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CESEC

DIGITAL SIMULATION OF A COMBUSTION ENGINEERING NUCLEAR STEAM SUPPLY SYSTEM

PLANT SYSTEMS ANALYSIS

DECEMBER, 1981

POWER SYSTEMS
COMBUSTION ENGINEERING, INC

LEGAL NOTICE

C E S E C

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ABSTRACT

This document describes the latest C-E version of the CESEC (Combustion Engineering Systems Excursion Code) computer program. CESEC provides a digital simulation of the Nuclear Steam Supply System (NSSS) for a wide range of operating conditions. The code is a highly flexible analytical tool which models the major plant components for both the primary and secondary systems, as well as the control and plant protection systems. CESEC is used by C-E in NSSS and reload licensing analyses, to provide analytical support to the plant start-up tests, and in support of the development of plant emergency procedure guidelines and training packages.

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1.0 INTRODUCTION

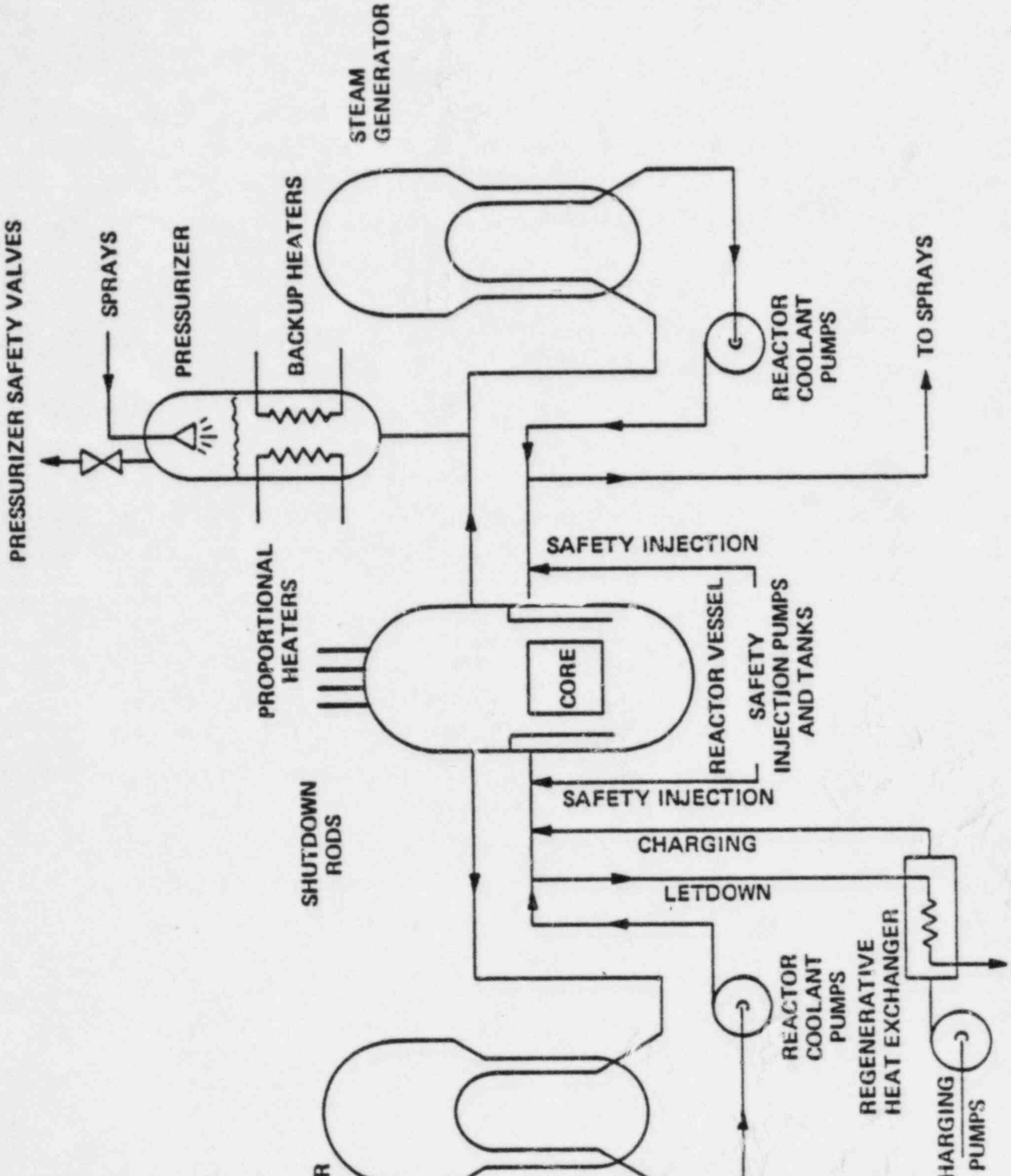
The CESEC digital computer program (References 1 through 8) provides for the simulation of a Combustion Engineering Nuclear Steam Supply System (NSSS). The program calculates the plant response for non-LOCA (loss of coolant accident) initiating events for a wide range of operating conditions. The information presented in this report revises information given in References 1 through 8.

The CESEC program, which numerically integrates the one-dimensional conservation equations, assumes a node/flow-path network to model the NSSS. The primary system components considered in the code include the reactor vessel, the reactor core, the primary coolant loops, the pressurizer, the steam generators, and the reactor coolant pumps (see Figure 1-1). The secondary system components, shown on Figure 1-2, include the secondary side of the steam generators, the main steam system, the feedwater system, and the various steam control valves. In addition, the program models some of the control and plant protection systems.

The code self-initializes for any given, but consistent, set of reactor power level, reactor coolant flow rate, and steam generator power sharing. During the transient calculation, the time rate of change in system pressure and enthalpy are obtained from the solution of the conservation equations. These derivatives are then numerically integrated in time, under the assumption of thermal equilibrium, to give the system pressure and nodal enthalpies. The fluid states recognized by the code are subcooled and saturated; superheating is allowed in the pressurizer. The fluid in the reactor coolant system is assumed to be homogeneous.

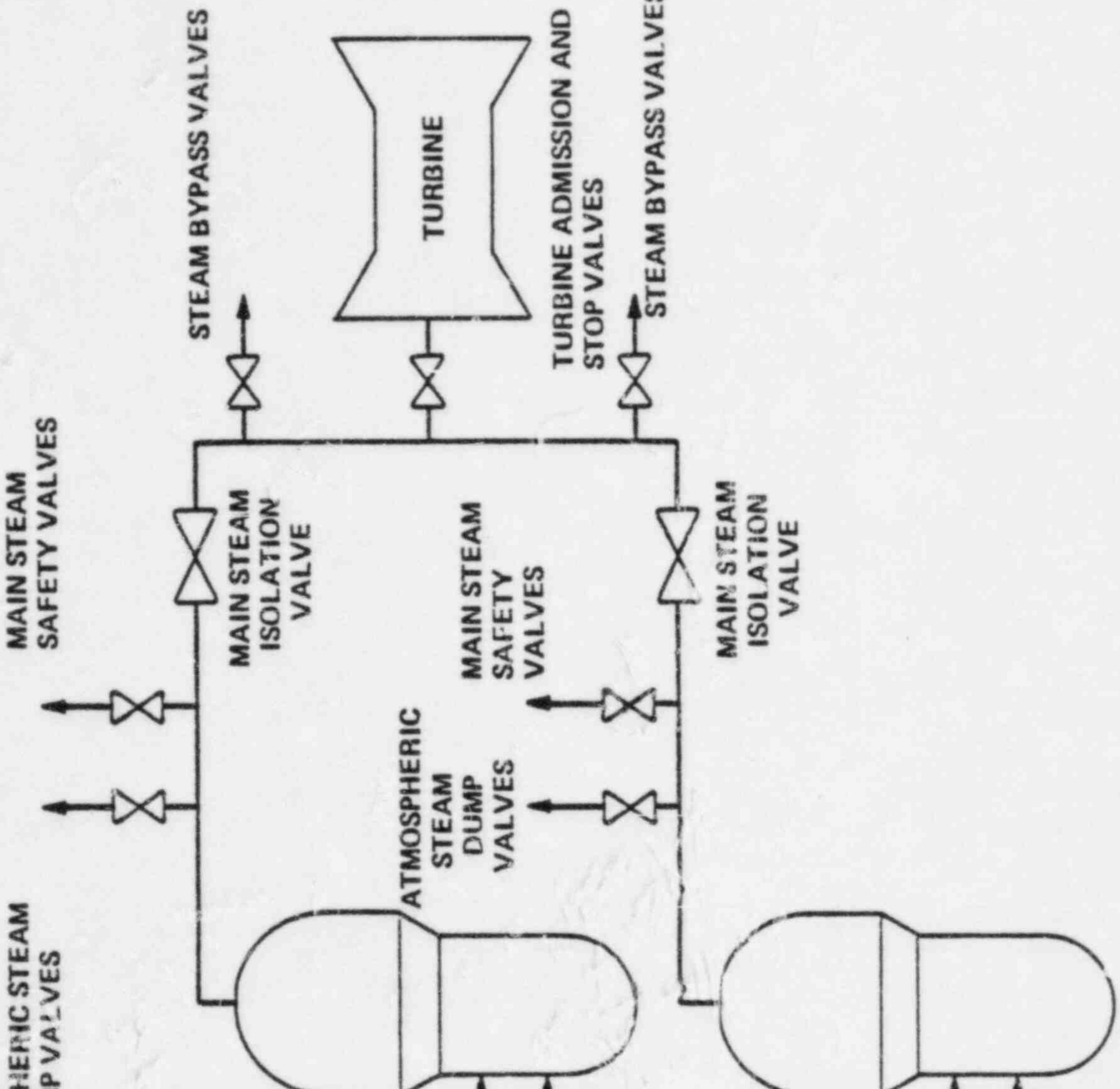
In the sections which follow, a description of the major models which comprise the latest version of the CESEC code, namely CESEC-III and hereafter referred to as CESEC, is given.

The input, output, and plot package descriptions are provided, respectively, in Appendices J, K, and L.



THE PRIMARY SYSTEM
AND CVCS COMPONENTS

Figure 1-1



THE SECONDARY SYSTEM COMPONENTS

Figure 1-2

2.0 RCS THERMALHYDRAULICS

The CESEC code uses a node/flow-path type network to model the Reactor Coolant System (RCS). The conservation of mass and energy equations are solved for control volumes or nodes. The conservation of momentum equation is solved independant of the conservation of mass and energy equations to obtain the pump flows for the thermalhydraulic model (see Section 3.0 on Flow Model).

The RCS, consisting of the reactor coolant loops, the reactor vessel, and the pressurizer is divided into 26 nodes of constant volume. The nodal scheme given in Figures 2-1A and 2-1B was chosen to appropriately simulate the RCS component volumes and, thus, provide an adequate description of the spatial variation of the coolant properties. Node 26, which is the pressurizer node, is subdivided into a steam and a liquid region having variable volumes. The fluid in nodes 1 through 25 is assumed to be homogeneous and in thermal equilibrium. Each reactor vessel channel represents one half of the inlet downcomer section, the lower plenum and inactive core region, the core region and bypass flow, and the upper plenum and inactive core region. The two symmetrical channels are linked by the cross flow at the reactor vessel inlet and outlet sections and by the flow mixing within the reactor vessel lower plenum, upper plenum, and closure or upper head. The nodal scheme for the reactor vessel allows for the effect of a temperature tilt in the reactor core to be explicitly accounted for during a steam line break event and other non-symmetric events.

During the rapid contraction of the primary coolant which takes place as a result of the limiting depressurization events, the pressurizer empties and/orvoids begin to form in the RCS. Since flow through the closure head is only a small fraction of the RCS flow, the temperatures in the closure head remain high and voiding first occurs there. To some extent, the closure head itself then begins to perform the function of a pressurizer. Therefore, the reactor vessel closure head region is explicitly modeled in CESEC to more accurately predict the RCS pressure. The coolant flow from the upper plenum nodes (upstream half) to the vessel head node is specified by user input fractions. The vessel head fluid returning into the outlet plenum nodes (downstream half) is assumed to be evenly distributed. The mixing flows* $W_{2,15}$, $W_{14,3}$, $W_{6,19}$, and $W_{18,7}$, are calculated using constant, experimentally determined mixing parameters, F_I and F_O, defined such that:

$$W_{2,15} = F_I \, W_{2,3}$$

$$W_{14,3} = F_I \, W_{14,15}$$

$$W_{6,19} = F_O \, W_{6,7}$$

and

$$W_{18,7} = F_O \, W_{18,19}$$

where $W_{2,3}$, $W_{14,15}$, $W_{6,7}$, and $W_{18,19}$ are found from the solution of the time dependent conservation of mass and energy equations.

The CESEC code thermalhydraulic model solves the conservation of mass and energy equations coupled with the equation of state for each control volume or node. The solution assumes that the volume of each node is constant (see Figure 2-2). The system of equations is solved by a matrix solution for the internodal flows, the pressurizer pressure time derivative, the rate of vaporization or water enthalpy time derivative of the pressurizer water region, and the rate of condensation or steam enthalpy time derivative of the pressurizer steam region. Computation of these parameters allows for the calculation of the RCS pressure time derivative, the time derivatives of the nodal enthalpies, the nodal specific volumes, and the nodal masses. The integral values of the time derivatives are obtained by using a forward (explicit) finite difference scheme. The flow model described in Section 3.0 is applied to determine the mass flow rate through each reactor coolant pump. A major assumption of the thermalhydraulic model in CESEC is that the pressure around the reactor coolant loops and vessel is assumed to be uniform.

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*The notation $W_{i,j}$ is used to denote the flow from the ith to the jth node.

The basic differential equation governing mass and energy conservation for each RCS node, i, can be written as follows (see Appendix B):

$$b_i\,(\Sigma W_{int})_i + \alpha_i(\Sigma h W_{int})_i + d_i \dot{P} = e_i \tag{2-1}$$

where $b_i = v_i - h_i \left.\frac{\partial v_i}{\partial h}\right|_P$

$\alpha_i = \left.\frac{\partial v_i}{\partial h}\right|_P$

$d_i = V_i \left.\frac{\partial v_i}{\partial h}\right|_P + m_i \left.\frac{\partial v_i}{\partial P}\right|_h$

$e_i = -Q_i \left.\frac{\partial v_i}{\partial h}\right|_P - b_i\,(\Sigma W_{ext})_i - \alpha_i\,(\Sigma h W_{ext})_i$

i = 1,..., 25 RCS nodes as defined in Figure 2-1 (Excludes Pressurizer)

V_i = node volume, ft^3

h_i = node specific enthalpy, BTU/lbm

P = RCS pressure, psia

v_i = node specific volume, ft^3/lbm

m_i = node mass, lbm

Q_i = net heat rate into ith node, BTU/sec (see Section 9.0 for wall heat addition, Section 10.0 for core heat addition, and Section 13.0 for steam generator heat load computation)

$(\Sigma W_{int})_i$ = net mass flow rate (lbm/sec) into ith node due to flows from all connected nodes.

$(\Sigma W_{ext})_i$ = net mass flow rate (lbm/sec) into ith node due to external flows.

$(\Sigma h W_{int})_i$ = net energy transport rate (BTU/sec) into ith node due to flows from connected nodes.

$(\Sigma h W_{ext})_i$ = net energy transport rate (BTU/sec) into ith node due to external flows.

For the pressurizer node (i=26), the governing equations depend on the state of the pressurizer. The CESEC pressurizer model (see Figure 6-1) assumes steam and liquid regions to exist in one of the following eight thermalhydraulic states:

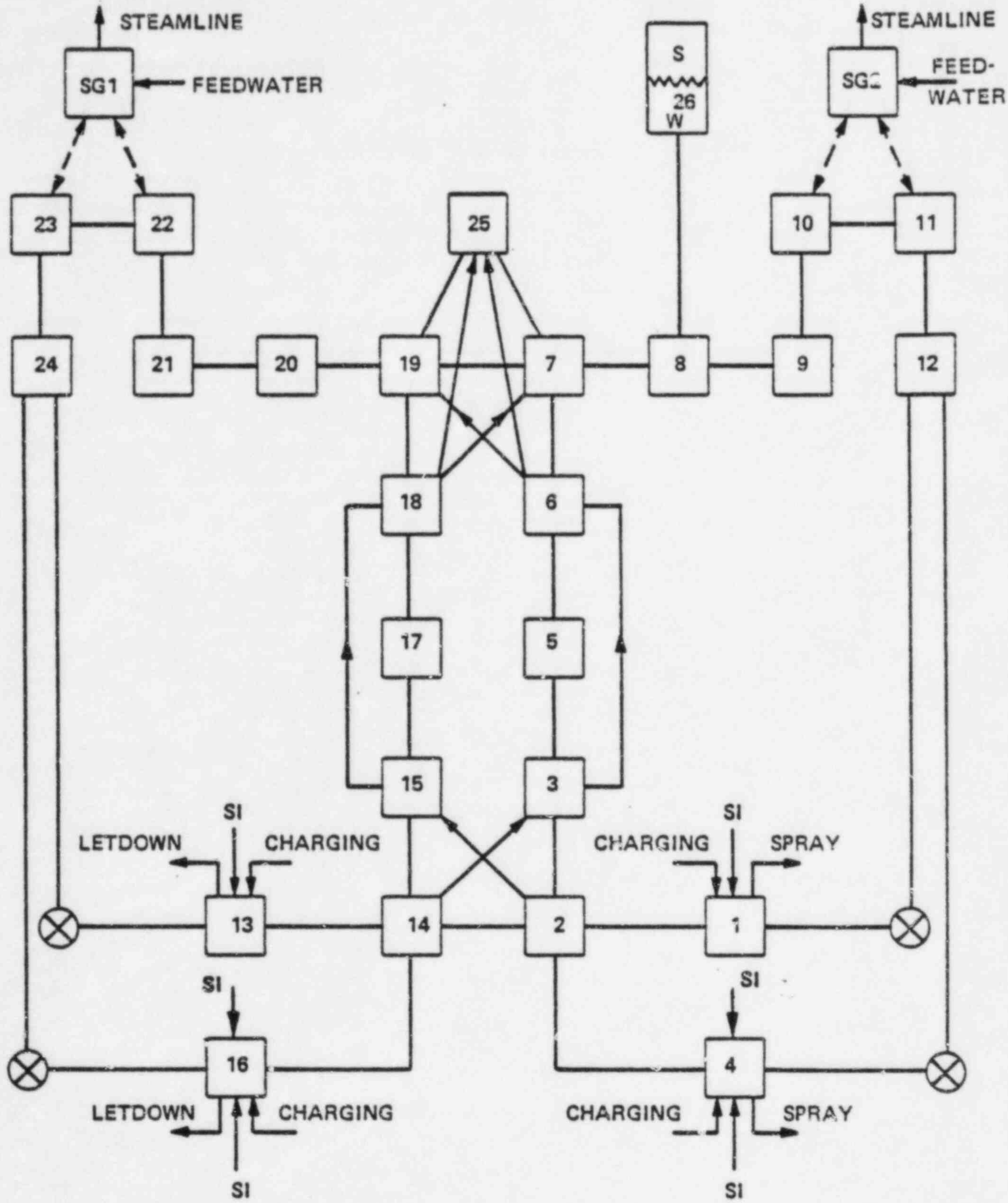
State 1: superheated steam, subcooled water
State 2: superheated steam, saturated water
State 3: saturated steam, subcooled water
State 4: saturated steam, saturated water
State 5: superheated steam, no water
State 6: saturated steam, no water
State 7: subcooled water, no steam
State 8: saturated water, no steam

The equations for each of these states are derived in Appendix B.

At each time step, the coefficients of the system of equations are calculated in CESEC by evaluating the fluid property derivatives as specified in Section 8.0. The updated values for the fluid property derivatives are then entered into the coefficient matrix in order to simultaneously solve the resultant matrix equation for the unknown parameters. There are 29 equations with 29 unknowns for the case that the pressurizer contains steam and liquid regions. For the case that only one phase exists in the pressurizer, the number of equations and unknowns is reduced to 28. A constraint in the calculational model is that the axial pressure drop for the two parallel halves of the reactor core is assumed to be equal. That is (see Figure 2-1A),

$$W^2_{3,5} v_3 = W^2_{15,17} v_{15} \qquad (2\text{-}2)$$

The constraint provided by Equation 2-2 is necessary in order to match the number of unknowns with the number of equations to be solved (see Appendix B).



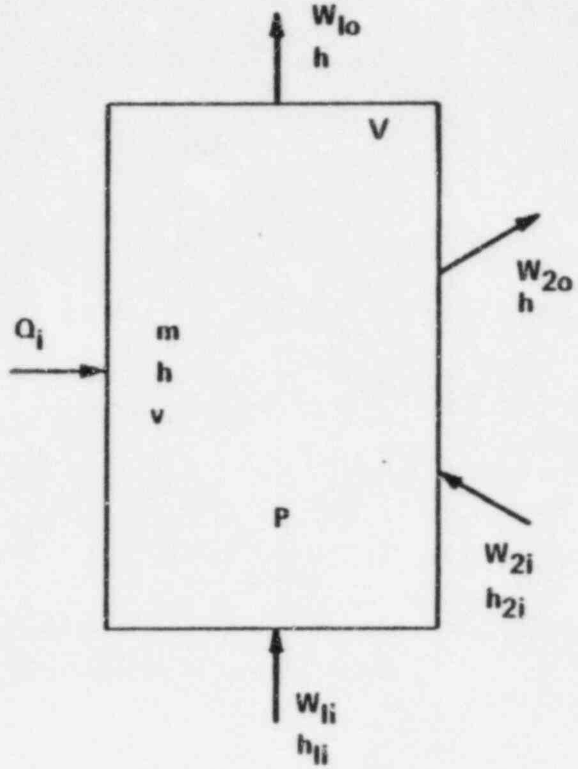
CESEC NODAL SCHEME

Figure 2-1A

NODE	PHYSICAL DESCRIPTION
1	COLD LEG A
2	UPSTREAM HALF OF INLET PLENUM (BEFORE FLOW MIXING)
3	DOWNSTREAM OF INLET PLENUM (AFTER FLOW MIXING)
4	COLD LEG B
5	CORE
6	UPSTREAM HALF OF OUTLET PLENUM
7	DOWNSTREAM HALF OF OUTLET PLENUM
8	HOT LEG
9	STEAM GENERATOR INLET PLENUM
10	UPSTREAM HALF OF STEAM GENERATOR TUBES
11	DOWNSTREAM HALF OF STEAM GENERATOR TUBES
12	STEAM GENERATOR OUTLET PLENUM
13	SAME AS 1 IN OTHER STEAM GENERATOR LOOP
14	SAME AS 2 IN OTHER STEAM GENERATOR LOOP
15	SAME AS 3 IN OTHER STEAM GENERATOR LOOP
16	SAME AS 4 IN OTHER STEAM GENERATOR LOOP
17	SAME AS 5 IN OTHER STEAM GENERATOR LOOP
18	SAME AS 6 IN OTHER STEAM GENERATOR LOOP
19	SAME AS 7 IN OTHER STEAM GENERATOR LOOP
20	SAME AS 8 IN OTHER STEAM GENERATOR LOOP
21	SAME AS 9 IN OTHER STEAM GENERATOR LOOP
22	SAME AS 10 IN OTHER STEAM GENERATOR LOOP
23	SAME AS 11 IN OTHER STEAM GENERATOR LOOP
24	SAME AS 12 IN OTHER STEAM GENERATOR LOOP
25	REACTOR VESSEL CLOSURE HEAD
26	PRESSURIZER

FIGURE 2-1B

PHYSICAL DESCRIPTION OF NODES



ENERGY EQUATION

$$\frac{d}{dt}(m\,h) - V\frac{dP}{dt} = Q + \sum_j W_{ji}\,h_{ji} - \sum_j W_{jo}\,h$$

MASS BALANCE

$$\frac{dm}{dt} = \sum_j W_{ji} - \sum_j W_{jo}$$

CONSTANT VOLUME

$$\frac{d\,(m\,v)}{dt} = 0.0$$

m = NODE TOTAL MASS
h = NODE AVERAGE ENTHALPY
V = NODE TOTAL VOLUME
v = NODE SPECIFIC VOLUME
Q = NODE HEAT RATE
W_{ji} = NODE INLET FLOWS, i DENOTES INLET
W_{jo} = NODE EXIT FLOWS, o DENOTES EXIT
h_{ji} = NODE INLET FLOW ENTHALPIES
P = COOLANT PRESSURE

GENERAL COOLANT NODE EQUATIONS

Figure 2-2

3.0 FLOW MODEL

The CESEC flow model calculates the mass flow rate (lbm/sec) through each reactor coolant pump. The model includes explicit simulations of the reactor coolant pumps and of the effects of natural circulation flow. The calculation is based on a solution of the one-dimensional momentum equation for each pump loop. Each pump loop (4 in all) also considers the reactor vessel, a hot leg, and a steam generator (SG). The loops are divided into a number of nodes (Figure 3-1) whose densities, temperatures, and flows are obtained from the thermalhydraulic model (The average of the properties and the total flows from parallel nodes are used for nodes representing the reactor vessel). The flow model utilizes this nodalization of the loop to calculate the sum of the various forces around the loop. The forces acting on the fluid volume consist of (1) gravitational forces due to density and elevation changes around the loop, (2) viscous forces due to wall friction and geometric expansions and contractions of the piping, and (3) forces due to the RCS pumps. The one-dimensional momentum equation for each closed loop is written as follows:

$$\frac{dW}{dt} = \frac{g\sum_{i=1}^{n} \rho_i Z_i - \sum_{i=1}^{n} W_i^2 \left[\frac{\phi_i f_i R_{fric,i}}{\rho_{is}} + \frac{R_{geo,i}}{\rho_{in}}\right] + \Delta P_{pump}}{\sum_{i=1}^{n} (L_i/A_i)} \qquad (3\text{-}1)$$

where,

W = mass flow rate at the pump, lbm/sec

W_i = mass flow rate of ith node, lbm/sec

ρ_{in} = average fluid density of ith node, lbm/ft^3

ρ_{is} = single-phase fluid density of ith node, lbm/ft^3

Z_i = $Z_{in,i} - Z_{out,i}$ = the elevation difference across the ith node, ft

ϕ = Two-phase multiplier for the ith node (Thom, $P \geq 250$ psia; Martinelli-Nelson, $P < 250$ psia)

f_i = Darcy friction factor for the ith node

L_i = effective flow path length for the ith node, ft

A_i = effective cross sectional flow area of ith node, ft^2

$$R_{fric,i} = \frac{L_i/D_{e,i}}{2A_i^2}$$

$$R_{geo,i} = \frac{K_{g,i}}{2A_i^2}$$

$D_{e,i}$ = effective diameter of ith node

$K_{g,i}$ = dimensionless geometric proportionality constant

The first term on the right hand side of Equation 3-1 represents the net pressure change around the loop due to the gravitational force acting on each fluid node. The second term represents the total pressure change around the loop due to the frictional loss and the geometric expansions and contractions. The R factors in the equation are constants and are determined by the initial conditions. The form loss K-factor is flow direction dependent, that is, steady state (design) values are input for forward and reverse flow conditions.

The homogeneous model is assumed in the calculation of the form losses. In the homogeneous model, a mixed mean value is employed for the fluid density to determine the form losses in a two-phase mixture.

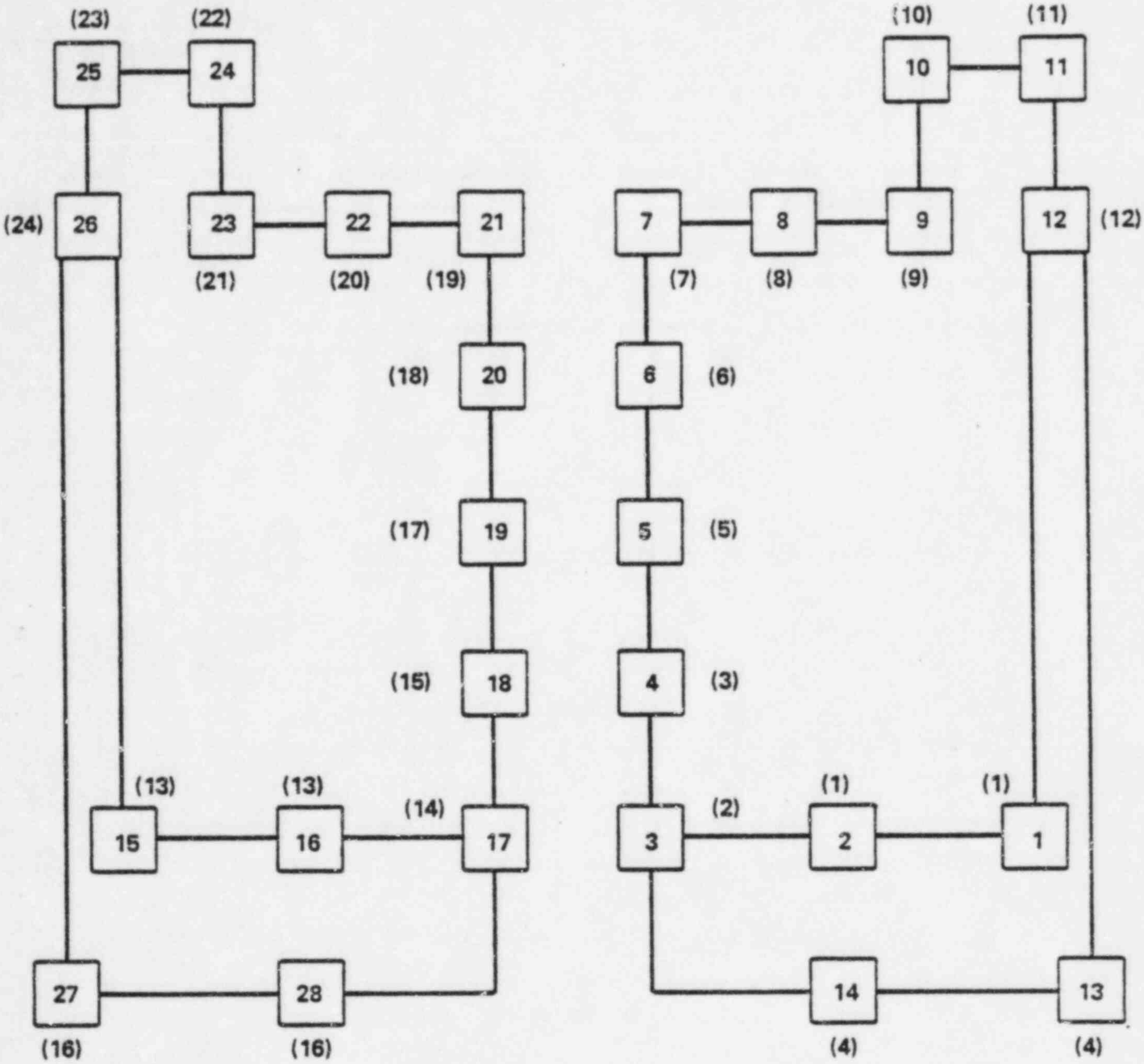
The non-recoverable frictional losses are based on an isothermal friction factor which is Reynolds number, Re, dependent. The Darcy friction factor, f, is determined by the following correlations:

$f = 64/Re$	$Re < 1250$
$f = (-0.000004)Re+0.056$	$1250 \leq Re < 6000$
$f = 0.184/Re^{0.2}$	$Re \geq 6000$

The friction factor is evaluated assuming saturated water is flowing at the mixture mass flow rate when vapor is present.

The single phase frictional pressure drop calculation is based on the flow path liquid density and the Reynolds number dependent friction factor. The code uses a combination of the Thom (References 9 and 10) and Martinelli-Nelson (References 10, 11, 12, 13, 14, and 15) two-phase pressure drop correlations for predicting the frictional losses in two-phase flow. The Thom correlation is used down to pressures of 250 psia at which pressure the code then switches to calculate the two-phase multipliers based on the Martinelli-Nelson correlation. The transition from the Thom correlation to the Martinelli-Nelson correlation is made by a step-wise change. The Martinelli-Nelson correlation as programmed in the CESEC code is corrected for mass flow dependency, while the Thom correlation is not (see Appendix C).

The third term in Equation 3-1 represents the pressure difference ΔP_{pump}, across the RCS pump, which is calculated by the dynamic pump model described in Section 4.0.



(1) NUMBER INSIDE THE PARENTHESIS REFERS TO THE CORRESPONDING THERMAL-HYDRAULIC NODE WHOSE PROPERTIES ARE USED IN THE CALCULATION

(2) THE AVERAGE OF THE PROPERTIES AND THE TOTAL FLOWS FROM PARALLEL NODES ARE USED FOR NODES REPRESENTING THE REACTOR VESSEL

(3) FOR NODES OTHER THAN THE REACTOR VESSEL AND THE REACTOR COOLANT PUMPS (1,13,15,27),THE AVERAGE OF THE UPSTREAM FLOW AND THE DOWNSTREAM FLOW IS USED

CESEC FLOW MODEL
NODAL SCHEME

Figure 3-1

4.0 RCS PUMPS

The reactor coolant pump algorithm is based on the homologous relationships between pumps of similar specific speeds and uses single-phase plant test data as its foundation. The fundamental equation of the model is an angular momentum balance applied to the pump/motor/flywheel assembly.

The homologous pump model in CESEC allows calculation of the pressure difference or pump head across each pump for use in the conservation of momentum equation, the pump speed, and the electrical, friction/windage, and hydraulic torques. Single-phase and degraded two-phase pump performance curves based on experimental data are used in conjunction with a two-phase degradation multiplier to generate a degradation function which is applied to the pump head equation. The algorithm models the following modes of operation: positive flow, positive rotation (normal operation); reverse flow, positive rotation (energy dissipation); reverse flow, reverse rotation (turbine operation); and positive flow, reverse rotation (reverse pump operation).

The pump head calculated from the homologous curves, which is a function of the pump speed, the volumetric flow, and the flow direction, is used to determine the time rate of change of the mass flow rate in each of the four pump loops. The hydraulic torque is also determined from the homologous curves and is a function of the pump speed, volumetric flow, flow direction, and fluid density. The hydraulic torque is used in conjunction with the electrical and friction/windage torques to determine the time rate of change in pump speed from an angular momentum balance. The electrical torque versus pump speed is a user input table in CESEC. The table is used to determine the electrical torque for a given speed using linear interpolation. The friction/windage torque is assumed to be proportional to the square of the ratio of the pump speed to the rated pump speed ($\alpha|\alpha|$).

CESEC options include capability for the user to cycle each RCP on and off at selected times during an event. Additionally, there is a loss of AC option. If the loss of AC option is not exercised by the user for simulating a coastdown, the user has the option of specifying a time at which all the RCPs will be shut off. This can also be accomplished by use of the individual pump speed versus time tables. The latter option takes precedence over the time tables and loss of AC options, and the loss of AC option takes precedence over the time tables. The pumps are shut off in all the above cases by simply setting the electrical torque equal to zero. Whenever the pumps are turned on, the electrical torque is determined by setting its value equal to the value calculated from the interpolation of the pump speed versus electrical torque table.

The CESEC locked rotor option allows the user to specify for which pump and at which time a locked rotor event is to occur. The rotor is assumed to stop instantaneously at the specified time. The locked rotor simulation does not use the homologous pump curves to determine pump head in that loop. Instead, the pump is modeled as a geometric loss within the specified loop.

The CESEC sheared shaft option also allows the user to specify which pump and at which time the event is to occur. The sheared shaft is modeled by setting the moment of inertia of the pump equal to the moment of inertia of the pump impeller and by setting the electrical torque equal to zero.

The CESEC pump model also includes an algorithm to lock out the reactor coolant pump rotor whenever the pump speed falls below 5 percent of the rated pump speed.

The mathematical model for the RCS pumps is described below.
The pump hydraulic torque is calculated from the following equation:

$$T_h = \begin{cases} (\beta/\alpha^2)(\alpha^2)(T_R)(\rho/\rho_R)(m_t) & \text{for } |\nu/\alpha| \leq 1.0 \\ (\beta/\nu^2)(\nu^2)(T_R)(\rho/\rho_R)(m_t) & \text{for } |\nu/\alpha| > 1.0 \end{cases} \quad (4\text{-}1)$$

where,

- β = Ratio of the hydraulic torque to the rated hydraulic torques, $\beta \equiv T_h/T_R$
- α = Ratio of the pump speed to the rated pump speed, $\alpha \equiv \omega/\omega_r$
- ν = Ratio of the volumetric flow rate to the rated volumetric flow rate, $\nu \equiv Q/Q_r$

ρ = Density of coolant, lbm/ft^3

ρ_R = Density corresponding to pump rated conditions, lbm/ft^3

m_t = Degradation multiplier (function of void fraction)

The values of β/α^2 and β/ν^2 as a function of ν/α and α/ν, respectively, are determined from the single phase homologous curves. The single-phase data is pump dependent and, thus, is input by the user (see Appendix A). The degradation multiplier for the hydraulic torque is also user input. The friction/windage torque is calculated from the following equation:

$$T_{f,w} = (K)\ \alpha|\alpha| \tag{4-2}$$

where K = Input constant, ft-lbf.

The pump head is determined from the following equation:

$$H = \begin{cases} (\alpha^2)(H_R)\left[(h/\alpha^2) - m_h(h/\alpha^2)_{TP}\right] & \text{for } |\nu/\alpha| \le 1.0 \\ (\nu^2)(H_R)\left[(h/\nu^2) - m_h(h/\nu^2)_{TP}\right] & \text{for } |\nu/\alpha| > 1.0 \end{cases} \tag{4-3}$$

where:

H = Pump head, ft of water

H_R = Rated pump head, ft of water

h = Ratio of the pump head to the rated pump head, $h \equiv H/H_R$

m_h = Degradation multiplier, the degradation multiplier is a function of the void fraction (see Appendix A).

$(h/\alpha^2)_{TP}$, $(h/\nu^2)_{TP}$ = Difference between single phase and degraded two-phase heads as obtained from the "difference" homologous head curve (See Appendix A).

The values of h/α^2, and h/ν^2 as a function of ν/α and α/ν, respectively, are determined from the single phase homologous curves. The single phase data is pump dependent and, thus, is input by the user. The degradation multiplier function is also user input (see Appendix A for recommended values). The tables for $(h/\alpha^2)_{TP}$ and $(h/\nu^2)_{TP}$ as a function of ν/α and α/ν, respectively, are included in the pump model in the form of "DATA" statements. These curves as well as the degradation multiplier for the pump head calculation were generated from the Semiscale 1 1/2 loop system pump (References 16 and 17).

The change in the pump impeller speed is determined from the angular momentum equation. The equation is

$$\frac{d\omega}{dt} = T_{net} \frac{g_c}{I} \qquad (4\text{-}4)$$

where,

ω = Angular velocity of the rotating assembly, rad/sec
t = Time, sec
g_c = Gravitational constant, 32.174 lbm-ft/lbf-sec^2
I = Moment of inertia of the rotating assembly, lbm-ft^2
T_{net} = Net torque, ft-lbf

The net torque $T_{net} = (T_{el} - T_h - T_{f,w})$; T_{el} being the electrical torque, T_h being the hydraulic torque, and $T_{f,w}$ being the friction/windage torque.

The locked rotor option models the pressure drop through the affected pump as a geometric loss. Thus, the homologous pump curves are not used to determine the differential pressure across the affected pump. The locked rotor pressure drop is calculated as follows:

$$\Delta P_{LR} = \frac{K_g \dot{M}^2}{288 \rho g_c} \qquad (4\text{-}5)$$

where,

ΔP_{LR} = Geometric pressure loss as a result of the locked rotor (psi)

K_g = Geometric K-factor/Area^2 $(\frac{1}{ft^4})$. For forward flow $K_g \equiv K$ forward loss, for reverse flow $K \equiv K$ reverse loss. These two loss factors in general are not equal.

$\dot{M}$ = Mass flow rate through the pump (lbm/sec)

5.0 ENTHALPY TRANSPORT CALCULATION (CORE AND STEAM GENERATOR NODES)

The heat addition and removal in the core and steam generator nodes accounts for the heating of the fluid as it traverses the nodes (Reference 18). Thus, the code can distinguish between the average and the exit fluid conditions in these nodes. That is, it provides for a relationship between average and exit node fluid conditions which is needed to perform a correct system energy balance. The equation for the enthalpy change is given as follows (see Appendix D for derivation):

[ ] (5-1) [5]

where,

h_ℓ = enthalpy of fluid leaving node i, Btu/lbm
$\overline{h}_i$ = average enthalpy of node i, Btu/lbm
m_i = total mass of node i, lbs
$\overline{W}_i$ = average flow in node i, lbm/sec
W_ℓ = flow out of node i, lbm/sec
Q_i = rate of heat deposited in node i, Btu/sec (see Sections 10.0 and 13.0)
V_i = volume of node i, ft^3
$\overline{P}_\ell$ = average pressure in flow path connected to node i, lbf/in^2

which has the solution

[ ] (5-2) [5]

where

$$a = \frac{2\left(\left|W_\ell + \overline{W}_i\right|\right)}{m_i}$$

$$b/a = \overline{h}_i + \frac{Q_i}{\left|W_\ell + \overline{W}_i\right|} + \frac{144.0}{777.98}\,\frac{V_i}{\left|W_\ell + \overline{W}_i\right|}\,\frac{d\overline{P}_\ell}{dt}$$

Note that at steady state (t=0) Equation (5-1) reduces to the following

$$h_{\ell} = \bar{h}_i + \frac{Q_i}{2W_{\ell}} \tag{5-3}$$

which represents the proper limit for heating under steady state conditions, since

$$\frac{dh_{\ell}}{dt} = 0, \ \frac{d\bar{P}_{\ell}}{dt} = 0, \text{ and } W_i = W_{\ell}$$

6.0 PRESSURIZER

The CESEC pressurizer model assumes steam and liquid regions to exist in one of the eight thermalhydraulic states shown in Figure 6-1. The model considers such components as sprays, heaters, and relief/safety valves. The Pressurizer Level Control System which controls charging flow and letdown flow by means of pressurizer level setpoints, is also modeled. The loss of heat through the pressurizer wall (user input constant heat rate) is accounted for in the conservation of energy equation.

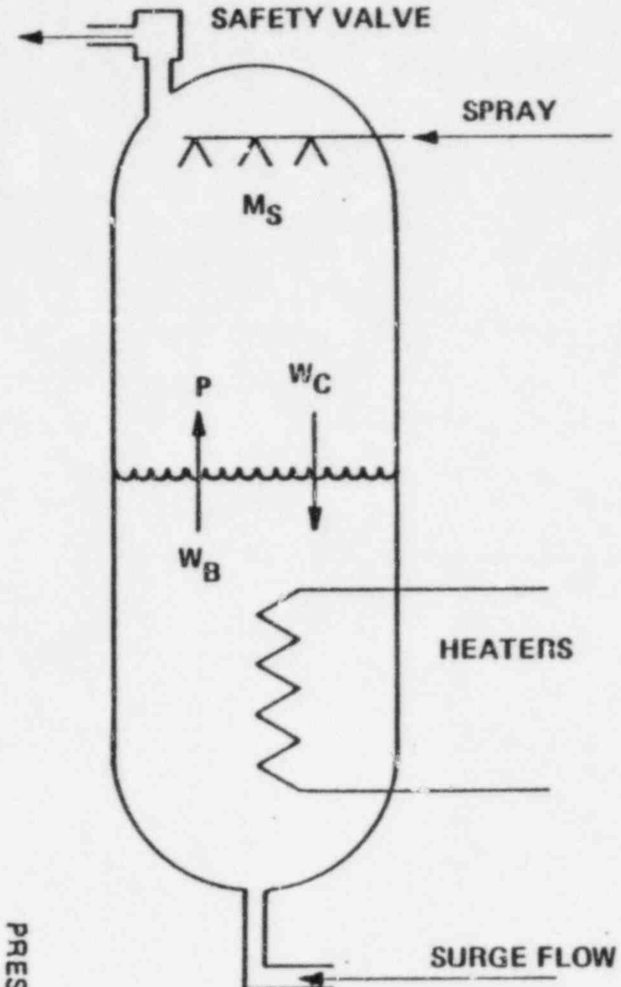
The mass and energy transport between the two fluid regions is assumed to occur as a result of liquid vaporization and/or steam condensation. The spray flow which enters the pressurizer is assumed to condense the steam if it is in the saturation state. That is,when the steam region is at saturation, the spray droplets are assumed to reach saturation temperature and will result in bulk condensation of the steam. However, when the steam region is superheated, the spray droplets are assumed to evaporate into the steam region.

The code models two spray operating modes, continuous and proportional. The continuous mode spray is a user input constant flow which is added continuously to the pressurizer. The proportional mode spray flow originates at the pump discharge in the RCS loop and is linked to the pressurizer. The spray flow for the proportional mode is controlled automatically by two pressure setpoints which turn the spray on and off, respectively. Within these two setpoints, the spray flow increases linearly with the pressurizer pressure.

The code also models two types of heaters located near the bottom of the pressurizer: (1) the proportional heaters which are controlled by the Pressurizer Pressure Control System to generate heat at a rate which decreases linearly with increasing pressure between two pressure setpoints and (2) the backup heaters which turn on and off at two pressure setpoints.

In addition, the backup heaters are also controlled by the measured deviation of the pressurizer liquid level from the programmed level. The addition of heat from heaters to the fluid is accounted for in the conservation of energy equation.

CESEC models the operation of the pressurizer safety valves. Figure 6-2 shows the valve opening and closing characteristics programmed in the code. The input parameters are the opening pressure, the accumulation and blowdown pressures which are input as percent of the opening pressure, and the fractional opening area at the corresponding pressures. Up to five individual valves may be simulated by the code. Various valve failure conditions may be modelled through user options on a per valve basis. When the valve opens, the discharge of the pressurizer fluid, either steam or water, is assumed to be choked. The critical flow is calculated by using the appropriate critical flow calculational model (see Section 16.0).



PRESSURIZER

TWO VOLUMES (STEAM AND WATER)

CONSTANT VOLUME CONSTRAINT

$M_S v_S + M_W v_W = V_P$ = CONSTANT

M_S = TOTAL MASS OF STEAM

v_S = SPECIFIC VOLUME OF STEAM

M_W = TOTAL MASS OF WATER

v_W = SPECIFIC VOLUME OF WATER

V_P = TOTAL VOLUME OF PRESSURIZER

INTERFACE FLOWS

W_B = BOILING FLOW RATE

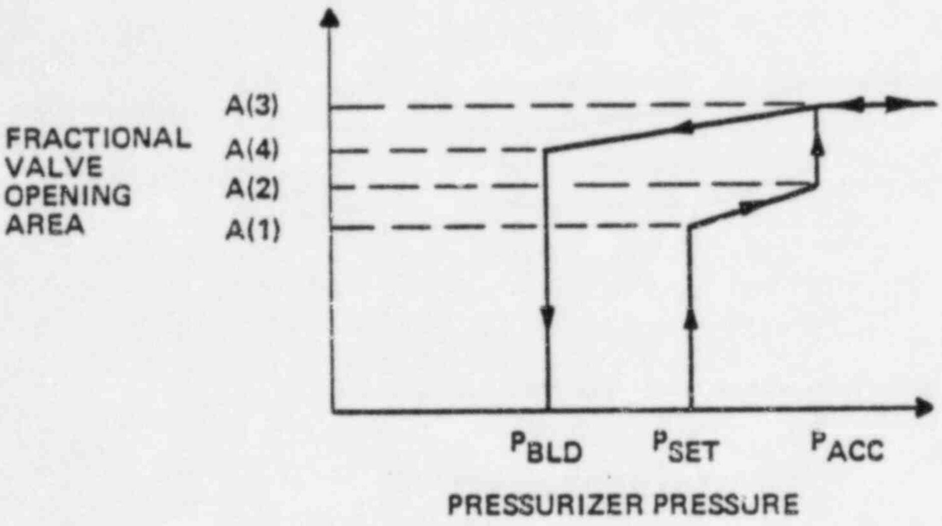
W_C = CONDENSATE FLOW RATE

CONDITIONS	WATER	STEAM
1	SUBCOOLED	SUPERHEATED
2	SATURATED	SUPERHEATED
3	SUBCOOLED	SATURATED
4	SATURATED	SATURATED
5	NONE	SUPERHEATED
6	NONE	SATURATED
7	SUBCOOLED	NONE
8	SATURATED	NONE

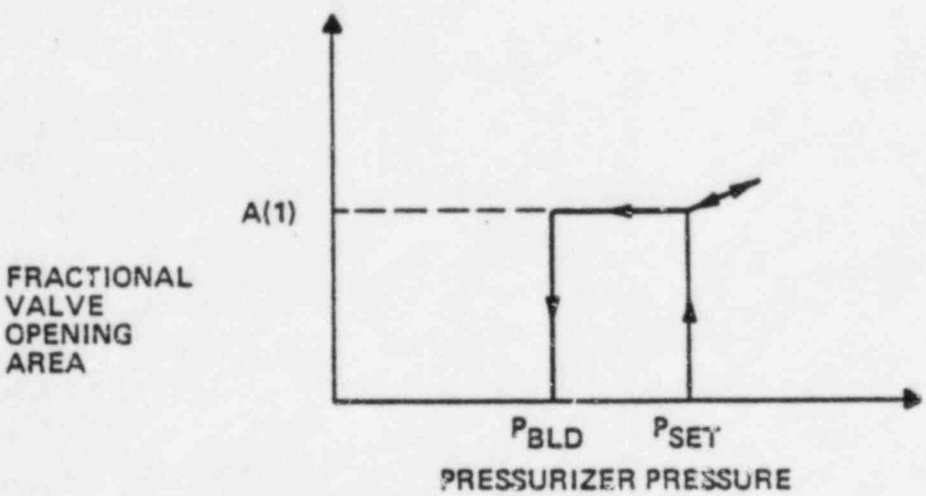
PRESSURIZER MODEL

Figure 6-1

A. PRESSURE REACHES P_{ACC}



B. PRESSURE DOES NOT REACH P_{ACC}



P_{ACC} = ACCUMULATED PRESSURE AT WHICH VALVE FULLY OPENS

P_{SET} = SET PRESSURE AT WHICH VALVE STARTS TO OPEN

P_{BLD} = BLOWDOWN PRESSURE AT WHICH VALVE CLOSES

PRESSURIZER SAFETY VALVE
OPERATING CHARACTERISTICS

Figure 6-2

7.0 SURGE LINE

7.1 MOMENTUM EQUATION

The terms included in the momentum equation for calculating the static pressure difference between the pressurizer and the RCS are friction, geometry, gravity, and inertia. Applied to the friction term is a two-phase multiplier to account for changes in frictional effects with quality. For pressures greater than or equal to 250 psia, the Thom correlation is used and for pressures less than 250 psia, the Martinelli-Nelson correlation is used (see References 9 and 10, respectively). The friction term is included to take into account the viscous effects, the geometric term considers the effects of sudden contractions or expansions and bends, the gravitational term accounts for the difference in elevation between the pressurizer fluid and the RCS, and the surge line fluid and the RCS, and the inertia term represents the temporal change in mass flow rate.

The mathematical model is as follows (see Figure 7-1):

$$P_1 - P_2 = \frac{\left(\frac{L}{A}\right)}{144g}\frac{dW}{dt} + \frac{f\,L/De\,|W|W}{288\,\rho g\,A^2}\phi + \frac{k_G|W|W}{288\,\bar{\rho} g\,A^2} + \frac{\rho_w}{144}(Z_w - Z_a) + \frac{\rho_s}{144}(Z_p - Z_w) + \frac{\bar{\rho}}{144}(Z_a - Z_2) \qquad (7\text{-}1)$$

where,

A = area of surgeline (ft^2)

ϕ = two-phase multiplier
Thom correlation used for surge
pressure >250 psia
Martinelli-Nelson correlation used for surge
pressure ≤250 psia
The surge pressure = $1/2\left(P_2 + \frac{\rho_w}{144}(Z_w - Z_a) + \frac{\rho_s}{144}(Z_p - Z_w) + P_1\right)$

L = surge line length (ft)

D_e = diameter of the surgeline (ft)

P_2 = pressurizer pressure (psia)

P_1 = reactor coolant system pressure (psia)

f = friction factor

= 64.0/Reynolds Number Re <1250

= (-0.000004* Re) + 0.056 $1250 \leq Re < 6000$

= $0.184/Re^{0.2}$ $6000 \leq Re \leq 15000$

For Re >15000 an interpolation from a table of values is used

g = acceleration due to gravity (32.174 ft/sec^2)

W = surgeline mass flow rate (lbm/sec) = W_s

k_g = surge line geometric "k" factor

(Z_w-Z_a) = pressurizer actual water level (ft)

(Z_p-Z_w) = column height of steam in the pressurizer (ft)

(Z_a-Z_2) = elevation of pressurizer above the hot leg (ft)

ρ_w = density of pressurizer water (lbm/ft^3)

ρ_s = density of pressurizer steam (lbm/ft^3)

$\overline{\rho}$ = density of surge fluid at the surge pressure (lbm/ft^3)

ρ = density of surge pressure for qualities ≤ 0 or ≥ 1.
For $0 <$ quality <1, $\rho=\rho_f$ (saturated water density) (lbm/ft^3)

7.2 SURGE ITERATION SCHEME

The surge line pressure drop iteration scheme requires a guess for the value of the time derivative of the pressure drop between the pressurizer and the reactor coolant system ($\Delta\dot{P}$). The equation used to determine this guess is presented below and is derived in Appendix E.

$$\Delta\dot{P}_{Th(m)} = \frac{\Delta\dot{P}_{Th(m-1)} - \frac{d\ (\Delta\dot{P}_{Th})}{d\ (\Delta\dot{P}_{W_s})}\ \Delta\dot{P}_{W_s(m-1)}}{1 - \frac{d\ (\Delta\dot{P}_{Th})}{d\ (\Delta\dot{P}_{W_s})}} \qquad (7\text{-}2)$$

where,

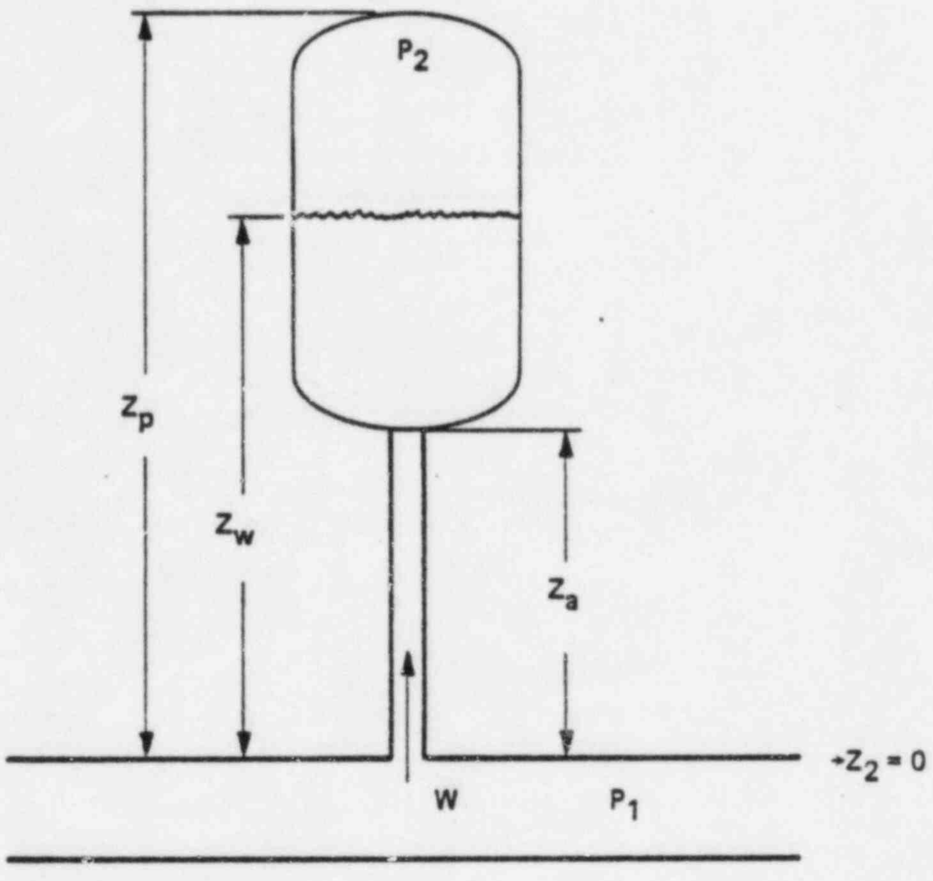
$\Delta\dot{P}_{Th(m)}$ = guess of time derivative of the static pressure drop between the pressurizer and the RCS for the m th iteration

$\Delta\dot{P}_{Th(m-1)}$ = m-1 iteration value of the time derivative of the static pressure drop between the pressurizer and the RCS

$d(\Delta\dot{P}_{Th})$ = difference between $\Delta\dot{P}$ used for the m-1 iteration and the m-2 iteration

$d(\Delta\dot{P}_{W_s})$ = difference between $\Delta\dot{P}$ as calculated from the surge line momentum equation for the m-1 iteration and m-2 iteration.

The $\Delta\dot{P}_{Th(m)}$ calculated from Equation (7-2) is inserted into the thermalhydraulic equations and a new surge flow rate (W_s) is determined. Knowing W_s, the pressure drop between the pressurizer and RCS is determined from the momentum equation (see Equation (7-1)). The time derivative $\Delta\dot{P}_{W_s(m)}$ is determined by taking a difference between the $\Delta\dot{P}$ calculated by the momentum equation and that used for the last time step and dividing this difference by the time step size. Convergence of the solution is determined by comparing the value of $\Delta\dot{P}_{W_s(m)}$ to that of $\Delta\dot{P}_{Th(m)}$. Whenever the absolute value of $|\Delta\dot{P}_{W_s(m)} - \Delta\dot{P}_{Th(m)}|$ is less than 2.0 psi/sec the solution is assumed to have converged.



MODEL FOR THE DEVELOPMENT
OF THE MOMENTUM EQUATION

Figure 7-1

8.0 FLUID STATE DETERMINATION

The steam table dynamic algorithm in CESEC uses data generated from the McClintock and Silvestri routines (Reference 19). The calculation of the subcooled, saturated, or superheated specific volume, temperature, and quality is performed with the VOLPHT function. This routine uses a random access file table of specific volumes and temperatures as functions of enthalpy for constant pressure. The data values are stored at pressure increments of 6 psi. The calculation of the water and steam specific volumes and enthalpies from known values of pressure and temperature are calculated using a modified version of the VOLPHT function, called VOLPTH. The modification included adding an entry point for this operation which searches the temperature data for a constant pressure. The specific volume and enthalpy are determined from an interpolation of the tabular data.

The specific heat is obtained from the ratio of the enthalpy change and the temperature change from the points in the tabular data used to interpolate the temperature when either VOLPHT or VOLPTH is used.

The saturation properties routine (SATUR3) obtains the saturation properties from the random access data stored in the table used by VOLPHT. Since large amounts of data storage would be required to store the whole table, only the saturation information is obtained from each record read by SATUR3. Five sets of data are stored for the tabular data interpolation to enable the program to retain data between calls and to minimize the number of reads required when the fluid properties are varying slowly with time. The calls were basically set-up for the following five pressure cases:

a. Pressurizer
b. RCS loop
c. Steam Generator
d. Secondary System
e. Other (includes cases when the saturation temperature is not to be evaluated)

The determination of a saturation pressure from a known saturation temperature uses a polynomial from the McClintock and Silvestri set of routines.

The CEFLASH-4A (Reference 18) routines DPOLY and WATPR have been incorporated into CESEC for determination of water property derivatives for pressures greater than 550 psia. Subroutine DPOLY is used to determine the total derivatives for the saturated liquid and saturated vapor enthalpies with respect to pressure ($\frac{dhf}{dp}$ and $\frac{dhg}{dp}$). All other derivatives are determined by using the function routine WATPR. This function routine has various entries for computing $\frac{\partial v}{\partial p}\Big|_h$, $\frac{\partial v}{\partial h}\Big|_p$, and $\frac{dv}{dp}$ for the subcooled and superheated regions. The two phase region partial derivatives $\frac{\partial v}{\partial p}\Big|_h$ and $\frac{\partial v}{\partial h}\Big|_p$ are determined from equations developed for this case directly from the water properties assuming a homogeneous mixture. These equations are used in subroutine PRPDER, the calling routine for subroutine DPOLY and function WATPR. These derivatives are a function of the quality, specific volume, enthalpy of saturated water and saturated steam, and the total derivatives $\frac{dvf}{dp}$, $\frac{dvg}{dp}$, $\frac{dhf}{dp}$, and $\frac{dhg}{dp}$.

The equations for these derivatives are presented in Appendix G. The two phase region derivatives are derived in Appendix H. Also presented in Appendix G are the Brookhaven National Laboratory (BNL) derivatives. These derivatives were generated from Reference 20 and have also been incorporated into subroutine PRPDER to represent the various partial and total derivatives needed for the CESEC thermalhydraulic calculation for pressures less than or equal to 550 psia.

The time derivative of enthalpy for each RCS node is determined from the conservation of energy equation and the equation of state:

$$\frac{d}{dt}(m_i h_i) - k\dot{P}V_i = Q_i + (\Sigma hWI)_i + (\Sigma hWE)_i \qquad (8\text{-}1)$$

where,

m_i = mass of node i (lbm)

h_i = enthalpy of node i (BTU/lbm)

k = conversion factor 0.18508 $\frac{BTU/ft^3}{psi}$

$\dot{P}$ = pressurizer pressure time derivative ($\frac{psi}{sec}$)

V_i = volume of node i (ft^3)

Q_i = heat addition to node i (BTU/sec), (see Section 2.0)

$(\Sigma hWI)_i$ = net rate of energy transport to node i from internal flow paths (BTU/sec)

$(\Sigma hWE)_i$ = net rate of energy transport to node i from external flow paths (i.e., charging, letdown, safety, injection, etc.) (BTU/sec)

Equation 8-1 can be written as:

$$\dot{m}_i h_i + m_i \dot{h}_i = k\dot{P}V_i + Q_i + (\Sigma hWI)_i + (\Sigma hWE)_i \qquad (8\text{-}2)$$

or $$\dot{h}_i = \frac{[Q_i + (\Sigma hWI)_i + (\Sigma hWE)_i + k\dot{P}V_i - \dot{m}_i h_i]}{m_i}$$

but from the conservation of mass equation

$$\dot{m}_i h_i = h_i\ ((\Sigma WI)_i + (\Sigma WE)_i) \qquad (8\text{-}3)$$

where,

$(\Sigma WI)_i$ = net mass flow rate to node i from internal flow paths (lbm/sec)

$(\Sigma WE)_i$ = net mass flow rate to node i from external flow paths (lbm/sec)

Thus,

$$\dot{h}_i = \frac{[Q_i + (\Sigma hWI)_i + (\Sigma hWE)_i + k\ (\dot{P} + \Delta\dot{P})V_i - h_i\ ((\Sigma WI)_i + (\Sigma WE)_i)]}{m_i} \qquad (8\text{-}4)$$

where,

$$\dot{P}_{pressurizer} \equiv \dot{P}_{RCS} + \Delta\dot{P}_{pressurizer - RCS}$$

9.0 WALL HEAT MODEL

The CESEC wall heat model allows the code to calculate the heat transfer to the primary system fluid caused by the thermal interaction between the NSSS component metal and the fluid (see Section 2.0).

The wall heat model allows for the interaction between one slab of metal and the fluid for each thermalhydraulic node. In addition, the model only allows for one wall thickness, one value of thermal conductivity, and one value of specific heat to be input for all NSSS components. However, these three parameters can be input separately for the cladding and the base metal.

The metal temperatures at thirteen nodal points throughout the base metal and the cladding are calculated using an equation of the form (Reference 21):

$$T_{\ell,i+1} = (1-2(Fo))\, T_{\ell,i} + Fo\, (T_{\ell+1,i} + T_{\ell-1,i}) \qquad (9\text{-}1)$$

where,

$T_{n,i+1}$ = Temperature at location n at the (i+1)th time step (^{o}F)
$T_{n,i}$ = Temperature at location n at the ith time step (^{o}F)
Fo = Fourier number

The heat conduction through the region closest to the coolant is used to calculate the overall heat transfer rate to the coolant. The outer surface of the wall (i.e., farthest away from coolant) is assumed to have zero heat transfer to the environment.

For the explicit modeling of the vessel internals in the upper head region a simplified model has been incorporated into CESEC. The model assumes the temperature of the wall to follow that of the coolant. This assumption is valid since the thickness of the CEA shrouds is small, typically 1/2 inch. The heat rate to the coolant is determined by the following equation:

$$\left(\frac{dq}{dt}\right)_{i+1} = -M_{sh} C_p \frac{T_{c(i+1)} - T_{c(i)}}{\Delta t} \qquad (9\text{-}2)$$

where,

$\left(\frac{dq}{dt}\right)_{i+1}$ = The heat rate to the closure heat fluid on the (i+1) th time step. (Btu/sec)

M_{sh} = Total CEA shroud metal mass (lbm)

C_p = Specific heat of CEA shrouds (Btu/lbm F°)

$T_{c(i+1)}$ = Temperature of the closure head fluid (CEA shrouds) at the (i+1) th time step (F°)

$T_c(i)$ = Temperature of the closure head fluid (CEA shrouds) at the ith time step (F°)

Δt = Time step size (sec)

10.0 REACTOR CORE

10.1 REACTOR KINETICS

The energy source in the CESEC code is from fission in the fuel. This fission energy consists of two parts, the instantaneous fission power and the decay power released by the fission products. The instantaneous power is determined by solving the standard point kinetics neutron equations with six delayed neutron groups while the decay power is calculated from an 11 fission product group decay heat model (see Figures 10-1 through 10-4 and Reference 22). The kinetics input includes provision for the user to select the values of the effective delayed neutron fractions and decay constants. The decay heat level is based on the fission product inventory which would result from long term steady-state operation at a specified initial power level. The code also has the capability for calculating the core power from a user specified function of time. Additionally, there is an option in the code to shut off the reactor kinetics calculations and follow the ANS decay heat curve for the hypothetical infinite reactor operating time (Reference 23).

The kinetics equation is solved numerically by a fourth order Runge-Kutta/Merson method for the power generation at each time step.

The total reactivity in the point kinetics equation is calculated as the sum of the control rods, moderator, fuel temperature (Doppler), and boron contributions. The code also has an explicit function of time simulating control rod reactivity insertion. The table of rod reactivity versus time after initiation of scram is user input. The moderator feedback effects considered include the moderator density or the moderator temperature. The moderator and Doppler reactivity feedback terms are calculated at each time step by interpolation of user input tables. The boron reactivity effect includes the contribution from the Safety Injection System and the letdown and charging portions of the Chemical and Volume Control System.

For steam line breaks CESEC incorporates a 3-D reactivity feedback model to more accurately represent the post-trip reactivity effects of the temperature distribution at the core inlet plane, the stuck CEA, and changes in the core power distribution. The 3-D reactivity contributions based on neutronic analyses are input into CESEC as tabular functions of normalized core flow fraction, normalized fission power to normalized core flow ratio, and temperature tilt (the difference between the hot and cold edge temperatures at the core inlet plane). Table interpolation routines determine the dynamic 3-D feedback from this input data for each time step after CEAs are inserted.

10.2 HEAT CONDUCTION MODEL

The CESEC core heat transfer model represents a fuel rod at core average conditions. The cylindrical configuration (see Figure 10-5) models the fuel, gap, and clad. The fuel rod is divided into three equal-volume radial nodes. The third radial node is assumed to contain the outer portion of the fuel, the gap, and the clad. The radial energy equation (see Figure 10-6) is formulated for each node with the nodal properties (e.g.., specific heat and thermal conductivity of fuel and clad) determined by temperature dependent correlations. The input parameters required by the model include the fractions of power generated within the fuel, the clad, and the moderator and the gap conductance which is assumed to be a constant. Within the fuel region, a uniform power distribution is assumed by the code. The heat transfer to the primary system fluid from the thermal interaction between the fuel rods and the fluid and that directly transfer from the fuel to the fluid is calculated from equation given in Figure 10-6 (see Section 2.0).

Initially, the steady state fuel temperature distribution is determined by a scheme which solves the radial energy equation iteratively based on the initial reactor power output, the gap conductance, and the initial coolant condition. The radial energy equation is solved numerically at each time step by a fourth order Runge-Kutta/Merson method.

10.3 HEAT TRANSFER

The heat transfer at the clad-coolant interface is assumed to be given by the following correlation for all fluid conditions (Reference 24):

$$h = 0.148\,(1+0.01T - 0.00001T^2)\,\frac{V^{0.8}}{D^{0.2}} \qquad (10\text{-}1)$$

where,

T = fluid temperature, ^{o}F

V = fluid velocity, ft/sec

D = channel hydraulic diameter, ft

h = convective heat transfer coefficient, $Btu/hr\text{-}ft^2\text{-}^{o}F$

FIGURE 10-1

RATE OF FISSION AND PRECURSOR CONCENTRATION EQUATIONS

FISSION RATE

$$\frac{dn(t)}{dt} = \frac{\delta k - \bar{\beta}}{l^*} n(t) + \sum_{i=1}^{6} \lambda_{Pi} C_{Pi} + S$$

$n(t)$ = Fission Rate

δk = Total Reactivity

$\bar{\beta}$ = Effective Delayed Neutron Fraction

l^* = Prompt Neutron Lifetime

λ_{Pi} = Decay Constant for ith Group of Delayed Neutron Precursors

C_{Pi} = Delayed Neutron Precursor Concentration

S = Source Term

DELAYED NEUTRON PRECURSORS

$$\frac{dC_{Pi}}{dt} = \frac{\bar{\beta}_i}{l^*} n(t) - \lambda_{Pi} C_{Pi}$$

$\bar{\beta}_i$ = Effective Delayed Neutron Fraction for ith Group of Delayed Neutron Precursors

NORMALIZED PRECURSOR CONCENTRATION

$$X_{Pi} = \frac{l^* \lambda_{Pi}}{\bar{\beta}_i \, n(0)} C_{Pi}$$

FIGURE 10-1 (continued)

NORMALIZED RATE OF FISSION EQUATION

$$\frac{d}{dt}\frac{n(t)}{n(0)} = \frac{\delta k-\bar{\beta}}{l^*}\frac{n(t)}{n(0)} + \frac{1}{l^*}\sum_{i=1}^{6}\bar{\beta}_i X_{Pi} + \frac{S(t)}{n(0)}$$

NORMALIZED PRECURSOR CONCENTRATION EQUATION

$$\frac{dX_{Pi}(t)}{dt} = \lambda_{Pi}\left[\frac{n(t)}{n(0)} - X_{Pi}(t)\right]$$

FIGURE 10-2

FISSION PRODUCTS

PRODUCTION OF FISSION PRODUCTS

$$\frac{dC_{Dj}}{dt} = \gamma_{Dj} n(t) - \lambda_{Dj} C_{Dj}$$

C_{Dj} = INVENTORY OF jth FISSION PRODUCT

γ_{Dj} = YIELD OF jth FISSION PRODUCT

λ_{Dj} = DECAY CONSTANT OF jth FISSION PRODUCT

NORMALIZED FISSION PRODUCT CONCENTRATION

$$X_{Dj} = \frac{\lambda_{Dj} C_{Dj}}{\gamma_{Dj} n(0)}$$

NORMALIZED FISSION PRODUCT CONCENTRATION EQUATION

$$\frac{dX_{Dj}}{dt} = \lambda_{Dj} \left(\frac{n(t)}{n(0)} - X_{Dj}\right)$$

FIGURE 10-3

TOTAL VARYING NORMALIZED POWER

$$\frac{P(t)}{P(0)} = (1 - \sigma_D) \frac{n(t)}{n(0)} + \sum_{j=1}^{11} \alpha_{Dj} X_{Dj}$$

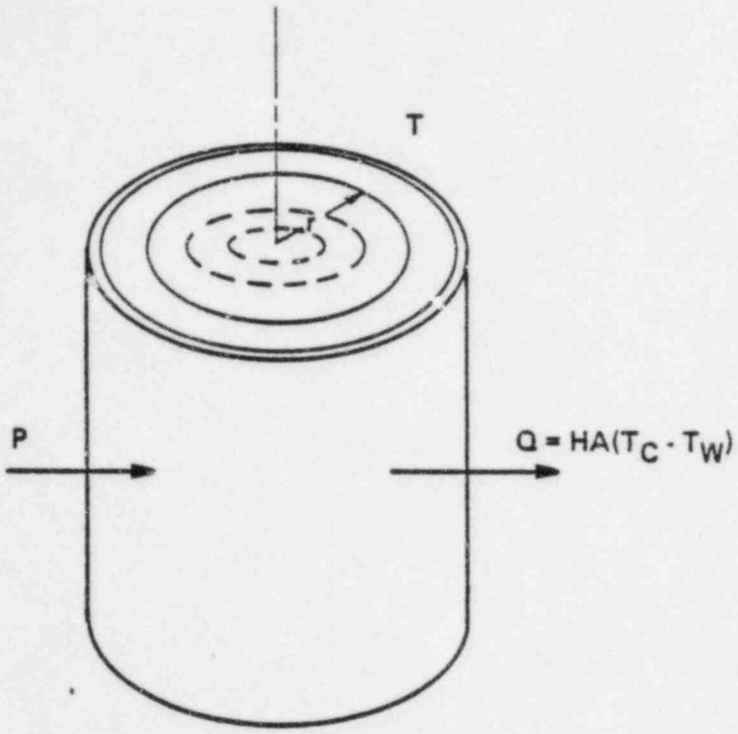
σ_D FRACTIONAL POWER FROM DISINTEGRATION OF FISSION PRODUCTS

α_{Dj} FRACTIONAL POWER FROM DISINTEGRATION OF jth FISSION PRODUCT

FIGURE 10-4

PROGRAMMED FISSION PRODUCTS

GROUP NUMBER	FRACTION	DECAY CONSTANT
1	0.00299	1.772 E+00
2	0.00825	5.774 E-01
3	0.01550	6.743 E-02
4	0.01935	6.214 E-03
5	0.01165	4.739 E-04
6	0.00645	4.810 E-05
7	0.00231	5.344 E-06
8	0.00164	5.726 E-07
9	0.00085	1.036 E-07
10	0.00043	2.959 E-08
11	0.00057	7.585 E-10



$$\rho C \frac{\partial T}{\partial t} = K \left[\frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} \right] + \frac{\partial K}{\partial r} \cdot \frac{\partial T}{\partial r} + q(r, P)$$

ρ	=	DENSITY
C	=	SPECIFIC HEAT
T	=	TEMPERATURE AT RADIUS r
r	=	RADIUS
K	=	THERMAL CONDUCTIVITY
t	=	TIME
q (r,P)	=	SPECIFIC HEAT GENERATION DEPENDING ON RADIUS AND THE REACTOR KINETICS POWER

HEAT FLOW EQUATION

Figure 10-5

FIGURE 10-6

FINITE DIFFERENCE EQUATIONS

HEAT BALANCE IN FUEL ROD

$$(MC)_1 \frac{dT_{F1}}{dt} = C_1P - K_{12}(T_{F1} - T_{F2})$$

$$(MC)_2 \frac{dT_{F2}}{dt} = C_2P + K_{12}(T_{F1} - T_{F2}) - K_{23}(T_{F2} - T_{F3})$$

$$(MC)_3 \frac{dT_{F3}}{dt} = C_3P + K_{23}(T_{F2} - T_{F3}) - K_{3W}(T_{F3} - T_W)$$

HEAT TO WATER

$$Q_W = K_{3W}(T_{F3} - T_{W1}) + C_wP$$

T_F AVERAGE FUEL NODE TEMPERATURE

MC NODE THERMAL CAPACITY

C HEAT GENERATION FACTOR

K EFFECTIVE THERMAL CONDUCTANCE

Q HEAT RATE

P REACTOR TOTAL POWER FRACTION

11.0 CHARGING AND LETDOWN

The CESEC code provides a model for calculating the charging and letdown flows. The contributions from the charging and letdown flows are included in the conservation of mass and energy equations for the corresponding RCS nodes. Included in the model is a Pressurizer Level Control System which determines the deviation between the measured pressurizer water level and the programmed level. The programmed level is given by an input table as a function of either power or average RCS temperature. The algorithm by which the measured level is calculated is described in Reference 5. The charging flow is provided by a set of constant speed charging pumps, with the charging flow rate automatically controlled by switching each pump on or off at two input level deviation setpoints. The letdown flow control is provided either by a set of letdown control and backpressure valves, with the flow rate either controlled by the opening or the closing of each set of valves at two level deviation setpoints, or by a linear letdown flow control model.

The letdown fluid temperature downstream of the heat exchanger is user input. The charging and the letdown fluid temperatures are selected to be those corresponding to the steam generator outlet temperature. The boron concentration from the letdown and charging portion of the Chemical and Volume Control System (CVCS) is only accounted for in CESEC when the Safety Injection System is activated. However, the user can optionally turn off the letdown and charging systems and take no credit for the boron reactivity contribution from the letdown and charging systems. The calculation of the boron concentration in the reactor coolant is described in the Safety Injection System section.

The letdown line break model is provided in Appendix F.

12.0 SAFETY INJECTION SYSTEM

The borated safety injection water from the high and low pressure safety injection pumps is injected into each cold leg node downstream of the reactor coolant pumps. The borated injection flow rates versus pressure are specified by input tables. Once the safety injection flow reaches the cold leg node, it is assumed to mix homogeneously with the reactor coolant in that node. The boron is transported through the RCS by solving at each time step the continuity equation for each coolant node for the boron concentration:

$$M \frac{dC}{dt} = W_{in} C_{in} - W_{out} C \qquad (12\text{-}1)$$

where,

- C is the boron concentration
- C_{in} is the inlet boron concentration
- W_{in} is the inlet flow rate
- W_{out} is the outlet flow rate
- M is the mass inventory in the node

The boron concentration for the reactor core nodes is used to calculate the reactivity contribution due to boron via an input reciprocal boron worth.

A time delay is input to CESEC to account for the time required to start the diesel generator and/or to bring the safety injection pumps to full speed. An additional time delay is calculated to account for the time required for the unborated water in the safety injection line to be swept out before borated water from the refueling water tanks enters the cold legs.

CESEC also solves an orifice equation to determine the rate of safety injection flow from the safety injection tanks into the RCS as a function of time. The input paramters are the initial nitrogen pressure, volume of water, volume of gas, water specific volume, and elevation head of the safety injection tanks.

The flow coefficient and flow area of the safety injection lines are also user input. In addition to the nitrogen pressure within the safety injection tank, the static head of fluid within the safety injection piping is considered when calculating the instantaneous pressure difference across the orifice. The nitrogen expansion process is assumed to be isentropic.

In computing the safety injection flow rate by means of an orifice equation, the code takes into account the effect of piping friction, bends, and expansion/contraction losses through the use of a single equivalent loss coefficient which is based on the minimum cross-sectional flow area. The instantaneous liquid discharge rate at time t is given by

$$W(t) = A\left(\frac{288\, g_c \Delta P(t)}{Kv}\right)^{1/2} \qquad (12\text{-}2)$$

$$\Delta P(t) = P_G(t) + P_E - P_{RCS}(t) \qquad (12\text{-}3)$$

where,

- W is the mass flow rate in lbm/sec
- A is the flow area of safety injection tank line in ft^2
- K is the friction loss coefficient for the flow area
- v is the specific volume of liquid in ft^3/lbm
- $P_G(t)$ is the nitrogen pressure at time t
- P_E is the elevation head
- $P_{RCS}(t)$ is the RCS pressure at time t

If ΔP is less than or equal to zero, the code sets this variable equal to zero in order that no liquid mass be ejected from the tank for this condition.

The instantaneous liquid volume V in the tank at time t is then

$$V(t) = V(t-\Delta t) - W(t)\, \Delta t\, v \qquad (12\text{-}4)$$

where Δt is the time step interval.

The instantaneous gas volume V_G in the tank at time t is given by

$$V_G(t) = V_G(0) + V(0) - V(t) \qquad (12\text{-}5)$$

where $V_G(0)$ and $V\ (0)$ are the initial gas volume and liquid volume, respectively.

The instantaneous gas pressure in the tank at time t is given by:

$$P_G(t) = P_G\ (0)\left(\frac{V_G(0)}{V_G(t)}\right)^{1.4} \qquad (12\text{-}6)$$

13.0 STEAM GENERATOR

13.1 HEAT BALANCE

The CESEC steam generator model performs a detailed computation of the overall heat transfer coefficient for each steam generator node. The heat load for each steam generator primary node (see Section 2.0) is computed at each time step from the following relationship:

$$Q_n = U_n A_n \left(T_{Pri_n} - T_{sec}\right) \quad (13\text{-}1)$$

for n = 1 through 4

where,

U is the overall heat transfer coefficient, Btu/hr-ft^2-^{o}F
A is the outside surface tube heat transfer area, ft^2
T_{pri} is the average primary fluid nodal temperature, ^{o}F
T_{sec} is the secondary fluid temperature, ^{o}F

The overall heat transfer coefficient is defined as

$$U = \frac{1.0}{R_{pri} + R_{wf} + R_{sec}} \quad (13\text{-}2)$$

where,

R_{pri} is the primary side resistance = $\frac{1}{h_{Pri}}$

R_{wf} is the wall/fouling resistance

R_{sec} is the secondary side resistance = $\frac{1}{h_{sec}}$

h_{pri} is the primary side heat transfer coefficient

h_{sec} is the secondary side heat transfer coefficient

For each time step during the transient the appropriate heat transfer regime is selected and the local heat transfer coefficients are calculated for the primary and secondary sides of the steam generators. The tube wall/fouling resistance is determined initially from design full power conditions and is assumed to be constant thereafter during the transient.

To prevent instabilities in the transient solution, a user input option allows the steam generator heat transfer area to be reduced on decreasing secondary water mass. For steam generator inventories above a user input water mass, the user input heat transfer area is used in Equation (13-1). For liquid inventories less than a second user input water mass, the heat transfer area is reduced to zero. For liquid inventories between the two user input water masses, the heat transfer area is scaled linearly between the setpoints. This effective heat transfer area is then used in Equation (13-1).

13.2 MODES OF HEAT TRANSFER

The CESEC steam generator model allows for forward (primary-to-secondary heat flow) and reverse (secondary-to-primary heat flow) heat transfer. During forward heat transfer, the primary side heat transfer regimes considered by the code are subcooled forced convection and two-phase flow with condensation. The secondary side heat transfer mechanism is pool boiling. During reverse heat transfer, the primary side heat transfer regimes are subcooled forced convection and two-phase flow with boiling. The secondary side heat transfer mechanism is free convection. For each of the five heat transfer mechanisms the code allows the user to input a minimum coefficient. The code will then select the maximum of the calculated and input coefficient. Initially (t=0.0), the steam generator model assumes the subcooled forced convection and pool boiling modes of heat transfer for the primary and secondary sides, respectively.

$$h_b = 0.00122 \left[\frac{k_B^{0.79}\ C_p^{0.45}\ \rho_f^{0.49}\ g_c^{0.25}}{\sigma_f^{0.5}\ \mu_f^{0.29}\ h_{fg}^{0.24}\ \rho_g^{0.24}} \right] (\Delta T)^{0.24}\ (\Delta P)^{0.75} S \tag{13.7}$$

$$F = 1 + 1.6 \left[\left(\frac{\mu_g}{\mu_f}\right)^{0.1} \left(\frac{\rho_f}{\rho_g}\right)^{0.5} \left(\frac{X}{1-X}\right)^{0.9} \right]^{0.8174} \tag{13-8}$$

$$S = \frac{1}{1 + (1.63)(10^5)(1-X)\ Re_B\ F^{-1.25}} \tag{13-9}$$

$\Delta T = |T_w - T_{sat}|$

T_w is the wall temperature, ^oF

T_{sat} is the saturated fluid temperature, ^oF

$\Delta P = |P_{sat}(T_w) - P_{sat}(T_{sat})|$

P_{sat} is the saturation pressure, psia

h_{fg} is the latent heat of vaporization, Btu/lbm

C_p is the fluid specific heat, Btu/lbm-^oF

g_c = 32.174 lbm-ft/lbf-sec^2

σ is the surface tension, lbf/ft

μ is the viscosity, lbm/ft-hr

Primary side:

For subcooled flow, the film heat transfer coefficient is given by the Dittus-Boelter correlation (Reference 25):

$$h_{pri} = 0.023 \frac{k_B}{D} Re_B^{0.8} Pr_B^{0.4} \quad (13-3)$$

where,

k is the liquid conductivity, Btu/hr-ft-^oF

D is the hydraulic diameter, ft

Re is the Reynolds number

Pr is the Prandtl number

B refers to the fluid properties evaluated at the bulk temperature

In the two-phase flow with condensation regime, the correlation used is (References 26 and 27):

$$h_{pri} = 0.0265 \frac{k_B}{D} Re_e^{0.8} Pr_B^{0.333} \quad (13-4)$$

where,

$$Re_e = Re_B \left[(1-X) + X \left(\frac{\rho_g}{\rho_f}\right)^{0.5}\right]$$

X is the quality

ρ_f is the saturated liquid density, lbm/ft^3

ρ_g is the saturated steam density, lbm/ft^3

In the two-phase flow with boiling regime, the correlation used is (References 28 and 29):

$$h_{pri} = h_{tp} + h_b \quad (13-5)$$

where,

$$h_{tp} = 0.023 \frac{k_B}{D} \left[(1-X) Re_B\right]^{0.8} (Pr_B)^{0.4} F \quad (13-6)$$

Secondary side:

The modified Rohsenow pool boiling correlation is used in the calculation of the secondary side heat transfer coefficient during forward heat transfer (Reference 6):

$$h_{sec} = K_R \; (Q/A)^{2/3} \qquad (13\text{-}10)$$

where,

h_{sec} is the secondary heat transfer coefficient, $Btu/hr\text{-}ft^2\text{-}^{o}F$
Q is the heat rate, Btu/sec
A is the heat transfer area, ft^2

$$K_R = \begin{cases} \left[\qquad\qquad\qquad \right] & \text{for } P_{sec} < 800 \text{ psia} \\ \left[\qquad\qquad \right] & \text{for } P_{sec} \geq 800 \text{ psia} \end{cases} \qquad [5]$$

During reverse heat transfer the McAdams (Reference 30) correlation for free convection is used to determine the secondary side heat transfer coefficient:

$$h_{sec} = C \; \frac{k_B}{L} \, (Gr_B \; Pr_B)^n \qquad (13\text{-}11)$$

where,

$$\left.\begin{array}{l} C = 0.13 \\ n = 1/3 \end{array}\right\} \text{for } Gr_B Pr_B > 10^9$$

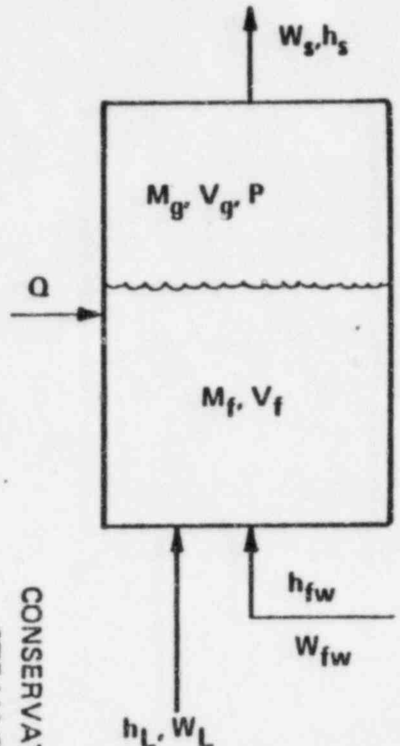
$$\left.\begin{array}{l} C = 0.59 \\ n = 1/4 \end{array}\right\} \text{for } Gr_B Pr_B \leq 10^9$$

Gr is the Grashof number
L is the tube length, ft

The selection of the appropriate primary side heat transfer coefficient is based on the direction of heat flow between primary and secondary and an enthalpy check (determines if fluid is saturated). In the secondary side, the selection of the secondary heat transfer coefficient is solely based on the direction of heat flow.

13.3 SECONDARY SIDE MODEL

The secondary side of each steam generator is represented by a control volume (see Figure 13-1). The control volume consists of saturated liquid and saturated steam. The fluid properties and mass inventory are determined by solving the conservation of mass and energy equations in conjunction with the equation of state. The initial conditions of the secondary side of the steam generator are determined by iterating on the secondary pressure, given the initial heat flux and load demand as specified by the user.



STEAM GENERATOR
SHELL SIDE

MASS BALANCE

$$\frac{dM_g}{dt} + \frac{dM_f}{dt} = W_{fw} + W_L - W_S$$

VOLUME BALANCE

$$\frac{d(M_g V_g)}{dt} + \frac{d(M_f V_f)}{dt} = \frac{dV}{dt} = 0$$

ENERGY BALANCE

$$\frac{d(M_f h_f)}{dt} + \frac{d(M_g h_g)}{dt} = Q + 144 \frac{V}{J} \frac{dP}{dt} +$$

$$W_{fw} h_{fw} + W_L h_L - W_s h_s$$

STATE: SATURATION

P = STEAM GENERATOR SECONDARY PRESSURE

M_g = TOTAL STEAM MASS IN STEAM GENERATOR

V_g = SPECIFIC VOLUME OF STEAM

M_f = TOTAL WATER MASS IN STEAM GENERATOR

V_f = SPECIFIC VOLUME OF WATER

W_{fw} = MASS FLOW RATE OF FEEDWATER

h_{fw} = ENTHALPY OF FEEDWATER

W_s = MASS FLOW RATE OF STEAM LEAVING STEAM GENERATOR

h_s = ENTHALPY OF STEAM FLOW

W_L = MASS FLOW RATE OF WATER LEAKING OUT OF STEAM GENERATOR TUBES

h_L = ENTHALPY OF LEAK FLOW

Q = HEAT RATE

V = TOTAL VOLUME

J = $778 \frac{LBF\text{-}FT}{BTU}$

CONSERVATION EQUATIONS FOR THE STEAM GENERATOR SHELL SIDE

Figure 13-1

14.0 FEEDWATER SYSTEM

The feedwater flow is optionally determined in CESEC by the following three methods: 1) matching the steam flow, 2) input table of flow rate versus time, and 3) automatic feedwater control on the steam generator water level. The initial feedwater flow is assumed to match that corresponding to the power demand at time zero. The flow during an event is calculated according to the user option selected. The feedwater isolation valves are programmed to close at a specified rate of closure following the main steam isolation signal which is actuated on low steam generator pressure. The feedwater enthalpy can be specified by input tables of enthalpy as a function of either power demand or time.

The auxiliary feedwater flow can be optionally controlled by the following five methods: 1) manual control through an input table of flow rate versus time, 2) low steam generator pressure setpoint trip to actuate the auxiliary feedwater flow, 3) low steam generator water level trip setpoint to actuate the auxiliary feedwater flow, 4) automatic steam generator water level control (actuation on low steam generator water level), and 5) automatic steam generator pressure difference control. The auxiliary feedwater enthalpy is modeled using an input table of enthalpy versus time.

15.0 STEAM SYSTEM

The path of the steam flow from the secondary side of the steam generator is illustrated in Figure 1-2. Downstream of the main steam isolation valve, the main steam lines from each steam generator are connected together at a common steam header (see Figure 15-1). At the initial steady state, the steam flow in each steam line is determined consistent with the reactor coolant flow rate in each steam generator loop.

During the transient calculation, the steam flow (see Figure 15-2) is determined by the turbine power demand and the operation of the secondary valves or for steam line break events the break area.

The code simulates the turbine stop and admission valves, the steam bypass valves, the main steam safety valves, the atmospheric dump valves, and the main steam isolation valves. The steam flow through each valve is assumed to be choked. Thus, a critical flow correlation (see Section 16.0) for steam is used to calculate the flow rate. The control schemes for these valves are briefly described below.

Turbine Admission and Stop Valve:

The area of the turbine admission valve is sized at each time step such that the power demand which is input as a tabular function of time, is met. At the time of a turbine trip, the valve is closed at a rate specified by a user input to simulate the closing of the turbine stop valves.

Steam Bypass Valves:

The code provides three options for the control of the steam bypass valves:

1. An input table of valve area as a function of time,

2. A proportional-plus-integral-plus derivative (PID) controller model, and

3. A linear control scheme which operates the bypass valves as a function of the steam line header pressure. That is, the valves start to open when the pressure reaches an input setpoint and then open linearly as the pressure increases. As the pressure drops, the valves will close by following the same path.

Main Steam Safety Valves (MSSVs):

The main steam safety valves are of the accumulation, blowdown type (see Figure 6-2). Up to ten individual banks of valves may be used with associated opening, accumulation, and blowdown pressures. Various types of valve malfunctions, such as valve sticks open, valve sticks closed, and one valve inadvertently opens, can be simulated for each individual valve.

Atmospheric Dump Valves (ADVs):

The operation of the atmospheric dump valves can be simulated by the following four techniques:

1. an input table of valve area as a function of time,

2. a step function control scheme which operates the ADVs as a function of the steam generator pressure and allows the simulation of various types of valve malfunctions (one valve sticks open, one valve sticks closed, and one valve inadvertently opens initially).

3. a PID controller model, and

4. a control scheme operated on the reactor coolant temperature.

IMAGE EVALUATION
TEST TARGET (MT-3)

150mm

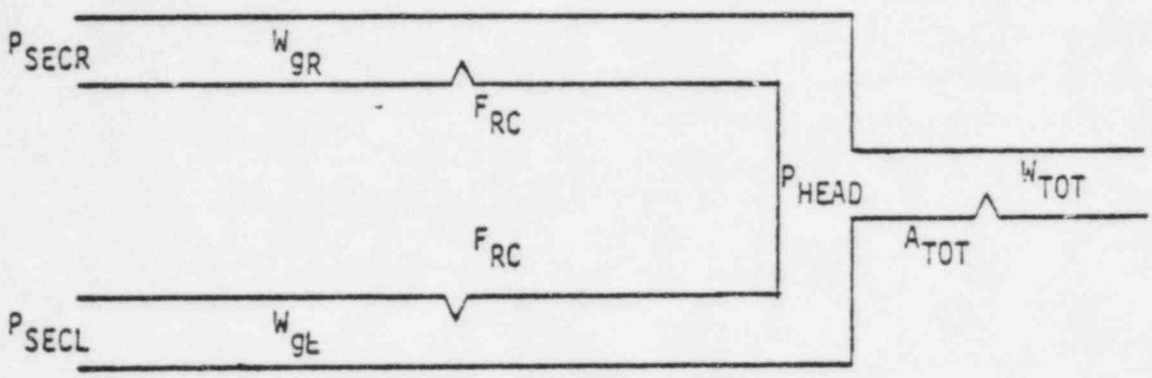
6"

Main Steam Isolation Valves (MSIVs):

The code simulates two main steam isolation valves, one for each main steam line. These valves are normally open and do not affect steam generator operation unless the steam generator pressure drops below a specified setpoint. Once this occurs, the MSIVs begin to close after an input delay time. As the MSIVs close, steam flow to the turbine and other downstream components terminates. The steam flow from the main steam safety valves, the atmospheric dump valves, and from a steam line break upstream of the MSIVs is unaffected by MSIV closure.

FIGURE 15-1A

HEADER SIMULATION



$$W_{TOT} = A_{TOT}\ P_{HEAD}\ \frac{1977.6}{h_g - 185}$$

$$W_{gR} = F_{RC} \left(\frac{P_{SECR} - P_{HEAD}}{v_R} \right)^{1/2}$$

$$W_{gL} = F_{RC} \left(\frac{P_{SECR} - P_{HEAD}}{v_L} \right)^{1/2}$$

P_{HEAD}	HEADER PRESSURE
W_{TOT}	TOTAL STEAM FLOW THROUGH HEADER
h_g	ENTHALPY OF STEAM AT HEADER PRESSURE
W_{gR}	FLOW FROM RIGHT STEAM GENERATOR
W_{gL}	FLOW FROM LEFT STEAM GENERATOR
P_{SECR}	RIGHT S.G. STEAM PRESSURE
P_{SECL}	LEFT S.G. STEAM PRESSURE
F_{RC}	EFFECTIVE FRICTION COEFFICIENT OF PIPING
v_R	RIGHT S.G. STEAM SPECIFIC VOLUME

FIGURE 15-1A (continued)

v_L LEFT S.G. STEAM SPECIFIC VOLUME

$$A_{TOT} = A_{TUB} + A_{BYP} + A_{DMP} + \varepsilon$$

A_{TUB} TURBINE VALVE AREA = $\dfrac{P_{TBD}\ f_D(t)}{\frac{1977.6}{h_g - 185}\ P_{HEAD}\ h_g}$

P_{TBD} DESIGN TURBINE POWER

$f_D(t)$ TIME FUNCTION POWER DEMAND FRACTION

A_{BYP} AREA OF BYPASS VALVE

A_{DMP} AREA OF DUMP VALVE

ε SMALL LEAKAGE FACTOR (ELIMINATES POSSIBLE DIVISION BY ZERO)

FIGURE 15-1B

HEADER SIMULATION

NEWTON-RAPHSON ITERATION ON HEADER PRESSURE SUCH THAT:

$$\left| W_{TOT} - W_{gR} - W_{gL} \right| < 1 \times 10^{-8}$$

W_{TOT} TOTAL STEAM FLOW THROUGH HEADER

W_{gR} FLOW FROM RIGHT S.G.

W_{gL} FLOW FROM LEFT S.G.

FIGURE 15-2

STEAM GENERATOR STEAM FLOW

$$W_{SR} = W_{gR} + W_{SAR} + W_{DMPR}$$

$$W_{SL} = W_{gL} + W_{SAL} + W_{DMPL}$$

W_{SR}	TOTAL RIGHT STEAM GENERATOR STEAM FLOW
W_{SL}	TOTAL LEFT STEAM GENERATOR STEAM FLOW
W_{gR}	RIGHT STEAM GENERATOR STEAM FLOW TO HEADER
W_{gL}	LEFT STEAM GENERATOR STEAM FLOW TO HEADER
W_{SAR}	RIGHT STEAM GENERATOR SAFETY VALVE FLOW
W_{SAL}	LEFT STEAM GENERATOR SAFETY VALVE FLOW
W_{DMPR}	RIGHT STEAM GENERATOR ADV FLOW
W_{DMPL}	LEFT STEAM GENERATOR ADV FLOW

16.0 CRITICAL FLOW MODELS

The CESEC computer code provides the user with the options to select one of two critical flow correlations for steam discharge and one of four sets of critical flow tables for subcooled liquid/saturated liquid/two-phase mixture discharge. The correlations for steam discharge are CRITCO (Reference 31) and Murdock and Bauman (Reference 32). The liquid and two phase discharge tables built into the code are Henry-Fauske (H-F), Moody (M), Henry-Fauske/Moody (H-F/M), and the Homogeneous Equilibrium Model (HEM). The above sets of tables were extracted from the CEFLASH-4A code (Reference 18).

The above correlations have general applicability (see Figure 16-1) for calculating mass flow rates for all fluid phases through primary safety and relief valves, secondary safety and atmospheric dump valves, tube ruptures in right hand and left hand steam generators, and arbitrary nodal leaks in all RCS thermalhydraulic nodes (see Figure 2-1A) with the exception of the pressurizer. If a nodal leak is specified only one steam generator tube rupture is allowed. If two nodal leaks are specified no steam generator tube ruptures are allowed. Secondary side breaks to which the critical flow routines apply are a main steam line break with or without moisture carryover and a feedwater line break. Other features of the CESEC critical flow model are as follows: the sink pressure for each of the specified applications is a user input quantity except for the case of a steam generator tube rupture. For this case the sink pressure is assumed to be the secondary system pressure of the steam generator where the tube rupture occurs. The leak flow areas for the steam generator tube rupture and RCS nodal leaks are also user input and are a function of time. Finally, the user can input a discharge coefficient which is multiplied by the calculated mass flow rate and is a function of quality, for calculating the net flow rate for each application discussed above.

The H-F, M, H-F/M, and HEM critical flow correlations (see Figure 16-2) used in CESEC are in table form. For given values of stagnation pressure, a range of values is tabulated for stagnation enthalpy versus mass flow rate per unit area and stagnation enthalpy versus throat pressure. Thus, the mass flow rate per unit area and throat pressure are determined by interpolation. The calculated mass flow rate per unit area is then multiplied by the flow area and an appropriate discharge coefficient to generate the net mass flow rate flowing through a specified component and/or rupture. If the calculated throat pressure is less than the sink pressure then the mass flow rate is calculated using the orifice equation.

The CRITCO relationship is the standard technique used for determination of the critical mass flow rate for steam. A complete discussion of this empirical relationship, as well as the test data from which it was developed, can be found in Reference 31. The formulation, which is given in terms of the source pressure, is as follows:

$$G = \frac{1977.6\ P}{H-185.0} \qquad (16\text{-}1)$$

where,

G = Mass flow rate per unit area ($lbm/sec\text{-}ft^2$)

P = The source pressure (psia).

H = Enthalpy of the steam (Btu/lbm)

The net mass flow rate of steam is determined from the relation

$$W = G \times D \times AREA \qquad (16\text{-}2)$$

where,

W = Mass Flow Rate (lbm/sec)

D = Discharge Coefficient (dimensionless)

AREA = Break Area (ft^2)

The throat pressure is calculated by assuming a critical pressure ratio, R_c, equal to 54.5% (Reference 33). This value is an average value in the expected range of operation (Reference 32).

The Murdock and Bauman relationship is also used (as a user's option) for determination of the critical mass flow rate for steam. The mass flux is calculated as follows:

$$G = Fs\ (P\rho)^{1/2} \qquad (16\text{-}3)$$

where,

Fs = constant $(in/sec\text{-}ft^{1/2})$ dependent on liquid and two-phase discharge table

•

ρ = density of the steam at source conditions (lbm/ft^3)

The net mass flow rate of steam and the throat pressure are calculated in the same manner as with CRITCO.

Whenever the sink pressure is greater than the calculated throat pressure, the orifice equation is used to calculate the mass flow rate. This equation is of the following form:

$$G = (C\Delta P\rho)^{1/2} \qquad (16\text{-}4)$$

where,

ρ is the fluid density (lbm/ft^3)
ΔP is the source to sink pressure drop (lb/ft^2)
C = 2 x acceleration due to gravity = 62.4 ft/sec^2

The net mass flow rate is then calculated in the same manner as with CRITCO.

For the case that the steam generator tube rupture option is exercised, the orifice equation is multiplied by $(1/K)^{1/2}$ where K is representative of the friction and geometric losses.

The CESEC computer code does not account for primary to secondary mass depletion for steam generator tube leakage. The amount of fluid leaked is relatively small, its main influence being in the calculation of any activity transferred between the reactor coolant and main steam systems. The analyses properly account for any activity transferred and its effect on the doses calculated from the steam releases.

FIGURE 16-1

CRITICAL FLOW MODELS

APPLICATIONS

PRIMARY SAFETY AND RELIEF VALVES

SECONDARY SAFETY VALVES

RIGHT HAND STEAM GENERATOR TUBE RUPTURE

LEFT HAND STEAM GENERATOR TUBE RUPTURE

ATMOSPHERIC DUMP VALVES

STEAM LINE BREAK

FEEDWATER LINE BREAK

UP TO TWO ARBITRARY LEAKS IN ALL NODES EXCEPT PRESSURIZER

FIGURE 16-2

TABLE LOOK-UP (SUBCOOLED WATER, SATURATED WATER (OR WATER-STEAM MIXTURE))

$$W = A\ f(P,h)\ D(X)$$

A AREA

h ENTHALPY

P PRESSURE

W MASS FLOW RATE

D DISCHARGE COEFFICIENT

X QUALITY

CORRELATIONS (f(P,h)):

HENRY-FAUSKE

MOODY

HEM

HENRY-FAUSKE/MOODY

17.0 REACTOR PROTECTIVE SYSTEM TRIPS

The reactor is shutdown by the insertion of the control element assemblies (CEAs) following the generation of a trip signal. A trip signal is initiated when a certain system parameter reaches a value which exceeds the corresponding user input trip setpoints. The delay time between the initiation of the trip signal and the start of CEA motion is accounted for in CESEC. The CEA motion is represented by an input rod worth versus time table. The following trips are programmed in the CESEC code:

1. high power trip,
2. high pressurizer pressure trip,
3. low pressurizer pressure trip,
4. low coolant flow trip,
5. low steam generator pressure trip,
6. low steam generator level trip, and
7. manual trip.

To generate the trip signal on the low steam generator water level, the steam generator water level is determined from a set of steady state input data and the transient liquid inventory in the steam generator. The set of steady state curves relates steam generator water level to secondary water mass and steam generator load. This data is then used in a table look-up routine to obtain the steam generator water level for the purpose of determining the trip signal.

18.0 MAJOR DIFFERENCES BETWEEN CESEC-I, CESEC-II, AND CESEC-III

The significant differences impacting analyses between the different CESEC versions, namely CESEC-I, CESEC-II, and CESEC-III are summarized in Figure 18-1.

For all Chapter 15 events for which the pressurizer fluid is calculated to drain into the hot leg, or the system pressure drops below the saturation pressure of the hottest fluid in the system, the hottest fluid will be located in the relatively stagnant upper head region of the reactor vessel. The CESEC-I and CESEC-II versions do not explicitly model the steam formation in the reactor vessel upper head region. The latest version of CESEC, namely CESEC-III, explicitly models steam void formation and collapse in the upper head region of the reactor vessel. Heat transfer from metal structures to the reactor coolant system (RCS) fluid is modeled in addition to flashing of the reactor coolant into steam during depressurization of the RCS. Following the reactor coolant pump (RCP) coastdown due to loss of offsite power or manual shutoff following SIAS, thermalhydraulic decoupling of the upper head region is characterized in the latest version of CESEC by progressively decreasing flow to the upper head from the upper plenum region.

FIGURE 18-1

SUMMARY OF SIGNIFICANT DIFFERENCES

BETWEEN CESEC-I, CESEC-II, AND CESEC-III

MODEL	CESEC-III	CESEC-I, II
THERMALHYDRAULIC*	26 NODES, UPPER HEAD EXPLICITLY MODELED	16 NODES
RCS FLOW	EXPLICITLY MODELED	INPUT TABLE
RCPs	FOUR, EXPLICITLY MODELED	TWO SIMULATED
WALL HEAT	EXPLICITLY MODELED	NONE
SGTR OPTION	CRITICAL FLOW CHECK	DARCY EQUATION
MIXING IN RV	ASYMMETRIC RESPONSE EXPLICITLY MODELED	ASYMMETRIC RESPONSE INCLUDED IN REACTIVITY CALCULATION FOR SLB
3D FEEDBACK	YES	NO

* MASS CONSERVATION: CESEC-I,-II,-III MODELED

ENERGY CONSERVATION: CESEC-II,-III MODELED, CESEC-I ASSUMED

19.0 VERIFICATION

Assessment of CESEC by C-E includes comparisons of code predictions to existing experimental data for C-E operating plants and to other C-E design codes. This information is presented in Appendix I.

Observations that can be made from the CESEC model validation effort against experimental data to date are as follows:

1. CESEC predicts transient response consistent with physical assumptions made.
2. CESEC deviations from test data are in most cases within the uncertainty of the measurement.
3. CESEC satisfactorily predicts the transient response trends for cases that the data collected is not comprehensive enough for performing an in-depth code assessment.
4. CESEC is basically a best estimate code. The conservatism of analyses for Chapter 15 events is mainly introduced through the input rather than the code.

The main conclusion from the CESEC model validation activity to date is that the code is capable of predicting system response for PWR non-LOCA initiating events for a range of operating conditions. Thus, CESEC can be effectively used as a predictive tool for the non-LOCA events analyzed in Chapter 15 of C-E's safety analysis reports. The CESEC verification effort will be continued with the assessment of the code against data which will be gathered during the power ascension testing of San Onofre Unit 2, Waterford Unit 3, St. Lucie Unit 2, and Palo Verde Unit 1.

20.0 REFERENCES

1. CENPD-107, "CESEC-Digital Simulation of a Combustion Engineering Nuclear Steam Supply System", C-E Proprietary Report (April, 1974).

2. CENPD-107, Supplement 1, "ATWS Model Modifications to CESEC", C-E Proprietary Report (September, 1974).

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APPENDIX A

TWO-PHASE PUMP HEAD PERFORMANCE INFORMATION

A.1 Pump Head Degradation Multiplier vs. Void Fraction

Void Fraction (α)	Degradation Multiplier (m_h)
0.0	0.0
0.10	0.0
0.15	0.05
0.24	0.80
0.30	0.96
0.40	0.98
0.60	0.97
0.80	0.90
0.90	0.80
0.96	0.50
1.00	0.0

A.2 Homologous Pump Data for the Difference Between Single-Phase and Degraded Two-Phase Heads

See Table A-1.

TABLE A-1

HOMOLOGOUS PUMP DATA FOR THE DIFFERENCE BETWEEN SINGLE-PHASE AND DEGRADED TWO-PHASE HEADS

$\lvert\frac{\alpha}{\nu}\rvert$ or $\lvert\frac{\nu}{\alpha}\rvert$	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	.10
HAN	0.000	0.833	1.089	1.098	1.048	1.017	1.014	1.012	0.983	0.940	1.000
HVN	0.000	-0.040	0.003	0.095	0.210	0.331	0.449	0.560	0.674	0.804	1.000
HAD	0.000	-0.495	-1.295	-2.090	-2.667	-2.909	-2.786	-2.360	-1.773	-1.242	-1.111
HVD	0.110	0.083	0.054	0.020	-0.023	-0.084	-0.174	-0.307	-0.501	-0.776	-1.111
HAT	0.000	-0.178	-0.345	-0.504	-0.652	-0.792	-0.927	-1.058	-1.188	-1.323	-1.468
HVT	0.110	0.134	0.151	0.152	0.130	0.071	-0.043	-0.230	-0.512	-0.915	-1.467
HAR	0.000	0.667	0.811	0.785	0.761	0.734	0.701	0.655	0.591	0.502	0.380
HVR	[illegible]	-0.043	-0.066	-0.071	-0.058	-0.027	0.021	0.086	0.168	0.266	0.380

LEGEND FOR TABLE A-1

Dependent variables are of the form XYZ. The definition of X, Y, and Z are provided below:

X ≡ H implies a head curve

X ≡ B implies a torque curve

Y ≡ A implies ν/α is the independent variable

Y ≡ V implies α/ν is the independent variable

Z ≡ N implies normal operation (positive flow, positive rotation)

Z ≡ D implies energy dissipation (reverse flow, positive rotation)

Z ≡ T implies turbine operation (reverse flow, reverse rotation)

Z ≡ R implies reverse pump operation (positive flow, reverse rotation)

APPENDIX B

DERIVATION OF THE THERMALHYDRAULIC EQUATIONS

B-1 Physical Assumptions

Physical assumptions used in simplifying the basic differential equations are stated below.

1. The basic differential equations for mass and energy conservation are simplified assuming pressure to be spatially uniform throughout the entire primary coolant system.

2. Each RCS node is assumed to have homogeneous flow. When voids are present, the node is assumed to consist of saturated steam and liquid in thermal equilibrium. Slip between phases is neglected in RCS nodes. (One exception is the closure head node).

3. Complete phase separation is assumed to occur in the pressurizer. The pressurizer node consists of separate steam and liquid regions. Initially (consistent with steady state operation) both regions are assumed to be at saturation. Thereafter, the thermodynamic state of each pressurizer region is calculated including mass and energy transport across the steam-liquid interface as follows. When the steam region is at saturation, instantaneous removal of liquid droplets formed by bulk condensation is assumed. When the water region is at saturation, instantaneous surface evaporation is assumed. If a region is not at saturation, it is not a source for mass or energy transport across the steam-liquid interface (i.e., surface evaporation and surface condensation at the interface are neglected).

4. The spray flow in the pressurizer is assumed to be 100% effective in condensing steam. When the steam region is at saturation, the spray droplets are assumed to reach saturation temperature and can result in bulk condensation, consistent with the basic differential equations for mass and energy conservation. When the steam region is superheated, the spray droplets are assumed to evaporate into the steam region.

B-2 Derivation of Equations

Mass Conservation

$$\dot{m}_i = (\Sigma W)_i = (\Sigma W_{ext})_i + (\Sigma W_{int})_i \qquad \text{B-1}$$

$i = 1, \ldots, 25, S, W$

S = pressurizer steam region, if existing

W = pressurizer liquid region, if existing

Energy Conservation

$$\frac{d}{dt}(m_i h_i) - \dot{p}V_i = Q_i + (\Sigma hW)_i \qquad \text{B-2}$$

which can be written,

$$\dot{m}_i h_i + m_i \dot{h}_i = Q_i + (\Sigma h\dot{W})_i + \dot{p}V_i \qquad \text{B-3}$$

$i = 1, \ldots, 25, S, W$

Constant Volume Node Constraint

$$m_i v_i = V_i = \text{constant}, \; i = 1, \ldots, 25 \qquad \text{B-4}$$

which in differential form can be written,

$$\dot{m}_i v_i + m_i \dot{v}_i = \text{constant}, \; i = 1, \ldots, 25 \qquad \text{B-5}$$

For the pressurizer node which can consist of a steam and a liquid region, the constant volume constraint is:

$$m_s v_s + m_w v_w = V_p = \text{constant} \qquad \text{B-6}$$

which in differential form can be written,

$$\dot{m}_s v_s + m_s \dot{v}_s + \dot{m}_w v_w + m_w \dot{v}_w = 0 \qquad \text{B-7}$$

Equation of State

The following equation of state is applied for subcooled liquid or superheated steam:

$$v_i = v(h_i, p), \; i = 1, \ldots, 25, S, W \qquad \text{B-8}$$

which in differential form can be written,

$$\dot{v}_i = \frac{\partial v_i}{\partial h}\bigg|_p \dot{h}_i + \frac{\partial v_i}{\partial h}\bigg|_h \dot{p}, \; i = 1, \ldots, 25, S, W \qquad \text{B-9}$$

For saturated liquid in the pressurizer, the equations of state are:

$$v_w = v_f(p) \quad \text{B-10}$$

$$h_w = h_f(p) \quad \text{B-11}$$

which can be written in differential form as

$$\dot{v}_w = \frac{dvf}{dp} \dot{p} \quad \text{B-12}$$

$$\dot{h}_w = \frac{dhf}{dp} \dot{p} \quad \text{B-13}$$

For saturated steam in the pressurizer, the equations of state are:

$$v_s = v_g(p) \quad \text{B-14}$$

$$h_s = h_g(p) \quad \text{B-15}$$

which can be written in differential form as

$$\dot{v}_s = \frac{dvg}{dp} \dot{p} \quad \text{B-16}$$

$$\dot{h}_s = \frac{dhg}{dp} \dot{p} \quad \text{B-17}$$

Using Equations B-9, B-12, and B-16, $\dot{v}_i$ for $i = 1,\ldots,25,S,W$ can be eliminated from the basic conservation Equations B-1, B-3, B-5, and B-7. At any given time, the following physical variables are known.

1. heat rates, Q_i
2. external mass flow rates, $(\Sigma W_{ext})_i$
3. external enthalpy transport rates $(\Sigma W_{ext})_i$
4. mass flow rates at the RCS pumps $(w_{24,13}, W_{24,16}, W_{12,1}, W_{12,4})$
5. volumes, V_i
6. pressures, P_{PRE} and P_{SYS}
7. enthalpies, h_i
8. masses, m_i
9. specific volumes, v_i

In addition, the following derivatives are known at any given time (see Reference 4)

$$\left.\frac{\partial v_i}{\partial h}\right|_p \; ; \quad \left.\frac{\partial v_i}{\partial p}\right|_h \; ; \quad \frac{dvf}{dp} \; ; \quad \frac{dhf}{dp} \; ; \quad \frac{dvg}{dp} \; ; \quad \frac{dhg}{dp}$$

The unknowns in Equations B-1, B-3, B-5, and B-7 (assuming elimination of v_i using the equations of state) are:

$\dot{p}$, $\dot{h}_s$ or W_c, $\dot{h}_w$ or W_B, $\dot{m}_s$, $\dot{m}_w$, $\dot{h}_i$ for i = 1,...,25, $\dot{m}_i$ for i = 1,...,25, $W_{1,2}$, $W_{2,3}$, $W_{3,5}$, $W_{5,6}$, $W_{4,2}$, $W_{6,7}$, $W_{7,8}$, $W_{8,9}$, $W_{9,10}$, $W_{10,11}$, $W_{11,12}$, $W_{14,2}$, $W_{19,7}$, $W_{13,14}$, $W_{14,15}$, $W_{15,17}$, $W_{17,18}$, $W_{16,14}$, $W_{18,19}$, $W_{19,20}$, $W_{20,21}$, $W_{21,22}$, $W_{22,23}$, $W_{23,24}$, $W_{25,19} = W_{25,7} = 1/2W_{25}$, $W_{8,26}$

Either $\dot{h}_s$ or W_c are unknowns but not both. Likewise, either $\dot{h}_w$ or W_B are unknowns but not both. W_B and W_c are unknowns which appear in the terms $(\Sigma W_{int})_i$ and $(\Sigma hW_{int})_i$ for i = S,W when either region of the pressurizer is at saturation. For this condition, Equations B-13 and B-17 can be used to eliminate $\dot{h}_w$ or $\dot{h}_s$.

Thus, we have identified 80 equations and 81 unknowns. Consequently, one additional constraint equation is necessary. The additional equation was selected by assuming that the axial pressure drop for the two parallel halves of the reactor core are equal. This can be expressed as:

$$W_{3,5}^2 v_3 = W_{15,17}^2 v_{15} \qquad \text{B-18}$$

or

$$W_{3,5}\sqrt{v_3} - W_{15,17}\sqrt{v_{15}} = 0 \qquad \text{B-19}$$

Therefore, Equations B-1, B-3, B-5, B-7, and B-9 are a set of 81 linear simultaneous equations involving 81 unknowns. This set of equations could be solved numerically for all unknowns. In order to reduce computation time, the set of 81 equations was analytically reduced to a set of 29 equations and 29 unknowns. The analytical simplification for nodes 1 through 25 follows.

Equation B-3 for conservation of energy may be written:

$$m_i\dot{h}_i = -\dot{m}_i h_i + Q_i + (\Sigma hW)_i + \dot{p}V \qquad \text{B-20}$$

Combining Equations B-5 and B-9

$$\dot{m}_i v_i + m_i \dot{h}_i \left.\frac{\partial v_i}{\partial h}\right|_p + m_i \left.\frac{\partial v_i}{\partial p}\right|_h \dot{P} = 0 \qquad \text{B-21}$$

Substituting Equation B-20 into B-21 yields

$$\dot{m}_i v_i + \left.\frac{\partial v_i}{\partial h}\right|_p \left[-\dot{m}_i h_i + Q_i + (\Sigma hW)_i + \dot{p}V\right] + m_i \left.\frac{\partial v_i}{\partial p}\right|_h \dot{p} = 0 \qquad \text{B-22}$$

Expressing $(\Sigma W)_i$ as the sum of net flow from connected nodes and net flow from external flows and $(\Sigma hW)_i$ as a sum of net enthalpy transport rate due to flows from connected nodes and due to external flows, we have:

$$(\Sigma W)_i = (\Sigma W_{ext})_i + (\Sigma W_{int})_i \qquad \text{B-23}$$

$$(\Sigma hW)_i = (\Sigma hW_{ext})_i + (\Sigma hW_{int})_i \qquad \text{B-24}$$

and defining terms as follows:

$$\beta_i = v_i - h_i \left.\frac{\partial v_i}{\partial h}\right|_p \qquad \text{B-25}$$

$$\alpha_i = \left.\frac{\partial v_i}{\partial h}\right|_p \qquad \text{B-26}$$

$$\delta_i = V_i \left.\frac{\partial v_i}{\partial h}\right|_p + m_i \left.\frac{\partial v_i}{\partial p}\right|_h \qquad \text{B-27}$$

$$\epsilon_i = -Q_i \left.\frac{\partial v_i}{\partial h}\right|_p - \beta_i (\Sigma W_{ext})_i - \alpha_i (\Sigma hW_{ext})_i \qquad \text{B-28}$$

yields the following equation:

$$\beta_i (\Sigma W_{int})_i + \alpha_i (\Sigma hW_{int})_i + \delta_i \dot{P} = \epsilon_i \qquad \text{B-29}$$

$i = 1,...,25$

This equation describes the conservation of mass and energy for each coolant node except the pressurizer. The specific nodal equations for i = 1,25 consistent with Figure 1 follow. The definition of $h_{\substack{i\\j}} = \begin{cases} h_i & W > 0 \\ h_j & W < 0 \end{cases}$ is used for enthalpy.

Node 1

$$-(\beta_1 + \alpha_1 h_{\substack{1\\2}})W_{1,2} + \delta_1\dot{P} = \varepsilon_1 - (\beta_1 + \alpha_1 h_{\substack{12\\1}})\ W^R_{P1} \qquad \text{B-30}$$

where

$$(\Sigma W_{ext})_1 = W_{si} + W_{charging} - W_{sprays}$$

$$(\Sigma hW_{ext})_1 = h_{si}\ W_{si} + h_{charging}\ W_{charging} - h_{sprays}W_{sprays}$$

Node 2

$$(\beta_2 + \alpha_2 h_{\substack{1\\2}})W_{1,2} - (\beta_2 + \alpha_2 h_2)(1 + F_I)W_{2,3} + (\beta_2 + \alpha_2 h_{\substack{14\\2}})W_{14,2} \qquad \text{B-31}$$

Node 3

$$(\beta_3 + \alpha_3 h_2)W_{2,3} + (\beta_3 + \alpha_3 h_{14}) \cdot F_I \cdot W_{14,15} - (\beta_3 + \alpha_3 h_3)(1 + F_B)W_{3,5}$$
$$+ \delta_3\dot{P} = \varepsilon_3 \qquad \text{B-32}$$

Node 4

$$-(\beta_4 + \alpha_4 h_{\substack{4\\2}})W_{4,12} + \delta_4\dot{P} = \varepsilon_4 - (\beta_4 + \alpha_4 h_{\substack{12\\4}})W^R_{P2} \qquad \text{B-33}$$

where

$$(\Sigma W_{ext})_4 = W_{si} + W_{charging} - W_{sprays}$$
$$(\Sigma hW_{ext})_4 = h_{si}W_{si} + h_{charging}W_{charging} - h_{sprays}W_{sprays}$$

Node 5

$$(\beta_5 + \alpha_5 h_3)W_{3,5} - (\beta_5 + \alpha_5 h_5')W_{5,6} + \delta_5\dot{P} = \varepsilon_5 \qquad \text{B-34}$$

where h_5' is the enthalpy at the outlet of node 5 (core).

Node 6

$$(\beta_6 + \alpha_6 h'_5)\, W_{5,6} + (\beta_6 + \alpha_6 h_3)\, F_R W_{3,5} - (\beta_6 + \alpha_6 h_6)(1 + F_o + F_H)\, W_{6,7} + \delta_6 \dot{P} = \varepsilon_6 \qquad \text{B-35}$$

Node 7

$$(\beta_7 + \alpha_7 h_6)\, W_{6,7} + (\beta_7 + \alpha_7 h_{18})\, F_o W_{18,19} + (\beta_7 + \alpha_7 h_{\substack{19\\7}})\, W_{19,7} + 0.5\,(\beta_7 + \alpha_7 h_{\substack{25\\7}})\, W_{25} - (\beta_7 + \alpha_7 h_{\substack{7\\8}})\, W_{7,8} + \delta_7 \dot{P} = \varepsilon_7 \qquad \text{B-36}$$

Node 8

$$(\beta_8 + \alpha_8 h_{\substack{7\\8}})\, W_{7,8} - (\beta_8 + \alpha_8 h_{\substack{8\\9}})\, W_{8,9} - (\beta_8 + \alpha_8 h_{\substack{8\\26}})\, W_{8,26} + \delta_8 \dot{P} = \varepsilon_8 \qquad \text{B-37}$$

Node 9

$$(\beta_9 + \alpha_9 h_{\substack{8\\9}})\, W_{8,9} - (\beta_9 + \alpha_9 h'_{\substack{9\\10}})\, W_{9,10} + \delta_9 \dot{P} = \varepsilon_9 \qquad \text{B-38}$$

where $h'_{\substack{9\\10}}$ is the enthalpy at the intersection of nodes 9 and 10.

Node 10

$$(\beta_{10} + \alpha_{10} h'_{\substack{9\\10}})\, W_{9,10} - (\beta_{10} + \alpha_{10} h'_{\substack{10\\11}})\, W_{10,11} + \delta_{10} \dot{P} = \varepsilon_{10} \qquad \text{B-39}$$

where $h'_{\substack{10\\11}}$ is the enthalpy at the intersection of nodes 10 and 11.

Node 11

$$(\beta_{11} + \alpha_{11} h'_{\substack{10\\11}})\, W_{10,11} - (\beta_{11} + \alpha_{11} h'_{\substack{11\\12}})\, W_{11,12} + \delta_{11} \dot{P} = \varepsilon_{11} \qquad \text{B-40}$$

where $h'_{\substack{11\\12}}$ is the enthalpy at the intersection of nodes 11 and 12.

Node 12

$$(\beta_{12} + \alpha_{12} h'_{\substack{11\\12}})\, W_{11,12} + \delta_{12} \dot{P} = \varepsilon_{12} + (\beta_{12} + \alpha_{12} h_{\substack{12\\1}})\, W^R_{P1} + (\beta_{12} + \alpha_{12} h_{\substack{12\\4}})\, W^R_{P2} \qquad \text{B-41}$$

Node 13

$$-(\beta_{13}+\alpha_{13}h_{\substack{13\\14}})\,W_{13,14}+\delta_{13}\dot{P}=\varepsilon_{13}-(\beta_{13}+\alpha_{13}h_{\substack{24\\13}})\,W^{L}_{p\,1} \qquad \text{B-42}$$

where

$$(\Sigma W_{ext})_{13}=W_{si}+W_{charging}-W_{letdown}$$

$$(\Sigma hW_{ext})_{13}=h_{si}W_{si}+h_{charging}W_{charging}-h_{letdown}W_{letdown}$$

Node 14

$$(\beta_{14}+\alpha_{14}h_{\substack{13\\14}})\,W_{13,14}-(\beta_{14}+\alpha_{14}h_{\substack{14\\2}})\,W_{14,2}-(\beta_{14}+\alpha_{14}h_{14})\,(1+F_I)\,W_{14,15}+\delta_{14}\dot{P}=\varepsilon_{14} \qquad \text{B-43}$$

Node 15

$$(\beta_{15}+\alpha_{15}h_{14})\,W_{14,15}+(\beta_{15}+\alpha_{15}h_{2})\,F_I\cdot W_{2,3}-(\beta_{15}+\alpha_{15}h_{15})(1+F_B)W_{15,17}+\delta_{15}\dot{P}=\varepsilon_{15} \qquad \text{B-44}$$

Node 16

$$-(\beta_{16}+\alpha_{16}h_{\substack{16\\14}})\,W_{16,14}+\delta_{16}\dot{P}=\varepsilon_{16}-(\beta_{16}+\alpha_{16}h_{\substack{24\\16}})\,W^{L}_{p\,2} \qquad \text{B-45}$$

where

$$(\Sigma W_{ext})_{16}=W_{si}+W_{charging}-W_{letdown}$$

$$(\Sigma hW_{ext})_{16}=h_{si}W_{si}+h_{charging}W_{charging}-h_{letdown}W_{letdown}$$

Node 17

$$(\beta_{17}+\alpha_{17}h_{15})\,W_{15,17}-(\beta_{17}+\alpha_{17}h'_{17})\,W_{17,18}+\delta_{17}\dot{P}=\varepsilon_{17} \qquad \text{B-46}$$

where h'_{17} is the enthalpy at the outlet of node 17 (core).

Node 18

$$(\beta_{18}+\alpha_{18}h'_{17})\,W_{17,18}+(\beta_{18}+\alpha_{18}h_{15})\,F_B\cdot W_{15,17}-(\beta_{18}+\alpha_{18}h_{18})(1+F_o+F_H)\,W_{18,19}+\delta_{18}\dot{P}=\varepsilon_{18} \qquad \text{B-47}$$

Node 19

$$(\beta_{19} + \alpha_{19} h_{18})\, W_{18,19} + (\beta_{19} + \alpha_{19} h_{6})\; F_o \cdot W_{6,7} + 0.5\,(\beta_{19} + \alpha_{19} h_{25})\, W_{\substack{25\\19}}$$
$$- (\beta_{19} + \alpha_{19} h_{\substack{19\\7}})\, W_{19,7} - (\beta_{19} + \alpha_{19} h_{\substack{19\\20}})\, W_{19,20} + \delta_{19} \dot{P} = \epsilon_{19} \qquad \text{B-48}$$

Node 20

$$(\beta_{20} + \alpha_{20} h_{\substack{19\\20}})\, W_{19,20} - (\beta_{20} + \alpha_{20} h_{\substack{20\\21}})\, W_{20,21} + \delta_{20} \dot{P} = \epsilon_{20} \qquad \text{B-49}$$

Node 21

$$(\beta_{21} + \alpha_{21} h_{\substack{20\\21}})\, W_{20,21} - (\beta_{21} + \alpha_{21} h'_{\substack{21\\22}})\, W_{21,22} + \delta_{21} \dot{P} = \epsilon_{21} \qquad \text{B-50}$$

where $h'_{\substack{21\\22}}$ is the enthalpy at the intersection of nodes 21 and 22.

Node 22

$$(\beta_{22} + \alpha_{22} h'_{\substack{21\\22}})\, W_{21,22} - (\beta_{22} + \alpha_{22} h'_{\substack{22\\23}}) + \delta_{22} \dot{P} = \epsilon_{22} \qquad \text{B-51}$$

where $h'_{\substack{22\\23}}$ is the enthalpy at the intersection of nodes 22 and 23.

Node 23

$$(\beta_{23} + \alpha_{23} h'_{\substack{22\\23}})\, W_{22,23} - (\beta_{23} + \alpha_{23} h'_{\substack{23\\24}})\, W_{23,24} + \delta_{23} \dot{P} = \epsilon_{23} \qquad \text{B-52}$$

where $h'_{\substack{23\\24}}$ is the enthalpy at the intersection of nodes 23 and 24.

Node 24

$$(\beta_{24} + \alpha_{24} h'_{\substack{23\\24}})\, W_{23,24} + \delta_{24} \dot{P} = \epsilon_{24} + (\beta_{24} + \alpha_{24} h_{\substack{24\\13}})\, W^L_{p1} + (\beta_{24} + \alpha_{24} h_{\substack{24\\16}})\, W^L_{p2} \qquad \text{B-53}$$

Node 25

$$(\beta_{25} + \alpha_{25} h_{\substack{6\\25}})\; F_H W_{6,25} + (\beta_{25} + \alpha_{25} h_{\substack{18\\25}})\, F_H W_{18,19} - (\beta_{25} + \alpha_{25} h_{25})\, W_{25} + \delta_{25} \dot{P} = \epsilon_{25} \qquad \text{B-54}$$

The pressurizer equations will be derived next. When both the steam and liquid regions exist in the pressurizer, any of the following 4 pressurizer states can occur:

State 1: Superheated steam, subcooled liquid

State 2: Superheated steam, saturated liquid

State 3: Saturated steam, subcooled liquid

State 4: Saturated steam, saturated liquid

When only a single phase exists in the pressurizer, any of the following 4 states can occur:

State 5: Superheated steam, no liquid

State 6: Saturated steam, no liquid

State 7: Subcooled liquid, no steam

State 8: Saturated liquid, no steam

<u>State 1: Superheated Steam, Subcooled Liquid</u>

Using Equations B-1 and B-2 for conservation of mass and energy, respectively, and the definitions from Equations B-23 and B-23, we obtain for the steam and liquid regions:

$$- m_s v_s \dot{p} + h_s (\Sigma W_{int})_s - (\Sigma hW_{int})_s + m_s \dot{h}_s = Q_s + (\Sigma hW_{ext})_s - h_s(\Sigma W_{ext})_s \qquad \text{B-55}$$

$$-m_w v_w \dot{p} + h_w (\Sigma W_{int})_w - (\Sigma hW_{int})_w + m_w \dot{h}_w = Q_w + (\Sigma hW_{ext})_w - h_w(\Sigma W_{ext})_w \qquad \text{B-56}$$

For this state $(\Sigma W_{int})_s$ and $(\Sigma hW_{int})_s$ are zero since there is no flow or enthalpy transport between the liquid and steam phase. The terms $(\Sigma W_{ext})_s$ and $(\Sigma hW_{ext})_s$ include the mass flow rate and enthalpy transport due to sprays, relief valves, and safety valves. Q_s is the net heat rate into the steam region due to wall heat losses. The terms $(\Sigma W_{int})_w$ and $(\Sigma hW_{int})_w$ are

$$(\Sigma W_{int})_w = W_{8,26} \qquad \text{B-57}$$

$$(\Sigma hW_{int})_w = h_{srg} W_{8,26} \qquad \text{B-58}$$

where

$$h_{srg} = \begin{cases} h_g, & W_{8,26} > 0 \\ h_w, & W_{8,26} < 0 \end{cases} \qquad \text{B-59}$$

Consequently, Equations B-55 and B-56 become:

$$-m_s v_s \dot{P} + m_s \dot{h}_s = Q_s + (\Sigma hW_{ext})_s - h_s(\Sigma W_{ext})_s \qquad \text{B-60}$$

$$-m_w v_w \dot{P} + \left[h_w - h_{srg}\right] W_{8,26} + m_w \dot{h}_w = Q_w + (\Sigma hW_{ext})_w - h_w(\Sigma W_{ext})_w \qquad \text{B-61}$$

Substituting the mass balance (Equation B-1) and steam properties into the constant volume constraint (Equation B-7) yields:

$$\left[m_s \left.\frac{\partial v_s}{\partial p}\right|_h + m_w \left.\frac{\partial v_w}{\partial p}\right|_h\right] \dot{P} + v_w W_{8,26} + m_s \left.\frac{\partial v_s}{\partial h}\right|_p \dot{h}_s + m_w \left.\frac{\partial v_w}{\partial h}\right|_p \dot{h}_w = - v_s (\Sigma W_{ext})_s - v_w (\Sigma W_{ext})_w \quad \text{B-62}$$

These equations (B-60, B-61, and B-62) describe the conservation of mass and energy consistent with the equation of state and the pressurizer constant volume constraint for pressurizer State 1.

<u>State 2: Superheated Steam, Saturated Liquid</u>

In a similar manner we derive the equations for state 2:

$$- m_s v_s \dot{P} + m_s \dot{h}_s + \left(h_s - h_g\right) W_B = Q_s + (\Sigma h W_{ext})_s - h_s (\Sigma W_{ext})_s \quad \text{B-63}$$

$$\left[\frac{dhf}{dp} - v_f\right] m_w \dot{P} + \left(h_f - h_{srg}\right) W_{8,26} + \left(h_g - h_f\right) W_B = Q_w + (\Sigma h W_{ext})_w - h_f (\Sigma W_{ext})_w \quad \text{B-64}$$

$$\left(m_s \left.\frac{\partial v_s}{\partial p}\right|_h + m_w \frac{dv_f}{dp}\right) \dot{P} + v_f W_{8,26} + m_s \left.\frac{\partial v_s}{\partial dh}\right|_p \dot{h}_s + \left(v_s - v_f\right) W_B = -v_s (\Sigma W_{ext})_s - v_f (\Sigma W_{ext})_w \quad \text{B-65}$$

<u>State 3: Saturated Steam, Subcooled Liquid</u>

$$\left(\frac{dhg}{dp} - v_g\right) m_s \dot{P} + \left(h_f - h_g\right) W_c = Q_s + (\Sigma h W_{ext})_s - h_g (\Sigma W_{ext})_s \quad \text{B-66}$$

$$- m_w v_w \dot{P} + \left(h_w - h_{srg}\right) W_{8,26} + \left(h_w - h_f\right) W_c + m_w \dot{h}_w = Q_w + (\Sigma h W_{ext})_w - h_w (\Sigma W_{ext})_w \quad \text{B-67}$$

$$\left[m_s \frac{dv_g}{dp} + m_w \left.\frac{\partial v_w}{\partial p}\right|_h\right]\dot{P} + v_w W_{8,26} + \left(v_w - v_g\right) W_c + m_w \left.\frac{\partial v_w}{\partial h}\right|_p \dot{h}_w = \qquad \text{B-68}$$

$$-v_g (\Sigma W_{ext})_s - v_w (\Sigma W_{ext})_w$$

State 4: Saturated Steam, Saturated Liquid

$$\left(\frac{dh_g}{dp} - v_g\right) m_s\dot{P} + \left(h_f - h_g\right) W_c = Q_s + (\Sigma hW_{ext})_s - h_g (\Sigma W_{ext})_s \qquad \text{B-69}$$

$$\left(\frac{dhf}{dp} - v_f\right) m_w\dot{P} + \left(h_f - h_{srg}\right) W_{8,26} + \left(h_g - h_f\right) W_B = Q_w + \qquad \text{B-70}$$

$$(\Sigma hW_{ext})_w - h_f(\Sigma W_{ext})_w$$

$$\left(m_s \frac{dvs}{dp} + m_w \frac{dvf}{dp}\right)\dot{P} + v_f W_{8,26} + \left(v_f - v_g\right) W_C + \left(v_g - v_f\right) W_B \qquad \text{B-71}$$

$$= - v_g (\Sigma W_{ext})_s - v_w (\Sigma W_{ext})_w$$

State 5: Superheated Steam, No liquid

$$-V_p\dot{P} + W_{8,26}(h_s - h_{srg}) + m_s\dot{h}_s = Q_s + (\Sigma hW_{ext})_s - h_s (\Sigma W_{ext})_s \qquad \text{B-72}$$

$$m_s \left.\frac{\partial v_g}{\partial p}\right|_h \dot{P} + v_s W_{8,26} + m_s \left.\frac{\partial v_s}{\partial h}\right|_p \dot{h}_s = - v_s(\Sigma W_{ext})_s \qquad \text{B-73}$$

State 6: Saturated Steam, No Liquid

$$\left(m_s \frac{dh_g}{dp} - V_p\right)\dot{P} + W_{8,26}(h_g - h_{srg}) + \left(h_f - h_g\right) W_C = Q_s + (\Sigma hW_{ext})_s - h_g (\Sigma W_{ext})_s \qquad \text{B-74}$$

$$m_s \frac{dv_g}{dp}\dot{P} - v_g W_c + v_g W_{8,26} = - v_g(\Sigma W_{ext})_s \qquad \text{B-75}$$

State 7: Subcooled Liquid, No Steam

$$- V_p \dot{P} + \left(h_w - h_{srg}\right) W_{8,26} + m_w \dot{h}_w = Q_w + (\Sigma hW_{ext})_w - h_w \, (\Sigma W_{ext})_w \qquad \text{B-76}$$

$$m_w \left.\frac{\partial v_w}{\partial p}\right|_h \dot{P} + v_w W_{8,26} + m_w \left.\frac{\partial v_w}{\partial h}\right|_p \dot{h}_w = - v_w \, (\Sigma W_{ext})_w \qquad \text{B-77}$$

State 8: Saturated Liquid, No Steam

$$\left(m_w \frac{dh_f}{dp} - V_p\right) \dot{P} + \left(h_f - h_{srg}\right) W_{8,26} + \left(h_g - h_f\right) W_B = Q_w + (\Sigma hW_{ext})_w - h_f (\Sigma W_{ext})_w \qquad \text{B-78}$$

$$m_w \frac{dv_f}{dp} \dot{P} + v_f W_{8,26} = - v_f (\Sigma W_{ext})_w \qquad \text{B-79}$$

For this state, boiling flow is included when the pressurizer valves are open. The single phase saturated liquid state can exist only if the relief and safety valve flow rate exceeds the rate of formation of saturated steam due to boiling at the top of the pressurizer. In deriving the equations for this pressurizer state, it is assumed that $W_B \leq W_{valve}$, where W_{valve} = total mass flow rate (lbm/sec) through the pressurizer relief and safety valves. We also define h_{valve} = average specific enthalpy (Btu/lbm) of the above flow, W_{valve}. It is assumed that there is no slip between phases at the valves, so that the relation

$$h_{valve} W_{valve} = h_g W_B + h_f (W_{valve} - W_B) \qquad \text{B-80}$$

is applicable. In deriving the equations for this state, we have used:

$$(\Sigma hW_{ext})_w = - h_{valve} W_{valve} + h_{spray} W_{spray} \qquad \text{B-81}$$

This can be re-expressed as

$$(\Sigma hW_{ext})_w = (\Sigma hW_{ext})_w' - (h_g - h_f) W_B \qquad \text{B-82}$$

where $(\Sigma hW_{ext})_w' = - h_f W_{valve} + h_{spray} W_{spray}$ B-83

APPENDIX C

THE THOM AND MARTINELLI-NELSON TWO-PHASE PRESSURE DROP CORRELATIONS

The CESEC code has a treatment of two-phase multipliers based on a combination of the Thom and Martinelli-Nelson correlations. The Thom correlation is used down to pressures of 250 psia at which pressure the code then switches to calculate the two-phase multipliers based on the Martinelli-Nelson correlation. The switch at 250 psia takes place because the data taken on unheated pipes applies only down to this pressure. The transition from the Thom correlation to the Martinelli-Nelson correlation is made by a step-wise change. At low pressures the Martinelli-Nelson correlation is still considered the best.

The Thom two-phase multipliers are given as functions of pressure and quality. CESEC uses the unheated tube data (see Table C-1).

The formulation of the modified Martinelli-Nelson correlation presently employed by the code is as follows. Note that bulk boiling is assumed. in the flow paths. When the quality is 0.0, the two-phase multiplier is set equal to 1.0

In the bulk boiling range where the quality, x, is >0.0, the following equations are used for the calculation of the two phase multiplier.

For pressures, P, less than or equal to 2000 psia ϕ^2 is given by:

$$\phi^2 = 1.0 \qquad 0 \leq X \geq 0.02 \qquad \text{(C-1)}$$

TABLE C-1

VALUES OF FRICTION MULTIPLIER USED IN THOM'S CORRELATION FOR UNHEATED TUBES AS A FUNCTION OF PRESSURE AND QUALITY

		Pressure (psia)				
	Quality	250	600	1250	2100	3000
1	0.0	1.00	1.00	1.00	1.00	1.00
2	.010	2.12	1.46	1.10	1.00	1.00
3	.015	2.71	1.60	1.16	1.00	1.00
4	.020	3.22	1.79	1.22	1.06	1.00
5	.030	4.29	2.13	1.35	1.11	1.00
6	.040	5.29	2.49	1.48	1.16	1.00
7	.050	6.29	2.86	1.62	1.21	1.02
8	.060	7.25	3.23	1.77	1.26	1.03
9	.070	8.20	3.61	1.92	1.31	1.04
10	.080	9.15	3.99	2.07	1.37	1.05
11	.090	10.1	4.38	2.22	1.42	1.06
12	.100	11.1	4.78	2.39	1.48	1.08
13	.150	15.8	6.60	3.03	1.75	1.16
14	.200	20.6	8.42	3.77	2.02	1.24
15	.300	30.2	12.1	5.17	2.57	1.40
16	.400	39.8	15.8	6.59	3.12	1.57
17	.500	49.4	19.5	8.03	3.69	1.73
18	.600	59.1	23.2	9.49	4.27	1.88
19	.700	68.8	26.9	10.19	4.86	2.03
20	.800	78.7	30.7	12.40	5.45	2.18
21	.900	88.6	34.5	13.80	6.05	2.33
22	1.000	98.86	38.3	15.33	6.664	2.480

$$\phi^2 = \frac{X^{(0.9326 - 0.226\times10^{-3}\,P)}}{1.65\times10^{-3} + P\,[\,2.988\times10^{-5} + P\,(-2.528\times10^{-9}) + P^2\,(1.14\times10^{-11})\,]}$$

$$0.02 < X \leq 0.2 \qquad \text{(C-2)}$$

$$\phi^2 = \frac{X^{(1.0205 - 0.2053\times10^{-3}\,P)}}{7.876\times10^{-4} + P\,[\,3.177\times10^{-5} + P\,(-8.728\times10^{-9}) + P^2\,(1.073\times10^{-11})\,]}$$

$$0.2 < X \leq 1.0 \qquad \text{(C-3)}$$

The values of ϕ^2 are then corrected for mass velocity, thus, the following equations are yielded for low pressure (<1850 psia) bulk boiling

for $G > 0.7\times10^6$

$$\phi^2 = \left[1.26 - 0.0004\,P + 0.119\left(\frac{10^6}{G}\right) + 0.00028\,P\left(\frac{10^6}{G}\right)\right]\phi^2 \qquad \text{(C-4)}$$

for $G \leq 0.7\times10^6$:

$$\phi^2 = \left[1.36 + 0.0005\,P + 0.1\left(\frac{G}{10^6}\right) - 0.000714\,P\left(\frac{G}{10^6}\right)\right]\phi^2 \qquad \text{(C-5)}$$

APPENDIX D

DERIVATION OF ENTHALPY TRANSPORT EQUATION (CORE AND STEAM GENERATOR NODES)

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[5]

In the steam generator nodes, a reference exit temperature is calculated for comparison with the calculated exit temperature to insure that the heat transfer has not violated the 2nd law of thermodynamics. The reference temperature of the exiting flow of a node for heat transfer into the secondary side must be $\geq$ to $T_{secondary}$. For heat transfer into the primary side, the reference temperature must be $\leq$ to $T_{secondary}$.

If the temperature of the exiting flow does not violate the 2nd law, then the solution progresses without corrections. However, if the calculated temperature does not satisfy the applicable constraint (see previous paragraph), then the enthalpy of the exiting flow is recalculated.

For subcooled water and two-phase fluid, the exiting enthalpy is set equal to the node enthalpy:

$$h_{\ell}(t + \Delta t) = h_{node} \qquad \text{(D-15)}$$

When the exit fluid temperature is set equal to the reference temperature, the net heat transfer rate into the node must be recalculated using Equations D-13, D-14, and D-15 and solving for Q. If the temperature of the primary fluid is close to the temperature of the secondary side node, it is possible that the heat transfer rate as recalculated will be in the opposite direction from the heat transfer rate originally calculated by the steam generator algorithm. When this condition occurs, the heat transfer rate for the node in question is set equal to zero for that time step.

APPENDIX E

DERIVATION OF THE SURGE ITERATION SCHEME

Let $\Delta\dot{P}_{Th(i)}$ = Delta in pressure between the pressurizer and RCS pressure derivatives with respect to time. Used in the thermal-hydraulic equations to determine the surge mass flowrate, w_s((ith) iteration).

$\Delta\dot{P}_{w_s(i)}$ = Delta in pressure between the pressurizer and RCS pressure derivatives with respect to time. Determined from the solution of the momentum equation ((ith) iteration).

In order for convergence to occur the values of $\Delta\dot{P}_{Th}$ and $\Delta\dot{P}_{w_s}$ must intersect the 45° line shown in Figure E-1 at the same point or the intersections must be within a certain deviation of each other. The deviation is defined by the convergence criterion.

Let $\Delta\dot{P}_{Th(m)}$ be the value used for the mth iteration of the solution of the thermal-hydraulic equations. In order to predict the new value of $\Delta\dot{P}_{w_s(m)}$ let

$$(\Delta\dot{P}_{Th(m)} - \Delta\dot{P}_{Th(m-1)}) \frac{d(\Delta\dot{P}_{w_s})}{d(\Delta\dot{P}_{Th})} = \text{change in } \Delta\dot{P}_{w_s} \qquad (E-1)$$

where,

$$\frac{d(\Delta\dot{P}_{w_s})}{d(\Delta\dot{P}_{Th})} = \frac{\Delta\dot{P}_{w_s(m-1)} - \Delta\dot{P}_{w_s(m-2)}}{\Delta\dot{P}_{Th(m-1)} - \Delta\dot{P}_{Th(m-2)}}$$

As shown in Figure E-1 "a" must equal "b" for convergence to occur, thus,

$$\text{change in } \Delta\dot{P}_{w_s} = \Delta\dot{P}_{Th(m)} - \Delta\dot{P}_{w_s(m-1)} \qquad (E-2)$$

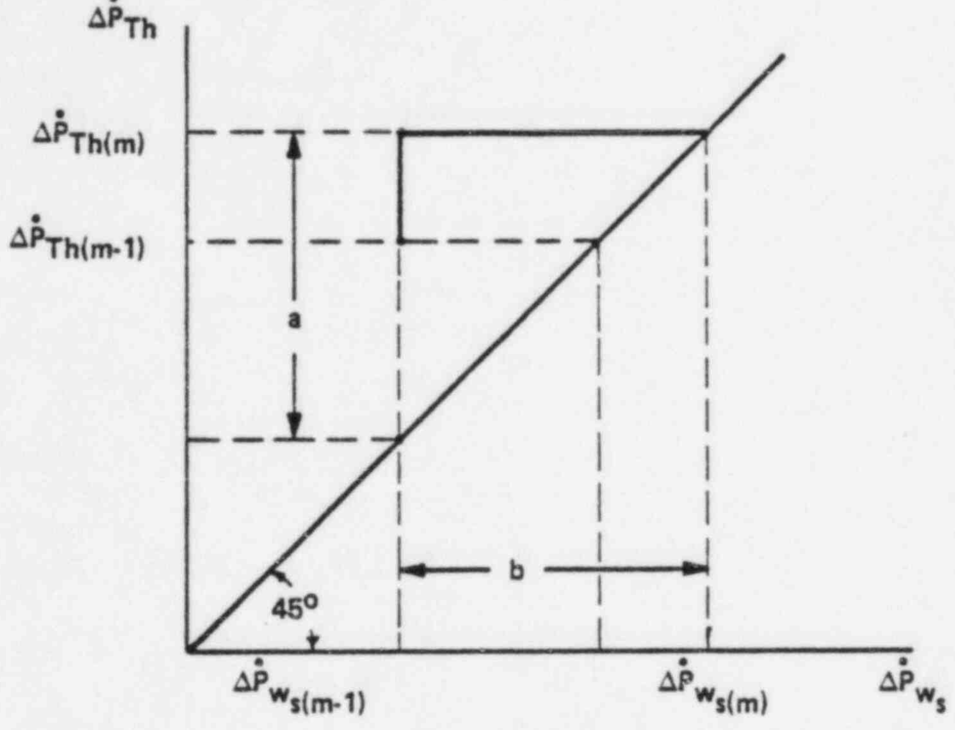
and

$$\Delta\dot{P}_{Th(m)} - \Delta\dot{P}_{Th(m-1)} = \frac{d(\Delta\dot{P}_{Th})}{d(\Delta\dot{P}_{w_s})} (\Delta\dot{P}_{Th(m)} - \Delta\dot{P}_{w_s(m-1)}) \qquad (E-3)$$

Rearranging terms and solving for $\Delta\dot{P}_{Th(m)}$ yields,

$$\Delta\dot{P}_{Th(m)} = \frac{\Delta\dot{P}_{Th(m-1)} - \frac{d(\Delta\dot{P}_{Th})}{d(\Delta\dot{P}_{w_s})} \Delta\dot{P}_{w_s(m-1)}}{1 - \frac{d(\Delta\dot{P}_{Th})}{d(\Delta\dot{P}_{w_s})}} \qquad (E-4)$$

The above equation has the characteristic of predicting the resulting $\Delta\dot{P}_{w_s(m)}$ given a $\Delta\dot{P}_{Th(m)}$. Thus, it intrinsically converges on the proper solution. In coding Equation (E-4), consideration was given to the possibility of the denominator and $d(\Delta\dot{P}_{w_s})$ being equal to zero. The logic built into the code prevents a division by zero.



SURGE LINE ITERATION SCHEME

Figure E-1

APPENDIX F

LETDOWN LINE BREAK MODEL

F.1 Introduction

The model of the letdown line break used in CESEC is briefly described in this appendix. A sample schematic of the main components of the Chemical and Volume Control System (CVCS) associated with the event is shown in Figure F-1. As seen from this figure one end of the letdown line is connected to the cold leg of the Reactor Coolant System (RCS). The letdown flow passes through the tube side of the Regenerative Heat Exchanger (RHX) and to the outside of the containment building through a penetration in the containment wall. The letdown flow is cooled in the RHX by the charging flow in the shell side. The letdown line can be isolated by means of isolation valves inside the containment. A break in the letdown line upstream of the letdown control valve is identified for the purpose of illustrating the model.

The pressure and enthalpy of the primary coolant in the cold leg of the RCS at any given time is known from the CESEC code computations. The letdown line break model iteratively calculates the pressure drop in the letdown line and the heat transfer in the RHX. The flow through the break is computed using critical flow tables.

F.2 Mathematical Model

Two simplifying assumptions are made in the model. The pressure drop in the letdown line assumes single phase (liquid) flow. The heat transfer in the RHX also assumes single phase (liquid) flow in the tube and the shell sides of the RHX.

The single phase turbulent flow pressure drop in the letdown line can be calculated using the Darcy equation

$$\Delta P_{1\to4} = \frac{\dot{m}_1^2}{A^2} \frac{K_{1\to4}}{2\, g_c \bar{\rho}} \qquad \text{(F-1)}$$

where,

$\Delta P_{1\to4}$ is the pressure drop between points 1 and 4 in the letdown line (see Figure F-1), lbf/ft^2

$\dot{m}_1$ is the letdown flow rate, lbm/hr

A is the cross sectional area of the letdown line, ft^2

g_c is the gravitational constant (4.17×10^8 lbm ft/lbf hr^2)

$\bar{\rho}$ is the average density of the coolant in the letdown line, lbm/ft^3

$K_{1\to4}$ is the total loss coefficient (i.e., friction + entrance + exit + bends) and is assumed to be constant.

The pressure at the break location (location 4 in Figure F-1) is given by

$$\Delta P_4 = P_1 - P_{1\to4} \qquad \text{(F-2)}$$

The pressure drop between points 1 and 4 is smaller for single phase flow than for corresponding two-phase phase flow. Consequently, the pressure at the break location would be larger for single phase flow, leading to a larger mass discharge through the break. Hence, the assumption made in the model, that the pressure drop calculation assumes single phase fluid leads to conservative results.

The enthalpy drop of the letdown fluid through the RHX is dependent on the mass flow rates and the inlet temperatures of the letdown and charging fluids.

The temperature of the letdown fluid at the RHX exit is calculated from the following equations:

$$t_{lo} = \frac{t_{ci}\left\{1-\exp\left[\frac{UA(1-R)}{\dot{M}_l\ C_{P_l}}\right]\right\} - t_{li}\ (1-R)}{R - \exp\ \frac{UA(1-R)}{\dot{M}_l\ C_{P_l}}} \tag{F-3}$$

where,

$$R = \frac{\dot{M}_l\ C_{pl}}{\dot{M}_c\ C_{pc}}$$

t_{li} and t_{lo} are the temperatures of the letdown fluid at the RHX inlet and outlet, ^oF.

t_{ci} is the temperature of the charging fluid at the RHX inlet, ^oF

$\dot{M}_l$, $\dot{M}_c$ are letdown and charging flow rates, lbm/hr

C_{P_l}, C_{pc} are the specific heats of letdown and charging fluids, BTU/lbm-^oF

U is the overall heat transfer coefficient, BTU/hr-ft^2-^oF

A is the heat transfer area, ft^2.

The heat transfer coefficient U is dependent on the letdown and charging flow rates. UA is given by the following C-E generated empirical equation.

$$(UA)^{-1} = X \cdot G_l^{-0.8} + Y \cdot G_c^{-0.8} + Z \tag{F-4}$$

where,

G_l and G_c are the letdown and charging flows in gallons/minute.

X,Y, and Z are constants dependent on the design of the RHX.

The enthalpy of the letdown fluid at the exit of the RHX is assumed to be the saturation liquid enthalpy at temperature t_{lo}. Once the pressure and enthalpy of the letdown fluid at the break are computed, the flow through the break can be solved for from the critical flow tables built into CESEC.

F.3 Iterative Procedure

The following iterative procedure is used to calculate the flow through the break

1) A reasonable value is assumed for the pressure drop $\Delta P_{1\to4}$ (e.g., $\Delta P_{1\to4} = \frac{P_{RCS}}{2}$)

2) The pressure at the break location is calculated from Equation F-2.

3) Using Equation F-1 the Darcy flow rate in the letdown line is calculated.

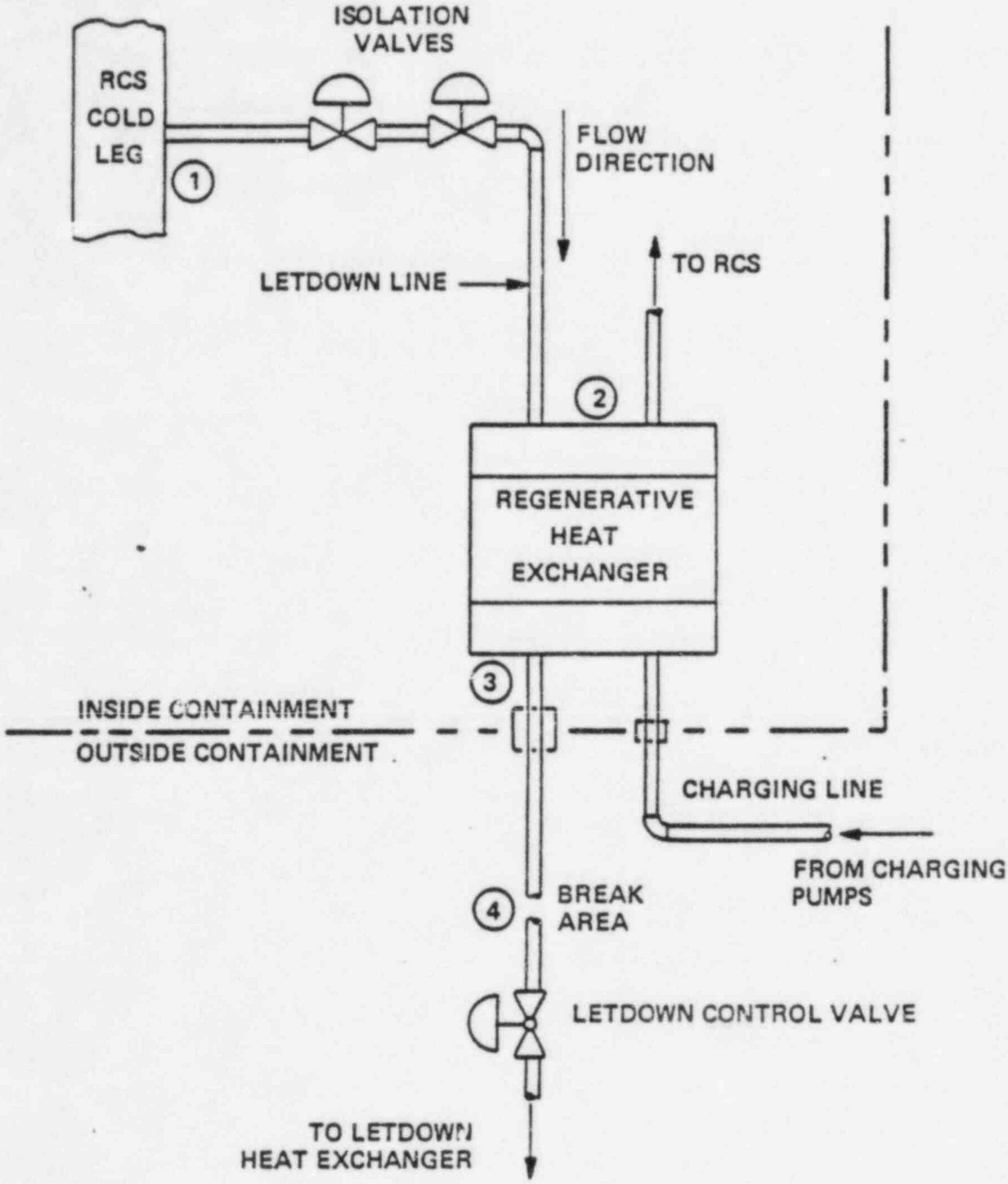
4) Using the Darcy flow rate in Equations F-3 and F-4, the temperature of the letdown flow at the RHX exit and the corresponding saturation enthalpy can be calculated. The values of other parameters such as t_{li}, t_{ci}, and m_c are provided by CESEC.

5) Knowing the pressure and enthalpy at the break location the critical flow through the break is calculated from tables.

6) Steps 1 to 5 are repeated by iterating on ΔP (Newton's method) until the calculated values of the Darcy flow rate and the critical flow agree within a specified criterion.

7) The value of $\overline{\rho}$ (see Equation F-1) is recalculated based on the new flow rate and temperatures. ($\overline{\rho}$ is the average density at P_{RCS} and T when $T = (T_1+T_2)/2$ (See Figure F-1).

8) Steps 1 to 7 are repeated using the new average density until two successive values of $\overline{\rho}$ converge within a specified criterion.



SAMPLE SCHEMATIC
OF MODEL COMPONENTS
Figure F-1

APPENDIX G

FLUID PROPERTY DERIVATIVES

G.1 Pressures Greater than 550 psia

Saturated fluid enthalpy total derivatives (Subroutine DPOLY):

$$\frac{dh_f}{dp} = \sum_{n=1}^{8} nA_n P^{n-1} \tag{G.1}$$

$$\frac{dh_g}{dp} = \sum_{n=1}^{8} nB_n P^{n-1} \tag{G.2}$$

Subcooled water specific volume partial derivatives (Function WATPR):

$$\left.\frac{\partial v}{\partial p}\right|_h = \sum_{k=0}^{4} \left[(C_{k,1}h^k + 2C_{k,2}ph^k)\right] \quad V_{sub}(p,h) \tag{G.3}$$

$$\left.\frac{\partial v}{\partial h}\right|_p = \sum_{n=0}^{2} \left[(C_{1,n}p^n + 2C_{2,n}p^n h + 3C_{3,n}p^n h^2 + 4C_{4,n}p^n h^3)\right] \quad V_{sub}(p,h) \tag{G.4}$$

where

$$V_{sub}(p,h) = \exp\left[Z(p,h)\right] \tag{G.5}$$

$$Z(p,h) = \sum_{k=0}^{4} \sum_{n=0}^{2} C_{k,n} p^n h^k \tag{G.6}$$

Superheated vapor specific volume partial derivatives (Function WATPR):

$$\left.\frac{\partial v}{\partial p}\right|_h = E_2 - E_2 p^{-2} + E_5 h - E_6 h p^{-2} \qquad (G.7)$$

$$\left.\frac{\partial v}{\partial h}\right|_p = E_4 + E_5 p + E_6 p^{-1} \qquad (G.8)$$

Two phase specific volume partial derivatives (Subroutine PRPDER):

$$\left.\frac{\partial v}{\partial p}\right|_h = (1-x)\frac{dv_f}{dp} + x\frac{dv_g}{dp} - \left(\frac{v_g - v_f}{h_g - h_f}\right)\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] \qquad (G.9)$$

$$\left.\frac{\partial v}{\partial h}\right|_p = \frac{v_g - v_f}{h_g - h_f} = \frac{v_{fg}}{h_{fg}} \qquad (G.10)$$

Total derivative of specific volume (Function WATPR):

$$\frac{dv}{dp} = \left.\frac{\partial v}{\partial p}\right|_h + \left.\frac{\partial v}{\partial h}\right|_p \frac{dh}{dp} \qquad (G.11)$$

G.2 Pressures Less Than or Equal to 550 psia

Saturated fluid enthalpy total derivatives (Subroutine PRPDER):

$$\frac{dh_f}{dp} = A1\ (L10E)/\left(P(A2 - \log_{10}(P)\ )^2\right) + A4\ (L10E)/\ p + 2A5\ (\log_{10}(P)\ )L10E/p \qquad (G.12)$$

$$\frac{dh_g}{dp} = \frac{dh_f}{dp} - B1(L10E)/\ \left(p\ (\log_{10}(P) + B2)^2\right) + B4(L10E)/p \qquad (G.13)$$

Subcooled water specific volume partial derivatives, $h \leq 277.2$ BTU/lbm (Subroutine PRPDER):

$$\left.\frac{\partial v}{\partial p}\right|_h = -(C4 + C5h^2 + C6h^4)/(\rho 1^2) \quad (G.14)$$

$$\left.\frac{\partial v}{\partial p}\right|_p = -(2C2h + 4C3h^3 + 2C5ph + 4C6ph^3)/(\rho 1^2) \quad (G.15)$$

where

$$\rho 1 = C1 + C2h^2 + C3h^4 + C4p + C5ph^2 + C6ph^4 \quad (G.16)$$

Subcooled water specific volume partial derivatives, $h > 282.8$ BTU/lbm (Subroutine PRPDER):

$$\left.\frac{\partial v}{\partial p}\right|_h = -(1/\rho 2^2)\left(D4 + \left(1/(h-D3-D6p)\right)\left(D6\left(D2 + D5p\right) / \left(h-D3-D6p\right) + D5\right)\right) \quad (G.17)$$

$$\left.\frac{\partial v}{\partial h}\right|_p = (1/\rho 2^2)(D2 + D5p) / (h - D3 - D6p)^2 \quad (G.18)$$

where

$$\rho 2 = D1 + D4p + (D2 + D5p)/(h - D3 - D6\ p) \quad (G.19)$$

Subcooled water specific volume partial derivatives, $277.2 < h < 282.8$ BTU/lbm (Subroutine PRPDER):

$$\rho_3 = K\rho_1 + (1-K)\ \rho_2 \quad (G.20)$$

where

$$K = (-3S^5 + 10S^3 - 15S + 8)/16 \quad (G.21)$$

$$S = (h - 280)/2.8 \quad (G.22)$$

$$\left.\frac{\partial v}{\partial p}\right|_h = -(1/\rho_3^2)\left(K(C4 + C5h^2 + C6h^4) + (1-K)\left(D4 + (D2 + D5p)D6/(h- D3 - D6p)^2 + D5/(h - D3 - D6p)\right)\right) \quad (G.23)$$

$$\left.\frac{\partial v}{\partial h}\right|_p = -(1/\rho_3{}^2)\ \left(K(2C2h + 4C3h^3 + 2C5ph + 4C6ph^3) + \frac{dK}{dh}(\rho_1 - \rho_2) - (1-K)\ (DZ + D5p)/(h - D3 - D6p)^2\right. \qquad (G.24)$$

where

$$\frac{dK}{dh} = 1/16\ \left(S^2(-5.357143S^2 + 10.71429) - 5.357143\right) \qquad (G.25)$$

Superheated vapor specific volume partial derivatives (Subroutine PRPDER):

$\left.\frac{\partial v}{\partial h}\right|_h$ is given by Equation G.7

$\left.\frac{\partial v}{\partial h}\right|_p$ is given by Equation G.8

The total derivatives of the saturated liquid and saturated vapor specific volumes with respect to pressure are given by Equation G.11.

The equation used for the partial derivatives $\left.\frac{\partial v}{\partial h}\right|_p$ and $\left.\frac{\partial v}{\partial h}\right|_p$ for the case of a two phase mixture are the same as was used for pressures greater than 550 psia except the independent variable derivatives are determined using the BNL functionals.

G.3 Nomenclature and Constants

h	Enthalpy (BTU/lbm)
p	Pressure (psia)
$C_{k,n}$	

k/n	0	1	2
0	-0.41345E + 01	-0.59428E - 05	0.15681E - 08
1	0.13252E - 04	0.63377E - 07	-0.40711E - 10
2	0.15812E - 05	-0.39974E - 09	0.25401E - 12
3	-0.21959E - 08	0.69391E - 12	-0.52372E - 15
4	0.21683E - 11	-0.36159E - 15	0.32503E - 18

v	Specific volume (ft^3/lbm)
x	Quality
v_f	Specific volume of saturated water (ft^3/lbm)
v_g	Specific volume of saturated steam (ft^3/lbm)
h_f	Enthalpy of saturated water (BTU/lbm)
h_g	Enthalpy of saturated steam (BTU/lbm)
A_o	0.182609E + 03
A_1	0.144140E + 01
A_2	-0.387216E - 02
A_3	0.651417E - 05
A_4	-0.638144E - 08
A_5	0.369701E - 11
A_6	-0.124626E - 14
A_7	0.225589E - 18
A_8	-0.169253E - 22
B_0	0.115216E + 04
B_1	0.460395E + 00
B_2	-0.159024E - 02
B_3	0.286502E - 05

B_4	-0.299850E - 08
B_5	0.185137E - 11
B_6	-0.664224E - 15
B_7	0.127776E - 18
B_8	-0.101790E - 22
E_1	$-8.1735849 \times 10^{-4}$
E_2	1.2378514×10^{-5}
E_3	-1.0339904×10^{3}
E_4	$-6.2941689 \times 10^{-6}$
E_5	-8.729216×10^{-9}
E_6	1.2460225
L10E	$\log_{10}(e)$
A1	1376.8
A2	5.1085
A3	-199.78
A4	24.262
A5	1.71
B1	500.0
B2	-4.062
B3	1158.86
B4	-13.56
C1	62.4
C2	-8.73×10^{-5}
C3	2.32×10^{-10}
C4	2.14×10^{-4}
C5	1.43×10^{-9}
C6	-6.2×10^{-15}
D1	92.924
D2	39440.2
D3	1377.35
D4	5.761×10^{-4}
D5	1.6386
D6	0.035704
ρ	Density (lbm/ft^3)

APPENDIX H

DERIVATION OF THE SPECIFIC VOLUME PARTIAL DERIVATIVES FOR A TWO-PHASE MIXTURE

For a two-phase mixture

$$v(p,h) = (1 - x(p,h)\ v_f(p,h_f) + x\ (p,h)v_g\ (p,h_g)$$

For $\left.\frac{\partial v}{\partial h}\right|_p$ we have (H.1)

$$\left.\frac{\partial v}{\partial h}\right|_p = \left.\frac{\partial}{\partial h}(1 - x\ (p,h))\right|_p v_f(p,h_f) + (1 - x(p,h)) \left.\frac{\partial v_f(p,h_f)}{\partial h}\right|_p + \tag{H.2}$$

$$\left.\frac{\partial}{\partial h} x(p,h)\right|_p v_g(p,h_g) + x(p,h) \left.\frac{\partial v_g(p,h_g)}{\partial h}\right|_p$$

and

$$\left.\frac{\partial x\ (p,h)}{\partial h}\right|_p = \left.\frac{\partial}{\partial h}\left(\frac{h-h_f}{h_g-h_f}\right)\right|_p = \frac{1}{h_g-h_f} \tag{H.3}$$

Therefore,

$$\left.\frac{\partial\ v}{\partial\ h}\right|_p = \frac{-v_f}{h_g-h_f} + \frac{v_g}{h_g-h_f} = \frac{v_g-v_f}{h_g-h_f} \tag{H.4}$$

For $\left.\frac{\partial v}{\partial p}\right|_h$ we have

$$\left.\frac{\partial v}{\partial p}\right|_h = \left.\frac{\partial\left(1 - x(p,h)\right)}{\partial p}\right|_h v_f(p,h_f) + \left(1 - x(p,h)\right) \left.\frac{\partial v_f(p,h_f)}{\partial p}\right|_h + \tag{H.5}$$

$$\left.\frac{\partial x(p,h)}{\partial p}\right|_h v_g(p,h_g) + x(p,h) \left.\frac{\partial v_g(p,h_g)}{\partial p}\right|_h$$

and,

$$\left.\frac{\partial x(p,h)}{\partial p}\right|_h = \frac{\partial}{\partial p}\left.\left(\frac{h - h_f(p)}{h_g(p) - h_f(p)}\right)\right|_h \tag{H.6}$$

which yields

$$\left.\frac{\partial\, x(p,h)}{\partial p}\right|_h = -\left(h - h_f(p)\right)\left(h_g(p) - h_f(p)\right)^{-2}\left(\frac{dh_g}{dp} - \frac{dh_f}{dp}\right) -$$

$$\left(h_g(p) - h_f(p)\right)^{-1}\frac{dh_f}{dp}$$

$$\left.\frac{\partial x(p,h)}{\partial p}\right|_h = -\frac{1}{h_g(p) - h_f(p)}\left[x\frac{dh_g}{dp} - x\frac{dh_f}{dp} + \frac{dh_f}{dp}\right]$$

$$\left.\frac{\partial x(p,h)}{\partial p}\right|_h = -\frac{1}{h_g - h_f}\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] \tag{H.7}$$

Therefore,

$$\left.\frac{\partial v}{\partial p}\right|_h = \frac{v_f}{h_g - h_f}\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] + (1-x)\frac{dv_f}{dp} - \frac{v_g}{h_g - h_f}$$

$$\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] + x\frac{dv_g}{dp} \tag{H.8}$$

or

$$\left.\frac{\partial v}{\partial p}\right|_h = (1-x)\frac{dv_f}{dp} + x\frac{dv_g}{dp} - \left(\frac{v_g - v_f}{h_g - h_f}\right)\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] \tag{H.9}$$

In summary, for a two-phase mixture

$$\left.\frac{\partial v}{\partial h}\right|_p = \frac{v_{fg}}{h_{fg}} \tag{H.10}$$

and

$$\left.\frac{\partial v}{\partial p}\right|_h = (1-x)\frac{dv_f}{dp} + x\frac{dv_g}{dp} - \left(\frac{v_{fg}}{h_{fg}}\right)\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] \tag{H.11}$$

The total derivative of specific volume with respect to pressure is

$$\frac{dv}{dp} = (1-x)\frac{dv_f}{dp} + x\frac{dv_g}{dp} - \frac{v_{fg}}{h_{fg}}\left[(1-x)\frac{dh_f}{dp} + x\frac{dh_g}{dp}\right] + \frac{v_{fg}}{h_{fg}}\frac{dh}{dp} \tag{H.12}$$

or

$$\frac{dv}{dp} = (1-x)\frac{dv_f}{dp} + x\frac{dv_g}{dp} + v_{fg}\frac{dx}{dp} \tag{H.13}$$

where

$$\frac{dx}{dp} = \left.\frac{\partial x}{\partial p}\right|_h + \left.\frac{\partial x}{\partial h}\right|_p \frac{dh}{dp} \tag{H.14}$$

APPENDIX I

CODE VERIFICATION

The purpose of the assessment of CESEC is to examine the capability of the code to predict system response for PWR non-LOCA initiating events for a range of operating conditions. This activity includes verification of code/models through comparison to applicable experimental data and benchmarking of code/models through comparison to other code/models performing a similar calculation. The assessment of the code against plant test data satisfies an NRC request that experimental data be used in the verification of safety analysis computer codes.

Direct comparison of CESEC has been performed against the following C-E codes:

1) COAST[1] - Four pump coastdown
2) CEFLASH-4AS[2] - Depressurization event

Qualification of the CESEC code against experimental results includes the following tests:

1) Hot zero power four pump coastdown
2) Turbine trip
3) Natural circulation cooldown

To show the accuracy of the pump model described in Section 4.0, a comparison has been made of the volumetric core flow fraction during a four pump coastdown transient. Figure I-1 shows excellent agreement between the CESEC and COAST codes. The COAST code is an NRC approved digital computer program used by C-E to analyze coastdown transients for the reactor coolant pumps.

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(1) CENPD-98, "COAST CODE DESCRIPTION", April, 1973

(2) Supplement 1 to CENPD-133, "CEFLASH-4AS A Computer Program for the Reactor Blowdown Analysis of the Small Break Loss of Coolant Accident", August, 1979.

Figure I-2 shows a comparsison of the flow fraction predicted by the CESEC code against test data. The data corresponds to a hot zero power coastdown transient performed during the plant start-up of a C-E NSSS. Again excellent agreement is shown between CESEC and the reference data.

To show the adequacy of CESEC in predicting pressurization and depressurization transients, a comparison has been made of the code response during a full power turbine trip test. The test data was compiled during the plant start-up testing of a C-E NSSS. The turbine trip is an event which results in a rapid increase in primary and secondary system pressures. For the test, the plant control systems were all in the automatic mode and operating normally except for the steam dump and bypass control system (SBCS). One atmospheric dump valve (ADV) located downstream of the main steam isolation valves (MSIVs) was isolated and the two atmospheric dump valves located upstream of the MSIVs were in the manual mode.

The test was initiated by manually tripping the main turbine from the control room. The SDBCS responded to the turbine closure by initiating quick open signals to the dump and bypass valves. However, the capacity of the valves to pass steam was degraded to about 45 percent of the full power steam flow. The main feedwater flow which tried to match steam flow was also degraded. Therefore, as a result of the mismatch between energy generation and energy removal, both the primary and secondary systems internal energies increased, the primary and secondary temperatures increased, the primary and secondary pressures increased, and the steam generator level decreased. The pressurizer spray flow also increased in an attempt to moderate the increase in pressurizer pressure. At 6.1 seconds into the transient, the reactor tripped on a steam generator low level water signal. Following the reactor trip, the pressure increases terminated.

After the primary and secondary pressures reached peak values, the pressures began to decline and signals were generated to close both the pressurizer spray valve and the steam dump and bypass valves. The three turbine bypass valves fully closed, but the pressurizer spray valve failed to reseat and the atmospheric dump valve remained fully open. The unexpected failures of these valves enhanced the cooldown of the system. All three charging pumps were automatically activated and a SIAS was generated. The pressurizer pressure and temperature continued to decrease and the pressurizer emptied. Following NRC's directive, the operator shut off all four RCPs after the SIAS was generated. After isolation of the ADV by closure of the MSIVs, following a main steam isolation valve signal (MSIS), the cooldown was terminated and the pressurizer began to refill.

Comparisons of the turbine trip test were performed using the CESEC-I and CESEC-III versions of the CESEC code. Table I-1 summarizes key events during the transient and demonstrates the closeness of the CESEC predictions with test data.

The steam generators 1 and 2 pressure responses are given in Figure I-3. The pressure responses exhibit non-symmetric behavior caused by the non-symmetric steam flow. Steam generator 1 experiences a lower peak pressure and a lower minimum pressure than steam generator 2. This is consistent with the steam flow behavior which is caused by having two bypass valves and the single operable dump valve connected to the steam generator 1 steam line header and only the third bypass valve connected to the steam generator 2 steam line header. The calculated CESEC results agree well with the experimental results as seen from Figure I-3. The peak pressures calculated by CESEC are higher than those recorded in the test. This difference in secondary peak pressure can be partly attributed to the selection of the data values for steam flow which were used for driving CESEC during this initial transient time period.

Figure I-4 shows the response of the pressurizer pressure. The pressurizer pressure calculated by CESEC agrees well with the test results over the entire transient time simulated. The agreement is within the range of uncertainty one would expect to exist from the assumptions made in the analysis and from uncertainty within the data. The pressurizer water level was not directly recorded until about 22 minutes into the event. However, Figure I-5 shows a comparison of the CESEC predicted water volume in the pressurizer against that calculated by related test data. Again as seen from Figures I-4 and I-5, the calculated CESEC results agree well with the experimental results.

The CESEC-III calculated subcooled margin had a minimum value of about 10°F in the closure head node which is the hottest point in the reactor coolant system during the cooldown portion of the transient.

The conclusions from the turbine trip simulation can be summarized as follows:

1. CESEC is able to satisfactorily predict the major features of the transient.

2. Improved information on the experimental steam and feedwater flow rates and feedwater enthalpy would have eliminated much of the uncertainty in the simulation as these parameters were used to drive CESEC. For example, the experimental steam flows level out at a dump capacity of about 12 percent until the MSIVs are closed. Closure of the MSIVs should terminate all steam flow. However, the reduced data indicates a small steam flow fraction. This inconsistency is believed to be due to uncertainty in the ΔP measurement used to calculate steam flow rate at low flow conditions. The uncertainty in the measurement during low flow conditions is the highest. Similarly, this inconsistency was observed in the feedwater flow during low flow conditions. The ramped down design value is 5 percent. However, data indicated a ramped down value of 10 percent of the full power value. Additionally, the emergency feedwater flow was not measured because the test circuitry used to measure this parameter was not available for the test. Finally, the temperature (or enthalpy) of the emergency feedwater was not measured in the test.

To demonstrate CESEC's capability for predicting steam formation in the reactor vessel upper head, a comparison has been made of the code response against data during a natural circulation cooldown. On June 12, 1980 a loss of component cooling water event occurred at a C-E NSSS. The event was initiated by a short across a terminal board which caused the cooling water return valve from the reactor coolant pumps (RCPs) to fail closed. Once the failure was discovered by the operators a manual reactor trip was initiated and all the RCPs were tripped within the next two minutes. RCP 1B1 was started and stopped once thereafter. With the reactor coolant system in a natural circulation mode, the operators began the cooldown by reducing the pressure within the primary system.

This was accomplished by using charging, letdown, and auxiliary spray and by cycling the atmospheric dump valves. At approximately 3.5 hours after reactor trip the operators observed an unexpected rate of pressurizer level increase when depressurizing with the auxiliary spray system. Subsequently, a drop in pressurizer level was observed when charging flow was shifted from the auxiliary spray to the cold legs.

The results of the CESEC analysis are presented in Figures I-6 and I-7. Figure I-6 shows the pressurizer pressure and level as a function of time and Figure I-7 shows the core inlet and outlet temperatures as a function of time (number in parenthesis is wall clock). The plant pressurizer response was simulated in CESEC by the proper selection of charging, sprays, and letdown flows. This information was not available and, thus, in running the code, assumptions had to be made for the simulation of the operator actions in regard to charging, sprays, and letdown.

The following conclusions were drawn from the CESEC simulation of the natural circulation cooldown.

1. The pressurizer liquid response is a good indicator of voiding within the closure head. The pressurizer level behavior occurring after 12000 seconds is the result of a steam bubble being formed in the reactor vessel closure head region and part of the upper plenum. This indicated rate of increase of the pressurizer liquid level is as much as four times as great as should have been caused by the rate of volumetric addition of liquid to the reactor coolant system.

2. The maximum fraction of voids predicted did not exceed the reactor vessel fluid volume above the top of the hot leg nozzle. The CESEC results indicated that the steam bubble reached a maximum size of about 1158 ft^3 before the voids started to collapse. Collapse of the voids was predicted to occur before the hot legs started to void (about 1300 ft^3). Additionally, the CESEC simulation indicated that the voiding did not mitigate to other regions of the reactor coolant system. The reactor vessel outlet temperature was sufficiently subcooled to prevent this phenomenon from occurring.

3. The CESEC code was able to satisfactorily predict the transient response of the natural circulation cooldown event. The code predicted results which were consistent with the physical assumptions made. More information on the transient, such as operator actions annd auxiliary feedwater enthalpy and flow, would have reduced the number of assumptions which had to be made to drive CESEC. Thus, the additional information would have provided a more realistic data base with which to assess the code predictions.

To further substantiate CESEC's capability to simulate depressurization events, a comparison was also made between CESEC and another C-E thermalhydraulic code, CEFLASH-4AS. The event analyzed was a leak in the cold leg piping at the junction between the cold leg and the letdown line. The size of the leak was representative of twice the size of the letdown line. The results shown in Figures I-8 through I-10 should only be viewed in terms of the capability of both codes to simulate the system response resulting from such a leak (e.g., partial depletion of the reactor vessel water inventory) and not in terms of consequences resulting from a letdown line break as analyzed in Chapter 15.6 of a FSAR (e.g., no depletion of reactor vessel water inventory). The assumptions for this analysis in terms of systems operation (e.g., CVCS in manual), location of break (e.g., inside containment), etc., are not compatible with the assumptions made for Chapter 15.6 analyses (e.g., CVCS in automatic) for the limiting letdown line break which for dose consequences is located outside the containment.

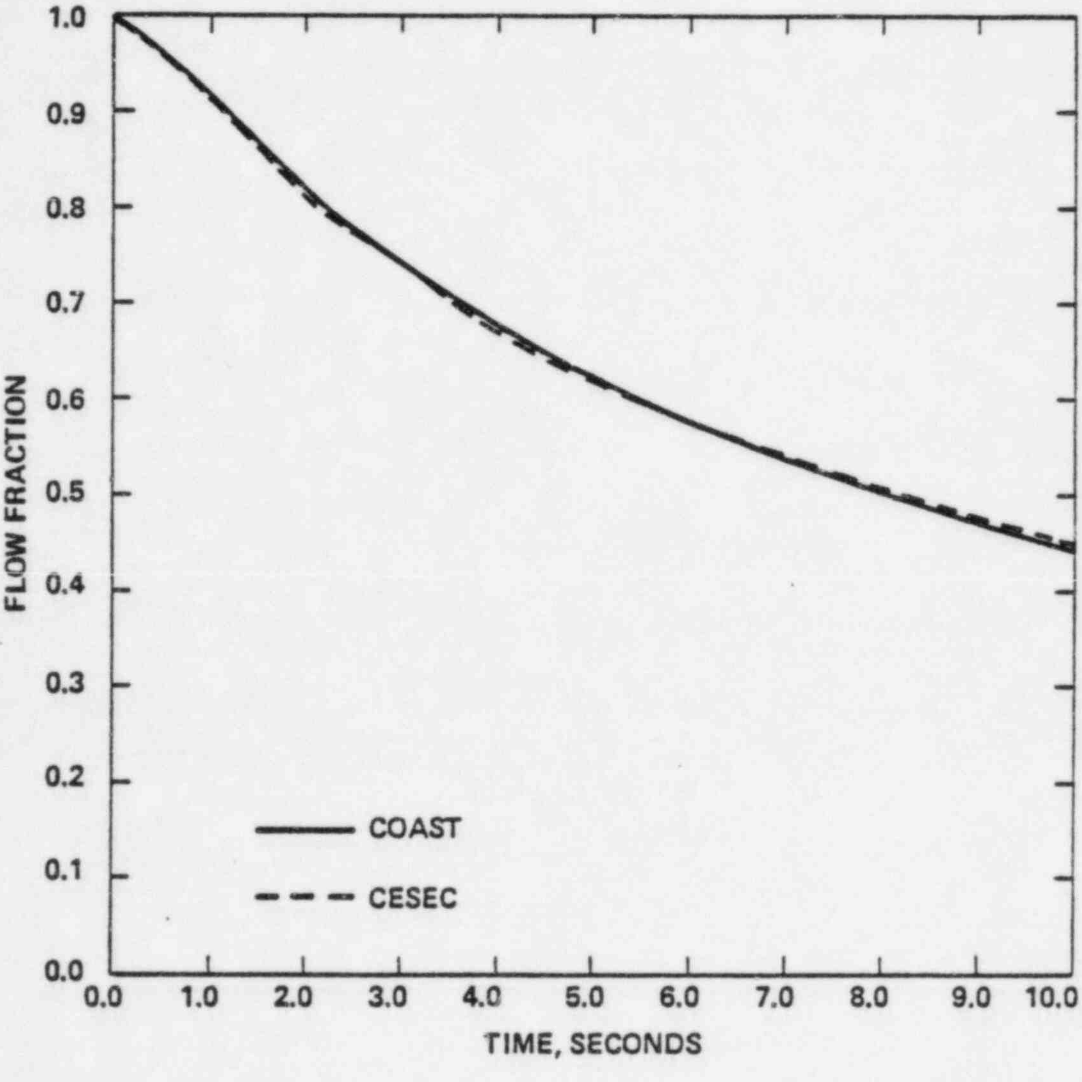
Figure I-8 shows a comparison of the RCS pressure response between the two codes for 1000 seconds of transient time. The comparison was terminated at 1000 seconds as after 421 seconds the safety injection flow (HPSI) begins and starts balancing the mass losses resulting from the leak. The peak in RCS pressure predicted by CESEC at about 175 seconds results from the partial closing of the turbine admission valve which is trying to maintain the load (steam flow) constant as CEFLASH-4AS did (note that the reactor power increases prior to reactor trip). No pressure peak is shown by CEFLASH-4AS as the turbine admission valve is not modeled by the code. The second RCS pressure peak predicted by CESEC following reactor trip results from the full closing of the turbine admission valve following turbine trip. Again CEFLASH-4AS did not predict this peak as it does not model this system. After reactor trip CESEC predicts a slightly lower RCS pressure than CEFLASH-4AS. This is compatible with results shown in Figures I-9 and I-10 which show, respectively, that CESEC inventory in the inner vessel is slightly higher than that predicted by CEFLASH-4AS and the integrated leak flow at 1000 seconds is slightly lower.

The conclusion from this comparison is that both codes predict very compatible results. The maximum deviation in RCS pressure, excluding pressure peaks, between both predictions is within 60 psi. The variation in effective inner vessel two-phase mixture volume after trip is within 200 ft^3. Lastly, the difference in integrated leak flow at 1000 seconds is within 5 percent of each other. Calculational differences between both codes as shown in Figures I-8 through I-10 are attributed to modelling differences. For example, CEFLASH-4AS is basically a heterogeneous code with nodal fluid conditions evaluated at local pressures while CESEC is basically a homogeneous code with nodal fluid conditions evaluated at the average system pressure.

TABLE I-1

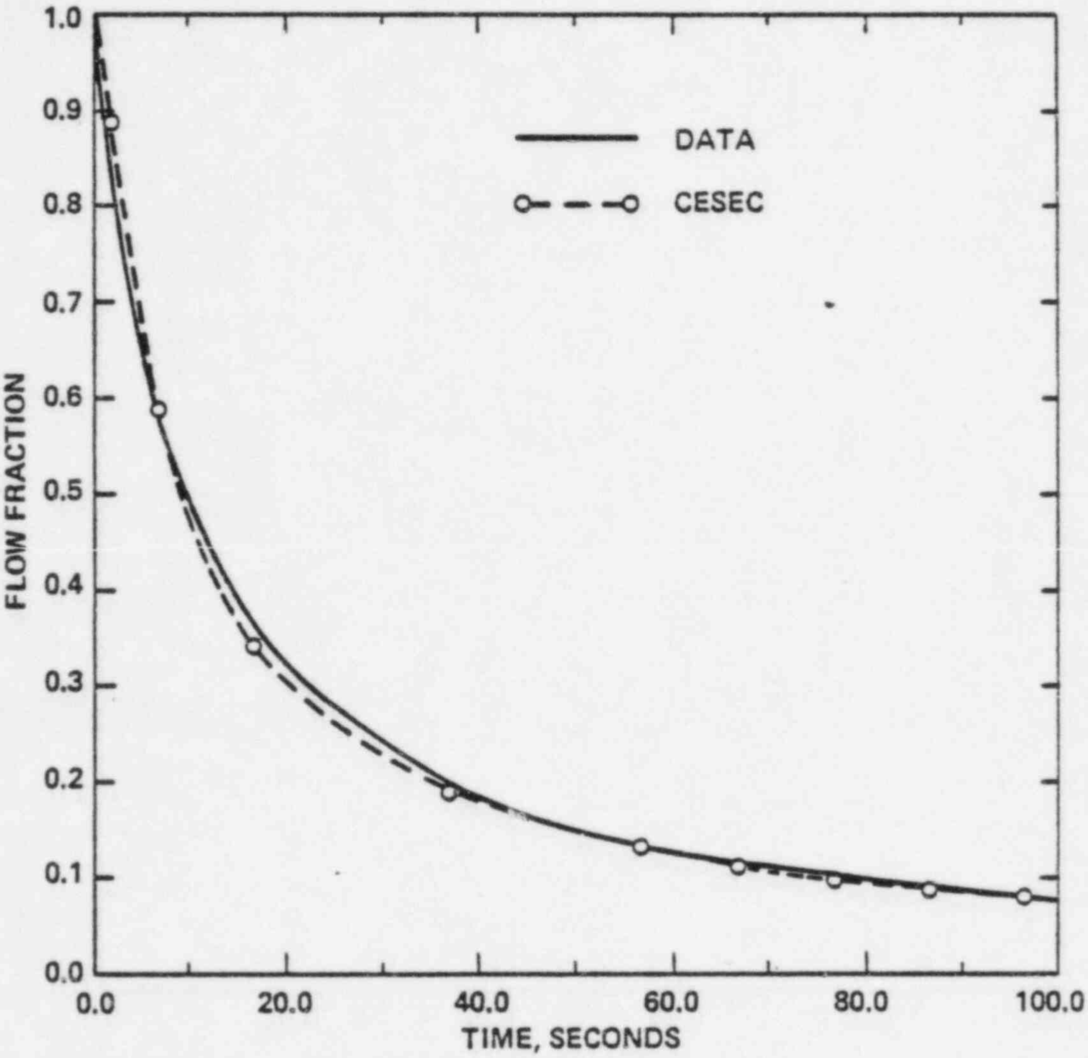
TURBINE TRIP CESEC COMPARISON
(98 PERCENT POWER)

EVENT	TEST	CESEC-III	CESEC-I
MAXIMUM PRESSURIZER PRESSURE	2382 PSIA/ 8.0 SECS.	2389 PSIA/ 8.5 SECS.	2362 PSIA/ 9.55 SECS.
MAXIMUM SG1 PRESSURE	1029 PSIA/ 12.7 SECS.	1054 PSIA/ 14.5 SECS.	1071 PSIA/ 18.3 SECS.
MAXIMUM SG2 PRESSURE	1091 PSIA/ 12.7 SECS.	1114 PSIA/ 14.5 SECS.	1134 PSIA/ 18.3 SECS.
MSIS	241.5 SECS.	231.0 SECS.	231.3 SECS.
MINIMUM PRESSURIZER PRESSURE	1350 PSIA/ 248.0 SECS.	1269 PSIA/ 237.0 SECS.	1299 PSIA/ 245.0 SECS.
PRESSURIZER EMPTIES	151.0 SECS.	135.0 SECS.	165.0 SECS.
PRESSURIZER STARTS TO REFILL	308.0 SECS.	331.0 SECS.	323.4 SECS.



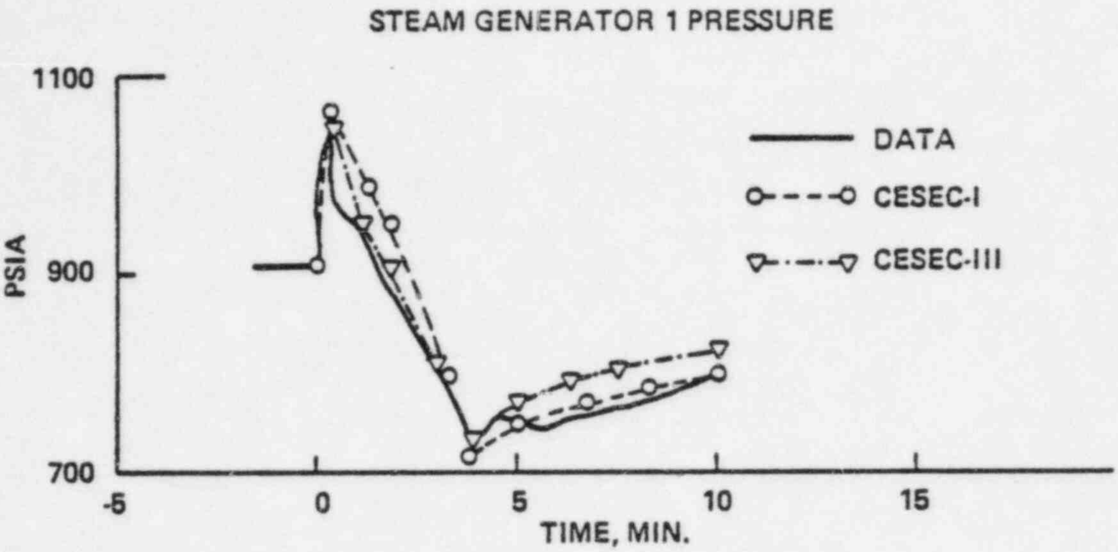
FOUR PUMP FLOW COASTDOWN
COMPARISON OF CESEC
WITH COAST

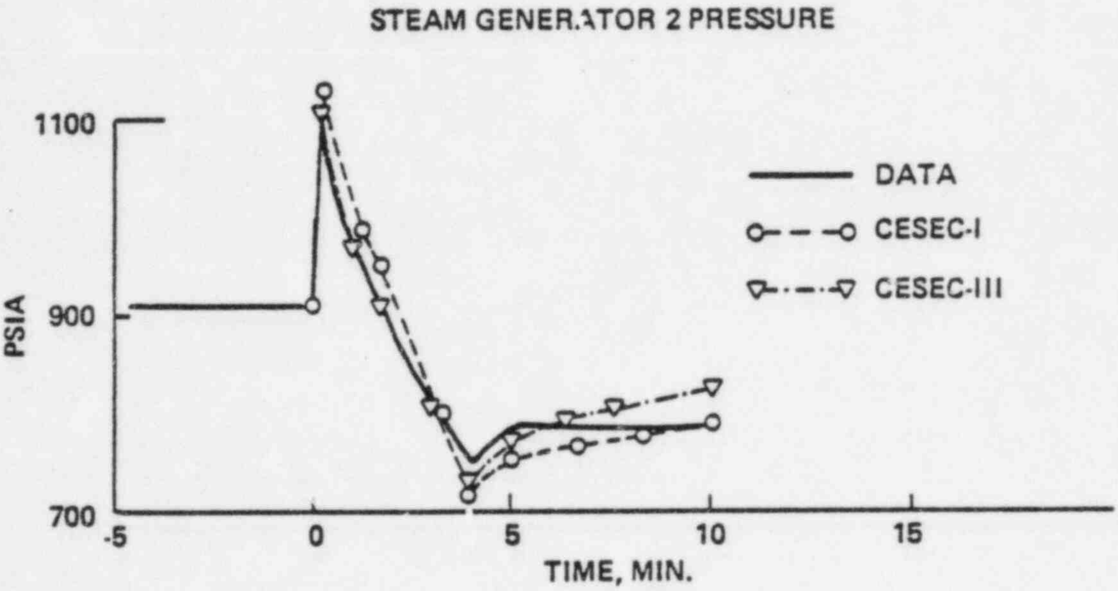
Figure I-1



FOUR PUMP COASTDOWN
CESEC COMPARISON
(HOT ZERO POWER)

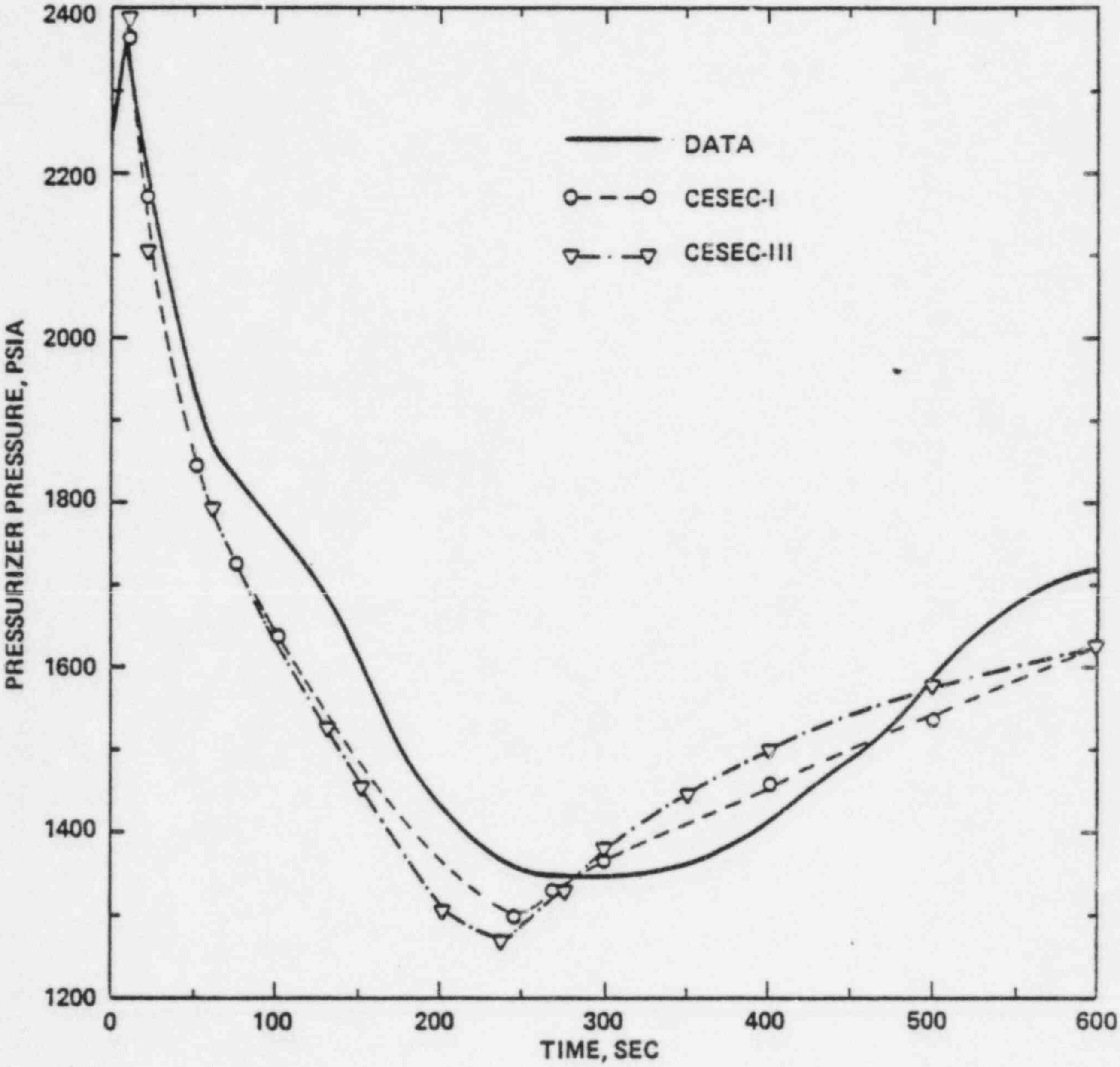
Figure I-2





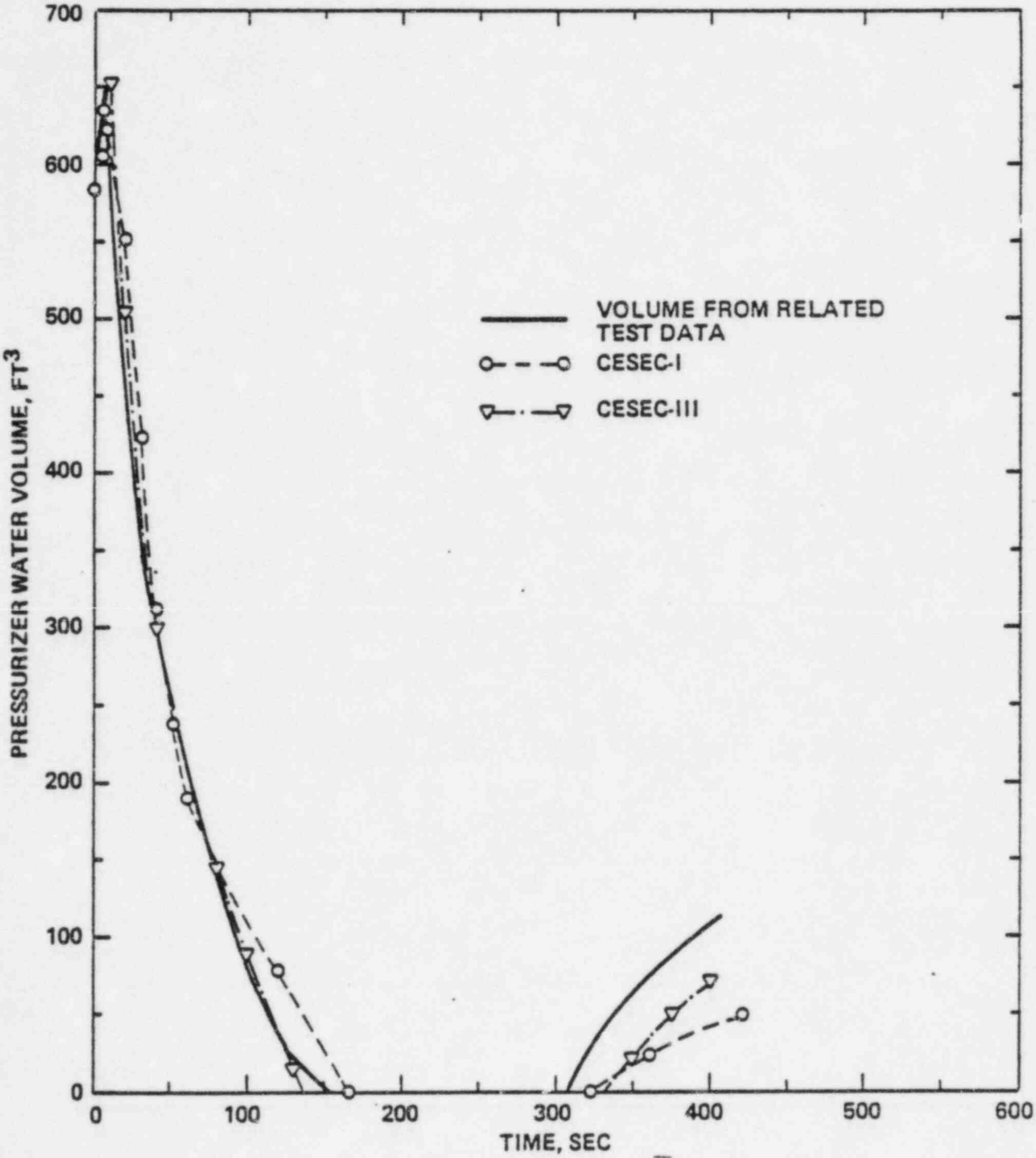
SECONDARY PRESSURE vs TIME
TURBINE TRIP CESEC COMPARISON
(98 PERCENT POWER)

Figure I-3



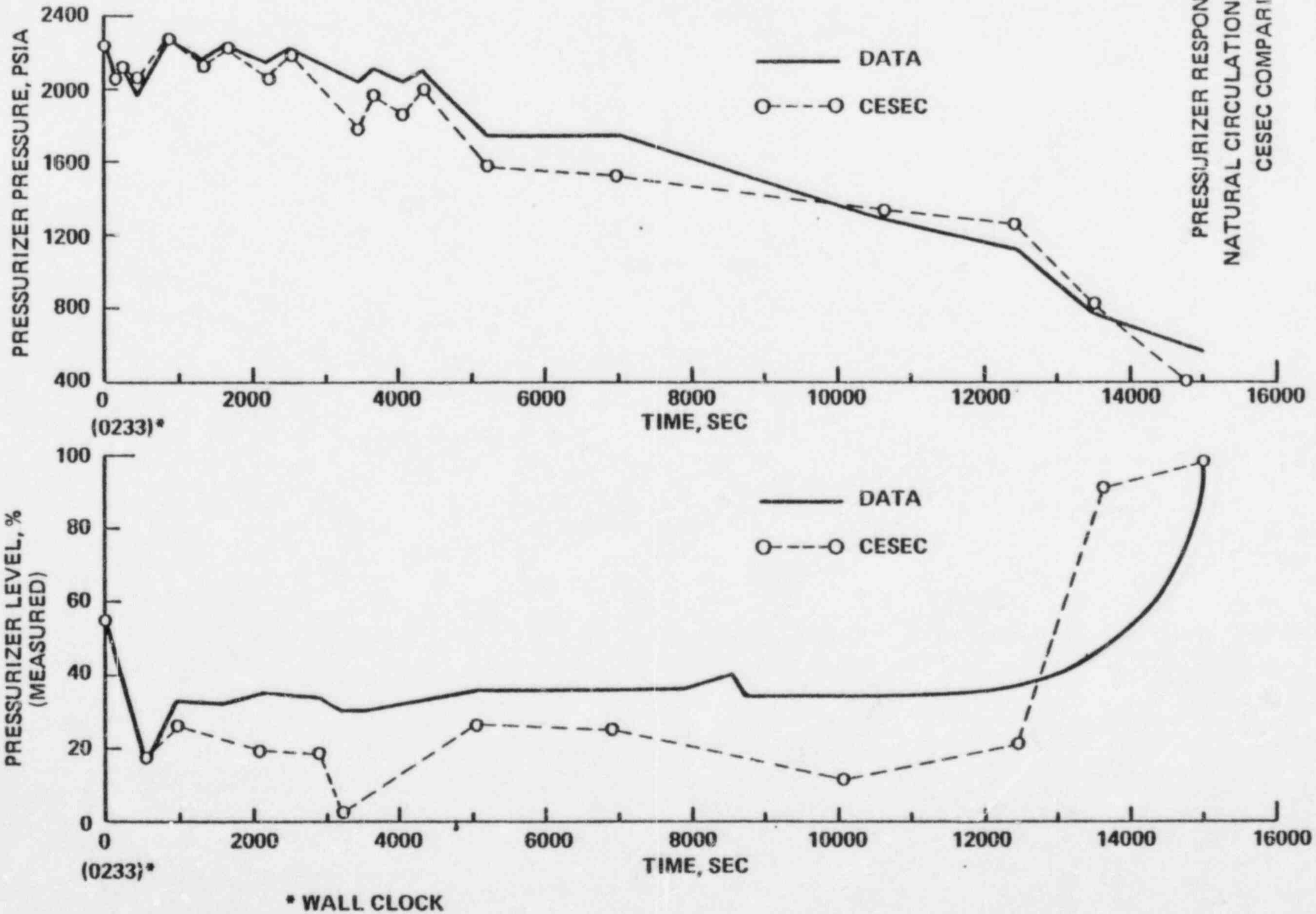
PRESSURIZER PRESSURE vs TIME
TURBINE TRIP CESEC COMPARISON
(98 PERCENT POWER)

Figure I-4



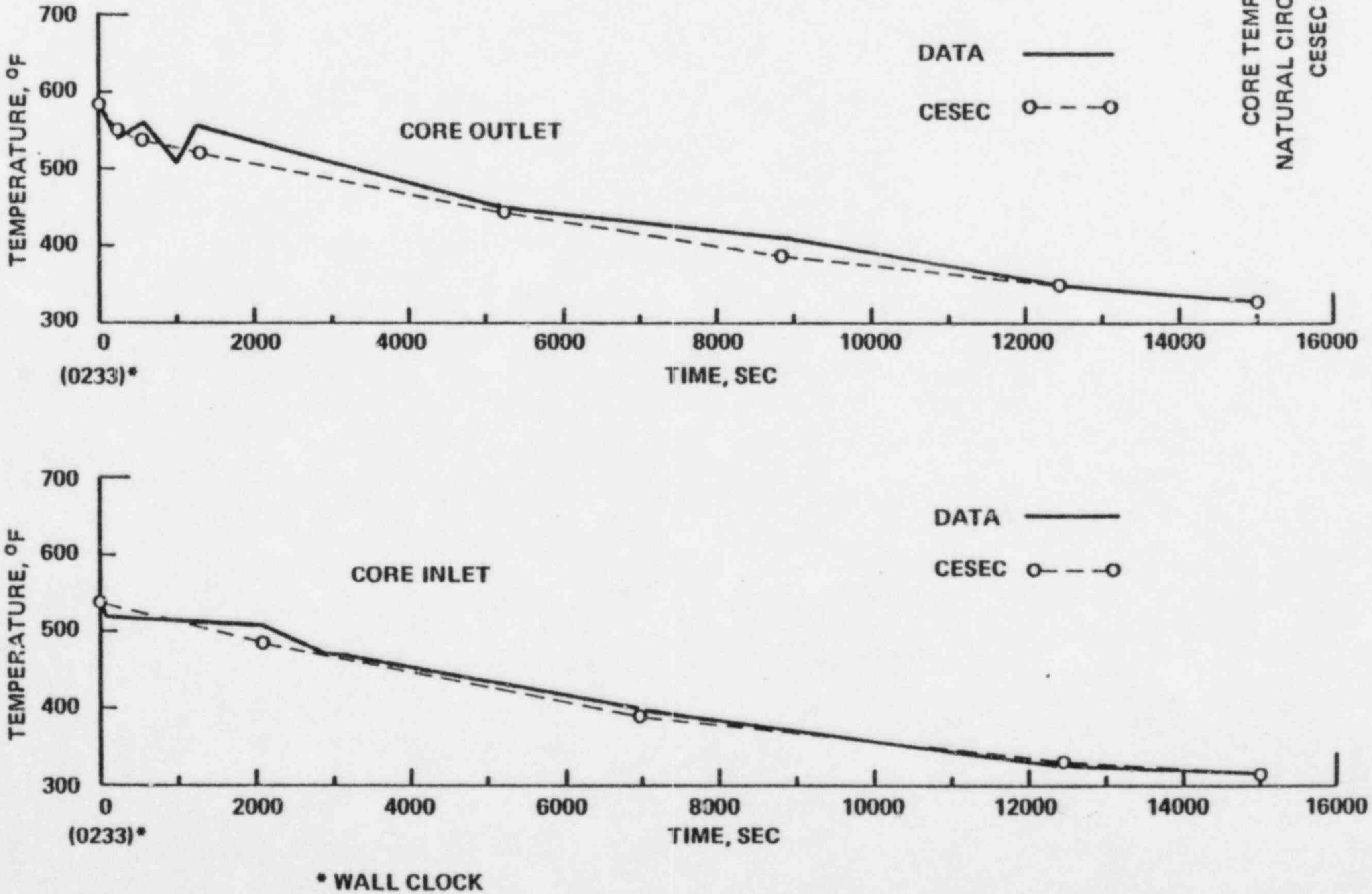
PRESSURIZER WATER VOLUME
vs TIME
TURBINE TRIP CESEC COMPARISON
(98 PERCENT POWER)

Figure I-5



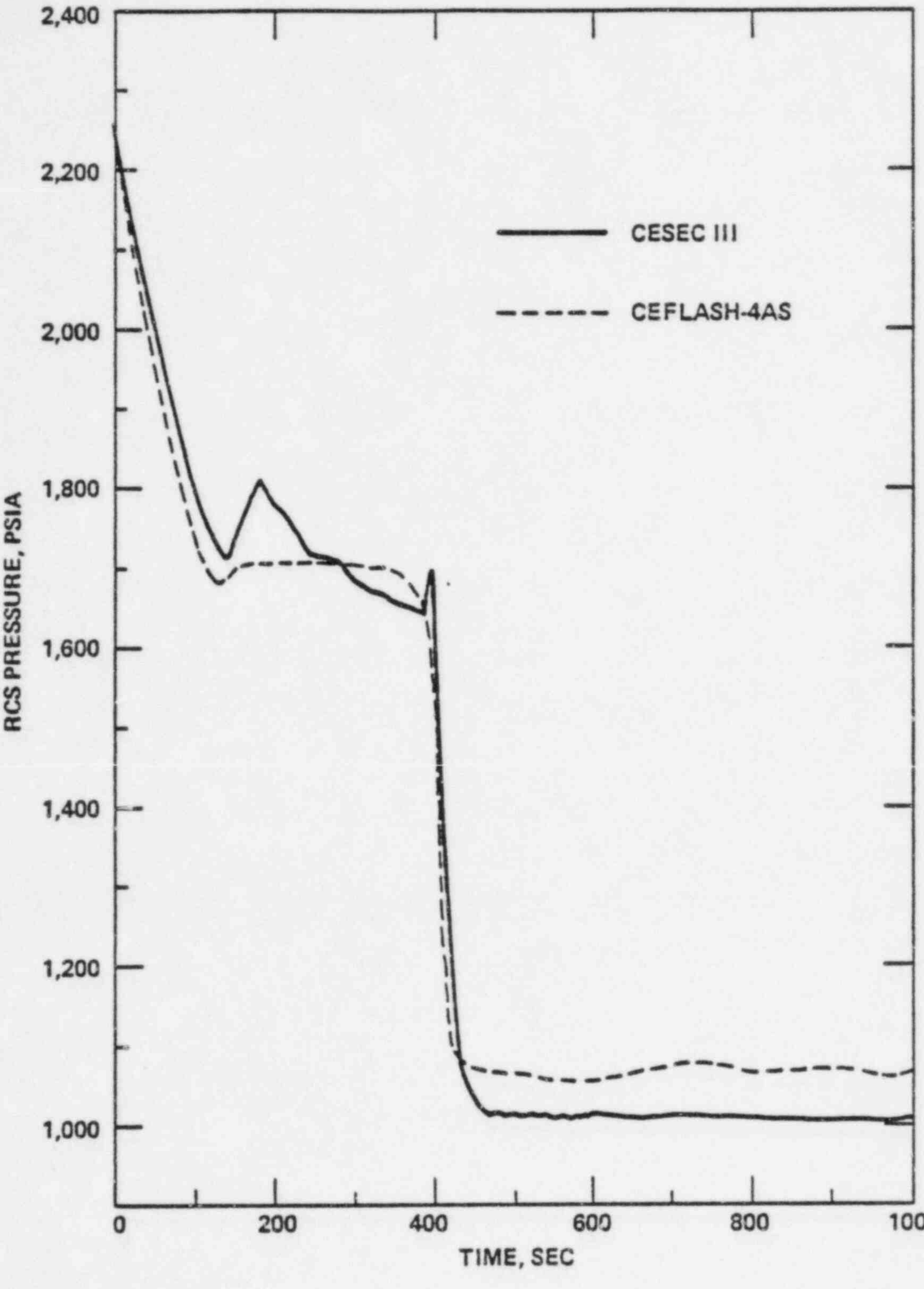
PRESSURIZER RESPONSE vs TIME
NATURAL CIRCULATION COOLDOWN
CESEC COMPARISON

Figure I-6



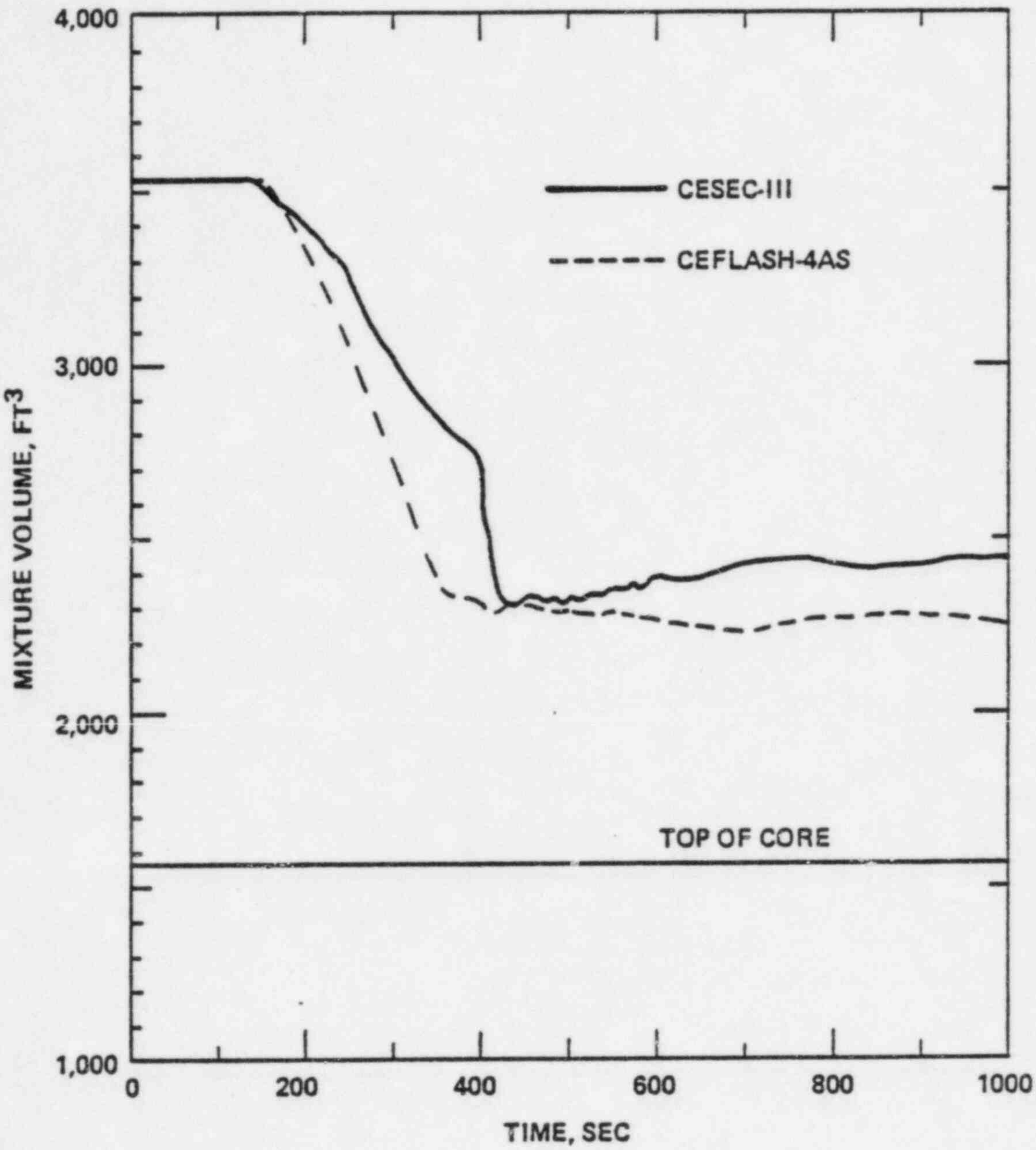
CORE TEMPERATURE vs TIME
NATURAL CIRCULATION COOLDOWN
CESEC COMPARISON

Figure I-7



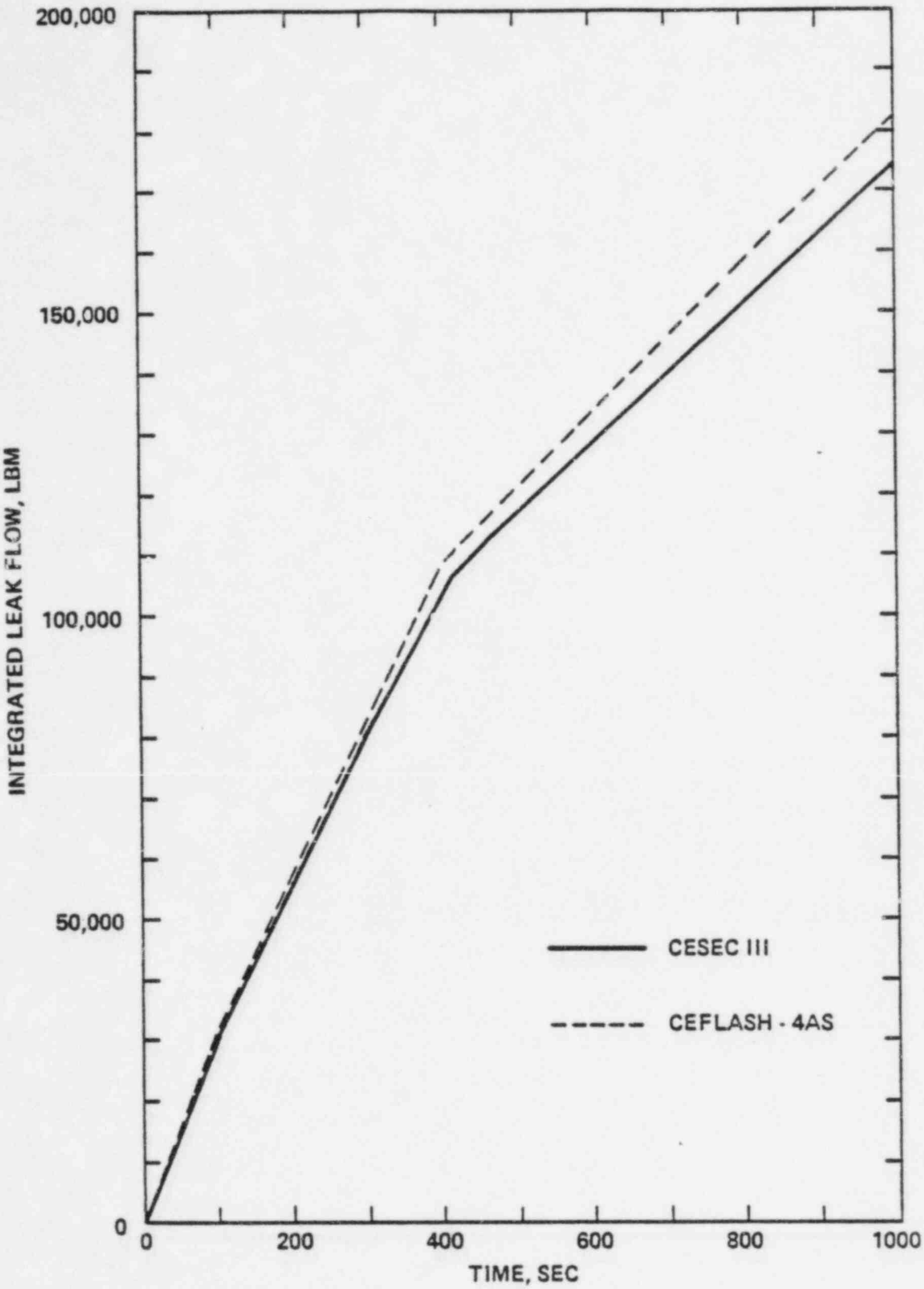
RCS PRESSURE vs TIME
(0.015 FT^2 BREAK)

Figure I-8



INNER VESSEL TWO-PHASE MIXTURE VOLUME
vs TIME
(0.015 FT^2 BREAK)

Figure I-9



INTEGRATED LEAK FLOW vs TIME
($0.015\ FT^2$ BREAK)

Figure I-10

APPENDIX J

INPUT DESCRIPTION

(With Sample Input)

```
CCCC  EEEE  SSSS  EEEE  CCCC
C     E     S     E     C
C     EEE   SSSS  EEE   C
C     E        S  E     C
CCCC  EEEE  SSSS  EEEE  CCCC

IIIII  N   N  PPPP   U   U  TTTTT
  I    NN  N  P   P  U   U    T
  I    N N N  PPPP   U   U    T
  I    N  NN  P      U   U    T
IIIII  N   N  P      UUUU     T

DDDD    AAA   TTTTT   AAA
D   D  AA AA    T    AA AA
D   D  AAAAA    T    AAAAA
D   D  A   A    T    A   A
DDDD   A   A    T    A   A

DDDD  EEEE  SSSS  CCCC  RRRR  IIIII  PPPP  TTTTT  IIIII  OOOO  N   N
D   D E     S     C     R  R    I    P  P    T      I    O  O  NN  N
D   D EEE   SSSS  C     RRRR    I    PPPP    T      I    O  O  N N N
D   D E        S  C     R R     I    P       T      I    O  O  N  NN
DDDD  EEEE  SSSS  CCCC  R  R  IIIII  P       T    IIIII  OOOO  N   N
```

A-VECTOR CATEGORY LIST

CATEGORY	DESCRIPTION	A-VECTORS IN CATEGORY
1	GENERAL TIME AND PRINT INFORMATION	1-23,70-91,900-940,999,1082-1091,2062
2	GENERAL REACTOR COOLANT SYSTEM INFORMATION	1000-1014,1514,4002
3	FLOW MODEL INFORMATION	2052-2055,2061,4976-77,6000-6180
4	GENERAL REACTOR CORE INFORMATION	500,501,1020,1025,1500,1502-1510,1514-1517,1532,1583-2025,2051, 2056-2060,2063-2067,3950
5	REACTIVITY INFORMATION	505,511-530,640,645,647,649,1101-1115,1121-1135,1141-1154,1161-1174, 1181-1207,3300-3350,3400-3450,3500-3550,3600-3650,3700-3750,3800-3850, 3877-3879,3881,3942-3943,5500-5899
6	REACTOR KINETICS INFORMATION	1300-1451,1518-1530
7	REACTOR COOLANT PUMP MODEL	1021-1024,1097-1099,1531,1533-1582,2026-2050,6252-6262,6265,7000-7058, 7060-7064,7101-7442,7500
8	PRESSURIZER INFORMATION	436,3971-3992,3997-4010,4012-4028,4033,4051-4284,4286, 4331-4335,4337,4338,4573
9	SAFETY INJECTION INFORMATION	251,272-425,435,475,5900-5907
10	STEAM GENERATOR INFORMATION	105,133,2180-2284,2290-2292,2507,3001-3005,3008-3033,3040,3041,3151-3155, 3158,3160-3182,3190,3191,3201,4574,4990,4991,4994,4995,6500-6600
11	FEEDWATER SYSTEMS (MAIN + AUX.)	2301-2432,2600-2602,2603-2664,4760
12	U N A S S I G N E D	
13	STEAM SYSTEM AND VALVES	4539-4548,4564,4575-4577,4600-4651,4653-4661,4664-4666,4713-4759, 4761-4763,4765-4767,4799-4895,4922-4924,4935-4938
14	SPECIAL OPTIONS	2303,3006-3008,3156,3157,4340-4343,4550-4558,4600,4667-4712,4920,4921 4924,4950-4975,4978,4992,4996-4999 7079-7081,7085
15	TRIP INFORMATION	250,252-258,260-265,426,428-434,442,443,4571,4572
16	CRITICAL FLOW MODEL	5001-5008,5011-5018,5021-5028,5031-5038,5041,5042,5048-5369
17	BORON CONCENTRATION	266-271,3891-3941
18	CESEC III PLOT PACKAGE	24-65,1026-1081

```
****  LIST OF UNUSED A-VECTORS   66-69,92-104,106-132,134-249,427,437-41,444-9,451-74,
                                 476-99,502-10,531-639,650-899,941-98,1092-96,1100,
                                 1116-20,1136-40,1155-60,1175-80,1208-99,1452-99,
                                 1511-13,2068-179,2285-89,2293-300,2433-506,2508-99,
                                 2657-3000,3034-40,3042-150,3183-9,3192-200,3202-99,
                                 3351-99,3451-99,3551-99,3651-99,3751-99,3851-76,3880,
                                 3882-90,3944-9,3951-70,3993-4001,4011,4029-32,
                                 4034-50,4285,4287-330,4336,4344-538,4549,4559-63,
                                 4565-70,4578-99,4652,4662-63,4768-98,4896-919,
                                 4925-34,4939-49,4979-89,5000,5009-10,5019-20,
                                 5029-30,5034-40,5443-7,5370-499,5900-99,6181-251,
                                 6263-4,6266-499,6991-9,7059,7065-78,7086-100,7443-99
```

```
        TO SELECT CATEGORIES SPECIFY AS FOLLOWS

A(84-89)=NUMBERS OF CATEGORIES REQUESTED, MAXIMUM 6 CATE-
         GORIES NUMBERED FROM 1 TO 18 ARE ALLOWED
A(84)=19 FOR PRINTING GENERAL INFORMATION ONLY
         A(84).GT.19 = ALL 18 CATEGORIES WILL BE PRINTED
         A(85-89) ARE IGNORED FOR A(84).GE.19
```

```
 AAA           V   V EEEEE  CCC  TTTTT  OOO  RRRR
A   A          V   V E     C       T   O   O R   R
AAAAA  =====   V   V EEE   C       T   O   O RRRR
A   A           V V  E     C       T   O   O R  R
A   A            V   EEEEE  CCC    T    OOO  R   R

  CCC   AAA  TTTTT EEEEE  GGG    OOO   RRRR  Y   Y
 C     A   A   T   E     G      O   O  R   R  Y Y
 C     AAAAA   T   EEE   G  GGG O   O  RRRR    Y
 C     A   A   T   E     G    G O   O  R  R    Y
  CCC  A   A   T   EEEEE  GGGGG  OOO   R   R   Y

 AAA   SSS   SSS  III  GGGG  N   N M   M EEEEE N   N TTTTT
A   A S     S      I  G      NN  N MM MM E     NN  N   T
AAAAA SSSSS SSSSS  I  G  GGG N N N M M M EEE   N N N   T
A   A     S     S  I  G    G N  NN M   M E     N  NN   T
A   A  SSS   SSS  III  GGGGG N   N M   M EEEEE N   N   T
```

AVCT	1	2	3	4	5	6	7	8	9	10	AVCT	AVCT	1	2	3	4	5	6	7	8	9	10	AVCT
1	1	1	1	1	1	1	1	1	1		10	11	1	1	1	1	1	1	1	1	1	1	20
21	1	1	1	18	18	18	18	18	18	18	30	31	18	18	18	18	18	18	18	18	18	18	40
41	18	18	18	18	18	18	18	18	18	18	50	51	18	18	18	18	18	18	18	18	18	18	60
61	18	18	18	18	18	0	0	0	0	1	70	71	1	1	1	1	1	1	1	1	1	1	80
81	1	1	1	1	1	1	1	1	1	1	90	91	1	0	0	0	0	0	0	0	0	0	100
101	0	0	0	0	10	0	0	0	0	0	110	111	0	0	0	0	0	0	0	0	0	0	120
121	0	0	0	0	0	0	0	0	0	0	130	131	0	0	10	0	0	0	0	0	0	0	140
241	0	0	0	0	0	0	0	0	0	15	250	251	9	15	15	15	15	15	15	15	0	15	260
261	15	15	15	15	15	17	17	17	17	17	270	271	17	9	9	9	9	9	9	9	9	9	280
281	9	9	9	9	9	9	9	9	9	9	290	291	9	9	9	9	9	9	9	9	9	9	300
301	9	9	9	9	9	9	9	9	9	9	310	311	9	9	9	9	9	9	9	9	9	9	320
321	9	9	9	9	9	9	9	9	9	9	330	331	9	9	9	9	9	9	9	9	9	9	340
341	9	9	9	9	9	9	9	9	9	9	350	351	9	9	9	9	9	9	9	9	9	9	360
361	9	9	9	9	9	9	9	9	9	9	370	371	9	9	9	9	9	9	9	9	9	9	380
381	9	9	9	9	9	9	9	9	9	9	390	391	9	9	9	9	9	9	9	9	9	9	400
401	9	9	9	9	9	9	9	9	9	9	410	411	9	9	9	9	9	9	9	9	9	9	420
421	9	9	9	9	9	15	0	15	15	15	430	431	15	15	15	15	9	0	0	0	0	0	440
441	0	15	15	0	0	0	0	0	0	1	450	451	0	0	0	0	0	0	0	0	0	0	460
461	0	0	0	0	0	0	0	0	0	0	470	471	0	0	0	0	9	0	0	0	0	0	480
481	0	0	0	0	0	0	0	0	0	0	490	491	0	0	0	0	0	0	0	0	0	4	500
501	4	0	0	0	5	0	0	0	0	0	510	511	5	5	5	5	5	5	5	5	5	5	520
521	5	5	5	5	5	5	5	5	5	5	530	531	0	0	0	0	0	0	0	0	0	0	540
621	0	0	0	0	0	0	0	0	0	0	630	631	0	0	0	0	0	0	0	0	0	5	640
641	0	0	0	0	5	0	5	0	5	0	650	651	0	0	0	0	0	0	0	0	0	0	660
881	0	0	0	0	0	0	0	0	0	0	890	891	0	0	0	0	0	0	0	0	0	1	900
901	1	1	1	1	1	1	1	1	1	1	910	911	1	1	1	1	1	1	1	1	1	1	920
921	1	1	1	1	1	1	1	1	1	1	930	931	1	1	1	1	1	1	1	1	1	1	940
981	0	0	0	0	0	0	0	0	0	0	990	991	0	0	0	0	0	0	0	0	1	2	1000
1001	2	2	2	2	2	2	2	2	2	2	1010	1011	2	2	2	2	0	0	0	0	0	4	1020
1021	7	7	7	7	4	18	18	18	18	18	1030	1031	18	18	18	18	18	18	18	18	18	18	1040
1041	18	18	18	18	18	18	18	18	18	18	1050	1051	18	18	18	18	18	18	18	18	18	18	1060
1061	18	18	18	18	18	18	18	18	18	18	1070	1071	18	18	18	18	18	18	18	18	18	18	1080
1081	18	1	1	1	1	1	1	1	1	1	1090	1091	1	0	0	0	0	0	7	7	7	0	1100
1101	5	5	5	5	5	5	5	5	5	5	1110	1111	5	5	5	5	5	0	0	0	0	0	1120
1121	5	5	5	5	5	5	5	5	5	5	1130	1131	5	5	5	5	5	0	0	0	0	0	1140
1141	5	5	5	5	5	5	5	5	5	5	1150	1151	5	5	5	5	0	0	0	0	0	0	1160
1161	5	5	5	5	5	5	5	5	5	5	1170	1171	5	5	5	5	0	0	0	0	0	0	1180
1181	5	5	5	5	5	5	5	5	5	5	1190	1191	5	5	5	5	5	5	5	5	5	5	1200
1201	5	5	5	5	5	5	5	0	0	0	1210	1211	0	0	0	0	0	0	0	0	0	0	1220
1281	0	0	0	0	0	0	0	0	0	0	1290	1291	0	0	0	0	0	0	0	0	0	6	1300
1301	6	6	6	6	6	6	6	6	6	6	1310	1311	6	6	6	6	6	6	6	6	6	6	1320
1321	6	6	6	6	6	6	6	6	6	6	1330	1331	6	6	6	6	6	6	6	6	6	6	1340
1341	6	6	6	6	6	6	6	6	6	6	1350	1351	6	6	6	6	6	6	6	6	6	6	1360
1361	6	6	6	6	6	6	6	6	6	6	1370	1371	6	6	6	6	6	6	6	6	6	6	1380
1381	6	6	6	6	6	6	6	6	6	6	1390	1391	6	6	6	6	6	6	6	6	6	6	1400
1401	[illegible]	6	6	6	6	6	6	6	6	6	1410	1411	6	6	6	6	6	6	6	6	6	6	1420
1421	6	6	6	6	6	6	6	6	6	6	1430	1431	6	6	6	6	6	6	6	6	6	6	1440
1441	6	6	6	6	6	6	6	6	6	6	1450	1451	6	0	0	0	0	0	0	0	0	0	1460
1481	0	0	0	0	0	0	0	0	0	0	1490	1491	0	0	0	0	0	0	0	0	0	4	1500
1501	0	4	4	4	4	4	4	4	4	4	1510	1511	0	0	0	4	4	4	4	6	6	6	1520
1521	6	6	6	6	6	6	6	6	6	6	1530	1531	7	4	7	7	7	7	7	7	7	7	1540
1541	7	7	7	7	7	7	7	7	7	7	1550	1551	7	7	7	7	7	7	7	7	7	7	1560
1561	7	7	7	7	7	7	7	7	7	7	1570	1571	7	7	7	7	7	7	7	7	7	7	1580
1581	7	7	4	4	4	4	4	4	4	4	1590	1591	4	4	4	4	4	4	4	4	4	4	1600
AVCT	1	2	3	4	5	6	7	8	9	10	AVCT	AVCT	1	2	3	4	5	6	7	8	9	10	AVCT

CESEC-III/81300-INFO (BASEDECK81300)DATA COMBUSTION ENGINEERING DEPT. 9487 CESEC-III PAGE 19
RUN DATE 11/06/81 JOB NO.AUNADIV BEGIN TIME 15.53.35. CPU SECONDS 1.129 VERSION 81300 CASE NO. 1

AVCT	1	2	3	4	5	6	7	8	9	10	AVCT	AVCT	1	2	3	4	5	6	7	8	9	10	AVCT
1601	4	4	4	4	4	4	4	4	4	4	1610	1611	4	4	4	4	4	4	4	4	4	4	1620
1621	4	4	4	4	4	4	4	4	4	4	1630	1631	4	4	4	4	4	4	4	4	4	4	1640
1641	4	4	4	4	4	4	4	4	4	4	1650	1651	4	4	4	4	4	4	4	4	4	4	1660
1661	4	4	4	4	4	4	4	4	4	4	1670	1671	4	4	4	4	4	4	4	4	4	4	1680
1681	4	4	4	4	4	4	4	4	4	4	1690	1691	4	4	4	4	4	4	4	4	4	4	1700
1701	4	4	4	4	4	4	4	4	4	4	1710	1711	4	4	4	4	4	4	4	4	4	4	1720
1721	4	4	4	4	4	4	4	4	4	4	1730	1731	4	4	4	4	4	4	4	4	4	4	1740
1741	4	4	4	4	4	4	4	4	4	4	1750	1751	4	4	4	4	4	4	4	4	4	4	1760
1761	4	4	4	4	4	4	4	4	4	4	1770	1771	4	4	4	4	4	4	4	4	4	4	1780
1781	4	4	4	4	4	4	4	4	4	4	1790	1791	4	4	4	4	4	4	4	4	4	4	1800
1801	4	4	4	4	4	4	4	4	4	4	1810	1811	4	4	4	4	4	4	4	4	4	4	1820
821	4	4	4	4	4	4	4	4	4	4	1830	1831	4	4	4	4	4	4	4	4	4	4	1840
1841	4	4	4	4	4	4	4	4	4	4	1850	1851	4	4	4	4	4	4	4	4	4	4	1860
1861	4	4	4	4	4	4	4	4	4	4	1870	1871	4	4	4	4	4	4	4	4	4	4	1880
1881	4	4	4	4	4	4	4	4	4	4	1890	1891	4	4	4	4	4	4	4	4	4	4	1900
1901	4	4	4	4	4	4	4	4	4	4	1910	1911	4	4	4	4	4	4	4	4	4	4	1920
1921	4	4	4	4	4	4	4	4	4	4	1930	1931	4	4	4	4	4	4	4	4	4	4	1940
1941	4	4	4	4	4	4	4	4	4	4	1950	1951	4	4	4	4	4	4	4	4	4	4	1960
1961	4	4	4	4	4	4	4	4	4	4	1970	1971	4	4	4	4	4	4	4	4	4	4	1980
1981	4	4	4	4	4	4	4	4	4	4	1990	1991	4	4	4	4	4	4	4	4	4	4	2000
2001	4	4	4	4	4	4	4	4	4	4	2010	2011	4	4	4	4	4	4	4	4	4	4	2020
2021	4	4	4	4	4	7	7	7	7	7	2030	2031	7	7	7	7	7	7	7	7	7	7	2040
2041	7	7	7	7	7	7	7	7	7	7	2050	2051	4	3	3	3	3	4	4	4	4	4	2060
2061	3	1	4	4	4	4	4	0	0	0	2070	2071	0	0	0	0	0	0	0	0	0	0	2080
2161	0	0	0	0	0	0	0	0	0	0	2170	2171	0	0	0	0	0	0	0	0	0	10	2180
2181	10	10	10	10	10	10	10	10	10	10	2190	2191	10	10	10	10	10	10	10	10	10	10	2200
2201	10	10	10	10	10	10	10	10	10	10	2210	2211	10	10	10	10	10	10	10	10	10	10	2220
2221	10	10	10	10	10	10	10	10	10	10	2230	2231	10	10	10	10	10	10	10	10	10	10	2240
2241	10	10	10	10	10	10	10	10	10	10	2250	2251	10	10	10	10	10	10	10	10	10	10	2260
2261	10	10	10	10	10	10	10	10	10	10	2270	2271	10	10	10	10	10	10	10	10	10	10	2280
2281	10	10	10	10	0	0	0	0	0	10	2290	2291	10	10	0	0	0	0	0	0	0	0	2300
2301	11	11	11	11	11	11	11	11	11	11	2310	2311	11	11	11	11	11	11	11	11	11	11	2320
2321	11	11	11	11	11	11	11	11	11	11	2330	2331	11	11	11	11	11	11	11	11	11	11	2340
2341	11	11	11	11	11	11	11	11	11	11	2350	2351	11	11	11	11	11	11	11	11	11	11	2360
2361	11	11	11	11	11	11	11	11	11	11	2370	2371	11	11	11	11	11	11	11	11	11	11	2380
2381	11	11	11	11	11	11	11	11	11	11	2390	2391	11	11	11	11	11	11	11	11	11	11	2400
2401	11	11	11	11	11	11	11	11	11	11	2410	2411	11	11	11	11	11	11	11	11	11	11	2420
2421	11	11	11	11	11	11	11	11	11	11	2430	2431	11	11	0	0	0	0	0	0	0	0	2440
2501	0	0	0	0	0	0	10	0	0	0	2510	2511	0	0	0	0	0	0	0	0	0	0	2520
2581	0	0	0	0	0	0	0	0	0	0	2590	2591	0	0	0	0	0	0	0	0	0	11	2600
2601	11	11	11	11	11	11	11	11	11	11	2610	2611	11	11	11	11	11	11	11	11	11	11	2620
2621	11	11	11	11	11	11	11	11	11	11	2630	2631	11	11	11	11	11	11	11	11	11	11	2640
2641	11	11	11	11	11	11	11	11	11	11	2650	2651	11	11	11	11	11	11	11	11	11	11	2660
2661	11	11	11	11	0	0	0	0	0	0	2670	2671	0	0	0	0	0	0	0	0	0	0	2680
3001	10	10	10	10	10	14	14	14	10	10	3010	3011	10	10	10	10	10	10	10	10	10	10	3020
3021	10	10	10	10	10	10	10	10	10	10	3030	3031	10	10	10	0	0	0	0	0	0	10	3040
3041	10	0	0	0	0	0	0	0	0	0	3050	3061	0	0	0	0	0	0	0	0	0	0	3060
3141	0	0	0	0	0	0	0	0	0	0	3150	3151	10	10	10	10	10	14	14	10	0	10	3160
3161	10	10	10	10	10	10	10	10	10	10	3170	3171	10	10	10	10	10	10	10	10	10	10	3180
3181	10	10	0	0	0	0	0	0	0	10	3190	3191	10	0	0	0	0	0	0	0	0	0	3200
3201	10	0	0	0	0	0	0	0	0	0	3210	3211	0	0	0	0	0	0	0	0	0	0	3220
3281	0	0	0	0	0	0	0	0	0	0	3290	3291	0	0	0	0	0	0	0	0	0	5	3300
3301	5	5	5	5	5	5	5	5	5	5	3310	3311	5	5	5	5	5	5	5	5	5	5	3320
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7281	7	7	7	7	7	7	7	7	7	7	7290	7291	7	7	7	7	7	7	7	7	7	7	7300
7301	7	7	7	7	7	7	7	7	7	7	7310	7311	7	7	7	7	7	7	7	7	7	7	7320
7321	7	7	7	7	7	7	7	7	7	7	7330	7331	7	7	7	7	7	7	7	7	7	7	7340
7341	7	7	7	7	7	7	7	7	7	7	7350	7351	7	7	7	7	7	7	7	7	7	7	7360
7361	7	7	7	7	7	7	7	7	7	7	7370	7371	7	7	7	7	7	7	7	7	7	7	7380
7381	7	7	7	7	7	7	7	7	7	7	7390	7391	7	7	7	7	7	7	7	7	7	7	7400
7401	7	7	7	7	7	7	7	7	7	7	7410	7411	7	7	7	7	7	7	7	7	7	7	7420
7421	7	7	7	7	7	7	7	7	7	7	7430	7431	7	7	7	7	7	7	7	7	7	7	7440
7441	7	7	0	0	0	0	0	0	0	0	7450	7451	0	0	0	0	0	0	0	0	0	0	7460
7481	0	0	0	0	0	0	0	0	0	0	7490	7491	0	0	0	0	0	0	0	0	0	7	7500
AVCT	1	2	3	4	5	6	7	8	9	10	AVCT	AVCT	1	2	3	4	5	6	7	8	9	10	AVCT

ALL 18 CATEGORIES REQUESTED, A(84)= 20

* 1. GENERAL TIME AND PRINT INFORMATION *

*** TRANSIENT TIME CONTROLS ***

A(1)	MINIMUM TIME STEP TO BE USED	SEC	.1000E-03
A(2)	A PREASSIGNED ACCURACY TO ADJUST STEP SIZE		.1000E-02
A(3)	TIME TO END PROBLEM	SEC	.6600E+02
A(450)	TIME AFTER TRIP TO END PROBLEM	SEC	0.
A(999)	CP TIME LIMIT MARGIN TO END RUN	SEC	12.00
A(2062)	+N = RESTRICTS TIME STEP TO N PERCENT CHANGE OF POWER/TIME STEP BEFORE TRIP 0 = REVERTS TO OTHER TIME STEP REGULATION IN CODE -N = RESTRICTS TIME STEP TO N PERCENT CHANGE OF POWER/TIME STEP BEFORE AND AFTER TRIP		0.

*** DAYFILE PRINT ***

A(1082)	INDEX NUMBER 1 FOR DAYFILE AND MINOR EDIT VARIABLE PRINT		9521.00
A(1083)	INDEX NUMBER 2 FOR DAYFILE AND MINOR EDIT VARIABLE PRINT		255.000
A(1084)	INDEX NUMBER 3 FOR DAYFILE AND MINOR EDIT VARIABLE PRINT		256.000
A(1085)	INDEX NUMBER 4 FOR DAYFILE AND MINOR EDIT VARIABLE PRINT		260.000
A(1086)	START TIME FOR DAYFILE PRINT	SEC	0.
A(1087)	DAYFILE TRIP REASON OPTION1 1.0 = YES 0.0 = NO		.1000E+01
A(1088)	NUMBER OF VARIABLES (1. THROUGH 4.) FOR PRINT IN MINOR EDIT (OPTION OFF = 0.)		4.000
A(1089)	TIME AFTER TRIP FOR START OF DAYFILE PRINT	SEC	0.
A(1090)	TIME TO START PRINTING VARIABLES IN MINOR EDIT	SEC	2.000
A(1091)	TIME TO END PRINTING VARIABLES IN MINOR EDIT	SEC	65.00

*** SUBROUTINE PRINT OPTIONS ***

*** NOTE ***

FOR THE FOLLOWING A-VECTORS% 0.0 - INDICATES SUPPRESS PRINT OF SUBROUTINE

A(70)	COREQ PRINT CONTROL	.1000E+01
A(71)	RHOEQ PRINT CONTROL	.1000E+01
A(72)	PRESEQ PRINT CONTROL	.1000E+01
A(73)	LOOPEQ PRINT CONTROL	.1000E+01
A(74)	SGREQ PRINT CONTROL	.1000E+01
A(75)	SCLEQ PRINT CONTROL	.1000E+01
A(76)	SECEQ PRINT CONTROL	.1000E+01
A(77)	FEEDEQ PRINT CONTROL	.1000E+01
A(78)	PROTEQ PRINT CONTROL	.1000E+01
A(79)	RODEQ PRINT CONTROL	.1000E+01
A(80)	COOLEQ PRINT CONTROL	.1000E+01
A(81)	FLOWEQ PRINT CONTROL	.1000E+01
A(82)	WALLEQ PRINT CONTROL	.1000E+01
A(83)	BOREQ PRINT CONTROL	.1000E+01

MAJOR EDIT FREQUENCY IN INTERVALS

TIME(SEC) A-VECTOR	VALUE	SIZE(SEC) A-VECTOR	VALUE
A(4)	.1440E+04	A(14)	.6000E+02
A(5)	.1000E+05	A(15)	.6000E+02

*** MINOR EDITS ***

TIME INTERVAL ENDS A-VECTOR	VALUE	TIME STEP INPUT A-VECTOR	VALUE	OPTIONS FOR RECORDING DATA ON TAPE95 FOR DNBR CALCULATIONS (IF POSITIVE VALUES) DATA RECORDED FOR N-TH TIME STEP A-VECTOR	VALUE	MINOR EDIT FREQUENCY EDIT PRINTED FOR N-TH TIME STEP A-VECTOR	VALUE
A(901)	10.00	A(911)	.2000	A(921)	2.100	A(931)	-1.000
A(902)	50.00	A(912)	.2000	A(922)	2.100	A(932)	0.
A(903)	100.0	A(913)	.2000	A(923)	2.100	A(933)	5.000
A(904)	0.	A(914)	0.	A(924)	0.	A(934)	0.
A(905)	0.	A(915)	0.	A(925)	0.	A(935)	0.
A(906)	0.	A(916)	0.	A(926)	0.	A(936)	0.
A(907)	0.	A(917)	0.	A(927)	0.	A(937)	0.
A(908)	0.	A(918)	0.	A(928)	0.	A(938)	0.
A(909)	0.	A(919)	0.	A(929)	0.	A(939)	0.
A(910)	0.	A(920)	0.	A(930)	0.	A(940)	0.

NOTE COMPLETE MINOR EDIT AVAILABLE ON FILE FICH
FILE CAN BE COPIED ON FILMPL, OUTPUT

NEGATIVE VALUES OF A-VECTORS A(931-940) SUPPRESS
MINOR EDITS FOR TIME INTERVALS SPECIFIED

MINOR EDITS PRINTED ALWAYS FOR TIME VALUES WHEN
ALARM AND/OR TRIP SIGNALS ARE GENERATED

A(900) OPTION TO ACTIVATE FILE FICH (OPTION OFF = 0.0
1.0 = OPTION ON, 2.0 = COPY FICH ON USER OUTPUT) 2.000

NOTE NON-ZERO VALUE OF ANY FRACTIONAL PART OF SPECIFIED A-VECTORS A(921-930)
RESULTS IN PRINT-OUT OF TAPE95 CONTENTS BEFORE CASE SUMMARY

```
                              INPUT DATA DESCRIPTION PRINTOUT
                              -----------------------------------

A(84)         OPTION TO PRINT CESEC INPUT DATA DESCRIPTION                    20.00

                   0.0    = OPTION OFF
                  10.0    = OPTION ON, GENERAL INFORMATION ONLY
                 OVER 19.= OPTION ON, ALL OF 18 CATEGORIES PRINTED
              1.THROUGH 18.= SPECIFIED CATEGORY PRINTED
                           (AS LISTED BELOW)

                FOR A(84) IN THE RANGE FROM 1. THROUGH 18.THE FOLLOWING A-VECTORS
                 SPECIFY CATEGORIES OFTHE INPUT DESCRIPTION TO BE PRINTED ...

A(84)           1ST CATEGORY TO BE PRINTED IS ... 20.0
A(85)           2ND CATEGORY TO BE PRINTED IS ...  0.0
A(86)           3RD CATEGORY TO BE PRINTED IS ...  0.0
A(87)           4TH CATEGORY TO BE PRINTED IS ...  0.0
A(88)           5TH CATEGORY TO BE PRINTED IS ...  0.0
A(89)           6TH CATEGORY TO BE PRINTED IS ...  0.0

A(90)         OPTION TO SUPPRESS SPACING BLANK LINE IN THE INTERMEDIATE PARTIAL SYSTEM EDIT A(90) =  0.0
                0.0    = SPACING LINE IS GENERATED
              NON-ZERO= SPACING LINE IS SUPPRESSED

A(91)         OPTION TO PRINT OUT THE MAP OF INDEX  1.0
              NUMBERS OF CESEC VARIABLES
                  0. = NO MAP
                  1. = MAP PRINTED
```

2. GENERAL REACTOR COOLANT SYSTEM INFORMATION

*** REACTOR COOLANT VOLUME ***

A(1000)	VOLUME OF CLOSURE HEAD	FT3	.1136E+04
A(1001)	CORE COLD PLENUM VOLUME	FT3	.2129E+04
A(1002)	RHSG HOT LEG VOLUME	FT3	.1468E+03
A(1003)	RHSG HOT PLENUM VOLUME	FT3	.2991E+03
A(1004)	RHSG COLD PLENUM VOLUME	FT3	.2819E+03
A(1005)	COMBINED VOLUME OF RHSG COLD LEG	FT3	.6397E+03
A(1006)	TOTAL TUBE VOLUME OF RHSG	FT3	.1117E+04
A(1007)	VOLUME OF LHSG HOT LEG	FT3	.1468E+03
A(1008)	LHSG HOT PLENUM VOLUME	FT3	.2991E+03
A(1009)	LHSG COLD PLENUM VOLUME	FT3	.2819E+03
A(1010)	COMBINED VOLUME OF LHSG COLD LEG	FT3	.6397E+03
A(1011)	TOTAL TUBE VOLUME OF LHSG	FT3	.1117E+04
A(1012)	VOLUME BETWEEN ACTIVE CORE AND FUEL ALIGNMENT PLATE	FT3	.3093E+03
A(1013)	VOLUME BETWEEN FAP AND UGS SUPPORT PLATE PLUS OUTLET NOZZLE VOLUME	FT3	.5681E+03
A(1014)	SURGE LINE VOLUME	FT3	.2930E+02
A(1514)	CORE COOLANT CHANNEL VOLUME	FT3	.7026E+03
A(4002)	PRESSURIZER VOLUME	FT3	.1519E+04

3. FLOW MODEL INFORMATION

A(6000)	NUMBER OF NODES IN FLOW MODEL		.2800E+02
A(2052)	FRACTION OF TOTAL CORE FLOW TO CLOSURE HEAD		.1241E-01
A(2053)	INLET PLENUM MIXING FACTOR		
A(2054)	OUTLET PLENUM MIXING FACTOR		
A(2055)	NUMBER OF TUBE NODES PER STEAM GENERATOR		.2000E+01
A(2061)	0.0 - NO SLIP ASSUMED FOR FLUID LEAVING THE CLOSURE HEAD 1.0 - SLIP IS ASSUMED FOR FLUID LEAVING THE CLOSURE HEAD		0.
A(4976)	TIME TO ALTER FLOW TO CLOSURE HEAD VIA CEA SHROUDS	SEC	0.
A(4977)	FRACTION OF TOTAL CORE FLOW THROUGH CEA SHROUDS TO THE CLOSURE HEAD	FRAC	0.

NODE 1

A(6001)	EFFECTIVE DIAMETER OF NODE 1	FT	.1352E+01
A(6002)	HEIGHT OF NODE 1 (DELTA H = (H-IN)-(H-OUT))	FT	.2070E+01
A(6003)	AVERAGE FLOW AREA OF NODE 1	FT2	.3584E+01
A(6004)	FLOW PATH LENGTH OF NODE 1	FT	.1587E+02
A(6005)	FORWARD GEOMETRIC LOSS FOR NODE 1	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07
A(6006)	REVERSE GEOMETRIC LOSS FOR NODE 1	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07

NODE 2

A(6007)	EFFECTIVE DIAMETER OF NODE 2	FT	.2075E+01
A(6008)	HEIGHT OF NODE 2 (DELTA H = (H-IN)-(H-OUT))	FT	-.1920E+01
A(6009)	AVERAGE FLOW AREA OF NODE 2	FT2	.5500E+01
A(6010)	FLOW PATH LENGTH OF NODE 2	FT	.4184E+02
A(6011)	FORWARD GEOMETRIC LOSS FOR NODE 2	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07
A(6012)	REVERSE GEOMETRIC LOSS FOR NODE 2	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07

NODE 3

A(6013)	EFFECTIVE DIAMETER OF NODE 3	FT	.1210E+01
A(6014)	HEIGHT OF NODE 3 (DELTA H = (H-IN)-(H-OUT))	FT	.2250E+02
A(6015)	AVERAGE FLOW AREA OF NODE 3	FT2	.8097E+02
A(6016)	FLOW PATH LENGTH OF NODE 3	FT	.6456E+02
A(6017)	FORWARD GEOMETRIC LOSS FOR NODE 3	LBF-SEC**2/ LBM*IN**2*FT**3	.3540E-06
A(6018)	REVERSE GEOMETRIC LOSS FOR NODE 3	LBF-SEC**2/ LBM*IN**2*FT**3	.2800E-06

NODE 4

A(6019)	EFFECTIVE DIAMETER OF NODE 4	FT	.9000E+99
A(6020)	HEIGHT OF NODE 4 (DELTA H = (H-IN)-(H-OUT))	FT	-.5130E+01
A(6021)	AVERAGE FLOW AREA OF NODE 4	FT2	.1050E+03
A(6022)	FLOW PATH LENGTH OF NODE 4	FT	.7591E+01
A(6023)	FORWARD GEOMETRIC LOSS FOR NODE 4	LBF-SEC**2/ LBM*IN**2*FT**3	.5250E-06
A(6024)	REVERSE GEOMETRIC LOSS FOR NODE 4	LBF-SEC**2/ LBM*IN**2*FT**3	.1590E-05

NODE 5

A(6025)	EFFECTIVE DIAMETER OF NODE 5	FT	.3838E-01
A(6026)	HEIGHT OF NODE 5 (DELTA H = (H-IN)-(H-OUT))	FT	-.1139E+02
A(6027)	AVERAGE FLOW AREA OF NODE 5	FT2	.5226E+02
A(6028)	FLOW PATH LENGTH OF NODE 5	FT	.1077E+02
A(6029)	FORWARD GEOMETRIC LOSS FOR NODE 5	LBF-SEC**2/ LBM*IN**2*FT**3	.6720E-06
A(6030)	REVERSE GEOMETRIC LOSS FOR NODE 5	LBF-SEC**2/ LBM*IN**2*FT**3	.6720E-06

NODE 6

A(6031)	EFFECTIVE DIAMETER OF NODE 6	FT	.7582E-01
A(6032)	HEIGHT OF NODE 6 (DELTA H = (H-IN)-(H-OUT))	FT	-.3600E+01
A(6033)	AVERAGE FLOW AREA OF NODE 6	FT2	.1102E+03
A(6034)	FLOW PATH LENGTH OF NODE 6	FT	.5686E+01
A(6035)	FORWARD GEOMETRIC LOSS FOR NODE 6	LBF-SEC**2/ LBM*IN**2*FT**3	.1540E-06
A(6036)	REVERSE GEOMETRIC LOSS FOR NODE 6	LBF-SEC**2/ LBM*IN**2*FT**3	.1900E-06

NODE 7

A(6037)	EFFECTIVE DIAMETER OF NODE 7	FT	.9000E+99
A(6038)	HEIGHT OF NODE 7 (DELTA H = (H-IN)-(H-OUT))	FT	-.2380E+01
A(6039)	AVERAGE FLOW AREA OF NODE 7	FT2	.4581E+02
A(6040)	FLOW PATH LENGTH OF NODE 7	FT	.1643E+02
A(6041)	FORWARD GEOMETRIC LOSS FOR NODE 7	LBF-SEC**2/ LBM*IN**2*FT**3	.8970E-06
A(6042)	REVERSE GEOMETRIC LOSS FOR NODE 7	LBF-SEC**2/ LBM*IN**2*FT**3	.1350E-05

NODE 8

A(6043)	EFFECTIVE DIAMETER OF NODE 8	FT	.2503E+01
A(6044)	HEIGHT OF NODE 8 (DELTA H = (H-IN)-(H-OUT))	FT	-.9400E+00
A(6045)	AVERAGE FLOW AREA OF NODE 8	FT2	.7256E+01
A(6046)	FLOW PATH LENGTH OF NODE 8	FT	.1044E+02
A(6047)	FORWARD GEOMETRIC LOSS FOR NODE 8	LBF-SEC**2/ LBM*IN**2*FT**3	.7980E-07
A(6048)	REVERSE GEOMETRIC LOSS FOR NODE 8	LBF-SEC**2/ LBM*IN**2*FT**3	.7980E-07

NODE 9

A(6049)	EFFECTIVE DIAMETER OF NODE 9	FT	.9000E+99
A(6050)	HEIGHT OF NODE 9 (DELTA H = (H-IN)-(H-OUT))	FT	-.4990E+01
A(6051)	AVERAGE FLOW AREA OF NODE 9	FT2	.3211E+02
A(6052)	FLOW PATH LENGTH OF NODE 9	FT	.1210E+02
A(6053)	FORWARD GEOMETRIC LOSS FOR NODE 9	LBF-SEC**2/ LBM*IN**2*FT**3	.6850E-06
A(6054)	REVERSE GEOMETRIC LOSS FOR NODE 9	LBF-SEC**2/ LBM*IN**2*FT**3	.4590E-06

NODE 10

A(6055)	EFFECTIVE DIAMETER OF NODE 10	FT	.2879E+00
A(6056)	HEIGHT OF NODE 10 (DELTA H = (H-IN)-(H-OUT))	FT	-.2690E+02
A(6057)	AVERAGE FLOW AREA OF NODE 10	FT2	.1155E+01
A(6058)	FLOW PATH LENGTH OF NODE 10	FT	.1579E+01
A(6059)	FORWARD GEOMETRIC LOSS FOR NODE 10	LBF-SEC**2/ LBM*IN**2*FT**3	.7120E-07
A(6060)	REVERSE GEOMETRIC LOSS FOR NODE 10	LBF-SEC**2/ LBM*IN**2*FT**3	.7120E-07

NODE 11

A(6061)	EFFECTIVE DIAMETER OF NODE 11	FT	.2891E+00
A(6062)	HEIGHT OF NODE 11 (DELTA H = (H-IN)-(H-OUT))	FT	.2690E+02
A(6063)	AVERAGE FLOW AREA OF NODE 11	FT2	.1107E+01
A(6064)	FLOW PATH LENGTH OF NODE 11	FT	.1514E+01
A(6065)	FORWARD GEOMETRIC LOSS FOR NODE 11	LBF-SEC**2/ LBM*IN**2*FT**3	.1780E-07
A(6066)	REVERSE GEOMETRIC LOSS FOR NODE 11	LBF-SEC**2/ LBM*IN**2*FT**3	.1780E-07

NODE 12

A(6067)	EFFECTIVE DIAMETER OF NODE 12	FT	.9000E+99
A(6068)	HEIGHT OF NODE 12 (DELTA H = (H-IN)-(H-OUT))	FT	.5780E+01
A(6069)	AVERAGE FLOW AREA OF NODE 12	FT2	.3185E+02
A(6070)	FLOW PATH LENGTH OF NODE 12	FT	.1216E+02
A(6071)	FORWARD GEOMETRIC LOSS FOR NODE 12	LBF-SEC**2/ LBM*IN**2*FT**3	.4010E-07
A(6072)	REVERSE GEOMETRIC LOSS FOR NODE 12	LBF-SEC**2/ LBM*IN**2*FT**3	.3120E-07

NODE 13

A(6073)	EFFECTIVE DIAMETER OF NODE 13	FT	.1352E+01
A(6074)	HEIGHT OF NODE 13 (DELTA H = (H-IN)-(H-OUT))	FT	.2070E+01
A(6075)	AVERAGE FLOW AREA OF NODE 13	FT2	.3584E+01
A(6076)	FLOW PATH LENGTH OF NODE 13	FT	.1587E+02
A(6077)	FORWARD GEOMETRIC LOSS FOR NODE 13	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07
A(6078)	REVERSE GEOMETRIC LOSS FOR NODE 13	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07

NODE 14

A(6079)	EFFECTIVE DIAMETER OF NODE 14	FT	.2075E+01
A(6080)	HEIGHT OF NODE 14 (DELTA H = (H-IN)-(H-OUT))	FT	-.1920E+01
A(6081)	AVERAGE FLOW AREA OF NODE 14	FT2	.5500E+01
A(6082)	FLOW PATH LENGTH OF NODE 14	FT	.4184E+02
A(6083)	FORWARD GEOMETRIC LOSS FOR NODE 14	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07
A(6084)	REVERSE GEOMETRIC LOSS FOR NODE 14	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07

NODE 15

A(6085)	EFFECTIVE DIAMETER OF NODE 15	FT	.1352E+01
A(6086)	HEIGHT OF NODE 15 (DELTA H = (H-IN)-(H-OUT))	FT	.2070E+01
A(6087)	AVERAGE FLOW AREA OF NODE 15	FT2	.3584E+01
A(6088)	FLOW PATH LENGTH OF NODE 15	FT	.1587E+02
A(6089)	FORWARD GEOMETRIC LOSS FOR NODE 15	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07
A(6090)	REVERSE GEOMETRIC LOSS FOR NODE 15	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07

NODE 16

A(6091)	EFFECTIVE DIAMETER OF NODE 16	FT	.2075E+01
A(6092)	HEIGHT OF NODE 16 (DELTA H = (H-IN)-(H-OUT))	FT	-.1920E+01
A(6093)	AVERAGE FLOW AREA OF NODE 16	FT2	.5500E+01
A(6094)	FLOW PATH LENGTH OF NODE 16	FT	.4184E+02
A(6095)	FORWARD GEOMETRIC LOSS FOR NODE 16	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07
A(6096)	REVERSE GEOMETRIC LOSS FOR NODE 16	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07

NODE 17

A(6097)	EFFECTIVE DIAMETER OF NODE 17	FT	.1210E+01
A(6098)	HEIGHT OF NODE 17 (DELTA H = (H-IN)-(H-OUT))	FT	.2250E+02
A(6099)	AVERAGE FLOW AREA OF NODE 17	FT2	.8097E+02
A(6100)	FLOW PATH LENGTH OF NODE 17	FT	.6456E+02
A(6101)	FORWARD GEOMETRIC LOSS FOR NODE 17	LBF-SEC**2/ LBM*IN**2*FT**3	.3540E-06
A(6102)	REVERSE GEOMETRIC LOSS FOR NODE 17	LBF-SEC**2/ LBM*IN**2*FT**3	.2800E-06

NODE 18

A(6103)	EFFECTIVE DIAMETER OF NODE 18	FT	.9000E+99
A(6104)	HEIGHT OF NODE 18 (DELTA H = (H-IN)-(H-OUT))	FT	-.5130E+01
A(6105)	AVERAGE FLOW AREA OF NODE 18	FT2	.1050E+03
A(6106)	FLOW PATH LENGTH OF NODE 18	FT	.7591E+01
A(6107)	FORWARD GEOMETRIC LOSS FOR NODE 18	LBF-SEC**2/ LBM*IN**2*FT**3	.5250E-06
A(6108)	REVERSE GEOMETRIC LOSS FOR NODE 18	LBF-SEC**2/ LBM*IN**2*FT**3	.1590E-05

NODE 19

A(6109)	EFFECTIVE DIAMETER OF NODE 19	FT	.3838E-01
A(6110)	HEIGHT OF NODE 19 (DELTA H = (H-IN)-(H-OUT))	FT	-.1139E+02
A(6111)	AVERAGE FLOW AREA OF NODE 19	FT2	.5226E+02
A(6112)	FLOW PATH LENGTH OF NODE 19	FT	.1077E+02
A(6113)	FORWARD GEOMETRIC LOSS FOR NODE 19	LBF-SEC**2/ LBM*IN**2*FT**3	.6720E-06
A(6114)	REVERSE GEOMETRIC LOSS FOR NODE 19	LBF-SEC**2/ LBM*IN**2*FT**3	.6720E-06

NODE 20

A(6115)	EFFECTIVE DIAMETER OF NODE 20	FT	.7582E-01
A(6116)	HEIGHT OF NODE 20 (DELTA H = (H-IN)-(H-OUT))	FT	-.3600E+01
A(6117)	AVERAGE FLOW AREA OF NODE 20	FT2	.1102E+03
A(6118)	FLOW PATH LENGTH OF NODE 20	FT	.5686E+01
A(6119)	FORWARD GEOMETRIC LOSS FOR NODE 20	LBF-SEC**2/ LBM*IN**2*FT**3	.1540E-06
A(6120)	REVERSE GEOMETRIC LOSS FOR NODE 20	LBF-SEC**2/ LBM*IN**2*FT**3	.1900E-06

NODE 21

A(6121)	EFFECTIVE DIAMETER OF NODE 21	FT	.9000E+99
A(6122)	HEIGHT OF NODE 21 (DELTA H = (H-IN)-(H-OUT))	FT	-.2380E+01
A(6123)	AVERAGE FLOW AREA OF NODE 21	FT2	.4581E+02
A(6124)	FLOW PATH LENGTH OF NODE 21	FT	.1643E+02
A(6125)	FORWARD GEOMETRIC LOSS FOR NODE 21	LBF-SEC**2/ LBM*IN**2*FT**3	.8970E-06
A(6126)	REVERSE GEOMETRIC LOSS FOR NODE 21	LBF-SEC**2/ LBM*IN**2*FT**3	.1350E-05

NODE 22

A(6127)	EFFECTIVE DIAMETER OF NODE 22	FT	.2503E+01
A(6128)	HEIGHT OF NODE 22 (DELTA H = (H-IN)-(H-OUT))	FT	-.9400E+00
A(6129)	AVERAGE FLOW AREA OF NODE 22	FT2	.7256E+01
A(6130)	FLOW PATH LENGTH OF NODE 22	FT	.1044E+02
A(6131)	FORWARD GEOMETRIC LOSS FOR NODE 22	LBF-SEC**2/ LBM*IN**2*FT**3	.7980E-07
A(6132)	REVERSE GEOMETRIC LOSS FOR NODE 22	LBF-SEC**2/ LBM*IN**2*FT**3	.7980E-07

NODE 23

A(6133)	EFFECTIVE DIAMETER OF NODE 23	FT	.9000E+99
A(6134)	HEIGHT OF NODE 23 (DELTA H = (H-IN)-(H-OUT))	FT	-.4990E+01
A(6135)	AVERAGE FLOW AREA OF NODE 23	FT2	.3211E+02
A(6136)	FLOW PATH LENGTH OF NODE 23	FT	.1210E+02
A(6137)	FORWARD GEOMETRIC LOSS FOR NODE 23	LBF-SEC**2/ LBM*IN**2*FT**3	.6850E-06
A(6138)	REVERSE GEOMETRIC LOSS FOR NODE 23	LBF-SEC**2/ LBM*IN**2*FT**3	.4590E-06

NODE 24

A(6139)	EFFECTIVE DIAMETER OF NODE 24	FT	.2879E+00
A(6140)	HEIGHT OF NODE 24 (DELTA H = (H-IN)-(H-OUT))	FT	-.2690E+02
A(6141)	AVERAGE FLOW AREA OF NODE 24	FT2	.1155E+01
A(6142)	FLOW PATH LENGTH OF NODE 24	FT	.1579E+01
A(6143)	FORWARD GEOMETRIC LOSS FOR NODE 24	LBF-SEC**2/ LBM*IN**2*FT**3	.7120E-07
A(6144)	REVERSE GEOMETRIC LOSS FOR NODE 24	LBF-SEC**2/ LBM*IN**2*FT**3	.7120E-07

NODE 25

A(6145)	EFFECTIVE DIAMETER OF NODE 25	FT	.2891E+00
A(6146)	HEIGHT OF NODE 25 (DELTA H = (H-IN)-(H-OUT))	FT	.2690E+02
A(6147)	AVERAGE FLOW AREA OF NODE 25	FT2	.1107E+01
A(6148)	FLOW PATH LENGTH OF NODE 25	FT	.1514E+01
A(6149)	FORWARD GEOMETRIC LOSS FOR NODE 25	LBF-SEC**2/ LBM*IN**2*FT**3	.1780E-07
A(6150)	REVERSE GEOMETRIC LOSS FOR NODE 25	LBF-SEC**2/ LBM*IN**2*FT**3	.1780E-07

NODE 26

A(6151)	EFFECTIVE DIAMETER OF NODE 26	FT	.9000E+99
A(6152)	HEIGHT OF NODE 26 (DELTA H = (H-IN)-(H-OUT))	FT	.5780E+01
A(6153)	AVERAGE FLOW AREA OF NODE 26	FT2	.3185E+02
A(6154)	FLOW PATH LENGTH OF NODE 26	FT	.1216E+02
A(6155)	FORWARD GEOMETRIC LOSS FOR NODE 26	LBF-SEC**2/ LBM*IN**2*FT**3	.4010E-07
A(6156)	REVERSE GEOMETRIC LOSS FOR NODE 26	LBF-SEC**2/ LBM*IN**2*FT**3	.3120E-07

NODE 27

A(6157)	EFFECTIVE DIAMETER OF NODE 27	FT	.1352E+01
A(6158)	HEIGHT OF NODE 27 (DELTA H = (H-IN)-(H-OUT))	FT	.2070E+01
A(6159)	AVERAGE FLOW AREA OF NODE 27	FT2	.3584E+01
A(6160)	FLOW PATH LENGTH OF NODE 27	FT	.1587E+02
A(6161)	FORWARD GEOMETRIC LOSS FOR NODE 27	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07
A(6162)	REVERSE GEOMETRIC LOSS FOR NODE 27	LBF-SEC**2/ LBM*IN**2*FT**3	.8870E-07

NODE 28

A(6163)	EFFECTIVE DIAMETER OF NODE 28	FT	.2075E+01
A(6164)	HEIGHT OF NODE 28 (DELTA H = (H-IN)-(H-OUT))	FT	-.1920E+01
A(6165)	AVERAGE FLOW AREA OF NODE 28	FT2	.5500E+01
A(6166)	FLOW PATH LENGTH OF NODE 28	FT	.4184E+02
A(6167)	FORWARD GEOMETRIC LOSS FOR NODE 28	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07
A(6168)	REVERSE GEOMETRIC LOSS FOR NODE 28	LBF-SEC**2/ LBM*IN**2*FT**3	.2690E-07

4. GENERAL REACTOR CORE INFORMATION

A(500)	DESIGN AVERAGE CORE MASS VELOCITY	LB/HR-FT2	.2150E+07
A(501)	DESIGN AVERAGE CORE HEAT FLUX	BTU/HR-FT2	.1558E+06
A(1020)	INITIAL CORE INLET TEMPERATURE	DEG,F	.5480E+03
A(1025)	DESIGN FULL POWER CORE INLET TEMPERATURE FOR ABOVE VOLUMETRIC FLOW RATES	DEG,F	.5500E+03
A(1532)	COOLANT SYSTEM PRESSURE	PSIA	.2250E+04
A(2025)	POWER FOR WHICH CORE IS DESIGNED TO OPERATE	MWT	.2570E+04

CORE BYPASS FLOW FRACTION VS TIME

A(2051) NUMBER OF POINTS IN TABLE .2000E+01

TIME(SEC) A-VECTOR	VALUE	FLOW(FRAC) A-VECTOR	VALUE
A(2056)	0.	A(2063)	.3700E-01
A(2057)	.1000E+05	A(2064)	.3700E-01

A(3950) UNEVEN TEMPERATURE DISTRIBUTION OPTION 0.
1.0 = YES
0.0 = NO

*** FUEL HEAT TRANSFER ***

A(1500)	NUMBER OF AXIAL CORE NODES		.1000E+01
A(1502)	NUMBER OF FUEL PINS		.4958E+05
A(1503)	RADIUS OF FUEL IN AVERAGE FUEL PIN	FT	.1354E-01
A(1504)	WIDTH OF GAP BETWEEN FUEL PIN AND CLAD	FT	.2917E-03
A(1505)	GAP THERMAL CONDUCTIVITY	BTU/SEC-FT2-F	.1139E+00
A(1506)	WIDTH OF CLADDING	FT	.2083E-02
A(1507)	FRACTION OF ENERGY LIBERATED IN FUEL	FRAC	.9631E+00
A(1508)	FRACTION OF ENERGY LIBERATED IN CLAD	FRAC	.1040E-01
A(1509)	FRACTION OF ENERGY LIBERATED IN MODERATOR	FRAC	.2650E-01
A(1510)	INITIAL CORE POWER	MWT	.2630E+04
A(1514)	VOLUME OF CORE COOLANT CHANNELS	FT3	.7026E+03
A(1515)	ACTIVE LENGTH OF FUEL PIN	FT	.1136E+02
A(1516)	SOURCE STRENGTH		0.
A(1517)	SEPARATION BETWEEN FUEL PINS CENTER-TO-CENTER	FT	.4223E-01

AXIAL POWER DISTRIBUTION

A(1583)	NUMBER OF AXIAL POWER DISTRIBUTION TIME INTERVALS	.2000E+01
A(1584)	NUMBER OF SPACE POINTS IN AXIAL LENGTH	.2000E+02

*** A-VECTORS 1605 THROUGH 1624 ARE THE TIME VALUES ASSOCIATED WITH EACH AXIAL POWER DISTRIBUTION. THE AXIAL LENGTH AND CORRESPONDING POWER FRACTIONS ARE SHOWN FOR EACH TIME INTERVAL. ***

TIME = A(1605) = 0. SEC.

AXIAL LENGTH(FT) A-VECTOR	VALUE	POWER FRACTION(FRAC) A-VECTOR	VALUE
A(1585)	.2848E+00	A(1625)	.1000E+01
A(1586)	.8544E+00	A(1626)	.1000E+01
A(1587)	.1424E+01	A(1627)	.1000E+01
A(1588)	.1994E+01	A(1628)	.1000E+01
A(1589)	.2563E+01	A(1629)	.1000E+01
A(1590)	.3133E+01	A(1630)	.1000E+01
A(1591)	.3702E+01	A(1631)	.1000E+01
A(1592)	.4272E+01	A(1632)	.1000E+01
A(1593)	.4841E+01	A(1633)	.1000E+01
A(1594)	.5411E+01	A(1634)	.1000E+01
A(1595)	.5981E+01	A(1635)	.1000E+01
A(1596)	.6550E+01	A(1636)	.1000E+01
A(1597)	.7120E+01	A(1637)	.1000E+01
A(1598)	.7689E+01	A(1638)	.1000E+01
A(1599)	.8259E+01	A(1639)	.1000E+01
A(1600)	.8828E+01	A(1640)	.1000E+01
A(1601)	.9398E+01	A(1641)	.1000E+01
A(1602)	.9968E+01	A(1642)	.1000E+01
A(1603)	.1054E+02	A(1643)	.1000E+01
A(1604)	.1139E+02	A(1644)	.1000E+01

TIME = A(1606) = 10000.0 SEC.

AXIAL LENGTH(FT) A-VECTOR	VALUE	POWER FRACTION(FRAC) A-VECTOR	VALUE
A(1585)	.2848E+00	A(1645)	0.
A(1586)	.8544E+00	A(1646)	0.
A(1587)	.1424E+01	A(1647)	0.
A(1588)	.1994E+01	A(1648)	0.
A(1589)	.2563E+01	A(1649)	0.
A(1590)	.3133E+01	A(1650)	0.
A(1591)	.3702E+01	A(1651)	0.
A(1592)	.4272E+01	A(1652)	0.
A(1593)	.4841E+01	A(1653)	0.
A(1594)	.5411E+01	A(1654)	0.
A(1595)	.5981E+01	A(1655)	0.
A(1596)	.6550E+01	A(1656)	0.
A(1597)	.7120E+01	A(1657)	0.
A(1598)	.7689E+01	A(1658)	0.
A(1599)	.8259E+01	A(1659)	0.
A(1600)	.8828E+01	A(1660)	0.
A(1601)	.9398E+01	A(1661)	0.
A(1602)	.9968E+01	A(1662)	0.
A(1603)	.1054E+02	A(1663)	0.
A(1604)	.1139E+02	A(1664)	0.

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                         * 5. REACTIVITY INFORMATION *
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                    DOPPLER REACTIVITY VS FUEL TEMPERATURE
                    --------------------------------------

A(3300)      NUMBER OF ENTRIES IN TABLE                                   .1000E+02

             FUEL TEMPERATURES(F)                           DOPPLER COEFFICIENTS(RHO)
         A-VECTOR          VALUE                        A-VECTOR          VALUE

         A(3326)          .2699E+03                     A(3301)          .1120E-01
         A(3327)          .4959E+03                     A(3302)          .7800E-02
         A(3328)          .1061E+04                     A(3303)          .5000E-03
         A(3329)          .1287E+04                     A(3304)         -.2000E-02
         A(3330)          .1626E+04                     A(3305)         -.5500E-02
         A(3331)          .2191E+04                     A(3306)         -.1080E-01
         A(3332)          .2755E+04                     A(3307)         -.1560E-01
         A(3333)          .3320E+04                     A(3308)         -.2000E-01
         A(3334)          .3885E+04                     A(3309)         -.2410E-01
         A(3335)          .4450E+04                     A(3310)         -.2800E-01

A(3877)      UNCERTAINTY MULTIPLIER FOR ABOVE TABLE                       .1150E+01

                   MODERATOR REACTIVITY VS FUEL TEMPERATURE
                   ----------------------------------------

A(3400)      NUMBER OF ENTRIES IN TABLE                                   .2000E+01

             MODERATOR TEMPERATURES(F)                      MODERATOR REACTIVITIES(RHO)
         A-VECTOR          VALUE                        A-VECTOR          VALUE

         A(3426)          0.                            A(3401)          0.
         A(3427)          .1000E+04                     A(3402)          .1000E+00

A(3878)      UNCERTAINTY MULTIPLIER FOR ABOVE TABLE                       .4000E+00

                      REACTIVITY VS BORON CONCENTRATION
                      ---------------------------------

A(3500)      NUMBER OF ENTRIES IN TABLE                                   .2000E+01

             BORON CONCENTRATION(PPM)                       BORON REACTIVITIES(RHO)
         A-VECTOR          VALUE                        A-VECTOR          VALUE

         A(3526)          0.                            A(3501)          0.
         A(3527)          .1000E+05                     A(3502)         -.1163E+01
```

CONTROL ROD POSITION VS WORTH

A(3600) NUMBER OF ENTRIES IN TABLE 0.

ROD POSITION(FRAC) A-VECTOR	VALUE	ROD WORTH(FRAC) A-VECTOR	VALUE
A(3626)	0.	A(3601)	0.

A(3881) CONTROL ROD BANK WORTH 0.

SCRAM ROD WORTH VS TIME

A(3700) NUMBER OF ENTRIES IN TABLE .1600E+02

TIME(SEC) A-VECTOR	VALUE	ROD WORTH(FRAC) A-VECTOR	VALUE
A(3726)	0.	A(3701)	0.
A(3727)	.3400E+00	A(3702)	0.
A(3728)	.8400E+00	A(3703)	.2000E-03
A(3729)	.1150E+01	A(3704)	.7000E-03
A(3730)	.1400E+01	A(3705)	.2100E-02
A(3731)	.1730E+01	A(3706)	.5600E-02
A(3732)	.2000E+01	A(3707)	.1260E-01
A(3733)	.2260E+01	A(3708)	.3150E-01
A(3734)	.2500E+01	A(3709)	.6690E-01
A(3735)	.2630E+01	A(3710)	.1043E+00
A(3736)	.2750E+01	A(3711)	.1671E+00
A(3737)	.2870E+01	A(3712)	.2820E+00
A(3738)	.3000E+01	A(3713)	.5000E+00
A(3739)	.3500E+01	A(3714)	.8309E+00
A(3740)	.4000E+01	A(3715)	.1000E+01
A(3741)	.1000E+05	A(3716)	.1000E+01

A(3879) SCRAM ROD MULTIPLIER DELTA RHO -.5500E-01

REACTIVITY VS TIME

A(3800) NUMBER OF ENTRIES IN TABLE .2000E+01

TIME(SEC) A-VECTOR	VALUE	REACTIVITIES(DELTA RHO) A-VECTOR	VALUE
A(3826)	0.	A(3801)	0.
A(3827)	.3000E+00	A(3802)	0.

```
A(3942)        ROD DROP INDICATOR                                         0.
                  0.0 = NO
                  1.0 = YES

A(3943)        TOTAL WORTH OF DROPPED RODS                 DELTA RHO      0.
```

*** VOID REACTIVITY INFORMATION ***

A(1188)	VDRC OPTIONX 1.0 = USE VDRC 0.0 = NO VDRC	0.
A(1183)	FRACTION OF VOID REACTIVITY FLUX SQUARE WEIGHTED	0.
A(1189)	LOWER VOID LIMIT FOR USE OF VDRC	0.
A(1204)	DOPPLER WEIGHTING COEFFICIENT	.1000E+01
A(1205)	MODERATOR DENSITY COEFFICIENT	0.
A(1206)	MODERATOR VOID COEFFICIENT	0.
A(1207)	MODERATOR TEMPERATURE(SPECTRAL) COEFFICIENT	.1000E+01

FACTORS USED IN CHANNEL DELTA H CORRELATION IN VDRC

A-VECTOR	VALUE
A(1184)	0.
A(1185)	0.
A(1186)	0.
A(1187)	0.

EMPIRICAL COEFFICIENTS USED IN VDRC

A-VECTOR	VALUE
A(1190)	0.
A(1191)	0.
A(1192)	0.
A(1193)	0.
A(1194)	0.
A(1195)	0.
A(1196)	0.
A(1197)	0.
A(1198)	0.
A(1199)	0.
A(1200)	0.
A(1201)	0.
A(1202)	0.
A(1203)	0.

DENSITY VS, REACTIVITY

A(1181) NUMBER OF POINTS IN TABLE .3000E+01

DENSITY(LB/FT3) A-VECTOR	VALUE	REACTIVITY(DELTA RHO) A-VECTOR	VALUE
A(1101)	.6740E+01	A(1121)	-.3640E+00
A(1102)	.4290E+02	A(1122)	.2280E-02
A(1103)	.5090E+02	A(1123)	.3760E-02

RADIALS VS, FUEL

A(1182) NUMBER OF POINTS IN TABLE .3000E+01

RADIAL PEAKING FACTORS A-VECTOR	VALUE	FUEL PINS PER INTERVAL(PERCENT) A-VECTOR	VALUE
A(1141)	.5000E+00	A(1161)	0.
A(1142)	.1350E+01	A(1162)	.2350E+01
A(1143)	.2000E+01	A(1163)	.2350E+01

AXIAL POWER DISTRIBUTION FOR VDRC CALCULATIONS

(505) NUMBER OF POINTS IN TABLE .2000E+02

AXIAL POINT	AVG CORE A.P.D. FACTORS A-VECTOR	VALUE
1	A(511)	.7197E+00
2	A(512)	.1051E+01
3	A(513)	.1150E+01
4	A(514)	.1136E+01
5	A(515)	.1086E+01
6	A(516)	.1036E+01
7	A(517)	.9969E+00
8	A(518)	.9704E+00
9	A(519)	.9542E+00
10	A(520)	.9461E+00
11	A(521)	.9451E+00
12	A(522)	.9516E+00
13	A(523)	.9674E+00
14	A(524)	.9950E+00
15	A(525)	.1036E+01
16	A(526)	.1087E+01
17	A(527)	.1133E+01
18	A(528)	.1136E+01
19	A(529)	.1020E+01
20	A(530)	.6848E+00

A(640)	ENTHALPY RISE FACTOR FOR VDRC CALCULATIONS	,1320E+01
A(645)	PITCH AND BOW FACTOR FOR VDRC CALCULATIONS	,1065E+01
A(647)	PLENUM MALDISTRIBUTION FACTOR FOR VDRC CALCULATIONS	,1050E+01
A(649)	ONE PIN VERSUS FOUR PIN FACTOR FOR VDRC CALCULATIONS	,1012E+01

3-D REACTIVITY FEEDBACK TABLES

A(5500)	TIME DELAY FOR START OF 3-D FEEDBACK. IF THIS VALUE IS .LE. 0, THE HERMITE-TORC FEEDBACK MODEL WILL NOT BE USED.	SECONDS		-.1000E-07
A(5501)	FRACTION OF HERMITE-TORC FEEDBACK CREDITED.			.7500E+00
A(5502)	TEMPERATURE TILT BELOW WHICH A MESSAGE WILL BE PRINTED INDICATING THAT A NEGATIVE TILT HAS BEEN SET TO ZERO.	DEGREES,F		-.1000E+01
A(5503)	MINIMUM POWER-TO-FLOW RATIO IN THE 3D REACTIVITY FEEDBACK TABLES. WHEN LOWER VALUES OF THIS RATIO ARE CALCULATED THEY ARE REPLACED BY THIS VALUE (0.01).			.1000E-01
A(5504)	MINIMUM FLOW FRACTION FOR WHICH THE 3-D FEEDBACK TABLES ARE VALID.			0.
A(5505)	MAXIMUM TEMPERATURE TILT FOR WHICH THE 3-D FEEDBACK TABLES ARE VALID.	DEGREES,F		.3000E+03
A(5506)	MAXIMUM POWER-TO-FLOW FRACTION FOR WHICH THE 3-D FEEDBACK TABLES ARE VALID.			.5000E+01
A(5508)	POWER TO WHICH POWERS ARE NORMALIZED IN THE 3-D FEEDBACK DATA	MW		.2560E+04
A(5509)	FLOW TO WHICH FLOWS ARE NORMALIZED IN THE 3-D FEEDBACK DATA	LBM/S		.3730E+05
A(5510)	NUMBER OF FLOW FRACTIONS IN THE HERMITE-TORC 3-D FEEDBACK TABLES.			.6000E+01
A(5550)	1.0 INDICATES THE FIRST SUB-TABLE OF REACTIVITY VS TEMPERATURE TILT AND POWER-TO-FLOW RATIO AT A FIXED FLOW FRACTION		.1000E+01	
A(5551)	DEGREE OF INTERPOLATION TO BE USED		.1000E+01	
A(5552)	NUMBER OF TEMPERATURE TILTS (NX)		.3000E+01	
A(5553)	NUMBER OF POWER-TO-FLOW RATIO (NY)		.8000E+01	

** NOTE **

A(5511-5518) ARE THE CORE FLOW FRACTIONS FOR THE HERMITE-TORC 3D FEEDBACK TABLES.

A(5554) THROUGH A(5553 + NX) ARE THE TEMPERATURE TILTS

A(5554 + NX) THROUGH A(5553 + NX + NY)ARE THE POWER-TO-FLOW RATIOS

A(5554 + NX + NY) THROUGH A(5553 + NX + NY + NX*NY) ARE THE 3-D REACTIVITY FEEDBACK VALUES FOR THE FIRST FLOW FRACTION,A(5511),AND THE FIRST TEMPERATURE TILT, A(5554), FOR ALL POWER-TO-FLOW RATIOS, FOLLOWED BY FEEDBACK VALUES FOR AGAIN THE FIRST FLOW FRACTION, A(5511), BUT THE SECOND TEMPERATURE TILT, A(5555), FOR ALL POWER-TO-FLOW RATIOS, ETC.

A(5554 + NX + NY + NX*NY)=2.0 INDICATES THE SECOND SUB-TABLE OF REACTIVITY VS. TEMPERATURE TILT AND POWER-TO-FLOW RATIO AT A FIXED FLOW FRACTION; THE PATTERN GIVEN FOR A(5551) AND FOLLOWING FOR THE FLOW FRACTION VALUE ENTERED IN A(5511) IS REPEATED FOR A(5554 + NX + NY + NX*NY) AND FOLLOWING FOR THE SECOND FLOW FRACTION VALUE, WHICH IS ENTERED IN A(5512). THIS ENTIRE PATTERN IS THEN REPEATED FOR THE THIRD FLOW FRACTION, ETC., UP THROUGH THE N-TH FLOW FRACTION.

A(5554 + NX + NY + NX*NY)=2.0 INDICATES THE SECOND SUB-TABLE OF REACTIVITY VS. TEMPERATURE TILT AND POWER-TO-FLOW RATIO AT A FIXED FLOW FRACTION; THE PATTERN GIVEN FOR A(5551) AND FOLLOWING FOR THE FLOW FRACTION VALUE ENTERED IN A(5511) IS REPEATED FOR A(5554 + NX + NY + NX*NY) AND FOLLOWING FOR THE SECOND FLOW FRACTION VALUE, WHICH IS ENTERED IN A(5512). THIS ENTIRE PATTERN IS THEN REPEATED FOR THE THIRD FLOW FRACTION, ETC., UP THROUGH THE N-TH FLOW FRACTION.

CORE FLOW FRACTION 1 A(5511) 0.

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5556)	.3000E+01	A(5564)	.5000E+01	A(5588)	0.
A(5557)	.1000E-01	A(5565)	0.	A(5589)	.2000E+01
A(5558)	.1000E+00	A(5566)	0.	A(5590)	.1000E+01

CORE FLOW FRACTION 2 A(5512) .2000E-01

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5559)	.2000E+00	A(5564)	.5000E+01	A(5591)	.3000E+01
A(5560)	.3000E+00	A(5565)	0.	A(5592)	.8000E+01
A(5561)	.4000E+00	A(5566)	0.	A(5593)	0.

CORE FLOW FRACTION 3 A(5513) .5000E-01

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5562)	.5000E+00	A(5564)	.5000E+01	A(5594)	.1500E+03
A(5563)	.6000E+00	A(5565)	0.	A(5595)	.3000E+03
A(5564)	.5000E+01	A(5566)	0.	A(5596)	.1000E-01

CORE FLOW FRACTION 4 A(5514) .1000E+00

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5565)	0.	A(5564)	.5000E+01	A(5597)	.1000E+00
A(5566)	0.	A(5565)	0.	A(5598)	.2000E+00
A(5567)	0.	A(5566)	0.	A(5599)	.3000E+00

CORE FLOW FRACTION 5 A(5515) .2000E+00

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5568)	0.	A(5564)	.5000E+01	A(5600)	.4000E+00
A(5569)	0.	A(5565)	0.	A(5601)	.5000E+00
A(5570)	0.	A(5566)	0.	A(5602)	.6000E+00

CORE FLOW FRACTION 6 A(5516) .3000E+01

TEMPERATURE TILTS,F		POWER-TO-FLOW RATIOS		3-D REACTIVITY,DELTA RHO	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(5571)	0.	A(5564)	.5000E+01	A(5603)	.5000E+01
A(5572)	0.	A(5565)	0.	A(5604)	-.4000E-02
A(5573)	0.	A(5566)	0.	A(5605)	-.4800E-02

6. REACTOR KINETICS INFORMATION

A(1530) NEUTRON LIFE TIME SEC .2760E-04

DELAYED NEUTRONS

GROUP	NEUTRON FRACTION A-VECTOR	NEUTRON FRACTION VALUE	DECAY CONSTANT A-VECTOR	DECAY CONSTANT VALUE
1	A(1518)	.2180E-03	A(1524)	.1250E-01
2	A(1519)	.1494E-02	A(1525)	.3080E-01
3	A(1520)	.1389E-02	A(1526)	.1149E+00
4	A(1521)	.2885E-02	A(1527)	.3106E+00
5	A(1522)	.1001E-02	A(1528)	.1230E+01
6	A(1523)	.3340E-03	A(1529)	.3292E+01

A(1300) TIME FOR SWITCHING OFF REACTOR KINETICS AND FOLLOWING ANS DECAY HEAT CURVE. CAN ONLY BE USED AFTER REACTOR TRIP AND RODS ARE DROPPED. SEC 0.

A(1451) OPTION TO USE THE HEAT FLUX INPUT TABLE 0. = NO, 1. = YES 0.

HEAT FLUX VS POWER FRACTION VS TIME

A(1350) NUMBER OF POINTS IN TABLE 0.

TIME(SEC) A-VECTOR	TIME(SEC) VALUE	HEAT FLUX(FRAC OF DESIGN) A-VECTOR	HEAT FLUX(FRAC OF DESIGN) VALUE	POWER FRACTION(FRAC) A-VECTOR	POWER FRACTION(FRAC) VALUE
A(1301)	0.	A(1351)	0.	A(1401)	0.

*** 7. REACTOR COOLANT PUMP MODEL ***

A(7500)	FLOW MODEL OPTION 1.0 = USE FLOW MODEL 0.0 = TABULAR INPUT	.1000E+01
A(1099)	TWO OR FOUR PUMP OPTIONS 0.0 = TWO-PUMP OPTION 1.0 = FOUR-PUMP OPTION	.1000E+01

*** PUMP SPEED VS. ELECTRICAL TORQUE ***

A(7000)	NUMBER OF POINTS IN TABLE	.1600E+02

PUMP SPEED(RPM)		ELECTRICAL TORQUE(FT-LBF)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(7001)	-.1800E+03	A(7025)	.5464E+05
A(7002)	0.	A(7026)	.5512E+05
A(7003)	.1800E+03	A(7027)	.5609E+05
A(7004)	.3600E+03	A(7028)	.5706E+05
A(7005)	.4500E+03	A(7029)	.5802E+05
A(7006)	.5400E+03	A(7030)	.5944E+05
A(7007)	.6300E+03	A(7031)	.6264E+05
A(7008)	.6750E+03	A(7032)	.6502E+05
A(7009)	.7200E+03	A(7033)	.6950E+05
A(7010)	.7650E+03	A(7034)	.7595E+05
A(7011)	.7875E+03	A(7035)	.8059E+05
A(7012)	.8100E+03	A(7036)	.7969E+05
A(7013)	.8325E+03	A(7037)	.7132E+05
A(7014)	.8550E+03	A(7038)	.5873E+05
A(7015)	.8860E+03	A(7039)	.3224E+05
A(7016)	.9000E+03	A(7040)	.1280E+05

A-VECTOR	DESCRIPTION	UNITS	VALUE	COMMENTS
A(7051)	RATED PUMP SPEED	RPM	.8860E+03	
A(7052)	RATED PUMP FLOW (ONE PUMP ONLY)	GPM	.8120E+05	
A(7053)	RATED PUMP HEAD	FT	.3100E+03	
A(7054)	RATED PUMP HYDRAULIC TORQUE	FT-LBF	.2950E+05	
A(7055)	RATED PUMP FLUID DENSITY	LBM/FT3	.4586E+02	
A(7056)	PUMP MOMENT OF INERTIA	LBM-FT2	.1020E+06	
A(7057)	RATED FRICTION AND WINDAGE TORQUE	FT-LBF	.2735E+04	
A(7058)	OPTION TO INITIALIZE PART LOOP SIMULATION (0. = NO)		0.	
A(1021)	VOLUMETRIC FLOW RATE FOR RIGHT-HAND LOOP	GPM	.1624E+06	
A(1022)	VOLUMETRIC FLOW RATE FOR LEFT-HAND LOOP	GPM	.1624E+06	
A(1023)	INITIAL PUMP FLOW IN LOOP 1	GPM	.9250E+05	
A(1024)	INITIAL PUMP FLOW IN LOOP 2	GPM	.9250E+05	
A(1097)	INITIAL PUMP FLOW IN LOOP 3	GPM	.9250E+05	
A(1098)	INITIAL PUMP FLOW IN LOOP 4	GPM	.9250E+05	
A(7061)	PUMP NODE FOR LOOP 1		.1000E+01	
A(7062)	PUMP NODE FOR LOOP 2		.1500E+02	
A(7063)	PUMP NODE FOR LOOP 3		.1300E+02	
A(7064)	PUMP NODE FOR LOOP 4		.2700E+02	

A(6252)	NODE FOR START OF LOOP 1		.1000E+01
A(6253)	NODE FOR END OF LOOP 1		.1200E+02
A(6254)	NODE FOR START OF LOOP 2		.1500E+02
A(6255)	NODE FOR END OF LOOP 2		.2600E+02
A(6256)	NODE FOR START OF LOOP 3		.3000E+01
A(6257)	NODE FOR END OF LOOP 3		.1400E+02
A(6258)	NODE FOR START OF LOOP 4		.1700E+02
A(6259)	NODE FOR END OF LOOP 4		.2800E+02
A(6265)	OPTION FOR MOMENTUM TRANSFER 0.0 = NO 1.0 = YES		0.
A(6260)	FLUX AREA IN LOWER PLENUM FOR MOMENTUM TRANSFER BETWEEN LOOPS	FT2	0.
A(6261)	FLUX AREA IN UPPER PLENUM FOR MOMENTUM TRANSFER BETWEEN LOOPS	FT2	0.
A(6262)	FLUX AREA FOR SURGE LINE FOR MOMENTUM TRANSFER TO RCS	FT2	.9621E+01
A(7060)	TIME TO SHUT OFF RCP"S	SEC	0.
A(7082)	ANTI-REVERSE DESIGN TORQUE FOR REACTOR COOLANT PUMPS	FT-LBF	.6650E+05
A(7083)	FRACTIONAL TOLERANCE ON FRICTION AND WINDAGE CONSTANT (FOR INITIALIZATION)	FRAC	.2000E+00
A(7084)	MINIMUM PUMP SPEED, USE A LARGE NEGATIVE NUMBER FOR LICENSING CALCULATIONS.	RPM	-.5000E+06

*** LOCKED ROTOR EVENT ***

SEE SPECIAL OPTIONS - CATEGORY 14.

*** HOMOLOGOUS HEAD CURVES ***

*** NOTE ***

FOR ALL HOMOLOGOUS CURVES, THE INDEPENDENT VARIABLE (NU/ALPHA) OR (ALPHA/NU) RANGES BETWEEN 0.0 AND 1.0 IN INCREMENTS OF 0.1

THE VARIABLES USED IN CALCULATING THE FOLLOWING HOMOLOGOUS HEAD CURVES ARE DEFINED AS FOLLOWS:

ALPHA - PUMP SPEED/RATED PUMP SPEED
NU - VOLUMETRIC FLOW RATE-RATED VOLUMETRIC FLOW RATE

H - PUMP HEAD/RATED PUMP HEAD

HAN - H/(ALPHA)2 - NORMAL OPERATION
HVN - H/(NU)2 - NORMAL OPERATION
HAD - H/(ALPHA)2 - ENERGY DISSIPATION
HVD - H/(NU)2 - ENERGY DISSIPATION
HAT - H/(ALPHA)2 - TURBINE OPERATION
HVT - H/(NU)2 - TURBINE OPERATION
HAR - H/(ALPHA)2 - REVERSE PUMP
HVR - H/(NU)2 - REVERSE PUMP

HAN		HAD		HAT		HAR	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(7101)	.1580E+01	A(7123)	.1580E+01	A(7145)	.4330E+00	A(7167)	.4330E+00
A(7102)	.1500E+01	A(7124)	.1660E+01	A(7146)	.4740E+00	A(7168)	.3430E+00
A(7103)	.1420E+01	A(7125)	.1760E+01	A(7147)	.5020E+00	A(7169)	.1120E-01
A(7104)	.1370E+01	A(7126)	.1870E+01	A(7148)	.5120E+00	A(7170)	-.2460E+00
A(7105)	.1330E+01	A(7127)	.2000E+01	A(7149)	.5240E+00	A(7171)	-.5130E+00
A(7106)	.1295E+01	A(7128)	.2130E+01	A(7150)	.5460E+00	A(7172)	-.8300E+00
A(7107)	.1270E+01	A(7129)	.2300E+01	A(7151)	.5830E+00	A(7173)	-.1035E+01
A(7108)	.1240E+01	A(7130)	.2470E+01	A(7152)	.6410E+00	A(7174)	-.1600E+01
A(7109)	.1182E+01	A(7131)	.2700E+01	A(7153)	.7120E+00	A(7175)	-.2050E+01
A(7110)	.1105E+01	A(7132)	.2930E+01	A(7154)	.8000E+00	A(7176)	-.2550E+01
A(7111)	.1000E+01	A(7133)	.3150E+01	A(7155)	.9080E+00	A(7177)	-.3100E+01

HVN		HVD		HVT		HVR	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(7112)	-.1420E+01	A(7134)	.1220E+01	A(7156)	.1220E+01	A(7178)	-.1420E+01
A(7113)	-.1215E+01	A(7135)	.1285E+01	A(7157)	.1182E+01	A(7179)	-.1715E+01
A(7114)	-.1082E+01	A(7136)	.1345E+01	A(7158)	.1140E+01	A(7180)	-.1960E+01
A(7115)	-.9120E+00	A(7137)	.1440E+01	A(7159)	.1085E+01	A(7181)	-.2150E+01
A(7116)	-.7280E+00	A(7138)	.1550E+01	A(7160)	.1045E+01	A(7182)	-.2340E+01
A(7117)	-.4940E+00	A(7139)	.1720E+01	A(7161)	.1000E+01	A(7183)	-.2520E+01
A(7118)	0.	A(7140)	.1930E+01	A(7162)	.9500E+00	A(7184)	-.2690E+01
A(7119)	.2080E+00	A(7141)	.2180E+01	A(7163)	.9000E+00	A(7185)	-.2810E+01
A(7120)	.4350E+00	A(7142)	.2490E+01	A(7164)	.8700E+00	A(7186)	-.2930E+01
A(7121)	.7080E+00	A(7143)	.2810E+01	A(7165)	.8650E+00	A(7187)	-.3010E+01
A(7122)	.1000E+01	A(7144)	.3150E+01	A(7166)	.9080E+00	A(7188)	-.3100E+01

*** HOMOLOGOUS TORQUE CURVES ***

*** NOTE ***

THE VARIABLES USED IN CALCULATING THE FOLLOWING HOMOLOGOUS TORQUE CURVES ARE DEFINED AS FOLLOWS%

ALPHA - PUMP SPEED/RATED PUMP SPEED
NU - VOLUMETRIC FLOW RATE/RATED VOLUMETRIC FLOW RATE

B - HYDRAULIC TORQUE/RATED HYDRAULIC TORQUE

BAN - B/(ALPHA)2 - NORMAL OPERATION
BVN - B/(NU)2 - NORMAL OPERATION
BAD - B/(ALPHA)2 - ENERGY DISSIPATION
BVD - B/(NU)2 - ENERGY DISSIPATION
BAT - B/(ALPHA)2 - TURBINE OPERATION
BVT - B/(NU)2 - TURBINE OPERATION
BAR - B/(ALPHA)2 - REVERSE PUMP
BVR - B/(NU)2 - REVERSE PUMP

BAN		BAD		BAT		BAR	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(7189)	.7700E+00	A(7211)	.7700E+00	A(7233)	-.1440E+01	A(7255)	-.1440E+01
A(7190)	.8020E+00	A(7212)	.8100E+00	A(7234)	-.9200E+00	A(7256)	-.1660E+01
A(7191)	.8450E+00	A(7213)	.8800E+00	A(7235)	-.6300E+00	A(7257)	-.1910E+01
A(7192)	.8660E+00	A(7214)	.9800E+00	A(7236)	-.4200E+00	A(7258)	-.2190E+01
A(7193)	.8850E+00	A(7215)	.1090E+01	A(7237)	-.2500E+00	A(7259)	-.2490E+01
A(7194)	.9100E+00	A(7216)	.1235E+01	A(7238)	-.1000E+00	A(7260)	-.2830E+01
A(7195)	.9300E+00	A(7217)	.1390E+01	A(7239)	.2000E-01	A(7261)	-.3240E+01
A(7196)	.9530E+00	A(7218)	.1580E+01	A(7240)	.1300E+00	A(7262)	-.3600E+01
A(7197)	.9730E+00	A(7219)	.1785E+01	A(7241)	.2510E+00	A(7263)	-.4050E+01
A(7198)	.9890E+00	A(7220)	.2040E+01	A(7242)	.3900E+00	A(7264)	-.4540E+01
A(7199)	.1000E+01	A(7221)	.2290E+01	A(7243)	.5620E+00	A(7265)	-.5030E+01

BVN		BVD		BVT		BVR	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(7200)	-.1450E+01	A(7222)	.1315E+01	A(7244)	.1315E+01	A(7266)	-.1450E+01
A(7201)	-.1112E+01	A(7223)	.1380E+01	A(7245)	.1245E+01	A(7267)	-.1850E+01
A(7202)	-.8720E+00	A(7224)	.1450E+01	A(7246)	.1180E+01	A(7268)	-.2200E+01
A(7203)	-.6480E+00	A(7225)	.1510E+01	A(7247)	.1110E+01	A(7269)	-.2520E+01
A(7204)	-.4420E+00	A(7226)	.1580E+01	A(7248)	.1042E+01	A(7270)	-.2850E+01
A(7205)	-.2700E+00	A(7227)	.1640E+01	A(7249)	.9750E+00	A(7271)	-.3150E+01
A(7206)	.2600E+00	A(7228)	.1720E+01	A(7250)	.9050E+00	A(7272)	-.3490E+01
A(7207)	.4300E+00	A(7229)	.1830E+01	A(7251)	.8170E+00	A(7273)	-.3840E+01
A(7208)	.6130E+00	A(7230)	.1960E+01	A(7252)	.7280E+00	A(7274)	-.4230E+01
A(7209)	.8000E+00	A(7231)	.2120E+01	A(7253)	.6280E+00	A(7275)	-.4610E+01
A(7210)	.1000E+01	A(7232)	.2290E+01	A(7254)	.5620E+00	A(7276)	-.5030E+01

*** PUMP DEGRADATION MODEL ***

A(7500)	FLOW MODEL OPTION 1.0 = USE FLOW MODEL 0.0 = TABULAR INPUT		.1000E+01
A(1021)	DESIGN VOLUMETRIC FLOW RATE FOR RIGHT HAND COOLANT PUMP1	GPM	.1624E+06
A(1022)	DESIGN VOLUMETRIC FLOW RATE FOR RIGHT HAND COOLANT PUMP2	GPM	.1624E+06
A(1023)	DESIGN VOLUMETRIC FLOW RATE FOR LEFT HAND COOLANT PUMP1	GPM	.9250E+05
A(1024)	DESIGN VOLUMETRIC FLOW RATE FOR LEFT HAND COOLANT PUMP 2	GPM	.9250E+05

FRACTION OF FULL MASS FLOW VS TIME

A(1531) NUMBER OF POINTS IN TABLE .2000E+01

TIME(SEC)		RH LOOP FLOW(FRAC)		LH LOOP FLOW(FRAC)	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(1558)	0.	A(1533)	.1139E+01	A(2026)	.1139E+01
A(1559)	.1000E+05	A(1534)	.1139E+01	A(2027)	.1139E+01

HEAD MULTIPLIER VS. VOID FRACTION TABLE

A(7277) NUMBER OF POINTS IN TABLE .1100E+02

HEAD MULTIPLIERS		VOID FRACTIONS	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(7279)	0.	A(7299)	0.
A(7280)	0.	A(7300)	.1000E+00
A(7281)	.5000E-01	A(7301)	.1500E+00
A(7282)	.8000E+00	A(7302)	.2400E+00
A(7283)	.9600E+00	A(7303)	.3000E+00
A(7284)	.9800E+00	A(7304)	.4000E+00
A(7285)	.9700E+00	A(7305)	.6000E+00
A(7286)	.9000E+00	A(7306)	.8000E+00
A(7287)	.8000E+00	A(7307)	.9000E+00
A(7288)	.5000E+00	A(7308)	.9600E+00
A(7289)	0.	A(7309)	.1000E+01

TORQUE MULTIPLIER VS. VOID FRACTION TABLE

A(7278) NUMBER OF POINTS IN TABLE .2000E+01

TORQUE MULTIPLIERS		VOID FRACTIONS	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(7319)	.1000E+01	A(7339)	0.
A(7320)	.1000E+01	A(7340)	.1000E+01

PUMP STATE VS. TIME TABLES

*** NOTE *** FOR PUMP STATE 0.0 = ON TIME FOR PUMP TO SWITCH FROM
1.0 = OFF OFF TO ON OR ON TO OFF

LOOP 1

A(7439) NUMBER OF ON/OFF TIMES .2000E+01

TIME(SEC) A-VECTOR	VALUE	PUMP STATE A-VECTOR	VALUE
A(7359)	0.	A(7399)	0.
A(7360)	.1000E+05	A(7400)	0.

LOOP 2

A(7440) NUMBER OF ON/OFF TIMES .2000E+01

TIME(SEC) A-VECTOR	VALUE	PUMP STATE A-VECTOR	VALUE
A(7369)	0.	A(7409)	0.
A(7370)	.1000E+05	A(7410)	0.

LOOP 3

A(7441) NUMBER OF ON/OFF TIMES .2000E+01

TIME(SEC) A-VECTOR	VALUE	PUMP STATE A-VECTOR	VALUE
A(7379)	0.	A(7429)	0.
A(7380)	.1000E+05	A(7430)	0.

LOOP 4

A(7442) NUMBER OF ON/OFF TIMES .2000E+01

TIME(SEC) A-VECTOR	VALUE	PUMP STATE A-VECTOR	VALUE
A(7389)	0.	A(7429)	0.
A(7390)	.1000E+05	A(7430)	0.

8. PRESSURIZER INFORMATION

A(4002)	PRESSURIZER VOLUME	FT3	.1519E+04
A(4003)	PRESSURIZER CROSS-SECTIONAL AREA	FT2	.5020E+02
A(4334)	INITIAL VOLUME OF WATER IN THE PRESSURIZER IF SETPOINT VALUE NOT USED. IF 0.0, SETPOINT VALUE IS USED.		0.
A(4331)	ACTUAL LENGTH OF PRESSURIZER SURGE LINE	FT	.5625E+02
A(4332)	DIAMETER OF PRESSURIZER SURGE LINE	FT	.8438E+00
A(4333)	GEOMETRIC K-FACTOR - FLOW INTO THE PRESSURIZER		.2380E+01
A(4335)	HEAT LOSS THROUGH PRESSURIZER WALLS	BTU/SEC	.2070E+02
A(4337)	ELEVATION OF PRESSURIZER ABOVE THE HOT LEG	FT	.1042E+02
A(4338)	GEOMETRIC REVERSE K-FACTOR - FLOW OUT OF THE PRESSURIZER		.3170E+01
A(4004)	TEMP. OF WATER IN VCT AND REFUELING WATER TANK	DEG.F	.1200E+03
A(4573)	SURGE LINE ITERATION OPTION		.1000E+01

PRESSURIZER PROGRAMMED LEVEL VS POWER OR COOLANT AVERAGE TEMPERATURE

A(4027)	GAIN CONSTANT ON WATER LEVEL ERROR AS CALCULATED FROM POWER VS LEVEL PROGRAM	0.
A(4028)	GAIN FOR PRESSURIZER WATER LEVEL ERROR AS CALCULATED FROM LEVEL VS T-AVG PROGRAM	.1000E+01
A(4033)	NUMBER OF POINTS IN TABLE	.5000E+01

POWER(FRAC)		TEMPERATURE(F)		VOLUME(FT3)	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(4201)	0.	A(4251)	.1000E+03	A(4226)	.4500E+03
A(4202)	.1500E+00	A(4252)	.5380E+03	A(4227)	.4500E+03
A(4203)	.1000E+01	A(4253)	.5728E+03	A(4228)	.8000E+03
A(4204)	.1200E+01	A(4254)	.5810E+03	A(4229)	.8000E+03
A(4205)	.2000E+01	A(4255)	.1000E+04	A(4230)	.8000E+03

HEATERS
****

*** GENERAL ***

A(4015)	OVERALL HEAT TRANSFER COEFFICIENT	BTU/HR-F	.5120E+05
A(4016)	SPECIFIC HEAT OF HEATERS	BTU/F	.1138E+03
A(4020)	MINIMUM WATER VOLUME REQUIRED FOR PRESSURIZER HEATER OPERATION	FT3	.3250E+03
A(4021)	HIGH LEVEL ERROR SIGNAL TO ACTUATE ALL HEATERS	FT	.1083E+01

*** PROPORTIONAL HEATERS ***

A(4012)	MAXIMUM HEAT RATE	BTU/SEC	.3128E+03
A(4013)	PRESSURE FOR FULL OUTPUT OF HEATERS	PSIA	.2225E+04
A(4014)	PRESSURE FOR ZERO OUTPUT OF HEATERS	PSIA	.2275E+04

*** BACKUP HEATERS ***

A(4017)	BACKUP HEATER HEAT RATE	BTU/SEC	.1251E+04
A(4018)	PRESSURE AT WHICH BACKUP HEATERS ENERGIZED	PSIA	.2200E+04
A(4019)	PRESSURE AT WHICH BACKUP HEATERS ARE DEENERGIZED	PSIA	.2220E+04

SPRAY FLOW
****

A(4022)	CONTINUOUS SPRAY FLOW	GPM	.1500E+01
A(4023)	MINIMUM PROPORTIONAL SPRAY FLOW	GPM	0.
A(4024)	OPENING PRESSURE OF PROPORTIONAL SPRAY VALVE	PSIA	.2300E+04
A(4025)	MAXIMUM PROPORTIONAL SPRAY FLOW	GPM	.3750E+03
A(4026)	FULL OPEN PRESSURE OF PROPORTIONAL SPRAY VALVES	GPM	.2325E+04

*** HETEROGENEOUS FLOW PASS MODEL FOR SAFETY VALVES ***

A(3999)	OPTION TO USE MODEL, 1.=YES, 0.=NO	0.
A(3997)	TOP RADIUS OF PRESSURIZER DOME, FEET	0.
A(3998)	VOLUME BELOW THE BOTTOM OF SPRAY NOZZLE, FT3	0.
A(4000)	SAFETY VALVE NOZZLE RADIUS, FEET	0.
A(4001)	VOLUME BELOW SAFETY VALVE NOZZLE BASE, FT3	0.

SAFETY + RELIEF VALVES
****

*** RELIEF VALVES ***

A(4007)	MAXIMUM PRIMARY RELIEF VALVE AREA	FT2/VALVE	0.
A(4008)	NUMBER OF PRIMARY RELIEF VALVES		.2000E+01
A(3981)	PERCENT PRESSURE ACCUMULATION		0.
A(3982)	PERCENT PRESSURE BLOWDOWN		.1000E+01
A(3985)	FRACTIONAL RELIEF VALVE AREA AT PSET	FRAC	.1000E+01
A(3986)	FRACTIONAL RELIEF VALVE AREA AT PACC -	FRAC	.1000E+01
A(3987)	FRACTIONAL RELIEF VALVE AREA AT PACC +	FRAC	.1000E+01
A(3988)	FRACTIONAL RELIEF VALVE AREA AT PBLD +	FRAC	.1000E+01

*** SAFETY VALVES ***

A(4009)	MAXIMUM PRIMARY SAFETY VALVE AREA	FT2/VALVE	.1010E-01
A(4010)	NUMBER OF PRIMARY SAFETY VALVES		.3000E+01
A(3983)	PERCENT PRESSURE ACCUMULATION		-.1000E+01
A(3984)	PERCENT PRESSURE BLOWDOWN		.4000E+01
A(3989)	FRACTIONAL SAFETY VALVE AREA AT PSET	FRAC	.1000E+01
A(3990)	FRACTIONAL SAFETY VALVE AREA AT PACC -	FRAC	.1000E+01
A(3991)	FRACTIONAL SAFETY VALVE AREA AT PACC +	FRAC	.1000E+01
A(3992)	FRACTIONAL SAFETY VALVE AREA AT PBLD +	FRAC	.7000E+00

SAFETY AND RELIEF VALVE PRESSURE SETPOINTS

VALVE NUMBER	OPENING SETPOINT (PSET) A-VECTOR	VALUE
1	A(3971)	.1000E+05
2	A(3972)	.1000E+05
3	A(3973)	.2525E+04
4	A(3974)	.2525E+04
5	A(3975)	.2525E+04

*** VALVE FAILURE CONTROL ***

VECTORS A(3976) THROUGH A(3980) ARE USED, ONE FOR EACH VALUE, AS SWITCHES TO SELECT ONE OF THE FOLLOWING VALVE CONDITIONS

0.0 - NORMAL VALVE OPERATION
1.0 - VALVE STUCK CLOSED
2.0 - VALVE STUCK OPEN

VALVE NUMBER	VALVE OPTION A-VECTOR	VALUE
1	A(3976)	0.
2	A(3977)	0.
3	A(3978)	0.
4	A(3979)	0.
5	A(3980)	0.

A(436) OPTION TO USE CONSTANT CHARGING AND LETDOWN FLOW 0.
0.0 = NO
1.0 = YES

CHARGING FLOW
****

*** ON-OFF CHARGING PUMPS ***

A(4005) NUMBER OF ON-OFF CHARGING PUMPS .3000E+01

PUMP NUMBER	CHARGING PUMP FLOW (GPM) A-VECTOR	VALUE	WATER LEVEL ERROR(MEASURED-PROGRAMMED) BELOW WHICH PUMP IS ACTIVATED (FT) A-VECTOR	VALUE	WATER LEVEL ERROR ABOVE WHICH PUMP IS TURNED OFF (FT) A-VECTOR	VALUE
1	A(4051)	.4400E+02	A(4076)	.1000E+03	A(4101)	.1000E+03
2	A(4052)	.4400E+02	A(4077)	-.7500E+00	A(4102)	-.3300E+00
3	A(4053)	.4400E+02	A(4078)	-.1167E+01	A(4103)	-.5000E+00

A(4286) SHUTOFF HEAD OF CHARGING PUMPS PSIA .2735E+04

A(4276) CONSTANT CHARGING FLOW RATE GPM 0.

LETDOWN FLOW
****

A(4279)	LETDOWN FLOW OPTIONS 0.0 = LETDOWN ORIFICE MODEL 1.0 = LINEAR LETDOWN MODEL		.1000E+01
A(4278)	TEMPERATURE AT WHICH LETDOWN FLOW IS MEASURED FOR LETDOWN FLOW INPUT	DEG.F	.1200E+03
A(4277)	CONSTANT LETDOWN FLOW RATE	GPM	0.

*** LETDOWN ORIFICE MODEL ***

A(4006)	NUMBER OF LETDOWN ORIFICES	.1000E+01

PUMP NUMBER	ORIFICE FLOW(GPM) A-VECTOR	ORIFICE FLOW(GPM) VALUE	WATER LEVEL ERROR(MEASURED-PROGRAMMED) AT WHICH ORIFICE IS OPENED (FT) A-VECTOR	VALUE	WATER LEVEL ERROR AT WHICH ORIFICE IS CLOSED (FT) A-VECTOR	VALUE
1	A(4126)	0.	A(4151)	.1000E+03	A(4176)	-.1000E+03

*** LINEAR LETDOWN MODEL ***

A(4280)	LETDOWN FLOW FOR ZERO PRESSURIZER LEVEL DEVIATION	GPM	.4400E+02
A(4281)	MAXIMUM LETDOWN FLOW	GPM	.1320E+03
A(4282)	MINIMUM LETDOWN FLOW	GPM	.3400E+02
A(4283)	PRESSURIZER LEVEL ERROR FOR MAXIMUM LETDOWN FLOW	FT	.2667E+01
A(4284)	PRESSURIZER LEVEL ERROR FOR MINIMUM LETDOWN FLOW	FT	-.3030E+00

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*                                  *
* 9. SAFETY INJECTION INFORMATION  *
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*** SAFETY INJECTION PUMPS ***

A-VECTOR	DESCRIPTION	UNITS	VALUE	COMMENTS
A(251)	SAFETY INJECTION SET POINT	PSIA	.1578E+04	
A(272)	NUMBER OF SAFETY INJECTION PUMPS 1. IF A(272) = 1.0 -- USE TABLE 1 2. IF A(272) = 2.0 -- USE TABLE 2 3. IF A(272) = 3.0 -- USE TABLE 3		.2000E+01	

TABLE 1 ONE-PUMP SAFETY INJECTION FLOW VS PRESSURE

A(273) NUMBER OF POINTS IN TABLE .1500E+02

PRESSURE(PSIA) A-VECTOR	VALUE	FLOW(GPM) A-VECTOR	VALUE
A(299)	0.	A(274)	.3346E+04
A(300)	.1050E+03	A(275)	.2070E+04
A(301)	.2900E+03	A(276)	.4960E+03
A(302)	.4450E+03	A(277)	.4520E+03
A(303)	.5910E+03	A(278)	.4080E+03
A(304)	.7110E+03	A(279)	.3600E+03
A(305)	.8240E+03	A(280)	.3160E+03
A(306)	.9290E+03	A(281)	.2720E+03
A(307)	.1008E+04	A(282)	.2280E+03
A(308)	.1068E+04	A(283)	.1800E+03
A(309)	.1105E+04	A(284)	.1360E+03
A(310)	.1142E+04	A(285)	.9200E+02
A(311)	.1158E+04	A(286)	.4800E+02
A(312)	.1165E+04	A(287)	0.
A(313)	.2000E+05	A(288)	0.

TABLE 2 TWO-PUMP SAFETY INJECTION FLOW VS PRESSURE

A(324) NUMBER OF POINTS IN TABLE .2500E+02

PRESSURE(PSIA) A-VECTOR	VALUE	FLOW(GPM) A-VECTOR	VALUE
A(350)	0.	A(325)	.6480E+04
A(351)	.5200E+02	A(326)	.5400E+04
A(352)	.9300E+02	A(327)	.4320E+04
A(353)	.1050E+03	A(328)	.3960E+04
A(354)	.1160E+03	A(329)	.3600E+04
A(355)	.1250E+03	A(330)	.3240E+04
A(356)	.1350E+03	A(331)	.2880E+04
A(357)	.1430E+03	A(332)	.2520E+04
A(358)	.1500E+03	A(333)	.2160E+04
A(359)	.1570E+03	A(334)	.1800E+04
A(360)	.1620E+03	A(335)	.1440E+04
A(361)	.1660E+03	A(336)	.1080E+04
A(362)	.2900E+03	A(337)	.9920E+03
A(363)	.4450E+03	A(338)	.9000E+03
A(364)	.5910E+03	A(339)	.8120E+03
A(365)	.7110E+03	A(340)	.7200E+03
A(366)	.8240E+03	A(341)	.6320E+03
A(367)	.9290E+03	A(342)	.5400E+03
A(368)	.1008E+04	A(343)	.4520E+03
A(369)	.1048E+04	A(344)	.3600E+03
A(370)	.1105E+04	A(345)	.2720E+03
A(371)	.1142E+04	A(346)	.1800E+03
A(372)	.1158E+04	A(347)	.9200E+02
A(373)	.1165E+04	A(348)	0.
A(374)	.2000E+05	A(349)	0.

TABLE 3 THREE-PUMP SAFETY INJECTION FLOW VS PRESSURE

A(375) NUMBER OF POINTS IN TABLE 0.

PRESSURE(PSIA) A-VECTOR	VALUE	FLOW(GPM) A-VECTOR	VALUE
A(401)	0.	A(376)	0.

A(435)	TIME DELAY FROM SAFETY INJECTION ACTUATION SIGNAL UNTIL HPSI PUMPS REACH FULL SPEED	SEC	.1800E+02
A(475)	TIME TO MANUALLY INITIATE SIAS	SEC	.1000E+05

*** SAFETY INJECTION TANK ***

A-VECTOR	DESCRIPTION	UNITS	VALUE	COMMENTS
A(5900)	FLOW AREA OF SAFETY INJECTION LINE	FT2	.2237E+01	
A(5901)	K LOSS COEFFICIENT FOR ABOVE FLOW AREA		.7890E+01	
A(5902)	SPECIFIC VOLUME OF LIQUID	FT3/LBM	.1617E-01	
A(5903)	INITIAL PRESSURE OF GAS IN SAFETY INJECTION TANKS	PSIA	.5830E+03	
A(5904)	ELEVATION HEAD OF SAFETY INJECTION TANKS	PSIA	.8250E+01	
A(5905)	INITIAL VOLUME OF LIQUID IN SAFETY INJECTION TANKS	FT3	.5680E+04	
A(5906)	INITIAL VOLUME OF NITORGEN GAS IN SAFETY INJECTION TANKS	FT3	.1720E+04	
A(5907)	SPECIFIC ENTHALPY OF FLUID IN SAFETY INJECTION TANKS	BTU/LBM	.8956E+02	

10. STEAM GENERATOR INFORMATION

*** STEAM GENERATOR SPECIFICATIONS ***

DESCRIPTION	UNITS	RHSG LOCATION	RHSG VALUE	LHSG LOCATION	LHSG VALUE	COMMENTS
STEAM GENERATOR VOLUME	FT3	A(3001)	.8006E+04	A(3151)	.8006E+04	
NUMBER OF TUBES		A(3002)	.8411E+04	A(3152)	.8411E+04	
U-TUBE SURFACE AREA	FT2	A(3003)	.8945E+05	A(3153)	.8945E+05	
U-TUBE SPECIFIC HEAT	BTU/F	A(3004)	.1960E+05	A(3154)	.1960E+05	
VOLUME OF WATER CONTAINED IN U-TUBES	FT3	A(3005)	.1117E+04	A(3155)	.1117E+04	
INSIDE DIAMETER OF TUBE	IN	A(3008)	.6540E+00	A(3158)	.6540E+00	
NUMBER OF U-TUBES (DESIGN)		A(3040)	.8485E+04	A(3190)	.8485E+04	
DESIGN MASS	LBS	A(3041)	.1411E+06	A(3191)	.1411E+06	
NUMBER OF STEAM GENERATORS IN PLANT		A(3012)	.2000E+01			
RHSG & LHSG DESIGN U-TUBE SURFACE AREA	FT2	A(3201)	.9023E+05			

STEAM GENERATOR MASS VS POWER LEVEL

A(3013) NUMBER OF POINTS FOR RHSG TABLE .1000E+02 A(3162) NUMBER OF POINTS FOR LHSG TABLE .1000E+02

RHSG POWER LEVEL A-VECTOR	VALUE	RHSG MASS(LBM) A-VECTOR	VALUE	LHSG POWER LEVEL A-VECTOR	VALUE	LHSG MASS(LBM) A-VECTOR	VALUE
A(3024)	0.	A(3014)	.2231E+06	A(3173)	0.	A(3163)	.2231E+06
A(3025)	.1000E+00	A(3015)	.2110E+06	A(3174)	.1000E+00	A(3164)	.2110E+06
A(3026)	.2000E+00	A(3016)	.1954E+06	A(3175)	.2000E+00	A(3165)	.1954E+06
A(3027)	.3000E+00	A(3017)	.1845E+06	A(3176)	.3000E+00	A(3166)	.1845E+06
A(3028)	.5000E+00	A(3018)	.1681E+06	A(3177)	.5000E+00	A(3167)	.1681E+06
A(3029)	.6000E+00	A(3019)	.1620E+06	A(3178)	.6000E+00	A(3168)	.1620E+06
A(3030)	.8000E+00	A(3020)	.1508E+06	A(3179)	.8000E+00	A(3169)	.1508E+06
A(3031)	.9000E+00	A(3021)	.1456E+06	A(3180)	.9000E+00	A(3170)	.1456E+06
A(3032)	.1000E+01	A(3022)	.1411E+06	A(3181)	.1000E+01	A(3171)	.1411E+06
A(3033)	.1100E+01	A(3023)	.1365E+06	A(3182)	.1100E+01	A(3172)	.1365E+06

*** STEAM GENERATOR TRIPS AND ALARMS ***

STEAM GENERATOR MASS TRIP TABLE

A(6500)   NUMBER OF POINTS IN TABLE (I = 1,N)   .1600E+02

SGMLT(I) = A(6500 + I) - TOTAL SG MASS AT WHICH A LOW LEVEL TRIP IS GENERATED

SGMHT(I) = A(6520 + I) - TOTAL SG MASS AT WHICH A HIGH LEVEL TRIP IS GENERATED

SGMLA(I) = A(6540 + I) - TOTAL SG MASS AT WHICH A LOW LEVEL ALARM IS ACTIVATED

SGMHA(I) = A(6560 + I) - TOTAL SG MASS AT WHICH A HIGH LEVEL ALARM IS ACTIVATED

WSOUT(I) = A(6580 + I) - STEAM FLOW OUT OF THE STEAM GENERATOR

WSOUT(I)		SGMLT(I)		SGMHT(I)		SGMLA(I)			
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(6581)	-.1000E+04	A(6501)	.1174E+06	A(6521)	.2708E+06	A(6541)	.1648E+06	A(6561)	.2610E+06
A(6582)	0.	A(6502)	.1174E+06	A(6522)	.2708E+06	A(6542)	.1648E+06	A(6562)	.2610E+06
A(6583)	.1556E+03	A(6503)	.1347E+06	A(6523)	.2353E+06	A(6543)	.1785E+06	A(6563)	.2277E+06
A(6584)	.3113E+03	A(6504)	.1265E+06	A(6524)	.2177E+06	A(6544)	.1662E+06	A(6564)	.2103E+06
A(6585)	.4669E+03	A(6505)	.1185E+06	A(6525)	.2057E+06	A(6545)	.1562E+06	A(6565)	.1985E+06
A(6586)	.6226E+03	A(6506)	.1113E+06	A(6526)	.1963E+06	A(6546)	.1476E+06	A(6566)	.1889E+06
A(6587)	.7782E+03	A(6507)	.6506E+07	A(6527)	.1881E+06	A(6547)	.1405E+06	A(6567)	.1809E+06
A(6588)	.9338E+03	A(6508)	.9985E+05	A(6528)	.1816E+06	A(6548)	.1348E+06	A(6568)	.1745E+06
A(6589)	.1089E+04	A(6509)	.9464E+05	A(6529)	.1755E+06	A(6549)	.1293E+06	A(6569)	.1684E+06
A(6590)	.1245E+04	A(6510)	.8962E+05	A(6530)	.1698E+06	A(6550)	.1240E+06	A(6570)	.1627E+06
A(6591)	.1401E+04	A(6511)	.8489E+05	A(6531)	.1646E+06	A(6551)	.1189E+06	A(6571)	.1575E+06
A(6592)	.1556E+04	A(6512)	.8052E+05	A(6532)	.1599E+06	A(6552)	.1144E+06	A(6572)	.1527E+06
A(6593)	.1712E+04	A(6513)	.7691E+05	A(6533)	.1558E+06	A(6553)	.1106E+06	A(6573)	.1489E+06
A(6594)	.1868E+04	A(6514)	.7263E+05	A(6534)	.1514E+06	A(6554)	.1063E+06	A(6574)	.1443E+06
A(6595)	.4825E+04	A(6515)	0.	A(6535)	.1514E+06	A(6555)	.1063E+06	A(6575)	.1443E+06
A(6596)	.1556E+06	A(6516)	0.	A(6536)	.1514E+06	A(6556)	.1063E+06	A(6576)	.1443E+06

A(4574)   SG LOW LEVEL TRIP MASS   LBS   0.

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** NOTE **

STEAM GENERATOR ISOLATION OPTION - SEE FEEDWATER CONTROL OPTION - CATEGORY 11

*** GENERAL INFORMATION ***

A(4990)	LHSG MINIMUM WATER MASS AT WHICH SG HEAT TRANSFER AREA BEGINS DECREASING	LBS	0.
A(4991)	LHSG WATER MASS FOR ZERO HEAT TRANSFER AREA	LBS	0.
A(4994)	RHSG MINIMUM WATER MASS AT WHICH SG HEAT TRANSFER AREA BEGINS DECREASING	LBS	0.
A(4995)	RHSG WATER MASS FOR ZERO HEAT TRANSFER AREA	LBS	0.
A(105)	SG REFERENCE HEIGHT	FT	0.
(133)	SG LEVEL DEBUG OPTION 1.0 - YES 0.0 - NO		0.

PERCENT LOAD VS. MASS

A(2292)	OPTION TO USE SG LEVEL VS. MASS TABLES 0.0 = NO 1.0 = YES		.1000E+01
A(2180)	NUMBER OF POINTS IN TABLE		.1600E+02
A(2290)	NUMBER OF LEVELS FOR PERCENT LOAD VS MASS TABLES		.4000E+01

TABLE 1

A(2281) STEAM GENERATOR LEVEL FOR TABLE 1 FT .2605E+02

PERCENT LOAD		SG MASS(LBS)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(2181)	-.1000E+04	A(2201)	.1174E+06
A(2182)	0.	A(2202)	.1174E+06
A(2183)	.1000E+02	A(2203)	.1347E+06
A(2184)	.2000E+02	A(2204)	.1265E+06
A(2185)	.3000E+02	A(2205)	.1185E+06
A(2186)	.4000E+02	A(2206)	.1113E+06
A(2187)	.5000E+02	A(2207)	.1051E+06
A(2188)	.6000E+02	A(2208)	.9985E+05
A(2189)	.7000E+02	A(2209)	.9464E+05
A(2190)	.8000E+02	A(2210)	.8962E+05
A(2191)	.9000E+02	A(2211)	.8489E+05
A(2192)	.1000E+03	A(2212)	.8052E+05
A(2193)	.1100E+03	A(2213)	.7691E+05
A(2194)	.1200E+03	A(2214)	.7263E+05
A(2195)	.3100E+03	A(2215)	0.
A(2196)	.1000E+05	A(2216)	0.

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TABLE 2

A(2282) STEAM GENERATOR LEVEL FOR TABLE 2 FT .2980E+02

PERCENT LOAD		SG MASS(LBS)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(2181)	-.1000E+04	A(2221)	.1558E+06
A(2182)	0.	A(2222)	.1558E+06
A(2183)	.1000E+02	A(2223)	.1714E+06
A(2184)	.2000E+02	A(2224)	.1597E+06
A(2185)	.3000E+02	A(2225)	.1500E+06
A(2186)	.4000E+02	A(2226)	.1417E+06
A(2187)	.5000E+02	A(2227)	.1349E+06
A(2188)	.6000E+02	A(2228)	.1292E+06
A(2189)	.7000E+02	A(2229)	.1237E+06
A(2190)	.8000E+02	A(2230)	.1182E+06
A(2191)	.9000E+02	A(2231)	.1134E+06
A(2192)	.1000E+03	A(2232)	.1089E+06
A(2193)	.1100E+03	A(2233)	.1051E+06
A(2194)	.1200E+03	A(2234)	.1007E+06
A(2195)	.3100E+03	A(2235)	.1007E+06
A(2196)	.1000E+05	A(2236)	.1007E+06

TABLE 3

A(2283) STEAM GENERATOR LEVEL FOR TABLE 3 FT .3580E+02

PERCENT LOAD		SG MASS(LBS)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(2181)	-.1000E+04	A(2241)	.2111E+06
A(2182)	0.	A(2242)	.2111E+06
A(2183)	.1000E+02	A(2243)	.2132E+06
A(2184)	.2000E+02	A(2244)	.1969E+06
A(2185)	.3000E+02	A(2245)	.1855E+06
A(2186)	.4000E+02	A(2246)	.1761E+06
A(2187)	.5000E+02	A(2247)	.1683E+06
A(2188)	.6000E+02	A(2248)	.1621E+06
A(2189)	.7000E+02	A(2249)	.1561E+06
A(2190)	.8000E+02	A(2250)	.1505E+06
A(2191)	.9000E+02	A(2251)	.1453E+06
A(2192)	.1000E+03	A(2252)	.1407E+06
A(2193)	.1100E+03	A(2253)	.1368E+06
A(2194)	.1200E+03	A(2254)	.1323E+06
A(2195)	.3100E+03	A(2255)	.1323E+06
A(2196)	.1000E+05	A(2256)	.1323E+06

TABLE 4

A(2284) STEAM GENERATOR LEVEL FOR TABLE 4 FT .3880E+02

PERCENT LOAD		SG MASS(LBS)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(2181)	-.1000E+04	A(2261)	.2708E+06
A(2182)	0.	A(2262)	.2708E+06
A(2183)	.1000E+02	A(2263)	.2353E+06
A(2184)	.2000E+02	A(2264)	.2177E+06
A(2185)	.3000E+02	A(2265)	.2057E+06
A(2186)	.4000E+02	A(2266)	.1963E+06
A(2187)	.5000E+02	A(2267)	.1881E+06
A(2188)	.6000E+02	A(2268)	.1816E+06
A(2189)	.7000E+02	A(2269)	.1755E+06
A(2190)	.8000E+02	A(2270)	.1698E+06
A(2191)	.9000E+02	A(2271)	.1646E+06
A(2192)	.1000E+03	A(2272)	.1599E+06
A(2193)	.1100E+03	A(2273)	.1558E+06
A(2194)	.1200E+03	A(2274)	.1514E+06
A(2195)	.3100E+03	A(2275)	.1514E+06
A(2196)	.1000E+05	A(2276)	.1514E+06

A(2291)	DESIGN DOWNCOMER HEIGHT	FT	.3506E+02
A(2507)	FULL POWER SECONDARY PRESSURE	PSIA	.8150E+03
A(3009)	MINIMUM VALUE OF HT COEFFICIENT FOR SATURATED FLOW NUCLEATE BOILING INSIDE SG TUBES	BTU/F-FT2-HR	.5000E+03
A(3010)	MINIMUM VALUE OF HT COEFFICIENT FOR CONVECTIVE CONDENSING SATURATED FLUID FLOW INSIDE SG TUBES	BTU/F-FT2-HR	.6500E+02
A(3011)	MINIMUM VALUE OF HT COEFFICIENT FOR SUBCOOLED CONVECTIVE FLOW INSIDE THE SG TUBES.	BTU/F-FT2-HR	.8000E+03
A(3160)	MINIMUM VALUE OF HT COEFFICIENT FOR SATURATED FLUID WITH NATURAL CONVECTION IN THE SG SHELL SIDE	BTU/F-FT2-HR	.6500E+02
A(3161)	MINIMUM VALUE OF HT COEFFICIENT FOR SATURATED FLUID WITH POOL BOILING IN THE SG SHELL SIDE	BTU/F-FT2-HR	.5000E+03

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* 11.   FEEDWATER  SYSTEMS   *
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A(2301)     FEEDWATER FLOW CONTROL OPTIONS:                                        .1000E+01
               1. IF A(2301) = 1.0 -- USE FLOW OPTION 1
               2. IF A(2301) = 2.0 -- USE FLOW OPTION 2
               3. IF A(2301) = 3.0 -- USE FLOW OPTION 3
--------------------------------------------------------------------------------------------

                         *** FLOW OPTION 1 ***
                  FEEDWATER FLOW MATCHES STEAM FLOW
                  ---------------------------------

A(2305)     FEEDWATER RAMP DOWN RATE AFTER TRIP                  FRAC/SEC       .1000E+06

A(2407)     MAXIMUM ALLOWABLE FEEDWATER FLOW                     FRAC           .1071E 01

A(2409)     FRACTION OF FEEDWATER FLOW AT COMPLETION OF RAMP DOWN  FRAC         .1000E-05
            AFTER TRIP
A(2600)     OPTION TO USE FEEDWATER ISOLATION AT MSIS                          0.
               1.0 - YES
               0.0 - NO
--------------------------------------------------------------------------------------------
```

*** FLOW OPTION 2 ***

INPUT FEEDWATER FLOW TABLE

A(2306) NUMBER OF POINTS IN TABLE .3000E+01

FEEDWATER FLOW BEFORE TRIP

TIME(SEC) A-VECTOR	VALUE	FLOW TO RHSG(FRAC) A-VECTOR	VALUE	FLOW TO LHSG(FRAC) A-VECTOR	VALUE
A(2307)	0.	A(2317)	.1023E+01	A(2327)	.1023E+01
A(2308)	.1000E+01	A(2318)	.1023E+01	A(2328)	.1023E+01
A(2309)	.1000E+05	A(2319)	.1023E+01	A(2329)	.1023E+01
THE FOLLOWING A-VECTORS ARE NOT ASSIGNED VALUES					
A(2310)	0.	A(2320)	0.	A(2330)	0.
A(2311)	0.	A(2321)	0.	A(2331)	0.
A(2312)	0.	A(2322)	0.	A(2332)	0.
A(2313)	0.	A(2323)	0.	A(2333)	0.
A(2314)	0.	A(2324)	0.	A(2334)	0.
A(2315)	0.	A(2325)	0.	A(2335)	0.
A(2316)	0.	A(2326)	0.	A(2336)	0.

FEEDWATER FLOW AFTER TRIP

TIME(SEC) A-VECTOR	VALUE	FLOW TO RHSG(FRAC) A-VECTOR	VALUE	FLOW TO LHSG(FRAC) A-VECTOR	VALUE
A(2397)	0.	A(2337)	.1023E+01	A(2347)	.1020E+01
A(2398)	.1000E+01	A(2338)	.1000E-03	A(2348)	.1000E-03
A(2399)	.1000E+05	A(2339)	.1000E-03	A(2349)	.1000E-03
THE FOLLOWING A-VECTORS ARE NOT ASSIGNED VALUES					
A(2400)	0.	A(2340)	0.	A(2350)	0.
A(2401)	0.	A(2341)	0.	A(2351)	0.
A(2402)	0.	A(2342)	0.	A(2352)	0.
A(2403)	0.	A(2343)	0.	A(2353)	0.
A(2404)	0.	A(2344)	0.	A(2354)	0.
A(2405)	0.	A(2345)	0.	A(2355)	0.
A(2406)	0.	A(2346)	0.	A(2356)	0.

*** FLOW OPTION 3 ***
AUTOMATIC LEVEL CONTROL

A(2303)	RHSG LEVEL SETPOINT FOR AUTOMATIC FEEDWATER CONTROL	FT OR LBS	0.
A(2304)	LHSG LEVEL SETPOINT FOR AUTOMATIC FEEDWATER CONTROL	FT OR LBS	0.
A(2305)	- SEE OPTION 1 -		.1000E+06
A(2407)	- SEE OPTION 1 -		.1071E+01
A(2408)	FEEDWATER CONTROL VALVE CLOSING OR OPENING SPEED	FRAC/SEC	0.
A(2409)	- SEE OPTION 1 -		.1000E-05
A(2410)	DEAD BAND ON WATER LEVEL ERROR SIGNAL = A(2303) - RHSG LEVEL = A(2304) - LHSG LEVEL		0.
A(2411)	DEAD BAND ON FLOW ERROR SIGNAL (STEAM FLOW - FW FLOW)		0.

A(2302)   FEEDWATER ENTHALPY CONTROL OPTIONS   .1000E+01
1. IF A(2302) = 1.0 -- USE ENTHALPY OPTION 1
2. IF A(2302) = 2.0 -- USE ENTHALPY OPTION 2

A(4760)   FULL POWER FEEDWATER ENTHALPY   BTU/LB   .4138E+03

*** ENTHALPY OPTION 1 ***
FUNCTION OF POWER DEMAND

FEEDWATER ENTHALPY VS REACTOR POWER LEVEL

A(2412)   NUMBER OF POINTS IN TABLE   .7000E+01

ENTHALPIES(BTU/LBM) A-VECTOR	VALUE	POWER LEVELS(FRAC) A-VECTOR	VALUE
A(2413)	.1852E+03	A(2423)	0.
A(2414)	.2610E+03	A(2424)	.2000E+00
A(2415)	.3156E+03	A(2425)	.4000E+00
A(2416)	.3544E+03	A(2426)	.6000E+00
A(2417)	.3862E+03	A(2427)	.8000E+00
A(2418)	.4138E+03	A(2428)	.1000E+01
A(2419)	.4193E+03	A(2429)	.1200E+01

THE FOLLOWING A-VECTORS ARE NOT ASSIGNED VALUES

A(2420)	0.	A(2430)	0.
A(2421)	0.	A(2431)	0.
A(2422)	0.	A(2432)	0.

*** ENTHALPY OPTION 2 ***
INPUT FEEDWATER ENTHALPY TABLES

A(2306) - SEE FLOW OPTION 2 -

FEEDWATER ENTHALPY BEFORE TRIP

TIME(SEC)		ENTHALPY TO RHSG(BTU/LBM)		ENTHALPY TO LHSG(BTU/LBM)	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(2307)	0.	A(2357)	.4144E+03	A(2367)	.4144E+03
A(2308)	.1000E+01	A(2358)	.4144E+03	A(2368)	.4144E+03
A(2309)	.1000E+05	A(2359)	.4144E+03	A(2369)	.4144E+03
THE FOLLOWING A-VECTORS ARE NOT ASSIGNED VALUES					
A(2310)	0.	A(2360)	0.	A(2370)	0.
A(2311)	0.	A(2361)	0.	A(2371)	0.
A(2312)	0.	A(2362)	0.	A(2372)	0.
A(2313)	0.	A(2363)	0.	A(2373)	0.
A(2314)	0.	A(2364)	0.	A(2374)	0.
A(2315)	0.	A(2365)	0.	A(2375)	0.
A(2316)	0.	A(2366)	0.	A(2376)	0.

FEEDWATER ENTHALPY AFTER TRIP

TIME(SEC)		ENTHALPY TO RHSG(BTU/LBM)		ENTHALPY TO LHSG(BTU/LBM)	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(2397)	0.	A(2377)	.4144E+03	A(2387)	.4144E+03
A(2398)	.1000E+01	A(2378)	.4144E+03	A(2388)	.4144E+03
A(2399)	.1000E+05	A(2379)	.4144E+03	A(2389)	.4144E+03
THE FOLLOWING A-VECTORS ARE NOT ASSIGNED VALUES					
A(2400)	0.	A(2380)	0.	A(2390)	0.
A(2401)	0.	A(2381)	0.	A(2391)	0.
A(2402)	0.	A(2382)	0.	A(2392)	0.
A(2403)	0.	A(2383)	0.	A(2393)	0.
A(2404)	0.	A(2384)	0.	A(2394)	0.
A(2405)	0.	A(2385)	0.	A(2395)	0.
A(2406)	0.	A(2386)	0.	A(2396)	0.

AUXILIARY FEEDWATER SYSTEM

A(2603) OPTION TO INITIATE AUX. FEEDWATER WHEN LOW SG LEVEL TRIP SETPOINT IS REACHED .1000E+01
1.0 = NO
0.0 = YES

A(2604) OPTION TO INITIATE AUX. FEEDWATER WHEN LOW SG PRESSURE TRIP SETPOINT IS REACHED .1000E+01
1.0 = NO
0.0 = YES

A(2605) OPTION TO INITIATE AUX. FEEDWATER MANUALLY ACCORDING TO TIME 0.
1.0 = YES
0.0 = NO

FRACTION OF FLOW TO STEAM GENERATOR VS TIME

A(2606) NUMBER OF POINTS IN TABLE .4000E+01

TIME(SEC) A-VECTOR	VALUE	FLOW TO RHSG(FRAC) A-VECTOR	VALUE	FLOW TO LHSG(FRAC) A-VECTOR	VALUE
A(2607)	0.	A(2617)	0.	A(2627)	0.
A(2608)	.1800E+04	A(2618)	0.	A(2628)	0.
A(2609)	.1800E+04	A(2619)	.2200E-01	A(2629)	.2200E-01
A(2610)	.1000E+05	A(2620)	.2200E-01	A(2630)	.2200E-01

ENTHALPY TO STEAM GENERATOR VS TIME

TIME(SEC) A-VECTOR	VALUE	ENTHALPY TO RHSG(FRAC) A-VECTOR	VALUE	ENTHALPY TO LHSG(FRAC) A-VECTOR	VALUE
A(2607)	0.	A(2637)	.9065E+02	A(2647)	.9065E+02
A(2608)	.1800E+04	A(2638)	.9065E+02	A(2648)	.9065E+02
A(2609)	.1800E+04	A(2639)	.9065E+02	A(2649)	.9065E+02
A(2610)	.1000E+05	A(2640)	.9065E+02	A(2650)	.9065E+02

*** AUXILIARY FEEDWATER CONTROL OPTION ***

** NOTE **

OPTION UNUSED IF A(2657)=A(2658)=0.

A(2657)	LOW STEAM GENERATOR WATER LEVEL FOR WHICH AUXILIAR FEEDWATER IS TURNED ON	0.
A(2658)	STEAM GENERATOR PRESSURE DIFFERENCE FOR WHICH AUXILIARY FEEDWATER IS TURNED OFF	0.
A(2659)	HIGH STEAM GENERATOR WATER LEVEL FOR WHICH AUXILIARY FEEDWATER IS TURNED OFF	0.
A(2660)	R.H. AUX. FEEDWATER FLOW FRACTION TO LHSG WHEN R.H. AUX. FEEDWATER IS TURNED OFF	0.
A(2661)	L.H. AUX. FEEDWATER FLOW FRACTION TO RHSG WHEN L.H. AUX. FEEDWATER IS TURNED OFF	0.
A(3000)	OPTION TO TURN OFF FEEDWATER FLOW WHEN STEAM GENERATOR EMTIES, 1.=YES, 0.=NO	0.

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*                              *
* 13. STEAM SYSTEM AND VALVES  *
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*** GENERAL INFORMATION ***

TURBINE POWER DEMAND VS TIME TABLE

A(4602)	NUMBER OF POINTS IN TABLE		.2000E+01

TIME(SECONDS) A-VECTOR	VALUE	POWER DEMAND(FRAC) A-VECTOR	VALUE
A(4603)	0.	A(4618)	.1023E+01
A(4604)	.1000E+05	A(4619)	.1023E+01

A(4633)	DESIGN TURBINE POWER	MWT	.2570E+04
A(4601)	PRESSURE DROP FROM SG TO TURBINE ADMISSION VALVE	PSIA	.3075E+02
A(4759)	CONTROL PARAMETER ON HEADER PRESSURE		.6400E+02
A(4765)	DAMPING COEFFICIENT FOR LOW POWER SG OPERATION		.2000E+03
A(4666)	FRICTION LOSS COEFFICIENT FOR STEAM LINE		.1240E-04

LEFT HAND MOISTURE CARRYOVER TABLE

A(4799)	NUMBER OF POINTS IN TABLE	0.

TIME(SECONDS) A-VECTOR	VALUE	QUALITY A-VECTOR	VALUE
A(4801)	0.	A(4811)	0.

RIGHT HAND MOISTURE CARRYOVER TABLE

A(4800)	NUMBER OF POINTS IN TABLE	0.

TIME(SECONDS) A-VECTOR	VALUE	QUALITY A-VECTOR	VALUE
A(4821)	0.	A(4831)	0.

*** TURBINE ADMISSION VALVES ***

A(4634)	TURBINE FULL POWER FLOW RATE	LBM/HR	.1121E+08
A(4635)	PRESSURE AT ABOVE FLOW RATE	PSIA	.7843E+03
A(4575)	MAXIMUM TURBINE VALVE AREA LIMIT MULTPLIER		0.
A(4636)	TURBINE ADMISSION VALVE TRIP DELAY TIME	SEC	.2500E+00
A(4637)	TIME TO FAST CLOSE TURBINE ADMISSION VALVE	SEC	.2100E+00
A(4922)	IF GREATER THAN 0.0, TURBINE ADMISSION VALVE RATE OF CLOSURE ON TRIP	FT2/SEC	0.

*** MAIN STEAM ISOLATION VALVES ***

A(4647)	MAXIMUM ISOLATION VALVE AREA PER VALVE	FT2	.2917E+01
A(4648)	RATE OF CLOSURE OF THE ISOLATION VALVE	FT2/SEC	.5209E+00
A(4649)	PRESSURE AT WHICH ISOLATION VALVE CLOSES	PSIA	.4600E+03
A(4576)	MSIV CLOSURE DELAY TIME	SEC	.9000E+00
A(4577)	NUMBER OF MSIV*S IN THE PLANT		.1000E+01

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*** STEAM DUMP AND BYPASS VALVES ***

A(4600)	0.0 = NORMAL OPERATION 1.0 = SLB UPSTREAM OF ISOLATION VALVE 2.0 = SLB DOWNSTREAM OF ISOLATION VALVE 3.0 = EXCESS LOAD - DUMP AND BYPASS INITIALLY OPEN, THEN ON CONTROLLER 4.0 = EXCESS LOAD - DUMP AND BYPASS FUNCTION OF TIME		0.
A(4891)	1.0 = USE OF PID CONTROLLER FOR STEAM DUMP AND BYPASS 0.0 = OLD STEAM DUMP AND BYPASS CONTROLLER		.3000E+01
A(4924)	0.0 = NO AUTOMATIC CLOSURE OF DUMP VALVE AT LOAC 1.0 = AUTOMATIC CLOSURE OF DUMP VALVE AT LOAC		0.
A(4761)	STEAM DUMP VALVE FLOW RATE	LBM/HR	.1100E+07
A(4762)	PRESSURE AT ABOVE FLOW	PSIA	.9850E+03
A(4923)	RATE OF CLOSURE OF STEAM DUMP AND BYPASS VALVES, IF NOT 0.0. IF 0.0,A(4923)=RBV-(NORMAL CLOSURE RATE)	FT2/SEC	0.
A(4645)	BYPASS VALVE STEAM FLOW RATE	LBM/HR	.5080E+07
A(4646)	PRESSURE FOR ABOVE FLOW	PSIA	.8150E+03

ATMOSPHERIC DUMP VALVE(A.D.V.) CONDITIONS

*** NOTE ***

VALVE CONDITION SWITCHES FOR THE ATMOSPHERIC DUMP VALVES ON THE RH AND LH STEAM GENERATORS ARE AS FOLLOWS

0.0 - NORMAL VALVE OPERATION
1.0 - ONE A.D.V. STUCK OPEN
2.0 - ONE A.D.V. INADVERTENTLY OPENS AT TIME ZERO
3.0 - ONE A.D.V. STUCK CLOSED

A(4894)	VALVE CONDITION SWITCH FOR THE A.D.V."S ON THE RHSG		0.
A(4895)	VALVE CONDITION SWITCH FOR THE A.D.V."S ON THE LHSG		0.
A(4766)	RIGHT HAND A.D.V. AREA	FT2	.7910E-01
A(4767)	LEFT HAND A.D.V. AREA	FT2	.7910E-01
A(4892)	NUMBER OF A.D.V.S PER STEAM GENERATOR		.2000E+01
A(4893)	A.D.V. OPENING PRESSURE	PSIA	.9650E+03
A(4763)	OPTION FOR A.D.V. UPSTREAM OF ISOLATION VALVE - 1.0 = YES, 0.0 = NO		.1000E+01

IF A(4600) = 4.0, USE THE FOLLOWING TABLE --

DUMP AND BYPASS VALVE AREA VS TIME

A(4713)	NUMBER OF POINTS IN TABLE	0.

TIME(SEC)		DUMP VALVE FRACTIONAL AREA		BYPASS VALVE FRACTIONAL AREA	
A-VECTOR	VALVE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(4729)	0.	A(4744)	0.	A(4714)	0.

IF A(4600) = 0.0 AND A(4891) = 0.0 , USE TEMPERATURE CONTROL AFTER REACTOR TRIP FOR DUMP VALVE AND PRESSURE CONTROL FOR BYPASS VALVES

A(4638)	CORE AVERAGE TEMPERATURE SETPOINT FOR DUMP VALVES	DEGREES,F	.5320E+03
A(4639)	TEMPERATURE AT WHICH DUMP VALVE IS FULLY CLOSED	DEGREES,F	.1000E+04
A(4640)	TEMPERATURE AT WHICH DUMP VALVE OPENS	DEGREES,F	.2000E+04
A(4641)	TEMPERATURE AT WHICH DUMP VALVE IS FULLY OPEN	DEGREES,F	.3000E+04
A(4642)	PRESSURE AT WHICH BYPASS VALVE STARTS TO OPEN	PSIA	.8950E+03
A(4643)	PRESSURE AT WHICH BYPASS IS FULLY OPEN	PSIA	.9050E+03
A(4644)	TIME TO FULLY CLOSE BYPASS	SEC	.3000E+01

IF A(4600) = 0.0 AND A(4891) = 1.0, USE 1ST PID CONTROLLER

A(4841)	TIME CONSTANT FOR DELAY OF HEADER PRESSURE SIGNAL	SEC	0.
A(4842)	TIME CONSTANT FOR DELAY OF BYPASS FLOW SIGNAL	SEC	0.
A(4843)	TIME CONSTANT FOR INTEGRAL PORTION OF PID CONTROLLER	SEC	0.
A(4844)	TIME CONSTANT FOR DERIVATIVE PORTION OF PID CONTROLLER	SEC	0.
A(4845)	GAIN FACTOR ON PID CONTROLLER		0.

STEAM GENERATOR PRESSURE VS FLOW SETPOINT TABLE (PID CONTROLLER)

A(4846) NUMBER OF POINTS IN TABLE 0.

STEAM FLOW(PERCENT)		PRESSURE SETPOINT(PSIA)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(4852)	0.	A(4847)	0.

1ST BYPASS VALVE TABLE

A(4857) NUMBER OF POINTS IN TABLE 1 0.

ERROR SIGNAL(VOLTS)		VALVE CAPACITY(PERCENT)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(4858)	0.	A(4863)	0.

2ND BYPASS TABLE

A(4868) NUMBER OF POINTS IN TABLE 2 0.

ERROR SIGNAL(VOLTS)		VALVE CAPACITY(PERCENT)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(4869)	0.	A(4874)	0.

3RD BYPASS TABLE

A(4879) NUMBER OF POINTS IN TABLE 3 0.

ERROR SIGNAL(VOLTS)		VALVE CAPACITY(PERCENT)	
A-VECTOR	VALUE	A-VECTOR	VALUE
A(4880)	0.	A(4885)	0.

A(4890) TOTAL AMOUNT OF TURBINE FLOW THAT DUMP AND BYPASS SYSTEM CAN ACCEPT PERCENT .4530E+02

IF A(4600) = 0.0 AND A(4891) = 2.0 USE 2ND PID CONTROLLER - THIS IS THE SAME AS THE FIRST PID CONTROLLER EXCEPT THAT THE FIRST BYPASS TABLE REPRESENTS THE TOTAL VALVE CAPACITY AND THE SECOND AND THIRD VALVE TABLES ARE NOT USED.

1ST BYPASS VALVE TABLE

A(4857) NUMBER OF POINTS IN TABLE 1 0.

ERROR SIGNAL(VOLTS) A-VECTOR	ERROR SIGNAL(VOLTS) VALUE	VALVE CAPACITY(PERCENT) A-VECTOR	VALVE CAPACITY(PERCENT) VALUE
A(4858)	0.	A(4863)	0.

A(4890) TOTAL AMOUNT OF TURBINE FLOW THAT DUMP AND BYPASS SYSTEM CAN ACCEPT PERCENT .4530E+02

*** SAFETY VALVES ***

GENERAL INFORMATION

A(4650)	MAXIMUM AREA OF RH SAFETY VALVE	FT2	.1013E+01
A(4651)	MAXIMUM AREA OF LH SAFETY VALVE	FT2	.1013E+01
A(4653)	TOTAL NUMBER OF SAFETY VALVES PER STEAM GENERATOR		.8000E+01

VALVE CHARACTERISTICS

OPENING PRESSURE SETPOINT

VALVE NUMBER	SETPOINT(PSIA)	A-VECTOR
1	.9900E+03	A(4654)
2	.9900E+03	A(4655)
3	.9900E+03	A(4656)
4	.9900E+03	A(4657)
5	.1030E+04	A(4658)
6	.1030E+04	A(4659)
7	.1030E+04	A(4660)
8	.1030E+04	A(4661)

A(4664)	ACCUMULATION TO FULLY OPEN SAFETY VALVES	PERCENT	.3000E+01
A(4665)	BLOWDOWN TO FULLY CLOSED SAFETY VALVES	PERCENT	.5000E+01
A(4935)	FRACTIONAL VALVE OPENING AREA AT PSET	FRAC	.7000E+00
A(4936)	FRACTIONAL VALVE OPENING AREA AT ACCUMULATED PRESSURE (-)	FRAC	.8200E+00
A(4937)	FRACTIONAL VALVE OPENING AREA AT ACCUMULATED PRESSURE	FRAC	.1000E+01
A(4938)	FRACTIONAL VALVE OPENING AREA AT BLOWDOWN PRESSURE (+)	FRAC	.9500E+00

VALVE FAILURE SIMULATION

A(4564) OPTION TO SIMULATE ONE SAFETY VALVE IN RH STEAM GENERATOR INADVERTENTLY OPENS AT TIME 0. 1.0 = YES 0.0 = NO — 0.

VECTORS A(4539) THRU A(4548) REPRESENT RH AND CORRESPONDING LH VALVE PAIR CONDITIONS, ONE VECTOR IS USED FOR EACH VALVE PAIR. VALVE PAIR CONDITIONS ARE REPRESENTED BY SWITCH NUMBERS AS FOLLOWS

INPUT VALVE SWITCH	RH VALVE CONDTIONS	LH VALVE CONDITION
0.0	NORMAL	NORMAL
1.0	STUCK CLOSED	NORMAL
2.0	NORMAL	STUCK CLOSED
3.0	STUCK CLOSED	STUCK CLOSED
4.0	STUCK OPEN	NORMAL
5.0	NORMAL	STUCK OPEN
6.0	STUCK OPEN	STUCK OPEN

VALVE NUMBER IN EACH SG	A-VECTOR	FAILURE DESCRIPTION(SWITCH)
1	A(4539)	0.
2	A(4540)	0.
3	A(4541)	0.
4	A(4542)	0.
5	A(4543)	0.
6	A(4544)	0.
7	A(4545)	0.
8	A(4546)	0.

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                    *                      *
                    * 14. SPECIAL OPTIONS  *
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              *** STEAM GENERATOR TUBE RUPTURE ***

A(3006)    OPTION FOR RHSG TUBE RUPTURE                              0.
              1.0 - YES
              0.0 - NO

A(3007)    FLOW CONSTANT FOR RUPTURED TUBE (RHSG)                    0.

A(3156)    OPTION FOR LHSG TUBE RUPTURE                              0.
              1.0 - YES
              0.0 - NO

A(3157)    FLOW CONSTANT FOR RUPTURED TUBE (LHSG)                    0.

A(3008)    INSIDE DIAMETER OF TUBES                   IN             .6540E+00

*** NOTE ***
     DISCHARGE COEFFICIENTS FOR RHSG AND LHSG TUBE RUPTURE CAN BE FOUND IN THE CRITICAL FLOW MODELS SECTION

              *** TRANSIENT INFORMATION ***

A(4600)    PLANT EVENT OPTIONS                                       0.
              0.0 = NORMAL OPERATION
              1.0 = SLB UPSTREAM OF ISOLATION VALVE
              2.0 = SLB DOWNSTREAM OF ISOLATION VALVE
              3.0 = EXCESS LOAD - DUMP AND BYPASS INITIALLY OPEN,
                    THEN ON CONTROLLER
              4.0 = EXCESS LOAD - DUMP AND BYPASS FUNCTION OF TIME
```

*** STEAM LINE BREAK OPTION ***

STEAM LINE BREAK AREA VS. TIME

A(4667) NUMBER OF POINTS IN TABLE 0.

TIME(SEC)		LMSG BREAK AREA (FT2)		RMSG BREAK AREA (FT2)	
A-VECTOR	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
A(4668)	0.	A(4683)	0.	A(4698)	0.

A(4340)	AREA FOR FLUID LEAKAGE IN STEAM LINE BREAK CALCULATIONS FOR RMSG	FT2	0.
A(4341)	AREA FOR FLUID LEAKAGE IN STEAM LINE BREAK CALCULATIONS FOR LMSG	FT2	0.
A(4342)	TIME FOR MSIV LEAKAGE TO OCCUR IN RMSG	SEC	0.
A(4343)	TIME FOR MSIV LEAKAGE TO OCCUR IN LMSG	SEC	0.

*** FEEDWATER LINE BREAK ***

A(4992)	FEEDWATER LINE BREAK AREA - LHSG ONLY	FT2	0.
A(4996)	AUXILIARY FEEDWATER DELAY TIME FOR RHSG FROM TIME A(2303) SETPOINT IS REACHED	SEC	0.
A(4997)	AUXILIARY FEEDWATER FLOW TO THE RHSG	LBS/SEC	0.
A(4998)	HEIGHT OF FEEDWATER NOZZLE ABOVE THE TUBE SHEET, IF A(4990) IS GREATER THAN ZERO, UNITS ARE IN LBS.	FT OR LBS	0.
A(4999)	ENTHALPY OF AUXILIARY FEEDWATER TO THE RHSG	BTU/LB	0.
A(2303)	SG LEVEL SETPOINT THAT ACTIVATES AUXILIARY FEEDWATER. IF A(4994) IS GREATER THAN ZERO, UNITS ARE IN LBS.	FT OR LBS	0.

*** LOSS OF AC (LOAC) ***

A(4921)	LOSS OF AC OPTION 0.0 = NO LOAC 1.0 = LOAC AT TIME = A(4920) 2.0 = LOAC AT T = TIME OF TRIP + A(4920)		0.
A(4920)	TIME OF LOAC (USED IF A(4921) IS 1.0 OR 2.0).	SEC	0.
A(4924)	AUTOMATIC CLOSURE OF DUMP VALVE AT LOAC OPTION 1.0 = YES 0.0 = NO		0.

*** LOCKED ROTOR EVENT ***

A(7079)	TIME FOR 1-PUMP LOCKED ROTOR EVENT TO OCCUR	SEC	.1000E+05
A(7080)	LOOP IN WHICH LOCKED ROTOR OCCURS		1.0000
A(7081)	FORWARD FLOW K-FACTOR FOR LOCKED ROTOR EVENT DIVIDED BY EFFECTIVE AREA SQUARED	1/FT4	.5641
A(7085)	REVERSE FLOW K-FACTOR FOR LOCKED ROTOR EVENT DIVIDED BY EFFECTIVE AREA SQUARED	1/FT4	.5890

*** LETDOWN LINE BREAK ***

A(4550)	LETDOWN LINE BREAK OPTION 1.0 = YES 0.0 = NO		0.
A(4551)	LETDOWN LINE BREAK AREA	FT2	0.
A(4552)	TOTAL LETDOWN LINE SLOW RESISTANCE(K-FACTOR)		0.
A(4553)	LETDOWN LINE RESISTANCE FROM THE RCS TO THE OUTLET OF THE REGENERATIVE HEAT EXCHANGER (K-FACTOR)		0.
A(4554)	PRODUCT OF THE NORMAL CHARGING FLOW RAISED TO THE 0.8 POWER AND THE CHARGING FLOW FILM RESISTANCE	GPM	0.
A(4555)	PRODUCT OF THE NORMAL LETDOWN FLOW RAISED TO THE 0.8 POWER AND THE LETDOWN FLOW FILM RESISTANCE	GPM	0.
A(4556)	REGENERATIVE HEAT EXCHANGER TUBE WALL RESISTANCE (DELTA X/K, DELTA X = WALL THICKNESS, K = THERMAL CONDUCTIVITY) DIVIDED BY THE AREA (FT2)	1/(BTU/HR-DEG.F)	0.
A(4557)	CHARGING FLOW INLET PRESSURE	PSIA	0.
A(4558)	LETDOWN LINE MASS FLOW RATE MULTIPLIER		0.

WALL HEAT MODEL

A(4970)	WALL HEAT MODEL OPTION 0.0 = NO 1.0 = YES		0.
A(4967)	THICKNESS OF BASE METAL FOR WALL HEAT CALCULATIONS	FT	0.
A(4968)	THICKNESS OF CLAD FOR WALL HEAT CALCULATIONS	FT	0.
A(4969)	THERMAL CONDUCTIVITY OF BASE METAL	(BTU-FT)/ (FT2-SEC-F)	0.
A(4971)	THERMAL CONDUCTIVITY OF CLAD	(BTU-FT)/ (FT2-SEC-F)	0.
A(4972)	SPECIFIC HEAT OF BASE METAL	BTU/(LB-F)	0.
A(4973)	SPECIFIC HEAT OF CLAD	BTU/(LB-F)	0.
A(4974)	DENSITY OF BASE METAL	LB/FT3	0.
A(4975)	DENSITY OF CLAD	LB/FT3	0.
A(4978)	SPECIFIC HEAT OF CLOSURE HEAD AND INTERNAL STRUCTURALS	BTU/F	0.

DATA FOR WALL HEAT MODEL

*** SURFACE AREAS OF MAJOR COMPONENTS/SYSTEMS ***

*** NOTE ***

THE FOLLOWING A-VECTORS ARE USED ONLY IF THE WALL HEAT MODEL OPTION IS USED (IE, IF A(4970) = 1.0)

A(4950)	CLOSURE HEAD	FT2	0.
A(4951)	CORE COOLANT CHANNEL	FT2	0.
A(4952)	CORE BYPASS	FT2	0.
A(4953)	CORE COLD PLENUM	FT2	0.
A(4954)	RHSG HOT LEG	FT2	0.
A(4955)	RHSG HOT PLENUM NODE	FT2	0.
A(4956)	RHSG TUBES	FT2	0.
A(4957)	RHSG COLD PLENUM	FT2	0.
A(4958)	RHSG COLD LEG	FT2	0.
A(4959)	LHSG HOT LEG	FT2	0.
A(4960)	LHSG HOT PLENUM	FT2	0.
A(4961)	LHSG TUBES	FT2	0.
A(4962)	LHSG COLD PLENUK	FT2	0.
A(4963)	LHSG COLD LEG	FT2	0.
A(4964)	PRESSURIZER SURGE LINE	FT2	0.
A(4965)	REGION BETWEEN TOP OF ACTIVE CORE AND FUEL ALIGNMENT PLATE	FT2	0.
A(4966)	REGION BETWEEN FUEL ALIGNMENT PLATE AND UPPER GUIDE STRUCTURE SUPPORT PLATE AND OUTLET NOZZLES	FT2	0.

15, TRIP INFORMATION

TRIP SETPOINTS				OVERRIDE 1.0 = YES 0.0 = NO		TRIP TIME CONSTANT(SEC)	
TRIP	A-VECTOR	UNIT	VALUE	A-VECTOR	VALUE	A-VECTOR	VALUE
HIGH POWER	A(250)	FRAC	,1300E+01	A(258)	,1000E+01	A(426)	,1000E+00
HIGH PZR PRESSURE	A(252)	PSIA	,2455E+04	A(260)	0,	A(428)	,7500E+00
LOW PZR PRESSURE	A(253)	PSIA	,1728E+04	A(261)	,1000E+01	A(429)	,7500E+00
LOW COOLANT FLOW	A(254)	FRAC	,1059E+01	A(262)	0,	A(430)	,2500E+00
LOW SG PRESSURE	A(255)	PSIA	,5100E+03	A(263)	0,	A(431)	,7500E+00
LOW SG WATER LEVEL	A(256)	FT OR LB	,2980E+02	A(264)	,1000E+01	A(432)	,7500E+00
MANUAL TRIP	A(257)	SEC	,1000E+05	A(265)	,1000E+01	A(433)	0,
HIGH SG LEVEL	A(442)	FT OR LB	0,	A(443)	,1000E+01	A(432)	,7500E+00

A(434)	SENSOR SIGNAL DELAY TIME FROM TIME SENSOR SIGNAL REACHES ACTUATIONN SETPOINT UNTIL TRIP CIRCUIT BREAKER OPENS	SEC	,4000E+00
A(4571)	MAXIMUM FRACTIONAL POWER TRIP VALUE FOR VARIABLE OVER-POWER TRIP		0,
A(4572)	MAXIMUM FRACTIONAL POWER TRIP RATE FOR VARIABLE OVER-POWER TRIP,(IF 0,0, DO NOT USE VARIABLE OVER-POWER TRIP,)		0,

```
****************************
*                          *
* 16. CRITICAL FLOW MODELS *
*                          *
****************************
```

*** PRIMARY SAFETY AND RELIEF VALVES ***

```
A(5001)     SINK PRESSURE                                     PSIA      0.

A(5011)     STEAM DISCHARGE OPTION                                      0.
               1.0 - USE MURDOCK AND BAUMAN
               0.0 - USE CRITCO

A(5021)     TWO PHASE OR SUBCOOLED DISCHARGE OPTION                     .1000E+01
               1.0 - HENRY-FAUSKE
               2.0 - HENRY-FAUSKE/MOODY
               3.0 - MOODY
               4.0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS. QUALITIES

```
A(5031)     NUMBER OF POINTS IN TABLE                                   0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5058)	0.	A(5048)	0.

*** SECONDARY SAFETY VALVES ***

```
A(5002)    SINK PRESSURE                                        PSIA    .1470E+02

A(5012)    STEAM DISCHARGE OPTION                                       0.
              1.0 - USE MURDOCK AND BAUMAN
              0.0 - USE CRITCO

A(5022)    TWO PHASE OR SUBCOOLED DISCHARGE OPTION                      .1000E+01
              1.0 - HENRY-FAUSKE
              2.0 - HENRY-FAUSKE/MOODY
              3.0 - MOODY
              4.0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS. QUALITIES

```
A(5032)    NUMBER OF POINTS IN TABLE                                    0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5078)	0.	A(5068)	0.

*** RCS LEAK 1 OR RHSG TUBE RUPTURE ***

A(5003)	SINK PRESSURE	PSIA	.1470E+02
A(5013)	STEAM DISCHARGE OPTION 1.0 - USE MURDOCK AND BAUMAN 0.0 - USE CRITCO		0.
A(5023)	TWO PHASE OR SUBCOOLED DISCHARGE OPTION 1.0 - HENRY-FAUSKE 2.0 - HENRY-FAUSKE/MOODY 3.0 - MOODY 4.0 - HOMOGENEOUS EQUILIBRIUM MODEL		.1000E+01

DISCHARGE COEFFICIENTS VS. QUALITIES

A(5033) NUMBER OF POINTS IN TABLE 0.

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5098)	0.	A(5088)	0.

RCS LEAK 1 OR RHSG TUBE RUPTURE TIME VS. AREA

A(5041) NUMBER OF POINTS IN TABLE 0.

TIME(SEC) A-VECTOR	VALUE	AREA(FT2) A-VECTOR	VALUE
A(5258)	0.	A(5248)	0.

A(5368) NODE FOR RCS LEAK 1,FOR RHSG TUBE RUPTURE,USE 0.0 0.

*** RCS LEAK 2 OR LHSG TUBE RUPTURE ***

```
A(5004)     SINK PRESSURE                                     PSIA          .1470E+02

A(5014)     STEAM DISCHARGE OPTION                                          0.
              1.0 - USE MURDOCK AND BAUMAN
              0.0 - USE CRITCO

A(5024)     TWO PHASE OR SUBCOOLED DISCHARGE OPTION                         .1000E+01
              1.0 - HENRY-FAUSKE
              2.0 - HENRY-FAUSKE/MOODY
              3.0 - MOODY
              4.0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS. QUALITIES

```
A(5034)     NUMBER OF POINTS IN TABLE                                       0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5118)	0.	A(5108)	0.

RCS LEAK 2 OR LHSG TUBE RUPTURE AREA VS. TIME

```
A(5042)     NUMBER OF POINTS IN TABLE                                       0.
```

TIME(SEC) A-VECTOR	VALUE	AREA(FT2) A-VECTOR	VALUE
A(5278)	0.	A(5268)	0.

```
A(5369)     NODE FOR RCS LEAK 2,FOR LHSG TUBE RUPTURE,USE 0.0               0.
```

*** ATMOSPHERIC DUMP VALVES ***

```
A(5005)    SINK PRESSURE                                PSIA    .1470E+02

A(5015)    STEAM DISCHARGE OPTION                               0.
              1.0 - USE MURDOCK AND BAUMAN
              0.0 - USE CRITCO

A(5025)    TWO PHASE OR SUBCOOLED DISCHARGE OPTION              .1000E+01
              1.0 - HENRY-FAUSKE
              2.0 - HENRY-FAUSKE/MOODY
              3.0 - MOODY
              4.0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS. QUALITIES

```
A(5035)    NUMBER OF POINTS IN TABLE                            0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5138)	0.	A(5128)	0.

*** STEAM LINE BREAK - RH STEAM GENERATOR ***

```
A(5006)    SINK PRESSURE                                PSIA    .1470E+02

A(5016)    STEAM DISCHARGE OPTION                               0.
              1.0 - USE MURDOCK AND BAUMAN
              0.0 - USE CRITCO

A(5026)    TWO PHASE OR SUBCOOLED DISCHARGE OPTION              .1000E+01
              1.0 - HENRY-FAUSKE
              2.0 - HENRY-FAUSKE/MOODY
              3.0 - MOODY
              4.0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS. QUALITIES

```
A(5036)    NUMBER OF POINTS IN TABLE                            0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5158)	0.	A(5148)	0.

*** STEAM LINE BREAK - LH STEAM GENERATOR ***

```
A(5007)     SINK PRESSURE                                  PSIA          .1470E+02

A(5017)     STEAM DISCHARGE OPTION                                       0.
               1,0 - USE MURDOCK AND BAUMAN
               0,0 - USE CRITCO

A(5027)     TWO PHASE OR SUBCOOLED DISCHARGE OPTION                      .1000E+01
               1,0 - HENRY-FAUSKE
               2,0 - HENRY-FAUSKE/MOODY
               3,0 - MOODY
               4,0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS, QUALITIES

```
A(5037)     NUMBER OF POINTS IN TABLE                                    0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5178)	0.	A(5168)	0.

*** FEEDWATER LINE BREAK - LH STEAM GENERATOR ***

```
A(5008)     SINK PRESSURE                                  PSIA          .1470E+02

A(5018)     STEAM DISCHARGE OPTION                                       .
               1,0 - USE MURDOCK AND BAUMAN
               0,0 - USE CRITCO

A(5028)     TWO PHASE OR SUBCOOLED DISCHARGE OPTION                      .1000E+01
               1,0 - HENRY-FAUSKE
               2,0 - HENRY-FAUSKE/MOODY
               3,0 - MOODY
               4,0 - HOMOGENEOUS EQUILIBRIUM MODEL
```

DISCHARGE COEFFICIENTS VS, QUALITIES

```
A(5038)     NUMBER OF POINTS IN TABLE                                    0.
```

QUALITIES(FRAC) A-VECTOR	VALUE	DISCHARGE COEFFICIENTS(FRAC) A-VECTOR	VALUE
A(5198)	0.	A(5188)	0.

17. BORON CONCENTRATION

A(266)	BORON CONCENTRATION IN REFUELING WATER TANK	PPM	.1364E+04
A(267)	CRITICAL BORON CONCENTRATION	PPM	0.
A(268)	BORON CONCENTRATION IN SAFETY INJECTION TANK	PPM	.1363E+04
A(269)	VOLUME TO BE SWEPT OUT IN THE SAFETY INJECTION LINE BEFORE BORON ENTERS THE RCS	FT3	.1569E+02
A(270)	VOLUME TO BE SWEPT OUT OF CHARGING LINE BEFORE BORON ENTERS THE RCS	FT3	.3000E+02
A(271)	BORON CONCENTRATION IN BORIC ACID TANK	PPM	.1320E+05

BORON DILUTION TABLE

(3891) NUMBER OF POINTS IN TABLE 0.

TIME(SEC) A-VECTOR	TIME(SEC) VALUE	BORON CONCENTRATION(PPM) A-VECTOR	BORON CONCENTRATION(PPM) VALUE
A(3892)	0.	A(3917)	0.

* 18. CESEC III PLOT PACKAGE *

A-VECTOR	UNITS	DESCRIPTION	VALUE	COMMENTS
A(24)		COMPACT HARDCOPY PLOT OPTION 1. YES(FOUR FIGURES ON THE SAME PAGE) 0. NO	0.	
A(25)		PLOT TYPE 0. NO PLOT 1. HARDCOPY PLOTS 2. REGULAR AND HARDCOPY PLOTS 3. REGULAR PLOTS	.3000E+01	

NOTE THE FOLLOWING 10 PLOTS ARE PREDETERMINED VARIABLES WHICH CESEC SPECIFIES. EACH PLOT REQUIRES 4 A-VECTORS, THE FIRST BEING THE PLOT OPTION(1=YES, 0=NO), AND THE REMAINING THREE SPECIFYING THE PLOT SCALE. CESEC SETS ITS OWN PLOT SCALE IF IT IS NOT SPECIFIED BY THE USER.

A-VECTOR	UNITS	DESCRIPTION	VALUE	COMMENTS
A(26)		1 = PLOT VS. TIME	.1000E+01	
A(27)	SECONDS	INITIAL TIME VALUE	0.	
A(28)	INCHES	TIME AXIS LENGTH	0.	
A(29)	SEC/IN	TIME AXIS SCALE FACTOR	0.	
A(30)		1 = PLOT CORE POWER	.1000E+01	
A(31)	PERCENT	MINIMUM CORE POWER	0.	
A(32)	INCHES	Y-AXIS LENGTH	0.	
A(33)	PERCENT/INCH	PERCENTAGE OF POWER PER INCH	0.	
A(34)		1 = PLOT SYSTEMS TEMPERATURES	.1000E+01	
A(35)	DEGREES,F	MINIMUM TEMPERATURE	0.	
A(36)	INCHES	Y-AXIS LENGTH	0.	
A(37)	DEGREES,F/INCH	DEGREES,F PER INCH	0.	
A(38)		1 = PLOT PRIMARY PRESSURE	.1000E+01	
A(39)	PSIA	MINIMUM PRESSURE	0.	
A(40)	INCHES	Y-AXIS LENGTH	0.	
A(41)	PSIA/INCH	PSIA PER INCH	0.	
A(42)		1 = PLOT STEAM GENERATOR PRESSURE	.1000E+01	
A(43)	PSIA	MINIMUM PRESSURE	0.	
A(44)	INCHES	Y-AXIS LENGTH	0.	
A(45)	PSIA/INCH	PSIA PER INCH	0.	
A(46)		1 = PLOT REACTIVITIES	.1000E+01	
A(47)	PERCENT DELTA RHO	MINIMUM REACTIVITY	0.	
A(48)	INCHES	Y-AXIS LENGTH	0.	
A(49)	PERC DELT RHO/IN	PERCENT DELTA RHO PER INCH	0.	
A(50)		1 = PLOT HEAT FLUX	.1000E+01	
A(51)	PERCENT	MINIMUM HEAT FLUX	0.	
A(52)	INCHES	Y-AXIS LENGTH	0.	
A(53)	PERCENT/INCH	PERCENT PER INCH	0.	

J-91

A(54)		1 = PLOT INTEGRATED LEAK RATE	.1000E+01
A(55)	LBS	MINIMUM INTEGRATED LEAK	0.
A(56)	INCHES	Y-AXIS LENGTH	0.
A(57)	LBS/INCH	POUNDS PER INCH	0.
A(58)		1 = PLOT DNBR	0.
A(59)		MINIMUM VALUE DNBR	0.
A(60)	INCHES	Y-AXIS LENGTH	0.
A(61)	DNBR/INCH	DNBR PER INCH	0.
A(62)		1 = PLOT INTEGRATED STEAM FLOW	.1000E+01
A(63)		MINIMUM INTEGRATED FLOW	0.
A(64)	INCHES	Y-AXIS LENGTH	0.
A(65)	LBS/IN	POUNDS PER INCH	0.

NOTE THE FOLLOWING PLOTS(MAX-14) ARE DETERMINED BY THE USER. EACH PLOT REQUIRES 4 A-VECTORS,THE FIRST BEING THE INDEX NUMBER OF THE VARIABLE TO BE PLOTTED, AND THE REMAINING THREE SPECIFYING THE PLOT SCALE. CESEC SETS ITS OWN PLOT SCALE IF IT IS NOT SPECIFIED BY THE USER.

ADDITIONAL PLOTS

INDEX NUMBER	AXIS STARTS (UNITS)	AXIS LENGTH (INCHES)	SCALE (UNITS PER INCH)
A(1026) = -2113.00	A(1027) = 0.	A(1028) = 0.	A(1029) = 0.
A(1030) = 7193.00	A(1031) = 0.	A(1032) = 0.	A(1033) = 0.
A(1034) = -9623.00	A(1035) = 0.	A(1036) = 0.	A(1037) = 0.
A(1038) = 9622.00	A(1039) = 0.	A(1040) = 0.	A(1041) = 0.
A(1042) = 7487.00	A(1043) = 0.	A(1044) = 0.	A(1045) = 0.
A(1046) = -2116.00	A(1047) = 0.	A(1048) = 0.	A(1049) = 0.
A(1050) = 2183.00	A(1051) = 0.	A(1052) = 0.	A(1053) = 0.
A(1054) = -2184.00	A(1055) = 0.	A(1056) = 0.	A(1057) = 0.
A(1058) = 7192.00	A(1059) = 0.	A(1060) = 0.	A(1061) = 0.
A(1062) = 10764.0	A(1063) = 0.	A(1064) = 0.	A(1065) = 0.
A(1066) = 12251.0	A(1067) = 0.	A(1068) = 0.	A(1069) = 0.
A(1070) = 10922.0	A(1071) = 0.	A(1072) = 0.	A(1073) = 0.
A(1074) = -4026.00	A(1075) = 0.	A(1076) = 0.	A(1077) = 0.
A(1078) = 4030.00	A(1079) = 0.	A(1080) = 0.	A(1081) = 0.

NOTE NEGATIVE INDEX NUMBER MOVES THE CURVE TO THE NEXT GRAPH WITH POSITIVE INDEX
****

APPENDIX K

OUTPUT DESCRIPTION

K.1 Major Edits

I. Transient time and CPU time, seconds

II. Reactor Core Information

A. Core Power and Heat Flux

Total Power, MWt
Instant Power, MWt
Decay Power, MWt
Power Fraction
Heat Flux Fraction
Average Linear Heat Rate, KW/ft

B. Core Temperatures, ^{o}F

Core Inlet
Core Outlet
Coolant Channel
Cladding Surface
Radial Fuel Nodes

C. Core Boron (PPM)

D. Reactivity Insertion, $\delta k = k(t) - k(0)$

Total
Doppler
Moderator (D), Reactivity as a function of moderator density
Boron
Control Rods
Scram Rods
Time Reactivity
Moderator (T), Reactivity as a function of moderator temperature

III. Reactor Coolant System Information

A. Pressurizer

Pressure, psia (steam and water)
Volume, ft^3 (steam and water)
Temperature, ^oF (steam and water)
Mass, lbm (steam and water)
Enthalpy, BTU/lbm (steam and water)
Pressurizer status
Flows, lbm/sec
- Surge line
- Sprays
- Condensation
- Boiling

Heaters, BTU/sec
- Proportional
- Backup
- Heat loss
- Net heat to pressurizer
- Average heater temperature, ^oF

Safety and Relief Valves
- Flow, lbm/sec
- Integral flow, lbm
- Area, ft^2
- Throat pressure, psia
- Sink pressure, psia
- Type of fluid discharged (steam, water (pure water or steam/water mixture))
- Correlation used for flow calculation

Pressurizer Levels, ft
- Actual
- Deviation (measured-programmed)
- Measured
- Programmed

B. RCS Flow and Pressure

RCS Pressure, psia
Left Loop Flow, lbm/sec and Flow Fraction
Core Flow, lbm/sec and Flow Fraction
Right Loop Flow, lbm/sec and Flow Fraction
Bypass Flow, lbm/sec and Flow Fraction
Charging: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)
Letdown: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)
Safety Injection Pumps: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)
Safety Injection Tanks: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)
RHSG Tube Rupture: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)
LHSG Tube Rupture: Flow (lbm/sec), Enthalpy (BTU/lbm), Integral (lbm)

C. RCS Temperatures, ^oF

RCS Loops
Reactor Vessel
Steam Generator (tubes)
Pressurizer (steam, water, surge line)

IV. Steam Generator Heat Transfer

A. Primary Side

Right and Left Hand Steam Generators
Fluid condition
Correlation used for heat transfer calculation
Temperature, ^oF
Heat transfer coefficient, BTU/sec-^oF-ft^2
Wall fouling coefficient, BTU/sec-^oF-ft^2

B. Secondary Side

Right and Left Hand Steam Generators
Fluid condition
Correlation used for heat transfer calculation
Temperature, ^{o}F
Heat transfer coefficient, BTU/sec-^{o}F-ft^2

C. Overall Heat Transfer Coefficient

Right and Left Hand Steam Generators
Heat transfer area, ft^2
UA, BTU/sec-^{o}F
Heat Rate, BTU/sec

V. Secondary Systems Information

A. Right Hand Steam Generator

Steam Generator level, ft
Pressure, psia
Temperature, ^{o}F
Water Mass, lbm
Steam Mass, lbm
Steam Flow, lbm/sec
Feedwater Flow, lbm/sec
Leak Rate, lbm/sec
Integral Steam Flow, lbm
Integral Feedwater Flow, lbm
Integral Leak Flow, lbm

B. Left Hand Steam Generator

Same parameters as Right Hand Steam Generator

C. Normal Secondary Valve Operation

Header Pressure, psia

Exit Power Fraction - $(W_s h_s - W_{fw} h_{fw})$/design full power

Flow (lbm/sec), Area (ft^2), Integral of flow (lbm)

- LH Safeties
- RH Safeties
- RH Dumps
- LH Dumps
- Bypass
- Turbine
- Total

Critical Flow Calculation for Valves (RH + LH Safeties, Dumps)

- Throat pressure, psia
- Sink pressure, psia
- Fluid state
- Correlation used for flow calculation

D. Feedwater System

Feedwater Control Options:

Feedwater Flow:

1. Matches steam flow (flow after trip ramps down)
2. Input table (pre-trip and post-trip tables)
3. Automatic Level Control (after trip ramps down)

Feedwater Enthalpy

1. Function of steam delivery to turbine (function of power)
2. Input time table (pre-trip and post-trip tables)

Main Feedwater:

1. Flow to RHSG & LHSG, lbm/sec
2. Enthalpy - RHSG & LHSG, BTU/lbm

Auxiliary Feedwater:

Same parameters as Main Feedwater

VI. Reactor Protective System Information (Trip Signals)

A. Scram
B. Power Change Rate
C. Power Level
D. High Pressurizer Pressure
E. Low Pressurizer Pressure
F. Low Flow
G. Low Steam Generator Pressure
H. Manual Trip
I. Low Steam Generator Level
J. Safety Injection Actuation Signal

VII. Control Rod Information

A. Rod Speed
B. Temperature Reference
C. Temperature Error
D. Power Demand
E. Power Error
F. Pressure Error
G. Total Error

VIII. CESEC Energy and Mass Conservation (Conservation Check on Primary Coolant)

A. Energy (mass x enthalpy): Pressurizer, RCS & Surge Node, Total

Now, (current value)
Initial, (initial value)
Change, (= now - initial)
Check, (= VDP + Heat + ext. flow)
VDP, (volume x P)
Heat, (external heat addition)
Ext. Flow, (heat carried by the external flows)

B. Mass (lbm)

Now, (current value)
Initial (initial value)
Change, (= now - initial)
Check, (= Ext. Flow)

C. Percentage of Non-Conservation for Energy and Mass
(Change-Check)* 100.0/Check

IX. Thermalhydraulic Summary

A. Table

Node (RCS nodes & surge line)
Volume, ft^3
Q, BTU/sec
WE, lbm/sec (external flow)
HWE, BTU/sec (enthalpy x external flow)
H, BTU/lbm
SPVOL, ft^3/lbm
Mass (lbm)
DH/DT
Temperature, ^oF
Quality
Void Fraction

B. Pressurizer Region (steam and water)

Same parameters as above (Steam and water volumes are printed in the Pressurizer section of the Reactor Coolant System Information. Total volume is shown in this section.)

C. Additional Pressurizer & System Information

PPRES, Pressurizer Pressure, psia

PRCS, Reactor Coolant System Pressure, psia

PDOT, Rate of Change in Pressurizer Pressure, psia/sec

WS, Surge Line Flow, lbm/sec

MDOT, Rate of Change in Pressurizer Mass, lbm/sec

WB, Rate of Boiling in Pressurizer, lbm/sec

WC, Rate of Condensation in Pressurizer, lbm/sec

D. Thermalhydraulic Solutions of Unknown Vector Elements

X. Flow Model Summary

A. Loop Information

Loop Number

Mass Flow, lbm/sec

Mass Flow Derivative, lbm/sec^2

Mass Flow Ratio

Node Number (Flow Model Nodal Scheme)

Path Height, ft

Path Area, ft^2

Path Lenght, ft

L/A, ft^{-1}

RHUGH, Elevation Pressure drop, psi

PFRIC, Frictional Pressure drop, psi

PGEOM, Geometric Pressure drop, psi

Hydraulic Diameter, ft

R-NUM, Reynolds Number

Friction Factor

PHI, Two-phase multiplier

B. Pump Information

Net Torque, ft-lbf

Electrical Torque, ft-lbf

Hydraulic Torque, ft-lbf

Friction and Windage Torque, ft-lbf

Pump Head, ft and psi

Pump Speed, rad/sec and rpm

Ratio of Volumetric Flow to Rated Volumetric Flow

Ratio of Pump Speed to Rated Pump Speed

K.2 Intermediate Partial System Edits

1. Time, sec
2. Power Fraction; Heat Flux Fraction
3. Reactivity, δk; Core Flow, lbm/sec
4. Core Inlet Temperature, ^{o}F; Core Outlet Temperature, ^{o}F
5. Core Average Temperature, ^{o}F; Pressurizer Status
6. Pressurizer Pressure, psia; RCS Pressure, psia
7. Left Hand Steam Generator Pressure, psia; Right Hand Steam Generator Pressure, psia
8. Left hand Steam Generator Level, ft; Right Hand Steam Generator Level, ft
9. Left Steam Flow, lbm/sec; Right Steam Flow, lbm/sec
10. Left Water mass, lbm; Right Water mass, lbm
11. Closure Head Flow, lbm/sec; Quality Node 25
12. Surge Line Flow, lbm/sec; Void Fraction Node 25

K.3 Special Print Edits

Refer to Section K.1 for items I, II, and III, and to Section K.2 for item IV.

I. Moderator Density at Core Edge or Average Moderator Density are printed for Steam Line Break transients in the Reactor Core Information section.

II. Steam Line Break (SLB) Information: (printed in Secondary Systems Information)

A. Indication of SLB - position of break
B. Break Size (ft^2)
C. Break Flow Rate (lbm/sec)
D. Integral Flow (lbm)
E. Throat Pressure at the Break (psia)
F. Sink Pressure (psia)
G. Type of Fluid Discharged (steam/water)
H. Correlation Used for Flow Calculation

III. Feedwater Line Break (FWLB) Information: (printed in Secondary Systems Information)

A. Indication of FWLB
B. Break Size (ft^2)
C. Break Flow Rate (lbm/sec)
D. Integral Flow (lbm)
E. Type of Fluid Discharged (water/steam)
F. Correlation Used for Flow Calculation

IV. Intermediate Partial System Edits Special Prints

A. Alarms and Trip Signals
B. Pressurizer Status - Status Change Flag
C. FWLB Break Flow (lbm/sec) printed at every 1 second interval

APPENDIX L

PLOT PACKAGE

L.1 General Capabilities of the CESEC Plot Package

The CESEC plot package enables the user to plot any variable as a function of time. Three types of plots are presently available:

1. Fixed format line printer plots; size of plot is fixed (50 lines by 100 columns) generated at the end of the print of a CESEC run.

2. Variable format drum plots; size of plot is user defined (usually 6" X 5") plotted at the data center from the plot file.

3. Fixed format drum plots; size of plot is 2" X 5", four plots per sheet, common time axis, plotted at the data center from the plot file.

The plot package, when exercised, consists of nine standard plots. In addition, the user has the option of selecting any of fourteen user determined plots. The user determined additional plots whose Y-axis labels are supplied by the user require parameter identification by index number. Multiple curves can be plotted in the same graph by the use of negative index numbers.

L.2 User Information

The line printer plots can be requested by the user by setting A(25) equal to 3.0 (or 2.0 if both printer and drum plots are desired). The user must then define the CPLOT variables in vectors A(26-65) and A(1026-1031). These vectors specify the information relevant to the variables to be plotted. As a user's option, the scale factor and axis length for a plot may be set by the code. The user should only exercise this option when he cannot anticipate the case results and, therefore, would not know what scale factor to use.

The variable format drum plots are requested by setting A(25) equal to 1.0 (or 2.0 for both printer and drum plots). The CPLOT variables are defined as detailed in the previous paragraph.

The fixed format drum plot option (4 curves per sheet) is requested by setting A(24) equal to 1.0. The CPLOT variables must be defined for a 6" X 5" plot. This is necessary for the code to convert to the proper scale factor. Whenever A(24) is set equal to 1.0, then A(25) must not be set equal to 0.0 or no plots will be generated.

The generation of drum plots requires the user to attach the CALCOMP post processor by inserting the following control cards after the "CESEC" control card:

```
ATTACH(POP,POP,ID=SYSLIBE)
POP.
```

L.3 CESEC Plot Package Input Description

Options

A-vector	Description
A(24)	2" X 5" PLOT OPTION (For A(25) > 0.0)
	0.0 Option off 1.0 Four plots per sheet
A(25)	NPLOT PLOT VARIABLE
	0.0 No plots 1.0 Drum plots only 2.0 Printer and drum plots 3.0 Printer plots only

Time Information

A-vector	Fortran Name	Description
A(26)	CPLOT (1,1)	1.0 if plots are requested
A(27)	CPLOT (1,2)	Initial time value (seconds)
A(28)	CPLOT (1,3)	Time axis length (inches)
A(29)	CPLOT (1,4)	Time axis scale factor (seconds/inch)

If A(28) and A(29) are set equal to 0.0, the code will set the X-axis length to either 4 or 5 inches, whichever fits the data better. For the fixed format plots (A(24) = 1.0), the time axis is automatically set to 5 inches.

Y-Axis Information (A(30-65), A(1026-1081))

A-vector	Fortran Name	Description
A(N)	CPLOT (J,1)	0.0 for no plot 1.0 for standard nine plots or ± Variable index number for user determined plots
A(N+1)	CPLOT (J,2)	Initial Y-axis value (Parameter units)
A(N+2)	CPLOT (J,3)	Y-axis length (inches)
A(N+3)	CPLOT (J,4)	Scale factor (units/inch)

When A(N+2) and A(N+3) are set equal to 0.0, the Y-axis length (maximum length is 10 inches) and scale factor are selected by the plot package. For the fixed format plots (A(24) = 1.0) the Y-axis length is automatically set to 2 inches.

Standard Plots

The following is a list of nine standard plots with their corresponding A vectors. The user has no control over the printed order of these plots.

A-vector	Description
A(30-33)	Reactor power
A(34-37)	RCS temperatures
A(38-41)	RCS pressure
A(42-45)	SG pressures (right and left)
A(46-49)	Reactivities
A(50-53)	Core heat flux
A(54-57)	Integrated leak flow
A(58-61)	Minimum DNBR
A(62-65)	Integrated steam flow

User Determined Plots

The user determined plots are specified by exercising A-vectors 1026-1081 (4 per parameter). The index number for the desired parameters must be entered in CPLOT (J,1). Multiple curves on the same graph can be plotted by using a negative value of the index number in CPLOT (J,1). A positive index number must be used for the last parameter to be plotted on the same graph.

The Y-axis labels for the fourteen additional plots must be supplied by the user. The labels are input in the first ten columns of the last input card (/line) for an A-vector series. Thus, since each additional plot has four input values associated with it, all of the information (label and A (N) through A (N+3) can be defined on the same card (/line)).

For the fixed format drum plot option, the plots are arranged (4 per sheet) in the order they are requested in the input. The parameters are plotted from bottom to top.

L.4 Subroutines in the Plot Package

GRAPH2 - writes CESEC variables to N17 at each time step

PLOTR2 - main calling program for the plot package

GRAPH2 - title and call for printer plots

TWGRF2 - writes printer plots to output file

PRAX2 - calculates scale factor and axis size if not supplied by the user

AXIS2 - locates axis, writes title, writes scales, and generates curves for user format drum plots

AXIS4 - locates axis, writes title, writes scales, and generates curves for fixed format drum plots

PLOTP - writes binary coded decimal pen motion commands to DISK file for drum plots

LOGP - writes large CESEC letters at end of CESEC run

L.5 Files Used by Plot Package

A list of files used by the CESEC plot package is provided below:

OUTPUT - printed output file (also sent to FILMPL for fiche)

TAPE6 - same as OUTPUT

PLOTP - short form printer output, includes dayfile, A-vector array, and line printer plots

TAPE16 - same as PLOTP

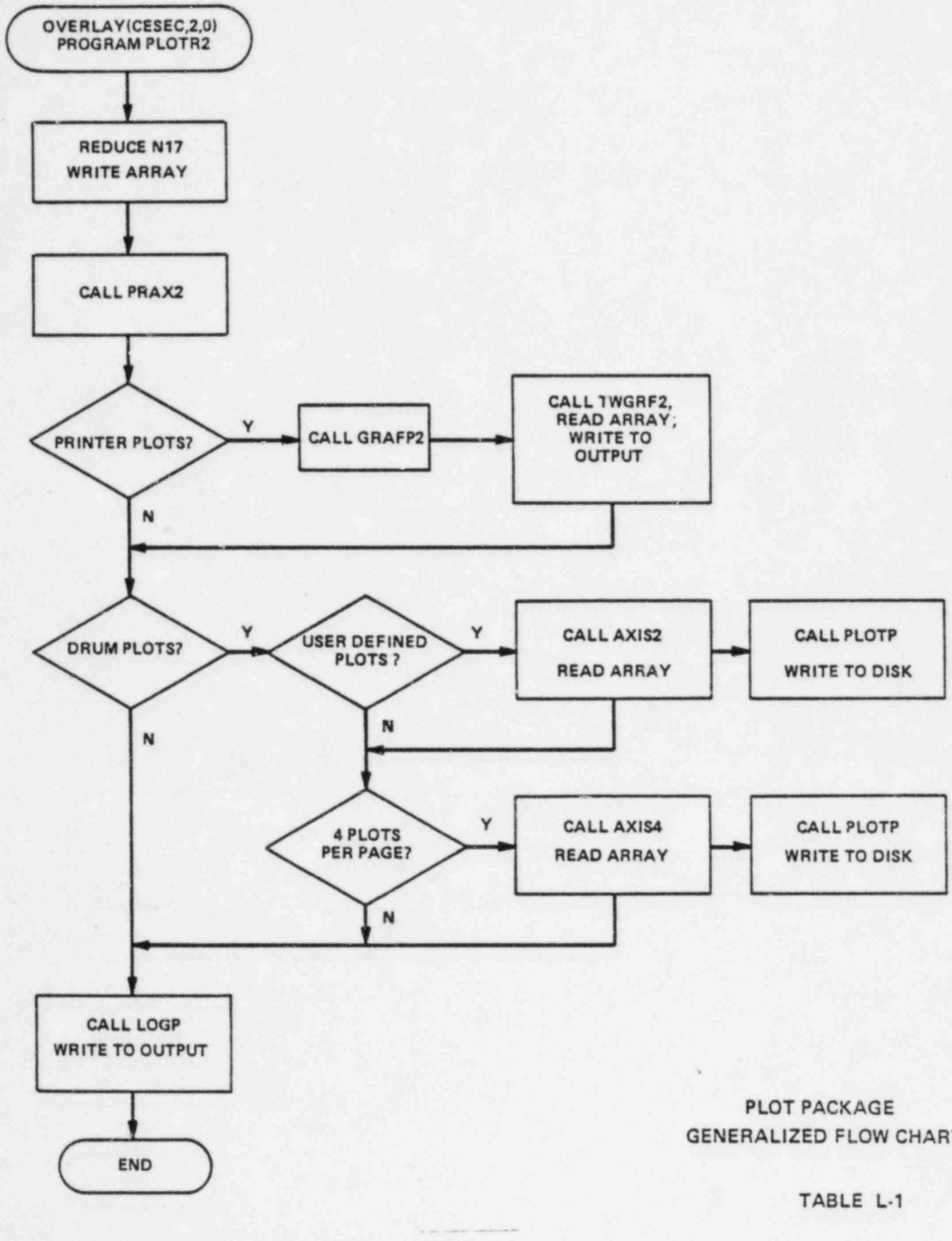
DISK - drum plotter file, to be read by plotter post processor

TAPE8 - same as disk

N17 - list of variable values at each time step, also called TAPE17

ARRAY - $\leq$ 400 point reduced plot file

A generalized flow chart of the plot package is provided in Table L-1.



PLOT PACKAGE
GENERALIZED FLOW CHART

TABLE L-1

COMBUSTION ENGINEERING, INC.