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A Report To

AEC-NASA SPACE PROPULSION OFFICE

NUCLEAR ENGINE TRANSIENT ANALYSIS PROGRAM

Vol. I - TEXT, PROGRAM NOMENCLATURE,
AND FORTRAN LISTINGS

MASTER

Contract SNP-1

October 1965

NERVA Program

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A Report To
AEC-NASA SPACE PROPULSION OFFICE
NUCLEAR ENGINE TRANSIENT ANALYSIS PROGRAM,³⁰⁸
Vol. I,^{2, 202} TEXT, PROGRAM NOMENCLATURE,
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ROCKET ENGINE OPERATIONS - NUCLEAR

Contract SNP-1

October 1965

NERVA Program

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ABSTRACT

The Nuclear Engine Transient Analysis Program (NETAP) is an IBM 7094 digital computer program which simulates the low frequency transient and the steady-state operation of the NERVA hot-bleed engine, the NRX reactor test system, and the Cold Flow Development Test System, over the full operational range of temperatures and pressures. This simulation includes an analytical description of each engine component, including the nozzle, reflector, shield, core, turbine inlet line heat exchanger, and turbopump. All of these component calculations are performed in sufficient detail to provide an accurate determination of the energies added or subtracted from the fluid, the pressure drops, the flow rates, and the component operating temperatures. A modified relaxation method is used to solve the heat transfer and pressure drop equations.

W. D. Stinnett
Program Manager
RDN

FOREWORD

This report, submitted in partial fulfillment of SNP-1 Contract Subtask Item 1.8 is issued in two volumes. Volume I (Text, Program Nomenclature, and FORTRAN Listings) is Unclassified; Volume II (Sample Input-Output) is classified Confidential - Restricted Data.

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APPENDIX B - FORTRAN LISTINGS

I. SUMMARY

The Nuclear Engine Transient Analysis Program (NETAP) is an IBM 7094 digital computer program which simulates the low-frequency transient and the steady-state operation of the NERVA hot-bleed engine, the NRX reactor test system, and the Cold Flow Development Test System, over the full operational range of temperatures and pressures. This simulation includes an analytical description of each engine component, including the nozzle, reflector, shield, core, turbine inlet line heat exchanger, and turbopump. All of these component calculations are performed in sufficient detail to provide an accurate determination of the energies added or subtracted from the fluid, the pressure drops, the flow rates, and the component operating temperatures - all as a function of time.

The program includes the option of demanding the same parameters as are possible in the NERVA engine. Several different pairs of control parameters versus time may be used in the program, including chamber pressure and chamber temperature, chamber pressure and nuclear power level, turbine power control valve position and chamber temperature, and turbine power control valve position and nuclear power level. Thus, when the pair of control parameters are chamber pressure and chamber temperature, the nuclear power level and turbine power control valve position are adjusted to be those values required to obtain the demanded chamber temperature and pressure, respectively. An engine startup may be simulated by initiating program operation with turbine power control valve position and nuclear power level used as the control parameters. When an input chamber temperature value is reached, the program begins to use chamber temperature rather than nuclear power level as a control parameter. When an input chamber pressure value is reached, the program begins to use chamber pressure rather than turbine power control valve position as a control parameter. The program thus uses chamber pressure and chamber temperature as its two control parameters to

accelerate to full power. There is also available an NRX reactor test system option in which the turbopump loop is eliminated. In this NRX option, chamber pressure must be used as one of the control parameters since there is no turbine power control valve available to control the system pressure level. Because the logic of the control system (but no details of the response of the actual control elements) is included in the program, the model of the control system assumes perfect response.

The program is split into two basic parts: a thermal computational loop, and a pressure-flow computational loop. These loops are computed independently by changing appropriate variables until the calculated thermal and the calculated pressure-flow parameters are consistent with each other (i.e., agree in successive iterations). For example, if chamber pressure and chamber temperature are the pair of control parameters, the program begins a computation at any time step by reading the demanded chamber pressure and temperature. The temperatures are then computed in the nozzle, reflector, shield, and reactor core. The computed chamber temperature is compared with the demanded value; if they are not in agreement, the program continues to iterate through the thermal loop by adjusting the nuclear power level until agreement is reached. The program then proceeds to the pressure-flow loop where it iterates by adjusting the turbine power control valve position and the pump discharge pressure until they reach the values required to produce the necessary flow rate and the demanded chamber pressure. The thermal and pressure-flow loops are then recomputed, continuing until the other convergence tests on turbine inlet temperature and turbopump power are passed.

The thermal computational loop consists of all of the calculations used to obtain the solid material and the fluid temperatures in the nozzle, reflector, shield, core, and turbine inlet line heat exchanger. During these calculations, all pressures and flow rates are held fixed. For the thermal loop, the temperature distribution from the previous time point is known, and the heat sources are known; the problem is to determine the new temperature distribution. The equation which is solved in the thermal loop is the implicit form of the finite difference expression for the thermal diffusion equation. The set of equations obtained by using this expression is computationally stable under all circumstances. A time

step, therefore, may be chosen solely on considerations such as desired accuracy and frequency response. The computational method which has been used to solve this set of equations is a modified relaxation method. There are faster methods available, but the approach will always step progressively towards the solution without problems of computational stability. Included in the thermal loop is a subroutine which computes, as a function of temperature, the thermal conductivity and enthalpy for each of the solid materials used in the engine.

The pressure-flow computational loop is solved by an explicit analytical solution of the equation of continuity of flow at each node of the engine flow network. Subroutines have been written to compute the flow conductance of each type of flow element including flow through orifices and valves, flow in tubes, and inlet and exit losses. Included in the pressure-flow calculations are the effect of flow capacitance at each plenum and of flow choking at the points of greatest restriction in the system (including the nozzle coolant tubes and the inlet to each nuclear component). Multiple parallel flow channels may be modeled in the reflector, shield, and core. The program includes hydrogen properties subroutines which provide a complete representation of the thermal and transport properties of hydrogen.

The pump is simulated by the inclusion of a complete performance map, and the turbine is simulated by a curve relating turbine efficiencies and turbopump speed. The storage of energy by the turbopump assembly is included by computation of the rotational momentum of the turbopump.

The program output consists of temperatures, pressures, and flow rates throughout the system, as well as turbopump speed, pump specific speed, turbine power control valve position, nuclear power, engine thrust, and specific impulse. The output variables as a function of time not only are printed but also may be plotted in any grouping desired.

II. PROGRAM DESCRIPTION

A. PROBLEM

The objective of the Nuclear Engine Transient Analysis Program is the simulation of the NERVA hot-bleed engine, the NRX reactor test system, and the Cold Flow Development Test System, over their entire ranges of transient and steady-state operation in sufficient detail to: (1) define the effect of each component on the overall system operation, (2) define the component operating conditions, and (3) determine the system operating constraints imposed by the various components. All component calculations must be performed in enough detail to provide an accurate determination of the energies added or subtracted from the fluid, the pressure drops, the flow rates, and the component operating temperatures. Therefore, the problem which this program solves is the calculation of those parameters which describe the low-frequency transient and the steady-state operation of the NERVA hot-bleed engine, the NRX reactor test systems, and the Cold Flow Development Test System. The program accomplishes this through analytical models which have been constructed to simulate the operation of each engine component.

In Figure 1, the physical and functional arrangement of the NERVA hot-bleed engine components may be seen. The basic flow pattern of the propellant fluid is from the propellant tank through the propellant shutoff valve and the pump inlet line to the pump. The pump, which is directly driven by the turbine, boosts the pressure of the propellant and discharges it into the pump discharge line. The propellant then flows through the coolant tubes of the exhaust nozzle. From there, the fluid flows through a nuclear reflector and an internal nuclear shield into the reactor core. After flowing through the reactor core, the main propellant flow passes through the exhaust side of the nozzle and exhausts to the atmosphere. The turbine is driven by bleed gases which are obtained by mixing fluid obtained from the nozzle chamber (through a hot-bleed port) with diluent fluid obtained from the plenum between the first and second passes of the shield. The turbine inlet line is cooled by a counter-flow heat exchanger in which the diluent is used as a coolant before it is mixed with the hot-bleed gases. The turbine drive fluid exhausts to the atmosphere through turbine exhaust nozzles. Table 1 shows the subscripts which are used to define engine locations for calculations internal to the Nuclear Engine Transient Analysis Program.

The functional arrangement of the engine components, and the inter-relationships among the components, may be seen more clearly by referring to Figure 2. In this diagram, each engine component, or significant part of a component, is indicated by a block. The flow of functions among the components is indicated by lines linking the component blocks. Thus, propellant flow between components is indicated by the lines defining pressure (P), temperature (T), and flow rate ($\dot{w}$) between components. The other lines describe flow of other functions, such as heat flow (q''), nuclear heat generation (n), valve position (ϕ), turbopump speed (N), and torque (M). The goal in constructing the Nuclear Engine Transient Analysis Program has been to write a digital computer program which solves for the system parameters as a function of time for the particular hot-bleed engine configuration shown in the functional diagram. An NRX reactor test system option is available, however, in which the turbopump loop is eliminated. This NRX option also is used to compute modes of operation of the NERVA engine for which the turbine power control valve is closed (e.g., during cooldown operation). For the NRX option, the physical and functional arrangement of the components may be seen in Figure 3. The subscripts used to define engine location for this option are the same as are shown in Table 1.

There are three major feedback control loops on the NERVA engine: the chamber temperature, the chamber pressure, and the neutron flux loops. The logic of the control system, but no details of the response of the actual control elements, is included in the Nuclear Engine Transient Analysis Program. This means that the model of the control system assumes perfect response to the demanded input parameters. Thus, all system parameters are determined by a pair of demanded control parameters for any particular time.

The pairs of control parameters versus time which may be used in the program include chamber pressure and chamber temperature, chamber pressure and nuclear power level, turbine power control valve position and chamber temperature, and turbine power control valve position and nuclear power level. The chamber temperature of the propellant may be controlled by varying the power level of the reactor, which, in turn, is controlled by movement of the reactor control drums.

In the program, the demanded chamber temperature is compared with the computed value at the end of each iteration; if they do not agree, the nuclear

power level is adjusted until agreement is reached. The chamber pressure of the propellant may be controlled by adjusting the position of the turbine power control valve. The turbine power control valve, by controlling the amount of flow through the turbine, adjusts the energy supplied to the pump and, therefore, the pressure level of the entire flow system. In the NRX option, chamber pressure must be used as one of the control parameters since there is no turbine power control valve available to control the system pressure level.

In simulating the NERVA engine, it is possible to demand that the system follow input ramps of any pair of the demanded control parameters, or that it follow a normal startup control scheme. Thus, under the startup control option, the nuclear power level is ramped until such time as an input chamber temperature limit is exceeded (at which time the system begins to follow a ramp of chamber temperature). Concurrently, the turbine power control valve position is ramped until an input chamber pressure limit is exceeded, at which time the system begins to follow a ramp of chamber pressure.

In addition to the transient modes of control described above, the program contains a steady-state option. For single point values of any of the pairs of control parameters given above, the program will compute the steady-state values of all of the system parameters. For a summary of the possible program options and the input flags used with them, refer to Section V,C.

To construct an analytical model of the nozzle, the unit may be split into as many as 20 axial increments. Multiple groups of parallel flow channels are allowed in the reflector, shield, and core. For each group of channels, as many as 10 axial increments may be assumed. Flow balancing between the groups of flow channels is computed for each component. As many as five groups of flow channels may be assumed in each component. In the turbine inlet line heat exchanger, as many as 10 axial increments may be assumed. These groups of parallel flow channels may represent groups of channels which are physically different, or which represent differing radial positions (and thus, different heat generation levels) in the system.

B. MATHEMATICAL METHODS

The problem which this program solves is the simulation of both the low-frequency transient operation and the steady-state operation of the NERVA hot-bleed engine, NRX reactor test systems, and cold flow development test systems over their full operational range of temperatures and pressures. This simulation has required the development of an analytical description of each engine component, including the nozzle, reflector, shield, core, turbine inlet line heat exchanger, and turbopump. All of these component calculations must be performed in enough detail to provide an accurate determination of the energy added or subtracted from the fluid, the pressure drops, the flow rates, and the component operating temperatures - all as a function of time.

Mathematical formulation of the engine system results in a large set of thermal and fluid-flow equations. These equations are solved by splitting the program into a thermal computational loop and a pressure-flow computational loop and then solving the two sets of equations separately. Pressures and flow rates are assumed for each point in the engine system, and are used in the solution of the thermal equations. The set of temperatures obtained as solutions to the thermal equations are then held fixed and used in the solution of the fluid-flow equations. This alternative calculation of the thermal and pressure-flow loops continues until the temperatures, pressures, and flow rates throughout the system agree in successive iterations. The calculational loops are computed independently by changing the appropriate variables within each loop until the calculated thermal and flow parameters are consistent with each other.

The thermal loop consists of all of the calculations used to obtain the solid material and the fluid temperatures in the nozzle, reflector, shield, and core. During these calculations, all pressures and flow rates are held fixed. Also, although for programming purposes they are included in the pressure-flow loop, the turbine inlet line heat exchanger thermal equations are solved using the same mathematical methods as the parts of the thermal loop.

For the thermal loop, the initial temperature distribution is known and the heat sources are known; the problem is to determine the temperature distribution at the end of the computing time intervals.

If the temperature distribution at some time, t , is denoted by

$$T = T(X, t)$$

where

T = Temperature

X = Position vector

and if

$k = k(X, T)$ = thermal conductivity of the material

$E = E(X, T)$ = internal energy per unit volume

$\phi = \phi(X, t)$ = heat source (heat produced/unit time-unit volume).

then, by conservation of energy,

$$\frac{\partial E}{\partial t} = \nabla \cdot k \nabla T + \phi \quad (1)$$

If $C = C(X, T)$ denotes the specific heat of the material and ρ the density, the following partial differential equation for the temperature is obtained:

$$C\rho \frac{\partial T}{\partial t} = \nabla \cdot k \nabla T + \phi \quad (2)$$

If the thermal conductivity, k , is a constant, then the above equation may be rearranged as follows:

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T + \frac{1}{C\rho} \phi \quad (3)$$

where α is the thermal diffusivity and is equal to $k/C\rho$. The above parabolic partial differential equation is a modified diffusion equation. (Technically, the internal-energy source, ϕ , is zero in the diffusion equation but the above form will be referred to as the diffusion equation in this report.) This equation must be supplemented by boundary conditions of temperature or heat flux, both in space and time, for the problem to be fully defined.

The diffusion equation arises in electrical systems containing resistance and capacitance, or conductance and inductance. In more general terms, the equation is characteristic of systems containing energy-dissipative elements and one type of energy storage element. The energy-storage element may be a reservoir either of potential or of kinetic energy, but only one type may be present in the system.

For partial differential equations such as the diffusion equation or the wave equation to be solved on digital computers or by other numerical techniques, both the time and the space variables must be written in discrete form by means of finite-difference expansions. The potential distribution within the field at any time, t_0 , is calculated, and an extrapolation method is used to predict the resulting potential distribution within the field at a later time, $t_0 + \Delta t$.

Let ΔX and Δt be increments of the variables X and t . The set of points in the X, t -plane given by $X = j\Delta X$, $t = m\Delta t$ (where $j = 0, 1, 2, \dots$ and $n = 0, 1, 2, \dots$) is called a net (grid or lattice) and its mesh size is determined by ΔX and Δt ; ΔX and Δt are thought of as small increments. The approximation to $T(j\Delta X, n\Delta t)$ is denoted by T_j^n . Thus, assuming C and k are constants, the diffusion equation may be written in finite difference form as

$$C_p \frac{T_j^{n+1} - T_j^n}{\Delta t} = k \frac{T_{j+1}^n - 2T_j^n + T_{j-1}^n}{(\Delta X)^2} + Q_j^n \quad (4)$$

This equation is known as the explicit form of the finite-difference equation since at any time interval, all temperatures but one (T_j^{n+1}) are known - a circumstance making it possible to solve explicitly for the one temperature. In this equation, the first derivative of temperature with respect to time has been approximated by

$$\frac{\partial T}{\partial t} = \frac{T_j^{n+1} - T_j^n}{\Delta t} \quad (5)$$

which involves the temperature at a point at the present time and the temperature at the same point Δt in the future. This expression is known as the forward difference approximation.

In the development of digital techniques, it was soon recognized that unless the time interval Δt is sufficiently small compared to the spatial net spacing, represented by ΔX , something radically wrong occurs in the calculating process. In particular, any small error made at some time t_0 (and round-off errors are inevitable in numerical work) is propagated and increases with each successive calculation at $t_0 + \Delta t$, $t_0 + 2\Delta t$, $t_0 + 3\Delta t$, etc. After a few such steps the error terms completely overshadow the desired solution of the problem, making the calculation worthless. Such behavior is termed computational instability and must be carefully avoided in all calculation procedures. While some types of finite-difference approximations are always stable, regardless of the relative ratio of the net intervals, there exists in the case of other expansions critical values of the ratio $\Delta t/\Delta X$. If this critical value is exceeded, the solution exhibits instability, while it is stable under other conditions. Criteria for stability are therefore of great importance in numerical work, and analytical methods for testing finite-difference equations for stability have been derived.* Thus, the computational stability of the explicit form of the finite-difference equation (that involving the forward time difference approximation) is misleading since the solution can become computationally unstable. It can be shown that in this equation the time step, Δt , and the net spacing, ΔX , must be chosen to satisfy the computational stability criterion

$$\frac{\alpha \Delta t}{(\Delta X)^2} \leq \frac{1}{2} \quad (6)$$

if the errors of any sort which accumulate are not to be amplified to an unacceptable degree after a relatively small number of time steps.

The stability criterion arrived at for the simple difference system considered above has the unfortunate consequence that if ΔX is chosen rather small in the interest of accuracy, the allowed Δt may turn out to be so very small that an enormous number of cycles of calculation is required to complete a problem. The situation is different with the finite-difference equation,

* R. D. Richtmyer, Difference Methods for Initial-Value Problems, Interscience Publishers, Inc., New York, 1957.

$$C_p \frac{T_j^{n+1} - T_j^n}{\Delta t} = k \frac{T_{j+1}^{n+1} - 2T_j^{n+1} + T_{j-1}^{n+1}}{(\Delta X)^2} + \phi_j^{n+1} \quad (7)$$

which is the same as the previous finite-difference version of the diffusion equation except for the superscripts on the right side. In this equation, the first derivative of temperature with respect to time has been obtained from a backward time difference (meaning relative to the time, t , at which space differences are expressed) in contrast to the forward time difference of the previous equation. Thus, the equation above involves only temperatures at the present point in time and temperatures previously computed. We shall see that this equation is stable under all circumstances, but it is more instructive to consider a general family of difference systems obtained by making the right side a weighted average of the right sides of Equations (4) and (7). Thus a more general finite-difference expression for the diffusion equation is

$$C_p \frac{T_j^{n+1} - T_j^n}{\Delta t} = k \frac{\theta (\delta^2 T)_j^{n+1} + (1 - \theta) (\delta^2 T)_j^n}{(\Delta X)^2} + \phi_j^n \quad (8)$$

where θ is a real constant lying in the interval $0 \leq \theta \leq 1$,

and $\delta^2 T_j^n = T_{j+1}^n - 2T_j^n + T_{j-1}^n$

When $\theta = 0$, as in Equation (4), the system is called explicit. Each equation of an explicit system gives one of the unknowns T_j^{n+1} directly in terms of the known quantities T_j^n . If θ is not 0, one must solve a set of simultaneous linear equations to obtain the T_j^{n+1} , and the system is called implicit. It has been shown that the general stability criterion for Equation (8) is

$$\frac{2\alpha\Delta t}{(\Delta X)^2} \leq \frac{1}{1 - 2\theta} ; \quad \text{if } 0 \leq \theta \leq \frac{1}{2} \quad (9)$$

no restriction; if $\frac{1}{2} \leq \theta \leq 1$

The favorite choices for θ are 0, $\frac{1}{2}$, 1. The first gives the explicit equation [Equation (4)]; the other two give implicit equations which are unconditionally stable. The choice $\theta = 1$ gives Equation (7). Thus, at the expense of solving systems of simultaneous equations, all computational stability worries may be avoided by using Equation (7). A time step, Δt , may then be chosen solely on considerations such as desired accuracy and frequency response. For these reasons, and because with modern high-speed digital computers the computational difficulty is of little importance, the implicit form was chosen for the present program.

The finite-difference approach involves, inherently, the replacement of a distributed system of continuous independent variables in space and time, by an assemblage of lumped elements in such a manner that the characteristics of the original system are approximately preserved. Particularly, the behavior of any regular electrical network can be described compactly by finite-difference methods. Conversely, any finite-difference equation, such as the heat conduction equation, may be considered to have an electrical network as its analog. This electrical network will be a system of resistances which are the energy-dissipative elements, capacitances which are the reservoirs of potential energy, and applied voltages which are the system boundary conditions. Therefore, since the analogous energy-dissipative, potential energy reservoir and boundary condition elements are known for heat transfer and fluid flow systems, the mathematical problem to be solved may be defined by drawing an electrical network diagram. Thus, the technique used in this program has been to construct an electrical network which is the analog of the heat transfer or fluid flow system being analyzed and to solve this network by digital computer techniques. Once the network has been drawn, defining the problem, the straightforward repetitive application of the numerical techniques described below will assure a compact, easily programmed solution to the problem. The primary value of the electrical network analogy as used in this program is simply ease of definition of the problem and ease of programming the solution. This method is not a new idea, the use of circuit analogy concepts and techniques in heat transfer being fairly common.

In solving heat transfer problems, the electrical voltages are analogous to temperature, the conductances to thermal conductivity times area, the capacitances to specific heat times mass, and the current to heat flux. By reference to the implicit finite-difference [Equation (7)], it can be seen that each capacitance can be replaced by a resistor of magnitude $C_p/\Delta t$ joining the node representing the temperature T_j^{n+1} with a node representing the temperature T_j^n of that same node at the previous time step. This transforms the finite-difference [Equation (7)] into an electrical analog where, for all values of j , a conductance of $C_p/\Delta t$ joins nodes representing temperatures T_j^{n+1} and T_j^n , and conductances of $k/(\Delta X)^2$ join nodes representing temperatures at time $n+1$ for all values of j . In addition, a conductance determined by the convective heat transfer parameters joins the nodes representing temperatures at time $n+1$, for all applicable values of j , with nodes representing the temperatures of the corresponding fluid elements. The temperatures of the fluid elements are treated as applied boundary conditions. Thus, the heat conduction equation can be considered to have an electrical analog in which each grid line of the finite-difference net is replaced by a resistor of suitable magnitude. An example of this type of network for a heat transfer problem may be seen by referring to Figure 4 (General Thermal Network Diagram). This is the network solved by Subroutine TEM9 for heat transfer calculations for the reflector, shield, and core channels. Figure 5 (Nozzle Thermal Network Diagram) shows the network solved by the program for the nozzle heat transfer calculations. Figure 6 (Heat Exchanger Thermal Network Diagram) shows the network solved by the program for the heat exchanger heat transfer calculations.

The means of solving the resulting set of simultaneous finite-difference equations which has been adopted in this program is the relaxation method. This method is not the fastest available, but has the virtue that it will always step progressively towards the solution. The relaxation method is a form of the Gauss-Seidel iterative technique which involves changing all variables simultaneously as an attempt is made to reduce the computational error to zero. From Figure 4 it may be seen that by Kirchoff's law that the algebraic sum of all currents or heat fluxes into any node, at any time, must be zero. The relaxation technique begins by assuming a set of potentials (temperatures or voltages) at all nodes and computing all flows (heat flux or electrical current).

The heat fluxes are simply the conductance between any two nodes times the temperature difference between the two nodes. The flow into all nodes is then algebraically summed and the result is the residual or the computational error. Thus, at any node,

$$\text{ERROR} = \Sigma \text{ heat fluxes}$$

To obtain the potential (temperature) values for the next iteration, the computational errors at each node are multiplied by a corresponding relaxation factor, RELAX, to obtain the required change in potential. The relaxation parameter is nothing more than an input relaxation coefficient (always 1.0 or less) divided by the sum of all conductances into a node. The equation is,

$$\text{RELAX} = \frac{\text{Coefficient}}{\Sigma \text{ Conductance}}$$

where the conductance of a capacitor = $\frac{\text{capacitance}}{\Delta t}$ and, if the coefficient equals 1.0, RELAX is then the inverse of the conductance between any node and ground. The use of RELAX to change the nodal temperature values is a form of block relaxation which entails the simultaneous application of incremental corrections to all of the unknowns (the temperatures) at the same time. Thus the temperatures to be used in the next iteration are

$$\text{new temperature} = \text{old temperature} + \text{RELAX} * \text{ERROR}$$

for the nodes in the relaxation network. The reasoning behind this procedure is as follows: Since by Ohm's law, $E = I/Z$ (where E = potential, I = flow, and Z = conductance), it is assumed that the required change in potential is $\Delta E = \frac{\Delta I}{Z}$, where ΔE = the change in potential, ΔI = the error in flow, and $\frac{1}{Z} = 1/\text{conductance} = \text{RELAX}$. Since the above equation is not exactly correct, the change in potential will not be exactly that required to reduce the error in flow to zero, but it can be shown that the equation steps the error toward zero in successive iterations. In those cases which do not converge, the problem is over-relaxation of the nodal temperatures. Since this can occur for certain combinations of network conductances, the coefficient in RELAX is inputted. Thus, the speed of convergence can be controlled, and over-relaxation corrected by varying this coefficient.

The temperatures of the nodes representing the fluid are not relaxed, but are computed at each iteration from the solid material temperatures

$$\text{enthalpy} = \text{enthalpy at previous fluid node} + \Sigma \text{ heat flux into fluid node}$$

The fluid nodes are thus referred to as fixed nodes. Although they are recomputed at each iteration, they are mathematically equivalent to applied boundary conditions. No difficulties have been encountered in this program, but it can be seen that if the ratio of fixed nodes to relaxed nodes were allowed to be too large, the problem would not converge.

In fluid-dynamic systems where the fluid is compressible, and both viscous and inertial forces are appreciable, the damped-wave equation applies. Thus, the general form of the equation which describes the pressure-flow relations is

$$\Delta^2 \rho = k_1 \frac{\partial^2 \rho}{\partial t^2} + k_2 \frac{\partial \rho}{\partial t} + k_3 \rho \quad (10)$$

Hyperbolic partial differential equations of this type arise in the study of any field which contains both kinetic- and potential-energy storage elements, as well as energy dissipating elements. The characteristic response of such a system to a step-function excitation at a boundary is one of damped oscillation. That is, an equilibrium condition is gradually approached. This approach is not monotonic as in the case of the diffusion equation, but may involve overshooting and oscillating about the equilibrium value as energy is traded back and forth between the kinetic- and potential-energy terms. For solution, the potentials or potential gradient at every boundary must be specified, and the kinetic- and potential-energy stored at each point within the field at the initial instant must be given.

In the NERVA engine system, the kinetic energy of the fluid is very small relative to the other energy terms and has therefore been neglected. If the kinetic energy term is neglected, then the damped wave equation reduces to the diffusion equation. Thus, the same methods as are used in the solution of the thermal loop may be applied to the pressure-flow loop. An electrical network

analog of the pressure-flow loop is constructed in which the voltages are analogous to pressure, the conductances to the inverse of the flow resistance, the capacitances to the mass storage per psi change in pressure per second, and the current to the mass flow rate. Figure 7 gives the pressure-flow network diagram for the NERVA hot-bleed engine.

Because of construction of the electrical network, the method used to solve the pressure-flow loop is different from that used in the thermal loop. In the pressure-flow loop, the law of continuity of flow is applied at each node in the flow network in succession, to solve for the branch flow rates and the node pressures. This can be done because in some options, one node pressure has been input and is therefore known exactly, or the pressure at one node is simply assumed to be known so that the other nodes may be calculated in terms of the assumed node. In other words, the fluid flow into any node must equal the fluid flow out of that node; given the fluid flow in any branch and the conductance of that branch, the pressure at one node of the branch may be calculated in accordance with Ohm's law, in terms of the pressure at the other node.

Under this procedure, the last nodal pressure in the chain of calculations will have the greatest error. It is therefore used to test the convergence of the calculation during successive pressure-flow iterations. When this pressure has values in two successive iterations which are sufficiently close, the pressure-flow calculation is assumed to have converged.

The crux of the pressure-flow calculations is the computation of the flow conductances. Subroutines Y1, Y2 and Y3 have been written to compute the flow conductance of each type of flow element including flow through orifices and valves, flow in tubes, and inlet and exit losses. The calculation of these flow conductances always lags the pressure calculations by one iteration, since the pressures just calculated are used to calculate the flow conductances which are then used to calculate new pressures. Included in the pressure-flow calculations is the effect of flow capacitance (i.e., mass storage) at each plenum. This is the potential energy reservoir which appears on the network diagram. The effect of flow choking at the points of greatest restriction in the system, including the nozzle coolant tubes and the inlet to each nuclear component, is included. This

is done by ensuring that the flow conductance subroutines (currently only Subroutine Y1) include equations which are valid for both the subsonic and sonic flow regimes and are continuous for Mach 1. As many as five parallel flow channel groups each in the reflector, shield, and core may be modeled. The program automatically computes the proper flow balance between the different groups of flow channels. All pressure-flow calculations make use of hydrogen properties subroutines which provide a complete representation of the thermal and transport properties of hydrogen.

C. DESCRIPTION OF PROGRAM LOGIC

The Nuclear Engine Transient Analysis Program is composed of two basic sections (i.e., chains). These two chains in turn consist of separate series of calculations which, when performed in conjunction with each other, analytically model the NERVA hot-bleed engine. A diagram of the overall program logic, with the major operations indicated, appears in Figure 8.

The two chains differ in the basic type of calculation performed within each. Chain 1 consists primarily of routines for reading in and storing input data, and for setting up the initial conditions of the engine problem as defined by the input. On the other hand, Chain 2 contains all of the routines which are involved in the calculation of all system parameters for each calculational time point. All iterative calculations necessary for the solution of the complete engine problem (steady-state or transient) are performed within either Chain 2 or subroutines called by Chain 2.

Chain 1

Chain 1 consists primarily of operations (1), (2), and (3) of Figure 8. A more detailed description of the sequence of operations performed in Chain 1 is given below.

1. Read in and store input data.
2. Compute constants used in calculating mass flow conductances in Chain 2.
3. Print out input.
4. Assuming sonic flow on the hot-side of the nozzle throat, isentropic conditions in the nozzle, and ideal gas behavior of the fluid, compute the Mach number at the midpoint of each nozzle hot-side flow segment.

$$M = \frac{1}{\epsilon} \left[\left(\frac{2}{\gamma+1} \right) + \left(\frac{\gamma-1}{\gamma+1} \right) M^2 \right]^{\frac{1}{2}} \left(\frac{\gamma+1}{\gamma-1} \right)$$

Solve for M where

M = Mach number

ϵ = area ratio

γ = specific heat ratio

5. Compute the geometry groups which are used in the calculation of thermal conductances in Chain 2.

6. Is an ~~IP~~W steady-state option being run?

No. Set the chosen time-dependent control parameters to their time-zero values.

Is an ~~IP~~W option being run?

Yes. Set ~~P~~OWER to its initial value.

No. Continue to operation 7 of Chain 1.

Yes. Set the chosen time-dependent control parameters to their given full power values.

7. Set the solid material mode and fluid mode temperatures and solid node enthalpies to their given time-zero values.

8. Is an ~~IP~~W option being run?

Yes. Is an ~~IS~~TEADY option being run?

No. Make a guess for TXC at the first time point.

Yes. Continue to operation 9 of Chain 1.

No. Continue to operation 9 of Chain 1.

9. Is a PTPCV option being run?

Yes. Is an ISTEDY option being run?

No. Make a guess for PXC at the first time point.

Yes. Continue to operation 10 of Chain 1.

No. Continue to operation 10 of Chain 1.

10. Guess an initial pressure distribution based upon the initial value of PXC.

11. Call Subroutine PARAH for the quality and enthalpy at each fluid node as a function of the initial temperature and pressure.

12. Proceed to Chain 2.

Chain 2

Chain 2 consists of operations (4) through (22) of Figure 8. To simplify the logic, Chain 2 may be considered to be composed of two main logic loops: a thermal loop which includes operations (7) through (11), and a pressure-flow loop which contains operations (13) through (18). The other operations of Chain 2 merely set up the problem for the time point and connect the logic of these two loops so that a consistent solution results. The following is a more detailed description of the sequence of operations performed in Chain 2.

1. Set the counter for the time-dependent control parameter profiles.

2. Is an ISTEDY steady-state option being run?

Yes. Bypass the following calculations.

No. If calculations are to be performed at time plots between those at which the control parameters are defined in the input, linear interpolation is used to define the control parameter values at these intermediate time points. Therefore, calculate the slopes of the control parameters between the two input points of immediate concern.

$$\text{Slope} = \left[(\text{Control Parameter})_{n+1} - (\text{Control Parameter})_n \right] / \text{TAU}$$

where n and n+1 refer to the number of the time point at which the parameter is defined in the input profile, and TAU is the time increment between the values at n and n+1. The real time for the current time point then must lie between $\left[(n-1) \text{ TAU} \right]$ and $\left[(n-1) \text{ TAU} + \text{TAU} \right]$ seconds after the initial time.

3. Set the counter for the current time point and let LATCH = 1.

4. Is an IP~~OW~~ option being run?

Yes. Is $\text{TXC} \geq \text{TXCLIM}$?

Yes. Set IP~~OW~~ = -1 and continue to operation 5 of Chain 2.

No. Continue to operation 5 of Chain 2.

No. Continue to operation 5 of Chain 2.

5. Is a PTPCV option being run?

Yes. Is $\text{PXC} \geq \text{PXCLIM}$?

Yes. Set PTPCV = -1 and continue to operation 6 of Chain 2.

No. Continue to operation 6 of Chain 2.

No. Continue to operation 6 of Chain 2.

6. Is an ISTEDY option being run?

No. Bypass the following.

Yes. Set $\text{DELTA} = 10^{20}$ sec and P~~OWER~~ = input value.

7. Store the solid material node temperatures and enthalpies, the fluid node pressures and densities, and the turbopump shaft speed from the previous calculational time point.

8. Is an INRX option being run?

No. Calculate H2 as a function of $P\phi_{WP}$ and W2.

Continue to operation 9 of Chain 2.

Yes. Continue to operation 9 of Chain 2.

9. Is an ISTEDY option being run?

No. Set the control parameters to their values for the current time point.

Is an INRX option being run?

Yes. Set H2 to its value for the current time point.
Then continue.

No. Continue

Is an $IP\phi_W$ option being run?

Yes. Set POWER to its value for the current time point.
Then guess TXC for this time point by linear extrapolation from the two previous time points and continue.

No. Continue

Is a PTPCV option being run?

Yes. Set TPCV to its value for the current time point.
Then guess PXC for this time point by linear extrapolation from the two previous time points and continue.

No. Continue to operation 10 of Chain 2.

Yes. Continue to operation 10 of Chain 2.

10. Call Subroutine PARAH for T2. Equate the temperatures and enthalpies at the pump discharge and nozzle inlet.

11. Assuming isentropic nozzle flow and ideal gas fluid behavior, calculate the bulk static temperature and pressure and the adiabatic recovery temperature at the midpoint of each nozzle hot-side flow segment.

$$T_b = \frac{T_o}{1 + M^2 \left(\frac{\gamma-1}{2} \right)} \approx \frac{T_c}{1 + M^2 \left(\frac{\gamma-1}{2} \right)}$$

$$T_{ar} = T_b \left(1 + RM^2 \left(\frac{\gamma-1}{2} \right) \right)$$

$$P_b = \frac{P_o}{\left[1 + M^2 \left(\frac{\gamma-1}{2} \right) \right] \frac{\gamma}{\gamma-1}} \approx \frac{P_c}{\left[1 + M^2 \left(\frac{\gamma-1}{2} \right) \right] \frac{\gamma}{\gamma-1}}$$

where

T_b = bulk static temperature, $^{\circ}\text{R}$

P_b = bulk static pressure, psia

T_{ar} = adiabatic recovery temperature, $^{\circ}\text{R}$

M = Mach number

γ = specific heat ratio

R = recovery factor

T_o = stagnation temperature, $^{\circ}\text{R}$

P_o = stagnation pressure, psia

T_c = nozzle chamber temperature, $^{\circ}\text{R}$

P_c = nozzle chamber pressure, psia

12. Calculate the nozzle hot-side mass flow rate for the current time point. Adjust all pressures and flow rates from previous time point to serve as first guesses for the corresponding parameters at the current time point.

13. Set the counter for the overall thermal-flow iterative loop.

a. Thermal Computational Loop

The thermal loop contains all of the iterative calculations used to solve for the thermal state of the solid material and fluid in the nozzle, reflector, shield, and core. During these calculations, all mass flow parameters are held invariant.

Basically, this loop may be considered to be composed of a routine for the solution of the nozzle fluid and solid node temperatures, and a series of call statements for Subroutine TEM9, in which the reflector, shield, and core solid and fluid node temperatures are calculated.

14. Set the counter for the thermal loop.

Is the counter $<$ limit?

No. Printout error diagnostic and stop.

Yes. Continue.

15. Is an IP~~OW~~ option being run?

No. Bypass the following.

Yes. Recalculate bulk static and adiabatic recovery temperatures at the midpoint of each nozzle hot-side flow segment based upon the latest TXC.

Nozzle

16. Set the counter for the nozzle thermal calculations.

17. Calculate the internal nuclear heat generation rates in the nozzle, reflector, shield, core, and heat exchanger solid nodes for the current time point.

18. For each solid material node in the nozzle:

a. Is the preceding cold-side fluid node two-phase?

No. Calculate the convective heat transfer coefficient by the Thompson "A" Correlation.

Yes. Calculate the Martinelli parameter, X_{tt} , and then the two-phase convective heat transfer coefficient by the Graham, Hendricks, and Hsu correlation.

b. Calculate a mean heat capacity for the solid by

$$CPM = \frac{HS\cancel{O}LN(k) - H\cancel{O}S\cancel{O}LN(k)}{TCN(k) - TC\cancel{O}N(k)}$$

$$\text{If } TCN(k) = TC\cancel{O}N(k), \text{ let } CPM = \frac{H\cancel{O}S\cancel{O}LN(k)}{TC\cancel{O}N(k)}$$

- c. Calculate $Z3N(k)$, axial conductive heat conductance between solid nodes.
- d. Calculate a mean heat capacity for the fluid between each pair of nodes by

$$CP = \frac{HHN(K) - HHN(K-1)}{TN(K) - TN(K-1)}$$

If $TN(K) - TN(K-1) = 0$, let $CP = 2000$.

- e. Calculate the thermal conductance of half the nozzle tube wall.
- f. Calculate $Z2N(K)$, net thermal conductance between the solid node and the cold fluid.
- g. Calculate the Eckert reference temperature

$$T_E = 0.28 T_c + 0.5 T_s + 0.22 T_{ar}$$

where

T_E = Eckert reference temperature, $^{\circ}R$

T_c = nozzle chamber temperature, $^{\circ}R$

T_s = solid node temperature, $^{\circ}R$

T_{ar} = adiabatic recovery temperature, $^{\circ}R$

- h. Calculate the hot-side convective heat transfer coefficient by the Bartz correlation.
- i. Calculate $Z4N(K)$, net thermal conductance between the solid node and the hot fluid.
- j. Calculate $Z5N(K)$, the radiative heat transfer conductance between the solid node and the bottom face of the core.
- k. Calculate $RELAX(K)$ from the thermal conductances and $C\phi_{EFF}$.

- l. Calculate $Q_{ZN}(K)$, $Q_{3N}(K)$, $Q_{4N}(K)$, $Q_{5N}(K)$ and $SN(K)$, the energy flows into and out of the solid node.
 - m. Calculate $ERROR(K) = \text{Energy In} - \text{Energy Out}$, from the energy flows.
 - n. Recompute the solid node temperature by the relaxation equation $TCN(K) = TCN(K) + RELAX(K) * ERROR(K)$.
19. For each fluid node, compute the specific enthalpy by $HHN(K) = HHN(K-1) + \frac{Q_{2N}(K-1)}{WN(K-1)}$ and then call Subroutine PARA H with $HHN(K)$ and $PN(K)$ to obtain $TN(K)$.
20. Test for relaxation network convergence.
- a. Sum all residual $ERROR$ terms for the solid nodes.
 - b. Sum all heat flows ($QN, SN, Q_{2N}, Q_{3N}, Q_{4N}, Q_{5N}$) for all solid nodes.
 - c. Let SUM be defined by

$$SUM = \frac{\text{Sum of all nozzle solid node residuals}}{\text{Sum of all nozzle solid node heat flows}}$$
 - d. Is $SUM < TTOLER$?
 - No. Is counter $<$ limit?
 - Yes. Return to operation 13 of Chain 2 and repeat calculations.
 - No. Print out error diagnostic and stop.
 - Yes. Nozzle thermal calculations have converged. Continue.

Reflector

21. Equate the specific enthalpy of fluid at the nozzle exit to that at the reflector inlet.
22. Call TEM9 for relaxation of reflector solid and fluid node temperatures.

Shield

23. Assuming perfect mixing, calculate the specific enthalpy of the fluid in the reflector exit plenum and equate to that at the shield inlet.

$$HHS(1,1) = \frac{\sum_{I=1}^{NR} ALPHAR(I)*WR(I)*HHR(I, MR)}{\sum_{I=1}^{NR} ALPHAR(I)*WR(I)}$$

24. Call TEM9 for relaxation of shield solid and fluid node temperatures.

Core

25. Assuming perfect mixing, calculate the specific enthalpy of the fluid in the shield exit plenum and equate to that at the core inlet.

$$HHC(1,1) = \frac{\sum_{I=1}^{NS} ALPHAS(I)*WS(I)*HHS(I, MS)}{\sum_{I=1}^{NS} ALPHAS(I)*WS(I)}$$

26. Call TEM9 for relaxation of core solid and fluid node temperatures.

27. Is LATCH = 2?

Yes. The system is therefore converged for the time point.
Go to final printout at operation 73 of Chain 2.

No. Continue.

Test for Tl0 Convergence

28. Is an IP~~O~~W option being run?

Yes. Is $\left| \frac{T_{10} - T_{XC}}{T_{10}} \right| < TXCTOL?$

No. Recalculate the chamber flow rate based upon the new TXC and update all system flow rates based upon this new WDPT. Then return to operation 14 of Chain 2 and repeat the calculations.

Yes. Proceed to Operation 29 of Chain 2 since the thermal loop has been relaxed to within the given convergence tolerance.

No. Is $\left| \frac{T_{10} - T_{XC}}{T_{10}} \right| < TXCTOL?$

No. Adjust POWER and return to operation 14 of Chain 2. Then repeat the calculations.

Yes. Continue since the thermal loop has been relaxed to within the given convergence tolerance.

Pressure-Flow Computational Loop

The pressure-flow loop contains all of the iterative calculations used to solve for the pressure state of the fluid in the nozzle, reflector, shield, core, and heat exchanger, as well as for the thermal state of the solid material and fluid in the hot-bleed port and turbine inlet line heat exchanger. Since the thermal state of the heat exchanger and associated components is highly dependent upon the flow distribution in the heat exchanger, and since this in turn is highly dependent upon the pressure state of the system, the thermal heat exchanger calculations were included in the pressure-flow computational loop. During the pressure calculations, all temperatures of solid and fluid nodes in the nozzle, reflector, shield, and core are held invariant.

The pressure-flow loop consists of a routine for solution of temperatures within the heat exchanger followed by routines for calculation of component mass flow conductances, pump and turbine parameters, and fluid node pressure.

29. Assuming perfect mixing at the core exit, compute the specific enthalpy of the exit fluid.

$$H10 = \frac{\sum_{I=1}^{NC} ALPHAC(I)*WC(I)*HHC(I, MC)}{\sum_{I=1}^{NC} ALPHAC(I)*WC(I)}$$

30. Set the flow loop counter.

31. Is an INRX option being run?

Yes. Proceed directly to operation 39 of Chain 2.

No. Continue.

32. Calculate the specific enthalpy of the pump discharge fluid from the pump power.

$$H2 = H1 + \frac{P\phi_{WP}}{W2*9338}$$

Heat Exchanger

33. Set the heat exchanger counter.

34. For each solid node in the heat exchanger model:

a. Calculate a mean heat capacity for the solid node.

$$CPM = \frac{HS\phi_{LH} (K) - H\phi_{S\phi H} (K)}{THE (K) - THE\phi (K)}$$

$$\text{If } THE (K) - THE\phi (K) = 0, \text{ let } CPM = \frac{H\phi_{S\phi LH} (K)}{THE\phi (K)}$$

b. Calculate $Z3H (K)$, axial conductive heat conductance between solid nodes.

c. Calculate the diluent side heat transfer coefficient by the McCarthy-Wolf correlation.

d. Calculate the thermal resistance of one-half the duct wall.

- e. Calculate ZZ (K), net thermal conductance between the solid node and the diluent fluid.
- f. Calculate the hot-side heat transfer coefficient by the McCarthy-Wolf correlation.
- g. Calculate $Z4$ (K), net thermal conductance between the solid node and the turbine drive fluid.
- h. Calculate $RELAX$ (K), from the thermal conductances and $C\phi HEX$.
- i. Calculate $Q1H$ (K), $Q2H$ (K), $Q3H$ (K), and SH (K), energy flows into and out of the solid node.
- j. Calculate $ERR\phi R$ (K) = Energy In - Energy Out, from the energy flows.
- k. Recompute the solid node temperature by the relaxation equation

$$THE (K) = THE (K) + RELAX (K) * ERR\phi R (K)$$

35. For each diluent fluid node, compute enthalpy by

$$HHHD (K) = HHHD (K-1) + \frac{Q1H (K-1)}{W15}$$

and then call Subroutine PARAH with $HHHD (K)$ and $PDST (K)$ to obtain $THE (K)$.

36. Assuming perfect mixing at bleed port, calculate temperature of mixed diluent and hot bleed.

$$HHHT (MH) = \frac{W15 * HHHD (MH) + W13 * HHXC}{W18}$$

Call Subroutine PARAH with $HHHT (MH)$ and PXC to obtain $THH (MH)$.

37. For each turbine drive fluid node, compute the enthalpy by

$$HHHT (MK-K) = HHHT (MH - (K-1)) - \frac{Q2H (MH-K)}{W18}$$

and then call Subroutine PARAH with $HHHT (MH-K)$ and $PHST (MH-K)$ to obtain $THH (MH-K)$.

38. Test for heat exchanger relaxation network convergence.

a. Sum all residual ~~ERROR~~ terms for the solid nodes.

b. Sum all heat flows (QH, SH, Q1H, Q2H, Q3H) for all solid nodes.

c. Let SUM be defined by

$$SUM = \frac{\text{Sum of all solid node residuals}}{\text{Sum of all solid node heat flows}}$$

d. Is SUM < TTOLER?

No. Is the counter < limit?

Yes. Return to operation 29 of Chain 2 and repeat the calculations.

No. Print out error diagnostic and stop.

Yes. Heat exchanger calculations have converged. Continue.

Mass Flow Conductances

39. Using Subroutines Y1, Y2 and Y3, compute the total mass flow conductances of the nozzle, reflector, shield, and core.

40. Is an INRX option being run?

Yes. Proceed directly to operation 44 of Chain 2.

No. Continue.

41. Calculate the mass flow conductances of the heat exchanger annulus and inner flow channel.

Turbopump

42. Calculate the mass flow conductance of the diluent orifice and then the total mass flow conductance of the diluent side of the heat exchanger.

43. Calculate the mass flow conductance of the turbine inlet line orifice.

44. Is a PTPCV option being run?

Yes. Look up XKTCV as a function of TPCV. Then calculate YTPCV and proceed to operation 45 of Chain 2.

No. Calculate YTPCV. Then calculate XKTCV and continue.

45. Is $P_2 > P_1$?

No. Set $P_2 = P_1 + 1.0$. Then continue to operation 46 of Chain 2.

Yes. Continue.

46. Calculate the turbopump parameters (XNS, ETAP, ETAT, P_{WP} , U, $C\phi$, Q_1 , HLD2).

47. Calculate the mass flow conductance of the turbine by equating turbine and pump power.

48. Calculate the turbine exit temperature.

49. Calculate the mass flow conductance of the roll nozzle for either sonic or subsonic conditions at the throat.

50. Sum the mass flow conductances on the hot side of the heat exchanger to obtain the net conductance of this line.

51. Using Subroutine Y2, calculate the mass flow conductance of the pump inlet line.

52. Is an INRX option being run?

No. Calculate the mass flow conductance of the bleed port. Then continue to operation 53 of Chain 2.

Yes. Continue to operation 53 of Chain 2.

53. For stations 4, 5, 6, 7, 10 and 14, calculate the mass storage rates.

Pressure Relaxation

54. Is an INRX option being run?

Yes. Recalculate system flow rates and pressures from the continuity principle and the mass flow conductances.

Convergence Test

$$\text{Is } \frac{P2 - P2CK}{P2} \leq PXCT\phi L?$$

Yes. Pressure loop has converged. Proceed to operation 66 of Chain 2.

No. Pressure loop has not converged. Proceed to operation 67 of Chain 2.

No. Proceed to operation 55 of Chain 2.

55. Recalculate and computationally damp W18 if required.

56. Recalculate the system flow rates.

57. Is a PTPCV option being run?

Yes. Recalculate P2 from P~~OWT~~ by a turbopump energy balance. Calculationally damp P2 if the maximum number of undamped iterations is exceeded. Then recalculate all major plenum pressures, at the same time forcing P10 to be at least as large as PA and to be no larger than the minimum of the other major plenum pressures. Proceed to operation 60 of Chain 2.

No. Proceed to operation 58 of Chain 2.

58. Calculate RELAX and ERR~~OR~~ for node 10.

59. Recalculate P10 by relaxation and the other major plenum pressures from the flow rates and mass flow conductances.

60. Recalculate the pressures in the heat exchanger and turbine inlet line, as well as the pressures at the turbine inlet and exhaust.

61. Is a PTPCV option being run?

$$\text{Yes. Is } \left| \frac{PXC - PXCCK}{PXC} \right| \leq PXCT\phi L?$$

$$\text{Yes. Is } \left| \frac{T18 - T18CK}{T18} \right| \leq TXCT\phi L?$$

Yes. Proceed to operation 66 of Chain 2.

No. Proceed to operation 62 of Chain 2.

No. Proceed to operation 62 of Chain 2.

No. Test for convergence of flow loop.

Is $SUM \leq PTOL$?

No. Proceed to operation 62 of Chain 2.

Yes. Proceed to operation 65 of Chain 2.

62. Recompute $WDOT$ computationally damp $WDOT$ if required and re-adjust system plenum pressures.

63. Recalculate and computationally damp $W18$ if required.

64. Recalculate the pressures in the heat exchanger and turbine inlet line, as well as the pressures at the turbine inlet and exhaust. Then proceed to operation 67 of Chain 2.

65. Is $\left| \frac{PXC - P10}{PXC} \right| \leq PXCTOL$?

Yes. Proceed to operation 66 of Chain 2.

No. Proceed to operation 62 of Chain 2.

66. Flow loop has converged. Set, latch, flow loop convergence flag.

67. Recalculate nodal pressures and channel flow rates in the nozzle, reflector, shield, and core.

68. Has the flow loop converged?

Yes. Proceed to operation 69 of Chain 2.

No. Proceed to operation 60 of Chain 2.

69. Is an INRX option being run?

No. Is $\left| \frac{T18 - T18OLD}{T18} \right| \leq T18TOL$?

Yes. Proceed to operation 71 of Chain 2.

No. Proceed to operation 72 of Chain 2.

Yes. Is $\left| \frac{P2 - P2OLD}{P2} \right| \leq PXCTOL$?

Yes. Proceed to operation 70 of Chain 2.

No. Proceed to operation 60 of Chain 2.

70. Is $\left| \frac{TXC\emptyset - T10}{T10} \right| \leq TXCT\emptyset L?$

Yes. The entire engine system has converged. Therefore set LATCH = 2 and proceed to operation 13 of Chain 2 to update systems temperatures a final time.

No. Proceed to operation 13 of Chain 2 with LATCH = 1.

71. Calculate $P\emptyset WT$. Is $\left| \frac{P\emptyset WT - P\emptyset WP}{P\emptyset WT} \right| \leq P\emptyset WT\emptyset L?$

Yes. The entire engine system has converged. Therefore, set LATCH = 2 and proceed to operation 13 of Chain 2 to update the system temperatures a final time.

No. The engine system has not yet converged. Therefore, proceed directly to operation 13 of Chain 2.

72. Check the overall engine loop counter.

Is counter < limit?

Yes. Proceed to operation 13 of Chain 2.

No. Print out error diagnostic and stop.

73. Print out all converged engine system parameters for the time point.

74. Has the real time limit been reached?

Yes. The calculations have been completed through the real time specified. Therefore, stop.

No. Continue.

75. Has the end of the range over which the current control parameter slopes hold been reached?

Yes. Return of operation 1 of Chain 2 and proceed to the next time point.

No. Return to operation 3 of Chain 2 and proceed to the next time point.

III. PROGRAM EQUATIONS

A. HEAT TRANSFER IN A TUBE

Given below is the derivation of the equation for heat transfer in a tube where surface temperature varies only axially. The equation is employed in the channel calculations for the reflector, shield, core, and heat exchanger, as well as for the nozzle tubes without the nozzle jacket. The thermal network of concern is shown at the top of Figure 9.

By an energy balance,

$$WC_p \frac{dT_y}{dy} = h_l P (T_{w_l} - T_y)$$

where

W = mass flow rate, lbm/sec

C_p = fluid heat capacity, Btu/lbm-°R

P = wetted perimeter, in.

h = heat transfer coefficient, Btu/in.²-sec-°R

T = temperature, °R

The subscripts y and w refer to the axial direction and the tube wall, respectively.

$$\frac{dT_y}{T_{w_l} - T_y} = \frac{h_l P}{WC_p} dy$$

Integrating, we get

$$-\ln(T_{w_l} - T_y) \Big|_{T_x}^{T_{out}} = \frac{h_l P}{WC_p} y \Big|_x^L$$

where x = some undefined position in the y direction.

$$\ln \left(\frac{T_{w1} - T_x}{T_{w1} - T_{out}} \right) = \frac{h_1 P}{WC_p} (L - x)$$

$$\frac{T_{w1} - T_x}{T_{w1} - T_{out}} = e^{\frac{h_1 P}{WC_p} (L - x)}$$

$$T_{w1} - T_x = (T_{w1} - T_{out}) e^{\frac{h_1 P}{WC_p} (L - x)}$$

$$T_x = (T_{out} - T_{w1}) e^{\frac{h_1 P}{WC_p} (L - x)} + T_{w1}$$

By definition,

$$\bar{T} = \frac{1}{L} \int_0^L T_x dx$$

where $\bar{T}$ = average axial fluid temperature for increment L , °R.

$$\begin{aligned} \bar{T} &= \frac{1}{L} \int_0^L \left[(T_{out} - T_{w1}) e^{\frac{h_1 P}{WC_p} (L - x)} + T_{w1} \right] dx \\ &= \frac{1}{L} \left[(T_{out} - T_{w1}) \frac{WC_p}{h_1 P} e^{\frac{h_1 P}{WC_p} (L - x)} \right]_0^L + T_{w1} x \left[\right]_0^L \\ &= \frac{1}{L} \left[(T_{out} - T_{w1}) \frac{WC_p}{h_1 P} \left(e^{\frac{h_1 PL}{WC_p}} - 1 \right) + T_{w1} L \right] \end{aligned}$$

$$\phi = h_1 P L \left(T_{w_1} - \bar{T} \right)$$

where ϕ = overall rate of heat transfer between tube wall and fluid in increment L , Btu/sec.

$$\phi = h_1 P L \left[T_{w_1} - \left(T_{out} - T_{w_1} \right) \frac{WC_p}{h_1 P L} \left(e^{\frac{h_1 P L}{WC_p}} - 1 \right) - T_{w_1} \right]$$

$$\phi = \left(T_{w_1} - T_{out} \right) WC_p \left(e^{\frac{h_1 P L}{WC_p}} - 1 \right)$$

The following is the derivation of the equation for heat transfer in a tube, whose wall is considered to be composed of two parallel sections. Each section forms a part of the circumference of the tube. There is assumed to be no heat conduction between these tube sections, and the temperatures of the sections vary only axially. This equation is employed only for the nozzle tubes with the nozzle jacket. The thermal network of concern is shown at the bottom of Figure 9.

By an energy balance,

$$WC_p \frac{dT_y}{dy} = h_1 P_1 \left(T_{w_1} - T_y \right) + h_2 P_2 \left(T_{w_2} - T_y \right)$$

let

$$a = WC_p$$

$$b = h_1 P_1 T_{w_1} + h_2 P_2 T_{w_2}$$

$$c = h_1 P_1 + h_2 P_2$$

then

$$\frac{a \frac{dT_y}{dy}}{b - c T_y} = dy$$

Integrating,

$$-\frac{a}{c} \log_e \left(b - c T_y \right) \Big|_{T_x}^{T_{out}} = y \Big|_x^L$$

$$\log_e \frac{b - c T_x}{b - c T_{out}} = \frac{c}{a} (L - x)$$

$$\frac{b - c T_x}{b - c T_{out}} = e^{\frac{c}{a} (L - x)}$$

$$b - c T_x = \left(b - c T_{out} \right) e^{\frac{c}{a} (L - x)}$$

$$T_x = \left(T_{out} - \frac{b}{c} \right) e^{\frac{c}{a} (L - x)} + \frac{b}{c}$$

As before,

$$\begin{aligned} \bar{T} &= \frac{1}{L} \int_0^L \left[\left(T_{out} - \frac{b}{c} \right) e^{\frac{c}{a} (L - x)} + \frac{b}{c} \right] dx \\ &= \frac{1}{L} \left[\left(T_{out} - \frac{b}{c} \right) \left(-\frac{a}{c} \right) e^{\frac{c}{a} (L - x)} \Big|_0^L + \frac{b}{c} x \Big|_0^L \right] \\ &= \frac{1}{L} \left[\left(T_{out} - \frac{b}{c} \right) \left(\frac{a}{c} \right) \left(e^{\frac{c}{a} L} - 1 \right) + \frac{b}{c} L \right] \end{aligned}$$

$$\begin{aligned} \phi &= h_1 P_1 L \left(T_{w_1} - \bar{T} \right) + h_2 P_2 L \left(T_{w_2} - \bar{T} \right) \\ &= L \left(h_1 P_1 T_{w_1} + h_2 P_2 T_{w_2} \right) - \left(h_1 P_1 + h_2 P_2 \right) (L \bar{T}) \end{aligned}$$

$$\begin{aligned}
 &= b L - c L \bar{T} \\
 &= b L - c L \frac{1}{L} \left[\left(T_{\text{out}} - \frac{b}{c} \right) \left(\frac{a}{c} \right) \left(e^{\frac{c}{a} L} - 1 \right) + \frac{b}{c} L \right] \\
 &= b h - \left(T_{\text{out}} - \frac{b}{c} \right) (a) \left(e^{\frac{c}{a} L} - 1 \right) - b h \\
 Q &= \left(\frac{a b}{c} - a T_{\text{out}} \right) \left(e^{\frac{c}{a} L} - 1 \right)
 \end{aligned}$$

A relation for Q in terms of T_{in} may be derived as follows:

$$- \frac{a}{c} \log_e \left(b - c T_y \right) \Big|_{T_{\text{in}}}^{T_x} = y \Big|_0^x$$

$$\log_e \frac{b - c T_{\text{in}}}{b - c T_x} = \frac{c}{a} x$$

$$\frac{b - c T_{\text{in}}}{b - c T_x} = e^{\frac{c}{a} x}$$

$$b - c T_x = \left(b - c T_{\text{in}} \right) e^{-\frac{c}{a} x}$$

$$T_x = - \frac{1}{c} \left(b - c T_{\text{in}} \right) e^{-\frac{c}{a} x} + \frac{b}{c}$$

$$T_x = \left(T_{\text{in}} - \frac{b}{c} \right) e^{-\frac{c}{a} x} + \frac{b}{c}$$

$$\bar{T} = \frac{1}{L} \int_0^L \left[\left(T_{\text{in}} - \frac{b}{c} \right) e^{-\frac{c}{a} x} + \frac{b}{c} \right] dx$$

$$\begin{aligned}
&= \frac{1}{L} \left[\left(T_{in} - \frac{b}{c} \right) \left(-\frac{a}{c} \right) e^{-\frac{c}{a} x} \right]_0^L + \frac{b}{c} x \left[\right]_0^L \\
&= \frac{1}{L} \left[\left(T_{in} - \frac{b}{c} \right) \left(-\frac{a}{c} \right) \left(e^{-\frac{c}{a} L} - 1 \right) + \frac{b}{c} L \right]
\end{aligned}$$

$$\phi = b L - c L \bar{T}$$

$$\begin{aligned}
&= b L - c L \frac{1}{L} \left[\left(T_{in} - \frac{b}{c} \right) \left(1 - e^{-\frac{c}{a} L} \right) + \frac{b}{c} L \right] \\
Q &= \left(\frac{a b}{c} - a T_{in} \right) \left(1 - e^{-\frac{c}{a} L} \right)
\end{aligned}$$

B. PRESSURE DROP IN A TUBE

The calculation of the pressure drop in a tube is performed by Subroutine Y2 which calculates the flow conductance for flow in a tube. To derive the momentum equation, neglecting gravitational and work terms, for steady flow in a coolant passage of varying area, a force balance may be made by referring to Figure 10 (Fluid Element).

$$\begin{aligned}
P_1 A_1 + \frac{1}{\alpha g_c} \left(\rho_1 V_1^2 \right) A_1 + \frac{P_1 + P_2}{2} (A_2 - A_1) &= P_2 A_2 + \frac{1}{\alpha g_c} \left(\rho_2 V_2^2 \right) A_2 \\
&+ P_f \frac{A_1 + A_2}{2}
\end{aligned}$$

where

P = static pressure of fluid, lbf/in.²

V = average fluid velocity, in./sec

ρ = fluid density, lbm/in.³

A = flow area, in.²

P_f = frictional pressure, lbf/in.²

g_c = gravitational constant, 386 lbm-in./lbf-sec²

$\alpha = 1$, for laminar flow in circular tubes

$= 2$, for turbulent flow in circular tubes

(Subscripts 1 and 2 refer to inlet and exit condition, respectively)

Rearranging,

$$P_1 \left(A_1 + \frac{A_2}{2} - \frac{A_1}{2} \right) - P_2 \left(A_2 - \frac{A_2}{2} + \frac{A_1}{2} \right) = \frac{1}{\alpha g_c} \left(A_2 \rho_2 V_2^2 - A_1 \rho_1 V_1^2 \right) + P_f \frac{A_1 + A_2}{2}$$

$$(P_1 - P_2) \left(\frac{A_1 + A_2}{2} \right) = \frac{1}{\alpha g_c} \left(A_2 \rho_2 V_2^2 - A_1 \rho_1 V_1^2 \right) + P_f \frac{A_1 + A_2}{2}$$

Since

$$\Delta P = P_1 - P_2$$

$$A_{\text{avg}} = \frac{A_1 + A_2}{2}$$

$$\Delta P_f = \frac{f \rho_{\text{avg}} V_{\text{avg}}^2}{2 g_c d_{\text{avg}}} \Delta \ell$$

where

f = Blasius friction factor

$\Delta \ell$ = length of increment, in.

V_{avg} = average fluid velocity over increment, $\Delta \ell$, in./sec

d_{avg} = average hydraulic diameter over increment, $\Delta \ell$, in.

ρ_{avg} = average fluid density over increment, $\Delta \ell$, lbm/in.³

Thus,

$$\Delta P = \frac{1}{A_{\text{avg}}} \left[\frac{f \rho_{\text{avg}} V_{\text{avg}}^2 \Delta \ell A_{\text{avg}}}{2 g_c d_{\text{avg}}} + \frac{1}{\alpha g_c} \left(A_2 \rho_2 V_2^2 - A_1 \rho_1 V_1^2 \right) \right]$$

Since

$$V = \frac{W}{\rho A}$$

where

W = mass flow rate, lbm/sec

$$\begin{aligned}\Delta P &= \frac{1}{A_{avg}} \left[\frac{f \Delta \ell W^2}{2 g_c d_{avg} A_{avg} \rho_{avg}} + \frac{W^2}{\alpha g_c} \left(\frac{1}{A_2 \rho_2} - \frac{1}{A_1 \rho_1} \right) \right] \\ &= \frac{W^2}{g_c A_{avg}} \left[\frac{f \Delta \ell}{2 d_{avg} A_{avg} \rho_{avg}} + \frac{1}{\alpha} \left(\frac{1}{A_2 \rho_2} - \frac{1}{A_1 \rho_1} \right) \right]\end{aligned}$$

C. TWO-PHASE HEAT TRANSFER

An analytical device was employed to permit simulation of two-phase heat transfer. During a constant pressure boiling phenomenon, energy is transferred to the fluid with no change in the sensible heat. This is tantamount to an infinite heat capacity for the fluid during boiling. Equation (11) is the general integrated equation for heat transfer between a solid node and the fluid.

$$Q = \dot{w} C_p \left(e^{\frac{k}{\dot{w} C_p}} - 1 \right) (T_o - T_w) \quad (11)$$

where

$$k = hPL = Ah$$

If, as in boiling, the fluid heat capacity appears to approach infinity

$$\frac{k}{\dot{w} C_p} \longrightarrow 0$$

it can be readily shown that for a very small positive number, x ,

$$e^x \approx 1 + x$$

Therefore,

$$e^{\frac{k}{\dot{w} C_p}} \approx 1 + \frac{k}{\dot{w} C_p}$$

We then obtain

$$Q = \dot{w} C_p \left(1 + \frac{k}{\dot{w} C_p} - 1 \right) (T_o - T_w) = k (T_o - T_w)$$

or

$$Q = hA (T_o - T_w) \quad (12)$$

Thus, for a sufficiently large C_p , the integrated heat transfer equation becomes equivalent to that with an average heat transfer coefficient and a constant driving force. Since the process of forced convective boiling will take place at almost constant pressure over an increment, the temperature over the increment will change an insignificant amount ($T_i \approx T_o$), and the equation for description of the heat transfer occurring is identical to Equation (12).

Equation (11) is the relation built into the program logic to calculate convective heat transfer between the solid material and the fluid. It is desirable from a programming standpoint to use this relation under all conditions so as not to complicate the program logic. Therefore, when a condition of two-phase flow exists, the fluid heat capacity is set to a sufficiently large value (2000 Btu/lbm-°R) so that the fluid temperature does not change due to the heat addition (some change occurs due to change in pressure). As shown above, this leads to a simplified form of the integrated heat transfer equation. Thus, this device permits retention of a general heat transfer scheme and at the same time permits calculations during two-phase flow.

The correct heat transfer coefficient to be used in Equation (12) is that for two-phase flow. The Graham, Hendricks, and Hsu correlation^{*} was chosen to evaluate this parameter. This correlation represents the forced convective boiling heat transfer coefficient for hydrogen as a function of the Martinelli two-phase parameter, X_{tt} , which is defined by

^{*}R. C. Hendricks, R. W. Graham, Y. Y. Hsu, and R. Friedman, Experimental Heat Transfer and Pressure Drop of Liquid Hydrogen Flowing Through a Heated Tube, NASA Technical Note D-765, May 1961.

$$\frac{1}{X_{tt}} = \left(\frac{x}{1-x} \right)^{0.9} \left(\frac{\mu_g}{\mu_l} \right)^{0.1} \left(\frac{\rho_l}{\rho_g} \right)^{0.5}$$

where

x = quality of the fluid mixture

μ = viscosity, lbm/in.-sec

ρ = density, lbm/in.³

and the subscripts l and g refer to liquid phase and gas phase, respectively.

The Graham, Hendricks, and Hsu correlation may be expressed as

$$\frac{Nu_{exp}}{Nu_{calc}} = \frac{1}{0.611 + 1.93 X_{tt}}$$

where

$$Nu_{exp} = \frac{h_{exp} D}{k_f}$$

h_{exp} = experimental two-phase heat transfer coefficient, Btu/in.²-sec-°R

k_f = thermal conductivity of gas phase evaluated at the film temperature, Btu/in.-sec-°R

D = tube diameter, in.

$Nu_{calc, f}$ = Nusselt Number evaluated at the film temperature with a mean density of the film defined by

$$\rho_{f,m} = \frac{1}{\frac{x}{\rho_{g,f}} + \frac{1-x}{\rho_l}}$$

where the subscript f refers to evaluation at the film temperature. It can be easily seen from the above definitions that

$$\frac{h_{exp,f}}{h_{calc,f}} = \frac{1}{0.611 + 1.93 X_{tt}}$$

or

$$h_{exp,f} = \frac{h_{calc,f}}{0.611 + 1.93 X_{tt}}$$

In the nozzle, $h_{calc,f}$ is evaluated using the Thompson "A" correlation with a mean film density and gas transport properties evaluated at the film temperature:

$$h_{calc,f} = \frac{0.028}{(D_h)^{0.2}} \left(\frac{\dot{w}}{A_{fl}} \right)^{0.8} (\Phi_f) \left(\frac{T_b}{T_w} \right)^{0.64}$$

where

D_h = channel hydraulic diameter, in.

$\dot{w}$ = channel flow rate, lbm/sec

A_{fl} = channel flow area, in.²

T_b = fluid bulk static temperature, °R

T_w = wall temperature, °R

$$\Phi_f = \left(\frac{k^{0.6} C_p^{0.4}}{\mu^{0.4}} \right)_f$$

For the reflector, shield, core, and heat exchanger, the McCarthy-Wolf correlation is used with a mean film density and gas transport properties evaluated at the film temperature:

$$h_{calc,f} = \frac{0.025}{(D_h)^{0.2}} \left(\frac{\dot{w}}{A_{fl}} \right)^{0.8} (\Phi_f) \left(\frac{T_b}{T_w} \right)^{0.55}$$

D. NOZZLE HEAT TRANSFER - HOT SIDE

The Bartz heat transfer correlation with a variable coefficient is used on the hot-gas side of the nozzle. This correlation defines the heat transfer coefficient by

$$h_H = C_B \left(\frac{4 \dot{w}_c}{\pi} \right)^{0.8} \frac{1}{(D_h)^{0.8}} \frac{1}{\epsilon^{0.9}} \left(\frac{T_b}{T_E} \right)^{0.8} \left(\Phi_{T_E} \right) \quad (13)$$

where

- h_H = hot-gas side heat transfer coefficient, Btu/in.²-sec-°R
- C_B = variable Bartz coefficient which is a function of axial position in the nozzle. It varies because of boundary layer build-up starting at the entrance to the nozzle.
- $\dot{w}$ = chamber flow rate, lbm/sec
- ϵ = local nozzle area ratio
- T_E = Eckert reference temperature

It is implied in Equation (13) that the gas transport properties in the Bartz heat transfer correlation are evaluated at the Eckert reference temperature, which is defined by

$$T_E = T_C + 0.5 (T_{WH} - T_C) + 0.22 (T_{ar} - T_C)$$

where

- T_E = Eckert reference temperature, °R
- T_C = nozzle chamber temperature, °R
- T_{WH} = hot-side tube wall temperature, °R
- T_{ar} = adiabatic recovery temperature, °R

E. TURBOPUMP AND HOT-BLEED SYSTEM EQUATIONS

The turbopump section of the Nuclear Engine Transient Analysis Program is composed of the heat exchanger, bleedport, turbopump, and roll nozzles. The thermal analysis of the heat exchanger has been explained in detail in a preceding discussion. Therefore, primary concern will be given in this section to a discussion of the calculation of other parameters pertinent to these components.

The mass flow rate conductance of the diluent side of the heat exchanger is calculated completely by use of subroutines. The conductances

of the trim orifice and the diluent orifice are calculated by Subroutine Y1, while the conductances of the diluent side flow segments are calculated by Subroutine Y2.

The mass flow conductance of the bleedport is calculated by the standard incompressible flow equation:

$$\Delta P_{BP} = k \frac{\rho_c U_{BP}^2}{2 g_c} = \frac{k (W13)^2}{2 g_c \rho_c A_{BP}^2}$$

where

ΔP_{BP} = pressure drop, psia = $P_{10} - P_{14}$

k = total loss coefficient for bleedport inlet

ρ = fluid density, lbm/in.³

U = fluid velocity, in./sec

g_c = acceleration of gravity, (lbm/lbf) (in./sec²)

$W13$ = bleedport mass flow rate, lbm/sec

A_{BP} = flow area, in.²

and the subscripts c and BP refer to the nozzle chamber and the bleedport, respectively.

By definition

$$W13 = WYBPT (\Delta P_{BP})$$

or

$$WYBPT = \frac{W13}{\Delta P_{BP}} = \frac{(W13)^2 g_c \rho_c A_{BP}^2}{K (W13)^2}$$

$$WYBPT = \frac{2 g_c \rho_c A_{BP}^2}{K (W13)}$$

where

$WYBPT$ = mass flow rate conductance of bleedport, $\left(\frac{\text{lbm}}{\text{sec}} \right) \left(\frac{\text{in.}^2}{\text{lbf}} \right)$

$$K = 1 + CBPT$$

The mass flow rate conductance of each hot-side duct flow segment of the heat exchanger is calculated by Subroutine Y2, while that of the turbine orifice is calculated by Subroutine Y1.

For purposes of flow conductance, the TPCV is assumed to be an infinitely variable resistance to flow. Thus, the mass flow rate conductance is defined by

$$Y_{TPCV} = \frac{W_{18}}{\Delta P_{TPCV}}$$

where

$$Y_{TPCV} = \text{mass flow rate conductance of TPCV, } \left(\frac{\text{lbm}}{\text{sec}} \right) \left(\frac{\text{in.}^2}{\text{lb f}} \right)$$

$$W_{18} = \text{turbine flow rate, lbm/sec}$$

$$\Delta P_{TPCV} = \text{pressure drop across the TPCV, } \frac{\text{lb f}}{\text{in.}^2} = P_{17P5} - P_{18}$$

The volumetric pump flow rate is calculated from the pump discharge conditions by

$$Q_1 = 0.2598 \frac{W_1}{\rho_2}$$

where

$$Q_1 = \text{pump flow rate, gal/min}$$

$$W_1 = \text{pump flow rate, lbm/sec}$$

$$\rho_2 = \text{fluid density at pump discharge conditions, } \frac{\text{lbm}}{\text{in.}^3}$$

The head rise across the pump is defined by

$$H_{LD2} = \frac{\Delta P_P}{12 \rho_2}$$

or

$$DELH = \frac{\Delta P_P}{\rho_2}$$

where

$$H_{LD2} = \text{pump head rise, ft}$$

$$DELH = \text{pump head rise, in.}$$

$$\Delta P_P = \text{pressure rise across the pump} = P_2 - P_1, \text{ lb f/in.}^2$$

The shaft speed, XNS, is calculated as a function of Q1 and H1D2. For a noncavitating Mark III Mod 4 turbopump, this expression becomes

$$XNS = -1.4Q1 + \sqrt{1.955(Q1)^2 + \frac{(22.7(Q1)^2 + H1D2 \times 10^5)}{4.65}}$$

where

XNS = shaft speed, rpm

The pump efficiency, ETAP, is calculated as a function of Q1/XNS by a curve fit of the form

$$ETAP = CP2 \left(\frac{Q1}{XNS} \right)^2 + CP3 \left(\frac{Q1}{XNS} \right) + CP4$$

where

CP2, CP3, and CP4 are constants from a polynomial curve fit.

In general, the total pump power requirement, P ϕ WP, is composed of two terms - one representing a steady-state contribution and the other a transient contribution:

$$P\phi WP = P\phi WP_s + P\phi WP_t$$

where

P ϕ WP_s = pump power necessary to provide the demanded fluid head rise, in.-lbf/sec

P ϕ WP_t = pump power necessary to accelerate the shaft, in.-lbf/sec

By definition,

$$P\phi WP_s = \frac{W1 (DELH)}{ETAP}$$

$$P\phi WP_t = 12 I \alpha \omega$$

so that

$$P\phi WP = \frac{W1 (DELH)}{ETAP} + 12 I \alpha \omega \quad (14)$$

where

I = shaft moment of inertia, ft-lbf-sec²

α = angular acceleration of the shaft, radians/sec²

ω = angular velocity of the shaft, radians/sec

It is also true that

$$\omega = \frac{(XNS)}{60} \quad 2\pi$$

and

$$\alpha = \frac{\partial \omega}{\partial \theta} = \frac{2\pi}{60} \frac{\partial (XNS)}{\partial \theta}$$

where

$$\theta = \text{time, sec}$$

Thus

$$\begin{aligned} P\phi_{WP_t} &= 12 \text{ I } \frac{2\pi}{60} (XNS) \frac{2\pi}{60} \frac{\partial (XNS)}{\partial \theta} \\ &= 0.132 \text{ I } (XNS) \frac{\partial (XNS)}{\partial \theta} \end{aligned}$$

Equation (14) now becomes

$$P\phi_{WP} = \frac{W1 (DELH)}{ETAP} + 0.132 \text{ I } (XNS) \frac{\partial (XNS)}{\partial \theta}$$

By differencing the above equation, we obtain

$$P\phi_{WP} = \frac{W1 (DELH)}{ETAP} + 0.132 (I) \frac{(XNS^2 - XNS\phi^2)}{2 \text{ DELTA}} \quad (15)$$

where

$XNS\phi$ = shaft speed at previous time point, rpm

DELTA = time between time points, sec

The first term in Equation (15) is the steady-state pump power necessary to obtain the required pump work, while the second term is the transient power necessary to accelerate the shaft.

The enthalpy of the turbine inlet fluid, $H18$, is obtained from Subroutine PARAH. For an isentropic turbine driven by an ideal gas, the enthalpy of the fluid at the turbine exit conditions may be obtained as indicated below.

For an ideal gas, C_p is a constant and

$$\Delta H = C_p \Delta T$$

For an isentropic process of an ideal gas,

$$\frac{T_{18}}{T_{19}} = \left(\frac{P_{18}}{P_{19}} \right)^{\frac{\gamma-1}{\gamma}}$$

For a zero datum level of $T = 0^\circ R$, or for a level close to $0^\circ R$ and temperature far above $0^\circ R$, H is proportional to T and

$$H_{19} = H_{18} \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}}$$

where

H = fluid enthalpy, Btu/lbm

P = static fluid pressure, lbf/in.²

γ = specific heat ratio

and where stations 18 and 19 are at the inlet and exit of the turbine, respectively.

The isentropic spouting velocity, $C\phi$, is the velocity the turbine fluid would attain if the turbine expansion process were isentropic. For an ideal gas, and a negligible inlet velocity, this may be expressed as

$$C\phi = \sqrt{\frac{2 g_c \gamma}{\gamma - 1} R (T_{18}) \left[1 - \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}} \right]} \quad (16)$$

where

R = universal gas constant = 1544 ft-lbf/lb-mole- $^\circ R$

But, as above,

$$\Delta H = C_p \Delta T$$

For an isentropic turbine process involving an ideal gas,

$$\frac{T_{18}}{T_{19}} = \left(\frac{P_{18}}{P_{19}} \right)^{\frac{\gamma-1}{\gamma}}$$

or

$$T_{19} = T_{18} \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}}$$

Also, for an ideal gas, $\frac{\gamma}{\gamma-1} = \frac{C_p}{R}$.

This leads to

$$\begin{aligned} H_{18} - H_{19} &= C_p \left[T_{18} - T_{18} \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}} \right] \\ &= C_p T_{18} \left[1 - \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}} \right] \end{aligned}$$

As a result

$$c\phi = \sqrt{2 g_c (H_{18} - H_{19})}$$

Equation (16) can be then reduced to

$$c\phi = 223.8 \sqrt{H_{18} - H_{19}}$$

The turbine tip speed, U , is calculated from XNS by

$$U = 0.04768(XNS), \text{ ft/sec}$$

ETAT, the turbine efficiency, is determined as a function of the ratio $U/C\phi$ by a curve fit of the form

$$ETAT = CT2 \left(\frac{U}{C\phi} \right)^3 + CT3 \left(\frac{U}{C\phi} \right)^2 + CT4 \left(\frac{U}{C\phi} \right)$$

where $CT2$, $CT3$, and $CT4$ are constants from a polynomial curve fit. The useful turbine power required is equated to the total pump power:

$$P\phi_{WT_useful} = P\phi_{WP_ideal} (ETAT) \quad (17)$$

But

$$P\phi_{WT_ideal} = 9336 W18 (\Delta H_T), \text{ in.-lbf}$$

where

$$\Delta H_T = H18 - H19$$

Thus, one can see that the appropriate definition for ETAT as used in Equation (17) is

$$ETAT = \frac{P\phi_{WT_useful}}{P\phi_{WT_ideal}}$$

where $P\phi_{WT_ideal}$ is evaluated at the static conditions of the turbine inlet and exhaust. Conditions at the turbine inlet are such that static and stagnation temperatures and pressures are sufficiently close to approximate each other. Therefore, $P\phi_{WT_ideal}$ may be considered to be evaluated at total-to-static conditions and ETAT is then defined as the total-to-static turbine efficiency.

By definition, the turbine mass flow rate conductance, Y_6 , is

$$Y_6 = \frac{W_{18}}{\Delta P_T}$$

where

$$\Delta P_T = P_{18} - P_{19}$$

Equation (17) then becomes

$$\begin{aligned} \dot{P}_{WP} &= (ETAT) \ 9336 \ W_{18} \ (\Delta H_T) \\ &= (ETAT) \ 9336 \ \Delta H_T \ Y_6 \ \Delta P_T \end{aligned}$$

or

$$Y_6 = \frac{\dot{P}_{WP}}{ETAT \ 9336 \ \Delta H_T \ \Delta P_T}$$

The turbine operates at a turbine efficiency, $ETAT$, of less than 1.00. By definition of $ETAT$,

$$\dot{P}_{WT_a} = ETAT \ (\dot{P}_{WT_i})$$

where the subscripts a and i refer to actual and isentropic (or ideal), respectively. For an isentropic turbine,

$$\dot{P}_{WT_i} = W_{18} \ \Delta H_{Ti} \cdot 9336$$

Thus

$$\dot{P}_{WT_a} = ETAT \ (W_{18}) \ \Delta H_{Ti} \ 9336$$

However

$$\dot{P}_{WT_a} = W_{18} \ 9336 \ \Delta H_{Ta}$$

which leads to

$$9336 \ ETAT \ (W_{18}) \ \Delta H_{Ti} = W_{18} \ 9336 \ \Delta H_{Ta}$$

For an isentropic process with a fluid following ideal gas behavior,

$$\Delta H = C_p \Delta T \text{ and } \Delta T = T_1 \left[1 - \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} \right]$$

Thus

$$ETAT (C_p) T_{18} \left[1 - \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}} \right] = C_p (T_{18} - T_{19_a})$$

As a result, the actual turbine exit temperature, T_{19_a} , is

$$T_{19_a} = T_{18} \left[1 - ETAT \left(1 - \left(\frac{P_{19}}{P_{18}} \right)^{\frac{\gamma-1}{\gamma}} \right) \right]$$

The model of the roll nozzle accounts for both subsonic and sonic flow at the throat. If the pressure ratio, P_A/P_{19} , across the roll nozzle is greater than 0.528, there is subsonic flow at the nozzle throat. The mass flow rate conductance is then obtained as shown below.

For an isentropic nozzle and a fluid following ideal gas behavior

$$W_{18} = \frac{A_{RN} P_{19}}{R} \sqrt{2 g_c \frac{C_p J}{T_{19}} \left[\left(\frac{P_t}{P_{19}} \right)^{2/\gamma} - \left(\frac{P_t}{P_{19}} \right)^{\frac{\gamma+1}{\gamma}} \right]} \quad (18)$$

where

A_{RN} = total throat area of roll nozzles, in.²

C_p = fluid heat capacity, Btu/lbm-°R

J = mechanical equivalent of heat = 778.2 ft-lbf/Btu

P_t = pressure at the nozzle throat $\approx P_A$, psia

By definition, the roll nozzle mass flow rate conductance, Y_{RN} , is

$$Y_{RN} = \frac{W_{18}}{\Delta P_{RN}} \quad (19)$$

where

$\Delta P_{RN} = P_{19} - P_A$

Thus, by combination of constants, approximation of P_t as P_A , and substitution of Equation (18) into Equation (19)

$$Y_{RN} = \frac{0.534 A_{RN} P_{19}}{P_{19} - P_A} \sqrt{\frac{1}{T_{19}} \left[\left(\frac{P_A}{P_{19}} \right)^{2/\gamma} - \left(\frac{P_A}{P_{19}} \right)^{\frac{\gamma+1}{\gamma}} \right]} \quad (20)$$

Let

$$C_{19} = A_{RN} \sqrt{\frac{g_c \gamma}{R} \left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}}} = 0.14 A_{RN} \quad (21)$$

where

$\gamma = 1.4$ for gaseous hydrogen

$$C_{19} = 0.14 A_{RN}$$

The mass flow rate conductance of the subsonic roll nozzles then becomes

$$Y_{RN} = \frac{3.87 C_{19} (P_{19})}{P_{19} - P_A} \sqrt{\frac{1}{T_{19}} \left[\left(\frac{P_A}{P_{19}} \right)^{2/\gamma} - \left(\frac{P_A}{P_{19}} \right)^{\frac{\gamma+1}{\gamma}} \right]}$$

If, however, $\frac{P_A}{P_{19}} \leq 0.528$, the nozzles are sonic at the throat and

$$W_{18} = \frac{P_{19}}{\sqrt{T_{19}}} A_{RN} \sqrt{\frac{g_c \gamma}{R} \left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}}} \quad (22)$$

By substituting Equation (21) into Equation (22), and rearranging, we obtain as the mass flow rate conductance of sonic roll nozzles

$$Y_{RN} = \frac{C_{19} (P_{19})}{\sqrt{T_{19}} (P_{19} - P_A)}$$

Over the operating range for which the program is designed, the turbine inlet nozzle may be sonic or subsonic. Therefore, the program has the capability to account for such variation in flow conditions at the turbine inlet. In general

$$W_{18} = \frac{C_{T5} (P_{18})}{\sqrt{T_{18}}} \quad (23)$$

where

C_{T5} = the empirically evaluated turbine inlet nozzle coefficient of flow.

C_{T5} is found to be a strong function of P_{18}/P_{19} up to a value of P_{18}/P_{19} of about 1.6. Beyond $P_{18}/P_{19} = 1.6$, C_{T5} is constant and the nozzle is sonic. The turbine inlet pressure, P_{18} , is calculated from Equation (23). It is first assumed that the value of P_{18}/P_{19} is greater than 1.6 and

$$P_{18} = \frac{\sqrt{T_{18}} W_{18}}{C_{T5}} \quad (24)$$

where

C_{T5} is constant, implying sonic flow.

If, however, the P_{18} obtained from Equation (24) yields a value of P_{18}/P_{19} less than 1.6, P_{18} is recalculated using a functional approximation for C_{T5} between P_{18}/P_{19} values of 1.0 and 1.6. This leads to an expression of the form

$$P_{18} = 0.5 \left[P_{19} + \sqrt{P_{19}^2 + 5 P_{19} \sqrt{T_{18}} W_{18}} \right]$$

which implies subsonic flow in the turbine inlet nozzle.

IV. SUBROUTINES

A. SUBROUTINE TEM9

Subroutine TEM9 is a general heat transfer subroutine which calculates the transient or steady-state solid material and fluid temperature distribution in parallel flow channels. Implied in Subroutine TEM9 are the assumptions that each channel is adiabatic with respect to all other channels, and that the temperatures and pressures of the fluid entering each of the parallel flow passages are equal. The subroutine iteratively solves for the solid material and fluid node temperatures of each channel type, given the fluid inlet temperature, pressure, and enthalpy, and the solid material temperatures at the previous time step, as boundary conditions. Since Subroutine TEM9 is only a thermal analysis routine, all fluid flow parameters are held invariant during the calculations. At the conclusion of the analysis for all channel types, a mean exit temperature for all of the channels discharging into a common plenum is calculated, under the assumption of perfect mixing of all fluid streams. This subroutine is an adequate thermal model of any component which may be represented as a series of parallel flow channels which have common inlet and exit plenums. As such, it is capable of performing all of the reflector, shield, and core thermal calculations.

The calculational method employed in Subroutine TEM9 is the same as that described in Section II,A and employed in the nozzle, heat exchanger, and pressure calculations in Chain 2 of the main program. A diagram of the subroutine logic appears in Figure 11. The subroutine logic is as follows:

1. Enter with input data from the main program.
2. For each channel type I, and considering only one channel type at a time, perform the following operations:
 - a. Equate the temperature and specific enthalpy of the fluid in the inlet plenum to those at the first fluid node in the channel.
 - b. Set counter for the iteration loop within Subroutine TEM9.
 - c. For each solid material node:
 - (1) Is the preceding fluid node two-phase?

No. Calculate the convective heat transfer coefficient by the McCarthy-Wolf correlation.

Yes. Calculate the Martinelli parameter, X_{tt} , and then the two-phase convective heat transfer coefficient, by the Graham, Hendricks, and Hsu correlation.

- (2) Calculate a mean heat capacity for the fluid by

$$CP = \frac{HH(I,K+1) - HH(I,K)}{T(I,K+1) - T(I,K)}$$

If $T(I,K+1) - T(I,K) = 0$, let $CP = 2,000$.

- (3) Calculate $Z1$, thermal conductance associated with fluid flow between two nodes.

- (4) Calculate a mean heat capacity for the solid by

$$CPM = \frac{HSOL(I,K) - H\phi SOL(I,K)}{TC(I,K) - TC\phi(I,K)}$$

If $TC(I,K) - TC\phi(I,K) = 0$, let $CPM = \frac{H\phi SOL(I,K)}{TC\phi(I,K)}$

- (5) Calculate $Z3(I,K)$, axial conductive heat conductance between solid nodes.

- (6) Calculate $Z2(I,K)$, convective heat conductance between the solid node and the fluid.

- d. Calculate ZETA, the radiative thermal conductance between the last solid node and the adjacent face of the following component.

- e. Calculate the RELAX terms for each solid node from the conductances and $C\phi EFF$.

- f. Calculate all values of the heat flows, $Q1(I,K)$, $Q2(I,K)$, $Q3(I,K)$, $S(I,K)$ and TERM.

- g. Calculate the ~~ERROR~~ terms for each solid node by

$$\text{~~ERROR~~}(K) = \text{Energy In} - \text{Energy Out}$$

- h. Recompute all solid node temperatures by

$$TC(I,K) = TC(I,K) + RELAX(K)*\text{~~ERROR~~}(K)$$

- i. For each fluid node, recompute the specific enthalpy by

$$HH(I,K) = HH(I,K-1) + \frac{Q2(I,K-1)}{W(I)}$$

and then call Subroutine PARAH with HH(I,K) and P(I,K) to obtain T(I,K).

- j. Test for relaxation network convergence.

- (1) Sum all residual ~~ERROR~~ terms for the solid nodes.
- (2) Sum all heat flows (Q1, Q2, Q3, S, TERM) for all solid nodes.
- (3) Let SUM be defined by

$$SUM = \frac{\text{Sum of all solid node residuals}}{\text{Sum of all solid node heat flows}}$$

- (4) Is SUM < ~~TOL~~ER?

No. Is counter < limit?

Yes. Return to operation 2 and repeat calculations.

No. Printout error diagnostic and stop.

Yes. Return to operation 2 if another channel type is to be considered - otherwise continue.

3. Assuming perfect mixing of all fluid streams in the exit plenum, calculate the specific enthalpy of the fluid in the exit plenum.

$$H2 = \frac{\sum_{I=1}^N ALPHA(I) * W(I) * HH(I,M)}{\sum_{I=1}^N ALPHA(I) * W(I)}$$

Then call Subroutine PARAH with H2 and P(I,M) to obtain T2.

4. Return to main program.

B. SUBROUTINE Y1

Subroutine Y1 calculates the mass flow conductance for isentropic flow of an ideal gas. The calculations account for choking conditions by first checking the pressure ratio across the passage to see if the flow is sonic or subsonic, and then performing different calculations for sonic or subsonic conditions.

The flow is assumed to be sonic when

$$\frac{P_2}{P_1} \leq \frac{2}{\gamma+1}$$

where

P = static pressure, psia

γ = specific heat ratio

and the subscripts 1 and 2 refer to the passage inlet and exit.

The mass flow conductance, Y1, is then calculated from the defining equation

$$\dot{w} = Y1 (P_1 - P_2)$$

where

$\dot{w}$ = mass flow rate, lbm/sec

Y1 = mass flow rate conductance, $\left(\frac{\text{lbm}}{\text{sec}} \right) \left(\frac{\text{in.}^2}{\text{lbf}} \right)$

and the sonic flow equation for isentropic flow of an ideal gas. The resulting expression for Y1 is

$$Y1 = \frac{AP_1 g_c \gamma}{\sqrt{g_c \gamma RT_1}} \sqrt{\left(\frac{2}{\gamma+1} \right)^{\frac{\gamma+1}{\gamma-1}}} \frac{1}{(P_1 - P_2)}$$

where

A = flow area of the passage, in.²

g_c = gravitational constant, $\left(\frac{\text{lbm}}{\text{lbf}}\right) \left(\frac{\text{in.}}{\text{sec}^2}\right)$

R = universal gas constant, $\frac{\text{in. lbf}}{\text{lbm } ^\circ\text{R}}$

T = temperature, $^\circ\text{R}$

The flow is assumed to be subsonic when,

$$\frac{P_2}{P_1} > \left(\frac{2}{\gamma+1}\right)^{\frac{\gamma}{\gamma-1}}$$

The subsonic isentropic flow equation for an ideal gas is then used with the defining equation to yield

$$Y1 = \frac{A P_1}{R T_1} \left(\frac{P_2}{P_1}\right)^{1/\gamma} \sqrt{\frac{2 g_c \gamma}{\gamma-1} R T_1 \left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]} \frac{1}{(P_1 - P_2)}$$

C. SUBROUTINE Y2

Subroutine Y2 calculates the mass flow conductance of a flow passage with constant flow area. Essentially, this subroutine solves the momentum equation, as applied to a constant area duct, by balancing the forces associated with momentum changes in the fluid, friction between the fluid and the duct wall, and the fluid pressure. A derivation of the momentum equation is given in Section III,B.

By taking the momentum balance across the flow passage and using the basic definition of a mass flow conductance, Y2, the mass flow conductance of the passage is

$$Y2 = \frac{A^2 g_c}{\dot{w} \left[\left(\frac{1}{\rho_2} - \frac{1}{\rho_1} \right) + f \frac{L}{8R_h} \frac{1}{P} \right]}$$

where

A = flow area for passage, in.²

$\dot{w}$ = flow rate, lbm/sec

ρ = fluid density, lbm/in.³

f = Blasius friction factor

L = flow passage length, in.

R_h = hydraulic radius, in.

$\bar{P} = (P_1 + P_2)/2$

and subscripts 1 and 2 refer to the flow passage entrance and exit, respectively.

The friction factor, f, is calculated from a series of curve fits which are valid over separate ranges of the Reynolds Number, Re.

$$\text{If } Re < 1200, f = \frac{64}{Re}$$

$$\text{If } 1200 < Re < 2 \times 10^5, f = \frac{0.316}{Re^{0.25}}$$

$$\text{If } Re > 2 \times 10^5, f = \frac{0.106}{Re^{0.161}}$$

where

$$Re = \frac{\dot{w} R_h}{A \mu}$$

μ = fluid viscosity, lbm/in.-sec

The values of the fluid density are obtained from Subroutine PARAH as a function of the fluid enthalpy and static pressure.

D. SUBROUTINE Y3

Subroutine Y3 calculates the mass flow conductance associated with a pressure loss at a flow passage inlet or exit. The loss coefficient for the exit or inlet is defined by the incompressible flow equation in terms of velocity heads

$$K_L = \frac{\Delta P}{p_1 v_1^2 / 2 g_c}$$

where

K_L = loss coefficient

p = fluid density, lbm/in.³

v = fluid velocity, in./sec

ΔP = pressure loss at the inlet or exit, lbf/in.²

and the subscript 1 refers to the conditions immediately upstream of the inlet or exit.

From this definition of K_L and the basic definition of a mass flow conductance, the mass flow conductance, Y_3 , for an inlet or exit through which fluid following ideal gas behavior is flowing becomes,

$$Y_3 = \frac{2 g_c A_1^2 P_1 M_w}{K_L \dot{w}_1 R T_1}$$

where

A = flow area of exit or inlet, in.²

P = static fluid pressure, lbf/in.²

T = static fluid temperature, °R

$\dot{w}$ = mass flow rate, lbm/sec

M_w = molecular weight of fluid, lbm/lb-mole

Y_3 = mass flow rate conductance, $\left(\frac{\text{lbm}}{\text{sec}} \right) \left(\frac{\text{in.}^2}{\text{lbf}} \right)$

E. SUBROUTINE READKM

Subroutine READKM is a general purpose tabular routine for one-dimensional linear interpolation of functions. Each function is stored within READKM as a table consisting of a series of data points. Since READKM may have many such functions and therefore many tables, each must be numbered. The subroutine is entered with the table number and the value of the independent variable

at which it is desired to evaluate the dependent variable. A search is then made in the appropriate table for the two tabular values between which the input independent variable lies. A linear interpolation is then performed between the corresponding dependent variable values to obtain the desired dependent variable value. Sufficient functions points are stored in the tables to make linear interpolation valid.

In general, READKM is used to evaluate temperature-dependent properties of the solid materials of the engine system. For any value of temperature ($^{\circ}\text{R}$) within the range of the table, a value of the desired property can be obtained. The following is a list of the tables of thermal properties data presently available in Subroutine READKM:

<u>Table No.</u>	<u>Thermal Data</u>
1	k for 347 stainless steel
2	k for beryllium
3	k for aluminum
4	k for graphite
5	k for pyrographite (radial direction) - old data
6	k for lithium hydride
7	k for A-110-AT (a titanium alloy)
8	k for parahydrogen
9	k for Inconel
10	k for tungsten
11	k for Inconel-X
12	k for pyrographite (axial direction)
13	k for pyrographite (radial direction) - new data
14	h for beryllium
15	h for graphite
16	h for aluminum
17	h for stainless steel
18	h for Inconel

where

k = thermal conductivity, Btu/in.-sec- $^{\circ}\text{R}$

h = solid enthalpy, Btu/lbm

In addition, READKM is used to calculate the loss coefficient and setting (in degrees) of the turbine power control valve. This data is stored in the following tables:

<u>Table No.</u>	<u>Data</u>
19	XKTCV as a function of TPCV
20	TPCV as a function of XKTCV

where

TPCV = valve setting in degrees

XKTCV = loss coefficient of the valve

F. SUBROUTINE PARAH

Both Chain 1 and 2 use Subroutine PARAH for communication between the transient analysis routines and the appropriate parahydrogen properties packages. Thus, a new properties package (not necessarily a parahydrogen deck) could be inserted into either one or both chains merely by altering the PARAH subroutine for the chain in question. The transient analysis program could therefore be easily changed to run using a different propellant if desired.

V. PROGRAM OPERATIONA. ORGANIZATION1. Machine and System Requirements

The Nuclear Engine Transient Analysis Program was written for an IBM 7090 or 7094 with a Fortran II Version II system. The large program size created storage problems, forcing the use of this system.

2. Description

Since the program exceeds available core, it is divided into two chains (links) with each chain calling the other under appropriate conditions.

Both chains are on tape unit A4. Chain 1 merely loads data, prints this input, and calculates initial values needed to start the run. Chain 2 computes the transient calculations for the entire run and calls Chain 1 for the next run.

The user may keep the tape for unit A4 in a storage bin after an initial card run in which the monitor system will set up this chain tape. Then for subsequent machine use, the user will mount this tape on tape unit A4 and input a chain calling routine followed by his data cards. To dismount tape A4, the last data card should be the unload card as mentioned in the input section.

3. Run Time

Run time is dependent upon the number of iterations required for convergence of each time step and the number of time steps. The number of iterations depends on the guessed starting values and the options used, but generally the first few time steps will be slower in converging. Steady-state runs will require 2 to 3 min, while transient cases may require approximately 30 sec per time step.

B. INPUT INSTRUCTIONS*

The program input requires a title card followed by individually loaded data cards. Each data card contains a numerical input designation in columns 1-12 followed by five input values. The card format is F 12.0, 5 E 12.8. So if columns 1-12 contain +1.0, data will be loaded into inputs 1-5; if they contain +1000.0,

* Array inputs are stored in column form (i.e., column 1 - I = 1,N; column 2 - I = 1,N, etc.)

data will be loaded into inputs 1000-1005. The load routine (SL~~Ø~~AD) will (1) load "over" a previous input, (2) skip loading a previously defined input when it reads a negative zero, and (3) stop the loading process by sensing a negative value in columns 1-12. The user may unload chain tape A4 by following the last data card with a card which has UNL~~Ø~~AD in columns 1-6. This card is printed on-line for the operator to note. A sample input sheet is shown in Figure 12.

C. PROGRAM OPTIONS

For all program options, the choice of steady-state or transient calculations is controlled by the input flag, XSTY:

For steady state: $A(2524) = XSTY = 1.0$

For transient case: $A(2524) = XSTY = 0.0$

1. Engine Options

For all hot-bleed engine options the NRX flag, XINRX = A(2559), must be set equal to zero.

a. Chamber Temperature-Chamber Pressure

(1) Steady State

$XIP\cancel{Ø}W = A(2272) = 0.0$

$PTPCV = A(218) = 0.0$

$XSTY = A(2524) = 1.0$

$XINRX = A(2559) = 0.0$

The user inputs the desired chamber temperature, TCF, and the desired chamber pressure, PCF, as well as an initial guess for the normalized power factor, P~~Ø~~WER. The program then changes P~~Ø~~WER and the TPCV setting until the desired TXC and PXC are obtained.

(2) Transient

$XIP\cancel{Ø}W = A(2272) = 0.0$

$PTPCV = A(218) = 0.0$

$XSTY = A(2524) = 0.0$

$XINRX = A(2559) = 0.0$

The user inputs the desired TXC ramp (for which at each time point $TXC = TCF * \phi RDTC$), and PXC ramp (for which at each time point $PXC = PCF * \phi RDPC$), as well as an initial time point guess for the power factor, $P\phi WER$. For each time step, the program then changes $P\phi WER$ and the TPCV setting until the desired TXC and PXC are obtained.

b. Chamber Temperature - TPCV

(1) Steady State

$$XIP\phi W = A(2272) = 0.0$$

$$PTPCV = A(218) = 1.0$$

$$XSTY = A(2524) = 1.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired TXC, TCF, and the desired TPCV setting (TPCVX), as well as initial guesses for the power factor ($P\phi WER$) and for PXC, PCG. The program then changes $P\phi WER$ and PXC until the desired TXC and TPCV are obtained.

(2) Transient

$$XIP\phi W = A(2272) = 0.0$$

$$PTPCV = A(218) = 1.0$$

$$XSTY = A(2524) = 0.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired TXC ramp (for which at each time point $TXC = TFC * \phi RDTC$), and TPCV ramp (for which at each time point $TPCV = \phi RDTC$), as well as an initial time point guess for the power factor ($P\phi WER$) and for PXC, PCG. For each time step, the program then changes $P\phi WER$ and PXC until the desired TXC and TPCV are obtained.

c. $P\phi WER$ - Chamber Pressure

(1) Steady State

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(2524) = 1.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired PXC, PCF, and the desired power factor ($P\phi WER$) as well as an initial guess for TXC, TCG. The program then changes TPCV and TXC until the desired $P\phi WER$ and PXC are obtained.

(2) Transient

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(2524) = 0.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired PXC ramp (for which at each time point $PXC = PCF * \phi RDPC$) and $P\phi WER$ ramp (for which at each time point $P\phi WER = \phi RDP\phi W$) as well as an initial time point guess for TXC, TCG. For each time step, the program then changes TXC and TPCV until the desired PXC and $P\phi WER$ are obtained.

d. $P\phi WER$ - TPCV

(1) Steady State

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 1.0$$

$$XSTY = A(2524) = 1.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired power factor ($P\phi WER$) and TPCV setting TPCVX, as well as an initial guess for TXC, TCG, and PXC, PCG. The program then changes TXC and PXC until the desired $P\phi WER$ and TPCVX are obtained.

(2) Transient

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 1.0$$

$$XSTY = A(2524) = 0.0$$

$$XINRX = A(2559) = 0.0$$

The user inputs the desired $P\phi WER$ ramp (for which at each time point $P\phi WER = \phi RDP\phi W$) and TPCV ramp (for which at each time point $TPCV = \phi RDTCV$) as well as an initial time point guess for TXC, TCG, and PXC, PCG. For each time

step, the program then changes PXC and TXC until the desired P~~OWER~~ and TPCV are obtained.

e. Control Logic Option

If a transient P~~OWER~~ option is being run ($XIP\phi W = 1.0$), temperature loop control will be switched to TXC when the value of TXC exceeds the input limit, TXCLIM. The demand then becomes the TXC ramp, $\phi RDTC$. If the user does not wish to switch temperature loop control during a case, TXCLIM must be set higher than the maximum TXC to be encountered during the case. If a transient TPCV option is being run ($PTPCV = 1.0$), the pressure loop control will be switched to PXC when the value of PXC exceeds the input limit, PXCLIM. The demand then becomes the PXC ramp, $\phi RDPC$. If the user does not wish to switch pressure loop control during a case, PXCLIM must be set higher than the maximum PXC to be encountered during the case.

By proper use of the control logic option, an engine startup may be initiated on P~~OWER~~-TPCV control. Control may then be switched independently to TXC and PXC at the desired levels of chamber temperature and pressure.

2. NRX Options

For all NRX options, the NRX flag, $XINRX = A(2559)$, must be set equal to 1.0. This permits the program to skip all heat exchanger and turbopump calculations.

a. Chamber Temperature-Chamber Pressure

(1) Steady State

$$XIP\phi W = A(2272) = 0.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(2524) = 1.0$$

$$XINRX = A(2559) = 1.0$$

The user inputs the desired TXC, TCF, and the desired PXC, PCF, as well as the desired H2F and an initial guess for the power factor, P~~OWER~~. The program then changes P~~OWER~~ and P2 until the desired TXC and PXC are obtained.

(2) Transient

$$XIP\phi W = A(2272) = 0.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(2524) = 0.0$$

$$XINRX = A(2559) = 1.0$$

The user inputs the desired TXC ramp (for which at each time point $TXC = TCF*\phi RDTC$) and PXC ramp (for which at each time point $PXC = PCF*\phi RDPC$) as well as the desired H2 ramp and an initial time point guess for the power factor, $P\phi WER$. For each time step, the program then changes $P\phi WER$ and P2 until the desired TXC and PXC are obtained.

b. Chamber Pressure - $P\phi WER$

(1) Steady State

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(2524) = 1.0$$

$$XINRX = A(2559) = 1.0$$

The user inputs the desired power factor ($P\phi WER$) and PXC, PCF, as well as the desired H2F and an initial guess for TXC, TCG. The program then changes TXC and P2 until the desired $P\phi WER$ and PXC are obtained.

(2) Transient

$$XIP\phi W = A(2272) = 1.0$$

$$PTPCV = A(218) = 0.0$$

$$XSTY = A(218) = 0.0$$

$$XINRX = A(2559) = 1.0$$

The user inputs the desired $P\phi WER$ ramp ($\phi RDP\phi W$) and PXC ramp ($\phi RDPC$) as well as the desired H2 ramp ($\phi RDH2$) and an initial time point guess for TXC, TCG. For each time step, the program then changes TXC and P2 until the desired $P\phi WER$ and PXC are obtained.

D. ERROR COMMENTS

CHAIN 11. Main Routine of Chain 1

a. "Mach Number out of range"

b. "Routine First, Bad Prpty lookup. Nostat = XXXXX

Data 1										
6										

Look at statement number. Probably low or high temperature or pressure input.

c. "First-Nostat is XXXXXXXX, I XXXXX, K XXXXX"

Bad lookup in READKM; check statement number. Probably bad temperature guess.

2. READKM

Error condition in main program will result when division by zero is attempted or error condition is indicated by VKM negative.

NFlagr = XX, MK = XXXX, TAVG = XXXXX, VKM = XXXX." Refer to 1,c.

3. SLOAD

"Bad input"

Probably zero numerical designation on the printed input card.

CHAIN 21. Main Routine

a. "Temperature Looping"

This means that the temperature loop (i.e., nozzle, reflector, shield, and core) cannot converge. Possibly bad input, but if correct, try changing relaxation coefficients or loosening tolerance values.

b. "Bad CPM K XXXX STAT NØ XXXX

MAT	SØLH	ØLD H	T	ØLD T
-----	------	-------	---	-------

XXXX	XXXXX	XXXXX	XXXXX	XXXXX"
------	-------	-------	-------	--------

This means that CPMN of nozzle or heat exchanger is negative.
Check material number and curves in READKM.

- c. "Nozzle temp. looping
NOZZLE temperatures"

There is no convergence within the nozzle relaxation loop.
Try changing relaxation coefficient or loosening tolerance values.

- d. "Heat exchanger does not converge"

Try changing relaxation coefficient or loosening tolerance.

- e. "Bad TPCV - XXXXX Nostat = XXXX"

Check inputs TPCVX and ϕ RDTCV(L).

TPCV greater than 90.

- f. "Shaft speed does not converge"

P2-P1 XXXXX W2 XXXXX VPSP XXXXXX XNS XXXXX"

Check curves in subroutine curve. The area of interest
may be outside these fits. Also P2-P1 may not be consistent with W2 value.

- g. "TPCV ϕ P. Rho2 No conv.

H2 XXXXX RH02 XXXXX RH02CK XXXXX"

Probably a bad parahydrogen properties area. Check
smoothness of Rho values through this area of interest.

- h. "Turbopump does not converge"

If pressure profiles look correct, try changing relaxation
coefficient or loosening tolerance. If PTPCV option is used, no relaxation is used.

- i. "Pl8 bad"

Negative Pl8 value.

- j. "System does not converge"

Pressure cycle not converged.

Probably ϕ WT (i.e., turbine power) and ϕ WP (i.e., pump
power) are not sufficiently matched. Possibly Tl8 not converged.

k. "Temperature and pressure looping"

l. "Routine second, bad prpty lookup.

Nostat = XXXXX

Data 1 XXXX XXXX XXXX XXXX XXXX

Data 6 XXXX XXXX XXXX XXXX XXXX "

Check statement number to determine type and values of lookup.

m. "Second-nostat is XXXX I XXXX K XXXX"

Bad lookup in READKM. Check material number and READKM tables. Possibly expand these tables.

2. Subroutine TEM 9

a. "TEM 9 CPM = XXXX I XXX K XXX ØLD Solid H XXXX

Solid H XXXX T XXXX MAT XXXX"

Check material number and curves in READKM.

b. "TEM 9 does not converge"

If inputs are correct, try changing relaxation coefficient or loosen tolerance value.

c. "Routine TEM 9, bad prpty lookup

Nostat = XXXX

Data 1 XXX XXX XXX XXX XXX

Data 6 XXX XXX XXX XXX XXX "

Check statement number for values used.

3. Function XFPI

a. "Routine XFPI, bad prpty lookup.

Nostat = XXXX

Data 1 XXX XXX XXX XXX XXX

Data 6 XXX XXX XXX XXX XXX "

Check values used for lookup.

4. Subroutine PARAH

a. "TEM 9 outside range"

Check if values used are in II phase or close to this area.

5. Subroutine Y2

a. "Routine Y2, bad prpty lookup"

Nostat = XXX

Data 1 XXX XXX XXX XXX XXX

6 XXX XXX XXX XXX XXX "

Check values used for lookup.

E. SUMMARY OF SUBROUTINES

CHAIN 11. Subroutine ~~SL~~AD (A)

This scatter load routine loads individual cards into five sequential locations starting with the location designated by column 1-12. The format is F12.0, 5E12.8. A value of negative zero will cause a load skip for that location. When column 1-12 is negative, that card will be loaded and the subroutine will return to the calling routine, thus terminating loading.

INPUT: array A

2. Subroutine READKM (T, MAT, VKM, Flag)

This FAP routine selects the curve given by MAT and performs linear interpolation with T and its interval values to get VKM. If bad input, Flag = 1; otherwise, Flag = 0.

INPUT: T, MAT

ØUTPUT: VKM, FLAG

3. Subroutine PARAH (Data, A, N, B, M, K)

This parahydrogen properties routine uses Aerojet Azusa Computing Sciences Division Job 373 (Thermodynamic Properties of Parahydrogen) to obtain the properties, given any two property values. This PARAH deck and Job 373 are used only in Chain 1 because we do pressure, temperature lookups in all regions.

INPUTS: Data array to fill in property values

A = given property

N = data number of A

B = second given property

M = data number of B

K = error flag (zero = good data; one = bad data)

OUTPUT: 8 data values

Data (1) = pressure

(2) = specific volume

(3) = enthalpy

(4) = entropy

(5) = quality

(6) = temperature

(7) = density

(8) = specific heat

(9) = conductivity

(10) = viscosity

4. Subroutine REWIND

Routine rewinds and unloads only unit A4.

CHAIN 2

1. Subroutine SECOND

Routine calls Chain 1

2. Subroutine DINT⁴

This Sacramento library routine used in subroutine CURVE.

3. Subroutine INT4

This Sacramento library routine used in subroutine CURVE.

4. Subroutine CURVE (P2-P1, W, VPSP, XNS)

FAP routine does iterative double linear interpolation with P2-P1 and W to get XNS. Uses liner interpolation on XNS values obtained on either side of VPSP to get final XNS.

INPUTS: P2-P1 = pressure drop through pump

W = flow through pump

VPSP = pressure into pump - vapor pressure

OUTPUT:

XNS = pump shaft speed

5. Subroutine CHECK (P2, P1, W)

Routine used in subroutine CURVE to see if P2-P1 and W are in the range of the fit.

6. Subroutine PARAH (Data,A, N, B, M, K)

Routine works in the same manner as PARAH of Chain 1 except that a different parahydrogen properties deck is used. The Los Alamos deck by O. Farmer (memorandum dated 28 September 1964) is used. This deck is a pressure, enthalpy routine; however, it will work for pressure, temperature lookups definitely not in II phase region. The Farmer deck was originally written in Fortran IV, but changed to FAP and Fortran II.

INPUT: Same as PARAH Chain 1

OUTPUT: Same as PARAH Chain 1 except Data (2) omitted.

7. Function XFPI (T, P)

Routine computes (conductivity^{0.6}) (CP/Visc.)^{0.4}. Uses curve fit for $T \leq 3000$.

INPUT: T-temp. and P-pressure

8. XP18 (W18, T18, CT5, P18, P19)

Routine computes P18 using quadratic if $P18/P19 < CT5RAT$

INPUT: W18 - flow, T18 - temp., CT5, P19 = pressure

OUTPUT: P18

9. XCP (T, T2, H, H2)

Routine computes $(T2-T)/(H2-H)$

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TABLE 1

STATION DESIGNATIONS

<u>SYMBOL</u>	<u>LOCATION</u>
Z	PROPELLANT TANK
1	PUMP INLET
2	PUMP DISCHARGE
4	PUMP DISCHARGE LINE OUTLET (NOZZLE OUTLET)
5	REFLECTOR INLET (NOZZLE EXIT)
6	SHIELD INLET (REFLECTOR EXIT)
7	CORE INLET (SHIELD EXIT)
10	COMPUTED CHAMBER CONDITIONS
14	CONDITIONS JUST AFTER MIXING OF DILUENT AND HOT BLEED IN THE HOT BLEED PORT
15	INLET TO DILUENT SIDE OF TURBINE INLET LINE HEAT EXCHANGER
16	DILUENT ORIFICE INLET
17	TURBINE INLET LINE ORIFICE INLET
17P5	TURBINE POWER CONTROL VALVE INLET
18	TURBINE INLET
19	TURBINE EXHAUST
21	TANK PRESSURIZATION BLEED CONDITIONS
C	DEMANDED CHAMBER CONDITIONS

Table 1

Figure 1

Cycle Schematic Diagram, NERVA Hot-Bleed Engine

Figure 2

NERVA Hot-Bleed Engine Functional Diagram

Figure 3

Cycle Schematic Diagram, NRX Option

Figure 4

General Thermal Network Diagram

Figure 5

Nozzle Thermal Network Diagram

Figure 6

Heat Exchanger Thermal Network Diagram

Figure 7

Pressure-Flow Network Diagram

TUBE WITH ENTIRE SURFACE AT ONE WALL TEMPERATURE

TUBE WITH HALF OF ITS SURFACE AT ONE WALL TEMPERATURE
AND THE OTHER HALF AT ANOTHER

Figure 9

Network for Heat Transfer in a Tube

Figure 10
Fluid Element

Figure 11

Logic Diagram for Subroutine TEM 9

FORTRAN FLOATING DATA

ANALYST								DATE				WORK ORDER				JOB NUMBER				PAGE OF				SEQ
1	2	9	10	13	14	21	22	25	26	33	34	37	38	45	46	49	50	57	58	61	62	69	70	
CASE 1				SAMPLE				INPUT				TITLE				9/30/64								
001		-		1		+	01	2		+	01	3		+	01	4		+	01	5		+	01	
006		-		6		+	20	70		+	02	3		-	01	2		-	02	05		+	00	
100		-		0		+	00	5		+	01	600		+	03	20		+	02	21		+	02	
050		-		7		+	01	62		+	00	45		+	01	5		+	00	100		+	03	
009		-		4		+	00	5		+	00	10		+	01	20		+	02	30		+	01	
100		-		0		-		400		+	02	0		-		0		-		0		-		
500		-		1		+	01	2		+	01	3		+	01	4		+	01	5		+	01	
CASE 2								9/30/64																
001		-		11		+	01	0		-		0		-		0		-		55		+	01	
		-				-				-				-				-				-		
UNLOAD TAPE B3 AND RETURN TO BIN																								

Figure 12

Sample Input Sheet

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APPENDIX A

PROGRAM NOMENCLATURE

I. INPUT DATA LIST*

Input locations for all input data (including that necessary to describe the nozzle jacket) are included in this appendix. It should be noted that when the program without the nozzle jacket is being used, data pertaining specifically to the nozzle jacket must not be input.

<u>Numerical Designation</u>	<u>Variable</u>	<u>Numerical Designation</u>	<u>Variable</u>
1	TAU	263-282	AN (20)
2	CDELTA	283-302	RHN (20)
3	N25	303-322	DN (20)
4	YOUTN (not used)	323-342	Z3NX (20)
5	CCOEFF	343-362	CNX (20)
6	PCF	363-382	ARATIO (20)
7	TCF	383-402	EN (20)
8	H2F	403-422	SFN (20)
9	PAF	423-442	ALN (20)
10	POWER	443-462	AK4 (20)
11-61	ORDH2 (51)	463-472	ALPHAR (10)
62-112	ORDTC (51)	473-482	AREAR (10)
113-163	ORDPC (51)	483-492	AR (10)
164-214	ORDPA (51)	493-502	XKR (10)
215	CGAMMA	503-522	RHR (20)
216	CXMW	523-622	DR (100)
217	TPCVX	623-722	Z3R (100)
218	PTPCV	723-822	CR (100)
219	Not used	823-832	ALPHAS (10)
220	DNT	833-842	AREAS (10)
221	CTWALL (not used)	843-852	AS (10)
222	XKN	853-862	XKS (10)
223-242	ALPHAN (20)	863-872	RHS (10)
243-262	Not used	873-972	DS (100)

* For definition of all variables, see Section II (Nomenclature Definitions) of this appendix.

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<u>Numerical Designation</u>	<u>Variable</u>	<u>Numerical Designation</u>	<u>Variable</u>
973-1072	Z3S (100)	2273-2292	Not used
1073-1172	CS (100)	2293	PCON1
1173-1182	ALPHAC (10)	2294	PCON2
1183-1192	AREAC (10)	2295	PCON3
1193-1202	AC (10)	2296	PCON4
1203-1212	XKC (10)	2297	WCON1
1213-1222	RHC (10)	2298	WCON2
1223-1232	E (10)	2299	DH
1233-1242	SF (10)	2300	AHC
1243-1252	Al (10)	2301	RHD
1253-1352	DC (100)	2302	AHH
1353-1452	Z3C (100)	2303	RHH
1453-1552	CC (100)	2304-2313	Z3HX (10)
1553-1572	FLUXN (20)	2314-2323	CHX (10)
1573-1672	FLUXR (100)	2324-2333	FLUXH (10)
1673-1772	FLUXS (100)	2334-2344	THEZER (11)
1773-1872	FLUXC (100)	2345	AREADT
1873-1892	TCZERN (20)	2346	AREADO
1893-1992	TCZERR (100)	2347	AHBP
1993-2092	TCZERS (100)	2348	RHBP
2093-2192	TCZERC (100)	2349	DHBP
2193	TMAX	2350	AREATO
2194	COEFS	2351	CBPT
2195	COEFR	2352	CP1
2196	COEFC	2353	CP2
2197	HMAX	2354	CP3
2198	TRNO	2355	CP4
2199	TURBM	2356	CPS
2200	THKTD	2357	XNSS
2201-2220	THIK (20)	2358	CT1
2221-2271	ORDPOW (51)	2359	CT2
2272	XIPOW	2360	CT3

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<u>Numerical Designation</u>	<u>Variable</u>	<u>Numerical Designation</u>	<u>Variable</u>
2361	CT4	2418-2427	WHST (10) (not used)
2362	CT5	2428	TXCTOL
2363	APD1	2429	PXCTOL
2364	RHPD1	2430	T18TOL
2365	DPD1	2431	TTOLER
2366	TZ	2432	PTOLER
2367	PZ	2433	COHEX
2368	V4	2434	COTUR
2369	V5	2435	YKA
2370	V6	2436	T9S
2371	V7	2437	T9R
2372	V10	2438	T9C
2373	V14	2439	POWTOL
2374	WYEDT	2440-2491	ORDTCV (51)
2375	WYDST (not used)	2492	TCG
2376	WYBPT (not used)	2493	PCG
2377	WYENT (not used)	2494	TXCLIM
2378	YRN (not used)	2495	PXCLIM
2379	P1 (not used)	2496-2499	Not used
2380	P2 (not used)	2500	XLIMIT
2381	XIR	2501	XMINOR
2382	P4 (not used)	2502	XI1
2383	P5 (not used)	2503	XI2
2384	P6 (not used)	2504	XI3
2385	P7 (not used)	2505	XI4
2386	P14 (not used)	2506	XI5
2387	C19	2507	XI6
2388-2397	PDST (10) (not used)	2508	XI7
2398-2407	WDST (10) (not used)	2509	XI8
2408-2417	PHST (10) (not used)	2510	XITEMI

<u>Numerical Designation</u>	<u>Variable</u>	<u>Numerical Designation</u>	<u>Variable</u>
2511	XIPI	2533-2537	XMATS (5)
2512	XITI	2538-2542	XMATC (5)
2513	XITNI	2543	XMATH
2514	EMN	2544-2548	SMATR (5)
2515	EMR	2549-2553	SMATS (5)
2516	EMS	2554-2558	SMATC (5)
2517	EMC	2559	XIRNX
2518	XMH	2560-2579	TCZERJ (20)
2519	XM	2580-2599	FLUXJ (20)
2520	XNR	2600-2619	CNXJ (20)
2521	FNS	2620-2639	Z3JX (20)
2522	XNC	2640	XMATNJ
2523	XNN	2641	XMKNJ
2524	XSTY	2642	DRNT
2525	XMKN	2643	XPRATR
2526	XMKTD	2644	XPRATM
2527	XMATN	2645	EFFMN
2528-2532	XMATR (5)	2646	EFFRN
		2647	CT5RAT

II. NUCLEAR ENGINE TRANSIENT ANALYSIS PROGRAM NOMENCLATURE

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
A(L)	Location (L) in the general scatter load input array	
Al(I)	Surface area of bottom face of core for channel type (I) for thermal radiation to nozzle, in. ²	1243-1252
AlN(K)	Surface area of nozzle segment (K) for thermal radiation to bottom face of core, in. ²	423-442
AC(I)	Flow area for a core channel of Type (I), in. ²	1193-1202
AHBP	Flow area of hot-bleed port inlet, in. ²	2347
AHC	Flow area on diluent side of heat exchanger, in. ²	2300
AHH	Flow area on turbine drive fluid side of heat exchanger, in. ²	2302
AK4(K)	Coefficient in nozzle hot-side heat transfer correlation for nozzle segment (K)	443-462
ALPHAC(I)	Number of core channels of channel Type (I)	1173-1182
ALPHAN(K)	Number of nozzle tubes for segment (K)	223-242
ALPHAR(I)	Number of reflector channels of channel Type (I)	463-472
ALPHAS(I)	Number of shield channels of channel Type (I)	823-832
AN(K)	Flow area for nozzle segment (K) for one tube, in. ²	263-282
ANT	Nozzle hot-side throat area, in. ²	
APD1	Flow area of pump inlet line, in. ²	2363
AR(I)	Flow area for a reflector channel of Type (I), in. ²	483-492
ARATIO(K)	Nozzle area ratio for segment (K) greater than 1.0 for divergent flow; less than -1.0 for convergent flow (the sign denotes only convergent or divergent)	363-382
AREAC(I)	Core inlet loss orifice passage area, channel Type (I), in. ²	1183-1192
AREADO	Diluent orifice area, in. ²	2346
AREADT	Area of trim orifice in diluent line, in. ²	2345
AREAR(I)	Reflector inlet loss orifice passage area, channel Type (I), in. ²	473-482
AREAS(I)	Shield inlet loss orifice passage area, channel Type (I), in. ²	833-842
AREATO	Area of trim orifice in turbine inlet line, in. ²	2350
AS(I)	Flow area for a shield channel of Type (I), in. ²	843-852

Variable	Description	Numerical Designation
CBPT	Loss coefficient for hot-bleed port inlet, ft/lbm-sec	2351
CC(I,K)	Mass associated with core solid material node (K) of channel Type (I), lbm	1453-1552
CCOEFF	Relaxation coefficient for nozzle calculations	5
CDELTA	Time step between calculated time points, seconds (called Delta in Program)	2
CFVAC	Vacuum thrust coefficient	
CFVACM	CFVAC for main nozzle	
CFVACR	CFVAC for roll nozzle	
CGAMMA	Ratio of specific heats (called Gamma in Program)	215
CHNOC	Summation of all ALPHAC(I), i.e., total number of core channels	
CHNOR	Summation of all ALPHAR(I), i.e., total number of reflector channels	
CHNOS	Summation of all ALPHAS(I), i.e., total number of shield channels	
CHX(K)	Mass associated with heat exchanger wall solid material node (K), lbm	2314-2323
CJ	Mechanical equivalent of heat = 778 ft-lb/Btu	
CNX(K)	Mass associated with nozzle tube solid material node (K), lbm	343-362
CNXJ(K)	Mass associated with nozzle jacket solid material node (K), lbm	2600-2619
CO	Isentropic spouting velocity for turbine, ft/sec	
COEFC	Relaxation coefficient for core calculations	2196
COEFF	General relaxation coefficient which is assigned a particular value for each component calculation	
COEFR	Relaxation coefficient for reflector calculations	2195
COEFS	Relaxation coefficient for shield calculations	2194
COHEX	Relaxation coefficient for the heat exchanger calculations	2433
COTUR	Relaxation coefficient for pressure calculations	2434
C1	$\text{SQRTF}(2*\text{Gamma}/(\text{Gamma}-1.0))/(\text{SQRTF}((\text{Gamma}+1.0)/(\text{Gamma}-1.0))*(((\text{Gamma}+1.0)/2.0)**(1.0/(\text{Gamma}-1.0))))$, a constant used in Subroutine Y1	

Variable	Description	Numerical Designation
C2	$(\text{SQRTF}((\text{Gamma}+1.0)/(\text{Gamma}-1.0))*((\text{Gamma}+1.0)/2.0)**(1.0/(\text{Gamma}-1.0))))$, a constant used in Subroutine Y1	
Cl9	Coefficient for roll nozzle = $W18*\text{SQRTF}(T19)/P19$	2387
CP	Specific heat of coolant fluid, Btu/lbm degrees R	
CP1	Conversion factor = $Q1(\text{RHO2})/W1 = 0.2598 \text{ gal-sec/min ft}^3$	2352
CP2,CP3,CP4	Coefficients in equation for pump efficiency, $\text{ETAP} = \text{CP2}(Q1/\text{XNS})*(Q1/\text{XNS}) + \text{CP3}(Q1/\text{XNS}) + \text{CP4}$	2353-2355
CPS	Conversion factor for turbopump power equation = .132	2356
CR(I,K)	Mass associated with reflector solid material node (K) of channel Type (I), lbm	723-822
CRIT	$(2.0/(\text{Gamma}+1.0))*(\text{Gamma}/(\text{Gamma}-1.0))$, a constant used in Subroutine Y1	
CS(I,K)	Mass associated with shield solid material node (K) of channel Type (I), lbm	1073-1182
CTL	Conversion factor = $U/\text{XNS} = 0.04768$	2358
CT2,CT3,CT4	Coefficients in equation for turbine efficiency, $\text{ETAT} = \text{CT2}(U/\text{CO})(U/\text{CO})(U/\text{CO}) + \text{CT3}(U/\text{CO})(U/\text{CO}) + \text{CT4}(U/\text{CO})$	2359-2361
CT5	Coefficient for turbine inlet nozzle = $W18 \text{ SQRTF}(T18)/P18$ at design	2362
CT5RAT	Turbine pressure ratio at which turbine inlet nozzle becomes sonic	2647
CW4,CW5,CW6, CW7,CW10,CW14	Mass capacitance conductances at the respective plenums, $\text{lbm-in.}^2/\text{lb-sec}$	
CXMW	Molecular weight of fluid, lbm/lb-mole (called XMW in program)	216
DATA(1)	Static pressure, psia	
DATA(2)	Fluid specific volume, $\text{in.}^3/\text{lbm}$	
DATA(3)	Fluid enthalpy, Btu/lbm	
DATA(4)	Fluid entropy, Btu/sec-Deg R	
DATA(5)	Fluid quality	
DATA(6)	Fluid static temperature, Deg R	
DATA(7)	Fluid density, lbm/ft^3 in chain 1 and lbm/in.^3 in chain 2	
DATA(8)	Fluid heat capacity, Btu/lbm-deg R	

Variable	Description	Numerical Designation
DATA(9)	Fluid thermal conductivity, Btu/in.-sec-Deg R	
DATA(10)	Fluid viscosity, lbm/in.-sec	
DC(I,K)	Length of core passage segment (K), channel Type (I), in.	1253-1352
DDD(K)	$XMACH * XMACH * (\text{Gamma} - 1.0) / 2.0$, a constant used to calculate TAR, TBB, and PHX for nozzle segment (K)	
DELH	Pump head rise, in.	
DELTA	CDELTA	
DH	Length of heat exchanger segment, in.	2299
DHBP	Equivalent length of hot-bleed port, in.	2347
DIV	0.63212, a constant used in Subroutine YL	
DN(K)	Length of nozzle passage segment (K), in.	303-322
DNT	Nozzle throat diameter, in.	220
DP	Change in pressure across component, lbf/in. ²	
DPD1	Equivalent length of pump inlet line, in.	2365
DR(I,K)	Length of reflector passage segment (K), channel Type (I), in.	523-622
DRNT	Diameter of roll nozzle throat, in.	2642
DS(I,K)	Length of shield passage segment (K), channel Type (I), in.	873-972
DT	Change in temperature across component, degrees R	
E(I)	Emissivity of bottom face of a core channel of Type (I)	1223-1232
EEFMN	Efficiency of main nozzle (fraction)	2645
EFFRN	Efficiency of roll nozzle (fraction)	2646
EMC	Number of core fluid nodes per channel (called MC in program)	2517
EMN	Number of nozzle tube fluid nodes = number of nozzle jacket fluid nodes (called MN in program)	2514
EMR	Number of reflector fluid nodes per channel (called MR in program)	2515
EMS	Number of shield fluid nodes per channel (called MS in program)	2516
EN(K)	Emissivity of nozzle inner surface for segment (K)	383-402

Variable	Description	Numerical Designation
ERROR(K)	Flow residual at relaxation node (K), Btu/sec for heat flow or lb/sec for mass flow	383-402
ETAP	Pump efficiency	
ETAT	Turbine efficiency	
EXPRAT	Nozzle expansion ratio	
FIG	$((4.0/PI)**0.8)/DNT**1.8$	
FLUXC(I,K)	Nuclear heat generation rate in core solid node (K), channel type (I), at design point, Btu/sec	1773-1872
FLUXJ(K)	Nuclear heat generation rate in nozzle jacket solid node (K), at design point, Btu/sec	2580-2599
FLUXH(K)	Nuclear heat generation rate in heat exchanger duct wall solid node (K), at design point, Btu/sec	2324-2333
FLUXN(K)	Nuclear heat generation rate in nozzle tube solid node (K), at design point, Btu/sec	1553-1572
FLUXR(I,K)	Nuclear heat generation rate in reflector solid node (K), channel type (I), at design point, Btu/sec	1573-1672
FLUXS(I,K)	Nuclear heat generation rate in shield solid node (K), channel type (I), at design point, Btu/sec	1673-1772
FMAIN	Main nozzle thrust, lbf	
FNS	Number of shield channel types (called NS in program)	2521
FPI	$(CP**0.4)*(XC**0.6)/(XMU**0.4)$	
FROLL	Total roll nozzle thrust, lbf	
FTOT	Total engine thrust, lbf	
GAMMA	CGAMMA	
GC	Conversion factor = $32.2 \text{ (lbm/lbf) (ft/sec}^2\text{)}$	
H(K)	(Subroutine TEM9) Heat transfer coefficient for passage segment (K), Btu/in. ² -sec-deg R	
H1	Fluid enthalpy at pump inlet, Btu/lbm	
H2	Fluid enthalpy at pump discharge, Btu/lbm	
H4	Fluid enthalpy at nozzle torus, Btu/lbm	
H5	Fluid enthalpy at reflector inlet, Btu/lbm	
H6	Fluid enthalpy at shield inlet, Btu/lbm	
H7	Fluid enthalpy at core inlet, Btu/lbm	
H8	Fluid enthalpy at nozzle chamber, Btu/lbm	
H14	Fluid enthalpy at mixture point in hot bleedport, Btu/lbm	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
H18	Fluid enthalpy at turbine inlet, Btu/lbm	
H19	Fluid enthalpy at turbine exit, Btu/lbm	
H1D2	Pump head rise, ft	
H2F	H2 at design, Btu/lbm (for NRX option only)	8
HCCAL	Coefficient including all non-temperature dependent terms of diluent side heat transfer coefficient for heat exchanger, $1N^{**}1.8$	
HCCON(K)	Coefficient including all non-temperature dependent terms of cold-side heat transfer coefficient for nozzle segment (K), $in.^{*}1.8$	
HD(K)	Heat transfer coefficient for diluent side of heat exchanger at fluid node (K), $BTU/in.^2\text{-sec-deg R}$	
HH(K)	Heat transfer coefficient for hot-side of heat exchanger at fluid node (K), $Btu/in.^2\text{-sec-deg R}$	
HH(I,K)	(Subroutine TEM9) specific enthalpy of fluid node (K), channel type (I), Btu/lbm	
HHC(I,K)	Core fluid specific enthalpy at fluid node (K), channel type (I), Btu/lbm	
HHCAL	Coefficient including all non-temperature dependent terms of hot-side heat transfer coefficient for heat in changer, $in.^{*}1.8$	
HHCON(K)	Coefficient including all non-temperature-dependent terms of hot-side heat transfer coefficient for nozzle segment (K), $in.^{*}1.8$	
HHHD(K)	He diluent side fluid specific enthalpy at fluid node (K), Btu/lbm	
HHHT(K)	He turbine inlet-side drive fluid specific enthalpy at fluid node (K), Btu/lbm	
HHN(K)	Nozzle cold-side fluid specific enthalpy at fluid node (K), Btu/lbm	
HHR(I,K)	Reflector fluid specific enthalpy at fluid node (K), channel type (I), Btu/lbm	
HHS(I,K)	Shield fluid specific enthalpy at fluid node (K), channel type (I), Btu/lbm	
HHXC	Specific fluid enthalpy at chamber conditions, Btu/lbm	
HMAX	Maximum number of iterations in heat exchanger per pass	2197
HOSOL(I,K)	(Subroutine TEM9) HSOL(I,K) from previous time step, Btu/lbm	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
HOSOLC(I,K)	HSOLC(I,K) from previous time step, Btu/lbm	
HOSOLH(K)	HSOLH(K) from previous time step, Btu/lbm	
HOSOLN(K)	HSOLN(K) from previous time step, Btu/lbm	
HOSOLR(I,K)	HSOLR(I,K) from previous time step, Btu/lbm	
HOSOLS(I,K)	HSOLS(I,K) from previous time step, Btu/lbm	
HSOL(I,K)	(Subroutine TEM9) specific solid material enthalpy for node (K), channel type (I), Btu/lbm	
HSOLC(I,K)	Specific solid material enthalpy for core node (K), channel type (I), Btu/lbm	
HSOLH(K)	Specific solid material enthalpy for heat exchanger node (K), Btu/lbm	
HSOLN(K)	Specific solid material enthalpy for nozzle tube node (K), Btu/lbm	
HSOLR(I,K)	Specific solid material enthalpy for reflector node (K), channel type (I), Btu/lbm	
HSOLS(I,K)	Specific solid material enthalpy for shield node (K), channel type (I), Btu/lbm	
I	Index for channel type number	
I1	X11	
I2	X12	
I3	X13	
I4	X14	
I5	X15	
I6	X16	
I7	X17	
I8	X18	
II	Counter for time steps between major input time intervals, TAU	
IPI	XIPI	
IPOW	XIPOW	
ISTEDY	XSTY	
ITEMI	XITEMI	
ITFLAH	General nonconvergence flag Positive - some iteration loop has failed to converge Zero or negative - no nonconvergence	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
ITI	XITI	
ITMAX	Maximum number of iterations in the pressure loop	
ITNI	XITNI	
ITRNO	Pressure loop iteration counter	
K	Index for axial node number	
LATCH	Overall system convergence flag Latch = 1, system has not yet converged at this time step Latch = 2, system has converged at this time step	
LIMIT	XLIMIT	
LIST	Index for number of time points for which time varying functions are defined	
M	(Subroutine TEM9) number of fluid nodes per channel.	
M1C	MC-1 = number of core solid nodes per channel	
M1H	MH-1 = number of heat exchanger solid nodes	
M1N	MN-1 = number of nozzle tube solid nodes = number of nozzle jacket solid nodes	
M1R	MR-1 = number of reflector solid nodes per channel	
M1S	MS-1 = number of shield solid nodes per channel	
MATC(I)	XMATC(I)	
MATH	XMATH	
MAJOR	Number of calculational time steps per input profile time interval, TAU	
MATN	XMATN	
MATR(I)	XMATR(I)	
MATS(I)	XMATS(I)	
MATSC(I)	SMATC(I)	
MATSR(I)	SMATR(I)	
MATSS(I)	SMATS(I)	
MC	EMC	
MH	XMH	
MINOR	XMINOR	
MKN	XMKN	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
MKTD	XMKTD	
MN	EMN	
MR	EMR	
MS	EMS	
N	(Subroutine TEM9) number of channel types	
N25	TRNO - number of allowable undamped pressure loop iterations (this input controls all program calculational damping)	3
NC	XNC	
NN	XNN	
NR	XNR	
NS	FNS	
ORDH2(LIST)	Normalized value of H2 at end of list-1 time intervals TAU (for NRX option only).	11-61
ORDPA(LIST)	Normalized value of PA at end of list-1 time intervals TAU.	164-214
ORDPC(LIST)	Normalized value of PXC at end of list-1 time intervals TAU (for PC option only)	113-163
ORDPOW(LIST)	Normalized value of power at end of list-1 time intervals TAU (for POWER option only)	2221-2271
ORDTCV(LIST)	Normalized value of TPCV at end of list-1 time intervals TAU (for TPCV option only)	2440-2491
ORDTC(LIST)	Normalized value of PXC at end of list-1 time intervals TAU (for TC option only)	62-112
P(I,K)	(Subroutine TEM9) fluid static pressure at fluid node (K), channel type (I), lbf/in. ²	
P1	Fluid pressure at pump inlet, psia	
P2	Fluid pressure at pump exit, psia	
P4	Fluid pressure at nozzle inlet, psia	
P5	Fluid pressure at reflector inlet, psia	
P6	Fluid pressure at shield inlet, psia	
P7	Fluid pressure at core inlet, psia	
P10	Computed core exit pressure, psia	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
Pl4	Static pressure in bleed port, psia	
Pl6	Pressure on inlet side of diluent orifice, psia	
Pl7	Fluid pressure on inlet side of turbine power control valve orifice, psia	
Pl7P5	Turbine power control valve inlet pressure, psia	
Pl8	Turbine inlet pressure, psia	
Pl9	Turbine exit pressure, psia	
PA	Ambient pressure, psia	
PAF	Ambient pressure at design point, psia	9
PC(I,K)	Core fluid pressure at fluid node (K), channel type (I), node (K), psia	
PCF	Chamber pressure at design, psia	6
PCG	Initial guess for PXC at first time step in a TPCV option, deg R	2493
PCON1	Constant used for first guess at Pl7 = (Pl7-PA)/(Pl4-PA) at design	2293
PCON2	Constant used for first guess at Pl7P5 = (Pl7P5-PA)/(Pl4-PA) at design	2294
PCON3	Constant used for first guess at Pl8 = (Pl8-PA)/(Pl4-PA) at design	2295
PCON4	Constant used for first guess at Pl9 = (Pl9-PA)/(Pl4-PA) at design	2296
FDST(K)	Pressure in diluent side of heat exchanger at fluid node K, psia	
PHST(K)	Pressure in turbine inlet side of heat exchanger at fluid node (K), psia	
PHX(K)	Nozzle hot-side static pressure for segment (K), psia	
PI	3.1416	
PN(K)	Nozzle fluid pressure at fluid node (K), psia	
POWER	Nuclear heat generation/nuclear heat generation at design, equivalent to power factor	10
POWP	Pump power, in-lbf/sec	
POWT	Turbine power, in-lbf/sec	
POWTOL	Normalized convergence tolerance to test equality of pump and turbine powers (POWP and POWT)	2439

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
PR(I,K)	Reflector fluid pressure at fluid node (K), channel type (I), psia	
PS(I,K)	Shield fluid pressure at fluid node (K), channel type (I), psia	
PSIC(I)	Thermal radiation parameter for radiation from bottom face of core channel type (I) to inner surface of nozzle, Btu/sec-deg R**4	
PSIN(K)	Thermal radiation parameter for radiation to inner surface of nozzle segment (K) from bottom face of core, Btu/sec-deg R**4	
PSIR(I)	Dummy parameter	
PSIS(I)	Dummy parameter	
PTOLER	Normalized convergence tolerance on pressure-flow calculations	2432
PTPCV	Flag for TPCV option PTPCV = 1.0, turbine power control valve option PTPCV = 0.0, chamber pressure option	218
PXC	Nozzle chamber pressure, psia	
PXCL	PXC from time point two time steps preceding, psia	
PXCLIM	Value of PXC at which control is switched from TPCV to PXC in pressure loop, deg R	2495
PXCTOL	Normalized convergence tolerance on PXC calculation	2429
PZ	Fluid pressure at the tank, psia	2367
Q1	Pump volume flow rate, gal/min	
Q1(I,K)	(Subroutine TEM9) heat flow carried by coolant in channel type (I), from fluid node (K) to (K+1), Btu/sec	
Q1H(K)	Heat exchanger convective heat flow from solid material node (K) to diluent fluid between fluid nodes (K) and (K+1), Btu/sec	
Q1N(K)	Nozzle heat flow carried by coolant from fluid node (K) to (K+1), Btu/sec	
Q2(I,K)	(Subroutine TEM9) convective heat flow from solid material node (K) to coolant between fluid nodes (K) and (K+1), channel type (I), Btu/sec	
Q2H(K)	Heat exchanger convective heat flow from turbine drive fluid between nodes (K) and (K+1) to solid material node (K), Btu/sec	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
Q2N(K)	Nozzle convective heat flow from solid material node (K) to coolant between fluid nodes (K) and (K+1) Btu/sec	
Q3(I,K)	(Subroutine TEM9) conductive heat flow axially from solid nodes (K) to (K-1), channel type (I), Btu/sec	
Q3C(I,K)	Q3(I,K) for core	
Q3H(K)	Heat exchanger duct wall conductive heat flow axially from solid node (K+1) to (K), Btu/sec	
Q3N(K)	Nozzle tube conductive heat transfer axially from solid node (K) to (K-1), Btu/sec	
Q3R(I,K)	Q3(I,K) for reflector	
Q3S(I,K)	Q3(I,K) for shield	
Q4N(K)	Convective heat transfer from hot-gas fluid node (K) to nozzle tube solid node (K), Btu/sec	
Q5N(K)	Radiative heat transfer from core face to nozzle tube solid node (K), Btu/sec	
QC(I,K)	Core nuclear heat generation rate at solid node (K) channel type (I), Btu/sec	
QH(K)	Heat exchanger duct wall nuclear heat generation rate at solid node (K), Btu/sec	
QN(K)	Nozzle tube nuclear heat generation rate at solid node (K), Btu/sec	
QR(I,K)	Reflector nuclear heat generation rate at solid node (K), channel type I, Btu/sec	
QS(I,K)	Shield nuclear heat generation rate at solid node (K), channel type I, Btu/sec	
QUALC(I,K)	Fluid quality at core fluid node (K), channel type (I)	
QUALHD(K)	Fluid quality at diluent fluid node (K)	
QUALHT(I)	Fluid quality at heat exchanger turbine inlet side fluid node (K)	
QUALN(K)	Fluid quality at nozzle fluid node (K)	
QUALR(I,K)	Fluid quality at reflector fluid node (K), channel type (I)	
QUALS(I,K)	Fluid quality at shield fluid node (K), channel type (I)	
R	Universal gas constant = 1.987 btu/lb-mole deg R	
RECOV	Recovery factor	
RELAX(K)	Relaxation coefficient/sum of conductances for node (K)	

Variable	Description	Numerical Designation
RHBP	Hydraulic radius of hot-bleed port, in.	2348
RHC(I,K)	Core passage hydraulic radius at fluid node (K), channel type I, in.	1213-1222
RHD	Hydraulic radius on diluent side of heat exchanger, in.	2301
RHH	Hydraulic radius on hot side of heat exchanger, in.	2303
RHN(K)	Nozzle passage hydraulic radius at fluid node (K), in.	283-302
RHO	Fluid density, lbm/in. ³	
RHPD1	Hydraulic radius of pump inlet line, in.	2364
RHR(I,K)	Reflector passage hydraulic radius at fluid node (K) channel type I, in.	503-522
RHS(I,K)	Shield passage hydraulic radius at fluid node (K) channel type I, in.	863-872
S(I,K)	(Subroutine TEM9) heat storage rate in solid material node (K), channel type (I), Btu/sec	
SC(I,K)	S(I,K) for core	
SF(I)	Blackbody shape factor for thermal radiation of bottom face of core channel type (I)	1233-1242
SFN(K)	Blackbody shape factor for thermal radiation of inner surface of nozzle node (K)	403-422
SH(K)	Heat storage rate in heat exchanger solid material node (K), Btu/sec	
SIGMA	Boltzmann constant = 3.356×10^{-15} Btu/sec in ² (degrees R) ⁴	
SMATC(I)	Number of table in subroutine READKM for solid material enthalpy of core channel type (I). (Called MATSC(I) in program)	2554-2558
SMATR(I)	Number of table in subroutine READKM for solid enthalpy of reflector channel type (I). (Called MATSR(I) in program)	2544-2548
SMATS(I)	Number of table in subroutine READKM for solid material enthalpy of shield channel type (I). (Called MATSS(I) in program)	2549-2553
SN(K)	Heat storage rate in nozzle tube solid material node (K), Btu/sec	
SR(I,K)	S(I,K) for reflector	
SS(I,K)	S(I,K) for shield	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
T(I,K)	(Subroutine TEM9) fluid temperature at fluid node (K), channel type (I), deg R	
T1	Fluid temperature at pump inlet, deg R	
T2	Fluid temperature at pump outlet, deg R	
T4	Fluid temperature at nozzle inlet, deg R	
T5	Fluid temperature at reflector inlet, deg R	
T6	Fluid temperature at shield inlet, deg R	
T7	Fluid temperature at core inlet, deg R	
T9C	Normalized convergence tolerance for core solid temperature calculations	2438
T9R	Normalized convergence tolerance for reflector solid temperature calculations	2437
T9S	Normalized convergence tolerance for shield solid temperature calculations	2436
T10	Computed mixed-mean core exit temperature, deg R	
T14	Fluid temperature in bleed port after mixing of diluent and hot bleed, deg R	
T16	Fluid temperature at diluent orifice, deg R	
T16T	Diluent temperature at diluent orifice throat, degrees R	
T17	Fluid temperature at inlet to turbine power control valve orifice, deg R	
T17P5	Fluid temperature at turbine power control inlet, deg R	
T18	Fluid temperature at turbine inlet, degrees R	
T18TOL	Normalized convergence tolerance on T18 calculation	2430
T19	Fluid temperature at turbine exit, deg R	
TAR(K)	Adiabatic recovery temperature on hot side of nozzle at nozzle solid node K, deg R	
TAU	Time interval between points at which time varying functions are defined, sec	1
TBB(K)	Bulk static temperature of fluid on hot side of nozzle at nozzle solid node (K), deg R	
TC(I,K)	(For main program) fluid temperature at core fluid node (K), channel type (I), deg R (Subroutine TEM9) solid material temperature at node (K), channel type (I), deg R.	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
TCC(I,K)	Core solid material temperature at solid node (K), channel type I, deg R	
TCF	Chamber temperature at design, degrees R	7
TCG	Initial guess for TXC at first time step in a power option, deg R	2492
TCJ(K)	Nozzle jacket solid material temperature at solid node (K), deg R	
TCN(K)	Nozzle tube solid material temperature, at solid node K, deg R	
TCO(I,K)	(Subroutine TEM9) TC(I,K) from previous time step, deg R	
TCOC(I,K)	TCC(K,K) from previous time step, deg R	
TCON(K)	TCN(K) from previous time step, deg R	
TCOR(I,K)	TCR(I,K) from previous time step, deg R	
TCOS(I,K)	TCS(I,K) from previous time step, deg R	
TCR(I,K)	Reflector solid material temperature at solid node (K), channel type (I), deg R	
TCS(K,K)	Shield solid material temperature at solid node (K), channel type I, deg R	
TCZERC(I,K)	Initial value of TCC(I,K), deg R	2093-2192
TCZERJ(K)	Initial value of TCJ(K), deg R	2560-2579
TCZERN(K)	Initial value of TCN(K), deg R	1873-1892
TCZERR(I,K)	Initial value of TCR(I,K), deg R	1893-1992
TCZERS(I,K)	Initial value of TCS(I,K), deg R	1993-2092
TEK(K)	Eckert reference temperature for fluid on hot-side of nozzle at nozzle solid node (K), deg R	
TEM9	Subroutine for calculation of reflector, shield, and core solid and fluid temperatures	
TERM	(Subroutine TEM9) radiative heat,flow from last solid node of a channel to the face of the following component, Btu./sec	
TERMD	Geometry group used to calculate heat exchanger diluent side heat transfer conductance, in. ²	
TERMH	Geometry group used to calculate heat exchanger hot-side heat transfer conductance, in. ²	
THC(K)	Diluent temperature at heat exchange side fluid node (K), deg R	

Variable	Description	Numerical Designation
THE(K)	Heat exchanger duct wall temperature at solid node (K), degrees R	
THEO(K)	THE(K) from previous time step, degrees R	
THEZER(K)	Initial value of THE(K), degrees R	2334-2344
THH(K)	Turbine drive fluid temperature at heat exchange hot-side fluid node (K), deg R	
THIK(K)	Thickness of nozzle tube wall in segment (K), in.	2201-2220
THKTD	Thickness of heat exchanger duct wall, in.	2200
TIME	Total real time elapsed since start of transient calculations, seconds	
TMAX	Maximum total elapsed real time over which transient calculations are performed, seconds	2193
TN(K)	Fluid temperature at nozzle fluid node (K), deg R	
TOLER	Normalized convergence tolerance in TEM9	
TPCV	Turbine power control valve position, deg	
TPCVX	TPCV at design, degrees (for TPCV option only)	217
TR(I,K)	Fluid temperature at reflector fluid node (K), channel type (I), deg R	
TRNO	Maximum number of pressure loop iterations per pass	2198
TS(I,K)	Fluid temperature at shield fluid node (K), channel type (I), deg R	
TTOLER	Normalized convergence tolerance for nozzle temperature calculations	2431
TXC	Nozzle chamber temperature, deg R	
TXC1	TXC from time point two time steps preceding, deg R	
TXCLIM	Value of TXC at which control is switched from power to TXC in temperature loop, deg R	2494
TXCTOL	Normalized convergence tolerance for T10 calculation with a TC-PC option	2428
TZ	Fluid temperature at tank, degrees R	2366
U	Turbine rotor tip speed, ft/sec	
V4,V5,V6, V7,V10,V14	Volumes of plenums associated with the respective station locations, in. ³	2368-2373
VAL1	CJ*R/XMW*GC	
VK	(Main program) axial thermal conductivity of solid material node in the nozzle or heat exchanger (Sub-routine TEM9) axial thermal conductivity of solid material node, Btu/in.-sec-deg R	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
VKN	Radial thermal conductivity of solid material node in the nozzle, Btu/in.-sec-deg R	
VKTD	Radial thermal conductivity of solid material node in the heat exchanger, Btu/in.-sec-deg R	
W1	Coolant mass flow rate from tank to pump inlet, lbm/sec	
W2	Coolant mass flow rate from pump to nozzle inlet, lbm/sec	
W4	Coolant mass flow rate through nozzle tubes, lbm/sec	
W5	Coolant mass flow rate through reflector, lbm/sec	
W6	Coolant mass flow rate through shield, lbm/sec	
W7	Coolant mass flow rate through core, lbm/sec	
W13	Chamber bleed flow rate, lbm/sec	
W15	Diluent flow rate, lbm/sec	
W18	Turbine drive fluid flow rate, lbm/sec	
WC(I)	Core channel mass flow rate, channel type (I), lbm/sec	
WCON1	Constant used for first guess at W13 =(W13/WDOT) at design	2297
WCON2	Constant used for first guess at W15 =(W15/WDOT) at design	2298
WDOT	Total nozzle chamber mass flow rate, lbm/sec	
WN(K)	Nozzle channel mass flow rate per tube in segment (K), lbm/sec	
WR(I)	Reflector channel mass flow rate, channel type (I), lbm/sec	
WS(I)	Shield channel mass flow rate, channel type (I), lbm/sec	
WV4,WV5,WV6, WV7, WV10, WV14	Mass storage rate at plenums associated with respective station locations, lbm/sec	
WY1	Mass flow conductance for pump inlet line, (lbm/sec) (in. ² /lbf)	
WYBPT	Chamber bleed port mass flow conductance, (lbm/sec) (in. ² /lbf)	
WYDST	Total mass flow conductance of diluent side of heat exchanger, (lbm/sec) (in. ² /lbf)	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
WYEC(I)	Core channel mass flow conductance of a core channel of type (I) (lbm/sec) (in. ² /lbf)	
WYECT	Total core mass flow conductance, (lbm/sec) (in. ² /lbf)	
WYEDT	Mass flow conductance of pump discharge line, (lbr/sec) (in. ² /lbf)	2374
WYENT	Nozzle hot side mass flow rate conductance, (lbm/sec) (in. ² /lbf)	
WYER(I)	Mass flow conductance of a reflector channel type (I) (lbm/sec) (in. ² /lbf)	
WYERT	Total reflector mass flow rate conductance, (lbm/sec) (sq in./lbf)	
WYES(I)	Mass flow conductance of a shield channel of type (I) (lbm/sec) in. ² /lbf)	
WYEST	Total shield mass flow conductance, (lbm/sec) (in. ² /lbf)	
WYETT	Total nozzle mass flow conductance, (lbm/sec) (in. ² /lbf)	
WYTIT	Total turbine inlet line mass flow conductance, (lbm/sec) (in. ² /lbf)	
XC	Fluid thermal conductivity, Btu/in.-sec-deg R	
XI1	Flag for intermediate printout from Y1, Y2 and Y3 subroutines. (Called I1 in program)	2502
XI2	Flag for heat flow printout at end of each time step (called I2 in program)	2503
XI3	Flag for intermediate printout from temperature loop (called I3 in program)	2504
XI4	Flag for intermediate printout from pressure loop (called I4 in program)	2505
XI5	Unused intermediate printout/flag (called I5 in program)	2506
XI6	Flag for live comments (on-line printout) (called I6 in program)	2507
XI7	Flag for printout of intermediate values at temperature, pressure and turbine and pump power convergence tests. (Called I7 in program)	2508
XI8	Flag for printout of final values at temperature, pressure, turbine and pump power convergence tests. (Called I8 in program)	2508

Variable	Description	Numerical Designation
XINRX	Flag for NRX option (called INRX in program) XINRX = 1.0, NRX option XINRX = 0.0, hot-bleed engine option	2559
XIPOW	Flag for power input option. (Called IPOW in program) XIPOW = 0, TXC is input, POWER is calculated XIPOW = 1, POWER is input, TXC is calculated	2272
XIR	TPA rotor moment of inertia, ft-lbf-sec ²	2381
XISPM	Main nozzle specific impulse, see Sec.	
XISPR	Roll nozzle specific impulse, sec.	
XITEMI	Maximum number of nozzle iterations per pass	2510
XITI	Maximum number of engine iterations per time step	2512
XITNI	Maximum number of temperature loop iterations per pass	2513
XKC(I)	Exit loss coefficient associated with core channel type (I)	1203-1212
XKN	Exit loss coefficient associated with nozzle	222
XKR(I)	Exit loss coefficient associated with reflector channel type (I)	493-502
XKS(I)	Exit loss coefficient associated with shield channel type (I)	853-862
XLIMIT	Number of time points at which time varying functions are inputed. (Called limit in program)	2500
XMACH(K)	Mach number for hot-side fluid at nozzle solid node (K)	
XMATC(I)	Number of table in subroutine called READKM in program for thermal conductivity of core channel type (I). (called MATC(I) in program)	2538-2542
XMATH	Number of table in subroutine called READKM in program for solid enthalpy of heat exchanger. (Called MATH in program)	2543
XMATN	Number of table in subroutine called READKM in program for nozzle solid material enthalpy. (Called MATN in program)	2527
XMATNJ	Number of table in subroutine called READKM in program for nozzle jacket solid material enthalpy	2640
XMATR(I)	Number of table in subroutine called READKM in program for solid material thermal conductivity of reflector channel type (I). (Called MATR(I) in program)	2528-2532

Variable	Description	Numerical Designation
XMATS(I)	Number of table in subroutine called READKM in program for solid material thermal conductivity of shield channel type (I) (called MATS(I) in program)	2533-2537
XMH	Number of fluid nodes on each side of heat exchanger (Called MH in program)	2518
XMINOR	Number of time steps between printouts (called MINOR in program)	2501
XMKN	Number of table in subroutine called READKM in program for nozzle solid material thermal conductivity	2525
XMKNJ	Number of table in subroutine called READKM in program for nozzle jacket solid material thermal conductivity	2641
XMKTD	Number of table in subroutine called READKM in program for solid material thermal conductivity of heat exchanger. (called MKTD in program)	2526
XMU	Fluid viscosity, lb/in.-sec	
XMW	CXMW	
XNC	Number of core channel types. (Called NC in program)	2522
XNN	Axial station number of nozzle throat flow segment (Called NN in program)	2523
XNR	Number of reflector channel types. (Called NR in program)	2520
XNS	Pump shaft speed, rpm	
XNSO	XNS from previous time point, rpm	
XNSS	Initial value of XNS, rpm	2357
XPRATM	Expansion ratio of main nozzle	2644
XPRATR	Expansion ratio of roll nozzle	2643
XSPNET	Overall engine specific impulse, sec	
XSTY	Flag for steady state calculation (called ISTEDY in program) XSTY = 0, transient calculation XSTY = 1, steady state calculation	2524
Y1	Subroutine which computes mass flow conductance of an orifice	
Y1DO	Diluent orifice mass flow conductance, (lbm/sec) (in ² /lbf)	
Y1DST	Trim orifice mass flow conductance, (lbm/sec) (in ² /lbf)	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
Y1TO	Turbine inlet orifice mass flow conductance, (lbm/sec) (in. ² /lbf)	
Y2	Subroutine which computes mass flow conductance of a duct	
Y3	Subroutine which computes mass flow conductance of a duct exit	
Y6	Turbine mass flow conductance, (lbm/sec) (in. ² /lbf)	
YC(I,K)	Mass flow conductance of core flow segment (K), channel type (I), (lbm/sec) (in. ² /lbf)	
YDST(K)	Heat exchanger diluent side mass flow conductance of flow segment (K), (lbm/sec) (in. ² /lbf)	
YHST(K)	Heat exchanger turbine inlet side mass flow con- ductance of flow segment (K), (lbm/sec) (in. ² /lbf)	
YINC(I)	Mass flow conductance of core inlet, channel type (I), (lbm/sec) (in. ² /lbf)	
YINN	Mass flow conductance of nozzle inlet (lbm/sec) (in. ² /lbf)	
YINR(I)	Mass flow conductance of reflector inlet, channel type (I), (lbm/sec) (in. ² /lbf)	
YINS(I)	Mass flow conductance of shield inlet, channel type (I), (lbm/sec) (in. ² /lbf)	
YKA	Factor by which the cylindrical inner surface area of nozzle segment (K) is multiplied to obtain the hot-side heat transfer area	2435
YN(K)	Mass flow conductance of nozzle flow segment (K) (lbm/sec) (in. ² /lbf)	
YOUTC(I)	Mass flow conductance of core exit, channel, (Type (I) (lbm/sec) (in. ² /lbf)	
YOUTN	Mass flow conductance of nozzle exit (lbm/sec)/ (IN ² /lbf) (I), (lbm/sec) (in. ² /lbf)	
YOUTR(I)	Mass flow conductance of reflector exit, channel type (I), (lbm/sec) (in. ² /lbf)	
YOUTS(I)	Mass flow conductance of shield exit, channel type (I), (lbm/sec) (in. ² /lbf)	
YR(I,K)	Mass flow conductance of reflector flow segment K, channel type I, (lbm/sec) (in. ² /lbf)	
YRN	Turbine roll nozzle, mass flow conductance (lbm/sec) (in. ² /lbf)	
YS(I,K)	Mass flow conductance of shield flow segment (K), channel type (I), (lbm/sec) (in. ² /lbf)	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
YTPCV	Turbine power control valve mass flow conductance, (lbm/sec) (in. ² /lbf)	
Z1	(Subroutine TEM9) heat conductance of fluid flowing from one fluid node to the next, Btu/sec-deg R	
Z1N(K)	Heat conductance of nozzle coolant flow from fluid node (K) to (K+1), Btu/sec-deg R	
Z2(I,K)	(Subroutine TEM9) convective heat conductance from solid node (K) to between fluid nodes (K) and (K+1), channel type (I), Btu/sec-deg R	
Z2(K)	Net thermal conductance from heat exchanger duct wall solid node (K) to diluent fluid between diluent node (K) (K+1), Btu/sec-deg R	
Z3(I,K)	(Subroutine TEM9) conductive heat conductance from solid node (K) to (K-1), channel type (I), Btu/sec-deg R	
Z3C(I,K)	Axial heat transfer area for core solid node (K), channel type (I) divided by DC(I,K), in.	1353-1452
Z3H(K)	Conductive heat conductance from heat exchanger duct wall solid node (K+1) to (K), Btu/sec-deg R	
Z3HX(K)	Axial heat transfer area for heat exchanger solid node (K) divided by DH(K), in.	2304-2313
Z3JX(K)	Nozzle jacket conductive heat conductance from jacket solid node (K) to (K-1), Btu/sec-deg R	2620-2639
Z2N(K)	Net thermal conductance from nozzle solid node K to coolant between fluid nodes (K) and (K+1), Btu/sec-deg R	
Z3N(K)	Nozzle conductive heat conductance from solid node (K) to (K-1), Btu/sec-degrees R	
Z3NX(K)	Axial heat transfer area for nozzle solid node (K) divided by DN(K), in.	323-342
Z3R(I,K)	Axial heat transfer area for reflector solid node (K), channel type (I) divided by DR(I,K), in.	623-722
Z3S(I,K)	Axial heat transfer area for shield solid node (K) channel type (I) divided by DS(I,K), in.	973-1072
Z4(K)	Convective heat conductance to heat exchanger duct wall solid node (K) from turbine drive fluid between hot fluid nodes (K+1) and (K), Btu/sec-deg R	
Z4N(K)	Nozzle convective heat conductance from hot-gas node (K) to solid node (K), Btu/sec-deg R	
Z5N(K)	Nozzle radiative heat conductance from bottom core face to nozzle solid node (K), Btu/sec-deg R	

<u>Variable</u>	<u>Description</u>	<u>Numerical Designation</u>
ZETA	(Subroutine TEM9) radiative thermal conductance between the last solid node of a channel and the adjacent face of the following component, Btu/sec-deg R	

APPENDIX B

FORTRAN LISTINGS

This section contains listings of the main program as well as all relevant functions and subroutines. Included are listings of Chains 1 and 2 for the program with the nozzle without the jacket, as well as Chains 1 and 2 with the nozzle calculations accounting for the jacket. In the latter case, the nozzle calculations are in the form of a subroutine.

Also included is a listing of Chain 3 which contains the plotting routine and thrust calculations performed in subroutine PERFØR. The operations of Chain 3 are executed only upon completion of a particular case and are not linked to the logic of Chains 1 and 2. Also, the calculations performed in Chain 3 are quite straightforward. Therefore, merely the listing of Chain 3 has been presented in this report.

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CHAIN 1 (WITH NOZZLE TUBE JACKET)

```

C      FIRST PART WITH TPCV OPTION      11/20/64      000000
C      000020
C      000040
C      000060
C      000080
C      000100
C      000120
C      000140
C      000160
C      000180
C      000200
C      000220
C      000240
C      000260
C      000280
C      000300
C      000320
C      000360
C      000380
C      000400
C      000420
C      000440
C      000460
C      000480
C      000500
C      000520
C      000540
C      000560
C      000580
C      000600
C      000620
C      000640
C      000660
C      000680
C      000700
C      000720
C      000740
C      000760
C      000780
C      000800
C      000820
C      000840
C      000860
C      000880
C      000900
C      000920
C      000940
C      000960
C      000980
C      001000
C      001020
C      001040
C      001060
C      001080
C      001100

      MAIN ROUTINE

      ARITH. EXPRES- USED IN TURBO-PUMP TO COMPUTE TOLERANCE
      RHOFF(T,P)=P/(XMLL*T)

      ARITHMETIC EXPRES. USED IN TURBO-PUMP TO COMPUTE TOLERANCE
      CUEFF(V,R,RC,F,PC)=V*(R-RC)/(DELTA*(P-PC))

      ARITH. EXPRES. TO FIX FLOATING NUMBERS
      XKKKF(X)=X + 1.0E-05 *X

      DIMENSION A(2700),TITLE(12),PD(10),HH(10),DAI(10)

      EQUIVALENCE INPUTS TO Y ROUTINES TO PRESERVE ORDER (COMMON)
      EQUIVALENCE (GAMMA,DUM1), (XMW,DUM2), (C1,DUM3), (C2,DUM4),
      1 (CRIT,DUM0), (ITRND,DUM1), (LOCK,DUM2), (LATC,DUM3), (II,
      1 IDUM0), (II,
      2 IDUM4), (I2,DUM5), (I3,DUM6), (I4,DUM7), (I5,DUM8), (SIGMA,
      3 DUM5), (DIV,DUM6), (SMALL,DUM7), (VAL1,DUM8), (CUEFF,DUM9),
      4 (TLLS,DUM10), (DELTA,DUM11), (F1,DUM12), (C,DUM13), (R,DUM14),
      5 (CJ,DUM15), (TWALL,DUM16), (TIME,DUM17)

      INPUT VALUES

      A(3) USED TO CALCULATE NODE TOLERANCE IN THE NOZZLE
      EQUIVALENCE (A(1),TAU), (A(2),CDELTA), (A(4),YLOUTN),
      1 (A(5),CUEFF), (A(6),PCF), (A(7),ICF), (A(8),I2P), (A(9),PAF), (A(1
      20),POWERK), (A(11),ORLFF(1)), (A(12),CHETC(1)), (A(13),CHIFC), (A(
      3104),ORLFA), (A(215),GAMMA), (A(216),XMW), (A(217),TPCVX),
      4 (A(218),PTCV), (A(219),DNT), (A(221),CTWALL), (A(222),XKN), (A
      5(223),ALPHAN(1)), (A(243),AREAN(1)), (A(263),AN(1)), (A(283),RHN(1
      6)), (A(303),N(1)), (A(323),ZSNX), (A(343),CNX), (A(363),ARAT1
      7L(1)), (A(383),RHN(1)), (A(403),SFN(1)), (A(423),AIN(1)), (A(443),A
      8K4(1)), (A(463),LPHAR(1)), (A(473),AREAR(1)), (A(493),AR(1)), (A(4
      993),XKR(1)), (A(513),RHR(1)), (A(523),LF(1)), (A(543),ZSR(1))
      EQUIVALENCE (A(563),ZSR(1)), (A(583),ALPHAS(1)), (A(603),AREAS(1)
      1), (A(643),ZSR(1)), (A(663),XKS(1)), (A(683),RHN(1)), (A(703),DS(1)
      2), (A(743),ZSR(1)), (A(763),CS(1)), (A(783),ALPHAC(1)), (A(803),
      3(1183),AREAC(1)), (A(1193),AC(1)), (A(1203),XKC(1)), (A(1213),RHC(
      41)), (A(1223),L(1)), (A(1233),SH(1)), (A(1243),A1(1)), (A(1253),DC
      5(1)), (A(1263),ZSR(1)), (A(1453),CL(1)), (A(1463),FLUXN(1)),
      6 (A(1573),FLUXR(1)), (A(1673),FLUXS(1)), (A(1773),FLUXC(1)),
      7 (A(1873),TCZERL(1)), (A(1893),TCZERF(1)), (A(1913),TCZERH(1))
      8, (A(2093),TCZER(1)), (A(2193),TMAX)
      EQUIVALENCE (A(2194),CLEFS), (A(2195),CLEFF), (A(2196),CLEFC)
      9, (A(2197),FMAX), (A(2198),TNN), (A(2199),TURN), (A(2200),
      3 THKTD), (A(2201),TTHK), (A(2202),LRDPCA), (A(2203),XIPOW)

      TURBO-PUMP AND HEAT EXCHANGER INPUTS

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RN-DR-0068

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C      EQUIVALENCE (A(2293),PCCN1), (A(2294),PCCN2), (A(2295),PCCN3),
1      (A(2296),PCCN4), (A(2297),WCCN1), (A(2298),WCCN2), (A(2299),DH),
2      (A(2300),AHC), (A(2301),RHD), (A(2302),AHH), (A(2303),RHH),
3      (A(2304),Z3HX), (A(2314),CHX), (A(2324),FLUXH), (A(2334),THEZER),
4      (A(2345),AREADT), (A(2346),AREADO), (A(2347),AHEP), (A(2348),
5      RHBP), (A(2349),DHBP), (A(2350),AREATU), (A(2351),CBPT), (A(2352),
6      CP1), (A(2353),CP2), (A(2354),CP3), (A(2355),CF4), (A(2356),
7      CPS), (A(2357),XNSS), (A(2358),CT1), (A(2359),CT2), (A(2360),
8      CT3), (A(2361),CT4), (A(2362),CT5), (A(2363),AFD1), (A(2364),
9      RHPC1), (A(2365),DPD1), (A(2366),TZ), (A(2367),FZ), (A(2368),V4)
EQUIVALENCE (A(2369),V5), (A(2370),V6), (A(2371),V7), (A(2372),
1     V10), (A(2373),V14), (A(2374),WYEDT), (A(2375),WYDST), (A(2376),
2     WYBPI), (A(2377),WYENT), (A(2378),YRN), (A(2379),P1), (A(2380),
3     P2), (A(2381),XIR), (A(2382),P4), (A(2383),P5), (A(2384),P6),
4     (A(2385),P7), (A(2386),P14), (A(2387),C19), (A(2388),PDST(1)),
5     (A(2398),WDST(1)), (A(2408),PHST(1)), (A(2418),WHST(1))
6     , (A(2428),TXCTCL), (A(2429),PXCTOL), (A(2430),T18TOL), (A(2431),
7     TTOLER), (A(2432),PTOLER), (A(2433),COHEX), (A(2434),COTUR)
8     , (A(2435),YKA), (A(2436),T9S), (A(2437),T9R), (A(2438),T9C)
9     , (A(2439),POWTOL), (A(2440),GRDTCV)
EQUIVALENCE (A(2492),TCG), (A(2493),PCG), (A(2494),TXCLIM),
1     (A(2495),PXCLIM)
C
C      FIXED POINT INPUTS
C
C      EQUIVALENCE (A(2500),XLIMIT), (A(2501),XMINCR), (A(2502),XI1), (A
1     (2503),XI2), (A(2504),XI3), (A(2505),XI4), (A(2506),XI5), (A(2507)
2     ,XI6), (A(2508),XI7), (A(2509),XI8), (A(2510),XITEMI), (A(2511),XIP
3     JI), (A(2512),XITI), (A(2513),XITNI), (A(2514),EMN), (A(2515),EMR)
4     , (A(2516),EMS), (A(2517),EMC), (A(2518),XMH), (A(2519),XM)
5     , (A(2520),XNR), (A(2521),FNS), (A(2522),XNC), (A(2523),XNN)
6     , (A(2524),XSTY), (A(2525),XMKN), (A(2526),XMKTD)
7     , (A(2527),XMATN), (A(2528),XMATR), (A(2533),XMATS), (A(2538),
8     XMATC), (A(2543),XMATH), (A(2544),SMATR), (A(2549),SMATS),
9     (A(2554),SMATC), (A(2559),XIRNX)
EQUIVALENCE (A(2560),TCZERJ), (A(2580),FLUXJ), (A(2600),CNXJ),
1     (A(2620),Z3JX), (A(2640),XMATNJ), (A(2641),XMKNJ)
2     , (A(2642),DRNT), (A(2643),XPRATR), (A(2644),XPRATM), (A(2645),EFFMN),
3     (A(2646),EFFRN)
C
C      DIMENSION THC(11),THE(11),THH(11),Z3H(10),CH(10),THEC(10),
1     FLUXH(10),THEZER(10),PDST(11),WDST(10),PHST(11),WHST(11),Z2(20),
2     YDST(10),YHST(10),Z4(20)
3     DIMENSION Q1H(10),Q2H(10),Q3H(10),SH(10),QH(10)
C
C      COMMON GAMMA,XMW,C1,C2,CRIT,ITRNO,LECK,LATCH,II,I1,I2,I3,I4,I5,SI
1     GMA,DIV,SMALL,VALI,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME,A
2     ,LIMIT,MINOR,I6,I7,I8,ITEMI,IPI,ITI,ITNI,MH,M,MN,MC,MS,MR,NN,NS,
3     NK,NC,M1F,M2H,MAJOR,M1N,M2N,M1R,M2R,M1S,M2S,M1C,M2C,DDO,FIG,FPI,
4     HCCAL,HCCAL,HCCCN,HCCCN,PSIN,PSIR,PSIS,PSIC,CHNOR,CHNDS,CHNOC,T2
5     ,TXC,PXC,PA,ICN,ICR,TCS,TCC,THE,THC,THH,TN,TS,TR,T6,TS,T7,TC,
6     T10,T14,T16,T17,T17PS,T18,T19,EM1N,EM1R,EM1S,EM1C,P10,PC,PS,PR,
7     PN,P17,P17PS,P18,P19,TERMH,TERND,MAJOF,ANT,IDUMP,ISTEDY,PPP,

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8 RECOV,T4,XMUL,XNSD,GUALN,HHN,GUALR,HHR,GUALS,HHS,GUALC,FHC,
9 QUALFT,HHHT,QUALFD,HHHD,H1,TCX1,H2,TPCV,PXC1

002140

002160

002180

002200

002220

002240

002260

002280

002300

002320

002340

002360

COMMON MATN,MATR,MATS,MATC,MATH,HSCLN,HSCLS,HSCLR,HSCLC,HSOLH
1 ,MATSR,MATSS,MATSC
DIMENSION HUSCLN(20),HUSCLS(5,10),HUSCLR(5,10),HUSCLC(5,10)
1 ,HSCLN(20),HSOLH(5,10),HSCLS(5,10),HSCLC(5,10),HSOLH(20)
2,HUSCLH(20),CNX(20),Z3NX(20),CHX(10),Z3HX(10)
3,XMATR(5),MATR(5),XMATS(5),MATS(5),XMATC(5),MATC(5)
4 ,SMATH(5),SMATS(5),SMATC(5),MATSR(5),MATSS(5),MATSC(5)

DIMENSION ORDH2(51),URDTC(51),ORDPC(51),CRDPA(51),LRCFLW(51)
DIMENSION ALPHAR(5),AREAR(5),AR(5),XKR(5),RHR(5),DR(5,10),Z3R(5,10)
1),(CR(5,10),PSIR(5),URDTCV(51),ALPHAC(5),AREAC(5),AC(5),XKC(5),
2,KFC(5),DC(5,10),Z3C(5,10),CC(5,10),PSIC(5),GR(5,10),WR(5),WYLR(5),
3,(5,11),TCR(5,10),TCOR(5,10),TR(5,11),FLUXR(5,10),FLUXS(5,10),
4,FLXC(5,10),TCZER(5,10),TCZERS(5,10),TCZER(5,10),E(5),SF(5),
5,PSI(5),Y(5),QS(5,10),WS(5),WYES(5),PS(5,11),TCS(5,10),TCCS
6(5,10),TS(5,11),CC(5,10),WC(5),WYEC(5),PC(5,11),TCC(5,10),TCDC
7(5,10),TC(5,11),YINR(5),YCLTR(5),YR(5,10),YINS(5),YCLTS(5),YS(5,10)
8),YINC(5),YCLTC(5),YC(5,10)

DIMENSION ALPHAN(20),AN(20),RHN(20),DN(20),Z3N(20),CN(20),
1 ,AN(20),THETA(20),TN(20),TCN(20),H(20),BETA(20),Z2N(20),Z
24N(20),PSIN(20),ZEN(20),RELAX(20),Q2N(20),Q3N(20),Q4N(20),
3GSN(20),TAR(20),SN(20),TCOJ(20),QN(20),ERRCR(20),FLUXN(20),TCZER(20),
4EN(20),SFN(20),AIN(20),YN(20),FN(21),ARATIC(20),TEB(20),PHX
5(21),DDL(20),FCCCN(20),HHCON(20),AK4(20),TEK(20),GUALN(21),HHN(21)
6,GUALR(5,11),HHK(5,11),GUALS(5,11),HHS(5,11),GUALC(5,11),HHC(5,11)
7,GUALHT(5,11),HHHT(5,11),QUALHD(5,11),HHHD(5,11),THIK(20),CP(20),
8ALPHAS(5),AREAS(5),XKS(5),RHS(5),DS(5,10),Z3S(5,10),CS(5,10),
9PSIS(5),AS(5)

002740

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002800

DIMENSION QJ(20),FLUXJ(20),TCJ(20),HSCLNJ(20),HSCLJ(20),TCOJ(20),
1CNJ(20),CNXJ(20),Z3J(20),THETAJ(20),FJ(20),BETAJ(20),Z2J(20),
2RELAXJ(20),SJ(20),Q2J(20),Q3J(20),ERRCRJ(20),Z3JX(20)
3,TCZERJ(20)

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COMMON QJ,FLUXJ,TCJ,HSCLNJ,HSCLJ,TCOJ,CNJ,CNXJ,Z3J,THETAJ,FJ,
1BETAJ,Z2J,RELAXJ,SJ,Q2J,Q3J,ERRCRJ,NOZ,Z3JX,MATNJ,MKNJ
2,WDOT,W4,TAR,TBE,POWER,TCZERJ

*

*

COMMON EETA,CH,CN,CF,DAT,ERRCR,HC,
1 HH,HSCLC,HCSOLH,HCSOLN,HSCLR,HSCLS,H,PFH,
2 PSI,Q1H,Q2H,Q2N,Q3C,Q3H,Q3N,Q3K,
3 Q3S,Q4N,Q5N,QC,QH,QN,GR,GS,
4 RELAX,SC,SH,SN,SR,SS,TCCC,TCUN,
5 TCR,TCOS,TEK,THED,THETA,TITLE,WC,WN,
6 WR,WS,WYEC,WYER,WYES,YC,YDST,YFST,
7 YINC,YINR,YINS,YN,YOUTC,YCLTR,YOUTS,YR,
8 Y,YS,Z2N,Z2,Z3H,Z3N,Z4N,Z4,
9 Z5N

4 FORMAT(12X,8HNODE NO. I3,4HTCR= F10.1)

002940

5 FORMAT(12X,8HNODE NO. I3,4HTCS= F10.1)

002960

6 FORMAT(12X,8HNODE NO. I3,4HTCC= F10.1)

002980

671 FORMAT(//////28H NODE MASS FLOW RATES ////)

003000

674 FORMAT(//////26H NOZZLE CHANNEL PRESSURES ////)

003020

674 FORMAT(23X,9H P4 = F10.1/23X, 9H P5 = F10.1//)

003040

674 FORMAT(11X10H NODE NO. I3,5X 6H PN = F10.1)

003060

674 FORMAT(//20H CHANNEL NUMBER I3//)

003080

C		003100
C		003120
C		003140
C	BLOCK A READ PROGRAM PARAMETERS	003160
C	PRINTOUT PROBLEM DATA (INPUT)	003180
C		003200
C		003220
C	LOAD INPUT	003240
C		003260
30	READ INPUT TAPE 5,997,TITLE	003280
	WRITE OUTPUT TAPE 6,998,TITLE	003300
	IF(TITLE(1)-6HUNLOAD)26,25,26	003320
C		003340
C	UNLOAD CHAIN TAPE	003360
C		003380
25	CALL REWUNL	003400
	PRINT 27,TITLE	003420
27	FORMAT (1F-,12A6 ///)	003440
26	CALL SLOAD (A)	003460
997	FORMAT (12A6)	003480
998	FORMAT (1H1,12A6// 40X,15H-GENERAL INPUT-)	003500
	ITFLAH=0	003520
	LIMIT=XKKKF(XLIMIT)	003540
	MINOR=XKKKF(XMINCR)	003560
	I1=XKKKF(XI1)	003580
	I2=XKKKF(XI2)	003600
	I3=XKKKF(XI3)	003620
	I4=XKKKF(XI4)	003640
	I5=XKKKF(XI5)	003660
	I6=XKKKF(XI6)	003680
	I7=XKKKF(XI7)	003700
	I8=XKKKF(XI8)	003720
	ITEM1=XKKKF(XITEM1)	003740
	IPI=XKKKF(XIPI)	003760
	ITI=XKKKF(XITI)	003780
	ITNI=XKKKF(XITNI)	003800
	MH=XKKKF(XMH)	003820
	M=XKKKF(XM)	003840
	MN=XKKKF(XMN)	003860
	MC=XKKKF(XMC)	003880
	MS=XKKKF(XMS)	003900
	MR=XKKKF(XMR)	003920
	NN=XKKKF(XNN)	003940
	NS=XKKKF(XNS)	003960
	NR=XKKKF(XNR)	003980
	NC=XKKKF(XNC)	004000
	ISTEDY=XKKKF(XSTY)	004020
	IPGW=XKKKF(XIPGW)	004040
	MATNJ=XKKKF(XMATNJ)	
	MKNJ=XKKKF(XMKNJ)	
	M1F=M1-1	004060
	M2F=M1-2	004080
	GAMMA=CGAMMA	004100
	XMW=CMW	004120
	TCLER=TTCLER	004140
	DELTA=CDELTA	004160

COEFF=CCOEFF
 TWALL=CTWALL
 MAJOR = TAU / DELTA + .01
 XNS=XNSS

THERMCDYNAMIC CONSTANTS USEFUL IN COMPUTING THE MASS FLOW
 RATE CONDUCTANCE OF AN ORIFICE

IDUMP = 0
 PI = 3.1416
 SIGMA = 3.356E-15
 R = 1.987
 GC = 32.174
 CJ = 778.2
 VAL1 = (CJ*R)/(XMW*GC)
 CRIT = (2.0/(GAMMA+1.0))*(GAMMA/(GAMMA-1.0))
 PART1 = ((GAMMA+1.0)/2.0)*(1.0/(GAMMA-1.0))
 PART2 = SQRTF((GAMMA+1.0)/(GAMMA-1.0))
 TERMA = SQRTF((2.0*GAMMA)/(GAMMA-1.0))
 TERMB = PART1*PART2
 C1 = TERMA/TERMB
 C2 = TERMB
 ANT = .7853982*DN**2
 DIV = 0.63212
 SMALL = 0.0001
 RECOV = 0.9

DO 88888 I=1,529
 L2=I+529
 L3=L2+529
 L4=L3+529
 L5=L4+529

88888 WRITE OUTPLT TAPE 6,88889,I,A(I),L2,A(L2),L3,A(L3),L4,A(L4)
 1 ,L5,A(L5)
 88889 FORMAT (5X,14,1PE13.5,15,E13.5,15,E13.5,15,E13.5,15,E13.5)

WRITE OUTPUT TAPE 6,998,1111

WRITE OUTPUT TAPE 6,1111,LIMIT,TAU,DELTA,MINOR,CCOEFF,TXCTOL,PXCTOL
 1 ,T18TOL,TTOLER,PTOLER,CGHEX,CCTUR
 1111 FORMAT(7H0LIMIT= 14, 5H TAU=E12.5, 7H DELTA=E12.5,7H MINOR=14,2X,
 15HCCOEFF E13.5/7HCTXCTOL E13.5,2X,6HPXCTOL E13.5,2X,6HT18TOL E13.5
 2 ,2X,6HTTOLER E13.5 / 7HCPTOLER E13.5,2X,5HCGHEX E13.5,2X,
 3 5HCCTUR E13.5)

BLOCK E READ DESIGN POINT VALUES

BLOCK B1 READ INITIAL GUESS FOR POWER

WRITE OUTPUT TAPE 6,1222,PCF, TCF,H2F,PAF,POWER
 1222 FORMAT(5H0PCF=E9.3,5H TCF=E9.3,5H H2F=E9.3,5H PAF=E9.3,7H POWER=E9
 1.3/)

BLOCK C READ TRANSIENT DIMENTIONLESS RATIOS OF DESIGN POINT VALUES

004180
 004200
 004220
 004240
 004260
 004280
 004300
 004320
 004340
 004360
 004380
 004400
 004420
 004440
 004460
 004480
 004500
 004520
 004540
 004560
 004580
 004600
 004620
 004640
 004660
 004680
 004700
 004720

004840
 004860
 004880
 004900
 004920
 004940
 004960
 004980
 005000
 005020
 005040
 005060
 005080
 005100
 005120
 005140
 005160
 005180
 005200
 005220
 005240
 005260
 005280

C	WRITE OUTPUT TAPE 6,1003, (CRDH2(LIST),LIST=1,LIMIT)	005300
1003	FORMAT (7H00RDCH2 / (5X8E12.5))	005320
	WRITE OUTPUT TAPE 6,1004, (ORDTC(LIST),LIST=1,LIMIT)	005340
1004	FORMAT (7H00RDTC / (5X8E12.5))	005360
	WRITE OUTPUT TAPE 6,1005, (ORDPC(LIST),LIST=1,LIMIT)	005380
1005	FORMAT (7H00RDPC / (5X8E12.5))	005400
	WRITE OUTPUT TAPE 6,1006, (CRDPA(LIST),LIST=1,LIMIT)	005420
1006	FORMAT (6H00RDPA / (5X8E12.5))	005440
C		005460
C	BLOCK E READ COOLANT FLUID PROPERTIES DATA	005480
C		005500
	WRITE OUTPUT TAPE 6,1008,GAMMA,XMW,CP,XMU,XC	005520
1008	FORMAT (7H0GAMMA=E12.5,5H XMW=E12.5,4H CP=E12.5, 5H XMU=E12.5,4H XC	005540
	1=E12.5)	005560
		005580
C		005600
C	BLOCK E READ NOZZLE DATA	005620
C		005640
	WRITE OUTPUT TAPE 6,1007,DNT,TWALL	005660
1007	FORMAT (5H0DNT= E12.5, 7H TWALL= E12.5)	005680
C		005700
C		005720
C		005740
	WRITE OUTPUT TAPE 6,1771	005760
1771	FORMAT (1H1 40X 14H-NOZZLE INPUT-)	005780
C		005800
	M1N = MN-1	005820
	M2N = MN-2	005840
	WRITE OUTPUT TAPE 6, 1775, XKN	005860
1775	FORMAT (4H0XKN / E12.5)	005880
	WRITE OUTPUT TAPE 6,1772, (ALPHAN(K),K=1,M1N)	005900
1772	FORMAT (7H0ALPHAN / (9E12.5))	005920
	WRITE OUTPUT TAPE 6,1773, AREAN	005940
1773	FORMAT (7H0AREAN / (9E12.5))	005960
	WRITE OUTPUT TAPE 6, 1774, (AN(K),K=1,M1N)	005980
1774	FORMAT (3H0AN / (9E12.5))	006000
	WRITE OUTPUT TAPE 6, 1776, (RHN(K),K=1,M1N)	006020
1776	FORMAT (5H0RHN / (9E12.5))	006040
	WRITE OUTPUT TAPE 6, 1777, (DN(K),K=1,M1N)	006060
1777	FORMAT (3H0DN / (9E12.5))	006080
1778	FORMAT (5H0Z3NX / (9E12.5))	006100
	WRITE OUTPUT TAPE 6, 1778, (Z3NX(K),K=1,M1N)	006120
	WRITE OUTPUT TAPE 6, 1779, (CNX(K),K=1,M1N)	006140
1779	FORMAT (4H0CNX / (9E12.5))	006160
	WRITE OUTPUT TAPE 6, 1791, (ARATIC(K), K= 1,M1N)	006180
1791	FORMAT (7H0ARATIO / (9E12.5))	006200
	WRITE OUTPUT TAPE 6, 1792, (EN(K),K= 1,M1N)	006220
1792	FORMAT (3H0EN / (9E12.5))	006240
	WRITE OUTPUT TAPE 6, 1793, (SFN(K), K=1,M1N)	006260
1793	FORMAT (4H0SFN / (9E12.5))	006280
	WRITE OUTPUT TAPE 6, 1794, (A1N(K),K =1,M1N)	006300
1794	FORMAT (4H0A1N / (9E12.5))	006320
	WRITE OUTPUT TAPE 6, 1780, (AK4(K),K=1,M1N)	006340
1780	FORMAT (4H0AK4 / (9E12.5))	006360
C		006380
C	BLOCK F READ REFLECTOR DATA	006400


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WRITE OUTPUT TAPE 6,1027,(AREAC(I),I=1,NC)
1027 FORMAT( 6H0AREAC / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1028,(AC(I),I=1,NC)
1028 FORMAT( 3H0AC / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1029,(XKC(I),I=1,NC)
1029 FORMAT( 4H0XKC / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1030,(RHC(I),I=1,NC)
1030 FORMAT( 4H0RHC / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1031,(E(I),I=1,NC)
1031 FORMAT( 2H0E / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1032,(SF(I),I=1,NC)
1032 FORMAT( 3H0SF / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1033,(A1(I),I=1,NC)
1033 FORMAT( 3H0A1 / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1034,((DC(I,L),I=1,NC),L=1,M1C)
1034 FORMAT( 3H0DC / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1035,((Z3C(I,K),I=1,NC),K=2,M1C)
1035 FORMAT( 4H0Z3C / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1036,((CC(I,K),I=1,NC),K=1,M1C)
1036 FORMAT( 3H0CC / (9E12.5 /) )
C
C BLOCK I READ FULL POWER HEAT GENERATION DISTRIBUTION
C
WRITE OUTPUT TAPE 6,1037
1037 FORMAT(55H1 FULL POWER HEAT GENERATION DISTRIBUTION INPUT)
WRITE OUTPUT TAPE 6,1782,( FLUXN(K),K=1,M1N)
1782 FORMAT ( //// 6H0FLUXN / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1038,((FLUXR(I,K),I=1,NR),K=1,M1R)
1038 FORMAT( //// 6H0FLUXR / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1039,((FLUXS(I,K),I=1,NS),K=1,M1S)
1039 FORMAT ( //// 6H0FLUXS / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1040,((FLUXC(I,K),I=1,NC),K=1,M1C)
1040 FORMAT ( //// 6H0FLUXC / (9E12.5 /) )
C
C BLOCK J READ INITIAL SOLID MATERIAL TEMPERATURES
C
WRITE OUTPUT TAPE 6,1041
1041 FORMAT(1H19X41HINITIAL SOLID MATERIAL TEMPERATURES INPUT)
C
WRITE OUTPUT TAPE 6,1783,( TCZERN(K),K=1,M1N)
1783 FORMAT ( //// 7H0TCZERN / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1042,((TCZERR(I,K),I=1,NR),K=1,M1R)
1042 FORMAT ( //// 7H0TCZERR / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1043,((TCZERS(I,K),I=1,NS),K=1,M1S)
1043 FORMAT ( //// 7H0TCZERS / (9E12.5 /) )
WRITE OUTPUT TAPE 6,1044,((TCZERC(I,K),I=1,NC),K=1,M1C)
1044 FORMAT ( //// 7H0TCZERC / (9E12.5 /) )
C
C HEAT EXCHANGER INPUTS
C
WRITE OUTPUT TAPE 6,1360
1360 FORMAT(////1H1 43X, 23H -HEAT EXCHANGER INPUT-)
WRITE OUTPUT TAPE 6,1361, DH,AHC,RHD,AHH,RHF, MH, I9
1361 FORMAT (5X,2HDH E16.8,2X,3HAHC E16.8,2X,3HRHD E16.8,2X,3HAHH E16.8
1,2X,3HRRH E16.8 ,2X,2HMH I4,2X,2HI9 I5/ )
WRITE OUTPUT TAPE 6,1362, (Z3HX(K),K=1,M2H)
WRITE OUTPUT TAPE 6,1363, (CHX(K),K=1,M1H)

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WRITE OUTPUT TAPE 6,1364, (FLUXH(K), K=1,M1H)
WRITE OUTPUT TAPE 6,1365, (THEZER(K), K=1,M1H)
1364 FORMAT(/5X, 15H FLUXH(K=1,M1H)/ 11X,6(3X,E15.8))
1365 FORMAT(/5X, 16H THEZER(K=1,M1H)/ 11X,6(3X,E15.8))
1362 FORMAT(/5X, 13HZ3HX(K=1,M2H)/ 11X,6(3X,E15.8))
1363 FORMAT(/5X, 12HCHX(K=1,M1H)/ 11X,6(3X,E15.8))
C
C TURBO-PUMP INPUTS
C
WRITE OUTPUT TAPE 6,1370,PCCN1,PCCN2,PCCN3,PCCN4,WCCN1,CT5,
1AREADT,AREADD,AFBP,RHBP,DHBP,AREATC,CP1,CP2,CP3,CP4,CPS,XNSU,CT1,
2CT2,CT3,CT4,APD1,RHPD1,DPC1,T2,P2,V4,V5,V6,V7,V10,V14,WYEDT,WYDST
3,MF,M,WCCN2
WRITE OUTPUT TAPE 6,1371,WYBPT,WYENT,YRN,P1,P2,P4,P5,P6,P7,P14,
1 PXC.(PDST(I),I=1,MH)
A(975)=5H0WDST
WRITE OUTPUT TAPE 6,1372,A(975) ,(WDST(I),I=1,MH)
A(975)=5H0PHST
WRITE OUTPUT TAPE 6,1372,A(975) ,(PHST(I),I=1,MH)
A(975)=5H0WHST
WRITE OUTPUT TAPE 6,1372,A(975) ,(WHST(I),I=1,MH)
1370 FORMAT (1H1,40X,18H-TURBO-PUMP INPUT- //6H PCUN1 E13.5,2X,5HPCCN2
1 E13.5,2X,5HPCCN3 E13.5 ,2X,5HPCCN4 E13.5 /6H0WCCN1 E13.5,2X,3HCT5
2 E13.5,2X, 6HAREADT E13.5,2X,6HAREADD E13.5 /5H0AHBP E13.5,2X,
3 4HRHBP E13.5,2X,5HDHBP E13.5,2X,6HAREATC E13.5 /4H0CP1 E13.5,2X,
4 3HCP2 E13.5,2X,3HCP3 E13.5,2X,3HCP4 E13.5 /4H0CPS E13.5,2X,4HXNSU
5 E13.5,2X,3HCT1 E13.5,2X,3HCT2 E13.5 /4H0CT3 E13.5,2X,3HCT4 E13.5
6 ,2X,4HAPD1 E13.5 / 6HCRHPD1 E13.5,2X,4HDPD1 E13.5 ,
7 2X,2HTZ E13.5,2X,2HPZ E13.5 / 3H0V4 E13.5,2X,2HV5 E13.5,2X,2HV6
8 E13.5,2X,2HV7 E13.5/4H0V10 E13.5,2X,3HV14 E13.5,2X,5HWYEDT E13.5
9,2X,5HWYDST E13.5,2X,2HMH 13,2X,1HM,13 / 6H0WCCN2 E13.5)
1371 FORMAT(6H0WYEDT E13.5,2X,5HWYENT E13.5,2X,3HYRN E13.5,2HP1 E13.5/
1 3H0P2 E13.5, 2X,2HP4 E13.5,2X,2HP5 E13.5/3HCP6 E13.5,
2 2X,2HP7 E13.5,2X,3HP14 E13.5,2X,3HPXC E13.5/5H0PDST/(6E13.5) )
1372 FORMAT (A6/(6E13.5))
C
C BLOCK K READ PRINTOUT FLAGS
C
C
WRITE OUTPUT TAPE 6,1045
1045 FORMAT( 1H1 40X 15H PRINTOUT FLAGS )
IF 11 IS NON-ZERO INTERMEDIATE VALUES ARE PRINTED FROM Y1, Y2, AND
Y3.
C
C
IF 12 IS NON-ZERO HEAT FLOW RATES AT THE END OF EACH MAJOR TIME STE
P WILL BE PRINTED. TEMPERATURES, PRESSURES, AND MASS FLOW RATES A
RE ALWAYS WRITTEN OUT AT THE END OF EACH MAJOR TIME STEP.
C
C
IF 13 IS NON-ZERO INTERMEDIATE RESULTS FROM TEMPERATURE LOOP ARE P
RINTED.
C
C
IF 14 IS NON-ZERO INTERMEDIATE RESULTS FROM PRESSURE LOOP ARE PRIN
TED.
C
C
15 IS OPEN FOR FURTHER USE
C
C
IF 16 IS NON-ZERO ON LIVE COMMENTS (TEMPERATURE, PRESSURE, DELTA,

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C      PROBLEM.
C
C      IF I7 IS NON-ZERO INTERMEDIATE VALUES OF QUANTITIES FOR CONVERGENT
C      TESTS FOR TEMPERATURE, PRESSURE, AND THE OVERALL LOCP ARE PRINTED.
C
C      IF I8 IS NON-ZERO FINAL VALUES OF QUANTITIES FOR CONVERGENT TESTS F
C      OR TEMPERATURE, PRESSURE, AND THE OVERALL LOCP ARE PRINTED.
C      WRITE OUTPUT TAPE 6,1046,11,12,13,14,15,16,17,18,ITEM1,IPI,ITI,
      XITNI
1046 FORMAT( 3X, 3HI1= 11, 9X, 3HI2= 11, 9X, 3HI3= 11, 9X, 3HI4=,11,
      19X, 3HI5= 11, 9X, 3HI6= 11, 9X, 3HI7= 11,
      X      9X, 3HI8= 11,/3X, 6HITEM1=
      2 13, 8X, 4HIPI= 13, 8X, 4HITI= 13, 6X, 6HITNI= 13)
C
C      PPP = GAMMA / (GAMMA - 1.)
      PPP1= (GAMMA - 1.) / 2.
      PPP2= (GAMMA + 1.) / (GAMMA - 1.)
      PPP3= 2. / (GAMMA + 1.)
      DO 616 K=1,M1N
      ARATIN = ABSF ( ARATIO(K))
      XMACH = 1.0
      IF (ARATIO (K)-1.) 606,616,607
606  DELM = -.1
      GO TO 608
607  DELM = 1.0
608  XMACH = XMACH + DELM
      IF (XMACH - 0.5E-06) 609,609,610
609  XMACH = XMACH - DELM
      DELM = .1*DELM
      GO TO 608
610  TMPX = (PPP3 + XMACH*XMACH/PPP2)
      AX = (1./XMACH)*EXP(.5*PPP2*LOGEF (TMPX))
      IF (ABSF (AX-ARATIN)-.3E-03) 616,616,611
611  IF (AX-ARATIN) 612,616,614
613  IF (XMACH-.4E-06) 615,615,608
612  IF (XMACH-.1E+03) 613,613,615
614  XMACH = XMACH - DELM
      DELM = .5*DELM
      GO TO 608
615  WRITE OUTPUT TAPE 6,617
617  FORMAT (25H MACH NUMBER OUT OF RANGE ///)
620  GO TO 30
616  DDD(K) = XMACH*XMACH*PPP1
C
C      FIG = (4.0 / PI) ** 0.8 / DNT ** 1.8
      FPI = (CP**0.4)*(XC**0.6) / XMU ** 0.4
      HCCAL=(.023/(4.0*RHD)) *((4.0*RHD/AHC)**0.8)
      HHCAL=(0.023/(4.0*RHH)) *((1.0/(PI*RHH))**0.8
      TERMH=DM*AHH/RHH
      TERMD=TERMH
      DO 604 K = 1, M1N

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      FCCUN(K)=(0.028/(4.0*RFN(K))) * (4.0*RFN(K)/AN(K))*C.
      ARAT=AESEF(ARATIC(K))
      PULT=DN(K)*YKA*PI*DNT*SQRTF(ARAT)
      HFCCN(K)=AK4(K)*FIG*FLLT/ARAT*C.9
604  PSIN(K) = SIGMA * EN(K) * SFN(K) * A1N(K)
      DO 601 I = 1,NR
601  PSIR(I) = -5.0E-30
      DO 602 I=1,NS
602  PSIS(I) = -5.0E-30
C
      DO 603 I=1,NC
603  PSIC(I) = SIGMA*I(I)*SF(I)*A1(I)
C
C
      CFNOR = 0.0
      DO 400 I=1,NR
400  CFNOR = CFNOR + ALPFAR(I)
C
      CHNCS = 0.0
      DO 402 I=1,NS
402  CHNCS = CHNCS + ALPFAS(I)
C
      CHNCC = 0.0
      DO 1434 I=1,NC
1434  CHNCC = CHNCC + ALPFAC(I)
C
C
C
      TIME = 0.0
C
C
C
C
C
C
      INITIAL VALUES OF EXCESSIVE VARIABLES
C
C
      IF(ISTEDY)500,500,501
500  TXC = CRDTC(1)*TCF
      PXC = CRDPC(1)*PCF
      PA = CRDPA(1) * PAF
      H2=CRDHF(1)*H2F
      TPCV=CRDTCV(1)
      IF(IPCW)13059,13059,13058
13058 POWER = CRDPCW(1)
13059 GC TG 502
501  TXC=TCF
      PXC=PCF
      PA=PAF
      H2=H2F
      TPCV=TPCVX
C
C
C

```

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010900
010920
010940
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011000
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011080
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011120
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011200
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011500
011520
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011600
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011980
012000

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C		012020
C		012040
C	INITIAL SOLID MATERIAL TEMPERATURES	012060
C		012080
C		012100
C		012120
		012140
502	MATN=XKKKF(XMATN)	
	NOSTAT=493	
	DO 493 K1=1,M1N	
	CALL READKM(TCZERJ(K1),MATNJ,HSCLNJ(K1),NK)	
	IF(NK)493,493,11999	
493	TCJ(K1)=TCZERJ(K1)	
	NOSTAT=494	012160
	DO 494 K=1,M1N	012180
	CALL READKM(TCZERN(K),MATN,HSCLN(K),NK)	012200
	IF(NK)494,494,11999	012220
494	TCN(K) = TCZERN(K)	012240
	NOSTAT=490	012260
	DO 490 I=1,NR	012280
	MATR(I)=XKKKF(XMATR(I))	012300
	MATSR(I)=XKKKF(SMATR(I))	012320
	DO 490 K=1,M1R	012340
	CALL READKM(TCZERR(I,K),MATSR(I),HSCLR(I,K),NK)	012360
	IF(NK)490,490,11999	012380
490	TCR(I,K) = TCZERR(I,K)	012400
	NOSTAT=491	012420
	DO 491 I=1,NS	012440
	MATS(I)=XKKKF(XMATS(I))	012460
	MATSS(I)=XKKKF(SMATS(I))	012480
	DO 491 K=1,M1S	012500
	CALL READKM(TCZERS(I,K),MATSS(I),HSOLS(I,K),NK)	012520
	IF(NK)491,491,11999	012540
491	TCS(I,K) = TCZERS(I,K)	012560
	NOSTAT=492	012580
	DO 492 I=1,NC	012600
	MATC(I)=XKKKF(XMATC(I))	012620
	MATSC(I)=XKKKF(SMATC(I))	012640
	DO 492 K=1,M1C	012660
	CALL READKM(TCZERC(I,K),MATSC(I),HSCLC(I,K),NK)	012680
	IF(NK)492,492,11999	012700
492	TCC(I,K) = TCZERC(I,K)	012720
	MATH=XKKKF(XMATH)	012740
	NOSTAT=1321	012760
	IF(IPDW)13061,13061,13062	012780
13062	IF(ISTEDY)13060,13060,13061	012800
13060	IXC=TCG	012820
	IXC1=TC(1,M1C)	012840
13061	IF(PTPCV)14020,14020,14040	012860
14040	IF(ISTEDY)14050,14050,14020	012880
14050	PXC=PCG	012900
	PXC1=0.7*PCG	012920
14020	CONTINUE	012940
	DO 1321 K=1,M1H	012960
	CALL READKM(THEZER(K),MATH,HSOLH(K),NK)	012980
	IF(NK)1321,1321,11999	013000
1321	THE(K)=THEZER(K)	013020

C
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C

OUTPUT INITIAL SOLID MATERIALS TEMPERATURES

```

      WRITE OUTPUT TAPE 6,1784
1784  FORMAT ( 28F11INITIAL NUZZLE TEMPERATURES ///)
      DO 1785 K=1,M1N
1785  WRITE OUTPUT TAPE 6,1786,K,TCN(K)
1786  FORMAT (12X 9H NODE NO. 13, 6F TCN = F10.1)
C
      WRITE OUTPUT TAPE 6,1101
1101  FORMAT(31H1INITIAL REFLECTOR TEMPERATURES///)
      DO 495 I = 1,NR
      WRITE OUTPUT TAPE 6,14,I
      DO 495 K = 1,M1R
495  WRITE OUTPUT TAPE 6,4,K,TCR (I,K)
      WRITE OUTPUT TAPE 6,1102
1102  FORMAT(28F11INITIAL SHIELD TEMPERATURES///)
      DO 496 I = 1,NS
      WRITE OUTPUT TAPE 6,14,I
      DO 496 K = 1,M1S
496  WRITE OUTPUT TAPE 6,5,K,TCS (I,K)
      WRITE OUTPUT TAPE 6,1103
1103  FORMAT(27H1 INITIAL CORE TEMPERATURES///)
      DO 497 I = 1,NC
      WRITE OUTPUT TAPE 6,14,I
      DO 497 K = 1,M1C
497  WRITE OUTPUT TAPE 6,6,K,ICC (I,K)

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INITIAL FLUID TEMPERATURES

```

      DO 1322 K=1,M1H
      THC(K)=THE(K)
1322  THF(K)=THE(K)
      THC(MH)=THE(M1H)
      THF(MH)=THE(M1H)
C
      DO 300 K = 1,M1N
300  TN(K) = TCZERN(K)
      TN(MN)= TCZERN(M1N)
      T5 = TN(MN)
      DO 302 I=1,NR
      DO 301 K=1,M1R
301  TR(I,K) = TCZERR(I,K)
302  TR(I,MR) = TCZERR(I,M1R)
      T6 = TR(NR,MR)

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013180
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013800
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013860
013880
013900
013920
013940
013960
013980
014000
014020
014040
014060
014080
014100
014120
014140

```

DO 304 I=1,NS
DO 303 K=1,M1S
303 TS(I,K) = TCZERS(I,K)
304 TS(I,MS) = TCZERS(I,M1S)
I7 = TS(NS,MS)
DO 306 I=1,NC
DO 305 K=1,M1C
305 TC(I,K) = TCZERC(I,K)
306 TC(I,MC) = TCZERC(I,M1C)
T10 = TC(NC,MC)
T14=5.0*T6
T16=T6
T17=T14
T17P5=T14
T18=T14
T19=4.5*T6

```

C
C
C
C
C
C

INITIAL PRESSURE GUESSES

```

P2=1.63*PXC
P4=1.62*PXC
P5=1.33*PXC
P6=1.2555*PXC
P7=1.25*PXC
P14=0.99*PXC
P1=P2
EM1N=M1N
EM1R=M1R
EM1S=M1S
EM1C=M1C
P10=PXC
DELP=(P7-P10)/EM1C
DO 1505 I=1,NC
PC(I,1)=P7
PC(I,MC)=P10
NOSTAT=10000
CALL PARAH (DAT,P7,1,TC(I,1),6,NK)
IF(NK)99999,10000,99999
10000 QUALC(I,1)=DAT(5)
HHC(I,1)=DAT(3)
PC(I,MC)=P10
NOSTAT=10001
CALL PARAH (DAT,P10,1,TC(I,MC),6,NK)
IF(NK)99999,10001,99999
10001 QUALC(I,MC)=DAT(5)
1505 HHC(I,MC)=DAT(3)
NOSTAT=10002
DO 505 K=2,M1C
XXK=K-1
PRE=P7 - DELP*XXK
DO 505 I=1,NC
PC(I,K)=PRE

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014180
01418C
014200
014220
014240
014260
014280
014300
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014920
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014980
015000
015020
015040
015060
015080
015100
015120
015140
015160
015180
015200
015220
015240
015260

```

	CALL PARAH (DAT,PRE,1,TC(I,K),6,NK)	015280
	IF(NK)99999,10002,99999	015300
10002	QUALC(I,K)=DAT(5)	015320
505	FHC(I,K)=DAT(3)	015340
	DELP=(P6-P7)/EM1S	015360
	DO 1506 I=1,NS	015380
	PS(I,MS)=P7	015400
	PS(I,1)=P6	015420
	NOSTAT=10003	015440
	CALL PARAH (DAT,P6,1,TS(I,1),6,NK)	015460
	IF(NK)99999,10003,99999	015480
10003	QUALS(I,1)=DAT(5)	015500
	FHS(I,1)=DAT(3)	015520
	NOSTAT=10004	015540
	CALL PARAH (DAT,P7,1,TS(I,MS),6,NK)	015560
	IF(NK)99999,10004,99999	015580
10004	QUALS(I,MS)=DAT(5)	015600
1506	FHS(I,MS)=DAT(3)	015620
	NOSTAT=10005	015640
	DO 506 K=2,M1S	015660
	XXK=K-1	015680
	PRE=P6 - DELP*XXK	015700
	DO 506 I=1,NS	015720
	PS(I,K)=PRE	015740
	CALL PARAH (DAT,PRE,1,TS(I,K),6,NK)	015760
	IF(NK)99999,10005,99999	015780
10005	QUALS(I,K)=DAT(5)	015800
506	FHS(I,K)=DAT(3)	015820
	DELP=(P5-P6)/EM1R	015840
	DO 1507 I=1,NR	015860
	PR(I,MR)=P6	015880
	PR(I,1)=P5	015900
	NOSTAT=10006	015920
	CALL PARAH(DAT,P5,1,TR(I,1),6,NK)	015940
	IF(NK)99999,10006,99999	015960
10006	QUALR(I,1)=DAT(5)	015980
	FHR(I,1)=DAT(3)	016000
	NOSTAT=10007	016020
	CALL PARAH(DAT,P6,1,TR(I,MR),6,NK)	016040
	IF(NK)99999,10007,99999	016060
10007	QUALR(I,MR)=DAT(5)	016080
1507	FHR(I,MR)=DAT(3)	016100
	NOSTAT=10008	016120
	DO 507 K=2,M1R	016140
	XXK=K-1	016160
	PRE=P5-DELP*XXK	016180
	DO 507 I=1,NR	016200
	PR(I,K)=PRE	016220
	CALL PARAH(DAT,PRE,1,TR(I,K),6,NK)	016240
	IF(NK)99999,10008,99999	016260
10008	QUALR(I,K)=DAT(5)	016280
507	FHR(I,K)=DAT(3)	016300
	DELP=(P4-P5)/EM1N	016320
	PN(1)=P4	016340
	PN(MN)=P5	016360
	NOSTAT=10009	016380

	CALL PARAH(DAT,P4,1,TN(1),6,NK)	016400
	IF(NK)99999,10009,99999	016420
10009	QUALN(1)=DAT(5)	016440
	HHN(1)=DAT(3)	016460
	NGSTAT=10010	016480
	CALL PARAH(DAT,P5,1,TN(MN),6,NK)	016500
	IF(NK)99999,10010,99999	016520
10010	QUALN(MN)=DAT(5)	016540
	HHN(MN)=DAT(3)	016560
	NGSTAT=10011	016580
	DO 508 K=2,M1N	016600
	XXK=K-1	016620
	PN(K)=P4 - DELP*XXK	016640
	CALL PARAH (DAT,PN(K),1,TN(K),6,NK)	016660
	IF(NK)99999,10011,99999	016680
10011	QUALN(K)=DAT(5)	016700
508	HHN(K)=DAT(3)	016720
	P14=PXC-1.0	016740
	PDST(1)= PXC*1.2	016760
	DO 1350 K=1,MH	016780
	PHST(K)=P14	016800
	NGSTAT=10012	016820
	CALL PARAH(DAT,P14,1,THH(K),6,NK)	016840
	IF(NK)99999,10012,99999	016860
10012	QUALHT(K)=DAT(5)	016880
	HHHT(K)=DAT(3)	016900
	NGSTAT=10013	016920
	CALL PARAH(DAT,PDST(1),1,THC(K),6,NK)	016940
	IF(NK)99999,10014,99999	016960
10014	QUALHD(K)=DAT(5)	016980
	HHFD(K)=DAT(3)	017000
1350	PDST(K)=PDST(1)	017020
	NGSTAT=10015	017040
	CALL PARAH (DAT,PZ,1,TZ,6,NK)	017060
	IF(NK)99999,10015,99999	017080
10015	H1=DAT(3)	017100
	DIFP=P14-PA	017120
C		017140
C	SUM OF PCON1 THRU PCON4 MUST BE LESS THAN 1.0	017160
C		017180
	P17=PCON1*DIFP + PA	017200
	P17P5=PCON2*DIFP + PA	017220
	P18=PCON3*DIFP + PA	017240
	P19=PCON4*DIFP + PA	017260
	M1H=MH-1	017280
	M2H=MH-2	017300
C		017320
	LOCK=0	017340
C		017360
	CALL CHAIN (2,4)	017380
C		017400
C		017420
99999	OUT=SHFIRST	017440
	WRITE OUTPUT TAPE6,99998,OUT,NGSTAT, (DAT(I),I=1,10)	017460
	GO TO 30	017480
11999	WRITE OUTPUT TAPE 6,11998,NGSTAT,I,K	017500

```

      CO TC 30
11998 FORMAT (20H-      FIRST-NOSTAT IS 17,1HI 15,1HK 15 )
99998 FORMAT (/14H-      ROUTINE ,A6,29H, BAD PRPTY LOOKUP.  NOSTAT= 18
      1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
      END
017520
017540
017560
017580
017600

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CHAIN 2 (WITH NOZZLE TUBE JACKET)

SECOND PART WITH TPCV OPTION 11/00/84

ARITH. EXPRES- USED IN TURBO-PUMP TO COMPUTE DENSITY
RHLFF(I,P)=P/(XMCU*I)

ARITHMETIC EXPRES. USED IN TURBO-PUMP TO COMPUTE FLOW STORAGES
CWFF(V,R,RG,P,PC)=V*(R-RG)/(DELTA*(P-PC))

ARITH. EXPRES. TO FIX FLICATING NMEERS
XKKKF(X)=X + 1.0E-05 *X

DIMENSION A(2700),TITLE(12),HD(10),HH(10),DAT(10)

EQUIVALENCE INPUTS TO Y ROUTINES TO PRESERVE ORDER OF COMMON

EQUIVALENCE (GAMMA,DUM1), (XMW,DUM2), (C1,DUM3), (C2,DUM4),
1 (CRIT,DUM0), (ITRNO,IDUM1), (LOCK,IDUM2), (LATCH,IDUM3), (II,
1 IDUM0), (I1,
2 IDUM4), (I2,IDUM5), (I3,IDUM6), (I4,IDUM7), (I5,IDUM8), (SIGMA,
3 DUM5), (DIV,DUM6), (SMALL,DUM7), (VAL1,DUM8), (CCEFF,DUM9),
4 (TOLER,DUM10), (DELTA,DUM11), (PI,DUM12), (GC,DUM13), (R,DUM14),
5 (CJ,DUM15), (TWALL,DUM16), (TIME,DUM17)

INPUT VALUES

EQUIVALENCE (A(1),TAU), (A(2),CDELTA), (A(4),YOUTN),
1(A(5),CCOEFF), (A(6),PCF), (A(7),TCF), (A(8),H2F), (A(9),PAF), (A(1
20),POWER), (A(11),ORDH2(1)), (A(12),CRDTC(1)), (A(113),GRDPC), (A(
3164),ORDPA), (A(215),CGAMMA), (A(216),CXMW), (A(217),TPCVX),
4 (A(218),PTPCV), (A(220),DNT), (A(221),CTWALL), (A(222),XKN), (A
5(223),ALPHAN(1)), (A(243),AREAN(1)), (A(263),AN(1)), (A(283),RHN(1
6)), (A(303),DN(1)), (A(323),Z3NX), (A(343),CNX), (A(363),ARATI
70(1)), (A(383),EN(1)), (A(403),SFN(1)), (A(423),A1N(1)), (A(443),A
8K4(1)), (A(463),ALPHAR(1)), (A(473),AREAR(1)), (A(483),AR(1)), (A(4
993),XKR(1)), (A(503),RHR(1)), (A(523),DR(1)), (A(623),Z3R(1))
EQUIVALENCE (A(723),CR(1)), (A(823),ALPHAS(1)), (A(833),AREAS(1)
1), (A(843),AS(1)), (A(853),XKS(1)), (A(863),RHS(1)), (A(873),DS(1)
2), (A(973),Z3S(1)), (A(1073),CS(1)), (A(1173),ALPHAC(1)), (A
3(1183),AREAC(1)), (A(1193),AC(1)), (A(1203),XKC(1)), (A(1213),RHC(
41)), (A(1223),E(1)), (A(1233),SF(1)), (A(1243),A1(1)), (A(1253),DC
5(1)), (A(1353),Z3C(1)), (A(1453),CC(1)), (A(1553),FLUXN(1)),
6 (A(1573),FLUXR(1)), (A(1673),FLUXS(1)), (A(1773),FLUXC(1)),
7 (A(1873),TCZERN(1)), (A(1893),TCZERR(1)), (A(1993),TCZERS(1))
8, (A(2093),TCZERC(1)), (A(2193),TMAX)

EQUIVALENCE (A(2194),COEFS), (A(2195),COEFR), (A(2196),COEFC)
2, (A(2197),HMAX), (A(2198),TRNO), (A(2199),TURBM), (A(2200),
3 THKTD), (A(2201),THIK), (A(2221),ORDPOW), (A(2272),XIPOW)

TURBO-PUMP AND HEAT EXCHANGER INPUTS

EQUIVALENCE (A(2293),PCCN1), (A(2294),PCCN2), (A(2295),PCCN3),
1 (A(2296),PCCN4), (A(2297),WCCN1), (A(2298),WCCN2), (A(2299),DH),
2 (A(2300),AHC), (A(2301),RHD), (A(2302),AHH), (A(2303),RHH),
2 (A(2304),Z3HX), (A(2314),CHX), (A(2324),FLUXH), (A(2334),THEZER),
3 (A(2345),AREADT), (A(2346),AREADO), (A(2347),AHBP), (A(2348),

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4 RHBP), (A(2349),DHBP), (A(2350),AREATC), (A(2351),CEPT), (A(2352),
5 ,CP1), (A(2353),CP2), (A(2354),CP3), (A(2355),CF4), (A(2356),
6 CPS), (A(2357),XNSS), (A(2358),CT1), (A(2359),CT2), (A(2360),
7 CT3), (A(2361),CT4), (A(2362),CT5), (A(2363),AFD1), (A(2364),
8 RHPD1), (A(2365),DPD1), (A(2366),TZ), (A(2367),PZ), (A(2368),V4)

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C
EQUIVALENCE (A(2369),V5), (A(2370),V6), (A(2371),V7), (A(2372),
1 V10), (A(2373),V14), (A(2374),WYEDT), (A(2375),WYDST), (A(2376),
2 WYBPT), (A(2377),WYENT), (A(2378),YRN), (A(2379),P1), (A(2380),
3 P2), (A(2381),X1R), (A(2382),P4), (A(2383),P5), (A(2384),P6),
4 (A(2385),P7), (A(2386),P14), (A(2387),C19), (A(2388),FDST(1)),
5 (A(2398),WDST(1)), (A(2408),PHST(1)), (A(2418),WHST(1))
6 (A(2428),TXCTOL), (A(2429),PXCTOL), (A(2430),T18TCL), (A(2431),
7 TTOLER), (A(2432),PTOLER), (A(2433),COMEX), (A(2434),CCTUR)
8 (A(2435),YKA), (A(2436),T9S), (A(2437),T9R), (A(2438),T9C)
9 (A(2439),PCWTOL), (A(2440),CHDTCV)
EQUIVALENCE (A(2492),TCG), (A(2493),PCG), (A(2494),TXCLIM),
1 (A(2495),PXCLIM)

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FIXED POINT INPUTS

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C
C
C
EQUIVALENCE (A(2500),XLIMIT), (A(2501),XMINCR), (A(2502),X11), (A
1 (2503),X12), (A(2504),X13), (A(2505),X14), (A(2506),X15), (A(2507)
2 ,X16), (A(2508),X17), (A(2509),X18), (A(2510),XITEM1), (A(2511),XIP
3 I), (A(2512),XITI), (A(2513),XITNI), (A(2514),EMN), (A(2515),EMR)
4 , (A(2516),EMS), (A(2517),EMC), (A(2518),XNH), (A(2519),XM)
5 (A(2520),XNR), (A(2521),FNS), (A(2522),XNC), (A(2523),XNN)
6 (A(2524),XSTY), (A(2525),XMKN), (A(2526),XMKTD)
7 (A(2527),XMATN), (A(2528),XMATR), (A(2533),XMATS), (A(2538),
8 XMATC), (A(2543),XMATH), (A(2544),SMATR), (A(2549),SMATS),
9 (A(2554),SMATC), (A(2559),XINRX)
EQUIVALENCE (A(2560),TCZERJ), (A(2580),FLUXJ), (A(2600),CNXJ),
1 (A(2620),Z3JX), (A(2640),XMATNJ), (A(2641),XMKNJ)
2 (A(2642),DRNT), (A(2643),XFRATR), (A(2644),XPRATM), (A(2645),EFFMN),
3 (A(2646),EFFRN)

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C
DIMENSION THC(11),THE(11),THH(11),Z3H(10),CH(10),THEC(10),
1 FLUXH(10),THEZER(10),PDST(11),WDST(10),PHST(11),WHST(11),Z2(20),
1 YDST(10),YHST(10),Z4(20)
DIMENSION G1H(10),Q2H(10),G3H(10),SH(10),QH(10)

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C
COMMON GAMMA,XMW,C1,C2,CRIT,ITRND,LOCK,LATCH,I1,I1,I2,I3,I4,I5,SI
1 GMA,DIV,SMALL,VAL1,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME,A
2 ,LIMIT,MINOR,I6,I7,I8,ITEM1,IFI,I11,ITNI,MH,M,MN,MC,MS,MR,NN,NS,
3 NR,NC,M1H,M2H,MAJOR,M1N,M2N,M1R,M2R,M1S,M2S,M1C,M2C,DDD,FIG,FPI,
4 HCCAL,HHCAL,HCCCN,HHCON,PSIN,PSIR,PSIS,PSIC,CHNCR,CHNGS,CHNOC,T2
5 ,TXC,PXC,PA,TCN,TCR,TCS,TCC,TFC,THC,THH,IN,T5,TR,T6,TS,T7,TC,
6 T10,T14,T16,T17,T17P5,T16,T19,EM1N,EM1R,EM1S,EM1C,F10,PC,PS,PR,
7 PN,P17,P17P5,P1E,P19,TERMH,TERMD,MAJOR,ANT,IDUMP,ISTEDY,PPP,
8 RECOV,T4,XMUL,XNSC,GUALN,HHN,GUALR,HHR,GUALS,FHS,GUALC,HHC,
9 QUALHT,HHHT,QUALHD,HHHD,H1,TXC1,H2,TPCV,PXC1

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```

C
COMMON MATN,MATR,MATS,MATC,MATH,HSCLN,HSCLS,HSCLR,HSCLC,HSCLF
1 ,MATSR,MATSS,MATSC
DIMENSION HSCLN(20),HSCLS(5,10),HSCLR(5,10),HSCLC(5,10)

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```

1 ,HSCLN(20),HSCLH(5,10),HSCLS(5,10),HSCLC(5,10),FSLLH(20)
2,HSCLH(20),CNX(20),Z3NX(20),CHX(10),Z3HX(10)
3,XMATR(5),MATR(5),XMATS(5),MATS(5),XMATC(5),MATC(5)
4 ,SMATR(5),SMATS(5),SMATC(5),MATSR(5),MATSS(5),MATSC(5)

```

C

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    DIMENSION DRDH2(51), DRDTC(51), CRDPC(51), CRDPA(51), CRDFCW(51)
    DIMENSION ALPHAR(5),AREAR(5),AR(5),XKR(5),RHR(5),DR(5,10),Z3R(5,10)
    1),CR(5,10),PSIR(5),ORDTCV(51),ALPHAC(5),AREAC(5),AC(5),XKC(5),
    2RHC(5),DC(5,10),Z3C(5,10),CC(5,10),PSIC(5),GR(5,10),WR(5),WYER(5),
    3PR(5,11),TCR(5,10),TCUR(5,10),TR(5,11),FLUXR(5,10),FLUXS(5,10),
    4FLUXC(5,10),TCZERR(5,10),TCZERS(5,10),TCZERC(5,10),E(5),SF(5),
    5A1(5),PSI(5),Y(5),QS(5,10),WS(5),WYES(5),PS(5,11),TCS(5,10),TCCS
    6(5,10),TS(5,11),GC(5,10),WC(5),WYEC(5),PC(5,11),TCC(5,10),TCOC
    7(5,10),TC(5,11),YINR(5),YOUTR(5),YR(5,10),YINS(5),YCUTS(5),YS(5,10)
    8),YINC(5),YOUTC(5),YC(5,10)

```

```

    DIMENSION ALPHAN(20),AN(20),RHN(20),DN(20),Z3N(20),CN(20),
    1 WN(20),THETA(20),TN(20),TCN(20),H(20),BETA(20), Z2N(20),Z
    24N(20),PSIN(20),Z5N(20),RELAX(20), Q2N(20),Q3N(20),Q4N(20),
    3Q5N(20),TAR(20),SN(20),TCON(20),QN(20),ERRCR(20),FLUXN(20),TCZERN(
    420),EN(20),SFN(20),A1N(20),YN(20),PN(21),ARATIC(20),TBB(20),PHX
    5(21),DDD(20),HCCCN(20),HHCCN(20),AK4(20),TEK(20),QUALN(21),HHN(21)
    6,QUALR(5,11),HHR(5,11),QUALS(5,11),HHS(5,11),QUALC(5,11),HHC(5,11)
    7,QUALHT(5,11),HHHT(5,11),QUALHD(5,11),HHHD(5,11),THIK(20),CP(20),
    8ALPHAS(5),AREAS(5),XKS(5),RHS(5),DS(5,10),Z3S(5,10),CS(5,10),
    9PSIS(5),AS(5)

```

```

    DIMENSION QJ(20),FLUXJ(20),TCJ(20),HSCLNJ(20),HCSCLJ(20),TCQJ(20),
    1CNJ(20),CNXJ(20),Z3J(20),THETAJ(20),HJ(20),BETAJ(20),Z2J(20),
    2RELAXJ(20),SJ(20), Q2J(20),Q3J(20), ERRCRJ(20),Z3JX(20)
    3,TCZERJ(20)

```

```

    COMMON QJ,FLUXJ,TCJ,HSCLNJ,HCSCLJ,TCQJ,CNJ,CNXJ,Z3J,THETAJ,HJ,
    1BETAJ,Z2J,RELAXJ,SJ, Q2J,Q3J, ERRORJ,NOZ,Z3JX,MATNJ,MKNJ
    2,WDDT,W4,TAR,TBB,POWER,TCZERJ

```

```

    COMMON BETA ,CH ,CN ,CP ,DAT ,ERRCR ,HD ,
    1 HH ,HOSCLC ,HOSCLH ,HOSCLN ,HOSCLR ,HOSCLS ,H ,PHX ,
    2 PSI ,Q1H ,Q2H ,Q2N ,Q3C ,Q3H ,Q3N ,Q3R ,
    3 Q3S ,Q4N ,Q5N ,QC ,QH ,QN ,GR ,QS ,
    4 RELAX ,SC ,SH ,SN ,SR ,SS ,TCCC ,TCON ,
    5 TCR ,TCUS ,TEK ,THEC ,THETA ,TITLE ,WC ,WN ,
    6 WR ,WS ,WYEC ,WYER ,WYES ,YC ,YDST ,YHST ,
    7 YINC ,YINR ,YINS ,YN ,YOUTC ,YOUTR ,YOUTS ,YR ,
    8 Y ,YS ,Z2N ,Z2 ,Z3H ,Z3N ,Z4N ,Z4 ,
    9 Z5N

```

```

    COMMON ITFLAG,ARAT,CPMN,ITRC,MKN,ITRNOT,NFLAG,K,NK,SUM,L,NCSTAT,
    1TAVG

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```

671 FORMAT(///// 28H NOZZLE NODE MASS FLOW RATES ///)
673 FORMAT(/////26H NOZZLE CHANNEL PRESSURES ///)
674 FORMAT(23X,9H P4 = F10.1/23X, 9H P5 = F10.1//)
676 FORMAT(11X10H NODE NO. 13,5X 6H PN = F10.1)

```

C

C

C

C

C

C

SLOPES OF EXOGENOUS VARIABLES FOR NEXT MAJOR TIME INTERVAL, TAU

CALL TAB1H ONLY ONCE

IF(LOCK-5)13080,13081,13080

13080 CALL TAB1H

13081 LOCK=5

*
*

*
*
*

*
*

FN-IDF-0068

```

C
C***** REWIND 4 ***** ERASEAELE PLOT TAPE FOR CHAIN(3,4) PLOT *
REWIND 22 PLOT *
CALL SETDEN(22,1) PLOT *
KSET=0
ITFLAH=0
LIST = 1
ITURB=1
N25=A(3)
P2TOL=0.1*PXCTOL
IHMAX=XKKKF(HMAX)
ITMAX=XKKKF(TURBM)
MKN=XKKKF(XMKN)
MKTD=XKKKF(XMKTD)
IPOW=XKKKF(XIPOW)
INRX=XKKKF(XINRX)
XNS=XNSS
NCAV=0
T1CSAV=0.0
POWSAV=0.0

C
510 LIST = LIST + 1
C
IF(ISTEDY)404,404,406
404 SLOPTC = (ORDTC(LIST) - ORDTC(LIST-1)) / TAU
SLOPPC = (ORDPC(LIST) - ORDPC(LIST-1)) / TAU
SLOPPA = (ORDPA(LIST) - ORDPA(LIST-1)) / TAU
SLOPH2=(ORDH2(LIST) - ORDH2(LIST-1)) / TAU
IF(IPOW)13063,13063,13062
13062 SLCPPG=(ORDPOW(LIST)-ORDPOW(LIST-1))/ TAU
13063 SLOPIV=(ORDTCV(LIST)-ORDTCV(LIST-1))/TAU
C
406 II=0
C
515 II = II + 1
POWSAV=0.0
T1CSAV=0.0
ITRND = 0
LATCH = 1
PPOWT=4H*NC*
C
IF(IPCW)13407,13407,13405 *
13405 IF(TXC-TXCLIM)13407,13406,13406
13406 IPOW=-1
13407 IF(PTPCV)13410,13410,13408 *
13408 IF(PXC-PXCLIM)13410,13409,13409
13409 PTPCV=-1.0
13410 CONTINUE
C
C
C START OF CALCULATION LOOP FOR TIME INTERVAL, DELTA
C
C
C
C JJ = 0

```

```

12357 JJ          = JJ + 1
C
      IF(ISTEDY)411,411,410
410   DELTA=1.0E+21
C     POWER=POWER
411   TIME=TIME + DELTA
C
      ITIME = 0
C
C     SOLID MATERIAL TEMPERATURES AT PREVIOUS TIME INTERVAL
C
      DO1504 K = 1, MIN
      HSOLJ(K)=HSCLNJ(K)
      TCCJ(K)=TCJ(K)
      HSCLN(K)=HSCLN(K)
1504   TCCN(K) = TCN(K)
      DO 500 I=1,NR
      DO 500 K=1,MIR
      HCSOLR(I,K)=HSOLR(I,K)
500   TCCR(I,K) = TCR(I,K)
      DO 501 I=1,NS
      DO 501 K=1,MIS
      HOSOLS(I,K)=HSOLS(I,K)
501   TCOS(I,K) = TCS(I,K)
      DO 502 I=1,NC
      DO 502 K=1,MIC
      HOSOLC(I,K)=HSOLC(I,K)
502   TCCO(I,K) = TCC(I,K)
      DO 1323 K=1,M1H
      HOSCLH(K)=HSCLH(K)
1323   THEO(K)=THE(K)
      P1C=P1
      F2C=P2
      P4C=P4
      F5C=P5
      P6C=P6
      F7C=P7
      F10C=P10
      P14C=P14
      PXC=C=PXC
      XNSC=XNS
      NCSTAT=10003
10003  CALL PARA# (DAT,P5,1,HHR(1,1),3,K)
      IF(K)99999,10004,99999
10004  RHG5C=DAT(7)
      NCSTAT=10005
10005  CALL PARA# (DAT,P6,1,HHS(1,1),3,K)
      IF(K)99999,10006,99999
10006  RHG6C=DAT(7)
      NCSTAT=10007
10007  CALL PARA# (DAT,P7,1,HFC(1,1),3,K)
      IF(K)99999,10008,99999
10008  RHG7C=DAT(7)
      NCSTAT=10009
10009  CALL PARA# (DAT,P10,1,T1C,6,K)
      IF(K)99999,10010,99999

```

```

10010 RHO100=DAT(7)
      IF(INRX)10011,10011,13114
10011 NOSTAT=10011
      CALL PARAH (DAT,P14,1,HHHT(1),3,K)
      IF(K)99999,10012,99999
10012 RHO140=DAT(7)
C
      TXCD=TXC
      PXCD=PXC
C
C      VALUES OF EXOGENOUS VARIABLES FOR TIME INTERVAL, DELTA
C
      H2=H1 + POWP/(W2*9338.0)
13114 IF(ISTEDY)415,415,416
      415 TXC=TXC + SLCPTC * DELTA * TCF
      PXC = PXC + SLOPPC * DELTA * PCF
      PA = PA + SLOPPA * DELTA * PAF
      IF(INRX)13100,13100,13113
13113 H2=H2 + SLOPH2*DELTA*H2F
13100 IF(IPDW)13065,13065,13064
13064 POWER = POWER + SLOPPG*DELTA
      IF(LIST +11 -3)13400,13400,13072
13400 TXC=TXCD
      GO TO 13065
13072 TXC=2.0*TXCD-TXC1
      TXC1 =(TXC+TXC1)/2.0
13065 IF(PTPCV)416,416,14100
14100 TPCV=TPCV + SLOPIV * DELTA
      IF(LIST +11 -3)13401,13401,14130
13401 PXC=PXCD
      GO TO 416
14130 PXC=2.0*PXCD-PXC1
      PXC1=(PXC + PXC1)*0.5
C
      416 NOSTAT=10034
      CALL PARAH (DAT,P2,1,H2,3,NK)
      IF(NK)99999,10034,99999
10034 T2=DAT(6)
      T4 = T2
      HHN(1)=H2
      NOSTAT=10001
10001 CALL PARAH (DAT,P4,1,H2,3,K)
      IF(K)99999,10002,99999
10002 RHC40=DAT(7)
C
      NOSTAT=10027
      CALL PARAH (DAT,PXC,1,IXC,6,NK)
      IF(NK)99999,10027,99999
10027 HHXC=DAT(3)
C
      DO 516 K = 1, MIN
      TBB(K) = TXC/(( 1.0 + DDD(K)))
      TAR(K)=TBB(K)*((1.0+RECGV*DDD(K)) )
      516 PHX(K) = PXC/((( 1.0 + DDD(K))*PPP)
C
C

```



```

C      IITRNL = 0
C
C      CALCULATE NOZZLE MASS FLOWRATE
C
C      WYENT=Y1(ANT,TXC,TXC,PA,PXC)
C
      W40=W4
      W130=W13
      W150=W15
      WDOTL=WDOT
      WDOT=WYENT*(PXC - PA)
      DIV2=PXC/P10
      P2=DIV2*P2
      P4=DIV2*P4
      P5=DIV2*P5
      P6=DIV2*P6
      P7=DIV2*P7
      P10=PXC
      P14=DIV2*P14
      P17=DIV2*P17
      P17P5=DIV2*P17P5
      P18=DIV2*P18
      P19=DIV2*P19
      IF(KSET)1355,1355,1356
1355  W13=WCON1 * WDOT
      W7=WDOT + W13
      W6=W7
      W15=WCON2 * W6
      W5=W6 + W15
      W4=W5
      W2=W4
      W1=W2
      W18=W15 + W13
      KSET=1
      DO 13333 K=1,MN
1444  WN(K)=W4/ALPHAN(K)
13333 PN(K) = PN(K) * DIV2
      J = 0
13332 J = J + 1
      WK(J) = W5 / CFNCR
      DO 13334 K=1,MR
13334 PR(J,K)= PR(J,K) * DIV2
      IF (J-NR) 13332,13336,13336
13336 J = 0
13337 J = J + 1
      WS(J) = W6 / CFNCS
      DO 13335 K=1,MS
13335 PS(J,K) = PS(J,K)*DIV2
      IF (J-NS) 13337,13338,13338
13338 J = 0
13339 J = J + 1
      WC(J) = W7 / CFNCC
      DO 13340 K=1,MC

```

```

13340 PC(J,K)      = PC(J,K)*DIV2
      IF(J-NC) 13339,478,478
1356 DIV2=WDOT/WDOT0
      W4=W40*DIV2
      W13=W130*DIV2
      W15=W150*DIV2
      W5=W4
      W2=W4
      W1=W2
      W6=W5-W15
      W7=W6
      W18=W13+W15
      PN(1)=P4-W4/YINN
      DO 40000 K=1,M1N
      WN(K)=W4/ALPHAN(K)
40000 PN(K+1)=PN(K)-WN(K)/YN(K)
      DO 40001 I=1,NR
      WR(I) = WYER(I)*(P5-P6)
      PR(I,1)=P5 - WR(I)/YINR(I)
      DO 40001 K=1,M1R
40001 PR(I,K+1)=PR(I,K) - WR(I)/YR(I,K)
      DO 40002 I=1,NS
      WS(I) = WYES(I)*(P6-P7)
      PS(I,1)=P6 - WS(I)/YINS(I)
      DO 40002 K=1,M1S
40002 PS(I,K+1)=PS(I,K) - WS(I)/YS(I,K)
      DO 40003 I=1,NC
      WC(I) = WYEC(I)*(P7-P1C)
      PC(I,1)=P7 - WC(I)/YINC(I)
      DO 40003 K=1,M1C
40003 PC(I,K+1)= PC(I,K) - WC(I)/YC(I,K)
C
478  CONTINUE
C
      W180=W18
C
C
C
C
C
C
C
C
      COMPUTE HEAT FLOWS AND TEMPERATURES
C
549 IF (I6) 476,476,474
474 PRINT 4203
4203 FORMAT (/13F TEMPERATURES)
476 CONTINUE
C
      IITRNC = IITRNC + 1
C
C
      TN(1) = T4
      ITRTOT = 0
      TXCD=T10
550  ITRTOT = ITRTOT + 1
      IF(ITRTOT - ITNI) 550,580,575

```

```

575 WRITE OUTPUT TAPE 6,376
576 FORMAT(1F1 // // // // 2CH TEMPERATURE LOOPING )
    IDUMP = 5
    CALL NCZZLE(0)
580 CONTINUE
    IF(IPGW)13077,13077,13075
13075 DO 13076 K=1,MIN
    TBB(K) = TXC/(1.0 + DDD(K))
13076 TAR(K) = TBB(K)*(1.0 + RECOV*DDD(K))
13077 CONTINUE
C
C
C    HEAT GENERATION
C
421 DO 517 K=1,MIN
    GJ(K)=POWER*FLUXJ(K)
    517 GN(K) = POWER * FLUXN(K)
C
    DO 518 I=1,NR
    DO 518 K=1,M1R
    518 QN(I,K) = POWER*FLUXR(I,K)
C
    DO 519 I=1,NS
    DO 519 K=1,M1S
    519 QS(I,K) = POWER*FLUXS(I,K)
C
    DO 520 I=1,NC
    DO 520 K=1,M1C
    520 QC(I,K) = POWER*FLUXC(I,K)
    DO 1324 K=1,M1H
1324 QH(K)=POWER*FLUXH(K)
C
    CALL NCZZLE(1)
    NZ=NZ
    GO TO (922,31,10009,11999,921),NZ
    921 IF(NZ-5)922,99999,922
    922 CONTINUE
C
C
C    COEFF=CCLEPR
    TOLER=TSR
    SENSE=SHREFLC
    FHR(1,1)=FHN(MN)
    IF (13) 926,926,917
    917 WRITE OUTPUT TAPE 6, 923
    923 FORMAT(// // // //23H REFLECTOR TEMPERATURES //)
    926 CALL TEMS (NR,MR,AR,ALPHAR,CR,DR,GR,RHR,TR,TB,T6,QUALR,
    1 FHR,FH,TOR,TOR,WH,23R,Q3R,SR,PSIR,MATR,HSCLR,HCSCLR,MATSE)
C
C
    IF(SENSE LIGHT 1)1790,1771
1771 SENSE=6FSHIELD
    COEFF=CCEFS
    TOLER=TSB
    SUM=C.0
    SUMN=C.0

```

```

DO 10028 I=1,NR
SUM=SUM + ALPHAR(I)*WR(I)*FHR(I,MR)
10028 SUMN=SUMN + ALPHAR(I)*WR(I)
HHS(1,1)=SUM/SUMN
IF (I3) 927,927,918
918 WRITE OUTPUT TAPE 6, 924
924 FORMAT(/////2CH SHIELD TEMPERATURES //)
927 CALL TEN9 (NS,MS,AS,ALPHAS,CS,DS,GS,KHS,TS,T6,T7,QUALS,
1 HHS,PS,TCS,TCOS,WS,Z3S,Q3S,SS,PSIS,MATS,HSCLS,HCSCLS,MATSS)

```

C
C

```

IF(SENSE LIGHT 1)1790,1772
1772 SENSE=4HCCRE
COEFF=COEFC
TOLER=T9C
SUM=0.0
SUMN=0.0
DO 10029 I=1,NS
SUM=SUM + ALPHAS(I)*WS(I)*HHS(I,MS)
10029 SUMN=SUMN + ALPHAS(I)*WS(I)
HHC(1,1)=SUM/SUMN
IF(I3) 928,928,919
919 WRITE OUTPUT TAPE 6, 925
925 FORMAT(/////18H CRE TEMPERATURES //)
928 CALL TEN9 (NC,MC,AC,ALPHAC,CC,DC,QC,RHC,TC,T7,T10,QUALC,
1 HHC,PC,TCC,TCOC,WC,Z3C,Q3C,SC,PSIC,MATC,HSCLC,HCSCLC,MATSC)

```

C

```

IF(SENSE LIGHT 1)1790,1773
1773 COEFF=CCOEFF
TOLER=TTOLER
SUM=0.0
SUMN=0.0
DO 10014 I=1,NC
SUM=SUM + ALPHAC(I)*WC(I)*FHC(I,MC)
10014 SUMN=SUMN + ALPHAC(I)*WC(I)
H10=SUM/SUMN

```

C
C
C
C
C
C
C
C

```

TEST FOR T10 CONVERGENCE
IF(IPDW)13074,13074,13066
13066 IF(ABS(T10-TXC)/T10 - TXCTOL)13073,13073,13067
13067 TXC = T10
WDOT1 = WDOT
WYENT = Y1(ANT,TXC,TXC,PA,PXC)
WDOT = WYENT*(PXC - PA)
DIV2 = WDOT/WDOT1
W13 = W13*DIV2
W15 = W15*DIV2
W18 = W15 + W13
W7 = WDOT + W13
W6 = W7
W5 = W6 + W15

```

```

      W4 = WC
      W2 = W4
      W1 = W2
      DO 13066 K=1,MIN
13066  WN(K)=WN(K)*DIV2
      DO 13069 I=1,NK
13069  WR(I)= WR(I)*DIV2
      DO 13070 I=1,NS
13070  WS(I)= WS(I)*DIV2
      DO 13071 I=1,NC
13071  WC(I)= WC(I)*DIV2
      IF(I7)957,950,957
13073  TXC = T10
      GO TO 980
13074  IF(ABS(T10-TXC)/TXC - TXCTOL)980,980,6999
C
C
C      CHANCE POWER FOR NEXT ITERATION
C
C
6999  PURPC = TXC/T10
      CLDPC = POWER
      POWER=POWSAV + (CLDPC-POWSAV)*(TXC-T10SAV)/(T10-T10SAV)
      IF(POWER + 0.1)13116,13117,13117
13116  POWER = CLDPC*PURPC
13117  IF(POWER+0.1)14425,14430,14430
14425  POWER=-.1
14430  IF(POWER) 14440,14440,14435
14435  IF(POWER-2.0)14440,14440,14436
14436  POWER=2.0
14440  POWSAV=CLDPC
      T10SAV=T10
      IF(I7)957,950,957
      957  WRITE OUTPUT TAPE 6, 958, T10, TXC, POWER, CLDPC
      958  FORMAT(/// 5F0T10= F8.1, 5H TXC= F8.1, 7H POWER= F14.6, 11H OL
10 POWER= F14.6 )
      GO TO 950
      980  CONTINUE
      GO TO (956, 8800), LATCH
C
956  LATCH = 1
      KCOUNTS=1
C
      IF(I8) 955,950,955
955  WRITE OUTPUT TAPE 6,958, T10,TXC,POWER
C
C      COMPUTE MASS FLOWS AND PRESSURES
C
C      (1) CALCULATE MASS FLOW RATE CONDUCTANCES
C
950  IF (I6) 952,952,951
951  PRINT 4303
4303  FORMAT (10F PRESSURES )
952  CONTINUE

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```

      ITRNP=0
      KIP = 1
      T18OLD=T18
      WT=WDOT
      KTURE=0
      PXC20=PXC/20.0
      ITRNO=XKKKF(ITRNO)
      HPHD(1)=HFS(1,1)
C
C      START OF HEAT EXCHANGER AND TURBO-PUMP LOOP
C
      IP2      = 0
      P2CLD=P2
1000  ITRNOH=0
      P2CK2=P2CK
      P2CK=P2
      ITRNO=ITRNO-1
      IF(INRX)13101,13101,1320
13101 ITRCH=0
      W158=W15**0.8
      W188=W18**0.8
      H2=H1 + POWP/(W2*9338.0)
C
      START OF ITERATION LOOP
1314  ITRNOH=ITRNOH+1
      ITRCH=ITRCH+1
C
C      CONVECTIVE HEAT TRANSFER CONDUCTANCES
C
      DO 1301 K=1,M1H
      GET SOLID ENTHALPY
      NOSTAT=13012
      CALL READKM (THE(K),MATH,HSOLH(K),NK)
      IF(NK)13026,13026,11999
13026 CPMN=(HSOLH(K)-HOSOLH(K))/(THE(K)-THEO(K))
      IF(CPMN)13997,13012,13013
13997 WRITE OUTPUT TAPE 6,13999,K,NOSTAT,MATH,HSOLH(K),HOSOLH(K),
1 THE(K ),THEO(K)
13012 CPMN =HOSOLH(K)/THEO(K)
13013 CH(K)=CHX(K) * CPMN
C
      IF(K-M2H)13020,13020,13022
13020 TAVG=(THE(K)+THE(K+1))/2.0
      NOSTAT=13020
      CALL READKM (TAVG,MKTD,VK,NK)
      IF(NK)13021,13021,11999
13021 Z3H(K)=Z3HX(K) * VK
13022 CONTINUE
C
      THETA=(THC(K+1)/THE(K))*0.55
      FPI=XFPI (THC(K),PDST(K))
      CP=XCP(THC(K),THC(K+1),HHHD(K),HHHD(K+1))
      Z1=W15*CP
      Z5=W18*CP
      HD(K)=HCCAL*FPI*THETA*W158

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      EETA=FD(K)*TERMD/((W18+1.0E-05)*CP)
      NCSTAT=11001
      CALL READKM (THE(K),MKTD,VKID,NFLAG)
      IF(NFLAG)11001,11001,11001
11001  ZW=8.0*(VKID*PI*DT*RHH / THKTL
      DIV2=1.0/ZW
      Z2(K)=Z1*(EXP(-BETA)-1.0)
      Z2(K)=1.0/(1.0/Z2(K) + DIV2)
      THETA=(THF(K)/THE(K))*0.55
      FPI=XFPI (THF(K),PHSI(K))
      CP=XCP(THF(K),THF(K+1),HHHT(K),HHHT(K+1))
      Z5=W18*CP
      FH(K)=HHCAL*FPI*THETA*W188
      EETA=FF(K)*TERMD/((W18+1.0E-05)*CP)
      Z4(K)=Z5*(EXP(EETA)-1.0)
1301  Z4(K)=1.0/(1.0/Z4(K) + DIV2)
C
C      RELAXATION COEFFICIENTS
C
      RELAX(1)=COEX/(Z2(1)+Z3H(1)+Z4(1)+CH(1)/DELTA)
      DO 1302 K=2,M2H
1302  RELAX(K)=COEX/(Z2(K)+Z3H(K-1)+Z3H(K)+Z4(K)+CH(K)/DELTA)
      RELAX(M1H)=COEX/(Z2(M1H)+Z3H(M2H)+Z4(M1H)+CH(M1H)/DELTA)
C
C      HEAT FLUXES
C
      DO 1303 K=1,M1H
      Q1H(K)=Z2(K)*(THE(K)-THC(K+1))
      Q2H(K)=Z4(K)*(THF(K)-THE(K))
1303  SH(K)=CH(K)*(THE(K) - THEC(K))/DELTA
      DO 1304 K=1,M2H
1304  Q3H(K)=Z3H(K)*(THE(K+1)-THE(K))
C
C      ERRORS IN FLOWS AT NODES
C
      ERROR(1)=QH(1)-SH(1)-Q1H(1)+Q2H(1)+Q3H(1)
      DO 1305 K=2,M2H
1305  ERROR(K)=QH(K)-SH(K)-Q1H(K)+Q2H(K)-Q3H(K-1)+Q3H(K)
      ERROR(M1H)=QH(M1H)-SH(M1H)-Q1H(M1H)+Q2H(M1H)-Q3H(M2H)
C
C      NEW VALUES OF TEMPERATURES
C
      DO 1306 K=1,M1H
1306  THE(K)=THE(K)+RELAX(K)*ERROR(K)
      THC(1)=T6
      DO 1307 K=2,MH
      HHFD(K)=HHFD(K-1) + Q1H(K-1)/W18
      NCSTAT=10030
      CALL PARAF (DAT,PDST(K),1,HHFD(K),3,NK)
      IF(NK)99999,10030,99999
10030  QUALFD(K)=DAT(5)
1307  THF(K)=DAT(6)
      IF(W13)2335,2336,2336
2335  THF(MF)=THC(MH)
      HHFT(MF)=HHFD(MF)
      GO TO 2337

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2336 HHHT(MH)=(W15*HHFD(MH) + W13*HHXC)/W18
      NOSTAT=10031
      CALL PARAH (DAT,PXC,1,HHHT(MH),3,NK)
      IF(NK)99999,10031,99999
10031 THH(MH)=DAT(6)
      QUALHT(MH)=DAT(5)
2337 DO 1308 K=1,M1H
      I=MH-K
      HHHT(I)=HHHT(I+1) - Q2H(I)/W18
      NOSTAT=10032
      CALL PARAH (DAT,PHST(I),1,HHHT(I),3,NK)
      IF(NK)99999,10032,99999
10032 QUALHT(I)=DAT(5)
1308 THH(I)=DAT(6)
C
C      CONVERGANCE TEST
      SUM=0.0
      DO 1309 K=1,M1H
1309 SUM=SUM+ABSF(ERRGR(K))
      SUMHX= 0.0
      DO 1004 J=1,M1H
1004 SUMHX = SUMHX + ABSF(QH(J))+ABSF(SH(J))+ ABSF(Q1H(J))+ABSF(Q2H(J))
      DO 1005 J=1,M2H
1005 SUMHX = SUMHX+ABSF(Q3H(J))
      SUM = SUM/SUMHX
C
      IF(I4)5505,5506,5505
5505 WRITE OUTPUT TAPE 6,1331, (K,PHST(K),THC(K),THE(K),THF(K),
      1 PDST(K),HSOLH(K),K=1,MH)
      WRITE OUTPUT TAPE 6,5504,SUM,WDOT,W13,W15,W18
5504 FORMAT (1H0,10X,3HSUM 1PE13.5,6H WDOT E13.5,5H W13 E13.5,5H W15
      1 E13.5,5H W18 E13.5 )
5506 CONTINUE
      IF(ITRNOH-1)1314,1314,1310
1310 IF(ITRNOH-IHMAX)1311,1311,1312
1311 IF(SUM-TTOLER)1320,1320,1314
1312 ITFLAH=1
      WRITE OUTPUT TAPE 6,1313
      GO TO 9999
1313 FORMAT (1H-.32HHEAT EXCHANGER DOES NOT CONVERGE )
1320 CONTINUE
C
      AINN=AN(1)*ALPHAN(1)
      ADUTN=AN(M1N)*ALPHAN(M1N)
      YINN=Y3(AINN,XKN,W4,T4,P4)
      YOUTN=Y3(ADUTN,XKN,W4,TN(MN),PN(MN) )
C
      NNP1= NN + 1
      NN1 = NN - 1
      DO 2004 K = 1,NN1
2004 YN(K)=Y2 (AN(K),RHN(K),DN(K),HHN(K+1),HHN(K),PN(K+1),PN(K),WN(K) )
      YN(NN)=Y1 (AN(NN),TN(NNP1),TN(NN),PN(NNP1),PN(NN) )
      DO 1574 K=NNP1,M1N
1574 YN(K)=Y2 (AN(K),RHN(K),DN(K),HHN(K+1),HHN(K),PN(K+1),PN(K),WN(K) )
      SUM = 0.0
      DO 1804 K = 1,MN

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1804 SUM = SUM + 1.0/(YN(K)*ALPHAN(K))
SUM = SUM + 1.0 / YINN + 1.0 / YOUTN
WYETT = 1.0 / SUM

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C
C
C

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      DO 2000 I = 1, NR
      YINR(I)=Y1 (AREAR(I),TR(I,1),T5,PR(I,1),P5)
      YOUTR(I)=Y3(AR(I),XKR(I),WR(I),TR(I,MR),PR(I,MR) )
      DO 1500 L=1,M1R
1500 YR(I,L)=Y2 (AR(I),RHR(I),DR(I,L),HHR(I,L+1),HHR(I,L),PR(I,L+1),
1 PR(I,L),WR(I) )
      SUM = 0.0
      DO 1800 L=1,M1R
1800 SUM = SUM + 1.0/YR(I,L)
      SUM = SUM + 1.0/YINR(I) + 1.0/YOUTR(I)
2000 WYER(I) = 1.0 / SUM

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C
C
C

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      DO 2001 I=1,NS
      YINS(I)=Y1(AREAS(I),TS(I,1),T6,PS(I,1),P6)
      YOUTS(I)=Y3(AS(I),XKS(I),WS(I),TS(I,MS),PS(I,MS) )
      DO 1501 L=1,M1S
1501 YS(I,L)=Y2 (AS(I),RHS(I),DS(I,L),HHS(I,L+1),HHS(I,L),PS(I,L+1),
1 PS(I,L),WS(I) )
      SUM = 0.0
      DO 1801 L=1,M1S
1801 SUM = SUM + 1.0/YS(I,L)
      SUM = SUM + 1.0/YINS(I) + 1.0/YOUTS(I)
2001 WYES(I) = 1.0/SUM

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C
C
C

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      DO 2002 I=1,NC
      YINC(I)=Y1(AREAC(I),TC(I,1),T7,PC(I,1),P7)
      YOUTC(I)=Y3(AC(I),XKC(I),WC(I),TC(I,MC),PC(I,MC))
      DO 1502 L=1,M1C
1502 YC(I,L)=Y2 (AC(I),RHC(I),DC(I,L),HHC(I,L+1),HHC(I,L),PC(I,L+1),
1 PC(I,L),WC(I) )
      SUM = 0.0
      DO 1802 L=1,M1C
1802 SUM = SUM + 1.0/YC(I,L)
      SUM = SUM + 1.0/YINC(I) + 1.0/YOUTC(I)
2002 WYEC(I) = 1.0/SUM

```

C
C
C

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      WYERT = 0.0
      DO 2200 I=1,NR
2200 WYERT = WYERT + WYER(I)*ALPHAR(I)
      WYEST = 0.0
      DO 2201 I=1,NS
2201 WYEST = WYEST + WYES(I)*ALPHAS(I)

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C

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      WYECT = 0.0
      DO 2202 I=1,NC
2202  WYECT = WYECT + WYEC(I)*ALPHAC(I)
C
      (2)  CALCULATE PRESSURES
C
      IF(INRX)2300,2300,1382
2300  Y1DST=Y1(AREACT,T6,T6,PDST(1),P6)
      DO 2310 L=1,M1H
2310  YDST(L)=Y2 (AHC,RHD,DH,HHHD(L+1),HHHD(L),PDST(L+1),PDST(L),W15)
      T14=TFF(MH)
      T16=THC(MH)
      P16=PDST(MH)
      Y1DD=Y1(AREADD,T14,T16,P14,P16)
      SUM=0.0
      SUM=1.0/Y1DST + 1.0/Y1DD
      DO 2315 L=1,M1H
2315  SUM=SUM + 1.0/YDST(L)
      WYDST = 1.0/SUM
      DO 2320 L=1,M1H
      K=MH-L+1
2320  YHST(K)=Y2 (AHH,RHH,DH,HHHT(K),HHHT(K-1),PHST(K),PHST(K-1),W18)
      T17=THH(1)
      T18CK=T18
      T18=(T17 + T18)/2.0
      Y1TD=Y1(AREATD,T18,T17,P17P5,P17)
      DIV2 = 11.475*P17P5/(W18*T17) - 2.0*W18/P18
      IF(PTPCV)14200,14200,14210
14210  NOSTAT=14210
      IF(90.0-TPCV)14212,14215,14215
14212  WRITE OUTPUT TAPE 6,14213,TPCV,NOSTAT
14213  FORMAT (12H- BAD TPCV= 1PE16.7, 9H NOSTAT= 18 )
      GO TO 31
C
      LOCK UP XKTCV AS F(TPCV)
C
14215  CALL READKM (TPCV,19,XKTCV,NK)
      IF(NK)14211,14211,11999
14211  YTPCV=DIV2 /XKTCV
      GO TO 14220
14200  YTPCV=W18/(P17P5-P18)
      XKTCV=DIV2/YTPCV
14220  NOSTAT=10015
      CALL PARAH (DAT,P2,1,H2,3,K)
      IF(K)99999,10015,99999
10015  RHQ2=DAT(7)
      T2=DAT(6)
      P2MP1 = P2 - P1
      IF(P2MP1) 12006,12006,12299
12006  IP2 = IP2 + 1
      IF(IP2 - 90) 12198,12198,12199
12198  P2=P1 + 1.0
      P2MP1=1.0
      GO TO 12299
12199  WRITE OUTPUT TAPE 6, 12007

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12007 FORMAT (12H - P1 GT P2 )
      ITFLAH=1
      GO TO 9961
12299 DELH=(P2-P1)/RHO2
C
C      XNS = SHAFT SPEED
C
      Q1=CP1*W1/RHO2
12008 H1D2=P2MP1/(12.0*RHO2)
      NOSTAT=13198
      CALL PARAH (DAT,P1,1,H1,3,NK)
      IF(NK)99999,13198,99999
13198 T1=DAT(6)
      RHO1=DAT(7)
      PVAP =EXP(2.3025851*(2.9304-(79.821/T1)+.011627*T1))
      VPSP=P1-PVAP
      IF(VPSP)13203,13203,13199
13199 VPSH=VPSP/(12.0*RHO1)
C
      XNS2=XNS
      DIV2=P2-P1
      CALL CURVE(DIV2,W2,VPSP,XNS)
      IF(XNS)13203,13203,13205
13203 WRITE OUTPUT TAPE 6,13204,DIV2,W2,VPSP,XNS
      GO TO 31
13204 FORMAT (25H- SHAFT SPEED NO CONVERGE //6H P2-P1 E16.8,3H W2 E16.8
1 ,5H VPSP E16.8,4H XNS E16.8)
13205 CONTINUE
      IF(ITRNC-N25)13200,13200,13201
13200 XNS=(XNS2 + XNS)/2.0
13201 CONTINUE
C
      PUMP1=Q1/XNS
      PUMP2=VPSH/XNS**2
      CALL PLMP(PUMP1,PUMP2,ETAP)
      IF(ETAP-0.05)2322,2324,2324
2322 ETAP=0.05
2324 POWP=W1*DELH/ETAP + (CPS*XIR*(XNS*XNS - XNSC*XNSC))/(2.0*DELTA)
      U=CT1*XNS
      GAT=1.0 - (P19/P18)**.286
      NOSTAT=10033
      CALL PARAH (DAT,P18,1,T18,6,NK)
      IF(NK)99999,10033,99999
10033 H18=DAT(3)
      H19=H18*(1.0-GAT)
      CO=223.8 * SQRTF(ABSF(H18-H19))
      ETAT=CT2*(U/CO)*((U/CO)*(U/CO)) + CT3*((U/CO)*(U/CO)) + CT4*(U/CO)
      IF(ETAT-0.01)2326,2328,2328
2326 ETAT=C.01
2328 Y6=POWP/((P18-P19)*ETAT*9336.0*(H18-H19) )
      T19=T18 * (1.0 - ETAT*GAT)
      DIV2=PA/P19
      IF(DIV2 - .528) 12009,12009,12010
12009 YRN=C19*P19/(SQRTF(T19)*(P19-PA))
      GO TO 12011
12010 YRN=(3.87*C19*P19/(P19-PA)) * SQRTF( (DIV2**1.43 - DIV2**1.715)

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      1 /T19 )
12011 SUM=C.0
      DO 2330 L=1,M1H
2330  SUM=SUM + 1.0/YHST(L)
      SUM=SUM + 1.0/Y1TD + 1.0/YTPCV + 1.0/Y6 + 1.0/YRN
      WYTIT=1.0/SUM
C
C      CHECK WYTIT
C
      IF(WYTIT)1381,1381,1382
1381  WYTIT=C.003
1382  CONTINUE
C
      ITRNP=ITRNP + 1
C
      WY1=Y2 (APD1,RHPD1,DPD1,H1,H1,P1,PZ,W2)
      NOSTAT=10018
      CALL PARAH (DAT,P5,1,HHR(1,1),3,K)
      IF(K)99999,10018,99999
10018  RH05=DAT(7)
      NOSTAT=10020
      CALL PARAH (DAT,P6,1,HHS(1,1),3,K)
      IF(K)99999,10020,99999
10020  RH06=DAT(7)
      NOSTAT=10021
      CALL PARAH (DAT,P7,1,HHC(1,1),3,K)
      IF(K)99999,10021,99999
10021  RH07=DAT(7)
      NOSTAT=10023
      CALL PARAH (DAT,P10,1,H10,3,K)
      IF(K)99999,10023,99999
10023  RH010=DAT(7)
      IF(INRX)13102,13102,13103
13102  NOSTAT=10024
      CALL PARAH (DAT,P14,1,HHHT(MH),3,K)
      IF(K)99999,10024,99999
10024  RH014=DAT(7)
      WYBPT=(772.18*AHH*AHH*RH010)*((1.0+CBPT)/W13
      CW14=CWFF(V14,RHC14,RH0140,P14,P14C)
      WV14=CW14 *(P14-P140)
13103  CW4=CWFF(V4,RHC4,RHC4C,P4,P40)
      CW5=CWFF(V5,RH05,RH050,P5,P50)
      CW6=CWFF(V6,RH06,RH060,P6,P60)
      CW7=CWFF(V7,RH07,RHC7C,P7,P70)
      CW10=CWFF(V10,RHC10,RHC10C,P10,P10C)
      WV4=CW4 *(P4-P40)
      WV5=CW5 *(P5-P50)
      WV6=CW6 *(P6-P60)
      WV7=CW7 *(P7-P70)
      WV10=CW10 *(P10-P100)
      IF(INRX)13104,13104,13105
13105  W15=0.0
      W18=0.0
      W13=0.0
      W7=WDCT + WV10
      W6=W7 + WV7

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W5=W6 + WV6
W4=W5 + WV5
W2=W4 + WV4
P10=PX C
P00=P10
P7=P10 + W7/WYECT
P6=P7 + W6/WYEST
P5=P6 + W5/WYERT
P4=P5 + W4/WYETT
P2=P4 + W2/WYEDT
P1=P2 - W2/WY1
NOSTAT=13115
CALL PARA H (CAT,P2,1,H2,3,NK)
IF(NK)99999,13115,99999
13115 T2=DAT(6)
IF(ABS F(P2-P2CK)/P2 - PXCTOL)2370,2370,2367
13104 W15=WYDST*(P6-P14)
W1802=W180
W180=W18
W18=WYIT*(P14-PA)
IF(W18-.001)14454,14455,14455
14454 W18=.001
14455 CONTINUE
14410 W18=(W18 + W180 + W1802)/3.0
14415 POWT=W18*ETAT*9336.0*(H18-H19)
DIV2=ABS F(POWT/POWP)
IF(DIV2-100.)13055,13054,13054
13055 IF(DIV2-.01)13054,13054,13056
13054 W18=2.0E-6 * POWP
13056 W13=W18-W15+WV14
C
W7=WDOT + W13 + WV10
W6=W7 + WV7
W5=W6 + W15 + WV6
W4=W5 + WV5
W2=W4 + WV4
W1=W2
C
IF(P1PCV)14330,14330,14320
14320 POWT=W18*ETAT*9336.0*(H18-H19)
SPTX= CPS*XIR*(XNS*XNS-XNSO*XNSO)/(2.0*DELTA)
P1=P2 - W2/WY1
KURVE=50
NOSTAT=14370
14370 P2IT=P2
P2=P1 + (POWT - SPTX)*ETAP*RH02/W2
IF(P2-P1)14445,14446,14446
14445 P2=P1 + 1.0
14446 CALL PARA H (CAT,P2,1,H2,3,NK)
IF(NK)99999,14375,99999
14375 RH02=DAT(7)
WRITE OUTPUT TAPE 6,14470, P2,H2,RH02,POWT,SPTX,H18,H19,
1 (DAT(I),I=1,10)
14470 FORMAT (2H-R 7E16.8/2H R 7E16.8/2H R 3E16.8)
IF(ABS F(P2IT-P2)/P2 - P2TOL)14390,14390,14380
14380 KURVE=KURVE-1

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      IF(KURVE)14385,14370,14370
14385 WRITE OUTPUT TAPE 6,14386,H2,RH02,RHC2CK
14386 FORMAT (24H- TPCV OP. RHC2 NC CONVE. / 5X,2HH2 1PE16.7,5H RH02
      1E16.7,7H RH02CK E16.7)
      GC TO 31
14390 IF(ITERNO-N25)14465,14465,14466
14465 P2=(P2 + P2CK + P2CK2)/3.0
14466 P4=P2 - W2/WYEDT
      P5=P4 - W4/WYETT
      P6=P5 - W5/WYERT
      P7=P6 - W6/WYEST
      P10=P7 - W7/WYECT
      WRITE OUTPUT TAPE 6,14469,P2,P4,P5,P6,P7,P10,W2,W4,W5,W6,W7,
      1 WYEDT,WYETT,WYERT,WYEST,WYECT
14469 FORMAT (5H- P2= 6E16.8/ 3H W2 5E16.8/ 4H CCN 5E16.8)
14461 IF(P10-PA)14462,14462,14456
14462 P10=0.5*(PXC + PA)
      GO TO 14463
14456 P10=0.5*(PXC+P10)
14463 DIV2=MIN1F(P4,P5,P6,P7,P10)
      IF(DIV2-P10)14458,14457,14457
14458 WYCAL= 1.0/((1.0/WYEDT + 1.0/WYETT + 1.0/WYERT + 1.0/WYEST +
      1 1.0/WYECT))
      DIV2=P2-P10
      P4=P2 - WYCAL*DIV2/WYEDT
      P5=P4 - WYCAL*DIV2/WYETT
      P6=P5 - WYCAL*DIV2/WYERT
      P7=P6 - WYCAL*DIV2/WYEST
      WRITE OUTPUT TAPE 6,14469,P2,P4,P5,P6,P7,P10,W2,W4,W5,W6,W7,
      1 WYEDT,WYETT,WYERT,WYEST,WYCAL
14457 PXCCK=PXC
      PXC=P10
      GO TO 14340

C
14330 RELAX(10)=COTLR/(CW10 + WYECT + WYENT)
      ERROR(10)=W7-WV10-W13-WDOT
      P10=P10 + ERROR(10)*RELAX(10)
      P7=P10 + W7/WYECT
      P6=P7 + W6/WYEST
      P5=P6 + W5/WYERT
      P4=P5 + W4/WYETT
      P2=P4 + W2/WYEDT
      P1=P2 - W2/WY1

C
14340 POC=P10
      P14=P10 - W13/WYBPT
      PDST(1)=P6 - W15/Y1DST
      DO 2340 L=2,MH
2340 PDST(L)=PDST(L-1) - W15/YDST(L-1)
      P16=PDST(MH)
      PHST(MH)=P14
      DO 2345 K=1,M1H
      L=MH-K
2345 PHST(L)=PHST(L+1) - W18/YHST(L)
      P17=PHST(1)
      P17P5=P17 - W18/Y1TO

```

```

P19=PA + W18/YRN
P18=XP18 (W18,T18,CT5,P18,P19)
DIV2= MIN1F (P2,P4,P5,P6,P7,P10,P14,P16,P17, P18,P19)
IF(DIV2)2369,2369,13051
13051 IF(PTPCV)14360,14360,14350
14350 IF(ABSF(PXC-PXCCK)/PXC - PXCTOL)14420,14420,2366
14420 IF(ABSF(T18-T18CK)/T18 - TXCTOL)2370,2370,2366
14360 SUM=ABSF(ERROR(10))/W2
IF(ITRNP-1)2366,2366,2350
2350 IF(ITRNP-ITMAX)2352,2352,2369
2352 IF(SUM-PTOLER)2354,2354,2366
2369 WRITE OUTPUT TAPE 6,2342
ITFLAH=1
GO TO S999
2342 FORMAT (1H-,28HTURBO-PUMP DOES NOT CONVERGE )
2366 IF(P10-PXC20)2376,2376,2377
2377 IF(PTPCV)14270,14270,14260
14260 PXC=P10
WDOT1=WDOT
WYENT=Y1(ANT,TXC,TXC,PA,PXC)
WDOT=WYENT*(PXC-PA)
IF(ITRND-N25)14480,14480,14481
14480 WDOT=(WDOT + WDOT1)/2.0
14481 CONTINUE
DIV2=1.0
GO TO 14280
2376 P10=C.75*P7
IF(PTPCV)14270,14270,14260
14270 DIV2=PXC/P10
14280 P2=DIV2*P2
P4= DIV2*P4
P5= DIV2*P5
P6= DIV2*P6
P7= DIV2*P7
P10=PXC
P14=DIV2*P14
CW14=CWFF(V14,RHO14,RHO140,P14,P140)
WV14=CW14 *(F14-P140)
W15=WYDST*(P6-P14)
IF(W15)2390,2391,2391
2390 W15=0.1
2391 W18=WYTTT*(P14-PA)
W18=(W18 + W180 + W1802)/3.0
IF(W18-0.001)2392,2393,2393
2392 W18=0.001
2393 W13=W18-W15+WV14
IF(PTPCV)14300,14300,14310
14310 W7=WDOT +W13 +WV10
W6=W7 +WV7
W5=W6 +W15 +WV6
W4=W5 +WV5
W2=W4 +WV4
W1=W2
14300 PDST(1)=P6 -W15/Y1DST
DO 2380 L=2,MH
2380 PDST(L)=PDST(L-1) - W15/YDST(L-1)

```

```

P16=PDST(MH)
PHST(MH)=P14 - W18/YHST(1)
DO 2362 K=1,M1H
L=MH-K
2382 PHST(L)=PHST(L+1) - W18/YHST(L)
P17=PHST(1)
P17P5=P17 - W18/Y1T0
IF(P17P5)14452,14452,14453
14452 P17P5=P17*.9
14453 CONTINUE
P19=PA + W18/YRN
P18=XP18 (W18,T18,CT5,P18,P19)
IF(P18)13050,13050,13052
13050 WRITE OUTPUT TAPE 6,13053
13053 FORMAT (10H- P18 BAD)
ITFLAH=1
GO TO 9999
13052 CONTINUE
C
C
GO TO 2367
C
C CHECK PRESSURE CONVERGENCE
C
2354 IF(ABS(PXC-P10)/PXC - PXCTOL)2370,2370,2366
2370 ITURB=ITRNO
ITRNO=-1
T4=T2
H1N(1)=H2
2367 DO 1404 K=1,M1N
1404 WN(K)=W4/ALPHAN(K)
PN(1)=P4-W4/YINN
DO 1904 K=1,M1N
1904 PN(K+1) = PN(K) - WN(K) / YN(K)
C
DO 1900 I = 1, NR
WR(I) = WYER(I)*(P5-P6)
1400 PR(I,1) = P5 - WR(I)/YINR(I)
DO 1900 K=1,M1R
1900 PR(I,K+1) = PR(I,K) - WR(I)/YR(I,K)
C
DO 1901 I = 1, NS
WS(I) = WYES(I)*(P6-P7)
1401 PS(I,1) = P6 - WS(I)/YINS(I)
DO 1901 K=1,M1S
1901 PS(I,K+1) = PS(I,K) - WS(I)/YS(I,K)
C
DO 1902 I = 1, NC
WC(I) = WYEC(I)*(P7-P10)
1402 PC(I,1) = P7 - WC(I)/YINC(I)
DO 1902 K=1,M1C
1902 PC(I,K+1) = PC(I,K) - WC(I)/YC(I,K)
W1=W2
5510 WRITE OUTPUT TAPE 6,5520,PXC,P00,P2,P4,P5,P6,P7,P14,P16,P17,P17P5
1 ,P18,P19,SUM,Q1,H1D2,XNS,ETAP,PCWP,ETAT,WDCT,W13,W15,W18
2 ,W2,W4,W5,W6,W7,T14,T16,T17,T18,T19,PXCTCL,PTCLER,ITRNO,ITRNOH,

```



```

      3 T6,P2,P1
      IF(ITRNO)2371,2368,1000
5520 FORMAT(6H0 PXC,11X,3HP10,12X,2HP2,13X,2HP4,13X,2HP5,13X,2HP6
1/1P6E15.7/ 5H0 P7,12X,3HP14,12X,3HP16,12X,3HP17,12X,5HP17P5,
2 10X,3HP18/1P6E15.7/6H0 P19,11X,3HSUM,12X,2H01,13X,4HH1D2,11X
3 ,3HXNS,12X,4HETAP /1P6E15.7/ 7H0 PCWP,10X,4HETAT,11X,4HWOOT,
4 11X,3HW13,12X,3HW15,12X,3HW18/ 1P6E15.7 /5H0 W2,12X,
5 2HW4,13X,2HW5,13X,2HW6,13X,2HW7,13X,3HT14 /1P6E15.7 / 6H0 T18 ,
611X,3HT17,12X,3HT18,12X,3HT19,12X,6HPXCTCL,9X,6HPTCLER /1P6E15.7/
7 7H0 TURB,11X,5HHEAT EXCH,6X,2HT6,13X,2HP2,13X,2HP1 / 4X,13,12X,
8 13,8X,1P3E15.7 / 1H- )
2368 WRITE OUTPUT TAPE 6,2356
      ITFLAH=1
      GO TO 9999
2356 FORMAT (1H-,24HSYSTEM DOES NOT CONVERGE )
C
2371 IF(INRX)13109,13109,13110
13109 IF(ABSF(T18OLD-T18)/T18 - T18TOL)8000,8000,8200
13110 WRITE OUTPUT TAPE 6,13111,P2,P2CLD
13111 FORMAT ( 4H- P2 F15.3,5X,5HP2CLD F15.3)
      IF(ABSF(P2-P2OLD)/P2 - PXCTOL)13112,13112,8009
13112 IF(ABSF(TXCO-T10)/T10 - TXCTCL)13120,13120,8009
13120 LATCH=2
      GO TO 549
C
C CHECK TURBINE POWER CONVERGENCE
C
8000 POWT=W18*ETAT*(H18-H19)*9336.0
      IF(ABSF(PCWP/POWT - 1.0) - POWTOL)8005,8005,8006
8005 LATCH=2
      PPOWT=4H*OK*
8006 IF(I8)8009,8009,8007
8007 WRITE OUTPUT TAPE 6,8008,PCWP,PCWT,PPOWT
8001 WRITE OUTPUT TAPE 6,8002,T18,T18CLD,T18TOL
8002 FORMAT (5H0T18= 1PE15.7,2X,7HT18CLD= E15.7,2X,7HT18TOL= 1PE15.7)
8008 FORMAT (2H- ,5HPCWP= 1PE15.7,6H POWT= E15.7,5X,A6)
8009 GO TO (8400,549),LATCH
8200 LATCH = 1
      IF(I7) 8201,8400,8201
8201 WRITE OUTPUT TAPE 6,8002,T18,T18CLD,T18TOL
8400 CONTINUE
      IF (IITRNG -ITI) 549,549,2810
2810 IDUMP = 5
      WRITE OUTPUT TAPE 6,2809
2809 FORMAT(1H1 ///// 33H TEMPERATURE AND PRESSURE LOOPING )
      ITFLAH=1
      GO TO 9999
C
C
C
C
C TRANSFER POINT ON CONVERGENCE FOR TIME INTERVAL, DELTA
C
8800 LATCH = 1

```

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WRITE OUTPUT TAPE 6,958, T10, TXC, POWER
IF (I6) 8801, 8801, 8801, 8802
8802 PRINT 8805
8805 FORMAT (//6H DELTA)
8801 FLIMIT = LIMIT
IF (TIME - FLIMIT * TAU) 9000, 9000, 9960
C
C END OF DO LOOP ON JJ=1, MINOR
C
9000 IF (JJ - MINOR) 12357, 9001, 9001
9001 NOTICE = -5
C
GO TO 9961
9999 CONTINUE
9960 NOTICE = 5
C
9561 ITRNO = ITRNO/MINOR
PRINT 50, TIME
50 FORMAT(9H TIME = E11.4)
C
C
DIMENSION HR(10,10), HS(10,10), HC(10,10), HN(20)
7055 FORMAT (1H1, 3X, 9H REFLECTOR, 68X, 5HTIME E11.4/ 1H0 )
7001 FORMAT (9X, A6, F8.2, 7H LB/SEC /)
7004 FORMAT( 9X 4HDP = F8.2, 4H PSI 5X 4HDT = F8.2, 6H DEG R 5X
14HQ = F8.2, 7H BTU/LB / 1H- )
7006 FORMAT(1H-, 6X, 14H CHANNEL NUMBER I3, 7X, 3HWR( I2, 2H)= E11.4 )
7007 FORMAT(//10X 4HNODE, 7X 2HPR, 9X 2HTR, 9X 3HTCR, 10X 2HGR, 12X 2HHR
1 / 9X 6HNUMBER )
7009 FORMAT( I13, 5X F8.2, 3X F8.2, 3X F8.2, 3X 1PE11.4, 2E14.4 )
7011 FORMAT (1H1, 3X, 6H SHIELD, 71X, 5HTIME E11.4/ 1H0 )
7018 FORMAT(1H- 6X 14H CHANNEL NUMBER I3, 7X 3HWS(, I2, 3H) = E11.4 )
7019 FORMAT(// 10X 4HNODE, 7X, 2HPS, 9X, 2HTS, 9X 3HTCS, 10X 2HGS, 12X, 2HH
1S / 9X 6HNUMBER )
7023 FORMAT (1H1, 3X, 4H CORE, 73X, 5HTIME E11.4/ 1H0 )
7002 FORMAT( 9X 4HP5 = F8.2, 4H PSI 5X 4HT5 =, F8.2, 6H DEG R 5X 4HH5
1=, 1PE15.7, 6HBTU/LB /)
7003 FORMAT( 9X 4HP6 = F8.2, 4H PSI 5X 4HT6 = F8.2, 6H DEG R 5X
14HH6 = 1PE15.7, 6HBTU/LB /)
7015 FORMAT( 9X 4HP7 = F8.2, 4H PSI, 5X, 4HT7 = F8.2, 6H DEG R, 5X
1, 4HH7 = 1PE15.7, 6HBTU/LB /)
7027 FORMAT( 9X 4HP10 = F8.2, 4H PSI, 5X, 4HT10 = F8.2, 6H DEG R, 5
1X, 4HH10 = 1PE15.7, 6HBTU/LB /)
7029 FORMAT(1H- 6X 14H CHANNEL NUMBER I3, 7X 3HWC(, I2, 3H) = E11.4)
7030 FORMAT(// 10X 4HNODE, 7X, 2HPC, 9X, 2HTC, 9X 3HTCC, 10X 2HQC, 12X,
12HHC / 9X 6HNUMBER )
7035 FORMAT(1H1, 3X, 6HNOZZLE, 71X, 5HTIME E11.4/ 1H-, 8X, 4HW4 = F8.2,
1 7H LB/SEC //9X, 4HP4 = F8.2, 4H PSI 5X, 4HT4 = F8.2, 6H DEG R 5X,
2 4HH4 = F8.2, 6HBTU/LB /)
7040 FORMAT(1H-, 4X, 4HNODE, 7X, 2HPN, 9X, 2HTN, 9X, 3HTCN, 8X, 3HTAR, 10X, 2HQN
1 , 11X, 2HHC, 11X, 2HHN, 11X, 5HHSOLN / 3X, 6HNUMBER )
7041 FORMAT( 5X, I2, 5X, F8.2, 3F11.2, 3X, E11.4, 3E14.4)
7050 FORMAT (1H1, 3X, 9HTURBOPUMP 68X, 4HTIME E12.4/ 1H0, 10X, 5HPOWER F12.6,
1 5X, 3HTXC F8.2, 5X, 3HPXC F8.2//9X, 7HSTATION 20X, 1HP 14X, 1HT 12X,
2 4HWDOT 12X, 5HWDCTV / 9X, 6HNUMBER )
7051 FORMAT (10X, A6, 5X, 4F15.5)

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```

7052 FORMAT (10X,A6,35X,F15.5)
7053 FORMAT (1H0,8X,4HWDOT 4X,F17.5 /9X,2HQ1 6X,F17.5 /9X,4HH1D2 4X,
1 F17.5 /9X,3HXNS 5X,F17.5 /9X,4HETAP 4X,F17.5 /9X,4HPCWP 4X,F17.5
2 /9X,4HETAT 4X,F17.5 /9X,1HU 7X,F17.5 /9X,3HGAT 5X,F17.5 /9X,2HCO
3 F23.5/9X,4HDELH F21.5/9X,2HPA F23.5/9X,4HTPCV F21.5/9X,5HXKTCV
4 F20.5/9X,4HTURBI21,6H ITER./9X,10HHEAT EXCH.115,6H ITER. )
1331 FORMAT (1H1,40X,29HHEAT EXCHANGER TEMPERATURES ///9X, 4HNODE
1 11X,4HPHST 9X,3HTHC 10X,3HTHE 10X,3HTHH 10X,4HPDST/9X,6HNUMBER//
2 (13X,12,5F13.2,F14.3) )

```

C
C

```

WRITE OUTPUT TAPE 6,7050,TIME ,PCWER,TXC,PXC
G=1H0
WRITE OUTPUT TAPE 6,7051, G, P2,TZ
G=1H1
WRITE OUTPUT TAPE 6,7051, G, P1,T1,W1
G=1H2
WRITE OUTPUT TAPE 6,7051, G, P2,T2,W2
G=1H4
WRITE OUTPUT TAPE 6,7051, G, P4,T4,W4,WV4
G=1H5
WRITE OUTPUT TAPE 6,7051, G, P5,T5,W5,WV5
G=1H6
WRITE OUTPUT TAPE 6,7051, G, P6,T6,W6,WV6
G=1H7
WRITE OUTPUT TAPE 6,7051, G, P7,T7,W7,WV7
G=2H10
WRITE OUTPUT TAPE 6,7051, G, P10,T10,WDCT,WV10
G=2H14
WRITE OUTPUT TAPE 6,7051, G, P14,T14,W14,WV14
G=2H13
WRITE OUTPUT TAPE 6,7052,G,W13
G=2H15
WRITE OUTPUT TAPE 6,7052,G,W15
G=2H16
WRITE OUTPUT TAPE 6,7051, G, P16,T16
G=2H17
WRITE OUTPUT TAPE 6,7051, G, P17,T17
G=4H17P5
WRITE OUTPUT TAPE 6,7051, G, P17P5,T17P5
G=2H18
WRITE OUTPUT TAPE 6,7051, G, P18,T18,W18
G=2H19
WRITE OUTPUT TAPE 6,7051, G, P19,T19
ITURB=XKKKF(TRNO)~ITURB
WRITE OUTPUT TAPE 6,7053,WDCT,G1,H1D2,XNS,ETAP,PCWP,ETAT,U,GAT,
1 CO,DELH,PA,TPCV,XKTCV,ITURB,ITRNOH
NOSTAT=16998
DO 16998 K=1,M1H
CALL READKM (THE(K),MATH,HSOLH(K),NK)
IF(NK)16998,16998,11999
16998 CONTINUE
WRITE OUTPUT TAPE 6,1331, (K,PHST(K),THC(K),THE(K),THH(K),
1 PDST(K),HSOLH(K),K=1,MH)
WRITE OUTPUT TAPE 6,7035,TIME,W4,P4,T4,HHN(1)
WRITE OUTPUT TAPE 6,7002,P5,T5,HHR(1,1)

```

1331

```

DP=P4 - P5
DT=T5 - T4
Q=HHR(1,1) - HHN(1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
WRITE OUTPUT TAPE 6,7040
NOSTAT=17000
DO 17000 K=1,MN
IF(K-MN)16999,17000,17000
16999 CALL READKM (TCN(K),MATN,HSOLN(K),NK)
IF(NK)17000,17000,11999
17000 WRITE OUTPUT TAPE 6,7041, K,PN(K),TN(K),TCN(K),TAR(K),QN(K),
1 H(K),HHN(K),HSOLN(K)
W5 = 0.0
DO 7000 I=1,NR
7000 W5 = W5 + WR(I) * ALPHAR(I)
WRITE OUTPUT TAPE 6,7055,TIME
G=3HW5=
WRITE OUTPUT TAPE 6,7001,G,W5
WRITE OUTPUT TAPE 6,7002,P5,T5,HHR(1,1)
WRITE OUTPUT TAPE 6,7003,P6,T6,HHS(1,1)
DP=P5 - P6
DT=T6 - T5
Q=HHS(1,1) - HHR(1,1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
DO 7008 I=1,NR
WRITE OUTPUT TAPE 6,7006,I,I,WR(I)
WRITE OUTPUT TAPE 6,7007
DO 7008 J=1,MR
7008 WRITE OUTPUT TAPE 6,7009, J,PR(I,J),TR(I,J),TCR(I,J),CR(I,J),
1 HHR(I,J),HSOLR(I,J)
WRITE OUTPUT TAPE 6, 7011,TIME
W6 = 0.0
DO 7012 I=1,NS
7012 W6 = W6 + WS(I) * ALPHAS(I)
G=3HW6=
WRITE OUTPUT TAPE 6,7001,G,W6
WRITE OUTPUT TAPE 6,7003,P6,T6,HHS(1,1)
WRITE OUTPUT TAPE 6,7015,P7,T7,HHC(1,1)
DP=P6 - P7
DT=T7 - T6
Q=HHC(1,1) - HHS(1,1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
DO 7020 I=1,NS
WRITE OUTPUT TAPE 6,7018,I,I,WS(I)
WRITE OUTPUT TAPE 6,7019
DO 7020 J= 1,MS
7020 WRITE OUTPUT TAPE 6,7009, J,PS(I,J),TS(I,J),TCS(I,J),QS(I,J),
1 HHS(I,J),HSOLS(I,J)
WRITE OUTPUT TAPE 6,7023,TIME
W7 = 0.0
DO 7024 I=1,NC
7024 W7 = W7 + WC(I) * ALPHAC(I)
G=3HW7=
WRITE OUTPUT TAPE 6,7001,G,W7
WRITE OUTPUT TAPE 6,7015,P7,T7,HHC(1,1)
WRITE OUTPUT TAPE 6,7027,P00,T10,HHXC

```

```

DP=P7 - P00
DT=T10 - T7
Q=HHXC - HHC(1,1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
DO 7031 I=1,NC
WRITE OUTPUT TAPE 6,7029,I,I,WC(I)
WRITE OUTPUT TAPE 6,7030
DO 7031 J= 1,MC
7031 WRITE OUTPUT TAPE 6,7009, J,PC(I,J),TC(I,J),TCC(I,J),GC(I,J),
1 HHC(I,J),HSOLC(I,J)

```

C
C
C
C
C

```

ITFLAH IS A FLAG ASSIGNED 0 UNLESS STOPPAGE CONDITION OCCURS.
THEN IT IS 1

```

```

WDOT13=WDOT+W13
P18P19=P18/P19

```

PLOT *
PLOT *
PLOT *
PLOT *
PLOT *
PLOT *
PLOT *
PLOT *

```

C***** WRITE BINARY TAPE FOR CHAIN(3,4)
WRITE TAPE 22, TIME, TXC, PXC, WDOT, POWER, W1, WDOT13,
1 W2, W15, W13, W18, T10, T2, T4, T5, T6,
2 T7, W4, T16, T14, T17, T19, T18, P2, P4,
3 P5, P6, P7, P10, W5, P14, W6, W7, P17,
4 P17P5, P18, P19, FTOT, PSIN, PA, TPCV, P18P19, XNS,
5 ETAT, ETAP, POWT, VPSP
IF(ISTEDY)9899,9899,30
9899 IF(ITFLAH)9901,9901,30
9901 IF(TMAX-TIME)9951,9951,9902
9902 IF(NTICE)9900,9900,9951
9900 IF(II-MAJOR) 515, 9950, 9950
9950 IF (LIST-LIMIT) 510,9951,9951
9951 PRINT 9954
9954 FORMAT (// 8H PROBLEM)
9953 CONTINUE

```

C
C

```

30 CALL CHAIN(3,4)

```

PLOT *

C

```

1790 WRITE OUTPUT TAPE 6,1791,SENSE
31 ITFLAH=1
GO TO 9961
1791 FORMAT (17H- TEM9 FOR THE ,A6 )

```

C

```

99999 OUT=6HSECOND
WRITE OUTPUT TAPE6,99998,OUT,NOSTAT, (DAT(I),I=1,10)
GO TO 31
99998 FORMAT (/13H- ROUTINE ,A6,29H, BAD PRPTY LOOKUP. NOSTAT= 18
1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
11999 WRITE OUTPUT TAPE 6,11998,NOSTAT,I,K
IF(ITFLAH)31,31,30
11998 FORMAT (20H- SECOND-NOSTAT IS 17,1H1 15,1HK 15 )
13999 FORMAT (10H- BAD CPM ,5X,1HK 14,2X,7HSTAT NO 18// 5X,3HMAT ,
1 5X,5HSOL H,10X,5HOLD H,10X,1HT 14X,5HCLD T / 2X,13, 4E19.7)
END

```

NOZZLE SUBROUTINE (WITH JACKET)

SUBROUTINE NOZZLE(NZZLE)

DIMENSION A(2700),TITLE(12),HD(10),HH(10),DAT(10)

EQUIVALENCE INPUTS TO Y ROUTINES TO PRESERVE ORDER OF COMMON

EQUIVALENCE (GAMMA,DUM1), (XMW,DUM2), (C1,DUM3), (C2,DUM4),
1 (CRIT,DUM5), (ITRNO,IDUM1), (LOCK,IDUM2), (LATCH,IDUM3), (I1,
1 IDUM0), (I1,
2 IDUM4), (I2,IDUM5), (I3,IDUM6), (I4,IDUM7), (I5,IDUM8), (SIGMA,
3 DUM5), (DIV,DUM6), (SMALL,DUM7), (VAL1,DUM8), (CCEFF,DUM9),
4 (TOLER,DUM10), (DELTA,DUM11), (PI,DUM12), (GC,DUM13), (R,DUM14),
5 (CJ,DUM15), (TWALL,DUM16), (TIME,DUM17)

INPUT VALUES

EQUIVALENCE (A(1),TAU), (A(2),CDELTA), (A(4),YDUTN),
1 (A(5),CCOEFF), (A(6),PCF), (A(7),TCF), (A(8),H2F), (A(9),PAF), (A(1
20),POWER), (A(11),ORDH2(1)), (A(62),CRDTC(1)), (A(113),ORDPC), (A(
3164),ORDPA), (A(215),CGAMMA), (A(216),CXMW), (A(217),TPCVX),
4 (A(218),PTPCV), (A(220),DNT), (A(221),CTWALL), (A(222),XKN), (A
5(223),ALPHAN(1)), (A(243),AREAN(1)), (A(263),AN(1)), (A(283),RHN(1
6)), (A(303),DN(1)), (A(323),Z3NX), (A(343),CNX), (A(363),ARATI
7C(1)), (A(383),EN(1)), (A(403),SFN(1)), (A(423),AIN(1)), (A(443),A
8K4(1)), (A(463),ALPHAR(1)), (A(473),AREAR(1)), (A(483),AR(1)), (A(4
993),XKR(1)), (A(503),RHR(1)), (A(523),DR(1)), (A(623),Z3R(1))
EQUIVALENCE (A(723),CR(1)), (A(823),ALPHAS(1)), (A(833),AREAS(1)
1), (A(843),AS(1)), (A(853),XKS(1)), (A(863),RHS(1)), (A(873),DS(1)
2), (A(973),Z3S(1)), (A(1073),CS(1)), (A(1173),ALPHAC(1)), (A
3(1183),AREAC(1)), (A(1193),AC(1)), (A(1203),XKC(1)), (A(1213),RHC(
41)), (A(1223),E(1)), (A(1233),SF(1)), (A(1243),AI(1)), (A(1253),DC
5(1)), (A(1353),Z3C(1)), (A(1453),CC(1)), (A(1553),FLUXN(1)),
6 (A(1573),FLUXR(1)), (A(1673),FLUXS(1)), (A(1773),FLUXC(1)),
7 (A(1873),TCZERN(1)), (A(1893),TCZERR(1)), (A(1993),TCZERS(1))
8, (A(2093),TCZERC(1)), (A(2193),TMAX)

EQUIVALENCE (A(2194),CCEFS), (A(2195),CCEFR), (A(2196),CCEFC)
2, (A(2197),FMAX), (A(2198),TRNC), (A(2199),TLREM), (A(2200),
3 THKTD), (A(2201),THIK), (A(2221),CRDPCW), (A(2272),XIPOW)

TURBO-PUMP AND HEAT EXCHANGER INPUTS

EQUIVALENCE (A(2293),PCCN1), (A(2294),PCGN2), (A(2295),PCGN3),
1 (A(2296),PCCN4), (A(2297),WCGN1), (A(2298),WCLN2), (A(2299),DH),
2 (A(2300),AHC), (A(2301),RHD), (A(2302),AHH), (A(2303),RHH),
2 (A(2304),Z3FX), (A(2314),CHX), (A(2324),FLUXH), (A(2334),THEZER),
3 (A(2345),AREADT), (A(2346),AREADO), (A(2347),AFBP), (A(2348),
4 RHBP), (A(2349),DHBP), (A(2350),AREATO), (A(2351),CBPT), (A(2352)
5,CP1), (A(2353),CP2), (A(2354),CP3), (A(2355),CP4), (A(2356),
6 CPS), (A(2357),XNSS), (A(2358),CT1), (A(2359),CT2), (A(2360),
7 CT3), (A(2361),CT4), (A(2362),CT5), (A(2363),APD1), (A(2364),
8 RHPD1), (A(2365),DPD1), (A(2366),I2), (A(2367),FZ), (A(2368),V4)

EQUIVALENCE (A(2369),VS), (A(2370),V6), (A(2371),V7), (A(2372),
1 V10), (A(2373),V14), (A(2374),WYEDT), (A(2375),WYDST), (A(2376),

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2 WYBPT), (A(2077),XY,NT), (A(2078),YRN), (A(2079),F1), (A(2080),
3 P2), (A(2081),XIR), (A(2082),F4), (A(2083),F5), (A(2084),F6),
4 (A(2085),P7), (A(2086),F14), (A(2087),C1), (A(2088),L-1(1)),
5 (A(2089),ADST(1)), (A(2090),PHST(1)), (A(2091),AFJIT(1))
6 (A(2420),TXCLL), (A(2425),PXCILL), (A(2430),T1-T1L), (A(2431),
7 T1LLEK), (A(2432),P1LLEK), (A(2433),CLHEX), (A(2434),CLTUN)
8 (A(2435),YKA), (A(2436),T9S), (A(2437),T9K), (A(2438),T9C)
9 (A(2439),PCWTGL), (A(2440),CRDTCV)
EQUIVALENCE (A(2492),TCC), (A(2493),FCG), (A(2494),TXCLIM),
1(A(2495),PXCLIM)

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FIXED POINT INPUTS

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EQUIVALENCE (A(2500),XLIMIT), (A(2501),XMINOR), (A(2502),XI1), (A
1(2503),XI2), (A(2504),XI3), (A(2505),XI4), (A(2506),XI5), (A(2507)
2,XI6), (A(2508),XI7), (A(2509),XI8), (A(2510),XITEM1), (A(2511),XIP
31), (A(2512),XITI), (A(2513),XITNI), (A(2514),EMN), (A(2515),EMK)
4 (A(2516),EMS), (A(2517),LMC), (A(2518),XMF), (A(2519),XM)
5 (A(2520),XNR), (A(2521),FNS), (A(2522),XNC), (A(2523),XNN)
6 (A(2524),XSTY), (A(2525),XMKK), (A(2526),XMKTD)
7 (A(2527),XMATN), (A(2528),XMATR), (A(2533),XMATS), (A(2538),
8XMATC), (A(2543),XMATH), (A(2544),SMATR), (A(2549),SMATS),
9 (A(2554),SMATC), (A(2559),XINH)
EQUIVALENCE (A(2560),TC/LRJ), (A(2560),FLUXJ), (A(2600),CNXJ),
1(A(2620),Z3JX), (A(2640),XMATNJ), (A(2641),XMKNJ)
2 (A(2642),DRNT), (A(2643),XFRATR), (A(2644),XFRATM), (A(2645),EFFMN),
3(A(2646),EFFRN)

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DIMENSION THC(11),THE(11),THF(11),Z3H(10),CH(10),THEL(10),
1FLUXH(10),THEZER(10),PDST(11),WLST(10),PHST(11),WHST(11),Z2(20),
1 YDST(10),YHST(10),Z4(20)
DIMENSION G1H(10),Q2H(10),Q3H(10),SH(10),GF(10)

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COMMON GAMMA,XMW,C1,C2,CRIT,ITERNC,LOCK,LATCH,I1,I1,I2,I3,I4,I5,SI
1 GMA,DIV,SMALL,VAL1,CLEFF,TCLEK, DELTA,PI,GC,R,CJ,FWALL,TIME,A
2 ,LIMIT,MINOR,I6,I7,I8,ITEM1,IPI,ITI,ITNI,MH,M,MN,MC,MS,MK,NN,NS,
3 NR,NC,M1H,M2H,MAJOR,M1N,M2N,M1R,M2R,M1S,M2S,M1C,M2C,OLD,FIG,FPI,
4 HCCAL,FHCAL,HCCLN,HHCON,PSIN,PSIR,PSIS,PSIC,CHNCR,CHNOS,CHNOC,T2
5 ,TXC,PXC,PA,TCN,TCR,TCS,TCC,THE,THC,THH,TN,T5,TR,T6,TS,T7,TC,
6 T10,T14,T16,T17,T17P5,T18,T19,EM1N,EM1R,EM1S,EM1C,F10,PC,PS,PR,
7 PN,P17,P17P5,P18,P19,TERMH,TERMD,MAJOR,ANT,IDUMP,ISTEDY,PPP,
8 RECDV,T4,XMUL,XNSC,GUALN,HHN,GUALR,HHR,GUALS,HFS,GUALC,HFC,
9 QUALHT,HHHT,GUALHD,HHHD,H1,TXC1,H2,TPCV,PXC1

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COMMON MATN,MATR,MATS,MATC,MATH,FSCLN,HSCLS,FSCLR,HSCLC,HSCLH
1 ,MATK,MATSS,MATSC
DIMENSION FUSCLN(20),HCSCLS(5,10),HCSCLR(5,10),HCSCLC(5,10)
1 ,FSCLN(20),FSCLR(5,10),HSCLS(5,10),HSCLC(5,10),FSCLF(20)
2 ,HCSCLH(20),CNX(20),Z3NX(20),CHX(10),Z3HX(10)
3 ,XMATR(5),MATR(5),XMATS(5),MATS(5),XMATC(5),MATC(5)
4 ,SMATR(5),SMATS(5),SMATC(5),MATSR(5),MATSS(5),MATSC(5)

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DIMENSION CRDH2(51), CRDTC(51), CRDPC(51), CRDPA(51),LCHFCW(51)
DIMENSION ALPHAR(5),AREAR(5),AR(5),XKR(5),RFR(5),DR(5,10),Z3R(5,10
1),CK(5,10),PSIR(5),CRDTCV(51),ALPHAC(5),AREAC(5),AC(5),XKC(5),

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2RHC(5),DC(5,10),Z3C(5,10),CC(5,10),PSIC(5),QR(5,10),WR(5),WYER(5),
3PR(5,11),TCR(5,10),TCOR(5,10),TR(5,11),FLUXR(5,10),FLUXS(5,10),
4FLUXC(5,10),TCZERR(5,10),TCZERKS(5,10),TCZERK(5,10),E(5),SF(5),
5A1(5),PSI(5),Y(5),GS(5,10),WS(5),WYES(5),PS(5,11),TCS(5,10),TCCS
6(5,10),TS(5,11),GC(5,10),WC(5),WYEC(5),PC(5,11),TCC(5,10),TCCC
7(5,10),TC(5,11),YINR(5),YOUTR(5),YR(5,10),YINS(5),YOUTS(5),YS(5,10
8),YINC(5),YOUTC(5),YC(5,10)

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DIMENSION ALPHAN(20),AN(20),RHN(20),DN(20),Z3N(20),CN(20),
1 WN(20),THETA(20),TN(20),TCN(20),H(20),BETA(20), Z2N(20),Z
24N(20),PSIN(20),Z5N(20),RELAX(20), Q2N(20),Q3N(20),Q4N(20),
3Q5N(20),TAR(20),SN(20),TCON(20),QN(20),ERRCR(20),FLUXN(20),TCZERN(
420),EN(20),SFN(20),A1N(20),YN(20),PN(21),ARATIC(20),TEE(20),PHX
5(21),DDD(20),HCCCN(20),HHCON(20),AK4(20),TEK(20),GUALN(21),HHN(21)
6,QUALR(5,11),FHR(5,11),GUALS(5,11),HHS(5,11),QUALC(5,11),HHC(5,11)
7,QUALHT(5,11),HHHT(5,11),QUALHD(5,11),HHHD(5,11),THIK(20),CP(20),
8ALPHAS(5),AREAS(5),XKS(5),RHS(5),DS(5,10),Z3S(5,10),CS(5,10),
9PSIS(5),AS(5)

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DIMENSION QJ(20),FLUXJ(20),TCJ(20),HSCLNJ(20),HCSOLJ(20),TCUJ(20),
1CNJ(20),CNXJ(20),Z3J(20),THETAJ(20),HJ(20),BETAJ(20),Z2J(20),
2RELAXJ(20),SJ(20),Q2J(20),Q3J(20), ERRORJ(20),Z3JX(20)
3,TCZERJ(20)

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COMMON QJ,FLUXJ,TCJ,HSCLNJ,HCSOLJ,TCUJ,CNJ,CNXJ,Z3J,THETAJ,HJ,
1BETAJ,Z2J,RELAXJ,SJ, Q2J,Q3J, ERRORJ,NCZ,Z3JX,MATNJ,MKNJ
2,WCDT,W4,TAR,TBB,POWER,TCZERJ

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COMMON BETA ,CH ,CN ,CP ,DAT ,ERRCR ,HC ,
1 HH ,HCSOLC ,HCSOLH ,HCSOLN ,HCSOLR ,HCSCLS,H ,PHX ,
2 PSI ,Q1H ,Q2H ,Q2N ,Q3C ,Q3H ,Q3N ,Q3R ,
3 Q3S ,Q4N ,Q5N ,QC ,QH ,QN ,QR ,QS ,
4 RELAX ,SC ,SH ,SN ,SR ,SS ,TCCC ,TCON ,
5 TCR ,TCUS ,TEK ,THEO ,THETA ,TITLE ,WC ,WN ,
6 WR ,WS ,WYEC ,WYER ,WYES ,YC ,YDST ,YHST ,
7 YINC ,YINR ,YINS ,YN ,YOUTC ,YOUTR ,YCLTS ,YR ,
8 Y ,YS ,Z2N ,Z2 ,Z3H ,Z3N ,Z4N ,Z4 ,
9 Z5N

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COMMON ITFLAG,ARAT,CPMN,ITRC,MKN,ITRNET,NFLAG,K,NK,SUM,L,NOSTAT,
1TAVG

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C

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IF(NZZLF)107,59C,107
107 WTE=WCDT*.8
ITRC = C
ITRNET = 0

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560 ITRNET = ITRNET + 1
ITRC = ITRC + 1
ITFLAG = 5
DO 600 K=1,M1N

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C

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GET SOLID ENTHALPY
NCSTAT=13010

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CALL READKM (TCN(K),MATN,HSCLN(K),NK)

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IF(NK)13025,13025,11999

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13025 CPMN=(HSCNLN(K)-HCSCLN(K))/(TCN(K)-TCCN(K))

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IF(CPMN)13596,13010,13011

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13996 WRITE OUTPUT TAPE 6,13999,K,NOSTAT,MATN,HSCLN(K),HCSCLN(K)

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1,TCN(K),TCOIN(K)

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13010 CPMN =HOSULN(K)/TCCN(K)

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13011 CN(K)=CNX(K) * CPMN

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NCSTAT=110

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B-50

[illegible]

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      Z2N(K)=1.0/(1.0/Z2N(K) + DIV2)
11010 TEK(K)=0.28*TXC + 0.5*TCN(K) + 0.22*TAR(K)
      FPI=XFPI (TEK(K),PXC)
      Z4N(K) = HHCDN(K)* WT8*FPI*(TBE(K) / TEK(K))*0.8
      Z4N(K)=1.0/(1.0/Z4N(K) + DIV2)
      NOSTAT=125
      CALL READKM(TCJ(K),MKNJ,VKN,NFLAG)
      IF(NFLAG)125,125,11999
125  ZWN=2.0*VKN*DN(K)*PI*DNT*ARAT/THIK(K)
      Z2J(K)=WWW*(EXPF(BETAJ(K))-1.0)
      IF(ZWN)130,10009,130
130  IF(Z2J(K))140,135,140
135  Z2J(K)=0.0
      GO TO 145
140  DIV2=1.0/ZWN
      Z2J(K)=1.0/(1.0/Z2J(K)+DIV2)
145  CONTINUE
C
      PSIN(K)=SIGMA*EN(K)*SFN(K)*A1N(K)
      ITN = TCN(K)*TCN(K)
      ITTN = ITN * TCN(K)
600  Z5N(K) = PSIN(K)*((ITTN+TCC(1,M1C)*(ITN +TCC(1,M1C)*(TCN(K) + TCC(1
      1,M1C))))
      DO 200 K=1,M1N
      ATERM=PI*DNT*ARAT/ALPHAN(K)
      BTERM=ATERM*YKA
      CTERM=F(K)*BTERM
      DTERM=FJ(K)*ATERM
      ACOEF=WN(K)*CP(K)
      ECOEF=CTERM*TCN(K)+DTERM*TCJ(K)
      CCOEF=CTERM+DTERM
      ETERM=1.0-EXPF(-(CCOEF/ACCOEF*DN(K))
      FTERM=((BCOEF/CCOEF-TN(K))*ACCOEF/CCOEF*ETERM-BCCEF/CCOEF*DN(K))/DN
      1(K)
      Q2N(K)=CTERM*(TCN(K)+FTERM)*DN(K)
      Q2J(K)=DTERM*(TCJ(K)+FTERM)*DN(K)
      Z2N(K)=Q2N(K)/(TCN(K)-TN(K))
      Z2J(K)=Q2J(K)/(TCJ(K)-TN(K))
      Q4N(K)=Z4N(K)*(TAR(K)-TCN(K))
200  Q5N(K) = Z5N(K)*(TCC(1,M1C)-TCN(K))
      DO 250 K = 2,M1N
      Q3J(K)=Z3J(K)*(TCJ(K)-TCJ(K-1))
250  Q3N(K) = Z3N(K) * (TCN(K)-TCN(K-1))
      DO 260 K = 1,M1N
      SJ(K) = (CNJ(K)*ALPHAN(K)/DELTA)*(TCJ(K)-TCCJ(K))
260  SN(K)=(CN(K)*ALPHAN(K)/DELTA)*((TCN(K)-TCON(K))
      ERROR(1) = QN(1) - SN(1) - Q2N(1) + Q3N(2) + Q4N(1) + Q5N(1)
      ERRORJ=QJ-SJ-Q2J+Q3J
      DO 280 K = 2,M2N
      ERRORJ(K)=QJ(K)-SJ(K)-Q2J(K)-Q3J(K)+Q3J(K+1)
280  ERROR(K) = QN(K) - SN(K) - Q2N(K) - Q3N(K) + Q3N(K+1) + Q4N(K) + Q
      15N(K)
      ERROR(M1N) = QN(M1N) - SN(M1N) - Q2N(M1N) - Q3N(M1N) + Q4N(M1N) +
      1Q5N(M1N)
      ERRORJ(M1N)=QJ(M1N)-SJ(M1N)-Q2J(M1N)-Q3J(M1N)
      RELAX(1) = COEFF / (Z2N(1) + Z3N(2) + Z4N(1) + Z5N(1)+CN(1)*ALPHAN

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1(1) / DELTA )
RELAXJ = COEFF/(Z2J+Z3J(2)+CNJ*ALPHAN/DELTA)
DO359 K=2,M2N
RELAXJ(K)=COEFF/(Z2J(K)+Z3J(K)+Z3J(K+1)+CNJ(K)*ALPHAN(K)/DELTA)
359 RELAX(K) = COEFF / (Z2N(K)+Z3N(K)+Z3N(K+1)+Z4N(K)+Z5N(K)+ CN(K)*AL
1PHAN(K) /DELTA)
RELAX(M1N) = COEFF / (Z2N(M1N)+Z3N(M1N)+Z4N(M1N)+Z5N(M1N)+CN(M1N)*
1ALPHAN(M1N) / DELTA)
RELAXJ(M1N)=COEFF/(Z2J(M1N)+Z3J(M1N)+CNJ(M1N)*ALPHAN(M1N)/DELTA)
DO 800 K = 1,M1N
TCJ(K)=RELAXJ(K)*ERRORJ(K)+TCJ(K)
800 TCN(K) = TCN(K) + RELAX(K) * ERROR(K)
DO 850 K=1,M1N
ATERM=PI*DNT*ARAT/ALPHAN(K)
BTERM=ATERM*YKA
CTERM=F(K)*BTERM
DTERM=FJ(K)*ATERM
ACCOEF=WN(K)*CP(K)
BCOEF=CTERM*TCN(K)+DTERM*TCJ(K)
CCOEF=CTERM+DTERM
ETERM=1.0-EXP(-CCOEF/ACCOEF*DN(K))
FTERM=((BCOEF/CCOEF-TN(K))*ACCOEF/CCOEF*ETERM-BCOEF/CCOEF*DN(K))/DN
1(K)
HHN(K+1)=HHN(K)+ACCOEF*(BCOEF/CCOEF-TN(K))*ETERM
NOSTAT=10026
CALL PARA4 (DAT,PN(K+1),1,HHN(K+1),3,NK)
IF(NK)12012,10026,12012
12012 IF(HHN(K+1))12013,99999,12014
12013 TN(K+1)=36.0
QUALN(K+1)=0.0
GO TO 850
12014 TN(K+1)=4990.0
QUALN(K+1)=1.0
GO TO 850
10026 QUALN(K+1)=DAT(5)
TN(K+1)=DAT(6)
850 CONTINUE
SUM = 0.0
DO 880 K=1,M1N
DIV3=AESE(ERROR(K))
1+AESE(ERRORJ(K))
880 SUM=SUM + DIV3
SUMN = 0.0
DO 1002 J=1,M1N
1002 SUMN = SUMN +ABSF(QN(J))+ABSF(SN(J))+ABSF(Q2N(J))+ABSF(Q4N(J))+ABS
1F(Q5N(J))
1+ABSF(QJ(J))+ABSF(SJ(J))+ABSF(Q2J(J))
DO 1003 K=2,M1N
1003 SUMN = SUMN +ABSF(Q3N(K))
1+ABSF(Q3J(K))
SUM = SUM/SUMN
9572 IF (1TRNOT-ITEMI)568,568,569
568 IF(SUM - TTOLER)571,571,572
569 IDUMP = 5
WRITE OUTPUT TAPE 6,507
907 FORMAT(1H1 ////////////// 20H NOZZLE TEMP LCCPING )

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GO TO 590
572 IF (ITRC-I3) 560,573,573
573 ITRC = 0

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C

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GO TO 574
571 ITFLAG = -5
ITRC=0
IF (ITRNOT- 1) 560,560,574
574 IF (I3) 909,909,590
590 WRITE OUTPUT TAPE 6,84
84 FORMAT (/////20H NOZZLE TEMPERATURES //)
WRITE OUTPUT TAPE 6,85, TIME, ITRNOT
85 FORMAT (/////12H TIME = E11.4,5H SEC.,8X,
143H NO. OF ITER. IN TEMP. LOOP PER TIME STEP = I5)
WRITE OUTPUT TAPE 6, 16
DO 592 K=1,MN
592 WRITE OUTPUT TAPE 6, 18, K,TN(K)
WRITE OUTPUT TAPE 6, 19
DO 593 K=1,M1N
593 WRITE OUTPUT TAPE 6, 20, K, TCN(K),TCJ(K)
WRITE OUTPUT TAPE 6, 32
L = 1
WRITE OUTPUT TAPE 6,33,L,Q2N(K),Q4N(K),Q5N(K),Q2J(K),Q3J(K)
33 FORMAT(15H BRANCH NUMBER I3,7H Q2N= E11.4,18X,7H Q4N= E11.4,
17H Q5N= E11.4,7H Q2J= E11.4,7H Q3J= E11.4)
DO 594 K=2,M1N
594 WRITE OUTPUT TAPE 6,34,K,Q2N(K),Q3N(K),Q4N(K),Q5N(K),Q2J(K),Q3J(K)
34 FORMAT(15H BRANCH NUMBER I3,7H Q2N= E11.4,7H Q3N= E11.4,
17H Q4N= E11.4,7H Q5N= E11.4,7H Q2J= E11.4,7H Q3J= E11.4)
DO 595 K=1,M1N
595 WRITE OUTPUT TAPE 6,35,K,SN(K),QN(K),SJ(K),QJ(K)
14 FORMAT (//20H CHANNEL NUMBER I3//)
16 FORMAT (/////21H LIQUID TEMPERATURES///)
17 FORMAT (23X,9H T1 = F10.1/23X,9H T2 = F10.1/
171 23X,9H TWALL = F10.1//)
18 FORMAT (20H NODE NO. I3,9H TN= F10.1)
19 FORMAT (/////19H SOLID TEMPERATURES///)
20 FORMAT(15H NODE NO. I3,7H TCN= F10.1,7H TCJ= F10.1)
21 FORMAT (/////12H TIME = E11.4,5H SEC.,8X,
211 30H NO. OF ITER. PER TIME STEP = I5)
32 FORMAT (/////16H HEAT FLOW RATES///)

WRITE OUTPUT TAPE 6,86,SUM
86 FORMAT (//19X,9H SUM = E11.4//)

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35 FORMAT(15H NODE NO. I3,7H SN= E11.4,7H QN= E11.4,
17H SJ= E11.4,7H QJ= E11.4)
36 FORMAT (20H CHANNEL NUMBER I3,9H TERM = 511.4)
WRITE OUTPUT TAPE 6, 652,(Z2N(K), K=1,M1N)
652 FORMAT (8H0--Z2N-- / (8E12.5//))
WRITE OUTPUT TAPE 6, 653,(Z3N(K), K=1,M1N)
653 FORMAT (8H0--Z3N-- / (8E12.5//) )
WRITE OUTPUT TAPE 6, 655,(SN(K),K=1,M1N)
655 FORMAT ( 7H0--SN-- / (8E12.5) )

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        WRITE OUTPUT TAPE 6, 656, (RELAX(K), K=1, MIN)
656  FORMAT (11H0--RELAXN-- / (8E12.5) )
        WRITE OUTPUT TAPE 6, 657, (ERRCR(K), K=1, MIN)
657  FORMAT (11H0--ERRCRN-- / (8E12.5) )
        WRITE OUTPUT TAPE 6, 658, (Z2J(K), K=1, MIN)
658  FORMAT (8H0--Z2J-- / (8E12.5/))
        WRITE OUTPUT TAPE 6, 659, (Z3J(K), K=1, MIN)
659  FORMAT (8H0--Z3J-- / (8E12.5/))
        WRITE OUTPUT TAPE 6, 660, (SJ(K), K=1, MIN)
660  FORMAT ( 7H0--SJ-- / (8E12.5) )
        WRITE OUTPUT TAPE 6, 661, (RELAXJ(K), K=1, MIN)
661  FORMAT (11H0--RELAXJN-- / (8E12.5) )
        WRITE OUTPUT TAPE 6, 662, (ERRCRJ(K), K=1, MIN)
662  FORMAT (11H0--ERRCRJN-- / (8E12.5) )
C
        IF (IDUMP) 909, 909, 31
909  IF (ITFLAG) 910, 910, 560
910  SUM2 = WN * ALPHAN
        IF (SUM2 - .00001) 922, 922, 921
921  T5 = TN(MN)
922  CONTINUE
13999 FORMAT (10H- BAD CPM ,5X,1HK 14,2X,7HSTAT NO 18// 5X,3HMAT ,
1 5X,5HSOL H,10X,5HOLD H,10X,1HT 14X,5HOLD I / 2X,I3, 4E19.7)
C
        NOZ = 1
        GO TO 12345
31  NOZ = 2
        GO TO 12345
10009 NOZ=3
        GO TO 12345
11999 NOZ=4
        GO TO 12345
99999 NOZ=5
12345 RETURN
C
        END

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CHAIN 3

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C      THIRD PART WITH TPCV CPTILN      3/21/65
C      PLOT DATA FROM TAPE
      DIMENSION IFRAM(100),IWRD(100),ISYM(100),LINE(100),XNCRM(100),
      1XL(2),YL(2,100),HD(6,100),YPLT(100,100),WRD(12)
      DIMENSION PC(100),PIS(100),EXPRAT(100),CFVAC(100),FA(100),
      1WDDT(100),W18(100)
      DIMENSION FMAIN(100),XISPM(100),FRCLL(100),XISPR(100),FTOT(100),
      1XSPNET(100),TIME(101)
      DIMENSION X(101),Y(101,100)
      EQUIVALENCE (PC,Y(1920)),(PIS,Y(2425)),(FA,Y(4647)),(FMAIN,Y(5455)
      1),(XISPM,Y(5556)),(FRCLL,Y(5657)),(XISPR,Y(5758)),(FTCT,Y(5859)),
      2(XSPNET,Y(5960)),(WDDT,Y(708)),(W18,Y(1011))
      3,(TIME,X)
      COMMON X,Y
      IDIM=100
      JDIM=60
      IDIM1=IDIM+1
      TIMEND=-1.0E+37
      XL(1)=(+6H TIME(S)
      XL(2)=(+6HEC.)
      WRITE TAPE 22,TIMEND,(TIMEND,KTIME=1,100)
      READ INPUT TAPE 5,1002,(WRD(IW),IW=1,10),NTIME,WRD(11),WRD(12),
      1NPAR
      IF(NPAR)250,12,5
      5 IF(NPAR-100)6,6,250
      6 CONTINUE
      DO 10 IN=1,NPAR
      READ INPUT TAPE 5,1004,IFRAM(IN),IWRD(IN),ISYM(IN),LINE(IN),
      1XNORM(IN),YL(1,IN),YL(2,IN),(HD(IM,IN),IM=1,6)
      10 CONTINUE
      12 IREC=0
      15 IREC = IREC+1
      REWIND 22
      DO 20 K=1,IDIM1
      DO 20 I=1,IREC
      READ TAPE 22,X(K),(Y(K,J),J=1,JDIM)
      NREC=K
      IF(X(K))21,20,20
      20 CONTINUE
      GO TO 15
      21 IF(NPAR)250,300,14
      14 CALL PERFOR
      WRITE OUTPUT TAPE 6,1001
      WRITEOUTPUTTAPE 6,1003,(WRD(JW),JW=1,10),NTIME,WRD(11),WRD(12),
      1NPAR
      DO 22 IN=1,NPAR
      WRITEOUTPUTTAPE 6,1005,IFRAM(IN),IWRD(IN),ISYM(IN),LINE(IN),
      1XNCRM(IN),YL(1,IN),YL(2,IN),(HD(IM,IN),IM=1,6)
      22 CONTINUE
      WRITE OUTPUT TAPE 6,1006
      DO 23 KL=1,IDIM1
      WRITE OUTPUT TAPE 6,1007,X(KL),(Y(KL,JK),JK=1,JDIM)
      23 CONTINUE
      25 NREC = NREC-1
      IF(NREC-2)250,27,27
      27 IF(NTIME)28,28,29

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28 NTIME = 1
29 NTIME = -NTIME
   DO 220 L=1,NPAR
   YMAX=TIMEND
   YMIN=-YMAX
30 DO 150 MM =1,NPAR
   IF(IFRAM(MM)-L)150,40,150
40 N = IWRD(MM)
   K = MM
   YLGE = TIMEND
   YSML = -YLGE
   DO 80 M=1,NREC
   YSML = MIN1F(YSML,Y(M,N))
   YLGE = MAX1F(YLGE,Y(M,N))
80 CONTINUE
   IF(XNORM(MM))110,90,110
90 DO 100 MX=1,NREC
100 YPLOT(MX,MM) = Y(MX,N)
   GO TO 130
110 YLG = MAX1F(ABSF(YLGE),ABSF(YSML))
   YSM = MIN1F(ABSF(YLGE),ABSF(YSML))
   DO 120 MY=1,NREC
120 YPLOT(MY,MM) = ABSF(Y(MY,N))/YLG*XNORM(MM)
   YLS = YSM/YLG*XNORM(MM)
   YLGE = MAX1F(YLS,XNORM(MM))
   YSML = MIN1F(YLS,XNORM(MM))
130 YMAX = MAX1F(YMAX,YLGE)
   YMIN = MIN1F(YMIN,YSML)
150 CONTINUE
   IF(YMIN+TIMEND)155,220,220
155 IF(YMIN)157,156,156
156 YMIN=0.0
157 CALL FRAME(0.,X(NREC),YMIN,YMAX,XL,YL(1,K),HD(1,K),1,0,NTIME,0,0)
   DO 210 MN=1,NPAR
160 IF(IFRAM(MN)-L)210,170,210
170 IF(ISYM(MN))180,190,180
180 CALL CURVE(X,YPLOT(1,MN),NREC,ISYM(MN),LINE(MN))
190 IF(LINE(MN))210,210,200
200 CALL CURVE(X,YPLOT(1,MN),NREC,-1,0)
210 CONTINUE
220 CONTINUE
   CALL PEND
250 CALL CHAIN(1,4)
300 CALL PERFCR
   GO TO 250
1001 FORMAT(19H1PLOT CONTROL INPUT)
1002 FORMAT(9A6,A5,I3,A6,A1,I3)
1003 FORMAT(1H0,9A6,A5,I3,A6,A1,I3)
1004 FORMAT(1X,I3,1X,I3,4X,I2,2X,I2,F6.0,8A6)
1005 FORMAT(1H,1X,I3,1X,I3,4X,I2,2X,I2,F6.0,8A6)
1006 FORMAT(1H1,9HPLOT DATA)
1007 FORMAT(2X,1PEE16.7/(18X,1P7E16.7))
   END

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NERVA PERFORMANCE PROGRAM

```

SUBROUTINE PERFOR
SUBROUTINE PERFOR
DIMENSION PC(100),P19(100),EXPRAT(100),CFVAC(100),PA(100),
1WDOT(100),W18(100)
DIMENSION FMAIN(100),XISPM(100),FRCLL(100),XISPR(100),FTCT(100),
1XSPNET(100),TIME(101)
DIMENSION X(101),Y(101,100)
EQUIVALENCE (PC,Y(1920)),(P19,Y(2425)),(PA,Y(4647)),(FMAIN,Y(5455)
1),(XISPM,Y(5556)),(FRCLL,Y(5657)),(XISPR,Y(5758)),(FTCT,Y(5859)),
2(XSPNET,Y(5960)),(WDCT,Y(708)),(W18,Y(1011))
3,(TIME,X)
COMMON X,Y
IF(EXPRAT)4,3,4
3 EXPRAT( 1) = 1.0
  EXPRAT( 2) = 1.2
  EXPRAT( 3) = 1.4
  EXPRAT( 4) = 1.6
  EXPRAT( 5) = 1.8
  EXPRAT( 6) = 2.0
  EXPRAT( 7) = 2.2
  EXPRAT( 8) = 2.4
  EXPRAT( 9) = 2.6
  EXPRAT(10) = 2.8
  EXPRAT(11) = 3.0
  EXPRAT(12) = 3.2
  EXPRAT(13) = 3.4
  EXPRAT(14) = 3.6
  EXPRAT(15) = 3.8
  EXPRAT(16) = 4.0
  EXPRAT(17) = 4.2
  EXPRAT(18) = 4.4
  EXPRAT(19) = 4.6
  EXPRAT(20) = 4.8
  EXPRAT(21) = 5.0
  EXPRAT(22) = 5.2
  EXPRAT(23) = 5.4
  EXPRAT(24) = 5.6
  EXPRAT(25) = 5.8
  EXPRAT(26) = 6.0
  EXPRAT(27) = 6.2
  EXPRAT(28) = 6.4
  EXPRAT(29) = 6.6
  EXPRAT(30) = 6.8
  EXPRAT(31) = 7.0
  EXPRAT(32) = 7.5
  EXPRAT(33) = 8.0
  EXPRAT(34) = 8.5
  EXPRAT(35) = 9.0
  EXPRAT(36) = 9.5
  EXPRAT(37) = 10.0
  EXPRAT(38) = 11.0
  EXPRAT(39) = 12.0
  EXPRAT(40) = 13.0
  EXPRAT(41) = 14.0
  EXPRAT(42) = 15.0

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EXPRAT(43) = 16.0
EXPRAT(44) = 17.0
EXPRAT(44) = 17.0
EXPRAT(45) = 18.0
EXPRAT(46) = 19.0
EXPRAT(47) = 20.0
EXPRAT(48) = 25.0
EXPRAT(49) = 30.0
EXPRAT(50) = 35.0
EXPRAT(51) = 40.0
EXPRAT(52) = 50.0
EXPRAT(53) = 100.0
EXPRAT(54) = 200.0
EXPRAT(55) = 500.0
EXPRAT(56) = 1000.0
CFVAC( 1) = 1.2679
CFVAC( 2) = 1.3360
CFVAC( 3) = 1.3795
CFVAC( 4) = 1.4117
CFVAC( 5) = 1.4370
CFVAC( 6) = 1.4576
CFVAC( 7) = 1.4749
CFVAC( 8) = 1.4896
CFVAC( 9) = 1.5025
CFVAC(10) = 1.5137
CFVAC(11) = 1.5237
CFVAC(12) = 1.5327
CFVAC(13) = 1.5408
CFVAC(14) = 1.5482
CFVAC(15) = 1.5549
CFVAC(16) = 1.5611
CFVAC(17) = 1.5669
CFVAC(18) = 1.5722
CFVAC(19) = 1.5771
CFVAC(20) = 1.5818
CFVAC(21) = 1.5861
CFVAC(22) = 1.5902
CFVAC(23) = 1.5940
CFVAC(24) = 1.5976
CFVAC(25) = 1.6011
CFVAC(26) = 1.6043
CFVAC(27) = 1.6074
CFVAC(28) = 1.6103
CFVAC(29) = 1.6131
CFVAC(30) = 1.6158
CFVAC(31) = 1.6184
CFVAC(32) = 1.6243
CFVAC(33) = 1.6297
CFVAC(34) = 1.6346
CFVAC(35) = 1.6390
CFVAC(36) = 1.6431
CFVAC(37) = 1.6469
CFVAC(38) = 1.6537
CFVAC(39) = 1.6597
CFVAC(40) = 1.6649
CFVAC(41) = 1.6696

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CFVAC(42) = 1.6738
CFVAC(43) = 1.6776
CFVAC(44) = 1.6811
CFVAC(45) = 1.6843
CFVAC(46) = 1.6872
CFVAC(47) = 1.6899
CFVAC(48) = 1.7010
CFVAC(49) = 1.7093
CFVAC(50) = 1.7158
CFVAC(51) = 1.7210
CFVAC(52) = 1.7292
CFVAC(53) = 1.7498
CFVAC(54) = 1.7652
CFVAC(55) = 1.7757
CFVAC(56) = 1.7875
N=56
4 DNT = Y(5455)
DRNT = Y(5556)
XPRATR = Y(5657)
XPRATM = Y(5758)
EFFMN = Y(5859)
EFFRN = Y(5960)
IF(DRNT)300,9,9
9 IROLL=0
MAIN=0
DO 10 K=1,N
IF(EXPRAT(K)-XPRATM)10,20,16
10 CONTINUE
WRITE OUTPUT TAPE 6,230,XPRATM
WRITE OUTPUT TAPE 6,240,(EXPRAT(L),L=1,N)
MAIN=1
GO TO 22
16 CFVACM = ((CFVAC(K) - CFVAC(K-1))/(EXPRAT(K) - EXPRAT(K-1)))*
1XPRATM - EXPRAT(K-1) + CFVAC(K-1)
GO TO 22
20 CFVACM = CFVAC(K)
22 DO 30 K=1,N
IF(EXPRAT(K)-XPRATR)30,40,36
30 CONTINUE
WRITE OUTPUT TAPE 6,250,XPRATR
WRITE OUTPUT TAPE 6,240,(EXPRAT(L),L=1,N)
IROLL=1
GO TO 42
36 CFVACR = ((CFVAC(K) - CFVAC(K-1)) / (EXPRAT(K) - EXPRAT(K-1)))*
1XPRATR - EXPRAT(K-1) + CFVAC(K-1)
GO TO 42
40 CFVACR = CFVAC(K)
42 AN = 0.7854*DNT*DRNT
ARN = 0.7854*DRNT*DRNT*2.
WRITE OUTPUT TAPE 6,270
DO 100 I=1,100
IF(TIME(I))110,90,90
90 IF(MAIN)50,50,60
50 FMAIN(I) = AN*PC(I)*(CFVACM-XPRATM*PA(I)/PC(I))*EFFMN
XISPM(I) = FMAIN(I)/WDDT(I)
60 IF(IROLL)70,70,80

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70 FRCLL(I) = ARN*P19(I)*(CFVACH-XPRATR*PA(I)/P19(I))*EFFRN
   XISPR(I) = FRCLL(I)/W18(I)
80 FTOT(I) = FMAIN(I) + FRCLL(I)
   XSPNET(I) = FTOT(I)/(WDCT(I) + W18(I))
100 WRITE OUTPUT TAPE 6,260,FMAIN(I),XISPM(I),FRCLL(I),XISPR(I),
   1FTOT(I),XSPNET(I),TIME(I),PC(I),P19(I),PA(I)
110 WRITE OUTPUT TAPE 6,280
   WRITE OUTPUT TAPE 6,260,XPRATR,XPRATM,DNT,DRNT,EFFMN,EFFRN
230 FORMAT(1HC,9HXPRATM = ,F10.0,4X,23HCUTSIDE RANGE OF DATA = )
240 FORMAT(1X,10F13.2)
250 FORMAT(1H0,9HXPRATR = ,F10.0,4X,23HCUTSIDE RANGE OF DATA = )
260 FORMAT(1HC,10F13.2)
270 FORMAT(1H1,8X,5HFMAIN,9X,4HISPM,8X,5HFRCLL,9X,4HISPR,9X,4HFTOT,7X,
   16HISPNET,9X,4FTIME,8X,5HPC(I),7X,6HP19(I),8X,5HPA(I))
280 FORMAT(1HC,7X,6HXPRATR,7X,6HXPRATM,10X,3HDNT,9X,4HCRNT,8X,5HEFFMN,
   18X,5HEFFRN)
300 RETURN
   END

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*	FAP		AS188002
*	MODIFIED	PLOT SUBROUTINE(AS188F)	
*AS188F		GENERALIZED PLCT ROUTINE	AS188003
	COUNT	350	8000 21
	ENTRY	FRAME	AS188005
	ENTRY	CURVE	AS188006
*		IDELTA,IQUAD)	AS188009
*	AS188F	CALL SEC....	AS188007
*		CALL FRAME(XMIN,XMAX,YMIN,YMAX,XLAB,YLAB,TITLE,	AS188008
*		CALL CURVE (X1,Y1,NPT1,ISYMB)	AS188010
*		CALL CURVE (X2,Y2,NPT2,ISYMB)	AS188011
*		ETC	AS188012
*			AS188013
*		1,4 XMIN	AS188014
*		2,4 XMAX	AS188015
*		3,4 YMIN	AS188016
*		4,4 YMAX	AS188017
*		5,4 XLAB	AS188018
*		6,4 YLAB	AS188019
*		7,4 TITLE	AS188020
*		8,4 IDELTA	AS188021
*		9,4 IQUAD	AS188022
	FRAME SXA	PLOTZ,1	AS188024
	SXA	PLOTZ+1,2	AS188025
	SXA	PLOTZ+2,4	AS188026
	SXA	*+1,4	AS188027
	AXT	** ,2	AS188028
	CLA	5,2	AS188029
	PAC	,4	AS188030
	LDQ	0,4	AS188031
	STQ	XLAB	AS188032
	LDQ	-1,4	AS188033
	STQ	XLAB-1	AS188034
	CLA	6,2	AS188035
	PAC	,4	AS188036
	LDQ	0,4	AS188037
	STQ	YLAB	AS188038
	LDQ	-1,4	AS188039
	STQ	YLAB-1	AS188040
	CLA	FL1.8	AS188041
	STQ	XDEC	
	AXT	1000,1	
	SXD	DPZE,1	
	SXA	APZE,1	
	CLA*	10,2	
	TPL	MFS	
	CLA	FL1	
	STQ	XD	
	STZ	XP	
	CLA*	10,2	
	STD	B2	
	STD	B4	
	AXT	C,1	
	TRA	E2-1	
B1	CLA	XP	

LOCATION OF X-AXIS LABEL

LOCATION OF Y-AXIS LABEL

	FSB	FL1		
	STO	XP		
	LDQ	XD		
	FMP	FL10		
	STO	XD		
B2	TXI	**1,1,10		
	TXL	E1,1,**		
	STZ	XDEC		
B3	AXT	1,1		
	CLA	XDEC		
	FAD	FL10		
	STO	XDEC		
B4	TXI	**1,1,1		
	TXL	B3,1,**		
	CLA*	2,2		
	FSB*	1,2		
	FDP	XDEC		
	STQ	XDEC		
	FMP	FL500		
	FAD	FL200		
	UFA	FIX		
	STA	APZE		
	ALS	18		
	STO	DPZE		
	LDQ*	2,2		
	FMP	FL.55		
	STO*	2,2		
	AXT	0,1		
	CLA	APZE		
	SUB	FX150		
	SUB	FX150		
	TMI	*+3		
	TXI	*+1,1,-1		
	TXH	*-3,1,-6		
	SCD	NEWHD+2,1		
MFS	NZT*	10,2	*12028	MULTIPLE FRAME SIZE *
	TRA	VNO	*12028*	NO *
	STZ	VRESCA		
	STZ	VDEC	*12028*	XAXIS A MULTIPLE OF YAXIS DISTANCE *
	CLA	VERASE	*12028*	*
	STO	VFRAME	*12028*	*
	CLA*	10,2	*12028*	*
	PDX	0,1		
VADD	CLA	VDEC	*12028*	*
	FAD	XDEC		
	STO	VDEC	*12028*	SCALING FACTOR *
	CLA	VRESCA		
	ADD	APZE		
	STO	VRESCA		
	CLA	VFRAME	*12028*	*
	SUB	DPZE		
	STO	VFRAME	*12028*	*
	CLA*	10,2		
	TMI	VNO		
VNO	TIK	VADD,1,1		
	AXT	9,4	*12028*	*

	AXT	3,1		8000 2B
	ZET*	10,2	TEST FOR 2 PAGE PLOT	
	TXI	*+2,4,-1		
	ZET*	11,2	TEST FOR SMALL PRINT(12ECD WD TITLE)	
	TXI	*+1,4,-1		
	CLA	NEWHD+9,4		8000 2G
	STO	TITLE+3,1		8000 2C
	TXI	*+1,1,-1		
	TIX	*-3,4,3		
	CLA	RESCA+3,4		8000 2J
	STO	FX2+1		
	CLA	RESCA+6,4		8000 2L
	STO	FLN		
	AXT	10,1		
	AXT	10,4	TEST FOR 2 PAGE PLOT	
	NZT*	10,2		8000 3H
	TRA	*+3	CENTER X LABEL	
	ZET*	12,2	YES	8000 2D
	TXI	*+1,4,-1	NO	8000 2P
	CLA	INST+10,4		8000 2Q
	STO	INMOD+10,1		8000 2R
	TXI	*+1,1,-2		8000 2S
	TIX	*-3,4,2		AS188042
	CLA	7,2	LOCATION OF PLOT TITLE	AS188043
	STA	TITLE	STORAGE INCREMENT	AS188044
	CLA*	8,2		AS188045
	PDX	,4		AS188046
	SXA	CURV,4		AS188047
	SXD	CURV,4		AS188052
	CLA	FL10		AS188053
	TSX	\$LOG,4		AS188054
	STO	L10		AS188055
	AXT	0,1		
	CLA*	10,2		
AAA	TMI	AA1		
	CLA*	2,2		
	TZE	*+2		
	TPL	*+3		
	CLA*	1,2		
	SSP			AS188057
	TSX	LOG,4		AS188058
	FDP	L10		AS188059
	XCA			AS188060
	UFA	FIX		AS188061
	FAD	FIX		AS188062
	STO	XP,1	X,(Y) AXIS EXPONENTS	AS188063
	XCA			AS188064
	FMP	L10		AS188065
	TSX	\$EXP,4		AS188066
	STO	XD,1	X,(Y) AXIS COMMON DIVISOR	AS188067
	CLA	XP,1		AS188068
	TZE	*+3		AS188069
	CHS			AS188070
	STO	XP,1		AS188071
AA1	TXI	*+1,2,-2		
	TXI	*+1,1,-1		AS188073

	TXH	AAA,1,-2		AS188074
	TXI	*+1,2,4		AS188075
	CLA*	1,2	XMIN	AS188076
	FDP	XD		AS188077
	STQ	XMIN		AS188078
	CLA*	2,2	XMAX	AS188079
	FDP	XD		AS188080
	STQ	XMAX		AS188081
	CLA*	3,2	YMIN	AS188082
	FDP	YD		AS188083
	STQ	YMIN		AS188084
	CLA*	4,2	YMAX	AS188085
	FDP	YD		AS188086
	STQ	YMAX		AS188087
	LMTM			AS188088
	AXT	0,1		AS188089
	SXA	AAF,3		AS188090
	SXA	AAF+1,5		AS188091
AAB	AXT	0,3		AS188092
	AXT	2,5		AS188093
	AXT	202,4		AS188094
	CLA	XMAX,1	CALCULATE AND	AS188095
	FSB	XMIN,1	TEST FOR ANY	AS188096
	FDP	FLN,1	REDUNDANT	AS188097
	XCA		CHARACTERS	AS188098
AAC	LDQ	FL1	IN FINDING	AS188099
	TLQ	AAD	THE LABELING	AS188100
	XCA		INCREMENTS.	AS188101
	FMP	FL10	IF THERE ARE	AS188102
	TXI	*+1,5,1	ANY, INCREASE	AS188103
	TXI	*+1,4,100	THE NUMBER	AS188104
	TXI	*+1,3,-1	OF DECIMAL	AS188105
	TXH	AAC,3,-5	PLACES IN	AS188106
AAD	TXH	*+4,1,0	THE LABELING	AS188107
	SXD	SET1,4	OF THE AXES	AS188108
	SXD	XSC,5		AS188110
	TRA	*+3		AS188111
	SXD	SET1+1,4		AS188112
	SXD	YSC,5		AS188114
	SXA	AAE,3		AS188115
	UFA	FIX		AS188116
	ADD	FX1		AS188117
	FAD	FIX		AS188118
	FDP	FL100		AS188119
AAE	AXT	*,3		AS188120
	TXL	*+5,3,0		AS188121
	XCA			AS188122
	FDP	FL10		AS188123
	TXI	*+1,3,1		AS188124
	TXH	*-3,3,0		AS188125
	STQ	XSCALE,1		AS188126
	FMP	FL40		AS188127
	STD	X1,1	FINAL X,(Y) LABELING INCREMENT	AS188128
	FDP	FL,4		AS188129
	FMP	FLN,1		AS188130
	FAD	XMIN,1		AS188132

	STO	XMAX,1	FINAL XMAX,(YMAX)	AS188141
	TXI	*+1,1,-1		AS188142
	TXH	AAB,1,-2		AS188143
AAF	AXT	**,3		AS188144
	AXT	**,5		AS188145
	EMTM			AS188146
	XEC	FRAME+4		
	CLA*	10,2		
	TMI	*+3		
	AXT	3,4		
	TRA	*+2		
	LXD	NEWHD+2,4		
	TXH	*+6,4,0		
	TXI	*+1,4,1		
	CLA	LDBLK		
	STA	TITLE		
	CLA	BLANK		
	STO	XLAB		
	AXT	3,2		
	SXD	INMOD-1,2		
	AXT	0,1		
	SXD	INMOD+1,1		
	AXT	1,1		
	CLA	RP		
	STO	ZP		
	CLA	SCALE		
	STO	ZCALE		
	CLA	TITLE		
LDBLK	LDQ	BLANK		
	TXH	*+5,4,2		
	SXD	INMOD-1,4		
	SXD	INMOD+1,1		
	STP	INMOD+1		
	STQ	XP		
	TXL	*+2,4,1		
	CLA	YSC		
	TXL	*+2,4,2		
	STP	INMOD+1		
	STP	XSC		
	TXH	*+5,4,1		
	SXD	XSC,1		
	STQ	ZCALE		
	STQ	ZP		
	STQ	XSCALE		
	TSX	\$SETUP,4		AS188147
	PZE	XMIN,,100		AS188148
	PZE	YMIN,,100		AS188149
SET 1	PZE	XI,,**		AS188150
	PZE	YI,,**		AS188151
	PZE	80,3,80		AS188152
	PTH	XLAB,,3		AS188153
INMOD	PZE	384,,4		AS188154
	PTW	XP		AS188155
	PZE	810,1,38		AS188156
	PTH	ZCALE,,1		
	PZE	510,1,58		AS188158

DRAW NO AXES

XSC	PTW	XSCALE,,**				AS188159
	PZE	630,1,58				AS188160
	PTH	2P,,1				
	PZE	678,1,58				AS188162
	PTH	YLAB,,3				AS188163
	PCN	30,,384				AS188164
	PTW	YP				AS188165
	PCN	12,1,810				AS188166
	PTH	SCALE,,1				AS188167
	PCN	58,1,485				AS188168
YSC	PTW	YSCALE,,**				AS188169
	PON	58,1,605				AS188170
	PTH	RP,,1				AS188171
	PCN	58,1,653				AS188172
TITLE	PTH	**,,6				AS188173
	PZE	168,,1056				AS188174
	FVE	ERASE,,1150				AS188175
	CLA	ERASE-1				
	FDP	XD				
	STQ	ERASE-1				
	CLA	ERASE-3				
	FDP	YD				
	STQ	ERASE-3				
	XEC	PLOTZ+2				AS188192
	CLA*	9,4				AS188193
	TMI	AAI				AS188194
	AXT	600,4	*	IF	9,4 = 0	GUAD 1
	LGR	19	*		9,4 = 1	GUAD 1,4
	LBT		*		9,4 = 2	GUAD 1,2
	TXI	*+1,4,-500	*		9,4 = 3	GUAD ALL 4
	SXA	VERT,4				AS188198
	SXA	VERT-1,4				AS188199
	AXT	100,4				AS188200
	TQP	*+2				AS188201
	TXI	*+1,4,500				AS188202
	SXD	HORZ,4				AS188203
	SXD	HORZ-1,4				AS188204
	TRA	AAK				AS188205
AAI	AXT	0,1				AS188206
	CLA	XMIN,1				AS188207
	TMI	*+3				AS188208
	AXT	100,4				AS188209
	TRA	AAJ				AS188210
	CLA	XMAX,1				AS188211
	TZE	*-3				AS188212
	TMI	*-4				AS188213
	CLS	XMIN,1				AS188214
	FDP	XI,1				AS188215
	FMP	FL200				AS188216
	FAD	FL100				AS188217
	UFA	FIX				AS188218
	PAX	,4				AS188219
AAJ	TXH	*+4,1,0				AS188220
	SXA	VERT,4				AS188221
	SXA	VERT-1,4				AS188222
	TXI	AAI+1,1,-1				AS188223
						AS188224

	SXD	HORZ,4		AS188225
	SXD	HORZ-1,4		AS188226
AAK	AXT	0,1		AS188227
	CAL	\$PTAPE		AS188228
	ACL	FX1		AS188229
	STA	DRAW+1		AS188230
DRAW	CAL	CONTR		AS188231
	TSX	**,4		AS188232
	STZ*	\$PPEN		AS188233
	CAL	VERT,1		AS188234
	TSX	\$PTAPE,4		AS188235
	CAL	*		AS188236
	STP*	\$PPEN		AS188237
	CAL	VERT-1,1		AS188238
	TSX	\$PTAPE,4		AS188239
	TXI	*+1,1,2		AS188240
	TXL	DRAW,1,2		AS188241
	STZ*	\$PPEN		AS188242
PLOTZ	AXT	**,1		AS188243
	AXT	**,2		AS188244
	AXT	**,4		AS188245
	TRA	13,4	RETURN	8000 1U
*				AS188247
*				AS188248
*		THIS IS WHERE THE CURVES ARE PLOTTED		AS188249
*				AS188250
*				AS188251
CURVE	SXA	PLOX,1		24000706
	SXA	PLOX+1,4		24000707
	CLA*	5,4		
	PDX	,1	SKIP PNTS	
	TNZ	**4		
	CLA*	3,4		24000713
	STD	CURV-2		24000714
	AXT	1,1	ALL PNTS	
	SXA	CURV,1		
	SXD	CURV,1		
	NZT*	5,4		
	TRA	CURVZ		
	PXA	,0		
	LDQ*	3,4		
	DVP*	5,4		
	RQL	18		
	SLQ	CURV-2		
	IZE	CURVZ		
	XCA			
	ACL	DFX1		
	STD	CURV-2		
CURVZ	CLA	1,4		24000709
	STA	CURV-1		24000710
	CLA	2,4		24000711
	PAX	,1		24000712
	SXD	CURV-1,1		24000715
	AXT	1,1		24000716
	CLA*	4,4		24000717
	TPL	*+2		

	AXI	C,1		24000718
	SXD	CURV+1,1		24000719
	PCX	,1		24000720
	SXA	CURV+1,1		24000721
	CLA	TSX		24000722
	AXT	3841,1		
	CLA*	5,4		
	TMI	TSX-1		
	NZT*	5,4		
	AXT	3840,1		
	SXD	TSX,1		
TSX	TSX	\$FPLCT,4		24000735
	PZE	ERASE,,**	,,NPTS	24000727
	PZE	**,,**	X,,Y	24000728
CURV	PZE	**,,**	DX,,DY	24000729
	PZE			24000730
	STZ*	\$PPEN		24000731
PLOX	AXT	**,,1		24000732
	AXT	**,,4		24000733
	TRA	6,4		24000734
DFX1	PZE	0,0,1		24000736
*				AS188275
*				AS188276
*				AS188277
*				AS188278
*				AS188279
ERASE	ELS	4		AS188280
	PZE			AS188281
L10	PZE			AS188283
XMIN	PZE			AS188284
YMIN	PZE			AS188285
XMAX	PZE			AS188286
YMAX	PZE			AS188287
XP	PZE			AS188288
YP	PZE			AS188289
XC	PZE			AS188290
YC	PZE			AS188291
XI	PZE			AS188292
YI	PZE			AS188293
XSCALE	PZE			AS188294
YSCALE	PZE			AS188295
ZCALE	BSS	1		
ZP	BSS	1		
BLANK	BCI	1,		
FIX	OCT	233000000000		AS188297
CCNTH	OCT	700000000002		AS188298
FX1	PZE	1		AS188299
FX2	PZE	2		AS188300
	PZE	1100,,**		AS188301
HGRZ	PZE	100,,**		AS188302
	PZE	**,,100		AS188303
VERT	PZE	**,,1050		AS188304
FL.4	DEC	0.4		AS188305
FL.95	DEC	.9999999		
FL1.8	DEC	1.8	*12028*	
FL1	DEC	1.0		* AS188306

FL4	DEC	4.0		AS188308
FL10	DEC	10.0		AS188309
FL40	DEC	40.0		AS188310
FL100	DEC	100.0		AS188311
FL200	DEC	200.0		AS188312
FL400	DEC	400.0		AS188313
FL500	DEC	500.		
FL1TH	DEC	1000.0		
XDEC	PZE			
FX150	PZE	150		
FLN	DEC	2.0,1.9		AS188314
SCALE	BCI	1,SCALE(		AS188315
RP	BCI	1,)		AS188316
	BCI	1, X 10		AS188317
	BCI	1,		AS188318
XLAB	BCI	1,		AS188319
	BCI	1, X 10		AS188320
	BCI	1,		AS188321
YLAB	BCI	1,		AS188322
INST	PZE	150,,4		
	PZE	884,,4		8000 1B
	PZE	576,1,3E		
	PZE	1310,1,3E		8000 1D
	PZE	276,1,5E		
	PZE	1010,1,5E		8000 1F
	PZE	396,1,5E		
	PZE	1130,1,5E		8000 1H
	PZE	444,1,5E		
	PZE	1178,1,5E		8000 1J
NEWHD	PTH	*,,6		8000 1K
	PTH	*,,12		8000 1L
	PTH	*,,**		
	PZE	168,,10E6		8000 1M
	PZE	168,1,10E6		8000 1N
	PZE	150,,10E6		
	FVE	ERASE,,1150		8000 1O
	FVE	ERASE,,1150		
VFRAME	PZE		*12028*	*
RESCA	PZE	1100,,**		8000 1Q
	PZE	1100,,**		
VRESCA	PZE			
	DEC	2.0		8000 1S
	DEC	2.0		
VDEC	PZE		*12028*	*
DPZE	PZE			
APZE	PZE			
VERASE	FVE	ERASE,,0		
	END			AS188323

FUNCTION XCP

```
      FUNCTION XCP (T,T2,HH,HH2)
      DIFT=T2-T
      DIFH=HH2-HH
      IF(DIFH)4,11007,4
4      IF(DIFT)11008,11007,11008
11007 XCP=3.6
      RETURN
11008 XCP=DIFH/DIFT
      IF(XCP-2.0)8,9,9
      8 XCP=2.0
      9 RETURN
      END
```

B-70

RW-DR-0068

SCATTER LOADING SUBROUTINE

```

CSLOAD          SCATTER LOADING SUBROUTINE
SUBROUTINE SLOAD (A)
  DIMENSION A(500),B(5)
100  READ INPUT TAPE 5,1,XJ,(B(I),I=1,5)
      J=XJ + 1.0E-06 * XJ
      J2=XABS(J)
      DO 9 I=1,5
        IF(B(I))8,7,2
7      IF(SIGN(2.0,B(I)))9,10,8
8      A(J2)=B(I)
9      J2=J2+1
      IF(J)12,10,100
10   WRITE OUTPUT TAPE 6,11,XJ,(B(I),I=1,5)
      CALL EXIT
12   RETURN
1    FORMAT (F12.0,5E12.8)
11   FORMAT (1H-,15X,5HBAD INPUT ,1H ,15X,F12.0,5F16.8)
      END

```

SUBROUTINE Y1

CY1 SUBROUTINE Y1

NOTATION

SUBRT. Y1 COMPUTES THE CONDUCTANCE OF AN ORIFICE
P2 = DOWNSTREAM PRESSURE, LBF./SQ.IN.
P1 = UPSTREAM PRESSURE, LBF./SQ.IN.
T2 = DOWNSTREAM TEMPERATURE, DEG R
T1 = UPSTREAM TEMPERATURE, DEG R
A = NOZZLE CROSS-SECTIONAL AREA, SQ.IN.
R = UNIVERSAL GAS CONSTANT = 1.987 BTU/LB.MOLE-DEG R
XNW = MOLECULAR WEIGHT OF GAS, LB./LB.MOLE
CJ = MECHANICAL EQUIVALENT OF HEAT = 778.0 FT.LBF./BTU
GC = CONVERSION FACTOR = 32.2 LB.(FT./SEC.SEC.)/LBF.
GAMMA = RATIO OF SPECIFIC HEATS OF GAS
CRIT = CRITICAL PRESSURE RATIO. CRIT =
 $(2.0 / (GAMMA + 1.0)) * (GAMMA / (GAMMA - 1.0))$
C1 = TERMA/TERME
TERMA = $SQRTF((2.0 * GAMMA) / (GAMMA - 1.0))$
TERME = PART1 * PART2
PART1 = $((GAMMA + 1.0) / 2.0) * ((1.0 / (GAMMA - 1.0))$
PART2 = $SQRTF((GAMMA + 1.0) / (GAMMA - 1.0))$
LINK = BRANCH NUMBER
DIV = $1.0 - 1.0 / EXPF(1.0) = 0.63212$
ERROR = TERM INCLUDED IN THE EXPRESSION FOR Y, SO THAT Y WILL
C2 = TERMB
REMAIN FINITE AT P2/P1 = 1.0

SWITCHES

IF SW 1 IS ON, WRITE INTERMEDIATE RESULTS OUT ON TAPE

FUNCTION Y1 (A,T2,T1,P2,P1)

COMMON GAMMA,XNW,C1,C2,CRIT,ITRNO,LOCK,LATCH,I1,I2,I3,I4,I5,S1
1 GMA,DIV,SMALL,VAL1,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME

15 RATIO = P2/P1
TERM1 = $SQRTF(VAL1 * T1)$
DIFF = $1.0 - RATIO$
20 IF(DIFF)30,75,60

```

30  RATIO = 1.0/RATIO
60  TERM2 = RATIO**((1.0/GAMMA)
    TERM3 = RATIO**((GAMMA-1.0)/GAMMA)
    ERROR = SMALL*(1.0-1.0/EXPF(RATIO))/DIV
    IF(RATIO-CRIT) 75, 75, 70
70  PHI = C2*TERM2*SQRTE(ABS(1.0-TERM3))
    GO TO 80
75  PHI = 1.0
    ERROR=SMALL
80  Y1 = C1*A*(PHI+ERROR*ERROR)/(TERM1*(1.0+ERROR-RATIO))
C
C
    IF (I1) 90,90,10
10  WRITE OUTPUT TAPE 6, 250,
25  WRITE OUTPUT TAPE 6, 200, LINK, A, XMW, GAMMA, C1, C2, CRIT,
251  T2, T1, P2, P1, RATIO, TERM1, TERM2, TERM3, ERROR, PHI
250  FORMAT (////14H SUBROUTINE Y1//)
200  FORMAT (9H LINK = I3,9H      A = F10.3,9H      XMW = F10.3,
2001  9H GAMMA = F10.3/9H      C1 = F10.4,9H      C2 = F10.4,
2002  9H CRIT = F10.4/9H      T2 = F10.2,9H      T1 = F10.2/
2003  9H P2 = F10.2,9H      P1 = F10.2,9H RATIO = F10.5/
2004  9H TERM1 = F10.4,9H TERM2 = F10.5,9H TERM3 = F10.5/
2005  9H ERROR = E13.5/9H      PHI = F10.5/)
C
C
95  WRITE OUTPUT TAPE 6, 220, Y
220  FORMAT (9H      Y = E13.5/)
C
90  RETURN
    END

```


SUBROUTINE PARAH

```
1  SUBROUTINE PARAH (DATA,A,L,E,N,K)
    DIMENSION DATA(10)
    DO 1 I=1,10
    DATA(I)=0.0
    DATA(L)=A
    DATA(N)=E
    CALL PRPTY (DATA,K)
    DATA(7)=DATA(7)/1728.0
    RETURN
    END
```

NEW SUBROUTINE Y2 FOR CONSTANT AREA

```

CY2  NEW SUBROUTINE Y2 FOR CONSTANT AREA
C
C  NOTATION
C
C  SUBRT. Y2 COMPUTES THE CONDUCTANCE OF GAS FLOW IN A DUCT
C  Y = CONDUCTANCE, SQ.IN./SEC.
C  P2 = DOWNSTREAM PRESSURE, LBF./SQ.IN.
C  P1 = UPSTREAM PRESSURE, LBF./SQ.IN.
C  T2 = DOWNSTREAM TEMPERATURE, DEG R
C  T1 = UPSTREAM TEMPERATURE, DEG R
C  A = PASSAGE CROSS-SECTIONAL AREA, SQ.IN.
C  RH = PASSAGE HYDRAULIC RADIUS, IN.
C  FACT = FRICTION FACTOR
C  DIST = PASSAGE LENGTH, IN.
C  R = UNIVERSAL GAS CONSTANT = 1.987 BTU/LB.MOLE-DEG R
C  XMW = MOLECULAR WEIGHT OF GAS, LB./LB.MOLE
C  GC = CONVERSION FACTOR = 32.2 LB.(FT./SEC.SEC.)/LBF.
C  CJ = MECHANICAL EQUIVALENT OF HEAT, FT.LBF./BTU
C  LINK = BRANCH NUMBER
C  DIV = 1.0 - 1.0/EXP(1.0) = 0.63212
C
C  SWITCHES
C
C  IF I1 IS NON-ZERO , WRITE INTERMEDIATE RESULTS OUT ON TAPE
C
C  FUNCTION Y2 (A,RH,XL,      H2,H1,P2,P1,W)
C
C  COMMON GAMMA,XMW,C1,C2,CRIT,IIRNG,LOCK,LATCH,I1,I2,I3,I4,I5,SI
1  GMA,DIV,SMALL,VAL1,CDEFF,TCLER,  DELTA,PI,GC,R,CJ,TWALL,TIME
C
C  DIMENSION DAT(10)
C  NOSTAT=80
C  CALL PARAH (DAT,P1,1,H1,3,K)
C  IF(K)1000,80,1000
80  RHO1=DAT(7)
C  NOSTAT=81
C  CALL PARAH (DAT,P2,1,H2,3,K)
C  IF(K)1000,81,1000
81  RHO2=DAT(7)
C  XMU1=DAT(10)
C  RHOB=(RHO1 + RHO2)/2.0
C  RE=((ABSF(W)+1.0E-04)*4.0*RH)/(A*XMU1)
C  IF(RE - 2.0E+05)5,5,11
C  IF(1200.0 - RE)15,20,20
C  11  F= 0.106/(RE**0.161)
C  GO TO 25
C  15  F=0.316/(RE**0.25)
C  GO TO 25
C  20  F=64.0/RE
C  25  Y2=(A*A*12.*GC)/(W*((1.0/RHO2 -1.0/RHO1) + (F*XL)/(8.0*RH*RHOB)))
C
C  IF (I1) 100,100,60
C  60  WRITE OUTPUT TAPE 6,200,A,RH,XL,H2,H1,P2,P1,W,RHO2,RHO1,Y2
C  200  FORMAT (12H- ROUTINE Y2 // 10X,1HA 1PE15.7,2X,2HRH E15.7,2X,2HXL

```

```

1 E15.7,2X,2HF2 E15.7,2X,2HF1 E15.7 / 9X,3H P2 E15.7,2X,2FP1 E15.7,
23H W E15.7,2X,4FRH02 E15.7,2X,4FRH01 E15.7/10X,2FY2 E15.7 )

```

C
C

```

100 RETURN
1000 WRITE OUTPUT TAPE 6,1001,NCSTAT,A,RH,(DAT(I),I=1,10)
      LOCK=1
      CALL SECOND
1001 FORMAT(1H-,5X,12FY2 NCSTAT=I6/10X,1HA E15.7,5X,2HFH E15.7 /
1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
      END

```

```
*      FAP
*      ROUTINE REWINDS AND UNLOADS ONLY UNIT A4
      ENTRY REWUNL
      X      TAPENG A4
REWUNL RUN      X
      TRA      1.4
      END
```

FUNCTION Y3

```

CY3      FUNCTION Y3
          FUNCTION Y3(A,XK,W,T1,P1)
          COMMON GAMMA,XMW,C1,C2,CRIT,ITRND,LOCK,LATCH,I1,I1,I2,I3,I4,IS,SI
1  GMA,DIV,SMALL,VAL1,CDEFF,TCLEN, DELTA,P1,GC,R,CJ,TWALL,TIME
          Y3=A*A*P1/(XK*VAL1*T1*0.5*(W+0.0001) )
          RETURN
          END

```

SUBROUTINE INT4

	SUBROUTINE INT4(X,Y,XI,YC)	AS104004
	DIMENSION X(9),Y(9),XC(4),YC(4)	AS104005
	EQUIVALENCE (XC(1),X1),(XC(2),X2),(XC(3),X3),(XC(4),X4),(YC(1),Y1)	AS104006
	1, (YC(2),Y2),(YC(3),Y3),(YC(4),Y4)	AS104007
20	ASSIGN 30 TO NA	AS104008
	J=2	AS104009
	B=XI	AS104010
21	IF(X(J))26,22,26	AS104011
26	GO TO NA,(30,40)	AS104012
22	IF(Y(J))26,23,26	AS104013
23	IF(J-2)24,24,25	AS104014
24	YE=0.	AS104015
	GO TO 50	AS104016
25	ASSIGN 32 TO NB	AS104017
	J=J-1	AS104018
27	X1=X(J)	AS104019
	X2=X(J-1)	AS104020
	X3=X(J-2)	AS104021
	Y1=Y(J)	AS104022
	Y2=Y(J-1)	AS104023
	Y3=Y(J-2)	AS104024
	GO TO NB,(32,42)	AS104025
30	IF(X(J)-B)29,37,37	AS104026
37	IF(J-2)31,31,28	AS104027
28	ASSIGN 40 TO NA	AS104028
29	J=J+1	AS104029
	GO TO 21	AS104030
31	DO 60 J=1,3	AS104031
	XC(J)=X(J)	AS104032
60	YC(J)=Y(J)	AS104033
32	D=X2-X1	AS104034
	A1=B-X1	AS104035
	A2=B-X2	AS104036
	YE=A1*A2/2./D*((Y3-Y2)/(X3-X2)-(Y2-Y1)/D)-A2/D*Y1+A1/D*Y2	AS104037
	GO TO 50	AS104038
40	ASSIGN 42 TO NB	AS104039
	GO TO 27	AS104040
42	X4=X(J-3)	AS104041
	Y4=Y(J-3)	AS104042
	D=X3-X2	AS104043
	A1=B-X2	AS104044
	A2=B-X3	AS104045
	XM12=(Y2-Y1)/(X2-X1)	AS104046
	XM23=(Y3-Y2)/D	AS104047
	XM34=(Y4-Y3)/(X4-X3)	AS104048
	YE=A1*A2**2/2./D**2*(XM12-XM23)+A2*A1**2/2./D**2*(XM34-XM23)-A2*Y2	AS104049
	1/D+A1*Y3/D	AS104050
50	YO=YE	AS104051
	RETURN	AS104052
	END	AS104053

FUNCTION FXPI

```

FUNCTION FXPI (T,P)
DIMENSION DAT(10)
IF(T-5000.0)3,3,1
1  T2=T
  IF(5000.0-T2)5,6,6
5  T2=5000.0
6  CALL PARAF (DAT,P,1,T2,6,K)
  IF(K)1000,2,1000
2  XFPI=(DAT(9)**0.6)*((DAT(8)/DAT(10))**0.4)
  GO TO 4
3  XFPI=0.23625 + 3.5178E-05 * T - 4.5916/T
4  RETURN
1000 OUT=4HFXPI
  NOSTAT=2
  WRITE OUTPUT TAPE 6,1001,OUT,NOSTAT, (DAT(I),I=1,10)
  LOCK=1
  CALL SECOND
1001 FORMAT (/13H-      ROUTINE ,A6,29H, BAD PRPTY LCKUP.  NOSTAT= 18
1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
END

```

SUBROUTINE SECOND
CALL CHAIN (1,4)
RETURN
END

SUBROUTINE DINT4

```

CDINT4  SUBROUTINE DINT4(AXT,AYT,AZT,NXZT,NY,X,Y,Z)
        SUBROUTINE DINT4(AXT,AYT,AZT,NXZT,NY,X,Y,Z)
        DIMENSION TABY(5),TABZ(5),AXT(5),AYT(5),AZT(5)
        I=1
9        IF(AYT(1)-Y)3,1,1
1       IF(I-2)4,4,2
4       K=-1
        GO TO 7
2       K=I-4
        TABY(4)=AYT(I+1)
        L=I*NXZT+1
        CALL INT4(AXT(L),AZT(L),X,TABZ(4))
        GO TO 8
3       I=I+1
5       IF(I-NY)9,6,6
6       K=I-4
7       TABY(4)=0.
        TABZ(4)=0.
8       DO 10 M=1,3
        L=K+M+1
        TABY(M)=AYT(L)
        L=(K+M)*NXZT+1
10      CALL INT4(AXT(L),AZT(L),X,TABZ(M))
11      CALL INT4(TABY,TABZ,Y,Z)
        RETURN
        END

```

```

AS167F03
AS167F06
AS167F07
AS167F08
AS167F09
AS167F10
AS167F11
AS167F12
AS167F13
AS167F14
AS167F15
AS167F16
AS167F17
AS167F18
AS167F19
AS167F20
AS167F21
AS167F22
AS167F23
AS167F24
AS167F25
AS167F26
AS167F27
AS167F28
AS167F29
AS167F30

```

FUNCTION XP18

FUNCTION XP18 (W18,T18,CT5,P18,P19,CT5RAT)

0/00/65

FUNCTION XP18 (W18,T18,CT5,P18,P19,CT5RAT)

VOID=P18

DIV2=SQRTF(T18) * W18

XP18=DIV2/CT5

DIV=XP18/P19

IF(DIV-CT5RAT)1,2,2

1 DIV3=CT5/(CT5RAT-1.0)

DIV4=DIV2/DIV3

XP18=.5 * (P19 + SQRTF(P19*P19 + 4.0*DIV4*P19))

2 WRITE OUTPUT TAPE 6,5,XP18

5 FORMAT (/5H P18= F8.2)

XP18=XP18

RETURN

END(1.0,0.0,0.0,0.1,0.0,1.0,0,0,0,0,0)

SUBROUTINE CURVE

```

* SUBROUTINE CURVE
* FAP
COUNT 300
REM SUBROUTINE CURVE (DELPH,X2,NPSP, XNS)
REM
REM DELP = PRESSURE RISE THRU THE PUMP (PSI) INPUT
REM W2 = FLOW RATE (LB/SEC) INPUT
REM NPSP = PRESSURE - VAPOR PRESSURE (PSI) INPUT
REM XNS = SHAFT SPEED (RPM) ANSW
REM
REM SUBROUTINE COMPUTES XNS BY ITERATING ON COMPUTED DELP
REM MATCHED AGAINST THE GIVEN DELP. IF THE INPUT NPSP EQUALS
REM A GIVEN SURFACE VALUE, ONLY ONE SURFACE IS USED. IF NPSP
REM IS BETWEEN 2 SURFACES, LINEAR INTERPOLATION IS USED WITH
REM THE XNS VALUES FOR THE INTERVAL SURFACES.
REM
ENTRY CURVE

SUBROUTINE DINT4(AXT,AYT,AZT,NXZT,NY,X,Y,Z)
OBTAINED FROM LIBRARY. IS A SACTO ROUTINE BY R. D. GLAUZ.
AXT ADDRESS OF X TABLE
AYT ADDRESS OF Y TABLE
AZT ADDRESS OF Z TABLE
NXZT FIRST DIMENSION OF X AND Z TABLES, X(NXZT,J)
NY NUMBER OF Y TABLE PTS.
X ARGUMENT
Y ARGUMENT
Z ANSWER

*****
NOTE THAT LAST POINT OF EACH XW2 AND XDELPH CURVE MUST BE 0.0 FOR
DINT4 USE.
*****

REG PZE
PZE
PZE
CURVE SXD REG,4
SXD REG+1,1
SXD REG+2,2
CLA* 1,4
STU DELP
CLA* 2,4
STU W2
CLA* 3,4
STU NPSP
CLA* 4,4
STU XNS
REM CHECK IF DELP OUTSIDE LOW SPEED LEVEL
REM LOW SPEED LEVELS ARE SAME FOR ALL SURFACES
CLA DELP
LDQ XDELPH DELP MAY BE NEGATIVE
TLQ HIGH
CLA DELP

```

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00000020
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00000060
00000080
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00001080
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00002020
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00006000
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00006060
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00007000
00007020
00007040
00007060
00007080
00008000
00008020
00008040
00008060
00008080
00009000
00009020
00009040
00009060
00009080
00010000
00010020
00010040
00010060
00010080
00011000

```

	LDQ	=-.05	XXNS=1.0 AT DELP=-.05	0001120
	TLQ	*+3		0001140
	XCA		DELP TOO SMALL	0001160
	STO	DELP		0001180
	REM			0001200
	CLA	=-.05		0001220
	FSB	XDELP		0001240
	STO	DIV		0001260
	CLA	DELP		0001280
	FSB	XDELP	XNS=XXNS + (1.0-XXNS)*(DELP-XDELP)	0001300
	STO	MULT	/(-.05-XDELP)	0001320
	CLA	=1.0		0001340
	FSB	XXNS		0001360
	FDP	DIV		0001380
	FMP	MULT		0001400
	FAD	XXNS		0001420
	STO	XNS		0001440
	TRA	RETURN		0001460
	REM			0001480
HIGH	STZ	FLAG	FLAG= +0	0001500
	REM	CHECK FOR PROPER SURFACE INTERVAL, USING INDEX REG. 1		0001520
	AXT	1,1		0001540
	CLA	XNPSP+1,1		0001560
	FSB	NPSP		0001580
	TZE	AAA	ONLY 1 SURFACE REQUIRED	0001600
	TPL	AA		0001620
	TXI	*+1,1,1		0001640
	TXL	*-5,1,7	7 SURFACES	0001660
	REM	NPSP TOO LARGE, USE LARGEST XNPSP		0001680
	CLA	XNPSP+1,1		0001700
	FSB	NPSP	IF NPSP GT. 75.0, SET TC 75.0	0001720
	TZE	*+4		0001740
	TPL	*+3		0001760
	CLA	XNPSP+1,1		0001780
	STO	NPSP		0001800
	TIX	*+1,1,1		0001820
AAA	CLA	FLAG		0001840
	SSM		FLAG=-0	0001860
	STO	FLAG		0001880
	TRA	B		0001900
	REM			0001920
AA	TXH	B,1,1		0001940
	REM	NPSP TOO SMALL USE SMALLEST XNPSP		0001960
	CLA	XNPSP+1,1		0001980
	STO	NPSP		0002000
	TRA	AAA		0002020
	REM			0002040
	REM	SET PROPER ADDRESSES, ACCORDING TO XNPSP USED		0002060
B	CLA	ADDRESS+1,1		0002080
	STA	LOOK+3	XDELP	0002100
	STA	A+3	XDELP	0002120
	PDX	0,2		0002140
	PXA	0,2		0002160
	STA	LOOK+1	XW2	0002180
	STA	A+4	XW2	0002200
	CLA	S+1,1		0002220

	TI	II	NO. XXNS CURVES FOR THIS SURFACE	0002240
	PAX	0.2		0002260
	PXU	0.2		0002280
	STO	JJ	NO. XW2 PTS. FOR THIS SURFACE	0002300
	RLM		CHECK CURVE RANGE AND GET FIRST GUESS FOR XNS	0002320
A	TSX	\$CHECK,4		0002340
	PZE	DELP		0002360
	PZE	W2		0002380
	PZE	XDELP		0002400
	PZE	XW2		0002420
	PZE	XXNS		0002440
	PZE	II		0002460
	PZE	JJ		0002480
	PZE	XNS	STARTING GUESS VALUE	0002500
	REM			0002520
	STZ	NSAV		0002540
	STZ	PSAV		0002560
	CLA	=036000000		0002580
	STO	COUNT		0002600
	REM			0002620
LOOK	TSX	\$DINT4,4		0002640
	PZE	XW2		0002660
	PZE	XXNS		0002680
	PZE	XDELP		0002700
	PZE	JJ		0002720
	PZE	II		0002740
	PZE	W2		0002760
	PZE	XNS		0002780
	PZE	DELPCK	ANSWER FROM DINT4	0002800
	REM			0002820
	TSX	\$PRINT,4		0002840
	PZE	DELP		0002860
	PZE	DELPCK		0002880
	PZE	W2		0002900
	PZE	PSAV		0002920
	PZE	NSAV		0002940
	PZE	XNS		0002960
	PZE	FLAG		0002980
	REM			0003000
	REM			0003020
	CLA	COUNT		0003040
	SUB	=001000000		0003060
	STO	COUNT		0003080
	TZE	BAD		0003100
	REM	CHECK IF CONVERGENCE CLOSE ENOUGH		0003120
	CLA	DELPCK		0003140
	FSB	DELP		0003160
	FDP	DELPCK		0003180
	XCA		IF (ABS((DELPCK-DELP)/DELPCK)-.001)	0003200
	SSP			0003220
	FSB	=.001		0003240
	TMI	CC		0003260
	TZE	CC		0003280
	REM	NEW XNS GUESS		0003300
	CLA	DELPCK	XNS= NSAV + (XNS-NSAV)*(DELP-PSAV)/	0003320
	FSB	PSAV	(DELPCK-PSAV)	0003340

	STO	DIV		0003360
	CLA	DELP		0003380
	FSB	PSAV		0003400
	STO	MULT		0003420
	CLA	XNS		0003440
	FSB	NSAV		0003460
	FDP	DIV		0003480
	FMP	MULT		0003500
	FAD	NSAV		0003520
	XCA		PUT ANSW IN MQ FOR NOW	0003540
	CLA	XNS		0003560
	STO	NSAV		0003580
	XCA			0003600
	STO	XNS		0003620
	CLA	DELPCK		0003640
	STO	PSAV		0003660
	REM			0003680
	TSX	\$PRINT,4		0003700
	PZE	DELP		0003720
	PZE	DELPCK		0003740
	PZE	W2		0003760
	PZE	PSAV		0003780
	PZE	NSAV		0003800
	PZE	XNS		0003820
	PZE	COUNT		0003840
	REM			0003860
	TRA	LOOK		0003880
	REM			0003900
BAC	STZ	XNS		0003920
	TRA	RETURN		0003940
	REM			0003960
	REM	GET ANSWER BETWEEN SURFACES		0003980
	REM			0004000
CC	CLA	FLAG		0004020
	TMI	RETURN	ONLY 1 SURFACE (XNPSP) REQUIRED	0004040
	TZE	*+2		0004060
	TRA	C		0004080
	REM	LOOK AT XNPSP(I-1) SURFACE FOR XNS VALUE		0004100
	CLA	XNS		0004120
	STO	XNS2		0004140
	TIX	*+1,1,1	XR 1=I-1	0004160
	CLA	FLAG		0004180
	ADD	=001000000		0004200
	STO	FLAG		0004220
	TRA	B		0004240
	REM			0004260
C	CLA	XNPSP,1	XNS= XNS + (XNS2 - XNS) *	0004280
	FSB	XNPSP+1,1	{NPSP - XNPSP(I-1))	0004300
	STO	DIV	/ (XNPSP(I) - XNPSP(I-1))	0004320
	CLA	NPSP		0004340
	FSB	XNPSP+1,1		0004360
	STO	MULT		0004380
	CLA	XNS2		0004400
	FSB	XNS		0004420
	FDP	DIV		0004440
	FMP	MULT		0004460

	FA)	XNS		0004480
	STG	XNS		0004500
	REM			0004520
RETURN	LXD	REG,4	RETURN	0004540
	LXD	REG+1,1		0004560
	LXD	REG+2,2		0004580
	CLA	XNS		0004600
	STO*	4,4		0004620
	TRA	5,4		0004640
	REM			0004660
DELP	PZE			0004680
W2	PZE			0004700
NPSP	PZE			0004720
XNS	PZE			0004740
DELPCK	PZE			0004760
DIV	PZE			0004780
MULT	PZE			0004800
COUNT	PZE			0004820
PSAV	PZE			0004840
NSAV	PZE			0004860
II	PZE			0004880
JJ	PZE			0004900
FLAG	PZE			0004920
XNS2	PZE			0004940
	REM			0004960
	PZE	6,0,17	SURFACE 7	6 PTS., 17 CURVES
	PZE	6,0,17	SURFACE 6	6 PTS., 17 CURVES
	PZE	6,0,17	SURFACE 5	6 PTS., 17 CURVES
	PZE	5,0,17	SURFACE 4	5 PTS., 17 CURVES
	PZE	5,0,17	SURFACE 3	5 PTS., 17 CURVES
	PZE	5,0,17	SURFACE 2	5 PTS., 17 CURVES
S	PZE	5,0,14	SURFACE 1	5 PTS., 14 CURVES
	REM			0005120
	REM			0005140
	REM			0005160
	PZE	XDELP-529,0,XW2-529	SURFACE 7	0005180
	PZE	XDELP-427,0,XW2-427	SURFACE 6	0005200
	PZE	XDELP-325,0,XW2-325	SURFACE 5	0005220
	PZE	XDELP-240,0,XW2-240	SURFACE 4	0005240
	PZE	XDELP-155,0,XW2-155	SURFACE 3	0005260
	PZE	XDELP-70,0,XW2-70	SURFACE 2	0005280
ADDRES	PZE	XDELP,0,XW2	SURFACE 1	0005300
	REM			0005320
	REM			0005340
	REM			0005360
	DEC	28000.,26000.,24000.,22000.,20000.,18000.,15000.		0005380
	DEC	12000.,9000.,6000.,3000.,2000.,1000.,750.,500.,250.		0005400
XXNS	DEC	75.0		0005420
	REM			0005440
	REM			0005460
	REM			0005480
	DEC	75.	USED ONLY AS OUTER LIMIT CHECK	0005500
	DEC	45.,35.,25.,20.,15.,5.		0005520
XXNSP	DEC	2.		0005540
	REM			0005560
	REM			0005580
	REM			0005600
	REM			0005620
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	REM			0009980
	REM			0010000

REM					0005600
REM	SURFACE 7	NPSP=45-75	PSI		0005620
DEC	0.,161.,131.,105.,82.,54.				0005640
DEC	0.,149.,124.,100.,74.,50.				0005660
DEC	0.,137.,115.,90.,67.,46.				0005680
DEC	0.,126.,105.,84.,63.,42.				0005700
DEC	0.,115.,95.,75.,56.,39.				0005720
DEC	0.,103.,85.,69.,50.,35.				0005740
DEC	0.,86.,75.,64.,46.,30.				0005760
DEC	0.,69.,55.,40.,30.,23.				0005780
DEC	0.,51.5,43.,39.,27.,17.				0005800
DEC	0.,35.,30.,25.,20.,11.				0005820
DEC	0.,17.25,14.3,11.5,9.,5.75				0005840
DEC	0.,11.5,8.6,6.7,5.25,3.85				0005860
DEC	0.,5.85,4.5,3.35,2.4,1.9				0005880
DEC	0.,4.34,3.56,2.88,2.52,1.34				0005900
DEC	0.,2.88,2.39,1.91,1.44,.95				0005920
DEC	0.,1.44,1.2,1.0,.8,.48				0005940
DEC	0.,.54,.52,.42,.30,.18				0005960
REM	SURFACE 6	NPSP=35	PSI		0005980
DEC	0.,161.,135.,105.,90.,54.				0006000
DEC	0.,150.,125.,101.,73.,50.				0006020
DEC	0.,138.,111.,92.,66.,46.				0006040
DEC	0.,126.,102.,80.,59.,42.				0006060
DEC	0.,115.,95.,76.,56.,38.5				0006080
DEC	0.,103.,82.,68.,51.,35.				0006100
DEC	0.,86.,70.,55.,42.,29.				0006120
DEC	0.,69.,58.,45.,35.,23.				0006140
DEC	0.,52.,43.,35.,26.,17.				0006160
DEC	0.,36.,30.,20.,15.,11.5				0006180
DEC	0.,17.25,14.3,11.5,9.,5.75				0006200
DEC	0.,11.5,8.6,6.7,5.25,3.85				0006220
DEC	0.,5.85,4.5,3.35,2.4,1.9				0006240
DEC	0.,4.34,3.56,2.88,2.52,1.34				0006260
DEC	0.,2.88,2.39,1.91,1.44,.95				0006280
DEC	0.,1.44,1.2,1.0,.8,.48				0006300
DEC	0.,.54,.52,.42,.30,.18				0006320
REM	SURFACE 5	NPSP=25	PSI		0006340
DEC	0.,161.,134.,107.5,80.5,54.				0006360
DEC	0.,150.,125.,100.,75.,50.				0006380
DEC	0.,138.,114.,100.,75.,46.				0006400
DEC	0.,126.,105.,90.,69.,46.				0006420
DEC	0.,115.,95.,76.,67.,38.				0006440
DEC	0.,103.,86.,69.,51.,35.				0006460
DEC	0.,85.,70.,57.,42.,30.				0006480
DEC	0.,68.,67.,45.,34.,23.				0006500
DEC	0.,51.,43.,35.,25.,17.5				0006520
DEC	0.,35.,29.,20.,15.,11.				0006540
DEC	0.,17.25,14.3,11.5,9.,5.75				0006560
DEC	0.,11.5,8.6,6.7,5.25,3.85				0006580
DEC	0.,5.85,4.5,3.35,2.4,1.9				0006600
DEC	0.,4.34,3.56,2.88,2.52,1.34				0006620
DEC	0.,2.88,2.39,1.91,1.44,.95				0006640
DEC	0.,1.44,1.2,1.0,.8,.48				0006660
DEC	0.,.54,.52,.42,.30,.18				0006680
REM	SURFACE 4	NPSP=20	PSI		0006700


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DEC      0.,145.,120.,90.,51.5
DEC      0.,145.,126.,86.5,50.
DEC      0.,135.,115.,80.,47.
DEC      0.,125.5,105.,70.,42.5
DEC      0.,115.,95.,65.,38.
DEC      0.,103.,85.,60.,35.
DEC      0.,85.,75.,56.,31.
DEC      0.,68.,60.,46.,24.
DEC      0.,51.,43.,31.,18.
DEC      0.,36.,30.,20.,11.5
DEC      0.,17.25,13.9,10.,5.75
DEC      0.,11.5,7.7,5.75,3.85
DEC      0.,5.85,3.85,2.4,1.9
DEC      0.,4.34,3.24,2.52,1.34
DEC      0.,2.88,2.15,1.66.,95
DEC      0.,1.44,1.2.,95.,48
DEC      0.,.54.,.42.,.30.,.18
REM      SURFACE 3  NPSP=15 PSI
DEC      0.,120.5,103.,85.,54.
DEC      0.,123.,116.,82.,50.
DEC      0.,125.,104.,80.,46.
DEC      0.,125.,103.,72.,42.
DEC      0.,115.,95.,67.,38.
DEC      0.,103.,82.,60.,35.
DEC      0.,86.,70.,50.,30.
DEC      0.,68.,55.,40.,23.
DEC      0.,52.,43.,30.,17.
DEC      0.,35.,25.,15.,11.
DEC      0.,17.25,13.9,10.,5.75
DEC      0.,11.5,7.7,5.75,3.85
DEC      0.,5.85,3.85,2.4,1.9
DEC      0.,4.34,3.24,2.52,1.34
DEC      0.,2.88,2.15,1.66.,95
DEC      0.,1.44,1.2.,95.,48
DEC      0.,.54.,.42.,.30.,.18
REM      SURFACE 2  NPSP=5 PSI
DEC      0.,95.,87.,75.,50.
DEC      0.,91.,87.5,80.,50.
DEC      0.,86.5,81.5,72.,46.
DEC      0.,82.,75.,63.,42.5
DEC      0.,77.5,72.,58.,38.5
DEC      0.,75.,69.,55.,35.
DEC      0.,70.,65.,50.,29.
DEC      0.,64.,55.,44.,23.
DEC      0.,47.,38.,26.,18.
DEC      0.,33.,25.,17.,11.
DEC      0.,17.25,13.9,10.,5.75
DEC      0.,11.5,7.7,5.75,3.85
DEC      0.,5.85,3.85,2.4,1.9
DEC      0.,4.34,3.24,2.52,1.34
DEC      0.,2.88,2.15,1.66.,95
DEC      0.,1.44,1.2.,95.,48
DEC      0.,.54.,.42.,.30.,.18
REM      SURFACE 1  NPSP=2 PSI
DEC      0.,65.,63.75,52.5,42.5
DEC      0.,64.5,58.75,53.,38.75

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000672C
0006740
0006760
0006780
0006800
0006820
0006840
0006860
0006880
0006900
0006920
0006940
0006960
0006980
0007000
0007020
0007040
0007060
0007080
0007100
0007120
0007140
0007160
0007180
0007200
0007220
0007240
0007260
0007280
0007300
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0007580
0007600
0007620
0007640
0007660
0007680
0007700
0007720
0007740
0007760
0007780
0007800
0007820

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XW2

DEC	0.,61.25,60.,53.75,34.5	0007840
DEC	0.,55.,50.5,43.5,28.75	0007860
DEC	0.,49.,46.25,34.5,23.25	0007880
DEC	0.,45.,43.,30.5,17.5	0007900
DEC	0.,32.5,26.5,17.5,10.5	0007920
DEC	0.,17.25,13.9,10.,5.75	0007940
DEC	0.,11.5,7.7,5.75,3.85	0007960
DEC	0.,5.85,3.85,2.4,1.9	0007980
DEC	0.,4.34,3.24,2.52,1.34	0008000
DEC	0.,2.88,2.15,1.66,.95	0008020
DEC	0.,1.44,1.2,.95,.48	0008040
DEC	0.,.54,.42,.30	0008060
DEC	.18	0008080
REM		0008100
REM	XDELP ARRAYS	0008120
REM		0008140
REM	SURFACE 7 NPSP=45-75 PSI	0008160
DEC	0.,1230.,1420.,1500.,1530.,1480.	0008180
DEC	0.,1060.,1210.,1290.,1315.,1270.	0008200
DEC	0.,910.,1030.,1100.,1120.,1080.	0008220
DEC	0.,760.,840.,925.,940.,920.	0008240
DEC	0.,630.,715.,765.,780.,759.	0008260
DEC	0.,510.,580.,620.,630.,610.	0008280
DEC	0.,350.,395.,420.,432.,430.	0008300
DEC	0.,230.,265.,280.,280.,270.	0008320
DEC	0.,130.,145.,150.,160.,150.	0008340
DEC	0.,100.,110.,115.,120.,120.	0008360
DEC	0.,14.2,15.9,17.1,17.5,16.9	0008380
DEC	0.,6.4,7.3,7.75,7.8,7.5	0008400
DEC	0.,1.5,1.8,2.0,1.95,1.9	0008420
DEC	0.,.895,1.01,1.085,1.1,1.052	0008440
DEC	0.,.385,.449,.48,.485,.475	0008460
DEC	0.,.1,.11,.117,.12,.12	0008480
DEC	0.,0.,0.,0.,0.,0.	0008500
REM	SURFACE 6 NPSP=35 PSI	0008520
DEC	0.,1170.,1375.,1500.,1525.,1480.	0008540
DEC	0.,1040.,1195.,1280.,1310.,1280.	0008560
DEC	0.,900.,1050.,1100.,1120.,1090.	0008580
DEC	0.,760.,870.,930.,945.,920.	0008600
DEC	0.,630.,720.,765.,780.,750.	0008620
DEC	0.,510.,590.,620.,630.,615.	0008640
DEC	0.,550.,405.,430.,440.,420.	0008660
DEC	0.,230.,259.,280.,285.,270.	0008680
DEC	0.,130.,140.,155.,160.,160.	0008700
DEC	0.,60.,70.,70.,70.,69.	0008720
DEC	0.,14.2,15.9,17.1,17.5,16.9	0008740
DEC	0.,6.4,7.3,7.75,7.8,7.5	0008760
DEC	0.,1.5,1.8,2.0,1.95,1.9	0008780
DEC	0.,.895,1.01,1.085,1.1,1.052	0008800
DEC	0.,.385,.449,.48,.485,.475	0008820
DEC	0.,.1,.11,.117,.12,.12	0008840
DEC	0.,0.,0.,0.,0.,0.	0008860
REM	SURFACE 5 NPSP=25 PSI	0008880
DEC	0.,1060.,1360.,1490.,1520.,1470.	0008900
DEC	0.,960.,1180.,1280.,1310.,1270.	0008920
DEC	0.,850.,1020.,1075.,1115.,1080.	0008940

CF	0.,740.,810.,910.,940.,910.	0008960
DEC	0.,710.,710.,760.,775.,750.	0008980
DEC	0.,505.,580.,615.,620.,610.	0009000
DEC	0.,550.,400.,420.,430.,430.	0009020
DEC	0.,215.,255.,275.,280.,270.	0009040
DEC	0.,120.,140.,150.,155.,155.	0009060
DEC	0.,50.,60.,70.,70.,70.	0009080
DEC	0.,14.2,15.9,17.1,17.5,16.9	0009100
DEC	0.,6.4,7.3,7.75,7.8,7.5	0009120
DEC	0.,1.5,1.8,2.0,1.95,1.9	0009140
DEC	0.,.895,1.01,1.085,1.1,1.052	0009160
DEC	0.,.385,.449,.48,.485,.475	0009180
DEC	0.,.1,.11,.117,.12,.12	0009200
DEC	0.,0.,0.,0.,0.,0.	0009220
REM	SURFACE 4 NPSP=20 PSI	0009240
DEC	0.,1160.,1420.,1510.,1440.	0009260
DEC	0.,910.,1160.,1100.,1250.	0009280
DEC	0.,800.,1000.,1110.,1070.	0009300
DEC	0.,710.,850.,930.,900.	0009320
DEC	0.,610.,710.,770.,950.	0009340
DEC	0.,500.,590.,630.,610.	0009360
DEC	0.,350.,390.,425.,430.	0009380
DEC	0.,220.,250.,270.,269.	0009400
DEC	0.,120.,145.,160.,155.	0009420
DEC	0.,45.,60.,65.,68.	0009440
DEC	0.,14.2,16.5,17.4,16.9	0009460
DEC	0.,6.4,7.6,7.8,7.5	0009480
DEC	0.,1.5,1.9,1.95,1.9	0009500
DEC	0.,.895,1.05,1.1,1.052	0009520
DEC	0.,.385,.465,.485,.475	0009540
DEC	0.,.1,.11,.119,.12	0009560
DEC	0.,0.,0.,0.,0.,0.	0009580
REM	SURFACE 3 NPSP=15 PSI	0009600
DEC	0.,1320.,1470.,1510.,1430.	0009620
DEC	0.,1060.,1230.,1300.,1250.	0009640
DEC	0.,850.,1030.,1100.,1060.	0009660
DEC	0.,660.,850.,930.,900.	0009680
DEC	0.,570.,700.,770.,750.	0009700
DEC	0.,480.,590.,630.,610.	0009720
DEC	0.,350.,410.,430.,430.	0009740
DEC	0.,220.,260.,280.,280.	0009760
DEC	0.,130.,150.,160.,155.	0009780
DEC	0.,50.,65.,70.,69.	0009800
DEC	0.,14.2,16.5,17.4,16.9	0009820
DEC	0.,6.4,7.6,7.8,7.5	0009840
DEC	0.,1.5,1.9,1.95,1.9	0009860
DEC	0.,.895,1.05,1.1,1.052	0009880
DEC	0.,.385,.465,.485,.475	0009900
DEC	0.,.1,.11,.119,.12	0009920
DEC	0.,0.,0.,0.,0.,0.	0009940
REM	SURFACE 2 NPSP=5 PSI	0009960
DEC	0.,1450.,1510.,1500.,1340.	0009980
DEC	0.,1220.,1270.,1300.,1200.	0010000
DEC	0.,1020.,1090.,1120.,1020.	0010020
DEC	0.,840.,870.,890.,870.	0010040
DEC	0.,650.,730.,770.,720.	0010060

XDELP

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DEC      0.,530.,600.,630.,590.
DEC      0.,350.,400.,440.,410.
DEC      0.,230.,260.,270.,270.
DEC      0.,130.,150.,150.,150.
DEC      0.,60.,70.,70.,60.
DEC      0.,14.2,16.5,17.4,16.9
DEC      0.,6.4,7.6,7.8,7.5
DEC      0.,1.5,1.9,1.95,1.9
DEC      0.,.895,1.05,1.1,1.052
DEC      0.,.385,.465,.485,.475
DEC      0.,.1,.11,.119,.12
DEC      0.,0.,0.,0.,0.
REM      SURFACE 1  NPSP=2  PSI
DEC      0.0,920.,925.,900.,860.
DEC      0.,745.,765.,750.,715.
DEC      0.,570.,590.,620.,580.
DEC      0.,375.,420.,435.,410.
DEC      0.,225.,260.,375.,260.
DEC      0.,130.,150.,160.,150.
DEC      0.,60.,70.,70.,75.
DEC      0.,14.2,16.5,17.4,16.9
DEC      0.,6.4,7.6,7.8,7.5
DEC      0.,1.5,1.9,1.95,1.9
DEC      0.,.895,1.05,1.1,1.052
DEC      0.,.385,.465,.485,.475
DEC      0.,.1,.11,.119,.12
DEC      0.,0.,0.,0.,0.
DEC      0.
END

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0010080
0010100
0010120
0010140
0010160
0010180
0010200
0010220
0010240
0010260
0010280
0010300
0010320
0010340
0010360
0010380
0010400
0010420
0010440
0010460
0010480
0010500
0010520
0010540
0010560
0010580
0010600
0010620
0010640

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SUBROUTINE CURV.K

```

*      LIST
SUBROUTINE CURVCK (Q,HCV,DELF,GIN,HSVIN,NFLAC, ANSV)
DIMENSION G(19,5),HSV(5), DELF(19,5)
NFLAC=1

C      IF THE G(1,1),G(1,2), ..., G(1,J), I. E. THE COLUMNS, ARE NOT ALL
C      EQUAL, WE WOULD HAVE TO FIND J BY CHECKING HSVIN AGAINST HSV(J).
C
DO 1 I=1,18
  IF(GIN-G(1,1))2,2,1
1  CONTINUE

C      GIN TOO LARGE
C
C      GIN=G(18,5)
  HSVIN=HSV(5)
  ANSW=DELF(18,5)
  GO TO 88
2  IF(I-1)3,3,4

C      GIN TOO SMALL
C
C      GIN=G(1,1)
  HSVIN=HSV(1)
  ANSW=DELF(1,1)
  GO TO 88
3  IF(HSVIN-HSV(1))5,5,6

C      HSVIN TOO SMALL
C
C      HSVIN=HSV(1)
  J=1
  GO TO 8
6  IF(HSVIN-HSV(5))9,7,7

C      HSVIN TOO LARGE
C
C      HSVIN=HSV(5)
  J=5
8  ANSW=DELF(I-1,J) + (DELF(1,J)-DELF(I-1,J)) * (GIN-G(I-1,J))
  1 / (G(1,J)-G(I-1,J))

C      NFLAC=0 SIGNALS CURVE ROUTINE THAT WE HAVE THE ANSW WITHOUT INTERPOLATION
C
C      88
  NFLAC=0
9  RETURN
END

```

SUBROUTINE FOR PUMP DATA (EFFICIENCY)

```

*      FAP
*      COUNT      300
*      SUBROUTINE CONTAINING PUMP DATA(MK 3 MCD 4)
*
*      SUBROUTINE ETAP2 (QIN,HSVIN,ANSW)
*      ENTRY      ETAP2
*
*
*      Q IS G/N
*      DELH IS PUMP EFFECIENCY
*      HSV IS RPM
*
*      SUBROUTINE DINT4(AXT,AYT,AZT,NXZT,NY,X,Y,Z)
*      OBTAINED FROM LIBRARY. IS A SACTO ROUTINE BY R. D. GLAUZ.
*
*      AXT      ADDRESS OF X TABLE
*      AYT      ADDRESS OF Y TABLE
*      AZT      ADDRESS OF Z TABLE
*      NXZT     FIRST DIMENSION OF X AND Z TABLES.      X(NXZT,J)
*      NY       NUMBER OF Y TABLE PTS.
*      X        ARGUMENT
*      Y        ARGUMENT
*      Z        ANSWER
*
***** NOTE THAT LAST POINT OF EACH DELH AND Q COLUMNS MUST BE ZERO FOR
***** DINT4 USE.
*
REG      PZE
PZE
PZE
ETAP2    SXD      REG,4
SXD      REG+1,1
SXD      REG+2,2
CLA*     1,4
STO      QIN
CLA*     2,4
STO      HSVIN
CLA      3,4
STA      ANSW
STA      LOOK+8
REM      CHECK IF POINTS ARE IN TABLE REGION
AXT      1,1
CLA      QIN
FSB      Q+1,1
TZE      X2
IMI      X2
TXI      *+1,1,1
TXL      *-5,1,13
REM
REM      QIN TOO LARGE
CLA      DELH-180
STO*     ANSW
TRA      RETURN
REM
X2       TXH      X4,1,1

```

A

C

H

```

      REM      CIN TOO SMALL
      REM      DELH
      CLA      DELH(1,1)
      STO*     ANSW
      TRA      RETURN
X4     REM      HSVIN
      CLA      HSVIN
      FSB      HSV
      TZE      *+2
      TPL      X6
      REM      HSVIN TO SMALL
      CLA      HSV
      STO      HSVIN
      TRA      LOOK
X6     REM      HSVIN
      CLA      HSVIN
      FSB      HSV-12
      TZE      *+2
      TMI      LOOK
      REM      HSVIN OK, DO INTERPOLATION
      REM      HSVIN TOO LARGE
      CLA      HSV-12
      STO      HSVIN
      REM
      REM
      LOOK     TSX      $DINT4,4
      PZE      Q
      PZE      HSV
      PZE      DELH
      PZE      NTAB
      PZE      NCURV
      PZE      CIN
      PZE      HSVIN
      PZE      *
      RETURN   LXI      REG,4
      LXI      REG+1,1
      LXI      REG+2,2
      REM
      TRA      4,4
*****
NTAB    PZE      IF FIVE AND N14 CHANGED, CHANGE CARDS FOR --QIN TOO LARGE--
NCURV   PZE      0,0,14
DIV      PZE      0,0,13
DIV2     PZE
QIN      PZE
HSV IN   PZE
ANSW     PZE
*
*
      REM      HSV ARRAY
      DEC      3.E+4,2.5E+4,2.E+4,1.5E+4,1.E+4,8.E+3,6.E+3,5.E+3,4.E+3
      DEC      3.E+3,2.E+3,1.E+3
      HSV      DEC      0.
*
*      REM      DELH ARRAY
      LAST PT MUST BE ZERO

```

I
G
T
I
J

*
*

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REM COLUMN 13 STORED IN BACKWARDS ORDER
DEC 0.,.556,.589,.62,.645,.664,.679,.688,.692,.682,.66,.632
DEC .594,.552
REM COLUMN 12 STORED IN BACKWARDS ORDER
DEC 0.,.552,.586,.616,.637,.657,.672,.682,.686,.676,.655,.626
DEC .588,.549
REM COLUMN 11 STORED IN BACKWARDS ORDER
DEC 0.,.548,.582,.61,.633,.65,.665,.676,.678,.67,.648,.62
DEC .584,.544
REM COLUMN 10 STORED IN BACKWARDS ORDER
DEC 0.,.543,.576,.604,.627,.644,.659,.669,.671,.664,.643,.616
DEC .58,.542
REM COLUMN 9 STORED IN BACKWARDS ORDER
DEC 0.,.53,.56,.588,.608,.628,.643,.65,.652,.646,.626,.6,.564
DEC .522
REM COLUMN 8 STORED IN BACKWARDS ORDER
DEC 0.,.514,.543,.568,.59,.608,.622,.63,.63,.626,.609,.58
DEC .544,.499
REM COLUMN 7 STORED IN BACKWARDS ORDER
DEC 0.,.483,.507,.53,.55,.566,.583,.594,.596,.588,.568,.542
DEC .504,.462
REM COLUMN 6 STORED IN BACKWARDS ORDER
DEC 0.,.458,.48,.5,.517,.534,.554,.564,.566,.558,.536,.51
DEC .473,.43
REM COLUMN 5 STORED IN BACKWARDS ORDER
DEC 0.,.424,.437,.456,.477,.494,.51,.52,.518,.512,.494,.466
DEC .432,.392
REM COLUMN 4 STORED IN BACKWARDS ORDER
DEC 0.,.37,.384,.396,.414,.43,.446,.452,.45,.444,.428,.404
DEC .372,.336
REM COLUMN 3 STORED IN BACKWARDS ORDER
DEC 0.,.266,.277,.288,.3,.308,.319,.324,.322,.316,.306,.294
DEC .278,.259
REM COLUMN 2 STORED IN BACKWARDS ORDER
DEC 0.,.13,.137,.144,.153,.158,.164,.166,.165,.162,.159,.154
DEC .148,.14
REM COLUMN 1 STORED IN BACKWARDS ORDER
DEC 0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.
DEC 0.

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DELH

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*

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REM G ARRAY LAST PT MUST BE ZERO

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*

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REM COLUMN 13 STORED IN BACKWARDS ORDER
DEC 0.,.6,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM COLUMN 12 STORED IN BACKWARDS ORDER
DEC 0.,.6,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM COLUMN 11 STORED IN BACKWARDS ORDER
DEC 0.,.6,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM COLUMN 10 STORED IN BACKWARDS ORDER
DEC 0.,.6,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM COLUMN 9 STORED IN BACKWARDS ORDER
DEC 0.,.6,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.

```



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R1 /    COLUMN 8 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 7 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 6 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 5 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 4 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 3 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 2 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05,0.
REM     COLUMN 1 STORED IN BACKWARDS ORDER
DEC     0.,.6.,.55,.5,.45,.4,.35,.3,.25,.2,.15,.1,.05
DEC     0.
Q
*
END

```

K

```

SUBROUTINE TAB2(H,P,XQ,T,Z,G,CP,SV,S,C,V
1,TL,ZL,GL,CPL,SVL,SL,CL,VL,NDIMX,LCC,XC,DX,DY,H2)
DIMENSION LOC(12 ),NDIMX(6),XD(6),YD(2),DX(6),DY(12),EZ(8)
1 ,H2(6312)

```

```

C
C IF NEW PROPERTIES DATA IS INSERTED, THESE CARDS MAY NEED TO BE
C CHANGED.

```

```

NPROP=8
NPTS=789
YD(1)=0.0
YD(2)=300.0

```

```

C
IG=0
Y=P
HY=H
IF(Y-186.51)30,10,10
10 X=HY
15 ASSIGN 20 TO KGC
GO TO 200
20 T=EZ(1)
Z=EZ(2)
G=EZ(3)
CP=EZ(4)
SV=EZ(5)
S=EZ(6)
C=EZ(7)
V=EZ(8)
IF(IG)21,21,130
21 IF(HY-0.0)22,22,23
22 XQ=0.
GO TO 25
23 XQ=1.
25 CONTINUE
RETURN
30 IF(HY-100.)3000,10,10
3000 IF(HY-0.0)60,50,50
50 HG=HGAS(Y)
IF(HY-HG)70,10,10
60 HL=HLIG(Y)
IF(HY-HL)10,10,80
70 HL=HLIG(Y)
GO TO 100
80 HG=HGAS(Y)
100 XQ=(HL-HY)/(HL-HG)
110 X=20.
IG=1
GO TO 15
130 X=0.
ASSIGN 160 TO KGC
GO TO 200
160 TL=EZ(1)
ZL=EZ(2)
GL=EZ(3)
CPL=EZ(4)
SVL=EZ(5)
SL=EZ(6)

```

```

      (L= 2.7)
      VL= 2.0)
      RETURN
200  IF(X-500.0)3001,225,225
3001 IF(X-100.0)210,212,212
    210 IR=1
        GO TO 300
    212 IR=2
        GO TO 300
225  IF(X-1600.0)230,240,240
    230 IR=3
        GO TO 300
240  IF(X-3000.0)250,260,260
    250 IR=4
        GO TO 300
260  IF(X-15000.0)270,280,280
    270 IR=5
        GO TO 300
    280 IR=6
300  IF(Y-300.0)310,320,320
    310 JR=1
        GO TO 330
    320 JR=2
330  NREG=IR+(JR-1)*6
      NAD=LCC(NREG)
      XR=(X-XU(IR))/DX(IR)
      YR=(Y-YC(JR))/DY(NREG)
      IX=XR
      IY=YR
      FA= MODF(XR,1.0)
      FB= MODF(YR,1.0)
      FA1=1.-FA
      FB1=1.-FB
      NDX=NDIMX(IR)
      F11=FB1*FA1
      F12=FA*FB1
      F21=FB*FA1
      F22=FA*FB
      NBA=NAD+IX+IY*NDX
      DO 350 K=1,8
      JL=NEA+NPTS *(K-1)
      JH=JL+NDX
350  EZ(K)=F11*H2(JL)+F12*H2(JL+1)+F22*H2(JH+1)+F21*H2(JH)
      GO TO KGC,(20,160)
      END

```

(I,J)

REG.NC.
T(1)/REG

X1-INDEX
Y1-INDEX

P11-ADD.

SUBROUTINE TEM9

```

CTEM9
  SUBROUTINE TEM9(N,M,A,ALPHA,CX,D,Q,RH,T,T1,T2, QUAL,HH,P, TC,TCO,
1    W,Z3X,Q3,S,PSI,MAT,HSOL,HOSOL,MATSOL)
  C
    COMMON GAMMA,XMW,C1,C2,CRIT,ITRND,LOCK,LATCH,II,I1,I2,I3,I4,I5,SI
1    GMA,DIV,SMALL,VAL1,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME
  C
    DIMENSION W( 5),RH( 5),T( 5,11),D( 5,10),A( 5),Z3( 5,10),
1    C( 5,10),TCO( 5,10),Q( 5,10),ALPHA( 5),H(10),DAT(10),CP(10),
1    QUAL(5,11),HH(5,11),P( 5,11),
2    BETA(10),Z2(10),PSI(10),RELAX(10), Q2( 5,10),Q3(10,10),
3    S(10,10),ERROR(10),TC( 5,10)
4    ,MAT(5),CX( 5,10),Z3X( 5,10),HSOL(5,10),HOSOL(5,10)
5    ,MATSOL(5)
  C
    M1=M-1
    M2=M1-1
  C
    COMPUTE HEAT FLOWS AND TEMPERATURES
  C
    (1) CALCULATE BOUNDARY LAYER HEAT TRANSFER COEFFICIENTS
  C
    DO 900 I=1,N
  C
549 T(I,1) = T1
    HH(I,1)=HH(1,1)
    ITRND = 0
550 ITRND = ITRND + 1
    DO 650 K=1,M1
      FPI=XFPI (T(I,1),P(I,1))
      IF(QUAL(I,K))11003,11003,11001
11001 DIV2=1.0-QUAL(I,K)
      IF(DIV2)11003,11003,11002
11002 FKI=.611 + 1.93 *(((DIV2/QUAL(I,K))**.9)* ((.34901 - .2723E-03*
1    P(I,K)) * P(I,K)*1.0E-02 + .13923) )
      TERM2= .007*FPI*(((W(I)/(PI*RH(I))**.8) / (RH(I)*FKI)
      GO TO 600
11003 TERM2=(.007/RH(I)) * ((W(I)/(PI*RH(I))**.8) *FPI
      TERM2=TERM2 * (((T(I,K+1)/TC(I,K))**.55)
600 H(K)=TERM2
  C
  C
  C
  C
  C
  C
  C
  C
  C
  C
  C
    (2) CALCULATE THERMAL CONDUCTANCES
  C
    IF(QUAL(I,K))11006,11006,11004
11004 IF(1.0-QUAL(I,K))11006,11006,11005
11005 CP(K)=2000.0
    GO TO 11007
11006 CP(K)=XCP(T(I,K),T(I,K+1),HH(I,K),HH(I,K+1))
11007 BETA(K)=H(K)*D(I,K)*(A(I)/RH(I))/((W(I)+1.0E-05)*CP(K))

```

```

      Z1=. (1)*CP(K)
C      GET SLLIL ENTHALPY
      NOSTAT=11007
      CALL READKM (TC(I,K),MATSOL(I),HSOL(I,K),NK)
      IF(NK)11015,11015,950
11015 CPM=(HSOL(I,K) - HOSOL(I,K))/(TC(I,K)-TCC(I,K))
      IF(CPM)11008,11010,646
11008 WRITE OUTPUT TAPE 6,11009,CPM,I,K,HOSOL(I,K),TCC(I,K),HSOL(I,K)
      1,TC(I,K),MATSOL(I)
11010 CPM=HOSOL(I,K)/TCC(I,K)
      646 C(I,K)=CX(I,K) * CPM
      IF(K-1)649,649,647
      647 TAVG=(TC(I,K) + TC(I,K-1))/2.0
      NOSTAT=647
      CALL READKM (TAVG,MAT(I),VK,NK)
      IF(NK)648,648,950
      648 Z3(I,K)=Z3X(I,K) * VK
      649 CONTINUE
      650 Z2(K)=Z1*(EXP(BETA(K)) - 1.0)
C
C
C      IF(TSI(1))702,702,701
C
C
701 CONTINUE
      TT=TC(I,M-1)*TC(I,M-1)
      TTT=TC(I,M-1)*TT
      700 Z1TA=TSI(I)*(TTT + TT*TWALL + TC(I,M-1)*(TWALL*TWALL) +
      1 (TWALL*TWALL)*TWALL)
      GO TO 704
C
C
702 CONTINUE
703 ZETA=C.0
C
C
C
C
C      (3) CALCULATE HEAT FLOW RATE RELAXATION COEFFICIENTS
C
C
704 CONTINUE
      RELAX(1)=COEFF/(Z2(1) + Z3(I,2) + C(I,1)/DELTA)
C
      DO 50 K=2,M2
      50 RELAX(K)=COEFF/(Z3(I,K) + Z2(K) + Z3(I,K+1) + C(I,K)/DELTA)
C
      80 RELAX(M1)=COEFF/(Z3(I,M1) + Z2(M1) + ZETA + C(I,M1)/DELTA)
C
C
C
C
C      (4) CALCULATE HEAT FLOW RATES

```



```

      GO TO 850
10000 T(I,K)=DAT(6)
      850 QUAL(I,K)=DAT(5)
C
C      DO 880 K=1,M1
      880 SUM=SUM + ABSF(ERROR(K))
          SUMQ = 0.0
          Q3(I,1)=0.0
          DO 1000 K=1,M1
10000 SUMQ = SUMQ+ABSF(Q(I,K))+ABSF(Q2(I,K))+ABSF(S(I,K))+ ABSF(Q3(I,K))
          SUM = SUM/SUMQ
          IF(ITRNO-1)550,550,570
570   IF(999-ITRNO)950,571,571
571   IF(SUM-TOLER)1900,1900,550
C
C      UPDATE SOLID ENTHALPYS
C
C      DO 1922 K=1,M1
          TAVG=TC(I,K)
          CALL READKM (TAVG,MATSOL(I),HSOLID,NK)
          IF(NK)1922,1922,950
1922  HSOL(I,K)=HSOLID
C
C      900 CONTINUE
C
          SUM1=0.0
          SUM2 = 0.0
          T2=0.0
          DO 920 I=1,N
          SUM1=SUM1 + W(I)*ALPHA(I)*HH(I,M)
920   SUM2 = SUM2 + W(I)*ALPHA(I)
C
          IF (SUM2 - .00001) 922,922,921
C
921   H2=SUM1/SUM2
          NOSTAT=10001
          CALL PARAH (DAT,P(1,M),1,H2,3,NK)
          IF(NK)99999,10001,99999
10001 T2=DAT(6)
C
          IF(I3)922,922,924
924   WRITE OUTPUT TAPE 6, 16
          WRITE OUTPUT TAPE 6, 17, T1, T2, TWALL
922  RETURN
C
C
C      16 FORMAT (/////20H LIQUID TEMPERATURES///)
      17 FORMAT (23X,9H T1 = F10.1/23X,9H T2 = F10.1/
      171 23X,9H TWALL = F10.1//)
C
C      ERROR STATEMENT. TURNS SL 1 ON FOR RETURN
C
C      950 WRITE OUTPUT TAPE 6,951
      952 SENSE LIGHT 1
      GO TO 922

```

```

99999 OUT=4HTEMS
      WRITE OUTPUT TAPE6,99998,OUT,NOSTAT, (DAT(I),I=1,10)
      GO TO 952
C
951  FORMAT (/1H-,20X,22HTEM9 DOES NOT CONVERGE /1H- )
99998 FORMAT (/13H-      ROUTINE ,A6,29H, BAD PRPTY LOOKUP.      NOSTAT= 18
1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
11009 FORMAT (12H- TEM9 CPM =,1PE14.7,2X,1HI 13,2X,1HK 13,2X,
1 11HOLD SOLID H  E15.7,2X, SHOLD T E15.7 / 1X, 7HSOLID H  E15.7,
2 2X, 1HT E15.7 ,2X,3HMAT 15)
      END

```


SUBROUTINE READKM

```

*      FAP
*      COUNT      800
*      SUBROUTINE  READKM (TAVG,MK, VKM,FLAG)
*
*      THERMAL CONDUCTIVITY TABLES T=DEGREES R, VK=BTU/SEC IN DEGREE R
*      MK IS COLUMN INDICATOR FOR THE ARRAYS
*
      ENTRY      READKM
      REG        PZE
      PZE
      PZE
      PZE
READKM          SXD      REG,1          STORE INDEX REGS.
                SXD      REG+1,2
                SXD      REG+2,4
                CLA      1,4
                STA      TAVG          STORE
                CLA      2,4          ARGUMENT
                STA      MK            ADDRESSES
                CLA      3,4
                STA      VKM
                CLA      4,4
                STA      FLAG
                AXT      0,1
                CLA*     MK            ZERO XR 1
                PDX      ,2            LOCATE
                TXH      G25,2,21      CORRECT
                TIX      *+2,2,1      CHECK IF MK GT 21 (21 CURVES)
                TRA      *+2          MATERIAL
                TXI      *-2,1,-15     COLUMN
                AXT      1,2           IN XR 1
                PXA      ,0            SET XR 2=1
                STO*     VKM           SET VKM =0
                STO*     FLAG          ZERO FLAG
                CLA*     TAVG
                TMI      G25           NEG. TEMP ERROR
                TZE      G1
                TPL      G2            CHECK FOR ZERO TEMP.
      G1         CLA      VK,1
                STO*     VKM
                TRA      G20+1
      G2         CLA      T+1,1        START OF DO STATEMENT
                FSB*     TAVG
                TZE      G3
                TMI      G4
      G6         CLA      VK+1,1
                FSB      VK,1
                STO      DIV
                CLA      T+1,1
                FSB      T,1
                STO      DIV2
                CLA*     TAVG
                FSB      T,1
                FDP      DIV2
                FMP      DIV
                FAD      VK,1
                STO*     VKM

```

A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P

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H
J
M
N
B
C
D
E
F
G
H
I
J
K
L
M

```

G3   TRA      G20+1
     CLA      VK+1,1
     STO*     VKM
     TRA      G20+1
G4   CLA      T+1,1
     TZE      G5
     TPL      G10
G5   CLA      VK,1
     STO*     VKM
     TRA      G20+1
G10  TXI      *+1,1,-1
     TXI      *+1,2,1
     TXL      G2,2,15
G20  CLA*     VKM
     TZE      G25
     TPL      G30
G25  CLA      ONE
     STO*     FLAG
     CAL      SIX
     TSX      $(STH),4
     PZE      WOT
     LDQ*     FLAG
     STR
     LDQ*     MK
     STR
     LDQ*     TAVG
     STR
     LDQ*     VKM
     STR
     TSX      $(FIL),4
G30  LXD      REG,1
     LXD      REG+1,2
     LXD      REG+2,4
     TRA      5,4
           RETURN
ONE  OCT      +000001000000
SIX  OCT      +000006000000
DIV  PZE      1
DIV2 PZE      1
TAVG PZE      1
MK   PZE      1
VKM  PZE      1
FLAG PZE      1
*
*   TEMPERATURE ARRAY
*
*   TABLE 1  347(CRES)                12/27/62          MK=1
*
T    DEC      0.0,100.0,300.0,500.0,700.0,1500.0,0.,0.,0.,0.
     DEC      0.,0.,0.,0.,0.
*
*   TABLE 2  BE                        12/27/62          MK=2
*
     DEC      0.0,100.0,500.0,1000.0,1500.0,2000.0,3000.0,0.,0.,0.
     DEC      0.,0.,0.,0.,0.
*

```

CURRENT MAX. I IS 15, T (I,J)

ERROR
PRINT
ROUTINE

RETURN

D
PA
C
O
E
F
F
I
C
I
E
N
TB
C
D
E
F
G
H
I
L

```

*      TABLE 3 AL                      12/27/62          MK=3
*
DEC      0.,100.,200.,300.,500.,1000.,0.,0.,0.,0.
DEC      0.,0.,0.,0.,0.
*
*      TABLE 4 GRAPHITE                12/27/64          MK=4
*
DEC      0.,400.,500.,800.,1000.,1500.,2000.,3000.,4000.,5000.
DEC      10000.,0.,0.,0.,0.
*
*      TABLE 5 PYRO GRAPHITE           12/27/62          MK=5
*
DEC      0.,200.,400.,500.,600.,700.,800.,1000.,1500.,2000.
DEC      5000.,10000.,0.,0.,0.
*
*      TABLE 6 LIH                    12/27/62          MK=6
*
DEC      0.,200.,300.,400.,600.,1000.,1500.,0.,0.,0.,0.,0.,0.
DEC      0.
*
*      TABLE 7 A-110-AT                12/27/62          MK=7
*
DEC      0.,500.,1000.,1500.,2000.,0.,0.,0.,0.,0.,0.,0.,0.
*
*      TABLE 8      H2 GAS AS F(T)      8/14/64          MK=8
*
DEC      0.,100.,200.,300.,400.,600.,800.,1000.,1500.,2000.,2500.
DEC      3000.,4000.,1.0E+10,0.
*
*      TABLE 9 INCONEL                 05/31/63          MK=9
*
DEC      0.,500.,1000.,5000.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.
*
*      TABLE 10 TUNGSTEN               2/5/64           MK=10
*
DEC      0.,500.,1000.,1500.,2000.,3000.,4000.,7000.,0.,0.
DEC      0.,0.,0.,0.,0.
*
*      TABLE 11 INCONEL-X              6/30/64          MK=11
*
DEC      0.0,200.,400.,1000.,1500.,2000.,4000.,0.
DUP      1,7
DEC      0.
*
*      TABLE 12 AND 13 ARE NEW DATA FOR THE MATERIAL IN TABLE 5
*      TABLE 5 IS RADIAL DIRECTION DATA
*
*      TABLE 12 PYROLITIC GRAPHITE  AXIAL DIRECTION      7/31/64  MK=12
*
DEC      0.,500.,1000.,1500.,2500.,3500.,4500.,5500.
DUP      1,7
DEC      0.
*
*      TABLE 13 PYROLITIC GRAPHITE  RADIAL DIRECTION      7/31/64  MK=13

```

M
N
C
PA
EC
C
I
J
K

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```

DEC      0.,600.,1000.,1500.,2000.,2500.,3000.,3500.
DUP      1,7
DEC      0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64      BE      K=14
DEC      0.,300.,400.,500.,600.,800.,1000.,1200.,1400.,1600.
DEC      1800.,2000.,2200.,10000.,0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64      GRAPHITE      K=15
DEC      0.,300.,400.,600.,800.,1200.,1600.,2000.,2600.,3200.
DEC      4000.,10000.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64      AL      K=16
DEC      0.,200.,300.,400.,600.,800.,1000.,1200.,1400.,1600.
DEC      10000.,0.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64      STEEL      K=17
DEC      0.,300.,400.,600.,800.,1200.,1600.,2200.,2800.
DEC      10000.,0.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 11/5/64      INCONEL      K=18
DEC      0.,200.,300.,400.,500.,800.,1200.,3000.,10000.,0.
DEC      0.,0.,0.,0.,0.

```

TABLE 19 - TURBINE POSITION CONTROL VALVE (DEGREES) VS LOSS COEFFICIENT

```

DEC      0.,1.E-10,26.4,30.,33.2,36.,37.4,40.8,45.4,49.7,56.7
DEC      67.3,78.4,90.,0.

```

TABLE 20 - LOSS COEFFICIENT VS TURBINE POSITION CONTROL VALVE (DEGREES)

```

DEC      0.,1.70,1.80,2.2,3.8,6.8,10.6,18.2,28.,38.8,61.,116.
DEC      300.,1.0E10,0.

```

TABLE 21 U/CO VS TURBINE EFFICIENCY MK=21 3-15-65

```

DEC      0.,.02,.04,.06,.08,.1,.12,.14,.16,.18,.2,.22,.24,.26,0.

```

THERMAL CONDUCTIVITY ARRAY

```

TABLE 1 347(CRES)      12/27/62      MK=1
DEC      0.,9.02E-05,15.7E-05,19.2E-05,21.5E-05,30.1E-05,0.,0.,0.
DEC      0.,0.,0.,0.,0.,0.

```

```

TABLE 2 BE      12/27/62      MK=2
DEC      0.,109.E-05,220.E-05,171.E-05,120.E-05,102.E-05,97.E-05
DEC      0.,0.,0.,0.,0.,0.,0.,0.

```

```

TABLE 3 AL      12/27/62      MK=3
DEC      0.,74.E-05,106.E-05,129.6E-05,169.E-05,213.E-05,0.,0.,0.
DEC      0.,0.,0.,0.,0.,0.

```

```

TABLE 4 GRAPHITE      12/27/64      MK=4
DEC      0.,208.E-05,208.E-05,189.E-05,169.E-05,106.E-05,83.E-05
DEC      51.E-05,44.E-05,39.4E-05,37.0E-05,0.,0.,0.,0.

```

```
*
*   TABLE 5 PYRU GRAPHITE          12/27/64          MK=5
*   DEC      0.,.4E-05,1.2E-05,2.52E-05,2.8E-05,2.88E-05,2.78E-05
*   DEC      2.42E-05,1.87E-05,1.58E-05,.2E-05,.24E-5,0.,0.,0.
*
*   TABLE 6 LIH                    12/27/64          MK=6
*   DEC      6.9E-05,10.6E-05,11.2E-05,11.1E-05,0.37E-05,7.08E-05
*   DEC      5.09E-05,0.,0.,0.,0.,0.,0.,0.,0.
*
*   TABLE 7 A-110-AT              12/27/64          MK=7
*   DEC      0.,10.2E-05,14.1E-05,19.0E-05,25.0E-05,0.,0.,0.,0.,0.
*   DEC      0.,0.,0.,0.,0.
*
*   TABLE 8      H2 GAS AS F(T)    8/14/64          MK=3
*   DEC      1.E-7,.104E-5,.128E-5,.169E-5,.202E-5,.274E-5,.343E-5
*   DEC      .406E-5,.58E-5,.754E-5,.956E-5,1.16E-5,1.53E-5,1.74E-5,0.
*
*   TABLE 9 INCCNEL                05/31/64          MK=9
*   DEC      11.6E-05,16.2E-05,31.2E-05,79.5E-05,0.,0.,0.,0.,0.,0.
*   DEC      0.,0.,0.,0.,0.
*
*   TABLE 10 TUNGSTEN              2/5/64           MK=10
*   DEC      250.,215.,185.,169.,157.,144.,134.,130.,0.,0.,0.,0.,0.
*   DEC      0.,0.
*
*   TABLE 11 INCCNEL-X             6/30/64          MK=11
*   DEC      0.,14.E-05,16.E-05,20.E-05,26.E-05,32.E-05,35.E-05,0.
*   DUP      1,7
*   DEC      0.
*
*   TABLE 12 AND 13 ARE NEW DATA FOR THE MATERIAL IN TABLE 5
*   TABLE 5 IS RADIAL DIRECTION DATA
*
*   TABLE 12 PYROLITIC GRAPHITE AXIAL DIRECTION    7/31/64    MK=12
*   DEC      0.,8.32E-3,4.62E-3,3.E-3,1.E-3,1.34E-3,1.27E-3,1.27E-3
*   DUP      1,7
*   DEC      0.
*
*   TABLE 13 PYROLITIC GRAPHITE RADIAL DIRECTION    7/31/64    MK=13
*   DEC      0.,1.16E-5,8.79E-6,7.4E-6,6.2E-6,5.5E-6,5.09E-6,5.32E-6
*   DUP      1,7
*   DEC      0.
*   REM      **TABLE FOR SOLID ENTHALPY** 10/28/64    BE            K=14
*   DEC      0.,15.,40.,73.,115.,215.,332.,460.,587.,720.,860.
*   DEC      1006.,1160.,7246.,0.
*   REM      **TABLE FOR SOLID ENTHALPY** 10/28/64    GRAPHITE     K=15
```

```

DEC      0.,15.,30.,68.,115.,243.,400.,568.,832.,1120.
DEC      1520.,4520.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64    AL      K=16
DEC      0.,10.,25.,43.,83.,127.,176.,228.,283.,340.,2734.
DEC      0.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 10/28/64    STEEL    K=17
DEC      0.,12.,20.,40.,63.,113.,167.,258.,355.,1519.
DEC      0.,0.,0.,0.,0.
REM      **TABLE FOR SOLID ENTHALPY** 11/5/64    INCCNEL    K=18
DEC      0.,6.,13.6,23.9,35.4,72.,125.2,411.4,1524.4,0.
DEC      0.,0.,0.,0.,0.

```

*
*
*
TABLE 19 - TURBINE POSITION CONTROL VALVE (DEGREES) VS LOSS COEFFICIENT

```

DEC      0.,1.0E10,300.,116.,61.,38.8,28.,18.2,10.6,6.8,3.8,2.2
DEC      1.80,1.70,0.

```

*
*
*
TABLE 20 - LOSS COEFFICIENT VS TURBINE POSITION CONTROL VALVE (DEGREES)

```

DEC      0.,90.,78.4,67.3,56.7,49.7,45.4,40.8,37.4,36.,33.2,30.0
DEC      26.4,1.E-10,0.

```

*
*
*
TABLE 21 U/CD VS TURBINE EFFICIENCY MK=21 3-15-65

```

DEC      0.,.1.,.182.,.253.,.315.,.363.,.4.,.43.,.45.,.465.,.473.,.48.,.483
DEC      .485,0.

```

*
BCD 116.8/)
BCD 1VKM=,E
BCD 1,5X,4H
BCD 1,E16.8
BCD 1HTAVG=
BCD 1=,I4,5
BCD 12,3HMK
BCD 1AGR=,I
BCD 1,7HNFL
BCD 1VE./2X
BCD 1NEGATI
BCD 1Y VKM
BCD 1ATED B
BCD 1 INDIC
BCD 1ION IS
BCD 1CONDIT
BCD 1ERROR
BCD 19H OR
BCD 1TED./4
BCD 1ATTEMP
BCD 1RO IS
BCD 1 BY ZE
BCD 1VISION
BCD 1HEN DI
BCD 1SULT W
BCD 1ILL RE
BCD 1GRAM W
BCD 1IN PRJ
BCD 1 IN MA

WOT BCD 1DIT ION
BCD 1CR CON
BCD 1CH ERR
BCD 1ADKM/8
BCD 1INE RE
BCD 1LBROUT
BCD 1(18H S
END

FUNCTION HGAS

```
C  FUNCTION HGAS(P)
C  COMPUTES ENTHALPY OF SAT.GAS USING DATA FROM NBS-TN-130
EQ.4.3 FROM NBS-TN-7246 IS USED USING H(BTU/LB) AND P(Psia)
X=187.506-P
HGAS=542.1156*X**.37-1.7509247E-5*X**2.9-496.16457*X**.4+6.234816*
1X**.8
RETURN
END
```


FUNCTION HLIQ

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```

C      FUNCTION HLIQ(P)
C      COMPUTES ENTHALPY OF SAT.LIQ.FROM DATA FROM NBS-TN-130
      ENTHALPY (BTU/LB) AND PRESSURE (PSIA)
      HLIQ=-127.06816+P*(1.3751869+P*(-.017245489+P*(1.7668388E-4+P*(
1-9.1258098E-7+P*1.8932681E-9))))
      RETURN
      END
  
```

CHAIN 1 (WITHOUT NOZZLE JACKET)

```

* TRANSIENT WITH ALL OPTIONS AND OPTION SHIFT
C FIRST PART WITH TPCV OPTION 3/21/65
C
C MAIN ROUTINE
C
C ARITH. EXPRES- USED IN TURBO-PUMP TO COMPUTE DENSITY
C RHOFF(T,P)=P/(XMUL*T)
C
C ARITHMETIC EXPRES. USED IN TURBO-PUMP TO COMPUTE FLOW STORAGES
C CWFF(V,R,RO,P,PO)=V*(R-RO)/(DELTA*(P-PO))
C
C ARITH. EXPRES. TO FIX FLOATING NUMBERS
C
C XKKKF(X)=X + 1.0E-05 *X
C
C
C DIMENSION A(2700),TITLE(12),HD(10),HH(10),DAT(10)
C
C EQUIVALENCE INPUTS TO Y ROUTINES TO PRESERVE ORDER OF COMMON
C
C EQUIVALENCE (GAMMA,DUM1), (XMW,DUM2), (C1,DUM3), (C2,DUM4),
1 (CRIT,DUM0), (ITRNO,IDUM1), (LOCK,IDUM2), (LATCH,IDUM3), (I1,
1 IDUM0), (I1,
2 IDUM4), (I2,IDUM5), (I3,IDUM6), (I4,IDUM7), (I5,IDUM8), (SIGMA,
3 DUM5), (DIV,DUM6), (SMALL,DUM7), (VAL1,DUM8), (COEFF,DUM9),
4 (TOLER,DUM10), (DELTA,DUM11), (PI,DUM12), (GC,DUM13), (R,DUM14),
5 (CJ,DUM15), (TWALL,DUM16), (TIME,DUM17)
C
C INPUT VALUES
C
C A(3) USED TO CALCULATE NODE TOLERANCE IN THE NOZZLE
C EQUIVALENCE (A(1),TAU), (A(2),CDELTA), (A(4),YOUTN),
1 (A(5),CCOEFF), (A(6),PCF), (A(7),TCF), (A(8),H2F), (A(9),PAF), (A(1
20),POWER), (A(11),ORDH2(1)), (A(62),ORDTC(1)), (A(113),ORDPC), (A(
3164),ORDPA), (A(215),CGAMMA), (A(216),CXMW), (A(217),TPCVX),
4 (A(218),PTPCV), (A(220),DNT), (A(221),CTWALL), (A(222),XKN), (A
5(223),ALPHAN(1)), (A(243),AREAN(1)), (A(263),AN(1)), (A(283),RHN(1
6)), (A(303),DN(1)), (A(323),Z3NX), (A(343),CNX), (A(363),ARATI
70(1)), (A(383),EN(1)), (A(403),SFN(1)), (A(423),A1N(1)), (A(443),A
8K4(1)), (A(463),ALPHAR(1)), (A(473),AREAR(1)), (A(483),AR(1)), (A(4
993),XKR(1)), (A(503),RHR(1)), (A(523),DR(1)), (A(623),Z3R(1))
C EQUIVALENCE (A(723),CR(1)), (A(823),ALPHAS(1)), (A(833),AREAS(1)
1), (A(843),AS(1)), (A(853),XKS(1)), (A(863),RHS(1)), (A(873),DS(1)
2), (A(973),Z3S(1)), (A(1073),CS(1)), (A(1173),ALPHAC(1)), (A
3(1183),AREAC(1)), (A(1193),AC(1)), (A(1203),XKC(1)), (A(1213),RHC
41)), (A(1223),E(1)), (A(1233),SF(1)), (A(1243),A1(1)), (A(1253),DC
5(1)), (A(1353),Z3C(1)), (A(1453),CC(1)), (A(1553),FLUXN(1)),
6 (A(1573),FLUXR(1)), (A(1673),FLUXS(1)), (A(1773),FLUXC(1)),
7 (A(1873),TCZERN(1)), (A(1893),TCZERR(1)), (A(1993),TCZERS(1))
8, (A(2093),TCZER(1)), (A(2193),TMAX)
C EQUIVALENCE (A(2194),COEFS), (A(2195),COEFR), (A(2196),COEFC)
2, (A(2197),HMAX), (A(2198),TRNO), (A(2199),TURBM), (A(2200),
3 THKTD), (A(2201),THIK), (A(2221),ORDPOW), (A(2272),XIPOW)
C
C TURBO-PUMP AND HEAT EXCHANGER INPUTS

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EQUIVALENCE (A(2293),PCON1), (A(2294),PCON2), (A(2295),PCON3),
1 (A(2296),PCON4), (A(2297),WCON1), (A(2298),WCON2), (A(2299),DH),
2 (A(2300),AHC), (A(2301),RHD), (A(2302),AHH), (A(2303),RHH),
3 (A(2304),Z3HX), (A(2314),CHX), (A(2324),FLUXH), (A(2334),THEZER),
4 (A(2345),AREADT), (A(2346),AREADD), (A(2347),AHBP), (A(2348),
5 RHBP), (A(2349),DHBP), (A(2350),AREATO), (A(2351),CBPT), (A(2352),
6 CP1), (A(2353),CP2), (A(2354),CP3), (A(2355),CP4), (A(2356),
7 CPS), (A(2357),XNSS), (A(2358),CT1), (A(2359),CT2), (A(2360),
8 CT3), (A(2361),CT4), (A(2362),CT5), (A(2363),APD1), (A(2364),
9 RHPD1), (A(2365),DPD1), (A(2366),TZ), (A(2367),PZ), (A(2368),V4)
EQUIVALENCE (A(2369),V5), (A(2370),V6), (A(2371),V7), (A(2372),
1 V10), (A(2373),V14), (A(2374),WYEDT), (A(2375),WYDST), (A(2376),
2 WYBPT), (A(2377),WYENT), (A(2378),YRN), (A(2379),P1), (A(2380),
3 P2), (A(2381),XIR), (A(2382),P4), (A(2383),P5), (A(2384),P6),
4 (A(2385),P7), (A(2386),P14), (A(2387),C19), (A(2388),PDST(1)),
5 (A(2398),WDST(1)), (A(2408),PHST(1)), (A(2418),WHST(1))
6 (A(2428),TXCTOL), (A(2429),PXCTUL), (A(2430),T18TDL), (A(2431),
7 TTOLER), (A(2432),PTOLER), (A(2433),COHEX), (A(2434),COTUR)
8 (A(2435),YKA), (A(2436),T9S), (A(2437),T9K), (A(2438),T9C)
9 (A(2439),POWTOL), (A(2440),ORDTCV)
EQUIVALENCE (A(2492),TCG), (A(2493),PCG), (A(2494),TXCLIM),
1 (A(2495),PXCLIM)
2 (A(2642),DRNT), (A(2643),XPRATR), (A(2644),XPRATM), (A(2645),EFFMN),
3 (A(2646),EFFRN), (A(2647),CTSRAT)

FIXED POINT INPUTS

EQUIVALENCE (A(2500),XLIMIT), (A(2501),XMINOR), (A(2502),XI1), (A
1 (2503),XI2), (A(2504),XI3), (A(2505),XI4), (A(2506),XI5), (A(2507)
2 ,XI6), (A(2508),XI7), (A(2509),XI8), (A(2510),XITEMI), (A(2511),XIP
3 I), (A(2512),XITI), (A(2513),XITNI), (A(2514),EMN), (A(2515),EMR)
4 , (A(2516),EMS), (A(2517),EMC), (A(2518),XMH), (A(2519),XM)
5 (A(2520),XNR), (A(2521),FNS), (A(2522),XNC), (A(2523),XNN)
6 (A(2524),XSTY), (A(2525),XMKM), (A(2526),XMKTD)
7 (A(2527),XMATN), (A(2528),XMATR), (A(2533),XMATS), (A(2538),
8 XMATC), (A(2543),XMATH), (A(2544),SMATR), (A(2549),SMATS),
9 (A(2554),SMATC), (A(2559),XIRNX)

DIMENSION THC(11),THE(11),THH(11),Z3H(10),CH(10),THEO(10),
1 FLUXH(10),THEZER(10),PDST(10),WDST(10),PHST(10),WHST(10),Z2(20),
2 YDST(10),YHST(10),Z4(20)
3 DIMENSION Q1H(10),Q2H(10),Q3H(10),SH(10),QH(10)

COMMON GAMMA,XMW,C1,C2,CRIT,ITRND,LOCK,LATCH,I1,I2,I3,I4,I5,SI
1 GMA,DIV,SMALL,VAL1,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME,A
2 ,LIMIT,MINOR,I6,I7,I8,ITEMI,IPI,ITI,ITNI,MH,M,MN,MC,MS,MR,NN,NS,
3 NR,NC,M1H,M2H,MAJOR,M1N,M2N,M1R,M2R,M1S,M2S,M1C,M2C,DDD,FIG,FPI,
4 HCCAL,HHCAL,HCCON,HHCN,PSIN,PSIR,PSIS,PSIC,CHNDR,CHNDS,CHNOC,T2
5 ,TXC,PXC,PA,TCN,TCR,TCS,TCC,THE,THC,THH,TN,T5,TR,T5,TS,T7,TC,
6 T10,T14,T16,T17,T17P5,T18,T19,EM1N,EM1R,EM1S,EM1C,P10,PC,PS,PR,
7 PN,P17,P17P5,P18,P19,TERMH,TERVD,MAJOR,ANT,IDUMP,ISTEDY,PPP,
8 RECDV,T4,XMUL,XNSD,QUALN,HHN,QUALR,HRH,QUALS,HHS,QUALC,HHC,
9 QUALHT,HHHT,QUALHD,HHHD,H1,TXC1,H2,TPCV,PXC1

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002000
002020
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002120
002140
002160

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C      COMMON MATN,MATR,MATS,MATC,MATH,HSOLN,HSOLS,HSOLR,HSOLC,HSOLH
1      ,MATSR,MATSS,MATSC
      DIMENSION HSOLN(20),HSOLS(5,10),HSOLR(5,10),HSOLC(5,10)
1      ,HSOLN(20),HSOLR(5,10),HSOLS(5,10),HSOLC(5,10),HSOLH(20)
2      ,HSOLH(20),CNX(20),Z3NX(20),CHX(10),Z3HX(10)
3      ,XMATR(5),MATR(5),XMATS(5),MATS(5),XMATC(5),MATC(5)
4      ,SMATR(5),SMATS(5),SMATC(5),MATSR(5),MATSS(5),MATSC(5)

C      DIMENSION ORDH2(51),ORDTC(51),ORDPC(51),ORDPA(51),ORDPOW(51)
      DIMENSION ALPHAR(10),AREAR(10),AR(10),XKR(10),RHR(10),DR(10,10),Z3
1      R(10,10),CR(10,10),PSIR(10),ORDTCV(51)
      DIMENSION ALPHAS(10),AREAS(10),AS(10),XKS(10),RHS(10),DS(10,10),Z3
1      S(10,10),CS(10,10),PSIS(10)
      DIMENSION ALPHAC(10),AREAC(10),AC(10),XKC(10),RHC(10),DC(10,10),Z3
1      C(10,10),CC(10,10),PSIC(10)
      DIMENSION QR(10,10),WR(10),WYER(10),PR(10,10),TCR(10,10),TCOR(10,1
1      0),TR(10,10),Q3R(10,10),SR(10,10)
      DIMENSION FLUXR(10,10),FLUXS(10,10),FLUXC(10,10)
      DIMENSION TCZERR(10,10),TCZERS(10,10),TCZERC(10,10)
      DIMENSION E(10),SF(10),AI(10),PSI(10),Y(10)
      DIMENSION QS(10,10),WS(10),WYES(10),PS(10,10),TCS(10,10),TCOS(10,1
1      0),TS(10,10),Q3S(10,10),SS(10,10)
      DIMENSION QC(10,10),WC(10),WYEC(10),PC(10,10),TCC(10,10),TCOC(10,1
1      0),TC(10,10),Q3C(10,10),SC(10,10)
      DIMENSION YINR(10),YOUTR(10),YR(10,10)
      DIMENSION YINS(10),YOUTS(10),YS(10,10)
      DIMENSION YINC(10),YUTC(10),YC(10,10)
      DIMENSION ALPHAN(20),AN(20),RHN(20),DN(20),Z3N(20),CN(20),
1      WN(20),THETA(20),TN(20),TCN(20),H(20),BETA(20),Z1N(20),Z2N(20),Z
2      4N(20),PSIN(20),Z5N(20),RELAX(20),Q1N(20),Q2N(20),Q3N(20),Q4N(20),
3      Q5N(20),TAR(20),SN(20),TCON(20),QN(20),ERROR(20),FLUXN(20),TCZERN(
4      20),EN(20),SFN(20),AIN(20),YN(20),PN(20),ARATIO(20),
5      STBB(20),PHX(20),DDD(20)
      DIMENSION HCCON(20),HHCON(20),AK4(20),TEK(20)
1      ,QUALN(20),HHN(20),QUALR(5,10),HHR(5,10),QUALS(5,10),HHS(5,10),
2      ,QUALC(5,10),HHC(5,10),QUALHT(5,10),HHHT(5,10),QUALHD(5,10),
3      ,HHHD(5,10),THIK(20)
4      FORMAT(12X,8HNODE NO. I3,4HTCR= F10.1)
5      FORMAT(12X,8HNODE NO. I3,4HTCS= F10.1)
6      FORMAT(12X,8HNODE NO. I3,4HTCC= F10.1)
671  FORMAT(///// 28H NOZZLE NODE MASS FLOW RATES ///)
673  FORMAT(/////26H NOZZLE CHANNEL PRESSURES ///)
674  FORMAT(23X,9H P4 = F10.1/23X, 9H P5 = F10.1//)
676  FORMAT(11X10H NODE NO. I3,5X 6H PN = F10.1)
14  FORMAT (//20H CHANNEL NUMBER I3//)

C      BLOCK A READ PROGRAM PARAMETERS
C      PRINTOUT PROBLEM DATA (INPUT)

C      LOAD INPUT

C      30 READ INPUT TAPE 5,997,TITLE

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003100
003120
003140
003160
003180
003200
003220
003240
003260
003280

```

	WRITE OUTPUT TAPE 5,998,TITLE	003300
	IF(TITLE(1)-6HUNL AD)26,25,26	003320
C		003340
C	UNLOAD CHAIN TAPE	003360
C		003380
25	CALL REWUNL	003400
	PRINT 27,TITLE	003420
27	FORMAT (1H-,12A6 ///)	003440
26	CALL SLOAD (A)	003460
997	FORMAT (12A6)	003480
998	FORMAT (1H1,12A6// 40X,15--GENERAL INPUT-)	003500
	ITFLAH=0	003520
	LIMIT=XKKKF(XLIMIT)	003540
	MINOR=XKKKF(XMINOR)	003560
	I1=XKKKF(XI1)	003580
	I2=XKKKF(XI2)	003600
	I3=XKKKF(XI3)	003620
	I4=XKKKF(XI4)	003640
	I5=XKKKF(XI5)	003660
	I6=XKKKF(XI6)	003680
	I7=XKKKF(XI7)	003700
	I8=XKKKF(XI8)	003720
	ITEMI=XKKKF(XITEMI)	003740
	IPI=XKKKF(XIPI)	003760
	ITI=XKKKF(XITI)	003780
	ITNI=XKKKF(XITNI)	003800
	MH=XKKKF(XMH)	003820
	M=XKKKF(XM)	003840
	MN=XKKKF(XMN)	003860
	MC=XKKKF(XMC)	003880
	MS=XKKKF(XMS)	003900
	MR=XKKKF(XMR)	003920
	NN=XKKKF(XNN)	003940
	NS=XKKKF(XNS)	003960
	NR=XKKKF(XNR)	003980
	NC=XKKKF(XNC)	004000
	ISTEDY=XKKKF(XSTY)	004020
	IPOW=XKKKF(XIPOW)	004040
	M1H=MH-1	004060
	M2H=MH-2	004080
	GAMMA=CGAMMA	004100
	XMW=XXMW	004120
	TOLER=TTOLER	004140
	DELTA=CDELTA	004160
	COEFF=CCOEF	004180
	TWALL=CTWALL	004200
	MAJOR = TAG / DELTA + .01	004220
	XNS=XNS	004240
		004260
		004280
C		004300
C	THERMODYNAMIC CONSTANTS USED IN COMPUTING THE MASS FLOW	004320
C	RATE CONDUCTANCE OF AN ORIFICE	004340
C		004360
	IDUMP = 0	004380
	PI = 3.1416	004400
	SIGMA = 4.356E-15	

```

R = 1.987
GC = 32.174
CJ = 778.2
VAL1 = (CJ*R)/(XMW*GC)
CRIT = (2.0/(GAMMA+1.0))*((GAMMA/(GAMMA-1.0))
PART1 = ((GAMMA+1.0)/2.0)*((1.0/(GAMMA-1.0))
PART2 = SQRTF((GAMMA+1.0)/(GAMMA-1.0))
TERMA = SQRTF((2.0*GAMMA)/(GAMMA-1.0))
TERMB = PART1*PART2
C1 = TERMA/TERMB
C2 = TERMB
ANT = .7853982*DNT**2
DIV = 0.63212
SMALL = 0.0001
RECDV = 0.9

C
DO 88888 I=1,514
L2=I+514
L3=L2+514
L4=L3+514
L5=L4+514
88888 WRITE OUTPUT TAPE 6,88889,I,A(I),L2,A(L2),L3,A(L3),L4,A(L4)
1 ,L5,A(L5)
88889 FORMAT (5X,I4,1PE13.5,I5,E13.5,I5,E13.5,I5,E13.5,I5,E13.5)
C
WRITE OUTPUT TAPE 6,998,TITLE
C
WRITE OUTPUT TAPE 6,1111,LIMIT,TAU,DELTA,MINOR,COEFF,TXCTOL,PXCTOL
1 ,T18TOL,TTOLER,PTOLER,COHEX,COTUR
1111 FORMAT(7H0LIMIT= I4, 5H TAU=E12.5, 7H DELTA=E12.5,7H MINOR=I4.2X,
15HCOEFF E13.5/7H0TXCTOL E13.5,2X,6HPXCTOL E13.5,2X,6HT18TOL E13.5
2 ,2X,6HTTOLER E13.5 / 7H0PTOLER E13.5,2X,5HCOHEX E13.5,2X,
3 5HCOTUR E13.5)
C
BLOCK B READ DESIGN POINT VALUES
C
C
C
BLOCK B1 READ INITIAL GUESS FOR POWER
C
C
C
WRITE OUTPUT TAPE 6,1222,PCF,TCF,H2F,PAF,POWER
1222 FORMAT(5H0PCF=E9.3,5H TCF=E9.3,5H H2F=E9.3,5H PAF=E9.3,7H POWER=E9
1.3/)
C
BLOCK C READ TRANSIENT DIMENTIONLESS RATIOS OF DESIGN POINT VALUES
C
C
WRITE OUTPUT TAPE 6,1003,(ORDH2(LIST),LIST=1,LIMIT)
1003 FORMAT (7H0ORDH2 /(5X8E12.5))
WRITE OUTPUT TAPE 6,1004,(ORDTC(LIST),LIST=1,LIMIT)
1004 FORMAT(7H0ORDTC /(5X8E12.5))
WRITE OUTPUT TAPE 6,1005,(ORDPC(LIST),LIST=1,LIMIT)
1005 FORMAT (7H0ORDPC /(5X8E12.5))
WRITE OUTPUT TAPE 6,1006,(ORDPA(LIST),LIST=1,LIMIT)
1006 FORMAT (6H0ORDPA/(5X8E12.5))
C
C
BLOCK E READ COOLANT FLUID PROPERTIES DATA
C

```

```

004420
004440
004460
004480
004500
004520
004540
004560
004580
004600
004620
004640
004660
004680
004700
004720
004740
004760
004780
004800
004820
004840
004860
004880
004900
004920
004940
004960
004980
005000
005020
005040
005060
005080
005100
005120
005140
005160
005180
005200
005220
005240
005260
005280
005300
005320
005340
005360
005380
005400
005420
005440
005460
005480
005500
005520

```

	WRITE OUTPUT TAPE 6,1008,GAMMA,XMW,CP,XML,XC	005540
1008	FORMAT(7H0GAMMA=E12.5,5H XMW=E12.5,4H CP=E12.5, 5H XMU=E12.5,4H XC	005560
	1=E12.5)	005580
C		005600
C	BLOCK E READ NOZZLE DATA	005620
C		005640
	WRITE OUTPUT TAPE 6,1007,DNT,TWALL	005660
1007	FORMAT(5H0DNT= E12.5, 7H TWALL= E12.5)	005680
C		005700
C		005720
C		005740
	WRITE OUTPUT TAPE 6,1771	005760
1771	FORMAT (1H1 40X 14H-NOZZLE INPUT-)	005780
C		005800
	M1N = MN-1	005820
	M2N = MN-2	005840
	WRITE OUTPUT TAPE 6, 1775, XKN	005860
1775	FORMAT (4H0XKN / E12.5)	005880
	WRITE OUTPUT TAPE 6,1772,(ALPHAN(K),K=1,M1N)	005900
1772	FORMAT (7H0ALPHAN / (9E12.5))	005920
	WRITE OUTPUT TAPE 6,1773, AREAN	005940
1773	FORMAT (7H0AREAN / (9E12.5))	005960
	WRITE OUTPUT TAPE 6, 1774,(AN(K),K=1,M1N)	005980
1774	FORMAT (3H0AN / (9E12.5))	006000
	WRITE OUTPUT TAPE 6, 1776, (RHN(K),K=1,M1N)	006020
1776	FORMAT (5H0RHN / (9E12.5))	006040
	WRITE OUTPUT TAPE 6, 1777, (DN(K),K=1,M1N)	006060
1777	FORMAT (3H0DN / (9E12.5))	006080
1778	FORMAT (5H0Z3NX / (9E12.5))	006100
	WRITE OUTPUT TAPE 6, 1778,(Z3NX(K),K=1,M1N)	006120
	WRITE OUTPUT TAPE 6, 1779,(CNX(K),K=1,M1N)	006140
1779	FORMAT (4H0CNX / (9E12.5))	006160
	WRITE OUTPUT TAPE 6, 1791,(ARATIO(K), K= 1,M1N)	006180
1791	FORMAT(7H0ARATIO / (9E12.5))	006200
	WRITE OUTPUT TAPE 6, 1792,(EN(K),K= 1,M1N)	006220
1792	FORMAT(3H0EN / (9E12.5))	006240
	WRITE OUTPUT TAPE 6, 1793,(SFN(K), K=1,M1N)	006260
1793	FORMAT(4H0SFN / (9E12.5))	006280
	WRITE OUTPUT TAPE 6, 1794,(A1N(K),K =1,M1N)	006300
1794	FORMAT(4H0A1N / (9E12.5))	006320
	WRITE OUTPUT TAPE 6, 1780, (AK4(K),K=1,M1N)	006340
1780	FORMAT(4H0AK4 / (9E12.5))	006360
C		006380
C	BLOCK F READ REFLECTOR DATA	006400
C		006420
	WRITE OUTPUT TAPE 6,999	006440
999	FORMAT (//// 1H1 40X 17H-REFLECTOR INPUT-)	006460
C		006480
	M1R = MR-1	006500
	M2R = MR-2	006520
	WRITE OUTPUT TAPE 6,1008,(ALPHAR(I),I=1,NR)	006540
1008	FORMAT(7H0ALPHAR / (9E12.5 /))	006560
	WRITE OUTPUT TAPE 6,1009,(AREAR(I),I=1,NR)	006580
1009	FORMAT(6H0AREAR / (9E12.5 /))	006600
	WRITE OUTPUT TAPE 6,1010,(AR(I),I=1,NR)	006620
1010	FORMAT(3H0AR / (9E12.5 /))	006640

	WRITE OUTPUT TAPE 6,1011,((XKR(I),I=1,NR)	006660
1011	FORMAT(4H0XKR / (9E12.5 /))	006680
	WRITE OUTPUT TAPE 6,1012,((RHR(I),I=1,NR)	006700
1012	FORMAT(4H0RHR / (9E12.5 /))	006720
	WRITE OUTPUT TAPE 6,1013,((DR(I,L),I=1,NR),L=1,M1R)	006740
1013	FORMAT(3H0DR / (9E12.5 /))	006760
	WRITE OUTPUT TAPE 6,1014,((Z3R(I,K),I=1,NR),K=2,M1R)	006780
1014	FORMAT(4H0Z3R / (9E12.5 /))	006800
	WRITE OUTPUT TAPE 6,1015,((CR(I,K),I=1,NR),K=1,M1R)	006820
1015	FORMAT(3H0CR / (9E12.5 /))	006840
C		006860
C	BLOCK G READ SHIELD DATA	006880
C		006900
	WRITE OUTPUT TAPE 6,1016	006920
1016	FORMAT (//// 1H1 40X 14H-SHIELD INPUT-)	006940
C		006960
	M1S = MS - 1	006980
	M2S = MS - 2	007000
	WRITE OUTPUT TAPE 6,1017,((ALPHAS(I),I=1,NS)	007020
1017	FORMAT(7H0ALPHAS / (9E12.5 /))	007040
	WRITE OUTPUT TAPE 6,1018,((AREAS(I),I=1,NS)	007060
1018	FORMAT(6H0AREAS / (9E12.5 /))	007080
	WRITE OUTPUT TAPE 6,1019,((AS(I),I=1,NS)	007100
1019	FORMAT(3H0AS / (9E12.5 /))	007120
	WRITE OUTPUT TAPE 6,1020,((XKS(I),I=1,NS)	007140
1020	FORMAT(4H0XKS / (9E12.5 /))	007160
	WRITE OUTPUT TAPE 6,1021,((RHS(I),I=1,NS)	007180
1021	FORMAT(4H0RHS / (9E12.5 /))	007200
	WRITE OUTPUT TAPE 6,1022,((DS(I,L),I=1,NS),L=1,M1S)	007220
1022	FORMAT(3H0DS / (9E12.5 /))	007240
	WRITE OUTPUT TAPE 6,1023,((Z3S(I,K),I=1,NS),K=2,M1S)	007260
1023	FORMAT(4H0Z3S / (9E12.5 /))	007280
1024	FORMAT(3H0CS / (9E12.5 /))	007300
	WRITE OUTPUT TAPE 6,1024,((CS(I,K),I=1,NS),K=1,M1S)	007320
C		007340
C	BLOCK H READ CORE DATA	007360
C		007380
	WRITE OUTPUT TAPE 6,1025	007400
1025	FORMAT (//// 1H1 40X 12H-CORE INPUT-)	007420
C		007440
	M1C = MC - 1	007460
	M2C = MC - 2	007480
	WRITE OUTPUT TAPE 6,1026,((ALPHAC(I),I=1,NC)	007500
1026	FORMAT(7H0ALPHAC / (9E12.5 /))	007520
	WRITE OUTPUT TAPE 6,1027,((AREAC(I),I=1,NC)	007540
1027	FORMAT(6H0AREAC / (9E12.5 /))	007560
	WRITE OUTPUT TAPE 6,1028,((AC(I),I=1,NC)	007580
1028	FORMAT(3H0AC / (9E12.5 /))	007600
	WRITE OUTPUT TAPE 6,1029,((XKC(I),I=1,NC)	007620
1029	FORMAT(4H0XKC / (9E12.5 /))	007640
	WRITE OUTPUT TAPE 6,1030,((RHC(I),I=1,NC)	007660
1030	FORMAT(4H0RHC / (9E12.5 /))	007680
	WRITE OUTPUT TAPE 6,1031,((E(I),I=1,NC)	007700
1031	FORMAT(2H0E / (9E12.5 /))	007720
	WRITE OUTPUT TAPE 6,1032,((SF(I),I=1,NC)	007740
1032	FORMAT(3H0SF / (9E12.5 /))	007760


```

      WRITE OUTPUT TAPE 6,1033,((A1(I),I=1,NC)
1033  FORMAT( 3H0A1 / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1034,((DC(I,L),I=1,NC),L=1,M1C)
1034  FORMAT( 3H0DC / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1035,((Z3C(I,K),I=1,NC),K=2,M1C)
1035  FORMAT( 4H0Z3C / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1036,((CC(I,K),I=1,NC),K=1,M1C)
1036  FORMAT( 3H0CC / (9E12.5 /))
C
C      BLOCK I READ FULL POWER HEAT GENERATION DISTRIBUTION
C
      WRITE OUTPUT TAPE 6,1037
1037  FORMAT(55H1 FULL POWER HEAT GENERATION DISTRIBUTION INPUT)
      WRITE OUTPUT TAPE 6,1782,((FLUXN(K),K=1,M1N)
1782  FORMAT( //// 6H0FLUXN / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1038,((FLUXR(I,K),I=1,NR),K=1,M1R)
1038  FORMAT( //// 6H0FLUXR / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1039,((FLUXS(I,K),I=1,NS),K=1,M1S)
1039  FORMAT( //// 6H0FLUXS / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1040,((FLUXC(I,K),I=1,NC),K=1,M1C)
1040  FORMAT( //// 6H0FLUXC / (9E12.5 /))
C
C      BLOCK J READ INITIAL SOLID MATERIAL TEMPERATURES
      WRITE OUTPUT TAPE 6,1041
1041  FORMAT(1419X41HINITIAL SOLID MATERIAL TEMPERATURES INPUT)
C
      WRITE OUTPUT TAPE 6,1783,((TCZLRN(K),K=1,M1N)
1783  FORMAT( //// 7H0TCZLRN / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1042,((TCZLR(I,K),I=1,NR),K=1,M1R)
1042  FORMAT( //// 7H0TCZLR / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1043,((TCZLS(I,K),I=1,NS),K=1,M1S)
1043  FORMAT( //// 7H0TCZLS / (9E12.5 /))
      WRITE OUTPUT TAPE 6,1044,((TCZLC(I,K),I=1,NC),K=1,M1C)
1044  FORMAT( //// 7H0TCZLC / (9E12.5 /))
C
C      HEAT EXCHANGER INPUTS
C
      WRITE OUTPUT TAPE 6,1300
1300  FORMAT(////1H1 43X, 25H -HEAT EXCHANGER INPUT-)
      WRITE OUTPUT TAPE 6,1301, DH, AH, RHD, AHH, RHH, MH, IY
1301  FORMAT( /5X, 25H DH E16.3, 2X, 5H AH E16.8, 2X, 5H RHD E16.8, 2X, 5H AHH E16.8,
1, 2X, 5H RHH E16.3, 2X, 25H I4, 2, 5H I5 / )
      WRITE OUTPUT TAPE 6,1302, ((Z1(K),K=1,M2H)
      WRITE OUTPUT TAPE 6,1303, ((Z2(K),K=1,M1H)
      WRITE OUTPUT TAPE 6,1304, ((FL1(K),K=1,M1H)
      WRITE OUTPUT TAPE 6,1305, ((FL2(K),K=1,M1H)
1304  FORMAT( /5X, 15H FLUXH(K=1,M1H) 11X, 6(3X, E15.8))
1305  FORMAT( /5X, 16H THEZL(K=1,M1H) 11X, 6(3X, E15.8))
1306  FORMAT( /5X, 13H Z3HX(K=1,M2H) 11X, 6(3X, E15.8))
1307  FORMAT( /5X, 12H CHX(K=1,M1H) 11X, 6(3X, E15.8))
C
C      BLOCK K PUMP INPUTS
      WRITE OUTPUT TAPE 6,1370, PC1, PC2, PC3, PC4, PC5,
1370  FORMAT( /5X, 5H PC1 E16.3, 2X, 5H PC2 E16.3, 2X, 5H PC3 E16.3, 2X, 5H PC4 E16.3, 2X, 5H PC5 E16.3 / )
      WRITE OUTPUT TAPE 6,1371, CP1, CP2, CP3, CP4, CP5, XNSU, CT1,
1371  FORMAT( /5X, 5H CP1 E16.3, 2X, 5H CP2 E16.3, 2X, 5H CP3 E16.3, 2X, 5H CP4 E16.3, 2X, 5H CP5 E16.3, 2X, 5H XNSU E16.3, 2X, 5H CT1 E16.3 / )
      WRITE OUTPUT TAPE 6,1372, V1, V2, V3, V4, V5, V6, V7, V8, V9, V10, V11, V12, V13, V14, WYEDT, WYDST
1372  FORMAT( /5X, 14H V1 E16.3, 2X, 5H V2 E16.3, 2X, 5H V3 E16.3, 2X, 5H V4 E16.3, 2X, 5H V5 E16.3, 2X, 5H V6 E16.3, 2X, 5H V7 E16.3, 2X, 5H V8 E16.3, 2X, 5H V9 E16.3, 2X, 5H V10 E16.3, 2X, 5H V11 E16.3, 2X, 5H V12 E16.3, 2X, 5H V13 E16.3, 2X, 5H V14 E16.3, 2X, 5H WYEDT E16.3, 2X, 5H WYDST E16.3 / )

```

```

3,MH,M,WCON2
WRITE OUTPUT TAPE 6,1371,WYBPT,WYENT,YRN,P1,P2,P4,P5,P6,P7,P14.
1 PXC,{PDST(I),I=1,MH)
A(975)=5H0WDST
WRITE OUTPUT TAPE 6,1372,A(975) ,(WDST(I),I=1,MH)
A(975)=5H0PHST
WRITE OUTPUT TAPE 6,1372,A(975) ,(PHST(I),I=1,MH)
A(975)=5H0WHST
WRITE OUTPUT TAPE 6,1372,A(975) ,(WHST(I),I=1,MH)
1370 FORMAT (1H1,40X,18H-TURBO-PUMP INPUT- //6H PCQN1 E13.5,2X,5HPCON2
1 E13.5,2X,5HPCON3 E13.5 ,2X,5HPCON4 E13.5 /6H0WCON1 E13.5,2X,3HCT5
2 E13.5,2X, 6HAREADT E13.5,2X,6HAREADO E13.5 /5H0AHBP E13.5,2X,
3 4HRHBP E13.5,2X,5HDHBP E13.5,2X,6HAREATO E13.5 /4H0CP1 E13.5,2X,
4 3HCP2 E13.5,2X,3HCP3 E13.5,2X,3HCP4 E13.5 /4H0CPS E13.5,2X,4HXNSD
5 E13.5,2X,3HCT1 E13.5,2X,3HCT2 E13.5 /4H0CT3 E13.5,2X,3HCT4 E13.5
6 ,2X,4HAPD1 E13.5 / 6H0RHPD1 E13.5,2X,4HDPD1 E13.5 ,
7 2X,2HTZ E13.5,2X,2HPZ E13.5 / 3H0V4 E13.5,2X,2HV5 E13.5,2X,2HV6
8 E13.5,2X,2HV7 E13.5/4H0V10 E13.5,2X,3HV14 E13.5,2X,5HWYEDT E13.5
9,2X,5HWYDST E13.5,2X,2HMH I3,2X,1HM,I3 / 6H0WCON2 E13.5)
1371 FORMAT(6H0WYBPT E13.5,2X,5HWYENT E13.5,2X,3HYRN E13.5,2HP1 E13.5/
1 3H0P2 E13.5, 2X,2HP4 E13.5,2X,2HP5 E13.5/3H0P6 E13.5,
2 2X,2HP7 E13.5,2X,3HP14 E13.5,2X,3HPXC E13.5/5H0PDST/(8E13.5) )
1372 FORMAT (A6/(8E13.5))
C
C BLOCK K READ PRINTOUT FLAGS
C
C WRITE OUTPUT TAPE 6,1045
1045 FORMAT( 1H1 40X 15H PRINTOUT FLAGS )
C IF I1 IS NON-ZERO INTERMEDIATE VALUES ARE PRINTED FROM Y1, Y2, AND
C Y3.
C
C IF I2 IS NON-ZERO HEAT FLOW RATES AT THE END OF EACH MAJOR TIME STE
C P WILL BE PRINTED. TEMPERATURES, PRESSURES, AND MASS FLOW RATES A
C RE ALWAYS WRITTEN OUT AT THE END OF EACH MAJOR TIME STEP.
C
C IF I3 IS NON-ZERO INTERMEDIATE RESULTS FROM TEMPERATURE LOOP ARE P
C RINTED.
C
C IF I4 IS NON-ZERO INTERMEDIATE RESULTS FROM PRESSURE LOOP AGE PRIN
C TED.
C
C I5 IS OPEN FOR FURTHER USE
C
C IF I6 IS NON-ZERO ON LIVE COMMENTS (TEMPERATURE, PRESSURE, DELTA,
C PROBLEM.
C
C IF I7 IS NON-ZERO INTERMEDIATE VALUES OF QUANTITIES FOR CONVERGENT
C TESTS FOR TEMPERATURE, PRESSURE, AND THE OVERALL LOOP ARE PRINTED.
C
C IF I8 IS NON-ZERO FINAL VALUES OF QUANTITIES FOR CONVERGENT TESTS F
C OR TEMPERATURE, PRESSURE, AND THE OVERALL LOOP ARE PRINTED.
C
C WRITE OUTPUT TAPE 6,1046,I1,I2,I3,I4,I5,I6,I7,I8,ITEMI,IPI,ITI,
C FIRST PART WITH TPCV OPTION 11/30/64
C
C
C XITNI
1046 FORMAT( 3X, 3HI1= I1, 9X, 3HI2= I1, 9X, 3HI3= I1, 9X, 3HI4=,I1,

```

```

008900
008920
008940
008960
008980
009000
009020
009040
009060
009080
009100
009120
009140
009160
009180
009200
009220
009240
009260
009280
009300
009320
009340
009360
009380
009400
009420
009440
009460
009480
009500
009520
009540
009560
009580
009600
009620
009640
009660
009680
009700
009720
009740
009760
009780
009800
009820
009840
009860
009880
009900
009920
000000
000020
009940
009960

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```

19X, 3HI5= 11, 9X, 3HI6= 11, 9X, 3HI7= 11,
X          9X,          3HI8= 11./3X, 6HITEMI=
2 13, 8X, 4HIPI= 13, 8X, 4HITI= 13, 6X, 6HITNI= 13)

```

```

009980
010000
010020
010040

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C

```

      PPP = GAMMA / (GAMMA - 1.)
      PPP1= (GAMMA - 1.) / 2.
      PPP2= (GAMMA + 1.) / (GAMMA - 1.)
      PPP3= 2. / (GAMMA + 1.)
      DO 616 K=1,M1N
      ARATIN = ABSF ( A ATIO(K))
      XMACH = 1.0
      IF (ARATIO (K)-1.) 606,615,607
606  DELM = -.1
      GO TO 608
607  DELM = 1.0
608  XMACH = XMACH + DELM
      IF (XMACH - 0.5E-06) 609,609,610
609  XMACH = XMACH - DELM
      DELM = .1*DELM
      GO TO 608
610  TMPX = (PPP3 + XMACH*XMACH/PPP2)
      AX = (1./XMACH)*EXP(.5*PPP2*LOGEF (TMPX))
      IF (ABSF (AX-ARATIN)-.3E-03) 616,616,611
611  IF (AX-ARATIN) 612,616,614
613  IF (XMACH-.4E-06) 615,615,605
612  IF (XMACH-.1E+03) 613,613,615
614  XMACH = XMACH - DELM
      DELM = .5*DELM
      GO TO 608
615  WRITE OUTPUT TAPE 6,617
617  FORMAT (25H MACH NUMBER OUT OF RANGE ///)
620  GO TO 30
616  DDD(K) = XMACH*XMACH*PPP1

```

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010060
010080
010100
010120
010140
010160
010180
010200
010220
010240
010260
010280
010300
010320
010340
010360
010380
010400
010420
010440
010460
010480
010500
010520
010540
010560
010580
010600
010620
010640

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C

```

      FIG    = (4.0 / PI) ** 0. / DNT ** 1.8
      FPI    = (CP**0.4)*(XC**0.4) / XMU ** 0.4
      HCCAL=(0.023/(4.0*RHD)) * ((1.0*RHD/AHC)**0.8)
      HHCAL=(0.023/(4.0*RHH)) * ((1.0/(PI*RHH))**0.8)
      TERMH=DH*AHH/RHH
      TERMD=TERMH
      DO 604 K = 1, M1N
      HCCON(K)=(0.028/(4.0*RHN( ))) * (4.0*RHN(K)/AN(K))**0.8
      ARAT=ABSF(ARATIO(K))
      PULT=DN(K)*YKA*PI*DNT*SQ (F(ARAT)
      HHCUN(K)=AK4(K)*FIG*PULT/ XAT**0.9
604  PSIN(K) = SIGMA * EN(K) + JFN(K) * A1N(K)
      DO 601 I = 1,NR
601  PSIR(I) = -5.0E-30
      DO 602 I=1,NL
602  PSIG(I) = -5.0E-30

```

```

010660
010680
010700
010720
010740
010760
010780
010800
010820
010840
010860
010880
010900
010920
010940
010960
010980
011000
011020
011040
011060
011080

```

C

```

      DO 603 I=1,NC
603 PSIC(I) = SIGMA*E(I)*SF(I)*A1(I)
C
C      CHNDR = 0.0
      DO 400 I=1,NR
400 CHNDR = CHNDR + ALPHAR(I)
C
      CHNDS = 0.0
      DO 402 I=1,NS
402 CHNDS = CHNDS + ALPHAS(I)
C
      CHNDC = 0.0
      DO 1434 I=1,NC
1434 CHNDC = CHNDC + ALPHAC(I)
C
C
C
C      TIME = 0.0
C
C
C
C
C      INITIAL VALUES OF EXOGENOUS VARIABLES
C
C
C      IF(ISTEDY)500,500,501
500 TXC = ORDTC(1)*TCF
      PXC = ORDPC(1)*PCF
      PA = ORDPA(1) * PAF
      H2=ORDH2(1)*H2F
      TPCV=ORDTCV(1)
      IF(IPOW)13059,13059,13058
13058 POWER = ORDPOW(1)
13059 GO TO 502
501 TXC=TCF
      PXC=PCF
      PA=PAF
      H2=H2F
      TPCV=TPCVX
C
C
C
C
C      INITIAL SOLID MATERIAL TEMPERATURES
C
C
C
C
502 MATN=XKKKF(XMATN)
      NSTAT=494
      DO 494 K=1,M1N
      CALL R_ADKM (TCZERN(K),MATN,HSOLN(K),NK)

```

```

011100
011120
011140
011160
011180
011200
011220
011240
011260
011280
011300
011320
011340
011360
011380
011400
011420
011440
011460
011480
011500
011520
011540
011560
011580
011600
011620
011640
011660
011680
011700
011720
011740
011760
011780
011800
011820
011840
011860
011880
011900
011920
011940
011960
011980
012000
012020
012040
012060
012080
012100
012120
012140
012160
012180
012200

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```

      IF(NK)494,494,11999
494  TCN(K) = TCZERN(K)
      NOSTAT=490
      DO 490 I=1,NR
      MATR(I)=XKKKF(XMATR(I))
      MATSR(I)=XKKKF(SMATR(I))
      DO 490 K=1,M1R
      CALL READKM (TCZERR(I,K),MATSR(I),HSOLR(I,K),NK)
      IF(NK)490,490,11999
490  TCR(I,K) = TCZERR(I,K)
      NOSTAT=491
      DO 491 I=1,NS
      MATS(I)=XKKKF(XMATS(I))
      MATSS(I)=XKKKF(SMATS(I))
      DO 491 K=1,M1S
      CALL READKM (TCZERS(I,K),MATSS(I),HSOLS(I,K),NK)
      IF(NK)491,491,11999
491  TCS(I,K) = TCZERS(I,K)
      NOSTAT=492
      DO 492 I=1,NC
      MATC(I)=XKKKF(XMATC(I))
      MATSC(I)=XKKKF(SMATC(I))
      DO 492 K=1,M1C
      CALL READKM (TCZERC(I,K),MATSC(I),HSOLC(I,K),NK)
      IF(NK)492,492,11999
492  TCC(I,K) = TCZERC(I,K)
      MATH=XKKKF(XMATH)
      NOSTAT=1321
      IF(IPOW)13061,13061,13062
13062 IF(ISTEDY)13060,13060,13061
13060 TXC=TCG
      TXC1=TCC(1,M1C)
13061 IF(PTPCV)14020,14020,14040
14040 IF(ISTEDY)14050,14050,14020
14050 PXC=PCG
      PXC1=0.7*PCG
14020 CONTINUE
      DO 1321 K=1,M1H
      CALL READKM (THEZER(K),MATH,HSOLH(K),NK)
      IF(NK)1321,1321,11999
1321 THE(K)=THEZER(K)
C
C
C
C
C
C      OUTPUT INITIAL SOLID MATERIALS TEMPERATURES
C
C      WRITE OUTPUT TAPE 6,1784
1784 FORMAT ( 23H11INITIAL NOZZLE TEMPERATURES ///)
      DO 1785 K=1,M1N
1785 WRITE OUTPUT TAPE 6,1785,K,TCN(K)
1786 F10.1) (12X 5H NOZZLE NO. 13, 5H TCN = F10.1)
C

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012220
012240
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012300
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012400
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012500
012520
012540
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012800
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013000
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013100
013120
013140
013160
013180
013200
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013280
013300
013320

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	WRITE OUTPUT TAPE 6,1101	013340
1101	FORMAT(31H1INITIAL REFLECTOR TEMPERATURES///)	013360
	DO 495 I = 1,NR	013380
	WRITE OUTPUT TAPE 6,14,I	013400
	DO 495 K = 1,M1R	013420
495	WRITE OUTPUT TAPE 6,4,K,TCR (I,K)	013440
	WRITE OUTPUT TAPE 6,1102	013460
1102	FORMAT(28H1INITIAL SHIELD TEMPERATURES///)	013480
	DO 496 I = 1,NS	013500
	WRITE OUTPUT TAPE 6,14,I	013520
	DO 496 K = 1,M1S	013540
496	WRITE OUTPUT TAPE 6,5,K,TCS (I,K)	013560
	WRITE OUTPUT TAPE 6,1103	013580
1103	FORMAT(27H1 INITIAL CORE TEMPERATURES///)	013600
	DO 497 I = 1,NC	013620
	WRITE OUTPUT TAPE 6,14,I	013640
	DO 497 K = 1,M1C	013660
497	WRITE OUTPUT TAPE 6,6,K,TCC (I,K)	013680
		013700
		013720
		013740
		013760
	INITIAL FLUID TEMPERATURES	013780
		013800
		013820
		013840
	DO 1322 K=1,M1H	013860
	THC(K)=THE(K)	013880
1322	THH(K)=THE(K)	013900
	THC(MH)=THE(M1H)	013920
	THH(MH)=THE(M1H)	013940
		013960
	DO 300 K = 1,M1N	013980
300	TN(K) = TCZERN(K)	014000
	TN(MN)= TCZERN(M1N)	014020
	T5 = TN(MN)	014040
	DO 302 I=1,NR	014060
	DO 301 K=1,M1R	014080
301	TR(I,K) = TCZERR(I,K)	014100
302	TR(I,MR) = TCZERR(I,M1R)	014120
	T6 = TR(NR,MR)	014140
	DO 304 I=1,NS	014160
	DO 303 K=1,M1S	014180
303	TS(I,K) = TCZERS(I,K)	014200
304	TS(I,MS) = TCZERS(I,M1S)	014220
	T7 = TS(NS,MS)	014240
	DO 306 I=1,NC	014260
	DO 305 K=1,M1C	014280
305	TC(I,K) = TCZERC(I,K)	014300
306	TC(I,MC) = TCZERC(I,M1C)	014320
	T10 = TC(NC,MC)	014340
	T14=5.0*T6	014360
	T16=T6	014380
	T17=T14	014400
	T17P5=T14	014420
	T18=T14	014440

C
C
C
C
C
C
C

T19=4.5*T6

INITIAL PRESSURE GUESSES

P2=1.63*PXC
 P4=1.62*PXC
 P5=1.33*PXC
 P6=1.2555*PXC
 P7=1.25*PXC
 P14=0.99*PXC
 P1=PZ

EM1N=M1N

EM1R=M1R

EM1S=M1S

EM1C=M1C

P10=PXC

DELP=(P7-P10)/EM1C

DO 1505 I=1,NC

PC(I,1)=P7

PC(I,MC)=P10

NOSTAT=10000

CALL PARAH (DAT,P7,1,TC(I,1),6,NK)

IF(NK)99999,10000,99999

10000 QUALC(I,1)=DAT(5)

HHC(I,1)=DAT(3)

PC(I,MC)=P10

NOSTAT=10001

CALL PARAH (DAT,P10,1,TC(I,MC),6,NK)

IF(NK)99999,10001,99999

10001 QUALC(I,MC)=DAT(5)

1505 HHC(I,MC)=DAT(3)

NOSTAT=10002

DO 505 K=2,M1C

XXK=K-1

PRE=P7 - DELP*XXK

DO 505 I=1,NC

PC(I,K)=PRE

CALL PARAH (DAT,PRE,1,TC(I,K),6,NK)

IF(NK)99999,10002,99999

10002 QUALC(I,K)=DAT(5)

505 HHC(I,K)=DAT(3)

DELP=(P6-P7)/EM1S

DO 1506 I=1,NS

PS(I,MS)=P7

PS(I,1)=P6

NOSTAT=10003

CALL PARAH (DAT,P6,1,TS(I,1),6,NK)

IF(NK)99999,10003,99999

10003 QUALS(I,1)=DAT(5)

HHS(I,1)=DAT(3)

NOSTAT=10004

CALL PARAH (DAT,P7,1,TS(I,MS),6,NK)

014460

014480

014500

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014580

014600

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015000

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015080

015100

015120

015140

015160

015180

015200

015220

015240

015260

015280

015300

015320

015340

015360

015380

015400

015420

015440

015460

015480

015500

015520

015540

015560

	IF(NK)99999,10004,99999	015580
10004	QUALS(I,MS)=DAT(5)	015600
1506	HHS(I,MS)=DAT(3)	015620
	NOSTAT=10005	015640
	DO 506 K=2,M1S	015660
	XXK=K-1	015680
	PRE=P6 - DELP*XXK	015700
	DO 506 I=1,NS	015720
	PS(I,K)=PRE	015740
	CALL PARAH (DAT,PRE,1,TS(I,K),6,NK)	015760
	IF(NK)99999,10005,99999	015780
10005	QUALS(I,K)=DAT(5)	015800
506	HHS(I,K)=DAT(3)	015820
	DELP=(P5-P6)/EM1R	015840
	DO 1507 I=1,NR	015860
	PR(I,MR)=P6	015880
	PR(I,1)=P5	015900
	NOSTAT=10006	015920
	CALL PARAH(DAT,P5,1,TR(I,1),6,NK)	015940
	IF(NK)99999,10006,99999	015960
10006	QUALR(I,1)=DAT(5)	015980
	HHR(I,1)=DAT(3)	016000
	NOSTAT=10007	016020
	CALL PARAH(DAT,P6,1,TR(I,MR),6,NK)	016040
	IF(NK)99999,10007,99999	016060
10007	QUALR(I,MR)=DAT(5)	016080
1507	HHR(I,MR)=DAT(3)	016100
	NOSTAT=10008	016120
	DO 507 K=2,M1R	016140
	XXK=K-1	016160
	PRE=P5-DELP*XXK	016180
	DO 507 I=1,NR	016200
	PR(I,K)=PRE	016220
	CALL PARAH(DAT,PRE,1,TR(I,K),6,NK)	016240
	IF(NK)99999,10008,99999	016260
10008	QUALR(I,K)=DAT(5)	016280
507	HHR(I,K)=DAT(3)	016300
	DELP=(P4-P5)/EM1N	016320
	PN(1)=P4	016340
	PN(MN)=P5	016360
	NOSTAT=10009	016380
	CALL PARAH(DAT,P4,1,TN(1),6,NK)	016400
	IF(NK)99999,10009,99999	016420
10009	QUALN(1)=DAT(5)	016440
	HHN(1)=DAT(3)	016460
	NOSTAT=10010	016480
	CALL PARAH(DAT,P5,1,TN(MN),6,NK)	016500
	IF(NK)99999,10010,99999	016520
10010	QUALN(MN)=DAT(5)	016540
	HHN(MN)=DAT(3)	016560
	NOSTAT=10011	016580
	DO 508 K=2,M1N	016600
	XXK=K-1	016620
	PN(K)=P4 - DELP*XXK	016640
	CALL PARAH (DAT,PN(K),1,TN(K),6,NK)	016660
	IF(NK)99999,10011,99999	016680

10011	QUALN(K)=DAT(5)	016700
508	HHN(K)=DAT(3)	016720
	P14=PXC-1.0	016740
	PDST(1)= PXC*1.2	016760
	DO 1350 K=1,MH	016780
	PHST(K)=P14	016800
	NOSTAT=10012	016820
	CALL PARAH(DAT,P14,1,THH(K),6,NK)	016840
	IF(NK)99999,10012,99999	016860
10012	QUALHT(K)=DAT(5)	016880
	HHHT(K)=DAT(3)	016900
	NOSTAT=10013	016920
	CALL PARAH(DAT,PDST(1),1,THC(K),6,NK)	016940
	IF(NK)99999,10014,99999	016960
10014	QUALHD(K)=DAT(5)	016980
	HHHD(K)=DAT(3)	017000
1350	PDST(K)=PDST(1)	017020
	NOSTAT=10015	017040
	CALL PARAH (DAT,PZ,1,TZ,6,NK)	017060
	IF(NK)99999,10015,99999	017080
10015	H1=DAT(3)	017100
	DIFP=P14-PA	017120
C		017140
C	SUM OF PCUN1 THRU PCUN4 MUST BE LESS THAN 1.0	017160
C		017180
	P17=PCUN1*DIFP + PA	017200
	P17P5=PCUN2*DIFP + PA	017220
	P18=PCUN3*DIFP + PA	017240
	P19=PCUN4*DIFP + PA	017260
	M1H=MH-1	017280
	M2H=MH-2	017300
C		017320
	LOCK=0	017340
C		017360
	CALL CHAIN (2,4)	017380
C		017400
C		017420
99999	OUT=5HFIRST	017440
	WRITE OUTPUT TAPE6,99998,OUT,NOSTAT, (DAT(I),I=1,10)	017460
	GO TO 30	017480
11999	WRITE OUTPUT TAPE 6,11998,NOSTAT,I,K	017500
	GO TO 30	017520
11998	FORMAT (20H- SECOND-NOSTAT IS 17,1HI 15,1HK 15)	017540
99998	FORMAT (/14H- ROUTINE ,A6,29H, BAD PRPTY LOOKUP. NOSTAT= 18	017560
	1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)	017580
	END	017600

CHAIN 2 (WITHOUT NOZZLE JACKET)

SECOND PART WITH TPCV OPTION 3/21/65

ARITH. EXPRES- USED IN TURBO-PUMP TO COMPUTE DENSITY
 $\text{RHOFF}(T,P)=P/(\text{XMUL}*T)$

ARITHMETIC EXPRES. USED IN TURBO-PUMP TO COMPUTE FLOW STORAGES
 $\text{CWFF}(V,R,\text{RO},P,\text{PO})=V*(R-\text{RO})/(\text{DELTA}*(P-\text{PO}))$

ARITH. EXPRES. TO FIX FLOATING NUMBERS
 $\text{XKKKF}(X)=X + 1.0\text{E}-05 *X$

$\text{DIMENSION A}(2700), \text{TITLE}(12), \text{HD}(10), \text{HH}(10), \text{DAT}(10)$

EQUIVALENCE INPUTS TO Y ROUTINES TO PRESERVE ORDER OF COMMON

EQUIVALENCE (GAMMA,DUM1), (XMW,DUM2), (C1,DUM3), (C2,DUM4),
 1 (CRIT,DUM0), (ITRNO,IDUM1), (LOCK,IDUM2), (LATCH,IDUM3), (I1,
 1 IDUM0), (I1,
 2 IDUM4), (I2,IDUM5), (I3,IDUM6), (I4,IDUM7), (I5,IDUM8), (SIGMA,
 3 DUM5), (DIV,DUM6), (SMALL,DUM7), (VAL1,DUM8), (COEFF,DUM9),
 4 (TOLER,DUM10), (DELTA,DUM11), (PI,DUM12), (GC,DUM13), (R,DUM14),
 5 (CJ,DUM15), (TWALL,DUM16), (TIME,DUM17)

INPUT VALUES

EQUIVALENCE (A(1),TAU), (A(2),CDELTA), (A(4),YOUTN),
 1 (A(5),CCOEFF), (A(6),PCF), (A(7),TCF), (A(8),H2F), (A(9),PAF), (A(1
 20),POWER), (A(11),ORDH2(1)), (A(62),ORDTC(1)), (A(113),ORDPC), (A(
 3164),ORDPA), (A(215),CGAMMA), (A(216),CXMW), (A(217),TPCVX),
 4 (A(218),PTPCV), (A(220),DNT), (A(221),CTWALL), (A(222),XKN), (A
 5(223),ALPHAN(1)), (A(243),AREAN(1)), (A(263),AN(1)), (A(283),RHN(1
 6)), (A(303),DN(1)), (A(323),Z3NX), (A(343),CNX), (A(363),ARATI
 70(1)), (A(383),EN(1)), (A(403),SFN(1)), (A(423),AIN(1)), (A(443),A
 8K4(1)), (A(463),ALPHAR(1)), (A(473),AREAR(1)), (A(483),AR(1)), (A(4
 993),XKR(1)), (A(503),RHR(1)), (A(523),DR(1)), (A(623),Z3R(1))
 EQUIVALENCE (A(723),CR(1)), (A(823),ALPHAS(1)), (A(833),AREAS(1)
 1), (A(843),AS(1)), (A(853),XKS(1)), (A(863),RHS(1)), (A(873),DS(1)
 2), (A(973),Z3S(1)), (A(1073),CS(1)), (A(1173),ALPHAC(1)), (A
 3(1183),AREAC(1)), (A(1193),AC(1)), (A(1203),XKC(1)), (A(1213),RHC(
 41)), (A(1223),E(1)), (A(1233),SF(1)), (A(1243),AI(1)), (A(1253),DC
 5(1)), (A(1353),Z3C(1)), (A(1453),CC(1)), (A(1553),FLUXN(1)),
 6 (A(1573),FLUXR(1)), (A(1673),FLUXS(1)), (A(1773),FLUXC(1)),
 7 (A(1873),TCZERN(1)), (A(1893),TCZERR(1)), (A(1993),TCZERS(1))
 8, (A(2093),TCZERC(1)), (A(2193),TMAX)

EQUIVALENCE (A(2194),COEFS), (A(2195),COEFR), (A(2196),COEFC)
 2, (A(2197),HMAX), (A(2198),TRNO), (A(2199),TURBM), (A(2200),
 3 THKTD), (A(2201),THIK), (A(2221),ORDPOW), (A(2272),XIPOW)

TURBO-PUMP AND HEAT EXCHANGER INPUTS

EQUIVALENCE (A(2293),PCON1), (A(2294),PCON2), (A(2295),PCON3),
 1 (A(2296),PCON4), (A(2297),WCON1), (A(2298),WCON2), (A(2299),DH),
 2 (A(2300),AHC), (A(2301),RHD), (A(2302),AHH), (A(2303),RHH),
 2 (A(2304),Z3HX), (A(2314),CHX), (A(2324),FLUXH), (A(2334),THEZER),
 3 (A(2345),AREADT), (A(2346),AREADO), (A(2347),AHBP), (A(2348),

4 RHBP), (A(2349),DHBP), (A(2350),AREATO), (A(2351),CBPT), (A(2352),
5 ,CP1), (A(2353),CP2), (A(2354),CP3), (A(2355),CP4), (A(2356),
6 CPS), (A(2357),XNSS), (A(2358),CT1), (A(2359),CT2), (A(2360),
7 CT3), (A(2361),CT4), (A(2362),CT5), (A(2363),APD1), (A(2364),
8 RHPD1), (A(2365),DPD1), (A(2366),TZ), (A(2367),PZ), (A(2368),V4)

EQUIVALENCE (A(2369),V5), (A(2370),V6), (A(2371),V7), (A(2372),
1 V10), (A(2373),V14), (A(2374),WYEDT), (A(2375),WYDST), (A(2376),
2 WYBPT), (A(2377),WYENT), (A(2378),YRN), (A(2379),P1), (A(2380),
3 P2), (A(2381),XIR), (A(2382),P4), (A(2383),P5), (A(2384),P6),
4 (A(2385),P7), (A(2386),P14), (A(2387),C19), (A(2388),PDST(1)),
5 (A(2398),WDST(1)), (A(2408),PHST(1)), (A(2418),WHST(1))
6 , (A(2428),TXCTOL), (A(2429),PXCTOL), (A(2430),T18TOL), (A(2431),
7 TTOLER), (A(2432),PTOLER), (A(2433),COHEX), (A(2434),COTUR)
8 , (A(2435),YKA), (A(2436),T9S), (A(2437),T9R), (A(2438),T9C)
9 , (A(2439),POWTOL), (A(2440),ORDTCV)
EQUIVALENCE (A(2492),TCG), (A(2493),PCG), (A(2494),TXCLIM),
1 (A(2495),PXCLIM)

FIXED POINT INPUTS

EQUIVALENCE (A(2500),XLIMIT), (A(2501),XMINOR), (A(2502),XI1), (A
1 (2503),XI2), (A(2504),XI3), (A(2505),XI4), (A(2506),XI5), (A(2507)
2 ,XI6), (A(2508),XI7), (A(2509),XI8), (A(2510),XITEM1), (A(2511),XIP
3 I), (A(2512),XITI), (A(2513),XITNI), (A(2514),EMN), (A(2515),EMR)
4 , (A(2516),EMS), (A(2517),EMC), (A(2518),XMH), (A(2519),XM)
5 , (A(2520),XNR), (A(2521),FNS), (A(2522),XNC), (A(2523),XNN)
6 , (A(2524),XSTY), (A(2525),XMKN), (A(2526),XMKTD)
7 , (A(2527),XMATN), (A(2528),XMATR), (A(2533),XMATS), (A(2538),
8 XMATC), (A(2543),XMATH), (A(2544),SMATR), (A(2549),SMATS),
9 (A(2554),SMATC), (A(2559),XINRX)
EQUIVALENCE (A(2492),TCG), (A(2493),PCG), (A(2494),TXCLIM),
1 (A(2495),PXCLIM)
2 , (A(2642),DRNT), (A(2643),XPRATR), (A(2644),XPRATM), (A(2645),EFFMN),
3 (A(2646),EFFRN), (A(2647),CT5RAT)

DIMENSION THC(11),THE(11),THH(11),Z3H(10),CH(10),THEO(10),
1 FLUXH(10),THEZER(10),PDST(10),WDST(10),PHST(10),WHST(10),Z2(20),
1 YDST(10),YHST(10),Z4(20)
DIMENSION Q1H(10),Q2H(10),Q3H(10),SH(10),QH(10)

COMMON GAMMA,XMW,C1,C2,CRIT,ITRND,LOCK,LATCH,II,I1,I2,I3,I4,I5,SI
1 GMA,DIV,SMALL,VAL1,COEFF,TOLER, DELTA,PI,GC,R,CJ,TWALL,TIME,A
2 ,LIMIT,MINOR,I6,I7,I8,ITEM1,IPI,ITI,ITNI,MH,M,MN,MC,MS,MR,NN,NS,
3 NR,NC,M1H,M2H,MAJOR,M1N,M2N,M1R,M2R,M1S,M2S,M1C,M2C,DDD,FIG,FPI,
4 HCCAL,HHCAL,HCCON,HHCON,PSIN,PSIR,PSIS,PSIC,CHNOR,CHNDS,CHNOC,T2
5 ,TXC,PXC,PA,TCN,TCR,TCS,TCC,THE,THC,THH,TN,T5,TR,T6,TS,T7,TC,
6 T10,T14,T16,T17,T17P5,T18,T19,EM1N,EM1R,EM1S,EM1C,P10,PC,PS,PR,
7 PN,P17,P17P5,P18,P19,TERMH,TERMD,MAJOR,ANT,IDUMP,ISTEDY,PPP,
8 RECDV,T4,XMUL,XNSD,QUALN,HHN,QUALR,HHR,QUALS,HHS,QUALC,HHC,
9 QUALHT,HHHT,QUALHD,HHHD,H1,TXC,H2,TPCV,PXC1

COMMON MATN,MATR,MAT, MATC,MATH HSOLN,HSOLS,HSOLR,HSOLC,HSOLH
1 ,MATSR,MATSS,MATSC
DIMENSION HOSOLN(20),HOSOLS(5,10),HOSOLR(5,10),HOSOLC(5,10)

```

1 ,HSOLN(20),HSOLR(5,10),HSOLS(5,10),HSOLC(5,10),HSOLH(20)
2 ,HOSOLH(20),CNX(20),Z3NX(20),CHX(10),Z3HX(10)
3 ,XMATR(5),MATR(5),XMATS(5),MATS(5),XMATC(5),MATC(5)
4 ,SMATR(5),SMATS(5),SMATC(5),MATSR(5),MATSS(5),MATSC(5)

```

C

```

    DIMENSION ORDH2(51), ORDTC(51), ORDPC(51), ORDPA(51),ORDPOW(51)
    DIMENSION ALPHAR(10),AREAR(10),AR(10),XKR(10),RHR(10),DR(10,10),Z3
1R(10,10),CR(10,10),PSIR(10),ORDTCV(51)
    DIMENSION ALPHAS(10),AREAS(10),AS(10),XKS(10),RHS(10),DS(10,10),Z3
1S(10,10),CS(10,10),PSIS(10)
    DIMENSION ALPHAC(10),AREAC(10),AC(10),XKC(10),RHC(10),DC(10,10),Z3
1C(10,10),CC(10,10),PSIC(10)
    DIMENSION QR(10,10),WR(10),WYER(10),PR(10,10),TCR(10,10),TCOR(10,1
10),TR(10,10),Q3R(10,10),SR(10,10)
    DIMENSION FLUXR(10,10),FLUXS(10,10),FLUXC(10,10)
    DIMENSION TCZERR(10,10),TCZERS(10,10),TCZERC(10,10)
    DIMENSION E(10),SF(10),A1(10),PSI(10),Y(10)
    DIMENSION QS(10,10),WS(10),WYES(10),PS(10,10),TCS(10,10),TCDS(10,1
10),TS(10,10),Q3S(10,10),SS(10,10)
    DIMENSION QC(10,10),WC(10),WYEC(10),PC(10,10),TCC(10,10),TCDC(10,1
10),TC(10,10),Q3C(10,10),SC(10,10)
    DIMENSION YINR(10),YOUTR(10),YR(10,10)
    DIMENSION YINS(10),YOUTS(10),YS(10,10)
    DIMENSION YINC(10),YOUTC(10),YC(10,10)
    DIMENSION ALPHAN(20),AN(20),RHN(20),DN(20),Z3N(20),CN(20),
1 WN(20),THETA(20),TN(20),TCN(20),H(20),BETA(20),Z1N(20),Z2N(20),Z
24N(20),PSIN(20),Z5N(20),RELAX(20),Q1N(20),Q2N(20),Q3N(20),Q4N(20),
3Q5N(20),TAR(20),SN(20),TCN(20),QN(20),ERROR(20),FLUXN(20),TCZERN(
420),EN(20),SFN(20),AIN(20),YN(20),PN(20),ARATIO(20),
5TBB(20),PHX(20),DDD(20)
    DIMENSION HCCQN(20),HHCON(20),AK4(20),TEK(20)
1 ,QUALN(20),HHN(20),QUALR(5,10),HHR(5,10),QUALS(5,10),HHS(5,10),
2 QUALC(5,10),HHC(5,10),QUALHT(5,10),HHHT(5,10),QUALHD(5,10),
3 HHHD(5,10),THIK(20),CP(20)
671 FORMAT(///// 28H NOZZLE NODE MASS FLOW RATES ///)
673 FORMAT(/////26H NOZZLE CHANNEL PRESSURES ///)
674 FORMAT(23X,9H P4 = F10.1/23X, 9H P5 = F10.1//)
676 FORMAT(11X10H NODE NO. 13,5X 6H PN = F10.1)

```

SLOPES OF EXOGENOUS VARIABLES FOR NEXT MAJOR TIME INTERVAL, TAU

CALL TAB1H ONLY ONCE

IF(LOCK-5)13080,13081,13080

13080 CALL TAB1H

13081 LOCK=5

C

REWIND 4

C***** ***** ERASEABLE PLOT TAPE FOR CHAIN(3,4)

REWIND 22

CALL SETDEN(22,1)

KSET=0

ITFLAH=0

LIST = 1

ITURB=1

N25=A(3)

PLOT *
PLOT *
PLOT *

```

P2TOL=0.1*PXCTOL
IHMAX=XKKKF(HMAX)
ITMAX=XKKKF(TURBM)
MKN=XKKKF(XMKN)
MKTD=XKKKF(XMKTD)
IPOW=XKKKF(XIPOW)
INRX=XKKKF(XINRX)
XNS=XNSS
NCAV=0
T10SAV=0.0
POWSAV=0.0

```

```

C
510  LIST = LIST + 1
C
    IF(ISTEDY)404,404,406
404  SLOPTC = (ORDTC(LIST) - ORDTC(LIST-1)) / TAU
      SLOPPC = (ORDPC(LIST) - ORDPC(LIST-1)) / TAU
      SLOPPA = (ORDPA(LIST) - ORDPA(LIST-1)) / TAU
      SLOPH2=(ORDH2(LIST) - ORDH2(LIST-1)) / TAU
      IF(IPOW)13063,13063,13062
13062 SLOPPQ=(ORDPOW(LIST)-ORDPOW(LIST-1))/ TAU
13063 SLOPTV=(ORDTCV(LIST)-ORDTCV(LIST-1))/TAU
C
406  II=0
C
515  II = II + 1
      POWSAV=0.0
      T10SAV=0.0
      ITRND = 0
      LATCH = 1
      PPOWT=4H*NO*
C
    IF(IPOW)13407,13407,13405
13405 IF(TXC-TXCLIM)13407,13406,13406
13406 IPOW=-1
13407 IF(PTPCV)13410,13410,13408
13408 IF(PXC-PXCLIM)13410,13409,13409
13409 PTPCV=-1.0
13410 CONTINUE
C
C
C  START OF CALCULATION LOOP FOR TIME INTERVAL, DELTA
C
C
C
C
12357 JJ      = 0
      JJ      = JJ + 1
C
    IF(ISTEDY)411,411,410
410  DELTA=1.0E+21
C  POWER=POWER
411  TIME=TIME + DELTA
C
      ITIME = 0
C
C  SOLID MATERIAL TEMPERATURES AT PREVIOUS TIME INTERVAL

```

*
*

C
 DO1504 K = 1, MIN
 HOSOLN(K)=HSOLN(K)
 1504 TCON(K) = TCN(K)
 DO 500 I=1,NR
 DO 500 K=1,M1R
 HOSOLR(I,K)=HSOLR(I,K)
 500 TCR(I,K) = TCR(I,K)
 DO 501 I=1,NS
 DO 501 K=1,M1S
 HOSOLS(I,K)=HSOLS(I,K)
 501 TCS(I,K) = TCS(I,K)
 DO 502 I=1,NC
 DO 502 K=1,M1C
 HOSOLC(I,K)=HSOLC(I,K)
 502 TCC(I,K) = TCC(I,K)
 DO 1323 K=1,M1H
 HOSOLH(K)=HSOLH(K)
 1323 THEO(K)=THE(K)
 P10=P1
 P20=P2
 P40=P4
 P50=P5
 P60=P6
 P70=P7
 P100=P10
 P140=P14
 PXC0=PXC
 XNS0=XNS
 NOSTAT=10003
 10003 CALL PARAH (DAT,P5,1,HHR(1,1),3,K)
 IF(K)99999,10004,99999
 10004 RH050=DAT(7)
 NOSTAT=10005
 10005 CALL PARAH (DAT,P6,1,HHS(1,1),3,K)
 IF(K)99999,10006,99999
 10006 RH060=DAT(7)
 NOSTAT=10007
 10007 CALL PARAH (DAT,P7,1,HHC(1,1),3,K)
 IF(K)99999,10008,99999
 10008 RH070=DAT(7)
 NOSTAT=10009
 10009 CALL PARAH (DAT,P10,1,T10,6,K)
 IF(K)99999,10010,99999
 10010 RH0100=DAT(7)
 IF(INRX)10011,10011,13114
 10011 NOSTAT=10011
 CALL PARAH (DAT,P14,1,HHHT(1),3,K)
 IF(K)99999,10012,99999
 10012 RH0140=DAT(7)
 C
 TXCD=TXC
 PXCD=PXC
 C
 C
 C VALUES OF EXOGENOUS VARIABLES FOR TIME INTERVAL, DELTA

```

      H2=H1 + POWP/(W2*9338.0)
13114 IF(ISTEDY)415,415,416
      415 TXC=TXC + SLOPTC * DELTA * TCF
        PXC = PXC + SLOPPC * DELTA * PCF
        PA = PA + SLOPPA * DELTA * PAF
        IF(INRX)13100,13100,13113
13113 H2=H2 + SLOPH2*DELTA*H2F
13100 IF(IPOW)13065,13065,13064
13064 POWER = POWER + SLOPPD*DELTA
        IF(LIST +II -3)13400,13400,13072
13400 TXC=TXCD
        GO TO 13065
13072 TXC=2.0*TXCD-TXC1
        TXC1 =(TXC+TXC1)/2.0
13065 IF(PTPCV)416,416,14100
14100 TPCV=TPCV + SLOPTV * DELTA
        IF(LIST +II -3)13401,13401,14130
13401 PXC=PXCD
        GO TO 416
14130 PXC=2.0*PXCD-PXC1
        PXC1=(PXC + PXC1)*0.5
C
      416 NOSTAT=10034
        CALL PARAH (DAT,P2,1,H2,3,NK)
        IF(NK)99999,10034,99999
10034 T2=DAT(6)
        T4 = T2
        HHN(1)=H2
        NOSTAT=10001
10001 CALL PARAH (DAT,P4,1,H2,3,K)
        IF(K)99999,10002,99999
10002 RHD40=DAT(7)
C
        NOSTAT=10027
        CALL PARAH (DAT,PXC,1,TXC,6,NK)
        IF(NK)99999,10027,99999
10027 HHXC=DAT(3)
C
        DD 516 K = 1, MIN
        TBB(K) = TXC/(( 1.0 + DDD(K)))
        TAR(K)=TBB(K)*((1.0+RECOV*DDD(K)) )
      516 PHX(K) = PXC/((( 1.0 + DDD(K))**PPP)
C
C
C
      IITRND = 0
C
C
C
      CALCULATE NOZZLE MASS FLOWRATE
C
      WYENT=Y1(ANT,TXC,TXC,PA,PXC)
C
      W40=W4
      W130=W13
      W150=W15

```

```

WDOT0=WDOT
WDOT=WYENT*(PXC - PA)
DIV2=PXC/P10
P2=DIV2*P2
P4=DIV2*P4
P5=DIV2*P5
P6=DIV2*P6
P7=DIV2*P7
P10=PXC
P14=DIV2*P14
P17=DIV2*P17
P17P5=DIV2*P17P5
P18=DIV2*P18
P19=DIV2*P19
IF(KSET)1355,1355,1356
1355 W13=WCON1 * WDOT
      W7=WDOT + W13
      W6=W7
      W15=WCON2 * W6
      W5=W6 + W15
      W4=W5
      W2=W4
      W1=W2
      W18=W15 + W13
      KSET=1
      DO 13333 K=1,MN
1444  WN(K)=W4/ALPHAN(K)
13333 PN(K) = PN(K) * DIV2
      J = 0
13332 J = J + 1
      WR(J) = W5 / CHNOR
      DO 13334 K=1,MR
13334 PR(J,K)= PR(J,K) * DIV2
      IF (J-NR) 13332,13336,13336
13336 J = 0
13337 J = J + 1
      WS(J) = W6 / CHNOS
      DO 13335 K= 1,MS
13335 PS(J,K) = PS(J,K)*DIV2
      IF (J-NS) 13337,13338,13338
13338 J = 0
13339 J = J + 1
      WC(J) = W7 / CHNOC
      DO 13340 K= 1,MC
13340 PC(J,K) = PC(J,K)*DIV2
      IF(J-NC) 13339,478,478
1356 DIV2=WDOT/WDOT0
      W4=W40*DIV2
      W13=W130*DIV2
      W15=W150*DIV2
      W5=W4
      W2=W4
      W1=W2
      W6=W5-W15
      W7=W6
      W18=W13+W15

```



```

      PN(1)=P4-W4/YINN
      DO 40000 K=1,M1N
      WN(K)=W4/ALPHAN(K)
40000  PN(K+1)=PN(K)-WN(K)/YN(K)
      DO 40001 I=1,NR
      WR(I) = WYER(I)*(P5-P6)
      PR(I,1)=P5 - WR(I)/YINR(I)
      DO 40001 K=1,M1R
40001  PR(I,K+1)=PR(I,K) - WR(I)/YR(I,K)
      DO 40002 I=1,NS
      WS(I) = WYES(I)*(P6-P7)
      PS(I,1)=P6 - WS(I)/YINS(I)
      DO 40002 K=1,M1S
40002  PS(I,K+1)=PS(I,K) - WS(I)/YS(I,K)
      DO 40003 I=1,NC
      WC(I) = WYEC(I)*(P7-P10)
      PC(I,1)=P7 - WC(I)/YINC(I)
      DO 40003 K=1,M1C
40003  PC(I,K+1)= PC(I,K) - WC(I)/YC(I,K)
C
      478  CONTINUE
C
      W18D=W18
C
C
C
C
C
C
      COMPUTE HEAT FLOWS AND TEMPERATURES
C
      549  IF (Ib) 476,476,474
      474  PRINT 4203
      4203  FORMAT (//13H TEMPERATURES)
      476  CONTINUE
C
      IITRND = IITRND + 1
C
C
      TN(1) = T4
      ITRC=0
      ITRTOT = 0
      TXCD=T10
      550  ITRTOT = ITRTOT + 1
      IF(ITRTOT - ITNI) 580,580,575
      575  WRITE OUTPUT TAPE 6,576
      576  FORMAT(1H1 //13H 20H TEMPERATURE LOOPING )
      IDUMP = 5
      GO TO 590
      580  CONTINUE
      IF(IPQW)13077,13077,13075
      13075 DO 13076 K=1,M1N
      TBB(K) = TXC/(1.0 + DDD(K))
      13076 TAR(K) = TBB(K)*(1.0 + RECOV*DDD(K))
      13077 CONTINUE
C

```

```

      ITRNOT=0
560  ITRNOT=ITRNOT+1
      ITRC=ITRC+1
      ITFLAG=5
C
C      HEAT GENERATION
C
421  DO 517 K=1,M1N
517  QN(K) = POWER * FLUXN(K)
C
      DO 518 I=1,NR
      DO 518 K=1,M1R
518  QR(I,K) = POWER*FLUXR(I,K)
C
      DO 519 I=1,NS
      DO 519 K=1,M1S
519  QS(I,K) = POWER*FLUXS(I,K)
C
      DO 520 I=1,NC
      DO 520 K=1,M1C
520  QC(I,K) = POWER*FLUXC(I,K)
      DO 1324 K=1,M1H
1324 QH(K)=POWER*FLUXH(K)
C
      WT8 = WDOT**0.8
      DO 600 K=1,M1N
      GET SOLID ENTHALPY
      NOSTAT=13010
      CALL READKM (TCN(K),MATN,HSOLN(K),NK)
      IF(NK)13025,13025,11999
13025 CPMN=(HSOLN(K)-HOSOLN(K))/(TCN(K)-TCON(K))
      IF(CPMN)13996,13010,13011
13996 WRITE OUTPUT TAPE 6,13999,K,NOSTAT,MATN,HSOLN(K),HOSOLN(K)
1,TCN(K),TCON(K)
13010 CPMN =HOSOLN(K)/TCON(K)
13011 CN(K)=CNX(K) * CPMN
C
      IF(K-1)13017,13017,13015
13015 TAVG=(TCN(K)+TCN(K-1))/2.0
      NOSTAT=13015
      CALL READKM (TAVG,MKN,VK,NK)
      IF(NK)13016,13016,11999
13016 Z3N(K)=Z3NX(K) * VK
13017 CONTINUE
C
      THETA(K)=TN(K+1)/TCN(K)
      FPI=XFPI (TN(K),PN(K))
      IF(QUALN(K))11005,11005,11003
11003 DIV2=1.0-QUALN(K)
      IF(DIV2)11005,11005,11004
11004 FPI=XFPI ((TCN(K)+TN(K))/2.0 ,PN(K))
      FKITT=((DIV2/QUALN(K))**0.9) * ((.34901 - .2723E-03*PN(K)) * PN(K)
1 *1.0E-02 + 0.13923)
      H(K)=HCCON(K)*FPI*(WN(K)**0.8)/(0.611 + 1.93*FKITT)
      CP(K)=2000.0
      GO TO 11006

```

```

11005 H(K) = HCCON(K) * FPI*(THETA(K)**0.64)*WN(K)**0.8
      CP(K)=XCP (TN(K),TN(K+1),HHN(K),HHN(K+1))
11006 ARAT=SQRTF(ABSF(ARATID(K)))
      WWW=W4*CP(K)
      BETA(K)=(H(K)*DN(K)*PI*DNT*ARAT*YKA/ALPHAN(K))/((WN(K)+1.0E-05)
      1 *CP(K) )
C
      NOSTAT=11000
      CALL READKM (TCN(K),MKN,VKN,NFLAG)
      IF(NFLAG)11000,11000,11999
11000 ZWN=2.0*VKN* DN(K)*PI*DNT*ARAT/ THIK(K)
      Z1N(K) = WWW
      Z2N(K) = WWW * (EXPF(BETA(K))-1.0)
      IF(ZWN)11007,10009,11007
11007 IF(Z2N(K))11008,11009,11008
11009 Z2N(K)=0.0
      GO TO 11010
11008 DIV2=1.0/ZWN
      Z2N(K)=1.0/(1.0/Z2N(K) + DIV2)
11010 TEK(K)=0.28*TXC + 0.5*TCN(K) + 0.22*TAR(K)
      FPI=XFPI (TEK(K),PXC)
      Z4N(K) = HHCN(K)* WT8*FPI*(TBB(K) / TEK(K))**0.8
      Z4N(K)=1.0/(1.0/Z4N(K) + DIV2)
C
      PSIN(K)=SIGMA*EN(K)*SFN(K)*A1N(K)
      TTN = TCN(K)*TCN(K)
      TTTN = TTN * TCN(K)
600 Z5N(K) = PSIN(K)*((TTTN+TCC(1,M1C))*((TTN +TCC(1,M1C))*((TCN(K) + TCC(1
1,M1C))))
      RELAX(1) = COEFF / (Z2N(1) + Z3N(2) + Z4N(1) + Z5N(1)+CN(1)*ALPHAN
1(1) / DELTA )
      DO359 K=2,M2N
359 RELAX(K) = COEFF / (Z2N(K)+Z3N(K)+Z3N(K+1)+Z4N(K)+Z5N(K)+ CN(K)*AL
1PHAN(K) /DELTA)
      RELAX(M1N) = COEFF / (Z2N(M1N)+Z3N(M1N)+Z4N(M1N)+Z5N(M1N)+CN(M1N)*
1ALPHAN(M1N) / DELTA)
      DO 200 K=1,M1N
      Q1N(K) = Z1N(K)*((TN(K+1)-TN(K))
      Q2N(K) = Z2N(K)*((TCN(K) - TN(K+1))
      Q4N(K)=Z4N(K)*((TAR(K)-TCN(K))
200 Q5N(K) = Z5N(K)*((TCC(1,M1C)-TCN(K))
      DO 250 K = 2,M1N
250 Q3N(K) = Z3N(K) * (TCN(K)-TCN(K-1))
      DO 260 K = 1,M1N
260 SN(K)=(CN(K)*ALPHAN(K)/DELTA)*((TCN(K)-TCN(K))
      ERROR(1) = QN(1) - SN(1) - Q2N(1) + Q3N(2) + Q4N(1) + Q5N(1)
      DO 280 K = 2,M2N
280 ERROR(K) = QN(K) - SN(K) - Q2N(K) - Q3N(K) + Q3N(K+1) + Q4N(K) + Q
15N(K)
      ERROR(M1N) = QN(M1N) - SN(M1N) - Q2N(M1N) - Q3N(M1N) + Q4N(M1N) +
1Q5N(M1N)
      DO 800 K = 1,M1N
800 TCN(K) = TCN(K) + RELAX(K) * ERROR(K)
      DO 850 K = 2,MN
      HHN(K)=HHN(K-1) + (TCN(K-1)-TN(K-1))*CP(K-1)*((1.0-EXPF(-BETA(K-1)
1 ))

```

```

      NOSTAT=10026
      CALL PARAH (DAT,PN(K),1,HHN(K),3,NK)
      IF(NK)12012,10026,12012
12012 IF(HHN(K))12013,99999,12014
12013 TN(K)=36.0
      QUALN(K)=0.0
      GO TO 850
12014 TN(K)=4990.0
      QUALN(K)=1.0
      GO TO 850
10026 QUALN(K)=DAT(5)
      TN(K)=DAT(6)
      850 CONTINUE
      SUM = 0.0
      DO 880 K=1,M1N
      DIV3=ABSF(ERROR(K))
      880 SUM=SUM + DIV3
      SUMN = 0.0
      DO 1002 J=1,M1N
      1002 SUMN = SUMN +ABSF(QN(J))+ABSF(SN(J))+ABSF(Q2N(J))+ABSF(Q4N(J))+ABS
      IF(Q5N(J))
      DO 1003 K=2,M1N
      1003 SUMN = SUMN +ABSF(Q3N(K))
      SUM = SUM/SUMN
      9572 IF (ITRNOT-ITEMI)568,568,569
      568 IF(SUM - TTOLER)571,571,572
      569 IDUMP = 5
      WRITE OUTPUT TAPE 6,907
      907 FORMAT(1H1 /////// 20H NOZZLE TEMP LOOPING )
      GO TO 590
      572 IF(ITRC - 10) 560,573,573
      573 ITRC = 0
C
      GO TO 574
      571 ITFLAG = -5
      ITRC=0
      IF (ITRNOT- 1) 560,560,574
      574 IF (I3) 909,909,590
      590 WRITE OUTPUT TAPE 6,84
      84 FORMAT (/////20H NOZZLE TEMPERATURES //)
      WRITE OUTPUT TAPE 6,85, TIME, ITRNOT
      85 FORMAT (////////12H TIME = E11.4,5H SEC.,8X,
      143H NO. OF ITER. IN TEMP. LOOP PER TIME STEP = 15)
      WRITE OUTPUT TAPE 6, 16
      DO 592 K=1,MN
      592 WRITE OUTPUT TAPE 6, 18, K,TN(K)
      WRITE OUTPUT TAPE 6, 19
      DO 593 K=1,M1N
      593 WRITE OUTPUT TAPE 6, 20, K, TCN(K)
      WRITE OUTPUT TAPE 6, 32
      L = 1
      WRITE OUTPUT TAPE 6,33, L, Q1N(K),Q2N(K),Q4N(K),Q5N(K)
      33 FORMAT (20H BRANCH NUMBER 13,9H Q1N= E11.4, 9H Q2N= E
      111.4,20X , 9H Q4N= E11.4, 9H Q5N= E11.4 )
      DO 594 K=2,M1N
      594 WRITE OUTPUT TAPE 6,34, K, Q1N(K),Q2N(K),Q3N(K),Q4N(K),Q5N(K)

```

```

34 FORMAT (20H          BRANCH NUMBER I3, 9H      Q1N=  E11.4,9H      Q2N= E
    111.4, 9H      Q3N= E11.4, 9H      Q4N= E11.4,9H      Q5N= E11.4)
    DO 595 K=1,M1N
595 WRITE OUTPUT TAPE 6, 35, K, SN(K) ,QN(K)
    14 FORMAT (//20H          CHANNEL NUMBER I3//)
    16 FORMAT (////////21H LIQUID TEMPERATURES//)
    17 FORMAT (23X,9H      T1 = F10.1/23X,9H      T2 = F10.1/
    171 23X,9H TWALL = F10.1//)
    18 FORMAT (20H          NODE NO. I3,9H      TN= F10.1)
    19 FORMAT (////////19H SOLID TEMPERATURES//)
    20 FORMAT (20H          NODE NO. I3,9H      TCN= F10.1)
    21 FORMAT (////////12H      TIME = E11.4,5H SEC.,8X,
    211 30H NO. OF ITER. PER TIME STEP = I5)
    32 FORMAT (////////16H HEAT FLOW RATES//)

```

```

WRITE OUTPUT TAPE 6,86,SUM
86 FORMAT (//19X,9H      SUM = E11.4//)

```

```

35 FORMAT (20H          NODE NO. I3,9H      SN= E11.4,
351 9H      QN= E11.4)
36 FORMAT (20H          CHANNEL NUMBER I3,9H      TERM = 511.4)
WRITE OUTPUT TAPE 6, 651,(Z1N(K), K=1,M1N)
651 FORMAT (//////// 8H0--Z1N-- / (8E12.5//))
WRITE OUTPUT TAPE 6, 652,(Z2N(K), K=1,M1N)
652 FORMAT (8H0--Z2N-- / (8E12.5//))
WRITE OUTPUT TAPE 6, 653,(Z3N(K), K=1,M1N)
653 FORMAT (8H0--Z3N-- / (8E12.5//))
WRITE OUTPUT TAPE 6, 655,(SN(K),K=1,M1N)
655 FORMAT ( 7H0--SN-- / (8E12.5) )
WRITE OUTPUT TAPE 6, 656,(RELAX(K),K=1,M1N)
WRITE OUTPUT TAPE 6, 657,(ERROR(K), K=1,M1N)
656 FORMAT (11H0--RELAXN-- / (8E12.5) )
657 FORMAT (11H0--ERRORN-- / (8E12.5) )

```

```

C
IF(IDUMP)909,909,31
909 IF (ITFLAG) 910,910,560
910 SUM2 = WN * ALPHAN
    IF (SUM2 - .00001) 922,922,921
921 T5 = TN(MN)
922 CONTINUE

```

```

C
C
C
COEFF=COEFR
TOLER=T9R
SENSE=5HREFLC
HHR(1,1)=HHN(MN)
    IF (I3) 926,926,917
917 WRITE OUTPUT TAPE 6, 923
923 FORMAT(////////23H REFLECTOR TEMPERATURES //)
926 CALL TEM9 (NR,MR,AR,ALPHAR,CR,DR,QR,RHR,TR,T5,T6,QUALR,
    1 HHR,PR,TCR,TCOR,WR,Z3R,Q3R,SR,PSIR,MATR,HSOLR,HOSOLR,MATSR)

```

```

1771 IF(SENSE LIGHT 1)1790,1771
SENSE=6HSHIELD
COEFF=COEFS
TOLER=T9S
SUM=0.0
SUMN=0.0
DO 10028 I=1,NR
SUM=SUM + ALPHAR(I)*WR(I)*HHR(I,MR)
10028 SUMN=SUMN + ALPHAR(I)*WR(I)
HHS(1,1)=SUM/SUMN
IF (13) 927,927,918
918 WRITE OUTPUT TAPE 6, 924
924 FORMAT(/////20H SHIELD TEMPERATURES //)
927 CALL TEM9 (NS,MS,AS,ALPHAS,CS,DS,QS,RHS,TS,T6,T7,QUALS,
1 HHS,PS,TCS,TCDS,WS,Z3S,Q3S,SS,PSIS,MATS,HSOLS,HQSOLS,MATSS)

```

C
C

```

1772 IF(SENSE LIGHT 1)1790,1772
SENSE=4HCORE
COEFF=COEFC
TOLER=T9C
SUM=0.0
SUMN=0.0
DO 10029 I=1,NS
SUM=SUM + ALPHAS(I)*WS(I)*HHS(I,MS)
10029 SUMN=SUMN + ALPHAS(I)*WS(I)
HHC(1,1)=SUM/SUMN
IF(13) 928,928,919
919 WRITE OUTPUT TAPE 6, 925
925 FORMAT(/////18H CORE TEMPERATURES //)
928 CALL TEM9 (NC,MC,AC,ALPHAC,CC,DC,QC,RHC,TC,T7,T10,QUALC,
1 HHC,PC,TCC,TCDC,WC,Z3C,Q3C,SC,PSIC,MATC,HSOLC,HQSOLC,MATSC)

```

C

```

1773 IF(SENSE LIGHT 1)1790,1773
COEFF=CCOEFF
TOLER=T10TOLER
SUM=0.0
SUMN=0.0
DO 10014 I=1,NC
SUM=SUM + ALPHAC(I)*WC(I)*HHC(I,MC)
10014 SUMN=SUMN + ALPHAC(I)*WC(I)
H10=SUM/SUMN

```

C
C
C
C
C
C
C
C

TEST FOR T10 CONVERGENCE

```

IF(IPDW)13074,13074,13066
13066 IF(ABSF(T10-TXC)/T10 - TXCTOL)13073,13073,13067
13067 TXC = T10
WDOT1 = WDOT
WYENT = Y1(ANT,TXC,TXC,PA,PXC)
WDOT = WYENT*(PXC - PA)
DIV2 = WDOT/WDOT1

```

```

W13 = W13*DIV2
W15 = W15*DIV2
W18 = W15 + W13
W7 = WDOT + W13
W6 = W7
W5 = W6 + W15
W4 = W5
W2 = W4
W1 = W2
DO 13068 K=1,M1N
13068 WN(K)=WN(K)*DIV2
DO 13069 I=1,NR
13069 WR(I)= WR(I)*DIV2
DO 13070 I=1,NS
13070 WS(I)= WS(I)*DIV2
DO 13071 I=1,NC
13071 WC(I)= WC(I)*DIV2
IF(I7)957,550,957
13073 TXC = T10
GO TO 980
13074 IF(ABS(T10-TXC)/TXC - TXCTOL)980,980,6999
C
C
C CHANGE POWER FOR NEXT ITERATION
C
C
6999 PURPO = TXC/T10
OLDPO = POWER
POWER=POWSAV + (OLDPO-POWSAV)*(TXC-T10SAV)/(T10-T10SAV)
IF(POWER + 0.1)13116,13117,13117
13116 POWER = OLDPO*PURPO
13117 IF(POWER+0.1)14425,14430,14430
14425 POWER=-.1
14430 IF(POWER) 14440,14440,14435
14435 IF(POWER-2.0)14440,14440,14436
14436 POWER=2.0
14440 POWSAV=OLDPO
T10SAV=T10
IF(I7)957,550,957
957 WRITE OUTPUT TAPE 6, 958, T10, TXC, POWER, OLDPO
958 FORMAT( /// 5H0T10= F8.1, 5H TXC= F8.1, 7H POWER= F14.6, 11H OL
10 POWER= F14.6 )
GO TO 550
980 CONTINUE
GO TO (956, 8800), LATCH
C
956 LATCH = 1
KOUNTS=1
C
IF(I8) 959,950,959
959 WRITE OUTPUT TAPE 6,958, T10,TXC,POWER
C
C COMPUTE MASS FLOWS AND PRESSURES
C
C
C (1) CALCULATE MASS FLOW RATE CONDUCTANCES

```

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```

C
C
950 IF (16) 952,952,951
951 PRINT 4303
4303 FORMAT (10H PRESSURES )
952 CONTINUE
    ITRNP=0
    KIP = 1
    T18OLD=T18
    WT=WDOT
    KTURB=0
    PXC20=PXC/20.0
    ITRND=XKKKF(1RND)
    HHD(1)=HHS(1,1)
C
C    START OF HEAT EXCHANGER AND TURBO-PUMP LOOP
C
    IP2      = 0
    P2OLD=P2
1000  ITRNDH=0
    P2CK2=P2CK
    P2CK=P2
    ITRND=ITRND-1
    IF(1NRX)13101,13101,1320
13101 ITRCH=0
    W158=W15**0.8
    W188=W18**0.8
    H2=H1 + POWP/(W2*9338.0)
C
C    START OF ITERATION LOOP
1314  ITRNDH=ITRNDH+1
    ITRCH=ITRCH+1
C
C    CONVECTIVE HEAT TRANSFER CONDUCTANCES
C
    DO 1301 K=1,M1H
    GET SOLID ENTHALPY
    NOSTAT=13012
    CALL READKM (THE(K),MATH,HSOLH(K),NK)
    IF(NK)13026,13026,11999
13026 CPMN=(HSOLH(K)-HOSOLH(K))/(THE(K)-THEO(K))
    IF(CPMN)13997,13012,13013
13997 WRITE OUTPUT TAPE 6,13999,K,NOSTAT,MATH,HSOLH(K),HOSOLH(K),
1    THE(K ),THEO(K)
13012 CPMN    =HOSOLH(K)/THEO(K)
13013 CH(K)=CHX(K) * CPMN
C
    IF(K-M2H)13020,13020,13022
13020 TAVG=(THE(K)+THE(K+1))/2.0
    NOSTAT=13020
    CALL READKM (TAVG,MKTD,VK,NK)
    IF(NK)13021,13021,11999
13021 Z3H(K)=Z3HX(K) * VK
13022 CONTINUE
C

```



```

      THETA=(THC(K+1)/THE(K))*0.55
      FPI=XFPI (THC(K),PDST(K))
      CP=XCP(THC(K),THC(K+1),HHHD(K),HHHD(K+1))
      Z1=W15*CP
      Z5=W18*CP
      HD(K)=HCCAL*FPI*THETA*W158
      BETA=HD(K)*TERMD/((W15+1.0E-05)*CP)
      NOSTAT=11001
      CALL READKM (THE(K),MKTD,VKTD,NFLAG)
      IF(NFLAG)11001,11001,11999
11001  ZW=8.0*VKTD*PI*DH*RHH / THKTD
      DIV2=1.0/ZW
      Z2(K)=Z1*(EXPF(BETA)-1.0)
      Z2(K)=1.0/(1.0/Z2(K) + DIV2)
      THETA=(THH(K)/THE(K))*0.55
      FPI=XFPI (THH(K),PHST(K))
      CP=XCP(THH(K),THH(K+1),HHHT(K),HHHT(K+1))
      Z5=W18*CP
      HH(K)=HHCAL*FPI*THETA*W188
      BETA=HH(K)*TERMH/((W18+1.0E-05)*CP)
      Z4(K)=Z5*(EXPF(BETA)-1.0)
1301  Z4(K)=1.0/(1.0/Z4(K) + DIV2)
C
C      RELAXATION COEFFICIENTS
C
      RELAX(1)=COHEX/{Z2(1)+Z3H(1)+Z4(1)+CH(1)/DELTA}
      DO 1302 K=2,M2H
1302  RELAX(K)=COHEX/{Z2(K)+Z3H(K-1)+Z3H(K)+Z4(K)+CH(K)/DELTA}
      RELAX(M1H)=COHEX/{Z2(M1H)+Z3H(M2H)+Z4(M1H)+CH(M1H)/DELTA}
C
C      HEAT FLUXES
C
      DO 1303 K=1,M1H
      Q1H(K)=Z2(K)*(THE(K)-THC(K+1))
      Q2H(K)=Z4(K)*(THH(K)-THE(K))
1303  SH(K)=CH(K)*(THE(K) - THE0(K))/DELTA
      DO 1304 K=1,M2H
1304  Q3H(K)=Z3H(K)*(THE(K+1)-THE(K))
C
C      ERRORS IN FLOWS AT NODES
C
      ERROR(1)=QH(1)-SH(1)-Q1H(1)+Q2H(1)+Q3H(1)
      DO 1305 K=2,M2H
1305  ERROR(K)=QH(K)-SH(K)-Q1H(K)+Q2H(K)-Q3H(K-1)+Q3H(K)
      ERROR(M1H)=QH(M1H)-SH(M1H)-Q1H(M1H)+Q2H(M1H)-Q3H(M2H)
C
C      NEW VALUES OF TEMPERATURES
C
      DO 1306 K=1,M1H
1306  THE(K)=THE(K)+RELAX(K)*ERROR(K)
      THC(1)=T6
      DO 1307 K=2,MH
      HHHD(K)=HHHD(K-1) + Q1H(K-1)/W15
      NOSTAT=10030
      CALL PARAH (DAT,PDST(K),1,HHHD(K),3,NK)
      IF(NK)99999,10030,99999

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```

10030 QUALHD(K)=DAT(5)
1307 THC(K)=DAT(6)
      IF(W13)2335,2336,2336
2335 THH(MH)=THC(MH)
      HHHT(MH)=HHHD(MH)
      GO TO 2337
2336 HHHT(MH)=(W15*HHHD(MH) + W13*HHXC)/W18
      NQSTAT=10031
      CALL PARAH (DAT,PXC,1,HHHT(MH),3,NK)
      IF(NK)99999,10031,99999
10031 THH(MH)=DAT(6)
      QUALHT(MH)=DAT(5)
2337 DO 1308 K=1,M1H
      I=MH-K
      HHHT(I)=HHHT(I+1) - Q2H(I)/W18
      NQSTAT=10032
      CALL PARAH (DAT,PHST(I),1,HHHT(I),3,NK)
      IF(NK)99999,10032,99999
10032 QUALHT(I)=DAT(5)
1308 THH(I)=DAT(6)
C
C      CONVERGANCE TEST
      SUM=0.0
      DO 1309 K=1,M1H
1309 SUM=SUM+ABSF(ERROR(K))
      SUMHX= 0.0
      DO 1004 J=1,M1H
1004 SUMHX = SUMHX + ABSF(QH(J))+ABSF(SH(J))+ ABSF(Q1H(J))+ABSF(Q2H(J))
      DO 1005 J=1,M2H
1005 SUMHX = SUMHX+ABSF(Q3H(J))
      SUM = SUM/SUMHX
C
      IF(I4)5505,5506,5505
5505 WRITE OUTPUT TAPE 6,1331, (K,PHST(K),THC(K),THE(K),THH(K),
1 PDST(K),HSOLH(K),K=1,MH) 1331
      WRITE OUTPUT TAPE 6,5504,SUM,WDOT,W13,W15,W18
5504 FORMAT (1H0,10X,3HSUM 1PE13.5,6H WDOT E13.5,5H W13 E13.5,5H W15
1 E13.5,5H W18 E13.5 )
5506 CONTINUE
      IF(ITRNOH-1)1314,1314,1310
1310 IF(ITRNOH-IHMAX)1311,1311,1312
1311 IF(SUM-TTOLER)1320,1320,1314
1312 ITFLAH=1
      WRITE OUTPUT TAPE 6,1313
      GO TO 9999
1313 FORMAT (1H-.32HHEAT EXCHANGER DOES NOT CONVERGE )
1320 CONTINUE
C
      AINN=AN(1)*ALPHAN(1)
      AOUTN=AN(MIN)*ALPHAN(MIN)
      YINN=Y3(AINN,XKN,W4,T4,P4)
      YOUTN=Y3(AOUTN,XKN,W4,TN(MN),PN(MN) )
C
      NNP1= NN + 1
      NN1 = NN - 1
      DO 2004 K = 1,NN1

```

```

2004 YN(K)=Y2 (AN(K),RHN(K),DN(K),HHN(K+1),HHN(K),PN(K+1),PN(K),WN(K) )
      YN(NN)=Y1 (AN(NN),TN(NNP1),TN(NN),PN(NNP1),PN(NN) )
      DO 1574 K=NNP1,M1N
1574 YN(K)=Y2 (AN(K),RHN(K),DN(K),HHN(K+1),HHN(K),PN(K+1),PN(K),WN(K) )
      SUM = 0.0
      DO 1804 K = 1,MN
1804 SUM = SUM + 1.0/(YN(K)*ALPHAN(K))
      SUM = SUM + 1.0 / YINN + 1.0 / YOUTN
      WYETT = 1.0 / SUM

```

C
C
C

```

      DO 2000 I = 1, NR
      YINR(I)=Y1 (AREAR(I),TR(I,1),T5,PR(I,1),P5)
      YOUTR(I)=Y3(AR(I),XKR(I),WR(I),TR(I,MR),PR(I,MR) )
      DO 1500 L=1,M1R
1500 YR(I,L)=Y2 (AR(I),RHR(I),DR(I,L),HHR(I,L+1),HHR(I,L),PR(I,L+1),
      1 PR(I,L),WR(I) )
      SUM = 0.0
      DO 1800 L=1,M1R
1800 SUM = SUM + 1.0/YR(I,L)
      SUM = SUM + 1.0/YINR(I) + 1.0/YOUTR(I)
2000 WYER(I) = 1.0 / SUM

```

C
C
C

```

      DO 2001 I=1,NS
      YINS(I)=Y1(AREAS(I),TS(I,1),T6,PS(I,1),P6)
      YOUTS(I)=Y3(AS(I),XKS(I),WS(I),TS(I,MS),PS(I,MS) )
      DO 1501 L=1,M1S
1501 YS(I,L)=Y2 (AS(I),RHS(I),DS(I,L),HHS(I,L+1),HHS(I,L),PS(I,L+1),
      1 PS(I,L),WS(I) )
      SUM = 0.0
      DO 1801 L=1,M1S
1801 SUM = SUM + 1.0/YS(I,L)
      SUM = SUM + 1.0/YINS(I) + 1.0/YOUTS(I)
2001 WYES(I) = 1.0/SUM

```

C
C
C

```

      DO 2002 I=1,NC
      YINC(I)=Y1(AREAC(I),TC(I,1),T7,PC(I,1),P7)
      YOUTC(I)=Y3(AC(I),XKC(I),WC(I),TC(I,MC),PC(I,MC))
      DO 1502 L=1,M1C
1502 YC(I,L)=Y2 (AC(I),RHC(I),DC(I,L),HHC(I,L+1),HHC(I,L),PC(I,L+1),
      1 PC(I,L),WC(I) )
      SUM = 0.0
      DO 1802 L=1,M1C
1802 SUM = SUM + 1.0/YC(I,L)
      SUM = SUM + 1.0/YINC(I) + 1.0/YOUTC(I)
2002 WYEC(I) = 1.0/SUM

```

C
C
C

```

      WYER1 = 0.0
      DO 2200 I=1,NR

```

```

2200 WYERT = WYERT + WYER(I)*ALPHAR(I)
C
WYEST = 0.0
DO 2201 I=1,NS
2201 WYEST = WYEST + WYES(I)*ALPHAS(I)
C
WYECT = 0.0
DO 2202 I=1,NC
2202 WYECT = WYECT + WYEC(I)*ALPHAC(I)
C
C
C      (2) CALCULATE PRESSURES
C
IF(INRX)2300,2300,1382
2300 Y1DST=Y1(AREADT,T6,T6,PDST(1),P6)
DO 2310 L=1,M1H
2310 YDST(L)=Y2 (AHC,RHD,DH,HHHD(L+1),HHHD(L),PDST(L+1),PDST(L),W15)
T14=THH(MH)
T16=THC(MH)
P16=PDST(MH)
Y1D0=Y1(AREAD0,T14,T16,P14,P16)
SUM=0.0
SUM=1.0/Y1DST + 1.0/Y1D0
DO 2315 L=1,M1H
2315 SUM=SUM + 1.0/YDST(L)
WYDST = 1.0/SUM
DO 2320 L=1,M1H
K=MH-L+1
2320 YHST(K)=Y2 (AHH,RHH,DH,HHHT(K),HHHT(K-1),PHST(K),PHST(K-1),W18)
T17=THH(1)
T18CK=T18
T18=(T17 + T18)/2.0
Y1T0=Y1(AREAT0,T18,T17,P17P5,P17)
DIV2 = 11.475*P17P5/(W18*T17) - 2.0*W18/P18
IF(PTPCV)14200,14200,14210
14210 NOSTAT=14210
IF(90.0-TPCV)14212,14215,14215
14212 WRITE OUTPUT TAPE 6,14213,TPCV,NOSTAT
14213 FORMAT (12H- BAD TPCV= 1PE16.7, 9H NOSTAT= 18 )
GO TO 31
C
C      LOOK UP XKTCV AS F(TPCV)
C
14215 CALL READKM (TPCV,19,XKTCV,NK)
IF(NK)14211,14211,11999
14211 YTPCV=DIV2 /XKTCV
GO TO 14220
14200 YTPCV=W18/(P17P5-P18)
XKTCV=DIV2/YTPCV
14220 NOSTAT=10015
CALL PARAH (DAT,P2,1,H2,3,K)
IF(K)99999,10015,99999
10015 RHQ2=DAT(7)
T2=DAT(6)
P2MP1 = P2 - P1
IF(P2MP1) 12006,12006,12299

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```

12006 IP2      = IP2 + 1
      IF(IP2 - 90) 12198,12198,12199
12198 P2=P1 + 1.0
      P2MP1=1.0
      GO TO 12299
12199 WRITE OUTPUT TAPE 6, 12007
12007 FORMAT (12H - P1 GT P2 )
      ITFLAH=1
      GO TO 9961
12299 DELH=(P2-P1)/RH02
C
C      XNS = SHAFT SPEED
C
      Q1=CP1*W1/RH02
12008 H1D2=P2MP1/(12.0*RH02)
      NUSTAT=13198
      CALL PARAH (DAT,P1,1,H1,3,NK)
      IF(NK)99999,13198,99999
13198 T1=DAT(6)
      RH01=DAT(7)
      PVAP =EXP(2.3025851*(2.9304-(79.821/T1)+.011627*T1))
      VPSP=P1-PVAP
      IF(VPSP)13203,13203,13199
13199 VPSH=VPSP/(12.0*RH01)
C
C      USE CURVE FIT EQUATION FOR FIRST GUESS
C
      KURVE = 100
      IF (NCAV)13200,13200,13201
13200 NCAV = 1
      XNS=-1.4*Q1 + SQRTF(1.955*(Q1*Q1)+(22.7*(Q1*Q1)+H1D2*1.0E+5)/4.65)
13201 XNSQ=XNS*XNS
      XQIN =Q1/XNS
      XHSVNS =VPSH/XNSQ
      CALL CURVE3 (XQIN, XHSVNS,H1D2P)
      H1D2P =H1D2P*XNSQ
      IF(ABSF(H1D2-H1D2P)/H1D2 - 0.001)13205,13205,13202
13202 XNS=XNS * SQRTF(H1D2/H1D2P)
      KURVE =KURVE -1
      IF(KURVE)13203,13203,13201
13203 WRITE OUTPUT TAPE 6,13204,H1D2,H1D2P,XNS,VPSP
13204 FORMAT (25H- SHAFT SPEED NO CONVERGE // 6H H1D2 1PE16.7, 6H H1D2P
1 E16.7, 4H XNS E16.7, 5H VPSP E16.7)
      GO TO 31
13205 CONTINUE
      IF(PTPCV)19040,19040,19001
19001 IF(ITRNO-N25)19050,19050,19040
19050 XNS=(XNS2 + XNS)/2.0
19040 CONTINUE
C
      XQIN = Q1/XNS
      CALL ETAP2(XQIN,XNS,ETAP)
      IF(ETAP -0.001) 2322,2324,2324
2322 ETAP =0.001
2324 POWP=W1*DELH/ETAP + (CPS*XIR*(XNS*XNS - XNSQ*XNSQ))/(2.0*DELTA)
      U=CT1*XNS

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```

      GAT=1.0 - (P19/P18)**.286
      NOSTAT=10033
      CALL PARAH (DAT,P18,1,T18,6,NK)
      IF(NK)99999,10033,99999
10033  H18=DAT(3)
      H19=H18*(1.0-GAT)
      CO=223.8 * SQRTF(ABSF(H18-H19))
      UCO=U/CO
      CALL READKM(UCO,21,ETAT,NCBA)
      IF(ETAT-0.01)2326,2328,2328
2326  ETAT=0.01
2328  Y6=POWP/((P18-P19)*ETAT*9336.0*(H18-H19) )
      T19=T18 * (1.0 - ETAT*GAT)
      DIV2=PA/P19
      IF(DIV2 - .528) 12009,12009,12010
12009  YRN=C19*P19/(SQRTF(T19)*(P19-PA))
      GO TO 12011
12010  YRN=(3.87*C19*P19/(P19-PA)) * SQRTF( (DIV2**1.43 - DIV2**1.715)
1 /T19 )
12011  SUM=0.0
      DO 2330 L=1,M1H
2330  SUM=SUM + 1.0/YHST(L)
      SUM=SUM + 1.0/Y1TD + 1.0/YTPCV +1.0/Y6 + 1.0/YRN
      WYTIT=1.0/SUM
C
C      CHECK WYTIT
C
      IF(WYTIT)1381,1381,1382
1381  WYTIT=0.003
1382  CONTINUE
C
C      ITRNP=ITRNP + 1
C
      WY1=Y2 (APD1,RHPD1,DPD1,H1,H1,P1,PZ,W2)
      NOSTAT=10018
      CALL PARAH (DAT,P5,1,HHR(1,1),3,K)
      IF(K)99999,10018,99999
10018  RH05=DAT(7)
      NOSTAT=10020
      CALL PARAH (DAT,P6,1,HHS(1,1),3,K)
      IF(K)99999,10020,99999
10020  RH06=DAT(7)
      NOSTAT=10021
      CALL PARAH (DAT,P7,1,HHC(1,1),3,K)
      IF(K)99999,10021,99999
10021  RH07=DAT(7)
      NOSTAT=10023
      CALL PARAH (DAT,P10,1,H10,3,K)
      IF(K)99999,10023,99999
10023  RH010=DAT(7)
      IF(INRX)13102,13102,13103
13102  NOSTAT=10024
      CALL PARAH (DAT,P14,1,HHHT(MH),3,K)
      IF(K)99999,10024,99999
10024  RH014=DAT(7)
      WYBPT=(772.18*AHH*AHH*RH010)*(1.0+CBPT)/W13

```

```

      CW14=CWFF(V14,RH014,RH0140,P14,P140)
      WV14=CW14 *(P14-P140)
13103  CW4=CWFF(V4,RH04,RH040,P4,P40)
      CW5=CWFF(V5,RH05,RH050,P5,P50)
      CW6=CWFF(V6,RH06,RH060,P6,P60)
      CW7=CWFF(V7,RH07,RH070,P7,P70)
      CW10=CWFF(V10,RH010,RH0100,P10,P100)
      WV4=CW4 *(P4-P40)
      WV5=CW5 *(P5-P50)
      WV6=CW6 *(P6-P60)
      WV7=CW7 *(P7-P70)
      WV10=CW10 *(P10-P100)
      IF(INRX)13104,13104,13105
13105  W15=0.0
      W18=0.0
      W13=0.0
      W7=WDOT + WV10
      W6=W7 + WV7
      W5=W6 + WV6
      W4=W5 + WV5
      W2=W4 + WV4
      P10=PX
      P00=P10
      P7=P10 + W7/WYECT
      P6=P7 + W6/WYEST
      P5=P6 + W5/WYERT
      P4=P5 + W4/WYETT
      P2=P4 + W2/WYEDT
      P1=PZ - W2/WY1
      NOSTAT=13115
      CALL PARAH (DAT,P2,1,H2,3,NK)
      IF(NK)99999,13115,99999
13115  T2=DAT(6)
      IF(ABSF(P2-P2CK)/P2 - PXCTOL)2370,2370,2367
13104  W15=WYDST*(P6-P14)
      W1802=W180
      W180=W18
      W18=WYTIT*(P14-PA)
      IF(W18-.001)14454,14455,14455
14454  W18=.001
14455  CONTINUE
      IF(PTPCV) 14415,14415,19020
19020  IF(ITRNO-N25) 14410,14410,14415
14410  W18=(W18 + W180 + W1802)/3.0
14415  POWT=W18*ETAT*9336.0*(H18-H19)
      DIV2=ABSF(POWT/POWP)
      IF(DIV2-100.)13055,13054,13054
13055  IF(DIV2-.01)13054,13054,13056
13054  W18=2.0E-6 * POWP
13056  W13=W18-W15+WV14
C
      W7=WDOT + W13 + WV10
      W6=W7 + WV7
      W5=W6 + W15 + WV6
      W4=W5 + WV5
      W2=W4 + WV4

```

```

      W1=W2
C
      IF(PTPCV)14330,14330,14320
14320 POWT=W18*ETAT*9336.0*(H18-H19)
      SPTX= CPS*XIR*(XNS*XNS-XNSO*XNSO)/(2.0*DELTA)
      P1=PZ - W2/WY1
      KURVE=50
      NOSTAT=14370
14370 P2IT=P2
      P2=P1 + (POWT - SPTX)*ETAP*RHO2/W2
      IF(P2-P1)14445,14446,14446
14445 P2=P1 + 1.0
14446 CALL PARAH (DAT,P2,1,H2,3,NK)
      IF(NK)99999,14375,99999
14375 RHO2=DAT(7)
      WRITE OUTPUT TAPE 6,14470, P2,H2,RHO2,POWT,SPTX,H18,H19,
1 (DAT(I),I=1,10)
14470 FORMAT (2H-R 7E16.8/2H R 7E16.8/2H R 3E16.8)
      IF(ABSF(P2IT-P2)/P2 - P2TOL )14390,14390,14380
14380 KURVE=KURVE-1
      IF(KURVE)14385,14370,14370
14385 WRITE OUTPUT TAPE 6,14386,H2,RHO2,RHO2CK
14386 FORMAT (24H- TPCV OP. RHO2 NO CONVE. / 5X,2HH2 1PE16.7,5H RHO2
1E16.7,7H RHO2CK E16.7)
      GO TO 31
14390 IF(ITRNO-N25)14465,14465,14466
14465 P2=(P2 + P2CK + P2CK2)/3.0
14466 P4=P2 - W2/WYEDT
      P5=P4 - W4/WYETT
      P6=P5 - W5/WYERT
      P7=P6 - W6/WYEST
      P10=P7 - W7/WYECT
      WRITE OUTPUT TAPE 6,14469,P2,P4,P5,P6,P7,P10,W2,W4,W5,W6,W7,
1 WYEDT,WYETT,WYERT,WYEST,WYECT
14469 FORMAT (5H- P2= 6E16.8/ 3H W2 5E16.8/ 4H CON 5E16.8)
14461 IF(P10-PA)14462,14462,14456
14462 P10=0.5*(PXC + PA)
      GO TO 14463
14456 P10=0.5*(PXC+P10)
14463 DIV2=MIN1F(P4,P5,P6,P7,P10)
      IF(DIV2-P10)14458,14457,14457
14458 WYCAL= 1.0/(1.0/WYEDT + 1.0/WYETT + 1.0/WYERT + 1.0/WYEST +
1 1.0/WYECT)
      DIV2=P2-P10
      P4=P2 - WYCAL*DIV2/WYEDT
      P5=P4 - WYCAL*DIV2/WYETT
      P6=P5 - WYCAL*DIV2/WYERT
      P7=P6 - WYCAL*DIV2/WYEST
      WRITE OUTPUT TAPE 6,14469,P2,P4,P5,P6,P7,P10,W2,W4,W5,W6,W7,
1 WYEDT,WYETT,WYERT,WYEST,WYCAL
14457 PXCCK=PXC
      PXC=P10
      GO TO 14340
C
14330 RELAX(10)=COTUR/(CW10 + WYECT + WYENT)
      ERRDR(10)=W7-WV10-W13-WDOT

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```

P10=P10 + ERROR(10)*RELAX(10)
P7=P10 + W7/WYECT
P6=P7 + W6/WYEST
P5=P6 + W5/WYERT
P4=P5 + W4/WYETT
P2=P4 + W2/WYEDT
P1=PZ - W2/WY1

```

```

C
14340 P00=P10
      P14=P10 - W13/WYBPT
      PDST(1)=P6 - W15/Y1DST
      DO 2340 L=2,MH
2340  PDST(L)=PDST(L-1) - W15/YDST(L-1)
      P16=PDST(MH)
      PHST(MH)=P14
      DO 2345 K=1,M1H
      L=MH-K
2345  PHST(L)=PHST(L+1) - W18/YHST(L)
      P17=PHST(1)
      P17P5=P17 - W18/Y1TD
      P19=PA + W18/YRN
      P18 = XP18(W18,T18,CT5,P19,CT5RAT)
      DIV2= MIN1F (P2,P4,P5,P6,P7,P10,P14,P16,P17,      P18,P19)
      IF(DIV2)2369,2369,13051
13051 IF(PTPCV)14360,14360,14350
14350 IF(ABSF(PXC-PXCCK)/PXC - PXCTOL)14420,14420,2366
14420 IF(ABSF(T18-T18CK)/T18 - TXCTOL)2370,2370,2366
14360 SUM=ABSF(ERROR(10))/W2
      IF(ITRNP-1)2366,2366,2350
2350  IF(ITRNP-ITMAX)2352,2352,2369
2352  IF(SUM-PTOLER)2354,2354,2366
2369  WRITE OUTPUT TAPE 6,2342
      ITFLAH=1
      GO TO 9999
2342  FORMAT (1H-.28HTURBD-PUMP DOES NOT CONVERGE )
2366  IF(P10-PXC20)2376,2376,2377
2377  IF(PTPCV)14270,14270,14260
14260  PXC=P10
      WDOT1=WDOT
      WYENT=Y1(ANT,TXC,TXC,PA,PXC)
      WDOT=WYENT*(PXC-PA)
      IF(ITRNO-N25)14480,14480,14481
14480  WDOT=(WDOT + WDOT1)/2.0
14481  CONTINUE
      DIV2=1.0
      GO TO 14280
2376  P10=0.75*P7
      IF(PTPCV)14270,14270,14260
14270  DIV2=PXC/P10
14280  P2=DIV2*P2
      P4= DIV2*P4
      P5= DIV2*P5
      P6= DIV2*P6
      P7= DIV2*P7
      P10=PXC
      P14=DIV2*P14

```

```

      CW14=CWFF(V14,RHQ14,RHQ140,P14,P140)
      WV14=CW14 *(P14-P140)
      W15=WYDST*(P6-P14)
      IF(W15)2390,2391,2391
2390  W15=0.1
2391  W18=WYTIT*(P14-PA)
      IF(PTPCV)19014,19014,19012
19012 IF(ITRND-N25)19016,19016,19014
19016 W18=(W18+W180+W1802)/3.0
19014 IF(W18-0.001)2392,2393,2393
2392  W18=0.001
2393  W13=W18-W15+WV14
      IF(PTPCV)14300,14300,14310
14310 W7=WDOT +W13 +WV10
      W6=W7 +WV7
      W5=W6 +W15 +WV6
      W4=W5 +WV5
      W2=W4 +WV4
      W1=W2
14300 PDST(1)=P6 -W15/Y1DST
      DO 2380 L=2,MH
2380  PDST(L)=PDST(L-1) - W15/YDST(L-1)
      P16=PDST(MH)
      PHST(MH)=P14 + W18/YHST(1)
      DO 2382 K=1,M1H
      L=MH-K
2382  PHST(L)=PHST(L+1) - W18/YHST(L)
      P17=PHST(1)
      P17P5=P17 - W18/Y1T0
      IF(P17P5)14452,14452,14453
14452 P17P5=P17*.9
14453 CONTINUE
      P19=PA + W18/YRN
      P18 = XP18(W18,T18,CT5,P19,CT5RAT)
      IF(P18)13050,13050,13052
13050 WRITE OUTPUT TAPE 6,13053
13053 FORMAT (10H- P18 BAD)
      ITFLAH=1
      GO TO 9999
13052 CONTINUE
C
C
      GO TO 2367
C
C
      CHECK PRESSURE CONVERGENCE
C
2354 IF(ABSF(PXC-P10)/PXC - PXCTOL)2370,2370,2366
2370  ITURB=ITRND
      ITRND=-1
      T4=T2
      HHN(1)=H2
2367 DO 1404 K=1,M1N
1404  WN(K)=W4/ALPHAN(K)
      PN(1)=P4-W4/YINN
      DO 1904 K=1,M1N
1904  PN(K+1) = PN(K) - WN(K) / YN(K)

```

```

C      DO 1900 I = 1, NR
      WR(I) = WYER(I)*(P5-P6)
1400   PR(I,1) = P5 - WR(I)/YINR(I)
      DO 1900 K=1,M1R
1900   PR(I,K+1) = PR(I,K) - WR(I)/YR(I,K)
C
      DO 1901 I = 1, NS
      WS(I) = WYES(I)*(P6-P7)
1401   PS(I,1) = P6 - WS(I)/YINS(I)
      DO 1901 K=1,M1S
1901   PS(I,K+1) = PS(I,K) - WS(I)/YS(I,K)
C
      DO 1902 I = 1, NC
      WC(I) = WYEC(I)*(P7-P10)
1402   PC(I,1) = P7 - WC(I)/YINC(I)
      DO 1902 K=1,M1C
1902   PC(I,K+1) = PC(I,K) - WC(I)/YC(I,K)
      W1=W2
5510   WRITE OUTPUT TAPE 6,5520,PXC,P00,P2,P4,P5,P6,P7,P14,P16,P17,P17P5
      1 ,P18,P19,SUM,Q1,H1D2,XNS,ETAP,POWP,ETAT,WDOT,W13,W15,W18
      2 ,W2,W4,W5,W6,W7,T14,T16,T17,T18,T19,PXCTOL,PTOLER,ITRNO,ITRNOH,
      3 T6,PZ,P1
      IF(ITRNO)2371,2368,1000
5520   FORMAT(6H0 PXC,11X,3HP10,12X,2HP2,13X,2HP4,13X,2HP5,13X,2HP6
      1/1P6E15.7/ 5H0 P7,12X,3HP14,12X,3HP16,12X,3HP17,12X,5HP17P5,
      2 10X,3HP18/1P6E15.7/6H0 P19,11X,3HSUM,12X,2HQ1,13X,4HH1D2,11X
      3 ,3HXNS,12X,4HETAP /1P6E15.7/ 7H0 POWP,10X,4HETAT,11X,4HWDOT,
      4 11X,3HW13,12X,3HW15,12X,3HW18/ 1P6E15.7 /5H0 W2,12X,
      5 2HW4,13X,2HW5,13X,2HW6,13X,2HW7,13X,3HT14 /1P6E15.7 / 6H0 T16 ,
      611X,3HT17,12X,3HT18,12X,3HT19,12X,6HPXCTOL,9X,6HPTOLER /1P6E15.7/
      7 7H0 TURB,11X,9HHEAT EXCH,6X,2HT6,13X,2HPZ,13X,2HP1 / 4X,13,12X,
      8 13,8X,1P3E15.7 / 1H- )
2368   WRITE OUTPUT TAPE 6,2356
      ITFLAH=1
      GO TO 9999
2356   FORMAT (1H-,24HSYSTEM DOES NOT CONVERGE )
C
2371   IF(INRX)13109,13109,13110

13109   IF(ABSF(T18OLD-T18)/T18 - T18TOL)8000,8000,8200
13110   WRITE OUTPUT TAPE 6,13111,P2,P2OLD
13111   FORMAT ( 4H- P2 F15.3,5X,5HP2OLD F15.3)
      IF(ABSF(P2-P2OLD)/P2 - PXCTOL)13112,13112,8009
13112   IF(ABSF(TXC0-T10)/T10 - TXCTOL)13120,13120,8009
13120   LATCH=2
      GO TO 549
C
C      CHECK TURBINE POWER CONVERGENCE
C
8000   POWT=W18*ETAT*(H18-H19)*9336.0
      IF(ABSF(POWP/POWT - 1.0) - POWTOL)8005,8005,8006
8005   LATCH=2
      PPOWT=4H*OK*
8006   IF(I8)8009,8009,8007
8007   WRITE OUTPUT TAPE 6,8008,POWP,POWT,PPOWT

```

TRANSFER POINT ON CONVERGENCE FOR TIME INTERVAL, DELTA

```

C      END OF DO LOOP ON JJ=1,MINOR
C
9000 IF(JJ - MINOR) 12357,9001,9001
9001 NOTICE =-5

```

```

C 9961      ITRNO = ITRNO/MINOR
      PRINT 50, TIME
      50 FORMAT(9H, TIME = E11.4)

```

```

C
C
C      DIMENSION HR(10,10),HS(10,10),HC(10,10),HN(20)
7055  FORMAT (1H1,3X,9HREFLECTOR .68X,5HTIME E11.4/ 1H0 )

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```

7023 FORMAT (1H1,3X,4HCORE ,73X,5HTIME E11.4/ 1H0 )
7002 FORMAT( 9X 4HP5 = F8.2,4H PSI 5X 4HT5 =, F8.2, 6H DEG R 5X 4HH5
1=, 1PE15.7,6HBTU/LB / )
7003 FORMAT( 9X 4HP6 = F8.2, 4H PSI 5X 4HT6 = F8.2, 6H DEG R 5X
14HH6 = 1PE15.7, 6HBTU/LB / )
7015 FORMAT( 9X 4HP7 = F8.2, 4H PSI, 5X, 4HT7 = F8.2, 6H DEG R, 5X
1,4HH7 = 1PE15.7, 6HBTU/LB / )
7027 FORMAT( 9X 4HP10= F8.2, 4H PSI, 5X, 4HT10= F8.2, 6H DEG R,5
1X,4HH10=1PE15.7,6HBTU/LB / )
7029 FORMAT(1H- 6X 14HCHANNEL NUMBER I3, 7X 3HWC(, I2, 3H) = E11.4)
7030 FORMAT(// 10X 4HNODE, 7X,2HPC, 9X, 2HTC, 9X 3HTCC, 10X 2HQC, 12X,
12HHC / 9X 6HNUMBER )
7035 FORMAT(1H1,3X,6HNOZZLE,71X,5HTIME E11.4/ 1H-,8X,4HW4 = F8.2,
1 7H LB/SEC //9X,4HP4 = F8.2, 4H PSI 5X,4HT4 = F8.2,6H DEG R 5X,
2 4HH4 = F8.2, 6HBTU/LB / )
7040 FORMAT(1H-, 4X,4HNODE,7X,2HPN,9X,2HTN,9X,3HTCN,8X,3HTAR,10X,2HQN
1 ,11X,2HHC,11X,2HHN,11X,5HHSOLN / 3X,6HNUMBER )
7041 FORMAT( 5X,I2,5X,F8.2,3F11.2,3X,E11.4,3E14.4)
7050 FORMAT (1H1,3X,9HTURBOPUMP 68X,4HTIMEE12.4/1H0,10X,5HPOWER F12.6,
1 5X,3HTXC F8.2,5X,3HPXC F8.2//9X,7HSTATION 20X,1HP 14X,1HT 12X,
2 4HWDOT 12X,5HWDOTV / 9X,6HNUMBER )
7051 FORMAT (10X,A6,5X,4F15.5)
7052 FORMAT (10X,A6,35X,F15.5)
7053 FORMAT (1H0,8X,4HWDOT 4X,F17.5 /9X,2HQ1 6X,F17.5 /9X,4HH1D2 4X,
1 F17.5 /9X,3HXNS 5X,F17.5 /9X,4HETAP 4X,F17.5 /9X,4HPOWP 4X,F17.5
2 /9X,4HETAT 4X,F17.5 /9X,1HU 7X,F17.5 /9X,3HGAT 5X,F17.5 /9X,2HCO
3 F23.5/9X,4HDELH F21.5/9X,2HPA F23.5/9X,4HTPCV F21.5/9X,5HXKTCV
4 F20.5/9X,4HTURB121,6H ITER./9X,10HHEAT EXCH,I15,6H ITER. )
1331 FORMAT (1H1,40X,29HHEAT EXCHANGER TEMPERATURES ///9X, 4HNODE
1 11X,4HPHST 9X,3HTHC 10X,3HTHE 10X,3HTHH 10X,4HPDST/9X,6HNUMBER//
2 (13X,I2,5F13.2,F14.3) )

```

LOOK UP TPCV AS F(XKTCV) FOR PRINT OUT PURPOSES ONLY

```

C
C
C
C
IF (INRX) 14203,14203,14201
14203 IF(PTPCV)14202,14202,14201
14202 CALL READKM (XKTCV,20,TPCV,NK)
14201 CONTINUE
WRITE OUTPUT TAPE 6,7050,TIME ,POWER,TXC,PXC
G=1H0
WRITE OUTPUT TAPE 6,7051, G, PZ,TZ
G=1H1
WRITE OUTPUT TAPE 6,7051, G, P1,T1,W1
G=1H2
WRITE OUTPUT TAPE 6,7051, G, P2,T2,W2
G=1H4
WRITE OUTPUT TAPE 6,7051, G, P4,T4,W4,WV4
G=1H5
WRITE OUTPUT TAPE 6,7051, G, P5,T5,W5,WV5
G=1H6
WRITE OUTPUT TAPE 6,7051, G, P6,T6,W6,WV6
G=1H7
WRITE OUTPUT TAPE 6,7051, G, P7,T7,W7,WV7
G=2H10

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```

WRITE OUTPUT TAPE 6,7051, G, P10,T10,WDOT,WV10
G=2H14
WRITE OUTPUT TAPE 6,7051, G, P14,T14,W14,WV14
G=2H13
WRITE OUTPUT TAPE 6,7052,G,W13
G=2H15
WRITE OUTPUT TAPE 6,7052,G,W15
G=2H16
WRITE OUTPUT TAPE 6,7051, G, P16,T16
G=2H17
WRITE OUTPUT TAPE 6,7051, G, P17,T17
G=4H17P5
WRITE OUTPUT TAPE 6,7051, G, P17P5,T17P5
G=2H18
WRITE OUTPUT TAPE 6,7051, G, P18,T18,W18
G=2H19
WRITE OUTPUT TAPE 6,7051, G, P19,T19
ITURB=XKKKF(TRNO)-ITURB
WRITE OUTPUT TAPE 6,7053,WDOT,Q1,H1D2,XNS,ETAP,POWP,ETAT,U,GAT,
1 CO,DELH,PA,TPCV,XKTCV,ITURB,ITRNOH
NOSTAT=16998
DO 16998 K=1,M1H
CALL READKM (THE(K),MATH,HSOLH(K),NK)
IF(NK)16998,16998,11999
16998 CONTINUE
WRITE OUTPUT TAPE 6,1331, (K,PHST(K),THC(K),THE(K),THH(K),
1 PDST(K),HSOLH(K),K=1,MH)
WRITE OUTPUT TAPE 6,7035,TIME,W4,P4,T4,HHN(1)
WRITE OUTPUT TAPE 6,7002,P5,T5,HHR(1,1)
DP=P4 - P5
DT=T5 - T4
Q=HHR(1,1) - HHN(1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
WRITE OUTPUT TAPE 6,7040
NOSTAT=17000
DO 17000 K=1,MN
IF(K-MN)16999,17000,17000
16999 CALL READKM (TCN(K),MATN,HSOLN(K),NK)
IF(NK)17000,17000,11999
17000 WRITE OUTPUT TAPE 6,7041, K,PN(K),TN(K),TCN(K),TAR(K),QN(K),
1 H(K),HHN(K),HSOLN(K)
W5 = 0.0
DO 7000 I=1,NR
7000 W5 = W5 + WR(I) * ALPHAR(I)
WRITE OUTPUT TAPE 6,7055,TIME
G=3HWS=
WRITE OUTPUT TAPE 6,7001,G,W5
WRITE OUTPUT TAPE 6,7002,P5,T5,HHR(1,1)
WRITE OUTPUT TAPE 6,7003,P6,T6,HHS(1,1)
DP=P5 - P6
DT=T6 - T5
Q=HHS(1,1) - HHR(1,1)
WRITE OUTPUT TAPE 6,7004,DP,DT,Q
DO 7008 I=1,NR
WRITE OUTPUT TAPE 6,7006,I,I,WR(I)
WRITE OUTPUT TAPE 6,7007

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```

      DU 7008 J=1,MR
7008 WRITE OUTPUT TAPE 6,7009, J,PR(I,J),TR(I,J),TCR(I,J),QR(I,J),
      1 HHR(I,J),HSOLR(I,J)
      WRITE OUTPUT TAPE 6, 7011,TIME
      W6 = 0.0
      DO 7012 I=1,NS
7012 W6 = W6 + WS(I) * ALPHAS(I)
      G=3HW6=
      WRITE OUTPUT TAPE 6,7001,G,W6
      WRITE OUTPUT TAPE 6,7003,P6,T6,HHS(1,1)
      WRITE OUTPUT TAPE 6,7015,P7,T7,HHC(1,1)
      DP=P6 - P7
      DT=T7 - T6
      Q=HHC(1,1) - HHS(1,1)
      WRITE OUTPUT TAPE 6,7004,DP,DT,Q
      DO 7020 I=1,NS
      WRITE OUTPUT TAPE 6,7018,I,I,WS(I)
      WRITE OUTPUT TAPE 6,7019
      DO 7020 J= 1,MS
7020 WRITE OUTPUT TAPE 6,7009, J,PS(I,J),TS(I,J),TCS(I,J),QS(I,J),
      1 HHS(I,J),HSOLS(I,J)
      WRITE OUTPUT TAPE 6,7023,TIME
      W7 = 0.0
      DO 7024 I=1,NC
7024 W7 = W7 + WC(I) * ALPHAC(I)
      G=3HW7=
      WRITE OUTPUT TAPE 6,7001,G,W7
      WRITE OUTPUT TAPE 6,7015,P7,T7,HHC(1,1)
      WRITE OUTPUT TAPE 6,7027,P00,T10,HHXC
      DP=P7 - P00
      DT=T10 - T7
      Q=HHXC - HHC(1,1)
      WRITE OUTPUT TAPE 6,7004,DP,DT,Q
      DO 7031 I=1,NC
      WRITE OUTPUT TAPE 6,7029,I,I,WC(I)
      WRITE OUTPUT TAPE 6,7030
      DO 7031 J= 1,MC
7031 WRITE OUTPUT TAPE 6,7009, J,PC(I,J),TC(I,J),TCC(I,J),QC(I,J),
      1 HHC(I,J),HSOLC(I,J)

```

```

      ITFLAH IS A FLAG ASSIGNED 0 UNLESS STOPPAGE CONDITION OCCURS.
      THEN IT IS 1

```

```

      WDOT13=WDOT+W13
      P18P19=P18/P19

```

```

      WRITE TAPE 22, TIME, W1, W2, W4, W5, W6, W7,
      1WDOT13, WDOT, W15, W13, W18, PZ, P1, P2, P4,
      2 P5, P6, P7, P10, PXC, P14, P17, P17P5, P18,
      3 P19, T2, T1, T2, T4, T5, T6, T7, T10,
      4 TXC, T16, T14, T17, T18, T19, WV4, WV5, WV6,
      5 WV7, WV10, WV14, POWER, PA,P18P19, TPCV, XNS, ETAT,
      6, ETAP, POWT, VPSP, DNT, DRNT,XPRATR,XPRATM, EFFMN, EFFRN

```

```

9899 IF(ITFLAH)9901,9901,30
9901 IF(TMAX-TIME)9951,9951,9902
9902 IF(NOTICE)9900,9900,9951

```

PLOT *

K
L
M
N
O
P
Q

```

9900 IF (II-MAJOR) 515, 9950, 9950
9950 IF (LIST-LIMIT) 510, 9951, 9951
9951 PRINT 9954
9954 FORMAT (// 8H PROBLEM)
9953 CONTINUE

```

C
C

```

30 CALL CHAIN(3,4)

```

PLOT *

C

```

1790 WRITE OUTPUT TAPE 6,1791,SENSE
31 ITFLAH=1
GO TO 9961
1791 FORMAT (17H- TEM9 FOR THE ,A6 )

```

C

```

99999 OUT=6HSECOND
WRITE OUTPUT TAPE6,99998,OUT,NOSTAT. (DAT(I),I=1,10)
GO TO 31
99998 FORMAT (/13H- ROUTINE ,A6,29H, BAD PRPTY LOOKUP. NOSTAT= I8
1 / 7X,6HDATA 1 1P5E15.7 / 12X,1H6 5E15.7)
11999 WRITE OUTPUT TAPE 6,11998,NOSTAT,I,K
IF(ITFLAH)31,31,30
11998 FORMAT (20H- SECOND-NOSTAT IS 17.1HI 15,1HK 15 )
13999 FORMAT (10H- BAD CPM ,5X,1HK 14,2X,7HSTAT NO I8// 5X,3HMAT
1 5X,5HSOL H,10X,5HOLD H,10X,1HT 14X,5HOLD T / 2X,13, 4E19.7)
END

```


SUBROUTINE FOR PUMP DATA (HEAD RISE)

```

*      FAP
*      CCUNT 300
*      SUBROUTINE CONTAINING PUMP DATA(MK 3 MOD 4)
*
*      SUBROUTINE CURVE3(QIN,HSVIN,ANSW)
*      ENTRY CURVE3
*
*
*      Q IS G/N
*      DELH IS HEAD RISE
*      HSV IS HSV/N**2
*
*      SUBROUTINE DINTX(AXT,AYT,AZT,NXZT,NY,X,Y,Z)
*      AXT ADDRESS OF X TABLE
*      AYT ADDRESS OF Y TABLE
*      AZT ADDRESS OF Z TABLE
*      NXZT FIRST DIMENSION OF X AND Z TABLES, X(NXZT,J)
*      NY NUMBER OF Y TABLE PTS.
*      X ARGUMENT
*      Y ARGUMENT
*      Z ANSWER
*
***** NOTE THAT LAST POINT OF EACH DELH AND G COLUMNS MUST BE ZERO FOR
***** DINTX USE.
*
REG PZE
PZE
PZE
CURVE3 SXD REG,4
SXD REG+1,1
SXD REG+2,2
CLA* 1,4
STO QIN
CLA* 2,4
STO HSVIN
CLA 3,4 ANSW
STA ANSW
STA RETURN-1
X4 CLA HSVIN QIN OK, CHECK HSVIN
FSB HSV
TZE *+2
IPL X6
REM
CLA HSV HSVIN TO SMALL
STO HSVIN
TRA LOCK
REM
X6 CLA HSVIN
FSB ENDFSV
TZE *+2
IMI LOOK HSVIN OK, DO INTERPOLATION
REM
REV HSVIN TOO LARGE
CLA ENDFSV

```

A
C

FN-DR-0068

```

      STO      HSVIN
      REM
      REM
      LOOK    TSX      $DINTX,4          DC DOUBLE LINEAR INTERPOLATION
      PZE      0
      PZE      HSV
      PZE      DELH
      PZE      NTAB
      PZE      NCURV
      PZE      QIN
      PZE      HSVIN
      PZE      *
      RETURN  LXI      REG,4             PUT ANSW HERE
      LXI      REG+1,1                 RETURN
      LXI      REG+2,2
      REM
      TRA      4,4
      NTAB    PZE      0,0,Q-ENDQ+1
      NCURV   PZE      0,0,HSV-ENDHSV+1
      DIV     PZE
      DIV2    PZE
      QIN     PZE
      HSVIN   PZE
      ANSW    PZE
      *
      REM     HSV  ARRAY
      *
      ENDHSV  DEC      2.E-6,1.E-6,.5E-6,.2E-6
      HSV     DEC      .15E-6
      *
      REM     DELH ARRAY          LAST PT MUST BE ZERO
      REM     COLUMN 5 STORED IN BACKWARDS ORDER
      DEC     .0
      DEC     5.E-5,5.E-5,5.26E-5,5.59E-5,5.74E-5,5.99E-5,6.25E-5,6.31E-5
      DEC     6.36E-5,6.43E-5,6.47E-5,6.48E-5,6.49E-5,6.495E-5,6.498E-5
      DEC     6.5E-5,6.495E-5,6.43E-5,6.31E-5,6.14E-5,6.04E-5,5.8E-5
      DEC     5.67E-5,5.52E-5,5.35E-5,5.E-5
      DEC     5.E-5
      REM     COLUMN 4 STORED IN BACKWARDS ORDER
      DEC     .0
      DEC     5.E-5,5.E-5,5.02E-5,5.06E-5,5.25E-5,5.75E-5,6.16E-5,6.25E-5
      DEC     6.32E-5,6.4E-5,6.43E-5,6.45E-5,6.46E-5,6.465E-5,6.47E-5
      DEC     6.47E-5,6.46E-5,6.37E-5,6.18E-5,5.94E-5,5.8E-5,5.49E-5
      DEC     5.33E-5,5.15E-5,5.03E-5,5.E-5
      DEC     5.E-5
      REM     COLUMN 3 STORED IN BACKWARDS ORDER
      DEC     .0
      DEC     5.E-5,5.E-5,5.E-5,5.01E-5,5.02E-5,5.03E-5,5.05E-5,5.77E-5
      DEC     6.1E-5,6.31E-5,6.39E-5,6.42E-5,6.43E-5,6.45E-5,6.45E-5
      DEC     6.44E-5,6.4E-5,6.27E-5,6.06E-5,5.77E-5,5.6E-5,5.25E-5
      DEC     5.09E-5,5.04E-5,5.02E-5,5.E-5
      DEC     5.E-5
      REM     COLUMN 2 STORED IN BACKWARDS ORDER
      DEC     .0
      DEC     5.E-5,5.E-5,5.E-5,5.01E-5,5.01E-5,5.02E-5,5.03E-5
      DEC     5.04E-5,5.14E-5,5.14E-5,6.27E-5,6.35E-5,6.41E-5,6.43E-5

```

I
G
H
I
J

```

DEC      6.4E-5,6.35E-5,6.18E-5,5.95E-5,5.64E-5,5.48E-5,5.1E-5
DEC      5.05E-5,5.02E-5,5.01E-5,5.E-5
DEC      5.E-5
REM      COLUMN 1 STORED IN BACKWARDS ORDER
DEC      .0
DEC      5.E-5,5.E-5,5.E-5,5.E-5,5.E-5,5.E-5,5.E-5,5.01E-5,5.015E-5
DEC      5.02E-5,5.03E-5,5.04E-5,5.05E-5,5.06E-5,5.07E-5,5.08E-5
DEC      5.09E-5,5.10E-5,5.11E-5,5.12E-5,5.13E-5,5.14E-5,5.15E-5
DEC      5.02E-5,5.015E-5,5.01E-5
DEC      5.E-5
DEC      5.E-5
DELT
*
*
REM      COLUMN 5 STORED IN BACKWARDS ORDER
DEC      .0
DEC      7.,.628.,.6.,.56.,.54.,.5.,.44.,.42.,.4.,.37.,.35.,.34.,.33.,.32.,.31
DEC      .3.,.28.,.24.,.2.,.16.,.14.,.1.,.08.,.06.,.04.,.004
DEC      .0
REM      COLUMN 4 STORED IN BACKWARDS ORDER
DEC      .0
DEC      7.,.628.,.6.,.56.,.54.,.5.,.44.,.42.,.4.,.37.,.35.,.34.,.33.,.32.,.31
DEC      .3.,.28.,.24.,.2.,.16.,.14.,.1.,.08.,.06.,.04.,.004
DEC      .0
REM      COLUMN 3 STORED IN BACKWARDS ORDER
DEC      .0
DEC      7.,.628.,.6.,.56.,.54.,.5.,.44.,.42.,.4.,.37.,.35.,.34.,.33.,.32.,.31
DEC      .3.,.28.,.24.,.2.,.16.,.14.,.1.,.08.,.06.,.04.,.004
DEC      .0
REM      COLUMN 2 STORED IN BACKWARDS ORDER
DEC      .0
DEC      7.,.628.,.6.,.56.,.54.,.5.,.44.,.42.,.4.,.37.,.35.,.34.,.33.,.32.,.31
DEC      .3.,.28.,.24.,.2.,.16.,.14.,.1.,.08.,.06.,.04.,.004
DEC      .0
REM      COLUMN 1 STORED IN BACKWARDS ORDER
DEC      .0
DEC      7.,.628.,.6.,.56.,.54.,.5.,.44.,.42.,.4.,.37.,.35.,.34.,.33.,.32.,.31
DEC      .3.,.28.,.24.,.2.,.16.,.14.,.1.,.08.,.06.,.04
DEC      .004
DEC      .0
Q
*
END

```

SUBROUTINE INTX

C

```
SUBROUTINE INTX(X,Y,XI,YO)
DIMENSION X(1),Y(1)
I = 1
10 I = I + 1
IF(X(I+1))20,30,20
20 IF(X(I)-X1)10,30,30
30 YO = (XI-X(I-1))/(X(I)-X(I-1))*(Y(I)-Y(I-1)) +Y(I-1)
RETURN
END
```

SUBROUTINE DINTX

C

```

SUBROUTINE DINTX(X,Z,Y,M,N,XIN,ZIN,YOUT)
DIMENSION X(1),Y(1),Z(1),XZ(3),YZ(3)
NN=N
DO 10 I=2,NN
J=(I-2)*M+1
K=(I-1)*M+1
XZ=Z(I-1)
XZ(2)=Z(1)
IF(Z(I)-ZIN)10,20,20
10 CONTINUE
20 CALL INTX(X(J),Y(J),XIN,YZ)
CALL INTX(X(K),Y(K),XIN,YZ(2))
CALL INTX(XZ,YZ,ZIN,YOUT)
RETURN
END

```