— KAPP 4 —

Digital Computer Program for
Solution of Reactor Kinetics and
Primary System Pressure Response

by

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KAPP4 — Digital Computer Program for Solution
of Reactor Kinetics and Primary System
Pressure Response

B. E. Bingham, W. R. Rhyne

Key Words: KAPP4, Computer Program, Neutron Kinetics,
Core Heat Transfer, Temperature Response,
Pressurizer Pressure

ABSTRACT

KAPP4 is a digital computer program that solves the time-dependent neutron kinetics equations, the core heat transfer, the temperature response in the primary coolant loop, and the pressure in the pressurizer and loop. It includes options for any of the normal reactor trip signals, as well as decay heat and secondary coastdown in the steam generator. The heat transfer is based on the average fuel pin, which the program simulates.

The program is characterized by speed and flexibility in accepting both fast and slow reactivity transients. The printout is compact and the running time is short. The printout for each time zone may be as little as four pages. The running time varies from two to three times the real problem time on the CDC-6600. The run time ratio may be larger depending on the simulation models chosen.

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1. INTRODUCTION

KAPP4 is a program that solves the time-dependent neutron kinetics equations, the core heat transfer, the temperature response in several parts of the primary coolant loop, and the pressure in the pressurizer and loop. The program can be used for a variety of investigations including transient coolant flow cases where the flow rate is input through time tables. It can be used with or without trip, where the trip action can be based on any of the normal reactor trip parameters. The input reactivity and the trip reactivity can be entered in tabular form as coefficients of up to a second-order polynomial to obtain a flexible, nonlinear driving function. The heat demand on the secondary side of the steam generator can also be input in tabular form. Typical problems for which this program can be used include rod ejection, rod withdrawal from any power level (source to ultimate), and other uncontrolled reactivity, flow variation or heat demand changes.

Only one primary loop is simulated, so it is assumed that the steam generator response is identical in each loop of an actual plant. The pressurizer heaters, sprays, and safety valves are simulated in the pressurizer model. It is also assumed that energy is transferred to and from the pressurizer during pressure transients depending on the surge direction.

No automatic control is included. Only the average coolant channel and the average fuel pin are simulated. And, since the program uses point kinetics, the flux shape is assumed to be constant with time.

The heat transfer in the fuel pin can be considered in up to 30 radial mesh points in the fuel and cladding with 1 mesh point in the coolant. The heat-transfer model takes into account the gap conductivity between the fuel and cladding and the film coefficient of heat transfer from the cladding to the coolant. Energy may be deposited directly in each of the three regions. Both the heat capacity and the

conductivity are input separately for each mesh point in the fuel and cladding, and remain constant with time. The initial temperature distribution in the average pin may be computed on the basis of the data or input if desired.

Linear coefficients of reactivity as a function of temperature may be input for the fuel and the coolant. The kinetics model will handle any number of delayed neutron groups up to six.

The reactor outlet temperature is delayed by the transit time required for reactor outlet fluid to reach the steam generator before it becomes the steam generator inlet temperature. The steam generator is simulated by two differential equations describing the average temperatures of the coolant and the tubes, and the heat demand is applied to the equation for the tube temperature. The outlet temperature of the steam generator uses a modification of Bender's method with five nodes to effect the time lag from the steam generator inlet to outlet. The same method is used to compute the reactor outlet temperature given the inlet temperature. The reactor inlet temperature is computed from the steam generator outlet temperature by applying a delay equal to the fluid transient time.

The system average temperature is computed by mass-weighting the average temperature in each of four portions of the loop: core, steam generator, hot leg and cold leg. The surge flow is calculated on the basis of system expansion or contraction as a function of the change in density due to temperature fluctuations in each of the four regions of the loop with flow. The pressure is then computed from the conservation laws.

The printout at every selected time step includes the current time, percent neutron power, percent thermal power, integrated power, total reactivity, reactivity feedback from the fuel and moderator, pressure, surge flow, and several temperatures for the fuel pin and coolant loop.

2. MATHEMATICAL MODEL

2. 1. Formulation of Equations

2. 1. 1. Neutronics Model

The point kinetics equations can be expressed as

$$\frac{dN}{dt} = \frac{\rho - \beta}{\Lambda} N + \sum_{i=1}^6 \lambda_i C_i \quad (1)$$

$$\frac{dC_i}{dt} = \frac{\beta_i N}{\Lambda} - \lambda_i C_i \quad (2)$$

As shown in reference 1, the point reactor kinetics equations can be convoluted with the weighting factors A(t) and B(t) to give

$$\int_{t-\Delta t}^t \frac{dN}{dt}(\tau) B(t - \tau) d\tau = \int_{t-\Delta t}^t \text{RHS}(\tau) A(t - \tau) d\tau \quad (3)$$

where RHS(t) is the right hand side of equation 1. The weighting factors are $A(0) = 1$, $A(\Delta t) = 1/2$, and $B(\Delta t) = 1/2$. The nominal value of B(0) is 1, but varies slightly with the value of Δt to give a better value of reactivity introduced during Δt to produce the ramp in the reference transient of reference 1.

2. 1. 2. Heat-Transfer Model

The lumped parameter model (Figure 1) for heat transfer in the fuel and cladding is expressed as

- - - - -

¹W. R. Rhyne, Numerical Solution of the Space- and Time-Dependent Neutron Diffusion Equations, D. Sc. Dissertation, University of Virginia, 1969.

Figure 1. Diagram of Heat Transfer Model

$$(\rho C_p)_i V_i \frac{dT_i}{dt} = Q_i + (UA)_{i-1} (T_{i-1} - T_i) - (UA)_i (T_i - T_{i+1}) \quad (4)$$

where $i = 1, 2, \dots, I1, I1 + 1, \dots, I1 + I2$. A similar expression can be written for the coolant associated with this average fuel pin:

$$(\rho C_p)_i V_i \frac{dT_i}{dt} = Q_i + (UA)_{i-1} (T_{i-1} - T_i) - 2(WC_p)_i (T_i - T_I) \quad (5)$$

where $i = I1 + I2 + 1$. The heat addition term for both (4) and (5) is

$$Q_i = \frac{FR_k}{VF_k} V_i N$$

where k denotes the region: fuel, cladding, or coolant. The fuel and cladding may be considered in up to a total of 30 mesh points (i). The coolant has only a single mesh point.

The coolant average temperature, T_i , in (5) is the average over the entire core. Given the coolant inlet temperature, T_I , the outlet temperature is found using a modification of Bender's² method. The axial length is divided into k equal length nodes for which the outlet temperature of any node at time t is

$$T_{out}^t(k) = T_{out}^{t-\Delta t}(k) - 2 \left[T_{out}^{t-\Delta t}(k) - \bar{T}^{t-\Delta t}(k) \right] \frac{\Delta t}{\lambda} + \left[Q_i^t + (UA)_{i-1} (T_{i-1}^t - T_i^t) \right] f(k) \quad (6)$$

for

$$\Delta t^t \leq \lambda^t$$

- - - - -
²D. J. Bender. "An Explicit Unlimited Stability Approach to the Transient Conduction-Convection Equations." The Effective Use of Computers in the Nuclear Industry, U.S. Atomic Energy Commission, Division of Technical Information, April 21 - 23, 1969, pp 561 - 585.

and

$$T_{out}^t(k) = T_{in}^{t-\Delta t}(k) + \dot{T}_{in}^t(k) \left[\Delta t^t - \lambda^t \right] + \left[Q_i^t + (UA)_{i-1} \left(T_{i-1}^t - T_i^t \right) \right] f(k) \quad (7)$$

for

$$\Delta t^t > \lambda^t$$

where

$$\bar{T}^{t-\Delta t}(k) = \frac{T_{out}^{t-\Delta t}(k) + T_{in}^{t-\Delta t}(k)}{2},$$

$$T_{in}^{t-\Delta t}(k) = T_{out}^{t-\Delta t}(k-1),$$

λ^t = coolant transient time through a node,

T_i^t = average core coolant temperature,

T_{i-1}^t = average cladding wall temperature,

$f(k)$ = fraction of total energy which is generated or transferred in axial node k.

A cosine is assumed for the distribution factor $f(k)$.

2.1.3. Reactivity Model

The Doppler feedback due to fuel temperature changes is computed by volume-averaging the fuel temperature for each fuel node and then multiplying the result by the linear coefficient:

$$\rho(\text{Doppler}) = a_D(\bar{T}_F - \bar{T}_{FO}) \quad (8)$$

where

$$\bar{T}_F = \sum_i T_i V_i / \sum_i V_i.$$

The feedback due to coolant temperature changes is computed as in (8), except that no temperature averaging is necessary since there is only one node:

$$\rho(\text{moderator}) = a_m (T_m - T_{m0}). \quad (9)$$

Reactivity may be input as coefficients of a second-order polynomial

$$\rho(\text{input}) = a + bt + ct^2 \quad (10)$$

where the time (t) is the elapsed time from the start of the time zone. A new time zone is started by changing a or b and c. Following a trip, reactivity can be added to represent the scram according to the quadratic expression

$$\rho(\text{trip}) = dt + et^2. \quad (11)$$

The coefficients d and e may also be changed, and again a new time zone is defined for each set of different values. The time zones for the trip reactivity and input reactivity need not coincide in elapsed time, but the last input reactivity time zone must extend to the end of, or beyond, the last trip reactivity time zone in elapsed time. As in (10), the time (t) in (11) is the time from the start of its own time zone. The total number of time zones for the input and trip reactivities is limited to 30.

All these reactivities are added together to get the total reactivity for the kinetics equation. If a ramp is being input at the time of trip, and it is desired to stop this ramp when trip or scram (actual rod insertion) occurs, then this same ramp must be subtracted as part of the trip reactivity expression (11). The problem is terminated at the end of the last trip reactivity time zone

2.1.4. Decay Heat

Decay heat based on infinite operation at full power is included as part of the program. On option, the decay heat will be added to the neutron power when it passes through full power following trip. It is this total power that is input to equations 4 and 5, and is printed out as percent neutron power. The expression used is

$$\text{total neutron power} = 0.921 (\text{neutron power}) + \text{decay heat}. \quad (12)$$

The neutron power continues to be calculated in the same fashion just as if this relation didn't exist. The decay heat is a tabulation of power as a function of time following the switchover at full power. The initial decay heat is the complement of the neutron power coefficient, or 0.079.

2. 1. 5. Loop Temperatures and Steam Generator

The delay mechanism for obtaining the inlet temperature to the steam generator from the core outlet temperature, and the core inlet from the steam generator outlet temperature is a real delay mechanism. The outlet temperature in each case is stored for each time step along with the corresponding elapsed time. To get the inlet temperatures, a search is made for the time corresponding to the present time minus the transit time; when this time is found, the corresponding temperature is used. If the present time minus the transit time is less than the next stored time, the temperature used for the previous time step is used again.

The heat transfer equations for the steam generator follow the same form as in the core:

$$(MC_p)_c \frac{dT_c}{dt} = 2(WC_p)_c (T'_o - T_c) - (UA)_c (T_c - T_t) \quad (13)$$

$$(MC_p)_t \frac{dT_t}{dt} = (UA)_c (T_c - T_t) - Q_D \quad (14)$$

where T_c is the average coolant temperature, T_t is the average tube temperature, and T'_o is the steam generator inlet temperature—the core outlet delayed by the transit time. Q_D is the heat demand as applied by the steam flow on the secondary side. Also, the outlet temperature is calculated as in the core using a modified form of Bender's method except that there is no direct heat generation term in the coolant and the energy axial temperature distribution factor, $f(k)$, is assumed to be linear. The steam generator outlet temperature is delayed by the transit time to get the core inlet temperature (T_I).

2.1.6. Pressurizer Model

The energy and mass conservation laws and the first law of thermodynamics that describe the dynamics of a pressurizer are solved. The forcing function is a surge rate with safety valves, heaters, and sprays to restrain the transient to within acceptable limits. Included in the energy and mass balances are energy transferred to the pressurizer walls, energy transfer across the steam-liquid interface, condensation and evaporation.

No a priori assumptions are made about the conditions in the pressurizer during the transient. There are no restrictions on the maximum pressure and KAPP4 permits the pressurizer to be completely filled with liquid flowing out the safety relief valves.

2.1.6.1. General Description of the Thermodynamic Systems

Normally two distinct phases, each having its own essentially uniform properties, exist in the pressurizer. These systems are illustrated in Figure 2, which shows the state of the pressurizer at time t . The steam phase includes all steam in the pressurizer, including any steam bubbles rising through the liquid phase, and the liquid phase includes all liquid in the pressurizer including spray and any other condensate falling through the steam phase. During the time interval Δt , any or all of the following may be occurring:

$w_1\Delta t$	pounds of surge liquid enter and mix with the liquid phase
$w_2\Delta t$	pounds of spray are injected into the steam space absorbing
$q_2\Delta t$	Btu's of energy from the steam
$w_3\Delta t$	pounds of steam leave through the safety valve
$w_4\Delta t$	pounds of liquid evaporate
$w_5\Delta t$	pounds of steam condense
$q_6\Delta t$	Btu's of energy transfer at the steam-liquid interface
$q_7\Delta t$	Btu's of energy transfer to the wall from the steam
$q_8\Delta t$	Btu's of energy transfer to the wall from the liquid
$q_9\Delta t$	Btu's of energy transfer from the heaters to the liquid

Figure 2. Pressurizer Model

2.1.6.2. Derivation of the Conservation Laws

The conservation of energy for the system is expressed as the first law of thermodynamics,

$$\Delta Q = \Delta U + P\Delta V, \quad (15)$$

where U is the system internal energy, ΔQ is the heat transferred and ΔV is the change in system volume. In writing the first law in the above form, constant mass is assumed, potential and kinetic energies are neglected, and the assumption is made that there is only PV work

Figure 3 shows a general system with a moving boundary for which the first law will be written. Although only one entering and one leaving mass transfer mode is shown, the equation will be written for several modes.

The work done by the system in changing boundaries is $P\dot{A}\Delta t$. The work done by the system in pushing mass out of boundary is $\sum w_l \Delta t v_l P$. The work done on the system by mass pushing in is $\sum w_e \Delta t v_e P$. The mass that enters is $\sum w_e \Delta t$, and the mass that leaves is $\sum w_l \Delta t$. Therefore,

$$Q = \sum w_l (u_l + P v_l) \Delta t - \sum w_e (u_e + P v_e) \Delta t + U^{t+\Delta t} - U^t + P\dot{A}\Delta t \quad (16)$$

or

$$U^{t+\Delta t} = U^t + Q + w_e h_e \Delta t - \sum w_l h_l \Delta t - P\dot{A}\Delta t. \quad (17)$$

Similarly, the mass balance is

$$M^{t+\Delta t} = M^t + \sum w_e \Delta t - \sum w_l \Delta t. \quad (18)$$

Rather than writing the foregoing general equations for both the steam phase and the liquid phase, the sum of the two phases will be considered, and the liquid phase will be considered separately. The numerical values for the steam phase are obtained by subtracting the latter from the first.

Figure 3. General System With Moving Boundary

Mass Originally in Boundary
Which Crosses Boundary
Out of System

The mass and energy conservation equations for the entire pressurizer are then

$$U_T^{t+\Delta t} = U_T^t + q_9 \Delta t - q_8 \Delta t - q_7 \Delta t + w_1 h_1 \Delta t + w_2 h_2 \Delta t - w_3 h_3 \Delta t, \quad (19)$$

$$M_T^{t+\Delta t} = M_T^t + w_1 \Delta t + w_2 \Delta t - w_3 \Delta t; \quad (20)$$

for the liquid phase, the corresponding equations are

$$U_L^{t+\Delta t} = U_L^t + q_9 \Delta t - q_8 \Delta t + q_6 \Delta t + q_2 \Delta t + w_1 h_1 \Delta t + w_2 h_2 \Delta t + w_5 h_5 \Delta t - w_4 h_4 \Delta t - PV_L \Delta t, \quad (21)$$

$$M_L^{t+\Delta t} = M_L^t + w_1 \Delta t + w_2 \Delta t + w_5 \Delta t - w_4 \Delta t. \quad (22)$$

2. 1. 6. 3. Description of the Energy and Mass Transfer Processes

The individual terms in equations 19 through 22 are evaluated below. The subscripts L and S refer to liquid and steam.

Surge Enthalpy and Surge Line Pressure Drop

The surge enthalpy corresponds to the current value of the hot leg temperature. The surge line pressure drop is calculated using the equation

$$\Delta P_1 = K_1 W_1^{1.8} + K_x W_1^2 \quad (23)$$

where K_1 and K_x are input parameters.

Relief Valves and Line Pressure Drop

The relief valve flow rate is obtained from an input table of flow rate versus pressure using linear interpolation

between points. The steam enthalpy is that at the average steam conditions, e.g., $h_3 = h_S$. The pressure drop in the line between the pressurizer to the valve is $\Delta P_3 = K_3 w_3^2$ where K_3 is an input parameter.

Spray Calculations

The spray rate is constant and the spray temperature is the current temperature of the cold leg. The heat transfer from the steam to the spray droplets is

$$q_2 = (UA)_2(T_S - T_2). \quad (24)$$

If the value input for UA is unrealistically large, then more energy could be removed than is physically possible. To prevent this from occurring, an energy balance is made to determine how much saturated steam could be condensed assuming that the spray droplet and condensate both reach saturated liquid conditions. The corresponding heat transfer coefficient is considered as a maximum value for UA. The expression for $UA_{\max}$ is

$$UA_{\max} = \frac{w_2(h_f - h_2)(h_S - h_L)}{(T_{\text{sat}} - T_2)(h_S - h_f)}. \quad (25)$$

Heater Bank Calculations

The total heater bank energy input to the liquid is the sum of the groups of heaters:

$$q_g = \sum F(i)q(i) \quad (26)$$

where $q(i)$ is the rated group output and $F(i)$ is the output factor. For the heaters on,

$$F(i) = 1 - \exp \left\{ -\lambda[t - t_o(i)] \right\}; \quad (27)$$

for the heaters off,

$$F(i) = \exp \left\{ -\lambda[t - t_f(i)] \right\} \quad (28)$$

where $t_o(i)$ and $t_f(i)$ are the equivalent on and off times.

Surface Heat Transfer

The heat transfer rate from the steam to the liquid at the steam-liquid interface is

$$q_6 = U_6 A (T_S - T_L). \quad (29)$$

Unless the steam is superheated and/or the liquid is subcooled, no heat transfer will occur.

Wall Heat Transfer

The heat transfer rate from the steam to the wall is given by

$$q_7 = (UA)_7 \frac{S}{S_o} (T_S - T_7) \quad (30)$$

where

$$M_7 C_{p7} \frac{dT_7}{dt} = q_7. \quad (31)$$

The ratio S/S_o reflects the mass and the surface area of the wall that is in contact with the steam as compared to the initial condition. The heat transfer coefficient, U , may be constant or may be dependent on the direction of the heat flow.

In general, the water temperature drops due to in-surge of subcooled water; therefore, the pressurizer wall usually acts as an energy source for the liquid. The quantity, q_8 , however, is calculated as positive for heat flow into the wall with a negative sign in equations 19 and 21 to take care of the direction. Thus,

$$q_8 = (UA)_8 \frac{L}{L_0} (T_L - T_8) \quad (32)$$

and

$$M_8 C_{p8} \frac{dT_8}{dt} = q_8 \quad (33)$$

where the heat transfer area is proportional to the liquid level in the pressurizer.

Evaporation and Condensation

If the steam (liquid) enthalpy falls below (exceeds) the saturated value, then condensation (evaporation) will occur. The evaporation and condensation rates are as follows:

$$w_4 = \frac{M_L (h_L - h_f)}{4(h_S - h_L)\Delta t} \quad (34)$$

$$w_5 = \frac{M_S (h_g - h_s)}{4(h_S - h_L)\Delta t} \quad (35)$$

The corresponding enthalpies are $h_4 = h_s$ and $h_5 = h_L$. The factor of four is used in the denominators to reduce the possibility of starting an oscillation.

2.2. Options

This program offers the user many options:

1. The program will calculate the initial precursor concentrations and the initial temperatures in the fuel pin unless this information is supplied by the user.

2. Several cases can be run back-to-back as a single job. A complete data deck is required for each case (except card 01000).

3. The decay heat will be taken into account, if desired, starting at 100% full power on the down side of the transient only. The decay heat calculation is based on infinite operation at full power.

4. The heat demand in the steam generator can be varied with time with up to 15 number pairs. This may be used with or without reactivity input changes. Also, this table may be replaced with a new table at the time of a trip to simulate the heat demand for a secondary coastdown.

5. The program can be run with and without trip. If run with trip, the trip point can be selected for any of the normal trip parameters.

6. The reactivity can be input in two separate sequences to represent a driving function and a scram function. Each series can be input in several time zones, where each input reactivity time zone may have a new print time and maximum time step size, and each time zone may have new linear and quadratic coefficients.

7. A maximum time step is specified to ensure stability of the heat transfer equations in the fuel pin.

8. The fuel pin region may be in any geometry—plane, sphere, or cylinder. The fuel pin may be considered in two parts—fuel and clad. Each part may be divided into several regions, and each region can have a different value for the heat capacity (ρC_p) and the conductivity.

3. INPUT CARD DESCRIPTION

3.1. Preparation of Data Card Input

Input to the program is read by the "SCANNER" routine. SCANNER starts reading at Column 9 of the card and will read through Column 80. Columns 1-8 may be used for comments. Fields are not required, since a comma separating the variables signals the end of a particular variable. The general format of a card is as follows:

The read routine will expect to find the number of variables specified below on the card. If an input variable has a zero value, it must be put on the card. Card numbers have also been assigned. The only editing of input data performed by the program is a check of the input card sequence and a check for the proper number of variables. If an error is found in either of these, an error message is printed and the program terminates the case and the job.

Input is in engineering units; however, the program performs its calculations using the cgs system with the exception of subroutine LOOP, which uses engineering units. Proper conversions are made after input and before printing.

Any number of cases may be run as one job. If a particular case is terminated because of an error, the program will go to the next case.

The following control cards are required:

KAPP4, CM55000.

YOURNAME

Charge Card

ATTACH(KAPP4, XKAPP, CY = 59)
LOADER(PPLOADR)

KAPP4.

7-8-9

Data

6-7-8-9

1. Case Identification (Columns 2-72)

2. 01000, NOCAS

*NOCAS: Number of cases to be run ($\text{NOCAS} \geq 1$); input this card for first case only. It is suggested that cases not be stacked.

3. 01001, M, NTEQ, NCYC, ISCRAM, NODKHT, IG, I1, I2

*M: Number of precursor groups ($1 \leq M \leq 6$).

*NTEQ: 0 — Program computes initial temperature distribution.

1 — Initial temperatures are input on the 01012 card.

*NCYC: Number of input reactivity zones. $[1 \leq \text{NCYC} \leq 15 \text{ \& } (\text{NCYC} + \text{NSCRM}) \leq 30]$

*ISCRAM: 0 — No scram input, i. e., case not to trip on power or pressure.

5 — Scram data to be input.

*NODKHT 0 — Decay heat not to be added on this case.

5 — Decay heat to be added on this case.

*IG: Fuel geometry — 0 Sphere
1 Cylinder
2 Plate

- - - - -
*Indicates an integer; all other variables are floating point (containing a decimal point).

- *I1: Number of intervals in fuel region ($I1 \geq 1$).
- *I2: Number of intervals in cladding region ($I2 \geq 1$).
($I1 + I2 \leq 30$)
4. 01002, B(1), B(2), . . . , B(M)
- B(1) — Effective yield fraction for 1st precursor group.
- B(2) — Effective yield fraction for 2nd precursor group.
- B(3) — Etc.
5. 01003, AL(1), AL(2), . . . , AL(M)
- AL(1) — Decay constant for 1st precursor group, s^{-1} .
- AL(2) — Decay constant for 2nd precursor group, s^{-1} .
- AL(3) — Etc.
6. 01004, AN(1), R1, ALIFE, PZERO
- AN(1): Initial power density, W/cm^3 , (total power/total reactor volume).
- R1: Initial reactivity, $\Delta k/k$.
- ALIFE: Neutron generation time, s.
- PZERO: Subcritical reactivity, $\Delta k/k$.
7. 01006, RC(1, 1), FR(1), VF(1), HAI(1), RADI(1)
- RC(1, 1): Linear temperature coefficient (dk/dT) for fuel region, $^{\circ}F^{-1}$.
- FR(1): Power fraction for fuel region.
- VF(1): Volume fraction for fuel region.
- HAI(1): Heat transfer coefficient across the outside boundary of fuel region, $Btu/ft^2-h-^{\circ}F$.
- RADI(1): Radius of fuel, inches.
8. 01007, RC(2, 1), FR(2), VF(2), HAI(2), RADI(2)
- Same as the 01006 card for cladding region.

*Indicates an integer; all other variables are floating point (containing a decimal point).

9. 01008, RC(3, 1), FR(3), VF(3)
For variables shown — same as 01006 card for coolant region.
10. 01009, COND(1), COND(2), . . . , COND(I1 + I2)
COND(i): Conductivity of each interval of the fuel and cladding starting at the centerline of the fuel, Btu/h-ft- °F.

Note: Use as many cards as required with the data starting in Column 9, or after, of the second and following cards.
11. 01010, RCP(1), RCP(2), . . . , RCP(I1 + I2 + 1)
RCP(i): Heat capacity of each interval of the fuel, cladding and water, starting at the centerline of the fuel, Btu/ft³- °F.

Note: Use as many cards as required with the data starting in Column 9, or after, of second and following cards.
12. 01011, IFLOW, W, CP, PINSNO, COLGTH, PERPOW
IFLOW: 0 — No flow vs time table.
 ≠ 0 — Number of pairs to be read in for variable loop flow table ($2 \leq \text{IFLOW} \leq 30$).
W: Reference (100%) flow rate through the reactor at full power, lb/s.
CP: Specific heat of the average coolant, Btu/lb- °F (Used for both reactor and steam generator.)
PINSNO: Number of pins in the core.
COLGTH: Length of the active core, inches.
PERPOW: Multiplier on the initial power level to get 100% power ($\text{PERPOW} \times \text{Initial Power (\%)} = 100.0$).
13. 01012, TP(1, 1), TP(2, 1), . . . , TP(I1 + I2 + 1, 1)
(Optional, omit if NTEQ on Card 01001 is zero.)
TP(K, 1): Initial temperature of each interval of the fuel, clad, and water. Start at the centerline of the fuel, F.

Note: Use as many cards as required with the data starting in Column 9, or after, on the second and following cards.

14. 01013, R22(1, 1), R33(1, 1), HMAX1(1, 1), TMAX1(1, 1), PRTTII(1, 1), IYP(1)

01014, R22(2, 1), R33(2, 1), HMAX1(2, 1), TMAX1(2, 1), PRTTII(2, 1), IYP(2)

ETC.

R22(1, 1): Linear coefficient for first input time zone, $\Delta k/s$.

R33(1, 1): Quadratic coefficient for first input time zone, $\Delta k/s^2$.

HMAX1(1, 1): Suggested time step for first input time zone, s.

TMAX1(1, 1): Terminal time for first input time zone, s.

PRTTII(1, 1): Number of time steps per print interval for first input time zone (Floating point number).

IYP(1): 1 — Print temperature distribution at end of this zone.

0 — Do not print. (This option currently not available.)

The 01014, 01015, etc., cards contain the same variables for the second, third, etc., input time zones as specified by the variable NCYC on the 01001 card.

15. 01045, NTI, TINPUT(I)

NTI: 0 — Input one initial coolant inlet temperature, F, and the rest of inlet temperatures will be calculated by the program.

1 — Input one initial coolant inlet temperature, F, and program will use this inlet temperature for the entire problem.

>1 — Indicates a table of temperature vs time for inlet will be input. NTI is the number of pairs to be read in. ($2 \leq NTI \leq 20$).

TINPUT(1): Initial coolant inlet temperature, F.

Note: If $NTI \leq 1$, no more variables are required on this card.

TINPUT(2): Time corresponding to TINPUT(1) e. g. 0.0, s.
 TINPUT(3): Coolant inlet temperature at time TINPUT(≤),
 F.
 TINPUT(4). Time, s.
 ETC.

Note: If NTI > 1, input NTI pairs of temperature vs time.
 Use as many cards as required with the data starting in Column 9, or later, on the second and following cards.

16. 01050, TW(IFLOW), F(IFLOW)

(Optional, omit if IFLOW on Card 1011 is zero.)

IFLOW ≤ 30

TW(N): Input IFLOW values of time, s.

F(N): Input corresponding IFLOW values of variable loop flow expressed as a decimal fraction of W on Card 1011.

Note: Linear interpolation is used between pairs of points.
 All values of TW are input then all values of F are input.

*17. 01060, OPOWER, PRESHI, PRESLO, WILCO, THCO, RHPW, APLVAR, BPLVAR, NSCRM

OPOWER: Power level at which reactor is to scram.
 Input as a decimal; i. e., 114% is input as 1.14.

PRESHI: Pressurizer high level pressure for scram, psia.

PRESLO: Pressurizer low level pressure for scram, psia.

WILCO: Fraction of original core outlet flow at which trip occurs.

THCO: High core outlet temperature, F.

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*Note: If ISCRAM = 0 on the 01001 card, the 01060 and 01100 series cards must be omitted with the 2000 series cards being next in the data deck.

RHPW: Fraction of high neutron power to flow ratio.
Input as a decimal. (fraction of full power/
fraction of full flow).

APLVAR &

BPLVAR: Variable low pressure trip coefficients.

($P = APLVAR + BPLVAR \times TOUT$).

NSCRM: Number of trip reactivity zones ($NSCRM \leq 15$).

*18. 01062 R22(1, 2), R33(1, 2), TIMS(1), ISYP(1)

R22(1, 2): Linear coefficient for first trip time zone,
 $\Delta k/s$.

R33(1, 2): Quadratic coefficient for first trip time zone,
 $\Delta k/s^2$.

TIMS(1): Elapsed time for this zone, s.

ISYP(1): 1 — Print temperature distribution at end of
time zone.

0 — No print. (This option currently not avail-
able.)

The 01063, 01064, etc., cards contain the same variables
for the second, third, etc., trip zones as specified by
NSCRM on the 01060 card.

*19. 01100, PRDT(6) preferenced delay times input in priority order.

All values must be finite.

PRDT(1): Overpower delay, s.

PRDT(2): High and low level pressurizer delay, s.

PRDT(3): Variable low pressure delay, s.

PRDT(4): High neutron power to flow delay, s.

PRDT(5): Low core outlet flow delay, s.

PRDT(6): High core outlet temperature delay, s.

- - - - -
*Note: If ISCRAM = 0 on the 01001 card, the 01060 and 01100
series cards must be omitted with the 2000 series cards
being next in the data deck.

20. 02000, TRANSG, TRANSRE

TRANSG: Transit time from the reactor outlet to the steam generator inlet, s.

TRANSRE: Transit time from the steam generator outlet to the reactor inlet, s.

21. 02001, REAM, SGM, HLEGM, TOPMPM

REAM: Quantity of coolant in the reactor core, lb. This is only the mass involved in actual heat transfer from the fuel pins.

SGM: Quantity of coolant in the steam generator, lb. This is just the mass involved in heat transfer to the secondary coolant.

HLEGM: Quantity of coolant in the hot leg from reactor to steam generator, lb. This is the mass in actual transit between the two masses above in the hot leg.

TOPMPM: Quantity of coolant in the cold leg from steam generator to reactor, lb.

22. 02002, VOLCO, VOLHL, VOLSG, VOLTP

VOLCO: The core volume, ft³.

VOLHL: The hot leg volume, ft³.

VOLSG: The steam generator volume on the primary side, ft³.

VOLTP: The cold leg volume, ft³.

23. 02003, PINIT, PMASI, VT

PINIT: Steady state pressurizer pressure, psia.

PMASI: Water quantity in pressurizer at the steady state condition, lb.

VT: Total volume of the pressurizer, ft³.

24. 02004, HASH, MCP SH, NOHEAT, ITRPHT

HASH: Heat transfer coefficient for the steam generator tubes, Btu/s-°F.

MCP SH: The mass of the steam generator tubes times the specific heat of the tubes, lb-Btu/°F.

NOHEAT: Number of time-vs-heat demand pairs being input for the steam generator ($2 \leq \text{NOHEAT} \leq 15$).

ITRPHT: Number of time-vs-heat demand pairs being input for the steam generator which are implemented at the time of trip. If used, this table replaces the table specified by NOHEAT at the time of trip. If the initial heat demand table doesn't require alteration, input a zero here. If not specified as zero, $2 \leq \text{ITRPHT} \leq 15$.

25. 02005, HEATTI(N), N = 1, NOHEAT, HEATDE(N), N = 2, NOHEAT

HEATTI(N): This is the time corresponding to HEATDE(N). The first time is 0.0 and the last time should be a time greater than the duration of the case, s.

HEATDE(N): This is the steam generator heat demand at the time specified by HEATTI. The first heat demand is computed by the program and is for the steady state condition. Input heat demands must be expressed as a fraction of the steady state demand.

26. 02006, TRPTI(1), . . . , TRPTI(ITRPHT), TRPHT(1), . . . , TRPHT(ITRPHT) (OPTIONAL, Omit if ITRPHT on Card 2004 is zero)

TRPTI(N): This is the elapsed time from the time of trip plus the delay time (input on the 1100) card at which TRPHT(N) will be used, s.

TRPHT(N): This is the steam generator heat demand at the time specified by TRPTI(N), (input as decimal fraction of steady state demand). See example below.

27. 02007, HETERON(1), . . . HETERON(4), HETEROF(1), . . . HETEROF(4), ALAMBDA, QHO(1), . . . QHO(4), TLENGTH, PCON1

HETERON(N): Pressure at which heater comes on — four heaters so four pressures, psia.

HETEROF(N): Pressure at which heater goes off — four pressures which correspond to the HETERON (N) pressures, psia.

ALAMBDA: Thermal time constant of the heaters, s^{-1} .

QHO(N): The rated group input for heaters — four required Btu/s.

TLENGTH: Total equivalent length of pressurizer, ft.

PCON: Surge line pressure drop coefficient. $\text{psi}/(\text{lbm/s})^{1.8}$.

PCON1: Surge line pressure drop coefficient, $\text{psi}/(\text{lbm/s})^2$.

28. 02008, REACAVH, REACAVT, SPRAYON, SPRAYOF, SPRAFLO

REACAVH: Reactor average enthalpy, Btu/lbm.

REACAVT: Reactor average temperature, F.

SPRAYON: Pressure which turns spray line on, psia.

SPRAYOF: Pressure which turns spray line off, psia.

SPRAFLO: Spray line flow rate, lbm/s.

(If flow rate changes, change spray surface area on Card 2011.)

Note: The average temperature and enthalpy input here are only used in the calculation of the hot and cold leg enthalpies.

29. 02009, Safety valve flow vs pressure tables.

NOPAIRS(1), SAFPRES(1, 1), SAFETYV(1, 1), . . . ,
SAFPRES(NOPAIRS, 1), SAFETYV(1, NOPAIRS)

NOPAIRS(2), SAFPRES(1, 2), SAFETYV(2, 1), . . . ,
SAFPRES(NOPAIRS, 2), SAFETYV(2, NOPAIRS)

NOPAIRS(1): Number of pairs to be read in for first valve. $2 \leq \text{NOPAIRS}(1) \leq 10$

SAFPRES(N, 1): Pressure which goes with flow, psia,
(Lowest valves first)

SAFETYV(N, 1): Flow rate — goes with above pressure,
lbm/s.

ETC.

NOPAIRS(2): Number of pairs to be read in for second
valve. $2 \leq \text{NOPAIRS}(2) \leq 10$.

SAFPRES(N, 2): Pressure which goes with flow, psia.

SAFETYV(N, 2): Flow rate — goes with above pressure,
lbm/s.

ETC.

Note: Linear interpolation is used between pairs of points.

30. 02010, PON(1), POFF(1), PON(2), POFF(2)

PON(1): Pressure at which first safety valve opens,
psia.

POFF(1): Pressure at which first safety valve closes,
psia.

PON(2): Pressure at which second safety valve
opens, psia.

POFF(2): Pressure at which second safety valve
closes, psia.

Note: This table must not exceed limits set by 2009 card.

31. 02011, HNOW, HEATTRN

HNOW: Heat transfer coefficient liquid to steam,
Btu/ft²- °F-s.

HEATTRN: Heat transfer coefficient times area from
spray to steam, Btu/°F-s.

Note: Spray surface area varies with spray rate on Card 2008.

4. OUTPUT DESCRIPTION

There are four principal parts to the output: a complete listing of the input as it appears in the input deck (card image), a detailed listing of the input as the program interprets it, several parameters as a function of time (the main printout), and a heat balance summary. The first two items are short and self-explanatory; the other two are discussed below. There are no output options.

The time-dependent output is printed in four parts for each time zone. The first page for each new time zone gives a summary of the current reactivity, time, reactivity to be input, print time, and scram parameters. The kinetics output lists the solution of the kinetics equations, including time, number of successful time steps in the time zone, neutron and thermal powers, reactivity components, and fuel pin coolant temperatures. The primary loop output lists the primary system parameters, including time, pressure, surge line flow, and temperatures around the loop. The pressurizer output lists time, condensing and boiling mass transfer, spray heat removal, temperature profile and system pressure. This format is repeated for each input and trip reactivity time zone until the end of the problem. The problem is terminated by the end of the trip reactivity input, or the end of the input reactivity in cases where there is no trip.

The last page of printout is a summary of the heat generated in the core which has reached the coolant (both directly and by heat transfer from the clad), the heat removed by the steam generator, and the difference between the two. Any difference must be accounted for (ideally) by a rise or fall in the average system temperature. This difference is then compared with the heat required to change the average system temperature as calculated by the program. An error is calculated in terms of percent heat lost or gained and in degrees. Dumps, of course, are optional.

APPENDIX A
Sample Input and Printout

01000, 1
 01001, 6, 0, 1, 5, 0, 1, 6, 1
 BETAS 01002, 2.10-4, 1.415-3, 1.307-3, 2.724-3, 9.23-4, 3.27-4
 LAMBDA 01003, 1.25-2, 3.080-2, 1.140-1, 3.076-1, 1.190, 3.190
 01004, 101.63, 0.0, 27.1-6, 0.0
 FUEL 01006, -1.260-5, 0.973, 0.295189, 1300.0, 0.162
 CLAD 01007, 0.0, 0.0, 0.100467, 4900.0, 0.1895
 COOL. 01008, +0.5-4, 0.027, 0.564515
 COND. 01009, 1.80, 1.85, 1.92, 2.03, 2.20, 2.43, 9.60
 HCAP 01010, 45.501, 45.306, 45.046, 44.656, 43.941, 42.901, 30.908, 61.271
 01011, 0, 4.1808+4, 1.444, 54120.0, 143.0, 1.000
 INRHO 01013, 0.00074, 6.0, 0.025, 10.0, 0.05, 1
 TIN 01045, 0, 572.3
 TRIP 01060, 1.120, 2450.0, 1995.0, 0.0, 646.0, 1.20, -4736.0, 10.94, 16
 ROD 01061, 0.0, 0.0, 0.5, 1
 4 01062, -.001006400000, 0.0, .10000,1
 4 01063, -.001539200000, 0.0, .10000,1
 4 01064, -.002074400000, 0.0, .10000,1
 4 01065, -.003140000000, 0.0, .10000,1
 4 01066, -.005540000000, 0.0, .10000,1
 4 01067, -.007940000000, 0.0, .20000,1
 4 01068, -.012740000000, 0.0, .10000,1
 4 01069, -.016340000000, 0.0, .10000,1
 4 01070, -.019940000000, 0.0, .20000,1
 4 01071, -.024260000000, 0.0, .50000,1
 4 01072, -.015140000000, 0.0, .10000,1
 4 01073, -.009140000000, 0.0, .10000,1
 4 01074, -.005540000000, 0.0, .10000,1
 4 01075, -.002172835821, 0.0, .33500,1
 4 01076, -.000740000000, 0.0, 5.00000,1
 DELAYS 01100, 0.40, 0.60, 5.0, 0.75, 0.75, 5.0
 02000, 3.91, 3.85
 MASS 02001, 29110.9, 127060.8, 163477.1, 161038.4
 VOL. 02002, 674.5, 4051.0, 2944.0, 3567.0
 02003, 2250.0, 45000.0, 2250.0
 OTSG 02004, 1.338+5, 4.6344+4, 2, 15
 02005, 0.0, 500.0, 1.0
 HEAT 02006, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0, 2.0,
 DEMAND 2.0, 2.0, 2.0, 4.0, 6.0, 90.0,
 AFTER .8752, .7659, .6703, .5866, .5134, .4493, .3932,
 TRIP .3442, .3012, .2636, .2307, .2019, .1546, .1037,
 .0695
 HEATR 02007, 2500.0, 2500.0, 2500.0, 2500.0,
 2501.0, 2501.0, 2501.0, 2501.0,
 0.0333, 0.0, 0.0, 0.0, 0.0, 35.37, 0.0, 1.834-5
 02008, 614.68, 601.0, 2000.0, 1999.0, 0.0
 SAFVLV 02009, 2, 2000.0, 138.89, 3000.0, 138.89,
 2, 2000.0, 138.89, 3000.0, 138.89
 02010, 2515.0, 2475.0, 2515.0, 2475.0
 02011, 0.20, 20.73

* THIS IS A KAPP4 TEST CASE

CURRENT REACTIVITY DATA ****

THE CURRENT TIME (SECONDS)	=	0.0000	
THE CURRENT REACTIVITY (DELTA K) =		0.	
LINEAR COEFFICIENT (DELTA K/SEC) =	RAMP	7.4000E-04	SCRAM
QUADRATIC COEF. (DELTA K/SEC ²) =		0.	0.

TIME DATA FOR THIS TIME ZONE

SUGGESTED TIME STEP-SECONDS.....= .02500

TERMINAL TIME FOR THIS ZONE-SECONDS = 10.00000

PRINT TIME FOR THIS ZONE - SECONDS = .02500

NUMBER OF TIME ZONES.....= 1

SCRAM DATA ****

PREFERENCED DELAY

SCRAM ON REACTOR POWER OF (PC).....	1.1200E+02	.40000
SCRAM ON LOW PRESSURIZER PRESSURE....	1.9950E+03	.60000
SCRAM ON HIGH PRESSURIZER PRESSURE...	2.4500E+03	.60000
SCRAM ON LOW VARIABLE PRESSURE (P=A+B TOUT)		
A =	-4.7360E+03	
B =	1.0940E+01	5.00000
SCRAM ON HIGH RATIO N POWER TO FLOW..	1.2000E+00	.75000
SCRAM ON LOW FLOW.....	0.	.75000
SCRAM ON HIGH OUTLET TEMPERATURE.....	6.4600E+02	5.00000

INITIAL THERMAL POWER (MW)..... 3.5028E+03

INITIAL TOTAL HEAT ADDITION (MW)..... 3.6000E+03

THE TIME STEP IS .02500 SEC

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF NEUTRON	FULL POWER THERMAL	NEUTRON POWER FULL POWER-SEC	RHO (DELTA K)	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
0.0000	100.00	100.0	0.	0.	0.	0.	1200.46	660.97	600.56	4.18080E+04
.0250	100.2	100.0	2.503E-02	1.843E-05	-7.182E-08	2.984E-09	1200.46	660.97	600.56	4.18080E+04
.0500	100.5	100.0	5.012E-02	3.671E-05	-3.013E-07	1.274E-08	1200.48	660.98	600.56	4.18080E+04
.0750	100.8	100.0	7.528E-02	5.483E-05	-7.019E-07	3.063E-08	1200.51	660.98	600.56	4.18080E+04
.1000	101.0	100.0	1.005E-01	7.279E-05	-1.272E-06	5.799E-08	1200.56	660.98	600.56	4.18080E+04
.1250	101.3	100.0	1.258E-01	9.059E-05	-2.010E-06	9.647E-08	1200.62	660.99	600.56	4.18080E+04
.1500	101.6	100.0	1.512E-01	1.082E-04	-2.915E-06	1.479E-07	1200.69	660.99	600.56	4.18080E+04
.1750	101.9	100.0	1.766E-01	1.257E-04	-3.987E-06	2.139E-07	1200.77	661.00	600.57	4.18080E+04
.2000	102.2	100.1	2.021E-01	1.431E-04	-5.223E-06	2.964E-07	1200.87	661.01	600.57	4.18080E+04
.2250	102.5	100.1	2.277E-01	1.603E-04	-6.624E-06	3.969E-07	1200.98	661.03	600.57	4.18080E+04
.2500	102.7	100.1	2.533E-01	1.773E-04	-8.189E-06	5.169E-07	1201.11	661.04	600.57	4.18080E+04
.2750	103.0	100.1	2.791E-01	1.942E-04	-9.916E-06	6.578E-07	1201.24	661.06	600.57	4.18080E+04
.3000	103.3	100.1	3.049E-01	2.110E-04	-1.181E-05	8.268E-07	1201.39	661.08	600.58	4.18080E+04
.3250	103.6	100.2	3.307E-01	2.277E-04	-1.386E-05	1.007E-06	1201.56	661.10	600.58	4.18080E+04
.3500	103.9	100.2	3.567E-01	2.441E-04	-1.607E-05	1.217E-06	1201.73	661.13	600.59	4.18080E+04
.3750	104.2	100.2	3.827E-01	2.605E-04	-1.844E-05	1.453E-06	1201.92	661.15	600.59	4.18080E+04
.4000	104.5	100.3	4.088E-01	2.767E-04	-2.097E-05	1.714E-06	1202.12	661.18	600.60	4.18080E+04
.4250	104.8	100.3	4.349E-01	2.928E-04	-2.366E-05	2.002E-06	1202.33	661.21	600.60	4.18080E+04
.4500	105.1	100.4	4.612E-01	3.088E-04	-2.651E-05	2.317E-06	1202.56	661.24	600.61	4.18080E+04
.4750	105.4	100.4	4.875E-01	3.246E-04	-2.952E-05	2.659E-06	1202.80	661.28	600.61	4.18080E+04
.5000	105.7	100.5	5.139E-01	3.404E-04	-3.268E-05	3.030E-06	1203.05	661.31	600.62	4.18080E+04
.5250	106.0	100.5	5.403E-01	3.559E-04	-3.600E-05	3.429E-06	1203.31	661.35	600.63	4.18080E+04
.5500	106.3	100.6	5.669E-01	3.714E-04	-3.947E-05	3.857E-06	1203.59	661.39	600.64	4.18080E+04
.5750	106.6	100.6	5.935E-01	3.867E-04	-4.310E-05	4.315E-06	1203.88	661.44	600.65	4.18080E+04
.6000	106.9	100.7	6.202E-01	4.019E-04	-4.689E-05	4.801E-06	1204.18	661.48	600.66	4.18080E+04
.6250	107.2	100.7	6.470E-01	4.170E-04	-5.083E-05	5.318E-06	1204.49	661.53	600.67	4.18080E+04
.6500	107.6	100.8	6.738E-01	4.319E-04	-5.492E-05	5.864E-06	1204.82	661.58	600.68	4.18080E+04
.6750	107.9	100.9	7.008E-01	4.468E-04	-5.916E-05	6.440E-06	1205.15	661.63	600.69	4.18080E+04
.7000	108.2	100.9	7.278E-01	4.615E-04	-6.356E-05	7.046E-06	1205.50	661.68	600.70	4.18080E+04
.7250	108.5	101.0	7.548E-01	4.761E-04	-6.811E-05	7.682E-06	1205.86	661.73	600.71	4.18080E+04
.7500	108.8	101.1	7.820E-01	4.905E-04	-7.281E-05	8.348E-06	1206.24	661.79	600.73	4.18080E+04
.7750	109.1	101.1	8.093E-01	5.049E-04	-7.766E-05	9.044E-06	1206.62	661.85	600.74	4.18080E+04
.8000	109.5	101.2	8.366E-01	5.191E-04	-8.266E-05	9.771E-06	1207.02	661.91	600.76	4.18080E+04
.8250	109.8	101.3	8.640E-01	5.332E-04	-8.781E-05	1.053E-05	1207.43	661.97	600.77	4.18080E+04
.8500	110.1	101.4	8.915E-01	5.472E-04	-9.311E-05	1.131E-05	1207.85	662.03	600.79	4.18080E+04
.8750	110.4	101.5	9.190E-01	5.611E-04	-9.856E-05	1.213E-05	1208.28	662.10	600.80	4.18080E+04
.9000	110.7	101.5	9.467E-01	5.748E-04	-1.042E-04	1.298E-05	1208.72	662.17	600.82	4.18080E+04
.9250	111.1	101.6	9.744E-01	5.885E-04	-1.099E-04	1.385E-05	1209.18	662.24	600.84	4.18080E+04
.9500	111.4	101.7	1.002E+00	6.020E-04	-1.158E-04	1.476E-05	1209.65	662.31	600.86	4.18080E+04
.9750	111.7	101.8	1.030E+00	6.154E-04	-1.218E-04	1.570E-05	1210.12	662.38	600.87	4.18080E+04
1.0000	112.0	101.9	1.058E+00	6.287E-04	-1.280E-04	1.666E-05	1210.62	662.46	600.89	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*	STM GEN OUTLET	STM GEN INLET	STM GEN AVG	STM GEN OUTLET	REACTOR INLET	HEAT DEMAND BTU/SEC
.0000	2250.0	19.09	0	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.0250	2250.0	19.09	0	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.0500	2250.0	19.09	0	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.0750	2250.0	19.09	1	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.1000	2250.0	19.09	1	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.1250	2250.0	19.09	2	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.1500	2250.0	19.09	3	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.1750	2250.0	19.09	3	0.00	0.00	0.00	628.82	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.2000	2250.0	19.09	4	0.00	0.00	0.00	628.83	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.2250	2250.0	19.09	5	0.00	0.00	0.00	628.83	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.2500	2250.0	19.09	7	0.00	0.00	0.00	628.83	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.2750	2250.1	19.09	8	0.00	0.00	0.00	628.83	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.3000	2250.1	19.09	9	0.00	0.00	0.00	628.84	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.3250	2250.1	19.09	11	0.00	0.00	0.00	628.84	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.3500	2250.1	19.09	13	0.00	0.00	0.00	628.85	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.3750	2250.1	19.09	15	0.00	0.00	0.00	628.85	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.4000	2250.2	19.09	17	0.00	0.00	0.00	628.86	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.4250	2250.2	19.09	19	0.00	0.00	0.00	628.87	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.4500	2250.2	19.09	21	0.00	0.00	0.00	628.87	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.4750	2250.3	19.09	23	0.00	0.00	0.00	628.88	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.5000	2250.3	19.09	26	0.00	0.00	0.00	628.89	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.5250	2250.4	19.09	29	0.00	0.00	0.00	628.91	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.5500	2250.4	19.09	32	0.00	0.00	0.00	628.92	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.5750	2250.5	19.09	35	0.00	0.00	0.00	628.93	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.6000	2250.5	19.09	38	0.00	0.00	0.00	628.95	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.6250	2250.6	19.09	41	0.00	0.00	0.00	628.96	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.6500	2250.7	19.09	45	0.00	0.00	0.00	628.98	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.6750	2250.7	19.09	48	0.00	0.00	0.00	629.00	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.7000	2250.8	19.09	52	0.00	0.00	0.00	629.02	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.7250	2250.9	19.09	56	0.00	0.00	0.00	629.04	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.7500	2251.0	19.09	60	0.00	0.00	0.00	629.06	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.7750	2251.1	19.09	64	0.00	0.00	0.00	629.09	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.8000	2251.2	19.09	69	0.00	0.00	0.00	629.11	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.8250	2251.3	19.09	73	0.00	0.00	0.00	629.14	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.8500	2251.5	19.10	78	0.00	0.00	0.00	629.16	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.8750	2251.6	19.10	83	0.00	0.00	0.00	629.19	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.9000	2251.7	19.10	88	0.00	0.00	0.00	629.22	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.9250	2251.9	19.10	93	0.00	0.00	0.00	629.25	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.9500	2252.1	19.10	98	0.00	0.00	0.00	629.29	628.82	600.56	572.30	572.30	572.30	3.412275E+06
.9750	2252.2	19.10	104	0.00	0.00	0.00	629.32	628.82	600.56	572.30	572.30	572.30	3.412275E+06
1.0000	2252.4	19.10	109	0.00	0.00	0.00	629.36	628.82	600.56	572.30	572.30	572.30	3.412275E+06

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS(LB)	BOILING MASS(LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES STEAM	SAT	WATER	CONVERGENCE TEST	SYSTEM PRESSURE
.0250	0.0	0.0	0.000	0.000	0	652.683	652.683	652.683	4.440892E-16	2250.0
.0500	0.0	0.0	0.000	0.000	0	652.683	652.683	652.683	1.879205E-09	2250.0
.0750	0.0	0.0	0.000	0.000	0	652.683	652.683	652.683	1.273700E-10	2250.0
.1000	0.0	0.0	0.000	0.000	0	652.683	652.683	652.683	9.342574E-10	2250.0
.1250	0.0	0.0	0.000	0.000	0	652.683	652.683	652.683	9.258476E-10	2250.0
.1500	0.0	0.0	0.000	0.000	0	652.684	652.684	652.660	4.613637E-10	2250.0
.1750	0.0	0.0	0.000	0.000	0	652.684	652.684	652.660	1.413787E-09	2250.0
.2000	0.0	0.0	0.000	0.000	0	652.684	652.684	652.660	9.816563E-10	2250.0
.2250	0.0	0.0	0.000	0.000	0	652.685	652.685	652.660	1.053589E-10	2250.0
.2500	0.0	0.0	0.000	0.000	0	652.685	652.685	652.660	7.105597E-10	2250.0
.2750	0.0	0.0	0.000	0.000	0	652.686	652.686	652.660	4.998457E-10	2250.1
.3000	0.0	0.0	0.000	0.000	0	652.687	652.687	652.660	4.833409E-10	2250.1
.3250	0.0	0.0	0.000	0.000	0	652.688	652.688	652.660	2.020804E-09	2250.1
.3500	0.0	0.0	0.000	0.000	0	652.590	652.689	652.660	1.947875E-09	2250.1
.3750	0.0	0.0	0.000	0.000	0	652.592	652.690	652.661	1.465486E-09	2250.1
.4000	0.0	0.0	0.000	0.000	0	652.594	652.692	652.661	1.063094E-09	2250.2
.4250	0.0	0.0	0.000	0.000	0	652.597	652.694	652.661	1.711040E-10	2250.2
.4500	0.0	0.0	0.000	0.000	0	652.600	652.696	652.661	5.511391E-10	2250.2
.4750	0.0	0.0	0.000	0.000	0	652.603	652.698	652.661	1.543412E-09	2250.3
.5000	0.0	0.0	0.000	0.000	0	652.607	652.700	652.661	7.102667E-10	2250.3
.5250	0.0	0.0	0.000	0.000	0	652.611	652.703	652.661	3.275462E-10	2250.4
.5500	0.0	0.0	0.000	0.000	0	652.616	652.706	652.661	4.111922E-10	2250.4
.5750	0.0	0.0	0.000	0.000	0	652.621	652.709	652.661	5.897258E-10	2250.5
.6000	0.0	0.0	0.000	0.000	0	652.627	652.713	652.661	1.340640E-09	2250.5
.6250	0.0	0.0	0.000	0.000	0	652.633	652.717	652.662	9.877974E-10	2250.6
.6500	0.0	0.0	0.000	0.000	0	652.639	652.721	652.662	6.516785E-10	2250.7
.6750	0.0	0.0	0.000	0.000	0	652.647	652.726	652.662	1.002050E-09	2250.8
.7000	0.0	0.0	0.000	0.000	0	652.654	652.731	652.662	5.092274E-10	2250.9
.7250	0.0	0.0	0.000	0.000	0	652.663	652.736	652.662	2.119284E-10	2251.0
.7500	0.0	0.0	0.000	0.000	0	652.672	652.742	652.663	1.440180E-10	2251.1
.7750	0.0	0.0	0.000	0.000	0	652.681	652.748	652.663	3.155356E-10	2251.2
.8000	0.0	0.0	0.000	0.000	0	652.692	652.755	652.663	1.469591E-11	2251.3
.8250	0.0	0.0	0.000	0.000	0	652.703	652.762	652.663	6.577281E-10	2251.4
.8500	0.0	0.0	0.000	0.000	0	652.715	652.770	652.664	3.831953E-10	2251.6
.8750	0.0	0.0	0.000	0.000	0	652.727	652.778	652.664	3.673676E-10	2251.7
.9000	0.0	0.0	0.000	0.000	0	652.740	652.787	652.665	7.610290E-10	2251.9
.9250	0.0	0.0	0.000	0.000	0	652.754	652.796	652.665	5.337155E-10	2252.1
.9500	0.0	0.0	0.000	0.000	0	652.769	652.806	652.665	7.592094E-10	2252.2
.9750	0.0	0.0	0.000	0.000	0	652.785	652.816	652.666	1.432629E-09	2252.4
1.0000	0.0	0.0	0.000	0.000	0	652.802	652.827	652.666	8.664750E-10	2252.6

* THIS IS A KAPP4 TEST CASE

THE REACTOR SCRAMED AT 1.0000 SECONDS

SCRAM OPTIONS

- 1 = REACTOR POWER LEVEL REACHED
- 2 = PRESSURIZER HIGH OR LOW LEVEL PRESSURE REACHED
- 3 = LOW VARIABLE PRESSURE (P=A+B TOUT)
- 4 = HIGH RATIO OF NEUTRON POWER TO FLOW
- 5 = LOW FLOW
- 6 = HIGH OUTLET TEMPERATURE

REACTOR SCRAMED ON OPTION 1

CURRENT REACTIVITY DATA ****

THE CURRENT TIME (SECONDS)	=	1.0000	
THE CURRENT REACTIVITY (DELTA K)	=	6.2867E-04	
LINEAR COEFFICIENT (DELTA K/SEC)	=	RAMP 7.4000E-04	SCRAM 0.
QUADRATIC COEF. (DELTA K/SEC2)	=	0.	0.

TIME DATA FOR THIS TIME ZONE

SUGGESTED TIME STEP-SECONDS.....= .02500

TERMINAL TIME FOR THIS ZONE-SECONDS = 1.40000

PRINT TIME FOR THIS ZONE - SECONDS = .02500

NUMBER OF TIME ZONES.....= 16

SCRAM DATA ****

PREFERENCED DELAY

SCRAM ON REACTOR POWER OF (PC).....	1.1200E+02	.40000
SCRAM ON LOW PRESSURIZER PRESSURE....	1.9950E+03	.60000
SCRAM ON HIGH PRESSURIZER PRESSURE...	2.4500E+03	.60000
SCRAM ON LOW VARIABLE PRESSURE (P=A+B TOUT)		
A =	-4.7360E+03	
B =	1.0940E+01	5.00000
SCRAM ON HIGH RATIO N POWER TO FLOW..	1.2000E+00	.75000
SCRAM ON LOW FLOW.....	0.	.75000
SCRAM ON HIGH OUTLET TEMPERATURE.....	6.4600E+02	5.00000

INITIAL THERMAL POWER (MW)..... 3.5020E+03

INITIAL TOTAL HEAT ADDITION (MW)..... 3.6000E+03

THE TIME STEP IS .02500 SEC

TEMPERATURE DISTRIBUTION AT 1.0000 SECONDS		
REGION	INTERVAL	TEMPERATURE-DEG.F
1	1	1577.56
1	2	1532.05
1	3	1443.42
1	4	1315.15
1	5	1152.87
1	6	964.50
2	1	662.46
3	1	600.89

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF FULL POWER NEUTRON	PERCENT OF FULL POWER THERMAL	NEUTRON POWER FULL POWER-SEC (DELTA K)	RHO	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
1.0000	112.0	101.9	1.058E+00	6.287E-04	-1.280E-04	1.666E-05	1210.62	662.46	600.89	4.18080E+04
1.0250	112.4	102.0	1.086E+00	6.418E-04	-1.343E-04	1.766E-05	1211.12	662.53	600.91	4.18080E+04
1.0500	112.7	102.1	1.114E+00	6.549E-04	-1.408E-04	1.868E-05	1211.63	662.61	600.93	4.18080E+04
1.0750	113.0	102.2	1.142E+00	6.678E-04	-1.474E-04	1.974E-05	1212.15	662.69	600.96	4.18080E+04
1.1000	113.4	102.3	1.171E+00	6.807E-04	-1.542E-04	2.082E-05	1212.69	662.77	600.98	4.18080E+04
1.1250	113.7	102.4	1.199E+00	6.934E-04	-1.610E-04	2.193E-05	1213.24	662.86	601.00	4.18080E+04
1.1500	114.0	102.5	1.228E+00	7.060E-04	-1.681E-04	2.307E-05	1213.80	662.94	601.02	4.18080E+04
1.1750	114.4	102.6	1.256E+00	7.185E-04	-1.753E-04	2.424E-05	1214.37	663.03	601.05	4.18080E+04
1.2000	114.7	102.7	1.285E+00	7.309E-04	-1.826E-04	2.544E-05	1214.95	663.12	601.07	4.18080E+04
1.2250	115.0	102.8	1.314E+00	7.431E-04	-1.900E-04	2.667E-05	1215.54	663.21	601.09	4.18080E+04
1.2500	115.4	102.9	1.342E+00	7.553E-04	-1.976E-04	2.792E-05	1216.14	663.30	601.12	4.18080E+04
1.2750	115.7	103.0	1.371E+00	7.673E-04	-2.054E-04	2.920E-05	1216.76	663.39	601.15	4.18080E+04
1.3000	116.1	103.2	1.400E+00	7.793E-04	-2.133E-04	3.051E-05	1217.38	663.49	601.17	4.18080E+04
1.3250	116.4	103.3	1.429E+00	7.911E-04	-2.213E-04	3.185E-05	1218.02	663.59	601.20	4.18080E+04
1.3500	116.7	103.4	1.458E+00	8.028E-04	-2.294E-04	3.322E-05	1218.66	663.69	601.23	4.18080E+04
1.3750	117.1	103.5	1.488E+00	8.144E-04	-2.377E-04	3.461E-05	1219.32	663.79	601.25	4.18080E+04
1.4000	117.4	103.6	1.517E+00	8.259E-04	-2.461E-04	3.603E-05	1219.99	663.89	601.28	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*	STM GEN INLET	STM GEN AVG	STM GEN OUTLET	REACTOR INLET	HEAT DEMAND BTU/SEC
1.0000	2252.4	19.10	109	0.00	0.00	0.00	629.36	628.82	600.56	572.30	572.30	3.412275E+06
1.0250	2252.6	19.10	115	0.00	0.00	0.00	629.39	628.82	600.56	572.30	572.30	3.412275E+06
1.0500	2252.8	19.10	121	0.00	0.00	0.00	629.43	628.82	600.56	572.30	572.30	3.412275E+06
1.0750	2253.0	19.10	127	0.00	0.00	0.00	629.47	628.82	600.56	572.30	572.30	3.412275E+06
1.1000	2253.2	19.10	133	0.00	0.00	0.00	629.51	628.82	600.56	572.30	572.30	3.412275E+06
1.1250	2253.4	19.11	139	0.00	0.00	0.00	629.55	628.82	600.56	572.30	572.30	3.412275E+06
1.1500	2253.7	19.11	146	0.00	0.00	0.00	629.59	628.82	600.56	572.30	572.30	3.412275E+06
1.1750	2253.9	19.11	152	0.00	0.00	0.00	629.64	628.82	600.56	572.30	572.30	3.412275E+06
1.2000	2254.2	19.11	159	0.00	0.00	0.00	629.68	628.82	600.56	572.30	572.30	3.412275E+06
1.2250	2254.4	19.11	166	0.00	0.00	0.00	629.73	628.82	600.56	572.30	572.30	3.412275E+06
1.2500	2254.7	19.11	173	0.00	0.00	0.00	629.77	628.82	600.56	572.30	572.30	3.412275E+06
1.2750	2255.0	19.11	180	0.00	0.00	0.00	629.82	628.82	600.56	572.30	572.30	3.412275E+06
1.3000	2255.3	19.12	187	0.00	0.00	0.00	629.87	628.82	600.56	572.30	572.30	3.412275E+06
1.3250	2255.6	19.12	195	0.00	0.00	0.00	629.92	628.82	600.56	572.30	572.30	3.412275E+06
1.3500	2256.0	19.12	202	0.00	0.00	0.00	629.97	628.82	600.56	572.30	572.30	3.412275E+06
1.3750	2256.3	19.12	210	0.00	0.00	0.00	630.03	628.82	600.56	572.30	572.30	3.412275E+06
1.4000	2256.7	19.12	217	0.00	0.00	0.00	630.08	628.82	600.56	572.30	572.30	3.412275E+06

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS(LB)	BOILING MASS(LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES STEAM	SAT	WATER	CONVERGENCE TEST	SYSTEM PRESSURE
1.0250	0.0	0.0	0.000	0.000	0	652.819	652.838	652.667	2.838022E-10	2252.8
1.0500	0.0	0.0	0.000	0.000	0	652.838	652.850	652.667	6.321256E-10	2253.1
1.0750	0.0	0.0	0.000	0.000	0	652.857	652.863	652.668	1.196789E-09	2253.3
1.1000	0.0	0.0	0.000	0.000	0	652.877	652.876	652.669	3.475716E-10	2253.5
1.1250	0.0	0.0	0.000	0.000	0	652.899	652.890	652.669	2.130597E-10	2253.8
1.1500	0.0	0.0	0.000	0.000	0	652.921	652.904	652.670	0.930767E-11	2254.1
1.1750	0.0	0.0	0.000	0.000	0	652.945	652.920	652.671	1.693689E-10	2254.3
1.2000	0.0	0.0	0.000	0.000	0	652.969	652.935	652.671	2.797009E-10	2254.6
1.2250	0.0	0.0	0.000	0.000	0	652.994	652.952	652.672	8.128054E-10	2254.9
1.2500	0.0	0.0	0.000	0.000	0	653.021	652.969	652.673	7.704832E-10	2255.3
1.2750	0.0	0.0	0.000	0.000	0	653.049	652.987	652.674	7.813877E-10	2255.6
1.3000	0.0	0.0	0.000	0.000	0	653.078	653.006	652.675	0.982939E-10	2256.0
1.3250	0.0	0.0	0.000	0.000	0	653.108	653.026	652.676	0.718859E-11	2256.3
1.3500	0.0	0.0	0.000	0.000	0	653.139	653.046	652.677	1.390977E-10	2256.7
1.3750	0.0	0.0	0.000	0.000	0	653.171	653.067	652.678	1.932913E-10	2257.1
1.4000	0.0	0.0	0.000	0.000	0	653.205	653.089	652.679	7.033475E-10	2257.5

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF NEUTRON	FULL POWER THERMAL	NEUTRON POWER FULL POWER-SEC (DELTA K)	RHO	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
1.5000	116.9	104.1	1.634E+00	7.724E-04	-2.789E-04	4.188E-05	1222.59	664.30	601.40	4.18080E+04
1.5250	116.6	104.2	1.663E+00	7.462E-04	-2.866E-04	4.336E-05	1223.20	664.40	601.43	4.18080E+04
1.5500	116.1	104.4	1.692E+00	7.263E-04	-2.940E-04	4.484E-05	1223.79	664.50	601.46	4.18080E+04
1.5750	115.7	104.5	1.721E+00	6.947E-04	-3.011E-04	4.631E-05	1224.35	664.60	601.49	4.18080E+04
1.6000	115.4	104.6	1.750E+00	6.694E-04	-3.078E-04	4.777E-05	1224.89	664.69	601.52	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*					REACTOR INLET	HEAT DEMAND BTU/SEC
							REACTOR OUTLET	STM GEN INLET	STM GEN AVG	STM GEN OUTLET			
1.5000	2258.2	19.13	252	0.00	0.00	0.00	630.31	628.82	600.56	572.30	572.30	3.390982E+06	
1.5250	2258.6	19.13	261	0.00	0.00	0.00	630.37	628.82	600.56	572.30	572.30	3.385659E+06	
1.5500	2259.1	19.14	270	0.00	0.00	0.00	630.43	628.82	600.56	572.30	572.30	3.380336E+06	
1.5750	2259.5	19.14	279	0.00	0.00	0.00	630.49	628.82	600.56	572.30	572.30	3.375013E+06	
1.6000	2260.0	19.14	289	0.00	0.00	0.00	630.55	628.82	600.57	572.31	572.30	3.369690E+06	

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS (LB)	BOILING MASS (LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES			CONVERGENCE TEST	SYSTEM PRESSURE
						STEAM	SAT	WATER		
1.5250	0.0	0.0	0.000	0.000	0	653.393	653.211	652.685	4.269999E-10	2259.9
1.5500	0.0	0.0	0.000	0.000	0	653.435	653.239	652.686	1.089948E-09	2260.4
1.5750	0.0	0.0	0.000	0.000	0	653.478	653.267	652.687	2.123604E-10	2261.0
1.6000	0.0	0.0	0.000	0.000	0	653.523	653.296	652.689	1.243891E-09	2261.5

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF NEUTRON	FULL POWER THERMAL	NEUTRON POWER FULL POWER-SEC	RHO (DELTA K)	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
1.8030	108.7	105.1	1.975E+00	2.695E-04	-3.447E-04	5.820E-05	1227.82	665.23	601.72	4.18080E+04
1.8250	107.0	105.1	2.002E+00	1.489E-04	-3.463E-04	5.923E-05	1227.94	665.26	601.75	4.18080E+04
1.8500	105.0	105.2	2.029E+00	2.943E-05	-3.467E-04	6.016E-05	1227.98	665.29	601.76	4.18080E+04
1.8750	103.1	105.1	2.055E+00	-8.898E-05	-3.460E-04	6.098E-05	1227.91	665.30	601.78	4.18080E+04
1.9000	101.3	105.1	2.080E+00	-2.064E-04	-3.441E-04	6.166E-05	1227.76	665.30	601.79	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*					REACTOR INLET	HEAT DEMAND BTU/SEC
							REACTOR OUTLET	STM GEN INLET	STM GEN AVG	STM GEN OUTLET			
1.8000	2264.3	19.16	357	0.00	0.00	0.00	631.01	628.82	600.59	572.33	572.30	3.327105E+06	
1.8250	2264.9	19.17	363	0.00	0.00	0.00	631.06	628.82	600.59	572.33	572.30	3.321782E+06	
1.8500	2265.5	19.17	369	0.00	0.00	0.00	631.11	628.82	600.60	572.34	572.30	3.316458E+06	
1.8750	2266.1	19.17	374	0.00	0.00	0.00	631.16	628.82	600.60	572.35	572.30	3.311135E+06	
1.9000	2266.7	19.18	378	0.00	0.00	0.00	631.20	628.82	600.61	572.35	572.30	3.305812E+06	

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS(LB)	BOILING MASS(LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES STEAM	SAT	WATER	CONVERGENCE TEST	SYSTEM PRESSURE
1.8250	0.0	0.0	0.000	3.645	0	653.991	653.601	652.704	1.669950E-10	2267.3
1.8500	0.0	0.0	0.000	4.361	0	654.049	653.639	652.706	1.725051E-10	2268.0
1.8750	0.0	0.0	0.000	5.087	0	654.108	653.677	652.708	2.555452E-09	2268.6
1.9000	0.0	0.0	0.000	5.822	0	654.168	653.716	652.710	3.802582E-10	2269.3

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF FULL POWER NEUTRON	NEUTRON POWER THERMAL	NEUTRON POWER FULL POWER-SEC (DELTA K)	RHO	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
2.3000	62.48	101.8	2.410E+00	-4.207E-03	-1.316E-04	4.822E-05	1210.90	663.03	601.53	4.18080E+04
2.3250	59.82	101.4	2.426E+00	-4.665E-03	-1.066E-04	4.546E-05	1208.92	662.74	601.47	4.18080E+04
2.3500	57.27	101.0	2.440E+00	-5.122E-03	-8.027E-05	4.245E-05	1206.83	662.43	601.41	4.18080E+04
2.3750	54.93	100.6	2.454E+00	-5.577E-03	-5.268E-05	3.918E-05	1204.64	662.10	601.34	4.18080E+04
2.4000	52.75	100.1	2.468E+00	-6.032E-03	-2.397E-05	3.567E-05	1202.36	661.75	601.27	4.18080E+04
2.4250	50.72	99.64	2.481E+00	-6.486E-03	5.733E-06	3.191E-05	1200.00	661.40	601.20	4.18080E+04
2.4500	48.82	99.15	2.493E+00	-6.940E-03	3.634E-05	2.791E-05	1197.57	661.02	601.12	4.18080E+04
2.4750	47.05	98.66	2.505E+00	-7.393E-03	6.777E-05	2.367E-05	1195.08	660.64	601.03	4.18080E+04
2.5000	45.38	98.14	2.517E+00	-7.845E-03	9.993E-05	1.921E-05	1192.53	660.24	600.95	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*	STM GEN INLET	STM GEN AVG	STM GEN OUTLET	REACTOR INLET	HEAT DEMAND BTU/SEC
2.3000	2276.0	19.23	294	0.00	0.00	0.00	631.13	628.82	600.75	572.53	572.30	3.220642E+06
2.3250	2276.5	19.23	279	0.00	0.00	0.00	631.06	628.82	600.76	572.54	572.30	3.215319E+06
2.3500	2276.9	19.23	262	0.00	0.00	0.00	630.98	628.82	600.78	572.56	572.30	3.209995E+06
2.3750	2277.3	19.23	244	0.00	0.00	0.00	630.89	628.82	600.79	572.57	572.30	3.204672E+06
2.4000	2277.7	19.23	225	0.00	0.00	0.00	630.78	628.82	600.80	572.59	572.30	3.199349E+06
2.4250	2278.0	19.24	205	0.00	0.00	0.00	630.67	628.82	600.82	572.61	572.30	3.194026E+06
2.4500	2278.3	19.24	184	0.00	0.00	0.00	630.55	628.82	600.83	572.63	572.30	3.188703E+06
2.4750	2278.6	19.24	162	0.00	0.00	0.00	630.41	628.82	600.85	572.65	572.30	3.183380E+06
2.5000	2278.8	19.24	140	0.00	0.00	0.00	630.27	628.82	600.86	572.67	572.30	3.178057E+06

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS (LB)	BOILING MASS (LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES SIEM	SAT	WATER	CONVERGENCE TEST	SYSTEM PRESSURE
2.3250	0.0	0.0	0.000	17.774	0	655.144	654.353	652.747	1.265166E-09	2277.9
2.3500	0.0	0.0	0.000	18.315	0	655.189	654.382	652.749	1.176365E-09	2278.2
2.3750	0.0	0.0	0.000	18.823	0	655.230	654.410	652.751	1.120254E-09	2278.4
2.4000	0.0	0.0	0.000	19.295	0	655.269	654.435	652.753	5.530845E-10	2278.6
2.4250	0.0	0.0	0.000	19.730	0	655.305	654.459	652.754	4.019640E-10	2278.8
2.4500	0.0	0.0	0.000	20.125	0	655.338	654.480	652.756	2.102335E-09	2278.9
2.4750	0.0	0.0	0.000	20.479	0	655.367	654.499	652.757	1.279626E-09	2279.1
2.5000	0.0	0.0	0.000	20.790	0	655.392	654.516	652.758	2.120520E-09	2279.2

* THIS IS A KAPP4 TEST CASE

SOLUTION OF KINETICS EQUATIONS BELOW

TIME (SEC)	PERCENT OF NEUTRON	FULL POWER THERMAL	NEUTRON POWER FULL POWER-SEC (DELTA K)	RHO	RHO 1	RHO 3	TEMP 1 (FUEL)	TEMP 2 (CLAD)	TEMP 3 (WATER)	FLOW LB/SEC
3.0000	23.22	86.77	2.678E+00	-1.899E-02	8.420E-04	-1.059E-04	1133.63	650.86	598.44	4.18080E+04
3.0250	22.80	86.19	2.684E+00	-1.932E-02	8.810E-04	-1.132E-04	1130.54	650.37	598.30	4.18080E+04
3.0500	22.40	85.62	2.689E+00	-1.964E-02	9.199E-04	-1.267E-04	1127.45	649.87	598.15	4.18080E+04
3.0750	22.01	85.05	2.695E+00	-1.997E-02	9.587E-04	-1.281E-04	1124.37	649.38	598.00	4.18080E+04
3.1000	21.63	84.49	2.700E+00	-2.030E-02	9.973E-04	-1.356E-04	1121.30	648.89	597.85	4.18080E+04

*** PRIMARY LOOP OUTPUT ** CASE 1 OF 1 ***

TIME (SEC)	PRESSURIZER PSIA	LIQUID LEVEL FT	FLOW LB/SEC	SPRAY FLOW LB/SEC	HEATER BTU/SEC	RELIEF VALVE FLOW LB/SEC	* LOOP TEMPERATURES-DEG.F*					REACTOR INLET	HEAT DEMAND BTU/SEC
							REACTOR OUTLET	STM GEN INLET	STM GEN AVG	STM GEN OUTLET			
3.0000	2273.2	19.21	-446	0.00	0.00	0.00	625.59	628.82	601.23	573.19	572.30	3.071594E+06	
3.0250	2272.4	19.21	-479	0.00	0.00	0.00	625.29	628.82	601.25	573.22	572.30	3.066270E+06	
3.0500	2271.4	19.20	-511	0.00	0.00	0.00	624.99	628.82	601.27	573.25	572.30	3.060947E+06	
3.0750	2270.5	19.20	-544	0.00	0.00	0.00	624.69	628.82	601.29	573.29	572.30	3.055624E+06	
3.1000	2269.4	19.19	-577	0.00	0.00	0.00	624.38	628.82	601.32	573.32	572.30	3.050301E+06	

*** PRESSURIZER OUTPUT ***

TIME (SEC)	CONDENSING MASS (LB)	BOILING MASS (LB)	SPRAY Q (BTU/SEC)	INTERFACE (BTU/SEC)	ITERATION NUMBER	TEMPERATURES			CONVERGENCE TEST	SYSTEM PRESSURE
						STEAM	SAT	WATER		
3.0250	0.0	0.0	0.000	14.824	0	654.859	654.174	652.694	2.260475E-10	2268.2
3.0500	0.0	0.0	0.000	13.862	0	654.774	654.119	652.684	6.399572E-10	2266.7
3.0750	0.0	0.0	0.000	12.836	0	654.683	654.060	652.674	3.848821E-11	2265.0
3.1000	0.0	0.0	0.000	11.744	0	654.566	653.997	652.663	3.505319E-10	2263.3

* THIS IS A KAPP4 TEST CASE

GEOMETRY SPECIFICATIONS AND TEMPERATURE DISTRIBUTION LISTED BELOW

I	ZONE	RADIUS(FT)	AVG RADIUS(FT)	AREA(FT ²)	VOLUME(FT ³)	TEMPERATURE (DEG.F)	CONDUCTIVITY BTU/HR-FT-DEGF	HEAT CAP. BTU/CU.FT-DEGF
1	1	2.25000E-03	1.12500E-03	1.41372E-02	1.59043E-05	8.87298E+02	1.80000E+00	4.55010E+01
2	1	4.53000E-03	3.37500E-03	2.82743E-02	4.77129E-05	8.69401E+02	1.85000E+00	4.53060E+01
3	1	6.75000E-03	5.62500E-03	4.24115E-02	7.95215E-05	8.35782E+02	1.92000E+00	4.50460E+01
4	1	9.03000E-03	7.87500E-03	5.65487E-02	1.11330E-04	7.89862E+02	2.03000E+00	4.46560E+01
5	1	1.12500E-02	1.01250E-02	7.06858E-02	1.43139E-04	7.36244E+02	2.20000E+00	4.39410E+01
6	1	1.35000E-02	1.23750E-02	8.48230E-02	1.74947E-04	6.80069E+02	2.43000E+00	4.29010E+01
7	2	1.57917E-02	1.46458E-02	9.92219E-02	2.10885E-04	6.00414E+02	9.60000E+00	3.09080E+01
8	3	0.	0.	0.	1.09495E-03	5.83963E+02	0.	6.12710E+01

THE CALCULATED TIME STEP FOR THE CASE IS .03044

APPENDIX B
Nomenclature

a	Input reactivity step
A	Weighting factors
b	Reactivity ramp rate, s^{-1}
B	Weighting factors
C	Reactivity quadratic coef, s^{-2}
C_i	Precursor concentrations of ith delayed neutron group. $C_{i,j}$ is the concentration at the jth time step
C_p	Specific heat, Btu/lbm-F
d	Scram reactivity ramp rate, s^{-1}
e	Scram reactivity quadratic coef, s^{-2}
FR_k	Energy deposition fraction in region k—fuel, clad, or coolant
f	Fraction of energy generated or transferred in an axial node
h	Enthalpy, Btu/lbm
h_f	Enthalpy of saturated water, Btu/lb
h_{fg}	Enthalpy difference between saturated steam and saturated water, Btu/lb
i	Interval index for fuel pin model
j	Time step index
L	Liquid level, ft
M	Mass, lb
$(MC_p)_c$	Mass times the specific heat of the coolant in the steam generator, Btu/F
$(MC_p)_t$	Mass times the specific heat of the steam generator tubes (in actual heat transfer), Btu/F
N	Neutron power, neutrons/cm ³
P	Pressure, psia
q	Heat flow rate Btu/s
Q	Heat transferred Btu/s

Q_D	Heat demand being imposed by the secondary system at the steam generators, Btu/s
Q_i	Heat deposition in the i th interval of the fuel pin, Btu/s
Q_T	Thermal power; the power being transferred to the coolant from the clad, Btu/s
S	Steam level, ft
t	Time, s
T_c	Temperature of the cold leg (see M_c), F
$\bar{T}_F$	Average fuel temperature, F
$\bar{T}_{FO}$	Initial average fuel temperature, F
T_i	Temperature of i th interval in fuel pin, F
T_I'	Steam generator outlet temperature, F
T_{in}	Node inlet temperature, F
T_m	Average core moderator (coolant) temperature, F
T_{mo}	Initial average core moderator temperature, F
T_O	Core outlet temperature, F
T_{out}	Node outlet temperature, F
T_O'	Steam generator inlet temperature, F
T_t	Average temperature of steam generator tubes, F
U	Internal energy, Btu
u	Specific internal energy, Btu/lbm
UA	Heat transfer coefficient times the area, Btu/s-F
v	Specific volume, ft ³ /lb
v_f	Specific volume of saturated water, ft ³ /lb
v_g	Specific volume of saturated steam, ft ³ /lb
V	Volume, ft ³
V_i	Volume of i th interval in fuel pin, in. ³
V_s	Steam volume in pressurizer, ft ³

V_T	Total volume of pressurizer, ft^3
VF_k	Volume fraction of the kth region
$(WC_p)_c$	Flow times the specific heat for the primary coolant in the steam generator, Btu/s-F
$(WC_p)_i$	Flow times specific heat for the core coolant, Btu/s-F
W	Flow rate, lb/s
α_D	Doppler coefficient of reactivity, $(\Delta k/k)/F$
α_m	Moderator coefficient of reactivity, $(\Delta k/k)/F$
β	Delayed neutron fraction
λ_i	Delayed neutron decay constant, s^{-1}
λ^t	Transient time through a node, s
Λ	Neutron generation time, s
ρ	Net reactivity
ρ	Density, lbm/ft^3
$(\rho C_p)_i$	Density times specific heat for the ith interval in the fuel pin, $\text{Btu/ft}^3\text{-F}$
τ	Time, s