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**BLAST: A Digital Computer Program for
the Dynamic Simulation of the High
Temperature Gas Cooled Reactor
Reheater-Steam Generator Module**

R. A. Hedrick
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OAK RIDGE NATIONAL LABORATORY

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**BLAST: A DIGITAL COMPUTER PROGRAM FOR THE DYNAMIC
SIMULATION OF THE HIGH TEMPERATURE GAS COOLED
REACTOR REHEATER-STEAM GENERATOR MODULE**

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Reactor Division

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ABSTRACT

BLAST simulates the high temperature gas cooled reactor reheater-steam generator module with a multi-node, fixed boundary, homogenous flow model. The time dependent conservation of energy, mass, and momentum equations are solved by an implicit integration technique. The code contains equation of state formulations for both helium and water as well as heat transfer and friction factor correlations. Normal operational transients and more severe transients such as those resulting in low and/or reverse flow can be simulated. The code calculates helium and water temperature, pressure, flow rate, and tube bulk and wall temperatures at various points within the reheater-steam generator module during the transients. BLAST predictions will be compared with dynamic test results obtained from the Fort St. Vrain reactor owned by Public Service of Colorado, and, based on these comparisons, appropriate improvements will be made in BLAST. BLAST is written in FORTRAN IV for the IBM 360/91 computer at the Oak Ridge National Laboratory.

Keywords: gas cooled reactors, dynamic response, programs (computer), once-through steam generator.

TABLE OF NOMENCLATURE

Symbols

A	flow area (ft^2)
C	conductance ($\text{Btu/sec-}^\circ\text{F}$)
c_p	specific heat capacity at constant pressure ($\text{Btu/lbm-}^\circ\text{R}$)
c_v	specific heat capacity at constant volume ($\text{Btu/lbm-}^\circ\text{R}$)
D_H	hydraulic diameter (in.)
ϵ	tube surface roughness (in.)
f_{Re}	friction factor
g	acceleration of gravity (32.2 ft/sec^2)
g_c	conversion constant ($32.2 \text{ lbm-ft/sec}^2\text{-lbf}$)
H	specific enthalpy (Btu/lbm)
h	convective heat transfer coefficient ($\text{Btu/sec-ft}^2\text{-}^\circ\text{F}$)
k	tube conductivity ($\text{Btu/sec-ft-}^\circ\text{F}$)
L	flow length of node (ft)
M	mass (lbm)
N	number of water nodes, number of tube nodes
N^*	number of helium nodes
Nu	Nusselt number
P	pressure (psia)
Pr	Prandtl number
Re	Reynolds number
R_{in}	tube inner radius (in.)
R_{out}	tube outer radius (in.)
ρ	density (lbm/ft^3)

T	temperature ($^{\circ}\text{F}$)
t	time (sec)
Δt	calculational time step (sec)
U	internal energy (Btu)
u	specific internal energy (Btu/lbm)
v	specific volume (ft^3/lbm)
W	mass flow rate (lbm/sec)
z	axial height (ft)

Superscripts

w	denotes water node variable
h	denotes helium node variable
t	denotes tube node variable

Subscripts

i, j or k	water or tube node index
i*, j*, k*	helium node index
f	denotes saturated liquid property
g	denotes saturated vapor property
SAT	denotes saturation property
out	nodal outlet
in	nodal inlet
I	index denoting table entry

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INTRODUCTION

BLAST was developed specifically to predict the dynamic response of the high temperature gas cooled reactor (HTGR) reheater-steam generator module for use in a system response code for the HTGR plant. A typical HTGR reheater-steam generator module, developed by the General Atomic Company, is shown in Figure 1. The HTGR utilizes a once-through steam generator. The code is not limited to the specific design shown in Figure 1 and can be used to simulate different designs with appropriate input description. The version of BLAST described here is the component simulation. Slight modifications are required to incorporate this component simulation into a system response code.

This report contains a derivation of the integration technique used to solve the conservation equations, a discussion of the heat transfer and friction factor calculations, and of the equation of state formulation both for helium and for water, an input description and a sample problem. A FORTRAN IV listing or deck is available upon request.

STEAM GENERATOR DESCRIPTION

Identical reheater-steam generator modules are located in symmetric cavities within the prestressed concrete reactor vessel (PCRV) of the HTGR. The 2000 MW(t) HTGR contains four such modules, and the 3000 MW(t)

Fig. 1. Large HTGR plant steam generator.

plant contains six. Each module is composed of reheater and main steam tube bundles arranged as shown in Figure 1. The heat exchanger bundles consist of multistart coils wound in a helical arrangement. Hot helium enters the reheater near the bottom of the module, flows down over the reheater tube banks, up through a central duct, and down over the main steam bundle. The reheater tubes are coiled upward and then downward so that the reheat steam flow is initially countercurrent and then co-current to the helium flow. The water-steam flow in the main steam bundle is upward, countercurrent to the helium flow. Further design details of the module shown in Figure 1 are indicated in the input to the sample problem (Appendix B).

CONSERVATION EQUATIONS

BLAST solves the conservation of energy, mass, and momentum equations for both helium and water and the conservation of energy equation for the tube in nodal form. Figure 2 shows schematically a nodal arrangement representing the design shown in Figure 1. Since a more detailed nodal structure is often desirable on the water side than on the helium side, the code allows for more than one tube metal node to receive heat from a given helium node. Each tube node must have one associated water node. As many as twenty water nodes, twenty helium nodes, and twenty tube nodes may be used to represent the four sections—reheater, economizer, evaporator, and superheater—of the reheater-steam generator module. Another version of the code has been developed which allows as many as 100 water nodes, 100 helium nodes, and 100 tube nodes and allows parallel flow paths. This version yields nodal temperatures and pressures in sufficient detail for input to stress analyses.

Fig. 2. HTGR reheater-steam generator nodal arrangement.

Figure 3 shows a general case in which three tube nodes receive heat from one helium node. The conservation equations for water node j are as follows:

Conservation of energy:

$$\frac{dU_j^w}{dt} = H_j^w W_i^w - H_k^w W_j^w + C_j^w (T_j^t - T_j^w), \quad (1)$$

(rate of change
of nodal inter-
nal energy)

(net rate of en-
ergy flow into
node via trans-
port)

(rate of energy
transfer via
convection and
conduction)

where H_j^w is the inlet enthalpy to water node j , and C_j^w , the conductance from the tube node to the water node, is given by

$$C_j^w = \frac{2\pi R_{in,j} L_j^w}{\left[\frac{R_{in,j} \ln(R_j/R_{in,j})}{k_j} \right] + \frac{1}{h_j^w}},$$

with

$$\bar{R}_j = \frac{R_{in,j} + R_{out,j}}{2}.$$

Conservation of mass:

$$\frac{dM_j^w}{dt} = W_i^w - W_j^w, \quad (2)$$

(rate of change
in nodal mass)

(mass flow rate
into node)

(mass flow rate
out of node)

Conservation of momentum:

$$L_j^w \frac{dW_j^w}{dt} = 144g_c A_j^w (P_j^w - P_k^w) - \rho_j^w g A_j^w (z_{out,j}^w - z_{in,j}^w) +$$

(rate of change
of momentum of
fluid in node)

(net force on fluid
in node due to pres-
sure difference)

(gravitational force
on fluid in node)

UPSTREAM HELIUM NODE IS i*
DOWNSTREAM HELIUM NODE IS k*

Fig. 3. Typical nodal description.

$$\left[\frac{(W_i^w)^2}{\rho_i^w A_i^w} - \frac{(W_j^w)^2}{\rho_j^w A_j^w} \right] - f_{Re} \left[\frac{12L_j^w}{D_{H,j}} \frac{|W_i^w| |W_j^w|}{2\rho_j^w A_j^w} \right] \quad (3)$$

(rate of momentum inflow - rate of momentum outflow) (drag due to frictional force)

Note that changes of kinetic and potential energy have been neglected in the conservation of energy equation.

The water node pressures and temperatures are considered to be functions of internal energy and mass, i.e.,

$$P_j^w = P_j^w(U_j^w, M_j^w) \quad \text{and} \quad T_j^w = T_j^w(U_j^w, M_j^w)$$

Since the typical nodal description shown in Figure 2 allows more than one tube node to transfer heat with the helium node, the conservation of energy equation for the helium node j^* is:

Conservation of Energy:

$$\frac{dU_{j^*}^h}{dt} = H_{j^*}^h W_{j^*}^h - H_{k^*}^h W_{j^*}^h - \sum_{\alpha=i,j,k} C_{j^*,\alpha}^h (T_{j^*}^h - T_{\alpha}^t) \quad (4)$$

(rate of change of nodal internal energy)	(net rate of energy flow into node via transport)	(rate of energy transfer via convection and conduction)
---	---	---

where $C_{j^*,\alpha}^h$ the conductance from helium node j^* to tube node α (with $\alpha = i, j$, or k) is

$$C_{j^*,\alpha}^h = \frac{2\pi R_{out,\alpha} L_{\alpha}^t (NT)_{\alpha}}{\left[\frac{R_{out,\alpha} \ln(R_{out,\alpha}/R_{\alpha})}{k_{\alpha}} \right] + \frac{1}{h_{j^*}^h}}$$

where L_{α}^t is the length of tubing in tube node α , and $(NT)_{\alpha}$ is the number of tube coils which receive heat from the helium node. The summation over i, j and k accounts for the fact that in the typical configuration shown in Figure 3, three tube nodes transfer heat with one helium node.

The conservation of mass and momentum equations for helium node j^* are similar to those for water node j . They are given below for later reference.

Conservation of mass:

$$\frac{dM_{j^*}^h}{dt} = W_{i^*}^h - W_{j^*}^h \quad (5)$$

(rate of change
in nodal mass)
(mass flow rate
into node)
(mass flow rate
out of node)

Conservation of momentum:

$$L_j^h \frac{dW_{j^*}^h}{dt} = 144g_c A_{j^*}^h (P_{j^*}^h - P_{k^*}^h) - \rho_{j^*}^h z_{j^*}^h (z_{out,j^*}^h - z_{in,j^*}^h) +$$

(rate of change
of momentum of
fluid in node)
(net force on fluid
in node due to pres-
sure difference)
(gravitational force
on fluid in node)

$$\left(\frac{(W_{i^*}^h)^2}{\rho_{i^*}^h A_{i^*}^h} - \frac{(W_{j^*}^h)^2}{\rho_{j^*}^h A_{j^*}^h} \right) - f_{Re} \left(\frac{12L_{j^*}^h}{D_{H,j^*}} \frac{|W_{j^*}^h| W_{j^*}^h}{2\rho_{j^*}^h A_{j^*}^h} \right) \quad (6)$$

(rate of momentum in-
flow - rate of momentum
outflow)
(drag due to fric-
tional force)

The helium nodal pressures and temperatures are considered to be functions of nodal internal energy and mass, i.e.,

$$P_{j*}^h = P_{j*}^h \left(U_{j*}^h, M_{j*}^h \right), \quad T_{j*}^h = T_{j*}^h \left(U_{j*}^h, M_{j*}^h \right).$$

The conservation of energy equation for tube node j is:

$$M_j^t c_p^t \frac{dT_j^t}{dt} = C_{j*,j}^h (T_{j*}^h - T_j^t) - C_j^w (T_j^t - T_j^w). \quad (7)$$

(rate of change
of internal energy
in tube node)

(rate of heat transfer
from helium by
conduction and con-
vection)

(rate of heat transfer
to water by con-
duction and convection)

HEAT TRANSFER CORRELATIONS, FRICTION FACTOR CORRELATIONS AND TUBE PROPERTIES

In order to solve the conservation equations (Eqs. 1-7), values for convective heat transfer coefficients on both the helium and water side and the tube properties, ρ , c_p and k must be obtained. To obtain the convective heat transfer coefficient on the helium side, BLAST uses the modified Grimson correlation¹ for helium flowing over banks of tubes:

$$Nu = B(Re)^n (Pr/0.69)^{0.33},$$

where B and n are tabulated in Reference 1 as functions of the transverse and longitudinal pitch to diameter ratios. These functions are stored in the code.

For the helium side friction factor, the code uses correlations² for flow over banks of tubes based on the transverse and longitudinal pitch to diameter ratios and the Reynolds number. Allowance is made for tube arrangements that are partly inline and partly staggered by

weighting the correlations for inline tubes and staggered tubes appropriately.

Various correlations are used to determine the heat transfer coefficient on the water side depending on the water flow regime. These correlations are listed in Table 1. The correlations for departure from nucleate boiling (DNB) flux, also given in Table 1, are used as trips to determine when two phase correlations beyond DNB rather than the nucleate boiling correlation should be applied. Trips from other flow regimes are based on quality (e.g., from film boiling to superheat forced convection) or on a comparison of tube wall to bulk fluid temperature drop as calculated by correlations for adjacent flow regimes. For example, if a Dittus-Boelter correlation in the subcooled forced convection flow regime results in a tube wall to bulk temperature drop greater than the Thom nucleate boiling correlation, but the DNB flux has not been exceeded, the nucleate boiling heat transfer correlation is used.

Friction factors on the water side are obtained from fits to the Fanning friction factor curves.¹² In the two phase regions, Martinelli-Nelson two phase multipliers¹³ or Thom modified Martinelli-Nelson two phase multipliers¹⁴ are applied depending on the pressure. The curvature effects for helically wound tubes are also taken into account based on information in Reference 1.

Presently the code contains density, conductivity and specific heat for three tube types: Carbon steel (SA-210-A1), Incoloy 800 and Croloy (SA-213-T22). Properties for other tube materials could easily be added by the user if necessary.

Table 1. Heat transfer and DNB flux correlations*

Regime	Correlation
Subcooled forced convection	Dittus-Boelter
Two phase	
a. Nucleate boiling (subcooled and saturated)	Thom ³
b. Transition boiling	McDonough-Milich & King ⁴
c. Film boiling	Dougall Rosenhow ⁵ or Groeneveld ⁶ or Morgan ⁷ (for low flow)
Superheat forced convection	Dittus-Boelter
DNB flux	W-3 ⁸ , Jansen-Levy ⁹ or B&W-2 ¹⁰ , Barnett ¹¹

*These correlations were chosen on the basis that they are acceptable for emergency core cooling system evaluations for light water cooled reactors (10-CFR-50, Appendix K).

STEADY STATE SEARCH TECHNIQUE

At the beginning of each run, the code performs a steady state search. The flow rate in each node is input equal to the specified inlet flow rate so that the steady state conservation of mass equations (2) and (5) are automatically satisfied. Starting with initial guesses at nodal pressures and enthalpies, the code determines $\frac{dW}{dt}$ for each helium and water node by evaluating the right hand side of the momentum equations (3) and (6). Unless the correct steady state values of nodal enthalpies and pressures have been supplied, $\frac{dW}{dt}$ will not be zero. Beginning with the inlet nodes to the reheater and main steam bundle, the code next adjusts the nodal pressures so that this time derivative is zero for each node. Using these adjusted pressures and the original enthalpies, the above process is repeated (i.e., $\frac{dW}{dt}$ is computed for each node from equations (3) and (6) and the nodal pressures readjusted to force $\frac{dW}{dt}$ to equal zero) for the new states until nodal pressures converge.

Next, a guess at nodal tube temperatures is made so that the temperature dependent tube conductivity can be estimated. Heat transfer coefficients for helium and water nodes are also calculated so that the nodal heat fluxes can be found. These nodal heat fluxes, along with the inlet flow rates and enthalpies to the reheater and main steam bundle are then used to determine nodal outlet enthalpies, assuming steady state. The average nodal enthalpies are then determined and compared with the previous guesses of nodal enthalpies. If they differ by more than a preset convergence criteria, the code repeats the iteration on nodal pressure discussed in the previous paragraph using the new values of nodal enthalpy. This iterative technique is continued until convergence

is achieved on helium and water nodal pressures and enthalpies and on nodal tube temperatures.

INTEGRATION TECHNIQUE FOR TRANSIENT SOLUTION

Defining N to be the number of water nodes and the number of tube nodes and N^* to be the number of helium nodes, the conservation equations (1-7) can be written in state variable form as

$$\dot{\underline{y}}(t) = \underline{f}[\underline{y}(t)] , \quad (8)$$

where $\underline{y}$ is the $4N + 3N^*$ column vector of state variables:

$$\underline{y} = \left(U_1^w, \dots, U_n^w, M_1^w, \dots, M_n^w, W_1^w, \dots, W_n^w, T_1^t, \dots, T_n^t, U_1^h, \dots, U_{n^*}^h, M_1^h, \dots, M_{n^*}^h, W_1^h, \dots, W_{n^*}^h \right) ,$$

and $\underline{f}[\underline{y}(t)]$ is the $4N + 3N^*$ column vector of functions determined by the right-hand sides of equations (1-7). The value of the n th state variable at time $t + \Delta t$, where Δt is the computational time step, can be written in terms of state variables at time t by a linearized implicit formulation:

$$y_n(t + \Delta t) \doteq y_n(t) + (\Delta t) \frac{dy_n(t + \Delta t)}{dt} , \quad (9)$$

where, using Eq. 8,

$$\frac{dy_n(t + \Delta t)}{dt} = f_n[\underline{y}(t + \Delta t)] \doteq f_n[\underline{y}(t)] + (\Delta t) \frac{d}{dt} f_n[\underline{y}(t)] . \quad (10)$$

Applying the chain rule to the $\frac{d}{dt}f_n[y(t)]$ term gives

$$\frac{dy_n(t+\Delta t)}{dt} = f_n[y(t)] + (\Delta t) \sum_{m=1}^{4N+3N^*} \frac{\partial f_n[y(t)]}{\partial y_m} \frac{dy_m(t)}{dt} . \quad (11)$$

Approximating $\frac{dy_m(t)}{dt}$ in Eq. 11 by $\frac{y_m(t+\Delta t) - y_m(t)}{\Delta t}$ and substituting Eq. 11 into Eq. 9 gives

$$\Delta y_n - (\Delta t) \sum_{m=1}^{4N+3N^*} \frac{\partial f_n[y(t)]}{\partial y_m} \Delta y_m = (\Delta t) f_n[y(t)] , \quad (12)$$

where $\Delta y_n \equiv y_n(t+\Delta t) - y_n(t)$.

This equation can be written in terms of the Jacobian matrix, $J[y(t)]$, as

$$[\underline{I} - (\Delta t)J[y(t)]]\Delta y = (\Delta t)f[y(t)] ,$$

where $\underline{I}$ is the identity matrix, and the lm th element of $\underline{J}$ is $\frac{\partial f_l}{\partial y_m}$.

Next, each of the conservation equations (1-7) is cast in the form of Equation 12. For example, the conservation of energy equation for water node j (Eq. 1) becomes,

$$\Delta U_j^w - (\Delta t) \left[H_j^w \Delta W_1^w - H_k^w \Delta W_j^w + C_j^w \left(\Delta T_j^t - \frac{\partial T_j^w}{\partial U_j} \Delta U_j^w - \frac{\partial T_j^w}{\partial M_j} \Delta M_j^w \right) \right] = (\Delta t) \frac{dU_j^w(t)}{dt} . \quad (13)$$

Note that the two partial derivative terms appear because the nodal water temperature, T_j^w , is considered to be a function of the state variables, U_j^w and M_j^w . Note also that H_j^w and H_k^w , the nodal inlet and

outlet enthalpies, and C_j^w , the conductance from the tube node to the water, have been assumed constant during Δt so that, for instance, there is no $\partial H_j^w / \partial U_j^w$ term in Equation 13. Inlet and outlet enthalpies and conductances are recomputed at the end of each time step.

Writing the momentum Equations (3) and (6) for water and helium in the form of Equation (12) introduces $\frac{\partial P}{\partial U}$, $\frac{\partial P}{\partial M}$, $\frac{\partial \rho}{\partial U}$, $\frac{\partial \rho}{\partial M}$ terms. However, terms containing the derivatives of density are orders of magnitude smaller than terms containing the derivatives of pressure and are, therefore, neglected. Also, the friction factors are assumed constant during Δt and are recomputed at the end of each time step.

When all of the conservation Equations (1-7) have been written in the implicit form of Equation (12), terms containing ΔU^w , ΔM^w , ΔW^w , $\partial T^w / \partial U$, $\partial T^w / \partial M$, $\partial P^w / \partial U$, and $\partial P^w / \partial M$ for water nodes, similar terms for the helium nodes, and ΔT^t for the tube nodes have been introduced. The ΔU^w , ΔU^h , ΔM^w , and ΔM^h terms can be eliminated from the $4N + 3N^*$ equations by algebraic manipulation, leaving a $2N + N^*$ system of equations that may be written

$$\underline{A} \underline{v} = \underline{b} , \quad (14)$$

where $\underline{v}$ is the $2N + N^*$ column vector

$$\left(\Delta W_1^w, \dots, \Delta W_N^w, \Delta T_1^t, \dots, \Delta T_N^t, \Delta W_1^h, \dots, \Delta W_{N^*}^h \right) .$$

$\underline{A}$ and $\underline{b}$ are determined by the values, at time t , of heat transfer coefficients, tube properties, friction factors, enthalpies the derivatives

of pressure and temperature with respect to internal energy and mass and the values of the right-hand sides of the conservation Equations (1-7). Once the components of $\underline{A}$ and $\underline{b}$ have been determined, Equation (14) is solved by inverting $\underline{A}$. From the resulting values of ΔW^w and ΔW^h for the water and helium nodes and ΔT^t for the tube nodes ΔU^w , ΔU^h , ΔM^w , ΔM^h can be determined by back substitution into the conservation equations which were written in the form of Equation 12.

Results obtained using the implicit integration technique described above agree quite well with results obtained using an explicit Euler integration technique. For HTGR transients, which tend to be "slow"—from a few minutes to an hour or two in duration—the implicit integration technique is judged superior since explicit techniques are limited to small time steps by stability considerations. A discussion of the stability and error propagation for the implicit technique is given in Reference 15.

The version of the code which allows up to 100 helium nodes, 100 water nodes, and 100 tube nodes to provide the detailed temperature and pressure distributions required for stress analysis employs the explicit integration technique. The implicit technique is not suitable for simulations using this large number of nodes because it requires inversion of the $\underline{A}$ matrix (Eq. 14).

EQUATION OF STATE AND THERMODYNAMIC TRANSPORT PROPERTIES - HELIUM

In order to calculate terms in the $\underline{A}$ matrix and the $\underline{b}$ vector in Equation (14), the helium state and thermodynamic transport properties must be found. The solution at time t yields values of $U(t)$ and $M(t)$

for each helium node. From internal energy and mass, the code determines temperature and pressure and their derivatives with respect to internal energy and mass as well as the transport properties μ , c_p and k . The helium nodal temperature, in degrees Rankine, is found by

$$T = \frac{1}{c_v} u, \quad (15)$$

where u is specific internal energy (Btu/lbm-°R) and c_v is the specific heat at constant volume (.75 Btu/lbm-°R). Nodal pressure follows from the helium equation of state (Ref. 16).

$$P = \frac{1}{\frac{B}{\rho T} - \frac{A}{T^{1.2}}}, \quad (16)$$

where A and B are constants. The derivatives of temperature with respect to internal energy and mass are found from Equation (15):

$$\left. \frac{\partial T}{\partial u} \right|_M = \frac{1}{M} \left. \frac{\partial T}{\partial u} \right|_\rho = \frac{1}{M c_v},$$

and

$$\begin{aligned} \left. \frac{\partial T}{\partial M} \right|_U &= \frac{1}{V} \left. \frac{\partial T}{\partial \rho} \right|_{u\rho}, \\ &= \frac{1}{V} \frac{dT}{du} \left. \frac{\partial u}{\partial \rho} \right|_{u\rho}, \\ &= \frac{1}{V c_v} \left. \frac{\partial}{\partial \rho} \left(\frac{u\rho}{\rho} \right) \right|_{u\rho}, \\ &= - \frac{1}{V c_v} \left(\frac{u}{\rho} \right). \end{aligned} \quad (17)$$

The derivatives of pressure with respect to internal energy and mass are obtained as follows:

$$\left. \frac{\partial P}{\partial U} \right|_M = \frac{1}{M} \left. \frac{\partial P}{\partial u} \right|_\rho = \frac{1}{M} \frac{dT}{du} \left. \frac{\partial P}{\partial T} \right|_\rho .$$

From Equation (16)

$$\left. \frac{\partial P}{\partial T} \right|_\rho = \frac{P^2}{T} \left[\frac{B}{\rho T} - \frac{1.2A}{T^{1.2}} \right] ,$$

so

$$\left. \frac{\partial P}{\partial U} \right|_M = \frac{1}{Mc_v} \frac{P^2}{T} \left[\frac{B}{\rho T} - \frac{1.2A}{T^{1.2}} \right] . \quad (18)$$

Finally

$$\left. \frac{\partial P}{\partial M} \right|_U = \frac{1}{V} \left. \frac{\partial P}{\partial \rho} \right|_{u\rho} .$$

Equations (15) and (16) can be combined to give

$$P = \frac{1}{\frac{Bc_v}{\rho u} - \frac{A(\rho c_v)^{1.2}}{(\rho u)^{1.2}}} ,$$

and it follows that

$$\left. \frac{\partial P}{\partial M} \right|_U = \frac{P^2}{V} \frac{(1.2)A}{\rho T^{1.2}} . \quad (19)$$

The thermodynamic transport properties are obtained from the following fits to data in the indicated references

$$\begin{aligned} \mu &= 5.9178 \times 10^{-4} T^{0.7} \text{ (lbm/ft-hr) } , \text{ (Ref. 16) } , \\ k_{he} &= 1.29 \times 10^{-3} T^{0.674} + 8.15 \times \\ &\quad 10^{-4} (P - 14.69)^{0.28} \text{ (Btu/hr-ft-}^\circ\text{R) } , \text{ (Ref. 17) } , \end{aligned}$$

$$c_p = 1.2462 \frac{\text{Btu}}{\text{lb}_m \text{ } ^\circ\text{R}}, \text{ (Ref. 16) },$$

where T is in degrees Rankine, and P is psia.

EQUATION OF STATE AND THERMODYNAMIC TRANSPORT PROPERTIES - WATER

Determining the state and transport properties for each water node is somewhat more involved than for helium. The water equation of state is determined by data from the 1967 ASME Steam Tables (Ref. 18), that is stored in BLAST in tabular form. For a series of values of saturation pressure the tables contain the corresponding values of ρ_f , ρ_g , u_f , u_g , and T_{SAT} . In the subcooled region the code also stores

$$\left. \frac{\partial u}{\partial P} \right|_{\rho}, \left. \frac{\partial h}{\partial P} \right|_{\rho}, \left. \frac{\partial T}{\partial P} \right|_{\rho},$$

and in the superheat region, the code stores

$$\left. \frac{\partial P}{\partial u} \right|_{\rho}, \left. \frac{\partial h}{\partial P} \right|_{\rho}, \left. \frac{\partial T}{\partial P} \right|_{\rho}.$$

This information was obtained from References 19 and 20. The thermodynamic transport properties of viscosity, conductivity, specific heat and Prandtl number are determined from fits to the 1967 ASME steam tables.

The code applies interpolation and iteration techniques to calculate pressure, temperature and the required derivatives using the above information from values of specific internal energy, u , and density, ρ , known at time t . In the single phase regions the techniques are basically those presented in Reference 20.

The first step in the pressure search is to compare the density, ρ , to the critical density, and the specific internal energy, u , to the saturated specific internal energy, u_{SAT} , at the known density ρ . The value of u_{SAT} is calculated by interpolation on density. From this, it can be determined whether the water is in a liquid, two phase or vapor state.

If the water is in the liquid phase, the saturation pressure, P_{SAT} , and the derivative, $\left. \frac{\partial P}{\partial u} \right|_{\rho}$ at the known density, are determined by linear interpolation on density from data stored in the tables. Then the pressure, P , is found from

$$P = P_{SAT} + \left. \frac{\partial P}{\partial u} \right|_{\rho} (u - u_{SAT}) . \quad (20)$$

The enthalpy follows since $h = u + P/\rho$. Nodal temperatures are next determined using interpolated values from the tables of T_{SAT} and $\left. \frac{\partial T}{\partial P} \right|_{\rho}$ at the known density:

$$T = T_{SAT} + \left. \frac{\partial T}{\partial P} \right|_{\rho} (P - P_{SAT}) . \quad (21)$$

To calculate $\left. \frac{\partial P}{\partial \rho} \right|_{u\rho}$, recall that pressure may be considered a function of specific internal energy and density, i.e.,

$$P = P(u, \rho) .$$

Let ρ_I and ρ_{I+1} be the densities stored in the tables that bracket the known density, ρ , as shown on the constant density lines in the pressure-enthalpy diagram, Figure 4. Values of pressure at densities ρ_I and ρ_{I+1}

Fig. 4. Pressure vs enthalpy for water.

with a constant product of internal energy and density are determined

$$P(u, \rho_I) = P_{SAT, I} + (u - u_{SAT, I}) \left. \frac{\partial P}{\partial u} \right|_{\rho_I}, \quad (22)$$

and

$$P\left(\frac{u\rho_I}{\rho_{I+1}}, \rho_{I+1}\right) = P_{SAT, I+1} + \left(\frac{u\rho_I}{\rho_{I+1}} - u_{SAT, I+1}\right) \left. \frac{\partial P}{\partial u} \right|_{\rho_{I+1}}, \quad (23)$$

where the variables subscripted with I and I+1 are found in the tables.

Then

$$\left. \frac{\partial P}{\partial \rho} \right|_{u\rho} = \frac{P\left(\frac{u\rho_I}{\rho_{I+1}}, \rho_{I+1}\right) - P(u, \rho_I)}{\rho_{I+1} - \rho_I}. \quad (24)$$

The value of $\left. \frac{\partial T}{\partial \rho} \right|_{u\rho}$ is calculated next using the values of pressure, determined in Equations (22) and (23), and values of $T_{SAT, I}$, $T_{SAT, I+1}$, $\left. \frac{\partial T}{\partial P} \right|_{\rho_I}$ and $\left. \frac{\partial T}{\partial P} \right|_{\rho_{I+1}}$ from the tables, i.e.,

$$T(u, \rho_I) = T_{SAT, I} + \left. \frac{\partial T}{\partial P} \right|_{\rho_I} [P(u, \rho_I) - P_{SAT, I}],$$

and

$$T\left(\frac{u\rho_I}{\rho_{I+1}}, \rho_{I+1}\right) = T_{SAT, I+1} + \left. \frac{\partial T}{\partial P} \right|_{\rho_{I+1}} \left[P\left(\frac{u\rho_I}{\rho_{I+1}}, \rho_{I+1}\right) - P_{SAT, I+1} \right].$$

Then

$$\left. \frac{\partial T}{\partial \rho} \right|_{u\rho} = \frac{T\left(\frac{u\rho_I}{\rho_{I+1}}, \rho_{I+1}\right) - T(u, \rho_I)}{\rho_{I+1} - \rho_I}. \quad (25)$$

The remaining temperature derivative can be written

$$\left. \frac{\partial T}{\partial u} \right|_P = \left. \frac{\partial T}{\partial P} \right|_u \left. \frac{\partial P}{\partial u} \right|_P . \quad (26)$$

Both of the terms on the right-hand side can be determined by interpolation on density in the tables.

A very similar technique to that described above for the state search for the liquid phase is followed if the water is in the vapor phase.

In the two phase region, a different search technique is used to find temperature, pressure, and the required derivatives from known internal energy and density. Iterating on nodal pressure, two values of pressure, P_α and P_β , are found such that the corresponding specific volumes, v_α and v_β , bracket the known specific volume $\left(v = \frac{1}{\rho} \right)$, i.e.,

$$v_\alpha < v < v_\beta ,$$

and are as close to v as desired, i.e.,

$$|v_\alpha - v| < \epsilon \quad \text{and} \quad |v_\beta - v| < \epsilon , \quad (27)$$

where ϵ is a preset convergence. The values of v_α and v_β are determined from P_α and P_β by, e.g.,

$$v_\alpha = v_f(P_\alpha) + \frac{u + P_\alpha v - h_f(P_\alpha)}{h_{fg}(P_\alpha)} \cdot v_{fg}(P_\alpha) ,$$

where u and v are known, and the saturation properties at P_α and P_β are determined by interpolation on pressure using the tables. Having found v_α and v_β which bracket v and satisfy the restrictions in Equation 27, the pressure corresponding to the known u and v is found by interpolation:

$$P = P_\alpha + \frac{(v - v_\alpha)}{(v_\beta - v_\alpha)} * (P_\beta - P_\alpha) . \quad (28)$$

Now the saturation properties at P can be determined.

The required derivatives, $\frac{\partial P}{\partial u}\bigg|_\rho$, $\frac{\partial P}{\partial \rho}\bigg|_{u\rho}$, $\frac{\partial T}{\partial u}\bigg|_\rho$ and $\frac{\partial T}{\partial \rho}\bigg|_{u\rho}$, in the two phase region can now also be determined. The first of these is found from the relation

$$\frac{\partial P}{\partial u}\bigg|_\rho \frac{\partial u}{\partial \rho}\bigg|_P \frac{\partial \rho}{\partial P}\bigg|_u = -1 . \quad (29)$$

Since

$$\frac{\partial \rho}{\partial u}\bigg|_P = -\frac{1}{v^2} \frac{\partial v}{\partial u}\bigg|_P = -\frac{1}{v^2} \frac{v_{fg}}{u_{fg}} ,$$

and

$$\frac{\partial \rho}{\partial P}\bigg|_u = -\frac{1}{v^2} \frac{(v_\beta - v_\alpha)}{(P_\beta - P_\alpha)} , \quad (30)$$

it follows that

$$\frac{\partial P}{\partial u}\bigg|_\rho = -\frac{v_{fg}}{u_{fg}} \frac{(P_\beta - P_\alpha)}{(v_\beta - v_\alpha)} . \quad (31)$$

To find the other derivative of pressure, $\frac{\partial P}{\partial \rho}\bigg|_{u\rho}$, Eq. (29) can be combined with

$$\left. \frac{\partial P}{\partial \rho} \right|_{u\rho} \left. \frac{\partial \rho}{\partial (u\rho)} \right|_P \left. \frac{\partial (u\rho)}{\partial P} \right|_\rho = -1 ,$$

to obtain

$$\left. \frac{\partial P}{\partial \rho} \right|_{u\rho} = \left. \frac{\partial P}{\partial \rho} \right|_u - \frac{u}{\rho} \left. \frac{\partial P}{\partial u} \right|_\rho .$$

The derivatives on the right-hand side come from Equations (30) and (31).

Since temperature in the two phase region is a function of pressure only, the derivatives of temperature follow from the derivatives of pressure in the following way:

$$\left. \frac{\partial T}{\partial \rho} \right|_{u\rho} = \left(\frac{dT}{dP} \right)_{\text{SAT}} \left. \frac{\partial P}{\partial \rho} \right|_{u\rho} ,$$

and

$$\left. \frac{\partial T}{\partial u} \right|_\rho = \left(\frac{dT}{dP} \right)_{\text{SAT}} \left. \frac{\partial P}{\partial u} \right|_\rho ,$$

where

$$\left(\frac{dT}{dP} \right)_{\text{SAT}} = \frac{T_{\text{SAT},I} - T_{\text{SAT},I-1}}{P_{\text{SAT},I} - P_{\text{SAT},I-1}} .$$

$P_{\text{SAT},I}$ and $P_{\text{SAT},I-1}$ are the pressures in the tables that bracket P , and $T_{\text{SAT},I}$ and $T_{\text{SAT},I-1}$ are the corresponding saturation temperatures.

SAMPLE CALCULATION

The sample calculation presented in this section is intended to illustrate the use and features of BLAST. This calculation simulates the dynamic response of the reheater-steam generator module to a reactor

trip from 100% power. The nodal arrangement shown in Fig. 2 was used for this sample problem. Time dependent boundary conditions required as input to the component simulation were derived from printout to a sample problem supplied with the General Atomic TAP program²¹ which simulates the HTGR nuclear steam supply system. Input instructions for BLAST are given in Appendix A, and a listing of the user supplied sub-routines, the input data card images and sample transient printout for this sample calculation are given in Appendix B. Plots generated by BLAST for the reactor trip are included in this section. The IBM 360/91 CPU time required for this sample calculation was 0.2 sec/time step.

A description of the event sequences corresponding to reactor cool-down using the reheater-steam generator modules following a reactor trip is given in Reference 22. The sequence of events for this sample problem are quite similar and are summarized below. The signal for reactor trip causes the control rods to be rapidly inserted into the core. The plant control system ramps the feedwater flow down to 25% at a rate of 0.5% per sec as shown in Fig. 5. The helium flow (Fig. 6) is also reduced by the plant control system during the initial part of the transient to -27% and then increases as the control system increases the circulator rpm in an attempt to maintain the main steam temperature at a preset value. Upon initiation of the reactor trip, the high pressure turbine throttle valve area is decreased, resulting in an increase in main steam pressure as shown in Fig. 7. Two minutes after the reactor is tripped, a turbine trip occurs, and the steam generator outlet pressure remains essentially constant at 2603 psia as the steam is discharged to the main steam bypass system.

The reheater helium inlet temperature is shown in Fig. 8, and the calculated steam generator helium outlet temperature is shown in Fig. 9. This outlet temperature initially decreases with the decreasing inlet temperature and then peaks again at 370 sec due to the peak in the helium flow rate (Fig. 6). The main steam outlet temperature is shown in Fig. 10. The small oscillations shown here are due to changes in flow regime, and the resulting change in the water side heat transfer coefficients, in the evaporator and superheater nodes. Note that wet steam is emitted from the steam generator from 385 sec to 550 sec at which time the steam generator is completely flooded.

To illustrate the capabilities of the code, the temperatures, heat transfer coefficients, and heat fluxes for the first superheater section shown in Fig. 2 (represented by nodes H 10, W 15 and T 15) were plotted in Figs. 11-17. Also the fluid quality, defined as $(H - H_f) / (H_g - H_f)$, in water node 15 is plotted in Figs. 18-a and 18-b. Figures 12 and 18-a show that this first superheater section contains wet steam of decreasing quality from ~100 sec to ~490 sec. At 400 sec, the fluid quality has declined sufficiently such that the flow regime changes from a film boiling regime to a nucleate boiling regime with a considerably higher heat transfer coefficient (Figs. 16-a and 16-b). The resultant large increase in heat flux (Figs. 17-a and 17-b) drives up the quality (Figs. 18-a and 18-b) causing a return to the film boiling regime. This lowers the heat transfer coefficient and therefore the heat flux causing the quality to decrease, thereby producing the oscillation in quality, heat transfer coefficient, and heat flux shown in the figures. The oscillations in fluid quality in water node 15 from ~150 sec to 180 sec are the

Fig. 5. Steam generator water inlet flow following a reactor trip.

Fig. 6. Reheater helium inlet flow following a reactor trip.

Fig. 7. Steam generator water outlet pressure following a reactor trip.

Fig. 8. Reheater helium inlet temperature following a reactor trip.

Fig. 9. Steam generator helium outlet temperature following a reactor trip.

Fig. 10. Steam generator water outlet temperature following a reactor trip.

Fig. 11. Helium node 10 temperature following a reactor trip.

Fig. 12. Water node 15 temperature following a reactor trip.

Fig. 13. (a) Tube node 15 bulk temperature following a reactor trip,
 (b) Tube node 15 surface temperature, helium side, following a reactor trip,
 (c) Tube node 15 surface temperature, water side, following a reactor trip.

Fig. 15. Helium node 10 heat flux following a reactor trip.

Fig. 14. Helium node 10 heat transfer coefficient following a reactor trip.

Fig. 16. (a) Water node 15 heat transfer coefficient following a reactor trip, (b) Water node 15 heat transfer coefficient following a reactor trip.

Fig. 17. (a) Water node 15 heat flux following a reactor trip, (b) Water node 15 heat flux following a reactor trip.

Fig. 18. (a) Water node 15 quality following a reactor trip, (b) Water node 15 quality following a reactor trip.

result of oscillations in the heat transfer coefficient in the upstream node between film boiling and nucleate boiling.

PLANS FOR FUTURE USE

The future uses of BLAST include analyzing other transients resulting from normal plant operation and from postulated accident conditions. BLAST is currently being used to model the Fort St. Vrain reheater steam generator module. Results obtained with this model will first be compared with a linear model developed by the University of Tennessee and then with FSV dynamic test results. BLAST will also be used to analyze the transient behavior of the steam generator during postulated depressurization and partial loss of forced circulation accidents.

BLAST is being used to obtain information concerning pressures and temperatures necessary for stress analyses on the General Atomic redesigned reheater-steam generator module for the Delmarva plant. Also, BLAST has been incorporated into ORTAP, a system simulation code for the HTGR. A comparison of the modeling techniques used in BLAST with those used by General Atomic for the steam generator model in TAP²¹ will be made once the TAP code is made operational at ORNL.

REFERENCES

1. G. M. Schultz, "Large HTGR Steam Generator Design Verification and Support Programs - Heat Transfer, Fluid Flow, and Stability," Gulf-GA-A12808. Volume II (GA-LTR-5), (December 15, 1973).
2. F. Kreith, Principles of Heat Transfer, International Text Book Co., Scranton, Pennsylvania, 1966.

3. J. R. S. Thom, et al., "Boiling in Subcooled Water During Flow Up Heated Tubes or Annuli," Proc. Inst. Mech. Eng. 180 (Part 3C), pp. 226-46 (1966).
4. J. B. McDonough, W. Milich, and E. C. King, Partial Film Boiling with Water at 2000 psig in a Round Vertical Tube, MSA Research Corporation, Technical Report 62 (1958) (NP-6976).
5. R. S. Dougall and W. M. Rosenhow, Film Boiling on the Inside of Vertical Tubes with Upward Flow of the Fluid at Low-Qualities, MIT-TR-9079-26 (1963).
6. D. C. Groenvelt, An Investigation of Heat Transfer in the Liquid Deficient Regime, AECL-3281 (Rev.).
7. C. D. Morgan, "A Study of Film Boiling from Vertical Surfaces," Ph.D. Dissertation, Lehigh University, (1965).
8. L. S. Tong, DNB Prediction for an Axially Non-Uniform Heat Flux Distribution, WCAP-5584, Rev. 1 (1966).
9. E. Jansen, S. Levy, and J. A. Kervinen, "Investigation of Burnout-Internally Heated Annulus Cooled by Water at 600 to 1450 psi," ASME No. 63-WA-149 (1963).
10. J. S. Gellerstedt, et al., "Correlation of Critical Heat Flux in a Bundle Cooled by Pressurized Water," pp. 63-71 in Two Phase Flow and Heat Transfer in Rod Bundles Symposium, Symposium presented at the Winter Annual Meeting of the ASME, Los Angeles, California (November 1969).
11. P. G. Barnett, A Correlation of Burnout Data for Uniformly Heated Annuli and Its Use for Predicting Burnout in Uniformly Heated Rod Bundles, AEEW-R463 (1966).

12. Crane Technical Paper 410, Flow of Fluids Through Valves, Fittings and Pipe, Crane Industrial Products Group, Chicago, Illinois.
13. R. C. Martinelli and D. B. Nelson, "Prediction of Pressure Drop During Forced-Circulation Boiling of Water," Trans. ASME, 781 (1948), pp. 695-702.
14. J. R. S. Thom, "Prediction of Pressure Drop During Forced-Circulation Boiling of Water," Int. J. Heat Mass Transfer, Vol. 7, Pergamon Press (1964), pp. 709-24.
15. R. A. Hedrick, "An Implicit Solution Technique for Analysis of Loss-of-Coolant Accidents," MS Thesis, University of Tennessee, (1974).
16. H. Petersen, Risö Report No. 224, September 1970.
17. J. R. Tallackson, "The Thermal Transport Properties of Helium, Helium-Air Mixtures, Water and Tubing Steel Used in the CACHE Program to Compute HTGR Auxiliary Heat Exchanger Performance," ORNL/TM-4931.
18. Thermodynamic and Transport Properties of Steam, ASME, 1967.
19. R. C. Foltz, WPRØP - A Program to Calculate Water Properties, Babcock and Wilcox, NPCD, September 1973.
20. T. A. Porsching, J. H. Murphy, J. A. Redfield, and V. C. Davis, FLASH-4: A Fully Implicit FORTRAN-IV Program for the Digital Simulation of Transients in a Reactor Plant, WAPD-TM-840, March 1969.
21. "Transient Analysis Program," Gulf General Atomic Report GAMD-7248 (Revision), 1973.
22. An Analysis of HTGR Core Cooling Capability, Gulf General Atomic, Gulf-GA-A12504 (GA-LTR-1), 1973.

APPENDIX A: INPUT DESCRIPTION

The input data required by the code is described below. Subroutines which must be supplied by the user are described in Appendix B. The input will be more easily understood if studied in conjunction with the input card listing and initial printout of the sample problem in Appendix B and with the nodal description for this sample problem shown in Figure 2. In determining a nodal arrangement such as in Figure 2, the user should place nodal boundaries where the tube material or diameter changes. Also, dividing a length of tube of a given material and diameter into more than one node provides finer calculational detail and therefore more accurate results.

The first entry on each data card is a card series number. The data cards must be ordered numerically according to this series number. The series number is in format I10, and the remaining entries are in 10 column fields.

<u>CARD SERIES</u>	<u>CARD FORMAT</u>
------------------------	------------------------

10NN	I10, 7D10.2
------	-------------

NN = 01,...,k where $k \leq 9$

Time interval and associated time step information in ordered triplets: $\Delta t(\text{sec})$, end of interval (sec), number of output edits during interval. Up to twenty ordered triplets are allowed.

The time step Δt should be chosen less than nodal mass transport times,

<u>CARD</u> <u>SERIES</u>	<u>CARD</u> <u>FORMAT</u>
------------------------------	------------------------------

ρ_i/ω_i . The last card in series 10NN should be blank in columns 71-80.

25NN

Optional series. See p. 49.

70NN 110, 4D10.2, 3110

$NN = 2*N_w - 1$ where $N_w \equiv$ water node number and $(1 \leq N_w \leq 20)$.

Columns 11-20: Water node N_w pressure guess (psia) for steady state search.

Columns 21-30: Water node N_w enthalpy guess (Btu/lbm) for steady state search.

Columns 31-40: Water node N_w flow area (ft^2).

Columns 41-50: Tube length (ft) associated with water node N_w .

Columns 51-60: Outlet position (1 = top, 0 = bottom) Note: If node is horizontal, input 0 in column 60 and column 70.

Normally the code uses the height (ft) of the associated helium node for the Δz factor in the static head term in the water side momentum equation. However, the user can specify the value of Δz by inputting, in integer form, $1000*\Delta z$ in columns 61-70.

<u>CARD</u>	<u>CARD</u>
<u>SERIES</u>	<u>FORMAT</u>

Columns 71-80: Number of helium node
(N_h) which can transfer heat to this water
node.

70KK 2I10, D10.2, 2I10

KK = $2*N_w$; Continuation of information on
card 70NN for water node N_w .

Columns 11-20: Tube type (Specify 1, 2,
or 3)

= 1 for carbon steel (SA-210-A1)

= 2 for Incoloy 800

= 3 for Croloy (SA-213-T22)

Columns 21-30: Number of tubes which
transfer heat with the helium node referred
to in columns 71-80 of previous card.

Columns 31-40: Upstream node number

(= 201 for first reheater node)

(= 230 for first economizer node.)

Columns 41-50: Downstream node number.

(= 215 for last reheater node.)

Use 216, 217,... for multiple reheater
exits.

(= 251 for last superheater node.)

Use 252, 253,... for multiple superheater
exits.

<u>CARD SERIES</u>	<u>CARD FORMAT</u>
------------------------	------------------------

75LL	I10, 4D10.2, I10, D10.2, I10
------	---------------------------------

$$LL = 2 * N_w - 1$$

Columns 11-20: Mass flow rate (lbm/sec)
in one tube coil in water node N_w at
initial steady state conditions.

Columns 21-30: Tube inner radius (in.)

Columns 31-40: Tube outer radius (in.)

Columns 41-50: Tube hydraulic diameter
(in.)

Columns 51-60: DNB correlation number

= 1 for user supplied correlation.

See card series 9101.

= 2 for W-3, Jansen, Levy. See card
series 9101.

= 3 for B&W-2, Barnett.

If 1, 2, or 3 is chosen, the code will not
return to nucleate boiling once DNB has
occurred.

= 4 for user supplied correlation.

See card series 9101.

= 5 for W-3, Jansen, Levy. See card
series 9101.

= 6 for B&W-2, Barnett.

If 4, 5, or 6 is chosen, the code will
return to nucleate boiling once DNB has
occurred.

<u>CARD</u>	<u>CARD</u>
<u>SERIES</u>	<u>FORMAT</u>

Columns 61-70: Minimum heat transfer coefficient ($\text{Btu/hr-ft}^2\text{-}^\circ\text{F}$).

Columns 71-80: Film boiling correlation key.

(= 0 for Dougall-Rosenhow)

(= 1 for Groeneveld)

75MM I10, 3D10.2

MM = $2*N_w$; Continuation of information on card 75LL for node N_w .

Columns 11-20: Constant friction factor for node N_w . This friction factor is added to that calculated from the Fanning friction factor curves to determine the friction losses.

Columns 21-30: ϵ/D (Roughness to diameter ratio for tube; D = inner diameter)

Columns 31-40: Relative curvature of tubes associated with water node N_w .

(Input 0.0 for straight tubes).

80NN I10, 5D10.2, 2I10

NN = $2*N_h - 1$ where $N_h \equiv$ helium node number and $(1 \leq N_h \leq 20)$.

Columns 11-20: Helium node N_h pressure guess (psia) for steady state search.

<u>CARD</u>	<u>CARD</u>
<u>SERIES</u>	<u>FORMAT</u>

Columns 21-30: Helium node N_h enthalpy guess (Btu/lbm) for steady state search.

Columns 31-40: Helium node N_h flow area (ft^2).

Columns 41-50: Helium node N_h flow length (ft).

Columns 51-60: Height of nodal volume (ft).

Columns 61-70: Inlet position (1=top, 0=bottom).

Columns 71-80: Outlet position (1=top, 0=bottom).

Note: Input 0 in column 70 and column 80 if node is horizontal.

80KK 110, D10.2, 2110

KK = $2*N_h$; Continuation of information on card 80NN for node N_h .

Columns 11-20: Nodal volume (ft^3).

Columns 21-30: Upstream node number.

(= 201 for first reheater node)

(= 215 for first tunnel node)

(= 230 for first superheater node)

Columns 31-40: Downstream node number.

(= 215 for last reheater node)

Use 216, 217, ..., for multiple reheater exits.

<u>CARD</u>	<u>CARD</u>
<u>SERIES</u>	<u>FORMAT</u>

(= 230 for last tunnel node)

(= 251 for last steam generator node)

Use 252, 253, ..., for multiple steam generator exits.

85LL I10, 4D10.2, 2I10,
 D10.2

LL = $2 * N_h - 1$

Columns 11-20: Mass flow rate (lbm/sec) in helium node N_h at initial steady state conditions.

Columns 21-30: Average tube OD (in.) in helium node N_h .

Columns 31-40: Constant friction factor.

Columns 41-50: ϵ/D (Roughness to diameter ratio: D = outer diameter.). This is used as a key. If $\epsilon/D \leq 0.0$, only the constant friction factor will be used to compute friction losses. If $\epsilon/D > 0.0$, the code will calculate a friction factor based on the correlation described in section 6 and add this to the constant friction factor to determine the friction losses.

Columns 51-60: Number of inline rows of tubes in helium node N_h .

Columns 61-70: Number of staggered rows of tubes in helium node N_h .

<u>CARD</u> <u>SERIES</u>	<u>CARD</u> <u>FORMAT</u>
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Columns 71-80: Pitch to diameter ratio-transverse.

85MM	I10, D10.2
------	------------

$MM = 2 \cdot N_h$; Continuation of information on card 85LL for helium node N_h .

Columns 11-20: Pitch to diameter ratio-longitudinal.

9001	3I10
------	------

Columns 11-20: Number of first helium node in tunnel.

Columns 21-30: Number of last helium node in tunnel.

9101	
------	--

This card series is required if DNB correlation number on card series 75LL is 1, 2, 4 or 5. Otherwise, this series is omitted.

Columns 11-20: DNB flux (Btu/hr-ft^2) for zero quality. Used only for DNB correlation number = 1 or 4.

Columns 21-30: Quality at which DNB occurs. Used only for DNB correlation number = 1 or 4.

Columns 31-40: Quality at which DNB flux becomes zero. Used only for DNB correlation number = 1 or 4.

<u>CARD</u>	<u>CARD</u>
<u>SERIES</u>	<u>FORMAT</u>

Columns 41-50: "E factor" in Jansen-Levy correlation. See Reference 9. Used only for DNB correlation number = 2 or 5.

9201 I10, 2D10.2

Columns 11-20: Allowable temperature change for water before recomputing thermodynamic transport properties.

Columns 21-30: Allowable temperature change for helium before recomputing thermodynamic transport properties.

18001 2I10, 6D10.2

Steam generator (water side) inlet flow rate vs time in one tube.

Columns 11-20: Number of pairs (time, flow rate) describing water side inlet flow rate vs time. Up to 150 pairs may be input.

Columns 21-30: Time (sec).

Columns 31-40: Flow rate (lbm/sec).

Columns 41-60: Repeat Columns 21-30.

Columns 61-80: Repeat Columns 31-40.

NOTE: Code interpolates linearly between input values.

180NN I10, 7D10.2

NN = 2,...,k where $k \leq 42$. Continuation of card 18001.

<u>CARD SERIES</u>	<u>CARD FORMAT</u>
------------------------	------------------------

18101	2I10, 6D10.2
-------	--------------

Steam generator (water side) inlet pressure vs time.

Columns 11-20: Number of pairs, (time, pressure) describing water side inlet pressure vs time.

Columns 21-30: Time (sec).

Columns 31-40: Pressure (psia).

Columns 41-50: Repeat Columns 21-30.

Columns 61-80: Repeat Columns 31-40.

181NN	110, 7D10.2
-------	-------------

NN = 2, ..., k where $k \leq 42$. Continuation of card 18101.

18201	2I10, 6D10.2
-------	--------------

Steam generator (water side) inlet enthalpy vs time.

Columns 11-20: Number of pairs (time, enthalpy).

Columns 21-30: Time (sec).

Columns 31-40: Enthalpy (Btu/lbm).

Columns 41-60: Repeat Columns 21-30.

Columns 61-80: Repeat Columns 31-40.

182NN	110, 7D10.2
-------	-------------

NN = 2, ..., k where $k \leq 42$. Continuation of card 18201.

<u>CARD SERIES</u>	<u>CARD FORMAT</u>	
18501	2I10, 6D10.2	<p>Reheater (helium side) inlet flow rate vs time.</p> <p>Columns 11-20: Number of pairs (time, flow rate) describing helium inlet flow rate vs time).</p> <p>Columns 21-30: Time (sec).</p> <p>Columns 31-40: Flow rate (lbm/sec).</p> <p>Columns 41-60: Repeat Columns 21-30.</p> <p>Columns 61-80: Repeat Columns 31-40.</p>
185NN	I10, 7D10.2	<p>NN = 2,...,k where $k \leq 42$. Continuation of card 18501.</p>
18601	2I10, 6D10.2	<p>Reheater (helium side) inlet pressure vs time.</p> <p>Columns 11-20: Number of pairs (time, pressure) describing helium inlet pressure vs time.</p> <p>Columns 21-30: Time (sec).</p> <p>Columns 31-40: Pressure (psia).</p> <p>Columns 41-60: Repeat Columns 21-30.</p> <p>Columns 61-80: Repeat Columns 31-40.</p>
186NN	I10, 7D10.2	<p>NN = 2,...,k where $k \leq 6$. Continuation of card 18601.</p>

<u>CARD</u> <u>SERIES</u>	<u>CARD</u> <u>FORMAT</u>
------------------------------	------------------------------

18701	2I10, 6D10.2
-------	--------------

Reheater (helium side) inlet enthalpy vs time.

Columns 11-20: Number of pairs (time, enthalpy) describing helium inlet enthalpy vs time.

Columns 21-30: Time (sec).

Columns 31-40: Enthalpy (Btu/lbm).

Columns 41-60: Repeat Columns 21-30.

Columns 61-80: Repeat Columns 31-40.

187NN	I10, 7D10.2
-------	-------------

NN = 2, ..., k where $k \leq 42$. Continuation of card 18701.

In addition to the above required input, data cards may be supplied which request plots. Two data cards with successive card series numbers are required for each plot. Card series numbers for the plot request cards begin with 2501, cannot exceed 2580 and must be consecutive. They must also be in numerical order with the required input cards, i.e., they must follow the last 10NN card.

The two cards required for each plot are:

First Card: (2I10, 3D10.2, I10, D10.2)

Columns 1-10: Card series number.

Columns 11-20: IDPLT - a number defining variable to be plotted vs time. (See Table A-1)

Columns 21-30: XMINP - Minimum value of time (sec) for plot.

Columns 31-40: XMAXP - Maximum value of time (sec) for plot.

Columns 41-50: XLENP - Length of plot (in.) including vertical axis label. (Choose 8.5 for 8-1/2 x 11 sheet)

Columns 51-60: Not used.

Columns 61-70: YMINP - Minimum value of dependent variable for plot.

Second Card (I10, 2D10.2, 2I10)

Columns 1-10: Value of series number on first card (for this plot) plus 1.

Columns 11-20: YMAXP - Maximum value of dependent variable for plot.

Note: If YMINP and YMAXP are both input as 0.0, the code searches for a maximum and a minimum.

Columns 21-30: YLENP - Height of plot (in.) including horizontal axis labels. (Choose 11.0 for 8-1/2 x 11 sheet)

Columns 31-40: NIPLT - If plotting ΔP , NIPLT is the first node number for the ΔP . Otherwise NIPLT = 0.

Columns 41-50 N2PLT - If plotting ΔP , N2PLT is the second node number for the ΔP . Otherwise N2PLT = 0.

Table A-1. Values of IDPLT for card series 25NN

IDPLT		
1100	Steam generator helium inlet pressure	psia
1200	Steam generator helium outlet pressure	psia
1300	Steam generator helium inlet temperature	°F
1400	Steam generator helium outlet temperature	°F
1500	Steam generator helium inlet flow rate	lbm/sec
1600	Steam generator helium outlet flow rate	lbm/sec
1700	Steam generator helium inlet enthalpy	Btu/lbm
1800	Steam generator helium outlet enthalpy	Btu/lbm
2100	Reheater helium inlet pressure	psia
2200	Reheater helium outlet pressure	psia
2300	Reheater helium inlet temperature	°F
2400	Reheater helium outlet temperature	°F
2500	Reheater helium inlet flow rate	lbm/sec
2600	Reheater helium outlet flow rate	lbm/sec
2700	Reheater helium inlet enthalpy	Btu/lbm
2800	Reheater helium outlet enthalpy	Btu/lbm
3100	Steam generator water inlet pressure	psia
3200	Steam generator water outlet pressure	psia
3300	Steam generator water inlet temperature	°F
3400	Steam generator water outlet temperature	°F
3500	Steam generator water inlet flow rate	lbm/sec
3600	Steam generator water outlet flow rate	lbm/sec
3700	Steam generator water inlet enthalpy	Btu/lbm
3800	Steam generator water outlet enthalpy	Btu/lbm
4100	Reheater water inlet pressure	psia
4200	Reheater water outlet pressure	psia
4300	Reheater water inlet temperature	°F
4400	Reheater water outlet temperature	°F
4500	Reheater water inlet flow rate	lbm/sec
4600	Reheater water outlet flow rate	lbm/sec
4700	Reheater water inlet enthalpy	Btu/lbm
4800	Reheater water outlet enthalpy	Btu/lbm

Table A-1. (Continued)

IDPLT	NNN $\equiv$ NODE NUMBER
11NNN	Helium pressure of node NNN, psia
12NNN	Helium temperature of node NNN, °F
13NNN	Helium flow rate of node NNN, lbm/sec
14NNN	Heat flux from helium node NNN, Btu/hr-ft ²
16NNN	Heat transfer coefficient for helium node NNN, Btu/hr-ft ² -°F
17NNN	Helium density of node NNN, lbm/ft ³
18NNN	Tube wall temperature, helium side, for tube node NNN, °F
22NNN	Tube temperature for tube node NNN, °F
31NNN	Water pressure of node NNN, psia
32NNN	Water temperature of node NNN, °F
33NNN	Water flow rate of node NNN, lbm/sec
34NNN	Heat flux to water for water node NNN, Btu/hr-ft ²
35NNN	Quality in water node NNN
36NNN	Heat transfer coefficient for water node NNN, Btu/hr-ft ² -°F
37NNN	Water density in node NNN, lbm/ft ³
38NNN	Tube wall temperature, water side, for tube node NNN, °F
50000	ΔP Helium node N1PLT to Helium node N2PLT, psid
51000	ΔP Helium node N1PLT to water node N2PLT, psid
52000	ΔP Water node N1PLT to water node N2PLT, psid

APPENDIX B

BLAST requires the user to supply three subroutines. They are

SUBROUTINE POH: Through this subroutine the user supplies the fractional change, FH, in the helium pressure at the outlet of the last helium node as a function of time. This pressure is used only to obtain a value for the ΔP term in the momentum equation (6) for the last helium node. Since BLAST calculates the helium outlet pressure for the initial steady-state conditions, the outlet pressure used in the ΔP term is found from $P = P_{out}(t=0) * FH$. The user must supply the values of the fractional change in helium pressure at the outlet of the last helium node at selected times through the DATA statements. The code then linearly interpolates to determine FH at each time step.

SUBROUTINE POW: This subroutine supplies the fractional change, FREHET, in pressure at the outlet of the last reheat steam node and the fractional change, FSGEN, in pressure at the outlet of the last main steam node as functions of time. These pressures are used to determine the ΔP terms in the momentum equation for the last reheater node and the last superheater node respectively. The user must supply values for the fractional change in pressure at the outlet of the last reheat steam node at selected times through the DATA statements. The code then linearly interpolates to find FREHET and FSGEN at each time step.

SUBROUTINE REHETW: This subroutine is used to provide values of reheater inlet flow rate (REWI), inlet enthalpy (HREWI) and inlet pressure (PREWI) on the steam side vs time. The user must input values of inlet flow rate, inlet enthalpy and inlet pressure at selected times through DATA statements. The code then linearly interpolates to determine inlet flow rate, enthalpy and pressure at each time step.

The first output generated by the code is the listing of the input data card images followed by several pages which display this input information in tabular form. Next, results of the steady-state iteration are displayed. The "calculated friction factors" listed in this steady-state output are obtained from the user supplied information and pressure drop correlations while the "input friction factor" is the sum of the constant friction factor (input by the user on card series 75MM) plus an adjustment made by the code to force dW/dt (Eqs. 3 and 6) to be exactly zero after all parameters have achieved steady-state convergence. This adjustment factor should be an order of magnitude or more smaller than the calculated friction factor. At various times, determined by input on card series 10NN, the code prints out information concerning the water side, helium side and tubes in the reheater and steam generator. These tables contain information concerning the nodal pressure, mass, internal energy, temperature, flow rate (in one tube on the water side, the total flow rate on the helium side) values for each of the terms in the momentum equations (3 and 6), heat transfer coefficient, heat flux, tube surface and bulk temperatures, heat transfer mode and the heat flux required to cause a departure from the nucleate boiling mode. The keys used to indicate the heat transfer mode are given below:

1. subcooled forced convection,
2. nucleate boiling,
3. transition boiling,
4. film boiling (Dougall-Rosenhow correlation),
5. film boiling (Groeneveld correlation),
6. film boiling (Morgan correlation), and
7. superheat forced convection.

For the sample problem, the steady-state printout at $t=0$ indicates that the reheater (tube nodes 1-8 in Fig. 2) is in the superheat forced convection mode, the three economizer nodes and the first evaporator node are in subcooled forced convection, the second evaporator node is in nucleate boiling, the third is in film boiling, and the superheater is in the superheat forced convection mode. The nodal heat transfer modes given at $t=200$ sec indicate that the last evaporator node has returned to nucleate boiling, and the first superheater node contains a two-phase fluid in the film boiling mode. By $t=500$ sec, the evaporator has flooded, and wet steam is being emitted from the superheater, and by $t=600$ sec, the superheater has also flooded.

```

SUBROUTINE PHFEL1
  IMPLICIT REAL*8(A-H,O-Z)
  INTEGER*4 NHELIN,NFLOUT
  COMMON /HELIN/ DELT(20), FINEP(20),
1  FLAME(20), FFLAME(20), NFEL(20),
2  HELIN(20), HELFOUT(20), NFLOUT(20),
3  NNFEL(20), NNFPM(20), NNP(20),
4  FFLAME(20), NFEL(20), NFLOUT(20),
5  NNFPE(20), NNFSE(20), NNFCE(20),
6  NNGC(20), NNF(20)

  COMMON /EVERY/ DELT , , DELT(20), ,
1  TAU , , NFEL(20), , NFEL(20),
2  LASTME , , LASTME , ,
3  ATINSE , , ATINSE , , NFOUT

  COMMON /STATE/ IPRAWE(20), TNASSWE(20), PWATE(20),
1  TH2(20), WE(20), GME(20), WME(20),
2  DDTIME(20), DDTIME(20), DDTIME(20),
3  DDDIME(20), DDDIME(20), DDTIME(20), DDTIME(20),
4  TTIME(20), DDTIME(20),
5  JPAWE(20), TNASSWE(20), PHFEL(20), THFEL(20),
6  WFL(20), DDTIME(20), DDTIME(20),
7  DDDIME(20), DDDIME(20), DDTIME(20), DDTIME(20)

  REAL*8 NOTUP
  INTEGER*4 TURIN,TUROUT
  COMMON /TURIN/ FINEP(20), FLAME(20),
1  NNFPM(20), NNFEL(20), NFEL(20),
2  ATTYPE(20), NNP(20), FFLAME(20),
3  TPEPE(20), TUBEME(20), TURLE(20),
4  TURIN(20), TURIN(20), TURLE(20),
5  TUROUT(20), TURPE(20), TURV(20),
6  WDFE(20), WDFME(20), WDFPE(20),
7  WDSH(20), WDFCE(20), WGC(20),
8  WDF(20), WDF(20)

  COMMON /OUTLET/PWATSV(60),PHFELSV(20),POUTT
  DIMENSION TH(20),F(20)
  DATA TH/0.0,20.0,100.0,150.0,160.0,200.0,250.0,300.0,350.0,370.0,
1  400.0,440.0,450.0,460.0,480.0,500.0,560.0,570.0,600.0,620.0,
2  640.0,700.0/
  DATA F/1.0,0.958137,0.928519,0.906026,0.903623,0.896223,0.879113,
1  0.872572,0.865529,0.864413,0.861917,0.844732,0.840343,0.835011,
2  0.827030,0.813173,0.800949,0.798060,0.789350,0.786034,0.779025,
3  0.763072/
  DATA NH/1/
  DATA NM/22/
  IF(TAU.GT.0.0001) GO TO 10
  NM1 = NM-1
  POUTT = 2.0 * PHFEL(1) - PHFEL(NNFPM)
  RETURN
10 J = NNFPM(1) + 250
  DO 21 II=1,NM1
  K=1
  IF(TAU.LT.TH(K+1)) GO TO 32
31 CONTINUE
32 IM = K
  FM = F(K) + (F(K+1)-F(K))/(TH(K+1)-TH(K)) * (TAU-TH(K))
  POUTT = FM + PHFELSV(J)
  RETURN
  END

```

```

SUBROUTINE PHFEL2
  IMPLICIT REAL*8(A-H,O-Z)
  COMMON /EVERY/ DELT , , DELT(20), ,
1  TAU , , NFEL(20), , NFEL(20),
2  LASTME , , LASTME , ,
3  ATINSE , , ATINSE , , NFOUT

  COMMON /STATE/ IPRAWE(20), TNASSWE(20), PWATE(20),
1  TH2(20), WE(20), GME(20), WME(20),
2  DDTIME(20), DDTIME(20), DDTIME(20),
3  DDDIME(20), DDDIME(20), DDTIME(20), DDTIME(20),
4  TTIME(20), DDTIME(20),
5  JPAWE(20), TNASSWE(20), PHFEL(20), THFEL(20),

```

```

A  WFL( 20),  COTIME( 20),  COTIME( 20),  COTIME( 20),
7  COTIME( 20),  COTIME( 20),  COTIME( 20),  COTIME( 20)
C  AL=3-STEP
C  FIVE=54  TURNS, TUNOUT
COMMON /TUNING/  FINFPE( 20),  FLJAW( 20),
1  FINFPE( 20),  NINPSE( 20),  NIFTUR( 20),
2  NIFTUR( 20),  NUPPE( 20),  RECONWE( 20),
3  TONFPE( 20),  TONFPE( 20),  TUNLEN( 20),
4  TUNLEN( 20),  TUNPRE( 20),  TUNPRE( 20),
5  TUNPRE( 20),  TUNPRE( 20),  TUNPRE( 20),
6  TUNPRE( 20),  TUNPRE( 20),  TUNPRE( 20),
7  TUNPRE( 20),  TUNPRE( 20),  TUNPRE( 20),
8  TUNPRE( 20),  TUNPRE( 20)
C  PWR=4.0E12  PWR/PWTSV( 20), PWR/ SV( 20), POUTT
C  F5( 5) = TUN( 1), F5( 1), TUN( 14), F5( 14)
C  AT4  T170, 0, 170, 0, 270, 0, 370, 0, 400, 0, 500, 0, 600, 0, 700, 0,
1  800, 0, 900, 0, 1000, 0/
C  AT4  F5/1, 0, 0, 26411, 0, 265777, 0, 265576, 0, 145102, 0, 346170, 0, 375945,
1  0, 349375, 0, 3520578, 0, 3452264, 0, 0390035/
C  AT4  T150, 0, 150, 0, 270, 0, 30, 0, 40, 0, 50, 0, 60, 0, 70, 0, 80, 0, 90, 0, 100, 0,
1  110, 0, 120, 0, 2000, 0/
C  AT4  F5/1, 0, 1, 0192, 1, 0335, 1, 0500, 1, 0656, 1, 0706, 1, 0723, 1, 0735,
1  1, 0748, 1, 0754, 1, 0764, 1, 0771, 1, 07760, 1, 07760/
C  AT4  F5/15/1, 1/
C  AT4  N2/15/11, 14/
C  F5( 10, 17, 20) = 0  C  T= 10
C  I= 15-1
C  N2=15-1
C  POUTT = 2.0 * PWR*( 1 - PWR*( NUPPE( 1) )
C  Z=Z0
10  IF( NINPWE( 1), GE, 25) GO TO 20
J = NINPWE( 1) - 214
C  J= 3) I=10, N91
C  I=11
IF( TUN( 17, TUN( K+1) ) GO TO 11
30  CONTINUE
11  F=K
F5FMT = F5( K) * ( F5( K+1) - F5( K) ) / ( TUN( K+1) - TUN( K) )
I = ( TUN- TUN( K) )
POUTT = F5FMT * PWR* SV( J)
C  F5=J
20  J = NINPWE( 1) - 214
J= 1) I=15, N51
C  I=11
IF( TUN( 17, TUN( K+1) ) GO TO 21
40  CONTINUE
21  I=K
F5GEN = F5( K) * ( F5( K+1) - F5( K) ) / ( TUN( K+1) - TUN( K) )
I = ( TUN- TUN( K) )
POUTT = F5GEN * PWR* SV( 1)
C  F5=J
C  T=

```

```

SUBROUTINE MFMCTM
IMPLICIT REAL*8(A-H,O-Z)

```

```
COMMON /VEE9Y/      DELT      , DELTTC(20), FTIME(20),
1      TAU      , HPINSC      , HPININT(20),
2      LA:THE      , LASTUR      ,
3      NTINST      , NTIN      , NOUT
COMMON /PLENIUM/  NDTUN,NDLTUN,      TAREW,TAREH,TASGW,TASGH,
1      REWT,REWD,REHT,REHC,      SGWI,SGWI,SGHT,SGHC,
2      PREWT,PREWD,PREHT,PREHC,      PSGWI,PSGWI,PSGHT,PSGHC,
3      VSRWT,VSRWD,VSRHT,VSRHC,      VSSGI,VSSGI,VSSGH,VSSGH,
4      HREWT,HREWD,HREHT,HREHC,      HSGWI,HSGWI,HSGHT,HSGHC,
5      REWIT,REWIT,REHT,REHT,      SGWIT,SGWIT,SGHIT,SGHIT

DIMENSION TIF(16),TIME(16),TIP(16)
DIMENSION FLOW(16),ENTHAL(16),PRES(16)
DATA NF,NH,NP/16,16,16/
DATA IF,IN,IP/1,1,1/
DATA TIF/0.0,100.0,200.0,300.0,400.0,500.0,600.0,700.0,800.0,
1  900.0,1000.0,1100.0,1200.0,1300.0,1400.0,1500.0/
DATA FLOW/2225.0,1126.7,501.3,553.3,306.6,173.8,152.9,98.2,108.3,
```

```

1  93.7,78.7,64.2,49.5,35.1,22.0,8.8/
   DATA TIM/0.0,100.0,200.0,300.0,400.0,500.0,600.0,700.0,800.0,
1  500.0,1000.0,1100.0,1200.0,1300.0,1400.0,1500.0/
   DATA ETHAL/1311.3,1323.8,1339.8,1359.9,1373.0,1389.2,1396.2,
1  1269.0,1280.2,1273.3,1268.2,1264.4,1261.8,1259.7,1258.7,1259.5/
   DATA TFP/0.0,100.0,200.0,300.0,400.0,500.0,600.0,700.0,800.0,
1  500.0,1000.0,1100.0,1200.0,1300.0,1400.0,1500.0/
   DATA PRES/628.9,316.2,144.6,155.6,86.9,50.1,44.7,28.3,30.2,26.2,
1  22.6,17.0,14.4,14.2,13.9,13.5/
   NP1=NP-1
   DO 10 I1=TF,NP1
   I=I1
   IF (TAU(I).GT(TIME(I+1))) GO TO 11
10 CONTINUE
11 I=I
   RFW1 = FLOW(I) * (FLOW(I+1)-FLOW(I))/(TIME(I+1)-TIME(I))
   I = I + 1
   TAU = TAU - TIME(I)

   NP1=NP-1
   DO 20 I1=TM,NP1
   I=I1
   IF (TAU(I).GT(TIME(I+1))) GO TO 21
20 CONTINUE
21 I=I
   RFW1 = ETHAL(I) * (ETHAL(I+1)-ETHAL(I))/(TIME(I+1)-TIME(I))
   I = I + 1
   TAU = TAU - TIME(I)

   NP1=NP-1
   DO 30 I1=TP,NP1
   I=I1
   IF (TAU(I).GT(TIME(I+1))) GO TO 31
30 CONTINUE
31 I=I
   RFW1 = PRES(I) * (PRES(I+1)-PRES(I))/(TIME(I+1)-TIME(I))
   I = I + 1
   TAU = TAU - TIME(I)

   RFW1 = RFW1/(3.) * 220.01
   RETURN
END

```

LISTING OF INPUT DATA CAPDS

2001	.020	10.0	2.0	.025	610.0	50.0
2501	11010	390.0	420.0	8.5		
2502		11.0	0	0		
2503	31015	0.0	600.0	8.5		
2504		11.0	0	0		
2505	3215	0.0	600.0	8.5		
2506		11.0	0	0		
2507	31014	0.0	600.0	8.5		
2508		11.0	0	0		
2509	31014	152.0	200.0	8.5		
2510		11.0	0	0		
2511	34015	152.0	200.0	8.5		
2512		11.0	0	0		
2513	36015	152.0	200.0	8.5		
2514		11.0	0	0		
2515	14010	390.0	420.0	8.5		
2516		11.0	0	0		
2517	16010	390.0	420.0	8.5		
2518		11.0	0	0		
2519	22014	0.0	600.0	8.5		
2520		11.0	0	0		
2521	22015	152.0	200.0	8.5		
2522		11.0	0	0		
2523	18015	0.0	600.0	8.5		
2524		11.0	0	0		
2525	18015	152.0	200.0	8.5		
2526		11.0	0	0		
2527	18014	152.0	200.0	8.5		
2528		11.0	0	0		
2529	18014	390.0	420.0	8.5		
2530		11.0	0	0		
2531	38014	0.0	600.0	8.5		
2532		11.0	0	0		
2533	14010	0.0	600.0	8.5		
2534		11.0	0	0		
2535	34015	0.0	600.0	8.5		
2536		11.0	0	0		
2537	35015	0.0	600.0	8.5		
2538		11.0	0	0		
2539	35014	152.0	200.0	8.5		
2540		11.0	0	0		
2541	35015	390.0	420.0	8.5		
2542		11.0	0	0		
2543	35015	152.0	200.0	8.5		
2544		11.0	0	0		
2545	34015	390.0	420.0	8.5		
2546		11.0	0	0		
2547	36015	390.0	420.0	8.5		
2548		11.0	0	0		
2549	36015	0.0	600.0	8.5		
2550		11.0	0	0		
2551	18015	390.0	420.0	8.5		
2552		11.0	0	0		
2553	1400	0.0	600.0	8.5		
2554		11.0	0	0		
2555	3400	0.0	600.0	8.5		
2556		11.0	0	0		
2557	22015	390.0	420.0	8.5		
2558		11.0	0	0		
2559	22014	152.0	200.0	8.5		
2560		11.0	0	0		
2561	16010	0.0	600.0	8.5		
2562		11.0	0	0		
2563	38014	152.0	200.0	8.5		
2564		11.0	0	0		
2565	38015	390.0	420.0	8.5		
2566		11.0	0	0		
2567	38015	152.0	200.0	8.5		
2568		11.0	0	0		
2569	32015	0.0	600.0	8.5		
2570		11.0	0	0		
2571	38015	0.0	600.0	8.5		
2572		11.0	0	0		
2573	12010	0.0	600.0	8.5		
2574		11.0	0	0		
2575	22015	0.0	600.0	8.5		

2576			11.0	0	0				
2577		14011	152.0	200.0	8.5				
2578			11.0	0	0				
7001	630.000		1324.700	.00963335	4.8375	0	1	4	
7002	2		228.0	.201	2				
7003	629.000		1355.400	.00963335	4.8375	0	1	3	
7004	2		228.0	1	3				
7005	625.000		1304.900	.00963335	4.8375	0	1	2	
7006	2		228.0	2	4				
7007	621.000		1413.400	.00963335	4.8375	0	1	1	
7008	2		228.0	3	5				
7009	604.000		1440.700	.00963335	4.8375	1	0	1	
7010	2		228.0	4	6				
7011	591.000		1464.600	.00963335	4.8375	1	0	2	
7012	2		228.0	5	7				
7013	587.000		1484.400	.00963335	4.8375	1	0	3	
7014	2		228.0	6	8				
7015	582.000		1501.200	.00963335	4.8375	1	0	4	
7016	2		228.0	7	215				
7017	2683.060		405.280	.00320026	38.25	0	1	16	
7018	2		328.0	230	10				
7019	2601.060		512.030	.00320026	38.25	0	1	15	
7020	3		328.0	9	11				
7021	2751.850		607.880	.00320026	42.9	0	1	14	
7022	3		328.0	10	12				
7023	2783.540		704.030	.00295449	46.4	0	1	13	
7024	3		328.0	11	13				
7025	2772.280		825.230	.00295449	46.4	0	1	12	
7026	3		328.0	12	14				
7027	2754.690		991.900	.00329293	38.6	0	1	11	
7028	3		328.0	13	15				
7029	2736.270		1182.200	.00217163	39.6	0	1	10	
7030	3		328.0	14	16				
7031	2584.910		1344.300	.00269549	43.6	0	1	9	
7032	3		328.0	15	251				
7501	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7502	0.0		7.00-4	0.0154	1.329	6	30.0	0	
7503	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7504	0.0		7.00-4	0.0154	1.329	6	30.0	0	
7505	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7506	0.0		7.00-4	0.0154	1.329	6	30.0	0	
7507	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7508	0.0677		7.00-4	0.0154	1.329	6	30.0	0	
7509	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7510	0.0677		7.00-4	0.0110	1.329	6	30.0	0	
7511	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7512	0.0		7.00-4	0.0110	1.329	6	30.0	0	
7513	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7514	0.0		7.00-4	0.0110	1.329	6	30.0	0	
7515	1.626462		0.6645	0.8125	1.329	6	30.0	0	
7516	0.0		7.00-4	0.0110	1.329	6	30.0	0	
7517	1.1453		0.383	0.5	0.766	6	30.0	0	
7518	0.5		3.00-3	0.0070	0.766	6	30.0	0	
7519	1.1453		0.383	0.5	0.766	6	30.0	0	
7520	0.0		3.00-3	0.0070	0.766	6	30.0	0	
7521	1.1453		0.383	0.5	0.766	6	30.0	0	
7522	0.0		3.00-3	0.0070	0.766	6	30.0	0	
7523	1.1453		0.383	0.5	0.766	6	30.0	0	
7524	0.0		3.00-3	0.0068	0.736	6	30.0	0	
7525	1.1453		0.383	0.5	0.736	6	30.0	0	
7526	0.0		3.00-3	0.0068	0.736	6	30.0	0	
7527	1.1453		0.383	0.5625	0.777	6	30.0	0	
7528	0.0		3.00-3	0.0071	0.777	6	30.0	0	
7529	1.1453		0.3155	0.5625	0.631	6	30.0	0	
7530	0.0		7.00-3	0.0058	0.703	6	30.0	0	
7531	1.1453		0.3515	0.5625	0.703	6	30.0	0	
7532	0.0		7.00-3	0.0065	0.703	6	30.0	0	
8001	714.670		2216.000	29.17	1.1775	1	1	0	
8002	58.7039		201	2	1.1775	1	1	0	
8003	714.320		2178.700	29.17	1.1775	1	1	0	
8004	58.7039		201	3	1.1775	1	1	0	
8005	713.980		2143.500	29.17	1.1775	1	1	0	
8006	58.7039		201	4	1.1775	1	1	0	
8007	713.650		2110.000	29.17	1.1775	1	1	0	
8008	58.7039		201	5	1.1775	1	1	0	
8009	713.260		2093.500	215	2.28125	2.3333	1	1	
8010	168.2059		215	6	2.28125	2.3333	1	1	
8011	713.570		2093.500	21.3603	19.9592	19.9592	0	1	
8012	428.7337		5	7	19.9592	19.9592	0	1	
8013	712.420		2093.500	21.3603	19.9592	19.9592	0	1	

6014	426.7337	2093.566	36.2764	2.5	3.5933	0	0
6015	712.270	2093.566	230			0	
6016	281.1518	2031.000	40.000	3.1139	3.1139	1	0
6017	712.470	230	18			0	
6018	191.0015	1901.300	40.000	2.8283	2.8283	1	0
6019	711.920	1745.000	40.000	2.7560	2.7560	1	0
6020	173.4857	169.0975	11			0	
6021	711.480	1645.500	12	3.0418	3.0418	1	0
6022	169.0975	1558.600	13	3.0418	3.0418	1	0
6023	711.000	1558.600	14	2.8124	2.8124	1	0
6024	200.00255	1489.600	15			0	
6025	710.810	1420.900	16			0	
6026	200.00255	1420.900	17			0	
6027	710.540	1344.400	18			0	
6028	104.9705	1344.400	19			0	
6029	710.310	122.9	20			0	
6030	164.8711	116.8	21			0	
6031	710.070	116.8	22			0	
6032	164.8711	116.8	23			0	
6033	522.200	1.625	24			1.5274	
6034	522.200	1.625	25			1.5274	
6035	522.200	1.625	26			1.5274	
6036	522.200	1.625	27			1.5274	
6037	522.200	1.625	28			1.5274	
6038	522.200	1.625	29			1.5274	
6039	522.200	1.625	30			1.5274	
6040	522.200	1.625	31			1.5274	
6041	522.200	1.625	32			1.5274	
6042	522.200	1.625	33			1.5274	
6043	522.200	1.625	34			1.5274	
6044	522.200	1.625	35			1.5274	
6045	522.200	1.625	36			1.5274	
6046	522.200	1.625	37			1.5274	
6047	522.200	1.625	38			1.5274	
6048	522.200	1.625	39			1.5274	
6049	522.200	1.625	40			1.5274	
6050	522.200	1.625	41			1.5274	
6051	522.200	1.625	42			1.5274	
6052	522.200	1.625	43			1.5274	
6053	522.200	1.625	44			1.5274	
6054	522.200	1.625	45			1.5274	
6055	522.200	1.625	46			1.5274	
6056	522.200	1.625	47			1.5274	
6057	522.200	1.625	48			1.5274	
6058	522.200	1.625	49			1.5274	
6059	522.200	1.625	50			1.5274	
6060	522.200	1.625	51			1.5274	
6061	522.200	1.625	52			1.5274	
6062	522.200	1.625	53			1.5274	
6063	522.200	1.625	54			1.5274	
6064	522.200	1.625	55			1.5274	
6065	522.200	1.625	56			1.5274	
6066	522.200	1.625	57			1.5274	
6067	522.200	1.625	58			1.5274	
6068	522.200	1.625	59			1.5274	
6069	522.200	1.625	60			1.5274	
6070	522.200	1.625	61			1.5274	
6071	522.200	1.625	62			1.5274	
6072	522.200	1.625	63			1.5274	
6073	522.200	1.625	64			1.5274	
6074	522.200	1.625	65			1.5274	
6075	522.200	1.625	66			1.5274	
6076	522.200	1.625	67			1.5274	
6077	522.200	1.625	68			1.5274	
6078	522.200	1.625	69			1.5274	
6079	522.200	1.625	70			1.5274	
6080	522.200	1.625	71			1.5274	
6081	522.200	1.625	72			1.5274	
6082	522.200	1.625	73			1.5274	
6083	522.200	1.625	74			1.5274	
6084	522.200	1.625	75			1.5274	
6085	522.200	1.625	76			1.5274	
6086	522.200	1.625	77			1.5274	
6087	522.200	1.625	78			1.5274	
6088	522.200	1.625	79			1.5274	
6089	522.200	1.625	80			1.5274	
6090	522.200	1.625	81			1.5274	
6091	522.200	1.625	82			1.5274	
6092	522.200	1.625	83			1.5274	
6093	522.200	1.625	84			1.5274	
6094	522.200	1.625	85			1.5274	
6095	522.200	1.625	86			1.5274	
6096	522.200	1.625	87			1.5274	
6097	522.200	1.625	88			1.5274	
6098	522.200	1.625	89			1.5274	
6099	522.200	1.625	90			1.5274	
6100	522.200	1.625	91			1.5274	
6101	522.200	1.625	92			1.5274	
6102	522.200	1.625	93			1.5274	
6103	522.200	1.625	94			1.5274	
6104	522.200	1.625	95			1.5274	
6105	522.200	1.625	96			1.5274	
6106	522.200	1.625	97			1.5274	
6107	522.200	1.625	98			1.5274	
6108	522.200	1.625	99			1.5274	
6109	522.200	1.625	100			1.5274	
6110	522.200	1.625	101			1.5274	
6111	522.200	1.625	102			1.5274	
6112	522.200	1.625	103			1.5274	
6113	522.200	1.625	104			1.5274	
6114	522.200	1.625	105			1.5274	
6115	522.200	1.625	106			1.5274	
6116	522.200	1.625	107			1.5274	
6117	522.200	1.625	108			1.5274	
6118	522.200	1.625	109			1.5274	
6119	522.200	1.625	110			1.5274	
6120	522.200	1.625	111			1.5274	
6121	522.200	1.625	112			1.5274	
6122	522.200	1.625	113			1.5274	
6123	522.200	1.625	114			1.5274	
6124	522.200	1.625	115			1.5274	
6125	522.200	1.625	116			1.5274	
6126	522.200	1.625	117			1.5274	
6127	522.200	1.625	118			1.5274	
6128	522.200	1.625	119			1.5274	
6129	522.200	1.625	120			1.5274	
6130	522.200	1.625	121			1.5274	
6131	522.200	1.625	122			1.5274	
6132	522.200	1.625	123			1.5274	
6133	522.200	1.625	124			1.5274	
6134	522.200	1.625	125			1.5274	
6135	522.200	1.625	126			1.5274	
6136	522.200	1.625	127			1.5274	
6137	522.200	1.625	128			1.5274	
6138	522.200	1.625	129			1.5274	
6139	522.200	1.625	130			1.5274	
6140	522.200	1.625	131			1.5274	
6141	522.200	1.625	132			1.5274	
6142	522.200	1.625	133			1.5274	
6143	522.200	1.625	134			1.5274	
6144	522.200	1.625	135			1.5274	
6145	522.200	1.625	136			1.5274	
6146	522.200	1.625	137			1.5274	
6147	522.200	1.625	138			1.5274	
6148	522.200	1.625	139			1.5274	
6149	522.200	1.625	140			1.5274	
6150	522.200	1.625	141			1.5274	
6151	522.200	1.625	142			1.5274	
6152	522.200	1.625	143			1.5274	
6153	522.200	1.625	144			1.5274	
6154	522.200	1.625	145			1.5274	
6155	522.200	1.625	146			1.5274	
6156	522.200	1.625	147			1.5274	
6157	522.200	1.625	148			1.5274	
6158	522.200	1.625	149			1.5274	
6159	522.200	1.625	150			1.5274	
6160	522.200	1.625	151			1.5274	
6161	522.200	1.625	152			1.5274	
6162	522.200	1.625	153			1.5274	
6163	522.200	1.625	154			1.5274	
6164	522.200	1.625	155			1.5274	
6165	522.200	1.625	156			1.5274	
6166	522.200	1.625	157			1.5274	
6167	522.200	1.625	158			1.5274	
6168	522.200	1.625	159			1.5274	
6169	522.200	1.625	160			1.5274	
6170	522.200	1.625	161			1.5274	
6171	522.200	1.625	162			1.5274	
6172	522.200	1.625	163			1.5274	
6173	522.200	1.625	164			1.5274	
6174	522.200	1.625	165			1.5274	
6175	522.200	1.625	166			1.5274	
6176	522.200	1.625	167			1.5274	
6177	522.200	1.625	168			1.5274	
6178	522.200	1.625	169			1.5274	
6179	522.200	1.625	170			1.5274	
6180	522.200	1.625	171			1.5274	
6181	522.200	1.625	172			1.5274	
6182	522.200	1.625	173			1.5274	
6183	522.200	1.625	174			1.5274	
6184	522.200	1.625	175			1.5274	
6185	522.200	1.625	176			1.5274	
6186	522.200	1.625	177			1.5274	
6187	522.200	1.625	178			1.5274	
6188	522.200	1.625	179			1.5274	
6189	522.200	1.625	180			1.5274	
6190	522.200	1.625	181			1.5274	
6191	522.200	1.625	182			1.5274	
6192	522.200	1.625	183			1.5274	
6193	522.200	1.625	184			1.5274	
6194	522.200	1.625	185			1.5274	
6195	522.200	1.625	186			1.5274	
6196	522.200	1.625	187			1.5274	
6197	522.200	1.625	188			1.5274	

18603	540.8	700.0	542.0	800.0	530.4	900.0	519.7
18604	1000.0	509.4	1100.0	500.0	1200.0	490.4	1300.0
18605	479.9	1400.0	470.5	1500.0	444.5		
18701	26	0.0	2269.3	10.	2269.9	20.0	2255.1
18702	30.0	2232.0	40.0	2200.7	40.0	2155.2	100.0
18703	2056.6	110.0	2035.0	130.0	2000.5	140.0	1980.6
18704	150.0	1900.4	230.0	1850.2	250.0	1823.0	290.0
18705	1739.7	350.0	1602.3	370.0	1565.6	390.0	1536.1
18706	410.0	1512.7	460.0	1475.2	500.0	1447.3	540.0
18707	1415.1	600.0	1395.0	620.0	1386.5	640.0	1382.4
18708	700.0	1366.1	740.0	1351.5	760.0	1344.6	800.0
18709	1333.0	840.0	1321.6	900.0	1305.6		

LISTING OF THE INPUT DATA

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*                                     *
*      IMPLICIT SOLUTION TECHNIQUE   *
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TIME STEP AND PRINT INTERVAL INPUT

TIME STEP	END OF INTERVAL	EDITS	TIME STEP	END OF INTERVAL	EDITS	TIME STEP	END OF INTERVAL	EDITS
0.20000-01	0.10000 02	2	0.25000-01	0.01000 03	60			

PLOT INFORMATION

IOPLT	XIMF	XMAXP	XLEMP	KINDV	VMIMP	VMAXP	VLEMP	N1PLT	N2PLT
11010	0.35000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
31015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
3215	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
31014	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
31014	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
34015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
34015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
14010	0.35000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
22014	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
22015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
18015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
18015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
18014	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
18014	0.35000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
38014	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
14010	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
34015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
35015	0.0	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
35014	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
35015	0.35000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
34015	0.35000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0

PRESSURE PSIA	ENTHALPY BTU/LBM	FLOW AREA FT ² @2	WATER MODE INPUT				TUBE TYPE	UPSTREAM MODE	DNSTREAM MODE
			TUBE LENGTH FT	INLET POSITION 1-TOP	OUTLET POSITION 0-BOTTOM	ASSOC. HFL. MODE			
35015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
36015	0.0	0.40000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
14015	0.39000F 03	0.42000F 03	0.85000E 01	0	0.0	0.0	0.11000F 02	0	0
1400	0.0	0.60000F 03	0.85000E 01	0	0.0	0.0	0.11000F 02	0	0
3400	0.0	0.60000F 03	0.85000E 01	0	0.0	0.0	0.11000F 02	0	0
22015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
22014	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
16010	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
38014	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
38015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
39015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000F 02	0	0
32015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
38015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
12010	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
22015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
14011	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
0.4300000 03	0.1324700 04	0.9633350-02	0.4837500 01	0	1	4	0.2280000 03	201	2
0.4280000 03	0.1355400 04	0.9633350-02	0.4837500 01	0	1	3	0.2280000 03	1	3
0.4250000 03	0.1394900 04	0.9633350-02	0.4837500 01	0	1	2	0.2280000 03	2	2
0.4210000 03	0.1413400 04	0.9633350-02	0.4837500 01	0	1	1	0.2280000 03	3	3
0.4060000 03	0.1440700 04	0.9633350-02	0.4837500 01	1	0	1	0.2280000 03	4	4
0.5910000 03	0.1464600 04	0.9633350-02	0.4837500 01	1	0	2	0.2280000 03	5	7
0.5870000 03	0.1484600 04	0.9633350-02	0.4837500 01	1	0	3	0.2280000 03	6	8
0.5820000 03	0.1501200 04	0.9633350-02	0.4837500 01	1	0	4	0.2280000 03	7	215
0.2883000 04	0.4032800 03	0.3200260-02	0.3825000 02	0	1	16	0.3280000 03	230	10
0.2801000 04	0.5120300 03	0.3200260-02	0.3825000 02	0	1	15	0.3280000 03	9	11
0.2791800 04	0.6078800 03	0.3200260-02	0.4290000 02	0	1	14	0.3280000 03	10	12
0.2783500 04	0.7040300 03	0.2954490-02	0.4640000 02	0	1	13	0.3280000 03	11	13
0.2722800 04	0.8223000 03	0.2954490-02	0.4640000 02	0	1	12	0.3280000 03	12	14
0.2754600 04	0.9919000 03	0.3292830-02	0.3860000 02	0	1	11	0.3280000 03	13	15
0.2736270 04	0.1182200 04	0.27171630-02	0.3960000 02	0	1	10	0.3280000 03	14	16
0.2584910 04	0.1364300 04	0.2693490-02	0.4360000 02	0	1	9	0.3280000 03	15	241

WATER SIDE HYDRAULIC INDENT

[illegible]

ANALYSIS MODE INPUT

PRESSURE PSIA	ENTHALPY BTU/LBM	FLOW AREA FT ²	FLOW LENGTH FT	VOL. HEIGHT FT	INLET POSITION 1-770P	OUTLET POSITION 0-80110M	MOAL VOLUME FT ³	UPSTREAM NODE	ONSTREAM NODE
0.216700 03	0.2216000 04	0.2917000 02	0.1177500 01	0.1177500 01	1	0	0.5870390 02	201	?
0.216700 03	0.2178750 04	0.2917000 02	0.1177500 01	0.1177500 01	1	0	0.5870390 02	1	3
0.216700 03	0.2143500 04	0.2917000 02	0.1177500 01	0.1177500 01	1	0	0.5870390 02	2	3
0.216700 03	0.2110000 04	0.2917000 02	0.1177500 01	0.1177500 01	1	0	0.5870390 02	3	215
0.216700 03	0.2095500 04	0.2917000 02	0.2261250 01	0.2333500 01	1	1	0.1682000 03	215	6
0.216700 03	0.2095500 04	0.2130030 02	0.1995920 02	0.1995920 02	0	1	0.4267340 03	5	7
0.216700 03	0.2095500 04	0.2130030 02	0.1995920 02	0.1995920 02	0	1	0.4267340 03	6	6
0.216700 03	0.2095500 04	0.2095000 02	0.2095000 02	0.2095000 02	0	0	0.2811920 03	7	210
0.216700 03	0.2031800 04	0.4000000 02	0.3113900 01	0.3113900 01	0	0	0.1910020 03	230	10
0.216700 03	0.1901300 04	0.4000000 02	0.2828300 01	0.2828300 01	1	0	0.1734860 03	9	11

MELIUM HYDRAULIC INPUT											
MASS FLOW RATE LBM/SEC	AVG. TUBE OUTSIDE DIA. IN	CONSTANT PRIC. FACT.	EPS/DIA.	NO. ROWS IN LINE	NO. ROWS STAGGERED	PITCH TO DIA. TRANSVERSE	PITCH TO DIA. LONGITUDINAL				
0.7114800 03	0.1745000 04	0.4000000 02	0.2754800 01	0.2754800 01	1	0	0.1440000 03	10	12		
0.7110800 03	0.1645500 04	0.4581000 02	0.3041800 01	0.3041800 01	1	0	0.2000000 03	11	13		
0.7108100 03	0.1558600 04	0.4581000 02	0.3041800 01	0.3041800 01	1	0	0.2000000 03	12	14		
0.7105400 03	0.1489600 04	0.4581000 02	0.2812400 01	0.2812400 01	1	0	0.1440000 03	13	15		
0.7103100 03	0.1420900 04	0.4581000 02	0.2507500 01	0.2507500 01	1	0	0.1440000 03	14	16		
0.7100700 03	0.1344400 04	0.4581000 02	0.2507500 01	0.2507500 01	1	0	0.1440000 03	15	251		
0.5222000 03	0.1625000 01	0.0	0.1000000 01	0.1000000 01	4	2	0.1527400 01	0.1558200 01			
0.5222000 03	0.1625000 01	0.0	0.1000000 01	0.1000000 01	4	2	0.1527400 01	0.1558200 01			
0.5222000 03	0.1625000 01	0.0	0.1000000 01	0.1000000 01	4	2	0.1527400 01	0.1558200 01			
0.5222000 03	0.1625000 01	0.7500000-01	0.1000000 01	0.1000000 01	4	2	0.1527400 01	0.1558200 01			
0.5222000 03	0.1625000 01	0.7500000-01	0.1000000 01	0.1000000 01	7	7	0.4551100 01	0.1527400 01			
0.5222000 03	0.4000000 02	0.8000000-01	-0.1000000 02	-0.1000000 02	0	0	0.1000000 01	0.1000000 01			
0.5222000 03	0.4000000 02	0.8000000-01	-0.1000000 02	-0.1000000 02	0	0	0.1000000 01	0.1000000 01			
0.5222000 03	0.1125000 01	0.7500000-01	0.1000000 01	0.1000000 01	11	10	0.7252800 01	0.1493300 01			
0.5222000 03	0.1125000 01	0.0	0.1000000 01	0.1000000 01	16	4	0.1493300 01	0.1396400 01			
0.5222000 03	0.1125000 01	0.0	0.1000000 01	0.1000000 01	16	5	0.1493300 01	0.1396400 01			
0.5222000 03	0.1125000 01	0.0	0.1000000 01	0.1000000 01	16	5	0.1493300 01	0.1396400 01			
0.5222000 03	0.1000000 01	0.0	0.1000000 01	0.1000000 01	19	7	0.1493300 01	0.1442000 01			
0.5222000 03	0.1000000 01	0.0	0.1000000 01	0.1000000 01	19	6	0.1493300 01	0.1442000 01			
0.5222000 03	0.1000000 01	0.0	0.1000000 01	0.1000000 01	18	5	0.1493300 01	0.1442000 01			
0.5222000 03	0.1000000 01	0.0	0.1000000 01	0.1000000 01	16	6	0.1493300 01	0.1442000 01			
0.5222000 03	0.1000000 01	0.0	0.1000000 01	0.1000000 01	15	5	0.1493300 01	0.1442000 01			

TUNNEL INPUT *****

THE FIRST NODE IN THE TUNNEL IS 5
THE LAST NODE IN THE TUNNEL IS 8

***** WATER AND HELIUM ALLOWABLE TEMPERATURE CHANGES *****

ALLOWABLE TEMPERATURE CHANGE FOR WATER = 0.10000000 01
ALLOWABLE TEMPERATURE CHANGE FOR HELIUM = 0.20000000 00

***** WATER SIDE *****
***** FLOW RATE VS. TIME *****

TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE
0.0	1.1430 00	1.0000 01	1.0830 00	1.2000 02	4.9380-01
1.5000 02	2.8840-01	1.6000 02	2.8610-01	1.4000 03	2.8610-01
					3.3890-01

***** WATER SIDE *****
***** PRESSURE VS. TIME *****

TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE
0.0	2.9650 03	1.6000 02	2.74120 03	1.4000 03	2.7260 03

***** WATER SIDE *****
***** ENTHALPY VS. TIME *****

TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY
0.0	3.4680 02	1.0000 02	3.0610 02	2.0000 02	2.7760 02
1.0000 02	2.4760 02	5.0000 02	2.3440 02	6.0000 02	2.2270 02
9.0000 02	2.1250 02	1.4000 03	2.1200 02	7.0000 02	2.1430 02

HELIUM SIDE				HELIUM SIDE			
FLOW RATE VS. TIME				FLOW RATE VS. TIME			
TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE
0.0	5.22200 02	1.00000 01	4.90400 02	2.00000 01	4.54000 02	3.00000 01	4.21000 02
4.00000 01	3.87500 02	5.00000 01	3.58100 02	6.00000 01	3.33500 02	7.00000 01	3.13500 02
8.00000 01	2.96900 02	9.00000 01	2.80400 02	1.00000 02	2.63400 02	1.10000 02	2.43100 02
1.20000 02	2.19500 02	1.30000 02	1.97500 02	1.40000 02	1.70800 02	1.50000 02	1.43300 02
1.60000 02	1.50000 02	1.80000 02	1.49800 02	1.90000 02	1.49200 02	2.00000 02	1.49200 02
2.10000 02	1.49700 02	2.20000 02	1.51700 02	2.30000 02	1.53100 02	2.40000 02	1.60300 02
2.50000 02	1.67200 02	2.60000 02	1.78100 02	2.70000 02	1.87200 02	2.80000 02	2.00500 02
2.90000 02	2.15400 02	3.00000 02	2.32800 02	3.10000 02	2.43200 02	3.20000 02	2.54300 02
3.30000 02	2.63500 02	3.40000 02	2.70900 02	3.50000 02	2.78700 02	3.60000 02	2.76900 02
3.70000 02	2.75700 02	3.80000 02	2.48300 02	3.90000 02	2.31500 02	4.00000 02	2.17000 02
4.10000 02	2.01600 02	4.20000 02	1.75100 02	4.30000 02	1.37300 02	4.40000 02	1.52600 02
4.50000 02	1.52000 02	4.60000 02	1.52500 02	4.70000 02	1.33300 02	4.80000 02	1.31200 02
5.20000 02	1.46500 02	5.30000 02	1.40800 02	5.40000 02	1.37900 02	5.70000 02	1.38000 02
6.00000 02	1.44500 02	6.20000 02	1.47100 02	6.40000 02	1.11900 02	7.00000 02	1.14500 02
7.40000 02	1.22900 02	7.60000 02	1.28500 02	8.00000 02	1.21600 02	8.40000 02	1.16800 02
9.00000 02	1.13000 02						

HELIUM SIDE				HELIUM SIDE			
PRESSURE VS. TIME				PRESSURE VS. TIME			
TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE
0.0	7.15000 02	1.00000 02	6.64500 02	2.00000 02	6.29400 02	3.00000 02	6.20500 02
4.00000 02	6.12900 02	5.00000 02	5.81300 02	6.00000 02	5.60800 02	7.00000 02	5.42000 02
8.00000 02	5.30400 02	9.00000 02	5.19700 02	1.00000 03	5.09400 02	1.10000 03	5.00000 02
1.20000 03	4.90400 02	1.30000 03	4.79900 02	1.40000 03	4.70500 02	1.50000 03	4.64500 02

HELIUM SIDE				HELIUM SIDE			
ENTHALPY VS. TIME				ENTHALPY VS. TIME			
TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY
0.0	2.26930 03	1.00000 01	2.24990 03	2.00000 01	2.15510 03	3.00000 01	2.23200 03
4.00000 01	2.20670 03	6.00000 01	2.15520 03	1.00000 02	2.05660 03	1.10000 02	2.03500 03
1.30000 02	2.00950 03	1.40000 02	1.98860 03	1.50000 02	1.98040 03	2.30000 02	1.81820 03
2.50000 02	1.83300 03	2.90000 02	1.73970 03	3.50000 02	1.60230 03	3.70000 02	1.56360 03
3.90000 02	1.53610 03	4.10000 02	1.51270 03	4.60000 02	1.47520 03	5.00000 02	1.44730 03
5.60000 02	1.41510 03	6.10000 02	1.39580 03	6.20000 02	1.38650 03	6.40000 02	1.38240 03
7.00000 02	1.36410 03	7.40000 02	1.35150 03				

STEADY STATE OUTPUT

INPUT FRICTION FACTOR	CALCULATED FRICTION FACTOR	CALCULATED CURVATURE FACTOR	WATER SIDE	TWO - PHASE MULTIPLIER	TRANSITION REGION PARAMETERS A	P-A=EXP(PI)*B
-3.20401429D-03	1.83714700D-02	1.38977809D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-7.84749461D-03	1.83667392D-02	1.38531814D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-8.65606942D-03	1.84023748D-02	1.38099078D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-7.5103072D-02	1.84174219D-02	1.37703429D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
6.74837199D-02	1.84319647D-02	1.31564589D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-4.26913024D-04	1.84444144D-02	1.31303428D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-6.30282349D-04	1.84559850D-02	1.31077019D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
-1.17037138D-03	1.84651740D-02	1.30902173D 00		1.00000000D 00	1.01322658D-03	4.44959862D-01
5.09345540D-01	2.66722503D-02	1.18106459D 00		1.00000000D 00	5.34557246D-04	5.28552283D-01
7.72517648D-03	2.65794524D-02	1.19117383D 00		1.00000000D 00	5.34557246D-04	5.28552283D-01
3.99275042D-03	2.65213345D-02	1.19820498D 00		1.00000000D 00	5.34557246D-04	5.28552283D-01
1.1074663D-04	2.64737450D-02	1.20261880D 00		1.00000000D 00	5.34557246D-04	5.28552283D-01
3.06059191D-07	2.64637898D-02	1.20431488D 00		9.36019542D-01	5.34557246D-04	5.28552283D-01
-5.93631702D-04	2.64605745D-02	1.20589052D 00		9.10428837D-01	5.34557246D-04	5.28552283D-01
-4.80649325D-03	3.37675572D-02	1.25109547D 00		1.00000000D 00	2.00812770D-04	6.56539890D-01
-2.31882778D-03	3.37787364D-02	1.25345808D 00		1.00000000D 00	2.00812770D-04	6.56539890D-01

INPUT FRICTION FACTOR	CALCULATED FRICTION FACTOR	MEDIUM SIDE	TUBE NUMBER	GAINWISSON PARAMETERS η	MU-BORGESON (PR/.691001/3) N
-2.021701740-03	3.856499070-01		4	2.565118210-01	6.150858160-01
-9.149886170-04	3.849274570-01		5	2.565118210-01	6.150858160-01
-8.757281740-04	3.842349100-01		6	2.565118210-01	6.150858160-01
7.406085780-02	3.835659470-01		7	2.565118210-01	6.150858160-01
7.307838070-02	4.230909460-01		8	2.565118210-01	6.150858160-01
7.780053420-02	0.0				
7.948882180-02	0.0				
7.336783470-02	6.165629540-01		16	1.670145080-01	6.623726030-01
-1.894353290-02	1.268069090 00		15	1.670145080-01	6.623726030-01
-1.991043300-02	1.093854430 00				
-1.434499740-02	1.085053710 00		14	1.670145080-01	6.623726030-01
-8.791583790-03	1.17899720 00		13	1.468547440-01	6.756699200-01
-9.991237000-03	1.099332580 00		12	1.468547440-01	6.756699200-01
-1.300589030-02	9.883832740-01		11	1.468547440-01	6.756699200-01
-1.971564480-02	9.821114730-01		10	1.468547440-01	6.756699200-01
1.496301090-01	8.719246280-01		9	1.468547440-01	6.756699200-01

***** WATER LICE *****

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	QUALITY	MASS FLOW RATE LBM/SEC	***** PRESSURE ORCP - PSI *****				
							INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	PROJECTION
1	629.30	4.779300-02	5.803330 01	679.50	1.17	1.626460 00	2.88210-13	3.54840 00	-4.38620-03	-1.98530-01	-3.34150 00
2	626.25	4.471840-02	5.538650 01	729.75	1.22	1.626460 00	3.32180-13	3.97670 00	-7.84670-03	-4.12540-01	-3.55630 00
3	622.77	4.201230-02	5.303260 01	781.11	1.26	1.626460 00	4.09250-12	4.19590 00	-7.37180-03	-4.13040-01	-3.77550 00
4	618.02	3.963510-02	5.094410 01	839.55	1.30	1.626460 00	-7.50510-14	1.50910 01	-6.95470-03	-4.09370-01	-1.46750 01
5	602.99	3.691930-02	4.825350 01	878.76	1.33	1.626460 00	2.45830-11	1.60870 01	6.47820-03	-5.32230-01	-1.55610 01
6	586.90	3.455960-02	4.587790 01	920.04	1.37	1.626460 00	-9.40890-12	4.83560 00	6.06410-03	-5.30340-01	-4.31140 00
7	582.06	3.321080-02	4.457030 01	958.08	1.39	1.626460 00	5.01620-11	4.77420 00	5.82750-03	-3.36990-01	-4.44310 00
8	577.29	3.211540-02	4.352410 01	988.36	1.42	1.626460 00	6.44090-10	4.77420 00	5.63520-03	-7.94510-01	-6.48560 00
9	2681.59	6.543600 00	2.594450 03	426.31	-1.44	1.145300 00	1.06580-14	4.33670 01	-9.30850-01	-2.05640-02	-8.24160 01
10	2798.22	5.965070 00	3.014090 03	524.32	-0.89	1.145300 00	0.0	7.59290 00	-6.48550-01	-5.01600-02	-6.69420 00
11	2790.63	5.974210 00	3.601360 03	602.68	-0.54	1.145300 00	3.33200-12	8.55490 00	-8.49870-01	-6.80000-02	-7.63700 00
12	2787.07	5.043350 00	3.55170 03	664.17	-0.18	1.145300 00	1.11020-15	1.16430 01	-7.77120-01	-7.46390-01	-1.06170 01
13	2770.43	2.677930 00	2.195630 03	683.35	0.27	1.145300 00	-3.55270-15	1.99300 01	-4.12640-01	-7.78840-01	-1.87310 01
14	2750.50	1.298450 00	1.267940 03	682.27	0.88	1.145300 00	0.0	2.28240 01	-1.95630-01	-8.94960-01	-2.17340 01
15	2727.68	4.904590-01	5.551920 02	766.09	1.51	1.145300 00	-5.96860-13	1.56500 02	-1.12020-01	-7.97210 00	-1.68470 02
16	2571.18	4.340080-01	5.531680 02	938.57	1.90	1.145300 00	-7.10540-15	1.56500 02	-8.02250-02	2.10570-02	-1.56440 02

NODE	PRESSURE	TOTAL MASS	INTERNAL	TEMP.	MASS	HELIUM SIZE	*****		
	PSIA	LB	ENERGY	DEG. F	FLOW RATE		INERTIA	PRESSURE	PRESSURE DROP - PSI
			BTU		LB/SEC			STATIC HEAD	MOMENTUM
									FRICTION

1	716.67	8.641120 00	1.167200 04	1341.31	5.222000 02		4.16330-17	3.54540-01	1.20370-03
2	716.32	8.787230 00	1.164490 04	1310.29	5.222000 02		4.16330-17	3.45010-01	1.22400-03
3	713.97	8.929800 00	1.165800 04	1281.03	5.222000 02		4.16330-17	3.39180-01	1.24390-03
4	713.63	9.069800 00	1.165120 04	1253.11	5.222000 02		2.77560-17	4.00480-01	1.26340-03
5	713.23	2.618060 01	3.336400 04	1239.48	5.222000 02		1.98780-17	7.09920-01	0.0

6	712.52	6.633350 01	8.459970 04	1239.49	5.222000 02		0.0	1.50910-01	-2.15520-02
7	712.37	6.633950 01	8.454190 04	1239.49	5.222000 02		0.0	1.51070-01	-2.15470-02
8	712.22	4.369820 01	5.568820 04	1239.49	5.222000 02		-1.38780-17	-2.02040-01	0.0
9	712.42	3.052980 01	3.783510 04	1192.49	5.222000 02		8.32670-17	5.63540-01	3.45440-03
10	711.85	2.950530 01	3.432210 04	1091.31	5.222000 02		1.52660-16	4.46250-01	3.34040-03

11	711.41	3.096580 01	3.341250 04	979.00	5.222000 02		6.93490-17	4.09390-01	3.50580-03
12	711.00	3.942690 01	3.947020 04	875.11	5.222000 02		-1.38780-17	2.68920-01	4.16410-03
13	710.73	4.176060 01	3.943710 04	799.33	5.222000 02		1.38780-17	2.79570-01	4.41040-03
14	710.45	4.043780 01	3.642760 04	741.42	5.222000 02		0.0	2.39250-01	4.27040-03
15	710.21	3.781890 01	3.245000 04	684.36	5.222000 02		2.77560-17	2.26790-01	3.99430-03

16	709.99	3.999250 01	3.241850 04	621.13	5.222000 02		-2.77560-17	2.26790-01	4.27390-03

TUBES									
ASSOC. MEDIUM NODE	HEAT FLUX BTU/MR-FT2	MELTUM TRAN. COEF. BTU/MR-FT2-F	MELTUM SURFACE TEMP. DEG. F	TUBE AVERAGE TEMP. DEG. F	WATER SURFACE TEMP. DEG. F	WATER TRAN. COEF. BTU/MR-FT2-F	WATER HEAT FLUX BTU/MR-FT2	MEAT TRAN. WIDE	MASS FLUX LB/MR-FT2
1	9.22713D 04	3.91440D 02	1017.51	945.54	908.08	4.91483D 02	1.12822D 05	7	6.07812D 05
2	8.89079D 04	3.93164D 02	1056.86	1005.67	951.27	4.90756D 02	1.08710D 05	7	6.07812D 05
3	8.58533D 04	3.94750D 02	1092.80	1046.11	996.48	4.91978D 02	1.04975D 05	7	6.07812D 05
4	8.35122D 04	3.96408D 02	1130.64	1083.47	1036.58	4.93616D 02	1.02112D 05	7	6.07812D 05
5	7.60370D 04	3.96408D 02	1149.50	1109.21	1064.66	5.00117D 02	9.29730D 04	7	6.07812D 05
6	6.42948D 04	3.94750D 02	1147.41	1113.41	1075.80	5.04698D 02	7.86138D 04	7	6.07812D 05
7	5.33443D 04	3.93164D 02	1145.32	1117.14	1085.99	5.09916D 02	6.52259D 04	7	6.07812D 05
8	4.38103D 04	3.91440D 02	1141.25	1118.11	1092.54	5.14213D 02	5.35737D 04	7	6.07812D 05
9	4.51325D 04	3.90353D 02	680.89	645.83	448.63	2.87368D 03	6.41414D 04	1	1.28834D 06
10	4.10010D 04	3.54270D 02	548.62	556.05	541.70	3.08079D 03	5.35239D 04	1	1.28834D 06
11	3.59670D 04	3.57430D 02	640.85	629.82	617.23	3.22747D 03	4.69541D 04	1	1.24834D 06
12	3.48093D 04	3.60938D 02	702.89	690.75	676.61	3.80265D 03	6.72946D 04	1	1.39533D 06
13	5.42600D 04	3.65097D 02	726.49	707.37	685.92	3.39917D 04	7.37221D 05	2	1.39533D 06
14	7.55321D 04	3.85387D 02	790.79	757.02	716.41	3.07631D 03	1.05016D 05	4	1.29214D 06
15	6.68084D 04	3.91417D 02	920.63	874.75	813.59	2.50708D 03	1.19098D 05	7	1.89861D 06
16	5.20167D 04	3.96584D 02	1061.53	1031.59	993.76	1.50819D 03	8.32356D 04	7	1.52962D 06
REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS									
STEAM GENERATOR									
PRESSURE	6.2880D 02	7.1500D 02	5.7490D 02	7.1323D 02	2.9450D 03	7.1123D 02	2.4929D 03	7.0987D 02	
TEMPERATURE	6.5140D 02	1.3573D 03	1.0016D 03	1.2395D 03	3.6767D 02	1.2395D 03	1.0326D 03	5.8666D 02	
ENTHALPY	1.3113D 03	2.2693D 03	1.5180D 03	2.1235D 03	3.6680D 02	2.1235D 03	1.4780D 03	1.3094D 03	
SPEC. VOL.	9.4280D-01	6.8503D 00	1.4734D 00	6.4248D 00	1.7943D-02	6.4248D 00	3.1584D-01	3.9933D 00	
FLOW RATE	1.6265D 00	5.2220D 02	1.6265D 00	5.2220D 02	1.1453D 00	5.2220D 02	1.1453D 00	5.2220D 02	

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***** TRANSIENT OUTPUT NUMBER 21 *****
***** TIME STEP NUMBER 8100 *****
***** TRANSIENT TIME = 200.0000 SEC. *****
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***** WATER SIDE *****

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	QUALITY	MASS FLOW RATE LBM/SEC	***** INERTIA	PRESSURE DROP - PSI *****			
								PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	152.67	1.09359D-02	1.35105D 01	664.52	1.19	3.65692D-01	-1.2441D-03	6.8533D-01	-1.9169D-03	2.9909D-02	-7.1456D-01
2	151.99	1.02977D-02	1.29640D 01	721.47	1.22	3.66817D-01	-6.4886D-04	8.4298D-01	-1.8067D-03	-8.3573D-02	-7.5825D-01
3	151.14	9.76793D-03	1.25000D 01	778.22	1.25	3.66934D-01	-6.7646D-04	8.7888D-01	-1.7140D-03	-7.772D-02	-8.0007D-01
4	150.24	9.32457D-03	1.2112D 01	826.98	1.28	3.67045D-01	-1.3839D-03	3.2210D 00	-1.6373D-03	-7.1153D-02	-3.1496D 00
5	147.04	8.82757D-03	1.16018D 01	867.12	1.31	3.67150D-01	-1.4634D-03	3.3887D 00	1.5490D-03	-8.9961D-02	-3.3017D 00
6	143.65	8.40186D-03	1.11510D 01	896.52	1.32	3.67250D-01	-7.7578D-04	9.7318D-01	1.4743D-03	-8.4824D-02	-8.9060D-01
7	142.68	8.18806D-03	1.09461D 01	918.28	1.34	3.67349D-01	-7.8222D-04	9.5100D-01	1.4367D-03	-4.6402D-02	-9.0681D-01
8	141.73	8.02638D-03	1.07850D 01	933.01	1.35	3.67449D-01	3.8781D-02	9.7868D-01	1.4084D-03	-3.6961D-02	-9.0435D-01
9	2624.16	6.73265D 00	2.38102D 03	385.21	-1.16	2.85133D-01	1.9744D-04	5.9264D 00	-9.5774D-01	-1.3423D-03	-4.9671D 00
10	2618.23	6.06967D 00	2.94887D 03	506.87	-0.75	2.85014D-01	-1.3454D-03	1.2710D 00	-8.6343D-01	-3.3741D-03	-4.0557D-01
11	2616.96	6.19567D 00	3.55178D 03	579.42	-0.49	2.85240D-01	3.2811D-03	1.3399D 00	-8.8137D-01	-3.4706D-03	-4.5182D-01
12	2615.62	5.59237D 00	3.60214D 03	629.96	-0.27	2.84779D-01	4.6288D-03	1.4592D 00	-8.6171D-01	-1.1163D-02	-5.8167D-01
13	2614.16	4.92704D 00	3.49181D 03	665.60	-0.07	2.82506D-01	-5.4699D-03	1.4088D 00	-7.5920D-01	-5.7515D-03	-6.4934D-01
14	2612.75	2.96742D 00	2.04423D 03	674.63	0.22	2.69407D-01	2.1099D-03	1.0164D 00	-3.8671D-01	-1.6621D-02	-6.1100D-01
15	2611.74	8.80245D-01	8.37141D 02	674.57	0.75	2.67901D-01	8.8717D-04	4.0609D 00	2.0104D-01	-2.3990D-01	-3.6190D 00
16	2607.67	6.22818D-01	7.10722D 02	766.04	1.45	2.62489D-01	5.3569D-03	5.6207D 00	-1.1460D-01	-7.4833D-02	-5.4259D 00

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*****
HELIUM SIZE *****

NODE  PRESSURE  TOTAL MASS  INTERNAL  TEMP.  MASS  *****  PRESSURE DROP - PSI *****
      PSIA      LBM        ENERGY  DEG. F  FLOW RATE  INERTIA  PRESSURE  STATIC HEAD  MOMENTUM  FRICTION
                               BTU
                               LBW/SEC

1  629.50  9.04538D 00  1.02762D 04  1055.07  1.49198D 02  1.2265D-07  3.1940D-02  1.2600D-03  2.2257D-04  -3.3423D-02
2  629.46  9.15652D 00  1.02748D 04  1036.48  1.49197D 02  4.3761D-07  3.1332D-02  1.2754D-03  4.4520D-04  -3.3052D-02
3  629.43  9.26656D 00  1.02734D 04  1018.51  1.49198D 02  -1.4486D-07  3.0900D-02  1.2908D-03  4.2976D-04  -3.2620D-02
4  629.40  9.37825D 00  1.02720D 04  1000.70  1.49199D 02  -2.1654D-07  3.9742D-02  1.3061D-03  4.2550D-04  -3.7474D-02
5  629.37  2.70337D 01  2.94295D 04  991.81  1.49203D 02  -3.1533D-07  6.0576D-02  0.0  -3.0061D-02  -3.0515D-02

6  629.31  6.85775D 01  7.46547D 04  991.80  1.49215D 02  -2.3087D-07  3.7445D-02  -7.2274D-02  -1.6399D-05  -1.0154D-02
7  629.27  6.85702D 01  7.46509D 04  991.88  1.49227D 02  -2.9769D-07  3.2667D-02  -2.2272D-02  -1.7406D-05  -1.0377D-02
8  629.24  4.51701D 01  4.91810D 04  992.04  1.49235D 02  -1.0257D-07  -1.0605D-02  0.0  4.7429D-02  -3.6824D-02
9  629.23  3.18587D 01  3.34022D 04  938.24  1.49742D 02  -1.7568D-07  4.9286D-02  3.6069D-03  6.8645D-04  -5.3580D-02
10 629.20  3.12327D 01  3.03175D 04  834.58  1.49252D 02  -2.6122D-07  3.7780D-02  3.5360D-03  1.3218D-03  -4.2638D-02

11 629.16  3.24362D 01  2.95320D 04  754.26  1.49266D 02  -3.5368D-07  3.5161D-02  3.6723D-03  1.0231D-03  -3.9856D-02
12 629.13  3.98476D 01  3.49148D 04  708.59  1.49284D 02  -2.1913D-07  2.3727D-02  4.2086D-03  4.1650D-03  -3.2101D-02
13 629.10  4.03445D 01  3.49041D 04  676.94  1.49301D 02  -2.1817D-07  2.4601D-02  4.3244D-03  3.0557D-04  -2.9232D-02
14 629.08  3.90883D 01  3.22601D 04  640.73  1.49319D 02  -2.0562D-07  2.0924D-02  4.1283D-03  3.5027D-04  -2.5403D-02
15 629.06  3.63195D 01  2.87486D 04  595.71  1.49336D 02  -2.0472D-07  1.9851D-02  3.8360D-03  4.3653D-04  -2.4124D-02

16 629.04  3.86857D 01  2.87269D 04  530.40  1.49353D 02  7.7199D-03  2.6349D-02  4.0859D-03  6.3474D-04  -2.3350D-02

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TUBES										
ASSOC. MELTUM MODE	MELTUM HEAT FLUX BTU/HR-FT2	MELTUM TRAN. COEF. BTU/HR-FT2-F	MELTUM SURFACE TEMP. DEG. F	TUBE AVERAGE TEMP. DEG. F	WATER SURFACE TEMP. DEG. F	WATER TRAN. COEF. BTU/HR-FT2-F	WATER HEAT FLUX BTU/HR-FT2	HEAT TRAN. MODE	MASS FLUX LBM/HR-FT2	DNF FLUX BTU/HR-FT2
1	4	2.12882D 04	1.74314D 02	866.02	852.57	1.34143D 02	2.52298D 04	7	1.37033D 05	0.0
2	3	1.90524D 04	1.74821D 02	898.46	886.60	1.36740D 02	2.25809D 04	7	1.37080D 05	0.0
3	2	1.89267D 04	1.75326D 02	930.25	920.00	1.39651D 02	1.97995D 04	7	1.37124D 05	0.0
4	1	1.99663D 04	1.75833D 02	961.52	952.42	1.42270D 02	1.78658D 04	7	1.37165D 05	0.0
5	1	1.22436D 04	1.75833D 02	978.59	971.00	1.44471D 02	1.50065D 04	7	1.37205D 05	0.0
6	2	9.00463D 03	1.75326D 02	980.08	974.33	1.46227D 02	1.13770D 04	7	1.37242D 05	0.0
7	3	6.34240D 03	1.74821D 02	978.68	974.49	1.47252D 02	8.27761D 03	7	1.37279D 05	0.0
8	4	4.15191D 03	1.74314D 02	974.56	971.65	1.48089D 02	5.72281D 03	7	1.37316D 05	0.0
9	16	1.83276D 04	1.47735D 02	414.87	409.05	9.09979D 02	2.16450D 04	1	3.20749D 05	1.37495D 04
10	15	1.02777D 04	1.49566D 02	523.87	520.27	1.00216D 03	1.34335D 04	1	3.20814D 05	1.13603D 04
11	14	7.18698D 03	1.50778D 02	590.86	588.35	1.04634D 03	9.35013D 03	1	3.20869D 05	8.45084D 05
12	13	5.40929D 03	1.51725D 02	638.71	636.44	1.17101D 03	7.58992D 03	1	3.40993D 05	6.30993D 05
13	12	5.10841D 03	1.52525D 02	673.31	671.17	1.28766D 03	7.16761D 03	1	3.44225D 05	4.05821D 05
14	11	1.09188D 04	1.62350D 02	681.88	675.77	1.38943D 04	1.58234D 04	2	2.94538D 05	5.93203D 04
15	10	1.74456D 04	1.64387D 02	716.47	700.53	1.19531D 03	3.10352D 04	4	4.37480D 05	0.0
16	9	1.70972D 04	1.67009D 02	826.03	813.11	6.03819D 02	2.84228D 04	7	3.50371D 05	0.0

REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS									
REHEATER					STEAM GENERATOR				
INLET	MELTUM	WATER	OUTLET	MELTUM	INLET	MELTUM	WATER	CUTLET	MELTUM
1.4444D 02	6.2961D 02	1.4126D 02	6.2937D 02	2.7407D 03	6.2924D 02	2.8049D 03	6.2903D 02	4.9036C 02	1.1899D 03
6.2993D 02	1.0644D 03	9.4192D 02	9.0218D 02	3.0271D 02	9.9204D 02	8.8673D 02	4.9036C 02	1.1899D 03	4.0915C 00
1.3398D 03	1.9041D 03	1.4996D 03	1.8134D 03	2.7761D 02	1.8137D 03	1.3337D 03	2.4473D 01	1.4935D 02	2.8249D 01
4.3600D 00	6.5292D 00	5.8368D 00	6.7221D 00	1.7581D 02	6.2243D 00	2.4473D 01	2.8249D 01	1.4935D 02	2.8249D 01
3.6656D 01	1.4920D 02	3.6745D 01	1.4920D 02	2.8610D 01	1.4923D 02	2.8249D 01	1.4935D 02	2.8249D 01	1.4935D 02

 ***** TRANSIENT OUTPUT NUMBER 51 *****
 ***** TIME STEP NUMBER 20100 *****
 ***** TRANSIENT TIME = 500.0000 SEC. *****

***** WATER SIDE *****

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	QUALITY	MASS FLOW RATE LBM/SEC	***** PRESSURE DROP - PSI *****				
							INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	52.89	4.078450-03	4.919780 00	582.14	1.14	1.270980-01	-1.31630-04	2.24210-01	-7.15640-04	1.45510-02	-2.38170-01
2	52.67	3.934790-03	4.794500 00	613.36	1.17	1.271240-01	-1.44180-04	2.63500-01	-6.90430-04	-1.58630-02	-2.47090-01
3	52.40	3.824340-03	4.689620 00	636.40	1.19	1.271510-01	-1.48090-04	2.68260-01	-6.71090-04	-1.30470-02	-2.54690-01
4	52.14	3.738350-03	4.616850 00	653.52	1.20	1.271770-01	-2.49610-04	9.64470-01	-6.55960-04	-1.07320-02	-9.53350-01
5	51.17	3.620410-03	4.491560 00	664.72	1.20	1.272020-01	-2.77570-04	9.92100-01	6.35270-04	-1.54720-02	-9.77540-01
6	50.18	3.513140-03	4.374360 00	672.52	1.21	1.272370-01	-1.55430-04	3.81400-01	6.16450-04	-1.49860-02	-2.67190-01
7	49.90	3.464760-03	4.326330 00	679.75	1.22	1.272520-01	-1.55670-04	2.75310-01	6.07960-04	-7.17090-03	-2.68910-01
8	49.62	3.424670-03	4.285520 00	684.85	1.22	1.272760-01	8.12280-03	2.79870-01	6.00920-04	-6.12860-03	-2.66270-01
9	2617.62	6.878130 00	7.199000 03	352.43	-1.26	2.852180-01	-1.86700-02	5.82730 00	-9.78440-01	-1.32900-03	-6.86620 00
10	2611.79	6.128350 00	2.912710 03	497.55	-0.78	2.827320-01	8.98690-02	1.36030 00	-6.71850-01	-3.13670-03	-3.95440-01
11	2610.43	6.162020 00	3.559570 03	582.83	-0.47	2.783220-01	-5.75220-02	1.25440 00	-8.76590-01	-2.72580-03	-4.32620-01
12	2609.18	5.548810 00	3.601650 03	630.12	-0.27	2.738390-01	-3.39870-02	1.37470 00	-8.61170-01	-9.11040-03	-5.38430-01
13	2607.81	5.193120 00	3.555430 03	653.95	-0.14	2.699030-01	3.25130-02	1.39750 00	-8.00190-01	-2.06860-03	-5.62720-01
14	2606.41	4.551820 00	3.232300 03	666.11	-0.06	2.664870-01	-1.53940-02	1.02450 00	-6.85600-01	8.07700-03	-3.62330-01
15	2605.38	2.948380 00	2.145430 03	673.06	-0.01	2.645500-01	2.77440-03	1.93260 00	-6.73390-01	-5.39590-02	-1.20240 00
16	2603.45	3.366190 00	2.519160 03	674.10	0.06	2.446340-01	1.48350-03	1.39680 00	-6.19380-01	3.13620-02	-8.07320-01

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*****
HELIUM SIDE
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NODE  PRESSURE  TOTAL MASS  INTERNAL  TEMP.  MASS  *****  PRESSURE DROP - PSI  *****
      PSIA      LBM        ENERGY  DEG. F  FLOW RATE  INFRTJA  PRESSURE  STATIC HEAD  MOMENTUM  FRICTION
                               BTU
                               LBM/SEC

 1  581.19  1.091010 01  9.472270 03  697.92  1.512030 02  -1.03520-05  2.60640-02  1.51970-03  -2.01380-07  -2.75850-02
 2  581.16  1.091520 01  9.471750 03  697.32  1.512040 02  -1.04020-06  2.61040-02  1.52040-03  1.41690-05  -2.76400-02
 3  581.14  1.092300 01  9.471240 03  696.43  1.512050 02  -1.04740-06  2.60760-02  1.52150-03  2.20440-05  -2.76210-02
 4  581.11  1.093550 01  9.470740 03  695.05  1.512060 02  -1.06860-06  3.06810-02  1.52320-03  3.50580-05  -3.22400-02
 5  581.09  3.135370 01  2.713520 04  694.25  1.512090 02  2.34960-03  5.55210-02  0.0          -2.47880-02  -2.63840-02

 6  581.03  7.953400 01  6.883470 04  694.28  1.512160 02  -2.09720-05  3.48170-02  -2.58330-02  -1.27580-05  -8.99190-03
 7  580.59  7.951970 01  6.883070 04  694.42  1.512240 02  -2.09080-05  3.50130-02  -2.58280-02  -1.62520-05  -9.18970-03
 8  580.96  5.237820 01  4.534620 04  694.64  1.512290 02  -3.07160-06  -9.66700-03  0.0          4.14730-02  -3.18090-02
 9  580.97  3.576290 01  3.080520 04  688.81  1.512370 02  2.32050-03  4.60680-02  4.04890-03  8.14530-05  -4.78780-02
10  580.92  3.271010 01  2.797620 04  680.68  1.512400 02  -2.18980-06  3.73330-02  3.70320-03  1.11620-04  -4.11500-02

11  580.88  3.202390 01  2.726560 04  675.53  1.512630 02  -2.13130-06  3.73730-02  3.62560-03  6.92830-05  -4.10700-02
12  580.85  3.812590 01  3.224480 04  667.97  1.512750 02  -1.91620-06  2.42700-02  4.02670-03  3.95120-03  -3.42500-02
13  580.82  3.856380 01  3.223980 04  654.99  1.512920 02  -1.92950-06  2.75230-02  4.07300-03  1.37990-04  -3.17360-02
14  580.79  3.641250 01  2.980120 04  631.55  1.513010 02  -1.66160-06  2.38170-02  3.84570-03  2.52300-04  -2.79160-02
15  580.77  3.371710 01  2.655890 04  590.58  1.513070 02  -1.42820-06  2.26020-02  3.56110-03  4.43360-04  -2.66080-02

16  580.74  3.613920 01  2.653810 04  519.42  1.513150 02  7.85600-03  2.08520-02  3.81690-03  7.70630-04  -2.55860-02

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TUBES										
ASSOC. MELTUM NODE	MELTUM HEAT FLUX BTU/MR-FY2	MELTUM TRAN. COEFF. BTU/MR-FY2-F	MELTUM SURFACE TEMP. DEG. F	TUBE AVERAGE TEMP. DEG. F	WATER SURFACE TEMP. DEG. F	WATER TRAN. COEFF. BTU/MR-FY2-F	WATER HEAT FLUX BTU/MR-FY2	HEAT TRAN. MODE	MASS FLUX LBM/MR-FY2	DNB FLUX BTU/MR-FY2
1	4	2.09590 03	1.661010 02	674.41	671.54	5.459590 01	4.80510 03	7	4.749670 04	0.0
2	3	2.021030 03	1.661450 02	682.96	680.78	5.526900 01	3.726520 03	7	4.750600 04	0.0
3	2	1.204360 03	1.661750 02	689.30	687.63	5.579030 01	2.859210 03	7	4.751650 04	0.0
4	1	5.843520 02	1.661640 02	694.03	692.74	5.617150 01	2.703440 03	7	4.752620 04	0.0
5	1	1.505090 02	1.661840 02	696.92	695.89	5.642690 01	1.758810 03	7	4.753570 04	0.0
6	2	1.592820 02	1.661750 02	698.28	697.56	5.660680 01	1.417710 03	7	4.754490 04	0.0
7	3	4.321580 02	1.661450 02	699.03	698.49	5.676210 01	1.074930 03	7	4.755410 04	0.0
8	4	6.403780 02	1.661010 02	698.91	698.86	5.688700 01	7.967300 02	7	4.756330 04	0.0
9	16	1.873290 04	1.486360 02	393.38	380.94	8.764720 02	2.498800 04	1	3.208440 05	1.684990 06
10	15	1.067410 04	1.507020 02	519.75	512.50	9.906040 02	1.481130 04	1	3.180400 05	1.168610 06
11	14	5.587430 03	1.518430 02	594.76	590.83	1.079240 03	8.240980 03	1	3.130870 05	9.248730 05
12	13	2.817780 03	1.524290 02	636.51	634.15	1.134450 03	4.587550 03	1	3.336690 05	6.223400 05
13	12	1.593950 03	1.528120 02	656.98	656.19	1.173500 03	2.640610 03	1	3.288720 05	4.817770 05
14	11	1.037340 03	1.614250 02	668.67	667.86	1.115930 03	1.958640 03	1	2.913460 05	1.694280 05
15	10	8.056870 02	1.615560 02	675.14	674.16	1.746730 03	1.908310 03	1	4.385550 05	3.924660 05
16	9	1.886140 03	1.617400 02	676.07	674.62	6.182600 03	3.198370 03	2	3.267290 05	2.572390 05

REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS									
STEAM GENERATOR									
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TRANSIENT OUTPUT NUMBER 61
 TIME STEP NUMBER 24100
 TRANSIENT TIME = 600.0000 SEC.

***** WATER SIDE *****

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	QUALITY	MASS FLOW RATE LBM/SEC	***** PRESSURE DROP - PSI *****				
							INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	47.04	3.730900-03	4.462890 00	547.49	1.14	1.117760-01	-2.07550-05	1.91780-01	-6.54660-04	1.14580-02	-2.02610-01
2	46.85	3.600290-03	4.349630 00	576.22	1.16	1.117800-01	-2.20250-05	2.23910-01	-6.31740-04	-1.31920-02	-2.10100-01
3	46.63	3.500160-03	4.260630 00	597.34	1.17	1.117830-01	-2.24360-05	2.27830-01	-6.14170-04	-1.07860-02	-2.16490-01
4	46.40	3.422210-03	4.189830 00	613.00	1.18	1.117870-01	-6.69850-05	8.15420-01	-6.00490-04	-8.83420-03	-8.06040-01
5	45.58	3.319770-03	4.080620 00	631.53	1.19	1.117900-01	-3.38460-05	8.36700-01	5.82520-04	-1.22370-02	-8.25080-01
6	44.75	3.234760-03	3.984990 00	646.61	1.19	1.117930-01	-2.02600-05	2.36110-01	5.67600-04	-1.07440-02	-2.25450-01
7	44.51	3.205800-03	3.953840 00	652.95	1.20	1.117950-01	-2.06210-05	2.29480-01	5.62520-04	-3.80300-03	-2.26260-01
8	44.28	3.183220-03	3.928250 00	656.76	1.20	1.117980-01	1.30240-03	2.26680-01	5.58560-04	-3.01680-03	-2.22920-01
9	2617.94	6.966540 00	2.077270 03	331.28	-1.32	2.857540-01	5.27700-03	5.82090 00	-9.91010-01	-1.21460-03	-4.82360 00
10	2612.12	6.333210 00	2.768290 03	463.39	-0.90	2.647090-01	7.23430-04	1.29300 00	-9.00920-01	-2.78150-03	-3.88600-01
11	2610.82	6.494810 00	3.458610 03	546.72	-0.61	2.825670-01	1.63000-02	1.36620 00	-9.23930-01	-2.55190-03	-4.23430-01
12	2609.46	5.974210 00	3.584850 03	599.57	-0.40	2.797980-01	-9.39910-03	1.44610 00	-9.20550-01	-8.85130-03	-5.26100-01
13	2608.01	5.581240 00	3.601330 03	630.64	-0.28	2.764710-01	-3.57520-02	1.37570 00	-8.60000-01	-2.00370-03	-5.49490-01
14	2606.64	4.915600 00	3.313810 03	648.14	-0.17	2.728390-01	-3.11320-02	1.05290 00	-7.40390-01	8.10800-03	-3.51730-01
15	2605.58	3.210700 00	2.220620 03	657.57	-0.12	2.699760-01	3.89320-02	1.47310 00	-7.33300-01	-5.10390-02	-1.14990 00
16	2603.61	4.296760 00	3.012920 03	662.15	-0.09	2.649630-01	1.38440-02	1.55500 00	-7.90600-01	3.23090-02	-7.82870-01

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*****
HELIUM SIDE *****
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CODE  PRESSURE  TOTAL MASS  INTERNAL  TEMP.  MASS  *****  PRESSURE DROP - PSI  *****
      PSIA      LBM      ENRGY    DEG. F  FLOW RATE  INERTIA  PRESSURE  STATIC HEAD  MOMENTUM  FRICTION
                               BTU
1    560.58    1.091370 01    9.137410 03    656.64    1.444950 02    2.01620-06    2.37420-02    1.52020-03    8.88290-07    -2.52610-02
2    560.66    1.091880 01    9.136980 03    656.06    1.444950 02    2.00980-06    2.37790-02    1.52090-03    1.31510-05    -2.53110-02
3    560.63    1.092510 01    9.136550 03    655.37    1.444960 02    2.00820-06    2.37610-02    1.52180-03    1.63110-05    -2.52970-02
4    560.61    1.093510 01    9.136080 03    654.28    1.444960 02    2.00240-06    2.79750-02    1.52320-03    2.60210-05    -2.95220-02
5    560.58    3.134900 01    2.617640 04    653.65    1.444970 02    -4.67800-03    4.39550-02    0.0          -2.44690-02    -2.41640-02

6    560.54    7.952330 01    6.640370 04    653.67    1.445010 02    4.38740-05    3.40930-02    -2.58300-02    -7.88260-06    -8.21210-03
7    560.50    7.951070 01    6.639980 04    653.78    1.445040 02    4.39510-05    3.42720-02    -2.58260-02    -1.07940-05    -8.39200-03
8    560.47    5.237430 01    4.374460 04    653.95    1.445060 02    6.25480-06    -8.62840-03    0.0          3.77650-02    -2.91300-02
9    560.43    3.550040 01    2.971920 04    656.51    1.445090 02    -4.62940-03    3.55980-02    4.01920-03    -3.47200-05    -4.42120-02
10   560.44    3.217050 01    2.699260 04    659.04    1.445130 02    3.41210-06    3.47850-02    3.64210-03    -3.58900-05    -3.83880-02

11   560.41    3.142300 01    2.630770 04    656.59    1.445170 02    3.08970-06    3.48210-02    3.55760-03    3.10790-05    -3.84070-02
12   560.37    3.744200 01    3.111180 04    648.22    1.445230 02    2.92050-06    2.43580-02    3.95490-03    3.68660-03    -3.19960-02
13   560.35    3.801260 01    3.110600 04    631.39    1.445300 02    2.92440-06    2.53400-02    4.01480-03    1.71310-04    -2.95230-02
14   560.32    3.608700 01    2.275170 04    502.62    1.445350 02    2.73700-06    2.17100-02    3.81140-03    2.93920-04    -2.58130-02
15   560.30    3.357120 01    2.562250 04    557.95    1.445420 02    2.40370-06    2.04770-02    3.54570-03    4.57210-04    -2.44770-02

16   560.28    3.602300 01    2.560220 04    487.93    1.445520 02    5.15400-03    2.41280-02    3.80460-03    7.16960-04    -2.34950-02

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TUBES									
ASSOC. NODE	MELIUM HEAT FLUX BTU/MM-FT2	MELIUM TRAN. COEF. BTU/MM-FT2-F	MELIUM SURFACE TEMP. DEG. F	TUBE AVERAGE TEMP. DEG. F	WATER SURFACE TEMP. DEG. F	WATER TRAN. COEF. BTU/MM-FT2-F	WATER HEAT FLUX BTU/MM-FT2	HEAT TRAN. MODE	MASS FLUX LBM/MM-FT2
1	4	2.41029D 03	1.60054D 02	637.97	633.73	4.85087D 01	4.18350D 03	7	4.17710D 04
2	3	1.76334D 03	1.60101D 02	645.35	641.28	4.90590D 01	3.19144D 03	7	4.17724D 04
3	2	1.12473D 03	1.60102D 02	648.04	646.84	4.94719D 01	2.44875D 03	7	4.17736D 04
4	1	6.44970D 02	1.60138D 02	652.61	651.06	4.97860D 01	1.89460D 03	7	4.17749D 04
5	1	1.08664D 02	1.60138D 02	655.46	654.65	5.01740D 01	1.15967D 03	7	4.17761D 04
6	2	-3.31938D 02	1.60102D 02	658.14	656.01	5.04611D 01	5.75478D 02	7	4.17771D 04
7	3	-5.83483D 02	1.60101D 02	659.01	659.21	5.05950D 01	3.16542D 02	7	4.17781D 04
8	4	-7.56631D 02	1.60054D 02	659.01	659.43	5.06550D 01	1.35190D 02	7	4.17790D 04
9	16	1.70504D 04	1.43089D 02	368.77	351.53	8.54149D 02	2.24260D 04	1	3.21443D 05
10	15	1.05747D 04	1.45061D 02	485.05	477.99	9.73083D 02	1.42158D 04	1	3.20272D 05
11	14	6.29314D 03	1.46276D 02	558.60	555.32	1.01982D 03	8.76521D 03	1	3.17862D 05
12	13	3.54508D 03	1.47084D 02	607.28	604.42	1.12300D 03	5.44612D 03	1	3.40930D 05
13	12	1.93548D 03	1.47455D 02	635.09	634.42	1.14551D 03	3.22284D 03	1	3.36876D 05
14	11	8.46717D 02	1.55990D 02	651.17	650.01	1.05820D 03	1.97850D 03	1	2.98290D 05
15	10	1.08595D 01	1.56035D 02	658.97	658.34	1.57292D 03	1.21374D 03	1	4.47550D 05
16	9	-7.80020D 02	1.55588D 02	661.51	662.03	1.29859D 03	-1.52231D 02	1	3.53875D 05
									4.42355D 05

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REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS									
REHEATER					STEAM GENERATOR				
INLET	MELIUM	WATER	OUTLET	MELIUM	INLET	MELIUM	WATER	OUTLET	MELIUM
WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER	WATER
4.4701D 01	5.4081D 02	4.4168D 01	5.4059D 02	5.4059D 02	2.7360D 03	5.6047D 02	2.6028D 03	5.6027D 02	5.6027D 02
5.2548D 02	6.5693D 02	6.5693D 02	6.5693D 02	6.5693D 02	2.4828D 02	6.5395D 02	6.4348D 02	4.4730D 02	4.4730D 02
1.2962D 03	1.3958D 03	1.3958D 03	1.3958D 03	1.3958D 03	2.2270D 02	1.3921D 03	7.1793D 02	1.1315D 03	1.1315D 03
1.2066D 01	5.3791D 00	1.4669D 01	5.3658D 00	5.3658D 00	1.6025D 02	5.3681D 00	2.7572D 02	4.3705D 00	4.3705D 00
1.1177D 01	1.4449D 02	1.1100D 01	1.4450D 02	1.4450D 02	2.8610D 01	1.4451D 02	2.6696D 01	1.4455D 02	1.4455D 02

PRESSURE 4.4701D 01 5.4081D 02 4.4168D 01 5.4059D 02 5.4059D 02 2.7360D 03 5.6047D 02 2.6028D 03 5.6027D 02
 TEMPERATURE 5.2548D 02 6.5693D 02 6.5693D 02 6.5693D 02 6.5693D 02 2.4828D 02 6.5395D 02 6.4348D 02 4.4730D 02
 ENTHALPY 1.2962D 03 1.3958D 03 1.3958D 03 1.3958D 03 1.3958D 03 2.2270D 02 1.3921D 03 7.1793D 02 1.1315D 03
 SPEC. VOL. 1.2066D 01 5.3791D 00 1.4669D 01 5.3658D 00 5.3658D 00 1.6025D 02 5.3681D 00 2.7572D 02 4.3705D 00
 FLOW RATE 1.1177D 01 1.4449D 02 1.1100D 01 1.4450D 02 1.4450D 02 2.8610D 01 1.4451D 02 2.6696D 01 1.4455D 02