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## PHENIX, a Two-Dimensional Diffusion-Burnup-Refueling Code

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

Printed in the United States of America. Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U. S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy \$3.00; Microfiche \$0.65

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IN REPLY
REFER TO:

TO: Holders of Report LA-4231

SUPPLEMENT

This supplement to LA-4231, "PHENIX, a Two-Dimensional Diffusion-Burnup-Refueling Code," consists of two additions to the original version of the code given in Table I, pp. 9 to 15. These are (1) the capability of performing a series of burnup intervals in one run, and (2) a provision for a buckling correction to be used in X-Y and R-$\theta$ calculations. Each addition is discussed briefly below.

The capability of performing a series of burnup intervals allows an entire fuel-cycle analysis to be performed in one run. Thus, if the clean reactor configuration and the appropriate refueling fractions are specified, the equilibrium fuel-cycle parameters can be calculated in a single run. Data dump capabilities are also provided so that the problem can be restarted after any number of burnup intervals. This multi-interval modification requires only two additional input control words, but reduces the maximum allowable storage in the A Common Block from $30{,}000_{10}$ to $27{,}000_{10}$ words.

The buckling correction option is made available by use of the newly added control word BUCK (on control Card 8). If BUCK is input as 0.0 (or left blank), no buckling correction is made. If BUCK > 0.0, and the geometry is X-Y or R-$\theta$, BUCK is used in one of two ways:

a. If $0.0 < \text{BUCK} < 1.0$, BUCK is used directly as $B^2_{g,I}$, the same for all groups g and regions I.

b. If BUCK > 1.0, it is assumed to be the buckling height of the reactor and the buckling for each group g, and region I is computed as

$$B^2_{g,I} = \left[\frac{3.1416}{\text{BUCK} + 2\left(0.71\ \lambda^{g,I}_{tr}\right)}\right]^2$$

to give the group/region-dependent buckling.

In both cases, the buckling correction consists of adding the quantity $D_{g,I}\ B^2_{g,I}$ to the macroscopic absorption cross section in each region I for each group g. (This quantity is also subtracted from the macroscopic self-scatter cross section to maintain the correct total cross section.) $D_{g,I}$ is computed as $1.0/\ 3\Sigma^{g,I}_{tr}$ .

## New Input Format

This section specifies the new input required for the additions to the code discussed previously. All references to card numbers are to the original version of the code (Table I).

Card 5 (Now becomes 9I6 format)

| | | |
|---|---|---|
| IBUMAX | Columns 49-54 | The number of burnup intervals to be performed during this run. |

Card 8 (Now becomes 3E12.4 format)

| | | |
|---|---|---|
| DAYST | Columns 13-24 | The time in the fuel-cycle analysis when this run begins. |
| BUCK | Column 25-36 | Buckling, $CM^{-2}$ (if BUCK < 1.0), or buckling height, CM (if BUCK > 1.0). If a buckling correction is not desired, BUCK should be set = 0. |

If a multiple burnup interval run is being made, i.e., IBUMAX > 1, then before the criticality calculation for the second and any subsequent burnup intervals, new values of the parameters PV, EV, and EVM are read in. This allows changes to be made in the search parameters as the fuel-cycle analysis proceeds to equilibrium. The format for this card is 3E12.4, and for the second burnup interval, this card should follow Card 36, the last refueling data card. A blank card can be inserted if only straight $k_{eff}$ calculations are being performed, i.e., IEVT = 1. There is no additional refueling input required for a multiple-burnup-interval run.

The input sequence for such a run is illustrated by an example:

EXAMPLE: A depletion problem is to be run for three burnup intervals, with one burnup time step per interval (NBSTP = 1) of length 100 days. The calculational sequence is that outlined in Part C, p. 21 of the report, i.e., Search-Burnup-$k_{eff}$ after burnup-Refuel.

The card input format for this run is as follows:

1. Cards 1 through 36 as described in Table I of the report; this takes care of the entire input for the first burnup interval.
2. A PV, EV, EVM card (a new input card) for burnup interval 2.
3. An NCON, DELT card (Card 26) with NCON < 0 and DELT = 100.
4. An NCON, DELT card (Card 26) with NCON < 0 and DELT = 0.
5. A PV, EV, EVM card (a new input card) for burnup interval 3.
6. Repeat Items 3 and 4 from above, i.e., Card 26.
7. FINISH card (Card 37).

This procedure is repeated for up to IBUMAX burnup intervals.

A revised listing of the code is available from the Argonne Code Center, in which all changes or additions to the original version of the source deck are noted with a letter next to the card index number in Columns 73-80.

Written: June 1969

Distributed: April 3, 1970

LA-4231
UC-80, REACTOR
TECHNOLOGY
TID-4500

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# PHENIX, a Two-Dimensional Diffusion-Burnup-Refueling Code

by

R. Douglas O'Dell
Thomas J. Hirons

CONTENTS

PHENIX, A TWO-DIMENSIONAL DIFFUSION-BURNUP-REFUELING CODE

by

R. Douglas O'Dell and Thomas J. Hirons

ABSTRACT

PHENIX is a two-dimensional, multigroup, diffusion-burnup-refueling code for use with fast reactors. The code is designed primarily for fuel-cycle analysis of fast reactors and can be used to calculate the detailed burnup and refueling history of fast breeder reactor concepts having any generalized fractional-batch reloading scheme. Either ordinary $k_{eff}$ calculations or searches on material concentrations or on region dimensions can be performed at any time during the burnup history, using the standard source iteration technique. The refueling option of the code accounts for the spatial flux shifts over the reactor lifetime in the calculation of fuel discharge. All programming is in FORTRAN-IV, and the storage requirements are designed so that the code fits in a 64k memory of a CDC-6600 computer.

## I. INTRODUCTION

This report describes the two-dimensional diffusion-burnup-refueling code, PHENIX. The mathematical models are described in Sec. II, and users' information is given in Sec. III. A basic code flow chart, the source-deck listing, and a sample problem are presented in Appendices A through C, respectively.

PHENIX is of specific value for analyzing the burnup and refueling history of fast breeder reactors. Much of PHENIX is based on 2DB, a Battelle-Northwest Laboratory code.[1]

Eigenvalues are computed by source-iteration techniques, with group rebalancing, successive line overrelaxation, and fission-source overrelaxation used to accelerate convergence. Variable dimensioning is used to make maximum use of the fast memory available in the computer. In addition, only one energy group is treated at any given time, so that the storage requirements are relatively insensitive to the number of energy groups being treated.

The code searches on material concentrations and region dimensions to achieve a desired value of $k_{eff}$. Concentration searches can also be performed during the burnup, if desired, to account for fuel depletion. Following burnup, any or all regions of the reactor can be refueled using any desired refueling fraction. The refueling option accounts for the spatial flux shifts over the reactor lifetime.

The format of the input data blocks (e.g., microscopic cross sections, geometry specifications, and material compositions) is, for the most part, similar to the Los Alamos $S_n$ codes[2,3] DTF-IV and 2DF, as well as to 2DB.

## II. PROGRAM DESCRIPTION

### A. Formulation and Solution of Difference Equations

1. Neutron Balance Equations. The time-independent multigroup diffusion equations can be written

$$D_g \nabla^2 \phi_g - \Sigma_g^r \phi_g + S_g = 0 \quad ,$$

$$g = 1, \ldots, G \quad , \tag{1}$$

where

G = the number of energy groups,

g = energy group index (g = 1 denotes highest energy group),

$\phi_g$ = group flux,

$D_g$ = diffusion coefficient ( = $\lambda_g^{tr}/3$),

$\Sigma_g^r$ = removal cross section,

$$= \Sigma_g^a + \sum_{g'=g+1}^{G} \Sigma(g \to g') \ ,$$

$\Sigma_g^a$ = absorption cross section,

$\Sigma(g \to g')$ = down-scatter cross section from group g to g',

$S_g$ = neutron source rate.

The neutron source term, $S_g$, for group g consists of two terms, a fission source term and an inscatter source term from higher energy groups,

$$S_g = \frac{\chi_g}{k_{eff}} \sum_{g'=1}^{G} (\nu\Sigma^f)_{g'} \ \phi_{g'} + \sum_{g''=1}^{g-1} \Sigma(g'' \to g) \ \phi_{g''} \ , \tag{2}$$

where

$\chi_g$ = fission fraction,

$k_{eff}$ = effective multiplication factor,

$(\nu\Sigma^f)_g \ \phi_g$ = fission source rate from neutrons in group g.

Equation 1 can be recast into a set of spatially coupled difference equations suitable for iterative solution by digital computer. These difference equations are formed by overlaying a mesh grid on the reactor to produce a grid of incremental mesh subvolumes. The mesh spacing is the same for all energy groups. Associated with each mesh subvolume is a mesh point at which the diffusion equation is to be discretely evaluated. In this code, the mesh point is located at the geometric center of its mesh subvolume (instead of at the intersection of mesh grid lines). In this manner, each mesh point has associated with it the mesh subvolume established by the mesh grid.

The spatial difference equations for each mesh point are formed by integrating Eqs. 1 and 2 over the mesh subvolume associated with the mesh point. The group flux at each mesh point is assumed to be the average group flux in the associated mesh subvolume, and the group constants at each mesh point are constant over its mesh subvolume. If we consider the (i,j) mesh point shown in Fig. 1, the integration of the removal and source terms of Eq. 1 yields

$$\int_{V_{i,j}} \Sigma_g^r \ \phi_g(i,j) \ dV = (\Sigma_g^r \ \phi_g \ V)_{i,j} \ , \tag{3}$$

and

$$\int_{V_{i,j}} S_g(i,j) \ dV = (S_g \ V)_{i,j} \ , \tag{4}$$

where $V_{i,j}$ is the mesh subvolume associated with the (i,j)th mesh point. In performing the subvolume integration on the leakage term, $D_g \ \nabla^2 \ \phi_g$, we can apply Green's theorem:

$$\int_V D \ \nabla^2 \ \phi \ dV = \int_A D \ \nabla\vec{\phi} \cdot d\vec{A} \ . \tag{5}$$

The flux gradient at the mesh boundary is approximated, in the usual manner, by the forward (or backward) difference technique. Applying Eq. 5, together with Eqs. 3 and 4, to the diffusion equation at point (i,j) yields the basic difference equation (dropping the group index for simplicity):

$$(\overline{D}A/\ell)_{i,i-1} \ (\phi_{i-1,j} - \phi_{i,j}) + (\overline{D}A/\ell)_{i,i+1}$$
$$\cdot \ (\phi_{i+1,j} - \phi_{i,j}) + (\overline{D}A/\ell)_{j,j-1} \ (\phi_{i,j-1} - \phi_{i,j})$$
$$+ \ (\overline{D}A/\ell)_{j,j+1} \ (\phi_{i,j+1} - \phi_{i,j}) - (\Sigma^r \ \phi \ V)_{i,j}$$
$$+ \ (SV)_{i,j} = 0 \ , \tag{6}$$

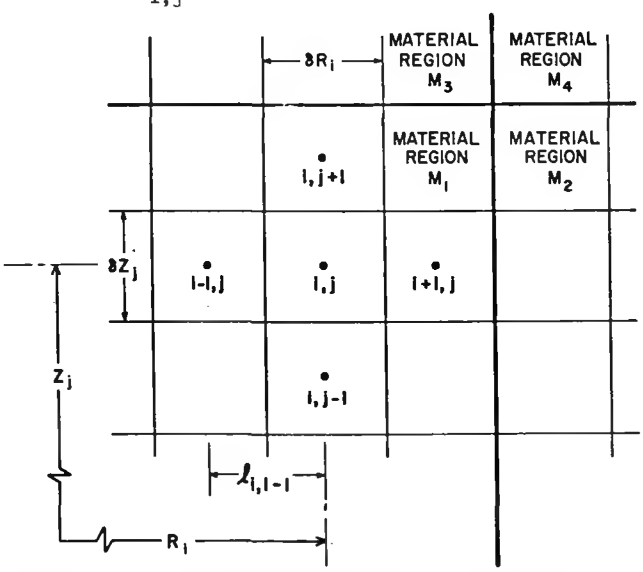


Fig. 1. Mesh grid and mesh point configuration.

where, referring to Fig. 1,

$\ell$ = distance between mesh point (i,j) and the adjacent mesh point indicated by the subscripts in Eq. 6, e.g., $\ell_{i,i-1} = R_i - R_{i-1}$,

A = area of common boundary between mesh subvolume (i,j) and the subvolume indicated by the subscripts in Eq. 6,

$\bar{D}$ = effective diffusion coefficient between mesh point (i,j) and the mesh point indicated by the subscripts in Eq. 6, e.g., between points (i,j) and (i-1,j),

$$\bar{D} = \frac{D_{i,j}\, D_{i-1,j}\, (\delta R_i + \delta R_{i-1})}{D_{i,j}\, \delta R_{i-1} + D_{i-1,j}\, \delta R_i} ,$$

chosen to ensure continuity of current between mesh subvolumes.

If the point (i,j) does not lie on an exterior boundary, Eq. 6 can be rearranged into the form

$$\phi_{i,j} = \frac{(SV)_{i,j} + \sum_{k=1}^{4} C_k^{i,j}\, \phi_k}{\Gamma_{i,j}} , \tag{7}$$

where

$\phi_k$ = the flux at one of the four mesh points adjacent to the point (i,j),

$$C_k^{i,j} = \bar{D}A/\ell , \tag{8}$$

$$\Gamma_{i,j} = (\Sigma^r\, V)_{i,j} + \sum_{k=1}^{4} C_k . \tag{9}$$

It should be remembered that an equation of the form of Eq. 7 exists for each group g at every interior mesh point. Thus, there is a system of equations of the form of Eq. 7 that is amenable to iterative solution.

2. Boundary Conditions. Two boundary conditions are available for use in PHENIX, zero flux gradient and flux vanishing. These are shown graphically in Fig. 2.

If we consider the *zero flux gradient* condition and refer to the left boundary of the model shown in Fig. 2, we see that we can place, in principle, an effective mesh interval, e.g., interval 0, outside the left boundary. Since zero flux gradient at the left boundary implies symmetry, the pseudo mesh interval is the mirror image of interval 1.

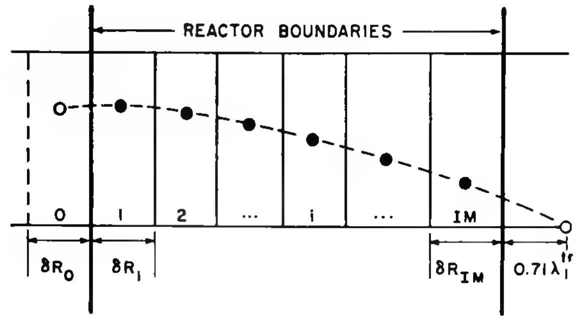


Fig. 2. One-dimensional schematic diagram of reactor boundary conditions.

For difference Eq. 6 applied at the point with i = 1, the first term represents the left leakage from the mesh subvolume on the left boundary. Because of symmetry, however, there is no net leakage and the first term of Eq. 6 must vanish. This is accomplished in the code by setting the coefficient $\bar{D}A/\ell$ equal to zero. (The setting of the flux difference $\phi_{0,j} - \phi_{1,j} = 0$ is not possible in the code because $\phi_{0,j}$ does not exist.) In the simplified form of Eq. 7, therefore, a zero flux gradient boundary condition is treated by setting the appropriate $C_k = 0$.

To consider the basic handling of the *flux vanishing* boundary condition, refer to the right reactor boundary in Fig. 2. Let the right-most mesh subvolume in the reactor be called the (IM,j)th. The flux vanishing condition requires that we effectively place an additional mesh point (IM + 1,j) a distance of 0.71 $\lambda_g^{tr}$ to the right of the reactor boundary and require that the flux $\phi_{IM+1,j}$ at that point be zero. From the second term of Eq. 6 (with i = IM), the flux difference is merely $-\phi_{IM,j}$, and, further, the distance $\ell$ between the IMth and (IM+1)st mesh interval is 0.5 $\delta R_{IM}$ + 0.71 $\lambda_g^{tr}$. In the simplified form of Eq. 7, then, the flux vanishing condition is treated by eliminating the zero flux term in the four-term sum of the numerator and by setting the appropriate $C_k$ in the denominator equal to

$$\frac{\bar{D}A}{0.5\ \delta R + 0.71\ \lambda^{tr}} .$$

3. Method of Solution. The group flux distributions and the eigenvalue are computed by the source-iteration technique. This technique consists of the following process: A guess is made of the initial flux distribution for all groups, and an initial fission source distribution, $FSD_0$, is

calculated. For group 1, the source term $(S_1V)_{i,j}$ is computed for each mesh point, and a set of coupled, inhomogeneous algebraic equations of the form of Eq. 7 is produced. The set of equations is solved iteratively by systematically proceeding through the mesh. Each use of the entire set of equations is called an *inner iteration* (or mesh sweep). Several inner iterations are usually performed until the flux distribution (for group 1) that conforms to the initial source distribution is found. Once this is done, $FSD_0$ is used to calculate the fission source for group 2, and the group 1 fluxes just calculated are used to calculate the inscatter source for group 2. These two terms are combined to produce the source term $(S_2V)_{i,j}$ for group 2. The group 2 equations are then iteratively solved for the group 2 fluxes that conform to the source distribution. This sequence is repeated through all groups. The determination of all group flux distributions that result from the initial fission source distribution, $FSD_0$, constitutes an *outer iteration*.

After an outer iteration, a new fission source distribution (FSD) is computed from the new flux distributions. The multiplication ratio, $\lambda$, is then obtained as the ratio of the new total fission source rate to the previous total fission source rate where the total fission source rate is merely the volume-weighted sum of the fission source distributions.

Before beginning a new outer iteration, the FSD is effectively multiplied by $1/\lambda$ (in the code the fission fractions $\chi_g$ are multiplied by $1/\lambda$) in order to maintain the steady-state condition that total reactor neutron production equals total reactor neutron losses.

With the new FSD, a second outer iteration is performed to give a second set of group fluxes and a second value of $\lambda$. From these, another FSD is computed and another outer iteration performed. As this procedure continues, the value of $\lambda$ approaches unity, and the problem is converged when $|1 - \lambda| <$ EPS, where EPS is the eigenvalue convergence criterion, an input parameter. The value of $k_{eff}$ for the reactor is simply the product of the successive $\lambda$'s.

Several features are incorporated in PHENIX to accelerate the convergence. These are line inversion with successive line overrelaxation, fission source overrelaxation, and group rebalancing.

The iterative technique is improved by the use of line inversion with successive line overrelaxation. In this method, the entire set of equations of the form of Eq. 7 for a row or column are solved simultaneously, yielding the group fluxes a row or a column at a time. The fluxes are then overrelaxed using the extrapolated Liebmann scheme,

$$\phi^{\nu+1} = \phi^{\nu} + \text{ORF} \cdot \left(\phi_{br}^{\nu+1} - \phi^{\nu}\right) , \qquad (10)$$

where

$\phi^{\nu}$ = the group flux calculated in the $\nu$th inner iteration,

$\phi_{br}^{\nu+1}$ = the group flux just calculated in the ($\nu$+1) inner iteration before overrelaxation,

ORF = overrelaxation factor,

$\phi^{\nu+1}$ = overrelaxed group flux.

The overrelaxation factor is an input parameter that is somewhat problem dependent. An ORF of 1 produces no overrelaxation, an ORF < 1 constitutes underrelaxation. For most problems, an ORF of 1.5 or 1.6 is best.

The line inversion can be performed by rows (radially), by columns (axially), or by alternating the direction from one mesh sweep to the next. On the basis of experiments with different core geometries and different combinations of boundary conditions, the code will determine the best direction by considering the boundary conditions together with the average axial and radial mesh spacing. Specifically, in R-$\theta$ geometry, inversion is done axially; for problems with an even number of reflective boundary conditions, inversion is done in the direction of least average mesh spacing; and for problems with an odd number of reflective boundary conditions, the mesh is swept in alternating directions.

Fission-source overrelaxation is also used to accelerate convergence. The extrapolated Liebmann method is applied to the FSD by comparing the FSD from the outer iteration just completed with the FSD from the previous outer iteration. Specifically,

$$\text{FSD}^{n+1} = \text{FSD}^{n} + \text{ORFF} \cdot \left(\text{FSD}_{br}^{n+1} - \text{FSD}^{n}\right) , \qquad (11)$$

where the notation is similar to that used in Eq. 10. The fission source overrelaxation factor ORFF is computed internally as

$$ORFF = 1.0 + 0.6 \cdot (ORF - 1). \quad (12)$$

Group rebalancing is also used to improve the convergence rate. In group rebalancing, the flux in each group is normalized by balancing the total reactor loss rate for the group with total reactor source for the group. The latter quantity is merely the sum of $(S_g V)_{i,j}$ over all mesh points. This rebalancing is performed immediately before the series of inner iterations for the group is begun. With group rebalancing, a one-region reactor problem with zero flux gradient boundary conditions would be solved in one outer iteration.

B. Search Options

1. General Operation of the Search Routine. It is possible in PHENIX to adjust material concentration or reactor dimensions to achieve a desired value of $k_{eff}$. (The desired value of $k_{eff}$ is input as PV, and the code is also instructed to use this value by setting the input quantity, IPVT, to 2.)

Regardless of the parameter being adjusted, the search is conducted by performing a sequence of $k_{eff}$-type calculations, each for a different value of the desired parameter, to find the value of the desired parameter which makes $\lambda$ (described in Sec. A.3) equal to unity.

For the initial system, the sequence of outer iterations continues until two successive values of $\lambda$ differ by less than the parametric eigenvalue convergence criterion EPSA. After the first converged $\lambda$ is obtained, the initial value of the eigenvalue* (the input quantity EV) is altered by the eigenvalue modifier EVM, an input number. If $\lambda > 1$, the new eigenvalue is equal to EV + EVM; if $\lambda < 1$, the new value is EV - EVM. With a new eigenvalue and hence a new value of the parameter being searched on, a second converged value of $\lambda$ is computed. Basically, then, after two values of $\lambda$ (or $k_{eff}$) are obtained for two different system parameter values, the program attempts to fit a curve through the most recent values of $\lambda$ to extrapolate or interpolate to a value of unity. Depending on the amount of information available and the magnitude of $|1 - \lambda|$, this curve fit proceeds in different ways. A parabolic curve fit cannot be made until three converged values of $\lambda$ are available and is not attempted, even then, unless $|1 - \lambda|$ is between input limits XLAL and XLAH. If the parabolic fit is tried and the roots are imaginary, the root closest to the previous EV is used as the new value of EV. Once a bracket is obtained (change of sign of $\lambda - 1$), the fit procedure is not allowed to move out of the range of this bracket. Should the parabolic fit select an eigenvalue outside the bracket region, this value is rejected, and the new value is taken as the average of the two previous values.

Whenever the parabolic fit is not used, a linear fit is incorporated from which the new eigenvalue is

$$EV_{new} = EV_{old} + POD \cdot EQ \cdot (1 - \lambda) , \quad (13)$$

where POD is an input parameter oscillation damper designed to restrict the amount of change in the eigenvalue, and EQ is a measure of the slope of the curve. When $|1 - \lambda| >$ XLAH, $(1 - \lambda)$ in Eq. 13 is replaced by XLAH with the sign of $(1 - \lambda)$ to prevent too large a change in EV. After $|1 - \lambda| <$ XLAL, the value of EQ is fixed and kept constant to prevent numerical difficulty in approximating the derivative when $\lambda$ is close to unity.

Because parametric search problems involve a series of $k_{eff}$ calculations, it is to the user's advantage to study his particular problem in order to optimize his calculations and to assure himself that a solution is possible. Ideally, the user will have some reasonable estimate of the critical parameter before beginning the search calculation.

2. Material Concentration Search. The general search procedure just described can be applied to the problem of selectively determining material concentrations (atom densities) to produce the desired value of $k_{eff}$. The concentration search can

*It should be noted that the term *eigenvalue* assumes a different meaning in the search mode than in the ordinary $k_{eff}$ calculation described in Sec. A.3. In the latter calculation, *eigenvalue* simply refers to the product of the $\lambda$'s, so that the *eigenvalue* approaches $k_{eff}$ as $\lambda$ approaches unity. In the search calculation, however, *eigenvalue* is a quantity that is used directly to alter the parameter being searched on.

be performed on any of the materials in any or all of the reactor zones. The eigenvalue EV is applied to the input atom density for a particular material in a given zone to yield an adjusted material atom density

$$N^i = N^i_{input} \cdot (1.0 + EV \cdot I4^i) \quad . \tag{14}$$

The superscript i denotes both the material and the reactor zone, and I4 is an input quantity, the search material modifier. The use of material modifiers permits a high degree of flexibility in the search. All materials whose modifiers are zero are unaltered by the search. On the other hand, if a particular region contains, for example, $^{235}U$ and $^{238}U$, the proper enrichment can be determined by giving $^{235}U$ and $^{238}U$ modifiers that differ in sign. In this manner, when the $^{235}U$ concentration is increased, the $^{238}U$ concentration will be decreased. In a similar manner, control rods with fueled followers can be properly treated in the search.

3. Dimensional Search (Delta Calculation). In applying the search option to the reactor dimensions, the reactor zone boundaries are selectively modified. Because each radial and axial zone is subdivided into its particular radial and axial mesh, the dimension changes are determined by adjusting the mesh widths $\delta r^i$ and $\delta z^j$ for the ith radial and jth axial zone by means of the algorithms

$$\delta r^i = \delta r^i_0 (1 + R3^i \cdot EV) \tag{15}$$

and

$$\delta z^j = \delta z^j_0 (1 + Z3^j \cdot EV) \quad . \tag{16}$$

In Eqs. 15 and 16, the subscript 0 refers to the initial (input) widths. $R3^i$ is an input quantity, the mesh modifier for the ith radial zone, while $Z3^j$, also an input quantity, is the mesh modifier for the jth axial zone. If one of the R3 or Z3 values is zero, the associated mesh width is unchanged, whereas if all the mesh modifiers are unity, all reactor dimensions are uniformly expanded or contracted. The proper selection of the mesh modifiers can produce a wide variety of dimensional change combinations. For example, an interface between two zones can be moved while the rest of the system is left unchanged.

## C. Burnup Method

Burnup is performed by PHENIX using the point burnup equation applied separately to each burnable isotope in each zone. The point burnup equation can be written

$$\frac{dN_i}{dt} = -\lambda_i N_i - \bar{\sigma}_{a,i} N_i \bar{\phi} + \lambda_k N_k + \sum_j \left(\bar{\sigma}_{c,j} N_j \bar{\phi}\right) + \sum_m \left(\bar{\sigma}_{f,m} N_m \bar{\phi}\right) , \tag{17}$$

where

$N_i$ = atom density of burnable nuclide i,

$\lambda_i$ = decay constant for nuclide i,

$\bar{\sigma}_{a,i}$ = zone- and group-averaged absorption cross section for nuclide i,

$\bar{\sigma}_{f,i}$ = zone- and group-averaged fission cross section for nuclide i,

$\bar{\sigma}_{c,i}$ = zone- and group-averaged capture cross section for nuclide i,

$\bar{\phi}$ = zone-averaged total flux for the zone.

The last two sums in Eq. 17 provide for two capture and seven fission sources of $N_i$, respectively. The fission sources are necessary if fission product buildup is to be considered.

The burnup time is an input quantity, DELT, and is arbitrarily subdivided into ten smaller substeps. The point burnup equation is then solved iteratively as a marchout problem using the substeps. The zone-averaged fluxes and cross sections used in Eq. 17 are computed before each burnup time. The total reactor power from the burnable isotopes, and the relative flux distributions (both spectral and spatial), are assumed constant throughout the burnup calculation. The iterative marchout algorithm is best seen if Eq. 17 is rewritten in the form

$$\frac{d\vec{N}}{dt} = \vec{G}(\vec{N},t) \quad . \tag{18}$$

The basic marchout difference equation is then

$$\vec{N}(t_j) = \vec{N}(t_{j-1}) + \frac{\delta t}{2}\left(\vec{G}_{j-1} + \vec{G}_j\right) \quad , \tag{19}$$

where j is the index on time (j = 1, 2, ..., 10), and $\delta t$ is the length of the substep. Equation 19 is transcendental in that $\vec{N}(t_j)$ must be known in order for $\vec{G}_j$ to be known. The code, therefore, iterates on the $\vec{N}$ at each substep, using the iteration algorithm,

$$\vec{N}^{\nu}(t_j) = \vec{N}(t_{j-1}) + \frac{\delta t}{2}\left(\vec{G}_{j-1} + \vec{G}_j^{\nu-1}\right), \qquad (20)$$

where $\nu$ is the iteration index. Because the length of the substep is usually short, only a few iterations are necessary. Rather than complicate the marchout procedure with convergence tests on the $\vec{N}^{\nu}(t_j)$, therefore, the code automatically performs five iterations at each substep. Because of this, together with the assumption that relative flux profiles are unchanged during burnup, relatively short substeps should be employed if rapid burnup is expected or if large spatial or spectral flux shifts are anticipated.

D. The Refueling Option

1. The Refueling Method. Since the burnup analysis of large fast reactors is frequently performed in conjunction with fuel-cycle analyses (especially for fast breeder reactors), a flexible and comprehensive refueling option has been included in PHENIX. For total reactor refueling following a specified length of burnup, the refueling problem is simple. For mixed-batch fractional refueling, however, the problem is considerably more difficult. For example, if one-fourth of the core fuel is to be discharged and replaced with clean fuel at the end of each burnup interval (the total time a reactor is operated between refuelings), it is necessary to distinguish this fuel fraction from that which remains in the reactor. In this type of refueling scheme, the core fuel at the end of a burnup interval consists of four distinct constituents: fuel that has resided in the reactor for four successive burnup intervals and is ready to be discharged, fuel that has burned for three burnup intervals, fuel that has burned for two burnup intervals, and fuel that has been burned for one interval. (In this example, we assume that the reactor has been operated for a time equal to at least four burnup intervals.)

Since PHENIX deals with homogenized atom densities, the analysis could, of course, be done by explicitly tagging the elements (or isotopes) of each constituent. For example, for the fractional refueling described above, the core could be assigned four separate $^{239}Pu$ constituents, each characterized by an atom density and each corresponding to one of the resident constituents of the core. The sum of these constituent atom densities would be the total $^{239}Pu$ atom density in the core. Note that, although this method is conceptually straightforward, it poses a severe bookkeeping problem. The code will treat each tagged constituent isotope or element separately and will require both a cross-section table and an atom density specification for each. This considerably increases the required input data and storage requirements for the code.

An alternative to the explicit tagging method that eliminates this bookkeeping problem has been employed in PHENIX. The method used in PHENIX requires that all fuel discharged from a given zone begin its life as clean fuel with the same relative isotopic content, i.e., the isotopic content of the fuel charge is invariant from one burnup interval to the next for a given zone.

The method of calculation is best described by an example. Suppose that the i burnup interval has just been completed and that the discharge from a given region is to be computed. Let the refueling fraction for this region be 1/4 and assume that $i \geq 4$. Thus, the fuel to be discharged consists of the constituent fuel that has been burned over the four burnup intervals (i - 3) through i. Using the clean fuel charge atom densities for the region, the basic burnup equation, Eq. 17, is applied using the zone-averaged total flux and zone- and group-averaged cross sections for the region during the (i-3) burnup interval. The resulting atom densities are then used as input to burnup over the (i-2) burnup interval using the average flux and cross sections for that burnup interval. This procedure is continued through the i burnup interval. The atom densities determined in this manner are those that resulted from the successive burnup of clean fuel over the last four burnup intervals. Because the charge for the (i-3) burnup interval was only one-fourth of the clean fuel atom density, the discharge atom densities are merely one-fourth of the atom densities obtained by successive burnup.

With the discharge thus determined for the i burnup interval, the homogenized initial atom densities for the (i+1) burnup interval can be directly computed. This is possible since the burnup portion of PHENIX has calculated the homogenized atom densities, $N_i$, at the end of the i burnup interval, as well as the discharge, $D_i$, following the i burnup interval, and the charge, $C_0$, for all burnup intervals is known. The homogenized input atom density for the (i+1) burnup interval, $N^0_{i+1}$, for the particular zone and isotope is then

$$N^0_{i+1} = N_i - D_i + C_0 \quad . \tag{21}$$

Note that the successive burnup calculations account for both the spectral and spatial flux shifts from one burnup interval to the next.

2. Specific Features of the Refueling Option. The refueling option is designed for use in the detailed analysis of a reactor over its operational lifetime, with refueling occurring periodically. Accordingly, the analysis must begin with the initial burnup interval and proceed through successive burnup intervals in order. Information such as zone-averaged total fluxes and zone- and group-averaged cross sections from previous burnup intervals must be supplied as input for the refueling subroutines. Either a card or a tape dump can be used for input. Because of the cumulative requirements for data as the burnup analysis progresses, it is recommended that magnetic tape be used for data storage for the refueling.

Refueling can be performed using any refueling fraction and with any frequency, with each zone being treated independently. For example, zone 1 can have two-thirds of its fuel replaced every third refueling, while zone 2 can have one-half of its fuel replaced at each refueling.

After the detailed refueling (zone by zone) has been computed, any combination of zones can be collapsed one or more times, if desired, to provide mass summary subtotals for the burnable isotopes. This is useful, for example, for collapsing a many-region fast breeder reactor into the three basic regions of core, radial blanket, and axial blanket. A further option provides for the charge-discharge masses for the first NECOP (see Input Instructions) collapses to be punched on cards. These punched data can be used as input for economic analysis, if desired.

## III. USERS' INFORMATION

### A. Input Instructions

This section describes the input format and deck setup for PHENIX. Several of the data blocks (RO, ZO, MO, K7, IO, I1, I2, R2, R3, Z2, Z3, and I4) are read by the two generalized input subroutines, REARL (for floating point data), or REAFXP (for fixed point data). These routines streamline the input block and allow for the ganging of input in the case of repeated identical entries. When REARL and REAFXP are used, all cards contain six data fields of 12 columns each. The last nine columns of each field contain the data associated with the particular field; columns 2-3 contain an integer N from 0 to 99. The first column of each field must contain

0 or blank - no effect ($N \neq 0$),

1 - repeat associated entry N times,

2 - do N linear interpolations between associated data entry and succeeding data entry,

3 - terminate reading of this array with previous data entry.

The data blocks mentioned above (except K7) contain information concerning the materials and geometric composition of the reactor and can be conveniently calculated and punched by a data preparation code[4] such as DPC. This sequence of data blocks is also compatible as input to the transport theory codes DTF-IV and 2DF which were developed at LASL.

An additional subroutine, TRIG, is used in PHENIX to read trigger data for burnup and refueling problems. This routine uses a dense format, 24I3 per card, which is useful in condensing the size of the input deck for a large number of mixture specifications.

The input blocks required when the refueling option is used are all read by the subroutine INPR. This isolation of the refueling input streamlines the flow of the code and helps to conserve storage requirements. The input card format is given in Table I.

TABLE I

INPUT CARD FORMAT FOR PHENIX

| Variable | Columns | Description |
|---|---|---|
| Card 1 (12A6 format) | | To run a series of problems, repeat data input starting with this card. |
| ID(12) | 1-72 | Identification Card 1 |
| Card 2 (11A6, F6.1 format) | | |
| ID(11) | 1-66 | Identification Card 2 |
| TMAX | 67-72 | Maximum running time in minutes; this allows a final dump to be obtained if convergence is forced; if zero, not used. |
| Card 3 (12I6 format) | | |
| IGE | 1-6 | Geometry specification<br>= 0, X-Y<br>= 1, R-Z<br>= 2, R-$\theta$ |
| IZM | 7-12 | Number of material zones |
| IBL | 13-18 | Left boundary condition<br>= 0, vacuum<br>= 1, reflective |
| IBR | 19-24 | Right boundary condition (same conditions as for IBL) |
| IBT | 25-30 | Top boundary condition (same conditions as for IBL) |
| IBB | 31-36 | Bottom boundary condition (same conditions as for IBL) |
| IEVT | 37-42 | Eigenvalue type<br>= 1, $k_{eff}$<br>= 2, concentration search<br>= 3, dimensional (delta) search |
| IPVT | 43-48 | Parametric value type<br>= 1, none<br>= 2, $k_{eff}$ |
| IM | 49-54 | Number of radial mesh intervals ($\geq 3$) |
| JM | 55-60 | Number of axial mesh intervals ($\geq 3$) |
| IZ | 61-66 | Number of radial zones (delta option only) |
| JZ | 67-72 | Number of axial zones (delta option only) |
| Card 4 (12I6 format) | | |
| IGM | 1-6 | Number of energy groups ($\leq 50$) |
| ML | 7-12 | Number of input materials |
| ICST | 13-18 | Cross-section type. For a detailed discussion of these types, see Cards 10 and 11.<br>= 1, Type 1<br>= 2, Type 2 |
| IHT | 19-24 | Position of sigma total in cross-section table |
| IHS | 25-30 | Position of sigma self-scatter in cross-section table |
| ITL | 31-36 | Cross-section table length |
| IXSEC | 37-42 | Read cross sections<br>= 0, from cards<br>= 1, from tape |
| MO1 | 43-48 | Total number of mixture specifications (see cards 17-19) |
| OITM | 49-54 | Maximum number of outer iterations allowed |
| IITM | 55-60 | Maximum number of inner iterations per group per outer iteration. Recommended value is 5. |

TABLE I (continued)

| Variable | Columns | Description |
|---|---|---|
| Card 4 (12I6 format) continued | | |
| MSHSWP | 61-66 | Direction of line inversion in solution for the group fluxes<br>= 1, alternating direction<br>= 2, radial<br>= 3, axial<br>= 4, code decides |
| ISTART | 67-72 | Initial flux guess<br>= 0, none (code assumes a flat flux in all groups)<br>= 1, $\phi(r)*\phi(z)$ from cards (same for all groups)<br>= 2, $\phi(r,z,E)$ from cards<br>= 3, $\phi(r,z,E)$ from tape<br>= 4, $\phi(r)*\phi(z)$, sinusoids (calculated by code, same for all groups) |
| Card 5 (8I6 format) | | |
| IREF | 1-6 | Burnup-refuel control parameter<br>= 0, no burnup<br>= 1, burnup only<br>= 2, burnup and refuel |
| NBSTP | 7-12 | Number of burnup time steps in a burnup interval |
| IFS | 13-18 | Perform a concentration search after the final burnup time step<br>= 0, no<br>= 1, yes |
| NPOIS | 19-24 | Material number of control poison |
| MWDT | 25-30 | Calculate burnup in MWd/T<br>= 0, no<br>= 1, yes (used only in burnup calculations) Must be set = 1 then. |
| IPFLX | 31-36 | Control for punching flux dump<br>= 0, no punching<br>= 1, punch fluxes before burnup<br>= 2, punch fluxes after burnup |
| IPRIN | 37-42 | Print control<br>= 1, full print always<br>= 2, full print for DAY = 0 only<br>= 3, partial print always (In a partial print, the cross sections, group fluxes, and fission source rate are omitted.) |
| IDMTPS | 43-48 | Prepare data dump tape<br>= 0, no<br>= 1, yes |
| Card 6 (6E12.4 format) | | |
| EPS | 1-12 | Eigenvalue convergence criterion, i.e., criterion applied to the total fission source rate. Typical value is $10^{-5}$ to $10^{-6}$ for straight $k_{eff}$ calculations and $10^{-4}$ for search calculations. |
| SRCRT | 13-24 | Neutron source rate for normalization (not used if POWR is used) |
| POWR | 25-36 | Reactor power in MWT for normalization (must be set to zero if SRCRT is used) |
| ORF | 37-48 | Overrelaxation factor used in inner iteration flux calculation. The optimum value of this parameter is somewhat problem dependent, but a value of 1.4 to 1.6 is satisfactory for most cases. |
| FLXTST | 49-60 | Inner iteration flux test<br>= EP, check convergence of all fluxes using the criterion EP<br>= 0., code uses EPS as convergence criterion for all fluxes |
| PV | 61-72 | Desired parametric value (used only for search problems, i.e., IPVT = 2 ) |

TABLE I (continued)

| Variable | Columns | Description |
|---|---|---|
| Card 7 (6E12.4 format) | | |
| EPSA | 1-12 | Parametric value convergence criterion (used only in search calculations). Recommended value is ≈10 EPS. |
| EV | 13-24 | Initial eigenvalue guess (used only in search calculations) |
| EVM | 25-36 | Initial eigenvalue modifier (search only). This value should decrease reactivity; i.e., EV + EVM should produce a lower reactivity than EV. This parameter is extremely problem dependent. |
| EV2 | 37-48 | Eigenvalue guess for second and succeeding searches |
| XLAL | 49-60 | Lower limit on $\lvert\lambda - 1\rvert$. Recommended value is ≈0.001 (search only). |
| XLAH | 61-72 | Upper limit on $\lvert\lambda - 1\rvert$. Recommended value is ≈0.5 (search only). |
| Card 8 (E12.4 format) | | |
| POD | 1-12 | Parameter oscillation damper. Ratio of the computed eigenvalue change to the predicted eigenvalue change. It can be used to accelerate convergence or damp out oscillations. The appropriate value is problem dependent but should be near 1.0. (A POD of exactly 1.0 produces no damping.) |
| Card 9 (A6, 2E6.2 format) (used only if IXSEC = 0) | | |
| HOLN(ML) | 1-6 | Identification (name) of first material |
| ATW(ML) | 7-12 | Atomic weight of first material |
| ALAM(ML) | 13-18 | Decay constant for first material in days$^{-1}$. Used only in burnup calculations. |
| Card 10 (6E12.5 format) (used only if IXSEC = 0) (Begins cross-section data for first group for first material.) | | |
| C(1,IGM,ML) | 1-12 | $\sigma_c$ |
| C(2,IGM,ML) | 13-24 | $\sigma_f$ |
| C(3,IGM,ML) | 25-36 | $\sigma_{s_{total}}$ |
| C(4,IGM,ML) | 37-48 | $\sigma_a$ |
| C(5,IGM,ML) | 49-60 | $\nu\sigma_f$ |
| C(6,IGM,ML) | 61-72 | $\sigma_{tr}$ (= $\sigma_{total}$) |
| Card 11 (6E12.5 format) | | |
| C(7,IGM,ML) | 1-12 | $\sigma_s(g \rightarrow g)$, self-scatter |
| C(8,IGM,ML) | 13-24 | $\sigma_s(g - 1 \rightarrow g)$ |
| C(9,IGM,ML) | 25-36 | $\sigma_s(g - 2 \rightarrow g)$ |

Continue for the remaining downscatter terms, and then repeat for the remaining groups for material 1. Then repeat Cards 9 through 11 for all groups in all remaining materials.

The format given above is for the Type 2 cross sections (ICST = 2), which is the punched output format for the MC$^2$ code.[5] In this format, the data for each material are punched continuously, i.e., no new card is started for each group. Also, $\sigma_c$ and $\sigma_{s_{total}}$ are not used, and these positions in the table length (1 and 3) are deleted by the code.

In the Type 1 cross section format, $\sigma_c$ and $\sigma_{s_{total}}$ do not appear, and all other cross sections are appropriately adjusted in the table length. In addition, the data for each new energy group must begin on a new card.

TABLE I (continued)

For both cross-section types, the code checks the input data to ensure that $\sigma_{tr} = \sigma_a + \sum_{g'} \sigma(g \rightarrow g')$ within a certain error criterion.

If IXSEC = 1, all data on Cards 9 through 11 will be on tape, and these cards will be omitted. Note that, if the cross-section data are on tape, the order in which the materials are read and numbered must be consistent with the material numbering in the I1 block (see Card 18).

| Variable | Columns | Description |
|---|---|---|
| Card 12a (6E12.6 format) (used only if ISTART = 1) | | |
| RF(IM) | 1-12 | Initial flux guess for first radial interval |
| RF(IM) | 13-24 | Initial flux guess for second radial interval |

Continue for all radial intervals. This flux profile is used for all energy groups.

| | | |
|---|---|---|
| Card 12b (6E12.6 format) (used only if ISTART = 1) | | |
| ZF(JM) | 1-12 | Initial flux guess for first axial interval |
| ZF(JM) | 13-24 | Initial flux guess for second axial interval |

Continue for all axial intervals. This flux profile is used for all energy groups.

| | | |
|---|---|---|
| Card 12c (6E12.6 format) (used only if ISTART = 2) | | |
| NO(IMJM) | 1-12 | Initial flux guess for first mesh point in first group |
| NO(IMJM) | 13-24 | Initial flux guess for second mesh point in first group |

Continue for all mesh points and all energy groups.

| | | |
|---|---|---|
| Card 13 [6(I1,I2,E9) format] | | |
| RO(IM+1) | 1-12 | Radial position of first mesh boundary (0.0) |
| RO(IM+1) | 13-24 | Radial position of second mesh boundary (cm) |

Continue for IM+1 radial boundary positions.

| | | |
|---|---|---|
| Card 14 [6(I1,I2,E9) format] | | |
| ZO(JM+1) | 1-12 | Axial position of first mesh boundary (0.0) |
| ZO(JM+1) | 13-24 | Axial position of second mesh boundary (cm) |

Continue for JM+1 axial boundary positions. For an R-$\theta$ calculation, the $\theta$ increments should be in fractions of 360°, e.g., 180° = 0.5.

| | | |
|---|---|---|
| Card 15 [6(I1,I2,I9) format] | | |
| MO(IMJM) | 1-12 | Zone (mix) number for first mesh interval |
| MO(IMJM) | 13-24 | Zone (mix) number for second mesh interval |

Continue for all mesh intervals. The mesh intervals are numbered beginning at the lower left and then proceeding through each row in order.

| | | |
|---|---|---|
| Card 16 [6(I1,I2,E9) format] | | |
| K7(IGM) | 1-12 | Fission fraction (spectrum) for first energy group |
| K7(IGM) | 13-24 | Fission fraction for second energy group |

Continue for all energy groups.

| | | |
|---|---|---|
| Card 17 [6(I1,I2,I9) format] | | |
| IO(MO1) | 1-12 | Material number assigned to Zone (mix) 1 |

Repeat same entry for a total of N + 1 times where N is the number of materials in Mix 1. Then repeat the same procedure for all remaining zones (mixes).

TABLE I (continued)

| Variable | Columns | Description |
|---|---|---|
| Card 18 [6(I1,I2,I9) format] | | |
| I1(MO1) | 1-12 | = 0 (to trigger storage area for Mix 1) |
| I1(MO1) | 13-24 | Number of first material in Mix 1 |
| I1(MO1) | 25-36 | Number of second material in Mix 1 |

Continue for all materials in Mix 1. Then repeat the same procedure for all remaining mixes.

| Variable | Columns | Description |
|---|---|---|
| Card 19 [6(I1,I2,E9) format] | | |
| I2(MO1) | 1-12 | = 0 |
| I2(MO1) | 13-24 | Concentration of first material in Mix 1 (atoms/b-cm) |
| I2(MO1) | 25-36 | Concentration of second material in Mix 1 |

Continue for all materials in Mix 1. Then repeat the same procedure for all remaining mixes. Note that the length of the I0, I1, and I2 blocks is the same (= MO1).

| Variable | Columns | Description |
|---|---|---|
| Card 20 [6(I1,I2,I9) format] (used only if IEVT = 3) | | |
| R2(IM) | 1-12 | Dimensional search zone number for first radial interval |
| R2(IM) | 13-24 | Dimensional search zone number for second radial interval |

Continue for all radial mesh intervals.

| Variable | Columns | Description |
|---|---|---|
| Card 21 [6(I1,I2,E9) format] (used only if IEVT = 3) | | |
| R3(IZ) | 1-12 | Dimensional modifier for first radial zone |
| R3(IZ) | 13-24 | Dimensional modifier for second radial zone |

Continue for all radial zones.

| Variable | Columns | Description |
|---|---|---|
| Card 22 [6(I1,I2,I9) format] (used only if IEVT = 3) | | |
| Z2(JM) | 1-12 | Dimensional search zone number for first axial interval |
| Z2(JM) | 13-24 | Dimensional search zone number for second axial interval |

Continue for all axial mesh intervals.

| Variable | Columns | Description |
|---|---|---|
| Card 23 [6(I1,I2,E9) format] (used only if IEVT = 3) | | |
| Z3(JZ) | 1-12 | Dimensional modifier for first axial zone |
| Z3(JZ) | 13-24 | Dimensional modifier for second axial zone |

Continue for all axial zones.

| Variable | Columns | Description |
|---|---|---|
| Card 24 [6(I1,I2,E9) format] (used only if IEVT = 2) | | |
| I4(MO1) | 1-12 | Search material modifier for first position in the MO1 block |
| I4(MO1) | 13-24 | Search material modifier for second position in the MO1 block |

Continue for all positions in the MO1 block.

| Variable | Columns | Description |
|---|---|---|
| Card 25 (24I3 format) (used only if MWDT = 1) | | |
| NTRIG(MO1) | 1-3 | Trigger for total fuel mass calculation for first position in MO1 block<br>= 0, not a fuel isotope<br>= 1, a fuel isotope |
| NTRIG(MO1) | 4-6 | Same conditions as above for the second position in MO1 block |

Continue for all positions in the MO1 block.

TABLE I (continued)

| Variable | Columns | Description |
|---|---|---|
| Card 26 (I6,E12.0 format) (burnup control card) | | |
| NCON | 1-6 | Burnup control<br>= 0, end of problem, read input data for next case<br>= N, read burnup parameters for N isotopes and take time step of DELT<br>< 0, take time step of DELT |
| DELT | 7-18 | Length of time step in days |

Card 27 (12I6 format) (used only if NCON > 0). This card contains all burnup parameters for the first burnable isotope.

| Variable | Columns | Description |
|---|---|---|
| MATN(NCON) | 1-6 | Material sequence number (I1 number) of first burnable isotope |
| NBR(NCON) | 7-12 | Control for breeding ratio calculation<br>= 0, no effect<br>= 1, fertile isotope<br>= 2, fissile isotope |
| LD(NCON) | 13-18 | = 0, no decay source<br>= N, decay source from burnable isotope N |
| LCN(NCON,2) | 19-24 | = 0, no capture source<br>= N, capture source from burnable isotope N |
| LCN(NCON,2) | 25-30 | = 0, no capture source<br>= N, capture source from burnable isotope N |
| LFN(NCON,7) | 31-36 | = 0, no fission source<br>= N, fission source from burnable isotope N |
| LFN(NCON,7) | 37-42 | = 0, no fission source<br>= N, fission source from burnable isotope N |

Continue for other five possible fission sources. Repeat Card 27 for all burnable isotopes. Then repeat Card 26 for additional time steps. For these additional time steps, NCON should be <0. After all time steps have been calculated, a final Card 26 should be used with NCON < 0 and DELT = 0. This allows the final values of the zone-averaged total fluxes and cross sections and the final breeding ratio to be calculated and printed before the problem is ended.

Note: This section begins the input for the refueling option of the code. All succeeding data (except for the final Card 37) should be input only if IREF = 2.

Card 28 (6I6 format)

| Variable | Columns | Description |
|---|---|---|
| KNT | 1-6 | The burnup interval just completed in the fuel-cycle history |
| NREG | 7-12 | The maximum number of regions requiring refueling during the burnup history |
| NREPO | 13-18 | Refuel control rods during refueling<br>= 0, no<br>= 1, yes |
| KLAPS | 19-24 | Region collapse option<br>= 0, no collapse<br>= N, number of collapses to be performed |
| INTMAX | 25-30 | Maximum number of burnup intervals to be analyzed in the total fuel-cycle history |
| NECOP | 31-36 | Punch option for input to economics code<br>= 0, no punched output<br>= N, data from the first N collapses will be punched |

TABLE I (continued)

| Variable | Columns | Description |
|---|---|---|
| Card 29 (I6,F12.5,I6 format) | | |
| K(NREG) | 1-6 | Zone number of first region to be refueled |
| XO(NREG) | 7-18 | Fraction of fuel in Zone K which is to be replaced |
| NFRE(NREG) | 19-24 | Number of burnup intervals between refueling for Zone K, i.e., the refueling frequency |

Repeat Card 29 for NREG zones that are to be refueled.

| | | |
|---|---|---|
| Card 30 (24I3 format) | | |
| TRG(NCON) | 1-3 | Trigger to refuel first burnable isotope<br>= 0, no<br>= 1, yes |
| TRG(NCON) | 3-6 | Same conditions for second burnable isotope |

Continue for all burnable isotopes.

| | | |
|---|---|---|
| Card 31 (6F12.7 format) [omit if using tape dump (IDMTPS = 1) and KNT > 1] | | |
| HNO(M01) | 1-12 | Clean atom density (no burnup) of material in the first position of the M01 block |
| HNO(M01) | 13-24 | Same conditions for material in the second position of the M01 block |

Continue for all positions in the M01 block. (Note: The HNO block is identical to the I2 block at the reactor beginning-of-life.)

| | | |
|---|---|---|
| Card 32 (6E12.5 format) [omit if using tape dump (IDMTPS = 1)] | | |
| PHI(IZM,KLNT) | 1-12 | Zone-averaged total flux used to burn the constituent material in REFUEL for the first zone in the first burnup interval |
| PHI(IZM,KLNT) | 13-24 | Same conditions for second zone in the first burnup interval |

Continue for all zones in the first burnup interval. Then repeat Card 32 for all burnup intervals up to KLNT.

| | | |
|---|---|---|
| Card 33 (6E12.5 format) [omit if using tape dump (IDMTPS = 1)] | | |
| ABXS(NCON,IZM,KLNT) | 1-12 | Zone-group-averaged absorption cross section used to burn the constituent material in REFUEL for the first burnable isotope in the first zone in the first burnup interval |
| ABXS(NCON,IZM,KLNT) | 13-24 | Same conditions for second burnable isotope in the first zone in the first burnup interval |

Continue for all burnable isotopes in the first zone. Then repeat Card 33 for all zones in the first burnup interval. Then repeat this entire sequence for all burnup intervals up to KLNT.

| | | |
|---|---|---|
| Card 34 (6E12.5 format) [omit if using tape dump (IDMTPS = 1)] | | |
| FIXS(NCON,IZM,KLNT) | 1-12 | Zone-group-averaged fission cross section used to burn the constituent material in REFUEL for the first burnable isotope in the first zone in the first burnup interval |

Continue same format as with the ABXS values (Card 33).

| | | |
|---|---|---|
| Card 35 (I6 format) (omit if KLAPS = 0) | | |
| KZNS(KLAPS) | 1-6 | The number of regions involved in the first collapse |
| Card 36 (24I3 format) (omit if KLAPS = 0) | | |
| IZON(KLAPS,KZNS(1)) | 1-3 | Region number of the first region in the first collapse |
| IZON(KLAPS,KZNS(1)) | 3-6 | Region number of the second region in the first collapse |

Continue for KZNS(1) regions in the first collapse. Then repeat Cards 35 and 36 for KLAPS collapses.

| | | |
|---|---|---|
| Card 37 (A6 format) | | |
| 6H FINISH | 1-6 | Card to terminate the entire run. This is the final data card for all problems and is used only once, even if a series of problems are run. |

B. Output Information

In this section, a brief description of the complete PHENIX printed output is given. The only portions of this output list which are not always given are the cross sections, group fluxes, and fission-source rate, which may be deleted by use of the IPRIN control word. All output arrays are clearly defined by headings that designate the particular quantity or variable. For a description of quantities that can be output on cards or tape, refer to the Input Instructions (Sec. A).

1. Problem Identification and Input Control Words: The information on Cards 1-8, along with a description of each parameter, is listed in tabular form.

2. Variable Storage Requirements: The amount of storage required to store the data arrays in the A Common Block is printed as the variable LAST. This is followed by the amount of temporary storage required to rearrange the microscopic cross sections and write this disk file. If either of these values exceeds the maximum allowable storage (presently $30{,}000_{10}$ words), the problem will abort.

3. Input Materials: The input materials (total of ML) are listed by number and name.

4. Microscopic Cross-Section Check: All microscopic cross sections (see Input Instructions) are checked for consistency by the code, and those found to be in error by >1.0% or >0.01% are flagged, and the corresponding material and group numbers are printed.

5. Flux Guess: If fluxes of the form $\phi = \phi(r) * \phi(z)$ are input using cards or the subroutine SINUS (ISTART = 1 or 4), the respective radial and axial profiles are printed. When the sinusoidal guess is used, the flux profiles are printed after the radial and axial mesh blocks, since these r and z values are needed to generate the sinusoid. When fluxes of the form $\phi(r,z,E)$ are input (ISTART = 2 or 3), these values are not printed in order to conserve space.

6. Mesh Boundaries: The R0 and Z0 mesh boundary blocks are printed directly from the input.

7. Zone Numbers by Mesh Point: The M0 block (zone numbers by mesh point) is printed directly from the input.

8. Material Numbers by Zone (Mix Number): These values (M2 block) are calculated by assigning zone 1 material number ML + 1, zone 2 material number ML + 2, etc., and are used as indices for the macroscopic cross sections for each zone. The total cross-section array for any group (microscopic + macroscopic) then has dimensions (ITL,MT) where MT = ML + IZM.

9. Fission Spectrum: The K7 block (fission fractions) are printed directly from the input.

10. Mixture Specifications: The I0/I1/I2 blocks (mix number/material number for mix/material atom density) are printed directly from the input.

11. Picture Plot of Reactor: The subroutine MAPR prints a picture plot of the reactor, mesh point by mesh point. This plot appears twice, the first time by zone number (M0 number), and the second time by material number (M2 number). After the second plot, the direction of line inversion to be used in the solution of the flux equations is printed. This is particularly useful if the code has selected this option, since the picture of the reactor is available on the same page.

12. Mixture Specifications: The I0/I1/I2 blocks are printed in tabular form, along with the NTRIG block (trigger for MWd/T calculation if MWDT = 1). The time (in days) for the burnup interval is printed at the beginning of this output block, and this value is incremented by the time step DELT as the specified burnup steps are performed. This output of the mixture specifications is particularly useful for times other than zero, since the change in atom density of the burnable isotopes from their previous values can be observed.

13. Cross-Section Edit: A complete listing by group of both the microscopic and macroscopic cross sections is given. The first ML materials are the microscopic values, while the remaining IZM are the macroscopic. In the printing of the table length, position 1 is $\sigma_f$; 2 is $\sigma_a$; 3 is $\nu\sigma_f$; 4 is $\sigma_{tr}(= \sigma_{total})$; 5 is $\sigma(g \rightarrow g)$, self-scatter; and 6 and all succeeding positions contain the inscatter cross sections, e.g., $\sigma(g - 1 \rightarrow g)$, $\sigma(g - 2 \rightarrow g)$, etc. The entire cross-section edit may be omitted, depending on the value of IPRIN (see Card 5 in the Input Instructions).

14. Eigenvalue Print: After each outer iteration, the running time, outer iteration number, inner iteration total for that outer iteration, eigenvalue slope, eigenvalue, and $\lambda$ are printed. The eigenvalue slope has meaning only in a search calculation and will be printed as zero in a regular $k_{eff}$ calculation (IEVT = 1).

15. Searched Atom Densities: In a concentration search (IEVT = 2), the atom densities that have been changed to produce the desired parametric eigenvalue are printed by zone and material number.

16. Final Neutron Balance Table: The final values of fission rate, inscatter and outscatter, absorption, and leakage are printed for each group, along with the sum over all groups. For the sum over groups, inscatter should equal outscatter, and absorption plus total leakage should equal fission source.

17. Mesh Coordinates and Spacing: The mesh boundaries (RO and ZO blocks) are printed along with the actual coordinates of the mesh points (R4 and Z4 blocks). Note that R4(I) = [RO(I + 1) + RO(I)]/2, same for Z4. This output block is printed only the first time through the code, i.e., for DAY = 0.

18. Group Fluxes. The final normalized group fluxes are printed for each mesh point with the entire axial profile appearing in column form for each radial mesh point. The vertical mesh coordinates (Z4 block) are also included at the right-hand side of the page after every fifth radial flux value. The entire group flux output may be omitted, depending on the value of IPRIN (see Card 5 in the Input Instructions).

19. Total Flux: The sum of the group fluxes at each mesh point is printed in the same format used for the group fluxes. This output block is printed after each criticality calculation.

20. Power Density: The normalized power density (MWt/$\ell$) at each mesh point is printed, again using the group-flux format. These values are calculated by summing the product, $\phi * \Sigma_f$, at each mesh point over all groups. This output block is printed after each criticality calculation.

21. Power Fraction: The fraction of the total power produced by each zone is listed. This calculation is performed only if the normalization is made on thermal power rather than neutron source rate.

22. Fuel Burnup: In burnup calculations, the fuel burnup for each zone in MWd/T, along with the total zone fuel mass, is printed following each burnup step. The calculation is performed using the fuel mass at the beginning of the burnup step along with a linearly averaged power fraction.

23. Fission Source Rate: The normalized fission neutron source rate (n/cm$^3$-sec) at each mesh point is printed, again using the group-flux format. These values are calculated by summing the product, $\phi * \nu\Sigma_f$, at each mesh point over all groups. This output block may be omitted, depending on the value of IPRIN (see Card 5 in the Input Instructions).

24. Material Inventory: For each zone, the volume and mass of each material in the zone (in kg) are printed. This output block is printed after each criticality calculation.

25. Burnup Parameters: For burnup calculations, the names and material numbers of each of the burnable isotopes are printed, along with all the information contained on Card 27 in the Input Instructions.

26. Burnup Edit: For each region in the reactor, the zone-averaged total flux and zone volume are printed, along with the following quantities for each burnable isotope: atom density, total fission and absorption rates, and the zone-spectrum-averaged fission and absorption microscopic cross sections used in the actual burnup. At the end of the burnup edit, the contribution to the breeding ratio from each zone is given along with the total breeding ratio for the reactor. In this code, breeding ratio is an instantaneous quantity and is defined as the sum over all fertile isotopes of absorption minus fission divided by the sum over all fissile isotopes of absorption. Both sums are, of course, taken over the entire reactor.

NOTE: ALL SUBSEQUENT OUTPUT BLOCKS ARE OBTAINED ONLY IF THE REFUELING OPTION OF THE CODE IS USED (IREF = 2).

27. Zone-Averaged Total Fluxes: For each zone, the zone-averaged total flux from the previous burnup interval to be used in the flux shift correction for calculating discharge is printed. These values are based on a linear average of the fluxes at the beginning and end of the burnup steps in the previous burnup interval.

28. REFUEL Input Control Words: The control parameters for REFUEL (see Card 28 in the Input Instructions) are printed in tabular form along with the length of the previous burnup interval. The amount of storage for REFUEL required for the various data arrays in the A Common Block is also printed as LAST (not to exceed $30{,}000_{10}$ as mentioned previously). In the A Common Block for REFUEL, all quantities contained previously in A which are not needed in REFUEL are destroyed, and the storage space is used for the new variables that are introduced in REFUEL (see statement INP 53 in Appendix B).

29. Clean Fuel Atom Densities: The clean atom density (beginning of burnup life) for each position in the M01 block is printed, along with the corresponding I0 and I1 numbers.

30. Refueling Fractions and Frequencies: For each region to be refueled after the particular burnup interval, the refueling fraction and frequency are printed. A list of the burnable isotopes to be refueled in these regions is also given.

31. Microscopic Absorption Cross Sections: For each burnable isotope in each reactor zone, the zone- and group-averaged microscopic absorption cross section used to burn materials in REFUEL is printed for the two previous burnup intervals, i.e., for KLNT and KNT burnup intervals.

32. Microscopic Fission Cross Sections: Same as output block number 31, except absorption is replaced by fission.

33. Zone-Averaged Total Fluxes: For each zone, the zone-averaged total fluxes from previous burnup intervals (up to a maximum of 8) used in burning materials in REFUEL are printed. The final column of fluxes (for burnup interval KNT) is identical to that given in output block number 27.

34. Burnable Isotopes in Each Zone: All burnable isotopes in all regions are listed according to their positions in the M01 block.

35. Zone Summary of Charge and Discharge: For each zone and for all materials in that zone, the following quantities are printed.

a. Discharge atom density and mass (in kg) from burnup interval KNT,

b. Charge atom density and mass (in kg) for burnup interval INT(= KNT + 1),

c. Initial composition (atom density and mass) for burnup interval INT.

36. Refueled Atom Densities: The input atom densities, after refueling, for the next burnup interval INT are printed in order of their appearance in the M01 block. These are the same atom densities (given in a different format) as those listed in Part c of the previous output block.

37. Region Collapse Data: For each of the region collapses performed (total of KLAPS), the regions involved in the given collapse are listed along with the total volume of these regions. Then, for each burnable isotope, the following collapsed masses (in kg) are printed.

a. Composition at end of burnup interval KNT,

b. Discharge from burnup interval KNT,

c. Charge for burnup interval INT,

d. Composition for beginning of burnup interval INT.

38. Total Reactor Summary: For each material in the reactor (total of ML), the following masses (in kg) are printed.

a. Total reactor discharge from burnup interval KNT,

b. Total reactor charge for burnup interval INT,

c. Total mass in reactor at beginning of burnup interval INT.

## C. Data Storage Requirements

The variable dimensioned arrays used in the code require LMX storage locations where

LMX = MAX(L1,L2,L3),

and

L1 = storage required for criticality and burnup (if desired) calculations,

L2 = temporary storage required for cross-section rearrangement,

L3 = storage required if the refueling option of the code is used.

Storage locations L1 and L2 are required for all problems, whereas L3 is needed only for refueling. If any of these three parameters exceeds the $30{,}000_{10}$ word maximum, the problem will abort. In terms of input quantities, the three storage parameters are defined as follows.

L1 = 5 + ITL*MT + 2*IGM + 4*M01 + 5*JM + 7*IM

+ 7*IZM + 10*IMJM + 15*ML + 6*IZM*ML

+ 2*MAX(IM,JM)

if delta search calculation,

+ (IM + JM + IZ + JZ)

if concentration search calculation,

+ (M01)

if burnup (MWd/T) calculation,

+ (M01 + 3*IZM).

L2 = 3*ML + ITL*MT*(IGM + 1).

L3 = NREG + KLAPS + IMJM + ITL*MT + 5*M01 + 16*ML

+ NCON*(1 + 2*NECOP) + IZM*[5 + INTMAX

+ KLAPS * 2*ML + NCON*(4 + 2*INTMAX)].

For nearly all practical problems, L1 is greater than both L2 and L3. L2 may be unusually large if a fine energy group structure with a large table length is used.

Note that the $30,000_{10}$ word maximum mentioned above can easily be raised or lowered by changing that number on the following cards of the source deck:

1. MAIN 421
2. INP 33
3. " 35
4. " 93
5. " 412

(see Appendix B).

## D. Representative Running Times on the CDC-6600 Computer

PHENIX running times for $k_{eff}$ calculations for various fast reactor compositions are shown in Table II. The running times listed are actual execution times and do not include system-dependent operation times, such as compiling time. All problems listed in Table II used the sinusoidal flux guess (ISTART = 4) and an eigenvalue convergence criterion, EPS, of $10^{-5}$.

TABLE II

RUNNING TIMES FOR $k_{eff}$ CALCULATIONS

| Geometry | No. of Reflective Boundary Conditions | No. of Groups | No. of Mesh Points | Execution Time (min) |
|---|---|---|---|---|
| R-Z | 1 | 2 | 306 | 0.10 |
| R-Z | 1 | 8 | 1462 | 1.42 |
| R-Z | 1 | 16 | 1462 | 3.10 |
| R-Z | 2 | 8 | 900 | 0.64 |
| R-Z | 2 | 8 | 1224 | 1.33 |
| X-Y | 0 | 8 | 1064 | 0.57 |
| R-θ | 3 | 8 | 600 | 0.58 |

## REFERENCES


1. W. W. Little, Jr., and R. W. Hardie, "2DB User's Manual," BNWL-831 Rev. 1, Battelle Northwest Laboratory (1969).

2. K. D. Lathrop, "DTF-IV, A FORTRAN-IV Program for Solving the Multigroup Transport Equation with Anisotropic Scattering," LA-3373, Los Alamos Scientific Laboratory (1965).

3. Unpublished data. 2DF, A Two-Dimensional Transport Theory Code from the Los Alamos Scientific Laboratory.

4. W. H. Hannum and B. M. Carmichael, "DPC, A Two-Dimensional Data Preparation Code," LA-3427-MS, Los Alamos Scientific Laboratory (1966).

5. B. J. Toppel, A. L. Rago, and D. M. O'Shea, "$MC^2$, A Code to Calculate Multigroup Cross Sections," ANL-7318, Argonne National Laboratory (1967).


# APPENDIX A

## LOGICAL FLOW OF PHENIX

The basic logical flow of PHENIX is shown by Fig. A.1. The subroutine blocks referred to in the figure are listed below with a brief description of each subroutine. Additional information concerning the logical flow is included.

Subroutine Block 1

| | |
|---|---|
| INP | Controls the reading and printing of input data and computes variable dimension pointers and various program constants. |
| ERRO2 | Prints an error message. |
| XSECT | Reads cross sections from cards or tape and writes the cross-section file, NCR1. |
| INPFLX | Reads input fluxes (if any) and writes the flux file, NFLUX1. |
| SINUS | Calculates sinusoidal flux guess both radially and axially, for any combination of vacuum and reflective boundary conditions, and writes the flux file, NFLUX1. |
| REARL | Reads real (floating-point) data. |
| REAFXP | Reads fixed-point (integer) data. |
| TRIG | Reads trigger data used in burnup and refueling calculations. |
| MAPR | Produces picture plot of reactor by zone and material. |

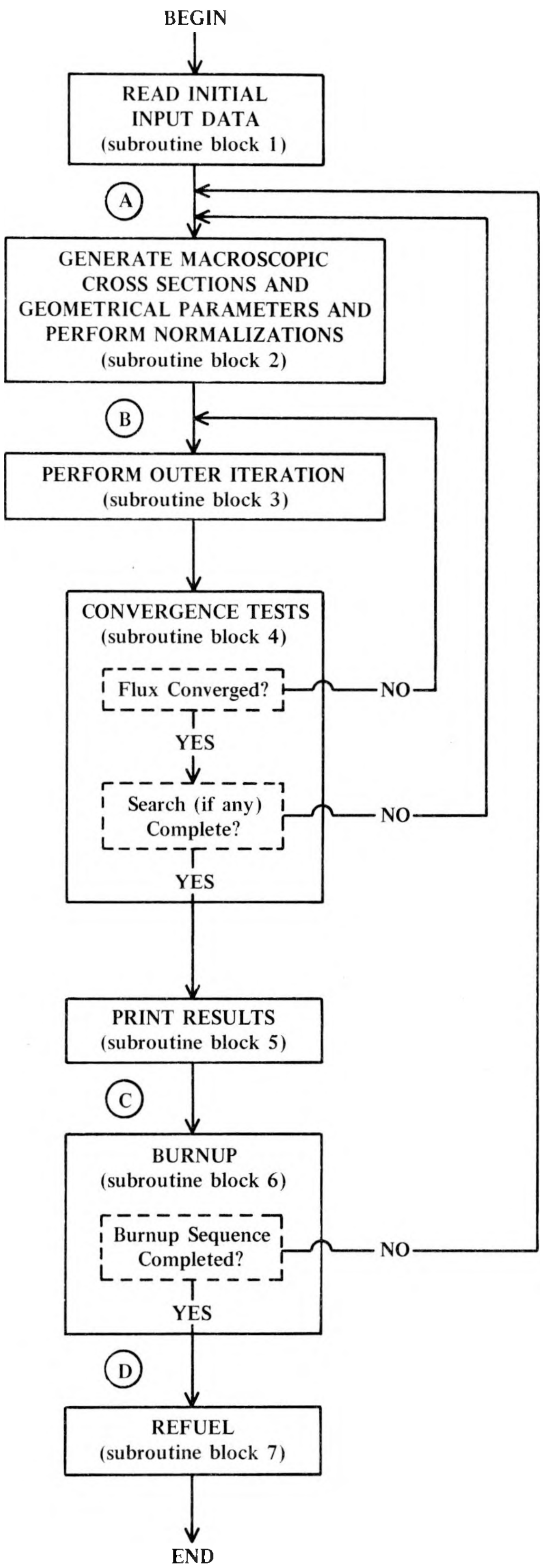


Fig. A.1. Simplified logical flow chart for PHENIX.

Subroutine Block 2

| | |
|---|---|
| INIT | Mixes cross sections, modifies geometry (if delta search), calculates mesh areas and volumes, and calculates initial fission distributions. |
| ERRO2 | Prints an error message. |
| FISCAL | Calculates fission sums and performs normalization. |

Subroutine Block 3

| | |
|---|---|
| EVPRT | Prints and monitors the eigenvalue calculation. It prints time, eigenvalue, lambda, etc., after each outer iteration. |
| OUTER | Performs and controls a complete outer iteration. |
| ICOEF | Calculates the coefficients for the pointwise flux equations. |
| INNER | Calculates the fluxes in a specified group using line inversion. |
| REBAL | Performs group rebalancing and flux normalization before each group calculation. |

Subroutine Block 4

| | |
|---|---|
| CONVRG | Performs convergence tests and computes new eigenvalue in search problems. |
| ERRO2 | Prints an error message. |

Subroutine Block 5

| | |
|---|---|
| SUMMRY | Prints the final totals, including group fluxes, total flux, power density, power fraction, and fission source rate. Also calculates and prints burnup rates (MWd/T) in burnup calculations. |
| GRPTOT | Computes and prints group totals. |
| PRT | Prints any IM*JM array. |
| EVPRT | See Subroutine Block 3. |
| ERRO2 | Prints an error message. |
| GRAM | Calculates and prints the mass of each material in each zone, and the zone volume. |

Note: If no burnup is to be performed, the program terminates at this point (C on Fig. A.1).

Subroutine Block 6

| | |
|---|---|
| INPB | Reads and prints the input burnup data. |
| AVERAG | Calculates the zone-averaged total fluxes, zone- and group-averaged fission and absorption cross sections, and breeding ratio. |

EIGTRG Controls the flow of the eigenvalue type in search calculations.

MARCH Calculates the time-dependent isotopic concentrations, i.e., performs the burnup.

With regard to the flow of the code in burnup calculations, it should be noted that the flow is controlled by both the initial type of calculation ($k_{eff}$, concentration search, or delta search) and the number of burnup steps to be performed.

a. If the initial type of calculation is $k_{eff}$ (IEVT = 1), the code returns to point A after each and every burnup step and does a "$k_{eff}$ after burnup" calculation.

b. If the initial type of calculation is a delta search (IEVT = 3), only the initial calculation is a delta search. Following completion of the initial search, the code becomes a $k_{eff}$-type and all subsequent operations are performed as such.

c. If the initial type of calculation is a concentration search (IEVT = 2), the code flows as "search-burnup-$k_{eff}$ after burnup." This cycle is repeated for each burnup step. Following completion of the last such sequence, the code proceeds directly to refueling (if desired) or performs a final search before refueling. If the concentration searches have been on the control poison, the final search can be of value in determining whether or not enough poison remains to ensure the desired degree of criticality at the end of the burnup interval.

Note: If no refueling is to be performed, the program terminates at this point (D in Fig. A.1).

<u>Subroutine Block 7</u>

REFUEL Calculates atom densities of constituents with greatest burnup, to compute the actual discharge, the charge, and the initial composition for the next burnup interval.

INPR Reads, writes, and punches data to be used in REFUEL.

TRIG Reads trigger data used in burnup and refueling calculations.

APPENDIX B

FORTRAN LISTING OF SOURCE DECK

```
      PROGRAM PHENIX(INPUT,TAPE10=INPUT,OUTPUT,TAPE9=OUTPUT,NCR1,TAPE3=  MAIN
     1NCR1, ISCRAT,TAPE4=NSCRAT,ISCRAT,TAPE5=ISCRAT,NFLUX1,TAPE8=NFLUX1,  MAIN
     2TAPE11,TAPE12,PUNCH)                                                MAIN
C                                                                         MAIN
C     * * * * *  DESCRIPTION OF SUBROUTINES  * * * * *                    MAIN
C                                                                         MAIN
C     PHENIX     MAIN PROGRAM - SETS UP TAPE UNITS AND DISK FILES AND     MAIN
C                CALLS THE FOLLOWING SUBROUTINES.. INP,INIT,FISCAL,EVPRT, MAIN
C                ERRO2,OUTER,CONVRG,SUMMRY,GRAM,INPB,AVERAG,EIGTHG,MARCH. MAIN
C                                                                         MAIN
C     INP        SUBROUTINE TO CONTROL THE READING AND PRINTING OF INPUT  MAIN
C                DATA, COMPUTE VARIABLE DIMENSION POINTERS AND VARIOUS    MAIN
C                PROGRAM CONSTANTS. INP IS CALLED BY PHENIX AND CALLS     MAIN
C                XSECT,INPFLX,REARL,REAFXP,MAPR,ERRO2,TRIG,AND REFUEL.    MAIN
C                                                                         MAIN
C     ERRO2      SUBROUTINE TO PRINT AN ERROR MESSAGE. IT IS CALLED BY    MAIN
C                PHENIX,INP,REARL,REAFXP,INIT,CONVRG, AND SUMMRY.         MAIN
C                                                                         MAIN
C     XSECT      SUBROUTINE TO READ CROSS SECTIONS FROM CARDS OR TAPE,    MAIN
C                AND WRITE THE CROSS SECTION FILE NCR1.  IT IS CALLED     MAIN
C                BY INP.                                                  MAIN
C                                                                         MAIN
C     INPFLX     SUBROUTINE TO READ INPUT FLUXES AND WRITE THE FLUX FILE  MAIN
C                NFLUX1. IT IS CALLED BY INP.                             MAIN
C                                                                         MAIN
C     SINUS      SUBROUTINE TO CALCULATE SINUSOIDAL FLUX INPUT GUESS BOTH MAIN
C                RADIALLY AND AXIALLY, FOR ANY COMBINATION OF  VACUUM AND MAIN
C                REFLECTIVE BOUNDARY CONDITIONS. IT IS CALLED BY INP.     MAIN
C                                                                         MAIN
C     REARL      SUBROUTINE TO READ FLOATING POINT DATA. IT IS CALLED BY  MAIN
C                INP AND CALLS ERRO2.                                     MAIN
C                                                                         MAIN
C     REAFXP     SUBROUTINE TO READ INTEGER DATA.  IT IS CALLED BY INP ANDMAIN
C                CALLS ERRO2.                                             MAIN
C                                                                         MAIN
C     TRIG       SUBROUTINE TO READ TRIGGER DATA USED IN BURNUP AND       MAIN
C                REFUELING CALCULATIONS. IT IS CALLED BY INP AND INPR.    MAIN
C                                                                         MAIN
C     MAPR       SUBROUTINE TO PRODUCE A PICTURE PLOT BY ZONE AND MATERIALMAIN
C                IT IS CALLED BY INP.                                     MAIN
C                                                                         MAIN
C     INIT       SUBROUTINE TO MIX CROSS SECTIONS, MODIFY GEOMETRY,       MAIN
C                CALCULATE MESH AREAS AND VOLUMES, AND CALCULATE INITIAL  MAIN
C                FISSION DISTRIBUTIONS.  IT IT CALLED BY PHENIX AND CALLS MAIN
C                ERRO2.                                                   MAIN
C                                                                         MAIN
C     FISCAL     SUBROUTINE TO CALCULATE FISSION SUMS AND PERFORM         MAIN
C                NORMALIZATION. IT IS CALLED BY PHENIX.                   MAIN
C                                                                         MAIN
C     EVPRT      SUBROUTINE TO PRINT AND MONITOR THE EIGENVALUE           MAIN
C                CALCULATION. IT  PRINTS TIME, EIGENVALUE, LAMBDA, ETC.   MAIN
C                AFTER EACH OUTER ITERATION.  IT IS CALLED BY PHENIX AND  MAIN
C                SUMMRY.                                                  MAIN
C                                                                         MAIN
C     OUTER      SUBROUTINE TO PERFORM AND CONTROL A COMPLETE OUTER       MAIN
C                ITERATION.  IT IS CALLED BY PHENIX AND CALLS TCOEF,      MAIN
C                AND INNER.                                               MAIN
C                                                                         MAIN
```

```
C     ICOEF       SUBROUTINE TO CALCULATE COEFFICIENTS FOR THE FLUX
C                 EQUATION. IT IS CALLED BY OUTER.
C
C     INNER       SUBROUTINE TO CALCULATE THE FLUXES IN A SPECIFIED GROUP
C                 USING LINE INVERSION. IT IS CALLED BY OUTER AND CALLS
C                 REBAL.
C
C     REBAL       SUBROUTINE TO PERFORM GROUP REBALANCING AND FLUX
C                 NORMALIZATION BEFORE EACH GROUP FLUX CALCULATION. IT IS
C                 CALLED BY INNER.
C
C     CONVRG      SUBROUTINE TO PERFORM CONVRG TESTS AND COMPUTE NEW EIGVAL
C                 IN SRCH PROBLEMS.IT IS CALLED BY PHENIX AND CALLS ERRO2.
C
C     SUMMRY      SUBROUTINE TO PRINT THE FINAL TOTALS, INCLUDING GROUP
C                 FLUXES,TOTAL FLUX,POWER DENSITY,POWER FRACTION, AND
C                 FISSION SOURCE RATE. ALSO CALCULATES AND PRINTS MWD/T
C                 BURNUP RATES IN BURNUP CALCULATIONS. IT IS CALLED BY
C                 PHENIX AND CALLS EVPRT,PRT, GRPTOT, AND ERRO2.
C
C     GRPTOT      SUBROUTINE TO COMPUTE AND PRINT GROUP TOTALS. IT IS
C                 CALLED BY SUMMRY.
C
C     PRT         SUBROUTINE TO PRINT ANY IM*JM ARRAY. IT IS CALLED
C                 BY SUMMRY.
C
C     GRAM        SUBROUTINE TO CALCULATE AND PRINT THE MASS OF EACH
C                 MATERIAL IN EACH ZONE AND THE ZONE VOLUME. IT IS CALLED
C                 BY PHENIX.
C
C     INPB        SUBROUTINE TO READ AND PRINT THE INPUT BURNUP DATA.
C                 IT IS CALLED BY PHENIX.
C
C     AVERAG      SUBROUTINE TO CALCULATE ZONE-AVERAGED TOTAL FLUXES,ZONE-
C                 AND GROUP-AVERAGED FISSION AND ABSORPTION CROSS SECTIONS,
C                 AND BREEDING RATIO. IT IS CALLED BY PHENIX.
C
C     EIGTRG      SUBROUTINE TO CONTROL THE FLOW OF THE EIGENVALUE TYPE
C                 IN SEARCH CALCULATIONS. IT IS CALLED BY PHENIX.
C
C     MARCH       SUBROUTINE TO CALCULATE THE TIME-DEPENDENT ISOTOPIC
C                 CONCENTRATIONS. IT IS CALLED BY PHENIX.
C
C     REFUEL      SUBROUTINE TO CALCULATE ATOM DENSITIES OF CONSTITUENTS
C                 WITH GREATEST BURNUP, TO COMPUTE THE ACTUAL DISCHARGE,
C                 THE CHARGE, AND THE INITIAL COMPOSITION FOR THE NEXT
C                 BURNUP INTERVAL. IT IS CALLED BY INP AND CALLS INPR.
C
C     INPR        SUBROUTINE TO READ, WRITE, AND PUNCH DATA TO BE USED IN
C                 REFUEL.  IT IS CALLED BY REFUEL AND CALLS TRIG.
C
C      * * * * *  INPUT CONTROL WORDS  * * * * *
C
C      DELT           LENGTH OF BURNUP TIME STEP (DAYS)
C      EPS            EIGENVALUE CONVERGENCE CRITERION
C      EPSA           PARAMETRIC EIGENVALUE CONVERGENCE CRITERION (SEARCH)
C      EV             INITIAL EIGENVALUE GUESS (SEARCH ONLY)
C      EVM            EIGENVALUE MODIFIER (SEARCH ONLY)
```

```
C       EV2          EIGENVALUE GUESS FOR THE 2ND AND ALL OTHER SEARCHES
C       FLXTST       INNER ITERATION FLUX TEST
C                      (0/EP = TEST WITH EPS/TEST WITH EP)
C       IBB          BOTTOM BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)
C       IBL          LEFT   BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)
C       IBR          RIGHT  BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)
C       IBT          TOP    BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)
C       ICST         CROSS SECTION TYPE (1/2=TYPE1/TYPE2)
C       ID(23)       IDENTIFICATION (COL 1-72,CARD 1, COL 1-66,CARD 2)
C       IDMTPS       PREPARE DATA DUMP TAPE (0/1 = NO/YES)
C       IEVT         EIGENVALUE TYPE (1/2/3=KEFF/CONCENTRATION/DELTA)
C       IFS          PERFORM FINAL SEARCH (0/1 = NO/YES)
C       IGE          GEOMETRY (0/1/2 = X-Y/R-Z/R-THETA)
C       IGM          NUMBER OF GROUPS
C       IHS          POSITION OF SIGMA SELF-SCATTER IN X-SECT TABLE
C       IHT          POSITION OF SIGMA-TOTAL IN CROSS SECTION TABLE
C       IITM         MAX NO. OF INNER ITERATIONS PER GRP PER OUTER ITER.
C       IM           NUMBER OF RADIAL MESH INTERVALS
C       INTMAX       MAX. NO. OF BURNUP INTERVALS TO BE ANALYZED
C       IPFLX        PUNCH FLUX DUMP (0/1/2=NO/FLUX BEFORE BURNUP/FLUX
C                      AFTER BURNUP)
C       IPRIN        PRINT CONTROL (1/2/3=FULL PRINT ALWAYS/FULL PRINT
C                      ONLY FOR DAY=0./PARTIAL PRINT ALWAYS)
C       IPVT         PARAMETRIC EIGENVALUE TYPE (1/2 = NONE/KEFF)
C       IREF         BURNUP/REFUEL CONTROL (0/1/2=NO BURNUP/BURNUP ONLY/
C                      BURNUP AND REFUEL)
C       ISTART       INPUT FLUX GUESS (0/1/2/3/4=NONE/CARDS/CARDS/TAPE/
C                      SINUSOID,  1=X(R)*X(Z), 2=X(R,Z,E), 3=X(R,Z,E)
C                      FROM TAPE, 4=X(R)*X(Z),SINUSOIDS)
C       ITL          CROSS SECTION TABLE LENGTH
C       IXSEC        READ CROSS SECTIONS FROM TAPE (0/1 = NO/YES)
C       IZ           NO. OF RADIAL ZONES (DELTA OPTION ONLY)
C       IZM          NUMBER OF MATERIAL ZONES
C       JM           NUMBER OF AXIAL MESH INTERVALS
C       JZ           NO. OF AXIAL ZONES  (DELTA OPTION ONLY)
C       KLAPS        REGION COLLAPSE OPTION IN REFUEL (0=NO/N=NO. OF
C                      COLLAPSES
C       KNT          BURNUP INTERVAL BEING ANALYZED
C       ML           NUMBER OF INPUT MATERIALS
C       MSHSWP       CONTROL FOR LINE INVERSION DIRECTION (1/2/3/4 = ALT
C                      DIR/RAD/AXIAL/LET CODE DECIDE)
C       MWDT         CALCULATE BURNUP IN MWD/T (0/1 = NO/YES)
C       M01          TOTAL NUMBER OF MIXTURE SPECIFICATIONS
C       NBSTP        NO. OF BURNUP TIME STEPS IN THE BURNUP INTERVAL
C       NCON         NEG/ZERO/POS=TAKE TIME STEP OF DELT/END OF PROBLEM/
C                      TAKE TIME STEP OF DELT AND READ BURNUP DATA
C       NECOP        PUNCH OPTION FOR CHARGE/DISCHARGE DATA (DATA FROM
C                      FIRST NECOP COLLAPSES WILL BE PUNCHED)
C       NPOIS        MATERIAL NO. OF CONTROL POISON
C       NREG         NO. OF REGIONS(ZONES) REQUIRING REFUELING
C       NREPO        REFUEL CONTROL POISON DURING REFUELING (0/1=NO/YES)
C       OITM         MAX NO. OF OUTER ITERATIONS ALLOWED
C       ORF          OVER-RELAXATION FACTOR
C       POD          PARAMETER OSCILLATION DAMPER (SEARCH ONLY)
C       POWR         REACTOR POWER (MWT)
C       PV           DESIRED VALUE OF PARAMETRIC EIGENVALUE (SEARCH ONLY)
C       SRCRT        NEUTRON SOURCE RATE
C       TMAX         MAX ALLOWABLE RUNNING TIME IN MINUTES
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C      XLAH           LAMBDA-1 UPPER LIMIT (SEARCH ONLY)                  MAIN 175
C      XLAL           LAMBDA-1 LOWER LIMIT (SEARCH ONLY)                  MAIN 176
C                                                                         MAIN 177
C      * * * * *  INTERNAL VARIABLES  * * * * *                           MAIN 178
C                                                                         MAIN 179
C      NINP           INPUT TAPE (DISK FILE)                              MAIN 180
C      NOUT           OUTPUT TAPE (DISK FILE)                             MAIN 181
C      NCR1           CROSS SECTION TAPE (DISK FILE)                      MAIN 182
C      NFLUX1         FLUX TAPE (DISK FILE)                               MAIN 183
C      NSCRAT         SCRATCH TAPE (DISK FILE)                            MAIN 184
C      ISCRAT         DISK FILE FOR FLUX COEFF. AND TEMPORARY FLUX DUMP   MAIN 185
C      NDUMP          TAPE FOR INPUT AND OUTPUT FLUXES AND ATOM DENSITIES MAIN 186
C      NMICR          MICROSCOPIC CROSS SECTION TAPE                      MAIN 187
C      ALA            LAMBDA                                              MAIN 188
C      B07            USED FOR INTERNAL COMPUTATION IN FISCAL AND INIT    MAIN 189
C      CNT            CONVERGENCE TRIGGER FOR LAMBDA                      MAIN 190
C      CVT            CONVERGENCE TRIGGER                                 MAIN 191
C      DAY            BURNUP TIME IN DAYS                                 MAIN 192
C      EPF            (MW-SEC)/(FISSION)   (BASED ON 215 MEV/FISSION)     MAIN 193
C      E01            TEMPORARY                                           MAIN 194
C      E02            TEMPORARY                                           MAIN 195
C      E03            TEMPORARY                                           MAIN 196
C      EQ             TEMPORARY FOR CONVRG                                MAIN 197
C      EVP            PREVIOUS EIGENVALUE                                 MAIN 198
C      EVPP           EIGENVALUE FOR TWO ITERATIONS BACK                  MAIN 199
C      GBAR           GROUP INDICATOR FOR TAPE MOTION IN OUTER            MAIN 200
C      IBPTRG         TEMPORARY TRIGGER FOR DETERMINING WHETHER AN        MAIN 201
C                        NCON-DELT CARD IS TO BE READ                     MAIN 202
C      IBUR           RUNNING COUNT OF THE NUMBER OF BURNUP STEPS         MAIN 203
C      IGEP           IGE + 1                                             MAIN 204
C      IGP            IGM + 1                                             MAIN 205
C      IGV            GROUP INDICATOR FOR INNER AND OUTER                 MAIN 206
C      II             INNER ITERATION COUNT FOR A SINGLE GROUP            MAIN 207
C      IMJM           IM*JM                                               MAIN 208
C      INT            NO. OF NEXT BURNUP INTERVAL (= KNT+1)  (IN REFUEL)  MAIN 209
C      IP             IM + 1                                              MAIN 210
C      ITEMS          TEMPORARY                                           MAIN 211
C      ITEMP          TEMPORARY                                           MAIN 212
C      ITEMP1         TEMPORARY                                           MAIN 213
C      ITEMP2         TEMPORARY                                           MAIN 214
C      IZP            IZM + 1                                             MAIN 215
C      JP             JM + 1                                              MAIN 216
C      KLNT           NO. OF PREVIOUS BURNUP INTERVAL (=KNT-1)  (IN REFUEL)MAIN 217
C      K07            TEMPORARY                                           MAIN 218
C      KPAGE          PAGE COUNTER FOR MONITOR PRINT                      MAIN 219
C      LAP            LAMBDA FOR PREVIOUS EIGENVALUE                      MAIN 220
C      LAPP           LAMBDA FOR TWO ITERATIONS BACK                      MAIN 221
C      LAR            LAMBDA FOR PREVIOUS ITERATION                       MAIN 222
C      LC             LOOP COUNT  (TOTAL II IN A SINGLE OUTER ITERATION)  MAIN 223
C      MT             TOTAL NUMBER OF MATERIALS INCLUDING MIXES (ML+IZM)  MAIN 224
C      NCOEF          TRIGGER FOR A NEW CALCULATION OF FLUX               MAIN 225
C                        COEFFICIENTS.(SEARCH ONLY)                       MAIN 226
C      NGO            TEMPORARY FOR FLOW OF EIGENVALUE TYPE               MAIN 227
C      NGOTO          TEMPORARY                                           MAIN 228
C      NSWEEP         INTERNAL CONTROL FOR DIRECTION OF LINE INVERSION    MAIN 229
C      P02            OUTER ITERATION COUNT                               MAIN 230
C      PBAR           TEMPORARY                                           MAIN 231
C      SBAR           TEMPORARY                                           MAIN 232
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C       SK7           SUM OF K7 OVER ALL GROUPS
C       T06           0/1=NOT DELTA/DELTA CALCULATION
C       T11           PREVIOUS FISSION TOTAL
C       TEMF          TEMPORARY
C       TEMI          TEMPORARY
C       TEMP          TEMPORARY
C       TEMP1         TEMPORARY
C       TEMP2         TEMPORARY
C       TEMP3         TEMPORARY
C       TEMP4         TEMPORARY
C       TI            TIME
C       V11           TOTAL SOURCE FOR THE GROUP
C
C       * * * * *  SUBSCRIPTED VARIABLES  * * * * *
C
C       ABXS(NCON,IZM,INIMAX)
C                     ZONE- GROUP-AVG ABSORPTION X-SECT USED TO BURN MTLS
C                        IN REFUEL
C       ALAM(ML)      DECAY CONSTANT  (DAYS-1)
C       ATW(ML)       MATERIAL ATOMIC WEIGHT
C       AXS(ML,IZM)   SPECTRUM AVERAGED ABSORPTION CROSS SECTION
C       A0(IP)        RADIAL AREA ELEMENT
C       A1(IM)        AXIAL  AREA ELEMENT
C       BREDRT(IZM)   CONTRIBUTION TO BREEDING RATIO FROM ZONE IZM
C       BURNUP(IZM)   AVERAGE BURNUP RATE IN MWD/T FOR ZONE IZM
C       CG(NFCOP,NCON)
C                     CHARGE MASSES TO BE PUNCHED (IN REFUEL)
C       CHARGE(ML)    TOTAL CHARGE MASSES FOR EACH MATERIAL (IN REFUEL)
C       CN(IZM,NCON)  CHARGE ATOM DENSITIES (IN REFUEL)
C       CNP(IZM,NCON) TEMPORARY ATOM DENSITY STORAGE (IN REFUEL)
C       C0(ITL,MT)    CROSS SECTION ARRAY FOR CURRENT GROUP
C       CXR(JM)       CONSTANTS FOR RIGHT BOUNDARY
C       CXS(IM,JM,3)  CONSTANTS INVOLVING CROSS SECTIONS FOR FLUX CALC.
C       CXT(IM)       CONSTANTS FOR TOP BOUNDARY
C       DG(NECOP,NCON)
C                     DISCHARGE MASSES TO BE PUNCHED (IN REFUEL)
C       DISCHG(ML)    TOTAL DISCHARGE MASSES FOR EACH MTL
C       DN(IZM,NCON)  DISCHARGE ATOM DENSITIES (IN REFUEL)
C       E0(IGP)       FISSION RATE
C       E1(IGP)       FISSION SOURCE
C       E2(IGP)       IN-SCATTER
C       E3(IGP)       OUT-SCATTER
C       E4(IGP)       ABSORPTIONS
C       E5(IGP)       LEFT LEAKAGE
C       E6(IGP)       RIGHT LEAKAGE
C       E7(IGP)       TOP LEAKAGE
C       E8(IGP)       BOTTOM LEAKAGE
C       E9(IGP)       TOTAL LEAKAGE
C       FIXS(NCON,IZM,INIMAX)
C                     ZONE- GROUP-AVG FISSION X-SECT USED TO BURN MTLS
C                        IN REFUEL
C       FUTOT(IZM)    TOTAL FUEL MASS IN TONS FOR ZONE IZM
C       FXS(ML,IZM)   SPECTRUM AVERAGED FISSION CROSS SECTION
C       F0(IM,JM)     FISSIONS  (OLD)
C       F2(IM,JM)     FISSIONS  (NEW)
C       HA(IM OR JM)  TEMPORARY STORAGE FOR LINE INVERSION
C       HN0(MW1)      CLEAN (NO BURNUP) ATOM DENSITIES OF MTLS IN EACH MIX
C       HNI(MW1)      INITIAL ATOM DENSITY OF EACH MTL IN EACH MIX FOR
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C                      INPUT TO NEXT BURNUP (I2 BLOCK FOR NEXT INTERVAL)
C      HOLN(ML)        MATERIAL NAME
C      IZON(KLAPS,IZM)
C                      ACTUAL REGION NUMBERS OF REGIONS TO BE COLLAPSED IN
C                         EACH COLLAPSE (IN REFUEL)
C      I0(M01)         MIX NUMBER
C      I1(M01)         MATERIAL NUMBER FOR MIX
C      I2(M01)         MATERIAL DENSITY
C      I3(M01)         MATERIAL DENSITIES FOR GRAM CALCULATION
C      I4(M01)         SEARCH MATERIAL MODIFIER (CONC SEARCH ONLY)
C      K6(IGM)         FISSION SPECTRUM  (EFFECTIVE)
C      K7(IGM)         FISSION SPECTRUM  (INPUT)
C      KZNS(KLAPS)     NO. OF REGIONS TO BE COLLAPSED IN EACH COLLAPSE IN
C                         REFUEL
C      LCN(ML,2)       SOURCE ISOTOPES FOR CAPTURE
C      LD(ML)          SOURCE ISOTOPE FOR DECAY
C      LFN(ML,7)       SOURCE ISOTOPES FOR FISSION
C      MASS(ML,IZM)    MATERIAL INVENTORY IN EACH ZONE
C      MASSP(ML,IZM)   MATERIAL INVENTORY IN EACH ZONE (PREVIOUS)
C      MATN(ML)        MATERIAL NUMBER FOR BURNABLE ISOTOPES
C      M0(IM,JM)       ZONE NUMBERS
C      M2(IZM)         MATERIAL NUMBERS BY ZONE
C      NBIFLG(IZM,NCON)
C                      VALUES IN M01 ARRAY THAT ARE BURNABLE ISOTOPES
C                         (IN REFUEL)
C      NBF(ML)         0/1/2=NO EFFECT/FERTILE/FISSILE ISOTOPE
C      NFRE(IZM)       NO. OF BURNUP INTERVALS BETWEEN REFUELING FOR EACH
C                         REGION TO BE REFUELED
C      NTRIG(M01)      TRIGGER FOR TOTAL FUEL MASS CALCULATION
C      N0(IM,JM)       TOTAL FLUX  (OLD)
C      N2(IM,JM)       TOTAL FLUX  (NEW)
C      PA(IM OR JM)    TEMPORARY STORAGE FOR LINE INVERSION
C      PFRAC(IZM)      FRACTION OF TOTAL POWER PRODUCED BY ZONE IZM
C      PFPREV(IZM)     PREVIOUS POWER FRACTION FOR ZONE IZM
C      PHI(INTMAX,IZM)
C                      ZONE- AVG TOTAL FLUX USED TO BURN THE CONSTITUENT
C                         MTLS IN REFUEL
C      PHIB(IZM)       ZONE AVERAGED FLUX
C      R0(IP)          INITIAL RADII
C      R1(IP)          CURRENT RADII
C      R2(IM)          RADIAL ZONE NUMBERS  (DELTA CALCULATION ONLY)
C      R3(IZ)          RADIAL ZONE MODIFIERS  (DELTA CALCULATION ONLY)
C      R4(IM)          AVERAGE RADII
C      R5(IM)          DELTA-R
C      S2(IM,JM)       FIXED SOURCE
C      TRG(NCON)       TRIGGER TO REFUEL EACH BURNABLE ISOTOPE(0/1=NO/YES)
C      VOL(IZM)        ZONE VOLUME (LITERS)
C      V0(IM,JM)       VOLUME ELEMENTS
C      X0(IZM)         REFUELING FRACTION FOR REGIONS TO BE REFUELED
C      Z0(JP)          INITIAL AXII
C      Z1(JP)          CURRENT AXII
C      Z2(JM)          AXIAL ZONE NUMBERS  (DELTA CALCULATION ONLY)
C      Z3(JZ)          AXIAL ZONE MODIFIERS  (DELTA CALCULATION ONLY)
C      Z4(JM)          AVERAGE AXII
C      Z5(JM)          DELTA-Z
C
C      * * * * *   INPUT DATA BLOCKS   * * * * *
C
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C     DATA BLOCK 1      CROSS SECTION DATA
C             (OMIT IF IXSEC = 1)
C
C     DATA BLOCK 2      INPUT FLUX GUESS DATA
C             (OMIT IF ISTART = 0 OR 4)
C
C     DATA BLOCK 3      RADIAL MESH BOUNDARIES (P0 BLOCK)
C
C     DATA BLOCK 4      AXUAL  MESH BOUNDARIES (Z0 BLOCK)
C
C     DATA BLOCK 5      ZONE NUMBERS AT EACH MESH POINT (M0 BLOCK)
C
C     DATA BLOCK 6      FISSION FRACTION FOR EACH GROUP (K7 BLOCK)
C
C     DATA BLOCK 7      MIXTURE NUMBERS (I0 BLOCK)
C
C     DATA BLOCK 8      MATERIALS IN EACH MIX (I1 BLOCK)
C
C     DATA BLOCK 9      ATOM DENSITIES OF MATERIALS IN EACH MIX (I2 BLOCK)
C
C     DATA BLOCK 10     ZONE NUMBERS FOR RADIAL INTERVALS (R2 BLOCK)
C             (OMIT IF IEVT.NE.3)
C
C     DATA BLOCK 11     RADIAL DIMENSIONAL MODIFIERS (R3 BLOCK)
C             (OMIT IF IEVT.NE.3)
C
C     DATA BLOCK 12     ZONE NUMBERS FOR AXIAL INTERVALS (Z2 BLOCK)
C             (OMIT IF IEVT.NE.3)
C
C     DATA BLOCK 13     AXIAL DIMENSIONAL MODIFIERS (Z3 BLOCK)
C             (OMIT IF IEVT.NE.3)
C
C     DATA BLOCK 14     SEARCH MATERIAL MODIFIERS.(I4 BLOCK)
C             (OMIT IF IEVT.NE.2)
C
C     DATA BLOCK 15     TRIGGER FOR MTLS THAT ARE FUEL (NTRIG BLOCK)
C             (OMIT IF MWDT = 0)
C
C
C       * * * * *  MAIN PROGRAM  * * * * *
C
      COMMON   NINP,    NOUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51),  E2(51),  E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51),  E9(51),     E01,    E02,    E03
      COMMON     EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1          IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2          IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3           LC,   NGOTO,    ORFP,    P02,   PBAR,
     4         SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5        TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON IO(23),    IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1          IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2           ML,      MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3           IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4       IDMTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON    EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1           EV,     EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
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     2       NBSTP,    IBUR,     EV2,     NGO,  IBRTRG,  NCOEF, NSWEEP
      COMMON  LATW,   LHOLN,   LALAM,    LC0,     LI0,    LI1,    LI2,
     2       LPHIP,    LVOL,     LN0,   LAXX,    LFXX,  LMATN,    LLD,
     3        LLCN,    LLFN,     LN2,    LA0,     LA1,    LF0,    LF2,
     4         LI3,     LK6,     LK7,    LM0,     LM2,    LR0,    LR1,
     5         LR2,     LR3,     LR4,    LR5,     LS2,    LV0,    LZ0,
     6         LZ1,     LZ2,     LZ3,    LZ4,     LZ5,   LCXS,  LMASS,
     7        LNBR,   LPHIB,    LAXS,   LFXS,  LMASSP,   LCXR,   LCXT,
     8         LHA,     LPA,  LPFRAC, LNTRIG,  LPFPRV, LBURUP, LFUTOT,
     9      LBRDRT,  LPHIPP,     LI4
      INTEGER  B07,     CNT,     CVT,    P02,     T06,     R2,     Z2
      INTEGER  OITM
      REAL      I2,      I3,      K6,     K7,     LAP,   LAPP,    LAR,
     1          N0,      N2,    MASS,  MASSP,      I4
      COMMON A(30000)
      DAY=0.
    1 CONTINUE
      REWIND 3
      REWIND 4
      REWIND 5
      REWIND 8
      CALL INP
   10 CALL INIT(A(LK6), A(LK7), A(LI0), A(LI1), A(LI2), A(LM0), A(LM2),
     1          A(LN0), A(LR0), A(LR1), A(LR2), A(LR3), A(LR4), A(LR5),
     2          A(LZ0), A(LZ1), A(LZ2), A(LZ3), A(LZ4), A(LZ5), A(LA0),
     3          A(LA1), A(LF0), A(LC0), A(LV0),     ITL,      IM,
     4          JM,MT,A(LNTRIG),A(LI4))
      CALL FISCAL (A(LN0),A(LF0) ,A(LV0) ,A(LC0) ,A(LK6) ,
     2             A(LM0) ,A(LM2),ITL,MT)
C     CALL MONITOR PRINT
   20 CALL EVPRT
      GO TO (50, 30, 30, 40), NGOTO
   30 CALL ERRO2(6H*MONPR, 30,1)
C     PERFORM AN OUTER ITERATION
   40 CALL OUTER( A(LA0), A(LA1), A(LC0), A(LF0), A(LK6),
     1            A(LM0), A(LM2), A(LN0), A(LN2), A(LS2), A(LV0),A(LZ5),
     2            A(LF2), ITL, MT, A(LCXS), IM, JM, A(LR5), A(LR4),
     3            A(LZ4), A(LCXR), A(LCXT), A(LHA), A(LPA))
C     PERFORM FISSION CALCULATION
      CALL FISCAL (A(LN0),A(LF0) ,A(LV0) ,A(LC0) ,A(LK6) ,
     2             A(LN0) ,A(LM2),ITL,MT)
C     PERFORM CONVERGENCE AND NEW PARAMETER CALCULATIONS
      CALL CONVRG (A(LF2), A(LK6))
      GO TO (50,20,10), NGOTO
C     50/20/10=FINAL PRINT/MONITOR PRINT/SEARCH CALCULATION
   50 CALL SUMMRY (A(LF2), A(LN2), A(LR1), A(LZ1), A(LR4), A(LZ4),
     1          IM,JM,A(LN2),A(LC0),A(LN0),A(LM0),A(LM2),A(LF0),ITL,MT,
     2             A(LV0),A(LFUTOT),A(LI0),A(LI1),A(LI2),A(LPFRAC),
     3             A(LPFPRV),A(LBURUP),A(LI4))
      CALL GRAM(A(LMASS), A(LVOL),  A(LATW), A(LHOLN), IM, JM,
     1          A(LM0), A(LM2), A(LV0), A(LI0), A(LI1), A(LI2), ML,
     2          A(LI3),A(LFUTOT),A(LNTRIG),A(LI4))
      CALL INPH(A(LMATN),A(LNBR),A(LLD),A(LLCN),A(LLFN),A(LALAM),
     1          A(LHOLN),ML,A(LI2))
      IF(NCOM)   60,1,60
   60 CALL AVERAG(A(LPHIB),A(LAXS),A(LFXS),A(LMATN),A(LMASS),A(LATW),
     1            A(LVOL),A(LC0),A(LN2),A(LM0),A(LV0),A(LHOLN),ML,ITL,
     2            A(LNBR), A(LAXX), A(LFXX),A(LBRDRT))
      CALL EIGTRG(IEVT,K07,IBUR,EV,EV2,NGO,EQ,IPVT)
      IF(NGO.EQ.1) GO TO 65
      IF(DELT) 10,1,10
   65 IF(DELT) 70,1,70
   70 CALL MARCH(A(LPHIB),A(LMATN),A(LFXS),A(LAXS),A(LVOL),A(LMASS),
     1           A(LMASSP),A(LALAM),A(LLD),A(LLCN),A(LLFN),ML,
     2           A(LI0),A(LI1),A(LI2),A(LM2),A(LPHIP),A(LPHIPP),IZM)
      GO TO 10
      END
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      SUBROUTINE INP
      COMMON   NINP,    NOUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,   NDUMP,
     1        NMICR,     ALA,     B07,    CNT,    CVT,     DAY, E0(51),
     2       E1(51),  E2(51),  E3(51), E4(51), E5(51),  E6(51), E7(51),
     3       E8(51),  E9(51),     E01,    E02,    E03
      COMMON     EQ,     EVP,    EVPP,    EPF,   GBAR,    IGEP,    IGP,
     1          IGV,      II,    IMJM,     IP,  ITEMP,  ITEMP1, ITEMP2,
     2          IZP,      JP,     K07,  KPAGE,    LAP,    LAPP,    LAR,
     3           LC,   NGOTO,    ORFP,    P02,   PBAR,
     4         SBAR,     SK7,     T06,    T11,   TEMP,   TEMP1,  TEMP2,
     5        TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON ID(23),    IMAX,     IGE,    IZM,     IM,      JM,    IBL,
     1          IBR,     IBT,     IBB,    IGM,   IEVT,    IPVT, ISTART,
     2           ML,      MT,     M01,   ICST,    IHT,     IHS,    ITL,
     3           IZ,      JZ,    OITM,   IITM,   MWDT,   IPFLX,  IPRIN,
     4       IOUTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON    EPS,   SRCRI,    POWR,    ORF, FLXTST,      PV,   EPSA,
     1           EV,     EVM,    XLAL,   XLAH,    POD,    DELT,    IFS,
     2        NBSTP,    IBUR,     EV2,    NGO, IBRTRG,   NCOEF, NSWEEP
      COMMON   LATW,   LHCLN,   LALAM,    LC0,    LI0,     LI1,    LI2,
     2        LPHIP,    LVOL,     LN0,   LAXX,   LFXX,   LMATN,    LLD,
     3         LLCN,    LLFN,     LN2,    LA0,    LA1,     LF0,    LF2,
     4          LI3,     LK6,     LK7,    LM0,    LM2,     LR0,    LR1,
     5          LR2,     LR3,     LR4,    LR5,    LS2,     LV0,    LZ0,
     6          LZ1,     LZ2,     LZ3,    LZ4,    LZ5,    LCXS,  LMASS,
     7         LNBR,   LPFIB,    LAXS,   LFXS, LMASSP,    LCXR,   LCXT,
     8          LMA,     LPA,  LPFRAC, LNTRIG, LPFPRV,  LBURUP, LFUTOT,
     9       LBRDRT,  LPFIPP,     LI4
      INTEGER   B07,     CNT,     CVT,    P02,    T06,      R2,     Z2
      INTEGER  OITM
      REAL       I2,      I3,      K6,     K7,    LAP,    LAPP,    LAR,
     1           N0,      N2,    MASS,  MASSP,     I4
      COMMON A(30000)
      EQUIVALENCE (A,INTT),(A,AA)
       DIMENSION  INTT(30000),AA(30000)
C     THIS SUBROUTINE CONTROLS THE READING OF ALL INPUT DATA
      NCR1 = 3
      NSCRAT = 4
      ISCRAT=5
      NINP=10
      NOUT=6
      NFLUX1 = 8
      NDUMP = 11
      NMICR = 12
      PRINT 5
    5 FORMAT(1H1)
      IF(DAY.EQ.0.) GO TO 45
      IF (IREF.NE.2) GO TO 45
      READ (NINP,10)  KNT, NREG, NREPO, KLAPS, INTMAX, NECOP
   10 FORMAT (6I6)
      INT = KNT+1
      KLNT = KNT-1
      LX0=LI2
      LNFRE = LX0 + IZM
      LTRG = LNFRE + IZM
      LHN0 = LTRG + NCON
      LPHI = LHN0 + M01
      LABXS = LPHI + IZM*INTMAX
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      LFIXS = LABXS + NCON*IZM*INTMAX
      LKZNS = LFIXS + NCON*IZM*INTMAX
      LIZON = LKZNS + KLAPS
      LNZN = LIZON + KLAPS*IZM
      LDN = LNZN + NREG
      LCN = LDN + IZM*NCON
      LCNP = LCN + IZM*NCON
      LHNI = LCNP + IZM*NCON
      LDG = LHNI + M01
      LCG = LDG + NECOP*NCON
      LDIS= LCG + NECOP*NCON
      LCHG = LDIS + ML
      LNBI = LCHG + ML
      LAST = LNBI + IZM*NCON
      PRINT 15, KNT,INT
15    FORMAT(1H1,//10X,42H * * * * * REFUEL BETWEEN BURNUP INTERVALS,
     1      I3,4H AND,I3,10H * * * * *////)
      PRINT 20, KNT, NREG, NREPO, KLAPS, INTMAX, NECOP
20    FORMAT (//
     180H  KNT      BURNUP INTERVAL JUST COMPLETED
     A                                          I2/
     280H  NREG     NO. OF REGIONS REQUIRING REFUELING
     A                                          I2/
     380H  NREPO    REFUEL CONTROL RODS DURING REFUELING (0/1=NO/YES)
     A                                          I2/
     480H  KLAPS    REGION COLLAPSE OPTION (0=NO / N=NO.OF COLLAPSES)
     A                                          I2/
     580H  INTMAX   MAX. NO. OF BURNUP INTERVALS TO BE ANALYZED
     A                                          I2/
     680H  NECOP    PUNCH OPTION FOR INPUT TO ECONOMICS CODE
     A                                          I2/
     860H           (DATA FROM FIRST NECOP COLLAPSES WILL BE PUNCHED)   )
      PRINT 25, LAST
25    FORMAT (////5X,7H LAST =  I6)
      IF (LAST - 30000) 35,35,30
30    STOP
35    DO 40 I=LNZN,LAST
40    A(I) = 0.
      CALL REFUEL (KNT,NREG,NREPO,NPOIS,KLAPS,INTMAX,NECOP, A(LX0),
     1      A(LNFRE), A(LTRG), A(LHNO), A(LPHI), A(LABXS), A(LFIXS),
     2      A(LKZNS),A(LIZON),IZM,M01,ML,DAY,IGM,IMJM,ISTART,NCON,
     3      IDMTPS, A(LI0), A(LI1), A(LI2), A(LPHIP), A(LNO), A(LVOL),
     4      A(LAXX), A(LFXX), A(LMATN), A(LALAM), A(LLD), A(LLCN),
     5      A(LLFN), A(LHCLN), A(LATW), A(LNZN), A(LDN), A(LCN), A(LCNP),
     6      A(LHNI), A(LDG), A(LCG), A(LDIS), A(LCHG), A(LCNP), A(LNBI))
45    CONTINUE
      PRINT 50
50    FORMAT(30X,40H  *   *   *   *    P H E N I X   *   *   *   * ///)
      READ(IINP,55)  (ID(I),I=1,12)
55    FORMAT (12A6)
      IF(ID(1).EQ.6HFINISH) 320,56
56    READ(IINP,57)   (ID(I),I=13,23), TMAX
57    FORMAT (11A6,F6.1)
      IF(ID(13).EQ.6HFINISH) 320,60
60    CONTINUE
      PRINT 63
63    FORMAT(/5X,29H CARDS 1 AND 2  (ID AND TMAX)/)
      PRINT 65, (ID(I),I=1,23), TMAX
```

```
65    FORMAT(10X,12A6/10X,11A6/10X, 8H  TMAX = F6.1, 5H MIN. //)
      READ (NINP, 70) IGE,IZM,IBL,IBR,IBT,IBB,IEVT,IPVT,IM,JM,IZ,JZ,
     1   IGM,ML,ICST,IHT,IHS,ITL,IXSEC,M01,OITM,IITM,MSHSWP,ISTART,
     2   IREF,NBSTP,IFS,NPOIS,MWDT,IPFLX,IPRIN,IDMTPS,
     3   EPS,SHCRT,POWR,CRF,FLXTST,PV,
     4   EPSA,EV,EVM,EV2,XLAL,XLAH,PUD
70    FORMAT (12I6 / 12I6 / 8I6 / 6E12.4 / 6E12.4 / E12.4)
      PRINT 72
72    FORMAT (/5X,26H CARD 3 DATA   12I6 FORMAT     /)
      PRINT 75, IGE, IZM, IBL, IBR, IBT, IBB
75    FORMAT (
     180H  IGE     GEOMETRY (0/1/2 = X-Y/R-Z/R-THETA)
     A                     I12/
     280H  IZM     NUMBER OF MATERIAL ZONES(REGIONS)
     A                     I12/
     380H  IBL     LEFT BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)
     A                     I12/
     480H  IBR     RIGHT BOUNDARY CONDITION (SAME AS IBL)
     A                     I12/
     580H  IBT     TOP BOUNDARY CONDITION (SAME AS IBL)
     A                     I12/
     680H  IBB     BOTTOM BOUNDARY COND. (SAME AS IBL)
     A                     I12)
      PRINT 80, IEVT, IPVT, IM, JM, IZ, JZ
80    FORMAT (
     180H  IEVT    EIGENVALUE TYPE (1/2/3=KEFF/CONC/DELTA)
     A                     I12/
     280H  IPVT    PARAMETRIC EIGENVALUE TYPE (1/2=NONE/KEFF)
     A                     I12/
     380H  IM      NUMBER OF RADIAL MESH INTERVALS
     A                     I12/
     480H  JM      NUMBER OF AXIAL MESH INTERVALS
     A                     I12/
     580H  IZ      NO. OF RADIAL ZONES (DELTA OPTION ONLY)
     A                     I12/
     680H  JZ      NO. OF AXIAL  ZONES (DELTA OPTION ONLY)
     A                     I12)
      PRINT 85
85    FORMAT (/5X,26H CARD 4 DATA   12I6 FORMAT  /)
      PRINT 90, IGM, ML, ICST, IHT, IHS, ITL
90    FORMAT (
     180H  IGM     NUMBER OF GROUPS
     A                     I12/
     280H  ML      NUMBER OF INPUT MATERIALS
     A                     I12/
     380H  ICST    CROSS SECTION TYPE (1/2=TYPE1/TYPE2)
     A                     I12/
     480H  IHT     POSITION OF SIGMA TOTAL IN X-SECT TABLE
     A                     I12/
     580H  IHS     POSITION OF SIGMA SELF-SCATTER IN X-SECT TABLE
     A                     I12/
     680H  ITL     CROSS SECTION TABLE LENGTH
     A                     I12)
      PRINT 95, IXSEC, M01, OITM, IITM, MSHSWP, ISTART
95    FORMAT (
     180H  IXSEC   READ X-SECTS FROM TAPE (0/1=NO/YES)
     A                     I12/
     280H  M01     TOTAL NO. OF MIXTURE SPECIFICATIONS
```

```
     A                         I12/
     380H   OITM    MAX NO. OF OUTER ITERATIONS ALLOWED
     A                         I12/
     480H   IITM    MAX NO. OF INNER ITERATIONS ALLOWED PER OUTER ITER.
     A                         I12/
     580H   ISHSWP LINE INVERSION DIRECTION (1/2/3/4=ALT DIR/RAD/AX/CODE
     ADECIDES                  I12/
     680H   ISTART FLUX GUESS (0/1/2/3/4=NONE/CARDS/CARDS/TAPE/SINUSOID)
     A                         I12)
      PRINT 100
100   FORMAT (/5X,26H CARD 5 DATA     BIG FORMAT  /)
      PRINT 105, IREF, NBSTP, IFS, NPOIS, MWDT
105   FORMAT (
     180H   IREF    BURNUP/REFUEL CONTROL (0/1/2=NO BURNUP/BURNUP ONLY/BUR
     ANUP AND REFUEL)          I12/
     280H   NBSTP   NUMBER OF BURNUP TIME STEPS IN A BURNUP INTERVAL
     A                         I12/
     380H   IFS     PERFORM FINAL SEARCH (0/1 = NO/YES)
     A                         I12/
     480H   NPOIS   MATERIAL NO. OF CONTROL POISON
     A                         I12/
     580H   MWDT    CALCULATE BURNUP IN MWD/T (0/1=NO/YES)
     A                         I12)
      PRINT 107, IPFLX, IPRIN, IDMTPS
107   FORMAT (
     180H   IPFLX   PUNCH FLUX DUMP (0/1/2=NO/FLUX BEFORE BURNUP/FLUX AFTE
     AR BURNUP)                I12/
     280H   IPRIN   PRINT CONTROL(1/2/3=FULL PRINT/FULL PRINT FOR DAY=0 ON
     ALY/PARTIAL PRINT)        I12/
     380H   IDMTPS PREPARE DATA DUMP TAPE (0/1=NO/YES)
     A                         I12)
      PRINT 110
110   FORMAT (/5X,28H CARD 6 DATA     6E12.4 FORMAT  /)
      PRINT 115, EPS, SRCRT, POWR, ORF, FLXTST, PV
115   FORMAT (
     180H   EPS     EIGENVALUE CONVERGENCE CRITERION
     A                         1PE12.4/
     280H   SRCRT   NEUTRON SOURCE RATE (FOR NORMALIZATION)
     A                         1PE12.4/
     380H   POWR    REACTOR POWER (MWT) (FOR NORMALIZATION)
     A                         1PE12.4/
     480H   ORF     OVERRELAXATION FACTOR
     A                         1PE12.4/
     580H   FLXTST  INNER ITERATION FLUX TEST (0/EP=EPS/EP FOR TEST)
     A                         1PE12.4/
     680H   PV      DESIRED VALUE OF PARAMETRIC EIGENVALUE (SEARCH ONLY)
     A                         1PE12.4)
      PRINT 120
120   FORMAT (/5X,28H CARD 7 DATA     6E12.4 FORMAT  /)
      PRINT 125, EPSA, EV, EVM, EV2, XLAL, XLAH
125   FORMAT (
     180H   EPSA    PARAMETRIC EIGNVALUE CONVERGENCE CRITERION(SEARCH ONLY
     A                         1PE12.4/
     280H   EV      INITIAL EIGENVALUE GUESS (SEARCH ONLY)
     A                         1PE12.4/
     380H   EVM     EIGENVALUE MODIFIER (SEARCH ONLY)
     A                         1PE12.4/
     480H   EV2     EIGENVALUE GUESS FOR 2ND AND ALL OTHER SEARCHES
```

```
     A                                 1PE12.4/
     580H  XLAL    LAMBDA-1 LOWER LIMIT (SEARCH ONLY)
     A                                 1PE12.4/
     680H  XLAM    LAMBDA-1 UPPER LIMIT (SEARCH ONLY)
     A                                 1PE12.4)
      PRINT 130
130   FORMAT (/5X,28H CARD 8 DATA      E12.4 FORMAT   /)
      PRINT 135, POD
135   FORMAT(
     180H  POD     PARAMETER OSCILLATION DAMPER (SEARCH ONLY)
     A                                 1PE12.4//)
      NXCM = ITL - IHS
      IF (POWR.EQ.0 ) GO TO 145
      SRCRT = POWR
145   CONTINUE
      EPF = 215.*1.602*10.**(-19)
      TMAX = TMAX*60.
      KPAGE = 55
      IZP = IZM + 1
      IP  = IM + 1
      JP  = JM + 1
      IGP = IGM + 1
      IGEP = IGE + 1
      IMJM = IM*JM
      MT=ML + IZM
      EQ = .0
      LAP = .0
      LAPP = .0
      LAR = 0.0
      ALA = .0
      LC = 0
      P02 = 0
      CVT = 0
      CUT = 0
      NCON = 0
      I06 = 0
      IBUR= 0
      IF (FLXTST.EQ.0.) FLXTST = EPS
      TEMF= 0.
      IF (IEVT.EQ.2) TEMF= 1.
      K07=IEVT
      IF (IEVT.NE.3) GO TO 155
      I06 = 1
155   CONTINUE
      IF(ISTART.NE.3) GO TO 165
      REWIND NDUMP
165   CONTINUE
C     COMPUTE DIMENSION POINTERS
      LATW = 1
      LHOLN = LATW + ML
      LALAM = LHOLN + ML
      LC0 = LALAM + ML
      LI0 = LC0 + ITL*MT
      LI1 = LI0 + M01
      LI2 = LI1 + M01
      LPHIP = LI2 + M01
      LPHIPP = LPHIP + IZM
      LVOL = LPHIPP + IZM
```

```
      LN0 = LVOL + IZM
      LAXX = LN0 + IMJM
      LFXX = LAXX + ML*IZM
      LMATN = LFXX + ML*IZM
      LLD = LMATN + ML
      LLCN = LLD + ML
      LLFN = LLCN + ML*2
      LN2 = LLFN + ML*7
      LA0 = LN2 + IMJM
      LA1 = LA0 + IP
      LF0 = LA1 + IM
      LF2 = LF0 + IMJM
      LI3 = LF2 + IMJM
      LI4 = LI3 + M01
      LK6 = LI4 + M01*IEMF
      LK7 = LK6 + IGM
      LM0 = LK7 + IGM
      LM2 = LM0 + IMJM
      LR0 = LM2 + IZM
      LR1 = LR0 + IP
      LR2 = LR1 + IP
      LR3 = LR2 + IM*I06
      LR4 = LR3 + IZ*I06
      LR5 = LR4 + IM
      LS2 = LR5 + IM
      LV0 = LS2 + IMJM
      LZ0 = LV0 + IMJM
      LZ1 = LZ0 + JP
      LZ2 = LZ1 + JP
      LZ3 = LZ2 + JM*I06
      LZ4 = LZ3 + JZ*I06
      LZ5 = LZ4 + JM
      LCXS  = LZ5 + JM
      LMASS = LCXS + IMJM*3
      LNBR = LMASS + ML*IZM
      LPHIB = LNBR + ML
      LAXS = LPHIB + IZM
      LFXS = LAXS + ML*IZM
      LMASSP = LFXS + ML*IZM
      LCXR = LMASSP + ML*IZM
      LCXT = LCXR + JM
      LHA = LCXT + IM
      LPA=LHA + MAX0(IM,JM)
      LPFRAC = LPA + MAX0(IM,JM)
      LNTRIG = LPFRAC + IZM
      LPFPRV = LNTRIG + M01*MWDT
      LBURUP = LPFPRV + IZM*MWDT
      LFUTOT = LBURUP + IZM*MWDT
      LBRDRT = LFUTOT + IZM*MWDT
      LAST = LBRDRT + IZM
  175 ITEMP = 1 + 3*ML + IGP*ITL*MT
      PRINT 180, LAST,ITEMP
  180 FORMAT(/2X,5HLAST=I6/,2X,50HTEMPORARY STORAGE FOR CROSS SECTION RE
     2ARRANGEMENT=,I6)
      IF(LAST - ITEMP) 185,190,190
  185 LAST=ITEMP
  190 CONTINUE
C     READ CROSS SECTIONS AND WRITE CROSS SECTION TAPE
```

```
      CALL XSECT( A(LNO),A(LCO),ITL,IGM,MT,A(LATW),A(LHOLN),A(LALAM))
      DO 195  I=LCO, LAST
  195 A(I)=0.
C     READ FLUXES AND WRITE FLUX TAPE
      IF (ISTART.EQ.4) GO TO 199
      CALL INPFLX ( A(LNO), A(LRO), A(LZO))
  199 PRINT 200
  200 FORMAT(51H0MESH BOUNDARIES (R0/Z0=RADIAL POINTS/AXIAL POINTS))
C     READ RADIAL INTERVALS
      CALL REARL(6H     R0,A(LRO),IP)
C     READ AXIAL INTERVALS
      CALL REARL(6H     Z0,A(LZO),JP)
      IF (ISTART.NE.4) GO TO 210
C     DETERMINE SINUSOIDAL FLUX GUESS AND PREPARE FLUX TAPE
      CALL SINUS(A(LNO),A(LRO),A(LR1),A(LZO),A(LZ1),IP,JP,IBL,IBR,IBT,
     1           IBB,IGM)
  210 CONTINUE
C     READ ZONE NUMBERS
      PRINT 215
  215 FORMAT(30H0ZONE NUMBERS BY MESH INTERVAL)
      CALL REAFXP(6H     M0,A(LMO),IMJM)
C     SET MATERIAL NUMBERS FOR REGIONS
      PRINT 220
  220 FORMAT(25H0MATERIAL NUMBERS BY ZONE)
      LM3=LM2 + IZM - 1
      K=1
      DO 221 I=LM2,LM3
      INTT(I)=K + ML
  221 K=K + 1
      PRINT 222, IZM, (INTT(I),I=LM2,LM3)
  222 FORMAT(10X,2HM2,I6/(10I12))
C     READ FISSION FRACTIONS
      PRINT 225
  225 FORMAT(17H0FISSION SPECTRUM)
      CALL REARL(6H     K7,A(LK7),IGM)
      IF(M01) 250,250,230
  230 PRINT 240
  240 FORMAT(82H0MIXTURE SPECIFICATIONS (I0/I1/I2=MIX NUMBER/MAT. NUMBER
     1 FOR MIX/MATERIAL DENSITY))
      CALL REAFXP (6H      I0, A(LI0), M01)
      CALL REAFXP (6H      I1, A(LI1), M01)
      CALL REARL  (6H      I2, A(LI2), M01)
      GO TO 255
  250 CALL ERR02(6H** INP,250,1)
C     CHECK FOR DELTA CALCULATION
  255 IF (IEVT.NE.3) GO TO 280
      PRINT 270
  270 FORMAT(85H0DELTA OPTION DATA    (R2/Z2/R3/Z3=RADIAL/AXIAL ZONE NOS.
     1/RADIAL/AXIAL ZONE MODIFIERS))
      CALL REAFXP(6H     R2, A(LR2), IM)
      CALL REARL(6H     R3,A(LR3),IZ)
      CALL REAFXP(6H      Z2, A(LZ2), JM)
      CALL REARL(6H     Z3,A(LZ3),JZ)
C     CHECK FOR SEARCH CALCULATION
  280 IF(IEVT.NE.2) GO TO 285
      CALL REARL(6H      I4,A(LI4),M01)
C     CHECK FOR BURNUP CALCULATION
  285 IF (MUDT.EQ.0) GO TO 290
```

```
C       READ IN THE NTRIG ARRAY
        CALL TRIG(A(LNTRIG),M01)
C       END OF INPUT DATA
C
 290    CALL MAPR(A(LM0),A(LM2),IM,JM,A(LC0))
        IF(LAST - 30000) 330, 330,300
 300    PRINT 310
 310    FORMAT(26H PROGRAM CAPACITY EXCEEDED)
 320    STOP
 330    CONTINUE
C
C       DETERMINE DIRECTION OF LINE INVERSION
C
        IF (IGE.EQ.2) GO TO 370
        GO TO (350, 360, 370, 340) MSHSWP
 340    IBSUM = IBL + IBR + IBT + IBB
        IF (IBSUM.EQ.1) GO TO 350
        RM = AA(LR1 - 1)
        ZM = AA(LZ1 - 1)
        IF ((RM*JM/(ZM*IM)) - 1.) 360,370,370
 350    NSWEEP = 0
        GO TO 380
 360    NSWEEP = -1
        GO TO 380
 370    NSWEEP = 1
 380    PRINT 385
 385    FORMAT(////5X, 12H * * * * * * /)
        ITEMP = NSWEEP + 2
        GO TO (390,400,410) ITEMP
 390    PRINT 395
 395    FORMAT (5X,38H DIRECTION OF LINE INVERSION = RADIAL   )
        GO TO 420
 400    PRINT 405
 405    FORMAT(5X,52HDIRECTION OF LINE INVERSION = ALTERNATING DIRECTION )
        GO TO 420
 410    PRINT 415
 415    FORMAT (5X, 36H DIRECTION OF LINE INVERSION = AXIAL   )
 420    RETURN
        END
```

```
        SUBROUTINE ERRO2( HOL,JSUBR,I)
        COMMON    MINP   ,NOUT   ,NCRI   ,NFLUXI,NSCRAT
        PRINT 5 ,  HOL, JSUBR
 5      FORMAT(2H */9H ERROR IN,A6,3H AT,I6/2H */2H *)
        GO TO (10,15) I
 10     STOP
 15     RETURN
        END
```

```
      SUBROUTINE XSECT (C, CO, JTL, JGM, JMT, ATW, HOLN, ALAM)           XSEC
      COMMON     NINP,     NCUT,     NCR1, NFLUX1, NSCRAT, ISCRAT,   NDUMP,  XSEC
     1          NMICR,      ALA,      B07,    CNT,     CVT,     DAY, E0(51),  XSEC
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),  XSEC
     3        E8(51), E9(51),      E01,    E02,     E03                XSEC
      COMMON       EQ,      EVP,     EVPP,    EPF,    GBAR,    IGEP,     IGP,  XSEC
     1            IGV,       II,     IMJM,     IP,   ITEMP,  ITEMP1,  ITEMP2,  XSEC
     2            IZP,       JP,      K07,  KPAGE,     LAP,    LAPP,     LAR,  XSEC
     3             LC,   NGCTO,     OHFP,    P02,    PBAR,                    XSEC
     4           SBAR,      SK7,      T06,    T11,    TEMP,   TEMP1,   TEMP2,  XSEC
     5          TEMP3,    TEMP4,       TI,    V11,    NXCM                    XSEC
      COMMON  ID(23),     IMAX,      IGE,    IZM,      IM,      JM,     IBL,  XSEC
     1            IBR,      IBT,      IBB,    IGM,    IEVT,    IPVT,  ISTART,  XSEC
     2             ML,       MT,      M01,   ICST,     IHT,     IHS,     ITL,  XSEC
     3             IZ,       JZ,     OITM,   IITM,    MWDT,   IPFLX,   IPRIN,  XSEC
     4         IOUTPS,     IREF,    IXSEC,  NPOIS,    NCON                    XSEC
      COMMON      EPS,    SRCRT,     POWR,    ORF,  FLXTST,      PV,    EPSA,  XSEC
     1             FV,      EVM,     XLAL,   XLAH,     POD,    DELT,     IFS,  XSEC
     2          NBSTP,     IBUR,      EV2,    NGO,  IBRTRG,   NCOEF,  NSWEEP   XSEC
      INTEGER     B07,      CNT,      CVT,    P02,     T06,      R2,      Z2   XSEC
      INTEGER    OITM                                                        XSEC
      REAL         I2,       I3,       K6,     K7,     LAP,    LAPP,     LAR,  XSEC
     1             N0,       N2,     MASS,  MASSP,      I4                    XSEC
      DIMENSION C(JTL,JGM,JMT), CO(JTL,JMT), ATW(1), HOLN(1), ALAM(1)     XSEC
C                                                                            XSEC
C     THIS SUBROUTINE READS CROSS SECTIONS FROM CARDS OR TAPE AND WRITESXSEC
C     CROSS SECTION TAPE (DISK FILE)                                        XSEC
C                                                                            XSEC
      PRINT 5, (ID(I),I=1,23)                                                XSEC
    5 FORMAT (1H1,12A6/11A6///)                                              XSEC
      IF(IXSEC.EQ.1) REWIND NMICR                                            XSEC
      DO 150 I=1,ML                                                          XSEC
      IF(IXSEC.EQ.1) GO TO 15                                                XSEC
      READ(NINP,10) HOLN(I),ATW(I),ALAM(I)                                   XSEC
   10 FORMAT(A6,2E6.2)                                                       XSEC
      GO TO 20                                                               XSEC
   15 READ(NMICR) HOLN(I),ATW(I),ALAM(I)                                     XSEC
      READ(NMICR) ((C(L,IIG,I),L=1,ITL),IIG=1,IGM)                           XSEC
   20 ALAM(I)=ALAM(I)/(24.*3600.)                                            XSEC
      PRINT 25, I,HOLN(I)                                                    XSEC
   25 FORMAT(I3,6X,A6)                                                       XSEC
      IF(IXSEC.EQ.1) GO TO 150                                               XSEC
C     DETERMINE TYPE OF XSECT CARDS,ICST=1/2=TYPE1/TYPE2                     XSEC
      IF (ICST.EQ. 2) GO TO 70                                               XSEC
      DO 30 IIG=1,IGM                                                        XSEC
   30 READ(NINP,35) (C(L,IIG,I),L=1,ITL)                                     XSEC
   35 FORMAT(6E12.5)                                                         XSEC
      GO TO 150                                                              XSEC
   70 READ(NINP,35) ((C(L,IIG,I),L=1,ITL),IIG=1,IGM)                         XSEC
  150 CONTINUE                                                               XSEC
      IF(IXSEC.EQ.1) REWIND NMICR                                            XSEC
      IF (ICST.EQ.1) GO TO 190                                               XSEC
C     SECTION TO DELETE POSITIONS ONE AND THREE FROM CROSS SECTIONS          XSEC
      ITL = ITL - 2                                                          XSEC
      INDL = 0                                                               XSEC
      DO 180 M=1,ML                                                          XSEC
      DO 180 J=1,IGM                                                         XSEC
      DO 170 I = 1, ITL                                                      XSEC
```

```
      IF ( I .GE. 2 ) GO TO 160
      L = I + 1 +INDL
      TEMPX = C ( L, J, M )
      C ( I, J, M ) = TEMPX
      GO TO 170
160   IF ( I .GT.ITL) GO TO 170
      L = I + 2    +INDL
      TEMPX = C ( L, J, M )
      C ( I, J, M ) = TEMPX
170   CONTINUE
      INDL = INDL + 2
180   CONTINUE
      IHS = IHS - 2
      IHT = IHT - 2
190   CONTINUE
C     CHECK ON CROSS SECTION CONSISTENCY AND ORDER
      TEMP1=1.0
      TEMP2=0.01
      DO 260 J=1,ML
      DO 260  I=1,IGM
      G = C (IHT-2, I,J ) + C ( IHS, I, J)
      DO 210  K = 1, NXCM
      KK = I + K
      M = IHS + K
      IF(KK - IGM)  200, 200, 210
200   G = G + C(M,KK,J)
210   CONTINUE
      IF ( ABS((G-C(IHT,I,J))/C(IHT,I,J))-.01) 240,220,220
220   PRINT 265, J,I,TEMP1
      GO TO 260
240   IF (ABS((G-C(IHT,I,J))/C(IHT,I,J))-.0001) 260,250,250
250   PRINT 265, J,I,TEMP2
260   CONTINUE
265   FORMAT(1H /,16H CHECK MATERIAL I2,5X, 7H GROUP I2,2X,36HCROSS SECT
     2ION IMBALANCE IN EXCESS OF,F5.2,8H PERCENT)
C     WRITE CROSS SECTION TAPE
      DO 280 IIG=1,IGM
      DO 270  M=1,MT
      DO 270  L=1,ITL
270   CO(L,M)=C(L,IIG,M)
280   WRITE (NCR1)     ((CO(L,M),L=1,ITL),M=1,MT)
      REWIND NCR1
      RETURN
      END
```

```
      SUBROUTINE INPFLX (NO, RF, ZF)
      COMMON   NINP,    NCUT,    NCRI,  NFLUXI,  NSCRAT,  ISCRAT,   NDUMP,
     1        NMICR,     ALA,     B07,     CNT,     CVT,     DAY,  E0(51),
     2       E1(51),  E2(51),  E3(51),  E4(51),  E5(51),  E6(51),  E7(51),
     3       E8(51),  E9(51),     E01,     E02,     E03
      COMMON     EQ,     EVP,    EVPP,     EPF,    GBAR,    IGEP,     IGP,
     1          IGV,      II,    IMJM,      IP,   ITEMP,  ITEMP1,  ITEMP2,
     2          IZP,      JP,     K07,   KPAGE,     LAP,    LAPP,     LAR,
     3           LC,   NGCTO,    ORFP,     P02,    PBAR,
     4         SBAR,     SK7,     T06,     T11,    TEMP,   TEMP1,   TEMP2,
     5        TEMP3,   TEMP4,      TI,     V11,    NXCM
      COMMON ID(23),    IMAX,     IGE,     IZM,      IM,      JM,     IBL,
     1          IBR,     IBT,     IBB,     IGM,    IEVT,    IPVT,  ISTART,
     2           ML,      MT,     M01,    ICST,     IHT,     IHS,     ITL,
     3           IZ,      JZ,    OITM,    IITM,    MWDT,   IPFLX,   IPRIN,
     4       NUMTPS,    IREF,   IXSEC,   NPOIS,    NCON
      COMMON    EPS,   SRCRT,    POWR,     ORF,  FLXTST,      PV,    EPSA,
     1           EV,     EVM,    XLAL,    XLAH,     POD,    DELT,     IFS,
     2        NBSTP,    IBUR,     EV2,     NGO,  IBRTRG,   NCOEF,  NSWEEP
      INTEGER   B07,     CNT,     CVT,     P02,     T06,      R2,      Z2
      INTEGER  OITM
      REAL       I2,      I3,      K6,      K7,     LAP,    LAPP,     LAR,
     1           NO,      N2,    MASS,   MASSP,      I4
      DIMENSION NO(1), RF(1), ZF(1)
C     THIS SUBROUTINE READS INPUT FLUXES AND PREPARES FLUX TAPE (DISK)
      PRINT 5
    5 FORMAT(1H1)
C     ISTART = 0/1/2/3/4=NO FLUX/CARDS/CARDS/TAPE/SINUSOID
      KK = ISTART + 1
      DO 120  IIG = 1, IGM
      GO TO (10,30,80,100,120) KK
   10 DO 20  I=1, IM
      DO 20  J = 1, JM
      ITEMP = (J - 1)*IM + I
   20 NO(ITEMP) = 1.0
      GO TO 110
   30 IF(IIG - 1)  40,40,60
   40 PRINT 50
   50 FORMAT(55H0FLUX GUESS   (RF/ZF=TOTAL RADIAL FLUX/TOTAL AXIAL FLUX))
      READ(NINP,90)  (RF(I),I=1,IM)
      READ(NINP,90)  (ZF(J),J=1,JM)
      PRINT 52, IM, (RF(I),I=1,IM)
   52 FORMAT (6X,3H RF,I6/(10E12.5))
      PRINT 54, JM,(ZF(J),J=1,JM)
   54 FORMAT (6X,3H ZF,I6/(10E12.5))
   60 DO 70  I = 1, IM
      DO 70  J = 1, JM
      ITEMP = (J - 1)*IM + I
   70 NO(ITEMP) = RF(I)*ZF(J)
      GO TO 110
   80 READ(NINP,90)    (NO(I), I=1, IMJM)
   90 FORMAT(6E12.6)
      GO TO 110
  100 READ (NDUMP) (NO(I), I=1,IMJM)
  110 WRITE(NFLUXI)   (NO(I), I=1, IMJM)
  120 CONTINUE
      REWIND NFLUXI
      REWIND NDUMP
      RETURN
      END
```

```
      SUBROUTINE SINUS(NO,RO,R1,ZO,Z1,IP,JP,IBL,IBR,IBT,IBB,IGM)
      COMMON NIMP,NOUT,NCR1,NFLUX1
      REAL NO
      DIMENSION NO(1), RO(1), R1(1),ZO(1), Z1(1)
C     RADIAL SINUSOID CALCULATION
      KRAD = 2*IBL + IBR + 1
      MIM = IP-1
      GO TO (10,20,30,40), KRAD
 10   RTOT = 5. + RO(IP) -RO(1) + 5.
      DO 11 I=1,MIM
      R1(I) = ((RO(I) + RO(I+1))*0.5 + 5.)*3.14159/RTOT
 11   R1(I) = SIN(R1(I))
      GO TO 50
 20   RTOT = 5. + RO(IP) - RO(1)
      DO 21 I=1,MIM
      R1(I) = ((RO(I)+RO(I+1)) *0.5 + 5.0)*3.14159/(2.0*RTOT)
 21   R1(I) = SIN(R1(I))
      GO TO 50
 30   RTOT = 5.0 + RO(IP)-RO(1)
      DO 31 I=1,MIM
      R1(I) = ((RO(I)+RO(I+1))*0.5)*3.14159/(2.0*RTOT)
 31   R1(I)= COS(R1(I))
      GO TO 50
 40   DO 41 I=1,MIM
 41   R1(I) = 1.0
C     AXIAL SINUSOID CALCULATION
 50   KVERT = 2*IBB + IBT + 1
      MJM = JP-1
      GO TO (60,70,80,90), KVERT
 60   ZTOT = 5.0 + ZO(JP) - ZO(1) + 5.0
      DO 61 J=1,MJM
      Z1(J) = ((ZO(J)+ZO(J+1))*0.5 + 5.0)*3.14159/ZTOT
 61   Z1(J) = SIN(Z1(J))
      GO TO 100
 70   ZTOT = 5.0 + ZO(JP) -ZO(1)
      DO 71 J=1,MJM
      Z1(J) = ((ZO(J) + ZO(J+1))*0.5 + 5.0)*3.14159/(2.0*ZTOT)
 71   Z1(J) = SIN(Z1(J))
      GO TO 100
 80   ZTOT = 5.0 + ZO(JP) - ZO(1)
      DO 81 J=1,MJM
      Z1(J) = ((ZO(J)+ZO(J+1))*0.5 )*3.14159/(2.0*ZTOT)
 81   Z1(J)= COS(Z1(J))
      GO TO 100
 90   DO 91 J = 1,MJM
 91   Z1(J) = 1.0
 100  PRINT 101
 101  FORMAT (55H0FLUX GUESS  (RF/ZF=TOTAL RADIAL FLUX/TOTAL AXIAL FLUX)
     1)
      PRINT 102 ,       MIM,( R1(I),I=1,MIM)
 102  FORMAT (6X,3H RF,I6/(10E12.5))
      PRINT 103,        MJM,(Z1(J),J=1,MJM)
 103  FORMAT (6X,3H ZF,I6/(10E12.5))
      DO 104 I=1,MIM
      DO 104 J=1,MJM
      ITEMP = (J-1)*MIM + I
 104  NO(ITEMP) = R1(I)*Z1(J)
      MIMJM = MIM*MJM
      DO 105 II=1,IGM
 105  WRITE(NFLUX1) (NO(I),I=1,MIMJM)
      REWIND NFLUX1
      RETURN
      END
```

```
      SUBROUTINE REARL (HOLL,ARRAY,NCOUNT)
      DIMENSION ARRAY(1),V(12),K(12),IN(12)
      COMMON   NINP  ,NOUT  ,NCR1  ,NFLUX1,NSCRAT
      JFLAG=0
      J=1
   10 IF(JFLAG)20,40,20
   20 DO 30 JJ=1,6
      K(JJ)=K(JJ+6)
      IN(JJ)=IN(JJ+6)
   30 V(JJ)=V(JJ+6)
      JFLAG=0
      GO TO 60
   40 READ (NINP,50)        (K(I),IN(I),V(I),I=1,6)
   50 FORMAT(6(I1,I2,E9.4))
   60 DO 140 I=1,6
      L=K(I)+1
      GO TO (70,80,100,150),L
C     NO MODIFICATION
   70 ARRAY(J)=V(I)
      J=J+1
      GO TO 140
C     REPEAT
   80 L=IN(I)
      DO 90 M=1,L
      ARRAY(J)=V(I)
      J=J+1
   90 CONTINUE
      GO TO 140
C     INTERPOLATE
  100 IF(I-6) 120,110,110
  110 READ (NINP,50)        (K(JJ),IN(JJ),V(JJ),JJ=7,12)
      JFLAG=1
  120 L=IN(I)+1
      DEL=(V(I+1)-V(I))/FLOAT (L)
      DO 130 M=1,L
      ARRAY(J)=V(I)+DEL*FLOAT (M-1)
      J=J+1
  130 CONTINUE
  140 CONTINUE
      GO TO 10
C     TERMINATE
  150 J=J-1
      PRINT 160,           HOLL,J      ,( ARRAY(I),I=1,J)
  160 FORMAT(6X,A6,I6/(10E12.5))
      IF(J   -NCOUNT)170,180,170
  170 CALL ERRO2( 6HREARL,170,1)
  180 RETURN
      END
```

```
      SUBROUTINE REAFXP (HOLL, IARRAY, NCOUNT)
      DIMENSION IARRAY(1),IV(6),K(6),IN(6)
      COMMON    NINP   ,NOUT   ,NCR1   ,NFLUX1,NSCRAT
      J=1
   10 READ(NINP,20)          (K(I),IN(I),IV(I),I=1,6)
   20 FORMAT(6(I1,I2,I9))
      DO 70 I=1,6
      L=K(I)+1
      GO TO (30,40,60,80 ),L
C     NO MODIFICATION
   30 IARRAY(J)=IV(I)
      J=J+1
      GO TO 70
C     REPEAT
   40 L=IN(I)
      DO 50 M=1,L
      IARRAY(J)=IV(I)
      J=J+1
   50 CONTINUE
      GO TO 70
C     INTERPOLATE
   60 CALL ERRO2(6H*REAFX,60,1)
   70 CONTINUE
      GO TO 10
C     TERMINATE
   80 J=J-1
      PRINT 90,             HOLL,J       ,(IARRAY(I),I=1,J)
      IF(J   -NCOUNT)100,110,100
   90 FORMAT(6X,A6,I6/(10I12))
  100 CALL ERRO2( 6H*REAFX,100,1)
  110 RETURN
      END
```

```
      SUBROUTINE TRIG (NDUM,MM)
      COMMON    NINP,NOUT
      DIMENSION  NDUM(1)
      READ( NINP,10) (NDUM(I) , I=1,MM)
   10 FORMAT(24I3)
      RETURN
      END
```

```
      SUBROUTINE MAPR (M0,M2, JIM,JJM, K)
      COMMON    NINP,    NCUT,    NCRI, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1         NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),     E01,    E02,    E03
      COMMON      EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3            LC,   NGCTO,    ORFP,    P02,   PBAR,
     4          SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5         TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON ID(23),    IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,      MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IDMTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON     EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,     EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2         NBSTP,    IBUR,     EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,     CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER   OITM
      REAL        I2,      I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,      N2,    MASS,  MASSP,     I4
      DIMENSION M0(JIM,JJM), M2(1), K(1)
C     PRODUCE A PICTURE PRINT BY ZONE AND MATERIAL
      PRINT 10, (ID(I), I=1,23)
   10 FORMAT (1H1,12A6/11A6///)
      DO 20  JJ=1,JM
      J=JM- JJ+1
   20 PRINT 30,             (M0(I,J),I=1,IM)
   30 FORMAT( 5H      ,55I2)
      PRINT 40
   40 FORMAT(2H A/2H X/2H I/2H A/2H L//8H  RADIAL)
      PRINT 10, (ID(I),I=1,23)
      DO 60 JJ=1,JM
      J=JM- JJ+1
      DO  50 L=1,IM
      N=M0(L,J)
   50 K(L)=IABS (M2(N))
   60 PRINT 30,           (K(L),L=1,IM)
      PRINT 40
      RETURN
      END
```

```
      SUBROUTINE INIT (K6, K7, I0, I1, I2, M0, M2, N0, R0, R1, R2,
     1                 R3, R4, R5, Z0, Z1, Z2, Z3, Z4, Z5, A0, A1,
     2                 F0, C0, V0, JTL, JIM, JJM, JMT, NTRIG, I4)
      COMMON    NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1         NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),     E01,    E02,    E03
      COMMON      EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3            LC,   NGCTO,    ORFP,    P02,   PBAR,
     4          SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5         TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON  ID(23),    TMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,      MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IDMTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON     EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,     EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2         NBSTP,    IBUR,     EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,     CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER   OITM
      REAL        I2,      I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,      N2,    MASS,  MASSP,     I4
      DIMENSION   K6(1), K7(1), I0(1), I1(1), I2(1), R0(1), R1(1),
     1            R2(1), R3(1), R4(1), R5(1), Z0(1), Z1(1), Z2(1),
     2            Z3(1), Z4(1), Z5(1), A0(1), A1(1), C0(JTL,JMT),
     3            V0(JIM,JJM), M0(1), M2(1), N0(1), F0(1),
     4            NTRIG(1) , I4(1)
      IF(P02) 15,5,15
    5 PRINT 10, DAY
   10 FORMAT(1H1,30X,11H T I M E  =F8.3,8H D A Y S///)
   15 B07=1
C     PRINT ATOM DENSITIES IF P02=0
      IF(P02) 65,20,65
   20 IF(MWDT.EQ.1) GO TO 35
      PRINT 25,      (J, I0(J), I1(J), I2(J) , J=1,M01)
   25 FORMAT(1H0,3X,16H MIXTURE NUMBER ,18H   MIX COMMAND     ,24H MATERI
     2AL ATOMIC DENSITY//(I4,1X,I8,8X,I8,8X,E20.8))
      GO TO 45
   35 PRINT 40,      (J, I0(J), I1(J), I2(J), NTRIG(J),  J=1,M01)
   40 FORMAT(1H0,3X, 16H MIXTURE NUMBER ,18H   MIX COMMAND      ,
     224H MATERIAL ATOMIC DENSITY,12H      NTRIG//(I4,1X,I8,8X,I8,8X,E2
     30.8,9X,I6))
   45 IF(IPRIN.EQ.3) GO TO 70
      IF(DAY.NE.0.) GO TO 60
   50 PRINT 55
   55 FORMAT(/19H1CROSS-SECTION EDIT)
      GO TO 70
   60 IF(IPRIN.EQ.1) GO TO 50
      GO TO 70
   65 IF(IEVT.NE.2) GO TO 175
C     CALCULATE MACROSCOPIC CROSS SECTIONS
   70 REWIND NCR1
      DO 170 IIG=1,IGM
      READ (NCR1)     ((C0(I,J),I=1,ITL),J=1,MT)
      DO 120 M=1,M01
```

```
      IF(I0(M) - MT) 80,80,75
75    CALL ERR02(6H* INIT,75,1)
80    IF(I1(M) -MT) 85,75,75
85    N=I0(M)
      L=I1(M)
      TEMP=0.
      IF(IEVT.EQ.2) TEMP=I4(M)
      E01 = I2(M)*(1. + EV*TEMP)
105   DO 120 I=1,ITL
      IF(L) 110,115,110
110   C0(I,N)=C0(I,N)+C0(I,L)*E01
      GO TO 120
115   C0(I,N)=C0(I,N)*E01
120   CONTINUE
      IF(P02) 165,125,165
125   IF(IPRIN.EQ.3) GO TO 165
      IF(DAY.NE.0.) GO TO 150
130   PRINT 135, IIG
135   FORMAT(7H GROUP I3,15H CROSS-SECTIONS)
      DO 140 N=1,MT
140   PRINT 145, N, (C0(I,N),I=1,ITL)
145   FORMAT(4H MAT,I3,(10E11.3))
      GO TO 165
150   IF(IPRIN.EQ.1) GO TO 130
165   WRITE (NSCRAT)    ((C0(I,J),I=1,ITL),J=1,MT)
170   CONTINUE
      REWIND NCR1
      REWIND NSCRAT
C     SWITCH TAPE DESIGNATIONS
      ITEMP=NSCRAT
      NSCRAT=NCR1
      NCR1=ITEMP
175   CONTINUE
      NCOEF=1
C     MODIFY GEOMETRY
      IF(P02) 200,180,200
180   IF(NCON) 300,185,300
185   DO 190 I=1,IP
190   R1(I)=R0(I)
      DO 195 J=1,JP
195   Z1(J)=Z0(J)
200   IF(IEVT.NE.3) GO TO 230
      DO 205 I=1,IM
      K=R2(I)
205   R1(I+1)=R1(I)+(R0(I+1)-R0(I))*(1.0+ EV*R3(K))
      DO 210 J=1,JM
      K=Z2(J)
210   Z1(J+1)=Z1(J)+(Z0(J+1)-Z0(J))*(1.0+ EV*Z3(K))
      IF(IGE - 2) 230,215,230
215   IF(ABS (Z1(JP)-1.0)-1.0E-04)230,230,220
220   CALL ERR02(6H* INIT,220,1)
230   CONTINUE
C     CALCULATE AREAS AND VOLUMES
      PI2=6.28318
      IF(P02) 235,240,235
235   IF(IEVT.NE.3) GO TO 300
240   DO 270 I=1,IM
      R4(I)=(R1(I+1)+R1(I))*0.5
```

```
      R5(I)=R1(I+1)-R1(I)
      IF( R5(I) ) 245,245,250
  245 CALL ERRO2(6H* INIT,245,1)
  250 GO TO (255,260,265) , IGEP
  255 A0(I)=1.
      A0(IP)=1.
      A1(I)=R5(I)
      GO TO 270
  260 A0(I)=PI2*R1(I)
      A0(IP)=PI2*R1(IP)
      A1(I)=PI2*R5(I)*R4(I)
      GO TO 270
  265 A0(I)=PI2*R1(I)
      A0(IP)=PI2*R1(IP)
      A1(I)=R5(I)
  270 CONTINUE
      DO 295 J=1,JM
      Z4(J)=(Z1(J+1)+Z1(J))*0.5
      Z5(J)=Z1(J+1)-Z1(J)
      IF( Z5(J) ) 275,275,280
  275 CALL ERRO2(6H* INIT,275,1)
  280 DO 295 I=1,IM
      GO TO (285,290,290) , IGEP
  285 V0(I,J)=R5(I)*Z5(J)
      GO TO 295
  290 V0(I,J)=PI2*R5(I)*Z5(J)*R4(I)
  295 CONTINUE
  300 CONTINUE
C     CHECK PARAMETRIC EIGENVALUE
      IF(P02) 330,305,330
  305 SK7=0.
      DO 320 IIG=1,IGM
      IF(IPVT.EQ.1) GO TO 310
      K6(IIG)=K7(IIG)/PV
      GO TO 320
  310 K6(IIG)=K7(IIG)
  320 SK7=SK7+K7(IIG)
  330 CONTINUE
C
C     CALCULATE INITIAL (OR NEW) FISSION NEUTRON SOURCES
      T11=E1(IGP)
      DO 350 I=1,IMJM
  350 F0(I)=0.
      DO 360 IIG=1,IGM
      E0(IIG) = .0
      READ (NFLUX1)      (N0(I),I=1,IMJM)
      READ (NCR1)     ((C0(I,J),I=1,IIL),J=1,MT)
      DO 360 J=1,JM
      DO 360 K=1,IM
      I = K + (J-1)*IM
      ITEMP=M0(I)
      ITEMP=M2(ITEMP)
      E0(IIG) = E0(IIG) + V0(K,J)*N0(I)*C0(1,ITEMP)
      F0(I)=F0(I) + C0(3,ITEMP)*N0(I)
  360 CONTINUE
      REWIND NFLUX1
      REWIND NCR1
      RETURN
      END
```

```
      SUBROUTINE FISCAL  (N0, F0, V0, C0, K6, M0, M2, JTL,JMT)
      COMMON   MINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),     E01,    E02,    E03
      COMMON      EQ,    EVP,    EVPP,    EPF,   GBAR,   IGEP,     IGP,
     1           IGV,     II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,     JP,     K07,  KPAGE,    LAP,   LAPP,     LAR,
     3            LC,  NGCTO,    ORFP,    P02,   PBAR,
     4          SBAR,    SK7,     T06,    T11,   TEMP,  TEMP1,   TEMP2,
     5         TEMP3,  TEMP4,      TI,    V11,   UXCM
      COMMON ID(23),    IMAX,     IGE,    IZM,     IM,     JM,     IBL,
     1           IBR,    IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,     MT,     M01,   ICST,    IHT,    IHS,     ITL,
     3            IZ,     JZ,    OITM,   IITM,   MWDT,  IPFLX,   IPRIN,
     4        IDMTPS,   IREF,   IXSEC,  NPOIS,   NCON
      COMMON     EPS,  SRCRT,    POWR,    ORF, FLXTST,     PV,    EPSA,
     1            EV,    EVM,    XLAL,   XLAH,    POD,   DELT,     IFS,
     2         NBSTP,   IBUR,     EV2,    NGO, IBRTRG, NCOEF, NSWEEP
      INTEGER    B07,    CNT,     CVT,    P02,    T06,     R2,      Z2
      INTEGER   OITM
      REAL        I2,     I3,      K6,     K7,    LAP,   LAPP,     LAR,
     1            N0,     N2,    MASS,  MASSP,     I4
      DIMENSION  N0(1), F0(1), V0(1), C0(JTL,JMT),K6(1), M0(1), M2(1)
      LAR = ALA
C
C     FISSION SUMS
C
      IF(B07.EQ.0) GO TO 40
      E01=0.
      DO 10  I=1,IMJM
   10 E01=E01+V0(I)*F0(I)
      DO 20  IIG=1,IGM
   20 E1(IIG)=K6(IIG)*E01
      E0(IGP)=0.
      E1(IGP)=0.
      DO 30  IIG=1,IGM
      E0(IGP)=E0(IGP)+E0(IIG)
   30 E1(IGP)=E1(IGP)+E1(IIG)
      IF(B07) 70, 40, 70
   40 ALA = E1(IGP)/T11
      TEMP=1.0/ALA
      IF (IEVT-1) 70,50,70
   50 DO 60  IIG=1,IGM
      E1(IIG)=E1(IIG)*TEMP
   60 K6(IIG)=K6(IIG)*TEMP
      E1(IGP)=E1(IGP)*TEMP
   70 CONTINUE
C
C     NORMALIZATION
C
      B07=0
      IF (POWR) 140,100,90
   90 E01 = SRCRT/(E0(IGP)*EPF)
      GO TO 110
  100 E01 = SRCRT/E1(IGP)
  110 DO 120 IIG=1,IGP
  120 E1(IIG)=E01*E1(IIG)
      DO 130 I=1,IMJM
  130 F0(I)=E01*F0(I)
  140 RETURN
      END
```

```
      SUBROUTINE EVPRT
      COMMON  MINP,     NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51), E9(51),     E01,    E02,    E03
      COMMON    EQ,      EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1         IGV,       II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2         IZP,       JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3          LC,    NGOTO,    OHFP,    P02,   PBAR,
     4        SBAR,      SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5       TEMP3,    TEMP4,      TI,    V11,   NXCM
      COMMON ID(23),    IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1         IBR,      IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2          ML,       MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3          IZ,       JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4      IDMTPS,     IREF,   IXSEC,  NPOIS,   NCON
      COMMON   EPS,    SRCRT,    POWR,    OHF, FLXTST,     PV,   EPSA,
     1          EV,      EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2       NBSTP,     IBUR,     EV2,    NGO, IHRTRG,  NCOEF, NSWEEP
      INTEGER  B07,      CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER  OITM
      REAL      I2,       I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1          N0,       N2,    MASS,  MASSP,     I4
C     MONITOR PRINT
      CALL SECOND(TI)
      TI = TI/60.
      KPAGE = KPAGE + 1
      IF(KPAGE - 40) 40,10,10
   10 KPAGE=0
      PRINT 20
   20 FORMAT(105H1     TIME              OUTER           IN. IT.      EIGENVAL
     1UE      EIGENVALUE           LAMBDA                   )
      PRINT 30
   30 FORMAT(105H    (MINUTES)      ITERATIONS       PER LOOP          SLOPE
     1                                                      /)
   40 PRINT 50, TI,P02, LC,EQ,EV, ALA
   50 FORMAT(4X,F6.3,10X,I4,11X,I4,6X,E15.8,E15.8,E15.8)
      P02=P02 + 1
      LC=0
      IF(P02 - OITM) 70,70,60
   60 NGOTO=1
      GO TO 80
   70 NGOTO=4
   80 RETURN
      END
```

```
      SUBROUTINE OUTER( A0, A1, C0, F0, K6, M0, M2, N0, N2,
     1                  S2, V0,  Z5,  F2,  JTL,  JMT,  CXS,
     2                  JIM, JJM,  R5,  R4,  Z4, CXR, CXT, HA, PA)
      COMMON   NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51), E9(51),     E01,    E02,    E03
      COMMON     EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1          IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2          IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3           LC,   NGCTO,    ORFP,    P02,   PBAR,
     4         SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5        TEMP3,   TEMP4,      TI,    V11,   HXCM
      COMMON ID(23),    IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1          IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2           ML,      MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3           IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IOMTPS,   IREF,   IXSEC,  NPOIS,   NCON
      COMMON    EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1           EV,     EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2       NBSTP,     IBUR,     EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER   B07,     CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER  OITM
      REAL      I2,       I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1          N0,       N2,    MASS,  MASSP,     I4
      DIMENSION  A0(1), A1(1), F0(1), K6(1), M0(1), M2(1),N0(1),N2(1),
     2          V0(1), V7(1), Z5(1), F2(1), C0(JTL,JMT),  HA(1), PA(1),
     3         CXS(JIM,JJM,3), R5(1), R4(1), Z4(1), CXR(1), CXT(1),S2(1)
      INTEGER          GBAR, PBAR, SBAR
      IGV=1
   10 READ(NCR1)      ((C0(I,M),I=1,ITL),M=1,MT)
C     CALCULATION OF FISSION SOURCE FOR GROUP IGV AT EACH MESH POINT
      DO 20 I=1,IMJM
   20 S2(I)=K6(IGV)*F0(I)
C     CALCULATION OF IN-SCATTERING SOURCE FOR GROUP IGV AT EACH MESH PT.
      GBAR=IGV+IHS-ITL
      IF(GBAR - 1) 40,50,50
   40 GBAR=1
   50 PBAR = IHS + IGV - 1
      IF(PBAR - ITL) 70,70,60
   60 PBAR = ITL
   70 IF(GBAR - IGV) 80,100,100
   80 READ (NSCRAT) (N2(I),I=1,IMJM)
      DO 90 I=1,IMJM
      ITEMP=M0(I)
      ITEMP=M2(ITEMP)
      TEMP=C0(PBAR,ITEMP)
   90 S2(I)=S2(I)+N2(I)*TEMP
      GO TO 110
  100 READ (NFLUX1) (N2(I),I=1,IMJM)
  110 GBAR=GBAR+1
      PBAR=PBAR-1
      IF(GBAR - IGV) 80,100,120
  120 IF(IGV - IGM) 140,130,140
  130 REWIND NCR1
  140 V11=0.
C     CALCULATION OF TOTAL SOURCE FOR GROUP IGV
      DO 150 I=1,IMJM
```

```
      S2(I)=S2(I)*V0(I)
  150 V11=V11+S2(I)
      IF(IGV.EQ.1) GO TO 160
      E2(IGV) = V11 - E1(IGV)
      GO TO 170
  160 E2(1)=0.
  170 CONTINUE
C     GROUP FLUX CALCULATION
      II=0
      IF(P02.NE.1) GO TO 200
  190 CALL ICOEF(M0,M2,CXS,V0,C0,A0,Z5,R5,R4,Z4,A1,IM,JM,ITL,CXR,CXT)
      GO TO 220
  200 IF(IEVT.EQ.1) GO TO 210
      IF(NCOEF.EQ.1) GO TO 190
  210 READ (ISCRAT) (((CXS(KI,KJ,KF),KI=1,IM),KJ=1,JM),KF=1,3)
      READ (ISCRAT) (CXR(KJ),KJ=1,JM), (CXT(KI),KI=1,IM)
  220 CALL INNER(N0,N2,CXS,S2,M0,M2,V0,C0,IM,JM,ITL,CXR,CXT,HA,PA)
  240 WRITE (NSCRAT) (N2(I),I=1,IMJM)
C     REPOSITION FLUX FILE FOR NEXT INSCATTERING CALCULATION(IF NEEDED)
      SBAR=ITL-IHS
      IF(SBAR) 260,260,250
  250 DO 255 IS=1,SBAR
  255 BACKSPACE NSCRAT
  260 CONTINUE
C     CALCULATE NEW FISSION SOURCES
      E0(IGV)=0.
      DO 270 I=1,IMJM
      ITEMP=M0(I)
      ITEMP=M2(ITEMP)
      E0(IGV)=E0(IGV) + C0(1,ITEMP)*N2(I)*V0(I)
  270 F2(I)=F2(I) + C0(3,ITEMP)*N2(I)
      IGV=IGV+1
      IF(IGV - IGM) 10,10,280
  280 T11 = E1(IGP)
C     SWITCH TAPE DESIGNATIONS
      REWIND ISCRAT
      NCOEF=0
      REWIND NCR1
      REWIND NSCRAT
      REWIND NFLUX1
      ITEMP = NSCRAT
      NSCRAT = NFLUX1
      NFLUX1 = ITEMP
C     OVER-RELAX FISSION SOURCE
      ORFF= 1. + .6*(OMF-1.)
      E01=0.
      E02=0.
      DO 290 I=1,IMJM
      E01=E01+V0(I)*F2(I)
      F2(I)=F0(I)+ORFF*(F2(I)-F0(I))
  290 E02=E02+V0(I)*F2(I)
      TEMP1=E01/E02
      DO 300 I=1,IMJM
  300 F0(I)=TEMP1*F2(I)
C     CALCULATE NEW GROUP FISSION SOURCES
      DO 310 IIG=1,IGM
  310 E1(IIG)=K6(IIG)*E01
      E0(IGP)=0.
      E1(IGP)=0.
      DO 320 IIG=1,IGM
      E0(IGP)=E0(IGP)+E0(IIG)
  320 E1(IGP)=E1(IGP)+E1(IIG)
      RETURN
      END
```

```
      SUBROUTINE ICOEF (M0, M2, CXS, V0, C0, A0, Z5, R5, R4, Z4, A1,
     2                  JIM,JJM,JTL,CXR,CXT)
      COMMON    NINP,    NCUT,    NCR1,  NFLUX1, NSCRAT,  ISCRAT,   NDUMP,
     1          MICR,     ALA,     B07,     CNT,    CVT,     DAY,  E0(51),
     2       E1(51),  E2(51),  E3(51),  E4(51),  E5(51),  E6(51),  E7(51),
     3       E8(51),  E9(51),     E01,     E02,     E03
      COMMON      EQ,     EVP,    EVPP,     EPF,   GBAR,    IGEP,     IGP,
     1           IGV,      II,    IMJM,      IP,  ITEMP,  ITEMP1,  ITEMP2,
     2           IZP,      JP,     K07,   KPAGE,    LAP,    LAPP,     LAR,
     3            LC,   NGCTO,    ORFP,     P02,   PBAR,
     4          SBAR,     SK7,     T06,     T11,   TEMP,   TEMP1,   TEMP2,
     5         TEMP3,   TEMP4,      TI,     V11,   UXCM
      COMMON IO(23),     IMAX,     IGE,     IZM,     IM,      JM,     IBL,
     1           IBR,     IBT,     IBB,     IGM,   IEVT,    IPVT,  ISTART,
     2            ML,      MT,     M01,    ICST,    IHT,     IHS,     ITL,
     3            IZ,      JZ,    OITM,    IIIM,   IWDT,   IPFLX,   IPRIN,
     4        IOUTPS,    IREF,   IXSEC,   NPOIS,   NCON
      COMMON     EPS,   SRCRT,    POWR,     ORF, FLXTST,      PV,    EPSA,
     1            EV,     EVM,    XLAL,    XLAH,    POD,    DELT,     IFS,
     2         NOSTP,    IBUR,     EV2,     NGO, IBRTRG,   NCOEF,  NSWEEP
      INTEGER    B07,     CNT,     CVT,     P02,    T06,      R2,      Z2
      INTEGER   OITM
      REAL        I2,      I3,      K6,      K7,    LAP,    LAPP,     LAR,
     1            N0,      N2,    MASS,   MASSP,     I4
      DIMENSION  M0(1), M2(1),CXS(JIM,JJM,3),V0(1), C0(JTL,1),
     1           A0(1), Z5(1), R5(1), R4(1), Z4(1), A1(1),CXR(1), CXT(1)
C     THIS SUBROUTINE CALCULATES COEFFICIENTS FOR THE FLUX EQUATION
      PI2 = 6.28318
C
C     FIRST MASTER LOOP CALCULATES THE FOLLOWING QUANTITIES
C        1. REMOVAL X-SECT(I)*V0(I) FOR ALL MESH POINTS
C        2. CXS(KI,KJ,1) FOR ALL MESH POINTS EXCEPT KI=1
C        3. CXS(KI,KJ,2) FOR ALL MESH POINTS EXCEPT KJ=1
C
      DO 60 KJ=1,JM
      DO 60 KI=1,IM
      GO TO (10,10, 5), IGEP
    5 TEMP = PI2*(Z4(KJ) - Z4(KJ-1))*R4(KI)
      GO TO 15
   10 TEMP = Z4(KJ) - Z4(KJ-1)
   15 I = KI + (KJ-1)*IM
      ITEMP = M0(I)
      ITEMP = M2(ITEMP)
      CXS(KI,KJ,3)=V0(I)*(C0(4,ITEMP) - C0(5,ITEMP))
      IF(KI - 1) 35,35,20
   20 ITEMP1 = M0(I-1)
      ITEMP1 = M2(ITEMP1)
      IF (ITEMP - ITEMP1) 30,25,30
   25 CXS(KI,KJ,1)=A0(KI   )*Z5(KJ)/(3.*C0(4   ,ITEMP)*(R4(KI)-R4(KI-1)))
      GO TO 35
   30 CXS(KI,KJ,1) = A0(KI)*Z5(KJ)*(R5(KI-1)+R5(KI))/((R4(KI)-R4(KI-1))*
     1 (3.*(R5(KI-1)*C0(4   ,ITEMP1) + R5(KI)*C0(4   ,ITEMP))))
   35 IF(KJ - 1) 60,60,40
   40 ITEMP3 = M0(I - IM)
      ITEMP3 = M2(ITEMP3)
      IF (ITEMP - ITEMP3) 50,45,50
   45 CXS(KI,KJ,2) = A1(KI)/(3.*C0(4   ,ITEMP)*TEMP)
      GO TO 60
```

```
 50    CXS(KI,KJ,2) = A1(KI)*(Z5(KJ-1) + Z5(KJ))/(TEMP*
     1 (3.*(Z5(KJ-1)*CO(4   ,ITEMP3) + Z5(KJ)*CO(4   ,ITEMP))))
 60    CONTINUE
C
C      SECOND MASTER LOOP CALCULATES FLUX COEFFICIENTS ALL AROUND THE
C      REACTOR PERIMETER,AND SUMS THE COEFFICIENTS AT EACH MESH POINT.
C
       DO 190 KJ=1,JM
       DO 190 KI=1,IM
       GO TO (70,70,65) , IGEP
 65    TEMP = .5*PI2*Z5(KJ)*R4(KI)
       GO TO 75
 70    TEMP = .5*Z5(KJ)
 75    I = KI + (KJ-1)*IM
       ITEMP = MO(I)
       ITEMP = M2(ITEMP)
       TEMP1 = CXS(KI+1,KJ,1)
       TEMP2 = CXS(KI,KJ+1,2)
C      CHECK FOR BOTTOM ROW CALCULATION
       IF(KJ - 1) 80,80,110
 80    IF(IBB.EQ.1) GO TO 85
       CXS(KI,KJ,2) = A1(KI)/(3.*CO(4   ,ITEMP)*( TEMP    +.71/
     1 CO(4   ,ITEMP)))
       GO TO 140
 85    CXS(KI,KJ,2)=0.
       GO TO 140
C      CHECK FOR TOP ROW CALCULATION
 110   IF(KJ - JM) 140,115,115
 115   IF(IBT.EQ.1) GO TO 120
       TEMP2          = A1(KI)/(3.*CO(4   ,ITEMP)*( TEMP    +.71/
     1 CO(4   ,ITEMP)))
       CXT(KI) = TEMP2
       GO TO 140
 120   TEMP2=0.
       CXT(KI)=0.
C      CHECK FOR LEFT HAND COLUMN CALCULATION
 140   IF(KI - 1) 145,145,160
 145   IF(IBL.EQ.1) GO TO 150
       CXS(KI,KJ,1) = A0(KI   )*Z5(KJ)/(3.*CO(4   ,ITEMP)*
     1 (.5*R5(KI) + .71/CO(4   ,ITEMP)))
       GO TO 180
 150   CXS(KI,KJ,1)=0.
       GO TO 180
C      CHECK FOR RIGHT HAND COLUMN CALCULATION
 160   IF(KI - IM) 180,165,165
 165   IF(IBR.EQ.1) GO TO 175
       TEMP1          = A0(KI+1)*Z5(KJ)/(3.*CO(4   ,ITEMP)*
     1 (.5*R5(KI) + .71/CO(4   ,ITEMP)))
       CXR(KJ) = TEMP1
       GO TO 180
 175   TEMP1=0.
       CXR(KJ)=0.
 180   CXS(KI,KJ,3) = CXS(KI,KJ,3) + CXS(KI,KJ,1) + CXS(KI,KJ,2)
     1  + TEMP1 + TEMP2
 190   CONTINUE
       WRITE(ISCRAT) (((CXS(KI,KJ,KF),KI=1,IM),KJ=1,JM),KF=1,3)
       WRITE(ISCRAT) (CXR(KJ),KJ=1,JM), (CXT(KI),KI=1,IM)
       RETURN
       END
```

```
      SUBROUTINE INNER(N0, N2, CXS, S2, M0, M2, V0, C0,JIM,JJM, JTL,
     1                 CXR,CXT, HA, PA)
      COMMON  NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,    ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51), E9(51),     E01,    E02,    E03
      COMMON     EQ,    EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1          IGV,     II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2          IZP,     JP,     K07,  KPAGE,    LAP,   LAPP,    LAR,
     3           LC,  NGCTO,    ORFP,    P02,   PBAR,
     4         SBAR,    SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5        TEMP3,  TEMP4,      TI,    V11,   NXCM
      COMMON ID(23),   IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1          IBR,    IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2           ML,     MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3           IZ,     JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4       IDMTPS,   IREF,   IXSEC,  NPOIS,   NCON
      COMMON    EPS,  SHCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1           EV,    EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2        NBSTP,   IPUR,     EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER   B07,    CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER  OITM
      REAL       I2,     I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1           N0,     N2,    MASS,  MASSP,     I4
      DIMENSION  N0(1), N2(1),CXS(JIM,JJM,3),S2(1), M0(1), M2(1),
     1           V0(1), C0(JTL,1), CXR(1), CXT(1), HA(1), PA(1)
      CALL REBAL  (N2, C0, V0, CXS, M0, M2, ITL, IM, JM, CXR, CXT)
      IKB = IM - 1
      JKB = JM - 1
      IF (NSWEEP) 5, 5, 205
    5 DO 10 I=1,IMJM
   10 N0(I) = N2(I)
C     FLUX CALCULATION USING SOR WITH LINE INVERSION
C
C     CALCULATION OF BOTTOM BOUNDARY FLUX
      KI = 1
      KJ = 1
      I = KI + (KJ - 1)*IM
      HA(KI)= CXS(KI+1,KJ,1)/CXS(KI,KJ,3)
      PA(KI)= (S2(I) + CXS(KI,KJ+1,2)*N2(I+IM))/CXS(KI,KJ,3)
      DO 15 KI = 2,IKB
      I = KI + (KJ - 1)*IM
      HA(KI) = CXS(KI+1,KJ,1)/(CXS(KI,KJ,3)- CXS(KI,KJ,1)*HA(KI-1))
   15 PA(KI) = (S2(I) + CXS(KI,KJ+1,2)*N2(I+IM)+ CXS(KI,KJ,1)*PA(KI-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      KI = IM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI,KJ+1,2)*N2(I+IM)+ CXS(KI,KJ,1)*PA(KI-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      DO 20 KII = 2,IM
      KI = IM - KII + 1
      I = KI + (KJ - 1)*IM
   20 N2(I) = PA(KI) + HA(KI) * N2(I+1)
      DO 25 KI = 1,IM
      I = KI + (KJ - 1)*IM
   25 N2(I) = N0(I) + ORF*(N2(I) - N0(I))
C     PRINCIPAL FLUX LOOP
      DO 45 KJ = 2,JKB
```

```
      KI = 1
      I = KI + (KJ - 1)*IM
      HA(KI)= CXS(KI+1,KJ,1)/CXS(KI,KJ,3)
      PA(KI)= (S2(I) + CXS(KI,KJ,2)*N2(I-IM)+ CXS(KI,KJ+1,2)*N2(I+IM))/
     1  CXS(KI,KJ,3)
      DO 30 KI = 2,IKB
      I = KI + (KJ - 1)*IM
      HA(KI) = CXS(KI+1,KJ,1)/(CXS(KI,KJ,3)- CXS(KI,KJ,1)*HA(KI-1))
   30 PA(KI) = (S2(I) + CXS(KI,KJ,2)*N2(I-IM)+ CXS(KI,KJ+1,2)*N2(I+IM)+
     1 CXS(KI,KJ,1)*PA(KI-1))/(CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      KI = IM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI,KJ,2)*N2(I-IM)+ CXS(KI,KJ+1,2)*N2(I+IM)+
     1 CXS(KI,KJ,1)*PA(KI-1))/(CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      DO 35 KII = 2,IM
      KI = IM - KII + 1
      I = KI + (KJ - 1)*IM
   35 N2(I) = PA(KI) + HA(KI) * N2(I+1)
      DO 40 KI = 1,IM
      I = KI + (KJ - 1)*IM
   40 N2(I) = N0(I) + ORF*(N2(I) - N0(I))
   45 CONTINUE
C     CALCULATION OF TOP BOUNDARY FLUX
      KJ = JM
      KI = 1
      I = KI + (KJ - 1)*IM
      HA(KI)= CXS(KI+1,KJ,1)/CXS(KI,KJ,3)
      PA(KI) = (S2(I) + CXS(KI,KJ,2)*N2(I-IM))/CXS(KI,KJ,3)
      DO 50 KI = 2,IKB
      I = KI + (KJ - 1)*IM
      HA(KI) = CXS(KI+1,KJ,1)/(CXS(KI,KJ,3)- CXS(KI,KJ,1)*HA(KI-1))
   50 PA(KI) = (S2(I) + CXS(KI,KJ,2)*N2(I-IM)+ CXS(KI,KJ,1)*PA(KI-1))/
     1   (CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      KI = IM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI,KJ,2)*N2(I-IM)+ CXS(KI,KJ,1)*PA(KI-1))/
     1   (CXS(KI,KJ,3) - CXS(KI,KJ,1)*HA(KI-1))
      DO 55 KII = 2,IM
      KI = IM - KII + 1
      I = KI + (KJ - 1)*IM
   55 N2(I) = PA(KI) + HA(KI) * N2(I+1)
      DO 60 KI = 1,IM
      I = KI + (KJ - 1)*IM
   60 N2(I) = N0(I) + ORF*(N2(I) - N0(I))
C
C     INNER ITERATION CONTROL
C
      LC = LC + 1
      II = II + 1
      IF(II - IITM) 80,95,95
   80 TEMP1=0.
      DO 90 I=1,IMJM
      TEMP2=ABS (1.0-N0(I)/N2(I))
      IF(TEMP1-TEMP2)85,90,90
   85 TEMP1=TEMP2
   90 CONTINUE
      IF(TEMP1 - FLXTS!) 95,95,92
   92 IF (NSWEEP) 5, 205, 205
```

```
 95   CONTINUE
      RETURN
 205  DO 210 I=1,IMJM
 210  N0(I) = N2(I)
C     FLUX CALCULATION USING SOR WITH LINE INVERSION
C
C     CALCULATION OF LEFT BOUNDARY FLUX
      KI = 1
      KJ = 1
      I = KI + (KJ - 1)*IM
      HA(KJ)= CXS(KI,KJ+1,2)/CXS(KI,KJ,3)
      PA(KJ)= (S2(I) + CXS(KI+1,KJ,1)*N2(I+1))/CXS(KI,KJ,3)
      DO 215  KJ=2,JKB
      I = KI + (KJ - 1)*IM
      HA(KJ) = CXS(KI,KJ+1,2)/(CXS(KI,KJ,3)- CXS(KI,KJ,2)*HA(KJ-1))
 215  PA(KJ) = (S2(I) + CXS(KI+1,KJ,1)*N2(I+1) + CXS(KI,KJ,2)*PA(KJ-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      KJ = JM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI+1,KJ,1)*N2(I+1)  + CXS(KI,KJ,2)*PA(KJ-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      DO 220  KJJ=2,JM
      KJ = JM - KJJ + 1
      I = KI + (KJ - 1)*IM
 220  N2(I) = PA(KJ) + HA(KJ) * N2(I+IM)
      DO 225  KJ = 1,JM
      I = KI + (KJ - 1)*IM
 225  N2(I) = N0(I) + ORF*(N2(I) - N0(I))
C     PRINCIPAL FLUX LOOP
      DO 245  KI = 2,IKB
      KJ = 1
      I = KI + (KJ - 1)*IM
      HA(KJ)= CXS(KI,KJ+1,2)/CXS(KI,KJ,3)
      PA(KJ)= (S2(I) + CXS(KI,KJ,1)*N2(I-1) + CXS(KI+1,KJ,1)*N2(I+1))/
     1  CXS(KI,KJ,3)
      DO 230  KJ = 2,JKB
      I = KI + (KJ - 1)*IM
      HA(KJ) = CXS(KI,KJ+1,2)/(CXS(KI,KJ,3)- CXS(KI,KJ,2)*HA(KJ-1))
 230  PA(KJ) = (S2(I) + CXS(KI,KJ,1)*N2(I-1) + CXS(KI+1,KJ,1)*N2(I+1) +
     1 CXS(KI,KJ,2)*PA(KJ-1))/(CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      KJ = JM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI,KJ,1)*N2(I-1) + CXS(KI+1,KJ,1)*N2(I+1) +
     1 CXS(KI,KJ,2)*PA(KJ-1))/(CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      DO 235  KJJ = 2,JM
      KJ = JM - KJJ + 1
      I = KI + (KJ - 1)*IM
 235  N2(I) = PA(KJ) + HA(KJ) * N2(I+IM)
      DO 240  KJ = 1,JM
      I = KI + (KJ - 1)*IM
 240  N2(I) = N0(I) + ORF*(N2(I) - N0(I))
 245  CONTINUE
C     CALCULATION OF RIGHT BOUNDARY FLUX
      KI = IM
      KJ = 1
      I = KI + (KJ - 1)*IM
      HA(KJ)= CXS(KI,KJ+1,2)/CXS(KI,KJ,3)
      PA(KJ)= (S2(I) + CXS(KI,KJ,1)*N2(I-1))/CXS(KI,KJ,3)
```

```
      DO 250 KJ= 2,JKB
      I = KI + (KJ - 1)*IM
      HA(KJ) = CXS(KI,KJ+1,2)/(CXS(KI,KJ,3)- CXS(KI,KJ,2)*HA(KJ-1))
  250 PA(KJ) = (S2(I) + CXS(KI,KJ,1)*N2(I-1) + CXS(KI,KJ,2)*PA(KJ-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      KJ = JM
      I = KI + (KJ - 1)*IM
      N2(I)  = (S2(I) + CXS(KI,KJ,1)*N2(I-1) + CXS(KI,KJ,2)*PA(KJ-1))/
     1  (CXS(KI,KJ,3) - CXS(KI,KJ,2)*HA(KJ-1))
      DO 255  KJJ = 2,JM
      KJ = JM - KJJ + 1
      I = KI + (KJ - 1)*IM
  255 N2(I) = PA(KJ) + HA(KJ) * N2(I+IM)
      DO 260  KJ = 1,JM
      I = KI + (KJ - 1)*IM
  260 N2(I) = N0(I) + ORF*(N2(I) - N0(I))
C
C     INNER ITERATION CONTROL
      LC = LC + 1
      II = II + 1
      IF(II - IITM) 280, 295,295
  280 TEMP1=0.
      DO 290  I=1,IMJM
      TEMP2=ABS (1.0-N0(I)/N2(I))
      IF(TEMP1-TEMP2) 285, 290, 290
  285 TEMP1=TEMP2
  290 CONTINUE
      IF(TEMP1 - FLXTST) 295, 295, 292
  292 IF (NSWEEP) 5, 5, 205
  295 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE REBAL  (N2, C0, V0, CXS, M0, M2, JTL,JIM,JJM, CXR, CXT)
      COMMON   MINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1         NMICR,    ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),     E01,    E02,    E03
      COMMON      EQ,    EVP,   EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,     II,   IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,     JP,    K07,  KPAGE,    LAP,   LAPP,    LAR,
     3            LC,  NGCTO,   ORFP,    P02,   PBAR,
     4          SBAR,    SK7,    T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5         TEMP3,  TEMP4,     TI,    V11,   NXCM
      COMMON  ID(23),   TMAX,    IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,    IBT,    IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,     MT,    M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,     JZ,   OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IDMTPS,   IREF,  IXSEC,  MPOIS,   NCON
      COMMON     EPS,  SRCRT,   POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,    EVM,   XLAL,   XLAH,    POD,   DELT,    IFS,
     2         NBSTP,   IBUR,    EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,    CNT,    CVT,    P02,    T06,     R2,     Z2
      INTEGER   OITM
      REAL        I2,     I3,     K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,     N2,   MASS,  MASSP,     I4
      DIMENSION   N2(1), C0(JTL,1), V0(1),CXS(JIM,JJM,3),M0(1), M2(1),
     1            CXR(1), CXT(1)
C     THIS SUBROUTINE NORMALIZES FLUXES BEFORE EACH GROUP CALCULATION
C     CALCULATE ABSORPTION AND OUT-SCATTER
      E3(IGV)=0.
      E4(IGV)=0.
      DO 10  I=1, IMJM
      TEMP = V0(I)*N2(I)
      ITEMP = M0(I)
      ITEMP = M2(ITEMP)
      E3(IGV) = E3(IGV) + (C0(4,ITEMP) - C0(5,ITEMP) - C0(2,ITEMP))*TEMP
   10 E4(IGV) = E4(IGV) + C0(2,ITEMP)*TEMP
C     CALCULATE LEFT LEAKAGE
      E5(IGV)=0.
      IF(IBL) 15,15,25
   15 DO 20 KJ=1,JM
      I = (KJ - 1)*IM + 1
   20 E5(IGV) = E5(IGV) + CXS(1,KJ,1)*N2(I)
C     CALCULATE RIGHT LEAKAGE
   25 E6(IGV)=0.
      IF(IBR) 30,30,40
   30 DO 35 KJ=1,JM
      I = KJ*IM
   35 E6(IGV) = E6(IGV) + CXR(KJ)*N2(I)
C     CALCULATE TOP LEAKAGE
   40 E7(IGV)=0.
      IF(IBT) 45,45,55
   45 DO 50 KI=1,IM
      I = IMJM - IM + KI
   50 E7(IGV) = E7(IGV) + CXT(KI)*N2(I)
C     CALCULATE BOTTOM LEAKAGE
   55 E8(IGV)=0.
      IF(IBB) 60,60,70
   60 DO 65 KI=1,IM
   65 E8(IGV) = E8(IGV) + CXS(KI,1,2)*N2(KI)
```

```
70    E9(IGV) = E5(IGV) + E6(IGV) + E7(IGV) + E8(IGV)
      TEMP = (E1(IGV) + E2(IGV))/(E3(IGV) + E4(IGV) + E9(IGV))
      DO 75 I=1,IMUM
75    N2(I) = TEMP*N2(I)
      E3(IGV) = TEMP*E3(IGV)
      E4(IGV) = TEMP*E4(IGV)
      E5(IGV) = TEMP*E5(IGV)
      E6(IGV) = TEMP*E6(IGV)
      E7(IGV) = TEMP*E7(IGV)
      E8(IGV) = TEMP*E8(IGV)
      E9(IGV) = TEMP*E9(IGV)
      RETURN
      END
```

```
      SUBROUTINE CONVRG(F2,K6)
      COMMON     NIRP,     NCUT,     NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1          NMICR,      ALA,      B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),      E01,    E02,    E03
      COMMON      EQ,      EVP,     EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,       II,     IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,       JP,      K07,  KPAGE,    LAP,   LAPP,    LAR,
     3            LC,    NGOTO,     ORFP,    P02,   PBAR,
     4          SBAR,      SK7,      T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5         TEMP3,    TEMP4,       TI,    V11,   NXCM
      COMMON  IO(23),     TMAX,      IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,      IBT,      IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,       MT,      M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,       JZ,     OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IDMTPS,     IREF,    IXSEC,  NPOIS,   NCON
      COMMON     EPS,    SRCRT,     POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,      EVM,     XLAL,   XLAH,    POD,   DELT,    IFS,
     2         NBSTP,     IBUR,      EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,      CNT,      CVT,    P02,    T06,     R2,     Z2
      INTEGER   OITM
      REAL        I2,       I3,       K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,       N2,     MASS,  MASSP,     I4
      DIMENSION F2(1), K6(1)
C     CHECK TIME LIMIT
      IF(TMAX) 25,25,10
 10   CALL SECOND(TEMP)
      IF(TEMP - TMAX) 25,15,15
 15   NGOTO=1
      PRINT 20
 20   FORMAT(53H1 * *  RUNNING TIME EXCEEDED--FORCED CONVERGENCE  * *//)
      RETURN
C     CHECK EIGENVALUE CONVERGENCE
 25   E01=1. - ALA
      E02=ABS(E01)
      IF(E1(IGP)) 30,30,35
 30   CALL ERRO2(6HCONVRG,30,1)
 35   IF(E02 - EPS) 40,40,45
 40   CVT=1
      IF(P02.LE.3) CVT=0
C     INITIALIZE FISSION NEUTRON SOURCE RATES FOR NEXT ITERATION
 45   DO 50 I=1,IMJM
 50   F2(I)=0.
      IF(CVT.NE.1) GO TO 80
C     FINAL EIGENVALUE CALCULATION
      NGOTO=1
      IF(IEVT.NE.1) GO TO 75
 55   EV=0.
      DO 60 I=1,IGM
 60   EV=EV + K6(I)
      EV=SK7/EV
 65   RETURN
 75   EV=EV+POD*EQ*E01
      GO TO 65
C     EIGENVALUE CALCULATION IF NOT CONVERGED
 80   IF(IEVT.NE.1) GO TO 85
      NGOTO=2
      GO TO 55
```

```
C     CHECK FOR CALCULATION OF NEW EV IN SEARCH PROBLEM(IEVT=2 OR 3)
 85   E03=ABS (ALA-LAR)
      IF(LAPP) 250,95,250
 95   IF(LAP) 170,105,170
 105  IF(EQ)  225,115,225
 115  IF(E03 - EPSA) 145,145,125
C     RETURN TO MAIN PROGRAM WITH EV STILL = TO THE PREVIOUS(SAME) VALUE
 125  NGOTO=2
      RETURN
C     FIRST CHANGE IN EV. IT IS NOW SET TO EV + OR - EVM. PROGRAM
C     RETURNS TO INIT FOR RECALCULATION OF X-SECT OR ZONE THICKNESSES
 145  LAP=ALA
      EVP=EV
      IF(E01) 155,155,150
 150  EV=EV - EVM
      GO TO 160
 155  EV=EV + EVM
 160  NGOTO=3
      RETURN
C     SECOND CHANGE IN EV.(IF E03.LE.EPSA). TRIGGERED BY LAP GT. 0
 170  IF(E03 - EPSA) 175,175,125
 175  EQ=(EVP-EV)/(LAP-ALA)
      IF(CNT) 210,185,210
 185  IF(E02 - XLAL) 215,215,190
 190  IF(E02 - XLAH) 210,210,195
 195  E01=SIGN (XLAH,E01)
 210  LAPP=LAP
      LAP=ALA
      EVPP=EVP
      EVP=EV
      GO TO 225
 215  CNT=1
      LAP=0.
      LAPP=0.
 225  EV=EV+POD*EQ*E01
 230  IF ((LAPP-1.0)/(LAP-1.0)) 235,160,160
 235  TEMP1=AMIN1(EVP,EVPP)
      IF (EV-TEMP1) 240,245,245
 240  EV=(EVPP+EVP)/2.
      GO TO 160
 245  TEMP1=AMAX1(EVP,EVPP)
      IF (EV-TEMP1) 160,240,240
C     THIRD(AND SUCCEEDING) CHANGE IN EV(IF E03.LE.EPSA). TRIGGERED
C     BY LAPP GT. 0
 250  IF(E03 - EPSA) 260,260,125
C     CALCULATE QUADRATIC COEFFICIENTS.
 260  TEMP1=EVP-EV
      TEMP2=EVPP-EV
      TEMP3=EVPP-EVP
      TEMP4=TEMP1*(EVP+EV)
      TEMP5=-TEMP2*(EV+EVPP)
      TEMP6=TEMP3*(EVPP+EVP)
      DENOM=TEMP3*TEMP2*TEMP1
      EQA=((LAPP-1.0)*TEMP1*EVP*EV-(LAP-1.0)*TEMP2
     1*EV*EVPP+(ALA-1.0)*TEMP3*EVPP*EVP)/DENOM
      EQB=-(LAPP*TEMP4+LAP*TEMP5+ALA*TEMP6)/DENOM
      EQC=(LAPP*TEMP1-LAP*TEMP2+ALA*TEMP3)/DENOM
      DISCR=EQB*EQB-4.0*EQA*EQC
```

```
      IF(DISCR) 175,270,270
270   IF(EQ2 - XLAL) 215,215,280
280   TEMP1=EQC+EQC
      TEMP=SQRT (DISCR)
      EQ=1.0/(EQB+EV*TEMP1)
      LAPP=LAP
      LAP=ALA
      EVPP=EVP
      EVP=EV
      EV1=(TEMP-EQB)/TEMP1
      EV2=-(TEMP+EQB)/TEMP1
      EVA=ABS (EV-EV1)
      EVB=ABS (EV-EV2)
      IF (EVA-EVB) 290,290,300
290   EV=EV1
      GO TO 230
300   EV=EV2
      GO TO 230
      END
```

```
      SUBROUTINE SUMMRY(F2,N2,R1,Z1,R4,Z4,JIM,JJM,FN2,
     2               C0,N0,M0,M2,F0,JTL,JMT,V0,FUTOT,I0,I1,I2,
     3               PFRAC,PFPREV,BURNUP,I4)
      COMMON    NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,   NDUMP,
     1         NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2        E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3        E8(51), E9(51),     E01,    E02,    E03
      COMMON      EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,     IGP,
     1           IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,     LAR,
     3            LC,   NGCTO,    ORFP,    P02,   PBAR,
     4          SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,   TEMP2,
     5         TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON ID(23),    TMAX,     IGE,    IZM,     IM,     JM,     IBL,
     1           IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT,  ISTART,
     2            ML,      MT,     M01,   ICST,    IHT,    IHS,     ITL,
     3            IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,   IPRIN,
     4        TOHTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON     EPS,   SHCRT,    POWR,    ORF, FLXTST,     PV,    EPSA,
     1            EV,     EVM,    XLAL,   XLAH,    POD,   DELT,     IFS,
     2        NBSTP,    IBUR,     EV2,    NGO, IBRTRG,  NCOEF,  NSWEEP
      INTEGER    B07,     CNT,     CVT,    P02,    T06,     R2,      Z2
      INTEGER   OITM
      REAL        I2,      I3,      K6,     K7,    LAP,   LAPP,     LAR,
     1            N0,      N2,    MASS,  MASSP,     I4
      DIMENSION F2(JIM,JJM), N2(JIM,JJM), R1(1), Z1(1), R4(1), Z4(1),
     1          FLUX(6), FN2(1), C0(JTL,JMT), N0(JIM,JJM), M0(JIM,JJM),
     2          M2(1), F0(JIM,JJM)
      DIMENSION  V0(JIM,JJM),FUTOT(1),I0(1),I1(1),I2(1),PFRAC(1),
     2           PFPREV(1),BURNUP(1),I4(1)
C     FINAL PRINT
      ICARD=1
C     PRINT FINAL EIGENVALUE AND OTHER FINAL OUTER ITERATION PARAMETERS
      CALL EVPRT
C     PRINT ATOM DENSITIES FROM SEARCH CALCULATION (IF IEVT=2)
      IF(IEVT.NE.2) GO TO 60
      PRINT 10, PV
   10 FORMAT(1H1///,2X,100HTHESE ARE THE DESIRED ATOM DENSITIES OBTAINED
     1 FROM THE CONC SEARCH TO GIVE A PARAMETRIC VALUE OF PV=  F9.6///)
      DO 30 M=1,M01
      IF (I4(M).EQ.0.) GO TO 30
      TEMF = I2(M)*(1.0 + EV*I4(M))
      K = I0(M) - ML
      PRINT 20, K, I1(M), TEMF
   20 FORMAT(10X,7HREGION=I2,5X,9HMATERIAL=I2,5X,15HMATL ATOM DENS=F10.7
     1 )
   30 CONTINUE
   50 CONTINUE
C     PRINT FINAL GROUP TOTALS
   60 CALL GRPTOT
      IF(DAY.NE.0.) GO TO 105
C     PRINT MESH INTERVALS AND COORDINATES
      J=IP
      IF(IP - JP) 70,70,65
   65 J=JP
   70 PRINT 80,         (I,R1(I),R4(I),Z1(I),Z4(I),I=1,J)
   80 FORMAT(      84H1                      RADII              AVG RADII
     1          AXII                  AVG AXII//(I4,4F20.4))
```

```
      J=J + 1
      IF(IP - JP) 85,105,95
85    PRINT 90,           (I,Z1(I),Z4(I),I=J,JP)
90    FORMAT(I4,40X,2F20.4)
      GO TO 105
95    PRINT 100,          (I,R1(I),R4(I),I=J,IP)
100   FORMAT(I4,2F20.4)
105   CONTINUE
C     INITIALIZE TOTAL FLUX AND POWER DENSITY ARRAYS
      DO 110 I=1,IM
      DO 110 J=1,JM
      N0(I,J)=0.
110   F2(I,J)=0.
C     MASTER LOOP FOR OUTPUTTING OF FLUXES (PRINT/TAPE/PUNCH OPTIONS)
      DO 350 IIG=1,IGM
      READ (NFLUX1)((N2(I,J),I=1,IM),J=1,JM)
      READ(ICR1)((C0(II,J), II = 1, ITL), J = 1, MT)
C     CALCULATE TOTAL FLUX AND POWER DENSITY
      DO 120 I=1,IM
      DO 120 J=1,JM
      N0(I,J) = N0(I,J) + N2(I,J)
      ITEMP = M0(I,J)
      ITEMP = M2(ITEMP)
120   F2(I,J)= F2(I,J) + C0(1,ITEMP)*N2(I,J)*1000.*EPF
C     PRINT GROUP FLUXES (IF DESIRED)
      IF(IPRIN.EQ.3) GO TO 160
      IF(DAY.NE.0.) GO TO 140
125   PRINT 130,IIG
130   FORMAT(1H1, 20X,14HFLUX FOR GROUP,I2)
      CALL PRT(IM,JM,N2,Z4)
      GO TO 160
140   IF(IPRIN.EQ.1) GO TO 125
C     WRITE FLUXES ON TAPE(FOR IREF=0 OR 1),OR DISK(FOR IREF=2),IF DESRD
160   IF(IDMTPS) 230,230,170
170   IF(DAY.NE.0.) GO TO 200
      IF(IREF.NE.0) GO TO 230
180   WRITE(NDUMP)  ((N2(I,J),I=1,IM),J=1,JM)
      GO TO 230
200   IF(IREF.EQ.1) GO TO 180
      IF(IREF.EQ.0) GO TO 220
      WRITE(ISCRAT)  ((N2(I,J),I=1,IM),J=1,JM)
      GO TO 230
220   CALL ERRO2(6HSUMMRY,220,1)
C     PUNCH FLUXES (IF DESIRED)
230   IF(IPFLX.EQ.0) GO TO 350
      IF(DAY.NE.0.) GO TO 245
      IF(IPFLX.EQ.1) GO TO 255
      GO TO 350
245   IF(IPFLX.NE.2) GO TO 350
255   DO 300 I=1,IMJM,6
      DO 280 J=1,6
280   FLUX(J) = 0.
      II = MIN0(I+5,IMJM)
      JI = 1
      DO 290 J=I,II
      FLUX(JI) = FN2(J)
290   JI = JI + 1
      PUNCH 310, (FLUX(J),J=1,6),ICARD
```

```
300   ICARD = ICARD + 1
310   FORMAT(1P6E12.6,4HFLUX,I4)
350   CONTINUE
C     PRINT TOTAL FLUX AND POWER DENSITY
      PRINT 355
355   FORMAT(1H1//, 19X,11H TOTAL FLUX//)
      CALL PRT(IM,JM,NU,Z4)
      PRINT 360
360   FORMAT(1H1//, 19X, 26HPOWER DENSITY  (MWT/LITER))
      CALL PRT(IM,JM,F2,Z4)
C     CALCULATE AND PRINT REGIONAL POWER FRACTIONS
      IF(POWR.LE.0.) GO TO 475
      DO 365 I=1,IZM
365   PFRAC(I)=0.
      DO 370 I=1,IM
      DO 370 J=1,JM
      ITEMP=M0(I,J)
      ITEMP=M2(ITEMP) - ML
370   PFRAC(ITEMP)=PFRAC(ITEMP) + F2(I,J)*V0(I,J)*.001
      PRINT 375
375   FORMAT(1H1,///10X,39HPOWER PRODUCTION FRACTION FOR EACH ZONE///)
      DO 380 I=1,IZM
      PFRAC(I)=PFRAC(I)/POWR
380   PRINT 385, I,PFRAC(I)
385   FORMAT(/20X,2HI=I2,2X,6HPFRAC=F9.6)
C     CALCULATE AND PRINT BURNUP RATES FOR EACH ZONE
      IF(MWDT.EQ.0) GO TO 475
      IF(DAY.EQ.0.) GO TO 460
      IF(IBRTRG.EQ.0) GO TO 460
      PRINT 400
400   FORMAT(1H1,///10X,83HTHESE ARE THE AVERAGE BURNUP RATES,IN MWD/TON
     2,FOR EACH ZONE OVER THE PREVIOUS CYCLE///)
      PRINT 405, DELT
405   FORMAT(//10X,5HDELT=F8.2,7H    DAYS////)
      DO 425 I=1,IZM
      IF(FUTOT(I).EQ.0.) GO TO 415
      BURNUP(I)= (PFRAC(I) + PFPREV(I))*POWR*DELT/(2.*FUTOT(I))
      BRNMET=BURNUP(I)*1.10
      GO TO 425
415   BURNUP(I)=0.
      BRNMET=0.
425   PRINT 430,      I,FUTOT(I),BURNUP(I),BRNMET
430   FORMAT(/5X,2HI=I2,4X,24HFUEL MASS IN SHORT TONS=F7.3,4X,29HAVG. BU
     2RNUP IN MWD/SHORT TON=F9.2,5X,30HAVG. BURNUP IN MWD/METRIC TON=F9.
     32)
460   DO 470 II=1,IZM
470   PFPREV(II)=PFRAC(II)
475   IF(IPRIN.EQ.3) GO TO 500
      IF(DAY.NE.0.) GO TO 490
480   PRINT 485
485   FORMAT(1H1,20X,19HFISSION SOURCE RATE)
      CALL PRT(IM,JM,F0,Z4)
      GO TO 500
490   IF(IPRIN.EQ.1) GO TO 480
500   REWIND NCR1
      REWIND NFLUX1
      REWIND NDUMP
      RETURN
      END
```

```
      SUBROUTINE GRPT01
      COMMON   MINP,   NCUT,   NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1        NMICR,    ALA,    B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51), E9(51),    E01,    E02,    E03
      COMMON     EQ,    EVP,   EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1          IGV,     II,   IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2          IZP,     JP,    K07,  KPAGE,    LAP,   LAPP,    LAR,
     3           LC,  NGCTO,   ORFP,    P02,   PBAR,
     4         SBAR,    SK7,    T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5        TEMP3,  TEMP4,     TI,    V11,   NXCM
      COMMON ID(23),   IMAX,    IGE,    IZM,     IM,     JM,    IBL,
     1          IBR,    IBT,    IBB,    IGM,   IEVT,   IPVT, ISTART,
     2           ML,     MT,    M01,   ICST,    IHT,    IHS,    IIL,
     3           IZ,     JZ,   OITM,   IITM,   MWOT,  IPFLX,  IPRIN,
     4       IDMTPS,   IREF,  IXSEC,  NPOIS,   NCON
      COMMON    EPS,  SRCRT,   POWR,    ORF, FLXTST,     PV,   EPSA,
     1           EV,    EVM,   XLAL,   XLAH,    POD,   DELT,    IFS,
     2        NBSTP,   IBUR,    EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER   B07,    CNT,    CVT,    P02,    T06,     R2,     Z2
      INTEGER  OITM
      REAL       I2,     I3,     K6,     K7,    LAP,   LAPP,    LAR,
     1           N0,     N2,   MASS,  MASSP,     I4
      E2(IGP) = .0
      E3(IGP) = .0
      E4(IGP) = .0
      E5(IGP) = .0
      E6(IGP) = .0
      E7(IGP) = .0
      E8(IGP) = .0
      E9(IGP) = .0
      DO 10 I = 1,IGM
      E2(IGP) = E2(IGP) + E2(I)
      E3(IGP) = E3(IGP) + E3(I)
      E4(IGP) = E4(IGP) + E4(I)
      E5(IGP) = E5(IGP) + E5(I)
      E6(IGP) = E6(IGP) + E6(I)
      E7(IGP) = E7(IGP) + E7(I)
      E8(IGP) = E8(IGP) + E8(I)
   10 E9(IGP) = E9(IGP) + E9(I)
      PRINT 20
   20 FORMAT (1H1, 28H FINAL NEUTRON BALANCE TABLE///
     159H GROUP  FISSION SOURCE  IN-SCATTER  OUT-SCATTER  ABSORPTION,1X,
     265H     L. L.          R. L.        T. L.          B. L.     TOTAL LEAKA
     3GE//)
      DO 30 I = 1,IGM
   25 FORMAT (I5, 1P9E13.3)
   30 PRINT 25,      I,E1(I),E2(I),E3(I),E4(I),E5(I),E6(I),E7(I),
     1 E8(I),E9(I)
      PRINT 35
   35 FORMAT (1H )
      I = IGM + 1
      PRINT 25,      I,E1(I),E2(I),E3(I),E4(I),E5(I),E6(I),E7(I),
     1 E8(I),E9(I)
      RETURN
      END
```

```
      SUBROUTINE PRT (JIM,JJM, N2, Z4)
      DIMENSION N2(JIM,JJM), Z4(1)
      REAL  I2
      IM = JIM
      JM = JJM
      DO  50  I=1,IM,5
      I1=I
      I2=I+4
      IF(I2-IM) 20, 20, 10
   10 I2=IM
   20 PRINT 30,           ( JJ,JJ=I1,I2)
   30 FORMAT( 5I20)
      DO  50  JJ=1,JM
      J=JJ
   40 FORMAT(I5,E15.7,5E20.7)
   50 PRINT 40,          J,(N2(K,J),K=I1,I2),Z4(J)
      RETURN
      END
```

```
      SUBROUTINE GRAM(MASS, VOL,  ATW, HOLN,JIM,JJM, M0, M2, V0,
     2             I0, I1, I2, JML, I3,FUTOT, NTRIG, I4)
      COMMON    NINP,     NCUT,     NCRI, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1          NMICR,     ALA,      B07,    CNT,    CVT,    DAY, E0(51),
     2       E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3       E8(51), E9(51),      E01,    E02,    E03
      COMMON      EQ,      EVP,     EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,       II,     IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,       JP,      K07,  KPAGE,    LAP,   LAPP,    LAR,
     3            LC,   NGCTO,     ORFP,    P02,   PBAR,
     4          SBAR,      SK7,      T06,    T11,  TEMP,   TEMP1,  TEMP2,
     5         TEMP3,    TEMP4,       TI,    V11,   NXCM
      COMMON ID(23),     IMAX,      IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,      IBT,      IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,       MT,      M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,       JZ,     OITM,   TITM,   MWDT,  IPFLX,  IPRIN,
     4        IOUTPS,     IREF,    IXSEC,  NPOIS,   NCON
      COMMON     EPS,    SHCRT,     POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,      EVM,     XLAL,   XLAH,    POD,   DELT,    IFS,
     2         NBSTP,     IBUR,      EV2,    NG0, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,      CNT,      CVT,    P02,    T06,     R2,     Z2
      INTEGER OITM
      REAL        I2,       I3,       K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,       N2,     MASS,  MASSP,     I4
      DIMENSION MASS(JML,1), VOL(1), ATW(1), HOLN(1), M0(JIM,JJM),
     1          M2(1), V0(JIM,JJM), I0(1), I1(1), I2(1), I3(1),
     2          FUTOT(1),NTRIG(1),I4(1)
C     THIS SUBROUTINE CALCULATES THE MASS OF THE VARIOUS MATERIALS
      IF(MWDT.EQ.0) GO TO 6
      DO 5 N=1,IZM
    5 FUTOT(N)=0.
    6 CONTINUE
      PRINT 10, (ID(I),I=1,23)
   10 FORMAT (1H1, 12A6/11A6///)
      PRINT 20
   20 FORMAT(45H MATERIAL INVENTORY (KILOGRAMS) FOR EACH ZONE /   )
      DO 25 I=1,IZM
   25 VOL(I) = 0.0
      DO 30 I=1,ML
      DO 30 J=1,IZM
   30 MASS(I,J) = 0.0
      DO 40  J = 1, JM
      DO 40  I = 1, IM
      K = M0(I,J)
   40 VOL(K) = VOL(K) + V0(I, J)*.001
      DO 50  M=1,M01
      I3(M) = I2(M)
      IF (IEVT.NE.2) GO TO 50
      I3(M) = I2(M)*(1.0 + EV*I4(M))
   50 CONTINUE
      DO  90 N =1, IZM
      NN = M2(N)
      DO  90 M = 1,M01
      IF(I0(M) - NN)  90,60,90
   60 L = I1(M)
   70 IF (L) 90,90,80
   80 E01 = I3(M)
      MASS(L,N) = ((E01*ATW(L)*VOL(N))/.6023) + MASS(L,N)
```

```
      IF (MODT.EQ.0) GO TO 90
      IF(NTRIG(M).EQ.0) GO TO 90
      FUTOT(N)=FUTOT(N) + MASS(L,N)*0.0011
90    CONTINUE
      DATA   ZONE/6H ZONE /
      DO 160 L = 1, IZM, 5
      LL = L + 4
      IF(LL - IZM) 110, 110, 100
100   LL = IZM
110   PRINT 120,        ((ZONE, K), K=L, LL)
120   FORMAT(//26H   MATERIAL   ATOMIC WT.   ,3X, 5(A6,I2,12X))
      PRINT 130,        (VOL(K), K = L, LL)
130   FORMAT(25X, 5(F8.3, 7H LITERS, 5X))
      DO 140 K = 1, ML
140   PRINT 150,        K, HOLN(K), ATW(K), (MASS(K, I), I = L, LL)
150   FORMAT( I3,1X, A6, F13.3, 1X, 1PE13.3, 1P4E20.3)
      IF(LL - IZM)  160, 170, 170
160   CONTINUE
170   RETURN
      END
```

```
      SUBROUTINE INPB(MATN,NBR,LD,LCN,LFN,ALAM,HOLN,JML,I2)
      COMMON    NINP,     NCUT,     NCR1,  NFLUX1, NSCRAT, ISCRAT,   NDUMP,
     1         NMICR,      ALA,      B07,     CNT,    CVT,    DAY, E0(51),
     2        E1(51),  E2(51),  E3(51),  E4(51),  E5(51),  E6(51), E7(51),
     3        E8(51),  E9(51),      E01,     E02,     E03
      COMMON        EQ,      EVP,     EVPP,     EPF,   GBAR,   IGEP,    IGP,
     1             IGV,       II,     IMJM,      IP,  ITEMP, ITEMP1, ITEMP2,
     2             IZP,       JP,      K07,   KPAGE,    LAP,   LAPP,    LAR,
     3              LC,    NGCTO,     ORFP,     P02,   PBAR,
     4            SBAR,      SK7,      T06,     T11,   TEMP,  TEMP1,  TEMP2,
     5           TEMP3,    TEMP4,       TI,     V11,   NXCM
      COMMON ID(23),      IMAX,      IGE,     IZM,     IM,     JM,    THL,
     1             IBR,      IBT,      IBB,     IGM,   IEVT,   IPVT, ISTART,
     2              ML,       MT,      M01,    ICST,    IHT,    IHS,    ITL,
     3              IZ,       JZ,     OITM,    IITM,   MWDT,  IPFLX,  IPRIN,
     4          IOUTPS,     IREF,    IXSEC,   NPOIS,   NCON
      COMMON       EPS,    SRCR1,     POWR,     ORF, FLXTST,     PV,   EPSA,
     1              EV,      EVM,     XLAL,    XLAH,    POD,   DELT,    IFS,
     2          NBSTP,     IBUR,      EV2,     NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,      CNT,      CVT,     P02,    T06,     R2,     Z2
      INTEGER OITM
      REAL          I2,       I3,       K6,      K7,    LAP,   LAPP,    LAR,
     1              N0,       N2,     MASS,   MASSP,     I4
      DIMENSION  MATN(1), NBR(1), LD(1),LCN(JML,1),LFN(JML,1), ALAM(1),
     1 HOLN(1), I2(1)
C
C     * * * * *  BURNUP DATA  * * * * *
C
C    CARD 1             NCON, DELT (BURNUP CONTROL WORDS)
C
C    CARD BLOCK 2      MATN, NBR, LD, LCN, LFN    (NCON CARDS)
C          (OMIT IF NCON.LE.0)
C
C    REPEAT ABOVE CARDS FOR MULTIPLE BURNUP STEPS AS PER INSTRUCTIONS
C
C    FINAL CARD IN BURNUP DATA DECK SHOULD BE A CARD 1
C
C     THIS SUBROUTINE READS AND PRINTS THE BURNUP DATA
      IF(DAY.EQ.0.) GO TO 5
      IF(K07.NE.2) GO TO 5
      IF(IEVT.NE.2) GO TO 12
    5 READ(NINP,10) ITEMP,DELT
   10 FORMAT(I6,E12.0)
      DAY=DAY + DELT
      IBRTRG=1
      IBUR=IBUR + 1
      GO TO 14
   12 IBRTRG=0
      IF(IBUR.NE.NBSTP) GO TO 14
      IF(IFS) 13,13,14
   13 READ(NINP,10) ITEMP,DELT
   14 CVT=0
      CNT = 0
      P02 = 0
      ALA = 0.0
      LAP = 0.0
      LAPP = 0.0
      LAR = 0.0
```

```
      KPAGE=50
      IF(IBRTRG.EQ.0) GO TO 100
      IF(ITEMP) 100,15,20
15    NCON = ITEMP
      GO TO 100
20    NCON = ITEMP
      DO 40  N = 1, NCON
30    FORMAT(12I6)
40    READ(INP,30)  MATN(N),NBR(N),LD(N),(LCN(N,K),K=1,2),(LFN(N,K),
     1 K=1,7)
      PRINT 60
60    FORMAT(12H1BURNUP DATA///)
      PRINT 70
70    FORMAT(130H BURNABLE         MATERIAL          NAME           LAMBDA
     1      IBR            *  *  *  *  *  *  SOURCE ISOTOPE FOR  *  *  *  *
     2  *  *   /
     3        130H  ISOTOPE              NO.                        (DAYS-1)
     4                     DECAY                  CAPTURE                FISS
     5ION      /9H      NC.  )
      DO 90  N=1, NCON
      ITEMP = MATN(N)
      ALAM(ITEMP) = 24.*3600.*ALAM(ITEMP)
      PRINT 80,          N, MATN(N), HOLN(ITEMP), ALAM(ITEMP), NBR(N),
     1LD(N),    (LCN(N,K),K=1,2),  (LFN(N,K),K=1,7)
80    FORMAT(3X, I3, 12X, I3, 10X, A6, 7X, E9.3, I9, 15X, I3, 13X, 2I3,
     1      10X, 7I3)
90    ALAM(ITEMP) = ALAM(ITEMP)/(3600.*24.)
100   RETURN
      END
```

```
      SUBROUTINE AVERAG(PHIB,AXS,FXS,MATN,MASS,ATW,VOL,CO,N2,MO,VO,
     1                  HOLN, JML, JTL, NBR, AXX, FXX,BREDRT)
      COMMON    NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,  NDUMP,
     1         NMICR,     ALA,     B07,    CNT,    CVT,    DAY, E0(51),
     2      E1(51), E2(51), E3(51), E4(51), E5(51), E6(51), E7(51),
     3      E8(51), E9(51),     E01,    E02,    E03
      COMMON      E0,     EVP,    EVPP,    EPF,   GBAR,   IGEP,    IGP,
     1           IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1, ITEMP2,
     2           IZP,      JP,     K07, KPAGE,    LAP,   LAPP,    LAR,
     3            LC,   NGCTO,    ORFP,    P02,   PBAR,
     4          SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,  TEMP2,
     5         TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON I0(23),    IMAX,     IGE,    IZM,     IM,     JM,    IBL,
     1           IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT, ISTART,
     2            ML,      MT,     M01,   ICST,    IHT,    IHS,    ITL,
     3            IZ,      JZ,    OITM,   IITM,   MWDT,  IPFLX,  IPRIN,
     4        IOUTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON     EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,   EPSA,
     1            EV,     EVM,    XLAL,   XLAH,    POD,   DELT,    IFS,
     2        NBSTP,    IBUR,     EV2,    NGO, IBRTRG,  NCOEF, NSWEEP
      INTEGER    B07,     CNT,     CVT,    P02,    T06,     R2,     Z2
      INTEGER OITM
      REAL        I2,      I3,      K6,     K7,    LAP,   LAPP,    LAR,
     1            N0,      N2,    MASS,  MASSP,     I4
      DIMENSION PHIB(1), AXS(JML,1), FXS(JML,1), MATN(1), MASS(JML,1),
     1          ATW(1), VOL(1), CO(JTL,1), N2(1), MO(1), VO(1), HOLN(1)
     2          ,NBR(1), AXX(JML,1), FXX(JML,1), BREDRT(1)
C
C     THIS SUBROUTINE CALCULATES ZONE AVERAGED FLUXES, FISSION CROSS
C     SECTIONS, AND ABSORPTION CROSS SECTIONS.
C
      PRINT 5
    5 FORMAT(1H1)
      RL = 0.0
      RC = 0.0
      DO 10  KZ=1,IZM
      PHIB(KZ) = 0.0
      DO 10  KN =1,NCON
      AXS(KN,KZ) = 0.0
      FXS(KN,KZ) = 0.0
      LN = MATN(KN)
   10 MASS(LN,KZ) = (MASS(LN,KZ)*.6023)/(ATW(LN)*VOL(KZ))
      DO 20  IIG=1,IGM
      READ(NCR1)  ((CO(II,J), II=1,ITL),J=1,MT)
      READ(NFLUX1)  (N2(I), I=1,IMJM)
      DO 20   I=1,IMJM
      KZ = MO(I)
      PHIB(KZ) = PHIB(KZ) + N2(I)*VO(I)
      DO 20   KN=1,NCON
      LN = MATN(KN)
      AXS(KN,KZ) = AXS(KN,KZ) + CO(2,LN)*N2(I)*VO(I)
   20 FXS(KN,KZ) = FXS(KN,KZ) + CO(1,LN)*N2(I)*VO(I)
      DO 80   KZ=1,IZM
      BREDRT(KZ)=0.
      TEMP3 = PHIB(KZ)
      PHIB(KZ) = PHIB(KZ)/(VOL(KZ)*1000.)
      PRINT 30,         KZ, PHIB(KZ), VOL(KZ)
   30 FORMAT(/////,30X,9H Z O N E ,I3,7X,7H FLUX =,1PE10.4,7X,9H VOLUME
```

```
     1=,1PE10.4,7H LITERS/)
      PRINT 40
 40   FORMAT(115H BURNABLE       MATERIAL          NAME           ATOM
     1       FISSION     ABSORPTION        SIGMA          SIGMA    /
     2      115H  ISOTOPE          NO.                          DENSITY
     3        RATE           RATE          FISSION       ABSORPTION/
     4        7H     NO./)
      DO 80   KN=1,NCON
      LN = MATN(KN)
      TEMP1 = AXS(KN,KZ)*MASS(LN,KZ)
      TEMP2 = FXS(KN,KZ)*MASS(LN,KZ)
      AXS(KN,KZ) = AXS(KN,KZ)/TEMP3
      FXS(KN,KZ) = FXS(KN,KZ)/TEMP3
      IF (IBRTRG.EQ.0) GO TO 45
      IF (DELT.NE.0.) AXX(KN,KZ) = AXS(KN,KZ)/NBSTP + AXX(KN,KZ)
      IF (DELT.NE.0.) FXX(KN,KZ) = FXS(KN,KZ)/NBSTP + FXX(KN,KZ)
 45   CONTINUE
 50   FORMAT(4X,I3,11X,I3,10X,A6,2X,1P5E15.3)
      PRINT 50,         KN, LN, HOLN(LN), MASS(LN,KZ), TEMP2, TEMP1,
     1 FXS(KN,KZ), AXS(KN,KZ)
      ITEMP = NBR(KN)
      IF(ITEMP - 1)  80, 60, 70
 60   RC = RC + TEMP1 - TEMP2
      BREDRT(KZ)=BREDRT(KZ) + TEMP1 - TEMP2
      GO TO 80
 70   RL = RL + TEMP1
 80   CONTINUE
      DO 90  KZ = 1,IZM
      BREDRT(KZ)=BREDRT(KZ)/RL
 90   PRINT 100, KZ, BREDRT(KZ)
 100  FORMAT(30X,3HKZ=I2,2X,11HBREDRT(KZ)=F7.4)
      TEMP = RC/RL
      PRINT 110, TEMP
 110  FORMAT(1H ///18H  BREEDING RATIO =F7.4)
      REWIND NCR1
      REWIND NFLUX1
      RETURN
      END
```

```
      SUBROUTINE EIGTRG(IEVT,K07,IBUR,EV,EV2,NGO,EQ,IPVT)
      IF(IEVT.NE.1) GO TO 100
      IF(K07.NE.2) GO TO 200
      IEVT=2
      EV=EV2
      IPVT=2
      NGO=2
      RETURN
 100  IEVT=1
      IPVT=1
      EV=0.
      EQ=0.
 200  NGO=1
      RETURN
      END
```

```
      SUBROUTINE MARCH(PHIB,MATN,FXS,AXS,VOL,MASS,MASSP,ALAM,LD,LCN,
     1                 LFN,JML,I0,I1,I2,M2,PHIP,PHIPP,JZM)
      COMMON     NINP,    NCUT,    NCR1, NFLUX1, NSCRAT, ISCRAT,   NDUMP,
     1          NMICR,     ALA,     B07,    CNT,    CVT,    DAY,  E0(51),
     2         E1(51),  E2(51),  E3(51), E4(51), E5(51), E6(51),  E7(51),
     3         E8(51),  E9(51),     E01,    E02,    E03
      COMMON       EQ,     EVP,    EVPP,    EPF,   GBAR,   IGEP,     IGP,
     1            IGV,      II,    IMJM,     IP,  ITEMP, ITEMP1,  ITEMP2,
     2            IZP,      JP,     K07,  KPAGE,    LAP,   LAPP,     LAR,
     3             LC,   NGOTO,    ORFP,    P02,   PBAR,
     4           SBAR,     SK7,     T06,    T11,   TEMP,  TEMP1,   TEMP2,
     5          TEMP3,   TEMP4,      TI,    V11,   NXCM
      COMMON   ID(23),    TMAX,     IGE,    IZM,     IM,     JM,     IBL,
     1            IBR,     IBT,     IBB,    IGM,   IEVT,   IPVT,  ISTART,
     2             ML,      MT,     M01,   ICST,    IHT,    IHS,     ITL,
     3             IZ,      JZ,    OITM,   TITM,   MWDT,  IPFLX,   IPRIN,
     4         IOUTPS,    IREF,   IXSEC,  NPOIS,   NCON
      COMMON      EPS,   SRCRT,    POWR,    ORF, FLXTST,     PV,    EPSA,
     1             EV,     EVM,    XLAL,   XLAH,    POD,   DELT,     IES,
     2          NBSTP,    IBUR,     EV2,    NGO, IBRTRG,  NCOEF,  NSWEEP
      INTEGER     B07,     CNT,     CVT,    P02,    T06,     R2,      Z2
      INTEGER OITM
      REAL         I2,      I3,      K6,     K7,    LAP,   LAPP,     LAR,
     1             N1,      N2,    MASS,  MASSP,     I4
      DIMENSION  PHIB(1), MATN(1), FXS(JML,1),AXS(JML,1),VOL(1),
     1           MASS(JML,1),MASSP(JML,1),ALAM(1), LD(1), LCN(JML,1),
     2           LFN(JML,1),I0(1),I1(1),I2(1),M2(1),PHIP(1),PHIPP(1)
C
C     THIS SUBROUTINE COMPUTES THE TIME DEPENDENT ISOTOPIC CONCENTRATION
C
      TEMP = DELT * 24. * 3600. / 10.
      TEMP1 = .0
      DO 5 KZ = 1,IZM
      PHIPP(KZ) = PHIB(KZ)
      PHIB(KZ) = PHIB(KZ) * 10.**(-24)
      DO 5 KN = 1,NCON
      LN = MATN(KN)
    5 TEMP1 = TEMP1 + FXS(KN,KZ)*PHIB(KZ)*MASS(LN,KZ)*VOL(KZ)
      DO 120 KT = 1,10
      TEMP3 = .0
      DO 10 KZ = 1,IZM
      DO 10 KN = 1,NCON
      LN = MATN(KN)
   10 MASSP(LN,KZ) = MASS(LN,KZ)
      DO 90  KZ = 1,IZM
      DO 80 KKK = 1,5
      DO 80 KN = 1,NCON
      LN = MATN(KN)
      TEMP2=-(MASS(LN,KZ)+MASSP(LN,KZ))*(ALAM(LN)+AXS(KN,KZ)*PHIB(KZ))
      IF (LD(KN)) 30, 30, 20
   20 KK = LD(KN)
      KK = MATN(KK)
      TEMP2 = TEMP2 + ALAM(KK)*(MASS(KK,KZ) + MASSP(KK,KZ))
   30 DO 50 K = 1,2
      KK = LCN(KN,K)
      KL = MATN(KK)
      IF (KK) 50, 50, 40
   40 TEMP2 = TEMP2 + (AXS(KK,KZ) - FXS(KK,KZ))*PHIB(KZ)*
```

```
     1 (MASS(KL,KZ) + MASSP(KL,KZ))                                     MAR
50    CONTINUE                                                          MAR
      DO 70 K = 1,7                                                     MAR
      KK = LFN(KN,K)                                                    MAR
      KL = MATN(KK)                                                     MAR
      IF (KK) 70, 70, 60                                                MAR
60    TEMP2 = TEMP2 + FXS(KK,KZ)*PHIB(KZ)*(MASS(KL,KZ)+MASSP(KL,KZ))    MAR
70    CONTINUE                                                          MAR
80    MASS(LN,KZ) = MASSP(LN,KZ) + .5*TEMP*TEMP2                        MAR
      DO 90  KN = 1,NCON                                                MAR
      LN = MATN(KN)                                                     MAR
90    TEMP3 = TEMP3 + FXS(KN,KZ)*PHIB(KZ)*MASS(LN,KZ)*VOL(KZ)           MAR
      IF(TEMP3)  120, 120, 100                                          MAR
100   DO 110 KZ = 1,IZM                                                 MAR
110   PHIB(KZ) = PHIB(KZ) * TEMP1/TEMP3                                 MAR
120   CONTINUE                                                          MAR
      DO 130 KZ = 1,IZM                                                 MAR
130   PHIB(KZ) = PHIB(KZ)*10.**(24)                                     MAR
      IF(IREF.NE.2) GO TO 165                                           MAR
      IF (IBUR.LT.NBSTP) GO TO 145                                      MAR
      PRINT 140                                                         MAR
140   FORMAT(1H1///,8X,105H THESE ARE THE ZONE-AVERAGED TOTAL FLUXES TO MAR
     2BE USED IN THE FLUX SHIFT CORRECTION FOR SUBROUTINE REFUEL    ///)MAR
145   DO 150 KZ=1,IZM                                                   MAR
      PHIP(KZ) =(PHIPP(KZ) + PHIB(KZ))*.5/NBSTP + PHIP(KZ)              MAR
      IF (IBUR.LT.NBSTP) GO TO 150                                      MAR
      PRINT 160,  KZ, PHIP(KZ)                                          MAR
150   CONTINUE                                                          MAR
160   FORMAT (20X,7H ZONE =,I2,4X,11H AVG FLUX =,1PE10.4/)              MAR
165   DO 200  KZ=1,IZM                                                  MAR
      DO 200  M=1,N01                                                   MAR
      IF(I9(M) - M2(KZ))  200, 170, 200                                 MAR
170   DO 190  KN=1,NCON                                                 MAR
      LN = MATN(KN)                                                     MAR
      IF(LN - I1(M))  190, 180, 190                                     MAR
180   I2(M) = MASS(LN,KZ)                                               MAR
190   CONTINUE                                                          MAR
200   CONTINUE                                                          MAR
      RETURN                                                            MAR
      END                                                               MAR
```

```
      SUBROUTINE REFUEL( KNT,NREG,NREPO,NPOIS,KLAPS,INTMAX,NECOP,X0,
     1      NFRE, TRG, HNO, PHI, ABXS, FIXS, KZNS, IZON, IZM, M01, ML,
     2      DAY, IGM, IMJM,ISTART,NCON,IDMTPS, I0, I1, I2, PHIP, PSI,
     3      V, AXS, FXS, MATN, ALAM, LD, LCN, LFN, HOLN, ATW, NZN, DN,
     4      CN , CNP, HNI, DG, CG, DISCHG, CHARGE, COMPO, NBIFLG)
      DIMENSION X0(1), NFRE(1), TRG(1), HNO(1), PHI(INTMAX,IZM),
     1      ABXS(NCON,IZM,INTMAX), FIXS(NCON,IZM,INTMAX), KZNS(1),
     2      IZON(KLAPS,IZM), I0(1), I1(1), I2(1), PHIP(1), PSI(1),V(1),
     3      AXS(ML,IZM), FXS(ML,IZM), MATN(1), ALAM(1), LD(1), LCN(ML,7),
     4      LFN(ML,7), HOLN(1), ATW(1), NZN(1), DN(IZM,NCON),
     5      CN(IZM,NCON), CNP(IZM,NCON), HNI(1), DG(NECOP,NCON),
     6      CG(NECOP,NCON), DISCHG(1), CHARGE(1), COMPO(1),
     7      NBIFLG(IZM,NCON)
      COMMON  NINP,  NOUT,  NCR1,  NFLUX1,  NSCRAT,  ISCRAT,  NDUMP
      INTEGER TRG
      REAL I2
C
C     CARD BLOCK 1      K,X0(K), NFRE(K)  K=1,NREG             I6,F12.5,I6
C
C     CARD BLOCK 2      TRG(N)       N=1,NCON   (1 CARD)               24I3
C
C     CARD BLOCK 3      HNO(I)       I=1,M01                         6F12.7
C       (OMIT IF USING TAPE NDUMP AND KNT GT. 1)
C
C     CARD BLOCK 4      PHI(I,J)     I=1,IZM J=1,KLNT                6E12.5
C       (OMIT IF USING TAPE NDUMP)
C
C     CARD BLOCK 5      ABXS(I,J,K) I=1,NCON J=1,IZM K=1,KLNT       6E12.5
C       (OMIT IF USING TAPE NDUMP)
C
C     CARD BLOCK 6      FIXS(I,J,K) I=1,NCON J=1,IZM K=1,KLNT       6E12.5
C       (OMIT IF USING TAPE NDUMP)
C
C     CARD BLOCK 7      KZNS(I)      (KLAPS PAIRS OF CARDS)               I6
C                       IZON(I,J)    J=1,KZNS(I)                       24I3
C
C
C     READ IN THE INPUT DATA
C
      INT = KNT + 1
      KLNT = KNT - 1
      CALL INPR (KNT, NREG, KLAPS, INTMAX, X0, NFRE,  TRG, HNO, PHI,
     1          ABXS, FIXS, KZNS, IZON, IZM, M01, ML, DAY, IGM, IMJM,
     2            ISTART, NCON, IDMTPS, I0, I1, I2, PHIP, PSI, AXS, FXS,
     3            MATN, HOLN, NZN, NBIFLG )
C
C  MAIN LOOP (CALC OF ATOM DENS OF CONSTITUENTS HAVING THE MOST BURNUP
C
      DAYP = DAY*24.*3600./10.
      DO 505 N=1,NREG
      KZ =  IZN(N)
      X = KNT/NFRE(KZ)
      IF (X.EQ.1.0.OR.X0(KZ).EQ.1.0) GO TO 485
      DIFF = 1.0 - X*X0(KZ)
      IF(ABS(DIFF).LE..005) DIFF=0.0
      IF (DIFF) 375,375,390
  375 KK=1
  380 DIFF = DIFF + X0(KZ)
```

```
      IF (ABS(DIFF).LE..005) DIFF=0.0
      DIFP = ABS(DIFF - X0(KZ))
      IF (DIFP.LE..005) DIFF = X0(KZ)
      IF (DIFF.GT.0.) GO TO 385
      KK = KK + NFRE(KZ)
      GO TO 380
385   ISTRT = KK
      COEF = DIFF
      DIFP = X0(KZ) - COEF
      GO TO 395
390   ISTRT = 1
      COEF = X0(KZ)
      DIFP = X0(KZ) - COEF
395   ITEMS = ISTRT
400   DO 415 I=1,NCON
      II = NBIFLG(KZ,I)
      IF (II) 405,405,410
405   CN(KZ,I) = 0.
      GO TO 415
410   CN(KZ,I) = HN0(II)
415   CONTINUE
420   PHY = PHI(ITEMS,KZ)*10.**(-24)
      DO 470 KT=1,10
      DO 425 KN=1,NCON
425   CNP(KZ,KN) = CN(KZ,KN)
      DO 465 KKK=1,5
      DO 460 KN=1,NCON
      IF (NBIFLG(KZ,KN).EQ.0) GO TO 460
      LN = IATN(KN)
      TEMP2=-(CN(KZ,KN)+CNP(KZ,KN))*(ALAM(LN)+ABXS(KN,KZ,ITEMS)*PHY)
      IF (LD(KN)) 435,435,430
430   KK = LD(KN)
      KLN = NATN(KK)
      TEMP2 = TEMP2 + ALAM(KLN)*(CN(KZ,KK)+CNP(KZ,KK))
435   DO 445 K=1,2
      KK = LCN(KN,K)
      IF(KK) 445,445,440
440   TEMP2 =TEMP2 + (ABXS(KK,KZ,ITEMS)-FIXS(KK,KZ,ITEMS))*PHY*(CN(KZ,
     1KK) + CNP(KZ,KK))
445   CONTINUE
      DO 455 K=1,7
      KK = LFN(KN,K)
      IF(KK) 455,455,450
450   TEMP2 = TEMP2 + FIXS(KK,KZ,ITEMS)*PHY*(CN(KZ,KK)+CNP(KZ,KK))
455   CONTINUE
      CN(KZ,KN) = CNP(KZ,KN) + 0.5*DAYP*TEMP2
460   CONTINUE
465   CONTINUE
470   CONTINUE
      ITEMS = ITEMS + 1
      IF (ITEMS.GT.KNT) GO TO 475
      GO TO 420
475   DO 480 KN=1,NCON
      DN(KZ,KN) = DN(KZ,KN) + CN(KZ,KN)*COEF
      IF (ITG(KN).EQ.0) DN(KZ,KN)=0.
480   CONTINUE
      IF(DIFP.LE.0.) GO TO 505
      COEF = DIFP
```

```
      DIFP = 0.
      ISTRT = ISTRT + NFRE(KZ)
      GO TO 395
  485 DO 500 KN=1,NCON
      II = NBIFLG(KZ,KN)
      IF (II) 490,490,495
  490 DN(KZ,KN) = 0.
      GO TO 500
  495 DN(KZ,KN) = X0(KZ)*I2(II)
      IF (TRG(KN).EQ.0) DN(KZ,KN) = 0.
  500 CONTINUE
  505 CONTINUE
      DO 510 KZ=1,IZM
      DO 510 N=1,NCON
  510 CN(KZ,N) = 0.
C
C     CALCULATE AND PUNCH THE INPUT ATOM DENSITIES (I2 BLOCK) FOR NEXT
C     BURNUP INTERVAL AND PRINT REGION-BY-REGION SUMMARY
C
      PRINT 515
  515 FORMAT (1H1,/10X,77H REGION DISCHARGE AND CHARGE AND INITIAL COMPO
     1SITION FOR NEXT BURNUP INTERVAL    //)
      IIK=1
      PRINT 520, IIK,V(IIK)
  520 FORMAT (//3X,7H REGION I3,9H  VOLUME= 1PE10.4,7H LITERS /)
      PRINT 525, KNT,INT,INT
  525 FORMAT (7X,29H ELEMENT     DISCHARGE FROM BI I3,9X, 14H CHARGE FOR
     1BI I3,8X,23H INITIAL COMPOSITION BI I3)
      PRINT 530
  530 FORMAT(16X,10H ATOM DENS,5X,9H MASS(KG),5X,10H ATOM DENS,5X,9H MAS
     1S(KG),5X,24H ATOM DENS        MASS(KG) /)
      DO 560 I=1,M01
      HNI(I) = I2(I)
      IF (I1(I).EQ.0) GO TO 560
      IF (I1(I).EQ.NPOIS.AND.NREPO.EQ.1) HNI(I) = HN0(I)
      IK = I0(I) - ML
      I1FLAG = I1(I)
      COEF = ATW(I1FLAG)*V(IK)/.6023
      IF(IK.EQ.IIK) GO TO 535
      IIK = IIK + 1
      PRINT 520, IIK,V(IIK)
      PRINT 525,KNT,INT,INT
      PRINT 530
  535 DIS = 0.
      CHG = 0.
      DO 545 N=1,NREG
      KZ = NZN(N)
      IF (KZ.LT.IK) GO TO 545
      IF (KZ.GT.IK) GO TO 550
      DO 540 L=1,NCON
      IF (MATN(L).NE.I1FLAG) GO TO 540
      IF (TRG(L).EQ.0) GO TO 550
      DIS = DN(KZ,L)
      CHG = X0(KZ)*HN0(I)
      CN(KZ,L) = CHG
      HNI(I) = HNI(I) + CHG - DIS
      GO TO 550
  540 CONTINUE
```

```
  545 CONTINUE
  550 TEMD = DIS*COEF
      TEMC = CHG*COEF
      TEMP = HNI(I)*COEF
      PRINT 555, IIFLAG,DIS,TEMD,CHG,TEMC,HNI(I),TEMP
  555 FORMAT(10X,I2,4X,F10.7,5X,1PE10.4,4X,0PF10.7,4X,1PE10.4,5X,
     1       0PF10.7,5X,1PE10.4)
  560 CONTINUE
C
C     I2 BLOCK FOR NEXT BURNUP INTERVAL
C
      PUNCH 565, INT,DAY
  565 FORMAT (2X,16H I2 BLOCK FOR BI,I3,10H OF LENGTH ,F6.1,5H DAYS )
      PUNCH 570, (HNI(I),I=1,M01)
  570 FORMAT (6F12.7)
      PRINT 575, INT
  575 FORMAT (1H1,/10X,52H INPUT ATOM DENSITIES (I2 BLOCK) FOR BURNUP IN
     1TERVAL  I3//)
      DO 580 I=1,M01
  580 PRINT 585,I,I0(I),I1(I),HNI(I)
  585 FORMAT(5X,2HI=,I3,3X,3HI0=,I2,3X,3HI1=,I3,3X,7HI2(I) =,F10.7)
C
C     REGION COLLAPSING (VOLUME AVERAGED)
C
      IF (KLAPS) 665,665,590
  590 PRINT 595
  595 FORMAT (1H1,10X,57H REGION COLLAPSED INFORMATION FOR ELEMENTS TO B
     1E REFUELED /)
      DO 660 I=1,KLAPS
      TOTV = 0.
      KK = KZNS(I)
      DO 600 K=1,KK
      KZ = IZON(I,K)
  600 TOTV = TOTV + V(KZ)
      PRINT 605, I, (IZON(I,K),K=1,KK)
  605 FORMAT (//5X,20H REGION COLLAPSE NO. I3,13H FROM REGIONS 24I3)
      PRINT 610, TOTV
  610 FORMAT (/ 8X,21H VOL AFTER COLLAPSE = 1PE10.4,8H  LITERS /)
      PRINT 615
  615 FORMAT (10X, 84H ELEMENT   COMPOSITION AT END    DISCHARGE FROM
     1 CHARGE FOR    INITIAL COMPOSITION  )
      PRINT 620, KNT, KNT, INT, INT
  620 FORMAT(22X, 7H OF BI ,I2,5H, KG., 8X, 4H BI ,I2,5H, KG.,5X,4H BI ,
     1       I2,5H, KG. ,5X,8H FOR BI ,I2,5H, KG. /)
      DO 640 N=1,NCON
      DIS = 0.
      CHG = 0.
      TEMF = 0.
      TEMI = 0.
      LN = MAIN(N)
      DO 625 K=1,KK
      KZ = IZON(I,K)
      DIS = DIS + DN(KZ,N)*V(KZ)/TOTV
      CHG = CHG + CN(KZ,N)*V(KZ)/TOTV
      II = NBIFLG(KZ,N)
      IF (II) 625,625,624
  624 TEMI = TEMI + HNI(II)*V(KZ)/TOTV
      TEMF = TEMF + I2(II)*V(KZ)/TOTV
```

```
 625  CONTINUE                                                            REF   233
      TEMF = TEMF*TOTV*ATW(LN)/.6023                                      REF   234
      DIS  = DIS*TOTV*ATW(LN)/.6023                                       REF   235
      CHG  = CHG*TOTV*ATW(LN)/.6023                                       REF   236
      TEMI = TEMI*TOTV*ATW(LN)/.6023                                      REF   237
      PRINT 630, LN, TEMF, DIS, CHG, TEMI                                 REF   238
 630  FORMAT (13X,I2,9X,1PE10.4,11X,1PE10.4,6X,1PE10.4,8X,1PE10.4)        REF   239
C                                                                         REF   240
C     PREPARE AND PUNCH CHARGE AND DISCHARGE MASSES FOR FURTHER           REF   241
C     ECONOMICS ANALYSIS (IF DESIRED).  FIRST NECOP COLLAPSES WILL        REF   242
C     BE PUNCHED.                                                         REF   243
C                                                                         REF   244
      IF (I.GT.NECOP) GO TO 635                                           REF   245
      DG(I,N) = DIS                                                       REF   246
      CG(I,N) = CHG                                                       REF   247
 635  CONTINUE                                                            REF  248A
 640  CONTINUE                                                            REF  248B
      IF (I.GT.NECOP) GO TO 660                                           REF   249
      PUNCH 645, I,KNT                                                    REF   250
 645  FORMAT (2X,9H COLLAPSE I2,18H DISCHARGE FROM BI I3)                 REF   251
      PUNCH 650, (DG(I,N),N=1,NCON)                                       REF   252
 650  FORMAT (6F12.4)                                                     REF   253
      PUNCH 655,I,INT                                                     REF   254
 655  FORMAT (2X,9H COLLAPSE I2,14H CHARGE FOR BI I3)                     REF   255
      PUNCH 650, (CG(I,N),N=1,NCON)                                       REF   256
 660  CONTINUE                                                            REF   257
 665  CONTINUE                                                            REF   258
      IF (NECOP.LE.KLAPS) GO TO 675                                       REF   259
      PRINT 670                                                           REF   260
 670  FORMAT(1H1,48H * * * NECOP IS GREATER THAN KLAPS - ERROR * * *///)REF   261
C                                                                         REF   262
C     MASS SUMMARY FOR ENTIRE REACTOR                                     REF   263
C                                                                         REF   264
 675  DO 680 K=1,ML                                                       REF   265
      COMPO(K) = 0.                                                       REF   266
      DISCHG(K) = 0.                                                      REF   267
 680  CHARGE(K) = 0.                                                      REF   268
      DO 685 I=1,M01                                                      REF   269
      IK = I0(I) - ML                                                     REF   270
      K = I1(I)                                                           REF   271
 685  COMPO(K) = COMPO(K) + HNI(I)*V(IK)*ATW(K)/.6023                     REF   272
      DO 690 KZ=1,IZM                                                     REF   273
      DO 690 N=1,NCON                                                     REF   274
      LN = MATN(N)                                                        REF   275
      COEF= V(KZ)*ATW(LN)/.6023                                           REF   276
      CHARGE(LN) = CHARGE(LN) + CN(KZ,N)*COEF                             REF   277
 690  DISCHG(LN) = DISCHG(LN) + DN(KZ,N)*COEF                             REF   278
      PRINT 695,KNT,INI,INT                                               REF   279
 695  FORMAT(1H1,3X,18H DISCHARGE FROM BI I3,16H,  CHARGE FOR BI I3,      REF   280
     1     29H   AND INITIAL COMPOS. FOR BI  I3,14H  IN KILOGRAMS //)     REF   281
      DO 700 I=1,ML                                                       REF   282
 700  PRINT 705, I,HOLN(I),DISCHG(I),CHARGE(I),COMPO(I)                   REF   283
 705  FORMAT (5X,8H ELEMENT I3,2X,A9,3X,18H TOTAL DISCHARGE = 1PE11.4,   REF   284
     1     3X,15H TOTAL CHARGE = 1PE11.4,3X,24H TOTAL MASS IN REACTOR = REF   285
     2     1PE11.4/)                                                      REF   286
      RETURN                                                              REF   287
      END                                                                 REF   288
```

```
      SUBROUTINE INPR (KNT, NREG, KLAPS, INTMAX, X0, NFRE, TRG, HNO,PHI,
     1          ABXS, FIXS, KZNS, IZON, IZM, M01, ML, DAY, IGM, IMJM,
     2             ISTART, NCON, IDMTPS, I0, I1, I2, PHIP, PSI, AXS, FXS,
     3             MATN, HOLN, NZN, NBIFLG )
      DIMENSION  X0(1), NFRE(1), TRG(1), HNO(1), PHI(INTMAX,IZM),
     1        ABXS(NCON,IZM,INTMAX), FIXS(NCON,IZM,INTMAX), KZNS(1),
     2        IZON(KLAPS,IZM), I0(1), I1(1), I2(1), PHIP(1), PSI(1),
     3        AXS(ML,IZM), FXS(ML,IZM), MATN(1), HOLN(1), NZN(1),
     4        NBIFLG(IZM,NCON)
      COMMON  NINP,  NOUT,  NCR1,  NFLUX1,  NSCRAT,  ISCRAT,  NDUMP
      INTEGER TRG
      REAL I2
C
C     THIS SUBROUTINE READS, PRINTS AND PUNCHES INPUT DATA FOR REFUEL
C
      INT= KNT + 1
      KLNT = KNT - 1
    5 FORMAT (I6,F12.5,I6)
      IN = 0
      DO 15 I=1,NREG
      READ (NINP,5)  K, X0(K), NFRE(K)
      KNF = NFRE(K)
      IF (MOD(KNT,KNF).NE.0) GO TO 10
      IN = IN + 1
      NZN(IN) = K
      GO TO 15
   10 X0(K) = 0.
   15 CONTINUE
      NREG = IN
      CALL TRIG (TRG,NCON)
   20 FORMAT (24I3)
      IF (ISTART.EQ.3) GO TO 30
      READ (NINP,25)  (HNO(J), J=1,M01)
   25 FORMAT (6E12.7)
      GO TO 40
   30 CONTINUE
      DO 35 IIG=1,IGM
   35 READ (NDUMP)
      READ(NDUMP)  (HNO(J) ,J=1,M01)
   40 CONTINUE
      IF (KLNT.EQ.0) GO TO 65
      IF (IDMTPS.EQ.1) GO TO 55
      DO 45 I=1,KLNT
   45 READ(NINP,50)(PHI(I,J),J=1,IZM)
   50 FORMAT (6E12.5)
      GO TO 65
   55 DO 60 I=1,INTMAX
   60 READ (NDUMP)  (PHI(I,J), J=1,IZM)
   65 CONTINUE
      DO 70 J=1,IZM
   70 PHI(KNT,J) = PHIP(J)
      IF (IDMTPS.EQ.1) GO TO 100
      PUNCH 75, KNT
   75 FORMAT(2X,5H PHI(  I2,3H,J))
      PUNCH 50 , (PHI(KNT,J),J=1,IZM)
      IF (KLNT.EQ.0) GO TO 120
      DO 85 K=1,KLNT
      DO 80 J=1,IZM
```

```
 80    READ (NINP,50)  (ABXS(I,J,K), I=1,NCON)
 85    CONTINUE
       DO 95 K=1,KLNT
       DO 90 J=1,IZM
 90    READ (NINP,50)  (FIXS(I,J,K), I=1,NCON)
 95    CONTINUE
       GO TO 120
100    IF(KLIT.EQ.0) GO TO 120
105    DO 110 K=1,INTMAX
       DO 110 J=1,IZM
110    READ (NDUMP)  (ABXS(I,J,K),I=1,NCON)
       DO 115 K=1,INTMAX
       DO 115 J=1,IZM
115    READ (NDUMP)  (FIXS(I,J,K),I=1,NCON)
120    DO 130 J=1,IZM
       DO 125 I=1,NCON
       ABXS(I,J,KNT) = AXS(I,J)
125    FIXS(I,J,KNT) = FXS(I,J)
130    CONTINUE
       IF (IDMTPS.EQ.1) GO TO 155
       PUNCH 135, KNT
135    FORMAT(2X,10H ABXS(I,J,  I2,2H) )
       DO 140 J=1,IZM
140    PUNCH 50, (ABXS(I,J,KNT),I=1,NCON)
       PUNCH 145, KNT
145    FORMAT(2X,10H FIXS(I,J,  I2,2H) )
       DO 150 J=1,IZM
150    PUNCH 50, (FIXS(I,J,KNT),I=1,NCON)
       GO TO 180
155    CONTINUE
C
C      WRITE INFORMATION ON TAPE (NDUMP) IF DESIRED
C
       REWIND NDUMP
       DO 160 I=1,IGM
       READ (ISCRAT) (PSI(J),J=1,IMJM)
160    WRITE(NDUMP) (PSI(J),J=1,IMJM)
       WRITE (NDUMP)  (HNO(I),I=1,MU1)
       DO 165 I=1,INTMAX
165    WRITE(NDUMP)  (PHI(I,J),J=1,IZM)
       DO 170 K=1,INTMAX
       DO 170 J=1,IZM
170    WRITE(NDUMP)  (ABXS(I,J,K),I=1,NCON)
       DO 175 K=1,INTMAX
       DO 175 J=1,IZM
175    WRITE(NDUMP)  (FIXS(I,J,K),I=1,NCON)
       REWIND NDUMP
180    CONTINUE
C
C      COMPLETE READING OF INPUT DATA
C
       IF (KLAPS) 200,200,185
185    DO 195 I=1,KLAPS
       READ(NINP,190) KZNS(I)
190    FORMAT (I6)
       KK = KZNS(I)
195    READ(NINP,20)  (IZCN(I,J),J=1,KK)
200    CONTINUE
```

```
C
C     PRINT THE INPUT DATA
C
      PRINT 210, DAY
  210 FORMAT(////10X,20H LENGTH OF BURNUP INTERVAL,F6.1,6H  DAYS)
      PRINT 215
  215 FORMAT (1H1,//10X,33H CLEAN FUEL ATOM DENSITIES,HNO(I)   ///)
      DO 220 I=1,M01
  220 PRINT 225,  I, I0(I),  I1(I),  HNO(I)
  225 FORMAT(5X,2HI=,I3,5H  I0=,I2,5H  I1=,I2,16H  CLEAN DENSITY=F10.7)
      PRINT 230,  KNT
  230 FORMAT (1H1,/10X,35H REFUELING DATA FOR BURNUP INTERVAL  I3///)
      PRINT 235
  235 FORMAT (15X,38H REGION   REFUELING    NO.OF INTERVALS /,
     1      24X,  31H FRACTIONS   BETWEEN REFUELINGS  /)
      DO 240 I=1,NREG
      K = NZN(I)
  240 PRINT 245,  K,  X0(K),  NFRE(K)
  245 FORMAT(18X,I2,4X,F9.5,12X,I2)
      PRINT 250
  250 FORMAT (///15X,65H ELEMENTS (BURNABLE ISOTOPES) TO BE REFUELED IN
     1THE ABOVE REGIONS  /)
      DO 260 N=1,NCON
      IF (TRG(N).EQ.0) GO TO 260
      LN = JATN(N)
      PRINT 255, LN,HOLN(LN)
  255 FORMAT (20X,9H ELEMENT ,I2,3X,A9)
  260 CONTINUE
      PRINT 265
  265 FORMAT (1H1,/10X,89H ZONE, GROUP AVERAGED ABSORPTION X-SECTIONS FO
     1R BURNABLE ISOTOPES, ABXS(I,J,K) K=KLNT,KNT  ///)
      N = KLNT
      IF (KLNT.EQ.0) N=1
      NN = KNT
      DO 285 K=N,NN
      PRINT 270, K
  270 FORMAT(/4X,19H BURNUP INTERVAL K=  I3)
      DO 275 J=1,IZM
  275 PRINT 280, J, (ABXS(I,J,K),I=1,NCON)
  280 FORMAT(6X, 8H REGION ,I2/,(10F12.4))
  285 CONTINUE
      PRINT 290
  290 FORMAT (1H1,//10X,83H ZONE, GROUP AVERAGED FISSION X-SECT FOR BURN
     1ABLE ISOTOPES, FIXS(I,J,K), K=KLNT,KNT   ///)
      N = KLNT
      IF (KLNT.EQ.0) N=1
      NN = KNT
      DO 300 K=N,NN
      PRINT 270, K
      DO 295 J=1,IZM
  295 PRINT 280, J, (FIXS(I,J,K),I=1,NCON)
  300 CONTINUE
      PRINT 305
  305 FORMAT (1H1,/10X,59H AVG FLUX USED IN PREVIOUS EIGHT BURNUP INTERV
     1ALS, PHI(I,J)   ///)
      NN = KNT - 7
  310 IF (NN) 315,315,320
  315 NN = NN+1
```

```
      GO TO 310
  320 PRINT 325, (J,J=NN,KNT)
  325 FORMAT(10X,8(6H   PHI(,I2,6H,J)    )/)
      DO 330 J=1,IZM
  330 PRINT 335, J, (PHI(I,J),I=NN,KNT)
  335 FORMAT (2X,2HJ=,I2,4X,8(E12.5,2X))
C
C     TAG THE BURNABLE ISOTOPES IN THE M01 ARRAY
C
      DO 350 I=1,M01
      IK = I0(I) - ML
      I1FLAG = I1(I)
      DO 345 K=1,NREG
      KZ = IZN(K)
      IF (KZ.LT.IK) GO TO 345
      IF (KZ.GT.IK) GO TO 350
      DO 340 N=1,NCON
      LN = MATN(N)
      IF (LN.NE.I1FLAG) GO TO 340
      NBIFLG(KZ,N) = 1
  340 CONTINUE
  345 CONTINUE
  350 CONTINUE
      PRINT 355
  355 FORMAT(1H1,//10X,49H I VALUES IN M01 ARRAY THAT ARE BURNABLE ISOTO
     1PES  //)
      DO 370 K=1,NREG
      KZ = IZN(K)
      DO 360 N=1,NCON
  360 PRINT 365, NBIFLG(KZ,N),KZ,N,MATN(N)
  365 FORMAT (5X,2HI=,I3,3X,9H REGION = I2,3X,13H BURN ISO NO.  I2,3X,
     1       12H ELEMENT NO. I2)
  370 CONTINUE
      RETURN
      END
```

APPENDIX C

SAMPLE PROBLEM

In this section, the printed PHENIX output is shown for a Search → Burnup → $k_{eff}$ → Refuel calculation (2 groups, 4 regions).

```
* * * *   P H E N I X   * * * *


CARDS 1 AND 2  (ID AND TMAX)

     PHENIX EXAMPLE / 2 GROUP / ARGONNE CODE CNTR SAMPLE REACTOR
      SEARCH-BURN-KEFF-REFUEL
       TMAX =  -[illegible].0 MIN.


CARD 3 DATA    12I6 FORMAT

IGE     GEOMETRY (0/1/2 = X-Y/R-Z/R-THETA)                                        1
IZM     NUMBER OF MATERIAL ZONES(REGIONS)                                         4
IBL     LEFT BOUNDARY CONDITION (0/1=VACUUM/REFLECTIVE)                           1
IBR     RIGHT BOUNDARY CONDITION (SAME AS IBL)                                    0
IBT     TOP BOUNDARY CONDITION (SAME AS IBL)                                      0
IBB     BOTTOM BOUNDARY COND. (SAME AS IBL)                                       0
IEVT    EIGENVALUE TYPE (1/2/3=KEFF/CONC/DELTA)                                   2
IPVT    PARAMETRIC EIGENVALUE TYPE (1/2=NONE/KEFF)                                2
IM      NUMBER OF RADIAL MESH INTERVALS                                          17
JM      NUMBER OF AXIAL MESH INTERVALS                                           18
IZ      NO. OF RADIAL ZONES (DELTA OPTION ONLY)                                   0
JZ      NO. OF AXIAL  ZONES (DELTA OPTION ONLY)                                   0

CARD 4 DATA    12I6 FORMAT

IGM     NUMBER OF GROUPS                                                          2
ML      NUMBER OF INPUT MATERIALS                                                10
ICST    CROSS SECTION TYPE (1/2=TYPE1/TYPE2)                                      2
IHT     POSITION OF SIGMA TOTAL IN X-SECT TABLE                                   6
IHS     POSITION OF SIGMA SELF-SCATTER IN X-SECT TABLE                            7
ITL     CROSS SECTION TABLE LENGTH                                                8
IXSEC   READ X-SECTS FROM TAPE (0/1=NO/YES)                                       0
M01     TOTAL NO. OF MIXTURE SPECIFICATIONS                                      36
OITM    MAX NO. OF OUTER ITERATIONS ALLOWED                                     100
IITM    MAX NO. OF INNER ITERATIONS ALLOWED PER OUTER ITER.                       5
MSHSWP  LINE INVERSION DIRECTION (1/2/3/4=ALT DIR/RAD/AX/CODE DECIDES             4
ISTART  FLUX GUESS (0/1/2/3/4=NONE/CARDS/CARDS/TAPE/SINUSOID)                     4

CARD 5 DATA     8I6 FORMAT

IREF    BURNUP/REFUEL CONTROL (0/1/2=NO BURNUP/BURNUP ONLY/BURNUP AND REFUEL)     2
NBSTP   NUMBER OF BURNUP TIME STEPS IN A BURNUP INTERVAL                          1
IFS     PERFORM FINAL SEARCH (0/1 = NO/YES)                                       0
NPOIS   MATERIAL NO. OF CONTROL POISON                                           10
MWDT    CALCULATE BURNUP IN MWD/T (0/1=NO/YES)                                    1
IPFLX   PUNCH FLUX DUMP (0/1/2=NO/FLUX BEFORE BURNUP/FLUX AFTER BURNUP)           0
IPRIN   PRINT CONTROL(1/2/3=FULL PRINT/FULL PRINT FOR DAY=0 ONLY/PARTIAL PRINT)   2
IDMTPS  PREPARE DATA DUMP TAPE (0/1=NO/YES)                                       0

CARD 6 DATA    6E12.4 FORMAT

EPS     EIGENVALUE CONVERGENCE CRITERION                              1.0000E-04
SRCRT   NEUTRON SOURCE RATE (FOR NORMALIZATION)                       0.
POWR    REACTOR POWER (MWT) (FOR NORMALIZATION)                       3.0000E+02
ORF     OVERRELAXATION FACTOR                                         1.5000E+00
FLXTST  INNER ITERATION FLUX TEST (0/EP=EPS/EP FOR TEST)              0.
PV      DESIRED VALUE OF PARAMETRIC EIGENVALUE (SEARCH ONLY)          1.0000E+00
```

```
    CARD 7 DATA    6E12.4 FORMAT

EPSA   PARAMETRIC EIGNVALUE CONVERGENCE CRITERION(SEARCH ONLY                   1.0000E-03
EV     INITIAL EIGENVALUE GUESS (SEARCH ONLY)                                  -1.0000E-01
EVM    EIGENVALUE MODIFIER (SEARCH ONLY)                                       -1.0000E-01
EV2    EIGENVALUE GUESS FOR 2ND AND ALL OTHER SEARCHES                          0.
XLAL   LAMBDA-1 LOWER LIMIT (SEARCH ONLY)                                       5.0000E-03
XLAH   LAMBDA-1 UPPER LIMIT (SEARCH ONLY)                                       5.0000E-01

    CARD 8 DATA    E12.4 FORMAT

POD    PARAMETER OSCILLATION DAMPER (SEARCH ONLY)                               1.0000E+00


LAST=  4073
TEMPORARY STORAGE FOR CROSS SECTION REARRANGEMENT=    367
```

```
PHENIX EXAMPLE / 2 GROUP / ARGONNE CODE CNTR SAMPLE REACTOR
SEARCH-BURN-KEFF-REFUEL


 1        IRON
 2        CHROM
 3        NICK
 4        NA
 5        PUA
 6        PUB
 7        U238
 8        OXY
 9        FPB
10        B-10

MESH BOUNDARIES (RO/ZO=RADIAL POINTS/AXIAL POINTS)
        RO    18
0.          .66667E+01  .13333E+02  .20000E+02  .26667E+02  .33333E+02  .40000E+02  .46667E+02  .53333E+02  .60000E+02
 .66667E+02 .73333E+02  .80000E+02  .86000E+02  .92000E+02  .98000E+02  .10400E+03  .11000E+03
        ZO    19
0.          .40000E+01  .80000E+01  .12000E+02  .16000E+02  .20000E+02  .25000E+02  .30000E+02  .35000E+02  .40000E+02
 .45000E+02 .50000E+02  .55000E+02  .60000E+02  .64000E+02  .68000E+02  .72000E+02  .76000E+02  .80000E+02

FLUX GUESS  (RF/ZF=TOTAL RADIAL FLUX/TOTAL AXIAL FLUX)
     RF     17
 .99896E+00 .99069E+00  .97420E+00  .94964E+00  .91721E+00  .87718E+00  .82989E+00  .77571E+00  .71511E+00  .64858E+00
 .57668E+00 .50000E+00  .42331E+00  .34772E+00  .26980E+00  .19007E+00  .10906E+00
     ZF     18
 .24192E+00 .37461E+00  .50000E+00  .61566E+00  .71934E+00  .81915E+00  .90631E+00  .96593E+00  .99619E+00  .99619E+00
 .96593E+00 .90631E+00  .81915E+00  .71934E+00  .61566E+00  .50000E+00  .37461E+00  .24192E+00

ZONE NUMBERS BY MESH INTERVAL
        MO    306
        2          2          2          2          2          2          2          2          2          2
        2          2          4          4          4          4          4          2          2          2
        2          2          2          2          2          2          2          2          2          4
        4          4          4          4          2          2          2          2          2          2
        2          2          2          2          2          2          4          4          4          4
        4          2          2          2          2          2          2          2          2          2
        2          2          2          4          4          4          4          4          2          2
        2          2          2          2          2          2          2          2          2          2
        4          4          4          4          4          1          1          1          1          1
        1          1          1          1          1          1          1          4          4          4
        4          4          1          1          1          1          1          1          1          1
        1          1          1          1          4          4          4          4          4          1
        1          1          1          1          1          1          1          1          1          1
        1          4          4          4          4          4          1          1          1          1
        1          1          1          1          1          1          1          1          4          4
        4          4          4          1          1          1          1          1          1          1
        1          1          1          1          1          4          4          4          4          4
        1          1          1          1          1          1          1          1          1          1
        1          1          4          4          4          4          4          1          1          1
```

```
        1          1          1          1          1          1          1          1          1          4
        4          4          4          4          1          1          1          1          1          1
        1          1          1          1          1          1          4          4          4          4
        4          3          3          3          3          3          3          3          3          3
        3          3          3          4          4          4          4          4          3          3
        3          3          3          3          3          3          3          3          3          3
        4          4          4          4          4          3          3          3          3          3
        3          3          3          3          3          3          3          4          4          4
        4          4          3          3          3          3          3          3          3          3
        3          3          3          3          4          4          4          4          4          3
        3          3          3          3          3          3          3          3          3          3
        3          4          4          4          4          4

MATERIAL NUMBERS BY ZONE
        M2     4
        11         12         13         14

FISSION SPECTRUM
        K7     2
 .99234E+00  .76570E-02

MIXTURE SPECIFICATIONS (I0/I1/I2=MIX NUMBER/MAT. NUMBER FOR MIX/MATERIAL DENSITY)
        I0     36
        11         11         11         11         11         11         11         11         11         11
        11         12         12         12         12         12         12         12         12         12
        12         13         13         13         13         13         13         13         13         13
        13         14         14         14         14         14
        I1     36
         0          4          1          2          3          5          6          7          9          8
        10          0          4          1          2          3          5          6          7          9
         8          0          4          1          2          3          5          6          7          9
         8          0          1          2          3          4
        I2     36
0.          .12733E-01 .10033E-01 .25797E-02 .16131E-02 .21241E-02 .30220E-03 .29357E-02 0.          .10730E-01
 .50000E-03 0.          .12733E-01 .10033E-01 .25797E-02 .16131E-02 0.          0.          .53735E-02 0.
 .10730E-01 0.          .12733E-01 .10033E-01 .25797E-02 .16131E-02 0.          0.          .53735E-02 0.
 .10730E-01 0.          .81738E-02 .21016E-02 .13142E-02 .19220E-01
        I4     36
0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 .10000E+01 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.
```

```
PHENIX EXAMPLE / 2 GROUP / ARGONNE CODE CNTR SAMPLE REACTOR
SEARCH-BURN-KEFF-REFUEL


          3  3  3  3  3  3  3  3  3  3  3  3  4  4  4  4  4
          3  3  3  3  3  3  3  3  3  3  3  3  4  4  4  4  4
          3  3  3  3  3  3  3  3  3  3  3  3  4  4  4  4  4
          3  3  3  3  3  3  3  3  3  3  3  3  4  4  4  4  4
          3  3  3  3  3  3  3  3  3  3  3  3  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          1  1  1  1  1  1  1  1  1  1  1  1  4  4  4  4  4
          2  2  2  2  2  2  2  2  2  2  2  2  4  4  4  4  4
          2  2  2  2  2  2  2  2  2  2  2  2  4  4  4  4  4
          2  2  2  2  2  2  2  2  2  2  2  2  4  4  4  4  4
          2  2  2  2  2  2  2  2  2  2  2  2  4  4  4  4  4
          2  2  2  2  2  2  2  2  2  2  2  2  4  4  4  4  4
A
X
I
A
L

 RADIAL



        1313131313131313131313131414141414
        1313131313131313131313131414141414
        1313131313131313131313131414141414
        1313131313131313131313131414141414
        1313131313131313131313131414141414
        1111111111111111111111111414141414
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        1111111111111111111111111414141414
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        1111111111111111111111111414141414
        1111111111111111111111111414141414
        1212121212121212121212121414141414
        1212121212121212121212121414141414
        1212121212121212121212121414141414
        1212121212121212121212121414141414
        1212121212121212121212121414141414
A
X
I
A
L

 RADIAL


          *  *  *  *  *  *

        DIRECTION OF LIN. INVERSION = ALTERNATING DIRECTION
```

TIME = 0.000 DAYS

| | MIXTURE NUMBER | MIX COMMAND | MATERIAL ATOMIC DENSITY | NTRIG |
|---|---|---|---|---|
| 1 | 11 | 0 | 0. | 0 |
| 2 | 11 | 4 | .12733000E-01 | 0 |
| 3 | 11 | 1 | .10033000E-01 | 0 |
| 4 | 11 | 2 | .25797000E-02 | 0 |
| 5 | 11 | 3 | .16131000E-02 | 0 |
| 6 | 11 | 5 | .21241000E-02 | 1 |
| 7 | 11 | 6 | .30220000E-03 | 1 |
| 8 | 11 | 7 | .29357000E-02 | 1 |
| 9 | 11 | 9 | 0. | 0 |
| 10 | 11 | 8 | .10730000E-01 | 0 |
| 11 | 11 | 10 | .50000000E-03 | 0 |
| 12 | 12 | 0 | 0. | 0 |
| 13 | 12 | 4 | .12733000E-01 | 0 |
| 14 | 12 | 1 | .10033000E-01 | 0 |
| 15 | 12 | 2 | .25797000E-02 | 0 |
| 16 | 12 | 3 | .16131000E-02 | 0 |
| 17 | 12 | 5 | 0. | 1 |
| 18 | 12 | 6 | 0. | 1 |
| 19 | 12 | 7 | .53735000E-02 | 1 |
| 20 | 12 | 9 | 0. | 0 |
| 21 | 12 | 8 | .10730000E-01 | 0 |
| 22 | 13 | 0 | 0. | 0 |
| 23 | 13 | 4 | .12733000E-01 | 0 |
| 24 | 13 | 1 | .10033000E-01 | 0 |
| 25 | 13 | 2 | .25797000E-02 | 0 |
| 26 | 13 | 3 | .16131000E-02 | 0 |
| 27 | 13 | 5 | 0. | 1 |
| 28 | 13 | 6 | 0. | 1 |
| 29 | 13 | 7 | .53735000E-02 | 1 |
| 30 | 13 | 9 | 0. | 0 |
| 31 | 13 | 8 | .10730000E-01 | 0 |
| 32 | 14 | 0 | 0. | 0 |
| 33 | 14 | 1 | .81738000E-02 | 0 |
| 34 | 14 | 2 | .21016000E-02 | 0 |
| 35 | 14 | 3 | .13142000E-02 | 0 |
| 36 | 14 | 4 | .19220000E-01 | 0 |

CROSS-SECTION EDIT

GROUP 1 CROSS-SECTIONS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MAT | 1 | 0. | .473E-02 | 0. | .267E+01 | .261E+01 | 0. |
| MAT | 2 | 0. | .446E-02 | 0. | .235E+01 | .233E+01 | 0. |
| MAT | 3 | 0. | .217E-01 | 0. | .336E+01 | .326E+01 | 0. |
| MAT | 4 | 0. | .807E-03 | 0. | .301E+01 | .291E+01 | 0. |
| MAT | 5 | .160E+01 | .174E+01 | .473E+01 | .735E+01 | .557E+01 | 0. |
| MAT | 6 | .492E+00 | .679E+00 | .151E+01 | .756E+01 | .680E+01 | 0. |
| MAT | 7 | .653E-01 | .217E+00 | .183E+00 | .744E+01 | .710E+01 | 0. |
| MAT | 8 | 0. | .117E-02 | 0. | .305E+01 | .291E+01 | 0. |
| MAT | 9 | 0. | .300E+01 | 0. | .300E+01 | 0. | 0. |
| MAT | 10 | 0. | .143E+01 | 0. | .369E+01 | .222E+01 | 0. |
| MAT | 11 | .373E-02 | .529E-02 | .110E-01 | .151E+00 | .142E+00 | 0. |
| MAT | 12 | .351E-03 | .128E-02 | .986E-03 | .149E+00 | .144E+00 | 0. |
| MAT | 13 | .351E-03 | .128E-02 | .986E-03 | .149E+00 | .144E+00 | 0. |
| MAT | 14 | 0. | .919E-04 | 0. | .891E-01 | .865E-01 | 0. |

GROUP 2 CROSS-SECTIONS

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MAT | 1 | 0. | .310E-01 | 0. | .541E+01 | .537E+01 | .590E-01 |
| MAT | 2 | 0. | .603E-01 | 0. | .454E+01 | .448E+01 | .201E-01 |
| MAT | 3 | 0. | .220E-01 | 0. | .158E+02 | .158E+02 | .708E-01 |
| MAT | 4 | 0. | .171E-02 | 0. | .555E+01 | .555E+01 | .972E-01 |
| MAT | 5 | .282E+01 | .427E+01 | .811E+01 | .164E+02 | .121E+02 | .434E-01 |
| MAT | 6 | .904E-01 | .111E+01 | .260E+00 | .155E+02 | .144E+02 | .817E-01 |
| MAT | 7 | .100E-49 | .482E+00 | 0. | .117E+02 | .112E+02 | .119E+00 |
| MAT | 8 | 0. | 0. | 0. | .348E+01 | .348E+01 | .131E+00 |
| MAT | 9 | 0. | .499E-02 | 0. | .270E+01 | .269E+01 | 0. |
| MAT | 10 | 0. | .550E+01 | 0. | .658E+01 | .108E+01 | .351E-01 |
| MAT | 11 | .602E-02 | .138E-01 | .173E-01 | .276E+00 | .262E+00 | .388E-02 |
| MAT | 12 | .537E-52 | .311E-02 | 0. | .262E+00 | .259E+00 | .404E-02 |
| MAT | 13 | .537E-52 | .311E-02 | 0. | .262E+00 | .259E+00 | .404E-02 |
| MAT | 14 | 0. | .442E-03 | 0. | .181E+00 | .181E+00 | .249E-02 |

| TIME (MINUTES) | OUTER ITERATIONS | IN. IT. PER LOOP | EIGENVALUE SLOPE | EIGENVALUE | LAMBDA |
|---|---|---|---|---|---|
| .475 | 0 | 0 | 0. | -.10000000E+00 | 0. |
| .484 | 1 | 10 | 0. | -.10000000E+00 | .98057572E+00 |
| .490 | 2 | 10 | 0. | -.10000000E+00 | .10005892E+01 |
| .495 | 3 | 10 | 0. | -.10000000E+00 | .10069641E+01 |
| .501 | 4 | 10 | 0. | -.10000000E+00 | .10105221E+01 |
| .507 | 5 | 10 | 0. | -.10000000E+00 | .10125627E+01 |
| .513 | 6 | 10 | 0. | -.10000000E+00 | .10137181E+01 |
| .520 | 7 | 10 | 0. | -.20000000E+00 | .10143945E+01 |
| .528 | 8 | 10 | 0. | -.20000000E+00 | .10230155E+01 |
| .535 | 9 | 10 | -.10153142E+02 | .46149150E-01 | .10242436E+01 |
| .543 | 10 | 10 | -.10153142E+02 | .46149150E-01 | .10019617E+01 |
| .550 | 11 | 10 | -.10153142E+02 | .66932114E-01 | .10020469E+01 |
| .559 | 12 | 10 | -.10153142E+02 | .69774132E-01 | .10002799E+01 |
| .567 | 13 | 10 | -.10153142E+02 | .70511256E-01 | .10000726E+01 |

THESE ARE THE DESIRED ATOM DENSITIES OBTAINED FROM THE CONC SEARCH TO GIVE A PARAMETRIC VALUE OF PV= 1.000000

REGION= 1 MATERIAL=10 MATL ATOM DENS= .0005353

FINAL NEUTRON BALANCE TABLE

| GROUP | FISSION SOURCE | IN-SCATTER | OUT-SCATTER | ABSORPTION | L. L. | R. L. | T. L. | B. L. | TOTAL LEAKAGE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.535E+19 | 0. | 9.328E+18 | 9.398E+18 | 0. | 1.560E+18 | 2.531E+18 | 2.531E+18 | 6.621E+18 |
| 2 | 1.956E+17 | 9.328E+18 | 3.677E+15 | 6.991E+18 | 0. | 6.056E+17 | 9.617E+17 | 9.617E+17 | 2.529E+18 |
| 3 | 2.554E+19 | 9.328E+18 | 9.331E+18 | 1.639E+19 | 0. | 2.166E+18 | 3.492E+18 | 3.493E+18 | 9.150E+18 |

| | RADII | AVG RADII | AXII | AVG AXII |
|---|---|---|---|---|
| 1 | 0.0000 | 3.3333 | 0.0000 | 2.0000 |
| 2 | 6.6667 | 10.0000 | 4.0000 | 6.0000 |
| 3 | 13.3333 | 16.6667 | 8.0000 | 10.0000 |
| 4 | 20.0000 | 23.3333 | 12.0000 | 14.0000 |
| 5 | 26.6667 | 30.0000 | 16.0000 | 18.0000 |
| 6 | 33.3333 | 36.6666 | 20.0000 | 22.5000 |
| 7 | 40.0000 | 43.3333 | 25.0000 | 27.5000 |
| 8 | 46.6667 | 50.0000 | 30.0000 | 32.5000 |
| 9 | 53.3333 | 56.6666 | 35.0000 | 37.5000 |
| 10 | 60.0000 | 63.3334 | 40.0000 | 42.5000 |
| 11 | 66.6667 | 70.0000 | 45.0000 | 47.5000 |
| 12 | 73.3333 | 76.6666 | 50.0000 | 52.5000 |
| 13 | 80.0000 | 83.0000 | 55.0000 | 57.5000 |
| 14 | 86.0000 | 89.0000 | 60.0000 | 62.0000 |
| 15 | 92.0000 | 95.0000 | 64.0000 | 66.0000 |
| 16 | 98.0000 | 101.0000 | 68.0000 | 70.0000 |
| 17 | 104.0000 | 107.0000 | 72.0000 | 74.0000 |
| 18 | 110.0000 | 6.6667 | 76.0000 | 78.0000 |
| 19 | | | 80.0000 | 4.0000 |

FLUX FOR GROUP 1

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .5422699E+15 | .5343457E+15 | .5186429E+15 | .4954960E+15 | .4654120E+15 | .2000000E+01 |
| 2 | .8859576E+15 | .8734018E+15 | .8473403E+15 | .8095183E+15 | .7603608E+15 | .6000000E+01 |
| 3 | .1266603E+16 | .1248069E+16 | .1211374E+16 | .1157295E+16 | .1087006E+16 | .1000000E+02 |
| 4 | .1700074E+16 | .1675188E+16 | .1625927E+16 | .1553334E+16 | .1458979E+16 | .1400000E+02 |
| 5 | .2204445E+16 | .2172161E+16 | .2108277E+16 | .2014145E+16 | .1891792E+16 | .1800000E+02 |
| 6 | .2879612E+16 | .2837424E+16 | .2753966E+16 | .2631006E+16 | .2471185E+16 | .2250000E+02 |
| 7 | .3460358E+16 | .3409650E+16 | .3309341E+16 | .3161561E+16 | .2969473E+16 | .2750000E+02 |
| 8 | .3856439E+16 | .3799915E+16 | .3688103E+16 | .3523379E+16 | .3309260E+16 | .3250000E+02 |
| 9 | .4057471E+16 | .3997992E+16 | .3880333E+16 | .3707000E+16 | .3481587E+16 | .3750000E+02 |
| 10 | .4057500E+16 | .3998014E+16 | .3880344E+16 | .3706999E+16 | .3481677E+16 | .4250000E+02 |
| 11 | .3856524E+16 | .3799981E+16 | .3688135E+16 | .3523378E+16 | .3309231E+16 | .4750000E+02 |
| 12 | .3460495E+16 | .3409757E+16 | .3309394E+16 | .3161561E+16 | .2969431E+16 | .5250000E+02 |
| 13 | .2879783E+16 | .2837559E+16 | .2754035E+16 | .2631011E+16 | .2471141E+16 | .5750000E+02 |
| 14 | .2204635E+16 | .2172303E+16 | .2108348E+16 | .2014151E+16 | .1891749E+16 | .6200000E+02 |
| 15 | .1700266E+16 | .1675326E+16 | .1625995E+16 | .1553341E+16 | .1458941E+16 | .6600000E+02 |
| 16 | .1266786E+16 | .1248202E+16 | .1211443E+16 | .1157309E+16 | .1086980E+16 | .7000000E+02 |
| 17 | .8861134E+15 | .8731082E+15 | .8473917E+15 | .8095241E+15 | .7603335E+15 | .7400000E+02 |
| 18 | .5423971E+15 | .5344386E+15 | .5186954E+15 | .4955137E+15 | .4654133E+15 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .4290574E+15 | .3872552E+15 | .3409968E+15 | .2914909E+15 | .2403153E+15 | .2000000E+01 |
| 2 | .7009509E+15 | .6328201E+15 | .5569584E+15 | .4758677E+15 | .3917398E+15 | .6000000E+01 |
| 3 | .1002046E+16 | .9042931E+15 | .7959627E+15 | .6796402E+15 | .5584299E+15 | .1000000E+02 |
| 4 | .1344912E+16 | .1213620E+16 | .1068001E+16 | .9113475E+15 | .7474164E+15 | .1400000E+02 |
| 5 | .1743859E+16 | .1573536E+16 | .1384498E+16 | .1180821E+16 | .9669209E+15 | .1800000E+02 |
| 6 | .2277936E+16 | .2055391E+16 | .1808271E+16 | .1541714E+16 | .1261032E+16 | .2250000E+02 |
| 7 | .2737176E+16 | .2469586E+16 | .2172277E+16 | .1851216E+16 | .1512359E+16 | .2750000E+02 |
| 8 | .3050292E+16 | .2751914E+16 | .2420256E+16 | .2061821E+16 | .1682993E+16 | .3250000E+02 |
| 9 | .3209169E+16 | .2895142E+16 | .2546015E+16 | .2168555E+16 | .1769368E+16 | .3750000E+02 |
| 10 | .3209153E+16 | .2895125E+16 | .2545999E+16 | .2168542E+16 | .1769358E+16 | .4250000E+02 |
| 11 | .3050248E+16 | .2751864E+16 | .2420209E+16 | .2061782E+16 | .1682964E+16 | .4750000E+02 |
| 12 | .2737109E+16 | .2469510E+16 | .2172205E+16 | .1851156E+16 | .1512314E+16 | .5250000E+02 |
| 13 | .2277861E+16 | .2055304E+16 | .1808188E+16 | .1541646E+16 | .1260981E+16 | .5750000E+02 |
| 14 | .1743786E+16 | .1573452E+16 | .1384419E+16 | .1180756E+16 | .9668727E+15 | .6200000E+02 |
| 15 | .1344846E+16 | .1213544E+16 | .1067929E+16 | .9112880E+15 | .7473726E+15 | .6600000E+02 |
| 16 | .1001994E+16 | .9042292E+15 | .7959300E+15 | .6795873E+15 | .5583901E+15 | .7000000E+02 |
| 17 | .7009037E+15 | .6325650E+15 | .5569054E+15 | .4758236E+15 | .3917076E+15 | .7400000E+02 |
| 18 | .4290313E+15 | .3872202E+15 | .3409604E+15 | .2914583E+15 | .2402897E+15 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .1898504E+15 | .1440463E+15 | .1235482E+15 | .9950273E+14 | .7500337E+14 | .2000000E+01 |
| 2 | .3079044E+15 | .2295314E+15 | .1792238E+15 | .1414399E+15 | .1056494E+15 | .6000000E+01 |
| 3 | .4263536E+15 | .3191623E+15 | .2392149E+15 | .1851507E+15 | .1366983E+15 | .1000000E+02 |
| 4 | .5807214E+15 | .4174467E+15 | .3028066E+15 | .2299418E+15 | .1676467E+15 | .1400000E+02 |
| 5 | .7475851E+15 | .5285364E+15 | .3689741E+15 | .2745923E+15 | .1976484E+15 | .1800000E+02 |
| 6 | .9712480E+15 | .6758482E+15 | .4431508E+15 | .3223943E+15 | .2290015E+15 | .2250000E+02 |
| 7 | .1160883E+16 | .7994417E+15 | .5120757E+15 | .3670673E+15 | .2580254E+15 | .2750000E+02 |
| 8 | .1289174E+16 | .8831312E+15 | .5607680E+15 | .3990286E+15 | .2787960E+15 | .3250000E+02 |
| 9 | .1354024E+16 | .9255255E+15 | .5858599E+15 | .4156344E+15 | .2896103E+15 | .3750000E+02 |
| 10 | .1354018E+16 | .9255217E+15 | .5858579E+15 | .4156334E+15 | .2896100E+15 | .4250000E+02 |
| 11 | .1289155E+16 | .8831202E+15 | .5607623E+15 | .3990258E+15 | .2787953E+15 | .4750000E+02 |
| 12 | .1160854E+16 | .7994257E+15 | .5120672E+15 | .3670629E+15 | .2580241E+15 | .5250000E+02 |
| 13 | .9712147E+15 | .6758290E+15 | .4431400E+15 | .3223884E+15 | .2289994E+15 | .5750000E+02 |
| 14 | .7475537E+15 | .5285178E+15 | .3689628E+15 | .2745861E+15 | .1976465E+15 | .6200000E+02 |
| 15 | .5806923E+15 | .4174283E+15 | .3027948E+15 | .2299352E+15 | .1676446E+15 | .6600000E+02 |
| 16 | .4263260E+15 | .3191435E+15 | .2392026E+15 | .1851436E+15 | .1366959E+15 | .7000000E+02 |
| 17 | .3078834E+15 | .2295174E+15 | .1792148E+15 | .1414353E+15 | .1056489E+15 | .7400000E+02 |
| 18 | .1898322E+15 | .1440324E+15 | .1235369E+15 | .9949530E+14 | .7500008E+14 | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | .5258362E+14 | .3264966E+14 | .2000000E+01 |
| 2 | .7371027E+14 | .4565379E+14 | .6000000E+01 |
| 3 | .9471599E+14 | .5844897E+14 | .1000000E+02 |
| 4 | .1152589E+15 | .7082611E+14 | .1400000E+02 |
| 5 | .1348148E+15 | .8248679E+14 | .1800000E+02 |
| 6 | .1549439E+15 | .9438457E+14 | .2250000E+02 |
| 7 | .1733808E+15 | .1052016E+15 | .2750000E+02 |
| 8 | .1865216E+15 | .1128820E+15 | .3250000E+02 |
| 9 | .1933562E+15 | .1168702E+15 | .3750000E+02 |
| 10 | .1933562E+15 | .1168704E+15 | .4250000E+02 |
| 11 | .1865216E+15 | .1128827E+15 | .4750000E+02 |
| 12 | .1733806E+15 | .1052030E+15 | .5250000E+02 |
| 13 | .1549434E+15 | .9438613E+14 | .5750000E+02 |
| 14 | .1348148E+15 | .8248888E+14 | .6200000E+02 |
| 15 | .1152590E+15 | .7082826E+14 | .6600000E+02 |
| 16 | .9471638E+14 | .5845111E+14 | .7000000E+02 |
| 17 | .7371175E+14 | .4565677E+14 | .7400000E+02 |
| 18 | .5258287E+14 | .3265239E+14 | .7800000E+02 |

FLUX FOR GROUP 2

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .2468438E+15 | .2432449E+15 | .2361227E+15 | .2256411E+15 | .2120498E+15 | .2000000E+01 |
| 2 | .4412055E+15 | .4347687E+15 | .4220350E+15 | .4032963E+15 | .3789972E+15 | .5000000E+01 |
| 3 | .6123979E+15 | .6034580E+15 | .5857768E+15 | .5597577E+15 | .5260148E+15 | .1000000E+02 |
| 4 | .7495488E+15 | .7385985E+15 | .7169467E+15 | .6850850E+15 | .6437594E+15 | .1400000E+02 |
| 5 | .8374072E+15 | .8251638E+15 | .8009594E+15 | .7653414E+15 | .7191368E+15 | .1800000E+02 |
| 6 | .8574062E+15 | .8448626E+15 | .8203631E+15 | .7835663E+15 | .7362114E+15 | .2250000E+02 |
| 7 | .9090511E+15 | .8957461E+15 | .8694371E+15 | .8307133E+15 | .7804567E+15 | .2750000E+02 |
| 8 | .9577585E+15 | .9437364E+15 | .9160065E+15 | .8751873E+15 | .8222025E+15 | .3250000E+02 |
| 9 | .9860101E+15 | .9715722E+15 | .9430184E+15 | .9009842E+15 | .8464180E+15 | .3750000E+02 |
| 10 | .9860130E+15 | .9715748E+15 | .9430199E+15 | .9009842E+15 | .8464167E+15 | .4250000E+02 |
| 11 | .9577661E+15 | .9437426E+15 | .9160093E+15 | .8751858E+15 | .8221971E+15 | .4750000E+02 |
| 12 | .9090632E+15 | .8957567E+15 | .8694422E+15 | .8307113E+15 | .7804483E+15 | .5250000E+02 |
| 13 | .8574237E+15 | .8448789E+15 | .8200719E+15 | .7835650E+15 | .7362011E+15 | .5750000E+02 |
| 14 | .8374329E+15 | .8251854E+15 | .8009693E+15 | .7653378E+15 | .7191220E+15 | .6200000E+02 |
| 15 | .7495834E+15 | .7386235E+15 | .7169562E+15 | .6850793E+15 | .6437421E+15 | .6600000E+02 |
| 16 | .6124373E+15 | .6034835E+15 | .5857856E+15 | .5597522E+15 | .5259988E+15 | .7000000E+02 |
| 17 | .4412424E+15 | .4347896E+15 | .4220398E+15 | .4032889E+15 | .3789816E+15 | .7400000E+02 |
| 18 | .2468739E+15 | .2432643E+15 | .2361304E+15 | .2256395E+15 | .2120418E+15 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .1956833E+15 | .1769655E+15 | .1564184E+15 | .1346758E+15 | .1125029E+15 | .2000000E+01 |
| 2 | .3497340E+15 | .3162615E+15 | .2795093E+15 | .2406050E+15 | .2008986E+15 | .5000000E+01 |
| 3 | .4853712E+15 | .4388681E+15 | .3877881E+15 | .3336898E+15 | .2784433E+15 | .1000000E+02 |
| 4 | .5939697E+15 | .5369797E+15 | .4743473E+15 | .4079760E+15 | .3401872E+15 | .1400000E+02 |
| 5 | .6634520E+15 | .5996841E+15 | .5295580E+15 | .4551988E+15 | .3792708E+15 | .1800000E+02 |
| 6 | .6791172E+15 | .6136945E+15 | .5416876E+15 | .4652694E+15 | .3872685E+15 | .2250000E+02 |
| 7 | .7198401E+15 | .6503395E+15 | .5737827E+15 | .4924721E+15 | .4094986E+15 | .2750000E+02 |
| 8 | .7582783E+15 | .6849564E+15 | .6041475E+15 | .5182742E+15 | .4306390E+15 | .3250000E+02 |
| 9 | .7805776E+15 | .7050434E+15 | .6217749E+15 | .5332632E+15 | .4429237E+15 | .3750000E+02 |
| 10 | .7805754E+15 | .7050408E+15 | .6217723E+15 | .5332608E+15 | .4429217E+15 | .4250000E+02 |
| 11 | .7582704E+15 | .6849475E+15 | .6041389E+15 | .5182666E+15 | .4306327E+15 | .4750000E+02 |
| 12 | .7198274E+15 | .6503251E+15 | .5737688E+15 | .4924601E+15 | .4094888E+15 | .5250000E+02 |
| 13 | .6791010E+15 | .6136760E+15 | .5416697E+15 | .4652540E+15 | .3872561E+15 | .5750000E+02 |
| 14 | .6634303E+15 | .5996601E+15 | .5295354E+15 | .4551799E+15 | .3792561E+15 | .6200000E+02 |
| 15 | .5939457E+15 | .5369538E+15 | .4743235E+15 | .4079566E+15 | .3401725E+15 | .6600000E+02 |
| 16 | .4853492E+15 | .4388444E+15 | .3877664E+15 | .3336722E+15 | .2784301E+15 | .7000000E+02 |
| 17 | .3497142E+15 | .3162411E+15 | .2794912E+15 | .2405910E+15 | .2008387E+15 | .7400000E+02 |
| 18 | .1956718E+15 | .1764529E+15 | .1564067E+15 | .1346663E+15 | .1124961E+15 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .9083261E+14 | .7098349E+14 | .5917706E+14 | .4764549E+14 | .3589638E+14 | .2000000E+01 |
| 2 | .1619401E+15 | .1253353E+15 | .9816644E+14 | .7833034E+14 | .5893587E+14 | .6000000E+01 |
| 3 | .2241841E+15 | .1728894E+15 | .1338651E+15 | .1066505E+15 | .8029838E+14 | .1000000E+02 |
| 4 | .2737334E+15 | .2113782E+15 | .1646142E+15 | .1317973E+15 | .9954639E+14 | .1400000E+02 |
| 5 | .3051750E+15 | .237[illegible]826E+15 | .1891937E+15 | .1532033E+15 | .1163401E+15 | .1800000E+02 |
| 6 | .3116836E+15 | .2449867E+15 | .2096299E+15 | .1729339E+15 | .1322641E+15 | .2250000E+02 |
| 7 | .3295017E+15 | .2605457E+15 | .2274791E+15 | .1895766E+15 | .1457602E+15 | .2750000E+02 |
| 8 | .3463060E+15 | .2741493E+15 | .2402537E+15 | .2009787E+15 | .1549281E+15 | .3250000E+02 |
| 9 | .3560260E+15 | .2817898E+15 | .2469614E+15 | .2068118E+15 | .1595788E+15 | .3750000E+02 |
| 10 | .3560245E+15 | .2817887E+15 | .2469607E+15 | .2068114E+15 | .1595787E+15 | .4250000E+02 |
| 11 | .3463015E+15 | .2741463E+15 | .2402517E+15 | .2009777E+15 | .1549278E+15 | .4750000E+02 |
| 12 | .3294948E+15 | .2605411E+15 | .2274761E+15 | .1895750E+15 | .1457597E+15 | .5250000E+02 |
| 13 | .3116749E+15 | .2449809E+15 | .2096262E+15 | .1729319E+15 | .1322634E+15 | .5750000E+02 |
| 14 | .3051646E+15 | .2370759E+15 | .1891896E+15 | .1532011E+15 | .1163393E+15 | .6200000E+02 |
| 15 | .2737230E+15 | .2113715E+15 | .1646101E+15 | .1317951E+15 | .9954563E+14 | .6600000E+02 |
| 16 | .2241749E+15 | .1728831E+15 | .1338612E+15 | .1066485E+15 | .8029782E+14 | .7000000E+02 |
| 17 | .1619400E+15 | .1253313E+15 | .9816413E+14 | .7832937E+14 | .5893596E+14 | .7400000E+02 |
| 18 | .9082812E+14 | .7098028E+14 | .5917462E+14 | .4764393E+14 | .3589576E+14 | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | .2430454E+14 | .1292396E+14 | .2000000E+01 |
| 2 | .3990008E+14 | .2120998E+14 | .6000000E+01 |
| 3 | .5440027E+14 | .2892276E+14 | .1000000E+02 |
| 4 | .6755370E+14 | .3594004E+14 | .1400000E+02 |
| 5 | .7914678E+14 | .4215144E+14 | .1800000E+02 |
| 6 | .9025577E+14 | .4812987E+14 | .2250000E+02 |
| 7 | .9972524E+14 | .5324360E+14 | .2750000E+02 |
| 8 | .1061564E+15 | .5672042E+14 | .3250000E+02 |
| 9 | .1094127E+15 | .5848078E+14 | .3750000E+02 |
| 10 | .1094127E+15 | .5848084E+14 | .4250000E+02 |
| 11 | .1061563E+15 | .567[illegible]059E+14 | .4750000E+02 |
| 12 | .9972503E+14 | .5324381E+14 | .5250000E+02 |
| 13 | .9025550E+14 | .4813009E+14 | .5750000E+02 |
| 14 | .7914656E+14 | .4215165E+14 | .6200000E+02 |
| 15 | .6755362E+14 | .3594036E+14 | .6600000E+02 |
| 16 | .5440035E+14 | .2892324E+14 | .7000000E+02 |
| 17 | .3990057E+14 | .2121071E+14 | .7400000E+02 |
| 18 | .2430451E+14 | .1292459E+14 | .7800000E+02 |

TOTAL FLUX

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .7891136E+15 | .7775905E+15 | .7547655E+15 | .7211372E+15 | .6774618E+15 | .2000000E+01 |
| 2 | .1327163E+16 | .1307770E+16 | .1269375E+16 | .1212815E+16 | .1139358E+16 | .6000000E+01 |
| 3 | .1879001E+16 | .1851527E+16 | .1797151E+16 | .1717052E+16 | .1613021E+16 | .1000000E+02 |
| 4 | .2449623E+16 | .2413787E+16 | .2342873E+16 | .2238419E+16 | .2102738E+16 | .1400000E+02 |
| 5 | .3041852E+16 | .2997325E+16 | .2909236E+16 | .2779486E+16 | .2610929E+16 | .1800000E+02 |
| 6 | .3737018E+16 | .3682287E+16 | .3574029E+16 | .3414572E+16 | .3207397E+16 | .2250000E+02 |
| 7 | .4369409E+16 | .4305396E+16 | .4178778E+16 | .3992274E+16 | .3749930E+16 | .2750000E+02 |
| 8 | .4814197E+16 | .4743652E+16 | .4604110E+16 | .4398567E+16 | .4131462E+16 | .3250000E+02 |
| 9 | .5043481E+16 | .4969564E+16 | .4823352E+16 | .4607984E+16 | .4328105E+16 | .3750000E+02 |
| 10 | .5043513E+16 | .4969589E+16 | .4823364E+16 | .4607984E+16 | .4328094E+16 | .4250000E+02 |
| 11 | .4814290E+16 | .4743724E+16 | .4604145E+16 | .4398563E+16 | .4131429E+16 | .4750000E+02 |
| 12 | .4369558E+16 | .4305514E+16 | .4178837E+16 | .3992273E+16 | .3749880E+16 | .5250000E+02 |
| 13 | .3737206E+16 | .3682438E+16 | .3574107E+16 | .3414576E+16 | .3207342E+16 | .5750000E+02 |
| 14 | .3042068E+16 | .2997489E+16 | .2909317E+16 | .2779488E+16 | .2610871E+16 | .6200000E+02 |
| 15 | .2449849E+16 | .2413950E+16 | .2342951E+16 | .2238420E+16 | .2102683E+16 | .6600000E+02 |
| 16 | .1879223E+16 | .1851685E+16 | .1797229E+16 | .1717061E+16 | .1612978E+16 | .7000000E+02 |
| 17 | .1327356E+16 | .1307898E+16 | .1269432E+16 | .1212813E+16 | .1139315E+16 | .7400000E+02 |
| 18 | .7892709E+15 | .7777030E+15 | .7548258E+15 | .7211532E+15 | .6774451E+15 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .6247407E+15 | .5642207E+15 | .4974152E+15 | .4261667E+15 | .3528183E+15 | .2000000E+01 |
| 2 | .1050685E+16 | .9488816E+15 | .8364677E+15 | .7164727E+15 | .5926384E+15 | .6000000E+01 |
| 3 | .1487418E+16 | .1343161E+16 | .1183751E+16 | .1013330E+16 | .8368732E+15 | .1000000E+02 |
| 4 | .1938881E+16 | .1750599E+16 | .1542348E+16 | .1319324E+16 | .1087604E+16 | .1400000E+02 |
| 5 | .2407311E+16 | .2173220E+16 | .1914056E+16 | .1636020E+16 | .1346192E+16 | .1800000E+02 |
| 6 | .2957053E+16 | .2669085E+16 | .2349958E+16 | .2006984E+16 | .1648301E+16 | .2250000E+02 |
| 7 | .3457016E+16 | .3119926E+16 | .2746060E+16 | .2343688E+16 | .1921857E+16 | .2750000E+02 |
| 8 | .3808571E+16 | .3436871E+16 | .3024404E+16 | .2580096E+16 | .2113632E+16 | .3250000E+02 |
| 9 | .3989746E+16 | .3600185E+16 | .3167790E+16 | .2701819E+16 | .2212292E+16 | .3750000E+02 |
| 10 | .3989729E+16 | .3600165E+16 | .3167771E+16 | .2701803E+16 | .2212280E+16 | .4250000E+02 |
| 11 | .3808518E+16 | .3436811E+16 | .3024348E+16 | .2580049E+16 | .2113596E+16 | .4750000E+02 |
| 12 | .3456936E+16 | .3119835E+16 | .2745974E+16 | .2343617E+16 | .1921803E+16 | .5250000E+02 |
| 13 | .2956962E+16 | .2668980E+16 | .2349858E+16 | .2006900E+16 | .1648237E+16 | .5750000E+02 |
| 14 | .2407216E+16 | .2173112E+16 | .1913954E+16 | .1635936E+16 | .1346129E+16 | .6200000E+02 |
| 15 | .1938792E+16 | .1750497E+16 | .1542252E+16 | .1319245E+16 | .1087545E+16 | .6600000E+02 |
| 16 | .1487343E+16 | .1343074E+16 | .1183666E+16 | .1013260E+16 | .8368202E+15 | .7000000E+02 |
| 17 | .1050618E+16 | .9488061E+15 | .8363966E+15 | .7164146E+15 | .5925963E+15 | .7400000E+02 |
| 18 | .6247031E+15 | .5641731E+15 | .4973671E+15 | .4261246E+15 | .3527857E+15 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .2806830E+15 | -.2156297E+15 | .1827253E+15 | .1471482E+15 | .1108997E+15 | .2000000E+01 |
| 2 | .4698505E+15 | -.3548667E+15 | .2773903E+15 | .2197702E+15 | .1645853E+15 | .6000000E+01 |
| 3 | .6605377E+15 | -.4920517E+15 | .3730800E+15 | .2918012E+15 | .2169967E+15 | .1000000E+02 |
| 4 | .8544548E+15 | -.6288249E+15 | .4674208E+15 | .3617392E+15 | .2671931E+15 | .1400000E+02 |
| 5 | .1052760E+16 | -.7656189E+15 | .5581678E+15 | .4277956E+15 | .3139885E+15 | .1800000E+02 |
| 6 | .1282932E+16 | -.9208349E+15 | .6527807E+15 | .4953282E+15 | .3612656E+15 | .2250000E+02 |
| 7 | .1490384E+16 | -.1059987E+16 | .7395548E+15 | .5566439E+15 | .4037856E+15 | .2750000E+02 |
| 8 | .1635480E+16 | -.1157280E+16 | .8010217E+15 | .6000073E+15 | .4337241E+15 | .3250000E+02 |
| 9 | .1710050E+16 | -.1207315E+16 | .8328213E+15 | .6224462E+15 | .4491891E+15 | .3750000E+02 |
| 10 | .1710042E+16 | -.1207310E+16 | .8328186E+15 | .6224448E+15 | .4491887E+15 | .4250000E+02 |
| 11 | .1635456E+16 | -.1157266E+16 | .8010141E+15 | .6000035E+15 | .4337231E+15 | .4750000E+02 |
| 12 | .1490349E+16 | -.1059967E+16 | .7395433E+15 | .5566379E+15 | .4037838E+15 | .5250000E+02 |
| 13 | .1282890E+16 | -.9208099E+15 | .6527662E+15 | .4953202E+15 | .3612628E+15 | .5750000E+02 |
| 14 | .1052718E+16 | -.7655936E+15 | .5581525E+15 | .4277872E+15 | .3139858E+15 | .6200000E+02 |
| 15 | .8544153E+15 | -.6287999E+15 | .4674049E+15 | .3617303E+15 | .2671902E+15 | .6600000E+02 |
| 16 | .6605009E+15 | -.4920266E+15 | .3730638E+15 | .2917921E+15 | .2169937E+15 | .7000000E+02 |
| 17 | .4698234E+15 | -.3548487E+15 | .2773790E+15 | .2197647E+15 | .1645849E+15 | .7400000E+02 |
| 18 | .2806603E+15 | -.2156127E+15 | .1827115E+15 | .1471392E+15 | .1108958E+15 | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | .7688817E+14 | -.4557362E+14 | .2000000E+01 |
| 2 | .1136103E+15 | -.6686377E+14 | .6000000E+01 |
| 3 | .1491163E+15 | -.8737173E+14 | .1000000E+02 |
| 4 | .1828126E+15 | -.1067661E+15 | .1400000E+02 |
| 5 | .2139616E+15 | -.1246382E+15 | .1800000E+02 |
| 6 | .2451996E+15 | -.1425144E+15 | .2250000E+02 |
| 7 | .2731060E+15 | -.1584452E+15 | .2750000E+02 |
| 8 | .2926780E+15 | -.1696024E+15 | .3250000E+02 |
| 9 | .3027689E+15 | -.1753509E+15 | .3750000E+02 |
| 10 | .3027688E+15 | -.1753512E+15 | .4250000E+02 |
| 11 | .2926779E+15 | -.1696033E+15 | .4750000E+02 |
| 12 | .2731056E+15 | -.1584468E+15 | .5250000E+02 |
| 13 | .2451989E+15 | -.1425162E+15 | .5750000E+02 |
| 14 | .2139614E+15 | -.1246405E+15 | .6200000E+02 |
| 15 | .1828127E+15 | -.1067686E+15 | .6600000E+02 |
| 16 | .1491167E+15 | -.8737435E+14 | .7000000E+02 |
| 17 | .1136123E+15 | -.6686748E+14 | .7400000E+02 |
| 18 | .7688738E+14 | -.4557698E+14 | .7800000E+02 |

POWER DENSITY (MWT/LITER)

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .6551828E-02 | .6456086E-02 | .6266361E-02 | .5986696E-02 | .5623214E-02 | .2000000E+01 |
| 2 | .1070434E-01 | .1054781E-01 | .1023776E-01 | .9780785E-02 | .9186852E-02 | .6000000E+01 |
| 3 | .1530339E-01 | .1507946E-01 | .1463609E-01 | .1398270E-01 | .1313346E-01 | .1000000E+02 |
| 4 | .2054068E-01 | .2024001E-01 | .1964482E-01 | .1876773E-01 | .1762772E-01 | .1400000E+02 |
| 5 | .2663460E-01 | .2624454E-01 | .2547268E-01 | .2433536E-01 | .2285706E-01 | .1800000E+02 |
| 6 | .5476929E+00 | .5396727E+00 | .5238095E+00 | .5004468E+00 | .4700975E+00 | .2250000E+02 |
| 7 | .6329843E+00 | .6237120E+00 | .6053719E+00 | .5783598E+00 | .5432649E+00 | .2750000E+02 |
| 8 | .6939530E+00 | .6837851E+00 | .6636730E+00 | .6340502E+00 | .5955601E+00 | .3250000E+02 |
| 9 | .7256304E+00 | .7149966E+00 | .6939628E+00 | .6629823E+00 | .6227267E+00 | .3750000E+02 |
| 10 | .7256347E+00 | .7150000E+00 | .6939645E+00 | .6629823E+00 | .6227252E+00 | .4250000E+02 |
| 11 | .6939655E+00 | .6837948E+00 | .6636777E+00 | .6340497E+00 | .5955553E+00 | .4750000E+02 |
| 12 | .6330044E+00 | .6237280E+00 | .6053798E+00 | .5783594E+00 | .5432578E+00 | .5250000E+02 |
| 13 | .5477185E+00 | .5396934E+00 | .5238203E+00 | .5004472E+00 | .4700897E+00 | .5750000E+02 |
| 14 | .2663691E-01 | .2624626E-01 | .2547354E-01 | .2433543E-01 | .2285654E-01 | .6200000E+02 |
| 15 | .2054300E-01 | .2024167E-01 | .1964564E-01 | .1876782E-01 | .1762726E-01 | .6600000E+02 |
| 16 | .1530560E-01 | .1508106E-01 | .1463693E-01 | .1398287E-01 | .1313314E-01 | .7000000E+02 |
| 17 | .1070622E-01 | .1054909E-01 | .1023838E-01 | .9780854E-02 | .9186523E-02 | .7400000E+02 |
| 18 | .6553365E-02 | .6457209E-02 | .6266996E-02 | .5986909E-02 | .5623108E-02 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .5183970E-02 | .4676905E-02 | .4120001E-02 | .3521859E-02 | .2903545E-02 | .2000000E+01 |
| 2 | .8469048E-02 | .7643461E-02 | .6729298E-02 | .5749542E-02 | .4733090E-02 | .6000000E+01 |
| 3 | .1210695E-01 | .1092588E-01 | .9617003E-02 | .8211568E-02 | .6747078E-02 | .1000000E+02 |
| 4 | .1624953E-01 | .1466323E-01 | .1290383E-01 | .1101111E-01 | .9030456E-02 | .1400000E+02 |
| 5 | .2106970E-01 | .1901182E-01 | .1672782E-01 | .1426695E-01 | .1168256E-01 | .1800000E+02 |
| 6 | .4334346E+00 | .3912816E+00 | .3446066E+00 | .2945204E+00 | .2422919E+00 | .2250000E+02 |
| 7 | .5008569E+00 | .4520734E+00 | .3980094E+00 | .3399089E+00 | .2791781E+00 | .2750000E+02 |
| 8 | .5490409E+00 | .4955109E+00 | .4361538E+00 | .3723073E+00 | .3054764E+00 | .3250000E+02 |
| 9 | .5740698E+00 | .5180713E+00 | .4559605E+00 | .3891235E+00 | .3191171E+00 | .3750000E+02 |
| 10 | .5740674E+00 | .5180685E+00 | .4559579E+00 | .3891213E+00 | .3191154E+00 | .4250000E+02 |
| 11 | .5490336E+00 | .4955026E+00 | .4361459E+00 | .3723007E+00 | .3054713E+00 | .4750000E+02 |
| 12 | .5008456E+00 | .4520607E+00 | .3979973E+00 | .3398986E+00 | .2791704E+00 | .5250000E+02 |
| 13 | .4334217E+00 | .3912666E+00 | .3445923E+00 | .2945085E+00 | .2422828E+00 | .5750000E+02 |
| 14 | .2106882E-01 | .1901081E-01 | .1672686E-01 | .1426616E-01 | .1168198E-01 | .6200000E+02 |
| 15 | .1624873E-01 | .1466231E-01 | .1290296E-01 | .1101039E-01 | .9029927E-02 | .6600000E+02 |
| 16 | .1210632E-01 | .1092510E-01 | .9616245E-02 | .8210929E-02 | .6746596E-02 | .7000000E+02 |
| 17 | .8468478E-02 | .7642794E-02 | .6728658E-02 | .5749009E-02 | .4732700E-02 | .7400000E+02 |
| 18 | .5183654E-02 | .4678483E-02 | .4119561E-02 | .3521466E-02 | .2903235E-02 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .2293816E-02 | .1747649E-02 | 0. | 0. | 0. | .2000000E+01 |
| 2 | .3720171E-02 | .2773250E-02 | 0. | 0. | 0. | .6000000E+01 |
| 3 | .5272123E-02 | .3856191E-02 | 0. | 0. | 0. | .1000000E+02 |
| 4 | .7016409E-02 | .5043686E-02 | 0. | 0. | 0. | .1400000E+02 |
| 5 | .9032493E-02 | .6385897E-02 | 0. | 0. | 0. | .1800000E+02 |
| 6 | .1893958E+00 | .1376230E+00 | 0. | 0. | 0. | .2250000E+02 |
| 7 | .2174446E+00 | .1567225E+00 | 0. | 0. | 0. | .2750000E+02 |
| 8 | .2374057E+00 | .1702920E+00 | 0. | 0. | 0. | .3250000E+02 |
| 9 | .2477502E+00 | .1773214E+00 | 0. | 0. | 0. | .3750000E+02 |
| 10 | .2477491E+00 | .1773207E+00 | 0. | 0. | 0. | .4250000E+02 |
| 11 | .2374023E+00 | .1702900E+00 | 0. | 0. | 0. | .4750000E+02 |
| 12 | .2174395E+00 | .1567195E+00 | 0. | 0. | 0. | .5250000E+02 |
| 13 | .1893897E+00 | .1376193E+00 | 0. | 0. | 0. | .5750000E+02 |
| 14 | .9032115E-02 | .6385672E-02 | 0. | 0. | 0. | .6200000E+02 |
| 15 | .7016056E-02 | .5043464E-02 | 0. | 0. | 0. | .6600000E+02 |
| 16 | .5271790E-02 | .3855965E-02 | 0. | 0. | 0. | .7000000E+02 |
| 17 | .3719917E-02 | .2773082E-02 | 0. | 0. | 0. | .7400000E+02 |
| 18 | .2293595E-02 | .1747481E-02 | 0. | 0. | 0. | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | 0. | 0. | .2000000E+01 |
| 2 | 0. | 0. | .6000000E+01 |
| 3 | 0. | 0. | .1000000E+02 |
| 4 | 0. | 0. | .1400000E+02 |
| 5 | 0. | 0. | .1800000E+02 |
| 6 | 0. | 0. | .2250000E+02 |
| 7 | 0. | 0. | .2750000E+02 |
| 8 | 0. | 0. | .3250000E+02 |
| 9 | 0. | 0. | .3750000E+02 |
| 10 | 0. | 0. | .4250000E+02 |
| 11 | 0. | 0. | .4750000E+02 |
| 12 | 0. | 0. | .5250000E+02 |
| 13 | 0. | 0. | .5750000E+02 |
| 14 | 0. | 0. | .6200000E+02 |
| 15 | 0. | 0. | .6600000E+02 |
| 16 | 0. | 0. | .7900000E+02 |
| 17 | 0. | 0. | .7400000E+02 |
| 18 | 0. | 0. | .7800000E+02 |

POWER PRODUCTION FRACTION FOR EACH ZONE

I= 1 PFRAC= .976125

I= 2 PFRAC= .011973

I= 3 PFRAC= .011973

I= 4 PFRAC= 0.000000

FISSION SOURCE RATE

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .5346153E+12 | .5267958E+12 | .5113047E+12 | .4884739E+12 | .4588042E+12 | .2000000E+01 |
| 2 | .8734486E+12 | .8606648E+12 | .8353499E+12 | .7980445E+12 | .7495642E+12 | .6000000E+01 |
| 3 | .1248716E+13 | .1230430E+13 | .1194231E+13 | .1140892E+13 | .1071572E+13 | .1000000E+02 |
| 4 | .1676061E+13 | .1651510E+13 | .1602916E+13 | .1531316E+13 | .1438261E+13 | .1400000E+02 |
| 5 | .2173304E+13 | .2141456E+13 | .2078439E+13 | .1985594E+13 | .1864926E+13 | .1800000E+02 |
| 6 | .4664901E+14 | .4596556E+14 | .4461377E+14 | .4262300E+14 | .4003706E+14 | .2250000E+02 |
| 7 | .5395914E+14 | .5316832E+14 | .5160414E+14 | .4930047E+14 | .4630766E+14 | .2750000E+02 |
| 8 | .5917810E+14 | .5831057E+14 | .5659465E+14 | .5406743E+14 | .5078389E+14 | .3250000E+02 |
| 9 | .6188806E+14 | .6098066E+14 | .5918586E+14 | .5654246E+14 | .5310784E+14 | .3750000E+02 |
| 10 | .6188839E+14 | .6098092E+14 | .5918599E+14 | .5654245E+14 | .5310772E+14 | .4250000E+02 |
| 11 | .5917907E+14 | .5831134E+14 | .5659503E+14 | .5406740E+14 | .5078355E+14 | .4750000E+02 |
| 12 | .5396071E+14 | .5316956E+14 | .5160476E+14 | .4930045E+14 | .4630713E+14 | .5250000E+02 |
| 13 | .4665101E+14 | .4596716E+14 | .4461460E+14 | .4262304E+14 | .4003647E+14 | .5750000E+02 |
| 14 | .2173458E+13 | .2141571E+13 | .2078495E+13 | .1985596E+13 | .1864888E+13 | .6200000E+02 |
| 15 | .1676217E+13 | .1651621E+13 | .1602969E+13 | .1531318E+13 | .1438226E+13 | .6600000E+02 |
| 16 | .1248866E+13 | .1230538E+13 | .1194287E+13 | .1140901E+13 | .1071547E+13 | .7000000E+02 |
| 17 | .8735765E+12 | .8607514E+12 | .8353906E+12 | .7980471E+12 | .7495392E+12 | .7400000E+02 |
| 18 | .5347214E+12 | .5268727E+12 | .5113473E+12 | .4884871E+12 | .4587952E+12 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .4229541E+12 | .3817358E+12 | .3361274E+12 | .2873209E+12 | .2368715E+12 | .2000000E+01 |
| 2 | .6909788E+12 | .6236025E+12 | .5490040E+12 | .4690589E+12 | .3861249E+12 | .6000000E+01 |
| 3 | .9877908E+12 | .8914028E+12 | .7845943E+12 | .6699148E+12 | .5504248E+12 | .1000000E+02 |
| 4 | .1325776E+13 | .1196317E+13 | .1052744E+13 | .8983027E+12 | .7366986E+12 | .1400000E+02 |
| 5 | .1719044E+13 | .1551098E+13 | .1364714E+13 | .1163913E+13 | .9530489E+12 | .1800000E+02 |
| 6 | .3691335E+14 | .3332206E+14 | .2934560E+14 | .2507839E+14 | .2062806E+14 | .2250000E+02 |
| 7 | .4269142E+14 | .3853176E+14 | .3392196E+14 | .2896785E+14 | .2378875E+14 | .2750000E+02 |
| 8 | .4681565E+14 | .4224960E+14 | .3718665E+14 | .3174064E+14 | .2603927E+14 | .3250000E+02 |
| 9 | .4895668E+14 | .4417941E+14 | .3888085E+14 | .3317898E+14 | .2720588E+14 | .3750000E+02 |
| 10 | .4895649E+14 | .4417920E+14 | .3888065E+14 | .3317881E+14 | .2720575E+14 | .4250000E+02 |
| 11 | .4681511E+14 | .4224899E+14 | .3718607E+14 | .3174015E+14 | .2603889E+14 | .4750000E+02 |
| 12 | .4269059E+14 | .3853081E+14 | .3392105E+14 | .2896709E+14 | .2378816E+14 | .5250000E+02 |
| 13 | .3691238E+14 | .3332094E+14 | .2934453E+14 | .2507748E+14 | .2062736E+14 | .5750000E+02 |
| 14 | .1718981E+13 | .1551026E+13 | .1364646E+13 | .1163858E+13 | .9530086E+12 | .6200000E+02 |
| 15 | .1325718E+13 | .1196251E+13 | .1052681E+13 | .8982519E+12 | .7366615E+12 | .6600000E+02 |
| 16 | .9877440E+12 | .8913469E+12 | .7845398E+12 | .6698693E+12 | .5503910E+12 | .7000000E+02 |
| 17 | .6909372E+12 | .6235545E+12 | .5489582E+12 | .4690211E+12 | .3860978E+12 | .7400000E+02 |
| 18 | .4229305E+12 | .3817049E+12 | .3360955E+12 | .2872925E+12 | .2368496E+12 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .1871252E+12 | -.1425666E+12 | 0. | 0. | 0. | .2000000E+01 |
| 2 | .3034839E+12 | -.2262310E+12 | 0. | 0. | 0. | .6000000E+01 |
| 3 | .4300884E+12 | -.3145729E+12 | 0. | 0. | 0. | .1000000E+02 |
| 4 | .5723805E+12 | -.4114420E+12 | 0. | 0. | 0. | .1400000E+02 |
| 5 | .7368417E+12 | -.5209298E+12 | 0. | 0. | 0. | .1800000E+02 |
| 6 | .1611927E+14 | -.1170246E+14 | 0. | 0. | 0. | .2250000E+02 |
| 7 | .1852210E+14 | -.1333669E+14 | 0. | 0. | 0. | .2750000E+02 |
| 8 | .2022984E+14 | -.1449636E+14 | 0. | 0. | 0. | .3250000E+02 |
| 9 | .2111428E+14 | -.1509677E+14 | 0. | 0. | 0. | .3750000E+02 |
| 10 | .2111419E+14 | -.1509671E+14 | 0. | 0. | 0. | .4250000E+02 |
| 11 | .2022957E+14 | -.1449619E+14 | 0. | 0. | 0. | .4750000E+02 |
| 12 | .1852170E+14 | -.1333643E+14 | 0. | 0. | 0. | .5250000E+02 |
| 13 | .1611878E+14 | -.1170214E+14 | 0. | 0. | 0. | .5750000E+02 |
| 14 | .7368158E+12 | -.5209150E+12 | 0. | 0. | 0. | .6200000E+02 |
| 15 | .5723561E+12 | -.4114271E+12 | 0. | 0. | 0. | .6600000E+02 |
| 16 | .4300653E+12 | -.3145573E+12 | 0. | 0. | 0. | .7000000E+02 |
| 17 | .3034669E+12 | -.2262159E+12 | 0. | 0. | 0. | .7400000E+02 |
| 18 | .1871101E+12 | -.1425553E+12 | 0. | 0. | 0. | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | 0. | -0. | .2000000E+01 |
| 2 | 0. | -0. | .6000000E+01 |
| 3 | 0. | -0. | .1000000E+02 |
| 4 | 0. | -0. | .1400000E+02 |
| 5 | 0. | -0. | .1800000E+02 |
| 6 | 0. | -0. | .2250000E+02 |
| 7 | 0. | -0. | .2750000E+02 |
| 8 | 0. | -0. | .3250000E+02 |
| 9 | 0. | -0. | .3750000E+02 |
| 10 | 0. | -0. | .4250000E+02 |
| 11 | 0. | -0. | .4750000E+02 |
| 12 | 0. | -0. | .5250000E+02 |
| 13 | 0. | -0. | .5750000E+02 |
| 14 | 0. | -0. | .6200000E+02 |
| 15 | 0. | -0. | .6600000E+02 |
| 16 | 0. | -0. | .7000000E+02 |
| 17 | 0. | -0. | .7400000E+02 |
| 18 | 0. | -0. | .7800000E+02 |

PHENIX EXAMPLE / 2 GROUP / ARGONNE CODE CNTR SAMPLE REACTOR
SEARCH-BURN-KEFF-REFUEL

MATERIAL INVENTORY (KILOGRAMS) FOR EACH ZONE

| | MATERIAL | ATOMIC WT. | ZONE 1 .804E+03 LITERS | ZONE 2 .402E+03 LITERS | ZONE 3 .402E+03 LITERS | ZONE 4 .143E+04 LITERS |
|---|---|---|---|---|---|---|
| 1 | IRON | 55.850 | 7.482E+02 | 3.741E+02 | 3.741E+02 | 1.086E+03 |
| 2 | CROM | 52.010 | 1.792E+02 | 8.958E+01 | 8.958E+01 | 2.600E+02 |
| 3 | NICK | 58.710 | 1.265E+02 | 6.323E+01 | 6.323E+01 | 1.835E+02 |
| 4 | NA | 22.990 | 3.909E+02 | 1.954E+02 | 1.954E+02 | 1.051E+03 |
| 5 | PUA | 239.130 | 6.782E+02 | 0. | 0. | 0. |
| 6 | PUB | 240.130 | 9.690E+01 | 0. | 0. | 0. |
| 7 | U238 | 238.120 | 9.334E+02 | 8.543E+02 | 8.543E+02 | 0. |
| 8 | OXY | 16.000 | 2.292E+02 | 1.146E+02 | 1.146E+02 | 0. |
| 9 | FPR | 119.000 | 0. | 0. | 0. | 0. |
| 10 | B-10 | 10.010 | 7.154E+00 | 0. | 0. | 0. |

BURNUP DATA

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | LAMBDA (DAYS-1) | NBR | * * * * * * DECAY | SOURCE ISOTOPE FOR CAPTURE | |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 0. | 2 | 0 | 3 | 0 |
| 2 | 6 | PUB | 0. | 1 | 0 | 1 | 0 |
| 3 | 7 | U238 | 0. | 1 | 0 | 0 | 0 |
| 4 | 9 | FPR | 0. | 0 | 0 | 0 | 0 |
| 5 | 10 | B-10 | 0. | 0 | 0 | 0 | 0 |

FISSION

| | | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 2 | 3 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |

ZONE 1 FLUX =2.5091E+15 VOLUME =8.0425E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 2.124E-03 | 7.949E+18 | 9.740E+18 | 1.855E+00 | 2.272E+00 |
| 2 | 6 | PUB | 3.022E-04 | 2.481E+17 | 4.701E+17 | 4.068E-01 | 7.709E-01 |
| 3 | 7 | U238 | 2.936E-03 | 3.050E+17 | 1.615E+18 | 5.149E-02 | 2.727E-01 |
| 4 | 9 | FPR | 0. | 0. | 0. | 0. | 2.367E+00 |
| 5 | 10 | B-10 | 5.353E-04 | 0. | 2.471E+18 | 0. | 2.288E+00 |

ZONE 2 FLUX =1.0700E+15 VOLUME =4.0212E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 0. | 0. | 0. | 1.975E+00 | 2.521E+00 |
| 2 | 6 | PUB | 0. | 0. | 0. | 3.676E-01 | 8.136E-01 |
| 3 | 7 | U238 | 5.373E-03 | 1.043E+17 | 6.906E+17 | 4.510E-02 | 2.987E-01 |
| 4 | 9 | FPR | 0. | 0. | 0. | 0. | 2.074E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.687E+00 |

ZONE 3 FLUX =1.0700E+15 VOLUME =4.0212E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 0. | 0. | 0. | 1.975E+00 | 2.521E+00 |
| 2 | 6 | PUB | 0. | 0. | 0. | 3.676E-01 | 8.136E-01 |
| 3 | 7 | U238 | 5.373E-03 | 1.043E+17 | 6.905E+17 | 4.510E-02 | 2.987E-01 |
| 4 | 9 | FPR | 0. | 0. | 0. | 0. | 2.074E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.687E+00 |

Z O N E 4 FLUX =3.1482E+14 VOLUME =1.4326E+03 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 0. | 0. | 0. | 2.015E+00 | 2.603E+00 |
| 2 | 6 | PUB | 0. | 0. | 0. | 3.545E-01 | 8.278E-01 |
| 3 | 7 | U238 | 0. | 0. | 0. | 4.298E-02 | 3.073E-01 |
| 4 | 9 | FPR | 0. | 0. | 0. | 0. | 1.977E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.819E+00 |

KZ= 1 BREDRT(KZ)= .1573
KZ= 2 BREDRT(KZ)= .0602
KZ= 3 BREDRT(KZ)= .0602
KZ= 4 BREDRT(KZ)= 0.0000

BREEDING RATIO = .2777

THESE ARE THE ZONE-AVERAGED TOTAL FLUXES TO BE USED IN THE FLUX SHIFT CORRECTION FOR SUBROUTINE REFUEL

ZONE = 1 AVG FLUX =2.5547E+15

ZONE = 2 AVG FLUX =1.9895E+15

ZONE = 3 AVG FLUX =1.9894E+15

ZONE = 4 AVG FLUX =3.2054E+14

TIME = 100.000 DAYS

| | MIXTURE NUMBER | MIX COMMAND | MATERIAL ATOMIC DENSITY | NTRIG |
|---|---|---|---|---|
| 1 | 11 | 0 | 0. | 0 |
| 2 | 11 | 4 | .12733000E-01 | 0 |
| 3 | 11 | 1 | .10033000E-01 | 0 |
| 4 | 11 | 2 | .25797000E-02 | 0 |
| 5 | 11 | 3 | .16131000E-02 | 0 |
| 6 | 11 | 5 | .20342950E-02 | 1 |
| 7 | 11 | 6 | .31608654E-03 | 1 |
| 8 | 11 | 7 | .29181180E-02 | 1 |
| 9 | 11 | 9 | .88672622E-04 | 0 |
| 10 | 11 | 8 | .10730000E-01 | 0 |
| 11 | 11 | 10 | .53894427E-03 | 0 |
| 12 | 12 | 0 | 0. | 0 |
| 13 | 12 | 4 | .12733000E-01 | 0 |
| 14 | 12 | 1 | .10033000E-01 | 0 |
| 15 | 12 | 2 | .25797000E-02 | 0 |
| 16 | 12 | 3 | .16131000E-02 | 0 |
| 17 | 12 | 5 | .12632449E-04 | 1 |
| 18 | 12 | 6 | .32460269E-07 | 1 |
| 19 | 12 | 7 | .53584436E-02 | 1 |
| 20 | 12 | 9 | .23686870E-05 | 0 |
| 21 | 12 | 8 | .10730000E-01 | 0 |
| 22 | 13 | 0 | 0. | 0 |
| 23 | 13 | 4 | .12733000E-01 | 0 |
| 24 | 13 | 1 | .10033000E-01 | 0 |
| 25 | 13 | 2 | .25797000E-02 | 0 |
| 26 | 13 | 3 | .16131000E-02 | 0 |
| 27 | 13 | 5 | .12632003E-04 | 1 |
| 28 | 13 | 6 | .32457998E-07 | 1 |
| 29 | 13 | 7 | .53584441E-02 | 1 |
| 30 | 13 | 9 | .23685917E-05 | 0 |
| 31 | 13 | 8 | .10730000E-01 | 0 |
| 32 | 14 | 0 | 0. | 0 |
| 33 | 14 | 1 | .81738000E-02 | 0 |
| 34 | 14 | 2 | .21016000E-02 | 0 |
| 35 | 14 | 3 | .13142000E-02 | 0 |
| 36 | 14 | 4 | .19220000E-01 | 0 |

| TIME (MINUTES) | OUTER ITERATIONS | IN. IT. PER LOOP | EIGENVALUE SLOPE | EIGENVALUE | LAMBDA |
|---|---|---|---|---|---|
| .590 | 0 | 0 | 0. | 0. | 0. |
| .598 | 1 | 10 | 0. | .96601428E+00 | .96601428E+00 |
| .604 | 2 | 10 | 0. | .96583630E+00 | .99981576E+00 |
| .606 | 3 | 2 | 0. | .96584509E+00 | .10000091E+01 |
| .609 | 4 | 2 | 0. | .96584196E+00 | .99999676E+00 |

FINAL NEUTRON BALANCE TABLE

| GROUP | FISSION SOURCE | IN-SCATTER | OUT-SCATTER | ABSORPTION | L. L. | R. L. | T. L. | B. L. | TOTAL LEAKAGE |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2.624E+19 | 0. | 9.590E+18 | 9.807E+18 | 0. | 1.606E+18 | 2.618E+18 | 2.618E+18 | 6.842E+18 |
| 2 | 2.025E+17 | 9.590E+18 | 3.876E+15 | 7.155E+18 | 0. | 6.314E+17 | 1.001E+18 | 1.001E+18 | 2.634E+18 |
| 3 | 2.644E+19 | 9.590E+18 | 9.594E+18 | 1.696E+19 | 0. | 2.238E+18 | 3.619E+18 | 3.619E+18 | 9.476E+18 |

TOTAL FLUX

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .8185213E+15 | .8065048E+15 | .7827466E+15 | .7477849E+15 | .7024168E+15 | .2000000E+01 |
| 2 | .1376544E+16 | .1356341E+16 | .1316342E+16 | .1257600E+16 | .1181305E+16 | .6000000E+01 |
| 3 | .1948429E+16 | .1919832E+16 | .1863282E+16 | .1780053E+16 | .1672035E+16 | .1000000E+02 |
| 4 | .2539244E+16 | .2501971E+16 | .2428261E+16 | .2319769E+16 | .2178940E+16 | .1400000E+02 |
| 5 | .3151687E+16 | .3105421E+16 | .3013917E+16 | .2879219E+16 | .2704344E+16 | .1800000E+02 |
| 6 | .3868589E+16 | .3811790E+16 | .3699451E+16 | .3534062E+16 | .3319301E+16 | .2250000E+02 |
| 7 | .4518396E+16 | .4452047E+16 | .4320815E+16 | .4127593E+16 | .3876652E+16 | .2750000E+02 |
| 8 | .4974843E+16 | .4901784E+16 | .4757278E+16 | .4544501E+16 | .4268131E+16 | .3250000E+02 |
| 9 | .5209940E+16 | .5133428E+16 | .4982088E+16 | .4759241E+16 | .4469774E+16 | .3750000E+02 |
| 10 | .5209868E+16 | .5133355E+16 | .4982020E+16 | .4759183E+16 | .4469730E+16 | .4250000E+02 |
| 11 | .4974618E+16 | .4901568E+16 | .4757079E+16 | .4544332E+16 | .4268002E+16 | .4750000E+02 |
| 12 | .4517989E+16 | .4451655E+16 | .4320453E+16 | .4127281E+16 | .3876402E+16 | .5250000E+02 |
| 13 | .3868086E+16 | .3811307E+16 | .3699007E+16 | .3533678E+16 | .3318993E+16 | .5750000E+02 |
| 14 | .3151156E+16 | .3104912E+16 | .3013453E+16 | .2878818E+16 | .2704019E+16 | .6200000E+02 |
| 15 | .2538712E+16 | .2501462E+16 | .2427797E+16 | .2319366E+16 | .2178610E+16 | .6600000E+02 |
| 16 | .1948017E+16 | .1919440E+16 | .1862926E+16 | .1779748E+16 | .1671789E+16 | .7000000E+02 |
| 17 | .1376241E+16 | .1356054E+16 | .1316134E+16 | .1257381E+16 | .1181132E+16 | .7400000E+02 |
| 18 | .8183263E+15 | .8063225E+15 | .7825856E+15 | .7476508E+15 | .7023136E+15 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .6476910E+15 | .5849076E+15 | .5156391E+15 | .4417905E+15 | .3657736E+15 | .2000000E+01 |
| 2 | .1089268E+16 | .9830648E+15 | .8671141E+15 | .7427492E+15 | .6144224E+15 | .6000000E+01 |
| 3 | .1541700E+16 | .1392098E+16 | .1226865E+16 | .1050288E+16 | .8674902E+15 | .1000000E+02 |
| 4 | .2008972E+16 | .1813782E+16 | .1598005E+16 | .1367019E+16 | .1127087E+16 | .1400000E+02 |
| 5 | .2493226E+16 | .2250658E+16 | .1982260E+16 | .1694454E+16 | .1394539E+16 | .1800000E+02 |
| 6 | .3059952E+16 | .2761811E+16 | .2431609E+16 | .2076926E+16 | .1706160E+16 | .2250000E+02 |
| 7 | .3573528E+16 | .3224906E+16 | .2838491E+16 | .2422858E+16 | .1987346E+16 | .2750000E+02 |
| 8 | .3934229E+16 | .3550090E+16 | .3124087E+16 | .2665476E+16 | .2184256E+16 | .3250000E+02 |
| 9 | .4120015E+16 | .3717567E+16 | .3271144E+16 | .2790348E+16 | .2285525E+16 | .3750000E+02 |
| 10 | .4119986E+16 | .3717555E+16 | .3271146E+16 | .2790361E+16 | .2285544E+16 | .4250000E+02 |
| 11 | .3934145E+16 | .3550051E+16 | .3124088E+16 | .2665509E+16 | .2184307E+16 | .4750000E+02 |
| 12 | .3573349E+16 | .3224797E+16 | .2838447E+16 | .2422867E+16 | .1987387E+16 | .5250000E+02 |
| 13 | .3059726E+16 | .2761668E+16 | .2431542E+16 | .2076921E+16 | .1706192E+16 | .5750000E+02 |
| 14 | .2492984E+16 | .2250501E+16 | .1982181E+16 | .1694437E+16 | .1394562E+16 | .6200000E+02 |
| 15 | .2008723E+16 | .1813616E+16 | .1597916E+16 | .1366992E+16 | .1127100E+16 | .6600000E+02 |
| 16 | .1541521E+16 | .1391986E+16 | .1226814E+16 | .1050286E+16 | .8675175E+15 | .7000000E+02 |
| 17 | .1089146E+16 | .9835943E+15 | .8670901E+15 | .7427607E+15 | .6144550E+15 | .7400000E+02 |
| 18 | .6476211E+15 | .5848708E+15 | .5156311E+15 | .4418036E+15 | .3657991E+15 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .2909915E+15 | .2234863E+15 | .1892360E+15 | .1523244E+15 | .1147588E+15 | .2000000E+01 |
| 2 | .4871504E+15 | .3678730E+15 | .2873751E+15 | .2275893E+15 | .1703805E+15 | .6000000E+01 |
| 3 | .6847889E+15 | .5100966E+15 | .3865616E+15 | .3022331E+15 | .2246771E+15 | .1000000E+02 |
| 4 | .8856571E+15 | .6518637E+15 | .4843401E+15 | .3746983E+15 | .2766718E+15 | .1400000E+02 |
| 5 | .1090905E+16 | .7936222E+15 | .5783866E+15 | .4431303E+15 | .3251343E+15 | .1800000E+02 |
| 6 | .1328564E+16 | .9542666E+15 | .6764438E+15 | .5130747E+15 | .3740841E+15 | .2250000E+02 |
| 7 | .1542025E+16 | .1097787E+16 | .7662109E+15 | .5765292E+15 | .4180886E+15 | .2750000E+02 |
| 8 | .1691166E+16 | .1198028E+16 | .8297317E+15 | .6213766E+15 | .4490603E+15 | .3250000E+02 |
| 9 | .1767794E+16 | .1249564E+16 | .8625828E+15 | .6445786E+15 | .4650573E+15 | .3750000E+02 |
| 10 | .1767812E+16 | .1249577E+16 | .8625921E+15 | .6445849E+15 | .4650614E+15 | .4250000E+02 |
| 11 | .1691218E+16 | .1198068E+16 | .8297579E+15 | .6213938E+15 | .4490709E+15 | .4750000E+02 |
| 12 | .1542076E+16 | .1097830E+16 | .7662421E+15 | .5765502E+15 | .4181019E+15 | .5250000E+02 |
| 13 | .1328610E+16 | .9543100E+15 | .6764723E+15 | .5130939E+15 | .3740960E+15 | .5750000E+02 |
| 14 | .1090945E+16 | .7936619E+15 | .5784124E+15 | .4431482E+15 | .3251456E+15 | .6200000E+02 |
| 15 | .8856861E+15 | .6518932E+15 | .4843634E+15 | .3747151E+15 | .2766824E+15 | .6600000E+02 |
| 16 | .6848261E+15 | .5101309E+15 | .3865881E+15 | .3022527E+15 | .2246902E+15 | .7000000E+02 |
| 17 | .4871896E+15 | .3679067E+15 | .2874020E+15 | .2276098E+15 | .1703949E+15 | .7400000E+02 |
| 18 | .2910213E+15 | .2235136E+15 | .1892598E+15 | .1523425E+15 | .1147714E+15 | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | .7953542E+14 | .4711851E+14 | .2000000E+01 |
| 2 | .1175678E+15 | .6915446E+14 | .6000000E+01 |
| 3 | .1543374E+15 | .9037884E+14 | .1000000E+02 |
| 4 | .1892284E+15 | .1104480E+15 | .1400000E+02 |
| 5 | .2214756E+15 | .1289379E+15 | .1800000E+02 |
| 6 | .2538081E+15 | .1474272E+15 | .2250000E+02 |
| 7 | .2826829E+15 | .1638998E+15 | .2750000E+02 |
| 8 | .3029288E+15 | .1754339E+15 | .3250000E+02 |
| 9 | .3133667E+15 | .1813765E+15 | .3750000E+02 |
| 10 | .3133692E+15 | .1813780E+15 | .4250000E+02 |
| 11 | .3029352E+15 | .1754376E+15 | .4750000E+02 |
| 12 | .2826909E+15 | .1639045E+15 | .5250000E+02 |
| 13 | .2538148E+15 | .1474307E+15 | .5750000E+02 |
| 14 | .2214818E+15 | .1289409E+15 | .6200000E+02 |
| 15 | .1892344E+15 | .1104513E+15 | .6600000E+02 |
| 16 | .1543456E+15 | .9038337E+14 | .7000000E+02 |
| 17 | .1175770E+15 | .6910021E+14 | .7400000E+02 |
| 18 | .7954364E+14 | .4712321E+14 | .7800000E+02 |

POWER DENSITY (MWT/LITER)

| | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|
| 1 | .7471976E-02 | .7362145E-02 | .7144972E-02 | .6825285E-02 | .6410210E-02 | .2000000E+01 |
| 2 | .1224986E-01 | .1200986E-01 | .1171385E-01 | .1118975E-01 | .1050923E-01 | .6000000E+01 |
| 3 | .1747578E-01 | .1721900E-01 | .1671113E-01 | .1596343E-01 | .1499247E-01 | .1000000E+02 |
| 4 | .2334085E-01 | .2299792E-01 | .2231962E-01 | .2132093E-01 | .2002392E-01 | .1400000E+02 |
| 5 | .3005759E-01 | .2961601E-01 | .2874257E-01 | .2745649E-01 | .2578606E-01 | .1800000E+02 |
| 6 | .5463631E+00 | .5383433E+00 | .5224821E+00 | .4991330E+00 | .4688183E+00 | .2250000E+02 |
| 7 | .6310000E+00 | .6217360E+00 | .6034135E+00 | .5764380E+00 | .5414088E+00 | .2750000E+02 |
| 8 | .6913727E+00 | .6812211E+00 | .6611426E+00 | .6315799E+00 | .5931862E+00 | .3250000E+02 |
| 9 | .7227031E+00 | .7123912E+00 | .6911018E+00 | .6601968E+00 | .6200573E+00 | .3750000E+02 |
| 10 | .7226931E+00 | .7123812E+00 | .6910923E+00 | .6601887E+00 | .6200512E+00 | .4250000E+02 |
| 11 | .6913414E+00 | .6811911E+00 | .6611148E+00 | .6315562E+00 | .5931682E+00 | .4750000E+02 |
| 12 | .6309436E+00 | .6216818E+00 | .6033635E+00 | .5763948E+00 | .5413743E+00 | .5250000E+02 |
| 13 | .5462927E+00 | .5382757E+00 | .5224201E+00 | .4990792E+00 | .4687751E+00 | .5750000E+02 |
| 14 | .3005223E-01 | .2961086E-01 | .2873785E-01 | .2745240E-01 | .2578275E-01 | .6200000E+02 |
| 15 | .2333551E-01 | .2299279E-01 | .2231492E-01 | .2131684E-01 | .2002056E-01 | .6600000E+02 |
| 16 | .1747174E-01 | .1721516E-01 | .1670765E-01 | .1596042E-01 | .1499004E-01 | .7000000E+02 |
| 17 | .1224692E-01 | .1200707E-01 | .1171135E-01 | .1118762E-01 | .1050754E-01 | .7400000E+02 |
| 18 | .7470042E-02 | .7360340E-02 | .7143378E-02 | .6823955E-02 | .6409184E-02 | .7800000E+02 |

| | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|
| 1 | .5909067E-02 | .5333326E-02 | .4696769E-02 | .4016100E-02 | .3312926E-02 | .2000000E+01 |
| 2 | .9687492E-02 | .8743189E-02 | .7698535E-02 | .6579977E-02 | .5420507E-02 | .6000000E+01 |
| 3 | .1381981E-01 | .1247173E-01 | .1097917E-01 | .9378096E-02 | .7711491E-02 | .1000000E+02 |
| 4 | .1845718E-01 | .1665537E-01 | .1465876E-01 | .1251306E-01 | .1027037E-01 | .1400000E+02 |
| 5 | .2376792E-01 | .2144621E-01 | .1887167E-01 | .1610059E-01 | .1319410E-01 | .1800000E+02 |
| 6 | .4322194E+00 | .3901657E+00 | .3436283E+00 | .2937163E+00 | .2416902E+00 | .2250000E+02 |
| 7 | .4991051E+00 | .4504717E+00 | .3966074E+00 | .3387552E+00 | .2783130E+00 | .2750000E+02 |
| 8 | .5468099E+00 | .4934768E+00 | .4343750E+00 | .3708415E+00 | .3043728E+00 | .3250000E+02 |
| 9 | .5715671E+00 | .5157935E+00 | .4539704E+00 | .3874834E+00 | .3178804E+00 | .3750000E+02 |
| 10 | .5715631E+00 | .5157917E+00 | .4539706E+00 | .3874851E+00 | .3178830E+00 | .4250000E+02 |
| 11 | .5467981E+00 | .4934712E+00 | .4343750E+00 | .3708459E+00 | .3043797E+00 | .4750000E+02 |
| 12 | .4990803E+00 | .4504567E+00 | .3966014E+00 | .3387564E+00 | .2783187E+00 | .5250000E+02 |
| 13 | .4321877E+00 | .3901455E+00 | .3436187E+00 | .2937152E+00 | .2416944E+00 | .5750000E+02 |
| 14 | .2376546E-01 | .2144460E-01 | .1887085E-01 | .1610041E-01 | .1319432E-01 | .6200000E+02 |
| 15 | .1845464E-01 | .1665365E-01 | .1465781E-01 | .1251275E-01 | .1027047E-01 | .6600000E+02 |
| 16 | .1381802E-01 | .1247060E-01 | .1097865E-01 | .9378060E-02 | .7711760E-02 | .7000000E+02 |
| 17 | .9686290E-02 | .8742495E-02 | .7698301E-02 | .6580097E-02 | .5420845E-02 | .7400000E+02 |
| 18 | .5908373E-02 | .5332965E-02 | .4696701E-02 | .4016245E-02 | .3313202E-02 | .7800000E+02 |

| | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|
| 1 | .2619476E-02 | .1996846E-02 | 0. | 0. | 0. | .2000000E+01 |
| 2 | .4265484E-02 | .3184187E-02 | 0. | 0. | 0. | .6000000E+01 |
| 3 | .6034392E-02 | .4423865E-02 | 0. | 0. | 0. | .1000000E+02 |
| 4 | .7992830E-02 | .5763869E-02 | 0. | 0. | 0. | .1400000E+02 |
| 5 | .1021864E-01 | .7253191E-02 | 0. | 0. | 0. | .1800000E+02 |
| 6 | .1890052E+00 | .1374107E+00 | 0. | 0. | 0. | .2250000E+02 |
| 7 | .2168867E+00 | .1564407E+00 | 0. | 0. | 0. | .2750000E+02 |
| 8 | .2366901E+00 | .1699349E+00 | 0. | 0. | 0. | .3250000E+02 |
| 9 | .2469460E+00 | .1769207E+00 | 0. | 0. | 0. | .3750000E+02 |
| 10 | .2469486E+00 | .1769225E+00 | 0. | 0. | 0. | .4250000E+02 |
| 11 | .2366971E+00 | .1699403E+00 | 0. | 0. | 0. | .4750000E+02 |
| 12 | .2168937E+00 | .1564467E+00 | 0. | 0. | 0. | .5250000E+02 |
| 13 | .1890115E+00 | .1374165E+00 | 0. | 0. | 0. | .5750000E+02 |
| 14 | .1021904E-01 | .7253606E-02 | 0. | 0. | 0. | .6200000E+02 |
| 15 | .7993109E-02 | .5764173E-02 | 0. | 0. | 0. | .6600000E+02 |
| 16 | .6034768E-02 | .4424231E-02 | 0. | 0. | 0. | .7000000E+02 |
| 17 | .4265892E-02 | .3184554E-02 | 0. | 0. | 0. | .7400000E+02 |
| 18 | .2619799E-02 | .1997150E-02 | 0. | 0. | 0. | .7800000E+02 |

| | 16 | 17 | |
|---|---|---|---|
| 1 | 0. | 0. | .2000000E+01 |
| 2 | 0. | 0. | .6000000E+01 |
| 3 | 0. | 0. | .1000000E+02 |
| 4 | 0. | 0. | .1400000E+02 |
| 5 | 0. | 0. | .1800000E+02 |
| 6 | 0. | 0. | .2250000E+02 |
| 7 | 0. | 0. | .2750000E+02 |
| 8 | 0. | 0. | .3250000E+02 |
| 9 | 0. | 0. | .3750000E+02 |
| 10 | 0. | 0. | .4250000E+02 |
| 11 | 0. | 0. | .4750000E+02 |
| 12 | 0. | 0. | .5250000E+02 |
| 13 | 0. | 0. | .5750000E+02 |
| 14 | 0. | 0. | .6200000E+02 |
| 15 | 0. | 0. | .6600000E+02 |
| 16 | 0. | 0. | .7000000E+02 |
| 17 | 0. | 0. | .7400000E+02 |
| 18 | 0. | 0. | .7800000E+02 |

POWER PRODUCTION FRACTION FOR EACH ZONE

I= 1 PFRAC= .972777

I= 2 PFRAC= .013610

I= 3 PFRAC= .013609

I= 4 PFRAC= 0.000000

THESE ARE THE AVERAGE BURNUP RATES,IN MWD/TON,FOR EACH ZONE OVER THE PREVIOUS CYCLE

DELT= 100.00 DAYS

| | | | | | | |
|---|---|---|---|---|---|---|
| I= 1 | FUEL MASS IN SHORT TONS= | 1.879 | AVG. BURNUP IN MWD/SHORT TON= | 15554.42 | AVG. BURNUP IN MWD/METRIC TON= | 17109.87 |
| I= 2 | FUEL MASS IN SHORT TONS= | .940 | AVG. BURNUP IN MWD/SHORT TON= | 408.37 | AVG. BURNUP IN MWD/METRIC TON= | 449.21 |
| I= 3 | FUEL MASS IN SHORT TONS= | .940 | AVG. BURNUP IN MWD/SHORT TON= | 408.35 | AVG. BURNUP IN MWD/METRIC TON= | 449.18 |
| I= 4 | FUEL MASS IN SHORT TONS= | 0.000 | AVG. BURNUP IN MWD/SHORT TON= | 0.00 | AVG. BURNUP IN MWD/METRIC TON= | 0.00 |

PHENIX EXAMPLE / 2 GROUP / ARGONNE CODE CNTR SAMPLE REACTOR
SEARCH-BURN-KEFF-REFUEL

MATERIAL INVENTORY (KILOGRAMS) FOR EACH ZONE

| MATERIAL | | ATOMIC WT. | ZONE 1<br>.804E+03 LITERS | ZONE 2<br>.402E+03 LITERS | ZONE 3<br>.402E+03 LITERS | ZONE 4<br>.143E+04 LITERS |
|---|---|---|---|---|---|---|
| 1 | IRON | 55.850 | 7.482E+02 | 3.741E+02 | 3.741E+02 | 1.086E+03 |
| 2 | CROM | 52.010 | 1.792E+02 | 8.958E+01 | 8.958E+01 | 2.600E+02 |
| 3 | NICK | 58.710 | 1.265E+02 | 6.323E+01 | 6.323E+01 | 1.835E+02 |
| 4 | NA | 22.990 | 3.900E+02 | 1.954E+02 | 1.954E+02 | 1.051E+03 |
| 5 | PUA | 239.130 | 6.496E+02 | 2.017E+00 | 2.017E+00 | 0. |
| 6 | PUB | 240.130 | 1.014E+02 | 5.204E-03 | 5.204E-03 | 0. |
| 7 | U238 | 238.120 | 9.278E+02 | 8.519E+02 | 8.519E+02 | 0. |
| 8 | OXY | 16.000 | 2.292E+02 | 1.146E+02 | 1.146E+02 | 0. |
| 9 | FPR | 119.000 | 1.409E+01 | 1.882E-01 | 1.882E-01 | 0. |
| 10 | B-10 | 10.010 | 6.803E+00 | 0. | 0. | 0. |

Z O N E 1 FLUX =2.5938E+15 VOLUME =8.0425E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 2.034E-03 | 7.894E+18 | 9.694E+18 | 1.860E+00 | 2.284E+00 |
| 2 | 6 | PUB | 3.161E-04 | 2.670E+17 | 5.097E+17 | 4.049E-01 | 7.730E-01 |
| 3 | 7 | U238 | 2.918E-03 | 3.116E+17 | 1.667E+18 | 5.119E-02 | 2.739E-01 |
| 4 | 9 | FPR | 8.867E-05 | 0. | 4.353E+17 | 0. | 2.353E+00 |
| 5 | 10 | B-10 | 5.089E-04 | 0. | 2.449E+18 | 0. | 2.307E+00 |

Z O N E 2 FLUX =1.1089E+15 VOLUME =4.0212E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 1.263E-05 | 1.114E+16 | 1.423E+16 | 1.978E+00 | 2.527E+00 |
| 2 | 6 | PUB | 3.246E-08 | 5.306E+12 | 1.179E+13 | 3.666E-01 | 8.146E-01 |
| 3 | 7 | U238 | 5.358E-03 | 1.074E+17 | 7.151E+17 | 4.495E-02 | 2.993E-01 |
| 4 | 9 | FPR | 2.369E-06 | 0. | 2.183E+15 | 0. | 2.067E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.696E+00 |

Z O N E 3 FLUX =1.1088E+15 VOLUME =4.0212E+02 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 1.263E-05 | 1.114E+16 | 1.423E+16 | 1.978E+00 | 2.527E+00 |
| 2 | 6 | PUB | 3.246E-08 | 5.306E+12 | 1.179E+13 | 3.666E-01 | 8.146E-01 |
| 3 | 7 | U238 | 5.358E-03 | 1.074E+17 | 7.151E+17 | 4.495E-02 | 2.993E-01 |
| 4 | 9 | FPR | 2.369E-06 | 0. | 2.183E+15 | 0. | 2.067E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.696E+00 |

Z O N E 4 FLUX =3.2600E+14 VOLUME =1.4326E+03 LITERS

| BURNABLE ISOTOPE NO. | MATERIAL NO. | NAME | ATOM DENSITY | FISSION RATE | ABSORPTION RATE | SIGMA FISSION | SIGMA ABSORPTION |
|---|---|---|---|---|---|---|---|
| 1 | 5 | PUA | 0. | 0. | 0. | 2.019E+00 | 2.612E+00 |
| 2 | 6 | PUB | 0. | 0. | 0. | 3.532E-01 | 8.292E-01 |
| 3 | 7 | U238 | 0. | 0. | 0. | 4.277E-02 | 3.082E-01 |
| 4 | 9 | FPR | 0. | 0. | 0. | 0. | 1.967E+00 |
| 5 | 10 | B-10 | 0. | 0. | 0. | 0. | 2.833E+00 |

KZ= 1 BREDRT(KZ)= .1644
KZ= 2 BREDRT(KZ)= .0625
KZ= 3 BREDRT(KZ)= .0625
KZ= 4 BREDRT(KZ)= 0.0000

BREEDING RATIO = .2894

* * * * * REFUEL BETWEEN BURNUP INTERVALS 1 AND 2 * * * * *

| | | |
|---|---|---|
| KNT | BURNUP INTERVAL JUST COMPLETED | 1 |
| NREG | NO. OF REGIONS REQUIRING REFUELING | 3 |
| NREPC | REFUEL CONTROL RODS DURING REFUELING (0/1=NO/YES) | 1 |
| KLAPS | REGION COLLAPSE OPTION (0=NO / N=NO.OF COLLAPSES) | 1 |
| INTMAX | MAX. NO. OF BURNUP INTERVALS TO BE ANALYZED | 1 |
| NECOP | PUNCH OPTION FOR INPUT TO ECONOMICS CODE (DATA FROM FIRST NECOP COLLAPSES WILL BE PUNCHED) | 0 |

LAST = 996

LENGTH OF BURNUP INTERVAL 100.0 DAYS

CLEAN FUEL ATOM DENSITIES,HNO(I)

```
I=  1   I0=11   I1= 0   CLEAN DENSITY= 0.0000000
I=  2   I0=11   I1= 4   CLEAN DENSITY=  .0127330
I=  3   I0=11   I1= 1   CLEAN DENSITY=  .0100330
I=  4   I0=11   I1= 2   CLEAN DENSITY=  .0025797
I=  5   I0=11   I1= 3   CLEAN DENSITY=  .0016131
I=  6   I0=11   I1= 5   CLEAN DENSITY=  .0021241
I=  7   I0=11   I1= 6   CLEAN DENSITY=  .0003022
I=  8   I0=11   I1= 7   CLEAN DENSITY=  .0029357
I=  9   I0=11   I1= 9   CLEAN DENSITY= 0.0000000
I= 10   I0=11   I1= 8   CLEAN DENSITY=  .0107300
I= 11   I0=11   I1=10   CLEAN DENSITY=  .0005000
I= 12   I0=12   I1= 0   CLEAN DENSITY= 0.0000000
I= 13   I0=12   I1= 4   CLEAN DENSITY=  .0127330
I= 14   I0=12   I1= 1   CLEAN DENSITY=  .0100330
I= 15   I0=12   I1= 2   CLEAN DENSITY=  .0025797
I= 16   I0=12   I1= 3   CLEAN DENSITY=  .0016131
I= 17   I0=12   I1= 5   CLEAN DENSITY= 0.0000000
I= 18   I0=12   I1= 6   CLEAN DENSITY= 0.0000000
I= 19   I0=12   I1= 7   CLEAN DENSITY=  .0053735
I= 20   I0=12   I1= 9   CLEAN DENSITY= 0.0000000
I= 21   I0=12   I1= 8   CLEAN DENSITY=  .0107300
I= 22   I0=13   I1= 0   CLEAN DENSITY= 0.0000000
I= 23   I0=13   I1= 4   CLEAN DENSITY=  .0127330
I= 24   I0=13   I1= 1   CLEAN DENSITY=  .0100330
I= 25   I0=13   I1= 2   CLEAN DENSITY=  .0025797
I= 26   I0=13   I1= 3   CLEAN DENSITY=  .0016131
I= 27   I0=13   I1= 5   CLEAN DENSITY= 0.0000000
I= 28   I0=13   I1= 6   CLEAN DENSITY= 0.0000000
I= 29   I0=13   I1= 7   CLEAN DENSITY=  .0053735
I= 30   I0=13   I1= 9   CLEAN DENSITY= 0.0000000
I= 31   I0=13   I1= 8   CLEAN DENSITY=  .0107300
I= 32   I0=14   I1= 0   CLEAN DENSITY= 0.0000000
I= 33   I0=14   I1= 1   CLEAN DENSITY=  .0081738
I= 34   I0=14   I1= 2   CLEAN DENSITY=  .0021016
I= 35   I0=14   I1= 3   CLEAN DENSITY=  .0013142
I= 36   I0=14   I1= 4   CLEAN DENSITY=  .0192200
```

REFUELING DATA FOR BURNUP INTERVAL 1

| REGION | REFUELING FRACTIONS | NO.OF INTERVALS BETWEEN REFUELINGS |
|---|---|---|
| 1 | .50000 | 1 |
| 2 | .50000 | 1 |
| 3 | .50000 | 1 |

ELEMENTS (BURNABLE ISOTOPES) TO BE REFUELED IN THE ABOVE REGIONS

| | | |
|---|---|---|
| ELEMENT | 5 | PUA |
| ELEMENT | 6 | PUB |
| ELEMENT | 7 | U238 |
| ELEMENT | 9 | FPR |

I VALUES IN MO1 ARRAY THAT ARE BURNABLE ISOTOPES

| | | | |
|---|---|---|---|
| I= 6 | REGION = 1 | BURN ISO NO. 1 | ELEMENT NO. 5 |
| I= 7 | REGION = 1 | BURN ISO NO. 2 | ELEMENT NO. 6 |
| I= 8 | REGION = 1 | BURN ISO NO. 3 | ELEMENT NO. 7 |
| I= 9 | REGION = 1 | BURN ISO NO. 4 | ELEMENT NO. 9 |
| I= 11 | REGION = 1 | BURN ISO NO. 5 | ELEMENT NO.10 |
| I= 17 | REGION = 2 | BURN ISO NO. 1 | ELEMENT NO. 5 |
| I= 18 | REGION = 2 | BURN ISO NO. 2 | ELEMENT NO. 6 |
| I= 19 | REGION = 2 | BURN ISO NO. 3 | ELEMENT NO. 7 |
| I= 20 | REGION = 2 | BURN ISO NO. 4 | ELEMENT NO. 9 |
| I= 0 | REGION = 2 | BURN ISO NO. 5 | ELEMENT NO.10 |
| I= 27 | REGION = 3 | BURN ISO NO. 1 | ELEMENT NO. 5 |
| I= 28 | REGION = 3 | BURN ISO NO. 2 | ELEMENT NO. 6 |
| I= 29 | REGION = 3 | BURN ISO NO. 3 | ELEMENT NO. 7 |
| I= 30 | REGION = 3 | BURN ISO NO. 4 | ELEMENT NO. 9 |
| I= 0 | REGION = 3 | BURN ISO NO. 5 | ELEMENT NO.10 |

AVG FLUX USED IN PREVIOUS EIGHT BURNUP INTERVALS, PHI(I,J)

| | PHI( 1,J) | PHI( |
|---|---|---|
| J= 1 | .25547E+16 | |
| J= 2 | .10895E+15 | |
| J= 3 | .10894E+15 | |
| J= 4 | .32054E+15 | |

```
ZONE, GROUP AVERAGED ABSORPTION X-SECTIONS FOR BURNABLE ISOTOPES, ARXS(I,J,K) K=KLNT,KNT


  BURNUP INTERVAL K=   1
     REGION    1
.2272E+01    .7709E+00    .2727E+00    .2367E+01    .2288E+01
     REGION    2
.2521E+01    .8136E+00    .2987E+00    .2074E+01    .2687E+01
     REGION    3
.2521E+01    .8136E+00    .2987E+00    .2074E+01    .2687E+01
     REGION    4
.2603E+01    .8278E+00    .3073E+00    .1977E+01    .2819E+01
```

```
ZONE, GROUP AVERAGED FISSION X-SECT FOR BURNABLE ISOTOPES, FIXS(I,J,K), K=KLNT,KNT


  BURNUP INTERVAL K=   1
     REGION    1
.1855E+01    .4068E+00    .5149E-01   0.             0.
     REGION    2
.1975E+01    .3676E+00    .4510E-01   0.             0.
     REGION    3
.1975E+01    .3676E+00    .4510E-01   0.             0.
     REGION    4
.2015E+01    .3545E+00    .4298E-01   0.             0.
```

REGION DISCHARGE AND CHARGE AND INITIAL COMPOSITION FOR NEXT BURNUP INTERVAL

REGION 1 VOLUME=8.0425E+02 LITERS

| ELEMENT | DISCHARGE FROM BI 1 | | CHARGE FOR BI 2 | | INITIAL COMPOSITION BI 2 | |
|---|---|---|---|---|---|---|
| | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) |
| 4 | 0.0000000 | 0. | 0.0000000 | 0. | .0127330 | 3.9088E+02 |
| 1 | 0.0000000 | 0. | 0.0000000 | 0. | .0100330 | 7.4822E+02 |
| 2 | 0.0000000 | 0. | 0.0000000 | 0. | .0025797 | 1.7916E+02 |
| 3 | 0.0000000 | 0. | 0.0000000 | 0. | .0016131 | 1.2646E+02 |
| 5 | .0010171 | 3.2478E+02 | .0010621 | 3.3912E+02 | .0020792 | 6.6391E+02 |
| 6 | .0001580 | 5.0676E+01 | .0001511 | 4.8449E+01 | .0003091 | 9.9125E+01 |
| 7 | .0014591 | 4.6392E+02 | .0014678 | 4.6672E+02 | .0029269 | 9.3064E+02 |
| 9 | .0000443 | 7.0450E+00 | 0.0000000 | 0. | .0000443 | 7.0450E+00 |
| 8 | 0.0000000 | 0. | 0.0000000 | 0. | .0107300 | 2.2924E+02 |
| 10 | 0.0000000 | 0. | 0.0000000 | 0. | .0005000 | 6.6831E+00 |

REGION 2 VOLUME=4.0212E+02 LITERS

| ELEMENT | DISCHARGE FROM BI 1 | | CHARGE FOR BI 2 | | INITIAL COMPOSITION BI 2 | |
|---|---|---|---|---|---|---|
| | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) |
| 4 | 0.0000000 | 0. | 0.0000000 | 0. | .0127330 | 1.9544E+02 |
| 1 | 0.0000000 | 0. | 0.0000000 | 0. | .0100330 | 3.7411E+02 |
| 2 | 0.0000000 | 0. | 0.0000000 | 0. | .0025797 | 8.9578E+01 |
| 3 | 0.0000000 | 0. | 0.0000000 | 0. | .0016131 | 6.3230E+01 |
| 5 | .0000063 | 1.0084E+00 | 0.0000000 | 0. | .0000063 | 1.0084E+00 |
| 6 | .0000000 | 2.6020E-03 | 0.0000000 | 0. | .0000000 | 2.6020E-03 |
| 7 | .0026792 | 4.2594E+02 | .0026868 | 4.2714E+02 | .0053660 | 8.5308E+02 |
| 9 | .0000012 | 9.4096E-02 | 0.0000000 | 0. | .0000012 | 9.4096E-02 |
| 8 | 0.0000000 | 0. | 0.0000000 | 0. | .0107300 | 1.1462E+02 |

REGION 3 VOLUME=4.0212E+02 LITERS

| ELEMENT | DISCHARGE FROM BI 1 | | CHARGE FOR BI 2 | | INITIAL COMPOSITION BI 2 | |
|---|---|---|---|---|---|---|
| | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) |
| 4 | 0.0000000 | 0. | 0.0000000 | 0. | .0127330 | 1.9544E+02 |
| 1 | 0.0000000 | 0. | 0.0000000 | 0. | .0100330 | 3.7411E+02 |
| 2 | 0.0000000 | 0. | 0.0000000 | 0. | .0025797 | 8.9578E+01 |
| 3 | 0.0000000 | 0. | 0.0000000 | 0. | .0016131 | 6.3230E+01 |
| 5 | .0000063 | 1.0084E+00 | 0.0000000 | 0. | .0000063 | 1.0084E+00 |
| 6 | .0000000 | 2.6019E-03 | 0.0000000 | 0. | .0000000 | 2.6019E-03 |
| 7 | .0026792 | 4.2594E+02 | .0026868 | 4.2714E+02 | .0053660 | 8.5308E+02 |
| 9 | .0000012 | 9.4092E-02 | 0.0000000 | 0. | .0000012 | 9.4092E-02 |
| 8 | 0.0000000 | 0. | 0.0000000 | 0. | .0107300 | 1.1462E+02 |

REGION 4 VOLUME=1.4326E+03 LITERS

| ELEMENT | DISCHARGE FROM BI 1 | | CHARGE FOR BI 2 | | INITIAL COMPOSITION BI 2 | |
|---|---|---|---|---|---|---|
| | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) | ATOM DENS | MASS(KG) |
| 1 | 0.0000000 | 0. | 0.0000000 | 0. | .0081738 | 1.0858E+03 |
| 2 | 0.0000000 | 0. | 0.0000000 | 0. | .0021016 | 2.5998E+02 |
| 3 | 0.0000000 | 0. | 0.0000000 | 0. | .0013142 | 1.8352E+02 |
| 4 | 0.0000000 | 0. | 0.0000000 | 0. | .0192200 | 1.0510E+03 |

INPUT ATOM DENSITIES (I2 BLOCK) FOR BURNUP INTERVAL 2

| | | | |
|---|---|---|---|
| I= 1 | I0=11 | I1= 0 | I2(I) = 0.0000000 |
| I= 2 | I0=11 | I1= 4 | I2(I) = .0127330 |
| I= 3 | I0=11 | I1= 1 | I2(I) = .0100330 |
| I= 4 | I0=11 | I1= 2 | I2(I) = .0025797 |
| I= 5 | I0=11 | I1= 3 | I2(I) = .0016131 |
| I= 6 | I0=11 | I1= 5 | I2(I) = .0020792 |
| I= 7 | I0=11 | I1= 6 | I2(I) = .0003091 |
| I= 8 | I0=11 | I1= 7 | I2(I) = .0029269 |
| I= 9 | I0=11 | I1= 9 | I2(I) = .0000443 |
| I= 10 | I0=11 | I1= 8 | I2(I) = .0107300 |
| I= 11 | I0=11 | I1= 10 | I2(I) = .0005000 |
| I= 12 | I0=12 | I1= 0 | I2(I) = 0.0000000 |
| I= 13 | I0=12 | I1= 4 | I2(I) = .0127330 |
| I= 14 | I0=12 | I1= 1 | I2(I) = .0100330 |
| I= 15 | I0=12 | I1= 2 | I2(I) = .0025797 |
| I= 16 | I0=12 | I1= 3 | I2(I) = .0016131 |
| I= 17 | I0=12 | I1= 5 | I2(I) = .0000063 |
| I= 18 | I0=12 | I1= 6 | I2(I) = .0000000 |
| I= 19 | I0=12 | I1= 7 | I2(I) = .0053660 |
| I= 20 | I0=12 | I1= 9 | I2(I) = .0000012 |
| I= 21 | I0=12 | I1= 8 | I2(I) = .0107300 |
| I= 22 | I0=13 | I1= 0 | I2(I) = 0.0000000 |
| I= 23 | I0=13 | I1= 4 | I2(I) = .0127330 |
| I= 24 | I0=13 | I1= 1 | I2(I) = .0100330 |
| I= 25 | I0=13 | I1= 2 | I2(I) = .0025797 |
| I= 26 | I0=13 | I1= 3 | I2(I) = .0016131 |
| I= 27 | I0=13 | I1= 5 | I2(I) = .0000063 |
| I= 28 | I0=13 | I1= 6 | I2(I) = .0000000 |
| I= 29 | I0=13 | I1= 7 | I2(I) = .0053660 |
| I= 30 | I0=13 | I1= 9 | I2(I) = .0000012 |
| I= 31 | I0=13 | I1= 8 | I2(I) = .0107300 |
| I= 32 | I0=14 | I1= 0 | I2(I) = 0.0000000 |
| I= 33 | I0=14 | I1= 1 | I2(I) = .0081738 |
| I= 34 | I0=14 | I1= 2 | I2(I) = .0021016 |
| I= 35 | I0=14 | I1= 3 | I2(I) = .0013142 |
| I= 36 | I0=14 | I1= 4 | I2(I) = .0192200 |

REGION COLLAPSED INFORMATION FOR ELEMENTS TO BE REFUELED

REGION COLLAPSE NO. 1 FROM REGIONS 2 3

VOL AFTER COLLAPSE =8.0425E+02 LITERS

| ELEMENT | COMPOSITION AT END OF BI 1, KG. | DISCHARGE FROM BI 1, KG. | CHARGE FOR BI 2, KG. | INITIAL COMPOSITION FOR BI 2, KG. |
|---|---|---|---|---|
| 5 | 4.0336E+00 | 2.0168E+00 | 0. | 2.0168E+00 |
| 6 | 1.0408E-02 | 5.2039E-03 | 0. | 5.2039E-03 |
| 7 | 1.7038E+03 | 8.5189E+02 | 8.5428E+02 | 1.7062E+03 |
| 9 | 3.7638E-01 | 1.8819E-01 | 0. | 1.8819E-01 |
| 10 | 0. | 0. | 0. | 0. |

DISCHARGE FROM BI 1, CHARGE FOR BI 2 AND INITIAL COMPOS. FOR BI 2 IN KILOGRAMS

| | | | | |
|---|---|---|---|---|
| ELEMENT 1 | IRON | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 2.5822E+03 |
| ELEMENT 2 | CROM | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 6.1829E+02 |
| ELEMENT 3 | NICK | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 4.3643E+02 |
| ELEMENT 4 | NA | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 1.8327E+03 |
| ELEMENT 5 | PUA | TOTAL DISCHARGE = 3.2680E+02 | TOTAL CHARGE = 3.3912E+02 | TOTAL MASS IN REACTOR = 6.6592E+02 |
| ELEMENT 6 | PUB | TOTAL DISCHARGE = 5.0681E+01 | TOTAL CHARGE = 4.8449E+01 | TOTAL MASS IN REACTOR = 9.9130E+01 |
| ELEMENT 7 | U238 | TOTAL DISCHARGE = 1.3158E+03 | TOTAL CHARGE = 1.3210E+03 | TOTAL MASS IN REACTOR = 2.6368E+03 |
| ELEMENT 8 | OXY | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 4.5849E+02 |
| ELEMENT 9 | FPR | TOTAL DISCHARGE = 7.2332E+00 | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 7.2332E+00 |
| ELEMENT 10 | B-10 | TOTAL DISCHARGE = 0. | TOTAL CHARGE = 0. | TOTAL MASS IN REACTOR = 6.6831E+00 |

* * * * P H E N I X * * * *