AN ABSTRACT OF THE THESIS OF

Ronald Leonard Hatteberg for the degree of Master of Science

in Nuclear Engineering presented on December 5, 1977.

Title: A Simulated Two-Group Method for Computing Boiling Water Reactor Power Distributions

Abstract approved: _____
Alan H. Robinson

A computer code capable of modeling the burnup dependent static behavior of a boiling water reactor was developed. The code calculates three-dimensional quarter core power distributions using a simulated two-group diffusion theory model. Thermal-hydraulic calculations account for the interaction between power, coolant flow, and void fraction distributions. Cross sections are corrected to account for the effect of control rods and local equilibrium xenon concentrations. Burnup step calculations are used to predict the effects of fuel depletion. The code will optionally calculate a unique power distribution which will minimize power peaking throughout a specified operating cycle. With these capabilities, the code can be used to develop BWR fuel loading and operation strategies which can aid in minimizing fuel cycle costs.

A Simulated Two-Group Method for Computing Boiling Water Reactor Power Distributions

by

Ronald Leonard Hatteberg

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Commencement June 1978

APPROVED:

Professor of Nuclear Engineering

Head of Department of Nuclear Engineering

Dean of Graduate School

Date thesis is presented December 5, 1977.

Typed by Delores Maneshi for Ronald Leonard Hatteberg.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

A Simulated Two-Group Method for Computing Boiling Water Reactor Power Distributions

1.0 INTRODUCTION

Analysis of the burnup dependent static behavior of a reactor core plays an important part in reactor fuel management. The ability to predict this behavior enables core design and operations strategies to be developed which can be used to minimize fuel cycle costs. The purpose of this project was to develop a boiling water reactor (BWR) model which could be used for this type of analysis.

A FORTRAN computer code capable of predicting three-dimensional power distributions in a BWR was developed. The model represents one quarter of a reactor core. Quadrant symetry is assumed. The mutual interaction between the core power, fuel exposure, coolant flow and void fraction, and equilibrium xenon distributions are accounted for. Control rod effects are also included. Only fuel regions can be represented by the code. Reflecting regions surrounding a core are accounted for by appropriate boundary conditions.

The global power distribution is solved by three successive levels of iteration. The inner iteration solves the neutron flux distribution for a fixed fission source distribution. The next level of iteration, the source iteration, calculates the fission source distribution and effective multiplication factor given the nuclear constants of the core. The final level of iteration solves for the power distribution and accounts for the feedback effects between power, void fraction, and equilibrium xenon distributions.

Fuel depletion effects are modeled by burnup step calculations.

During a burnup step the power distribution is assumed to remain constant. The exposure distribution at the end of a step is calculated directly from the initial exposure distribution and the power distribution. Relative power and exposure distribution arrays can be punched by the code to facilitate restart calculations.

Input to the code consists primarily of a description of the core geometry and fuel loading, core thermal-hydraulic parameters, and tables of exposure and void dependent nuclear constants of the fuel. Output includes the predicted core power distribution, effective multiplication factor, coolant flow and void fraction distributions, and the predicted exposure distribution at the end of each burnup step.

BWR's have a strongly negative local power coefficient of reactivity. This is because the reactor coolant is allowed to change phase. Voiding of the coolant causes a large decrease in its moderating ability. There is a natural tendency for the power distribution to peak near the bottom of the core due to the larger void fractions at the top. Increasing the coolant flow rate reduces void fractions. Regulation of the coolant flow provides one of the primary means of BWR reactivity control. Due to these effects, a thermal-hydraulic model is an essential part of a BWR simulator.

A BWR simulator must be able to calculate three-dimensional power distributions, with feedback effects included, using a minimal amount of computer time and memory in order to be practical for routine application. This precludes an accurate but costly fine mesh multi-group diffusion theory type of calculation. One approach, used by the FLARE[1] code, is a one group, coarse mesh model using transport kernels to cou-

ple the fluxes at mesh points. This is equivalent to a one-group diffusion theory calculation. Various versions of the FLARE code are currently in wide use, but the model has several drawbacks. It requires extensive a priori normalization.

The neutronics model chosen for this project is an extension of a two-dimensional model developed for PWR analysis by Stout[2]. A simulated two-group diffusion theory model is used. This is based on a one-fast-group 3DB[3] type of calculation. The model permits a coarse mesh representation and execution time is on the order of a one group model. It represents a higher order approximation than FLARE, since it is effectively a two-group calculation, and does not require extensive normalization. The applicability of this type of model to BWR analysis has been demonstrated by Børresen[4].

BWR operation is characterized by the concept of an operating cycle. An operating cycle is a period of operation at the end of which the reactor is shut down for refueling. Approximately one quarter of the most highly depleted fuel assemblies are replaced at this time in order to provide a sufficient amount of reactivity to sustain operation through the next cycle. Some important decisions that must be made by those concerned with fuel management are the length of the cycle, enrichment of the reload fuel, the number of assemblies to be replaced, and the rearrangement of assemblies within the core. A reactor simulator can be used to evaluate the consequences of these types of fuel management decisions.

The primary limiting factor which must be dealt with in reactor core design is the critical heat flux. This is a limiting heat flux

beyond which a sharp jump in the surface temperature of the fuel cladding occurs. The ratio of the critical heat flux to the maximum local heat flux is called the minimum critical heat flux ratio (MCHFR). A MCHFR calculation, using a design limit correlation, has been included in the code. Recent BWR designs have used a MCHFR design limit of 1.9. The reactors are designed so that critical heat flux ratios will not fall below this limit during normal operation.

Another important consideration in reactor design and operation is the power peaking ratio. It is defined as the ratio of the peak to average local power densities in a reactor. This is important for several reasons. Reactor fuel and thermal-hydraulic performance are generally improved by reducing power peaking ratios. Operation with a large power peak accelerates fuel depletion in the region of the peak. Excessive local fuel exposures incure an increased risk of fuel failure. Power peaking also limits the core power density, since design limits, such as the MCHFR limit, must not be exceeded at the power peak. Typical power peaking ratio design limits are 1.5 in the axial direction, 1.4 radially, and 2.6 overall.

BWR power peaking occurs in regions of relatively high reactivity, such as in freshly loaded or highly enriched fuel, and near the bottom of a core due to voiding. It can be controlled by inlet orificing, burnable poison distributions, and by the choice of fuel loading pattern and control rod positions.

The economic benefits of a reduction in power peaking can be very large. This is particularly true of nuclear generating systems built using the stretch concept[5]. Such a system is built with a turbine gen-

erator capable of handling a boiler rated at a higher output than the nominal output of the reactor. The purpose of this was to allow for expected improvements in technology and operating limits. A reduction in power peaking permits operation at a higher power density and increases the capacity of the generating system. Higher than expected power peaking could also force operation at less than the nominal or designed power density in order to stay within safe operating limits. Fuel fabrication costs can also be reduced if power peaking ratios are low.

A major problem in BWR operation is determining control rod withdrawal patterns which will optimize reactor performance. Optimal performance generally means maintaining the lowest possible power peaking ratio throughout the cycle. Control rods can be used to shape the power distribution, but are ideally fully withdrawn at the end of a cycle.

An option has been included in the code which will calculate the optimal power distribution for an operating cycle. This is called the Haling solution[6]. A Haling solution gives the end of life power and fuel exposure distrubutions which would result if the same power distribution were maintained throughout the cycle. This is determined from the beginning of cycle fuel loading and exposure distributions and the cycle length in terms of the average fuel exposure increment. If maintained, the Haling power distribution will minimize power peaking throughout the cycle. Haling solutions are useful for comparing fuel loading patterns as well as for determining optimal burnable poison distributions and control rod patterns.

The remainder of this thesis discusses the methods used in develop-

ing the code and results that have been obtained. The neutronics model is described in Chapter 2. Cross section input generation and evaluation are discussed in Chapter 3. Chapter 4 describes the thermal-hydraulic model and Chapter 5 describes the Haling solution logic. Results obtained from benchmarking and testing the code are given in Chapter 6. Conclusions are given in Chapter 7. Input instructions and a source listing are provided in the appendices.

2.0 NEUTRONICS MODEL

The reactor power distribution is calculated using a model which represents the reactor as a group of geometrically identical nodes. A node is defined as a homogeneous volume whose boundaries are defined by mesh lines. Mesh lines are chosen to lie between fuel assemblies and along the core periphery. The number of axial nodes represented is optional, but should be chosen such that the node height is approximately equal to the width.

The power distribution calculation is based on a finite difference approximation to the two-group neutron diffusion equations. The fast and thermal fluxes are calculated at points taken to be at the center of each node. An averaging scheme is then used to calculate node averaged fast and thermal fluxes. The power distribution is calculated from the node averaged flux distributions.

2.1.1 Formulation of Difference Equations

The two-group neutron diffusion equations may be written as

$$-D_1\nabla^2\phi_1 + (\Sigma_{a1} + \Sigma_r)\phi_1 = \frac{1}{k_{eff}} (\nu\Sigma_{f1}\phi_1 + \nu\Sigma_{f2}\phi_2) \qquad (2\text{-}1a)$$

$$-D_2\nabla^2\phi_2 + \Sigma_{a2}\phi_2 = \Sigma_r\phi_1 \quad . \qquad (2\text{-}1b)$$

ϕ_1 , ϕ_2 = fast and thermal fluxes

D_1 , D_2 = fast and thermal diffusion coefficients

Σ_{a1}, Σ_{a2} = fast and thermal macroscopic absorbtion cross sections

Σ_r = fast removal cross section

$\nu\Sigma_{f1}$, $\nu\Sigma_{f2}$ = fast and thermal ν-fission cross sections

k_{eff} = effective multiplication factor

These coupled equations are not suitable for direct formulation of coarse mesh difference equations. A mesh size characteristic of a BWR fuel assembly pitch (∿15 cm) would lead to a break down of the difference approximation for the thermal group. This is due to the comparitively small (3-7 cm) mean free path of thermal neutrons. This is not a problem for the fast group since the mean free path for this group is nearly the same as the assembly pitch.

A zero thermal buckling approximation can be made which will alleviate this problem. This is a reasonably good approximation for large node sizes. Equation 2-1b becomes

$$\phi_2 = \frac{\Sigma_r}{\Sigma_{a2}} \phi_1 \quad . \tag{2-2}$$

Equation 2-2 gives the asymptotic thermal flux solution.

It is now convienient to define a new ν-fission cross section.

$$\nu\Sigma_f = \nu\Sigma_{f1} + \frac{\Sigma_r}{\Sigma_{a2}} \nu\Sigma_{f2} \tag{2-3}$$

Using equations 2-2 and 2-3, equation 2-1a can be reformulated as

$$-D_1\nabla^2\phi_1 + (\Sigma_{a1} + \Sigma_r)\phi_1 = \frac{1}{k_{eff}} \nu\Sigma_f\phi_1 \quad . \tag{2-4}$$

The difference equations are obtained by integrating equation 2-4 over the node volume. A mesh point is taken to be at the center of a node of height DZ and width and depth DX as shown in figure 2.1.

Integration of the leakage term is accomplished by first trans-

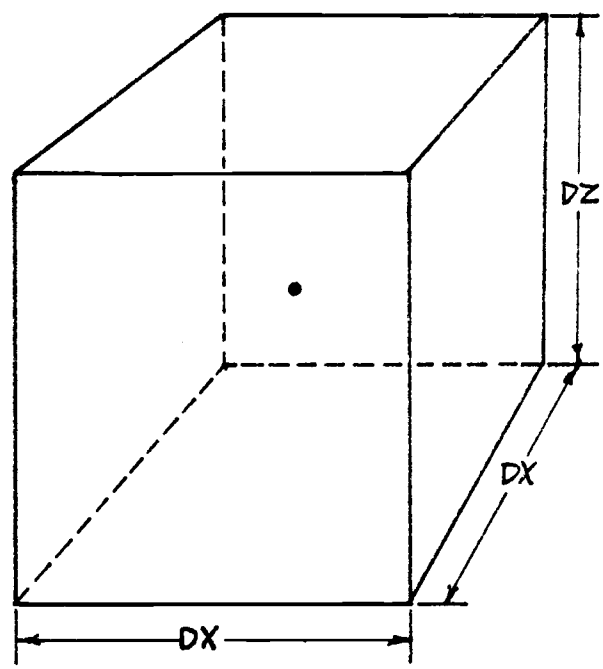


Figure 2.1 Node Dimensions.

forming the volume integral to a surface integral by means of Green's theorem.

$$\int_V D\nabla^2\phi dV = \int_S D\nabla\phi dA \tag{2-5}$$

The surface integral is carried out over the six faces of the node.

Evaluation of the flux gradient at the interface is easily understood by considering a one-dimensional case where two mesh points, ℓ and $\ell+1$, are separated by a distance, d, and equidistant from a mesh line separating two regions. The region to the left of the mesh line has diffusion coefficient D_ℓ, and that to the right has $D_{\ell+1}$.

Using difference approximations, continuity of the neutron current at the boundary gives

$$\frac{-D_\ell(\phi_{\ell+\frac{1}{2}} - \phi_\ell)}{d/2} = \frac{-D_{\ell+1}(\phi_{\ell+1} - \phi_{\ell+\frac{1}{2}})}{d/2} \quad . \tag{2-6}$$

$\phi_\ell, \phi_{\ell+\frac{1}{2}}$, and $\phi_{\ell+1}$ refer to the fluxes at point ℓ, the mesh line, and point $\ell+1$ respectively. The flux at the interface is given by

$$\phi_{\ell+\frac{1}{2}} = \frac{D_\ell\phi_\ell + D_{\ell+1}\phi_{\ell+1}}{D_\ell + D_{\ell+1}} \quad . \tag{2-7}$$

Using this expression, the flux gradient at the interface can be written in terms of ϕ_ℓ and $\phi_{\ell+1}$.

$$\nabla\phi_{\ell+\frac{1}{2}} = \left\{\frac{D_{\ell+1}}{D_\ell + D_{\ell+1}}\right\}\left\{\frac{\phi_{\ell+1} - \phi_\ell}{d/2}\right\} \tag{2-8}$$

The difference approximation of equation 2-4 for mesh point o becomes

$$\sum_{i=1}^{6} \frac{D_o D_i}{D_o+D_i} \frac{(\phi_o-\phi_i)A_i}{d_i/2} + (\Sigma_{a1}+\Sigma_r)_o\phi_o V_o = \frac{1}{k_{eff}}\nu\Sigma_{fo}\phi_o V_o \tag{2-9}$$

A_i = area of the interface between nodes o and i

V_o = volume of node o

d_i = distance between mesh points o and i

The summation is over all six nodes adjacent to node o as shown in figure 2.2. Since all nodes in the problem have equal dimensions, equation 2-9 can be simplified by dividing by V_o. It can then be expressed in a more convenient form as

$$\phi_o = \frac{S_o + \sum_{i=1}^{6} C_i \phi_i}{C_7} \quad . \tag{2-10}$$

$$S_o = \frac{1}{k_{eff}} \nu \Sigma_{fo} \phi_o \tag{2-11}$$

$$C_i = \frac{2D_o D_i}{d_i^2 (D_o + D_i)} \tag{2-12}$$

$$C_7 = (\Sigma_{al} + \Sigma_r)_o + \sum_{i=1}^{6} C_i \tag{2-13}$$

2.1.2 Boundary Conditions

Boundary conditions are treated by specifying the flux at a node's boundary interface as a fraction of the flux at the mesh point of that node. Consider a node with mesh point ℓ whose interface lies on the problem boundary. An imaginary node with mesh point ℓ+1, and with consistant mesh spacing is assumed to lie beyond the boundary as shown in figure 2.3. The nuclear properties of node ℓ+1 are assumed identical to those of node ℓ. From equation 2-7, the flux at the boundary is simply

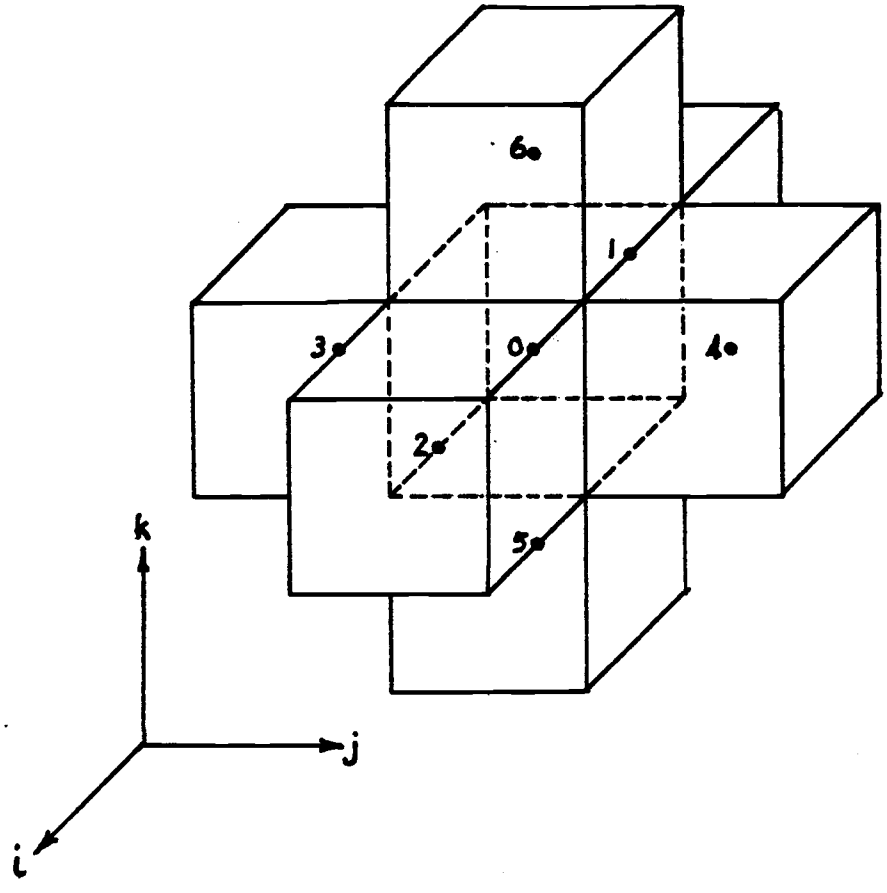


Figure 2.2 Schematic of Three-Dimensional Node Geometry.

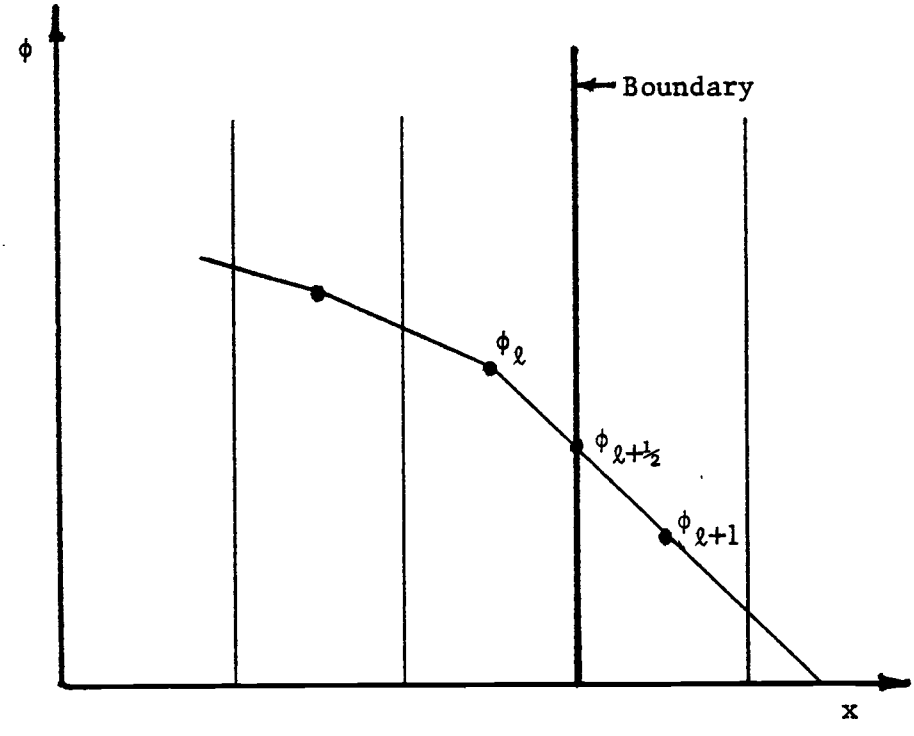


Figure 2.3 Boundary Condition Representation.

$$\phi_{\ell+\frac{1}{2}} = \frac{1}{2}(\phi_\ell + \phi_{\ell+1}) \quad . \tag{2-14}$$

Specifying the boundary flux as

$$\phi_{\ell+\frac{1}{2}} = ALB \cdot \phi_\ell \tag{2-15}$$

gives

$$\phi_{\ell+1} = (2ALB - 1)\phi_\ell \quad . \tag{2-16}$$

With prior knowledge of $\phi_{\ell+1}$ in the form of equation 2-16, an extra term, $(2/d_i^2)D_i(1 - ALB)$, can be added to the denominator of equation 2-10. One such term is added for each node interface that lies on the problem boundary. The summations in equations 2-10 and 2-13 then correspond to the remaining node interfaces which do not lie on a boundary.

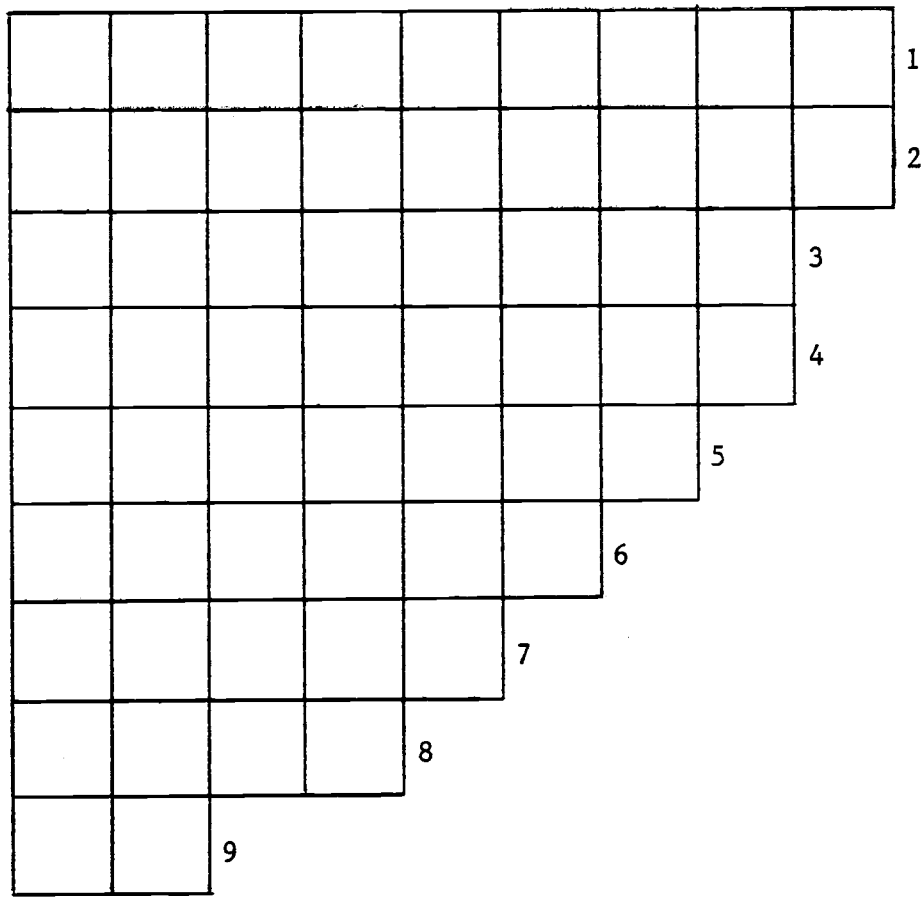
From equation 2-15 it is obvious that ALB = 1.0 corresponds to a zero current, or reflecting, boundary condition and ALB = 0.0 corresponds to a zero flux boundary condition. Thus, as ALB implies, it can be convieniently thought of as an albedo (although it is not in a strict sense of the word).

Boundary conditions are required for the core bottom and top and each of the radial faces of the core periphery. A problem represented by NX nodes in the radial direction requires NX separate boundary conditions to represent the complex geometry of the periphery. The NX boundaries are indexed as shown in figure 2.4.

In order to account for the increased leakage caused by voiding, boundary conditions are input as a function of void fraction.

$$ALB = A + B \cdot VOID(\ell) \tag{2-17}$$

A and B are input constants for each boundary. VOID(ℓ) is the void fraction of the appropriate boundary node. Separate boundary conditions



Number of radial nodes, NX = 9.

Figure 2.4 Boundary Node Indexing Convention.

are input for the fast and thermal fluxes.

2.1.3 Solution

Equation 2-4 is solved using the inner-outer iteration technique illustrated in figure 2.5. Using an initial flux distribution guess, a fission source distribution is calculated. Holding the source distribution fixed, MAXI inner iterations are carried out using equation 2-10. (MAXI is an input constant.) The eigenvalue for the next outer (source) iteration is calculated from

$$k_{eff}^{N} = k_{eff}^{N-1} \frac{TF^{N}}{TF^{N-1}} \quad . \tag{2-17}$$

TF^{N} = total fission source for iteration N

N = outer iteration counter

A new source distribution is then calculated as in equation 2-11 and the inner iteration is repeated. The outer iteration is terminated when the source distribution is converged or when the number of outer iterations is equal to an input limit, MAXO. The outer iteration is considered converged when the maximum relative change in nodal fission sources is less than or equal to an input convergence criterion, EPSO.

Convergence of the source iteration is accelerated by successive over-relaxation (SOR). The accelerated source distribution is calculated from

$$S_{\ell}^{N*} = S_{\ell}^{N-1} + \alpha(S_{\ell}^{N} - S_{\ell}^{N-1}) \quad . \tag{2-18}$$

S^{N*} = accelerated source for outer iteration N

α = over-relaxation factor

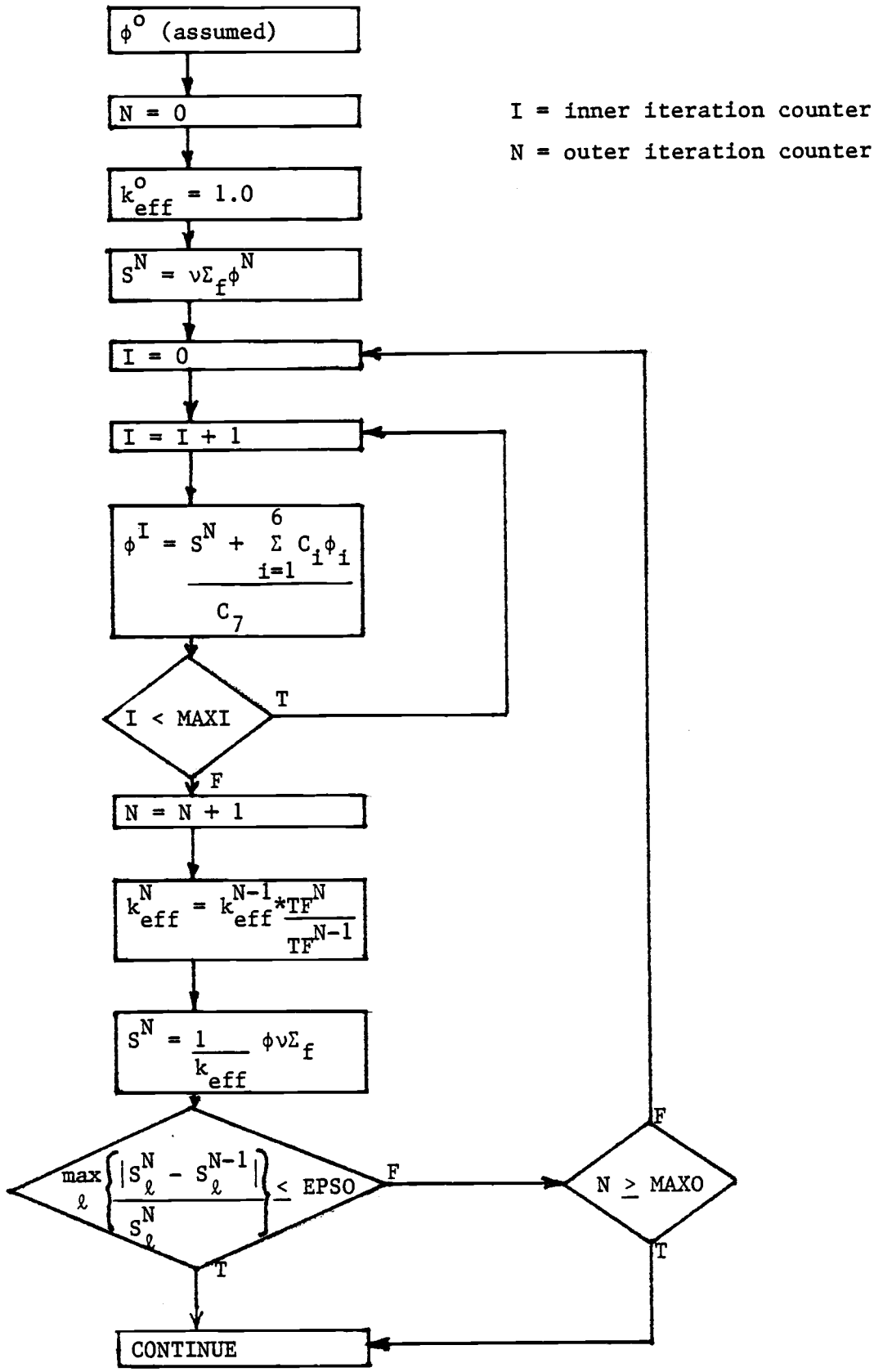


Figure 2.5 Flow Diagram of Inner and Outer Iterations.

The over-relaxation factor is input. A value of 1.65 is close to optimum for most cases and is the default value.

2.2 Node Averaging

A coarse mesh diffusion theory model tends to under-predict current densities at node interfaces. This is particularly true if there is a large difference between the diffusion coefficients of the two adjacent nodes or if the node is on the core periphery. This can lead to a fairly large error in the predicted power distribution. In order to reduce this error, a node averaging scheme proposed by Børresen[4] is employed.

The node averaged flux, $\overline{\phi}$, is calculated as a weighted average of the midpoint flux and the fluxes at the node interfaces.

$$\overline{\phi}_o = b \cdot \phi_o + c\left(\sum_{i=1}^{4} \psi_i + R \cdot \sum_{k=1}^{2} \psi_k\right) \tag{2-19}$$

$$b = \frac{3a}{3a + (1-a)(R+2)} \tag{2-20}$$

$$c = \frac{1 - a}{6a + 2(1-a)(R+2)} \tag{2-21}$$

$$R = \frac{DX^2}{DZ^2} \tag{2-22}$$

ϕ_o = flux at node midpoint

ψ = flux at node interface

a = input weighting factor

DX = horizontal mesh width

DZ = vertical mesh width

The first summation in equation 2-19 corresponds to interfaces with the

four horizontally adjacent nodes. The second corresponds to interfaces with the two vertically adjacent nodes.

For interfaces not on the problem boundary, interface fluxes are calculated as in equation 2-7. For the interface between node o and node i

$$\psi_i = \frac{D_o\phi_o + D_i\phi_i}{D_o + D_i} \quad . \tag{2-23}$$

For interfaces lying on the problem boundary, the interface flux is calculated as in equation 2-15.

$$\psi_i = ALB_i \cdot \phi_o \tag{2-24}$$

ALB_i is the appropriate boundary condition for that face.

Two different values of the weighting factor, a, are used to calculate the node averaged fast and thermal fluxes. Børresen recommends 0.3 and 0.7 for the fast and thermal groups respectively.

The procedure used in calculating node averaged fluxes is to first calculate node averaged fast fluxes from the fast flux distribution produced by the diffusion theory model. An assymptotic thermal flux distribution is calculated from the node averaged fast flux distribution. Then a node averaged thermal flux distribution is calculated from these assymptotic thermal fluxes.

2.3 Power Distribution and Burnup Calculations

A relative power distribution is calculated from the node averaged fast and thermal fluxes. The relative power at node o is given by

$$P_o = \frac{(\kappa\Sigma_{f1}\phi_1 + \kappa\Sigma_{f2}\phi_2)_0}{\frac{1}{N}\sum_{\ell=1}^{N}(\kappa\Sigma_{f1}\phi_1 + \kappa\Sigma_{f2}\phi_2)_\ell} \quad . \tag{2-24}$$

N = number of nodes represented in the problem

The cross sections used to calculate a flux and power distribution are themselves functions of power due to the feedback effects of void fraction and xenon concentration. The power distribution is solved iteratively. After a power distribution has been calculated, new cross sections consistant with this distribution are calculated. Another power distribution is calculated with the new cross sections, and so on, until convergence is achieved.

In a burnup step calculation, a power distribution is calculated consistant with an initial exposure distribution. Assuming the power distribution remains constant during the input exposure interval, the exposure distribution at the end of the step can be calculated. The exposure at each node is calculated from

$$E_\ell = E_\ell^i + P_\ell \cdot \Delta E \quad . \tag{2-25}$$

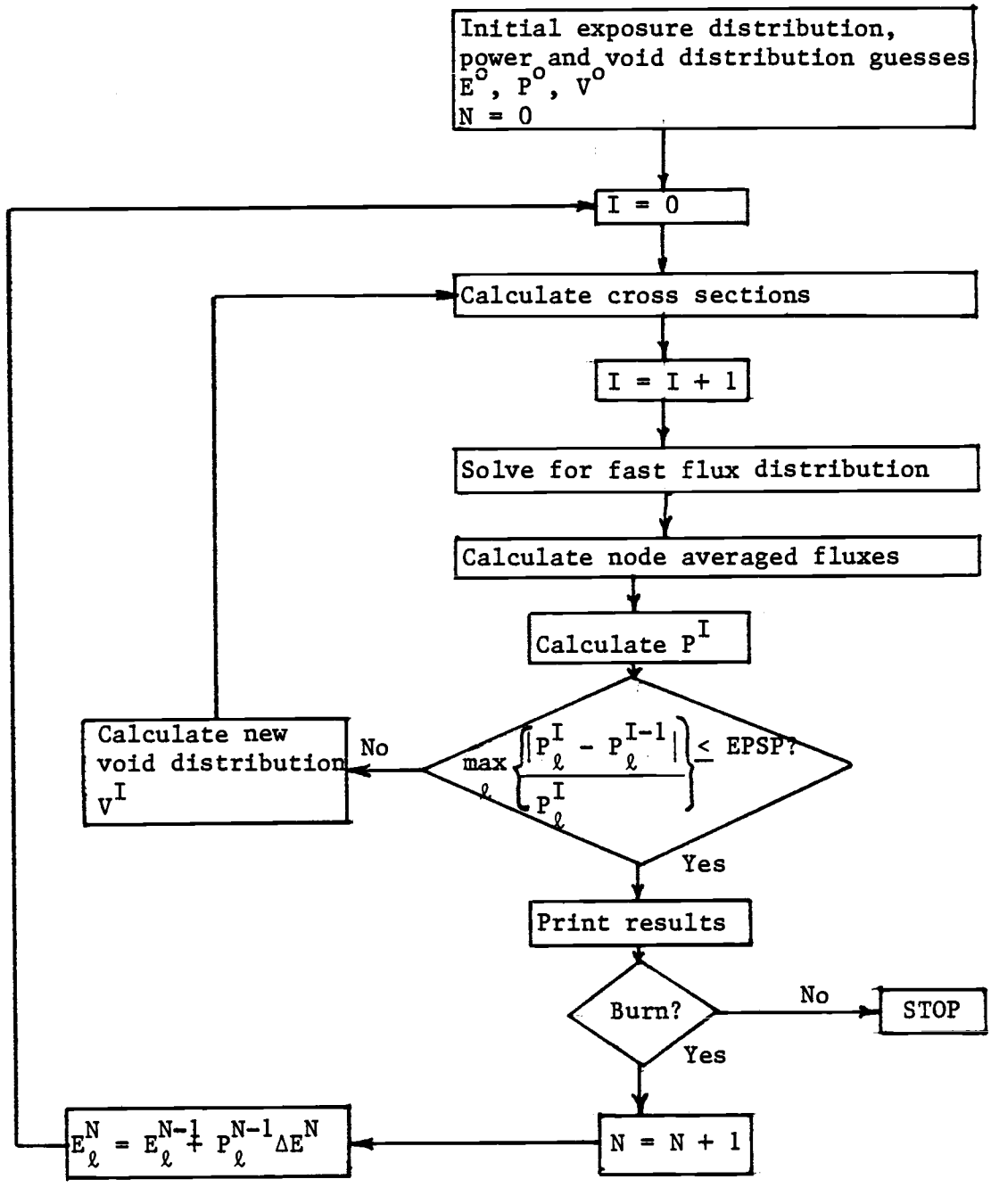
E_ℓ = fuel exposure at end of step (MWD/MTU)

E_ℓ^i = exposure at beginning of step

P_ℓ = relative power of node ℓ

ΔE = length of core burnup step (MWD/MTU)

The entire power distribution and burnup time-step solution procedure is illustrated in figure 2.6. Starting with the initial fuel exposure distribution and guesses of the power and void distributions, the code calculates nodal cross sections and then the corresponding flux and power distributions. A new void distribution is calculated



N = exposure step counter
I = power iteration counter

Figure 2.6 Flow Diagram of Power Iteration and Exposure Step Calculation

and the iteration continues until the maximum relative change in nodal power is less than an input convergence criterion, EPSP. The results are printed and if another burnup time-step is requested, the exposure array is updated before repeating the process.

The void-power iteration is sensitive to large perturbations in successive power distribution iterants. Requiring tight convergence on the source iteration when the power distribution is not yet close to being converged can cause an instability and divergence in the power iteration. The instability can be avoided by setting a low limit on the maximum number of source iterations per power iteration (MAXO). This minimizes perturbations between early iterants. If the code detects divergence in the power iteration, it will automatically decrease the limit on the maximum number of source iterations until convergence resumes.

3.0 CROSS SECTIONS

This chapter discusses the generation of two-group cross section input and the manner in which the code evaluates appropriate cross sections for each node.

3.1 Generation of Two-Group Input

The two-group constants required as input must be able to yield the appropriate node averaged reaction rates when multiplied by node averaged fast and thermal fluxes. This requires that the flux spectrum within each energy group be accounted for as well as the detailed flux variation due to heterogeneities within the node volume. This is done by flux averaging.

The node averaged flux for energy group i is defined as

$$\bar{\phi}_i = \left(\oint \partial^3 r \int_{u_{i-1}}^{u_i} \partial u \phi(r,u) \right) \div \left(\oint \partial^3 r \right) \tag{3-1}$$

$\phi(r,u)$ is the lethargy dependent flux at point r. The volume integral is carried out over the node volume and the lethargy integral from the lower to the upper lethargy bounds defining group i. In a two-group model, the fast group commonly corresponds to the energy range from 10 Mev to 0.625 ev while the thermal group represents energies below 0.625 ev.

A cross section consistant with equation 3-1 would be evaluated as

$$\Sigma_i = \frac{\oint \partial^3 r \int_{u_{i-1}}^{u_i} \Sigma(r,u)\phi(r,u)\, \partial u}{\oint \partial^3 r \int_{u_{i-1}}^{u_i} \phi(r,u)\, \partial u} \tag{3-2}$$

One method for calculating these cross sections will be briefly described here. It uses the LEOPARD[7] and PDQ/HARMONY[8,9] codes. For a more detailed discussion of multigroup constant generation see Duderstadt and Hamilton[10].

LEOPARD generates exposure dependent few group cross sections for a homogenized pin cell. A pin cell is a two-dimensional representation of a single fuel rod and the surrounding moderator region as it appears in the array of a fuel assembly. While the LEOPARD calculation is zero-dimensional and primarily spectral, the flux depression in the fuel rod is accounted for by means of disadvantage factors.

PDQ is a few-group diffusion theory code which uses the HARMONY depletion system. Using the few group output from LEOPARD, it can be used to model a fuel assembly in two dimensions. The spatial flux variation in the assembly can be accounted for by using PDQ to flux weight cross sections over this two-dimensional model. Using its depletion capabilities to account for the changes in isotopic concentrations, it can generate exposure dependent two-group cross sections suitable for a node representing the modeled assembly.

A node volume containing a highly absorbing region, such as a burnable poison curtain, may require special treatment. This is due to the limitations of diffusion theory for such regions. A transport theory calculation can be used in such a case.

3.2 Table Assignment

Two-group constants are input as table sets at various void fractions and exposures. One table set is required for each unique node

type represented. Several table sets may be required to model one assembly. This is due to the axial burnable poison distributions used in most BWR's.

The following definitions will be used in this thesis. Each unique fuel assembly type is refered to as a fuel type. Fuel types are assigned to various locations in the core model using a two-dimensional array called a fuel type overlay. Cross section table sets are assigned to each axial node in a given fuel type using a table set to fuel type overlay.

Using the table sets assigned to each node, the code is able to calculate the appropriate two-group constants as a function of void fraction, fuel exposure, and equilibrium xenon concentration. These calculations will be described in detail in the following sections.

3.3 Evaluation of Nodal Two-Group Constants

Cross sections for a particular node are calculated as follows. Cross sections as a function of void fraction and exposure are calculated from the appropriate table set. This accounts for changes in the neutron energy spectrum and in isotopic concentrations caused by coolant voiding and fuel depletion. Corrections are then made to these cross sections to account for the presence of a control rod, if the node is rodded, and to correct for the amount of equilibrium xenon present.

3.3.1 Void and Exposure Dependency

Cross sections as a function of average node void fraction and exposure are calculated from the input table sets by linear interpolation

or extrapolation. The set of exposure points used in the table sets is refered to as an exposure mask. This must be chosen such that linear interpolation between any two consecutive exposure points will yield acceptably accurate results over the range of fuel exposures likely to be encountered in a problem. Relatively fine exposure steps must be used at low exposures due to the fairly rapid changes in isotopic concentrations occurring in this range.

At each exposure point, cross sections are input at a number of void fractions refered to as a void mask. An acceptable void mask requires a minimum of three (preferably four or five) void fractions equally spaced over the void fraction range likely to be encountered.

3.3.2 Control Rod Model

BWR control rods are cruciform shaped, with blades situated between four adjacent fuel assemblies (see figure 3.1). Rods are inserted from the bottom of the core. In order to model the effect of a control rod inserted a distance of N axial mesh spaces from the core bottom, the two-group constants of the first N axial nodes of the four adjacent fuel assemblies must be modified to reflect the change in nuclear properties.

The effect of a control rod on the nuclear properties of a node can be expressed in terms of control rod worth. This is defined as

$$\Delta\rho = \frac{k_\infty^{UR} - k_\infty^{R}}{k_\infty^{UR}} \quad . \tag{3-3}$$

$\Delta\rho$ = control rod worth

k_∞^{UR} = infinite multiplication factor for unrodded node

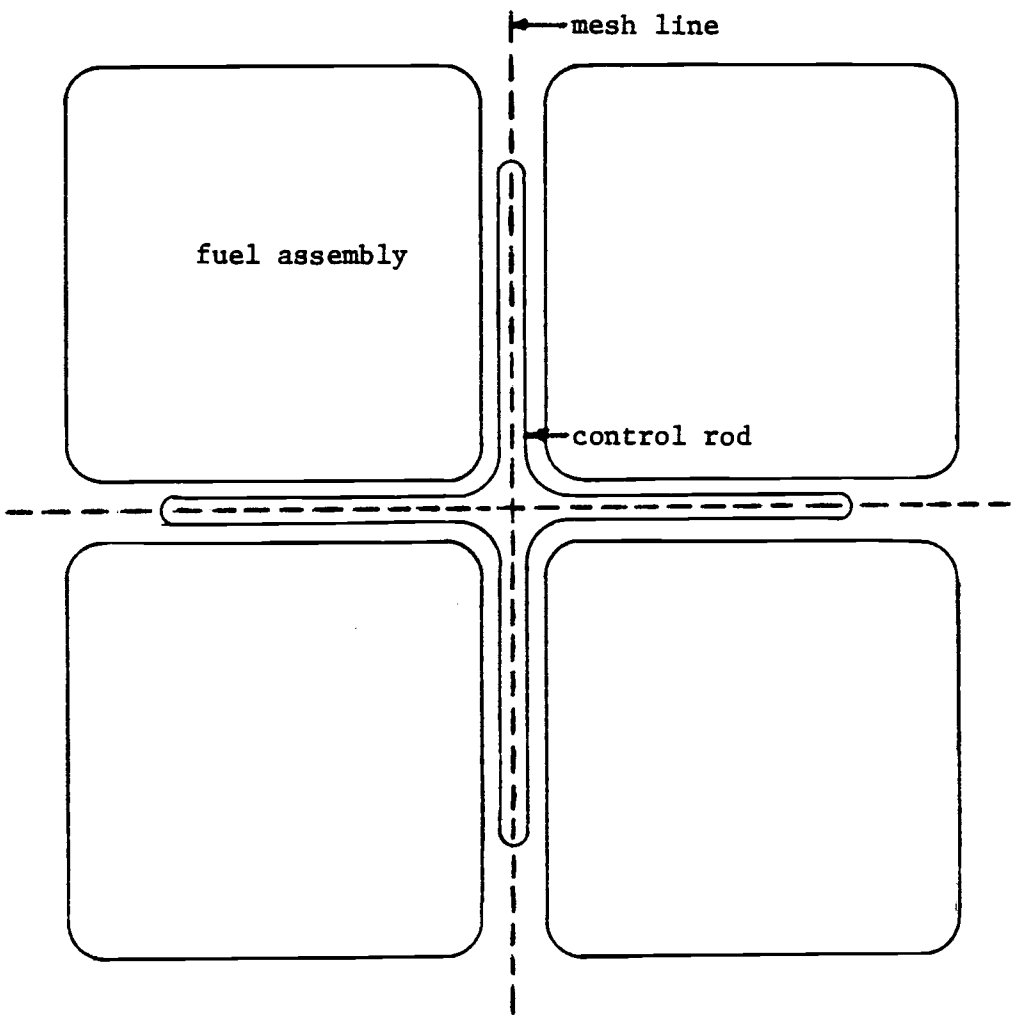


Figure 3.1 BWR Control Rod Geometry.

k_∞^R = infinite multiplication factor for rodded node

k_∞ can be expressed in terms of two-group constants as

$$k_\infty = \frac{\nu\Sigma_{f1} + \dfrac{\Sigma_r \nu\Sigma_{f2}}{\Sigma_{a2}}}{\Sigma_{a1} + \Sigma_r} \quad . \tag{3-4}$$

Control rod worth will increase as the void fraction of a node increases and will also vary as a function of exposure.

The major effect of a control rod is a large increase in the thermal absorbtion of a node. Other neutronic properties are effected to a much lesser extent. The technique employed for modeling a rodded node is to absorb the control rod worth entirely into the thermal absorbtion cross section. All other two-group constants remain the same as for the unrodded case. Thus, from equations 3-3 and 3-4,

$$\Sigma_{a2}^R = \frac{\Sigma_r \nu\Sigma_{f2}}{(1-\Delta\rho)\left[\nu\Sigma_{f1} + \dfrac{\Sigma_r \nu\Sigma_{f2}}{\Sigma_{a2}}\right] - \nu\Sigma_{f1}} \quad . \tag{3-5}$$

Σ_{a2}^R = thermal absorbtion cross section of rodded node

All constants on the right hand side of equation 3-5, except $\Delta\rho$, are those of the unrodded node.

Control rod worths are input for each cross section table set as a table of rod worth versus void and exposure using the same exposure and void points used in the table sets. The worth at a given exposure and void fraction is calculated by linear interpolation. The rod position for each fuel assembly location is input as an integer, greater than or equal to zero, indicating the rod position in terms of the number of

nodes from the core bottom.

3.3.3 Equilibrium Xenon Correction

A correction is made to account for the equilibrium Xe-135 concentration in a node for two reasons. First of all, Xe-135 has an extremely large thermal absorbtion cross section, typically about 1.6 million barns. Secondly, the equilibrium xenon concentration in a node is a function of the neutron flux in that node. Variations in reactor power as well as variations in power density from node to node require that the Xe-135 contribution to the thermal absorbtion cross sections, inherent in the table sets, be corrected. The effect on all other cross sections is negligibly small.

The Xe-135 corrected thermal absorbtion cross section is calculated at each node from

$$\Sigma_{a2} = \Sigma_{a2}^{No\ Xe} + N^{Xe}\sigma_{a2}^{Xe} \quad . \tag{3-6}$$

$\Sigma_{a2}^{No\ Xe}$ = thermal absorbtion cross section with the Xe-135 contribution removed

N^{Xe} = number density of Xe-135 (cm^{-3})

σ_{a2}^{Xe} = Xe-135 microscopic thermal absorbtion cross section (cm^2)

Xe-135 number densities and microscopic thermal absorbtion cross sections are included in the input interpolating table sets. $\Sigma_{a2}^{No\ Xe}$ is calculated at each of the interpolating exposure and void fraction state points by subtracting $N^{Xe}\sigma_{a2}^{Xe}$ from the corresponding macroscopic thermal absorbtion cross section.

In terms of two-group constants, the number density of Xe-135 is governed by the following pair of differential equations.

$$\frac{dN^I}{dt} = \gamma_I(\phi_1\Sigma_{f1} + \phi_2\Sigma_{f2}) - N^I\lambda_I \tag{3-7}$$

$$\frac{dN^{Xe}}{dt} = \gamma_{Xe}(\phi_1\Sigma_{f1} + \phi_2\Sigma_{f2}) + N^I\lambda_I - N^{Xe}(\phi_1\sigma_{a1}^{Xe} + \phi_2\sigma_{a2}^{Xe}) - N^{Xe}\lambda_{Xe} \tag{3-8}$$

N^{Xe}, N^I = Xe-135 and I-135 number densities

γ_{Xe}, γ_I = Xe-135 and I-135 fission yields

λ_{Xe}, λ_I = Xe-135 and I-135 decay constants

σ_{a1}^{Xe}, σ_{a2}^{Xe} = fast and thermal microscopic absorbtion cross sections for Xe-135

The equilibrium Xe-135 number density equation used by the code is obtained by setting the time derivatives in equations 3-7 and 3-8 to zero. The Xe-135 fast absorbtion cross section is neglected since it is relatively small(8 barns). The xenon transients which follow a change in power density are ignored in this model. These transients are on the order of eight hours and are not important in most burnup calculations. For each node, the Xe-135 number density is calculated from

$$N^{Xe} = \frac{\gamma_{I+Xe}(\phi_1\Sigma_{f1} + \phi_2\Sigma_{f2})}{\lambda_{Xe} + \phi_2\sigma_{a2}} \quad . \tag{3-9}$$

$$\lambda_{Xe} = 2.0997\text{x}10^{-5}\ \text{sec}^{-1}$$

The I-135 + Xe-135 fission yield is input as a table versus exposure for each table set. The appropriate yield is calculated by interpolation. Σ_{f1}, Σ_{f2}, and σ_{a2}^{Xe} are calculated by interpolation versus void

fraction and exposure.

The fast and thermal fluxes from the diffusion theory calculation are only relative values and must be converted to absolute fluxes before they can be used in equation 3-9. The absolute fluxes, ϕ_1^a and ϕ_2^a, are calculated from

$$\phi_1^a = CF \cdot \phi_1 \quad , \tag{3-10}$$

$$\phi_2^a = CF \cdot \phi_2 \quad . \tag{3-11}$$

The conversion factor, CF, is calculated from

$$CF = \frac{Pth \cdot 6.24146 \times 10^{18} \frac{Mev/sec}{Mw}}{Vol \cdot \sum_{\ell=1}^{N} (\phi_1 \kappa\Sigma_{f1} + \phi_2 \kappa\Sigma_{f2})_\ell} \quad . \tag{3-12}$$

Pth = power generated by the portion of the core being modeled (Mw_{th})

Vol = node volume (cm^3)

$\kappa\Sigma_f$ = κ-fission cross section (Mev/cm)

The summation in the denominator of equation 3-12 is over all nodes in the problem.

4.0 THERMAL-HYDRAULIC TREATMENT

A typical BWR coolant flow diagram is shown in figure 4.1. Subcooled water enters the core from the bottom. Inlet orifices direct the flow to the fuel channels and serve to restrict the flow in low power assemblies, primarily those on the core periphery. The "active" coolant flows up through the fuel channels. The small amount of coolant that flows between the fuel channels is termed bypass flow.

As coolant flows up a fuel channel, it is heated to saturation and becomes a two-phase mixture. The flow quality, X, at a given point in the channel is defined as the mass flow rate of the vapor phase divided by the mass flow rate of the mixture.

The void fraction is defined as the ratio of the local vapor volume to the total local volume. At a given point in a flow channel it can be expressed as

$$\alpha = \frac{A_v}{A_v + A_\ell} \quad . \tag{4-1}$$

α = void fraction

A_v = cross sectional area occupied by vapor phase

A_ℓ = cross sectional area occupied by liquid phase

The density of a two-phase mixture can be related to the void fraction by

$$R = 1. + \alpha(\rho_v/\rho_\ell - 1.) \quad . \tag{4-2}$$

ρ_v = density of saturated vapor

ρ_ℓ = density of saturated liquid

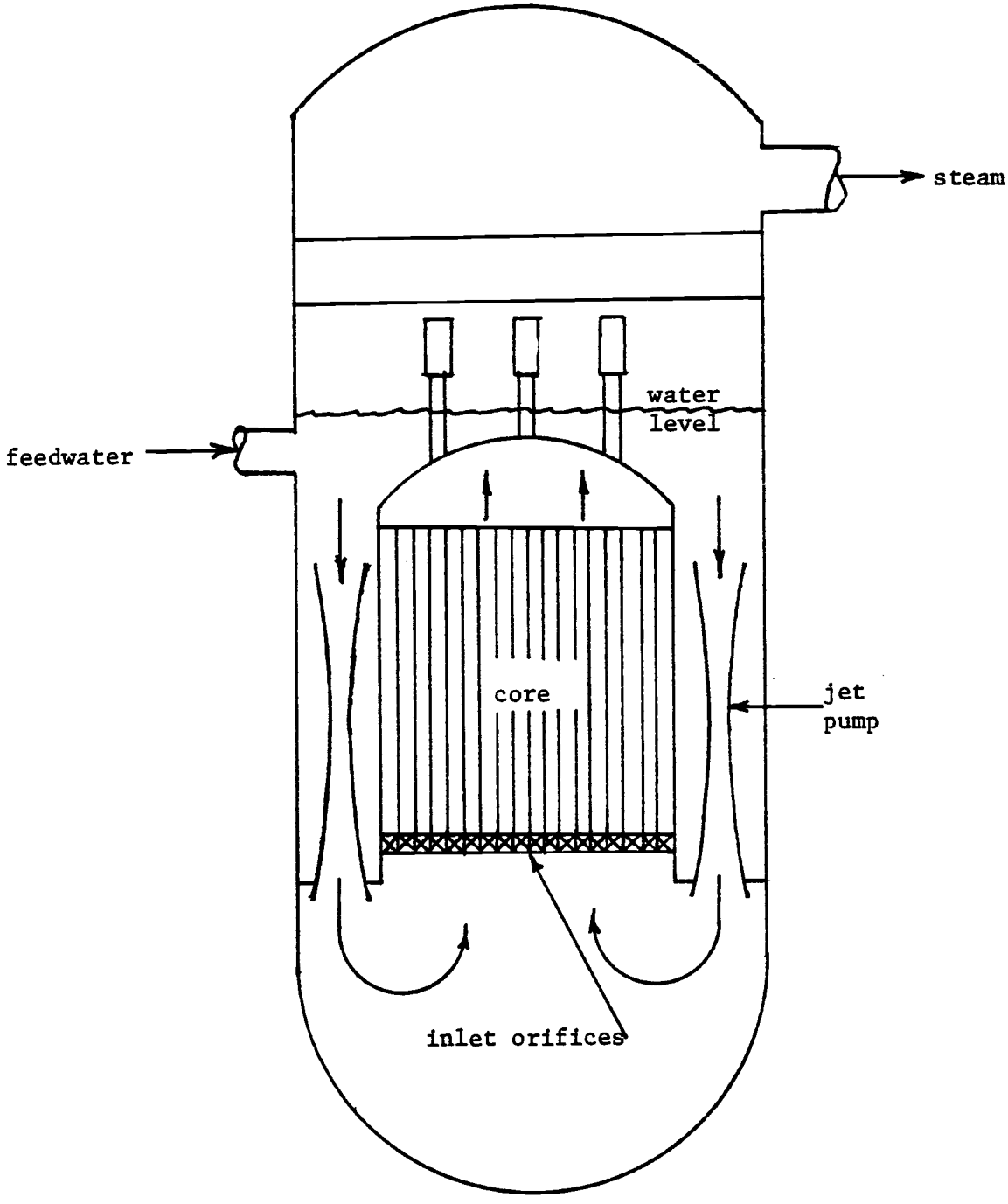


Figure 4.1 BWR Coolant Flow Diagram.

R = density of two-phase mixture relative to ρ_ℓ

As mentioned previously, a thermal-hydraulic feedback calculation is linked to the neutronics model. This is an iterative process by which new nodal nuclear properties are calculated as a function of the void fraction of the active coolant flow for each power distribution iterant. A minimum critical heat flux ratio (MCHFR) calculation has also been included in the thermal-hydraulics model. The calculational techniques used in the thermal-hydraulics model will be discussed in this chapter.

4.1 Coolant Flow Distribution

In order to calculate the quality of the coolant at a particular node, the coolant mass flow rate within the flow channel must be known. The flow rate varies considerably from channel to channel. This is primarily due to inlet orificing and variations in void content. The void content is, of course, coupled to the power generated in the assembly. In order to account for these effects, a polynomial fit of flow versus average assembly power is used.

$$F_r(I,J) = A + B\overline{P}(I,J) + C\overline{P}(I,J)^2 \qquad (4\text{-}3)$$

$F_r(I,J)$ = relative coolant mass flow rate in channel (I,J) at hot full power conditions

$\overline{P}(I,J)$ = assembly averaged power, relative to an "average" assembly at hot full power

A,B,C = input constants

A, B, and C are input for each hydraulicly unique flow channel type. These constants can be evaluated using a separate thermal-hydraulic code

capable of treating, in detail, effects such as inlet orifices, fuel rod array geometry, flow mixers, and the axial power distribution. This may require iteration between assembly power distributions and the flow polynomials. A channel type overlay is used to assign a set of flow constants to each channel location.

The assembly averaged power used in equation 4-3 is calculated from

$$\overline{P}(I,J) = \frac{PCTPWR}{100.} \frac{1.}{NZ} \sum_{k=1}^{NZ} P(I,J,k) \quad . \tag{4-4}$$

PCTPWR = reactor power in percent of rated power

NZ = number of axial nodes represented

P(I,J,K) = relative power of node (I,J,K)

After calculating flow rates from equation 4-3, the values are normalized to a mean of 1.0. The actual flow rate is then calculated from

$$F(I,J) = \frac{TFLOW}{Na} F_r(I,J) \quad . \tag{4-5}$$

F(I,J) = actual coolant mass flow rate in lbm/hr

TFLOW = total incore coolant flow rate (corrected for bypass flow) in lbm/hr

Na = number of assemblies in the core

4.2 Quality Calculation

The quality of the active coolant in a flow channel is calculated from

$$X = \frac{h - h_{sat}}{h_{fg}} \quad . \tag{4-6}$$

h = coolant enthalpy (Btu/lbm)

h_{sat} = enthalpy of saturated water

h_{fg} = heat of vaporization

The increase in coolant enthalpy for a given node, $\Delta h(I,J,K)$, can be calculated from

$$\Delta h(I,J,K) = \left[\frac{PCTPWR \cdot MWTH \cdot CF}{100. \cdot NZ}\right]\left[\frac{P(I,J,K)}{F(I,J)}\right] \quad . \tag{4-7}$$

PCTPWR = reactor power in percent of rated power

MWTH = rated reactor power (Mw_{th})

CF = $3.4127 \times 10^6 \ \frac{Btu/hr}{Mw}$

NZ = number of axial nodes in problem

P(I,J,K) = relative power of node (I,J,K)

F(I,J) = coolant flow rate through node (lbm/hr)

The coolant enthalpy at the exit of a node is given by

$$h_{exit}(I,J,K) = h_{in} + \sum_{k=1}^{K} \Delta h(I,J,k) \quad , \tag{4-8}$$

where h_{in} is the core inlet enthalpy. The average enthalpy of a node, $\overline{h}(I,J,K)$, is used to calculate the quality of that node.

$$\overline{h}(I,J,K) = \frac{1}{2}\left[h_{exit}(I,J,K-1) + h_{exit}(I,J,K)\right] \tag{4-9}$$

The numerical expression of equation 4-6 is then

$$X(I,J,K) = \frac{1.}{h_{fg}}\left\{h_{in} + \left[\frac{PCTPWR \cdot MWTH \cdot CF}{100. \cdot NZ}\right] \frac{1.}{F(I,J)} \times \left[\sum_{k=1}^{K-1} P(I,J,k) + \frac{1}{2} P(I,J,K)\right] - h_{sat}\right\} \quad . \tag{4-10}$$

4.3 Void Fraction

The void fraction of a node is calculated from the average node quality using the modified Armand correlation[11].

$$\alpha = 0. \qquad \text{for } X \leq 0.$$

$$\alpha = \frac{C_1 \cdot X + C_2 \cdot X^2}{\frac{\upsilon_f}{\upsilon_g} + X \cdot \left[1. - \frac{\upsilon_f}{\upsilon_g}\right]} \qquad \text{for } X > 0. \qquad (4\text{-}11)$$

υ_f = specific volume of saturated liquid

υ_g = specific volume of saturated steam

C_1 and C_2 are empirical constants. The default values are

$C_1 = 0.833$,

$C_2 = 0.167$.

A graph of void fraction versus quality using the above values for C_1 and C_2 and specific volumes for saturated steam and water at 1035 psia and 548.8^{o} Fahrenheit is shown in figure 4.2.

4.4 MCHFR Calculation

The local critical heat flux is calculated using the Janssen-Levy[12] correlation. At 1000 psia,

$$q''_{crit} = 7.05 \times 10^5 + 0.237 \cdot G \qquad \text{for } X<x_1 \qquad (4\text{-}12)$$

$$q''_{crit} = 1.635 \times 10^6 - 0.270 \cdot G - 4.710 \times 10^6 \cdot X \qquad \text{for } x_1<X<x_2$$

$$q''_{crit} = 6.05 \times 10^5 - 0.164 \cdot G - 6.53 \times 10^5 \cdot X \qquad \text{for } x_2<X$$

q''_{crit} = critical heat flux (Btu/hr ft^2)

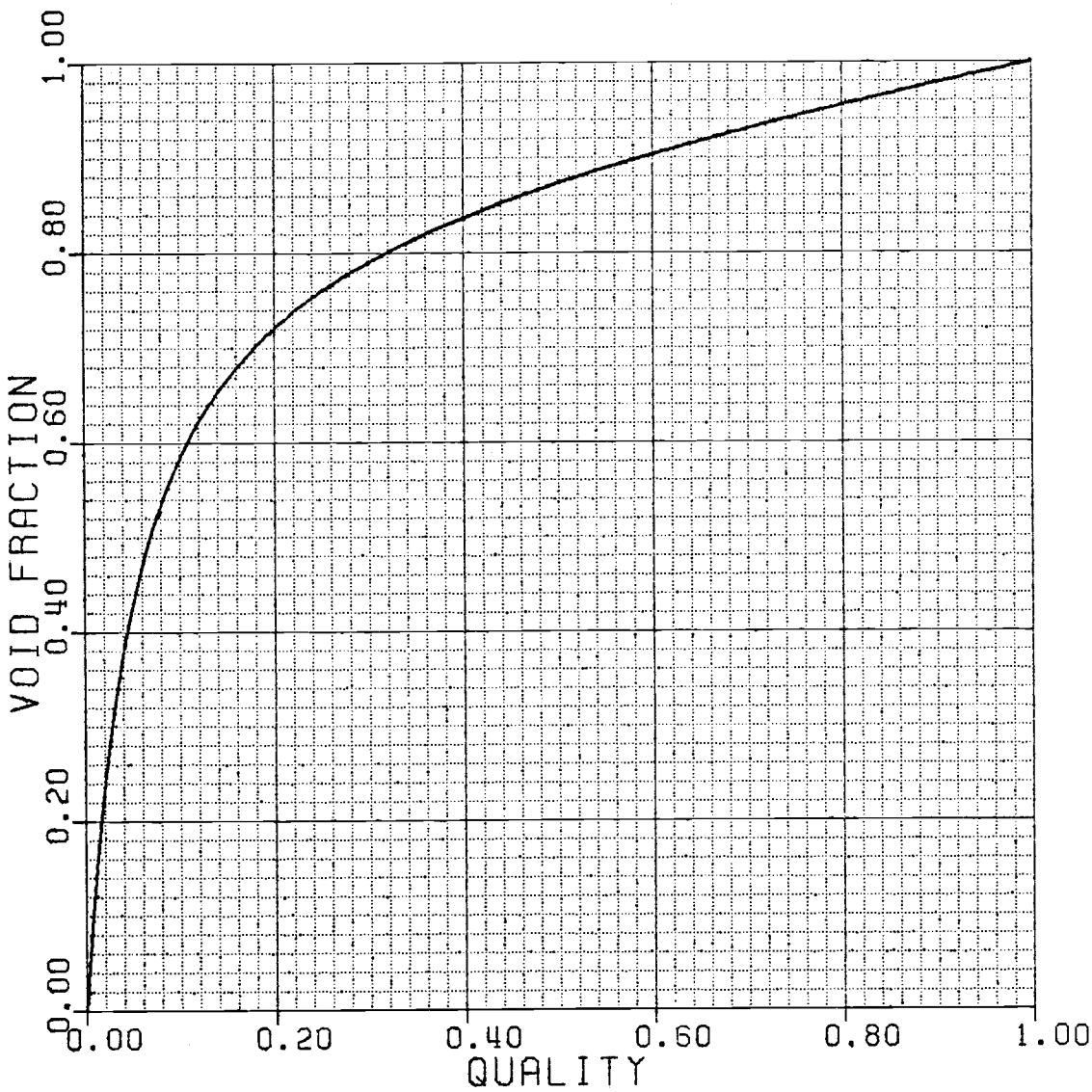


Figure 4.2 Void Fraction vs. Quality Calculated from Modified Armand Correlation at 1035 psia and 548.8° F.

X = quality

$x_1 = 0.197 - 1.08 \times 10^{-7} \cdot G$

$x_2 = 0.254 - 2.6 \times 10^{-8} \cdot G$

G = coolant mass flux (lbm/hr ft^2)

At pressures other than 1000 psia,

$$q''_{crit} = q''_{crit}(\text{at 1000 psia}) + 4.4 \times 10^5 - 4.4 \times 10^2 \cdot PSIA \qquad (4\text{-}12b)$$

PSIA = system pressure (psia)

The applicable range of the parameters used above are

PSIA = 600 to 1450 psia,

G = 4.0×10^5 to 6.0×10^6 lbm/hr ft^2,

X = negative to 0.45,

D_e = 0.125 to 0.6 in. (equivalent diameter of channel),

L = 29. to 108. in (channel length).

The local quality is calculated using equation 4-10. The coolant mass flux in each channel is calculated from the active coolant mass flow rate and the active channel flow area.

$$G(I,J) = \frac{F(I,J) \cdot (144 \text{ in}^2/\text{ft}^2)}{AREA} \qquad (4\text{-}13)$$

F(I,J) = mass flow rate calculated from equation 4-5

AREA = active flow area per channel (in^2)

The minimum critical heat flux ratio at each node is calculated from

$$MCHFR(I,J,K) = \frac{q''_{crit}(I,J,K)}{q''(I,J,K)} \quad . \qquad (4\text{-}14)$$

$q''(I,J,K)$ = local heat flux (Btu/hr ft^2)

The heat flux used above is evaluated from the relative power of the

node and three input quantities.

$$q''(I,J,K) = q''_{av} \cdot PEAKF \cdot \frac{PCTPWR}{100.} \cdot P(I,J,K) \tag{4-15}$$

q''_{av} = core average heat flux at rated power (Btu/hr ft^2) (input)

PEAKF = heat flux peaking factor (input)

PCTPWR = reactor power in percent of rated power (input)

P(I,J,K) = relative power of node (I,J,K)

The peak heat flux in a node will be slightly higher than the node average heat flux. Among other reasons, this may be due to fuel rods of varying enrichments within an assembly. PEAKF is intended primarily as a correction factor to account for this. Safety margins may also be included in PEAKF.

If the MCHFR calculation is requested, the calculation will be done at the beginning and end of each exposure step. The MCHFR and the indices of the node where it occurs will be printed. An edit of the MCHFR in each channel may also be requested.

5.0 HALING SOLUTION

The Haling solution option calculates the optimal power distribution for an operating cycle. This is determined from the beginning of cycle fuel loading description and the cycle length. The optimal power distribution is here defined as that which minimizes power peaking throughout the cycle.

The underlying principle of the Haling solution is that power peaking is minimized by a power distribution that does not change during the cycle.[6] It is assumed that fuel reactivity is a decreasing function of exposure near the end of the cycle. This may not be true at low exposures in fuel characterized by a high breeding ratio or containing burnable poisons. It is a generally good assumption in LWR's for the burnups encountered at the end of an operating cycle.

The Haling logic can be easily understood with the aid of figure 5.1. Curve A is postulated as the optimal reactor power distribution. Curve B has a lower power peaking ratio. This can occur only as the result of reduced reactivity, implying greater exposure, in the area of the peak. The higher exposure, however, is inconsistant with the lower peak. It implies that another power distribution, with a higher power peak, was used earlier in the cycle. Thus, power peaking can only be minimized if the power distribution and end of cycle exposure distribution are self consistant.

The Haling solution is of use in fuel reload design as well as operations. It provides a means of comparing fuel loading patterns on the basis of the minimum power peaking attainable with each. With a given

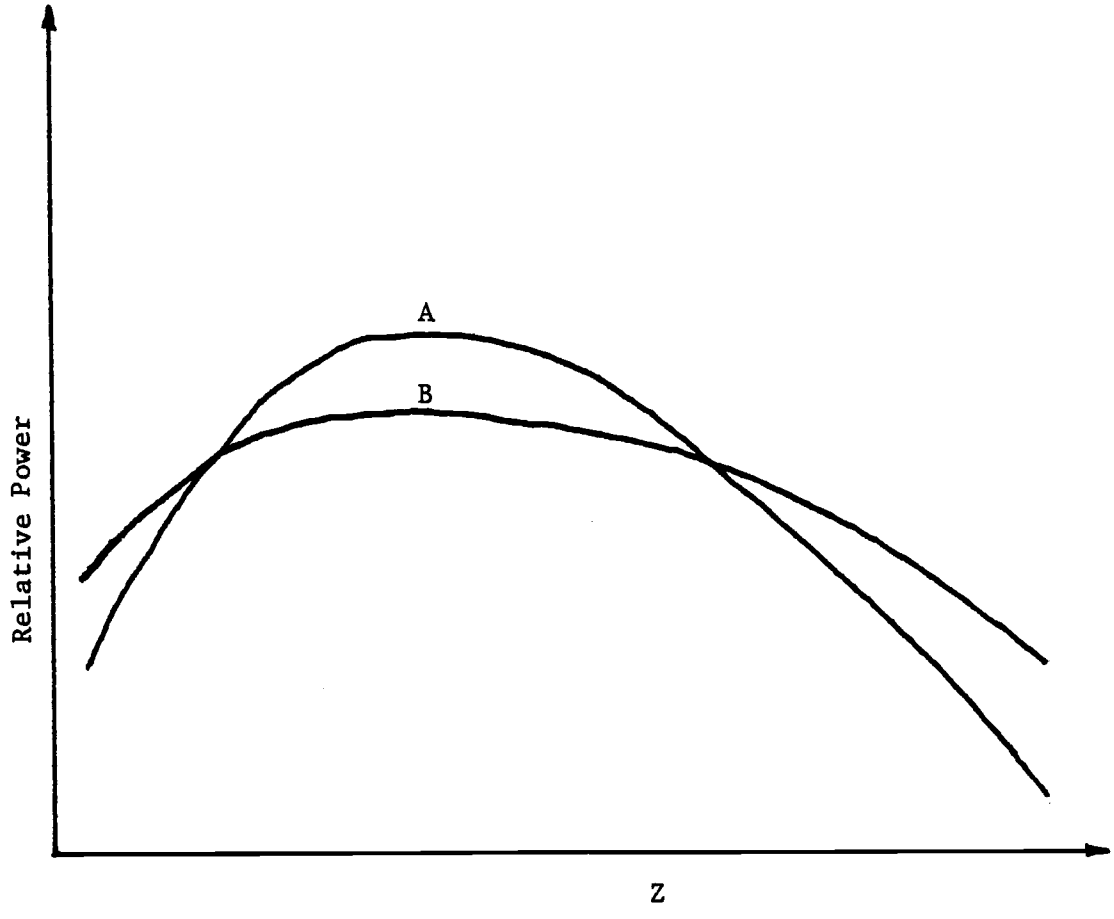


Figure 5.1 Illustration of Haling Solution Logic.

loading pattern, it can be used to determine the optimal control poison (i.e. burnable poison and control rods) distribution.

BWR control rods are very strong absorbers, producing large flux depressions in their vicinity. This makes it impractical to actually operate at the optimal power distribution. The Haling solution can, however, be used as an exposure averaged target distribution when planning rod withdrawal strategy.

The Haling solution is arrived at iteratively. Starting with an assumed power distribution, the void and end of cycle exposure distributions can be calculated. These can be used to calculate another power distribution. Due to the extremely unstable nature of the Haling iteration, an underrelaxation scheme is used.

$$P_\ell^H = P_\ell^{H-1} + \alpha_H \cdot \left(P_\ell(E^{H-1}, V^{H-1}) - P_\ell^{H-1}\right) \tag{5-1}$$

P_ℓ^H = power at node ℓ for iterant H

$P_\ell(E^{H-1}, V^{H-1})$ = power at node ℓ calculated using the exposure and void distributions consistant with the previous power iterant

H = Haling iteration counter

α_H = relaxation factor (=0.1)

The exposure for each Haling iterant is calculated from

$$E_\ell^H = E_{\ell o} + P_\ell^H \cdot BU \quad . \tag{5-2}$$

E_ℓ^H = exposure at node ℓ for iterant H

$E_{\ell o}$ = beginning of cycle exposure at node ℓ

BU = cycle length (MWD/MTU)

6.0 RESULTS

In this chapter, the results of test calculations used to demonstrate the model are presented. These include benchmarking tests used to check the neutronics model, and power and void distribution tests which demonstrate feedback effects, control rod effects, and the Haling solution option. Input for the cases described in sections 6.3 and 6.4 is basically the same as that given at the end of Appendix A.

6.1 Benchmarking of the Neutronics Model

A 9x9x9 node test case was used to benchmark the neutronics model. Fifteen centimeter mesh widths were used and all nodes were assigned the cross sections given in table 6.1. Various sets of boundary conditions were applied to the six boundary faces of the cubical model. The calculated flux distributions could then be compared to analytical solutions in order to verify the results.

Table 6.1 Cross Sections Used in Benchmarking Cases.

	D (cm)	Σ_a (cm^{-1})	$\nu\Sigma_f$ (cm^{-1})	$\kappa\Sigma_f$ (Mev/cm)	Σ_r (cm^{-1})
Fast	1.418	0.7104×10^{-2}	0.4074×10^{-2}	0.3231	0.1038×10^{-1}
Thermal	0.5492	0.7522×10^{-1}	0.1069	9.020	

The eleven cases which were run are summarized in table 6.2. Case 1 represented a reactor of infinite dimensions. A flat flux distribution was calculated as expected. The k-effective for this case was calculated as 1.1938 - the same as k-infinity calculated directly from the two-group cross sections.

Table 6.2 Neutronics Model Benchmarking Cases.

Case #	Description	Boundary Conditions	Analytical Solution
1	Infinite reactor	zero current on all 6 faces	$\phi(x,y,z) = C$
2	Cubical reactor 135x135x135 cm	zero flux on all 6 faces	$\phi(x,y,z) = C \cdot \sin(x\pi/a) \cdot \sin(y\pi/a) \cdot \sin(z\pi/a)$
3	Semi-infinite slab, 135 cm thick	zero flux faces 1 & 2, zero current faces 3,4,5, &6	$\phi(x,y,z) = C \cdot \sin(x\pi/a)$
4	Same as #3	zero flux faces 3 &4, zero current faces 1,2,5, &6	$\phi(x,y,z) = C \cdot \sin(y\pi/a)$
5	Same as #3	zero flux faces 5 &6, zero current faces 1,2,3, &4	$\phi(x,y,z) = C \cdot \sin(z\pi/a)$
6	Semi-infinite slab, 270 cm thick	zero flux face 1, zero current faces 2,3,4,5, &6	$\phi(x,y,z) = C \cdot \sin(x\pi/2a)$
7	Same as #6	zero flux face 2, zero current faces 1,3,4,5, &6	$\phi(x,y,z) = C \cdot \cos(x\pi/2z)$
8	Same as #6	zero flux face 3, zero current faces 1,2,4,5, &6	$\phi(x,y,z) = C \cdot \sin(y\pi/2a)$
9	Same as #6	zero flux face 4, zero current faces 1,2,3,5, &6	$\phi(x,y,z) = C \cdot \cos(y\pi/2a)$
10	Same as #6	zero flux face 5, zero current faces 1,2,3,4, &6	$\phi(x,y,z) = C \cdot \sin(z\pi/2a)$
11	Same as #6	zero flux face 6, zero current faces 1,2,3,4, &5	$\phi(x,y,z) = C \cdot \cos(z\pi/2a)$

C = constant

a = 135.

Case number 2 represented a cubical reactor. The x-y flux distribution calculated at the center plane is shown in figure 6.1. Figure 6.2 shows a graph of the flux distribution through the center of this plane. Calculated values are shown as small circles and the analytic solution is represented by a line.

Cases 3 through 5 represented a 135 centimeter thick semi-infinite slab reactor. A 270 centimeter semi-infinite slab reactor was represented in cases 6 through 11. The case descriptions and results were essentially identical except for orientation and slab thickness. The resulting transverse flux distributions are shown in figures 6.3 and 6.4. Again, calculated values are shown as circles and the analytic solutions are represented by lines.

℄

0.03	0.09	0.13	0.16	0.17	0.16	0.13	0.09	0.03
0.030	0.087	0.133	0.163	0.174	0.163	0.133	0.087	0.030
0.09	0.25	0.38	0.47	0.50	0.47	0.38	0.25	0.09
0.087	0.250	0.383	0.470	0.500	0.470	0.383	0.250	0.087
0.13	0.38	0.59	0.72	0.77	0.72	0.59	0.38	0.13
0.133	0.383	0.587	0.720	0.766	0.720	0.587	0.383	0.133
0.16	0.47	0.72	0.88	0.94	0.88	0.72	0.47	0.16
0.163	0.470	0.720	0.883	0.940	0.883	0.720	0.470	0.163
0.17	0.50	0.77	0.94	1.00	0.94	0.77	0.50	0.17
0.174	0.500	0.766	0.940	1.000	0.940	0.766	0.500	0.174
0.16	0.47	0.72	0.88	0.94	0.88	0.72	0.47	0.16
0.163	0.470	0.720	0.883	0.940	0.883	0.720	0.470	0.163
0.13	0.38	0.59	0.72	0.77	0.72	0.59	0.38	0.13
0.133	0.383	0.587	0.720	0.766	0.720	0.587	0.383	0.133
0.09	0.25	0.38	0.47	0.50	0.47	0.38	0.25	0.09
0.087	0.250	0.383	0.470	0.500	0.470	0.383	0.250	0.087
0.03	0.09	0.13	0.16	0.17	0.16	0.13	0.09	0.03
0.030	0.087	0.133	0.163	0.174	0.163	0.133	0.087	0.030

℄

calculated

analytic solution

Figure 6.1 Comparison of Calculated and Analytical Solutions of the Relative Flux Distribution for the Center Plane of a Cubical Reactor.

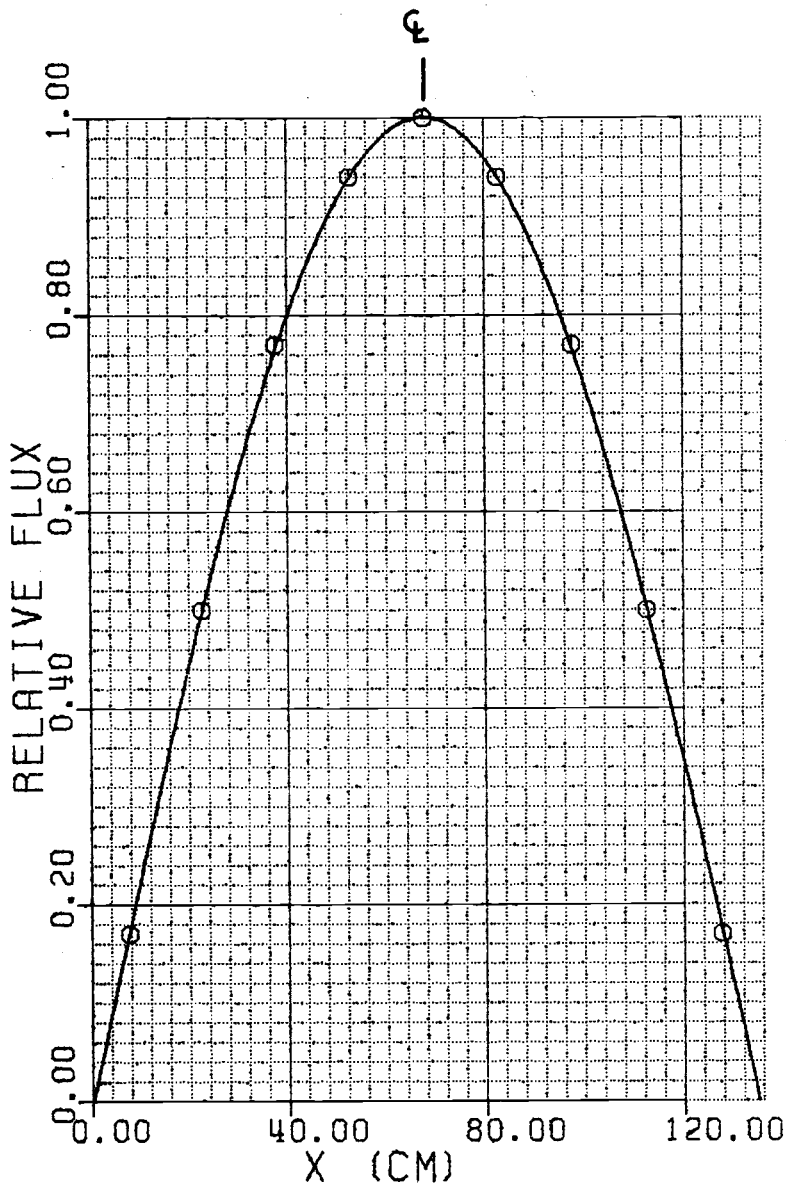


Figure 6.2 Comparison of Calculated and Analytical Solutions of the Relative Flux Profile through the Center of a Cubical Reactor.

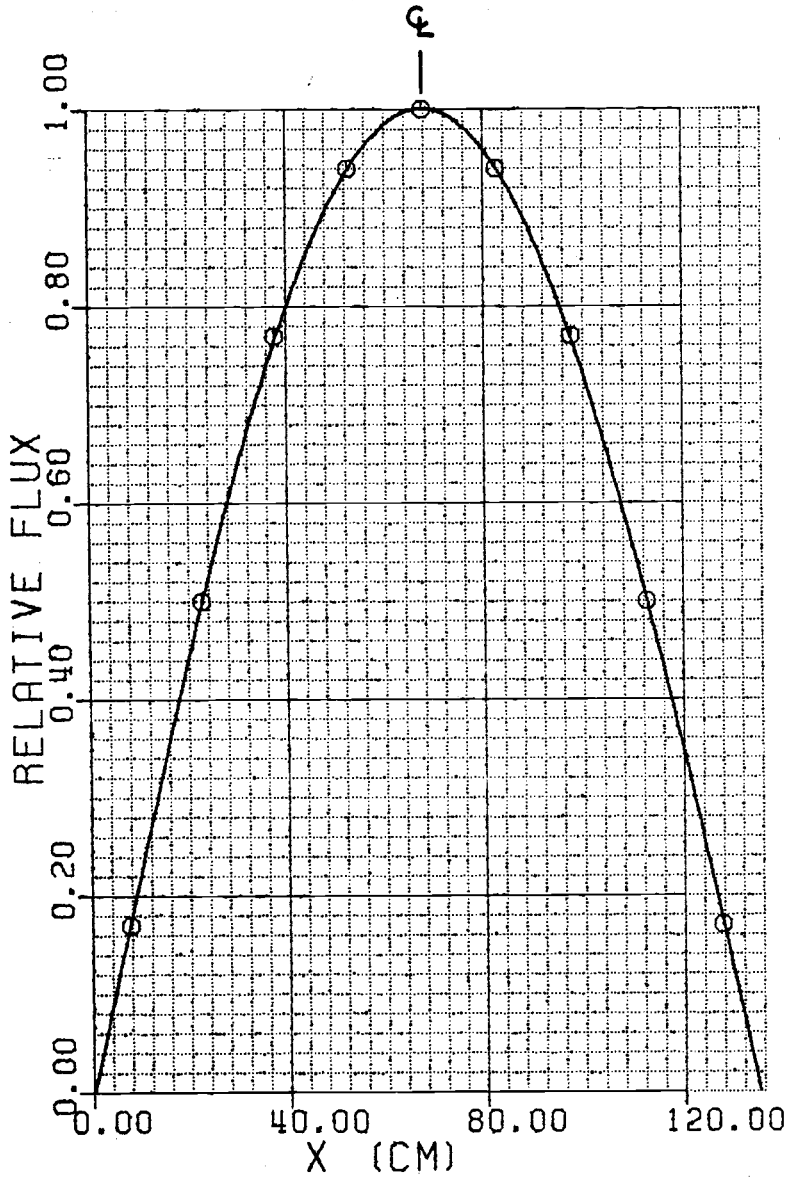


Figure 6.3 Comparison of Calculated and Analytical Solutions of the Relative Flux Distribution in a 135 cm Semi-Infinite Slab Reactor.

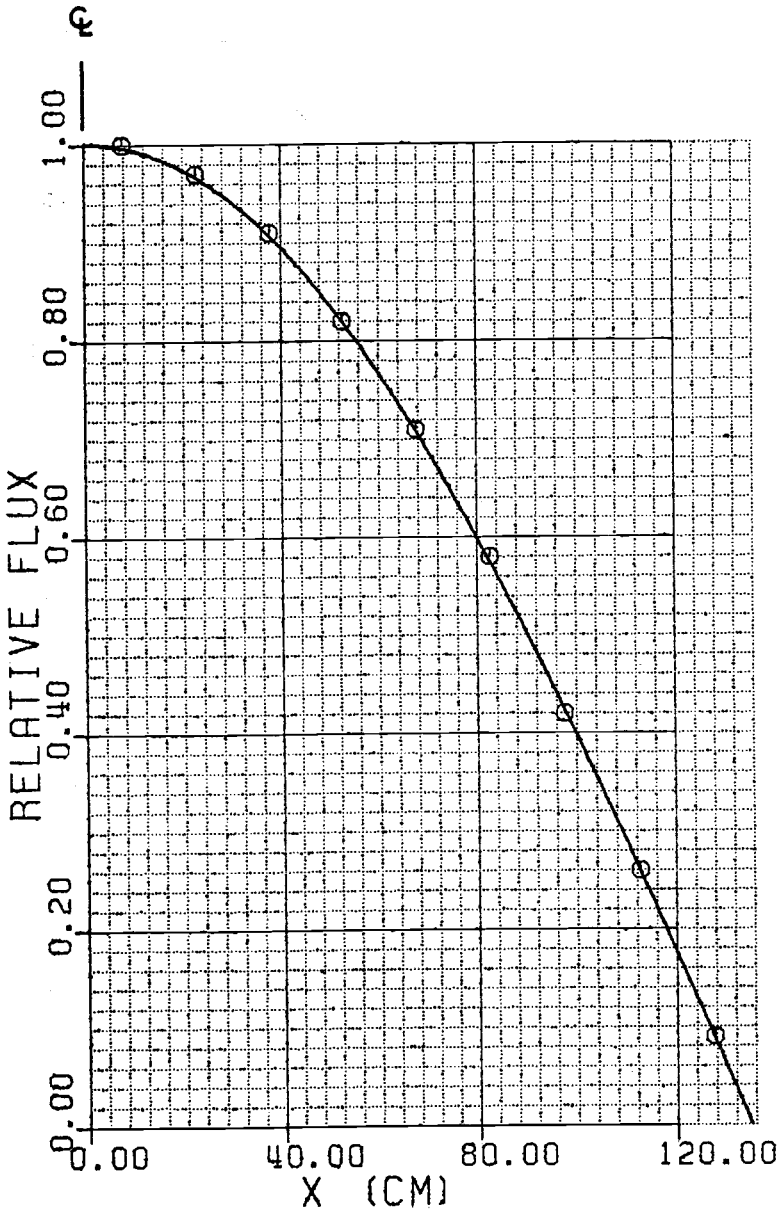


Figure 6.4 Comparison of Calculated and Analytical Solutions of the Relative Flux Distribution in a 270 cm Semi-Infinite Slab Reactor.

6.2 Reference Reactor

The Edwin Hatch Unit #2 reactor was used as the reference reactor for the following calculations. This is a boiling water reactor of recent design with a thermal output of 2436 megawatts. The cycle 1 fuel loading pattern was used and is shown in figure 6.5. Other pertinent information can be found in table 6.3[13].

BWR fuel assemblies commonly use more than one fuel pin enrichment in a single assembly as well as axial burnable poison distributions. This is the case with the core which was modeled. Due to limited resources it was not feasible to properly generate two-group input for use in the test calculations. A two dimensional depletion calculation, used to generate exposure dependent assembly averaged cross sections, could not be done. The burnable poison (gadolinium) distributions used were not available due to their proprietary nature, nor were cross sections for gadolinium. The approach taken was to generate cross sections for each assembly type with LEOPARD, using assembly average enrichments and volume fractions. Gadolinium was ignored. These restrictions limit the validity of the results obtained.

The control rod worths used are shown in table 6.4. These are typical rod worths for a BWR. It was not possible to obtain more accurate values. The rod worths of table 6.4 were used for all three fuel types at all exposures.

1	1	1	1	1	1	1	1	1	2	2	2	3
1	1	2	1	2	1	2	1	2	2	2	2	3
1	2	1	2	1	2	1	2	1	2	2	2	3
1	1	2	1	2	1	2	1	2	2	2	2	3
1	2	1	2	1	2	1	2	2	2	2	2	3
1	1	2	1	2	1	2	1	2	2	2	3	
1	2	1	2	1	2	1	2	2	2	3		
1	1	2	1	2	1	2	2	2	2	3		
1	2	1	2	2	2	2	2	2	2	3		
2	2	2	2	2	2	2	2	2	3			
2	2	2	2	2	2	3	3	3				
2	2	2	2	2	3							
3	3	3	3	3								

Region	Average Enrichment w/0 U-235
1	1.83
2	2.33
3	0.711

Figure 6.5 Edwin I. Hatch Nuclear Plant Unit #2 Fuel Loading Pattern.

Table 6.3 Design Data for Edwin I. Hatch Nuclear Plant Unit #2.

Nominal thermal output	2436	Mw
Incore coolant flow rate	7.70×10^7	lbm/hr
Nominal system pressure	1035.	psia
Coolant saturation temperature	548.8	^oF
Average heat flux	145,060.	Btu/hr ft^2
Core inlet enthalpy	526.9	Btu/lb
Active coolant flow area per assembly	15.82	in^2
Active fuel length	150.	in
Assembly lattice	8x8	
Assembly pitch	6.0	in

Table 6.4 Control Rod Worths.

Void Fraction	Rod Worth ($\Delta k/k$)
0.00	0.24
0.32	0.27
0.64	0.32

6.3 Power and Void Distributions

The effect of voiding on the axial power distribution is shown in figures 6.6 through 6.8. All three cases illustrated were run at beginning of life, nominal flow conditions with control rods completely withdrawn (ARO). At hot zero power (HZP), the distribution has a cosine shape as expected. At 50% power, coolant voiding decreases moderation in the upper core. This shifts the power distribution downward where the core is relatively more reactive. The increased voiding at hot full power (HFP) shifts the distribution even lower and results in a higher power peak. Control rods are used to offset this void induced tendency toward power peaking in the lower part of the core.

Control rod effects are illustrated in figure 6.9. These cases were run at beginning of life, hot full power conditions. Inserting all rods half way in the core shifts the power peak to the upper part of the core. The downward shift due to voiding is still evident, but the control rods have almost completely eliminated power production in the lower half of the core. Completely inserting all rods gives a very large peak at the bottom of the core. This case is unrealistic in that it is subcritical, but it does demonstrate the effect of increased control rod worths with increasing void fraction.

Three control rod pattern cases are described by figures 6.10 through 6.12. These were run at hot full power, beginning of life conditions. The resulting axial power distributions are shown in figure 6.13. The effects illustrated by the three previous cases are still evident, but have been complicated by varying rod positions. Deeply

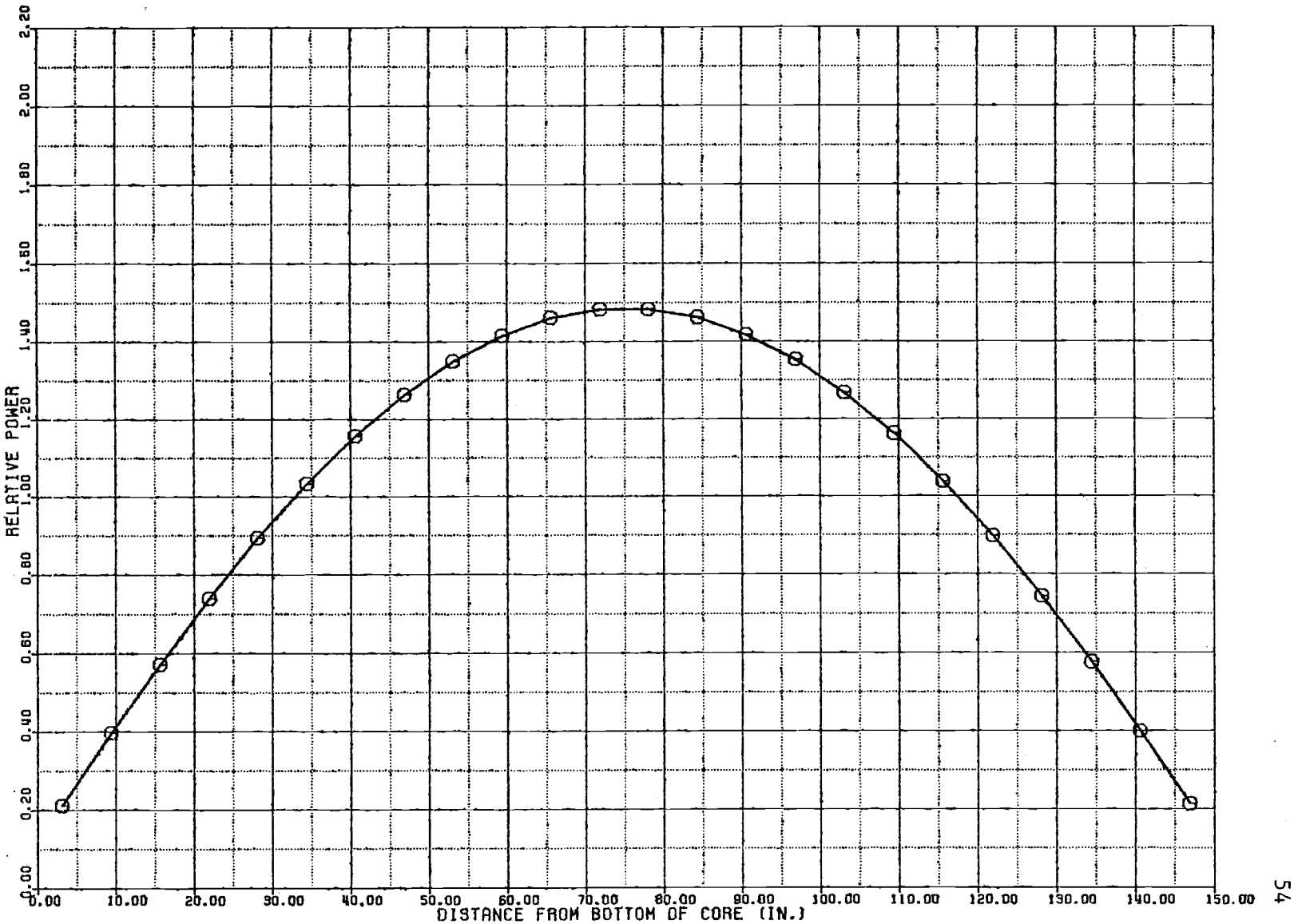


Figure 6.6 Axial Power Distribution, HZP, ARO.

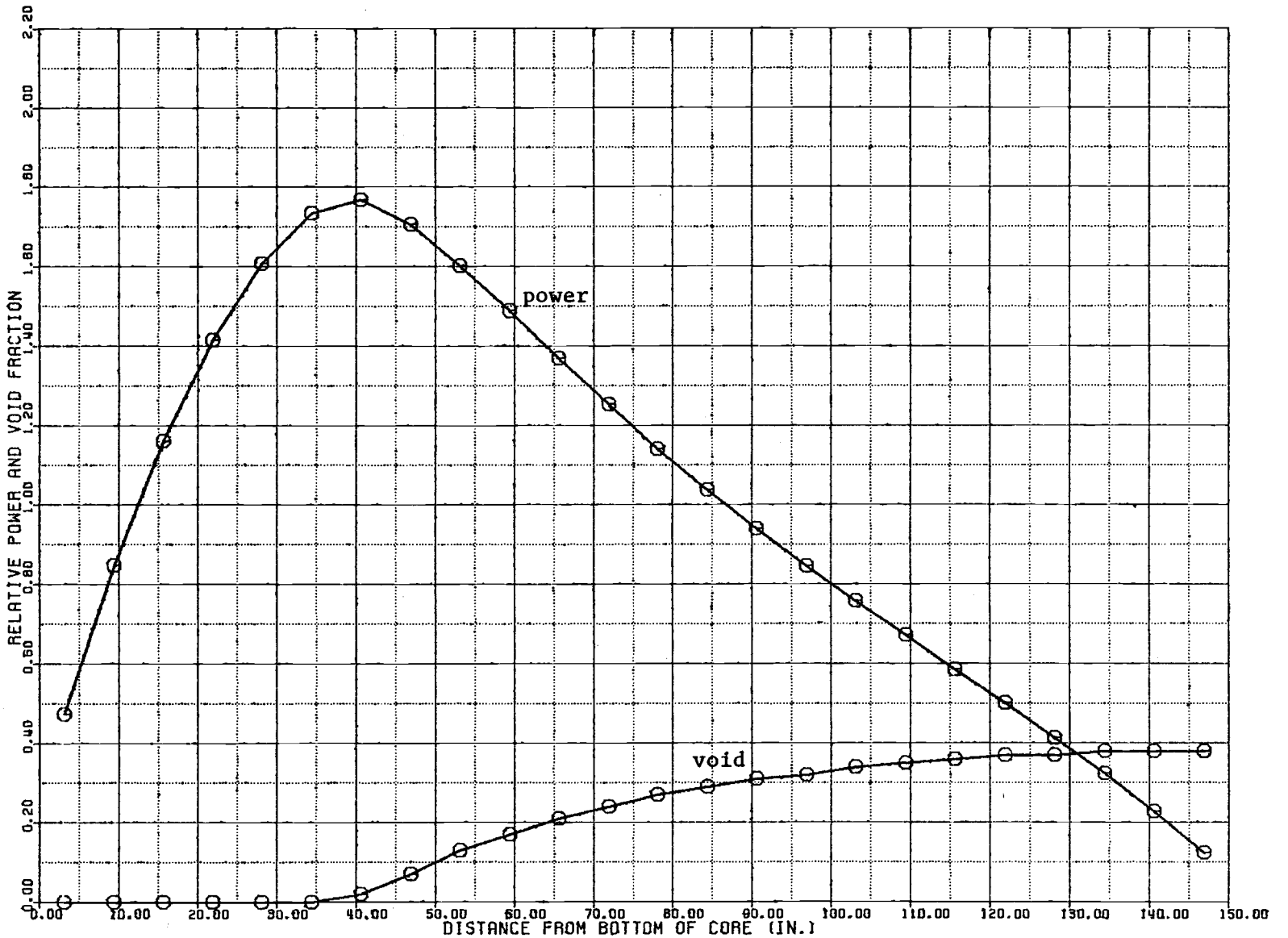


Figure 6.7 Axial Power and Void Fraction Distributions at 50% Power, ARO.

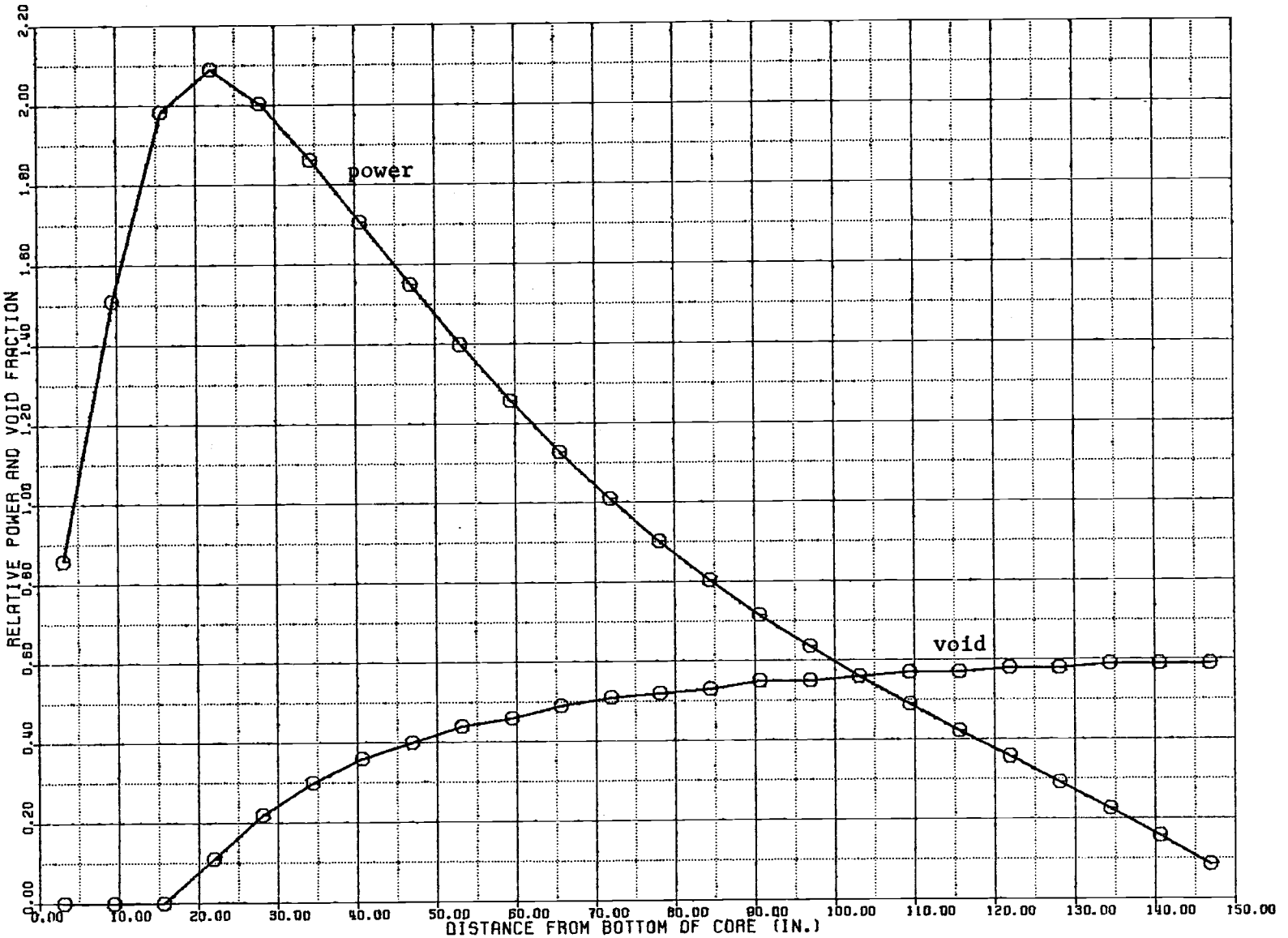


Figure 6.8 Axial Power and Void Fraction Distributions at Hot Full Power, ARO.

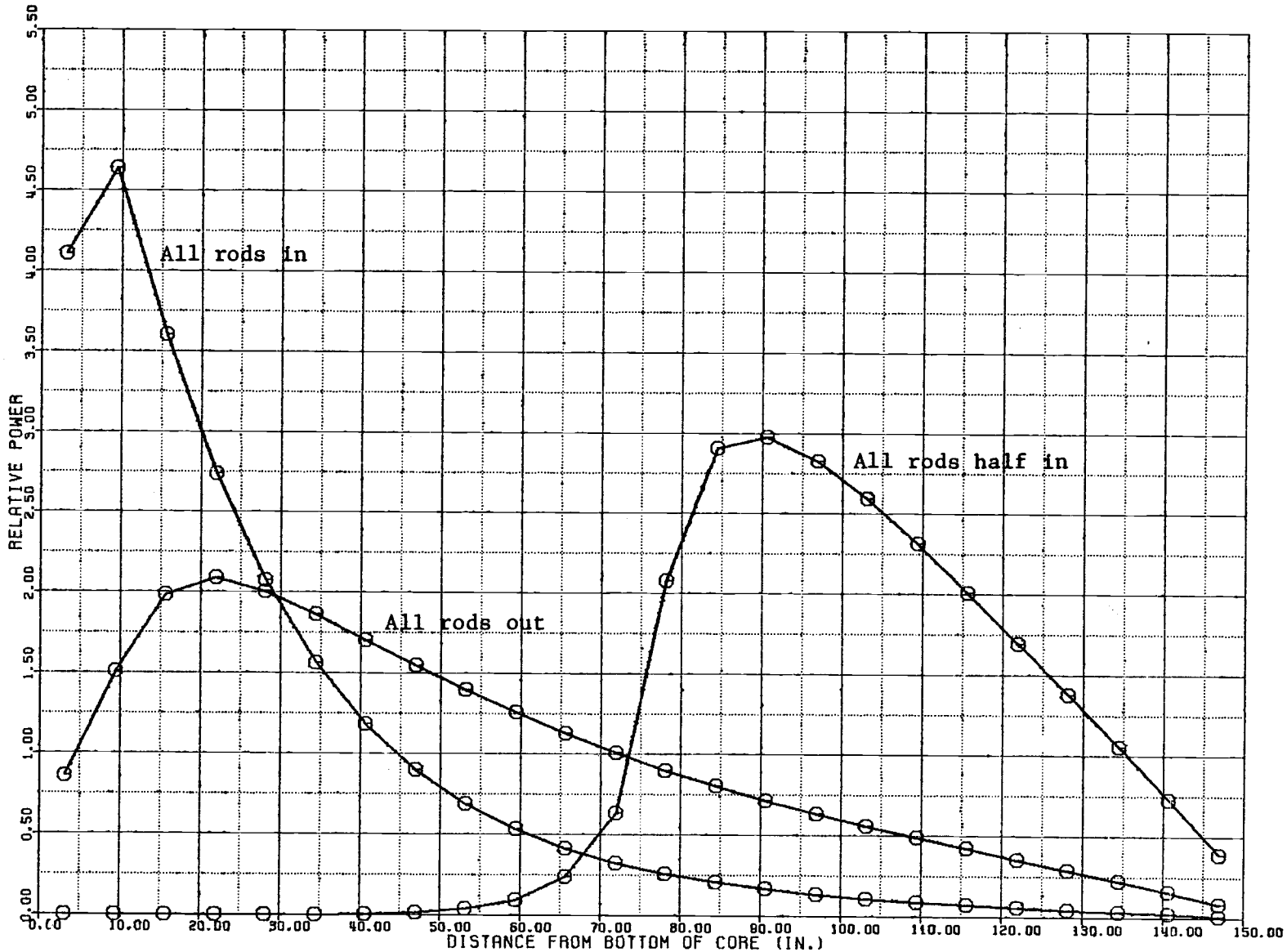


Figure 6.9 Illustration of Control Rod Effects on the Axial Power Distribution.

Nodes Inserted

24	0	24	0	24	0	12
0	8	0	8	0	8	0
24	0	24	0	24	0	0
0	8	0	8	0	8	
24	0	24	0	24	0	
0	8	0	8	0		
12	0	0				

k_{eff} = 1.0817
Peak = 3.242
Radial Peak = 1.455
Axial Peak = 2.088

Figure 6.10 Control Rod Positions for Control Rod Pattern Case #1.

Nodes Inserted

2	24	16	24	2	24	12
24	16	24	2	24	16	0
16	24	2	24	16	24	0
24	2	24	16	24	2	
2	24	16	24	2	0	
24	16	24	2	0		
12	0	0				

k_{eff} = 0.9764
Peak = 5.528
Radial Peak = 1.888
Axial Peak = 1.753

Figure 6.11 Control Rod Positions for Control Rod Pattern Case #2.

Nodes Inserted

23	0	23	0	23	0	12
0	16	0	16	0	16	0
23	0	23	0	23	0	0
0	16	0	16	0	16	
23	0	23	0	23	0	
0	16	0	16	0		
12	0	0				

k_{eff} = 1.0598
Peak = 3.307
Radial Peak = 1.496
Axial Peak = 2.081

Figure 6.12 Control Rod Positions for Control Rod Pattern Case #3.

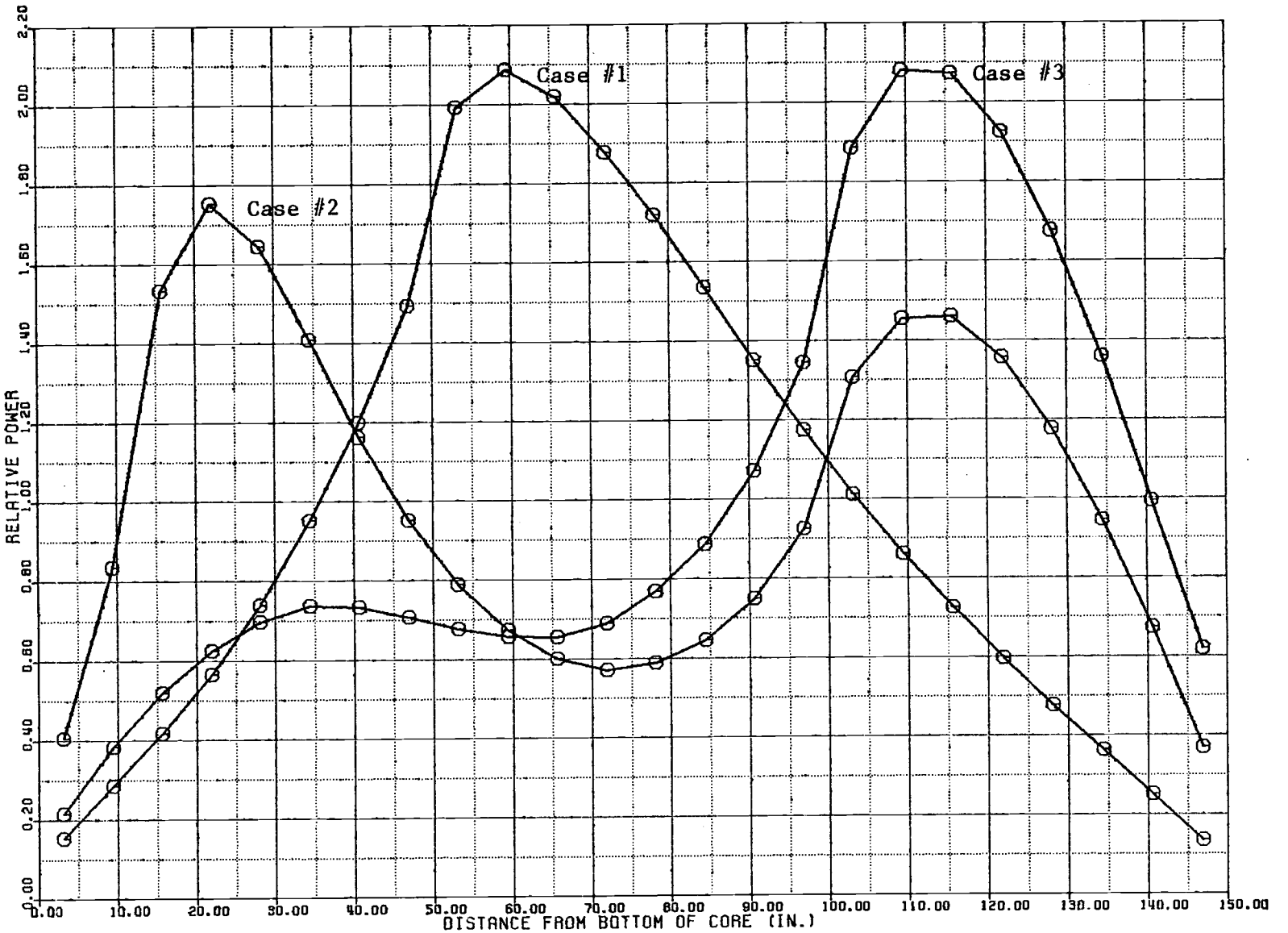


Figure 6.13 Axial Power Distributions Calculated from Control Rod Pattern Cases.

inserted rods coupled with coolant voiding tend to produce a peak near the bottom of the core. Another power peak occurs just above the tip of partially inserted rods. These effects make it difficult to achieve a relatively flat power distribution. The axially integrated two-dimensional power distributions are given in figure 6.14.

A beginning of life axial power distribution given in the Hatch Unit #2 Final Safety Analysis Report is shown in figure 6.15[13]. Control rod positions and axial burnable poison distributions for this case are not specified. This is a much flatter distribution than those obtained in the previously described cases. Several attempts to produce a comparable distribution were unsuccessful. Presumably the difficulty was due to improper input, particularly due to the fact that burnable poison distributions were not represented.

.706	1.168	1.193	.747	.757	1.239	1.253	.784	.812	1.455	1.407	.906	.243
1.075	.675	.659	.887	.948	.862	.943	1.441	1.405	.918	.839	1.021	.317
.736	1.166	1.194	.782	.794	1.242	1.259	.829	.865	1.496	1.472	1.082	.304
	1.207	1.330	1.255	1.366	1.275	1.383	1.306	1.431	1.424	1.333	1.070	.294
	.877	.971	.743	.905	1.434	1.583	.937	.938	1.136	1.141	1.222	.373
	1.099	1.212	1.261	1.372	1.161	1.260	1.320	1.452	1.307	1.232	1.122	.321
		1.266	1.377	1.290	1.393	1.302	1.411	1.319	1.394	1.303	1.071	.296
		.958	.909	.937	1.589	1.454	.939	.809	1.101	1.118	1.223	.374
		1.157	1.387	1.298	1.269	1.187	1.428	1.338	1.273	1.190	1.098	.313
			.788	.849	1.300	1.397	.791	.843	1.363	1.315	1.009	.276
			1.439	1.592	.950	.943	1.014	1.068	.829	.806	1.097	.333
			.832	.899	1.312	1.413	.839	.899	1.390	1.342	1.055	.288
				.791	1.386	1.275	.819	.793	1.247	1.154	.829	.196
				1.457	.943	.805	1.069	1.074	.862	.772	.923	.244
				.837	1.402	1.296	.872	.850	1.283	1.188	.871	.216
					1.262	1.324	1.192	1.205	1.054	.824	.265	
					1.008	1.069	.827	.942	1.402	1.124	.352	
					1.151	1.205	1.211	1.237	.972	.755	.268	
						1.190	1.226	1.101	.862	.292		
						1.037	1.024	1.087	1.512	.522		
						1.082	1.245	1.129	.791	.262		
							.692	.573	.669	.195		
							1.804	1.886	1.665	.518		
							.732	.610	.688	.197		
								.428	.468	.113		
								1.883	1.496	.401		
								.463	.503	.121		
									.140			
									.552			
									.153			

Case 1
Case 2
Case 3

Figure 6.14 Radial Power Distributions Calculated from Control Rod Pattern Cases.

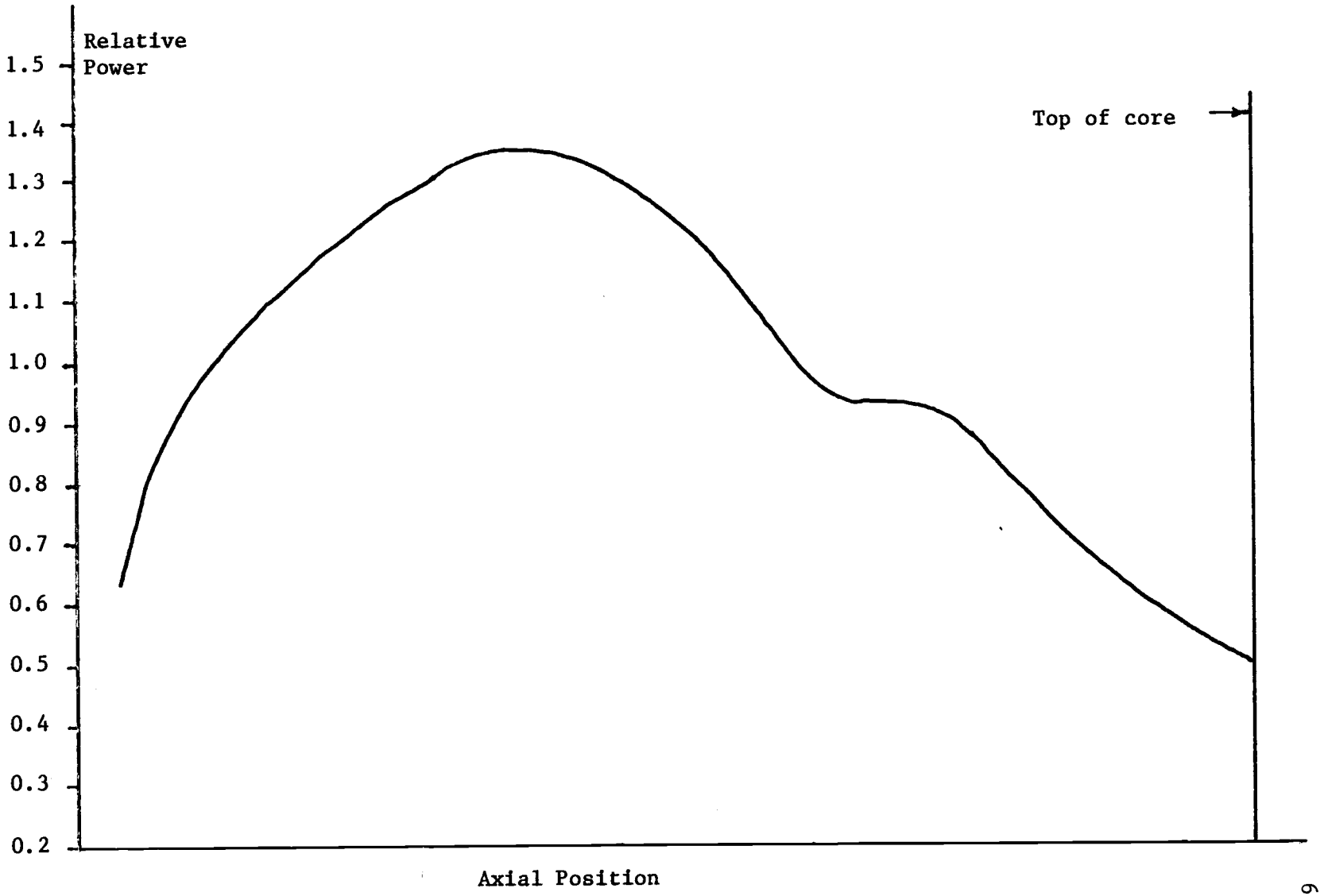


Figure 6.15 Axial Power Distribution from Edwin I. Hatch Nuclear Plant Unit #2 FSAR.

6.4 Haling Solution

A Haling solution calculation was run using an end of cycle average core exposure of 12000 MWD/MTU. The resulting x-y power distribution is shown in figure 6.16. Figure 6.17 shows the axial power and void distributions obtained. Judging from the control rod cases, it would be impossible to achieve this power distribution at beginning of life conditions without an axial distribution of burnable poison. As expected, a very flat power distribution was calculated with a very low peak to average power ratio. The peak to average ratio was 1.396 for this case.

Figure 6.18 shows a Haling axial power distribution for a typical BWR. The calculated power distribution in figure 6.17 compares very favorably with this.

1.057	1.069	1.084	1.090	1.097	1.098	1.103	1.106	1.119	1.203	1.125	0.923	0.338
	1.088	1.192	1.116	1.208	1.124	1.214	1.129	1.221	1.208	1.122	0.917	0.334
		1.127	1.223	1.142	1.231	1.145	1.231	1.142	1.203	1.108	0.897	0.322
			1.147	1.240	1.154	1.241	1.152	1.231	1.189	1.075	0.851	0.295
				1.156	1.244	1.154	1.238	1.220	1.151	0.999	0.741	0.223
					1.154	1.234	1.135	1.184	1.076	0.853	0.308	
						1.136	1.199	1.134	0.972	0.411		
							1.158	1.064	0.869	0.322		
								0.943	0.721	0.226		
									0.276			

Figure 6.16 Radial Power Distribution from Haling Solution Case.

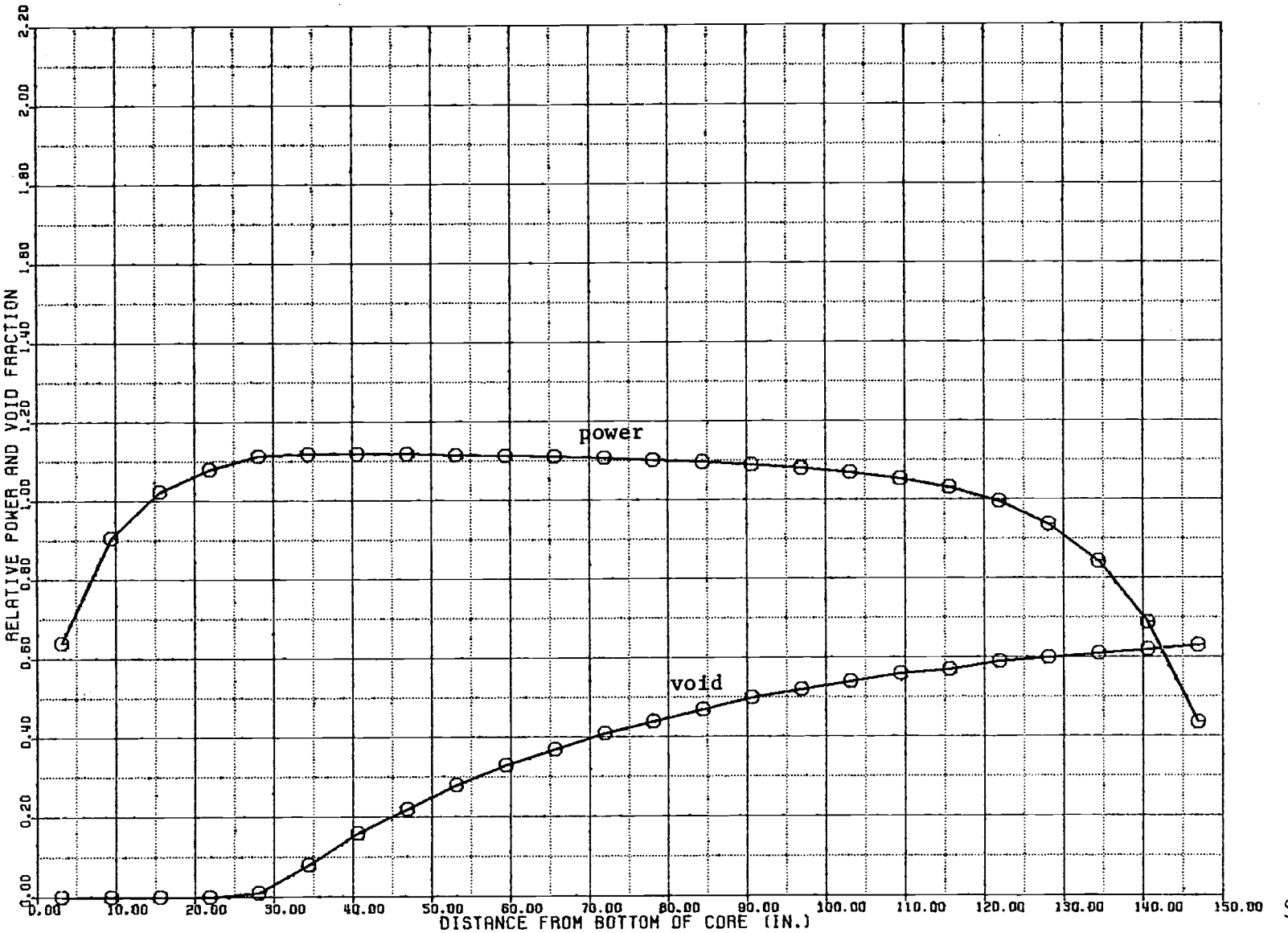


Figure 6.17 Axial Power and Void Fraction Distributions from Haling Solution Case.

Figure 6.18 Typical Haling Axial Power Distribution.

7.0 CONCLUSIONS

Test results indicate that the computer code which has been developed is capable of modeling the burnup dependent static behavior of a boiling water reactor with reasonable accuracy. Benchmarking tests of the neutronics model yielded results that agreed very well with analytical solutions. Control rod pattern tests did not give axial power distributions as flat as had been expected. This was presumably due to the absence of axial burnable poison distributions. It is also likely that better rod patterns would have improved these results. The determination of optimal rod patterns, however, was beyond the scope of this thesis. The end of cycle power distribution calculated by the Haling solution test showed close agreement with the expected distribution. Problems with control rods and burnable poisons would not affect the Haling solution results since burnable poisons are depleted and control rods are fully withdrawn at the end of an ideal operating cycle.

Unfortunately, a more rigorous test of the integrated model was not possible. A complete description of the nuclear design of the reference reactor's core was not obtainable due to the proprietary nature of part of the information. Cross section input could not be properly generated due to the unavailability of a PDQ type code. Cross sections suitable for test calculations were generated using the zero-dimensional LEOPARD code.

Control rods and burnable poisons can be used to shape the power distribution in order to improve core performance. The optimal power distribution is generally defined as that which minimizes power peaking

throughout an operating cycle and is given by the Haling solution. The control rod effects which have been demonstrated indicate that the Haling power distribution cannot be attained with control rods. As the rods are withdrawn to counteract fuel depletion, the fuel exposure distribution becomes the dominant influence on the power distribution. The problem that remains is how to select rod withdrawal patterns which, while minimizing power peaking and maintaining the core reactivity within flow control bounds, will yield an end of cycle exposure distribution consistant with the Haling power distribution.

With the proper input, the code which has been developed should provide a reasonable model of a boiling water reactor core. Such a model can be used to develop control rod withdrawal and fuel loading strategies which can be applied to improve reactor performance. A list of possible future modifications which can improve the accuracy and extend the applicability of the model are given below.

List of Future Improvements

1. Extension of the xenon model to include time dependency would enable the model to predict the effects of xenon transients.
2. The Doppler reactivity effect has not been included in the model. Increasing fuel temperature causes Doppler broadening of U-238 and Pu-240 resonance absorbtion peaks. This results in increased resonance absorbtion. The effect is worth about one-half of a percent in reactivity. Inclusion of this feedback effect should produce a slight improvement in results.
3. One of the largest reactivity effects is due to coolant voiding.

An improvement in the void fraction model could improve the accuracy of the predicted power distribution.

4. The model is limited to reactor cores with quadrant symetry. This is sufficient for most cases of interest since control rod patterns and most fuel loading patterns have octant or quadrant symetry. Extension to a half or full core model would require a great deal of modification to the program, but would extend its applicability.

5. The control rod model used assumes only the thermal absorbtion cross section changes when a node is rodded. Inclusion of separate table sets for rodded nodes may improve the predicted effects of control rods by correcting for the changes in other two-group constants.

6. The determination of optimal control rod withdrawal patterns is one of the biggest problems in BWR operation. A possible future project using this program is the development of a logic for an automated search for optimal control rod withdrawal patterns.

BIBLIOGRAPHY

1. D. L. Delp, D. L. Fischer, J. M. Harriman, and M. J. Stedwell, "FLARE, A Three-Dimensional Boiling Water Simulator," General Electric Company, USAEC Report GEAP-4598, (July 1964).

2. R. B. Stout, "Optimization of In-Core Nuclear Fuel Management in a Pressurized Water Reactor," Ph. D. Thesis, Oregon State University (1972).

3. R. W. Hardie, W. W. Little, Jr., "3DB, A Three-Dimensional Diffusion Theory Burnup Code," BNWL-1264, (March 1970).

4. S. Børresen, "A Simplified, Coarse-Mesh, Three-Dimensional Diffusion Scheme for Calculating The Gross Power Distribution in a Boiling Water Reactor," Nuclear Science and Engineering: 44, 37-43 (1971).

5. G. M. Roy, "Getting More Out of BWR's," Nucleonics: 24(11), 41-43 (1966).

6. R. K. Haling, "Operating Strategy for Maintaining an Optimum Power Distribution Throughout Life," USAEC Report TID-7072 (1964).

7. R. F. Barry, "The Revised LEOPARD Code, A Spectrum Dependent Non-Spatial Depletion Program," WCAP-2759, Westinghouse Electric Corp. (1965).

8. W. R. Cadwell, "PDQ-7 Reference Manual," WAPD-TM-678, Westinghouse Electric Corp. (1967).

9. R. J. Breen, O. J. Marlowe, and C. J. Pfeifer, "HARMONY: System for Nuclear Reactor Depletion Computation," WAPD-TM-478, Westinghouse Electric Corp., (1965).

10. J. J. Duderstadt and L. J. Hamilton, Nuclear Reactor Analysis, Ch. 8-10, John Wiley and Sons, Inc., New York, 1976.

11. A. A. Armand, "The Resistance During The Movement of a Two-Phase System in Horizontal Pipes," AERE-Trans., vol. 828 (1959), Izv. V. T. I. no. 1, 1946, p. 16.

12. E. Janssen and S. Levy, "Burnout Limit Curves for Boiling Water Reactors," General Electric Company Report APED 3892 (1962).

13. "Edwin I. Hatch Nuclear Plant Unit Number 2, Final Safety Analysis Report," Section 4, Georgia Power Company.

APPENDICES

APPENDIX A

Input Instructions

Unless otherwise noted, all input is in NAMELIST or free format. NAMELIST input is initiated with $INPUT (&INPUT on IBM computers). The dollar sign (or &) must begin in column 2 of an 80 column record. $INPUT is followed by a list of variable assignments in the form of

variable=value .

These are separated by commas. NAMELIST input is terminated by a dollar sign (&END on IBM) following the last variable assignment. NAMELIST variables not referenced retain their previous, or default, values.

Free format input consists of a list of values separated by blanks and/or commas. These are assigned, in order, to the variables in the input list. Free format input may continue on more than one record if needed. If desired, the input scan can be terminated by a slash (/). The remaining variables will retain their previous values.

The following variables and definitions are used in the input instructions:

NODES = total number of nodes represented

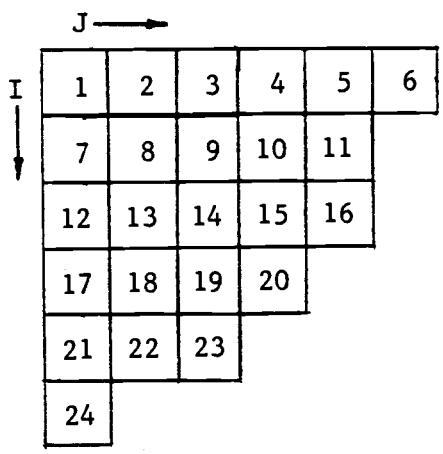
NP = number of nodes in each axial plane

NZ = number of axial nodes represented

NX = maximum number of nodes per row

2-D array format: In 2-D array format, NP values are input in free format. These values are assigned to planar locations in the order illustrated in figure A.1.

3-D array format: NODES values are input in free format and are assign-



NCOL(1) = 6

NCOL(2) = 5

NCOL(3) = 5

NCOL(4) = 4

NCOL(5) = 3

NCOL(6) = 1

NP = 24

NX = 6

Figure A.1 Quarter Core Plane Indexing Conventions.

ed to each node in the problem, plane by plane, as in 2-D array format. The first axial plane is at the bottom of the core, and the last is at the top.

Input records are cards or 80 column card images.

Detailed Input Description

(Listed in order of occurance)

1. Title card. FORMAT (20A4)

2. Problem description in NAMELIST format. NAMELIST name = INPUT. Recommended values are marked by asterisks (*).

NAMELIST Variable	Description	Default
IPTYPE	IPTYPE = 1 for burnup step problem. IPTYPE = 2 for Haling solution.	1
IGEOM	IGEOM = 1 for quarter core geometry. IGEOM = 2 for square plane geometry.	1
NCOL(NX)	NCOL(I),I=1,NX are the number of nodes in each horizontal row of a planar cross section. (see fig. A.1)	
DX	Node width in centimeters. (assembly pitch)	
DZ	Node height in centimeters.	
ICNTRL	ICNTRL = 0 if no control rods are used. ICNTRL = N if control rods are used. Control rod worths corresponding to N table sets will be read.	0
NBANKS	If NBANKS = 0, control rod positions will be input as a two-dimensional array giving rod positions at each planar coordinate. If NBANKS = N, rod positions will be set by banks. A rod bank is a defined set of coor-	

NAMELIST Variable	Description	Default
	dinates corresponding to a group of rods that are moved as a unit.	
IPDRD	IPDRD = 1 if a guess at the converged power distribution is to be input. This may speed convergence in some cases. If IPDRD = 0, a flat power distribution is used as the first guess.	0
IEXRD	IEXRD = 0 sets the fuel exposure at each node to 0.0 MWD/MTU. IEXRD = 1 if fuel exposures are to be input in 3-D array format. IEXRD = -1 if fuel exposures are to be input axially at selected planar coordinates. (IEXRD = -1 must be used if the exposure punch from a previous case is to be read.)	0
IEDIT(1)	IEDIT(1) = -1 if 3-D and integrated power distributions are to be edited. IEDIT(1) = 0 if only integrated (2-D) power distributions are to be edited. IEDIT(1) = 1 if only 3-D power distributions are to be edited.	-1
IEDIT(2)	IEDIT(2) = -1 if 3-D and assembly average exposure distributions are to be edited. IEDIT(2) = 0 if only assembly average exposure distributions are to be edited. IEDIT(2) = 1 if only 3-D exposure distributions are to be edited.	0
IEDIT(3)	IEDIT(3) = -1 to punch the exposure distribution at the end of each burnup step. IEDIT(3) = 0 for no exposure punch. IEDIT(3) = 1 to punch the exposure	0

NAMELIST Variable	Description	Default
	distribution at the end of the case.	
IEDIT(4)	IEDIT(4) = -1 to edit void fractions for the top plane only. IEDIT(4) = 0 for no void fraction edit. IEDIT(4) = 1 to edit 3-D void fraction distributions.	1
IEDIT(5)	IEDIT(5) = -1 to edit the location and value of the MCHFR. IEDIT(5) = 0 for no MCHFR edit. IEDIT(5) = 1 edits the location and value of the MCHFR plus the MCHFR for each channel.	1
IEDIT(6)	IEDIT(6) = -1 to punch the power distribution at the end of each burnup step. IEDIT(6) = 0 for no power distribution punch. IEDIT(6) = 1 to punch the power distribution at the end of the last burnup step only.	0
A1	Nodal weighting factor for fast fluxes.	0.31
A2	Nodal weighting factor for thermal fluxes.	0.73
MAXI	Number of inner iterations per outer iteration.	3*
MAXO	Maximum number of outer (source) iterations per power iteration.	6*
EPSO	Source iteration convergence criterion. The source iteration is considered converged when the relative change in the fission source for each node is less than or equal to EPSO: $\max_{\ell}\left(\frac{\lvert S_{\ell}^{I} - S_{\ell}^{I-1}\rvert}{S_{\ell}^{I}}\right) \leq \text{EPSO}$	1.0E-6
EPSP	The power distribution iteration is considered con-	0.5E-2

NAMELIST Variable	Description	Default
	verged when the relative change in power at each node is less than or equal to EPSP.	
ISOR	If ISOR = 1, successive overrelaxation will be used on the inner iterations. (Not recommended.)	0*
ALPHA	Overrelaxation factor used for outer iterations.	1.65*
IXE	If IXE = 0 no equilibrium xenon correction will be made.	1
ITSETS	Number of cross section table sets to be read.	1
IEXPTS	Number of exposure interpolating points used in the table sets.	1
IVDPTS	Number of void fraction interpolating points used in the table sets.	1
BUMASK	Exposure mask used by the table sets. BUMASK is an array of IEXPTS elements. Exposures must be in increasing order. (MWD/MTU)	0.
VMASK	Void fraction mask used by the table sets. VMASK is an array of IVDPTS elements. Void fractions must be in increasing order.	0.
ITSAS	Table set assignment format. If ITSAS = 1, table set #1 is assigned to all nodes. If ITSAS = 2, a one to one correspondence is used between fuel types and table sets (no axial variation). If ITSAS = 3, table set to fuel type overlays will be used.	2
IFTYPS	Number of fuel types used. (Required only if ITSAS = 3.)	1

NAMELIST Variable	Description	Default
TONNES	Core loading in Tonnes U. (Required only if burnup steps are input as hours.)	
PCTPWR	Core power in percent of rated power.	100.
MWTH	Rated reactor power (Mw-thermal).	
AVHFLX	Average heat flux at the clad surface at the rated reactor power. (Btu/hr ft^2)	
PEAKF	Heat flux peaking factor. (Used in MCHFR calculation)	1.05
AREA	Active flow area per node. (ft^2)	
HIN	Coolant inlet enthalpy. (Btu/lbm)	
HSAT	Saturation enthalpy at core average temperature and pressure. (Btu/lbm)	
HFG	Heat of vaporization. (Btu/lbm)	
VG	Specific volume of saturated steam. (ft^3/lbm)	
VF	Specific volume of saturated water. (ft^3/lbm)	
PSIA	Core average pressure. (psia)	
TFLOW	Total active incore coolant flow. (lbm/hr)	
AC1	Coefficients used in modified Armand correlation.	0.833
AC2	(See equation 4-11.)	0.167
IFLOW	If IFLOW = 0, the coolant flow in each channel will be assumed equal. If IFLOW = N, coefficients for a polynomial relating channel flow to the relative power of the channel will be read for N channel types.	0

Variables not used in a particular case need not be input. If IVDPTS = 1, no thermal-hydraulic calculations will be done. A list of

variables required for fuel exposure, void fraction, MCHFR, and equilibrium xenon calculations is given below.

Fuel exposure:	BUMASK, TONNES
Void fraction:	VMASK, PCPTWR, MWTH, HIN, HSAT, HFG, VG, VF, TFLOW, AC1, AC2.
MCHFR:	Same as for void fraction plus AVHFLX, PEAKF, AREA, PSIA.
Eq. Xenon:	PCTPWR, MWTH.

3. Boundary Conditions.

See section 2.1.2 for a detailed description of boundary condition treatment.

ALB = A + B·VOID(ℓ)

ALB = 0.0 for zero flux,

= 1.0 for zero current,

= x.x for leakage specified by A and B.

If IGEOM = 1: Enter six pairs of constants, A and B, for the fast group and then six pairs for the thermal group. Boundary conditions must be entered, in order, for boundary faces one through six using the directional indexing convention depicted in figure 2.2.

If IGEOM = 2 (quarter core geometry): Enter two pairs of constants, A and B, for the bottom and then top of the core: first for the fast group, then for the thermal group. Next enter NX pairs of constants for boundary faces 1 through NX as shown in figure 2.4: first for the fast group, then for the thermal group.

4. Xe-135 + I-135 fission yields. (Ignore if IXE = 0)

IEXPTS yields are required for each table set corresponding to the exposures in the exposure mask. Begin a new record for each table set. For each table set enter the table set number followed by IEXPTS yield values.

5. Table set input.

The following sequence is repeated for each of ITSETS table sets. Each table set begins with the following two cards:

a) table set number.

b) table set descriptor. FORMAT(20A4)

Cross section input is in the following order:

a) D_1, Σ_{a1}, $\nu\Sigma_{f1}$, $\kappa\Sigma_{f1}$, Σ_r,

D_2, Σ_{a2}, $\nu\Sigma_{f2}$, $\kappa\Sigma_{f2}$

b) N^{Xe}, σ_{a2}^{Xe}, Σ_{f1}, Σ_{f2}

Input in b above is included only if IXE = 1 and must begin on a seperate record from list a.

The cross sections are input at the first void interpolating point at exposure points 1 through IEXPTS, then at the second void interpolating point at these exposures, and so on. For each table set, cross sections must be input at (IEXPTS) x (IVDPTS) state points.

Units for D are cm.; Σ_a, $\nu\Sigma_f$, Σ_r, Σ_f are cm^{-1}; $\kappa\Sigma_f$ is in Mev/cm; N^{Xe} is atoms/barn-cm; σ_{a2}^{Xe} is in barns.

N^{Xe} and σ_{a2}^{Xe} must be consistant with Σ_{a2}.

6. Fuel type overlay. (Ignore if ITSAS = 1)

Enter NP integer fuel types corresponding to each planar coordinate in 2-D array format.

7. Table set to fuel type overlays. (Ignore if ITSAS ≠ 3)

IFTYPS overlays are required. Each overlay description begins on a new record. An overlay description consists of an integer fuel type number followed by NZ integer table set numbers corresponding to axial nodes 1 through NZ for that fuel type.

8. Control rod positions. (Ignore if ICNTRL = 0)

Rod positions are indicated as an integer, from 0 to NZ, giving the number of axial nodes that are rodded for each planar coordinate.

If NBANKS = 0: Enter NP control rod positions for each planar coordinate in 2-D array format.

If NBANKS ≠ 0: First define NBANKS control rod banks. Each bank definition must begin on a new record. A bank definition is input as a bank ID number, the number of planar coordinates assigned to the bank, and the I,J coordinates of each location. The last two coordinates must be followed by a slash(/). For example

4, 3, 7,1, 2,3, 8,11/

assigns coordinates (7,1), (2,3), and (8,11) to rod bank number 4.

After all banks are defined, each bank position is input. For each rod bank one record is required containing the bank ID followed by the axial position of the bank.

9. Control rod worths. (Ignore if ICNTRL = 0)

ICNTRL tables of control rod worths are required. For each table, the first record contains the number of the corresponding table set. This is followed by IVDPTS sets of rod worths. The first set contains IEXPTS worths for each successive exposure point in the exposure mask,

corresponding to the first point in the void fraction mask. The next set begins on a new record and contains the IEXPTS worths for the second void fraction, and so on.

10. Fuel exposures. (Ignore if IEXRD = 0)

If IEXRD = 1, enter the fuel exposure distribution in 3-D array format. Exposure units are MWD/MTU.

If IEXRD = -1, axial exposure distributions are input at seclected planar coordinates by repeating the following sequence for each desired coordinate.

a) I,J planar coordinate indices.

b) Fuel exposures for axial nodes 1 through NZ in MWD/MTU.

If less than NP axial distributions are to be input, follow the last exposure distribution by one record containing -99/ . All nodes which are not assigned exposures are set at 0.0 MWD/MTU.

11. Power distribution guess. (Ignore if IPDRD $\neq$ 1)

Enter the zero'th power distribution iterant in 3-D array format. (Code will normalize)

12. Flow channel type overlay. (Ignore if IFLOW = 0)

Enter the flow channel type indices for each planar coordinate in 2-D array format. NP integers are required.

13. Channel flow versus power polynomials. (Ignore if IFLOW = 0)

Enter the coefficients of the flow versus power polynomials on one record for each of IFLOW channel types. Each record contains the channel type index followed by A, B, and C for that channel type. (See equation 4-3.)

14. Burnup step input.

If IPTYPE = 2 (Haling solution) enter the exposure increment (cycle length) for which the solution is to be calculated in MWD/MTU. This completes the input for a Haling solution problem.

If IPTYPE = 1, and no burnup step calculations are desired, no further input is required. Only the power distribuiton at the initial input conditions will be calculated.

If IPTYPE = 1, and burnup step calculations are desired, the following input is needed.

Burnup step #1:

Enter the first burnup step increment in MWD/MTU or in hours. If burnup steps are input as hours, the values must be preceded by a negative sign and TONNES must have been included in the NAMELIST input.

For each additional step, the following input is required.

a) Burnup increment and update indicators:

BURN, NEWTH, NEWF, NEWCR

BURN = step length (MWD/MTU, or -hours)

NEWTH = 1 if thermal-hydraulic parameters are to be changed for this step. Otherwise set NEWTH = 0.

NEWF = N if the fuel loading is to be changed at N planar coordinates. This allows the fuel type overlay, channel type overlay, and fuel exposure array to be changed. Otherwise NEWF = 0.

NEWCR = 0 if control rod positions are to remain unchanged.

= N if NBANKS $\neq$ 0 and the positions of N rod banks are to be changed.

NEWCR = -1 if NBANKS = 0 and a new rod position array is to be read.

= N if NBANKS = 0 and the rod positions at N planar coordinates are to be changed.

b) Updated thermal-hydraulic data. (Ignore if NEWTH = 0)

PCTPWR, VG, VF, HIN, HSAT, HFG, PSIA, AC1, AC2, TFLOW, and PEAKF can be changed by repeating the NAMELIST input as described in #1. All variables listed above retain their previous values if unreferenced. Coefficients in the flow versus power polynomials can be changed by setting IFLOW to the number of polynomials to be changed. If IFLOW is reset to N, follow the NAMELIST input with N records containing new coefficients as in item 13.

c) Updated fuel loading. (Ignore if NEWF = 0)

The following sequence must be repeated NEWF times.

1) IFT, ICTYP, I, J

IFT = fuel type number

ICTYP = channel type number

I, J = planar coordinates

2) Exposures for nodes 1 through NZ (MWD/MTU)

d) Updated control rod positions. (Ignore if NEWCR = 0)

If NBANKS $\neq$ 0, NEWCR records must be input. Each record contains the rod bank ID number followed by the bank position.

If NBANKS = 0:

If NEWCR = -1, enter a new rod position array in 2-D array format.

If NEWCR = N, (N $\neq$ 0), NEWCR records must be input. Each re-

cord contains I, J coordinates followed by the rod position at those coordinates. The rod positions at all other coordinates remain unchanged.

Sample Input

```
EDWIN HATCH UNIT #2     100% POWER              7-11-77
 &INPUT
        ICNTRL=3, IEDIT=0,0,0,-1,1,
        MWT=2436.,
        DX=15.240, DZ=15.875, NCOL=5*13,12,3*11,10,9,6,5,
        IEXPTS=12, IVDPTS=3, IFTYPS=3, ITSETS=3, ITSAS=2,
        EPSP=.1E-2,
        BUMASK=0.,100.,500.,2000.,4000.,6000.,8000.,10000.,15000.,
        20000.,25000.,30000.,
        VMASK=0.,.32,.64,
        AVMFLX=145060., VG=.4297, VF=.0217,HSAT=547.8,
        HFG=642.8, PSIA=1035., IFLOW=2, IFLOW=77.E6, AREA=.1098611,
        HIN=526.9
 &END
  .568 0. .568 0. .208 0. .208 0.
  .568 0. .568 0. .568 0. .568 0. .568 0. .568 0. .568 0.
  .568 0. .568 0. .568 0. .568 0. .568 0. .568 0.
  .208 0. .208 0. .208 0. .208 0. .208 0. .208 0. .208 0.
  .208 0. .208 0. .208 0. .208 0. .208 0. .208 0.
3 .0661 .0666 .0683 .0696 .0706 .0713 .0717 .0723 .0727 .073 .0731 .0732
1 .066 .0661 .0666 .0674 .0681 .0686 .0691 .0698 .0706 .0712 .0718 .0722
2 .066 .0661 .0665 .067 .0679 .068 .0684 .0691 .0698 .0705 .0711 .0716
3
6X6 BWR UNIT CELL  .711 W/O
     .14236D+01    .60056D-02    .25781D-02    .20276D+00    .23311D-01
     .37853D+00    .25346D-01    .23376D-01    .20166D+01
     .0            .18695D+07    .96182D-03    .96197D-02
     .14214D+01    .60160D-02    .25810D-02    .20291D+00    .23361D-01
     .37902D+00    .26125D-01    .23773D-01    .20463D+01
     .27185D-09    .18633D+07    .96203D-03    .97288D-02
     .14243D+01    .60208D-02    .25878D-02    .20280D+00    .23284D-01
     .37940D+00    .27313D-01    .25366D-01    .21509D+01
     .34441D-09    .18560D+07    .96118D-03    .10189D-01
     .14295D+01    .60442D-02    .25852D-02    .20094D+00    .23141D-01
     .37963D+00    .30000D-01    .28829D-01    .23663D+01
     .37497D-09    .18424D+07    .95031D-03    .11114D-01
     .14289D+01    .60929D-02    .25692D-02    .19846D+00    .23132D-01
     .37960D+00    .32154D-01    .30802D-01    .24766D+01
     .40629D-09    .18325D+07    .93517D-03    .11535D-01
     .14267D+01    .61503D-02    .25541D-02    .19652D+00    .23159D-01
     .37956D+00    .33544D-01    .31685D-01    .25172D+01
     .42156D-09    .18264D+07    .92270D-03    .11645D-01
     .14242D+01    .62131D-02    .25411D-02    .19504D+00    .23190D-01
     .37954D+00    .34527D-01    .32078D-01    .25277D+01
     .42740D-09    .18220D+07    .91257D-03    .11630D-01
     .14220D+01    .62792D-02    .25306D-02    .19392D+00    .23213D-01
     .37956D+00    .35279D-01    .32236D-01    .25255D+01
     .42913D-09    .18186D+07    .90445D-03    .11566D-01
     .13568D+01    .64545D-02    .24618D-02    .18872D+00    .23405D-01
     .37976D+00    .36621D-01    .32280D-01    .25073D+01
     .42760D-09    .18117D+07    .87356D-03    .11383D-01
     .13534D+01    .66280D-02    .24465D-02    .18772D+00    .23437D-01
     .38009D+00    .37674D-01    .32238D-01    .24950D+01
     .42505D-09    .18056D+07    .86403D-03    .11260D-01
     .12694D+01    .68159D-02    .23956D-02    .18465D+00    .23679D-01
     .38053D+00    .38636D-01    .32313D-01    .24974D+01
     .42490D-09    .17994D+07    .84549D-03    .11228D-01
     .12685D+01    .69742D-02    .23895D-02    .18464D+00    .23677D-01
```

.38100D+00	.39494D-01	.32431D-01	.25064D+01	
.42550D-09	.17935D+07	.84204D-03	.11236D-01	
.15788D+01	.58017D-02	.25019D-02	.19720D+00	.18720D-01
.43981D+00	.24039D-01	.23047D-01	.19856D+01	
.0	.18331D+07	.93534D-03	.94843D-02	
.15764D+01	.58130D-02	.25055D-02	.19739D+00	.18765D-01
.44051D+00	.24832D-01	.23480D-01	.20179D+01	
.27743D-09	.18255D+07	.93580D-03	.96053D-02	
.15799D+01	.58186D-02	.25160D-02	.19753D+00	.18689D-01
.44112D+00	.26105D-01	.25227D-01	.21339D+01	
.35297D-09	.18161D+07	.93620D-03	.10120D-01	
.15860D+01	.58466D-02	.25240D-02	.19643D+00	.18550D-01
.44166D+00	.29065D-01	.29126D-01	.23825D+01	
.38874D-09	.17979D+07	.92907D-03	.11200D-01	
.15861D+01	.59010D-02	.25203D-02	.19485D+00	.18522D-01
.44186D+00	.31515D-01	.31582D-01	.25302D+01	
.42774D-09	.17840D+07	.91834D-03	.11797D-01	
.15845D+01	.59629D-02	.25160D-02	.19370D+00	.18523D-01
.44200D+00	.33156D-01	.32892D-01	.26034D+01	
.45001D-09	.17748D+07	.90975D-03	.12062D-01	
.15825D+01	.60292D-02	.25122D-02	.19289D+00	.18529D-01
.44214D+00	.34352D-01	.33655D-01	.26424D+01	
.46166D-09	.17681D+07	.90293D-03	.12182D-01	
.15805D+01	.60983D-02	.25095D-02	.19233D+00	.18533D-01
.44228D+00	.35284D-01	.34127D-01	.26643D+01	
.46826D-09	.17628D+07	.89757D-03	.12232D-01	
.15762D+01	.62744D-02	.25070D-02	.19178D+00	.18525D-01
.44271D+00	.36916D-01	.34677D-01	.26843D+01	
.47227D-09	.17527D+07	.88910D-03	.12228D-01	
.15574D+01	.64433D-02	.24903D-02	.19059D+00	.18530D-01
.44326D+00	.38185D-01	.34993D-01	.26985D+01	
.47685D-09	.17440D+07	.87867D-03	.12230D-01	
.15099D+01	.66078D-02	.24595D-02	.18878D+00	.18589D-01
.44390D+00	.39290D-01	.35301D-01	.27182D+01	
.48084D-09	.17358D+07	.86608D-03	.12275D-01	
.15086D+01	.67593D-02	.24614D-02	.18929D+00	.18553D-01
.44456D+00	.40266D-01	.35611D-01	.27410D+01	
.48499D-09	.17281D+07	.86516D-03	.12346D-01	
.17678D+01	.54763D-02	.23972D-02	.18961D+00	.14225D-01
.52466D+00	.22562D-01	.22491D-01	.19355D+01	
.0	.17784D+07	.89891D-03	.92553D-02	
.17652D+01	.54883D-02	.24017D-02	.18987D+00	.14262D-01
.52571D+00	.23369D-01	.22964D-01	.19707D+01	
.28466D-09	.17686D+07	.89969D-03	.93898D-02	
.17693D+01	.54956D-02	.24169D-02	.19034D+00	.14190D-01
.52674D+00	.24744D-01	.24897D-01	.21006D+01	
.36492D-09	.17557D+07	.90173D-03	.99698D-02	
.17765D+01	.55306D-02	.24388D-02	.19025D+00	.14058D-01
.52789D+00	.28042D-01	.29324D-01	.23896D+01	
.40801D-09	.17303D+07	.89946D-03	.11240D-01	
.17774D+01	.55930D-02	.24517D-02	.18988D+00	.14012D-01
.52861D+00	.30862D-01	.32383D-01	.25839D+01	
.45811D-09	.17099D+07	.89465D-03	.12056D-01	
.17767D+01	.56611D-02	.24623D-02	.18982D+00	.13989D-01
.52917D+00	.32823D-01	.34238D-01	.26992D+01	
.49067D-09	.16957D+07	.89139D-03	.12521D-01	
.17755D+01	.57323D-02	.24716D-02	.18995D+00	.13970D-01
.52965D+00	.34299D-01	.35489D-01	.27757D+01	

.51103D-09	.26850D+07	.88922D-03	.12819D-01	
.17743D+01	.58048D-02	.24602D-02	.19021D+00	.13950D-01
.53008D+00	.35475D-01	.36391D-01	.28305D+01	
.52511D-09	.16763D+07	.88789D-03	.13025D-01	
.17713D+01	.59854D-02	.24976D-02	.19108D+00	.13901D-01
.53102D+00	.37524D-01	.37680D-01	.29066D+01	
.53807D-09	.16604D+07	.88630D-03	.13286D-01	
.17689D+01	.61561D-02	.25115D-02	.19210D+00	.13849D-01
.53199D+00	.39104D-01	.38534D-01	.29611D+01	
.55298D-09	.16473D+07	.88652D-03	.13474D-01	
.17675D+01	.63132D-02	.25257D-02	.19334D+00	.13793D-01
.53301D+00	.40439D-01	.39236D-01	.30098D+01	
.56511D-09	.16355D+07	.88859D-03	.13653D-01	
.17669D+01	.64595D-02	.25398D-02	.19468D+00	.13730D-01
.53402D+00	.41602D-01	.39862D-01	.30557D+01	
.57632D-09	.16248D+07	.89162D-03	.13831D-01	

1
8X= FWR UNIT CELL 1.83 W/O

.14424D+01	.65222D-02	.37802D-02	.29943D+00	.21119D-01
.38986D+00	.39718D-01	.54707D-01	.46196D+01	
.0	.17495D+07	.14529D-02	.22513D-01	
.14451D+01	.65402D-02	.37796D-02	.29946D+00	.21235D-01
.39055D+00	.40704D-01	.54474D-01	.46060D+01	
.59018D-09	.17412D+07	.14523D-02	.22389D-01	
.14466D+01	.65484D-02	.37627D-02	.29784D+00	.21290D-01
.39077D+00	.41396D-01	.54673D-01	.46096D+01	
.73196D-09	.17369D+07	.14435D-02	.22362D-01	
.14485D+01	.65550D-02	.36891D-02	.29092D+00	.21354D-01
.39031D+00	.42399D-01	.55290D-01	.46099D+01	
.73649D-09	.17347D+07	.14069D-02	.22267D-01	
.14517D+01	.65664D-02	.35879D-02	.28178D+00	.21461D-01
.38945D+00	.43301D-01	.55162D-01	.45488D+01	
.73632D-09	.17346D+07	.13586D-02	.21856D-01	
.14553D+01	.65817D-02	.34890D-02	.27307D+00	.21579D-01
.38856D+00	.43842D-01	.54415D-01	.44487D+01	
.72824D-09	.17364D+07	.13123D-02	.21273D-01	
.14591D+01	.66008D-02	.33942D-02	.26486D+00	.21700D-01
.38773D+00	.44112D-01	.53292D-01	.43256D+01	
.71455D-09	.17392D+07	.12686D-02	.20589D-01	
.14630D+01	.66224D-02	.33041D-02	.25715D+00	.21815D-01
.38697D+00	.44182D-01	.51931D-01	.41893D+01	
.69736D-09	.17426D+07	.12273D-02	.19850D-01	
.14565D+01	.66907D-02	.31116D-02	.24093D+00	.22080D-01
.38546D+00	.43921D-01	.48310D-01	.38486D+01	
.66302D-09	.17514D+07	.11398D-02	.18042D-01	
.14449D+01	.67754D-02	.29475D-02	.22748D+00	.22324D-01
.38426D+00	.43333D-01	.44604D-01	.35198D+01	
.61426D-09	.17600D+07	.10668D-02	.16333D-01	
.14341D+01	.68765D-02	.28151D-02	.21691D+00	.22548D-01
.38344D+00	.42764D-01	.41303D-01	.32364D+01	
.56814D-09	.17668D+07	.10089D-02	.14873D-01	
.14097D+01	.69897D-02	.26966D-02	.20779D+00	.22756D-01
.38293D+00	.42369D-01	.38662D-01	.30146D+01	
.52923D-09	.17713D+07	.95901D-03	.13735D-01	
.16008D+01	.63148D-02	.37070D-02	.29412D+00	.16819D-01
.45486D+00	.37911D-01	.53453D-01	.45118D+01	
.0	.16929D+07	.14271D-02	.21997D-01	
.16034D+01	.63337D-02	.37071D-02	.29421D+00	.16919D-01

.45581D+00	.38887D-01	.53226D-01	.44983D+01	
.60566D-09	.16829D+07	.14268D-02	.21873D-01	
.16047D+01	.63436D-02	.36930D-02	.29279D+00	.16963D-01
.45616D+00	.39645D-01	.53552D-01	.45111D+01	
.75198D-09	.16774D+07	.14189D-02	.21890D-01	
.16066D+01	.63554D-02	.36289D-02	.28655D+00	.17010D-01
.45569D+00	.40918D-01	.54621D-01	.45456D+01	
.76062D-09	.16730D+07	.13857D-02	.21957D-01	
.16097D+01	.63738D-02	.35399D-02	.27831D+00	.17093D-01
.45473D+00	.42152D-01	.55022D-01	.45253D+01	
.76652D-09	.16708D+07	.13418D-02	.21740D-01	
.16130D+01	.63955D-02	.34532D-02	.27050D+00	.17183D-01
.45373D+00	.42998D-01	.54773D-01	.44639D+01	
.76431D-09	.16709D+07	.13000D-02	.21340D-01	
.16166D+01	.64204D-02	.33703D-02	.26317D+00	.17273D-01
.45282D+00	.43548D-01	.54129D-01	.43785D+01	
.75590D-09	.16723D+07	.12606D-02	.20835D-01	
.16200D+01	.64473D-02	.32916D-02	.25631D+00	.17357D-01
.45198D+00	.43879D-01	.53227D-01	.42780D+01	
.74359D-09	.16746D+07	.12236D-02	.20269D-01	
.16163D+01	.65255D-02	.31221D-02	.24180D+00	.17543D-01
.45032D+00	.44141D-01	.50559D-01	.40120D+01	
.71644D-09	.16812D+07	.11445D-02	.18819D-01	
.16057D+01	.66156D-02	.29760D-02	.22967D+00	.17709D-01
.44902D+00	.43982D-01	.47637D-01	.37446D+01	
.67629D-09	.16883D+07	.10782D-02	.17405D-01	
.15960D+01	.67169D-02	.28557D-02	.21997D+00	.17857D-01
.44809D+00	.43728D-01	.44911D-01	.35061D+01	
.63688D-09	.16942D+07	.10246D-02	.16159D-01	
.15876D+01	.68283D-02	.27614D-02	.21259D+00	.17972D-01
.44750D+00	.43535D-01	.42630D-01	.33119D+01	
.60253D-09	.16982D+07	.98332D-03	.15151D-01	
.17966D+01	.59901D-02	.36057D-02	.28686D+00	.12621D-01
.54520D+00	.35648D-01	.51410D-01	.43384D+01	
.0	.16110D+07	.13913D-02	.21157D-01	
.17989D+01	.60103D-02	.36068D-02	.28703D+00	.12705D-01
.54654D+00	.36599D-01	.51184D-01	.43244D+01	
.62547D-09	.15988D+07	.13914D-02	.21030D-01	
.18001D+01	.60220D-02	.35962D-02	.28587D+00	.12739D-01
.54712D+00	.37437D-01	.51663D-01	.43484D+01	
.77976D-09	.15912D+07	.13849D-02	.21100D-01	
.18019D+01	.60402D-02	.35443D-02	.28050D+00	.12767D-01
.54675D+00	.39049D-01	.53288D-01	.44251D+01	
.79442D-09	.15832D+07	.13560D-02	.21366D-01	
.18048D+01	.60677D-02	.34712D-02	.27342D+00	.12826D-01
.54573D+00	.40700D-01	.54342D-01	.44555D+01	
.80924D-09	.15774D+07	.13178D-02	.21390D-01	
.18080D+01	.60983D-02	.34007D-02	.26682D+00	.12890D-01
.54471D+00	.41927D-01	.54719D-01	.44431D+01	
.81564D-09	.15745D+07	.12819D-02	.21223D-01	
.18110D+01	.61299D-02	.33335D-02	.26065D+00	.12946D-01
.54378D+00	.42831D-01	.54682D-01	.44052D+01	
.81494D-09	.15734D+07	.12483D-02	.20946D-01	
.18141D+01	.61640D-02	.32702D-02	.25494D+00	.12999D-01
.54295D+00	.43495D-01	.54370D-01	.43512D+01	
.80986D-09	.15733D+07	.12169D-02	.20602D-01	
.18105D+01	.62553D-02	.31325D-02	.24277D+00	.13109D-01
.54131D+00	.44442D-01	.52956D-01	.41839D+01	

.79329D-09	.15755D+07	.11494D-02	.19626D-01	
.18015D+01	.63534D-02	.30128D-02	.23259D+00	.13201D-01
.54003D+00	.44877D-01	.51128D-01	.40023D+01	
.76629D-09	.15789D+07	.10927D-02	.18623D-01	
.17935D+01	.64569D-02	.29127D-02	.22433D+00	.13279D-01
.53913D+00	.45101D-01	.49285D-01	.38325D+01	
.73787D-09	.15820D+07	.10464D-02	.17706D-01	
.17868D+01	.65660D-02	.28322D-02	.21791D+00	.13336D-01
.53856D+00	.45261D-01	.47653D-01	.36882D+01	
.71203D-09	.15840D+07	.10098D-02	.16935D-01	

8X8 BWR UNIT CELL 2.33 W/O

.13616D+01	.67798D-02	.43437D-02	.34423D+00	.20401D-01
.39396D+00	.45384D-01	.67026D-01	.56424D+01	
.0	.17040D+07	.16781D-02	.27583D-01	
.14210D+01	.68017D-02	.43060D-02	.34196D+00	.20636D-01
.39471D+00	.46449D-01	.66615D-01	.56162D+01	
.70587D-09	.16950D+07	.16665D-02	.27389D-01	
.14407D+01	.68082D-02	.42692D-02	.33893D+00	.20736D-01
.39494D+00	.47105D-01	.66580D-01	.56032D+01	
.87561D-09	.16908D+07	.16508D-02	.27280D-01	
.14426D+01	.68096D-02	.41846D-02	.33124D+00	.20804D-01
.39442D+00	.47834D-01	.66719D-01	.55693D+01	
.87618D-09	.16902D+07	.16105D-02	.27026D-01	
.14454D+01	.68135D-02	.40693D-02	.32104D+00	.20912D-01
.39349D+00	.48479D-01	.66203D-01	.54790D+01	
.87145D-09	.16917D+07	.15569D-02	.26479D-01	
.14486D+01	.68199D-02	.39549D-02	.31110D+00	.21029D-01
.39251D+00	.48846D-01	.65171D-01	.53559D+01	
.86013D-09	.16948D+07	.15046D-02	.25783D-01	
.14519D+01	.68289D-02	.38432D-02	.30153D+00	.21150D-01
.39156D+00	.48984D-01	.63799D-01	.52116D+01	
.84415D-09	.16987D+07	.14541D-02	.24994D-01	
.14553D+01	.68394D-02	.37348D-02	.29232D+00	.21268D-01
.39066D+00	.48938D-01	.62190D-01	.50533D+01	
.82490D-09	.17034D+07	.14054D-02	.24145D-01	
.14641D+01	.68758D-02	.34926D-02	.27197D+00	.21546D-01
.38877D+00	.48368D-01	.57836D-01	.46469D+01	
.78585D-09	.17153D+07	.12974D-02	.22004D-01	
.14618D+01	.69244D-02	.32751D-02	.25404D+00	.21814D-01
.38716D+00	.47363D-01	.53167D-01	.42326D+01	
.72856D-09	.17279D+07	.12019D-02	.19862D-01	
.14501D+01	.69875D-02	.30852D-02	.23868D+00	.22071D-01
.38584D+00	.46246D-01	.48640D-01	.38428D+01	
.67014D-09	.17396D+07	.11198D-02	.17867D-01	
.14390D+01	.70698D-02	.29265D-02	.22609D+00	.22312D-01
.38482D+00	.45214D-01	.44602D-01	.35022D+01	
.61552D-09	.17494D+07	.10520D-02	.16135D-01	
.15776D+01	.65708D-02	.42282D-02	.33619D+00	.16296D-01
.46021D+00	.43324D-01	.65277D-01	.54936D+01	
.0	.16406D+07	.16390D-02	.26863D-01	
.15987D+01	.65898D-02	.42128D-02	.33520D+00	.16427D-01
.46121D+00	.44367D-01	.64862D-01	.54666D+01	
.72520D-09	.16300D+07	.16334D-02	.26666D-01	
.16001D+01	.65998D-02	.41961D-02	.33363D+00	.16479D-01
.46156D+00	.45081D-01	.64942D-01	.54620D+01	
.90036D-09	.16246D+07	.16247D-02	.26596D-01	
.16020D+01	.66066D-02	.41210D-02	.32663D+00	.16532D-01

.46101D+00	.46073D-01	.65524D-01	.54614D+01	
.90511D-09	.16222D+07	.15878D-02	.26499D-01	
.16048D+01	.66177D-02	.40180D-02	.31732D+00	.16618D-01
.45993D+00	.47049D-01	.65534D-01	.54116D+01	
.90579D-09	.16220D+07	.15387D-02	.26144D-01	
.16079D+01	.66315D-02	.39161D-02	.30831D+00	.16712D-01
.45879D+00	.47725D-01	.65004D-01	.53275D+01	
.89974D-09	.16237D+07	.14910D-02	.25634D-01	
.16110D+01	.66461D-02	.38165D-02	.29963D+00	.16802D-01
.45770D+00	.48151D-01	.64118D-01	.52212D+01	
.88850D-09	.16265D+07	.14449D-02	.25026D-01	
.16142D+01	.66626D-02	.37201D-02	.29132D+00	.16891D-01
.45669D+00	.48377D-01	.62983D-01	.51000D+01	
.87376D-09	.16302D+07	.14007D-02	.24355D-01	
.16222D+01	.67110D-02	.35036D-02	.27290D+00	.17094D-01
.45456D+00	.48381D-01	.59670D-01	.47755D+01	
.84178D-09	.16403D+07	.13022D-02	.22608D-01	
.16223D+01	.67684D-02	.33082D-02	.25662D+00	.17285D-01
.45275D+00	.47882D-01	.55934D-01	.44349D+01	
.79332D-09	.16515D+07	.12149D-02	.20821D-01	
.16117D+01	.68359D-02	.31357D-02	.24254D+00	.17465D-01
.45126D+00	.47183D-01	.52187D-01	.41068D+01	
.74261D-09	.16622D+07	.11393D-02	.19123D-01	
.16017D+01	.69177D-02	.29889D-02	.23079D+00	.17628D-01
.45008D+00	.46466D-01	.48735D-01	.38121D+01	
.69416D-09	.16716D+07	.10758D-02	.17612D-01	
.17939D+01	.62409D-02	.41057D-02	.32738D+00	.12200D-01
.55225D+00	.40675D-01	.62469D-01	.52567D+01	
.0	.15504D+07	.15954D-02	.25707D-01	
.17961D+01	.62617D-02	.41077D-02	.32765D+00	.12282D-01
.55364D+00	.41678D-01	.62042D-01	.52281D+01	
.75033D-09	.15375D+07	.15960D-02	.25503D-01	
.17974D+01	.62737D-02	.40946D-02	.32635D+00	.12322D-01
.55421D+00	.42461D-01	.62261D-01	.52335D+01	
.93522D-09	.15303D+07	.15886D-02	.25481D-01	
.17992D+01	.62878D-02	.40317D-02	.32023D+00	.12359D-01
.55370D+00	.43780D-01	.63385D-01	.52741D+01	
.94546D-09	.15250D+07	.15561D-02	.25578D-01	
.18021D+01	.63088D-02	.39446D-02	.31211D+00	.12426D-01
.55249D+00	.45170D-01	.64043D-01	.52745D+01	
.95408D-09	.15218D+07	.15128D-02	.25460D-01	
.18050D+01	.63303D-02	.38585D-02	.30426D+00	.12490D-01
.55123D+00	.46230D-01	.64134D-01	.52389D+01	
.95572D-09	.15209D+07	.14708D-02	.25181D-01	
.18078D+01	.63531D-02	.37750D-02	.29678D+00	.12553D-01
.55005D+00	.47018D-01	.63858D-01	.51807D+01	
.95156D-09	.15215D+07	.14306D-02	.24804D-01	
.18107D+01	.63771D-02	.36945D-02	.28965D+00	.12613D-01
.54897D+00	.47587D-01	.63324D-01	.51068D+01	
.94343D-09	.15231D+07	.13922D-02	.24360D-01	
.18178D+01	.64413D-02	.35126D-02	.27380D+00	.12744D-01
.54674D+00	.48326D-01	.61355D-01	.48884D+01	
.92170D-09	.15292D+07	.13064D-02	.23123D-01	
.18173D+01	.65105D-02	.33480D-02	.25981D+00	.12862D-01
.54487D+00	.48500D-01	.58869D-01	.46466D+01	
.88637D-09	.15369D+07	.12305D-02	.21812D-01	
.18084D+01	.65850D-02	.32015D-02	.24764D+00	.12968D-01
.54332D+00	.48391D-01	.56229D-01	.44056D+01	

```
      .847580-09     .154480+07     .116450-02     .205340-01
      .180020+01     .666850-02     .307490-02     .237370+00     .130600-01
      .542090+00     .481610-01     .536920-01     .418250+01
      .809370-09     .155190+07     .110830-02     .193660-01
 1 1 1 1 1 1 1 1 1 2 2 2 3
 1 1 2 1 2 1 2 1 2 2 2 2 3
 1 2 1 2 1 2 1 2 1 2 2 2 3
 1 1 2 1 2 1 2 1 2 2 2 2 3
 1 2 1 2 1 2 1 2 2 2 2 2 3
 1 1 2 1 2 1 2 1 2 2 2 3
 1 2 1 2 1 2 1 2 2 2 3
 1 1 2 1 2 1 2 2 2 2 3
 1 2 1 2 2 2 2 2 2 2 3
 2 2 2 2 2 2 2 2 2 3
 2 2 2 2 2 2 3 3 3
 2 2 2 2 2 3
 3 3 3 3 3
  24  0  0 24 24  0  0 24 24  0  0 12 12
   0  8  8  0  0  8  8  0  0  8  8  0  0
   0  8  8  0  0  8  8  0  0  8  8  0  0
  24  0  0 24 24  0  0 24 24  0  0  0  0
  24  0  0 24 24  0  0 24 24  0  0  0  0
   0  8  8  0  0  8  8  0  0  8  8  0
   0  8  8  0  0  8  8  0  0  8  8
  24  0  0 24 24  0  0 24 24  0  0
  24  0  0 24 24  0  0 24 24  0  0
   0  8  8  0  0  8  8  0  0  0
   0  8  8  0  0  8  8  0  0
  12  0  0  0  0  0
  12  0  0  0  0
 1
 12*.235
 12*.274
 12*.318
 2
 12*.235
 12*.274
 12*.318
 3
 12*.235
 12*.274
 12*.318
   1  1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  1  2
   1  1  1  1  1  1  1  1  2
   1  1  1  1  1  2
   2  2  2  2  2
 1 1. 0. 0.
 2 .5 .0 .0
```

```
TIME STEP #  1        << EDWIN HATCH UNIT #2   100% POWER                    7-11-77                    >>          PAGE   1

NODE WIDTH =    15.240 CM.
NODE HEIGHT =   15.875 CM.

NODAL WEIGHTING FACTORS:   A1 =    0.3100
                           A2 =    0.7300

      ================== BOUNDARY CONDITIONS ==================

       ALB = A + B*VOID(L)

       ALB =  1.  FOR ZERO CURRENT
              0.  FOR ZERO FLUX
             XX.  FOR LEAKAGE SPECIFIED BY  A  AND  B

                          === FAST ===            = THERMAL =

                           A        B              A        B
                         =====    =====          =====    =====

            BOTTOM       0.57     0.0            0.21     0.0
               TOP       0.57     0.0            0.21     0.0

     OTR. CORE EDGE
        ROW NUMBER

                1        0.57     0.0            0.21     0.0
                2        0.57     0.0            0.21     0.0
                3        0.57     0.0            0.21     0.0
                4        0.57     0.0            0.21     0.0
                5        0.57     0.0            0.21     0.0
                6        0.57     0.0            0.21     0.0
                7        0.57     0.0            0.21     0.0
                8        0.57     0.0            0.21     0.0
                9        0.57     0.0            0.21     0.0
               10        0.57     0.0            0.21     0.0
               11        0.57     0.0            0.21     0.0
               12        0.57     0.0            0.21     0.0
               13        0.57     0.0            0.21     0.0

      ============ CONVERGENCE PARAMETERS ============

       OUTER ITERATION WILL BE CONVERGED TO   0.10E-05
       POWER ITERATION WILL BE CONVERGED TO   0.10E-02

       MAXIMUM NUMBER OF INNER ITERATIONS =    3
       MAXIMUM NUMBER OF OUTER ITERATIONS =    6
       MAXIMUM NUMBER OF POWER ITERATIONS =   30
```

3 CROSS SECTION INTERPOLATING TABLES WILL BE READ AT 12 EXPOSURE AND 3 VOID INTERPOLATING POINTS

* EXPOSURE MASK *

TABLE INDEX	EXPOSURE (MWD/MT)
1	0.
2	100.
3	500.
4	2000.
5	4000.
6	6000.
7	8000.
8	10000.
9	15000.
10	20000.
11	25000.
12	30000.

* VOID MASK *

TABLE INDEX	VOID
1	0.0
2	0.320
3	0.640

CROSS SECTION INTERPOLATING TABLE

TABLE SET 3 8X8 BWR UNIT CELL .711 W/O

EXPOSURE (MWD/MT)	FAST D	FAST ABSORBTION	FAST NU-FISSION	FAST KAPPA-FISSION	FAST DOWN SCATTERING	THERMAL D	THERMAL ABSORBTION	THERMAL NU-FISSION	THERMAL KAPPA-FISSION
VOID = 0.0									
0.	0.1424E+01	0.6006E-02	0.2578E-02	0.2028E+00	0.2331E-01	0.3785E+00	0.2535E-01	0.2338E-01	0.2017E+01
100.	0.1421E+01	0.6016E-02	0.2581E-02	0.2029E+00	0.2336E-01	0.3790E+00	0.2612E-01	0.2377E-01	0.2046E+01
500.	0.1424E+01	0.6021E-02	0.2588E-02	0.2028E+00	0.2328E-01	0.3794E+00	0.2731E-01	0.2537E-01	0.2151E+01
2000.	0.1429E+01	0.6044E-02	0.2585E-02	0.2009E+00	0.2314E-01	0.3796E+00	0.3000E-01	0.2883E-01	0.2366E+01
4000.	0.1429E+01	0.6093E-02	0.2569E-02	0.1985E+00	0.2313E-01	0.3796E+00	0.3215E-01	0.3080E-01	0.2477E+01
6000.	0.1427E+01	0.6150E-02	0.2554E-02	0.1965E+00	0.2316E-01	0.3796E+00	0.3354E-01	0.3168E-01	0.2517E+01
8000.	0.1424E+01	0.6213E-02	0.2541E-02	0.1950E+00	0.2319E-01	0.3795E+00	0.3453E-01	0.3208E-01	0.2528E+01
10000.	0.1422E+01	0.6279E-02	0.2531E-02	0.1939E+00	0.2321E-01	0.3796E+00	0.3528E-01	0.3224E-01	0.2526E+01
15000.	0.1357E+01	0.6455E-02	0.2462E-02	0.1887E+00	0.2341E-01	0.3798E+00	0.3662E-01	0.3228E-01	0.2507E+01
20000.	0.1353E+01	0.6628E-02	0.2446E-02	0.1877E+00	0.2346E-01	0.3801E+00	0.3767E-01	0.3224E-01	0.2495E+01
25000.	0.1269E+01	0.6816E-02	0.2396E-02	0.1847E+00	0.2368E-01	0.3805E+00	0.3864E-01	0.3231E-01	0.2497E+01
30000.	0.1269E+01	0.6974E-02	0.2389E-02	0.1846E+00	0.2368E-01	0.3810E+00	0.3949E-01	0.3243E-01	0.2506E+01
VOID = 0.32									
0.	0.1579E+01	0.5802E-02	0.2502E-02	0.1972E+00	0.1872E-01	0.4398E+00	0.2404E-01	0.2305E-01	0.1986E+01
100.	0.1576E+01	0.5813E-02	0.2506E-02	0.1974E+00	0.1876E-01	0.4405E+00	0.2483E-01	0.2348E-01	0.2018E+01
500.	0.1580E+01	0.5819E-02	0.2516E-02	0.1975E+00	0.1869E-01	0.4411E+00	0.2611E-01	0.2523E-01	0.2134E+01
2000.	0.1586E+01	0.5847E-02	0.2524E-02	0.1964E+00	0.1855E-01	0.4417E+00	0.2907E-01	0.2913E-01	0.2382E+01
4000.	0.1586E+01	0.5901E-02	0.2520E-02	0.1949E+00	0.1852E-01	0.4419E+00	0.3151E-01	0.3158E-01	0.2530E+01
6000.	0.1585E+01	0.5963E-02	0.2516E-02	0.1937E+00	0.1852E-01	0.4420E+00	0.3316E-01	0.3289E-01	0.2603E+01
8000.	0.1583E+01	0.6029E-02	0.2512E-02	0.1929E+00	0.1853E-01	0.4421E+00	0.3435E-01	0.3365E-01	0.2642E+01
10000.	0.1580E+01	0.6098E-02	0.2509E-02	0.1923E+00	0.1853E-01	0.4423E+00	0.3528E-01	0.3413E-01	0.2664E+01
15000.	0.1576E+01	0.6274E-02	0.2507E-02	0.1918E+00	0.1853E-01	0.4427E+00	0.3692E-01	0.3468E-01	0.2684E+01
20000.	0.1557E+01	0.6443E-02	0.2490E-02	0.1906E+00	0.1853E-01	0.4433E+00	0.3819E-01	0.3499E-01	0.2698E+01
25000.	0.1510E+01	0.6608E-02	0.2459E-02	0.1888E+00	0.1859E-01	0.4439E+00	0.3929E-01	0.3530E-01	0.2718E+01
30000.	0.1509E+01	0.6759E-02	0.2461E-02	0.1893E+00	0.1855E-01	0.4446E+00	0.4027E-01	0.3561E-01	0.2741E+01
VOID = 0.64									
0.	0.1768E+01	0.5476E-02	0.2397E-02	0.1896E+00	0.1422E-01	0.5247E+00	0.2256E-01	0.2249E-01	0.1936E+01
100.	0.1765E+01	0.5488E-02	0.2402E-02	0.1899E+00	0.1426E-01	0.5257E+00	0.2337E-01	0.2296E-01	0.1971E+01
500.	0.1769E+01	0.5496E-02	0.2417E-02	0.1903E+00	0.1419E-01	0.5267E+00	0.2474E-01	0.2490E-01	0.2101E+01
2000.	0.1776E+01	0.5531E-02	0.2439E-02	0.1902E+00	0.1406E-01	0.5279E+00	0.2804E-01	0.2932E-01	0.2390E+01
4000.	0.1777E+01	0.5593E-02	0.2452E-02	0.1899E+00	0.1401E-01	0.5286E+00	0.3086E-01	0.3238E-01	0.2584E+01
6000.	0.1777E+01	0.5661E-02	0.2462E-02	0.1898E+00	0.1399E-01	0.5292E+00	0.3282E-01	0.3424E-01	0.2699E+01
8000.	0.1776E+01	0.5732E-02	0.2472E-02	0.1899E+00	0.1397E-01	0.5296E+00	0.3430E-01	0.3549E-01	0.2776E+01
10000.	0.1774E+01	0.5805E-02	0.2480E-02	0.1902E+00	0.1395E-01	0.5301E+00	0.3540E-01	0.3639E-01	0.2830E+01
15000.	0.1771E+01	0.5985E-02	0.2498E-02	0.1911E+00	0.1390E-01	0.5310E+00	0.3752E-01	0.3768E-01	0.2907E+01
20000.	0.1769E+01	0.6156E-02	0.2511E-02	0.1921E+00	0.1385E-01	0.5320E+00	0.3910E-01	0.3853E-01	0.2961E+01
25000.	0.1767E+01	0.6313E-02	0.2526E-02	0.1933E+00	0.1379E-01	0.5330E+00	0.4044E-01	0.3924E-01	0.3010E+01
30000.	0.1767E+01	0.6460E-02	0.2540E-02	0.1947E+00	0.1373E-01	0.5340E+00	0.4160E-01	0.3986E-01	0.3056E+01

CROSS SECTION INTERPOLATING TABLE

TABLE SET 3 8X8 BWR UNIT CELL .711 W/O

EXPOSURE (MWD/MT)	THERMAL ABSORBTION XE REMOVED	FAST FISSION	THERMAL FISSION	XE-135 MICRO ABSORBTION
VOID = 0.0				
0.	0.2535E-01	0.9618E-03	0.9620E-02	1869500.
100.	0.2562E-01	0.9620E-03	0.9729E-02	1863300.
500.	0.2667E-01	0.9612E-03	0.1019E-01	1856000.
2000.	0.2931E-01	0.9583E-03	0.1111E-01	1842600.
4000.	0.3141E-01	0.9352E-03	0.1154E-01	1832500.
6000.	0.3277E-01	0.9227E-03	0.1165E-01	1826400.
8000.	0.3375E-01	0.9176E-03	0.1163E-01	1822000.
10000.	0.3450E-01	0.9045E-03	0.1157E-01	1818600.
15000.	0.3585E-01	0.8736E-03	0.1138E-01	1811700.
20000.	0.3691E-01	0.8640E-03	0.1126E-01	1805600.
25000.	0.3787E-01	0.8455E-03	0.1123E-01	1799400.
30000.	0.3873E-01	0.8420E-03	0.1124E-01	1793500.
VOID = 0.32				
0.	0.2404E-01	0.9353E-03	0.9484E-02	1833100.
100.	0.2433E-01	0.9358E-03	0.9605E-02	1825500.
500.	0.2546E-01	0.9362E-03	0.1012E-01	1816100.
2000.	0.2837E-01	0.9291E-03	0.1120E-01	1797900.
4000.	0.3075E-01	0.9183E-03	0.1180E-01	1784000.
6000.	0.3236E-01	0.9098E-03	0.1206E-01	1774800.
8000.	0.3354E-01	0.9029E-03	0.1218E-01	1768100.
10000.	0.3446E-01	0.8976E-03	0.1223E-01	1762800.
15000.	0.3609E-01	0.8891E-03	0.1223E-01	1752700.
20000.	0.3735E-01	0.8787E-03	0.1223E-01	1744000.
25000.	0.3846E-01	0.8661E-03	0.1228E-01	1735800.
30000.	0.3943E-01	0.8652E-03	0.1235E-01	1728100.
VOID = 0.64				
0.	0.2256E-01	0.8989E-03	0.9255E-02	1778400.
100.	0.2287E-01	0.8997E-03	0.9390E-02	1768600.
500.	0.2410E-01	0.9017E-03	0.9970E-02	1755700.
2000.	0.2734E-01	0.8995E-03	0.1124E-01	1730300.
4000.	0.3008E-01	0.8946E-03	0.1206E-01	1709900.
6000.	0.3199E-01	0.8914E-03	0.1252E-01	1695700.
8000.	0.3293E-01	0.8892E-03	0.1282E-01	2685000.
10000.	0.3459E-01	0.8879E-03	0.1303E-01	1676300.
15000.	0.3663E-01	0.8863E-03	0.1329E-01	1660400.
20000.	0.3819E-01	0.8865E-03	0.1347E-01	1647300.
25000.	0.3951E-01	0.8886E-03	0.1365E-01	1635500.
30000.	0.4067E-01	0.8916E-03	0.1383E-01	1624800.

CROSS SECTION INTERPOLATING TABLE

TABLE SET 1 8X8 UWR UNIT CELL 1.43 W/O

EXPOSURE (MWD/MT)	FAST D	FAST ABSORBTION	FAST NU-FISSION	FAST KAPPA-FISSION	FAST DOWN SCATTERING	THERMAL D	THERMAL ABSORBTION	THERMAL NU-FISSION	THERMAL KAPPA-FISSION
VOID = 0.0									
0.	0.1442E+01	0.6522E-02	0.3780E-02	0.2994E+00	0.2112E-01	0.3899E+00	0.3972E-01	0.5471E-01	0.4620E+01
100.	0.1465E+01	0.6540E-02	0.3780E-02	0.2995E+00	0.2124E-01	0.3906E+00	0.4070E-01	0.5467E-01	0.4606E+01
500.	0.1447E+01	0.6548E-02	0.3763E-02	0.2978E+00	0.2129E-01	0.3908E+00	0.4140E-01	0.5467E-01	0.4610E+01
2000.	0.1448E+01	0.6555E-02	0.3689E-02	0.2909E+00	0.2135E-01	0.3903E+00	0.4240E-01	0.5529E-01	0.4610E+01
4000.	0.1452E+01	0.6566E-02	0.3588E-02	0.2818E+00	0.2146E-01	0.3895E+00	0.4330E-01	0.5516E-01	0.4549E+01
6000.	0.1455E+01	0.6582E-02	0.3489E-02	0.2731E+00	0.2158E-01	0.3886E+00	0.4384E-01	0.5441E-01	0.4449E+01
8000.	0.1459E+01	0.6601E-02	0.3394E-02	0.2649E+00	0.2170E-01	0.3877E+00	0.4411E-01	0.5329E-01	0.4326E+01
10000.	0.1463E+01	0.6622E-02	0.3304E-02	0.2571E+00	0.2181E-01	0.3870E+00	0.4418E-01	0.5193E-01	0.4189E+01
15000.	0.1457E+01	0.6691E-02	0.3112E-02	0.2409E+00	0.2208E-01	0.3855E+00	0.4392E-01	0.4831E-01	0.3849E+01
20000.	0.1445E+01	0.6775E-02	0.2947E-02	0.2275E+00	0.2232E-01	0.3843E+00	0.4333E-01	0.4460E-01	0.3520E+01
25000.	0.1434E+01	0.6876E-02	0.2815E-02	0.2169E+00	0.2255E-01	0.3834E+00	0.4276E-01	0.4130E-01	0.3236E+01
30000.	0.1410E+01	0.6990E-02	0.2697E-02	0.2078E+00	0.2276E-01	0.3829E+00	0.4237E-01	0.3866E-01	0.3015E+01
VOID = 0.32									
0.	0.1601E+01	0.6315E-02	0.3707E-02	0.2941E+00	0.1682E-01	0.4549E+00	0.3791E-01	0.5345E-01	0.4512E+01
100.	0.1603E+01	0.6334E-02	0.3707E-02	0.2942E+00	0.1692E-01	0.4558E+00	0.3889E-01	0.5323E-01	0.4498E+01
500.	0.1605E+01	0.6344E-02	0.3693E-02	0.2928E+00	0.1696E-01	0.4562E+00	0.3965E-01	0.5355E-01	0.4511E+01
2000.	0.1607E+01	0.6355E-02	0.3629E-02	0.2865E+00	0.1701E-01	0.4557E+00	0.4092E-01	0.5462E-01	0.4546E+01
4000.	0.1610E+01	0.6374E-02	0.3540E-02	0.2783E+00	0.1709E-01	0.4547E+00	0.4215E-01	0.5502E-01	0.4525E+01
6000.	0.1613E+01	0.6396E-02	0.3453E-02	0.2705E+00	0.1718E-01	0.4537E+00	0.4300E-01	0.5477E-01	0.4464E+01
8000.	0.1617E+01	0.6420E-02	0.3370E-02	0.2632E+00	0.1727E-01	0.4528E+00	0.4355E-01	0.5413E-01	0.4378E+01
10000.	0.1620E+01	0.6447E-02	0.3292E-02	0.2563E+00	0.1736E-01	0.4520E+00	0.4388E-01	0.5323E-01	0.4278E+01
15000.	0.1616E+01	0.6526E-02	0.3122E-02	0.2418E+00	0.1754E-01	0.4503E+00	0.4414E-01	0.5056E-01	0.4012E+01
20000.	0.1606E+01	0.6616E-02	0.2976E-02	0.2297E+00	0.1771E-01	0.4490E+00	0.4398E-01	0.4764E-01	0.3745E+01
25000.	0.1596E+01	0.6717E-02	0.2856E-02	0.2200E+00	0.1786E-01	0.4481E+00	0.4373E-01	0.4491E-01	0.3506E+01
30000.	0.1588E+01	0.6828E-02	0.2761E-02	0.2126E+00	0.1797E-01	0.4475E+00	0.4354E-01	0.4263E-01	0.3312E+01
VOID = 0.64									
0.	0.1797E+01	0.5990E-02	0.3606E-02	0.2869E+00	0.1262E-01	0.5452E+00	0.3565E-01	0.5141E-01	0.4338E+01
100.	0.1799E+01	0.6018E-02	0.3607E-02	0.2870E+00	0.1270E-01	0.5465E+00	0.3660E-01	0.5118E-01	0.4324E+01
500.	0.1800E+01	0.6022E-02	0.3596E-02	0.2859E+00	0.1274E-01	0.5471E+00	0.3744E-01	0.5166E-01	0.4348E+01
2000.	0.1802E+01	0.6040E-02	0.3544E-02	0.2805E+00	0.1277E-01	0.5468E+00	0.3905E-01	0.5329E-01	0.4425E+01
4000.	0.1805E+01	0.6068E-02	0.3471E-02	0.2734E+00	0.1283E-01	0.5457E+00	0.4070E-01	0.5434E-01	0.4455E+01
6000.	0.1808E+01	0.6098E-02	0.3401E-02	0.2668E+00	0.1289E-01	0.5447E+00	0.4193E-01	0.5472E-01	0.4443E+01
8000.	0.1811E+01	0.6130E-02	0.3333E-02	0.2606E+00	0.1295E-01	0.5438E+00	0.4283E-01	0.5468E-01	0.4405E+01
10000.	0.1814E+01	0.6164E-02	0.3270E-02	0.2549E+00	0.1300E-01	0.5429E+00	0.4349E-01	0.5437E-01	0.4351E+01
15000.	0.1811E+01	0.6255E-02	0.3132E-02	0.2428E+00	0.1311E-01	0.5413E+00	0.4444E-01	0.5296E-01	0.4184E+01
20000.	0.1802E+01	0.6353E-02	0.3013E-02	0.2326E+00	0.1320E-01	0.5400E+00	0.4488E-01	0.5113E-01	0.4002E+01
25000.	0.1793E+01	0.6457E-02	0.2913E-02	0.2243E+00	0.1328E-01	0.5391E+00	0.4510E-01	0.4928E-01	0.3833E+01
30000.	0.1787E+01	0.6566E-02	0.2832E-02	0.2179E+00	0.1334E-01	0.5386E+00	0.4526E-01	0.4765E-01	0.3688E+01

CROSS SECTION INTERPOLATING TABLE

TABLE SET 1 8X8 BWR UNIT CELL 1.83 W/O

EXPOSURE (MWD/MT)	THERMAL ABSORBTION XE REMOVED	FAST FISSION	THERMAL FISSION	XE-135 MICRO ABSORBTION
VOID = 0.0				
0.	0.3972E-01	0.1453E-02	0.2251E-01	1749500.
100.	0.3968E-01	0.1452E-02	0.2239E-01	1741200.
500.	0.4012E-01	0.1444E-02	0.2236E-01	1736900.
2000.	0.4112E-01	0.1407E-02	0.2227E-01	1734700.
4000.	0.4202E-01	0.1359E-02	0.2186E-01	1734600.
6000.	0.4258E-01	0.1312E-02	0.2127E-01	1736400.
8000.	0.4287E-01	0.1269E-02	0.2059E-01	1739200.
10000.	0.4297E-01	0.1227E-02	0.1985E-01	1742600.
15000.	0.4276E-01	0.1140E-02	0.1804E-01	1751400.
20000.	0.4225E-01	0.1067E-02	0.1633E-01	1760000.
25000.	0.4176E-01	0.1009E-02	0.1487E-01	1766800.
30000.	0.4143E-01	0.9590E-03	0.1374E-01	1771300.
VOID = 0.32				
0.	0.3791E-01	0.1427E-02	0.2200E-01	1692900.
100.	0.3787E-01	0.1427E-02	0.2187E-01	1682900.
500.	0.3838E-01	0.1419E-02	0.2189E-01	1677400.
2000.	0.3965E-01	0.1386E-02	0.2196E-01	1673000.
4000.	0.4087E-01	0.1342E-02	0.2174E-01	1670800.
6000.	0.4172E-01	0.1300E-02	0.2134E-01	1670900.
8000.	0.4228E-01	0.1261E-02	0.2084E-01	1672300.
10000.	0.4263E-01	0.1224E-02	0.2027E-01	1674600.
15000.	0.4294E-01	0.1145E-02	0.1882E-01	1681200.
20000.	0.4284E-01	0.1078E-02	0.1741E-01	1688300.
25000.	0.4265E-01	0.1025E-02	0.1616E-01	1694200.
30000.	0.4251E-01	0.9833E-03	0.1515E-01	1698200.
VOID = 0.64				
0.	0.3565E-01	0.1391E-02	0.2116E-01	1611000.
100.	0.3560E-01	0.1391E-02	0.2103E-01	1598800.
500.	0.3620E-01	0.1385E-02	0.2110E-01	1591200.
2000.	0.3779E-01	0.1356E-02	0.2137E-01	1583200.
4000.	0.3942E-01	0.1318E-02	0.2139E-01	1577400.
6000.	0.4064E-01	0.1282E-02	0.2122E-01	1574500.
8000.	0.4155E-01	0.1248E-02	0.2095E-01	1573400.
10000.	0.4222E-01	0.1217E-02	0.2060E-01	1573300.
15000.	0.4319E-01	0.1149E-02	0.1963E-01	1575500.
20000.	0.4367E-01	0.1093E-02	0.1862E-01	1578900.
25000.	0.4393E-01	0.1046E-02	0.1771E-01	1582000.
30000.	0.4413E-01	0.1010E-02	0.1694E-01	1584000.

TIME STEP # 1 ss EDWIN HATCH UNIT #2 100% POWER 7-11-77 ** PAGE 7

CROSS SECTION INTERPOLATING TABLE

TABLE SET 2 8X8 BWR UNIT CELL 2.33 W/O

	FAST					THERMAL			
EXPOSURE (MWD/MT)	D	ABSORBTION	NU-FISSION	KAPPA-FISSION	DOWN SCATTERING	D	ABSORBTION	NU-FISSION	KAPPA-FISSION
VOID = 0.0									
0.	0.1362E+01	0.6780E-02	0.4344E-02	0.3442E+00	0.2040E-01	0.3940E+00	0.4538E-01	0.6703E-01	0.5642E+01
100.	0.1421E+01	0.6802E-02	0.4306E-02	0.3420E+00	0.2064E-01	0.3947E+00	0.4645E-01	0.6661E-01	0.5616E+01
500.	0.1441E+01	0.6808E-02	0.4269E-02	0.3389E+00	0.2074E-01	0.3949E+00	0.4710E-01	0.6658E-01	0.5603E+01
2000.	0.1443E+01	0.6810E-02	0.4185E-02	0.3312E+00	0.2080E-01	0.3944E+00	0.4783E-01	0.6672E-01	0.5569E+01
4000.	0.1445E+01	0.6814E-02	0.4069E-02	0.3210E+00	0.2091E-01	0.3935E+00	0.4848E-01	0.6620E-01	0.5479E+01
6000.	0.1449E+01	0.6820E-02	0.3955E-02	0.3111E+00	0.2103E-01	0.3925E+00	0.4885E-01	0.6517E-01	0.5356E+01
8000.	0.1452E+01	0.6829E-02	0.3843E-02	0.3015E+00	0.2115E-01	0.3916E+00	0.4898E-01	0.6380E-01	0.5212E+01
10000.	0.1455E+01	0.6839E-02	0.3735E-02	0.2923E+00	0.2127E-01	0.3907E+00	0.4894E-01	0.6219E-01	0.5053E+01
15000.	0.1464E+01	0.6876E-02	0.3493E-02	0.2720E+00	0.2155E-01	0.3888E+00	0.4837E-01	0.5784E-01	0.4647E+01
20000.	0.1462E+01	0.6924E-02	0.3275E-02	0.2540E+00	0.2181E-01	0.3872E+00	0.4736E-01	0.5317E-01	0.4233E+01
25000.	0.1450E+01	0.6988E-02	0.3085E-02	0.2387E+00	0.2207E-01	0.3858E+00	0.4625E-01	0.4864E-01	0.3843E+01
30000.	0.1439E+01	0.7070E-02	0.2927E-02	0.2261E+00	0.2231E-01	0.3848E+00	0.4521E-01	0.4460E-01	0.3502E+01
VOID = 0.32									
0.	0.1578E+01	0.6571E-02	0.4228E-02	0.3362E+00	0.1630E-01	0.4602E+00	0.4332E-01	0.6528E-01	0.5494E+01
100.	0.1599E+01	0.6590E-02	0.4213E-02	0.3352E+00	0.1643E-01	0.4612E+00	0.4437E-01	0.6486E-01	0.5467E+01
500.	0.1600E+01	0.6600E-02	0.4196E-02	0.3336E+00	0.1648E-01	0.4616E+00	0.4508E-01	0.6494E-01	0.5462E+01
2000.	0.1602E+01	0.6607E-02	0.4121E-02	0.3266E+00	0.1653E-01	0.4610E+00	0.4607E-01	0.6552E-01	0.5461E+01
4000.	0.1605E+01	0.6618E-02	0.4018E-02	0.3173E+00	0.1662E-01	0.4599E+00	0.4705E-01	0.6553E-01	0.5412E+01
6000.	0.1608E+01	0.6632E-02	0.3916E-02	0.3083E+00	0.1671E-01	0.4588E+00	0.4772E-01	0.6500E-01	0.5328E+01
8000.	0.1611E+01	0.6646E-02	0.3817E-02	0.2996E+00	0.1680E-01	0.4577E+00	0.4815E-01	0.6412E-01	0.5221E+01
10000.	0.1614E+01	0.6663E-02	0.3720E-02	0.2913E+00	0.1689E-01	0.4567E+00	0.4838E-01	0.6298E-01	0.5100E+01
15000.	0.1622E+01	0.6711E-02	0.3504E-02	0.2729E+00	0.1709E-01	0.4546E+00	0.4838E-01	0.5967E-01	0.4776E+01
20000.	0.1622E+01	0.6768E-02	0.3308E-02	0.2566E+00	0.1729E-01	0.4528E+00	0.4788E-01	0.5593E-01	0.4435E+01
25000.	0.1612E+01	0.6836E-02	0.3136E-02	0.2425E+00	0.1746E-01	0.4513E+00	0.4718E-01	0.5219E-01	0.4107E+01
30000.	0.1602E+01	0.6918E-02	0.2989E-02	0.2308E+00	0.1763E-01	0.4501E+00	0.4647E-01	0.4874E-01	0.3812E+01
VOID = 0.64									
0.	0.1794E+01	0.6241E-02	0.4106E-02	0.3274E+00	0.1220E-01	0.5523E+00	0.4067E-01	0.6247E-01	0.5257E+01
100.	0.1796E+01	0.6262E-02	0.4108E-02	0.3277E+00	0.1228E-01	0.5536E+00	0.4168E-01	0.6204E-01	0.5228E+01
500.	0.1797E+01	0.6274E-02	0.4095E-02	0.3263E+00	0.1232E-01	0.5542E+00	0.4246E-01	0.6226E-01	0.5233E+01
2000.	0.1799E+01	0.6288E-02	0.4032E-02	0.3202E+00	0.1236E-01	0.5537E+00	0.4378E-01	0.6339E-01	0.5274E+01
4000.	0.1802E+01	0.6309E-02	0.3945E-02	0.3121E+00	0.1243E-01	0.5525E+00	0.4517E-01	0.6404E-01	0.5274E+01
6000.	0.1805E+01	0.6330E-02	0.3858E-02	0.3043E+00	0.1249E-01	0.5512E+00	0.4623E-01	0.6413E-01	0.5239E+01
8000.	0.1808E+01	0.6353E-02	0.3775E-02	0.2968E+00	0.1255E-01	0.5501E+00	0.4702E-01	0.6386E-01	0.5181E+01
10000.	0.1811E+01	0.6377E-02	0.3695E-02	0.2897E+00	0.1261E-01	0.5490E+00	0.4759E-01	0.6332E-01	0.5107E+01
15000.	0.1818E+01	0.6441E-02	0.3513E-02	0.2738E+00	0.1274E-01	0.5467E+00	0.4833E-01	0.6135E-01	0.4888E+01
20000.	0.1817E+01	0.6510E-02	0.3340E-02	0.2598E+00	0.1286E-01	0.5449E+00	0.4850E-01	0.5887E-01	0.4647E+01
25000.	0.1808E+01	0.6585E-02	0.3202E-02	0.2476E+00	0.1297E-01	0.5433E+00	0.4839E-01	0.5623E-01	0.4406E+01
30000.	0.1800E+01	0.6669E-02	0.3075E-02	0.2374E+00	0.1306E-01	0.5421E+00	0.4816E-01	0.5369E-01	0.4182E+01

CROSS SECTION INTERPOLATING TABLE

TABLE SET 2 8X8 BWR UNIT CELL 2.33 W/O

EXPOSURE (MWD/MT)	THERMAL ABSORBTION XE REMOVED	FAST FISSION	THERMAL FISSION	XE-135 MICRO ABSORBTION
VOID = 0.0				
0.	0.4538E-01	0.1678E-02	0.2758E-01	1704000.
100.	0.4525E-01	0.1667E-02	0.2739E-01	1695000.
500.	0.4562E-01	0.1651E-02	0.2728E-01	1690800.
2000.	0.4635E-01	0.1611E-02	0.2703E-01	1690200.
4000.	0.4700E-01	0.1557E-02	0.2648E-01	1691700.
6000.	0.4739E-01	0.1505E-02	0.2578E-01	1694800.
8000.	0.4755E-01	0.1454E-02	0.2499E-01	1698700.
10000.	0.4753E-01	0.1405E-02	0.2415E-01	1703400.
15000.	0.4702E-01	0.1297E-02	0.2200E-01	1715300.
20000.	0.4610E-01	0.1202E-02	0.1986E-01	1727900.
25000.	0.4508E-01	0.1120E-02	0.1787E-01	1739600.
30000.	0.4416E-01	0.1052E-02	0.1613E-01	1749400.
VOID = 0.32				
0.	0.4332E-01	0.1639E-02	0.2686E-01	1640600.
100.	0.4318E-01	0.1633E-02	0.2667E-01	1630000.
500.	0.4362E-01	0.1625E-02	0.2660E-01	1624600.
2000.	0.4460E-01	0.1588E-02	0.2650E-01	1622200.
4000.	0.4558E-01	0.1539E-02	0.2614E-01	1622000.
6000.	0.4626E-01	0.1491E-02	0.2563E-01	1623700.
8000.	0.4671E-01	0.1445E-02	0.2503E-01	1626500.
10000.	0.4695E-01	0.1401E-02	0.2436E-01	1630200.
15000.	0.4700E-01	0.1302E-02	0.2261E-01	1640300.
20000.	0.4657E-01	0.1215E-02	0.2082E-01	1651500.
25000.	0.4595E-01	0.1139E-02	0.1912E-01	1662200.
30000.	0.4531E-01	0.1076E-02	0.1761E-01	1671600.
VOID = 0.64				
0.	0.4067E-01	0.1595E-02	0.2571E-01	1550400.
100.	0.4052E-01	0.1596E-02	0.2550E-01	1537500.
500.	0.4103E-01	0.1589E-02	0.2548E-01	1530300.
2000.	0.4234E-01	0.1556E-02	0.2558E-01	1525000.
4000.	0.4372E-01	0.1513E-02	0.2546E-01	1521800.
6000.	0.4478E-01	0.1471E-02	0.2518E-01	1520900.
8000.	0.4557E-01	0.1431E-02	0.2480E-01	1521500.
10000.	0.4615E-01	0.1392E-02	0.2436E-01	1523100.
15000.	0.4692E-01	0.1306E-02	0.2312E-01	1529200.
20000.	0.4714E-01	0.1231E-02	0.2181E-01	1536900.
25000.	0.4708E-01	0.1165E-02	0.2053E-01	1544800.
30000.	0.4690E-01	0.1108E-02	0.1937E-01	1551900.

****** XE-135 + I-135 FISSION YIELDS ******

EXPOSURE (MWD/MT)	TABLE SET = 1	2	3
0.	0.0660	0.0660	0.0661
100.	0.0661	0.0661	0.0666
500.	0.0666	0.0665	0.0683
2000.	0.0674	0.0670	0.0696
4000.	0.0681	0.0679	0.0706
6000.	0.0686	0.0680	0.0713
8000.	0.0691	0.0686	0.0717
10000.	0.0698	0.0691	0.0723
15000.	0.0706	0.0698	0.0727
20000.	0.0712	0.0705	0.0730
25000.	0.0718	0.0711	0.0731
30000.	0.0722	0.0716	0.0732

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 10

*** FUEL TYPE EDIT ***

FTYPE (I,J)

J=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	1	1	1	1	1	1	1	1	2	2	2	3
2	1	1	2	1	2	1	2	1	2	2	2	2	3
3	1	2	1	2	1	2	1	2	1	2	2	2	3
4	1	1	2	1	2	1	2	1	2	2	2	2	3
5	1	2	1	2	1	2	1	2	2	2	2	2	3
6	1	1	2	1	2	1	2	1	2	2	2	3	
7	1	2	1	2	1	2	1	2	2	2	3		
8	1	1	2	1	2	1	2	2	2	2	3		
9	1	2	1	2	2	2	2	2	2	2	3		
10	2	2	2	2	2	2	2	2	2	3			
11	2	2	2	2	2	2	3	3	3				
12	2	2	2	2	2	3							
13	3	3	3	3	3								

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 11

*** CONTROL ROD POSITIONS ***

NOTCH (I,J)

I \ J=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	23	0	0	23	23	0	0	23	23	0	0	12	12
2	0	16	16	0	0	16	16	0	0	16	16	0	0
3	0	16	16	0	0	16	16	0	0	16	16	0	0
4	23	0	0	23	23	0	0	23	23	0	0	0	0
5	23	0	0	23	23	0	0	23	23	0	0	0	0
6	0	16	16	0	0	16	16	0	0	16	16	0	
7	0	16	16	0	0	16	16	0	0	16	16		
8	23	0	0	23	23	0	0	23	23	0	0		
9	23	0	0	23	23	0	0	23	23	0	0		
10	0	16	16	0	0	16	16	0	0	0			
11	0	16	16	0	0	16	16	0	0				
12	12	0	0	0	0	0							
13	12	0	0	0	0								

*** CONTROL ROD WORTH FOR TABLE SET 1 ***

	EXPOSURE (MWD/MT)	WORTH
VOID = 0.0		
	0.0	0.24
	0.10E+03	0.24
	0.50E+03	0.24
	0.20E+04	0.24
	0.40E+04	0.24
	0.60E+04	0.24
	0.80E+04	0.24
	0.10E+05	0.24
	0.15E+05	0.24
	0.20E+05	0.24
	0.25E+05	0.24
	0.30E+05	0.24
VOID = 0.32		
	0.0	0.27
	0.10E+03	0.27
	0.50E+03	0.27
	0.20E+04	0.27
	0.40E+04	0.27
	0.60E+04	0.27
	0.80E+04	0.27
	0.10E+05	0.27
	0.15E+05	0.27
	0.20E+05	0.27
	0.25E+05	0.27
	0.30E+05	0.27
VOID = 0.64		
	0.0	0.32
	0.10E+03	0.32
	0.50E+03	0.32
	0.20E+04	0.32
	0.40E+04	0.32
	0.60E+04	0.32
	0.80E+04	0.32
	0.10E+05	0.32
	0.15E+05	0.32
	0.20E+05	0.32
	0.25E+05	0.32
	0.30E+05	0.32

*** CONTROL ROD WORTH FOR TABLE SET 2 ***

	EXPOSURE (MWD/MT)	WORTH
VOID = 0.0		
	0.0	0.24
	0.10E+03	0.24
	0.50E+03	0.24
	0.20E+04	0.24
	0.40E+04	0.24
	0.60E+04	0.24
	0.80E+04	0.24
	0.10E+05	0.24
	0.15E+05	0.24
	0.20E+05	0.24
	0.25E+05	0.24
	0.30E+05	0.24
VOID = 0.32		
	0.0	0.27
	0.10E+03	0.27
	0.50E+03	0.27
	0.20E+04	0.27
	0.40E+04	0.27
	0.60E+04	0.27
	0.80E+04	0.27
	0.10E+05	0.27
	0.15E+05	0.27
	0.20E+05	0.27
	0.25E+05	0.27
	0.30E+05	0.27
VOID = 0.64		
	0.0	0.32
	0.10E+03	0.32
	0.50E+03	0.32
	0.20E+04	0.32
	0.40E+04	0.32
	0.60E+04	0.32
	0.80E+04	0.32
	0.10E+05	0.32
	0.15E+05	0.32
	0.20E+05	0.32
	0.25E+05	0.32
	0.30E+05	0.32

*** CONTROL ROD WORTH FOR TABLE SET 3 ***

	EXPOSURE (MWD/MT)	WORTH
VOID = 0.0		
	0.0	0.24
	0.10E+03	0.24
	0.50E+03	0.24
	0.20E+04	0.24
	0.40E+04	0.24
	0.60E+04	0.24
	0.80E+04	0.24
	0.10E+05	0.24
	0.15E+05	0.24
	0.20E+05	0.24
	0.25E+05	0.24
	0.30E+05	0.24
VOID = 0.32		
	0.0	0.27
	0.10E+03	0.27
	0.50E+03	0.27
	0.20E+04	0.27
	0.40E+04	0.27
	0.60E+04	0.27
	0.80E+04	0.27
	0.10E+05	0.27
	0.15E+05	0.27
	0.20E+05	0.27
	0.25E+05	0.27
	0.30E+05	0.27
VOID = 0.64		
	0.0	0.32
	0.10E+03	0.32
	0.50E+03	0.32
	0.20E+04	0.32
	0.40E+04	0.32
	0.60E+04	0.32
	0.80E+04	0.32
	0.10E+05	0.32
	0.15E+05	0.32
	0.20E+05	0.32
	0.25E+05	0.32
	0.30E+05	0.32

```
* THERMAL-HYDRAULIC DATA FOR THIS TIME STEP *

CORE POWER                  2436.0   MW-THERMAL
AV. HEAT FLUX               145060.  BTU/HR/FT**2
PEAKING FACTOR                1.05
SAT. VAP. SPEC. VOL.        0.4297   FT**3/LBM
SAT. LIQ. SPEC. VOL.        0.02170  FT**3/LBM
INLET ENTHALPY              526.90   BTU/LBM
HEAT OF VAPORIZATION        642.80   BTU/LBM
ENTHALPY OF SAT. LIQ.       547.80   BTU/LBM
CORE PRESSURE               1035.0   PSIA
INCORE FLOW               7.700E+07  LBM/HR
FLOW AREA PER CHANNEL       0.1099   FT**2

ARMANO CORRELATION COEFICIENTS
          AC1 =   0.433
          AC2 =   0.167

COOLANT FLOW VARIATION WITH POWER

     P = RELATIVE POWER IN CHANNEL
     FLOW = RELATIVE COOLANT FLOW IN CHANNEL  (UNNORMALIZED)

     CHANNEL TYPE
     ============

                1    FLOW = 0.100E+01 + 0.0      *P + 0.0      *P**2

                2    FLOW = 0.500E+00 + 0.0      *P + 0.0      *P**2
```

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 16

*** CHANNEL TYPE EDIT ***

CTYPE (I,J)

J=	1	2	3	4	5	6	7	8	9	10	11	12	13
I													
1	1	1	1	1	1	1	1	1	1	1	1	1	2
2	1	1	1	1	1	1	1	1	1	1	1	1	2
3	1	1	1	1	1	1	1	1	1	1	1	1	2
4	1	1	1	1	1	1	1	1	1	1	1	1	2
5	1	1	1	1	1	1	1	1	1	1	1	1	2
6	1	1	1	1	1	1	1	1	1	1	1	2	
7	1	1	1	1	1	1	1	1	1	1	2		
8	1	1	1	1	1	1	1	1	1	1	2		
9	1	1	1	1	1	1	1	1	1	1	2		
10	1	1	1	1	1	1	1	1	1	2			
11	1	1	1	1	1	1	1	1	2				
12	1	1	1	1	1	2							
13	2	2	2	2	2								

I J 1.0548 0.2808E-05

ITERATION MONITOR

VOID ITERATION	OUTER ITERATION	INNER ITERATION	K-EFF	TESTO	TESTP
1					
	1	3	1.0322	0.312E-01	
	2	3	1.0530	0.197E-01	
	3	3	1.0706	0.163E-01	
	4	3	1.0798	0.876E-02	
	5	3	1.0837	0.357E-02	
	6	3	1.0852	0.136E-02	
2					
	1	3	1.0455	0.379E-01	
	2	3	1.0463	0.818E-03	
	3	3	1.0442	0.202E-02	
	4	3	1.0432	0.997E-03	
	5	3	1.0432	0.143E-04	
	6	3	1.0436	0.441E-03	0.561E+00
3					
	1	3	1.0450	0.132E-02	
	2	3	1.0454	0.351E-03	
	3	3	1.0459	0.521E-03	
	4	3	1.0463	0.392E-03	
	5	3	1.0466	0.285E-03	
	6	3	1.0469	0.214E-03	0.309E+00
4					
	1	3	1.0498	0.278E-02	
	2	3	1.0493	0.463E-03	
	3	3	1.0492	0.887E-04	
	4	3	1.0492	0.304E-04	
	5	3	1.0493	0.874E-04	
	6	3	1.0495	0.117E-03	0.144E+00
5					
	1	3	1.0523	0.268E-02	
	2	3	1.0519	0.325E-03	
	3	3	1.0519	0.114E-04	
	4	3	1.0520	0.544E-04	
	5	3	1.0521	0.709E-04	
	6	3	1.0521	0.861E-04	0.127E+00
6					
	1	3	1.0546	0.232E-02	
	2	3	1.0543	0.273E-03	
	3	3	1.0543	0.191E-04	
	4	3	1.0543	0.333E-04	
	5	3	1.0543	0.276E-04	
	6	3	1.0544	0.641E-04	0.135E+00
7					
	1	3	1.0563	0.182E-02	
	2	3	1.0561	0.196E-03	
	3	3	1.0561	0.124E-04	
	4	3	1.0561	0.272E-04	
	5	3	1.0562	0.274E-04	
	6	3	1.0562	0.162E-04	0.140E+00
8					

	1	3	[illegible]	[illegible]
	2	3	1.0575	0.134E-03
	3	3	1.0575	0.477E-05
	4	3	1.0575	0.241E-04
	5	3	1.0575	0.721E-05	0.105E+00
9				
	1	3	1.0583	0.756E-03
	2	3	1.0582	0.515E-04
	3	3	1.0582	0.114E-04
	4	3	1.0582	0.596E-05
	5	3	1.0582	0.668E-05	0.936E-01
10				
	1	3	1.0588	0.525E-03
	2	3	1.0587	0.296E-04
	3	3	1.0588	0.328E-05
	4	3	1.0588	0.596E-05
	5	3	1.0588	0.954E-06	0.824E-01
11				
	1	3	1.0591	0.371E-03
	2	3	1.0591	0.143E-04
	3	3	1.0591	0.191E-05
	4	3	1.0591	0.381E-05
	5	3	1.0591	0.572E-05	0.701E-01
12				
	1	3	1.0594	0.255E-03
	2	3	1.0594	0.763E-05
	3	3	1.0594	0.757E-05
	4	3	1.0594	0.381E-05
	5	3	1.0594	0.668E-05	0.579E-01
13				
	1	3	1.0596	0.171E-03
	2	3	1.0596	0.685E-05
	3	3	1.0596	0.381E-05
	4	3	1.0596	0.417E-05
	5	3	1.0596	0.477E-05	0.471E-01
14				
	1	3	1.0597	0.105E-03
	2	3	1.0597	0.471E-05
	3	3	1.0597	0.0	0.213E-01
15				
	1	3	1.0597	0.346E-04
	2	3	1.0597	0.151E-04
	3	3	1.0597	0.668E-05
	4	3	1.0597	0.0	0.240E-01
16				
	1	3	1.0597	0.280E-04
	2	3	1.0597	0.650E-05
	3	3	1.0598	0.721E-05
	4	3	1.0597	0.572E-05
	5	3	1.0597	0.417E-06	0.271E-01
17				
	1	3	1.0598	0.208E-04
	2	3	1.0598	0.829E-05
	3	3	1.0598	0.417E-06	0.121E-01
18				
	1	3	1.0598	0.596E-05
	2	3	1.0598	0.136E-04
	3	3	1.0598	0.0	0.937E-02
19				
	1	3	1.0598	0.668E-05
	2	3	1.0598	0.111E-04
	3	3	1.0598	0.0	0.803E-02
20				
	1	3	1.0598	0.954E-06	0.311E-02
21				
	1	3	1.0598	0.286E-05

	2	3	1.0598	0.417E-06	0.286E-02
22					
	1	3	1.0598	0.954E-06	0.217E-02
23					
	1	3	1.0598	0.507E-05	
	2	3	1.0598	0.572E-05	
	3	3	1.0598	0.435E-05	
	4	3	1.0598	0.167E-05	0.671E-02
24					
	1	3	1.0598	0.954E-05	
	2	3	1.0598	0.918E-05	
	3	3	1.0598	0.310E-05	
	4	3	1.0598	0.0	0.668E-02
25					
	1	3	1.0598	0.954E-05	
	2	3	1.0598	0.381E-05	
	3	3	1.0598	0.703E-05	
	4	3	1.0598	0.381E-05	0.504E-02
26					
	1	3	1.0598	0.668E-05	
	2	3	1.0598	0.954E-06	0.193E-02
27					
	1	3	1.0598	0.131E-05	
	2	3	1.0598	0.191E-05	
	3	3	1.0598	0.507E-05	
	4	3	1.0598	0.858E-05	0.293E-02
28					
	1	3	1.0598	0.286E-05	
	2	3	1.0598	0.775E-06	0.123E-02
29					
	1	3	1.0598	0.0	0.525E-03

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7=11=77 >> PAGE 18
EXPOSURE = 0. MWD/MT

*** INTEGRATED POWER EDIT ***

P (I,J)

I \ J=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.736	1.166	1.194	0.782	0.794	1.242	1.259	0.829	0.865	1.496	1.472	1.082	0.304
2	1.166	1.099	1.212	1.261	1.372	1.161	1.260	1.320	1.452	1.307	1.232	1.122	0.321
3	1.194	1.212	1.157	1.387	1.298	1.269	1.187	1.428	1.338	1.273	1.190	1.098	0.313
4	0.782	1.261	1.387	0.832	0.899	1.312	1.413	0.839	0.899	1.390	1.342	1.055	0.288
5	0.794	1.372	1.298	0.899	0.837	1.402	1.290	0.872	0.850	1.283	1.188	0.871	0.210
6	1.242	1.161	1.269	1.312	1.402	1.151	1.205	1.211	1.237	0.972	0.755	0.268	
7	1.259	1.260	1.188	1.413	1.290	1.206	1.082	1.245	1.129	0.791	0.262		
8	0.830	1.320	1.428	0.840	0.872	1.211	1.245	0.732	0.610	0.688	0.197		
9	0.865	1.452	1.338	0.900	0.850	1.237	1.130	0.610	0.463	0.503	0.121		
10	1.496	1.307	1.273	1.390	1.284	0.973	0.793	0.688	0.503	0.153			
11	1.473	1.232	1.190	1.342	1.189	0.757	0.276	0.201	0.120				
12	1.082	1.122	1.098	1.055	0.871	0.268							
13	0.304	0.321	0.313	0.288	0.210								

EXPOSURE = 0. MWD/MT

AXIAL AVERAGES
==========

K	POWER	VOID
1	0.215	0.0
2	0.383	0.0
3	0.520	0.0
4	0.626	0.0
5	0.699	0.0
6	0.738	0.00
7	0.735	0.02
8	0.708	0.05
9	0.678	0.08
10	0.658	0.11
11	0.657	0.15
12	0.698	0.18
13	0.770	0.22
14	0.889	0.26
15	1.072	0.30
16	1.346	0.35
17	1.887	0.40
18	2.081	0.45
19	2.074	0.50
20	1.926	0.53
21	1.677	0.56
22	1.360	0.58
23	0.994	0.59
24	0.621	0.60

PEAK POWER = 3.307 AT LOCATION (10, 2,18)

PEAK ASSEMBLY INTEGRATED POWER = 1.496 AT LOCATION (10, 1)

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 28
EXPOSURE = 0. MWD/MT

*** AVERAGE EXPOSURE EDIT ***

EX (I,J)

I \ J=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0				
12	0.0	0.0	0.0	0.0	0.0	0.0							
13	0.0	0.0	0.0	0.0	0.0								

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 21

*** RELATIVE FLOW EDIT *** TOTAL FLOW = 0.770E+08 LBM/HR

FLOW (I,J)

I \ J=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53
2	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53
3	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53
4	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53
5	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53
6	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53	
7	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53		
8	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53		
9	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53		
10	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53			
11	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	0.53				
12	1.06	1.06	1.06	1.06	1.06	0.53							
13	0.53	0.53	0.53	0.53	0.53								

TIME STEP # 1 << EDWIN HATCH UNIT #2 100% POWER 7-11-77 >> PAGE 22

*** VOID FRACTION EDIT ***

VOID (I,J,24)

I=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.54	0.67	0.67	0.56	0.56	0.68	0.68	0.58	0.59	0.72	0.72	0.65	0.48
2	0.67	0.65	0.67	0.68	0.70	0.66	0.68	0.69	0.72	0.69	0.68	0.66	0.50
3	0.67	0.67	0.66	0.71	0.69	0.69	0.67	0.71	0.70	0.69	0.67	0.65	0.49
4	0.56	0.68	0.71	0.58	0.60	0.69	0.71	0.58	0.60	0.71	0.70	0.64	0.46
5	0.56	0.70	0.69	0.60	0.58	0.71	0.69	0.59	0.58	0.69	0.67	0.59	0.34
6	0.68	0.66	0.69	0.69	0.71	0.66	0.67	0.68	0.68	0.62	0.55	0.43	
7	0.68	0.68	0.67	0.71	0.69	0.67	0.65	0.68	0.66	0.56	0.42		
8	0.58	0.69	0.71	0.58	0.59	0.68	0.68	0.54	0.48	0.52	0.31		
9	0.59	0.72	0.70	0.60	0.58	0.68	0.66	0.48	0.38	0.41	0.08		
10	0.72	0.69	0.69	0.71	0.69	0.62	0.56	0.52	0.41	0.20			
11	0.72	0.68	0.67	0.70	0.67	0.55	0.14	0.0	0.07				
12	0.65	0.66	0.65	0.64	0.59	0.43							
13	0.48	0.50	0.49	0.46	0.34								

*** MINIMUM CRITICAL HEAT FLUX RATIO EDIT ***

MCHFR (I,J)

I=	1	2	3	4	5	6	7	8	9	10	11	12	13
1	4.32	2.12	2.04	4.22	4.22	1.93	1.89	4.08	3.90	1.30	1.34	2.39	7.45
2	2.12	2.03	1.73	1.88	1.58	1.89	1.64	1.75	1.41	1.54	1.72	2.37	7.90
3	2.04	1.73	1.89	1.55	1.79	1.62	1.84	1.47	1.73	1.64	1.85	2.56	8.54
4	4.22	1.88	1.55	4.07	3.69	1.78	1.52	4.17	3.86	1.64	1.78	2.96	9.96
5	4.22	1.58	1.79	3.69	4.13	1.55	1.87	4.03	4.30	2.01	2.37	4.08	13.74
6	1.93	1.89	1.62	1.78	1.55	1.97	1.83	2.18	2.16	2.72	3.51	10.00	
7	1.89	1.64	1.84	1.52	1.87	1.83	2.22	2.09	2.60	3.39	7.86		
8	4.08	1.75	1.47	4.17	4.03	2.18	2.09	5.16	6.16	5.04	12.89		
9	3.90	1.41	1.73	3.86	4.30	2.16	2.60	6.16	8.01	7.19	22.59		
10	1.29	1.54	1.64	1.64	2.01	2.71	3.38	5.04	7.20	18.61			
11	1.34	1.72	1.85	1.78	2.37	3.51	8.72	14.94	22.94				
12	2.39	2.37	2.56	2.96	4.07	9.99							
13	7.45	7.89	8.54	9.95	13.73								

MINIMUM CRITICAL HEAT FLUX RATIO = 1.295 AT LOCATION (10, 1, 21)

*** END OF CASE ***

APPENDIX B

Source Listing

```
C=====================================================================
C=====================================================================
C
      PROGRAM STORM (INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7=OUTPUT)
C
C A THREE DIMENSIONAL BWR SIMULATION PROGRAM USING SIMULATED TWO-GROUP
C DIFFUSION THEORY WITH THERMAL-HYDRAULIC FEEDBACK.
C
C---------------------------------------------------------------------
C
C VERSION 77222
C
C DIMENSIONING INSTRUCTIONS
C ==========================
C
C REPLACE ALL OCCURENCES OF N01 THROUGH N11 WITH THE VALUE INDICATED
C BELOW.  GEOMETRIC DIMENSIONS MUST BE EXACTLY THOSE OF THE PROBLEM
C TO BE SOLVED.  TABLE SET DIMENSIONS (N07-N11) MAY BE EQUAL TO OR
C GREATER THAN THE ACTUAL DIMENSIONS OF THE TABLES USED.
C
C   N01 = NUMBER OF NODES IN ENTIRE PROBLEM
C   N02 = NUMBER OF NODES PER PLANE
C   N03 = N01-N02
C   N04 = MAXIMUM NUMBER OF NODES PER ROW
C   N05 = N04-1
C   N06 = NUMBER OF AXIAL NODES
C   N07 = NUMBER OF EXPOSURE POINTS USED IN TABLE SETS
C   N08 = NUMBER OF VOID POINTS USED IN TABLE SETS
C   N09 = NUMBER OF TABLE SETS
C   N10 = N07*N08*N09
C   N11 = NUMBER OF FUEL TYPES
C
C FOR CONVERSION TO IBM COMPUTERS CHANGE END OF FILE (EOF) CHECKS AND
C CHANGE PROGRAM CARD TO COMMENT CARD.
C
C---------------------------------------------------------------------
```

```
C                                                                       A   370
C  DATA SET  USE                                                       A   380
C  --------  -------------------                                       A   390
C   5        INPUT (CARD READER)                                       A   400
C   6        OUTPUT (PRINTER)                                          A   410
C   7        PUNCH                                                     A   420
C                                                                       A   430
C-----------------------------------------------------------------------A   440
C                                                                       A   450
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP                        A   460
      COMMON /CSINP / BUMASK(N07),  VMASK(N08),    DFI(N10),    DTI(N10) A   470
     $                  SAFI(N10), SATI(N10),  NSFFI(N10),  NSFTI(N10), A   480
     $                  SDSI(N10), IEXPTS    , IVDPTS    , ITSETS    ,  A   490
     $                  KSFTI(N10), KSFFI(N10),                         A   500
     $                  DIMTS    ,  DIMEX    ,  DIMVD    , NOTCH(N02),  A   510
     $                 TABSET(N01),  WORTH(N09,N07,N08)                 A   520
      INTEGER DIMTS, DIMEX, DIMVD, TABSET                               A   530
      REAL    NSFFI,NSFTI,KSFFI,KSFTI                                   A   540
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)              A   550
      INTEGER FTYPE                                                     A   560
      COMMON /NODAL / DF    (N01), DT    (N01), KSFF  (N01)            A   570
     $,               KSFT  (N01), TFR   (N01), NSF1G (N01)            A   580
     $,               C2    (N01), C4    (N01), C6    (N03)            A   590
     $,               C7    (N01)                                       A   600
      REAL KSFF, KSFT, NSF1G                                            A   610
      COMMON /GEOM  / NODES     , NP        , NDSMNP    , NX           A   620
     $,               NZ        , NXM1      , GX        , GZ           A   630
     $,               NCOL  (N04)                                      A   640
      COMMON /BC    / AF1, AF3, AF5, AF6, AFQ(N04),                     A   650
     $                BF1, BF3, BF5, BF6, BFQ(N04),                     A   660
     $                AT1, AT3, AT5, AT6, ATQ(N04),                     A   670
     $                BT1, BT3, BT5, BT6, BTQ(N04)                      A   680
      EQUIVALENCE (AFQ(1), AF2), (AFQ(2), AF4),                         A   690
     $            (BFQ(1), BF2), (BFQ(2), BF4),                         A   700
     $            (ATQ(1), AT2), (ATQ(2), AT4),                         A   710
     $            (BTQ(1), BT2), (BTQ(2), BT4)                          A   720
```

```
      COMMON /CONVRG/   MAXI,  MAXO,  MAXP,  EPSO,  EPSP,  ALPHA,   SOR  A   730
      LOGICAL SOR                                                        A   740
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)       A   750
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)    A   760
     $,                 NOXE,  FIRST                                    A   770
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST                 A   780
      COMMON /WEIGHT/   R,  CF,  CT, RCF, RCT, B1N, B2N                  A   790
      COMMON /THERMO/ HFG, XIN, AC1, AC2, AC3, AREA, AVFLUX, AVPWR, PSIA A   800
     $,               B1(4), B2(4), B3(4), CTYPE(N02), FLOW(N02),TFLOW   A   810
     $,               PCTPWR                                             A   820
      INTEGER CTYPE                                                      A   830
      COMMON /XENON / PD, PRSA1(N10), PRSA2(N10), SAXE(N10)              A   840
C                                                                        A   850
      NAMELIST /INPUT/ IPTYPE, ICNTRL,  IEDIT,  IPDRD,  IEXRD, TONNES,   A   860
     $                 PCTPWR,   MWTH,  IGEOM,     DX,     DZ,     A1,   A   870
     $                     A2,   NCOL, IEXPTS, IVDPTS, ITSETS, BUMASK,   A   880
     $                  VMASK,   MAXI,   MAXO,   MAXP,  ALPHA,   ISOR,   A   890
     $                   EPSO,   EPSP, AVHFLX,     VG,     VF,    HIN,   A   900
     $                   HSAT,    HFG,   PSIA,    AC1,    AC2,  IFLOW,   A   910
     $                  TFLOW,   AREA,  PEAKF, NBANKS,    IXE,  ITSAS,   A   920
     $                 IFTYPS                                            A   930
      REAL MWTH                                                          A   940
      COMMON /CROD  / NRODS(6,2), RODIND(N02)                            A   950
      INTEGER RODIND                                                     A   960
      DIMENSION ASMEX(N06), WORD(20), YIX(N09,N07)                       A   970
      INTEGER TSOVLY(N11,N06)                                            A   980
      DATA  A1/ .31/,  A2/ .73/, PEAKF/ 1.05/, MWTH/0./, IFTYPS/1/,      A   990
     $      TONNES/0./, IGEOM/1/, ICNTRL/0/, IPDRD/0/, IEXRD/0/          A  1000
     $,     NBANKS/0/, IFLOW/0/, ISOR/0/, IXE/1/, IPTYPE/1/, ITSAS/2/   A  1010
C                                                                        A  1020
C-----------------------------------------------------------------------A  1030
C                                                                        A  1040
      READ (5,1000) NTITLE                                               A  1050
      CALL HEADER (1)                                                    A  1060
C                                                                        A  1070
C READ PROBLEM DESCRIPTION                                               A  1080
```

```
      READ (5, INPUT)                                                   A  1090
      IF ( IPTYPE .EQ. 2 ) NOHAL = .FALSE.                              A  1100
      IF ( ICNTRL .NE. 0 ) NOCROD = .FALSE.                             A  1110
      IF ( IGEOM .EQ. 2 ) QTRKOR = .FALSE.                              A  1120
      IF ( ISOR .EQ. 1 ) SOR = .TRUE.                                   A  1130
      IF ( IXE .EQ. 1 ) NOXE = .FALSE.                                  A  1140
C                                                                       A  1150
CHECK FOR INPUT GEOMETRY ERRORS                                         A  1160
      IF ( NCOL(1) .NE. NX) CALL ERROR (2)                              A  1170
      ISUM = 0                                                          A  1180
      DO 222 I=1,NX                                                     A  1190
222   ISUM = ISUM+NCOL(I)                                               A  1200
      IF ( ISUM .NE. NP) CALL ERROR (3)                                 A  1210
      IF ( NZ*NP .NE. NODES) CALL ERROR (4)                             A  1220
C                                                                       A  1230
C READ B.C. DATA                                                        A  1240
      IF ( QTRKOR ) GO TO 111                                           A  1250
      READ (5,*) AF1,BF1,AF2,BF2,AF3,BF3,AF4,BF4,AF5,BF5,AF6,BF6        A  1260
     $                  ,AT1,BT1,AT2,BT2,AT3,BT3,AT4,BT4,AT5,BT5,AT6,BT6 A  1270
      WRITE (6,4010) DX,DZ,A1,A2                                        A  1280
      WRITE (6,4020) AF1,BF1,AT1,BT1,AF2,BF2,AT2,BT2,AF3,BF3,AT3,BT3,   A  1290
     $               AF4,BF4,AT4,BT4,AF5,BF5,AT5,BT5,AF6,BF6,AT6,BT6    A  1300
      GO TO 112                                                         A  1310
111   AF1 = 1.                                                          A  1320
      BF1 = 0.                                                          A  1330
      AF3 = 1.                                                          A  1340
      BF3 = 0.                                                          A  1350
      AT1 = 1.                                                          A  1360
      BT1 = 0.                                                          A  1370
      AT3 = 1.                                                          A  1380
      BT3 = 0.                                                          A  1390
      READ (5,*) AF5,BF5,AF6,BF6                                        A  1400
     $                  ,AT5,BT5,AT6,BT6                                A  1410
     $                  ,(AFQ(I),BFQ(I), I=1,NX)                        A  1420
     $                  ,(ATQ(I),BTQ(I), I=1,NX)                        A  1430
      WRITE (6,4010) DX, DZ, A1, A2                                     A  1440
```

```
      WRITE (6,4022) AF5,BF5,AT5,BT5,AF6,BF6,AT6,BT6,                    A  1450
     $               (I, AFQ(I), BFQ(I), ATQ(I), BTQ(I), I=1,NX)         A  1460
C                                                                        A  1470
112   WRITE (6,4000) EPSO,EPSP,MAXI,MAXO,MAXP                            A  1480
C                                                                        A  1490
CHECK INTERPOLATING TABLE DESCRIPTION                                    A  1500
      INTTYP = 1                                                         A  1510
      IF ( IVDPTS .GT. 1) INTTYP = 3                                     A  1520
      IF ( IEXPTS .GT. 1) INTTYP = INTTYP+1                              A  1530
      IF ( INTTYP .GT. 2) NOVOID = .FALSE.                               A  1540
      IF ( IPTYPE .EQ. 2  .AND.  IEXPTS .EQ. 1 ) CALL ERROR (5)          A  1550
      IF ( ITSETS .GT. DIMTS) CALL ERROR (6)                             A  1560
      IF ( IEXPTS .GT. DIMEX) CALL ERROR (7)                             A  1570
      IF ( IVDPTS .GT. DIMVD) CALL ERROR (8)                             A  1580
C                                                                        A  1590
CHECK FOR ERRORS IN MASKS                                                A  1600
      IF ( IEXPTS .LE. 1) GO TO 114                                      A  1610
      DO 113 I=2,IEXPTS                                                  A  1620
      IF ( BUMASK(I-1) .GT. BUMASK(I) ) CALL ERROR (9)                   A  1630
113   CONTINUE                                                           A  1640
114   IF ( IVDPTS .LE. 1 ) GO TO 116                                     A  1650
      DO 115 I=2,IVDPTS                                                  A  1660
      IF ( VMASK(I-1) .GT. VMASK(I) ) CALL ERROR (10)                    A  1670
115   CONTINUE                                                           A  1680
C                                                                        A  1690
C EDIT VOID AND EXPOSURE MASKS                                           A  1700
116   CALL HEADER (1)                                                    A  1710
      WRITE (6,7000) ITSETS, IEXPTS, IVDPTS                              A  1720
      WRITE (6,7002) (IEX, BUMASK(IEX), IEX=1,IEXPTS)                    A  1730
      IF ( .NOT. NOVOID ) WRITE (6,7004) (IVD, VMASK(IVD), IVD=1,IVDPTS) A  1740
C                                                                        A  1750
      IF ( NOXE ) GO TO 3                                                A  1760
C READ XE + I FISSION YIELDS                                             A  1770
      DO 5 NTS=1,ITSETS                                                  A  1780
5     READ (5,*) (ITS,(YIX(ITS,IEX),IEX=1,IEXPTS))                       A  1790
C                                                                        A  1800
```

```
C READ CROSS SECTION INTERPOLATING TABLES                                A  1810
3     DO 10 NTS=1,ITSETS                                                 A  1820
      CALL HEADER (1)                                                    A  1830
      READ (5,*) ITS                                                     A  1840
      READ (5,8000) WORD                                                 A  1850
      WRITE (6,120) ITS, WORD                                            A  1860
      IF ( NOVOID ) GO TO 6                                              A  1870
      DO 4  IVD=1,IVDPTS                                                 A  1880
      WRITE (6,122) VMASK(IVD)                                           A  1890
      DO 4  IEX=1,IEXPTS                                                 A  1900
      N = ITS+DIMTS*(DIMEX*(IVD-1)+IEX-1)                                A  1910
      READ  (5,*)      DFI(N),SAFI(N),NSFFI(N),KSFFI(N),SDSI(N),         A  1920
     $                         DTI(N),SATI(N),NSFTI(N),KSFTI(N)         A  1930
      WRITE (6,124) BUMASK(IEX),DFI(N),SAFI(N),NSFFI(N),KSFFI(N),SDSI(N) A  1940
     $,                          DTI(N),SATI(N),NSFTI(N),KSFTI(N)       A  1950
      IF ( NOXE ) GO TO 4                                                A  1960
      READ (5,*) XEND, SAXE(N), SFF, SFT                                 A  1970
      SATI(N) = SATI(N) - XEND*SAXE(N)                                   A  1980
      PRSA1(N) = YIX(ITS,IEX)*SFF*SAXE(N)*1.E-24                         A  1990
      PRSA2(N) = YIX(ITS,IEX)*SFT*SAXE(N)*1.E-24                         A  2000
4     CONTINUE                                                           A  2010
      GO TO 9                                                            A  2020
6     WRITE (6,126)                                                      A  2030
      DO 8  IEX=1,IEXPTS                                                 A  2040
      N = ITS+(IEX-1)*DIMTS                                              A  2050
      READ  (5,*)      DFI(N),SAFI(N),NSFFI(N),KSFFI(N),SDSI(N),         A  2060
     $                         DTI(N),SATI(N),NSFTI(N),KSFTI(N)         A  2070
      WRITE (6,124) BUMASK(IEX),DFI(N),SAFI(N),NSFFI(N),KSFFI(N),SDSI(N) A  2080
     $,                          DTI(N),SATI(N),NSFTI(N),KSFTI(N)       A  2090
      IF ( NOXE ) GO TO 8                                                A  2100
      READ (5,*) XEND, SAXE(N), SFF, SFT                                 A  2110
      SATI(N) = SATI(N) - XEND*SAXE(N)                                   A  2120
      PRSA1(N) = YIX(ITS,IEX)*SFF*SAXE(N)*1.E-24                         A  2130
      PRSA2(N) = YIX(ITS,IEX)*SFT*SAXE(N)*1.E-24                         A  2140
8     CONTINUE                                                           A  2150
9     IF ( NOXE ) GO TO 10                                               A  2160
```

```
      CALL HEADER (1)                                                   A  2170
      WRITE (6,121) ITS,WORD                                            A  2180
      DO 7 IVD=1,IVDPTS                                                 A  2190
      IF ( .NOT. NOVOID ) WRITE (6,122) VMASK(IVD)                      A  2200
      IF ( NOVOID ) WRITE (6,126)                                       A  2210
      DO 7 IEX=1,IEXPTS                                                 A  2220
      N = ITS + DIMTS*(DIMEX*(IVD-1)+IEX-1)                             A  2230
      SFF = PRSA1(N)/(YIX(ITS,IEX)*SAXE(N))*1.E24                       A  2240
      SFT = PRSA2(N)/(YIX(ITS,IEX)*SAXE(N))*1.E24                       A  2250
      WRITE (6,129) BUMASK(IEX), SATI(N), SFF, SFT, SAXE(N)             A  2260
7     SAXE(N) = SAXE(N)*1.E-24                                          A  2270
10    CONTINUE                                                          A  2280
C                                                                       A  2290
C                                                                       A  2300
      IF ( NOXE ) GO TO 13                                              A  2310
C EDIT XE + I FISSION YIELDS                                            A  2320
      CALL HEADER (1)                                                   A  2330
      WRITE (6,123) (I,I=1,ITSETS)                                      A  2340
      WRITE (6,126)                                                     A  2350
      DO 19 IEX=1,IEXPTS                                                A  2360
19    WRITE (6,125) BUMASK(IEX),(YIX(ITS,IEX),ITS=1,ITSETS)             A  2370
CALCULATE FACTOR USED IN ABSOLUTE FLUX CALCULATION                      A  2380
      PD = MWTH*PCTPWR*6.2418E16/(DZ*DX*DX)                             A  2390
      IF ( QTRKOR ) PD = PD*.25                                         A  2400
C                                                                       A  2410
C READ TABLE SET ASSIGNMENTS                                            A  2420
13    IF ( ITSAS .EQ. 1 ) GO TO 650                                     A  2430
      READ (5,*) FTYPE                                                  A  2440
      IF ( ITSAS .EQ. 3 ) GO TO 652                                     A  2450
      DO 654 LB=1,NP                                                    A  2460
      LT = LB + NDSMNP                                                  A  2470
      DO 654 L=LB,LT,NP                                                 A  2480
654   TABSET(L) = FTYPE(LB)                                             A  2490
      GO TO 650                                                         A  2500
C                                                                       A  2510
652   CALL HEADER (1)                                                   A  2520
```

```
      WRITE (6,670) (K,K=1,NZ)                                          A  2530
      DO 658   NTS = 1,IFTYPS                                           A  2540
      READ (5,*) IFT, (TSOVLY(IFT,K),K=1,N06)                           A  2550
658   WRITE (6,662) IFT, (TSOVLY(IFT,K),K=1,N06)                        A  2560
      DO 660 LB=1,NP                                                    A  2570
      LT = LB + NDSMNP                                                  A  2580
      K = 0                                                             A  2590
      IFT = FTYPE(LB)                                                   A  2600
      DO 660 L=LB,LT,NP                                                 A  2610
      K = K + 1                                                         A  2620
660   TABSET(L) = TSOVLY(IFT,K)                                         A  2630
650   CALL EDIT (7)                                                     A  2640
C                                                                       A  2650
C READ CONTROL ROD POSITIONS                                            A  2660
      IF ( NOCROD ) GO TO 11                                            A  2670
      IF ( NBANKS .GT. 0 ) GO TO 623                                    A  2680
      READ (5,*) NOTCH                                                  A  2690
      GO TO 621                                                         A  2700
C DEFINE ROD BANKS                                                      A  2710
623   CALL HEADER (1)                                                   A  2720
      WRITE (6,4034)                                                    A  2730
      IND = 0                                                           A  2740
      DO 608 NB=1,NBANKS                                                A  2750
      READ (5,*) ID, NR, NOTCH                                          A  2760
      M = 2*NR                                                          A  2770
      WRITE (6,4036) ID, (NOTCH(N),N=1,M)                               A  2780
      NRODS(ID,1) = NR                                                  A  2790
      NRODS(ID,2) = IND+1                                               A  2800
      DO 608 N=1,NR                                                     A  2810
      IND = IND+1                                                       A  2820
      M = 2*N                                                           A  2830
608   RODIND(IND) = LOC (NOTCH(M-1), NOTCH(M), 1)                       A  2840
C SET ROD BANKS                                                         A  2850
      DO 612 L=1,NP                                                     A  2860
612   NOTCH(L) = 0                                                      A  2870
      DO 610 NB=1,NBANKS                                                A  2880
```

```
      READ (5,*) ID, NTCH                                               A  2890
610   CALL BANK (ID, NTCH)                                              A  2900
C                                                                       A  2910
C READ CONTROL ROD WORTHS                                               A  2920
621   CALL EDIT (6)                                                     A  2930
      DO 604 NTS=1,ICNTRL                                               A  2940
      READ (5,*) ITS                                                    A  2950
      CALL HEADER (1)                                                   A  2960
      WRITE (6,6004) ITS                                                A  2970
      IF ( NOVOID ) GO TO 602                                           A  2980
      DO 600 IVD=1,IVDPTS                                               A  2990
      WRITE (6,6000) VMASK(IVD)                                         A  3000
      READ (5,*) (WORTH(ITS,IEX,IVD),IEX=1,IEXPTS)                      A  3010
600   WRITE (6,6002) (BUMASK(IEX),WORTH(ITS,IEX,IVD),IEX=1,IEXPTS)      A  3020
      GO TO 604                                                         A  3030
602   READ (5,*) (WORTH(ITS,IEX,1),IEX=1,IEXPTS)                        A  3040
      WRITE (6,6002  ) (BUMASK(IEX),WORTH(ITS,IEX,1),IEX=1,IEXPTS)      A  3050
604   CONTINUE                                                          A  3060
C                                                                       A  3070
C READ FUEL EXPOSURE ARRAY                                              A  3080
11    IF ( IEXRD) 12,18,16                                              A  3090
12    DO 14 LC=1,NP                                                     A  3100
      READ (5,*) I,J                                                    A  3110
      IF ( I .EQ. -99) GO TO 18                                         A  3120
      LB = LOC (I,J,1)                                                  A  3130
      LT = LB+NDSMNP                                                    A  3140
      K = 0                                                             A  3150
      READ (5,*) ASMEX                                                  A  3160
      DO 14 L=LB,LT,NP                                                  A  3170
      K = K+1                                                           A  3180
14    BU(L) = ASMEX(K)                                                  A  3190
      GO TO 18                                                          A  3200
16    READ (5,*) BU                                                     A  3210
C                                                                       A  3220
C READ INITIAL POWER GUESS                                              A  3230
18    IF ( IPDRD .NE. 1) GO TO 21                                       A  3240
```

```
      READ (5,*) POWER                                                  A  3250
      CALL NORM (POWER,NODES)                                           A  3260
21    IF ( NOVOID ) GO TO 24                                            A  3270
C                                                                       A  3280
CALCULATE THERMAL-HYDRAULIC CONSTANTS FOR VOID AND MCHFR CALCULATIONS   A  3290
      CALL HEADER (1)                                                   A  3300
      PMWTH = PCTPWR*.01*MWTH                                           A  3310
      AVFLUX = AVHFLX*PEAKF*PCTPWR*.01                                  A  3320
      XIN = (HIN-HSAT)/HFG                                              A  3330
      AVPWR = PCTPWR*MWTH*3.4127E4/FLOAT(NODES)                         A  3340
      IF ( QTRKOR ) AVPWR = AVPWR*.25                                   A  3350
      AC3 = VF/VG                                                       A  3360
      WRITE (6,4012) PMWTH,AVHFLX,PEAKF,VG,VF,HIN,HFG,HSAT,PSIA,TFLOW,  A  3370
     $               AREA,AC1,AC2                                       A  3380
C                                                                       A  3390
C READ FLOW CHANNEL CHARACTERISTICS                                     A  3400
      IF ( IFLOW .EQ. 0) GO TO 23                                       A  3410
      READ (5,*) CTYPE                                                  A  3420
      WRITE (6,4030)                                                    A  3430
      DO 20 N=1,IFLOW                                                   A  3440
      READ (5,*) M, B1(M), B2(M), B3(M)                                 A  3450
20    WRITE (6,4032) M, B1(M), B2(M), B3(M)                             A  3460
      CALL EDIT (9)                                                     A  3470
23    CALL VOIDFR                                                       A  3480
C                                                                       A  3490
CALCULATE NODAL WEIGHTING FACTORS                                       A  3500
24    R = DX*DX/DZ/DZ                                                   A  3510
      B1N = 3.*A1/(3.*A1+(1.-A1)*(R+2.))                                A  3520
      B2N = 3.*A2/(3.*A2+(1.-A2)*(R+2.))                                A  3530
      CF = B1N/6./A1*(1.-A1)                                            A  3540
      CT = B2N/6./A2*(1.-A2)                                            A  3550
      RCF = R*CF                                                        A  3560
      RCT = R*CT                                                        A  3570
C                                                                       A  3580
CALCULATE GEOMETRIC CONSTANTS USED IN INNER ITERATION                   A  3590
      GX = 2./DX/DX                                                     A  3600
```

```
      GZ = 2./DZ/DZ                                                     A  3610
C                                                                       A  3620
      IF ( .NOT. NOHAL ) GO TO 300                                      A  3630
C                                                                       A  3640
C-----------------------------------------------------------------------A  3650
C                                                                       A  3660
C BURN TYPE PROBLEM                                                     A  3670
C                                                                       A  3680
CALCULATE CORE AVERAGE EXPOSURE                                         A  3690
      AVEXP = 0.                                                        A  3700
      DO 202 L=1,NODES                                                  A  3710
202   AVEXP = AVEXP+BU(L)                                               A  3720
      AVEXP = AVEXP/FLOAT(NODES)                                        A  3730
C READ BURNUP TIME STEP                                                 A  3740
      READ (5,*) BURN                                                   A  3750
      IF ( EOF(5) ) 208,800                                             A  3760
800   IF ( BURN .LT. 0.) BURN = -BURN/2400.*PCTPWR*MWTH/TONNES          A  3770
CALCULATE INITIAL POWER DISTRIBUTION                                    A  3780
      CALL STG                                                          A  3790
      CALL EDIT (5)                                                     A  3800
      CALL EDIT (3)                                                     A  3810
      IF ( IEDIT(6) .EQ. -1 ) CALL EDIT (10)                            A  3820
      IF ( NOVOID ) GO TO 204                                           A  3830
      CALL EDIT (1)                                                     A  3840
      CALL EDIT (4)                                                     A  3850
      CALL EDIT (2)                                                     A  3860
CALCULATE NEW EXPOSURE ARRAY                                            A  3870
204   DO 206 L=1,NODES                                                  A  3880
206   BU(L) = BU(L)+POWER(L)*BURN                                       A  3890
      AVEXP = AVEXP+BURN                                                A  3900
CALCULATE NEW POWER DISTRIBUTION                                        A  3910
      CALL STG                                                          A  3920
      CALL EDIT (5)                                                     A  3930
      CALL EDIT (3)                                                     A  3940
      IF ( IEDIT(6) .EQ. -1 ) CALL EDIT (10)                            A  3950
      IF ( IEDIT(3) .EQ. -1 ) CALL EDIT (8)                             A  3960
```

```
      IF ( NOVOID ) GO TO 210                                           A  3970
      CALL EDIT (1)                                                     A  3980
      CALL EDIT (4)                                                     A  3990
      CALL EDIT (2)                                                     A  4000
C                                                                       A  4010
C READ DATA FOR NEXT TIME STEP                                          A  4020
210   NEWTH = 0                                                         A  4030
      NEWF = 0                                                          A  4040
      NEWCR = 0                                                         A  4050
      NTSTEP = NTSTEP + 1                                               A  4060
      READ (5,*) BURN, NEWTH, NEWF, NEWCR                               A  4070
      IF ( EOF(5) ) 234,802                                             A  4080
802   IF ( BURN .LT. 0.) BURN = -BURN/2400.*PCTPWR*MWTH/TONNES          A  4090
      IF ( NEWTH .EQ. 0) GO TO 220                                      A  4100
C READ NEW THERMAL-HYDRAULIC DATA                                       A  4110
      IFLOW = 0                                                         A  4120
      OLDFLO = TFLOW                                                    A  4130
      READ (5, INPUT)                                                   A  4140
      PMWTH = PCTPWR*.01*MWTH                                           A  4150
      AVFLUX = AVHFLX*PEAKF*PCTPWR*.01                                  A  4160
      XIN = (HIN-HSAT)/HFG                                              A  4170
      AVPWR = PCTPWR*MWTH*3.4127E4/FLOAT (NODES)                        A  4180
      IF ( QTRKOR ) AVPWR = AVPWR*.25                                   A  4190
      AC3 = VF/VG                                                       A  4200
      CALL HEADER (1)                                                   A  4210
      WRITE (6,4012) PMWTH,AVHFLX,PEAKF,VG,VF,HIN,HFG,HSAT,PSIA,TFLOW,  A  4220
     $               AREA,AC1,AC2                                       A  4230
      IF ( IFLOW .EQ. 0) GO TO 220                                      A  4240
      WRITE (6,4030)                                                    A  4250
      DO 212 N=1,IFLOW                                                  A  4260
      READ (5,*) M, B1(M), B2(M), B3(M)                                 A  4270
212   WRITE (6,4032) M, B1(M), B2(M), B3(M)                             A  4280
      CALL EDIT (9)                                                     A  4290
220   IF ( NEWF .EQ. 0) GO TO 226                                       A  4300
C READ NEW FUEL TYPE ARRAY                                              A  4310
      DO 2222 L=1,NODES                                                 A  4320
```

```
2222  BU(L) = BU(L)+POWER(L)*BURN                                A  4330
      CALL HEADER (1)                                            A  4340
      WRITE (6,2002) NEWF                                        A  4350
      DO 224 NN=1,NEWF                                           A  4360
      READ (5,*) IFT, ICTYP, I, J                                A  4370
      WRITE (6,2004) I,J                                         A  4380
      LB = LOC (I,J,1)                                           A  4390
      READ (5,*) ASMEX                                           A  4400
      FTYPE(LB) = IFT                                            A  4410
      LT = LB + NDSMNP                                           A  4420
      IF ( ITSAS .EQ. 3 ) GO TO 696                              A  4430
      DO 690 L=LB,LT,NP                                          A  4440
690   TABSET(L) = IFT                                            A  4450
      GO TO 699                                                  A  4460
696   K = 0                                                      A  4470
      DO 698 L=LB,LT,NP                                          A  4480
      K = K + 1                                                  A  4490
698   TABSET(L) = TSOVLY(IFT,K)                                  A  4500
699   CTYPE(LB) = ICTYP                                          A  4510
      K = 0                                                      A  4520
      LT = LB+NDSMNP                                             A  4530
      DO 224 L=LB,LT,NP                                          A  4540
      K = K+1                                                    A  4550
224   BU(L) = ASMEX(K)                                           A  4560
C                                                                A  4570
      IF ( NEWCR .EQ. 0 ) GO TO 206                              A  4580
      IF ( NBANKS .EQ. 0 ) GO TO 226                             A  4590
C MOVE NEWCR ROD BANKS TO NEW POSITIONS                          A  4600
      DO 280 I=1,NEWCR                                           A  4610
      READ (5,*) ID, NTCH                                        A  4620
280   CALL BANK (ID, NTCH)                                       A  4630
      GO TO 206                                                  A  4640
226   IF ( NEWCR) 228,206,230                                    A  4650
C READ NEW CONTROL ROD POSITION ARRAY                            A  4660
C IF NEWCR = -1 ... READ NEW NOTCH ARRAY                         A  4670
C              0 ... NO CHANGE IN NOTCH ARRAY                    A  4680
```

```
C              N ... READ N NEW NOTCH POSITIONS                          A  4690
228   READ (5,*) NOTCH                                                   A  4700
      CALL EDIT (6)                                                      A  4710
      DO 2229 L=1,NODES                                                  A  4720
2229  F(L) = 1.                                                          A  4730
      GO TO 204                                                          A  4740
230   DO 232 N=1,NEWCR                                                   A  4750
      READ (5,*) I, J, NTCH                                              A  4760
      L = LOC (I,J,1)                                                    A  4770
232   NOTCH(L) = NTCH                                                    A  4780
      CALL EDIT (6)                                                      A  4790
      GO TO 204                                                          A  4800
C                                                                        A  4810
CALCULATE POWER DISTRIBUTION FOR CASE WITH NO TIME STEP                  A  4820
208   CALL STG                                                           A  4830
      CALL EDIT (5)                                                      A  4840
      CALL EDIT (3)                                                      A  4850
      IF ( NOVOID ) GO TO 234                                            A  4860
      CALL EDIT (1)                                                      A  4870
      CALL EDIT (4)                                                      A  4880
      CALL EDIT (2)                                                      A  4890
234   IF ( IEDIT(3) .EQ. 1 ) CALL EDIT (8)                               A  4900
      IF ( IEDIT(6) .NE. 0 ) CALL EDIT (10)                              A  4910
      WRITE (6,2000)                                                     A  4920
      STOP                                                               A  4930
C-----------------------------------------------------------------------A  4940
C                                                                        A  4950
C HALING SOLUTION                                                        A  4960
C                                                                        A  4970
300   READ (5,*) BURN                                                    A  4980
      IF ( BURN .LT. 0.) BURN = -BURN/2400.*PCTPWR*MWTH/TONNES           A  4990
      AVEXP = 0.                                                         A  5000
      DO 301 L=1,NODES                                                   A  5010
301   AVEXP = AVEXP + BU(L)                                              A  5020
      AVEXP = AVEXP/FLOAT(NODES)                                         A  5030
      CALL EDIT (3)                                                      A  5040
```

```
      CALL HEADER (1)                                                   A  5050
      CALL HALING (BURN)                                                A  5060
      AVEXP = AVEXP + BURN                                              A  5070
      CALL EDIT (3)                                                     A  5080
      CALL EDIT (5)                                                     A  5090
      IF ( IEDIT(3) .EQ. 1 ) CALL EDIT (8)                              A  5100
      IF ( IEDIT(6) .NE. 0 ) CALL EDIT (10)                             A  5110
      IF ( NOVOID ) GO TO 316                                           A  5120
      CALL EDIT (4)                                                     A  5130
      CALL EDIT (2)                                                     A  5140
      CALL EDIT (1)                                                     A  5150
316   WRITE (6,2000)                                                    A  5160
      STOP                                                              A  5170
C                                                                       A  5180
C-----------------------------------------------------------------------A  5190
C                                                                       A  5200
7004  FORMAT (//10X,'*  VOID MASK  *'//10X,'TABLE'/                     A  5210
     $10X,'INDEX      VOID'/10X,'=====   ========'/10(/I15,F11.3))      A  5220
6004  FORMAT (1X,'***  CONTROL ROD WORTH FOR TABLE SET',I5,'  ***',//   A  5230
     $20X,'EXPOSURE'/20X,'(MWD/MT)   WORTH'/20X,'========   ====='//)   A  5240
6000  FORMAT (4X,'VOID =',F8.2)                                         A  5250
6002  FORMAT (18X,E10.2,F8.2)                                           A  5260
7000  FORMAT (1X,I3,' CROSS SECTION INTERPOLATING TABLES WILL BE READ AT A  5270
     $'                  ,I3,' EXPOSURE AND',I3,              ' VOID INTE A  5280
     $RPOLATING POINTS'///10X,'* EXPOSURE MASK *'///10X,'TABLE     EXPOS A  5290
     $URE'/10X,'INDEX     (MWD/MT)'/10X,'=====   =========='//)        A  5300
7002  FORMAT (10X,I5,F13.0)                                             A  5310
2000  FORMAT (//1X,'***  END OF CASE  ***')                             A  5320
2002  FORMAT (1X,I5,' NEW ASSEMBLIES LOADED AT THESE LOCATIONS'//21X,'  A  5330
     $  I      J'/21X,'===== ======'//)                                 A  5340
2004   FORMAT (20X,2I6)                                                 A  5350
1000  FORMAT (20A4)                                                     A  5360
4010  FORMAT (3X,'NODE WIDTH  =',F10.3,' CM.'/3X,'NODE HEIGHT =',F10.3,' A  5370
     $ CM.'//3X,'NODAL WEIGHTING FACTORS:   A1 =',F10.4/30X,'A2 =',    A  5380
     $F10.4)                                                            A  5390
4000  FORMAT (/9X,'============  CONVERGENCE PARAMETERS  ============'  A  5400
```

```
     $//10X,                                                            A  5410
     $'OUTER ITERATION WILL BE CONVERGED TO ',E10.2/10X,                A  5420
     $'POWER ITERATION WILL BE CONVERGED TO ',E10.2//10X,               A  5430
     $'MAXIMUM NUMBER OF INNER ITERATIONS =',I5/10X,                    A  5440
     $'MAXIMUM NUMBER OF OUTER ITERATIONS =',I5/10X,                    A  5450
     $'MAXIMUM NUMBER OF POWER ITERATIONS =',I5//)                      A  5460
8000  FORMAT (20A4)                                                    A  5470
120   FORMAT (1X, '=============================================   CROS A  5480
     $S SECTION INTERPOLATING TABLE   ================================ A  5490
     $=============''//1X,'TABLE SET',I3,5X,20A4//27X,'----------------- A  5500
     $--- F A S T -----------------------        ------------- T H E R M A  5510
     $ A L --------------''/13X,'EXPOSURE',35X,'NU-',6X,'KAPPA-',8X,'DOWN A  5520
     $',35X,'NU-',6X,'KAPPA-'/13X,'(MWD/MT)',13X,'D  ABSORBTION     FISS A  5530
     $ION     FISSION  SCATTERING',13X,'D  ABSORBTION     FISSION     FI A  5540
     $SSION'/11X,'==========',2X,5('  =========='),2X,4('  ==========')) A  5550
122   FORMAT (1X,'VOID =',F5.2)                                         A  5560
124   FORMAT (11X,F10.0,2X,5E12.4,2X,4E12.4)                            A  5570
126   FORMAT (/)                                                        A  5580
121   FORMAT (1X, '=============================================   CROS A  5590
     $S SECTION INTERPOLATING TABLE   ================================ A  5600
     $=============''//1X,'TABLE SET',I3,5X,20A4//28X,'THERMAL',30X,'XE-1 A  5610
     $35'/13X,'EXPOSURE    ABSORBTION        FAST     THERMAL       MICR A  5620
     $O'/13X,'(MWD/MT)    XE REMOVED     FISSION     FISSION  ABSORBTION A  5630
     $'/11X,'==========',2X,4('  ==========')) A  5640
123   FORMAT (1X,'======  XE-135 + I-135 FISSION YIELDS  ======''//3X,'EX A  5650
     $POSURE'/3X,'(MWD/MT)  TABLE SET =',15I8)                          A  5660
125   FORMAT (1X,F10.0,13X,15F8.4)                                      A  5670
129   FORMAT (11X,F10.0,2X,3E12.4,F12.0)                                A  5680
4012  FORMAT (15X,'*  THERMAL-HYDRAULIC DATA FOR THIS TIME STEP  *'///  A  5690
     $15X,'CORE POWER',T37,F12.1,T52,'MW-THERMAL'//                     A  5700
     $15X,'AV. HEAT FLUX',T37,F12.0,T52,'BTU/HR/FT**2'//                A  5710
     $15X,'PEAKING FACTOR',T37,F12.2//                                  A  5720
     $15X,'SAT. VAP. SPEC. VOL.',T37,F12.4,T52,'FT**3/LBM'//            A  5730
     $15X,'SAT. LIQ. SPEC. VOL.',T37,F12.5,T52,'FT**3/LBM'//            A  5740
     $15X,'INLET ENTHALPY',T37,F12.2,T52,'BTU/LBM'//                    A  5750
     $15X,'HEAT OF VAPORIZATION',T37,F12.2,T52,'BTU/LBM'//              A  5760
```

```
     $15X,'ENTHALPY OF SAT. LIQ.',T37,F12.2,T52,'BTU/LBM'//                A  5770
     $15X,'CORE PRESSURE',T37,F12.1,T52,'PSIA'//                           A  5780
     $15X,'INCORE FLOW',T37,1PE12.3,T52,'LBM/HR'//                         A  5790
     $15X,'FLOW AREA PER CHANNEL',T37,0PF12.4,T52,'FT**2'///               A  5800
     $15X,'ARMAND CORRELATION COEFICIENTS'/25X,'AC1 =',F8.3/25X,'AC2 =',   A  5810
     $F8.3)                                                                A  5820
4020  FORMAT(/9X,'================  BOUNDARY CONDITIONS  ============ A  5830
     $=====''//11X,'ALB = A + B*VOID(L)'//11X,'ALB =  1.  FOR ZERO CURREN A  5840
     $T'/18X,'0.  FOR ZERO FLUX'/17X,'XX.  FOR LEAKAGE SPECIFIED BY  A    A  5850
     $AND  B'                                                              A  5860
     $//32X,'--- FAST ---',12X,'- THERMAL -'//33X,'A',8X,'B',14X,          A  5870
     $'A',8X,'B'/21X,2('          =====    =====')//16X,'FACE #1',4X,2F9 A  5880
     $.2,6X,2F9.2/16X,'FACE #2',4X,2F9.2,6X,2F9.2/16X,'FACE #3',4X,2F9    A  5890
     $.2,6X,2F9.2/16X,'FACE #4',4X,2F9.2,6X,2F9.2/17X,'BOTTOM',4X,2F9.    A  5900
     $2,6X,2F9.2/20X,'TOP',4X,2F9.2,6X,2F9.2)                              A  5910
4022  FORMAT(/9X,'================  BOUNDARY CONDITIONS  ============ A  5920
     $=====''//11X,'ALB = A + B*VOID(L)'//11X,'ALB =  1.  FOR ZERO CURREN A  5930
     $T'/18X,'0.  FOR ZERO FLUX'/17X,'XX.  FOR LEAKAGE SPECIFIED BY  A    A  5940
     $AND  B'                                                              A  5950
     $//32X,'--- FAST ---',12X,'- THERMAL -'//33X,'A',8X,'B',14X,          A  5960
     $'A',8X,'B'/21X,2('          =====    =====')                        A  5970
     $//17X,'BOTTOM',4X,2F9                                                A  5980
     $.2,6X,2F9.2/20X, 'TOP',4X,2F9.2,6X,2F9.2//9X,'QTR. CORE EDGE'/13X   A  5990
     $,'ROW NUMBER'//20(I23,4X,2F9.2,6X,2F9.2/))                           A  6000
4030  FORMAT (//15X,'COOLANT FLOW VARIATION WITH POWER'//20X,'P = RELATI A  6010
     $VE POWER IN CHANNEL'/20X,'FLOW = RELATIVE COOLANT FLOW IN CHANNEL   A  6020
     $ (UNNORMALIZED)'//20X,'CHANNEL TYPE'/20X,'============'//)           A  6030
4032  FORMAT (2X,I30,5X,'FLOW =',E10.3,' +',E10.3,' *P +',E10.3,' *P**2   A  6040
     $ '//)                                                                A  6050
4034  FORMAT (10X,'***  ROD BANK ASSIGNMENT  ***'//)                       A  6060
4036  FORMAT (20X,'BANK NUMBER',I5/20X,'LOCATION OF NODES WHICH ARE RODD A  6070
     $ED BY THIS BANK:  (I,J)'//(25X,8('(',I3,',',I3,')',4X)//)/)          A  6080
670   FORMAT (1X,'TABLE SET TO FUEL TYPE ASSIGNMENT'//1X,'FUEL    TABLE   A  6090
     $SET'/1X,'TYPE  K=',N06I4,/1X,'----    ',N06(----)/)                  A  6100
662   FORMAT (1X,I4,4X,N06I4)                                              A  6110
C                                                                          A  6120
```

END

A 6130

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE INTERP
C
C---------------------------------------------------------------------
C THIS ROUTINE INTERPOLATES USING THE INPUT CROSS SECTION
C INTERPOLATING TABLES TO DETERMINE NODAL CONSTANTS
C---------------------------------------------------------------------
C
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP
      COMMON /CSINP / BUMASK(N07),  VMASK(N08),    DFI(N10),    DTI(N10)
     $                SAFI(N10), SATI(N10),  NSFFI(N10),  NSFTI(N10),
     $                SDSI(N10), IEXPTS    , IVDPTS    , ITSETS    ,
     $                KSFTI(N10), KSFFI(N10),
     $                DIMTS    ,  DIMEX    ,  DIMVD    , NOTCH(N02),
     $                TABSET(N01),  WORTH(N10)
      INTEGER DIMTS, DIMEX, DIMVD, TABSET
      REAL    NSFFI,NSFTI,KSFFI,KSFTI
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /NODAL / DF    (N01), DT    (N01), KSFF  (N01)
     $,               KSFT  (N01), TFR   (N01), NSF1G (N01)
     $,               C2    (N01), C4    (N01), C6    (N03)
     $,               C7    (N01)
      REAL KSFF, KSFT, NSF1G
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL  (N04)
      COMMON /BC    / AF1, AF3, AF5, AF6, AFQ(N04),
     $                BF1, BF3, BF5, BF6, BFQ(N04),
     $                AT1, AT3, AT5, AT6, ATQ(N04),
     $                BT1, BT3, BT5, BT6, BTQ(N04)
      EQUIVALENCE (AFQ(1), AF2), (AFQ(2), AF4),
     $            (BFQ(1), BF2), (BFQ(2), BF4),
```

```
     $              (ATQ(1), AT2), (ATQ(2), AT4),                          B   370
     $              (BTQ(1), BT2), (BTQ(2), BT4)                           B   380
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)      B   390
     $,                  NOXE,  FIRST                                      B   400
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST                   B   410
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)        B   420
      REAL NSFF, NSFT                                                      B   430
      COMMON /XENON / PD, PRSA1(N10), PRSA2(N10), SAXE(N10)                B   440
      LOGICAL NOXEN                                                        B   450
C                                                                          B   460
C------------------------------------------------------------------------- B   470
C                                                                          B   480
C  INTTYP =  1  FOR NO EXPOSURE OR VOID INTERPOLATION                      B   490
C            2  FOR EXPOSURE INTERPOLATION ONLY                            B   500
C            3  FOR VOID INTERPOLATION ONLY                                B   510
C            4  FOR EXPOSURE AND VOID INTERPOLATION                        B   520
C                                                                          B   530
C  DF     =  FAST DIFFUSION COEFFICIENT                                    B   540
C  SAF    =  FAST ABSORBTION CROSS SECTION                                 B   550
C  NSFF   =  FAST NU-FISSION CROSS SECTION                                 B   560
C  KSFF   =  FAST KAPPA-FISSION CROSS SECTION                              B   570
C  SDS    =  FAST TO THERMAL DOWN SCATTERING CROSS SECTION                 B   580
C  DT     =  THERMAL DIFFUSION COEFFICIENT                                 B   590
C  SAT    =  THERMAL ABSORBTION CROSS SECTION                              B   600
C  NSFT   =  THERMAL NU-FISSION CROSS SECTION                              B   610
C  KSFT   =  THERMAL KAPPA-FISSION CROSS SECTION                           B   620
C  SAX    =  XENON THERMAL MICRO-ABSORBTION CROSS SECTION                  B   630
C  PR1    =  (FAST FISSION C.S.) * (I-135 + XE-135 FISSION YIELD) *        B   640
C            (XENON MICRO-ABS. C.S.)                                       B   650
C  PR2    =  SAME AS ABOVE FOR THERMAL GROUP                               B   660
C  SA     =  THERMAL ABSORBTION CROSS SECTION WITH XE-135 REMOVED          B   670
C  TFR    =  ASSYMPTOTIC THERMAL TO FAST FLUX RATIO                        B   680
C  NSF1G  =  ONE GROUP (FAST) NU-FISSION CROSS SECTION                     B   690
C  RHO    =  CONTROL ROD WORTH                                             B   700
C                                                                          B   710
C------------------------------------------------------------------------- B   720
```

```
C                                                                       B   730
      NOXEN = NOXE                                                      B   740
      IF ( FIRST ) NOXEN = .TRUE.                                       B   750
      IF ( NOXEN ) GO TO 3                                              B   760
CALCULATE ABSOLUTE FLUXES                                               B   770
      SUM = 0.                                                          B   780
      DO 1 L=1,NODES                                                    B   790
1     SUM = SUM + FASTA(L)*KSFF(L) + THERMA(L)*KSFT(L)                  B   800
      FACTOR = PD/SUM                                                   B   810
      DO 2 L=1,NODES                                                    B   820
      FASTA(L) = FACTOR*FASTA(L)                                        B   830
2     THERMA(L) = FACTOR*THERMA(L)                                      B   840
C                                                                       B   850
3     GO TO (10, 20, 30, 40), INTTYP                                    B   860
C=======================================================================B   870
C                                                                       B   880
C                                                                       B   890
C NO VOID OR EXPOSURE INTERPOLATION                                     B   900
10    DO 12 LB=1,NP                                                     B   910
      LT = LB+NDSMNP                                                    B   920
      DO 12 L=LB,LT,NP                                                  B   930
      NTS = TABSET(L)                                                   B   940
      DF    (L) = DFI   (NTS)                                           B   950
      DT    (L) = DTI   (NTS)                                           B   960
      SDS       = SDSI  (NTS)                                           B   970
      NSFF      = NSFFI(NTS)                                            B   980
      NSFT      = NSFTI(NTS)                                            B   990
      KSFF  (L) = KSFFI(NTS)                                            B  1000
      KSFT  (L) = KSFTI(NTS)                                            B  1010
      IF ( NOXEN ) GO TO 11                                             B  1020
C XENON CORRECTION                                                      B  1030
      PS1       = PRSA1(NTS)                                            B  1040
      PS2       = PRSA2(NTS)                                            B  1050
      SAX       = SAXE  (NTS)                                           B  1060
      SA        = SATI(NTS)                                             B  1070
      SAT     = SA + (PS1*FASTA(L) + PS2*THERMA(L))/(2.0997E-5 +        B  1080
```

```
     $            THERMA(L)*SAX)                                          B  1090
      GO TO 15                                                            B  1100
11    SAT       = SATI (NTS)                                              B  1110
15    SAF       = SAFI (NTS)                                              B  1120
      C7    (L) = SAF+SDS                                                 B  1130
      TFR   (L) = SDS/SAT                                                 B  1140
      NSF1G(L)  = NSFF+TFR(L)*NSFT                                        B  1150
CHECK TO SEE IF NODE IS RODDED                                            B  1160
      IF ( NOCROD ) GO TO 12                                              B  1170
      K = (L-1)/NP+1                                                      B  1180
      IF ( NOTCH(LB) .LT. K) GO TO 12                                     B  1190
CHANGE THERMAL ABSORBTION CROSS SECTION TO ACCOUNT FOR CONTROL ROD        B  1200
      RHO = WORTH(NTS)                                                    B  1210
      SAT = NSFT*SDS*SAT/(NSFT*SDS-RHO*NSF1G(L)*SAT)                      B  1220
      TFR(L) = SDS/SAT                                                    B  1230
      NSF1G(L) = NSFF+TFR(L)*NSFT                                         B  1240
12    CONTINUE                                                            B  1250
      GO TO 60                                                            B  1260
C=================================================================       B  1270
C                                                                         B  1280
C                                                                         B  1290
C EXPOSURE INTERPOLATION ONLY                                             B  1300
20    DO 26 LB=1,NP                                                       B  1310
      LT = LB+NDSMNP                                                      B  1320
      DO 26 L=LB,LT,NP                                                    B  1330
C LOCATE EXPOSURE INTERPOLATING POINTS                                    B  1340
      E = BU(L)                                                           B  1350
      DO 22 NE = 2,IEXPTS                                                 B  1360
      IF ( E .LT. BUMASK(NE)) GO TO 24                                    B  1370
22    CONTINUE                                                            B  1380
      NE = IEXPTS                                                         B  1390
CALCULATE INTERPOLATING WEIGHTS AND INDICES                               B  1400
24    W2 = (E-BUMASK(NE-1))/(BUMASK(NE)-BUMASK(NE-1))                     B  1410
      W1 = 1.-W2                                                          B  1420
      M2 = TABSET(L)+(NE-1)*DIMTS                                         B  1430
      M1 = M2-DIMTS                                                       B  1440
```

```
C                                                                       B  1450
      DF    (L) = W1*DFI   (M1) + W2*DFI   (M2)                         B  1460
      DT    (L) = W1*DTI   (M1) + W2*DTI   (M2)                         B  1470
      SDS       = W1*SDSI  (M1) + W2*SDSI  (M2)                         B  1480
      NSFF      = W1*NSFFI(M1) + W2*NSFFI(M2)                           B  1490
      NSFT      = W1*NSFTI(M1) + W2*NSFTI(M2)                           B  1500
      KSFF  (L) = W1*KSFFI(M1) + W2*KSFFI(M2)                           B  1510
      KSFT  (L) = W1*KSFTI(M1) + W2*KSFTI(M2)                           B  1520
      IF ( NOXEN ) GO TO 21                                             B  1530
C XENON CORRECTION                                                      B  1540
      PS1       = W1*PRSA1(M1) + W2*PRSA1(M2)                           B  1550
      PS2       = W1*PRSA2(M1) + W2*PRSA2(M2)                           B  1560
      SAX       = W1*SAXE  (M1) + W2*SAXE  (M2)                         B  1570
      SA        = W1*SATI  (M1) + W2*SATI  (M2)                         B  1580
      SAT     = SA + (PS1*FASTA(L) + PS2*THERMA(L))/(2.0997E-5 +        B  1590
     $          THERMA(L)*SAX)                                          B  1600
      GO TO 25                                                          B  1610
21    SAT       = W1*SATI  (M1) + W2*SATI  (M2)                         B  1620
25    SAF       = W1*SAFI  (M1) + W2*SAFI  (M2)                         B  1630
      C7    (L) = SAF+SDS                                               B  1640
      TFR   (L) = SDS/SAT                                               B  1650
      NSF1G(L) = NSFF+TFR(L)*NSFT                                       B  1660
CHECK TO SEE IF NODE IS RODDED                                          B  1670
      IF ( NOCROD ) GO TO 26                                            B  1680
      K = (L-1)/NP+1                                                    B  1690
      IF ( NOTCH(LB) .LT. K) GO TO 26                                   B  1700
CHANGE THERMAL ABSORBTION CROSS SECTION TO ACCOUNT FOR CONTROL ROD      B  1710
      RHO = W1*WORTH(M1) + W2*WORTH(M2)                                 B  1720
      SAT = NSFT*SDS*SAT/(NSFT*SDS-RHO*NSF1G(L)*SAT)                    B  1730
      TFR(L) = SDS/SAT                                                  B  1740
      NSF1G(L) = NSFF+TFR(L)*NSFT                                       B  1750
26    CONTINUE                                                          B  1760
      GO TO 60                                                          B  1770
C=================================================================      B  1780
C                                                                       B  1790
C                                                                       B  1800
```

```
C VOID INTERPOLATION ONLY                                              B  1810
30    DO 36 LB=1,NP                                                    B  1820
      LT = LB+NDSMNP                                                   B  1830
      DO 36 L=LB,LT,NP                                                 B  1840
C LOCATE VOID INTERPOLATING POINTS                                     B  1850
      V = VOID(L)                                                      B  1860
      DO 32 NV=2,IVDPTS                                                B  1870
      IF ( V .LT. VMASK(NV)) GO TO 34                                  B  1880
32    CONTINUE                                                         B  1890
      NV = IVDPTS                                                      B  1900
CALCULATE INTERPOLATING WEIGHTS AND INDICES                            B  1910
34    W2 = (V-VMASK(NV-1))/(VMASK(NV)-VMASK(NV-1))                     B  1920
      W1 = 1.-W2                                                       B  1930
      M2 = TABSET(L)+(NV-1)*DIMTS*DIMEX                                B  1940
      M1 = M2-DIMTS*DIMEX                                              B  1950
C                                                                      B  1960
      DF    (L) = W1*DFI   (M1) + W2*DFI   (M2)                        B  1970
      DT    (L) = W1*DTI   (M1) + W2*DTI   (M2)                        B  1980
      SDS       = W1*SDSI  (M1) + W2*SDSI  (M2)                        B  1990
      NSFF      = W1*NSFFI(M1) + W2*NSFFI(M2)                          B  2000
      NSFT      = W1*NSFTI(M1) + W2*NSFTI(M2)                          B  2010
      KSFF  (L) = W1*KSFFI(M1) + W2*KSFFI(M2)                          B  2020
      KSFT  (L) = W1*KSFTI(M1) + W2*KSFTI(M2)                          B  2030
      IF ( NOXEN ) GO TO 31                                            B  2040
C XENON CORRECTION                                                     B  2050
      PS1       = W1*PRSA1(M1) + W2*PRSA1(M2)                          B  2060
      PS2       = W1*PRSA2(M1) + W2*PRSA2(M2)                          B  2070
      SAX       = W1*SAXE  (M1) + W2*SAXE  (M2)                        B  2080
      SA        = W1*SATI  (M1) + W2*SATI  (M2)                        B  2090
      SAT     = SA + (PS1*FASTA(L) + PS2*THERMA(L))/(2.0997E-5 +       B  2100
     $          THERMA(L)*SAX)                                         B  2110
      GO TO 35                                                         B  2120
31    SAT       = W1*SATI  (M1) + W2*SATI  (M2)                        B  2130
35    SAF       = W1*SAFI  (M1) + W2*SAFI  (M2)                        B  2140
      C7    (L) = SAF+SDS                                              B  2150
      TFR   (L) = SDS/SAT                                              B  2160
```

```
      NSF1G(L) = NSFF+TFR(L)*NSFT                                       B  2170
CHECK TO SEE IF NODE IS RODDED                                          B  2180
      IF ( NOCROD ) GO TO 36                                            B  2190
      K = (L-1)/NP+1                                                    B  2200
      IF ( NOTCH(LB) .LT. K) GO TO 36                                   B  2210
CHANGE THERMAL ABSORBTION CROSS SECTION TO ACCOUNT FOR CONTROL ROD      B  2220
      RHO = W1*WORTH(M1) + W2*WORTH(M2)                                 B  2230
      SAT = NSFT*SDS*SAT/(NSFT*SDS-RHO*NSF1G(L)*SAT)                    B  2240
      TFR(L) = SDS/SAT                                                  B  2250
      NSF1G(L) = NSFF+TFR(L)*NSFT                                       B  2260
36    CONTINUE                                                          B  2270
      GO TO 60                                                          B  2280
C=================================================================      B  2290
C                                                                       B  2300
C                                                                       B  2310
C EXPOSURE AND VOID INTERPOLATION                                       B  2320
40    DO 50 LB=1,NP                                                     B  2330
      LT = LB+NDSMNP                                                    B  2340
      DO 50 L=LB,LT,NP                                                  B  2350
C LOCATE EXPOSURE INTERPOLATING POINTS                                  B  2360
      E = BU(L)                                                         B  2370
      DO 42 NE = 2,IEXPTS                                               B  2380
      IF ( E .LT. BUMASK(NE)) GO TO 44                                  B  2390
42    CONTINUE                                                          B  2400
      NE = IEXPTS                                                       B  2410
C LOCATE VOID INTERPOLATING POINTS                                      B  2420
44    V = VOID(L)                                                       B  2430
      DO 46 NV=2,IVDPTS                                                 B  2440
      IF ( V .LT. VMASK(NV)) GO TO 48                                   B  2450
46    CONTINUE                                                          B  2460
      NV = IVDPTS                                                       B  2470
CALCULATE INTERPOLATING WEIGHTS AND INDICES                             B  2480
48    WE = (E-BUMASK (NE-1))/(BUMASK (NE)-BUMASK (NE-1))                B  2490
      WV = (V-VMASK(NV-1))/(VMASK(NV)-VMASK(NV-1))                      B  2500
      W4 = WE*WV                                                        B  2510
      W3 = WE-W4                                                        B  2520
```

```
      W2 = WV-W4                                                        B  2530
      W1 = 1.-W2-WE                                                     B  2540
      M4 = TABSET(L)+DIMTS*((NE-1)+DIMEX*(NV-1))                        B  2550
      M3 = M4-DIMTS*DIMEX                                               B  2560
      M2 = M4-DIMTS                                                     B  2570
      M1 = M3-DIMTS                                                     B  2580
C                                                                       B  2590
      DF    (L) = W1*DFI   (M1) + W2*DFI   (M2) +                       B  2600
     $           W3*DFI   (M3) + W4*DFI   (M4)                          B  2610
      DT    (L) = W1*DTI   (M1) + W2*DTI   (M2) +                       B  2620
     $           W3*DTI   (M3) + W4*DTI   (M4)                          B  2630
      SDS       = W1*SDSI  (M1) + W2*SDSI  (M2) +                       B  2640
     $           W3*SDSI  (M3) + W4*SDSI  (M4)                          B  2650
      NSFF      = W1*NSFFI(M1) + W2*NSFFI(M2) +                         B  2660
     $           W3*NSFFI(M3) + W4*NSFFI(M4)                            B  2670
      NSFT      = W1*NSFTI(M1) + W2*NSFTI(M2) +                         B  2680
     $           W3*NSFTI(M3) + W4*NSFTI(M4)                            B  2690
      KSFF  (L) = W1*KSFFI(M1) + W2*KSFFI(M2) +                         B  2700
     $           W3*KSFFI(M3) + W4*KSFFI(M4)                            B  2710
      KSFT  (L) = W1*KSFTI(M1) + W2*KSFTI(M2) +                         B  2720
     $           W3*KSFTI(M3) + W4*KSFTI(M4)                            B  2730
      IF ( NOXEN ) GO TO 41                                             B  2740
C XENON CORRECTION                                                      B  2750
      PS1       = W1*PRSA1(M1) + W2*PRSA1(M2) +                         B  2760
     $           W3*PRSA1(M3) + W4*PRSA1(M4)                            B  2770
      PS2       = W1*PRSA2(M1) + W2*PRSA2(M2) +                         B  2780
     $           W3*PRSA2(M3) + W4*PRSA2(M4)                            B  2790
      SAX       = W1*SAXE  (M1) + W2*SAXE  (M2) +                       B  2800
     $           W3*SAXE  (M3) + W4*SAXE  (M4)                          B  2810
      SA        = W1*SATI  (M1) + W2*SATI  (M2) +                       B  2820
     $           W3*SATI  (M3) + W4*SATI  (M4)                          B  2830
      SAT     = SA + (PS1*FASTA(L) + PS2*THERMA(L))/(2.0997E-5 +        B  2840
     $          THERMA(L)*SAX)                                          B  2850
      GO TO 45                                                          B  2860
41    SAT       = W1*SATI  (M1) + W2*SATI  (M2) +                       B  2870
     $           W3*SATI  (M3) + W4*SATI  (M4)                          B  2880
```

```
45    SAF       = W1*SAFI (M1) + W2*SAFI (M2) +                          B  2890
     $            W3*SAFI (M3) + W4*SAFI (M4)                            B  2900
      C7    (L) = SAF+SDS                                               B  2910
      TFR   (L) = SDS/SAT                                               B  2920
      NSF1G(L)  = NSFF+TFR(L)*NSFT                                      B  2930
CHECK TO SEE IF NODE IS RODDED                                          B  2940
      IF ( NOCROD ) GO TO 50                                            B  2950
      K = (L-1)/NP+1                                                    B  2960
      IF ( NOTCH(LB) .LT. K) GO TO 50                                   B  2970
CHANGE THERMAL ABSORBTION CROSS SECTION TO ACCOUNT FOR CONTROL ROD      B  2980
      RHO = W1*WORTH(M1) + W2*WORTH(M2) +                               B  2990
     $      W3*WORTH(M3) + W4*WORTH(M4)                                 B  3000
      SAT = NSFT*SDS*SAT/(NSFT*SDS-RHO*NSF1G(L)*SAT)                    B  3010
      TFR(L) = SDS/SAT                                                  B  3020
      NSF1G(L) = NSFF+TFR(L)*NSFT                                       B  3030
50    CONTINUE                                                          B  3040
C                                                                       B  3050
C=======================================================================B  3060
C                                                                       B  3070
C                                                                       B  3080
C ADD B.C. CONTRIBUTIONS TO C7                                          B  3090
C FACES 5 & 6                                                           B  3100
60    DO 62 L=1,NP                                                      B  3110
      C7(L) = C7(L)-GZ*DF(L)*(AF5+BF5*VOID(L)-1.)                       B  3120
      LL = L+NDSMNP                                                     B  3130
62    C7(LL) = C7(LL)-GZ*DF(LL)*(AF6+BF6*VOID(LL)-1.)                   B  3140
C FACE 1                                                                B  3150
      DO 64 LB=1,NX                                                     B  3160
      LT = LB+NDSMNP                                                    B  3170
      DO 64 L=LB,LT,NP                                                  B  3180
64    C7(L) = C7(L)-GX*DF(L)*(AF1+BF1*VOID(L)-1.)                       B  3190
C FACE 3                                                                B  3200
      LB = 1                                                            B  3210
      DO 68 I=1,NX                                                      B  3220
      LT = LB+NDSMNP                                                    B  3230
      DO 66 L=LB,LT,NP                                                  B  3240
```

```
66    C7(L) = C7(L)-GX*DF(L)*(AF3+BF3*VOID(L)-1.)                       B  3250
68    LB = LB+NCOL(I)                                                   B  3260
C                                                                       B  3270
      IF ( QTRKOR ) GO TO 76                                            B  3280
C                                                                       B  3290
C-----------------------------------------------------------------------B  3300
C RECTANGULAR PLANE GEOMETRY                                            B  3310
C-----------------------------------------------------------------------B  3320
C                                                                       B  3330
C FACE 2                                                                B  3340
      LB1 = NP-NXM1                                                     B  3350
      DO 72 LB=LB1,NP                                                   B  3360
      LT = LB+NDSMNP                                                    B  3370
      DO 72 L=LB,LT,NP                                                  B  3380
72    C7(L) = C7(L)-GX*DF(L)*(AF2+BF2*VOID(L)-1.)                       B  3390
C-----------------------------------------------------------------------B  3400
C                                                                       B  3410
C FACE 4                                                                B  3420
      DO 74 LB=NX,NP,NX                                                 B  3430
      LT = LB+NDSMNP                                                    B  3440
      DO 74 L=LB,LT,NP                                                  B  3450
74    C7(L) = C7(L)-GX*DF(L)*(AF4+BF4*VOID(L)-1.)                       B  3460
      GO TO 131                                                         B  3470
C                                                                       B  3480
C-----------------------------------------------------------------------B  3490
C                                                                       B  3500
C QUARTER CORE PLANE GEOMETRY                                           B  3510
C-----------------------------------------------------------------------B  3520
C                                                                       B  3530
C FACE 2                                                                B  3540
76    J = 0                                                             B  3550
      L1 = NP-NCOL(NX)+1                                                B  3560
      L2 = NP                                                           B  3570
      DO 78 LB=L1,NP                                                    B  3580
      LT = LB+NDSMNP                                                    B  3590
      J = J+1                                                           B  3600
```

```
      AF = AFQ(J)-1.                                                    B  3610
      BF = BFQ(J)                                                       B  3620
      DO 78 L=LB,LT,NP                                                  B  3630
78    C7(L) = C7(L)-GX*DF(L)*(AF+BF*VOID(L))                            B  3640
      I = NX                                                            B  3650
      NCL = NCOL(NX)                                                    B  3660
      DO 82 IC=2,NX                                                     B  3670
      I = I-1                                                           B  3680
      NCI = NCOL(I)                                                     B  3690
      L2 = L2-NCL                                                       B  3700
      L1 = L2-NCI+NCL+1                                                 B  3710
      IF ( NCI .EQ. NCL) GO TO 82                                       B  3720
      DO 80 LB=L1,L2                                                    B  3730
      LT = LB+NDSMNP                                                    B  3740
      J = J+1                                                           B  3750
      AF = AFQ(J)-1.                                                    B  3760
      BF = BFQ(J)                                                       B  3770
      DO 80 L=LB,LT,NP                                                  B  3780
80    C7(L) = C7(L)-GX*DF(L)*(AF+BF*VOID(L))                            B  3790
82    NCL = NCI                                                         B  3800
C                                                                       B  3810
C FACE 4                                                                B  3820
      LB = 0                                                            B  3830
      DO 84 I=1,NX                                                      B  3840
      LB = LB+NCOL(I)                                                   B  3850
      LT = LB+NDSMNP                                                    B  3860
      AF = AFQ(I)-1.                                                    B  3870
      BF = BFQ(I)                                                       B  3880
      DO 84 L=LB,LT,NP                                                  B  3890
84    C7(L) = C7(L)-GX*DF(L)*(AF+BF*VOID(L))                            B  3900
C-----------------------------------------------------------------------B  3910
C                                                                       B  3920
CALCULATE C5 & C6                                                       B  3930
131   DO 132 L=1,NDSMNP                                                 B  3940
      LT = L+NP                                                         B  3950
      C6(L) = GZ*DF(L)*DF(LT)/(DF(L)+DF(LT))                            B  3960
```

```
      C7(L) = C7(L)+C6(L)                                               B  3970
132   C7(LT) = C7(LT)+C6(L)                                             B  3980
C-----------------------------------------------------------------------B  3990
C                                                                       B  4000
CALCULATE C3 & C4                                                       B  4010
      LR = -1                                                           B  4020
      DO 138 I=1,NX                                                     B  4030
      LL = LR+2                                                         B  4040
      LR = LR+NCOL(I)                                                   B  4050
      IF ( 1-NCOL(I)) 134,138,138                                       B  4060
134   DO 136 LB=LL,LR                                                   B  4070
      LT = LB+NDSMNP                                                    B  4080
      DO 136 L=LB,LT,NP                                                 B  4090
      LP = L+1                                                          B  4100
      C4(L) = GX*DF(L)*DF(LP)/(DF(L)+DF(LP))                            B  4110
      C7(L) = C7(L)+C4(L)                                               B  4120
136   C7(LP) = C7(LP)+C4(L)                                             B  4130
138   CONTINUE                                                          B  4140
C-----------------------------------------------------------------------B  4150
C                                                                       B  4160
CALCULATE C1 & C2                                                       B  4170
      LL = 1                                                            B  4180
      NCOLI = 0                                                         B  4190
      DO 140 I=1,NXM1                                                   B  4200
      LL = LL+NCOLI                                                     B  4210
      NCOLI = NCOL(I)                                                   B  4220
      LR = LL+NCOL(I+1)-1                                               B  4230
      DO 140 LB=LL,LR                                                   B  4240
      LT = LB+NDSMNP                                                    B  4250
      DO 140 L=LB,LT,NP                                                 B  4260
      LP = L+NCOLI                                                      B  4270
      C2(L) = GX*DF(L)*DF(LP)/(DF(L)+DF(LP))                            B  4280
      C7(L) = C7(L)+C2(L)                                               B  4290
140   C7(LP) = C7(LP)+C2(L)                                             B  4300
C                                                                       B  4310
      RETURN                                                            B  4320
```

END

B 4330

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE STG
C
C---------------------------------------------------------------------
C ROUTINE TO CALCULATE POWER DISTRIBUTION USING SIMULATED TWO-GROUP
C DIFFUSION THEORY MODEL
C---------------------------------------------------------------------
C
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /NODAL / DF     (N01), DT     (N01), KSFF   (N01)
     $,               KSFT   (N01), TFR    (N01), NSF1G  (N01)
     $,               C2     (N01), C4     (N01), C6     (N03)
     $,               C7     (N01)
      REAL KSFF, KSFT, NSF1G
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL   (N04)
      COMMON /BC    / AF1, AF3, AF5, AF6, AFQ(N04),
     $                BF1, BF3, BF5, BF6, BFQ(N04),
     $                AT1, AT3, AT5, AT6, ATQ(N04),
     $                BT1, BT3, BT5, BT6, BTQ(N04)
      EQUIVALENCE (AFQ(1), AF2), (AFQ(2), AF4),
     $            (BFQ(1), BF2), (BFQ(2), BF4),
     $            (ATQ(1), AT2), (ATQ(2), AT4),
     $            (BTQ(1), BT2), (BTQ(2), BT4)
      COMMON /CONVRG/   MAXI,  MAXO,  MAXP,  EPSO,  EPSP,  ALPHA,   SOR
      LOGICAL SOR
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)
     $,                 NOXE,  FIRST
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST
```

```
      COMMON /WEIGHT/   R,  CF,  CT, RCF, RCT, B1N, B2N                 C
      DIMENSION  T(N01), S(N01)                                         C
      REAL KEFF, LAMDA                                                  C
      DIMENSION FLX(N01), FO(N01), SAVE(N01), PO(N01)                   C
      EQUIVALENCE (FO(1),  PO(1), T(1)), (FASTA(1), SAVE(1))            C
      LOGICAL CONVSR, FLAG1, FLAG2                                      C
C                                                                       C
C-----------------------------------------------------------------------C
C                                                                       C
C C2, C4, C6, &C7 ARE FAST FLUX COUPLING COEFFICENTS                    C
C F       = POINTWISE FAST FLUX                                         C
C T       = POINTWISE THERMAL FLUX                                      C
C FASTA   = NODE AVERAGED FAST FLUX                                     C
C THERMA  = NODE AVERAGED THERMAL FLUX                                  C
C POWER   = RELATIVE POWER OF NODE                                      C
C                                                                       C
C-----------------------------------------------------------------------C
C                                                                       C
      MAXOUT = MAXO                                                     C
      FLAG1 = .FALSE.                                                   C
      CALL INTERP                                                       C
      FIRST = .FALSE.                                                   C
      ITPOWR = 1                                                        C
      KEFF = 1.                                                         C
      SR = 0.                                                           C
      TLFIS = 0.                                                        C
      DO 603 L=1,NODES                                                  C
      S(L) = F(L)*NSF1G(L)                                              C
603   TLFIS = TLFIS + S(L)                                              C
      IF ( .NOT. NOHAL ) GO TO 602                                      C
      CALL HEADER (1)                                                   C
      WRITE (6,1000)                                                    C
C BEGINNING OF POWER ITERATION                                          C
602   ITOUT = 0                                                         C
      CONVSR = .FALSE.                                                  C
      RSQ = 1.                                                          C
```

```
      IF ( NOHAL ) WRITE (6,1003) ITPOWR                                C   730
C=================================================================== C   740
C                                                                     C   750
C BEGINING OF OUTER ITERATION                                         C   760
500   ITIN = 0                                                        C   770
C=================================================================== C   780
C                                                                     C   790
C                                                                     C   800
C BEGINING OF INNER ITERATION                                         C   810
502   F(1) = (S(1)                          + C2(1)*F(NX+1)           C   820
     $                                      + C4(1)*F(2   )           C   830
     $                                      + C6(1)*F(1+NP) )/C7(1)   C   840
      DO 2 L=2,NXM1                                                   C   850
2     F(L) = (S(L)                          + C2(L)*F(L+NX)           C   860
     $                + C4(L-1 )*F(L-1 )    + C4(L)*F(L+1 )           C   870
     $                                      + C6(L)*F(L+NP) )/C7(L)   C   880
      F(NX) = (S(NX)                        + C2(NX)*F(NX+NX)         C   890
     $                + C4(NXM1)*F(NXM1)                              C   900
     $                                      + C6(NX)*F(NX+NP) )/C7(NX) C   910
      I2 = NX                                                         C   920
      LR = NX                                                         C   930
      DO 6 I=2,NXM1                                                   C   940
      I1 = I2                                                         C   950
      I2 = NCOL(I)                                                    C   960
      LL = LR+1                                                       C   970
      LR = LR+I2                                                      C   980
      LRM1 = LR-1                                                     C   990
      LLP1 = LL+1                                                     C  1000
      F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1) + C2(LL)*F(LL+I2)           C  1010
     $                                      + C4(LL)*F(LLP1)          C  1020
     $                                      + C6(LL)*F(LL+NP) )/C7(LL) C  1030
      IF ( LLP1 .EQ. LR) GO TO 6                                      C  1040
      DO 4 L=LLP1,LRM1                                                C  1050
4     F(L) = (S(L) + C2(L-I1)*F(L-I1) + C2(L)*F(L+I2)                 C  1060
     $                + C4(L-1 )*F(L-1 )    + C4(L)*F(L+1)            C  1070
     $                                      + C6(L)*F(L+NP) )/C7(L)   C  1080
```

```
6     F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1) + C2(LR)*F(LR+I2)
     $              + C4(LRM1 )*F(LRM1 )
     $                                  + C6(LR)*F(LR+NP) )/C7(LR)
      I1 = I2
      LL = LR+1
      LR = NP
      LRM1 = LR-1
      LLP1 = LL+1
      IF ( LRM1-LL) 10,12,14
10    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)
     $                                  + C6(LL)*F(LL+NP) )/C7(LL)
      GO TO 20
12    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)
     $                                  + C4(LL)*F(LLP1)
     $                                  + C6(LL)*F(LL+NP) )/C7(LL)
      GO TO 18
14    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)
     $                                  + C4(LL)*F(LLP1)
     $                                  + C6(LL)*F(LL+NP) )/C7(LL)
      DO 16 L=LLP1,LRM1
16    F(L) = (S(L) + C2(L-I1)*F(L-I1)
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)
     $                                  + C6(L)*F(L+NP) )/C7(L)
18    F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1)
     $              + C4(LRM1 )*F(LRM1 )
     $                                  + C6(LR)*F(LR+NP) )/C7(LR)
20    DO 40 K=3,NZ
      I2 = NX
      LL = LR+1
      LR = LR+I2
      LRM1 = LR-1
      LLP1 = LL+1
      F(LL) = (S(LL)                     + C2(LL)*F(LL+I2)
     $                                  + C4(LL)*F(LLP1)
     $              + C6(LL-NP)*F(LL-NP) + C6(LL)*F(LL+NP) )/C7(LL)
      DO 22 L=LLP1,LRM1
```

```
22    F(L) = (S(L)                          + C2(L)*F(L+I2)                    C  1450
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                          C  1460
     $              + C6(L-NP)*F(L-NP) + C6(L)*F(L+NP) )/C7(L)                 C  1470
      F(LR) = (S(LR)                          + C2(LR)*F(LR+I2)                C  1480
     $              + C4(LRM1 )*F(LRM1 )                                       C  1490
     $              + C6(LR-NP)*F(LR-NP) + C6(LR)*F(LR+NP) )/C7(LR)            C  1500
      DO 26 I=2,NXM1                                                           C  1510
      I1 = I2                                                                  C  1520
      I2 = NCOL(I)                                                             C  1530
      LL = LR+1                                                                C  1540
      LR = LR+I2                                                               C  1550
      LRM1 = LR-1                                                              C  1560
      LLP1 = LL+1                                                              C  1570
      F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1) + C2(LL)*F(LL+I2)                    C  1580
     $                                     + C4(LL)*F(LLP1)                    C  1590
     $              + C6(LL-NP)*F(LL-NP) + C6(LL)*F(LL+NP) )/C7(LL)            C  1600
      IF ( LLP1 .EQ. LR) GO TO 26                                              C  1610
      DO 24 L=LLP1,LRM1                                                        C  1620
24    F(L) = (S(L) + C2(L-I1)*F(L-I1) + C2(L)*F(L+I2)                          C  1630
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                          C  1640
     $              + C6(L-NP)*F(L-NP) + C6(L)*F(L+NP) )/C7(L)                 C  1650
26    F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1) + C2(LR)*F(LR+I2)                    C  1660
     $              + C4(LRM1 )*F(LRM1 )                                       C  1670
     $              + C6(LR-NP)*F(LR-NP) + C6(LR)*F(LR+NP) )/C7(LR)            C  1680
      I1 = I2                                                                  C  1690
      LL = LR+1                                                                C  1700
      LR = LR+NCOL(NX)                                                         C  1710
      LRM1 = LR-1                                                              C  1720
      LLP1 = LL+1                                                              C  1730
      IF ( LRM1-LL) 30,32,34                                                   C  1740
30    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)                                      C  1750
     $              + C6(LL-NP)*F(LL-NP) + C6(LL)*F(LL+NP) )/C7(LL)            C  1760
      GO TO 40                                                                 C  1770
32    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)                                      C  1780
     $                                     + C4(LL)*F(LLP1)                    C  1790
     $              + C6(LL-NP)*F(LL-NP) + C6(LL)*F(LL+NP) )/C7(LL)            C  1800
```

```
      GO TO 38                                                          C  1810
34    F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)                               C  1820
     $                                 + C4(LL)*F(LLP1)                 C  1830
     $              + C6(LL-NP)*F(LL-NP) + C6(LL)*F(LL+NP) )/C7(LL)     C  1840
      DO 36 L=LLP1,LRM1                                                 C  1850
36    F(L) = (S(L) + C2(L-I1)*F(L-I1)                                   C  1860
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                   C  1870
     $              + C6(L-NP)*F(L-NP) + C6(L)*F(L+NP) )/C7(L)          C  1880
38    F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1)                               C  1890
     $              + C4(LRM1 )*F(LRM1 )                                C  1900
     $              + C6(LR-NP)*F(LR-NP) + C6(LR)*F(LR+NP) )/C7(LR)     C  1910
40    CONTINUE                                                          C  1920
      LL = LR+1                                                         C  1930
      LR = LR+NX                                                        C  1940
      LLP1 = LL+1                                                       C  1950
      LRM1 = LR-1                                                       C  1960
      F(LL) = (S(LL)                     + C2(LL)*F(LL+NX)              C  1970
     $                                 + C4(LL)*F(LLP1)                 C  1980
     $              + C6(LL-NP)*F(LL-NP)                  )/C7(LL)       C  1990
      DO 42 L=LLP1,LRM1                                                 C  2000
42    F(L) = (S(L)                       + C2(L)*F(L+NX)                C  2010
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                   C  2020
     $              + C6(L-NP)*F(L-NP)                   )/C7(L)        C  2030
      F(LR) = (S(LR)                     + C2(LR)*F(LR+NX)              C  2040
     $              + C4(LRM1 )*F(LRM1 )                                C  2050
     $              + C6(LR-NP)*F(LR-NP)                  )/C7(LR)       C  2060
      I2 = NX                                                           C  2070
      DO 54 I=2,NXM1                                                    C  2080
      I1 = I2                                                           C  2090
      I2 = NCOL(I)                                                      C  2100
      LL = LR+1                                                         C  2110
      LR = LR+I2                                                        C  2120
      LLP1 = LL+1                                                       C  2130
      LRM1 = LR-1                                                       C  2140
      F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1) + C2(LL)*F(LL+I2)             C  2150
     $                                 + C4(LL)*F(LLP1)                 C  2160
```

```
     $              + C6(LL-NP)*F(LL-NP)                    )/C7(LL)          C  2170
      IF ( LRM1 .EQ. LL) GO TO 48                                             C  2180
      DO 46 L=LLP1,LRM1                                                       C  2190
      IF ( L+I2-NODES) 942,942,44                                             C  2200
942   F(L) = (S(L) + C2(L-I1)*F(L-I1) + C2(L)*F(L+I2)                         C  2210
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                         C  2220
     $              + C6(L-NP)*F(L-NP)                  )/C7(L)               C  2230
      GO TO 46                                                                C  2240
44    F(L) = (S(L) + C2(L-I1)*F(L-I1)                                         C  2250
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                         C  2260
     $              + C6(L-NP)*F(L-NP)                  )/C7(L)               C  2270
46    CONTINUE                                                                C  2280
48    IF ( LR+I2-NODES) 50,50,52                                              C  2290
50    F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1) + C2(LR)*F(LR+I2)                   C  2300
     $              + C4(LRM1 )*F(LRM1 )                                      C  2310
     $              + C6(LR-NP)*F(LR-NP)                )/C7(LR)              C  2320
      GO TO 54                                                                C  2330
52    F(LR) = (S(LR) + C2(LR-I1)*F(LR-I1)                                     C  2340
     $              + C4(LRM1 )*F(LRM1 )                                      C  2350
     $              + C6(LR-NP)*F(LR-NP)                )/C7(LR)              C  2360
54    CONTINUE                                                                C  2370
      I1 = I2                                                                 C  2380
      IF ( 2-NCOL(NX) ) 60,58,56                                              C  2390
56    F(NODES) = (S(NODES) + C2(NODES-I1)*F(NODES-I1)                         C  2400
     $              + C6(NDSMNP)*F(NDSMNP)                  )/C7(NODES)       C  2410
      GO TO 138                                                               C  2420
58    LL = NODES-1                                                            C  2430
      F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)                                     C  2440
     $                              + C4(LL)*F(NODES)                        C  2450
     $              + C6(LL-NP)*F(LL-NP)                )/C7(LL)              C  2460
      GO TO 64                                                                C  2470
60    LL = LR+1                                                               C  2480
      LLP1 = LL+1                                                             C  2490
      LRM1 = NODES-1                                                          C  2500
      F(LL) = (S(LL) + C2(LL-I1)*F(LL-I1)                                     C  2510
     $                              + C4(LL)*F(LLP1)                         C  2520
```

```
     $              + C6(LL-NP)*F(LL-NP)                    )/C7(LL)          C  2530
      DO 62 L=LLP1,LRM1                                                       C  2540
62    F(L) = (S(L) + C2(L-I1)*F(L-I1)                                         C  2550
     $              + C4(L-1 )*F(L-1 ) + C4(L)*F(L+1)                         C  2560
     $              + C6(L-NP)*F(L-NP)                    )/C7(L)             C  2570
64    F(NODES) = (S(NODES) + C2(NODES-I1)*F(NODES-I1)                         C  2580
     $              + C4(NODES-1 )*F(NODES-1 )                                C  2590
     $              + C6(NDSMNP)*F(NDSMNP)                    )/C7(NODES)     C  2600
C=====================================================================      C  2610
C                                                                            C  2620
C                                                                            C  2630
138   ITIN = ITIN + 1                                                        C  2640
C---------------------------------------------------------------------      C  2650
C                                                                            C  2660
C SUCCESSIVE OVER-RELAXATION ROUTINE                                         C  2670
      IF ( .NOT. SOR ) GO TO 1396                                            C  2680
C                                                                            C  2690
      IF ( CONVSR ) GO TO 804                                                C  2700
C                                                                            C  2710
CALCULATE SPECTRAL RADIUS                                                    C  2720
      RSQO = RSQ                                                             C  2730
      RSQ = 0.                                                               C  2740
      DO 800 L=1,NODES                                                       C  2750
      RSQ = RSQ + ( F(L) - FO(L) )**2                                        C  2760
800   FO(L) = F(L)                                                           C  2770
      SRO = SR                                                               C  2780
      SR = SQRT (RSQ/RSQO)                                                   C  2790
C                                                                            C  2800
      IF ( ABS (1.-SRO/SR) .LE. .001 ) GO TO 803                             C  2810
      IF ( ITIN .GE. 20 ) GO TO 803                                          C  2820
      GO TO 502                                                              C  2830
C                                                                            C  2840
803   CONVSR = .TRUE.                                                        C  2850
      IF ( SR .GE. 1. ) SOR = .FALSE.                                        C  2860
      IF ( .NOT. SOR ) GO TO 1396                                            C  2870
      WRITE (6,1005) SR                                                      C  2880
```

```
      IF ( SR .LT. 1. ) GO TO 806                                       C  2890
      ALP = 2./(1. + SQRT (1. - SR))                                    C  2900
      GO TO 1396                                                        C  2910
806   ALP = 1.                                                          C  2920
      GO TO 1396                                                        C  2930
804   DO 805 L=1,NODES                                                  C  2940
      F(L) = FO(L) + ALP* (F(L) - FO(L))                                C  2950
805   FO(L) = F(L)                                                      C  2960
C                                                                       C  2970
1396  IF ( ITIN.LT.MAXI) GO TO 502                                      C  2980
C-----------------------------------------------------------------------C  2990
C                                                                       C  3000
CALCULATE K-EFF                                                         C  3010
      TLFISO = TLFIS                                                    C  3020
      TLFIS = 0.                                                        C  3030
      DO 550 L=1,NODES                                                  C  3040
550   TLFIS = TLFIS+F(L)*NSF1G(L)                                       C  3050
      LAMDA = TLFIS/TLFISO                                              C  3060
      KEFF = KEFF*LAMDA                                                 C  3070
      TESTO = ABS (1. - TLFISO/TLFIS)                                   C  3080
      ITOUT = ITOUT+1                                                   C  3090
      IF ( ITOUT .EQ. 1) GO TO 554                                      C  3100
C=======================================================================C  3110
C                                                                       C  3120
C                                                                       C  3130
C ACCELERATE SOURCE BY SUCCESSIVE OVER-RELAXATION                       C  3140
      TFISOR = 0.                                                       C  3150
      DO 552 L=1,NODES                                                  C  3160
      SAVE(L) = SAVE(L)+ALPHA*(F(L)-SAVE(L))                            C  3170
552   TFISOR = TFISOR+SAVE(L)*NSF1G(L)                                  C  3180
      GO TO 558                                                         C  3190
554   TFISOR = TLFIS                                                    C  3200
      DO 556 L=1,NODES                                                  C  3210
556   SAVE(L) = F(L)                                                    C  3220
558   TEMP = TLFIS/TFISOR/KEFF                                          C  3230
      DO 560 L=1,NODES                                                  C  3240
```

```
      S(L) = SAVE(L)*NSF1G(L)*TEMP                                      C  3250
560   SAVE(L) = F(L)                                                    C  3260
      TLFISO = TLFIS                                                    C  3270
C=================================================================== C  3280
C                                                                       C  3290
CONVERGENCE CHECK                                                       C  3300
      WRITE (6,1002) ITOUT,ITIN,KEFF,TESTO                              C  3310
      IF ( ITOUT .GE. MAXOUT) GO TO 200                                 C  3320
      IF ( TESTO .GT. EPSO) GO TO 500                                   C  3330
C=================================================================== C  3340
C                                                                       C  3350
C NODAL WEIGHTING SECTION                                               C  3360
C------------------------------------------------------------------- C  3370
C                                                                       C  3380
CALCULATE AVERAGED FAST FLUX                                            C  3390
200   DO 202 L=1,NODES                                                  C  3400
      FASTA(L) = B1N*F(L)                                               C  3410
202   FLX(L) = CF*F(L)*DF(L)                                            C  3420
C FACE 5 BOUNDARY                                                       C  3430
      DO 204 L=1,NP                                                     C  3440
204   FASTA(L) = FASTA(L)+RCF*(AF5+BF5*VOID(L))*F(L)                    C  3450
C FACE 6 BOUNDARY                                                       C  3460
      L1 = NDSMNP+1                                                     C  3470
      DO 206 L=L1,NODES                                                 C  3480
206   FASTA(L) = FASTA(L)+RCF*(AF6+BF6*VOID(L))*F(L)                    C  3490
C HORIZONTAL PLANES                                                     C  3500
      DO 208 L=1,NDSMNP                                                 C  3510
      LP = L+NP                                                         C  3520
      FF = R*(FLX(L)+FLX(LP))/(DF(L)+DF(LP))                            C  3530
      FASTA(L) = FASTA(L)+FF                                            C  3540
208   FASTA(LP) = FASTA(LP)+FF                                          C  3550
C FACE 1 BOUNDARY                                                       C  3560
      DO 210 LB=1,NX                                                    C  3570
      LT = LB+NDSMNP                                                    C  3580
      DO 210 L=LB,LT,NP                                                 C  3590
210   FASTA(L) = FASTA(L)+CF*(AF1+BF1*VOID(L))*F(L)                     C  3600
```

```
C                                                                       C  3610
      IF ( QTRKOR ) GO TO 218                                           C  3620
C RECTANGULAR PLANE GEOMETRY                                            C  3630
C FACE 2                                                                C  3640
      L1 = NP-NXM1                                                      C  3650
      DO 214 LB=L1,NP                                                   C  3660
      LT = LB+NDSMNP                                                    C  3670
      DO 214 L=LB,LT,NP                                                 C  3680
214   FASTA(L) = FASTA(L)+CF*(AF2+BF2*VOID(L))*F(L)                     C  3690
C FACE 4                                                                C  3700
      DO 216 LB=NX,NP,NX                                                C  3710
      LT = LB+NDSMNP                                                    C  3720
      DO 216 L=LB,LT,NP                                                 C  3730
216   FASTA(L) = FASTA(L)+CF*(AF4+BF4*VOID(L))*F(L)                     C  3740
      GO TO 272                                                         C  3750
C                                                                       C  3760
C QUARTER CORE PLANE GEOMETRY                                           C  3770
C FACE 2                                                                C  3780
218   J = 0                                                             C  3790
      L1 = NP-NCOL(NX)+1                                                C  3800
      L2 = NP                                                           C  3810
      DO 220 LB=L1,L2                                                   C  3820
      LT = LB+NDSMNP                                                    C  3830
      J = J+1                                                           C  3840
      AF = AFQ(J)                                                       C  3850
      BF = BFQ(J)                                                       C  3860
      DO 220 L=LB,LT,NP                                                 C  3870
220   FASTA(L) = FASTA(L)+CF*(AF+BF*VOID(L))*F(L)                       C  3880
      I = NX                                                            C  3890
      NCL = NCOL(NX)                                                    C  3900
      DO 224 IC=2,NX                                                    C  3910
      I = I-1                                                           C  3920
      NCI = NCOL(I)                                                     C  3930
      L2 = L2-NCL                                                       C  3940
      L1 = L2-NCI+NCL+1                                                 C  3950
      IF ( NCI .EQ. NCL) GO TO 224                                      C  3960
```

```
      DO 222 LB=L1,L2                                                   C  3970
      LT = LB+NDSMNP                                                    C  3980
      J = J+1                                                           C  3990
      AF = AFQ(J)                                                       C  4000
      BF = BFQ(J)                                                       C  4010
      DO 222 L=LB,LT,NP                                                 C  4020
222   FASTA(L) = FASTA(L)+CF*(AF+BF*VOID(L))*F(L)                       C  4030
224   NCL = NCI                                                         C  4040
C FACE 4                                                                C  4050
      LB = 0                                                            C  4060
      DO 226 I=1,NX                                                     C  4070
      LB = LB+NCOL(I)                                                   C  4080
      LT = LB+NDSMNP                                                    C  4090
      AF = AFQ(I)                                                       C  4100
      BF = BFQ(I)                                                       C  4110
      DO 226 L=LB,LT,NP                                                 C  4120
226   FASTA(L) = FASTA(L)+CF*(AF+BF*VOID(L))*F(L)                       C  4130
C                                                                       C  4140
C FACE 3 BOUNDARY                                                       C  4150
272   LB = 1                                                            C  4160
      DO 276 I=1,NX                                                     C  4170
      LT = LB+NDSMNP                                                    C  4180
      DO 274 L=LB,LT,NP                                                 C  4190
274   FASTA(L) = FASTA(L)+CF*(AF3+BF3*VOID(L))*F(L)                     C  4200
276   LB = LB+NCOL(I)                                                   C  4210
C J FACES                                                               C  4220
      L2 = -1                                                           C  4230
      DO 280 I=1,NX                                                     C  4240
      L1 = L2+2                                                         C  4250
      L2 = L2+NCOL(I)                                                   C  4260
      IF ( L2 .LT. L1) GO TO 280                                        C  4270
      DO 278 LB=L1,L2                                                   C  4280
      LT = LB+NDSMNP                                                    C  4290
      DO 278 L=LB,LT,NP                                                 C  4300
      LP = L+1                                                          C  4310
      FF = (FLX(L)+FLX(LP))/(DF(L)+DF(LP))                              C  4320
```

```
      FASTA(L) = FASTA(L)+FF                                            C  4330
278   FASTA(LP) = FASTA(LP)+FF                                          C  4340
280   CONTINUE                                                          C  4350
C I FACES                                                               C  4360
      LR = 0                                                            C  4370
      NCI = NX                                                          C  4380
      DO 284 I=1,NXM1                                                   C  4390
      NCIP = NCOL(I+1)                                                  C  4400
      L2 = LR+NCIP                                                      C  4410
      L1 = LR+1                                                         C  4420
      LR = LR+NCI                                                       C  4430
      DO 282 LB=L1,L2                                                   C  4440
      LT = LB+NDSMNP                                                    C  4450
      DO 282 L=LB,LT,NP                                                 C  4460
      LP = L+NCI                                                        C  4470
      FF = (FLX(L)+FLX(LP))/(DF(L)+DF(LP))                              C  4480
      FASTA(L) = FASTA(L)+FF                                            C  4490
282   FASTA(LP) = FASTA(LP)+FF                                          C  4500
284   NCI = NCIP                                                        C  4510
C=================================================================== C  4520
C                                                                       C  4530
CALCULATE AVERAGED THERMAL FLUX                                         C  4540
      DO 302 L=1,NODES                                                  C  4550
      T(L) = F(L)*TFR(L)                                                C  4560
      THERMA(L) = B2N*T(L)                                              C  4570
302   FLX(L) = CT*T(L)*DT(L)                                            C  4580
C FACE 5 BOUNDARY                                                       C  4590
      DO 304 L=1,NP                                                     C  4600
304   THERMA(L) = THERMA(L)+RCT*(AT5+BT5*VOID(L))*T(L)                  C  4610
C FACE 6 BOUNDARY                                                       C  4620
      L1 = NDSMNP+1                                                     C  4630
      DO 306 L=L1,NODES                                                 C  4640
306   THERMA(L) = THERMA(L)+RCT*(AT6+BT6*VOID(L))*T(L)                  C  4650
C HORIZONTAL PLANES                                                     C  4660
      DO 308 L=1,NDSMNP                                                 C  4670
      LP = L+NP                                                         C  4680
```

```
      FF = R*(FLX(L)+FLX(LP))/(DT(L)+DT(LP))                            C  4690
      THERMA(L) = THERMA(L)+FF                                          C  4700
308   THERMA(LP) = THERMA(LP)+FF                                        C  4710
C FACE 1 BOUNDARY                                                       C  4720
      DO 310 LB=1,NX                                                    C  4730
      LT = LB+NDSMNP                                                    C  4740
      DO 310 L=LB,LT,NP                                                 C  4750
310   THERMA(L) = THERMA(L)+CT*(AT1+BT1*VOID(L))*T(L)                   C  4760
C                                                                       C  4770
      IF ( QTRKOR ) GO TO 318                                           C  4780
C RECTANGULAR PLANE GEOMETRY                                            C  4790
C FACE 2 BOUNDARY                                                       C  4800
      L1 = NP-NXM1                                                      C  4810
      DO 314 LB=L1,NP                                                   C  4820
      LT = LB+NDSMNP                                                    C  4830
      DO 314 L=LB,LT,NP                                                 C  4840
314   THERMA(L) = THERMA(L)+CT*(AT2+BT2*VOID(L))*T(L)                   C  4850
C FACE 4 BOUNDARY                                                       C  4860
      DO 316 LB=NX,NP,NX                                                C  4870
      LT = LB+NDSMNP                                                    C  4880
      DO 316 L=LB,LT,NP                                                 C  4890
316   THERMA(L) = THERMA(L)+CT*(AT4+BT4*VOID(L))*T(L)                   C  4900
      GO TO 372                                                         C  4910
C                                                                       C  4920
C QUARTER CORE PLANE GEOMETRY                                           C  4930
C FACE 2 BOUNDARY                                                       C  4940
318   J = 0                                                             C  4950
      L1 = NP-NCOL(NX)+1                                                C  4960
      L2 = NP                                                           C  4970
      DO 320 LB=L1,L2                                                   C  4980
      LT = LB+NDSMNP                                                    C  4990
      J = J+1                                                           C  5000
      AT = ATQ(J)                                                       C  5010
      BT = BTQ(J)                                                       C  5020
      DO 320 L=LB,LT,NP                                                 C  5030
320   THERMA(L) = THERMA(L)+CT*(AT+BT*VOID(L))*T(L)                     C  5040
```

```
      I = NX                                                            C  5050
      NCL = NCOL(NX)                                                    C  5060
      DO 324 IC=2,NX                                                    C  5070
      I = I-1                                                           C  5080
      NCI = NCOL(I)                                                     C  5090
      L2 = L2-NCL                                                       C  5100
      L1 = L2-NCI+NCL+1                                                 C  5110
      IF ( NCI .EQ. NCL) GO TO 324                                      C  5120
      DO 322 LB=L1,L2                                                   C  5130
      LT = LB+NDSMNP                                                    C  5140
      J = J+1                                                           C  5150
      AT = ATQ(J)                                                       C  5160
      BT = BTQ(J)                                                       C  5170
      DO 322 L=LB,LT,NP                                                 C  5180
322   THERMA(L) = THERMA(L)+CT*(AT+BT*VOID(L))*T(L)                     C  5190
324   NCL = NCI                                                         C  5200
C FACE 4 BOUNDARY                                                       C  5210
      LB = 0                                                            C  5220
      DO 326 I=1,NX                                                     C  5230
      LB = LB+NCOL(I)                                                   C  5240
      LT = LB+NDSMNP                                                    C  5250
      AT = ATQ(I)                                                       C  5260
      BT = BTQ(I)                                                       C  5270
      DO 326 L=LB,LT,NP                                                 C  5280
326   THERMA(L) = THERMA(L)+CT*(AT+BT*VOID(L))*T(L)                     C  5290
C                                                                       C  5300
C FACE 3 BOUNDARY                                                       C  5310
372   LB = 1                                                            C  5320
      DO 376 I=1,NX                                                     C  5330
      LT = LB+NDSMNP                                                    C  5340
      DO 374 L=LB,LT,NP                                                 C  5350
374   THERMA(L) = THERMA(L)+CT*(AT3+BT3*VOID(L))*T(L)                   C  5360
376   LB = LB+NCOL(I)                                                   C  5370
C J FACES                                                               C  5380
      L2 = -1                                                           C  5390
      DO 380 I=1,NX                                                     C  5400
```

```
      L1 = L2+2                                                         C  5410
      L2 = L2+NCOL(I)                                                   C  5420
      IF ( L2 .LT. L1) GO TO 380                                        C  5430
      DO 378 LB=L1,L2                                                   C  5440
      LT = LB+NDSMNP                                                    C  5450
      DO 378 L=LB,LT,NP                                                 C  5460
      LP = L+1                                                          C  5470
      FF = (FLX(L)+FLX(LP))/(DT(L)+DT(LP))                              C  5480
      THERMA(L) = THERMA(L)+FF                                          C  5490
378   THERMA(LP) = THERMA(LP)+FF                                        C  5500
380   CONTINUE                                                          C  5510
C I FACES                                                               C  5520
      LR = 0                                                            C  5530
      NCI = NX                                                          C  5540
      DO 384 I=1,NXM1                                                   C  5550
      NCIP = NCOL(I+1)                                                  C  5560
      L2 = LR+NCIP                                                      C  5570
      L1 = LR+1                                                         C  5580
      LR = LR+NCI                                                       C  5590
      DO 382 LB=L1,L2                                                   C  5600
      LT = LB+NDSMNP                                                    C  5610
      DO 382 L=LB,LT,NP                                                 C  5620
      LP = L+NCI                                                        C  5630
      FF = (FLX(L)+FLX(LP))/(DT(L)+DT(LP))                              C  5640
      THERMA(L) = THERMA(L)+FF                                          C  5650
382   THERMA(LP) = THERMA(LP)+FF                                        C  5660
384   NCI = NCIP                                                        C  5670
C=================================================================== C  5680
C                                                                       C  5690
CALCULATE RELATIVE POWER                                                C  5700
      DO 400 L=1,NODES                                                  C  5710
      PO(L) = POWER(L)                                                  C  5720
400   POWER(L) = FASTA(L)*KSFF(L) + THERMA(L)*KSFT(L)                   C  5730
      CALL NORM (POWER, NODES)                                          C  5740
      IF ( .NOT. NOHAL ) RETURN                                         C  5750
CHECK CONVERGENCE                                                       C  5760
```

```
      FLAG2 = FLAG1                                                     C  5770
      TESTPO = TESTP                                                    C  5780
      TESTP = 0.                                                        C  5790
      DO 402 L=1,NODES                                                  C  5800
      TEST = ABS (1.-PO(L)/POWER(L))                                    C  5810
      IF ( TEST .GT. TESTP) TESTP = TEST                                C  5820
402   CONTINUE                                                          C  5830
      IF ( ITPOWR .EQ. 1 ) GO TO 403                                    C  5840
C IF VOID ITERATION IS DIVERGING DECREASE NUMBER OF OUTERS PER VOID IT. C  5850
      FLAG1 = TESTP .GT. TESTPO                                         C  5860
      IF ( FLAG1 .AND. FLAG2 ) MAXOUT = MAXOUT - 1                      C  5870
      WRITE (6,1006) TESTP                                              C  5880
      IF ( TESTP .LE. EPSP) RETURN                                      C  5890
      IF ( ITPOWR .GE. MAXP) GO TO 412                                  C  5900
403   ITPOWR = ITPOWR+1                                                 C  5910
C                                                                       C  5920
      IF ( NOVOID ) GO TO 404                                           C  5930
      CALL VOIDFR                                                       C  5940
404   IF ( NOXE   ) GO TO 602                                           C  5950
405   CALL INTERP                                                       C  5960
      GO TO 602                                                         C  5970
412   WRITE (6,1004) ITPOWR                                             C  5980
      RETURN                                                            C  5990
C                                                                       C  6000
C-----------------------------------------------------------------------C  6010
C                                                                       C  6020
1000  FORMAT (10X,'================='/10X,'ITERATION MONITOR'/10X,'===== C  6030
     $============='//1X,T11,'VOID',T22,'OUTER',T33,'INNER',            C  6040
     $ /1X,T11,3('ITERATION  '),T47,'K-EFF'         ,T59,'TESTO',T71,'TES C  6050
     $TP'/10X,3('---------  '),  '--------  ',1X,2('---------   ')//)  C  6060
1002  FORMAT (1X,T20,2I11,F10.4,T52,E12.3)                             C  6070
1003  FORMAT (1X,T10,I9)                                                C  6080
1004  FORMAT (1X,'WARNING:  POWER ITERATION HAS NOT CONVERGED IN ',I5,  C  6090
     $' ITERATIONS.  FURTHER ITERATION HAS BEEN SUPPRESSED.')           C  6100
1005  FORMAT (1H+,T81,'SPECTRAL RADIUS =',F10.3)                        C  6110
1006  FORMAT (1H+,T64,E12.3)                                            C  6120
```

```
C                                                                       C  6130
      END                                                               C  6140
```

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE HEADER (N)
C
C---------------------------------------------------------------------
C ROUTINE TO PRINT PAGE HEADING
C---------------------------------------------------------------------
C
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP
      DATA NPAGE/1/
C
C---------------------------------------------------------------------
C
      GO TO (10,20), N
10    WRITE (6,2) NTSTEP, NTITLE, NPAGE
      GO TO 30
20    WRITE (6,4) NTSTEP, NTITLE, NPAGE, AVEXP
30    NPAGE = NPAGE+1
      RETURN
C
C---------------------------------------------------------------------
C
2     FORMAT (1H1,'TIME STEP #',I4,9X,'<<  ',20A4,'  >>',11X,'PAGE',I5//
     $/)
4     FORMAT (1H1,'TIME STEP #',I4,9X,'<<  ',20A4,'  >>',11X,'PAGE',I5/
     $1X,'EXPOSURE =',F7.0,' MWD/MT'///)
C
      END
```

```
C*=================================================================== E    10
C=================================================================== E    20
C                                                                     E    30
C                                                                     E    40
      SUBROUTINE ERROR (N)                                            E    50
C                                                                     E    60
C------------------------------------------------------------------- E    70
C ROUTINE TO PRINT ERROR MESSAGE AND ABORT JOB                        E    80
C------------------------------------------------------------------- E    90
C                                                                     E   100
      GO TO (11,12,13,14,15,16,17,18,19,20), N                        E   110
11    WRITE (6,1)                                                     E   120
      STOP                                                            E   130
12    WRITE (6,2)                                                     E   140
      STOP                                                            E   150
13    WRITE (6,3)                                                     E   160
      STOP                                                            E   170
14    WRITE (6,4)                                                     E   180
      STOP                                                            E   190
15    WRITE (6,5)                                                     E   200
      STOP                                                            E   210
16    WRITE (6,6)                                                     E   220
      STOP                                                            E   230
17    WRITE (6,7)                                                     E   240
      STOP                                                            E   250
18    WRITE (6,8)                                                     E   260
      STOP                                                            E   270
19    WRITE (6,9)                                                     E   280
      STOP                                                            E   290
20    WRITE (6,10)                                                    E   300
      STOP                                                            E   310
C                                                                     E   320
C------------------------------------------------------------------- E   330
C                                                                     E   340
1     FORMAT (//1X,'***  FORMAT ERROR IN INPUT.  JOB ABORTED.  ***')  E   350
2     FORMAT (//1X,'***  ERROR IN INPUT:  NCOL(1) .NE. NX .  JOB ABORTED E   360
```

```
     $.  ***')                                                          E   370
3     FORMAT (//1X,'***  ERROR IN INPUT:  SUM( NCOL(I) ) .NE. NP .  JOB  E   380
     $ABORTED.  ***')                                                   E   390
4     FORMAT (//1X,'***  ERROR IN INPUT:  NZ*NP < OR > NODES.  JOB ABORT E   400
     $ED.  ***')                                                        E   410
5     FORMAT (//1X,'***  ERROR IN INPUT:  IPTYPE=2 & IEXPTS=1.  JOB ABOR E   420
     $TED.  ***')                                                       E   430
6     FORMAT (//1X,'***  ERROR IN INPUT:  ITSETS > DIMTS.  JOB ABORTED.  E   440
     $ ***')                                                            E   450
7     FORMAT (//1X,'***  ERROR IN INPUT:  IEXPTS > DIMEX.  JOB ABORTED.  E   460
     $ ***')                                                            E   470
8     FORMAT (//1X,'***  ERROR IN INPUT:  IVDPTS > DIMVD.  JOB ABORTED.  E   480
     $ ***')                                                            E   490
9     FORMAT (//1X,'***  ERROR IN INPUT:  EXPOSURE MASK NOT IN ASCENDING E   500
     $ ORDER.   JOB ABORTED.  ***')                                     E   510
10    FORMAT (//1X,'***  ERROR IN INPUT:  VOID MASK NOT IN ASCENDING ORD E   520
     $ER.   JOB ABORTED.  ***')                                         E   530
C                                                                       E   540
      END                                                               E   550
```

```
C*=====================================================================
C=====================================================================
C
C
      FUNCTION LOC(I,J,K)
C
C---------------------------------------------------------------------
C ROUTINE TO CONVERT (I,J,K) POSITION INDICES TO AN 'L' POSITION INDEX
C---------------------------------------------------------------------
C
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL   (N04)
C
C---------------------------------------------------------------------
C
      LOC = (K-1)*NP+J
      IF ( I .EQ. 1) RETURN
      IM1 = I-1
      DO 10 II=1,IM1
10    LOC = LOC+NCOL(II)
      RETURN
      END
```

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE HALING (BURN)
C
C---------------------------------------------------------------------
C ROUTINE TO CALCULATE HALING SOLUTION FOR OPTIMUM POWER DISTRIBUTION
C---------------------------------------------------------------------
C
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL  (N04)
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)
      COMMON /CONVRG/   MAXI,  MAXO,  MAXP,  EPSO,  EPSP,  ALPHA,   SOR
      LOGICAL SOR
      DIMENSION PO(N01), EXS(N01)
C
C---------------------------------------------------------------------
      NOCONV = 0
      ITHAL = 1
      TESTH = 1.E6
      WRITE (6,1000)
C
      DO 10 L=1,NODES
      EXS(L) = BU(L)
      BU(L) = EXS(L) + POWER(L)*BURN
10    PO(L) = POWER(L)
      GO TO 20
C
15    CALL VOIDFR
20    WRITE (6,1003) ITHAL
      CALL STG
      TESTHO = TESTH
```

```
      TESTH = 0.                                                        G   370
      DO 30 L=1,NODES                                                   G   380
      POWER(L) = .9*PO(L) + .1*POWER(L)                                 G   390
      TEST = ABS (1.-PO(L)/POWER(L))                                    G   400
      IF ( TEST .GT. TESTH ) TESTH = TEST                               G   410
      PO(L) = POWER(L)                                                  G   420
30    BU(L) = EXS(L) + POWER(L)*BURN                                    G   430
C                                                                       G   440
      ITHAL = ITHAL + 1                                                 G   450
      WRITE (6,1006) TESTH                                              G   460
      IF ( TESTH .LT. TESTHO ) GO TO 50                                 G   470
      NOCONV = NOCONV + 1                                               G   480
      IF ( NOCONV .GE. 3 ) GO TO 60                                     G   490
      GO TO 51                                                          G   500
50    NOCONV = 0                                                        G   510
51    CONTINUE                                                          G   520
      IF ( TESTH .GT. EPSP ) GO TO 15                                   G   530
      RETURN                                                            G   540
60    WRITE (6,110)                                                     G   550
      RETURN                                                            G   560
C-----------------------------------------------------------------------G   570
C                                                                       G   580
1000  FORMAT (10X,'================'/10X,'ITERATION MONITOR'/10X,'===== G   590
     $============'//1X,T11,'HALING',T22,'OUTER',T33,'INNER',           G   600
     $ /1X,T11,3('ITERATION  '),T47,'K-EFF'        ,T59,'TESTO',T71,'TES G   610
     $TH'/10X,3('---------  '),  '--------  ',1X,2('---------   ')//)   G   620
1003  FORMAT (1X,T10,I9)                                               G   630
1006  FORMAT (1H+,T64,E12.3)                                            G   640
110   FORMAT (1X,'HALING ITERATION IS DIVERGING.  FURTHER ITERATION HAS G   650
     $BEEN SUPRESSED.')                                                 G   660
      END                                                               G   670
```

```
C*=====================================================================  H    10
C=====================================================================  H    20
C                                                                      H    30
C                                                                      H    40
      SUBROUTINE NORM (A, N)                                           H    50
C---------------------------------------------------------------------  H    60
C ROUTINE TO NORMALIZE AN ARRAY TO A MEAN OF 1.00                      H    70
C---------------------------------------------------------------------  H    80
C                                                                      H    90
      DIMENSION A(N)                                                   H   100
C                                                                      H   110
C---------------------------------------------------------------------  H   120
C                                                                      H   130
      SUM = 0.                                                         H   140
      DO 10 L=1,N                                                      H   150
10    SUM = SUM + A(L)                                                 H   160
      AVG = SUM/FLOAT (N)                                              H   170
      DO 12 L=1,N                                                      H   180
12    A(L) = A(L)/AVG                                                  H   190
      RETURN                                                           H   200
      END                                                              H   210
```

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE VOIDFR
C
C---------------------------------------------------------------------
C ROUTINE TO CALCULATE CHANNEL FLOW AND MODERATOR VOID DISTRIBUTION
C---------------------------------------------------------------------
C
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL  (N04)
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)
     $,                 NOXE,  FIRST
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST
      COMMON /THERMO/ HFG, XIN, AC1, AC2, AC3, AREA, AVFLUX, AVPWR, PSIA
     $,               B1(4), B2(4), B3(4), CTYPE(N02), FLOW(N02),TFLOW
     $,               PCTPWR
      INTEGER CTYPE
C
C---------------------------------------------------------------------
C
C  FLOW     = COOLANT FLOW IN CHANNEL  (LBM/HR)
C  CTYPE    = FLOW CHANNEL TYPE ARRAY
C  PCTPWR   = PER CENT OF RATED POWER
C  TFLOW    = TOTAL INCORE COOLANT FLOW  (LBM/HR)
C  PAV      = RELATIVE CHANNEL POWER
C  B1,B2,B3 = COEFFICIENTS USED TO CALCULATE RELATIVE CHANNEL FLOW
C             AS A FUNCTION OF AVERAGE CHANNEL POWER:
C             FLOW = B1 + B2*PAV + B3*PAV**2
C  AVPWR    = AVERAGE POWER PER NODE  (BTU/HR)
C  X        = COOLANT QUALITY
```

```
C  XIN       = INLET QUALITY                                          I   370
C  HFG       = HEAT OF VAPORIZATION  (BTU/LBM)                        I   380
C  AC1,AC2   = ARMAND CORRELATION COEFFICIENTS                        I   390
C  AC3       = VF/VG                                                  I   400
C                                                                     I   410
C-----------------------------------------------------------------    I   420
C                                                                     I   430
      AC4 = 1.-AC3                                                    I   440
CALCULATE CHANNEL FLOW                                                I   450
C                                                                     I   460
      DO 10 LB=1,NP                                                   I   470
      LT = LB+NDSMNP                                                  I   480
CALCULATE AVERAGE CHANNEL POWER                                       I   490
      PAV = 0.                                                        I   500
      DO 12 L=LB,LT,NP                                                I   510
12    PAV = PAV + POWER(L)                                            I   520
      PAV = PAV*PCTPWR*.01/FLOAT(NZ)                                  I   530
CALCULATE RELATIVE CHANNEL FLOW                                       I   540
      N = CTYPE(LB)                                                   I   550
10    FLOW(LB) = ( B3(N)*PAV + B2(N) )*PAV + B1(N)                    I   560
C NORMALIZE RELATIVE FLOWS AND CALCULATE ACTUAL FLOW                  I   570
      CALL NORM (FLOW, NP)                                            I   580
      AVF = TFLOW/FLOAT(NP)                                           I   590
      IF ( QTRKOR ) AVF = AVF*.25                                     I   600
      DO 16 L=1,NP                                                    I   610
16    FLOW(L) = FLOW(L)*AVF                                           I   620
C                                                                     I   630
C-----------------------------------------------------------------    I   640
C                                                                     I   650
CALCULATE QUALITY                                                     I   660
C                                                                     I   670
      C = AVPWR/HFG*.5                                                I   680
      DO 18 LB=1,NP                                                   I   690
      LT = LB + NDSMNP                                                I   700
      DX = C/FLOW(LB)                                                 I   710
      X = XIN                                                         I   720
```

```
      DO 18 L=LB,LT,NP                                                  I   730
      X = X + DX* POWER(L)                                              I   740
C                                                                       I   750
      VOID(L) = 0.                                                      I   760
      IF ( X .LE. 0.) GO TO 18                                          I   770
CALCULATE VOID USING MODIFIED ARMAND CORRELATION                        I   780
      VOID(L) = X*(X*AC2 + AC1)/(X*AC4 + AC3)                           I   790
18    X = X + DX* POWER(L)                                              I   800
C                                                                       I   810
      RETURN                                                            I   820
      END                                                               I   830
```

```
C*=====================================================================  J    10
C=====================================================================  J    20
C                                                                       J    30
C                                                                       J    40
      SUBROUTINE IJK (L, I, J, K)                                       J    50
C                                                                       J    60
C---------------------------------------------------------------------  J    70
C ROUTINE TO CONVERT AN 'L' POSITION INDEX TO (I,J,K) POSITION INDICES  J    80
C---------------------------------------------------------------------  J    90
C                                                                       J   100
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX        J   110
     $,               NZ         , NXM1       , GX         , GZ        J   120
     $,               NCOL   (N04)                                     J   130
C                                                                       J   140
C---------------------------------------------------------------------  J   150
C                                                                       J   160
      K = (L-1)/NP+1                                                    J   170
      LL = L-(K-1)*NP                                                   J   180
      ISUM = 0                                                          J   190
      I = 0                                                             J   200
      DO 10 J=1,NX                                                      J   210
      I = I+1                                                           J   220
      ISUM = ISUM+NCOL(I)                                               J   230
      IF ( ISUM .GE. LL) GO TO 20                                       J   240
10    CONTINUE                                                          J   250
20    IF ( I .EQ. 1) GO TO 30                                           J   260
      J = LL-ISUM+NCOL(I)                                               J   270
      RETURN                                                            J   280
30    J = LL                                                            J   290
      RETURN                                                            J   300
      END                                                               J   310
```

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE EDIT (N)
C
C---------------------------------------------------------------------
C ROUTINE TO EDIT CHANNEL TYPES, COOLANT FLOW DISTRIBUTION, MINIMUM
C CRITICAL HEAT FLUX RATIO, EXPOSURE DISTRIBUTION, VOID DISTRIBUTION,
C RELATIVE POWER DISTRIBUTION, CONTROL ROD POSITIONS, AND FUEL TYPE
C DISTRIBUTION
C---------------------------------------------------------------------
C
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP
      COMMON /CSINP / BUMASK(N07),  VMASK(N08),    DFI(N10),    DTI(N10)
     $                SAFI(N10), SATI(N10),  NSFFI(N10),  NSFTI(N10),
     $                SDSI(N10), IEXPTS    , IVDPTS    , ITSETS    ,
     $                KSFTI(N10), KSFFI(N10),
     $                DIMTS    ,  DIMEX    ,  DIMVD    , NOTCH(N02),
     $                TABSET(N01),  WORTH(N10)
      INTEGER DIMTS, DIMEX, DIMVD, TABSET
      REAL    NSFFI,NSFTI,KSFFI,KSFTI
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /NODAL / DF     (N01), DT     (N01), KSFF   (N01)
     $,               KSFT   (N01), TFR    (N01), NSF1G  (N01)
     $,               C2     (N01), C4     (N01), C6     (N03)
     $,               C7     (N01)
      REAL KSFF, KSFT, NSF1G
      COMMON /GEOM  / NODES      , NP         , NDSMNP     , NX
     $,               NZ         , NXM1       , GX         , GZ
     $,               NCOL   (N04)
      COMMON /BC    / AF1, AF3, AF5, AF6, AFQ(N04),
     $                BF1, BF3, BF5, BF6, BFQ(N04),
     $                AT1, AT3, AT5, AT6, ATQ(N04),
     $                BT1, BT3, BT5, BT6, BTQ(N04)
```

```
      EQUIVALENCE (AFQ(1), AF2), (AFQ(2), AF4),                         K
     $            (BFQ(1), BF2), (BFQ(2), BF4),                         K
     $            (ATQ(1), AT2), (ATQ(2), AT4),                         K
     $            (BTQ(1), BT2), (BTQ(2), BT4)                          K
      COMMON /CONVRG/   MAXI,  MAXO,  MAXP,  EPSO,  EPSP,  ALPHA,   SOR K
      LOGICAL SOR                                                       K
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)     K
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)   K
     $,                 NOXE,  FIRST                                   K
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST                K
      COMMON /WEIGHT/   R,  CF,  CT, RCF, RCT, B1N, B2N                 K
      COMMON /THERMO/ HFG, XIN, AC1, AC2, AC3, AREA, AVFLUX, AVPWR, PSIA K
     $,               B1(4), B2(4), B3(4), CTYPE(N02), FLOW(N02),TFLOW  K
     $,               PCTPWR                                            K
      INTEGER CTYPE                                                     K
      DIMENSION TEMP(N04)                                               K
      LOGICAL OPT                                                       K
      REAL MCHFR                                                        K
C                                                                       K
C-----------------------------------------------------------------------K
C                                                                       K
      L2 = 0                                                            K
      GO TO (2,6,10,14,18,22,32,36,40,60), N                            K
C                                                                       K
C=======================================================================K
C                                                                       K
CHANNEL TYPE EDIT                                                       K
C                                                                       K
40    CALL HEADER (1)                                                   K
      WRITE (6,142) (J,J=1,NX)                                          K
      WRITE (6,134)                                                     K
      DO 42 I=1,NX                                                      K
      L1 = L2+1                                                         K
      L2 = L2+NCOL(I)                                                   K
42    WRITE (6,132) I, (CTYPE(L),L=L1,L2)                               K
      RETURN                                                            K
```

```
C                                                                       K   730
C=======================================================================K   740
C                                                                       K   750
COOLANT FLOW EDIT                                                       K   760
2     CALL HEADER (1)                                                   K   770
      WRITE (6,100) TFLOW,  (J,J=1,NX)                                  K   780
      WRITE (6,134)                                                     K   790
      CALL NORM (FLOW, NP)                                              K   800
      DO 4 I=1,NX                                                       K   810
      L1 = L2+1                                                         K   820
      L2 = L2+NCOL(I)                                                   K   830
4     WRITE (6,102) I,(FLOW(L),L=L1,L2)                                 K   840
      RETURN                                                            K   850
C                                                                       K   860
C=======================================================================K   870
C                                                                       K   880
C MCHFR EDIT                                                            K   890
C                                                                       K   900
C AREA     = COOLANT FLOW AREA PER CHANNEL  (FT**2)                     K   910
C G        = COOLANT FLOW IN CHANNEL  (LBM/HR/FT**2)                    K   920
C AVPWR    = AVERAGE POWER IN NODE  (BTU/HR)                            K   930
C X        = COOLANT QUALITY                                            K   940
C XIN      = INLET QUALITY                                              K   950
C HFG      = HEAT OF VAPORIZATION  (BTU/LBM)                            K   960
C AVFLUX   = AVERAGE HEAT FLUX AT CLAD SURFACE (MULTIPLIED BY A PEAKING K   970
C            FACTOR TO ACCOUNT FOR NON-UNIFORM HEATING OF NODE)         K   980
C            (BTU/HR/FT**2)                                             K   990
C QCRIT    = CRITICAL HEAT FLUX DETERMINED FROM JANSSEN-LEVY CORRELATION K  1000
C            (BTU/HR/FT**2)                                             K  1010
C PRCOR    = PRESSURE CORRECTION TERM = 440*(1000-PSIA)                 K  1020
C MCHFR    = MINIMUM CRITICAL HEAT FLUX RATIO                           K  1030
C                                                                       K  1040
C-----------------------------------------------------------------------K  1050
C                                                                       K  1060
C                                                                       K  1070
6     IF ( IEDIT(5) .EQ. 0) RETURN                                      K  1080
```

```
      IF ( PCTPWR .EQ. 0. ) RETURN                                      K  1090
      OPT = IEDIT(5) .GT. 0                                             K  1100
      CALL HEADER (1)                                                   K  1110
      IF ( OPT) WRITE (6,104) (J,J=1,NX)                                K  1120
      IF ( OPT) WRITE (6,134)                                           K  1130
      C = AVPWR/HFG*.5                                                  K  1140
      PRCOR = 4.4E5-440.*PSIA                                           K  1150
      MCHFR = 1.E10                                                     K  1160
CALCULATE CHANNEL FLOW RATES IN LBM/HR                                  K  1170
      CALL NORM (FLOW, NP)                                              K  1180
      AVF = TFLOW/FLOAT (NP)                                            K  1190
      IF ( QTRKOR ) AVF = AVF*.25                                       K  1200
      DO 6019 L=1,NP                                                    K  1210
6019  FLOW(L) = FLOW(L)*AVF                                             K  1220
C                                                                       K  1230
      DO 6002 I=1,NX                                                    K  1240
      J = 0                                                             K  1250
      L1 = L2+1                                                         K  1260
      L2 = L2 + NCOL(I)                                                 K  1270
      DO 6003 LB=L1,L2                                                  K  1280
      J = J+1                                                           K  1290
      LT = LB+NDSMNP                                                    K  1300
      G = FLOW(LB)/AREA                                                 K  1310
      DX = C/FLOW(LB)                                                   K  1320
      X = XIN                                                           K  1330
      TEMP(J) = 1.E10                                                   K  1340
      DO 6003 L=LB,LT,NP                                                K  1350
      RELPWR = POWER(L)                                                 K  1360
      X = X + DX* RELPWR                                                K  1370
      XCHK = .197-.108E-6*G                                             K  1380
      IF ( X-XCHK) 6020,6020,6040                                       K  1390
6020  QCRIT = .705E6+.237*G+PRCOR                                       K  1400
      GO TO 6100                                                        K  1410
6040  XCHK = .254-.026E-6*G                                             K  1420
      IF ( X-XCHK) 6060,6060,6080                                       K  1430
6060  QCRIT = 1.634E6-.27*G-.471E7*X+PRCOR                              K  1440
```

```
      GO TO 6100                                                        K  1450
6080  QCRIT = .605E6-.164*G-.653E6*X+PRCOR                              K  1460
6100  CHFR = QCRIT/AVFLUX/RELPWR                                        K  1470
      IF ( CHFR .GE. TEMP(J) ) GO TO 6003                               K  1480
      TEMP(J) = CHFR                                                    K  1490
      IF ( CHFR .GE. MCHFR ) GO TO 6003                                 K  1500
      MCHFR = CHFR                                                      K  1510
      LMAX = L                                                          K  1520
6003  X = X + DX* RELPWR                                                K  1530
      IF ( OPT ) WRITE (6,102) I, (TEMP(JJ), JJ=1,J)                    K  1540
6002  CONTINUE                                                          K  1550
C                                                                       K  1560
      CALL IJK (LMAX, I, J, K)                                          K  1570
      WRITE (6,107) MCHFR,I,J,K                                         K  1580
      RETURN                                                            K  1590
C                                                                       K  1600
C=======================================================================K  1610
C                                                                       K  1620
C EXPOSURE EDIT                                                         K  1630
10    IF ( IEDIT(2) .EQ. 0 ) GO TO 12                                   K  1640
      DO 11 K=1,NZ                                                      K  1650
      CALL HEADER (2)                                                   K  1660
      WRITE (6,108) K,(J,J=1,NX)                                        K  1670
      WRITE (6,134)                                                     K  1680
      DO 11 I=1,NX                                                      K  1690
      L1 = L2+1                                                         K  1700
      L2 = L2+NCOL(I)                                                   K  1710
11    WRITE (6,110) I, (BU(L),L=L1,L2)                                  K  1720
      IF ( IEDIT(2) .EQ. 1 ) RETURN                                     K  1730
12    L2 = 0                                                            K  1740
      CALL HEADER (2)                                                   K  1750
      WRITE (6,109) (J,J=1,NX)                                          K  1760
      WRITE (6,134)                                                     K  1770
      DO 13 I=1,NX                                                      K  1780
      L1 = L2+1                                                         K  1790
      L2 = L2+NCOL(I)                                                   K  1800
```

```
      J = 0                                                             K  1810
      DO 1300 LB=L1,L2                                                  K  1820
      J = J+1                                                           K  1830
      LT = LB+NDSMNP                                                    K  1840
      SUM = 0.                                                          K  1850
      DO 1302 L=LB,LT,NP                                                K  1860
1302  SUM = SUM+BU(L)                                                   K  1870
1300  TEMP(J) = SUM/FLOAT(NZ)                                           K  1880
13    WRITE (6,110) I,(TEMP(N),N=1,J)                                   K  1890
      RETURN                                                            K  1900
C                                                                       K  1910
C=======================================================================K  1920
C                                                                       K  1930
C VOID EDIT                                                             K  1940
14    K1 = 1                                                            K  1950
      IF ( IEDIT(4) ) 1401,1400,1402                                    K  1960
1400  RETURN                                                            K  1970
1401  K1 = NZ                                                           K  1980
      L2 = NDSMNP                                                       K  1990
1402  DO 16 K=K1,NZ                                                     K  2000
      CALL HEADER (1)                                                   K  2010
      WRITE (6,112) K,(J,J=1,NX)                                        K  2020
      WRITE (6,134)                                                     K  2030
      DO 16 I=1,NX                                                      K  2040
      L1 = L2+1                                                         K  2050
      L2 = L2+NCOL(I)                                                   K  2060
16    WRITE (6,102) I,(VOID(L),L=L1,L2)                                 K  2070
      RETURN                                                            K  2080
C                                                                       K  2090
C=======================================================================K  2100
C                                                                       K  2110
C RELATIVE POWER EDIT                                                   K  2120
18    IF ( IEDIT(1) .EQ. 0 ) GO TO 20                                   K  2130
      DO 19 K=1,NZ                                                      K  2140
      CALL HEADER (2)                                                   K  2150
      WRITE (6,116) K,(J,J=1,NX)                                        K  2160
```

```
      WRITE (6,134)                                                     K  2170
      DO 19 I=1,NX                                                      K  2180
      L1 = L2+1                                                         K  2190
      L2 = L2+NCOL(I)                                                   K  2200
19    WRITE (6,118) I,(POWER(L),L=L1,L2)                                K  2210
      IF ( IEDIT(1) .EQ. 1) GO TO 62                                    K  2220
20    L2 = 0                                                            K  2230
      CALL HEADER (2)                                                   K  2240
      WRITE (6,119) (J,J=1,NX)                                          K  2250
      WRITE (6,134)                                                     K  2260
      DO 21 I=1,NX                                                      K  2270
      L1 = L2+1                                                         K  2280
      L2 = L2+NCOL(I)                                                   K  2290
      J = 0                                                             K  2300
      DO 2100 LB=L1,L2                                                  K  2310
      J = J+1                                                           K  2320
      LT = LB+NDSMNP                                                    K  2330
      SUM = 0.                                                          K  2340
      DO 2102 L=LB,LT,NP                                                K  2350
2102  SUM = SUM+POWER(L)                                                K  2360
2100  TEMP(J) = SUM/FLOAT(NZ)                                           K  2370
21    WRITE (6,118) I,(TEMP(N),N=1,J)                                   K  2380
C                                                                       K  2390
C-----------------------------------------------------------------------K  2400
C                                                                       K  2410
C EDIT AVERAGE AXIAL POWER AND VOID                                     K  2420
62    OPT = .NOT. NOVOID                                                K  2430
      CALL HEADER (2)                                                   K  2440
      WRITE (6,148)                                                     K  2450
      IF ( OPT) WRITE (6,150)                                           K  2460
      WRITE (6,152)                                                     K  2470
      IF ( OPT) WRITE (6,154)                                           K  2480
      L = 0                                                             K  2490
      DO 50 K=1,NZ                                                      K  2500
      V = 0.                                                            K  2510
      P = 0.                                                            K  2520
```

```
      DO 56 LL=1,NP                                                     K  2530
      L = L + 1                                                         K  2540
      IF ( NOVOID ) GO TO 56                                            K  2550
      V = V + VOID(L)                                                   K  2560
56    P = P + POWER(L)                                                  K  2570
      P = P/FLOAT (NP)                                                  K  2580
      IF ( OPT ) V = V/FLOAT (NP)                                       K  2590
      WRITE (6,156) K,P                                                 K  2600
      IF ( OPT ) WRITE (6,158) V                                        K  2610
50    CONTINUE                                                          K  2620
C                                                                       K  2630
C-----------------------------------------------------------------------K  2640
C                                                                       K  2650
C EDIT PEAK NODE AND PEAK ASSEMBLY                                      K  2660
      PEAKN = 0.                                                        K  2670
      PEAKA = 0.                                                        K  2680
      DO 54 LB=1,NP                                                     K  2690
      LT = LB + NDSMNP                                                  K  2700
      PAV = 0.                                                          K  2710
      DO 52 L=LB,LT,NP                                                  K  2720
      IF ( POWER(L) .LE. PEAKN ) GO TO 52                               K  2730
      PEAKN = POWER(L)                                                  K  2740
      LPN = L                                                           K  2750
52    PAV = PAV + POWER(L)                                              K  2760
      IF ( PAV .LE. PEAKA ) GO TO 54                                    K  2770
      PEAKA = PAV                                                       K  2780
      LPA = LB                                                          K  2790
54    CONTINUE                                                          K  2800
      PEAKA = PEAKA/FLOAT (NZ)                                          K  2810
      CALL IJK (LPN, I, J, K)                                           K  2820
      WRITE (6,160) PEAKN, I, J, K                                      K  2830
      CALL IJK (LPA, I, J, K)                                           K  2840
      WRITE (6,162) PEAKA, I, J                                         K  2850
      RETURN                                                            K  2860
C                                                                       K  2870
C=======================================================================K  2880
```

```
C                                                                       K  2890
CONTROL ROD POSITION EDIT                                               K  2900
C                                                                       K  2910
22    CALL HEADER (1)                                                   K  2920
      WRITE (6,120) (J,J=1,NX)                                          K  2930
      WRITE (6,134)                                                     K  2940
      DO 24 I=1,NX                                                      K  2950
      L1 = L2+1                                                         K  2960
      L2 = L2+NCOL(I)                                                   K  2970
24    WRITE (6,132) I,(NOTCH(L),L=L1,L2)                                K  2980
      RETURN                                                            K  2990
C                                                                       K  3000
C=======================================================================K  3010
C                                                                       K  3020
C FUEL TYPE EDIT                                                        K  3030
C                                                                       K  3040
32    CALL HEADER (1)                                                   K  3050
      WRITE (6,130) (J,J=1,NX)                                          K  3060
      WRITE (6,134)                                                     K  3070
      DO 34 I=1,NX                                                      K  3080
      L1 = L2+1                                                         K  3090
      L2 = L2+NCOL(I)                                                   K  3100
34    WRITE (6,132) I,(FTYPE(L),L=L1,L2)                                K  3110
      RETURN                                                            K  3120
C                                                                       K  3130
C=======================================================================K  3140
C                                                                       K  3150
C EXPOSURE ARRAY PUNCH                                                  K  3160
36    WRITE (7,136) NTITLE, AVEXP                                       K  3170
      DO 38 I=1,NX                                                      K  3180
      L1 = L2+1                                                         K  3190
      L2 = L2+NCOL(I)                                                   K  3200
      J = 0                                                             K  3210
      DO 38 LB=L1,L2                                                    K  3220
      LT = LB+NDSMNP                                                    K  3230
      J = J+1                                                           K  3240
```

```
      WRITE (7,138) I,J                                                 K  3250
38    WRITE (7,140) (BU(L),L=LB,LT,NP)                                  K  3260
      RETURN                                                            K  3270
C                                                                       K  3280
C=======================================================================K  3290
C                                                                       K  3300
C POWER ARRAY PUNCH                                                     K  3310
60    WRITE (7,144) NTITLE, NTSTEP, AVEXP                               K  3320
      WRITE (7,146) POWER                                               K  3330
      RETURN                                                            K  3340
C                                                                       K  3350
C-----------------------------------------------------------------------K  3360
C                                                                       K  3370
142   FORMAT (1X,'***  CHANNEL TYPE EDIT  ***'//5X,'CTYPE (I,J)'//7X,  K  3380
     $'J=',I4,15I6)                                                     K  3390
100   FORMAT (1X,'***  RELATIVE FLOW EDIT  ***        TOTAL FLOW =',   K  3400
     $ E10.3,'  LBM/HR'//5X,'FLOW (I,J)'//9X,'J=',I3,15I8)              K  3410
102   FORMAT (//I5,1X,14F8.2)                                           K  3420
107   FORMAT (//1X,'MINIMUM CRITICAL HEAT FLUX RATIO = ',F10.3,2X,'AT LO K  3430
     $CATION  (',I3,',',I3,',',I3,' )')                                 K  3440
104   FORMAT (1X,'***  MINIMUM CRITICAL HEAT FLUX RATIO EDIT  ***'//5X,' K  3450
     $MCHFR (I,J)'//9X,'J=',I3,15I8)                                    K  3460
108   FORMAT (1X,'***  EXPOSURE EDIT  ***'//5X,'EX (I,J,',I2,')'//9X,'J= K  3470
     $',I3,15I8)                                                        K  3480
110   FORMAT (//I5,1X,1P15E8.1)                                         K  3490
112   FORMAT (1X,'***  VOID FRACTION EDIT  ***'//5X,'VOID (I,J,',I2,')'/ K  3500
     $/9X,'J=',I3,15I8)                                                 K  3510
116   FORMAT (1X,'***  RELATIVE POWER EDIT  ***'//5X,'P (I,J,',I2,')'//9 K  3520
     $X,'J=',I3,15I8)                                                   K  3530
118   FORMAT (//I5,1X,15F8.3)                                           K  3540
120   FORMAT (1X,'***  CONTROL ROD POSITIONS  ***'//5X,'NOTCH (I,J)'//7 K  3550
     $X,'J=',I4,14I6)                                                   K  3560
130   FORMAT (1X,'***  FUEL TYPE EDIT  ***'//5X,'FTYPE (I,J)'//7X,'J=', K  3570
     $I4,14I6)                                                          K  3580
132   FORMAT (//I5,2X,15I6)                                             K  3590
134   FORMAT (4X,'I')                                                   K  3600
```

```
109   FORMAT (1X,'***  AVERAGE EXPOSURE EDIT  ***'//5X,'EX (I,J)'//9X,   K  3610
     $'J=',I3,15I8)                                                       K  3620
119   FORMAT (1X,'***  INTEGRATED POWER EDIT  ***'//5X,'P (I,J)'//9X,    K  3630
     $'J=',I3,15I8)                                                       K  3640
136   FORMAT (20A4/'AVEXP = ',E10.3)                                       K  3650
138   FORMAT (2I5)                                                         K  3660
140   FORMAT (6E13.3)                                                      K  3670
144   FORMAT (20A4/'TIME STEP #',I4,4X,'AVERAGE CORE EXPOSURE ='           K  3680
     $,E12.3,' MWD/MT')                                                   K  3690
146   FORMAT (13F6.2)                                                      K  3700
148   FORMAT (11X,'AXIAL AVERAGES'/11X,'==============='//11X,'K  POWER') K  3710
150   FORMAT (1H+,20X,'VOID')                                              K  3720
152   FORMAT (10X,'--  -----')                                             K  3730
154   FORMAT (1H+,20X,'----')                                              K  3740
156   FORMAT (I12,F7.3)                                                    K  3750
158   FORMAT (1H+,F24.2)                                                   K  3760
160   FORMAT (//10X,'PEAK POWER =',F8.3,'  AT LOCATION (',I2,',',I2,',',  K  3770
     $I2,')')                                                             K  3780
162   FORMAT (//10X,'PEAK ASSEMBLY INTEGRATED POWER =',F8.3,'  AT LOCATI K  3790
     $ON (',I2,',',I2,')')                                                K  3800
C                                                                         K  3810
      END                                                                 K  3820
```

```
C*=====================================================================
C=====================================================================
C
C
      SUBROUTINE BANK (BANKID, NTCH)
C
C---------------------------------------------------------------------
C ROUTINE TO SET CONTROL ROD POSITIONS BY BANK
C---------------------------------------------------------------------
C
      COMMON /CSINP / BUMASK(N07),  VMASK(N08),    DFI(N10),    DTI(N10)
     $                SAFI(N10), SATI(N10),  NSFFI(N10),  NSFTI(N10),
     $                SDSI(N10), IEXPTS    , IVDPTS    , ITSETS    ,
     $                KSFTI(N10), KSFFI(N10),
     $                DIMTS    ,  DIMEX    ,  DIMVD    , NOTCH(N02),
     $                TABSET(N01),  WORTH(N10)
      INTEGER DIMTS, DIMEX, DIMVD, TABSET
      REAL    NSFFI,NSFTI,KSFFI,KSFTI
      COMMON /CROD  / NRODS(6,2), RODIND(N02)
      INTEGER BANKID, RODIND
C
C---------------------------------------------------------------------
C
C RODIND           = ARRAY CONTAINING 2-D INDICES INDICATING LOCATIONS OF
C                    NODES WHICH CAN BE RODDED BY THE CONTROL BANKS
C NRODS(BANKID,1)  = NUMBER OF NODES IN A PLANE WHICH CAN BE RODDED
C                    BY ROD BANK 'BANKID'
C NRODS(BANKID,2)  = INDEX MARKING THE BEGINNING OF ELEMENTS OF THE
C                    ELEMENTS OF THE RODIND ARRAY ASSIGNED TO
C                    ROD BANK 'BANKID'
C NTCH             = AXIAL POSITION INDEX OF ROD BANK
C NOTCH            = ARRAY CONTAINING AXIAL POSITION INDICES FOR ALL
C                    RODDED NODES
C
C---------------------------------------------------------------------
C
```

```
      I1 = NRODS(BANKID,2)                                              L   370
      I2 = I1+NRODS(BANKID,1)-1                                         L   380
      DO 10 N=I1,I2                                                     L   390
      L = RODIND(N)                                                     L   400
10    NOTCH(L) = NTCH                                                   L   410
      RETURN                                                            L   420
      END                                                               L   430
```

```
C*=====================================================================
C=====================================================================
C
C
      BLOCK DATA
C
C---------------------------------------------------------------------
C
      COMMON /HEADR / NTITLE(20),  AVEXP, NTSTEP
      COMMON /CSINP / BUMASK(N07),  VMASK(N08),    DFI(N10),    DTI(N10)
     $                  SAFI(N10), SATI(N10),  NSFFI(N10),  NSFTI(N10),
     $                  SDSI(N10), IEXPTS    , IVDPTS    , ITSETS    ,
     $                  KSFTI(N10), KSFFI(N10),
     $                  DIMTS    ,  DIMEX    ,  DIMVD    , NOTCH(N02),
     $                  TABSET(N01),  WORTH(N10)
      INTEGER DIMTS, DIMEX, DIMVD, TABSET
      REAL    NSFFI,NSFTI,KSFFI,KSFTI
      COMMON /FUEL  /  FTYPE(N02),    BU(N01),   VOID(N01)
      INTEGER FTYPE
      COMMON /NODAL / DF    (N01), DT    (N01), KSFF  (N01)
     $,               KSFT  (N01), TFR   (N01), NSF1G (N01)
     $,               C2    (N01), C4    (N01), C6    (N03)
     $,               C7    (N01)
      REAL KSFF, KSFT, NSF1G
      COMMON /GEOM  / NODES     , NP        , NDSMNP    , NX
     $,               NZ        , NXM1      , GX        , GZ
     $,               NCOL  (N04)
      COMMON /BC    / AF1, AF3, AF5, AF6, AFQ(N04),
     $                BF1, BF3, BF5, BF6, BFQ(N04),
     $                AT1, AT3, AT5, AT6, ATQ(N04),
     $                BT1, BT3, BT5, BT6, BTQ(N04)
      EQUIVALENCE (AFQ(1), AF2), (AFQ(2), AF4),
     $            (BFQ(1), BF2), (BFQ(2), BF4),
     $            (ATQ(1), AT2), (ATQ(2), AT4),
     $            (BTQ(1), BT2), (BTQ(2), BT4)
      COMMON /CONVRG/   MAXI,  MAXO,  MAXP,  EPSO,  EPSP,  ALPHA,   SOR
```

```
      LOGICAL SOR                                                       M   370
      COMMON /FLUX  /   POWER(N01), FASTA(N01), THERMA(N01), F(N01)      M   380
      COMMON /PROB  / INTTYP, QTRKOR, NOHAL, NOCROD, NOVOID, IEDIT(6)   M   390
     $,                 NOXE,  FIRST                                   M   400
      LOGICAL QTRKOR, NOHAL, NOCROD, NOVOID, NOXE, FIRST                M   410
      COMMON /WEIGHT/   R,  CF,  CT, RCF, RCT, B1N, B2N                 M   420
      COMMON /THERMO/ HFG, XIN, AC1, AC2, AC3, AREA, AVFLUX, AVPWR, PSIA M   430
     $,               B1(4), B2(4), B3(4), CTYPE(N02), FLOW(N02),TFLOW  M   440
     $,               PCTPWR                                            M   450
      INTEGER CTYPE                                                     M   460
      COMMON /XENON / PD, PRSA1(N10), PRSA2(N10), SAXE(N10)             M   470
C                                                                       M   480
C-----------------------------------------------------------------------M   490
C                                                                       M   500
      DATA  F/N01*1./, C2/N01*0./, C4/N01*0./, C6/N03*0./               M   510
     $,    C7/N01*0./,BUMASK/N07*0./,VMASK/N08*0./                      M   520
     $,    DIMVD/N08/,DIMTS/N09/,DIMEX/N07/,VOID/N01*0./,BU/N01*0./     M   530
     $,    NODES/N01/,NP/N02/,NDSMNP/N03/,NX/N04/                       M   540
     $,    NXM1/N05/,NZ/N06/,MAXI/3/,MAXO/6/                            M   550
     $,    MAXP/30/,EPSO/1.E-6/,EPSP/.5E-2/                             M   560
     $,    ALPHA/1.65/,FLOW/N02*1./                                     M   570
     $,    AC1/.833/,AC2/.167/, AVEXP/0./                               M   580
     $,    WORTH/N10*0./, B1/4*1./, B2/4*0./, B3/4*0./                  M   590
     $,    IEDIT/-1,0,0,1,1,0/, CTYPE/N02*1/                            M   600
     $,    QTRKOR/.TRUE./, NOCROD/.TRUE./, NOVOID/.TRUE./, PCTPWR/100./ M   610
     $,    ITSETS/1/, IEXPTS/1/, IVDPTS/1/, POWER/N01*1./               M   620
     $,    NTSTEP/1/, NOHAL/.TRUE./, SOR/.FALSE./                       M   630
     $,    NOXE/.TRUE./, FIRST/.TRUE./, TABSET/N01*1/, FTYPE/N02*1/     M   640
     $,    FASTA/N01*0./, THERMA/N01*0./                                M   650
C                                                                       M   660
      END                                                               M   670
```