COMPUTATIONAL TECHNIQUES FOR DESIGN
OPTIMIZATION OF THERMAL PROTECTION SYSTEMS
FOR THE SPACE SHUTTLE VEHICLE

VOLUME II + USER'S MANUAL

GENERAL DYNAMICS
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COMPUTATIONAL TECHNIQUES FOR DESIGN OPTIMIZATION OF THERMAL PROTECTION SYSTEMS FOR THE SPACE SHUTTLE VEHICLE

VOLUME II • USER'S MANUAL

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FOREWORD

This investigation was performed for the NASA Manned Spacecraft Center 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 Dr. Whitehead and a project team consisting of Dr. K. T. Shih - Thermodynamics, Mr. G. L. Getline - Dynamics, Mr. R. S. Wilson - Stress, and Messrs R. H. Trelease and S. T. Hitchcock - Weights/Cost Analysis. All work was done at the San Diego Operation of the Convair Aerospace Division of General Dynamics with the exception of consultation provided by Mr. J. D. Anderson of the Fort Worth Operation on the acoustic fatigue computer program. Results of the study are published in two volumes; the Final Report (Vol I) and User's Manual (Vol II).
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SUMMARY

A study was performed to assimilate and develop 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 a sample problem to illustrate use of the program.

The major effort of the investigation consisted of the development of the computational techniques and programming of the subsequent methodology. The program itself was effected in modular fashion to allow continuing improvement and update of the performance prediction techniques. The program logic involves subroutines which handle the following basic functions: (1) a driver which calls for input, output, and communication between program and user and between the subroutines themselves, (2) a thermodynamic analysis which includes prediction of both the aerodynamic heating rates and the resulting heat transfer and temperature response of the TPS, (3) a thermal stress analysis which predicts the internal stresses and creep rates of the TPS by a discrete element analysis which structurally models the TPS subject to both external forces due to aerodynamic pressure and thermal stresses caused by heating, (4) an acoustic fatigue analysis which predicts both the noise excitation due to a number of external sources and the fatigue life of the panel, and (5) a weights/cost analysis which determines the weight and manufacturing cost of the system by identifying and evaluating these parameters for each of the TPS's components parts. 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. In a subsequent investigation these redesign iterations are being refined.
Optimization and sensitivity studies are performed by the user by varying panel size, material properties, and configuration (six different metallic panel cross-section geometries are provided) in a series of computer runs. The program sizes panel and insulation thicknesses. 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.

As the final task of this study, recommendations are made for computer program improvements which include new thermal protection systems (both active and passive) and improved computational and iterative techniques.
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 a sample problem. 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 data necessary to perform the thermal protection system (TPS) sizing. For a given trajectory, location on the spacecraft, and computational time interval, the subroutine THERMO computes the local pressure and aerodynamic heating rate. The temperature and stress response of the structure are then evaluated by the subroutines CONDTN and STRESS respectively. Panel and insulation thickness are sized by comparing the computed results to thermal and stress constraints. Once the TPS has been sized thermodynamically and structurally, the acoustic fatigue analysis subroutine FATIG computes the dynamic response of the TPS and compares it to the lifetime requirements of the vehicle. Finally, the weight/cost analysis subroutine DRVTPS predicts TPS unit weight and cost.

The 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.
SECTION 2
PROGRAM CAPABILITIES AND LIMITATIONS

The program has been written in modular fashion. The primary purpose of this is to provide ease of modification. A continual improvement of the program to maintain the state-of-the-art is being conducted under Contract NAS9-11992. 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 the distance from the leading edge (or diameter of the body in the case of high angle of attack), and the direction cosines of outer normal from the surface, a unit vector \( \bar{n} \)

\[
\bar{n} = iDnx + jDny + kDnz \quad (2.1)
\]

If the freestream unit velocity vector, \( \bar{v} \), is defined as

\[
\bar{v} = \frac{\bar{v}}{V} = \cos\alpha \cos\beta + j\sin\beta + k\sin\alpha \cos\beta \quad (2.2)
\]

where \( \alpha \) is the angle of attack and \( \beta \) is the yaw angle, the effective angle of attack, \( \alpha_{\text{eff}} \), is then

\[
\sin \alpha_{\text{eff}} = \bar{n} \cdot \bar{v} \quad (2.3)
\]

Figure 2-1. Coordinate System

2.2 AERODYNAMIC HEATING

Three 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). The third technique is simply a statement of the temperature of the first row of segments.

Prediction of aeroheating (subroutine THERMO) can be conveniently classified into two regimes: high and low local angle of attack. For low angle-of-attack applications, the shock waves are assumed attached to the body, and flow field properties can be computed from tangent wedge/cone techniques. Using these local properties, the algorithm then computes local heating rates using either the Eckert reference enthalpy method or the Spalding-Chi technique. Transitional heating between the laminar and turbulent boundary layers is calculated as a linear interpolation of turbulent and laminar 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.

At high angles of attack, the flow field cannot be predicted so conveniently as at low angles of attack. Thus, current state of the art techniques recommend aeroheating rate calculation by swept cylinder methods, either laminar or turbulent. At the moment, no transition criterion has been established for the switch from laminar to turbulent swept cylinder heating prediction techniques.

2.3 STRUCTURAL TEMPERATURE RESPONSE

The temperature response of the internal TPS structure is determined by solving an explicit statement of the Fourier heat conduction law. The structural temperature distributions are evaluated by simulating the TPS as a structure of lumped nodes. Nodal densities, specific heats, and other thermodynamic parameters as well as radiative and conductive heat transfer coefficients between nodes then determine the coefficients of the finite difference analog of the Fourier equation.

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. These points are tabulated data, and the properties at a specific temperature are established by linear interpolation.

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 ×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
describes radiation heat exchange, $Q_{ij}$, between two parallel plates $i$ and $j$, where $\sigma$ is the Boltzmann's constant, $\epsilon$ is the emissivity, $A$ is the area, $F$ is the view factor and $T$ is the temperature. Equation 2.4 is an approximate form. For rigorous calculations the "overall interchange factor," $\tau_{ij}$ should be computed and supplied as part of the problem input. By substituting $\epsilon_i = \epsilon_j = 1$ and $F_{ij} = \tau_{ij}$ into equation (2.4) we have

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

(2.5)

2.4 STRESS ANALYSIS

The stress analysis (subroutine STRESS) is performed for any of six simply-supported panels (Figures 2–3 and 2–4) with joints which permit free thermal expansion. Figure 2–3 gives overall geometrical dimensions for the panel, and geometries for individual panel configurations are given in Figure 2–4. 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 thermal stress analysis; Figure 2–5 shows the panel segmentations together with the conduction matrices. It is essential that the conduction input obeys the matrix given in this figure.

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.
2.5 ACOUSTIC FATIGUE

The acoustic fatigue analysis (subroutine FATIG) computes the fundamental frequency of each of four different panel configurations (Figure 2-6). Although not all of these are in use presently, they will be utilized for concepts under development. Noise computations are performed for each of four different sources (turbulent boundary layer, boost engines, jet flyback engine, or scubbing 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 of engine induced noise, or the run length distance for the turbulent boundary layer, Figure 2-7). The panel moment of inertia about the cross-section neutral axis is computed external to the program by standard methods of stress analysis (Reference 2). 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 weights/cost analysis predicts the weight and cost per unit area of three different panel configurations (Figure 2-6) and three different concepts of heat post supports (Figure 2-8). The type of panel and support structure is input to the program along
1. CONVAIR TRAPEZOIDAL

2. FLAT CORRUGATION WITH SKIN

3. RIB-STIFFENED PANEL

4. SKIN-STRINGER

5. OPEN CORRUGATION

6. OPEN CORRUGATION (CIRCULAR ARC CORRUGATION)

Figure 2-4. Panel Geometries

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### Figure 2-5. Configurations for Stress Analysis

<table>
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<th>CONDUCTION MATRIX</th>
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<tr>
<td>2</td>
<td><img src="image3.png" alt="Image 3" /></td>
<td><img src="image4.png" alt="Image 4" /></td>
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<tr>
<td>3</td>
<td><img src="image5.png" alt="Image 5" /></td>
<td><img src="image6.png" alt="Image 6" /></td>
</tr>
<tr>
<td>4</td>
<td><img src="image7.png" alt="Image 7" /></td>
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<tr>
<td>5</td>
<td><img src="image9.png" alt="Image 9" /></td>
<td><img src="image10.png" alt="Image 10" /></td>
</tr>
<tr>
<td>6</td>
<td><img src="image11.png" alt="Image 11" /></td>
<td><img src="image12.png" alt="Image 12" /></td>
</tr>
</tbody>
</table>

- **Metal** shaded area
- **Insulation** crosshatched area
- **Open Space** blank area
Figure 2-6. Sonic Fatigue Analysis Configurations

FLYBACK ENGINE PARAMETERS
AE NOZZLE EXIT AREA
VJ EXHAUST VELOCITY
WEJ WEIGHT FLOW
TJ THRUST
VV VEHICLE VELOCITY DURING FLYBACK

ROCKET ENGINE PARAMETERS
TT THRUST
WER WEIGHT FLOW
D NOZZLE DIAMETER
VS EXHAUST VELOCITY

Figure 2-7. Sonic Fatigue Input Nomenclature
with the panel and supporting structure geometry (Figures 2-9 through 2-13). 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, manufacturing, engineering, and refurbishment costs for each panel configuration and then dividing by panel size. Each individual cost (material, manufacturing, etc.) 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.

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. Since some of the basic cost information stored within the program is still under development, values for the manufacturing costs should be taken under advisement.

The program total cost is based upon techniques generated for the space shuttle booster. The primary driver is weight of the TPS, and all costs are based on an area of 22,000 ft$^2$ on the vehicle. Hence, unit area costs can be obtained by dividing total program costs by this number. All cost factors are currently embedded in the program, but refinements are being made to include a wider range of materials and configurations as well as to permit the user's input of his own cost information.
Figure 2-9. Panel Nomenclature for Weights/Cost

Figure 2-10. Cruciform and Support Post Assembly (Concept A)
Figure 2-11. Cruciform and Support Beams (Concept A)

Figure 2-12. Sheet Metal Standoff Post (Concept B)
2.7 TPS SIZING ROUTINE

A short discussion of the TPS sizing routine is included in this manual to facilitate the user's understanding of the mechanics of the procedure. First, it must be remembered that the two parameters varied in the sizing procedure are the panel thickness and the insulation thickness. All other material properties and geometric parameters remain constant. It is recommended that all support structure thicknesses be taken as minimum gauge for the particular material considered.

Thermodynamic constraints to the system are input as maximum allowable temperatures for each material in the parameter TALLW(I) (e.g., an aluminum substructure would be characterized by an allowable temperature of approximately 250°F). The temperature of each material is monitored throughout the flight and compared to the maximum allowable. A word of caution is in order here, however. The program user should be careful that the insulation to be sized lies between the exterior surface (more specifically, the heat source) and the material whose maximum allowable temperature will be the design point (Figure 2-14a). If this is not the case, then when the maximum allowable temperature is exceeded, the insulation thickness will be increased, thus driving the actual temperature of the critical material even higher. Consider as an example the configuration shown in Figure 2-14b. When the tank wall exceeds its maximum allowable temperature, the insulation will be thickened and the tank wall will get hotter. At the moment, there is no logic in the computer code to guard against this occurrence.

When an actual temperature exceeds the maximum allowable, the insulation thickness is increased, the program returns to the starting point of the calculations, and the computations are begun anew. The insulation thickness is continually increased until
either the actual temperature of the critical material is less than the maximum allowable, or until the insulation thickness reaches one foot. For the latter case, the run is terminated. Here, the program user should again be critical of the printed results. This first generation computer program does not decrease the insulation thickness once a value is found which satisfies the temperature constraints. Hence, the insulation thickness may be beyond design requirements, and only perusal of the resulting temperature distribution will determine this fact. A subsequent computer run with a different initial insulation thickness may be necessary. Messages describing all changes in insulation thicknesses and/or termination of the case (along with appropriate temperatures) are printed out.

Structural or stress constraints to the system are not input by the program user but instead are inherent in the design technique. Six different design factors are considered in the stress analysis of the TPS panel. Tests to satisfy these design constraints are made on each of the nodes comprising the discrete element analysis of the various panel configurations (Figure 2-5). Each design factor and an explanation of its use is presented in Table 2-1. All of these factors are ratios of actual stresses or strains to allowable values for the particular material; they are fundamental expressions used in determining margins of safety in any stress analysis.
Table 2-1. Stress Design Factors

<table>
<thead>
<tr>
<th>Design Factor</th>
<th>Design Point</th>
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<tbody>
<tr>
<td>T1MS</td>
<td>Ultimate Tension</td>
</tr>
<tr>
<td>Y2MS</td>
<td>Yield Strength</td>
</tr>
<tr>
<td>C3MS</td>
<td>Ultimate Compression</td>
</tr>
<tr>
<td>C4MS</td>
<td>Buckling of Corrugation*</td>
</tr>
<tr>
<td>F5MS</td>
<td>Crippling of Flange No. 1</td>
</tr>
<tr>
<td>F6MS</td>
<td>Crippling of Flange No. 2</td>
</tr>
</tbody>
</table>

*Applicable only to Configurations 1 and 2.

The stress analysis is called during each print interval of the trajectory. This increment is determined by the input parameter DELTA. When the subroutine STRESS is called, the discrete element thermal stress analysis is performed, and the design factors of Table 2-1 are stored for each discrete element of the cross-section. The stress analysis may be performed up to 99 times during the trajectory since this is the amount of storage now called in the program. At the end of the trajectory, the stress analysis subroutine assesses all of the design factors accumulated in the run and identifies the largest ones. If they are all positive and the actual values do not exceed the allowable ones, the analysis is terminated. On the other hand, if a design factor is negative, then the panel thickness is increased to accommodate the applied loads. On the first iteration, the skin thickness is increased by 0.010 in. and the stress analysis at the critical time is performed again using the temperature distribution and external forces stored for that particular time of the trajectory. If this new thickness is not sufficient, a Newton-Raphson technique is employed to extrapolate to a new thickness. The procedure continues until a thickness is determined for which all design factors are positive. The sizing of the structure is demonstrated in the sample problem run in Section 4.

There are two limitations to the present program which should be kept in mind by the program user. First, the stress analysis is complete when all design factors are positive. However, no check is made to see how far from zero these factors are. It is possible that panel thickness derived from an extrapolation which was determined from points below a design value may result in a panel thickness that is significantly above design requirements. Second, all thermal stress analyses are performed using the temperature distribution stored in core, i.e., that which corresponds to the panel thickness originally input to the program. Experience has shown, however, that since stresses are dependent on temperature gradients and not absolute values of temperature, the gradients are insensitive to small changes in panel thickness.
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).

Simplification has been made in the input subroutine to allow changing the input parameters by employing a namelist DATANU. This method is implemented when the parameter JI=2 (Record 1, Figure 3-1). In addition, two parameters NUDIM and NUTRAJ can be used to further simplify the input. If the parameter NUDIM=1, the program reads records 13 through 18. If NUTRAJ=1, the program reads the first trajectory card (this option may be used together with NANG=2). If NUTRAJ=2, the program looks for a new set of trajectory data. The definitions of the input symbols remain as given in Table 3-1. The namelist input starts with $ in column 2 followed immediately by the name DATANU with no embedded blanks. Succeeding are data items and a $ at the end. A sample of DATANU input is illustrated in Figure 3-2.

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 27.

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 phrase 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

<table>
<thead>
<tr>
<th>Record Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alphanumeric</strong></td>
<td>TITLE</td>
<td>Case identification and comments, maximum 10 cards</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>JI</td>
<td>Indicator marking the last title card which specifies the input data form, input a 1, 2 or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Use standard input formats</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Use the namelist DATANU (see Figure 3-2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Same as 1 but do not read trajectory cards</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>ICONF</td>
<td>Specifies body configuration, input a 1, 2 or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Flat plate, wedge or cylinder</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Cone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Sphere</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>IQCON</td>
<td>Specifies variation of input heat transfer multipliers, laminar and turbulent input a 1, 2, or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. QCONL(I) = QCONT(I) = 1 (no input required)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Input QCONL(I). QCONT(I) = QCONL(I)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Input both QCONL(I) and QCONT(I)</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>IQINP</td>
<td>Specifies variation of trajectory cards, input a 1, 2 or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Input trajectory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Input local heat flux and pressure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Input temperature of the 1st row segments and local pressure</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>ITURB</td>
<td>Specifies turbulent prediction method, input a 1 or 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Eckert reference enthalpy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Spalding-Chi</td>
</tr>
<tr>
<td><strong>Integer</strong></td>
<td>IWALT</td>
<td>Specifies conditions of wall temperature, input a 1 or 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Uniform</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Nonuniform</td>
</tr>
<tr>
<td>Record</td>
<td>Variable Type</td>
<td>Symbol</td>
</tr>
<tr>
<td>--------</td>
<td>----------------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| NANG   | Specified variation of input angle of attack, input a 1 or 2  
1. \( \alpha, \beta \) are function of trajectory  
2. \( \alpha = \text{ALPHA}(1), \beta = \text{BETA}(1) \) |        |            |
| NCOLM  | Number of Columns \( \leq 9 \)  
1. One-dimensional heat conduction  
2. Two-dimensional heat conduction |        |            |
| NSEG   | Number of segments \( \leq 9 \) |        |            |
| NMAT   | Number of materials \( \leq 9 \) |        |            |
| 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 \( \leq 18 \) |        |            |
| NCRC   | Specifies coordinate systems used for conduction analysis, input a 1 or 2  
1. Rectangular coordinate  
2. Cylindrical coordinate  
Use only 1 for this version |        |            |
| NSECT  | Panel configurations (see Figure 2-4) input a 1, 2, 3, 4, 5 or 6  
1. Convair trapezoidal  
2. Flat corrugation with skin  
3. Rib stiffened panel  
4. Skin stringer  
5. Open corrugation  
6. Circular arc corrugation |        |            |
<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NINS</td>
<td>Specifies input material number of the insulation (limited to one material) to be sized. If insulation sizing option is not used, leave blank.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NF</td>
<td>Number of flights.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NPRT</td>
<td>Specifies output form, input a 1 if 'long' print out option is used. Leave blank for 'short' print out</td>
</tr>
<tr>
<td>3</td>
<td>Real</td>
<td>DNX</td>
<td>Direction cosines of outer normal from surface</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DNY</td>
<td>(See Figure 2-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DNZ</td>
<td>(See Figure 2-1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XDST</td>
<td>Distance from the leading edge, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DIAM</td>
<td>Diameter of a sphere or cylinder, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AROD</td>
<td>Ratio of shoulder radius to body diameter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XEMIS</td>
<td>Outer surface emissivity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FACC</td>
<td>Factor to increase insulation thickness</td>
</tr>
<tr>
<td>4</td>
<td>Real</td>
<td>STAAT</td>
<td>Time to start computation, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DELTA</td>
<td>Computation interval, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WROTE</td>
<td>Print interval, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>STOOP</td>
<td>Time to stop computation, sec</td>
</tr>
<tr>
<td>5</td>
<td>Real</td>
<td>AS</td>
<td>Pitch of corrugations or ribs, in. (See Figure 2-4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>Radius of corrugations, in. (See Figure 2-4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HH</td>
<td>Depth of section, in. (See Figure 2-4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TS</td>
<td>Skin thickness, in. (See Figure 2-4)</td>
</tr>
<tr>
<td>Record</td>
<td>Variable Type</td>
<td>Symbol</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>---------------</td>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>TC</td>
<td>Real</td>
<td>TC</td>
<td>Corrugation thickness, in. (See Figure 2-4)</td>
</tr>
<tr>
<td>SL</td>
<td>Real</td>
<td>SL</td>
<td>Overall width of panel, in. (See Figure 2-3)</td>
</tr>
<tr>
<td>SLS</td>
<td>Real</td>
<td>SLS</td>
<td>Overall length of panel, in. (See Figure 2-3)</td>
</tr>
<tr>
<td>BE</td>
<td>Real</td>
<td>BE</td>
<td>Distance of reaction from panel edge, in. (See Figure 2-4)</td>
</tr>
<tr>
<td>6</td>
<td>Real</td>
<td>F07</td>
<td>Secant yield stress (\bar{F}) (Ramberg-Osgood) (\text{lb/in}^2). (Ref. 3)</td>
</tr>
<tr>
<td>UF</td>
<td>Real</td>
<td>UF</td>
<td>Ultimate factor</td>
</tr>
<tr>
<td>DST</td>
<td>Real</td>
<td>DST</td>
<td>Difference between two values of creep strain used for Lawson-Miller data in./in.</td>
</tr>
<tr>
<td>EALL</td>
<td>Real</td>
<td>EALL</td>
<td>Allowable creep strain in./in.</td>
</tr>
<tr>
<td>CRN</td>
<td>Real</td>
<td>CRN</td>
<td>Shape parameter for stress strain curve (Ramberg-Osgood) (Ref. 3)</td>
</tr>
<tr>
<td>BF</td>
<td>Real</td>
<td>BF</td>
<td>Width of flange or flat segment (Conf. 2) in. (See Figure 2-4)</td>
</tr>
<tr>
<td>BFL</td>
<td>Real</td>
<td>BFL</td>
<td>Width of inner flange (Conf. 4) in. (See Figure 2-4)</td>
</tr>
<tr>
<td>BL</td>
<td>Real</td>
<td>BL</td>
<td>Width of lip on inner flange (Conf. 4) in. (See Figure 2-4)</td>
</tr>
<tr>
<td>7</td>
<td>Real</td>
<td>TALLW(I)</td>
<td>Allowable temperature of the material, R°F</td>
</tr>
<tr>
<td>8</td>
<td>Real</td>
<td>EMIS(I)</td>
<td>Emissivity of the material</td>
</tr>
<tr>
<td>9</td>
<td>Real</td>
<td>RHO(I)</td>
<td>Density of the material, lb/ft³</td>
</tr>
<tr>
<td>10</td>
<td>Integer</td>
<td>ID(I, J)</td>
<td>Specifies input of material property tables input a 1 or 2 or leave blank to skip input</td>
</tr>
</tbody>
</table>
Table 3-1. Input Symbols, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Integer</td>
<td>ID(I, J)</td>
<td>(Cont'd)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Read AY only (AX same as before)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Read both AX and AY</td>
</tr>
<tr>
<td>10</td>
<td>Integer</td>
<td>MPT(I, J)</td>
<td>Number of pairs or points</td>
</tr>
<tr>
<td>11</td>
<td>Real</td>
<td>AX(I, J, K)</td>
<td>Independent variable</td>
</tr>
<tr>
<td>12</td>
<td>Real</td>
<td>AY(I, J, K)</td>
<td>Dependent variable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>I = 1, 2, ..., NMAT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>J = 1. Thermal conductivity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Heat capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Young's modulus</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4. Coefficient of thermal expansion</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5. Yield strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6. Ultimate tensile strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7. Larson Miller parameter for strain 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8. Larson Miller parameter for strain 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>K = 1, 2, ..., MPT(I, J)</td>
</tr>
<tr>
<td>13</td>
<td>Real</td>
<td>X(I)</td>
<td>Width of the Ith Column, ft</td>
</tr>
<tr>
<td>14</td>
<td>Real</td>
<td>QCONL(I)</td>
<td>Laminar heat transfer multiplier of the Ith column, omit if IQCON=1 or NCOLM=1</td>
</tr>
<tr>
<td>15</td>
<td>Real</td>
<td>QCONT(I)</td>
<td>Turbulent heat transfer multiplier for the Ith column, omit if IQCON#3 or NCOLM=1</td>
</tr>
<tr>
<td>16</td>
<td>Real</td>
<td>Y(J)</td>
<td>Thickness of the Jth segment, ft</td>
</tr>
<tr>
<td>17</td>
<td>Integer</td>
<td>MAT(I, J)</td>
<td>Specifies materials of column I, segment J</td>
</tr>
</tbody>
</table>

A zero denotes a void.

3-7
Table 3-1. Input Symbols, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Real</td>
<td>TAMP(I, J)</td>
<td>Specifies initial temperature of column I, segment J, °R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Omit record 18 if NCOLM=1 or NRSG=0</td>
</tr>
<tr>
<td>18</td>
<td>Integer</td>
<td>NR(N)</td>
<td>Specifies nodes with internal radiation exchange.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>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.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NI(N)</td>
<td>Number of nodes to be interacted with node NR(N), ≤ 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MR(M, N)</td>
<td>Specifies nodes to interchange with node NR(N)</td>
</tr>
<tr>
<td>18</td>
<td>Real</td>
<td>VFACT(M, N)</td>
<td>View factors or $f_{ij}$ with EMIS(I) = 1</td>
</tr>
</tbody>
</table>
| 19     | 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                                                                                                               |
|        |               | NPAN         | Panel configuration index
1 ~ flat plate
2 ~ honeycomb sandwich
3 ~ integrally stiffened
4 ~ corrugated                                                                                                                                 |

1-9, material number negative. The segment will be grouped together with the right-hand side segment for condition computations.
<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Real</td>
<td>DT(1)</td>
<td>Period of turbulent boundary layer noise excitation, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XL</td>
<td>Run length of turbulent boundary layer, feet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>REY</td>
<td>Local Reynolds number</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VU</td>
<td>Local velocity, ft/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>QL</td>
<td>Local dynamic pressure, psi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMACH</td>
<td>Local Mach number</td>
</tr>
<tr>
<td>21</td>
<td>Real</td>
<td>DT(2)</td>
<td>Period of rocket engine noise excitation, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TT</td>
<td>Rocket engine thrust, lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WER</td>
<td>Rocket engine weight flow, lb/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>Rocket nozzle exit diameter, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VS</td>
<td>Rocket exhaust velocity, ft/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XI</td>
<td>Distance between point of interest and rocket engine exit, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DVEH</td>
<td>Vehicle diameter, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YCL</td>
<td>Buttline distance between panel and vehicle centerline, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DREF</td>
<td>Reference distance between noise source on pad and rocket engine exhaust plane, ft</td>
</tr>
<tr>
<td>22</td>
<td>Real</td>
<td>DT(3)</td>
<td>Period of jet (flyback) engine noise excitation, sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AE</td>
<td>Nozzle exit area, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VJ</td>
<td>Jet velocity, ft/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WEJ</td>
<td>Jet engine weight flow, lb/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VV</td>
<td>Vehicle velocity at flyback cruise, ft/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TJ</td>
<td>Jet engine thrust, lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XJ</td>
<td>Axial distance from point of interest to jet engine exit nozzle, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YP</td>
<td>Radial distance from point of interest to jet engine nozzle, ft (less than 200 ft)</td>
</tr>
</tbody>
</table>
Table 3-1. Input Symbols, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>Real</td>
<td>DT(4)</td>
<td>Period of jet (flyback) engine scrubbing noise excitation, sec</td>
</tr>
<tr>
<td>24</td>
<td>Real</td>
<td>HPAN</td>
<td>Panel thickness, inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HC</td>
<td>Core thickness, inches (for honeycomb sandwich)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AI</td>
<td>Panel moment of inertia, in. $^4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AIY</td>
<td>Panel moment of inertia, in. $^4$ (for normal direction of corrugated panel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AW</td>
<td>Panel length, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BW</td>
<td>Panel width, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EP</td>
<td>Modulus of elasticity for panel, psi</td>
</tr>
<tr>
<td>25</td>
<td>Real</td>
<td>C(I)</td>
<td>Coefficients of a least squares, 3rd order curve fit of allowable S-N data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RHOP</td>
<td>Panel material density, lb/ft$^3$</td>
</tr>
<tr>
<td>26</td>
<td>Real</td>
<td>TIME(I)</td>
<td>Time in trajectory, sec, $I \leq 99$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ALT(I)</td>
<td>$IQINP=1$. Altitude, ft</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Local heat flux, Btu/ft$^2$-sec$^\circ$R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Temperature of 1st segments $^\circ$R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Note: $QCONL(I)$ may be used to obtain a distribution of $Q(I)$ or $TEMP(I,1)$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VINF(I)</td>
<td>If $IQINP=1$, free stream velocity, ft/sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>If $IQINP=2$, 3 local pressure psia</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ALPHA(I)</td>
<td>Angle of attack, degrees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BETA(I)</td>
<td>Yaw angle, degrees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HINSD(I)</td>
<td>Convection heat transfer coefficient to internal fluid. Btu/ft$^2$-sec$^\circ$R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(input 1.E9 to keep last row of segments at the initial temperature)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TINSD(I)</td>
<td>Bulk temperature of internal fluid, $^\circ$R</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NREADT</td>
<td>Non-zero indicator marking the last trajectory card</td>
</tr>
</tbody>
</table>

3-10
<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>Integer</td>
<td>KINDP</td>
<td>Specifies panel configuration, input a 1, 2, or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Corrugated (either open or closed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Integrally stiffened</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Honeycomb</td>
</tr>
<tr>
<td></td>
<td>Integer</td>
<td>KINDS</td>
<td>Specific supporting structure configuration, input a 1, 2, or 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1. Configuration type A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2. Configuration type B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3. Configuration type C</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>LENGTH</td>
<td>Panel length, in.</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>WIDTH</td>
<td>Panel width, in.</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>DLPANL</td>
<td>Panel length overlap, in.</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>DWPANL</td>
<td>Panel width overlap, in.</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>A</td>
<td>Distance between adjacent panels, in.</td>
</tr>
<tr>
<td>28</td>
<td>Real</td>
<td>B</td>
<td>Airspace gap between panel and insulation, in.</td>
</tr>
<tr>
<td>29^1</td>
<td>Integer</td>
<td>NRIBS</td>
<td>Number of corrugations across panel width</td>
</tr>
<tr>
<td>29^1</td>
<td>Real</td>
<td>CHORD</td>
<td>Corrugation chord length, in.</td>
</tr>
<tr>
<td>29^1</td>
<td>Real</td>
<td>RADIUS</td>
<td>Corrugation radius, in.</td>
</tr>
<tr>
<td>29^1</td>
<td>Real</td>
<td>PSKIN1</td>
<td>Density of material of skin panel, lb/in.³</td>
</tr>
<tr>
<td>29^1</td>
<td>Real</td>
<td>PSKIN2</td>
<td>Density of material of corrugated panel, lb/in.³</td>
</tr>
<tr>
<td>29^2</td>
<td>Real</td>
<td>GINSRT</td>
<td>Weight of honeycomb inserts, lb/100 inserts</td>
</tr>
<tr>
<td>29^2</td>
<td>Real</td>
<td>TCORE</td>
<td>Thickness of panel honeycomb core, in.</td>
</tr>
<tr>
<td>29^2</td>
<td>Real</td>
<td>TEDGE</td>
<td>Thickness of panel edge piece, in.</td>
</tr>
</tbody>
</table>

3-11
Table 3-1. Input Symbols, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real</td>
<td>PCORE</td>
<td>Density of material of honeycomb core, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PEDGE</td>
<td>Density of material of edge pieces, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PSKIN1</td>
<td>Density of material of skin panel, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PSKIN2</td>
<td>Density of material of corrugated panel, lb/ft³</td>
<td></td>
</tr>
<tr>
<td>Integer</td>
<td>NRIBS</td>
<td>Number of panel ribs</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>HRIB</td>
<td>Height of panel rib, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TEDGE</td>
<td>Thickness of panel edge piece, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PRIB</td>
<td>Density of rib material, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PEDGE</td>
<td>Density of material of edge piece, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PSKIN1</td>
<td>Density of material of skin panel, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>E1RIB</td>
<td>Width of panel rib, outside leg, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>E2RIB</td>
<td>Width of panel rib, base leg, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>E3RIB</td>
<td>Width of panel rib, inside leg, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>T1RIB</td>
<td>Thickness of panel rib, outside leg, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>T2RIB</td>
<td>Thickness of panel rib, base leg, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TWRIB</td>
<td>Thickness of panel rib, web, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>GBOLT</td>
<td>Weight of bolts, lb/100 bolts</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>GNUTPL</td>
<td>Weight of nutplates, lb/100 nutplates</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>GWASH</td>
<td>Weight of washers, lb/100 washers</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TCORN</td>
<td>Thickness of corner piece, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TPOST</td>
<td>Thickness of wall of corner post, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>PPOST</td>
<td>Density of material of corner post, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>ODPOST</td>
<td>Outside diameter of corner post, in.</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TPLATE</td>
<td>Thickness of corner plates</td>
<td></td>
</tr>
<tr>
<td>Real</td>
<td>TFNG1</td>
<td>Thickness of support tube flange, in.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTUBE</td>
<td>Thickness of wall of support tube, in.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PTUBE</td>
<td>Density of material of support tube, lb/in.³</td>
<td></td>
</tr>
</tbody>
</table>

3-12
<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LTUBE</td>
<td>Length of support tube, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TSEAL</td>
<td>Thickness of seal strip, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PSEAL</td>
<td>Density of material of seal strip, lb/in.³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TDOUBC</td>
<td>Thickness of long beam doubler channel, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TDOUBP</td>
<td>Thickness of corner doubler plate, in.</td>
</tr>
<tr>
<td></td>
<td>Real</td>
<td>TBMLA</td>
<td>Thickness of long beam, A, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TBMSA</td>
<td>Thickness of short beam, A, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HBEAMA</td>
<td>Height of long and short beams A, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WBEAMA</td>
<td>Width of long and short beam A, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PBM</td>
<td>Density of material of beams, lb/in.³</td>
</tr>
<tr>
<td></td>
<td>Real</td>
<td>GBOLT</td>
<td>Weight of bolts, lb/100 bolts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GNUTPL</td>
<td>Weight of nutplates, lb/100 nutplates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GWASH</td>
<td>Weight of washers, lb/100 washers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GINSUL</td>
<td>Weight of insulators, lb/100 insulators</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TPOST</td>
<td>Thickness of wall of corner post, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PPOST</td>
<td>Density of material of corner post, lb/in.³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WPOST</td>
<td>Width of post B, in.</td>
</tr>
<tr>
<td>30²</td>
<td>Real</td>
<td>GBOLT</td>
<td>Weight of bolts, lb/100 bolts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GNUTPL</td>
<td>Weight of nutplates, lb/100 nutplates</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GWASH</td>
<td>Weight of washers, lb/100 washers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GCLAMP</td>
<td>Weight of clamping washers, lb/100 washers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TPOST</td>
<td>Thickness of wall of corner post</td>
</tr>
<tr>
<td></td>
<td>Real</td>
<td>PPOST</td>
<td>Density of material of corner post, lb/in.³</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ODPOST</td>
<td>Outside diameter of corner post, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ODPOSR</td>
<td>Outside diameter of center post, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ODRING</td>
<td>Outside diameter of post support ring, in.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HRING</td>
<td>Height of post support ring, in.</td>
</tr>
</tbody>
</table>
Table 3-1. Input Symbols, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Variable Type</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFNG1</td>
<td>Thickness</td>
<td>Thickness of support tube flange, in.</td>
<td></td>
</tr>
<tr>
<td>TTUBE</td>
<td>Thickness</td>
<td>Thickness of wall of support tube, in.</td>
<td></td>
</tr>
<tr>
<td>PTUBE</td>
<td>Density</td>
<td>Density of material of support tube, lb/in.³</td>
<td></td>
</tr>
<tr>
<td>IDFNG1</td>
<td>Diameter</td>
<td>Outside diameter of support tube, corner post C, in.</td>
<td></td>
</tr>
<tr>
<td>IDFNG2</td>
<td>Diameter</td>
<td>Outside diameter of support tube, center post C, in.</td>
<td></td>
</tr>
<tr>
<td>HFNG1</td>
<td>Height</td>
<td>Height of support tube flange, corner post C, in.</td>
<td></td>
</tr>
<tr>
<td>HFNG2</td>
<td>Height</td>
<td>Height of support tube flange, center post C, in.</td>
<td></td>
</tr>
<tr>
<td>TRING1</td>
<td>Thickness</td>
<td>Thickness of post support ring, corner post C, in.</td>
<td></td>
</tr>
<tr>
<td>TRING2</td>
<td>Thickness</td>
<td>Thickness of post support ring, center post C, in.</td>
<td></td>
</tr>
</tbody>
</table>

Table 3-2. Input Records Format

<table>
<thead>
<tr>
<th>Record</th>
<th>Data</th>
<th>I, J, K Range</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>JI, TITLE</td>
<td></td>
<td>I1,9A8,A7</td>
</tr>
<tr>
<td>2</td>
<td>ICONF, IQCON, IQINP, ITURB, IWALT, NANG, NCOLM, NMAT, NRSG, NCRC, NSECT, NINS, NF, NPRT</td>
<td></td>
<td>20I4</td>
</tr>
<tr>
<td>3</td>
<td>DNX, DNY, DNZ, XDST, DIAM, AROD, XEMIS, FACC</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>4</td>
<td>STAAT, DELTA, WROTE, STOOP</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>5</td>
<td>AS, R, HH, TS, TC, SL, SLS, BE</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>6</td>
<td>F07, UF, DST, EALL, CRN, BF, BFL, BL</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>7</td>
<td>TALLW(I)</td>
<td>1-NMAT</td>
<td>10F8.0</td>
</tr>
<tr>
<td>8</td>
<td>EMIS(I)</td>
<td>1-NMAT</td>
<td>10F8.0</td>
</tr>
<tr>
<td>9</td>
<td>RHO(I)</td>
<td>1-NMAT</td>
<td>10F8.0</td>
</tr>
<tr>
<td>10</td>
<td>ID(I,J), MPT(I,J)</td>
<td>I = 1 - NMAT</td>
<td>20I4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>J = 1-8</td>
<td></td>
</tr>
</tbody>
</table>
Table 3-2. Input Record Format, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Data</th>
<th>I,J,K Range</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>AX(I,J,K)</td>
<td>I = 1-NMAT  J = 1-8  K = 1-MPT(I,J)</td>
<td>10F8.0</td>
</tr>
<tr>
<td>12</td>
<td>AY(I,J,K)</td>
<td>I = 1-NMAT  J = 1-8  K = 1-MPT(I,J)</td>
<td>10F8.0</td>
</tr>
<tr>
<td>13</td>
<td>X(I)</td>
<td>1-NCOLM</td>
<td>10F8.0</td>
</tr>
<tr>
<td>14</td>
<td>QCONL(I)</td>
<td>1-NCOLM</td>
<td>10F8.0</td>
</tr>
<tr>
<td>15</td>
<td>QCONT(I)</td>
<td>1-NCOLM</td>
<td>10F8.0</td>
</tr>
<tr>
<td>16</td>
<td>Y(I)</td>
<td>1-NSEG</td>
<td>10F8.0</td>
</tr>
<tr>
<td>17</td>
<td>MAT(I,J), TAMP(I,J)</td>
<td>I = 1-NCOLM  J = 1-NSEG</td>
<td>9(I2, F6.0)</td>
</tr>
<tr>
<td>18</td>
<td>NR(I), NI(I), MR(J,I), VFACT(J,I)</td>
<td>I = 1-NRSG  J = 1-NI(I)</td>
<td>12, I6, 9(I2, F6.0)</td>
</tr>
<tr>
<td>19</td>
<td>IPFI, IPF(1), IPF(2), IPF(3), IPF(4), IPAD, KFLEX, NPAN</td>
<td></td>
<td>20I4</td>
</tr>
<tr>
<td>20</td>
<td>DT(1), XL, REY, VU, QL, AMACH</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>21</td>
<td>DT(2), TT, WER, D, VS, XI, DVEH, YCYL, DREF</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>22</td>
<td>DT(3), AE, VJ, WEJ, VV, TJ, XJ, YP</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>23</td>
<td>DT(4)</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>24</td>
<td>HPAN, HC, AI, AIX, AW, BW, EP</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>25</td>
<td>C(1), C(2), C(3), C(4), RHOP</td>
<td></td>
<td>10F8.0</td>
</tr>
<tr>
<td>26</td>
<td>TIME(I), ALT(I), VINF(I), ALPHA(I), BETA(I), HINSD(I), TINSD(I), NREADT</td>
<td>1-NTRAJ</td>
<td>7F8.0, I24</td>
</tr>
<tr>
<td>27</td>
<td>KINDP, KINDS, LENGTH, WIDTH, DLPANL, DWPANL, A, B</td>
<td></td>
<td>2I4, 6E8.0</td>
</tr>
<tr>
<td>28</td>
<td>PINS1, PINS2, PINS3</td>
<td></td>
<td>10E8.0</td>
</tr>
<tr>
<td>29</td>
<td>NRIBS, CHORD, RADIUS, PSKIN1, PSKIN2</td>
<td></td>
<td>18, 9E8.0</td>
</tr>
</tbody>
</table>
Table 3-2. Input Record Format, continued

<table>
<thead>
<tr>
<th>Record</th>
<th>Data</th>
<th>I, J, K Range</th>
<th>Format</th>
</tr>
</thead>
<tbody>
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NOTE: In tables 3-1 and 3-2, the superscripts on record 29 denote values of the panel index KINDP whereas those on record 30 show values of the structural index KINDS.
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**Figure 3-1. Sample Chart for Standard Input Formats**
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**NOTE:** SUPERSCRIP'TS ON RECORD 29 DENOTE VALUES OF THE PANEL INDEX KINDP
WHEREAS THOSE ON RECORD 30 SHOW VALUES OF THE STRUCTURAL INDEX KINDS.

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**Figure 3-1. Sample Chart for Standard Input Formats, Contd**
Figure 3-2. Sample Chart for Simplified Input Format
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<td>Time in trajectory for which output is given, sec</td>
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<td>Altitude, ft</td>
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<td>VI</td>
<td>Free-stream velocity, ft/sec</td>
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<td>AOFA</td>
<td>Angle of attack, degrees</td>
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<td>PI</td>
<td>Free-stream static pressure, psia</td>
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<td>Free-stream Reynolds number/ft</td>
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<td>Q(I)</td>
<td>Boundary convective heat transfer rate at Ith Column, Btu/ft$^2$-sec</td>
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<td>QNET(I)</td>
<td>Net external surface heat transfer at Ith Column, Btu/ft$^2$-sec</td>
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<td>Temperature of Ith Column and Jth Segment at time TAU</td>
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<td>X-coordinate of the element, in.</td>
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<td>Youngs modules, lb/in.$^2$</td>
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SECTION 4
SAMPLE PROBLEM

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 LO₂ tank which is kept at 168°R until all the liquid oxygen is evacuated at 194 seconds in the trajectory. Figures 4-3 through 4-11 show the input, card images of the input, and output of the sample problem.
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Figure 4-5. Output of Sample Problem - Input Data
### Program Options Used

- **Configuration:** Plate
- **Turbulent Heating:** Eckert
- **Wall Temperature:** Nonuniform
- **Angle of Attack:** Varied
- **Local Heat Flux:** Calculated

### Direction Cosines of Cutter Normal from Surface
- \( dnx = 0.0000 \)
- \( dny = 0.0000 \)
- \( dnz = 1.0000 \)

### Distance from Leading Edge
- \( 22,000 \text{ ft} \)

### Body Diameter
- \( 22,000 \text{ ft} \)

### Scupper Radius/Body Diameter
- \( 0.0295 \)

### External Surface Emittance
- \( *5.86 * \)

### Initial Time
- \( 0.0 \text{ sec} \)

### End Time
- \( 440.9 \text{ sec} \)

### Calculation Time Interval
- \( 15.0 \text{ sec} \)

### Print Out Interval
- \( 10.0 \text{ sec} \)

### ***** Material Properties *****

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Figure 4-5. Output of Sample Problem - Input Data, Contd
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</table>

### Stress Input

<table>
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<tr>
<th>AC</th>
<th>HM</th>
<th>TS</th>
<th>TL</th>
<th>SL</th>
<th>SLS</th>
<th>RE</th>
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<tr>
<td>6.000E+00</td>
<td>6.000E+00</td>
<td>4.000E+01</td>
<td>-0.</td>
<td>4.000E+02</td>
<td>3.000E+01</td>
<td>1.500E+01</td>
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</tbody>
</table>

### Fatigue Input

<table>
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<tr>
<th>ICDN</th>
<th>KFLEX</th>
<th>NPAN</th>
<th>DT(1)</th>
<th>DT(2)</th>
<th>DT(3)</th>
<th>CT(4)</th>
<th>XL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1.000E+02</td>
<td>4.000E+01</td>
<td>2.000E+01</td>
<td>1.000E+01</td>
<td>1.000E+02</td>
</tr>
</tbody>
</table>

### END OF INPUT

Figure 4-5. Output of Sample Problem - Input Data, Contd
| ONET(1) | 1.4877E-01 | 1.7826E-01 | 1.7064E-02 | 7.4463E-02 | 6.5926E-02 | 5.7704E-02 | 4.8605E-02 | 4.4247E-02 | 3.9849E-02 |
| TFMP(1,2) | 4.9202E+02 | 4.9169E+02 | 4.9107E+02 | 4.9065E+02 | 4.904E+02 | 4.9006E+02 | 4.9002E+02 | 4.9000E+02 | 4.9000E+02 |
| TFMP(1,3) | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 | 1.6000E+02 |

![Figure 4-6. Output of Sample Problem - Results](image-url)
Figure 4-7. Output of Sample Problem - Results and Stress Redesign
### Stress Analysis Note

<table>
<thead>
<tr>
<th>TIME</th>
<th>Y2MS</th>
<th>G1MS</th>
<th>G4MS</th>
<th>G6MS</th>
<th>F5MS</th>
<th>F6MS</th>
<th>WAMS</th>
<th>EMAX</th>
<th>EMS</th>
<th>EMAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0376E+03</td>
<td>1.7374E+00</td>
<td>8.3L01E-01</td>
<td>1.7524E-01</td>
<td>1.0000E+02</td>
<td>1.0000E+02</td>
<td>1.0000E+02</td>
<td>2.7695E-01</td>
<td>1.7524E-01</td>
<td>1.9860E-08</td>
<td></td>
</tr>
</tbody>
</table>

### Stress Constraints Exceeded - Farfl Thickness Desired To
TC = .065 in.
TS = .000 in.

### End of Note

---

Figure 4-7. Output of Sample Problem - Results and Stress Redesign, Contd
Frequency = 716.2 Hz

Boundary Layer Noise = 121.6 dB - Reynolds No. = 2.6744E+06, Mach No. = 6.5537E-01
Dynamic Pressure = 3.3086E+02, Velocity = 7.0422E+02
Rocket Engine Noise = 123.1 dB - Apparent Noise Source at 40.8 ft
Ares Noise = 73.7 dB
Jet Scrubbing Noise = 127.1 dB

Maximum Bending Stress = 442 PSI
Maximum RMS Deflection = .00000 IN
Boundary Layer Noise Critical Stress = 2.0790E+01 PSI
No. of Stress Reversals = 1.1639E+06
***Panel is good for this condition
Critical Stress may be increased to 3.1072E+04 PSI

Maximum Bending Stress = 527 PSI
Maximum RMS Deflection = .00000 IN
Rocket Engine Noise Critical Stress = 2.6068E+01 PSI
No. of Stress Reversals = 4.4536E+05
***Panel is good for this condition
Critical Stress may be increased to 3.6749E+04 PSI

Maximum Bending Stress = 7 PSI
Maximum RMS Deflection = .00000 IN
Jet Flyback Engine Noise Critical Stress = 4.8264E-04 PSI
No. of Stress Reversals = 3.8470E+07
***Panel is good for this condition
Critical Stress may be increased to 2.2093E+04 PSI

Maximum Bending Stress = 832 PSI
Maximum RMS Deflection = .00001 IN
Jet Scrubbing Noise Critical Stress = 5.3767E+01 PSI
No. of Stress Reversals = 8.5209E+04
***Panel is good for this condition
Critical Stress may be increased to 4.9739E+04 PSI

Composite Critical Stress = 6.3266E+01 PSI
No. of Stress Reversals = 6.4067E+05
***Panel is good for this condition
Critical Stress may be increased to 3.4448E+04 PSI

Figure 4-8. Output of Sample Problem - Results of Fatigue Analysis
<table>
<thead>
<tr>
<th>KINDP</th>
<th>LENGTH</th>
<th>WIDTH</th>
<th>OLPANL</th>
<th>OMFPNL</th>
<th>A</th>
<th>B</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>6.000</td>
<td>24.000</td>
<td>1.000</td>
<td>1.000</td>
<td>.500</td>
<td>.500</td>
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<tr>
<td>KINGS</td>
<td>TINS1</td>
<td>TINS2</td>
<td>TINS3</td>
<td>PINS1</td>
<td>PINS2</td>
<td>PINS3</td>
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<tr>
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<td>0.000</td>
<td>0.000</td>
<td>-0.000</td>
<td>-0.000</td>
<td>-0.000</td>
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<tr>
<td>NRIPS</td>
<td>CHORD</td>
<td>RADIUS</td>
<td>TSKIN1</td>
<td>TSKIN2</td>
<td>PSKIN1</td>
<td>PSKIN2</td>
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<td>GBOLT</td>
<td>GWUTPL</td>
<td>GNASM</td>
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<td>TPOST</td>
<td>PPOST</td>
<td>ODPOST</td>
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<td>.500</td>
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<td>.010</td>
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<td>PTURE</td>
<td>LTUBE</td>
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<td>PSEAL</td>
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<tr>
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<td>.050</td>
<td>.020</td>
<td>.300</td>
<td>.500</td>
<td>.010</td>
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<td>TANURP</td>
<td>TAMLA</td>
<td>TRHSA</td>
<td>WAEAMA</td>
<td>WBEAMA</td>
<td>RAM</td>
</tr>
<tr>
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<td>.010</td>
<td>.010</td>
<td>.010</td>
<td>.500</td>
<td>1.000</td>
<td>.300</td>
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</table>

Figure 4-9. Output of Sample Problem - Input to Weight/Cost Analysis
<table>
<thead>
<tr>
<th>DESCRIPT</th>
<th>GT</th>
<th>THEOETCAL WEIGHT</th>
<th>ACTUAL WEIGHT</th>
<th>MATL WEIGHT</th>
<th>STD HOURS</th>
<th>LABOR HOURS</th>
<th>RATE HOURS</th>
<th>OV-HD RATE</th>
<th>LAST #</th>
<th>LAMOR</th>
<th>COST</th>
<th>FACTORY COST</th>
<th>MATERIAL COST</th>
<th>FABRICAT COST</th>
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</thead>
<tbody>
<tr>
<td>PANEL</td>
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<td>205.54</td>
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<td>13.50</td>
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<td>4.07</td>
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<td>14.50</td>
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<td>1.75</td>
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<td>0.00</td>
<td>60.22</td>
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</tr>
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</table>

**TOTAL THEORETICAL WEIGHT: 0.00 LR**
**TOTAL ACTUAL WEIGHT: 15.41 LR**
**TOTAL MATERIAL WEIGHT: 12.72 LR**
**TOTAL STANDARD HOURS: 10.86 HR**
**TOTAL LABOR HOURS: 96.57 HR**
**TOTAL LABOR COST: 1282.00 $**
**TOTAL OVER COST: 224.16 $**
**TOTAL FACTORY COST: 362.94 $**
**TOTAL MATERIAL COST: 750.61 $**
**TOTAL FABRICATION COST: 792.86 $**

SUB-ASSEMBLY COST

<table>
<thead>
<tr>
<th>TASK</th>
<th>STD HOURS</th>
<th>TOTAL HOURS</th>
<th>LABOR HOURS</th>
<th>RIC-HR</th>
<th>LAMOR</th>
<th>COST</th>
<th>OVERH</th>
<th>ASSEMBLY</th>
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<td>LOCATE</td>
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<td>DRILL</td>
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<td>0.49</td>
<td>0.86</td>
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</table>

Figure 4-10. Output of Sample Problem - Weight/Cost Results
<table>
<thead>
<tr>
<th>Component</th>
<th>Cost (M$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>THEORETICAL FIRST UNIT COSTS - TFU</td>
<td>8.340</td>
</tr>
<tr>
<td>NON RECURRING COST</td>
<td></td>
</tr>
<tr>
<td>FG AND D</td>
<td>50.919</td>
</tr>
<tr>
<td>TOOLING</td>
<td>57.809</td>
</tr>
<tr>
<td>GROUND TEST HARDWARE</td>
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<tr>
<td>FLIGHT TEST ARTICLES</td>
<td>16.681</td>
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<td>FLIGHT TEST S AND RP</td>
<td>5.588</td>
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<td>TOTAL NON RECURRING TEST COST</td>
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<td>RECURRING PRODUCTION COST</td>
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<td>SUSTAINING ENGINEERING</td>
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<tr>
<td>SUSTAINING TOOLING</td>
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<td>PRODUCTION ARTICLES (1)</td>
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</tr>
<tr>
<td>TEST ARTICLE CONVERSION</td>
<td>2.502</td>
</tr>
<tr>
<td>TOTAL RECURRING PRODUCTION COST</td>
<td>10.842</td>
</tr>
<tr>
<td>RECURRING OPERATIONS COST</td>
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<tr>
<td>REPLACEMENT S AND RP</td>
<td>11.109</td>
</tr>
<tr>
<td>TOTAL RECURRING OPERATIONS COST</td>
<td>11.109</td>
</tr>
<tr>
<td>TOTAL THERMAL PROTECTION SYS PROGRAM COST</td>
<td>168.333</td>
</tr>
</tbody>
</table>

Figure 4-11. Output of Sample Problem - Results of Program Total Cost Analysis
SECTION 5
REFERENCES


Figure I-1. Source Listing — TPSOPT

I-2
DO 200 I=1, NCOLM
IF (IQINP.EQ.3) GO TO 190
G(I)=AL*QCONL(I)
PE=VI
GO TO 200
190 TEMP(I,1)=AL*QCONL(I)
PE=VI
200 CONTINUE
GO TO 230

CALL PRA63(AL, PI, Ti, KHOI, ICK)
IF (ICK.EQ.0) GO TO 310
IF (IQINP, EQ, 1) GO TO 220
AMI=VI/(49.01*SQRT(TI))
WI=0.5*RHOI*VI**2
IF (VI.LT.WL) GO TO 220
WL=WI
AMACH=AMI
VU=VI
KEY=KHOI*VU*XL/(2.27E-8*T)**1.5/(TI+198.6))
200 CONTINUE

CALL THERMO(1GO)
IF (1GO.EQ.1) GO TO 310
230 CALL CONDTN(IVF)
IF (IVF.NE.2) GO TO 240
WRITE (6,360) DELTA
GO TO 30
240 IF (NINS.EQ.0) GO TO 300
DO 250 I=1, NCOLM
DO 250 J=1, NSEG
K=MAT(I,J)
IF (TEMP(I,J).GT.TMAX(K)) TMAX(K)=TEMP(I,J)
250 CONTINUE
DO 260 K=1,9
IF (TMAX(K).GT.TALLW(K)) GO TO 270
260 CONTINUE
DO 280 L=1, NSEG
YINS=0.0
DO 280 L=1, NSEG

Figure I-1. Source Listing — TPSOPT, Contd
Figure I-1. Source Listing — TPSOPT, Contd

I-4
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)
COMMAPP1/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)**2)*(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.) GO TO 30
YY=Y-0.0001
IF (YY.GE.0.) GO TO 20
YY=Y
IF (A2(Y)*SLD.GT.A3(Y)) GO TO 10
WRITE (6*50) APP
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 ***** SONIC FATIGUE NOTE *****/5APP
10H THE NUMBER OF STRESS REVERSALS IS SO LOW THAT /50H FATIGUE APP
21S NOT A FACTOR FOR THIS CONFIGURATION /50H AND ALLOWABLE S-N CURVE
38S OMITTED. /50H THE ACOUSTIC FATIGUE /50H ANALYSIS FOR THIS NOISE SOURCE I
45S OMITTED. /50H ALLOWABLE S-N CURVE.)
60 FORMAT (47H APPLIED S-N CURVE EXCEEDS ALLOWABLE S-N CURVE.)
END

Figure I-3. Source Listing — APP
I-6
FUNCTION BANDW(F)

    THIS SUBROUTINE COMPUTES BANDWIDTH AS A FUNCTION
    OF FREQUENCY

    DIMENSION FTB(13),BWTB(13)
    DATA FTB/ 2., 4., 8., 16., 31.5, 63.0, 125., 250., 500., 1000., 2000., 4000., 8000. /
    DATA BWTB/ 1.35, 2.75, 5.5, 11., 22.5, 45.0, 90.0, 180., 355., 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

30 FORMAT (19HOFREQ, ARG, ERROR =E12.4)
END

Figure I-4. Source Listing - BANDW
Figure I-5. Source Listing — BLOCK DATA
2KRUN(12,1),KRUN(13,1),KRUN(21,1),KRUN(51,1)/
3.0050,.0060,.0080,.0100,.0160,.0200,.0240,.0160,.0300/
4,KRUN(61,1),KRUN(71,1),KRUN(91,1),KRUN(92,1),KRUN(93,1)/
5.0010,.0010,.0080,.0080,.0080/
DATA
1,KRUN(11,4),KRUN(12,4),KRUN(13,4),KRUN(21,4),KRUN(51,4)/
2.0100,.1100,.1200,.1400,.2000/
DATA
1,KRUN(1,7),KRUN(3,7),KRUN(4,7),KRUN(5,7)/
2.0120,.0160,.0180,.0200/
DATA
1,KRUN(1,10),KRUN(2,10),KRUN(3,10),KRUN(4,10),KRUN(5,10),
2,KRUN(11,10),KRUN(12,10),KRUN(13,10),KRUN(21,10)/
3.0200,.0250,.0300,.0350,.0400,.0500,.0700,.0900,.0500/
DATA
1,KRUN(1,13),KRUN(2,13),KRUN(3,13),KRUN(4,13),KRUN(5,13)/
2.0100,.0100,.0100,.0100/.0100/
DATA
1,KRUN(1,16),KRUN(2,16),KRUN(3,16),KRUN(4,16),KRUN(5,16),
2,KRUN(11,16),KRUN(12,16),KRUN(13,16),KRUN(21,16)/
3.0120,.0140,.0160,.0180,.0200,.0400,.0600,.0800,.0400/
DATA
1,KRUN(1,19),KRUN(2,19),KRUN(3,19),KRUN(4,19),KRUN(5,19),
2,KRUN(11,19),KRUN(12,19),KRUN(13,19),KRUN(21,19),KRUN(51,19)/
3.0080,.0080,.0090,.0090,.0100,.0140,.0160,.0180,.0140,.0200/
DATA
1,KCOSWT(1,1),KCOSWT(2,1),KCOSWT(3,1),KCOSWT(4,1),KCOSWT(5,1),
2,KCOSWT(11,1),KCOSWT(12,1),KCOSWT(13,1),KCOSWT(21,1),KCOSWT(51,1),
3,KCOSWT(81,1)/
4,15.00,14.50,14.00,13.50,13.00,12.00,12.50,14.00,10.50,5.50,65.00,
5,132.71/
6,KCOSWT(61,1),KCOSWT(71,1),KCOSWT(91,1),KCOSWT(92,1),KCOSWT(93,1)/
REAL TABLE
C RATE TABLE
C OVERHEAD RATE TABLE
DATA
1,KCC(5,1),KCC(5,2),KCC(5,3),/4,4.75,1.75/,
2,KCC(2,4),KCC(2,5),KCC(2,6),/4,4.75,1.75/,
3,KCC(2,7),KCC(2,8),KCC(2,9),/4,4.75,1.75/,
4,KCC(1,10),KCC(1,11),KCC(1,12),/4,4.75,1.75/,
5,KCC(1,13),KCC(1,14),KCC(1,15),/4,4.75,1.75/,
6,KCC(1,16),KCC(1,17),KCC(1,18),/4,4.75,1.75/,
7,KCC(3,19),KCC(3,20),KCC(3,21),/4,4.75,1.75/,
8,KCC(6,1),KCC(6,2),KCC(6,3),/4,5.20,1.75/,
9,KCC(7,1),KCC(7,2),KCC(7,3)/4,5.20,1.75/,
END

Figure I-5. Source Listing - BLOCK DATA, Contd
SUBROUTINE BUCKNG(E,F7,FCR,FCY,FTU,NCR)
DE=(1.-1./((1.+4.286*(FCR/F7)**(NCR-1)
IF (.001*E.GE.ABS(DE)) GO TO 20
ETAO=0.7
ETAA=F7/FCR
10 ETA1=ETAA*((1./ETAO-1.)*2.333)**(1./(FLOAT(NCR)-1.))
DETA=ETA1-ETAO
IF (ETA1.GT.1.) ETA1=1.
IF (.01*ETAO.GE.ABS(DETA)) GO TO 30
ETAU=0.5*(ETAO+ETA1)
GO TO 10
20 ETA1=1.
30 FCR=FCR*ETA1
IF (1.1*FCY.GE.FCR) GO TO 40
FCK=1.1*FCY
40 IF (FTU.GE.FCR) GO TO 50
FCR=FTU
50 RETURN
END

Figure I-6. Source Listing — BUCKNG
SUBROUTINE CONDTN(IVF)

DIMENSION A1(9,9),A2(9,9),A3(9,9),NRA(18),QN(4),Q2(9),VF(9,18),
1DX(9),DY(9,9),A4(9,9)

DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
1DIST(9),E(20,99),EAT(20,99),EDOT(20,99),EMIS(9),FCY(20,99),
2FNCT(20),FT(20),FTU(20,99),HINSD(99),MAT(9,9),MR(9,18),
3NI(18),NR(18),PINP(99),Q(9),QCONL(9),QCONT(9),QNET(9),
4RHO(9),T(20,99),TEMP(9,9),TIME(99),TINS(99),VFCT(9,18),
5VINF(99),X(9),XX(20),Y(9),ZZ(20),TALLW(9)

COMMON A,ALPHA,ALT,AME,AMI,AOFA,

IAROD,AS,AX,AY,BETA,BF,
2BL,BL,BL,BL,BL,
3BETA,BETAL,BETAT,BF,BL,
4BETA,BETA,BETA,BETA,BETA,
5BFL,BFL,BFL,BFL,BFL,
6BTA,BTA,BTA,BTA,BTA,
7BETA,BETA,BETA,BETA,BETA,
8BETA,BETA,BETA,BETA,BETA,
9BETA,BETA,BETA,BETA,BETA,
10BETA,BETA,BETA,BETA,BETA,

11=U

A1S=U.

oss=O.

IF (NRSG.EQ.O) GO TO 20

L=0

DO 10 I=1,NRSG

10 NRA(I)=NR(I)

20 X2=O.

DO 70 I=1,NCOLM

IF (NCRC.LT.2) GO TO 30

X1=X2

X2=XX(I)**2

DX(I)=3.1416*(X2-X1)

GO TO 40

30 DX(I)=X(I)

40 IF (IOINP.EQ.3) GO TO 50

QNET(I)=Q(I)-0.476E-12*XEMIS*TEMP(I,1)**4

50 DO 70 J=1,NSEG

K=MAT(I,J)

K=IABS(K)

IF (K,EQ.0) GO TO 70

CP=TRPLAT(AY,AX,TEM(I,J),K,1,MPT(K,1))

EK=1.83E3/TRPLAT(AY,AX,TEM(I,J),K,2,MPT(K,2))

A1(I,J)=CP*RHO(K)*DX(I)*Y(J)

XY=DX(I)/Y(J)

A3(I,J)=EK/XY

IF (NCRC.EQ.2) GO TO 60

DY(I,J)=Y(J)

A2(I,J)=EK/XJ

GO TO 70

60 A2(I,J)=.3183*EK*ALOG(XX(I)/XX(I)-.5*XX(I))/Y(J)

DY(I,J)=6.2832*XX(I)*Y(J)

IF (I,EQ.1) GO TO 70

A4(I,J)=.3183*EK*ALOG((XX(I)-.5*XX(I))/XX(I-1))/Y(J)

70 CONTINUE

DO 370 J=1,NSEG

Figure I-7. Source Listing — CONDTN
DO 370 I = 1, NCOLM
IF (MAT(I, J), EQ, 0) GO TO 370
IF (IQINP, EQ, 3, AND, J, EQ, 1) GO TO 190
QS = 0.
DO 330 K = 1, 4
GO TO (A0, 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, 160
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 370
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 = NI(L)
240 DO 310 IJ = 1, IJ
IF (NCOLM, EQ, 1) GO TO 250
M = MR(IJ, L)/10
N = MR(IJ, 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 = EM1S(M1)

Figure I-7. Source Listing – CONDTN, Contd
I-12
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
<80 E12=E1
290 VF(I,I,L)=0.476E-12*E12*RL*VFCT(I,I,L)
IF (L.EQ.NSEG.AND.II.EQ.IJ) IVF=1
300 QR=VF(I,I,L)*{(TEMP(I,N)**4-TEMP(I,J)**4)}
310 QN(K)=QN(K)+QR
GO TO 330
320 QN(4)=HINS*DX(1)*(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)
II=II+1
IF (MAT(I,J).LT.0.) GO TO 370
DET=DELTA*QSS/A1S
IF (ABS(DET).LT.500.) GO TO 340
WRITE (6,390) I,J
IVF=2
DELTA=0.5*DELTA
IF (DELTA.GE.0.1) GO TO 380
WRITE (6,400)
STOP
340 TEMP(I,J)=TEMP(I,J)+UET
IF (II.LE.1) GO TO 360
DO 350 I2=2,II
I3=I-I2+2
350 TEMP(I3-1,J)=TEMP(I3,J)
360 II=0
A1S=0.
QSS=0.
370 CONTINUE
380 RETURN
390 FORMAT (1H0,14HSEGMENT NUMBER,I3,I1,13HTEMPERATURE CHANGE IS GREAT)
1ER THEN 500 DEG.)
400 FORMAT (35H PROBLEM WAS DELETED AT THIS POINT.)
END

Figure 1-7. Source Listing — CONDTN, Contd
SUBROUTINE COST
COMMON/WTA/
1 A B CHORD E1RIB E2RIB E3RIB
2 HBEAMA HFNG1 HFNG2 HRIB HRING IDFNG1
3 IDFNG2 KINDP KINDS LENGTH DLPANL LTUBE
4 NRIBS ODPOSR ODPOST ODRING RADIUS TBMLA
5 TBMLC TBMSA TBMSC TCORE TCORN TDOUBC
6 IDOUBP TEDGE TFNG1 TINS1 TINS2 TINS3
7 TPLATE TPPOST TRIB TRIBL TRING1 TRING2 TRSEAL
8 NBMLC NBMLB NBMSC NBMSC TBMSC TBMSA NBM
9 TBMLA NBMSC NBMLB NBMSC NBMSC TBMLA NBM
0 TDOUBP TDOUBC TBMLA TBMLA TDOUBC TDOUBC
1 COMMON/WTCOST/
1 KLIC N ACWT KT ITL LEN WID LTUBER
2 MAWT KK AOP(7,7) KMUV(100,3) KSETUP(100,21) KRUN(100,21)
3 KS CC(5,21) TIME(7) TMAT(3) DIAM(6) WTNUT(6) TBTABL(6)
4 KS CC(100,3) COMMON/ZERO/
1 TOPWT TACWT TMAWT TSHR TTHR TNLHR TNLACO TTVT MCOS TTMOS
2 THSVCT LABHR LACOST VCOST TSDHR TLACOS TVCOST TFCOST
3 COMMON/COMTOT CF K1 STPS AT BT TDH C EGTH NFTA EFTS NPA ETA
1 EFA NPLT S TUNWT
1 REAL K1 K2
2 REAL KSETUP KRUN KCC MAWT KMUV
3 REAL KCSWT
4 COMMON/ALPHAN/
1 ANAM1(22) ANAM2(22) ANAM3(22)
2 REAL LBMLA LBMSA LPANL LPPOST LSEAL LEN
3 REAL LARATE LABHR LACOST MFCOS MATCOS
4 JJ=1
5 SHPSET=1.
6 OPWT=0
7 KOP=0
8 NOP=7
9 COSWT=KCSWT(KK,JJ)
10 MUV=KMUV(KK,JJ)
11 MATCOS=MAWT*MUV*COSWT
12 KOP=KOP+1
13 KS=JJ
14 KR=JJ
15 KF=1
16 KL=2
17 KV=3
10 IF (KOP,GT,NOP) GO TO 30
11 SETUP=ACWT*KSETUP(KK,KS)
12 RUNTM=ACWT*KRUN(KK,KR)
13 STDHR=(SETUP+(RUNTM*KT*SHPSET))*.10.
14 DO 20 KC=1,5
15 RECT=CSC(KC,KF)
16 IF (RECT,EQ,0.) GO TO 20
17 LARATE=KCC(KC,KL)
18 VRATE=CSC(KC,KV)
19 LABHR=LABHR*(STDHR/RECT)
20 CONTINUE
20 FCOST=LACOST+VCOST

Figure I-8. Source Listing — COST

I-14
**Figure I-8. Source Listing — COST, Contd**

```
MFCOST=FCOST+MATCOST
TSTDHR=TSTDHR+STDHR
TLBHR=TLBHR+LABHR
TLACOST=TLACOST+LACOST
TVCOST=TVCOST+VCOST
TFCOST=TFCOST+FCOST
KS=KS+3
KR=KR+3
KF=KF+3
KL=KL+3
KV=KV+3
KOP=KOP+1
LABHR=0
LACOST=0
VCOST=0
GO TO 10

30 IF (TLBHR.EQ.0) GO TO 40
AVEKA=TLACOS/TLBHR
AVERF=TSTDHR/TLBHR
TVKATE=TVCOST/TLBHR
GO 10 50

40 AVEKA=0.
AVERF=0.
TVRATE=0.
CONTINUE

50 TMFCOST=TFCOST+MATCOST
IF (ITL.GT.0) GO TO 60
TACWT=0
WRITE (6,120)
WRITE (6,130)
WRITE (6,200)
WRITE (6,200)

IF (KINDP.EQ.1) WRITE (6,140) LEN,WID
IF (KINDP.EQ.2) WRITE (6,150) LEN,WID
IF (KINDP.EQ.3) WRITE (6,160) LEN,WID
IF (KINDS.EQ.1) WRITE (6,170) LTUBER
IF (KINDS.EQ.2) WRITE (6,180) LTUBER
IF (KINDS.EQ.3) WRITE (6,190) LTUBER
WRITE (6,200)
WRITE (6,210)
WRITE (6,220)

60 CONTINUE
IF (KLIC.EQ.0) WRITE (6,200)
IF (KLIC.EQ.10) GO TO 70
IF (KLIC.EQ.0) TACWT=TACWT+ACWT
IF (KLIC.EQ.0) TMAWT=TMAWT+MAWT
WRITE (6,230) ANAM1(N),ANAM2(N),ANAM3(N),KT,OPW,T,ACWT,MAWT,TSTDHR

SUMMARY TOTALS AT BOTTOM OF PAGE

TOPWT=TOPWT+OPWT
TTSHR=TTSHR+TSTDHR
TTLBHR=TTLBHR+TLBHR
TTLACOST=TTLACOST+TLACOST
TTVCOST=TTVCOST+TVCOST
TTFCOST=TTFCOST+TFCOST
TMMFCOST=TTMFCOST+MATCOST
LABHR=0
LACOST=0
VCOST=0
TSTDHR=0
```
70 CONTINUE
WRITE (6*200)
WRITE (6*200)
DO 60 I=1,7
AOP(1,2)=AOP(I,1)/KCC(6,1)
AOP(I,3)=KCC(6,2)
AOP(I,4)=KCC(6,3)
AOP(I,5)=AOP(I,2)*AOP(I,3)
AOP(I,6)=AOP(I,3)*AOP(I,4)*AOP(I,2)
AOP(I,7)=AOP(I,5)*AOP(I,6)
60 CONTINUE
DO 90 I=1,7
TASYCO=TASYCO+AOP(I,7)
90 CONTINUE
TTMFCO=TTFCOS+TTMCOS
TMUFAC=TASYCO+TTMFCO
TTMFWT=TTMFCO/TACWT
CONOP=0
IF (TTLBHR.EQ.0) GO TO 100
TTRATE=TTFCOS/TTLBHR
TMAHAT=TTMFCO/TTLBHR
TTCOS=TTMCOS/TMAWT
TAVRA=TTLACO/TTLBHR
TTVRA=TTVCOS/TTLBHR
TAVFC=TTSHK/TTLBHR
GO TO 110
100 TTCOS=COSWT
TAVRA=0
TTVRA=0
TAVFC=0
110 CONTINUE
TUNITC=TMUFAC/(LEN*WID)
TUNIT=TAKCWT/(LEN*WID)
KEL=.4
WRITE (6*240) TOPW T
WRITE (6*250) TACWT
WRITE (6*260) TMAWT
WRITE (6*270) TTSHK
WRITE (6*280) TTLBHR
WRITE (6*290) TTTACO
WRITE (6*300) TTVCOS
WRITE (6*310) TTFCOS
WRITE (6*320) TTMFCO
WRITE (6*330) TMUFAC
WRITE (6*340) TASYCO
WRITE (6*350) TMUFAC
WRITE (6*360) TUNITC
WRITE (6*370) TUNIT
WRITE (6*380) TTCOS
WRITE (6*390) TAVRA
WRITE (6*400) TTVRA

Figure I-8. Source Listing — COST, Contd
<table>
<thead>
<tr>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>FORMAT (1H1)</td>
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<td>130</td>
<td>FORMAT (36X*49HTHERMAL PROTECTION SYSTEM, SPACE SHUTTLE STA XXXX)</td>
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<td>140</td>
<td>FORMAT (20X*60HCONFIGURATION PANEL TYPE 1, CORRUGATED Nominal PAC ST 196)</td>
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<tr>
<td>150</td>
<td>FORMAT (1NEL SIZE ,F4.1,3H X ,F4,1,3H FT)</td>
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<td>160</td>
<td>FORMAT (20X*60HCONFIGURATION PANEL TYPE 3, RIBED Nominal PAC ST 199)</td>
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<td>170</td>
<td>FORMAT (20X*65H STRUCTURE TYPE A Nominal STC ST 202)</td>
</tr>
<tr>
<td>180</td>
<td>FORMAT (20X*65H STRUCTURE TYPE B Nominal STC ST 204)</td>
</tr>
<tr>
<td>190</td>
<td>FORMAT (20X*65H STRUCTURE TYPE C Nominal STC ST 206)</td>
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<tr>
<td>200</td>
<td>FORMAT (1X/)</td>
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<tr>
<td>210</td>
<td>FORMAT (1X*128H THEORETICAL ACTUAL MAT DIS STC ST 209)</td>
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<tr>
<td>220</td>
<td>FORMAT (1X*128H DESCRIP QT WEIGHT WEIGHT WEIGHT HOUS STC ST 212)</td>
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<td>FORMAT (1X*128H 1RS HOURS RATE RATE PER LB COST COST COST STC ST 213)</td>
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<td>240</td>
<td>FORMAT (1X*128H TOTAL THEORETICAL WEIGHT F12.2,3H LB)</td>
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<td>FORMAT (1X*128H TOTAL ACTUAL WEIGHT F12.2,3H LB)</td>
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<td>FORMAT (1X*128H TOTAL MATERIAL WEIGHT F12.2,3H LB)</td>
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<td>FORMAT (1X*128H TOTAL STANDARD HOURS F12.2,3H HR)</td>
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<td>FORMAT (1X*128H TPS COST F12.2,8H $/SQ FT)</td>
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<td>FORMAT (1X*128H TPS WEIGHT F12,2,9H LB/SQ FT)</td>
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Figure I-8. Source Listing — COST, Contd
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<td>10 DRILL</td>
<td></td>
<td>F10.4F8.2F6.2F7.2F9.2</td>
<td></td>
<td></td>
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<tr>
<td>530</td>
<td>10 SECURE</td>
<td></td>
<td>F10.4F8.2F6.2F7.2F9.2</td>
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<td>10 INSPECT</td>
<td></td>
<td>F10.4F8.2F6.2F7.2F9.2</td>
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<tr>
<td>550</td>
<td>10 DISASSY</td>
<td></td>
<td>F10.4F8.2F6.2F7.2F9.2</td>
<td></td>
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<tr>
<td>560</td>
<td>10 CLEAN</td>
<td></td>
<td>F10.4F8.2F6.2F7.2F9.2</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Figure 1-8. Source Listing — COST, Contd
SUBROUTINE COSTOT

COMMON/COMTOT/ CF, K1, STPS, AT, K2, BT, TDH, C, EGTH, NFTA, EFTS, NPA, ETA, NFLTS, TUNWT

REAL K1, K2

WTPS = STPS * TUNWT

TENM6 = 1.E-6

TFU = (CF * K1 * WTPS ** AT)

EDD = (K2 * WTPS ** BT)

THLB = 306. * WTPS ** (C)

TOOL = (TDH * TENM6 * THLB * WTPS)

GTH = EGTH * TFU

FTA = NPA * TFU

TAC = ETA * TFU

TRPC = PA + TAC

RSRP = EFA * NFLTS * TFU

TTPSC = TNPSC + TRPC + TROC

WRITE (6, 10)
WRITE (6, 20)
WRITE (6, 30)
WRITE (6, 40)
WRITE (6, 50)
WRITE (6, 60)
WRITE (6, 70)
WRITE (6, 80)
WRITE (6, 90)
WRITE (6, 100)
WRITE (6, 110)
WRITE (6, 120)
WRITE (6, 130)
WRITE (6, 140)
WRITE (6, 150)
WRITE (6, 160)
WRITE (6, 170)
WRITE (6, 110)
WRITE (6, 180)
WRITE (6, 190)
WRITE (6, 200)
WRITE (6, 210)
WRITE (6, 220)

10 FORMAT (1H1)
20 FORMAT (10X, 44H THERMAL PROTECTION SYSTEM - COST SUMMARY//)
30 FORMAT (52X, 8HCOST(M$)//)
40 FORMAT (10X, 34HTHEORETICAL FIRST UNIT COSTS - TFU,F8.3,///)
50 FORMAT (10X, 18HNON RECURRING COST,///)
60 FORMAT (10X, 42HED AND D,F8.3)
70 FORMAT (10X, 42HTOOLING,F8.3)
80 FORMAT (10X, 42HGROUN TEST HARDWARE,F8.3)
90 FORMAT (10X, 42HFLIGHT TEST ARTICLES,F8.3)
100 FORMAT (10X, 42HFLIGHT TEST S AND RP,F8.3)
110 FORMAT (52X, 8H-------)
120 FORMAT (10X, 42HTOTAL NONRECURRING TPS COST,F8.3//)
130 FORMAT (10X, 28HRECURRING PRODUCTION COST,F8.3//)
140 FORMAT (10X, 51HSUSTAINING ENGINEERING - INCLUDED IN TFU,F8.3)
150 FORMAT (10X, 51HSUSTAINING TOOLING - INCLUDED IN TFU,F8.3)

Figure I-9. Source Listing — COSTOT
Figure I-9. Source Listing — COSTOT
FUNCTION CURVEF(F,FSTAR)

    THIS FUNCTION IS USED TO COMPUTE OBSPL

    ITER=0
    SUMDEL=0.
    IF (FSTAR.GT.F) GO TO 30
        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
30  FUNDAMENTAL FREQUENCY IS GREATER THAN F
    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
80  FORMAT (30H0ERROR IN OBSPL COMPUTATION F=E12.4,3X.6HFSTAR=E12.4)
    CURVEF = -1.
    RETURN
    END

Figure I-10. Source Listing — CURVEF
SUBROUTINE DRVTPS(T1,T2,T3,T5,T6,T7)

COMMON/WTA/
1A *P HCHORD *E1RIB *E2RIB *E3RIB
2HBEAMA *HFNG1 *HFNG2 *HRIB *HRING *IDFNG1
3IDFNG2 *KINDP *KINDS *LENGTH *DLPAU *LTUBE
4NRISS *ODPOS *ODPOST *ODRING *RADIUS *TBMA
5TBMLC *TBMSA *TBMSC *TCORE *TCLRS *TDOUBC
6TDOPJ *TEDGE *TFNG1 *TINS1 *TINS2 *TINS3
7TLPAT *TPORT *T1RIB *T2RIB *TWRIB *TRIBL
8STRIBS *TRING1 *TRING2 *TSEAL *TSKIN1 *TSKIN2
9TTUBE *WIDTH *WBEAMA *WBMSC *WBPANL
*SPINS1 *SPINS2 *SPINS3 *PCORE *PEDGE
*SPSKIN1 *PSKIN2 *PTUBE *GBOLT *GCLAMP
*SGINSUL *GNUTPL *GWASH

COMMON/WTCOST/
1KLIC *N *ACWT *KT *ITL LEN WID LTUBE
2,MAWT, KK, AOP(7,7), KMUV(10003), KSETUP(100,21), KRUN(100,21)
3, KCC(5,21), TIME(7), TMAT(3), DIAMA(6), WTNUM(6), BTJABL(6)
4, KCOSWT(100,3)

COMMON/ZERO/
1 TOPWT, ACWT, TMAWT, TSHR, TLBHR, TTLACO, TVTNCOS, TTFCS, TTMCS,
2TASYCO, LAHR, LACOST, VMCOST, TSHDR, TTAICOS, TVCOST, TFCOST

COMMON/COMTOT/ CF, K1, STPS, AT, K2, BT, TDH, C, EGTH, NFTA, EFTS, NPA, ETA,
1EFA, NFLTS, TUNWT

COMMON/ALPHAN/
1ANAM(22), ANAM(22), ANAM(22)
2DIMENSION IA(75), IB(17)
3EQUIVALENCE (IA, A)
4EQUIVALENCE (IB, TOPWT)
5REAL IDFNG1, IDFNG2, K1, K2, LENGTH, LTUBE

C ** INITIALIZE INPUT VARIABLES
C
DO 10 I=1,75
IA(I)=0
10 CONTINUE
DO 20 I=1,17
IB(I)=0
20 CONTINUE
C
CF=3.3
K1=.00171
STPS=22000
AT=.667
K2=6.58
BT=.187
TDH=14.13
C=.14
EGTH=2.45
NFTA=2
EFTS=.67
NPA=1
ETA=0.3
EFA=0.003
NFLTS=444
TINS1=T1*12.0
TINS2=T2*12.0
TINS3=T3*12.0
TSKIN1=TS
TSKIN2=TC

Figure I-11. Source Listing — DRVTPS

I-22
WRITE (6, 130)

C *** READ WEIGHT-COST INPUT
C
READ (5, 140) KINDP, KINDS, LENGTH, WIDTH, DLPANL, DWPANL, A, B
READ (5, 150) PINS1, PINS2, PINS3
WRITE (6, 160) KINDP, LENGTH, WIDTH, DLPANL, DWPANL, A, B, KINDS, TINS1, TINDRV
152, TINS3, PINS1, PINS2, PINS3
IF (KINDP, GT, 0, AND, KINDP, LT, 4) GO TO 30
WRITE (6, 170)
STOP
30 GO TO (40, 50, 60), KINDP
C *** KINDP = 1
C
40 READ (5, 180) NRIBS, CHORD, RADIUS, PSKIN1, PSKIN2
WRITE (6, 190) NRIBS, CHORD, RADIUS, PSKIN1, PSKIN2
GO TO 70
C *** KINDP = 2
C
50 READ (5, 150) GINSRT, TCORE, TEDGE, PCORE, PEDGE, PSKIN1, PSKIN2
WRITE (6, 200) GINSRT, TCORE, TEDGE, PSKIN1, PSKIN2
GO TO 70
C *** KINDP = 3
C
60 READ (5, 160) E1RIB, E2RIB, E3RIB, T1RIB, T2RIB, TWRIB
WRITE (6, 210) E1RIB, E2RIB, E3RIB, T1RIB, T2RIB, TWRIB
70 IF (KINDS, GT, 0, AND, KINDS, LT, 4) GO TO 80
WRITE (6, 220)
STOP
80 GO TO (90, 100, 110), KINDS
C *** KINDS = 1
C
90 READ (5, 150) GBOLT, GNUTPL, GWASH, TCORN, TPOST, PPOST, ODPOST, TPLATE
READ (5, 150) TFGN1, TUBE, PTUBE, LTUBE, TSEAL, PSEAL, TDDBC, TDUBP
READ (5, 150) TBMLA, TBMSA, HBEAMA, WBEAMA, PBM
WRITE (6, 230) GBOLT, GNUTPL, GWASH, TCORN, TPOST, PPOST, ODPOST, TPLATE, TDVB
1TFRNG1, TUBETUBE, PEC>TUBE, IDCNG1, IDCNG2, HFCNG1, HFCNG2, TRING1, TRINDV
2TFRNG2
READ (5, 150) TBMLC, TBMSC, WBMCLC, WBMSC, PBM, TRIBL, TRIBS, WRIBL, WRIBS
WRITE (6, 250) GBOLT, GNUTPL, GWASH, GCLAMP, TPOST, PPOST, ODPOST, ODRING, DRV 100
GO TO 120
C *** KINDS = 2
C
100 READ (5, 150) GBOLT, GNUTPL, GWASH, GINSUL, TPOST, PPOST, WPOST
WRITE (6, 240) GBOLT, GNUTPL, GWASH, GINSUL, TPOST, PPOST, WPOST
GO TO 120
C *** KINDS = 3
C
110 READ (5, 150) GBOLT, GNUTPL, GWASH, GCLAMP, TPOST, PPOST, ODPOST, ODPOSR, ODRV
1DING, HRING, TFGN1, TUBETUBE, PTUBE, IDCNG1, IDCNG2, HFCNG1, HFCNG2, TRING1, TRINDV
2TNG2
READ (5, 150) TBMLC, TBMSC, WBMCLC, WBMSC, PBM, TRIBL, TRIBS, WRIBL, WRIBS
WRITE (6, 250) GBOLT, GNUTPL, GWASH, GCLAMP, TPOST, PPOST, ODPOST, ODRING, DRV 110
GO TO 120

Figure I-11. Source Listing — DRVTPS, Contd
1HRING, TRING1, TRING2, HFNGL, HFNGL2, OPPOST, TFGN1, TTTUBE, PTUBE, IDFNG1, IDRNG 121
2FNG2, TRIBL, TRIBS, TBMLC, TBMSC, WBMLC, WBMSC, PBMB, WRIBL, WRIBS

120 WRITE (6, 260)
   CALL *TPS
   CALL COSTOT
   RETURN

C

130 FORMAT (1H1)
140 FORMAT (214, 6E8.0)
150 FORMAT (10E8.0)
160 FORMAT (46H1*** WEIGHT - COST INPUT *****/10X, 5HKINDP, 9X, 6F15.3)
170 FORMAT (65H0*** KIND OF PANEL FLAG, KINDP, WAS NOT PROPERLY ENTERED*****)
180 FORMAT (I8, 9E8.0)
190 FORMAT (/10X, 5HNRIBS, 10X, 5CHORD, 9X, 6HRADIUS, 9X, 6HTSKIN1, 9X, 6HTSKDRV)
200 FORMAT (/10X, 5HPINS, 10X, 5HCODE, 10X, 5HSGN, 9X, 6HPINS2, 10X, 5HINS3, 10X, 6F15.3)
210 FORMAT (65H0*** KIND OF STRUCTURE FLAG, KINDS, WAS NOT PROPERLY ENTERED*****)
220 FORMAT (69H0*** END OF INPUT *****)

Figure I-11. Source Listing — DRVTPS, Contd

I-24
SUBROUTINE FATIG(NSECT, TC, TS)

ACOUSTIC FATIGUE ANALYSIS

DESCRIPTION OF INPUT PARAMETERS

AE
NOZZLE EXIT AREA

AI
MOMENT OF INERTIA

AW
PANEL LENGTH

AMACH
LOCAL MACH NUMBER

BW
PANEL WIDTH

C
COEFFICIENTS OF A LEAST SQUARES, 3RD ORDER CURVE FIT OF ALLOWABLE S-N DATA

D
NOZZLE DIAMETER

DT
DURATION OF NOISE IN SECONDS

DVEH
VEHICLE DIAMETER

EP
PANELS YOUNGS MODULUS

HPAN
THICKNESS

HC
THICKNESS IN HONEYCOMB PANEL (MIDDLE)

HF
THICKNESS IN HONEYCOMB PANEL (OUTSIDE)

IPAD=0
VEHICLE IS IN FLIGHT

IPAD=1
VEHICLE IS IN THE PAD

KFLEX=0
RIGID AND SYMMETRICAL SUPPORTING STRUCTURE

KFLEX=1
FLEXIBLE AND/OR UNSYMMETRICAL SUPPORTING STRUCTURE

NENG
NUMBER OF ENGINES

NPAN =1
RECTANGULAR ISOTROPIC PLATE

NPAN =2
RECTANGULAR HONEYCOMB SANDWICH PANEL

NPAN =3
INTEGRALLY STIFFENED PANEL

QL
LOCAL DYNAMIC PRESSURE

REY
REYNOLDS NUMBER

RHO
MATERIAL DENSITY

TJ
JET THRUST

TT
TOTAL THRUST IN LB

VJ
JET VELOCITY

VS
LOCAL SPEED OF SOUND

VU
LOCAL VELOCITY

VV
VEHICLE VELOCITY

WEJ
WEIGHT FLOW OF JET ENGINE

WER
WEIGHT FLOW OF ROCKET ENGINE

VU
LOCAL VELOCITY

XI
DISTANCE BETWEEN BOOSTER ENGINE AND POINT OF INTEREST

XJ
DISTANCE TO EXIT PLANE OF JET ENGINE

XL
BOUNDARY LAYER LENGTH

YP
Y DISTANCE IN A NEAR FIELD LESS THAN 200 FT.

COMMON /BLOCKT/
1
TBBA(6), TBK1(6), TBK2(6)

COMMON/SONIC1/
AE, AT, AW, AMACH, BW, C(4)

10
DT(4), DVEH, EP, HPAN, HC, HF, IPAD

2KFLEX, NENG, NPAN, QL, REY, RHO, TJ, TT

3VJ, VS, VU, VV, WEJ, WER, IPF(4), XI

4XJ, XL, YP, IPFI, AIY, DREF, YCL

COMMON/APP1/NOAPP

DIMENSION ANL(4), ANRMS(4), ANML(4), SCR(4), PF(4), CY(4), SLD(4),
1ANC(4)

DATA AMU/.3/
DATA CCC/.02/

Figure I-12. Source Listing — FATIG

I-25
DATA CG/32.174/  
DATA NDIM/6/  
DATA PI/3.14159/  
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  
10 WRITE (6,350)  

C COMPUTE FUNDAMENTAL FREQUENCIES  
IF (NSECT.EQ.1.OR.NSCT.EQ.2.OR.NSCT.EQ.3.OR.NSCT.EQ.4) NPAN=3  
IF (NSECT.EQ.5.OR.NSCT.EQ.6) NPAN=4  
HPAN=TS  
IF (TS.EQ.0.) HPAN=TC  
HPAN2=HPAN*HPAN  
HPAN3=HPAN2*HPAN  
IF (AW.LE.BW) GO TO 20  
TEM1=AW  
AW=BW  
BW=TEM1  
20 AL2=AW*AW  
AL4=AL2*AL2  
AMASS=RHOP*HPAN/CG  
BA=BW/AW  
FSTAR=1.  
IF (KFLEX.NE.0) FSTARK=.25  
GO TO (30,40,60,70) NPAN  
C RECTANGULAR ISOTROPIC PLATE  
30 DR=EP*HPAN**3/(12.*(1.-AMU**2))  
AK=TABLE(BA, TBBA, TBK1, NDIM)  
IF (AK.EQ.0) GO TO 340  
GO TO 50  
C RECTANGULAR HONEYCOMB SANDWICH PANEL  
40 HF=,5*(HPAN-HC)  
JR=EP*HPAN*HF*HC/1.82  
AK=TABLE(BA, TBBA, TBK2, NDIM)  
IF (AK.EQ.0) GO TO 340  
50 FREQ=AK/12.*PI*AL2*SQRT(AMASS/DR)*FSTAR  
GO TO 80  
C INTEGRALLY STIFFENED PANEL  
60 DR=EP*HPAN/J/(12.**(1.-AMU**2))  
DX=DX+EP*A1/(B*12.)  
DY=DY  
AKM=PI/AW  
AKN=PI/BW  
AKM2=AKM*AKM  
AKN2=AKN*AKN  
AKTAU=(SQRT(DX/12.)*AKM2+SQRT(DY/12.)*AKN2)**2  
AKI=(DX/12.)*(AKM2+AKN2)**2  
SRT=AKTAU/AKI  
HEQ=HPAN*SRT**(1./3.)  
OMEGA=SQRT(2.*PI*AMASS)  
FREQ=OMEGA/(2.*PI)*FSTAR  
GO TO 80  
C CORRUGATED PANEL  

Figure I-12. Source Listing — FATIG, Contd  
I-26
70 AIX=AI
   UY=EP*AIX/(A**12.)
   UX=EP*AIY/(B**12.)
AKM=PI/AW
AKN=PI/BW
AKM2=AKM*AKM
AKN2=AKN*AKN
AKTAU=(SQRT(DX)*AKM2+SQRT(UY)*AKN2)**2
OMEGA=SQRT(AKTAU/AMASS)
FREQ=OMEGA/(2.*PI)*FSTAR
80 CONTINUE
WRITE (6,400) FREQ

C NOISE COMPUTATIONS
C
C DO 200 I=1,IPFI
   IPFF=IPF(I)
   GO TO (90,100,140,190), IRFF
C
1. BOUNDARY LAYER
90 SIGMAX=.37*REY**(-.2)*(1.+(REY/2.9E7)**2)**.1
FZERO=8.*VU/SIGMAX/XL
C PF IS SPECTRUM PRESSURE
PF(1)=QL*SQR T(.012/(1.+14*AMACH**2)*FZERO*(1.+(FREQ/FZERO)**2)**1)
FPLF=20.*AL0610(PF/41.8E-8>
WRITE (6,410) FPLFrR,AMACH,QL,VU
GO TO 200
C
C 2. ROCKET ENGINE NOISE (BOOOSTE AND ORBITER)
100 VEXH=TT*CG/WER
   FDV=FREO*D/VEXH
   IF (FDV.LE..175) GO TO 110
   RTERM=-.222-.1315*ALOG10(FUV)
   GO TO 120
110 RTERM=.625-.202*A|_OG10<FDv) FTG 156
120 XZERO=D*10.**RTERM
   IF (IPAD.EQ.O) GO TO 130
   IF (XZERO.GT.(DREF+YCL)) R=SQRT((XI+DREF)**2+(XZERO-DREF-YCL)**2)
   IF (XZERO.LE.DREF) R=SQRT( (XI-XZERO)**2+YCL**2)
C COMPUTE SPL SOUND PRESSURE LEVEL
   IF (FDV.LE..016) SPL=70.+16.6*ALOG10(FDV/.003) FTG 165
   IF (FDV.GE..152) SPL=70.-16.6*ALOG10(FDV/.003) FTG 165
   IF (FDV.LE..152. AND. FDV.GT..016) SPL=82.
   IF (FDV,GE,.152) SPL=70.-16.6*ALOG10(FDV/.8)
   CAPID=VS/(PI*DVEH)
   DEL8P=0.
   IF (FREQ.GE.CAPID) DEL8P=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 (6,420) SPLF,XZERO
   GO TO 200
C
3. JET FLYBACK ENGINE NOISE ON VEHICLE
140 VR=ABS(VV-VJ)

Figure I-12. Source Listing — FATIG, Contd
DJ = SQRT(4.*AE/PI)

KHOF = EJ/(AE*VJ)

FVRLG = 145.*100.*ALOG10(VR/1600.)

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 NONDIMENSIONALIZE 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 170
IF (YPDJ.LT.30.) GO TO 150
DELDB = 20.*ALOG10(Y200DJ/YPDJ)
GO TO 180

150 IF (YPDJ.LT.2.5) GO TO 160
DELDB = TERM1 + 16.*ALOG10(Y30DJ/YPDJ)
GO TO 180

160 IF (YPDJ.LT.1.) GO TO 170
DELDB = TERM1 + TERM2 + 14.*ALOG10(Y25DJ/YPDJ)
GO TO 180

170 WRITE (6,360) YP
GO TO 340

180 SPLNF = SPL200 + DELDB + 6.
FREQP = 0.8*VJ/DJ
BWD = BANDW(FREQ)
OBMAX = SPLNF - 5.
CVF = CURVEF(FREQP, FREQ)
IF (CVF.EQ.-1) GO TO 340
OBSP = OBMAX - CVF
SPLF = OBSP - 10.*ALOG10(BWD)
WRITE (6,370) SPLF
PF(I) = 41.8E-8*10**(SPLF/20.)
GO TO 200

4. JET SCRUBBING ON BODY
PE IS PRESSURE AT NOZZLE EXIT

190 PE = TJ*1.275/DJ**2

DX IS JET DIAMETER AT X FEET

DX = DJ*(1.+244*XJ/OJ)

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 340
OBSP = OBMAX - CVF
SPLF = OBSP - 10.*ALOG10(BWD)
WRITE (6, 430) SPLF
PF(I) = 41.8E-8*10**(SPLF/20.)
GO TO 200

CONTINUE

DYNAMIC STRESSES

BWD = .04*FREQ

Figure I-12. Source Listing – FATIG, Contd
C SMAX IS MAXIMUM BENDING STRESS
YMAX IS MAXIMUM DEFLECTION

\[ SMAX = SCON \times AL2 \times PBAR/HPAN^2 \]
\[ YMAX = DCON \times PBAR \times AL4/(tP \times HPAN^3) \]
\[ SLU(I) = 100 \times SMAX \] 

GO TO 250

\[ HEFF = 1.817 \times (HC \times HF \times HPAN)^{1/3} \]
\[ SMAX = SCON \times PBAR \times HEFF^{2/3} \times AL2 \]
\[ YMAX = DCON \times PBAR \times AL4/(tP \times HEFF^{3/3}) \]
\[ SLU(I) = 100 \times SMAX \] 

GO TO 250

\[ SMAX = SCON \times PBAR \times AL2/HEFF^{3/3} \]
\[ YMAX = DCON \times PBAR \times AL4/(tP \times HEQ^{3/3}) \]
\[ SD = 25 \times SMAX \]
\[ SLU(I) = 4 \times SD \] 

GO TO 250

\[ HEFF = (10.9 \times ((SQRT(AIW/\omega))/\omega^{2} + SQRT(AIX/\omega)/BW^{2}))/((1/\omega^{2} + 1/BFT)^{0.3333}) \]
\[ SMAX = SCON \times PBAR \times AL2/HEFF^{3/3} \]
\[ YMAX = DCON \times PBAR \times AL4/(tP \times HEFF^{3/3}) \]
\[ SLU(I) = 100 \times SMAX \] 

WRITE (6, 440) SLD(I), YMAX

STRESS REVERSALS PER MISSION OR FOR VEHICLE LIFETIME

IPF(I) = IPF(I)
ANL(I) = FREQ * DT(IPF(I))
ANRMS(I) = 61 * ANL(I)
CALL MININO(C, SLD(I), ANRMS(I), CY(I), SCR(I))
IF (NOAPP.EQ.2) GO TO 340
GO TO (260, 270, 280, 290), IPF

WRITE (6, 450) SCR(I)
GO TO 300

WRITE (6, 380) SCR(I)
GO TO 300

WRITE (6, 460) SCR(I)
GO TO 300

WRITE (6, 390) SCR(I)

IF (SCR(I).EQ.0.) GO TO 320
ANCR(I) = 1.261 * ANRMS(I) * SLD(I)/SCR(I)
WRITE (6, 470) 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.SCRM) GO TO 310
WRITE (6, 480) ALLST
GO TO 320

WRITE (6, 490) ALLST
320 CONTINUE

Figure I-12. Source Listing — FATIG, Contd
I-29
IF (SUM1.EQ.0.) GO TO 340
SBAR=SQRT(SUM1)
ANBAR=1.261*SUM2/SBAR
WRITE (6,500) SBAR,ANBAR
X=ALOG10(ANBAR)
ALLST=(C(1)+C(2)*X+C(3)**2+C(4)**3)*1000.
IF (ALLST.GE.SBAR) GO TO 330
WRITE (6,480) ALLST
GO TO 340
330 WRITE (6,490) ALLST
340 RETURN
C
350 FORMAT (1H1)
360 FORMAT (1H41*DISTANCE ERROR=E12.4)
370 FORMAT (1H41*NOISE = ,F6.1,3H DB)
380 FORMAT (1H41*ROCKET ENGINE NOISE CRITICAL STRESS = ,E12.4,4H PSI)
390 FORMAT (1H41*JET SCRUBBING NOISE CRITICAL STRESS = ,E12.4,4H PSI)
400 FORMAT (1H41*FREQUENCY = ,F7.1,3H HZ)
410 FORMAT (1H41*BOUNDARY LAYER NOISE = ,F6.1,3H DB - REYNOLDS NO. = ,E12.4) 39H
1E12.4,13H, MACH NO. = ,E12.4/20H DYNAMIC PRESSURE = ,E12.4,13H, VECTG 320
2LOCITY = ,E12.4)
420 FORMAT (1H41*ROCKET ENGINE NOISE = ,F6.1,31H DB - APPARENT NOISE SOFTG 322
1RCE AT ,F6.1,3H FT)
430 FORMAT (1H41*JET SCRUBBING NOISE = ,F6.1,3H DB)
440 FORMAT (1H41*MAXIMUM BENDING STRESS = ,F10.0,4H PSI/26H MAXIMUM RMS STG325
1 DEFLECTION = ,F10.5,3H IN)
450 FORMAT (1H41*BOUNDARY LAYER NOISE CRITICAL STRESS = ,E12.4,4H PSI)
460 FORMAT (1H41*JET FLYBACK ENGINE NOISE CRITICAL STRESS = ,E12.4,4H PFTG 328
151)
470 FORMAT (1H41*NO. OF STRESS REVERSALS = ,E12.4)
480 FORMAT (1H41*PANEL IS SUSCEPTIBLE TO FAILURE/39H CRITICAL STRFTG 331
1ESS MUST BE REDUCED TO ,E12.4,21H PSI TO AVOID FAILURE) 3FTG 332
490 FORMAT (1H41*PANEL IS GOOD FOR THIS CONDITION/40H CRITICAL STFTG 333
1RESS MAY BE INCREASED TO ,E12.4,4H PSI)
500 FORMAT (1H41*COMPOSITE CRITICAL STRESS = ,E12.4,4H PSI/27H NO. OF SFTG 335
1RESS REVERSALS = ,E12.4)
END

Figure I-12. Source Listing — FATIG, Contd
SUBROUTINE INPUT1
INP
DIMENSION CONF(3),TURB(4),WALT(4),ANGL(4),QLOC(6),ID(9,9)
INP
DIMENSION A(20),ALPHA(99),ALT(99),AX(9,9,9),AY(9,9,9),BETA(99),
INP
DIST(99),E(20,99),EAT(20,99),EDT(20,99),EMIS(9),FCY(20,99),
INP
2FTN(20),FTU(20,99),HINSD(99),MAT(9,9),MPT(9,9),MR(9,18),
INP
3N(18),NR(18),PIN(99),Q(99),QCONT(99),QINP(99),QNET(9,9),
INP
4RH0(9),T(20,99),TAMP(9,9),TEMP(9,9),TIME(99),TINS(99),VFAC(9,18)
INP
5,VINF(99),X(9,9),XX(20),Y(9,9),Z(20,99),TALLW(9)
INP
COMMON A,ALPHA,ALT,AME,AL,AOFA
INP
1AROD,AX,BETA,BF
INP
2bFL,DELTA,DST,DN2,DIAM,AROD,XEMIS,STAAT
INP
3,KFLEA,NENG,NPAN,QL,REY,RHOP,TJ,VT
INP
4VJ,VS,VU,VV,WEJ,WER,IPF(4),XI
INP
5XJ,VL,YP,IPH,AIY,DREF,YCL
INP
DIMENSION AIML(4),ANRMSC*,ANML*,ASCR(4),PF(4),CY(4),SLD(4)
INP
1SPMAX(4),TITLE(13)
INP
NAMLIST/DATANU/ICONK,IQCQN,IQINP,ITRB,IWALT,NCRC,NSECT,NTRAJ,NPRT
INP
NPSG=14
INP
IF (NSECT.EQ.4) NPSG=12
INP
IF (NSECT.EQ.3.OR.NSECT.EQ.6) NPSG=10
INP
NAMELIST/SOIC1/ AE,ALPHA,ALT,AME,AL,AOFA
INP
1AROD,AX,BETA,BF
INP
2bFL,DELTA,DST,DN2,DIAM,AROD,XEMIS,STAAT
INP
3,KFLEA,NENG,NPAN,QL,REY,RHOP,TJ,VT
INP
4VJ,VS,VU,VV,WEJ,WER,IPF(4),XI
INP
5XJ,VL,YP,IPH,AIY,DREF,YCL
INP
DIMENSION ANGL(4),ANRMS(4),ANML(4),SCR(4),PF(4),CY(4),SLD(4)
INP
1SPMAX(4),TITLE(13)
INP
NAMLIST/DATANU/ICONK,IQCQN,IQINP,ITRB,IWALT,NCRC,NSECT,NSEG,
INP
1MAT,NRSG,NPSG,NCR,NF,NSECT,DNX,DNY,DNZ,DXST,DIAM,AROD,XEMIS,STAAT
INP
2bFL,DELTA,WOKE,SToop,AS,R,HH,TS,TC,SL,SLS,BE,F07,UF,DST,EALL,BF,BFL
INP
3bL,X,Y,IPC,IPFI,AY,DIRF,YCL
INP
DATA CONF/6HPLATE,6HCONE,6HSPHERE/
INP
DATA TURB/6HECKER,6HSPALDI,6HANG,6HANG-CHI/
INP
DATA WALT/6HUNIFOR,6HNONUNI,6HANG/
READ (5,460) DNx,DNY,DNZ,XUST,DIAM,AROD,XEMIS,FACC
READ (5,460) STAAT,DELTA,WROTE,STOOP
READ (5,460) AE4,HH,T5,TC,SL,BE
READ (5,460) F07,UF,XST,EALL,CRN,BF,BFL,BL
NCR=IFIX(CRN)
READ (5,460) (TALLW(I),I=1,9)
READ (5,460) (EMIS(I),I=1,9)
READ (5,460) (RHO(I),I=1,9)
DO 90 J=1,NMAT
READ (5,450) ((ID(I,J),MPT(I,J)),J=1,8)
DO 90 J=1,8
IF (ID(I,J),EQ.0.) GO TO 90
KK=MPT(I,J)
IF (J.EQ.1.) GO TO 70
IF (ID(I,J),EQ.2.) GO TO 70
DO 60 K=1,KK
60 AX(I,J,K)=AX(I,J-1,K)
GO TO 80
70. READ (5,460) (AX(I,J,K),K=1,KK)
80 READ (5,460) (AY(I,J,K),K=1,KK)
90 CONTINUE
100 IF (NCOLM.GT.1) GO TO 110
X(I)=1.
K=1
QCONL(I)=1.0
QCONT(I)=1.0
GO TO 170
110 READ (5,460) (X(I),I=1,9)
K=2
IF (IQCON-2) 120,140,160
DO 130 I=1,9
QCONL(I)=1.0
QCONL(I)=1.0
GO TO 170
140 READ (5,460) (QCONL(I),I=1,9)
150 DO 160 I=1,9
QCONL(I)=QCONL(I)
GO TO 170
160 READ (5,460) (QCONL(I),I=1,9)
READ (5,460) (QCONT(I),I=1,9)
170 READ (5,460) (Y(I),I=1,9)
DO 180 J=1,NSEG
180 READ (5,470) (MAT(I,J),TAMP(I,J),I=1,K)
IF (NCOLM.EQ.1.OR,NRSG.EQ.0) GO TO 250
DO 190 J=1,NRSG
190 READ (5,480) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
READ (5,450) IPFI,(IPFI(I),I=1,4),IPAD,KFLEX,NPAN
DO 210 N1=1,IPFI
N2=IPFI(N1)
GO TO (200,210,220,230), N2
200 READ (5,460) DT(N2),XL,REY,VU,QL,AMACH
GO TO 240
210 READ (5,460) DT(N2),IT,WER,D,V,S,XI,DVEH,YCL,DREF
GO TO 240
220 READ (5,460) DT(N2),AE,VJ,WEJ,VP,TJ,XJ,YP
GO TO 240
230 READ (5,460) DT(N2)
240 CONTINUE
READ (5,460) HPAN,HC,AI,AIY,AW,BW,EP
READ (5,460) (C(I),I=1,4),KHOP

Figure I-13. Source Listing — INPUT1, Contd
IF (NUDIM.EQ.1.AND.NUTRAJ.EQ.0) GO TO 300
IF (JI.EQ.3) GO TO 300
NTRAJ=NTRAJ
DO 260 I=1,99
READ (5,490) TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I),TINS
ID(I),NREADT
NTRAJ=I
IF (NREADT.GT.0) GO TO 270
260 CONTINUE
WRITE (6,500)
STOP
IF (NUTRAJ.EQ.1) NTRAJ=NTRAJ1
IF (NANG.LT.2) GO TO 290
ALPHA(I)=ALPHA(1)
bETA(I)=BETA(1)
WRITE (6,510) ((I,TIME(I),ALT(I),VINF(I),ALPHA(I),BETA(I),HINSD(I),TINS
1,TINS(I)),I=1:NTRAJ)
DO 330 I=1,NMAT
WRITE (6,580) XQCONL,QCONT,(MAT(I,1),I=1,9),(TAMP(I,1),I=1,9)
DO 340 J=1,NRSG
WRITE (6,620) NR(J),NI(J),(MR(I,J),VFACT(I,J),I=1,9)
WRITE (6,710) AS,R,HH,TT,CRN,BF,BFL,RESTER,DST,EALL,
1,CRHOP
WRITE (6,630)
Figure I-13. Source Listing — INPUT1, Contd
IF (NCRC.LT.2) GO TO 400
XX(1)=X(1)
DO 390 I=2,NCOLM
390 XX(I)=XX(I-1)+X(I)
400 WRITE (6,410)
RETURN

FORMAT

20D1 DY DIAMETER ,F8.4
3H INITIAL TIME

30 FORMAT (///45H0**** NUMBER OF TITLE CARDS IS GREATER THAN 10 OR INP 198
10 OR LAST CARD WAS NOT FLAGGED *****) INP 199
51 FORMAT (///44H0**** TRAJECTORY INPUT *****/4X1H8/INP 200
1X7HTIME(I)9X6HALPHA(I)7X8HALPHA(I)8X7HBFETA(I)7X8HINS(I)INP 201
27X8HINS(I)///15,3F15.02F15.4E15.4F15.4) INP 202
52 FORMAT (///25H PROGRAM OPTIONS USED/27H CONFIGURATION 203
1- ,A6/27H TURBULENT HEATING- ,2A6/27H WALL TEMPEINP 204
3HEAT FLUX- ,2A6/)
53 FORMAT (///6X46HDIRECTION COSINES OF OUTER NORMAL FROM SURFACE/14H INP 205
1 DNX = ,F7.4/14H DNY = ,F7.4/14H DNZ = ,F7.4/)
54 FORMAT (///5X30DISTANCE FROM LEADING EDGE ,F8.4/35H BINF 206
10DY DIAMETER ,F8.4/35H SHOULDER RADIUS/BINP 207
20DY DIAMETER ,F8.4/35H EXTERNAL SURFACE EMISSIVITY ,F6.2/35P 208
1H INITIAL TIME ,F8.1/35H END TIME INP 209
4 ,F8.1/35H CALCULATION TIME INTERVAINP 210
5L ,F8.1/35H PRINT OUT INTERVAL ,F8.1 INP 211
6SEC//)
55 FORMAT (///50H0**** MATERIAL PROPERTIE S *****//INP 212
16H MATERIAL NUMBER,9(7X,1H-,1H-)) INP 213
56 FORMAT (///45H0**** CON DUCT I ON INPUT *****/) INP 214
57 FORMAT (108H SEGMENT NUMBER -1- ,2- ,3- -4- ,5- ,6- ,7- ,8- ,9- ,10-) INP 215
1-8- ,9- ,10-) INP 216
2SS FT ,9F10.4/18H MATERIAL ,9I10/18H INITIAL TEMP. R INP 217
3,9F10.0/)
58 FORMAT (///11H COLUMN NUMBER, 1 -1- ,2- ,3- -4- ,5- ,6- ,7- ,8- ,9- ,10-) INP 218
2H, X(I) FT ,9F10.4/16H HEATING FACTORS/21H LAMINAR INP 219
4-,I10,1H*,I9,7I10/14H THICK*, Y(J) = ,F7.4/10.0 2H**,F8.0/7F10.0) INP 221
59 FORMAT (///18X,1H-=I1.1H+=9I10/F21.4*9F10.0) INP 222
60 FORMAT (///5X,8H=-NOTE=-/27H * = MATERIAL NUMBER/3INP 223
17H ** = INITIAL TEMPERATURE DEG R/) INP 224
61 FORMAT (///55H0**** RADIAT I ON INTERCHANGE *****/INP 225
1#/#5H SEG NO. , NI INTERCHANGE NEIGHBORS AND VIEW FACTORS/) INP 226
62 FORMAT (///1X2H (+,I2,1H),I5,2X,9(2H ,(I2,1H)*F6.3)) INP 227
63 FORMAT (///36H0**** E ND OF I NPUT *****) INP 228
64 FORMAT (///18H0ALLOWABLE TEMP. R,9F10.3) INP 229
65 FORMAT (///11H0EMISSIVITY7X9F10.3) INP 230
66 FORMAT (///18H0MATERIAL DENSITY 9F10.3) INP 231
67 FORMAT (///16H MATERIAL NUMBER,8X19HHEAT CAPACITY,9X20HTHERMAL COIP 232
1DUCTIVITY,9X14HYOUNG'S MODULUS,8X22HTHERMAL EXPANSION COEF/12X4(12INP 233
2X2HAX,10X2HAY)) INP 240

Figure I-13. Source Listing — INPUT1, Contd
080 FORMAT (///16H MATERIAL NUMBER,8X14HYIELD STRENGTH,9X20MULT TENSILINP 241
   1E STRENGTH,5X22HLARSON-MILLER STRAIN,1,4X22HLARSON-MILLER STRAIN 2INP 242
   2/12X4(12X2HAX,10X2HAY))
690 FORMAT (/19,7X,4(2X2E12,3))
700 FORMAT (16X,4(2X2E12,3))
710 FORMAT (///36H0***** STRESS INPUT *****///3X2HAS,13X2HTS,13X2HTC,13X2HSL,12X3HSLS,13X2HBE,8E15,3//12X3HF07INP 247
   2,13X2HUF,12X3HDST,11X4HEALL,12X3HCRN,13X2HBF,12X3HBF,13X2HBL//8E15INP 248
   3,3) INP 249
720 FORMAT (///38H0***** FATIGUE INPUT *****///4X4HPAD,10X5HNPAN,10X5HDT(1),10X5HDT(2),10X5HDT(3),10X5HDT(4),13X2INP 250
   15HKFLEX,11X4HNPAN,10X5HDT(1),10X5HDT(2),10X5HDT(3),10X5HDT(4),13X2INP 251
   2HXL/3I15,5E15,3//12X3HREY,13X2HVU,13X2HQL,10X5HAMACH,13X2HTT,12X3HINP 252
   3WER,14X1HC,13X2HVS/8E15,3//13X2HXI,11X4HDOVEH,12X3HYCL,11X4HDREF,13INP 253
   4X2HAE,13X2HVJ,12X3HWEJ,13X2HVW/8E15,3//13X2HTJ,13X2HXJ,13X2HYP,11INP 254
   5X4HPAN,13X2HHC,13X2HAI,12X3HAIY,13X2HAW/6E15,3//21X2HBE,13X2HEP,11INP 255
   6X4HC(1),11X4HC(2),11X4HC(3),11X4HC(4),11X4HRHOP//8X7E15.3 INP 256
END INP 257-

Figure I-13. Source Listing — INPUT1, Contd

I-35
SUBROUTINE MININO(DI,SLD,CYL,CY,SCR)
DIMENSION DI(4)
COMMON/APP1/NOAPP
DIMENSION C(3)
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=ALL(DI,CY)
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
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
50 XI=XI
ETAL=ETA
60 ETA=0.5*(ETAL+ETAU)
CY=ETA*CYL
C1=ALL(DI,CY)
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
120 FORMAT (30H0,ITERATION FAILED TO CONVERGE.)
END

Figure I-14. Source Listing — MININO
SUBROUTINE PANEL

DIMENSION ALPHE(20)
DIMENSION A(20), ALPHA(99), ALT(99), AX(9,9,9), AY(9,9,9), BETA(99),
DIST(99), E(20,99), EAT(20,99), EDTOT(20,99), EMIS(9), FCY(20,99),
2FNET(20), FT(20), FTU(20,99), HINS(99), MAT(9,9), MPT(9,9), MR(9,18),
3NI(18), NR(18), PINP(99), Q(99), QCONF(99), QINT(99), QMTH(99),
4RHO(9), T(20,99), TAMP(9,9), TINS(99), TINSU(99), TIME(99), TINSU(99), VFACT(9,18),
5VIN(99), X(9,99), X(20), Y(99), ZZ(20), TALLW
COMMON A ,ALPHA ,ALT ,AM ,AML ,AM2A
ARQ ,AS ,AX ,AY ,BATA ,BE ,BETA ,BF
DELTA ,DIAM ,DIST ,DNY ,DNZ
EMP ,EMISS ,FCY ,FNET
FNET ,FT ,FTU ,FC ,HH ,HINS ,HINS ,HINTS
FTU ,HINTS ,INTS ,INTS ,INTS
UO ,I1NSD ,I1NSD ,I1NSD ,I1NSD
5INSP ,Q ,Q ,Q ,Q ,Q ,Q ,Q ,Q
MPT ,MR ,MPT ,MR ,MPT ,MR ,MPT ,MR ,MPT
NCOLM ,NCR ,NCR ,NCR ,NCR ,NCR ,NCR ,NCR ,NCR
NTRAJ ,PE ,PE ,PE ,PE ,PE ,PE ,PE ,PE
STAY ,STI ,STI ,STI ,STI ,STI ,STI ,STI ,STI
TIME ,TI ,TI ,TI ,TI ,TI ,TI ,TI ,TI
TIME ,TI ,TI ,TI ,TI ,TI ,TI ,TI ,TI
SWROT ,SWROT ,SWROT ,SWROT ,SWROT
NINS ,FACC ,NRTC ,TALLW
figu E 1. Source Listing — PANEL

C*****CONFIGURATION NO 1

GO TO (10,40,70,100,130,160), NSECT

INC 10 RHR=(R-HH)/K
THETA=A COS(RHR)
BW=AS-2.*R*SIN(THETA)
TC1=TC*S IN (THETA)/THETA
A(1)=.1*(AS-BF)*TS
XX(1)=.05*(AS-BF)
ZZ(1)=.5*TS
DO 20
1=2,
A(I)=A(I)
XX(I)=XX(I-1)+2.*XX(1)
ZZ(I)=ZZ(I-1)
A(6) = .25*BF*TS-FTC
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,
ALPHE=ALPHE(1)
A(8)=R*THETA*TC1/7.
XX(8)=R*SIN(ALPH)
ZZ(8)=R*COS(ALPH)-R+HH+TS
00 30 I=9,14
ALPHE(I-7)=ALPHE(I-8)-THETA/7.
ALPHE=ALPHE(I-7)
A(I)=A(I)
XX(I)=R*SIN(ALPH)
30 ZZ(I)=R*COS(ALPH)-R+HH+TS
RETURN

C*****CONFIGURATION NO 2

GO TO (40,70,100,130,160), NSECT

INC 40 THETA=ATAN(HH/(.5*AS-BF))
BW=HH/SIN(THETA)
DX1=.1*(AS-BF)
A(I)=DX1*TS
XX(I)=.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 50 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)
RETURN
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.
RETURN
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.

Figure I-15. Source Listing — PANEL, Contd
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)
RETURN

C*****CONFIGURATION NO 5

130 HR=1.-.5*HH/R
THETA=ACOS(HR)
A(1)=.25*BFL
XX(1)=.125*BFL
ZZ(1)=0.,
A(2)=A(1)
XX(2)=.375*BFL
ZZ(2)=0,
ALPH1=.1*THETA
A27=.2*R*THETA*TC
DO 140 I=3,7
A(I)=A27
ALPH1=ALPH1+.2*THETA
XX(I)=.5*BFL-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)
RETURN

C*****CONFIGURATION NO 6

160 THETA=ACOS(1.-.5*HH/R)
A(1)=.25*AS-2.*R*SIN(THETA)
XX(1)=.125*AS
ZZ(1)=R-R*COS(ALPH1)
A(2)=ALPH1+.2*THETA
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)
RETURN
END
SUBROUTINE PRA63(ALT*PINF,TINF,RHINF,ICK)

DIMENSION PB(14),ZI(5),PK(6,5),RHOK(6,3),TK(6,5),VT(6,3)
12ZB(14),TMB(14),LMB(14),DMB(14),MB(14)
REAL LMB,MB,MWT
DATA PBASE/6.231017E-7,9E-5/
DATA (zi(i),i=1,5)/0.83,8.78,5.3,2.8,0.9/
DATA (PK(I),I=1,5)/1.6871582E-2,-1.142576E-4,-1.761232E-9,7.362414E-14,-1.000315E-17/
DATA (RHOK(I),I=1,18)/0.3302117E-2,-8.850206E-5,-8.214156E-9,5.9517557E-13,-3.974478E-17,8.461980E-21/
DATA (TK(I),I=1,18)/2.9667877E2,-6.7731001E-3,-8.490966E-17,1.741160E-30/
DATA (ZB(I),I=1,14)/1.8,2.6,3.4,4.2,5.0,5.8,6.6,7.4,8.2,9.0,9.8,10.6,11.4/
DATA (TMB(I),I=1,14)/180.65,210.65,260.65,360.65,960.65,1.61,1.91,2.21,2.51,2.81,3.11,3.41,3.71/
DATA (LMB(I),I=1,14)/3.0E-3,5.0E-3,1.0E-2,2.0E-2,3.0E-2,4.0E-2,5.0E-2,6.0E-2,7.0E-2,8.0E-2,9.0E-2,1.0E-1,1.1E-1/
DATA (DMB(I),I=1,14)/-0.844E-5,-3.20E-5,-4.9E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5,-3.833E-5/
DATA (PB(I),I=1,14)/1.722436,4.2,3.159771,5.7,7.7438907,8.7,1.659771,5.6,5.3584938,7.3,3.9128495,7.7,2.9591111,7.7,2.1787156,8.7,2.057311,8.7,4.3045660,9.7,3.117315480,9.7,3.70198961,10.7,1.28115330,10.7/

10 Z=ALT*.3048
   IF (Z,GT.700000.) GO TO 160
   IF (Z,LT.0.) GO TO 160
   N=1
   IF (Z,GT.83004.) N=1
20 IF (Z-ZI(N)) 40,20,20
   N=N+1
30 GO TO 20
40 Z2=Z*Z
23=Z2*Z
Z4=Z2*Z2

... Figure I-16. Source Listing — PRA63...
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)*Z5

100 IF (Z<88000.) 100,110,110

100 PRES=10.000000*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N)*Z5)

110 PRES=.000980665*EXP(PK(1,N)+PK(2,N)*Z+PK(3,N)*Z2+PK(4,N)*Z3+PK(5,N)*Z5)

120 DENS=34.83676*(PRES/TEMPK)

130 TEMPK=180.65

PRES=PBASE*EXP((-1.373301523E12*(Z-83004.))/(180.65*(6344860.+Z))

140 MWT=MB(N)+OMB(N)*(Z-ZB(N))

TEMPM=TMb(N)+LMB(N)*tZ-2B(N))

TEMpK=(MVvT/2d.9614)*TEMPM

PRES=EXP(ALOG(PB(N))+(1.373301523E12)/(LMB(N)*(6344860.+Z))

150 PINF=PRES*208.6576

TINF=TEMPK*1.8

RH0INF=DENS*0.0019404

ICK=1

GO TO 170

160 ICK=0

170 CONTINUE

RETURN

END
SUBROUTINE PRINTKISS

DIMENSION A(20), ALPHA(99), ALT(99), AX(9,9,9), AY(9,9,9), BETA(99),
101ST(9), E(20,99), EDOT(20,99), EMIS(99), MPT(9,9), MIN(9,18),
3NR(18), PINP(99), Q(9), QCONL(9), QCONT(9), QINP(99), QNET(9),
4RHO(9), T(20,99), TEMP(9,9), TIME(99), TINS(99), VFACT(9,18)
5,VINF(99), X(9), XX(20), Y(9), ZZ(20), TALLW(9)

COMMON A, ALPHA, ALT, AME, AMI, AOFA, 1AROD
2BFL, BL, DELTA, DIAM, DIST, DNX, DNY, DNZ
3DST, E, EALL, EAT, EDOT, EMIS, FCY, FNET
4FT, FTU, F07, HH, HINS, HINSD, ICONF, IOINP
5ITURB, IWALT, MAT, MPT, MR, NCOLM, NCR, NF
6NI, NPSG, NR, NRSG, NSECT, NSEG, NTRAJ, PE
7PI, PINP, Q, QCNL, QCONT, QIP, QNET, R
8RHO, RHOI, RYE, RYI, SL, SLS, STAAT, STI
9STOOP, T, TAMP, TAU, TC, TC1, TEMP, TI
STIME, TINS, TINSU, TS, UF, VFAC, VI, VINF
5WROTE, X, XEMIS, XX, Y, ZZ, NCHC, TALLW
$WINS, FAC, NPRT

N=ISS

WRITE (6,30) TAU, AL, VI, AOFA, PI, AMI, AME, RYI, PE
WRITE (6,50) (I, I=1,N), Q, QNET
10 WRITE (6,60) J, (TEMP(I,J), I=1,9)
IF (NINS.EQ.1) GO TO 20
WRITE (6,70) (A(I), XX(I), ZZ(I), T(I,N), FT(I), FNET(I), EDOT(I), FTU(I),
IN), FCY(I,N), E(I,N), I=1, NPSG)
WRITE (6,40) NINS, FAC, NPRT

20 RETURN

30 FORMAT (1H0, 20X, HTAU, 10X, 2HVI, 10X, 2HAOFA, 10X, 2HP1, 9X, 3HAMI, 9X, 3HPR)
1AME, 9X, 3HRYI, 10X, 2HPE/12X, 9E12, 4)
40 FORMAT (1H1)
50 FORMAT (/11X, 9I12/, 8X, 4H8I(I), 9E12, 4/5X, 7H4NET(I), 9E12, 4/)
60 FORMAT (3X, 7HTEMP(I, I, 11), 9E12, 4)
70 FORMAT (/11X, 10X, XX, 10X, 2HZ, 11X, 1HT, 10X, 2HT, 8X, 4HFNET, 8X, 4HEDOT,
19X, 3HFU, 9X, 3HFCY, 11X, 1HE/(1UE12, 3))
END

Figure I-17. Source Listing — PRINT1

I-42
SUBROUTINE STRESS(ISS,IST)

COMMON A ,AL ,ALPHA ,ALT ,AME ,AMI ,AOFA ,STR 10
1AROD ,AS ,AX ,AY ,BATA ,BE ,BETA ,BF ,STR 11
2BFL ,BL ,DELTA ,DIAM ,DIST ,DNX ,DNY ,DNZ ,STR 12
3DIST ,E ,EALL ,EAT ,EDOT ,EMIS ,FCY ,FCY ,STR 13
4FT ,FU ,FTU ,HH ,HINS ,HINSD ,ICONF ,IQINP ,STR 14
5ITURB ,IWALT ,MAT ,MPT ,MR ,NCLM ,NCR ,NF ,STR 15
6NI ,NPNS ,NR ,NRS ,NSEC ,NSEG ,NTRAJ ,PE ,STR 16
7PI ,PINP ,Q ,QCNL ,QCONT ,QINP ,QNET ,R ,STR 17
8RH0 ,RHOI ,RYE ,RYL ,SL ,SLS ,STAAT ,STI ,STR 18
9STOOP ,T ,TAMP ,TAU ,TC ,TC1 ,TEMP ,TI ,STR 19
$TIME ,TINS ,TINSU ,TS ,UF ,VFAC ,VI ,VINF ,STR 20
$WRUTE ,X ,XEMIS ,XX ,Y ,ZZ ,NCHRC ,TALLW ,STR 21
$WINS ,FACC ,NPRT ,STR 22

M=1
KM=1
ISS=ISS+1
II=ISS
J=ISS
GO TO (10,10,40,10,120), NSECT
10 DO 20 I=1,5
20 T(I,J)=TEMP(I,1)
   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 140
40 DO 50 I=1,5
   K=7-I
50 T(I,J)=TEMP(K,1)
   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 140
70 DO 80 I=1,5
   K=7-I
80 T(I,J)=TEMP(K,1)
   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 140
100 DO 110 I=4,14
   K=I-3
   IF (K.GT.9) K=9

Figure I-18. Source Listing — STRESS
110 T(I,J)=TEMP(K,1)
T(1,J)=T(7,J)
T(2,J)=T(6,J)
T(3,J)=T(5,J)
GO TO 140
120 DO 130 I=3,10
K=I-2
130 T(I,J)=TEMP(K,1)
T(1,J)=T(5,J)
T(2,J)=T(4,J)
140 IF (IST.GE.1) GO TO 170
IST=1
L=MAT(1,J)
L=IAS(L)
CF=FLOAT(HF)*WROTE/7200.
FCY=AY(L,5,1)
150 CALL PANEL
R1M=0.
R2M=0.
R3M=0.
R4M=0.
R5M=0.
R6M=0.
DMAX=0.
WBMS=100.
DO 160 I=1,NPSG
E00(I)=0.
160 SUM=0.
IF (M.EQ.2.OR.KM.GT.1) GO TO 180
C****CORRUGATION BM AT MIU SPAN
170 w=PE*AS/144.
SLP=SLS-2.*BE
BMXX(ISS)=w*SLP*5P/8.
180 DO 460 I=1,ISS
190 SUM=0.
SUMTA=0.
SUMXX=0.
SUMAZ=0.
210 I=I+NPSG
IF (M.EQ.2.OR.KM.GT.1) GO TO 200
E(I,N)=THPLAT(AY,AX,T(I,N)*L,3,MPT(L,3))
ALFA=TRPLAT(AY,AX,T(I,N)*L,4,MPT(L,4))
FCY(I,N)=THPLAT(AY,AX,T(I,N)*L,5,MPT(L,5))
FTU(I,N)=THPLAT(AY,AX,T(I,N)*L,6,MPT(L,6))
EAT(I,N)=E(I,N)*ALFA*(T(I,N)-530.)
200 EATA=EAT(I,N)*A(I)
AE=E(I,N)*A(I)
SUM=SUMA+AE
SUMTA=SUMTA+EATA
SUMXX=SUMXX+AE*Z(I)
SUMAZ=SUMAZ+EATA*Z(I)**2
210 SUMAZ=SUMAZ+EATA*Z(I)
ABAR=SUMTA/SUMA
SBAR=SUMAZ/SUMA
SXXI=SUMX/SUMA
SXXI=(SUMX-ZBAR*SUMX)
SXXM=SUMX*(ZBAR-SBAR)
SXXW=SXXM/XXI
SXXW=SXXM/XXI
DFL = (1.042*WX - 125*XXW)*SLS**2
DMAX = MAX1(ABS(DMAX), ABS(DFL))
IF (ABS(DMAX), EQ, ABS(DFL)) DMAX = DFL

C***** THERMAL STRESS
UO 220 I=1,NPS6
FT(I) = E(I,N) *(ABAR + XXW*(ZBAR - ZZ(I)))*CAT(I,N)
220 FNET(I) = FT(I) - WX*E(I,N)*(ZBAR - ZZ(I))

C***** STRESS DUE TO APPLIED BM

C***** BUCKLING OF SKIN

C***** BUCKLING OF LEG SECT NO 3

C***** CREEP RATE

C***** STRUCTURAL INDICES FOR THE SELECTION OF CRITICAL TRAJECTORY POINTS

Figure I-18. Source Listing — STRESS, Contd
GO TO 290

290 R11=FX/FTU(I,N)
R22=FX/FCY(I,N)
R33=0,
R44=0,
R55=0,

290 K1M=AMAX1(R1M*R11)
R2M=AMAX1(R2M*R22)
R3M=AMAX1(R3M*R33)
IF (R3M,NE,R33) GO TO 300
I3=1
N3=N

FN3=FX
300 GO TO (310,350,350,320,330,340), NSECT
310 IF (I,GE,8) GO TO 340
GO TO 350
320 IF (I,GE,3,A.ND.I,LE,5) GO TO 340
GO TO 350
330 IF (I,GE,3,A.ND.I,LE,12) GO TO 340
GO TO 350
340 R4M=AMAX1(R4M,R44)
IF (R4M,NE,R44) GO TO 350
I4=1
N4=N

FN4=FX
350 GO TO (390,360,390,370,360,390), NSECT
360 IF (I,GE,13) GO TO 360
GO TO 390
370 IF (I,GE,11) GO TO 360
GO TO 390
380 R5M=AMAX1(R5M,R55)
IF (R5M,NE,R55) GO TO 390
I5=1
N5=N

FN5=FX
390 GO TO (400,400,410,420,420,440), NSECT
400 IF (I,EQ,6,OR,I,EQ,7) GO TO 430
GO TO 440
410 IF (I,LE,5) GO TO 430
GO TO 440
420 IF (I,LE,2) GO TO 430
GO TO 440
430 R6M=AMAX1(R6M,R65)
IF (R6M,NE,R65) GO TO 440
I6=1
N6=N

FN6=FX
440 IF (N,EQ,1) GO TO 450
SUME(I)=SUME(I)+CF*(EDOT(I)+EDO(I))
450 EDO(I)=EDOT(I)
460 CONTINUE
IF (IST,LE,2) GO TO 470
RETURN

C*****ULTIMATE TENSION
470 T1MS=1./(R1M*UF)-1.
C*****YIELD STRENGTH
Y2MS=1./(R2M-1.
C*****ULTIMATE COMPRESSION
IF (R3M,LE,0.) GO TO 480
FCU=AMIN1(1.1*FCY(I3,N3)*FTU(I3,N3))
C3MS=-FCU/(FN3*UF)-1.
GO TO 490

480 C3MS=100.

C***BUCKLING OF CORRUGATION

490 IF (H4M.LE.0.) GO TO 540
GO TO (500*540,540,510*520*520), NSECT

500 TX=TC1
GO TO 530

510 TX=TS
GO TO 530

520 TX=TL

530 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 550

540 C4MS=100.

C***CHIRPING OF FLANGE

550 IF (R5M.LE.0.) GO TO 580
GO TO (580*560*580*560*580), NSECT

560 I=15
N=N5
M=1
TX=TC

570 FCC=1.385*FCY(I,N)/(SQRT(FCY(I,N)/E(I,N))*NBY/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 640
F5MS=-FCC/(FN5*UF)-1.
GO TO 590

580 F5MS=100.

590 IF (R6M.LE.0.) GO TO 650
GO TO (600*600*610*620*650), NSECT

600 TX=TC+TS
GO TO 630

610 TX=TS
GO TO 630

620 TX=TC

630 M=2,
I=16
N=N6
GO TO 570

640 F6MS=-FCC/(FN6*UF)-1.
GO TO 660

650 F6MS=100.

C***TOTAL CREEP STRAIN

660 EMAX=0.
DO 670 I=1,NPSG

670 EMAX=AMAX1(EMAX,SUME(I))
EMS=AMAX1(TMS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS)
IF (NPRT.EQ.1) CALL PRINT1(TSS)
WRITE (6,680) TMS,Y2MS,C3MS,C4MS,F5MS,F6MS,WBMS,DMAX,EMS,EMAX
680 FORMAT (1/8X4HTMS,8X4HY2MS,8X4HC3MS,8X4HC4MS,8X4HF5MS,8X4HF6MS,8X4HWBMS,8XSTR
24HDMAX,9XHEMS,8X4HEMAX/10E12.4)

C***SELECTION OF MIN M.S.
IF (KM,EQ.2) GO TO 700
IF (EALL.GE.EMAX.AND.EMS.GE.0.) GO TO 750
KM=2
DT=.010

Figure I-18. Source Listing — STRESS, Contd

I-47
AMAX=EMAX

AMS=EMS
tc=tC+DT

if (NSECT.EQ.3.OR.NSECT.EQ.4) TS=TS+DT

II=1

while (6.770) TS

while (6.760)

M=1

go to 150

if (LALL.GE.EMAX.AND.EMS.GE.0.) go to 750

if (LALL.GE.EMAX) go to 710

DEUT=1.E2*(AMAX-EMAX)

DT1=(EMAX-.95*EALL)/DEDT

go to 720

/10 DT1=0.0

/20 if (EMS.GE.0.) go to 730

UMUT=1.E2*(EMS-AMS)

UT2=7.05*EMS/UMDT

go to 740

/30 UT2=0.0

/40 UT=AMAX1(DT1,DT2)

KM=2

go to 690

/750 while (6.760)

/760 format (34H0****** END OF NO j E *****)

/770 format (//58H STRESS CONSTRAINTS EXCEEDED - PANEL THICKNESS RESIZE)

go to /8H TC=F6.3*4H IN./8H TS=F6.3*4H IN./)

end

Figure I-18. Source Listing — STRESS, Contd
```fortran
FUNCTION TABLE(X, XTB, YTB, N)
C THIS SUBROUTINE DOES LINEAR INTERPOLATION,
C WHERE Y=F(X). IT WILL NOT EXTRAPOLATE.
C
DIMENSION XTB(1), YTB(1)
C
I=0
IF (X.GE.XTB(1) .AND. X.LE.XTB(N)) GO TO 10
WRITE (6, 60)
TABLE=0.
RETURN
TBL 1
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+YTB(I-1)+YTB(I)
GO TO 50
30 Y=YTB(I)
GO TO 50
40 Y=(YTB(I-1)-YTB(I))/(XTB(I)-XTB(I-1))*X+YTB(I)
50 TABLE=Y
RETURN
60 FORMAT (26HOX ARGUMENT ERROR IN TABLE)
END
```

Figure I-19. Source Listing — TABLE
Figure I-20. Source Listing — THERMO

I-50
VE=VI
TE=TI
EI=AI
AME=AMI

50 IF (AOFA.GE.0) GO TO 120

C*****PRANDTL MEYER EXPANSION

BETAI=SQRT(AM2-1.0)
UNI=140.34601*ATAN(.40825*BETAI)-57.29578*ATAN(BETAI)
IF (AOFA+.05) 60*.60*.40
60 UNE=UNI-57.29578*AOFA
IF (UNE+.50) 70*.70*.80
70 AME=-26.301065/(UNE-81.77828)+.7895902+.02791663*UNE
GO TO 110
80 IF (AOFA-.05) 60*.60*.40
80 UNE=UNI-57.29578*AOFA
IF (UNE-.50) 70*.70*.80
70 AME=-26.301065/(UNE-81.77828)+.7895902+.02791663*UNE
GO TO 110
100 AME=-28.84684/(UNE-130.43331)-1.0199074+.86803698E-03*UNE
GO TO 110
110 TR=(5.0+AM2)/(5.0+AM2**2)
PR=TR**3.5
VR=AME/AMI)*SQRT(TR)
PE=PR*PI
TE=TR*TI
VE=VR*VI
EI=FENTL(TE)

120 AMSA=AMI*SIN(AOFA)
IF (AMSA.LE.0.05) GO TO 40
AM2=AMSA**2
AM3=AMSA**2
REFM=VI/1086.0
RMSA=REFM*SIN(AOFA)
RMS2=RMSA**2
KMS3=RMSA*RMS2
IF (ICONF.EQ.2) GO TO 210
C*****WEIGHT
IF (AMSA.GT.8.0) GO TO 130
EI=AI*(.9167+.3203*AMSA+.236*AM2-.4484E-3*AM3)
GO TO 140
130 EI=AI*(1.107-.2209*AMSA+.3644*AM2-8.462E-3*AM3)
GO TO 140
140 IF (AMSA.GT.1.8) GO TO 150
PE=PI*1.041+.693*AMSA+.1.889*AM2-.0661*AM3)
GO TO 160
150 PE=PI*(2.32+.045*AMSA+.036*AM2+.0161*AM3)
160 IF (KMSA.GE.6.0) GO TO 170
VR=.1923+.4044*VR+.147*RMS2+.3301*RMS3
GO TO 190
170 IF (KMSA.GE.2.0) GO TO 180
VR=.5958+.4494*VR+.1.838*RMS2-.0331*RMS3
GO TO 190
180 VR=.78.03-.19.58*RMSA+.3.13*RMS2-.05504*RMS3
190 VE2=VI2-1.0E6*VR
IF (VE2.GT.0.) GO TO 200
IG0=1
RETURN
200 VE=SQRT(VE2)
GO TO 280
C*****ONE
210 IF (AMSA.GT.8.0) GO TO 220
EI=AI*(1.03+.0827*AMSA+.2354*AM2-.956E-4*AM3)
GO TO 230
220 EI=AII*(1.106-.3685*AMSA+.3466*AMS2-.766E-3*AMS3)
230 IF (AMSA.GE.1.5) GO TO 240
PE=PI*(1.007+.3816*AMSA+1.522*AMS2-.1593*AMS3)
GO TO 260
240 IF (AMSA.GE.5,0) GO TO 250
PE=PI*(2.397+1.161*AMSA+1.06*AMS2+.0489*AMS3)
GO TO 260
250 PE=PI*(-3.182+4.177*AMSA+.8373*AMS2+.0216*AMS3)
GO TO 190
260 VR=1.57+.75*RMSA+.981*RMS2+.06944*RMS3
IF (RTMSA.GE.4.4) GO TO 270
270 VR=0.187-1.038*AMSA+1.414*RMSA+.0062*RMS3
GO TO 190
280 TE=17.899+4.0675*EI-.83884E-4*EI**2-.3495E-6*EI**3
GO TO 300
290 IF (EI.GT.705.0) GO TO 300
EMU=FMUT(TE)
RHO=PE/(TE*53.3*32.2)
GO TO 320
300 IF (EI.GE.1300.0) GO TO 310
EMU=FMUT1(EI)
RHO=EMU/(TE*53.3*32.2)
GO TO 320
310 EMU=FMUT2(EI)
RHO=EMU/(TE*53.3*32.2)
GO TO 320
320 IF (TE.GT.4860.) GO TO 330
UD=1.432-4.86E-5*TE
GO TO 340
330 UD=1.2
340 AME=VE/SQRT(DD*PE/RHOE)
PR=0.71
GO 540 I=1,J
KYE=RHOE*VE*DIST(I)/EMU
IF (KYE.9T.1.9E) GO TO 350
IC=1
REC=0.84
GO TO 370
350 IF (KYE.9T.2.9E) GO TO 360
IC=2
REC=0.84
TFR=KYE/1.9E-1.0
GO TO 370
360 IC=3
REC=0.89
370 REC1=EI+REC*VE**2/500*61.5
C****LCKER REFERENCE ENTHALPY
RI=0.28*EI+0.22*REC+0.5*W1(I)
IF (RI.GE.1300.) GO TO 380
RMU=FMUI1(RI)
RHR=FRH01(PE+RI)
GO TO 390
380 RMU=FMUI2(RI)
RHR=FRH02(PE+RI)
390 TFR=RHR*VE*DIST(I)/RMU
IF (IC.NE.2.0R.REC.NE.0.84) 60 TO 400
KYR=RYR
RHR=HYR
REC=0.89
REC1=REC1
GO TO 370

Figure I-20. Source Listing — THERMO, Contd
400 GO TO (410, 420, 420), IC
410 CF=0.664/SQRT(RYR)
   ST=0.5*CF/PR**(2./3.)*QCONL(I)
   ID=1
   GO TO 440
420 IF (ITURB.EQ.2) GO TO 520
   CF=0.370/(ALOG10(RYR))**2.584
   ST=0.5*CF/PR**(2./3.)*QCONT(I)
430 ID=2
440 IF (IC.NE.2.OR.ID.NE.2) GO TO 450
   HW=ST*RHOR*VE*32.2
   RYR=RYRL
   RHOR=RHOL
   GO TO 410
450 HW=ST*RHOR*VE*32.2
   IF (IC.NE.2) GO TO 460
   HW=TFR*HW+(1.-TFR)*HW
   RECI=TFR*RECI+(1.-TFR)*RECL
460 IF (ICONF.NE.2) GO TO 500
   GO TO (470, 480, 490), IC
470 H=1.73*HW
   GO TO 510
480 H=1.176*HW
   GO TO 510
490 H=(1.73-0.554*TFR)*HW
   GO TO 510
500 H=HW
510 Q(I)=H*(REC1-W1(I))
   GO TO 540
C*****SPALDING-CHI
520 D1=WI(I)/EI
   D2=0.2*REC*AME**2
   D3=1.0+D2-U1
   D4=SQRT(D3**2+4.0*D1*D2)
   D5=ASIN((2.0*D2-D3)/U4)+ASIN(D3/D4)
   FC=(D5/SQRT(D2))**-2
   FR=(RECl/WI(I))**0.772/D1**0.702
   FX=FR/FC
   D6=ALOG(FX*RYE)
   D7=1.0
   D8=0.0
   D0 530 K=2,10
   D7=D6*D7
530 D8=D8+G(K)*D7
   CF=EXP(D8+G(11))/FC
   SS=1.05*SQRT(FC*CF/2.)*((PR-1.0)+ALOG((5.0*PR+1.0)/6.0))
   ST=CF*QCONT(I)/(2.0*SS)
   RHOR=RHOE
   GO TO 430
540 CONTINUE
   GO TO 710
550 PR=0.71
   AOFS=1.57079-AOFA
   XMI=AMI*COS(AOFS)
   XM2=XMI**2
   XMF=7.0*XMI**2
   IF (ICONF.NE.3.AND.XMF.GT.0) GO TO 570
C*****KEMP-RIDDELL
   H=3.16615E-4*SQRT(RHOI/DIAM)*VI**1.15
   IF (ICONF.EQ.3) GO TO 560

Figure I-20. Source Listing — THERMO, Contd
H = 0.75 * H * (COS(AOFS))**1.2
IF (AROD.LT.0.0001) GO TO 560
H = H * SQRT(0.745 + 3.14 * AROD) / 1.5215

560 IS = 1
GO TO 590

#*#*#*#*BECKWITH-GALLAGHER
70 FAM = (1.0 + 0.2 * AM2)
FXM = (1.0 + 2 * XM2)
PRB = (1.2 * XM2)**3.5 * (6.0 / XM2)**2.5
KMU = FMUT(TI * FXM)
SMU = FMUT(TI * FAM)
XMU1 = RMU / SMU
XMU2 = SMU / AMU

VGRD = 2. * XM1 * SQRT(FXM) * SQRT(1. - 1. / PRA) / 0.7
ST = 0.03231 / PRA**(2 / 3.0) * COS(AOFS)**2.5 * XMU2**2.5

1FS = 0.66 * (XMU1 * PRA / FXM)**0.8

H = 0.974 + 0.051 * AOF5S - 0.213 * AUF6S**2 + 0.1 * AOF5S**3
H = ST * RHOI * VI**2.315

IF (AROD.LT.0.0001) GO TO 580
H = H * (0.745 + 3.14 * AROD) / 2.315**0.2

580 IS = 2

#*#*#*#*LOCAL PRESSURE AND HEAT FLUX
90 IF (AMI.LE.1.0) GO TO 670

TW = TEMP(1, 1)
CBAST = 0.01132 * AMI - 0.3008 / (AMI - 0.5434) - 0.05252
IF (AMI.GT.6.0) CBAST = -1.436 / AMI

DO 600 K = 1, 16
IF (AMI.LE.XM(K)) GO TO 610

B50 CONTINUE

DLOVE = 0.
GO TO 620

610 DLOVE = (D(K-1) - D(K)) * (AMI - XM(K-1)) / (XM(K) - XM(K-1)) - D(K-1)
DLOVE = DLOVE / 57.2958

620 IF (TW.LE.0.) GO TO 630
TWTI = TW / TI
GO TO 640

630 TWTI = 1. + 0.17 * AMI
IW = TI * TWTI

640 CHAP = SQRT(TWTI) * (TI + 192.) / (TW + 192.)
CJ = 1.721 * TWTI + 0.132 * AMI
Z2 = SQRT(AW**2 - 1.0)
FACT = SQRT(CHAP) * CJ / (2. * SQRT(KYI))
Z13 = 0.734 * Z0**2 / AMI
DELS = 0.524
TEMPB = .577 * DIST(I)
IF (TEMPB.LE.FACT) GO TO 650
DELS = ATAN(FACT / DIST(I))

650 ETA = AOFA + DELST
IF (ETA.GE.1.0) ETA = 1.0
CETA = SIN(ETA)
IF (CETA.GE.1.571) ETA = 1.571

660 CETA = SIN(ETA)
IF (CETA.GE.1.571) ETA = 1.571
CETA = SIN(AOFA)**2

670 CPE = CPA*RI*VI**2/64.4 + PI
DO 700 I = 1, J

700 CPE = CPE + CPE**2
700 CONTINUE

780 CPE = CPE**2
790 PE = CPE*RI*VI**2/64.4 + PI
DO 800 I = 1, J

800 CPE = CPE + CPE**2
800 CONTINUE

Figure I-20. Source Listing - THERMO, Contd
IF (IS.EQ.2) GO TO 690
Q(I)=H*(STI-WI(I))*QCONL(I)
GO TO 700
690 Q(I)=H*(REC*STI-WI(I))*QCQNT(I)
700 CONTINUE
710 IF (IWALT.EQ.2) GO TO 730
DO 720 I=1,NCOLM
720 Q(I)=Q(I)
730 RETURN
END
FUNCTION TRPLAT (A>B>C>I>J>K)  
DIMENSION A(9,9,9), B(9,9,9)  
IF (C.LE.B(I,J,K)) 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-BTP) 
RETURN  
30 TRPLAT=A(I,J,1)  
RETURN  
40 TRPLAT=A(I,J,K)  
RETURN  
END  

Figure I-21. Source Listing – TRPLAT
SUBROUTINE WTTPS
COMMON/WT/,
1A ,Q .CHORD .E1RIB .E2RIB .E3RIB ,
2HBEAMA .HFNG1 .HFNG2 .HRIB .HRING .IDFNG1 ,
3IDFNG2 .KINDP .KINDS .LENGTH .DLPanL .LTUBE ,
4NRIBS .ODPOSR .ODPOST .ODRING .RADiUS .TbMLA ,
5TBMLC .TBMSA .TBMSC .TCORn .TCONF .TDouBC ,
6TDOSBP .TEDGE .TFNG1 .TINS1 .TINS2 .TINS3 ,
7TPLATE .TPOST .T1RIB .T2RIB .TWRIB .TRIBL ,
8TRIBS .TRING1 .TRING2 .TSEAL .TSKIN1 .TSKIN2 ,
9TTCU .WIDTH .WBEAMA .WBMLC .WBMSC .DPANL ,
$WPOST .WRIBL .WRIBS .PBm .PCONF .PEDGE ,
$PSkin1 .PSkin2 .PTube .GBolt .GCAMP .GINSRT ,
$SINSUL .GNUTPL .GWASH .
COMMON/WTCOST/,
1KLIC .N .ACWT .KT .ITL .LEN .WID .LTUBE ,
2MAWT .KK .AOP(7,7) .KMUv(100,3) .KSETUP(100,21) .KRUN(100,21) ,
3KCC(5+21) .TIME(7) .TMAT(3) .DIAMA(6) .WTNUT(6) .TBTABL(6) ,
4KCSWT(100,5) .
COMMON/ZERO/,
1TOPW .TACWT .TMAWT .TThR .TTLBHR .TTLACO .TVCO3 .TTFCOS .TTMCOS ,
2TASYCO .LBHR .LACOST .VCOST .TDHR .TLACO .TVCO3 .TFCCST ,
1EFA .NFLTS .TUNWT .
REAL K1,K2 ,
REAL KSETUP .KRUN .KCC .MUv .MAWT .KMUv ,
REAL KCOSWT ,
REAL IDFNG1 .IDFNG2 .IDRING .LENGTH .LBMLA .LBMLC .LBMSA .LBMSC ,
REAL LCONF .LDouBC .LEN .LPLANL .LPOST .L1RIB .L1RIBS .LSEAL ,
REAL LSTFRN .LTUBE .LTUBER .NXA .NYA ,
REAL LRARAT .LBHR .LACOST .MCONF .MATCOS ,
J=0 ,
LEN=LENGTH/12 ,
WID=WIDTH/12 ,
C INITIALIZE INSULATION VARIABLES
WTINS1=0 ,
WTINS2=0 ,
WTINS3=0 ,
C INITIALIZE PANEL VARIABLES
WTCORR=0 ,
WMCONF=0 ,
WTEDG2=0 ,
WMEDG2=0 ,
WTEDG3=0 ,
WMEDG3=0 ,
WTHYC8=0 ,
WMHYC8=0 ,
WTRIB5=0 ,
WMRIBS=0 ,
WTSKIN=0 ,
WMSKIN=0 ,
C INITIALIZE STRUCTURE VARIABLES
WTBMLA=0 ,
WMBMLA=0 ,
WTBMLC=0 ,
WMBMLC=0 ,
WTBMSA=0 ,
WMBMSA=0 ,
WTBMSC=0 ,

Figure I-22. Source Listing — WTTPS
I-57
WMBMSC=0
WTCOKN=0
WMCOHRN=0
WTHINA=0
WMHINA=0
WTMINB=0
WMHINB=0
WTTHINC=0
WMHINC=0
WTINS=0
WMINS=0
WTPOSR=0
WMPOSR=0
WTPOSA=0
WMPOSA=0
WTPOSB=0
WMPOSB=0
WTPOSC=0
WMPOSC=0
WTSEAL=0
WMSEAL=0
WTFASA=0
WMFASA=0
WTFASB=0
WMFASB=0
WTFASC=0
WMFASC=0

C
INITIALIZE TOTAL VARIABLES
WTINSL=0
WTPANL=0
WMPANL=0
WTSTK=0
WMSTR=0

C
GENERAL TERMS USED THROUGHOUT
PI=3.1416
PI4=.7854
DIABH1=.19
DIABH2=.50
DIAPTH=.50
DIAPGH=.19
DIAPOH=.19
DIAPGH=.19
EEDGE=1.20
HPLATE=.50
LDUDBR=2.00
R=.17
TBRAZ=.008
TPLUG=.25
WDUDBR=1.50
WDUDBP=1.00
IF (RADIUS .EQ. 0.) CIRCUM=0
IF ( RADIUS .EQ. 0.) GO TO 10
CIRCUM=RADIUS*ACOS(1-(CHORD**2)/(2.*RADIUS**2))

10 CONTINUE
HPOST=WPOST
IDRING=IDFNG2-2.*TUBE-2.*(IDFNG2-ODPOSR)
LBMLA=LENGTH-.75
LBMLC=LENGTH-.75
LBMSA=WIDTH-.75
LBMSC=WIDTH-.75

Figure I-22. Source Listing — WTPS, Contd

I-58
\[ S = R + 0.365 \times HBEAMA \]
\[ LCORN = 2. \times HPLATE + 2.5 \]
\[ LPANL = LENGTH - DLPLANL - A \]
\[ LPOST = TINS1 + TINS2 + TINS3 + B - 30 \]
\[ LRIBL = LBMLC \]
\[ LRIBS = LBMSC \]
\[ LSEAL = WIDTH \]
\[ LSTFN = LPOST - 50 \]
\[ LTUBE = TINS1 + TINS2 + TINS3 + B \]
\[ NXA = (LPANL + DLPLANL - 4. \times DIABH1) / (8 \times DIABH1) \]
\[ NYA = (LSEAL - 4. \times DIABH1) / (8 \times DIABH1) \]
\[ NX = NXA + 5 \]
\[ NY = NYA + 5 \]
\[ NX = NXA \]
\[ NY = NYA \]
\[ ODFN1 = OPOST + 0.5 \]
\[ ODFN2 = IDFN2 + 0.5 \]
\[ ODTUBE = OPOST - 2. \times TPOST \]
\[ TFNG2 = TFNG1 \]
\[ WPANL = WIDTH - UWPLANL - A \]
\[ WBMLA = 2. \times (WBEAMA + R - S + (S-R)^2 + HBEAMA^2) \times 0.5 \]
\[ WBMSC = WBMLC \]
\[ WCORN = R + S + (S-R)^2 + HBEAMA^2 \times 0.5 \]
\[ WCORR = WPANL + NRIBS \times (CIRCUM - CHORD) \]
\[ WPANL = WBEAMA + 2. \times R \]
\[ wPLATE = WBEAMA + 2. \times R \]
\[ LS = A + 0.5 \]
\[ ODFN1 = OPOST + 0.5 \]
\[ ODFN2 = IDFN2 + 0.5 \]
\[ ODTUBE = OPOST - 2. \times TPOST \]
\[ TFNG2 = TFNG1 \]
\[ WPANL = WIDTH - UWPLANL - A \]
\[ WBMLA = 2. \times (WBEAMA + R - S + (S-R)^2 + HBEAMA^2) \times 0.5 \]
\[ WBMSC = WBMLC \]
\[ WCORN = R + S + (S-R)^2 + HBEAMA^2 \times 0.5 \]
\[ WCORR = WPANL + NRIBS \times (CIRCUM - CHORD) \]
\[ WPANL = WBEAMA + 2. \times R \]
\[ wPLATE = WBEAMA + 2. \times R \]
\[ LS = A + 0.5 \]
\[ N = 0 \]
\[ ITL = 0 \]

C *** EQUATIONS FOR INSULATION

C *** EQUATION FOR INSUL 1

 IF (TINS1.EQ.0) GO TO 20
 WTINS1 = LENGTH \times WIDTH \times TINS1 \times PINS1 / 1728,
 IF (TINS2.EQ.0) GO TO 20

C *** EQUATION FOR INSUL 2
C  
  WTINS2=LENGTH*WIDTH*WTINS2*PINS2/1728,  
  IF (TINS3.EQ.0) GO TO 20  
C  
C *** EQUATION FOR INSUL 3  
:  
  WTINS3=LENGTH*WIDTH*WTINS3*PINS3/1728.  
C  
C *** TOTAL INSULATION WT  
C  
20 WTINSL=WTINS1+WTINS2+WTINS3  
  ACWT=WTINSL  
  MAWT=WTINSL  
  KK=97  
  KT=1  
  N=1  
  KLIC=0  
  IF (ACWT.GT.0.) CALL COST  
  IF (ACWT.GT.0) ITL=1  
  ACWT=WTINS1  
  MAWT=WTINS1  
  KK=91  
  KT=1  
  N=2  
  KLIC=1  
  IF (ACWT.GT.0.) CALL COST  
  ACWT=WTINS2  
  MAWT=WTINS2  
  KK=92  
  KT=1  
  N=3  
  IF (ACWT.GT.0.) CALL COST  
  ACWT=WTINS3  
  MAWT=WTINS3  
  KK=93  
  KT=1  
  N=4  
  KLIC=2  
  IF (ACWT.GT.0.) CALL COST  
  IF ((KINDP.LT.1).OR.(KINDP.GT.4)) GO TO 140  
C  
C FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR PANELS  
30 CONTINUE  
  Go TO (40,50,60), KINDP  
C  
C *** TYPE 1 CONSTRUCTION FOR PANELS (TYPE 1)  
C  
40 CONTINUE  
  J=J+1  
  Go TO (70,120,130), J  
C  
C *** TYPE 2 CONSTRUCTION FOR PANELS (TYPE 2)  
C  
50 CONTINUE  
  J=J+1  
  Go TO (80,100,130), J  
C  
C *** TYPE 3 CONSTRUCTION FOR PANELS (TYPE 3)  
C  
60 CONTINUE

Figure I-22. Source Listing — WTTPS, Contd
J=J+1
GO TO (90,110,120,130), J

*** EQUATIONS FOR PANELS

*** EQUATION FOR CORRUGNS (CORRUGATIONS)

70 CONTINUE
  WTCORR=LPANL*WCORR*TSKIN2*PSKIN2+WTBRZ1
  WMCORR=(LENGTH+1.)*(WCORR+1.)*(TSKIN2+.005)*PSKIN2
  GO TO 30

*** EQUATION FOR EDGES (EDGE MEMBERS 2)

80 CONTINUE
  WTEOGE2=(LPANL+WPANL+4.*TEOGE-2.*E2GE)*(TCORE+E2GE)*TEDGE*PEDGW
  1E+WTBRZ28
  WMEOGE2=(LPANL+.5+WPANL+.5)*(TCORE+E2GE+.25)*(TEDGE+.005)*PEDGW
  GO TO 30

*** EQUATION FOR EDGES (EDGE MEMBERS 3)

90 CONTINUE
  WTEOGE3=2.*WPANL*(HRIB+TEDGE+E2GE)*TEDGE*PEDGE+WTBR10
  WMEOGE3=2.*(WPANL+1.)*(HRIB+TEDGE+E2GE+.25)*(TEDGE+.005)*PEDGE
  GO TO 30

*** EQUATION FOR HONEYCOMB

100 CONTINUE
  IF (KINDS.EQ.1) WTHYCB=LPANL*WPANL+TSKIN2*PSKIN2-MLPANL*DLPANL)*LPANL+DWPANL)*TSKIN1*PSKIN1-MLPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
  2-NX4*PI4*CIABH**2*TSKIN1*PSKIN1+WTBR18
  IF (KINDS.EQ.2) WTHYCB=LPANL*WPANL+TSKIN2*PSKIN2-MLPANL*DLPANL)*(LPANL+DWPANL)*TSKIN1*PSKIN1-MLPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
  2-4.*PI4*DIAPTH**2*TSKIN1*PSKIN1+WTBR18
  IF (KINDS.EQ.3) WTHYCB=LPANL*WPANL+TSKIN2*PSKIN2-MLPANL*DLPANL)*(LPANL+DWPANL)*TSKIN1*PSKIN1-MLPANL-EEDGE)*(WPANL-EEDGE)*TCORE*PCORE
  2-PI4*DIARGH**2*TSKIN1*PSKIN1+WTBR18
  WTHRIB=LPANL*WPANL*(TCORE+.25)*PCORE+(LPANL+.1)*(WPANL+.184)*TSKIN1*PCORE
  WTHSIN=((LPANL+DLPANL)*(WPANL+DWPANL)-(NXA*PI4*DIABH**2))*TSKIN1*PSKIN1
  2-281
  2K1
  GO TO 30

*** EQUATION FOR RIBS

110 CONTINUE
  WTRIBS=NRI6S*(LPANL-E2GE)*(E1RIB*T1RIB+E2RIB*T2RIB+E3RIB*T1RIB+HRW
  1RIB+TWTRIB)*PRIB+WTBRZ9
  WMRIBS=NRI6S*LPANL*(E1RIB*(T1RIB+.005)+E2RIB*(T2RIB+.005)+E3RIB*(TWRIB+.005))*PRIB
  GO TO 30

*** EQUATION FOR SKIN

120 CONTINUE
  IF (KINDS.EQ.1) WTFSIN=((LPANL+DLPANL)*(WPANL+DWPANL)=(NXA*PI4*DIAW
  1B1**2)*TSKIN1*PSKIN1
  IF (KINDS.EQ.2) WTFSIN=((LPANL+DLPANL)*(WPANL+DWPANL)=(4.*PI4*DIAP
  1TH**2)*TSKIN1*PSKIN1

Figure I-22. Source Listing — WTTTPS, Contd
I-61
IF (KINDS.EQ.3) WTSKIN=((LPANL+DLPLANL)*(WPANL+DWPANL)-(PI4*DIARGH*WT T 301
1*2)) *TSKIN1 *PSKIN1
WMSKIN=(LENGTH+.1)*(WIDTH+.1)(TSKIN1+.005) *PSKIN1
GO TO 30

C  *** EQUATION FOR TOTAL PANEL
C 130 CONTINUE
WTPANL=WTCORR+WTEGD2+WTEGD3+WTHYCB+WTRIBS+WTSKIN
WMPANL=WMCORR+WMEGD2+WMEGD3+WMHYCB+WMRIBS+WMSKIN
ACWT=WTPANL
MAWT=WMPANL
KK=96
N=5
KLIC=0
IF (ACWT.GT.0.) CALL COST
IF (ACWT.GT.0.) ITL=1
ACWT=WTCORR
MAWT=WMCORR
KK=2
KT=1
N=6
KLIC=1
IF (ACWT.GT.0.) CALL COST
ACWT=WTEGD2
MAWT=WMEGD2
KK=1
KT=4
N=7
IF (ACWT.GT.0.) CALL COST
ACWT=WTEGD3
MAWT=WMEGD3
KK=1
KT=2
N=7
IF (ACWT.GT.0.) CALL COST
ACWT=WTHYCB
MAWT=WMHYCB
KK=51
KT=1
N=8
IF (ACWT.GT.0.) CALL COST
ACWT=WTRIBS
MAWT=WMRIBS
KK=5
KT=NHR1BS
N=9
IF (ACWT.GT.0.) CALL COST
ACWT=WTSKIN
MAWT=WMSKIN
KK=2
KT=1
N=10
KLIC=2
IF (ACWT.GT.0.) CALL COST
FORTRAN STATEMENT NUMBER ASSIGNMENTS FOR STRUCTURE
J=0
140 CONTINUE
IF ((KINDS.LT.1).OR.(KINDS.GT.4)) GO TO 360
GO TO (150,160,170), KINDS

Figure I-22. Source Listing — WTTPS, Contd

I-62
** *** TYPE A CONSTRUCTION FOR STRUCTURE

150 CONTINUE
J=J+1
GO TO (180,200,220,230,280,310,320,350), J

** *** TYPE B CONSTRUCTION FOR STRUCTURE

160 CONTINUE
J=J+1
GO TO (240,260,290,330,350), J

** *** TYPE C CONSTRUCTION FOR STRUCTURE

170 CONTINUE
J=J+1
GO TO (190,210,250,270,300,340,350), J

** *** EQUATIONS FOR STRUCTURE

** *** EQUATION FOR BEAM LN A (LONG BEAM A)

180 CONTINUE
WTBMLA=(LBMLA*WBMLA-PI4*(2.*NXA+1.)*DIABH1)**2+2.*DIABH2)**2)*TBMLA*PBM+KLDOUBR*WDOUBR+PI4*DlAbH1**2)*TDOUBC*PBM+WTBRZ2+WTBRZ3
WMBMLA=(LBMLA+1.)*(WBMLA+1.)*TBMLA*PBM
GO TO 140

** *** EQUATION FOR BEAM LN C (LONG BEAM C)

190 CONTINUE
WTBMLC=LBMLC*WBMLC*TBMLC*PBM+LRIBL*WRIBL*TRIBL*PBM+WTBR12
WMBMLC=(LBMLC+1.)*(WBMLC+1.)*TBMLC*PBM
GO TO 140

** *** EQUATION FOR BEAM SH A (SHORT BEAM A)

200 CONTINUE
WTBMSA=(LBMSA*WBMSA-PI4*(2.*NYA+1.)*DIABH1)**2)*TBMSA*PBM+WTBRZ4
WMBMSA=(LBMSA+1.)*(WBMSA+1.)*TBMSA*PBM
GO TO 140

** *** EQUATION FOR BEAM SH C (SHORT BEAM C)

210 CONTINUE
WTBSCB=LBMSC*WBMSC*TBMSC*PBM+LRIBS*WRIBS*TRIBS*PBM+WTBR13
WMBMSC=(LBMSC+1.)*(WBMSC+1.)*TBMSC*PBM
GO TO 140

** *** EQUATION FOR CORNERS

220 CONTINUE
WTCORN=(WDOUBP**2-PI4*DIAPGH**2)*TDUBP*PBM+(WPLATE**2)*WPLATWTT 415
1E*HPLATE-PI4*(DIAPGH**2+DIAPTH**2)*TPLATE*PBM=4.*(LCORN*WCORN-R**2-S**2)*TCORN*PBM+WTBRZ5
WMCORN=(WDOUBP+.25)**2*TDUBP*PBM+(WPLATE**2)*WPLATWTT 418
1E*PBM+4.*(LCORN+.5)*(WCORN+.25)*TCORN*PBM
GO TO 140

---

Figure I-22. Source Listing - WTTPS, Contd
C *** EQUATION FOR INSERTS (HONEYCOMB INSERTS A)

<30 CONTINUE

IF (KINDP.NE.2) GO TO 140
WTHINA=NXA*GINSRT/100.
WMHINA=WTHINA
GO TO 140

C *** EQUATION FOR INSERTS (HONEYCOMB INSERTS B)

<40 CONTINUE

IF (KINDP.NE.2) GO TO 140
WTHINB=4.*GINSRT/100.
WMHINB=WTHINB
GO TO 140

C *** EQUATION FOR INSERTS (HONEYCOMB INSERTS C)

<50 CONTINUE

IF (MINDP.NE.2) GO TO 140
WTHINC=GINSRT/100.
WMHINC=WTHINC
GO TO 140

C *** EQUATION FOR INSULATOR

<60 CONTINUE

WTINS=20.*GINSUL/100.
WMINS=WTINS
GO TO 140

C *** EQUATION FOR POST CENT (CENTER POST C)

<70 CONTINUE

WTPOST=PI*ODPOST*LTUBE*TTUBE*PPOST+PI*(ODPOST**2-ODTUBE**2)*TFNG2*PTUBE+PI*(ODFNG2**2-ODFNG1**2)*TFNG1*PTUBE
WMPOST=PI*ODPOST*(LTUBE+.5)*(TTUBE+.01)*PPOST+PI*(ODPOST**2-ODTUBE**2)*TFNG2*PTUBE+PI*(ODFNG2**2-ODFNG1**2)*TFNG1*PTUBE
GO TO 140

C *** EQUATION FOR POST CORN (CORNER POST A)

<80 CONTINUE

WTPOSA=2.*PI*(ODPOST**2-ODTUBE**2)*LOPOST*PPOST+2.*PI*(ODPOST**2-ODTUBE**2)*TFNG2*PTUBE+PI*(ODPOST**2-ODTUBE**2)*TFNG1*PTUBE
WMPOSA=2.*PI*(ODPOST**2-ODTUBE**2)*LOPOST*PPOST+2.*PI*(ODPOST**2-ODTUBE**2)*TFNG2*PTUBE+PI*(ODPOST**2-ODTUBE**2)*TFNG1*PTUBE
GO TO 140

C *** EQUATION FOR POST CORN (CORNER POST B)

<90 CONTINUE

WTPOSB=4.*PI*(3.*LPOST+2.*LOPOST)*HPOST+4.*PI*(3.*LSTFNR-WSTFNR)*WSTFNR+3.*PI*(3.*LSTFNR-WSTFNR)*WSTFNR+3.*PI*(3.*LSTFNR-WSTFNR)*WSTFNR
WMPOSB=2.*PI*(3.*LPOST+2.*LSTFNR)*HPOST+WPOST+WTBR11
Figure I-22. Source Listing - WTTPS, Contd
*** EQUATION FOR POST CORN (CORNER POST C)

500 CONTINUE

WTPOSC = PI * ODPOST * LPOST + PPOST + PI4 * (ODRING**2 - ODPOST**2) * TRING
11 * PPOST + PI4 * (ODPOST**2 - DIAPGH**2) * TPLUG + PPOST + PI4 * (ODFNG1**2 - ODPOST**2) * (HFNG1 - TFNG1) * PTUBE + WT
3BZ6 + WTBR16 + WTBR17

WMPOSC = PI * ODPOST * (LPOST + 0.5) * (TPOST + 0.01) * PPOST + PI4 * (ODRING + 0.01) ** 2 * WT
1 - ODPOST**2) * (TRING1 + 1) * PPOST + PI4 * (ODPOST + 0.01) ** 2 * (TPLUG + 1) * PPOST + WT
2 + PI4 * ((ODFNG1 + 0.01) ** 2 - ODPOST**2) * (HFNG1 + 1) * PTUBE

GO TO 140

*** EQUATION FOR SEAL

510 CONTINUE

WTSEAL = (LSEAL * (WSEAL + 0.03) - PI4 * NYA * DIABH1**2) * TSEAL * PSEAL

WMSEAL = (LSEAL + 1.) * (WSEAL + 1.) * TSEAL * PSEAL

GO TO 140

*** EQUATION FOR FASTENERS (FASTENERS A)

520 CONTINUE

WTFAZA = (NXA + NYA + 2.) * GBOLT / 100. + (NXA + 2.) * GWASH / 100. + (NXA + NYA) * GNUTPWT

1L / 100.

WMFAZA = 1.1 * WTFAZA

GO TO 140

*** EQUATION FOR FASTENERS (FASTENERS B)

530 CONTINUE


WMFA SB = 1.1 * WTFA SB

GO TO 140

*** EQUATION FOR FASTENERS (FASTENERS C)

540 CONTINUE

WTFASC = 2. * GBOLT / 100. + GWASH / 100. + GNUTPL / 100. + GCLAMP / 100.

WMFASC = 1.1 * WTFASC

GO TO 140

*** EQUATION FOR TOTAL STRUCTURE

550 CONTINUE

WTSTR = WTBMLA + WTBMC + WTMCS + WTCORN + WTHINA + WTHINB + WTHINC + WTIN

15 + WTPOSR + WTPOFA + WTPOBF + WTPOSC + WTSEAL + WTFAZA + WTFA SB + WT FASC

WMSTR = WMBMLA + WMBMC + WMBCS + WMCORN + WMHINA + WMHINB + WMHINC + WMIN

15 + WMPOSR + WMPOSF + WMPOBF + WMPOSC + WMSEAL + WMFAS A + WMFASB + WMFASC

ACWT = WTSTR

MAWT = WMSTR

KK = 99

N = 11

KLIC = 0

IF (ACWT.GT.0.) CALL COST

IF (ACWT.GT.0.) ITL = 1

ACWT = WTBMLA

MAWT = WMBMLA

KK = 3
IF (ACWT.GT.O.) CALL COST
ACWT=WTBMLC
MAWT=WMBMLC
KK=3
KT=1
N=12

IF (ACWT.GT.O.) CALL COST
ACWT=WTBMSA
MAWT=WMBMSA
KK=3
KT=1
N=19

IF (ACWT.GT.O.) CALL COST
ACWT=WTBMSC
MAWT=WMBMSC
KK=3
KT=1
N=13

IF (ACWT.GT.O.) CALL COST
ACWT=WTCORN
MAWT=WMCORN
KK=4
KT=1
N=14

IF (ACWT.GT.O.) CALL COST
ACWT=WTHINA
MAWT=WMHINA
KK=71
KT=NXA
N=15

IF (ACWT.GT.O.) CALL COST
ACWT=WTHINB
MAWT=WMHINB
KK=71
KT=4
N=15

IF (ACWT.GT.O.) CALL COST
ACWT=WTHINC
MAWT=WMHINC
KK=71
KT=1
N=15

IF (ACWT.GT.O.) CALL COST
ACWT=WTINS
MAWT=WMINS
KK=61
KT=1
N=18

IF (ACWT.GT.O.) CALL COST
ACWT=WTPOSR
MAWT=WMPOSR
KK=11
KT=1
N=21

IF (ACWT.GT.O.) CALL COST
ACWT=WTPOSA
MAWT=WMPOSA

Figure I-22. Source Listing — WTTPS, Contd
Figure I-22. Source Listing — WTTPS, Contd
APPENDIX II

SUBROUTINE DESCRIPTIONS

PROGRAM TPSOPT is the driver program, 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 output subroutine is also called from this driver.

FUNCTION ALL computes the slope of the allowable S-N curve of the acoustic fatigue subroutine from the input curve fit coefficients for stress in thousands of psi as a function of the number of stress reversals.

FUNCTION APP determines the slope of an applied sinusoidal S-N curve for an assumed Rayleigh probability distribution - two different fits for various portions of the curve are an integral part of this subroutine.

FUNCTION BANDWIDTH is a table that specifies the octave bandwidth as a function of the center frequency used in the fatigue analysis.

BLOCK DATA is an embedded data table used to determine all material and manufacturing costs of the TPS.

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.

SUBROUTINE CONDTN explicitly solves the energy equation to predict temperature response of the TPS. Energy terms include both conduction and radiation between nodes. For the latter case, values of the overall interchange factors between nodes must be input to the program. Since the solution is explicit, the possibility of numerical instability exists; nodal temperatures are monitored through the trajectory, and if a temperature changes too rapidly, provision is made to decrease the time step.

SUBROUTINE COST determines the weights of all component parts of the TPS. Material costs, manufacturing standard hours and realization factors, and manufacturing costs are computed here and printed out in the weight/cost summary. Data to compute these numbers are called from the data bank, BLOCK DATA.
SUBROUTINE COSTOT determines the total program cost to develop, manufacture, and test 22,000 square feet of the TPS. These costs, based on historical data, the weight of the TPS, and the complexity factor for the material/configuration predict total program costs for the theoretical first unit, non-recurring costs, engineering design and development, tooling ground and flight test hardware, spares, recurring production and operations, and refurbishment.

FUNCTION CURVEF computes the decrease of the octave band sound pressure level (OBSPL) from the maximum value (OBSPL\textsubscript{max}) as a function of the number of octaves difference between the frequency \( f' \) of OBSPL\textsubscript{max} given by \( f' = 0.8 \) and the fundamental frequency of the panel. The falloff is either 4 or 3.5 db/octave depending on whether the natural frequency \( f \) is above or below the characteristic frequency \( f' \). All calculations supplement the sonic fatigue analysis.

SUBROUTINE DRVTPS is the driver subroutine for the weights/cost analysis. Input to this analysis is read by DRVTPS instead of the major input subroutine INPUT1, and the input data are printed out by DRVTPS. All constants used in either the weight or cost analysis are initialized here. The weight and manufacturing cost subroutines are called through subroutine WTTPS from this point in the program, and the total program cost subroutine COSTOT is also called here.

SUBROUTINE FATIG performs all sonic fatigue analysis of the program except input of its own data. This is passed from the subroutine INPUT1 through the name common block SONIC1. Sound pressure levels are predicted at this point in the subroutine from any or all of the four sources considered, and the panel fundamental frequency is determined for the panel under consideration. Root mean square and peak dynamic stresses as well as the expected number of stress reversals for each noise source are determined, and the resulting S-N data derived from a Rayleigh probability function are compared to allowable S-N data which have been input to the program. Results of the analysis are printed out by FATIG.

SUBROUTINE INPUT1 reads and prints out all input data except those used in the weights/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.

SUBROUTINE MINING performs the iteration to compute the critical stress of the sonic fatigue analysis. This is performed mathematically by determining the stress at which the applied and allowable S-N curves are tangent. The slopes of these curves are obtained by calling subroutine APP and ALL, respectively.

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.

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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.

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

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 arrays 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.

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

SUBROUTINE THERMO is the procedure whereby local flow properties are computed from freestream values using either oblique or conical real gas shock relations for low angles of attack or swept cylinder methods for high angles. Heating rates are computed using either Eckert or Spalding-Chi heating prediction techniques for attached shock wave flows or either Fay-Riddell or Beckwith-Gallagher swept cylinder methods for high angles.

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

SUBROUTINE WTTPS computes the weights of all component parts of the TPS panel insulation and supporting structure. Manufacturing costs are computed by calling subroutine COST.
APPENDIX III
PROGRAM FLOW CHART