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Title: PERT-IV, A Two-Dimensional Perturbation Theory Code
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Abstract approved:

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A two-dimensional perturbation theory computer code, PERT-IV, has been developed that will calculate reactivity coefficients, the delayed neutron fraction, and the neutron generation time. The program uses the output flux and adjoint flux from either a diffusion theory or transport theory program. A discussion and derivation of the perturbation equation and expressions for the effective neutron delayed fraction and the neutron generation time are given. In addition, the reactivity coefficients as calculated by diffusion perturbation theory and S_N transport theory are compared.

The input flux and adjoint flux to PERT-IV can be taken directly from two-dimensional calculations or synthesized (by the code) from one-dimensional calculations. The code is compatible with the one-dimensional DTF-IV and two-dimensional 2DF transport theory codes from Los Alamos and the one-dimensional 1DX

and two-dimensional 2DB diffusion theory codes from Battelle-Northwest.

PERT-IV, A Two-Dimensional Perturbation Theory Code for Fast Reactors

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I. INTRODUCTION

Perturbation Theory in General

Nuclear Engineers often desire to calculate the change in the effective multiplication constant, k_{eff}, caused by small changes in the macroscopic cross sections of a nuclear reactor. This is necessary, for example, in the operational calculations of a reactor such as the Fast Test Reactor(2) where numerous samples will be inserted into the core at various test positions. Another example of the usefulness of computing reactivity coefficients ($\delta k_{eff}/k_{eff}$ per mass) is in the analysis of critical assemblies (e.g., ZPR-III, ZPR-VI(12)) where material worths are frequently measured for the purpose of checking cross section data and models.

One method of determining reactivity coefficients is to use a diffusion or transport theory computer code and calculate k_{eff} twice--with and without the sample. The disadvantage of this method is that a separate computer run is required for each reactivity coefficient at each position. Since a typical five energy group, two-dimensional transport theory problem can take from 15 to 30 minutes of UNIVAC 1108 computer time, the calculation of more than a couple material worths becomes very expensive. Moreover, since the change in k_{eff} is usually quite small, the problem must be well converged for accurate worth calculations. Perturbation theory offers the advantage that once the fluxes and adjoint fluxes are known for the unperturbed case, many reactivity coefficients can be calculated very rapidly. A secondary benefit of perturbation theory is that it lends an insight into the causes of the change in k_{eff} due to a variation in the reactor composition because the perturbation equation gives the reactivity coefficient as the sum of four components: fission, absorption, leakage, and moderation.

It should be mentioned at this point that the use of perturbation theory is not a panacea for all material worth calculations. The main disadvantage is that perturbation theory assumes the variation in the reactor composition is "small". Frequently, the variation is either obviously too large for perturbation theory to work well--the insertion of a high worth control rod, for example--or it is unclear whether the variation is too large. Large perturbations in the flux caused by the variation result in large errors in the worth calculations. Therefore, if very accurate worths are desired for samples big enough to significantly perturb the flux, perturbation theory should not be used.

PERT-IV, A Two-Dimensional Perturbation Code

PERT-IV uses flux and adjoint flux output (in the form of punched cards or a binary tape) from diffusion or transport theory codes (e.g., 1DX[7], 2DB[10], DTF-IV[8], 2DF[11]) and calculates reactivity coefficient traverses for any specified row or column in the reactor using first order perturbation theory based on the multigroup diffusion model. If one-dimensional fluxes are used, both an axial and a radial case must be run for the flux and adjoint; the code then synthesizes the fluxes into a two-dimensional array. Each component of the perturbation equation, in addition to the total reactivity coefficient, is printed at each mesh point in the specified row or column.

Input to PERT-IV, in addition to the fluxes, consists of cross sections, axial and radial mesh structure, fission source data, and cross section mixture information. If the absolute number of neutrons per fission for each fissionable isotope, the delayed fission source, and neutron velocities are included, the neutron generation time, Λ, and the effective delayed neutron fraction, β_{eff}, are also calculated. This is a reasonable addition to a perturbation theory code because the expressions for Λ and β_{eff} are similar in many respects to the perturbation equation.

In a 65K memory (and 4 tapes), the code can handle up to 35 materials, 26 energy groups, and a 50 x 50 spatial mesh. The code will calculate up to 20 reactivity coefficient traverses in one run. The running time for a typical run (5 groups) on the UNIVAC 1108 is roughly 20 seconds.

Outline of Thesis

A derivation of the perturbation equation is given in Section II followed by a derivation of the expressions for the neutron generation time and beta effective in Section III. Section IV gives a general description of PERT-IV. Finally, a comparison is given in Section V between worths calculated by first order perturbation theory (PERT-IV), diffusion theory (2DB), and transport theory (DTF-IV and 2DF). Input instructions, a sample problem, and a FORTRAN-IV source deck listing are given in the Appendices.

II. DERIVATION OF PERTURBATION EQUATION

Perturbation theory as applied to reactor physics was developed before the days of high speed computers by Wigner[13] to derive expressions for the change in the pile period due to cross-section changes in the two group equations for a bare, graphite pile. Another early contributor to the perturbation method was Brooks,[4] who derived an expression for the change in reactivity resulting from changes in the cross sections in the multigroup equations for a pile.

To derive the perturbation equation, we shall begin with the familiar multigroup time independent diffusion equation for an unperturbed system.

$$\overline{\nabla}\cdot D_i \overline{\nabla\phi}_i - \Sigma_a^i \phi_i - \sum_{j=i+1}^{N} \Sigma(i\to j)\phi_i + \frac{\chi_i}{k} \sum_{j=1}^{N} (\nu\Sigma_f)^j \phi_j + \sum_{j=1}^{i-1} \Sigma(j\to i)\phi_j = 0 \quad , \tag{2.1}$$

where:

N = number of energy groups,

ϕ_i = flux in group i (n-cm^{-2}-sec^{-1}),

χ_i = fission source born in group i ($\sum_{i=1}^{N} \chi_i = 1.0$),

Σ_a^i = macroscopic absorption cross section in group i (cm^{-1}),

D_i = diffusion coefficient for energy group i (cm),

$\Sigma(i \to j)$ = macroscopic transfer cross section from group i to group j (cm^{-1}),

k = effective multiplication factor,

$(\nu\Sigma_f)^i$ = macroscopic fission source cross section in group i (cm^{-1}).

Although the flux and cross sections are a function of position, for simplicity, the spatial variables are not explicitly shown.

A similar expression can also be written for a perturbed system.

$$\overline{\nabla} \cdot D_i' \overline{\nabla \phi_i'} - \Sigma_a^{i'} \phi_i' - \sum_{j=i+1}^{N} \Sigma'(i \to j) \phi_i' + \frac{\chi_i}{k'} \sum_{j=1}^{N} (\nu\Sigma_f)^{j'} \phi_j' + \sum_{j=1}^{i-1} \Sigma'(j \to i) \phi_j' = 0 \quad , \tag{2.2}$$

where: $\Sigma^{i'} = \Sigma^i + \delta\Sigma^i$ for $\Sigma_a^{i'}$, $\Sigma_f^{i'}$ and $\Sigma'(i \to j)$,

$D_i' = D_i + \delta D_i$,

$\phi_i' = \phi_i + \delta\phi_i$,

$k' = k + \delta k$.

First, we multiply Equations (2.1) and (2.2) by an arbitrary weighting function ψ_i (also a function of spatial position), sum over all groups, integrate over the entire volume of the reactor, and subtract the first integral equation from the second. This yields

$$\int_V \sum_{i=1}^{N} \psi_i(\overline{\nabla}\cdot D_i'\overline{\nabla\phi_i'} - \overline{\nabla}\cdot D_i\overline{\nabla\phi_i})dV - \int_V \sum_{i=1}^{N} \psi_i(\Sigma_a^{i'}\phi_i' - \Sigma_a^{i}\phi_i)dV$$

$$-\int_V \sum_{i=1}^{N} \psi_i(\sum_{j=i+1}^{N} \Sigma'(i\to j)\phi_i' - \sum_{j=i+1}^{N} \Sigma(i\to j)\phi_i)dV$$

$$+\int_V [\sum_{i=1}^{N} \frac{\psi_i\chi_i}{k'} \sum_{j=1}^{N} (\nu\Sigma_f)^{j'}\phi_j' - \sum_{i=1}^{N} \frac{\psi_i\chi_i}{k} \sum_{j=1}^{N} (\nu\Sigma_f)^{j}\phi_j]dV$$

$$+\int_V \sum_{i=1}^{N} \psi_i[\sum_{j=1}^{i-1} \Sigma'(j\to i)\phi_j' - \sum_{j=1}^{i-1} \Sigma(j\to i)\phi_j]dV = 0 \quad , \tag{2.3}$$

or,

$$I_1 + I_2 + I_3 + I_4 + I_5 = 0 \quad , \tag{2.4}$$

where I_1, I_2, I_3, I_4, and I_5 are the individual integrals.

The next step is to expand the primed quantities in Equation (2.3) and consider each integral separately. First order perturbation theory consists of ignoring all terms higher than first order. That is,

$$\Sigma'\phi' = (\Sigma + \delta\Sigma)(\phi + \delta\phi) \approx \Sigma\phi + \phi\delta\Sigma + \Sigma\delta\phi \quad .$$

Expanding the diffusion coefficient and fluxes to the first order and then cancelling the second term in the first integral leaves

$$I_1 = \int_V \sum_{i=1}^{N} \psi_i[\overline{\nabla}\cdot\delta D_i\overline{\nabla\phi_i} + \overline{\nabla}\cdot D_i\overline{\nabla\delta\phi_i}]dV \quad . \tag{2.5}$$

Equation (2.5) can also be written as

$$I_1 = \delta \int_V \sum_{i=1}^{N} \psi_i[\overline{\nabla}\cdot D_i\overline{\nabla\phi_i}]dV \quad . \tag{2.6}$$

To evaluate the above equation, we will make use of Green's theorem in first and second form.

$$\int_V D\overline{\nabla\phi}\cdot\overline{\nabla\psi}dV = \int_S \phi D\overline{\nabla\psi}\cdot d\overline{S} - \int_V \phi\overline{\nabla}\cdot D\overline{\nabla\psi}dV \quad , \tag{2.7}$$

and

$$\int_V D\overline{\nabla\phi}\cdot\overline{\nabla\psi}dV = \int_S \psi D\overline{\nabla\phi}\cdot d\overline{S} - \int_V \psi\overline{\nabla}\cdot D\overline{\nabla\phi}dV \quad . \tag{2.8}$$

Applying Green's theorem in second form to Equation (2.6),

$$I_1 = \delta \int_S \sum_{i=1}^{N} \psi_i D_i\overline{\nabla\phi_i}\cdot d\overline{S} - \delta \int_V \sum_{i=1}^{N} D_i\overline{\nabla\phi_i}\cdot\overline{\nabla\psi_i}dV \quad . \tag{2.9}$$

Now, since diffusion theory assumes that the current, $D_i\overline{\nabla\phi_i}$, is a continuous function across an interface of two dissimilar media, $D_i\overline{\nabla\phi_i}$ is constant at the surface of the volume where the perturbation occurs. Therefore, the first term in Equation (2.9) is zero. This assumes, of course, that ψ_i is also continuous across the interface. To circumvent the case when the perturbation is over the whole reactor and the interface is not between two media, we require that ψ_i vanish at the reactor boundary.

Taking the variation of the second term in Equation (2.9) gives

$$I_1 = -\int_V \sum_{i=1}^{N} \delta D_i \overline{\nabla\phi_i} \cdot \overline{\nabla\psi_i} dV - \int_V \sum_{i=1}^{N} D_i \overline{\nabla\delta\phi_i} \cdot \overline{\nabla\psi_i} dV \quad . \tag{2.10}$$

Using Green's theorem in first form in the second term of Equation (2.10),

$$I_1 = -\int_V \sum_{i=1}^{N} \delta D_i \overline{\nabla\phi_i} \cdot \overline{\nabla\psi_i} dV - \int_S \sum_{i=1}^{N} \delta\phi_i D_i \overline{\nabla\psi_i} \cdot d\overline{S}$$
$$+ \int_V \sum_{i=1}^{N} \delta\phi_i \overline{\nabla} \cdot D_i \overline{\nabla\psi_i} dV \quad . \tag{2.11}$$

The first term in Equation (2.9) was found to be equal to zero because the current is continuous across an interface. Similarly, the flux is a continuous function causing the surface integral in Equation (2.11) to also vanish.

Therefore, we conclude that

$$I_1 = -\int_V \sum_{i=1}^{N} \delta D_i \overline{\nabla\phi_i} \cdot \overline{\nabla\psi_i} dV + \int_V \sum_{i=1}^{N} \delta\phi_i \overline{\nabla} \cdot D_i \overline{\nabla\psi_i} dV \quad . \tag{2.12}$$

The second integral in Equation (2.3) is simply

$$I_2 = -\int_V \sum_{i=1}^{N} (\psi_i \phi_i \delta\Sigma_a^i) dV - \int_V \sum_{i=1}^{N} (\psi_i \Sigma_a^i \delta\phi_i) dV \quad . \tag{2.13}$$

To evaluate the fourth integral, we note that for small δk,

$$\frac{1}{k'} = \frac{1}{k + \delta k} \approx \frac{1}{k}\left(1 - \frac{\delta k}{k}\right) \quad . \tag{2.14}$$

Therefore,

$$I_4 = \int_V \frac{1}{k}\left[\sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} \phi_j \delta(\nu\Sigma_f)^j\right] dV$$

$$- \frac{\delta k}{k} \int_V \frac{1}{k}\left[\sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \phi_j\right] dV$$

$$+ \int_V \frac{1}{k}\left[\sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \delta\phi_j\right] dV \quad . \tag{2.15}$$

Since the third and fifth integrals are somewhat related, we shall work on them together.

$$I_3 + I_5 = - \int_V \left[\sum_{i=1}^{N} \psi_i \sum_{j=i+1}^{N} \phi_i \delta\Sigma(i\to j)\right] dV$$

$$- \int_V \left[\sum_{i=1}^{N} \psi_i \sum_{j=i+1}^{N} \Sigma(i\to j)\delta\phi_i\right] dV$$

$$+ \int_V \left[\sum_{i=1}^{N} \psi_i \sum_{j=1}^{i-1} \phi_j \delta\Sigma(j\to i)\right] dV$$

$$+ \int_V \left[\sum_{i=1}^{N} \psi_i \sum_{j=1}^{i-1} \Sigma(j\to i)\delta\phi_j\right] dV \quad . \tag{2.16}$$

To simplify the above expression, we consider the following double summation,

$$DS = \sum_{i=1}^{N} \psi_i \sum_{j=1}^{i-1} \phi_j \Sigma(j \rightarrow i) \quad . \tag{2.17}$$

If we put ψ_i inside the second summation, reverse the order of the summation, and note that $i > j$,

$$DS = \sum_{j=1}^{N} \sum_{i=j+1}^{N} \psi_i \Sigma(j \rightarrow i) \phi_j \quad . \tag{2.18}$$

Finally, interchanging the indices and pulling ϕ_i outside the second summation results in the following identity:

$$\sum_{i=1}^{N} \psi_i \sum_{j=1}^{i-1} \phi_j \Sigma(j \rightarrow i) = \sum_{i=1}^{N} \phi_i \sum_{j=i+1}^{N} \psi_j \Sigma(i \rightarrow j) \quad . \tag{2.19}$$

The above equation enables us to write Equation (2.16) as

$$I_3 + I_5 = \int_V \sum_{i=1}^{N} \phi_i \sum_{j=i+1}^{N} \delta\Sigma(i \rightarrow j) \left(\psi_j - \psi_i\right) dV$$

$$+ \int_V \sum_{i=1}^{N} \delta\phi_i \left(\sum_{j=i+1}^{N} \Sigma(i \rightarrow j) \psi_j - \sum_{j=i+1}^{N} \Sigma(i \rightarrow j) \psi_i \right) dV \quad . \tag{2.20}$$

Substituting the values for I_1, I_2, I_3, I_4, and I_5 in Equation (2.4) and solving for $\delta k/k$, we get

$$\frac{\delta k}{k} = \int_V \Bigg\{ \sum_{i=1}^{N} \Bigg[\frac{1}{k}\delta(\nu\Sigma_f)^i \phi_i \sum_{j=1}^{N} \chi_j\psi_j - \delta\Sigma_a^i \phi_i\psi_i$$

$$- \delta D_i(\overline{\nabla\phi}_i \cdot \overline{\nabla\psi}_i) + \sum_{j=i+1}^{N} \delta\Sigma(i\to j)\phi_i(\psi_j - \psi_i)$$

$$+ \delta\phi_i\Bigg(\overline{\nabla}\cdot D_i\overline{\nabla\psi}_i - \Sigma_a^i\psi_i - \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_i + \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_j$$

$$+ \frac{(\nu\Sigma_f)^i}{k} \sum_{j=1}^{N} \chi_j\psi_j\Bigg)\Bigg]\Bigg\} dV \Big/ \frac{1}{k}\int_V \sum_{i=1}^{N} \chi_i\psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \phi_j dV. \tag{2.21}$$

Now, we note that if the coefficient of $\delta\phi_i$ is equal to zero, then the variation in the flux doesn't contribute to the perturbation equation. Therefore, we define the weighting function as

$$\overline{\nabla}\cdot D_i\overline{\nabla\psi}_i - \Sigma_a^i\psi_i - \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_i + \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_j$$

$$+ \frac{(\nu\Sigma_f)^i}{k} \sum_{j=1}^{N} \chi_j\psi_j = 0 \quad . \tag{2.22}$$

Observe that this is simply the adjoint equation. The relationship between the diffusion equation, Equation (2.1), and the adjoint equation is easily understood since if one writes the diffusion equation in matrix form,

$$\bar{\bar{M}}\bar{\phi} = 0 \quad ,$$

the adjoint equation can be written as

$$\bar{\bar{M}}^T\bar{\psi} = 0 \quad ,$$

where $\bar{\bar{M}}^T$ is the transpose of $\bar{\bar{M}}$. It should be mentioned that, unlike the flux, the adjoint flux is dimensionless.

It is easy to show the physical significance of the adjoint flux. To do this, let ξ_i be the worth of a neutron in energy group i, where we have again not explicitly shown the spatial dependence.

The neutron worth, or total number of neutrons produced by inserting one neutron in energy group i is

$$\xi_i = \frac{\dfrac{(\nu\Sigma_f)^i\phi_i}{k}\displaystyle\sum_{j=1}^{N}\chi_j\xi_j + \sum_{j=i+1}^{N}\Sigma(i\to j)\phi_i\xi_j}{-\bar{\nabla}\cdot D_i\overline{\nabla\phi_i} + \Sigma_a^i\phi_i + \displaystyle\sum_{j=i+1}^{N}\Sigma(i\to j)\phi_i} \quad , \tag{2.23}$$

where the first term in the numerator is the number of neutrons emitted from fission multiplied by the worth of an averaged fission neutron, $\sum_{j=1}^{N}\chi_j\xi_j$, and the second term is the scattering into group j multiplied by the worth in j. The denominator is just the loss rate.

We now clear Equation (2.23) of fractions, integrate over the volume of the reactor, and use Green's theorem on the leakage term. Since the flux and adjoint flux vanish on the boundary, we can cancel ϕ_i from both sides and write

$$\overline{\nabla}\cdot D_i \overline{\nabla \xi_i} - \Sigma_a^i \xi_i - \sum_{j=i+1}^{N} \Sigma(i\to j)\xi_i + \sum_{j=i+1}^{N} \Sigma(i\to j)\xi_j + \frac{(\nu\Sigma_f)^i}{k} \sum_{j=1}^{N} \chi_j \xi_j = 0 \quad . \tag{2.24}$$

Comparing Equation (2.24) with Equation (2.22), $\xi_i = \psi_i$ and the weighting function is simply the neutron worth or adjoint flux.

With this interpretation of the adjoint flux, it is now possible to assign a physical meaning to each of the four components of Equation (2.21), the perturbation equation. Changes in the neutron fission source rate are weighted by the worth of an average fission neutron while changes in the absorption rate are weighted by the neutron worth at the point of capture. The third term is the worth due to a change in the leakage rate. Note that since $D = \frac{1}{3\Sigma_{tr}}$,

$$\delta D_i = - \frac{1}{3(\Sigma_{tr}^i)^2} \delta(\Sigma_{tr}^i) \quad ,$$

where Σ_{tr}^i = macroscopic transport cross section in group i(cm^{-1}). Finally, as seen in the fourth term, variations in $\Sigma(i \rightarrow j)$ are weighted by the worth in group i minus the worth in group j.

III. DERIVATION OF NEUTRON GENERATION TIME AND BETA EFFECTIVE EQUATIONS

The time dependent diffusion equation for energy group i with NP delayed precursor groups can be written as

$$\frac{1}{v_i}\frac{\partial \Phi_i}{\partial t} = \overline{\nabla}\cdot D_i \overline{\nabla \Phi_i} - \Sigma_a^i \Phi_i - \Sigma_r^i \Phi_i + \chi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \Phi_j$$

$$- \chi_i \sum_{j=1}^{N} \Phi_j \sum_{m=1}^{ND} \beta_m (\nu\Sigma_f)_m^j + \chi_i^D \sum_{K=1}^{NP} \lambda_K C_K$$

$$+ \sum_{j=1}^{i-1} \Sigma(j\to i)\Phi_j \quad , \tag{3.1}$$

where:

Φ_i = flux in group i (n-cm^{-2}-sec^{-1}),

v_i = neutron velocity in energy group i (cm/sec),

Σ_r^i = macroscopic scattering removal cross section in group i (cm^{-1}),

β_m = number of delayed neutrons/fission neutrons for fissionable isotope m,

ND = number of fissionable isotopes,

NP = number of precursor groups,

$(\nu\Sigma_f)^i_m$ = macroscopic fission source cross section in group i for fissionable isotope m (cm^{-1}),

χ^D_i = delayed fission source born in group i $\sum_{i=1}^{N} \chi^D_i = 1.0)$,

λ_K = decay constant for delayed precursor group K (sec^{-1}),

and C_K = density for delayed precursor group K (cm^{-3}).

All other symbols in the above equation were defined after Equation (2.1) in the previous section. It is obvious from Equation (3.1) that the flux and precursor density are functions of both spatial position and time. Note the assumption is made that χ^D_i is independent of the delayed precursor group.

The differential equation describing the time behavior of the Kth precursor group is

$$\frac{\partial C_K}{\partial t} = \sum_{j=1}^{N} \Phi_j \sum_{m=1}^{ND} \beta^K_m (\nu\Sigma_f)^j_m - \lambda_K C_K \quad , \tag{3.2}$$

where:

β^K_m = delayed neutron fraction for precursor group K for fissionable isotope m ($\beta_m = \sum_{K=1}^{NP} \beta^K_m$) .

From Section II, we saw that the time independent adjoint equation for energy group i is

$$0 = \overline{\nabla}\cdot D_i\overline{\nabla\psi}_i - \Sigma_a^i\psi_i - \Sigma_r^i\psi_i + \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_j + \frac{(\nu\Sigma_f)^i}{k}\sum_{j=1}^{N} \chi_j\psi_j \quad . \tag{3.3}$$

Equation (3.1) is now multiplied by the adjoint flux and Equation (3.3) by the flux, both equations summed over all groups and integrated over the volume of the reactor. Subtracting the second resulting integral equation from the first,

$$\begin{aligned}
\int_V \sum_{i=1}^{N} \frac{\psi_i}{v_i}\frac{\partial\Phi_i}{\partial t}\,dV &= \int_V \sum_{i=1}^{N} \psi_i\overline{\nabla}\cdot D_i\overline{\nabla\Phi}_i\,dV - \int_V \sum_{i=1}^{N} \psi_i\Sigma_a^i\Phi_i\,dV \\
&- \int_V \sum_{i=1}^{N} \psi_i\Sigma_r^i\Phi_i\,dV + \int_V \sum_{i=1}^{N} \chi_i\psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j\Phi_j\,dV \\
&- \int_V \sum_{i=1}^{N} \chi_i\psi_i \sum_{j=1}^{N} \Phi_j \sum_{m=1}^{ND} \beta_m(\nu\Sigma_f)_m^j\,dV + \int_V \sum_{i=1}^{N} \chi_i^D\psi_i \sum_{K=1}^{NP} \lambda_K C_K\,dV \\
&+ \int_V \sum_{i=1}^{N} \psi_i \sum_{j=1}^{i-1} \Sigma(j\to i)\Phi_j\,dV - \int_V \sum_{i=1}^{N} \Phi_i\overline{\nabla}\cdot D_i\overline{\nabla\psi}_i\,dV \\
&+ \int_V \sum_{i=1}^{N} \Phi_i\Sigma_a^i\psi_i\,dV + \int_V \sum_{i=1}^{N} \Phi_i\Sigma_r^i\psi_i\,dV - \int_V \sum_{i=1}^{N} \Phi_i \sum_{j=i+1}^{N} \Sigma(i\to j)\psi_j\,dV \\
&- \int_V \sum_{i=1}^{N} \frac{(\nu\Sigma_f)^i\Phi_i}{k} \sum_{j=1}^{N} \chi_j\psi_j\,dV \quad .
\end{aligned} \tag{3.4}$$

To simplify Equation (3.4), we shall utilize the following relationships.

Applying Green's theorem,

$$\int_V \sum_{i=1}^{N} \Phi_i \overline{\nabla}\cdot D_i \overline{\nabla\psi_i} dV = \int_V \sum_{i=1}^{N} \psi_i \overline{\nabla}\cdot D_i \overline{\nabla\Phi_i} dV$$

$$+ \int_V \sum_{i=1}^{N} D_i (\Phi_i \overline{\nabla\psi_i} - \psi_i \overline{\nabla\Phi_i})\cdot d\overline{S} \quad . \tag{3.5}$$

Since the flux and adjoint flux both vanish at the reactor boundary, the second integral on the right side of the above equation is zero and we can write

$$\int_V \sum_{i=1}^{N} \Phi_i \overline{\nabla}\cdot D_i \overline{\nabla\psi_i} dV = \int_V \sum_{i=1}^{N} \psi_i \overline{\nabla}\cdot D_i \overline{\nabla\Phi_i} dV \quad . \tag{3.6}$$

Defining ρ = reactivity = $\frac{k-1}{k}$,

$$\int_V \sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \Phi_j dV - \int_V \sum_{i=1}^{N} \frac{(\nu\Sigma_f)^i \Phi_i}{k} \sum_{j=1}^{N} \chi_j \psi_j dV$$

$$= \rho \int_V \sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \Phi_j dV \quad . \tag{3.7}$$

Substituting Equations (2.19), (3.6), and (3.7) into Equation (3.4) gives, after cancellation,

$$\int_V \sum_{i=1}^{N} \frac{\psi_i}{v_i} \frac{\partial \Phi_i}{\partial t} dV = \rho \int_V \sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \Phi_j dV$$
$$- \int_V \sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} \Phi_j \sum_{m=1}^{ND} \beta_m (\nu\Sigma_f)_m^j dV$$
$$+ \int_V \sum_{i=1}^{N} \chi_i^D \psi_i \sum_{K=1}^{NP} \lambda_K C_K dV \quad . \tag{3.8}$$

We now multiply Equation (3.2) by $\sum_{i=1}^{N} \chi_i^D \psi_i$ and integrate over the volume of the reactor.

$$\int_V \sum_{i=1}^{N} \chi_i^D \psi_i \frac{\partial C_K}{\partial t} dV = \int_V \sum_{i=1}^{N} \chi_i^D \psi_i \sum_{j=1}^{N} \Phi_j \sum_{m=1}^{ND} \beta_m^K (\nu\Sigma_f)_m^j dV$$
$$- \int_V \sum_{i=1}^{N} \chi_i^D \psi_i \lambda_K C_K dV \quad . \tag{3.9}$$

What is now desired is to reduce Equations (3.8) and (3.9) to the conventional form of the reactor kinetics equations,

$$\frac{dT(t)}{dt} = \frac{\rho - \beta}{\Lambda} T(t) + \sum_{K=1}^{NP} \lambda_K C_K \quad , \tag{3.10}$$

and

$$\frac{dC_K(t)}{dt} = \frac{\beta}{\Lambda} T(t) - \lambda_K C_K \quad . \tag{3.11}$$

As noted earlier, the flux in Equation (3.8) is a function of both space and time. For a homogeneous reactor, the spatial and time variables are separable and one can speak of the time behavior for the reactor as a whole. For a zoned reactor, however, the variables are not separable and it is necessary to express the flux as the product of two functions.

$$\Phi_i(r,t) = \phi_i(r,t)T(t) \quad . \tag{3.12}$$

At first glance, it doesn't appear that this helps much. However, it is assumed that the nonseparable portion of the flux, $\phi_i(r,t)$ becomes independent of time after a sufficiently large time following the perturbation. That is,

$$\lim_{t\to\infty} \Phi_i(r,t) = \phi_i(r) \equiv \phi_i \quad . \tag{3.13}$$

Therefore, $T(t)$ represents the asymptotic time behavior of the flux. A discussion of the transient neutron flux for a zoned reactor is given by Crawford,(5, p. 41-56) where, using diffusion theory, he expands the flux as a sum of model fluxes and writes the kinetics equations for each mode.

As a consequence of Equation (3.13), we write

$$\int_V \sum_{i=1}^{N} \frac{\psi_i}{v_i} \frac{\partial \Phi_i}{\partial t} dV \approx \int_V \sum_{i=1}^{N} \frac{\psi_i}{v_i} \phi_i \frac{dT(t)}{dt} dV$$

$$= \frac{dT(t)}{dt} \int_V \sum_{i=1}^{N} \frac{\psi_i \phi_i}{v_i} dV \quad . \tag{3.14}$$

Let

$$I = \int_V \sum_{i=1}^{N} \chi_i \psi_i \sum_{j=1}^{N} (\nu\Sigma_f)^j \phi_j dV \quad . \tag{3.15}$$

Now, we make the following definitions:

$$\Lambda = \frac{\int_V \sum_{i=1}^{N} \frac{\psi_i \phi_i}{v_i} dV}{I} \quad , \tag{3.16}$$

$$\beta_{eff} = \frac{\int_V \sum_{i=1}^{N} \chi_i^D \psi_i \sum_{j=1}^{N} \phi_j \sum_{m=1}^{ND} \beta_m (\nu\Sigma_f)_m^j dV}{I} \quad , \tag{3.17}$$

$$C_K = \frac{\int_V \sum_{i=1}^{N} \chi_i^D \psi_i \; c_K \, dV}{\Lambda I} \quad . \tag{3.18}$$

The next step is to substitute Equations (3.12), (3.13), (3.14), (3.15), (3.16), (3.17) and (3.18) into Equations (3.8) and (3.9). Equation (3.8) reduces to

$$\Lambda I \frac{dT(t)}{dt} = \rho I T(t) - \beta_{eff} I T(t) + \Lambda I \sum_{K=1}^{NP} \lambda_K C_K(t)$$
$$+ \int_V \sum_{j=1}^{N} \phi_j \sum_{m=1}^{ND} \beta_m (\nu\Sigma_f)_m^j \left(\sum_{i=1}^{N} \chi_i^D \psi_i - \sum_{i=1}^{N} \chi_i \psi_i \right) dV \quad . \tag{3.19}$$

Equation (3.9) reduces to

$$\Lambda I \frac{dC_K(t)}{dt} = \beta^K_{eff}\ IT(t) - \lambda_K C_K(t)\Lambda I \tag{3.20}$$

The last integral in Equation (3.19) is simply the difference in worth between the delayed neutrons and an equivalent number of prompt neutrons. Since the number of delayed neutrons is small, and the difference in their worths is also small, the product is a very small number and can be dropped for most purposes. Dividing Equations (3.19) and (3.20) by ΛI,

$$\frac{dT(t)}{dt} = \frac{\rho - \beta_{eff}}{\Lambda}\ T(t) + \sum_{K=1}^{NP} \lambda_K C_K(t) \tag{3.21}$$

$$\frac{dC_K(t)}{dt} = \frac{\beta^K_{eff}}{\Lambda} T(t) - \lambda_K C_K(t) \quad . \tag{3.22}$$

The expressions for beta effective and neutron generation time in Equations (3.16) and (3.17), therefore, result in equations in the same form as the kinetics equations, Equations (3.10) and (3.11). There are several obvious similarities between the equations for beta effective and neutron generation time and the perturbation equation derived in the previous section. For example, I appears in all of the denominators, and the steady-state flux and adjoint flux appear in all expressions.

IV. GENERAL DESCRIPTION OF PERT-IV

Limits on Problem Complexity

PERT-IV is written in FORTRAN-IV for use on the UNIVAC 1107 or 1108. The maximum value of the input variables are as follows:

Variable	Definition	Maximum Value
IGM	No. of Energy Groups	26
IST	No. of Downscattering Terms	10
IM	No. of Radial Intervals	50
JM	No. of Axial Intervals	50
MCR	No. of Cross Sections from Cards	25
MTP	No. of Cross Sections from Tape	25
IZM	No. of Material Zones	35
MT	No. of Materials Including Mixes	35
MO1	No. of Mixture Specifications	45
NDELK	No. of Reactivity Traverses	20
NIBC	No. of Isotopes in β_{eff} Calculation	20
NACT	No. of Activity Traverses	3

A 65K core and 4 scratch tapes are required for the above specifications. If a smaller core must be used, either reducing the number of radial and axial intervals or the number of groups is an easy way to decrease storage. Running time for a typical problem (5 groups, 20 reactivity traverses) is about 20 seconds on the 1108.

Format of Input Fluxes and Adjoint Fluxes

The input flux and adjoint flux options are:

- Flux and adjoint from 1-D
- Flux and adjoint from 2-D
- Flux from 1-D, adjoint from 2-D
- Flux from 2-D, adjoint from 1-D
- Flux from 1-D, no adjoint
- Flux from 2-D, no adjoint.

When 1-D flux dumps are used, PERT-IV synthesizes these into 2-D arrays by assuming that the fluxes and adjoint fluxes are separable in the two dimensions over the whole reactor. For the last two options, the code assumes a flat adjoint distribution. Flux input can be taken directly from DTF-IV or 2DF, although other diffusion or transport theory codes may be used to provide fluxes and adjoint fluxes.

Flux Normalization Options

Four options are available for normalizing the flux. These are:

- Center point flux
- Center point power density
- Total reactor power
- Denominator of perturbation equation (see Equation 2.21).

The adjoint flux is always normalized such that the fission source times the adjoint, summed over all groups, is unity at the center mesh point.

Reactivity Coefficient Calculations

PERT-IV will calculate reactivity coefficient (in units of $\delta k/k$ per kg) traverses for any specified row or column in R-Z, X-Y, or R-Θ geometry. The contribution of each component of the reactivity coefficient (e.g., moderation, capture) is also given.

Neutron Generation Time and Beta Effective Calculations

Using Equations (3.16) and (3.17), PERT-IV calculates the neutron generation time and the effective delayed neutron fraction. Additional input includes the neutron velocities for each group, the absolute number of neutrons per fission for each fissionable isotope (= $\beta\ \nu$), and the delayed fission source. A single delayed fission source distribution is assumed for all delayed groups and isotopes.

Activity Traverses

For any material and cross section (e.g., σ_f, σ_a), the code will calculate and print an activity map. A full print gives the activity at each mesh point for each group; a partial print gives the total over all groups at each mesh point. Zone averaged activities are also given.

Other Options

Minor options in PERT-IV include:

- Option to punch either flux or adjoint flux, or both.

- Full print option to print flux, adjoint flux and activity traverses for each group and an extended print out of cross sections
- Option to read in a value for k_{eff} to be used in reactivity coefficient calculations--useful when k_{eff} as calculated by PERT-IV is significantly different from the transport theory value.

Typical Results

A plot of the axial worth of Pu239 in a typical fast reactor as calculated by PERT-IV is shown in Figure 4.1. The graph also includes each component to the total reactivity coefficient. As one would expect, the magnitude of the contribution due to fissions, absorptions, and moderations is a maximum in the center of the core and decreases to the edge of the reactor. The leakage component, however, is zero at the center, reaches a maximum at the core-reflector interface, and then decreases to the reactor edge.

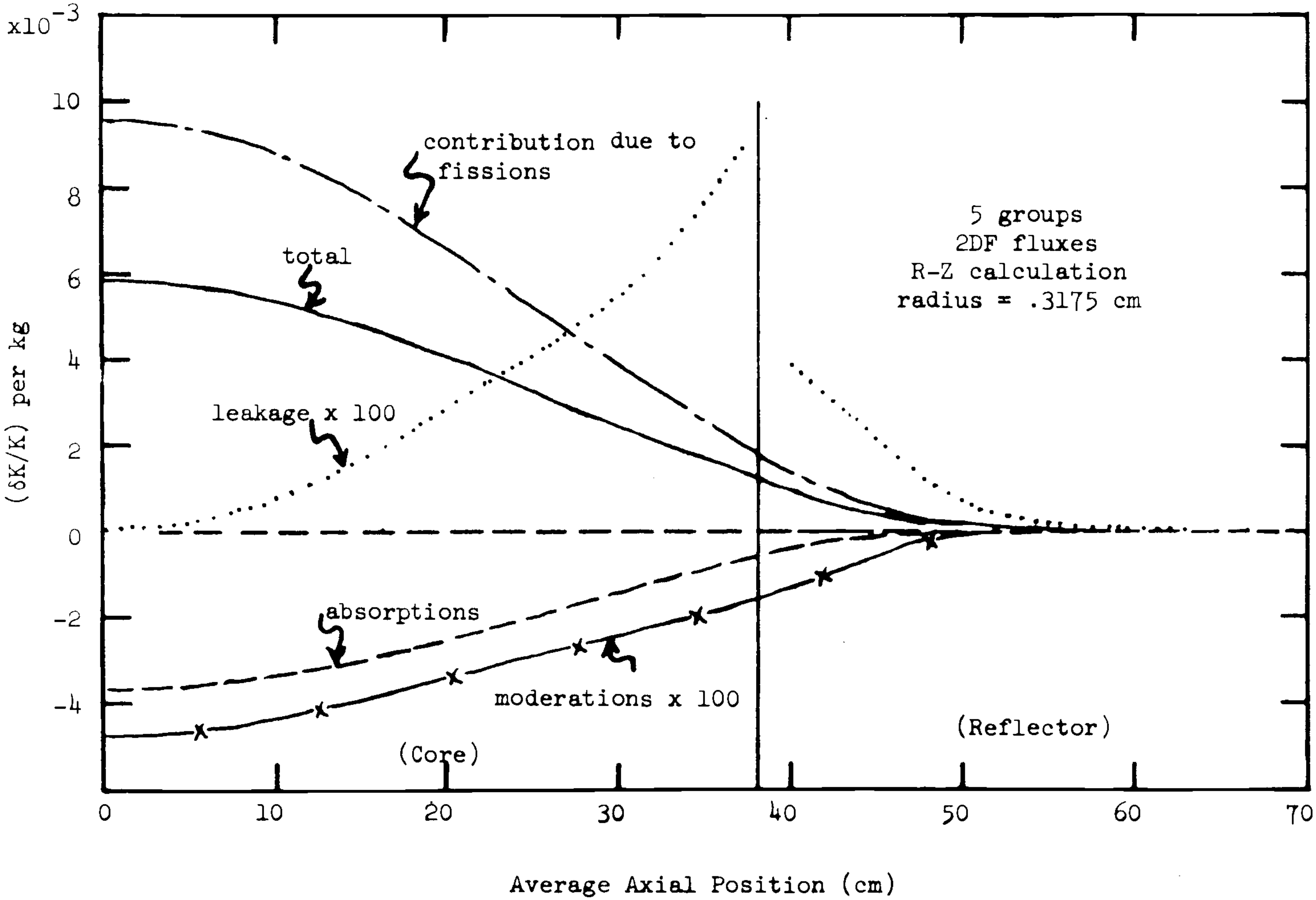

Figure 4.1. Axial worth curve of Pu-239 in ZPR-3 Assembly 48

V. COMPARISON BETWEEN DIFFUSION PERTURBATION THEORY AND TRANSPORT THEORY

Since the best way to assess diffusion perturbation theory is to compare results with a two-dimensional transport theory code, reactivity coefficients were computed using both PERT-IV and 2DF for a variety of materials and energy groups for a typical fast reactor core. Such a comparison is necessarily incomplete, however, because of the numerous items to check and the long time required for a 2-D transport theory calculation.

Calculations were performed using R-Z geometry for ZPR-III Assembly 48,[6, p. 57-64] a zero power fast critical assembly located at Idaho Falls. ZPR-III Assembly 48 was a 417 liter, plutonium fueled core, cylindrical in shape, and surrounded by a 30 cm thick reflector in both the axial and radial directions. The reactor dimensions and composition are given in Figure 5.1 and Table 5.1.

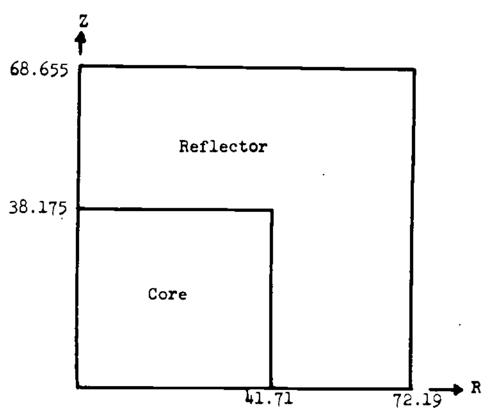

Figure 5.1. Reactor dimensions for ZPR-3 Assembly 48

Table 5.1

Reactor Composition for ZPR-III Assembly 48

(atoms-barn^{-1}-cm^{-1})

Material	Core Atom Densities	Reflector Atom Densities
Pu239	.001654	.0
Pu240	.000106	.0
U235	.000016	.000084
U238	.007406	.039976
C	.020765	.0
Na	.006230	.0
Fe	.009899	.004453
Cr	.002658	.001196
Ni	.001308	.000588
Mo	.000206	.0
Al	.000110	.0

Cross section input consisted of a modified version of the Russian data compilation.(1) The data was punched using FCC,(9) a fundamental mode fast reactor code that will punch an n group Russian cross section set, where $26 \geq n \geq 1$.

The calculated reactivity coefficients in units of $(\delta k/k)$ per kg in the center of ZPR-3 Assembly 48 (R-Z geometry) are shown in Table 5.2. To negate the effect of sample size, most of the 2DF

Table 5.2

Calculated Reactivity Coefficients

in the Center of ZPR-3 Assembly 48

Row	Number of Groups	Code	Order of SN Approximation	Pu239	Pu240	U235	Na	Fe	B10
1	1	2DF	S2	5.71†	-	4.09	-	-	-
2	1	PERT 2DF fluxes	S2	5.487	.429	3.942	-.098	-.171	-96.61
3	1	2DF	S4	5.45	-	-	-	-	-
4	1	PERT 2DF fluxes	S4	5.338	.429	3.847	-.094	-.164	-
5	1	2DF	S6	5.43	-	-	-	-	-
6	1	PERT 2DF fluxes	S6	5.336	.429	3.845	-.094	-.164	-
7	2	2DF	S2	5.86	.47	4.19	-.126	-.183	-99.58
8	2	PERT 2DF fluxes	S2	5.587	.450	4.045	-.118	-.174	-96.14
9	2	2DF	S4	5.56	-	-	-	-	-
10	2	PERT 2DF fluxes	S4	5.423	.446	3.931	-.110	-.167	-92.60
11	2	2DB	D.T.	5.21	-	-	-	-	-
12	2	PERT 2DB fluxes	D.T.	5.22	-	-	-	-	-
13	5	2DF	S2	6.17	-	-	-	-	-
14	5	PERT 2DF fluxes	S2	5.867	.496	4.254	-.113	-.182	-99.16
15	5	PERT DTF fluxes	S4	5.688	.513	4.126	-.118	-.178	-93.86
16	26	PERT DTF fluxes	S4	5.885	.615	4.252	-.207	-.195	-84.42

† Units are $(\delta k/k)$ per kg x 10^3

reactivity coefficient cases were run twice--with the sample in the test zone for both a positive and negative density and then the two averaged.

Rows 7 and 8 give a direct comparison between 2DF and PERT-IV calculations for several materials using two groups and the S2 option. The discrepancy between transport theory and diffusion perturbation theory is less than 4% for the fuels and the poison; for Na and Fe, however, the error is larger because their worths are the difference between two contributions (absorption and moderation) of the same magnitude. As an interesting sidelight, Los Alamos has written a one-dimensional transport perturbation theory code, DAC, compatible with DTF-IV, and report[3] differences in worths calculated by DAC and DTF-IV similar to those between PERT-IV and 2DF.

To determine whether the agreement is a function either of the number of energy groups or the order of the SN approximation, Pu239 worths were calculated using the S2, S4, and S6 options for 1 group, the S2 and S4 options for 2 groups, and the S2 option for 5 groups. A plot of this data can be seen in Figure 5.1. The percent error does not appear dependent upon the number of energy groups; however, the discrepancy decreases somewhat for higher orders of the SN approximation for both the one group and two group worth calculations. It is interesting to note that the 2DF value seems to be converging towards the PERT-IV value.

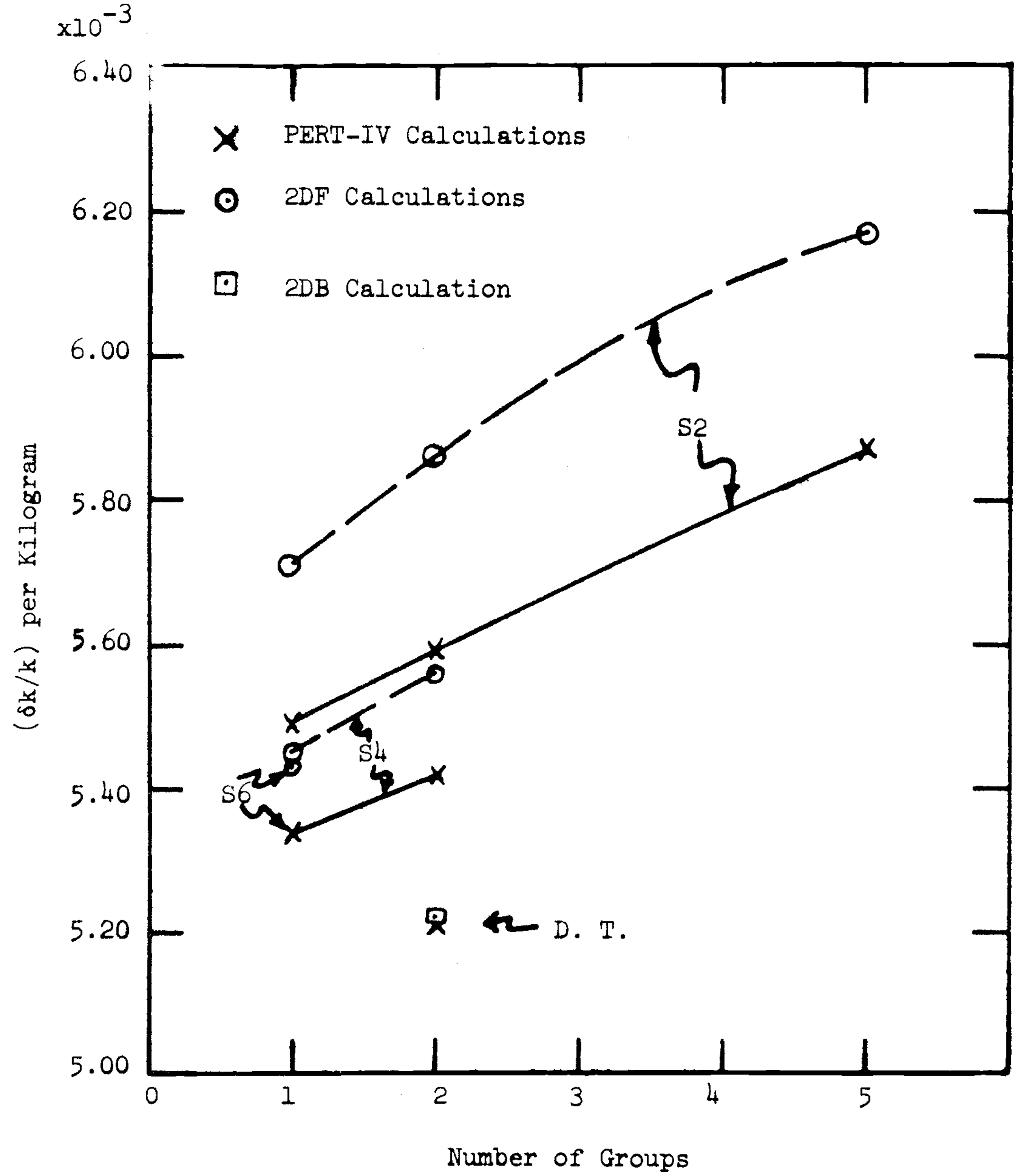

Figure 5.1. Comparison between PERT-IV, 2DF, and 2DB calculations in ZPR-3 Assembly 48

The worth of Pu239 was calculated using the two-dimensional diffusion theory program, 2DB, and compared with PERT-IV (using 2DB flux dumps). These results are shown in rows 11 and 12. As one would expect, since both codes are based on diffusion theory, the agreement is very good. Therefore, we conclude that inaccuracies in PERT-IV worths when compared to 2DF is because PERT-IV is based on the diffusion model.

The last two rows of Table 5.2 are PERT-IV calculations using one-dimensional DTF-IV fluxes. For this particular core there appears to be good agreement between PERT-IV calculations using DTF-IV fluxes and those using 2DF fluxes. It is not expected that this agreement will be as good for a multi-zoned reactor, however, since the assumption that the fluxes and adjoint fluxes are separable over the whole reactor will be less valid.

Recapitulating the above paragraphs, for the reactor studied, worths calculated using diffusion perturbation theory agree well with transport theory--especially fuel and poison worths. The agreement does not appear to be strongly dependent either on the number of groups or the order of the SN approximation in 2DF. If a two-dimensional diffusion theory code is used, the agreement is very good. Finally, using 1-D transport theory fluxes (radial and axial) in the diffusion perturbation code agrees fairly well with 2-D transport theory fluxes.

VI. SUMMARY AND CONCLUSIONS

This thesis has described a two-dimensional, first order perturbation theory computer code based on the multigroup diffusion model that will compute reactivity coefficient traverses, the neutron generation time, and the effective delayed neutron fraction. The derivations of the perturbation equation and of the expressions for the neutron generation time and effective delayed neutron fraction as used in the code were given. Finally, some comparisons between reactivity coefficients calculated by diffusion perturbation theory and transport theory were shown.

Given the type of errors shown in Table 5.2, one must now ask if PERT-IV is a useful method for calculating reactivity coefficients. One criterion could be that the discrepancy between PERT-IV and 2DF worths should be less than the discrepancy between two 2DF calculations where the number of groups or the order of the SN approximation is varied. For the reactor studied in this report, this criterion is certainly met for Pu239 since there is over a 10% change from a 1 group to a 5 group 2DF calculation and a 5% change from S2 to S4, while the difference between PERT-IV and 2DF worths is less than 4%.

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A P P E N D I C E S

APPENDIX I: INPUT INSTRUCTIONS

The following two pages describe the input data for PERT-IV.

For DTF-IV fluxes and all subsequent data, the cards consist of six data fields of 12 columns each. The last nine columns contain the data associated with the particular field; columns 2-3 contain an integer, N, from 0 (or blank) to 99. The first column of each field must contain:

0 - no effect (N=0),

1 - repeat associated data 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.

PERT - IV

Card	Field(s)	Variable (cols. 73–80)
IDENTIFICATION CARD		ID(12)

ND	IGM	IST	IFP	IM	JM	MCR	MTP	IZM	MT	MOL	NPRT
= 1, Fluxes from 1-D = 2, Fluxes from 2-D = 3, Flux from 1-D, Adjoint from 2-D = 4, Flux from 2-D, Adjoint from 1-D = 5, Flux from 1-D, No Adjoint = 6, Flux from 2-D, No Adjoint	No. of Energy Groups	No. of Downscattering Terms	= 0, No Effect = 1, Punch Fluxes = 2, Punch Adjoint Fluxes	No. of Radial Intervals	No. of Axial Intervals	No. of Materials From Cards	No. of Materials From Tape	No. of Material Zones	Total No. of Materials, Including Mixes	No. of Mixture Specifications	= 0, Partial Print = 1, Full Print

NDELK	NIBC	NACT	NFP	IGE
= 0, No Effect = n, n Reactivity Coefficient Calculations	= 0, No Effect = n, n Isotopes for β_{eff} Calculation	= 0, No Effect = n, n Activities	Flux Normalization: = 1, Center Pt. Flux = 2, Center Pt. Power Density = 3, Total Power = 4, Denominator of Perturbation Formula	Geometry: = 0, R-Z = 1, X-Y = 2, R-θ

FLPO	VF	FEF
Flux or Power (See NFP)	Volume Factor	Energy Released/Fission (MeV)

HOLN(MCR)	ATW(MCR)	A(MCR, 10)
Name of 1st Isotope	Atomic Wt. for 1st Isotope	Miscellaneous Information for 1st Isotope (10A6)

Card	Variable (cols. 73–80)
Cross Section Data for 1st Isotope (6E 12.4)	C(ITL, IGM, MT)
● ● ● (Repeat for Each Material)	
FLUX AND/OR ADJOINT FLUX: 2DF DATA (6E12.4) OR DTF DATA 6(I1, I2, E9.4)	PHI(IM, JM) AND ADJ(IM, JM)

Cols. 1–12	Cols. 13–24	Cols. 25–36	Cols. 37–48	Cols. 49–60	Cols. 61–72	Cols. 73–80
0.0	2ND RADIAL PT.	3RD RADIAL PT.	● ● ●			R1(IP)
0.0	2ND AXIAL PT.	3RD AXIAL PT.	● ● ●			Z1(JP)
ZONE NO. FOR 1ST INTERVAL	ZONE NO. FOR 2ND INTERVAL	● ● ●				M0(IM,JM)
MATERIAL NO. FOR ZONE 1	MATERIAL NO. FOR ZONE 2	● ● ●				M2(IZM)

	1–12	13–24	25–36	37–48	49–60	61–72	73–80
	FISSION SOURCE IN GROUP 1	FISSION SOURCE IN GROUP 2	• • •				CHI(IGM)
	FIRST MIX NO.	• • •	SECOND MIX NO.	• • •			I0(MOI)
	0	1ST MATERIAL IN MIX 1	2ND MATERIAL IN MIX 1	• • •			I1(MOI)
	0	DENSITY FOR 1ST MATERIAL IN MIX 1	DENSITY FOR 2ND MATERIAL IN MIX 1	• • •			I2(MOI)
IF(NIBC)≠ 0	MATERIAL NO. OF 1ST ISOTOPE FOR β_{eff} CALCULATION	MATERIAL NO. OF 2ND ISOTOPE FOR β_{eff} CALCULATION	• • •				NBET(NIBC)
IF(NIBC)≠ 0	f FOR 1ST MATERIAL FOR β_{eff} CALCULATION	f FOR 2ND MATERIAL FOR β_{eff} CALCULATION	• • •				BETA(NIBC)
IF(NIBC)≠ 0	DELAYED FISSION SOURCE IN GROUP 1	DELAYED FISSION SOURCE IN GROUP 2	• • •				CHIP(IGM)
IF(NIBC)≠ 0	NEUTRON VELOCITY IN GROUP 1	NEUTRON VELOCITY IN GROUP 2	• • •				VEL(IGM)
IF(NDELK)≠ 0	MATERIAL NO. FOR 1ST δK CALCULATION	MATERIAL NO. FOR 2ND δK CALCULATION	• • •				MATDK(NDELK)
IF(NDELK)≠ 0	ROW NO. FOR 1ST δK CALCULATION	ROW NO. FOR 2ND δK CALCULATION	• • •				NROW(NDELK)
IF(NDELK)≠ 0	COLUMN NO. FOR 1ST δK CALCULATION	COLUMN NO. FOR 2ND δK CALCULATION	• • •				NCOL(NDELK)
IF(NACT)≠ 0	MATERIAL NO. FOR 1ST ACTIVITY TRAVERSE	MATERIAL NO. FOR 2ND ACTIVITY TRAVERSE	• • •				MA(NACT)
IF(NACT)≠ 0	CROSS SECTION POSITION FOR 1ST ACTIVITY TRAVERSE	CROSS SECTION POSITION FOR 2ND ACTIVITY TRAVERSE	• • •				NX(NACT)

APPENDIX II: SAMPLE PROBLEM

The following pages show the input data (omitting input fluxes) and computer output for a two-group, three-region test problem in R-Z geometry.

```
 PERT-IV TEST CASE                    (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)
     2       2       1       0      21      20      16       0       3      19      31       0
     3       6       1       1       0
          1.0            2.0            206.
M2PU49239.05          2 GROUPS
  .172436+01   .184872+01   .511503+01   .669364+01   .476589+01   .000000
  .228419+01   .324006+01   .649503+01   .139176+02   .106775+02   .790403-01
PU240 240.05          2 GROUPS
  .697066-00   .973045-00   .210364+01   .654004+01   .549212+01   .000000
  .205185-01   .158456+01   .577565-01   .139455+02   .123609+02   .748743-01
M2U235235.04          2 GROUPS
  .132033+01   .150965+01   .332484+01   .622874+01   .457201+01   .000000
  .336017+01   .486972+01   .814961+01   .147169+02   .984715+01   .147083-00
U238   238.05         2 GROUPS
  .100100+00   .232887-00   .281437-00   .633569+01   .600524+01   .000000
  .000000      .532188-00   .000000      .131583+02   .126261+02   .975608-01
C      12.011         2 GROUPS
  .000000      .833620-05   .000000      .263926+01   .245083+01   .000000
  .000000      .456935-10   .000000      .448553+01   .448553+01   .188417-00
NA     22.990         2 GROUPS
  .000000      .713006-03   .000000      .309019+01   .300053+01   .000000
  .000000      .423424-02   .000000      .498455+01   .498031+01   .889546-01
M2 FE 55.847          2 GROUPS
  .000000      .591775-02   .000000      .255761+01   .251745+01   .000000
  .000000      .215431-01   .000000      .482144+01   .479990+01   .342399-01
CR     51.996         2 GROUPS
  .000000      .454490-02   .000000      .267339+01   .260924+01   .000000
  .000000      .149873-01   .000000      .472111+01   .470613+01   .596010-01
NI     58.71          2 GROUPS
  .000000      .305271-01   .000000      .307692+01   .300395+01   .000000
  .000000      .203676-01   .000000      .945337+01   .943300+01   .424393-01
MO     95.94          2 GROUPS
  .000000      .430943-01   .000000      .527468+01   .516105+01   .000000
  .000000      .303487-00   .000000      .788962+01   .758613+01   .705369-01
AL     26.981         2 GROUPS
  .000000      .205447-02   .000000      .282519+01   .272632+01   .000000
  .000000      .829689-02   .000000      .217056+01   .216227+01   .968106-01
M2U235235.04          2 GROUPS
  .134241+01   .156915+01   .333434+01   .679391+01   .505674+01   .000000
  .211779+01   .283935+01   .515408+01   .123173+02   .947794+01   .168022-00
U238   238.05         2 GROUPS
  .372181-01   .189516-00   .105378+00   .694904+01   .664718+01   .000000
  .000000      .404503-00   .000000      .122090+02   .118045+02   .112345+00
M2 FE 55.847          2 GROUPS
  .000000      .670574-02   .000000      .265143+01   .259971+01   .000000
  .000000      .120269-01   .000000      .449904+01   .448701+01   .450092-01
CR     51.996         2 GROUPS
```

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   .000000          .483021-02   .000000        .275887+01   .267499+01   .000000
   .000000          .923842-02   .000000        .441195+01   .440272+01   .790527-01
NI     58.71             2 GROUPS
   .000000          .182360-01   .000000        .338277+01   .330993+01   .000000
   .000000          .169131-01   .000000        .750107+01   .748416+01   .546002-01
2 3  0.0        2 8  2.54      2 7  41.71         72.19    3
2 3  0.0        2 7  2.54      2 7  38.175        68.655   3
1 4           11 9           21 8           31 4           11 9           21 8           3
1 4           11 9           21 8           31 4           11 9           21 8           3
113           21 8           3113           2108           3113           21 8           3
113           21 8           3113           2108           3113           21 8           3
113           21 8           3113           2108           3184           3184           3
3
             19             17             183
    .987           .013       3
112          17106          18113          193
              0              1              2              3              4              5
              6              7              8              9             10             11
              0             12             13             14             15             16
              0              1              2              3              4              5
              6              7              8              9             10             11
             173
              0        .001654        .000106        .000016        .007406        .020765
      .006230          .009899        .002658        .001308        .000206        .000110
              0        .000084        .039976        .004453        .001196        .000588
              0        .001654        .000106        .000016        .007406        .020765
      .006230          .009899        .002658        .001308        .000206        .000110
        1.0   -103
              1              2              3              4             12             13
3
         .0063          .0088          .0165          .0412          .0165          .0412
3
            1.0            0.03
   7.63085+8     1.16360+83
              1              1             63
              1              0             13
              0              5             03
             13
             13
```

* * * * P E R T - I V * * * *

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

ND	1/2/3/4/5/6/7=FLUXES FROM 1-D RUNS/FLUXES FROM 2-D RUN/FLUX FROM 1-D,ADJOINT FROM 2-D/FLUX FROM 2-D,ADJOINT FROM 1-D/FLUX FROM 1-D, NO ADJOINT/FLUX FROM 2-D,NO ADJOINT/2-D FLUXES FROM TAPE	2
IGM	NUMBER OF ENERGY GROUPS	2
IST	NUMBER OF DOWNSCATTERING TERMS	1
IFP	0/1/2=NO EFFECT/PUNCH FLUXES/PUNCH ADJOINT FLUXES	0
IM	NUMBER OF RADIAL INTERVALS	21
JM	NUMBER OF AXIAL INTERVALS	20
MCR	NUMBER OF MATERIALS FROM CARDS	16
MTP	NUMBER OF MATERIALS FROM TAPE	0
IZM	NUMBER OF MATERIAL ZONES	3
MT	TOTAL NUMBER OF MATERIALS INCLUDING MIXES	19
M01	NUMBER OF MIXTURE SPECIFICATIONS	31
NPRT	PRINT OPTION [0/1=PARTIAL PRINT/FULL PRINT]	0
NDELK	0/N=NO EFFECT/DO N REACTIVITY COEFFICIENT CALCULATIONS	3
NIBC	0/N=NO EFFECT/USE N MATERIALS FOR BETA EFFECTIVE CALCULATION	6
NACT	0/N=NO EFFECT/DO N ACTIVITY TRAVERSES	1
NFP	FLUX OR POWER NORMALIZATION [1/2/3/4=CENTER PT. FLUX/CENTER PT. POWER/TOTAL POWER/DENOMINATOR OF PERT FORMULA]	1
IGE	GEOMETRY [0/1/2=R-Z/X-Y/R-THETA]	0
FLPO	FLUX(N/CM2-SEC) OR POWER(MWT)	1.0000+00
VF	VOLUME FACTOR	2.0000+00
FEF	ENERGY(MEV) RELEASED PER FISSION	2.0600+02
ZKEFF	KEFF FOR DELTA K CALC. [IF ZERO, USE KEFF CALCULATED BY CODE]	-0.0000

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

THE FOLLOWING NUCLIDES ARE READ-IN

1	M2PU49	2 GROUPS
2	PU240	2 GROUPS
3	M2U235	2 GROUPS
4	U238	2 GROUPS
5	C	2 GROUPS
6	NA	2 GROUPS
7	M2 FE	2 GROUPS
8	CR	2 GROUPS
9	NI	2 GROUPS
10	MO	2 GROUPS
11	AL	2 GROUPS
12	M2U235	2 GROUPS
13	U238	2 GROUPS
14	M2 FE	2 GROUPS
15	CR	2 GROUPS
16	NI	2 GROUPS

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

INPUT FLUXES (PHR/PHZ/ADJR/ADJZ/PHI/ADJ=RADIAL FLUX/AXIAL FLUX/RADIAL ADJOINT FLUX/AXIAL ADJOINT FLUX/2-D FLUX/2-D ADJOINT FLUX)

PHI 840

.48222-03	.48215-03	.48181-03	.48131-03	.47674-03	.46453-03	.44519-03	.41920-03	.38712-03	.34971-03
.30787-03	.26261-03	.21373-03	.15665-03	.10533-03	.71757-04	.48494-04	.32370-04	.20945-04	.12615-04
.58700-05	.48207-03	.48201-03	.48171-03	.48118-03	.47657-03	.46437-03	.44505-03	.41905-03	.38699-03
.34959-03	.30777-03	.26253-03	.21366-03	.15660-03	.10529-03	.71732-04	.48477-04	.32363-04	.20934-04
.12608-04	.58744-05	.48181-03	.48172-03	.48138-03	.48086-03	.47625-03	.46405-03	.44477-03	.41877-03
.38672-03	.34937-03	.30756-03	.26235-03	.21351-03	.15649-03	.10522-03	.71680-04	.48449-04	.32341-04
.20915-04	.12604-04	.58682-05	.48131-03	.48123-03	.48089-03	.48037-03	.47577-03	.46358-03	.44431-03
.41836-03	.38632-03	.34901-03	.30726-03	.26208-03	.21330-03	.15634-03	.10511-03	.71611-04	.48404-04
.32300-04	.20899-04	.12592-04	.58607-05	.47677-03	.47670-03	.47639-03	.47588-03	.47133-03	.45925-03
.44014-03	.41444-03	.38271-03	.34572-03	.30436-03	.25962-03	.21129-03	.15486-03	.10412-03	.70937-04
.47937-04	.32000-04	.20703-04	.12471-04	.58056-05	.46447-03	.46440-03	.46408-03	.46359-03	.45916-03
.44739-03	.42877-03	.40371-03	.37279-03	.33676-03	.29645-03	.25285-03	.20578-03	.15083-03	.10140-03
.69080-04	.46690-04	.31168-04	.20163-04	.12147-04	.56565-05	.44456-03	.44450-03	.44420-03	.44371-03
.43948-03	.42821-03	.41037-03	.38639-03	.35677-03	.32224-03	.28366-03	.24193-03	.19687-03	.14428-03
.97006-04	.66093-04	.44664-04	.29815-04	.19293-04	.11626-04	.54122-05	.41742-03	.41735-03	.41708-03
.41663-03	.41263-03	.40204-03	.38528-03	.36273-03	.33493-03	.30247-03	.26617-03	.22698-03	.18470-03
.13536-03	.90998-04	.61984-04	.41896-04	.27979-04	.18113-04	.10915-04	.50827-05	.38350-03	.38344-03
.38318-03	.38277-03	.37910-03	.36935-03	.35394-03	.33317-03	.30759-03	.27777-03	.24437-03	.20829-03
.16944-03	.12415-03	.83445-04	.56859-04	.38443-04	.25691-04	.16641-04	.10033-04	.46798-05	.34342-03
.34337-03	.34314-03	.34276-03	.33948-03	.33074-03	.31690-03	.29829-03	.27529-03	.24852-03	.21854-03
.18615-03	.15135-03	.11085-03	.74501-04	.50742-04	.34350-04	.23001-04	.14918-04	.90183-05	.42050-05
.29787-03	.29782-03	.29762-03	.29730-03	.29444-03	.28686-03	.27484-03	.25866-03	.23867-03	.21533-03
.18921-03	.16083-03	.13049-03	.95448-04	.64023-04	.43721-04	.29758-04	.19995-04	.13027-04	.78938-05
.36874-05	.24605-03	.24600-03	.24584-03	.24557-03	.24322-03	.23694-03	.22701-03	.21362-03	.19709-03
.17775-03	.15607-03	.13236-03	.10658-03	.77480-04	.52313-04	.36196-04	.24860-04	.16836-04	.11040-04
.67154-05	.31495-05	.18350-03	.18346-03	.18334-03	.18314-03	.18138-03	.17670-03	.16928-03	.15928-03
.14694-03	.13248-03	.11627-03	.98450-04	.78724-04	.58583-04	.41387-04	.29071-04	.20342-04	.13882-04
.92031-05	.56163-05	.26504-05	.12639-03	.12636-03	.12627-03	.12614-03	.12493-03	.12171-03	.11660-03
.10970-03	.10118-03	.91201-04	.80011-04	.67591-04	.54317-04	.42197-04	.31706-04	.22880-04	.16345-04
.11320-04	.75492-05	.46643-05	.21899-05	.88048-04	.88025-04	.87964-04	.87864-04	.87027-04	.84790-04
.81221-04	.76423-04	.70470-04	.63529-04	.55706-04	.47163-04	.38375-04	.30262-04	.23341-04	.17407-04
.12667-04	.89861-05	.60253-05	.37616-05	.17789-05	.60744-04	.60727-04	.60681-04	.60613-04	.60042-04
.58492-04	.56038-04	.52721-04	.48621-04	.43845-04	.38495-04	.32767-04	.26904-04	.21610-04	.17021-04
.12923-04	.95290-05	.68654-05	.46995-05	.29230-05	.14119-05	.41347-04	.41334-04	.41305-04	.41266-04
.40867-04	.39816-04	.38146-04	.35888-04	.33111-04	.29884-04	.26293-04	.22459-04	.18584-04	.15047-04
.12033-04	.93601-05	.70041-05	.50583-05	.35128-05	.22122-05	.10564-05	.27270-04	.27263-04	.27247-04
.27213-04	.26953-04	.26262-04	.25160-04	.23677-04	.21858-04	.19740-04	.17391-04	.14924-04	.12432-04
.10177-04	.81899-05	.64100-05	.48988-05	.35856-05	.24835-05	.15853-05	.75639-06	.16746-04	.16741-04
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.14863-03	.12564-03	.10066-03	.72208-04	.47385-04	.31527-04	.20897-04	.13742-04	.87248-05	.50956-05
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.16964-03	.14858-03	.12559-03	.10063-03	.72184-04	.47369-04	.31517-04	.20889-04	.13738-04	.87216-05
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.20388-03	.18797-03	.16935-03	.14833-03	.12538-03	.10046-03	.72063-04	.47286-04	.31462-04	.20857-04
.13713-04	.87070-05	.50853-05	.21332-05	.23265-03	.23257-03	.23241-03	.23215-03	.22995-03	.22406-03
.21465-03	.20195-03	.18620-03	.16774-03	.14691-03	.12419-03	.99498-04	.71374-04	.46838-04	.31164-04
.20655-04	.13584-04	.86242-05	.50371-05	.21130-05	.22658-03	.22650-03	.22634-03	.22609-03	.22395-03
.21820-03	.20905-03	.19666-03	.18132-03	.16335-03	.14306-03	.12092-03	.96883-04	.69498-04	.45606-04
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.21422-03	.20872-03	.19996-03	.18811-03	.17342-03	.15622-03	.13681-03	.11563-03	.92636-04	.66450-04
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.18613-03	.18593-03	.18416-03	.17943-03	.17188-03	.16167-03	.14902-03	.13420-03	.11748-03	.99254-04
.79493-04	.57016-04	.37416-04	.24910-04	.16524-04	.10881-04	.69196-05	.40466-05	.17003-05	.16611-03
.16605-03	.16593-03	.16575-03	.16417-03	.15995-03	.15320-03	.14410-03	.13279-03	.11956-03	.10462-03
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.14289-03	.14285-03	.14274-03	.14259-03	.14123-03	.13759-03	.13178-03	.12393-03	.11420-03	.10278-03
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.13372-05	.11630-03	.11626-03	.11617-03	.11604-03	.11494-03	.11198-03	.10725-03	.10085-03	.92918-04
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.26969-05	.11403-05	.84931-04	.84903-04	.84841-04	.84747-04	.83943-04	.81777-04	.78322-04	.73644-04
.67848-04	.61036-04	.53334-04	.44863-04	.35421-04	.25880-04	.18045-04	.12512-04	.86238-05	.58281-05
.37988-05	.22500-05	.95819-06	.57102-04	.57081-04	.57039-04	.56979-04	.56438-04	.54984-04	.52659-04
.49513-04	.45617-04	.41033-04	.35871-04	.30147-04	.24015-04	.18414-04	.13685-04	.97851-05	.68947-05
.47298-05	.31111-05	.18614-05	.79001-06	.38822-04	.38809-04	.38781-04	.38739-04	.38371-04	.37385-04
.35803-04	.33668-04	.31016-04	.27913-04	.24409-04	.20589-04	.16657-04	.13038-04	.99889-05	.74099-05
.53339-05	.37336-05	.24764-05	.14980-05	.63786-06	.26250-04	.26240-04	.26221-04	.26191-04	.25945-04
.25277-04	.24210-04	.22766-04	.20979-04	.18890-04	.16549-04	.14045-04	.11480-04	.91683-05	.71842-05
.54446-05	.40045-05	.28482-05	.19187-05	.11632-05	.50311-06	.17590-04	.17583-04	.17570-04	.17553-04
.17386-04	.16939-04	.16225-04	.15260-04	.14067-04	.12679-04	.11137-04	.94929-05	.78335-05	.63208-05
.50292-05	.38906-05	.29074-05	.20933-05	.14272-05	.87425-06	.37593-06	.11379-04	.11375-04	.11368-04
.11354-04	.11247-04	.10959-04	.10497-04	.98750-05	.91082-05	.82183-05	.72327-05	.61963-05	.51486-05
.42028-05	.33762-05	.26348-05	.20005-05	.14575-05	.99908-06	.61773-06	.26689-06	.67761-05	.67741-05
.67678-05	.67610-05	.66975-05	.65258-05	.62516-05	.58826-05	.54281-05	.49016-05	.43248-05	.37148-05
.31010-05	.25414-05	.20625-05	.16274-05	.12388-05	.91226-06	.63099-06	.38974-06	.17041-06	.28918-05
.28901-05	.28891-05	.28860-05	.28585-05	.27851-05	.26687-05	.25111-05	.23177-05	.20957-05	.18491-05
.15920-05	.13346-05	.11014-05	.89156-06	.70602-06	.54555-06	.39947-06	.27783-06	.17355-06	.74801-07
ADJ	840								
.30709-03	.30699-03	.30676-03	.30642-03	.30344-03	.29543-03	.28261-03	.26518-03	.24337-03	.21744-03
.18750-03	.15386-03	.11499-03	.70220-04	.35814-04	.18943-04	.99324-05	.53091-05	.27942-05	.14115-05
.53776-06	.30698-03	.30688-03	.30666-03	.30632-03	.30333-03	.29533-03	.28252-03	.26509-03	.24329-03
.21736-03	.18743-03	.15380-03	.11495-03	.70195-04	.35801-04	.18937-04	.99275-05	.53088-05	.27928-05

.14097-05	.53969-06	.30678-03	.30668-03	.30644-03	.30610-03	.30312-03	.29512-03	.28232-03	.26490-03
.24311-03	.21721-03	.18730-03	.15370-03	.11487-03	.70146-04	.35777-04	.18921-04	.99222-05	.53053-05
.27388-05	.14109-05	.53759-06	.30646-03	.30636-03	.30613-03	.30578-03	.30281-03	.29481-03	.28203-03
.26463-03	.24286-03	.21699-03	.18711-03	.15353-03	.11475-03	.70076-04	.35735-04	.18902-04	.99146-05
.52956-05	.27883-05	.14084-05	.53713-06	.30347-03	.30338-03	.30315-03	.30281-03	.29986-03	.29195-03
.27928-03	.26205-03	.24050-03	.21487-03	.18528-03	.15203-03	.11362-03	.69380-04	.35383-04	.18715-04
.98096-05	.52443-05	.27592-05	.13937-05	.53166-06	.29530-03	.29520-03	.29498-03	.29465-03	.29178-03
.28408-03	.27175-03	.25498-03	.23400-03	.20906-03	.18027-03	.14791-03	.11054-03	.67487-04	.34406-04
.18191-04	.95357-05	.50959-05	.26804-05	.13539-05	.51681-06	.28197-03	.28188-03	.28167-03	.28135-03
.27861-03	.27126-03	.25948-03	.24346-03	.22342-03	.19959-03	.17209-03	.14119-03	.10550-03	.64386-04
.32808-04	.17342-04	.90829-05	.48528-05	.25523-05	.12895-05	.49168-06	.26354-03	.26345-03	.26326-03
.26296-03	.26039-03	.25352-03	.24250-03	.22752-03	.20878-03	.18650-03	.16078-03	.13189-03	.98525-04
.60098-04	.30594-04	.16151-04	.84561-05	.45166-05	.23755-05	.12001-05	.45798-06	.24000-03	.23993-03
.23975-03	.23948-03	.23714-03	.23087-03	.22083-03	.20717-03	.19009-03	.16978-03	.14634-03	.12001-03
.89599-04	.54581-04	.27733-04	.14633-04	.76521-05	.40884-05	.21518-05	.10883-05	.41641-06	.21117-03
.21110-03	.21094-03	.21070-03	.20864-03	.20312-03	.19427-03	.18225-03	.16719-03	.14929-03	.12862-03
.10543-03	.78635-04	.47815-04	.24241-04	.12757-04	.66751-05	.35772-05	.18867-05	.95906-06	.36580-06
.17689-03	.17683-03	.17670-03	.17650-03	.17477-03	.17014-03	.16272-03	.15263-03	.13999-03	.12496-03
.10760-03	.88061-04	.65534-04	.39661-04	.19970-04	.10547-04	.55629-05	.29988-05	.15960-05	.81374-06
.31265-06	.13470-03	.13466-03	.13455-03	.13440-03	.13309-03	.12955-03	.12389-03	.11617-03	.10652-03
.95022-04	.81724-04	.66718-04	.49244-04	.29563-04	.15074-04	.81656-05	.43711-05	.23979-05	.12901-05
.66486-06	.25789-06	.84091-04	.84063-04	.84000-04	.83903-04	.83082-04	.80861-04	.77306-04	.72454-04
.66383-04	.59123-04	.50736-04	.41207-04	.30144-04	.18975-04	.10649-04	.59261-05	.33191-05	.18350-05
.10238-05	.52310-06	.21141-06	.44358-04	.44341-04	.44307-04	.44261-04	.43821-04	.42642-04	.40748-04
.38162-04	.34920-04	.31029-04	.26555-04	.21415-04	.15834-04	.10928-04	.70218-05	.41373-05	.24267-05
.13831-05	.78312-06	.41549-06	.16029-06	.24161-04	.24153-04	.24136-04	.24107-04	.23867-04	.23222-04
.22178-04	.20761-04	.18970-04	.16841-04	.14374-04	.11629-04	.88106-05	.62500-05	.42492-05	.27330-05
.16716-05	.10076-05	.57308-06	.31701-06	.12240-06	.13018-04	.13014-04	.13002-04	.12985-04	.12859-04
.12506-04	.11942-04	.11167-04	.10197-04	.90412-05	.77209-05	.62958-05	.48415-05	.35891-05	.25577-05
.17154-05	.11063-05	.69200-06	.41526-06	.22405-06	.96053-07	.71149-05	.71117-05	.71059-05	.71011-05
.70267-05	.68337-05	.65224-05	.60971-05	.55653-05	.49360-05	.42283-05	.34689-05	.27142-05	.20319-05
.14938-05	.10605-05	.70924-06	.45541-06	.28359-06	.15971-06	.63433-07	.38252-05	.38240-05	.38227-05
.38156-05	.37777-05	.36734-05	.35049-05	.32757-05	.29901-05	.26541-05	.22789-05	.18869-05	.14936-05
.11575-05	.86468-06	.61786-06	.43655-06	.29038-06	.18080-06	.10629-06	.43104-07	.19708-05	.19704-05
.19666-05	.19657-05	.19459-05	.18916-05	.18047-05	.16871-05	.15400-05	.13687-05	.11813-05	.98178-06
.78529-06	.60552-06	.46906-06	.34895-06	.24110-06	.16781-06	.10872-06	.61522-07	.27396-07	.76526-06
.76404-06	.76530-06	.76411-06	.75586-06	.73474-06	.70132-06	.65498-06	.59840-06	.53324-06	.45915-06
.38415-06	.31042-06	.24822-06	.18486-06	.13795-06	.10504-06	.67868-07	.45217-07	.27882-07	.10280-07
.36080-03	.36075-03	.36050-03	.36013-03	.35674-03	.34765-03	.33328-03	.31399-03	.29023-03	.26262-03
.23191-03	.19897-03	.16420-03	.12384-03	.86060-04	.59774-04	.40995-04	.27645-04	.18014-04	.10899-04
.50838-05	.36070-03	.36065-03	.36043-03	.36004-03	.35661-03	.34754-03	.33318-03	.31388-03	.29014-03
.26254-03	.23183-03	.19890-03	.16415-03	.12380-03	.86030-04	.59754-04	.40980-04	.27639-04	.18006-04
.10894-04	.50864-05	.36051-03	.36045-03	.36019-03	.35980-03	.35637-03	.34730-03	.33297-03	.31367-03
.28994-03	.26237-03	.23167-03	.19877-03	.16404-03	.12372-03	.85972-04	.59712-04	.40955-04	.27620-04
.17990-04	.10890-04	.50813-05	.36014-03	.36008-03	.35983-03	.35944-03	.35601-03	.34695-03	.33263-03
.31337-03	.28964-03	.26210-03	.23145-03	.19856-03	.16387-03	.12359-03	.85882-04	.59653-04	.40917-04
.27587-04	.17975-04	.10879-04	.50751-05	.35676-03	.35670-03	.35648-03	.35609-03	.35271-03	.34372-03
.32952-03	.31045-03	.28695-03	.25964-03	.22928-03	.19671-03	.16233-03	.12243-03	.85077-04	.59093-04
.40524-04	.27330-04	.17807-04	.10775-04	.50276-05	.34762-03	.34756-03	.34732-03	.34696-03	.34366-03

.33490-03	.32106-03	.30246-03	.27956-03	.25296-03	.22335-03	.19161-03	.15813-03	.11925-03	.82865-04
.57551-04	.39472-04	.26620-04	.17343-04	.10495-04	.48984-05	.33283-03	.33278-03	.33256-03	.33220-03
.32905-03	.32066-03	.30740-03	.28959-03	.26764-03	.24213-03	.21379-03	.18339-03	.15132-03	.11411-03
.79287-04	.55069-04	.37764-04	.25467-04	.16596-04	.10046-04	.46872-05	.31272-03	.31267-03	.31247-03
.31214-03	.30915-03	.30127-03	.28880-03	.27204-03	.25143-03	.22743-03	.20073-03	.17216-03	.14205-03
.10710-03	.74425-04	.51663-04	.35433-04	.23903-04	.15383-04	.94332-05	.44023-05	.28768-03	.28764-03
.28745-03	.28714-03	.28440-03	.27713-03	.26565-03	.25019-03	.23119-03	.20913-03	.18452-03	.15817-03
.13044-03	.98327-04	.68280-04	.47418-04	.32527-04	.21957-04	.14322-04	.86733-05	.40544-05	.25827-03
.25823-03	.25806-03	.25778-03	.25532-03	.24378-03	.23845-03	.22456-03	.20742-03	.18756-03	.16542-03
.14169-03	.11677-03	.87957-04	.61050-04	.42370-04	.29095-04	.19675-04	.12847-04	.77992-05	.36446-05
.22522-03	.22519-03	.22504-03	.22480-03	.22264-03	.21694-03	.20791-03	.19577-03	.18079-03	.16335-03
.14394-03	.12299-03	.10112-03	.76041-04	.52640-04	.36597-04	.25250-04	.17124-04	.11228-04	.68315-05
.31975-05	.18859-03	.18856-03	.18843-03	.18823-03	.18643-03	.18165-03	.17408-03	.16389-03	.15132-03
.13666-03	.12031-03	.10253-03	.83533-04	.62269-04	.43255-04	.30410-04	.21148-04	.14443-04	.95272-05
.58166-05	.27331-05	.14472-03	.14469-03	.14459-03	.14444-03	.14306-03	.13939-03	.13357-03	.12573-03
.11606-03	.10477-03	.92152-04	.78375-04	.63246-04	.47811-04	.34447-04	.24555-04	.17349-04	.11938-04
.79508-05	.48715-05	.23012-05	.10303-03	.10300-03	.10292-03	.10282-03	.10184-03	.99224-04	.95071-04
.89477-04	.82575-04	.74502-04	.65475-04	.55513-04	.44877-04	.35109-04	.26636-04	.19441-04	.13990-04
.97551-05	.65360-05	.40476-05	.19055-05	.73181-04	.73162-04	.73111-04	.73029-04	.72335-04	.70482-04
.67526-04	.63552-04	.58629-04	.52894-04	.46449-04	.39432-04	.32212-04	.25545-04	.19829-04	.14891-04
.10898-04	.77594-05	.52285-05	.32686-05	.15486-05	.51236-04	.51221-04	.51183-04	.51125-04	.50644-04
.49341-04	.47276-04	.44488-04	.41043-04	.37034-04	.32555-04	.27766-04	.22861-04	.18417-04	.14563-04
.11117-04	.82392-05	.59505-05	.40820-05	.25472-05	.12282-05	.35241-04	.35231-04	.35205-04	.35171-04
.34833-04	.33939-04	.32519-04	.30600-04	.28240-04	.25500-04	.22458-04	.19211-04	.15925-04	.12929-04
.10363-04	.80800-05	.60707-05	.43999-05	.30579-05	.19290-05	.92250-06	.23413-04	.23407-04	.23393-04
.23365-04	.23142-04	.22550-04	.21605-04	.20335-04	.18776-04	.16965-04	.14957-04	.12848-04	.10718-04
.87854-05	.70864-05	.55599-05	.42543-05	.31213-05	.21672-05	.13834-05	.66152-06	.14445-04	.14441-04
.14427-04	.14412-04	.14277-04	.13910-04	.13328-04	.12550-04	.11588-04	.10475-04	.92590-05	.79730-05
.66745-05	.54922-05	.44774-05	.35460-05	.27098-05	.20112-05	.14119-05	.89863-06	.43591-06	.68594-05
.68567-05	.68544-05	.68479-05	.67814-05	.66073-05	.63329-05	.59605-05	.55057-05	.49852-05	.44061-05
.38000-05	.31937-05	.26419-05	.21481-05	.17122-05	.13305-05	.97951-06	.68853-06	.44430-06	.21692-06

MESH BOUNDARIES (R1/Z1=RADIAL POINTS/AXIAL POINTS)

R1	22								
-.00000	.63500-00	.12700+01	.19050+01	.25400+01	.68922+01	.11244+02	.15597+02	.19949+02	.24301+02
.28653+02	.33006+02	.37358+02	.41710+02	.45520+02	.49330+02	.53140+02	.56950+02	.60760+02	.64570+02
.68380+02	.72190+02								
Z1	21								
-.00000	.63500-00	.12700+01	.19050+01	.25400+01	.69944+01	.11449+02	.15903+02	.20358+02	.24812+02
.29266+02	.33721+02	.38175+02	.41985+02	.45795+02	.49605+02	.53415+02	.57225+02	.61035+02	.64845+02
.68655+02									

ZONE NUMBERS BY MESH INTERVAL

M0	420								
1	1	1	1	2	2	2	2	2	2
2	2	2	3	3	3	3	3	3	3
3	1	1	1	1	2	2	2	2	2
2	2	2	2	3	3	3	3	3	3
3	3	1	1	1	1	2	2	2	2

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

MATERIAL NUMBERS BY ZONE

M2 3

19	17	18

FISSION SPECTRUM

CHI 2

.98700-00	.13000-01

MIXTURE SPECIFICATIONS (I0/I1/I2=MIX NUMBER/MAT. NUMBER FOR MIX/MATERIAL DENSITY)

I0 31

17	17	17	17	17	17	17	17	17	17

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        17        17        18        18        18        18        18        18        19        19
        19        19        19        19        19        19        19        19        19        19
        19
        I1   31
         0         1         2         3         4         5         6         7         8         9
        10        11         0        12        13        14        15        16         0         1
         2         3         4         5         6         7         8         9        10        11
        17
        I2   31
   .00000  .16540-02 .10600-03 .16000-04 .74060-02 .20765-01 .62300-02 .98990-02 .26580-02 .13080-02
 .20600-03 .11000-03 .00000    .84000-04 .39976-01 .44530-02 .11960-02 .58800-03 .00000    .16540-02
 .10600-03 .16000-04 .74060-02 .20765-01 .62300-02 .98990-02 .26580-02 .13080-02 .20600-03 .11000-03
 .10000-09

MATERIAL NUMBERS FOR BETA CALCULATION
      NBET    6
         1         2         3         4        12        13
      BETA    6
 .63000-02 .88000-02 .16500-01 .41200-01 .16500-01 .41200-01

DELAYED FISSION SPECTRUM
      CHIP    2
 .10000+01 .00000

NEUTRON VELOCITY
       VEL    2
 .76309+09 .11636+09

PERTURBATION CALCULATION INFORMATION (MATDK/NROW/NCOL=MATERIAL NUMBER/ROW/COLUMN TO BE PERTURBED)
     MATDK    3
         1         1         6
      NROW    3
         1         0         1
      NCOL    3
         0         5         0

ACTIVITY TRAVERSE INFORMATION (MA/NX=MATERIAL NUMBER/CROSS SECTION POSITION)
        MA    1
         1
        NX    1
         1
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PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

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

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RADIAL

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

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RADIAL
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PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

CROSS-SECTION EDIT

GROUP 1 CROSS-SECTIONS

MAT 1	.172+01	.185+01	.512+01	.669+01	.477+01	.000
MAT 2	.697-00	.973-00	.210+01	.654+01	.549+01	.000
MAT 3	.132+01	.151+01	.332+01	.623+01	.457+01	.000
MAT 4	.100+00	.233-00	.281-00	.634+01	.601+01	.000
MAT 5	.000	.834-05	.000	.264+01	.245+01	.000
MAT 6	.000	.713-03	.000	.309+01	.300+01	.000
MAT 7	.000	.592-02	.000	.256+01	.252+01	.000
MAT 8	.000	.454-02	.000	.267+01	.261+01	.000
MAT 9	.000	.305-01	.000	.308+01	.300+01	.000
MAT 10	.000	.431-01	.000	.527+01	.516+01	.000
MAT 11	.000	.205-02	.000	.283+01	.273+01	.000
MAT 12	.134+01	.157+01	.333+01	.679+01	.506+01	.000
MAT 13	.372-01	.190-00	.105+00	.695+01	.665+01	.000
MAT 14	.000	.671-02	.000	.265+01	.260+01	.000
MAT 15	.000	.483-02	.000	.276+01	.267+01	.000
MAT 16	.000	.182-01	.000	.338+01	.331+01	.000
MAT 17	.369-02	.503-02	.108-01	.171-00	.160-00	.000
MAT 18	.160-02	.775-02	.449-02	.295-00	.283-00	.000
MAT 19	.369-02	.503-02	.108-01	.171-00	.160-00	.000

GROUP 2 CROSS-SECTIONS

MAT 1	.228+01	.324+01	.650+01	.139+02	.107+02	.790-01
MAT 2	.205-01	.158+01	.578-01	.139+02	.124+02	.749-01
MAT 3	.336+01	.487+01	.815+01	.147+02	.985+01	.147-00
MAT 4	.000	.532-00	.000	.132+02	.126+02	.976-01
MAT 5	.000	.457-10	.000	.449+01	.449+01	.188-00
MAT 6	.000	.423-02	.000	.498+01	.498+01	.890-01
MAT 7	.000	.215-01	.000	.482+01	.480+01	.342-01
MAT 8	.000	.150-01	.000	.472+01	.471+01	.596-01
MAT 9	.000	.204-01	.000	.945+01	.943+01	.424-01
MAT 10	.000	.303-00	.000	.789+01	.759+01	.705-01
MAT 11	.000	.830-02	.000	.217+01	.216+01	.968-01
MAT 12	.212+01	.284+01	.515+01	.123+02	.948+01	.168-00
MAT 13	.000	.405-00	.000	.122+02	.118+02	.112+00
MAT 14	.000	.120-01	.000	.450+01	.449+01	.450-01
MAT 15	.000	.924-02	.000	.441+01	.440+01	.791-01

MAT 16	.000	.169-01	.000	.759+01	.748+01	.546-01
MAT 17	.383-02	.992-02	.109-01	.321-00	.311-00	.591-02
MAT 18	.178-03	.165-01	.433-03	.519-00	.502-00	.483-02
MAT 19	.383-02	.992-02	.109-01	.321-00	.311-00	.591-02

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

	MIXTURE NUMBER	MIX COMMAND	MATERIAL ATOMIC DENSITY
1	17	0	.00000000
2	17	1	.16540000-02
3	17	2	.10600000-03
4	17	3	.16000000-04
5	17	4	.74060000-02
6	17	5	.20765000-01
7	17	6	.62300000-02
8	17	7	.98989999-02
9	17	8	.26580000-02
10	17	9	.13080000-02
11	17	10	.20600000-03
12	17	11	.11000000-03
13	18	0	.00000000
14	18	12	.83999999-04
15	18	13	.39976000-01
16	18	14	.44530000-02
17	18	15	.11960000-02
18	18	16	.58799999-03
19	19	0	.00000000
20	19	1	.16540000-02
21	19	2	.10600000-03
22	19	3	.16000000-04
23	19	4	.74060000-02
24	19	5	.20765000-01
25	19	6	.62300000-02
26	19	7	.98989999-02
27	19	8	.26580000-02
28	19	9	.13080000-02
29	19	10	.20600000-03
30	19	11	.11000000-03
31	19	17	.99999999-10

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

	RADII	AVG RADII	AXII	AVG AXII
1	-.0000	.3175	-.0000	.3175
2	.6350	.9525	.6350	.9525
3	1.2700	1.5875	1.2700	1.5875
4	1.9050	2.2225	1.9050	2.2225
5	2.5400	4.7161	2.5400	4.7672
6	6.8922	9.0683	6.9944	9.2216
7	11.2444	13.4206	11.4487	13.6759
8	15.5967	17.7728	15.9031	18.1303
9	19.9489	22.1250	20.3575	22.5847
10	24.3011	26.4772	24.8119	27.0391
11	28.6533	30.8294	29.2662	31.4934
12	33.0056	35.1817	33.7206	35.9478
13	37.3578	39.5339	38.1750	40.0800
14	41.7100	43.6150	41.9850	43.8900
15	45.5200	47.4250	45.7950	47.7000
16	49.3300	51.2350	49.6050	51.5100
17	53.1400	55.0450	53.4150	55.3200
18	56.9500	58.8550	57.2250	59.1300
19	60.7600	62.6650	61.0350	62.9400
20	64.5700	66.4750	64.8450	66.7500
21	68.3800	70.2850	68.6550	.0000
22	72.1900	.0000	.0000	.0000

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

MATERIAL INVENTORY (KILOGRAMS) FOR EACH ZONE

MATERIAL	ATOMIC WT.	ZONE 1 .10 LITERS	ZONE 2 417.19 LITERS	ZONE 3 1830.76 LITERS
1 M2PU49	239.050	.068	273.869	.000
2 PU240	240.050	.004	17.625	.000
3 M2U235	235.040	.001	2.605	.000
4 U238	238.050	.301	1221.155	.000
5 C	12.011	.043	172.755	.000
6 NA	22.990	.024	99.208	.000
7 M2 FE	55.847	.095	382.922	.000
8 CR	51.996	.024	95.729	.000
9 NI	58.710	.013	53.191	.000
10 MO	95.940	.003	13.689	.000
11 AL	26.981	.001	2.056	.000
12 M2U235	235.040	.000	.000	60.012
13 U238	238.050	.000	.000	28925.792
14 M2 FE	55.847	.000	.000	755.910
15 CR	51.996	.000	.000	189.025
16 NI	58.710	.000	.000	104.932

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

CENTER POINT FLUX (N/CM2-SEC) - - -	1.00000+00
CENTER POINT POWER (MWT/LITER) - - -	1.23298-16
TOTAL POWER (MWT) - - - - - -	3.22585-14
DENOMINATOR OF PERT. FORMULA - - -	1.56242+03
SOURCE RATE - - - - - - - -	2.82202+03
ABSORPTION RATE - - - - - - -	2.64820+03
LEAKAGE RATE (TOTAL) - - - - -	1.60694+02
RADIAL LEAKAGE - - - - - - -	1.18695+02
AXIAL LEAKAGE - - - - - - -	4.19992+01
KEFF - - - - - - - - -	1.00467

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

TOTAL FLUX

	1	2	3	4	5
1	.1000000+01	.9997979-00	.9990830-00	.9980266-00	.9885766-00
2	.9996795-00	.9994885-00	.9988517-00	.9977479-00	.9882198-00
3	.9991206-00	.9988865-00	.9981660-00	.9970762-00	.9875564-00
4	.9980810-00	.9978705-00	.9971487-00	.9960616-00	.9865670-00
5	.9886532-00	.9884525-00	.9877933-00	.9867203-00	.9773106-00
6	.9630553-00	.9628477-00	.9621774-00	.9611461-00	.9519887-00
7	.9215870-00	.9214073-00	.9207746-00	.9197572-00	.9110012-00
8	.8649799-00	.8647932-00	.8642093-00	.8632811-00	.8550156-00
9	.7941176-00	.7939573-00	.7934054-00	.7925511-00	.7849783-00
10	.7100870-00	.7099364-00	.7094487-00	.7086613-00	.7018953-00
11	.6142483-00	.6141215-00	.6136992-00	.6130372-00	.6071506-00
12	.5049654-00	.5048498-00	.5045000-00	.5039495-00	.4991318-00
13	.3740843-00	.3739965-00	.3737378-00	.3733268-00	.3697648-00
14	.2557237-00	.2556457-00	.2554644-00	.2551989-00	.2527595-00
15	.1768079-00	.1767568-00	.1766346-00	.1764353-00	.1747561-00
16	.1212360+00	.1211996+00	.1211076+00	.1209706+00	.1198328+00
17	.8213459-01	.8210798-01	.8204861-01	.8197043-01	.8118136-01
18	.5386170-01	.5384623-01	.5381417-01	.5374742-01	.5323652-01
19	.3278026-01	.3277143-01	.3273916-01	.3270521-01	.3239885-01
20	.1508522-01	.1507836-01	.1507447-01	.1505970-01	.1491372-01

	6	7	8	9	10
1	.9632435-00	.9230350-00	.8689002-00	.8019929-00	.7238461-00
2	.9629202-00	.9227451-00	.8685908-00	.8017239-00	.7236064-00
3	.9622554-00	.9221473-00	.8680069-00	.8011665-00	.7231326-00
4	.9612813-00	.9212066-00	.8671595-00	.8003386-00	.7223925-00
5	.9522604-00	.9125327-00	.8589985-00	.7928382-00	.7155625-00
6	.9275754-00	.8888636-00	.8366854-00	.7722239-00	.6969577-00
7	.8876345-00	.8505630-00	.8006229-00	.7388776-00	.6667833-00
8	.8330732-00	.7982482-00	.7513225-00	.6933776-00	.6256313-00
9	.7647834-00	.7327875-00	.6896176-00	.6363356-00	.5741373-00
10	.6838216-00	.6551480-00	.6165115-00	.5687023-00	.5129564-00
11	.5915143-00	.5666732-00	.5331930-00	.4917610-00	.4433232-00
12	.4862562-00	.4658231-00	.4382421-00	.4041525-00	.3642139-00
13	.3602213-00	.3450672-00	.3246087-00	.2993286-00	.2696928-00
14	.2462481-00	.2358777-00	.2218843-00	.2045823-00	.1842821-00
15	.1702648-00	.1630863-00	.1534238-00	.1414311-00	.1274341-00
16	.1167406+00	.1118352+00	.1052000+00	.9699593-01	.8742753-01
17	.7909443-01	.7577150-01	.7128031-01	.6574823-01	.5931518-01

18	.5187190-01	.4969257-01	.4675886-01	.4315451-01	.3896345-01
19	.3156643-01	.3024271-01	.2846849-01	.2627719-01	.2374065-01
20	.1453031-01	.1392529-01	.1310426-01	.1210034-01	.1094963-01
	11	12	13	14	15
1	.6361837-00	.5410697-00	.4381390-00	.3189418-00	.2128196-00
2	.6359663-00	.5408872-00	.4379912-00	.3188355-00	.2127468-00
3	.6355343-00	.5405206-00	.4376958-00	.3186210-00	.2126040-00
4	.6349128-00	.5399576-00	.4372568-00	.3183022-00	.2123760-00
5	.6289021-00	.5348737-00	.4331125-00	.3152794-00	.2103767-00
6	.6124993-00	.5208972-00	.4218000-00	.3070444-00	.2048719-00
7	.5859691-00	.4982984-00	.4034588-00	.2936808-00	.1959591-00
8	.5496544-00	.4673644-00	.3784029-00	.2754323-00	.1837746-00
9	.5042881-00	.4285925-00	.3469087-00	.2524737-00	.1684333-00
10	.4503637-00	.3825471-00	.3094855-00	.2251717-00	.1502390-00
11	.3889489-00	.3297401-00	.2662880-00	.1935384-00	.1289354-00
12	.3193412-00	.2701874-00	.2165982-00	.1565285-00	.1050921+00
13	.2363606-00	.1997223-00	.1590731-00	.1177081+00	.8282429-01
14	.1614953-00	.1362102-00	.1091641+00	.8446820-01	.6325743-01
15	.1116493+00	.9442040-01	.7669421-01	.6034269-01	.4644917-01
16	.7670968-01	.6523789-01	.5349239-01	.4289293-01	.3373243-01
17	.5216205-01	.4452837-01	.3681526-01	.2977864-01	.2377770-01
18	.3431639-01	.2943309-01	.2450025-01	.2003979-01	.1611872-01
19	.2096513-01	.1802974-01	.1507018-01	.1237310-01	.1006868-01
20	.9669658-02	.8331944-02	.6993311-02	.5778430-02	.4685162-02
	16	17	18	19	20
1	.1439374-00	.9670494-01	.6426194-01	.4134772-01	.2468116-01
2	.1438886-00	.9666885-01	.6424759-01	.4132899-01	.2466865-01
3	.1437844-00	.9661129-01	.6420466-01	.4129239-01	.2466053-01
4	.1436436-00	.9652322-01	.6412411-01	.4125875-01	.2463485-01
5	.1422893-00	.9559075-01	.6352681-01	.4087116-01	.2439971-01
6	.1385571-00	.9309911-01	.6187023-01	.3980315-01	.2376388-01
7	.1325453-00	.8904872-01	.5918125-01	.3808221-01	.2274352-01
8	.1242794+00	.8351636-01	.5552525-01	.3574597-01	.2135013-01
9	.1139538+00	.7660265-01	.5096772-01	.3283479-01	.1962216-01
10	.1016233+00	.6841017-01	.4561415-01	.2942777-01	.1763128-01
11	.8747756-01	.5921972-01	.3963178-01	.2568666-01	.1542624-01
12	.7230852-01	.4941399-01	.3334601-01	.2175316-01	.1311704-01
13	.5795153-01	.4036715-01	.2746870-01	.1811952-01	.1096255-01
14	.4552272-01	.3238660-01	.2236776-01	.1485646-01	.9094264-02
15	.3458529-01	.2508672-01	.1772631-01	.1184803-01	.7329826-02
16	.2559708-01	.1886049-01	.1353697-01	.9223159-02	.5694604-02
17	.1846630-01	.1381287-01	.9966567-02	.6884469-02	.4301264-02
18	.1260488-01	.9615001-02	.7028025-02	.4853389-02	.3070191-02
19	.7957160-02	.6061430-02	.4486154-02	.3134061-02	.1976217-02
20	.3726299-02	.2892055-02	.2120094-02	.1484617-02	.9507971-03
	21				
1	.1115890-01				
2	.1116591-01				
3	.1115376-01				

4	.1114041-01
5	.1103550-01
6	.1075131-01
7	.1028664-01
8	.9659150-02
9	.8891368-02
10	.7987053-02
11	.7002327-02
12	.5978204-02
13	.5028931-02
14	.4152796-02
15	.3368065-02
16	.2668762-02
17	.1996130-02
18	.1426049-02
19	.9329756-03
20	.4505314-03

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

FISSION SOURCE*ADJOINT FLUX

	1	2	3	4	5
1	.1000000+01	.9998566-00	.9991575-00	.9981228-00	.9887265-00
2	.9997082-00	.9995758-00	.9989677-00	.9978643-00	.9883608-00
3	.9991967-00	.9990066-00	.9982992-00	.9972069-00	.9876982-00
4	.9981490-00	.9979892-00	.9972818-00	.9962031-00	.9867193-00
5	.9887744-00	.9886256-00	.9879953-00	.9869360-00	.9775462-00
6	.9634279-00	.9632681-00	.9626160-00	.9615955-00	.9524663-00
7	.9224203-00	.9222937-00	.9216832-00	.9206657-00	.9119304-00
8	.8666416-00	.8664959-00	.8659325-00	.8650147-00	.8567460-00
9	.7971603-00	.7970429-00	.7965046-00	.7956617-00	.7880757-00
10	.7155165-00	.7154016-00	.7149272-00	.7141347-00	.7073398-00
11	.6236798-00	.6235873-00	.6231714-00	.6225064-00	.6165375-00
12	.5217756-00	.5216807-00	.5213290-00	.5207644-00	.5157970-00
13	.3996932-00	.3996127-00	.3993419-00	.3989080-00	.3951070-00
14	.2839814-00	.2839013-00	.2836999-00	.2834050-00	.2807031-00
15	.2014523-00	.2013986-00	.2012590-00	.2010318-00	.1991213-00
16	.1408999-00	.1408600-00	.1407549-00	.1405964-00	.1392727-00
17	.9684837-01	.9681921-01	.9674938-01	.9665492-01	.9572610-01
18	.6431098-01	.6429367-01	.6425497-01	.6417743-01	.6356540-01
19	.3966207-01	.3965219-01	.3961450-01	.3957171-01	.3920098-01
20	.1882821-01	.1882077-01	.1881459-01	.1879684-01	.1861417-01

	6	7	8	9	10
1	.9635367-00	.9236741-00	.8701791-00	.8042797-00	.7276684-00
2	.9632151-00	.9233965-00	.8698687-00	.8040108-00	.7274299-00
3	.9625498-00	.9228139-00	.8692865-00	.8034510-00	.7269614-00
4	.9615794-00	.9218796-00	.8684544-00	.8026194-00	.7262159-00
5	.9526340-00	.9132619-00	.8603525-00	.7951750-00	.7194023-00
6	.9281810-00	.8897997-00	.8382088-00	.7746911-00	.7008756-00
7	.8886799-00	.8519054-00	.8025043-00	.7416187-00	.6708557-00
8	.8348914-00	.8003097-00	.7538403-00	.6966636-00	.6300840-00
9	.7679067-00	.7360738-00	.6932179-00	.6405302-00	.5793174-00
10	.6892152-00	.6605636-00	.6220560-00	.5745450-00	.5194518-00
11	.6007419-00	.5757158-00	.5420802-00	.5005631-00	.4522364-00
12	.5025571-00	.4816016-00	.4533828-00	.4186036-00	.3780020-00
13	.3849568-00	.3688740-00	.3472105-00	.3205036-00	.2893081-00
14	.2735000-00	.2620483-00	.2466231-00	.2275867-00	.2053196-00
15	.1940197-00	.1858806-00	.1749370-00	.1613799-00	.1455845-00
16	.1356880-00	.1300092-00	.1223389+00	.1128624+00	.1018320+00
17	.9326935-01	.8936444-01	.8409075-01	.7760174-01	.7007153-01

18	.6193794-01	.5934339-01	.5585258-01	.5157118-01	.4659590-01
19	.3819477-01	.3659673-01	.3445790-01	.3181697-01	.2876049-01
20	.1813611-01	.1738289-01	.1636055-01	.1511202-01	.1368294-01
	11	12	13	14	15
1	.6423965-00	.5509008-00	.4542062-00	.3419633-00	.2371703-00
2	.6421776-00	.5507179-00	.4540512-00	.3418500-00	.2370899-00
3	.6417480-00	.5503440-00	.4537468-00	.3416208-00	.2369303-00
4	.6411326-00	.5497735-00	.4532957-00	.3412811-00	.2366796+00
5	.6350998-00	.5446406-00	.4490314-00	.3380629-00	.2344624-00
6	.6186818-00	.5305244-00	.4373947-00	.3292923-00	.2283628-00
7	.5921705-00	.5077493-00	.4185585-00	.3150896-00	.2184994-00
8	.5559800-00	.4766391-00	.3928962-00	.2957295-00	.2050385-00
9	.5110376-00	.4378435-00	.3607635-00	.2714719-00	.1881486-00
10	.4580285-00	.3921477-00	.3228864-00	.2428047-00	.1682050-00
11	.3984012-00	.3402804-00	.2798162-00	.2098494-00	.1449993-00
12	.3327061-00	.2834236-00	.2307304-00	.1717388-00	.1190996+00
13	.2544077-00	.2163040-00	.1744356-00	.1317286-00	.9479888-01
14	.1804157-00	.1529257-00	.1235730+00	.9662477-01	.7325826-01
15	.1278303-00	.1084975+00	.8860752-01	.7024148-01	.5450085-01
16	.8950693-01	.7633114-01	.6283389-01	.5060665-01	.4000641-01
17	.6170773-01	.5277882-01	.4374758-01	.3551077-01	.2845693-01
18	.4107843-01	.3528243-01	.2942965-01	.2412146-01	.1945406-01
19	.2542017-01	.2188833-01	.1832217-01	.1507516-01	.1228887-01
20	.1209317-01	.1042903-01	.8764614-02	.7250180-02	.5894209-02
	16	17	18	19	20
1	.1645175-00	.1127196+00	.7596333-01	.4947530-01	.2992415-01
2	.1644616-00	.1126786+00	.7594550-01	.4945305-01	.2990956-01
3	.1643443-00	.1126110+00	.7589521-01	.4940987-01	.2989837-01
4	.1641841-00	.1125071+00	.7580222-01	.4936819-01	.2986840-01
5	.1626413-00	.1114259+00	.7509625-01	.4890640-01	.2958365-01
6	.1583963-00	.1085321+00	.7314515-01	.4763207-01	.2881449-01
7	.1515628-00	.1038346+00	.6997808-01	.4557920-01	.2758152-01
8	.1421856-00	.9742277-01	.6567759-01	.4279743-01	.2589831-01
9	.1304953-00	.8942962-01	.6032924-01	.3933367-01	.2381155-01
10	.1165911+00	.7998497-01	.5405531-01	.3528023-01	.2141107-01
11	.1006870+00	.6940648-01	.4704387-01	.3083228-01	.1875368-01
12	.8364575-01	.5812072-01	.3967228-01	.2615945-01	.1596663-01
13	.6751579-01	.4767075-01	.3278747-01	.2182906-01	.1337088-01
14	.5343499-01	.3843198-01	.2678723-01	.1794243-01	.1110899-01
15	.4091229-01	.2993135-01	.2130376-01	.1435142-01	.8970361-02
16	.3053263-01	.2262247-01	.1633442-01	.1120330-01	.6989556-02
17	.2218456-01	.1666458-01	.1207609-01	.8391491-02	.5292970-02
18	.1526119-01	.1167612-01	.8565616-02	.5946467-02	.3795627-02
19	.9731747-02	.7435973-02	.5518396-02	.3873665-02	.2465255-02
20	.4697828-02	.3650536-02	.2687149-02	.1888795-02	.1218774-02
	21				
1	.1395338-01				
2	.1396063-01				
3	.1394663-01				

4	.1392956-01
5	.1379907-01
6	.1344455-01
7	.1286480-01
8	.1208266-01
9	.1112755-01
10	.1000244-01
11	.8775192-02
12	.7500386-02
13	.6314985-02
14	.5228608-02
15	.4248862-02
16	.3369931-02
17	.2530729-02
18	.1814705-02
19	.1195761-02
20	.5949106-03

POWER DENSITY (MWT/LITER)

	1	2	3	4	5
1	.1232984-15	.1232733-15	.1231851-15	.1230549-15	.1218897-15
2	.1232589-15	.1232351-15	.1231565-15	.1230204-15	.1218457-15
3	.1231899-15	.1231608-15	.1230720-15	.1229376-15	.1217639-15
4	.1230617-15	.1230356-15	.1229465-15	.1228125-15	.1216419-15
5	.1218992-15	.1218743-15	.1217930-15	.1216606-15	.1205005-15
6	.1187427-15	.1187170-15	.1186343-15	.1185071-15	.1173781-15
7	.1136292-15	.1136069-15	.1135288-15	.1134034-15	.1123238-15
8	.1066486-15	.1066254-15	.1065534-15	.1064389-15	.1054199-15
9	.9790969-16	.9788979-16	.9782170-16	.9771635-16	.9678274-16
10	.8754587-16	.8752719-16	.8746701-16	.8736993-16	.8653581-16
11	.7572469-16	.7570896-16	.7565686-16	.7557525-16	.7484960-16
12	.6224442-16	.6223008-16	.6218693-16	.6211907-16	.6152526-16
13	.1420256-16	.1419976-16	.1419013-16	.1417456-16	.1403901-16
14	.9771452-17	.9768704-17	.9761882-17	.9751752-17	.9658325-17
15	.6799078-17	.6797260-17	.6792591-17	.6784838-17	.6720208-17
16	.4686312-17	.4684999-17	.4681436-17	.4676144-17	.4632109-17
17	.3187558-17	.3186571-17	.3184292-17	.3181281-17	.3150555-17
18	.2100514-17	.2099966-17	.2098737-17	.2096107-17	.2076116-17
19	.1288134-17	.1287801-17	.1286506-17	.1285155-17	.1273129-17
20	.6076100-18	.6073578-18	.6072192-18	.6066417-18	.6007301-18

	6	7	8	9	10
1	.1187662-15	.1138082-15	.1071327-15	.9888191-16	.8924468-16
2	.1187263-15	.1137724-15	.1070946-15	.9884875-16	.8921513-16
3	.1186443-15	.1136987-15	.1070226-15	.9878003-16	.8915670-16
4	.1185242-15	.1135827-15	.1069181-15	.9867796-16	.8906547-16
5	.1174119-15	.1125132-15	.1059118-15	.9775310-16	.8822330-16
6	.1143680-15	.1095945-15	.1031604-15	.9521122-16	.8592927-16
7	.1094428-15	.1048716-15	.9871346-16	.9109932-16	.8220861-16
8	.1027145-15	.9842040-16	.9263401-16	.8548854-16	.7713414-16
9	.9429286-16	.9034769-16	.8502456-16	.7845425-16	.7078410-16
10	.8430753-16	.8077217-16	.7600823-16	.7011308-16	.6323895-16
11	.7292195-16	.6985934-16	.6573149-16	.6062308-16	.5465064-16
12	.5993816-16	.5741933-16	.5401924-16	.4981667-16	.4489284-16
13	.1367664-16	.1310224-16	.1232769-16	.1137160-16	.1025194-16
14	.9409541-17	.9013848-17	.8480549-17	.7821566-17	.7049236-17
15	.6547517-17	.6271844-17	.5901166-17	.5441209-17	.4904905-17
16	.4512524-17	.4323204-17	.4067202-17	.3750757-17	.3382078-17
17	.3069548-17	.2940757-17	.2766679-17	.2552480-17	.2303541-17

18	.2022911-17	.1937979-17	.1823741-17	.1683522-17	.1520374-17
19	.1240395-17	.1188418-17	.1118840-17	.1032836-17	.9332967-18
20	.5852792-18	.5609372-18	.5278842-18	.4875109-18	.4412514-18
	11	12	13	14	15
1	.7843313-16	.6670167-16	.5400543-16	.1212234-16	.8141006-17
2	.7840632-16	.6667916-16	.5398722-16	.1211831-16	.8138223-17
3	.7835305-16	.6663397-16	.5395080-16	.1211018-16	.8132738-17
4	.7827641-16	.6656456-16	.5389669-16	.1209804-16	.8124006-17
5	.7753533-16	.6593778-16	.5338581-16	.1198345-16	.8047754-17
6	.7551290-16	.6421465-16	.5199132-16	.1167123-16	.7837595-17
7	.7224175-16	.6142844-16	.4973034-16	.1116479-16	.7497635-17
8	.6776403-16	.5761451-16	.4664155-16	.1047381-16	.7033013-17
9	.6216992-16	.5283399-16	.4275891-16	.9605414-17	.6448714-17
10	.5551997-16	.4715620-16	.3814497-16	.8575225-17	.5756678-17
11	.4794573-16	.4064424-16	.3281895-16	.7381502-17	.4946016-17
12	.3936034-16	.3329980-16	.2669195-16	.5988554-17	.4039860-17
13	.8995221-17	.7614191-17	.6084869-17	.4524165-17	.3194231-17
14	.6183332-17	.5222242-17	.4194896-17	.3256914-17	.2445907-17
15	.4300383-17	.3640271-17	.2961184-17	.2334306-17	.1799932-17
16	.2969120-17	.2526996-17	.2074372-17	.1665773-17	.1311724-17
17	.2026597-17	.1730925-17	.1432085-17	.1159378-17	.9269056-18
18	.1339401-17	.1149268-17	.9572611-18	.7835343-18	.6305037-18
19	.8244304-18	.7092929-18	.5931295-18	.4872755-18	.3968928-18
20	.3897777-18	.3359361-18	.2820708-18	.2331581-18	.1891412-18
	16	17	18	19	20
1	.5540133-17	.3740779-17	.2495257-17	.1613177-17	.9702839-18
2	.5538244-17	.3739395-17	.2494741-17	.1612393-17	.9697918-18
3	.5534236-17	.3737226-17	.2493056-17	.1610935-17	.9694954-18
4	.5528901-17	.3733823-17	.2489881-17	.1609638-17	.9685137-18
5	.5476824-17	.3697740-17	.2466751-17	.1594584-17	.9592488-18
6	.5333433-17	.3601572-17	.2402561-17	.1552948-17	.9342771-18
7	.5102651-17	.3445197-17	.2298266-17	.1485920-17	.8942561-18
8	.4785300-17	.3231637-17	.2156652-17	.1395009-17	.8395413-18
9	.4389347-17	.2965082-17	.1980202-17	.1281623-17	.7716997-18
10	.3916703-17	.2649197-17	.1772789-17	.1148890-17	.6935834-18
11	.3374265-17	.2294749-17	.1540983-17	.1003197-17	.6070648-18
12	.2792875-17	.1916747-17	.1297390-17	.8500732-18	.5164021-18
13	.2242392-17	.1567985-17	.1069596-17	.7085421-18	.4318410-18
14	.1764329-17	.1259579-17	.8720217-18	.5811742-18	.3585791-18
15	.1342007-17	.9761131-18	.6920364-18	.4637994-18	.2891591-18
16	.9958270-18	.7342181-18	.5286848-18	.3616403-18	.2246880-18
17	.7208500-18	.5393811-18	.3894813-18	.2702633-18	.1699957-18
18	.4934121-18	.3769844-18	.2758675-18	.1909925-18	.1217535-18
19	.3138265-18	.2391171-18	.1772748-18	.1242596-18	.7888532-19
20	.1506328-18	.1170665-18	.8584845-19	.6024071-19	.3886715-19
	21				
1	.4495929-18				
2	.4499207-18				
3	.4494437-18				

4	.4488739-18
5	.4446553-18
6	.4332292-18
7	.4145158-18
8	.3892744-18
9	.3584034-18
10	.3220258-18
11	.2823815-18
12	.2411692-18
13	.2029402-18
14	.1676656-18
15	.1361704-18
16	.1080491-18
17	.8084084-19
18	.5786321-19
19	.3813085-19
20	.1890341-19

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

ACTIVITY 1 ISOTOPE 1 CROSS SECTION POSITION 1

	1	2	3	4	5
1	.1907972+01	.1907564+01	.1906193+01	.1904174+01	.1886147+01
2	.1907354+01	.1906968+01	.1905745+01	.1903638+01	.1885468+01
3	.1906278+01	.1905812+01	.1904432+01	.1902354+01	.1884203+01
4	.1904295+01	.1903875+01	.1902490+01	.1900416+01	.1882314+01
5	.1886302+01	.1885899+01	.1884633+01	.1882583+01	.1864640+01
6	.1837425+01	.1837010+01	.1835725+01	.1833756+01	.1816291+01
7	.1758240+01	.1757877+01	.1756663+01	.1754722+01	.1738025+01
8	.1650116+01	.1649742+01	.1648621+01	.1646849+01	.1631091+01
9	.1514715+01	.1514393+01	.1513335+01	.1511703+01	.1497267+01
10	.1354039+01	.1353738+01	.1352803+01	.1351301+01	.1338405+01
11	.1170667+01	.1170414+01	.1169604+01	.1168342+01	.1157129+01
12	.9614747-00	.9612448-00	.9605753-00	.9595262-00	.9503582-00
13	.7113178-00	.7111445-00	.7106505-00	.7098685-00	.7030990-00
14	.4855099-00	.4853590-00	.4850135-00	.4845093-00	.4798805-00
15	.3351690-00	.3350703-00	.3348383-00	.3344615-00	.3312791-00
16	.2295342-00	.2294642-00	.2292902-00	.2290308-00	.2268771-00
17	.1553528-00	.1553020-00	.1551894-00	.1550412-00	.1535500-00
18	.1017547+00	.1017248+00	.1016640+00	.1015382+00	.1005738+00
19	.6181158-01	.6179478-01	.6173424-01	.6167043-01	.6109259-01
20	.2826849-01	.2825536-01	.2824785-01	.2821996-01	.2794678-01

	6	7	8	9	10
1	.1837811+01	.1761057+01	.1657682+01	.1529882+01	.1380564+01
2	.1837195+01	.1760502+01	.1657093+01	.1529369+01	.1380106+01
3	.1835927+01	.1759359+01	.1655978+01	.1528306+01	.1379202+01
4	.1834068+01	.1757563+01	.1654359+01	.1526727+01	.1377791+01
5	.1816846+01	.1741006+01	.1638779+01	.1512408+01	.1364756+01
6	.1769713+01	.1695816+01	.1596181+01	.1473057+01	.1329247+01
7	.1693443+01	.1622680+01	.1527321+01	.1409392+01	.1271653+01
8	.1589230+01	.1522760+01	.1433165+01	.1322498+01	.1193078+01
9	.1458748+01	.1397687+01	.1315280+01	.1213534+01	.1094723+01
10	.1303943+01	.1249239+01	.1175509+01	.1084250+01	.9777997-00
11	.1127329+01	.1079964+01	.1016107+01	.9370678-00	.8446331-00
12	.9258428-00	.8869208-00	.8343673-00	.7693975-00	.6932588-00
13	.6849527-00	.6561260-00	.6171983-00	.5690844-00	.5126668-00
14	.4675180-00	.4478222-00	.4212380-00	.3883634-00	.3497820-00
15	.3227648-00	.3091523-00	.2908249-00	.2680761-00	.2415192-00
16	.2210234-00	.2117327-00	.1991645-00	.1836238-00	.1654940-00
17	.1496028-00	.1433157-00	.1348182-00	.1243487+00	.1121724+00

18	.9799564-01	.9387780-01	.8633344-01	.8152003-01	.7359881-01
19	.5952324-01	.5702670-01	.5367948-01	.4954623-01	.4476161-01
20	.2722840-01	.2609431-01	.2455555-01	.2267355-01	.2051615-01
	11	12	13	14	15
1	.1212966+01	.1031018+01	.8340428-00	.6063061-00	.4039465-00
2	.1212551+01	.1030670+01	.8337615-00	.6061038-00	.4038084-00
3	.1211726+01	.1029972+01	.8331990-00	.6056958-00	.4035375-00
4	.1210540+01	.1028898+01	.8323633-00	.6050899-00	.4031049-00
5	.1199075+01	.1019205+01	.8244689-00	.5993401-00	.3993074-00
6	.1167780+01	.9925559-00	.8029216-00	.5836763-00	.3888540-00
7	.1117158+01	.9494602-00	.7679814-00	.5582545-00	.3719251-00
8	.1047851+01	.8904602-00	.7202407-00	.5235330-00	.3487805-00
9	.9612321-00	.8164840-00	.6602146-00	.4798385-00	.3196312-00
10	.8582114-00	.7285764-00	.5888456-00	.4278482-00	.2850500-00
11	.7408136-00	.6277133-00	.5064451-00	.3676110-00	.2445635-00
12	.6076701-00	.5138909-00	.4116000-00	.2970919-00	.1992366-00
13	.4491811-00	.3793945-00	.3019339-00	.2231622-00	.1568970-00
14	.3064623-00	.2583961-00	.2069742-00	.1600196-00	.1197556+00
15	.2115671-00	.1788779-00	.1452444-00	.1142245+00	.8788827-01
16	.1451862-00	.1234512+00	.1011970+00	.8111586-01	.6377189-01
17	.9863476-01	.8418915-01	.6959432-01	.5628046-01	.4492506-01
18	.6481664-01	.5558752-01	.4626411-01	.3783481-01	.3042857-01
19	.3952561-01	.3398801-01	.2840575-01	.2331848-01	.1897113-01
20	.1811661-01	.1560937-01	.1310024-01	.1082340-01	.8774492-02
	16	17	18	19	20
1	.2727968-00	.1830578-00	.1215320+00	.7810529-01	.4653472-01
2	.2727045-00	.1829893-00	.1215044+00	.7807055-01	.4651116-01
3	.2725069-00	.1828796-00	.1214234+00	.7800178-01	.4649556-01
4	.2722392-00	.1827129-00	.1212717+00	.7793804-01	.4644680-01
5	.2696718-00	.1809479-00	.1201413+00	.7720508-01	.4600374-01
6	.2625952-00	.1762288-00	.1170068+00	.7518723-01	.4480461-01
7	.2511941-00	.1685580-00	.1119200+00	.7193503-01	.4287969-01
8	.2355186-00	.1580802-00	.1050016+00	.6751909-01	.4025179-01
9	.2159315-00	.1449823-00	.9637629-01	.6201759-01	.3699276-01
10	.1925388-00	.1294622-00	.8624610-01	.5557949-01	.3323727-01
11	.1657050-00	.1120525+00	.7492647-01	.4850942-01	.2907781-01
12	.1369265-00	.9347513-01	.6303309-01	.4107503-01	.2472255-01
13	.1096912+00	.7633570-01	.5191296-01	.3420831-01	.2065877-01
14	.8613173-01	.6122533-01	.4226020-01	.2804516-01	.1713402-01
15	.6541860-01	.4742000-01	.3347944-01	.2236228-01	.1380795-01
16	.4838641-01	.3564654-01	.2556471-01	.1740097-01	.1072706-01
17	.3487796-01	.2608667-01	.1881912-01	.1298480-01	.8099008-02
18	.2379097-01	.1814048-01	.1325594-01	.9148456-02	.5776055-02
19	.1499068-01	.1141859-01	.8447481-02	.5896537-02	.3711782-02
20	.6976309-02	.5412576-02	.3967471-02	.2776777-02	.1774915-02
	21				
1	.2090934-01				
2	.2092194-01				
3	.2089901-01				

4	.2087438-01
5	.2067770-01
6	.2014491-01
7	.1927412-01
8	.1809787-01
9	.1665846-01
10	.1496329-01
11	.1311777-01
12	.1119819-01
13	.9419254-02
14	.7777269-02
15	.6305405-02
16	.4994424-02
17	.3735344-02
18	.2667245-02
19	.1741740-02
20	.8352372-03

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

ZONE	AV FLUX	AV POWER	ACT 1
1	.9980257-00	.1230547-15	.1904171+01
2	.5448032-00	.6716426-16	.1038406+01
3	.5995134-01	.2308208-17	.1136144+00

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

BETA EFFECTIVE - - - - - - - 4.20647-03

NEUTRON GENERATION TIME - - - - - 3.02887-07

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

REACTIVITY COEFFICIENTS FOR MATERIAL 1 M2PU49 ROW 1

	ΔK/K PER KG	ΔK (NUSIGF)	ΔK (SIGA)	ΔK (SIGTR)	ΔK (SIGJXK)	ΔK (INTG)	AVG RADII	AVG AXII
1	.5455-02	.8937-02	-.3469-02	.2461-07	-.1278-04	.5455-02	.3175-00	.3175-00
2	.5454-02	.8933-02	-.3467-02	.7413-07	-.1279-04	.5454-02	.9525-00	.3175-00
3	.5446-02	.8921-02	-.3462-02	.2113-06	-.1277-04	.5450-02	.1587+01	.3175-00
4	.5435-02	.8902-02	-.3455-02	.7864-06	-.1275-04	.5443-02	.2222+01	.3175-00
5	.5335-02	.8735-02	-.3389-02	.2424-05	-.1253-04	.5350-02	.4716+01	.3175-00
6	.5071-02	.8294-02	-.3217-02	.5893-05	-.1197-04	.5176-02	.9068+01	.3175-00
7	.4667-02	.7619-02	-.2953-02	.1216-04	-.1113-04	.4932-02	.1342+02	.3175-00
8	.4152-02	.6756-02	-.2614-02	.1998-04	-.1009-04	.4629-02	.1777+02	.3175-00
9	.3560-02	.5763-02	-.2223-02	.2866-04	-.8949-05	.4280-02	.2212+02	.3175-00
10	.2930-02	.4706-02	-.1806-02	.3741-04	-.7795-05	.3901-02	.2648+02	.3175-00
11	.2301-02	.3650-02	-.1387-02	.4538-04	-.6744-05	.3507-02	.3083+02	.3175-00
12	.1714-02	.2661-02	-.9937-03	.5312-04	-.5844-05	.3114-02	.3518+02	.3175-00
13	.1203-02	.1775-02	-.6390-03	.7166-04	-.5188-05	.2736-02	.3953+02	.3175-00
14	.6701-03	.9717-03	-.3263-03	.2894-04	-.4143-05	.2404-02	.4361+02	.3175-00
15	.3264-03	.4491-03	-.1389-03	.1881-04	-.2610-05	.2096-02	.4742+02	.3175-00
16	.1557-03	.2104-03	-.6156-04	.8306-05	-.1445-05	.1828-02	.5123+02	.3175-00
17	.7281-04	.9677-04	-.2713-04	.3926-05	-.7430-06	.1601-02	.5504+02	.3175-00
18	.3304-04	.4330-04	-.1180-04	.1900-05	-.3566-06	.1410-02	.5885+02	.3175-00
19	.1410-04	.1813-04	-.4846-05	.9712-06	-.1572-06	.1250-02	.6266+02	.3175-00
20	.5307-05	.6534-05	-.1732-05	.5630-06	-.5904-07	.1115-02	.6647+02	.3175-00
21	.1440-05	.1370-05	-.3675-06	.4501-06	-.1316-07	.1001-02	.7028+02	.3175-00

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

REACTIVITY COEFFICIENTS FOR MATERIAL 1 M2PU49 COLUMN 5

	ΔK/K PER KG	ΔK (NUSIGF)	ΔK (SIGA)	ΔK (SIGTR)	ΔK (SIGJXK)	ΔK (INTG)	AVG RADII	AVG AXII
1	.5335-02	.8735-02	-.3389-02	.2424-05	-.1253-04	.5335-02	.4716+01	.3175-00
2	.5331-02	.8728-02	-.3387-02	.2472-05	-.1252-04	.5333-02	.4716+01	.9525-00
3	.5324-02	.8717-02	-.3382-02	.2579-05	-.1251-04	.5330-02	.4716+01	.1587+01
4	.5314-02	.8699-02	-.3376-02	.3094-05	-.1249-04	.5326-02	.4716+01	.2222+01
5	.5218-02	.8538-02	-.3312-02	.4597-05	-.1229-04	.5257-02	.4716+01	.4767+01
6	.4957-02	.8103-02	-.3142-02	.7954-05	-.1175-04	.5140-02	.4716+01	.9222+01
7	.4552-02	.7424-02	-.2875-02	.1428-04	-.1093-04	.4976-02	.4716+01	.1368+02
8	.4028-02	.6545-02	-.2530-02	.2246-04	-.9924-05	.4768-02	.4716+01	.1813+02
9	.3423-02	.5527-02	-.2127-02	.3197-04	-.8838-05	.4527-02	.4716+01	.2258+02
10	.2776-02	.4435-02	-.1693-02	.4220-04	-.7817-05	.4260-02	.4716+01	.2704+02
11	.2134-02	.3342-02	-.1255-02	.5403-04	-.6953-05	.3979-02	.4716+01	.3149+02
12	.1538-02	.2297-02	-.8325-03	.7973-04	-.6400-05	.3695-02	.4716+01	.3595+02
13	.8904-03	.1302-02	-.4404-03	.3430-04	-.5366-05	.3440-02	.4716+01	.4008+02
14	.4544-03	.6314-03	-.1968-03	.2339-04	-.3575-05	.3192-02	.4716+01	.4389+02
15	.2270-03	.3093-03	-.9115-04	.1090-04	-.2081-05	.2964-02	.4716+01	.4770+02
16	.1107-03	.1482-03	-.4183-04	.5422-05	-.1119-05	.2760-02	.4716+01	.5151+02
17	.5224-04	.6894-04	-.1889-04	.2753-05	-.5605-06	.2580-02	.4716+01	.5532+02
18	.2315-04	.2999-04	-.8056-05	.1476-05	-.2575-06	.2421-02	.4716+01	.5913+02
19	.9054-05	.1124-04	-.2999-05	.9068-06	-.1007-06	.2279-02	.4716+01	.6294+02
20	.2514-05	.2443-05	-.6573-06	.7512-06	-.2331-07	.2153-02	.4716+01	.6675+02

PERT-IV TEST CASE (2DF FLUX INPUT, 2 GROUPS, 3 ZONES)

REACTIVITY COEFFICIENTS FOR MATERIAL 6 NA ROW 1

	ΔK/K PER KG	ΔK (NUSIGF)	ΔK (SIGA)	ΔK (SIGTR)	ΔK (SIGJXK)	ΔK (INTG)	AVG RADII	AVG AXII
1	-.1773-03	.0000	-.2791-04	.1112-06	-.1495-03	-.1773-03	.3175-00	.3175-00
2	-.1772-03	.0000	-.2789-04	.3334-06	-.1496-03	-.1772-03	.9525-00	.3175-00
3	-.1764-03	.0000	-.2785-04	.9636-06	-.1495-03	-.1767-03	.1587+01	.3175-00
4	-.1734-03	.0000	-.2779-04	.3601-05	-.1492-03	-.1753-03	.2222+01	.3175-00
5	-.1628-03	.0000	-.2726-04	.1111-04	-.1467-03	-.1645-03	.4716+01	.3175-00
6	-.1389-03	.0000	-.2587-04	.2699-04	-.1400-03	-.1485-03	.9068+01	.3175-00
7	-.9827-04	.0000	-.2373-04	.5565-04	-.1302-03	-.1244-03	.1342+02	.3175-00
8	-.4767-04	.0000	-.2098-04	.9142-04	-.1181-03	-.9457-04	.1777+02	.3175-00
9	.8471-05	.0000	-.1779-04	.1310-03	-.1047-03	-.6097-04	.2212+02	.3175-00
10	.6510-04	.0000	-.1439-04	.1707-03	-.9122-04	-.2558-04	.2648+02	.3175-00
11	.1168-03	.0000	-.1096-04	.2066-03	-.7892-04	.9486-05	.3083+02	.3175-00
12	.1650-03	.0000	-.7729-05	.2411-03	-.6839-04	.4361-04	.3518+02	.3175-00
13	.2593-03	.0000	-.4804-05	.3248-03	-.6071-04	.8628-04	.3953+02	.3175-00
14	.8034-04	.0000	-.2291-05	.1311-03	-.4849-04	.8532-04	.4361+02	.3175-00
15	.5468-04	.0000	-.8857-06	.8611-04	-.3055-04	.8077-04	.4742+02	.3175-00
16	.2123-04	.0000	-.3626-06	.3850-04	-.1691-04	.7254-04	.5123+02	.3175-00
17	.9517-05	.0000	-.1490-06	.1836-04	-.8695-05	.6439-04	.5504+02	.3175-00
18	.4713-05	.0000	-.6145-07	.8948-05	-.4174-05	.5714-04	.5885+02	.3175-00
19	.2731-05	.0000	-.2416-07	.4595-05	-.1840-05	.5091-04	.6266+02	.3175-00
20	.1974-05	.0000	-.8338-08	.2673-05	-.6909-06	.4561-04	.6647+02	.3175-00
21	.1984-05	.0000	-.1697-08	.2140-05	-.1540-06	.4112-04	.7028+02	.3175-00

APPENDIX III: LISTING OF PERT-IV

```
-IL PDP  INCL
ABC*  FCOPY
      REAL I2
      DIMENSION    A(25,10), A0(50), A1(50), A2(50), ADJ(50,50), ATW(25)
     1 , BETA(20), C(15,26,35), C0(15,35), CHI(26), CHIP(26), DUM(2500),
     2 HOLN(25), PHC(26), PHI(50,50), PHR(50,50), PHZ(50,50), R1(51),
     3 R4(50), R5(50), SLOPR(50), SLOPZ(50), SORC1(50,50), SORC2(50,50),
     4 V0(50,50), VEL(26), VOL(40), Z1(51), Z4(50), Z5(50), ZACT(40,3),
     5 ZPHI(40), ZPOW(40)
      DIMENSION    I0(45), I1(45), I2(45), ID(12), L2(40), LDUM(2500),
     1 M0(50,50), M2(40), MA(15), MATDK(20), NBET(20), NCOL(20),
     2 NROW(20), NX(15)
      COMMON   NINP, NOUT, NCR1, NFLUX1, NSCRAT, NFLUX2,
     1 IFP, IGM, IGE, IGEP, IM, IMJM, IP, IST, ITL, IZM, JM, JP, M01,
     2  MCR, MT, MTP, NACT, ND, NDELK, NFP, NIBC, NPRT
      COMMON   AK, DENOM, FEF, FLPO, VF, ZKEFF
      COMMON   A, A0, A1, A2, ADJ, ATW, BETA, C, C0, CHI, CHIP, DUM,
     1 HOLN, PHC, PHI, PHR, PHZ, R1, R4, R5, SLOPR, SLOPZ, SORC1, SORC2,
     2 V0, VEL, VOL, Z1, Z4, Z5, ZACT, ZPHI, ZPOW
      COMMON   I0, I1, I2, ID, L2, LDUM, M0, M2, MA, MATDK, NBET, NCOL,
     1 NROW, NX
      END
```

```
-ITC FOR MAIN,MAIN
      INCLUDE ABC
C
C   MAIN          MAIN PROGRAM SETS UP TAPE UNITS AND CALLS INP1, MAPR,
C                 SETUP, GRAM, NORM, ABETA, AND CALC.
C
C   INP1          SUBROUTINE TO CONTROL THE READING AND PRINTING OF ALL
C                 INPUT DATA.  INP1 IS CALLED BY MAIN AND CALLS XSINP,
C                 FXINP, REAG2, AND REAI2.
C
C   XSINP         XSINP READS, CHECKS, PRINTS, AND WRITES THE CROSS
C                 SECTIONS TO TAPE.  THE SUBROUTINE IS CALLED BY INP1.
C
C   FXINP         SUBROUTINE TO READ AND PRINT THE INPUT FLUXES. IF FLUXES
C                 ARE IN 1-D FORM, THEY ARE COMBINED RESULTING IN THE 2-D
C                 FORM.  INP1 CALLS FXINP, REAG2, AND REAI2 AND IS CALLED
C                 BY MAIN.
C
C   REAI2         REAI2 READS ALL INTEGER DATA AFTER CARD 4.  IT IS CALLED
C                 BY FXINP AND INP1.
C
C   REAG2         REAG2 READS ALL REAL DATA AFTER THE CROSS SECTIONS EXCEPT
C                 FOR THE 2-D FLUXES.  IT IS CALLED BY FXINP AND INP1.
C
C   MAPR          SUBROUTINE TO PRODUCE A PICTURE PRINT BY ZONE AND BY
C                 MATERIAL.  MAPR IS CALLED BY MAIN.
C
C   PRT           SUBROUTINE PRINTS OUT TWO-DIMENSIONAL ARRAYS.  IT IS
C                 CALLED BY NORM.
C
C   ERRO2         SUBROUTINE TO PRINT AN ERROR MESSAGE.  ERRO2 IS CALLED
C                 BY REAI2 AND REAG2.
C
C   SETUP         SETUP MIXES THE CROSS SECTIONS AND CALCULATES THE AREAS
C                 AND VOLUMES.  IT IS CALLED BY MAIN.
C
C   GRAM          THIS SUBROUTINE CALCULATES THE MASS OF EACH MATERIAL IN
C                 EACH ZONE AND ALSO THE ZONE VOLUME.  IT IS CALLED BY
C                 MAIN.
C
C   NORM          NORM NORMALIZES THE FLUX AND ADJOINT FLUX AND CALCULATES
C                 K EFFECTIVE.  IT CALLS PRT AND IS CALLED BY MAIN.
C
C   AVG           THIS SUBROUTINE CALCULATES ZONE AVERAGED FLUXES, POWERS,
C                 AND ACTIVITIES.  IT IS CALLED BY NORM.
C
C   ABETA         ABETA PERFORMS THE NEUTRON LIFETIME AND BETA EFFECTIVE
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C               CALCULATION.  IT IS CALLED BY MAIN.
C
C    CALC       SUBROUTINE TO CALCULATE AND PRINT REACTIVITY
C               COEFFICIENTS.  IT IS CALLED BY MAIN.
C
C    AK          CALCULATED VALUE OF K EFFECTIVE
C    CAD         TOTAL CHI*ADJOINT AT CENTER
C    CFX         TOTAL CENTER POINT FLUX
C    CPW         TOTAL CENTER POINT POWER
C    DENOM       DENOMINATOR OF PERTURBATION FORMULA
C    FEF         AVERAGE ENERGY RELEASED PER FISSION (MEV/FISSION)
C    FLPO        FLUX OR POWER (SEE NFP)
C    IFP         FLUX PUNCH OPTION
C    IGE         TYPE OF GEOMETRY    (0/1/2=R-Z/X-Y/R-THETA)
C    IGEP        IGE + 1
C    IGM         NUMBER OF GROUPS  (< OR = 26)
C    IGP         NUMBER OF GROUPS PLUS 1
C    IM          NUMBER OF RADIAL INTERVALS       (< OR = 50)
C    IMJM        IM*JM
C    IP          IM + 1
C    IST         NUMBER OF DOWNSCATTERING TERMS   (< OR = 10)
C    ITL         CROSS SECTION TABLE LENGTH    (< OR = 15)
C    IZM         NUMBER OF MATERIAL ZONES   (< OR = 40)
C    JM          NUMBER OF AXIAL INTERVALS        (< OR = 50)
C    JP          JM + 1
C    M01         LENGTH OF MIX VECTORS (I0,I1,I2)       (< OR = 45)
C    MCR         NUMBER OF MATERIALS FROM CARDS   (< OR = 25)
C    MT          TOTAL NUMBER OF MATERIALS (< OR = 35)
C    MTP         NUMBER OF MATERIALS FROM TAPE
C    NACT        NUMBER OF ACTIVITY TRAVERSES  (< OR = 3)
C    NCR1        CROSS SECTION TAPE
C    ND          FLUX INPUT OPTION
C    NDELK       NUMBER OF REACTIVITY COEFFICIENT CALCULATIONS(< OR = 20)
C    NFLUX1      FLUX TAPE
C    NFLUX2      ADJOINT FLUX TAPE
C    NFP         FLUX NORMALIZATION OPTION
C    NIBC        NUMBER OF ISOTOPES FOR BETA CALCULATION  (< OR = 20)
C    NINP        LOGICAL INPUT TAPE
C    NOUT        LOGICAL OUTPUT TAPE
C    NPRT        PRINT OPTION
C    NSCRAT      SCRATCH TAPE
C    POWER       TOTAL REACTOR POWER
C    RABS        ABSORPTION RATE
C    RL          RADIAL LEAKAGE
C    RLEAK       LEAKAGE RATE
C    RSORS       SOURCE RATE
C    TSD         (MW-SEC)/(FISSIONS)
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C    VF            VOLUME FACTOR
C    ZKEFF         KEFF FOR DELTA K CALC.  (IF =0, USE KEFF CALC. BY CODE)
C    ZL            AXIAL LEAKAGE
C    A(MCR,10)     ID CARD FOR EACH MATERIAL CROSS SECTION SET
C    A0(IM)        RADIAL AREA ELEMENT
C    A1(JM)        AXIAL AREA ELEMENT
C    A2(JM)        AREA AT I=IP BETWEEN J-1 AND J
C    ACT(IM,JM,NACT)  ACTIVITY TRAVERSE
C    ADJ(IM,JM)    ADJOINT FLUX
C    ADJR(IGM,IM)    1-D RADIAL ADJOINT FLUX
C    ADJZ(IGM,JM)    1-D AXIAL ADJOINT FLUX
C    ATW(MCR)      MATERIAL ATOMIC WEIGHT
C    BETA(NIBC)    ABSOLUTE NEUTRON YIELD PER DELAYED FISSION
C    C(ITL,IGM,MT) CROSS SECTION ARRAY
C    C0(ITL,MT)    CROSS-SECTION ARRAY FOR CURRENT GROUP
C    CHI(IGM)      FISSION SPECTRUM
C    CHIP(IGM)     DELAYED NEUTRON FISSION SPECTRUM
C    CX(ITL,IGM)   CROSS SECTION ARRAY FOR MATDK  (EQUIVALENCED)
C    DUM(IMJM)     DUMMY VARIABLE
C    HOLN(MCR)     MATERIAL NAME
C    I0(M01)       MIX NUMBERS
C    I1(M01)       MATERIAL NUMBERS FOR MIX
C    I2(M01)       MATERIAL DENSITIES FOR MIX
C    ID(12)        IDENTIFICATION CARD ARRAY
C    L2(MT)        ZONE NUMBER BY MATERIAL
C    LDUM(IMJM)    DUMMY VARIABLE
C    M0(IM,JM)     ZONE NUMBERS
C    M2(IZM)       MATERIAL NUMBERS BY ZONE
C    MA(NACT)      MATERIAL NUMBER FOR ACTIVITY TRAVERSE
C    MASS(IZM,MT)    MASS OF MATERIAL IN ZONE
C    MATDK(NDELK)    MATERIAL NUMBER FOR REACTIVITY COEFFICIENT CALCULATION
C    NBET(NIBC)    MATERIAL NUMBER FOR BETA CALCULATION
C    NCOL(NDELK)   COLUMN NUMBER FOR REACTIVITY COEFFICIENT CALCULATION
C    NROW(NDELK)   ROW NUMBER FOR REACTIVITY COEFFICIENT CALCULATION
C    NX(NACT)      CROSS SECTION POSITION FOR ACTIVITY TRAVERSE
C    PHC(IGM)      CENTER POINT FLUX
C    PHI(IM,JM)    FLUX
C    PHR(IGM,IM)   1-D RADIAL FLUX
C    PHZ(IGM,JM)   1-D AXIAL FLUX
C    R1(IP)        RADII VALUES
C    R4(IM)        AVERAGE RADII
C    R5(IM)        DELTA-R
C    SLOAR(IM)     D(ADJOINT)/DR   (EQUIVALENCED)
C    SLOAZ(JM)     D(ADJOINT)/DZ   (EQUIVALENCED)
C    SLOPR(IM)     D(FLUX)/DR
C    SLOPZ(JM)     D(FLUX)/DZ
C    SORC1(IM,JM)    NU*SIGF*FLUX   (IN NORM)
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```
C     SORC2(IM,JM)   =CADJ(I,J)    CHI*ADJOINT    (IN NORM)
C     TPHI(IM,JM) TOTAL FLUX  (EQUIVALENCED)
C     VO(IM,JM)    VOLUME ELEMENTS
C     VEL(IGM)     NEUTRON VELOCITY
C     VOL(IZM)     ZONE VOLUME
C     Z1(JP)       AXII VALUES
C     Z4(JM)       AVERAGE AXII
C     Z5(JM)       DELTA-Z
C     ZACT(IZM,NACT)  ZONE AVERAGED ACTIVITIES
C     ZPHI(IZM)    ZONE AVERAGED FLUX
C     ZPOW(IZM)    ZONE AVERAGED POWER
      DIMENSION JLPTAB(28)
      CALL SETIO(9,2)
      CALL SETIO(10,1)
      CALL SETDR(3,525000,50000,JLPTAB)
      CALL SETDR(4,575000, 200000,JLPTAB(8))
      CALL SETDR(6,775000,200000,JLPTAB(15))
      CALL SETDR(7,  975000, 200000, JLPTAB(22))
      REWIND 3
      REWIND 4
      REWIND 6
      REWIND 7
      NCR1 = 3
      NSCRAT = 4
      NFLUX1 = 6
      NFLUX2 = 7
      NOUT = 9
      NINP = 10
      CALL INP1
      CALL MAPR(DUM)
      CALL SETUP
      CALL GRAM
      CALL NORM
      IF(NIBC)  8, 8, 6
6     CALL ABETA
8     CONTINUE
      IF(NDELK)  20, 20, 10
10    CALL CALC
20    CONTINUE
      END
```

```
-ITC FOR INP1,INP1
      SUBROUTINE INP1
      INCLUDE ABC
C  THIS SUBROUTINE CONTROLS THE READING OF ALL INPUT DATA
      WRITE(NOUT, 3)
3     FORMAT(42X,35H * * * *   P E R T - I V   * * * * //////)
      READ(NINP, 5)  (ID(I), I = 1, 12)
5     FORMAT(12A6)
      WRITE(NOUT, 5)  (ID(I), I = 1, 12)
      WRITE(NOUT, 6)
6     FORMAT(1H /)
      READ(NINP,10)   ND, IGM, IST, IFP, IM, JM, MCR, MTP, IZM, MT,
     1 M01, NPRT, NDELK, NIBC ,        NACT,NFP, IGE
10    FORMAT(12I6)
      READ(NINP,15)  FLPO,VF,FEF, ZKEFF
15    FORMAT(6E12.6)
      WRITE(NOUT, 20)  ND, IGM, IST, IFP,IM, JM
20    FORMAT (76H    ND      1/2/3/4/5/6/7=FLUXES FROM 1-D RUNS/FLUXES F
     1ROM 2-D RUN/FLUX FROM/,12X,66H1-D,ADJOINT FROM 2-D/FLUX FROM 2-D,A
     2DJOINT FROM 1-D/FLUX FROM 1-D,/12X,56HNO ADJOINT/FLUX FROM 2-D,NO
     3ADJOINT/2-D FLUXES FROM TAPE,13X,I9/
     4              35H   IGM      NUMBER OF ENERGY GROUPS,46X,I9/,42H
     5IST      NUMBER OF DOWNSCATTERING TERMS,39X,I9/,
     661H   IFP      0/1/2=NO EFFECT/PUNCH FLUXES/PUNCH ADJOINT FLUXES,
     720X,I9/,                              38H    IM       NUMBER OF RADIAL
     8INTERVALS,43X,I9/,37H    JM      NUMBER OF AXIAL INTERVALS,44X,I9)
      WRITE(NOUT, 30) MCR, MTP, IZM, MT, M01, NPRT
30    FORMAT (42H   MCR      NUMBER OF MATERIALS FROM CARDS,39X,I9/,41H
     1 MTP      NUMBER OF MATERIALS FROM TAPE,40X,I9/,36H    IZM      NU
     2MBER OF MATERIAL ZONES,45X,I9/,53H    MT       TOTAL NUMBER OF MATE
     3RIALS INCLUDING MIXES,28X,I9/,44H    M01      NUMBER OF MIXTURE SPE
     4CIFICATIONS,37X,I9/,57H  NPRT      PRINT OPTION   )0/1=PARTIAL PRI
     5NT/FULL PRINT*24X,I9/)
      WRITE(NOUT, 40) NDELK, NIBC ,        NACT
40    FORMAT (66H NDELK      0/N=NO EFFECT/DO N REACTIVITY COEFFICIENT C
     1ALCULATIONS,15X,I9/
     272H  NIBC      0/N=NO EFFECT/USE N MATERIALS FOR BETA EFFECTIVE CA
     3LCULATION, 9X,I9/
     449H  NACT      0/N=NO EFFECT/DO N ACTIVITY TRAVERSES,32X,I9)
      WRITE(NOUT, 50) NFP
50    FORMAT (78H   NFP      FLUX OR POWER NORMALIZATION    )1/2/3/4=CENT
     1ER PT. FLUX/CENTER PT. /,12X,46HPOWER/TOTAL POWER/DENOMINATOR OF P
     2ERT FORMULA*,23X,I9 )
      WRITE(NOUT,55)  IGE
55    FORMAT( 46H   IGE      GEOMETRY    )0/1/2=R-Z/X-Y/R-THETA*,35X,I9/)
      WRITE(NOUT, 60) FLPO,VF,FEF, ZKEFF
60    FORMAT (41H  FLPO      FLUX(N/CM2-SEC) OR POWER(MWT),39X,1PE10.4/4
```

```
     17H    VF       VOLUME FACTOR                          ,33X,1PE10.4/
     244H   FEF       ENERGY(MEV) RELEASED PER FISSION,36X,1PE10.4/
     374H ZKEFF       KEFF FOR DELTA K CALC.  )IF ZERO, USE KEFF CALCULAT
     4ED BY CODE*, 6X, 1PE10.4)
64    FORMAT(1H1, 12A6///)
      ITL = IST + 5
C   READ, CHECK, PRINT, AND WRITE CROSS SECTIONS TO TAPE
      WRITE(NOUT, 64)  (ID(I), I = 1, 12)
      CALL XSINP
C   READ FLUXES
      WRITE(NOUT, 64)  (ID(I), I = 1, 12)
      WRITE(NOUT, 82)
82    FORMAT(98H INPUT FLUXES (PHR/PHZ/ADJR/ADJZ/PHI/ADJ=RADIAL FLUX/AXI
     1AL FLUX/RADIAL ADJOINT FLUX/AXIAL ADJOINT /
     232H FLUX/2-D FLUX/2-D ADJOINT FLUX)/)
      CALL FXINP
      IP=IM + 1
      JP=JM + 1
C   READ RADIIR
      WRITE(NOUT, 84)
84    FORMAT(51H0MESH BOUNDARIES (R1/Z1=RADIAL POINTS/AXIAL POINTS))
      CALL REAG2(6H    R1,R1,IP)
C  READ AXII
      CALL REAG2(6H    Z1,Z1,JP)
C   READ ZONE NUMBERS
      WRITE(NOUT,86)
86    FORMAT(30H0ZONE NUMBERS BY MESH INTERVAL)
      CALL REAI2 (6H    MO,LDUM,IMJM)
      L = 0
      DO 87  J = 1, JM
      DO 87  I = 1, IM
      L = L + 1
87    MO(I,J) = LDUM(L)
C   READ MATERIAL NUMBERS
      WRITE(NOUT, 88)
88    FORMAT(25H0MATERIAL NUMBERS BY ZONE)
      CALL REAI2 (6H    M2,M2,IZM)
C   READ FISSION FRACTIONS
      WRITE(NOUT, 90)
90    FORMAT(17H0FISSION SPECTRUM)
      CALL REAG2 (6H   CHI,CHI,IGM)
C   READ MIXTURE SPECIFICATIONS
      WRITE(NOUT,92)
92    FORMAT(82H0MIXTURE SPECIFICATIONS (I0/I1/I2=MIX NUMBER/MAT. NUMBER
     1 FOR MIX/MATERIAL DENSITY))
      CALL REAI2 (6H    I0,I0,MO1)
      CALL REAI2 (6H    I1,I1,MO1)
```

```
      CALL REAG2 (6H    I2,I2,M01)
C  CHECK FOR LIFETIME AND BETA CALCULATIONS
      IF(NIBC )  120,120, 100
C  READ MATERIAL NUMBERS FOR BETAS
100   WRITE(NOUT,94)
94    FORMAT(38H0MATERIAL NUMBERS FOR BETA CALCULATION)
      CALL REAI2(6H  NBET,NBET,NIBC)
C  READ BETAS
      CALL REAG2(6H  BETA,BETA,NIBC)
C  READ DELAYED FISSION SPECTRUM
      WRITE(NOUT, 102)
102   FORMAT(25H0DELAYED FISSION SPECTRUM)
      CALL REAG2(6H  CHIP,CHIP,IGM)
C  READ VELOCITIES
      WRITE(NOUT,104)
104   FORMAT(17H0NEUTRON VELOCITY)
      CALL REAG2(6H   VEL,VEL,IGM)
C  CHECK FOR DELTA K CALCULATION
120   IF(NDELK)  160, 160, 140
C  READ MATERIAL NUMBERS, ROW NUMBERS, AND COLUMN NUMBERS FOR
C  PERTURBATION CALCULATION
140   WRITE(NOUT, 138)
138   FORMAT(98H0PERTURBATION CALCULATION INFORMATION (MATDK/NROW/NCOL=M
     1ATERIAL NUMBER/ROW/COLUMN TO BE PERTURBED))
      CALL REAI2(6H MATDK, MATDK,NDELK)
      CALL REAI2(6H  NROW,  NROW, NDELK)
      CALL REAI2(6H  NCOL,  NCOL, NDELK)
C  CHECK FOR ACTIVITIES
160   IF(NACT)  1000, 1000, 180
C  READ MATERIAL NUMBERS AND XS POSITION FOR ACTIVITIES
180   WRITE(NOUT, 178)
178   FORMAT(77H0ACTIVITY TRAVERSE INFORMATION (MA/NX=MATERIAL NUMBER/CR
     1OSS SECTION POSITION))
      CALL REAI2(6H    MA,MA,NACT)
      CALL REAI2(6H    NX, NX, NACT)
1000  CONTINUE
      RETURN
      END
```

```
-ITC FOR XSINP,XSINP
      SUBROUTINE XSINP
      INCLUDE ABC
C THIS SUBROUTINE READS, CHECKS, PRINTS, AND WRITES THE CROSS SECTIONS TO TAPE
      ITEMP = MCR + MTP
10    DO 50 I=1,ITEMP
      READ(NINP, 20)  HOLN(I), ATW(I), (A(I,J), J=1, 10)
20    FORMAT(A6, E6.2, 10A6)
      IF(MCR)  35,35,25
25    DO  40  IIG=1,IGM
40    READ(NINP,30)  (C(L,IIG,I), L=1,ITL)
30    FORMAT(6E12.5)
      GO TO 50
35    READ(15)  ((C(L,IIG,I), L=1,ITL), IIG=1,IGM)
50    CONTINUE
C   CHECK ON CROSS SECTION CONSISTENCY AND ORDER
      DO 200   J=1,ITEMP
      DO 200   I=1,IGM
      G = C(2,I,J) + C(5,I,J)
      DO  80  K=1,IST
      KK = I + K
      M = 5 + K
      IF(KK - IGM) 70, 70, 80
70    G = G + C(M,KK,J)
80    CONTINUE
      IF(ABS((G - C(4,I,J))/C(4,I,J)) - .01)  200,  90, 90
90    WRITE(NOUT,110) J,I
110   FORMAT(1H/,16H CHECK MATERIAL I2,5X, 7H GROUP I2)
200   CONTINUE
C  PRINT CROSS SECTIONS
      IF(NPRT) 210,210, 250
210   WRITE(NOUT, 220)
220   FORMAT(38H THE FOLLOWING NUCLIDES ARE READ-IN   //)
      DO 240  K=1,ITEMP
240   WRITE(NOUT, 245)  K, HOLN(K), (A(K,J), J=1,10)
245   FORMAT(I9,6X,11A6/)
      GO TO  510
250   DO 480  K=1,ITEMP
255   FORMAT(1H1)
      WRITE(NOUT, 245)  K, HOLN(K), (A(K,J), J=1,10)
      WRITE(NOUT,260)
260   FORMAT( 1H0,
     2113H GROUP    SIGF      SIGA      NUSIGF      SIGTR      SIGXG      G-1X
     3G      G-2XG      G-3XG      G-4XG      G-5XG      G-6XG/ )
      IF(IST - 6)  290, 290, 265
265   DO 270   I=1,IGM
268   FORMAT(I3,11F10.3)
```

```
270    WRITE(NOUT, 268) I,(C(J,I,K),J=1,11)
       WRITE(NOUT,275)
275    FORMAT (44H1GROUP  G-7XG     G-8XG     G-9XG     G-10XG/  )
       DO 279  I=1,IGM
279    WRITE(NOUT,268)  I,(C(J,I,K), J=12,ITL)
       GO TO 350
290    CONTINUE
       DO 300  I=1,IGM
300    WRITE(NOUT,268) I, (C(J,I,K), J=1,ITL )
350    IF(K -ITEMP) 460,480,480
460    WRITE(NOUT,255)
480    CONTINUE
C  WRITE CROSS SECTIONS TO TAPE
510    DO 1160  IIG=1,IGM
       DO 1060  M=1,MT
       DO 1060  L=1,ITL
1060   CO  (L,M) = C(L,IIG,M)
1160   WRITE (NCR1)  ((CO  (L,M), L=1,ITL),M=1,MT)
       REWIND NCR1
       RETURN
       END
```

```
-ITC FOR FXINP,FXINP
      SUBROUTINE FXINP
      INCLUDE ABC
      INTEGER  TEMP
C THIS SUBROUTINE READS FLUXES(REGULAR FLUX AND ADJOINT FLUX)    IF
C   FLUXES ARE IN I-D FORM, THEY ARE COMBINED IN SUCH A WAY TO PUT
C    THEM IN 2-D FORM
      IMJM = IM*JM
      JJR =IGM*IM
      JJZ =IGM*JM
      LLH = 1
      NND = ND
      ND = IABS(ND)
C LLH=1/2=REGULAR FLUX/ADJOINT FLUX
      GO TO (100, 800, 100, 800,  100, 800,800),ND
C  FLUX IS IN I-D FORM
100   CONTINUE
      ZFX = 0.0
      RFX = 0.0
      GO TO (110, 120), LLH
110   CALL REAG2(6H   PHR,DUM,JJR)
      GO TO 130
120   CALL REAG2(6H  ADJR,DUM,JJR)
C   IF NND IS POSITIVE, ADJOINT FLUXES ARE REVERSED BY GROUP
      IF(NND)  130, 130, 121
121   CONTINUE
      L = 0
      DO 126  K = 1, IGM
      DO 124  I = 1, IM
      L = L + 1
      KK = IGM + 1 - K
124   PHR(KK, I) = DUM(L)
126   RFX = RFX + PHR(KK, 1)
      GO TO 165
130   L = 0
      DO 160 K=1,IGM
      DO 158 I=1,IM
      L = L + 1
158   PHR(K,I) = DUM(L)
160   RFX    =  RFX  +   PHR(K,1)
165   CONTINUE
      GO TO (170, 180), LLH
170   CALL REAG2(6H   PHZ,DUM,JJZ)
      GO TO 190
180   CALL REAG2(6H  ADJZ,DUM,JJZ)
      IF(NND)  190, 190, 182
C   SWITCH GROUPS
```

```
182   CONTINUE
      L = 0
      DO 186  K = 1, IGM
      DO 184  I = 1, JM
      L = L + 1
      KK = IGM + 1 - K
184   PHZ(KK, I) = DUM(L)
186   ZFX = ZFX + PHZ(KK, 1)
      GO TO 262
190   L = 0
      DO 260 K=1,IGM
      DO 258 I=1,JM
      L = L + 1
258   PHZ(K,I) = DUM(L)
260   ZFX    =  ZFX  +   PHZ(K,1)
262   CONTINUE
      DO  300  K=1,IGM
      DO  280  I=1,IM
280   PHR(K,I) = PHR(K,I)/RFX
      DO  300  I=1,JM
300   PHZ(K,I) = PHZ(K,I)/ZFX
      DO 400  K=1,IGM
      PHC(K) = (PHZ(K,1) + PHR(K,1))*(.5)
      DO 320  I=2,IM
320   PHR(K,I) = PHR(K,I)/PHR(K,1)
      DO 360  I=2,JM
360   PHZ(K,I) = PHZ(K,I)/PHZ(K,1)
      PHR(K,1) = 1.0
      PHZ(K,1) = 1.0
      DO 380  I=1,IM
      DO 380  J=1,JM
      PHI(I,J) = PHR(K,I)*PHZ(K,J)*PHC(K)
380   CONTINUE
      WRITE(NFLUX1) ((PHI(I,J), I = 1, IM), J = 1, JM)
400   CONTINUE
      GO TO 1000
790   CALL NTRAN (14,8,1)
C  FLUX IS IN 2-D FORM
800   CONTINUE
      LWH = IGM*IMJM
      GO TO (810, 815), LLH
810   WRITE(NOUT, 812)  LWH
812   FORMAT(6X, 6H   PHI,I6)
      GO TO 817
815   WRITE(NOUT, 816)  LWH
816   FORMAT(6X, 6H   ADJ, I6)
818   FORMAT(10E12.5)
```

```
817    DO 840  K = 1, IGM
       IF (ND-6)  819,819,822
819    READ(NINP, 820)  ((PHI(I, J), I = 1, IM), J = 1, JM)
820    FORMAT(6E12.6)
       GO TO 825
822    READ (14)  ((PHI(I,J),I=1,IM),J=1,JM)
825    WRITE(NOUT,818)  ((PHI(I, J), I = 1, IM), J = 1, JM)
       WRITE(NFLUX1)((PHI(I,J),I=1,IM),J=1,JM)
840    CONTINUE
       GO TO (910, 850), LLH
850    CONTINUE
C   IF NND IS POSITIVE, ADJOINT FLUXES ARE REVERSED BY GROUP
       IF(NND)  910, 910, 860
860    CONTINUE
       REWIND NFLUX1
       DO 880  K = 1, IGM
       READ(NFLUX1)
880    CONTINUE
       DO 900  K = 1, IGM
       BACKSPACE NFLUX1
       READ(NFLUX1)  ((PHI(I, J), I = 1, IM), J = 1, JM)
       WRITE(NSCRAT)  ((PHI(I, J), I = 1, IM), J = 1, JM)
       BACKSPACE NFLUX1
900    CONTINUE
       REWIND NSCRAT
       REWIND NFLUX1
       TEMP = NSCRAT
       NSCRAT = NFLUX1
       NFLUX1 = TEMP
910    CONTINUE
1000   GO TO (1100, 2200), LLH
1100   LLH=2
C   SWITCH TAPE DESIGNATIONS
       TEMP = NFLUX1
       NFLUX1 = NFLUX2
       NFLUX2 = TEMP
C  READ ADJOINT FLUX
       GO TO (100, 800, 800, 100, 2000, 2000, 790), ND
C  THERE IS NO ADJOINT FLUX INPUT
2000   CONTINUE
       AAA = 1.0
       DO 2100  K = 1, IGM
       WRITE(NFLUX1)  ((AAA, I = 1, IM), J = 1, JM)
2100   CONTINUE
2200   REWIND NFLUX1
       REWIND NFLUX2
       IF(ND-6)  2220,2220,2210
```

```
2210  REWIND 14
C   SWITCH TAPE DESIGNATIONS
2220  TEMP = NFLUX2
      NFLUX2 = NFLUX1
      NFLUX1 = TEMP
      RETURN
      END
```

```
-IT   FOR REAI2,REAI2
      SUBROUTINE REAI2(HOLL,IARRAY,NCOUNT)
      DIMENSION IARRAY(10),IV(6),K(6),IN(6)
      COMMON   NINP, NOUT, NCR1, NFLUX1, NSCRAT, NFLUX2
      J=1
   10 READ(NINP,20)          (K(I),IN(I),IV(I),I=1,6)
   20 FORMAT(6(I1,I2,I9))
      DO 70I=1,6
      L=K(I)+1
      GO TO (30,40,60,80 ),L
CNO MODIFICATION
   30 IARRAY(J)=IV(I)
      J=J+1
      GO TO 70
C
CREPEAT
   40 L=IN(I)
      DO50M=1,L
      IARRAY(J)=IV(I)
      J=J+1
   50 CONTINUE
      GO TO70
C
CINTERPOLATE
   60 CALL ERRO2(6H  REAI,60,1)
C
C
   70 CONTINUE
      GO TO 10
C
C
CTERMINATE
   80 J=J-1
      WRITE (NOUT,90)          HOLL,J       ,(IARRAY(I),I=1,J)
      IF(J  -NCOUNT)100,110,100
   90 FORMAT(6X,A6,I6/(10I12))
  100 CALL ERRO2( 6H**REAI,100,1)
  110 RETURN
      END
```

```
-IT  FOR REAG2,REAG2
      SUBROUTINE REAG2(HOLL,ARRAY,NCOUNT)
      DIMENSION ARRAY(10),V(12),K(12),IN(12)
      COMMON   NINP, NOUT, NCR1, NFLUX1, NSCRAT, NFLUX2
      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
CNO MODIFICATION
   70 ARRAY(J)=V(I)
      J=J+1
      GO TO 140
C
CREPEAT
   80 L=IN(I)
      DO90M=1,L
      ARRAY(J)=V(I)
      J=J+1
   90 CONTINUE
      GO TO140
C
CINTERPOLATE
  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
C
C
  140 CONTINUE
      GO TO 10
C
C
```

```
CTERMINATE
  150 J=J-1
      WRITE (NOUT,160)       HOLL,J      ,( ARRAY(I),I=1,J)
      IF(J  -NCOUNT)170,180,170
  160 FORMAT(6X,A6,I6/(10E12.5))
  170 CALL ERRO2( 6H**REAG,170,1)
  180 RETURN
      END
```

```
-ITC FOR MAPR,MAPR
      SUBROUTINE MAPR(K)
      INCLUDE ABC
      DIMENSION  K(9)
    1 IX=IM
      IY=JM
      WRITE (NOUT,6)  (ID(I), I = 1, 12)
    6 FORMAT(1H1,12A6///)
    3 DO 5 JJ=1,IY
      J=IY-JJ+1
    5 WRITE (NOUT,4)            (MO(I,J),I=1,IX)
    4 FORMAT( 5H     ,55I2)
      WRITE(NOUT,15)
   15 FORMAT(2H A/2H X/2H I/2H A/2H L//8H  RADIAL)
      WRITE (NOUT,6)  (ID(I), I = 1, 12)
      DO 10 JJ=1,IY
      J=IY-JJ+1
      DO  11 L=1,IX
      N=MO(L,J)
   11 K(L)=IABS (M2(N))
   10 WRITE (NOUT,4)            (K(L),L=1,IX)
      WRITE(NOUT,15)
      RETURN
      END
```

```
-IT  FOR PRT,PRT
      SUBROUTINE PRT(IM, JM, PHI)
      COMMON   NINP, NOUT, NCR1, NFLUX1, NSCRAT, NFLUX2
      DIMENSION  PHI(50, 50)
      DO 60  I=1,IM,5
      I1=I
      I2=I+4
      IF(I2-IM) 20 ,20 ,10
   10 I2=IM
   20 WRITE ( NOUT,30 ) ( JJ,JJ=I1,I2)
   30 FORMAT( 5X, 5I20)
      DO 50  JJ=1,JM
      J=JJ
      WRITE(NOUT,40 ) J,(PHI(K,J),K=I1,I2)
   40 FORMAT(5X,I5,E15.7,4E20.7)
   50 CONTINUE
   60 CONTINUE
      RETURN
      END
```

```
-IT  FOR ERRO2,ERRO2
      SUBROUTINE ERRO2( HOL,JSUBR,I)
      COMMON   NINP, NOUT, NCR1, NFLUX1, NSCRAT, NFLUX2
      WRITE (NOUT,1)           HOL,JSUBR
    1 FORMAT(2H */9H ERROR IN,A6,3H AT,I6/2H */2H *)
      GO TO (3,4),I
    3 STOP
    4 RETURN
      END
```

```
-ITC FOR SETUP,SETUP
      SUBROUTINE SETUP
      INCLUDE ABC
C    MIX CROSS SECTIONS
      ITL = IST + 5
      WRITE(NOUT, 65)  (ID(I), I = 1, 12)
65    FORMAT(1H1,12A6///)
      WRITE (NOUT,70)
  70  FORMAT(/19H CROSS-SECTION EDIT)
      REWINDNCR1
      DO 100  IIG=1,IGM
      READ (NCR1)    ((CO(I,J),I=1,ITL),J=1,MT)
      DO 92   M=1,MO1
      IF(IO(M)-MT)74   ,74   ,72
 72   CALL ERRO2(6H**S807,72   ,1)
 74   IF(I1(M)-MT)80   ,72   ,72
 80   N=IO(M)
      L=I1(M)
      EO1=I2(M)
      DO 90   I=1,ITL
      IF(L)86   ,88   ,86
 86   CO(I,N)=CO(I,N)+CO(I,L)*EO1
      GOTO90
 88   CO(I,N)=CO(I,N)*EO1
 90   CONTINUE
 92   CONTINUE
      WRITE (NOUT,94   )  IIG
 94   FORMAT(   //7H GROUP I3,15H CROSS-SECTIONS/)
      DO 96   N=1,MT
 96   WRITE (NOUT,98   )            N,(CO(I,N),I=1,ITL)
 98   FORMAT(4H MAT,I3,10E11.3,/7X,10E11.3)
      WRITE (NSCRAT)   ((CO(I,J),I=1,ITL),J=1,MT)
 100  CONTINUE
      REWINDNCR1
      REWIND NSCRAT
C SWITCH TAPE DESIGNATIONS
      ITEMP=NSCRAT
      NSCRAT=NCR1
      NCR1=ITEMP
 101  FORMAT(1H1)
C    CALCULATE AREAS AND VOLUMES
C*****
C*****
      PI2=6.28318
      IGEP = IGE + 1
      DO 170 I=1,IM
      R4(I)=(R1(I+1)+R1(I))*0.5
```

```
      R5(I)=R1(I+1)-R1(I)
      IF( R5(I) ) 130, 130, 140
130   CALL ERRO2 (6H*R5(I),130 ,1)
140   CONTINUE
      GO TO (160, 150, 150), IGEP
150   CONTINUE
      A1(I)=R5(I)
      GO TO 170
160   CONTINUE
      A1(I)=PI2*R5(I)*R4(I)
170   CONTINUE
      DO 200  J=1, JM
      Z4(J)=(Z1(J+1)+Z1(J))*0.5
      Z5(J)=Z1(J+1)-Z1(J)
      IF(Z5(J))  175, 175, 180
175   CALL ERRO2 (6H*Z5(J),175 ,1)
180   CONTINUE
      GO TO (183, 182, 183), IGEP
182   A2(J) = Z5(J)
      GO TO 184
183   A2(J) = PI2*R1(IP)*Z5(J)
184   DO 195  I = 1, IM
      GO TO (190, 185, 190), IGEP
185   V0(I,J)=R5(I)*Z5(J)*VF
      GO TO 195
190   V0(I,J)=PI2*R5(I)*Z5(J)*R4(I)*VF
195   CONTINUE
200   CONTINUE
C    PRINT MIX INFORMATION AND RADII AND AXII INFORMATION
      WRITE(NOUT,204)  (ID(I), I = 1, 12)
204   FORMAT(1H1, 12A6///)
      WRITE(NOUT, 208)  (J, I0(J), I1(J), I2(J), J = 1, M01)
  208 FORMAT(3X, 16H MIXTURE NUMBER ,18H   MIX COMMAND        ,
     124H MATERIAL ATOMIC DENSITY//(I3,1X,I8,8X,I8,8X,E20.8))
      ZZ = 0.0
      IP = IM + 1
      JP = JM + 1
      WRITE(NOUT, 65)  (ID(I), I = 1, 12)
      WRITE(NOUT, 210)
210   FORMAT(84H                    RADII                AVG RADII
     1 AXII               AVG AXII /)
      IF(IM - JM)  240, 240, 280
240   WRITE(NOUT, 220) ((I, R1(I), R4(I), Z1(I), Z4(I)),I = 1, IP)
220   FORMAT(I4,4F20.4)
      IF(IM - JM)  241, 500, 241
241   III = IP + 1
      WRITE(NOUT, 220) ((I, ZZ, ZZ, Z1(I), Z4(I)), I = III,JP)
```

```
      GO TO 500
280   WRITE(NOUT, 220) ((I, R1(I), R4(I), Z1(I), Z4(I)),I = 1, JP)
      JJJ = JP + 1
      WRITE(NOUT, 220) ((I, R1(I), R4(I), ZZ, ZZ), I = JJJ, IP)
500   CONTINUE
      RETURN
      END
```

```
-ITC FOR GRAM,GRAM
      SUBROUTINE GRAM
      INCLUDE ABC
      REAL  MASS
      DIMENSION  MASS(50, 50)
      EQUIVALENCE  (C(1,1,1), MASS(1,1))
C    THIS SUBROUTINE CALCULATES THE MASS OF THE VARIOUS MATERIALS
      WRITE(NOUT,  1)  (ID(I), I = 1, 12)
1     FORMAT(1H1,12A6///)
      WRITE(NOUT, 5)
5     FORMAT(45H MATERIAL INVENTORY (KILOGRAMS) FOR EACH ZONE /   )
      DO 10  K=1,IZM
      VOL(K) = 0.0
10    CONTINUE
      DO 15  J = 1, 50
      DO 15  I = 1, 50
15    MASS(I, J) = 0.0
      DO 20  J = 1, JM
      DO 20  I = 1, IM
      K = M0(I,J)
      KK = M2(K)
      L2(KK) = K
      VOL(K) = VOL(K) + V0(I, J)*.001
20    CONTINUE
      KK = MCR + MTP
      DO 40  N =1, IZM
      NN = M2(N)
      DO 40  M = 1,M01
      IF(I0(M) - NN)  40,22,40
22    L = I1(M)
      IF(L - KK)  28,28,24
24    NNAA = L
      DO 35  MAA = 1,M01
      IF(I0(MAA) - NNAA)  35,32,35
32    L = I1(MAA)
      IF(L)  35,35,33
33    E01 = I2(MAA)*I2(M)
      MASS(N,L) = ((E01*ATW(L)*VOL(N))/.6023) + MASS(N,L)
35    CONTINUE
      GO TO 40
28    IF(L)  40,40,30
30    E01 = I2(M)
      MASS(N,L) = ((E01*ATW(L)*VOL(N))/.6023) + MASS(N,L)
40    CONTINUE
      DATA   ZONE/6H ZONE /
      DO 90  L = 1, IZM, 5
      LL = L + 4
```

```
      IF(LL - IZM) 62, 62, 61
61    LL = IZM
62    WRITE(NOUT, 72)  ((ZONE, K), K=L, LL)
72    FORMAT(//26H   MATERIAL   ATOMIC WT.   ,3X, 5(A6,I2,12X))
      WRITE(NOUT, 73)  (VOL(K), K = L, LL)
73    FORMAT(25X, 5(F8.2, 7H LITERS, 5X))
      DO 75  K = 1, KK
75    WRITE(NOUT, 76)  K, HOLN(K), ATW(K), (MASS(I, K), I = L, LL)
76    FORMAT(/I3,1X, A6, F13.3, F14.3, 4F20.3)
      IF(LL - IZM)  90, 94, 94
90    CONTINUE
94    CONTINUE
      RETURN
      END
```

```
-ITC FOR NORM,NORM
      SUBROUTINE NORM
      INCLUDE ABC
      DIMENSION  TPHI(50, 50), CADJ(50, 50), ACT(50, 50, 3), POW(50, 50)
      EQUIVALENCE  (SORC1(1,1),TPHI(1,1)), (SORC2(1,1),CADJ(1,1)),
     1(C(1,1,1),ACT(1,1,1)),(LDUM(1),POW(1,1))
C   THIS SUBROUTINE NORMALIZES THE FLUXES (REGULAR AND ADJOINT)
      CFX = 0.0
      CPW = 0.0
      POWER = 0.0
      DENOM = 0.0
      RL = 0.0
      ZL = 0.0
      RABS = 0.0
      RSORS = 0.0
      DO 10  J = 1, JM
      DO 10  I = 1, IM
      SORC1(I, J) = 0.0
      SORC2(I, J) = 0.0
10    CONTINUE
      REWIND NFLUX1
      REWIND NFLUX2
      REWIND NSCRAT
      REWIND NCR1
      DO 100  KK = 1, IGM
      READ(NCR1  )((CO(II, J), II = 1, ITL), J = 1, MT)
      READ(NFLUX1) ((PHI(I, J), I = 1, IM), J = 1, JM)
      READ(NFLUX2) ((ADJ(I, J), I = 1, IM), J = 1, JM)
      CFX = CFX + PHI(1, 1)
      K = MO(1, 1)
      K = M2(K)
      CPW = CPW + CO(1,K)*PHI(1,1)
      DO 20  J = 1, JM
      DO 20  I = 1, IM
      K = MO(I, J)
      K = M2(K)
      POWER = POWER + CO(1, K)*PHI(I, J)*VO(I, J)
      SORC1(I, J) = SORC1(I, J) + CO(3, K)*PHI(I, J)
      SORC2(I, J) = SORC2(I, J) + CHI(KK)*ADJ(I, J)
      RABS = RABS + CO(2, K)*PHI(I, J)*VO(I, J)
      RSORS = RSORS + CO(3, K)*PHI(I, J)*VO(I, J)
20    CONTINUE
      PI2 = 6.28318
      DO 50  I = 1, IM
      GO TO (35, 35, 25),  IGEP
25    SLOPZ(I) = (PHI(I,JM) - PHI(I,JM - 1))/((Z4(JM) - Z4(JM - 1))
     1 *PI2*R4(I))
```

```
      GO TO 40
35    SLOPZ(I) = (PHI(I,JM) - PHI(I,JM - 1))/(Z4(JM) - Z4(JM - 1))
40    CONTINUE
      K = M0(I, JM)
      K = M2(K)
      ZL     = ZL     + (SLOPZ(I)*A1(I))/(3.*C0(4,K))
 50   CONTINUE
      DO 60  I = 1, IM
      GO TO (55, 55, 52),  IGEP
52    SLOPZ(I) =-(PHI(I,2) - PHI(I,1))/((Z4(2) - Z4(1))*PI2*R4(I))
      GO TO 56
55    SLOPZ(I) =-(PHI(I,2) - PHI(I,1))/(Z4(2) - Z4(1))
56    CONTINUE
      K = M0(I,1)
      K = M2(K)
      ZL     = ZL     + (SLOPZ(I)*A1(I))/(3.*C0(4,K))
60    CONTINUE
      DO  80  J=1, JM
      SLOPR(J) = (PHI(IM,J) - PHI(IM - 1,J))/(R4(IM) - R4(IM - 1))
      K = M0(IM,J)
      K = M2(K)
      RL     = RL     + (SLOPR(J)*A2(J))/(3.*C0(4,K))
 80   CONTINUE
100   CONTINUE
      RLEAK = -ZL - RL
      RSORS = RSORS/VF
      RABS = RABS/VF
      AK = (RSORS)/(RABS + RLEAK)
C   TSD = (MW-SEC)/(FISSIONS)
      TSD = FEF*1.602*10.**(-19)
      CAD = SORC2(1, 1)
      CPW = CPW*TSD*1000.
      POWER = POWER*TSD
      REWIND NCR1
      REWIND NFLUX1
      REWIND NFLUX2
      DO 200  J = 1, JM
      DO 200  I = 1, IM
      DENOM = DENOM +(SORC1(I, J) *SORC2(I, J)*V0(I, J))/(SORC2(1,1)*AK)
200   CONTINUE
      GO TO (240, 260, 280, 300), NFP
240   CONST = FLPO/CFX
      GO TO 320
260   CONST = FLPO/CPW
      GO TO 320
280   CONST = FLPO/POWER
      GO TO 320
```

```
300   CONST = FLPO/DENOM
320   CONTINUE
      CFX = CONST*CFX
      CPW = CONST*CPW
      POWER = CONST*POWER
      DENOM = CONST*DENOM
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
328   FORMAT(1H1, 12A6//////)
      RSORS = RSORS*VF*CONST
      RABS = RABS*VF*CONST
      RLEAK = RLEAK*VF*CONST
      RL = -RL*VF*CONST
      ZL = -ZL*VF*CONST
      AAK = .1*AK
      WRITE(NOUT,330) CFX, CPW, POWER, DENOM,     RSORS, RABS, RLEAK
     1 , RL, ZL, AAK
330   FORMAT(44H CENTER POINT FLUX (N/CM2-SEC)   -   -   -  1PE12.5//
     1        44H CENTER POINT POWER (MWT/LITER)  -   -   -  1PE12.5//
     2        44H TOTAL POWER (MWT)   -   -   -   -   -   -  1PE12.5//
     3        44H DENOMINATOR OF PERT. FORMULA    -   -   -  1PE12.5//
     4        44H SOURCE RATE -   -   -   -   -   -   -   -  1PE12.5//
     5        44H ABSORPTION RATE -   -   -   -   -   -   -  1PE12.5//
     6        44H LEAKAGE RATE (TOTAL)    -   -   -   -   -  1PE12.5//
     7        44H RADIAL LEAKAGE  -   -   -   -   -   -   -  1PE12.5//
     8        44H AXIAL LEAKAGE   -   -   -   -   -   -   -  1PE12.5//
     9        44H KEFF    -   -   -   -   -   -   -   -   -  F12.5)
      DO 350  J = 1, JM
      DO 350  I = 1, IM
      DO 344  N = 1, 3
344   ACT(I, J, N) = 0.0
      TPHI(I, J) = 0.0
      CADJ(I, J) = 0.0
      POW(I, J) = 0.0
350   CONTINUE
      DO 400  K = 1, IGM
      READ(NFLUX1) ((PHI(I, J), I = 1, IM), J = 1, JM)
      READ(NFLUX2) ((ADJ(I,J), I = 1, IM), J = 1, JM)
      READ(NCR1)  ((CO(II, J), II = 1, ITL), J = 1, MT)
      DO 360  J = 1, JM
      DO 360  I = 1, IM
      KK = MO(I, J)
      KK = M2(KK)
      PHI(I, J) = PHI(I, J)*CONST
      ADJ(I, J) = ADJ(I, J)/CAD
      TPHI(I, J) = TPHI(I, J) + PHI(I, J)
      CADJ(I, J) = CADJ(I, J) + CHI(K) * ADJ(I, J)
      POW(I, J) = POW(I, J) + CO(1, KK)*PHI(I, J)*TSD*1000.
```

```
      IF(NACT)  360, 360, 352
352   CONTINUE
      DO 356  N = 1, NACT
      KK = MA(N)
      NN = NX(N)
356   ACT(I, J, N) = ACT(I, J, N) + CO(NN, KK)*PHI(I, J)
360   CONTINUE
      WRITE(NSCRAT)  ((PHI(I, J), I = 1, IM), J = 1, JM)
      WRITE(NSCRAT)  ((ADJ(I, J), I = 1, IM), J = 1, JM)
      LMN = IFP + 1
      GO TO (368, 362, 364), LMN
362   PUNCH 363, ((PHI(I, J), I = 1, IM), J = 1, JM)
363   FORMAT(6E12.6)
      GO TO 368
364   PUNCH 363, ((ADJ(I, J), I = 1, IM), J = 1, JM)
368   IF(NPRT)  376, 376, 370
370   CONTINUE
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      WRITE(NOUT, 372)  K
372   FORMAT(//15H FLUX FOR GROUP,I3/)
      CALL PRT(IM, JM, PHI)
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      WRITE(NOUT, 374)  K
374   FORMAT(//23H ADJOINT FLUX FOR GROUP,I3/)
      CALL PRT(IM, JM, ADJ)
376   CONTINUE
400   CONTINUE
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      WRITE(NOUT, 478)
478   FORMAT(11H TOTAL FLUX/)
      CALL PRT(IM, JM, TPHI)
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      WRITE(NOUT, 480)
480   FORMAT(28H FISSION SOURCE*ADJOINT FLUX/)
      CALL PRT(IM, JM, CADJ)
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      WRITE(NOUT, 482)
482   FORMAT (26H POWER DENSITY (MWT/LITER) /)
      CALL PRT(IM, JM, POW)
      IF(NACT)  490, 490, 484
484   DO 488  N = 1, NACT
      DO 486  J = 1, JM
      DO 486  I = 1, IM
486   SORC2(I, J) = ACT(I, J, N)
      WRITE(NOUT, 328)  (ID(IK), IK = 1, 12)
      KK = MA(N)
      NN = NX(N)
```

```
      WRITE(NOUT, 487)  N, KK, NN
487   FORMAT( 9H ACTIVITY, I3, 13H      ISOTOPE,I3, 28H      CROSS SECTI
     1ON POSITION,I3/)
      CALL PRT(IM, JM, SORC2)
488   CONTINUE
490   CONTINUE
      CALL AVG(TPHI,POW,ACT)
C    SWITCH TAPE DESIGNATIONS
      ITEMP = NSCRAT
      NSCRAT = NFLUX1
      NFLUX1 = ITEMP
      REWIND NSCRAT
      REWIND NFLUX1
      REWIND NFLUX2
      REWIND NCR1
      RETURN
      END
```

```
-ITC FOR AVG,AVG
      SUBROUTINE AVG(TPHI,POW,ACT)
      INCLUDE ABC
C    THIS SUBROUTINE CALCULATES ZONE AVERAGED FLUXES, POWERS,
C    AND ACTIVITIES
      DIMENSION  ACT(50, 50, 3), TPHI(50,50), POW(50,50)
      DATA     CAT/6H  ACT /
      WRITE(NOUT,328) (ID(IK),IK=1,12)
328   FORMAT(1H1,12A6//////)
      DO 340  KKK=1,IZM
      ZPHI(KKK) = 0.0
      ZPOW(KKK) = 0.0
      DO 340  N=1,3
340   ZACT(KKK,N) = 0.0
      DO 525   J=1,JM
      DO 525   I=1,IM
      KKK = MO(I,J)
      ZPHI(KKK) = ZPHI(KKK) + VO(I,J)*.001*TPHI(I,J)
      ZPOW(KKK) = ZPOW(KKK) + VO(I,J)*.001*POW(I,J)
      IF(NACT) 525,525,505
505   DO 508  N=1,NACT
508   ZACT(KKK,N) = ZACT(KKK,N) + VO(I,J)*.001*ACT(I,J,N)
525   CONTINUE
      DO 540   KKK=1,IZM
      ZPHI(KKK) = ZPHI(KKK)/VOL(KKK)
      ZPOW(KKK) = ZPOW(KKK)/VOL(KKK)
      IF(NACT) 540,540,535
535   DO 538  N=1, NACT
538   ZACT(KKK,N) =  ZACT(KKK,N)/VOL(KKK)
540   CONTINUE
      IF(NACT)  560,560,580
560   WRITE(NOUT,565)
565   FORMAT( 48H   ZONE            AV FLUX               AV POWER    //)
      DO 570  KKK=1,IZM
570   WRITE(NOUT,575)  KKK,ZPHI(KKK),ZPOW(KKK)
575   FORMAT(/I6,5E20.7)
      GO TO 600
580   WRITE(NOUT,585)  ((CAT,N), N=1,NACT)
585   FORMAT( 48H   ZONE            AV FLUX               AV POWER      6X,
     1 3(A6,I1,13X))
      DO 590  KKK=1,IZM
590   WRITE(NOUT,575) KKK, ZPHI(KKK),ZPOW(KKK), (ZACT(KKK,N),N=1,NACT)
600   CONTINUE
      RETURN
      END
```

```
-ITC FOR ABETA,ABETA
      SUBROUTINE ABETA
      INCLUDE ABC
      DIMENSION  BSIGF(50,50)
      EQUIVALENCE  (PHR(1,1), BSIGF(1,1))
C    THIS SUBROUTINE CALCULATES BETA EFFECTIVE AND NEUTRON LIFETIME
      WRITE(NOUT,5)  (ID(I), I=1,12)
5     FORMAT(1H1,12A6////)
      DO 10  J=1,50
      DO 10  I=1,50
      SORC1(I,J)=0.0
      SORC2(I,J)=0.0
      PHZ(I,J) = 0.0
      BSIGF(I,J) = 0.0
10    CONTINUE
      DO 1000  KK=1,IGM
      READ(NFLUX1) ((PHI(I,J), I=1,IM), J=1,JM)
      READ(NFLUX1) ((ADJ(I,J), I=1,IM), J=1,JM)
      READ(NCR1)   ((CO(II,J), II=1,ITL),J=1,MT)
      DO 500  J = 1, JM
      DO 500  I = 1, IM
      PHZ(I,J) = (PHI(I,J)*ADJ(I,J))/(VEL(KK)) + PHZ(I,J)
      KKK= MO(I,J)
      KKK = M2(KKK)
      DO 300  L = 1, NIBC
      DEN = 0.0
      DO 120  M=1, MO1
      IF(IO(M) -KKK)  120, 110, 120
110   IF(I1(M) - NBET(L))  120, 115, 120
115   DEN = DEN + I2(M)
120   CONTINUE
      NN = NBET(L)
      BSIGF(I,J) = BSIGF(I,J) + BETA(L)*DEN*CO(1,NN)*PHI(I,J)
300   CONTINUE
C    DELAYED NEUTRON SOURCE*ADJOINT FLUX  (SUMMED OVER ENERGY GROUPS)
      SORC2(I,J) = CHIP(KK)*ADJ(I,J) + SORC2(I,J)
500   CONTINUE
1000  CONTINUE
      BE = 0.0
      ALIFE = 0.0
      DO 2000  J = 1, JM
      DO 2000  I = 1, IM
      BE = BE + SORC2(I,J)*           BSIGF(I,J)*VO(I,J)
      ALIFE = ALIFE + (PHZ(I,J)*VO(I,J))
2000  CONTINUE
      ALIFE = ALIFE/(DENOM*AK)
      BEFF = BE/(DENOM*AK)
```

```
      WRITE(NOUT,2050)  BEFF, ALIFE
 2050 FORMAT( 43H BETA EFFECTIVE  -    -    -    -    -    -    - 1PE11.5//
     1        43H NEUTRON GENERATION TIME -    -    -    -    - 1PE11.5)
      RETURN
      END
```

```
-ITC FOR CALC,CALC
      SUBROUTINE CALC
      INCLUDE ABC
      DIMENSION  CX(15,26), FLUX(2,26,50,3),             SLOAR(50),
     1              SLOAZ(50)
      EQUIVALENCE  (CX(1,1), PHR(1,1)), (FLUX(1,1,1,1),C(1,1,1)),
     1                     (SLOAR(1), DUM(51)),
     2  (SLOAZ(1), DUM(151))
C   THIS SUBROUTINE USES PERTURBATION THEORY TO CALCULATE REACTIVITY
C   COEFFICIENTS
      DO 9999   III = 1, NDELK
      REWIND NCR1
      REWIND NFLUX1
      REWIND NFLUX2
      REWIND NSCRAT
      NR = NROW(III)
      NC = NCOL(III)
      MAT = MATDK(III)
C   CONVERSION FROM ATOMS TO KG
      CT= 602.3/ATW(MAT)
      PI2 = 6.28318
      DO 1  J = 1, 50
      DO 1  I = 1, 50
      SORC1(I, J) = 0.0
1     SORC2(I, J) = 0.0
      WRITE(NOUT, 2)  (ID(I), I = 1, 12)
2     FORMAT(1H1,12A6/// )
      DO 1000  K = 1, IGM
      READ(NFLUX1)  ((PHI(I, J), I = 1, IM), J = 1, JM)
      READ(NFLUX1)  ((ADJ(I, J), I = 1, IM), J = 1, JM)
      READ(NCR1)  ((CO(II, J), II = 1, ITL), J = 1, MT)
      DO 3  II = 1, ITL
3     CX(II, K) = CO(II, MAT)
      IF(NR)  400, 400, 10
C   DELTA K CALCULATION FOR ROW = NROW
10    CONTINUE
      DO 60   I = 1, IM
      IF(NR - JM)  20, 40,40
20    NN = NR + 1
      FLUX(1, K, I, 3) = PHI(I, NN)
      FLUX(2, K, I, 3) = ADJ(I, NN)
30    IF(NR - 1)  50, 50, 40
40    NN = NR - 1
      FLUX(1, K, I, 1) = PHI(I, NN)
      FLUX(2, K, I, 1) = ADJ(I, NN)
50    NN = NR
      FLUX(1, K, I, 2) = PHI(I, NN)
```

```
      FLUX(2, K, I, 2) = ADJ(I, NN)
      SORC2(I, 1) = CHI(K)*FLUX(2, K, I, 2) + SORC2(I, 1)
      SORC1(I, 1) = CO(3, MAT)*FLUX(1, K, I, 2) + SORC1(I, 1)
      SORC1(I, 2) = CO(2, MAT)*FLUX(1, K, I, 2)*FLUX(2, K, I, 2)
     1 + SORC1(I, 2)
60    CONTINUE
      DO 150   I=1,IM
      IF(I-1) 82,82,72
72    PSR1 =  (FLUX(1,K,I,2) - FLUX(1,K,I-1,2))/(R4(I) - R4(I-1))
      ASR1 =  (FLUX(2,K,I,2) - FLUX(2,K,I-1,2))/(R4(I) - R4(I-1))
76    IF(I-IM) 78,86,86
78    PSR2 =  (FLUX(1,K,I+1,2) - FLUX(1,K,I,2))/(R4(I+1) - R4(I))
      ASR2 =  (FLUX(2,K,I+1,2) - FLUX(2,K,I,2))/(R4(I+1) - R4(I))
      GO TO 90
82    SLOPR(I) = 0.0
      SLOAR(I) = 0.0
      GO TO 92
86    SLOPR(I) = PSR1
      SLOAR(I) = ASR1
      GO TO 92
90    SLOPR(I) =(PSR1 + PSR2)/2.0
      SLOAR(I) =(ASR1 + ASR2)/2.0
92    CONTINUE
      IF(NR - 1) 100, 100, 93
93    GO TO (96, 96, 94), IGEP
94    PSZ1 = (FLUX(1,K,I,2) - FLUX(1,K,I,1))/((Z4(NR)    - Z4(NR-1))
     1 *PI2*R4(I))
      ASZ1 = (FLUX(2,K,I,2) - FLUX(2,K,I,1))/((Z4(NR)    - Z4(NR-1))
     1 *PI2*R4(I))
      GO TO 97
96    PSZ1 = (FLUX(1,K,I,2) - FLUX(1,K,I,1))/(Z4(NR)    - Z4(NR-1))
      ASZ1 = (FLUX(2,K,I,2) - FLUX(2,K,I,1))/(Z4(NR)    - Z4(NR-1))
97    IF(NR -JM) 100, 115, 115
100   GO TO (105, 105, 102), IGEP
102   PSZ2 = (FLUX(1,K,I,3) - FLUX(1,K,I,2))/((Z4(NR+1) - Z4(NR))
     1 *PI2*R4(I))
      ASZ2 = (FLUX(2,K,I,3) - FLUX(2,K,I,2))/((Z4(NR+1) - Z4(NR))
     1 *PI2*R4(I))
      GO TO 106
105   PSZ2 = (FLUX(1,K,I,3) - FLUX(1,K,I,2))/(Z4(NR+1) - Z4(NR))
      ASZ2 = (FLUX(2,K,I,3) - FLUX(2,K,I,2))/(Z4(NR+1) - Z4(NR))
106   IF(NR-1) 108, 108, 120
108   SLOPZ(I) = PSZ2
      SLOAZ(I) = ASZ2
      GO TO  130
112   CONTINUE
      IF(NR -JM)  120,115,115
```

```
115    SLOPZ(I) = PSZ1
       SLOAZ(I) = ASZ1
       GO TO 130
120    CONTINUE
       SLOPZ(I)=(PSZ1 + PSZ2)/2.0
       SLOAZ(I)=(ASZ1 + ASZ2)/2.0
130    CONTINUE
       KK = M0(I, NR)
       KK = M2(KK)
       SORC1(I,3) = -((SLOPZ(I)*SLOAZ(I) + SLOPR(I)*SLOAR(I))*CO(4,MAT))/
      1  (CO(4,KK)*CO(4,KK)*3.0) + SORC1(I,3)
150    CONTINUE
       GO TO 1000
C    DELTA K CALCULATION FOR COLUMN = NCOL
400    CONTINUE
       DO 460  J=1,JM
       IF(NC - IM)  420,440,440
420    NN = NC + 1
       FLUX(1,K,J,3) = PHI(NN,J)
       FLUX(2,K,J,3) = ADJ(NN,J)
430    IF(NC - 1) 450,450,440
440    NN = NC - 1
       FLUX(1,K,J,1) = PHI(NN,J)
       FLUX(2,K,J,1) = ADJ(NN,J)
450    NN = NC
       FLUX(1,K,J,2) = PHI(NN,J)
       FLUX(2,K,J,2) = ADJ(NN,J)
       SORC2(J,1) = CHI(K)*FLUX(2,K,J,2) + SORC2(J,1)
       SORC1(J,1) = CO(3,MAT)*FLUX(1,K,J,2) + SORC1(J,1)
       SORC1(J,2) = CO(2,MAT)*FLUX(1,K,J,2)*FLUX(2,K,J,2)
      1 + SORC1(J,2)
460    CONTINUE
       DO 550  J=1,JM
       IF(J - 1)  478, 478, 472
472    GO TO (474, 474, 473), IGEP
473    PSZ1 = (FLUX(1,K,J,2) - FLUX(1,K,J-1,2))/((Z4(J) - Z4(J-1))
      1 *PI2*R4(NC))
       ASZ1 = (FLUX(2,K,J,2) - FLUX(2,K,J-1,2))/((Z4(J) - Z4(J-1))
      1 *PI2*R4(NC))
       GO TO 476
474    PSZ1 = (FLUX(1,K,J,2) - FLUX(1,K,J-1,2))/(Z4(J) - Z4(J-1))
       ASZ1 = (FLUX(2,K,J,2) - FLUX(2,K,J-1,2))/(Z4(J) - Z4(J-1))
476    IF(J-JM) 478,486,486
478    GO TO (480, 480, 479), IGEP
479    PSZ2 = (FLUX(1,K,J+1,2) - FLUX(1,K,J,2))/((Z4(J+1) - Z4(J))
      1 *PI2*R4(NC))
       ASZ2 = (FLUX(2,K,J+1,2) - FLUX(2,K,J,2))/((Z4(J+1) - Z4(J))
```

```
     1 *PI2*R4(NC))
      GO TO 481
480   PSZ2 = (FLUX(1,K,J+1,2) - FLUX(1,K,J,2))/(Z4(J+1) - Z4(J))
      ASZ2 = (FLUX(2,K,J+1,2) - FLUX(2,K,J,2))/(Z4(J+1) - Z4(J))
481   IF(J - 1)  482, 482, 490
482   SLOPZ(J) = PSZ2
      SLOAZ(J) = ASZ2
      GO TO 492
486   SLOPZ(J) = PSZ1
      SLOAZ(J) = ASZ1
      GO TO 492
490   SLOPZ(J) = (PSZ1 + PSZ2)/2.0
      SLOAZ(J) = (ASZ1 + ASZ2)/2.0
492   CONTINUE
      IF(NC - 1) 508, 508, 495
495   PSR1 = (FLUX(1,K,J,2) - FLUX(1,K,J,1))/(R4(NC) - R4(NC-1))
      ASR1 = (FLUX(2,K,J,2) - FLUX(2,K,J,1))/(R4(NC) - R4(NC-1))
498   IF(NC - IM)  500, 515, 515
500   PSR2 = (FLUX(1,K,J,3) - FLUX(1,K,J,2))/(R4(NC+1) - R4(NC))
      ASR2 = (FLUX(2,K,J,3) - FLUX(2,K,J,2))/(R4(NC+1) - R4(NC))
      IF(NC - 1) 508, 508, 520
508   SLOPR(J) = 0.0
      SLOAR(J) = 0.0
      GO TO 530
512   CONTINUE
      IF(NC - IM)  520,515,515
515   SLOPR(J) = PSR1
      SLOAR(J) = ASR1
      GO TO 530
520   CONTINUE
      SLOPR(J) = (PSR1 + PSR2)/2.0
      SLOAR(J) = (ASR1 + ASR2)/2.0
530   CONTINUE
      KK = M0(NC,J)
      KK = M2(KK)
      SORC1(J,3) = -((SLOPZ(J)*SLOAZ(J) + SLOPR(J)*SLOAR(J))*C0(4,MAT))/
     1  (C0(4,KK)*C0(4,KK)*3.0) + SORC1(J,3)
550   CONTINUE
1000  CONTINUE
      IF(IGM - 1)  1210, 1210, 1010
1010  IGGM = IGM - 1
      DO 1200  K = 1, IGGM
      IF(NR)  1100, 1100, 1050
1050  DO 1075  I = 1, IM
      DO 1070    NN = 1, IST
      N = NN + K
      L = 5 + NN
```

```
      SORC2(I, 2) = SORC2(I, 2) + FLUX(1, K, I, 2)*CX(L, N)*
     1  (FLUX(2, K, I, 2) - FLUX(2, N, I, 2))
      IF(N - IGM)  1070, 1075, 1075
1070  CONTINUE
1075  CONTINUE
      GO TO 1200
1100  DO 1175  J = 1, JM
      DO 1170  NN = 1, IST
      N = NN + K
      L = 5 + NN
      SORC2(J, 2) = SORC2(J, 2) + FLUX(1, K, J, 2)*CX(L, N)*
     1  (FLUX(2, K, J, 2) - FLUX(2, N, J, 2))
      IF(N- IGM)  1170, 1175, 1175
1170  CONTINUE
1175  CONTINUE
1200  CONTINUE
1210  CONTINUE
      IF(ZKEFF - .001)  1250, 1250, 1225
C   SET KEFF EQUAL TO READ IN VALUE
1225  DENOM = DENOM*AK/ZKEFF
      AK = ZKEFF
1250  CONTINUE
      IF(NR)  3000, 3000, 2000
2000  WRITE(NOUT, 2050)  MAT,HOLN(MAT), NR
      WRITE(NOUT, 2060)
      WRITE(NOUT, 2062)
      SUM = 0.0
      TOT = 0.0
      DO 2200  I = 1, IM
C   FISSIONS
      SORC2(I, 3) = (SORC2(I,1)*SORC1(I,1)*CT)/(AK*DENOM)
C   ABSORPTIONS
      SORC1(I, 2) = (SORC1(I, 2)*CT)/DENOM
C   SLOWING DOWN
      SORC2(I, 2) = (SORC2(I, 2)*CT)/DENOM
C   LEAKAGE
      SORC1(I, 3) = (SORC1(I, 3)*CT)/DENOM
C   DELTA K
      SORC2(I, 4) = SORC2(I,3) - SORC1(I,2) - SORC1(I,3) - SORC2(I,2)
      SUM = SUM + SORC2(I,4)*VO(I,NR)
      TOT = TOT + VO(I,NR)
      ST = SUM/TOT
2050  FORMAT(     38HOREACTIVITY COEFFICIENTS FOR MATERIAL I2,6X,A6,
     1 11H        ROW I2//)
2060  FORMAT(131HU          $K/K PER KG           $K              $K
     1          $K              $K              $K          AVG RADII
     2  AVG AXII )
```

```
2062  FORMAT( 99H                                          (NUSIGF)          (SIGA)
     1        (SIGTR)          (SIGJXK)          (INTG) / )
      SORC1(I,2) =-SORC1(I,2)
      SORC1(I,3) = - SORC1(I,3)
      SORC2(I,2) =-SORC2(I,2)
      WRITE(NOUT, 2080)  I, SORC2(I,4), SORC2(I,3), SORC1(I,2),
     1  SORC1(I,3), SORC2(I,2), ST, R4(I), Z4(NR)
2080  FORMAT(I3, 8F16.4)
2200  CONTINUE
      GO TO 3400
3000  WRITE(NOUT, 3050)  MAT,HOLN(MAT), NC
      WRITE(NOUT, 2060)
      WRITE(NOUT, 2062)
      SUM = 0.0
      TOT = 0.0
      DO 3200  I = 1, JM
C    FISSIONS
      SORC2(I, 3) = (SORC2(I,1)*SORC1(I,1)*CT)/(AK*DENOM)
C    ABSORPTIONS
      SORC1(I, 2) = (SORC1(I, 2)*CT)/DENOM
C    SLOWING DOWN
      SORC2(I, 2) = (SORC2(I, 2)*CT)/DENOM
C    LEAKAGE
      SORC1(I, 3) = (SORC1(I, 3)*CT)/DENOM
C    DELTA K
      SORC2(I, 4) = SORC2(I,3) - SORC1(I,2) - SORC1(I,3) - SORC2(I,2)
      SUM = SUM + SORC2(I,4)*V0(NC,I)
      TOT = TOT + V0(NC,I)
      ST = SUM/TOT
3050  FORMAT(     38H0REACTIVITY COEFFICIENTS FOR MATERIAL I2, 6X,A6,
     1 14H        COLUMN I2//)
      SORC1(I,2) =-SORC1(I,2)
      SORC1(I,3) = - SORC1(I,3)
      SORC2(I,2) =-SORC2(I,2)
      WRITE(NOUT, 2080)  I, SORC2(I,4), SORC2(I,3), SORC1(I,2),
     1  SORC1(I,3), SORC2(I,2),ST, R4(NC), Z4(I)
3200  CONTINUE
3400  CONTINUE
9999  CONTINUE
      REWIND NCR1
      REWIND NFLUX1
      REWIND NFLUX2
      REWIND NSCRAT
      RETURN
      END
```