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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
J. C. Cleveland

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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

J. C. Cleveland

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 (Btu/sec-°F)
c_p	specific heat capacity at constant pressure (Btu/lbm-°R)
c_v	specific heat capacity at constant volume (Btu/lbm-°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 lbm-ft/sec^2-lbf)
H	specific enthalpy (Btu/lbm)
h	convective heat transfer coefficient (Btu/sec-ft^2-°F)
k	tube conductivity (Btu/sec-ft-°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 (°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

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

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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)

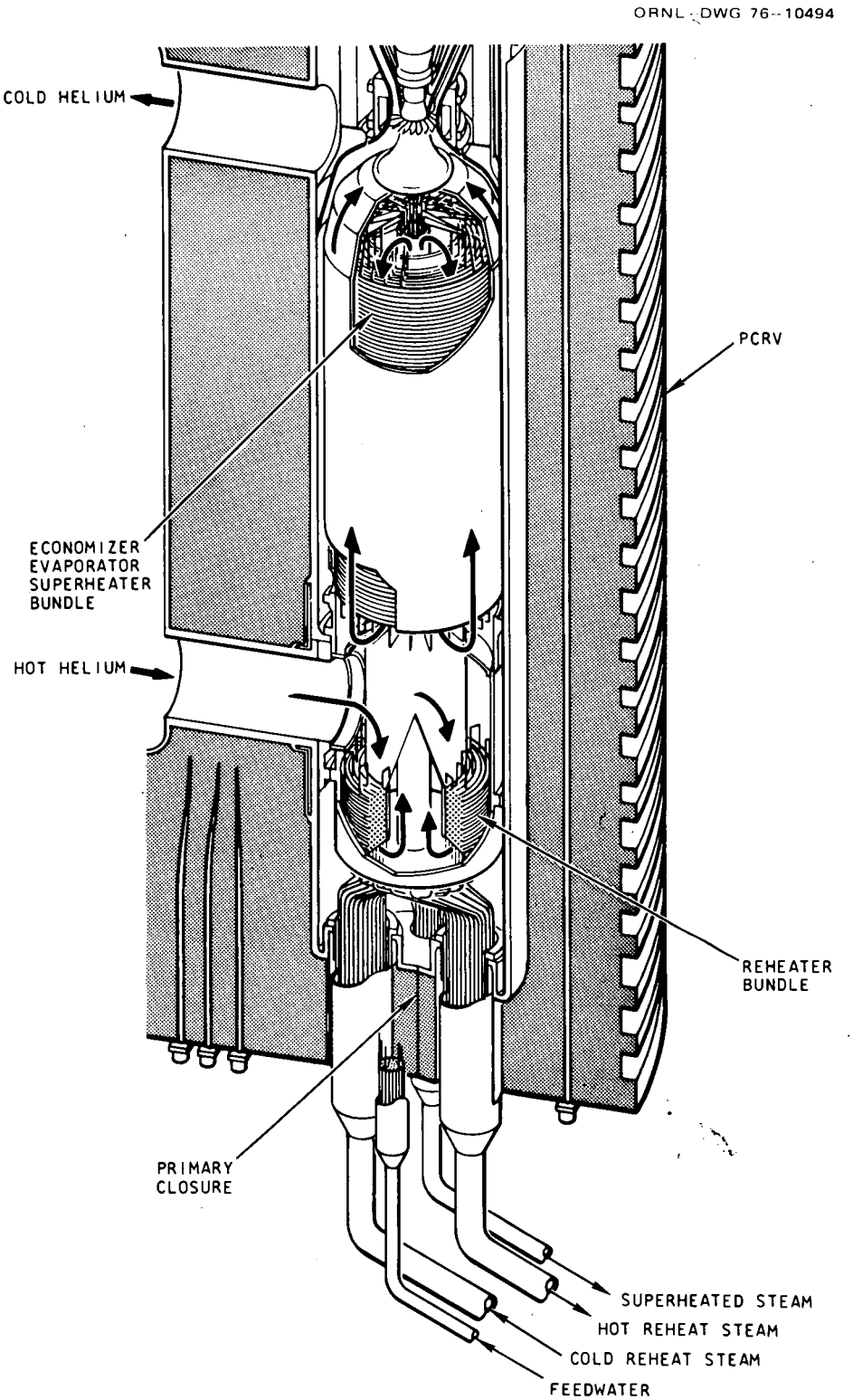

Fig. 1. Large HTGR plant steam generator.

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 cocurrent 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.

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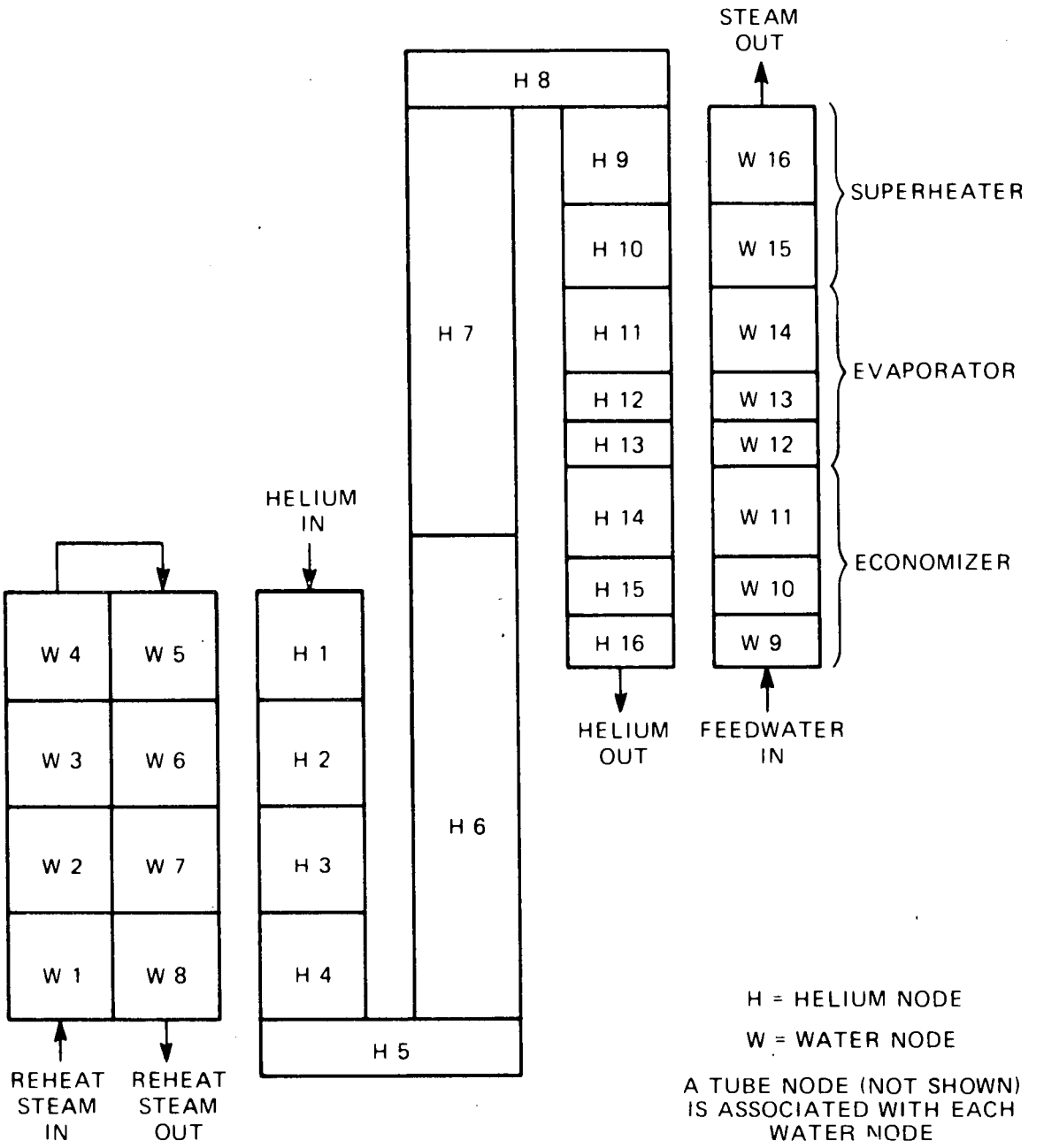

Fig. 2. HTGR reheater-steam generator nodal arrangement.

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:

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

(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 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

$$C_j^w = \frac{2\pi R_{in,j} L_j^w}{\left[\dfrac{R_{in,j}\,\ell n\left(\overline{R}_j/R_{in,j}\right)}{k_j}\right] + \dfrac{1}{h_j^w}},$$

with $$\overline{R}_j \equiv \frac{R_{in,j} + R_{out,j}}{2}.$$

Conservation of mass:

$$\frac{dM_j^w}{dt} = W_i^w - W_j^w, \tag{2}$$

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

Conservation of momentum:

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

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

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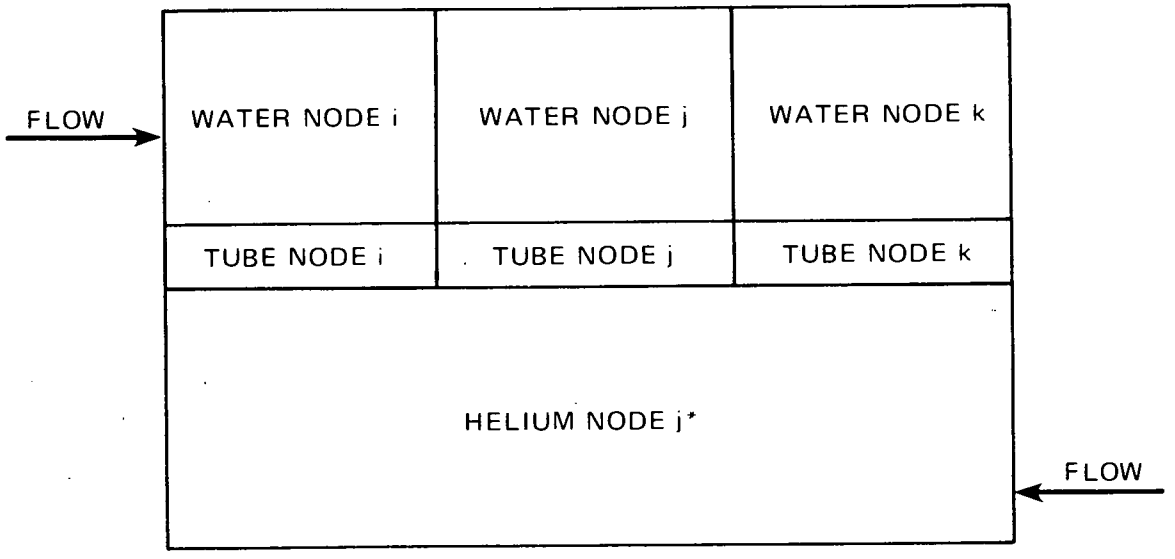

UPSTREAM HELIUM NODE IS i*
DOWNSTREAM HELIUM NODE IS k*

Fig. 3. Typical nodal description.

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

(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.,

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

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:

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

(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 α = i, j, or k) is

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

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:

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

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

Conservation of momentum:

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

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

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

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

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

$$P^h_{j*} = P^h_{j*}\left(U^h_{j*}, M^h_{j*}\right) \ , \ T^h_{j*} = T^h_{j*}\left(U^h_{j*}, M^h_{j*}\right) \ .$$

The conservation of energy equation for tube node j is:

$$M^t_j c^t_{p_j} \frac{dT^t_j}{dt} = C^h_{j*,j}\left(T^h_{j*} - T^t_j\right) - C^w_j\left(T^t_j - T^w_j\right) \ . \qquad (7)$$

(rate of change of internal energy in tube node) (rate of heat transfer from helium by conduction and convection) (rate of heat transfer to water by conduction 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 Grimison correlation[1] 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 correlations[2] 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 multipliers[13] or Thom modified Martinelli-Nelson two phase multipliers[14] 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

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

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

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

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 nth state variable at time t + Δt, where Δt is the computational time step, can be written in terms of state variables at time t by a linearized implicit formulation:

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

where, using Eq. 8,

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

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

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

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

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

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

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

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

where $\underline{\underline{I}}$ is the identity matrix, and the ℓmth element of $\underline{\underline{J}}$ is $\frac{\partial f_\ell}{\partial y_m}$.

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,

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

Note that the two partial derivitive 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

$$\underline{\underline{A}}\ \underline{v} = \underline{b}\ , \tag{14}$$

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

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

$\underline{\underline{A}}$ 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 $\underline{\underline{A}}$ and $\underline{b}$ have been determined, Equation (14) is solved by inverting $\underline{\underline{A}}$. 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 $\underline{\underline{A}}$ matrix (Eq. 14).

EQUATION OF STATE AND THERMODYNAMIC TRANSPORT PROPERTIES - HELIUM

In order to calculate terms in the $\underline{\underline{A}}$ 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

$$T = \frac{1}{c_v} u \ , \tag{15}$$

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).

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

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

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

and

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

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

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

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

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

and it follows that

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

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

$$\mu = 5.9178 \times 10^{-4} T^{0.7} \text{(lbm/ft-hr)} , \text{ (Ref. 16)} ,$$

$$k_{he} = 1.29 \times 10^{-3} T^{0.674} + 8.15 \times 10^{-4} (P - 14.69)^{0.28} \text{(Btu/hr-ft-°R)} , \text{ (Ref. 17)} ,$$

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

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

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

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:

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

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}

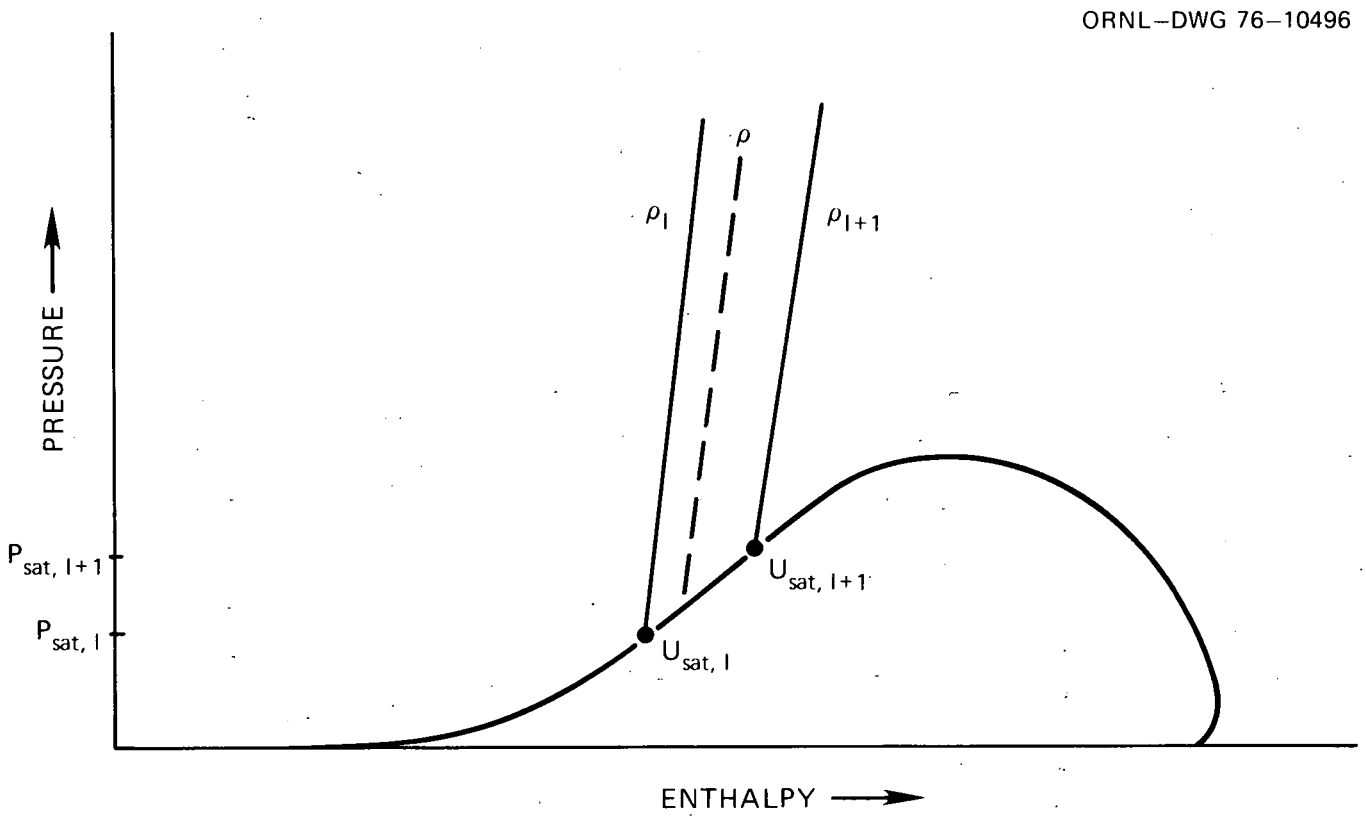

Fig. 4. Pressure vs enthalpy for water.

with a constant product of internal energy and density are determined

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

and

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

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

Then

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

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.,

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

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

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

The remaining temperature derivative can be written

$$\left.\frac{\partial T}{\partial u}\right|_{\rho} = \left.\frac{\partial T}{\partial P}\right|_{\rho} \left.\frac{\partial P}{\partial u}\right|_{\rho} . \tag{26}$$

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.,

$$\left|v_\alpha - v\right| < \varepsilon \quad \text{and} \quad \left|v_\beta - v\right| < \varepsilon , \tag{27}$$

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.,

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

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:

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

Now the saturation properties at P can be determined.

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

$$\left.\frac{\partial P}{\partial u}\right|_\rho \left.\frac{\partial u}{\partial \rho}\right|_P \left.\frac{\partial \rho}{\partial P}\right|_u = -1 . \tag{29}$$

Since

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

and

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

it follows that

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

To find the other derivative of pressure, $\left.\frac{\partial P}{\partial \rho}\right|_{u\rho}$, 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:

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

and

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

where

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

$P_{SAT,I}$ and $P_{SAT,I-1}$ are the pressures in the tables that bracket P, and $T_{SAT,I}$ and $T_{SAT,I-1}$ 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 program[21] which simulates the HTGR nuclear steam supply system. Input instructions for BLAST are given in Appendix A, and a listing of the user supplied subroutines, 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 cooldown 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 $\left(H - H_f\right)/\left(H_g - H_f\right)$, 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

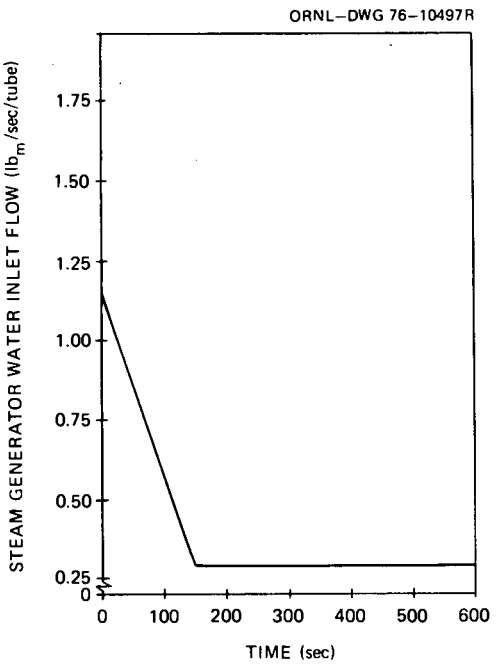

Fig. 5. Steam generator water inlet flow following a reactor trip.

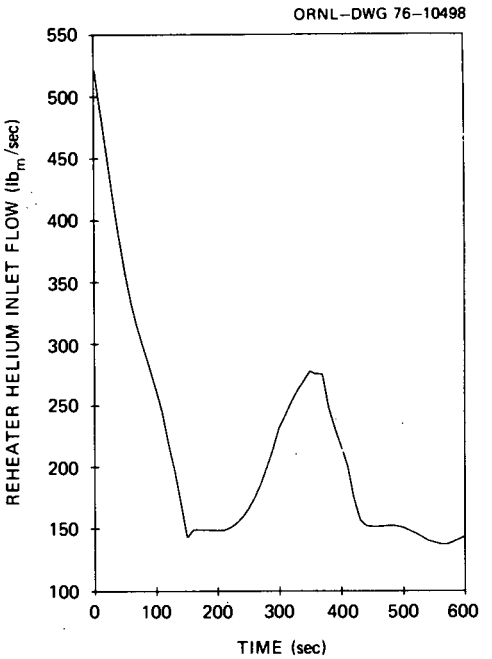

Fig. 6. Reheater helium inlet flow following a reactor trip.

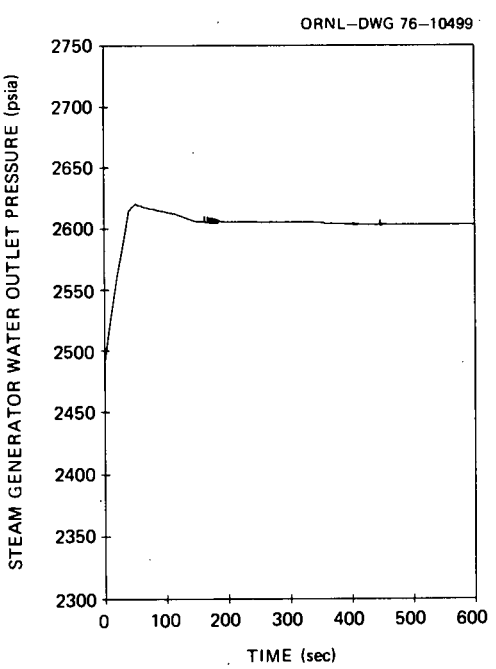

Fig. 7. Steam generator water outlet pressure following a reactor trip.

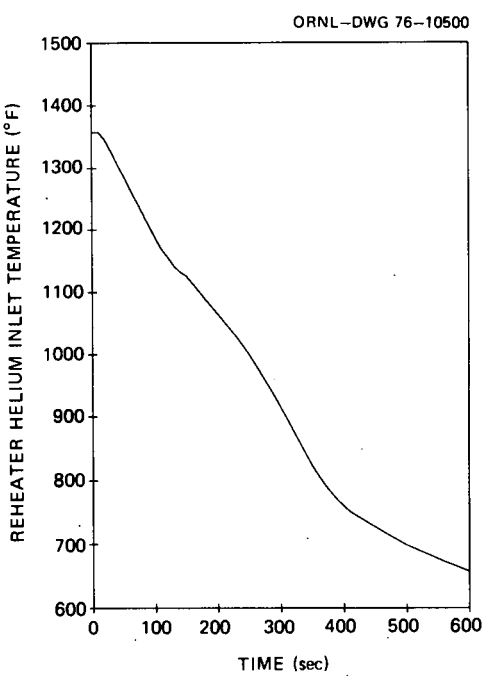

Fig. 8. Reheater helium inlet temperature following a reactor trip.

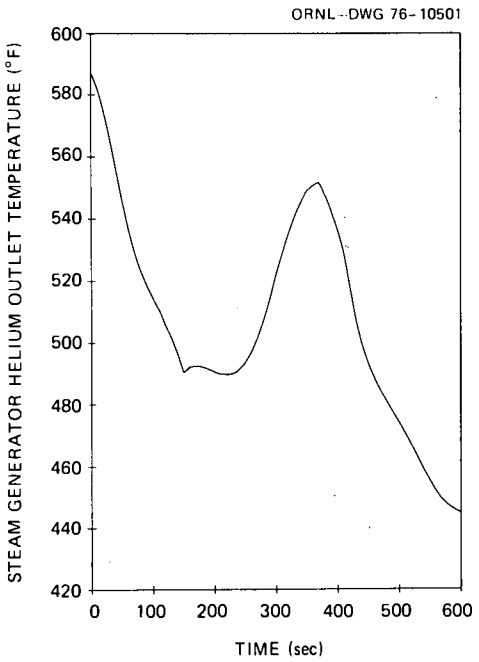

Fig. 9. Steam generator helium outlet temperature following a reactor trip.

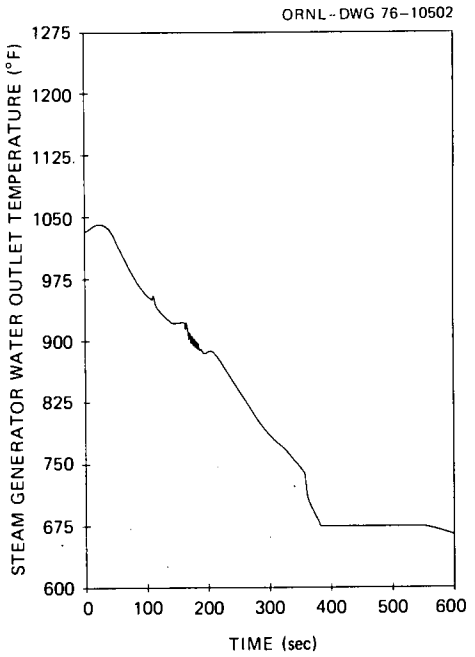

Fig. 10. Steam generator water outlet temperature following a reactor trip.

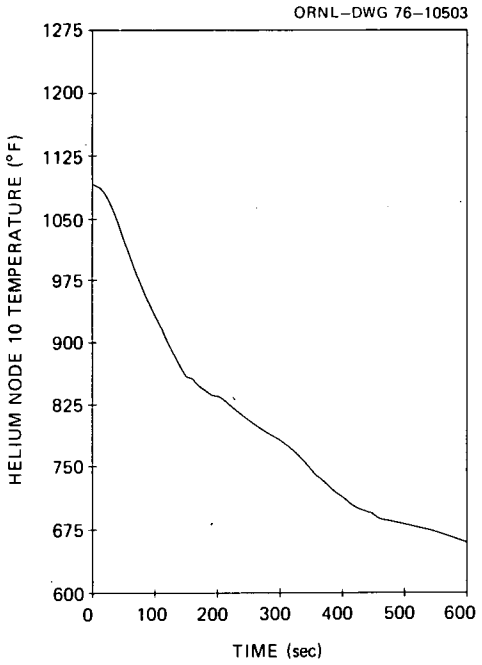

Fig. 11. Helium node 10 temperature following a reactor trip.

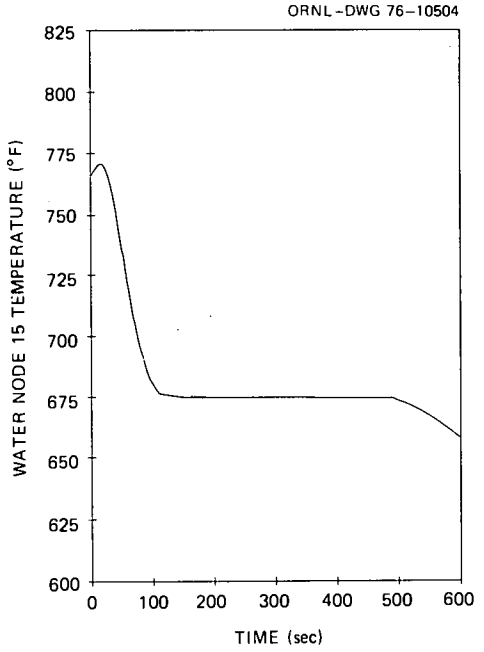

Fig. 12. Water node 15 temperature following a reactor trip.

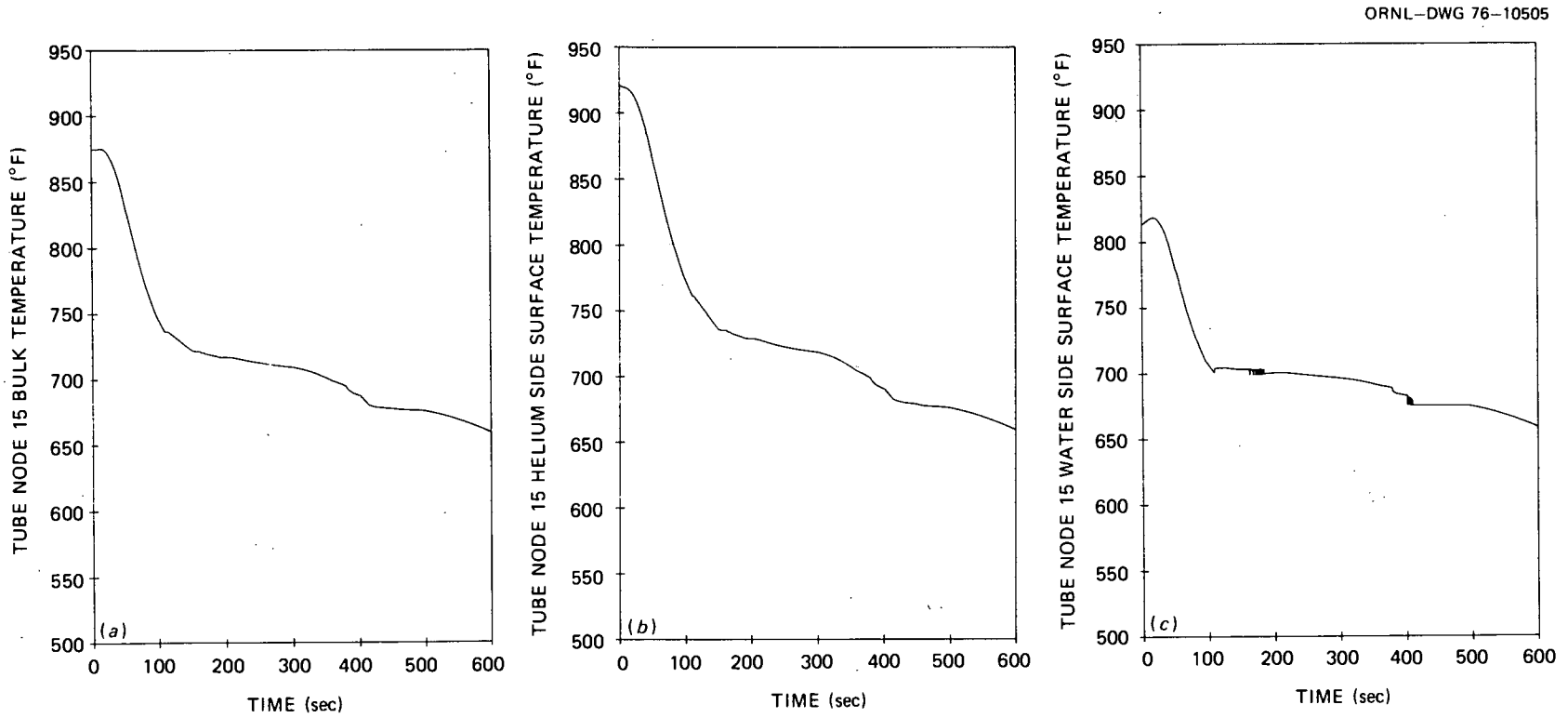

Fig. 13. (a) Tube node 15 bulk temperature following a reactor trip, (b) Tube node 15 surface temperature, helium side, following a reactor trip, (c) Tube node 15 surface temperature, water side, following a reactor trip.

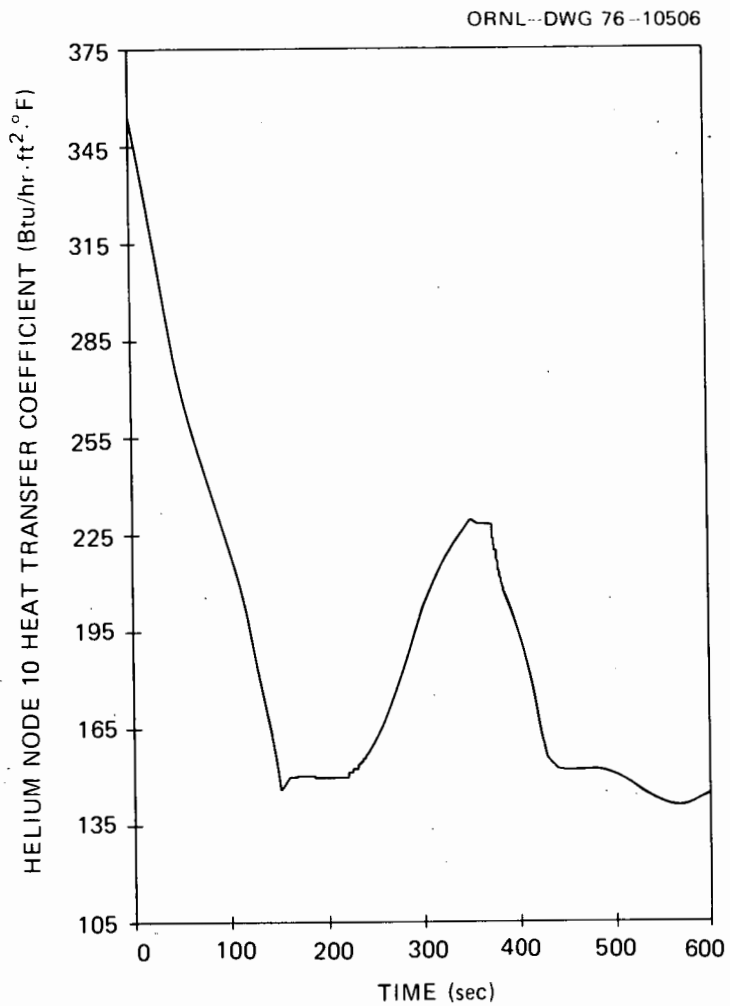

Fig. 14. Helium node 10 heat transfer coefficient following a reactor trip.

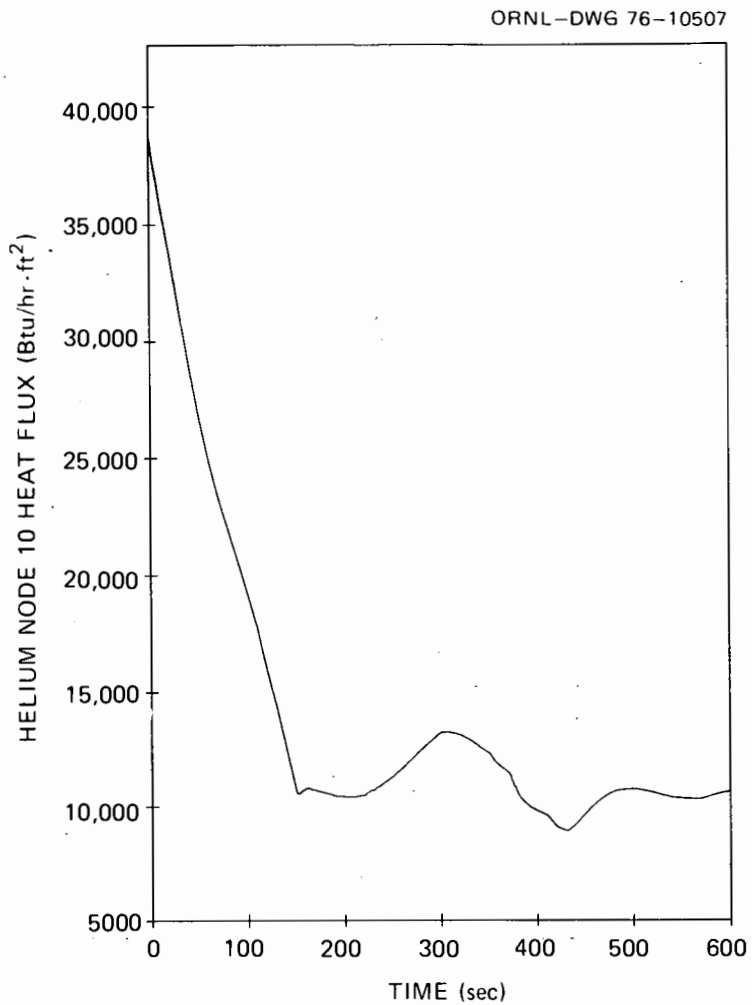

Fig. 15. Helium node 10 heat flux following a reactor trip.

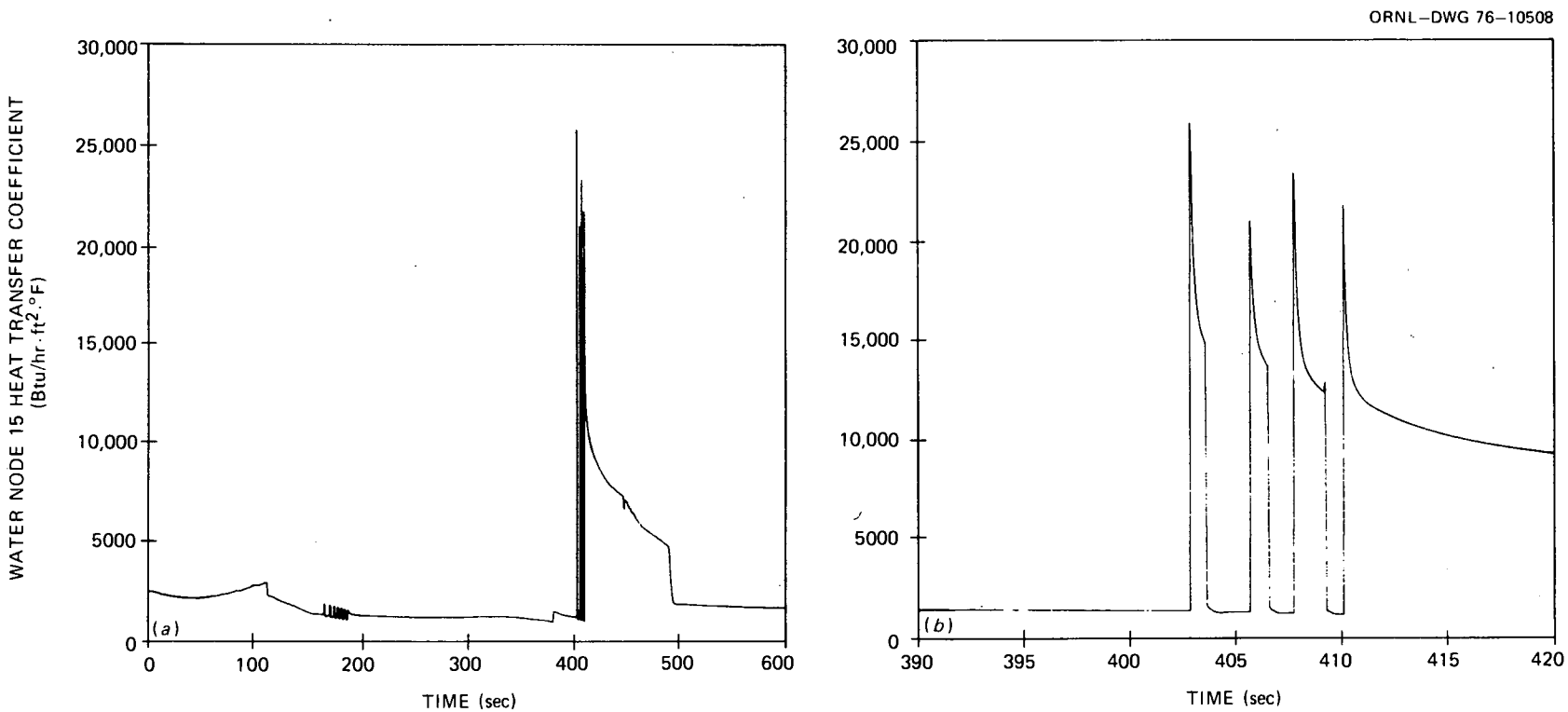

Fig. 16. (a) Water node 15 heat transfer coefficient following a reactor trip, (b) Water node 15 heat transfer coefficient following a reactor trip.

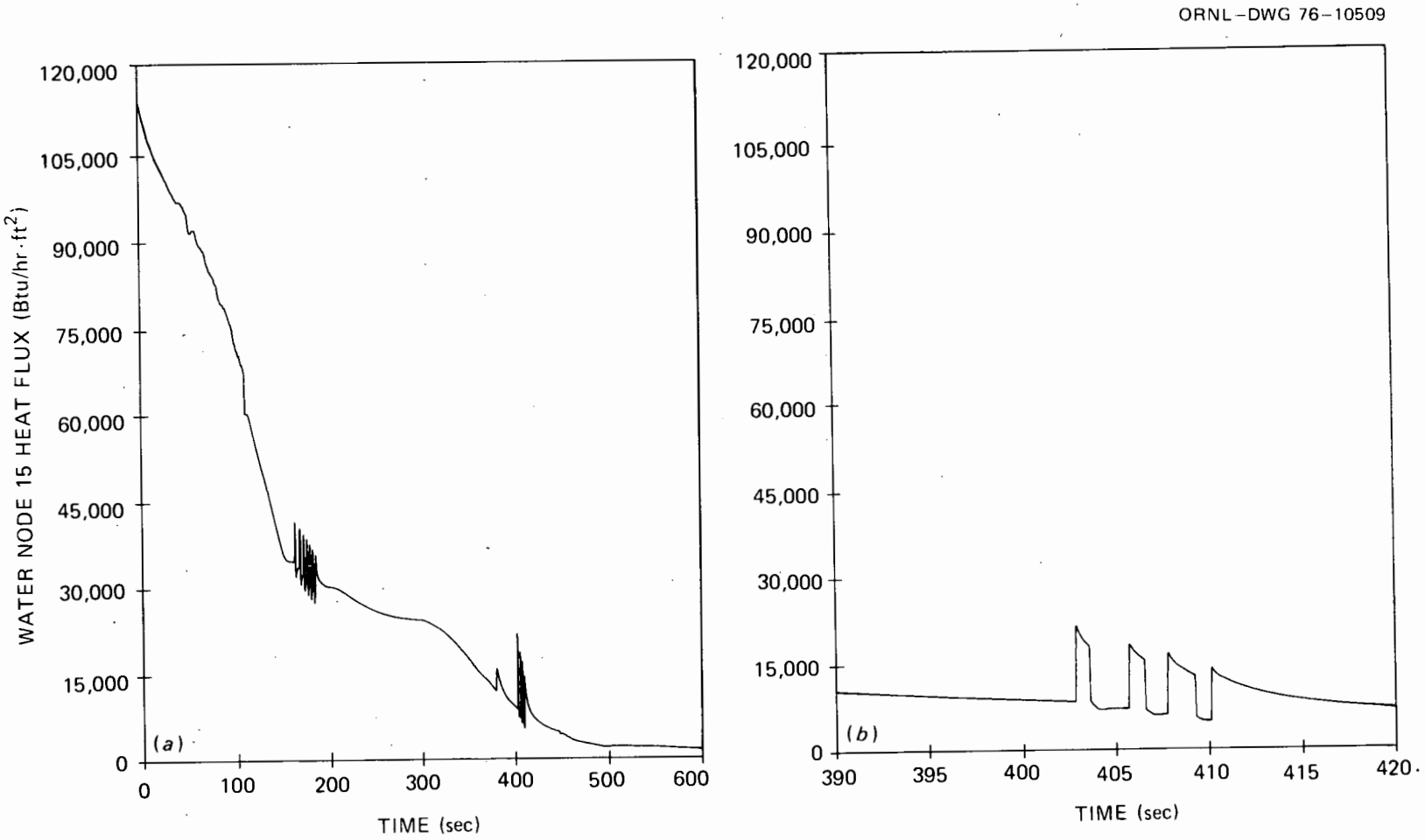

Fig. 17. (a) Water node 15 heat flux following a reactor trip, (b) Water node 15 heat flux following a reactor trip.

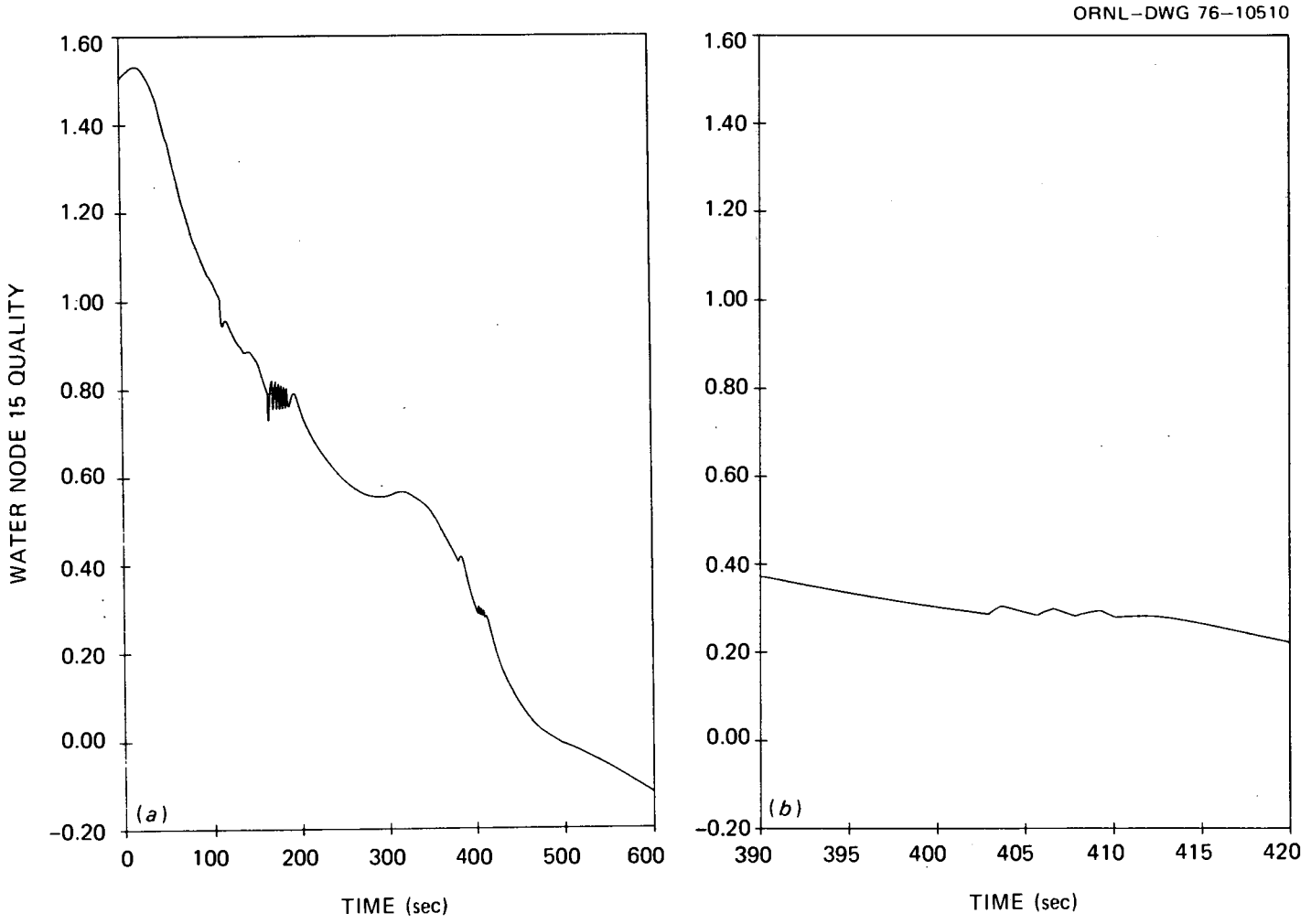

Fig. 18. (a) Water node 15 quality following a reactor trip, (b) Water node 15 quality following a reactor trip.

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 TAP[21] 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. Groenveld, 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, NPGD, 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.

CARD SERIES	CARD FORMAT	
10NN	I10, 7D10.2	NN = 01,...,k where $k \leq 9$ Time interval and associated time step information in ordered triplets: Δt(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,

CARD SERIES	CARD FORMAT	
		M_i/W_i. The last card in series 10NN should be blank in columns 71-80.
25NN		Optional series. See p. 49.
70NN	I10, 4D10.2, 3I10	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 inputing, in integer form, $1000*\Delta z$ in columns 61-70.

CARD SERIES	CARD FORMAT	
		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.

CARD SERIES	CARD FORMAT	
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.

CARD SERIES	CARD FORMAT	
		Columns 61-70: Minimum heat transfer coefficient (Btu/hr-ft^2-°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.

CARD SERIES	CARD FORMAT	
		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	I10, D10.2, 2I10	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.

CARD SERIES	CARD FORMAT	
		(= 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 $\varepsilon/D \leq 0.0$, only the constant friction factor will be used to compute friction losses. If $\varepsilon/D > 0.0$, 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.

CARD SERIES	CARD FORMAT	
		Columns 71-80: Pitch to diameter ratio-transverse.
85MM	I10, D10.2	MM = $2*N_h$; 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.

CARD SERIES	CARD FORMAT	
		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.

CARD SERIES	CARD FORMAT	
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	I10, 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	I10, 7D10.2	NN = 2,...,k where $k \leq 42$. Continuation of card 18201.

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

CARD SERIES	CARD FORMAT	
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 - Mimimum 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 × 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 × 11 sheet)

Columns 31-40: N1PLT - If plotting ΔP, N1PLT is the first node number for the ΔP. Otherwise N1PLT = 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 ≡ 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 PDH(I)
      IMPLICIT REAL*8(A-H,O-Z)
      INTEGER*4 HELIN,HELOUT
      COMMON /HELINN/      DELZ( 20),     FINPH( 20),
     1     FLOAH( 20),    FLOLGH( 20),    HELHD( 20),
     2     HELIN( 20),    HELOUT( 20),   HNDVOL( 20),
     3    HONEDI( 20),    NDOWNH( 20),     NUPH( 20),
     4    RECONH( 20),    WHDFRI( 20),   WHDMOM( 20),
     5    WHDPRE( 20),     WHDSH( 20),   WHFCON( 20),
     6    WHGCON( 20),     WHMOM( 20)
C
      COMMON /EVERY/       DELT      ,    DELTI( 20),       EDI( 20),
     1       TAU      ,    HRTOSC      ,   NPRINT( 20),
     2    LASTHE      ,    LASTUB      ,
     3    NTIMST      ,       NIN      ,      NOUT
C
      COMMON /STATE/      UBARW( 20),    TMASSW( 20),      PWAT( 20),
     1      TH2O( 20),         W( 20),        GM( 20),        WM( 20),
     2     DDTUW( 20),     DDTMW( 20),     DDTWW( 20),
     3     DPDUW( 20),     DPDMW( 20),     DTDUW( 20),     DTDMW( 20),
     4      TTUB( 20),    DDTTUB( 20),
     5     UBARH( 20),    TMASSH( 20),      PHEL( 20),      THEL( 20),
     6      WHEL( 20),     DDTUH( 20),     DDTMH( 20),     DDTWH( 20),
     7     DPDUH( 20),     DPDMH( 20),     DTDUH( 20),     DTDMH( 20)
C
      REAL*8 NOFTUB
      INTEGER*4 TUBIN,TUBOUT
      COMMON /TUBINN/    FINPFP( 20),     FLOAW( 20),
     1    NDOWNW( 20),    NODHEL( 20),    NOFTUB( 20),
     2    NTBTYP( 20),      NUPW( 20),    RECONW( 20),
     3     TPMFP( 20),    TUBEHD( 20),    TUBLEN( 20),
     4     TUBIN( 20),     TUBIP( 20),     TUBOR( 20),
     5    TUBOUT( 20),     TUBRV( 20),    TUBVOL( 20),
     6     WDFRI( 20),     WDMOM( 20),     WDPRE( 20),
     7      WDSH( 20),     WFCON( 20),     WGCON( 20),
     8      WMOM( 20),    WONEDI( 20)
      COMMON/OUTLET/PWATSV(60),PHELSV(20),POUTT
      DIMENSION TH(22),F(22)
      DATA TH/0.0,60.0,100.0,150.0,160.0,200.0,250.0,300.0,350.0,370.0,
     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/1.0,0.958137,0.928519,0.908026,0.903623,0.886220,0.879663,
     1  0.872572,0.866539,0.864413,0.861917,0.844782,0.840340,0.835910,
     2  0.827030,0.818173,0.800949,0.798060,0.789350,0.784034,0.779025,
     3  0.763072/
      DATA IH/1/
      DATA NH/22/
      IF(TAU.GT.0.0D0) GO TO 10
      NH1 = NH-1
      POUTT = 2.0 * PHEL(I) - PHEL(NUPH(I))
      RETURN
   10 J = NDOWNH(I) - 250
      DO 31 II=IH,NH1
      K=II
      IF(TAU.LT.TH(K+1)) GO TO 32
   31 CONTINUE
   32 IH = K
      FH = F(K) + (F(K+1)-F(K))/(TH(K+1)-TH(K)) * (TAU-TH(K))
      POUTT = FH * PHELSV(J)
      RETURN
      END
```

```
      SUBROUTINE PDW(I)
      IMPLICIT REAL*8(A-H,O-Z)
      COMMON /EVERY/       DELT      ,    DELTI( 20),       EDI( 20),
     1       TAU      ,    HRTOSC      ,   NPRINT( 20),
     2    LASTHE      ,    LASTUB      ,
     3    NTIMST      ,       NIN      ,      NOUT
C
      COMMON /STATE/      UBARW( 20),    TMASSW( 20),      PWAT( 20),
     1      TH2O( 20),         W( 20),        GM( 20),        WM( 20),
     2     DDTUW( 20),     DDTMW( 20),     DDTWW( 20),
     3     DPDUW( 20),     DPDMW( 20),     DTDUW( 20),     DTDMW( 20),
     4      TTUB( 20),    DDTTUB( 20),
     5     UBARH( 20),    TMASSH( 20),      PHEL( 20),      THEL( 20),
```

```
     6      WHEL( 20),     DOTUH( 20),     DOTMH( 20),     DOTWH( 20),
     7     DPDUH( 20),     DPDMH( 20),     DTDUH( 20),     DTDMH( 20)
      REAL*8 NOFTUB
      INTEGER*4 TUBIN,TUBOUT
      COMMON /TUBINN/    FINPFP( 20),     FLOAW( 20),
     1    NDOWNW( 20),    NODHEL( 20),    NOFTUB( 20),
     2    NTRTYP( 20),      NUPW( 20),    RECONW( 20),
     3     TPMFP( 20),    TUBEHD( 20),    TUBLEN( 20),
     4     TUBIN( 20),     TUBIR( 20),     TUBOR( 20),
     5    TUBOUT( 20),     TUBRV( 20),    TUBVOL( 20),
     6     WDFRI( 20),     WDMOM( 20),     WDPRE( 20),
     7      WDSH( 20),     WFCON( 20),     WGCON( 20),
     8      WMOM( 20),    WONFOT( 20)
      COMMON/OUTLET/PWATSV(60),PHELSV(20),POUTT
      DIMENSION TIR(11),FR(11),TIS(14),FS(14)
      DATA TIR/0.0,100.0,200.0,300.0,400.0,500.0,600.0,700.0,
     1  800.0,900.0,1000.0/
      DATA FR/1.0,0.524611,0.245777,0.265576,0.145102,0.086170,0.0769453
     1,0.0488075,0.0520578,0.0462264,0.0390035/
      DATA TIS/0.0,10.0,20.0,30.0,40.0,50.0,60.0,70.0,80.0,90.0,100.0,
     1  110.0,120.0,2000.0/
      DATA FS/1.0,1.0182,1.0356,1.0500,1.0656,1.0706,1.0723,1.0735,
     1  1.0748,1.0756,1.0764,1.0771,1.07760,1.07760/
      DATA IR,IS/1,1/
      DATA NP,NS/11,14/
      IF(TAU.GT.0.0D0) GO TO 10
      NR1 = NP-1
      NS1=NS-1
      POUTT = 2.0 * PWAT(I) - PWAT(NUPW(I))
      RETURN
   10 IF(NDOWNW(I).GE.251) GO TO 20
      J = NDOWNW(I) - 214
      DO 30 II=IR,NR1
      K=II
      IF(TAU.LT.TIR(K+1)) GO TO 11
   30 CONTINUE
   11 IR=K
      FREHET = FR(K) + (FR(K+1) - FR(K))/(TIR(K+1)-TIR(K))
     1 * (TAU-TIR(K))
      POUTT = FREHET * PWATSV(J)
      RETURN
   20 J = NDOWNW(I) - 214
      DO 40 II=IS,NS1
      K=II
      IF(TAU.LT.TIS(K+1)) GO TO 21
   40 CONTINUE
   21 IS=K
      FSGEN = FS(K) + (FS(K+1)-FS(K))/(TIS(K+1)-TIS(K))
     1  * (TAU-TIS(K))
      POUTT = FSGEN * PWATSV(J)
      RETURN
      END
```

```
      SUBROUTINE REHETW
      IMPLICIT REAL*8(A-H,O-Z)
C
      COMMON /EVERY/       DELT      ,     DELTI( 20),       EOI( 20),
     1       TAU      ,    HRTOSC      ,    NPRINT( 20),
     2    LASTHE      ,    LASTUB      ,
     3    NTIMST      ,       NIN      ,      NOUT
      COMMON /PLENUM/  NOFTUN,NDLTUN,    TAREW,TAREH,TASGW,TASGH,
     1    REWI,REWO,REHI,REHO,    SGWI,SGWO,SGHI,SGHO,
     2    PREWI,PREWO,PREHI,PREHO,    PSGWI,PSGWO,PSGHI,PSGHO,
     3    VSREWI,VSREWO,VSREHI,VSREHO,    VSSGWI,VSSGWO,VSSGHI,VSSGHO,
     4    HREWI,HREWO,HREHI,HREHO,    HSGWI,HSGWO,HSGHI,HSGHO,
     5    REWIT,REWOT,REHIT,REHOT,    SGWIT,SGWOT,SGHIT,SGHOT
C
      DIMENSION TIF(16),TIH(16),TIP(16)
      DIMENSION FLOW(16),ENTHAL(16),PRES(16)
      DATA NF,NH,NP/16,16,16/
      DATA IF,IH,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/2225.0,1126.7,501.3,553.3,304.6,173.8,152.9,98.2,108.3,
```

```
     1  93.7,78.7,64.2,49.5,35.1,22.0,8.8/
      DATA TIH/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 ENTHAL/1311.3,1323.8,1339.8,1339.9,1323.0,1309.2,1296.2,
     11289.0,1280.2,1273.3,1268.2,1264.4,1261.6,1259.7,1258.7,1258.5/
      DATA TIP/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 PRES/628.8,316.2,144.6,156.6,84.8,50.1,44.7,28.3,30.2,26.8,
     1  22.6,17.9,14.8,14.2,13.8,13.5/
      NF1=NF-1
      DO 10 II=IF,NF1
      I=II
      IF(TAU.LT.TIF(I+1)) GO TO 11
   10 CONTINUE
   11 IF=I
      REWI = FLOW(I) + (FLOW(I+1)- FLOW(I))/(TIF(I+1)-TIF(I))
     1  * (TAU - TIF(I))
C
      NH1=NH-1
      DO 20 II=IH,NH1
      I=II
      IF(TAU.LT.TIH(I+1)) GO TO 21
   20 CONTINUE
   21 IH=I
      HREWI = ENTHAL(I) + (ENTHAL(I+1)-ENTHAL(I))/(TIH(I+1)-TIH(I))
     1  * (TAU - TIH(I))
C
      NP1=NP-1
      DO 30 II=IP,NP1
      I=II
      IF(TAU.LT.TIP(I+1)) GO TO 31
   30 CONTINUE
   31 IP=I
      PREWI = PRES(I) + (PRES(I+1)-PRES(I))/(TIP(I+1)-TIP(I))
     1 * ( TAU - TIP(I))
C
      REWI = REWI/(6.0 * 228.0)
      RETURN
      END
```

LISTING OF INPUT DATA CARDS

```
1001     .020     10.0      2.0     .025    610.0     60.0
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	628.000	1355.400	.00963335	4.8375	0	1	3
7004	2	228.0	1	3			
7005	625.000	1384.900	.00963335	4.8375	0	1	2
7006	2	228.0	2	4			
7007	621.000	1413.600	.00963335	4.8375	0	1	1
7008	2	228.0	3	5			
7009	606.000	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	1484.600	.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	2883.060	405.280	.00320026	38.25	0	1	16
7018	3	328.0	230	10			
7019	2801.060	512.030	.00320026	38.25	0	1	15
7020	3	328.0	9	11			
7021	2791.850	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	.00329283	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	1364.300	.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	7.0D-4	0.0154				
7503	1.626462	0.6645	0.8125	1.329	6	30.0	0
7504	0.0	7.0D-4	0.0154				
7505	1.626462	0.6645	0.8125	1.329	6	30.0	0
7506	0.0	7.0D-4	0.0154				
7507	1.626462	0.6645	0.8125	1.329	6	30.0	0
7508	0.0677	7.0D-4	0.0154				
7509	1.626462	0.6645	0.8125	1.329	6	30.0	0
7510	0.0677	7.0D-4	0.0110				
7511	1.626462	0.6645	0.8125	1.329	6	30.0	0
7512	0.0	7.0D-4	0.0110				
7513	1.626462	0.6645	0.8125	1.329	6	30.0	0
7514	0.0	7.0D-4	0.0110				
7515	1.626462	0.6645	0.8125	1.329	6	30.0	0
7516	0.0	7.0D-4	0.0110				
7517	1.1453	0.383	0.5	0.766	6	30.0	0
7518	0.5	3.0D-3	0.0070				
7519	1.1453	0.383	0.5	0.766	6	30.0	0
7520	0.0	3.0D-3	0.0070				
7521	1.1453	0.383	0.5	0.766	6	30.0	0
7522	0.0	3.0D-3	0.0070				
7523	1.1453	0.368	0.5	0.736	6	30.0	0
7524	0.0	3.0D-3	0.0068				
7525	1.1453	0.368	0.5	0.736	6	30.0	0
7526	0.0	3.0D-3	0.0068				
7527	1.1453	0.3885	0.5625	0.777	6	30.0	0
7528	0.0	3.0D-3	0.0071				
7529	1.1453	0.3155	0.5625	0.631	6	30.0	0
7530	0.0	7.0D-3	0.0058				
7531	1.1453	0.3515	0.5625	0.703	6	30.0	0
7532	0.0	7.0D-3	0.0065				
8001	714.670	2216.000	29.17	1.1775	1.1775	1	0
8002	58.7039	201	2				
8003	714.320	2178.700	29.17	1.1775	1.1775	1	0
8004	58.7039	1	3				
8005	713.980	2143.500	29.17	1.1775	1.1775	1	0
8006	58.7039	2	4				
8007	713.650	2110.000	29.17	1.1775	1.1775	1	0
8008	58.7039	3	215				
8009	713.260	2093.500	33.6632	2.28125	2.3333	1	1
8010	168.2059	215	6				
8011	712.570	2093.500	21.3803	19.9592	19.9592	0	1
8012	426.7337	5	7				
8013	712.420	2093.500	21.3803	19.9592	19.9592	0	1

8014	426.7337	6	8				
8015	712.270	2093.500	36.2744	2.5	3.5833	0	0
8016	281.1518	7	230				
8017	712.470	2031.800	40.00	3.1139	3.1139	1	0
8018	191.0015	230	10				
8019	711.920	1901.300	40.00	2.8283	2.8283	1	0
8020	173.4857	9	11				
8021	711.480	1765.000	40.00	2.7568	2.7568	1	0
8022	169.0975	10	12				
8023	711.080	1645.500	45.81	3.0418	3.0418	1	0
8024	200.00255	11	13				
8025	710.810	1558.600	45.81	3.0418	3.0418	1	0
8026	200.00255	12	14				
8027	710.540	1489.600	45.81	2.8124	2.8124	1	0
8028	184.9205	13	15				
8029	710.310	1420.900	45.81	2.5075	2.5075	1	0
8030	164.8711	14	16				
8031	710.070	1344.400	45.81	2.5075	2.5075	1	0
8032	164.8711	15	251				
8501	522.200	1.625	0.0	1.0	4	2	1.5274
8502	1.5582						
8503	522.200	1.625	0.0	1.0	4	2	1.5274
8504	1.5582						
8505	522.200	1.625	0.0	1.0	4	2	1.5274
8506	1.5582						
8507	522.200	1.625	0.075	1.0	4	2	1.5274
8508	1.5582						
8509	522.200	1.625	0.075	1.0	7	7	4.5513
8510	1.5274						
8511	522.200	40.0	0.080	-10.0	0	0	1.0
8512	1.0						
8513	522.200	40.0	0.080	-10.0	0	0	1.0
8514	1.0						
8515	522.200	1.125	0.075	1.0	11	10	7.2528
8516	1.6933						
8517	522.200	1.125	0.0	1.0	18	6	1.6933
8518	1.3964						
8519	522.200	1.125	0.0	1.0	16	5	1.6933
8520	1.3964						
8521	522.200	1.125	0.0	1.0	16	5	1.6933
8522	1.3964						
8523	522.200	1.000	0.0	1.0	19	7	1.9050
8524	1.4420						
8525	522.200	1.000	0.0	1.0	19	6	1.9050
8526	1.4420						
8527	522.200	1.000	0.0	1.0	18	5	1.9050
8528	1.4420						
8529	522.200	1.000	0.0	1.0	16	6	1.9050
8530	1.4420						
8531	522.200	1.000	0.0	1.0	15	5	1.9050
8532	1.4420						
9001	5	8					
9201	1.0	.2					
18001	7	0.0	1.1453	10.0	1.0833	120.0	0.4538
18002	140.0	.3389	150.0	0.2886	160.0	0.2861	1400.0
18003	0.2861						
18101	3	0.0	2965.0	160.0	2741.2	1400.0	2726.6
18201	10	0.0	346.8	100.0	306.1	200.0	277.6
18202	300.0	262.3	400.0	247.6	500.0	234.6	600.0
18203	222.7	700.0	214.3	900.0	212.5	1400.0	212.0
18501	61	0.0	522.2	10.0	490.4	20.0	456.0
18502	30.0	421.0	40.0	387.5	50.0	358.1	60.0
18503	333.5	70.0	313.5	80.0	296.9	90.0	280.6
18504	100.0	263.4	110.0	245.1	120.0	219.5	130.0
18505	197.5	140.0	170.8	150.0	143.3	160.0	150.0
18506	180.0	149.8	190.0	149.2	200.0	149.2	210.0
18507	149.7	220.0	151.7	230.0	155.1	240.0	160.3
18508	250.0	167.2	260.0	176.1	270.0	187.2	280.0
18509	200.5	290.0	215.4	300.0	232.8	310.0	243.2
18510	320.0	254.3	330.0	263.5	340.0	270.9	350.0
18511	278.7	356.0	276.5	370.0	275.7	380.0	248.3
18512	390.0	231.5	400.0	217.0	410.0	201.6	420.0
18513	175.1	430.0	157.3	440.0	152.6	450.0	152.0
18514	460.0	152.5	480.0	153.3	500.0	151.2	520.0
18515	146.5	540.0	140.8	560.0	137.9	570.0	138.0
18516	600.0	144.5	620.0	147.1	640.0	111.9	700.0
18517	114.5	740.0	122.9	760.0	126.5	800.0	121.6
18518	840.0	116.8	900.0	113.0			
18601	16	0.0	715.0	100.0	660.5	200.0	629.6
18602	300.0	620.5	400.0	612.8	500.0	581.3	600.0

18603	560.8	700.0	542.0	800.0	530.4	900.0	519.7
18604	1000.0	509.6	1100.0	500.0	1200.0	490.4	1300.0
18605	479.9	1400.0	470.5	1500.0	464.5		
18701	26	0.0	2269.3	10.	2269.9	20.0	2255.1
18702	30.0	2232.0	40.0	2206.7	60.0	2155.2	100.0
18703	2056.6	110.0	2035.0	130.0	2000.5	140.0	1988.6
18704	150.0	1980.4	230.0	1858.2	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	560.0
18707	1415.1	600.0	1395.8	620.0	1386.5	640.0	1382.4
18708	700.0	1364.1	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
0.2000D-01	0.1000D 02	2	0.2500D-01	0.6100D 03	60			

PLOT INFORMATION

IDPLT	XMINP	XMAXP	XLENP	KINDY	YMINP	YMAXP	YLENP	N1PLT	N2PLT
11010	0.39000E 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
36015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
14010	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
16010	0.39000E 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	0.39000E 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	0.60000E 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	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
35015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
34015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0

36015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
36015	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
18015	0.39000E 03	0.42000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
1400	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 02	0	0
3400	0.0	0.60000E 03	0.85000E 01	0	0.0	0.0	0.11000E 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
38015	0.15200E 03	0.20000E 03	0.85000E 01	0	0.0	0.0	0.11000E 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

WATER NODE INPUT

PRESSURE PSIA	ENTHALPY BTU/LBM	FLOW AREA FT**2	TUBE LENGTH FT.	INLET POSITION 1=TOP	OUTLET POSITION 0=BOTTOM	ASSOC. HEL. NODE	TUBE TYPE	NO. OF TUBES	UPSTREAM NODE	DNSTREAM NODE
0.630000D 03	0.132470D 04	0.963335D-02	0.483750D 01	0	1	4	2	0.228000D 03	201	2
0.628000D 03	0.135540D 04	0.963335D-02	0.483750D 01	0	1	3	2	0.228000D 03	1	3
0.625000D 03	0.138490D 04	0.963335D-02	0.483750D 01	0	1	2	2	0.228000D 03	2	4
0.621000D 03	0.141360D 04	0.963335D-02	0.483750D 01	0	1	1	2	0.228000D 03	3	5
0.606000D 03	0.144070D 04	0.963335D-02	0.483750D 01	1	0	1	2	0.228000D 03	4	6
0.591000D 03	0.146460D 04	0.963335D-02	0.483750D 01	1	0	2	2	0.228000D 03	5	7
0.587000D 03	0.148460D 04	0.963335D-02	0.483750D 01	1	0	3	2	0.228000D 03	6	8
0.582000D 03	0.150120D 04	0.963335D-02	0.483750D 01	1	0	4	2	0.228000D 03	7	215
0.288306D 04	0.405280D 03	0.320026D-02	0.382500D 02	0	1	16	3	0.328000D 03	230	10
0.280106D 04	0.512030D 03	0.320026D-02	0.382500D 02	0	1	15	3	0.328000D 03	9	11
0.279185D 04	0.607880D 03	0.320026D-02	0.429000D 02	0	1	14	3	0.328000D 03	10	12
0.278354D 04	0.704030D 03	0.295449D-02	0.464000D 02	0	1	13	3	0.328000D 03	11	13
0.277228D 04	0.825230D 03	0.295449D-02	0.464000D 02	0	1	12	3	0.328000D 03	12	14
0.275469D 04	0.991900D 03	0.329283D-02	0.386000D 02	0	1	11	3	0.328000D 03	13	15
0.273627D 04	0.118220D 04	0.217163D-02	0.396000D 02	0	1	10	3	0.328000D 03	14	16
0.258491D 04	0.136430D 04	0.269549D-02	0.436000D 02	0	1	9	3	0.328000D 03	15	251

WATER SIDE HYDRAULIC INPUT

MASS FLOW RATE LBM/SEC	TUBE INSIDE RADIUS FT	TUBE OUTSIDE RADIUS FT	TUBE HYDRAU. DIA. IN	DNB CORREL.	MINIMUM H. T. COEF. BTU/SC-FT2	GROEN. CORREL.	CONSTANT FRIC. FACT.	EPS./DIA.	RELATIVE CURVITURE
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.154000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.154000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.154000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.677000D-01	0.700000D-03	0.154000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.677000D-01	0.700000D-03	0.110000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.110000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.110000D-01
0.162646D 01	0.553750D-01	0.677083D-01	0.132900D 01	6	0.833333D-02	F	0.0	0.700000D-03	0.110000D-01
0.114530D 01	0.319167D-01	0.416667D-01	0.766000D 00	6	0.833333D-02	F	0.500000D 00	0.300000D-02	0.700000D-02
0.114530D 01	0.319167D-01	0.416667D-01	0.766000D 00	6	0.833333D-02	F	0.0	0.300000D-02	0.700000D-02
0.114530D 01	0.319167D-01	0.416667D-01	0.766000D 00	6	0.833333D-02	F	0.0	0.300000D-02	0.700000D-02
0.114530D 01	0.306667D-01	0.416667D-01	0.736000D 00	6	0.833333D-02	F	0.0	0.300000D-02	0.680000D-02
0.114530D 01	0.306667D-01	0.416667D-01	0.736000D 00	6	0.833333D-02	F	0.0	0.300000D-02	0.680000D-02
0.114530D 01	0.323750D-01	0.468750D-01	0.777000D 00	6	0.833333D-02	F	0.0	0.300000D-02	0.710000D-02
0.114530D 01	0.262917D-01	0.468750D-01	0.631000D 00	6	0.833333D-02	F	0.0	0.700000D-02	0.580000D-02
0.114530D 01	0.292917D-01	0.468750D-01	0.703000D 00	6	0.833333D-02	F	0.0	0.700000D-02	0.650000D-02

HELIUM NODE INPUT

PRESSURE PSIA	ENTHALPY BTU/LBM	FLOW AREA FT**2	FLOW LENGTH FT	VOL. HEIGHT FT	INLET POSITION 1=TOP	OUTLET POSITION 0=BOTTOM	NODAL VOLUME FT**3	UPSTREAM NODE	DNSTREAM NODE
0.714670D 03	0.221600D 04	0.291700D 02	0.117750D 01	0.117750D 01	1	0	0.587039D 02	201	2
0.714320D 03	0.217870D 04	0.291700D 02	0.117750D 01	0.117750D 01	1	0	0.587039D 02	1	3
0.713980D 03	0.214350D 04	0.291700D 02	0.117750D 01	0.117750D 01	1	0	0.587039D 02	2	4
0.713650D 03	0.211000D 04	0.291700D 02	0.117750D 01	0.117750D 01	1	0	0.587039D 02	3	215
0.713260D 03	0.209350D 04	0.336632D 02	0.228125D 01	0.233330D 01	1	1	0.168206D 03	215	6
0.712570D 03	0.209350D 04	0.213803D 02	0.199592D 02	0.199592D 02	0	1	0.426734D 03	5	7
0.712420D 03	0.209350D 04	0.213803D 02	0.199592D 02	0.199592D 02	0	1	0.426734D 03	6	8
0.712270D 03	0.209350D 04	0.362744D 02	0.250000D 01	0.358330D 01	0	0	0.281152D 03	7	230
0.712470D 03	0.203180D 04	0.400000D 02	0.311390D 01	0.311390D 01	1	0	0.191002D 03	230	10
0.711920D 03	0.190130D 04	0.400000D 02	0.282830D 01	0.282830D 01	1	0	0.173486D 03	9	11

0.711480D 03	0.176500D 04	0.400000D 02	0.275680D 01	0.275680D 01	1	0	0.169098D 03	10	12
0.711080D 03	0.164550D 04	0.458100D 02	0.304180D 01	0.304180D 01	1	0	0.200003D 03	11	13
0.710810D 03	0.155860D 04	0.458100D 02	0.304180D 01	0.304180D 01	1	0	0.200003D 03	12	14
0.710540D 03	0.148960D 04	0.458100D 02	0.281240D 01	0.281240D 01	1	0	0.184921D 03	13	15
0.710310D 03	0.142090D 04	0.458100D 02	0.250750D 01	0.250750D 01	1	0	0.164871D 03	14	16
0.710070D 03	0.134440D 04	0.458100D 02	0.250750D 01	0.250750D 01	1	0	0.164871D 03	15	251

HELIUM HYDRAULIC INPUT

MASS FLOW RATE LBM/SEC	AVG. TUBE OUTSIDE DIA. IN	CONSTANT FRIC. FACT.	EPS/DIA.	NO. ROWS INLINE	NO. ROWS STAGGERED	PITCH TO DIA. TRANSVERSE	PITCH TO DIA. LONGITUDINAL
0.522200D 03	0.162500D 01	0.0	0.100000D 01	4	2	0.152740D 01	0.155820D 01
0.522200D 03	0.162500D 01	0.0	0.100000D 01	4	2	0.152740D 01	0.155820D 01
0.522200D 03	0.162500D 01	0.0	0.100000D 01	4	2	0.152740D 01	0.155820D 01
0.522200D 03	0.162500D 01	0.750000D-01	0.100000D 01	4	2	0.152740D 01	0.155820D 01
0.522200D 03	0.162500D 01	0.750000D-01	0.100000D 01	7	7	0.455130D 01	0.152740D 01
0.522200D 03	0.400000D 02	0.800000D-01	-0.100000D 02	0	0	0.100000D 01	0.100000D 01
0.522200D 03	0.400000D 02	0.800000D-01	-0.100000D 02	0	0	0.100000D 01	0.100000D 01
0.522200D 03	0.112500D 01	0.750000D-01	0.100000D 01	11	10	0.725280D 01	0.169330D 01
0.522200D 03	0.112500D 01	0.0	0.100000D 01	18	6	0.169330D 01	0.139640D 01
0.522200D 03	0.112500D 01	0.0	0.100000D 01	16	5	0.169330D 01	0.139640D 01
0.522200D 03	0.112500D 01	0.0	0.100000D 01	16	5	0.169330D 01	0.139640D 01
0.522200D 03	0.100000D 01	0.0	0.100000D 01	19	7	0.190500D 01	0.144200D 01
0.522200D 03	0.100000D 01	0.0	0.100000D 01	19	6	0.190500D 01	0.144200D 01
0.522200D 03	0.100000D 01	0.0	0.100000D 01	18	5	0.190500D 01	0.144200D 01
0.522200D 03	0.100000D 01	0.0	0.100000D 01	16	6	0.190500D 01	0.144200D 01
0.522200D 03	0.100000D 01	0.0	0.100000D 01	15	5	0.190500D 01	0.144200D 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 = 0.10000000D 01
ALLOWABLE TEMPERATURE CHANGE FOR HELIUM = 0.20000000D 00

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

TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE
0.0	1.1453D 00	1.0000D 01	1.0833D 00	1.2000D 02	4.5380D-01	1.4000D 02	3.3890D-01
1.5000D 02	2.8860D-01	1.6000D 02	2.8610D-01	1.4000D 03	2.8610D-01		

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

TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE
0.0	2.9650D 03	1.6000D 02	2.7412D 03	1.4000D 03	2.7266D 03		

********** WATER SICE **********
********** ENTHALPY VS. TIME **********

TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY
0.0	3.4680D 02	1.0000D 02	3.0610D 02	2.0000D 02	2.7760D 02	3.0000D 02	2.6230D 02
4.0000D 02	2.4760D 02	5.0000D 02	2.3460D 02	6.0000D 02	2.2270D 02	7.0000D 02	2.1430D 02
9.0000D 02	2.1250D 02	1.4000D 03	2.1200D 02				

HELIUM SIDE
FLOW RATE VS. TIME

TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE	TIME	FLOW RATE
0.0	5.2220D 02	1.0000D 01	4.9040D 02	2.0000D 01	4.5600D 02	3.0000D 01	4.2100D 02
4.0000D 01	3.8750D 02	5.0000D 01	3.5810D 02	6.0000D 01	3.3350D 02	7.0000D 01	3.1350D 02
8.0000D 01	2.9690D 02	9.0000D 01	2.8060D 02	1.0000D 02	2.6340D 02	1.1000D 02	2.4510D 02
1.2000D 02	2.1950D 02	1.3000D 02	1.9750D 02	1.4000D 02	1.7080D 02	1.5000D 02	1.4330D 02
1.6000D 02	1.5000D 02	1.8000D 02	1.4980D 02	1.9000D 02	1.4920D 02	2.0000D 02	1.4920D 02
2.1000D 02	1.4970D 02	2.2000D 02	1.5170D 02	2.3000D 02	1.5510D 02	2.4000D 02	1.6030D 02
2.5000D 02	1.6720D 02	2.6000D 02	1.7610D 02	2.7000D 02	1.8720D 02	2.8000D 02	2.0050D 02
2.9000D 02	2.1540D 02	3.0000D 02	2.3280D 02	3.1000D 02	2.4320D 02	3.2000D 02	2.5430D 02
3.3000D 02	2.6350D 02	3.4000D 02	2.7090D 02	3.5000D 02	2.7870D 02	3.5600D 02	2.7650D 02
3.7000D 02	2.7570D 02	3.8000D 02	2.4830D 02	3.9000D 02	2.3150D 02	4.0000D 02	2.1700D 02
4.1000D 02	2.0160D 02	4.2000D 02	1.7510D 02	4.3000D 02	1.5730D 02	4.4000D 02	1.5260D 02
4.5000D 02	1.5200D 02	4.6000D 02	1.5250D 02	4.8000D 02	1.5330D 02	5.0000D 02	1.5120D 02
5.2000D 02	1.4650D 02	5.4000D 02	1.4080D 02	5.6000D 02	1.3790D 02	5.7000D 02	1.3800D 02
6.0000D 02	1.4450D 02	6.2000D 02	1.4710D 02	6.4000D 02	1.1190D 02	7.0000D 02	1.1450D 02
7.4000D 02	1.2290D 02	7.6000D 02	1.2650D 02	8.0000D 02	1.2160D 02	8.4000D 02	1.1680D 02
9.0000D 02	1.1300D 02						

HELIUM SIDE
PRESSURE VS. TIME

TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE	TIME	PRESSURE
0.0	7.1500D 02	1.0000D 02	6.6050D 02	2.0000D 02	6.2960D 02	3.0000D 02	6.2050D 02
4.0000D 02	6.1280D 02	5.0000D 02	5.8130D 02	6.0000D 02	5.6080D 02	7.0000D 02	5.4200D 02
8.0000D 02	5.3040D 02	9.0000D 02	5.1970D 02	1.0000D 03	5.0960D 02	1.1000D 03	5.0000D 02
1.2000D 03	4.9040D 02	1.3000D 03	4.7990D 02	1.4000D 03	4.7050D 02	1.5000D 03	4.6450D 02

HELIUM SIDE
ENTHALPY VS. TIME

TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY	TIME	ENTHALPY
0.0	2.2693D 03	1.0000D 01	2.2699D 03	2.0000D 01	2.2551D 03	3.0000D 01	2.2320D 03
4.0000D 01	2.2067D 03	6.0000D 01	2.1552D 03	1.0000D 02	2.0566D 03	1.1000D 02	2.0350D 03
1.3000D 02	2.0005D 03	1.4000D 02	1.9886D 03	1.5000D 02	1.9804D 03	2.3000D 02	1.8582D 03
2.5000D 02	1.8230D 03	2.9000D 02	1.7397D 03	3.5000D 02	1.6023D 03	3.7000D 02	1.5656D 03
3.9000D 02	1.5361D 03	4.1000D 02	1.5127D 03	4.6000D 02	1.4752D 03	5.0000D 02	1.4473D 03
5.6000D 02	1.4151D 03	6.0000D 02	1.3958D 03	6.2000D 02	1.3865D 03	6.4000D 02	1.3824D 03
7.0000D 02	1.3641D 03	7.4000D 02	1.3515D 03				

********** STEADY STATE OUTPUT **********

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

INPUT FRICTION FACTOR	CALCULATED FRICTION FACTOR	CALCULATED CURVITURE FACTOR	TWO - PHASE MULTIPLIER	TRANSITION REGION PARAMETERS A	F=A*EXP(RE)**B B
-3.20601929D-05	1.83714700D-02	1.38977809D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
-7.84749961D-05	1.83867392D-02	1.38531816D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
-8.65606942D-05	1.84023748D-02	1.38099078D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
6.75103072D-02	1.84174219D-02	1.37703429D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
6.74837199D-02	1.84319847D-02	1.31556589D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
-4.26913026D-04	1.84444144D-02	1.31303928D 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	1.30902175D 00	1.00000000D 00	1.01322658D-03	4.44959862D-01
5.00365940D-01	2.66722503D-02	1.18106659D 00	1.00000000D 00	5.34557246D-04	5.28552283D-01
7.72517648D-03	2.65754524D-02	1.19117383D 00	1.00000000D 00	5.34557246D-04	5.28552283D-01
3.99275062D-03	2.65213365D-02	1.19820498D 00	1.00000000D 00	5.34557246D-04	5.28552283D-01
1.10766663D-06	2.64737450D-02	1.20261880D 00	1.00000000D 00	5.34557246D-04	5.28552283D-01
3.06059191D-07	2.64637898D-02	1.20431480D 00	9.36019542D-01	5.34557246D-04	5.28552283D-01
-5.93631702D-04	2.64805755D-02	1.20589052D 00	9.10428837D-01	5.34557246D-04	5.28552283D-01
-4.80693250D-03	3.37675532D-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

********** HELIUM SIDE **********

INPUT FRICTION FACTOR	CALCULATED FRICTION FACTOR	TUBE NUMBER	GRIMISON PARAMETERS B	NU=B*RE**N*(PR/.69)**1/3 N
-2.02170174D-03	3.85649907D-01	4	2.56511821D-01	6.15085816D-01
		5	2.56511821D-01	6.15085816D-01
-9.14988617D-04	3.84927457D-01	3	2.56511821D-01	6.15085816D-01
		6	2.56511821D-01	6.15085816D-01
-8.70728134D-04	3.84234910D-01	2	2.56511821D-01	6.15085816D-01
		7	2.56511821D-01	6.15085816D-01
7.40608538D-02	3.83565947D-01	1	2.56511821D-01	6.15085816D-01
		8	2.56511821D-01	6.15085816D-01
7.30783807D-02	4.23090946D-01			
7.78005348D-02	0.0			
7.94888218D-02	0.0			
7.33679342D-02	6.16562956D-01			
-1.89635529D-02	1.26806905D 00	16	1.67014588D-01	6.62372603D-01
-1.99104330D-02	1.09385443D 00	15	1.67014588D-01	6.62372603D-01
-1.63648924D-02	1.08505371D 00	14	1.67014588D-01	6.62372603D-01
-8.79158379D-03	1.17699772D 00	13	1.46854744D-01	6.75669920D-01
-9.99123700D-03	1.09933258D 00	12	1.46854744D-01	6.75669920D-01
-1.30058983D-02	9.88383274D-01	11	1.46854744D-01	6.75669920D-01
-1.97156448D-02	9.82111473D-01	10	1.46854744D-01	6.75669920D-01
1.49630109D-01	8.71924628D-01	9	1.46854744D-01	6.75669920D-01

********** 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	629.80	4.77930D-02	5.80333D 01	679.50	1.17	1.62646D 00	2.8821D-13	3.5484D 00	-8.3862D-03	-1.9853D-01	-3.3415D 00
2	626.25	4.47184D-02	5.53865D 01	729.75	1.22	1.62646D 00	3.3218D-13	3.9767D 00	-7.8467D-03	-4.1254D-01	-3.5563D 00
3	622.27	4.20123D-02	5.30326D 01	781.11	1.26	1.62646D 00	4.0925D-12	4.1959D 00	-7.3718D-03	-4.1304D-01	-3.7755D 00
4	618.08	3.96351D-02	5.09441D 01	830.55	1.30	1.62646D 00	-7.5051D-14	1.5091D 01	-6.9547D-03	-4.0937D-01	-1.4675D 01
5	602.99	3.69193D-02	4.82535D 01	878.76	1.33	1.62646D 00	2.4583D-11	1.6087D 01	6.4782D-03	-5.3223D-01	-1.5561D 01
6	586.90	3.45596D-02	4.58279D 01	920.04	1.37	1.62646D 00	-9.4089D-12	4.8356D 00	6.0641D-03	-5.3034D-01	-4.3114D 00
7	582.06	3.32108D-02	4.45703D 01	958.08	1.39	1.62646D 00	5.0402D-11	4.7742D 00	5.8275D-03	-3.3699D-01	-4.4431D 00
8	577.29	3.21154D-02	4.35241D 01	988.36	1.42	1.62646D 00	-4.4409D-16	4.7742D 00	5.6352D-03	-2.9451D-01	-4.4854D 00
9	2881.59	6.54360D 00	2.59445D 03	426.31	-1.44	1.14530D 00	1.0658D-14	8.3367D 01	-9.3085D-01	-2.0564D-02	-8.2416D 01
10	2798.22	5.96507D 00	3.01409D 03	524.32	-0.89	1.14530D 00	0.0	7.5929D 00	-8.4855D-01	-5.0160D-02	-6.6942D 00
11	2790.63	5.97421D 00	3.60136D 03	602.68	-0.54	1.14530D 00	3.3220D-12	8.5549D 00	-8.4987D-01	-6.8000D-02	-7.6370D 00
12	2782.07	5.04335D 00	3.53517D 03	664.17	-0.18	1.14530D 00	1.1102D-15	1.1643D 01	-7.7712D-01	-2.4639D-01	-1.0619D 01
13	2770.43	2.67793D 00	2.19563D 03	683.35	0.27	1.14530D 00	-3.5527D-15	1.9930D 01	-4.1264D-01	-7.7884D-01	-1.8738D 01
14	2750.50	1.29885D 00	1.26794D 03	682.27	0.88	1.14530D 00	0.0	2.2824D 01	-1.9563D-01	-8.9496D-01	-2.1734D 01
15	2727.68	4.90459D-01	5.55192D 02	766.09	1.51	1.14530D 00	-5.9686D-13	1.5650D 02	-1.1202D-01	-7.9721D 00	-1.4842D 02
16	2571.18	4.36008D-01	5.53168D 02	938.57	1.90	1.14530D 00	-7.1054D-15	1.5650D 02	-8.0225D-02	2.3057D-02	-1.5644D 02

********** HELIUM SIDE **********

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	MASS FLOW RATE LBM/SEC	PRESSURE DROP - PSI INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	714.67	8.64112D 00	1.16720D 04	1341.31	5.22200D 02	4.1633D-17	3.5454D-01	1.2037D-03	3.9248D-03	-3.5967D-01
2	714.32	8.78723D 00	1.16649D 04	1310.29	5.22200D 02	4.1633D-17	3.4501D-01	1.2240D-03	7.8149D-03	-3.5404D-01
3	713.97	8.92980D 00	1.16580D 04	1281.00	5.22200D 02	4.1633D-17	3.3918D-01	1.2439D-03	7.3790D-03	-3.4780D-01
4	713.63	9.06988D 00	1.16512D 04	1253.11	5.22200D 02	2.7756D-17	4.0048D-01	1.2634D-03	7.0238D-03	-4.0877D-01
5	713.23	2.61806D 01	3.33640D 04	1239.48	5.22200D 02	1.3878D-17	7.0992D-01	0.0	-3.7959D-01	-3.3033D-01
6	712.52	6.63535D 01	8.45597D 04	1239.49	5.22200D 02	0.0	1.5091D-01	-2.1552D-02	-8.2190D-04	-1.2853D-01
7	712.37	6.63395D 01	8.45419D 04	1239.49	5.22200D 02	0.0	1.5307D-01	-2.1547D-02	-1.7482D-04	-1.3135D-01
8	712.22	4.36982D 01	5.56882D 04	1239.49	5.22200D 02	-1.3878D-17	-2.0204D-01	0.0	5.9818D-01	-3.9614D-01
9	712.42	3.05298D 01	3.78351D 04	1192.69	5.22200D 02	8.3267D-17	5.6354D-01	3.4564D-03	6.5386D-03	-5.7354D-01
10	711.85	2.95053D 01	3.43221D 04	1091.31	5.22200D 02	1.5266D-16	4.4625D-01	3.3404D-03	1.3848D-02	-4.6344D-01
11	711.41	3.09658D 01	3.34125D 04	979.00	5.22200D 02	6.9389D-17	4.0939D-01	3.5058D-03	1.5417D-02	-4.2831D-01
12	711.00	3.94269D 01	3.94702D 04	875.11	5.22200D 02	-1.3878D-17	2.6882D-01	4.1641D-03	5.8614D-02	-3.3160D-01
13	710.73	4.17606D 01	3.94331D 04	799.33	5.22200D 02	1.3878D-17	2.7957D-01	4.4106D-03	7.9517D-03	-2.9193D-01
14	710.45	4.04378D 01	3.64276D 04	741.42	5.22200D 02	0.0	2.3925D-01	4.2709D-03	6.0674D-03	-2.4959D-01
15	710.21	3.78189D 01	3.24500D 04	684.36	5.22200D 02	2.7756D-17	2.2479D-01	3.9943D-03	5.9880D-03	-2.3477D-01
16	709.99	3.99925D 01	3.24185D 04	621.13	5.22200D 02	-2.7756D-17	2.2479D-01	4.2239D-03	6.6461D-03	-2.3566D-01

********** TUBES **********

NODE	ASSOC. HELIUM NODE	HELIUM HEAT FLUX BTU/HR-FT2	HELIUM TRAN. COEF. BTU/HR-FT2-F	HELIUM 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	DNB FLUX BTU/HR-FT2
1	4	9.22713D 04	3.91640D 02	1017.51	965.54	908.08	4.93583D 02	1.12822D 05	7	6.07812D 05	0.0
2	3	8.89079D 04	3.93166D 02	1054.86	1005.67	951.27	4.90756D 02	1.08710D 05	7	6.07812D 05	0.0
3	2	8.58533D 04	3.94750D 02	1092.80	1046.11	994.48	4.91978D 02	1.04975D 05	7	6.07812D 05	0.0
4	1	8.35122D 04	3.96408D 02	1130.64	1085.97	1036.58	4.95616D 02	1.02112D 05	7	6.07812D 05	0.0
5	1	7.60370D 04	3.96408D 02	1149.50	1109.21	1064.66	5.00117D 02	9.29730D 04	7	6.07812D 05	0.0
6	2	6.42948D 04	3.94750D 02	1147.41	1113.41	1075.80	5.04698D 02	7.86138D 04	7	6.07812D 05	0.0
7	3	5.33443D 04	3.93166D 02	1145.32	1117.14	1085.99	5.09916D 02	6.52259D 04	7	6.07812D 05	0.0
8	4	4.38103D 04	3.91640D 02	1141.25	1118.11	1092.54	5.14213D 02	5.35732D 04	7	6.07812D 05	0.0
9	16	4.91325D 04	3.50353D 02	480.89	465.83	448.63	2.87366D 03	6.41416D 04	1	1.28836D 06	1.92284D 06
10	15	4.10010D 04	3.54250D 02	568.62	556.05	541.70	3.08079D 03	5.35259D 04	1	1.28836D 06	1.50200D 06
11	14	3.59670D 04	3.57630D 02	640.85	629.82	617.23	3.22767D 03	4.69541D 04	1	1.28836D 06	1.11515D 06
12	13	3.48093D 04	3.60938D 02	702.89	690.75	676.61	3.80265D 03	4.72946D 04	1	1.39553D 06	7.54085D 05
13	12	5.42600D 04	3.65097D 02	726.49	707.57	685.52	3.39917D 04	7.37221D 04	2	1.39553D 06	2.21606D 05
14	11	7.25321D 04	3.85387D 02	790.79	757.02	716.41	3.07631D 03	1.05016D 05	4	1.25214D 06	0.0
15	10	6.68084D 04	3.91417D 02	920.63	874.75	813.59	2.50708D 03	1.19098D 05	7	1.89861D 06	0.0
16	9	5.20167D 04	3.96584D 02	1061.53	1031.59	993.76	1.50819D 03	8.32356D 04	7	1.52962D 06	0.0

********** REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS **********

	***** REHEATER *****				***** STEAM GENERATOR *****			
	INLET		OUTLET		INLET		OUTLET	
	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM
PRESSURE	6.2880D 02	7.1500D 02	5.7490D 02	7.1323D 02	2.9650D 03	7.1323D 02	2.4929D 03	7.0987D 02
TEMPERATURE	6.5140D 02	1.3573D 03	1.0016D 03	1.2395D 03	3.6967D 02	1.2395D 03	1.0328D 03	5.8666D 02
ENTHALPY	1.3113D 03	2.2693D 03	1.5180D 03	2.1225D 03	3.4680D 02	2.1225D 03	1.4780D 03	1.3094D 03
SPEC. VOL.	9.4280D-01	6.8503D 00	1.4734D 00	6.4248D 00	1.7963D-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

TRANSIENT OUTPUT NUMBER 21
TIME STEP NUMBER 8100
TRANSIENT TIME = 200.0000 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	152.67	1.09359D-02	1.35105D 01	664.52	1.19	3.66692D-01	-1.2441D-03	6.8533D-01	-1.9189D-03	2.9905D-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	-1.8069D-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	-7.7772D-02	-8.0007D-01
4	150.26	9.32957D-03	1.21112D 01	826.98	1.28	3.67045D-01	-1.3839D-03	3.2210D 00	-1.6370D-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	3.67448D-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	2.56742D 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	2.63901D-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

********** HELIUM SIDE **********

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	MASS FLOW RATE LBM/SEC	PRESSURE DROP - PSI INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
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	3.5742D-02	1.3063D-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	3.2445D-02	-2.2274D-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	629.25	3.18587D 01	3.34022D 04	938.24	1.49242D 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	4.09445D 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

TUBES

NODE	ASSOC. HELIUM NODE	HELIUM HEAT FLUX BTU/HR-FT2	HELIUM TRAN. COEF. BTU/HR-FT2-F	HELIUM 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	DNB FLUX BTU/HR-FT2
1	4	2.12882D 04	1.74314D 02	878.58	866.02	852.57	1.34143D 02	2.52258D 04	7	1.37033D 05	0.0
2	3	1.90524D 04	1.74821D 02	909.53	898.46	886.60	1.36740D 02	2.25809D 04	7	1.37080D 05	0.0
3	2	1.69267D 04	1.75326D 02	939.94	930.25	920.00	1.39651D 02	1.97995D 04	7	1.37124D 05	0.0
4	1	1.49665D 04	1.75853D 02	969.97	961.52	952.42	1.42270D 02	1.78458D 04	7	1.37165D 05	0.0
5	1	1.22436D 04	1.75853D 02	985.45	978.59	971.00	1.44471D 02	1.50065D 04	7	1.37205D 05	0.0
6	2	9.00463D 03	1.75326D 02	985.12	980.08	974.33	1.46227D 02	1.13770D 04	7	1.37242D 05	0.0
7	3	6.34240D 03	1.74821D 02	982.23	978.68	974.49	1.47252D 02	8.27761D 03	7	1.37279D 05	0.0
8	4	4.15191D 03	1.74314D 02	976.89	974.56	971.65	1.48089D 02	5.72281D 03	7	1.37316D 05	0.0
9	16	1.63296D 04	1.47735D 02	419.87	414.87	409.05	9.09979D 02	2.16945D 04	1	3.20749D 05	1.57495D 06
10	15	1.02727D 04	1.49566D 02	527.02	523.87	520.27	1.00216D 03	1.34335D 04	1	3.20614D 05	1.13603D 06
11	14	7.18658D 03	1.50778D 02	593.06	590.86	588.35	1.04634D 03	9.35013D 03	1	3.20869D 05	8.45084D 05
12	13	5.50929D 03	1.51722D 02	640.63	638.71	636.44	1.17101D 03	7.58992D 03	1	3.46999D 05	6.30993D 05
13	12	5.10861D 03	1.52525D 02	675.09	673.31	671.17	1.28766D 03	7.16761D 03	1	3.44229D 05	4.05821D 05
14	11	1.09188D 04	1.62255D 02	686.97	681.88	675.77	1.38942D 04	1.58234D 04	2	2.94538D 05	5.93203D 04
15	10	1.74456D 04	1.64387D 02	728.45	716.47	700.53	1.19531D 03	3.10352D 04	4	4.37480D 05	0.0
16	9	1.70972D 04	1.67009D 02	835.87	826.03	813.11	6.03819D 02	2.84228D 04	7	3.50571D 05	0.0

REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS

	***** REHEATER *****				***** STEAM GENERATOR *****			
	INLET		OUTLET		INLET		OUTLET	
	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM
PRESSURE	1.4464D 02	6.2961D 02	1.4126D 02	6.2937D 02	2.7407D 03	6.2924D 02	2.6049D 03	6.2903D 02
TEMPERATURE	6.2993D 02	1.0646D 03	9.4192D 02	9.9181D 02	3.0271D 02	9.9204D 02	8.8673D 02	4.9036D 02
ENTHALPY	1.3398D 03	1.9041D 03	1.4996D 03	1.8134D 03	2.7761D 02	1.8137D 03	1.3537D 03	1.1889D 03
SPEC. VOL.	4.3600D 00	6.5292D 00	5.8568D 00	6.2221D 00	1.7281D-02	6.2243D 00	2.4473D-01	4.0915D 00
FLOW RATE	3.6656D-01	1.4920D 02	3.6745D-01	1.4920D 02	2.8610D-01	1.4923D 02	2.6249D-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	4.07845D-03	4.91978D 00	582.14	1.16	1.27098D-01	-1.3163D-04	2.2421D-01	-7.1564D-04	1.4551D-02	-2.3817D-01
2	52.67	3.93479D-03	4.79450D 00	613.36	1.17	1.27124D-01	-1.4418D-04	2.6350D-01	-6.9043D-04	-1.5863D-02	-2.4709D-01
3	52.40	3.82434D-03	4.69562D 00	636.40	1.19	1.27151D-01	-1.4805D-04	2.6826D-01	-6.7105D-04	-1.3047D-02	-2.5469D-01
4	52.14	3.73835D-03	4.61685D 00	653.52	1.20	1.27177D-01	-2.6961D-04	9.6447D-01	-6.5596D-04	-1.0732D-02	-9.5335D-01
5	51.17	3.62041D-03	4.49156D 00	664.72	1.20	1.27202D-01	-2.7757D-04	9.9210D-01	6.3527D-04	-1.5472D-02	-9.7754D-01
6	50.18	3.51314D-03	4.37436D 00	672.52	1.21	1.27227D-01	-1.5543D-04	2.8140D-01	6.1645D-04	-1.4986D-02	-2.6719D-01
7	49.90	3.46476D-03	4.32633D 00	679.75	1.22	1.27252D-01	-1.5567D-04	2.7531D-01	6.0796D-04	-7.1709D-03	-2.6891D-01
8	49.62	3.42467D-03	4.28532D 00	684.85	1.22	1.27276D-01	8.1228D-03	2.7987D-01	6.0092D-04	-6.1286D-03	-2.6622D-01
9	2617.62	6.87813D 00	2.19900D 03	352.43	-1.26	2.85218D-01	-1.8670D-02	5.8273D 00	-9.7844D-01	-1.3290D-03	-4.8662D 00
10	2611.79	6.12885D 00	2.91271D 03	497.55	-0.78	2.82732D-01	8.9869D-02	1.3603D 00	-8.7185D-01	-3.1363D-03	-3.9544D-01
11	2610.43	6.16202D 00	3.55957D 03	582.83	-0.47	2.78322D-01	-5.7522D-02	1.2544D 00	-8.7659D-01	-2.7258D-03	-4.3262D-01
12	2609.18	5.58881D 00	3.60165D 03	630.12	-0.27	2.73839D-01	-3.3987D-02	1.3747D 00	-8.6117D-01	-9.1104D-03	-5.3843D-01
13	2607.81	5.19312D 00	3.55543D 03	653.95	-0.14	2.69903D-01	3.2513D-02	1.3975D 00	-8.0019D-01	-2.0686D-03	-5.6272D-01
14	2606.41	4.55182D 00	3.23230D 03	666.11	-0.06	2.66487D-01	-1.5394D-02	1.0245D 00	-6.8560D-01	8.0770D-03	-3.6233D-01
15	2605.38	2.94838D 00	2.14545D 03	673.06	-0.01	2.64550D-01	2.7744D-03	1.9326D 00	-6.7339D-01	-5.3959D-02	-1.2024D 00
16	2603.45	3.36619D 00	2.51916D 03	674.10	0.06	2.44634D-01	1.4835D-03	1.3968D 00	-6.1938D-01	3.1362D-02	-8.0732D-01

********** HELIUM SIDE **********

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	MASS FLOW RATE LBM/SEC	PRESSURE DROP - PSI INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	581.19	1.09101D 01	9.47222D 03	697.92	1.51203D 02	-1.0352D-06	2.6064D-02	1.5197D-03	-2.0138D-07	-2.7585D-02
2	581.16	1.09152D 01	9.47175D 03	697.32	1.51204D 02	-1.0402D-06	2.6104D-02	1.5204D-03	1.4169D-05	-2.7640D-02
3	581.14	1.09230D 01	9.47126D 03	696.43	1.51205D 02	-1.0474D-06	2.6076D-02	1.5215D-03	2.2044D-05	-2.7621D-02
4	581.11	1.09355D 01	9.47074D 03	695.05	1.51206D 02	-1.0686D-06	3.0681D-02	1.5232D-03	3.5058D-05	-3.2240D-02
5	581.08	3.13537D 01	2.71352D 04	694.25	1.51209D 02	2.3496D-03	5.5521D-02	0.0	-2.6788D-02	-2.6384D-02
6	581.03	7.95340D 01	6.88347D 04	694.28	1.51216D 02	-2.0972D-05	3.4817D-02	-2.5833D-02	-1.2758D-05	-8.9919D-03
7	580.99	7.95197D 01	6.88307D 04	694.42	1.51224D 02	-2.0908D-05	3.5013D-02	-2.5828D-02	-1.6252D-05	-9.1897D-03
8	580.96	5.23782D 01	4.53462D 04	694.64	1.51229D 02	-3.0716D-06	-9.6670D-03	0.0	4.1473D-02	-3.1809D-02
9	580.97	3.57629D 01	3.08052D 04	688.81	1.51237D 02	2.3205D-03	4.6068D-02	4.0489D-03	8.1453D-05	-4.7878D-02
10	580.92	3.27101D 01	2.79762D 04	680.68	1.51250D 02	-2.1898D-06	3.7333D-02	3.7032D-03	1.1162D-04	-4.1150D-02
11	580.88	3.20239D 01	2.72656D 04	675.53	1.51263D 02	-2.1313D-06	3.7373D-02	3.6256D-03	6.9283D-05	-4.1070D-02
12	580.85	3.81259D 01	3.22448D 04	667.97	1.51278D 02	-1.9162D-06	2.6270D-02	4.0267D-03	3.9512D-03	-3.4250D-02
13	580.82	3.85638D 01	3.22398D 04	654.99	1.51292D 02	-1.9295D-06	2.7523D-02	4.0730D-03	1.3799D-04	-3.1736D-02
14	580.79	3.64125D 01	2.98012D 04	631.55	1.51301D 02	-1.6616D-06	2.3817D-02	3.8457D-03	2.5230D-04	-2.7916D-02
15	580.77	3.37171D 01	2.65589D 04	590.58	1.51307D 02	-1.4282D-06	2.2602D-02	3.5611D-03	4.4336D-04	-2.6608D-02
16	580.74	3.61392D 01	2.65381D 04	519.42	1.51315D 02	7.8560D-03	2.8852D-02	3.8169D-03	7.7063D-04	-2.5584D-02

TUBES

NODE	ASSOC. HELIUM NODE	HELIUM HEAT FLUX BTU/HR-FT2	HELIUM TRAN. COEF. BTU/HR-FT2-F	HELIUM 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	DNB FLUX BTU/HR-FT2
1	4	3.09559D 03	1.66101D 02	676.42	674.41	671.54	5.45959D 01	4.88051D 03	7	4.74967D 04	0.0
2	3	2.02103D 03	1.66145D 02	684.27	682.96	680.78	5.52690D 01	3.72652D 03	7	4.75066D 04	0.0
3	2	1.20436D 03	1.66175D 02	690.08	689.30	687.63	5.57903D 01	2.85821D 03	7	4.75165D 04	0.0
4	1	5.84352D 02	1.66184D 02	694.40	694.03	692.74	5.61735D 01	2.20344D 03	7	4.75262D 04	0.0
5	1	1.50509D 02	1.66184D 02	697.01	696.92	695.89	5.64269D 01	1.75881D 03	7	4.75357D 04	0.0
6	2	-1.59282D 02	1.66175D 02	698.28	698.38	697.56	5.66068D 01	1.41771D 03	7	4.75449D 04	0.0
7	3	-4.32158D 02	1.66145D 02	699.03	699.31	698.69	5.67621D 01	1.07493D 03	7	4.75541D 04	0.0
8	4	-6.40378D 02	1.66101D 02	698.91	699.32	698.86	5.68870D 01	7.96730D 02	7	4.75633D 04	0.0
9	16	1.87329D 04	1.48636D 02	393.38	387.64	380.94	8.76472D 02	2.49880D 04	1	3.20844D 05	1.68699D 06
10	15	1.06741D 04	1.50702D 02	519.75	516.48	512.50	9.90604D 02	1.48113D 04	1	3.18048D 05	1.16865D 06
11	14	5.58743D 03	1.51843D 02	594.76	593.04	590.83	1.02924D 03	8.24058D 03	1	3.13087D 05	8.24823D 05
12	13	2.81778D 03	1.52429D 02	636.51	635.53	634.15	1.13645D 03	4.58755D 03	1	3.33669D 05	6.22340D 05
13	12	1.59395D 03	1.52812D 02	657.54	656.98	656.19	1.17530D 03	2.64061D 03	1	3.28872D 05	4.81777D 05
14	11	1.03734D 03	1.61425D 02	669.10	668.62	667.86	1.11593D 03	1.95664D 03	1	2.91346D 05	3.69428D 05
15	10	8.05687D 02	1.61556D 02	675.69	675.14	674.16	1.74673D 03	1.90831D 03	1	4.38555D 05	3.92466D 05
16	9	1.88414D 03	1.61760D 02	677.16	676.07	674.62	6.18260D 03	3.19837D 03	2	3.26725D 05	2.57239D 05

REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS

	***** REHEATER *****				***** STEAM GENERATOR *****			
	INLET		OUTLET		INLET		OUTLET	
	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM
PRESSURE	5.0109D 01	5.8131D 02	4.9486D 01	5.8108D 02	2.7372D 03	5.8096D 02	2.6028D 03	5.8073D 02
TEMPERATURE	5.5928D 02	6.9816D 02	6.8687D 02	6.9425D 02	2.6017D 02	6.9464D 02	6.7406D 02	4.7408D 02
ENTHALPY	1.3092D 03	1.4473D 03	1.3777D 03	1.4424D 03	2.3460D 02	1.4429D 03	7.8438D 02	1.1683D 03
SPEC. VOL.	1.1819D 01	5.3807D 00	1.3679D 01	5.3648D 00	1.6917D-02	5.3677D 00	4.0141D-02	4.3533D 00
FLOW RATE	1.2707D-01	1.5120D 02	1.2728D-01	1.5121D 02	2.8610D-01	1.5123D 02	2.4463D-01	1.5132D 02

********** 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	3.73090D-03	4.46289D 00	547.49	1.14	1.11776D-01	-2.0755D-05	1.9178D-01	-6.5466D-04	1.1458D-02	-2.0261D-01
2	46.85	3.60029D-03	4.34963D 00	576.22	1.16	1.11780D-01	-2.2025D-05	2.2391D-01	-6.3174D-04	-1.3192D-02	-2.1010D-01
3	46.63	3.50016D-03	4.26063D 00	597.34	1.17	1.11783D-01	-2.2436D-05	2.2783D-01	-6.1417D-04	-1.0786D-02	-2.1645D-01
4	46.40	3.42221D-03	4.18983D 00	613.00	1.18	1.11787D-01	-6.6985D-05	8.1542D-01	-6.0049D-04	-8.8392D-03	-8.0604D-01
5	45.58	3.31977D-03	4.08062D 00	631.53	1.19	1.11790D-01	-3.3846D-05	8.3670D-01	5.8252D-04	-1.2237D-02	-8.2508D-01
6	44.75	3.23476D-03	3.98499D 00	646.61	1.19	1.11793D-01	-2.0260D-05	2.3611D-01	5.6760D-04	-1.0744D-02	-2.2555D-01
7	44.51	3.20580D-03	3.95384D 00	652.95	1.20	1.11795D-01	-2.0621D-05	2.2948D-01	5.6252D-04	-3.8030D-03	-2.2626D-01
8	44.28	3.18322D-03	3.92825D 00	656.76	1.20	1.11798D-01	1.3024D-03	2.2668D-01	5.5856D-04	-3.0168D-03	-2.2292D-01
9	2617.94	6.96654D 00	2.07727D 03	331.28	-1.32	2.85754D-01	5.2770D-03	5.8209D 00	-9.9101D-01	-1.2146D-03	-4.8234D 00
10	2612.12	6.33321D 00	2.76829D 03	463.39	-0.90	2.84709D-01	7.2343D-04	1.2930D 00	-9.0092D-01	-2.7815D-03	-3.8860D-01
11	2610.82	6.49481D 00	3.45861D 03	546.72	-0.61	2.82567D-01	1.6300D-02	1.3662D 00	-9.2393D-01	-2.5515D-03	-4.2343D-01
12	2609.46	5.97421D 00	3.58485D 03	599.57	-0.40	2.79798D-01	-9.3991D-03	1.4461D 00	-9.2055D-01	-8.8513D-03	-5.2610D-01
13	2608.01	5.58124D 00	3.60133D 03	630.64	-0.26	2.76471D-01	-3.5752D-02	1.3757D 00	-8.6000D-01	-2.0037D-03	-5.4949D-01
14	2606.64	4.91560D 00	3.31381D 03	648.14	-0.17	2.72839D-01	-3.1132D-02	1.0529D 00	-7.4039D-01	8.1080D-03	-3.5173D-01
15	2605.58	3.21070D 00	2.22062D 03	657.57	-0.12	2.69976D-01	3.8932D-02	1.9731D 00	-7.3330D-01	-5.1039D-02	-1.1499D 00
16	2603.61	4.29676D 00	3.01292D 03	662.15	-0.09	2.64963D-01	1.3844D-02	1.5550D 00	-7.9060D-01	3.2309D-02	-7.8287D-01

********** HELIUM SIDE **********

NODE	PRESSURE PSIA	TOTAL MASS LBM	INTERNAL ENERGY BTU	TEMP. DEG. F	MASS FLOW RATE LBM/SEC	PRESSURE DROP - PSI INERTIA	PRESSURE	STATIC HEAD	MOMENTUM	FRICTION
1	560.68	1.09137D 01	9.13741D 03	656.64	1.44495D 02	2.0162D-06	2.3742D-02	1.5202D-03	8.8829D-07	-2.5261D-02
2	560.66	1.09188D 01	9.13698D 03	656.06	1.44495D 02	2.0098D-06	2.3779D-02	1.5209D-03	1.3151D-05	-2.5311D-02
3	560.63	1.09251D 01	9.13655D 03	655.37	1.44496D 02	2.0082D-06	2.3761D-02	1.5218D-03	1.6311D-05	-2.5297D-02
4	560.61	1.09351D 01	9.13608D 03	654.28	1.44496D 02	2.0024D-06	2.7975D-02	1.5232D-03	2.6021D-05	-2.9522D-02
5	560.58	3.13490D 01	2.61764D 04	653.65	1.44497D 02	-4.6780D-03	4.3955D-02	0.0	-2.4469D-02	-2.4164D-02
6	560.54	7.95233D 01	6.64037D 04	653.67	1.44501D 02	4.3874D-05	3.4093D-02	-2.5830D-02	-7.8826D-06	-8.2121D-03
7	560.50	7.95107D 01	6.63998D 04	653.78	1.44504D 02	4.3951D-05	3.4272D-02	-2.5826D-02	-1.0794D-05	-8.3920D-03
8	560.47	5.23743D 01	4.37446D 04	653.95	1.44506D 02	6.2548D-06	-8.6284D-03	0.0	3.7765D-02	-2.9130D-02
9	560.48	3.55004D 01	2.97192D 04	656.51	1.44509D 02	-4.6294D-03	3.5598D-02	4.0192D-03	-3.4720D-05	-4.4212D-02
10	560.44	3.21705D 01	2.69926D 04	659.04	1.44513D 02	3.4121D-06	3.4785D-02	3.6421D-03	-3.5890D-05	-3.8388D-02
11	560.41	3.14230D 01	2.63077D 04	656.59	1.44517D 02	3.0897D-06	3.4821D-02	3.5576D-03	3.1079D-05	-3.8407D-02
12	560.37	3.74420D 01	3.11118D 04	648.22	1.44523D 02	2.9205D-06	2.4358D-02	3.9545D-03	3.6866D-03	-3.1996D-02
13	560.35	3.80126D 01	3.11060D 04	631.39	1.44530D 02	2.9244D-06	2.5340D-02	4.0148D-03	1.7131D-04	-2.9523D-02
14	560.32	3.60870D 01	2.87517D 04	602.62	1.44535D 02	2.7370D-06	2.1710D-02	3.8114D-03	2.9392D-04	-2.5813D-02
15	560.30	3.35712D 01	2.56225D 04	557.95	1.44542D 02	2.4037D-06	2.0477D-02	3.5457D-03	4.5721D-04	-2.4477D-02
16	560.28	3.60230D 01	2.56022D 04	487.93	1.44552D 02	5.1540D-03	2.4128D-02	3.8046D-03	7.1696D-04	-2.3495D-02

********** TUBES **********

NODE	ASSOC. HELIUM NODE	HELIUM HEAT FLUX BTU/HR-FT2	HELIUM TRAN. COEF. BTU/HR-FT2-F	HELIUM 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	DNB FLUX BTU/HR-FT2
1	4	2.61029D 03	1.60054D 02	637.97	636.24	633.73	4.85087D 01	4.18350D 03	7	4.17710D 04	0.0
2	3	1.76334D 03	1.60101D 02	644.35	643.19	641.28	4.90590D 01	3.19144D 03	7	4.17724D 04	0.0
3	2	1.12473D 03	1.60102D 02	649.04	648.30	646.84	4.94719D 01	2.44875D 03	7	4.17736D 04	0.0
4	1	6.44976D 02	1.60138D 02	652.61	652.19	651.06	4.97860D 01	1.89460D 03	7	4.17749D 04	0.0
5	1	1.88664D 02	1.60138D 02	655.46	655.34	654.65	5.01740D 01	1.15967D 03	7	4.17761D 04	0.0
6	2	-3.31938D 02	1.60102D 02	658.14	658.36	658.01	5.04611D 01	5.75478D 02	7	4.17771D 04	0.0
7	3	-5.83483D 02	1.60101D 02	659.01	659.39	659.21	5.05950D 01	3.16542D 02	7	4.17781D 04	0.0
8	4	-7.56631D 02	1.60054D 02	659.01	659.51	659.43	5.06558D 01	1.35195D 02	7	4.17790D 04	0.0
9	16	1.70504D 04	1.43089D 02	368.77	363.55	357.53	8.54149D 02	2.24260D 04	1	3.21447D 05	1.75894D 06
10	15	1.05747D 04	1.45061D 02	485.05	481.81	477.99	9.73083D 02	1.42158D 04	1	3.20272D 05	1.29711D 06
11	14	6.29314D 03	1.46276D 02	559.60	557.67	555.32	1.01982D 03	8.76521D 03	1	3.17862D 05	9.78286D 05
12	13	3.54508D 03	1.47084D 02	607.28	606.05	604.42	1.12300D 03	5.44612D 03	1	3.40930D 05	7.78580D 05
13	12	1.93548D 03	1.47455D 02	635.09	634.42	633.46	1.14551D 03	3.22284D 03	1	3.36876D 05	6.21203D 05
14	11	8.46717D 02	1.55990D 02	651.17	650.77	650.01	1.05820D 03	1.97850D 03	1	2.98290D 05	4.92278D 05
15	10	1.08595D 01	1.56035D 02	658.97	658.97	658.34	1.57292D 03	1.21574D 03	1	4.47550D 05	5.33388D 05
16	9	-7.80020D 02	1.55898D 02	661.51	661.96	662.03	1.29859D 03	-1.52231D 02	1	3.53875D 05	4.42355D 05

********** REHEATER AND STEAM GENERATOR INLET AND OUTLET CONDITIONS **********

	***** REHEATER *****				***** STEAM GENERATOR *****			
	INLET		OUTLET		INLET		OUTLET	
	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM	WATER	HELIUM
PRESSURE	4.4701D 01	5.6081D 02	4.4168D 01	5.6058D 02	2.7360D 03	5.6047D 02	2.6028D 03	5.6027D 02
TEMPERATURE	5.2548D 02	6.5693D 02	6.5656D 02	6.5365D 02	2.4828D 02	6.5395D 02	6.6368D 02	4.4473D 02
ENTHALPY	1.2962D 03	1.3958D 03	1.3543D 03	1.3917D 03	2.2270D 02	1.3921D 03	7.1793D 02	1.1315D 03
SPEC. VOL.	1.2886D 01	5.3791D 00	1.4669D 01	5.3656D 00	1.6825D-02	5.3681D 00	2.7572D-02	4.3705D 00
FLOW RATE	1.1177D-01	1.4449D 02	1.1180D-01	1.4450D 02	2.8610D-01	1.4451D 02	2.6496D-01	1.4455D 02

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