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RELAPSE-I -- A DIGITAL PROGRAM FOR REACTOR BLOWDOWN AND POWER EXCURSION ANALYSIS

K. V. Moore, L. C. Richardson, J. W. Sielinsky

PHILLIPS PETROLEUM COMPANY

ATOMIC ENERGY DIVISION

NATIONAL REACTOR TESTING STATION
US ATOMIC ENERGY COMMISSION

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Atomic Energy Division
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SUMMARY

RELAPSE is a digital program, coded in FORTRAN IV, which calculates flow, mass inventories, temperatures, pressure, in addition to reactivities and power for a reactor primary system during a reactivity accident or a loss-of-coolant accident. Basically, RELAPSE is a modified version of the FLASH blowdown code.

The primary system is represented as three lumped volumes: (a) a pressurizer, (b) a hot volume, and (c) a cold volume. Pressure dependent coolant pumps and a flow dependent heat exchanger are included in the primary loop.

The reactor core is represented by a two-point heat transfer model and a one-point reactor kinetics model. Three modes of heat transfer are considered along with several types of reactivity functions.

Two-phase coolant flow is calculated with the aid of steam tables covering the range of 1 to 3200 psia. A constant velocity steam bubble rise model is included as part of the two-phase calculations.

Various control options describing reactor scrams, fill systems, and pump shutdown characteristics are available.

ACKNOWLEDGEMENTS

The basis for RELAPSE is the FLASH code developed by S. G. Margolis and J. A. Redfield of Westinghouse-Bettis Atomic Power Laboratory. We wish to thank Dr. Redfield for his special assistance in providing us with a detailed understanding of FLASH.

We also received a great deal of help from the Phillips staff, especially Dr. R. P. Rose, Sid Cohen, G. E. Gruen, and R. J. Wagner.

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1. INTRODUCTION

As part of the Loss of Fluid Test (LOFT) safety analysis effort, the FLASH Code [1] has been revised for the IBM-7040 and the CDC-6600 machines. This version of FLASH, called RELAPSE, can be used for many reactor system safety studies including large reactivity excursions as well as the original FLASH loss-of-coolant and pump-failure accidents. RELAPSE retains most of the calculational features of FLASH, but differs mainly in the reactor kinetics, reactor control options, and input/output form.

RELAPSE treats the reactor system as a core region, a heat exchanger, a main coolant pump, and three specific volumes - the hot leg, cold leg, and pressurizer. The core is treated as a two-point model for power generation, heat transfer, and reactivity generation and as a one-point model for the reactor kinetics, pressure balances and flow balances. Feedback reactivity is determined by the combination of void, temperature, Doppler, xenon, and energy dependent reactivity functions. Fluid discharge claculations through a system leak are based on the Moody method for single- and two-phase flow [2]. The output from the code includes temperatures, pressures, mass inventories, fluid properties, flow, reactivities, power and energy as time dependent variables. This version of RELAPSE should not be considered final since many improvements can be made in both the mathematical models and calculational techniques.

2. SYSTEM GEOMETRY

The reactor system is divided into three basic volumes: (a) the cold leg, which includes the fluid from the heat exchanger to the reactor inlet; (b) the hot leg from the reactor outlet to the heat exchanger; and (c) a system pressurizer connected to the hot volume. Each volume is defined as a simple cylindrical tank. Relative entrance and exit junctions within the volumes are specified by the user to approximate the particular system of interest (see Figure 1). System breaks involving leaks are allowed in any of the three volumes.

The reactor core is treated as an average single-pass hydrodynamic model with two points for power generation and heat transfer. A two-point hot channel model also is included but does not enter into the total system balance calculations.

3. TYPICAL TRANSIENT

Initially, the system is assumed to be in steady state operation with the coolant water flowing from the cold volume through the core

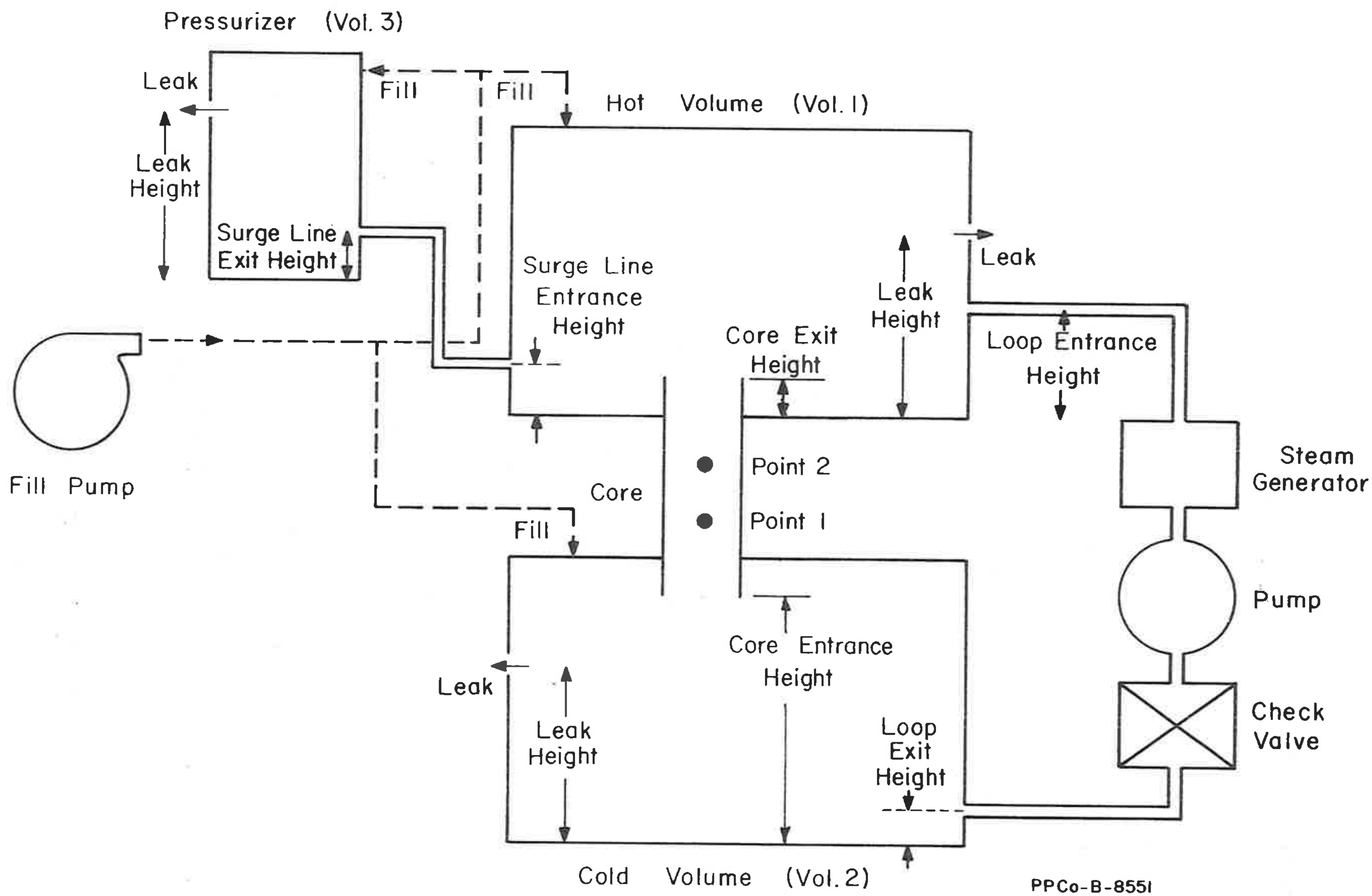

Fig. 1 Equivalent System Geometry.

to the hot volume and then through the heat exchanger and main coolant pumps back to the cold volume. In steady operation there is no flow from the pressurizer. The initial state of fluid in the pressurizer can be subcooled with an air head or saturated with a steam head.

The transient is initiated by any combination of reactivity input, system coolant leak, pump failure or power level changes. Partial control of the transient is available through nuclear scram options on pressure, liquid level, temperature, power level, reactor period, and core flow. Fill water may be injected into any volume if the system is loosing fluid through a rupture. The main pumps are described by a table of head versus flow along with coastdown characteristics. External reactivity is described by a constant velocity control rod and a time dependent table. Leak flow areas are described by a time dependent cubic equation.

During the transient, fluid properties are continuously calculated. Steam formation occurs if the system pressure drops below the saturation pressure. If two phase conditions occur, the fluid is assumed to be a mixture of liquid and bubbles with a steam head. A constant velocity bubble rise model is included to estimate the amount of entrained steam in the fluid.

As the system pressure changes, the net positive suction head to the main pumps also changes. Possibly, the coolant flow may reverse direction in the main loop if not prevented by a check valve. Reverse flow also may occur in the core. The core is cooled by the flow of subcooled water, two-phase mixture, or steam. Heat is transferred by convection to subcooled water, by nucleate boiling, or by film boiling to a steam-water mixture.

Feedback reactivity is generated by changes in coolant density and temperature, by changes in fuel temperature, by Doppler effects, and by possible burnup of xenon poison or some other energy dependent function. Complete mass, momentum, and energy balances are maintained throughout the transient.

4. TRANSIENT CALCULATIONS

Transient calculations are made by advancing the system conditions over a small time increment. The time dependent portion of the differential equations describing the system are expanded into forward finite difference forms. The basic equations for the calculations are as follows.

4.1 Mass and Energy Balances

The mass and energy stored in each volume are calculated from the basic conservation laws. Flow rates and fluid properties are assumed to be constant during a time step. Finite forward difference equations are used to advance the time solution.

The differential equation for mass balance is

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

where M_i is the total mass in volume i and W_{i_j} is the flow rate into volume i from pipe j.

The energy equation is

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

where U_i is the total energy content of the fluid in volume i, h_{i_j} is the enthalpy associated with W_{i_j}, and Q_i is a power source or sink in the volume.

The heat exchanger is included in the cold volume as a heat sink. The power removal by the heat exchanger is calculated by a flow dependent equation or determined from an input table of power versus time.

The flow dependent heat exchanger equation is

$$Q_{HE} = \left|\frac{W}{W_o}\right| H_{HE} (T_{Hot} - T_{Sec}) \tag{3}$$

where T_{Hot} is the outlet temperature of the hot volume, H_{HE} is the effective heat transfer coefficient in steady-state full power operation, W is the flow rate of primary coolant, and W_o is the initial coolant flow rate.

The term representing the secondary temperature, T_{Sec}, is determined internally in the code from the initial steady-state condition

$$T_{Sec} = T_{Hot}(o) - \frac{p(o)}{H_{HE}} \tag{4}$$

where p(o) is the initial power.

4.2 Pressure Balance

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

$$h_i = \frac{U_i}{M_i} + P_i \frac{V_i}{M_i} \tag{5}$$

By using this enthalpy, along with a pressure guess, the specific volume of the fluid is known from the available physical property tables. Thus, the product of the mass and the specific volume must equal the control volume.

$$M_i \, v_i = V_i \tag{6}$$

In the actual iteration, the pressure is changed by a given increment until successive approximations of $M_i v_i$ lie just above and below the true value V_i. Then a linear interpolation on the last two pressures are used to determine the correct pressure. The number of iterations is limited to prevent an indefinite loop. The physical property tables for water cover the range of $1 \leq P \leq 3206$ psia and $0 \leq h \leq 4539$ Btu/lb.

4.3 Leak Calculations

Leak calculations are performed on all volumes having non-zero leak areas. If the leak is sharp-edged and the water entering the leak is subcooled, the fluid does not flash. In this case, the mass velocity through the leak is given by the orifice equation

$$G = \sqrt{2g \, (144 \, \rho) \, (P_{source} - P_a)} \tag{7}$$

where P_{source} is the source pressure and P_a is the outside pressure.

If the fluid entering the leak is not subcooled, or if the leak is not sharp-edged, choked flow conditions are assumed at the leak throat. The mass velocity is then determined by the Moody correlation which is built into the code as tables of maximum flow, stagnation enthalpy, and fluid enthalpy versus leak pressure [2].

4.4 Fill Systems

Water can be injected into any volume by means of a fill system. This system is actuated, after a specified time delay, by a low-pressure signal, a rupture, or a low-liquid level trip from any specified volume. The actual fill water is delivered by both a constant displacement pump and head dependent pump. The total flow rate is the output of these two pumps.

$$W_{FILL} = W_{Fconst} + W_F(P) \tag{8}$$

The water from the fill system, with enthalpy h_{FILL}, is assumed to mix perfectly with the water already existing in the volume.

4.41 Exit State of Fluid. For an energy balance in each volume, the correct enthalpy, h_{ij}, must be determined for all incoming and exiting flows. The FLASH model, and hence RELAPSE, assumes that the exit state of the fluid through a junction is defined by the state of the fluid in contact with the junction point. In any given volume, the relative heights of entrances and exits are specified as input data. If the mixture level of liquid and entrained steam bubbles is below the junction, then the flow is assumed to be steam. Conversely, if the mixture level is above the junction, the flow is assumed to be pure liquid or two-phase.

4.5 Channel Energy Balance

Energy balances are performed on the first and second point average and hot channels. Heat fluxes and flows are assumed constant during a time step. For flow in the normal direction, the inlet enthalpy to the first point is the exit enthalpy from the cold leg volume. The inlet enthalpy to the second point is the exit enthalpy of the first point. For reverse flow, this sequence is reversed; ie, the inlet enthalpy to the second point is the enthalpy of the hot volume. Perfect longitudinal mixing is assumed for each point.

The energy equation for a single point is then

$$V\rho \frac{dh_{out}}{dt} = W\,h_{in} - W\,h_{out} + Q \qquad (9)$$

or

$$\frac{dh_{out}}{dt} = \frac{h_{in} - h_{out}}{\tau} + \frac{\phi A_{HT}}{V\rho} \qquad (10)$$

where ϕ is the heat flux into the coolant, A_{HT} is the heat transfer area, τ is the transport time $(V\rho/W)$, V is the channel point volume, and ρ is the fluid density.

4.6 Plate Equations

Fuel plate temperatures for the first and second point average and hot channels are calculated by an energy balance. The heat generation in the plate is determined by the reactor kinetics routine or a table look-up of power versus time. The energy balance per point assumes a uniform axial heat flux and temperature. This is

$$\frac{Q}{A_{HT}} - \phi_s = [(\rho C)_c \ell_c + (\rho C)_f \ell_f] \left(\frac{dT_f}{dt}\right) \qquad (11)$$

where ρC is the volumetric heat capacity, ℓ is the thickness of the clad or fuel, subscript c denotes the clad and f the fuel, Q is the power input, A_{HT} is the heat transfer area, ϕ_s is the surface heat flux, and T is the temperature.

The surface heat flux, ϕ_s, is determined by the mode of heat transfer. Thus,

$$\phi_s = \overline{H}\,(T_f - T_{sink}) \tag{12}$$

where $\overline{H}$, the overall heat transfer coefficient, and T_{sink} depend upon the mode of heat transfer.

For normal convective heat transfer

$$\frac{1}{\overline{H}} = \frac{1}{H} + \frac{\overline{\ell_c}}{k_c} \tag{13}$$

$$T_{sink} = T_{bc} \tag{14}$$

$$H = H_o \left[\frac{W(t)}{W_o}\right]^{0.8} \tag{15}$$

where $\overline{\ell_c}$ is the equivalent clad thickness, k_c is the clad conductivity, H_o is the nominal heat transfer film coefficient, W is the coolant flow rate, and T_{bc} is the temperature of the bulk coolant at the channel outlet.

For nucleate boiling[1]

$$\overline{H} = \frac{k_c}{\overline{\ell_c}} \tag{16}$$

$$T_{sink} = T_{crit}(\phi) \tag{17}$$

$$T_{crit} = T_{sat} + \frac{60}{e^{P/900}} \left(\frac{\phi}{10^6}\right)^{0.25} \tag{18}$$

For film boiling [1]

$$\frac{1}{\overline{H}} = \frac{1}{H_{FB}} + \frac{\overline{\ell_c}}{k_c} \tag{19}$$

$$T_{sink} = \max\,(T_{sat}, T_{bc}) \tag{20}$$

$$H_{FB} = \max \left\{ H_{min}, H_{FB_o} \left|\frac{W}{W_o}\right|^{0.8}, \quad H_{TB} \right\} \tag{21}$$

where H_{min} and H_{FB_o} are the minimum and nominal heat transfer coefficients for film boiling (input data). H_{TB} is the transition boiling heat transfer coefficient as calculated by the Departure from Nucleate Boiling (DNB) routine [see Equation (31)].

The actual mode of heat transfer is determined by a comparison of the estimated plate surface temperature, T_s', based on the average plate temperature versus the nucleate boiling sink temperature, T_{crit} (defined previously). The estimated surface temperature is

$$T_s' = T_f - \frac{\overline{\ell_c}}{k_c}\,\phi \tag{22}$$

The modes of heat transfer are then defined as

$$\text{Convection:} \quad T_s' < T_{crit} \tag{23}$$

and

$$T_{bc} < T_{sat} \tag{24}$$

$$\text{Nucleate Boiling:} \quad T_s' = T_{crit}, \text{ where } \phi \le \phi_{DNB} \tag{25}$$

and

$$\text{Film Boiling:} \quad T_s' > T_{crit} \tag{26}$$

The plate temperature, T_f, is calculated for a new time step by integrating Equation (11), assuming the heat transfer mode has not changed from the previous time step. Then the actual heat transfer mode is determined and if the mode has changed, the plate temperature is recalculated using the correct heat transfer mode.

4.7 Departure from Nucleate Boiling

The DNB heat flux is calculated from the following correlation[3]:*

$$\frac{\phi_{DNB}}{10^6} = k \sqrt{\frac{h^* - h}{h^* - h_o}} \tag{27}$$

$$k = d_1 \left[1 + \left(\frac{2000 - P}{800}\right)^2 \right] \tag{28}$$

$$h_o = d_2 - 0.004(2000-P)^{1.63} \tag{29}$$

and

$$h^* = h_g - d_3\, h_{fg} - d_4\, h_{fg} \left[\frac{300}{h_{fg}}\right]^{\frac{10^6}{G}} \tag{30}$$

where d_1 through d_4 are chosen as input, ϕ_{DNB} is the critical DNB heat flux, (Btu/hr-ft^2); h_g is the saturated gas enthalpy (Btu/lb); h_f is the saturated liquid enthalpy, (Btu/lb); h_{fg} is $h_g - h_f$, (Btu/lb); P is the pressure, (psia), and G is the mass flux of the coolant, (lb/hr-ft^2). The constants are part of the input data. From this calculation of ϕ_{DNB}, the heat transfer coefficient, H_{TB} is defined as [3]

$$H_{TB} = \frac{\phi_{DNB} - 10^4\,[T_s{}' - T_{crit}\,(\phi_{DNB})]}{[T_s{}' - T_{sink}]} \tag{31}$$

(*) The DNB equations in RELAPSE-I are somewhat different in form than the equations used in FLASH. The particular set chosen for interim use in RELAPSE was published by Westinghouse-Bettis as part of the Shippingport Project and no attempt has been made on the part of Phillips to evaluate the applicability of this form of correlation to fluid conditions representative of blowdown behavior.

4.8 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 the IREKIN program (4). The standard reactor kinetics equations are:

$$\frac{dn}{dt} = \left(\frac{\beta}{\Lambda}\right) [(\rho/\beta) - 1] n + \sum_{i=1}^{6} \lambda_i C_i + S \tag{32}$$

$$\frac{dC_i}{dt} + \lambda_i C_i = \frac{\beta_i}{\Lambda} n, \; i = 1, 2, . . 6 \tag{33}$$

where n is the fission power, (ρ/β) is the reactivity input, (β/Λ) is the ratio of effective delayed neutron fraction to neutron generation time, β_i is the effective delayed neutron fraction for group i, and λ_i is the decay constant for the delayed neutron precursor C_i.

Also included as an option in the kinetics code are eleven groups of gamma heat sources:

$$\frac{d\gamma_j}{dt} = \lambda_j \gamma_j = \epsilon_j n, \; j = 1, 2, . . 11 \tag{34}$$

where γ_j is the concentration of the j^{th} gamma precursor, λ_j is the decay constant, and ϵ_j is the fraction yield of the precursor, γ_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 plates and direct gamma heating of the coolant is not considered. The inclusion of the gamma terms allows for a more realistic shutdown transient. The total power, p, is

$$p = n E_f + \sum_{j=1}^{11} \lambda_j E_j \gamma_j \tag{35}$$

where the E_j's are the fraction of power produced in steady state by each production method. If the operational gamma heating is not used, then $E_f = 1$ or, with gamma heating, $E_f = 0.93$ and $\Sigma E_j = 0.07$.

4.9 Reactivity

As input to the reactor kinetics routine, 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 by an equation approximating a control rod. The control rod equation is

$$\left(\frac{\rho}{\beta}\right)_r = \left(\frac{\rho}{\beta}\right)_{max} \left[\frac{X(t)}{X_{max}} - \frac{\sin 2\pi \frac{X(t)}{X_{max}}}{2\pi} - \frac{X_o}{X_{max}} + \frac{\sin 2\pi \frac{X_o}{X_{max}}}{2\pi}\right] \tag{36}$$

and the rod position is

$$X(t) = X_o + vt, \; 0 \leq X \leq X_{max} \tag{37}$$

where v is the velocity of the rod and X is the position. The maximum rod worth, $(\rho/\beta)_{max}$, position limits X_o and X_{max}, and the velocity are input data and may be chosen to develop either positive or negative reactivity.

Feedback reactivity is determined by the combination of void, temperature, Doppler, xenon, and energy dependent functions. In general, both the hot and average channels are used to determine the void, temperature, and Doppler reactivities. The void reactivity is calculated by density changes in the coolant at four points (first and second points, average and hot channels).

$$\left(\frac{\rho}{\beta}\right)_v = \sum_{i=1}^{4} \alpha_{vi} \left(\frac{\rho_i(t)}{\rho_i(o)} - 1\right) \tag{38}$$

where $\rho_i(t)$ is the coolant density and α_{vi} is the reactivity void coefficient at point i.

Likewise, the temperature dependent reactivities are:

$$\left(\frac{\rho}{\beta}\right)_{WT} = \sum_{i=1}^{4} \alpha_{WT_i} \left[\Delta T_{sink_i}\right] \tag{39}$$

$$\left(\frac{\rho}{\beta}\right)_{FT} = \sum_{i=1}^{4} \alpha_{FT_i} \left[\Delta T_{m_i}\right] \tag{40}$$

and

$$\left(\frac{\rho}{\beta}\right)_{DOP} = \sum_{i}^{4} \beta_{DOP_i} \; f(\alpha_{DOP}, \Delta T_{m_i}) \tag{41}$$

where the subscript WT refers to the coolant temperature and FT refers to the fuel temperature. The Doppler reactivity is calculated for each fuel point from a table and then weighted by β_{DOP_i} for each point.

The energy dependent model is included for the transient where a more detailed knowledge of the reactivity feedback is not available. Reactivity is assumed proportional to the energy released but limited to a maximum value.

$$\left(\frac{\rho}{\beta}\right)_{E} = \left(\frac{\rho}{\beta}\right)_{E_{max}} \frac{E(t)}{E_{max}} \tag{42}$$

where the energy ratio is limited by $0 \leq E/E_{max} \leq 1$.

Reactivity due to xenon burnup is important for very large transients if a large fission product inventory exists initially. To estimate the reactivity effect of xenon during a transient, the neutron flux is assumed proportional to power and the radioactive decay of iodine and xenon is neglected.

$$\frac{d\left(\frac{\rho}{\beta}\right)_{xe}}{dt} = \sigma_{xe} \frac{\gamma'_{xe}}{\beta} \frac{\sigma_f}{\sigma_u} \phi_o \frac{p}{p_o} - \sigma_{xe} \phi_o \frac{p}{p_o} \left(\frac{\rho}{\beta}\right)_{xe} \tag{43}$$

where σ_f/σ_u is the ratio of fission to capture cross-section for the fuel, σ_{xe} is the capture cross-section of xenon, p/p_o is the relative power, ϕ_o is the initial average neutron flux level, and β is the delayed neutron fraction for dollar units.

The total reactivity input to the kinetics equation is then

$$\left(\frac{\rho}{\beta}\right) = f_{table}(t) + \left(\frac{\rho}{\beta}\right)_{r} + \left(\frac{\rho}{\beta}\right)_{v} + \left(\frac{\rho}{\beta}\right)_{WT} + \left(\frac{\rho}{\beta}\right)_{FT} + \left(\frac{\rho}{\beta}\right)_{E} + \left(\frac{\rho}{\beta}\right)_{xe} \tag{44}$$

4.10 Core Loop and Momentum Balance

Core and loop flows are calculated from simplified momentum balances. Included in the balance are the frictional forces, inertial forces, elevation terms, and pump head terms. The total pressure drop across the core is assumed to be the difference between the hot and cold volume pressures.

$$\Delta P_{core} = P_H - P_C \tag{45}$$

Integrating the basic one-dimensional momentum equations over the core length gives

$$\frac{L_c}{144\ A_c g}\frac{dW_c}{dt} = P_H - P_C - F - \frac{\rho_c \ell_{HC}}{144} \tag{46}$$

where W_c is the core flow rate, ρ_c is the exit density, ℓ_{HC} is the elevation difference between the hot and cold volumes, L_c is the core length, A_c is the flow area, and F is the flow dependent frictional head loss.

For the core, F is assumed to be

$$F = \frac{k_1 W_c}{\rho_c}\left|W_c\right|^{0.8} + \frac{k_2 W_c}{\rho_c}\left|W_c\right| \tag{47}$$

This form, with the two input constants, k_1 and k_2, allows for a small degree of freedom in fitting the actual frictional head loss as a function of flow. Likewise, the loop equation is

$$\frac{dW_L}{dt}\left(\Sigma \frac{L_i}{144\ A_i g}\right) = P_H - P_C + \Delta P_{pump} - \frac{K_L W_L}{\rho_L}\left|W_L\right| + \frac{\rho_L\ L_{HC}}{144} \tag{48}$$

where $\Sigma \frac{L_i}{144\ A_i g}$ is the inertial term based on the actual pipe geometry.

The above pressure equations are valid for both normal and reversed flow, and are limited in value to be greater than or equal to an ambient pressure supplied by the user.

5. RELAPSE OUTPUT

The output from the RELAPSE code consists of major and minor edits and graphs. The major edit is a single page listing approximating 200 quantities. The frequency of this edit is controlled by the user. Nearly all quantities of interest are included in this edit: power, energy, system pressure, flow rates, reactivities, temperatures, densities, heat transfer modes, heat transfer coefficients, heat fluxes, fluid qualities, head losses, and fluid saturation properties.

The minor edit is a listing of specified quantities for each time increment. The quantities included in the minor edit are chosen by the user from any of the major edit variables and are limited to a maximum of 27. Minor edits occur every 50-time increments.

The graphing portion of the output is done on the system printer following each minor edit. These optional graphs are rather crude but do provide a quick and easy picture of the system response. Any of the minor edit quantities may be graphed.

Normally, the time step size is determined by the type of transient. Realistic values range from 0.0001 to 0.050 seconds for rod ejection studies and up to 0.5 seconds for the latter portion of a blowdown transient. The running speed is approximately 40 time steps per minute on the IBM-7040 and approximately 730 time steps per minute on the CDC-6600.

II. RELAPSE INPUT

1. FORMATS

Input data cards are punched according to the following formats:

(1) Title card, any alphanumeric data in columns 1-72. The format is 72A1 (a).

(2) Control integer numbers with the format 20(I3,1X).

(3) Graph control cards with the format 8X, E8.5, 1X, E8.5, 5(1X,I3).

(4) Data cards with the format of 8X, 6(E8.5, 1X).

The 1X portion of these formats allow each number to be separated by a blank or a comma; integer numbers with the format I3 are written as 002 for 2, 014 for 14, etc. Floating point numbers, with the format E8.5, are written as + 25963+2 for 25.963, - 8430+14 for -8.43×10^{12}, etc.

(a) NOTE: Multiple cases can be run by stacking sets of input data cards together. The problem is terminated by reading a BLANK title card. Thus, the last card of the data deck must be a blank title card.

Table I

CONTROL CARD DEFINTIONS

Card	Format	FORTRAN Name	Definition
1	1		Title card, any alphanumeric characters.
2	2	NT	Number of time step cards ($1 \leq NT \leq 20$).
		NQCT	Number of pairs in table of ρ/β versus time or normalized power versus time ($1 \leq NQCT \leq 25$).
		NQSGT	Number of pairs in table of heat removal versus time ($1 \leq NQSGT \leq 25$).
		NHEAD	Number of pairs in table of pump head versus flow ($1 \leq NHEAD \leq 25$).
		NPDCAY	Number of pairs in table of pump coast-down multiplier versus time ($1 \leq NPDCAY \leq 25$).
		NFILL	Number of pairs in table of fill system flow versus head ($1 \leq NFILL \leq 25$).
		NI	Number of pairs in Henry's Law Table ($1 \leq NI \leq 10$).
		NDOP	Number of pairs in table of Doppler coefficient versus fuel temperature ($0 \leq NDOP \leq 25$).
		NPTYP	Type of power calculations: NPTYP = 000, reactor kinetics; NPTYP = 001, power versus time table.
		NTEMP	Type of initial temperature conditions: NTEMP = 001, same temperature in both volume 1 and 2; NTEMP = 002 volume 1 defined as hot and volume 2 as cold.
		NDNB	Type of DNB heat transfer: NDNB = 001, average coefficients for both hot and average channels: NDNB = 002, lower limit coefficients for both hot and average channels; NDNB = 003, average coefficients for average channel and lower limit coefficients for hot channel.

Table I - Cont'd

Card	Format	FORTRAN Name	Definition
2	2	NDPTYP	Type of Doppler reactivity calculation: NDPTYP = 000, no Doppler calculation; = 001, table of Doppler coefficients versus temperature; = 002, equation fit of Doppler coefficient versus temperature.
3-1	2	IQW(1)	Number of quantities included in the minor edit ($0 \leq IQW(1) \leq 27$).
3-1		IQW(2) . . .	Identification number for the first quantity in the minor edit (see Table IV for ID's).
3-1		IQW(18)	ID for the 17th quantity, last number of card 3-1.
3-2		IQW(19)	ID on card 3-2 for the 18th quantity, first number of card 3-2.
3-2		IQW(28)	ID for the 27th quantity. NOTE: If $IQW(1) \leq 18$, then card 3-2 is not needed.
4	2	NFIWR	Region for fill water injection.
		NFILR	Region for liquid level trip to actuate fill system.
		NFIPR	Region for pressure trip to actuate fill system.
		NPUPR	Region for pressure trip to turn-off main coolant pumps.
		IPLOTT	Number of graphs following minor edit ($0 \leq IPLOTT \leq 27$).
		NHTEX	Type of heat removal calculation; NHTEX = 000, table of normalized power versus time; = 001, heat exchanger approximated by flow dependent equation.

Table I - Cont'd

Card	Format	FORTRAN Name	Definition
		LVAR	Number of reactor kinetics equations: LVAR = 007, standard set with six delayed neutron groups; = 018, standard set plus eleven gamma decay equations. In steady state, 7 percent of the power is from gamma heating.
5-1	3	YBTM(1)	Lower limit for y axis of graph 1.
		YTOP(1)	Upper limit for y axis of graph 1.
		NCUV(1)	Number of time dependent quantities appearing on graph 1 (maximum of 4).
		NGRED(1,1)	ID of first quantity.
		NGRED(1,2)	ID of second quantity.
		NGRED(1,3)	ID of third quantity.
		NGRED(1,4)	ID of fourth quantity.
		. . . .	NOTE: The number of cards used in this set is IPLOTT. A maximum of 27 graphs are allowed with four curves on each graph. All quantities that are graphed <u>must</u> also appear in the minor edit.
5-27	3	YBTM(27)	Etc.

Table II

RELAPSE DATA SHEET 1, CONTROL CARDS

Card	Format	Definition
1	1	Title card with any alphanumeric characters in columns 1-72.
2	2	NT, NQCT, NQSGT, NHEAD, NPDCAY, NFILL, NI, NDOP, NPTYP, NTEMP, NDNB, NDPTYP
3-1	2	IQW(1), IQW(2), ... IWQ(19)
3-2	2	IQW(20), ... IQW(28)
4	2	NFIWR, NFILR, NFIPR, NPUPR, IPLOTT, NHTEX, LVAR
5-1	3	YBTM(1), YTOP(1), NCUV(1), NGRED(1,1), NGRED(1,2), NGRED(1,3), NGRED(1,4).
5-2	3	YBTM(2), YTOP(2), NCUV(2), NGRED(2,1), NGRED(2,2), NGRED(2,3), NGRED(2,4).
5-27		Maximum of 27 cards allowed.

Table III

RELAPSE DATA SHEET 2, DATA CARDS

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
6	TRUP Start time (sec)	ENDT End time (sec)					
7-1 . . 7-20	XXXDT(1) Time step (sec)	XXXNP(1) Number of steps per major edit	XXXL(1) End of internal (sec)				Time step cards; maximum of 20 cards.
8	V(1) Total volume (ft^3)	ZTOT(1) Total height (ft)	Z(1,1) Core exit height (ft)	Z(1,2) Loop entrance height (ft)	Z(1,3) Surge line entrance height (ft)	Z(1,4) Leak height (ft)	Volume 1, hot leg.
9	V(2) Total volume (ft^3)	ZTOT(2) Total height (ft)	Z(2,1) Loop exit height (ft)	Z(2,2) Core entrance height (ft)	Z(2,3) + 00000+0	Z(2,4) Leak height (ft)	Volume 2, cold leg.
10	V(3) Total volume (ft^3)	ZTOT(3) Total heights (ft)	Z(3,3) Surge line exit height (ft)	Z(3,4) Leak height (ft)	WH(2,3) Initial fluid enthalpy (Btu/lb)		Volume 3, pressurizer. NOTE: If the enthalpy ≤ 0 then saturated conditions are assumed.
11	B(1,1) Leak L/D	B(1,2) Maximum leak area (ft^2)	B(1,3) Leak co-efficient				Volume 1

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
12	B(2,1) Leak L/D	B(2,2) Maximum leak area (ft^2)	B(2,3) Leak co-efficient				Volume 2
13	B(3,1) Leak L/D	B(3,2) Maximum leak area (ft^2)	B(3,3) Leak co-efficient				Volume 3
14	ALIN Linear co-efficient for leak area	AQUAD Quadratic coefficient	ACUB Cubic coefficient				Leak area as a function of time: A/A_{max} = ALIN*t+AQUAD *t^2+ACUB*t^3, where $A \leq A_{max}$.
15	P(3) Pressure in vol. 3 (psia)	TLEV Liquid level in vol. 3 (ft)	WH(1,1) Enthalpy vol. 1 (Btu/lb)	WCORE(1) Core flow (lb/sec)	FLM Number of main pumps	HECOF Heat ex-changer H(Btu/hr-°F)	Initial conditions. NOTE: H is defined by Q = HΔT, where Q is the power removal (Btu/hr) and ΔT is tempera-ture differential across the exchanger.
16	CK1 Core K factor 1	CK2 Core K factor 2	CP Surge line K factor	PK1 + 00000+0 (loop K - calculated internally)	CVLVE1 Normal flow valve K factor $\Delta P_V = K\, W\left\|\frac{W}{\rho}\right\|$	CVLVE2 Reversed flow valve K factor with valve open	Hydraulic parameters. Units for K factors: flow(W) in lb/sec, ΔP in lb/in.^{2}, density in lb/ft^3 NOTE: K factors are com-puted with exit densities.

$$\Delta P_{core} = K_1\, W\left|\frac{W}{\rho}\right|^{.8} + K_2 W\left|\frac{W}{\rho}\right|$$

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
17	CVLVE3 Reversed flow valve K factor with valve closed	PSK Pump K factor (pump in-operative)	CI Core inertia $\frac{L(ft)}{144g\ (ft/sec^2)\ A(ft^2)}$	PI Surge line inertia	TLI Loop inertia $\Sigma \frac{L_i}{144g\ A_i}$	BPP Back pressure to close check valve (psi) (positive value)	
18	CL Elevation of vol. 1 over 2 (ft)	HP Elevation of vol. 3 over 1 (ft)	K Specific heat ratios for gas (air) head in pressurizer				
19	QTPD(1) Pressure scram vol. 1 (psia)	TTPD(1) Time delay on P(1) scram (sec)	QTPD(2) Pressure scram vol. 2 (psia)	TTPD(2) P(2) scram delay (sec)	QTPD(2) Pressure scram vol. 3 (psia)	TTPD(3) P(3) delay (sec)	Reactor scram parameters. NOTE: If scram not wanted supply a large number for the delay such as + 10000+5
20	QTPD(4) Liquid level scram vol. 1 (ft)	TTPD(4) Scram level 1 delay (sec)	QTPD(5) Liquid level scram vol. 2 (ft)	TTPD(5) Scram level 2 (ft)	QTPD(6) Liquid level scram vol. 3 (ft)	TTPD(6) Scram level 3 delay (sec)	Major edit lists scram type. These numbers refer to this set of data starting with 1 as a P(1) scram and 12 as a transient time scram. Zero is meant as no scram.

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
21	QTPD(7) Core ΔP scram (psi)	TTPD(7) ΔP scram delay (sec)	QTPD(8) Core flow scram (lb/sec)	TTPD(8) Flow scram delay (sec)	QTPD(9) Relative power scram	TTPD(9) Power scram delay (sec)	
22	QTPD(10) Core exit temperature scram (°F)	TTPD(10) Temperature scram delay (sec)	QTPD(11) Reactor period scram (sec^{-1})	TTPD(11) Period scram delay (sec)	QTPD(12) + 00000+0 (Transient start time from card set 6 used)	TTPD(12) Time delay after transient start (sec)	
23	ZLL1 Liquid level for fill system turn on (ft)	TLLD1 Level turn on delay (sec)	PTRIP1 Pressure trip point to turn on fill system (psi)	TLPD1 Pressure delay (sec)	D2 Time delay for fill system turn on from transient start (sec)		Fill system; Set delay = +10000+5 if option not wanted.
	Region NFILR on card set 4		Region NFIPR on card set 4				
24	CD Coefficient K_y, $f = [1-K_y(Pd-P)^2]$	PSH Manufactures net positive suction (ft)	PTEST Pump shutdown pressure (psia)	TDELAY Pressure pump shutdown delay (sec)	D3 Pump shutdown delay after transient start		Pump data; Set delay = +10000+5 if option not wanted.

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
25-1 25-4	HI(1) H1, Henry's Law constant [psi/(cc/kg)]	SI(1) S1 Concentration (cc/kg) at STP	HI(2) H2	SI(2) S2	H3	S3	Table I, Henry's Law function; NI pairs ($1 \leq NI \leq 10$). Supply as many cards as needed.

$$Pd = Pw + \sum_{i=1}^{NI} H_i S_i + N;$$

where Pw = vapor pressure of water

$N = N_1 P_1 S_1 H_1$

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
26-1 . . 26-7	HEAD(1) Main pump head (ft)	HEAD(2) Main pump flow (gpm)	Head	Flow	Head	Flow	Main pump head NHEAD pairs ($1 \leq NHEAD \leq 20$)
			Provide entries for negative flows and large positive flows				
27-1 . . . 27-7	PDCAY(1) Main pump coastdown multiplier	PDCAY(1) 00000+0 time after shutdown (sec)	Multiplier	Time	Multiplier	Time	Pump coastdown multiplier NPDCAY pairs (1 to 20), start with zero time and end with a large time.
28-1 . . 28-7	FILL(1) Fill system flow (gpm)	FILL(2) Head (psi)	Flow	Head	Flow	Head	Head dependent fill system flow NFILL pairs (1 to 20), include zero head and +3200+4

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
29-1 29-7	QCT(1) Reactivity ($) or relative power ($Q \neq 0$)	QCT(2) Time after transient start (sec) start with +00000+0	Reactivity or power	Time	Reactivity or power	Time	If NPTYP = 0, reactor kinetics; = 1, relative power; NQCT pairs (1 to 20), include a large time
30-1 30-7	QSGT(1) Heat exchanger power removal (Btu/sec)	QSGT(2) Time after transient start (sec)	Power	Time	Power	Time	Heat exchanger table NQSGT pairs (1 to 20), include a large time
31-1 . . 31-7	DOPLE1(1) Doppler coefficient ($/°F)	DOPLE1(2) Fuel temperature (°F)	Coefficient	Temperature	Coefficient	Temperature	Doppler reactivity tables; NDOP pairs (0 to 20), if NDOP = 0, then these cards are not included.
32	WCDP Constant displacement fill pump flow (gpm)	HCDP CD fill enthalpy (Btu/lb)	NFILL Head dependent fill system enthalpy (Btu/lb)	HBDNB Past DNB nominal convection coefficient (Btu/hr-ft^2-°F)	THETA +50000+0 (Weighting factor in calculation of surface temperature)	PATMO Compartment pressure (psia)	

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
33	TPN Leak area opening time (sec)	ASRG Surge line area (ft^2)	ZDEAD Core exit height in vol. 1 after fill systems turn on	SPF2 Hot channel point 1 flow factor after fill systems turn on	SPF4 Hot channel point 2, flow factor after fill systems turn on		
34	WCFLI Core flow increment (lb/sec)	WLFLI Loop flow increment (lb/sec)	WPFLI Surge line increment (lb/sec)				Flow search increments.
35	ZL1 Coolant channel half thickness (ft)	ZL2 Actual clad thickness (ft)	ZL3 Fuel half thickness (ft)	ZL4 Equivalent clad thickness (ft)	ZCORE Half core length (ft)		
36	CKC Clad conductivity (Btu/hr-ft-°F)	RHOCC Clad density x heat capacity (Btu/ft^3)	RHOCM Fuel density x heat capacity (Btu/ft^3)	A2 Point 1 flow area (ft^2)	A3 +00000+0 (interpass area)	A4 Point 2 flow area (ft^2)	
37	HSTAR Forced convection nominal film coefficient (Btu/hr-ft^2-°F)	HFB Minimum film coefficient beyond DNB (Btu/hr-ft^2-°F)	FF2 Point 1 hot channel flow factor	FF4 Point 2 hot channel flow factor	AHT(2) Point 1 heat transfer area (ft^2)	AHT(4) Point 2 heat transfer area (ft^2)	

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
38	PHIZ2 Point 1 initial heat flux (Btu/hr-ft^2)	PHIZ4 Point 2 initial heat flux (Btu/hr-ft^2)	RF2 Point 1 radial physics factor	RF4 Point 2 radial physics factor	AF2 Point 1 axial physics factor	AF4 Point 2 axial physics factor	NOTE: Physics factors are applied only to hot channel calculations.
39	PMW Initial reactor power (MW)	FLUX Initial reactor neutron flux (n/cm^2-sec)	ALFAV(1) Void coefficient point 1 average ($/% void)	ALFAV(2) Void coefficient point 2 average ($/% void)	ALFAV(3) Void coefficient point 1 hot ($/% void)	ALFAV(4) Void coefficient point 2 hot ($/% void)	
40	ENGYM Total energy release for maximum reactivity (MW-sec)	EXPRM Maximum reactivity for total E ($)	ENGDM Energy release above steady state for maximum reactivity (MW-sec)	EXPRD Maximum reactivity for ΔE ($)			Reactivity energy function.
41	ROXE Initial xenon reactivity ($) negative	SIGX Xenon capture cross section, σx	GAMX Ratio Xe yield to delayed neutron fraction γ_x/β	SIGFU Ratio $\frac{\sigma f}{\sigma u}$ for fuel			Xenon properties. NOTE: Use only for large power excursions since equations are only approximate. Both decay of xenon and iodine are neglected.

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
42	RODK Rod worth ($)	RODXO Initial position	RODXM Maximum position	RODV Velocity			Control rod.
43	ALFT(1) Coolant Point 1 average ($/°F)	ALFT(2) reactivity Point 2 average ($/°F)	ALFT(3) temperature Point 1 hot ($/°F)	ALFT(4) coefficients Point 2 hot ($/°F)	S Source $S = -\frac{\rho_o}{\Lambda}$	BOVL Ratio of effective delayed neutron fraction to lifetime $\frac{\beta}{\ell}$ (sec^{-1})	
44	ALFF(1) Fuel Point 1 average ($/°F)	ALFF(2) reactivity Point 2 average ($/°F)	ALFF(3) temperature Point 1 hot ($/°F)	ALFF(4) coefficients Point 2 hot ($/°F)	QL Accuracy Lower +10000-3	QH limits on IREKIN Upper +10000-2	
45	DOPX1(1) Weighting Point 1 average	DOPX1(2) factors for Point 2 average	DOPX1(3) Doppler Point 1 hot	DOPX1(4) table Point 2 hot	DOPX1(5) +00000+0	DOPX1(6) +00000+0	Doppler; if NDPYP = 0, then these cards are not required.

Table III - Cont'd

Card	Cols. 9-16	Cols. 18-25	Cols. 27-34	Cols. 36-43	Cols. 45-52	Cols. 54-61	Remarks
46	DOPX2(1) +00000+0	DOPX2(2) +00000+0	DOPX2(3) +00000+0	DOPX2(4) 0+++++0+	DOPX2(5) +00000+0	DOPX2(6) +00000+0	Extra
47	CDNB(1,1)	CDNB(1,2)	CDNB(1,3)	CDNB(1,4)			DNB coefficients; average conditions.
48	CDNB(2,1)	CDNB(2,2)	CDNB(2,3)	CDNB(2,4)			DNB coefficient; lower limit conditions.

END CARD - The data deck must end with a BLANK card. This card is read in as a new title card and tested for blanks. If this card is completely blank, the problem is terminated by an EXIT call. If the title card is not blank, a new set of data cards for the next case is read in by the machine.

Table IV

OUTPUT VARIABLES

Idenity Number	FORTRAN Name	Quantity Definition	Units
002	Q	Power	Normalized
003	P(1)	Pressure, volume 1	psia
004	P(2)	Pressure, volume 2	psia
005	P(3)	Pressure, volume 3	psia
006	P(2)-P(1)	Pressure across core	psi
007	WCORE	Core flow	lb/sec
008	WLOOP	Loop flow	lb/sec
009	AREALT	Total leak area	ft^2
010	RLEAK	Total fluid mass lost out of leak	lb
011	QLEAK	Total fluid energy lost out of leak	Btu
012		Power	MW
013		Power	Btu/hr
014		Heat exchanger power removal	Btu/hr
015		Heat exchanger power removal	Normalized
016		Heat exchanger power removal	MW
017	HECOF	Heat exchanger overall H	Btu/sec-°F
018	TEMHE	Heat exchanger fluid temperature	°F
128	PX(7,2)	Fill system mass flow	lb/sec
204	ENERGY	Total energy release after transient start	MW-sec
205	DENERG	Energy released above steady state conditions	MW-sec
206	TIMTR	Time based from transient starts	sec

Table IV - Cont'd

Idenity Number	FORTRAN Name		Quantity Definition	Units
			SATURATION PROPERTIES	
019	PSAT(1)	Volume 1	Saturation pressure	psia
020	TSAT(1)	Volume 1	Saturation temperature	°F
021	HF(1)	Volume 1	Saturation fluid enthalpy	Btu/lb
022	HG(1)	Volume 1	Saturated gas enthalpy	Btu/lb
023	VF(1)	Volume 1	Specific volume of fluid	ft^3/lb
024	VG(1)	Volume 1	Specific volume of gas	ft^3/lb
025	PSAT(2)	Volume 2		
026	TSAT(2)	Volume 2		
027	HF(2)	Volume 2		
028	HG(2)	Volume 2		
029	VF(2)	Volume 2		
030	VG(2)	Volume 2		
031	PSAT(3)	Volume 3		
032	TSAT(3)	Volume 3		
033	HF(3)	Volume 3		
034	HG(3)	Volume 3		
035	VF(3)	Volume 3		
036	VG(3)	Volume 3		

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Defintion		Units
		FLUID PROPERTIES IN EACH VOLUME		
037	CAPM(2,1)	Total fluid mass	Volume 1	lb
038	CAPM(2,2)		Volume 2	
039	CAPM(2,3)		Volume 3	
040	GM(2,1)	Total steam mass	Volume 1	lb
041	GM(2,2)		Volume 2	
042	GM(2,3)		Volume 3	
043	GMB(2,1)	Mass of entrained steam bubbles; as above		lb
044	GMB(2,2)			
045	GMB(2,3)			
046	WM(2,1)	Liquid mass	Volume 1	lb
047	WM(2,2)		Volume 2	
048	WM(2,3)		Volume 3	
049	U(2,1)	Total energy	as above	Btu
050	U(2,2)			
051	U(2,3)			
052	ZM(1)	Mixture level	as above	ft
053	ZM(2)			
054	ZM(3)			
055	ZL(1)	Liquid level	as above	ft
056	ZL(2)			
057	ZL(3)			

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
058	WV(2,1)	Liquid volume	as above	ft^3
059	WV(2,2)			
060	WV(2,3)			
061	GV(2,1)	Steam volume	as above	ft^3
062	GV(2,2)			
063	GV(2,3)			
064	WH(2,1)	Liquid enthalpy	as above	Btu/lb
065	WH(2,2)			
066	WH(2,3)			
067	GH(2,1)	Steam enthalpy	as above	Btu/lb
068	GH(2,2)			
069	GH(2,3)			
129	PX(8,1)	Leak throat pressure	as above	psi
130	PX(8,2)			
131	PX(8,3)			
132	WT(1)	Water temperature	as above	°F
133	WT(2)			
134	WT(3)			
135	GT(1)	Steam temperature	as above	°F
136	GT(2)			
137	GT(3)			

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
138	1/VLIQ(1)	Liquid density (Note: Specific volumes rather than densities are used internally.)	as above	lb/ft^3
139	1/VLIQ(2)			
140	1/VLIQ(3)			
141	1/VGAS(1)	Steam density	as above	lb/ft^3
142	1/VGAS(2)			
143	1/VGAS(3)			

PROPERTIES BETWEEN VOLUMES

Idenity Number	FORTRAN Name	Quantity Definition		Units
070	W(1,1)	Mass flow (Volume 1 base)	Core to volume 1	lb/sec
071	W(1,2)		Volume 1 to loop	
072	W(1,3)		Surge line to volume 1	
073	W(1,4)		Volume 1 to leak	
074	W(1,5)		Fill system to volume 1	
075	H(1,1)	Enthalpy (Volume 1 base)	Same as mass flow, volume 1 base	Btu/lb
076	H(1,2)			
077	H(1,3)			
078	H(1,4)			
079	H(1,5)			

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
080	X(1,1)	Fluid quality defined as $\frac{H - H_f}{H_g - H_f}$	Same as mass flow, volume 1 base	dimension-less
081	X(1,2)			
082	X(1,3)			
083	X(1,4)			
084	X(1,5)			
085	W(2,1)	Mass flow (Volume 2 base)	Loop to volume 2	lb/sec
086	W(2,2)		Volume 2 to core	
087	W(2,3)		Surge line to volume 2 = 0	
088	W(2,4)		Volume 2 to leak	
089	W(2,5)		Fill to volume 2	
090	H(2,1)	Enthalpy (Volume 2 base)	Same as mass flow, volume 2 base	Btu/lb
091	H(2,2)			
092	H(2,3)			
093	H(2,4)			
094	H(2,5)			
095	X(1,1)	Fluid quality (Volume 2 base)	Same as mass flow, volume 2 base	dimension-less
096	X(2,2)			
097	X(2,3)			
098	X(2,4)			
099	X(2,5)			

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
100	W(3,1)	Mass flow (Volume 3 base)		lb/sec
101	W(3,2)			
102	W(3,3)		Volume 3 to surge line	
103	W(3,4)		Volume 3 to leak	
104	W(3,5)		Fill to volume 3	
105	H(3,1)	Enthalpy (Volume 3 base)	Same as mass flow, volume 3 base	Btu/lb
106	H(3,2)			
107	H(3,3)			
108	H(3,4)			
109	H(3,5)			
110	X(3,1)	Fluid quality (Volume 3 base)	Same as mass flow, volume 3 base	dimension-less
111	X(3,2)			
112	X(3,3)			
113	X(3,4)			
114	X(3,5)			

FLUID HEADS

115	PX(4,4)	Core acceleration
116	PX(5,4)	Loop acceleration
117	PX(4,5)	Core friction
118	PX(5,5)	Loop friction
119	PX(4,6)	Core elevation

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
120	PX(5,6)	Loop elevation		psi
121	PX(6,1)	Pump inlet pressure		psi
122	PX(6,2)	Volume 1 to pump ΔP		psi
123	PX(6,3)	Pump head pressure		psi
124	PX(6,4)	Check valve loss		psi
125	PX(6,5)	Pump to Volume 2 ΔP		psi
126	PX(6,6)	Pump elevation		psi
127	PX(7,1)	FILL system head		psi
144	CH(2,1)	Enthalpy	Into point 1 average	Btu/lb
145	CH(2,2)	Enthalpy	Out of point 1 average	Btu/lb
146	CH(2,3)	Enthalpy	Into point 2 average	Btu/lb
147	CH(2,4)	Enthalpy	Out of point 2 average	Btu/lb
148	CH(2,5)	Enthalpy	Into point 1 hot	Btu/lb
149	CH(2,6)	Enthalpy	Out of point 1 hot	Btu/lb
150	CH(2,7)	Enthalpy	Into point 2 hot	Btu/lb
151	CH(2,8)	Enthalpy	Out of point 2 hot	Btu/lb

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
152	VSP(2,1)	Specific volume	Same as enthalpy	ft^3/lb
153	VSP(2,2)			
154	VSP(2,3)			
155	VSP(2,4)			
156	VSP(2,5)			
157	VSP(2,6)			
158	VSP(2,7)			
159	VSP(2,8)			
160	EXITX(2)	Quality	Point 1 average	dimensionless
161	EXITX(4)		Point 2 average	
162	EXITX(6)		Point 1 hot	
163	EXITX(8)		Point 2 hot	
164	TH2O(2)	Fluid temperature	Same as quality	°F
165	TH2O(4)			
166	TH2O(6)			
167	TH2O(8)			
168	T(2,2)	Average fuel temperature	Point 1 average	°F
169	T(2,4)		Point 2 average	
170	T(2,6)		Point 1 hot	
171	T(2,8)		Point 2 hot	

Table IV - Cont'd

Idenity Number	FORTRAN Name	Quantity Definition		Units
172	TS(2,2)	Fuel element surface temperature	Same as fuel temperature	°F
173	TS(2,4)			
174	TS(2,6)			
175	TS(2,8)			
176	DNPR(2)	DNB heat flux	Same as fuel temperature	Btu/hr-ft^2
177	DNPR(4)			
178	DNPR(6)			
179	DNPR(8)			
180	UEDI(1)	Overall heat transfer coefficient	Same as fuel temperature	Btu/hr-ft^2-°F
181	UEDI(2)			
182	UEDI(3)			
183	UEDI(4)			
184	PHI(2)	Average heat flux in coolant	Same as fuel temperature	Btu/hr-ft^2
185	PHI(4)			
186	PHI(6)			
187	PHI(8)			
188	Q(2)	Average heat flux in fuel	Same as fuel temperature	Btu/hr-ft^2
189	Q(4)			
190	Q(6)			
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