflection of middle span, in.	

SECTION 4

SAMPLE PROBLEM

4.1 SAMPLE PROBLEM No. 1

This problem concerns sizing a section of circular arc corrugation panel on the bottom centerline of the space shuttle booster. Figure 4-1 shows the panel corrugations. The panel is made of Rene' 41. For an initial trial, a thickness of 0.040 inch is used. Figure 4-2 shows the conduction matrix which is used for structural temperature response. QCONL(I) is used to accommodate the separation and reattachment of flow on the corrugations. For internal radiation, it is assumed (for simplicity) that each surface element interacts only with the base element at the same column. The inner surface is assumed to be an aluminum LO_2 tank which is kept at 168° R until all the liquid oxygen is evacuated at 194 seconds in the trajectory. Figures 4-3 through 4-9 show card images of the input, and output of the sample problem.

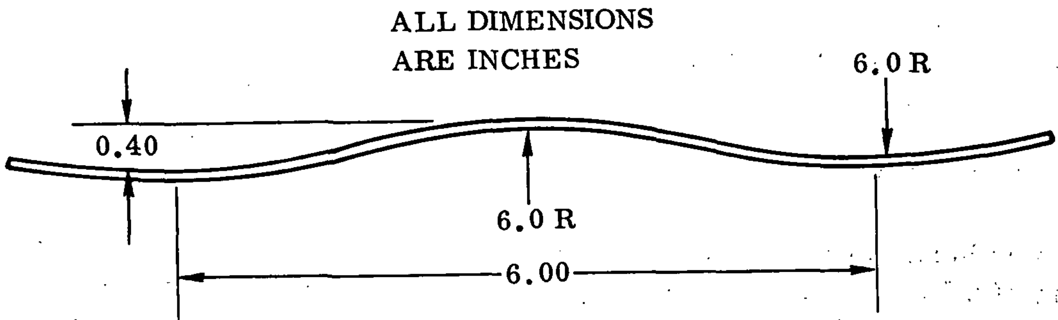

Figure 4-1. Corrugation

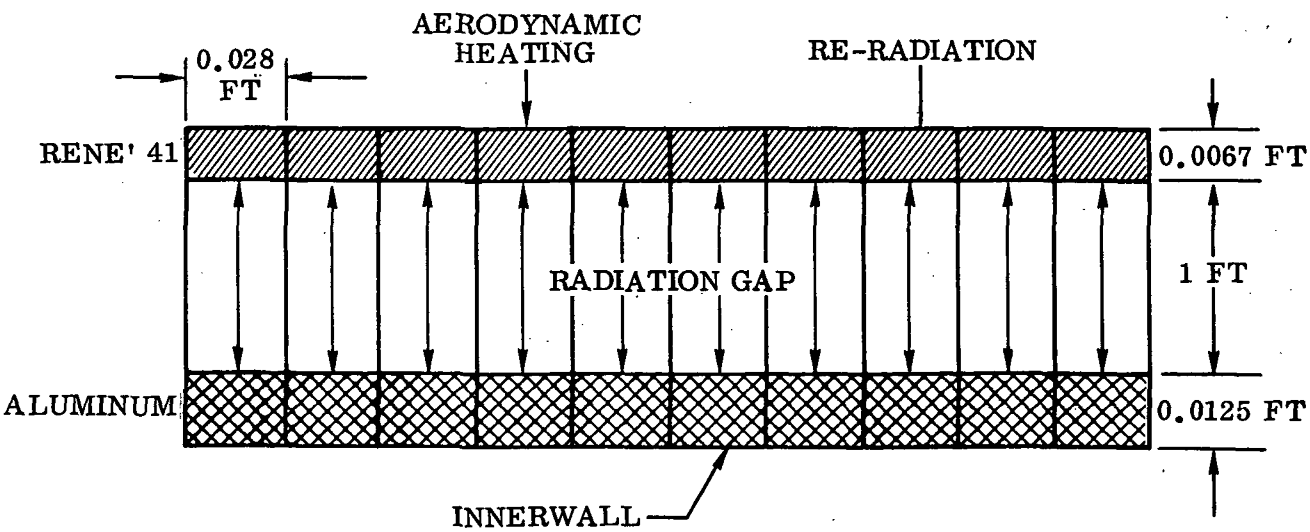

Figure 4-2. Conduction Nodes

4.2 SAMPLE PROBLEM NO. 2

This problem concerns sizing an RSI TPS on the bottom centerline of the space shuttle orbiter. The configuration includes one inch of RSI, 0.3" RTV bondline, 0.6" honeycomb substrate, and 1" backup insulation. Card images for the input are given in Figure 4-10, and selected output results are given in Figures 4-11 through 4-17. These results include, for the short part of the trajectory considered, results of the thermodynamics analysis, the discrete and finite element stress analyses, the fatigue analyses, and the weight/cost results.

4.3 SAMPLE PROBLEM NO. 3

This problem is a typical sample case of the charring ablator analysis performed with the modified computer program of Curry (Ref. 3) adapted to computer program P5490B. The modifications and computer code simplifications to Reference 3 are discussed in Reference 1. Typically the ablator is 1.0 inches thick with the backup structure consisting of 0.1 inches thick aluminum. Listing of the computer input is shown in Figure 4-18. Selected outputs are given in Figures 4-19 through 4-24.

4.4 SAMPLE PROBLEM NO. 4

This problem concerns sizing a phase change material (PCM) in the backup structure of a TPS panel. For this sample problem a RSI outer panel was assumed (0.25 inches thick) with a 0.08 inch bond line (PD 200-F8), 0.5 inch metallic PCM (Gallium) and a 0.2 inch aluminum backup material. Card images for the input are given in Figure 4-25, and selected output results are given in Figures 4-26 through 4-27. The computer output for this case is essentially identical to that given in Reference 3. Basically the key output is the temperature distribution in the TPS panel.

```
RECORD
  1   1         TPS - CORRUGATIONS
  2      1    3    1    1    2    1    9    3    2   18    1    6       100     1
  3                          32.0       32.0      0.01      0.85
  4      0.        0.5       10.        120.
  5           6         6         .4                  .025        24          6
  6    1.36E5     1.4      .005      .005               20
 32      2110       660
 33       .85        .2
 34       515       170
 35      2    1    2    8    1    8    1    8    1    8    1    8    2    7    1    7
 35
 36       540
 37      .108
 36       540       660       860      1060      1260      1460      1660      1860
 37      5.26      6.01      7.26      8.50      9.75     10.99     12.24     13.49
 37   31.60+6   31.00+6   30.00+6   28.75+6   27.65+6   26.20+6   24.60+6   22.75+6
 37    6.22-6    6.40-6    6.70-6    7.00-6    7.31-6    7.62-6    7.93-6    8.23-6
 37    1.35+5    1.33+5    1.31+5    1.31+5    1.31+5    1.31+5    1.30+5    1.08+5
 37    1.65+5    1.62+5    1.56+5    1.53+5    1.51+5    1.51+5    1.48+5    1.26+5
 36      6000     10000     20000     30000     50000     70000     90000
 37   47.25+3   46.00+3   44.15+3   42.90+3   41.05+3   39.60+3   38.00+3
 37   48.05+3   46.70+3   44.70+3   43.35+3   41.45+3   39.90+3   38.30+3
 35      2    1    1    1
 35
 36       540
 37       .24
 37        70
 38      .028      .028      .028      .028      .028      .028      .028      .028      .028
 39       2.0       1.8      1.3       1.10      1.00        .9        .8        .8        .7
 40       2.0       1.8      1.3       1.10      1.00        .9        .8        .8        .7
 41    .00208         1     .0125
 42   1   490 1     490 1     490 1     490 1     490 1     490 1     490 1     490 1     490
 42   0   490 0     490 0     490 0     490 0     490 0     490 0     490 0     490 0     490
 42   2   168 2     168 2     168 2     168 2     168 2     168 2     168 2     168 2     168 2     168
 43   11        113         1
      21        123         1
      31        133         1
      41        143         1
      51        153         1
      61        163         1
      71        173         1
      81        183         1
      91        193         1
      13        111         1
      23        121         1
      33        131         1
      43        141         1
      53        151         1
      63        161         1
      73        171         1
      83        181         1
 43   93        191         1
 44      4    1    2    3    4    0    0    1
 45      100.      100.      1.E7     8000.     1400.        6.
 46       40.      1.E6     1000.       12.      100.       20.       40.
 47       20.        3.     1200.      200.      650.      1.E4       10.       10.
 48       10.
```

Figure 4-3. Card Images of Input to Sample Problem No. 1

RECORD										
49	0.1	0.01	.001	.002	0.5	2.0	1.E7			
50	254.56	-62.717	4.4189	-.025179	180.					
51	0.0	368.0	0.0	0.0	0.0	1.E9	168.0			
	40.0	9681.0	499.3	0.0	0.0	1.E9	168.0			
	80.0	41750.0	1299.0	0.0	0.0	1.E9	168.0			
	120.0	96470.0	3063.0	0.0	0.0	1.E9	168.0			
	160.0	163500.0	5994.0	0.0	0.0	1.E9	168.0			
	174.0	186500.0	7234.0	0.0	0.0	1.E9	168.0			
	182.0	199100.0	7954.0	0.0	0.0	1.E9	168.0			
	190.0	211000.0	8681.0	0.0	0.0	1.E9	168.0			
	194.0	216700.0	9047.0	0.0	0.0	1.E9	168.0			
	194.25	217030.0	9045.7	0.4	0.0	0.0	0.0			
	199.0	223400.0	9021.0	7.5	0.0	0.0	0.0			
	209.0	234700.0	8971.0	22.5	0.0	0.0	0.0			
	219.0	243300.0	8927.0	37.5	0.0	0.0	0.0			
	229.0	249300.0	8892.0	52.5	0.0	0.0	0.0			
	244.0	253000.0	8856.0	60.0	0.0	0.0	0.0			
	264.0	248500.0	8842.0	60.0	0.0	0.0	0.0			
	284.0	233200.0	8849.0	60.0	0.0	0.0	0.0			
	304.0	207400.0	8826.0	60.0	0.0	0.0	0.0			
	324.0	172500.0	8593.0	60.0	0.0	0.0	0.0			
	344.0	134200.0	7436.0	60.0	0.0	0.0	0.0			
	354.0	118600.0	6450.0	40.7	0.0	0.0	0.0			
	364.0	107300.0	5647.0	31.9	0.0	0.0	0.0			
	374.0	100500.0	4898.0	30.5	0.0	0.0	0.0			
	384.0	97150.0	4122.0	35.0	0.0	0.0	0.0			
	394.0	94380.0	3255.0	46.2	0.0	0.0	0.0			
	404.0	91360.0	2411.0	44.6	0.0	0.0	0.0			
	414.0	87450.0	1971.0	38.1	0.0	0.0	0.0			
	424.0	82320.0	1731.0	29.5	0.0	0.0	0.0			
	434.0	75890.0	1596.0	24.7	0.0	0.0	0.0			
	444.0	68370.0	1497.0	21.3	0.0	0.0	0.0			
	454.0	60160.0	1406.0	17.9	0.0	0.0	0.0			
	464.0	52030.0	1305.0	14.1	0.0	0.0	0.0			
	474.0	46810.0	1174.0	9.1	0.0	0.0	0.0			
	484.0	44560.0	1048.0	5.0	0.0	0.0	0.0			
	494.0	43010.0	962.0	5.0	0.0	0.0	0.0			
	504.0	41040.0	918.0	5.0	0.0	0.0	0.0			
	514.0	38350.0	903.7	5.0	0.0	0.0	0.0			
	524.0	35080.0	899.5	5.0	0.0	0.0	0.0			
	534.0	31520.0	895.7	5.0	0.0	0.0	0.0			
	544.0	27860.0	886.6	5.2	0.0	0.0	0.0			
	554.0	24560.0	861.2	5.5	0.0	0.0	0.0			
	564.0	22190.0	814.4	6.1	0.0	0.0	0.0			
	574.0	21140.0	745.9	6.8	0.0	0.0	0.0			
	584.0	21440.0	658.3	7.6	0.0	0.0	0.0			
	594.0	22600.0	556.6	8.0	0.0	0.0	0.0			
	604.0	23570.0	467.9	8.0	0.0	0.0	0.0			
	624.0	22310.0	504.1	8.0	0.0	0.0	0.0			
51	638.0	19910.0	596.4	8.0	0.0	0.0	0.0			9
52	1 1	6.00	24.00	1.00	1.00	0.50	0.50	2		
53										
54	5	2.00	6.00	0.30	0.30					
55	0.40	0.50	0.10	0.01	0.02	0.50	0.60	0.02	0.05	
55	0.01	0.01	0.01	0.01	0.01	0.01	0.50	1.00		

Figure 4-3. Card Images of Input to Sample Problem No. 1 (Continued)

```
TPS - CORRUGATIONS


PROGRAM OPTIONS USED
   CONFIGURATION-      PLATE
   TURBULENT HEATING-  ECKERT
   WALL TEMPERATURE-   NONUNIFORM
   ANGLE OF ATTACK-    VARIED
   LOCAL HEAT FLUX-    CALCULATED


DIRECTION COSINES OF OUTER NORMAL FROM SURFACE
 THETA =   -0.0
   PHI =   -0.0

DISTANCE FROM LEADING EDGE       32.0000 FT
BODY DIAMETER                    32.0000 FT
SHOULDER RADIUS/BODY DIAMETER      .0100
EXTERNAL SURFACE EMISSIVITY        .85

INITIAL TIME                         0.0 SEC
END TIME                           120.0 SEC
CALCULATION TIME INTERVAL             .5 SEC
PRINT OUT INTERVAL                  10.0 SEC



***** S T R E S S   I N P U T *****

        AS           R          HH             TS           TC          SL         SLS           BE
 6.000E+00   6.000E+00   4.000E-01   -0.             2.500E-02   2.400E+01   6.000E+00   -0.

       F07          UF         DST        EALL          CRN          BF         BFL           BL
 1.360E+05   1.400E+00   5.000E-03   5.000E-03   2.000E+01   -0.         -0.         -0.


***** M A T E R I A L   P R O P E R T I E S *****

MATERIAL NUMBER       -1-       -2-       -3-       -4-       -5-       -6-       -7-       -8-       -9-

ALLOWABLE TEMP. R  2110.000   650.000

EMISSIVITY            .850      .200

MATERIAL DENSITY    515.000   170.000


MATERIAL NUMBER       HEAT   CAPACITY        THERMAL  CONDUCTIVITY        YOUNGS MODULUS        THERMAL EXPANSION COEF
                      AX           AY          AX           AY           AX           AY           AX           AY

      1          5.400E+02   1.080E-01   5.400E+02   5.260E+00   5.400E+02   3.160E+07   5.400E+02   6.220E-06
                 0.          0.          6.600E+02   6.010E+00   6.600E+02   3.100E+07   6.600E+02   6.400E-06
                 0.          0.          8.600E+02   7.260E+00   8.600E+02   3.000E+07   8.600E+02   6.700E-06
```

Figure 4-4. Output of Sample Problem No. 1 - Input Data

	0.	0.	1.060E+03	8.500E+00	1.060E+03	2.875E+07	1.060E+03	7.000E-06
	0.	0.	1.260E+03	9.750E+00	1.260E+03	2.765E+07	1.260E+03	7.310E-06
	0.	0.	1.460E+03	1.099E+01	1.460E+03	2.620E+07	1.460E+03	7.620E-06
	0.	0.	1.660E+03	1.224E+01	1.660E+03	2.460E+07	1.660E+03	7.930E-06
	0.	0.	1.860E+03	1.349E+01	1.860E+03	2.275E+07	1.860E+03	8.230E-06
	0.	0.	0.	0.	0.	0.	0.	0.
2	5.400E+02	2.400E-01	5.400E+02	7.000E+01	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

MATERIAL NUMBER	YIELD STRENGTH		ULT TENSILE STRENGTH		LARSON-MILLER STRAIN 1		LARSON-MILLER STRAIN 2	
	AX	AY	AX	AY	AX	AY	AX	AY
1	5.400E+02	1.350E+05	5.400E+02	1.650E+05	6.000E+03	4.725E+04	6.000E+03	4.805E+04
	6.600E+02	1.330E+05	6.600E+02	1.620E+05	1.000E+04	4.600E+04	1.000E+04	4.670E+04
	8.600E+02	1.310E+05	8.600E+02	1.560E+05	2.000E+04	4.415E+04	2.000E+04	4.470E+04
	1.060E+03	1.310E+05	1.060E+03	1.530E+05	3.000E+04	4.290E+04	3.000E+04	4.335E+04
	1.260E+03	1.310E+05	1.260E+03	1.510E+05	5.000F+04	4.105E+04	5.000E+04	4.145E+04
	1.460E+03	1.310E+05	1.460E+03	1.510E+05	7.000E+04	3.960E+04	7.000E+04	3.990E+04
	1.660E+03	1.300E+05	1.660E+03	1.480E+05	9.000E+04	3.800E+04	9.000E+04	3.830E+04
	1.860E+03	1.090E+05	1.860E+03	1.260E+05	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

MATERIAL NUMBER	ULT COMPRESSIVE STRENGTH		ULT SHEAR STRENGTH		SHEAR MODULUS	
	AX	AY	AX	AY	AX	AY
1	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.

Figure 4-4. Output of Sample Problem No. 1 - Input Data (Cont.)

```
          0.          0.          0.          0.          0.          0.
          0.          0.          0.          0.          0.          0.
          0.          0.          0.          0.          0.          0.


***** C O N D U C T I O N   I N P U T *****

COLUMN NUMBER, I           -1-     -2-     -3-     -4-     -5-     -6-     -7-     -8-     -9-
WIDTH, X(I) IN            .0280   .0280   .0280   .0280   .0280   .0280   .0280   .0280   .0280
HEATING FACTORS
  LAMINAR                  2.0     1.8     1.3     1.1     1.0      .9      .8      .8      .7
  TURBULENT                2.0     1.8     1.3     1.1     1.0      .9      .8      .8      .7

SEG.NO., J =    -1-        1*       1       1       1       1       1       1       1       1
THICK.,Y(J) =  .0021      490**    490     490     490     490     490     490     490     490

                -2-        0        0       0       0       0       0       0       0       0
              1.0000      490      490     490     490     490     490     490     490     490

                -3-        2        2       2       2       2       2       2       2       2
               .0125      168      168     168     168     168     168     168     168     168
---------------------------------------------------------------

    --NOTE--
      * = MATERIAL NUMBER
     ** = INITIAL TEMPERATURE DEG R


***** R A D I A T I O N   I N T E R C H A N G E *****

SEG NO.  NI    INTERCHANGE NEIGHBORS AND VIEW FACTORS

 (11)    1    (13) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (21)    1    (23) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (31)    1    (33) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (41)    1    (43) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (51)    1    (53) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (61)    1    (63) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (71)    1    (73) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (81)    1    (83) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (91)    1    (93) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (13)    1    (11) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (23)    1    (21) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (33)    1    (31) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (43)    1    (41) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (53)    1    (51) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (63)    1    (61) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (73)    1    (71) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (83)    1    (81) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000
 (93)    1    (91) 1.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000 (-0)-0.000


***** F A T I G U E   I N P U T *****

     IPAD        KFLEX        NPAN       DT(1)        DT(2)        DT(3)        DT(4)         XL
      0            0            1      1.000E+02    4.000E+01    2.000E+01    1.000E+01    1.000E+02
```

Figure 4-4. Output of Sample Problem No. 1 - Input Data (Cont.)

REY	VU	QL	AMACH	TT	WER	D	VS
1.000E+07	8.000E+03	1.400E+03	6.000E+00	1.000E+06	1.000E+03	1.200E+01	1.000E+02
XI	**DVEH**	**YCL**	**DREF**	**AE**	**VJ**	**WEJ**	**VV**
2.000E+01	4.000E+01	-0.	-0.	3.000E+00	1.200E+03	2.000E+02	6.500E+02
TJ	**XJ**	**YP**	**HPAN**	**HC**	**AI**	**AIY**	**AW**
1.000E+04	1.000E+01	1.000E+01	1.300E-01	1.000E-02	1.000E-03	2.000E-03	5.000E-01
BW	**EP**	**TIMEF**	**C(1)**	**C(2)**	**C(3)**	**C(4)**	**RHO?**
2.000E+00	1.000E+07	-0.	2.546E+02	-6.272E+01	4.419E+00	-2.518E-02	1.800E+02

***** T R A J E C T O R Y   I N P U T *****

I	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)	XSTG(I)
1	0.	3.6800E+02	0.	0.	0.	1.0000E+09	1.6800E+02	-0.
2	4.0000E+01	9.6810E+03	4.9930E+02	0.	0.	1.0000E+09	1.6800E+02	-0.
3	8.0000E+01	4.1750E+04	1.2990E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
4	1.2000E+02	9.6470E+04	3.0630E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
5	1.6000E+02	1.6350E+05	5.9940E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
6	1.7400E+02	1.8650E+05	7.2340E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
7	1.8200E+02	1.9910E+05	7.9540E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
8	1.9050E+02	2.1100E+05	8.6810E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
9	1.9400E+02	2.1670E+05	9.0470E+03	0.	0.	1.0000E+09	1.6800E+02	-0.
10	1.9425E+02	2.1703E+05	9.0457E+03	4.0000E-01	0.	0.	0.	-0.
11	1.9900E+02	2.2340E+05	9.0210E+03	7.5000E+00	0.	0.	0.	-0.
12	2.0900E+02	2.3470E+05	8.9710E+03	2.2500E+01	0.	0.	0.	-0.
13	2.1900E+02	2.4330E+05	8.9270E+03	3.7500E+01	0.	0.	0.	-0.
14	2.2900E+02	2.4930E+05	8.8920E+03	5.2500E+01	0.	0.	0.	-0.
15	2.4400E+02	2.5300E+05	8.8560E+03	6.0000E+01	0.	0.	0.	-0.
16	2.6400E+02	2.4850E+05	8.8420E+03	6.0000E+01	0.	0.	0.	-0.
17	2.8400E+02	2.3320E+05	8.8490E+03	6.0000E+01	0.	0.	0.	-0.
18	3.0400E+02	2.0740E+05	8.8260E+03	6.0000E+01	0.	0.	0.	-0.
19	3.2400E+02	1.7250E+05	8.5930E+03	6.0000E+01	0.	0.	0.	-0.
20	3.4400E+02	1.3420E+05	7.4360E+03	6.0000E+01	0.	0.	0.	-0.
21	3.5400E+02	1.1860E+05	6.4500E+03	4.0700E+01	0.	0.	0.	-0.
22	3.6400E+02	1.0730E+05	5.6470E+03	3.1900E+01	0.	0.	0.	-0.
23	3.7400E+02	1.0050E+05	4.8990E+03	3.0500E+01	0.	0.	0.	-0.
24	3.8400E+02	9.7150E+04	4.1220E+03	3.5000E+01	0.	0.	0.	-0.
25	3.9400E+02	9.4390E+04	3.2550E+03	4.6200E+01	0.	0.	0.	-0.
26	4.0400E+02	9.1360E+04	2.4110E+03	4.4600E+01	0.	0.	0.	-0.
27	4.1400E+02	8.7450E+04	1.9710E+03	3.8100E+01	0.	0.	0.	-0.
. . .	. . . .	. . . .						
44	5.8400E+02	2.1440E+04	6.5830E+02	7.6000E+00	0.	0.	0.	-0.
45	5.9400E+02	2.2600E+04	5.5660E+02	8.0000E+00	0.	0.	0.	-0.
46	6.0400E+02	2.3570E+04	4.6790E+02	9.0000E+00	0.	0.	0.	-0.
47	6.2400E+02	2.2310E+04	5.0410E+02	8.0000E+00	0.	0.	0.	-0.
48	6.3800E+02	1.9910E+04	5.9640E+02	8.0000E+00	0.	0.	0.	-0.

***** E N D   O F   I N P U T *****

Figure 4-4. Output of Sample Problem No. 1 - Input Data (Cont.)

```
***** S T R E S S   A N A L Y S I S   N O T E *****

      T1MS        Y2MS        C3MS        C4MS        F5MS        F6MS        WBMS        DMAX        EMS         EMAX
 4.2280E+00  4.9884E+00  3.8061E+00  2.7838E-01  1.0000E+02  1.0000E+02  1.0000E+02  1.3051E-02  2.7838E-01  0.

***** E N D   O F   N O T E *****

    NUMBER OF TIME STEPS =          1                     CPTIME =      29.939

              TAU          AL          VI        AOFA          PI         AMI         AME         RYI          PE
       1.2000E+02  9.6470E+04  3.0630E+03  0.          2.7688E+01  3.0750E+00  3.0750E+00  3.8391E+05  2.7688E+01

          I           1           2           3           4           5           6           7           8           9

       Q(I)  4.6162E-01  4.2535E-01  3.0625E-01  2.7226E-01  2.4458E-01  2.3056E-01  2.0273E-01  2.0826E-01  1.8156E-01
    QNET(I)  2.5988E-01  2.2881E-01  1.0903E-01  8.5918E-02  5.5624E-02  5.1776E-02  2.1571E-02  3.3003E-02  5.5019E-03

 TEMP(I, 1)  8.4031E+02  8.3485E+02  8.3556E+02  8.2379E+02  8.2667E+02  8.1531E+02  8.1801E+02  8.1126E+02  8.1219E+02
 TEMP(I, 2)  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02  4.9000E+02 -2.1738+142  4.9000E+02  4.9000E+02 -1.2723+135
 TEMP(I, 3)  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02  1.6800E+02

          A          XX          ZZ           T          FT        FNET        EDOT         FTU         FCY           E

  7.768E-03   1.553E-01   2.011E-03   8.356E+02   8.635E+02   5.456E+02   0.          1.567E+05   1.312E+05   3.012E+07
  7.768E-03   4.656E-01   1.809E-02   8.348E+02   8.094E+02   5.172E+02   0.          1.568E+05   1.313E+05   3.013E+07
  7.768E-03   7.746E-01   5.021E-02   8.403E+02  -7.781E+02  -1.019E+03   0.          1.566E+05   1.312E+05   3.010E+07
  7.768E-03   1.082E+00   9.828E-02   8.348E+02  -2.282E+02  -3.918E+02   0.          1.568E+05   1.313E+05   3.013E+07
  7.768E-03   1.386E+00   1.622E-01   8.356E+02  -1.209E+03  -1.270E+03   0.          1.567E+05   1.312E+05   3.012E+07
  7.768E-03   1.687E+00   2.378E-01   8.238E+02   3.315E+02   3.920E+02   0.          1.571E+05   1.314E+05   3.018E+07
  7.768E-03   1.991E+00   3.017E-01   8.267E+02  -1.111E+03  -9.484E+02   0.          1.570E+05   1.313E+05   3.017E+07
  7.768E-03   2.298E+00   3.498E-01   8.153E+02   6.922E+02   9.330E+02   0.          1.573E+05   1.314E+05   3.022E+07
  7.768E-03   2.607E+00   3.819E-01   8.180E+02  -3.000E+02  -7.700E+00   0.          1.573E+05   1.314E+05   3.021E+07
  7.768E-03   2.917E+00   3.980E-01   8.113E+02   9.299E+02   1.248E+03   0.          1.575E+05   1.315E+05   3.024E+07
```

Figure 4-5. Output of Sample Problem No. 1 - Results of Thermal and Stress Analysis

```
PANEL MOMENT OF INERTIA =  1.000E-03 INCHES**4

FREQUENCY =   527.9 HZ

BOUNDARY LAYER NOISE =  121.2 DB - REYNOLDS NO. =   2.4163E+08, MACH NO. =   1.5544E+00
DYNAMIC PRESSURE =   5.0730E+02, VELOCITY =   1.4700E+03
ROCKET ENGINE NOISE =  125.8 DB - APPARENT NOISE SOURCE AT   61.0 FT
ABES NOISE =   77.6 DB
JET SCRUBBING NOISE =  131.4 DB

MAXIMUM BENDING STRESS =         546 PSI
MAXIMUM RMS DEFLECTION =      .00000 IN
BOUNDARY LAYER NOISE CRITICAL STRESS =   3.0028E+01 PSI
NO. OF STRESS REVERSALS =   7.3921E+05
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   3.3605E+04 PSI

MAXIMUM BENDING STRESS =         923 PSI
MAXIMUM RMS DEFLECTION =      .00001 IN
ROCKET ENGINE NOISE CRITICAL STRESS =  7.5678E+01 PSI
NO. OF STRESS REVERSALS =   1.9809E+05
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   4.2595E+04 PSI

MAXIMUM BENDING STRESS =           4 PSI
MAXIMUM RMS DEFLECTION =      .00000 IN
JET FLYBACK ENGINE NOISE CRITICAL STRESS =   2.0902E-03 PSI
NO. OF STRESS REVERSALS =   1.3997E+07
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   2.2849E+04 PSI

MAXIMUM BENDING STRESS =        1757 PSI
MAXIMUM RMS DEFLECTION =      .00002 IN
JET SCRUBBING NOISE CRITICAL STRESS =  2.2858E+02 PSI
NO. OF STRESS REVERSALS =   3.1217E+04
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   5.9659E+04 PSI

COMPOSITE CRITICAL STRESS =   2.4265E+02 PSI
NO. OF STRESS REVERSALS =   1.8266E+05
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   4.3234E+04 PSI

PANEL FLUTTER ANALYSIS - DESIGN POINT AT   7.4305E+01 SECONDS OF FLIGHT
YOUNGS MODULUS =   3.1500E+07, MACH NO. =   1.2029E+00
Q LOCAL/FCN(AMI) =   1.0037E+03, PHI =   4.0750E-01
***PANEL IS STABLE FOR FLUTTER
   PANEL EFFECTIVE THICKNESS =   2.2534E-01 IN.
   PANEL EFFECTIVE THICKNESS NECESSARY FOR FLUTTER STABILITY =   1.4849E-02 IN.
```

Figure 4-6. Ouptut of Sample Problem No. 1 - Results of Fatigue Analysis

```
***** W E I G H T - C O S T   I N P U T *****

     KINOP      LENGTH       WIDTH      DLPANL      OWPANL           A           B        ICOS
         1       6.000      24.000       1.000       1.000        .500        .500          -0

     KINDS       TINS1       TINS2       TINS3       PINS1       PINS2       PINS3      MATLID
         1      -0.000      -0.000      -0.000      -0.000      -0.000      -0.000           2

                       NRIBS       CHORD      RADIUS      TSKIN1      TSKIN2
                           5       2.000       6.000       0.000        .025

                 GBOLT      GNUTPL       GWASH       TCORN       TPOST      ODPOST
                  .400        .500        .100        .010        .020        .500

                       LTUBE       TTUBE       TFNG1       TBMLA       TBMSA
                        .600        .020        .050        .010        .010

                TDOUBC      TDOUBP      TPLATE       TSEAL      HBEAMA      WBEAMA
                  .010        .010        .010        .010        .500       1.000

***** E N D   O F   I N P U T *****
```

Figure 4-7. Output of Sample Problem No. 1 - Input to Weight/Cost Analysis

THERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA 384.0

CONFIGURATION PANEL TYPE 1, METALLIC, CORRUGATED
STRUCTURE TYPE 1, CRUCIFORM BEAMS, SIX EDGE POSTS

NOMINAL PANEL SIZE .5 X 2.0 FT
NOMINAL PANEL STANDOFF DISTANCE .5 IN

PRIMARY PANEL / STRUCTURE MATERIAL TYPE 2 TITANIUM

DESCRIP	QT	ACTUAL WEIGHT	MATL WEIGHT	STD HOURS	LABOR HOURS	LABOR RATE	OV-HD RATE	MATL $ PER LB	LABOR COST	OVERHD COST	FACTORY COST	MATERIAL COST	FABRICAT COST
PANEL													
CORRUGNS	1	.423	.791	1.0399	2.60	4.75	8.31	23.08	12.35	21.61	33.96	20.08	54.04
PANL ASSY	1	.423	.909	.3253	.81	4.75	8.31	0.00	3.86	6.76	10.62	0.00	10.62
STRUCTURE													
BEAM LN A	1	.021	.051	.6750	1.59	4.75	8.31	27.91	8.02	14.03	22.04	1.56	23.60
BEAM DOUB	1	.009	.018	.5673	1.42	4.75	8.31	27.88	6.74	11.79	18.53	.55	19.08
BEAM ASSY	1	.030	.069	.4293	1.07	4.75	8.31	0.00	5.10	8.92	14.02	0.00	14.02
BEAM SH A	1	.116	.224	1.0366	2.59	4.75	8.31	27.68	12.31	21.54	33.85	6.83	40.68
BEAM ASSY	1	.116	.224	.3072	.77	4.75	8.31	0.00	3.65	6.38	10.03	0.00	10.03
CORNER	4	.016	.053	1.0601	2.65	4.75	8.31	27.87	12.59	22.03	34.62	1.64	36.26
CORN PLT	1	.007	.019	.4655	1.16	4.75	8.31	27.90	5.53	9.67	15.20	.59	15.80
CORN PLT	1	.007	.019	.4617	1.15	4.75	8.31	27.90	5.48	9.59	15.08	.59	15.67
CORN DOUB	1	.002	.005	.4297	1.07	4.75	8.31	27.87	5.10	8.93	14.03	.17	14.20
CORN ASSY	1	.031	.097	.5545	1.39	4.75	8.31	0.00	6.59	11.52	18.11	0.00	18.11
POST CORN	2	.002	.010	1.7938	4.48	4.75	8.31	7.87	21.30	37.28	58.58	.09	58.67
PLUG	2	.014	.034	2.1046	5.26	4.75	8.31	7.87	24.99	43.74	68.73	.29	69.02
FLANGE	2	.021	.347	1.8353	4.59	4.75	8.31	7.38	21.79	38.14	59.93	2.81	62.75
POST ASSY	2	.036	.391	.4886	1.22	4.75	8.31	0.00	5.80	10.15	15.95	0.00	15.95
SEAL	1	.039	.090	.9488	2.37	4.75	8.31	27.87	11.27	19.72	30.98	2.76	33.74
STR ASSY	1	.427	1.064	2.7409	6.85	4.75	8.31	0.00	32.55	56.96	89.51	0.00	89.51
FASTENERS	20	.175	.192	0.0000	0.00	0.00	0.00	104.00	0.00	0.00	0.00	22.02	22.02

TOTAL ACTUAL WEIGHT	.67	LB
TOTAL MATERIAL WEIGHT	1.66	LB
TOTAL STANDARD HOURS	17.26	HR
TOTAL LABOR HOURS	43.16	HR
TOTAL LABOR COST	205.01	$
TOTAL OVERHEAD COST	358.77	$
TOTAL FACTORY COST	563.78	$
TOTAL MATERIAL COST	59.99	$
TOTAL FABRICATION COST	623.77	$
TOTAL ASSEMBLY COST	26.01	$
TOTAL MANUFACTURING COST	649.78	$
TPS COST	649.78	$/SQ FT
TPS WEIGHT	.67	LB/SQ FT
AVERAGE MATERIAL	36.08	$/LB
AVERAGE LABOR RATE	4.75	$/HR
AVERAGE OVERHEAD RATE	8.31	$/HR
AVERAGE FACTORY RATE	13.06	$/HR
AVERAGE MFG. RATE	14.45	$/HR
AVERAGE MFG. RATE	924.26	$/LB
AVERAGE MFG. REALIZATION	.40	
AVERAGE ASSEMBLY REALIZATION	.40	

FINAL ASSEMBLY COST

TASK	STD HOURS	TOTAL HOURS	LABOR RATE	OV-HD RATE	LABOR COST	OVERHD COST	ASSEMBLY COST
SETUP	.2649	.66	4.75	8.31	3.15	5.51	8.65
CLAMP	.3500	.87	4.75	8.31	4.16	7.27	11.43
INSPECT	.0060	.01	4.75	8.31	.07	.12	.19
DISASSY	.1200	.30	4.75	8.31	1.42	2.49	3.92
CLEAN	.0036	.01	4.75	8.31	.04	.07	.12
SECURE	.0460	.11	4.75	8.31	.55	.96	1.50
INSPECT	.0060	.01	4.75	8.31	.07	.12	.19

Figure 4-8. Output of Sample Problem No. 1 - Results of Weight/Cost Analysis

THERMAL PROTECTION SYSTEM COST SUMMARY

		COST $/SQ FT
THEORETICAL FIRST UNIT COST (TFU)	461.49	
NON RECURRING COST		
ED AND D		22248.04
TOOLING		1172.26
GROUND TEST HARDWARE		1730.58
FLIGHT TEST ARTICLES		922.98
FLIGHT TEST S AND RP		309.20

TOTAL NONRECURRING TPS COST		26383.05
RECURRING PRODUCTION COST		
SUSTAINING ENGINEERING	-	INCLUDED IN TFU
SUSTAINING TOOLING	-	INCLUDED IN TFU
PRODUCTION ARTICLES		461.49
TEST ARTICLE CONVERSION		139.45

TOTAL RECURRING PRODUCTION COST		599.93
RECURRING OPERATIONS COST		
REPLENISHMENT S AND RP		614.70

TOTAL RECURRING OPERATIONS COST		614.70
TOTAL TPS PROGRAM COSTS		27597.68
NUMBER OF PRODUCTION UNITS		1.0

Figure 4-9. Output of Sample Problem No. 1 - Results of Total Cost Analysis

```
RECORD
  1     SPACE SHUTTLE ORBITER RSI TPS - BOTTOM CENTERLINE
  1    1K. D. WHITEHEAD  AUGUST, 1972
  2       1    1    1    2    1    1    1    3    5   18    1    7    0   20    1    0    0    0    1    2
  3          0.        0.       50.       20.      0.01      0.8       0.
  4          0.        5.       20.      100.
  5       1.      10.      0.5       0.05      .05    24.        24.      0.5
  6      1.36E5     1.4      .005       .01       20.       .3      1.5    .1875
  7     +2.0      +00 +4.0505 +09 +1.99     +04 +0.30     +00            12.            27.8
  8      RSI ANALYSIS
 9A     10000.     10000.     10000.      15.       10.          100.
 9B       0.8        0.8      129.06       1.5       100.         1.0
 9C       0.         1.0        1.0        1.0        1.0
 10       8    2    2    0    2    2    0
 11        0.0        1.0      10000.        1.
 12        0.0        1.0      10000.        1.
13B1      3    3   14.7       .147      .00147
13B2      360.      3.2E-2    1.9E-2    6.1E-3
  |      1460.      7.2E-2    5.0E-2    2.5E-2
13B2     2460.      1.6E-1    1.4E-1    1.0E-1
 14       250.        0.1      2500.        0.3
 15     +2200.0 +00 +9.0      -04 +8000.0 +00 +9.0      -04
 16       3    9    2.1
16A
 17       3.        3.         3.
 18       2    2    2    2    2    2
 19       MATERIAL PROPERTIES FOR RTV BONDLINE
 20       250.       0.234      1250.       0.162
 21       250.       0.268      1250.       0.35
 19      MATERIAL PROPERTIES FOR SUBSTRATE
 20      160.       35.        1160.       35.
 21      160.       0.08       1160.      0.38
 19      MATERIAL PROPERTIES FOR INSULATION
 20       250.       0.02       2460.       0.2
 21       250.       0.18       2460.       0.272
 22       88.6      0.3        0.8        0.8        161.4        0.6
 22      .6         0.8        6.         1.          0.8          0.8
 23        0.       0.         0.         0.
 23        0.       0.         0.         0.
 24      PROPERTIES OF BACKFACE ENVIRONMENT
 25       530.      0.          0.5        1.
 26      INITIAL TEMPERATURE DISTRIBUTION
 27       0.0       530.
 29       9
 30           0.0          0.0         342.9       1400.0        617.2       2400.0
 30         791.0       3000.0        1113.0       4000.0       1500.0       4336.0
 30        2300.0       6078.0        3200.0       7050.0       3900.0       8120.0
 31       1    8   40                   .446
 32      10000.  10000.  10000.  10000.  10000.
 33        .85     .85     .85     .85     .85
 34       135.     15.     87.    300.     30.
 35                        2    9    1    9    1    9    1    9    2    9    1    9
 35
 36       540.     660.     860.    1060.    1260.    1310.    1360.    1410.    1460.
 37     16.00E6  15.36E6  13.92E6  13.12E6  11.87E6  11.52E6  10.96E6   9.92E6   8.00E6
 37    05.22E-6  5.25E-6  5.80E-6  5.80E-6  5.80E-6  5.80E-6  5.80E-6  5.80E-6  5.80E-6
 37     126.0E3  113.4E3  97.02E3  85.68E3  79.38E3  74.65E3  69.93E3  65.21E3  60.48E3
 37     134.0E3  120.6E3  107.2E3  99.83E3  89.78E3  85.43E3  81.07E3  76.72E3  72.36E3
```

Figure 4-10. Card Images of Input to Sample Problem No. 2

```
RECORD
36       10000.  20000.  30000.  40000.  50000.  60000.  70000.  80000.  90000.
37       35000.  33400.  32250.  31400.  30550.  29700.  28830.  28000.  27100.
37       34250.  32500.  31400.  30550.  29800.  29100.  28350.  27600.  26650.
35                         2   9   1   9                                           2   2
35         1   2
36         540.    660.    860.   1060.   1260.   1310.   1360.   1410.   1460.
37      16.00E6 15.36E6 13.92E6 13.12E6 11.87E6 11.52E6 10.96E6  9.92E6  8.00E6
37      05.22E-6 5.25E-6 5.80E-6 5.80E-6 5.80E-6 5.80E-6 5.80E-6 5.80E-6 5.80E-6
36         540.   1460.
37         500.    500.
37       7.90E6  7.90E6
35                         2   2   1   2           2   2                           2   2
35         1   2
36         540.   1460.
37         300.    300.
37      011.5E-5 11.5E-5
36         540.   1460.
37         500.    500.
36         540.   1460.
37         500.    500.
37       1.20E2  1.20E2
35                         2   2   1   2           2   2                   2   2
35         2   2
36         540.   1460.
37       2.00E4  2.00E4
37      3.00E-7 3.00E-7
36         540.   1460.
37         500.    500.
36         540.   1460.
37         500.    500.
36         540.   1460.
37       8.00E3  8.00E3
35                         2   2   1   2           2   2                   2   2
35
36         540.   1460.
37       2.00E4  2.00E4
37      3.00E-7 3.00E-7
36         540.   1460.
37         500.    500.
36         540.   1460.
37         500.    500.
41           1.
44         4   1   2   3   4   0   1   2
45        100.0   100.0   1.0E7  8000.0  1400.0     6.0
46         40.0   1.0E6  1000.0    12.0   100.0    20.0    40.0
47         20.0     3.0  1200.0   200.0   650.0   1.0E4    10.0    10.0
48         10.0
49           .5     .45     .02             2.1     2.1   1.0E7
50         35.2    -4.8     0.0     0.0     6.0
51           0. 400000.  25115.     30.
|          250. 245017.  25084.     30.
|      .........
v         1500.  49072.    867.      7.
51        2100.      0.    395.      7.                                               1
52         4   1     30.     18.      .4      .1     .35     .25   2
53        88.6    6.0             0.3      1.0
54-4         1.      .5     .01     1.5     15.
55-1         .4      .5      .1    .012     .02      .5      .6     .02     .05
55-1        .01     .01     .01     .02     .02     .01      .5      1.
```

Figure 4-10. Card Images of Input to Sample Problem No. 2 (Continued)

```
SPACE SHUTTLE ORBITER RSI TPS - BOTTOM CENTERLINE
K. D. WHITEHEAD  AUGUST, 1972


   PROGRAM OPTIONS USED
      CONFIGURATION-       PLATE
      TURBULENT HEATING- SPALDING-CHI
      WALL TEMPERATURE-  UNIFORM
      ANGLE OF ATTACK-   VARIED
      LOCAL HEAT FLUX-   CALCULATED


   DIRECTION COSINES OF OUTER NORMAL FROM SURFACE
    THETA =    0.0
      PHI =    0.0

   DISTANCE FROM LEADING EDGE        50.0000 FT
   BODY DIAMETER                     20.0000 FT
   SHOULDER RADIUS/BODY DIAMETER       .0100
   EXTERNAL SURFACE EMISSIVITY         .80

   INITIAL TIME                          0.0 SEC
   END TIME                            100.0 SEC
   CALCULATION TIME INTERVAL             5.0 SEC
   PRINT OUT INTERVAL                   20.0 SEC


***** S T R E S S   I N P U T *****

         AS            R           HH           TF           TC           SL          SLS           BE
  1.000E+00    1.000E+01    5.000E-01    5.000E-02    5.000E-02    2.400E+01    2.400E+01    5.000E-01

        F07           UF          DST         EALL          CRN           TB           TR           DC
  1.360E+05    1.400E+00    5.000E-03    1.000E-02    2.000E+01    3.000E-01    1.500E+00    1.075E-01


***** A B L A T I O N   I N P U T *****

   ARRHENIUS EQUATION IS USED.
   N=   2.0000000E+00     A=    4.0505000E+03     B=    1.9900000E+04

   CPGAS=    3.0000000E-01     XMC=    1.2000000E+01     XMF=    2.7600000E+01


  RSI ANALYSIS

 TABL= 1.00000E+04  TCHAR= 1.00000E+04   TREC= 1.00000E+04   RHOV= 1.50000E+01   RHOC= 1.00000E+01
TBLOW= 1.00000E+02    EMV= 8.00000E-01    EMC= 8.00000E-01   H300= 1.29060E+02     VL= 1.50000E+00
   HV= 1.00000E+12     FV= 1.00000E+00     TV= 0.           CHARK= 1.00000E+00  CHARC= 1.00000E+00
 ABLK= 1.00000E+00   ABLC= 1.00000E+00
```

Figure 4-11. Output of Sample Problem No. 2 - Input Data

```
NP=   6   NKC=   2   NCPC=   2   NKV=   0   NCPV=   2   NREC=   2   IQBLCK=   0   NTKV=   3   NPKV=   3

                              VIRGIN MATERIAL

PRESSURE          1.47000E+01    1.47000E-01    1.47000E-03

TEMPERATURE       THERMAL CONDUCTIVITY
3.60000E+02       3.20000E-02    1.90000E-02    6.10000E-03
1.46000E+03       7.20000E-02    5.00000E-02    2.50000E-02
2.46000E+03       1.60000E-01    1.40000E-01    1.00000E-01

                                      SPECIFIC
                       TEMPERATURE      HEAT
                       2.50000E+02    1.00000E-01
                       2.50000E+03    3.00000E-01

                                CHAR  MATERIAL
                 THERMAL                                       SPECIFIC
TEMPERATURE    CONDUCTIVITY                      TEMPERATURE     HEAT
0.              1.00000E+00                      0.            1.00000E+00
1.00000E+04     1.00000E+00                      1.00000E+04   1.00000E+00

                           SURFACE RECESSION TABLE

                       TEMPERATURE      SR - IN/SEC
                       2.20000E+03    9.00000E-04
                       8.00000E+03    9.00000E-04

            PROPERTIES OF BACKUP STRUCTURE

 NO. OF MATERIALS IN BACK-UP SHIELD=    3
 TOTAL NUMBER OF NODES IN BACK-UP SHIELD=    9
 THICKNESS OF BACK-UP SHIELD= 2.10000E+00

MATERIAL PROPERTIES FOR RTV BONDLINE

                 THERMAL                                       SPECIFIC
TEMPERATURE    CONDUCTIVITY                      TEMPERATURE     HEAT
2.50000E+02     2.34000E-01                      2.50000E+02   2.68000E-01
1.25000E+03     1.62000E-01                      1.25000E+03   3.50000E-01

MATERIAL PROPERTIES FOR SUBSTRATE

                 THERMAL                                       SPECIFIC
TEMPERATURE    CONDUCTIVITY                      TEMPERATURE     HEAT
1.60000E+02     3.50000E+01                      1.60000E+02   3.00000E-02
1.16000E+03     3.50000E+01                      1.16000E+03   3.80000E-01

MATERIAL PROPERTIES FOR INSULATION

                 THERMAL                                       SPECIFIC
```

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

TEMPERATURE	CONDUCTIVITY
2.50000E+02	2.00000E-02
2.46000E+03	2.00000E-01

TEMPERATURE	HEAT
2.50000E+02	1.80000E-01
2.46000E+03	2.72000E-01

MATERIAL	DENSITY	THICKNESS	EMISSIVITY FRONT	EMISSIVITY BACK	NODES/MATERIAL
1	8.8600E+01	3.0000E-01	8.0000E-01	8.0000E-01	3.0000E+00
2	1.6140E+02	6.0000E-01	8.0000E-01	8.0000E-01	3.0000E+00
3	6.0000E+00	1.0000E+00	8.0000E-01	8.0000E-01	3.0000E+00

ADDITIONAL DATA FOR INDIVIDUAL MATERIALS IN BACKUP STRUCTURE

MATERIAL	FILM COEFFICIENT	GAP THICKNESS	FTEST	BTEST
1	0.	0.	0.	0.
2	*.	*.	0.	0.
3	0.	0.	-0.	-0.

PROPERTIES OF BACKFACE ENVIRONMENT

TEMPERATURE= 5.30000E+02 FILM COEFFICIENT= 0. VIEW FACTOR= 5.00000E-01 Q LOST= 1.00000E+00

INITIAL TEMPERATURE DISTRIBUTION

TEMPERATURE DISTRIBUTION IN HEAT SHIELD IS UNIFORM AND EQUAL TO 5.3000E+02

***** R S I INPUT *****

IPRINT	NC	NH	NLC	NV	PZ	VB
1	8	40	1	7	-0.	4.460E-01

***** M A T E R I A L P R O P E R T I E S *****

MATERIAL NUMBER	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
ALLOWABLE TEMP. R	10000.000	10000.000	10000.000	10000.000	10000.000				
EMISSIVITY	.850	.850	.850	.850	.850				
MATERIAL DENSITY	135.000	15.000	87.000	300.000	30.000				

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

MATERIAL NUMBER	HEAT CAPACITY AX	AY	THERMAL CONDUCTIVITY AX	AY	YOUNGS MODULUS AX	AY	THERMAL EXPANSION COEF AX	AY
1	0.	0.	0.	0.	5.400E+02	1.600E+07	5.400E+02	5.220E-06
	0.	0.	0.	0.	6.600E+02	1.536E+07	6.600E+02	5.250E-06
	0.	0.	0.	0.	8.600E+02	1.392E+07	8.600E+02	5.800E-06
	0.	0.	0.	0.	1.060E+03	1.312E+07	1.060E+03	5.800E-06
	0.	0.	0.	0.	1.260E+03	1.187E+07	1.260E+03	5.800E-06
	0.	0.	0.	0.	1.310E+03	1.152E+07	1.310E+03	5.800E-06
	0.	0.	0.	0.	1.360E+03	1.096E+07	1.360E+03	5.800E-06
	0.	0.	0.	0.	1.410E+03	9.920E+06	1.410E+03	5.800E-06
	0.	0.	0.	0.	1.460E+03	8.000E+06	1.460E+03	5.800E-06
2	0.	0.	0.	0.	5.400E+02	1.600E+07	5.400E+02	5.220E-06
	0.	0.	0.	0.	6.600E+02	1.536E+07	6.600E+02	5.250E-06
	0.	0.	0.	0.	8.600E+02	1.392E+07	8.600E+02	5.800E-06
	0.	0.	0.	0.	1.060E+03	1.312E+07	1.060E+03	5.800E-06
	0.	0.	0.	0.	1.260E+03	1.187E+07	1.260E+03	5.800E-06
	0.	0.	0.	0.	1.310E+03	1.152E+07	1.310E+03	5.800E-06
	0.	0.	0.	0.	1.360E+03	1.096E+07	1.360E+03	5.800E-06
	0.	0.	0.	0.	1.410E+03	9.920E+06	1.410E+03	5.800E-06
	0.	0.	0.	0.	1.460E+03	8.000E+06	1.460E+03	5.800E-06
3	0.	0.	0.	0.	5.400E+02	3.000E+02	5.400E+02	1.150E-04
	0.	0.	0.	0.	1.460E+03	3.000E+02	1.460E+03	1.150E-04
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	5.400E+02	2.000E+04	5.400E+02	3.000E-07
	0.	0.	0.	0.	1.460E+03	2.000E+04	1.460E+03	3.000E-07
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	5.400E+02	2.000E+04	5.400E+02	3.000E-07
	0.	0.	0.	0.	1.460E+03	2.000E+04	1.460E+03	3.000E-07
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

MATERIAL NUMBER	YIELD STRENGTH AX	AY	ULT TENSILE STRENGTH AX	AY	LARSON-MILLER STRAIN 1 AX	AY	LARSON-MILLER STRAIN 2 AX	AY
1	5.400E+02	1.260E+05	5.400E+02	1.340E+05	1.000E+04	3.500E+04	1.000E+04	3.425E+04
	6.600E+02	1.134E+05	6.600E+02	1.206E+05	2.000E+04	3.340E+04	2.000E+04	3.250E+04
	8.600E+02	9.702E+04	8.600E+02	1.072E+05	3.000E+04	3.225E+04	3.000E+04	3.140E+04
	1.060E+03	8.568E+04	1.060E+03	9.983E+04	4.000E+04	3.140E+04	4.000E+04	3.055E+04

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

	1.260E+03	7.938E+04	1.260E+03	8.976E+04	5.000E+04	3.055E+04	5.000E+04	2.980E+04
	1.310E+03	7.465E+04	1.310E+03	8.543E+04	6.000E+04	2.970E+04	6.000E+04	2.910E+04
	1.360E+03	6.993E+04	1.360E+03	8.107E+04	7.000E+04	2.883E+04	7.000E+04	2.835E+04
	1.410E+03	6.521E+04	1.410E+03	7.672E+04	8.000E+04	2.800E+04	8.000E+04	2.760E+04
	1.460E+03	6.048E+04	1.460E+03	7.236E+04	9.000E+04	2.710E+04	9.000E+04	2.665E+04
2	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
3	0.	0.	5.400E+02	5.000E+02	0.	0.	0.	0.
	0.	0.	1.460E+03	5.000E+02	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
4	0.	0.	5.400E+02	5.000E+02	0.	0.	0.	0.
	0.	0.	1.460E+03	5.000E+02	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
5	0.	0.	5.400E+02	5.000E+02	0.	0.	0.	0.
	0.	0.	1.460E+03	5.000E+02	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.

MATERIAL NUMBER	ULT COMPRESSIVE STRENGTH AX	AY	ULT SHEAR STRENGTH AX	AY	SHEAR MODULUS AX	AY
1	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
2	0.	0.	5.400E+02	5.000E+02	5.400E+02	7.900E+06
	0.	0.	1.460E+03	5.000E+02	1.460E+03	7.900E+06

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
3	0.	0.	5.400E+02	5.000E+02	5.400E+02	1.200E+02
	0.	0.	1.460E+03	5.000E+02	1.460E+03	1.200E+02
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
4	5.400E+02	5.000E+02	0.	0.	5.400E+02	8.000E+03
	1.460E+03	5.000E+02	0.	0.	1.460E+03	8.000E+03
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
5	5.400E+02	5.000E+02	0.	0.	0.	0.
	1.460E+03	5.000E+02	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.

***** C O N D U C T I O N   I N P U T *****

COLUMN-NUMBER, I	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
WIDTH, X(I) IN	1.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
HEATING FACTORS									
LAMINAR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TURBULENT	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

***** F A T I G U E   I N P U T *****

IPAD	KFLEX	NPAN	DT(1)	DT(2)	DT(3)	DT(4)	XL
0	1	2	1.000E+02	4.000E+01	2.000E+01	1.000E+01	1.000E+02
REY	**VU**	**QL**	**AMACH**	**TT**	**WER**	**O**	**VS**
1.000E+07	8.000E+03	1.400E+03	6.000E+00	1.000E+06	1.000E+03	1.200E+01	1.000E+02
XI	**DVEH**	**YCL**	**DREF**	**AE**	**VJ**	**WEJ**	**VV**
2.000E+01	4.000E+01	-0.	-0.	3.000E+00	1.200E+03	2.000E+02	6.500E+02

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

TJ	XJ	YP	HPAN	HC	AI	AIY	AW
1.000E+04	1.000E+01	1.000E+01	5.000E-01	4.500E-01	2.000E-02	-0.	2.100E+00

BW	EP	TIMEF	C(1)	C(2)	C(3)	C(4)	RHOP
2.100E+00	1.000E+07	-0.	3.520E+01	-4.800E+00	0.	0.	6.000E+00

***** T R A J E C T O R Y   I N P U T *****

I	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)	XSTG(I)
1	0.	4.0000E+05	2.5115E+04	3.0000E+01	-0.	-0.	-0.	-0.
2	2.5000E+02	2.4502E+05	2.5084E+04	3.0000E+01	-0.	-0.	-0.	-0.
3	3.0000E+02	2.2556E+05	2.4527E+04	3.0000E+01	-0.	-0.	-0.	-0.
4	4.0000E+02	2.1736E+05	2.2846E+04	3.0000E+01	-0.	-0.	-0.	-0.
5	5.0000E+02	2.1355E+05	2.1113E+04	3.0000E+01	-0.	-0.	-0.	-0.
6	9.0000E+02	1.6064E+05	1.3529E+04	3.0000E+01	-0.	-0.	-0.	-0.
7	1.2000E+03	1.3293E+05	5.8060E+03	2.9000E+01	-0.	-0.	-0.	-0.
8	1.3000E+03	1.0542E+05	3.4620E+03	2.1000E+01	-0.	-0.	-0.	-0.
9	1.4000E+03	5.2991E+04	2.1690E+03	1.6000E+01	-0.	-0.	-0.	-0.
10	1.5000E+03	4.9072E+04	8.6700E+02	7.0000E+00	-0.	-0.	-0.	-0.
11	2.1000E+03	0.	3.9500E+02	7.0000E+00	-0.	-0.	-0.	-0.

***** E N D   O F   I N P U T *****

Figure 4-11. Output of Sample Problem No. 2 - Input Data (Cont.)

```
TIME= 1.75000E+01               VELOCITY= 2.51128E+04          QIN= 9.10511E-02
GAS ABLATION RATE= 0.           CHAR ABLATION RATE= 0.         TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.             QBLOCK= 0.                     Q HOT WALL= 1.39328E-01
HTX= 0.                         HW= 0.                         Z= 0.

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  2.00000E+01 SECONDS

   TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL
```

X	TEMPERATURE	THETA	M DOT
0.00000	612.5	1.0000	0.
.21429	539.9	1.0000	0.
.42857	531.0	1.0000	0.
.64286	530.1	1.0000	0.
.85714	530.0	1.0000	0.
1.07143	530.0	1.0000	0.
1.28571	530.0	1.0000	0.
1.50000	530.0	1.0000	0.

```
TIME= 9.75000E+01               VELOCITY= 2.51029E+04          QIN= 1.91526E-01
GAS ABLATION RATE= 0.           CHAR ABLATION RATE= 0.         TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.             QBLOCK= 0.                     Q HOT WALL= 4.06368E-01
HTX= 0.                         HW= 0.                         Z= 0.

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  1.00000E+02 SECONDS

   TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL
```

X	TEMPERATURE	THETA	M DOT
0.00000	883.9	1.0000	0.
.21429	652.8	1.0000	0.
.42857	564.5	1.0000	0.
.64286	538.2	1.0000	0.
.85714	531.7	1.0000	0.
1.07143	530.3	1.0000	0.
1.28571	530.1	1.0000	0.
1.50000	530.0	1.0000	0.

Figure 4-12. Output of Sample Problem No. 2 - Results of Thermal Analysis

***** S T R E S S   A N A L Y S I S   N O T E *****

MSFT	MSFC	MSHS	MSIT	MSIC	MSCT	MSCC	DMAX	EMS	EMAX
3.4210E+03	6.1372E+03	2.7629E+04	2.6562E+03	1.8824E+02	1.0000E+02	1.8914E+02	-4.0966E-04	1.0300E+02	0.

***** E N D   O F   N O T E *****

NUMBER OF TIME STEPS = 0   CPTIME = 42.391

TAU	AL	VI	AOFA	PI	AMI	AME	RYI	PE
1.0000E+02	3.3956E+05	2.5103E+04	3.0000E+01	3.8962E-04	2.5362E+01	5.5138E+00	4.5005E+01	8.9019E-02

I	1	2	3	4	5	6	7	8	9
Q(I)	4.0637E-01	0.	0.	0.	0.	0.	0.	0.	0.
QNET(I)	0.	0.	0.	0.	0.	0.	0.	0.	0.
TEMP(I, 1)	8.8386E+02	6.5282E+02	5.6452E+02	5.3822E+02	5.3172E+02	5.3032E+02	5.3005E+02	5.3000E+02	5.3000E+02
TEMP(I, 2)	5.3000E+02	5.3000E+02	5.3000E+02	5.3000E+02	5.3000E+02	5.3000E+02	5.3000E+02	5.3000E+02	0.
TEMP(I, 3)	0.	0.	0.	0.	0.	0.	0.	0.	0.

A	XX	ZZ	T	FT	FNET	EDOT	FTU	FCY	E
5.000E-02	0.	2.425E+00	5.300E+02	-2.247E+01	-2.134E+01	0.	1.340E+05	1.260E+05	1.600E+07
0.	0.	2.150E+00	5.300E+02	2.970E+00	0.	0.	0.	0.	1.600E+07
5.000E-02	0.	1.875E+00	5.300E+02	2.841E+01	2.797E+01	0.	1.340E+05	1.260E+05	1.600E+07
0.	0.	1.700E+00	5.300E+02	8.266E-04	0.	0.	5.000E+02	0.	3.000E+02
1.071E-01	0.	1.496E+00	5.300E+02	7.928E-02	7.789E-02	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	1.336E+00	5.301E+02	9.755E-02	9.580E-02	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	1.121E+00	5.303E+02	1.207E-01	1.185E-01	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	9.071E-01	5.317E+02	1.371E-01	1.344E-01	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	6.929E-01	5.382E+02	1.229E-01	1.197E-01	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	4.786E-01	5.645E+02	-1.011E-02	-1.376E-02	0.	5.000E+02	0.	2.000E+04
2.143E-01	0.	2.643E-01	6.528E+02	-5.152E-01	-5.193E-01	0.	5.000E+02	0.	2.000E+04
1.071E-01	0.	1.036E-01	8.639E+02	-1.883E+00	-1.887E+00	0.	5.000E+02	0.	2.000E+04
5.000E-02	0.	2.500E-02	8.839E+02	-1.874E+00	-1.878E+00	0.	5.000E+02	0.	2.000E+04

EVALUATION OF MAXIMUM (AND MINIMUM) STRESSES

FVFT	FVFC	FVCT	FVCC	FSIM	FPIT	FPIC	FSCM	FSBM	FPRT	ZMAX
1.57E+01	-1.27E+01	0.	-1.88E+00	9.41E-01	2.05E-01	-1.88E+00	1.85E-01	1.77E-01	5.44E-02	-2.12E-04

Figure 4-13. Output of Sample Problem No. 2 - Results of Stress Analysis

```
PANEL MOMENT OF INERTIA =  2.000E-02 INCHES**4

FREQUENCY =    43.3 HZ

BOUNDARY LAYER NOISE =   28.9 DB - REYNOLDS NO. =   4.5005E+03, MACH NO. =   2.5362E+01
DYNAMIC PRESSURE =   1.7416E-01, VELOCITY =   2.5103E+04
ROCKET ENGINE NOISE =  132.3 DB - APPARENT NOISE SOURCE AT  113.9 FT
ABES NOISE =   72.6 DB
JET SCRUBBING NOISE =  133.8 DB

MAXIMUM BENDING STRESS =          0 PSI
MAXIMUM RMS DEFLECTION =     .00000 IN
BOUNDARY LAYER NOISE CRITICAL STRESS =   9.9219E-05 PSI
NO. OF STRESS REVERSALS =   1.1747E+07
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   1.2644E+03 PSI

MAXIMUM BENDING STRESS =      46184 PSI
MAXIMUM RMS DEFLECTION =     .04237 IN

APPLIED S-N CURVE EXCEEDS ALLOWABLE S-N CURVE.

PANEL FLUTTER ANALYSIS - DESIGN POINT AT   1.0000E+02 SECONDS OF FLIGHT
YOUNGS MODULUS =   3.7062E+06, MACH NO. =   2.5362E+01
Q LOCAL/FCN(AMI) =   6.6665E-03, PHI =   3.7000E-01
***PANEL IS STABLE FOR FLUTTER
   PANEL EFFECTIVE THICKNESS =   1.3103E-01 IN.
   PANEL EFFECTIVE THICKNESS NECESSARY FOR FLUTTER STABILITY =   2.1816E-03 IN.
```

Figure 4-14. Output of Sample Problem No. 2 - Results of Fatigue Analysis

```
***** W E I G H T - C O S T   I N P U T *****

     KINDP      LENGTH       WIDTH      OLPANL      DWPANL           A           B        ICOS
         4      30.000      18.000        .400        .100        .350        .250          -0

     KINDS       TINS1       TINS2       TINS3       PINS1       PINS2       PINS3      MATLID
         1        .300       1.000      -0.000      98.600       6.000      -0.000           2

          GINSRT       TCORE       TEDGE        TEXT        PEXT      TSKIN1      TSKIN2
           1.000        .500        .010       1.500      15.000        .050        .050

               GBOLT      GNUTPL       GWASH       TCORN       TPOST      ODPOST
                .400        .500        .100        .012        .020        .500

                    LTUBE       TTUBE       TFNG1       TBMLA       TBMSA
                     .660        .020        .350        .010        .010

               TDOUBC      TDOUBP      TPLATE       TSEAL      HBEAMA      WBEAMA
                 .010        .020        .020        .010        .500       1.000

***** E N D   O F   I N P U T *****
```

Figure 4-15. Output of Sample Problem No. 2 - Input to Weight/Cost Analysis

THERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA 600.0

CONFIGURATION PANEL TYPE 4, REUSABLE SURFACE INSULATION
STRUCTURE TYPE 1, CRUCIFORM BEAMS, SIX EDGE POSTS

NOMINAL PANEL SIZE 2.5 X 1.5 FT
NOMINAL PANEL STANDOFF DISTANCE 1.5 IN

PRIMARY PANEL / STRUCTURE MATERIAL TYPE 2 TITANIUM

DESCRIP	QT	ACTUAL WEIGHT	MATL WEIGHT	STD HOURS	LABOR HOURS	LABOR RATE	OV-HD RATE	MATL $ PER LB	LABOR COST	OVERHD COST	FACTORY COST	MATERIAL COST	FABRICAT COST
INSULATION													
INSUL1	1	8.306	9.844	.3221	.81	4.75	8.31	5.00	3.82	6.69	10.52	54.14	64.66
INSUL2	1	1.875	2.222	.3221	.81	4.75	8.31	5.00	3.82	6.69	10.52	12.22	22.74
INS ASSY	1	10.181	12.067	.3642	.91	4.75	8.31	0.00	4.32	7.57	11.89	0.00	11.89
PANEL													
EDGES	4	.312	.447	1.6152	4.04	4.75	8.31	27.88	19.18	33.57	52.75	13.72	66.47
CORE	1	1.211	2.332	10.3378	25.84	4.75	8.31	23.23	122.76	214.83	337.59	59.61	397.20
SKIN	1	4.182	4.794	2.1486	5.37	4.75	8.31	17.80	25.51	44.65	70.17	93.85	164.01
SKIN	1	4.107	4.938	1.0524	2.63	4.75	8.31	17.78	12.50	21.87	34.37	96.58	130.95
R S I	1	7.398	8.947	.3471	.87	4.75	8.31	0.00	4.12	7.21	11.33	0.00	11.33
PANL ASSY	1	17.209	21.460	1.2024	3.01	4.75	8.31	0.00	14.28	24.99	39.27	0.00	39.27

Figure 4-16. Output of Sample Problem No. 2 - Results of Weight/Cost Analysis

STRUCTURE													
BEAM LN A	1	.146	.282	1.2495	3.12	4.75	8.31	27.91	14.84	25.97	40.80	8.66	49.47
BEAM DOUB	1	.009	.018	.5673	1.42	4.75	8.31	27.88	6.74	11.79	18.53	.55	19.08
BEAM ASSY	1	.155	.309	.4345	1.09	4.75	8.31	0.00	5.16	9.03	14.19	0.00	14.19
BEAM SH A	1	.085	.165	.8931	2.23	4.75	8.31	27.91	10.61	18.56	29.17	5.11	34.27
BEAM ASSY	1	.085	.165	.3059	.76	4.75	8.31	0.00	3.63	6.36	9.99	0.00	9.99
CORNER	4	.018	.060	1.6601	2.65	4.75	8.31	27.49	12.59	22.03	34.62	1.83	36.45
CORN PLT	1	.014	.032	.4655	1.16	4.75	8.31	25.33	5.53	9.67	15.20	.90	16.10
CORN PLT	1	.014	.032	.4617	1.15	4.75	8.31	25.33	5.48	9.59	15.08	.90	15.98
CORN DOUB	1	.003	.009	.4298	1.07	4.75	8.31	25.30	5.10	8.93	14.03	.25	14.28
CORN ASSY	1	.049	.134	.5546	1.39	4.75	8.31	0.00	6.59	11.53	18.12	0.00	18.12
POST CORN	2	.012	.026	1.7968	4.49	4.75	8.31	7.88	21.34	37.34	58.68	.22	58.90
PLUG	2	.014	.034	2.1046	5.26	4.75	8.31	7.87	24.99	43.74	68.73	.29	69.02
FLANGE	2	.021	.347	1.8353	4.59	4.75	8.31	7.64	21.79	38.14	59.93	2.91	62.85
POST ASSY	2	.046	.407	.4886	1.22	4.75	8.31	0.00	5.80	10.15	15.95	0.00	15.95
SEAL	1	.025	.062	.8395	2.10	4.75	8.31	27.86	9.97	17.45	27.42	1.89	29.30
STR ASSY	1	.656	1.398	3.7960	9.49	4.75	8.31	0.00	45.08	78.89	123.96	0.00	123.96
FASTENERS	32	.299	.329	0.0000	0.00	0.00	0.00	104.00	0.00	0.00	0.00	37.63	37.63

TOTAL ACTUAL WEIGHT	27.75	LB
TOTAL MATERIAL WEIGHT	34.60	LB
TOTAL STANDARD HOURS	34.99	HR
TOTAL LABOR HOURS	87.49	HR
TOTAL LABOR COST	415.56	$
TOTAL OVERHEAD COST	727.23	$
TOTAL FACTORY COST	1142.79	$
TOTAL MATERIAL COST	391.27	$
TOTAL FABRICATION COST	1534.06	$
TOTAL ASSEMBLY COST	37.28	$
TOTAL MANUFACTURING COST	1571.34	$
TPS COST	419.02	$/SQ FT
TPS WEIGHT	7.40	LB/SQ FT
AVERAGE MATERIAL	11.31	$/LB
AVERAGE LABOR RATE	4.75	$/HR
AVERAGE OVERHEAD RATE	8.31	$/HR
AVERAGE FACTORY RATE	13.06	$/HR
AVERAGE MFG. RATE	17.53	$/HR
AVERAGE MFG. RATE	55.28	$/LB
AVERAGE MFG. REALIZATION	.40	
AVERAGE ASSEMBLY REALIZATION	.40	

FINAL ASSEMBLY COST

TASK	STD HOURS	TOTAL HOURS	LABOR RATE	OV-HD RATE	LABOR COST	OVERHD COST	ASSEMBLY COST
SETUP	.2719	.68	4.75	8.31	3.23	5.65	8.88
CLAMP	.5600	1.40	4.75	8.31	6.65	11.64	18.29
INSPECT	.0191	.05	4.75	8.31	.23	.40	.63
DISASSY	.1920	.48	4.75	8.31	2.28	3.99	6.27
CLEAN	.0058	.01	4.75	8.31	.07	.12	.19
SECURE	.0736	.18	4.75	8.31	.87	1.53	2.40
INSPECT	.0191	.05	4.75	8.31	.23	.40	.63

Figure 4-16. Output of Sample Problem No. 2 - Results of Weight/Cost Analysis (Cont.)

```
THERMAL PROTECTION SYSTEM   COST SUMMARY

                                         COST $/SQ FT

THEORETICAL FIRST UNIT COST (TFU)13687.22

NON RECURRING COST

ED AND D                                   120559.94
TOOLING                                     10574.01
GROUND TEST HARDWARE                        51327.08
FLIGHT TEST ARTICLES                        27374.44
FLIGHT TEST S AND RP                         9170.44
                                           ---------
TOTAL NONRECURRING TPS COST                219005.91

RECURRING PRODUCTION COST

SUSTAINING ENGINEERING         -      INCLUDED IN TFU
SUSTAINING TOOLING             -      INCLUDED IN TFU
PRODUCTION ARTICLES                         13687.22
TEST ARTICLE CONVERSION                      4106.17
                                            --------
TOTAL RECURRING PRODUCTION COST             17793.39

RECURRING OPERATIONS COST

REPLENISHMENT S AND RP                      18231.38
                                            --------
TOTAL RECURRING OPERATIONS COST             18231.36


TOTAL TPS PROGRAM COSTS                    255030.66



NUMBER OF PRODUCTION UNITS                    1.0
```

Figure 4-17. Output of Sample Problem No. 2 - Results of Total Cost Analysis

```
RECORD
  1    1   CONVERGENCE STUDY OF CHARRING ABLATOR--K. D. WHITEHEAD, 2-4-72
  2      1   3   4   1   2   1   1   3   2  18   1   8     100   1   1          1   1
  3          0       0       32      32       .01     .85
  4          0      .5       10      100
  5                          .05     .05      .05
  6
  7    +2.0     +00 +4.0505 +09 +1.99    +04 +0.30    +00             12.         27.8
  8       TYPICAL CHARRING ABLATION MATERIAL PROPERTIES
  9A   +9000.0 +00  9000.0 +00 +9000.0 +00 +15.0    +00 +10.0    +00 +400.00 +00
  9B   +0.65   +00 +1.00   +00 +129.06 +00 +1.00    +00 +250.0   +00 +1.0    +00
  9C   +0.0    +00 +0.12   +00 +0.43   +00 +0.070   +00 +0.43    +00
 10      5   2   2       7   2
 11    +1460.0 +00 +0.12   +00 +1.0    +04 +0.12    +00
 12    +1460.0 +00 +0.43   +00 +1.0    +04 +0.43    +00
 13B1     4    3   2.16E03   2.16E01   2.16E-1
 13B2    460.0     3.24E-2   1.91E-2   6.50E-3
 13B2    960.0     5.05E-2   3.06E-2   1.26E-2
 13B2   1460.0     7.20E-2   5.40E-2   2.48E-2
 13B2   1960.0     1.04E-1   7.92E-2   5.40E-2
 14       500.0       0.172       700.0       0.214       1000.0       0.25
 14      1500.0       0.28       2000.0       0.295       2500.0       0.3
 14      3000.0       0.3
 15    +2200.0 +00 +9.0    -04 +8000.0 +00 +9.0     -04
 16       1    3   +0.1    +00
 16A
 17    +3.0     +00
 18       9    2
 19       BACKUP MATERIAL IS 5026-39    0.1 INCHES THICK
 20    +360.0   +00 +0.065  +00 +460.0  +00 +0.065  +00 +560.0  +00 +0.0655 +00
 20    +660.0   +00 +0.066  +00 +760.0  +00 +0.0672 +00 +860.0  +00 +0.0684 +00
 20    +960.0   +00 +0.069  +00 +1060.0 +00 +0.07   +00 +1160.0 +00 +0.07   +00
 21    +360.00 +00 +0.43   +00 +1100.0 +00 +0.43    +00
 22    +34.0    +00 +0.1    +00 +0.9    +00 +0.9     +00
 23    +0.0     +00 +0.0    +00 +0.0    +00 +0.0     +00
 24     HEAT TRANSFER TO CABIN ENVIRONMENT - HENV=0.0
 25    +560.0   +00 +0.0    +00 +0.0    +00 +0.0     +00
 26     INITIAL TEMPERATURE IS CONSTANT
 27    +0.0     +00 +530.0  +00 +530.0  +00
 29       9
 30          0.0          0.0          342.9        1400.0        617.2        2400.0
 30        791.0       3000.0         1113.0        4000.0       1500.0        4336.0
 30       2300.0       6078.0         3200.0        7050.0       3900.0        8120.0
 38        1.
 39        1.
 40        1.
 44      4   1    2   3    4   0    1   2
 45      100.0    100.0   1.0E7   8000.0  1400.0     6.0
 46       40.0    1.0E6  1000.0     12.0   100.0    20.0    40.0
 47       20.0      3.0  1200.0    200.0   650.0   1.0E4    10.0    10.0
 48       10.0
 49         .5      .45     .02             2.1     2.1    1.0E7
 50       35.2     -4.8     0.0      0.0    6.0
 51         0.     2.01            25400.
 51   .........
 51     4000.     0.00               350.                                                 1
 52      5   1     30.      18.       .4      .1      .35      .25    2
 53
 54-5      1.      .33      .01      1.0     15.
 55-1      .4      .5       .1      .012     .02      .5       .6      .02      .05
 55-1     .01      .01      .01      .02     .02      .01      .5      1.
```

Figure 4-18. Card Images of Input to Sample Problem No. 3

```
CONVERGENCE STUDY OF CHARRING ABLATOR--K. D. WHITEHEAD, 2-4-72


PROGRAM OPTIONS USED
   CONFIGURATION-      PLATE
   TURBULENT HEATING-  ECKFRT
   WALL TEMPERATURE-   NONUNIFORM
   ANGLE OF ATTACK-    VARIED
   LOCAL HEAT FLUX-    INPUT Q- COLD WALL

DIRECTION COSINES OF OUTER NORMAL FROM SURFACE
 THETA =    0.0
   PHI =    0.0

DISTANCE FROM LEADING EDGE       32.0000 FT
BODY DIAMETER                    32.0000 FT
SHOULDER RADIUS/BODY DIAMETER      .0100
EXTERNAL SURFACE EMISSIVITY        .85

INITIAL TIME                         0.0 SEC
END TIME                           100.0 SEC
CALCULATION TIME INTERVAL             .5 SEC
PRINT OUT INTERVAL                  10.0 SEC


***** S T R E S S   I N P U T *****

        AS            R           HH           TS           TC           SL           SLS          BE
-0.          -0.          5.000E-02    5.000E-02    5.000E-02    -0.          -0.          -0.

       F07           UF          DST         EALL          CRN           BF           BFL          BL
-0.          -0.          -0.          -0.          -0.          -0.          -0.          -0.


***** A B L A T I O N   I N P U T *****

 ARRHENIUS EQUATION IS USED.
 N=   2.0000000E+00     A=   4.0505000E+09     B=   1.9900000E+04

 CPGAS=   3.0000000E-01     XMC=   1.2000000E+01     XMP=   2.7800000E+01


 TYPICAL CHARRING ABLATION MATERIAL PROPERTIES

 TABL= 9.00000E+03  TCHAR= 9.00000E+08  TREC= 9.00000E+03   RHOV= 1.50000E+01   RHOC= 1.00000E+01
TBLOW= 4.00000E+02    EMV= 6.50000E-01   EMC= 1.00000E+00   H30G= 1.29060E+02     VL= 1.00000E+00
   HV= 2.50000E+02     FV= 1.00000E+00    TV= 0.           CHARK= 1.20000E-01  CHARC= 4.30000E-01
 ABLK= 7.00000E-02   ABLC= 4.30000E-01
```

Figure 4-19. Output of Sample Problem No. 3 - Input Data

```
NP=   5    NKC=   2    NCPC=   2    NKV=  -0    NCPV=   7    NREC=   2    IQBLCK=  -0    NTKV=   4    NPKV=   3

                              VIRGIN MATERIAL

 PRESSURE          2.16000E+03    2.16000E+01    2.16000E-01

 TEMPERATURE       THERMAL CONDUCTIVITY
 4.60000E+02       3.24000E-02    1.91000E-02    6.50000E-03
 9.60000E+02       5.05000E-02    3.06000E-02    1.26000E-02
 1.46000E+03       7.20000E-02    5.40000E-02    2.48000E-02
 1.96000E+03       1.04000E-01    7.92000E-02    5.40000E-02

                                             SPECIFIC
                      TEMPERATURE              HEAT
                      5.00000E+02          1.72000E-01
                      7.00000E+02          2.14000E-01
                      1.00000E+03          2.50000E-01
                      1.50000E+03          2.80000E-01
                      2.00000E+03          2.95000E-01
                      2.50000E+03          3.00000E-01
                      3.00000E+03          3.00000E-01


                               CHAR  MATERIAL
                   THERMAL                                          SPECIFIC
 TEMPERATURE     CONDUCTIVITY                  TEMPERATURE            HEAT
 1.46000E+03      1.20000E-01                  1.46000E+03      4.30000E-01
 1.00000E+04      1.20000E-01                  1.00000E+04      4.30000E-01

                        SURFACE RECESSION TABLE

                      TEMPERATURE          SR - IN/SEC
                      2.20000E+03          9.00000E-04
                      8.00000E+03          9.00000E-04

        PROPERTIES OF BACKUP STRUCTURE

 NO. OF MATERIALS IN BACK-UP SHIELD=    1
 TOTAL NUMBER OF NODES IN BACK-UP SHIELD=    3
 THICKNESS OF BACK-UP SHIELD= 1.00000E-01


 BACKUP MATERIAL IS 5026-39     0.1 INCHES THICK

                   THERMAL                                          SPECIFIC
 TEMPERATURE     CONDUCTIVITY                  TEMPERATURE            HEAT
 3.60000E+02      6.50000E-02                  3.60000E+02      4.30000E-01
 4.60000E+02      6.50000E-02                  1.10000E+03      4.30000E-01
 5.60000E+02      6.55000E-02
 6.60000E+02      6.60000E-02
 7.60000E+02      6.72000E-02
 8.60000E+02      6.84000E-02
 9.60000E+02      6.90000E-02
 1.06000E+03      7.00000E-02
 1.16000E+03      7.00000E-02
```

Figure 4-19. Output of Sample Problem No. 3 - Input Data (Cont.)

MATERIAL	DENSITY	THICKNESS	EMISSIVITY FRONT	EMISSIVITY BACK	NODES/MATERIAL
1	3.4000E+01	1.0000E-01	9.0000E-01	5.0000E-01	3.0000E+00

ADDITIONAL DATA FOR INDIVIDUAL MATERIALS IN BACKUP STRUCTURE

MATERIAL	FILM COEFFICIENT	GAP THICKNESS	FTEST	PTEST
1	0.	0.	0.	0.

HEAT TRANSFER TO CABIN ENVIRONMENT - HENV=0.0

TEMPERATURE= 5.60000E+02 FILM COEFFICIENT= 0. VIEW FACTOR= 0. Q LOST= 0.

INITIAL TEMPERATURE IS CONSTANT

TEMPERATURE DISTRIBUTION IN HEAT SHIELD IS UNIFORM AND EQUAL TO 5.3000E+02

***** C O N D U C T I O N   I N P U T *****

COLUMN NUMBER, I	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
WIDTH, X(I) IN	1.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
HEATING FACTORS									
LAMINAR	1.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
TURBULENT	1.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0

***** F A T I G U E   I N P U T *****

IPAD	KFLEX	NPAN	DT(1)	DT(2)	DT(3)	DT(4)	XL
0	1	2	1.000E+02	4.000E+01	2.000E+01	1.000E+01	1.000E+02
REY	VU	QL	AMACH	TT	WER	D	VS
1.000E+07	8.000E+03	1.400E+03	6.000E+00	1.000E+06	1.000E+03	1.200E+01	1.000E+02
XI	DVEH	YCL	DREF	AE	VJ	WEJ	VV
2.000E+01	4.000E+01	-0.	-0.	3.000E+09	1.200E+03	2.000E+02	6.500E+02
TJ	XJ	YP	HPAN	HC	AI	AIY	AW
1.000E+04	1.000E+01	1.000E+01	5.000E-01	4.500E-01	2.000E-02	-0.	2.100E+00
BW	EP	TIMEF	C(1)	C(2)	C(3)	C(4)	RHOP
2.100E+00	1.000E+07	-0.	3.520E+01	-4.800E+00	0.	0.	6.000E+00

Figure 4-19. Output of Sample Problem No. 3 - Input Data (Cont.)

***** T R A J E C T O R Y   I N P U T *****

I	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)	XSTG(I)
1	0.	2.0100E+00	-0.	2.5400E+04	-0.	-0.	-0.	-0.
2	4.0000E+01	3.4700E+00	-0.	2.5500E+04	-0.	-0.	-0.	-0.
3	8.0000E+01	6.6500E+00	-0.	2.5550E+04	-0.	-0.	-0.	-0.
4	1.2000E+02	1.3620E+01	-0.	2.5550E+04	-0.	-0.	-0.	-0.
5	1.6000E+02	3.0490E+01	-0.	2.5450E+04	-0.	-0.	-0.	-0.
6	2.0000E+02	6.5550E+01	-0.	2.5300E+04	-0.	-0.	-0.	-0.
7	2.4000E+02	9.5520E+01	-0.	2.4650E+04	-0.	-0.	-0.	-0.
8	2.8000E+02	1.0745E+02	-0.	2.3500E+04	-0.	-0.	-0.	-0.
9	3.2000E+02	9.7780E+01	-0.	2.2000E+04	-0.	-0.	-0.	-0.
10	3.6000E+02	8.7500E+01	-0.	2.0000E+04	-0.	-0.	-0.	-0.
11	4.0000E+02	6.9280E+01	-0.	1.7700E+04	-0.	-0.	-0.	-0.
12	5.0000E+02	3.0160E+01	-0.	1.2200E+04	-0.	-0.	-0.	-0.
13	6.0000E+02	9.7200E+00	-0.	7.6000E+03	-0.	-0.	-0.	-0.
14	7.0000E+02	1.8600E+00	-0.	3.4000E+03	-0.	-0.	-0.	-0.
15	7.8000E+02	2.0000E-01	-0.	1.3000E+03	-0.	-0.	-0.	-0.
16	9.8000E+02	0.	-0.	9.5000E+02	-0.	-0.	-0.	-0.
17	1.8000E+03	0.	-0.	3.5000E+02	-0.	-0.	-0.	-0.
18	4.0000E+03	0.	-0.	3.5000E+02	-0.	-0.	-0.	-0.

***** E N D   O F   I N P U T *****

Figure 4-19. Output of Sample Problem No. 3 - Input Data (Cont.)

```
TIME= 9.97500E+01               VELOCITY= 2.55500E+04            CIN= 1.37817E+00
GAS ABLATION RATE= 0.           CHAR ABLATION RATE= 0.           TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.             OBLOCK= 0.                       C HOT WALL= 9.73603E+00
HTX= 1.31704E+04                HW= 5.88360E+02                  Z= 9.64781E-01

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  1.00000E+02 SECONDS

   TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL

                          X      TEMPERATURE  THETA     M DOT
                       0.00000     2300.5     1.0000   0.
                        .25000     1130.1     1.0000   0.
                        .50000      643.1     1.0000   0.
                        .75000      544.4     1.0000   0.
                       1.00000      530.9     1.0000   0.

   TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE

     5.30878E+02     5.30475E+02     5.30359E+02


    NUMBER OF TIME STEPS =          0                        CPTIME =      14.605

                  TAU          AL           VI          AOFA          PI           AMI          AME          RYI          PE
              1.0000E+02  1.0091E+01  0.          2.5550E+04  0.          0.          0.          0.          0.

           I           1           2           3           4           5           6           7           8           9

        Q(I)  1.0091E+01  0.          0.          0.          0.          0.          0.          0.          0.
     QNET(I)  0.          0.          0.          0.          0.          0.          0.          0.          0.

  TEMP(I, 1)  2.3005E+03  1.1301E+03  6.4310E+02  5.4441E+02  5.3088E+02  5.3086E+02  5.3047E+02  5.3036E+02  0.
  TEMP(I, 2)  0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 3)  0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Figure 4-20. Output of Sample Problem No. 3 - Results of Thermal Analysis

```
PANEL MOMENT OF INERTIA =  2.000E-02 INCHES**4

FREQUENCY =    102.5 HZ

BOUNDARY LAYER NOISE =  117.1 DB - REYNOLDS NO. =   1.0000E+07, MACH NO. =   6.0000E+00
DYNAMIC PRESSURE =   1.4000E+03, VELOCITY =   8.0000E+03
ROCKET ENGINE NOISE =  130.4 DB - APPARENT NOISE SOURCE AT   97.8 FT
ABES NOISE =   73.2 DB
JET SCRUBBING NOISE =  134.4 DB

MAXIMUM BENDING STRESS =       1931 PSI
MAXIMUM RMS DEFLECTION =     .00372 IN
BOUNDARY LAYER NOISE CRITICAL STRESS =   1.8241E+03 PSI
NO. OF STRESS REVERSALS =   8.3507E+03
***PANEL IS GOOD FOR THIS CONDITION
   CRITICAL STRESS MAY BE INCREASED TO   1.6376E+04 PSI

MAXIMUM BENDING STRESS =       8885 PSI
MAXIMUM RMS DEFLECTION =     .00331 IN

APPLIED S-N CURVE EXCEEDS ALLOWABLE S-N CURVE.

PANEL FLUTTER ANALYSIS - DESIGN POINT AT  -0.         SECONDS OF FLIGHT
YOUNGS MODULUS =   1.0000E+07, MACH NO. =   6.0000E+00
Q LOCAL/FCN(AMI) =   1.4000E+03, PHI =   3.7000E-01
***PANEL IS STABLE FOR FLUTTER
   PANEL EFFECTIVE THICKNESS =   3.2314E-01 IN.
   PANEL EFFECTIVE THICKNESS NECESSARY FOR FLUTTER STABILITY =   5.2796E-02 IN.
```

Figure 4-21. Output of Sample Problem No. 3 - Results of Fatigue Analysis

```
***** W E I G H T - C O S T   I N P U T *****

     KINDP        LENGTH         WIDTH        DLPANL        DWPANL             A             B          ICOS
         5        30.000        18.000          .400          .100          .350          .250            -0

     KINDS         TINS1         TINS2         TINS3         PINS1         PINS2         PINS3        MATLID
         1        -0.000        -0.000        -0.000        -0.000        -0.000        -0.000             2

            GINSRT         TCORE         TEDGE          TEXT          PEXT        TSKIN1        TSKIN2
             1.000          .330          .010         1.000        15.000          .050          .050

                   GBOLT        GNUTPL         GWASH         TCORN         TPOST        ODPOST
                    .400          .500          .100          .012          .020          .500

                          LTUBE         TTUBE         TFNG1         TBMLA         TBMSA
                           .600          .020          .050          .010          .010

                  TDOURC        TDOURP        TPLATE         TSEAL        HBEAMA        WBEAMA
                    .010          .020          .020          .010          .500         1.000

***** E N D   O F   I N P U T *****
```

Figure 4-22. Output of Sample Problem No. 3 - Input to Weight/Cost Analysis

THERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA 384.0

CONFIGURATION PANEL TYPE 5, ABLATIVE
STRUCTURE TYPE 1, CRUCIFORM BEAMS, SIX EDGE POSTS

NOMINAL PANEL SIZE 2.5 X 1.5 FT
NOMINAL PANEL STANDOFF DISTANCE .3 IN

PRIMARY PANEL / STRUCTURE MATERIAL TYPE 2 TITANIUM

DESCRIP	QT	ACTUAL WEIGHT	MATL WEIGHT	STD HOURS	LABOR HOURS	LABOR RATE	OV-HD RATE	MATL $ PER LB	LABOR COST	OVERHD COST	FACTORY COST	MATERIAL COST	FABRICAT COST
PANEL													
CORE	1	2.763	3.887	10.3580	25.90	4.75	8.31	23.23	123.00	215.25	338.25	99.34	437.60
SKIN	1	4.182	4.794	2.1486	5.37	4.75	8.31	17.80	25.51	44.65	70.17	93.85	164.01
ABLATIVE	1	4.538	6.391	.0923	.23	4.75	8.31	0.00	1.10	1.92	3.02	0.00	3.02
PANL ASSY	1	11.483	15.073	.9298	2.32	4.75	8.31	0.00	11.04	19.32	30.36	0.00	30.36
STRUCTURE													
BEAM LN A	1	.146	.282	1.2495	3.12	4.75	8.31	27.91	14.84	25.97	40.80	8.66	49.47
BEAM DOUB	1	.009	.018	.5673	1.42	4.75	8.31	27.88	6.74	11.79	18.53	.55	19.08
BEAM ASSY	1	.155	.300	.4345	1.09	4.75	8.31	0.00	5.16	9.03	14.19	0.00	14.19
BEAM SH A	1	.085	.166	.8931	2.23	4.75	8.31	27.91	10.61	18.56	29.17	5.11	34.27
BEAM ASSY	1	.085	.166	.3059	.76	4.75	8.31	0.00	3.63	6.36	9.99	0.00	9.99
CORNER	4	.018	.060	1.0601	2.65	4.75	8.31	27.49	12.59	22.03	34.62	1.83	36.45
CORN PLT	1	.014	.032	.4655	1.16	4.75	8.31	25.33	5.53	9.67	15.20	.90	16.10
CORN PLT	1	.014	.032	.4617	1.15	4.75	8.31	25.33	5.48	9.59	15.08	.90	15.98
CORN DOUB	1	.003	.009	.4298	1.07	4.75	8.31	25.30	5.10	8.93	14.03	.25	14.28
CORN ASSY	1	.049	.134	.5545	1.39	4.75	8.31	0.00	6.58	11.52	18.11	0.00	18.11
PLUG	2	.014	.034	2.1046	5.26	4.75	8.31	7.87	24.99	43.74	68.73	.29	69.02
FLANGE	2	.021	.347	1.8353	4.59	4.75	8.31	7.64	21.79	38.14	59.93	2.91	62.85
POST ASSY	2	.034	.387	.4886	1.22	4.75	8.31	0.00	5.80	10.15	15.95	0.00	15.95
SEAL	1	.025	.062	.8395	2.10	4.75	8.31	27.86	9.97	17.45	27.42	1.89	29.30
STR ASSY	1	.646	1.378	3.7960	9.49	4.75	8.31	0.00	45.08	78.89	123.96	0.00	123.96
FASTENERS	32	.299	.329	0.0000	0.00	0.00	0.00	104.00	0.00	0.00	0.00	37.63	37.63

TOTAL ACTUAL WEIGHT	11.83 LB
TOTAL MATERIAL WEIGHT	16.12 LB
TOTAL STANDARD HOURS	29.01 HR
TOTAL LABOR HOURS	72.54 HR
TOTAL LABOR COST	344.55 $
TOTAL OVERHEAD COST	602.96 $
TOTAL FACTORY COST	947.51 $
TOTAL MATERIAL COST	254.11 $
TOTAL FABRICATION COST	1201.62 $
TOTAL ASSEMBLY COST	37.28 $
TOTAL MANUFACTURING COST	1238.90 $
TPS COST	330.37 $/SQ FT
TPS WEIGHT	3.15 LB/SQ FT
AVERAGE MATERIAL	15.77 $/LB
AVERAGE LABOR RATE	4.75 $/HR
AVERAGE OVERHEAD RATE	8.31 $/HR
AVERAGE FACTORY RATE	13.06 $/HR
AVERAGE MFG. RATE	16.57 $/HR
AVERAGE MFG. RATE	101.57 $/LB
AVERAGE MFG. REALIZATION	.40
AVERAGE ASSEMBLY REALIZATION	.40

FINAL ASSEMBLY COST

TASK	STD HOURS	TOTAL HOURS	LABOR RATE	OV-HD RATE	LABOR COST	OVERHD COST	ASSEMBLY COST
SETUP	.2718	.68	4.75	8.31	3.23	5.65	8.88
CLAMP	.5600	1.40	4.75	8.31	6.65	11.64	18.29
INSPECT	.0191	.05	4.75	8.31	.23	.40	.63
DISASSY	.1920	.48	4.75	8.31	2.28	3.99	6.27
CLEAN	.0058	.01	4.75	8.31	.07	.12	.19
SECURE	.0736	.18	4.75	8.31	.87	1.53	2.40
INSPECT	.0191	.05	4.75	8.31	.23	.40	.63

Figure 4-23. Output of Sample Problem No. 3 - Results of Weight/Cost Analysis

```
THERMAL PROTECTION SYSTEM   COST SUMMARY

                                                COST $/SQ FT

THEORETICAL FIRST UNIT COST (TFU) 4142.21

NON RECURRING COST

ED AND D                                           37713.55
TOOLING                                             5079.39
GROUND TEST HARDWARE                               15533.27
FLIGHT TEST ARTICLES                                8284.41
FLIGHT TEST S AND RP                                2775.28
                                                   --------
TOTAL NONRECURRING TPS COST                        69385.90

RECURRING PRODUCTION COST

SUSTAINING ENGINEERING         -         INCLUDED IN TFU
SUSTAINING TOOLING             -         INCLUDED IN TFU
PRODUCTION ARTICLES                                 4142.21
TEST ARTICLE CONVERSION                             1242.66
                                                   --------
TOTAL RECURRING PRODUCTION COST                     5384.87

RECURRING OPERATIONS COST

REPLENISHMENT S AND RP                              5517.42
                                                   --------
TOTAL RECURRING OPERATIONS COST                     5517.42


TOTAL TPS PROGRAM COSTS                            80288.19



NUMBER OF PRODUCTION UNITS                            1.0
```

Figure 4-24. Output of Sample Problem No. 3 - Results of Total Cost Analysis

```
RECORD
  1    PCM CHECKOUT CASE
  1   1 SAME CASE AS RUN ON P5570
  2      1    1    4    1    1    1    1   13    1    0    0    8              1    1    1    1
  3     0.0       0.0       0.0       0.0       0.0       0.0       1.0
  4     0.0       1.0       10.       400.
  5          5.        10.        .5        .05        .05       24.        24.        .5
  6     1.36E5      1.4      .005       .01        20.        .3        1.5     .1875
  7    +2.0      +00 +4.0505 +09 +1.99    +04 +0.30    +00                 12.              27.8
  8       TYPICAL CHARRING ABLATION MATERIAL PROPERTIES
 9A     10000.0+00 +10000.0+00 +10000. +00 +34.0     +00 +16.5    +00 +400.0    +00
 9B    +0.65     +00 +1.00     +00 +129.06 +00 +0.25     +00 +250.0   +00 +1.0      +00
 9C    +0.0      +00 +0.12     +00 +0.43    +00 +0.070   +00 +0.43    +00
 10        5     2     2     9     2     2
 11    +1460.0 +00 +0.12     +00 +1.0     +04 +0.12     +00
 12    +1460.0 +00 +0.43     +00 +1.0     +04 +0.43     +00
 13A   +360.0  +00 +0.065    +00 +460.0   +00 +0.065    +00 +560.0   +00 +0.0655 +00
 13A   +660.0  +00 +0.066    +00 +760.0   +00 +0.0672   +00 +860.0   +00 +0.0684 +00
 13A   +960.0  +00 +0.069    +00 +1060.0  +00 +0.070    +00 +1160.0  +00 +0.070  +00
 14    +360.00 +00 +0.43     +00 +1100.0  +00 +0.43     +00
 15    +2200.0 +00 +9.0      -04 +8000.0  +00 +9.0      -04
 16        3    13 0.78      +00
 16A       1
 16B       2      1 545.6    +00 34.4     +00 277.0    +00 0.0      +00
 17    +5.0      +00+3.00     +00+5.0      +00
 18        2     4     2     4     5     2     6     6
 19     ELMERS GLUE OR WHAT ,PD200-F28  0.08 INCHES THICK
 20    +250.0  +00 +0.0641  +00 +3200.0 +00 +0.0641  +00
 21    +310.0  +00 +0.245   +00 +760.0  +00 +0.345   +00 +1110.0 +00 +0.4     +00
 21    +3200.0 +00 +0.4     +00
 19     PCM IS GALLIUM CHEMICAL FORMULA = GA
 20    0.0     +00 19.5     +00 3000.0  +00 19.5     +00
 21    0.0     +00 0.082    +00 545.0   +00 0.082    +00 547.0    +00 0.095   +00
 21    3000.0  +00 0.095
 19    BACKUP STRUCTURAL MATERIAL IS ALUMINUM
 20    +0.0    +00 +45.0    +00 +400.0  +00 +93.0    +00 +600.0   +00 +106.0  +00
 20    +800.0  +00 +111.0   +00 +1200.  +00 +112.0   +00
 21    +0.0    +00 +0.17    +00 +3000.0 +00 +0.49    +00
 19     FILLER IS TITANIUM
 20    250.0   +00 11.3     +00 460.0   +00 11.3     +00 660.     +00 10.9    +00
 20    860.0   +00 10.5     +00 1060.0  +00 10.5     +00 3000.0   +00 11.0    +00
 21    250.0   +00 0.12     +00 460.0   +00 0.12     +00 660.     +00 0.133   +00
 21    860.0   +00 0.146    +00 1060.0  +00 0.157    +00 3000.0   +00 0.181   +00
 22    33.7    +00 0.08     +00 0.9     +00 0.9      +00 375.0    +00 0.5     +00
 22    0.9     +00 0.9      +00 170.0   +00 0.2      +00 0.1      +00 0.1     +00
 23    0.0     +00 0.0      +00 0.0     +00 0.0      +00 0.0      +00 0.0     +00
 23    0.0     +00 0.0      +00 0.0     +00 0.0      +00 0.0      +00 0.0     +00
 24     HEAT TRANSFER TO CABIN ENVIRONMENT - HENV=0.0
 25    +500.0  +00 +0.0     +00 +0.0    +00 +0.0     +00
 26     INITIAL TEMPERATURE IS CONSTANT
 27    +0.0    +00 +530.0   +00 +530.0  +00
 29      10
 30            0.0          0.0          342.9         1400.0         617.2         2400.0
 30          791.0       3000.0         1113.0         4000.0        1500.0         4336.0
 30         2300.0       6078.0         3200.0         7050.0        3900.0         8120.0
 30         4400.0       9000.0
 31
 51       0.        2.01          25400.
 51    .........
 51    4000.        0.00          350.
```

Figure 4-25. Card Images of Input to Sample Problem No. 4

```
PCM CHECKOUT CASE
 SAME CASE AS RUN ON P5570


   PROGRAM OPTIONS USED
      CONFIGURATION-      PLATE
      TURBULENT HEATING-  ECKERT
      WALL TEMPERATURE-   UNIFORM
      ANGLE OF ATTACK-    VARIED
      LOCAL HEAT FLUX-    INPUT Q- COLD WALL

   DIRECTION COSINES OF OUTER NORMAL FROM SURFACE
    THETA =   0.0
      PHI =   0.0

   DISTANCE FROM LEADING EDGE        0.0000 FT
   BODY DIAMETER                     5.0000 FT
   SHOULDER RADIUS/BODY DIAMETER     0.0000
   EXTERNAL SURFACE EMISSIVITY       0.00

   INITIAL TIME                        0.0 SEC
   END TIME                          400.0 SEC
   CALCULATION TIME INTERVAL           1.0 SEC
   PRINT OUT INTERVAL                 10.0 SEC


***** S T R E S S   I N P U T *****

         AS            R           HH           TS           TC           SL          SLS           BE
  5.000E+00    1.000E+01    5.000E-01    5.000E-02    5.000E-02    2.400E+01    2.400E+01    5.000E-01

        FG7           UF          DST         EALL          CRN           BF          BFL           BL
  1.360E+05    1.400E+00    5.000E-03    1.000E-02    2.000E+01    3.000E-01    1.500E+00    1.875E-01


*****.A B L A T I O N   I N P U T *****

   ARRHENIUS EQUATION IS USED.
   N=   2.0000000E+00     A=   4.3505000E+09     B=   1.9900000E+04

   CPGAS=   3.0000000E-01     XMC=   1.2000000E+01     XMP=   2.7800000E+01


   TYPICAL CHARRING ABLATION MATERIAL PROPERTIES

 TABL= 1.00000E+04  TCHAR= 1.00000E+04  TREC= 1.00000E+04  RHOV= 3.40000E+01  RHOC= 1.65000E+01
TBLOW= 4.00000E+02    EMV= 6.50000E-01   EMC= 1.00000E+00  H300= 1.29060E+02    VL= 2.50000E-01
   HV= 2.50000E+02     FV= 1.00000E+00    TV= 0.        CHARK= 1.20000E-01 CHARC= 4.30000E-01
 ABLK= 7.00000E-02   ABLC= 4.30000E-01
```

Figure 4-26. Output of Sample Problem No. 4 - Input Data

NP= 5 NKC= 2 NCPC= 2 NKV= 9 NCPV= 2 NREC= 2 IOBLCK= -0 NTKV= 0 NPKV= 0

VIRGIN MATERIAL

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
3.60000E+02	6.50000E-02	3.60000E+02	4.30000E-01
4.60000E+02	6.50000E-02	1.10000E+03	4.30000E-01
5.60000E+02	6.55000E-02		
6.60000E+02	6.60000E-02		
7.60000E+02	6.72000E-02		
8.60000E+02	6.84000E-02		
9.60000E+02	6.90000E-02		
1.06000E+03	7.00000E-02		
1.16000E+03	7.00000E-02		

CHAR MATERIAL

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
1.46000E+03	1.20000E-01	1.46000E+03	4.30000E-01
1.00000E+04	1.20000E-01	1.00000E+04	4.30000E-01

SURFACE RECESSION TABLE

TEMPERATURE	SR - IN/SEC
2.20000E+03	9.00000E-04
3.00000E+03	9.00000E-04

PROPERTIES OF BACKUP STRUCTURE

NO. OF MATERIALS IN BACK-UP SHIELD= 3
TOTAL NUMBER OF NODES IN BACK-UP SHIELD= 13
THICKNESS OF BACK-UP SHIELD= 7.30000E-01

ELMERS GLUE OR WHAT ,PD200-F28 0.08 INCHES THICK

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
2.50000E+02	6.41000E-02	3.10000E+02	2.45000E-01
3.20000E+03	6.41000E-02	7.60000E+02	3.45000E-01
		1.11000E+03	4.00000E-01
		3.20000E+03	4.00000E-01

PCM IS GALLIUM CHEMICAL FORMULA = GA

TEMPERATURE	THERMAL CONDUCTIVITY	TEMPERATURE	SPECIFIC HEAT
0.	1.95000E+01	0.	8.20000E-02
3.00000E+03	1.95000E+01	5.45000E+02	8.20000E-02
		5.47000E+02	9.50000E-02
		3.00000E+03	9.50000E-02

Figure 4-26. Output of Sample Problem No. 4 - Input Data (Cont.)

BACKUP STRUCTURAL MATERIAL IS ALUMINUM

TEMPERATURE	THERMAL CONDUCTIVITY
0.	4.50000E+01
4.00000E+02	9.30000E+01
6.00000E+02	1.16000E+02
8.00000E+02	1.11000E+02
1.20000E+03	1.12000E+02

TEMPERATURE	SPECIFIC HEAT
0.	1.70000E-01
3.00000E+03	4.90000E-01

FILLER IS TITANIUM

TEMPERATURE	THERMAL CONDUCTIVITY
2.50000E+02	1.13000E+01
4.60000E+02	1.13000E+01
6.60000E+02	1.09000E+01
8.60000E+02	1.05000E+01
1.06000E+03	1.05000E+01
3.00000E+03	1.10000E+01

TEMPERATURE	SPECIFIC HEAT
2.50000E+02	1.26000E-01
4.60000E+02	1.20000E-01
6.60000E+02	1.33000E-01
8.60000E+02	1.46000E-01
1.06000E+03	1.57000E-01
3.00000E+03	1.61000E-01

MATERIAL	DENSITY	THICKNESS	EMISSIVITY FRONT	EMISSIVITY BACK	NODES/MATERIAL
1	3.3700E+01	8.0000E-02	9.0000E-01	9.0000E-01	5.0000E+00
2	3.7500E+02	5.0000E-01	9.0000E-01	9.0000E-01	3.0000E+00
3	1.7000E+02	2.0000E-01	1.0000E-01	1.0000E-01	5.0000E+00

ADDITIONAL DATA FOR PHASE CHANGE MATERIAL

NPC= 2 TMELT= 5.45600E+02 HEAT OF FUSION= 3.44000E+01 PHOFIL= 2.77000E+02 FIFR= 0.

ADDITIONAL DATA FOR INDIVIDUAL MATERIALS IN BACKUP STRUCTURE

MATERIAL	FILM COEFFICIENT	GAP THICKNESS	FTEST	BTEST
1	0.	0.	0.	0.
2	0.	0.	0.	0.
3	0.	0.	0.	0.

EQUIVALENT PROPERTIES OF PCM AND FILLER

TEMPERATURE	THERMAL CONDUCTIVITY
0.	1.95000E+01

TEMPERATURE	SPECIFIC HEAT
0.	8.20000E-02

Figure 4-26. Output of Sample Problem No. 4 - Input Data (Cont.)

```
3.00000E+03     1.95500E+01                        5.45000E+02   8.20000E-02
                                                   5.47000E+02   9.50000E-02
                                                   3.00000E+03   9.50000E-02
```

EQUIVALENT DENSITY OF PCM 3.75000E+02 DENSITY OF PCM DURING MELT 3.75000E+02

HEAT TRANSFER TO CABIN ENVIRONMENT - HENV=0.3

TEMPERATURE= 5.00000E+02   FIL4 COEFFICIENT= 0.   VIEW FACTOR= 0.   Q LOST= 0.

INITIAL TEMPERATURE IS CONSTANT

TEMPERATURE DISTRIBUTION IN HEAT SHIELD IS UNIFORM AND EQUAL TO 5.3000E+02

***** C O N D U C T I O N   I N P U T *****

COLUMN NUMBER, I	-1-	-2-	-3-	-4-	-5-	-6-	-7-	-8-	-9-
WIDTH, X(I) IN	1.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
HEATING FACTORS									
LAMINAR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TURBULENT	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

***** T R A J E C T O R Y   I N P U T *****

I	TIME(I)	ALT(I)	VINF(I)	ALPHA(I)	BETA(I)	HINSD(I)	TINSD(I)	XSTG(I)
1	0.	2.0100E+00	-0.	2.5400E+04	-0.	-0.	-0.	-0.
2	4.0000E+01	3.4700E+00	-0.	2.5500E+04	-0.	-0.	-0.	-0.
3	8.0000E+01	6.6500E+00	-0.	2.5550E+04	-0.	-0.	-0.	-0.
4	1.2000E+02	1.3620E+01	-0.	2.5550E+04	-0.	-0.	-0.	-0.
5	1.6000E+02	3.0490E+01	-0.	2.5450E+04	-0.	-0.	-0.	-0.
6	2.0000E+02	6.5550E+01	-0.	2.5300E+04	-0.	-0.	-0.	-0.
7	2.4000E+02	9.5520E+01	-0.	2.4650E+04	-0.	-0.	-0.	-0.
8	2.8000E+02	1.0745E+02	-0.	2.3500E+04	-0.	-0.	-0.	-0.
9	3.2000E+02	9.7730E+01	-0.	2.2000E+04	-0.	-0.	-0.	-0.
10	3.6000E+02	8.7500E+01	-0.	2.0000E+04	-0.	-0.	-0.	-0.
11	4.0000E+02	6.9280E+01	-0.	1.7700E+04	-0.	-0.	-0.	-0.
12	5.0000E+02	3.0160E+01	-0.	1.2200E+04	-0.	-0.	-0.	-0.
13	6.0000E+02	9.7200E+00	-0.	7.6000E+03	-0.	-0.	-0.	-0.
14	7.0000E+02	1.8600E+00	-0.	3.4000E+03	-0.	-0.	-0.	-0.
15	7.8000E+02	2.0000E-01	-0.	1.3000E+03	-0.	-0.	-0.	-0.
16	9.8000E+02	0.	-0.	9.5000E+02	-0.	-0.	-0.	-0.
17	1.8000E+03	0.	-0.	3.5000E+02	-0.	-0.	-0.	-0.
18	4.0000E+03	0.	-0.	3.5000E+02	-0.	-0.	-0.	-0.

***** E N D   O F   I N P U T *****

Figure 4-26. Output of Sample Problem No. 4 - Input Data (Cont.)

```
TIME= 9.50000E+00               VELOCITY= 2.54237E+04           QIN= 2.15794E+00
GAS ABLATION RATE= 0.           CHAR ABLATION RATE= 0.          TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.             QBLOCK= 0.                      Q HOT WALL= 2.34124E+00
HTX= 1.30418E+04                HW= 2.14063E+02                 Z= 9.93417E-01

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  1.00000E+01 SECONDS

  TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL

  0.         0.         0.         0.         0.         0.
  0.         0.         0.         0.         0.         0.
  0.         0.         0.         0.         0.         0.         0.

                 X      TEMPERATURE   THETA     M DOT
              0.00000      902.7      1.0000    0.
               .06250      604.9      1.0000    0.
               .12500      541.6      1.0000    0.
               .18750      531.5      1.0000    0.
               .25000      530.2      1.0000    0.

  TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE

    5.30225E+02   5.30110E+02   5.30051E+02   5.30020E+02   5.30001E+02   5.30001E+02
    5.30000E+02   5.30000E+02   5.30000E+02   5.30000E+02   5.30000E+02   5.30000E+02
    5.30000E+02

   NUMBER OF TIME STEPS =         0                  CPTIME =     10.947
                TAU          AL          VI          AOFA          PI          AMI          AME          RYI          PE
            1.0000E+01  2.3567E+00  0.          2.5424E+04  0.          0.          0.          0.          0.

          I           1           2           3           4           5           6           7           8           9

       Q(I)   2.3567E+00  0.          0.          0.          0.          0.          0.          0.          0.
    QNET(I)   0.          0.          0.          0.          0.          0.          0.          0.          0.

 TEMP(I, 1)   9.0269E+02  6.0494E+02  5.4158E+02  5.3151E+02  5.3022E+02  5.3022E+02  5.3011E+02  5.3005E+02  5.3002E+02
 TEMP(I, 2)   5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02  5.3000E+02
 TEMP(I, 3)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 4)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 5)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 6)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 7)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 8)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 9)   0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I,10)   0.          0.          0.          4.0000E+01  8.0000E+01  1.2000E+02  1.6000E+02  2.0000E+02  2.4000E+02
 TEMP(I,11)   0.          3.2000E+02  3.6000E+02  4.0000E+02  5.0000E+02  6.0000E+02  7.0000E+02  7.8000E+02  9.8000E+02
 TEMP(I,12)   0.          4.0000E+03  0.          0.          0.          0.          0.          0.          0.
 TEMP(I,13)   0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Figure 4-27. Output of Sample Problem No. 4 - Results of Thermal Analysis

```
TIME= 1.99500E+02                 VELOCITY= 2.53019E+04             CIN= 4.11949E+00
GAS ABLATION RATE= 0.             CHAR ABLATION RATE= 0.            TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.               OBLOCK= 0.                        C HOT WALL= 6.06555E+01
HTX= 1.29183E+04                  HW= 1.00436E+03                   Z= 9.31559E-01

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  2.00000E+02 SECONDS

   TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL

    1.18541E+00   0.            0.            2.40219E-04   0.            0.
    1.18517E+00   0.            0.            5.91187E+01   0.            0.
    6.41000E-02   1.95000E+01   1.35000E+01   1.95000E+01   1.95000E+01   1.95000E+01   1.02464E+02

                        Y      TEMPERATURE   THETA     M DOT
                     0.00000     3675.4      1.0000    0.
                      .06250     2702.8      1.0000    0.
                      .12500     1972.6      1.0000    0.
                      .16750     1433.5      1.0000    0.
                      .25000     1024.2      1.0000    0.

   TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE

     1.02425E+03    8.98566E+02    7.78176E+02    6.61117E+02    5.45600E+02    5.45600E+02
     5.45599E+02    5.45598E+02    5.45598E+02    5.45598E+02    5.45598E+02    5.45598E+02
     5.45598E+02


   NUMBER OF TIME STEPS =          0                      CPTIME =     16.792

                 TAU          AL              VI          AOFA         PI          AMI          AME          RYI          PE
             2.0000E+02  6.5112E+01  0.           2.5302E+04  0.          0.          0.          0.          0.

           I          1          2          3          4          5          6          7          8          9

        Q(I)   6.5112E+01  0.          0.          0.          0.          0.          0.          0.          0.
     QNET(I)   0.          0.          0.          0.          0.          0.          0.          0.          0.

 TEMP(I, 1)    3.6754E+03  2.7028E+03  1.9726E+03  1.4335E+03  1.0242E+03  1.0242E+03  8.9857E+02  7.7818E+02  6.6112E+02
 TEMP(I, 2)    5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02
 TEMP(I, 3)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 4)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 5)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 6)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 7)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 8)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I, 9)    0.          0.          0.          0.          0.          0.          0.          0.          0.
 TEMP(I,10)    0.          0.          0.          4.0000E+01  8.0000E+01  1.2000E+02  1.6000E+02  2.0000E+02  2.4000E+02
 TEMP(I,11)    0.          3.2000E+02  3.6000E+02  4.0000E+02  5.0000E+02  6.0000E+02  7.0000E+02  7.8000E+02  9.8000E+02
 TEMP(I,12)    0.          4.0000E+03  0.          0.          0.          0.          0.          0.          0.
 TEMP(I,13)    0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Figure 4-27. Output of Sample Problem No. 4 - Results of Thermal Analysis (Cont.)

```
TIME= 3.99500E+02                 VELOCITY= 1.77287E+04              CIN= 1.64323E+00
GAS ABLATION RATE= 0.             CHAR ABLATION RATE= 0.             TOTAL ABLATION RATE= 0.
RECESSION DEPTH= 0.               QBLOCK= 0.                         Q HOT WALL= 5.97298E+01
HTX= 6.40814E+03                  HW= 1.01237E+03                    Z= 3.59325E-01

TEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END OF THE TIME STEP, T=  4.00000E+02 SECONDS

   TEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL

    1.67666E+00   2.21955E+00   2.09603E+00   9.71367E-07  -6.24277E-11   2.01918E+00
    1.67666E+00   2.21955E+00   7.60542E-02   1.35398E+02   2.70365E+02   1.05781E+00
    6.41000E-02   1.95000E+01   1.95000E+01   1.95000E+01   1.95000E+01   1.95000E+01   1.02464E+02

                              Y      TEMPERATURE   THETA      M DOT
                           0.00000     3680.2      1.0000     0.
                            .06250     3166.1      1.0000     0.
                            .12500     2588.5      1.0000     0.
                            .18750     1990.7      1.0000     0.
                            .25000     1391.6      1.0000     0.

   TEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE

     1.39160E+03     1.18333E+03     9.75738E+02     7.68650E+02     5.61971E+02     5.61971E+02
     5.53662E+02     5.45600E+02     5.45600E+02     5.45600E+02     5.45600E+02     5.45600E+02
     5.45600E+02


     NUMBER OF TIME STEPS =          0                    CPTIME =      23.224

             TAU          AL          VI          AOFA          PI          AMI          AME          RYI          PE
          4.0000E+02  6.9508E+01  0.         1.7729E+04  0.          0.          0.           0.           0.

           I          1           2           3           4           5           6           7           8           9

        Q(I)   6.9508E+01  0.          0.          0.          0.          0.          0.          0.          0.
     QNET(I)   0.          0.          0.          0.          0.          0.          0.          0.          0.

  TEMP(I, 1)   3.6802E+03  3.1561E+03  2.5885E+03  1.9907E+03  1.3916E+03  1.3916E+03  1.1834E+03  9.7574E+02  7.6865E+02
  TEMP(I, 2)   5.6197E+02  5.6197E+02  5.5366E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02  5.4560E+02
  TEMP(I, 3)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 4)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 5)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 6)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 7)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 8)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I, 9)   0.          0.          0.          0.          0.          0.          0.          0.          0.
  TEMP(I,10)   0.          0.          0.          4.0000E+01  8.0000E+01  1.2000E+02  1.6000E+02  2.0000E+02  2.4000E+02
  TEMP(I,11)   0.          3.2000E+02  3.6000E+02  4.0000E+02  5.0000E+02  6.0000E+02  7.0000E+02  7.8000E+02  9.8000E+02
  TEMP(I,12)   0.          4.0000E+03  0.          0.          0.          0.          0.          0.          0.
  TEMP(I,13)   0.          0.          0.          0.          0.          0.          0.          0.          0.
```

Figure 4-27. Output of Sample Problem No. 4 - Results of Thermal Analysis (Cont.)

SECTION 5

REFERENCES

1. Optimization Studies for Space Shuttle Thermal Protection Systems, Volume I, Final Report, Convair Aerospace Division of General Dynamics, GDC-DDB-72-005, 30 September 1972.

2. Shanley, F. R., Strength of Materials, McGraw-Hill Book Company, New York, 1957.

3. Curry, D. M., An Analysis of a Charring Ablation Thermal Protection System, NASA TND-3150, December 1965.

APPENDIX I

PROGRAM SOURCE LISTINGS

```
      OVERLAY (P5490,0,0)
      PROGRAM P5490B (INPUT=1021,OUTPUT=1021,TAPE1=1021,TAPE3=1021,
     1                TAPE4=1021,TAPE5=INPUT,TAPE6=OUTPUT)
C
C     VERSION B OF PROGRAM P5490, TPS OPTIMIZATION STUDY PROGRAM
C     1 NOVEMBER 1971
C
      COMMON/BLOCK6/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON /FLAGS/ IFIRST, ISTRES, IFATIG, IWTCST
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON /MOMENT/ AII,PMI
      COMMON /SONIC1/ AE      ,AI      ,AIY     ,AMACH   ,AMF     ,AW      ,
     1BW      ,C(4)    ,D       ,DREF    ,DT(4)   ,DVEH    ,EP,EPP  ,HC      ,
     2HF      ,HPAN    ,IPAD    ,IPF(4)  ,IPFI    ,KFLEX   ,NENG    ,NPAN    ,
     3QF      ,QL      ,REY     ,RHOP    ,TIMEF   ,TJ      ,TT      ,VJ      ,
     4VS      ,VU      ,VV      ,WEJ     ,WER     ,XI      ,XJ      ,XL      ,
     5YCL     ,YP
      COMMON BLANK(21487)
C
      IFIRST=0
C     EXECUTE INPUT AND SIZING ROUTINES
   10 CALL OVERLAY(5HP5490,1,0,6HRECALL)
      IF (IWTCST.EQ.-1) GO TO 20
C     EXECUTE RSI ROUTINE IF RSI OPTION WAS SELECTED
      IF (NSECT.EQ.7) CALL OVERLAY(5HP5490,4,0)
C     EXECUTE FATIGUE ROUTINE UNLESS SUPRESS FLAG SET
      IF (IFATIG.EQ.0) CALL OVERLAY(5HP5490,2,0)
C     EXECUTE WEIGHT-COST ROUTINE UNLESS SUPRESS FLAG SET
      IF (IWTCST.EQ.0) CALL OVERLAY(5HP5490,3,0)
      GO TO 10
   20 CALL OVERLAY(5HP5490,3,0)
      GO TO 10
      END
```

```
      FUNCTION TABLE(X,XTB,YTB,N)
C                 THIS SUBROUTINE DOES LINEAR INTERPOLATION,
C                 WHERE Y=F(X).  IT WILL NOT EXTRAPOLATE.
      DIMENSION XTB(1),YTB(1)
C
      I=1
      IF (X.GE.XTB(I).AND.X.LE.XTB(N)) GO TO 10
      WRITE (6,60)
      TABLE=0.
      RETURN
   10 I=I+1
      IF (X.GE.XTB(I)) GO TO 10
      IF (YTB(I-1)-YTB(I)) 20,30,40
   20 Y=(YTB(I)-YTB(I-1))/(XTB(I)-XTB(I-1))*(X-XTB(I-1))+YTB(I-1)
      GO TO 50
   30 Y=YTB(I)
      GO TO 50
   40 Y=(YTB(I-1)-YTB(I))/(XTB(I)-XTB(I-1))*(XTB(I)-X)+YTB(I)
   50 TABLE=Y
      RETURN
C
   60 FORMAT (26H0X ARGUMENT ERROR IN TABLE)
      END
```

```
      FUNCTION TRPLAT (A,B,C,I,J,K)
      DIMENSION A(9,11,9),B(9,11,9)
      IF (C.LE.B(I,J,1)) GO TO 30
      IF (C.GE.B(I,J,K)) GO TO 40
      DO 10 L=1,K
      IF (B(I,J,L)-C) 10,10,20
   10 CONTINUE
   20 TRPLAT=A(I,J,L-1)+(A(I,J,L)-A(I,J,L-1))/(B(I,J,L)-B(I,J,L-1))*(C-B
     1(I,J,L-1))
      RETURN
   30 TRPLAT=A(I,J,1)
      RETURN
   40 TRPLAT=A(I,J,K)
      RETURN
      END
```

```
      OVERLAY (P5490,1,0)
      PROGRAM TPSOPT
C
      COMMON /ABLTN/ TEU,QIN,DTS,TX2(30),VELX,IQINPP,DELP,APRNT,INT,PEP
      COMMON /ARRH/ATHETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON /CCPG/CPGAS
      COMMON /CCSDOT/SDOT
      COMMON /CNDTN/ DEL,DTMAX,TTAU,ITER
      COMMON /DELX/ DELX1,DELX2,DELX3
      COMMON /DMND/ DUMMY(1119)
      COMMON /FLAGS/ IFIRST, ISTRES, IFATIG, IWTCST
      COMMON /HF/ HF1,HF2,HF3
      COMMON /KAN/ KAN1,KAN2,KAN3
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON /MOMENT/ AII,PMI
      COMMON/OLA/ TJO(10),CDJ(10)
      COMMON /PCM/ QRIN1,QRIN2,QRIN3,QROT1,QROT2,QROT3
      COMMON /QST/ QST1,QST2,QST3
      COMMON /SONIC1/ AE       ,AI      ,AIY     ,AMACH   ,AMF     ,AW      ,
     1BW      ,C(4)    ,D       ,DREF    ,DT(4)   ,DVEH    ,EP,EPP  ,HC      ,
     2HF      ,HPAN    ,IPAD    ,IPF(4)  ,IPFI    ,KFLEX   ,NENG    ,NPAN    ,
     3QF      ,QL      ,REY     ,RHOP    ,TIMEF   ,TJ      ,TT      ,VJ      ,
     4VS      ,VU      ,VV      ,WEJ     ,WER     ,XI      ,XJ      ,XL      ,
     5YCL     ,YP
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON /UNDM/ IDUMMY(56)
      EQUIVALENCE (NPF,IDUMMY(29))
      COMMON        AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA        ,AOFE        ,AROD       ,AS         ,AX(9,11,9) ,AY(9,11,9)
     2,BATA        ,BE          ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA       ,DIAM        ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99)  ,EDOT(20,99) ,EMIS(9)    ,FACC       ,FCU(20,99) ,FCY(20,99)
     5,FNET(20)    ,FSU(20,99)  ,FT(20)     ,FTU(20,99) ,FVE        ,F07
     6,G(20,99)    ,HH          ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP       ,ITURB       ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM       ,NCR         ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT        ,NMIN        ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG        ,NTRAJ       ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)    ,QCONL(9)    ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI        ,RYE         ,RYI        ,SL         ,SLS        ,STAAT
     $,STI         ,STOOP       ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1         ,TEMP(9,9)   ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)   ,UF          ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS       ,XSTG(99)    ,XX(20)     ,Y(9)       ,ZZ(20)
      DIMENSION TMAX(9)
      DIMENSION IA(1),IB(1)
      EQUIVALENCE (IA,NSECT),(IB,AL)
      DIMENSION AM(15), FM(15)
      DATA AM /
     1 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 2.5, 3.0,
     2 10.0, 30.0 /
      DATA FM /
     1.482,.482,.490,.513,.560,.660,.880,1.15,1.37,1.57,1.70,2.29,2.83,
     29.975, 31.0 /
C
      IF (IFIRST.NE.0) GO TO 60
```

```
      IFIRST=1
      DO 10 I=1,56
   10 IDUMMY(I)=0
      DO 20 I=1,1119
   20 DUMMY(I)=0.
      DO 30 I=1,9
   30 IA(I)=0
      DO 40 I=1,39
   40 A(I)=0.
      DO 50 I=1,21487
   50 IB(I)=0
      GO TO 80
   60 DO 70 I=1,9
      Q(I)=0.
      QNET(I)=0.
      DO 70 J=1,9
   70 TEMP(I,J)=0.
C     CALL INPUT ROUTINE
   80 CALL OVERLAY(5HP5490,1,1,6HRECALL)
      IF (IWTCST.EQ.-1) GO TO 500
      DTMAX=DELTA
      AII=AI
      EPP=EP
      AMF=AMACH
      IQINPP=IQINP
      IF (NSECT.GT.6) TAMP(1,1)=TX2(1)
      QF=QL
      IF (IQINP.GT.1) GO TO 90
      QL=0.
      QF=0.
   90 IGO=0
      ITER=0
      IVF=0
      ISS=0
      IST=0
      ICK=1
      YINS=0.0
      DO 100 I=1,NCOLM
      DO 100 J=1,NSEG
  100 TEMP(I,J)=TAMP(I,J)
      IF (NINS.EQ.0) GO TO 120
      DO 110 J=1,NSEG
      K=MAT(1,J)
      TMAX(K)=0.0
      IF (K.EQ.NINS) YINS=YINS+Y(J)
  110 CONTINUE
  120 TAU=STAAT
      TTAU=STAAT
      DEL=STAAT
      IF (NSECT.LT.7.AND.NMAT.NE.0) DELTA=1.0
      APRNT=WROTE
  130 IF (WROTE.GT.DEL) GO TO 140
      DEL=DEL-WROTE
      GO TO 130
  140 IF (NCOLM.GT.1.OR.NRSG.EQ.0) GO TO 160
      DO 150 I=1,NRSG
  150 VFACT(1,I)=1.
  160 TAU=TAU+DELTA
```

```
      TEU=TAU-0.5*DELTA
      IF (NTRAJ-2) 220,200,170
  170 DO 180 I=1,NTRAJ
      IF (TEU-TIME(I)) 190,230,180
  180 CONTINUE
      I=NTRAJ
  190 IF (I-1) 200,200,210
  200 I=2
  210 FR=(TEU-TIME(I-1))/(TIME(I)-TIME(I-1))
      AL=(ALT(I)-ALT(I-1))*FR+ALT(I-1)
      VI=(VINF(I)-VINF(I-1))*FR+VINF(I-1)
      AOFA=(ALPHA(I)-ALPHA(I-1))*FR+ALPHA(I-1)
      BATA=(BETA(I)-BETA(I-1))*FR+BETA(I-1)
      HINS=(HINSD(I)-HINSD(I-1))*FR+HINSD(I-1)
      TINS=(TINSD(I)-TINSD(I-1))*FR+TINSD(I-1)
      X0=(XSTG(I)-XSTG(I-1))*FR+XSTG(I-1)
      IF (IQINP.GT.1) GO TO 240
      GO TO 270
  220 I=1
  230 AL=ALT(I)
      VI=VINF(I)
      AOFA=ALPHA(I)
      BATA=BETA(I)
      HINS=HINSD(I)
      TINS=TINSD(I)
      X0=XSTG(I)
      IF (IQINP.GT.1) GO TO 240
      GO TO 270
  240 DO 260 I=1,NCOLM
      IF (IQINP.EQ.3) GO TO 250
      Q(I)=AL*QCONL(I)
      PE=VI
      GO TO 260
  250 TEMP(I,1)=AL*QCONL(I)
      PE=VI
  260 CONTINUE
      GO TO 360
  270 CALL PRA63(AL,PI,TI,RHOI,ICK)
      IF (ICK.EQ.0) GO TO 460
      IF (IFATIG.EQ.1) GO TO 310
      AMI=VI/(49.01*SQRT(TI))
      QI=0.5*RHOI*VI**2
      IF (QI.LT.QL) GO TO 280
      QL=QI
      AMACH=AMI
      VU=VI
      REY=RHOI*VU*XL/(2.27E-8*TI**1.5/(TI+198.6))
  280 IF (AMI.LT.1.) GO TO 310
      FCNAMI=TABLE(AMI,AM,FM,15)
      IF (FCNAMI.NE.0.) GO TO 290
      WRITE (6,610)
      GO TO 310
  290 QFF=QI/FCNAMI
      IF (QFF.LT.QF) GO TO 310
      QF=QFF
      AMF=AMI
      TIMEF=TAU
      IF (ISS.EQ.0) GO TO 310
```

```
      EPP=0.
      DO 300 I=1,NPSG
  300 EPP=EPP+E(I,ISS)
      EPP=EPP/NPSG
  310 ALF=AOFA/57.2957795
      BET=BATA/57.2957795
      PH=PHI/57.2957795
      TA=THETA/57.2957795
      C1=COS(ALF)*COS(BET)*SIN(TA)
      C2=SIN(ALF)*COS(BET)*COS(TA)
      CETA=C1+C2
      AOFE=ASIN(CETA)
      IF (ICONF.EQ.5) AOFE=1.5708
      DIST(1)=ABS(XDST-X0)
      IF (IWALT.LT.2) GO TO 330
      DO 320 I=2,NCOLM
  320 DIST(I)=DIST(I-1)+0.5*(X(I)+X(I-1))
  330 IF (PHI.LT.0.) GO TO 340
      CALL FLOWF(IGO)
      IF (IGO.EQ.1) GO TO 460
      CALL THERMO
      IF (PHI.EQ.0) GO TO 350
      IF (ALF.EQ.0.AND.BET.EQ.0) GO TO 350
  340 CETA=C1+C2*COS(PH)+SIN(BET)*COS(TA)*SIN(PH)
      AOFE=ASIN(CETA)
      CALL OFFCL
  350 IF (NMAT.EQ.0) GO TO 450
  360 IF (NSECT.GT.6) GO TO 370
C     CALL CONDTN SUBROUTINE
      CALL OVERLAY(5HP5490,1,2,6HRECALL)
      TAU=TTAU
      GO TO 390
  370 DTS=DELTA
      DELP=DEL
      IF (IQINP.EQ.1) VELX=VI
      IF (IQINP.EQ.4) VELX=AOFA
      QIN=Q(INT)
      PEP=PE
C     CALL ABLATION ROUTINES
      CALL OVERLAY(5HP5490,1,3,6HRECALL)
      DO 380 J=1,NPF
  380 TEMP(J)=TX2(J)
  390 IF (NINS.EQ.0) GO TO 450
      DO 400 I=1,NCOLM
      DO 400 J=1,NSEG
      K=MAT(I,J)
      IF (TEMP(I,J).GT.TMAX(K)) TMAX(K)=TEMP(I,J)
  400 CONTINUE
      DO 410 K=1,NMAT
      IF (TMAX(K).GT.TALLW(K).AND.K.GT.NINS) GO TO 420
  410 CONTINUE
      GO TO 450
  420 YINS=0.0
      DO 430 L=1,NSEG
      KK=MAT(1,L)
      IF (KK.NE.NINS) GO TO 430
      Y(L)=FACC*Y(L)
      YINS=YINS+Y(L)
```

```
  430 CONTINUE
      WRITE (6,570) K,K,TMAX(K),K,TALLW(K),TAU
      WRITE (6,590) YINS
      IF (YINS.GT.1.0) GO TO 440
      WRITE (6,600)
      GO TO 90
  440 WRITE (6,580)
      WRITE (6,600)
      STOP
  450 IF (NSECT.GT.6.OR.NMAT.EQ.0) DEL=DEL+DELTA
      GO TO 470
  460 IST=2
      GO TO 480
  470 IF (TAU+.01*DELTA.LT.STOOP.AND.DEL+.01*DELTA.LT.WROTE) GO TO 160
      IF (TAU+.01*DELTA.GE.STOOP) IST=2
      IF (NINS.EQ.1.OR.ISTRES.NE.0.OR.NSECT.EQ.8.OR.NMAT.EQ.0) GO TO 480
      CALL STRESS(ISS,IST)
  480 IF (NPRT.EQ.1) CALL PRINT1(ISS,ITER)
      IF (IST.EQ.2) GO TO 490
      DEL=0.
      ITER=0
      GO TO 160
  490 IF (IGO.EQ.1) WRITE (6,550)
      IF (ICK.EQ.0) WRITE (6,560)
      IF (IFATIG.EQ.0.AND.ISTRES.NE.0.AND.NSECT.LT.8) CALL PANEL
  500 GO TO (510,510,510,510,520,520,530,530), NSECT
  510 TSKIN1=TS
      TSKIN2=TC
      TINS1=YINS
      GO TO 540
  520 TSKIN1=0.
      TSKIN2=TC
      TINS1=YINS
      GO TO 540
  530 TSKIN1=TS
      TSKIN2=TS
      TINS1=BFL
      TINS2=BF
      TINS3=TC
  540 RETURN
C
C
  550 FORMAT (46H ***** LOCAL VELOCITY SQUARE IS NEGATIVE *****)
  560 FORMAT (42H ***** ALTITUDE.LT.0.OR.GT.700000 FT *****)
  570 FORMAT (//56H0***** I N S U L A T I O N   S I Z I N G   N O T E **
     1***//25H TEMPERATURE OF MATERIAL ,I2,17H BECAME TOO HIGH.,/6H TMAX
     2(,I1,3H) =,F5.0,6H DEG-R,/7H TALLW(,I1,3H) =,F5.0,6H DEG-R,/7H TIM
     3E =,F5.0,4H SEC,/)
  580 FORMAT (43H THICKNESS OF THE INSULATION IS UNREALISTIC/34H PROBLEM
     1 WAS DELETED AT THIS POINT)
  590 FORMAT (44H THICKNESS OF THE INSULATION WAS CHANGED TO ,F6.4,3H FT
     1)
  600 FORMAT (34H0***** E N D   O F   N O T E *****)
  610 FORMAT (40H MACH NUMBER WAS OUTSIDE OF TABLE LIMITS)
      END
```

```
      SUBROUTINE AIR(I,J,P,S,H,Z,RHO,TR,CS)
C
C     -I-    -INPUT
C      1      P(LB/FT2), S(BTU/LB-DEG R)
C      2      P(LB/FT2, H(BTU/LBM)
C      3      H, S AND 1ST GUEST OF P
C
C     -J-    -OUTPUT-
C      1      P, H, S
C      2      P, H, S AND Z(DIMENSIONLESS)
C      3      P, H, S AND RHO(SLUGS/FT3)
C      4      P, H, S, Z, RHO, TR(DEG R) AND CS(FT/SEC)
C
      PPA=P/2116.224
      PLOG=0.43429448*ALOG(PPA)
      IF (I.EQ.1) GO TO 160
      HY=H
      L=1
      DHM=1.0E6
      DH=0.
      IF (I.EQ.3) GO TO 160
      S=3.5
   10 IF (L.GT.21) 50,160
   20 DHP=DH
      DH=H-HY
      IF (ABS(DHM).LT.ABS(DHP)) GO TO 30
      DHM=DHP
      SYM=S
   30 L=L+1
      IF (ABS(DH/HY).LT.0.001) GO TO 350
      IF (L.EQ.2) GO TO 40
      DHS=(DH-DHP)/(S-SYP)
      SYP=S
      S=S-DH/DHS
      GO TO 10
   40 SYP=S
      S=S-0.01*S*ABS(DH)/DH
      GO TO 10
   50 X2=0.43429448*ALOG(14.587834*SYM)
      IF (ABS(X2-1.60).GT.0.01) GO TO 60
      X3=1.60
      GO TO 90
   60 IF (ABS(X2-1.76).GT.0.01) GO TO 70
      X3=1.76
      GO TO 90
   70 IF (ABS(X2-1.92).GT.0.01) GO TO 80
      X3=1.92
      GO TO 90
   80 WRITE (6,1060) S,H,HY
      CALL EXIT
   90 S=10.0**X3/14.587834
      GO TO 160
  100 IF (L.GT.21) 150,170
  110 DHP=DH
      DH=H-HY
      IF (ABS(DHM).LT.ABS(DHP)) GO TO 120
      DHM=DHP
  120 L=L+1
```

```
      IF (ABS(DH/HY).LT.0.001) GO TO 350
      IF (L.EQ.2) GO TO 130
      DHS=(DH-DHP)/(P-PY)
      PY=P
      P=P-DH/DHS
      GO TO 140
  130 PY=P
      P=P-0.01*P*ABS(DH)/DH
  140 PPA=P/2116.224
      PLOG=0.43429448*ALOG(PPA)
      GO TO 100
  150 WRITE (6,1070) P,PY,H,HY
      CALL EXIT
  160 SR=S*14.587834
      SRLOG=0.43429448*ALOG(SR)
      X15=-39.1442+83.0558*SRLOG-38.2842*SRLOG*SRLOG
  170 X151=-10.0*(PLOG-X15)
      IF (X151-40.0) 190,180,180
  180 T15=0.0
      GO TO 220
  190 IF (X151+40.0) 200,210,210
  200 T15=1.0
      GO TO 220
  210 T15=1.0/(1.0+EXP(X151))
  220 A=PLOG*PLOG
      B=SRLOG*SRLOG
      C=A*PLOG
      D=B*SRLOG
C     LOG(H/R)=F(LOGP,LOG(S/R))
      IF (SRLOG-1.6) 230,230,240
  230 HRCAL=12.693869+5.3975312*PLOG-48.729217*SRLOG-.14961521*A-5.87887
     174*PLOG*SRLOG+48.19278*B+.90144132E-03*C+.091151473*A*SRLOG+1.6282
     2829*PLOG*B-13.065267*D
      GO TO 340
  240 IF (SRLOG-1.76) 250,250,310
  250 HR22=-156.37194+6.6959228*PLOG+269.93097*SRLOG-.097179965*A-7.5379
     1714*PLOG*SRLOG-152.13866*B+.57029937E-03*C+.058364795*A*SRLOG+2.15
     292755*PLOG*B+28.940926*D
      HR21=-84.008522+2.5761318*PLOG+107.06198*SRLOG-.014352904*A-1.5313
     1194*PLOG*SRLOG-32.316439*B
      XH=-61.2053+114.103*SRLOG-47.5532*B
      XH1=-10.0*(PLOG-XH)
      IF (XH1-40.0) 260,290,290
  260 IF (XH1+40.0) 270,280,280
  270 TH=1.0
      GO TO 300
  280 TH=1.0/(1.0+EXP(XH1))
      GO TO 300
  290 TH=0.0
  300 HRCAL=HR21+(HR22-HR21)*TH
      GO TO 340
  310 IF (SRLOG-1.92) 320,320,330
  320 HRCAL=-35.160671+.5366924*PLOG+56.99585*SRLOG-.022661358*A-.484703
     105*SRLOG*PLOG-27.641087*B+.58568839E-03*C+.016299962*A*SRLOG+.1407
     23606*B*PLOG+4.712261*D
      GO TO 340
  330 HRCAL=-114.94796+4.004583*PLOG+180.08427*SRLOG-.041327787*A-4.0366
     1535*PLOG*SRLOG-90.76006*B+.40320694E-03*C+.024360248*A*SRLOG+1.046
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     22299*PLOG*B+15.467804*D
 340 HR15=28.160664-2.2339873*PLOG-59.053694*SRLOG+.054973544*A+3.71832
     157*PLOG*SRLOG+40.986503*B-.4292698E-03*C-.040726332*A*SRLOG-1.3704
     2505*PLOG*B-8.253645*D
      HRCAL=HR15+(HRCAL-HR15)*T15
      HRLOG=2.3025851*HRCAL
      HR=EXP(HRLOG)
      H=HR/8.1043525
      GO TO (350,20,110) I
 350  GO TO (1050,360,570,360) J
C     Z=F(LOGP,LOG(S/R))
 360  XZ12=62.91-41.5*SRLOG
      XZ23=72.945-45.75*SRLOG
      XZ34=65.75-37.5*SRLOG
      XZ45=62.92-32.0*SRLOG
      XZ121=-10.0*(PLOG-XZ12)
      XZ231=-10.0*(PLOG-XZ23)
      XZ341=-10.0*(PLOG-XZ34)
      XZ451=-10.0*(PLOG-XZ45)
      ZCAL2=519.80374-23.753514*PLOG-983.90729*SRLOG+.37296957*A+30.0843
     179*PLOG*SRLOG+620.04168*B-.21648826E-02*C-.23710079*A*SRLOG-9.4969
     203*PLOG*B-129.78921*D
      ZCAL3=366.40674-15.517444*PLOG-647.42436*SRLOG+.18701758*A+18.0403
     183*PLOG*SRLOG+379.59834*B-.87958438E-03*C-.10580129*A*SRLOG-5.1888
     2254*PLOG*B-73.504269*D
      ZCAL4=516.07331-16.59277*PLOG-808.49823*SRLOG+.07125b235*A+16.5268
     113*PLOG*SRLOG+418.45341*B+.94183347E-03*C-.019727817*A*SRLOG-3.994
     28906*PLOG*B-71.038921*D
      IF (XZ121-40.0) 370,400,400
 370  IF (XZ121+40.0) 380,390,390
 380  TZ12=1.0
      GO TO 410
 390  TZ12=1.0/(1.0+EXP(XZ121))
      GO TO 410
 400  TZ12=0.0
 410  IF (XZ231-40.0) 420,450,450
 420  IF (XZ231+40.0) 430,440,440
 430  TZ23=1.0
      GO TO 460
 440  TZ23=1.0/(1.0+EXP(XZ231))
      GO TO 460
 450  TZ23=0.0
 460  IF (XZ341-40.0) 470,500,500
 470  IF (XZ341+40.0) 480,490,490
 480  TZ34=1.0
      GO TO 510
 490  TZ34=1.0/(1.0+EXP(XZ341))
      GO TO 510
 500  TZ34=0.0
 510  IF (XZ451-40.0) 520,550,550
 520  IF (XZ451+40.0) 530,540,540
 530  TZ45=1.0
      GO TO 560
 540  TZ45=1.0/(1.0+EXP(XZ451))
      GO TO 560
 550  TZ45=0.0
 560  ZCAL=1.0+(ZCAL2-1.0)*TZ12+(ZCAL3-ZCAL2)*TZ23+(ZCAL4-ZCAL3)*TZ34+(4
     1.0-ZCAL4)*TZ45
```

```
      ZCAL=1.0+(ZCAL-1.0)*T15
      Z=ZCAL
      IF (J.EQ.4) 570,1050
C     LOG(RHO/RHOA)=F(LOGP,LOG(S/R))
  570 XR12=-16.5527+57.45*SRLOG-30.8036*B
      XR23=499.544-938.91*SRLOG+609.028*B-135.995*D
      XR34=360.507-634.538*SRLOG+389.174*B-82.4653*D
      XR45=489.628-458.5*SRLOG+106.25*B
      XR121=-10.0*(PLOG-XR12)
      XR231=-10.0*(PLOG-XR23)
      XR341=-10.0*(PLOG-XR34)
      XR451=-10.0*(PLOG-XR45)
      IF (XR121-40.0) 580,610,610
  580 IF (XR121+40.0) 590,600,600
  590 TR12=1.0
      GO TO 620
  600 TR12=1.0/(1.0+EXP(XR121))
      GO TO 620
  610 TR12=0.0
  620 IF (XR231-40.0) 630,660,660
  630 IF (XR231+40.0) 640,650,650
  640 TR23=1.0
      GO TO 670
  650 TR23=1.0/(1.0+EXP(XR231))
      GO TO 670
  660 TR23=0.0
  670 IF (XR341-40.0) 680,710,710
  680 IF (XR341+40.0) 690,700,700
  690 TR34=1.0
      GO TO 720
  700 TR34=1.0/(1.0+EXP(XR341))
      GO TO 720
  710 TR34=0.0
  720 IF (XR451-40.0) 730,760,760
  730 IF (XR451+40.0) 740,750,750
  740 TR45=1.0
      GO TO 770
  750 TR45=1.0/(1.0+EXP(XR451))
      GO TO 770
  760 TR45=0.0
  770 RHCL1=15.951867-.00228295*PLOG-15.994242*SRLOG+.65187267E-02*A+.53
     1079685*PLOG*SRLOG+3.175974*B
      RHCL2=1541.1666-63.93035*PLOG-2993.1662*SRLOG+.935437*A+84.30375*S
     1RLOG*PLOG+1938.7061*B-.004746016*C-.6128404*A*SRLOG-27.422666*B*PL
     2OG-419.0881*D
      RHCL3=427.4745-18.126622*PLOG-765.47626*SRLOG+.29343169*A+22.92687
     17*PLOG*SRLOG+456.717*B-.17033404E-02*C-.18068309*A*SRLOG-6.9143617
     22*B*PLOG-91.131851*D
      RHCL4=206.23144-8.2270278*PLOG-329.5465*SRLOG+.1324191*A+9.8884165
     11*PLOG*SRLOG+175.03931*B-.10178454E-02*C-.07654371*A*SRLOG-2.692014
     24*B*PLOG-31.237834*D
      RHCL5=-399.52358+12.899477*PLOG+411.64144*SRLOG-.097694919*A-6.220
     14477*PLOG*SRLOG-106.6733*B
      RHCAL=RHCL1+(RHCL2-RHCL1)*TR12+(RHCL3-RHCL2)*TR23+(RHCL4-RHCL3)*TR
     134+(RHCL5-RHCL4)*TR45
      RH15=-79.282533+6.3537078*PLOG+179.22721*SRLOG-.12607098*A-8.40131
     122*PLOG*SRLOG-129.95269*B+.10037437E-02*C+.09418551*A*SRLOG+3.125
     226966*PLOG*B+30.203862*D
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```
      RHCAL=RH15+(RHCAL-RH15)*T15                                        AIR 233
      RHRALG=2.3025851*RHCAL                                             AIR 234
      RHORHA=EXP(RHRALG)                                                 AIR 235
      RHO=2.50742E-3*RHORHA                                              AIR 236
      IF (J.NE.4) GO TO 1050                                             AIR 237
C     TR = F(LOG(P),Z), A/A0 = F(LOG(P),LOG(S/R))                        AIR 238
      T=(EXP((PLOG-RHCAL)*2.3025851)*273.15)/ZCAL                        AIR 239
      TR=1.8*T                                                           AIR 240
      IF (T-2100.0) 780,780,830                                          AIR 241
  780 IF (T-1500.0) 800,800,790                                          AIR 242
  790 IF (PLOG+1.0) 830,830,800                                          AIR 243
  800 CON1=SQRT(T/273.15)                                                AIR 244
      IF (T-273.15) 810,810,820                                          AIR 245
  810 AOAO=CON1                                                          AIR 246
      GO TO 1040                                                         AIR 247
  820 AOAO=-0.0753808+CON1*(1.12644-0.0552696*CON1)                      AIR 248
      GO TO 1040                                                         AIR 249
  830 XA12=635.054-1220.46*SRLOG+803.882*B-180.845*D                     AIR 250
      XA23=373.702-663.358*SRLOG+408.854*B-86.8056*D                     AIR 251
      XA34=1703.78-2602.97*SRLOG+1337.93*B-231.422*D                     AIR 252
      XA22=1043.37-1820.34*SRLOG+1076.36*B-215.445*D                     AIR 253
      XA121=-10.0*(PLOG-XA12)                                            AIR 254
      XA231=-10.0*(PLOG-XA23)                                            AIR 255
      XA341=-10.0*(PLOG-XA34)                                            AIR 256
      XA221=-10.0*(PLOG-XA22)                                            AIR 257
      A1=-4409.6241+196.82259*PLOG+8746.4634*SRLOG-3.1650299*A-262.32947AIR 258
     1*PLOG*SRLOG-5786.449*B+.020004186*C+2.1429825*A*SRLOG+87.589029*PLAIR 259
     2OG*B+1277.6718*D                                                   AIR 260
      A21=-1814.5117+86.096078*PLOG+3315.6099*SRLOG-1.7593034*A-107.2534AIR 261
     1*PLOG*SRLOG-2023.201*B+.016287679*C+1.1398134*A*SRLOG+33.659607*PLAIR 262
     2OG*B+413.41945*D                                                   AIR 263
      A22=2651.2944-81.405596*PLOG-3099.0064*SRLOG+.69752668*A+48.062596AIR 264
     1*PLOG*SRLOG+907.70889*B                                            AIR 265
      IF (XA221-40.0) 850,840,840                                        AIR 266
  840 TA22=0.0                                                           AIR 267
      GO TO 880                                                          AIR 268
  850 IF (XA221+40.0) 860,860,870                                        AIR 269
  860 TA22=1.0                                                           AIR 270
      GO TO 880                                                          AIR 271
  870 TA22=1.0/(1.0+EXP(XA221))                                          AIR 272
  880 A2=A21+(A22-A21)*TA22                                              AIR 273
      A3=-3217.8037+195.34964*PLOG+5348.2143*SRLOG-4.6268475*A-221.12705AIR 274
     1*PLOG*SRLOG-2970.8649*B+.044614358*C+2.7079177*A*SRLOG+63.042803*PAIR 275
     2LOG*B+553.12007*D                                                  AIR 276
      A4=16976.939-476.10242*PLOG-17445.315*SRLOG+3.6534057*A+246.41125*AIR 277
     1PLOG*SRLOG+4486.3118*B                                             AIR 278
      IF (XA121-40.0) 900,890,890                                        AIR 279
  890 TA12=0.0                                                           AIR 280
      GO TO 930                                                          AIR 281
  900 IF (XA121+40.0) 910,910,920                                        AIR 282
  910 TA12=1.0                                                           AIR 283
      GO TO 930                                                          AIR 284
  920 TA12=1.0/(1.0+EXP(XA121))                                          AIR 285
  930 IF (XA231-40.0) 950,940,940                                        AIR 286
  940 TA23=0.0                                                           AIR 287
      GO TO 980                                                          AIR 288
  950 IF (XA231+40.0) 960,960,970                                        AIR 289
  960 TA23=1.0                                                           AIR 290
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```
      GO TO 980
  970 TA23=1.0/(1.0+EXP(XA231))
  980 IF (XA341-40.0) 1000,990,990
  990 TA34=0.0
      GO TO 1030
 1000 IF (XA341+40.0) 1010,1010,1020
 1010 TA34=1.0
      GO TO 1030
 1020 TA34=1.0/(1.0+EXP(XA341))
 1030 AOAO=A1+(A2-A1)*TA12+(A3-A2)*TA23+(A4-A3)*TA34
 1040 CONTINUE
      CS=1086.98*AOAO
 1050 RETURN
C
 1060 FORMAT (35H ITERATION LIMIT EXCEEDED IN S-LOOP,3E15.4)
 1070 FORMAT (35H ITERATION LIMIT EXCEEDED IN P-LOOP,4E15.4)
      END
```

```
      SUBROUTINE BUCKNG(E,F7,FCR,FCY,FTU,NCR)
      DE=E*(1.-1./(1.+.4286*(FCR/F7)**(NCR-1)))
      IF (.001*E.GE.ABS(DE)) GO TO 20
      ETA0=0.7
      ETAA=F7/FCR
      DO 10 ITERNO=1,30
      ETA1=ETAA*((1./ETA0-1.)*2.333)**(1./(FLOAT(NCR)-1.))
      DETA=ETA1-ETA0
      IF (ETA1.GT.1.) ETA1=1.
      IF (.01*ETA0.GE.ABS(DETA)) GO TO 30
      ETA0=0.5*(ETA0+ETA1)
   10 CONTINUE
      GO TO 30
   20 ETA1=1.
   30 FCR=FCR*ETA1
      IF (1.1*FCY.GE.FCR) GO TO 40
      FCR=1.1*FCY
   40 IF (FTU.GE.FCR) GO TO 50
      FCR=FTU
   50 RETURN
      END
```

```
      SUBROUTINE FLOWF(IGO)
C
      COMMON/FOT/AM2,AMUI,EI,EMU,RHOE,TE,VE,WI(9),XMI,XM2,XVI,YVI,
     1PS,PY,RHOS,RHOY,SMU,TMU,YMU,P0
      COMMON/TIFO/IEQOS,ITRAS
      COMMON         AL         ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA        ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA        ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA       ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)      ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)    ,FSU(20,99),FT(20)      ,FTU(20,99),FVE         ,F07
     6,G(20,99)    ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINK0
     7,IQINP       ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM       ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT        ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG        ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)    ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI        ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI         ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1         ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)   ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS       ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
C
C*****ENTHALPY FUNCTIONS
      FENTL(T)=2.2864+0.2272*T+0.11571E-4*T*T+0.23676E-9*T**3
      FTEMP(E)=17.899+4.0675*E-.83884E-4*E*E-.3495E-6*E**3
C*****FREESTREAM PROPERTIES
      CSI=49.01*SQRT(TI)
      AMI=VI/CSI
      AM2=AMI*AMI
      VI2=VI**2
      AMUI=FMUT(PI,TI)
      RYI=VI*RHOI/AMUI
      AII=FENTL(TI)
      STI=AII+VI2/50061.5
      P0=PI*(1.+AM2/5.)**3.5
      IF (STI.GT.705.0.AND.IEQOS.LT.2) GO TO 10
      T0=TI*(1.+0.2*AM2)
      GO TO 20
   10 CALL AIR(2,4,P0,S0,STI,Z,RHO0,T0,CS0)
   20 XVI=VI*SIN(AOFE)
      YVI=VI*COS(AOFE)
      XMI=XVI/CSI
      XM2=XMI*XMI
      XM3=XMI*XM2
      XV2=XVI*XVI
      IF (IWALT.EQ.1) GO TO 30
      JW=NCOLM
      GO TO 40
   30 JW=1
   40 DO 50 I=1,JW
      IF (NMAT.EQ.0) TEMP(I,1)=540.
   50 WI(I)=FENTL(TEMP(I,1))
      GO TO (60,310,150,150,310,310,310) ICONF
   60 IF (AOFE.GT.0.524) GO TO 310
      IF (AOFE.LT.0) GO TO 80
      IF (AMI.GT.1.0) GO TO 150
C*****FLAT PLATE
```

```
   70 PE=PI
      VE=VI
      TE=TI
      EI=AII
      AME=AMI
      EMU=AMUI
      RHOE=RHOI
      GO TO 420
C*****PRANDTL MEYER EXPANSION
   80 BETAI=SQRT(AM2-1.0)
      UNI=140.34601*ATAN(.40825*BETAI)-57.29578*ATAN(BETAI)
      IF (AOFE+.05) 90,90,70
   90 UNE=UNI-57.29578*AOFE
      IF (UNE-50.0) 100,100,110
  100 AME=-26.301065/(UNE-81.77828)+.78959002+.02791663*UNE
      GO TO 140
  110 IF (UNE-102.32) 120,120,130
  120 AME=-280.09435/(UNE-130.19996)-.89411241+8.2845071E-03*UNE
      GO TO 140
  130 AME=-284.84684/(UNE-130.43433)-1.0199074+8.6803698E-03*UNE
  140 TR=(5.0+AM2)/(5.0+AME**2)
      PR=TR**3.5
      VR=(AME/AMI)*SQRT(TR)
      PE=PR*PI
      TE=TR*TI
      VE=VR*VI
      EI=FENTL(TE)
      RHOE=PE/(1714.87*TE)
      AME=VE/(49.01*SQRT(TE))
      GO TO 420
  150 IF (XMI.LE.0.05) GO TO 70
      RMI=XVI/1086.0
      RM2=RMI*RMI
      RM3=RMI*RM2
      IF (ICONF.NE.4) GO TO 240
C*****WEDGE
      IF (XMI.GT.8.0) GO TO 160
      EI=AII*(.9167+.3203*XMI+.236*XM2-.4484E-3*XM3)
      GO TO 170
  160 EI=AII*(1.107-.2209*XMI+.3644*XM2-8.462E-3*XM3)
  170 IF (XMI.GT.1.8) GO TO 180
      PE=PI*(1.041+.693*XMI+1.889*XM2-.0661*XM3)
      GO TO 190
  180 PE=PI*(-2.32+4.045*XMI+1.036*XM2+.0161*XM3)
  190 IF (RMI.GE.0.6) GO TO 200
      VR=.1923+1.404*RMI+1.147*RM2+.3361*RM3
      GO TO 220
  200 IF (RMI.GT.6.0) GO TO 210
      VR=.5958+.4494*RMI+1.838*RM2-.0331*RM3
      GO TO 220
  210 VR=78.03-19.58*RMI+3.13*RM2-.05054*RM3
  220 VE2=VI2-1.0E6*VR
      IF (VE2.GT.0.) GO TO 230
      IGO=1
      RETURN
  230 VE=SQRT(VE2)
      GO TO 340
C*****CONE
```

```
  240 IF (XMI.GT.8.0) GO TO 250
      EI=AII*(1.03+.0827*XMI+.2354*XM2-6.956E-4*XM3)
      GO TO 260
  250 EI=AII*(1.106-.3685*XMI+.3466*XM2-7.766E-3*XM3)
  260 IF (XMI.GE.1.5) GO TO 270
      PE=PI*(1.007+.3816*XMI+1.522*XM2-.1593*XM3)
      GO TO 290
  270 IF (XMI.GE.5.0) GO TO 280
      PE=PI*(.2397+1.161*XMI+1.06*XM2+.0489*XM3)
      GO TO 290
  280 PE=PI*(-3.182+4.177*XMI+.8373*XM2+.0216*XM3)
  290 IF (RMI.GE.4.4) GO TO 300
      VR=.157+.75*RMI+.9861*RM2+.06944*RM3
      GO TO 220
  300 VR=6.187-1.038*RMI+1.414*RM2-.0062*RM3
      GO TO 220
C*****HIGH ANGLE OF ATTACK
  310 IF (AMI.GT.1.0) GO TO 320
      PE=PI+RHOI*XV2
      GO TO 330
  320 SA=1.114*AOFE+.977/AM2
      IF (SA.GT.1.5708) SA=1.5708
      SMI=AMI*SIN(SA)
      CE=SIN(AOFE)**2
      CM=1.833*(1.-.455/AM2)
      PE=PI*(1.+.7*AM2*CE*CM)
      ES=AII+XV2/50061.5
      IF (SMI.GT.1.0) GO TO 370
  330 VE=YVI
      EI=STI-VE*VE/50061.5
  340 IF (EI.GT.1300.) GO TO 350
      TE=FTEMP(EI)
      RHOE=PE/(1714.87*TE)
      AME=VE/(49.01*SQRT(TE))
      GO TO 360
  350 CALL AIR(2,4,PE,S,EI,Z,RHOE,TE,CS)
      AME=VE/CS
  360 IF (ICONF.EQ.1) GO TO 410
      IF (ICONF.EQ.3.OR.ICONF.EQ.4) GO TO 420
      PS=PI*(1.+0.2*XM2)**3.5
      PY=P0
      GO TO 380
  370 VU=VI*SIN(SA)
      SM2=SMI*SMI
      IF (STI.GT.705.0.AND.IEQOS.LT.2) GO TO 400
      PY=P0*(6.*AM2/(AM2+5.))**3.5*(6./(7.*AM2-1.))**2.5
      PS=P0*(6.*SM2/(SM2+5.))**3.5*(6./(7.*SM2-1.))**2.5
      PEY=PE/PS
      AME=SQRT(5.*(1./PEY**.286-1.))
      TE=T0*PEY**.286
      EI=FENTL(TE)
      VE=AME*49.01*SQRT(TE)
      IF (ICONF.EQ.1) GO TO 390
      PS=PI*(1.2*XM2)**3.5*(6./(7.*XM2-1.))**2.5
  380 TS=TI*(1.+0.2*XM2)
      RHOS=PS/(1714.87*TS)
      RHOY=PY/(1714.87*T0)
  390 RHOE=PE/(1714.87*TE)
```

```
      GO TO 410                                                         FLF 175
  400 CALL SHOCK(AII,PI,PY,RHOI,VU,S)                                   FLF 176
      CALL AIR(1,4,PE,S,EI,Z,RHOE,TE,CS)                                FLF 177
      IF (EI.GT.STI) EI=STI                                             FLF 178
      VE=SQRT((STI-EI)*50061.5)                                         FLF 179
      AME=VE/CS                                                         FLF 180
      IF (ICONF.EQ.1) GO TO 410                                         FLF 181
      CALL SHOCK(AII,PI,PY,RHOI,VI,S)                                   FLF 182
      CALL AIR(3,4,PY,S,STI,Z,RHOY,T0,CS)                               FLF 183
      CALL SHOCK(AII,PI,PS,RHOI,XVI,S)                                  FLF 184
      CALL AIR(3,4,PS,S,ES,Z,RHOS,TS,CS)                                FLF 185
  410 IF (ICONF.EQ.1) GO TO 420                                         FLF 186
      SMU=FMUT(PS,TS)                                                   FLF 187
      TMU=FMUT(P0,T0)                                                   FLF 188
      YMU=FMUT(PY,T0)                                                   FLF 189
  420 EMU=FMUT(PE,TE)                                                   FLF 190
      RETURN                                                            FLF 191
      END                                                               FLF 192-
```

```
      FUNCTION FMUT(P,T)
C     VISCOSITY
      GG=ALOG10(P/2116.)
      HH=T/1800.
      IF (HH.GT.3.5) GO TO 10
      E=1.
      GO TO 20
   10 A=HH*(1.-.125*GG)-6.5
      B=1.5+.125*GG
      C=1.+.023*HH*(1.+TANH(A/B))
      D=(HH-14.5-1.5*GG)/(.9+.1*GG)
      E=C*(1.-EXP(D))
      IF (E.LT.0.05) E=0.05
   20 F=2.27E-8*T**1.5/(T+198.6)
      FMUT=F*E
      RETURN
      END
```

```
      SUBROUTINE MSMIN(A,B,J,K)                                         MSN    1
      IF (B-A) 10,20,20                                                 MSN    2
   10 A=B                                                               MSN    3
      K=J                                                               MSN    4
   20 RETURN                                                            MSN    5
      END                                                               MSN    6-
```

```
      SUBROUTINE OFFCL
C
      COMMON/FOT/AM2,AMUI,EI,EMU,RHOE,TE,VE,WI(9),XMI,XM2,XVI,YVI,
     1PS,PY,RHOS,RHOY,SMU,TMU,YMU,P0
      COMMON/TIFO/IEQOS,ITRAS
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON    AL        ,ALPHA(99) ,ALT(99)   ,AME       ,AMI
     1,AOFA     ,AOFE      ,AROD      ,AS        ,AX(9,11,9),AY(9,11,9)
     2,BATA     ,BE        ,BETA(99)  ,BF        ,BFL       ,BL
     3,DELTA    ,DIAM      ,DIST(9)   ,DST       ,E(20,99)  ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9) ,FACC      ,FCU(20,99),FCY(20,99)
     5,FNET(20) ,FSU(20,99),FT(20)    ,FTU(20,99),FVE       ,F07
     6,G(20,99) ,HH        ,HINS      ,HINSD(99) ,ICONF     ,ILINKO
     7,IQINP    ,ITURB     ,IWALT     ,MAT(9,9)  ,MPT(9,9)  ,MR(9,18)
     8,NCOLM    ,NCR       ,NCRC      ,NF        ,NI(18)    ,NINS
     9,NMAT     ,NMIN      ,NPRT      ,NPSG      ,NR(18)    ,NRSG
     $,NSEG     ,NTRAJ     ,N33       ,PE        ,PHI       ,PI
     $,PINP(99) ,QCONL(9)  ,QCONT(9)  ,QINP(99)  ,QNET(9)   ,RHO(9)
     $,RHOI     ,RYE       ,RYI       ,SL        ,SLS       ,STAAT
     $,STI      ,STOOP     ,T(20,99)  ,TALLW(9)  ,TAMP(9,9) ,TAU
     $,TC1      ,TEMP(9,9) ,THETA     ,TI        ,TIME(99)  ,TINS
     $,TINSD(99),UF        ,VFACT(9,18),VI       ,VINF(99)  ,WROTE
     $,XEMIS    ,XSTG(99)  ,XX(20)    ,Y(9)      ,ZZ(20)
C
C*****ENTHALPY FUNCTIONS
      FENTL(T)=2.2864+0.2272*T+0.11571E-4*T*T+0.23676E-9*T**3
      FTEMP(E)=17.899+4.0675*E-.83884E-4*E*E-.3495E-6*E**3
C*****LEE'S DISTRIBUTION
      PH=PHI/57.2957795
      VE=.362*XVI*SQRT((1.+5./XMI)*(1.-.715/XMI))*SIN(PH)
      VE=SQRT(VE*VE+YVI*YVI)
      EI=STI-VE*VE/50061.5
      CE=SIN(AOFE)**2
      CM=1.833*(1.-.455/AM2)
      PE=PI*(1.+.7*AM2*CE*CM)
      IF (EI.GT.1300.) GO TO 10
      TE=FTEMP(EI)
      RHOE=PE/(1714.87*TE)
      AME=VE/(49.01*SQRT(TE))
      GO TO 20
   10 CALL AIR(2,4,PE,S,EI,Z,RHOE,TE,CS)
      AME=VE/CS
   20 P2=PH*PH
      P5=PH*P2*P2
      EMU=FMUT(PE,TE)
      A=-.00665*P5
      B=-.0038*P5
      C=SIN(PH)**2
      D=SIN(2.*PH)*PH-C
      HR=(1.-.84*C+A)*PH/SQRT(.5*(.84*D+P2*(B+1.16)))
      Q=Q*HR
      RETURN
      END
```

```
      SUBROUTINE PANEL
C
      COMMON /FLAGS/ IFIRST, ISTRES, IFATIG, IWTCST
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON /MOMENT/ AII,PMI
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON      AL          ,ALPHA(99) ,ALT(99)   ,AME       ,AMI
     1,AOFA       ,AOFE       ,AROD      ,AS        ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)  ,BF        ,BFL       ,BL
     3,DELTA      ,DIAM       ,DIST(9)   ,DST       ,E(20,99)  ,EALL
     4,EAT(20,99) ,EDOT(20,99),EMIS(9)   ,FACC      ,FCU(20,99),FCY(20,99)
     5,FNET(20)   ,FSU(20,99) ,FT(20)    ,FTU(20,99),FVE       ,F07
     6,G(20,99)   ,HH         ,HINS      ,HINSD(99) ,ICONF     ,ILINKO
     7,IQINP      ,ITURB      ,IWALT     ,MAT(9,9)  ,MPT(9,9)  ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC      ,NF        ,NI(18)    ,NINS
     9,NMAT       ,NMIN       ,NPRT      ,NPSG      ,NR(18)    ,NRSG
     $,NSEG       ,NTRAJ      ,N33       ,PE        ,PHI       ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)  ,QINP(99)  ,QNET(9)   ,RHO(9)
     $,RHOI       ,RYE        ,RYI       ,SL        ,SLS       ,STAAT
     $,STI        ,STOOP      ,T(20,99)  ,TALLW(9)  ,TAMP(9,9) ,TAU
     $,TC1        ,TEMP(9,9)  ,THETA     ,TI        ,TIME(99)  ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI       ,VINF(99)  ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)    ,Y(9)      ,ZZ(20)
      DIMENSION ALPHE(20)
      EQUIVALENCE (TB,BF), (TF,TS), (TR,BFL)
C
      GO TO (10,40,70,100,130,160,210) NSECT
C*****CONFIGURATION NO 1
   10 RHR=(R-HH)/R
      THETA=ACOS(RHR)
      BF=AS-2.*R*SIN(THETA)
      TC1=TC*SIN(THETA)/THETA
      A(1)=.1*(AS-BF)*TS
      XX(1)=.05*(AS-BF)
      ZZ(1)=.5*TS
      DO 20 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)+2.*XX(1)
   20 ZZ(I)=ZZ(1)
      A(6)=.25*BF*(TS+TC)
      XX(6)=.5*AS-.375*BF
      ZZ(6)=.5*(TS+TC)
      A(7)=A(6)
      XX(7)=XX(6)+.25*BF
      ZZ(7)=ZZ(6)
      ALPHE(1)=THETA*13./14.
      ALPH=ALPHE(1)
      A(8)=R*THETA*TC1/7.
      XX(8)=R*SIN(ALPH)
      ZZ(8)=R*COS(ALPH)-R+HH+TS
      DO 30 I=9,14
      ALPHE(I-7)=ALPHE(I-8)-THETA/7.
      ALPH=ALPHE(I-7)
      A(I)=A(8)
      XX(I)=R*SIN(ALPH)
   30 ZZ(I)=R*COS(ALPH)-R+HH+TS
      GO TO 190
C*****CONFIGURATION NO 2
```

```
   40 THETA=ATAN(HH/(.5*AS-BF))
      BW=HH/SIN(THETA)
      DX1=.1*(AS-BF)
      A(1)=DX1*TS
      XX(1)=.5*DX1
      ZZ(1)=.5*TS
      DO 50 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)+DX1
   50 ZZ(I)=ZZ(1)
      A(6)=.25*BF*(TS+TC)
      XX(6)=.5*AS-.375*BF
      ZZ(6)=.5*(TS+TC)
      A(7)=A(6)
      XX(7)=XX(6)+.25*BF
      ZZ(7)=ZZ(6)
      DBW=.2*BW
      DXC=DBW*COS(THETA)
      DZC=DBW*SIN(THETA)
      A(8)=DBW*TC
      XX(8)=.5*(AS-BF-DXC)
      ZZ(8)=TS+.5*(TC+DZC)
      DO 60 I=9,12
      A(I)=A(8)
      XX(I)=XX(I-1)-DXC
   60 ZZ(I)=ZZ(I-1)+DZC
      A(13)=.25*BF*TC
      XX(13)=.375*BF
      ZZ(13)=HH+TS+.5*TC
      A(14)=A(13)
      XX(14)=.125*BF
      ZZ(14)=ZZ(13)
      GO TO 190
C*****CONFIGURATION NO 3
   70 DX=.1*(AS-TC)
      A(1)=DX*TS
      XX(1)=.5*(AS-DX)
      ZZ(1)=.5*TS
      DO 80 I=2,5
      A(I)=A(1)
      XX(I)=XX(I-1)-DX
   80 ZZ(I)=ZZ(1)
      A(6)=.1*HH*TC
      XX(6)=.25*TC
      ZZ(6)=.1*HH
      DO 90 I=7,10
      A(I)=A(6)
      XX(I)=XX(6)
   90 ZZ(I)=ZZ(I-1)+HH/5.
      GO TO 190
C*****CONFIGURATION NO 4
  100 ABR=.5*(AS-BF)/R
      THETA=ASIN(ABR)
      DZ=R-R*COS(THETA)
      BW=HH-.5*(TS+TC)-DZ
      A(1)=.25*BF*TS
      XX(1)=.5*AS-.125*BF
      ZZ(1)=0.
```

```
      A(2)=A(1)
      XX(2)=XX(1)-.25*BF
      ZZ(2)=0.
      ALPH=1.1666*THETA
      A35=R*THETA*TS/3.
      DO 110 I=3,5
      ALPH=ALPH-THETA/3.
      A(I)=A35
      XX(I)=R*SIN(ALPH)
  110 ZZ(I)=DZ-(R-R*COS(ALPH))
      A(6)=.125*BW*TC
      XX(6)=.25*TC
      ZZ(6)=DZ+.5*TS+.125*BW
      DO 120 I=7,9
      A(I)=A(6)
      XX(I)=XX(6)
  120 ZZ(I)=ZZ(I-1)+.25*BW
      A(10)=TC*BFL/4.
      XX(10)=.125*BFL
      ZZ(10)=HH
      A(11)=A(10)
      XX(11)=.375*BFL
      ZZ(11)=ZZ(10)
      A(12)=BL*TC
      XX(12)=.5*(BFL-TC)
      ZZ(12)=HH-.5*(TC+BL)
      GO TO 190
C*****CONFIGURATION NO 5
  130 HR=1.-.5*HH/R
      THETA=ACOS(HR)
      BF=.5*AS-2.*R*SIN(THETA)
      A(1)=.25*BF*TC
      XX(1)=.125*BF
      ZZ(1)=0.
      A(2)=A(1)
      XX(2)=.375*BF
      ZZ(2)=0.
      ALPH1=-0.1*THETA
      A27=.2*R*THETA*TC
      DO 140 I=3,7
      A(I)=A27
      ALPH1=ALPH1+.2*THETA
      XX(I)=.5*BF+R*SIN(ALPH1)
  140 ZZ(I)=R-R*COS(ALPH1)
      DO 150 I=1,7
      J=8-I
      A(I+7)=A(J)
      XX(I+7)=.5*AS-XX(J)
  150 ZZ(I+7)=HH-ZZ(J)
      GO TO 190
C*****CONFIGURATION NO 6
  160 THETA=ACOS(1.-.5*HH/R)
      AS=2.*(2.*R-HH)*TAN(THETA)
      ALPH1=-0.1*THETA
      A15=.2*R*THETA*TC
      DO 170 I=1,5
      A(I)=A15
      ALPH1=ALPH1+.2*THETA
```

```
      XX(I)=R*SIN(ALPH1)
  170 ZZ(I)=R-R*COS(ALPH1)
      DO 180 I=1,5
      J=6-I
      A(I+5)=A15
      XX(I+5)=.5*AS-XX(J)
  180 ZZ(I+5)=HH-ZZ(J)
  190 IF (IFATIG.NE.0.OR.AII.GT.0) RETURN
      XXMI=0.0
      AREA=0.0
      FIRSTM=0.0
      DO 200 I=1,NPSG
      XXMI=XXMI+A(I)*ZZ(I)**2
      AREA=AREA+A(I)
  200 FIRSTM=FIRSTM+A(I)*ZZ(I)
      ZZBAR=FIRSTM/AREA
      OMI=2.*(XXMI-AREA*ZZBAR**2)
      PMI=OMI*(SLS/AS)
      RETURN
C*****CONFIGURATION NO 7
  210 DO 220 I=1,NPSG
  220 XX(I)=0.
      A(1)=TF
      A(2)=0.
      A(3)=TF
      A(4)=0.
      A(5)=TR/14.
      ZZ(1)=TC+TR+TB+1.5*TF+HH
      ZZ(2)=ZZ(1)-.5*(HH+TF)
      ZZ(3)=ZZ(2)-.5*(HH+TF)
      ZZ(4)=ZZ(3)-.5*(TB+TF)
      ZZ(5)=ZZ(4)-.5*(TB+A(5))
      A(6)=TR/7.
      ZZ(6)=ZZ(5)-.5*(A(5)+A(6))
      DO 230 I=7,11
      A(I)=A(6)
  230 ZZ(I)=ZZ(I-1)-A(6)
      A(12)=A(5)
      ZZ(12)=TC+.5*A(12)
      A(13)=TC
      ZZ(13)=.5*TC
      GO TO 190
      END
```

```
      SUBROUTINE PRA63(ALT,PINF,TINF,RHOINF,ICK)
C
      DIMENSION  PB(14),ZI(5),PK(6,5),RHOK(6,3),TK(6,5),VTK(6,3),
     1ZB(14),TMB(14),LMB(14),DMB(14),MB(14)
      REAL LMB,MB,MWT
      DATA PBASE/6.23101759E-5/
      DATA (ZI(I),I=1,5)/10832.1,17853.3,28000.,49000.,83004./
      DATA (PK(I),I=1,30)           /1.6871582E-2,-1.1425176E-4,-1.3612327
     1E-9,7.3624145E-14,-1.0800315E-17,3.3046432E-22,-7.9910777E-2,-8.10
     246438E-5,-5.5522383E-9,3.1116969E-13,-1.6687827E-17,3.8319351E-22,
     39.8414277E-1,-2.6976917E-4,8.5227541E-9,-3.9620263E-13,1.0146471E-
     417,-1.0264318E-22,
     51.14118495E1,-4.11497477E-4,1.33664855E-8,-3.59518975E-13,
     65.10097254E-18,-2.89055894E-23,
     79.99324461,-2.58298177E-4,3.76139346E-9,-4.20887236E-14,
     81.60182148E-19,-1.92508927E-25/
      DATA (RHOK(I),I=1,18)          /1.3302117E-2,-8.8502064E-5,-4.21430
     156E-9,5.9517557E-13,-3.9744789E-17,7.8771273E-22,1.2667122E-1,
     2-1.3373147E-4,2.0667371E-9,2.3396109E-13,-3.2562503E-17,7.9035209E
     3-22,9.2751266E-1,-1.4349679E-4,-2.8271736E-9,4.7480092E-14,
     41.8863246E-18,-4.2702411E-23/
      DATA (TK(I),I=1,30)           /2.9667877E2,-6.7731001E-3,8.4619805E-
     17,-1.7004049E-10,1.1451454E-14,-2.4898788E-19,
     22.6892151E2,4.3075352E-3,-8.9159672E-7,-2.8929791E-11,5.0724856E-1
     35,-1.1490372E-19,
     43.7064557E2,-3.2858965E-2,2.0645636E-6,-4.3283944E-11,-5.7507242E-
     517,8.2924583E-21,
     62.044798E1,2.07698384E-2,-8.63038789E-7,1.66392417E-11,
     7-9.30076185E-17,-4.09005108E-22,
     8-4.98865953E2,3.92137281E-2,-4.95180601E-7,-3.26219854E-12,
     9 9.66650364E-17,-4.78844279E-22/
      DATA (ZB(I),I=1,14)/
     19.E4,1.E5,1.1E5,1.2E5,1.5E5,1.6E5,1.7E5,1.9E5,2.3E5,3.E5,4.E5,5.E5
     2,6.E5,7.E5/
      DATA (TMB(I),I=1,14)/          180.65,210.65,260.65,360.65,960.65,
     11110.65,1210.65,1350.65,1550.65,1830.65,2160.65,2420.65,2590.65,
     22700.65/
      DATA (LMB(I),I=1,14)/      3.E-3,5.E-3,10.E-3,20.E-3,15.E-3,10.E-3,
     17.E-3,5.E-3,4.E-3,3.3E-3,2.6E-3,1.7E-3,1.1E-3,1.1E-3/
      DATA (MB(I),I=1,14)/  28.9644,28.88,28.56,28.07,26.92,26.66,26.40,
     125.85,24.70,22.66,19.94,17.94,16.84,16.17/
      DATA (DMB(I),I=1,14)/      -0.844E-5,-3.20E-5,-4.9E-5,-3.833E-5,
     12*-2.60E-5,-2.75E-5,-2.875E-5,-2.914E-5,-2.72E-5,-2.0E-5,-1.1E-5,
     2-0.67E-5,-0.67E-5/
      DATA (PB(I),I=1,14)/.172244361E-4,.315971712E-5,.774389807E-6,
     1.265977111E-6,.535849383E-7,.391284945E-7,.295911117E-7,
     2.178715656E-7,.739258171E-8,.200573116E-8,.430456606E-9,
     3.117315480E-9,.370198961E-10,.128115330E-10/
C
   10 Z=ALT*.3048
      IF (Z.GT.700000.) GO TO 160
      IF (Z.LT.0.) GO TO 160
      N=1
      IF (Z-83004.) 20,50,50
   20 IF (Z-ZI(N)) 40,30,30
   30 N=N+1
      GO TO 20
   40 Z2=Z*Z
```

```
      Z3=Z2*Z
      Z4=Z2*Z2
      Z5=Z2*Z3
      GO TO 90
   50 IF (Z-90000.) 130,60,60
   60 IF (Z-ZB(N)) 80,140,70
   70 N=N+1
      GO TO 60
   80 N=N-1
      GO TO 140
   90 TEMPK=TK(1,N)+TK(2,N)*Z+TK(3,N)*Z2+TK(4,N)*Z3+TK(5,N)*Z4+TK(6,N)*Z
     15
      IF (Z-28000.) 100,110,110
  100 PRES=10.0000000*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N
     1)*Z4+PK(6,N)*Z5)
      DENS=(1.16790729)*EXP(RHOK(1,N)+RHOK(2,N)*Z+RHOK(3,N)*Z2+RHOK(4,N)
     1*Z3+RHOK(5,N)*Z4+RHOK(6,N)*Z5)
      GO TO 150
  110 PRES=.000980665*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N
     1)*Z4+PK(6,N)*Z5)
  120 DENS=34.83676*(PRES/TEMPK)
      GO TO 150
  130 TEMPK=180.65
      PRES=PBASE*EXP((-1.373301523E12*(Z-83004.))/(180.65*(6344860.+Z)*(
     16344860.+83004.)))
      GO TO 120
  140 MWT=MB(N)+DMB(N)*(Z-ZB(N))
      TEMPM=TMB(N)+LMB(N)*(Z-ZB(N))
      TEMPK=(MWT/28.9644)*TEMPM
      PRES=EXP(ALOG(PB(N))+(1.373301523E12/(LMB(N)*(6344860.+Z)*(6344860
     1.+ZB(N))))*ALOG(TMB(N)/(TMB(N)+(LMB(N)*(Z-ZB(N))))))
      DENS=34.83676*PRES/TEMPM
  150 PINF=PRES*208.8576
      TINF=TEMPK*1.8
      RHOINF=DENS*0.0019404
      ICK=1
      GO TO 170
  160 ICK=0
  170 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE PRINT1(ISS,ITER)
C
      COMMON /FLAGS/ IFIRST, ISTRES, IFATIG, IWTCST
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON     AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA      ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA      ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA     ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)  ,FSU(20,99),FT(20)      ,FTU(20,99),FVE         ,F07
     6,G(20,99)  ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP     ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM     ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT      ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG      ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)  ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI      ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI       ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1       ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99) ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS     ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
C
      N=ISS
      CALL SECOND(CPTIME)
      WRITE (6,80) ITER,CPTIME
      WRITE (6,30) TAU,AL,VI,AOFA,PI,AMI,AME,RYI,PE
      WRITE (6,50) (I,I=1,9),Q,QNET
      DO 10 J=1,NSEG
   10 WRITE (6,60) J,(TEMP(I,J),I=1,9)
      IF (NINS.EQ.1.OR.ISTRES.NE.0) GO TO 20
      WRITE (6,70) (A(I),XX(I),ZZ(I),T(I,N),FT(I),FNET(I),EDOT(I),FTU(I,
     1N),FCY(I,N),E(I,N),I=1,NPSG)
   20 WRITE (6,40)
      RETURN
C
   30 FORMAT (20X3HTAU,10X2HAL,10X2HVI,8X4HAOFA,10X2HPI,9X3HAMI,9X3HAME,
     19X3HRYI,10X2HPE/12X,9E12.4)
   40 FORMAT (1H1)
   50 FORMAT (//11X1HI,9I12//8X4HQ(I),9E12.4/5X7HQNET(I),9E12.4/)
   60 FORMAT (2X7HTEMP(I,I2,1H),9E12.4)
   70 FORMAT (//11X1HA,10X2HXX,10X2HZZ,11X1HT,10X2HFT,8X4HFNET,8X4HEDOT,
     19X3HFTU,9X3HFCY,11X1HE//(10E12.3))
   80 FORMAT (1H0,5X23HNUMBER OF TIME STEPS = ,I10,20X9HCPTIME = ,F10.3/
     1)
      END
```

```
      SUBROUTINE SHOCK(AII,PI,PY,RHOI,VU,S)
C
      M=1
      RY=3.5*RHOI
   10 IF (M.GT.11) GO TO 30
      VY=RHOI*VU/RY
      VY2=VY*VY
      VU2=VU*VU
      PY=PI+RHOI*VU*(VU-VY)
      HY=AII+(VU2-VY2)/50061.5
      CALL AIR(2,3,PY,S,HY,Z,RYP,TY,CS)
      DR=RYP-RY
      M=M+1
      IF (ABS(DR/RY).LT.0.001) GO TO 20
      IF (RYP.LT.RHOI) RYP=RHOI
      RYQ=RY
      RY=RYP
      GO TO 10
   20 PY=PY+RYP*VY2
      RETURN
   30 WRITE (6,40) RY,RYQ
      CALL EXIT
C
   40 FORMAT (35H ITERATION LIMIT EXCEEDED IN R-LOOP,2E15.4)
      END
```

```
      SUBROUTINE STRESS(ISS,IST)
C
      COMMON /CNDTN/ DEL,DTMAX,TTAU,ITER
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON          AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA       ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA      ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)   ,FSU(20,99),FT(20)     ,FTU(20,99),FVE         ,F07
     6,G(20,99)   ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINK0
     7,IQINP      ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT       ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG       ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI       ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI        ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1        ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
      DIMENSION BMMAX(99),EDO(20),SUME(20),PX(20)
      REAL MSCC, MSCT, MSFC, MSFT, MSHS, MSIC, MSIT
      EQUIVALENCE (TF,TS), (DC,BL)
C
      M=1
      KM=1
      R11M=0.
      R12M=0.
      R23M=0.
      R33M=0.
      R41M=0.
      R42M=0.
      R51M=0.
      R52M=0.
      ISS=ISS+1
      II=ISS
      J=ISS
      GO TO (10,10,40,70,100,120,140), NSECT
   10 DO 20 I=1,5
      T(I,J)=TEMP(I,1)
      IF (T(I,J).GT.TALLW(1)) GO TO 610
   20 CONTINUE
      T(6,J)=.5*(TEMP(6,1)+TEMP(6,2))
      T(7,J)=.5*(TEMP(7,1)+TEMP(7,2))
      T(8,J)=TEMP(6,3)
      DO 30 I=9,14
      K=15-I
   30 T(I,J)=TEMP(K,4)
      GO TO 160
   40 DO 50 I=1,5
      K=7-I
      T(I,J)=TEMP(K,1)
      IF (T(I,J).GT.TALLW(1)) GO TO 610
   50 CONTINUE
      XT=5.*TS/HH
      T(6,J)=XT*TEMP(1,1)+(1.-XT)*TEMP(1,2)
```

```
      DO 60 I=7,10
      K=I-4
   60 T(I,J)=TEMP(1,K)
      GO TO 160
   70 DO 80 I=1,5
      K=7-I
      T(I,J)=TEMP(K,1)
      IF (T(I,J).GT.TALLW(1)) GO TO 610
   80 CONTINUE
      DO 90 I=6,9
      K=I-4
   90 T(I,J)=TEMP(1,K)
      T(10,J)=TEMP(2,6)
      T(11,J)=TEMP(3,6)
      T(12,J)=TEMP(4,6)
      GO TO 160
  100 DO 110 I=4,14
      K=I-3
      IF (K.GT.9) K=9
      T(I,J)=TEMP(K,1)
      IF (T(I,J).GT.TALLW(1)) GO TO 610
  110 CONTINUE
      T(1,J)=T(7,J)
      T(2,J)=T(6,J)
      T(3,J)=T(5,J)
      GO TO 160
  120 DO 130 I=3,10
      K=I-2
      T(I,J)=TEMP(K,1)
      IF (T(I,J).GT.TALLW(1)) GO TO 610
  130 CONTINUE
      T(1,J)=T(5,J)
      T(2,J)=T(4,J)
      GO TO 160
  140 K=15
      DO 150 I=1,12
      IF (I.EQ.4.OR.I.EQ.5) K=K-1
  150 T(I,J)=TEMP(K-I)
      T(13,J)=TEMP(1)
  160 IF (IST.GE.1) GO TO 190
      IST=1
      L=IABS(MAT(1,1))
      IF (NSECT.EQ.7) L=1
      CF=FLOAT(NF)*WROTE/7200.
      FCY0=AY(L,5,1)
  170 CALL PANEL
      R1M=0.
      R2M=0.
      R3M=0.
      R4M=0.
      R5M=0.
      R6M=0.
      DMAX=0.
      WBMS=100.
      DO 180 I=1,NPSG
      EDO(I)=0.
  180 SUME(I)=0.
      IF (M.EQ.2.OR.KM.GT.1) GO TO 200
```

```
C*****CORRUGATION BM AT MID SPAN
  190 W=PE*AS/144.
      SLP=SLS-2.*BE
      BMMAX(ISS)=W*SLP*SLP/8.
      IF (NSECT.EQ.7) CRFS=ABS(W*SLP/(2.*(HH+TF)))
  200 DO 600 N=II,ISS
  210 SUMA=0.
      SUMPX=0.
      SUMTA=0.
      SUMMX=0.
      SUMXX=0.
      SUMAZ=0.
      L=IABS(MAT(1,1))
      DO 300 I=1,NPSG
      IF (M.EQ.2.OR.KM.GT.1) GO TO 290
      IF (NSECT.NE.7) GO TO 270
      GO TO (220,230,220,240,250,250,250,250,250,250,250,250,260) I
  220 L=1
      FCY(I,N)=TRPLAT(AY,AX,T(I,N),L,5,MPT(L,5))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
      GO TO 280
  230 L=2
      FCU(I,N)=TRPLAT(AY,AX,T(I,N),L,9,MPT(L,9))
      FSU(I,N)=TRPLAT(AY,AX,T(I,N),L,10,MPT(L,10))
      G(I,N)=TRPLAT(AY,AX,T(I,N),L,11,MPT(L,11))
      GO TO 280
  240 L=3
      FSU(I,N)=TRPLAT(AY,AX,T(I,N),L,10,MPT(L,10))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
      G(I,N)=TRPLAT(AY,AX,T(I,N),L,11,MPT(L,11))
      GO TO 280
  250 L=4
      FCU(I,N)=TRPLAT(AY,AX,T(I,N),L,9,MPT(L,9))
      FSU(I,N)=TRPLAT(AY,AX,T(I,N),L,10,MPT(L,10))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
      G(I,N)=TRPLAT(AY,AX,T(I,N),L,11,MPT(L,11))
      GO TO 280
  260 L=5
      FCU(I,N)=TRPLAT(AY,AX,T(I,N),L,9,MPT(L,9))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
      GO TO 280
  270 FCY(I,N)=TRPLAT(AY,AX,T(I,N),L,5,MPT(L,5))
      FTU(I,N)=TRPLAT(AY,AX,T(I,N),L,6,MPT(L,6))
  280 E(I,N)=TRPLAT(AY,AX,T(I,N),L,3,MPT(L,3))
      ALFA=TRPLAT(AY,AX,T(I,N),L,4,MPT(L,4))
      EAT(I,N)=E(I,N)*ALFA*(T(I,N)-530.)
  290 EATA=EAT(I,N)*A(I)
      AE=E(I,N)*A(I)
      SUMA=SUMA+AE
      SUMTA=SUMTA+EATA
      SUMMX=SUMMX+AE*ZZ(I)
      SUMXX=SUMXX+AE*ZZ(I)**2
  300 SUMAZ=SUMAZ+EATA*ZZ(I)
      IF (NSECT.EQ.7) L=1
      ABAR=SUMTA/SUMA
      SBAR=SUMAZ/SUMTA
      ZBAR=SUMMX/SUMA
      XXI=2.*(SUMXX-ZBAR*SUMMX)
```

```
      XXM=2.*SUMTA*(ZBAR-SBAR)
      XXW=XXM/XXI
      WX=BMMAX(N)/XXI
      DFL=(.1042*WX-.125*XXW)*SLS**2
      DMAX1=AMAX1(ABS(DMAX),ABS(DFL))
      IF (ABS(DMAX1).EQ.ABS(DFL)) DMAX=DFL
C*****THERMAL STRESS
      DO 310 I=1,NPSG
      FT(I)=E(I,N)*(ABAR+XXW*(ZBAR-ZZ(I)))-EAT(I,N)
  310 FNET(I)=FT(I)-WX*E(I,N)*(ZBAR-ZZ(I))
      IF (NSECT.NE.7) GO TO 330
      DO 320 I=5,13
      PX(I)=FNET(I)*A(I)
  320 SUMPX=SUMPX+PX(I)
C*****STRESS DUE TO APPLIED BM
C*****BUCKLING OF SKIN
  330 IF (M.EQ.2) GO TO 350
      IF (NSECT.GT.2) GO TO 350
      IF (FNET(1).GE.0.) GO TO 350
      F7=F07*FCY(1,N)/FCY0
      FCR=3.62*E(1,N)*(TS/(AS-BF))**2
      CALL BUCKNG(E(1,N),F7,FCR,FCY(1,N),FTU(1,N),NCR)
      IF (FCR.GE.ABS(FNET(1))) GO TO 350
      DO 340 I=1,4
  340 A(I)=0.
      M=2
      GO TO 210
  350 IF (NSECT.NE.3) GO TO 370
C*****BUCKLING OF LEG SECT NO 3
      BF=AS
      N3=0
      FTT=0.
      DO 360 I=6,NPSG
      IF (FNET(I).GT.0.) GO TO 360
      N3=N3+1
      FTT=FTT+FNET(I)
  360 CONTINUE
      IF (N3.EQ.0) GO TO 370
      BF3=.2*HH*FLOAT(N3)
      FAVE=FTT/FLOAT(N3)
      J=NPSG-N3+1
      F7=F07*FCY(J,N)/FCY0
      FCR=.385*E(J,N)*(TC/BF3)**2
      CALL BUCKNG(E(J,N),F7,FCR,FCY(J,N),FTU(J,N),NCR)
      WB=-FCR/(FAVE*UF)-1.
      GO TO 380
  370 WB=100.
C*****CREEP RATE
  380 WBMS=AMIN1(WBMS,WB)
      DO 600 I=1,NPSG
      IF (A(I).LE.0.) FNET(I)=0.
      FX=FNET(I)
      IF (NSECT.EQ.7.AND.(I.EQ.2.OR.I.GT.3)) GO TO 390
      PLM1=TRPLAT(AY,AX,ABS(FX),L,7,MPT(L,7))
      PLM2=TRPLAT(AY,AX,ABS(FX),L,8,MPT(L,8))
      E1=PLM1/T(I,N)-20.
      E2=PLM2/T(I,N)-20.
      IF (ABS(E1).LT.30.0.AND.ABS(E2).LT.30.0) GO TO 400
```

```
      EDOT(I)=0.0
      GO TO 410
  390 EDOT(I)=0.
      GO TO 990
  400 EDOT(I)=ABS(DST/(10.**E2-10.**E1))
  410 IF (NSECT.EQ.7) GO TO 990
C*****STRUCTURAL INDICES FOR THE SELECTION OF CRITICAL TRAJECTORY POINTS
      IF (FX.GT.0.) GO TO 420
      R11=0.
      R22=-FX/FCY(I,N)
      R33=R22
      R44=-FX/E(I,N)
      R55=SQRT(R22*R44)
      GO TO 430
  420 R11=FX/FTU(I,N)
      R22=FX/FCY(I,N)
      R33=0.
      R44=0.
      R55=0.
  430 R1M=AMAX1(R1M,R11)
      R2M=AMAX1(R2M,R22)
      R3M=AMAX1(R3M,R33)
      IF (R3M.NE.R33) GO TO 440
      I3=I
      N3=N
      FN3=FX
  440 GO TO (450,490,490,460,470,480), NSECT
  450 IF (I.GE.8) GO TO 480
      GO TO 490
  460 IF (I.GE.3.AND.I.LE.5) GO TO 480
      GO TO 490
  470 IF (I.GE.3.AND.I.LE.12) GO TO 480
      GO TO 490
  480 R4M=AMAX1(R4M,R44)
      IF (R4M.NE.R44) GO TO 490
      I4=I
      N4=N
      FN4=FX
  490 GO TO (530,500,530,510,500,530), NSECT
  500 IF (I.GE.13) GO TO 520
      GO TO 530
  510 IF (I.GE.11) GO TO 520
      GO TO 530
  520 R5M=AMAX1(R5M,R55)
      IF (R5M.NE.R55) GO TO 530
      I5=I
      N5=N
      FN5=FX
  530 GO TO (540,540,550,560,560,580), NSECT
  540 IF (I.EQ.6.OR.I.EQ.7) GO TO 570
      GO TO 580
  550 IF (I.LE.5) GO TO 570
      GO TO 580
  560 IF (I.LE.2) GO TO 570
      GO TO 580
  570 R6M=AMAX1(R6M,R55)
      IF (R6M.NE.R55) GO TO 580
      I6=I
```

```
      N6=N
      FN6=FX
  580 IF (NSECT.EQ.7.AND.(I.EQ.2.OR.I.GT.3)) GO TO 590
      SUME(I)=SUME(I)+CF*(EDOT(I)+EDO(I))
  590 EDO(I)=EDOT(I)
  600 CONTINUE
      GO TO 620
  610 IFLAG=1
  620 IF (IST.EQ.2) GO TO 630
      RETURN
C*****ULTIMATE TENSION
  630 IF (IFLAG.EQ.1) GO TO 860
      IF (NSECT.EQ.7) GO TO 820
      T1MS=1./(R1M*UF)-1.
C*****YIELD STRENGTH
      Y2MS=1./R2M-1.
C*****ULTIMATE COMPRESSION
      IF (R3M.LE.0.) GO TO 640
      FCUU=AMIN1(1.1*FCY(I3,N3),FTU(I3,N3))
      C3MS=-FCUU/(FN3*UF)-1.
      GO TO 650
  640 C3MS=100.
C*****BUCKLING OF CORRUGATION
  650 IF (R4M.LE.0.) GO TO 700
      GO TO (660,700,700,670,680,680), NSECT
  660 TX=TC1
      GO TO 690
  670 TX=TS
      GO TO 690
  680 TX=TC
  690 F7=F07*FCY(I4,N4)/FCY0
      FCR=.3*E(I4,N4)*TX/R
      CALL BUCKNG(E(I4,N4),F7,FCR,FCY(I4,N4),FTU(I4,N4),NCR)
      C4MS=-FCR/(FN4*UF)-1.
      GO TO 710
  700 C4MS=100.
C*****CRIPPLING OF FLANGE
  710 IF (R5M.LE.0.) GO TO 740
      GO TO (740,720,740,720,720,740), NSECT
  720 I=I5
      N=N5
      M=1
      TX=TC
  730 FCC=1.385*FCY(I,N)/(SQRT(FCY(I,N)/E(I,N))*BF/TX)**.808
      IF (1.1*FCY(I,N).LT.FCC) FCC=1.1*FCY(I,N)
      IF (FTU(I,N).LT.FCC) FCC=FTU(I,N)
      IF (M.EQ.2) GO TO 800
      F5MS=-FCC/(FN5*UF)-1.
      GO TO 750
  740 F5MS=100.
  750 IF (R6M.LE.0.) GO TO 810
      GO TO (760,760,770,770,780,810), NSECT
  760 TX=TC+TS
      GO TO 790
  770 TX=TS
      GO TO 790
  780 TX=TC
  790 M=2
```

```
      I=I6
      N=N6
      GO TO 730
  800 F6MS=-FCC/(FN6*UF)-1.
      GO TO 840
  810 F6MS=100.
      GO TO 840
C***** MSXX=100. INDICATES MARGIN IS NOT APPLICABLE.
  820 MSFT=100.
      IF (R11M.NE.0.) MSFT=1./(R11M*UF)-1.
      MSFC=100.
      IF (R12M.EQ.0.) GO TO 830
      FCRW=.5*(G(2,N12)*E(2,N12)*E(I12,N12))**.333
      F7=F07*FCY(I12,N12)/FCY0
      CALL BUCKNG(E(I12,N12),F7,FCRW,FCY(I12,N12),FTU(I12,N12),NCR)
      FCRD=3.*E(I12,N12)*(TF/DC)**2.
      CALL BUCKNG(E(I12,N12),F7,FCRD,FCY(I12,N12),FTU(I12,N12),NCR)
      FCR=AMIN1(FCRW,FCRD)
      MSFC=FCR/(R12M*FCY(I12,N12))-1.
  830 MSHS=100.
      IF (R23M.NE.0.) MSHS=1./(R23M*UF)-1.
      MSIT=100.
      IF (R41M.NE.0.) MSIT=1./(R41M*UF)-1.
      MSIC=100.
      IF (R42M.NE.0.) MSIC=1./(R42M*UF)-1.
      MSCT=100.
      IF (R51M.NE.0.) MSCT=1./(R51M*UF)-1.
      MCSS=100.
      IF (R52M.NE.0.) MSCC=1./(R52M*UF)-1.
C***** SELECTION OF MAX CREEP STRAIN AND MIN M.S.
  840 EMAX=0.
      IF (NSECT.EQ.7) GO TO 870
      DO 850 I=1,NPSG
  850 EMAX=AMAX1(EMAX,SUME(I))
      EMS=AMIN1(T1MS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS)
  860 IF (NPRT.EQ.1) CALL PRINT1(ISS,ITER)
      IF (IFLAG.EQ.1) GO TO 970
      WRITE (6,1220) T1MS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS,DMAX,EMS,EMAX
      GO TO 880
  870 EMAX=AMAX1(SUME(1),SUME(3))
      EMS=1000000000.
      CALL MSMIN(EMS,MSFT,N11,NMIN)
      CALL MSMIN(EMS,MSFC,N12,NMIN)
      CALL MSMIN(EMS,MSHS,N23,NMIN)
      CALL MSMIN(EMS,MSIT,N41,NMIN)
      CALL MSMIN(EMS,MSIC,N42,NMIN)
      CALL MSMIN(EMS,MSCT,N51,NMIN)
      CALL MSMIN(EMS,MSCC,N52,NMIN)
      IF (NPRT.EQ.1) CALL PRINT1(ISS,ITER)
      WRITE (6,1230) MSFT,MSFC,MSHS,MSIT,MSIC,MSCT,MSCC,DMAX,EMS,EMAX
  880 IF (KM.EQ.2) GO TO 920
C*****SELECTION OF MIN M.S.
      IF (EALL.GE.EMAX.AND.EMS.GE.0.) GO TO 980
      KM=2
      R11M=0.
      R12M=0.
      R23M=0.
      R33M=0.
```

```
      R41M=0.
      R42M=0.
      R51M=0.
      R52M=0.
      DT=.010
      IF (NSECT.EQ.7) DT=.05
  890 AMAX=EMAX
      AMS=EMS
      IF (NSECT.EQ.7) GO TO 900
      TC=TC+DT
      IF (NSECT.EQ.3.OR.NSECT.EQ.4) TS=TS+DT
      GO TO 910
  900 HH=HH+DT
      IF (HH.LT.6.) GO TO 910
      WRITE (6,1270)
      WRITE (6,1250)
      HH=HH-DT
      RETURN
  910 II=1
      WRITE (6,1260) TC,TS,HH
      WRITE (6,1250)
      M=1
      GO TO 170
  920 IF (EALL.GE.EMAX.AND.EMS.GE.0.) GO TO 980
      IF (EALL.GE.EMAX) GO TO 930
      DEDT=1.E2*(AMAX-EMAX)
      IF (NSECT.EQ.7) DEDT=(AMAX-EMAX)/.05
      DT1=(EMAX-.95*EALL)/DEDT
      GO TO 940
  930 DT1=0.
  940 IF (EMS.GE.0) GO TO 950
      DMDT=1.E2*(EMS-AMS)
      IF (NSECT.EQ.7) DMDT=(EMS-AMS)/.05
      DT2=(.05-EMS)/DMDT
      GO TO 960
  950 DT2=0.
  960 DT=AMAX1(DT1,DT2)
      KM=3
      GO TO 890
  970 WRITE (6,1240) TALLW(1),I,T(I,J)
      CALL EXIT
  980 WRITE (6,1250)
      RETURN
  990 IX=I
      GO TO (1000,1050,1000,1080,1110,1110,1110,1110,1110,1110,1110,1110
     1,1160) IX
 1000 R1=FX/FTU(IX,N)
      IF (R1.LT.0.) R1=0.
      IF (R1-R11M) 1020,1010,1010
 1010 R11M=R1
      I11=IX
      N11=N
 1020 R2=-FX/FCY(IX,N)
      IF (R2.LT.0.) R2=0.
      IF (R2-R12M) 1040,1030,1030
 1030 R12M=R2
      I12=IX
      N12=N
```

```
1040 GO TO 1210
1050 R3=CRFS/FSU(IX,N)
     IF (R3-R23M) 1070,1060,1060
1060 R23M=R3
     I23=2
     N23=N
1070 GO TO 1210
1080 R3=(ABS(SUMPX))/FSU(IX,N)
     IF (R3-R33M) 1100,1090,1090
1090 R33M=R3
     I33=4
     N33=N
1100 GO TO 1210
1110 R1=FX/FTU(IX,N)
     IF (R1.LT.0.) R1=0.
     IF (R1-R41M) 1130,1120,1120
1120 R41M=R1
     I41=IX
     N41=N
1130 R2=-FX/FCU(IX,N)
     IF (R2.LT.0.) R2=0.
     IF (R2-R42M) 1150,1140,1140
1140 R42M=R2
     I42=IX
     N42=N
1150 GO TO 1210
1160 R1=FX/FTU(IX,N)
     IF (R1.LT.0.) R1=0.
     IF (R1-R51M) 1180,1170,1170
1170 R51M=R1
     I51=IX
     N51=N
1180 R2=-FX/FCU(IX,N)
     IF (R2.LT.0.) R2=0.
     IF (R2-R52M) 1200,1190,1190
1190 R52M=R2
     I52=IX
     N52=N
1200 GO TO 1210
1210 CONTINUE
     GO TO 580
C
1220 FORMAT (//52H0***** S T R E S S   A N A L Y S I S   N O T E *****/
    1/8X4HT1MS,8X4HY2MS,8X4HC3MS,8X4HC4MS,8X4HF5MS,8X4HF6MS,8X4HWBMS,8X
    24HDMAX,9X3HEMS,8X4HEMAX/10E12.4)
1230 FORMAT (//52H0***** S T R E S S   A N A L Y S I S   N O T E *****/
    1/8X4HMSFT,8X4HMSFC,8X4HMSHS,8X4HMSIT,8X4HMSIC,8X4HMSCT,8X4HMSCC,8X
    24HDMAX,9X3HEMS,8X4HEMAX/10E12.4)
1240 FORMAT (///101H                                          ***************
    1 P R O B L E M   A B O R T E D   ***************//42H
    2         ALLOWABLE TEMPERATURE,E15.5,35H, OF THE TPS IS EXCEEDED B
    3Y ELEMENTI3,16H, TEMPERATURE = E15.5)
1250 FORMAT (34H0***** E N D   O F   N O T E *****)
1260 FORMAT (//58H STRESS CONSTRAINTS EXCEEDED - PANEL THICKNESS RESIZE
    1D TO /8H    TC =F6.3,4H IN./8H    TS =F6.3,4H IN./8H    HH =F6.3,4
    2H IN./)
1270 FORMAT (//64H PANEL THICKNESS HAS EXCEEDED 6 INCHES - STRESS ANALY
    1SIS ABORTED)
     END
```

```
      SUBROUTINE THERMO
C
      COMMON/FOT/AM2,AMUI,EI,EMU,RHOE,TE,VE,WI(9),XMI,XM2,XVI,YVI,
     1PS,PY,RHOS,RHOY,SMU,TMU,YMU,P0
      COMMON/TIFO/IEQOS,ITRAS
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON     AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA      ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA      ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA     ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)  ,FSU(20,99),FT(20)      ,FTU(20,99),FVE         ,F07
     6,GW(20,99) ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP     ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM     ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT      ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG      ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)  ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI      ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI       ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1       ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99) ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS     ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
      DIMENSION G(10)
      DATA (G(I), I=1,10)/9.2809,-4.734,0.66859,-4.1877E-2,-5.5055E-4,
     12.8367E-4,-2.125E-5,8.0162E-7,-1.5901E-8,1.3236E-10/
C
C*****ENTHALPY FUNCTIONS
      FTEMP(E)=17.899+4.0675*E-.83884E-4*E*E-.3495E-6*E**3
      FENTL(T)=2.2864+0.2272*T+0.11571E-4*T*T+0.23676E-9*T**3
      PR=0.71
      JW=NCOLM
      IF (IWALT.EQ.1) JW=1
      GO TO (10,30,10,10,270,270,290) ICONF
C*****CROSS-FLOW CORRECTION
   10 IF (AOFE.EQ.0.) GO TO 20
      VBAR=.448*(.745+3.14*AROD)*TAN(AOFE)
      VXOD=2.*VBAR*DIST(1)/DIAM
      XFLO=SQRT((1.-1./EXP(VXOD))/VXOD)
      XFLL=1./XFLO
      XFLT=(.5*VXOD/(1.-1./EXP(.5*VXOD)))**0.2
      GO TO 30
   20 XFLL=1.0
      XFLO=1.0
      XFLT=1.0
   30 DO 260 I=1,JW
C*****TRANSITION
      RYU=RHOE*VE/EMU
      IF (ICONF.EQ.2) GO TO 50
      RYE=RYU*DIST(I)
      REC=0.84
      IC=5
      GO TO 90
   40 ROMU=SQRT(RHOR/RHOE*RMU/EMU)
      CA=.664*ROMU*XFLO
      TBL=CA*DIST(I)/SQRT(RYE)
      CB=CA*RYU**0.3/AME
      FDL=CB*SQRT(DIST(I))
```

```
      FDT=12.686-17.264*AOFE+23.777*AOFE**2
      IF (FDL.GT.FDT) GO TO 60
      IC=1
      GO TO 120
   50 RYE=RYU*DIAM
      RYT=1.E5
      IF (RYE.GT.RYT) GO TO 70
      IC=1
      REC=0.84
      GO TO 90
   60 XVO=(FDT/CB)**2
      RYT=RYU*XVO
   70 IF (RYE.GT.2.*RYT) GO TO 80
      IC=2
      TFR=RYE/RYT-1.0
      GO TO 90
   80 IC=3
      REC=0.89
      IF (ICONF.EQ.2) GO TO 130
   90 RECI=EI+REC*VE**2/50061.5
C*****ECKERT REFERENCE ENTHALPY
      RI=0.28*EI+0.22*RECI+0.5*WI(I)
      IF (RI.GT.1300.) GO TO 100
      TR=FTEMP(RI)
      RHOR=PE/(1714.87*TR)
      GO TO 110
  100 CALL AIR(2,4,PE,S,RI,Z,RHOR,TR,CS)
  110 RMU=FMUT(PE,TR)
  120 IF (IC.EQ.5) GO TO 40
      RYR=RHOR*VE*DIST(I)/RMU
      IF (IC.NE.2.OR.REC.NE.0.84) GO TO 130
      RYRL=RYR
      RHOL=RHOR
      REC=0.89
      RECIL=RECI
      GO TO 90
  130 GO TO (140,170,170) IC
  140 IF (ICONF.EQ.2) GO TO 270
      CF=0.644/SQRT(RYR)
      ST=0.5*CF/PR**(2./3.)
      HW=32.174*RHOR*VE*ST*XFLL*QCONL(I)
      GO TO 160
  150 HW=H*QCONL(I)
  160 ID=1
      GO TO 210
  170 IF (ITURB.EQ.2) GO TO 240
      IF (ICONF.EQ.2) GO TO 290
      IF (ITRAS.EQ.2) RYR=RYR*(DIST(I)-XVO)/DIST(I)
      CF=0.370/(ALOG10(RYR))**2.584
      ST=0.5*CF/PR**(2./3.)
  180 HWT=32.174*RHOR*VE*ST*XFLT*QCONT(I)
      GO TO 200
  190 HWT=H*QCONT(I)
  200 ID=2
  210 IF (IC.NE.2.OR.ID.NE.2) GO TO 220
      RYR=RYRL
      RHOR=RHOL
      GO TO 140
```

```
  220 IF (IC.NE.2) GO TO 230
      HW=TFR*HWT+(1.0-TFR)*HW
      RECI=TFR*RECI+(1.0-TFR)*RECIL
  230 IF (IC.EQ.3) HW=HWT
      H=HW
      Q(I)=H*(RECI-WI(I))
      GO TO 260
C*****SPALDING-CHI
  240 D1=WI(I)/EI
      D2=0.2*REC*AME**2
      D3=1.0+D2-D1
      D4=SQRT(D3**2+4.0*D1*D2)
      D5=ASIN((2.0*D2-D3)/D4)+ASIN(D3/D4)
      FC=(D5/SQRT(D2))**-2
      FR=(RECI/WI(I))**0.772/D1**0.702
      FX=FR/FC
      IF (ITRAS.EQ.2) RYE=RYE*(DIST(I)-XVO)/DIST(I)
      D6=ALOG(FX*RYE)
      D7=1.0
      D8=0.0
      DO 250 K=2,10
      D7=D6*D7
  250 D8=D8+G(K)*D7
      CF=(EXP(D8+G(1)))/FC
      SS=1.+5.*SQRT(FC*CF/2.)*(PR-1.+ALOG((5.*PR+1.)/6.))
      ST=0.5*CF/SS
      RHOR=RHOE
      GO TO 180
  260 CONTINUE
      GO TO 340
C*****FAY-RIDDELL
  270 WMU=FMUT(PE,TEMP(1,1))
      RHOW=PE/(1714.87*TEMP(1,1))
      RMW=(RHOW*WMU)**0.1
      RMO=(RHOY*YMU)**0.4
      DUX=2.*SQRT(2.*(PY-PI)/RHOY)/DIAM
      H=30.25*RMO*RMW*SQRT(DUX)
      IF (ICONF.EQ.5) GO TO 280
      H=0.75*H*(SIN(AOFE))**1.2
      RECIL=STI
      RECI=STI
      IF (AROD.LT.0.0001) GO TO 280
      H=H*SQRT(0.745+3.14*AROD)/1.5215
  280 IF (ICONF.EQ.2) GO TO 150
      IS=1
      GO TO 310
C*****BECKWITH-GALLAGHER
  290 RMS=(RHOS*SMU)**0.8
      DUX=2.*SQRT(2.*(PS-PI)/RHOS)/DIAM
      H=1.30622*(VI*COS(AOFE)/TMU)**0.6*DUX**0.2*RMS
      REC=.916-.122*AOFE+.258*AOFE**2-.1*AOFE**3
      RECI=REC*STI
      IF (AROD.LT.0.0001) GO TO 300
      H=H*((0.745+3.14*AROD)/2.315)**0.2
  300 IF (ICONF.EQ.2) GO TO 190
      IS=2
  310 DO 330 I=1,JW
      IF (IS.EQ.2) GO TO 320
```

```
      Q(I)=H*(STI-WI(I))*QCONL(I)
      GO TO 330
  320 Q(I)=H*(RECI-WI(I))*QCONT(I)
  330 CONTINUE
  340 IF (IWALT.EQ.2) GO TO 360
      DO 350 I=1,NCOLM
  350 Q(I)=Q(1)
  360 RETURN
      END
```

```
      OVERLAY (P5490,1,1)
      PROGRAM INPUT1
C
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON /FLAGS/ IFIRST, ISTRES, IFATIG, IWTCST
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON /SONIC1/ AE      ,AI      ,AIY     ,AMACH   ,AMF     ,AW      ,
     1BW      ,C(4)    ,D       ,DREF    ,DT(4)   ,DVEH    ,EP,EPP  ,HC      ,
     2HF      ,HPAN    ,IPAD    ,IPF(4)  ,IPFI    ,KFLEX   ,NENG    ,NPAN    ,
     3QF      ,QL      ,REY     ,RHOP    ,TIMEF   ,TJ      ,TT      ,VJ      ,
     4VS      ,VU      ,VV      ,WEJ     ,WER     ,XI      ,XJ      ,XL      ,
     5YCL     ,YP
      COMMON/TIFO/IEQOS,ITRAS
      COMMON/TPS/A(20),Q(9),R,X(9)
      COMMON        AL           ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA        ,AOFE        ,AROD       ,AS         ,AX(9,11,9) ,AY(9,11,9)
     2,BATA        ,BE          ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA       ,DIAM        ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99)  ,EDOT(20,99) ,EMIS(9)    ,FACC       ,FCU(20,99) ,FCY(20,99)
     5,FNET(20)    ,FSU(20,99)  ,FT(20)     ,FTU(20,99) ,FVE        ,F07
     6,G(20,99)    ,HH          ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP       ,ITURB       ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM       ,NCR         ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT        ,NMIN        ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG        ,NTRAJ       ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)    ,QCONL(9)    ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI        ,RYE         ,RYI        ,SL         ,SLS        ,STAAT
     $,STI         ,STOOP       ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1         ,TEMP(9,9)   ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)   ,UF          ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS       ,XSTG(99)    ,XX(20)     ,Y(9)       ,ZZ(20)
C
      DIMENSION CONF(7),TURB(4),WALT(4),ANGL(4),QLOC(3,4),ID(9,9)
      DIMENSION ANL(4),ANRMS(4),ANML(4),SCR(4),PF(4),CY(4),SLD(4),
     1SPMAX(4),TITLE(13)
C
      DATA CONF/5HPLATE,3HCYL,4HCONE,5HWEDGE,6HSPHERE,5HL-CYL,5HT-CYL/
      DATA TURB/ 6HECKERT, 6HSPALDI, 6H      , 6HNG-CHI /
      DATA WALT/ 6HUNIFOR, 6HNONUNI, 6HM     , 6HFORM   /
      DATA ANGL/ 6HVARIED, 6HCONSTA, 6H      , 6HNT     /
      DATA QLOC/ 6HCALCUL, 6HATED  , 6H      , 6HINPUT , 6HQ- HOT,
     1 6H WALL , 6HINPUT , 6HT     , 6H      , 6HINPUT , 6HQ- COL,
     2 6HD WALL/
C
C
C
      WRITE (6,440)
      DO 20 I=1,10
      READ (5,450) JI,TITLE
      IF (EOF,5) 30,10
   10 WRITE (6,460) TITLE
      IF (JI.GT.0) GO TO 40
   20 CONTINUE
      WRITE (6,470)
   30 STOP
   40 READ (5,480) ICONF,IQCON,IQINP,ITURB,IWALT,NANG,NCOLM,NSEG,NMAT,NR
     1SG,NCRC,NSECT,NINS,NF,NPRT,ISTRES,IFATIG,IWTCST,IEQOS,ITRAS
      NPSG=14
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```
      IF (NSECT.EQ.4) NPSG=12
      IF (NSECT.EQ.3.OR.NSECT.EQ.6) NPSG=10
      IF (NSECT.EQ.7) NPSG=13
      READ (5,490) THETA,PHI,XDST,DIAM,AROD,XEMIS,FACC
      READ (5,490) STAAT,DELTA,WROTE,STOOP
      WRITE (6,570) CONF(ICONF),TURB(ITURB),TURB(ITURB+2),WALT(IWALT),WA
     1LT(IWALT+2),ANGL(NANG),ANGL(NANG+2),(QLOC(I,IQINP),I=1,3)
      WRITE (6,580) THETA,PHI
      WRITE (6,590) XDST,DIAM,AROD,XEMIS,STAAT,STOOP,DELTA,WROTE
      IF (NMAT.EQ.0) GO TO 340
      READ (5,490) AS,R,HH,TS,TC,SL,SLS,BE
      READ (5,490) F07,UF,DST,EALL,CRN,BF,BFL,BL
      NCR=IFIX(CRN)
      IF (NSECT.EQ.7) GO TO 50
      WRITE (6,800) AS,R,HH,TS,TC,SL,SLS,BE,F07,UF,DST,EALL,CRN,BF,BFL,B
     1L
      IF (NSECT.NE.8) GO TO 60
C     CALL ABLATION INPUT ROUTINE
      CALL INPUT2
      GO TO 140
   50 AS=1.
      WRITE (6,810) AS,R,HH,TS,TC,SL,SLS,BE,F07,UF,DST,EALL,CRN,BF,BFL,B
     1L
      CALL INPUT2
      READ (5,500) IPRINT,NH,PZ,VB
      NC=8
      NLC=1
      NV=7
      WRITE (6,550) IPRINT,NC,NH,NLC,NV,PZ,VB
   60 READ (5,490) (TALLW(I),I=1,9)
      READ (5,490) (EMIS(I),I=1,9)
      READ (5,490) (RHO(I),I=1,9)
      DO 100 I=1,NMAT
      READ (5,480) ((ID(I,J),MPT(I,J)),J=1,11)
      DO 100 J=1,11
      IF (ID(I,J).EQ.0.) GO TO 100
      KK=MPT(I,J)
      IF (J.EQ.1) GO TO 80
      IF (ID(I,J).EQ.2) GO TO 80
      DO 70 K=1,KK
   70 AX(I,J,K)=AX(I,J-1,K)
      GO TO 90
   80 READ (5,490) (AX(I,J,K),K=1,KK)
   90 READ (5,490) (AY(I,J,K),K=1,KK)
  100 CONTINUE
      WRITE (6,600) (I,I=1,9)
      WRITE (6,700) (TALLW(I),I=1,NMAT)
      WRITE (6,710) (EMIS(I),I=1,NMAT)
      WRITE (6,720) (RHO(I),I=1,NMAT)
      WRITE (6,730)
      DO 110 I=1,NMAT
      WRITE (6,760) I,(AX(I,J,1),AY(I,J,1),J=1,4)
      DO 110 K=2,9
  110 WRITE (6,780) (AX(I,J,K),AY(I,J,K),J=1,4)
      WRITE (6,740)
      DO 120 I=1,NMAT
      WRITE (6,760) I,(AX(I,J,1),AY(I,J,1),J=5,8)
      DO 120 K=2,9
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```
120 WRITE (6,780) (AX(I,J,K),AY(I,J,K),J=5,8)
    WRITE (6,750)
    DO 130 I=1,NMAT
    WRITE (6,770) I,(AX(I,J,1),AY(I,J,1),J=9,11)
    DO 130 K=2,9
130 WRITE (6,790) (AX(I,J,K),AY(I,J,K),J=9,11)
140 READ (5,490) (X(I),I=1,9)
    K=9
    IF (NCOLM.GT.1) GO TO 150
    K=1
    IF (X(1).EQ.0.) X(1)=1.
150 IF (IQCON-2) 160,180,200
160 DO 170 I=1,9
    QCONL(I)=1.0
170 QCONT(I)=1.0
    GO TO 210
180 READ (5,490) (QCONL(I),I=1,9)
    DO 190 I=1,9
190 QCONT(I)=QCONL(I)
    GO TO 210
200 READ (5,490) (QCONL(I),I=1,9)
    READ (5,490) (QCONT(I),I=1,9)
210 WRITE (6,610)
    IF (NSECT.LT.7) GO TO 220
    WRITE (6,630) X,QCONL,QCONT
    GO TO 280
220 READ (5,490) (Y(I),I=1,9)
    DO 230 J=1,NSEG
230 READ (5,510) (MAT(I,J),TAMP(I,J),I=1,K)
    IF (NCOLM.GT.1) GO TO 240
    WRITE (6,620) Y,(MAT(1,I),I=1,9),(TAMP(1,I),I=1,9)
    GO TO 280
240 WRITE (6,630) X,QCONL,QCONT
    WRITE (6,640) (MAT(I,1),I=1,9),Y(1),(TAMP(I,1),I=1,9)
    DO 250 J=2,NSEG
250 WRITE (6,650) J,(MAT(I,J),I=1,9),Y(J),(TAMP(I,J),I=1,9)
    WRITE (6,660)
    IF (NRSG.EQ.0) GO TO 280
    DO 260 J=1,NRSG
260 READ (5,520) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
    WRITE (6,670)
    DO 270 J=1,NRSG
270 WRITE (6,680) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
280 IF (IFATIG.NE.0) GO TO 340
    READ (5,480) IPFI,(IPF(I),I=1,4),IPAD,KFLEX,NPAN
    DO 330 N1=1,IPFI
    N2=IPF(N1)
    GO TO (290,300,310,320), N2
290 READ (5,490) DT(N2),XL,REY,VU,QL,AMACH
    GO TO 330
300 READ (5,490) DT(N2),TT,WER,D,VS,XI,DVEH,YCL,DREF
    GO TO 330
310 READ (5,490) DT(N2),AE,VJ,WEJ,VV,TJ,XJ,YP
    GO TO 330
320 READ (5,490) DT(N2)
330 CONTINUE
    READ (5,490) HPAN,HC,AI,AIY,AW,BW,EP,TIMEF
    READ (5,490) (C(I),I=1,4),RHOP
```

```
      WRITE (6,820) IPAD,KFLEX,NPAN,DT,XL,REY,VU,QL,AMACH,TT,WEP,D,VS,XI
     1,DVEH,YCL,DREF,AE,VJ,WEJ,VV,TJ,XJ,YP,HPAN,HC,AI,AIY,AW,BW,EP,TIMEF
     2,C,RHOP
  340 IF (JI.EQ.3) GO TO 390
      DO 350 I=1,99
      READ (5,530) TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I),TINS
     1D(I),XSTG(I),NREADT
      NTRAJ=I
      IF (NREADT.GT.0) GO TO 360
  350 CONTINUE
      WRITE (6,540)
      STOP
  360 IF (NANG.LT.2) GO TO 380
      DO 370 I=2,NTRAJ
      ALPHA(I)=ALPHA(1)
  370 BETA(I)=BETA(1)
  380 WRITE (6,560) ((I,TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I)
     1,TINSD(I),XSTG(I)),I=1,NTRAJ)
  390 WRITE (6,690)
      IF (NMAT.GT.0) GO TO 400
      X(1)=1.
      QCONL(1)=1.0
      QCONT(1)=1.0
  400 DO 410 I=1,9
      X(I)=X(I)/12.
  410 Y(I)=Y(I)/12.
      IF (NCRC.LT.2) GO TO 430
      XX(1)=X(1)
      DO 420 I=2,NCOLM
  420 XX(I)=XX(I-1)+X(I)
  430 WRITE (6,440)
      RETURN
C
  440 FORMAT (1H1)
  450 FORMAT (I1,13A6)
  460 FORMAT (1X13A6)
  470 FORMAT (////94H0***** NUMBER OF TITLE CARDS IS GREATER THAN 10 OR
     1JI WAS NOT ENTERED ON LAST TITLE CARD *****)
  480 FORMAT (20I4)
  490 FORMAT (10F8.0)
  500 FORMAT (I5,5X,I5,2F10.0)
  510 FORMAT (9(I2,F6.0))
  520 FORMAT (I2,I6,9(I2,F6.0))
  530 FORMAT (8F8.0,I16)
  540 FORMAT (////87H0***** NUMBER OR TRAJECTORY CARDS IS GREATER THAN 9
     10 OR LAST CARD WAS NOT FLAGGED *****)
  550 FORMAT (///34H0***** R   S   I   I N P U T *****//16X6HIPRINT,13X2
     1HNC,13X2HNH,12X3HNLC,13X2HNV,13X2HPZ,13X2HVB/7X,5I15,2E15.3)
  560 FORMAT (///44H0***** T R A J E C T O R Y   I N P U T *****//4X1HI5
     1X7HTIME(I)6X6HALT(I)5X7HVINF(I)4X8HALPHA(I)5X7HBETA(I)4X8HHINSD(I)
     24X8HTINSD(I)5X7HXSTG(I)//(I5,8E12.4))
  570 FORMAT (/////25H      PROGRAM OPTIONS USED/27H          CONFIGURATION
     1-      ,A6/27H          TURBULENT HEATING- ,2A6/27H          WALL TEMPE
     2RATURE-   ,2A6/27H          ANGLE OF ATTACK-    ,2A6/27H          LOCAL
     3HEAT FLUX-    ,3A6/)
  580 FORMAT (/5X,46HDIRECTION COSINES OF OUTER NORMAL FROM SURFACE/14H
     1       THETA = ,F5.1/14H          PHI = ,F5.1)
  590 FORMAT (/5X,30HDISTANCE FROM LEADING EDGE     ,F8.4,3H FT/35H      B
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 1ODY DIAMETER                        ,F8.4,3H FT/35H     SHOULDER RADIUS/B
 2ODY DIAMETER ,F8.4/35H     EXTERNAL SURFACE EMISSIVITY    ,F6.2//35
 3H     INITIAL TIME                        ,F8.1,4H SEC/35H     END TIME
 4                      ,F8.1,4H SEC/35H     CALCULATION TIME INTERVA
 5L     ,F8.1,4H SEC/35H     PRINT OUT INTERVAL                ,F8.1,4H
 6SEC//)
600 FORMAT (///50H0***** M A T E R I A L   P R O P E R T I E S *****//
 116H MATERIAL NUMBER,9(7X,1H-,I1,1H-))
610 FORMAT (///45H0***** C O N D U C T I O N   I N P U T *****//)
620 FORMAT (108H SEGMENT NUMBER              -1-       -2-       -3-
 1 -4-       -5-       -6-       -7-       -8-       -9-/18H THICKNE
 2SS FT      ,9F10.4/18H MATERIAL          ,9I10/18H INITIAL TEMP. R
 3,9F10.0//)
630 FORMAT (111H COLUMN NUMBER, I                -1-       -2-       -3-
 1    -4-       -5-       -6-       -7-       -8-       -9-/21H WIDT
 2H, X(I) IN      ,9F10.4/16H HEATING FACTORS/21H    LAMINAR
 3   ,9F10.1/21H    TURBULENT          ,9F10.1)
640 FORMAT (/21H SEG.NO., J  =     -1-,I10,1H*,I9,7I10/14H THICK.,Y(J)
 1=,F7.4,F10.0,2H**,F8.0,7F10.0)
650 FORMAT (/18X,1H-,I1,1H-,9I10/F21.4,9F10.0)
660 FORMAT (1X,60(1H-)//5X,8H--NOTE--/27H        * = MATERIAL NUMBER/3
 17H       ** = INITIAL TEMPERATURE DEG R//)
670 FORMAT (/55H0***** R A D I A T I O N   I N T E R C H A N G E ****
 1*//54H SEG NO.  NI    INTERCHANGE NEIGHBORS AND VIEW FACTORS/)
680 FORMAT (1X,2H (,I2,1H),I5,2X,9(2H (,I2,1H),F6.3)))
690 FORMAT (///36H0***** E N D   O F   I N P U T *****)
700 FORMAT (18H0ALLOWABLE TEMP. R,9F10.3)
710 FORMAT (11H0EMISSIVITY7X9F10.3)
720 FORMAT (18H0MATERIAL DENSITY 9F10.3)
730 FORMAT (///16H MATERIAL NUMBER,8X14HHEAT  CAPACITY,9X20HTHERMAL CO
 1NDUCTIVITY,9X14HYOUNGS MODULUS,8X22HTHERMAL EXPANSION COEF/12X4(12
 2X2HAX,10X2HAY))
740 FORMAT (///16H MATERIAL NUMBER,8X14HYIELD STRENGTH,9X20HULT TENSIL
 1E STRENGTH,5X22HLARSON-MILLER STRAIN 1,4X22HLARSON-MILLER STRAIN 2
 2/12X4(12X2HAX,10X2HAY))
750 FORMAT (///16H MATERIAL NUMBER,3X24HULT COMPRESSIVE STRENGTH,5X18H
 1ULT SHEAR STRENGTH,10X14HSHEAR  MODULUS/12X3(12X2HAX,10X2HAY))
760 FORMAT (/I9,7X,4(2X2E12.3))
770 FORMAT (/I9,7X,3(2X2E12.3))
780 FORMAT (16X,4(2X2E12.3))
790 FORMAT (16X,3(2X2E12.3))
800 FORMAT (///36H0***** S T R E S S   I N P U T *****//13X2HAS,14X1HR
 1,13X2HHH,13X2HTS,13X2HTC,13X2HSL,12X3HSLS,13X2HBE/8E15.3//12X3HF07
 2,13X2HUF,12X3HDST,11X4HEALL,12X3HCRN,13X2HBF,12X3HBFL,13X2HBL/8E15
 3.3)
810 FORMAT (///36H0***** S T R E S S   I N P U T *****//13X2HAS,14X1HR
 1,13X2HHH,13X2HTF,13X2HTC,13X2HSL,12X3HSLS,13X2HBE/8E15.3//12X3HF07
 2,13X2HUF,12X3HDST,11X4HEALL,12X3HCRN,13X2HTB,13X2HTR,13X2HDC/8E15.
 33)
820 FORMAT (///38H0***** F A T I G U E   I N P U T *****//11X4HIPAD10X
 15HKFLEX,11X4HNPAN,10X5HDT(1),10X5HDT(2),10X5HDT(3),10X5HDT(4),13X2
 2HXL/3I15,5E15.3//12X3HREY,13X2HVU,13X2HQL,10X5HAMACH,13X2HTT,12X3H
 3WER,14X1HD,13X2HVS/8E15.3//13X2HXI,11X4HDVEH,12X3HYCL,11X4HDREF,13
 4X2HAE,13X2HVJ,12X3HWEJ,13X2HVV/8E15.3//13X2HTJ,13X2HXJ,13X2HYP,11X
 54HHPAN,13X2HHC,13X2HAI,12X3HAIY,13X2HAW/8E15.3//13X2HBW,13X2HEP,10
 6X5HTIMEF,11X4HC(1),11X4HC(2),11X4HC(3),11X4HC(4),11X4HRHOP/8E15.3)
 END
```

```
      SUBROUTINE INPUT2
C
      COMMON /ABLTN/ T,QIN,DTS,TX2(30),VELX,IQINPP,DEL,APRNT,INT,PE
      COMMON /ARRH/THETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON /CCPG/CPGAS
      COMMON /CCSDOT/SDOT
      COMMON /DELX/ DELX1,DELX2,DELX3
      COMMON /DMND/         TKC(9),       XKC(9),      TCPC(9),       CPC(9),
     1       TKV(9),    XKV(9,7),     TCPV(9),      CPV(9),      XNPM(4),
     2     RHOBX(4),      XBM(4),      EMFB(4),     EMBB(4),      NKPB(4),
     3      NCPB(4),    TXK(9,4),     XK(9,4),    TCP(9,4),     CPX(9,4),
     4       NPM(4),     GAPX(4),     FTEST(4),    BTEST(4),    TEMDI(30),
     5      TX1(30),  TX2T(10,6),    TUL1(30),    TUL2(30),        A(30),
     6        B(30),       C(30),       D(30),       S(10),        R(10),
     7      AB(5,6),     BB(5,6),     CB(5,6),     DB(5,6),      SB(5,6),
     8     RB1(5,6),    RB2(5,6),      TY(30),    CPB(9,6),       DXB(6),
     9    XMDG(10),     RHO(10),      CP(10),      YK(10),     XKB(9,6),
     $        H(4),     IEM(10),      PKV(7),      XV(10),       TS(10),
     $       SR(10),      HX(20),      TW(20)
      COMMON /HF/ HF1,HF2,HF3
      COMMON /KAN/ KAN1,KAN2,KAN3
      COMMON/OLA/ TJO(10),CDJ(10)
      COMMON /PCM/ QRIN1,QRIN2,QRIN3,QROT1,QROT2,QROT3
      COMMON /QST/ QST1,QST2,QST3
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,   DT,   DX,  EMV,  EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,   FV, HENV,   HV, H300,  I17,   I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,  NMB,   NP, NPBS,  NPF, NREC,  NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,   TV,
     4   VL,  VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,  XMP,  XMT,  XNP,  NHP,
     5 NTKV, NPKV,IQBLCK
      DIMENSION     XIDNT(12,4),  HEADNG(12)
C
C
      I5=2
      I6=2
      I17=2
      INT=1
      NTKV=0
      NPKV=0
      NPC=0
      KUS=10
      KAS=10
      KOS=10
      KAN1=0
      KAN2=0
      KAN3=0
      XLOST=0.0
      XMT=0.0
      XMDT=0.0
      ERR2=0.0
      ERR3=0.0
      ERR4=0.0
      XMDC=0.0
      XLSTV=0.0
      NRS=2
      ERR5=0.0
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      SDOT=0.0
      AOPT=1.0
C
      WRITE (6,670)
C
C     LOCATION FACTORS FOR CONVECTIVE AND RADIATIVE HEATING
      READ (5,610) SN,CA,XB,CPGAS,XMC,XMP
      WRITE (6,680) SN,CA,XB
      WRITE (6,690) CPGAS,XMC,XMP
C
C     PROPERTIES OF ABLATION MATERIAL
      READ (5,600) (HEADNG(K),K=1,12)
      READ (5,610) TABL,TCHAR,TREC,RHOV,RHOC,TBLOW,EMV,EMC,H300,VL,HV,FV
     1,TV,CHARK,CHARC,ABLK,ABLC
      READ (5,620) NP,NKC,NCPC,NKV,NCPV,NREC,IQBLCK
      READ (5,610) (TKC(K),XKC(K),K=1,NKC)
      READ (5,610) (TCPC(M),CPC(M),M=1,NCPC)
      IF (NKV.GT.0) GO TO 20
      READ (5,650) NTKV,NPKV,(PKV(I),I=1,NPKV)
      DO 10 I=1,NTKV
   10 READ (5,660) TKV(I),(XKV(I,J),J=1,NPKV)
      GO TO 30
   20 READ (5,610) (TKV(L),XKV(L),L=1,NKV)
   30 READ (5,610) (TCPV(N),CPV(N),N=1,NCPV)
      READ (5,610) (TS(I),SR(I),I=1,NREC)
      WRITE (6,640) (HEADNG(K),K=1,12)
      WRITE (6,700) TABL,TCHAR,TREC,RHOV,RHOC,TBLOW,EMV,EMC,H300,VL,HV,F
     1V,TV,CHARK,CHARC,ABLK,ABLC
      VL=VL/12.0
      VLV=VL
      WRITE (6,710) NP,NKC,NCPC,NKV,NCPV,NREC,IQBLCK,NTKV,NPKV
      IF (NKV.GT.0) GO TO 50
      WRITE (6,720) (PKV(I),I=1,NPKV)
      WRITE (6,730)
      DO 40 I=1,NTKV
      WRITE (6,740) TKV(I),(XKV(I,J),J=1,NPKV)
   40 CONTINUE
      WRITE (6,750) (TCPV(I),CPV(I),I=1,NCPV)
      GO TO 80
   50 WRITE (6,760)
      KLLL=MIN0(NKV,NCPV)
      WRITE (6,770) (TKV(L),XKV(L),TCPV(L),CPV(L),L=1,KLLL)
      IF (NKV-NCPV) 60,80,70
   60 KLLLL=KLLL+1
      WRITE (6,780) (TCPV(L),CPV(L),L=KLLLL,NCPV)
      GO TO 80
   70 KLLLL=KLLL+1
      WRITE (6,790) (TKV(L),XKV(L),L=KLLLL,NKV)
   80 WRITE (6,800)
      KLLL=MIN0(NKC,NCPC)
      WRITE (6,770) (TKC(L),XKC(L),TCPC(L),CPC(L),L=1,KLLL)
      IF (NKC-NCPC) 90,110,100
   90 KLLLL=KLLL+1
      WRITE (6,780) (TCPC(L),CPC(L),L=KLLLL,NCPC)
      GO TO 110
  100 KLLLL=KLLL+1
      WRITE (6,790) (TKC(L),XKC(L),L=KLLLL,NKC)
  110 WRITE (6,810)
```

```
      WRITE (6,820) (TS(I),SR(I),I=1,NREC)
C
C     PROPERTIES OF BACK-UP STRUCTURE
      WRITE (6,830)
      READ (5,630) NMB,NPBS,BL
      NAMB=NMB
      READ (5,620) NIFPCM
      IF (NIFPCM) 130,130,120
  120 CONTINUE
C     PCM INPUT
      READ (5,840) NPC,NFIL,TMELT,HFUS,RHOFIL,FIFR
      NAMB=NMB+NFIL
  130 CONTINUE
      READ (5,610) (XNPM(K),K=1,NMB)
      READ (5,850) (NKPB(I),NCPB(I),I=1,NAMB)
      DO 140 K=1,NMB
      NPM(K)=XNPM(K)+0.00000002
  140 CONTINUE
      WRITE (6,860) NMB,NPBS,BL
      BL=BL/12.0
      DO 200 I=1,NAMB
      LK=NKPB(I)
      LCP=NCPB(I)
      READ (5,600) ((XIDNT(K,I)),K=1,12)
      READ (5,610) ((TXK(J,I),XK(J,I)),J=1,LK)
      READ (5,610) ((TCP(J,I),CPX(J,I)),J=1,LCP)
      WRITE (6,870) (XIDNT(K,I),K=1,12)
      WRITE (6,880)
      KLLL=MIN0(LK,LCP)
      DO 150 N=1,KLLL
      WRITE (6,770) (TXK(N,I),XK(N,I),TCP(N,I),CPX(N,I))
  150 CONTINUE
      IF (LK-LCP) 160,200,180
  160 KLLLL=KLLL+1
      DO 170 N=KLLLL,LCP
      WRITE (6,780) (TCP(N,I),CPX(N,I))
  170 CONTINUE
      GO TO 200
  180 KLLLL=KLLL+1
      DO 190 N=KLLLL,LK
      WRITE (6,790) (TXK(N,I),XK(N,I))
  190 CONTINUE
  200 CONTINUE
      READ (5,610) (RHOBX(L),XBM(L),EMFB(L),EMBB(L),L=1,NMB)
      READ (5,610) (H(J),GAPX(J),FTEST(J),BTEST(J),J=1,NMB)
      WRITE (6,890)
      DO 210 LLJ=1,NMB
      WRITE (6,900) LLJ,RHOBX(LLJ),XBM(LLJ),EMFB(LLJ),EMBB(LLJ),XNPM(LLJ
     1)
  210 CONTINUE
      IF (NIFPCM.LE.0) GO TO 220
      WRITE (6,910)
      WRITE (6,920) NPC,TMELT,HFUS,RHOFIL,FIFR
  220 CONTINUE
      WRITE (6,930)
      DO 230 J=1,NMB
      WRITE (6,940) J,H(J),GAPX(J),FTEST(J),BTEST(J)
  230 CONTINUE
```

```
      IF (NIFPCM) 450,450,240
  240 CONTINUE
C     CALCULATION OF REQUIRED PARAMETERS FOR HANDLING PCM
      NUB=NPC-1
      NBC=NPC-2
      NAP=NP
      IF (NBC.EQ.0) GO TO 260
      DO 250 JL=1,NBC
  250 NAP=NAP+(NPM(JL)-1)
  260 NAP=NAP+(NPM(NUB)-2)
      KU=NP+1
      DO 280 I=1,NMB
      KUM=NPC-I
      IF (KUM) 290,290,270
  270 KU=KU+NPM(I)
  280 CONTINUE
  290 KA=KU+NPM(NPC)
      DELX1=XBM(NPC-1)/(24.*(NPM(NPC-1)-1))
      DELX2=XBM(NPC)/(24.*(NPM(NPC)-1))
      DELX3=XBM(NPC+1)/(24.*(NPM(NPC+1)-1))
      HF1=RHOBX(NPC)*DELX2*HFUS
      HF2=2.*HF1
      HF3=HF1
      LAK=NKPB(NPC)
      LEK=NCPB(NPC)
      IF (FIFR.EQ.0.) GO TO 380
C     CALCULATION OF EQUIVALENT PROPERTIES OF PCM AND FILLER
      LO=NKPB(NAMB)
      LA=NCPB(NAMB)
      DO 330 J=1,LAK
      DO 320 IK=2,LO
      IF (TXK(IK,NAMB)-TXK(J,NPC)) 320,310,300
  300 CKFIL=XK(IK-1,NAMB)+(XK(IK,NAMB)-XK(IK-1,NAMB))*(TXK(J,NPC)-TXK(IK
     1-1,NAMB))/(TXK(IK,NAMB)-TXK(IK-1,NAMB))
      GO TO 330
  310 CKFIL=XK(IK,NAMB)
      GO TO 330
  320 CONTINUE
  330 XK(J,NPC)=XK(J,NPC)+(CKFIL-XK(J,NPC))*FIFR
      DO 370 J=1,LEK
      DO 360 IK=2,LA
      IF (TCP(IK,NAMB)-TCP(J,NPC)) 360,350,340
  340 CPFIL=CPX(IK-1,NAMB)+(CPX(IK,NAMB)-CPX(IK-1,NAMB))*(TCP(J,NPC)-TCP
     1(IK-1,NAMB))/(TCP(IK,NAMB)-TCP(IK-1,NAMB))
      GO TO 370
  350 CPFIL=CPX(IK,NAMB)
      GO TO 370
  360 CONTINUE
  370 CPX(J,NPC)=CPX(J,NPC)+(CPFIL-CPX(J,NPC))*FIFR
  380 WRITE (6,950)
      WRITE (6,880)
      KLLL=MIN0(LAK,LEK)
      I=NPC
      DO 390 N=1,KLLL
      WRITE (6,770) (TXK(N,I),XK(N,I),TCP(N,I),CPX(N,I))
  390 CONTINUE
      IF (LAK-LEK) 400,440,420
  400 KLLLL=KLLL+1
```

```
      DO 410 N=KLLLL,LEK
      WRITE (6,780) (TCP(N,I),CPX(N,I))
  410 CONTINUE
      GO TO 440
  420 KLLLL=KLLL+1
      DO 430 N=KLLLL,LEK
      WRITE (6,790) (TXK(N,I),XK(N,I))
  430 CONTINUE
  440 CONTINUE
      RHOPC=(1.-FIFR)*RHOBX(NPC)
      RHOBX(NPC)=RHOBX(NPC)+(RHOFIL-RHOBX(NPC))*FIFR
      WRITE (6,960) RHOBX(NPC),RHOPC
  450 CONTINUE
C
C     PROPERTIES OF ENVIRONMENT
      READ (5,600) (HEADNG(L),L=1,12)
      READ (5,610) TENV,HENV,FENV,QLOSS
      WRITE (6,640) (HEADNG(L),L=1,12)
      WRITE (6,970) TENV,HENV,FENV,QLOSS
C
C     INITIAL TEMPERATURE DISTRIBUTION
      READ (5,600) (HEADNG(L),L=1,12)
      NPF=NP+NPBS
      XNP=NP
      DX=VL/(XNP-1.0)
      READ (5,610) TEST2,TEMPI
      IF (TEST2) 470,480,460
  460 WRITE (6,980)
      STOP
  470 READ (5,610) (TEMDI(K),K=1,NPF)
  480 DO 490 K=1,NPF
      IF (TEST2.EQ.0.0) TEMDI(K)=TEMPI
      TX1(K)=TEMDI(K)
      TX2(K)=TX1(K)
      TUL1(K)=TX1(K)
      TUL2(K)=TX1(K)
  490 CONTINUE
      L=NP+1
      DO 510 I=1,NMB
      LN=NPM(I)
      DO 500 J=1,LN
      TX2T(J,I)=TEMDI(L)
      L=L+1
  500 CONTINUE
  510 CONTINUE
      WRITE (6,640) (HEADNG(L),L=1,12)
      IF (TEST2) 520,530,530
  520 WRITE (6,990)
      WRITE (6,1000) (TEMDI(K),K=1,NPF)
      GO TO 540
  530 WRITE (6,1010) TEMPI
  540 IF (AOPT.EQ.0.) GO TO 560
      AP=CA*(RHOV-RHOC)**(SN-1.)
      DO 550 I=1,NP
      TUL2(I)=1./(1.-SN)
      RHO(I)=RHOV
      IF (TX2(I).LE.TABL) GO TO 550
      WRITE (6,1020)
```

```
      STOP
  550 CONTINUE
C
C     ENTHALPY AS A FUNCTION OF TEMPERATURE
  560 READ (5,620) NHP
      READ (5,610) (HX(K),TW(K),K=1,NHP)
      DO 570 I=1,NP
      IEM(I)=0
      XMDG(I)=0.0
      THETA(I)=1.
      XMTPT(I)=0.
  570 CONTINUE
      DO 580 I=1,10
  580 CDJ(I)=0.
      DQIN1=0.
      DQIN2=0.
      DQIN3=0.
      QST1=0.
      QST2=0.
      QST3=0.
      QRIN1=0.
      QRIN2=0.
      QRIN3=0.
      QROT1=0.
      QROT2=0.
      QROT3=0.
      XV(1)=0.0
      DO 590 I=2,NP
      XV(I)=XV(I-1)+DX
  590 CONTINUE
      RETURN
C
  600 FORMAT (12A6)
  610 FORMAT (6E12.8)
  620 FORMAT (7I5)
  630 FORMAT (2I5,1E14.8)
  640 FORMAT (///1X,12A6)
  650 FORMAT (2I5,7E10.5)
  660 FORMAT (8E10.5)
  670 FORMAT (///40H0***** A B L A T I O N   I N P U T *****)
  680 FORMAT (//,5X,27HARRHENIUS EQUATION IS USED./,5X,2HN=E16.7,5X,2HA=
     1E16.7,5X,2HB=E16.7)
  690 FORMAT (/,5X,6HCPGAS=E16.7,5X,4HXMC=,E16.7,5X,4HXMP=,E16.7)
  700 FORMAT (/2X,5HTABL=,E12.5,2X,6HTCHAR=,E12.5,3X,5HTREC=,E12.5,3X,5H
     1RHOV=,E12.5,3X,5HRHOC=,E12.5,21X/1X,6HTBLOW=,E12.5,4X,4HEMV=,E12.5
     2,4X,4HEMC=,E12.5,3X,5HH300=,E12.5,5X,3HVL=,E12.5/4X,3HHV=,E12.5,5X
     3,3HFV=,E12.5,5X,3HTV=,E12.5,2X,6HCHARK=,E12.5,2X,6HCHARC=,E12.5/2X
     4,5HABLK=,E12.5,3X,5HABLC=,E12.5/)
  710 FORMAT (2X,3HNP=,1I4,4X,4HNKC=,1I4,4X,5HNCPC=,1I4,4X,4HNKV=,1I4,4X
     1,5HNCPV=,1I4,4X,5HNREC=,1I4,4X,7HIQBLCK=,1I4,4X,5HNTKV=,1I4,4X,5HN
     2PKV=,1I4)
  720 FORMAT (/32X,15HVIRGIN MATERIAL//3X,8HPRESSURE,4X,7(E15.5))
  730 FORMAT (/3X,11HTEMPERATURE,5X,20HTHERMAL CONDUCTIVITY)
  740 FORMAT (2X,E12.5,1X,7(E15.5))
  750 FORMAT (/45X,8HSPECIFIC/25X,11HTEMPERATURE,11X,4HHEAT/(24X,E12.5,7
     1X,E12.5))
  760 FORMAT (/32X,15HVIRGIN MATERIAL/20X,7HTHERMAL,38X,8HSPECIFIC/3X,11
     1HTEMPERATURE,4X,12HCONDUCTIVITY,19X,11HTEMPERATURE,7X,4HHEAT)
```

```
770 FORMAT (2X,E12.5,4X,E12.5,18X,E12.5,3X,E12.5)
780 FORMAT (48X,E12.5,3X,E12.5)
790 FORMAT (2X,E12.5,4X,E12.5)
800 FORMAT (//33X,14HCHAR  MATERIAL/20X,7HTHERMAL,38X,8HSPECIFIC/3X,11
   1HTEMPERATURE,4X,12HCONDUCTIVITY,19X,11HTEMPERATURE,7X,4HHEAT)
810 FORMAT (//28X,23HSURFACE RECESSION TABLE//25X,11HTEMPERATURE,8X,11
   1HSR - IN/SEC)
820 FORMAT (24X,E12.5,7X,E12.5)
830 FORMAT (//10X,31H PROPERTIES OF BACKUP STRUCTURE/)
840 FORMAT (2I5,4E12.5)
850 FORMAT (10I5)
860 FORMAT (/4X,35HNO. OF MATERIALS IN BACK-UP SHIELD=,1I4/4X,40HTOTAL
   1 NUMBER OF NODES IN BACK-UP SHIELD=,1I4/4X,28HTHICKNESS OF BACK-UP
   2 SHIELD=,E12.5//)
870 FORMAT (//12A6)
880 FORMAT (//20X,7HTHERMAL,38X,8HSPECIFIC/3X,11HTEMPERATURE,4X,12HCON
   1DUCTIVITY,19X,11HTEMPERATURE,7X,4HHEAT)
890 FORMAT (///55X,10HEMISSIVITY/8X,8HMATERIAL,5X,7HDENSITY,7X,9HTHICK
   1NESS,7X,5HFRONT,9X,4HBACK,7X,14HNODES/MATERIAL/)
900 FORMAT (11X,1I1,8X,E10.4,4X,E10.4,4X,E10.4,4X,E10.4,6X,E10.4/)
910 FORMAT (///,4X,41HADDITIONAL DATA FOR PHASE CHANGE MATERIAL)
920 FORMAT (/,6X,4HNPC=,I5,2X,6HTMELT=,E12.5,2X,15HHEAT OF FUSION=,E12
   1.5,2X,7HRHOFIL=,E12.5,2X,5HFIFR=,E12.5)
930 FORMAT (//4X,60HADDITIONAL DATA FOR INDIVIDUAL MATERIALS IN BACKUP
   1 STRUCTURE//11X,8HMATERIAL,5X,16HFILM COEFFICIENT,5X,13HGAP THICKN
   2ESS,8X,5HFTEST,13X,5HBTEST)
940 FORMAT (13X,1I3,12X,E10.4,9X,E10.4,7X,E11.4,7X,E11.4/)
950 FORMAT (///,4X,39HEQUIVALENT PROPERTIES OF PCM AND FILLER)
960 FORMAT (///,5X,25HEQUIVALENT DENSITY OF PCM,E12.5,2X,26HDENSITY OF
   1 PCM DURING MELT,E12.5)
970 FORMAT (/4X,12HTEMPERATURE=,E12.5,4X,17HFILM COEFFICIENT=,E12.5,4X
   1,12HVIEW FACTOR=,E12.5,4X,7HQ LOST=,E12.5)
980 FORMAT (//4X,52HLINEAR TEMPERATURE DISTRIBUTION IS NO LONGER ALLOW
   1ED)
990 FORMAT (4X,52HTEMPERATURE DISTRIBUTION IN HEAT SHIELD IS ARBRITARY
   1/)
1000 FORMAT (8E12.5)
1010 FORMAT (//4X,64HTEMPERATURE DISTRIBUTION IN HEAT SHIELD IS UNIFORM
   1 AND EQUAL TO ,E10.4/)
1020 FORMAT (////,5X,43HPROGRAM DOES NOT PERMIT INITIALIZATION WHEN22H
   1THERE IS INITIAL CHAR)
     END
```

```
      OVERLAY (P5490,1,2)                                               CND
      PROGRAM CONDTN                                                    CND
C                                                                       CND
      COMMON /CNDTN/ DEL,DTMAX,TTAU,ITER                                CND
      COMMON/TPS/A(20),Q(9),R,X(9)                                      CND
      COMMON       AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI        CND
     1,AOFA       ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)CND
     2,BATA       ,BE         ,BETA(99)   ,BF         ,BFL        ,BL         CND
     3,DELTA      ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL       CND
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)CND
     5,FNET(20)   ,FSU(20,99),FT(20)     ,FTU(20,99),FVE        ,F07        CND
     6,G(20,99)   ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO     CND
     7,IQINP      ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)   CND
     8,NCOLM      ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS       CND
     9,NMAT       ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG       CND
     $,NSEG       ,NTRAJ      ,N33        ,PE         ,PHI        ,PI         CND
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)     CND
     $,RHOI       ,RYE        ,RYI        ,SL         ,SLS        ,STAAT      CND
     $,STI        ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU        CND
     $,TC1        ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS       CND
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE      CND
     $,XEMIS      ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)                 CND
      DIMENSION A1(9,9),A2(9,9),A3(9,9),NRA(18),QN(4),Q2(9),VF(9,18),   CND
     1DX(9),DY(9,9),A4(9,9),DET(9,9)                                    CND
C                                                                       CND
      DO 440 JIJ=1,10                                                   CND
      I1=0                                                              CND
      A1S=0.                                                            CND
      QSS=0.                                                            CND
      IF (NRSG.EQ.0) GO TO 20                                           CND
      L=0                                                               CND
      DO 10 I=1,NRSG                                                    CND
   10 NRA(I)=NR(I)                                                      CND
   20 X2=0.                                                             CND
      DO 70 I=1,NCOLM                                                   CND
      IF (NCRC.LT.2) GO TO 30                                           CND
      X1=X2                                                             CND
      X2=XX(I)**2                                                       CND
      DX(I)=3.1416*(X2-X1)                                              CND
      GO TO 40                                                          CND
   30 DX(I)=X(I)                                                        CND
   40 IF (IQINP.EQ.3) GO TO 50                                          CND
      QNET(I)=Q(I)-0.476E-12*XEMIS*TEMP(I,1)**4                         CND
   50 DO 70 J=1,NSEG                                                    CND
      K=MAT(I,J)                                                        CND
      K=IABS(K)                                                         CND
      IF (K.EQ.0) GO TO 70                                              CND
      CP=TRPLAT(AY,AX,TEMP(I,J),K,1,MPT(K,1))                           CND
      EK=1.8E3/TRPLAT(AY,AX,TEMP(I,J),K,2,MPT(K,2))                     CND
      A1(I,J)=CP*RHO(K)*DX(I)*Y(J)                                      CND
      XY=DX(I)/Y(J)                                                     CND
      A3(I,J)=EK/XY                                                     CND
      IF (NCRC.EQ.2) GO TO 60                                           CND
      DY(I,J)=Y(J)                                                      CND
      A2(I,J)=EK*XY                                                     CND
      GO TO 70                                                          CND
   60 A2(I,J)=.3183*EK*ALOG(XX(I)/(XX(I)-.5*X(I)))/Y(J)                 CND
      DY(I,J)=6.2832*XX(I)*Y(J)                                         CND
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```
      IF (I.EQ.1) GO TO 70
      A4(I,J)=.3183*EK*ALOG((XX(I)-.5*X(I))/XX(I-1))/Y(J)
   70 CONTINUE
      DETMAX=0.0
      NEWDT=0
      DO 340 J=1,NSEG
      DO 340 I=1,NCOLM
      IF (MAT(I,J).EQ.0) GO TO 340
      IF (IQINP.EQ.3.AND.J.EQ.1) GO TO 190
      QS=0.
      DO 330 K=1,4
      GO TO (80,90,100,110), K
   80 IF (I.EQ.1) GO TO 120
      IF (MAT(I-1,J)) 120,210,140
   90 IF (I.EQ.NCOLM.OR.MAT(I,J).LT.0.) GO TO 120
      IF (MAT(I+1,J)) 160,210,160
  100 IF (J.EQ.1) GO TO 130
      IF (NCOLM.EQ.1) GO TO 150
      IF (MAT(I,J-1)) 150,210,150
  110 IF (J.EQ.NSEG) GO TO 320
      IF (MAT(I,J+1)) 190,200,190
  120 QN(K)=0.
      GO TO 330
  130 QN(3)=QNET(I)*DX(I)
      GO TO 330
  140 QN(1)=-QN(2)
      GO TO 330
  150 QN(3)=-Q2(I)
      GO TO 330
  160 IF (NCRC.LE.1) GO TO 170
      SA=A2(I,J)+A4(I+1,J)
      GO TO 180
  170 SA=A2(I,J)+A2(I+1,J)
  180 QN(2)=(TEMP(I+1,J)-TEMP(I,J))/SA
      GO TO 330
  190 QN(4)=(TEMP(I,J+1)-TEMP(I,J))/(A3(I,J+1)+A3(I,J))
      Q2(I)=QN(4)
      IF (IQINP.EQ.3.AND.J.EQ.1) GO TO 340
      GO TO 330
  200 QN(K)=0.
      IF (NCOLM.GT.1) GO TO 210
      IJ=1
      M=1
      L=L+1
      N=J+2
      GO TO 240
  210 QN(K)=0.
      IF (NRSG.EQ.0) GO TO 330
      NRP=10*I+J
      DO 220 L=1,NRSG
      IF (NRP.EQ.NRA(L)) GO TO 230
  220 CONTINUE
      GO TO 330
  230 NRA(L)=0
      IJ=N1(L)
  240 DO 310 II=1,IJ
      IF (NCOLM.EQ.1) GO TO 250
      M=MR(II,L)/10
```

```
      N=MR(II,L)-10*M
  250 IF (IVF.EQ.1) GO TO 300
      IF (K.EQ.1.OR.K.EQ.2) GO TO 260
      RL=DX(I)
      GO TO 270
  260 RL=DY(I,J)
  270 M1=MAT(I,J)
      E1=EMIS(M1)
      M2=MAT(M,N)
      IF (M2.EQ.0) GO TO 280
      E2=EMIS(M2)
      E12=E1*E2/(1.-(1.-E1)*(1.-E2))
      GO TO 290
  280 E12=E1
  290 VF(II,L)=0.476E-12*E12*RL*VFACT(II,L)
      IF (L.EQ.NRSEG.AND.II.EQ.IJ) IVF=1
  300 QR=VF(II,L)*(TEMP(M,N)**4-TEMP(I,J)**4)
  310 QN(K)=QN(K)+QR
      GO TO 330
  320 QN(4)=HINS*DX(I)*(TINS-TEMP(I,J))
      IF (HINS.GE.1.E9) QN(4)=-QS
  330 QS=QS+QN(K)
      QSS=QSS+QS
      A1S=A1S+A1(I,J)
      IF (MAT(I,J).LT.0.) GO TO 340
      DET(I,J)=DELTA*QSS/A1S
      DETMAX=AMAX1(DETMAX,ABS(DET(I,J)))
      A1S=0.
      QSS=0.
  340 CONTINUE
      IF (DETMAX.GT.10.) GO TO 350
      DEL=DEL+DELTA
      ITER=ITER+1
      TTAU=TTAU+DELTA
      DSTP=STOOP-TTAU
      IF (DETMAX.LT.3) GO TO 360
      GO TO 380
  350 DDELTA=DELTA
      DELTA=DELTA*(5.0/DETMAX)
      DWRT=WROTE-DEL
      DELTA=AMIN1(DELTA,DTMAX,DSTP,DWRT)
      DEL=DEL+DELTA
      ITER=ITER+1
      TTAU=TTAU+DELTA
      DSTP=STOOP-TTAU
      NEWDT=1
      GO TO 390
  360 IF (DETMAX.GT.0.01) GO TO 370
      DELTA=2.0*(DELTA+0.5)
      GO TO 380
  370 DELTA=DELTA*(6.75/DETMAX)
  380 DWRT=WROTE-DEL
      IF (DWRT.EQ.0.0) DWRT=10.0
      DELTA=AMIN1(DELTA,DTMAX,DSTP,DWRT)
  390 DO 430 J=1,NSEG
      DO 430 I=1,NCOLM
      IF (NEWDT.NE.1) GO TO 400
      DET(I,J)=DET(I,J)*(DELTA/DDELTA)
```

```
400 I1=I1+1
    IF (MAT(I,J).LT.0.) GO TO 430
    TEMP(I,J)=TEMP(I,J)+DET(I,J)
    IF (I1.LE.1) GO TO 420
    DO 410 I2=2,I1
    I3=I-I2+2
410 TEMP(I3-1,J)=TEMP(I3,J)
420 I1=0
430 CONTINUE
    IF (DEL.EQ.WROTE.OR.TTAU.EQ.STOOP) GO TO 450
440 CONTINUE
450 RETURN
    END
```

```
      OVERLAY (P5490,1,3)
      PROGRAM ABLATE
C
C     STRUCTURES AND MECHANICS DIVISION
C     THERMO-STRUCTURES BRANCH
C     THERMAL PROTECTION SYSTEMS SECTION
C
C     THIS PROGRAM DETERMINES THE PERFORMANCE OF A CHARRING ABLATOR
C
C     ANALYSIS AND PROGRAM DEVELOPED BY DONALD M. CURRY  *  ES21
C
      COMMON /ABLTN/ T,QIN,DTS,TX2(30),VELX,IQINPP,DEL,APRNT,INT,PE
      COMMON /ARRH/THETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON /CCSDOT/SDOT
      COMMON /DELX/ DELX1,DELX2,DELX3
      COMMON /DMND/       TKC(9),       XKC(9),      TCPC(9),      CPC(9),
     1       TKV(9),     XKV(9,7),      TCPV(9),       CPV(9),     XNPM(4),
     2     RHOBX(4),       XBM(4),      EMFB(4),      EMBB(4),     NKPB(4),
     3      NCPB(4),     TXK(9,4),      XK(9,4),     TCP(9,4),     CPX(9,4),
     4       NPM(4),      GAPX(4),     FTEST(4),     BTEST(4),    TEMDI(30),
     5      TX1(30),   TX2T(10,6),     TUL1(30),     TUL2(30),        A(30),
     6        B(30),        C(30),        D(30),        S(10),        R(10),
     7     AB(5,6),      BB(5,6),      CB(5,6),      DB(5,6),      SB(5,6),
     8    RB1(5,6),     RB2(5,6),       TY(30),    CPB(9,6),       DXB(6),
     9    XMDG(10),      RHO(10),       CP(10),       YK(10),     XKB(9,6),
     $        H(4),      IEM(10),       PKV(7),       XV(10),       TS(10),
     $       SR(10),       HX(20),       TW(20)
      COMMON /HF/ HF1,HF2,HF3
      COMMON /KAN/ KAN1,KAN2,KAN3
      COMMON/OLA/ TJO(10),CDJ(10)
      COMMON /PCM/ QRIN1,QRIN2,QRIN3,QROT1,QROT2,QROT3
      COMMON /QST/ QST1,QST2,QST3
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,    DT,     DX,   EMV,   EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,    FV, HENV,    HV, H300,   I17,    I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,  NMB,    NP, NPBS,   NPF, NREC,   NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,    TV,
     4   VL,  VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,   XMP,   XMT,   XNP,   NHP,
     5 NTKV, NPKV,IQBLCK
      DIMENSION      XVPNT(10)
      DATA BETAL,BETAT,FBLOWL,FBLOWT/0.25,0.2,1.44,0.87/
C
      DT=DTS/3600.
      QHW=QIN
      QCONX=QIN
      QBLOCK=0.0
      Z=0.
      HW=0.
      HTX=0.
      IF (XMDT.LE.0.01.AND.IQINPP.NE.4) GO TO 180
C
C     COMPUTE HEAT BLOCKAGE AT FRONT SURFACE
   10 IF (I17-1) 40,40,20
   20 IF (I17-NHP) 30,30,40
   30 IF (TX2(INT)-TW(I17)) 60,90,50
   40 WRITE (6,550) TX2(INT)
      GO TO 540
```

```
   50 I17=I17+1
      GO TO 20
   60 IF (TX2(INT)-TW(I17-1)) 70,90,80
   70 I17=I17-1
      GO TO 10
   80 HW=HX(I17-1)+((HX(I17)-HX(I17-1))/(TW(I17)-TW(I17-1)))*(TX2(INT)-T
     1W(I17-1))
      GO TO 100
   90 HW=HX(I17)
  100 HTX=H300+((VELX**2)/50056.5)
      IF (XMDT.LE.0.01.OR.IQBLCK.EQ.0) GO TO 110
      FBLOW=FBLOWL
      BETA=BETAL
      IF (T.GT.TBLOW) FBLOW=FBLOWT
      IF (T.GT.TBLOW) BETA=BETAT
      XM2=XMP/(1.-XMDC/XMDT*(1.-XMP/XMC))
      ALPHA=FBLOW*(28.97/XM2)**BETA
      BCOF=XMDT*(HTX-HW)/(QHW*3600.)
      XAB=ALPHA*BCOF
      IF (XAB.LE.0.) GO TO 110
      IF (XAB.GT.40.) XAB=40.
      G=XAB/(EXP(XAB)-1.)
      IF (G.GT.1.) G=1.
      QWB=G*QHW
      QBLOCK=QHW-QWB
  110 CONTINUE
      IF (IQINPP.NE.4) GO TO 180
C
C     COMPUTE Q-HOT WALL
      Z=(HTX-HW)/(HTX-H300)
      IF (Z-1.0) 120,140,150
  120 IF (Z) 130,130,150
  130 QHW=0.0
      GO TO 170
  140 QHW=QCONX
      GO TO 160
  150 QHW=Z*QCONX
  160 IF (QHW.EQ.0.) GO TO 170
      ZZZ=(QHW-QBLOCK)/QHW
      IF (ZZZ-0.2) 170,170,180
  170 QBLOCK=0.8*QHW
C
C     NET HEAT INTO FRONT SURFACE
  180 IF (IEM(INT)) 190,190,210
  190 IF (TX2(INT)-TCHAR) 200,200,210
  200 EMX=EMV
      GO TO 220
  210 IEM(INT)=1
      EMX=EMC
  220 QIN=QIN-QBLOCK-(4.8333E-13)*EMX*FV*((TX2(INT)**4)-(TV**4))
      QIN=QIN*3600.0
C
C     CHECK FOR FRONT SURFACE RECESSION (CHAR LAYER REMOVAL)
      CALL RECESS(XMDC,XLOST,TREC,DT,RHOC,TS,SR,TX2(1),NREC,NRS,ERR5,SDO
     1T)
      IF (ERR5) 230,230,540
  230 VLV=VLV-XLOST
      XLSTV=XLSTV+XLOST
```

```
      XLSTI=XLSTV*12.0
      DXV=VLV/(XNP-1.0)
      XV(1)=0.0
      DO 240 I=2,NP
      XV(I)=XV(I-1)+DXV
  240 CONTINUE
      DX=DXV
      IF (ERR4) 250,250,540
  250 CALL COEFF(NPFT,SDOT)
      IF (ERR2) 260,260,540
  260 IF (ERR3) 270,270,540
  270 CALL SWUFT(A,B,C,D,TY,NPFT)
      DO 280 I=1,NP
      TX1(I)=TX2(I)
      TX2(I)=TY(I)
  280 CONTINUE
      CALL MDTGAS
      XMDT=XMDG(INT)+XMDC
      LT=NP+1
      DO 310 I=1,NMB
      LLT=NPM(I)
      IF (I.EQ.1) GO TO 290
      IF (GAPX(I-1).EQ.0.) GO TO 290
      KKT=1
      GO TO 300
  290 KKT=2
  300 DO 310 J=KKT,LLT
      TX2T(J,I)=TY(LT)
      LT=LT+1
  310 CONTINUE
      DO 340 I=1,NMB
      IF (I.EQ.1) GO TO 320
      IF (GAPX(I-1).EQ.0.) GO TO 330
      GO TO 340
  320 TX2T(1,1)=TY(NP)
      GO TO 340
  330 LX=NPM(I-1)
      TX2T(1,I)=TX2T(LX,I-1)
  340 CONTINUE
      LM=NP+1
      DO 350 I=1,NMB
      LZ=NPM(I)
      DO 350 J=1,LZ
      TX2(LM)=TX2T(J,I)
      LM=LM+1
  350 CONTINUE
      IF (NIFPCM) 510,510,360
C     CALCULATION OF ACCUMULATED HEAT IN PCM NODES DUE TO HEAT OF FUSION
  360 CONTINUE
      IF (KAN3.GT.0) GO TO 510
      IF (KAN1.GT.0) GO TO 380
      IF (TX2(KU).GE.TMELT) GO TO 370
      GO TO 510
  370 TX2(KU-1)=TMELT
      TX2(KU)=TMELT
      KAS=-10
      GO TO 420
  380 IF (KAN2.GT.0) GO TO 400
```

```
      IF (TX2(KU+1).GE.TMELT) GO TO 390
      GO TO 510
  390 TX2(KU+1)=TMELT
      KUS=-10
      GO TO 420
  400 IF (KAN3.GT.0) GO TO 510
      IF (TX2(KA).GE.TMELT) GO TO 410
      GO TO 510
  410 TX2(KA)=TMELT
      TX2(KA-1)=TMELT
      KOS=-10
  420 CONTINUE
      TJO(1)=.5*(TX2(KU-2)+TX2(KU-1))
      TJO(2)=TX2(KU)
      TJO(3)=.5*(TX2(KU)+TX2(KU+1))
      TJO(4)=TX2(KU+1)
      TJO(5)=.5*(TX2(KU+1)+TX2(KA-1))
      TJO(6)=TX2(KA)
      TJO(7)=.5*(TX2(KA)+TX2(KA+1))
C     CALCULATION OF CONDUCTIVITIES FOR HEAT BALANCE OF PCM NODES
C     THIS IS DONE IN SUBROUTINE COND
      CALL CAND
      BIS=DELX1/CDJ(1)+DELX2/CDJ(3)
      BES=DELX2/CDJ(2)+DELX2/CDJ(4)
      BAS=DELX2/CDJ(4)+DELX2/CDJ(6)
      BOS=DELX2/CDJ(5)+DELX3/CDJ(7)
      IF (KAN1.GT.0) GO TO 450
      QRIN1=(TJO(1)-TJO(3))/(BIS*3600.)
      QROT1=(TJO(2)-TJO(4))/(BES*3600.)
      DQIN1=(QRIN1-QROT1)*DTS
      QST1=QST1+DQIN1
      IF (QST1-HF1) 440,440,430
  430 KAN1=10
      KAS=10
  440 CONTINUE
      GO TO 510
  450 CONTINUE
      IF (KAN2.GT.0) GO TO 480
      QRIN2=(TJO(2)-TJO(4))/(BES*3600.)
      QROT2=(TJO(4)-TJO(6))/(BAS*3600.)
      DQIN2=(QRIN2-QROT2)*DTS
      QST2=QST2+DQIN2
      IF (QST2-HF2) 470,470,460
  460 KAN2=10
      KUS=10
  470 CONTINUE
      GO TO 510
  480 CONTINUE
      QRIN3=(TJO(4)-TJO(6))/(BAS*3600.)
      QROT3=(TJO(5)-TJO(7))/(BOS*3600.)
      DQIN3=(QRIN3-QROT3)*DTS
      QST3=QST3+DQIN3
      IF (QST3-HF3) 500,500,490
  490 KAN3=10
      KOS=10
  500 CONTINUE
  510 CONTINUE
      IF (DEL+1.01*DTS.LT.APRNT) RETURN
```

```
      QIN1=QIN/3600.                                                    ABL 232
      WRITE (6,560) T,VELX,QIN1,XMDG(INT),XMDC,XMDT,XLSTI,QBLOCK,QHW,HTXABL 233
     1,HW,Z                                                             ABL 234
      TIME=T+.5*DTS                                                     ABL 235
      WRITE (6,570) TIME                                                ABL 236
      WRITE (6,580)                                                     ABL 237
      IF (NIFPCM.LE.0) GO TO 520                                        ABL 238
      WRITE (6,590) QRIN1,QRIN2,QRIN3,QROT1,QROT2,QROT3                 ABL 239
      WRITE (6,590) DQIN1,DQIN2,DQIN3,QST1,QST2,QST3                    ABL 240
      WRITE (6,600) (CDJ(J),J=1,7)                                      ABL 241
  520 CONTINUE                                                          ABL 242
      DO 530 I=1,NP                                                     ABL 243
  530 XVPNT(I)=XV(I)*12.+XLSTI                                          ABL 244
      WRITE (6,610) (XVPNT(I),TX2(I),THETA(I),XMTPT(I),I=1,NP)          ABL 245
      IJ=NP+1                                                           ABL 246
      WRITE (6,620)                                                     ABL 247
      WRITE (6,630) (TX2(I),I=IJ,NPF)                                   ABL 248
      WRITE (6,640)                                                     ABL 249
      RETURN                                                            ABL 250
  540 STOP                                                              ABL 251
C                                                                       ABL 252
  550 FORMAT (1H0,80H THE RANGE OF THE ENTHALPY-TEMPERATURE CURVE FIT WAABL 253
     1SEXCEEDED AT A TEMPERATURE OF,1E10.4)                             ABL 254
  560 FORMAT (6H0TIME=,E12.5,15X,9HVELOCITY=,E12.5,12X,4HQIN=,E12.5/19H ABL 255
     1GAS ABLATION RATE=,E12.5,2X,19HCHAR ABLATION RATE=,E12.5,2X,20HTOTABL 256
     2AL ABLATION RATE=,E12.5/17H RECESSION DEPTH=,E12.5,4X,7HQBLOCK=,E1ABL 257
     32.5,14X,11HQ HOT WALL=,E12.5/5H HTX=,E12.5,16X,3HHW=,E12.5,18X,2HZABL 258
     4=,E12.5/)                                                         ABL 259
  570 FORMAT (1H0,72HTEMPERATURE DISTRIBUTION IN HEAT SHIELD AT THE END ABL 260
     1OF THE TIME STEP, T= ,E12.5,1X,7HSECONDS//)                       ABL 261
  580 FORMAT (4X,49HTEMPERATURE DISTRIBUTION IN THE ABLATING MATERIAL//)ABL 262
  590 FORMAT (2X,6(2X,E12.5))                                           ABL 263
  600 FORMAT (2X,7(2X,E12.5)//)                                         ABL 264
  610 FORMAT (30X,1HX,4X,11HTEMPERATURE,2X,5HTHETA,5X,5HM DOT,/,(24X,F10ABL 265
     1.5,F10.1,F10.4,E16.7))                                            ABL 266
  620 FORMAT (//4X,49HTEMPERATURE DISTRIBUTION IN THE BACK-UP STRUCTURE/ABL 267
     1/)                                                                ABL 268
  630 FORMAT (6X,E12.5,5E16.5)                                          ABL 269
  640 FORMAT (//)                                                       ABL 270
      END                                                               ABL 271-
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```
      SUBROUTINE CAND
C     THIS ROUTINE CALCULATES THE CONDUCTIVITIES REQD. DURING MELTING
C     OF PCM
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON /UMND/      TKC(9),      XKC(9),      TCPC(9),      CPC(9),
     1        TKV(9),     XKV(9,7),     TCPV(9),      CPV(9),     XNPM(4),
     2     RHOBX(4),       XBM(4),      EMFB(4),      EMBB(4),     NKPB(4),
     3      NCPB(4),     TXK(9,4),      XK(9,4),     TCP(9,4),     CPX(9,4),
     4       NPM(4),      GAPX(4),     FTEST(4),     BTEST(4),   TEMDI(30),
     5      TX1(30),   TX2T(10,6),     TUL1(30),     TUL2(30),       A(30),
     6        B(30),        C(30),        D(30),        S(10),       R(10),
     7      AB(5,6),      BB(5,6),      CB(5,6),      DB(5,6),     SB(5,6),
     8     RB1(5,6),     RB2(5,6),       TY(30),     CPB(9,6),      DXB(6),
     9     XMDG(10),      RHO(10),       CP(10),       YK(10),    XKB(9,6),
     $         H(4),      IEM(10),       PKV(7),       XV(10),      TS(10),
     $       SR(10),       HX(20),       TW(20)
      COMMON/OLA/ TJO(10),CDJ(10)
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,    DT,    DX,   EMV,   EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,    FV, HENV,    HV, H300,   I17,    I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,   NMB,   NP, NPBS,   NPF, NREC,   NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,    TV,
     4   VL,   VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,  XMP,  XMT,  XNP,   NHP,
     5 NTKV, NPKV,IQBLCK
      DO 100 J=1,7
      I=NPC
      IF (J.EQ.1) I=NPC-1
      IF (J.EQ.7) I=NPC+1
      LKP=NKPB(I)
   10 IF (I5-1) 40,40,20
   20 IF (I5-LKP) 30,30,40
   30 IF (TJO(J)-TXK(I5,I)) 60,90,50
   40 GO TO 110
   50 I5=I5+1
      GO TO 20
   60 IF (TJO(J)-TXK(I5-1,I)) 70,90,80
   70 I5=I5-1
      GO TO 10
   80 CDJ(J)=XK(I5-1,I)+((XK(I5,I)-XK(I5-1,I))/(TXK(I5,I)-TXK(I5-1,I)))*
     1(TJO(J)-TXK(I5-1,I))
      GO TO 100
   90 CDJ(J)=XK(I5,I)
  100 CONTINUE
      I5=2
  110 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE COEFF(NPFT,SDOT)
C     THIS SUBROUTINE DETERMINES THE COEFFICIENTS OF THE MATRIX
C
      COMMON /ABLTN/ T,QIN,DTS,TX2(30),VELX,IQINPP,DEL,APRNT,INT,PE
      COMMON /ARRH/THETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON /CCPG/CPGAS
      COMMON /DMND/       TKC(9),        XKC(9),       TCPC(9),       CPC(9),
     1      TKV(9),    XKV(9,7),      TCPV(9),       CPV(9),       XNPM(4),
     2    RHOBX(4),      XBM(4),       EMFB(4),      EMBB(4),      NKPB(4),
     3     NCPB(4),    TXK(9,4),      XK(9,4),     TCP(9,4),     CPX(9,4),
     4      NPM(4),     GAPX(4),      FTEST(4),     BTEST(4),    TEMDI(30),
     5     TX1(30),  TX2T(10,6),     TUL1(30),     TUL2(30),        A(30),
     6       B(30),       C(30),        D(30),        S(10),        R(10),
     7     AB(5,6),     BB(5,6),      CB(5,6),      DB(5,6),      SB(5,6),
     8    RB1(5,6),    RB2(5,6),       TY(30),     CPB(9,6),       DXB(6),
     9    XMDG(10),     RHO(10),       CP(10),       YK(10),     XKB(9,6),
     $        H(4),     IEM(10),       PKV(7),       XV(10),       TS(10),
     $      SR(10),      HX(20),       TW(20)
      COMMON /KAN/ KAN1,KAN2,KAN3
      COMMON/SID/ NUP
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,    DT,    DX,  EMV,  EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,    FV, HENV,    HV, H300,  I17,   I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,  NMB,    NP, NPBS,  NPF, NREC,  NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,   TV,
     4   VL,  VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,  XMP,  XMT,  XNP,  NHP,
     5 NTKV, NPKV,IQBLCK
C
C
      KIP=-10
      KAP=NPC+1
      KOP=-10
      CALL PROP
      IF (ERR2.EQ.1.0) RETURN
      XFG1=1.
      XFG2=1.
      XIFG3=0.
      IF (AOPT.NE.0.) XFG1=0.
      IF (AOPT.NE.0.) XIFG3=1.
      IF (TX2(1).LT.TABL) XFG2=0.
      YNP=NP
      S(INT)=(RHO(INT)*DX*CP(INT))/(2.0*DT)
      R(INT)=(1.0)/((DX/2.0)*((1.0/YK(INT))+(1.0/YK(INT+1))))
      A(INT)=0.0
      B(INT)=-(S(1)+R(1))
      C(INT)=R(1)
      D(INT)=-QIN-S(1)*TX2(1)+(XMDG(1)-XMDG(2))*HV/2.*XFG1+XFG2*CA*DX/2.
     1*HV*(RHO(1)-RHOC)**SN*EXP(-XB/TX2(1))*XIFG3+XMDG(1)*CPGAS/2.*QIN/Y
     2K(1)*DX+RHO(1)*CP(1)*SDOT*QIN/2./YK(1)*DX
      XFG2=1.
      JNT=INT+1
      NPP=NP-1
      XFG2=1.
      DO 10 I=JNT,NPP
      XI=I
      S(I)=(RHO(I)*DX*CP(I))/DT
      R(I)=(1.0)/((DX/(2.0*YK(I)))+(DX/(2.0*YK(I+1))))
```

```
      A(I)=(R(I-1)-XMDG(I)*CPGAS/2.)
      B(I)=-(R(I-1)+R(I)+RHO(I)*CP(I)*SDOT*(YNP-XI)/(YNP-1.))-S(I)
      C(I)=(R(I)+XMDG(I)*CPGAS/2.+RHO(I)*CP(I)*SDOT*(YNP-XI)/(YNP-1.))
      IF (TX2(I).LT.TABL) XFG2=0.
      D(I)=-S(I)*TX2(I)+(XMDG(I)-XMDG(I+1))*HV*XFG1+XFG2*XIFG3*CA*HV*(RH
     1O(I)-RHOC)**SN*EXP(-XB/TX2(I))*DX
      XFG2=1.
   10 CONTINUE
      R(NP)=(1.0)/((DXB(1)/(2.0*XKB(1,1)))+(DXB(1)/(2.0*XKB(2,1))))
      S(NP)=(RHO(NP)*DX*CP(NP)+RHOBX(1)*CPB(1,1)*DXB(1))/(2.0*DT)
      A(NP)=R(NP-1)
      B(NP)=-(XMDG(NP)*CPGAS+R(NP-1)+R(NP))-S(NP)
      C(NP)=R(NP)
      IF (TX2(NP).LT.TABL) XFG2=0.
      D(NP)=(-S(NP)*TX2(NP))+XMDG(NP)*HV*XFG1+XFG2*CA*HV/2.*(RHO(NP)-RHO
     1C)**SN*EXP(-XB/TX2(NP))*DX*XIFG3
      DO 250 I=1,NMB
      IF (NPC.EQ.0) GO TO 20
      IF (KAS.LT.0.AND.I.EQ.NPC) GO TO 80
      IF (KOS.LT.0.AND.I.EQ.KAP) GO TO 80
   20 CONTINUE
      IF (I-1) 30,30,40
   30 AB(1,I)=A(NP)
      BB(1,I)=B(NP)
      CB(1,I)=C(NP)
      DB(1,I)=D(NP)
      GO TO 140
   40 L=NPM(I-1)
      IF (FTEST(I)) 100,50,100
   50 CONTINUE
      IF (NPC.EQ.0) GO TO 60
      IF (KAS.LT.0.AND.I.EQ.NPC) GO TO 90
      IF (KOS.LT.0.AND.I.EQ.KAP) GO TO 90
   60 CONTINUE
      SB(1,I)=(RHOBX(I)*CPB(1,I)*DXB(I)+RHOBX(I-1)*CPB(L,I-1)*DXB(I-1))/
     1(2.0*DT)
      RB1(1,I)=(1.0)/((DXB(I-1)/(2.0*XKB(L,I-1)))+(DXB(I-1)/(2.0*XKB(L-1
     1,I-1))))
      RB2(1,I)=(1.0)/((DXB(I)/(2.0*XKB(1,I)))+(DXB(I)/(2.0*XKB(2,I))))
      AB(1,I)=RB1(1,I)
      BB(1,I)=(-(RB1(1,I)+RB2(1,I)+SB(1,I)))
      CB(1,I)=RB2(1,I)
      DB(1,I)=(-(SB(1,I)*TX2T(1,I)))
      IF (KOP.LT.0) GO TO 70
      AB(1,I)=0.0
      DB(1,I)=DB(1,I)-RB1(1,I)*TMELT
      KOP=-10
   70 CONTINUE
      GO TO 140
C     MODIFICATION OF FIRST NODE OF PCM DUE TO HEAT OF FUSION
C     THIS IS THE HALF NODE OF THE FACE SHEET
   80 CONTINUE
      KLOK=I
      I=NPC-1
      IF (KOS.LE.0) I=NPC
      LNF=NPM(I)
      RB1(LNF,I)=(1.0)/((DXB(I)/(2.0*XKB(LNF-1,I)))+(DXB(I)/(2.0*XKB(LNF
     1,I))))
```

```
      RB2(LNF,I)=(1.0)/((DXB(I+1)/(2.0*XKB(1,I+1)))+(DXB(I+1)/(2.0*XKB(2
     1,I+1))))
      AB(LNF,I)=RB1(LNF,I)
      BB(LNF,I)=0.0
      CB(LNF,I)=RB2(LNF,I)
      DOBI=DQIN1/DTS
      IF (KOS.LE.0) DOBI=DQIN3/DTS
      DB(LNF,I)=DOBI+(RB1(LNF,I)+RB2(LNF,I))*TMELT
      LO=LNF-1
C     MODIFICATION OF NODE AHED WHEN FIRST PCM NODE AT TMELT
      CB(LO,I)=0.0
      DB(LO,I)=DB(LO,I)-RB2(LO,I)*TMELT
      KIP=10
      I=KLOK
      GO TO 20
   90 CONTINUE
C MODIFICATION OF FIRSTNODE OF PCM DUE TO HEAT OF FUSION
C     THIS IS THE FIRST HALF NODE OF PCM
      SB(1,I)=0.0
      RB1(1,I)=(1.0)/((DXB(I-1)/(2.0*XKB(L,I-1)))+(DXB(I-1)/(2.0*XKB(L-1
     1,I-1))))
      RB2(1,I)=(1.0)/((DXB(I)/(2.0*XKB(1,I)))+(DXB(I)/(2.0*XKB(2,I))))
      AB(1,I)=RB1(1,I)
      BB(1,I)=0.0
      CB(1,I)=RB2(1,I)
      DABI=DQIN1/DTS
      IF (KOS.LE.0) DABI=DQIN3/DTS
      DB(1,I)=DABI+(RB1(1,I)+RB2(1,I))*TMELT
      GO TO 140
  100 IF (FTEST(I)) 110,50,120
  110 G=(1.73E-09)/(1.0/EMBB(I-1)+1.0/EMFB(I)-1.0)
      GO TO 130
  120 G=0.0
  130 SB(1,I)=(RHOBX(I)*CPB(1,I)*DXB(I))/(2.0*DT)
      RB2(1,I)=(1.0)/((DXB(I)/(2.0*XKB(1,I)))+(DXB(I)/(2.0*XKB(2,I))))
      AB(1,I)=H(I-1)+4.0*G*(TX2T(L,I-1)**3)
      BB(1,I)=(-(H(I-1)+4.0*G*(TX2T(1,I)**3)+RB2(1,I)+SB(1,I)))
      CB(1,I)=RB2(1,I)
      DB(1,I)=3.0*G*((TX2T(L,I-1)**4)-(TX2T(1,I)**4))-SB(1,I)*TX2T(1,I)
  140 LF=NPM(I)-1
      DO 170 J=2,LF
      IF (KOS.LT.0.AND.I.EQ.NPC) GO TO 160
      SB(J,I)=(RHOBX(I)*CPB(J,I)*DXB(I))/DT
      RB1(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J-1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      RB2(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J+1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      AB(J,I)=RB1(J,I)
      BB(J,I)=(-(RB1(J,I)+RB2(J,I)+SB(J,I)))
      CB(J,I)=RB2(J,I)
      DB(J,I)=(-(SB(J,I)*TX2T(J,I)))
      IF (KIP.LT.0) GO TO 150
C     MODIFICATION OF CENTER PCM NODE WHEN FIRST NODE AT TMELT
      AB(J,I)=0.0
      DB(J,I)=DB(J,I)-RB1(J,I)*TMELT
      KIP=-10
  150 CONTINUE
      GO TO 170
C     MODIFICATION OF INTERIOR NODE OF PCM DUE TO HEAT OF FUSION
  160 CONTINUE
```

```
      RB1(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J-1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      RB2(J,I)=(1.0)/((DXB(I)/(2.0*XKB(J+1,I)))+(DXB(I)/(2.0*XKB(J,I))))
      AB(J,I)=RB1(J,I)
      BB(J,I)=0.0
      CB(J,I)=RB2(J,I)
      DB(J,I)=DQIN2/DTS+(RB1(J,I)+RB2(J,I))*TMELT
      CB(J-1,I)=0.0
      DB(J-1,I)=DB(J-1,I)-RB2(J-1,I)*TMELT
      JK=NPM(I-1)
      CB(JK,I-1)=0.0
      DB(JK,I-1)=DB(JK,I-1)-RB2(JK,I-1)*TMELT
      KOP=+10
  170 CONTINUE
      IF (I-NMB) 180,260,260
  180 LNF=NPM(I)
      IF (BTEST(I)) 210,190,210
  190 SB(LNF,I)=(RHOBX(I)*CPB(LNF,I)*DXB(I)+RHOBX(I+1)*CPB(1,I+1)*DXB(I+
     11))/(2.0*DT)
      RB1(LNF,I)=(1.0)/((DXB(I)/(2.0*XKB(LNF-1,I)))+(DXB(I)/(2.0*XKB(LNF
     1,I))))
      RB2(LNF,I)=(1.0)/((DXB(I+1)/(2.0*XKB(1,I+1)))+(DXB(I+1)/(2.0*XKB(2
     1,I+1))))
      AB(LNF,I)=RB1(LNF,I)
      BB(LNF,I)=(-(RB1(LNF,I)+RB2(LNF,I)+SB(LNF,I)))
      CB(LNF,I)=RB2(LNF,I)
      DB(LNF,I)=(-(SB(LNF,I)*TX2T(LNF,I)))
      IF (KOP.LT.0) GO TO 200
      AB(LNF,I)=0.0
      DB(LNF,I)=DB(LNF,I)-RB1(LNF,I)*TMELT
  200 CONTINUE
      GO TO 250
  210 IF (BTEST(I)) 220,190,230
  220 G=(1.73E-09)/(1.0/EMBB(I)+1.0/EMFB(I+1)-1.0)
      GO TO 240
  230 G=0.0
  240 SB(LNF,I)=(RHOBX(I)*CPB(LNF,I)*DXB(I))/(2.0*DT)
      RB1(LNF,I)=(1.0)/((DXB(I)/(2.0*XKB(LNF-1,I)))+(DXB(I)/(2.0*XKB(LNF
     1,I))))
      AB(LNF,I)=RB1(LNF,I)
      BB(LNF,I)=(-(RB1(LNF,I)+H(I)+SB(LNF,I)+4.0*G*(TX2T(LNF,I)**3)))
      CB(LNF,I)=H(I)+4.0*G*(TX2T(1,I+1)**3)
      DB(LNF,I)=3.0*G*((TX2T(1,I+1)**4)-(TX2T(LNF,I)**4))-SB(LNF,I)*TX2T
     1(LNF,I)
  250 CONTINUE
  260 MN=NPM(NMB)
      IF (QLOSS) 280,270,280
  270 SB(MN,NMB)=(RHOBX(NMB)*CPB(MN,NMB)*DXB(NMB))/(2.0*DT)
      RB1(MN,NMB)=(1.0)/((DXB(NMB)/(2.*XKB(MN-1,NMB)))+(DXB(NMB)/(2.0*XK
     1B(MN,NMB))))
      AB(MN,NMB)=RB1(MN,NMB)
      BB(MN,NMB)=(-(RB1(MN,NMB)+SB(MN,NMB)))
      CB(MN,NMB)=0.0
      DB(MN,NMB)=(-(SB(MN,NMB)*TX2T(MN,NMB)))
      GO TO 290
  280 SB(MN,NMB)=(RHOBX(NMB)*CPB(MN,NMB)*DXB(NMB))/(2.0*DT)
      RB1(MN,NMB)=(1.0)/((DXB(NMB)/(2.0*XKB(MN-1,NMB)))+(DXB(NMB)/(2.0*X
     1KB(MN,NMB))))
      AB(MN,NMB)=RB1(MN,NMB)
```

```
      BB(MN,NMB)=(-(RB1(MN,NMB)+HENV+(1.73E-09)*FENV*4.0*(TX2T(MN,NMB)**
     13)+SB(MN,NMB)))
      CB(MN,NMB)=0.0
      DB(MN,NMB)=(-(HENV*TENV+FENV*(1.73E-09)*((TENV**4)+3.0*(TX2T(MN,NM
     1B)**4))+SB(MN,NMB)*TX2T(MN,NMB)))
  290 L=NP+1
      DO 330 I=1,NMB
      K=NPM(I)
      IF (I.EQ.1) GO TO 300
      IF (GAPX(I-1).EQ.0.) GO TO 300
      KT=1
      GO TO 310
  300 KT=2
  310 DO 320 J=KT,K
      A(L)=AB(J,I)
      B(L)=BB(J,I)
      C(L)=CB(J,I)
      D(L)=DB(J,I)
      L=L+1
  320 CONTINUE
  330 CONTINUE
      NPFT=L-1
      IF (KAS.LT.0) NUP=NAP
      IF (KUS.LT.0) NUP=NAP+1
      IF (KOS.LT.0) NUP=NAP+2
      RETURN
      END
```

```
      SUBROUTINE MDTGAS
C     THIS SUBROUTINE DETERMINES THE MASS FLOW RATE FROM THE
C       ABLATING NODES
C
      COMMON /ABLTN/ T,QIN,DTS,TX2(30),VELX,IQINPP,DEL,APRNT,INT,PE
      COMMON /ARRH/THETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /CCSDOT/SDOT
      COMMON /UMND/       TKC(9),        XKC(9),      TCPC(9),       CPC(9),
     1      TKV(9),     XKV(9,7),      TCPV(9),       CPV(9),     XNPM(4),
     2    RHOBX(4),       XBM(4),       EMFB(4),      EMBB(4),     NKPB(4),
     3     NCPB(4),     TXK(9,4),     XK(9,4),     TCP(9,4),    CPX(9,4),
     4      NPM(4),      GAPX(4),     FTEST(4),     BTEST(4),   TEMDI(30),
     5     TX1(30),   TX2T(10,6),     TUL1(30),     TUL2(30),       A(30),
     6       B(30),        C(30),        D(30),        S(10),       R(10),
     7     AB(5,6),      BB(5,6),      CB(5,6),      DB(5,6),     SB(5,6),
     8    RB1(5,6),     RB2(5,6),       TY(30),     CPB(9,6),      DXB(6),
     9    XMDG(10),      RHO(10),       CP(10),       YK(10),    XKB(9,6),
     $        H(4),      IEM(10),       PKV(7),       XV(10),      TS(10),
     $      SR(10),       HX(20),       TW(20)
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,    DT,    DX,   EMV,  EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,    FV, HENV,   HV, H300,   I17,   I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,  NMB,    NP, NPBS,  NPF, NREC,  NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,   TV,
     4   VL,  VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,  XMP,  XMT,  XNP,  NHP,
     5 NTKV, NPKV,IQBLCK
C
C
      DO 10 I=1,NP
   10 TUL1(I)=TUL2(I)
      XNP=NP
      KI=NP
      KI1=NP-1
      IF (TX2(NP).GE.TABL) TUL2(NP)=TUL1(NP)-AP*DT*EXP(-XB/TX2(NP))
      IF (SN.EQ.1.) GO TO 20
      RHO(NP)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(NP))**(1./(1.-SN))
      GO TO 30
   20 RHO(NP)=RHOC+(RHOV-RHOC)*EXP(TUL2(NP))
   30 CONTINUE
      THETA(NP)=(RHO(NP)-RHOC)/(RHOV-RHOC)
      IF (THETA(NP).LE..01) RHO(NP)=RHOC
      IF (THETA(NP).GT.1.0) RHO(NP)=RHOV
      XMT=0.
      XMDG(NP)=XMT
      DO 90 I=1,KI1
      KI=NP-I
      ZKI=KI
      IF (TX2(KI).GE.TABL) GO TO 40
      IF (SDOT.EQ.0.) GO TO 50
      TUL2(KI)=(TUL1(KI)+SDOT*DT/DX*(XNP-ZKI)/(XNP-1.)*TUL2(KI+1))/(1.+S
     1DOT*DT/DX*(XNP-ZKI)/(XNP-1.))
      GO TO 50
   40 CONTINUE
      TUL2(KI)=(TUL1(KI)-AP*DT*EXP(-XB/TX2(KI))+SDOT*DT/DX*(XNP-ZKI)/(XN
     1P-1.)*TUL2(KI+1))/(1.+SDOT*DT/DX*(XNP-ZKI)/(XNP-1.))
   50 CONTINUE
      IF (SN.EQ.1.) GO TO 60
      RHO(KI)=RHOC+(RHOV-RHOC)*((1.-SN)*TUL2(KI))**(1./(1.-SN))
      GO TO 70
```

```
60 RHO(KI)=RHOC+(RHOV-RHOC)*EXP(TUL2(KI))
70 THETA(KI)=(RHO(KI)-RHOC)/(RHOV-RHOC)
   IF (THETA(KI).LE..01) RHO(KI)=RHOC
   IF (THETA(KI).GT.1.0) RHO(KI)=RHOV
   IF (TX2(KI).LT.TABL) GO TO 80
   XMT=XMT+CA*DX/2.*((RHO(KI)-RHOC)**SN*EXP(-XB/TX2(KI))+(RHO(KI+1)-R
  1HOC)**SN*EXP(-XB/TX2(KI+1)))
80 XMTPT(KI)=XMT
   XMDG(KI)=XMT
90 CONTINUE
   RETURN
   END
```

```
      SUBROUTINE PROP
C     THIS SUBROUTINE DETERMINES THE PHYSICAL PROPERTIES OF THE
C       HEAT SHIELD STRUCTURE
C
      COMMON /ABLTN/ T,QIN,DTS,TX2(30),VELX,IQINPP,DEL,APRNT,INT,PE
      COMMON /ARRH/THETA(10),AP,XB,SN,CA,XMTPT(10),AOPT
      COMMON /DMND/      TKC(9),      XKC(9),      TCPC(9),      CPC(9),
     1       TKV(9),    XKV(9,7),    TCPV(9),      CPV(9),     XNPM(4),
     2    RHOBX(4),      XBM(4),     EMFB(4),     EMBB(4),     NKPB(4),
     3     NCPB(4),    TXK(9,4),     XK(9,4),    TCP(9,4),    CPX(9,4),
     4      NPM(4),     GAPX(4),    FTEST(4),    BTEST(4),   TEMDI(30),
     5     TX1(30),  TX2T(10,6),    TUL1(30),    TUL2(30),       A(30),
     6       B(30),       C(30),       D(30),       S(10),       R(10),
     7     AB(5,6),     BB(5,6),     CB(5,6),     DB(5,6),     SB(5,6),
     8    RB1(5,6),    RB2(5,6),      TY(30),    CPB(9,6),      DXB(6),
     9    XMDG(10),     RHO(10),      CP(10),      YK(10),    XKB(9,6),
     $        H(4),     IEM(10),      PKV(7),      XV(10),      TS(10),
     $      SR(10),      HX(20),      TW(20)
      COMMON /UNDM/ABLC, ABLK,   BL,CHARC,CHARK,   DT,   DX,  EMV,  EMC,
     1 ERR2, ERR3, ERR4, ERR5, FENV,   FV, HENV,   HV, H300,  I17,    I5,
     2   I6, NCPC, NCPV,  NKC,  NKV,  NMB,   NP, NPBS,  NPF, NREC,  NRS,
     3QLOSS, RHOC, RHOV, TABL,TBLOW,TCHAR,TEMPI, TENV,TEST2, TREC,    TV,
     4   VL,  VLV,XLOST,XLSTV,  XMC, XMDC, XMDT,  XMP,  XMT,  XNP,   NHP,
     5 NTKV, NPKV,IQBLCK
C
C
      DO 40 I=1,NP
      IF (RHOV.EQ.RHOC) GO TO 20
      IF (RHO(I).NE.RHOC) GO TO 10
      CALL QDOT(1,TX2(I),TKC,YK(I),XKC,DUM,NKC)
      CALL QDOT(1,TX2(I),TCPC,CP(I),CPC,DUM,NCPC)
      GO TO 40
   10 IF (THETA(I).LT..99) GO TO 30
   20 CALL QDOT(1,TX2(I),TKV,YK(I),XKV,DUM,NKV,NTKV,NPKV,PKV,PE)
      CALL QDOT(1,TX2(I),TCPV,CP(I),CPV,DUM,NCPV)
      GO TO 40
   30 YK(I)=CHARK+(ABLK-CHARK)*((RHO(I)-RHOC)/(RHOV-RHOC))
      CP(I)=CHARC+(ABLC-CHARC)*((RHO(I)-RHOC)/(RHOV-RHOC))
   40 CONTINUE
C
C     DETERMINATION OF PROPER BACK-UP SHIELD MATERIAL PROPERTY
C
      DO 230 I=1,NMB
      DXB(I)=XBM(I)/((XNPM(I)-1.0)*12.0)
      LKP=NKPB(I)
      LCP=NCPB(I)
      NN=NPM(I)
      DO 220 J=1,NN
   50 IF (I5-1) 80,80,60
   60 IF (I5-LKP) 70,70,80
   70 IF (TX2T(J,I)-TXK(I5,I)) 100,130,90
   80 WRITE (6,250) I,TX2T(J,I)
      ERR2=1.0
      GO TO 240
   90 I5=I5+1
      GO TO 60
  100 IF (TX2T(J,I)-TXK(I5-1,I)) 110,130,120
  110 I5=I5-1
```

```
      GO TO 50
  120 XKB(J,I)=XK(I5-1,I)+((XK(I5,I)-XK(I5-1,I))/(TXK(I5,I)-TXK(I5-1,I))
     1)*(TX2T(J,I)-TXK(I5-1,I))
      GO TO 140
  130 XKB(J,I)=XK(I5,I)
  140 IF (I6-1) 80,80,150
  150 IF (I6-LCP) 160,160,80
  160 IF (TX2T(J,I)-TCP(I6,I)) 180,210,170
  170 I6=I6+1
      GO TO 150
  180 IF (TX2T(J,I)-TCP(I6-1,I)) 190,210,200
  190 I6=I6-1
      GO TO 140
  200 CPB(J,I)=CPX(I6-1,I)+((CPX(I6,I)-CPX(I6-1,I))/(TCP(I6,I)-TCP(I6-1,
     1I)))*(TX2T(J,I)-TCP(I6-1,I))
      GO TO 220
  210 CPB(J,I)=CPX(I6,I)
  220 CONTINUE
      I5=2
      I6=2
  230 CONTINUE
  240 RETURN
C
  250 FORMAT (1H0,32H THE RANGE OF ONE OF THE NUMBER ,I2,71H BACKUP STRU
     1CTURE PROPERTY CURVE FITS WAS EXCEEDED AT A TEMPERATURE OF ,E12.5)
      END
```

```
      SUBROUTINE QDOT(K,X,AXI,Y,AYI,DER,N,NT,NP,AZI,Z)
C
      DIMENSION AXI(1),AYI(9,7),AZI(1)
C
      I=0
      IF (N-2) 10,70,30
   10 IF (N-1) 90,20,30
   20 Y=AYI(1)
      DER=0.
      GO TO 230
C
   30 IF (K) 40,140,40
C
   40 I=I+1
      IF (N-I) 80,80,50
   50 IF (X-AXI(I)) 60,60,40
   60 IF (I-1) 70,70,80
   70 I=2
   80 J=I-1
      DER=(AYI(I)-AYI(J))/(AXI(I)-AXI(J))
      Y=AYI(J)+(X-AXI(J))*DER
      GO TO 230
   90 DO 100 I=1,NT
      IF (AXI(I).GT.X) GO TO 110
  100 CONTINUE
      I=NT
  110 IF (I.LT.2) I=2
      L=I-1
      DO 120 J=1,NP
      IF (AZI(J).GT.Z) GO TO 130
  120 CONTINUE
      J=NP
  130 IF (J.LT.2) J=2
      M=J-1
      DER1=(AYI(I,J)-AYI(L,J))/(AXI(I)-AXI(L))
      DER2=(AYI(I,M)-AYI(L,M))/(AXI(I)-AXI(L))
      Y1=AYI(L,J)+(X-AXI(L))*DER1
      Y2=AYI(L,M)+(X-AXI(L))*DER2
      DER=(Y1-Y2)/(AZI(J)-AZI(M))
      Y=Y2+(Z-AZI(M))*DER
      GO TO 230
C
  140 I=I+1
      IF (N-I) 210,210,150
  150 IF (X-AXI(I)) 160,160,140
  160 IF (I-1) 200,200,170
  170 IF (ABS(AXI(I)-X)-ABS(AXI(I-1)-X)) 190,190,180
  180 IF (I-2) 190,190,210
C
  190 J1=I-1
      J2=I
      J3=I+1
      GO TO 220
  200 J1=I
      J2=I+1
      J3=I+2
      GO TO 220
  210 J1=I-2
```

```
      J2=I-1
      J3=I
C
  220 A=((AYI(J3)-AYI(J2))/(AXI(J3)-AXI(J2))-(AYI(J1)-AYI(J2))/(AXI(J1)-
     1AXI(J2)))/(AXI(J3)-AXI(J1))
      B=(AYI(J1)-AYI(J2))/(AXI(J1)-AXI(J2))-A*(AXI(J1)-AXI(J2))
      Y=(A*(X-AXI(J2))+B)*(X-AXI(J2))+AYI(J2)
      DER=2.*A*(X-AXI(J2))+B
  230 RETURN
C
      END
```

```
      SUBROUTINE RECESS(XMDC,XLOST,TREC,DT,RHOC,TS,SR,TX2,NREC,NRS,ERR5,
     1SDOT)
C
C     THIS SUBROUTINE DETERMINES THE FRONT FACE LOCATION AND CHAR MASS
C     REMOVAL RATE
C
C
      DIMENSION TS(10),SR(10)
      IF (TX2-TREC) 10,20,20
   10 XMDC=0.0
      XLOST=0.0
      SDOT=0.0
      GO TO 120
   20 IF (NRS-1) 50,50,30
   30 IF (NRS-NREC) 40,40,50
   40 IF (TX2-TS(NRS)) 70,100,60
   50 WRITE (6,130) TX2
      ERR5=1.0
      GO TO 120
   60 NRS=NRS+1
      GO TO 30
   70 IF (TX2-TS(NRS-1)) 80,100,90
   80 NRS=NRS-1
      GO TO 20
   90 SX=SR(NRS-1)+((SR(NRS)-SR(NRS-1))/(TS(NRS)-TS(NRS-1)))*(TX2-TS(NRS
     1-1))
      GO TO 110
  100 SX=SR(NRS)
  110 XLOST=300.0*SX*DT
      XMDC=(XLOST*RHOC)/DT
      SDOT=SX*300.0
  120 RETURN
C
  130 FORMAT (1H0,75H THE RANGE OF THE SURFACE RECESSION TABLE WAS EXCEE
     1DED AT A TEMPERATURE OF ,1PE12.5)
      END
```

```
      SUBROUTINE SWUFT(A,B,C,D,T,N)
C     THIS SUBROUTINE DETERMINES THE FORWARD TIME STEP TEMPERATURES
C     BY SOLVING THE TRI-DIAGONAL MATRIX
      COMMON /BREV/ KUS,KAS,KOS,NAP,NPC,NIFPCM,DQIN1,DQIN2,DQIN3,KA,KU
     1, TMELT
      COMMON/SID/ NUP
      DIMENSION A(30),B(30),C(30),D(30),T(30),CP(30),DP(30)
      IF (NPC.EQ.0) GO TO 10
      IF (KAS.GT.0.AND.KUS.GT.0.AND.KOS.GT.0) GO TO 10
      M=N
      N=NUP
   10 CONTINUE
      CP(1)=C(1)/B(1)
      DP(1)=D(1)/B(1)
      DO 20 I=2,N
      CP(I)=C(I)/(B(I)-A(I)*CP(I-1))
      DP(I)=(D(I)-A(I)*DP(I-1))/(B(I)-A(I)*CP(I-1))
   20 CONTINUE
      T(N)=DP(N)
      NM1=N-1
      DO 30 J=1,NM1
      I=N-J
      T(I)=DP(I)-CP(I)*T(I+1)
   30 CONTINUE
      IF (NPC.EQ.0) GO TO 60
      IF (KAS.GT.0.AND.KUS.GT.0.AND.KOS.GT.0) GO TO 60
      T(NUP+1)=TMELT
      K=NUP+2
      CP(K)=C(K)/B(K)
      DP(K)=D(K)/B(K)
      KK=K+1
      DO 40 I=KK,M
      CP(I)=C(I)/(B(I)-A(I)*CP(I-1))
      DP(I)=(D(I)-A(I)*DP(I-1))/(B(I)-A(I)*CP(I-1))
   40 CONTINUE
      T(M)=DP(M)
      NM1=M-1
      DO 50 J=1,NM1
      I=M-J
      T(I)=DP(I)-CP(I)*T(I+1)
   50 CONTINUE
      N=M
   60 CONTINUE
      RETURN
      END
```

```
      OVERLAY (P5490,4,0)                                                RSI
      PROGRAM RSICMP                                                     RSI
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50RSI
     1),NL(5),V(50)                                                      RSI
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1RSI
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(RSI
     241,21)                                                             RSI
      DIMENSION B(40,1,40)                                               RSI
      COMMON/BLOCKA/A , AH     , AI     , ALFA1 , AV     , B      , C      , RSI
     1  DELX   , DELZ   , DX     , DZ     , FH     , FP     , FS     , FSM    , RSI
     2  FV     , GG     , GX     , H1     , H2     , H4     , H5     , I      , RSI
     3  I1     , I2     , I4     , I5     , IR     , J      , J1     , J2     , RSI
     4  J4     , J5     , JTA    , JTB    , JTC    , K      , KCL    , KI     , RSI
     5  KRW    , KSW1   , KSW2   , KT     , KX     , KZ     , L      , M      , RSI
     6  MS     , NCASE  , NH1    , NL     , NLJ    , NV1    , PARTA  , PARTB  , RSI
     7  PX     , Q      , R      , SF     , TH     , TV     , V      , X      , RSI
     8  XZ1    , XZ2    , XZ4    , XZ5    , ZX1    , ZX2    , ZX4    , ZX5      RSI
     9, NTEST1                                                           RSI
      COMMON      AL          ,ALPHA(99) ,ALT(99)    ,AME        ,AMI        RSI
     1,AOFA      ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)RSI
     2,BATA      ,BE         ,BETA(99)   ,BF         ,BFL        ,BL         RSI
     3,DELTA     ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL       RSI
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)RSI
     5,FNET(20)  ,FSU(20,99),FT(20)      ,FTU(20,99),FVE         ,F07        RSI
     6,G(20,99)  ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINK0     RSI
     7,IQINP     ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)   RSI
     8,NCOLM     ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS       RSI
     9,NMAT      ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG       RSI
     $,NSEG      ,NTRAJ      ,N33        ,PE         ,PHI        ,PI         RSI
     $,PINP(99)  ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)     RSI
     $,RHO1      ,RYE        ,RYI        ,SL         ,SLS        ,STAAT      RSI
     $,STI       ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU        RSI
     $,TC1       ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS       RSI
     $,TINSD(99) ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE      RSI
     $,XEMIS     ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)                 RSI
      WRITE (6,60) NMIN,N33                                              RSI
      DO 50 NTEST=1,2                                                    RSI
      GO TO (10,20) NTEST                                                RSI
   10 NTEST1=NMIN                                                        RSI
      GO TO 30                                                           RSI
   20 IF (N33.EQ.NMIN) GO TO 50                                          RSI
      NTEST1=N33                                                         RSI
   30 DO 40 II=1,12299                                                   RSI
   40 A(II)=0.0                                                          RSI
      CALL MAIN                                                          RSI
      CALL MATRX4                                                        RSI
   50 CONTINUE                                                           RSI
      RETURN                                                             RSI
C                                                                        RSI
   60 FORMAT (1H1,* NOW FOLLOWS OUTPUT FROM PROGRAM P2354 STRESS, CALCULRSI
     1ATED FOR TWO TIME FRAMES, SPECIFIED BY   NMIN =*,I3,*   AND   N33 RSI
     2=*,I3,* .*//)                                                      RSI
      END                                                                RSI
```

```
      SUBROUTINE INPUTX
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A , AH     , AI     , ALFA1  , AV     , B      , C      ,
     1  DELX  , DELZ  , DX     , DZ     , FH     , FP     , FS     , FSM    ,
     2  FV    , GG    , GX     , H1     , H2     , H4     , H5     , I      ,
     3  I1    , I2    , I4     , I5     , IR     , J      , J1     , J2     ,
     4  J4    , J5    , JTA    , JTB    , JTC    , K      , KCL    , KI     ,
     5  KRW   , KSW1  , KSW2   , KT     , KX     , KZ     , L      , M      ,
     6  MS    , NCASE , NH1    , NL     , NLJ    , NV1    , PARTA  , PARTB  ,
     7  PX    , Q     , R      , SF     , TH     , TV     , V      , X      ,
     8  XZ1   , XZ2   , XZ4    , XZ5    , ZX1    , ZX2    , ZX4    , ZX5
     9, NTEST1
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON      AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA       ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA      ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)   ,FSU(20,99),FT(20)     ,FTU(20,99),FVE        ,F07
     6,G(20,99)   ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINK0
     7,IQINP      ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT       ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG       ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI       ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI        ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9) ,TAU
     $,TC1        ,TEMP(9,9) ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
      DIMENSION MTL(13)
      DATA(MTL(I),I=1,13)/1,2,1,3,4,4,4,4,4,4,4,4,5/
      EQUIVALENCE (TB,TINS2), (TF,TSKIN1), (TR,TINS1)
C     SEE COMMENT ON PZ IN SUBROUTINE INPUTB.
C     IPRINT = NON-ZERO INTEGER   FOR DE-BUG PRINT-OUT.
C     IPRINT = 0 OR BLANK   FOR OMISSION OF DE-BUG PRINT-OUT.
C     NV IS AN INPUT PARAMETER, BUT NOTE MANY STATEMENTS SET UP FOR THE
C         PARTICULAR VALUE NV = 7.
      FVE=(1.-VB)/(1.+VB)/(1.-2.*VB)
      E(4,NTEST1)=E(4,NTEST1)*FVE
      NH1=NH-1
      NV1=NV-1
      NLJ=NH+2
      DX(1)=HH+TF
      DX(2)=TB
      DX(3)=2.*(TR+.5*TC)/7.
      DX(4)=DX(3)
      DX(5)=DX(3)
      DX(6)=.5*DX(3)
      DX(NV)=1.0
      DX(NV+1)=1.0
      N1=NH-15
```

```
      N2=N1+4
      N3=N2+6
      DO 10 I=1,NH1
      DZ(I)=.5*SL/(N1+5)
      IF (I.GT.N1) DZ(I)=DZ(1)/2.
      IF (I.GT.N2) DZ(I)=DZ(1)/3.
      IF (I.GT.N3) DZ(I)=DZ(1)/4.
   10 CONTINUE
      DZ(NH)=1.0
      DZ(NH+1)=1.0
      DO 30 J=1,7
      AH(1,J)=DZ(1)/2.
      DO 20 I=2,NH1
   20 AH(I,J)=.5*(DZ(I-1)+DZ(I))
   30 AH(NH,J)=DZ(NH1)/2.
      DO 40 J=1,6
      DO 40 I=1,NH
   40 TH(I,J)=T(2*J,NTEST1)-530.
      DO 50 I=1,NPSG
      LL=MTL(I)
   50 ALFA1(I)=TRPLAT(AY,AX,T(I,NTEST1),LL,4,MPT(LL,4))
      DO 60 I=1,NH1
      AV(I,1)=TF
      AV(I,2)=TF
      AV(I,3)=DX(6)
      AV(I,4)=DX(3)
      AV(I,5)=DX(3)
      AV(I,6)=DX(3)
   60 AV(I,7)=TC
      DO 70 J=1,7
      DO 70 I=1,NH
   70 TV(I,J)=T(2*J-1,NTEST1)-530.
      DO 80 I=1,6
      LL=MTL(2*I)
   80 GG(I)=TRPLAT(AY,AX,T(2*I,NTEST1),LL,11,MPT(LL,11))
      RETURN
      END
```

```
      SUBROUTINE INPUTY
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A , AH    , AI    , ALFA1 , AV    , B     , C     ,
     1  DELX  , DELZ  , DX    , DZ    , FH    , FP    , FS    , FSM   ,
     2  FV    , GG    , GX    , H1    , H2    , H4    , H5    , I     ,
     3  I1    , I2    , I4    , I5    , IR    , J     , J1    , J2    ,
     4  J4    , J5    , JTA   , JTB   , JTC   , K     , KCL   , KI    ,
     5  KRW   , KSW1  , KSW2  , KT    , KX    , KZ    , L     , M     ,
     6  MS    , NCASE , NH1   , NL    , NLJ   , NV1   , PARTA , PARTB ,
     7  PX    , Q     , R     , SF    , TH    , TV    , V     , X     ,
     8  XZ1   , XZ2   , XZ4   , XZ5   , ZX1   , ZX2   , ZX4   , ZX5
     9, NTEST1
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON        AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA        ,AOFE        ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA        ,BE          ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA       ,DIAM        ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99)  ,EDOT(20,99) ,EMIS(9)    ,FACC       ,FCU(20,99) ,FCY(20,99)
     5,FNET(20)    ,FSU(20,99)  ,FT(20)     ,FTU(20,99) ,FVE        ,F07
     6,G(20,99)    ,HH          ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP       ,ITURB       ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM       ,NCR         ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT        ,NMIN        ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG        ,NTRAJ       ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)    ,QCONL(9)    ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI        ,RYE         ,RYI        ,SL         ,SLS        ,STAAT
     $,STI         ,STOOP       ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1         ,TEMP(9,9)   ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)   ,UF          ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS       ,XSTG(99)    ,XX(20)     ,Y(9)       ,ZZ(20)
C  IF PZ IS ZERO, READ IT IN AS SUCH.  DO NOT OMIT A DATA CARD.
      PX=PE/144.
C  PRESSURE PE IS SENT VIA COMMON FROM PREVIOUS CALCULATION.
      NLJ=NH+2
      DO 10 I=1,NH
      KZ(I)=I
      KX(I)=7
      KT(I)=2
   10 C(I)=-PX*AH(I,7)
      KZ(NH+1)=NH
      KX(NH+1)=1
      KT(NH+1)=1
      C(NH+1)=PZ*.5
      KZ(NH+2)=NH
      KX(NH+2)=2
      KT(NH+2)=1
      C(NH+2)=PZ*.5
      RETURN
      END
```

```
      SUBROUTINE INPUTZ
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A   , AH    , AI    , ALFA1 , AV    , B     , C     ,
     1 DELX   , DELZ  , DX    , DZ    , FH    , FP    , FS    , FSM   ,
     2 FV     , GG    , GX    , H1    , H2    , H4    , H5    , I     ,
     3 I1     , I2    , I4    , I5    , IR    , J     , J1    , J2    ,
     4 J4     , J5    , JTA   , JTB   , JTC   , K     , KCL   , KI    ,
     5 KRW    , KSW1  , KSW2  , KT    , KX    , KZ    , L     , M     ,
     6 MS     , NCASE , NH1   , NL    , NLJ   , NV1   , PARTA , PARTB ,
     7 PX     , Q     , R     , SF    , TH    , TV    , V     , X     ,
     8 XZ1    , XZ2   , XZ4   , XZ5   , ZX1   , ZX2   , ZX4   , ZX5
     9, NTEST1
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON       AL          ,ALPHA(99) ,ALT(99)   ,AME       ,AMI
     1,AOFA       ,AOFE       ,AROD      ,AS        ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)  ,BF        ,BFL       ,BL
     3,DELTA      ,DIAM       ,DIST(9)   ,DST       ,E(20,99)  ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)   ,FACC      ,FCU(20,99),FCY(20,99)
     5,FNET(20)   ,FSU(20,99),FT(20)    ,FTU(20,99),FVE       ,F07
     6,G(20,99)   ,HH         ,HINS      ,HINSD(99) ,ICONF     ,ILINKO
     7,IQINP      ,ITURB      ,IWALT     ,MAT(9,9)  ,MPT(9,9)  ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC      ,NF        ,NI(18)    ,NINS
     9,NMAT       ,NMIN       ,NPRT      ,NPSG      ,NR(18)    ,NRSG
     $,NSEG       ,NTRAJ      ,N33       ,PE        ,PHI       ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)  ,QINP(99)  ,QNET(9)   ,RHO(9)
     $,RHOI       ,RYE        ,RYI       ,SL        ,SLS       ,STAAT
     $,STI        ,STOOP      ,T(20,99)  ,TALLW(9)  ,TAMP(9,9) ,TAU
     $,TC1        ,TEMP(9,9)  ,THETA     ,TI        ,TIME(99)  ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI       ,VINF(99)  ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)    ,Y(9)      ,ZZ(20)
      CONSTR=10.**20
      DO 10 I=1,7
      KZ(I)=1
      KX(I)=I
      KT(I)=1
   10 C(I)=CONSTR
      KZ(8)=NH
      KX(8)=1
      KT(8)=2
      C(8)=CONSTR
      RETURN
      END
```

```
      SUBROUTINE MAIN
C     TWO DIMENSIONAL STIFFENED SHEET
C
C     CDC VERSION    MAY 1967
C     PROGRAM NUMBER 2354
C
C     C.R. WITTKOW
C
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A  , AH     , AI     , ALFA1  , AV     , B      , C      ,
     1  DELX  , DELZ  , DX     , DZ     , FH     , FP     , FS     , FSM    ,
     2  FV    , GG    , GX     , H1     , H2     , H4     , H5     , I      ,
     3  I1    , I2    , I4     , I5     , IR     , J      , J1     , J2     ,
     4  J4    , J5    , JTA    , JTB    , JTC    , K      , KCL    , KI     ,
     5  KRW   , KSW1  , KSW2   , KT     , KX     , KZ     , L      , M      ,
     6  MS    , NCASE , NH1    , NL     , NLJ    , NV1    , PARTA  , PARTB  ,
     7  PX    , W     , R      , SF     , TH     , TV     , V      , X      ,
     8  XZ1   , XZ2   , XZ4    , XZ5    , ZX1    , ZX2    , ZX4    , ZX5
     9, NTEST1
      COMMON/BLOCK / IPRINT, NC, NH, NLC, NV, PZ, VR
      COMMON        AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA       ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA      ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99) ,EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99) ,FCY(20,99)
     5,FNET(20)   ,FSU(20,99) ,FT(20)     ,FTU(20,99) ,FVE        ,F07
     6,G(20,99)   ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP      ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT       ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG       ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI       ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI        ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TCI        ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
   10 JTA=1
      JTB=3
      JTC=4
      REWIND JTA
      REWIND JTB
      REWIND JTC
      CALL INPUTX
      MS=2*NV
      IF (IPRINT.EQ.0) GO TO 110
      WRITE (6,440)
      K=2
      KX(1)=NV1+6
      DO 40 I=1,NH
      K=K+KX(1)
      IF (K-56) 30,30,20
   20 WRITE (6,450)
```

```
      K=KX(1)
   30 WRITE (6,460) I
      WRITE (6,470) (J,DX(J),AH(I,J),E(2*J,NTEST1),T(2*J,NTEST1),ALFA1(2
     1*J),J=1,NV1)
   40 CONTINUE
      WRITE (6,480)
      K=2
      KX(1)=NH1+6
      DO 70 J=1,NV
      K=K+KX(1)
      IF (K-56) 60,60,50
   50 WRITE (6,450)
      K=KX(1)
   60 WRITE (6,490) J
      WRITE (6,470) (I,DZ(I),AV(I,J),E(2*J-1,NTEST1),T(2*J-1,NTEST1),ALF
     1A1(2*J-1),I=1,NH1)
   70 CONTINUE
      WRITE (6,500)
      K=2
      KX(1)=NV1+6
      THICK=1.
      DO 100 I=1,NH1
      K=K+KX(1)
      IF (K-56) 90,90,80
   80 WRITE (6,450)
      K=KX(1)
   90 I1=I+1
      WRITE (6,510) I,I1
      WRITE (6,520) (J,THICK,GG(J),J=1,NV1)
  100 CONTINUE
      WRITE (6,450)
  110 DO 140 J=1,NLC
      CALL INPUTY
      IF (IPRINT.EQ.0) GO TO 120
      WRITE (6,530) J
      WRITE (6,540) (KZ(I),KX(I),KT(I),C(I),I=1,NLJ)
  120 DO 130 I=1,NLJ
      KRW=2*(KX(I)-1)+KT(I)
      KCL=KZ(I)
      B(KRW,J,KCL)=C(I)
  130 CONTINUE
  140 CONTINUE
      CALL INPUTZ
      IF (IPRINT.EQ.0) GO TO 150
      WRITE (6,550)
      WRITE (6,540) (KZ(I),KX(I),KT(I),C(I),I=1,NC)
  150 DO 430 I=1,NH
      I4=I
      I5=I
      IF (I-1) 160,160,170
  160 I1=NH+1
      I2=I1
      KSW1=1
      GO TO 200
  170 I1=I-1
      I2=I1
      IF (I-NH) 180,190,190
  180 KSW1=2
```

```
      GO TO 200
  190 KSW1=3
  200 DO 360 J=1,NV
      TH(I,J)=TH(I,J)*ALFA1(2*J)
      TV(I,J)=TV(I,J)*ALFA1(2*J-1)
      AH(I,J)=AH(I,J)*E(2*J,NTEST1)
      AV(I,J)=AV(I,J)*E(2*J-1,NTEST1)
      GX(I,J)=GG(J)/4.0
      IF (I.EQ.NH) GX(I,J)=0.
C  THIS CALCULATION ASSUMES FIXED THICKNESS OF 1 INCH.
      IR=2*(J-1)+1
      J2=J
      J5=J
      IF (J-1) 210,210,220
  210 J1=NV+1
      J4=J1
      KSW2=1
      GO TO 250
  220 J1=J-1
      J4=J1
      IF (J-NV) 230,240,240
  230 KSW2=2
      GO TO 250
  240 KSW2=3
  250 ZX1=DZ(I1)/DX(J1)
      XZ1=1.0/ZX1
      ZX2=DZ(I2)/DX(J2)
      XZ2=1.0/ZX2
      ZX4=DZ(I4)/DX(J4)
      XZ4=1.0/ZX4
      ZX5=DZ(I5)/DX(J5)
      XZ5=1.0/ZX5
      H1=GX(I1,J1)
      H2=GX(I2,J2)
      H4=GX(I4,J4)
      H5=GX(I5,J5)
      A(IR,IR)=H1*ZX1+H2*ZX2+H4*ZX4+H5*ZX5+AV(I2,J2)/DZ(I2)+AV(I5,J5)/DZ
     1(I5)
      A(IR,IR+1)=H1-H2-H4+H5
      A(IR+1,IR)=A(IR,IR+1)
      A(IR+1,IR+1)=H1*XZ1+H2*XZ2+H4*XZ4+H5*XZ5+AH(I4,J4)/DX(J4)+AH(I5,J5
     1)/DX(J5)
      GO TO (260,260,270), KSW2
  260 A(IR,IR+2)=-H2*ZX2-H5*ZX5
      A(IR,IR+3)=-H2+H5
      A(IR+1,IR+2)=H2-H5
      A(IR+1,IR+3)=H2*XZ2+H5*XZ5-AH(I5,J5)/DX(J5)
  270 GO TO (280,280,320), KSW1
  280 GO TO (300,290,290), KSW2
  290 R(IR,IR-2)=-H4*ZX4
      R(IR,IR-1)=H4
      R(IR+1,IR-2)=H4
      R(IR+1,IR-1)=-H4*XZ4
      GO TO (300,300,310), KSW2
  300 R(IR,IR+2)=-H5*ZX5
      R(IR,IR+3)=-H5
      R(IR+1,IR+2)=-H5
      R(IR+1,IR+3)=-H5*XZ5
```

```
310 R(IR,IR)=H4*ZX4+H5*ZX5-AV(I5,J5)/DZ(I5)
    R(IR,IR+1)=H4-H5
    R(IR+1,IR)=-H4+H5
    R(IR+1,IR+1)=-H4*XZ4-H5*XZ5
320 GO TO (330,330,340), KSW2
330 A(IR+2,IR)=A(IR,IR+2)
    A(IR+2,IR+1)=A(IR+1,IR+2)
    A(IR+3,IR)=A(IR,IR+3)
    A(IR+3,IR+1)=A(IR+1,IR+3)
340 Q=AV(I2,J2)*TV(I2,J2)-AV(I5,J5)*TV(I5,J5)
    X=AH(I4,J4)*TH(I4,J4)-AH(I5,J5)*TH(I5,J5)
    DO 350 K=1,NLC
    B(IR,K,I)=B(IR,K,I)+Q
    B(IR+1,K,I)=B(IR+1,K,I)+X
350 CONTINUE
360 CONTINUE
    GO TO (370,370,390), KSW1
370 WRITE (JTB) R
    DO 380 K=1,MS
    DO 380 J=1,MS
    R(K,J)=0.0
380 CONTINUE
390 DO 410 J=1,NC
    IF (KZ(J)-I) 410,400,410
400 KRW=2*(KX(J)-1)+KT(J)
    A(KRW,KRW)=A(KRW,KRW)+C(J)
410 CONTINUE
    WRITE (JTA) A
    DO 420 K=1,MS
    DO 420 J=1,MS
420 A(K,J)=0.0
430 CONTINUE
    REWIND JTA
    REWIND JTB
    RETURN
C
440 FORMAT (1H1,42X,35HPROPERTIES OF HORIZONTAL STIFFENERS//)
450 FORMAT (1H1)
460 FORMAT (//47X,24HHORIZONTAL STIFFENER NO.I3//21X,7HSEGMENT,4X,6HLE
   1NGTH,10X,4HAREA,10X,7HMODULUS,6X,11HTEMPERATURE,3X,14HTHERMAL COEF
   2F.//)
470 FORMAT (I25,5E15.5)
480 FORMAT (1H1,43X,33HPROPERTIES OF VERTICAL STIFFENERS//)
490 FORMAT (//48X,22HVERTICAL STIFFENER NO.I3//21X,7HSEGMENT,4X,6HLENG
   1TH,10X,4HAREA,10X,7HMODULUS,6X,11HTEMPERATURE,3X,14HTHERMAL COEFF.
   2//)
500 FORMAT (1H1,49X,20HPROPERTIES OF PANELS//)
510 FORMAT (//35X,40HPANELS BETWEEN HORIZONTAL STIFFENERS NO.I3,4H AND
   1I3//42X,5HPANEL,4X,9HTHICKNESS,4X,13HSHEAR MODULUS//)
520 FORMAT (42X,I3,2E15.5)
530 FORMAT (1H0,45X,24HLOADING CONDITION NUMBERI3//46X,1HZ,6X,1HX,5X,4
   1HTYPE,6X,4HLOAD//)
540 FORMAT (40X,3I7,E15.5)
550 FORMAT (1H1,54X,11HCONSTRAINTS//46X,1HZ,6X,1HX,5X,4HTYPE,3X,10HCON
   1STRAINT//)
    END
```

```
      SUBROUTINE MATRX4
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A , AH    , AI    , ALFA1 , AV    , B     , C     ,
     1  DELX  , DELZ  , DX    , DZ    , FH    , FP    , FS    , FSM   ,
     2  FV    , GG    , GX    , H1    , H2    , H4    , H5    , I     ,
     3  I1    , I2    , I4    , I5    , IR    , J     , J1    , J2    ,
     4  J4    , J5    , JTA   , JTB   , JTC   , K     , KCL   , KI    ,
     5  KRW   , KSW1  , KSW2  , KT    , KX    , KZ    , L     , M     ,
     6  MS    , NCASE , NH1   , NL    , NLJ   , NV1   , PARTA , PARTB ,
     7  PX    , Q     , R     , SF    , TH    , TV    , V     , X     ,
     8  XZ1   , XZ2   , XZ4   , XZ5   , ZX1   , ZX2   , ZX4   , ZX5
     9, NTEST1
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON        AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA        ,AOFE        ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA        ,BE          ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA       ,DIAM        ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99),EDOT(20,99),EMIS(9)       ,FACC       ,FCU(20,99),FCY(20,99)
     5,FNET(20)    ,FSU(20,99),FT(20)       ,FTU(20,99),FVE         ,F07
     6,G(20,99)    ,HH          ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP       ,ITURB       ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MP(9,18)
     8,NCOLM       ,NCR         ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT        ,NMIN        ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG        ,NTRAJ       ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)    ,QCONL(9)    ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI        ,RYE         ,RYI        ,SL         ,SLS        ,STAAT
     $,STI         ,STOOP       ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1         ,TEMP(9,9)   ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)   ,UF          ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS       ,XSTG(99)    ,XX(20)     ,Y(9)       ,ZZ(20)
      NDIM=40
      SF=0.0
      READ (JTA) A
      WRITE (JTC) A
      DO 70 K=2,NH
      DO 20 I=1,MS
      DO 10 J=1,MS
      AI(I,J)=0.0
      AI(I,I)=1.0
   10 CONTINUE
   20 CONTINUE
      CALL SIMEQ(NDIM,MS,MS,A,AI,SF,V,M)
      GO TO (30,160,170), M
   30 READ (JTB) R
      DO 40 I=1,MS
      DO 40 J=1,MS
      AI(I,J)=0.0
      DO 40 IJ=1,MS
      AI(I,J)=AI(I,J)-R(IJ,I)*A(IJ,J)
   40 CONTINUE
      READ (JTA) A
      DO 50 I=1,MS
      DO 50 J=1,MS
```

```
      DO 50 IJ=1,MS
      A(I,J)=A(I,J)+AI(I,IJ)*R(IJ,J)
   50 CONTINUE
      WRITE (JTC) A
      DO 60 I=1,MS
      DO 60 J=1,NLC
      DO 60 IJ=1,MS
      B(I,J,K)=B(I,J,K)+AI(I,IJ)*B(IJ,J,K-1)
   60 CONTINUE
   70 CONTINUE
      BACKSPACE JTC
      READ (JTC) A
      REWIND JTA
      DO 80 I=1,MS
      DO 80 J=1,NLC
      AI(I,J)=B(I,J,NH)
   80 CONTINUE
      CALL SIMEQ(NDIM,MS,NLC,A,AI,SF,V,M)
      GO TO (90,160,170), M
   90 DO 100 I=1,MS
      DO 100 J=1,NLC
      B(I,J,NH)=A(I,J)
  100 CONTINUE
      DO 150 KI=2,NH
      K=NH+1-KI
      DO 110 I=1,MS
      DO 110 J=1,NLC
      DO 110 IJ=1,MS
      B(I,J,K)=B(I,J,K)-R(I,IJ)*A(IJ,J)
  110 CONTINUE
      BACKSPACE JTB
      BACKSPACE JTB
      READ (JTB) R
      BACKSPACE JTC
      BACKSPACE JTC
      READ (JTC) A
      DO 120 I=1,MS
      DO 120 J=1,NLC
      AI(I,J)=B(I,J,K)
  120 CONTINUE
      CALL SIMEQ(NDIM,MS,NLC,A,AI,SF,V,M)
      GO TO (130,160,170), M
  130 DO 140 I=1,MS
      DO 140 J=1,NLC
      B(I,J,K)=A(I,J)
  140 CONTINUE
  150 CONTINUE
      REWIND JTB
      REWIND JTC
      CALL SECOND(CHRON)
      WRITE (6,180) CHRON
      CALL STRES2
      RETURN
  160 WRITE (6,190)
      STOP
  170 WRITE (6,200)
      STOP
C
```

```
180 FORMAT (1H1,* NOW ENDING OVERLAY(2,0), ALIAS PROGRAM MATRX4, JUST MT4 117
   1PRIOR TO ENTERING SUBROUTINE STRESS.  CLOCK READS *,F7.3,* SECONDSMT4 118
   2,*/)                                                              MT4 119
190 FORMAT (///17H OVERFLOW OCCURED)                                  MT4 120
200 FORMAT (///19H MATRIX IS SINGULAR)                                MT4 121
    END                                                               MT4 122-
```

```
      SUBROUTINE MAX(A,IMAX,JMAX,AMAX,IFLAG)
C     IFLAG = 1 FOR SIGN AS IS.  IFLAG = 2 FOR ABSOLUTE VALUE OF A(I,J).
      DIMENSION A(40,8)
      AMAX=0.
      DO 30 I=1,IMAX
      DO 30 J=1,JMAX
      GO TO (10,20) IFLAG
   10 IF (A(I,J).GT.AMAX) AMAX=A(I,J)
      GO TO 30
   20 IF (ABS(A(I,J)).GT.AMAX) AMAX=ABS(A(I,J))
   30 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE MIN(A,IMAX,JMAX,AMIN,IFLAG)
C     IFLAG = 1 FOR SIGN AS IS.  IFLAG = 2 FOR ABSOLUTE VALUE OF A(I,J).
      DIMENSION A(40,8)
      AMIN=0.
      DO 30 I=1,IMAX
      DO 30 J=1,JMAX
      GO TO (10,20) IFLAG
   10 IF (A(I,J).LT.AMIN) AMIN=A(I,J)
      GO TO 30
   20 IF (ABS(A(I,J)).LT.AMIN) AMIN=ABS(A(I,J))
   30 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SIMEQ(IDIM,NN,MM,A,B,DET,IND,NOGO)
C
C
CSIMEQ           SOLVES THE EQUATION AX=B WHERE A,X, AND B ARE MATRICES
C                      WHERE
C       IDIM     IS A FIXED POINT CONSTANT OR VARIABLE WHOSE VALUE
C                MUST BE EQUAL TO THE MAXIMUM VALUE THAT MAY EVER BE
C                ASSUMED BY THE SUBSCRIPT I OF THE MATRIX A(I,J). THIS
C                VALUE IS IDENTICAL WITH THAT USED IN THE DIMENSION
C                STATEMENTS WHEN SETTING THE UPPER LIMIT OF THE
C                SUBSCRIPT.
C       NN       IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE
C                MUST EQUAL THE NUMBER OF ROWS IN THE MATRIX A.
C       MM       IS A FIXED POINT VARIABLE OR CONSTANT WHOSE VALUE
C                MUST EQUAL THE NUMBER OF COLUMNS IN THE MATRIX B.
C       A        IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO
C                DESIGNATE THE ELEMENTS OF MATRIX A.
C       B        IS THE SOURCE PROGRAM FLOATING POINT VARIABLE USED TO
C                DESIGNATE THE ELEMENTS OF MATRIX B.
C       DET      MUST BE A FLOATING POINT VARIABLE WHOSE VALUE SERVES
C                AS A SCALE FACTOR BY WHICH SIMEQ MULTIPLIES THE VALUE
C                OF THE DETERMINANT OF A. AFTER THE EXECUTION OF THIS
C                SUBROUTINE, DET CONTAINS THE SCALED VERSION OF THE
C                DETERMINANT.
C       IND      MUST BE A FIXED OR FLOATING POINT VARIABLE DESIGNATING
C                A ONE-DIMENSIONAL ERASABLE ARRAY OF LENGTH AT LEAST
C                EQUAL TO THE NUMBER OF ROWS IN MATRIX A. IT IS IN THIS
C                AREA SIMEQ KEEPS A RECORD OF THE COLUMN PERMUTATIONS.
C       NOGO     IS A FIXED POINT VARIABLE WHICH WILL BE ASSIGNED THE
C                FIXED POINT CONSTANTS.
C                    1 IF THE SOLUTION WAS SUCCESSFUL.
C                    3 IF THE MATRIX A WAS SINGULAR.
C
C                            DIMENSIONS
C       A        IDIM X IDIM     IF MM IS LESS THAN OR EQUAL TO IDIM
C                IDIM X MM       IF MM IS GREATER THAN IDIM
C       B        IDIM X MM
C       IND      IDIM
C
C                            NOTE
C                FOR MATRICES THE ROW DIMENSION MUST BE THE SAME AS
C                THAT GIVEN ABOVE. THE COLUMN DIMENSION MUST AT LEAST
C                BE THAT GIVEN ABOVE.
C                FOR THE VECTOR THE DIMENSION MUST AT LEAST BE THAT
C                GIVEN ABOVE
C
C                EXECUTION OF THIS ROUTINE DESTROYS THE ORIGINAL A AND
C                B MATRICES
C
C                AFTER A SUCCESSFUL EXIT FROM THIS SUBROUTINE, THE
C                ANSWERS OR THE X MATRIX REPLACE THE A MATRIX.
C                THIS REPLACEMENT IS DONE ACCORDING TO THE SCHEME.
C
C                            A(I,J) IS REPLACED BY X(I,J) .
C
C
      DIMENSION A(IDIM,1),B(IDIM,1),IND(1)
C        SET INITIAL CONSTANTS
```

```
      N=NN
      M=MM
      NOGO=1
C        SPECIAL CONSIDERATION WHEN THE ORDER OF MATRIX A IS 1.
      IF (N.NE.1) GO TO 20
      IF (A.EQ.0.) GO TO 180
      HOLD=A
      DO 10 I=1,M
   10 A(1,I)=B(1,I)/HOLD
      DET=DET*HOLD
      RETURN
   20 NM1=N-1
      NP1=N+1
C        INITIALIZE DETERMINANT
      DETM=DET
C        INITIALIZE COLUMN INDICATORS
      DO 30 I=1,N
   30 IND(I)=I
C        BEGIN TRIANGULARIZATION TO GET UPPER TRIANGLE
      DO 140 K=1,NM1
      KP1=K+1
      KR=K
      KC=K
C        SEARCH FOR PIVOTAL ELEMENT
      BIGA=ABS(A(K,K))
      DO 50 I=K,N
      DO 40 J=K,N
      IF (BIGA.GE.ABS(A(I,J))) GO TO 40
      BIGA=ABS(A(I,J))
      KR=I
      KC=J
   40 CONTINUE
   50 CONTINUE
C        TEST FOR SINGULAR MATRIX
      IF (BIGA.EQ.0.) GO TO 180
C        UPDATE DETERMINANT
      DETM=DETM*A(KR,KC)
C        INTERCHANGE ROWS
      IF (KR.EQ.K) GO TO 80
      DO 60 I=K,N
      HOLD=A(K,I)
      A(K,I)=A(KR,I)
   60 A(KR,I)=HOLD
C        INTERCHANGE ELEMENTS OF RIGHT HAND SIDES
      DO 70 L=1,M
      HOLD=B(K,L)
      B(K,L)=B(KR,L)
   70 B(KR,L)=HOLD
C        CHANGE SIGN OF DETERMINANT DUE TO ROW INTERCHANGE
      DETM=-DETM
C        INTERCHANGE COLUMNS
   80 IF (KC.EQ.K) GO TO 100
      DO 90 J=1,N
      HOLD=A(J,K)
      A(J,K)=A(J,KC)
   90 A(J,KC)=HOLD
C        INTERCHANGE COLUMN INDICATORS
      I=IND(K)
```

```
      IND(K)=IND(KC)
      IND(KC)=I
C        CHANGE SIGN OF DETERMINANT DUE TO COLUMN INTERCHANGE
      DETM=-DETM
C        DIVIDE REDUCED EQUATION-ON, BY LEADING ELEMENT
  100 DO 110 I=KP1,N
  110 A(K,I)=A(K,I)/A(K,K)
      DO 120 L=1,M
  120 B(K,L)=B(K,L)/A(K,K)
C        REDUCE MATRIX AND RIGHT HAND SIDES
      DO 140 I=KP1,N
      DO 130 J=KP1,N
  130 A(I,J)=A(I,J)-A(I,K)*A(K,J)
      DO 140 L=1,M
  140 B(I,L)=B(I,L)-A(I,K)*B(K,L)
C        FINAL TEST FOR SINGULAR MATRIX
      IF (A(N,N).EQ.0.) GO TO 180
C        COMPUTE FINAL DETERMINANT
      DET=DETM*A(N,N)
C        BACK SUBSTITUE TO OBTAIN SOLUTION VECTORS
      DO 160 L=1,M
      B(N,L)=B(N,L)/A(N,N)
      DO 160 I=1,NM1
      HOLD=0.
      J=N-I
      DO 150 KC=1,I
      K=NP1-KC
  150 HOLD=HOLD+A(J,K)*B(K,L)
  160 B(J,L)=B(J,L)-HOLD
C        REARRANGE SOLUTION VECTORS TO ORIGINAL ORDER
      DO 170 I=1,N
      J=IND(I)
      DO 170 L=1,M
  170 A(J,L)=B(I,L)
      RETURN
C        SINGULAR MATRIX - REDUNDANT SET OF EQUATIONS
  180 NOGO=3
      DET=0.
      RETURN
      END
```

```
      SUBROUTINE STRES2
      DIMENSION ALFA1(20),C(50),DX(21),DZ(41),GG(10),KT(50),KX(50),KZ(50
     1),NL(5),V(50)
      DIMENSION A(40,40),AH(41,21),AI(40,20),AV(41,21),FH(40,10),FP(40,1
     10),FS(40,10),FSM(40,10),FV(40,10),GX(41,21),R(40,40),TH(41,21),TV(
     241,21)
      DIMENSION B(40,1,40)
      COMMON/BLOCKA/A  , AH     , AI     , ALFA1 , AV     , B      , C      ,
     1  DELX   , DELZ   , DX     , DZ     , FH     , FP     , FS     , FSM    ,
     2  FV     , GG     , GX     , H1     , H2     , H4     , H5     , I      ,
     3  I1     , I2     , I4     , I5     , IR     , J      , J1     , J2     ,
     4  J4     , J5     , JTA    , JTB    , JTC    , K      , KCL    , KI     ,
     5  KRW    , KSW1   , KSW2   , KT     , KX     , KZ     , L      , M      ,
     6  MS     , NCASE  , NH1    , NL     , NLJ    , NV1    , PARTA  , PARTB  ,
     7  PX     , Q      , R      , SF     , TH     , TV     , V      , X      ,
     8  XZ1    , XZ2    , XZ4    , XZ5    , ZX1    , ZX2    , ZX4    , ZX5
     9, NTEST1
      COMMON/BLOCKB/ IPRINT, NC, NH, NLC, NV, PZ, VB
      COMMON         AL          ,ALPHA(99)  ,ALT(99)    ,AME        ,AMI
     1,AOFA       ,AOFE       ,AROD       ,AS         ,AX(9,11,9),AY(9,11,9)
     2,BATA       ,BE         ,BETA(99)   ,BF         ,BFL        ,BL
     3,DELTA      ,DIAM       ,DIST(9)    ,DST        ,E(20,99)   ,EALL
     4,EAT(20,99) ,EDOT(20,99),EMIS(9)    ,FACC       ,FCU(20,99) ,FCY(20,99)
     5,FNET(20)   ,FSU(20,99) ,FT(20)     ,FTU(20,99) ,FVE        ,F07
     6,G(20,99)   ,HH         ,HINS       ,HINSD(99)  ,ICONF      ,ILINKO
     7,IQINP      ,ITURB      ,IWALT      ,MAT(9,9)   ,MPT(9,9)   ,MR(9,18)
     8,NCOLM      ,NCR        ,NCRC       ,NF         ,NI(18)     ,NINS
     9,NMAT       ,NMIN       ,NPRT       ,NPSG       ,NR(18)     ,NRSG
     $,NSEG       ,NTRAJ      ,N33        ,PE         ,PHI        ,PI
     $,PINP(99)   ,QCONL(9)   ,QCONT(9)   ,QINP(99)   ,QNET(9)    ,RHO(9)
     $,RHOI       ,RYE        ,RYI        ,SL         ,SLS        ,STAAT
     $,STI        ,STOOP      ,T(20,99)   ,TALLW(9)   ,TAMP(9,9)  ,TAU
     $,TC1        ,TEMP(9,9)  ,THETA      ,TI         ,TIME(99)   ,TINS
     $,TINSD(99)  ,UF         ,VFACT(9,18),VI         ,VINF(99)   ,WROTE
     $,XEMIS      ,XSTG(99)   ,XX(20)     ,Y(9)       ,ZZ(20)
      KX(1)=NV+8
      DO 230 L=1,NLC
      K=1
      DO 40 I=1,NH
      I1=I+1
      DO 20 J=1,NV1
      IR=2*(J-1)+1
      DELX=B(IR+3,L,I)-B(IR+1,L,I)
      FH(I,J)=(DELX/DX(J)-TH(I,J))*E(2*J,NTEST1)
      IF (I-NH) 10,20,20
   10 PARTA=B(IR+1,L,I+1)+B(IR+3,L,I+1)-B(IR+1,L,I)-B(IR+3,L,I)
      PARTB=B(IR+2,L,I+1)+B(IR+2,L,I)-B(IR,L,I+1)-B(IR,L,I)
      FS(I,J)=GX(I,J)*(PARTA/DZ(I)+PARTB/DX(J))*2.
      DELZ=B(IR,L,I+1)-B(IR,L,I)
      FV(I,J)=(DELZ/DZ(I)-TV(I,J))*E(2*J-1,NTEST1)
   20 CONTINUE
      IR=2*NV1+1
      IF (I-NH) 30,50,50
   30 DELZ=B(IR,L,I+1)-B(IR,L,I)
      FV(I,NV+1)=(DELZ/DZ(I)-TV(I,NV))*E(2*NV-1,NTEST1)
C     WE NOW GENERATE AN ARTIFICIAL VALUE AND PRINT IT OUT IN THE COLUMN
C        PRECEDING THE TRUE FINAL VALUE.
   40 FV(I,NV)=FV(I,NV+1)/E(2*NV-1,NTEST1)*E(2*NV1-1,NTEST1)
```

```
 50 FSM(1,1)=FH(1,2)/2.
    DO 60 I=2,NH
 60 FSM(I,1)=SQRT(FH(I,2)**2+FS(I-1,2)**2)
    DO 70 J=2,6
 70 FSM(1,J)=(FV(1,J+1)-FH(1,J))/2.
    DO 80 I=2,NH
    DO 80 J=2,6
 80 FSM(I,J)=SQRT((FV(I-1,J+1)-FH(I,J))**2/4.+FS(I-1,J)**2)
    FP(1,1)=FH(1,2)
    DO 90 I=2,NH
    FP(I,1)=FH(I,2)/2.+FSM(I,1)
    IF (FH(I,2).LT.0.) FP(I,1)=FH(I,2)/2.-FSM(I,1)
 90 CONTINUE
    DO 100 J=2,NV1
    FP(1,J)=FV(1,J+1)
    IF (ABS(FH(1,J)).GT.ABS(FV(1,J+1))) FP(1,J)=FH(1,J)
100 CONTINUE
    DO 130 I=2,NH
    DO 130 J=2,NV1
    FPS=.5*(FV(I,J+2)+FH(I,J+2))+FSM(I,J)
    FPD=FPS-2.*FSM(I,J)
    IF (ABS(FPS)-ABS(FPD)) 120,110,110
110 FP(I,J)=(FV(I-1,J+1)+FH(I,J))/2.+FSM(I,J)
    GO TO 130
120 FP(I,J)=(FV(I-1,J+1)+FH(I,J))/2.-FSM(I,J)
130 CONTINUE
    WRITE (6,240)
    WRITE (6,250)
    WRITE (6,260)
    WRITE (6,270)
    WRITE (6,280)
    WRITE (6,290)
    DO 140 I=1,NH1
    WRITE (6,300) I,(FV(I,J),J=1,8)
140 CONTINUE
    WRITE (6,310)
    WRITE (6,320)
    WRITE (6,330)
    WRITE (6,340)
    WRITE (6,350)
    DO 150 I=1,NH
    WRITE (6,360) I,(FH(I,J),J=1,6)
150 CONTINUE
    WRITE (6,370)
    WRITE (6,380)
    WRITE (6,390)
    WRITE (6,340)
    WRITE (6,350)
    DO 160 I=1,NH1
    WRITE (6,360) I,(FS(I,J),J=1,6)
160 CONTINUE
    WRITE (6,400)
    WRITE (6,410)
    WRITE (6,420)
    WRITE (6,430)
    DO 170 I=1,NH
    WRITE (6,360) I,(FSM(I,J),J=1,NV1)
170 CONTINUE
```

```
      WRITE (6,440)
      WRITE (6,410)
      WRITE (6,420)
      WRITE (6,430)
      DO 180 I=1,NH
      WRITE (6,360) I,(FP(I,J),J=1,NV1)
  180 CONTINUE
      WRITE (6,450)
      WRITE (6,460)
      WRITE (6,470)
      WRITE (6,480)
      DO 190 I=1,NH
      WRITE (6,490) I,(B(J,1,I),J=2,14,2)
  190 CONTINUE
      WRITE (6,500)
      WRITE (6,460)
      WRITE (6,470)
      WRITE (6,480)
      DO 200 I=1,NH
      WRITE (6,490) I,(B(J,1,I),J=1,13,2)
  200 CONTINUE
C     FIND MAX/MIN STRESS VALUES IN FACE SHEETS.
      CALL MAX(FV,NH1,2,FVFT,1)
      IF (FVFT.LT.0.) FVFT=0.
      CALL MIN(FV,NH1,2,FVFC,1)
      IF (FVFC.GT.0.) FVFC=0.
C     FIND MAX/MIN STRESSES IN COATING.
      FVCT=0.
      DO 210 I=1,NH1
      IF (FV(I,8).GT.FVCT) FVCT=FV(I,8)
  210 CONTINUE
      IF (FVCT.LT.0.) FVCT=0.
      FVCC=0.
      DO 220 I=1,NH1
      IF (FV(I,8).LT.FVCC) FVCC=FV(I,8)
  220 CONTINUE
      IF (FVCC.GT.0.) FVCC=0.
C     FIND MAX SHEAR STRESS IN INSULATION.
      CALL MAX(FSM,NH,6,FSIM,2)
C     FIND MAX/MIN PRINCIPAL STRESSES IN INSULATION.
      CALL MAX(FP,NH,6,FPIT,1)
      IF (FPIT.LT.0.) FPIT=0.
      CALL MIN(FP,NH,6,FPIC,1)
      IF (FPIC.GT.0.) FPIC=0.
C     FIND MAX SHEAR STRESS IN CORE.
      CALL MAX(FS,NH1,1,FSCM,2)
C     FIND MAX SHEAR STRESS IN BOND.
      CALL MAX(FSM,NH,1,FSBM,2)
C     FIND MAX PRINCIPAL STRESS IN BOND
      CALL MAX(FP,NH,1,FPBT,1)
      ZMAX=-B(2,1,1)
      WRITE (6,510)
      WRITE (6,520)
      WRITE (6,530) FVFT,FVFC,FVCT,FVCC,FSIM,FPIT,FPIC,FSCM,FSBM,FPBT,ZM
     1AX
  230 CONTINUE
      RETURN
C
```

```
240 FORMAT (1H1,45X,*AXIAL  STRESSES  IN  LONGITUDINAL  BARS*///)
250 FORMAT (15X,*LONGITUDINAL  BAR  NUMBER*,10H * * * * *,//)
260 FORMAT (3X,*SEGMENT*,7X,*1*,14X,*2*,14X,*3*,14X,*4*,14X,*5*,14X,*6
   1*,14X*7*,14X,*8*)
270 FORMAT (3X,*NUMBER*)
280 FORMAT (13X,*INNER FACE*,5X,*OUTER FACE*,7X,*R.S.I.*,9X,*R.S.I.*,9
   1X,*R.S.I.*,9X,*R.S.I.*,9X,*R.S.I.*,8X,*COATING*)
290 FORMAT (15X,*SHEET*,10X,*SHEET*,9X,*AT BOND*,52X,*AT COATING*,///)
300 FORMAT (5X,I2,2X,8E15.5)
310 FORMAT (1H1,46X,*NORMAL  STRESSES IN  TRANSVERSE  BARS*///)
320 FORMAT (26X,*BARS  BETWEEN  LONGITUDINAL  STIFFENERS*,10H * * * *
   1*,//)
330 FORMAT (16X,*SEGMENT*,6X,*1 - 2*,10X,*2 - 3*,10X,*3 - 4*,10X,*4 -
   15*,10X,*5 - 6*,10X,*6 - 7*)
340 FORMAT (16X,*NUMBER*)
350 FORMAT (30X,*CORE*,11X,*BOND*,10X,*R.S.I.*,9X,*R.S.I.*,9X,*R.S.I.*
   1,9X,*R.S.I.*///)
360 FORMAT (18X,I2,3X,6E15.5)
370 FORMAT (1H1,53X,*SHEAR  STRESS  IN  PANELS*///)
380 FORMAT (26X,*PANELS  BETWEEN  LONGITUDINAL  BARS*,10H * * * * *,//
   1)
390 FORMAT (16X,*PANEL*,8X,*1 - 2*,10X,*2 - 3*,10X,*3 - 4*,10X,*4 - 5*
   1,10X,*5 - 6*,10X,*6 - 7*)
400 FORMAT (1H1,39X,*MAXIMUM  SHEAR  STRESSES  IN  BOND  AND  INSULATI
   1ON*///)
410 FORMAT (44X,*LONGITUDINAL  BAR  NUMBER*,10H * * * * *)
420 FORMAT (14X,*TRANSVERSE*)
430 FORMAT (13X,*BAR  NUMBER*,6X,*BOND*,12X,*3*,14X,*4*,14X,*5*,14X,*6
   1*,14X,*7*///)
440 FORMAT (1H1,39X,*MAXIMUM PRINCIPAL STRESSES IN BOND AND INSULATION
   1*///)
450 FORMAT (1H1,54X,*VERTICAL DEFLECTIONS*///)
460 FORMAT (21X,*LONGITUDINAL  BAR  NUMBER*,10H * * * * *)
470 FORMAT (8X,*VERTICAL*)
480 FORMAT (7X,*BAR NUMBER*,7X,*1*,14X,*2*,14X,*3*,14X,*4*,14X,*5*,14X
   1,*6*,14X,*7*,//)
490 FORMAT (11X,I2,3X,7E15.5)
500 FORMAT (1H1,52X,*LONGITUDINAL  DEFLECTIONS*///)
510 FORMAT (1H1,20X,*EVALUATION OF MAXIMUM (AND MINIMUM) STRESSES*////
   1)
520 FORMAT (6X,*FVFT        FVFC        FVCT        FVCC        FSIM
   1 FPIT        FPIC        FSCM        FSBM        FPBT        ZMAX *///)
530 FORMAT (1X,11E11.2)
    END
```

```
      OVERLAY (P5490,2,0,C000000)
      PROGRAM FATIG
C
C          A C O U S T I C   F A T I G U E   A N A L Y S I S
C
C
C       DESCRIPTION OF INPUT PARAMETERS
C
C                 AE       NOZZLE EXIT AREA
C                 AI       MOMENT OF INERTIA
C                 AW       PANEL LENGTH
C                 AMACH    LOCAL MACH NUMBER
C                 BW       PANEL WIDTH
C                 C        COEFFICIENTS OF A LEAST SQUARES, 3RD ORDER
C                          CURVE FIT OF ALLOWABLE S-N DATA
C                 D        NOZZLE DIAMETER
C                 DT       DURATION OF NOISE IN SECONDS
C                 DVEH     VEHICLE DIAMETER
C                 EP       PANELS YOUNGS MODULUS
C                 HPAN     THICKNESS
C                 HC       THICKNESS IN HONEYCOMB PANEL (MIDDLE)
C                 HF       THICKNESS IN HONEYCOMB PANEL (OUTSIDE)
C                 IPAD=0      VEHICLE IS IN FLIGHT
C                 IPAD=1      VEHICLE IS IN THE PAD
C                 KFLEX=0     RIGID AND SYMMETRICAL SUPPORTING STRUCTURE
C                 KFLEX=1     FLEXIBLE AND/OR UNSYMMETRICAL SUPPORTING
C                             STRUCTURE
C                 NENG     NUMBER OF ENGINES
C                 NPAN  =1    RECTANGULAR ISOTROPIC PLATE
C                 NPAN  =2    RECTANGULAR HONEYCOMB SANDWICH PANEL
C                 NPAN  =3    INTEGRALLY STIFFENED PANEL
C                 QL       LOCAL DYNAMIC PRESSURE
C                 REY      REYNOLDS NUMBER
C                 RHO      MATERIAL DENSITY
C                 TJ       JET THRUST
C                 TT       TOTAL THRUST IN LB
C                 VJ       JET VELOCITY
C                 VS       LOCAL SPEED OF SOUND
C                 VU       LOCAL VE LOCITY
C                 VV       VEHICLE VELOCITY
C                 WEJ      WEIGHT FLOW OF JET ENGINE
C                 WER      WEIGHT FLOW OF ROCKET ENGINE
C                 VU       LOCAL VELOCITY
C                 XI       DISTANCE BETWEEN BOOSTER ENGINE AND POINT OF
C                          INTEREST
C                 XJ       DISTANCE TO EXIT PLANE OF JET ENGINE
C                 XL       BOUNDARY LAYER LENGTH
C                 YP       Y DISTANCE IN A NEAR FIELD LESS THAN 200 FT.
      COMMON/APP1/NOAPP
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON /MOMENT/ AII,PMI
      COMMON /SONIC1/ AE     ,AI     ,AIY    ,AMACH  ,AMF    ,AW     ,
     1BW     ,C(4)   ,D      ,DREF   ,DT(4)  ,DVEH   ,EP,EPP ,HC     ,
     2HF     ,HPAN   ,IPAD   ,IPF(4) ,IPFI   ,KFLEX  ,NENG   ,NPAN   ,
     3QF     ,QL     ,REY    ,RHOP   ,TIMEF  ,TJ     ,TT     ,VJ     ,
     4VS     ,VU     ,VV     ,WEJ    ,WER    ,XI     ,XJ     ,XL     ,
     5YCL    ,YP
      DIMENSION ANL(4),ANRMS(4),ANML(4),SCR(4),PF(4),CY(4),SLD(4),
```

```
     1ANCR(4)
      DIMENSION ELW(11), PHI(11), TBBA(6), TBK1(6), TBK2(6)
C
      DATA AMU/.3/
      DATA CCC/.02/
      DATA CG/32.174/
      DATA NDIM/6/
      DATA PI/3.14159/
      DATA ELW /
     1 0.0,  1.0,  2.0,  3.0,  4.0,  5.0,  6.0,  7.0,  8.0,  9.0, 10.0 /
      DATA PHI /
     1.420, .370, .294, .220, .170, .144, .122, .105, .092, .083, .075 /
      DATA TBBA  /
     1    1.,    1.5,    2.0,    2.5,    3.0,    1.E30/
      DATA TBK1  /
     1    27.89, 20.63, 18.45, 17.61, 17.08, 16.12/
      DATA TBK2  /
     1    19.74, 14.26, 12.34, 11.45, 10.97,  9.87/
C
C
   10 WRITE (6,390)
C
C                 COMPUTE FUNDAMENTAL FREQUENCIES
      IF (NSECT.LT.7) GO TO 20
      NPAN=2
      IF (NSECT.EQ.8) GO TO 30
      HPAN=2*TS+TC
      HC=TC
      GO TO 30
   20 IF (NSECT.EQ.1.OR.NSECT.EQ.2.OR.NSECT.EQ.3.OR.NSECT.EQ.4) NPAN=3
      IF (NSECT.EQ.5.OR.NSECT.EQ.6) NPAN=4
      HPAN=TS
      IF (TS.EQ.0.) HPAN=TC
   30 HPAN2=HPAN*HPAN
      HPAN3=HPAN2*HPAN
      AWW=AW
      BWW=BW
      IF (AI.EQ.0.0) AI=PMI
      WRITE (6,410) AI
      IF (AW.LE.BW) GO TO 40
      TEM1=AW
      AW=BW
      BW=TEM1
      TEM1=AI
      AI=AIY
      AIY=TEM1
   40 AL2=AW*AW
      AL4=AL2*AL2
      AMASS=RHOP*HPAN/CG
      BA=BW/AW
C
      FSTAR=1.
      IF (KFLEX.NE.0) FSTAR=.25
      GO TO (50,60,80,90), NPAN
C                 RECTANGULAR ISOTROPIC PLATE
   50 DR=EP*HPAN3/(12.*(1.-AMU**2))
      AK=TABLE(BA,TBBA,TBK1,NDIM)
      IF (AK.EQ.0) GO TO 360
```

```
      GO TO 70
C                    RECTANGULAR HONEYCOMB SANDWICH PANEL
   60 HF=.5*(HPAN-HC)
      DR=EP*HPAN*HF*HC/1.82
      AK=TABLE(BA,TBBA,TBK2,NDIM)
      IF (AK.EQ.0) GO TO 360
   70 FREQ=AK/(2.*PI*AL2*SQRT(AMASS/DR))*FSTAR
      GO TO 100
C                    INTEGRALLY STIFFENED PANEL
   80 DR=EP*HPAN3/(12.*(1.-AMU**2))
      DX=DR+EP*AI/(BW*12.)
      DY=DR
      AKM=PI/AW
      AKN=PI/BW
      AKM2=AKM*AKM
      AKN2=AKN*AKN
      AKTAU=(SQRT(DX/12.)*AKM2+SQRT(DY/12.)*AKN2)**2
      AKI=(DY/12.)*(AKM2+AKN2)**2
      SRT=AKTAU/AKI
      HEQ=HPAN*SRT**(1./3.)
      OMEGA=SQRT(AKTAU*12./AMASS)
      FREQ=OMEGA/(2.*PI)*FSTAR
      GO TO 100
C                    CORRUGATED PANEL
   90 AIX=AI
      DY=EP*AIX/(AW*12.)
      DX=EP*AIY/(BW*12.)
      AKM=PI/AW
      AKN=PI/BW
      AKM2=AKM*AKM
      AKN2=AKN*AKN
      AKTAU=(SQRT(DX)*AKM2+SQRT(DY)*AKN2)**2
      OMEGA=SQRT(AKTAU/AMASS)
      FREQ=OMEGA/(2.*PI)*FSTAR
  100 CONTINUE
      WRITE (6,420) FREQ
C
C                    NOISE COMPUTATIONS
C
C
      DO 220 I=1,IPFI
      IPFF=IPF(I)
      GO TO (110,120,160,210), IPFF
C                    1.  BOUNDARY LAYER
  110 SIGMAX=.37*REY**(-.2)*(1.+(REY/2.9E7)**2)**.1
      FZERO=8.*VU/SIGMAX/XL
C                    PF IS SPECTRUM PRESSURE
      PF(I)=QL*SQRT(.012/((1.+.14*AMACH**2)*FZERO*(1.+(FREQ/FZERO)**2)**
     11.5))
      FPLF=20.*ALOG10(PF(I)/41.8E-8)
      WRITE (6,430) FPLF,REY,AMACH,QL,VU
      GO TO 220
C
C                    2.  ROCKET ENGINE NOISE     (BOOSTER AND ORBITER)
  120 VEXH=TT*CG/WER
      FDV=FREQ*D/VEXH
      IF (FDV.LE..175) GO TO 130
      RTERM=-.222-1.315*ALOG10(FDV)
```

```
      GO TO 140
  130 RTERM=.625-.202*ALOG10(FDV)
  140 XZERO=D*10.**RTERM
      R=XI+XZERO
      IF (IPAD.EQ.0) GO TO 150
      IF (XZERO.GT.(DREF+YCL)) R=SQRT((XI+DREF)**2+(XZERO-DREF-YCL)**2)
      IF (XZERO.GT.DREF.AND.XZERO.LE.(DREF+YCL)) R=SQRT((XI+DREF)**2+(YC
     1L-XZERO+DREF)**2)
      IF (XZERO.LE.DREF) R=SQRT((XI+XZERO)**2+YCL**2)
C                COMPUTE SPL SOUND PRESSURE LEVEL
  150 IF (FDV.LE..016) SPL=70.+16.6*ALOG10(FDV/.003)
      IF (FDV.LT..152.AND.FDV.GT..016) SPL=82.
      IF (FDV.GE..152) SPL=70.-16.6*ALOG10(FDV/.8)
      CAPID=VS/(PI*DVEH)
      DELBP=0.
      IF (FREQ.GE.CAPID) DELBP=6.0
C                OBSPL IS OCTAVE BAND SOUND PRESSURE LEVEL
      OBSPL=10.*ALOG10(.676*TT**2*CG/WER)+SPL-20.*ALOG10(R)+DELBP
      BWD1=BANDW(FREQ)
      SPLF=OBSPL-10.*ALOG10(BWD1)
      WRITE (6,440) SPLF,XZERO
      PF(I)=41.8E-8*10.**(SPLF/20.)
      GO TO 220
C
C                3.  JET FLYBACK ENGINE NOISE ON VEHICLE
  160 VR=ABS(VV-VJ)
      DJ=SQRT(4.*AE/PI)
      RHOF=WEJ/(AE*VJ)
      FVRLG=145.+100.*ALOG10(VR/1600.)
C                SPL200 IS OVERALL SOUND PRESSURE LEVEL FOR Y=200FT.
      SPL200=FVRLG+10.*ALOG10(RHOF**2*AE)
C                SPLNF IS SOUND PRESSURE LEVEL AT YP DISTANCE
C                NONDIMESIONALIZE DISTANCES
      Y200DJ=200./DJ
      Y30DJ=30./DJ
      Y25DJ=2.5/DJ
      YPDJ=YP/DJ
      TERM1=20.*ALOG10(Y200DJ/Y30DJ)
      TERM2=16.*ALOG10(Y30DJ/Y25DJ)
      IF (YPDJ.GT.200.) GO TO 190
      IF (YPDJ.LT.30.) GO TO 170
      DELDB=20.*ALOG10(Y200DJ/YPDJ)
      GO TO 200
  170 IF (YPDJ.LT.2.5) GO TO 180
      DELDB=TERM1+16.*ALOG10(Y30DJ/YPDJ)
      GO TO 200
  180 IF (YPDJ.LT.1.) GO TO 190
      DELDB=TERM1+TERM2+14.*ALOG10(Y25DJ/YPDJ)
      GO TO 200
  190 WRITE (6,400) YP
      GO TO 360
  200 SPLNF=SPL200+DELDB+6.
      FREQP=.8*VJ/DJ
      BWD=BANDW(FREQ)
      OBMAX=SPLNF-5.
      CVF=CURVEF(FREQP,FREQ)
      IF (CVF.EQ.-1) GO TO 360
      OBSPL=OBMAX-CVF
```

```
      SPLF=OBSPL-10.*ALOG10(BWD)
      WRITE (6,450) SPLF
      PF(I)=41.8E-8*10.**(SPLF/20.)
      GO TO 220
C
C                 4.  JET SCRUBBING ON BODY
C                 PE IS PRESSURE AT NOZZLE EXIT
  210 PE=TJ*1.275/DJ**2
C                 DX IS JET DIAMETER AT X FEET
      DX=DJ*(1.+.244*XJ/DJ)
C                 PX IS SCRUBBING PRESSURE
      PX=.155*TJ/DX**2
      SPLX=20.*ALOG10(PX/41.8E-8)
      FREQP=.4*VJ/DJ
      BWD=BANDW(FREQ)
      OBMAX=SPLX-5.
      CVF=CURVEF(FREQP,FREQ)
      IF (CVF.EQ.-1) GO TO 360
      OBSPL=OBMAX-CVF
      SPLF=OBSPL-10.*ALOG10(BWD)
      WRITE (6,460) SPLF
      PF(I)=41.8E-8*10.**(SPLF/20.)
  220 CONTINUE
C
C
C                 DYNAMIC STRESSES
C
      BWD=.04*FREQ
      SUM1=0.
      SUM2=0.
      SBWD=SQRT(BWD)
      DO 340 I=1,IPFI
      PBAR=PF(I)*SBWD
      CY(I)=0.
      SCR(I)=0.
      SCON=.5
      IF (KFLEX.NE.0.) SCON=.75
      DCON=4.089
      IF (KFLEX.NE.0.) DCON=20.445
      GO TO (230,240,250,260), NPAN
C                 SMAX IS MAXIMUM BENDING STRESS
C                 YMAX IS MAXIMUM DEFLECTION
  230 HEFF=HPAN
      SMAX=SCON*AL2*PBAR/HPAN2
      YMAX=DCON*PBAR*AL4/(EP*HPAN3)
      SLD(I)=100.*SMAX
      GO TO 270
  240 HEFF=1.817*(HC*HF*HPAN)**(1./3.)
      SMAX=SCON*PBAR/HEFF**2*AL2
      YMAX=DCON*PBAR*AL4/(EP*HEFF**3)
      SLD(I)=100.*SMAX
      GO TO 270
  250 HEFF=HEQ
      SMAX=SCON*PBAR*AL2/HEQ**2
      YMAX=DCON*PBAR*AL4/(EP*HEQ**3)
      SD=25.*SMAX
      SLD(I)=4.*SD
      GO TO 270
```

```
260 HEFF=(10.9*((SQRT(AIY/BW)/AW**2+SQRT(AIX/AW)/BW**2)/(1./AW**2+1./B
   1W**2))**2)**0.3333
    SMAX=SCON*PBAR*AL2/HEFF**2
    YMAX=DCON*PBAR*AL4/(EP*HEFF**3)
    SLD(I)=100.*SMAX
270 WRITE (6,470) SLD(I),YMAX
C                STRESS REVERSALS PER MISSION OR FOR VEHICLE LIFETIME
    IPFF=IPF(I)
    ANL(I)=FREQ*DT(IPFF)
    ANRMS(I)=.61*ANL(I)
    CALL MININO(C,SLD(I),ANRMS(I),CY(I),SCR(I))
    IF (NOAPP.EQ.2) GO TO 360
    GO TO (280,290,300,310), IPFF
280 WRITE (6,480) SCR(I)
    GO TO 320
290 WRITE (6,490) SCR(I)
    GO TO 320
300 WRITE (6,500) SCR(I)
    GO TO 320
310 WRITE (6,510) SCR(I)
320 IF (SCR(I).EQ.0.) GO TO 340
    ANCR(I)=1.261*ANRMS(I)*SLD(I)/SCR(I)
    WRITE (6,520) ANCR(I)
    SUM1=SCR(I)**2+SUM1
    SUM2=ANRMS(I)*SLD(I)+SUM2
    X=ALOG10(ANCR(I))
    ALLST=(C(1)+C(2)*X+C(3)*X**2+C(4)*X**3)*1000.
    IF (ALLST.GE.SCR(I)) GO TO 330
    WRITE (6,530) ALLST
    GO TO 340
330 WRITE (6,540) ALLST
340 CONTINUE
    IF (SUM1.EQ.0.) GO TO 360
    SBAR=SQRT(SUM1)
    ANBAR=1.261*SUM2/SBAR
    WRITE (6,550) SBAR,ANBAR
    X=ALOG10(ANBAR)
    ALLST=(C(1)+C(2)*X+C(3)*X**2+C(4)*X**3)*1000.
    IF (ALLST.GE.SBAR) GO TO 350
    WRITE (6,530) ALLST
    GO TO 360
350 WRITE (6,540) ALLST
360 X=AWW/BWW
    X=TABLE(X,ELW,PHI,11)
    IF (X.EQ.0.) WRITE (6,560)
    WRITE (6,570) TIMEF,EPP,AMF,QF,X
    TB=0.
    IF (QF.EQ.0.) GO TO 380
    TB=X*AWW*12.0/(EPP*144.0/QF)**0.333
    IF (TB.GT.HEFF) GO TO 370
    WRITE (6,580)
    GO TO 380
370 WRITE (6,590)
380 WRITE (6,600) HEFF,TB
    RETURN
C
390 FORMAT (1H1)
400 FORMAT (18HOY-DISTANCE ERROR=E12.4)
```

```
410 FORMAT (27H PANEL MOMENT OF INERTIA = ,E10.3,10H INCHES**4/)
420 FORMAT (13H FREQUENCY = ,F7.1,3H HZ/)
430 FORMAT (24H BOUNDARY LAYER NOISE = ,F6.1,21H DB - REYNOLDS NO. = ,
   1E12.4,13H, MACH NO. = ,E12.4/20H DYNAMIC PRESSURE = ,E12.4,13H, VE
   2LOCITY = ,E12.4)
440 FORMAT (23H ROCKET ENGINE NOISE = ,F6.1,31H DB - APPARENT NOISE SO
   1URCE AT ,F6.1,3H FT)
450 FORMAT (14H ABES NOISE = ,F6.1,3H DB)
460 FORMAT (23H JET SCRUBBING NOISE = ,F6.1,3H DB)
470 FORMAT (26H0MAXIMUM BENDING STRESS = ,F10.0,4H PSI/26H MAXIMUM RMS
   1 DEFLECTION = ,F10.5,3H IN)
480 FORMAT (40H BOUNDARY LAYER NOISE CRITICAL STRESS = ,E12.4,4H PSI)
490 FORMAT (39H ROCKET ENGINE NOISE CRITICAL STRESS = ,E12.4,4H PSI)
500 FORMAT (44H JET FLYBACK ENGINE NOISE CRITICAL STRESS = ,E12.4,4H P
   1SI)
510 FORMAT (39H JET SCRUBBING NOISE CRITICAL STRESS = ,E12.4,4H PSI)
520 FORMAT (27H NO. OF STRESS REVERSALS = ,E12.4)
530 FORMAT (35H ***PANEL IS SUSCEPTIBLE TO FAILURE/39H    CRITICAL STR
   1ESS MUST BE REDUCED TO ,E12.4,21H PSI TO AVOID FAILURE)
540 FORMAT (36H ***PANEL IS GOOD FOR THIS CONDITION/40H    CRITICAL ST
   1RESS MAY BE INCREASED TO ,E12.4,4H PSI)
550 FORMAT (29H0COMPOSITE CRITICAL STRESS = ,E12.4,4H PSI/27H NO. OF S
   1TRESS REVERSALS = ,E12.4)
560 FORMAT (43H AW/BW WAS OUTSIDE THE TABLE LIMITS FOR PHI)
570 FORMAT (42H0PANEL FLUTTER ANALYSIS - DESIGN POINT AT ,E12.4,18H SE
   1CONDS OF FLIGHT/18H YOUNGS MODULUS = ,E12.4,13H, MACH NO. = ,E12.4
   2/20H Q LOCAL/FCN(AMI) = ,E12.4,8H, PHI = ,E12.4)
580 FORMAT (31H ***PANEL IS STABLE FOR FLUTTER)
590 FORMAT (33H ***PANEL IS UNSTABLE FOR FLUTTER)
600 FORMAT (32H     PANEL EFFECTIVE THICKNESS = ,E12.4,4H IN./64H    PA
   1NEL EFFECTIVE THICKNESS NECESSARY FOR FLUTTER STABILITY = ,E12.4,4
   2H IN.)
    END
```

```
FUNCTION ALL(ARR,CY)
DIMENSION ARR(4)
A1(X)=(ARR(1)+ARR(2)*X+ARR(3)*X**2+ARR(4)*X**3)*1000.0
Y=ALOG10(CY)
YY=ALOG10(1.01*CY)
ALL=(A1(YY)-A1(Y))/(0.01*CY)*CY
RETURN
END
```

```
      FUNCTION APP(SLD,CY,CYL,ARR)
      COMMON/APP1/NOAPP
      DIMENSION C(3), ARR(4)
      DATA (C(I),I=1,3)/2.631102E-02,-2.635E-02,-4.939331E-01/
      A1(X)=2./PI*ACOS(1.-PI/1.212*(1.-X))
      A2(X)=(-C(2)-SQRT(C(2)**2-4.*C(3)*(C(1)-ALOG(X))))/(2.*C(3))
      A3(X)=(ARR(1)+ARR(2)*X+ARR(3)*X**2+ARR(4)*X**3)*1000.
      PI=3.14159
      Y=CY/CYL
      IF (Y.GT.0.455.AND.Y.LT.1.0) GO TO 30
      YY=Y-0.0001
      IF (YY.GE.0.) GO TO 20
      YY=0.
      IF (A2(Y)*SLD.GT.A3(Y)) GO TO 10
      WRITE (6,50)
      NOAPP=1
      RETURN
   10 NOAPP=2
      WRITE (6,60)
      RETURN
   20 Z=(A2(Y)-A2(YY))*10000.
      APP=Z*SLD/CYL*CY
      RETURN
   30 YY=Y+0.0001
      IF (YY.LE.1.) GO TO 40
      YY=1.
      FACT=YY-Y
      Z=(A1(YY)-A1(Y))/FACT
      APP=Z*SLD/CYL*CY
      RETURN
   40 Z=(A1(YY)-A1(Y))*10000.
      APP=Z*SLD/CYL*CY
      RETURN
C
   50 FORMAT (///50H ***** S O N I C    F A T I G U E    N O T E *****/5
     10H  THE NUMBER OF STRESS REVERSALS IS SO LOW THAT   /50H  FATIGUE
     2IS NOT A FACTOR FOR THIS CONFIGURATION  /50H  AND ALLOWABLE S-N CU
     3RVE.  THE ACOUSTIC FATIGUE  /50H  ANALYSIS FOR THIS NOISE SOURCE I
     4S OMITTED.       /7X,35H***** E N D    O F    N O T E *****//)
   60 FORMAT (47H0APPLIED S-N CURVE EXCEEDS ALLOWABLE S-N CURVE.)
      END
```

```
      FUNCTION BANDW(F)
C
C                    THIS SUBROUTINE COMPUTES BANDWIDTH AS A FUNCTION
C                    OF FREQUENCY
      DIMENSION FTB(13),BWTB(13)
      DATA FTB/  2.,     4.,     8.,     16.,
     1    31.5    ,63.0    ,125.    ,250.    ,500.    ,
     2    1000.   ,2000.   ,4000.   ,8000. /
      DATA BWTB/1.35, 2.75,  5.5,  11.,
     1    22.5    ,45.0    ,90.0    ,180.    ,355.    ,
     2    700.    ,1400.   ,2800.   ,5600.            /
      IF (F.GE..65.AND.F.LE.10800.) GO TO 10
      WRITE (6,30) F
      IF (F.LT.0.65) BANDW=1.35
      IF (F.GT.10800.) BANDW=5600.
      RETURN
   10 I=0
   20 I=I+1
      IF (F.GT.(FTB(I)+BWTB(I)/2.)) GO TO 20
      BANDW=BWTB(I)
      RETURN
C
   30 FORMAT (19H0FREQ. ARG. ERROR =E12.4)
      END
```

```
      FUNCTION CURVEF(F,FSTAR)
C                THIS FUNCTION IS USED TO COMPUTE OBSPL
      ITER=0
      SUMDEL=0.
      IF (FSTAR.GT.F) GO TO 30
C                FUNDAMENTAL FREQUENCY IS LESS THAN F
      DELDBP=4.
      FU=F
   10 FL=.5*FU
      IF (FL.LE.FSTAR) GO TO 20
      SUMDEL=SUMDEL+DELDBP
      FU=FL
      ITER=ITER+1
      IF (ITER.GT.100) GO TO 70
      GO TO 10
   20 DELDB=(FSTAR-FL)/(FU-FL)*DELDBP+SUMDEL
      GO TO 60
C                FUNDAMENTAL FREQUENCY IS GREATER THAN F
   30 DELDBP=3.5
      FL=F
   40 FU=2.*FL
      IF (FU.GE.FSTAR) GO TO 50
      SUMDEL=SUMDEL+DELDBP
      FL=FU
      ITER=ITER+1
      IF (ITER.GT.100) GO TO 70
      GO TO 40
   50 DELDB=(FSTAR-FL)/(FU-FL)*DELDBP+SUMDEL
   60 CURVEF=DELDB
      RETURN
   70 WRITE (6,80) F,FSTAR
      CURVEF=-1.
      RETURN
C
   80 FORMAT (30H0ERROR IN OBSPL COMPUTATION F=E12.4,3X,6HFSTAR=E12.4)
      END
```

```
      SUBROUTINE MININO(DI,SLD,CYL,CY,SCR)
      COMMON/APP1/NOAPP
      DIMENSION C(3)
      DIMENSION  DI(4)
      DATA C / 2.631102E-02, -2.635E-02, -4.939331E-01 /, PI / 3.14159 /
      NOAPP=0
      CYMAX=CYL
      XIU=1.E30
      ETAU=1.0
      XIL=0.0
      ETAL=0.0
      L=0
      DO 10 I=L,10
      ETA=0.999/10.**I
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
      IF (XI.GE.XIU) GO TO 90
      IF (ABS(XI/C1).LT.0.01) GO TO 70
      IF (XI.LT.0.0) GO TO 20
      XIU=XI
      ETAU=ETA
   10 CONTINUE
   20 XIL=XI
      ETAL=ETA
      ETA=0.5*(ETAL+ETAU)
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
   30 IF (ABS(XI/C1).LT.0.01) GO TO 70
      IF (XIL.LE.XI.AND.XI.LE.XIU) GO TO 40
      GO TO 90
   40 IF (XI.LT.0.0) GO TO 50
      XIU=XI
      ETAU=ETA
      GO TO 60
   50 XIL=XI
      ETAL=ETA
   60 ETA=0.5*(ETAL+ETAU)
      CY=ETA*CYL
      C1=APP(SLD,CY,CYL,DI)
      IF (NOAPP.NE.0) GO TO 100
      C2=ALL(DI,CY)
      XI=C2-C1
      GO TO 30
   70 Y=CY/CYL
      IF (Y.GT.0.455.AND.Y.LT.1.0) GO TO 80
      SCR=((-C(2)-SQRT(C(2)**2-4.*C(3)*(C(1)-ALOG(Y))))/(2.*C(3)))*SLD
      GO TO 110
   80 SCR=(2./PI*ACOS(1.-PI/1.212*(1.-Y)))*SLD
      GO TO 110
   90 WRITE (6,120)
  100 SCR=0.
  110 RETURN
```

```
C                                                                 MNN  59
  120 FORMAT (30H0ITERATION FAILED TO CONVERGE.)                  MNN  60
      END                                                         MNN  61-
```

```
      OVERLAY (P5490,3,0,C000000)
      PROGRAM DRVTPS
C
      COMMON/COMTOT/
     1AT        ,BT        ,CT        ,CF1       ,EGTH      ,ETA       ,
     2FTH       ,FTS       ,K1        ,K2        ,K3        ,NPA       ,
     3OS        ,STPS      ,TUNWT
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON/STDHR/
     1EOP       ,LARATE    ,MATLID    ,NN        ,PI        ,REFCT     ,
     2STDHR     ,VRATE
      COMMON/WTA/
     1A         ,B         ,CHORD     ,DIABH1    ,DIAPOH    ,DIARGH    ,
     2DIAPGH    ,DIAPTH    ,
     3DLPANL    ,DWPANL    ,EEDGE     ,E1RIB     ,E2RIB     ,E3RIB     ,
     4GBOLT     ,GCLAMP    ,GINSRT    ,GINSUL    ,GNUTPL    ,GWASH     ,
     5HBEAMA    ,HFNG1     ,HFNG2     ,HPLATE    ,HPOST     ,HRIB      ,
     6HRING     ,IDFNG1    ,IDFNG2    ,KINDP     ,KINDS     ,LBMLA     ,
     7LBMLC     ,LBMSA     ,LBMSC     ,LCORN     ,LDOUBR    ,LENGTH    ,
     8LPANL     ,LPOST     ,LRIBL     ,LRIBS     ,LSEAL     ,LSTFNR    ,
     9LTUBE     ,NRIBS     ,NXA       ,NYA       ,ODFNG1    ,ODFNG2    ,
     $ODPOSR    ,ODPOST    ,ODRING    ,PBM       ,PCORE     ,PEDGE     ,
     $PINS1     ,PINS2     ,PINS3     ,PPOST     ,PRIB      ,PSEAL     ,
     $PSKIN1    ,PSKIN2    ,PTUBE     ,R         ,RADIUS    ,S         ,
     $TBMLA     ,TBMLC     ,TBMSA     ,TBMSC     ,TCORE     ,TCORN     ,
     $TDOUBC    ,TDOUBP    ,TEDGE     ,TFNG1     ,TPLATE    ,TPLUG     ,
     $TPOST     ,TRIBL     ,TRIBS     ,TRING1    ,TRING2    ,TSEAL     ,
     $TTUBE     ,TWRIB     ,T1RIB     ,T2RIB     ,WBEAMA    ,WBMLA     ,
     $WBMLC     ,WBMSA     ,WBMSC     ,WCORN     ,WCORR     ,WDOUBP    ,
     $WDOUBR    ,WIDTH     ,WPANL     ,WPLATE    ,WPOST     ,WRIBL     ,
     $WRIBS     ,WSEAL     ,WSTFNR    ,ZFAS
      COMMON/WTCOST/
     1ACWT      ,AMUV      ,AOP(7,7)  ,ITL       ,KK        ,KLIC      ,
     2COSWT     ,KT        ,LEN       ,LTUBER    ,MAWT      ,N         ,
     3PEXT      ,TEXT      ,WID       ,ZZUB
      COMMON/ZERO/
     1LABHR     ,LACOST    ,TACWT     ,TALABH    ,TASTDH    ,TASYCO    ,
     2TFCOST    ,TLACOS    ,TLBHR     ,TMAWT     ,TSTDHR    ,TTFCOS    ,
     3TTLACO    ,TTLBHR    ,TTMCOS    ,TTSHR     ,TTVCOS    ,TVCOST    ,
     4VCOST
C
      DIMENSION IA(1), IB(1)
      EQUIVALENCE (IA,A), (IB,LABHR)
C
      REAL IDFNG1, IDFNG2, K1, K2, K3, LENGTH, LTUBE, NPA
C
C ***  INITIALIZE INPUT VARIABLES
C
      DO 10 I=1,105
      IA(I)=0
   10 CONTINUE
      DO 20 I=1,19
      IB(I)=0
   20 CONTINUE
      CT=.86
      EGTH=3.75
      ETA=0.3
      FTH=2.0
```

```
      FTS=.67
      NPA=1.0
      OS=1.332
      PI=3.1416
      STPS=1000.
      TINS1=TINS1*12.0
      WRITE (6,200)
C
C *** READ WEIGHT-COST INPUT
C
      READ (5,210) KINDP,KINDS,LENGTH,WIDTH,DLPANL,DWPANL,A,B,MATLID,ICO
     1S
      READ (5,220) PINS1,PINS2,PINS3,TINS1,TINS2,TINS3
      WRITE (6,230) KINDP,LENGTH,WIDTH,DLPANL,DWPANL,A,B,ICOS,KINDS,TINS
     11,TINS2,TINS3,PINS1,PINS2,PINS3,MATLID
      IF (KINDP.GT.0.AND.KINDP.LT.6) GO TO 30
      WRITE (6,240)
      RETURN
   30 GO TO (40,50,60,80,80), KINDP
C
C *** KINDP = 1
C
   40 READ (5,250) NRIBS,CHORD,RADIUS
      WRITE (6,260) NRIBS,CHORD,RADIUS,TSKIN1,TSKIN2
      GO TO 70
C
C *** KINDP = 2
C
   50 READ (5,220) GINSRT,TCORE,TEDGE
      WRITE (6,270) GINSRT,TCORE,TEDGE,TSKIN1,TSKIN2
      GO TO 70
C
C *** KINDP = 3
C
   60 READ (5,250) NRIBS,HRIB,TEDGE,E1RIB,E2RIB,E3RIB,T1RIB,T2RIB,TWRIB
      WRITE (6,280) NRIBS,HRIB,E1RIB,E2RIB,E3RIB,TEDGE,TSKIN1,T1RIB,T2RI
     1B,TWRIB
   70 AT=.667
      BT=.187
      CF1=0.
      K1=.00171
      K2=6.58
      K3=.004324
      GO TO 130
C
C *** KINDP = 4 OR 5
C
   80 READ (5,220) GINSRT,TCORE,TEDGE,TEXT,PEXT
      WRITE (6,290) GINSRT,TCORE,TEDGE,TEXT,PEXT,TSKIN1,TSKIN2
      PEXT=PEXT/1728.
      AT=0.6
      BT=0.6
      CF1=1.0
      K3=.004974
      IF (KINDP-5) 90,100,110
   90 K1=.06528
      GO TO 120
  100 K1=.03295
```

```
      K2=.300
      GO TO 130
  110 K1=.07181
  120 K2=.575
  130 IF (KINDS.EQ.0) GO TO 180
      IF (KINDS.GT.0.AND.KINDS.LT.4) GO TO 140
      WRITE (6,300)
      RETURN
  140 GO TO (150,160,170), KINDS
C
C *** KINDS = 1
C
  150 READ (5,220) GBOLT,GNUTPL,GWASH,TCORN,TPOST,ODPOST,LTUBE,TTUBE,TFN
     1G1,TBMLA,TBMSA,TDOUBC,TDOUBP,TPLATE,TSEAL,HBEAMA,WBEAMA
      WRITE (6,310) GBOLT,GNUTPL,GWASH,TCORN,TPOST,ODPOST,LTUBE,TTUBE,TF
     1NG1,TBMLA,TBMSA,TDOUBC,TDOUBP,TPLATE,TSEAL,HBEAMA,WBEAMA
      GO TO 180
C
C *** KINDS = 2
C
  160 READ (5,220) GBOLT,GNUTPL,GWASH,GINSUL,TPOST,WPOST
      WRITE (6,320) GBOLT,GNUTPL,GWASH,GINSUL,TPOST,WPOST
      GO TO 180
C
C *** KINDS = 3
C
  170 READ (5,220) GBOLT,GNUTPL,GWASH,GCLAMP,TPOST,ODPOST,ODPOSR,TTUBE,T
     1FNG1,TBMLC,TBMSC,WBMLC,WBMSC,TRIBL,TRIBS,WRIBL,WRIBS
      READ (5,220) HRING,ODRING,IDFNG1,IDFNG2,HFNG1,HFNG2,TRING1,TRING2
      WRITE (6,330) GBOLT,GNUTPL,GWASH,GCLAMP,TPOST,ODPOST,ODPOSR,TTUBE,
     1TFNG1,TBMLC,TBMSC,WBMLC,WBMSC,TRIBL,TRIBS,WRIBL,WRIBS,HRING,ODRING
     2,IDFNG1,IDFNG2,HFNG1,HFNG2,TRING1,TRING2
  180 IF (ICOS.EQ.0) GO TO 190
      READ (5,220) AT,BT,CT,CF1,EGTH,ETA
      READ (5,220) FTH,FTS,K1,K2,K3,NPA,OS,STPS
      WRITE (6,340) AT,BT,CT,CF1,EGTH,ETA,FTH,FTS,K1,K2,K3,NPA,OS,STPS
  190 WRITE (6,350)
      CALL WTTPS
      IF (KLIC.EQ.100) RETURN
      CALL COSTOT
      RETURN
C
  200 FORMAT (1H1)
  210 FORMAT (2I4,6E8.0,2I4)
  220 FORMAT (9E8.0)
  230 FORMAT (46H1***** W E I G H T - C O S T   I N P U T *****//10X,5HK
     1INDP,9X,6HLENGTH,10X,5HWIDTH,9X,6HDLPANL,9X,6HDWPANL,14X,1HA,14X,1
     2HB,11X,4HICOS/I15,6F15.3,I15//10X,5HKINDS,10X,5HTINS1,10X,5HTINS2,
     310X,5HTINS3,10X,5HPINS1,10X,5HPINS2,10X,5HPINS3,9X,6HMATLID/I15,6F
     415.3,I15)
  240 FORMAT (65H0***** KIND OF PANEL FLAG, KINDP, WAS NOT PROPERLY ENTE
     1RED. *****)
  250 FORMAT (I8,9E8.0)
  260 FORMAT (//32X,5HNRIBS,10X,5HCHORD,9X,6HRADIUS,9X,6HTSKIN1,9X,6HTSK
     1IN2/30X,I7,4F15.3)
  270 FORMAT (//31X,6HGINSRT,10X,5HTCORE,10X,5HTEDGE,9X,6HTSKIN1,9X,6HTS
     1KIN2/22X,5F15.3)
  280 FORMAT (//32X,5HNRIBS,11X,4HHRIB,10X,5HE1RIB,10X,5HE2RIB,10X,5HE3R
```

```
     1IB/30X,I7,4F15.3//32X,5HTEDGE,9X,6HTSKIN1,10X,5HT1RIB,10X,5HT2RIB,
     210X,5HTWRIB/22X,5F15.3)
  290 FORMAT (//16X,6HGINSRT,10X,5HTCORE,10X,5HTEDGE,11X,4HTEXT,11X,4HPE
     1XT,9X,6HTSKIN1,9X,6HTSKIN2/7X,7F15.3)
  300 FORMAT (69H0***** KIND OF STRUCTURE FLAG, KINDS, WAS NOT PROPERLY
     1ENTERED. *****)
  310 FORMAT (//25X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,10X,5HTCORN,10X,5HTP
     1OST,9X,6HODPOST/15X,6F15.3//32X,5HLTUBE,10X,5HTTUBE,10X,5HTFNG1,10
     2X,5HTBMLA,10X,5HTBMSA/22X,5F15.3//24X,6HTDOUBC,9X,6HTDOUBP,9X,6HTP
     3LATE,10X,5HTSEAL,9X,6HHBEAMA,9X,6HWBEAMA/15X,6F15.3)
  320 FORMAT (//25X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,9X,6HGINSUL,10X,5HTP
     1OST,10X,5HWPOST/15X,6F15.3)
  330 FORMAT (//17X,5HGBOLT,9X,6HGNUTPL,10X,5HGWASH,9X,6HGCLAMP,10X,5HTP
     1OST,9X,6HODPOST,9X,6HODPOSR/7X,7F15.3//25X,5HTTUBE,10X,5HTFNG1,10X
     2,5HTBMLC,10X,5HTBMSC,10X,5HWBMLC,10X,5HWBMSC/15X,6F15.3//25X,5HTRI
     3BL,10X,5HTRIBS,10X,5HWRIBL,10X,5HWRIBS,10X,5HHRING,9X,6HODRING/15X
     4,6F15.3//24X,6HIDFNG1,9X,6HIDFNG2,10X,5HHFNG1,10X,5HHFNG2,9X,6HTRI
     5NG1,9X,6HTRING2/15X,6F15.3)
  340 FORMAT (//20X,2HAT,13X,2HBT,13X,2HCT,12X,3HCF1,11X,4HEGTH,12X,3HET
     1A,12X,3HFTH/7X,7F15.3//19X,3HFTS,13X,2HK1,13X,2HK2,13X,2HK3,12X,3H
     2NPA,13X,2HOS,11X,4HSTPS/7X,7F15.3)
  350 FORMAT (36H0***** E N D   O F   I N P U T *****)
      END
```

```
      SUBROUTINE AMATL
C
      COMMON/COMTOT/
     1AT        ,BT        ,CT        ,CF1       ,EGTH      ,ETA       ,
     2FTH       ,FTS       ,K1        ,K2        ,K3        ,NPA       ,
     3OS        ,STPS      ,TUNWT
      COMMON/MATL/
     1CPERIM    ,HEIGHT     ,KEY       ,LENGT     ,WIDT
      COMMON/STDHR/
     1EOP       ,LARATE    ,MATLID    ,NN        ,PI        ,REFCT     ,
     2STDHR     ,VRATE
      COMMON/WTA/
     1A         ,B         ,CHORD     ,DIABH1    ,DIAPOH    ,DIARGH    ,
     2DIAPGH    ,DIAPTH    ,
     3DLPANL    ,DWPANL    ,EEDGE     ,E1RIB     ,E2RIB     ,E3RIB     ,
     4GBOLT     ,GCLAMP    ,GINSRT    ,GINSUL    ,GNUTPL    ,GWASH     ,
     5HBEAMA    ,HFNG1     ,HFNG2     ,HPLATE    ,HPOST     ,HRIB      ,
     6HRING     ,IDFNG1    ,IDFNG2    ,KINDP     ,KINDS     ,LBMLA     ,
     7LBMLC     ,LBMSA     ,LBMSC     ,LCORN     ,LDOUBR    ,LENGTH    ,
     8LPANL     ,LPOST     ,LRIBL     ,LRIBS     ,LSEAL     ,LSTFNR    ,
     9LTUBE     ,NRIBS     ,NXA       ,NYA       ,ODFNG1    ,ODFNG2    ,
     $ODPOSR    ,ODPOST    ,ODRING    ,PBM       ,PCORE     ,PEDGE     ,
     $PINS1     ,PINS2     ,PINS3     ,PPOST     ,PRIB      ,PSEAL     ,
     $PSKIN1    ,PSKIN2    ,PTUBE     ,R         ,RADIUS    ,S         ,
     $TBMLA     ,TBMLC     ,TBMSA     ,TBMSC     ,TCORE     ,TCORN     ,
     $TDOUBC    ,TDOUBP    ,TEDGE     ,TFNG1     ,TPLATE    ,TPLUG     ,
     $TPOST     ,TRIBL     ,TRIBS     ,TRING1    ,TRING2    ,TSEAL     ,
     $TTUBE     ,TWRIB     ,T1RIB     ,T2RIB     ,WBEAMA    ,WBMLA     ,
     $WBMLC     ,WBMSA     ,WBMSC     ,WCORN     ,WCORR     ,WDOUBP    ,
     $WDOUBR    ,WIDTH     ,WPANL     ,WPLATE    ,WPOST     ,WRIBL     ,
     $WRIBS     ,WSEAL     ,WSTFNR    ,ZFAS
      COMMON/WTCOST/
     1ACWT      ,AMUV      ,AOP(7,7)  ,ITL       ,KK        ,KLIC      ,
     2COSWT     ,KT        ,LEN       ,LTUBER    ,MAWT      ,N         ,
     3PEXT      ,TEXT      ,WID       ,ZZUB
C
      REAL LEN, LENG, LENGT, LENGX, MARKX, MAWT, MBASE, NPA
C
      FLATX=0
      HEATX=0
      LENGX=0
      MBASE=0
      MARKX=0
      PBASE=0
      PDIE=0
      PEXTRA=0
      PROTX=0
      PSAWX=0
      QUANX=0
      SIZEX=0
      TOLX=0
      USONX=0
      WIDTX=0
      ALBASE=.80
      EL=LENGT
      LENG=LENGT
      PERM=CPERIM
      QUANM=STPS*NPA*MAWT/(LEN*WID)
```

```
      THK=HEIGHT
      XARE=THK*WIDT
      XFACT=12.
C
C     MATERIAL IS INSULATION
      IF (KEY.EQ.0) GO TO 10
C
C     MATERIAL IS REUSABLE SURFACE INSULATION
      IF (KEY.EQ.11) GO TO 20
C
C     MATERIAL IS ABLATIVE MATERIAL
      IF (KEY.EQ.12) GO TO 30
C
      IF ((MATLID.LT.1).OR.(MATLID.GT.15)) RETURN
      GO TO (40,290,350,360,370,380,390,400,410,420,180,240,430,440,450)
     1, MATLID
C
C
C*****MATERIAL TYPE IS INSULATION *****
   10 CONTINUE
      AMUV=1.10
      COSWT=5.00
      RETURN
C
C*****MATERIAL IS REUSABLE SURFACE INSULATION
C
   20 CONTINUE
      AMUV=1.10
      KCOSWT=7.50
      RETURN
C
C*****MATERIAL TYPE IS ABLATIVE MATERIAL
C
   30 CONTINUE
      AMUV=1.10
      KCOSWT=3.50
      RETURN
C
C*****MATERIAL TYPE IS ALUMINUM (7075-T6) *****
C
   40 CONTINUE
      IF (MATLID.EQ.1) MBASE=ALBASE
      GO TO (50,60,100,130,140,150,160,170), KEY
C
C     MATERIAL FORM IS FASTENER
C
C
   50 CONTINUE
C     ANALYSIS ASSUMES FASTENER IS A BOLT
      AMUV=1.1
      PBASE=21.00
      IF (MATLID.GT.1) PBASE=XFACT*MBASE
C
      GO TO 470
C     MATERIAL FORM IS HONEYCOMB
C     ANALYSIS IS BASED ON THE 5052 ALUMINUM ALLOY, A 3/16 INCH CELL
C     SIZE, AND A .002 INCH FOIL THICKNESS
   60 CONTINUE
```

```
      AMUV=1.1
      CELL=.1875
      QUANM=QUANM*AMUV
      QUANM=QUANM/(144.*PCORE)
      IF (QUANM.LT.600.) GO TO 70
      IF (QUANM.GE.12000.) GO TO 80
      P=1.43
      PSAWX=.25
      GO TO 90
   70 CONTINUE
      P=1.72
      PSAWX=.45
      GO TO 90
   80 CONTINUE
      P=1.30
      PSAWX=.22
   90 CONTINUE
      PCELL=.3382*CELL**-.797
      PINFT2=PCELL*P/1.30
      SAWX=PSAWX/(144.*PCORE)
      PBASE=PINFT2/(144.*PCORE)+SAWX
      GO TO 460
C
C     MATERIAL FORM IS FOIL, SHEET, OR PLATE
C
C     ANALYSIS IS BASED ON 7075 AND 7079 ALUMINUM ALLOYS IN THE
C     FOLLOWING TEMPERS   -T6, -T651
  100 CONTINUE
      AMUV=1.1
      QUANM=QUANM*AMUV
      IF (THK.GE..1875) GO TO 110
      PBASE=-13.82*THK+1.218
      IF (THK.GE..044) PBASE=-.641*THK+.638
      WIDTX=.0106*WIDT-.510
      IF (WIDT.LE.48.) WIDTX=0
      PBASE=PBASE+WIDTX
      PROTX=-2.182*THK+.187
      IF (PROTX.LT.0) PROTX=0
      TOLX=.036
      IF (THK.LT..154) TOLX=.046
      PEXTRA=PROTX+TOLX
      GO TO 120
  110 CONTINUE
      PBASE=-.00642*THK+.536
      WIDTX=.00131*WIDT-.0327
      IF (WIDT.LE.25.) WIDTX=0
      PBASE=PBASE+WIDTX
      IF (THK.GE..250) FLATX=.01
      USONX=.05
      IF (THK.LT.1.5) USONX=.08
      IF (THK.LT..5) USONX=.025
      PEXTRA=FLATX+USONX
  120 CONTINUE
      QUANX=.1486*QUANM**-.000115
      IF (QUANM.LT.3500.) QUANX=113100.*QUANM**-1.667
      IF (QUANM.LT.1100.) QUANX=-.000516*QUANM+1.69
      MARKX=.01
      PACKX=0
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```
      IF (QUANM.LT.4000.) PACKX=.013
      IF (QUANM.LT.2000.) PACKX=.025
      PEXTRA=PEXTRA+QUANX+MARKX+PACKX
      GO TO 460
C
C     MATERIAL FORM IS WIRE, ROD, OR BAR
C
C     ANALYSIS IS BASED ON 7075 ALLUMINUM ALLOY IN THE FOLLOWING
C       TEMPERS  -T6, -T651
  130 CONTINUE
      AMUV=1.10
      PBASE=.9715*XARE**-.0521
      QUANM=QUANM*AMUV
      QUANX=0
      IF (QUANM.LT.5000.) QUANX=.025
      IF (QUANM.LT.1000.) QUANX=13.98*QUANM**-.742
      IF (QUANM.LT.25.) QUANX=1.30
      PEXTRA=QUANX
      GO TO 460
C
C     MATERIAL FORM IS EXTRUSION
C
C     ANALYSIS IS BASED ON 7075 AND 7079 ALUMINUM ALLOYS IN THE
C       FOLLOWING TEMPERS  -T6, -T6510, -T6511
  140 CONTINUE
      AMUV=1.10
      DIA=AMAX1(WIDT,HEIGHT)
      WTPFT=1.2*XARE
      K=PERM/WTPFT+.5
      QUANM=QUANM*AMUV
      IF (K.LE.1) P=.890
      IF (K.EQ.2.AND.DIA.LE.3.5) P=.9706*DIA**(-.05003)
      IF (K.EQ.2.AND.DIA.GT.3.5) P=.910
      IF (K.EQ.3.AND.DIA.LE.4.5) P=1.074*DIA**(-.091181)
      IF (K.EQ.3.AND.DIA.GT.4.5) P=0.8265*DIA**(.08922)
      IF (K.GE.4.A.K.LE.5.AND.DIA.LE.4.5) P=1.1510*DIA**(-.07893)
      IF (K.GE.4.A.K.LE.5.AND.DIA.GT.4.5) P=0.7522*DIA**(.19544)
      IF (K.GE.6.A.K.LE.8.AND.DIA.LE.4.5) P=1.2699*DIA**(-.09497)
      IF (K.GE.6.A.K.LE.8.AND.DIA.GT.4.5) P=0.6576*DIA**(.32524)
      IF (K.GE.9.A.K.LE.11.AND.DIA.LE.4.5) P=1.3904*DIA**(-.10852)
      IF (K.GE.9.A.K.LE.11.AND.DIA.GT.4.5) P=0.8826*DIA**(.20352)
      IF (K.GE.12.A.K.LE.14.AND.DIA.LE.3.5) P=1.5224*DIA**(-.14045)
      IF (K.GE.12.A.K.LE.14.AND.DIA.GT.3.5) P=.9888*DIA**(.20075)
      IF (K.GE.15.A.K.LE.20.AND.DIA.LE.2.5) P=1.7219*DIA**(-.23304)
      IF (K.GE.15.A.K.LE.20.AND.DIA.GT.2.5) P=1.1685*DIA**(.17168)
      IF (K.GE.21.A.K.LE.25.AND.DIA.LE.2.5) P=1.8625*DIA**(-.12561)
      IF (K.GE.21.A.K.LE.25.AND.DIA.GT.2.5) P=1.4733*DIA**(.12607)
      IF (K.GE.26.A.K.LE.30.AND.DIA.LE.2.5) P=2.0931*DIA**(-.09990)
      IF (K.GE.26.A.K.LE.30.AND.DIA.GT.2.5) P=1.7802*DIA**(.07680)
      IF (K.GE.31.A.K.LE.35.AND.DIA.LE.2.5) P=2.5361*DIA**(-.12580)
      IF (K.GE.31.A.K.LE.35.AND.DIA.GT.2.5) P=2.0320*DIA**(.11606)
      IF (K.GT.35) P=2.500
      LENGX=0
      IF (EL.GE.300..A.EL.LT.456..AND.WTPFT.LT..250) LENGX=.01
      IF (EL.GE.300..A.EL.LT.456..AND.WTPFT.GE..250.A.WTPFT.LT..499) LEN
     1GX=.005
      IF (EL.GE.300..A.EL.LT.456..AND.WTPFT.GE..499) LENGX=0
      IF (EL.GE.456..AND.WRPFT.LT..250) LENGX=.017
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      IF (EL.GE.450..AND.WTPFT.GE..499) LENGX=.005
      IF (EL.GE.450..A.WTPFT.GE..250.AND.WTPFT.LT..499) LENGX=.01
      PBASE=P+LENGX
      PDIE=115.8*EXP(.2188*DIA)/QUANM
      RQUAN=14020.*EXP(.2163*DIA)
      IF (QUANM.GE.RQUAN) PDIE=0
      QUANX=-.0000018*QUANM+.024
      IF (QUANM.LT.15000.) QUANX=-.0000153*QUANM+.195
      PACKX=.011
      TOLX=.03
      PEXTRA=PDIE+QUANX+PACKX+TOLX
      GO TO 460
C
C     MATERIAL FORM IS TUBING
  150 CONTINUE
      GO TO 480
C
C     MATERIAL FORM IS FORGING
  160 CONTINUE
      GO TO 480
C
C     MATERIAL FORM IS CASTING
  170 CONTINUE
      GO TO 480
C
C*****MATERIAL TYPE IS ALLOY STEEL (4130, 4340) *****
C
  180 CONTINUE
      MBASE=.40
      GO TO (190,40,200,230,40,40,40,40), KEY
C
C     MATERIAL FORM IS FASTENER
C
C     ANALYSIS ASSUMES FASTENER IS A BOLT
  190 CONTINUE
      AMUV=1.1
      PBASE=13.00
      GO TO 470
C
C     MATERIAL FORM IS FOIL, SHEET, OR PLATE
C
C     ANALYSIS IS BASED ON AN AVERAGE OF HOT ROLLED NORMALIZED AND
C     HOT ROLLED ANNEALED AIRCRAFT QUALITY 4130 ALLOY STEEL, AND ON HOT
C     ROLLED ANNEALED AIRCRAFT QUALITY 4340 ALLOY STEEL
  200 CONTINUE
      AMUV=1.1
      QUANM=QUANM*AMUV
      IF (THK.GE..250) GO TO 210
      PBASE=1.00
      IF (THK.GE..010) PBASE=.071*THK**-.546
      IF (THK.GE..050) PBASE=.0968*THK+.357
      PROTX=-2.182*THK+.187
      IF (PROTX.LT.0) PROTX=0
      GO TO 220
  210 CONTINUE
      PBASE=.006*THK+.439
      MARKX=-.015*THK+.03
  220 CONTINUE
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      QUANX=0
      IF (QUANM.LT.10000.) QUANX=.027
      IF (QUANM.LT.300.) QUANX=2.059*QUANM**-.5304
      IF (QUANM.LT.25.) QUANX=.50
      PEXTRA=QUANX+MARKX+PROTX
      GO TO 470
C
C     MATERIAL FORM IS WIRE, ROD, OR BAR
C
C     ANALYSIS IS BASED ON AN AVERAGE PRICE FOR HOT AND COLD ROLLED
C     AIRCRAFT QUALITY 4340 ALLOY STEEL
  230 CONTINUE
      AMUV=1.1
      QUANM=QUANM*AMUV
      PBASE=.361
      IF (XARE.LT.6.) PBASE=.442
      QUANX=0
      IF (QUANM.LT.10000.) QUANX=.027
      IF (QUANM.LT.300.) QUANX=2.059*QUANM**-.5304
      IF (QUANM.LT.25.) QUANX=.50
      MARKX=-.015*SQRT(XARE)+.03
      PEXTRA=QUANX+MARKX
      GO TO 470
C
C*****MATERIAL TYPE IS STAINLESS STEEL (301, 17-7PH) *****
C
  240 CONTINUE
      MBASE=.96
      GO TO (250,40,260,40,40,40,40,40), KEY
C
C     MATERIAL FORM IS FASTENER
C
C     ANALYSIS ASSUMES FASTENER IS A BOLT
  250 CONTINUE
      AMUV=1.1
      PBASE=39.00
      GO TO 470
C
C     MATERIAL IS FOIL, SHEET, OR PLATE
C
C     ANALYSIS IS BASED ON AN AVERAGE PRICE FOR TYPE 301 AND 17-7PH
C     STAINLESS STEEL
  260 CONTINUE
      AMUV=1.1
      QUANM=QUANM*AMUV
      IF (THK.GE..1875) GO TO 270
      PBASE=.892*THK**-.0654
      QUANX=0
      IF (QUANM.LT.2000.) QUANX=.939*EXP(-.00206*QUANM)
      IF (QUANM.LT.100.) QUANX=-.007*QUANM+1.475
      PROTX=-2.182*THK+.187
      IF (PROTX.LT.0) PROTX=0
      PEXTRA=QUANX+PROTX
      GO TO 280
  270 CONTINUE
      PBASE=.832
      IF (THK.LT..375) PBASE=-.3867*THK+.977
      QUANX=0
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      IF (QUANM.LT.10000.) QUANX=.055
      IF (QUANM.LT.1500.) QUANX=.8738*EXP(-.0012*QUANM)
      IF (QUANM.LT.100.) QUANX=-.007*QUANM+1.475
      MARKX=.01
      PEXTRA=QUANX+MARKX
  280 CONTINUE
      GO TO 470
C
C*****MATERIAL TYPE IS TITANIUM (TI-6AL-4V) *****
C
  290 CONTINUE
      MBASE=8.50
      GO TO (300,40,310,340,40,40,40,40), KEY
C
C     MATERIAL FORM IS FASTENER
C
C     ANALYSIS ASSUMES FASTENER IS A BOLT
  300 CONTINUE
      AMUV=1.1
      PBASE=104.00
      GO TO 470
C
C     MATERIAL FORM IS FOIL, SHEET, OR PLATE
C
C     ANALYSIS IS BASED ON THE 6AL-4V TITANIUM ALLOY
  310 CONTINUE
      AMUV=1.1
      QUANM=QUANM*AMUV
      IF (THK.GE..1875) GO TO 320
      PBASE=6.00
      LENGX=.0124*LENG-.935
      IF (LENG.LT.76.) LENGX=0
      WIDTX=4.121*EXP(.0056*WIDT)
      THKX=.218*THK**-.995
      IF (THK.LT..018) THKX=12.00
      PBASE=PBASE+LENGX+WIDTX+THKX
      QUANX=-.50
      IF (QUANM.LT.10000.) QUANX=-.000108*QUANM+.540
      IF (QUANM.LT.200.) QUANX=.75
      TOLX=.116*THK**-.705
      IF (THK.LT..010) TOLX=3.00
      HEATX=2.102*EXP(-5.502*THK)
      PEXTRA=QUANX+TOLX+HEATX
      GO TO 330
  320 CONTINUE
      PBASE=3.25
      LENGX=.00138*LENG-.0875
      IF (LENG.LT.76.) LENGX=0
      WIDTX=1.294*WIDT**-.0708
      THKX=.709*THK**-.579
      IF (THK.LT..167) THKX=2.00
      PBASE=PBASE+LENGX+WIDTX+THKX
      QUANX=0
      IF (QUANM.LT.4000.) QUANX=-.000184*QUANM+.811
      IF (QUANM.LT.200.) QUANX=1.00
      FLATX=.35
      HEATX=-.096*THK+1.108
      USONX=.15
```

```
      PEXTRA=QUANX+FLATX+HEATX+USONX
  330 CONTINUE
      GO TO 470
C
C     MATERIAL FORM IS WIRE, ROD, OR BAR
C
C     ANALYSIS IS BASED ON THE 6AL-4V TITANIUM ALLOY
  340 CONTINUE
      PBASE=2.10
      AMUV=1.1
      QUANM=QUANM*AMUV
      LENGX=.0058*LENG+.084
      SIZEX=3.11
      IF (THK.GE..5) SIZEX=2.292*THK**-.444
      PBASE=PBASE+LENGX+SIZEX
      QUANX=0
      IF (QUANM.LT.4000.) QUANX=-.000184*QUANM+.811
      IF (QUANM.LT.200.) QUANX=1.00
      TOLX=.25
      HEATX=1.22
      IF (THK.GE.1.) HEATX=.528*THK**-.3655
      USONX=.10
      PEXTRA=QUANX+TOLX+HEATX+USONX
      GO TO 470
C
C*****MATERIAL TYPE IS INCONEL 718 *****
  350 CONTINUE
      MBASE=6.00
      GO TO 40
C
C*****MATERIAL TYPE IS HASTELLOY X *****
  360 CONTINUE
      MBASE=15.00
      GO TO 40
C
C*****MATERIAL TYPE IS RENE 41 *****
  370 CONTINUE
      MBASE=8.00
      GO TO 40
C
C*****MATERIAL TYPE IS TD NICR *****
  380 CONTINUE
      MBASE=105.00
      GO TO 40
C
C*****MATERIAL TYPE IS COATED COLUMBIUM ALLOY CB 752 *****
  390 CONTINUE
      MBASE=110.00
      GO TO 40
C
C*****MATERIAL TYPE IS COATED COLUMBIUM ALLOY C 129Y *****
  400 CONTINUE
      MBASE=110.00
      GO TO 40
C
C*****MATERIAL TYPE IS HAYNES 188 *****
  410 CONTINUE
      MBASE=15.00
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      GO TO 40
C
C*****MATERIAL TYPE IS COATED TANTALUM *****
  420 CONTINUE
      MBASE=90.00
      GO TO 40
C
C*****MATERIAL TYPE IS MAGNESIUM *****
  430 CONTINUE
      MBASE=1.50
      GO TO 40
C
C*****MATERIAL TYPE IS BERYLLIUM *****
  440 CONTINUE
      MBASE=150.00
      GO TO 40
C
C*****MATERIAL TYPE IS L-605 *****
  450 CONTINUE
      MBASE=15.00
      GO TO 40
C
C
C     DETERMINATION OF TOTAL PRICE FOR MATERIAL
C
  460 CONTINUE
      PBASE=PBASE*MBASE/ALBASE
  470 CONTINUE
      IF (PBASE.EQ.0) PEXTRA=0
      COSWT=PBASE+PEXTRA
  480 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE ASTDHR
C
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3
      COMMON/MATL/
     1CPERIM    ,HEIGHT    ,KEY       ,LENGT     ,WIDT
      COMMON/STDHR/
     1EOP       ,LARATE    ,MATLID    ,NN        ,PI        ,REFCT     ,
     2STDHR     ,VRATE
      COMMON/WTA/
     1A         ,B         ,CHORD     ,DIABH1    ,DIAPOH    ,DIARGH    ,
     2DIAPGH    ,DIAPTH    ,
     3DLPANL    ,DWPANL    ,EEDGE     ,E1RIB     ,E2RIB     ,E3RIB     ,
     4GBOLT     ,GCLAMP    ,GINSRT    ,GINSUL    ,GNUTPL    ,GWASH     ,
     5HBEAMA    ,HFNG1     ,HFNG2     ,HPLATE    ,HPOST     ,HRIB      ,
     6HRING     ,IDFNG1    ,IDFNG2    ,KINDP     ,KINDS     ,LBMLA     ,
     7LBMLC     ,LBMSA     ,LBMSC     ,LCORN     ,LDOUBR    ,LENGTH    ,
     8LPANL     ,LPOST     ,LRIBL     ,LRIBS     ,LSEAL     ,LSTFNR    ,
     9LTUBE     ,NRIBS     ,NXA       ,NYA       ,ODFNG1    ,ODFNG2    ,
     $ODPOSR    ,ODPOST    ,ODRING    ,PBM       ,PCORE     ,PEDGE     ,
     $PINS1     ,PINS2     ,PINS3     ,PPOST     ,PRIB      ,PSEAL     ,
     $PSKIN1    ,PSKIN2    ,PTUBE     ,R         ,RADIUS    ,S         ,
     $TBMLA     ,TBMLC     ,TBMSA     ,TBMSC     ,TCORE     ,TCORN     ,
     $TDOUBC    ,TDOUBP    ,TEDGE     ,TFNG1     ,TPLATE    ,TPLUG     ,
     $TPOST     ,TRIBL     ,TRIBS     ,TRING1    ,TRING2    ,TSEAL     ,
     $TTUBE     ,TWRIB     ,T1RIB     ,T2RIB     ,WBEAMA    ,WBMLA     ,
     $WBMLC     ,WBMSA     ,WBMSC     ,WCORN     ,WCORR     ,WDOUBP    ,
     $WDOUBR    ,WIDTH     ,WPANL     ,WPLATE    ,WPOST     ,WRIBL     ,
     $WRIBS     ,WSEAL     ,WSTFNR    ,ZFAS
      COMMON/WTCOST/
     1ACWT      ,AMUV      ,AOP(7,7)  ,ITL       ,KK        ,KLIC      ,
     2COSWT     ,KT        ,LEN       ,LTUBER    ,MAWT      ,N         ,
     3PEXT      ,TEXT      ,WID       ,ZZUB
C
      DIMENSION FMAT(15)
C
      REAL LARATE ,MAWT              ,LBMLA    ,LBMLC    ,LBMSA  ,LBMSC    ,LCORN
      REAL LDOUBR ,LEN     ,LENGTH   ,LPANL    ,LPOST    ,LRIBL  ,LRIBS    ,LSEAL
      REAL LSTFNR ,LTUBE   ,LTUBER   ,NXA      ,NYA
      REAL LBURR  ,LENGT   ,LROUT    ,LSAW     ,LSCRIB   ,NHOLE
C
      DATA FMAT
     1/ 1.0, 4.2, 4.2, 4.0, 4.2, 5.0, 6.0, 6.0, 4.2, 6.0, 3.8, 4.2, 4.0,
     2  5.0, 4.2 /
C
      SDHR05=0
      SDHR08=0
      SDHR10=0
      SDHR11=0
      SDHR12=0
      SDHR14=0
      SDHR15=0
      SDHR16=0
      SDHR17=0
      SDHR18=0
      SDHR26=0
      SDHR32=0
      SDHR36=0
      SDHR37=0
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      SDHR38=0
      SDHR39=0
      SDHR40=0
      SDHR41=0
      SDHR43=0
      SDHR48=0
      SDHR53=0
      SDHR71=0
      SDHR75=0
      SDHR80=0
      SDHR82=0
      SDHR83=0
      SDHR85=0
      SDHR92=0
      SDHR97=0
      STDHR=0
      IF (ZZUB.GT.0) GO TO 10
      AMUV=0
      CAREA=0
      CLAMP=0
      COSWT=0
      CPERIM=0
      DHOLE=0
      DIA=0
      HEIGHT=0
      LARATE=0
      LBURR=0
      LENGT=0
      LROUT=0
      LSAW=0
      LSCRIB=0
      NANGLE=0
      NHOLE=0
      NSURF=2
      REFCT=0
      SAREA=0
      VRATE=0
      WIDT=0
      VOL=0
   10 CONTINUE
      IF (MATLID.GT.0.AND.MATLID.LT.16) GO TO 20
      EOP=1.
      RETURN
C
   20 CONTINUE
C
C     IDENTIFICATION OF MATERIAL TYPE AND ASSIGNMENT OF
C     MATERIAL COMPLEXITY FACTOR F
C
      F=FMAT(MATLID)
C
C     RELATE DETAIL PART TO MANUFACTURING OPERATIONS EQUATION CALLOUT
C
      IF (KK.EQ.9) GO TO 60
      IF (KK.EQ.10) GO TO 70
      IF (KK.EQ.11) GO TO 80
      IF (KK.EQ.12) GO TO 90
      IF (KK.EQ.15) GO TO 100
```

```
      IF (KK.EQ.20) GO TO 110
      IF (KK.EQ.21) GO TO 120
      IF (KK.EQ.22) GO TO 130
      IF (KK.EQ.23) GO TO 140
      IF (KK.EQ.25) GO TO 150
      IF (KK.EQ.26) GO TO 160
      IF (KK.EQ.27) GO TO 170
      IF (KK.EQ.29) GO TO 180
      IF (KK.EQ.30) GO TO 190
      IF (KK.EQ.31) GO TO 200
      IF (KK.EQ.32) GO TO 210
      IF (KK.EQ.33) GO TO 220
      IF (KK.EQ.40) GO TO 230
      IF (KK.EQ.41) GO TO 240
      IF (KK.EQ.42) GO TO 250
      IF (KK.EQ.43) GO TO 260
      IF (KK.EQ.50) GO TO 270
      IF (KK.EQ.51) GO TO 280
      IF (KK.EQ.52) GO TO 290
      IF (KK.EQ.53) GO TO 300
      IF (KK.EQ.55) GO TO 310
      IF (KK.EQ.56) GO TO 320
      IF (KK.EQ.57) GO TO 330
      IF (KK.EQ.60) GO TO 340
      IF (KK.EQ.61) GO TO 350
      IF (KK.EQ.62) GO TO 360
      IF (KK.EQ.63) GO TO 370
      IF (KK.EQ.65) GO TO 380
      IF (KK.EQ.66) GO TO 390
      IF (KK.EQ.67) GO TO 400
      IF (KK.EQ.68) GO TO 410
      IF (KK.EQ.69) GO TO 420
      IF (KK.EQ.70) GO TO 430
      IF (KK.EQ.75) GO TO 440
      IF (KK.EQ.76) GO TO 450
      IF (KK.EQ.79) GO TO 460
      IF (KK.EQ.80) GO TO 470
      IF (KK.EQ.81) GO TO 480
      IF (KK.EQ.82) GO TO 490
      IF (KK.EQ.83) GO TO 500
      IF (KK.EQ.84) GO TO 510
      IF (KK.EQ.85) GO TO 520
      IF (KK.EQ.86) GO TO 530
      IF (KK.EQ.88) GO TO 540
      IF (KK.EQ.91) GO TO 550
      IF (KK.EQ.92) GO TO 560
      IF (KK.EQ.93) GO TO 570
      IF (KK.EQ.94) GO TO 580
      IF (KK.EQ.95) GO TO 590
      IF (KK.EQ.96) GO TO 600
      IF (KK.EQ.97) GO TO 610
      IF (KK.EQ.98) GO TO 620
      IF (KK.EQ.199) GO TO 630
      EOP=1.
      GO TO 880
C
C
C     MANUFACTURING OPERATIONS EQUATION CALLOUT
```

```
C
C
   30 CONTINUE
      ASSIGN 30 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL+DLPANL
      WIDT=WPANL+DLPANL
      HEIGHT=TSKIN1
      LBURR=2.*CPERIM
      LROUT=CPERIM/3.
      DHOLE=TSKIN1
      DIA=DIABH1
      NHOLE=NXA
      GO TO (640,820,650,750,690,780,670,720,860,870), NN
   40 CONTINUE
      ASSIGN 40 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL+DLPANL
      WIDT=WPANL+DLPANL
      HEIGHT=TSKIN1
      LBURR=2.*CPERIM
      LROUT=2.*PI
      DHOLE=TSKIN1
      DIA=DIAPOH
      NHOLE=4.
      GO TO (640,820,650,750,780,840,690,670,720,860,870), NN
   50 CONTINUE
      ASSIGN 50 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL+DLPANL
      WIDT=WPANL+DLPANL
      HEIGHT=TSKIN1
      LBURR=2.*CPERIM
      LROUT=PI*ODPOST
      DHOLE=TSKIN1
      DIA=DIARGH
      NHOLE=1.
      GO TO (640,820,650,750,780,690,670,720,860,870), NN
C
C     FASTENERS
C
   60 CONTINUE
      ASSIGN 60 TO JJ
      NN=NN+1
      KEY=1
      GO TO (860,870), NN
C
C     ASSEMBLY, CORRUGATED PANEL (KINDP=1)
C
   70 CONTINUE
      ASSIGN 70 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=SQRT(RADIUS**2-(CHORD/2.)**2)+TSKIN1
```

```
      GO TO (640,840,670,770,720,860,880), NN
C
C     UPPER SKIN, CORRUGATED PANEL
C
   80 CONTINUE
      IF (KINDS.EQ.0) GO TO 30
      IF (KINDS.EQ.1) GO TO 30
      IF (KINDS.EQ.2) GO TO 40
      IF (KINDS.EQ.3) GO TO 50
      GO TO 880
C
C     CORRUGATIONS, CORRUGATED PANEL
C
   90 CONTINUE
      ASSIGN 90 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL
      WIDT=WCORR
      HEIGHT=TSKIN2
      LBURR=2.*CPERIM
      LSAW=2.8*NRIBS*SQRT(RADIUS**2-(CHORD/2)**2)
      GO TO (640,820,650,750,710,790,670,720,860,870), NN
C
C     ASSEMBLY, R S I PANEL (KINDP = 4)
C
  100 CONTINUE
      ASSIGN 100 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TCORE+TSKIN1+TSKIN2+TEXT
      NHOLE=NXA
      GO TO (640,840,840,800,670,770,720,660,840,860,880), NN
C
C     ASSEMBLY, HONEYCOMB PANEL (KINDP=2)
C
  110 CONTINUE
      ASSIGN 110 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TCORE+TSKIN1+TSKIN2
      NHOLE=NXA
      GO TO (640,840,840,800,670,770,720,860,880), NN
C
C     UPPER SKIN, HONEYCOMB PANEL
C
  120 CONTINUE
      IF (KINDS.EQ.0) GO TO 30
      IF (KINDS.EQ.1) GO TO 30
      IF (KINDS.EQ.2) GO TO 40
      IF (KINDS.EQ.3) GO TO 50
      GO TO 880
C
C     LOWER SKIN, HONEYCOMB PANEL
C
  130 CONTINUE
```

```
      ASSIGN 130 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL
      WIDT=WPANL
      HEIGHT=TSKIN2
      LBURR=2.*CPERIM
      GO TO (640,820,650,750,670,720,860,870), NN
C
C     EDGE PIECES, HONEYCOMB PANEL
C
  140 CONTINUE
      ASSIGN 140 TO JJ
      NN=NN+1
      KEY=3
      LENGT=(LPANL+WPANL)/2.
      WIDT=TCORE+EEDGE
      HEIGHT=TEDGE
      LBURR=2.*CPERIM
      GO TO (640,820,650,710,670,720,860,870), NN
C
C     ASSEMBLY, ABLATIVE PANEL (KINDP = 5)
C
  150 CONTINUE
      ASSIGN 150 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TSKIN1+TSKIN2+TEXT
      NHOLE=NXA
      GO TO (640,840,840,800,670,770,720,770,770,770,860,880), NN
C
C     PANEL REUSABLE SURFACE INSULATION
C
  160 CONTINUE
      ASSIGN 160 TO JJ
      NN=NN+1
      KEY=11
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TEXT
      F=1.0
      LSAW=2.*(LENGT+WIDT)
      GO TO (640,740,790,670,720,860,870), NN
C
C     PANEL ABLATIVE MATERIAL
C
  170 CONTINUE
      ASSIGN 170 TO JJ
      NN=NN+1
      KEY=12
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TEXT
      GO TO (640,730,720,860,870), NN
C
C     HONEYCOMB CORE
C
```

```
  180 CONTINUE
      ASSIGN 180 TO JJ
      NN=NN+1
      KEY=2
      LENGT=LPANL-EEDGE
      WIDT=WPANL-EEDGE
      HEIGHT=TCORE
      LSAW=CPERIM/2.
      VOL=.7*(MAWT-ACWT)/PCORE
      GO TO (640,790,760,670,720,860,870), NN
C
C     ASSEMBLY, RIBBED PANEL (KINDP=3)
C
  190 CONTINUE
      ASSIGN 190 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=HRIB+TSKIN1
      GO TO (640,840,840,670,770,720,860,880), NN
C
C     SKIN, RIBBED PANEL
C
  200 CONTINUE
      IF (KINDS.EQ.0) GO TO 30
      IF (KINDS.EQ.1) GO TO 30
      IF (KINDS.EQ.2) GO TO 40
      IF (KINDS.EQ.3) GO TO 50
      GO TO 880
C
C     RIBS, RIBBED PANEL
C
  210 CONTINUE
      ASSIGN 210 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LPANL-EEDGE
      WIDT=HRIB
      HEIGHT=E1RIB+TWRIB+E3RIB
      LBURR=2.*CPERIM
      GO TO (640,820,650,750,710,670,720,860,870), NN
C
C     EDGE PIECES, RIBBED PANEL
C
  220 CONTINUE
      ASSIGN 220 TO JJ
      NN=NN+1
      KEY=3
      LENGT=WPANL
      WIDT=HRIB+EEDGE
      HEIGHT=TEDGE
      LBURR=2.*CPERIM
      GO TO (640,820,650,710,670,720,860,870), NN
C
C     ASSEMBLY, INSULATION
C
  230 CONTINUE
      ASSIGN 230 TO JJ
```

```
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1+TINS2+TINS3
      GO TO (640,810,730,720,860,880), NN
C
C     INSULATION 1
C
  240 CONTINUE
      ASSIGN 240 TO JJ
      NN=NN+1
      KEY=0
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1
      LSAW=2.*(LENGT+WIDT)
      GO TO (640,790,720,860,870), NN
C
C     INSULATION 2
C
  250 CONTINUE
      ASSIGN 250 TO JJ
      NN=NN+1
      KEY=0
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS2
      LSAW=2.*(LENGT+WIDT)
      GO TO (640,790,720,860,870), NN
C
C     INSULATION 3
C
  260 CONTINUE
      ASSIGN 260 TO JJ
      NN=NN+1
      KEY=0
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS3
      LSAW=2.*(LENGT+WIDT)
      GO TO (640,790,720,860,870), NN
C
C     ASSEMBLY, STRUCTURE A (KINDS=1)
C
  270 CONTINUE
      ASSIGN 270 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1+TINS2+TINS3+B
      NHOLE=NXA
      GO TO (640,810,660,730,840,810,660,810,660,810,660,730,680,670,800
     1,800,730,860,880), NN
C
C     BEAM, LONG A
C
  280 CONTINUE
      ASSIGN 280 TO JJ
```

```
      NN=NN+1
      KEY=3
      LENGT=LBMLA
      WIDT=WBMLA
      HEIGHT=TBMLA
      LBURR=2.*CPERIM
      DHOLE=TBMLA
      DIA=DIABH1
      NHOLE=2.*NXA+2.
      GO TO (640,820,650,710,690,670,720,860,870), NN
C
C     BEAM DOUBLER CHANNEL, LONG A
C
  290 CONTINUE
      ASSIGN 290 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LDOUBR
      WIDT=WDOUBR
      HEIGHT=TDOUBC
      LBURR=2.*CPERIM
      DHOLE=TBMLA
      DIA=DIABH1
      NHOLE=1.
      GO TO (640,820,650,710,690,670,720,860,870), NN
C
C     BEAM, SHORT A
C
  300 CONTINUE
      ASSIGN 300 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LBMSA
      WIDT=WBMSA
      HEIGHT=TBMSA
      LBURR=2.*CPERIM
      DHOLE=TBMSA
      DIA=DIABH1
      NHOLE=2.*NYA
      GO TO (640,650,710,690,670,720,860,870), NN
C
C     POST, CORNER POST A
C
  310 CONTINUE
      ASSIGN 310 TO JJ
      NN=NN+1
      KEY=4
      LENGT=LPOST
      WIDT=ODPOST
      HEIGHT=ODPOST
      LBURR=4.*PI*ODPOST
      LSAW=ODPOST
      VOL=.7*(MAWT-ACWT)/PPOST
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     FLANGE, CORNER POST A
C
  320 CONTINUE
```

```
      ASSIGN 320 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODFNG1
      WIDT=ODFNG1
      HEIGHT=LTUBE
      LBURR=4.*PI*ODFNG1
      LSAW=ODFNG1
      UOL=.8*(MAWT-ACWT)/PTUBE
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     PLUG, CORNER POST A
C
  330 CONTINUE
      ASSIGN 330 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODPOST
      WIDT=ODPOST
      HEIGHT=TPLUG
      LBURR=4.*PI*ODPOST
      LSAW=ODPOST
      DHOLE=TPLUG
      DIA=DIAPGH
      NHOLE=1.
      UOL=.8*(MAWT-ACWT)/PPOST
      GO TO (640,790,830,700,670,720,860,870), NN
C
C     CORNER PIECE
C
  340 CONTINUE
      ASSIGN 340 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LCORN
      WIDT=WCORN
      HEIGHT=TCORN
      LBURR=2.*CPERIM
      LROUT=2.83*S+2.83*R
      GO TO (640,820,650,780,710,670,720,860,870), NN
C
C     UPPER CORNER PLATE
C
  350 CONTINUE
      ASSIGN 350 TO JJ
      NN=NN+1
      KEY=3
      LENGT=WPLATE+2.*HPLATE
      WIDT=WPLATE+2.*HPLATE
      HEIGHT=TPLATE
      LBURR=2.*CPERIM
      DHOLE=TPLATE
      DIA=DIAPTH
      NHOLE=1.
      GO TO (640,820,650,690,670,720,860,870), NN
C
C     LOWER CORNER PLATE
C
```

```
  360 CONTINUE
      ASSIGN 360 TO JJ
      NN=NN+1
      KEY=3
      LENGT=WPLATE+2.*HPLATE
      WIDT=WPLATE+2.*HPLATE
      HEIGHT=TPLATE
      LBURR=2.*CPERIM
      DHOLE=TPLATE
      DIA=DIAPGH
      NHOLE=1.
      GO TO (640,820,650,690,670,720,860,870), NN
C
C     CORNER DOUBLER PLATE
C
  370 CONTINUE
      ASSIGN 370 TO JJ
      NN=NN+1
      KEY=3
      LENGT=WDOUBP
      WIDT=WDOUBP
      HEIGHT=TDOUBP
      LBURR=2.*CPERIM
      DHOLE=TPLATE
      DIA=DIAPGH
      NHOLE=1.
      GO TO (640,820,650,690,670,720,860,870), NN
C
C     ASSEMBLY, LONG BEAM A
C
  380 CONTINUE
      ASSIGN 380 TO JJ
      NN=NN+1
      LENGT=LBMLA
      WIDT=WBEAMA
      HEIGHT=HBEAMA
      GO TO (640,840,840,670,770,720,860,880), NN
C
C     ASSEMBLY, SHORT BEAM A
C
  390 CONTINUE
      ASSIGN 390 TO JJ
      NN=NN+1
      LENGT=LBMSA
      WIDT=WBEAMA
      HEIGHT=HBEAMA
      GO TO (640,840,670,770,720,860,880), NN
C
C     ASSEMBLY, CORNER
C
  400 CONTINUE
      ASSIGN 400 TO JJ
      NN=NN+1
      LENGT=WPLATE+2.*HPLATE
      WIDT=WPLATE+2.*HPLATE
      HEIGHT=HBEAMA
      GO TO (640,840,840,670,770,720,860,880), NN
C
```

```
C     ASSEMBLY, CORNER POST A
C
  410 CONTINUE
      ASSIGN 410 TO JJ
      NN=NN+1
      LENGT=LPOST+TPLUG
      WIDT=ODFNG1
      HEIGHT=ODFNG1
      GO TO (640,840,840,840,670,770,720,860,880), NN
C
C     SEAL STRIP
C
  420 CONTINUE
      ASSIGN 420 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LSEAL
      WIDT=WSEAL
      HEIGHT=TSEAL
      LBURR=2.*CPERIM
      DHOLE=TSEAL
      DIA=DIABH1
      NHOLE=NYA
      GO TO (640,820,650,690,710,670,720,860,870), NN
C
C     ASSEMBLY, STRUCTURE B (KINDS=2)
C
  430 CONTINUE
      ASSIGN 430 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1+TINS2+TINS3+B
      NHOLE=4.
      GO TO (640,810,810,660,730,680,670,800,730,860,880), NN
C
C     POST, CORNER POST B
C
  440 CONTINUE
      ASSIGN 440 TO JJ
      NN=NN+1
      KEY=3
      LENGT=2.*LPOST+3.*WPOST
      WIDT=HPOST+2.*WSTFNR
      HEIGHT=TPOST
      LBURR=3.*CPERIM
      LROUT=CPERIM-4.*LSTFNR
      DHOLE=TPOST
      DIA=DIAPOH
      NHOLE=3.
      GO TO (640,820,650,780,690,710,670,720,860,870), NN
C
C     ASSEMBLY, CORNER POST B
C
  450 CONTINUE
      ASSIGN 450 TO JJ
      NN=NN+1
      LENGT=LPOST
```

```
      WIDT=WPOST
      HEIGHT=HPOST
      GO TO (640,840,670,770,720,860,880), NN
C
C     INSULATORS
C
  460 CONTINUE
      ASSIGN 460 TO JJ
      NN=NN+1
      KEY=0
      GO TO (860,870), NN
C
C     ASSEMBLY, STRUCTURE C (KINDS=3)
C
  470 CONTINUE
      ASSIGN 470 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1+TINS2+TINS3+B
      NHOLE=1.
      GO TO (640,810,660,730,800,810,660,810,660,730,680,670,800,800,730
     1,860,880), NN
C
C     BEAM, LONG C
C
  480 CONTINUE
      ASSIGN 480 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LBMLC
      WIDT=WBMLC
      HEIGHT=TBMLC
      LBURR=2.*CPERIM
      GO TO (640,820,650,670,720,860,870), NN
C
C     RIB, LONG C
C
  490 CONTINUE
      ASSIGN 490 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LRIBL
      WIDT=WRIBL
      HEIGHT=TRIBL
      LBURR=2.*CPERIM
      GO TO (640,820,650,670,720,860,870), NN
C
C     BEAM, SHORT C
C
  500 CONTINUE
      ASSIGN 500 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LBMSC
      WIDT=WBMSC
      HEIGHT=TBMSC
      LBURR=2.*CPERIM
```

```
      GO TO (640,820,650,670,720,860,870), NN
C
C     RIB, SHORT C
C
  510 CONTINUE
      ASSIGN 510 TO JJ
      NN=NN+1
      KEY=3
      LENGT=LRIBS
      WIDT=WRIBS
      HEIGHT=TRIBS
      LBURR=2.*CPERIM
      GO TO (640,820,650,670,720,860,870), NN
C
C     POST, CENTER POST C
C
  520 CONTINUE
      ASSIGN 520 TO JJ
      NN=NN+1
      KEY=4
      LENGT=LTUBER
      WIDT=ODPOSR
      HEIGHT=ODPOSR
      LBURR=4.*PI*ODPOSR
      LSAW=ODPOSR
      VOL=.7*(MAWT-ACWT)/PPOST
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     FLANGE (LOWER), CENTER POST C
C
  530 CONTINUE
      ASSIGN 530 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODFNG2
      WIDT=ODFNG2
      HEIGHT=HFNG2
      LBURR=4.*PI*ODFNG2
      LSAW=ODPOSR
      UOL=.8*(MAWT-ACWT)/PPOST
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     FLANGE (UPPER), CENTER POST C
C
  540 CONTINUE
      ASSIGN 540 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODPOSR
      WIDT=ODPOSR
      HEIGHT=HRING
      LBURR=4.*PI*ODPOSR
      LSAW=ODFNG2
      DHOLE=TRING2
      DIA=DIARGH
      NHOLE=1.
      UOL=.8*(MAWT-ACWT)/PTUBE
      GO TO (640,790,650,830,700,670,720,860,870), NN
```

```
C
C     ASSEMBLY, LONG BEAM C
C
  550 CONTINUE
      ASSIGN 550 TO JJ
      NN=NN+1
      LENGT=LBMLC
      WIDT=WBMLC
      HEIGHT=WRIBL+TBMLC
      GO TO (640,840,670,770,720,860,880), NN
C
C     ASSEMBLY, SHORT BEAM C
C
  560 CONTINUE
      ASSIGN 560 TO JJ
      NN=NN+1
      LENGT=LBMSC
      WIDT=WBMSC
      HEIGHT=WRIBS+TBMSC
      GO TO (640,840,670,770,720,860,880), NN
C
C     ASSEMBLY, CENTER POST C
C
  570 CONTINUE
      ASSIGN 570 TO JJ
      NN=NN+1
      LENGT=LTUBER
      WIDT=ODFNG2
      HEIGHT=ODFNG2
      GO TO (640,840,840,670,770,720,860,880), NN
C
C     ASSEMBLY, CORNER POST C
C
  580 CONTINUE
      ASSIGN 580 TO JJ
      NN=NN+1
      LENGT=LPOST
      WIDT=ODFNG1
      HEIGHT=ODFNG1
      GO TO (640,840,840,840,670,770,720,860,880), NN
C
C     POST, CORNER POST C
C
  590 CONTINUE
      ASSIGN 590 TO JJ
      NN=NN+1
      KEY=4
      LENGT=LPOST
      WIDT=ODPOST
      HEIGHT=ODPOST
      LBURR=4.*PI*ODPOST
      LSAW=ODPOST
      VOL=.7*(MAWT-ACWT)/PPOST
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     FLANGE (LOWER), CORNER POST C
C
  600 CONTINUE
```

```
      ASSIGN 600 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODFNG1
      WIDT=ODFNG1
      HEIGHT=HFNG1
      LBURR=4.*PI*ODFNG1
      LSAW=ODRING
      UOL=.8*(MAWT-ACWT)/PPOST
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     PLUG, CORNER POST C
C
  610 CONTINUE
      ASSIGN 610 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODPOST
      WIDT=ODPOST
      HEIGHT=TPLUG
      LBURR=4.*PI*ODPOST
      LSAW=ODPOST
      DHOLE=TPLUG
      DIA=DIAPGH
      NHOLE=1.
      UOL=.8*(MAWT-ACWT)/PPOST
      GO TO (640,790,830,700,670,720,860,870), NN
C
C     RING (UPPER), CORNER POST C
C
  620 CONTINUE
      ASSIGN 620 TO JJ
      NN=NN+1
      KEY=4
      LENGT=ODRING
      WIDT=ODRING
      HEIGHT=TRING1
      LBURR=4.*PI*ODRING
      LSAW=ODFNG1
      UOL=.8*(MAWT-ACWT)/PTUBE
      GO TO (640,790,650,830,670,720,860,870), NN
C
C     ASSEMBLY, COMPLETE TPS SYSTEM ASSEMBLY
C
  630 CONTINUE
      ASSIGN 630 TO JJ
      NN=NN+1
      LENGT=LENGTH
      WIDT=WIDTH
      HEIGHT=TINS1+TINS2+TINS3+B
      NHOLE=ZFAS
      GO TO (640,810,660,730,680,670,800,730,860,880), NN
C
C
C     INITIALIZE DETAIL PART VARIABLES
C
  640 CONTINUE
      CAREA=LENGT*WIDT
```

```
      CPERIM=2.*(LENGT+WIDT)
      IF (CPERIM.LT.3.) CPERIM=3.
      CLAMP=CPERIM/6.
      LSCRIB=CPERIM
      ATTPS=LEN*WID
      SHPSET=1.
      NUMP=(KT*ATTPS*SHPSET/(LEN*WID))+.5
      SAREA=2.*(LENGT*WIDT+LENGT*HEIGHT+WIDT*HEIGHT)
      FDRILL=(.0017*EXP(1.16*DIA)+.0062*DHOLE**1.89)*F
      GO TO JJ
C
C
C     MANUFACTURING OPERATION EQUATIONS
C
C     BURRING, EDGE
C
  650 SDHR05=(.01+.0007*F*LBURR)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     CLAMPING
C
  660 SDHR08=.035*CLAMP*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     CLEANING, BASKET (DEGREASE)
C
  670 SDHR10=(.0000626*CPERIM-.000179)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     CLEANUP, ASSEMBLY
C
      SDHR11=.01*NHOLE*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     DISASSEMBLY
C
  680 SDHR12=.012*CLAMP*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     DRILLING, SINGLE SPINDLE
C
  690 SDHR14=.25+(.013*EXP(.00096*CAREA)+NHOLE*FDRILL)*NUMP
      LARATE=4.75
```

```
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     DRILLING AND REAMING OR TAPPING, SINGLE SPINDLE
C
  700 SDHR14=.25+(.013*EXP(.00096*CAREA)+NHOLE*FDRILL)*NUMP
      SDHR15=SDHR14*1.25
      SDHR14=0
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     DRILLING, ASSEMBLY
C
      SDHR16=(.0017*EXP(1.16*DIA)+.0062*DHOLE**1.89)*F*NHOLE*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     FORMING, HOT PRESS FORMING SHEET STOCK
C
  710 SDHR17=.08+(.0396+.0000392*CAREA)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     FORMING, STRETCH FORMING EXTRUDED STOCK
C
      SDHR18=.52+(.082+.0004*LENGT)*F*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     HEAT TREATMENT AND STRAIGHTENING
C
      SDHR26=(.0142+.0024*LENGT)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     IDENTIFICATION, RUBBER OR STEEL STAMP
C
  720 SDHR32=.07+.0032*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     INSPECTION, ASSEMBLY
C
      SDHR36=.0008*NHOLE*NUMP
      LARATE=4.75
```

```
      REFCT=.40                                                        AST1045
      VRATE=1.75                                                       AST1046
      GO TO 850                                                        AST1047
C                                                                      AST1048
C     INSPECTION                                                       AST1049
C                                                                      AST1050
  730 SDHR37=(.001157+.0000333*CAREA)*NUMP                             AST1051
      LARATE=4.75                                                      AST1052
      REFCT=.40                                                        AST1053
      VRATE=1.75                                                       AST1054
      GO TO 850                                                        AST1055
C                                                                      AST1056
C     LAYOUT PART, SHEET METAL                                         AST1057
C                                                                      AST1058
  740 SDHR38=.015+(.008+.0006*LSCRIB)*NUMP                             AST1059
      LARATE=4.75                                                      AST1060
      REFCT=.40                                                        AST1061
      VRATE=1.75                                                       AST1062
      GO TO 850                                                        AST1063
C                                                                      AST1064
C     LAYOUT HOLES, SHEET METAL                                        AST1065
C                                                                      AST1066
      SDHR39=.015+(.008+.002*NHOLE)*NUMP                               AST1067
      LARATE=4.75                                                      AST1068
      REFCT=.40                                                        AST1069
      VRATE=1.75                                                       AST1070
      GO TO 850                                                        AST1071
C                                                                      AST1072
C     LAYOUT HOLES, MACHINE SHOP                                       AST1073
C                                                                      AST1074
      SDHR40=(.053+.031*NHOLE)*NUMP                                    AST1075
      LARATE=4.75                                                      AST1076
      REFCT=.40                                                        AST1077
      VRATE=1.75                                                       AST1078
      GO TO 850                                                        AST1079
C                                                                      AST1080
C     LAYOUT PART, MACHINE SHOP                                        AST1081
C                                                                      AST1082
      SDHR41=.18+(.053+.004*LSCRIB+.012*NANGLE)*NUMP                   AST1083
      LARATE=4.75                                                      AST1084
      REFCT=.40                                                        AST1085
      VRATE=1.75                                                       AST1086
      GO TO 850                                                        AST1087
C                                                                      AST1088
C     MILLING, CHEMICAL                                                AST1089
C                                                                      AST1090
  750 SDHR43=.1+.0164*CAREA**.442*NUMP                                 AST1091
      LARATE=4.75                                                      AST1092
      REFCT=.40                                                        AST1093
      VRATE=1.75                                                       AST1094
      GO TO 850                                                        AST1095
C                                                                      AST1096
C     MILLING, STRADDLE                                                AST1097
C                                                                      AST1098
  760 SDHR48=.925+(.1563+.0001251*CAREA+(.0216+.01413*VOL)*F)*NUMP     AST1099
      LARATE=4.75                                                      AST1100
      REFCT=.40                                                        AST1101
      VRATE=1.75                                                       AST1102
```

```
      GO TO 850
C
C     PAINTING, ONE COAT
C
  770 SDHR53=.10+(.0016*NSURF+.00003*SAREA)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     ROUTING, EDGE (SINGLE PIECE)
C
  780 SDHR71=.36+(.0267+.0019*LROUT*F)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     SAWING, CROSS CUT
C
  790 SDHR75=.16+.0036*EXP(.00153*CAREA)+.0002*LSAW*F*NUMP+(NUMP-1.)*(.0
     17+.0026*EXP(.00049*CAREA))
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     SECURING
C
  800 SDHR80=.0023*NHOLE*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     SETUP, ASSEMBLY
C
  810 SDHR82=.25+(.013*EXP(.00096*CAREA))*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     SHEARING TO SIZE
C
  820 SDHR83=.05+(.00103+.0000066*CAREA)*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
C
C     SURFACE TREATMENTS
C
      SDHR85=(.0019*EXP(.0189*LENGT))*NUMP
      LARATE=4.75
      REFCT=.40
      VRATE=1.75
      GO TO 850
```

```
C                                                                       AST1161
C     TURNING, TURRET LATHE                                             AST1162
C                                                                       AST1163
  830 SDHR48=.925+(.1563+.0001251*CAREA+(.0216+.01413*VOL)*F)*NUMP      AST1164
      SDHR92=SDHR48                                                     AST1165
      SDHR48=0                                                          AST1166
      LARATE=4.75                                                       AST1167
      REFCT=.40                                                         AST1168
      VRATE=1.75                                                        AST1169
      GO TO 850                                                         AST1170
C                                                                       AST1171
C     WELDING - BRAZING                                                 AST1172
C                                                                       AST1173
  840 SDHR97=.1+.026*NUMP                                               AST1174
      LARATE=4.75                                                       AST1175
      REFCT=.40                                                         AST1176
      VRATE=1.75                                                        AST1177
      GO TO 850                                                         AST1178
C                                                                       AST1179
C                                                                       AST1180
C     SUMMATION OF STANDARD HOURS                                       AST1181
C                                                                       AST1182
  850 CONTINUE                                                          AST1183
      STDHR=SDHR05+SDHR08+SDHR10+SDHR11+SDHR12+SDHR14+SDHR15+SDHR16+SDHRAST1184
     117+SDHR18+SDHR26+SDHR32+SDHR36+SDHR37+SDHR38+SDHR39+SDHR40+SDHR41+AST1185
     2SDHR43+SDHR48+SDHR53+SDHR71+SDHR75+SDHR80+SDHR82+SDHR83+SDHR85+SDHAST1186
     3R92+SDHR97                                                        AST1187
      GO TO 880                                                         AST1188
  860 CONTINUE                                                          AST1189
      EOP=1.                                                            AST1190
      GO TO JJ                                                          AST1191
  870 CONTINUE                                                          AST1192
      CALL AMATL                                                        AST1193
  880 CONTINUE                                                          AST1194
      RETURN                                                            AST1195
      END                                                               AST1196-
```

```
      SUBROUTINE COST
C
      COMMON/COMTOT/
     1AT        ,BT        ,CT        ,CF1       ,EGTH      ,ETA       ,
     2FTH       ,FTS       ,K1        ,K2        ,K3        ,NPA       ,
     3OS        ,STPS      ,TUNWT
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3,XDST
      COMMON/STDHR/
     1EOP       ,LARATE    ,MATLID    ,NN        ,PI        ,REFCT     ,
     2STDHR     ,VRATE
      COMMON/WTA/
     1A         ,B         ,CHORD     ,DIABH1    ,DIAPOH    ,DIARGH    ,
     2DIAPGH    ,DIAPTH    ,
     3DLPANL    ,DWPANL    ,EEDGE     ,E1RIB     ,E2RIB     ,E3RIB     ,
     4GBOLT     ,GCLAMP    ,GINSRT    ,GINSUL    ,GNUTPL    ,GWASH     ,
     5HBEAMA    ,HFNG1     ,HFNG2     ,HPLATE    ,HPOST     ,HRIB      ,
     6HRING     ,IDFNG1    ,IDFNG2    ,KINDP     ,KINDS     ,LBMLA     ,
     7LBMLC     ,LBMSA     ,LBMSC     ,LCORN     ,LDOUBR    ,LENGTH    ,
     8LPANL     ,LPOST     ,LRIBL     ,LRIBS     ,LSEAL     ,LSTFNR    ,
     9LTUBE     ,NRIBS     ,NXA       ,NYA       ,ODFNG1    ,ODFNG2    ,
     $ODPOSR    ,ODPOST    ,ODRING    ,PBM       ,PCORE     ,PEDGE     ,
     $PINS1     ,PINS2     ,PINS3     ,PPOST     ,PRIB      ,PSEAL     ,
     $PSKIN1    ,PSKIN2    ,PTUBE     ,R         ,RADIUS    ,S         ,
     $TBMLA     ,TBMLC     ,TBMSA     ,TBMSC     ,TCORE     ,TCORN     ,
     $TDOUBC    ,TDOUBP    ,TEDGE     ,TFNG1     ,TPLATE    ,TPLUG     ,
     $TPOST     ,TRIBL     ,TRIBS     ,TRING1    ,TRING2    ,TSEAL     ,
     $TTUBE     ,TWRIB     ,T1RIB     ,T2RIB     ,WBEAMA    ,WBMLA     ,
     $WBMLC     ,WBMSA     ,WBMSC     ,WCORN     ,WCORR     ,WDOUBP    ,
     $WDOUBR    ,WIDTH     ,WPANL     ,WPLATE    ,WPOST     ,WRIBL     ,
     $WRIBS     ,WSEAL     ,WSTFNR    ,ZFAS
      COMMON/WTCOST/
     1ACWT      ,AMUV      ,AOP(7,7)  ,ITL       ,KK        ,KLIC      ,
     2COSWT     ,KT        ,LEN       ,LTUBER    ,MAWT      ,N         ,
     3PEXT      ,TEXT      ,WID       ,ZZUB
      COMMON/ZERO/
     1LABHR     ,LACOST    ,TACWT     ,TALABH    ,TASTDH    ,TASYCO    ,
     2TFCOST    ,TLACOS    ,TLBHR     ,TMAWT     ,TSTDHR    ,TTFCOS    ,
     3TTLACO    ,TTLBHR    ,TTMCOS    ,TTSHR     ,TTVCOS    ,TVCOST    ,
     4VCOST
C
      DIMENSION ANAM(2,38), MTYPE(5,15)
C
      REAL LTUBER ,LABHR  ,LACOST ,LARATE ,MAWT   ,MATCOS,MUV    ,LEN
C
      DATA (ANAM(I),I=1,8)
     1/ 6HINSULA, 6HTION  , 6H INSUL, 6H1     , 6H INSUL, 6H2     ,
     2  6H INSUL, 6H3     /
      DATA (ANAM(I),I=9,20)
     1/ 6HPANEL , 6H      , 6H CORRU, 6HGNS   , 6H EDGES, 6H      ,
     2  6H CORE , 6H      , 6H RIBS , 6H      , 6H SKIN , 6H      /
      DATA (ANAM(I),I=21,72)
     1/ 6HSTRUCT, 6HURE   , 6H BEAM , 6HLN A  , 6H BEAM , 6HSH A  ,
     2  6H CORNE, 6HR     , 6H INSER, 6HTS    , 6H POST , 6HCORN  ,
     3  6H SEAL , 6H      , 6H INSUL, 6HATOR  , 6H BEAM , 6HLN C  ,
     4  6H BEAM , 6HSH C  , 6H POST , 6HCENT  , 6H FASTE, 6HNERS  ,
     5  6H INS A, 6HSSY   , 6H PANL , 6HASSY  , 6H BEAM , 6HDOUB  ,
     6  6H BEAM , 6HASSY  , 6H RIB L, 6HN C   , 6H RIB S, 6HH C   ,
     7  6H CORN , 6HPLT   , 6H CORN , 6HDOUB  , 6H CORN , 6HASSY  ,
```

```
     8  6H RING , 6H      , 6H FLANG, 6HE     , 6H POST , 6HASSY  ,
     9  6H PLUG , 6H      , 6H STR A, 6HSSY   /
      DATA (ANAM(I),I=73,76)
     1/ 6H R S I, 6H      , 6H ABLAT, 6HIVE   /
      DATA MTYPE /
     1 6H ALUMI, 6HNUM   , 6H      , 6H      , 6H      ,
     2 6H TITAN, 6HIUM   , 6H      , 6H      , 6H      ,
     3 6H INCON, 6HEL 718, 6H      , 6H      , 6H      ,
     4 6H HASTE, 6HLLOY X, 6H      , 6H      , 6H      ,
     5 6H RENE , 6H41    , 6H      , 6H      , 6H      ,
     6 6H TD NI, 6HCR    , 6H      , 6H      , 6H      ,
     7 6H COATE, 6HD COLU, 6HMBIUM , 6HALLOY , 6HCB 752,
     8 6H COATE, 6HD COLU, 6HMBIUM , 6HALLOY , 6HC 129Y,
     9 6H HAYNE, 6HS 188 , 6H      , 6H      , 6H      ,
     $ 6H COATE, 6HD TANT, 6HALUM  , 6H      , 6H      ,
     $ 6H ALLOY, 6H STEEL, 6H      , 6H      , 6H      ,
     $ 6H STAIN, 6HLESS S, 6HTEEL  , 6H      , 6H      ,
     $ 6H MAGNE, 6HSIUM  , 6H      , 6H      , 6H      ,
     $ 6H BERYL, 6HLIUM  , 6H      , 6H      , 6H      ,
     $ 6H L-605, 6H      , 6H      , 6H      , 6H      /
C
      NN=0
      EOP=0
      ZZUB=0
      IF (KK.EQ.1) GO TO 60
      IF (KLIC.EQ.100) GO TO 150
   10 CONTINUE
      IF (EOP.EQ.1.) GO TO 30
      CALL ASTDHR
      ZZUB=1.
      IF (KLIC.EQ.10) GO TO 110
      IF (REFCT.EQ.0.) STDHR=0
      IF (REFCT.EQ.0.) GO TO 20
      LABHR=LABHR+(STDHR/REFCT)
      LACOST=LACOST+(LABHR*LARATE)
      VCOST=VCOST+(LARATE*VRATE)*LABHR
   20 CONTINUE
      FCOST=LACOST+VCOST
      TSTDHR=TSTDHR+STDHR
      TLBHR=TLBHR+LABHR
      TLACOS=TLACOS+LACOST
      TVCOST=TVCOST+VCOST
      TFCOST=TFCOST+FCOST
      LABHR=0
      LACOST=0
      VCOST=0
      GO TO 10
   30 IF (TLBHR.EQ.0) GO TO 40
      AVERA=TLACOS/TLBHR
      AVERF=TSTDHR/TLBHR
      TVRATE=TVCOST/TLBHR
      GO TO 50
   40 AVERA=0.
      AVERF=0.
      TVRATE=0.
   50 CONTINUE
      MUV=AMUV
      MATCOS=MAWT*MUV*COSWT
```

```
      TMFCOS=TFCOST+MATCOS
   60 CONTINUE
      IF (ITL.GT.0) GO TO 80
      TACWT=0
      X=XDST*12.0
      WRITE (6,190) X
      IF (KINDP.EQ.1) WRITE (6,200)
      IF (KINDP.EQ.2) WRITE (6,210)
      IF (KINDP.EQ.3) WRITE (6,220)
      IF (KINDP.EQ.4) WRITE (6,230)
      IF (KINDP.EQ.5) WRITE (6,240)
      IF (KINDS.EQ.1) WRITE (6,250)
      IF (KINDS.EQ.2) WRITE (6,260)
      IF (KINDS.EQ.3) WRITE (6,270)
      WRITE (6,280) LEN,WID,LTUBER
      IF ((KINDP.EQ.0).AND.(KINDS.EQ.0)) GO TO 70
      IF ((MATLID.LT.1).OR.(MATLID.GT.15)) GO TO 70
      WRITE (6,520) MATLID,(MTYPE(I,MATLID),I=1,5)
   70 WRITE (6,290)
   80 CONTINUE
      IF (KK.EQ.1) GO TO 90
      IF (KLIC.LT.2) GO TO 100
      TACWT=TACWT+ACWT
      TMAWT=TMAWT+MAWT
      GO TO 100
   90 CONTINUE
      WRITE (6,300) ANAM(1,N),ANAM(2,N)
      RETURN
  100 WRITE (6,310) ANAM(1,N),ANAM(2,N),KT,ACWT,MAWT,TSTDHR,TLBHR,AVERA,
     1TVRATE,COSWT,TLACOS,TVCOST,TFCOST,MATCOS,TMFCOS
C     SUMMARY TOTALS AT BOTTOM OF PAGE
      TTSHR=TTSHR+TSTDHR
      TTLBHR=TTLBHR+TLBHR
      TTLACO=TTLACO+TLACOS
      TTVCOS=TTVCOS+TVCOST
      TTFCOS=TTFCOS+TFCOST
      TTMCOS=TTMCOS+MATCOS
      TSTDHR=0
      TLBHR=0
      TLACOS=0
      TVCOST=0
      TFCOST=0
      TMFCOS=0
      RETURN
  110 CONTINUE
      DO 140 I=1,7
      AOP(I,1)=STDHR
      IF (REFCT.EQ.0) GO TO 120
      AOP(I,2)=STDHR/REFCT
      GO TO 130
  120 CONTINUE
      AOP(I,2)=0
  130 CONTINUE
      AOP(I,3)=LARATE
      AOP(I,4)=VRATE*LARATE
      AOP(I,5)=AOP(I,2)*LARATE
      AOP(I,6)=AOP(I,2)*AOP(I,4)
      AOP(I,7)=AOP(I,5)+AOP(I,6)
```

```
      CALL ASTDHR
  140 CONTINUE
      DO 150 I=1,7
      TASTDH=TASTDH+AOP(I,1)
      TALABH=TALABH+AOP(I,2)
      TASYCO=TASYCO+AOP(I,7)
  150 CONTINUE
      TTMFCO=TTFCOS+TTMCOS
      TMUFAC=TASYCO+TTMFCO
      TTMFRT=TTMFCO/TACWT
      IF (TTLBHR.EQ.0) GO TO 160
      TTRATE=TTFCOS/TTLBHR
      TMRATE=TTMFCO/TTLBHR
      TTCOS=TTMCOS/TMAWT
      TAVRA=TTLACO/TTLBHR
      TTVRA=TTVCOS/TTLBHR
      TAVFC=TTSHR/TTLBHR
      GO TO 170
  160 CONTINUE
      TTCOS=TTMCOS/TMAWT
      TAVRA=0
      TTVRA=0
      TAVFC=0
  170 CONTINUE
      TUNITC=TMUFAC/(LEN*WID)
      TUNWT=TACWT/(LEN*WID)
      IF (TALABH.EQ.0) REL=0
      IF (TALABH.EQ.0) GO TO 180
      REL=TASTDH/TALABH
  180 CONTINUE
      WRITE (6,320) TACWT,TMAWT,TTSHR,TTLBHR,TTLACO,TTVCOS,TTFCOS,TTMCOS
     1,TTMFCO,TASYCO
      IF (KLIC.LT.100) WRITE (6,420)
      WRITE (6,330) TMUFAC,TUNITC
      IF (KLIC.LT.100) WRITE (6,430)
      WRITE (6,340) TUNWT
      IF (KLIC.LT.100) WRITE (6,440)
      WRITE (6,350) TTCOS,TAVRA
      IF (KLIC.LT.100) WRITE (6,450) (AOP(1,J),J=1,7)
      WRITE (6,360) TTVRA
      IF (KLIC.LT.100) WRITE (6,460) (AOP(2,J),J=1,7)
      WRITE (6,370) TTRATE
      IF (KLIC.LT.100) WRITE (6,470) (AOP(3,J),J=1,7)
      WRITE (6,380) TMRATE
      IF (KLIC.LT.100) WRITE (6,480) (AOP(4,J),J=1,7)
      WRITE (6,390) TTMFRT
      IF (KLIC.LT.100) WRITE (6,490) (AOP(5,J),J=1,7)
      WRITE (6,400) TAVFC
      IF (KLIC.LT.100) WRITE (6,500) (AOP(6,J),J=1,7)
      WRITE (6,410) REL
      IF (KLIC.LT.100) WRITE (6,510) (AOP(7,J),J=1,7)
      RETURN
C
C
  190 FORMAT (1H1,38X,45HTHERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA ,F
     17.1//)
  200 FORMAT (30X,51HCONFIGURATION   PANEL TYPE 1,  METALLIC, CORRUGATED
     1)
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210 FORMAT (30X,50HCONFIGURATION   PANEL TYPE 2,  METALLIC, HONEYCOMB)CST 233
220 FORMAT (30X,54HCONFIGURATION   PANEL TYPE 3,  METALLIC, RIB STIFFECST 234
   1NED)                                                              CST 235
230 FORMAT (30X,58HCONFIGURATION   PANEL TYPE 4,  REUSABLE SURFACE INSCST 236
   1ULATION)                                                          CST 237
240 FORMAT (30X,40HCONFIGURATION   PANEL TYPE 5,  ABLATIVE )          CST 238
250 FORMAT (30X,75H                STRUCTURE TYPE 1, CRUCIFORM BEAMS, SICST 239
   1X EDGE POSTS            )                                         CST 240
260 FORMAT (30X,75H                STRUCTURE TYPE 2, FOUR INSET SHEET MECST 241
   1TAL POSTS               )                                         CST 242
270 FORMAT (30X,75H                STRUCTURE TYPE 3, TEE BEAMS, CENTER ACST 243
   1ND FOUR CORNER POSTS    )                                         CST 244
280 FORMAT (/30X,20HNOMINAL PANEL SIZE  ,F4.1,3H X ,F4.1,3H FT/30X,33HCST 245
   1NOMINAL PANEL STANDOFF DISTANCE  ,F4.1,3H IN)                     CST 246
290 FORMAT (/29X,102HACTUAL     MATL       STD    LABOR LABOR  OV-HD  CST 247
   1  MATL $    LABOR   OVERHD  FACTORY MATERIAL FABRICAT/4X,7HDESCRIPCST 248
   2,6X,2HQT,10X,100HWEIGHT    WEIGHT     HOURS   HOURS  RATE   RATE  CST 249
   3  PER LB     COST    COST     COST     COST     COST//)           CST 250
300 FORMAT (/4X,2A6)                                                  CST 251
310 FORMAT (4X,A6,A4,I5,6X,2F10.3,F10.4,F8.2,F6.2,F7.2,F10.2,5F9.2)   CST 252
320 FORMAT (//28H TOTAL ACTUAL WEIGHT          F12.2,3H LB/1X,27HTOTAL MCST 253
   1ATERIAL WEIGHT       F12.2,3H LB/1X,27HTOTAL STANDARD HOURS      FCST 254
   212.2,3H HR/1X,27HTOTAL LABOR HOURS           F12.2,3H HR/1X,27HTOTACST 255
   3L LABOR COST           F12.2,2H $/1X,27HTOTAL OVERHEAD COST       CST 256
   4 F12.2,2H $/1X,27HTOTAL FACTORY COST          F12.2,2H $/1X,27HTOTACST 257
   5L MATERIAL COST        F12.2,2H $/1X,27HTOTAL FABRICATION COST    CST 258
   6 F12.2,2H $/1X,27HTOTAL ASSEMBLY COST         F12.2,2H $)         CST 259
330 FORMAT (1X,27HTOTAL MANUFACTURING COST   F12.2,2H $/1X,27HTPS COSTCST 260
   1                 F12.2,8H $/SQ FT)                                CST 261
340 FORMAT (1X,27HTPS WEIGHT                 F12.2,9H LB/SQ FT)       CST 262
350 FORMAT (1X,27HAVERAGE MATERIAL           F12.2,11H $/LB      /1X,2CST 263
   17HAVERAGE LABOR RATE         F12.2,11H $/HR       )               CST 264
360 FORMAT (1X,27HAVERAGE OVERHEAD RATE      F12.2,11H $/HR       )   CST 265
370 FORMAT (1X,27HAVERAGE FACTORY RATE       F12.2,11H $/HR       )   CST 266
380 FORMAT (1X,27HAVERAGE MFG. RATE          F12.2,11H $/HR       )   CST 267
390 FORMAT (1X,27HAVERAGE MFG. RATE          F12.2,11H $/LB       )   CST 268
400 FORMAT (1X,27HAVERAGE MFG. REALIZATION   F12.2)                   CST 269
410 FORMAT (1X,28HAVERAGE ASSEMBLY REALIZATIONF11.2)                  CST 270
420 FORMAT (1H+,87X,19HFINAL ASSEMBLY COST)                           CST 271
430 FORMAT (1H+,78X,52HSTD    TOTAL LABOR  OV-HD    LABOR   OVERHD ASSCST 272
   1EMBLY)                                                            CST 273
440 FORMAT (1H+,65X,63HTASK         HOURS   HOURS  RATE   RATE    COSTCST 274
   1    COST    COST)                                                 CST 275
450 FORMAT (1H+,62X,10HSETUP     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 276
460 FORMAT (1H+,62X,10HCLAMP     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 277
470 FORMAT (1H+,62X,10HINSPECT   F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 278
480 FORMAT (1H+,62X,10HDISASSY   F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 279
490 FORMAT (1H+,62X,10HCLEAN     F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 280
500 FORMAT (1H+,62X,10HSECURE    F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 281
510 FORMAT (1H+,62X,10HINSPECT   F10.4,F8.2,F6.2,F7.2,3F9.2)          CST 282
520 FORMAT (/30X,40HPRIMARY PANEL / STRUCTURE MATERIAL TYPE ,I2,5A6)  CST 283
    END                                                               CST 284-
```

```
      SUBROUTINE COSTOT                                                 CTT
C                                                                       CTT
      COMMON/COMTO1/                                                    CTT
     1AT        ,BT        ,CT        ,CF1       ,EGTH      ,ETA      , CTT
     2FTH       ,FTS       ,K1        ,K2        ,K3        ,NPA      , CTT
     3OS        ,STPS      ,TUNWT                                       CTT
      COMMON/STDHR/                                                     CTT
     1EOP       ,LARATE    ,MATLID    ,NN        ,PI        ,REFCT    , CTT
     2STDHR     ,VRATE                                                  CTT
      COMMON/WTA/                                                       CTT
     1A         ,B         ,CHORD     ,DIABH1    ,DIAPOH    ,DIARGH   , CTT
     2DIAPGH    ,DIAPTH    ,                                            CTT
     3DLPANL    ,DWPANL    ,EEDGE     ,E1RIB     ,E2RIB     ,E3RIB    , CTT
     4GBOLT     ,GCLAMP    ,GINSRT    ,GINSUL    ,GNUTPL    ,GWASH    , CTT
     5HBEAMA    ,HFNG1     ,HFNG2     ,HPLATE    ,HPOST     ,HRIB     , CTT
     6HRING     ,IDFNG1    ,IDFNG2    ,KINDP     ,KINDS     ,LBMLA    , CTT
     7LBMLC     ,LBMSA     ,LBMSC     ,LCORN     ,LDOUBR    ,LENGTH   , CTT
     8LPANL     ,LPOST     ,LRIBL     ,LRIBS     ,LSEAL     ,LSTFNR   , CTT
     9LTUBE     ,NRIBS     ,NXA       ,NYA       ,ODFNG1    ,ODFNG2   , CTT
     $ODPOSR    ,ODPOST    ,ODRING    ,PBM       ,PCORE     ,PEDGE    , CTT
     $PINS1     ,PINS2     ,PINS3     ,PPOST     ,PRIB      ,PSFAL    , CTT
     $PSKIN1    ,PSKIN2    ,PTUBE     ,R         ,RADIUS    ,S        , CTT
     $TBMLA     ,TBMLC     ,TBMSA     ,TBMSC     ,TCORE     ,TCORN    , CTT
     $TDOUBC    ,TDOUBP    ,TEDGE     ,TFNG1     ,TPLATE    ,TPLUG    , CTT
     $TPOST     ,TRIBL     ,TRIBS     ,TRING1    ,TRING2    ,TSEAL    , CTT
     $TTUBE     ,TWRIB     ,T1RIB     ,T2RIB     ,WBEAMA    ,WBMLA    , CTT
     $WBMLC     ,WBMSA     ,WBMSC     ,WCORN     ,WCORR     ,WDOUBP   , CTT
     $WDOUBR    ,WIDTH     ,WPANL     ,WPLATE    ,WPOST     ,WRIBL    , CTT
     $WRIBS     ,WSEAL     ,WSTFNR    ,ZFAS                             CTT
C                                                                       CTT
      DIMENSION CF(15,3)                                                CTT
C                                                                       CTT
      REAL K1       ,K2       ,K3       ,NPA                            CTT
C                                                                       CTT
      DATA CF /                                                         CTT
     1 1.3, 3.5, 3.2, 3.1, 4.0, 5.2, 17., 17., 3.2, 19., 1.8, 2.2, 2.2, CTT
     2 6.0, 3.8,                                                        CTT
     3 2.1, 6.0, 4.3, 3.1, 4.7, 6.9, 17., 17., 4.3, 19., 2.6, 3.0, 3.0, CTT
     4 10., 4.6,                                                        CTT
     5 1.0, 3.0, 2.5, 1.9, 3.0, 4.2, 12., 12., 2.5, 14., 1.4, 1.7, 1.7, CTT
     6 5.0, 2.8/                                                        CTT
C                                                                       CTT
      IF (KINDP.LT.1.OR.KINDP.GT.5) RETURN                              CTT
      IF (MATLID.LT.1.OR.MATLID.GT.15) RETURN                           CTT
      IF (CF1.GT.0) GO TO 10                                            CTT
      KINDPP=KINDP                                                      CTT
      IF (KINDP.GT.3) KINDPP=2                                          CTT
      CF1=CF(MATLID,KINDPP)                                             CTT
   10 CONTINUE                                                          CTT
      TEN6TH=1.E+6                                                      CTT
      WTPS=STPS*TUNWT                                                   CTT
      TFU=CF1*K1*WTPS**AT                                               CTT
      UTFU=TEN6TH*TFU/STPS                                              CTT
      EDD=K2*WTPS**BT                                                   CTT
      UEDD=TEN6TH*EDD/STPS                                              CTT
      TOOL=K3*WTPS**CT                                                  CTT
      UTOOL=TEN6TH*TOOL/STPS                                            CTT
      GTH=EGTH*TFU                                                      CTT
```

```
      UGTH=TEN6TH*GTH/STPS
      FTA=FTH*TFU
      UFTA=TEN6TH*FTA/STPS
      FTSRP=FTS*TFU
      UFTSRP=TEN6TH*FTSRP/STPS
      PA=NPA*TFU
      UPA=TEN6TH*PA/STPS
      TAC=ETA*TFU
      UTAC=TEN6TH*TAC/STPS
      RSRP=OS*TFU
      URSRP=TEN6TH*RSRP/STPS
      TNTPSC=EDD+TOOL+GTH+FTA+FTSRP
      UTNTPS=TEN6TH*TNTPSC/STPS
      TRPC=PA+TAC
      UTRPC=TEN6TH*TRPC/STPS
      TROC=RSRP
      UTROC=TEN6TH*TROC/STPS
      TTPSC=TNTPSC+TRPC+TROC
      UTTPSC=TEN6TH*TTPSC/STPS
      WRITE (6,20) UTFU,UEDD,UTOOL,UGTH,UFTA,UFTSRP
      WRITE (6,30)
      WRITE (6,40) UTNTPS,UPA,UTAC
      WRITE (6,30)
      WRITE (6,50) UTRPC,URSRP
      WRITE (6,30)
      WRITE (6,60) UTROC,UTTPSC,NPA
      RETURN
C
C
   20 FORMAT (1H1,13X,40HTHERMAL PROTECTION SYSTEM   COST SUMMARY///48X,
     112HCOST $/SQ FT///10X,33HTHEORETICAL FIRST UNIT COST (TFU),F8.2///
     210X,18HNON RECURRING COST//10X,8HED AND D,33X,F9.2/10X,7HTOOLING,3
     34X,F9.2/10X,20HGROUND TEST HARDWARE,21X,F9.2/10X,20HFLIGHT TEST AR
     4TICLES,21X,F9.2/10X,20HFLIGHT TEST S AND RP,21X,F9.2)
   30 FORMAT (52X,8H--------)
   40 FORMAT (10X,27HTOTAL NONRECURRING TPS COST,14X,F9.2///10X,25HRECUR
     1RING PRODUCTION COST//10X,50HSUSTAINING ENGINEERING        -     IN
     2CLUDED IN TFU/10X,50HSUSTAINING TOOLING             -     INCLUDED I
     3N TFU/10X,19HPRODUCTION ARTICLES,22X,F9.2/10X,23HTEST ARTICLE CONV
     4ERSION,18X,F9.2)
   50 FORMAT (10X,31HTOTAL RECURRING PRODUCTION COST,10X,F9.2///10X,25HR
     1ECURRING OPERATIONS COST//10X,22HREPLENISHMENT S AND RP,19X,F9.2)
   60 FORMAT (10X,31HTOTAL RECURRING OPERATIONS COST,10X,F9.2////10X,23H
     1TOTAL TPS PROGRAM COSTS,18X,F9.2,//////10X,26HNUMBER OF PRODUCTION
     2 UNITS,16X,F6.1)
      END
```

```
      SUBROUTINE WTTPS
C
      COMMON /LINK/ NSECT,TC,TS,TSKIN1,TSKIN2,TINS1,TINS2,TINS3
      COMMON/STDHR/
     1EOP      ,LARATE   ,MATLID   ,NN       ,PI       ,REFCT    ,
     2STDHR    ,VRATE
      COMMON/WTA/
     1A        ,B        ,CHORD    ,DIABH1   ,DIAPOH   ,DIARGH   ,
     2DIAPGH   ,DIAPTH   ,
     3DLPANL   ,DWPANL   ,EEDGE    ,E1RIB    ,E2RIB    ,E3RIB    ,
     4GBOLT    ,GCLAMP   ,GINSRT   ,GINSUL   ,GNUTPL   ,GWASH    ,
     5HBEAMA   ,HFNG1    ,HFNG2    ,HPLATE   ,HPOST    ,HRIB     ,
     6HRING    ,IDFNG1   ,IDFNG2   ,KINDP    ,KINDS    ,LBMLA    ,
     7LBMLC    ,LBMSA    ,LBMSC    ,LCORN    ,LDOUBR   ,LENGTH   ,
     8LPANL    ,LPOST    ,LRIBL    ,LRIBS    ,LSEAL    ,LSTFNR   ,
     9LTUBE    ,NRIBS    ,NXA      ,NYA      ,ODFNG1   ,ODFNG2   ,
     $ODPOSR   ,ODPOST   ,ODRING   ,PBM      ,PCORE    ,PEDGE    ,
     $PINS1    ,PINS2    ,PINS3    ,PPOST    ,PRIB     ,PSEAL    ,
     $PSKIN1   ,PSKIN2   ,PTUBE    ,R        ,RADIUS   ,S        ,
     $TBMLA    ,TBMLC    ,TBMSA    ,TBMSC    ,TCORE    ,TCORN    ,
     $TDOUBC   ,TDOUBP   ,TEDGE    ,TFNG1    ,TPLATE   ,TPLUG    ,
     $TPOST    ,TRIBL    ,TRIBS    ,TRING1   ,TRING2   ,TSEAL    ,
     $TTUBE    ,TWRIB    ,T1RIB    ,T2RIB    ,WBEAMA   ,WBMLA    ,
     $WBMLC    ,WBMSA    ,WBMSC    ,WCORN    ,WCORR    ,WDOUBP   ,
     $WDOUBR   ,WIDTH    ,WPANL    ,WPLATE   ,WPOST    ,WRIBL    ,
     $WRIBS    ,WSEAL    ,WSTFNR   ,ZFAS
      COMMON/WTCOST/
     1ACWT     ,AMUV     ,AOP(7,7) ,ITL      ,KK       ,KLIC     ,
     2COSWT    ,KT       ,LEN      ,LTUBER   ,MAWT     ,N        ,
     3PEXT     ,TEXT     ,WID      ,ZZUB
C
      DIMENSION PSKIN(15)
C
      REAL IDFNG1 ,IDFNG2 ,IDRING ,LBMLA  ,LBMLC  ,LBMSA  ,LBMSC  ,LCORN
      REAL LDOUBR ,LEN    ,LENGTH ,LPANL  ,LPOST  ,LRIBL  ,LRIBS  ,LSEAL
      REAL LSTFNR ,LTUBE  ,LTUBER ,NXA    ,NYA    ,MAWT
C
      DATA PSKIN /
     1 .102, .160, .297, .297, .298, .306, .326, .343, .333, .604, .283,
     2 .276, .066, .067, .300/
C
C
C     INITIALIZE INSULATION VARIABLES
      WTINS1=0
      WMINS1=0
      WTINS2=0
      WMINS2=0
      WTINS3=0
      WMINS3=0
C
C     INITIALIZE PANEL VARIABLES
      WTCORE=0
      WMCORE=0
      WTCORR=0
      WMCORR=0
      WTEDG2=0
      WMEDG2=0
      WTEDG3=0
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```
      WMEDG3=0
      WTEXT=0
      WMEXT=0
      WTRIBS=0
      WMRIBS=0
      WTSKIN=0
      WMSKIN=0
      WTSKN2=0
      WMSKN2=0
      VOLCOR=0
C
C     INITIALIZE STRUCTURE VARIABLES
      WTBMLA=0
      WMBMLA=0
      WTBMLC=0
      WMBMLC=0
      WTLRIB=0
      WMLRIB=0
      WTBMSA=0
      WMBMSA=0
      WTBMSC=0
      WMBMSC=0
      WTSRIB=0
      WMSRIB=0
      WTCORN=0
      WMCORN=0
      WTDOU=0
      WMDOU=0
      WTDOUB=0
      WMDOUB=0
      WTFNGA=0
      WMFNGA=0
      WTFNGC=0
      WMFNGC=0
      WTFNG2=0
      WMFNG2=0
      WTHINA=0
      WMHINA=0
      WTHINB=0
      WMHINB=0
      WTHINC=0
      WMHINC=0
      WTINS=0
      WMINS=0
      WTPLGA=0
      WMPLGA=0
      WTPLGC=0
      WMPLGC=0
      WTPLT1=0
      WMPLT1=0
      WTPLT2=0
      WMPLT2=0
      WTPOSR=0
      WMPOSR=0
      WTPOSA=0
      WMPOSA=0
      WTPOSB=0
      WMPOSB=0
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```
      WTPOSC=0
      WMPOSC=0
      WTRNG1=0
      WMRNG1=0
      WTRNG2=0
      WMRNG2=0
      WTSEAL=0
      WMSEAL=0
      WTFASA=0
      WMFASA=0
      WTFASB=0
      WMFASB=0
      WTFASC=0
      WMFASC=0
C
C     INITIALIZE TOTAL VARIABLES
      WTINSL=0
      WMINSL=0
      WTPANL=0
      WMPANL=0
      WTSTR=0
      WMSTR=0
C
C     IDENTIFICATION OF MATERIAL TYPE AND ASSIGNMENT OF MATERIAL DENSITY
C     FOR TPS PANEL AND STRUCTURE
C
      PSKIN1=0
      IF (MATLID.LT.1.OR.MATLID.GT.15) GO TO 10
      PSKIN1=PSKIN(MATLID)
C
   10 CONTINUE
      PCORE=.033*PSKIN1
      PSKIN2=PSKIN1
      PRIB=PSKIN1
      PEDGE=PSKIN1
      PPOST=PSKIN1
      PBM=PSKIN1
      PSEAL=PSKIN1
      PTUBE=PSKIN1
      PBOND=.07
C
C
C     GENERAL TERMS USED THROUGHOUT
      PI4=.7854
      DIABH1=.19
      DIABH2=.50
      DIAPTH=.50
      DIAPGH=.19
      DIAPOH=.19
      DIARGH=.19
      EEDGE=1.20
      HPLATE=.50
      LDOUBR=2.00
      R=.17
      TBOND=.010
      TBRAZE=.008
      TPLUG=.25
      WDOUBR=1.50
```

```
      WDOUBP=1.00
      IF (RADIUS.EQ.0.) CIRCUM=0
      IF (RADIUS.EQ.0.) GO TO 20
      CIRCUM=RADIUS*ACOS(1-(CHORD**2)/(2.*RADIUS**2))
   20 CONTINUE
      HPOST=WPOST
      IDRING=IDFNG2-2.*TTUBE-2.*(IDFNG2-ODPOSR)
      LEN=LENGTH/12.
      LBMLA=LENGTH-1.75
      LBMLC=LENGTH-.75
      LBMSA=WIDTH-1.75
      LBMSC=WIDTH-.75
      S=R+.365*HBEAMA
      LCORN=2.*HPLATE+2.*S
      LPANL=LENGTH-DLPANL-A
      LPOST=TINS1+TINS2+TINS3+B-.30
      LRIBL=LBMLC
      LRIBS=LBMSC
      LSEAL=WIDTH
      LSTFNR=LPOST-.50
      LTUBER=TINS1+TINS2+TINS3+B
      NXA=(LPANL+DLPANL-4.*DIABH1)/(8.*DIABH1)
      NYA=(LSEAL-4.*DIABH1)/(8.*DIABH1)
      NX=NXA+.5
      NY=NYA+.5
      NXA=NX
      NYA=NY
      ODFNG1=ODPOST+.60
      ODFNG2=IDFNG2+.50
      ODTUBE=ODPOST-2.*TPOST
      TFNG2=TFNG1
      WID=WIDTH/12.
      WPANL=WIDTH-DWPANL-A
      WBMLA=2.*(WBEAMA+R-S+((S-R)**2+HBEAMA**2)**.5)+.32
      WBMSA=WBMLA
      WCORN=R+S+((S-R)**2+HBEAMA**2)**.5
      WCORR=WPANL+NRIBS*(CIRCUM-CHORD)
      WPLATE=WBEAMA+2.*R
      WSEAL=A+.5
      WSTFNR=WPOST/3.
      WTBOND=(LPANL+DLPANL)*(WPANL+DWPANL)*TBOND*PBOND
      IF (KINDP.EQ.5) WTBOND=0
      WTBRZ1=LPANL*(NRIBS+1)*.5*TBRAZE*PSKIN2
      WTBRZ2=(LBMLA*.38-2.*NXA*PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ3=(LDOUBR*WDOUBR-PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ4=(LBMSA*.38-2.*NYA*PI4*DIABH1**2)*TBRAZE*PBM
      WTBRZ5=(4.*(LCORN*(R+S)-R**2-S**2)+WDOUBP**2-PI4*DIAPGH**2)*TBRAZE
     1*PBM
      WTBRZ6=2.*PI*ODPOST*TPOST*TBRAZE*PPOST
      WTBRZ7=2.*PI*ODPOST*LTUBE*TBRAZE*PPOST
      WTBRZ8=(LPANL+WPANL-EEDGE)*EEDGE*TBRAZE*PEDGE
      WTBRZ9=NRIBS*(LPANL-EEDGE)*(E2RIB+TWRIB)*TBRAZE*PRIB
      IF (E2RIB.EQ.0.) WTBRZ9=0
      WTBR10=2.*WPANL*(EEDGE-TEDGE)*TBRAZE*PEDGE
      WTBR11=4.*(WPOST*HPOST-2.*PI4*DIAPOH**2)*TBRAZE*PPOST
      WTBR12=LBMLC*TRIBL*TBRAZE*PBM
      WTBR13=LBMSC*TRIBS*TBRAZE*PBM
      WTBR14=PI*(ODPOSR-2.*TTUBE)*HRING*TBRAZE*PPOST
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      WTBR15=PI*ODPOSR*HFNG2*TBRAZE*PPOST
      WTBR16=PI*ODPOST*TRING1*TBRAZE*PPOST
      WTBR17=PI*ODPOST*HFNG1*TBRAZE*PPOST
      J=0
      N=0
      ITL=0
C
C ***
C *** EQUATIONS FOR INSULATION
C ***
C
C *** EQUATION FOR INSUL 1
C
      IF (TINS1.EQ.0) GO TO 30
      WTINS1=LENGTH*WIDTH*TINS1*PINS1/1728.
      WMINS1=(LENGTH+2.)*(WIDTH+2.)*TINS1*PINS1/1728.
C
C *** EQUATION FOR INSUL 2
C
   30 IF (TINS2.EQ.0) GO TO 40
      WTINS2=LENGTH*WIDTH*TINS2*PINS2/1728.
      WMINS2=(LENGTH+2.)*(WIDTH+2.)*TINS2*PINS2/1728.
C
C *** EQUATION FOR INSUL 3
C
   40 IF (TINS3.EQ.0) GO TO 50
      WTINS3=LENGTH*WIDTH*TINS3*PINS3/1728.
      WMINS3=(LENGTH+2.)*(WIDTH+2.)*TINS3*PINS3/1728.
C
C *** TOTAL INSULATION WT
C
   50 WTINSL=WTINS1+WTINS2+WTINS3
      WMINSL=WMINS1+WMINS2+WMINS3
      ACWT=WTINSL
      MAWT=WMINSL
      KK=1
      KT=1
      N=1
      KLIC=0
      IF (ACWT.GT.0.) CALL COST
      IF (ACWT.GT.0) ITL=1
      ACWT=WTINS1
      MAWT=WMINS1
      KK=41
      KT=1
      N=2
      KLIC=2
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTINS2
      MAWT=WMINS2
      KK=42
      KT=1
      N=3
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTINS3
      MAWT=WMINS3
      KK=43
      KT=1
```

```
      N=4
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTINSL
      MAWT=WMINSL
      KK=40
      KT=1
      N=23
      KLIC=1
      IF (ACWT.GT.0) CALL COST
      IF ((KINDP.LT.1).OR.(KINDP.GT.5)) GO TO 210
C
C
C     FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR PANELS
C
   60 CONTINUE
      GO TO (70,80,90,100,110), KINDP
C
C *** KINDP = 1, CORRUGATED METALLIC PANEL
C
   70 CONTINUE
      J=J+1
      GO TO (120,170,200), J
C
C *** KINDP = 2, HONEYCOMB METALLIC PANEL
C
   80 CONTINUE
      J=J+1
      GO TO (130,150,170,180,200), J
C
C *** KINDP = 3, RIB STIFFENED METALLIC PANEL
C
   90 CONTINUE
      J=J+1
      GO TO (140,160,170,200), J
C
C *** KINDP = 4, REUSABLE SURFACE INSULATED PANEL (RSI)
C
  100 CONTINUE
      J=J+1
      GO TO (130,150,170,180,190,200), J
C
C *** KINDP = 5, ABLATIVE PANEL
C
  110 CONTINUE
      J=J+1
      GO TO (150,170,190,200), J
C
C ***
C *** EQUATIONS FOR PANELS
C ***
C *** EQUATION FOR CORRUGNS   (CORRUGATIONS)
C
  120 CONTINUE
      WTCORR=LPANL*WCORR*TSKIN2*PSKIN2+WTBRZ1
      WMCORR=(LENGTH+1.)*(WCORR+1.)*(TSKIN2+.005)*PSKIN2
      GO TO 60
C
C *** EQUATION FOR EDGES   (EDGE MEMBERS 2)
```

```
C
  130 CONTINUE
      WTEDG2=2.*(LPANL+WPANL+4.*TEDGE-2.*EEDGE)*(TCORE+EEDGE)*TEDGE*PEDG
     1E+WTBRZ8
      WMEDG2=2.*(LPANL+.5+WPANL+.5)*(TCORE+EEDGE+.25)*(TEDGE+.005)*PEDGE
      GO TO 60
C
C *** EQUATION FOR EDGES   (EDGE MEMBERS 3)
C
  140 CONTINUE
      WTEDG3=2.*WPANL*(HRIB+TEDGE+EEDGE)*TEDGE*PEDGE+WTBR10
      WMEDG3=2.*(WPANL+1.)*(HRIB+TEDGE+EEDGE+.25)*(TEDGE+.005)*PEDGE
      GO TO 60
C
C *** EQUATION FOR HONEYCOMB CORE
C
  150 CONTINUE
      WTCORE=(LPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
      IF (KINDP.EQ.5) TCORE=TEXT
      IF (KINDP.EQ.5) WTCORE=(LPANL+DLPANL)*(WPANL+DWPANL)*TCORE*PCORE
      WMCORE=(LENGTH+1.)*(WIDTH+1.)*(TCORE+.25)*PCORE
      IF (PCORE.EQ.0) GO TO 60
      VOLCOR=WTCORE/PSKIN1
      IF (KINDP.EQ.4) VOLCOR=0
      GO TO 60
C
C *** EQUATION FOR RIBS
C
  160 CONTINUE
      WTRIBS=NRIBS*(LPANL-EEDGE)*(E1RIB*T1RIB+E2RIB*T2RIB+E3RIB*T1RIB+HR
     1IB*TWRIB)*PRIB+WTBRZ9
      WMRIBS=NRIBS*LPANL*(E1RIB*(T1RIB+.005)+E2RIB*(T2RIB+.005)+E3RIB*(T
     11RIB+.005)+(HRIB+.1)*(TWRIB+.005))*PRIB
      GO TO 60
C
C *** EQUATION FOR SKIN
C
  170 CONTINUE
      IF (KINDS.EQ.0) WTSKIN=(LPANL+DLPANL)*(WPANL+DWPANL)*TSKIN1*PSKIN1
      IF (KINDS.EQ.1) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(NXA*PI4*DIA
     1BH1**2))*TSKIN1*PSKIN1
      IF (KINDS.EQ.2) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(4.*PI4*DIAP
     1TH**2))*TSKIN1*PSKIN1
      IF (KINDS.EQ.3) WTSKIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(PI4*DIARGH*
     1*2))*TSKIN1*PSKIN1
      WMSKIN=(LENGTH+.1)*(WIDTH+.1)*(TSKIN1+.005)*PSKIN1
      GO TO 60
C
C *** EQUATION FOR HONEYCOMB INNER SKIN
C
  180 CONTINUE
      WTSKN2=LPANL*WPANL*TSKIN2*PSKIN2
      WMSKN2=(LPANL+1.)*(WPANL+1.)*(TSKIN2+.005)*PSKIN2
      GO TO 60
C
C *** EQUATION FOR EXTERNAL INSULATION OR ABLATIVE MATERIAL
C
  190 CONTINUE
```

```
      WTEXT=((LENGTH*WIDTH*TEXT)-VOLCOR)*PEXT+WTBOND                    WTT 407
      WMEXT=(LENGTH+1.)*(WIDTH+1.)*(TEXT+.25)*PEXT                      WTT 408
      GO TO 60                                                          WTT 409
C                                                                       WTT 410
C *** EQUATION FOR TOTAL PANEL                                          WTT 411
C                                                                       WTT 412
  200 CONTINUE                                                          WTT 413
      WTPANL=WTCORE+WTCORR+WTEDG2+WTEDG3+WTRIBS+WTSKIN+WTSKN2+WTEXT     WTT 414
      WMPANL=WMCORE+WMCORR+WMEDG2+WMEDG3+WMRIBS+WMSKIN+WMSKN2+WMEXT     WTT 415
      ACWT=WTPANL                                                       WTT 416
      MAWT=WMPANL                                                       WTT 417
      KK=1                                                              WTT 418
      KT=1                                                              WTT 419
      N=5                                                               WTT 420
      KLIC=0                                                            WTT 421
      IF (ACWT.GT.0.) CALL COST                                         WTT 422
      IF (ACWT.GT.0) ITL=1                                              WTT 423
      ACWT=WTCORR                                                       WTT 424
      MAWT=WMCORR                                                       WTT 425
      KK=12                                                             WTT 426
      KT=1                                                              WTT 427
      N=6                                                               WTT 428
      KLIC=2                                                            WTT 429
      IF (ACWT.GT.0.) CALL COST                                         WTT 430
      ACWT=WTEDG2                                                       WTT 431
      MAWT=WMEDG2                                                       WTT 432
      KK=23                                                             WTT 433
      KT=4                                                              WTT 434
      N=7                                                               WTT 435
      IF (ACWT.GT.0.) CALL COST                                         WTT 436
      ACWT=WTEDG3                                                       WTT 437
      MAWT=WMEDG3                                                       WTT 438
      KK=33                                                             WTT 439
      KT=2                                                              WTT 440
      N=7                                                               WTT 441
      IF (ACWT.GT.0.) CALL COST                                         WTT 442
      ACWT=WTCORE                                                       WTT 443
      MAWT=WMCORE                                                       WTT 444
      KK=29                                                             WTT 445
      KT=1                                                              WTT 446
      N=8                                                               WTT 447
      IF (ACWT.GT.0.) CALL COST                                         WTT 448
      ACWT=WTRIBS                                                       WTT 449
      MAWT=WMRIBS                                                       WTT 450
      KK=32                                                             WTT 451
      KT=NRIBS                                                          WTT 452
      N=9                                                               WTT 453
      IF (ACWT.GT.0.) CALL COST                                         WTT 454
      ACWT=WTSKIN                                                       WTT 455
      MAWT=WMSKIN                                                       WTT 456
      IF (KINDP.EQ.1) KK=11                                             WTT 457
      IF (KINDP.EQ.2) KK=21                                             WTT 458
      IF (KINDP.EQ.3) KK=31                                             WTT 459
      IF (KINDP.EQ.4) KK=21                                             WTT 460
      IF (KINDP.EQ.5) KK=21                                             WTT 461
      KT=1                                                              WTT 462
      N=10                                                              WTT 463
      IF (ACWT.GT.0.) CALL COST                                         WTT 464
```

```
      ACWT=WTSKN2
      MAWT=WMSKN2
      KK=22
      KT=1
      N=10
      IF (ACWT.GT.0) CALL COST
      ACWT=WTEXT
      MAWT=WMEXT
      IF (KINDP.EQ.4) KK=26
      IF (KINDP.EQ.5) KK=27
      KT=1
      IF (KINDP.EQ.4) N=37
      IF (KINDP.EQ.5) N=38
      IF (ACWT.GT.0) CALL COST
      ACWT=WTPANL
      MAWT=WMPANL
      IF (KINDP.EQ.1) KK=10
      IF (KINDP.EQ.2) KK=20
      IF (KINDP.EQ.3) KK=30
      IF (KINDP.EQ.4) KK=15
      IF (KINDP.EQ.5) KK=25
      KT=1
      N=24
      KLIC=1
      IF (ACWT.GT.0.) CALL COST
C
C
C     FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR STRUCTURE
C
      J=0
  210 CONTINUE
      IF ((KINDS.LT.1).OR.(KINDS.GT.3)) GO TO 560
      GO TO (220,230,240), KINDS
C
C *** TYPE A CONSTRUCTION FOR STRUCTURE
C
  220 CONTINUE
      J=J+1
      GO TO (250,260,290,320,330,340,350,360,430,440,450,510,520,550), J
C
C *** TYPE B CONSTRUCTION FOR STRUCTURE
C
  230 CONTINUE
      J=J+1
      GO TO (370,390,460,530,550), J
C
C
C *** TYPE C CONSTRUCTION FOR STRUCTURE
C
  240 CONTINUE
      J=J+1
      GO TO (270,280,300,310,380,400,410,420,470,480,490,500,540,550), J
C ***
C *** EQUATIONS FOR STRUCTURE
C ***
C
C *** EQUATION FOR BEAM LN A    (LONG BEAM A)
C
```

```
  250 CONTINUE
      WTBMLA=(LBMLA*WBMLA-PI4*((2.*NXA+1.)*DIABH1**2+2.*DIABH2**2))*TBML
     1A*PBM+WTBRZ2
      WMBMLA=(LBMLA+1.)*(WBMLA+1.)*(TBMLA+.005)*PBM
      GO TO 210
C
C
C *** EQUATION FOR BEAM DOUB  (BEAM DOUBLER)
C
  260 CONTINUE
      WTDOUB=(LDOUBR*WDOUBR-PI4*DIABH1**2)*TDOUBC*PBM+WTBRZ3
      WMDOUB=(LDOUBR+1.)*(WDOUBR+1.)*(TDOUBC+.005)*PBM
      GO TO 210
C *** EQUATION FOR BEAM LN C   (LONG BEAM C)
C
  270 CONTINUE
      WTBMLC=LBMLC*WBMLC*TBMLC*PBM
      WMBMLC=(LBMLC+1.)*(WBMLC+1.)*(TBMLC+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR RIB LN C  (LONG RIB C)
C
  280 CONTINUE
      WTLRIB=LRIBL*WRIBL*TRIBL*PBM+WTBR12
      WMLRIB=(LRIBL+1.)*(WRIBL+1.)*(TRIBL+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR BEAM SH A   (SHORT BEAM A)
C
  290 CONTINUE
      WTBMSA=(LBMSA*WBMSA-PI4*2.*NYA*DIABH1**2)*TBMSA*PBM+WTBRZ4
      WMBMSA=(LBMSA+1.)*(WBMSA+1.)*(TBMSA+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR BEAM SH C   (SHORT BEAM C)
C
  300 CONTINUE
      WTBMSC=LBMSC*WBMSC*TBMSC*PBM
      WMBMSC=(LBMSC+1.)*(WBMSC+1.)*(TBMSC+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR RIB SH C  (SHORT RIB C)
C
  310 CONTINUE
      WTSRIB=LRIBS*WRIBS*TRIBS*PBM+WTBR13
      WMSRIB=(LRIBS+1.)*(WRIBS+1.)*(TRIBS+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR CORNERS
C
  320 CONTINUE
      WTCORN=4.*(LCORN*WCORN-R**2-S**2)*TCORN*PBM+WTBRZ5
      WMCORN=4.*(LCORN+1.)*(WCORN+1.)*(TCORN+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR CORN PLT  (UPPER CORNER PLATE)
C
  330 CONTINUE
```

```
      WTPLT1=(WPLATE**2+4.*WPLATE*HPLATE-PI4*DIAPTH**2)*TPLATE*PBM
      WMPLT1=(WPLATE+2.*HPLATE+.5)**2*(TPLATE+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR CORN PLT  (LOWER CORNER PLATE)
C
  340 CONTINUE
      WTPLT2=(WPLATE**2+4.*WPLATE*HPLATE-PI4*DIAPGH**2)*TPLATE*PBM
      WMPLT2=(WPLATE+2.*HPLATE+.5)**2*(TPLATE+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR CORN DOU  (CORNER DOUBLER)
C
  350 CONTINUE
      WTDOU=(WDOUBP**2-PI4*DIAPGH**2)*TDOUBP*PBM
      WMDOU=(WDOUBP+.5)**2*(TDOUBP+.005)*PBM
      GO TO 210
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS A)
C
  360 CONTINUE
      IF (KINDP.NE.2) GO TO 210
      WTHINA=NXA*GINSRT/100.
      WMHINA=1.1*WTHINA
      GO TO 210
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS B)
C
  370 CONTINUE
      IF (KINDP.NE.2) GO TO 210
      WTHINB=4.*GINSRT/100.
      WMHINB=1.1*WTHINB
      GO TO 210
C
C *** EQUATION FOR INSERTS   (HONEYCOMB INSERTS C)
C
  380 CONTINUE
      IF (KINDP.NE.2) GO TO 210
      WTHINC=GINSRT/100.
      WMHINC=1.1*WTHINC
      GO TO 210
C
C *** EQUATION FOR INSULATOR
C
  390 CONTINUE
      WTINS=20.*GINSUL/100.
      WMINS=1.1*WTINS
      GO TO 210
C
C *** EQUATION FOR POST CENT   (CENTER POST C)
C
  400 CONTINUE
      WTPOSR=PI*ODPOSR*LTUBER*TTUBE*PPOST
      WMPOSR=PI*ODPOSR*(LTUBER+.5)*(TTUBE+.02)*PPOST
      GO TO 210
C
C *** EQUATION FOR FLANGE  (CENTER POST C)
C
```

```
  410 CONTINUE
      WTFNG2=PI4*(IDFNG2**2-ODPOSR**2)*HFNG2*PTUBE+PI4*(ODFNG2**2-IDFNG2
     1**2)*TFNG2*PTUBE+WTBR15
      WMFNG2=PI4*(ODFNG2+.02)**2*(HFNG2+.5)*PTUBE
      GO TO 210
C
C *** EQUATION FOR RING  (CENTER POST C)
C
  420 CONTINUE
      WTRNG2=PI4*(ODPOSR-2.*TTUBE)**2*HRING*PPOST-PI4*(IDRING**2*(HRING-
     1TRING2)+DIAPGH**2*TRING2)*PPOST+WTBR14
      WMRNG2=PI4*ODPOSR**2*(HRING+.25)*PPOST
      GO TO 210
C
C *** EQUATION FOR POST CORN   (CORNER POST A)
C
  430 CONTINUE
      WTPOSA=2.*PI4*(ODPOST**2-ODTUBE**2)*LPOST*PPOST
      WMPOSA=2.*PI4*((ODPOST+.02)**2-ODTUBE**2)*(LPOST+.5)*PPOST
      GO TO 210
C
C *** EQUATION FOR PLUG  (CORNER POST A)
C
  440 CONTINUE
      WTPLGA=2.*PI4*(ODPOST**2-DIAPGH**2)*TPLUG*PPOST+WTBRZ6
      WMPLGA=2.*PI4*(ODPOST+.02)**2*(TPLUG+.25)*PPOST
      GO TO 210
C
C *** EQUATION FOR FLANGE  (CORNER POST A)
C
  450 CONTINUE
      WTFNGA=2.*PI*ODTUBE*TTUBE*LTUBE*PTUBE+2.*PI4*(ODFNG1**2-ODTUBE**2)
     1*TFNG1*PTUBE+WTBRZ7
      WMFNGA=2.*PI4*(ODFNG1+.02)**2*(LTUBE+.5)*PTUBE
      GO TO 210
C
C *** EQUATION FOR POST CORN   (CORNER POST B)
C
  460 CONTINUE
      WTPOSB=4.*((3.*WPOST+2.*LPOST)*HPOST+4.*(LSTFNR-WSTFNR)*WSTFNR-3.*
     1PI4*DIAPGH**2)*TPOST*PPOST+WTBR11
      WMPOSB=(2.*LPOST+3.*WPOST+1.)*(HPOST+1.)*(TPOST+.005)*PPOST
      GO TO 210
C
C *** EQUATION FOR POST CORN   (CORNER POST C)
C
  470 CONTINUE
      WTPOSC=PI*ODPOST*LPOST*TPOST*PPOST
      WMPOSC=PI*ODPOST*(LPOST+.5)*(TPOST+.02)*PPOST
      GO TO 210
C
C *** EQUATION FOR RING  (CORNER POST C)
C
  480 CONTINUE
      WTRNG1=PI4*(ODRING**2-ODPOST**2)*TRING1*PPOST+WTBR16
      WMRNG1=PI4*(ODRING+.02)**2*(TRING1+.25)*PPOST
      GO TO 210
C
```

```
C *** EQUATION FOR FLANGE  (CORNER POST C)
C
  490 CONTINUE
      WTFNGC=PI4*(ODFNG1**2-ODPOST**2)*TFNG1*PTUBE+PI4*(IDFNG1**2-ODPOST
     1**2)*(HFNG1-TFNG1)*PTUBE+WTBR17
      WMFNGC=PI4*(ODFNG1+.02)**2*(HFNG1+.5)*PTUBE
      GO TO 210
C
C *** EQUATION FOR PLUG  (CORNER POST C)
C
  500 CONTINUE
      WTPLGC=PI4*(ODPOST**2-DIAPGH**2)*TPLUG*PPOST+WTBRZ6
      WMPLGC=PI4*(ODPOST+.02)**2*(TPLUG+.25)*PPOST
      GO TO 210
C
C *** EQUATION FOR SEAL
C
  510 CONTINUE
      WTSEAL=(LSEAL*(WSEAL+.03)-PI4*NYA*DIABH1**2)*TSEAL*PSEAL
      WMSEAL=(LSEAL+1.)*(WSEAL+.5)*(TSEAL+.005)*PSEAL
      GO TO 210
C
C *** EQUATION FOR FASTNERS   (FASTENERS A)
C
  520 CONTINUE
      WTFASA=(NXA+NYA+2.)*GBOLT/100.+(NXA+2.)*GWASH/100.+(NXA+NYA)*GNUTP
     1L/100.
      WMFASA=1.1*WTFASA
      ZFAS=NXA+NYA+2.
      GO TO 210
C
C *** EQUATION FOR FASTENERS   (FASTENERS B)
C
  530 CONTINUE
      WTFASB=8.*GBOLT/100.+4.*GWASH/100.+8.*GNUTPL/100.
      WMFASB=1.1*WTFASB
      ZFAS=8.
      GO TO 210
C
C *** EQUATION FOR FASTENERS   (FASTENERS C)
C
  540 CONTINUE
      WTFASC=2.*GBOLT/100.+GWASH/100.+GNUTPL/100.+GCLAMP/100.
      WMFASC=1.1*WTFASC
      ZFAS=2.
      GO TO 210
C
C *** EQUATION FOR TOTAL STRUCTURE
C
  550 CONTINUE
      WTSTR=WTBMLA+WTBMLC+WTBMSA+WTBMSC+WTCORN+WTDOU+WTDOUB+WTFNGA+WTFNG
     1C+WTFNG2+WTFASA+WTFASB+WTFASC+WTHINA+WTHINB+WTHINC+WTINS+WTPLGA+WT
     2PLGC+WTPLT1+WTPLT2+WTPOSR+WTPOSA+WTPOSB+WTPOSC+WTSEAL+WTRNG1+WTRNG
     32+WTLRIB+WTSRIB
      WMSTR=WMBMLA+WMBMLC+WMBMSA+WMBMSC+WMCORN+WMDOU+WMDOUB+WMFNGA+WMFNG
     1C+WMFNG2+WMFASA+WMFASB+WMFASC+WMHINA+WMHINB+WMHINC+WMINS+WMPLGA+WM
     2PLGC+WMPLT1+WMPLT2+WMPOSR+WMPOSA+WMPOSB+WMPOSC+WMSEAL+WMRNG1+WMRNG
     32+WMLRIB+WMSRIB
```

```
ACWT=WTSTR
MAWT=WMSTR
KK=1
KT=1
N=11
KLIC=0
IF (ACWT.GT.0.) CALL COST
IF (ACWT.GT.0) ITL=1
ACWT=WTBMLA
MAWT=WMBMLA
KK=51
KT=1
N=12
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTDOUB
MAWT=WMDOUB
KK=52
KT=1
N=25
IF (ACWT.GT.0) CALL COST
ACWT=WTBMLA+WTDOUB
MAWT=WMBMLA+WMDOUB
KK=65
KT=1
N=26
KLIC=1
IF (ACWT.GT.0) CALL COST
ACWT=WTBMLC
MAWT=WMBMLC
KK=81
KT=1
N=19
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTLRIB
MAWT=WMLRIB
KK=82
KT=1
N=27
IF (ACWT.GT.0) CALL COST
ACWT=WTBMLC+WTLRIB
MAWT=WMBMLC+WMLRIB
KK=91
KT=1
N=26
KLIC=1
IF (ACWT.GT.0) CALL COST
ACWT=WTBMSA
MAWT=WMBMSA
KK=53
KT=1
N=13
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTBMSA
MAWT=WMBMSA
KK=66
```

```
      KT=1                                                              WTT 813
      N=26                                                              WTT 814
      KLIC=1                                                            WTT 815
      IF (ACWT.GT.0) CALL COST                                          WTT 816
      ACWT=WTBMSC                                                       WTT 817
      MAWT=WMBMSC                                                       WTT 818
      KK=83                                                             WTT 819
      KT=1                                                              WTT 820
      N=20                                                              WTT 821
      KLIC=2                                                            WTT 822
      IF (ACWT.GT.0.) CALL COST                                         WTT 823
      ACWT=WTSRIB                                                       WTT 824
      MAWT=WMSRIB                                                       WTT 825
      KK=84                                                             WTT 826
      KT=1                                                              WTT 827
      N=28                                                              WTT 828
      IF (ACWT.GT.0) CALL COST                                          WTT 829
      ACWT=WTBMSC+WTSRIB                                                WTT 830
      MAWT=WMBMSC+WMSRIB                                                WTT 831
      KK=92                                                             WTT 832
      KT=1                                                              WTT 833
      N=26                                                              WTT 834
      KLIC=1                                                            WTT 835
      IF (ACWT.GT.0) CALL COST                                          WTT 836
      ACWT=WTCORN                                                       WTT 837
      MAWT=WMCORN                                                       WTT 838
      KK=60                                                             WTT 839
      KT=4                                                              WTT 840
      N=14                                                              WTT 841
      KLIC=2                                                            WTT 842
      IF (ACWT.GT.0.) CALL COST                                         WTT 843
      ACWT=WTPLT1                                                       WTT 844
      MAWT=WMPLT1                                                       WTT 845
      KK=61                                                             WTT 846
      KT=1                                                              WTT 847
      N=29                                                              WTT 848
      IF (ACWT.GT.0) CALL COST                                          WTT 849
      ACWT=WTPLT2                                                       WTT 850
      MAWT=WMPLT2                                                       WTT 851
      KK=62                                                             WTT 852
      KT=1                                                              WTT 853
      N=29                                                              WTT 854
      IF (ACWT.GT.0) CALL COST                                          WTT 855
      ACWT=WTDOU                                                        WTT 856
      MAWT=WMDOU                                                        WTT 857
      KK=63                                                             WTT 858
      KT=1                                                              WTT 859
      N=30                                                              WTT 860
      IF (ACWT.GT.0) CALL COST                                          WTT 861
      ACWT=WTCORN+WTPLT1+WTPLT2+WTDOU                                   WTT 862
      MAWT=WMCORN+WMPLT1+WMPLT2+WMDOU                                   WTT 863
      KK=68                                                             WTT 864
      KT=1                                                              WTT 865
      N=31                                                              WTT 866
      KLIC=1                                                            WTT 867
      IF (ACWT.GT.0) CALL COST                                          WTT 868
      ACWT=WTHINA                                                       WTT 869
      MAWT=WMHINA                                                       WTT 870
```

```
KK=28
KT=NXA
N=15
IF (ACWT.GT.0.) CALL COST
ACWT=WTHINB
MAWT=WMHINB
KK=28
KT=4
N=15
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTHINC
MAWT=WMHINC
KK=28
KT=1
N=15
IF (ACWT.GT.0.) CALL COST
ACWT=WTINS
MAWT=WMINS
KK=79
KT=20
N=18
IF (ACWT.GT.0.) CALL COST
ACWT=WTPOSR
MAWT=WMPOSR
KK=85
KT=1
N=21
IF (ACWT.GT.0.) CALL COST
ACWT=WTRNG2
MAWT=WMRNG2
KK=88
KT=1
N=32
IF (ACWT.GT.0) CALL COST
ACWT=WTFNG2
MAWT=WMFNG2
KK=86
KT=1
N=33
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSR+WTRNG2+WTFNG2
MAWT=WMPOSR+WMRNG2+WMFNG2
KK=93
KT=1
N=34
KLIC=1
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSA
MAWT=WMPOSA
KK=55
KT=2
N=16
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTPLGA
MAWT=WMPLGA
KK=57
```

```
KT=2
N=35
IF (ACWT.GT.0) CALL COST
ACWT=WTFNGA
MAWT=WMFNGA
KK=56
KT=2
N=33
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSA+WTPLGA+WTFNGA
MAWT=WMPOSA+WMPLGA+WMFNGA
KK=67
KT=2
N=34
KLIC=1
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSB
MAWT=WMPOSB
KK=75
KT=4
N=16
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTPOSB
MAWT=WMPOSB
KK=76
KT=1
N=34
KLIC=1
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSC
MAWT=WMPOSC
KK=95
KT=1
N=16
KLIC=2
IF (ACWT.GT.0.) CALL COST
ACWT=WTRNG1
MAWT=WMRNG1
KK=98
KT=1
N=32
IF (ACWT.GT.0) CALL COST
ACWT=WTFNGC
MAWT=WMFNGC
KK=96
KT=1
N=33
IF (ACWT.GT.0) CALL COST
ACWT=WTPLGC
MAWT=WMPLGC
KK=97
KT=1
N=35
IF (ACWT.GT.0) CALL COST
ACWT=WTPOSC+WTRNG1+WTFNGC+WTPLGC
MAWT=WMPOSC+WMRNG1+WMFNGC+WMPLGC
KK=94
```

```
      KT=1
      N=34
      KLIC=1
      IF (ACWT.GT.0) CALL COST
      ACWT=WTSEAL
      MAWT=WMSEAL
      KK=69
      KT=1
      N=17
      KLIC=2
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTSTR
      MAWT=WMSTR
      IF (KINDS.EQ.1) KK=50
      IF (KINDS.EQ.2) KK=70
      IF (KINDS.EQ.3) KK=80
      KT=1
      N=36
      KLIC=1
      IF (ACWT.GT.0) CALL COST
      IF (KINDP.EQ.0) GO TO 560
      ACWT=WTFASA
      MAWT=WMFASA
      KK=9
      KT=NXA+NYA+2.
      N=22
      KLIC=0
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTFASB
      MAWT=WMFASB
      KK=9
      KT=8
      N=22
      IF (ACWT.GT.0.) CALL COST
      ACWT=WTFASC
      MAWT=WMFASC
      KK=9
      KT=2
      N=22
      IF (ACWT.GT.0.) CALL COST
  560 KLIC=10
      IF (KINDP.EQ.0) KLIC=100
      IF (KINDS.EQ.0) KLIC=100
      KK=199
      KT=1
      IF (ITL.EQ.0) RETURN
      CALL COST
      RETURN
      END
```

APPENDIX II

SUBROUTINE DESCRIPTIONS

1. PROGRAM 5490B is the driver which executes various links or overlays of the computer program. These segments include (1) input, 2 two-dimensional explicit heat transfer and discrete element stress analysis, (2) additional input and one-dimensional, implicit ablator or RSI heat transfer analysis, (3) finite element stress analysis for the RSI configuration, (4) the sonic fatigue and panel flutter analysis, and (5) the weight/cost analysis. These links also handle various portions of their own selected outputs.

2. FUNCTION TRIPLATE is a specialized linear interpolation routine for a triply subscripted variable used for determining material properties in the stress analysis.

3. FUNCTION TABLE is a linear interpolation subroutine used for a number of table look-ups throughout the program.

4. SUBROUTINE TPSOPT is a driver subroutine which calls the program input routine, increments time in the trajectory, calls for atmospheric conditions, heating rates, temperature computations, the stress analysis, the sonic fatigue analysis, and the determination of weights and costs. The PINTI subroutine is also called from this driver.

5. SUBROUTINE AIR computes the real gas equilibrium thermodynamic properties of air (compressibility factor, density, temperature, speed of sound, and enthalpy or entropy) in terms of pressure and/or entropy and/or enthalpy (use only two of these three).

6. SUBROUTINE BUCKNG iteratively solves for the plasticity correction factor of the thermal stress analysis. In the expression solved, the stress is related to the tangent modulus and modulus of elasticity (the ratio being the plasticity correction factor) in terms of the applied and critical stresses and the Ramberg-Osgood shape parameter.

7. SUBROUTINE FLOWF solves for the flowfield properties for the six different geometric configurations available, (e.g., cone, wedge, sphere, cylinder, etc.). The procedure also calls subroutines SHOCK, AIR, and FMUT to solve the governing equations of energy, momentum, and state across the shock wave, to determine the equilibrium thermodynamic properties of air, and to calculate real gas viscosity.

8. FUNCTION FMUT specifies real gas, equilibrium viscosity of air in terms of pressure and temperature.

9. SUBROUTINE MSMIN compares two numbers and determines the smaller.

10. SUBROUTINE OFFCL computes off centerline heating peripherially around the body as a ratio to bottom centerline values.

11. SUBROUTINE PANEL computes geometric properties of the discrete elements for the thermal stress analysis from the general panel dimensions which have been input to the program.

12. SUBROUTINE PRA63 calculates freestream atmospheric properties of temperature, pressure, and density as a function of altitude using curve fits of properties of the 1963 Patrick Reference Atmosphere.

13. SUBROUTINE PRINT1 is the main output subroutine which writes out aerothermodynamic characteristics of the environment such as fluidynamic properties and vehicle attitude as well as temperature and stress distributions of the panel cross-section.

14. SUBROUTINE SHOCK determines flowfield properties down stream of a shock wave of a given angle by simultaneously solving the energy, momentum, and state equations.

15. SUBROUTINE STRESS performs the discrete element thermal stress analysis on each of the six panel configurations depending upon which is under consideration. At increments in the trajectory equal to the print interval, nodal temperatures are interpolated from the temperature distribution, and thermal stresses are determined along with design factors and creep rates. All these values are stored in array for use at the end of the trajectory at which time the minimum design factors are identified. If any are negative, the panel thickness is increased and stresses recomputed. The panel thickness is increased until all design factors are positive.

16. SUBROUTINE THERMO determines the heat transfer rates for each of the six different configurations (critical, cylinder, wedge, sphere), determines the state of the boundary layer, and corrects both heating rates and transition for cross flow.

17. SUBROUTINE INPUT1 reads and prints out all input data except those used in the RSI/ablator thermodynamic or the weight/cost analysis. Panel geometrical parameters, material properties, the trajectory, and radiation interchange factors as well as indices which specify options to be performed by the program are read and then written out for the program user.

18. SUBROUTINE INPUT2 reads in only the thermodynamic properties needed to perform the one-dimensional implicit heat transfer analysis for the RSI and ablator TPS.

19. SUBROUTINE CONDTN performs the one-or two-dimensional, explicit heat transfer calculations and interpolates to obtain temperature distributions needed for the stress analysis for the cover panels denoted by the values of NSECT equal to one through six.

20. SUBROUTINE ABLATE determines the thermodynamic performance of a charring ablator using essentially the computer code presented in NASA TN-D 3150 by Donald M. Curry. Corrections are made to the applied heating rates either for hot wall temperature effects or the decrease in net heating due to the blowing of pyrolysis gases and char.

21. SUBROUTINE COEFF calculates the coefficients of the tridiagonal matrices used in the implicit heat transfer calculations related to SUBROUTINE ABLATE.

22. SUBROUTINE MDOT determines the mass flow rate of pyrolysis gases produced by the charring ablator.

23. SUBROUTINE PROP calculates the physical, thermodynamic properties of the heat shield structures which relate to NSECT = 7 and 8, the RSI and ablative TPS's.

24. SUBROUTINE QDOT computes the temperatures of the receding ablator at the material nodal points by linear interpolation. In this manner, the same number of nodes always describe the ablator behavior.

25. SUBROUTINE RECESS computes the front face location and the char mass removal rate for the ablator.

26. SUBROUTINE SWUFT determines the forward time step temperatures by solving the tri-diagonal matrix of the charring ablator.

27. SUBROUTINE RSICMP computes the temperature distribution in the TPS panel using phase-change material in the backup structure. For cases when the phase-change material is contained in a honeycomb structure, the routine computes the equivalent thermodynamic properties of the phase-change material and the honeycomb.

APPENDIX III

PROGRAM FLOW CHART

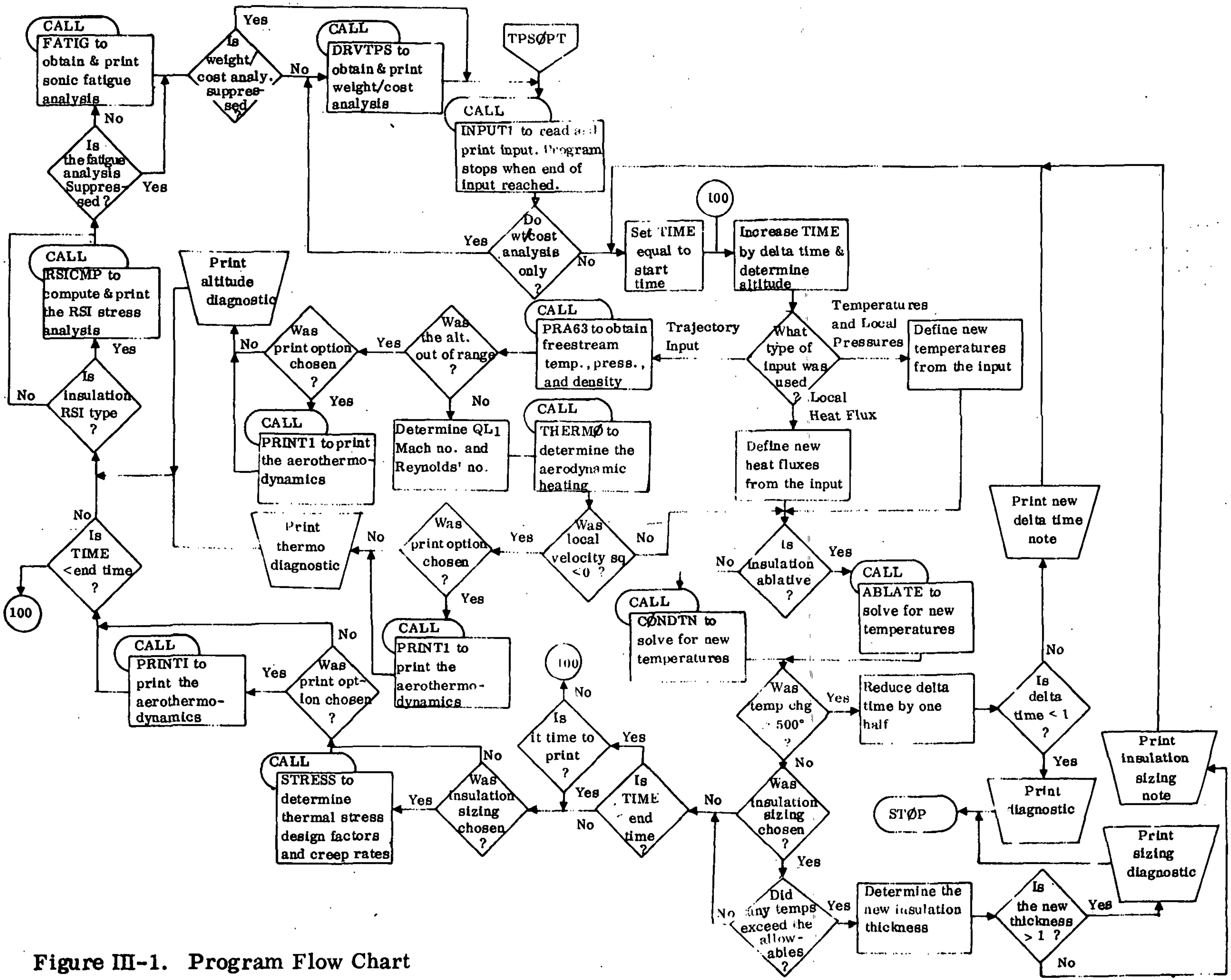

Figure III-1. Program Flow Chart