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RELAP3 -- A COMPUTER PROGRAM FOR REACTOR BLOWDOWN ANALYSIS

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RELAP3 -- A COMPUTER PROGRAM FOR REACTOR BLOWDOWN ANALYSIS

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ABSTRACT

RELAP3 is a computer program, written in FORTRAN IV, that describes the behavior of water-cooled nuclear reactors during postulated accidents such as loss-of-coolant, pump failure, or power transients. The behavior of the primary cooling system and the reactor is emphasized. The program calculates flows, mass inventories, energy inventories, pressures, temperatures, and qualities along with variables associated with reactor power, reactor heat transfer, or control systems. The program is sufficiently versatile to describe simple hydraulic systems as well as complex reactor systems.

The user must define the geometric description of the system to be analyzed as well as an appropriate set of initial conditions. RELAP3 then solves an integral form of the fluid conservation and state equations applied to each user-defined control volume. Currently, the number of these control volumes is limited to 20 and the number of junctions (flow paths) between volumes to 50. By simply increasing the array sizes these limits could be raised until the capacity of the particular computer is reached.

RELAP3 source decks are available in single (BCD) and double precision (EBCDIC) versions. Use of special timing and input-output routines (available for the IBM 7044 and the IBM 360 systems) is desirable, but not necessary. Sample problems have been run on a wide variety of computers: IBM 7044, Univac 1108, CDC 6600, and IBM 360/75. The most recent changes have only been tested on the IBM 360/75 computer.

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RELAP3 -- A COMPUTER PROGRAM FOR REACTOR BLOWDOWN ANALYSIS

I. INTRODUCTION

In support of the Loss-of-Fluid Test (LOFT) safety analysis effort, the RELAP series of computer programs[1] has been developed to describe hydrodynamic conditions inside a reactor primary system. The new version, RELAP3, can be used for many pressurized-water-reactor safety studies such as large reactivity excursions, coolant losses, or pump failures. RELAP3 retains most of the calculational methods used in previous versions but provides greater freedom in describing the system geometry. Unlike predecessors RELAP3 is built of dozens of specialized subroutines, each of which performs a limited portion of the calculation. Thus, extending or improving the models has been made easier.

RELAP3 represents the reactor system as a set of arbitrarily connected fluid volumes that describe the plenums, piping, reactor core, and heat exchangers. Any volume may be chosen independently as a core region or heat exchanger. Fluid compressibility in all volumes (including core regions) is considered in predicting the course of the transient. Each connection between volumes may be specified as a normal junction, a leak junction, or a fill water source. A normal junction may also include a pump and a valve. The transient is calculated time-step by time-step; the volume masses, energies, and bubble contents are advanced, and new junction conditions are obtained, and flows recomputed. Reactor conditions may be used to provide reactivity feedback.

Predecessors of RELAP3 were specifically designed to describe a reactor primary system of three volumes (a lower plenum, an upper plenum, and a pressurizer), a core, and an external loop. Full flow was required as an initial condition. These requirements prohibited analysis of simplified experiments such as single vessel blowdowns. At the other extreme, the three volume description could not provide enough detail to adequately describe a complete reactor primary system. RELAP3 does not contain these restrictions, thus analysis of both simplified and complex systems is allowed.

The RELAP3 program is being released, not as a final product, but as a current method for investigating the transients expected in pressurized water reactor accidents. Modifications currently planned to improve and extend the area of usefulness of the calculations will be included in the next version of the RELAP computer program. Future program modifications will be issued as compatible modules to the current code, and documentation of these modifications will be as addenda to this report.

The body of this computer program description is divided into two parts. The first contains descriptions of features included in RELAP3, with emphasis on those features which are different from those contained in previous versions. The second part contains the most important of the equations RELAP3 uses to describe a reactor primary system.

Several appendices are included to aid in the use or modification of RELAP3. The first three are to be used in determining junction constants, time step sizes, and other input quantities. Following these are three appendices (program structure charts, subroutine descriptions, and flow charts) of interest to a programmer who wishes to understand or modify the program. The final appendix contains two sample problems with solutions: a single vessel blowdown and a reactor primary system blowdown.

II. RELAP3 FEATURES

RELAP3 may be viewed either as an extension of the previous version (RELAP2) or as a completely new computer program. The physical models vary little from those used in the previous version, but the logic used to attack the problem has required almost all of the older programming to be scrapped. RELAP3 was designed so that changes could be made in the physical models without a major programming task, whereas previous versions were too interlocked in structure for such changes to be made easily.

To gain generality in RELAP3, no constraints were included on the nature of a specific volume or junction. For instance, any volume may be selected to represent any core region or heat exchanger. Likewise, any junction may represent a leak out of the system with no restrictions as to which or how many junctions must be so used. Thus, multiple breaks may be treated directly by specifying several leak junctions in the input.

1. GEOMETRIC DETAIL

In RELAP3 the terms volumes and junctions have the following meanings: volumes specify a region of fluid within a given set of fixed boundaries; and junctions are the common flow areas of connected volumes. Calculated results are limited in geometric detail by the size of each volume.

RELAP3 is general in the geometrical description allowed. RELAP2 required that exactly three volumes be used, with a fixed set of pipes connecting these volumes. RELAP3 allows a maximum of 20 volumes connected by a maximum of 50 junctions, with no restrictions as to the order of these connections. The number of volumes and junctions, 20 and 50, is arbitrary and can be increased to far greater limits on any large computer such as the IBM 360/75. Changes required consist almost entirely of increasing the array sizes given in the COMMON statements. These changes can be performed automatically by an auxiliary FORTRAN IV routine which is available separately. The smaller limits were chosen to ensure that RELAP3 would fit into an IBM 7044 size computer with only a simple overlay structure being required.

2. GRAVITY HEAD

In RELAP3 junctions connect volumes directly and thus contain no elevation changes. To account for gravity terms, the pressure calculated within a volume from thermodynamic relationships is assumed to occur at the center of gravity. Positive or negative gravity heads may then be found by integration of the fluid density from the center of gravity to the level of the junction connected to the volume.

3. CONTROL OPTIONS

Control parameters have been generalized in RELAP3. For instance, reactor scram may be initiated by the first condition detected among high power level, short period, fuel temperature, high pressure in any volume, low pressure in any volume, and so on. Opening the leaks (staggered leak openings might be accomplished through the individual opening-time curves), tripping the pumps, starting the fill systems, controlling up to five valves separately, or ending the problem also may be put under the control of many different conditions.

4. STEAM SEPARATION

One of several sets of coefficients (input) for the steam separation calculation may be chosen for each volume. Part of the required volume data is a bubble set index which determines, for each volume, the set of coefficients to be used. The zeroth set (a uniform liquid-steam mixture) is built-in; others must be supplied as input.

5. PUMP CHARACTERISTICS

Although only one pump coastdown curve is allowed, several different pump characteristic curves may be supplied. Each of these curves may be used as many times as desired so that no limit exists on the number of pumps in the system. Allowing only one coastdown curve may sometimes be a limitation because staggered loss-of-flow accidents cannot be handled in any convenient way. Should solutions for staggered loss-of-flow accidents be required, modifications to correct this problem are not expected to be difficult to make.

6. FRICTION COEFFICIENTS

An option which eliminates some input is the implicit calculation of friction coefficients. When the friction coefficient is left out of the data for a junction, RELAP3 will calculate a value which establishes steady state flow. This calculation, which is based on initial pressures including gravitational heads, often yields a negative friction coefficient that would cause numeric instabilities. If a negative friction coefficient is found after the input is processed, the RELAP3 run will be aborted to avoid lost computer time. Initial pressures must be readjusted by the user.

7. PROGRAM ORGANIZATION

Extraneous input requirements have been almost eliminated. For instance, a problem containing no core regions will require no reactor or heat transfer data. As a result, a typical single vessel blowdown (one volume, one leak junction) requires about 15 cards out of the several hundred currently possible.

Input simplification also has led to dropping options which were not used in RELAP2. RELAP3 includes no xenon transient capabilities, no provisions for a decrease of net positive suction head (Henry's Law), no analytic equations for rod worth, and no analytic expressions for the Doppler reactivity.

The input link of RELAP3 is broken into subroutines, each written to handle a different kind of input information. The construction into subroutines facilitates programming changes. For example, a change to the pump description would be limited to modifying the pump input and initialization and the pump head calculation with little worry about missing required changes hidden elsewhere in the program. Once the input and initialization programming has been used it is deleted as the transient link is pulled into the computer memory. Thus a programmer is guaranteed that only variables contained in common lists are transferred.

In RELAP3 all initialization is performed in the input link and the initial values are placed in the labeled common areas, simplifying the transient portion of the calculation considerably. Previously, initial conditions were set up within the same subroutine which performed the transient calculation. Changes were difficult because no indication existed as to which variables were recalculated each time step, and which were calculated only in the initial conditions. In addition, this technique added length to the already long transient routine making it even harder with which to work.

8. RESTART CAPABILITY

The major cause of failure of a RELAP3 calculation appears to be the time step size being too large. In addition, the probability of a computer failure during a very long run becomes significant. The restarting capability included in RELAP3 can salvage virtually all of the computer time spent prior to a failure, allowing the problem to be continued with a new time stepping sequence. The choice of edited variables and the edit frequency may also be modified in the continuation. Thus, a close look may be taken at a selected portion of a RELAP3 run without starting over again.

9. PLOTTING AND EDITING OPTIONS

The data tape used for storing the information required for restarting is also used for storing the editable variables at designated intervals. RELAP3 can process one of these tapes to obtain additional edits as required. The plotting program is adapted only to the NRTS computing system, but is available as a separate package for those who want to convert it.

III. EQUATIONS SOLVED

RELAP3 obtains a time-dependent thermal and hydraulic solution by integrating a set of differential equations subject to certain algebraic relationships. These equations and relationships are presented in the following sections.

A mass and energy balance is obtained from junction conditions, heat output of reactor regions, and heat removed by heat exchanger regions. By using the equation-of-state for water (in the form of tables) a pressure and a quality are obtained for each volume. If a linear density model for steam separation within a volume is assumed, fluid conditions can be determined for each junction. A one-dimensional momentum balance (flow calculation) is then obtained for each junction. The fluid conditions within a volume, the flow through a volume, and the reactor power level are then used to establish the reactor heat flux and the fuel element temperatures. By the use of reactivity feedback from reactor conditions, the space-independent reactor kinetics equations are then advanced to determine a new reactor power level. A new cycle is then begun with a new mass and energy balance.

1. MASS AND ENERGY BALANCES

As demonstrated in Appendix A, the mass and energy stored in each volume are calculated from the basic conservation equations by assuming constant flow and fluid properties during any given time step. The conservation equations are in the form of ordinary time-dependent differential equations describing the behavior within a fixed control volume, illustrated in Figure 1. The mass and energy equations are

$$\frac{dM_i}{dt} = \sum_{j=1}^{N} W_{ij} \tag{1}$$

and

$$\frac{dU_i}{dt} = \sum_{j=1}^{N} W_{ij} h_{ij} + Q_i \tag{2}$$

where

M_i = total mass in volume i

W_{ij} = flow rate into volume i through junction j

U_i = energy in volume i

h_{ij} = enthalpy of flowing fluid

Q_i = heat input to volume i.

Kinetic and frictional energies are neglected in Equation (2).

For an energy balance in each volume, the correct enthalpy must be determined for all incoming and exiting flows. In RELAP3, the exit state of the fluid through a junction is defined by the state of the fluid in contact with the junction point. If the mixture level of liquid and entrained steam bubbles is below a junction, the flow is assumed to be steam. Conversely, if the mixture level is above the junction, the flow is determined by the bubble gradient equations described in Section III-10.

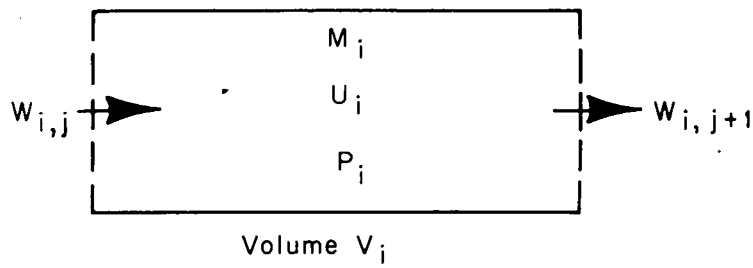

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FIG. 1 CONTROL VOLUME.

2. THERMODYNAMIC PRESSURE

Pressure, P_i, in each volume is determined implicitly by requiring the mass of fluid, M_i, with internal energy, U_i, to fill control volume V_i. The enthalpy, h_i, of volume i is calculated by the equation

$$h_i = \frac{U_i}{M_i} + P_i \frac{V_i}{M_i} \quad . \tag{3}$$

Through use of this enthalpy, along with an estimated pressure, the specific volume of the fluid is calculated from the available physical property tables. An iterative process of matching the specific volume from the steam tables with known specific volume V_i/M_i is used to determine the volume pressure. The property tables for water cover the range of $0.1 \le P \le 3206$ psi, and $32 \le T \le 5600°F$.

The values in the thermodynamic property tables were calculated from the 1967 ASME Steam Formulae[2]. For each pressure, P_j, the tables of water density, ρ, and steam specific volume, ν, are arranged as follows:

$$\text{liquid} \quad \left\{ \begin{array}{lll} h_{j,1} & \rho_{j,1} & T_{j,1} \\ h_{j,2} & \rho_{j,2} & T_{j,2} \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ h_{j,13} & \rho_{j,13} & T_{j,13} \end{array} \right.$$

$$
\text{steam}\quad \begin{cases} h_{j,1s} & \nu_{j,1s} & T_{j,1s} \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ \cdot & & \\ h_{j,5s} & \nu_{j,5s} & T_{j,5s} \end{cases}
$$

where

$T_{j,1} = 32°F$

$T_{j,13} = T_{j,1s} = T_{sat}(P_j)$

$T_{j,4s} = 1600°F$

$T_{j,5s} = 5600°F$

and P_j = 0.1, 0.3, 1.0, 5.0, 14.7, 50., 100., 200., 400., 600., ... 3000., 3206.2 psi

In the low-pressure (<50 psi) liquid range of the tables, entries are arranged along equal temperature lines for all pressures, as shown in Figure 2.

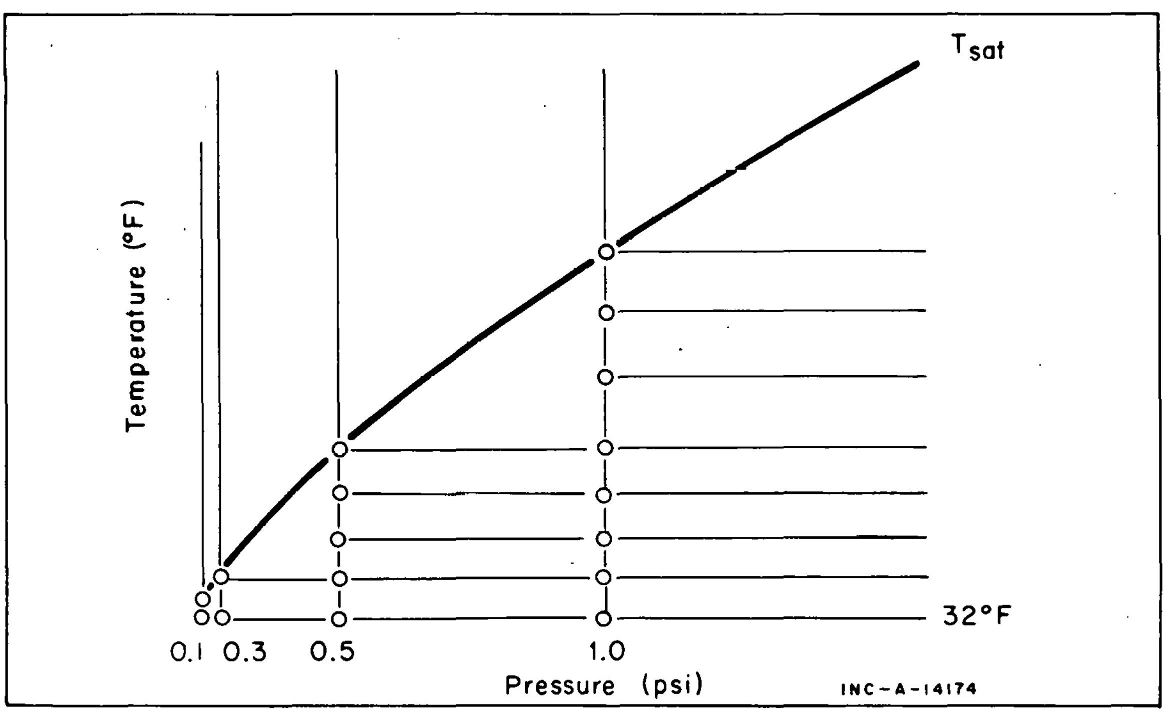

FIG. 2 LOW PRESSURE TABLE STRUCTURE.

For pressures > 100 psi, the liquid entries for a given pressure are at equally spaced temperature intervals from 32°F to T_{sat}. The entries for a given pressure in the steam region are equally spaced between T_{sat} and 1600°F with a final point at 5600°F.

In the liquid region, at high pressure (> 2200 psi) and within a few degrees of saturation temperature, the tables have proven inadequate. RELAP3 results should be carefully examined by the user for possible errors arising from this cause.

3. MOMENTUM BALANCE

The control volume used for the flow calculation is shifted to a mid-position between the two adjacent mass-energy control volumes, as shown in Figure 3. This shifting of the two types of control volumes has the advantage of minimizing the extrapolation of boundary conditions. The mass-energy calculations require a junction flow as a boundary condition, which, with the shifted flow volume, is approximately the average flow as given by Equation (4). Likewise, the flow volume requires as a boundary condition, the pressure which is available as the average thermodynamic pressure from mass-energy-volume, adjusted for gravity effects.

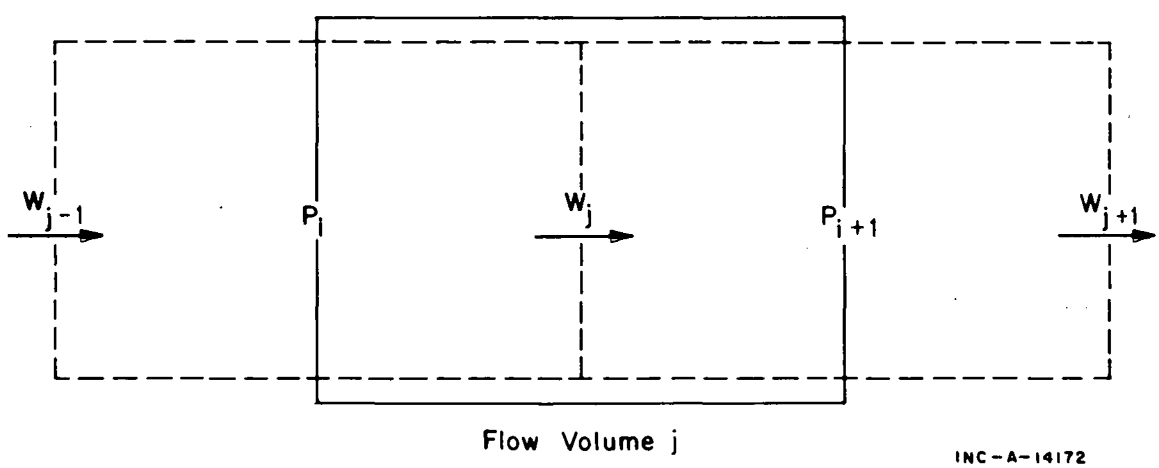

FIG. 3 FLOW VOLUME.

Junction flows are calculated from the one-dimensional momentum equation which in English units is:

$$\frac{1}{144 g_c}\left(\frac{\ell}{A}\right)\frac{dW_j}{dt} = P_i - P_{i+1} + \Delta P_p + \int_{V_j} \frac{\rho dz}{144} - \frac{K_j W_j \left| W_j \right|}{\rho_j} \quad (4)$$

where

g_c = gravitational conversion constant

$\frac{\ell}{A}$ = junction inertia

W_j = average flow from volume i to volume i+1

$P_i - P_{i+1}$ = thermodynamic pressure differential across the fluid contained in the flow volume

ΔP_p = pump head

$\int_{V_j} \rho dz$ = gravitational head across fluid column

K_j = net friction coefficient including normal friction losses (Appendix A).

ρ_i = fluid density in volume i.

The fluid contained within the flow volume has an associated inertia which depends on the actual shape of the volume.

The junction inertia for a homogeneous volume is

$$\left(\frac{\ell}{A}\right)_j = \int_{V_j} \frac{d\ell}{A} \tag{5}$$

where

ℓ = the length of the flow path

A = cross-sectional area for the flow.

In the simple example shown in Figure 3,

$$\left(\frac{\ell}{A}\right)_j = \frac{1}{2}\left(\frac{\ell_i + \ell_{i+1}}{A_i}\right) . \tag{6}$$

The normal friction coefficients should initially balance with the input pressure distributions for flowing systems. If initial flow exists between two volumes, RELAP3 can calculate the appropriate friction coefficient as

$$K_j = \frac{[(P_i + \Delta P_{grav,i}) - (P_{i+1} + \Delta P_{grav,i+1}) + \Delta P_{pump,j}]\rho_j}{W_j |W_j|} . \tag{7}$$

For junctions with no initial flow, the user must supply a value for K_j.

Elevation heads, which are included in Equation (4), are calculated by integrating the density distribution as defined by the steam separation model.

4. CHOKED FLOW

At the user's option, any junction except a fill junction can be limited by choking.

The limiting mass flow is defined by Moody's two-phase choked flow model[3],

$$W_{choke} = A_{choke} \; f_n(P_o, h_o) \tag{8}$$

where

W_{choke} = maximum junction flow

A_{choke} = minimum area in junction

f_n = mass flux as a function of stagnation pressure, P_o, and enthalpy, h_o.

The stagnation conditions are assumed to be the thermodynamic conditions within the volume feeding the junction and at the junction height.

The flow through a junction is chosen as the smaller of the inertial flow or the choked flow.

Moody's model also gives the throat pressure, P_{th}, as a function of P_o and h_o. In RELAP3, the sink pressure must be less than the throat pressure for choking to occur in a leak junction.

5. ENERGY REMOVAL

Energy removal by a heat exchanger is calculated from an input table or by the following flow-dependent equation:

$$Q_i = -Q_{HE} = -\frac{W}{W_o} H_{HE} \; (T_{Pri} - T_{Sec}) \tag{9}$$

where

Q_i = rate of heat addition to volume i

Q_{HE} = heat removal rate of the heat exchanger

W = flow of the primary coolant through volume i

W_o = initial coolant flow through volume i

H_{HE} = effective heat transfer coefficient during steady state full power operation

T_{Pri} = temperature of primary coolant in the heat exchanger

T_{Sec} = temperature of secondary coolant in the heat exchanger.

The term representing the heat transfer coefficient (H_{HE}) is determined internally in the code from initial steady state conditions:

$$H_{HE} = - \frac{Q_i}{(T_{Pri} - T_{Sec})} \quad . \tag{10}$$

Since heat exchangers are independent of each other, the choice of a flow dependent model for one does not eliminate the possibility of using an input table for another.

6. ENERGY ADDITION

Energy addition to the fluid occurs in the core volumes [a]. The rate of heat addition is calculated using a multinode pin conduction subroutine and a subroutine for predicting the heat transfer coefficients for the various modes of heat transfer.

An iterative process calls alternately the subroutine to calculate the heat transfer coefficient and the conduction subroutine to calculate the temperatures. The latter subroutine requires the heat transfer coefficient, the bulk fluid temperature, the surface flux (from previous time step), the time step size, and the heat generation rates as input. Convergence of the heat transfer coefficient terminates the iteration; that is, if after two successive iterations the change in the heat transfer coefficient is less than a specified tolerance, the calculation is terminated.

Flows, pressures, and densities of the coolant fluid are assumed constant during a single time step. The flow through a given core volume is obtained by averaging the flow through the inlet and outlet junctions.

Heat generation in the fuel pins is determined by reactor kinetics routines or by table look up of power versus time.

---

[a] The steam generator volumes can also be used as an energy source through the use of a negative heat removal curve.

The overall energy balance for the pin is

$$V\bar{\rho}\bar{C}\frac{d\bar{T}}{dt} = Q + S_N k_N \frac{dT_N}{dR} \qquad (11)$$

where

V = fuel pin volume

$\bar{\rho}$ = density

$\bar{C}$ = specific heat

$\frac{d}{dt}$ = derivative with respect to time

$\bar{T}$ = average pin temperature

Q = heat generation rate in fuel pin

S_N = pin surface area

k_N = thermal conductivity at surface of pin

$\frac{d}{dR}$ = derivative with respect to radius

T_N = surface temperature.

Equation (11) assumes a uniform heat flux and an average temperature defined by

$$\bar{T} = \frac{\int_V C\rho T dV}{\int_V C\rho\, dV} \simeq \frac{\sum_{n=1}^{N} (\rho V)_n C_n T_n}{\sum_{n=1}^{N} (\rho V)_n C_n}. \qquad (12)$$

where

N = total number of annuli used in pin

and

n = fuel pin annulus number.

6.1 Conduction Model

The pin conduction model solves the one-dimensional heat conduction equation for a cylindrical geometry. The pin conduction model and the method of solution are patterned after the model and method used in the HEAT1 code [4]. Currently, the model can accommodate up to 31 radial nodes, six different concentric regions, and six different materials. Core volumes can be stacked vertically to achieve axial definition.

For annulus n shown in the diagram, the conduction equation is

$$V_n \bar{\rho}_n \bar{C}_n \frac{d\bar{T}_n}{dt} = Q_n + S_n k_n \frac{dT_n}{dR} - S_{n-1} k_{n-1} \frac{dT_{n-1}}{dR} \qquad (13)$$

where

S = annulus surface area.

Equation (13) is approximated numerically by

$$V_n \bar{\rho}_n \bar{C}_n \frac{(T_n' - T_n)}{\Delta t} = Q_n' + \frac{S_n}{2\Delta R_n} \left[\bar{k}_{n,n+1}(T_{n+1} - T_n) + \bar{k}'_{n,n+1}(T'_{n+1} - T'_n) \right]$$

$$- \frac{S_{n-1}}{2\Delta R_{n-1}} \left[\bar{k}_{n-1,n}(T_n - T_{n-1}) + \bar{k}'_{n-1,n}(T'_n - T'_{n-1}) \right] \qquad (14)$$

where

$$\bar{k}_{n,n+1} = \frac{k_n + k_{n+1}}{2} \qquad (15)$$

and superscript prime (') designates the current iteration.

The boundary conditions are

$$\left.\frac{dT'}{dR}\right|_{R=0} = 0 \qquad (16)$$

and

$$\frac{dT'_N}{dR} = \frac{h(T'_N - T'_W)}{-k'_N} \qquad (17)$$

where

h = heat transfer coefficient.

N simultaneous equations of the form

$$a_n T'_{n-1} + b_n T'_n + g_n T'_{n+1} = d_n$$

are obtained by writing Equation (14) for each of the N regions

where

a, b, g, and d are constants for a given iteration.

The N equations form a matrix equation which is solved by the method described in Reference 4 for the temperatures at each node.

In order to solve the conduction equations, the pin is divided into annular regions as shown in Figure 4.

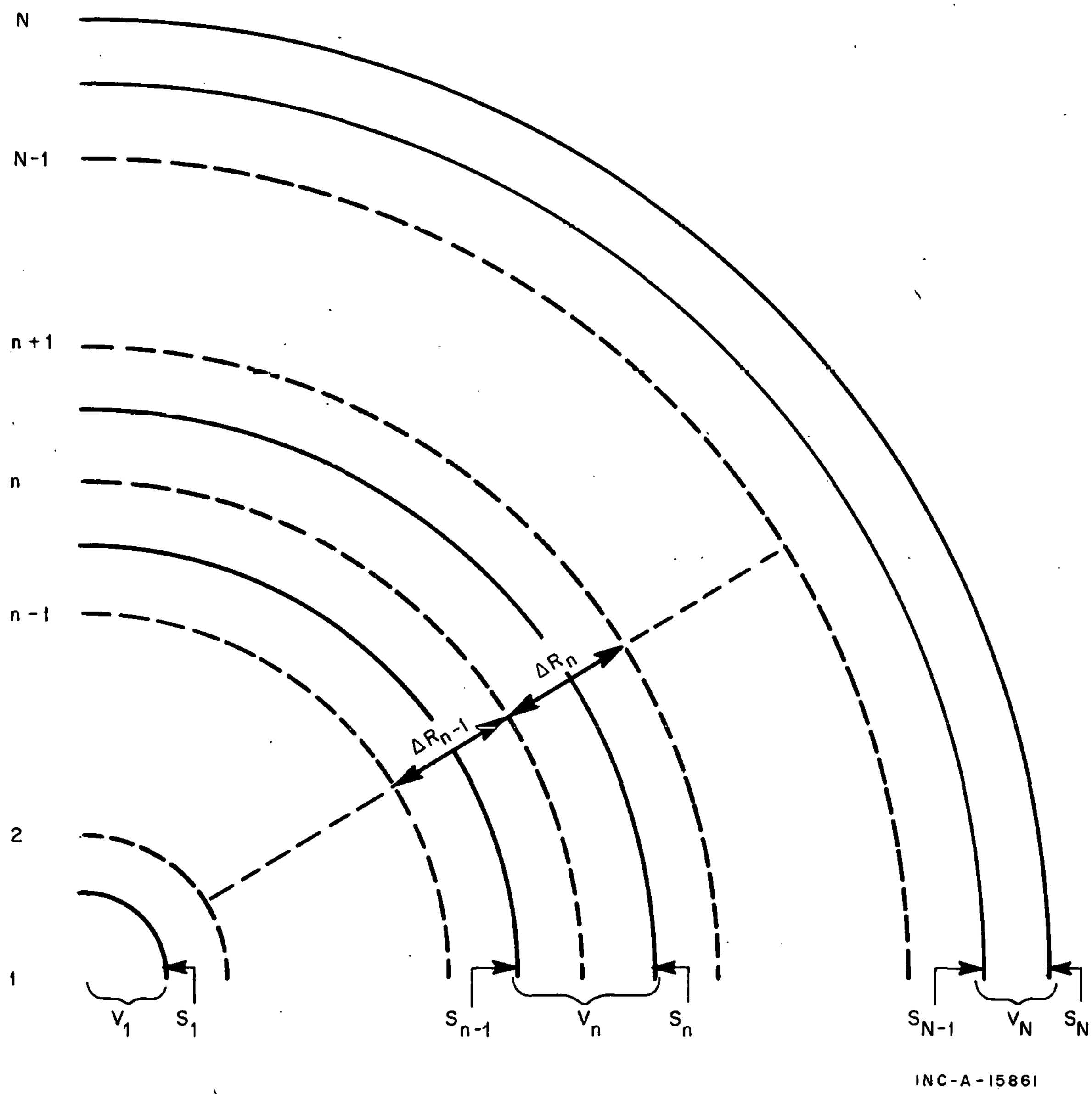

FIG. 4 FUEL ROD HEAT CONDUCTION MODEL.

6.2 Heat Transfer Correlations

Correlations for predicting heat transfer coefficients for seven different modes of heat transfer are provided. The correlations and conditions for which they are used are as follows:

Mode 1 -- Subcooled Forced Convection: $X < 0.0$, $T_s < T_{NB}$
Seider Tate correlation [5]

$$h = \frac{0.023 k_f(T_w)}{D} \left[\frac{DG}{\mu_f(T_w)}\right]^{0.8} \left[Pr(T_w)\right]^{1/3} \left[\frac{\mu_f(T_w)}{\mu_f(T_s)}\right]^{0.14} \tag{18}$$

where

h = heat transfer coefficient, Btu/ft^2-hr-°F

X = mass fraction of steam (quality)

T_{NB} = minimum surface temperature for nucleate boiling as defined by Equation (19), °F

$k_f(T_w)$ = saturated liquid thermal conductivity evaluated at T_w, Btu/ft-hr-°F

T_w = temperature of coolant, °F

D = hydraulic diameter of flow channel, ft

G = mass flux of coolant, lb/ft^2-hr

$\mu_f(T_w)$ = saturated liquid viscosity evaluated at T_w, lb/ft-hr

$Pr(T_w)$ = Prandtl number for coolant

$\mu_f(T_s)$ = saturated liquid viscosity evaluated at T_s, lb/ft-hr

T_s = fuel pin surface temperature, °F

subscript f indicates saturated liquid property

subscript g indicates vapor property.

Mode 2 -- Subcooled Nucleate Boiling: $X < 0.0$, $T_s = T_{NB}$
Thom correlation [6]

$$T_{NB} = T_{sat} + 0.072\, e^{-P/1260}\, \phi_S^{0.5} \tag{19}$$

$$h = \frac{\phi_S}{T_{NB} - T_W} \tag{20}$$

where

T_{sat} = saturation temperature, °F

P = pressure, psi

ϕ_S = surface flux, Btu/hr-ft^2.

Mode 3 -- Nucleate Boiling: $0 \leq X \leq 0.1$

The heat transfer coefficient is calculated by interpolating with respect to quality between Equations (20) and (21).

Mode 4 -- Forced Convection Boiling: $0.1 < X < 0.6$
Schrock and Grossman correlation with Wright constants [7]

$$h = 6700 \left[\frac{\phi_S}{GH_{fg}} + 0.00035 \left\{ \left(\frac{X}{1-X}\right)^{0.9} \left(\frac{\rho_f}{\rho_g}\right)^{0.5} \left(\frac{\mu_g}{\mu_f}\right)^{0.1} \right\}^{0.66} \right] \left[\left(\frac{0.023k_f}{D}\right) \left(\frac{DG(1-X)}{\mu_f}\right)^{0.8} \left(P_r\right)^{0.4} \right] \quad (21)$$

The physical properties are evaluated at saturation conditions where

H_{fg} = heat of vaporization, Btu/lb
ρ = density, lb/ft^3
k = thermal conductivity, Btu/hr-ft-°F.

Mode 5 -- Forced Convection Boiling: $0.6 < X \leq 1.0$

The heat transfer coefficient is calculated by interpolating with respect to quality between Equations (21) and (22).

Mode 6 -- Single Phase Steam: $X \geq 1.0$
Dittus-Boelter correlation [8]

$$h = 0.023 \frac{k_g}{D} \left(\frac{DG}{\mu_g}\right)^{0.8} \left(Pr_g\right)^{0.4} \quad (22)$$

Physical properties are evaluated at $\frac{T_W + T_S}{2}$.

Mode 7 -- Stable Film Boiling: ϕ_S has exceeded the critical heat flux.
Dougall-Rohsenow correlation [9]

$$h = 0.023 \frac{k_g}{D} \left[\left(\frac{DG}{\mu_g}\right) \left(\frac{\rho_g}{\rho_f} (1-X) + X\right) \right]^{0.8} \left[Pr_g\right]^{0.4} \quad (23)$$

The physical properties are evaluated at saturation conditions. If $X \leq 0.0$, the term $[\frac{\rho_g}{\rho_f} (1-X) + X]$ is set equal to 1.0, which reduces Equation (23) to Equation (22).

7. CRITICAL HEAT FLUX

The choice of a correlation for predicting the critical heat flux depends upon the pressure and mass flux. If the surface flux exceeds the predicted critical heat flux, stable film boiling is assumed to occur. The critical heat flux correlations and the conditions under which they are used are as follows:

Range 1 -- $P \leq 725$ psi: Modified Barnett correlation[a]

$$\frac{\phi_{CHF}}{10^6} = \frac{B + E\,(H_f - H_{in})}{F + L} \quad (24)$$

where

$$B = [73.71\, D_{HE}^{\;0.0523} G'^{0.663}\, (1.0 - 0.315 e^{-11.34 D_{HY} G'})\, 888.6]\,[H_{fg}]^{-1} \quad (25)$$

$$E = 0.104\, D_{HE}^{1.445}\, G'^{0.691} \quad (26)$$

and

$$F = 45.55\, D_{HY}^{\;0.0817}\, G'^{0.587} \quad (27)$$

P = pressure, psi

ϕ_{CHF} = critical heat flux, Btu/hr-ft^2

H_f = saturated liquid enthalpy, Btu/lb

H_{in} = inlet enthalpy, Btu/lb

L = channel length, in.

D_{HE} = heated equivalent diameter, in.

G' = mass flux, 10^6 lb/hr-ft^2

D_{HY} = $[Dr(Dr + D_{HE})]^{1/2} - Dr$, in. ($Dr$ = pin diameter)

H_{fg} = heat of vaporization, Btu/lb

Range 2 -- 725 psi $< P <$ 1000 psi

The critical heat flux is calculated by linear interpolation with respect to pressure between Equations (24) and (28).

Range 3 -- 1000 psi $\leq P <$ 1500 psi: Barnett correlation[10]

$$\frac{\phi_{CHF}}{10^6} = \frac{J + M\,(H_f - H_{in})}{R + L} \quad (28)$$

---

[a] New constants were derived for the Barnett [10] correlation for low pressure rod bundle data by Idaho Nuclear Corporation.

where

$$J = 67.45\, D_{HE}^{0.68} (G')^{0.192} \cdot [1.0 - 0.744 \exp(-6.512\, D_{HY} \cdot G')] \quad (29)$$

$$M = 0.2587\, D_{HE}^{1.261} (G')^{0.817} \quad (30)$$

$$R = 185.0\, D_{HY}^{1.415} (G')^{0.212}. \quad (31)$$

Range 4 -- 1500 psi < P < 1800 psi

The critical heat flux is calculated by linear interpolation with respect to pressure between Equations (28) and (32).

Range 5 -- $P \geq 1800$ psi, $G > 0.5 \times 10^6$ lb/hr-ft^2
B&W-2 correlation [11]

$$\phi_{CHF} = \frac{S[3.702 \times 10^7\, W^Z - 0.15208\, G\, H_{fg} X]}{12.71\, Y^N} \quad (32)$$

where

$$S = [1.15509 - 0.40703\, D_{HY}] \quad (33)$$

$$W = (5.9137 \times 10^{-7}\, G) \quad (34)$$

$$Z = [0.8304 + 6.8479 \times 10^{-4} (P - 2000)] \quad (35)$$

$$Y = (3.0545 \times 10^{-6}\, G) \quad (36)$$

and

$$N = [0.71186 + 0.00020729\, (P - 2000)] \quad (37)$$

where

G = mass flux, lb/hr-ft^2

X = quality.

Range 6 -- $P \geq 1800$ psi: $G \leq 0.5 \times 10^6$ lb/hr-ft^2

The critical heat flux is calculated by using the average value between Equations (28) and (32).

The inlet enthalpy used in the critical heat flux correlations is dependent on the flow direction and is determined in the following manner.

Flow at Normal Inlet	Flow at Normal Outlet	H_{in}
> 0	≥ 0	H at normal inlet
≤ 0	< 0	H at normal outlet
All other cases		H of core volume

8. POWER GENERATION

Power generation is determined by either a reactor kinetics calculation or by a tabular input of power versus time. The reactor kinetics equations are solved by a method similar to that used in the IREKIN program [12]. The standard reactor kinetics equations are

$$\frac{dn}{dt} = \frac{\beta}{\Lambda}\left[(\rho/\beta) - 1\right] n + \sum_{i=1}^{6} \lambda_i C_i + S \qquad (38)$$

$$\frac{dC_i}{dt} + \lambda_i C_i = \frac{\beta_i}{\Lambda} n, \quad i=1, 2 \ldots 6 \qquad (39)$$

$$\beta = \sum_{i=1}^{6} \beta_i \qquad (40)$$

where

n = reactor fission power

β = effective delayed neutron fraction

Λ = neutron generation time

ρ = reactivity

λ_i = decay constant of delayed neutron group i

C_i = concentration of delayed neutron group i

S = neutron source

β_i = effective fraction for delayed neutron group i.

Also included as an option in the reactor kinetics subroutine are 11 groups of radioactive gamma heat sources:

$$\frac{d\gamma_j}{dt} + \lambda_j \gamma_j = E_j n, \quad j=1, 2, \ldots 11 \qquad (41)$$

where

γ_j = concentration of delayed gamma group j

λ_j = decay constant of delayed gamma group j

E_j = yield fraction of delayed gamma group j.

The total power is a sum of the direct fission power and the instantaneous gamma heating. All power is assumed to be generated in the fuel elements, direct gamma heating of the coolant not being considered. The inclusion of the gamma terms gives a more realistic shutdown transient. The total power, P, is

$$P = n\, E_f + \sum_{j=1}^{11} \lambda_j \gamma_j \tag{42}$$

where

E_f = fraction of power produced in steady state by fission

If the gamma heating option is not used, then $E_f = 1$; otherwise, $E_f = 0.93$ and $\sum E_j = 0.07$.

9. REACTIVITY

As input to the reactor kinetics calculations, reactivity is developed explicitly as a known function of time and implicitly through core feedback mechanisms. The explicit input reactivity is calculated from a table of ρ/β versus time, and feedback reactivity is determined from coolant density, coolant temperature, and fuel temperature for each reactor volume.

The void reactivity is calculated by density changes in the coolant:

$$(\rho/\beta)_v = \sum_i 100\alpha_{vi} \left(1 - \frac{\rho_i}{\rho_{io}}\right) \tag{43}$$

where

$(\rho/\beta)_v$ = void reactivity

α_{vi} = void reactivity coefficient of core region i

ρ_i = coolant density in core region i

ρ_{io} = initial coolant density in core region i.

Likewise, the temperature-dependent reactivities are

$$(\rho/\beta)_{WT} = \sum_i \alpha_{WT_i} \Delta T_{bc_i} \tag{44}$$

$$(\rho/\beta)_{FT} = \sum_i \alpha_{FT_i} \quad \Delta T_{f_i} \tag{45}$$

$$(\rho/\beta)_{DOP} = \sum_i \beta_{DOP_i} \quad f(\alpha_{DOP}, \quad \Delta T_{f_i}) \tag{46}$$

where

$(\rho/\beta)_{WT}$ = coolant temperature reactivity

α_{WT_i} = coolant temperature reactivity coefficient of core region i

ΔT_{bc_i} = change in bulk coolant temperature in core region i

$(\rho/\beta)_{FT}$ = fuel element temperature reactivity

α_{FT_i} = fuel element temperature reactivity coefficient of core region i

ΔT_{f_i} = change in fuel element temperature in core region i

$(\rho/\beta)_{DOP}$ = Doppler reactivity

β_{DOP_i} = weighting factor of core region i for Doppler reactivity

$f(\alpha_{DOP}, \Delta T_{f_i})$ = Doppler function, input tables.

A total reactivity is obtained by summing the contributions from control rods, water void, water temperature, fuel temperature, and Doppler effects. This total reactivity is adjusted by an additive constant which yields the desired time step zero reactivity.

10. TWO-PHASE SEPARATION MODEL

The two-phase separation model used in RELAP3 is a semiempirical fit to a number of experimental, high pressure blowdowns[13].

The quantities necessary to describe the separation of steam bubbles into a gas dome are the partial density of the bubbles and the local bubble velocity at the steam-dome mixture interface. Physically, during a continuous decompression of a large stagnant volume, the density of bubbles is expected to be least near the bottom of the volume. This distribution is reasonable because the static pressure will be highest near the bottom and because the bubbles tend to accumulate as they rise through the mixture. The first order approximation is one in which the density of bubbles increases linearly as a function of height within the two-phase mixture. A limitation of this model is the inability to describe bubble distributions when physical conditions, such as oscillating pressure or an oscillating flow, would be expected to lead to a complicated situation.

The assumed bubble distribution is

$$\rho_{gb} = m \frac{z}{Z_m} + b \tag{47}$$

where

ρ_{gb} = partial steam density within the mixture

m,b = time-dependent slope and intercept

z = height above the bottom of the volume

Z_m = time-dependent height of mixture interface.

The slope and intercept of the assumed bubble distributions are evaluated by applying conservation of mass. Integrating the partial bubble density over the volume of the mixture gives the instantaneous mass of steam within the mixture. For an average void fraction less than 0.5, that is

$$0 \leq \frac{M_{gb}}{\rho_g V_m} \leq \frac{1}{2} \tag{48}$$

where

M_{gb} = mass of steam entrained in the mixture

ρ_g = density of saturated steam

V_m = volume of the mixture,

the slope and intercept are

$$m = 2C_o \frac{M_{gb}}{V_m} \tag{49}$$

$$b = (1-C_o) \frac{M_{gb}}{V_m} \quad . \tag{50}$$

For average void fractions between 0.5 and 1,

$$\frac{1}{2} \leq \frac{M_{gb}}{\rho_g V_m} \leq 1 \ , \tag{51}$$

the slope and intercept are

$$m = 2C_o\left(\rho_g - \frac{M_{gb}}{V_m}\right) \tag{52}$$

$$b = (1+C_o)\,\frac{M_{gb}}{V_m} - C_o\rho_g\,. \tag{53}$$

To generalize this model, an arbitrary constant, C_o, is included. This constant (which must be limited to values between zero and one) determines the maximum bubble gradient at any instant. If the constant is chosen as zero, the mixture is homogeneous; if chosen as one, the bubble gradient is always maximum within the permissible physical constraints. Values outside this range may give negative values for the partial bubble density and so are not allowed. Within RELAP3, each volume can have an individual C_o chosen by the user. Small volumes with high mass flux such as core channels or pipe sections are best described by a homogeneous model where $C_o = 0$. In plenums and tanks where the homogeneous model is not desirable, a value of $C_o = 0.8$ is recommended. This value was determined as a best choice for a one-volume description of experimental vessel blowdowns [14].

The velocity of steam bubbles relative to the mixture interface is another input quantity which can be different for each volume. In the preceeding referenced model test, a value of three feet per second was used. If the velocity is zero, no separation occurs although a bubble density gradient may still exist.

By using Equation (47), the local fluid quality is determined for each junction at its connection to a volume. The partial steam density at the surface of the mixture (needed to calculate the rate at which bubbles cross the interface) is also obtained from Equation (47).

To determine the mass and quality of the mixture, a balance for the entrained steam must be performed. Steam can be added to a volume either through a junction or by flashing of liquid within the mixture.

The differential equation describing the bubble mass balance within a given volume is

$$\frac{dM_{gb}}{dt} = \frac{dM_s}{dt} - \Sigma\, \psi_i X_i W_i - Av_{bub}\rho_{gb}\Big|_{Z_m} \tag{54}$$

where

M_{gb} = mass of steam (gas bubbles) entrained in the mixture

M_s = total mass of steam within the volume

ψ_i = fraction of steam flowing at the junction and originating within the steam dome

X_i = quality of junction flow

W_i = flow into or out of the volume at junction i

A = cross-sectional area of the volume

v_{bub} = bubble velocity at mixture surface

$\rho_{gb}|_{Z_m}$ = gas bubble density at the mixture surface.

11. JUNCTION QUALITIES

Since junctions at control volume boundaries are treated as points rather than distributed areas (so far as fluid properties within the volume are concerned), qualities at these points can oscillate between zero and one. Also, when junctions are near the top or the bottom of a volume, more gas or liquid can be extracted than really exists within the volume. If during a blowdown, the mixture level falls to a junction, then during one time step the flow will be two phase and then change to pure steam the following time step. Under these conditions the flow can be large enough to extract more steam than is physically present. To eliminate these difficulties, the flow during any single time step is assumed to be composed of a combination of steam and mixture when the mixture level is adjacent to the junction location. This modification smooths the time step variation of junction quality and virtually eliminates the time step size instability associated with oscillating mixture levels.

12. FILL SYSTEMS

Water may be injected into any volume by means of fill junctions. The junction flows are obtained by interpolating tabular input of flow versus either time or pressure. Several fill junctions may connect to the same volume if desired. Initiation of flow through fill junctions may be controlled by many different trip signals. No cut-off is allowed except implicitly through the flow versus time table.

13. SYSTEM BALANCES

An overall mass balance is performed:

$$M_B = \sum_i M_i + \int \sum_j W_j dt - \int \sum_k W_k dt \tag{55}$$

where

M_B = mass balance

M_i = mass in volume i

W_j = flow in leak junction j

W_k = flow in fill junction k.

Energy within the system described by RELAP3 can be stored, injected, or removed by several mechanisms. In general, the total energy at any time within the reactor system is

$$E_T = E_f + \Sigma\, E_i \tag{56}$$

where

E_T = total energy stored

E_f = energy stored within fuel elements

E_i = internal energy of water in volume i.

The energy stored within the fuel elements is

$$E_f = \sum_m \left[\sum_n (\rho V)_n\, C_n\, T_n \right]_m \tag{57}$$

where

m = core region number

n = node number

ρ = density

V = node volume

C = specific heat capacity

T = temperature.

Energy can be extracted from the system through leaks or heat exchangers, respectively, as

$$E_\ell = \int_0^t \sum_j W_j h_j\, dt \tag{58}$$

and

$$E_{HE} = \int_0^t \sum_m Q_{HE_m}\, dt \tag{59}$$

where

E_ℓ = energy lost through leakage

W_j = flow through leak j

h_j = enthalpy of fluid flowing through leak j

E_{HE} = heat removed by heat exchangers

Q_{HE_m} = rate of heat loss through heat exchanger n.

Energy can be added to the system by the reactor power and the fill water injection, respectively, as

$$E_{RP} = \int_0^t \sum_m Q_{RP_m} dt \tag{60}$$

and

$$E_F = \int_0^t \sum_k W_k h_k dt \tag{61}$$

where

E_{RP} = heat added through nuclear fission

Q_{RP_m} = rate of heat addition in core region m

E_f = heat added through fill water injection

W_k = flow through fill junction k

h_k = enthalpy of fluid flowing through fill k.

Applying the conservation of energy principle to the system gives

$$E_{initial} = E_{stored} + E_{extracted} - E_{injected} \tag{62}$$

or

$$\text{Energy Balance} = \sum E_i + E_f + E_\ell + E_{HE} - E_{RP} - E_F \ . \tag{63}$$

This energy balance is computed and available in the minor edit list. The first time step edit gives the initial energy inventory because the time integral terms are zero.

14. CHECK VALVES

Check valves may be placed, at the users option, in any RELAP3 junction. Three pressure loss coefficients, C_i, and the back pressure to close the valve, P_{CV}, are user supplied input constants. The user also has a choice of valve type; Type 1 without a hysteresis loop in the characteristic flow versus pressure curve and Type 2 with the hysteresis loop. The characteristic curves for these two types are shown in Figure 5.

Both types of check valves are controlled by flow dependent pressure losses of the form $C_i W|W|/\rho$.

Three regions of operation are defined for each valve:

(1) C_1 is used for positive flow with the valve open
(2) C_2 is used for negative flow with the valve open
(3) C_3 is used for negative flow with the valve almost closed.

For all positive flow, the valve remains open and sustains a pressure loss proportional to C_1. For negative flow, the valve remains open if the pressure loss, which is proportional to C_2, is less then the back pressure required to close the valve.

After the valve closes, the pressure loss is proportional to C_3 for small leakage flows. The hysteresis difference between Type 1 and Type 2 check valves is apparent in Figure 5. Type 1 check valves open in exactly the reverse procedure of the closing sequence. A Type 1 valve opens when negative flow has decreased to a value such that the pressure loss for the open phase is less than the loss required to keep the valve closed. A Type 2 valve reopens only when the pressure loss developed in the closed position is less than the required back pressure.

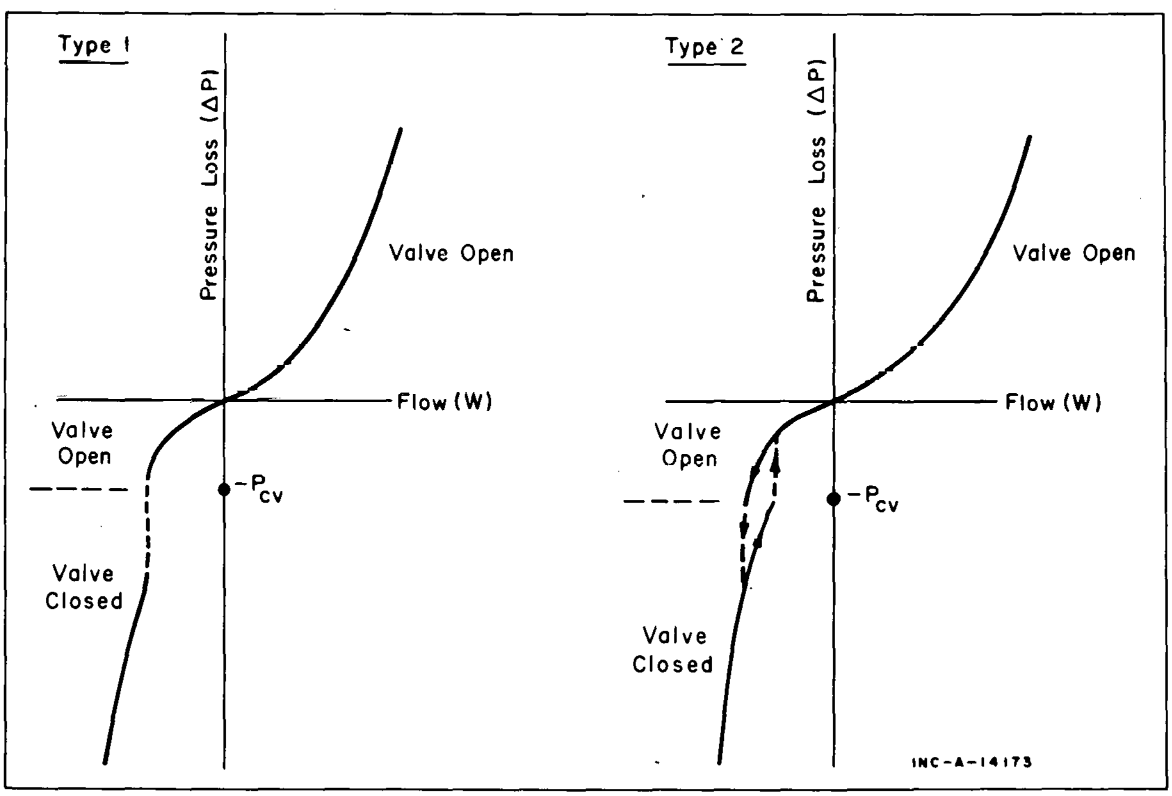

FIG. 5 CHECK VALVE CHARACTERISTIC CURVES.

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APPENDIX A

APPROXIMATIONS TO THE CONSERVATION EQUATIONS

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APPENDIX A

APPROXIMATIONS TO THE CONSERVATION EQUATIONS

The following brief description of the fluid equations used in RELAP3 is based upon the fundamental mass, energy, and momentum conservation equations[a].

These equations are

(a) Mass conservation

$$\frac{\partial \rho}{\partial t} = - \vec{\nabla} \cdot (\rho \vec{v}) \tag{A-1}$$

where

ρ = fluid density

and

$\vec{v}$ = local fluid velocity.

(b) Energy conservation

$$\frac{\partial (\rho e)}{\partial t} = - \vec{\nabla}.(\rho e \vec{v}) - \vec{\nabla}.\vec{q} - \vec{\nabla}.(p\vec{v}) - \vec{\nabla}.(\vec{\vec{\tau}}.\vec{v}) \tag{A-2}$$

where

$e = u + \frac{v^2}{2} + \Phi$

e = total specific energy

q = heat flux

p = pressure

τ = viscous stress tensor

u = thermodynamic internal energy

Φ = potential energy function.

(c) Momentum conservation

$$\frac{\partial \rho \vec{v}}{\partial t} = - \vec{\nabla}.(\rho \vec{v}\vec{v}) - \vec{\nabla} p - \vec{\nabla}.\vec{\vec{\tau}} + \rho \vec{g} \tag{A-3}$$

where

g = gravitional acceleration constant.

General assumptions include

(a) Stationary control volumes

---

[a] Several excellent references are available on thermal hydraulics; one being by R. B. Bird, W.E. Stewart, and E.N. Lightfoot, Transport Phenomena, John Wiley and Sons, Inc., New York, 1960.

(b) Axisymmetric, one-dimensional flow

(c) Negligible body forces (except gravity).

Integrating the mass equation over a fixed volume and applying the "Gauss Divergence Theorem" gives

$$\frac{d}{dt}\int_{\nu} \rho d\nu = -\int_{s} \rho\vec{v}\cdot d\vec{s} \qquad \text{(A-4)}$$

$$\frac{dM_i}{dt} = \sum W_{ij} \qquad \text{(A-5)}$$

where

M_i = total mass in volume i

and

W_{ij} = mass flow rate into volume i through junction j (surface area j).

For the energy equation, frictional, kinetic, and potential energy effects are assumed negligible.

Then using

$$\frac{\partial \rho u}{\partial t} = -\vec{\nabla}\cdot(\rho h\vec{v} - \vec{q}) \qquad \text{(A-6)}$$

where

h = enthalpy

and integrating over volume ν_i gives

$$\frac{dU_i}{dt} = \sum W_{ij} h_{ij} + Q_i \qquad \text{(A-7)}$$

where

U_i = thermodynamic energy in volume ν_i

h_{ij} = enthalpy content of fluid moving through junction j

Q_i = rate of energy transferred through surface s_i.

Restricting the momentum equation to one-dimensional flow and integrating over ν_i gives

$$\frac{d}{dt}\int_{\nu_i} \rho\vec{v}d\nu = -\int_{s_i} \vec{v}(\rho\vec{v}\cdot d\vec{s}) - \int_{s_i} \vec{\vec{\tau}}\cdot d\vec{s} - \int_{s_i} p d\vec{s} + \int \rho\vec{g} d\nu \ . \qquad \text{(A-8)}$$

For the friction term, the pressure losses are assumed proportional to v^2. If the volume ν_1 is a simple tube with no area changes, then in English units

$$\frac{1}{144 g_c} \frac{\ell_i}{A_i} \frac{d\overline{W}_i}{dt} = - \frac{k \overline{W}_i |\overline{W}_i|}{\rho_i} + P_{ij} - P_{ik} + (\Delta\rho_j)(\Delta z_j) \quad \text{(A-9)}$$

where

g_c = gravitational conversion constant

ℓ_i = length of pipe

A_i = pipe cross-sectional area

W_i = average flow

k_i = RELAP3 friction coefficient

P_{ij} = inlet pressure

P_{ik} = outlet pressure

$\Delta\rho_j$ = density change across junction j

Δz_j = elevation change between centers of mass across junction j.

For a straight section of pipe, the friction term k is directly related to the Fanning friction factor for a single pipe:

$$k = \frac{f A_w}{2(144 g_c) A^3} \quad \text{(single pipe)} \quad \text{(A-10)}$$

where

f = Fanning friction factor

A_w = wetted wall area

A = cross-sectional area for flow.

For a single flow path with several area changes, the ratio of control volume length to flow area is

$$\frac{\ell}{A} = \sum_{i=1}^{N} \frac{\ell_i}{A_i} \quad \text{(A-11)}$$

and momentum flux terms are included as a part of the friction term k. This last simplification is correct only when the flow is unidirectional during the transient. In complex loop systems, the best way to define k is from a steady state condition in which

$$k_i = \frac{[P_{ik} - P_{ij} - (\Delta\rho_j)(\Delta z_j)]\rho_i}{W_i^2} \quad . \quad \text{(A-12)}$$

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APPENDIX B

CHOICE OF TIME STEP SIZE

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APPENDIX B

CHOICE OF TIME STEP SIZE

The numerical advancement technique used in RELAP3 is a forward finite difference approximation with each conservation equation advanced independently for a small time step Δt. Since the same time step is used for all volumes and junctions, the overall stability of the solution is controlled by the most sensitive portion of the system.

For an isolated volume and junction the Helmholtz frequency f is

$$f = \frac{\omega}{2\pi} = \frac{a}{2\pi}\sqrt{\frac{A}{V\ell}} \qquad \text{(B-1)}$$

where

ω = angular velocity

a = velocity of sound

V = volume of fluid

ℓ/A = path "inertia"

The time step size must be smaller than the natural oscillation period, preferably by at least a factor of 5 to 10. When the time step size approaches the natural period, numeric instabilities can result. Thus, an appropriate time step is

$$\Delta t = \frac{2\pi}{na}\sqrt{V\ell/A} \qquad \text{(B-2)}$$

where

n = 5 to 10.

These values of Δt are only approximate and could be slightly larger in some cases. These relations show that the small volumes and inertias control the choice of time steps. If a single vessel with a total volume V_T, length ℓ_T, and cross section A (where $V_T = \ell_T A$) is divided into m equal subvolumes, the time step size becomes

$$\Delta t \approx \left(\frac{2\pi}{na}\right)\frac{\ell_T}{m} \quad . \qquad \text{(B-3)}$$

The computer time required goes up as the square of the number of volumes in this example of equal subvolumes because the number of time steps and the number of volumes increase.

Other types of numeric instability due to mass and energy flow are possible, but normally the frequencies associated with these instabilities are lower than the Helmholtz frequencies. Under certain conditions of extremely high flow, small mass content, or small energy content within a volume, the fluid within a large time step can be completely replaced. Time steps for mass and energy should be chosen such that

$$\Delta t_m < \frac{M}{\Sigma|W|} \qquad \text{(B-4)}$$

$$\Delta t_u < \frac{U}{\Sigma|Wh|}$$

where

W = flow

M = mass in volume

h = enthalpy

U = total internal energy of volume.

Nonlinearities, especially the rapid change in density that can occur at junctions, present instability problems. Since previous values of density are used to advance the equations, the possibility exists of exhausting a volume of all material near the end of a blowdown transient. The reverse problem of over-filling a volume and drastically increasing the pressure is also possible.

Currently the only method of verifying solution accuracy is to rerun the problem with smaller time steps. Numerical variations in solutions with different time steps will exist, but are generally negligible. Results of a RELAP3 calculation are dependent upon the computer word length. Single precision on the IBM 360 is not recommended except for problems involving very few time advancements (~ 1000). The EBCDIC punched source deck for the IBM 360 uses double precision (64 bit words) to avoid excessive roundoff.

Different computers and different time step sizes also affect the solution when control parameters are reached asymptotically. For example, blowdown problems are normally terminated at a chosen pressure, but since final pressures are usually approached asymptotically, the computer time and the number of total time advancements may show significant variation. From an engineering viewpoint these variations are considered negligible.

APPENDIX C

INPUT DEFINITIONS

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APPENDIX C

INPUT DEFINITIONS

CONTROL CARDS FOR THE NRTS SYSTEM

(1) // JOB

This card contains accounting information.

(2) //XQT EXEC RELAP3, options

The options are given in any order by using keywords. No blanks are allowed except after a comma on a card to be continued or after all wanted options have been selected. The keywords used and the choices to be made are

XTIME = the CPU time in minutes (10 seconds, if omitted).

PAGES = the approximate number of full pages to be printed (20, if omitted).

TPOUT = ________ (data set name out) The data set name should include the user's initials plus a maximum of five alphameric characters but no blanks. Big OS will tell which tape is saved. If TPOUT is omitted, the default is NULLFILE. In this case, calls to the tape writing routines internal to RELAP3 will be satisfied, but no output tape will be created.

TPIN = ________ (data set name in) This data set name must be one used on a previous TPOUT option. If TPIN is omitted, the default is NULLFILE. If TPIN is included, turning in an appropriate LIBRARY VOLUME NEEDED card will help avoid excessive wait time.

SER = T9XXXX, where XXXX is the serial number of the tape corresponding to TPIN.

(3) //X.SYSIN DD *

This card may be omitted without causing difficulties

(4) (following all data)/*

This card is one of the pink terminator cards.

RELAP3 INPUT DEFINITIONS

(1) Title (one card)

FORMAT: 18A4,2A4

At least one nonblank character must appear somewhere in columns 1-72.

(2) Problem Dimensions (one card)

FORMAT: 15I3,E10.6,17X,2A4

N1	LDMP	=	Tape control (only one tape may be generated during a job) (0 = no tape used) (-1 = store restart information on FORTRAN Unit 4) (-2 = store restart and plot information on FORTRAN Unit 4) (-3 = edit the tape on FORTRAN Unit 3) (N = restart at page number N using the tape on FORTRAN Unit 3) (-3 ≤ LDMP ≤ 999)
N2	NEDI	=	Number of minor edit variables desired (0 ≤ NEDI ≤ 9)
N3	NTC	=	Time step card count (1 ≤ NTC ≤ 20)
N4	NTR	=	Number of trip control cards (1 ≤ NTR ≤ 20)
N5	NVOL	=	Number of control volumes (1 ≤ NVOL ≤ 20)
N6	NBUB	=	Number of bubble parameter sets. A set may be used in several volumes (0 ≤ NBUB ≤ 5)
N7	NJUN	=	Number of junctions or flow paths (1 ≤ NJUN ≤ 50)
N8	NPMPC	=	Pump curve count. A curve may be used for several junctions (0 ≤ NPMPC ≤ 5)
N9	NCKV	=	Number of check valve types. A parameter set may be used for several junctions (0 ≤ NCKV ≤ 5)
N10	NLK	=	Number of normalized-area vs time curves. May be used many times (0 ≤ NLK ≤ 5)
N11	NFLL	=	Number of fill system curves. May be used many times (0 ≤ NFLL ≤ 5)
N12	NOCOR	=	Number of core regions (0 ≤ NOCOR ≤ 20)

N13	NMTL	=	Number of sets of rod geometry (1 ≤ NMTL ≤ 20) if NOCOR ≥ 1, (0 ≤ NMTL ≤ 20) if NOCOR = 0,
N14	NHTX	=	Number of heat exchanger data sets (0 ≤ NHTX ≤ 20)
N15	NKC	=	Number of thermal property tables (NKC ≤ 6)
X1	POWER	=	Reactor thermal power in megawatts (0. ≤ POWER)

(3) Edit Variable Cards (one card if NEDI > 0)

FORMAT: 9(1X,A2,1X, I2),18X,2A4

```
1    2    4    5    7    8    10   11   12       6I-4 6I+1        73
|    | X1 |    | N1 |    | X2 |    | N2 | ------| NI |-BLANK-|  ID  |
```

(I=NEDI, number of minor edit variables desired)

XI = Minor edit variable symbol

NI = Region number of variable desired

Symbols of available minor edit variables

Symbol	Variable (with reference to volume)
AP	Average pressure
TM	Total mass
TE	Total energy
AT	Average temperature
AR	Average density
AH	Average enthalpy
AX	Average quality
BM	Bubble mass
ML	Mixture level
VF	Specific volume of fluid
VG	Specific volume of gas
HF	Specific enthalpy of fluid
HG	Specific enthalpy of gas
TS	Saturation temperature
PS	Saturation pressure
WM	Liquid mass (for these variables, NI is volume number 1 ≤ NI ≤ 20)

Symbol	Variable (with reference to volumes which are core volumes only)
WQ	Power into coolant
DF	DNB heat flux
SF	Surface heat flux
HC	Surface heat transfer coefficient
FT	Fuel element temperature

Symbol	Variable (with reference to volumes which are core volumes only)
CT	Center-line temperature
ST	Surface temperature
FQ	Power generated in fuel

(for these variables, NI is volume number $1 \leq NI \leq 20$)

Symbol	Variable (with reference to junctions)
JW	Junction flow
JH	Junction enthalpy
JX	Junction quality
LF	Leak force
TD	Total pressure differential
FD	Pressure differential due to friction
ED	Pressure differential due to elevation
PD	Pressure differential due to pump
AD	Pressure differential due to acceleration

(for these variables, NI is junction number $1 \leq NI \leq 50$)

Symbol	Variable (with reference to the system)
NQ	Normalized power
AE	Total energy added during transient
FE	Energy stored in fuel
LE	Total energy leaked
HE	Energy removed by heat exchanger
EB	Energy balance term
LM	Total mass leaked
MB	Mass balance
TR	Total reactivity
RV	Reactivity due to coolant voids
RW	Reactivity due to temperature changes in coolant
RF	Reactivity due to temperature changes in fuel

RC	Reactivity due to control rod changes
RD	Reactivity due to Doppler effect
PO	Power
HL	Total heat removed
RP	Reactor period (these variables are system variables, NI = 0)

ALL THE FOLLOWING CARDS USE THIS FORMAT: 4I3,6E10.6,2A4

```
 1    4    7    10   13   23       63    73
| N1 | N2 | N3 | N4 | X1 | ....... | X6 |  ID |
```

In all cases ID is any legitimate BCD field (EBCDIC for an IBM 360). If fewer than four integers are required, the remaining integer fields are left blank. If more cards are required to fill the tables, a similar format is used:

```
 1    4    7    10   13   23       63    73
|    |    |    |    | X7 | ....... | X12 |  ID|
```

etc

(4) Time Step Cards (NTC Cards)

N1	Number of time steps per minor edit (0 is interpreted as 1)
N2	Number of minor edits per major edit (0 is interpreted as 50)
N3	Number of major edits per restart tape edit (0 is interpreted as 20)
N4	Number of time steps per plot tape edit (0 is interpreted as N1)
X1	DELTM = Time step size (sec) $(0 < DELTM)$
X2	TLAST = End of current time step data (sec) $(TLAST_{i-1} < TLAST_i)$

(5) Trip Controls (NTR Cards)

N1 IDTR = Action to be taken
$(1 \leq IDTRP \leq 10)$
1 = End of problem)
2 = Open leaks
3 = Reactor scram and heat exchanger cutoff
4 = Trip pumps
5 = Start fills
6-10 = Open (or close) valves

N2	IDSIG	=	Signal being compared (1 ≤ | IDSIG | ≤ 9)	
			1 = Elapsed time	+ = HIGH, - = HIGH
			2 = Normalized reactor power	+ = HIGH, - = LOW
			3 = Reactor period	+ = LOW, - = LOW
			4 = Pressure (Vol. N3)	+ = HIGH, - = LOW
			5 = Mixture level (Vol. N3)	+ = HIGH, - = LOW
			6 = Liquid Level (Vol. N3)	+ = HIGH, - = LOW
			7 = Water temperature (Vol. N3)	+ = HIGH, - = LOW
			8 = Metal temperature (Core N3)	+ = HIGH, - = LOW
			9 = Flow (JUNC N3)	+ = HIGH, - = LOW
N3	IX1	=	Volume, or Junction Index	
N4	IX2	=	Optional volume index If IX2 > 0 a high ΔP or ΔT test is used (for IDSIG = 4, -4, 7, -7)	
X1	SETPT	=	Signal setpoint	
X2	DELAY	=	Delay time for initiation of action after reaching setpoint.	

NOTE: On first trip card, N1 = N2 = 1.

(6) Volume Data (NVOL cards)

N1	IBUB	=	Bubble data index (0 ≤ IBUB ≤ NBUB)
N2	IQIN	=	Heat generation index (-NHTX ≤ IQIN ≤ NOCOR)
	IQIN <0	=	Heat exchanger region (same index may be repeated if it refers to a time dependent heat exchanger only)
	IQIN > 0	=	Core region (same index may not be repeated)
X1	P	=	Pressure (psi) (0.1 ≤ P ≤ 3206.2)
X2	TEMP	=	Temperature (or quality of mixture) (°F or dimensionless) (0. ≤ TEMP ≤ 1. or 32. ≤ TEMP ≤ 5600.)
X3	V	=	Volume (ft^3) (0. < V)
X4	ZVOL	=	Volume height, bottom to top (ft) (0. < ZVOL)
X5	ZM	=	Mixture level (from bottom) (ft) (0. ≤ ZM ≤ ZVOL) Liquid phase: ZM = 0. is interpreted as ZM = ZVOL Liquid phase: 0. < ZM < ZVOL implies an air head over the liquid
X6	ELEV	=	Elevation at the bottom of the volume (ft)

(7) Bubble Data (NBUB cards)

X1	ALPH	=	Bubble gradient parameter (0. ≤ ALPH)
X2	VBUB	=	Bubble velocity (ft/sec) (0. ≤ VBUB)

NOTE: Set number 0
(ALPHA = 0., VBUB = 0.) is built-in.

(8) Junction Data (NJUN cards)

N1	IW1	=	Volume index at junction inlet (0 ≤ IW1 ≤ NVOL)
N2	IW2	=	Volume index at junction exit (0 ≤ IW2 ≤ NVOL)
N3	IPUMP	=	(a) (IW1 > 0, IW2 > 0) Pump Index (0 ≤ IPUMP ≤ NPMPC) (b) (IW1 > 0, IW2 ≤ 0) Leak Index (1 ≤ IPUMP ≤ NLK) (c) (IW1 ≤ 0, IW2 > 0) Fill Index (1 ≤ IPUMP ≤ NFLL) (d) (IW1 ≤ 0, IW2 ≤ 0) 0 (NULL JUNCTION)
N4	IVALVE	=	Valve index (0 ≤ |IVALVE| ≤ NCKV or 6 ≤ |IVALVE| ≤ 10) (a) IVALVE = 0, No valve (b) 1 ≤ IVALVE ≤ NCKV, Type 1 check valve (c) -NCKV ≤ IVALVE ≤ -1, Type 2 check valve (d) 6 ≤ IVALVE ≤10, Initially open valve which closes under trip control (IDTRP =IVALVE) (e) -10 ≤ IVALVE ≤ -6, Initially closed valve which opens trip control (IDTRP =IVALVE)
X1	WP	=	Flow (lb/sec)
X2	AJUN	=	Minimum flow area for choked flow calculation (ft^2) (0. ≤ AJUN) (a) IW1 > 0, IW2 > 0 0. implies no restriction (b) IW1 > 0, IW2 ≤ 0 0. is interpreted as 1. (c) IW1 ≤ 0, IW2 > 0 0. is interpreted as 1. (d) IW1 ≤ 0, IW2 ≤ 0 AJUN is ignored
X3	ZJUN	=	Junction elevation (ft) (a) IW1 > 0, IW2 > 0 ZJUN must lie between bottom and top of both inlet and exit volumes (b) IW1 > 0, IW2 ≤ 0 ZJUN must lie between bottom and top of inlet volume

(c) IW1 ≤ 0, IW2 > 0
ZJUN must lie between bottom and top of exit volume

(d) IW1 ≤ 0, IW2 ≤ 0
ZJUN is ignored

X4 INERTA = Junction effective L/A (ft^{-1})
(0. ≤ INERTA)
(a) IW1 > 0, IW2 > 0
INERTA > 0
(b) IW1 ≤ 0 or IW2 ≤ 0
INERTA ≥ 0

X5 KJUN = Friction coefficient (lb_f-sec^2/lb_m-ft^3-$in.^2$)
(0. ≤ KJUN)
(a) IW1 > 0, IW2 > 0
KJUN = 0. implies value computed from pressure drop data. Must give positive answer.
(b) IW1 ≤ 0
KJUN ignored beyond this point
(c) IW2 ≤ 0. If KJUN ≤ 0, then KJUN is calculated internally from the orifice equation, which is

$$KJUN = \frac{1}{144 g_c \ (2A^2)} ,$$

where A is the effective leak area, including a contraction coefficient.

(9) <u>Pump Coastdown</u> (one curve if NPMPC > 0)

N1	NPUCD	=	Number of data points (2 ≤ NPUCD ≤ 20)
X1	CAVCON	=	Cavitation constant
X2			Ignored
X3	$TIME_1$		(sec)
X4	$MULTIPLIER_1$		
X5	$TIME_2$		
X6	$MULTIPLIER_2$		
X7	$TIME_3$		
X8	$MULTIPLIER_3$		
	etc		

where $TIME_1 < TIME_2 < TIME_3 < \ldots$

(10) Pump Head (NPMPC curves)

N1	NPUMP	=	Number of data points ($2 \leq NPUMP \leq 20$)
N2	IX	=	Flow variable type $IX \leq 0$ flow in pounds per second $IX > 0$ flow in gallons per minute
N3	IY	=	Head variable type $IY \leq 0$ head in pounds per square inch $IY > 0$ head in feet

X1	SPUMP	=	Net positive suction head (ft)
X2	FPUMP	=	Shutdown friction coefficient (lb_f-sec^2/lb_m-ft^3-$in.^2$)
X3	$FLOW_1$		lb/sec or gal/min
X4	$HEAD_1$		lb/$in.^2$ or ft
X5	$FLOW_2$		
X6	$HEAD_2$		
	etc		

where $FLOW_1 < FLOW_2 < \ldots$

(11) Check Valves (NCKV cards)

X1	PCV	=	Back pressure for closure (lb/$in.^2$)
X2	CV1	=	Forward flow friction coefficient (lb_f-sec^2/lb_m-ft^3-$in.^2$)
X3	CV2	=	Reverse flow friction coefficient, valve open (lb_f-sec^2/lb_m-ft^3-$in.^2$)
X4	CV3	=	Reverse flow friction coefficient, valve closed (lb_f-sec^2/lb_m-ft^3-$in.^2$)

(12) Leak Sets (NLK curves)

N1	NAREA	=	Number of data points (2 < NAREA < 20)
N2	ICHOKE	=	Leak type ICHOKE ≤ 0, no liquid phase choking ICHOKE > 0, liquid phase choking allowed
X1	SINK	=	Sink pressure (lb/$in.^2$)
X2	CONCO	=	Contraction coefficient
X3	$TIME_1$		(sec)
X4	$AREA_1$		(ft^2, dimensionless if AJUN > 0)
X5	$TIME_2$		
X6	$AREA_2$		
	etc		

where $TIME_1 < TIME_2 < \ldots$

(13) Fill Sets (NFLL curves)

N1	NFILL	=	Number of data points (2 < NFILL < 20)
N2	IX		Independent variable IX = 0, time IX > 0, pressure ($P_{vol} + P_{grav}$) IX < 0, differential pressure ($P_{vol} + P_{grav} - P_{fill}$)

N3	IY	=	Flow type IY ≤ 0, flow in pounds per second per square foot IY > 0, flow in gallons per minute per square foot
X1	FILPRS	=	pressure in fill reservoir
X2	FILTEM	=	Temperature (or quality) in fill reservoir (°F)
X3	$TIME_1$ or $PRESSURE_2$ (sec or lb/in.^{2})		
X4	$FLOW_1$		(lb/sec or gal/min)
X5	$TIME_2$ or $PRESSURE_2$		
X6	$FLOW_2$		
	etc		
	where $TIME_1 < TIME_2 < \ldots$		
	or $PRESSURE_1 < PRESSURE_2 \ldots .$		

(14) Kinetics Constants (One card if NOCOR > 0)

N1	NODEL	=	Number of delayed groups NODEL ≤ 0, explicit time-power curve NODEL = 7, one prompt neutron group plus six groups of delayed neutrons NODEL = 18, one prompt neutron group plus six groups of delayed neutrons plus eleven delayed gamma emitters
X1	BOVL	=	β/L = Effective delayed neutron fraction over mean lifetime (sec^{-1})
X2	RHOIN	=	Initial reactivity ($)

(15) Scram Curve (One curve if NOCOR > 0)

N1	NSCR	=	Number of data points (2 ≤ NSCR ≤ 20)
X1	$TIME_1$		(sec)
X2	$REACTIVITY_1$ or NORMALIZED POWER ($ or dimensionless)		
X3	$TIME_2$		
X4	$REACTIVITY_2$ or NORMALIZED POWER		
	etc		
	where $TIME_1 < TIME_2 < \ldots$		

(16) Doppler Curve (One curve if NOCOR > 0 and NODEL > 0)

N1	NDOP	=	Number of data points (2 ≤ NDOP ≤ 20)
X1	$TEMPERATURE_1$		(°F)
X2	$REACTIVITY_1$		($)

X3	$TEMPERATURE_2$		
X4	$REACTIVITY_2$		
	etc		

where $TEMPERATURE_1 < TEMPERATURE_2 < \ldots$

(17) Reactivity Coefficients (NOCOR cards if NODEL > 0)

X1	ALPHVW	=	Water void coefficient (\$/%void)
X2	ALPHTW	=	Water temperature coefficient (\$/°F)
X3	ALPHTM	=	Metal temperature coefficient (\$/°F)
X4	DOPWT	=	Doppler weighting fraction

(18) Channel Data (NOCOR cards)

N1	IMTL	=	Rod geometry index ($1 \le IMTL \le NMTL$)
N2	$NODT_1$	=	Node numbers at which temperatures are to be printed
N3	$NODT_2$		
N4	$NODT_3$		
X1	QFRAC	=	Fraction of total power generated in core volume
X2	ARHT	=	Total heat transfer area in core volume (ft^2)
X3	CHNL	=	Channel length (ft)
X4	HDIAM	=	Hydraulic diameter (ft)
X5	HEDIAM	=	Heated equivalent diameter (ft)

(19) Rod Geometry Constants (NMTL sets)

First card in a set:

N1	NR	=	Number of regions in rod and number of cards in this set ($1 \le NR \le 6$)
N2	IKCW	=	Thermal property table index for region ($1 \le IKCW \le NKC$)
N3	NDRW	=	Number of space steps in region
X1	DRW	=	Region space step size (ft)
X2	RHOIW	=	Region material density (lb/ft^3)
X3	POFRW	=	Power fraction for region

Successive cards in the set:

N1	NR	=	blank or 0

All other fields are the same as in the first card of the set.

For each set, $\Sigma NDRW < 31$.

(20) Thermal Property Tables (NKC sets)

One set:

N1	NKP	=	Number of points in thermal conductivity table ($2 \le NKP \le 20$)
X1	TPK_1	=	$Temperature_1$ (°F)
X2	TPK_2	=	Thermal $Conductivity_1$ (Btu/ft - hr-°F)
X3	TPK_3	=	$Temperature_2$
X4	TPK_4	=	Thermal $Conductivity_2$

etc, until NKP points are read,

where $Temperature_1 < Temperature_2 < \ldots$

N1	NCP	=	Number of points in heat capacity table ($2 \le NCP \le 20$)
X1	TPC_1	=	$Temperature_1$ (°F)
X2	TPC_2	=	Heat $capacity_1$ (Btu/lb-°F)
X3	TPC_3	=	$Temperature_2$
X4	TPC_4	=	Heat $capacity_2$

etc, until NCP points are read,

where $Temperature_1 < Temperature_2 < \ldots$

(21) Heat Exchanger Data (NHTX sets)

N1	IHTX	=	Number of data points, 0 meaning flow and temperature dependent. ($IHTX = 0$ or $2 \le IHTX \le 20$)
(A)	IHTX	=	0
X1		=	Fraction of power removed by heat exchanger
X2	TSEC	=	Secondary side temperature (°F)
X3	HTXCO	=	Heat exchanger coefficient (Btu/hr-°F). (Not used if heat exchanger starts with a nonzero flow)

(B) $IHTX > 0$

X1 $TIME_1$ (sec)

X2 NORMALIZED $POWER_1$

X3 $TIME_2$

X4 NORMALIZED $POWER_2$

etc

where $TIME_1 \leqslant TIME_2 < \ldots$

(22) End Card (1 card, optional)

Columns 1 through 72 blank

Omit this card if another problem follows.

INPUT FOR RESTARTING

An old restart data tape to be used must be mounted on FORTRAN Unit 3 and a blank tape must be mounted on Unit 4. The normal RELAP3 program is used with the following input definitions.

(1) Title (one card)

FORMAT: 18A4,2A4

The first 12 characters of the new title must be identical to the title of the problem which is to be restarted.

(2) Problem Dimensions (one card)

FORMAT: 15I3,E10.6,17X,2A4

N1	LDMP	=	N, the page number of the old problem where restart is to begin ($1 \leq LDMP \leq 999$)
N2	NEDI	=	Number of minor edit variables ($0 \leq NEDI \leq 9$)
N3	NTC	=	Time step card count ($1 \leq NTC \leq 20$)
N4	NTR	=	Number of trip control cards ($0 \leq NTR \leq 20$) NTR = 0 will cause the trip control values on the restart tape to be used, assuming chronological consistency.

Columns 13 through 72 are blank.

(3) Edit Variable Cards (one card if NEDI > 0)

The same rules apply as for the original problem. The quantities being edited on the new run need not have any relation to those of the original run.

(4) Time Step Cards (NTC cards)

The same rules apply as for the original problem. The time step sequence on the new run need not have any relation to that of the old run. No cards referring to problem times previous to the point of restart will be used, but they may be inputted.

(5) End Card (one card)

FORMAT: 20A4

Columns 1 through 72 are blank.

This card is omitted if another problem follows. A following problem must not use or generate a tape.

INPUT FOR TAPE EDITING

An old plot tape must be mounted on FORTRAN Unit 3. The normal RELAP3 program is used with the following input definitions.

(1) Title (one card)

FORMAT: 18A4,2A4

The first 12 characters of the new title must be identical to the title of the problem which is to be edited.

(2) Problem Dimensions (one card)

FORMAT: 15I3,E10.6,17X,2A4

N1	LDMP	=	-3
N2	NEDI	=	Number of minor edit variables ($0 \leq NEDI \leq 9$)
N3	NTC	=	Edit frequency control card count ($1 \leq NTC \leq 20$)

These are the only control integers required for a tape edit. The others will not be checked because the information will be retrieved from tape.

(3) Edit Variable Cards (one card if NEDI > 0)

The same rules apply as for the original problem. The quantities being edited need not have any relation to those of the original run.

(4) Edit Frequency Control Cards (NTC cards)

FORMAT: 2I3,6X,2E10.6,40X,2A4

N1	Number of plot records per minor edit (0 is interpreted as 1)		
N2	Number of minor edits per major edit (0 is interpreted as 50)		
X1	DELTM	=	Time step size (sec) ($0 < DELTM$)
X2	TLAST	=	End of current edit frequency control data ($TLAST_{i-1} < TLAST_i$)

(5) End Card (one card)

FORMAT: 20A4

Columns 1 through 72 are blank.

This card is omitted if another problem follows. A following problem cannot use a different input tape.

APPENDIX D

PROGRAM STRUCTURE

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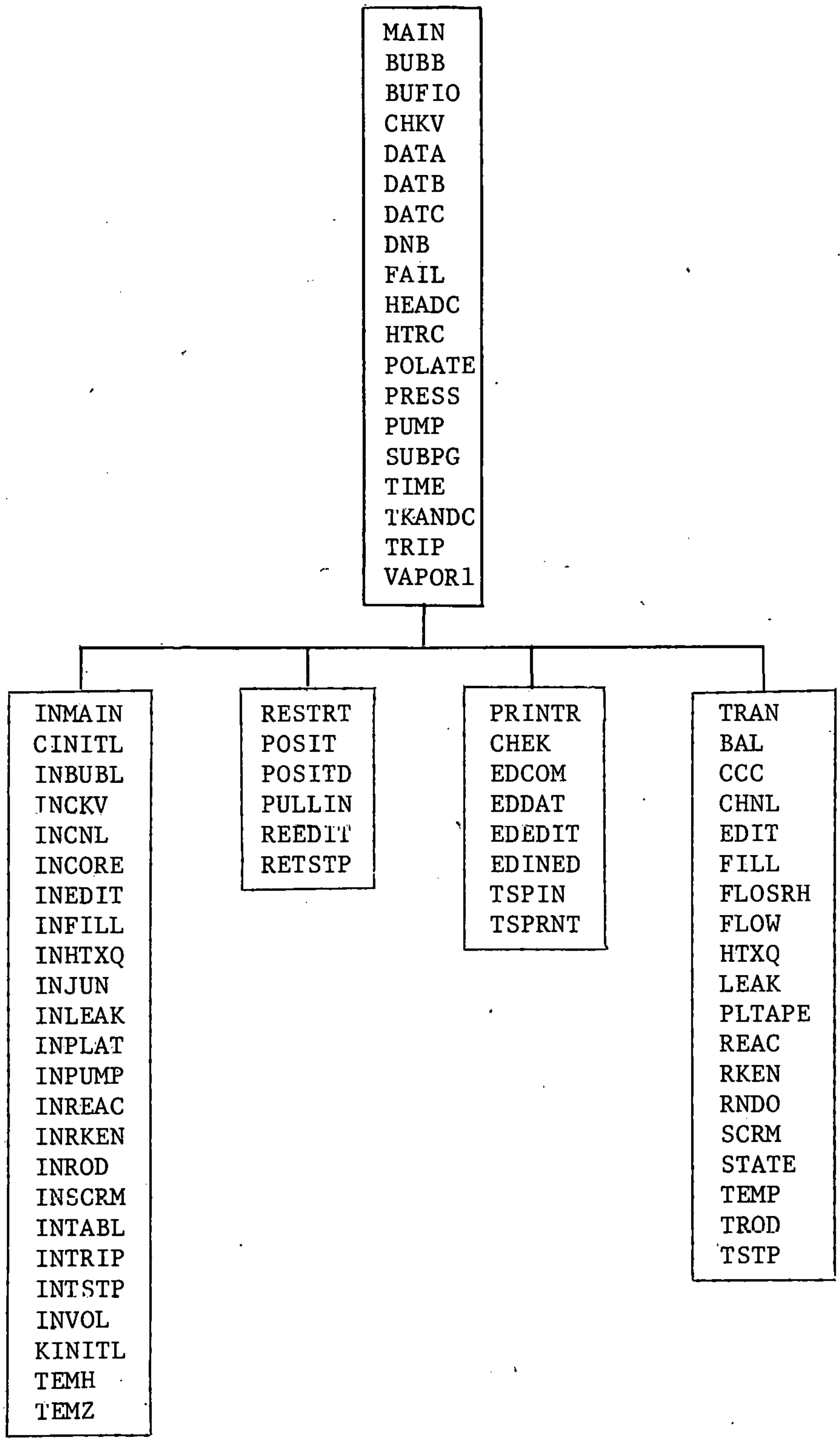
APPENDIX D

PROGRAM STRUCTURE

RELAY3 OVERLAY STRUCTURE



LABELED COMMON REFERENCES

COMMON BLOCK	MAIN	BUBB	BUFIO	CHKV	DATA	DATB	DATC	FAIL	HEADC	HTRC	POLATE	PRESS	PUMP	SUBPG	TIME	TKANDC	TRIP	VAPORI	INMAIN	CINTTL	INBUBL	INCKV	INCNL
BALED	x																			x			
BUBER	x	x							x									x					
BUBLER	x																	x			x		
CHKVER	x			x																		x	
CHNLER	x									x										x			x
CHNLES	x									x										x			x
DENC	x									x		x											
EDITER	x																						
EDITET	x						x																
ERRORZ	x						x																
FILLER	x																						
HEADER	x								x				x										
HEATC	x						x			x													
HEATED	x									x							x			x			
HEATV	x									x													x
HTXQER	x																						
IREKIN	x						x																
JUNED	x																						
JUNER	x			x					x	x			x				x						x
JUNES	x	x							x														
JUNET	x																						
LEAKC	x					x																	
LEEKER	x																						
LIMIT	x						x												x				
NUMBER	x	x		x			x		x	x	x	x	x		x	x	x	x		x	x	x	x
PAGEC	x						x							x									
PUMPER	x												x										
REACER	x																						
REACES	x																						
RKENER	x																						
RNDER	x																						
ROD	x									x										x			x
RODT	x															x				x			
RTHERM	x															x							
SCRMER	x																						
STATUS	x						x	x						x		x	x		x	x			x
TAPER	x						x																
TBLC	x				x				x			x											
TBLC2	x						x			x			x										
TRIPER	x																x						
TSTPER	x																						
VOLED	x																						
VOLER	x	x							x	x			x				x			x			x
VOLES1	x																						
VOLES2	x	x							x									x					
XUNITS	x						x		x	x			x							x			x

COMMON BLOCK	INCORE	INEDIT	INFILL	INHTXQ	INJUN	INLEAK	INPUMP	INREAC	INRKEN	INROD	INSCRM	INTABL	INTRIP	INTSTP	INVOL	KINITL	TEMH	TEMZ	RSTRT	POSIT	PULLIN	REEDIT	RETRIP	RETSTP
BALED				x											x						x			
BUBER															x						x			
BUBLER															x						x			
CHKVER																					x			
CHNLER	x									x											x			
CHNLES	x																				x			
DENC															x		x							
EDITER		x																				x		
EDITET		x																		x		x		
ERRORZ																	x							
FILLER			x																		x			
HEADER					x																x			
HEATC										x								x						
HEATED																x					x			
HEATV																					x			
HTXQER				x																	x			
IREKIN																								
JUNED					x																x			
JUNER	x		x	x	x																x			
JUNES					x										x						x			
JUNET					x																x			
LEAKC																								
LEEKER						x															x			
LIMIT					x					x									x	x	x			
NUMBER		x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x				x	x	x
PAGEC		x																	x	x	x	x		
PUMPER							x														x			
REACER								x								x					x			
REACES																x					x			
RKENER									x							x					x			
RNDER																x					x			
ROD										x								x			x			
RODT																		x		x	x			
RTHERM										x											x			
SCRMER											x					x					x			
STATUS				x									x				x		x	x	x		x	
TAPER																				x	x			
TBLC															x		x							
TBLC2																								
TRIPER													x								x		x	
TSTPER														x							x			x
VOLED															x						x			
VOLER	x			x	x										x						x			
VOLES1					x										x						x			
VOLES2															x						x			
XUNITS				x	x					x					x									

COMMON BLOCK	PRINTR	CHEK	EDCOM	EDDAT	EDEDIT	EDINED	TSPIN	TSPRNT	TRANS	BAL	CCC	CHNL	EDIT	FILL	FLOSRH	FLOW	HTXQ	LEAK	PLTAPE	REAC	RKEN	RNDO	SCRM	STATE	TEMP	TROD	TSTP
BALED									x	x		x	x				x		x								
BUBER																			x								
BUBLER										x									x								
CHKVER																			x								
CHNLER												x							x							x	
CHNLES										x		x	x						x							x	
DENC										x								x						x			
EDITER					x	x							x														
EDITET		x		x	x														x								
ERRORZ																x								x			
FILLER														x					x								
HEADER														x	x				x								
HEATC																x											
HEATED										x		x	x						x	x						x	
HEATV													x						x								
HTXQER													x				x		x								
IREKIN																					x						
JUNED										x			x		x				x								
JUNER			x		x					x		x	x	x	x		x		x								
JUNES										x			x		x				x								
JUNET													x		x				x								
LEAKC															x			x									
LEEKER															x				x								
LIMIT	x	x	x						x				x						x								
NUMBER					x	x	x	x		x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	x
PAGEC		x		x															x								
PUMPER																			x								
REACER																			x	x							
REACES													x						x	x							
RKENER																			x		x						
RNDER													x						x		x	x					
ROD												x							x							x	
RODT												x	x						x						x	x	
RTHERM																			x								
SCRMER																			x				x				
STATUS	x								x	x		x	x						x		x			x		x	x
TAPER		x	x	x															x								
TBLC										x														x			
TBLC2																		x									
TRIPER													x						x								
TSTPER							x	x					x						x								x
VOLED										x			x						x								
VOLER			x		x					x		x	x	x	x		x		x							x	
VOLES1										x			x		x				x								
VOLES2										x			x						x								
XUNITS										x		x		x	x		x							x		x	

APPENDIX E

SUBROUTINE DESCRIPTIONS

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APPENDIX E

SUBROUTINE DESCRIPTIONS

BAL

Performs the mass and energy balance for all volumes and then obtains new pressures.

Each junction is examined and then mass and energy contents of the inlet and outlet volumes are advanced. Each volume is tested for direct heat addition or removal, the corresponding energy transfer routines are called, subroutine STATE is entered to obtain a new average pressure, and mixture conditions are then calculated.

BUBB

Calculates both the enthalpy and a bubble indicator at the junction height within a volume.

BUFIO

Is an NRTS package to allow tape handling in an overlapped mode and with non-FORTRAN records. A FORTRAN routine is available.

CCC

Calculates some exponential relationships needed by the reactor kinetics routine (RKEN).

CHEK

Positions a plot tape to the first record for the tape edit routine.

CHKV

Either generates a friction coefficient for a check valve or controls an on-off valve using TRIP.

CHNALF

Replaces the IBM supplied CHAIN routine for the IBM 7044 so that chaining will function as the manual describes.

CHNL

Calls the core heat transfer routine (TROD), and calculates the energy in the fuel for a core volume.

CINITL

Performs the steady state initialization for all core volumes.

For each core volume water properties are found. With this information and the steady state heat fluxes, HTRZ and TEMZ are called to obtain the initial surface heat transfer coefficient and the initial radial temperature distribution.

DATA

Is a block data subroutine containing thermodynamic properties at saturation and the steam tables.

DATB

Is a block data subroutine containing the leak tables.

DATC

Is a block data subroutine containing physical properties at saturation, RELAP3 array limits, and miscellaneous numerical constants.

EDCOM

Reads from the plot tape the integers which are needed for the tape edit routine.

EDDAT

Reads a plot record from tape for the tape edit routine.

EDEDIT

Formats and prints output in the tape edit routine.

EDINED

Reads an edit control card for the tape edit routine.

EDIT

Will, as required by the time step cards, list a few variables frequently, a complete edit less frequently, and call PLTAPE to save data.

FAIL

Sets a flag to indicate the calculation has failed.

FILL

Provides the junction flow and enthalpy for a fill system type of junction.

FLOSRH

Performs the junction flow calculation.

Inlet pressure, output pressure, junction water properties, pump head, and check valve friction factor are obtained. Inertial and choked flow routines (FLOW and LEAK) are called and a choice made between these two flows. For a fill system a special routine (FILL) is invoked.

FLOW

Performs the inertial flow iteration for a junction.

HEADC

Calculates all junction gravity heads by assuming that the volume pressure obtained from thermodynamic relationships occurs at the center of gravity.

HTRC

Calculates critical heat flux, heat transfer mode, and heat transfer coefficient at the fuel pin surface.

HTXQ

Calculates the energy removed by a heat exchanger, allowing a choice between a flow-temperature dependence or an input curve of removal rate versus time.

INBUBL

Processes bubble data cards.

INCKV

Processes check valve data cards.

INCNL

Processes channel heat transfer cards.

INCORE

Calls, in succession, the reactor kinetics input (IREKIN), the core heat transfer input (INCNL and INRØD), steady state core heat transfer initialization (CINITL), and reactor kinetics initialization (KINITL).

INEDIT

Processes a card describing the variables to be monitored most often.

INFILL

Processes data describing the fill systems.

INHTXQ

Processes data describing the heat exchangers.

INJUN

Processes junction description cards and sets up initial conditions for all junctions.

After the junction description cards are read, pump and check valve input routines (INPUMP and INCKV) are called. Junction water properties, pump heads, and check valve friction coefficients are then obtained. Finally, junction friction coefficients required to produce steady state are calculated and checked. A negative friction coefficient will cause an error indication.

INMAIN

Calls in succession all of the input data processing and initial conditions routines.

INLEAK

Processes data describing the leaks.

INPUMP

Processes pump coastdown data and pump characteristics.

INREAC

Processes a set of Doppler data and then reactivity coefficient cards.

INRKEN

Processes the reactor kinetics data and then calls the scram and reactivity data processing routines (INSCRAM and INREAC).

INROD

Processes data describing the fuel rods; reads thermal property tables for the rod materials.

INSCRM

Processes the reactor scram curve.

INTABL

Is called by all input processing routines which require tabular data running beyond a single card.

INTRIP

Processes the trip parameter cards.

INTSTP

Processes the time step control cards.

INVOL

Processes volume description cards and sets up initial conditions for all volumes.

After the volume description cards are read, water properties are obtained. Then masses and energy contents are computed, and finally liquid and mixture levels are set up.

KINITL

Initializes the common areas associated with the reactor kinetics routine and calculates the beginning-of-problem reactivity feedback to be used as a base for perturbations.

LEAK

Performs the choked flow calculations by a double interpolation of the leak tables contained in a block data subroutine (DATB).

MAIN

Processes the title card and the integer data and controls the calling of the input, restart, transient, tape editing, and termination segments of the program.

PLTAPE

Saves all data for possible restarting. May also save editable variables for later re-edit or plot.

POLATE

Is a linear interpolation routine used by many other routines.

POSIT

Positions a restart tape to the correct page.

PRESS

Is the steam table interpolation routine.

Given a pressure and a pressure index, the saturation properties are obtained by a linear interpolation. If an enthalpy and an enthalpy index are also given, a double interpolation for specific volume and temperature are performed and the indices updated.

PRINTR

Controls the flow of tape editing routines.

PULLIN

Restores all of the labeled common blocks to their old values.

PUMP

Obtains a pump pressure head from the flow-head table, the coastdown curve, and the cavitation equation.

REAC

Adds the sum of the reactivity feedback terms to the reactivity obtained from the scram curve (SCRM).

REEDIT

Reads a new edit control card.

RETSTP

Reads a new set of time step control cards.

RKEN

Supplies the normalized reactor power level.

In the case of a power-time type of problem, the normalized power is obtained directly from the scram curve (SCRM).

For a kinetics type of run, the reactivity summing routine (REAC) is called and then a Runge-Kutta advancement is performed according to the reactor kinetics equations.

RNDO

Is a routine called to avoid round-off error in Runge-Kutta advancement of the reactor kinetics equations (RKEN).

RESTRT

Controls the flow of the restart procedure.

Routines which are called include an edit control input (REEDIT), a time step input (RETSTP), a tape positioning routine (POSIT), and the restoring routine (PULLIN).

SCRM

Obtains the current value of reactivity (or normalized power) from the scram table.

STATE

Calculates pressure and enthalpy, when given specific volume and internal energy, by using the steam tables directly to get to the proper interval and then iterating through PRESS.

SUBPG

Ejects a sheet of output and puts problem title, elapsed computer time, and page number at the top of the next page.

TEMH

Calculates enthalpy and specific volume when given pressure and temperature (or quality) by using the steam tables directly to get to the proper interval and then iterating through PRESS.

TEMP

Calculates transient fuel pin temperatures at radial modes, given heat generation rate, surface heat transfer coefficient, bulk coolant temperatures, and old time step value of surface heat flux.

TEMZ

Calculates initial fuel pin temperatures at radial modes, given heat generation rate, surface heat transfer coefficient, bulk coolant temperature, and steady state surface heat flux.

TIME

Obtains the elapsed computer time in seconds.

TKANDC

Interpolates, from the tables of thermal conductivity and heat capacity, values for the nodal pin temperatures. TKANDC is called by both TEMZ and TEMP.

TRAN

Controls the flow of the transient calculations.

Routines which are called by TRANS include the time step size and edit control (TSTP), the volume mass and energy balance (BAL), the flow calculation (FLOSRH), the reactor power calculation (RKEN), and the editing package (EDIT). Errors during one of these routines are detected after the return and will cause termination of the problem.

TRIP

Generates signals to end the problem, to open the leak junctions, to initiate a reactor scram, to shut down the pump, to start the fill systems, or to open or close a valve.

TROD

Is the core heat transfer routine. TROD calls HTRC and TEMP in an iterative procedure, until a convergence on the pin surface heat transfer coefficient is obtained.

TSPIN

Processes the edit frequency control cards for the tape edit routine.

TSPRNT

Determines the edit requirements during the tape edit routine.

TSTP

Obtains the new time step size and sets the edit control parameters.

VAPOR1

Sets up the coefficients needed for the height dependent bubble density calculation (BUBB).

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APPENDIX F

RELAP3 FLOW CHARTS

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APPENDIX F

RELAP3 FLOW CHARTS

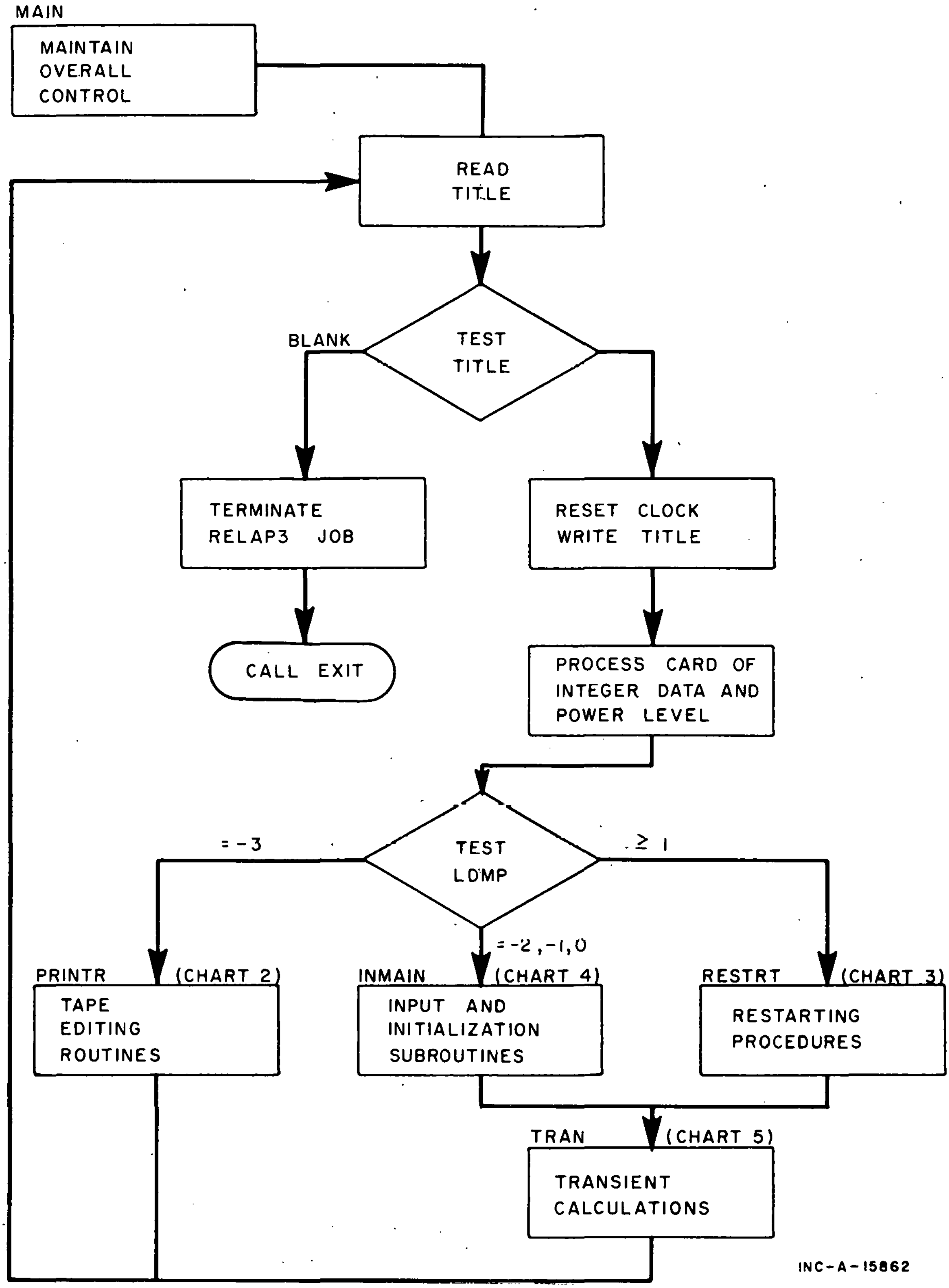

CHART 1, PROGRAM FLOW.

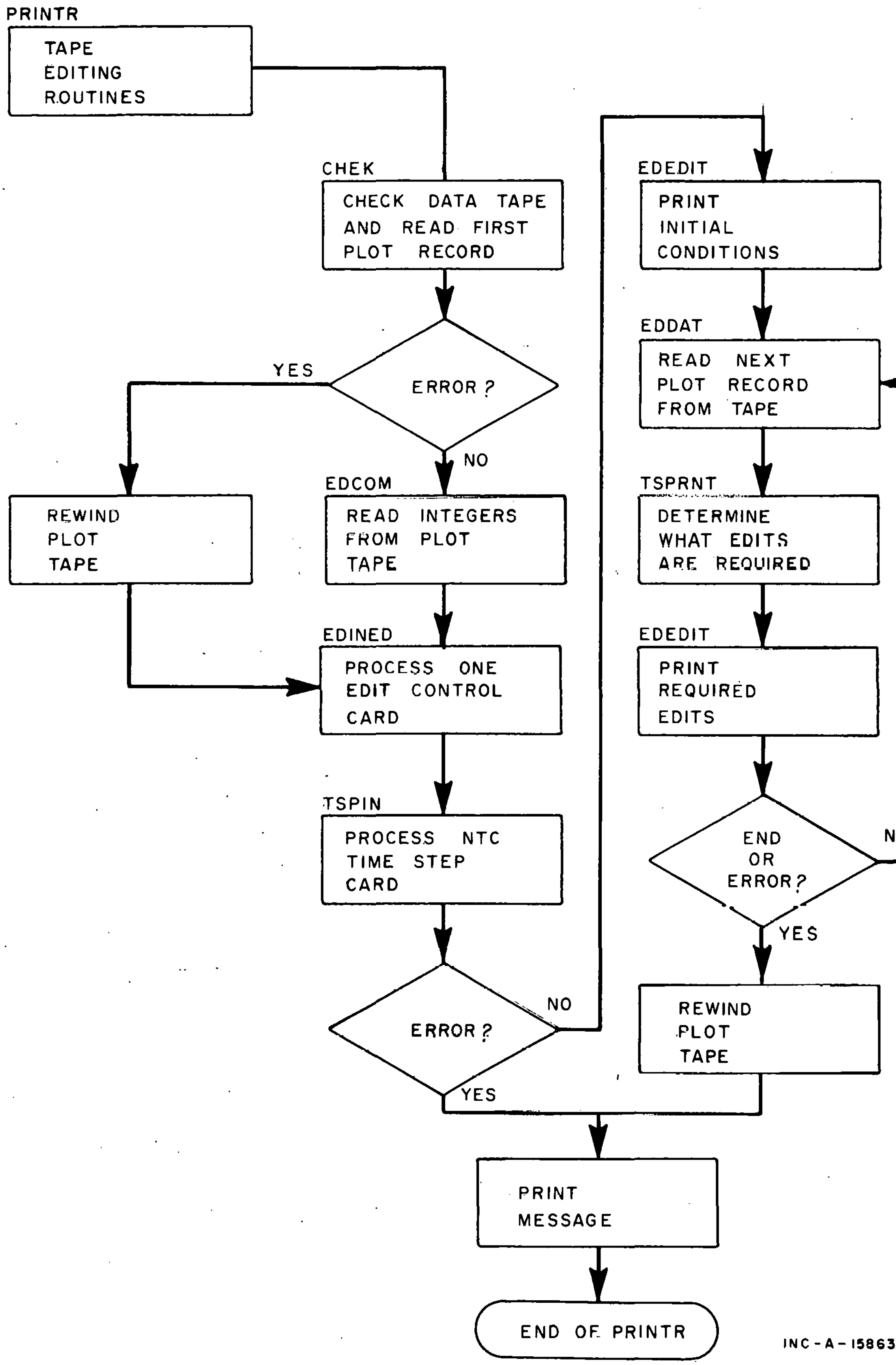

CHART 2. TAPE EDITING.

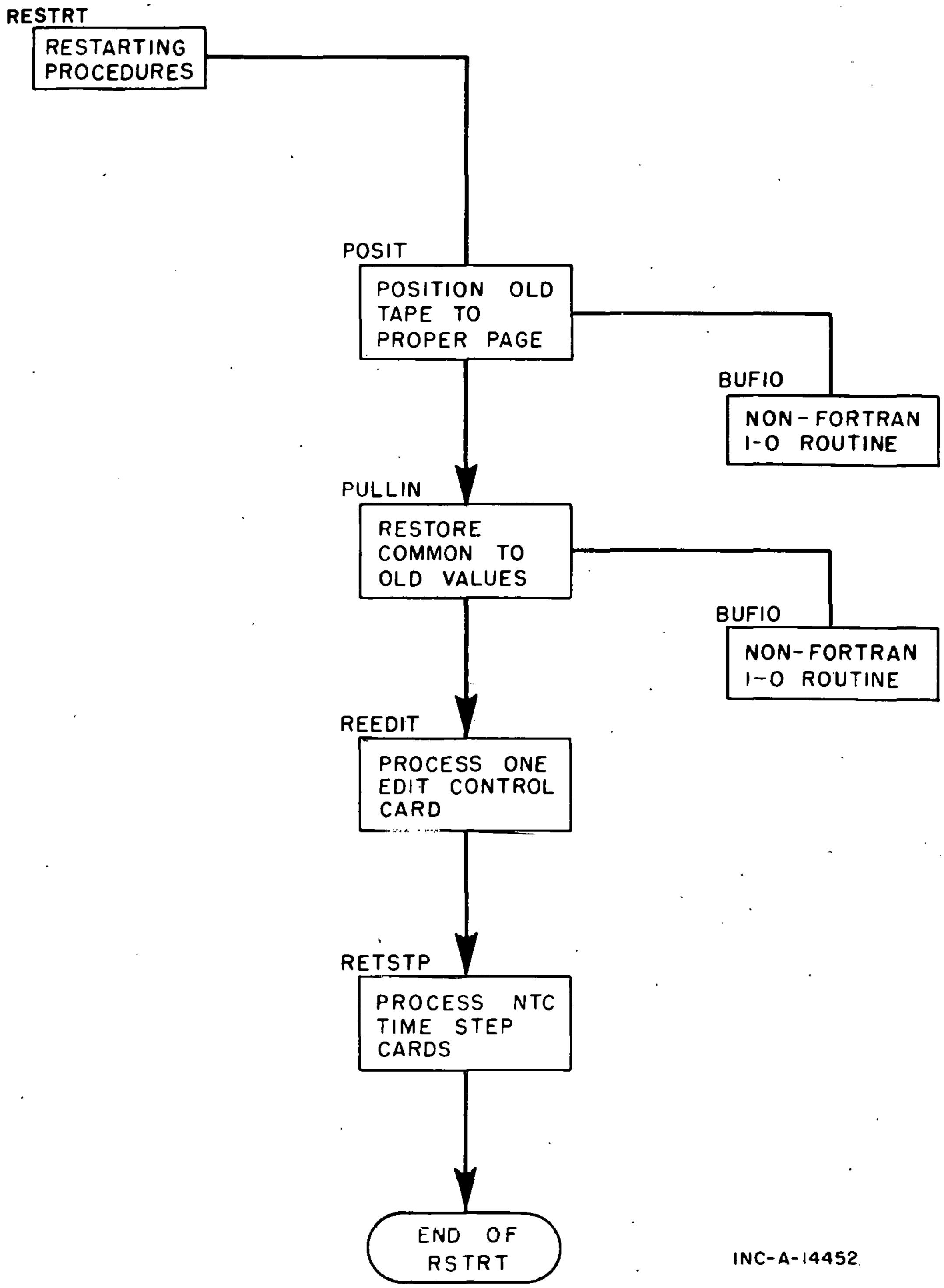

CHART 3. RESTARTING LINK.

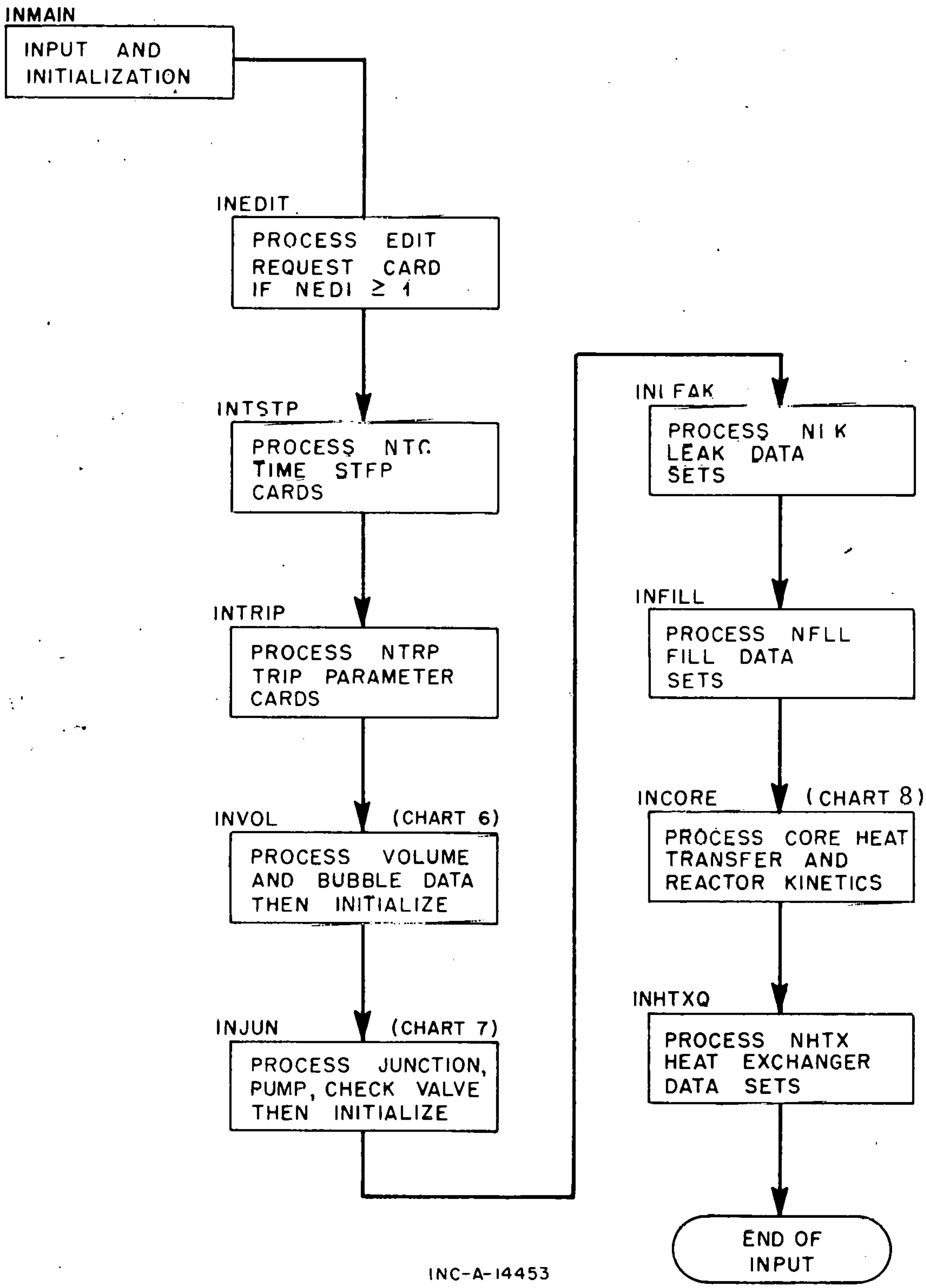

CHART 4. INPUT LINK.

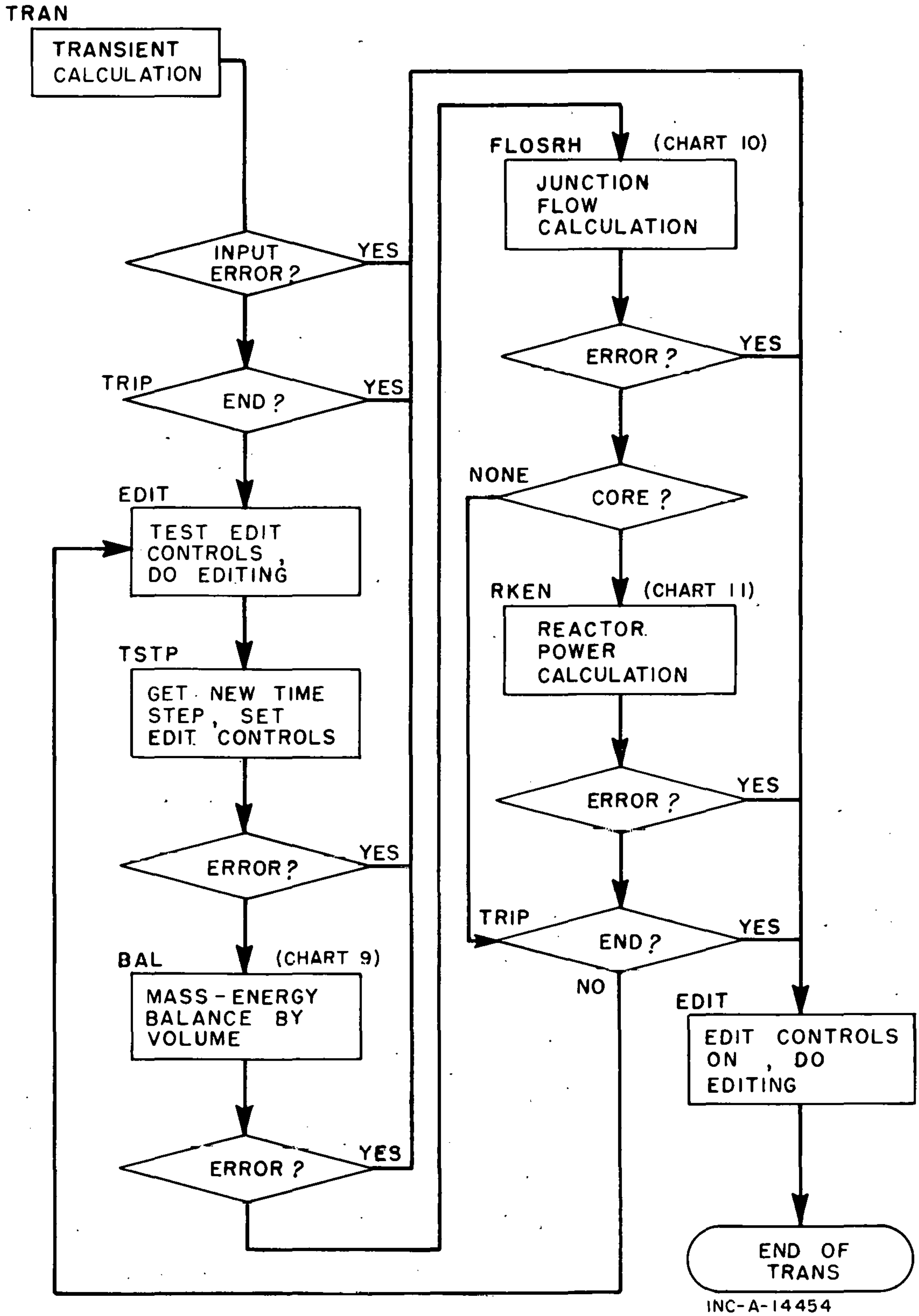

CHART 5. TRANSIENT LINK.

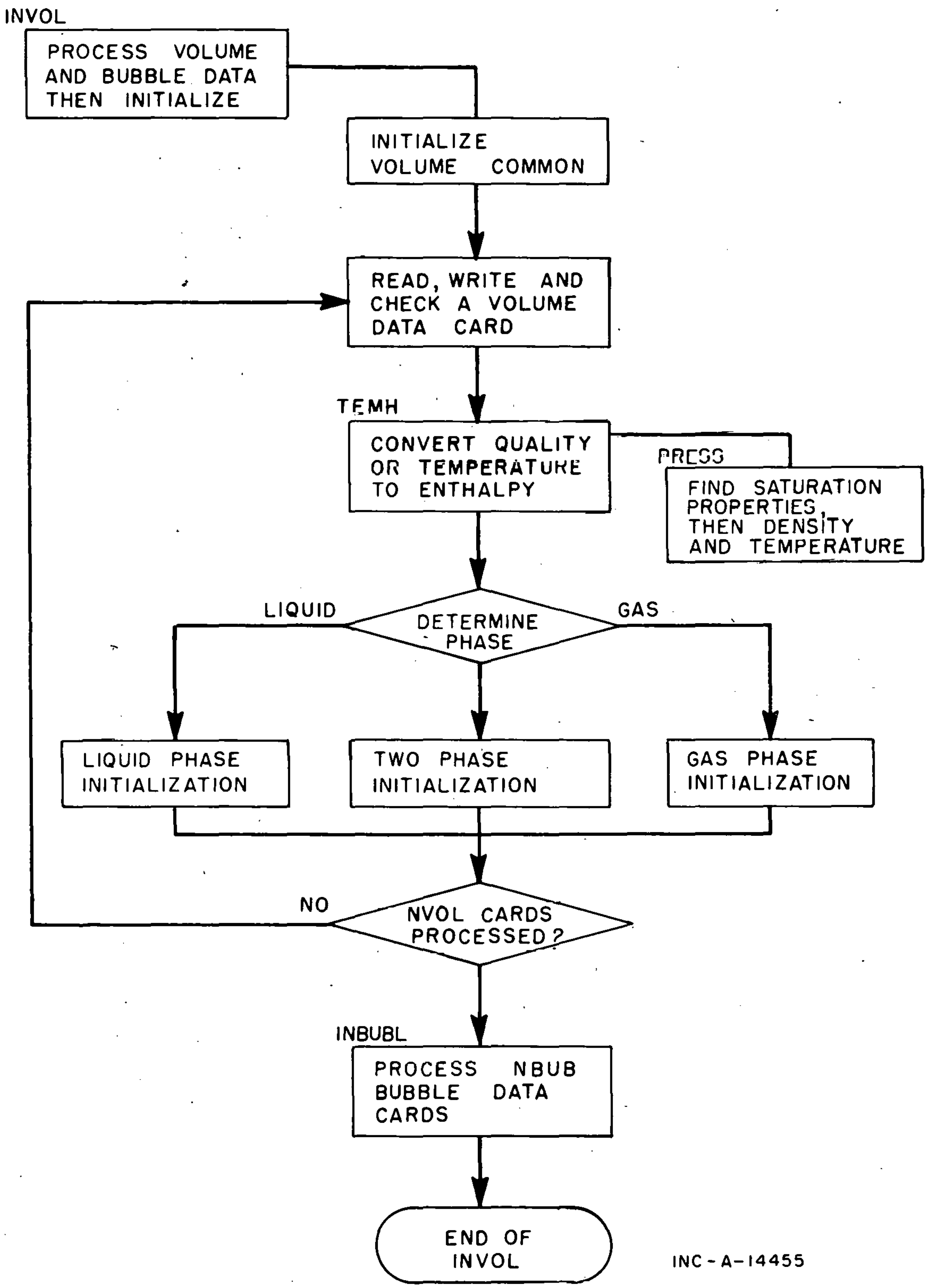

CHART 6. VOLUME DATA.

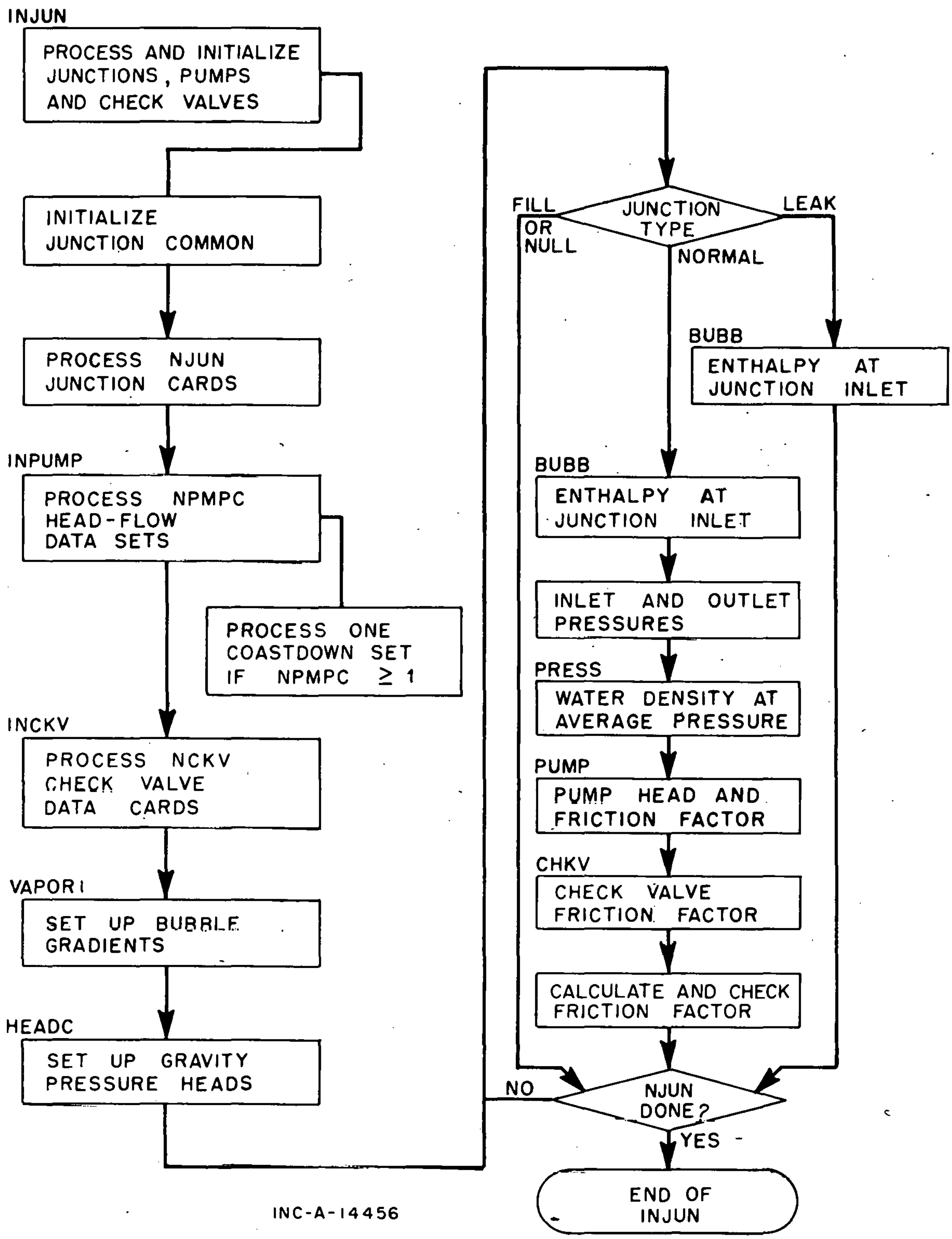

CHART 7. JUNCTION DATA.

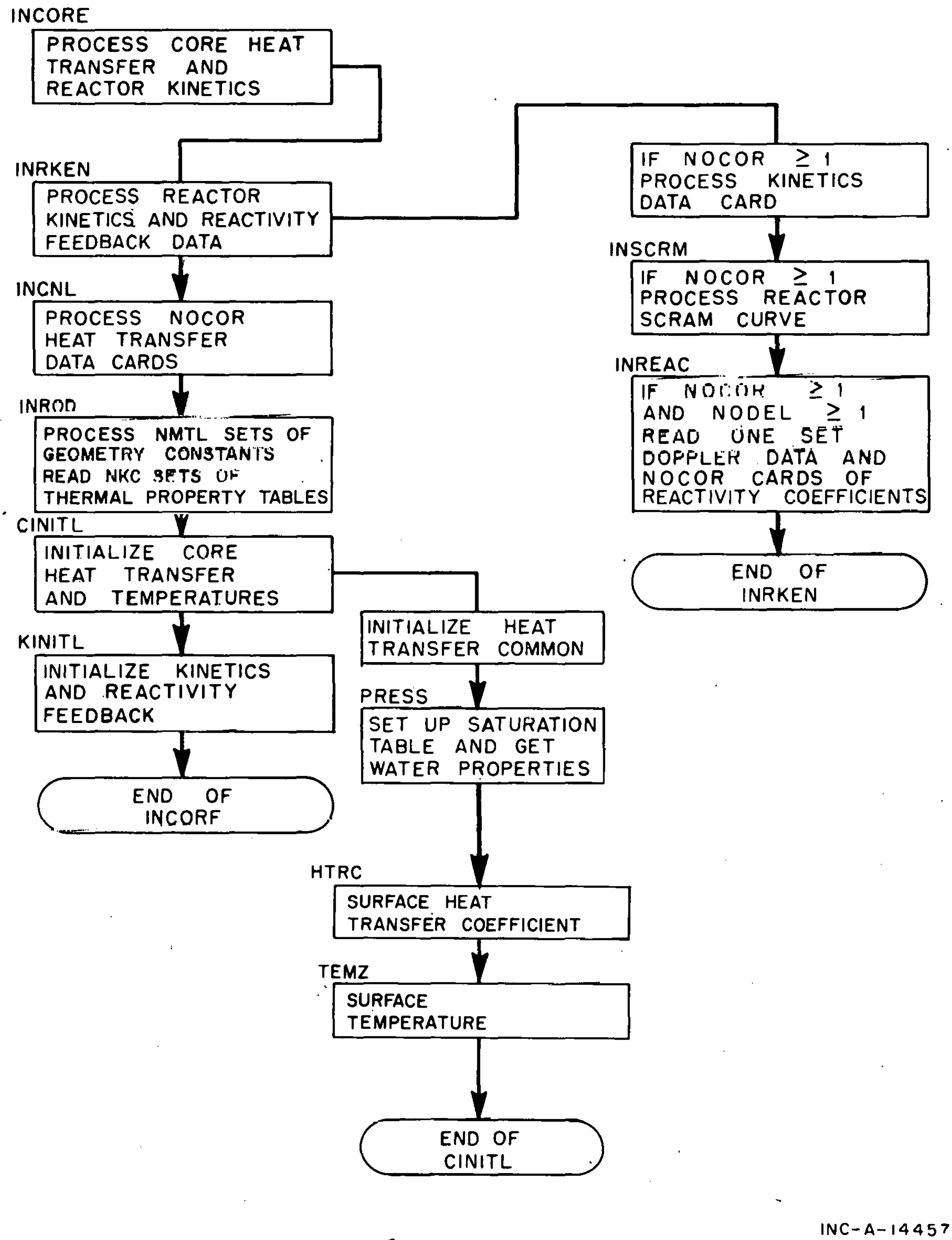

CHART 8. REACTOR DATA.

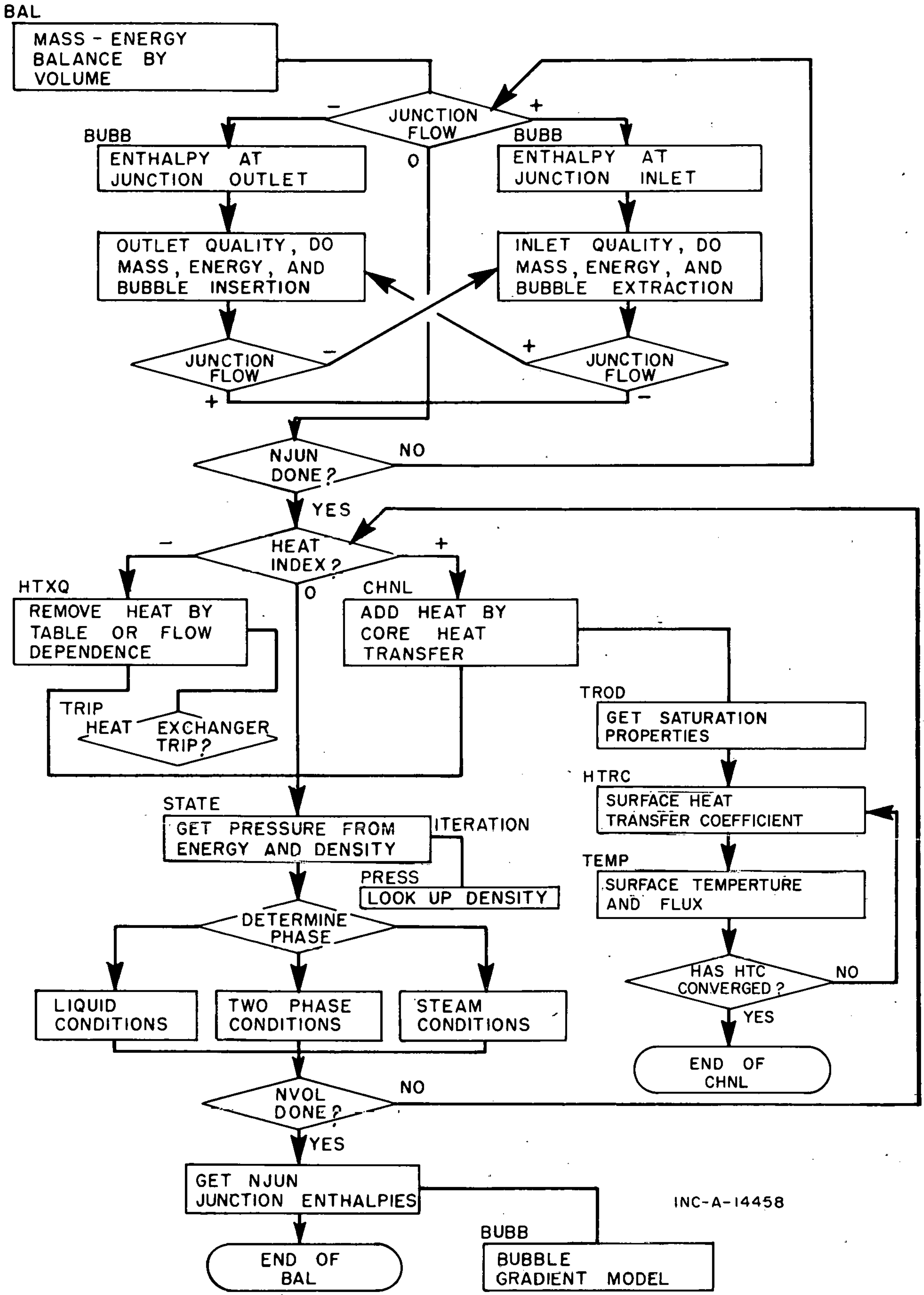

CHART 9. MASS AND ENERGY BALANCES.

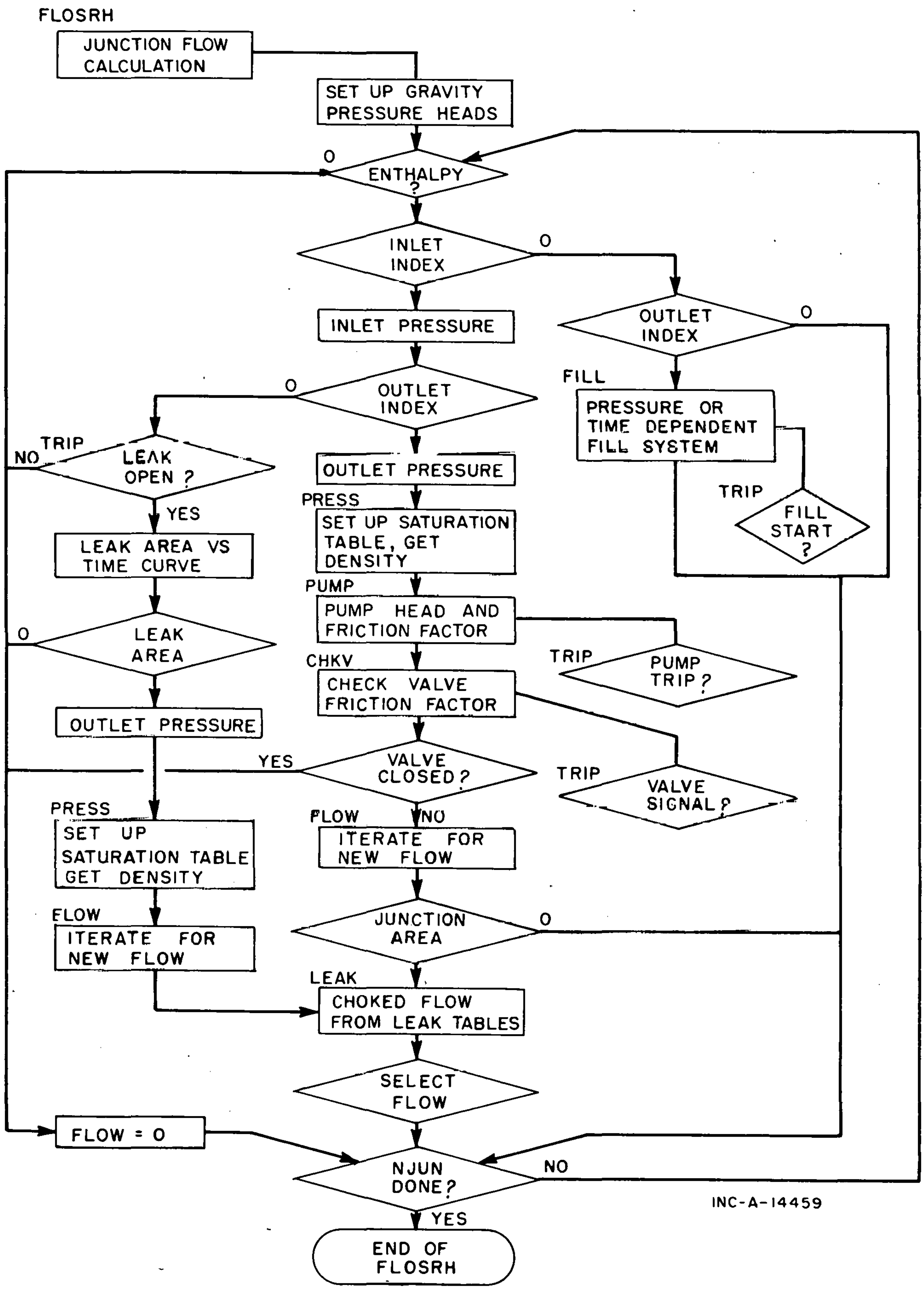

CHART 10. MOMENTUM BALANCE.

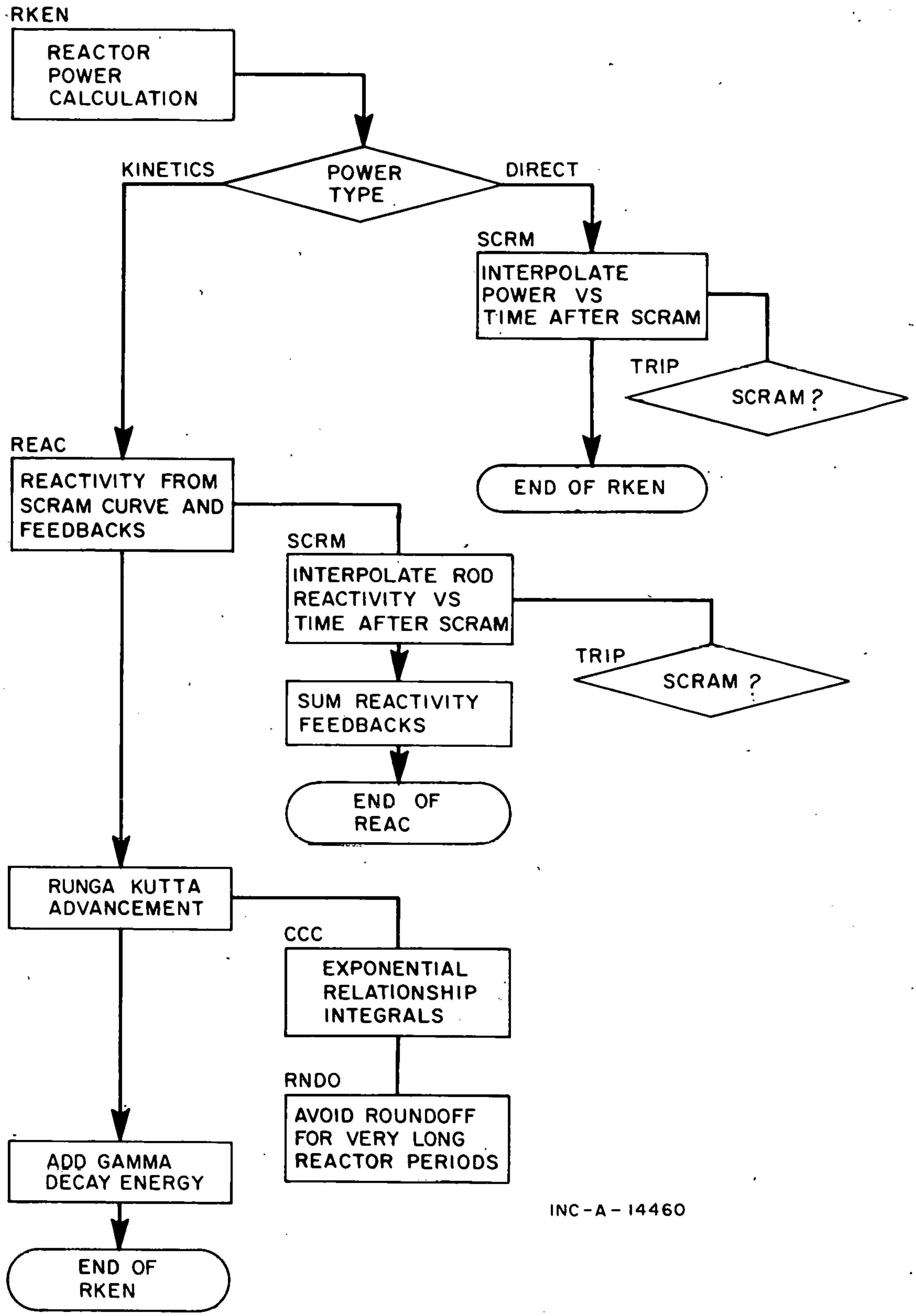

CHART 11. REACTOR KINETICS.

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APPENDIX G

SAMPLE PROBLEMS

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APPENDIX G

SAMPLE PROBLEMS

The test cases which follow show the input, output, and restart formats and provide results for comparison. The results were obtained from a double precision version and run on an IBM 360/75. Other computers using a longer word length produce the essential features of these results from a single precision version. These cases have been run on the CDC 6600, Univac 1108, and the IBM 7044 as well as the IBM 360/75. However, the RELAP3 version used on all but the IBM 360/75 was one which did not contain the current core geometry and heat transfer.

The test cases are designed to check the major features of RELAP3. The first case is a one-volume unheated blowdown, and the second case is a three-volume reactor blowdown with reactivity feedback. The last test case is a sample restart of the three-volume problem.

Execution time and to a lesser degree the numerical results depend upon the particular computer used. Observed timings are as follows:

Computer	Compiler	Compile Time[a] (min)	Execute Time[a] (min)
IBM 360/75	H/2	2.0	4.6
IBM 7044	IBSYS	27.	25.
CDC 6600	RUN	1.4	3.0
Univac 1108	FORTRAN V	1.2	4.5

[a] The running times can vary depending on the time of day, installed hardware, and costing algorithm.

SAMPLE PROBLEM 1 -- ONE VOLUME UNHEATED BLOWDOWN AND THREE-VOLUME TEST PROBLEM WITH REACTOR KINETICS

```
//GAJ3A#I5 JOB (R,M37001,10,X00760,0685),G.A.JAYNE,CLASS=A,PRTY=8
//XQT     EXEC  RELAP3,XTIME=10,PAGES=80,TPOUT='L.GAJR3001'
//X. SYSIN  DD  *
 RELAP3 STANDARD ONE VOLUME CASE  5/70    30.TOP,1VOL,2342.5P,520F       TITLE 10
  0  5  4  3  1  1  1  0  0  1  0  0  0  0  0          0.0                INTL  20
 AP   1 TM  1 ML  1 JW  1 JX  1                                           EDIT  30
 10             0.0005        0.2                                         TIME  40
 50             0.0010        1.0                                         TIME  41
 20             0.0025        2.0                                         TIME  42
 20             0.0050    10000.0                                         TIME  43
  1  1            25.0        0.0                                         ENDT  50
  1 -4  1         14.8        0.0                                         ENDP  51
  2  1           0.001        0.0                                         STRT  52
  1  0          2342.5      520.0      8.45    10.333       0.0        0.0VOL   60
                   0.8        3.0                                         BUB   70
  1  0  1          0.0   0.026167       9.5       0.0       0.0           LEAK  80
  3  1            12.5        0.6       0.0       0.0     0.001        1.0LAREA120
               10000.0        1.0                                         LAREA121
  THREE VOLUME TEST PROBLEM WITH REACTOR KINETICS ETC.    MAY, 1970       TITL  10
 -2  9  5  6  3  1  4  1  1  1  0  1  1  1  2        50.0                 CONT  20
 AP  3 JW  2 JW  3 AX  3 FT  3 ST  3 HC  3 DF  3 SF  3                    EDIT  30
 50 50  1 50    0.0002        0.5                                         TIME  40
 10 50  3 10    0.0010        2.0                                         TIME  41
  2 50  4  2    0.0050        4.0                                         TIME  42
  4 50  3  2    0.0050       10.0                                         TIME  43
  4 50  5  2    0.0050       25.0                                         TIME  44
  1  1            21.0        0.0                                         ENDT  50
  1 -4  1         50.0        0.0                                         ENDP  51
  2  1            0.01        0.0                                         LEAK  52
  3 -4  1       2000.0        0.2                                         SCRM  53
  3  1            0.01        1.0                                         SCRM  54
  4 -4  1       1000.0        0.1                                         PMPT  55
  1  0         2400.00      550.0     350.0      11.0       0.0        4.5VOL1  60
  1 -1         2408.81      521.5     250.0       8.0       0.0        0.0VOL2  61
  0 +1         2405.61      550.0      15.0       3.0       0.0        2.0VOL3  62
                   0.8        3.0                                         BUB   70
  1  0  1          0.0        1.5      10.5       0.0       0.0           JUN1  80
  2  3  0       1390.0        5.0       2.0       0.3       0.0           JUN2  81
  3  1  0       1390.0        5.0       5.0       0.3       0.0           JUN3  82
  1  2  1       1390.0        5.0       7.0      60.0       0.0           JUN4  83
  3             0.0002                  0.0       1.0       1.0        0.0PCD   90
                 100.0        0.0                                         PCD   91
  3  1  1        100.0     0.0001   -8.0E+6     400.0   10.0E+6      200.0PHEAD100
               20.0E+6  -300.0E+6                                         PHEAD101
                   0.4    0.00003      0.01     100.0                     CHKV 110
  3  0            50.0        0.6       0.0       0.0      0.05        1.0LAREA120
                 100.0        1.0                                         LAREA121
 18              300.0        0.0                                         KIN  140
  3                0.0        0.0       0.5     -20.0     100.0      -20.0SCRM 150
  3                0.0        0.0     500.0       0.0    4500.0      0.004DOPL 160
                  -0.3    -0.0001  0.000001       1.0                     REAC 170
```

```
  1  2  4  7     1.0     1068.0      3.0      0.05      0.05          CHNL 180
  2  1  3      0.005     1000.0      1.0                              ROD1 190
     2  5     0.0005      600.0      0.0                              ROD2 191
 20            100.0    5.00256    300.0   3.99600     500.0   3.32820K 11 200
               700.0    2.85408    900.0   2.50128    1100.0   2.22948K 12 200
              1300.0    2.01528   1500.0   1.84356    1700.0   1.70460K 13 200
              1900.0    1.55160   2100.0   1.46520    2300.0   1.38600K 14 200
              2500.0    1.33560   3000.0   1.27080    3500.0   1.23840K 15 200
              3700.0    1.23840   4000.0   1.26000    4300.0   1.31400K 16 200
              4700.0    1.40400   5100.0   1.50480                    K 17 200
 20            100.0    0.05779    300.0   0.06540     500.0   0.06914C 11 201
               700.0    0.07143    900.0   0.07306    1100.0   0.07435C 12 201
              1300.0    0.07543   1500.0   0.07639    1700.0   0.07728C 13 201
              2500.0    0.0797    2700.0   0.0810     3000.0   0.0850 C 14 201
              3200.0    0.0897    3500.0   0.0990     3800.0   0.1116 C 15 201
              4100.0    0.1265    4400.0   0.1403     4600.0   0.1474 C 16 201
              4800.0    0.1530    5100.0   0.1562                     C 17 201
 15            100.0    7.90920    300.0   8.22240     500.0   8.67600K 21 202
               700.0    9.27000    900.0  10.00080    1100.0  10.87200K 22 202
              1300.0   11.88720   1500.0  13.03560    1700.0   14.328 K 23 202
              1800.0   14.652     2000.0  16.02       2200.0  17.892  K 24 202
              2500.0   21.132     2900.0  26.28       3300.0  32.22   K 25 202
 11            100.0    0.06708    300.0   0.07318     500.0   0.07693C 21 203
               700.0    0.07981    900.0   0.08228    1100.0   0.08455C 22 203
              1300.0    0.08669   1500.0   0.08876    1700.0   0.09078C 23 203
              1800.0    0.0870    3300.0   0.0870                     C 24 203
  0              1.0      400.0                                       HTEX 210
                                                                      END  220
/*
//GAJ5C#I5 JOB (R,M37001,10,X00760,0685),G.A.JAYNE,CLASS=C,PRTY=8
//XQT     EXEC  RELAP3,XTIME=5,TPIN='L.GAJR3001'
//X.SYSIN  DD  *
  THREE VOLUME TEST PROBLEM RESTARTED FROM TAPE                       TITL  10
 37  8  2                                                             CONT  20
 JW   2 JW   3 AX   3 FT   3 ST   3 HC   3 DF   3 SF   3             EDIT  30
  4 50  3 10      0.005        10.0                                   TIME  40
  4 50  4 10      0.005        20.0                                   TIME  41
                                                                      END  220
```

RELAP3 STANDARD ONE VOLUME CASE 5/70 30.TOP,1VOL,2342.5P,520F TITLE 10

MISCELLANEOUS PROBLEM CONTROL DATA.

TAPE DUMP 0=NO	NUM EDIT VAR	NUM TIME SETS	NUM TRIP SGNL	NUM VOL	NUM BUBL SETS	NUM JUNC	NUM PUMP CURV	NUM CHK VALV	NUM LEAK CURV	NUM FILL CURV	NUM CORE REG	NUM ROD GEOM	NUM HEAT EXCH	NUM ROD MAT	INITIAL POWER (MEGAWATTS)	
0	5	4	3	1	1	1	0	0	1	0	0	0	0	0	0.0	INTL 20

EDIT IDENTIFICATION NUMBERS

1	2	3	4	5	6	7	8	9	
AP 1	TM 1	ML 1	JW 1	JX 1	0	0	0	0	EDIT 30

DATA FOR 4 TIME STEP SETS.

SET NUM	T S PER BRF	BRF PER LRG	LRG PER RST	T S PER PLT	TIME STEP SIZE	END OF INTERVAL	
1	10	0	0	0	0.500000D-03	0.200000D 00	TIME 40
2	50	0	0	0	0.100000D-02	0.100000D 01	TIME 41
3	20	0	0	0	0.250000D-02	0.200000D 01	TIME 42
4	20	0	0	0	0.500000D-02	0.100000D 05	TIME 43

GENERALIZED TRIP PARAMETERS FOR 3 SIGNALS.

TRIP NO.	TRIP ID	SIG ID	INDX 1	INDX 2	ACTION	TRIP SIGNAL	SET POINT	DELAY TIME		
1	1	1	0	0	END	ELAPSED TIME	0.2500000D 02	0.0	ENDT	50
2	1	-4	1	0	END	LOW PRESSURE	0.1480000D 02	0.0	ENDP	51
3	2	1	0	0	LEAK	ELAPSED TIME	0.1000000D-02	0.0	STRT	52

INPUT DATA FOR 1 VOLUMES.

VOL NUM	BUBL INDX	HEAT INDX	PRESSURE (PSI)	TEMPERATURE (OR QUALITY)	VOLUME (FT**3)	HEIGHT (FT)	MIXTURE LEVEL (FT)	ELEVATION (FT)		
1	1	0	0.2342500D 04	0.5200000D 03	0.8450000D 01	0.1033300D 02	0.0	0.0	VOL	60

INPUT FOR 1 SETS OF BUBBLE CONSTANTS

SET NO.	SLOPE PARAMETER	BUBBLE VELOCITY			
0	0.	0.	(BUILT-IN DATA)		
1	0.8000000D 00	0.3000000D 01		BUB	70

DESCRIPTIONS OF 1 JUNCTIONS.

FROM VOL	TO VOL	PUMP LEAK FILL	CHCK VALV INDX	INITIAL FLOW (LBS/SEC)	MINIMUM FLOW AREA (FT**2)	JUNCTION HEIGHT (FT)	JUNCTION INERTIA (1/FT)	FRICTION COEFFICIENT (DP=F*V*W**2)	
1	0	1	0	0.0	0.261670D-01	0.950000D 01	0.0	0.0	LEAK 80

PARAMETERS FOR 1 LEAKS.

LEAK NO.	DATA PTS.	LEAK TYPE	SINK PRESSURE	CONTRACTION COEFFICIENT	TIME	AREA	TIME	AREA	
1	3	1	0.125000D 02	0.600000D 00	0.0	0.0	0.100000D-02	0.100000D 01	LAREA120
			0.100000D 05	0.100000D 01					LAREA121

TIME STEP NUM 0. TIME = 0.0 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	0.0	0.0	0.0	0.0	0.0	2.065680 05	4.111540 02	0.0	0.0

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	2.342500 03	4.111540 02	5.113200 02	4.865720 01	5.200000 02	0.0	0.0	1.033300 01	4.111540 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	NO	0.0	5.113200 02	0.0	0.0	0.0	0.0	0.0	0.0

TIME SEC	AVG PRESS VOL 1 PSIA	TOTAL MASS VOL 1 LB	MIXT LEVEL VOL 1 FT	FLOW LB/ JUN 1 SEC	QUALITY JUN 1
0.00500	1.95840D 03	4.10102D 02	1.03330D 01	3.47518D 02	0.0
0.01000	1.47465D 03	4.08598D 02	1.03330D 01	2.57875D 02	0.0
0.01500	1.09838D 03	4.07498D 02	1.03330D 01	1.80132D 02	0.0
0.02000	8.18766D 02	4.06732D 02	1.03330D 01	1.16918D 02	0.0
0.02500	7.76325D 02	4.06178D 02	1.03330D 01	1.09766D 02	6.36454D-05
0.03000	7.76136D 02	4.05630D 02	1.03329D 01	1.09723D 02	1.48685D-04
0.03500	7.75945D 02	4.05081D 02	1.03328D 01	1.09681D 02	2.33816D-04
0.04000	7.75755D 02	4.04533D 02	1.03327D 01	1.09639D 02	3.19038D-04
0.04500	7.75563D 02	4.03985D 02	1.03326D 01	1.09596D 02	4.04354D-04
0.05000	7.75371D 02	4.03437D 02	1.03324D 01	1.09554D 02	4.89764D-04
0.05500	7.75179D 02	4.02889D 02	1.03321D 01	1.09511D 02	5.75269D-04
0.06000	7.74986D 02	4.02342D 02	1.03318D 01	1.09469D 02	6.60872D-04
0.06500	7.74792D 02	4.01794D 02	1.03315D 01	1.09426D 02	7.46573D-04
0.07000	7.74598D 02	4.01247D 02	1.03312D 01	1.09384D 02	8.32373D-04
0.07500	7.74403D 02	4.00701D 02	1.03308D 01	1.09341D 02	9.18274D-04
0.08000	7.74208D 02	4.00154D 02	1.03303D 01	1.09298D 02	1.00428D-03
0.08500	7.74013D 02	3.99608D 02	1.03299D 01	1.09256D 02	1.09038D-03
0.09000	7.73816D 02	3.99061D 02	1.03294D 01	1.09213D 02	1.17660D-03
0.09500	7.73619D 02	3.98515D 02	1.03288D 01	1.09170D 02	1.26291D-03
0.10000	7.73422D 02	3.97970D 02	1.03282D 01	1.09127D 02	1.34934D-03
0.10500	7.73224D 02	3.97424D 02	1.03276D 01	1.09085D 02	1.43587D-03
0.11000	7.73025D 02	3.96879D 02	1.03270D 01	1.09042D 02	1.52252D-03
0.11500	7.72826D 02	3.96334D 02	1.03263D 01	1.08999D 02	1.60927D-03
0.12000	7.72627D 02	3.95789D 02	1.03255D 01	1.08956D 02	1.69614D-03
0.12500	7.72426D 02	3.95244D 02	1.03248D 01	1.08913D 02	1.78312D-03
0.13000	7.72226D 02	3.94700D 02	1.03240D 01	1.08870D 02	1.87022D-03
0.13500	7.72024D 02	3.94155D 02	1.03231D 01	1.08827D 02	1.95744D-03
0.14000	7.71822D 02	3.93611D 02	1.03223D 01	1.08784D 02	2.04477D-03
0.14500	7.71620D 02	3.93068D 02	1.03213D 01	1.08741D 02	2.13222D-03
0.15000	7.71417D 02	3.92524D 02	1.03204D 01	1.08697D 02	2.21980D-03
0.15500	7.71213D 02	3.91981D 02	1.03194D 01	1.08654D 02	2.30749D-03
0.16000	7.71009D 02	3.91437D 02	1.03184D 01	1.08611D 02	2.39531D-03
0.16500	7.70804D 02	3.90894D 02	1.03173D 01	1.08568D 02	2.48326D-03
0.17000	7.70599D 02	3.90352D 02	1.03162D 01	1.08524D 02	2.57133D-03
0.17500	7.70393D 02	3.89809D 02	1.03151D 01	1.08481D 02	2.65953D-03
0.18000	7.70187D 02	3.89267D 02	1.03139D 01	1.08437D 02	2.74786D-03
0.18500	7.69979D 02	3.88725D 02	1.03127D 01	1.08394D 02	2.83632D-03
0.19000	7.69772D 02	3.88183D 02	1.03115D 01	1.08350D 02	2.92492D-03
0.19500	7.69564D 02	3.87641D 02	1.03102D 01	1.08307D 02	3.01365D-03
0.20000	7.69355D 02	3.87100D 02	1.03089D 01	1.08263D 02	3.10251D-03

TIME STEP NUM 400. TIME = 0.200000D 00 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	0.0	0.0	0.0	1.21770D 04	2.40539D 01	2.06568D 05	4.11154D 02	0.0	0.0

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	7.69355D 02	3.87100D 02	5.05281D 02	4.58106D 01	5.13304D 02	1.88178D-03	6.95223D-01	1.03089D 01	3.86371D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	YES	1.08263D 02	5.06137D 02	3.10251D-03	7.56855D 02	0.0	0.0	0.0	0.0

TIME SEC	AVG PRESS VOL 1 PSIA	TOTAL MASS VOL 1 LB	MIXT LEVEL VOL 1 FT	FLOW LB/ JUN 1 SEC	QUALITY JUN 1
12.10000	2.38347D 01	2.46446D 01	9.48415D 00	3.12368D 00	1.28431D-01
12.20000	2.32445D 01	2.43418D 01	9.48418D 00	2.92197D 00	1.29496D-01
12.30000	2.26836D 01	2.40594D 01	9.48421D 00	2.71551D 00	1.30976D-01
12.40000	2.21528D 01	2.37978D 01	9.48424D 00	2.50370D 00	1.33003D-01
12.50000	2.16529D 01	2.35578D 01	9.48427D 00	2.28397D 00	1.35807D-01
12.60000	2.11853D 01	2.33404D 01	9.48431D 00	2.04831D 00	1.39893D-01
12.70000	2.07535D 01	2.31484D 01	9.48437D 00	1.76243D 00	1.47028D-01
12.80000	2.03704D 01	2.29919D 01	9.48445D 00	1.42324D 00	1.61060D-01
12.90000	2.00152D 01	2.28549D 01	9.48447D 00	1.31065D 00	1.65883D-01
13.00000	1.96769D 01	2.27291D 01	9.48449D 00	1.20036D 00	1.71651D-01
13.10000	1.93553D 01	2.26143D 01	9.48451D 00	1.09156D 00	1.78672D-01
13.20000	1.90498D 01	2.25103D 01	9.48454D 00	9.82866D-01	1.87472D-01
13.30000	1.87606D 01	2.24172D 01	9.48456D 00	8.71314D-01	1.99093D-01
13.40000	1.84882D 01	2.23358D 01	9.48459D 00	7.48179D-01	2.16396D-01
13.50000	1.82362D 01	2.22689D 01	9.48464D 00	5.46859D-01	2.63091D-01
13.60000	1.79726D 01	2.21907D 01	9.48423D 00	2.09558D 00	1.24147D-01
13.70000	1.75571D 01	2.19863D 01	9.48425D 00	1.98664D 00	1.24861D-01
13.80000	1.71582D 01	2.17928D 01	9.48426D 00	1.87773D 00	1.25935D-01
13.90000	1.67756D 01	2.16102D 01	9.48428D 00	1.77028D 00	1.27248D-01
14.00000	1.64091D 01	2.14382D 01	9.48430D 00	1.66418D 00	1.28846D-01
14.10000	1.60584D 01	2.12768D 01	9.48432D 00	1.55930D 00	1.30781D-01
14.20000	1.57232D 01	2.11258D 01	9.48434D 00	1.45549D 00	1.33124D-01
14.30000	1.54033D 01	2.09851D 01	9.48436D 00	1.35260D 00	1.35967D-01
14.40000	1.50983D 01	2.08547D 01	9.48438D 00	1.25047D 00	1.39429D-01
14.50000	1.48081D 01	2.07345D 01	9.48441D 00	1.14892D 00	1.43676D-01
14.50500	1.47940D 01	2.07287D 01	9.48441D 00	1.14385D 00	1.43913D-01

RELAP3 STANDARD ONE VOLUME CASE 5/70 30.TOP,1VOL,2342.5P,520F TIME = 37.09 PAGE 18

TIME STEP NUM 4101. TIME = 0.145050D 02 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	0.0	0.0	0.0	2.02557D 05	3.90425D 02	2.06568D 05	4.11154D 02	0.0	0.0

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	1.47940D 01	2.07287D 01	1.94612D 02	2.45311D 00	2.12198D 02	1.46838D-02	2.78327D-01	9.48441D 00	2.04244D 01

JUNCTION NUMBER	CONNECTING VOLUMES		CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TD	0	NO	1.14385D 00	3.19885D 02	1.43913D-01	2.29400D 00	0.0	2.21544D 00	0.0	0.0

RELAP3 STANDARD ONE VOLUME CASE 5/70 30.TOP,1VOL,2342.5P,520F TIME = 37.12 PAGE 19

END TRIP SIGNAL.

THREE VOLUME TEST PROBLEM WITH REACTOR KINETICS ETC.   MAY, 1970   TITL 10

MISCELLANEOUS PROBLEM CONTROL DATA.

TAPE DUMP 0=NO	NUM EDIT VAR	NUM TIME SETS	NUM TRIP SGNL	NUM VOL	NUM BUBL SETS	NUM JUNC	NUM PUMP CURV	NUM CHK VALV	NUM LEAK CURV	NUM FILL CURV	NUM CORE REG	NUM ROD GEOM	NUM HEAT EXCH	NUM ROD MAT	INITIAL POWER (MEGAWATTS)	
-2	9	5	6	3	1	4	1	1	1	0	1	1	1	2	0.500000D 02	CONT 20

EDIT IDENTIFICATION NUMBERS

1	2	3	4	5	6	7	8	9	
AP 3	JW 2	JW 3	AX 3	FT 3	ST 3	HC 3	DF 3	SF 3	EDIT 30

DATA FOR 5 TIME STEP SETS.

SET NUM	T S PER BRF	BRF PER LRG	LRG PER RST	T S PER PLT	TIME STEP SIZE	END OF INTERVAL	
1	50	50	1	50	0.2000000D-03	0.5000000D 00	TIME 40
2	10	50	3	10	0.1000000D-02	0.2000000D 01	TIME 41
3	2	50	4	2	0.5000000D-02	0.4000000D 01	TIME 42
4	4	50	3	2	0.5000000D-02	0.1000000D 02	TIME 43
5	4	50	5	2	0.5000000D-02	0.2500000D 02	TIME 44

GENERALIZED TRIP PARAMETERS FOR 6 SIGNALS.

TRIP NO.	TRIP ID	SIG ID	INDX 1	INDX 2	ACTION	TRIP SIGNAL	SET POINT	DELAY TIME		
1	1	1	0	0	END	ELAPSED TIME	0.210000D 02	0.0	ENDT	50
2	1	-4	1	0	END	LOW PRESSURE	0.500000D 02	0.0	ENDP	51
3	2	1	0	0	LEAK	ELAPSED TIME	0.100000D-01	0.0	LEAK	52
4	3	-4	1	0	SCRAM	LOW PRESSURE	0.200000D 04	0.200000D 00	SCRM	53
5	3	1	0	0	SCRAM	ELAPSED TIME	0.100000D-01	0.100000D 01	SCRM	54
6	4	-4	1	0	PUMP	LOW PRESSURE	0.100000D 04	0.100000D 00	PMPT	55

INPUT DATA FOR 3 VOLUMES.

VOL NUM	BUBL INDX	HEAT INDX	PRESSURE (PSI)	TEMPERATURE (OR QUALITY)	VOLUME (FT**3)	HEIGHT (FT)	MIXTURE LEVEL (FT)	ELEVATION (FT)		
1	1	0	0.240000D 04	0.550000D 03	0.350000D 03	0.110000D 02	0.0	0.450000D 01	VOL1	60
2	1	-1	0.240881D 04	0.521500D 03	0.250000D 03	0.800000D 01	0.0	0.0	VOL2	61
3	0	1	0.240561D 04	0.550000D 03	0.150000D 02	0.300000D 01	0.0	0.200000D 01	VOL3	62

INPUT FOR 1 SETS OF BUBBLE CONSTANTS.

SET NO.	SLOPE PARAMETER	BUBBLE VELOCITY			
0	0.	0.	(BUILT-IN DATA)		
1	0.800000D 00	0.300000D 01		BUB	70

DESCRIPTIONS OF 4 JUNCTIONS.

FROM VOL	TO VOL	PUMP LEAK FILL	CHCK VALV INDX	INITIAL FLOW (LBS/SEC)	MINIMUM FLOW AREA (FT**2)	JUNCTION HEIGHT (FT)	JUNCTION INERTIA (1/FT)	FRICTION COEFFICIENT (DP=F*V*W**2)		
1	0	1	0	0.0	0.150000D 01	0.105000D 02	0.0	0.0	JUN1	80
2	3	0	0	0.139000D 04	0.500000D 01	0.200000D 01	0.300000D 00	0.0	JUN2	81
3	1	0	0	0.139000D 04	0.500000D 01	0.500000D 01	0.300000D 00	0.0	JUN3	82
1	2	1	0	0.139000D 04	0.500000D 01	0.700000D 01	0.600000D 02	0.0	JUN4	83

PARAMETERS FOR 1 PUMP TYPES.

DATA PTS.	CAVITATION CONSTANT		TIME AFTER TRIP	PUMP MULTIPLIER	TIME AFTER TRIP	PUMP MULTIPLIER	
3	0.2000000D-03		0.0	0.1000000D 01	0.1000000D 01	0.0	PCD 90
	0.1000000D 03	0.0					PCD 91

PUMP NO.	DAT PTS	IND VAR	DEP VAR	NET POSITIVE SUCTION HEAD	FRICTION COEFFICIENT	LBS/SEC (0) GAL/MIN (1)	PSI (0) FEET (1)	LBS/SEC (0) GAL/MIN (1)	PSI (0) FEET (1)	
1	3	1	1	0.1000000D 03	0.1000000D-03	-0.8000000D 07	0.4000000D 03	0.1000000D 08	0.2000000D 03	PHEAD100
				0.2000000D 08	-0.3000000D 09					PHEAD101

PARAMETERS FOR 1 CHECKVALVES.

VALVE NO.	BACK PRESSURE FOR CLOSURE	FORWARD FRIC. COEFF.	OPEN REVERSE FRIC. COEFF.	CLOSED REVERSE FRIC. COEFF.	
1	0.4000000D 00	0.3000000D-04	0.1000000D-01	0.1000000D 03	CHKV 110

PARAMETERS FOR 1 LEAKS.

LEAK NO.	DATA PTS.	LEAK TYPE	SINK PRESSURE	CONTRACTION COEFFICIENT	TIME	AREA	TIME	AREA	
1	3	0	0.5000000D 02	0.6000000D 00	0.0	0.0	0.5000000D-01	0.1000000D 01	LAREA120
			0.1000000D 03	0.1000000D 01					LAREA121

REACTOR KINETICS PARAMETERS.

NO. GRPS	BETA OVER LIFETIME	INITIAL REACTIVITY	
18	0.300000D 03	0.0	KIN 140

SCRAM CURVE.

DATA PTS.	TIME	REACTIVITY	TIME	REACTIVITY	TIME	REACTIVITY	
3	0.0	0.0	0.500000D 00	-0.200000D 02	0.100000D 03	-0.200000D 02	SCRM 150

DOPPLER REACTIVITY CURVE.

DATA PTS.	METAL TEMPERATURE	REACTIVITY (DOLLARS)	METAL TEMPERATURE	REACTIVITY (DOLLARS)	METAL TEMPERATURE	REACTIVITY (DOLLARS)	
3	0.0	0.0	0.500000D 03	0.0	0.450000D 04	0.400000D-02	DOPL 160

CORE REG. NO.	WATER VOID COEFFICIENT ($/PER CENT)	WATER TEMP. COEFFICIENT ($/DEG F)	METAL TEMP. COEFFICIENT ($/DEG F)	DOPPLER WEIGHTING FACTOR	
1	-0.300000D 00	-0.100000D-03	0.100000D-05	0.100000D 01	REAC 170

HEAT TRANSFER DATA FOR 1 CORE REGIONS.

CORE REG	ROD GEOM	PRINT T AT NODES	POWER FRACTION	HEAT TRANS. AREA	CHAN LENGTH	HYD DIAM	HTD EQ DIAM	
1	1	2 4 7	0.100000D 01	0.106800D 04	0.3000000 01	0.500000D-01	0.500000D-01	CHNL 180

ROD GEOM	REGION	K,C SET	SPACES	SIZE	DENSITY	POWER FRAC
1	1	1	3	0.50000D-02	0.10000D 04	0.10000D 01
1	2	2	5	0.50000D-03	0.60000D 03	0.0

K AND C TABLES, SET NUMBER 1

20	0.100000D 03	0.500256D 01	0.300000D 03	0.399600D 01	0.500000D 03	0.332820D 01	K 11 200
	0.700000D 03	0.285408D 01	0.900000D 03	0.250128D 01	0.110000D 04	0.222948D 01	K 12 200
	0.130000D 04	0.201528D 01	0.150000D 04	0.184356D 01	0.170000D 04	0.170460D 01	K 13 200
	0.190000D 04	0.155160D 01	0.210000D 04	0.146520D 01	0.230000D 04	0.138600D 01	K 14 200
	0.250000D 04	0.133560D 01	0.300000D 04	0.127080D 01	0.350000D 04	0.123840D 01	K 15 200
	0.370000D 04	0.123840D 01	0.400000D 04	0.126000D 01	0.430000D 04	0.131400D 01	K 16 200
	0.470000D 04	0.140400D 01	0.510000D 04	0.150480D 01			K 17 200
20	0.100000D 03	0.577900D-01	0.300000D 03	0.654000D-01	0.500000D 03	0.691400D-01	C 11 201
	0.700000D 03	0.714300D-01	0.900000D 03	0.730600D-01	0.110000D 04	0.743500D-01	C 12 201
	0.130000D 04	0.754300D-01	0.150000D 04	0.763900D-01	0.170000D 04	0.772800D-01	C 13 201
	0.250000D 04	0.797000D-01	0.270000D 04	0.810000D-01	0.300000D 04	0.850000D-01	C 14 201
	0.320000D 04	0.897000D-01	0.350000D 04	0.990000D-01	0.380000D 04	0.111600D 00	C 15 201
	0.410000D 04	0.126500D 00	0.440000D 04	0.140300D 00	0.460000D 04	0.147400D 00	C 16 201
	0.480000D 04	0.153000D 00	0.510000D 04	0.156200D 00			C 17 201

K AND C TABLES, SET NUMBER 2

15	0.100000D 03	0.790920D 01	0.300000D 03	0.822240D 01	0.500000D 03	0.867600D 01	K 21 202
	0.700000D 03	0.927000D 01	0.900000D 03	0.100008D 02	0.110000D 04	0.108720D 02	K 22 202
	0.130000D 04	0.118872D 02	0.150000D 04	0.130356D 02	0.170000D 04	0.143280D 02	K 23 202
	0.180000D 04	0.146520D 02	0.200000D 04	0.160200D 02	0.220000D 04	0.178920D 02	K 24 202
	0.250000D 04	0.211320D 02	0.290000D 04	0.262800D 02	0.330000D 04	0.322200D 02	K 25 202
11	0.100000D 03	0.670800D-01	0.300000D 03	0.731800D-01	0.500000D 03	0.769300D-01	C 21 203
	0.700000D 03	0.798100D-01	0.900000D 03	0.822800D-01	0.110000D 04	0.845500D-01	C 22 203
	0.130000D 04	0.866900D-01	0.150000D 04	0.887600D-01	0.170000D 04	0.907800D-01	C 23 203
	0.180000D 04	0.870000D-01	0.330000D 04	0.870000D-01			C 24 203

DATA SETS FOR 1 HEAT EXCHANGERS.

HTXG	VOL	IN	OUT	POWER FRAC	SEC TEMP	HTXQ COEFF	
1	2	4	2	0.100000D 01	0.400000D 03	0.0	HTEX 210

TIME STEP NUM 0. TIME = 0.0 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	1.00000D 00	5.00000D 01	1.70650D 08	0.0	0.0	1.58648D 07	2.92802D 04	0.0	0.0

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	2.40000D 03	1.64239D 04	5.47259D 02	4.69256D 01	5.50000D 02	0.0	0.0	1.10000D 01	1.64239D 04
2	2.40881D 03	1.21523D 04	5.13059D 02	4.86092D 01	5.21500D 02	0.0	0.0	8.00000D 00	1.21523D 04
3	2.40561D 03	7.03923D 02	5.47260D 02	4.69282D 01	5.50000D 02	0.0	0.0	3.00000D 00	7.03923D 02

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								-1.70650D 08	
3	1	1.59785D 05	1.60811D 06	2.78836D 03	6.07304D 02	8.57031D 02	1.21619D 03	1.70650D 08	5.00000D 01

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	1.14373D 03	4	6.54849D 02	7	6.25540D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	NO	0.0	5.47259D 02	0.0	0.0	0.0	0.0	0.0	0.0
2	2 TO 3	NO	1.39000D 03	5.13059D 02	0.0	3.20000D 00	-1.86292D-01	3.38629D 00	6.66134D-16	0.0
3	3 TO 1	NO	1.39000D 03	5.47260D 02	0.0	5.61000D 00	2.11820D 00	3.49180D 00	6.66134D-16	0.0
4	1 TO 2	NO	1.39000D 03	5.47259D 02	0.0	-8.81000D 00	-1.99031D 00	9.45191D 01	4.26326D-14	1.01339D 02

TIME STEP = 0, TIME = 0.0 , PAGE = 11

RESTART DATA BEING DUMPED.

TIME SEC	AVG PRESS VOL 3 PSIA	FLOW LB/ JUN 2 SEC	FLOW LB/ JUN 3 SEC	AVG QUALITY VOL 3	FUEL TEMP VOL 3 F	SURF TEMP VOL 3 F	H T COF B/H/ VOL 3 F2/F	DNB FLUX B/H VOL 3 /F2	SUR FLUX B/H VOL 3 /F2
0.01000	2.40560D 03	1.39020D 03	1.39001D 03	0.0	8.57031D 02	6.07303D 02	2.78853D 03	1.60815D 06	1.59797D 05
0.02000	2.32348D 03	2.96014D 03	3.03967D 03	0.0	8.56855D 02	6.02341D 02	5.08668D 03	1.93870D 06	2.68126D 05
0.03000	2.10085D 03	3.13259D 03	3.32996D 03	0.0	8.56279D 02	5.94922D 02	5.48605D 03	1.95163D 06	2.56330D 05
0.04000	1.73189D 03	4.06591D 03	4.16183D 03	0.0	8.55742D 02	5.90951D 02	6.53633D 03	1.80911D 06	2.94000D 05
0.05000	1.39562D 03	5.28024D 03	5.35024D 03	0.0	8.54857D 02	5.82632D 02	8.13692D 03	1.45358D 06	3.14554D 05
0.06000	1.05564D 03	4.74569D 03	4.82947D 03	0.0	8.53865D 02	5.73366D 02	1.61542D 04	1.13942D 06	5.04261D 05
0.07000	9.81064D 02	-9.28637D 02	1.44229D 03	6.13778D-04	8.52533D 02	5.70053D 02	2.41345D 01	3.08108D 05	6.74534D 02
0.08000	9.79136D 02	-8.05031D 02	1.94904D 03	1.32588D-04	8.52960D 02	5.95374D 02	4.47880D 01	4.69174D 05	2.39713D 03
0.09000	9.75583D 02	7.27617D 02	1.81818D 03	2.91461D-04	8.53422D 02	6.05672D 02	8.23712D 01	7.51542D 05	5.29617D 03
0.10000	9.72703D 02	1.46412D 03	5.53063D 02	2.10291D-04	8.53910D 02	6.13354D 02	6.78543D 01	6.75740D 05	4.91055D 03
0.11000	9.70160D 02	9.99802D 02	1.62737D 03	1.24199D-04	8.54377D 02	6.18008D 02	8.41060D 01	7.72301D 05	6.50552D 03
0.12000	9.67596D 02	5.43232D 02	1.48753D 03	4.74123D-05	8.54853D 02	6.21910D 02	6.84290D 01	6.89976D 05	5.58316D 03
0.13000	9.65002D 02	1.51666D 03	1.09177D 03	6.37604D-05	8.55339D 02	6.25564D 02	8.31942D 01	7.78276D 05	7.12062D 03
0.14000	9.91383D 02	5.75751D 02	1.63006D 03	0.0	8.55800D 02	6.27591D 02	8.54323D 02	6.86766D 05	7.49339D 04
0.15000	1.02482D 03	7.16960D 02	1.70109D 03	0.0	8.56254D 02	6.29376D 02	9.21762D 02	7.24152D 05	8.27223D 04
0.16000	9.58547D 02	9.35703D 02	1.41617D 03	1.24098D-05	8.56687D 02	6.30742D 02	7.60249D 01	7.52440D 05	6.96516D 03
0.17000	9.56386D 02	1.47207D 03	9.19972D 02	2.01509D-05	8.57148D 02	6.33063D 02	7.70571D 01	7.62407D 05	7.26988D 03
0.18000	1.06771D 03	1.07187D 03	1.32526D 03	0.0	8.57589D 02	6.34100D 02	9.14117D 02	7.18289D 05	8.70755D 04
0.19000	9.52726D 02	1.32430D 03	1.02194D 03	1.56763D-05	8.58019D 02	6.35250D 02	7.54406D 01	7.60320D 05	7.30990D 03
0.20000	9.51220D 02	1.02095D 03	1.34867D 03	6.39747D-06	8.58421D 02	6.35334D 02	9.01241D 02	7.57126D 05	8.75723D 04
0.21000	9.54351D 02	9.15260D 02	1.41648D 03	0.0	8.58831D 02	6.36318D 02	8.94406D 02	6.91377D 05	8.78833D 04
0.22000	9.51891D 02	9.20521D 02	1.40629D 03	0.0	8.59235D 02	6.37149D 02	8.93308D 02	6.90391D 05	8.86898D 04
0.23000	9.46937D 02	9.74072D 02	1.35178D 03	2.63534D-06	8.59635D 02	6.37840D 02	8.89673D 02	7.23505D 05	8.91413D 04
0.24000	9.45588D 02	1.03385D 03	1.27076D 03	6.31435D-06	8.60021D 02	6.38838D 02	8.79816D 02	7.63746D 05	8.92379D 04
0.25000	9.44288D 02	1.13319D 03	1.17684D 03	9.84335D-06	8.60270D 02	6.39805D 02	7.37956D 01	7.67063D 05	7.56865D 03
0.26000	9.43040D 02	1.21206D 03	1.08215D 03	1.08580D-05	8.60416D 02	6.40942D 02	7.32705D 01	7.66304D 05	7.61022D 03
0.27000	9.41837D 02	1.29475D 03	9.95193D 02	1.04874D-05	8.60495D 02	6.42062D 02	7.30828D 01	7.67513D 05	7.68426D 03
0.28000	9.40638D 02	1.32756D 03	9.49869D 02	1.00462D-05	8.60534D 02	6.43102D 02	7.26547D 01	7.67245D 05	7.72634D 03
0.29000	9.39523D 02	1.35465D 03	9.07493D 02	9.13511D-06	8.60531D 02	6.44060D 02	7.21898D 01	7.66569D 05	7.75668D 03
0.30000	9.38401D 02	1.32787D 03	9.19482D 02	1.01251D-05	8.60509D 02	6.45100D 02	7.17048D 01	7.65748D 05	7.78978D 03
0.31000	9.37371D 02	1.32464D 03	9.07437D 02	9.02462D-06	8.60458D 02	6.45636D 02	7.12259D 01	7.64771D 05	7.78560D 03
0.32000	9.36374D 02	1.34051D 03	8.77802D 02	9.25792D-06	8.60389D 02	6.46495D 02	7.08007D 01	7.64035D 05	7.80930D 03
0.33000	9.35362D 02	1.25297D 03	9.46971D 02	1.26628D-05	8.60313D 02	6.47210D 02	7.01961D 01	7.62144D 05	7.80209D 03
0.34000	9.34394D 02	1.17039D 03	1.00688D 03	1.27524D-05	8.60226D 02	6.48034D 02	6.95300D 01	7.59761D 05	7.79421D 03
0.35000	9.33464D 02	1.08596D 03	1.07202D 03	1.32192D-05	8.60127D 02	6.48544D 02	6.89416D 01	7.57758D 05	7.77180D 03
0.36000	9.32576D 02	9.43378D 02	1.18658D 03	1.03050D-05	8.60020D 02	6.49038D 02	6.81768D 01	7.54514D 05	7.72714D 03
0.37000	9.92593D 02	6.53783D 02	1.45006D 03	0.0	8.59923D 02	6.50185D 02	8.25038D 02	6.64115D 05	9.43935D 04
0.38000	1.02833D 03	9.23734D 02	1.18004D 03	0.0	8.59809D 02	6.51051D 02	8.25723D 02	6.65154D 05	9.52742D 04
0.39000	1.01455D 03	1.23591D 03	8.61667D 02	0.0	8.59698D 02	6.52323D 02	8.22389D 02	6.89921D 05	9.61328D 04
0.40000	9.29033D 02	1.41630D 03	6.66445D 02	2.71333D-07	8.59577D 02	6.53031D 02	6.68370D 01	7.52449D 05	7.87373D 03
0.41000	9.28179D 02	1.17617D 03	8.88807D 02	1.32430D-05	8.59454D 02	6.53347D 02	6.61544D 01	7.49385D 05	7.82157D 03
0.42000	9.27344D 02	9.57639D 02	1.07938D 03	1.35206D-05	8.59335D 02	6.54028D 02	6.53409D 01	7.45438D 05	7.77698D 03
0.43000	9.26569D 02	7.47189D 02	1.25481D 03	2.81196D-06	8.59216D 02	6.54572D 02	7.88207D 02	6.93555D 05	9.42727D 04
0.44000	1.00375D 03	6.47956D 02	1.33845D 03	0.0	8.59104D 02	6.55691D 02	7.88620D 02	6.45267D 05	9.51807D 04
0.45000	1.01688D 03	9.94888D 02	9.89796D 02	0.0	8.58991D 02	6.56858D 02	7.89333D 02	6.40901D 05	9.63201D 04
0.46000	9.47544D 02	1.34168D 03	6.40233D 02	0.0	8.58871D 02	6.57875D 02	6.39092D 01	7.41769D 05	7.88021D 03
0.47000	9.23359D 02	1.22332D 03	7.43679D 02	1.03510D-05	8.58735D 02	6.58250D 02	6.32977D 01	7.38704D 05	7.83446D 03
0.48000	9.22690D 02	9.93707D 02	9.39219D 02	1.42533D-05	8.58598D 02	6.58558D 02	6.22999D 01	7.32816D 05	7.73552D 03
0.49000	9.22073D 02	7.86630D 02	1.12017D 03	7.67547D-06	8.58458D 02	6.58782D 02	6.16442D 01	7.29301D 05	7.67285D 03
0.50000	1.01115D 03	6.59437D 02	1.22922D 03	0.0	8.58335D 02	6.60047D 02	7.58227D 02	6.29255D 05	9.52429D 04

TIME STEP NUM 2500. TIME = 0.500000D 00 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	1.40516D-01	7.02729D 00	1.05567D 08	1.80607D 06	3.33328D 03	1.58651D 07	2.92802D 04	-1.06540D 01	-4.50638D-01

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	9.46548D 02	1.32170D 04	5.41241D 02	3.77630D 01	5.37532D 02	1.12582D-02	1.33279D 02	1.07691D 01	1.30682D 04
2	9.48882D 02	1.20254D 04	5.07302D 02	4.81016D 01	5.15971D 02	0.0	0.0	8.00000D 00	1.20254D 04
3	1.01115D 03	7.04460D 02	5.30032D 02	4.69640D 01	5.34412D 02	0.0	0.0	3.00000D 00	7.04460D 02

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								-1.05567D 08	
3	7	9.52429D 04	6.29255D 05	7.58227D 02	6.60047D 02	8.58335D 02	1.19486D 03	1.01719D 08	7.02729D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	1.12245D 03	4	6.77952D 02	7	6.65965D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E D I F F E R E N T I A L S TOT. PSI	ELEV PSI	FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	YES	6.68164D 03	5.41227D 02	1.12326D-02	8.96548D 02	0.0	0.0	0.0	0.0
2	2 TO 3	NO	6.59437D 02	5.07302D 02	0.0	-6.22682D 01	-1.78870D-01	7.69969D-01	-6.28593D 01	0.0
3	3 TO 1	NO	1.22922D 03	5.30032D 02	0.0	6.46025D 01	1.81672D 00	2.72943D 00	6.00564D 01	0.0
4	1 TO 2	NO	9.48029D 02	5.37294D 02	5.28367D-03	-2.33431D 00	-1.72867D 00	4.95626D 01	-9.26254D 00	4.09057D 01

TIME STEP = 2500, TIME = 0.500000D 00, PAGE = 14

RESTART DATA BEING DUMPED.

TIME SEC	AVG PRESS VOL 3 PSIA	FLOW LB/ JUN 2 SEC	FLOW LB/ JUN 3 SEC	AVG QUALITY VOL 3	FUEL TEMP VOL 3 F	SURF TEMP VOL 3 F	H T COF B/H/ VOL 3 F2/F	DNB FLUX B/H VOL 3 /F2	SUR FLUX B/H VOL 3 /F2
0.51000	1.19180D 03	-1.97349D 03	3.43363D 03	0.0	8.58269D 02	6.62310D 02	8.18238D 01	8.23876D 05	1.05026D 04
0.52000	1.33482D 03	-5.31671D 03	4.32697D 03	0.0	8.58280D 02	6.64857D 02	1.26494D 01	2.49405D 05	1.66006D 03
0.53000	9.12547D 02	1.47070D 03	-1.52752D 03	4.35671D-06	8.58288D 02	6.66414D 02	6.62216D 01	7.48508D 05	8.83742D 03
0.54000	9.06238D 02	4.16095D 03	-1.32132D 03	6.13142D-04	8.58280D 02	6.67640D 02	1.24928D 02	1.02310D 06	1.69317D 04
0.55000	9.06883D 02	-2.15683D 03	4.15707D 03	4.30691D-04	8.58164D 02	6.67903D 02	2.82206D 02	3.64457D 05	3.75473D 04
0.56000	8.99470D 02	-7.22439D 02	2.56151D 03	1.25829D-03	8.58141D 02	6.68343D 02	3.97815D 01	5.54062D 05	5.44246D 03
0.57000	9.02435D 02	-1.70846D 03	-2.93097D 03	3.58343D-06	8.58168D 02	6.70909D 02	1.06640D 02	9.62751D 05	1.48520D 04
0.58000	9.00156D 02	4.00339D 03	2.44646D 03	6.04790D-04	8.57972D 02	6.68112D 02	1.45418D 02	1.14733D 06	1.98670D 04
0.59000	8.94599D 02	3.49001D 03	3.97309D 00	1.20875D-03	8.57945D 02	6.71121D 02	9.09776D 01	9.53470D 05	1.27782D 04
0.60000	8.97396D 02	2.76509D 03	-2.17563D 03	2.31163D-04	8.57913D 02	6.72188D 02	2.13321D 01	3.66723D 05	3.01281D 03
0.61000	8.94477D 02	3.08045D 03	1.56252D 03	7.11232D-04	8.57769D 02	6.71265D 02	1.21238D 02	1.08612D 06	1.70407D 04
0.62000	1.07063D 03	-2.02308D 03	5.70491D 02	0.0	8.57693D 02	6.71528D 02	9.73768D 02	7.40838D 05	1.36773D 05
0.63000	8.94264D 02	-1.91735D 03	4.70624D 03	3.92921D-04	8.57461D 02	6.70385D 02	1.18607D 03	8.80368D 05	1.63679D 05
0.64000	8.92086D 02	-1.10656D 03	-1.95935D 03	4.18678D-04	8.57454D 02	6.74119D 02	5.56776D 01	7.04414D 05	8.00814D 03
0.65000	8.91423D 02	5.74367D 03	2.99137D 02	5.94041D-04	8.57429D 02	6.75186D 02	1.39401D 02	1.15098D 06	2.02085D 04
0.66000	8.89366D 02	1.48833D 03	-7.30027D 02	5.51734D-04	8.57347D 02	6.75935D 02	5.49554D 01	7.11298D 05	8.02239D 03
0.67000	8.89013D 02	4.85524D 03	-4.61313D 02	5.92366D-04	8.57317D 02	6.77018D 02	9.92375D 01	1.01025D 06	1.46005D 04
0.68000	8.88090D 02	1.23874D 03	-8.87045D 02	2.70781D-04	8.57253D 02	6.77897D 02	4.96379D 01	6.71617D 05	7.35230D 03
0.69000	1.58414D 03	-5.43724D 03	7.30180D 03	0.0	8.57224D 02	6.79023D 02	8.79245D 01	9.31896D 05	1.31192D 04
0.70000	8.82437D 02	1.71288D 02	-1.08378D 03	6.09270D-04	8.57108D 02	6.79021D 02	4.06341D 01	5.95160D 05	6.09487D 03
0.71000	8.84002D 02	9.40223D 02	1.87991D 03	5.28862D-04	8.57102D 02	6.80469D 02	3.62688D 01	5.49382D 05	5.47812D 03
0.72000	8.83151D 02	2.42533D 02	-2.22892D 02	2.92037D-04	8.57006D 02	6.80608D 02	2.46375D 01	4.31172D 05	3.73086D 03
0.73000	8.84437D 02	1.24613D 03	1.51118D 03	1.09724D-04	8.56944D 02	6.79951D 02	7.97405D 02	6.15373D 05	1.19879D 05
0.74000	8.81662D 02	1.92422D 03	-2.07801D 02	3.60933D-04	8.56864D 02	6.81845D 02	8.18861D 01	9.39137D 05	1.25205D 04
0.75000	8.80300D 02	-4.11733D 03	6.09784D 03	6.87146D-04	8.56827D 02	6.83082D 02	2.44989D 01	8.21921D 05	3.69930D 03
0.76000	8.77707D 02	-3.64733D 02	-1.10290D 03	2.52041D-04	8.56788D 02	6.84009D 02	1.97671D 01	3.66848D 05	3.07575D 03
0.77000	8.79892D 02	2.57334D 03	1.23179D 02	5.65538D-05	8.56773D 02	6.85028D 02	4.11231D 01	6.23218D 05	6.42656D 03
0.78000	8.74802D 02	1.03971D 03	1.78464D 03	1.05285D-03	8.56606D 02	6.83786D 02	7.01718D 01	8.51120D 05	1.09208D 04
0.79000	8.77783D 02	-7.86986D 02	-2.59885D 03	1.58038D-04	8.56621D 02	6.86365D 02	9.35215D 01	9.73127D 05	1.47736D 04
0.80000	8.77499D 02	-4.97882D 01	3.22887D 03	2.27811D-04	8.56415D 02	6.81241D 02	1.29604D 03	8.07373D 05	1.97504D 05
0.81000	8.76557D 02	-1.01420D 02	-1.56569D 03	2.83447D-04	8.56399D 02	6.86860D 02	3.68135D 01	5.68675D 05	5.83911D 03
0.82000	8.77430D 02	2.11443D 03	2.10924D 03	3.07894D-04	8.56252D 02	6.84215D 02	9.24343D 01	1.00625D 06	1.43940D 04
0.83000	8.74067D 02	1.81772D 03	3.31831D 02	8.49627D-04	8.56186D 02	6.87234D 02	4.56361D 01	6.71749D 05	7.26730D 03
0.84000	8.71914D 02	2.25137D 03	1.03936D 03	1.14409D-03	8.56144D 02	6.88175D 02	5.19736D 01	7.32429D 05	8.33835D 03
0.85000	8.70075D 02	3.35212D 02	5.16504D 02	1.07629D-03	8.56124D 02	6.89582D 02	2.48254D 01	4.34637D 05	4.02275D 03
0.86000	8.69188D 02	7.38773D 02	5.04936D 02	9.08736D-04	8.56130D 02	6.91106D 02	4.48357D 00	1.48059D 05	7.33982D 02
0.87000	8.63516D 02	2.33151D 03	2.46396D 03	1.87073D-03	8.56133D 02	6.92149D 02	8.23341D 01	9.45224D 05	1.36219D 04
0.88000	8.66104D 02	-3.01052D 03	-1.95345D 03	6.64168D-04	8.56119D 02	6.93053D 02	1.05544D 02	1.05206D 06	1.75331D 04
0.89000	8.59201D 02	1.35021D 03	5.16294D 03	2.40435D-03	8.55988D 02	6.90579D 02	1.02498D 02	1.05184D 06	1.68338D 04
0.90000	8.60518D 02	-1.11239D 03	-9.30983D 02	1.03784D-03	8.55936D 02	6.93101D 02	1.77322D 01	3.51902D 05	2.96014D 03
0.91000	8.64324D 02	3.77492D 03	-3.18157D 03	3.71298D-04	8.55927D 02	6.94476D 02	1.53067D 01	3.17308D 05	2.57129D 03
0.92000	8.62520D 02	1.97026D 03	-5.48605D 01	3.42234D-04	8.55924D 02	6.95269D 02	9.65891D 01	1.06012D 06	1.63111D 04
0.93000	9.54428D 02	-2.39751D 02	1.04036D 03	0.0	8.55925D 02	6.96387D 02	2.08531D 02	2.60133D 05	3.52943D 04
0.94000	8.61218D 02	1.42582D 03	1.13150D 03	5.20774D-04	8.55805D 02	6.95567D 02	1.05013D 02	1.10093D 06	1.77772D 04
0.95000	8.61822D 02	2.43303D 03	-1.91951D 03	3.30885D-04	8.55835D 02	6.97922D 02	2.01579D 01	3.87010D 05	3.46062D 03
0.96000	8.56316D 02	3.41301D 03	9.30613D 02	1.08524D-03	8.55814D 02	6.97904D 02	1.48361D 02	1.25981D 06	2.55663D 04
0.97000	8.56172D 02	8.73466D 02	-2.11999D 03	1.11311D-03	8.55813D 02	6.99132D 02	7.72856D 01	9.32329D 05	1.34147D 04
0.98000	8.57378D 02	3.00198D 03	7.01405D 02	6.53274D-04	8.55833D 02	7.00435D 02	8.69829D 01	1.01761D 06	1.51935D 04
0.99000	8.59059D 02	1.00035D 02	-1.62895D 03	9.83870D-05	8.55843D 02	7.01281D 02	6.86700D 01	8.79355D 05	1.20390D 04
1.00000	8.57739D 02	1.03805D 03	6.92712D 02	4.39603D-05	8.55807D 02	7.01285D 02	8.59465D 01	1.01772D 06	1.50817D 04

TIME STEP NUM 4000. TIME = 0.200000D 01 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	8.02307D-02	4.01200D 00	1.47839D 08	6.53007D 06	1.20479D 04	1.58649D 07	2.92802D 04	-2.92743D 01	-3.12043D 00

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL.	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	6.89313D 02	6.23682D 03	5.28174D 02	1.78195D 01	5.00495D 02	5.53358D-02	1.51058D 02	6.94439D 00	5.89170D 03
2	7.51446D 02	1.05093D 04	5.04260D 02	4.20373D 01	5.10438D 02	5.28870D-03	4.84508D 01	7.86141D 00	1.04537D 04
3	7.27052D 02	4.86104D 02	5.07807D 02	3.24069D 01	5.06535D 02	1.68756D-02	8.20331D 00	3.00000D 00	4.77900D 02

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								-1.47839D 08	
3	7	4.34472D 04	1.56937D 06	1.85656D 02	7.40570D 02	8.51294D 02	1.07345D 03	4.64016D 07	4.01200D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	1.01489D 03	4	7.53443D 02	7	7.45428D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	YES	4.89993D 03	5.40829D 02	7.31058D-02	6.39313D 02	0.0	0.0	0.0	0.0
2	2 TO 3	NO	3.45534D 03	5.02422D 02	2.65637D-03	2.43938D 01	-2.10376D-01	2.45432D 01	6.09811D-02	0.0
3	3 TO 1	NO	3.55960D 03	5.07807D 02	1.68667D-02	3.77393D 01	9.47638D-01	3.67246D 01	6.70540D-02	0.0
4	1 TO 2	NO	-8.06107D 02	5.06271D 02	8.13682D-03	-6.21332D 01	-1.00818D 00	-4.78808D 01	-1.32442D 01	0.0

TIME STEP NUM 5000. TIME = 0.700000D 01 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	5.93840D-02	2.96962D 00	-6.29579D 06	1.39252D 07	2.57705D 04	1.58611D 07	2.92802D 04	-4.73328D 01	-8.61183D 00

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	1.65605D 02	2.58980D 03	3.72762D 02	7.39944D 00	3.63238D 02	4.29195D-02	5.29043D 01	5.97686D 00	2.47865D 03
2	1.72732D 02	8.57871D 02	4.29278D 02	3.43148D 00	3.67085D 02	1.04412D-01	6.85809D 01	6.23008D 00	7.68298D 02
3	1.69981D 02	6.20118D 01	4.10503D 02	4.13412D 00	3.65600D 02	8.41705D-02	5.21956D 00	3.00000D 00	5.67922D 01

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								6.29579D 06	
3	7	1.84228D 04	5.00380D 05	4.70921D 01	7.56974D 02	7.97990D 02	8.68935D 02	1.96755D 07	2.96962D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	8.52648D 02	4	7.62546D 02	7	7.59107D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. EMTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	YES	1.31109D 03	4.67793D 02	1.53652D-01	1.15605D 02	0.0	0.0	0.0	0.0
2	2 TO 3	NO	4.13244D 02	3.94321D 02	6.34908D-02	2.75122D 00	2.60016D-02	2.73474D 00	-9.52092D-03	0.0
3	3 TO 1	NO	4.41579D 02	4.10503D 02	8.41102D-02	4.37617D 00	2.84183D-01	4.10207D 00	-1.00868D-02	0.0
4	1 TO 2	NO	-3.33836D 01	1.19529D 03	1.00000D 00	-7.12739D 00	-5.62538D-02	-7.18745D 00	1.26310D-01	0.0

TIME STEP = 5000, TIME = 0.7000000 01, PAGE =   37

RESTART DATA BEING DUMPED.

TIME SEC	AVG PRESS VOL 3 PSIA	FLOW LB/ JUN 2 SEC	FLOW LB/ JUN 3 SEC	AVG QUALITY VOL 3	FUEL TEMP VOL 3 F	SURF TEMP VOL 3 F	H T COF B/H/ VOL 3 F2/F	DNB FLUX B/H VOL 3 /F2	SUR FLUX B/H VOL 3 /F2
7.02000	1.68743D 02	4.10287D 02	4.38445D 02	8.44107D-02	7.97904D 02	7.57056D 02	4.68674D 01	4.97863D 05	1.83701D 04
7.04000	1.67505D 02	4.07307D 02	4.35288D 02	8.46496D-02	7.97818D 02	7.57138D 02	4.66391D 01	4.95326D 05	1.83155D 04
7.06000	1.66269D 02	4.04308D 02	4.32112D 02	8.48872D-02	7.97733D 02	7.57220D 02	4.64074D 01	4.92772D 05	1.82593D 04
7.08000	1.65033D 02	4.01296D 02	4.28920D 02	8.51234D-02	7.97648D 02	7.57301D 02	4.61729D 01	4.90204D 05	1.82016D 04
7.10000	1.63799D 02	3.98274D 02	4.25716D 02	8.53581D-02	7.97564D 02	7.57382D 02	4.59357D 01	4.87623D 05	1.81425D 04
7.12000	1.62567D 02	3.95245D 02	4.22504D 02	8.55913D-02	7.97480D 02	7.57463D 02	4.56962D 01	4.85033D 05	1.80820D 04
7.14000	1.61335D 02	3.92210D 02	4.19286D 02	8.58230D-02	7.97397D 02	7.57544D 02	4.54546D 01	4.82435D 05	1.80203D 04
7.16000	1.60106D 02	3.89174D 02	4.16064D 02	8.60529D-02	7.97314D 02	7.57625D 02	4.52111D 01	4.79830D 05	1.79574D 04
7.18000	1.58878D 02	3.86136D 02	4.12840D 02	8.62812D-02	7.97232D 02	7.57706D 02	4.49658D 01	4.77221D 05	1.78934D 04
7.20000	1.57652D 02	3.83100D 02	4.09616D 02	8.65077D-02	7.97151D 02	7.57787D 02	4.47189D 01	4.74607D 05	1.78284D 04
7.22000	1.56428D 02	3.80066D 02	4.06395D 02	8.67324D-02	7.97070D 02	7.57868D 02	4.44705D 01	4.71991D 05	1.77624D 04
7.24000	1.55207D 02	3.77037D 02	4.03175D 02	8.69552D-02	7.96989D 02	7.57948D 02	4.42208D 01	4.69373D 05	1.76954D 04
7.26000	1.53987D 02	3.74011D 02	3.99960D 02	8.71761D-02	7.96910D 02	7.58029D 02	4.39698D 01	4.66754D 05	1.76274D 04
7.28000	1.52769D 02	3.70992D 02	3.96751D 02	8.73949D-02	7.96830D 02	7.58110D 02	4.37176D 01	4.64135D 05	1.75586D 04
7.30000	1.51554D 02	3.67979D 02	3.93547D 02	8.76117D-02	7.96752D 02	7.58191D 02	4.34644D 01	4.61516D 05	1.74890D 04
7.32000	1.50341D 02	3.64974D 02	3.90350D 02	8.78264D-02	7.96674D 02	7.58272D 02	4.32101D 01	4.58899D 05	1.74185D 04
7.34000	1.49131D 02	3.61976D 02	3.87160D 02	8.80389D-02	7.96597D 02	7.58353D 02	4.29549D 01	4.56283D 05	1.73471D 04
7.36000	1.47923D 02	3.58987D 02	3.83979D 02	8.82492D-02	7.96520D 02	7.58434D 02	4.26988D 01	4.53668D 05	1.72750D 04
7.38000	1.46719D 02	3.56006D 02	3.80807D 02	8.84572D-02	7.96444D 02	7.58515D 02	4.24419D 01	4.51056D 05	1.72021D 04
7.40000	1.45517D 02	3.53035D 02	3.77643D 02	8.86630D-02	7.96369D 02	7.58597D 02	4.21841D 01	4.48447D 05	1.71285D 04
7.42000	1.44317D 02	3.50074D 02	3.74490D 02	8.88663D-02	7.96294D 02	7.58678D 02	4.19257D 01	4.45841D 05	1.70541D 04
7.44000	1.43121D 02	3.47123D 02	3.71346D 02	8.90673D-02	7.96220D 02	7.58760D 02	4.16665D 01	4.43238D 05	1.69790D 04
7.46000	1.41928D 02	3.44173D 02	3.68159D 02	8.92657D-02	7.96147D 02	7.58842D 02	4.14054D 01	4.40629D 05	1.69027D 04
7.48000	1.40741D 02	3.41109D 02	3.64825D 02	8.94603D-02	7.96074D 02	7.58925D 02	4.11323D 01	4.37936D 05	1.68211D 04
7.50000	1.39560D 02	3.37899D 02	3.61361D 02	8.96513D-02	7.96003D 02	7.59009D 02	4.08439D 01	4.35132D 05	1.67326D 04
7.52000	1.38384D 02	3.34570D 02	3.57783D 02	8.98389D-02	7.95932D 02	7.59095D 02	4.05423D 01	4.32233D 05	1.66383D 04
7.54000	1.37215D 02	3.31147D 02	3.54113D 02	9.00234D-02	7.95862D 02	7.59182D 02	4.02295D 01	4.29254D 05	1.65388D 04
7.56000	1.36053D 02	3.27649D 02	3.50370D 02	9.02049D-02	7.95793D 02	7.59270D 02	3.99076D 01	4.26211D 05	1.64351D 04
7.58000	1.34897D 02	3.24097D 02	3.46573D 02	9.03833D-02	7.95724D 02	7.59360D 02	3.95782D 01	4.23116D 05	1.63277D 04
7.60000	1.33748D 02	3.20504D 02	3.42735D 02	9.05587D-02	7.95657D 02	7.59452D 02	3.92430D 01	4.19981D 05	1.62174D 04
7.62000	1.32606D 02	3.16886D 02	3.38871D 02	9.07310D-02	7.95591D 02	7.59545D 02	3.89030D 01	4.16815D 05	1.61046D 04
7.64000	1.31471D 02	3.13252D 02	3.34991D 02	9.09001D-02	7.95526D 02	7.59639D 02	3.85596D 01	4.13628D 05	1.59897D 04
7.66000	1.30344D 02	3.09613D 02	3.31105D 02	9.10661D-02	7.95462D 02	7.59735D 02	3.82135D 01	4.10427D 05	1.58731D 04
7.68000	1.29224D 02	3.05976D 02	3.27220D 02	9.12288D-02	7.95399D 02	7.59833D 02	3.78655D 01	4.07217D 05	1.57552D 04
7.70000	1.28111D 02	3.02348D 02	3.23343D 02	9.13882D-02	7.95337D 02	7.59931D 02	3.75163D 01	4.04003D 05	1.56362D 04
7.72000	1.27006D 02	2.98733D 02	3.19480D 02	9.15441D-02	7.95277D 02	7.60031D 02	3.71664D 01	4.00791D 05	1.55163D 04
7.74000	1.25909D 02	2.95137D 02	3.15634D 02	9.16965D-02	7.95217D 02	7.60133D 02	3.68163D 01	3.97583D 05	1.53957D 04
7.76000	1.24820D 02	2.91562D 02	3.11811D 02	9.18454D-02	7.95159D 02	7.60235D 02	3.64662D 01	3.94382D 05	1.52745D 04
7.78000	1.23738D 02	2.88011D 02	3.08012D 02	9.19906D-02	7.95101D 02	7.60339D 02	3.61166D 01	3.91192D 05	1.51530D 04
7.80000	1.22664D 02	2.84490D 02	3.04237D 02	9.21320D-02	7.95045D 02	7.60444D 02	3.57640D 01	3.88013D 05	1.50295D 04
7.82000	1.21598D 02	2.80997D 02	3.00492D 02	9.22693D-02	7.94990D 02	7.60551D 02	3.54112D 01	3.84848D 05	1.49055D 04
7.84000	1.20541D 02	2.77534D 02	2.96778D 02	9.24025D-02	7.94936D 02	7.60659D 02	3.50596D 01	3.81698D 05	1.47813D 04
7.86000	1.19491D 02	2.74100D 02	2.93096D 02	9.25317D-02	7.94883D 02	7.60768D 02	3.47093D 01	3.78564D 05	1.46571D 04
7.88000	1.18449D 02	2.70698D 02	2.89448D 02	9.26568D-02	7.94832D 02	7.60878D 02	3.43604D 01	3.75446D 05	1.45329D 04
7.90000	1.17416D 02	2.67327D 02	2.85833D 02	9.27779D-02	7.94781D 02	7.60990D 02	3.40130D 01	3.72346D 05	1.44088D 04
7.92000	1.16391D 02	2.63987D 02	2.82252D 02	9.28949D-02	7.94732D 02	7.61103D 02	3.36672D 01	3.69264D 05	1.42848D 04
7.94000	1.15374D 02	2.60680D 02	2.78706D 02	9.30078D-02	7.94684D 02	7.61216D 02	3.33231D 01	3.66200D 05	1.41609D 04
7.96000	1.14365D 02	2.57406D 02	2.75195D 02	9.31168D-02	7.94637D 02	7.61332D 02	3.29807D 01	3.63155D 05	1.40372D 04
7.98000	1.13365D 02	2.54163D 02	2.71719D 02	9.32218D-02	7.94591D 02	7.61448D 02	3.26401D 01	3.60129D 05	1.39137D 04
8.00000	1.12373D 02	2.50953D 02	2.68277D 02	9.33228D-02	7.94546D 02	7.61565D 02	3.23014D 01	3.57121D 05	1.37904D 04

TIME STEP NUM 5825. TIME = 0.111250D 02 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	5.43230D-02	2.71623D 00	-9.70112D 05	1.49074D 07	2.80034D 04	1.58606D 07	2.92802D 04	-4.92592D 01	1.56943D 01

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	4.99927D 01	8.84849D 02	2.91323D 02	2.52814D 00	2.81001D 02	4.45139D-02	2.01084D 01	5.84039D 00	8.45461D 02
2	4.95600D 01	3.74476D 02	3.19494D 02	1.49791D 00	2.80155D 02	7.58873D-02	0.0	1.91206D-01	3.46058D 02
3	4.97708D 01	1.74606D 01	3.40914D 02	1.16404D 00	2.80567D 02	9.86353D-02	1.72223D 00	3.00000D 00	1.57383D 01

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								9.70112D 05	
3	7	8.64003D 03	2.25436D 05	1.74395D 01	7.75951D 02	7.93458D 02	8.22069D 02	9.22756D 06	2.71623D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	8.15787D 02	4	7.78860D 02	7	7.77038D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E D I F F E R E N T I A L S TOT. PSI	ELEV PSI	FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	NO	0.0	1.17409D 03	1.00000D 00	-7.30239D-03	0.0	0.0	0.0	0.0
2	2 TO 3	NO	-5.38657D 01	3.40914D 02	1.02845D-01	-2.10788D-01	1.34200D-02	-2.13186D-01	-1.10223D-02	0.0
3	3 TO 1	NO	-1.88416D 02	2.62497D 02	1.33314D-02	-2.21882D-01	9.38900D-02	-3.97279D-01	8.15075D-02	0.0
4	1 TO 2	NO	3.69163D 01	2.69306D 02	2.06781D-02	4.32670D-01	2.12450D-03	6.45849D-01	-2.15304D-01	0.0

TIME STEP = 5825, TIME = 0.111250D 02, PAGE = 49

RESTART DATA BEING DUMPED.

TRAILER LABEL BEING WRITTEN.

END TRIP SIGNAL.

END 220

END-OF-DATA (BLANK CARD) ENCOUNTERED.

THREE VOLUME TEST PROBLEM RESTARTED FROM TAPE TIME = 0.0 PAGE 1

THREE VOLUME TEST PROBLEM RESTARTED FROM TAPE TITL 10

MISCELLANEOUS PROBLEM CONTROL DATA.

TAPE DUMP 0=NO	NUM EDIT VAR	NUM TIME SETS	
37	8	2	CONT 20

OLD RELAP3 PROBLEM WAS TITLED

THREE VOLUME TEST PROBLEM WITH REACTOR KINETICS ETC. MAY, 1970

DUMP AT PAGE NUMBER 37 HAS BEEN FOUND.

SUCCESSFUL RESTART, ENTERING TRANSIENT ROUTINE.

EDIT IDENTIFICATION NUMBERS

1	2	3	4	5	6	7	8	9	
JW 2	JW 3	AX 3	FT 3	ST 3	HC 3	DF 3	SF 3	0	EDIT 30

DATA FOR 2 TIME STEP SETS.

SET NUM	T S PER BRF	BRF PER LRG	LRG PER RST	T S PER PLT	TIME STEP SIZE	END OF INTERVAL	
1	4	50	3	10	0.500000D-02	0.100000D 02	TIME 40
2	4	50	4	10	0.500000D-02	0.200000D 02	TIME 41

TIME STEP NUM 5000. TIME = 0.700000D 01 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	5.938400-02	2.96962D 00	-6.29579D 06	1.39252D 07	2.57705D 04	1.58611D 07	2.92802D 04	-4.73328D 01	-8.61183D 00

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL.	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	1.65605D 02	2.58980D 03	3.72762C 02	7.39944D 00	3.63238D 02	4.29195D-02	5.29043D 01	5.97686D 00	2.47865D 03
2	1.72732D 02	8.57871D 02	4.29278C 02	3.43148D 00	3.67085D 02	1.04412D-01	6.858090 01	6.23008D 00	7.68298D 02
3	1.69981D 02	6.20118D 01	4.10503C 02	4.13412D 00	3.65600D 02	8.41705D-02	5.21956D 00	3.00000D 00	5.67922D 01

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								6.29579D 06	
3	7	1.84228D 04	5.00380D 05	4.70921D 01	7.56974D 02	7.97990D 02	8.68935D 02	1.96755D 07	2.96962D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	8.52648D 02	4	7.62546D 02	7	7.59107D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E TOT. PSI	ELEV PSI	D I F F E R E N T I A L S FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	YES	1.31109D 03	4.67793D 02	1.53652D-01	1.15605D 02	0.0	0.0	0.0	0.0
2	2 TO 3	NO	4.13244D 02	3.94321D 02	6.34908D-02	2.75122D 00	2.60016D-02	2.73474D 00	-9.52092D-03	0.0
3	3 TO 1	NO	4.41579D 02	4.10503D 02	8.41102D-02	4.37617D 00	2.84183D-01	4.10207D 00	-1.00868D-02	0.0
4	1 TO 2	NO	-3.33836D 01	1.19529D 03	1.00000D 00	-7.12739D 00	-6.62538D-02	-7.18745D 00	1.26310D-01	0.0

TIME STEP = 5000, TIME = 0.700000D 01, PAGE = 37

RESTART DATA BEING DUMPED.

TIME SEC	FLOW LB/ JUN 2 SEC	FLOW LB/ JUN 3 SEC	AVG QUALITY VOL 3	FUEL TEMP VOL 3 F	SURF TEMP VOL 3 F	H T COF B/H/ VOL 3 F2/F	DNB FLUX B/H VOL 3 /F2	SUR FLUX B/H VOL 3 /F2
7.02000	4.10287D 02	4.38445D 02	8.44107D-02	7.97904D 02	7.57056D 02	4.68674D 01	4.97863D 05	1.83701D 04
7.04000	4.07307D 02	4.35288D 02	8.46496D-02	7.97818D 02	7.57138D 02	4.66391D 01	4.95326D 05	1.83155D 04
7.06000	4.04308D 02	4.32112D 02	8.48872D-02	7.97733D 02	7.57220D 02	4.64074D 01	4.92772D 05	1.82593D 04
7.08000	4.01296D 02	4.28920D 02	8.51234D-02	7.97648D 02	7.57301D 02	4.61729D 01	4.90204D 05	1.82016D 04
7.10000	3.98274D 02	4.25716D 02	8.53581D-02	7.97564D 02	7.57382D 02	4.59357D 01	4.87623D 05	1.81425D 04
7.12000	3.95245D 02	4.22504D 02	8.55913D-02	7.97480D 02	7.57463D 02	4.56962D 01	4.85033D 05	1.80820D 04
7.14000	3.92210D 02	4.19286D 02	8.58230D-02	7.97397D 02	7.57544D 02	4.54546D 01	4.82435D 05	1.80203D 04
7.16000	3.89174D 02	4.16064D 02	8.60529D-02	7.97314D 02	7.57625D 02	4.52111D 01	4.79830D 05	1.79574D 04
7.18000	3.86136D 02	4.12840D 02	8.62812D-02	7.97232D 02	7.57706D 02	4.49658D 01	4.77221D 05	1.78934D 04
7.20000	3.83100D 02	4.09616D 02	8.65077D-02	7.97151D 02	7.57787D 02	4.47189D 01	4.74607D 05	1.78284D 04
7.22000	3.80066D 02	4.06395D 02	8.67324D-02	7.97070D 02	7.57868D 02	4.44705D 01	4.71991D 05	1.77624D 04
7.24000	3.77037D 02	4.03175D 02	8.69552D-02	7.96989D 02	7.57948D 02	4.42208D 01	4.69373D 05	1.76954D 04
7.26000	3.74011D 02	3.99960D 02	8.71761D-02	7.96910D 02	7.58029D 02	4.39698D 01	4.66754D 05	1.76274D 04
7.28000	3.70992D 02	3.96751D 02	8.73949D-02	7.96830D 02	7.58110D 02	4.37176D 01	4.64135D 05	1.75586D 04
7.30000	3.67979D 02	3.93547D 02	8.76117D-02	7.96752D 02	7.58191D 02	4.34644D 01	4.61516D 05	1.74890D 04
7.32000	3.64974D 02	3.90350D 02	8.78264D-02	7.96674D 02	7.58272D 02	4.32101D 01	4.58899D 05	1.74185D 04
7.34000	3.61976D 02	3.87160D 02	8.80389D-02	7.96597D 02	7.58353D 02	4.29549D 01	4.56283D 05	1.73471D 04
7.36000	3.58987D 02	3.83979D 02	8.82492D-02	7.96520D 02	7.58434D 02	4.26988D 01	4.53668D 05	1.72750D 04
7.38000	3.56006D 02	3.80807D 02	8.84572D-02	7.96444D 02	7.58515D 02	4.24419D 01	4.51056D 05	1.72021D 04
7.40000	3.53035D 02	3.77643D 02	8.86630D-02	7.96369D 02	7.58597D 02	4.21841D 01	4.48447D 05	1.71285D 04
7.42000	3.50074D 02	3.74490D 02	8.88663D-02	7.96294D 02	7.58678D 02	4.19257D 01	4.45841D 05	1.70541D 04
7.44000	3.47123D 02	3.71346D 02	8.90673D-02	7.96220D 02	7.58760D 02	4.16665D 01	4.43238D 05	1.69790D 04
7.46000	3.44173D 02	3.68159D 02	8.92657D-02	7.96147D 02	7.58842D 02	4.14054D 01	4.40629D 05	1.69027D 04
7.48000	3.41109D 02	3.64825D 02	8.94603D-02	7.96074D 02	7.58925D 02	4.11323D 01	4.37936D 05	1.68211D 04
7.50000	3.37899D 02	3.61361D 02	8.96513D-02	7.96003D 02	7.59009D 02	4.08439D 01	4.35132D 05	1.67326D 04
7.52000	3.34570D 02	3.57783D 02	8.98389D-02	7.95932D 02	7.59095D 02	4.05423D 01	4.32233D 05	1.66383D 04
7.54000	3.31147D 02	3.54113D 02	9.00234D-02	7.95862D 02	7.59182D 02	4.02295D 01	4.29254D 05	1.65388D 04
7.56000	3.27649D 02	3.50370D 02	9.02049D-02	7.95793D 02	7.59270D 02	3.99076D 01	4.26211D 05	1.64351D 04
7.58000	3.24097D 02	3.46573D 02	9.03833D-02	7.95724D 02	7.59360D 02	3.95782D 01	4.23116D 05	1.63277D 04
7.60000	3.20504D 02	3.42735D 02	9.05587D-02	7.95657D 02	7.59452D 02	3.92430D 01	4.19981D 05	1.62174D 04
7.62000	3.16886D 02	3.38871D 02	9.07310D-02	7.95591D 02	7.59545D 02	3.89030D 01	4.16815D 05	1.61046D 04
7.64000	3.13252D 02	3.34991D 02	9.09001D-02	7.95526D 02	7.59639D 02	3.85596D 01	4.13628D 05	1.59897D 04
7.66000	3.09613D 02	3.31105D 02	9.10661D-02	7.95462D 02	7.59735D 02	3.82135D 01	4.10427D 05	1.58731D 04
7.68000	3.05976D 02	3.27220D 02	9.12288D-02	7.95399D 02	7.59833D 02	3.78655D 01	4.07217D 05	1.57552D 04
7.70000	3.02348D 02	3.23343D 02	9.13882D-02	7.95337D 02	7.59931D 02	3.75163D 01	4.04003D 05	1.56362D 04
7.72000	2.98733D 02	3.19480D 02	9.15441D-02	7.95277D 02	7.60031D 02	3.71664D 01	4.00791D 05	1.55163D 04
7.74000	2.95137D 02	3.15634D 02	9.16965D-02	7.95217D 02	7.60133D 02	3.68163D 01	3.97583D 05	1.53957D 04
7.76000	2.91562D 02	3.11811D 02	9.18454D-02	7.95159D 02	7.60235D 02	3.64662D 01	3.94382D 05	1.52745D 04
7.78000	2.88011D 02	3.08012D 02	9.19906D-02	7.95101D 02	7.60339D 02	3.61166D 01	3.91192D 05	1.51530D 04
7.80000	2.84490D 02	3.04237D 02	9.21320D-02	7.95045D 02	7.60444D 02	3.57640D 01	3.88013D 05	1.50295D 04
7.82000	2.80997D 02	3.00492D 02	9.22693D-02	7.94990D 02	7.60551D 02	3.54112D 01	3.84848D 05	1.49055D 04
7.84000	2.77534D 02	2.96778D 02	9.24025D-02	7.94936D 02	7.60659D 02	3.50596D 01	3.81698D 05	1.47813D 04
7.86000	2.74100D 02	2.93096D 02	9.25317D-02	7.94883D 02	7.60768D 02	3.47093D 01	3.78564D 05	1.46571D 04
7.88000	2.70698D 02	2.89448D 02	9.26568D-02	7.94832D 02	7.60878D 02	3.43604D 01	3.75446D 05	1.45329D 04
7.90000	2.67327D 02	2.85833D 02	9.27779D-02	7.94781D 02	7.60990D 02	3.40130D 01	3.72346D 05	1.44088D 04
7.92000	2.63987D 02	2.82252D 02	9.28949D-02	7.94732D 02	7.61103D 02	3.36672D 01	3.69264D 05	1.42848D 04
7.94000	2.60680D 02	2.78706D 02	9.30078D-02	7.94684D 02	7.61216D 02	3.33231D 01	3.66200D 05	1.41609D 04
7.96000	2.57406D 02	2.75195D 02	9.31168D-02	7.94637D 02	7.61332D 02	3.29807D 01	3.63155D 05	1.40372D 04
7.98000	2.54163D 02	2.71719D 02	9.32218D-02	7.94591D 02	7.61448D 02	3.26401D 01	3.60129D 05	1.39137D 04
8.00000	2.50953D 02	2.68277D 02	9.33228D-02	7.94546D 02	7.61565D 02	3.23014D 01	3.57121D 05	1.37904D 04

TIME STEP NUM 5825. TIME = 0.111250D 02 SEC.

TOTAL SYSTEM QUANTITIES	NORM POWR	POWR (MW)	HEAT REM (BTU/HR)	ENGY LEAK (BTU)	MASS LEAK (LB)	ENGY BAL. (BTU)	MASS BAL. (LB)	TOT. REAC ($)	REAC T SEC.
	5.43230D-02	2.71623D 00	-9.70112D 05	1.49074D 07	2.80034D 04	1.58606D 07	2.92802D 04	-4.92592D 01	1.56943D 01

VOLUME NUMBER	AVG. PRES PSIA	TOT. MASS (LB)	AVG. ENTH (BTU/LB)	AVG. DENS (LB/FT3)	AVG. TEMP (F)	AVG. QUAL	BUBB MASS (LB)	MIXT LEVL (FT)	LIQ. MASS (LB)
1	4.99927D 01	8.84849D 02	2.91323D 02	2.52814D 00	2.81001D 02	4.45139D-02	2.01084D 01	5.84039D 00	8.45461D 02
2	4.95600D 01	3.74476D 02	3.19494D 02	1.49791D 00	2.80155D 02	7.58873D-02	0.0	1.91206D-01	3.46058D 02
3	4.97708D 01	1.74606D 01	3.40914D 02	1.16404D 00	2.80567D 02	9.86353D-02	1.72223D 00	3.00000D 00	1.57383D 01

VOLUME NUMBER	HEAT TRANS. MODE	SURF FLUX (BTU/HR/FT2)	DNB FLUX (BTU/HR/FT2)	H.T. COEF (BTU/H/F2/F)	SURF TEMP (F)	FUEL TEMP (F)	CENT TEMP (F)	POWR H2O (BTU/HR)	FUEL POWR (MW)
2								9.70112D 05	
3	7	8.64003D 03	2.25436D 05	1.74395D 01	7.75951D 02	7.93458D 02	8.22069D 02	9.22756D 06	2.71623D 00

VOLUME NUMBER	NODE	TEMP	NODE	TEMP	NODE	TEMP
3	2	8.15787D 02	4	7.78860D 02	7	7.77038D 02

JUNCTION NUMBER	CONNECTING VOLUMES	CHOKE	JCT. FLOW (LB/SEC)	JCT. ENTH (BTU/LB)	JCT. QUAL	P R E S S U R E D I F F E R E N T I A L S TOT. PSI	ELEV PSI	FRIC PSI	ACCL PSI	PUMP PSI
1	1 TO 0	NO	0.0	1.17409D 03	1.00000D 00	-7.30239D-03	0.0	0.0	0.0	0.0
2	2 TO 3	NO	-5.38657D 01	3.40914D 02	1.02845D-01	-2.10788D-01	1.34200D-02	-2.13186D-01	-1.10223D-02	0.0
3	3 TO 1	NO	-1.88416D 02	2.62497D 02	1.33314D-02	-2.21882D-01	9.38900D-02	-3.97279D-01	8.15075D-02	0.0
4	1 TO 2	NO	3.69163D 01	2.69306D 02	2.06781D-02	4.32670D-01	2.12450D-03	6.45849D-01	-2.15304D-01	0.0

TIME STEP = 5825, TIME = 0.111250D 02, PAGE = 49

RESTART DATA BEING DUMPED.

TRAILER LABEL BEING WRITTEN.

THREE VOLUME TEST PROBLEM RESTARTED FROM TAPE   TIME =   57.21 PAGE 50

END TRIP SIGNAL.

THREE VOLUME TEST PROBLEM RESTARTED FROM TAPE   TIME =   57.21 PAGE 51

END 220

END-OF-DATA (BLANK CARD) ENCOUNTERED.