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Solution of the two-dimensional multigroup neutron diffusion equation by a synthesis method

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SOLUTION OF THE TWO-DIMENSIONAL MULTIGROUP NEUTRON DIFFUSION EQUATION BY A SYNTHESIS METHOD

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ABSTRACT

A method, called the higher mode synthesis method, for the solution of the two-dimensional neutron diffusion equation is developed. In this method, the two-dimensional eigenfunction is expanded in terms of one-dimensional fundamental and higher eigenfunctions. A substitute, weight, and integration procedure is applied and the two-dimensional equation is reduced to a one-dimensional equation in terms of expansion coefficients. The expansion coefficients are combined with the trial functions in order to obtain the two-dimensional eigenfunction. This procedure results in a significant reduction of computation time as compared with standard iteration methods.

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I. INTRODUCTION

The purpose of this thesis is to demonstrate a method of solving the equation

$$-\nabla \cdot D(E,\underline{u}) \nabla \phi(E,\underline{u}) + \Sigma rem(E,\underline{u}) \phi(E,\underline{u}) = \int_0^\infty \Sigma_s(E' \to E,\underline{u}) \phi(E',\underline{u}) dE'$$

$$+ \nu/\lambda \; f(E,\underline{u}) \int_0^\infty \Sigma_f(E',\underline{u}) \phi(E',\underline{u}) dE' \; . \qquad (1)$$

This is the energy dependent, steady state diffusion equation of reactor physics. The symbols used in this equation are defined as follows:

$D(E,\underline{u})$	=	diffusion coefficient
$\phi(E,\underline{u})$	=	neutron flux
$\Sigma rem(E,u)$	=	removal cross section
$\Sigma_s(E' \to E,\underline{u})$	=	scattering kernel
$f(E,u)$	=	fission yield
$\Sigma_f(E,\underline{u})$	=	fission cross section
E	=	energy
$\underline{u}$	=	spatial variables
ν	=	number of neutrons/fission
λ	=	effective multiplication constant

Equation (1) has been used extensively to ascertain basic parameters of nuclear reactors when they are operating in the steady state. Many methods* of solving this equation

*Discussed in the Literature Survey

have been proposed and used. Almost without exception, the method of solution is so complex that digital computers must be used to do the calculations. Because of the high cost of computer time, a method of solution must be used that is no more accurate than is needed for a particular application. For example, in the final stages of designing a reactor, a method must be used which results in a high degree of accuracy. On the other hand, for survey studies a high degree of accuracy is not a necessity, and a method should be used which requires a minimum amount of computer time.

Many methods of solving the diffusion equation have been used in the past. These include the iteration method, a method which uses the assumption that the diffusion equation can be treated as an initial value problem, and various synthesis techniques. These are discussed in the Literature Survey.

The method of solution which is presented in this thesis is an approximate one requiring fewer calculations and, therefore, less computer time than comparable methods. This method is referred to as the Higher Mode Synthesis (HMS) method. HMS is based on the assumption that the spatial dependence of the eigenfunction of Eq. (1) can be expanded in terms of one-dimensional eigenfunctions. This method was first proposed by Edwards [1].

In the Discussion the multigroup approximation and a derivation of HMS are presented. A description of the code, MUD-SYN, used to verify HMS is also given. Next, results from MUD-SYN are compared to a more conventional production code. This thesis is concluded with a summary of the results and recommendations for further study.

II. LITERATURE SURVEY

Most methods of solving Eq. (1) use the multigroup approximation and usually divide the space interval into discrete segments [2]. Equation (1) is normally solved by iteration methods. However, other methods have been devised, such as the stabilized march technique [3] and various synthesis techniques. These methods are described below.

A. Iteration Methods

For simplification, Eq. (1) may be written in operator form as:

$$L\phi(\underline{x}) = 1/\lambda \; M\phi(\underline{x}) \tag{2}$$

where L and M are linear operators, $1/\lambda$ is the eigenvalue, and $\underline{x}$ represents all the independent variables [4]. The general iterative solution of Eq. (2) proceeds [5] as follows. Equation (2) is solved for $\phi(\underline{x})$ to give $\lambda\phi(\underline{x}) = L^{-1}M\phi(\underline{x})$. The iterative method requires an initial guess for both $\phi(\underline{x})$ and for λ, denoted by $\phi^{(0)}(\underline{x})$ and $\lambda^{(0)}$, respectively. A new approximation, $\phi^{(1)}(\underline{x})$, is obtained by the relation

$$\lambda^{(0)}\phi^{(1)}(\underline{x}) = L^{-1}M\phi^{(0)}(\underline{x}) \; .$$

After $\phi^{(1)}(\underline{x})$ is known, a new approximation may be obtained from the equation

$$\lambda^{(0)}\phi^{(2)}(\underline{x}) = L^{-1}M\phi^{(1)}(\underline{x}) \; .$$

This iteration may be continued until the difference between $\phi^{K-1}(\underline{x})$ and $\phi^{K}(\underline{x})$ is smaller than some preset value. This is what is normally called the inner iteration. After the $\phi(\underline{x})$ have converged, a new λ may be calculated using the relation

$$(1/\lambda^{(1)}) = \frac{\int\phi(\underline{x})L\phi(\underline{x})d\underline{x}}{\int\phi(\underline{x})M\phi(\underline{x})d\underline{x}} .$$

This is the outer iteration. The new value of λ is then used in the inner iteration. This procedure continues until both $\phi(\underline{x})$ and λ have satisfied the convergence criteria. Other iterative schemes have been used, but the general procedure varies only slightly from that presented above. Many computer codes have been written which use the iteration method [6-9].

B. The Stabilized March Technique

Another method for solving the multigroup diffusion equation is the Stabilized March Technique (SMT) [3]. The basis of SMT is that the diffusion equation can be treated as an initial value problem. This difference equation is inherently unstable. The instability cannot be eliminated, but it can be controlled by performing a conditioning transformation at various intervals during the march. The eigenvalue is determined by requiring that the flux goes to zero at the outer boundary or at the extrapolated boundary. The SMT requires an initial guess of the eigenvalue only. If the flux is not zero at the outer boundary, another guess for the eigenvalue is made and the march is repeated. This procedure is continued until an eigenvalue is found which makes the flux satisfy the boundary conditions.

A one-dimensional code, MUD-MO, which utilizes SMT, has been written. This code is used to solve the one-dimensional form of Eq. (1) in order to calculate the trial functions, adjoint functions and expansion coefficients used in HMS.

C. Comparison of SMT and Iteration Methods

The iteration methods have a disadvantage in that they are very sensitive to the form of the scattering matrix. When up-scattering is present, the convergence of the iteration methods is slowed considerably. For problems involving down-scattering only, the iteration methods are faster than SMT. However, SMT is independent of the type of scattering matrix; and for problems involving both up-scattering and down-scattering, SMT is faster.

SMT has an advantage in that it can be used to calculate higher eigenfunctions and eigenvalues. The higher eigenfunctions and eigenvalues can be calculated in the same amount of time as the fundamental. Only one iteration method is available to calculate higher eigenfunctions. This method is the Wielandt fractional iteration [10]. It requires a matrix inversion at each point along one of the spatial axes; therefore, it can run into trouble near internal zeroes of the higher eigenfunctions [11]. Both SMT and the iteration methods can be used to calculate the adjoint function.

D. Synthesis Methods

In many situations a one-dimensional method does not provide an adequate representation, and the problem must be treated two-dimensionally. The normal approach to this problem is to use an iteration method for a two-dimensional mesh; however, calculations on such a mesh require an inordinate amount of computer time. Because of this fact, a considerable amount of effort has been devoted to devising methods of constructing approximations to two-dimensional flux shapes using one-dimensional calculations. These methods are referred to as synthesis methods. Most synthesis methods rely on the assumption that the neutron flux is, or almost is, spatially separable. For most reactors this assumption can be made. However, if the reactor is small or highly heterogeneous, this is a bad assumption; then other methods must be used.

In the case of a cylindrical reactor, the flux is not truly separable if the materials are not uniform axially. However, the reactor may be divided into a small number of axial zones and the assumption may be made that the flux is separable within each zone. A method based on this assumption has been used extensively [12].

Two variations of the procedure may be illustrated by considering a reactor which is divided into two axial zones by a control rod bank partially inserted into the core in the axial direction. The first technique is to write:

$$\phi^j(r,z) = \theta^j(z) \begin{cases} H_2{}^j(r) & z_r < z < L \\ H_1{}^j(r) & 0 < z < z_r \end{cases} \tag{3}$$

j = group index

where r is the radial direction, z is the axial direction, z_r is the point where the control rods begin, L is the height of the reactor and $H_1{}^j(r)$ and $H_2{}^j(r)$ are solutions of the one-dimensional equation in zone (1) and zone (2), respectively.* This approximation is substituted into the two-dimensional equation and a one-dimensional equation in $\theta^j(z)$ obtained. The major failing of this method is that the synthesized flux normally has a large discontinuity at the zone interface.

The second technique eliminates the discontinuity by using an expansion of the form

$$\phi^j(r,z) = \sum_{k=1}^{K} a_k^j(z)\, H_k^j(r) \tag{4}$$

where the $a_k^j(z)$ are the expansion coefficients and the $H_k^j(r)$ are the trial functions which satisfy the boundary conditions in the r direction. The trial functions must be chosen intuitively such that this expansion would be expected to be a good approximation.

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*Zone (1) is the region without control rods, and zone (2) is the region with control rods.

An expansion of the form in Eq. (4) is much preferred over the form in Eq. (3) because it will not result in a discontinuity at the zone interface as will the form in Eq. (3).

There is no set rule as to how to determine the expansion coefficients, $a_k^j(z)$. The procedure to determine the expansion coefficients depends on the choice of trial functions. Several methods have been proposed and a few of these are described below.

In order to illustrate these methods, a right cylindrical reactor will be studied. The following notation will be used.*

$$-\nabla\cdot\underline{D}\nabla\vec{\phi}(r,z) + \underline{A}\vec{\phi}(r,z) = 1/\lambda\ \underline{M}\vec{\phi}(r,z) \qquad (5)$$

where

$$\vec{\phi}(r,z) = \text{col}\ [\phi^1(r,z),\ \ldots,\ \phi^J(r,z)]\ ,$$

$$\underline{D} = \text{diag}\ [D^1, D^2,\ \ldots,\ D^J]\ ,$$

$$\underline{A} = [\Sigma^{ij}]\ ,$$

$$\underline{M} = [\nu f^i \Sigma_f^j]\ ,$$

$\phi^j(r,z)$ = neutron flux of the j-th group,

D^j = diffusion coefficient of the j-th group,

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*Throughout this thesis the convention will be used that symbols representing matrices will be underscored and vectors will be represented with arrows above the symbols.

f^j = fission yield,

Σ_f^j = fission cross section,

Σ^{ij} = scattering cross section from group i to group j.

The boundary conditions to be used with Eq. (5) are $\vec{\phi}(r,z) = 0$ at the outer boundary

and $\frac{\partial\vec{\phi}(r,z)}{\partial r} = \frac{\partial\vec{\phi}(r,z)}{\partial z} = 0$ at the center.

The problem is to synthesize the flux of the form

$$\vec{\phi}(r,z) = \underline{H}(r)\vec{a}(z) \quad . \tag{6}$$

If K is the number of trial functions, $\vec{a}(z)$ has as its elements $[\vec{a}]_k(z)/k = 1,2,\ldots K$ and each $[\vec{a}]_k(z)$ has as its elements $[a]_j(z)/j = 1,2,..,J$. $\underline{H}(r)$ is a row matrix having as its elements $[\underline{H}]_k(r)/k = 1,2,\ldots K$, and each $[\underline{H}]_k(r)$ is a matrix having as its elements $[H]_{ij}(r)\delta_{ij}$.

In order to determine the expansion coefficients, $\vec{a}(z)$, Eq. (6) is substituted into Eq. (5), the governing equation. Equation (5) is then multiplied by $\underline{H}^{*T}(r)$, where $\underline{H}^{*T}(r)$ is the transpose of the matrix obtained when the adjoint function is used instead of its corresponding trial function. The result is integrated over r. If this is done, the following equation will result:

$$-\underline{D}' \frac{d^2\vec{a}(z)}{dz^2} + [\underline{A}' + (D'B_r^{\,2})]\,\vec{a}(z) = 1/\lambda \;\; M'\vec{a}(z) \tag{7}$$

where $\underline{D}' = \int_r \underline{H}^{*T}(r)\underline{DH}(r)dr$

and $\underline{A}'$, $(\underline{D'B_r}^2)$, and $\underline{M}'$ are similarly defined.

In order to obtain Eq. (7) it is assumed that the flux obeys the Helmholtz equation. The $\underline{D}\frac{1}{r}\frac{\partial}{\partial r} r \frac{\partial}{\partial r}$ term is replaced by $\underline{D}\ \underline{B}_r^2$. Equation (7) can also be derived from a variational principle [12, 13].

In the development of Eq. (7), $\underline{H}^*(r)$ was used as the weighting function. The choice of the weighting function is not necessarily limited to the adjoint function. If the exact solution is given by Eq. (6), Eq. (7) can be obtained no matter what weighting functions are used. An interesting method is to use $\underline{H}(r)$ as the weighting function. This method has the advantage that the necessity of calculating the adjoint function is eliminated. Hereafter, this method will be referred to as "Galerkin's Method."

Methods similar to the ones described above have proved themselves to be very useful in reactor analysis. Synthesis methods have been used to construct three-dimensional power shapes [14-16]. Very good results have been obtained for this application. The flux synthesis technique has also been used in burnup studies [17].

Another interesting synthesis technique is the Natural Mode Approximation, (NMA). This technique is similar to the one developed in this thesis except that the Natural Mode Approximation deals with reactor kinetics problems. The NMA is based on a modal expansion technique where the time-dependent and space-dependent variables are approximated by a series of products of time-dependent expansion coefficients and space-dependent expansion modes. The space-dependent modes are eigenvectors of the steady-state diffusion equation. The details of this method are not given here; however, the reader can find a more complete discussion in a paper by Foulke and Gyftopoulos [18]. NMA is similar to the other techniques described in this section. One difference is that instead of assuming that the spatial variables are separable, it is assumed that the time variable can be separated from the spatial variables. The major difference between NMA and other synthesis approximations lies in the choice of trial functions. The normal methods use as trial functions the solutions for different regions of the reactor. However, NMA uses as trial functions the fundamental and higher eigenfunctions of the equation which approximates the equation to be solved. NMA has been applied successfully to the calculation and interpretation of reactor kinetics experiments.

III. DISCUSSION

A. The Multigroup Approximation

The form of Eq. (1) which will be discussed is the two-dimensional, multi-group, multi-region diffusion equation. The coordinate systems used are the cartesian and cylindrical systems (x-y and r-z). The multigroup approximation of Eq. (1) may be made by multiplying by dE and integrating from E_i to E_{i-1}. If this is done Eq. (1) becomes, for the i-th group,

$$- \frac{1}{r^a} \frac{\partial}{\partial r} [D^i(r,z) r^a \frac{\partial \phi^i(r,z)}{\partial r}] - \frac{\partial}{\partial z} [D^i(r,z) \frac{\partial \phi^i(r,z)}{\partial z}] \quad (8)$$

$$+ \Sigma rem^i(r,z)\phi^i(r,z) = \sum_{\substack{j=1 \\ j \neq i}}^{Ng} \Sigma_s^{j,i}(r,z)\phi^j(r,z)$$

$$+ \nu/\lambda \; f^i(r,z) \sum_{j=1}^{Ng} \Sigma_f^j(r,z)\phi^j(r,z)$$

where

$$\phi^i(r,z) = \int_{Ei}^{E_{i-1}} \phi(E,r,z)dE$$

$$\Sigma rem^i(r,z) = \frac{\int_{Ei}^{E_{i-1}} \Sigma rem(E,r,z)\phi(E,r,z)dE}{\phi^i(r,z)}$$

$$\Sigma_s^{j,i}(r,z) = \frac{\int_{Ei}^{E_{i-1}} \int_{Ej}^{E_{j-1}} \Sigma_s(E' \rightarrow E,r,z)\phi(E',r,z)dE'dE}{\phi^j(r,z)}$$

and

Σ_f^j, f^i, and D^i are defined in a similar manner.

The exponent, a, has the value 0 for cartesian coordinates and 1 for cylindrical coordinates.

When the entire energy spectrum is considered, a set of coupled differential equations is the result. The number of these equations is equal to the number of energy groups being considered. This set of equations may be represented in matrix form by defining

$$\vec{\phi}(r,z) = \text{Col}[\phi^1(r,z),\ \phi^2(r,z), \ldots,\ \phi^{Ng}(r,z)]$$

where Ng is the number of groups [19]. The resulting equation is a matrix differential equation of the form

$$-\frac{1}{r^a}\frac{\partial}{\partial r}[\underline{D}(r,z)r^a\frac{\partial\vec{\phi}(r,z)}{\partial r}] - \frac{\partial}{\partial z}[\underline{D}(r,z)\frac{\partial\vec{\phi}(r,z)}{\partial z}] \tag{9}$$

$$+ \underline{\Sigma}\text{rem}(r,z)\vec{\phi}(r,z) = \underline{\Sigma}_s(r,z)\vec{\phi}(r,z) + \nu/\lambda\ \underline{F}(r,z)\vec{\phi}(r,z)$$

where

$\underline{D}(r,z)$ is a diagonal matrix with $[D(r,z)]_{ii} = D^i(r,z)$,

$\underline{\Sigma}\text{rem}(r,z)$ is a diagonal matrix with $[\Sigma\text{rem}(r,z)]_{ii} = \Sigma^i\text{rem}(r,z)$,

$\underline{\Sigma}_s(r,z)$ is the scatter matrix with $[\Sigma_s(r,z)]_{ji} = \Sigma_s^{j,i}(r,z)$, and

$\underline{F}(r,z)$ is the fission matrix with $[F(r,z)] = f^i(r,z)$ $\Sigma_f^j(r,z)$

B. Formulation of the Higher Mode Synthesis Method

Equation (9), the multigroup diffusion equation, is repeated here for easy reference. For simplicity, the form of Eq. (9) in cartesian coordinates, a=0, is considered.

$$- \frac{\partial}{\partial x} [\underline{D}(x,y) \frac{\partial \vec{\phi}(x,y)}{\partial x}] - \frac{\partial}{\partial y} [\underline{D}(x,y) \frac{\partial \vec{\phi}(x,y)}{\partial y}]$$
$$+ \underline{\Sigma}rem(x,y)\vec{\phi}(x,y) = \underline{\Sigma}_s(x,y)\vec{\phi}(x,y) + \nu/\lambda \ \underline{F}(x,y)\vec{\phi}(x,y) \ . \qquad (10)$$

The validity of HMS depends upon the amount of error introduced when the following approximation is made

$$\vec{\phi}(x,y) = \sum_{k=1}^{K} a_k(y)\vec{\theta}_k(x) \qquad (11)$$

where the $\vec{\theta}_k(x)$ are the fundamental (k=1) and higher eigenfunctions (k=2,3,4,...,K) which satisfy the one-dimensional form of Eq. (10). The expansion, Eq. (11), is substituted into Eq. (10). Each side of Eq. (10) is pre-multiplied by $\vec{\theta}_n^{*T}(x)$, where T denotes the transpose and the $\vec{\theta}_n^*(x)$ (the adjoint flux) are the fundamental and higher eigenfunctions obtained by using the adjoint operator in the one-dimensional case of Eq. (10). The result is then integrated over x, where x goes from center to the outer boundary. These operations on

Eq. (10) will now be done. For clarity, the equation is considered term by term. $\underline{D}$, $\underline{\Sigma}rem$, $\underline{\Sigma}_s$ and $\underline{F}$ are considered independent of spatial coordinates within each region.

FIRST TERM

$$- \frac{\partial}{\partial x} [\underline{D}(x,y) \frac{\partial \vec{\phi}(x,y)}{\partial x}] \rightarrow - \underline{D} \frac{\partial^2}{\partial x^2} \sum_{k=1}^{K} a_k(y) \vec{\theta}_k(x)$$

$$\rightarrow \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x) \; \underline{D} \frac{\partial^2}{\partial x^2} \vec{\theta}_k(x) dx \; \vec{a}(y)$$

where $\vec{a}(y) = \mathrm{Col}[a_1(y), \ldots, a_k(y)]$

SECOND TERM

$$- \frac{\partial}{\partial y} [\underline{D}(x,y) \frac{\partial \vec{\phi}(x,y)}{\partial y}] \rightarrow - \underline{D} \frac{\partial^2}{\partial y^2} \sum_{k=1}^{K} a_k(y) \vec{\theta}_k(x)$$

$$\rightarrow - \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x) \; \underline{D} \vec{\theta}_k(x) dx \frac{\partial^2 \vec{a}(y)}{\partial y^2} \rightarrow - \underline{D}' \; \frac{\partial^2 \vec{a}(y)}{\partial y^2}$$

where $[D']_{n,k} = \int_x \vec{\theta}_n^{*T}(x) \; \underline{D} \vec{\theta}_k(x) dx$

THIRD TERM

$$\underline{\Sigma}rem(x,y) \vec{\phi}(x,y) \rightarrow \underline{\Sigma}rem \sum_{k=1}^{K} a_k(y) \vec{\theta}_k(x)$$

$$\rightarrow \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x)\ \underline{\Sigma}\text{rem}\vec{\theta}_k(x)dx\vec{a}(y) \rightarrow \underline{\Sigma}'\text{rem}\vec{a}(y)$$

where $[\Sigma'\text{rem}]_{n,k} = \int_x \vec{\theta}_n^{*T}(x)\ \underline{\Sigma}\text{rem}\vec{\theta}_k(x)dx$

FOURTH TERM

$$\underline{\Sigma}_s(x,y)\vec{\phi}(x,y) \rightarrow \underline{\Sigma}_s \sum_{k=1}^{K} a_k(y)\vec{\theta}_k(x)$$

$$\rightarrow \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x)\ \underline{\Sigma}_s\vec{\theta}_k(x)dxa(y) \rightarrow \underline{\Sigma}_s'\vec{a}(y)$$

where $[\Sigma_s']_{n,k} = \int_x \vec{\theta}_n^{*T}(x)\ \underline{\Sigma}_s\vec{\theta}_k(x)dx$

FIFTH TERM

$$\nu/\lambda\ \underline{F}(x,y)\vec{\phi}(x,y) \rightarrow \nu/\lambda\ \underline{F} \sum_{k=1}^{K} a_k(y)\vec{\theta}_k(x)$$

$$\rightarrow \nu/\lambda \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x)\ \underline{F}\vec{\theta}_k(x)dx\vec{a}(y) \rightarrow \nu/\lambda\ \underline{F}'\ \vec{a}(y)$$

where $[F']_{n,k} = \int_x \vec{\theta}_n^{*T}(x)\ \underline{F}\vec{\theta}_k(x)dx$

These terms are substituted into Eq. (10) to give

$$- \underline{D}' \frac{d^2\vec{a}(y)}{dy^2} + [\underline{\Sigma}'rem - \sum_{k=1}^{K} \int_x \vec{\theta}_n^{*T}(x)\, \underline{D} \frac{d^2\vec{\theta}_k(x)}{dx^2} dx]\, \vec{a}(y) =$$

$$\underline{\Sigma}_s'\vec{a}(y) + \nu/\lambda\ \underline{F}'\ \vec{a}(y)\ . \qquad (12)$$

The $\frac{d^2\vec{\theta}_k(x)}{dx^2}$ term can be approximated by finite differences [20]. In general, the one-dimensional Laplacian operator can be written as

$$\nabla^2\theta = \frac{\partial^2\theta}{\partial r^2} + \frac{a}{r}\frac{\partial\theta}{\partial r}\ ,$$

but

$$\frac{\partial^2\theta_j}{\partial r^2} = \frac{\theta_{j+1} - 2\theta_j + \theta_{j-1}}{(\Delta r)^2}$$

and

$$\frac{\partial\theta_j}{\partial r} = \frac{\theta_{j+1} - \theta_{j-1}}{2\Delta r}\ ,$$

therefore

$$\nabla^2\theta_j = \frac{\theta_{j+1} - 2\theta_j + \theta_{j-1}}{(\Delta r)^2} + \frac{a}{r}\frac{(\theta_{j+1} - \theta_{j-1})}{2\Delta r}\ .$$

If this is done, the expansion coefficients can be determined by solving Eq. (12).

At this point both the expansion coefficients and the expansion functions are known; and by using Eq. (11), the two-dimensional flux, $\vec{\phi}(x,y)$, can be calculated.

This solution represents the solution of a perturbed system. For example, when the multigroup diffusion equation is solved in one dimension for a cylinder in the radial direction, the cylinder is considered infinite in the axial direction. Therefore, leakage in the axial direction is ignored. If the cylinder is not infinite, the axial leakage represents a perturbation to the one-dimensional solution.

This situation is analogous to the solution of systems which are time dependent. In this case, a common expansion for a slab reactor is

$$\phi(x,t) = \sum_{n,odd} \phi_n(t)\cos B_n x ,$$

where $Bn = \frac{n\pi}{a}$ and a = thickness of the reactor [21]. It has been found that the higher modes are present immediately after a perturbation, but they die out in time. This illustrates the major difference between the time-dependent and the time-independent expansion. The higher modes in the time-independent case do not die out in time, because they represent a perturbation due to constant leakage in the axial direction. The leakage is due to the system not being infinite in the axial direction and, obviously, the dimensions of a given system are time independent. Thus, it can be said that the system possesses "steady-state transients."

If, in Eq. (11) an infinite number of terms is used, Eq. (12) would be exact within the framework of diffusion theory. However, in actual practice only a finite number of terms can be used, and a truncation error is present. The magnitude of the truncation error depends upon the convergence of the series, and the convergence of the series in Eq. (11) depends upon the degree of separability of the spatial dependence of the eigenfunction of Eq. (10). Most reactors are very complex in the horizontal plane, and a high degree of inseparability would be expected. However, in the vertical plane the reactor configuration is usually fairly simple and convergence of the series in Eq. (11) would be expected to be fairly rapid. If this criteria is used, the trial functions (the eigenfunctions of the one-dimensional equation) should be those which describe the flux in the direction of highest complexity; and the synthesis should be in the direction of least complexity. Another aspect which should be considered is the size of the perturbation of the one-dimensional equation, i.e., the amount of axial leakage. The trial functions, $\vec{\theta}_k(x)$, should approximate the two-dimensional flux, $\vec{\phi}(x,y)$. Therefore, the trial functions should be calculated for the direction of largest leakage, and the synthesis should be done in the direction of least leakage. These are two criteria which should be used to decide in which direction the synthesis approximation should be made. These may be conflicting criteria, but normally the direction of greatest complexity is also the direction of largest leakage in a given reactor; and, when this is true, no conflict will result.

The advantage of HMS is the reduction in the number of computations which must be performed, thus the computation time should be considerably less than when the more conventional methods are used. Another advantage of HMS is that the trial functions (solutions of the one-dimensional equation) remain unchanged even if changes of parameters are made in the direction of synthesis. The trial functions may be stored and used at a later time if it is desired to make parameter changes in the synthesis direction. This would eliminate the need to calculate new trial functions. It would be necessary to calculate only the expansion coefficients and do the summation of Eq. (11), which would reduce the required computer time to a small fraction of the time that would otherwise be needed.

C. Results

A computer code, MUD-SYN, has been developed to test the Higher Mode Synthesis method. The code, MUD-MO, used to determine the trial functions, adjoint functions, and expansion coefficients, is based on the Stabilized March Technique. As mentioned previously, this code has the ability to calculate higher eigenfunctions; therefore, it is very adaptable to this application. MUD-MO is incorporated into MUD-SYN as a subroutine.

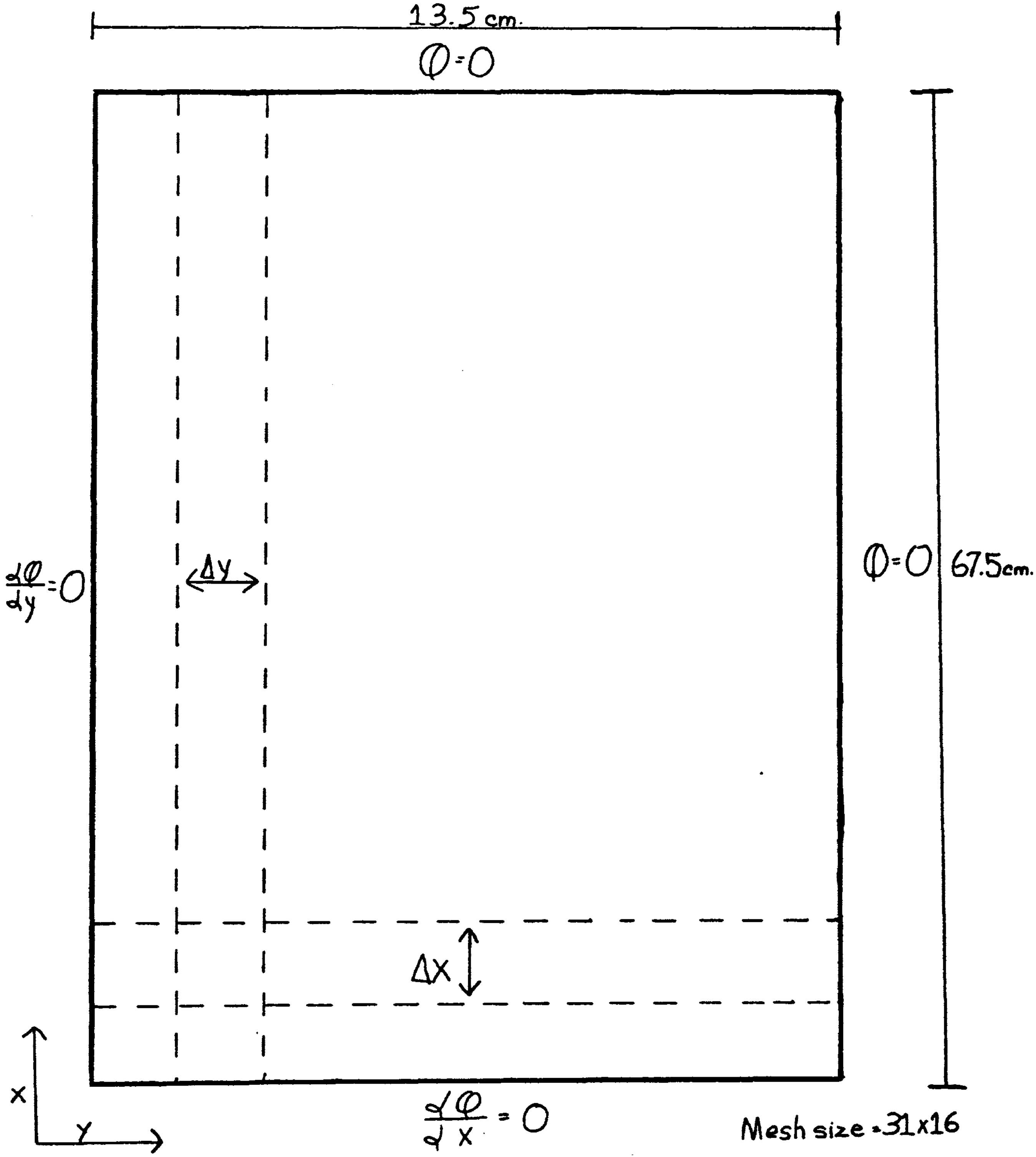
The capability of MUD-SYN was tested by studying three different types of reactors. These reactors were selected because of their various geometrical and material properties.

The main points of interest are the effective multiplication constant, the flux shape, and the computation time. Another important factor is the number of terms needed in the series in Eq. (11) in order to obtain accurate results. The results from MUD-SYN are compared with the results from a production code, EXTERMINATOR-2. EXTERMINATOR-2 is a two-dimensional code which uses an iteration method. Problem one is relatively simple and has an analytical solution. The results using HMS are compared directly to this analytical solution. In problems two and three, the flux shape and effective multiplication constant from EXTERMINATOR-2 are considered to be "exact."

1. PROBLEM ONE

The first problem studied is one selected from the Benchmark Problem Book [22]. This book is a compilation of problems of varying complexity for which analytical or very accurate approximate solutions exist. One of the main objectives of the book is to assist in evaluation of computer programs.

The problem selected, a homogeneous, two-dimensional slab, is one for which an analytical solution exists. The reactor configuration and boundary conditions are shown in Figure 1. Seven energy groups are used, four fast and three thermal; and full up-scattering is treated in the thermal



PROBLEM ONE CONFIGURATION

FIGURE 1

groups. Because of the criteria discussed previously, the synthesis was done in the x - direction. The mesh size used is 16 x 31 (16 points in the y - direction and 31 points in the x - direction).

Because of the simplicity of this problem, it was expected that convergence of the series in Eq. (11) would be fairly rapid and truncation error would be small. This proved to be true, and it is demonstrated by the relative size of the expansion coefficients. The first three expansion coefficients for various points in the x - direction are shown in Table I. For each point the third expansion coefficient is approximately 0.0001 times the first expansion coefficient. This suggests that good results could be obtained by truncating the series in Eq. (11) after only one or two terms. This is done and the results are summarized in Table II. Excellent agreement with the analytical solution is obtained by using only two terms in the series in Eq. (11). The calculation time as compared with that of EXTERMINATOR-2 is very low.

The relative flux shape as calculated by MUD-SYN is in good agreement with the flux shape as calculated by EXTERMINATOR-2. This is shown by Figures 2, 3, and 4. Figure 2 shows the group 1 flux shape in the y - direction for x = 0.0cm. Figure 3 shows the group 1 flux shape in the y - direction for x = 31.5cm. Figure 4 shows the group 1 flux shape in the x - direction for y = 0.9cm.

TABLE I

RELATIVE SIZE OF EXPANSION COEFFICIENTS

Distance From Center of Reactor (cm.)	Expansion Coefficients First	Second $\times 10^{-3}$	Third $\times 10^{-4}$
0.0	0.99999	0.19891	-0.95055
4.5	0.99452	0.18984	-0.94532
9.0	0.97815	0.18102	-0.92991
13.5	0.95105	0.17916	-0.90408
20.25	0.89098	0.16805	-0.84698
36.0	0.66900	0.12534	-0.63595
42.75	0.54445	0.10138	-0.51769
51.75	0.35809	0.06910	-0.34040
65.25	0.52142	0.02205	-0.04925

TABLE II

PROBLEM ONE DATA

	Machine Time (min.)	K_{eff}	% Difference*
Analytical Solution	———	0.7745	———
EXTERMINATOR-2	34.03	0.7731	0.18
MUD-SYN			
2 Terms	5.50	0.7747	0.025
3 Terms	10.10	0.7747	0.025

$$\text{*\% Difference} = 100 \times \frac{K_{eff}\text{(Analytical)} - K_{eff}}{K_{eff}\text{ (Analytical)}}$$

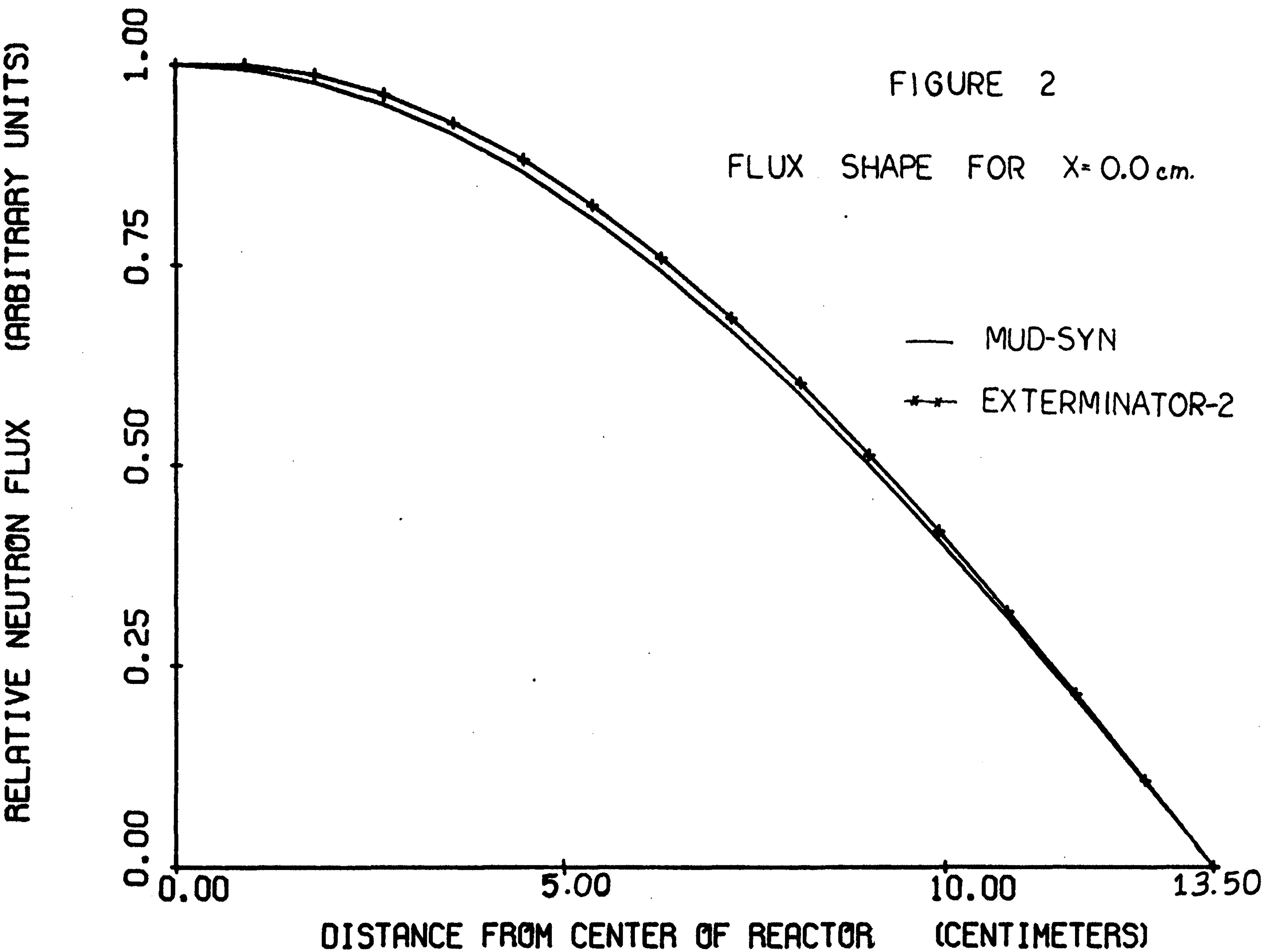


FIGURE 2

FLUX SHAPE FOR X= 0.0 cm.

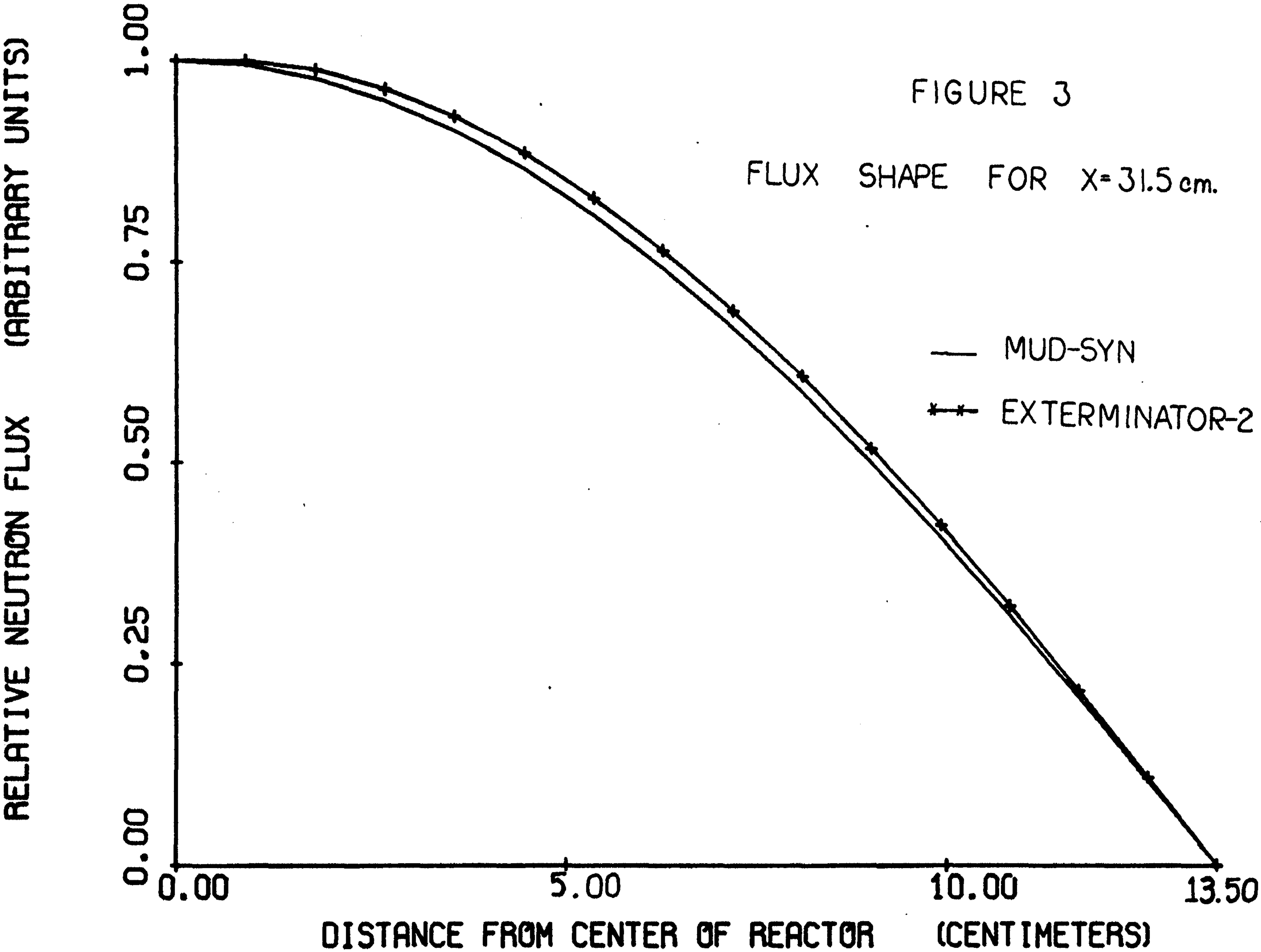


FIGURE 3

FLUX SHAPE FOR X=31.5 cm.

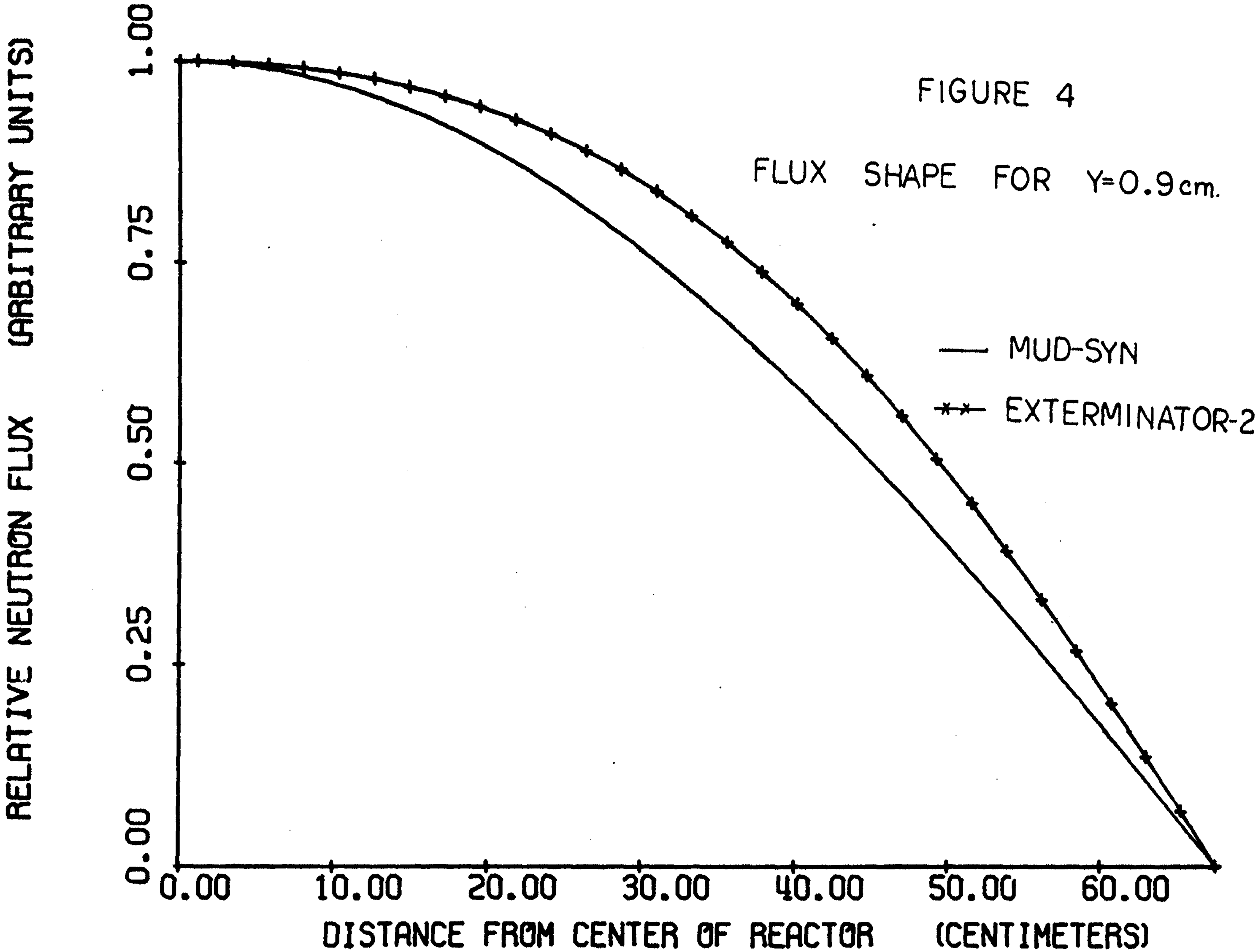


FIGURE 4
FLUX SHAPE FOR Y=0.9cm.
MUD-SYN
EXTERMINATOR-2
RELATIVE NEUTRON FLUX (ARBITRARY UNITS)
0.00
0.25
0.50
0.75
1.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
DISTANCE FROM CENTER OF REACTOR (CENTIMETERS)

2. PROBLEM TWO

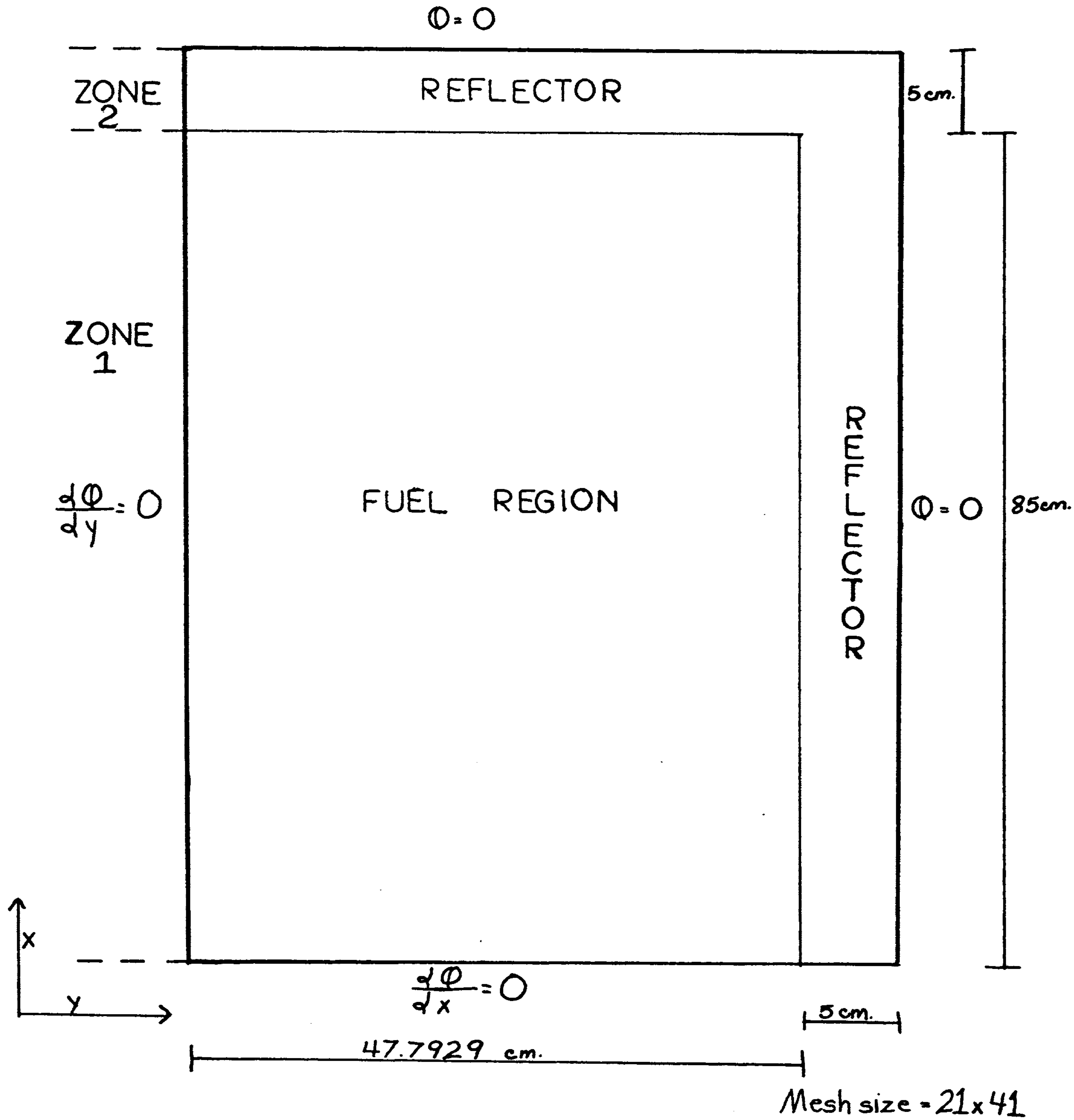
The second problem studied is a slab with a reflector. The configuration is shown in Figure 5. The mesh size is 21 x 41, and the energy spectrum is divided into two groups, one fast group and one thermal group.

This problem is not as separable as problem one and convergence of the series in Eq. (11) is not as fast for this problem as compared to problem one. This is illustrated by the expansion coefficients given in Table III. The third expansion coefficient is approximately one tenth the size of the first expansion coefficient.

Synthesis was done in the x direction. In order to determine the weighted cross sections in the upper reflector, the reactor is divided into two zones in the x direction as shown by Figure 5. The zone (2) trial functions are approximated by the zone (1) trial functions. Problem three is treated in a similar manner.

The computation time and value of K_{eff} for each run are given in Table IV. The value of K_{eff} obtained by using HMS is in good agreement with the value calculated by EXTERMINATOR-2 while the computation time of MUD-SYN is considerably less.

The flux shape as compared with the flux shape calculated by EXTERMINATOR-2 is illustrated by Figures 6 and 7. Figure 6 shows the flux shape in the y direction for x = 0.0cm. Figure 7 shows the flux shape in the x direction for y = 0.0cm.



PROBLEM TWO CONFIGURATION

FIGURE 5

TABLE III

RELATIVE SIZE OF EXPANSION COEFFICIENTS

Distance From Center of Reactor (cm.)	Expansion Coefficients		
	First	Second $\times 10^{-1}$	Third $\times 10^{-1}$
0.00	0.99999	-1.0391	0.76671
7.08	0.99240	-1.0311	0.76114
14.17	0.96969	-1.0075	0.74368
23.60	0.91650	-0.95220	0.70298
30.69	0.86024	-0.89375	0.65993
42.50	0.73785	-0.76659	0.56613
59.03	0.51556	-0.53568	0.39577
66.11	0.40605	-0.42199	0.31182
73.19	0.29036	-0.30081	0.22252
80.28	0.17025	-0.17556	0.13028
85.00	0.08849	-0.09026	0.06769

TABLE IV

PROBLEM TWO DATA

	Machine Time (min.)	K_{eff}	% Difference*
EXTERMINATOR-2	19.00	0.9548	——
MUD-SYN			
2 Terms	6.42	0.9563	0.15
3 Terms	7.77	0.9745	2.1

$$*\% \text{ Difference} = 100 \times \frac{K_{eff}(\text{EXTERMINATOR-2}) - K_{eff}(\text{MUD-SYN})}{K_{eff}(\text{EXTERMINATOR-2})}$$

Mesh size = 21 x 41

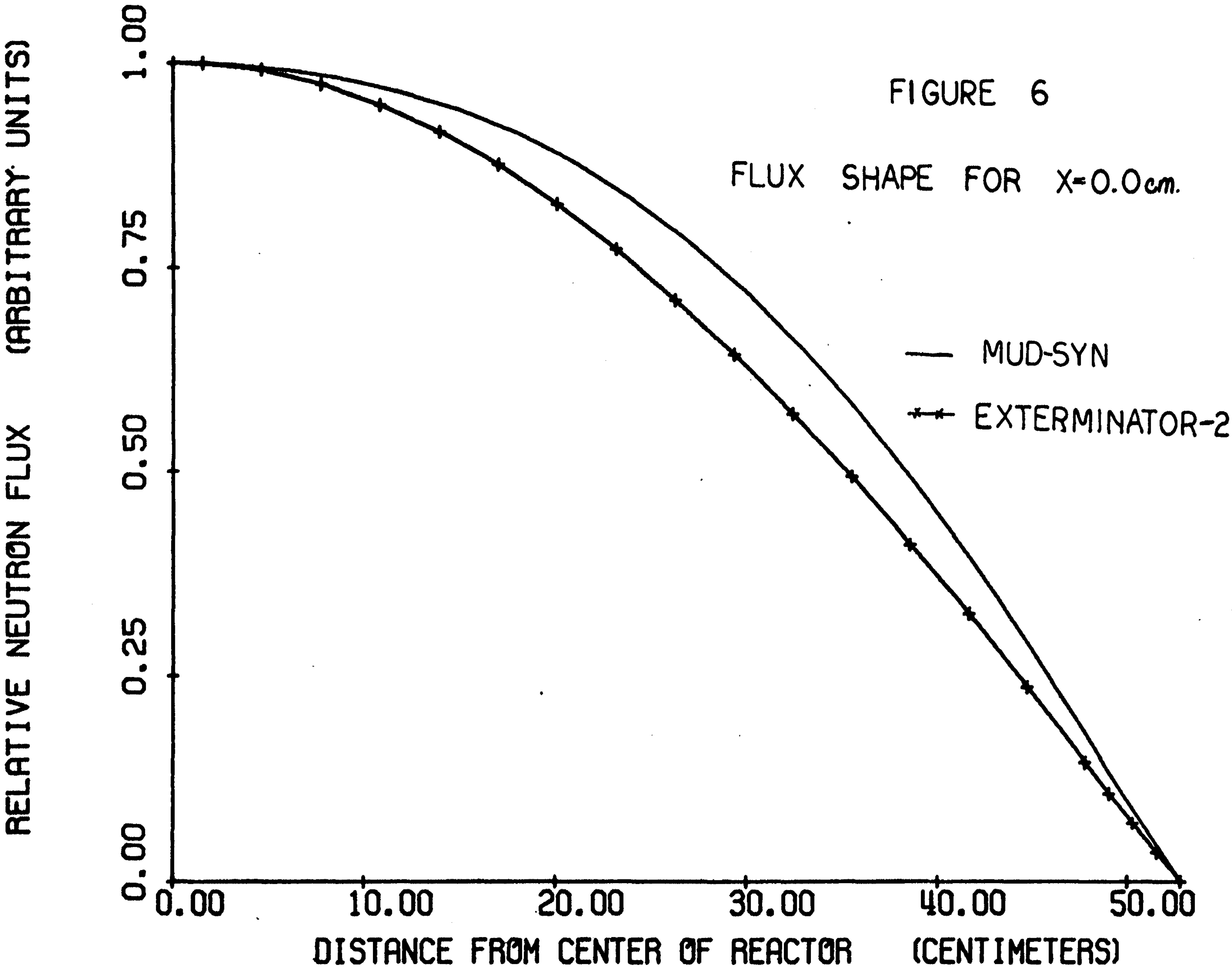


FIGURE 6

FLUX SHAPE FOR X=0.0cm.

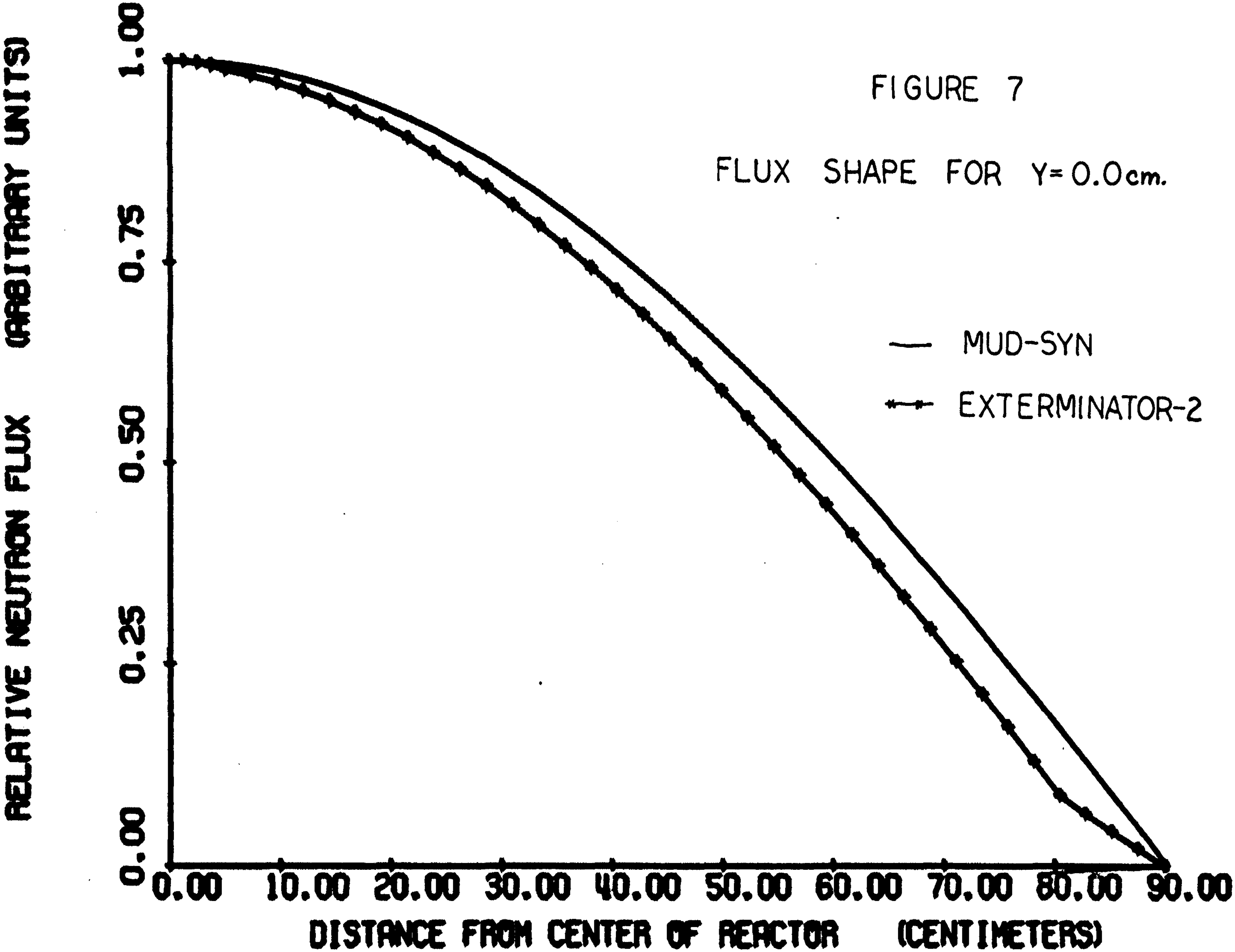


FIGURE 7
FLUX SHAPE FOR Y=0.0cm.
MUD-SYN
EXTERMINATOR-2
RELATIVE NEUTRON FLUX (ARBITRARY UNITS)
0.00
0.25
0.50
0.75
1.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00
DISTANCE FROM CENTER OF REACTOR (CENTIMETERS)

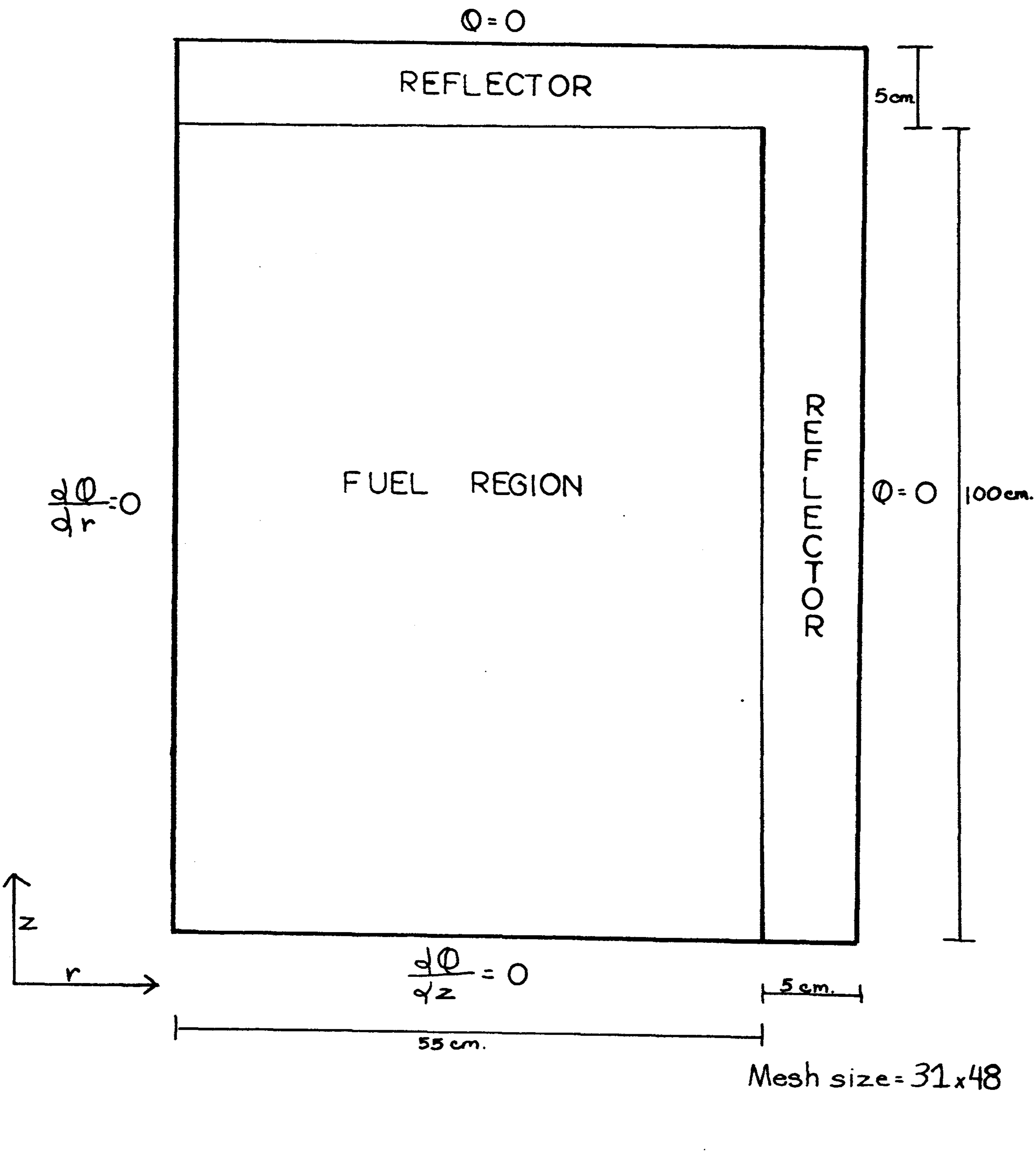
3. PROBLEM THREE

The third problem is a cylinder with axial and radial reflectors. The configuration is shown in Figure 8. The energy spectrum is divided into two groups, one thermal group and one fast group. The mesh size is 31 x 48 (31 points in the r direction and 48 points in the z direction). Synthesis is done in the axial direction.

In this case, convergence of the series in Eq. (11) is similar to that experienced with problem two. Two, three, and four terms are used in the expansion. The results are summarized in Table V. Because of available storage, the mesh size for EXTERMINATOR-2 is 31 x 32. Even though the mesh size for EXTERMINATOR-2 is much smaller, the computation time for MUD-SYN compares favorably. The value of K_{eff} calculated by MUD-SYN varies only slightly from the K_{eff} calculated by EXTERMINATOR-2.

The relative flux shape calculated by MUD-SYN and EXTERMINATOR-2 is illustrated by Figures 9 and 10. Figure 9 shows the flux shape in the r direction for z = 21.4cm. and Figure 10 shows the flux shape in the r direction for z = 35.7cm.

In problems two and three it is observed that as more terms are used in the expansion the value of K_{eff} calculated by MUD-SYN is converging to a value higher than the value of K_{eff} calculated by EXTERMINATOR-2. This error is partially due to the way the axial reflector was treated. As mentioned in problem two, the trial functions in the axial reflector



PROBLEM THREE CONFIGURATION

FIGURE 8

TABLE V

PROBLEM THREE DATA

	Mesh Size	Machine Time (min.)	K_{eff}	% Difference*
EXTERMINATOR-2	31 x 32	18.51	0.8376	——
MUD-SYN	31 x 48			
2 Terms		6.5	0.8392	0.19
3 Terms		7.5	0.8430	0.64
4 Terms		11.13	0.8527	1.80

$$*\%\ \text{Difference} = 100 \times \frac{K_{eff}(\text{EXTERMINATOR}) - K_{eff}(\text{MUD-SYN})}{K_{eff}\ (\text{EXTERMINATOR})}$$

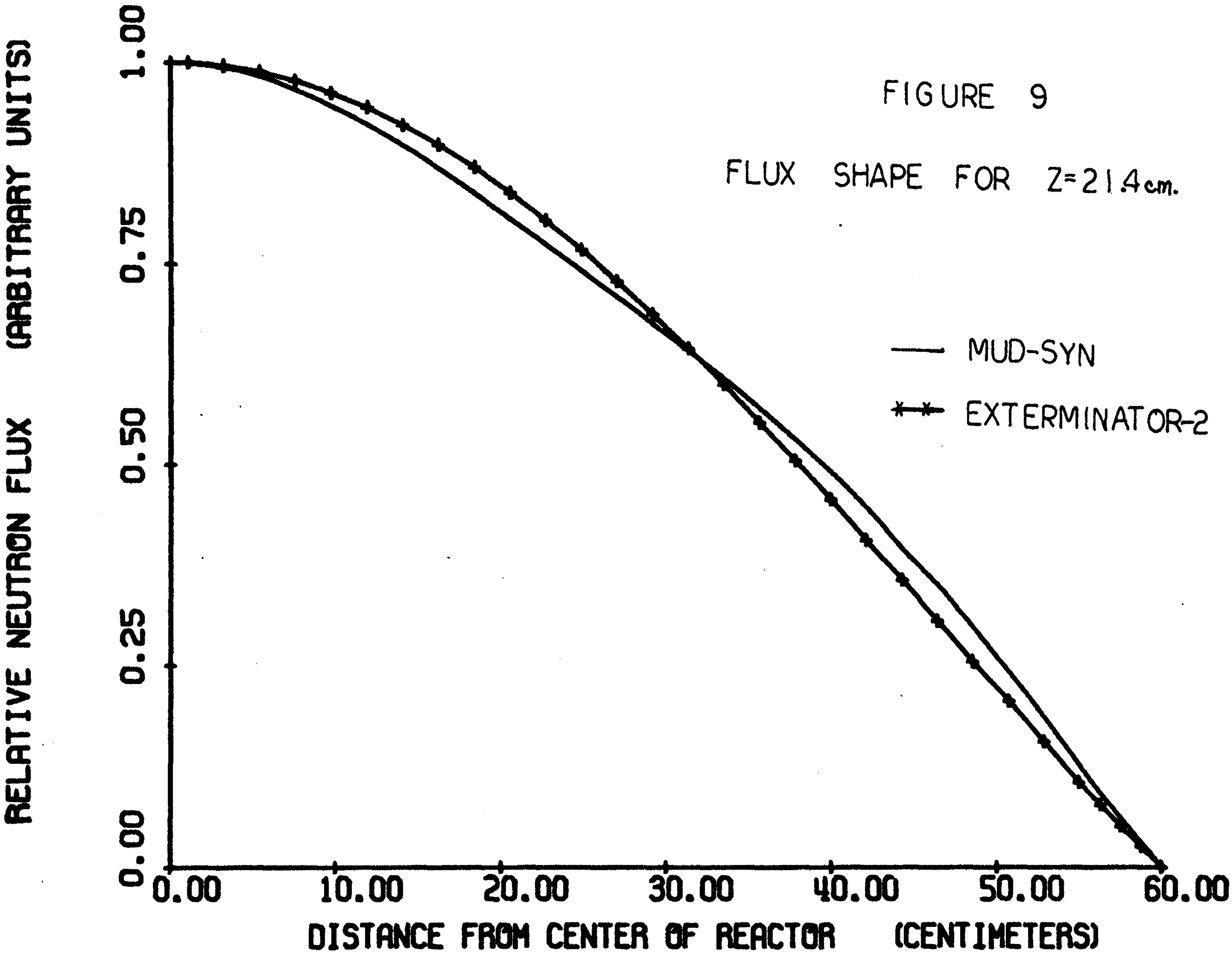


FIGURE 9
FLUX SHAPE FOR Z=21.4cm.
MUD-SYN
EXTERMINATOR-2
RELATIVE NEUTRON FLUX (ARBITRARY UNITS)
0.00
0.25
0.50
0.75
1.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
DISTANCE FROM CENTER OF REACTOR (CENTIMETERS)

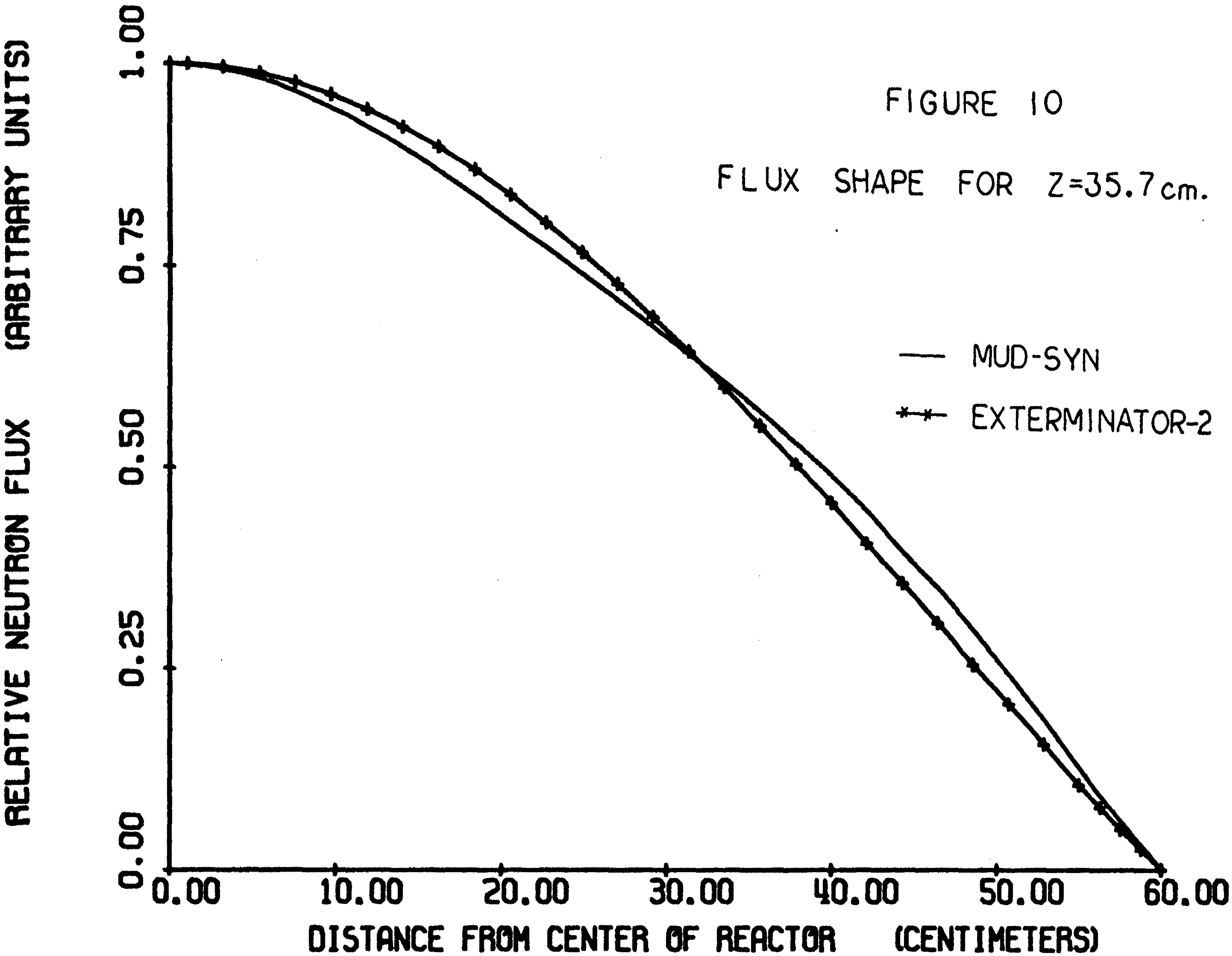


FIGURE 10
FLUX SHAPE FOR Z=35.7cm.
MUD-SYN
EXTERMINATOR-2
RELATIVE NEUTRON FLUX (ARBITRARY UNITS)
0.00
0.25
0.50
0.75
1.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
DISTANCE FROM CENTER OF REACTOR (CENTIMETERS)

were approximated by the trial functions in the core. Since the flux shape in the axial reflector is not the same as the flux shape in the core this approximation results in convergence to a K_{eff} slightly higher than the true value. The rest of the error is due to error in the integration and error in calculating the trial functions and expansion coefficients.

IV. CONCLUSIONS

The Higher Mode Synthesis method for the solution of the multigroup diffusion equation is very useful when this equation is used to describe systems of intermediate complexity. For most problems only two or three one-dimensional eigenfunctions are needed to provide an adequate representation. Using HMS, the flux shape and effective multiplication constant can be calculated with only a small error. This small error is not significant if the results are to be used in the first stages of reactor design, survey studies, or similar applications. HMS is from two to five times faster than EXTERMINATOR-2, depending on the complexity of the problem and the form of the scattering kernel. This savings in computation time is very important because of the high cost of computer time.

V. RECOMMENDATIONS

Three-dimensional studies of reactor systems are much preferred to one- or two-dimensional studies. However, the problem of obtaining three-dimensional flux and power shapes is, at best, very difficult. Three-dimensional computer codes, using iteration methods, have been written; but their requirement of large amounts of computer time restricts their use to problems of utmost importance.

Using the synthesis method tested in this thesis, three-dimensional problems could be studied. This could be done by substituting the expansion

$$\vec{\phi}(x,y,z) = \sum_{k=1}^{K} a_k(x)\vec{\theta}_k(y,z)$$

into the three-dimensional diffusion equation and using the adjoint weight and integration procedure to obtain a relation for the $a_k(x)$.

The two-dimensional trial functions and adjoint function could be obtained by using MUD-SYN or they could also be obtained by using a two-dimensional code based on SMT. At present, the latter code is not available; however, the problem is being studied.

In problem two and problem three, difficulty was experienced in obtaining proper trial functions for the reflector in the synthesis direction. The proper method is to use solutions of the one-dimensional diffusion equation for the reflector. In order to do this the core eigenfunctions must be considered as a source. This would involve the solution of an inhomogeneous equation. A code, similar to MUD-MO, which has the ability to solve inhomogeneous problems has been developed [23]. This code could be incorporated into MUD-SYN and an axial reflector could be treated more rigorously.

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APPENDIX A

The MUD-SYN Code

The MUD-SYN code solves the multigroup diffusion equation for a slab and for a cylinder in the r-z plane. It was written to prove that the Higher Mode Synthesis method is valid. Thus, it is a proof of principle code and not a production code, even though it was compared to a production code. The size of the problem is restricted to 10 energy groups and 50 mesh points in each direction. This limitation is not due to theoretical aspects, but is due to available storage capacity.

The MUD-SYN code is divided into subroutines. Subroutine MUDMOD calculates the trial functions, adjoint functions, and expansion coefficients. Several other subroutines are included in MUDMOD, but their functions are not significant to this application. Subroutine VOLINT does the integration by Simpson's rule. Subroutine TWOSYN calculates the two-dimensional flux by combining the expansion coefficients and trial functions in a manner dictated by Eq. (11). It also prints the two-dimensional flux.

The input required for MUD-SYN is described below. The first card is a title card with any characters permissible between columns 2 and 72. All the fixed point data is punched using a 20I3 format. Some of the variables are relevant only to the MUD-MO code. In these cases, recommended values will be given. The fixed point data is:

NREG This is the number of regions in the direction in which the trial functions are to be calculated, ≤ 3.

NFCT This is a dummy variable equal to the number of groups.

NOG This is the number of groups, ≤ 10.

NPTS This is the number of mesh points in the direction in which the trial functions are to be calculated, ≤ 50.

KCOND The recommended value is 5.

IFOUND If IFOUND equals 1, search for K-eff; 2, K-eff is read in.

IFUNCT The recommended value is 2.

INDEXM The recommended value is 120.

NUMAX The recommended value is 1.

KPOW The recommended value is 1.

MORE The recommended value is 1.

KAPP The recommended value is 0.

KBCI This is the inner boundary conditions. If KBCI is 1, the flux goes to zero at the zeroth space point. If KBCI is 2, the derivative of the flux goes to zero at the zeroth space point.

KBCO This is the outer boundary condition. If KBCO is 1, the flux goes to zero at the outer space point. If KBCO is 2, the flux at the outer space point is governed by the relation,

$\gamma\phi_{npts-1} + d\phi'_{npts-1} = 0$ where d is the extrapolation distance and γ is 1 or 0, depending on how the coordinate system is established.

KREG This is the region in which the criticality search takes place.

KCHO The recommended value is 2.

KHUNT If KHUNT is 1, no search for K-eff will be done. If KHUNT is 2, a search for K-eff will be done.

IA This variable has the value 0 for a slab and 1 for a cylinder.

K1 If K1 is 1, K_{eff}^{-1}, radius, EPA, EPB, and DEL are read in. If K1 is 2, these variables are not read in.

K2 If K2 is 2, the expansion coefficients and trial functions are punched on cards. If K2 is 3, these variables are printed.

K3 The recommended value is 0.

KG The recommended value is 1.

KGA This denotes the group in which the trial functions are normalized.

KNA This is the space point where the trial functions are normalized.

MODE This is the number of terms used in the expansion in Eq. (11).

KNORM If KNORM is 1, the flux in the fuel region is divided by the reciprocal of the fission cross section. If KNORM is 2, the flux is not normalized as stated above.

NPTZ This is the number of points in the synthesis direction.

NREGZ This is the number of regions in the synthesis direction, ≤ 2.

KNR This is the mesh point in the direction perpendicular to the synthesis direction where the flux is to be normalized.

KNZ This is the mesh point in the synthesis direction where the flux is to be normalized.

KNG This is the group for which the flux is normalized.

MPOW If MPOW is 2, the power shape will be calculated. If MPOW is 1, the power shape will not be calculated.

KGEL If KGEL is 1, the adjoint functions are used as the weighting functions. If KGEL is 2, the trial functions are used as the weighting functions and the adjoint functions are not calculated.

INDZ(I) This is the mesh point at the outer boundary of each region in the direction of synthesis. There are NREGZ values and INDZ(NREGZ) = NPTZ + 1-KBCO. INDZ(I) is given on a separate card from the rest of the fixed point data.

IND(I) This is the mesh point at the outer boundary of each region in the direction perpendicular to the direction of synthesis. There are NREG values and IND(NREG) = NPTS + 1 - KBCO. IND(I) is also given on a separate card.

The floating point data is read on a 15X 4E15.8 format. The first 15 spaces are reserved for card identification. The subscripted data is read as (((S(I,J,K),I=1,NI),J=1,NJ), k=1,NK). Each subscripted variable is begun on a new card. RRO and RZO are on the same card and EPA, APB, and DEL are on the same card.

RRO This is the space point corresponding to the first mesh point in the direction perpendicular to the direction of synthesis.

RZO This is the space point corresponding to the first mesh point in the direction of synthesis. RRO and RZO are normally input as 0.0.

The following data is not read if K1=2.

RAD(I) This is the thickness of each region in the direction perpendicular to the direction of synthesis. There are NREG values.

CEFT(I) This is the reciprocal of the guess of K_{eff} in each region. For a reflector region the value is usually input as 1.0. There are NREG values.

GNU(I) This is the number of neutrons per fission in each region. There are NREG values.

EPA This is the criteria for convergence of K_{eff}.

EPB It is recommended that EPB = EPA.

DEL This is the increment of K_{eff} before the true value is located.

At this point there are NOG + 2 cards which are used for problem identification. Any characters are permissible in columns 2 through 72. The cross section data is the next input.

SSIG(I,J,K) This is the scatter cross section. There are NOG X NOG X NREG values.

RSIG(I,J) This is the removal cross section. There are NOG X NREG values.

FSIG(I,J) This is the fission cross section. There are NOG X NREG values.

F(I,J) This is the fission yield. There are NOG X NREG values.

BUCK(I,J) The recommended value is 0.0. There are NOG X NREG values.

D(I,J) This is the diffusion coefficient. There are NOG X NREG values.

GAM(I) This is the γ for the outer boundary condition. There are NOG values.

EXTP(I) This is the extrapolation distance for the outer boundary condition. There are NOG values. If KBCO is 1, GAM(I) and EXTP(I) may be left blank.

APPENDIX B

Listing and Sample Input and Output for the MUD-SYN Code

In the following pages a Fortran listing of the MUD-SYN code and sample input and output are given. The sample input and output are for problem three with three terms used in the expansion.

```
C
C  1. FORTRAN LISTING OF THE MUD-SYN CODE
C
C
C
C     MUD-SYN    A TWO-DIMENSIONAL, MULTIGROUP DIFFUSION THEORY CODE
C     USING THE HIGHER MODE SYNTHESIS METHOD
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      DIMENSION RADR(3)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      IHOP=1
      DEFINE FILE 5(51,500,U,IFFILE)
C
C     CALCULATE TRIAL FUNCTIONS AND WEIGHTING FUNCTIONS
C
      CALL MUDMOD
C
C     CALCULATE PSEUDO CROSS SECTIONS
C
   70 CONTINUE
      CALL CALCRS
      IIA=IA
      DO 69 I=1,NMODE
      DO 69 J=1,NMODE
   69 ZA(I,J)=0.0
      DO 103 I=1,NMODE
      WA(I)=1.0
  103 ZA(I,I)=1.0
      NA=NMODE
      NB=NMODE
      NC=NMODE
      KAPP=-1
      IHOP=2
      CEFT(1)=BCEFT(1,1)
      NREGR=NREG
      NPTR=NPTS
      IJUMP=1
```

```
      DO 3 I=1,NREGR
      RADR(I)=RAD(I)
      RHOR(I)=RHO(I)
    3 INDR(I)=IND(I)
      INDEX=1
      NPTS=NPTZ
      NREG=NREGZ
      DO 2 I=1,NREGZ
      RAD(I)=RADZ(I)
    2 IND(I)=INDZ(I)
      IA=0
      DO 4 I=1,NA
      DO 4 J=1,NA
    4 Z(I,J)=0.0
      DO 5 I=1,NA
    5 Z(I,I)=1.0
      DEL=0.001
C
C     CALCULATE EXPANSION COEFFICIENTS
C
      CALL MUDMOD
      IA=IIA
C
C     CALCULATE 2-D EIGENFUNCTION
C
      CALL TWOSYN
      RETURN
      END
      SUBROUTINE MUDMOD
C
C     MUD-MO    A ONE-DIMENSIONAL, MULTIGROUP DIFFUSION THEORY CODE
C     USING THE MARCH-OUT METHOD
C
      INTEGER SKIP
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      NSCR=8-1,NREG
      JUMP=1
```

```
      SKIP=2
      MMM=1
      GO TO (5,10),IHOP
    5 SKIP=1
C
C     CALCULATE TRIAL FUNCTIONS
C
   10 CALL MUDONE(SKIP)
      IF(KQUIT) 20,20,60
   20 CALL MUDTWO
   28 SKIP=2
      IF(NUMBER-NUMAX) 30,60,60
   30 IFOUND=1
      GO TO (40,50),KCHO
   40 RAD(KREG)=RAD(KREG)+DEL
      GO TO 10
   50 CEFT(KREG)=CEFT(KREG)+DEL
      GO TO 10
   60 GO TO (70,5),MORE
   70 DO 13 I=1,4
      GO TO (13,169),JUMP
   13 N(I)=0
      KK=NMODE+1
      DO 73 J=KK,4
   73 N(J)=1
      JJJ=NPTS-2
  169 KONTE=1
      DO 12 I=2,JJJ
      IF (PHI(1,I+1)*PHI(1,I).LT.0.0) KONTE=KONTE+1
      IF (KAPP) 71,12,12
   12 CONTINUE
      DO 31 I=1,NOG
   31 FLX(I,1,KONTE)=PHIC(I)
      NN=NPTS+1
      DO 4 J=2,NN
      DO 4 I=1,NOG
    4 FLX(I,J,KONTE)=PHI(I,J-1)
      DO 99 I=1,NOG
      DO 99 J=1,NREG
   99 CURRN(I,J,KONTE)=CURR(I,J)
      GO TO (51,52),KGEL
   51 CONTINUE
C
C     TRANSPOSE MULTIGROUP OPERATOR
C
      DO 41 I=1,NREG
      DO 41 J=1,NOG
      EXTPA(J,I)=FSIG(J,I)
   41 GAMA(J,I)=F(J,I)
      DO 42 I=1,NREG
      DO 42 J=1,NOG
      F(J,I)=EXTPA(J,I)
   42 FSIG(J,I)=GAMA(J,I)
      DO 7 K=1,NREG
```

```
      DO 6 I=1,NOG
      DO 6 J=1,NOG
    6 TEMP(I,J)=SSIG(I,J,K)
      DO 7 I=1,NOG
      DO 7 J=1,NOG
    7 SSIG(I,J,K)=TEMP(J,I)
C
C     CALCULATE ADJOINT FUNCTION
C
      CALL MUDONE(SKIP)
      CALL MUDTWO
      DO 32 I=1,NOG
   32 PHIA(I,1,KONTE)=PHIC(I)
      DO 8 J=2,NN
      DO 8 I=1,NOG
    8 PHIA(I,J,KONTE)=PHI(I,J-1)
      DO 22 K=1,NREG
      DO 21 I=1,NOG
      DO 21 J=1,NOG
   21 TEMP(I,J)=SSIG(I,J,K)
      DO 22 I=1,NOG
      DO 22 J=1,NOG
   22 SSIG(I,J,K)=TEMP(J,I)
      DO 43 I=1,NREG
      DO 43 J=1,NOG
      EXTPA(J,I)=FSIG(J,I)
   43 GAMA(J,I)=F(J,I)
      DO 44 I=1,NREG
      DO 44 J=1,NOG
      F(J,I)=EXTPA(J,I)
   44 FSIG(J,I)=GAMA(J,I)
   52 CONTINUE
      BCEFT(1,KONTE)=CEFT(1)
      N(KONTE)=1
      IF (N(1).EQ.1.AND.N(2).EQ.0.AND.N(3).EQ.0.AND.N(4).EQ.0) GO TO 1
      IF (N(1).EQ.0.AND.N(2).EQ.1.AND.N(3).EQ.0.AND.N(4).EQ.0) GO TO 2
      IF (N(1).EQ.0.AND.N(2).EQ.0.AND.N(3).EQ.1.AND.N(4).EQ.0) GO TO 2
      IF (N(1).EQ.0.AND.N(2).EQ.0.AND.N(3).EQ.0.AND.N(4).EQ.1) GO TO 2
      IF (N(1).EQ.1.AND.N(2).EQ.1.AND.N(3).EQ.0.AND.N(4).EQ.0) GO TO 1
      IF (N(1).EQ.1.AND.N(2).EQ.0.AND.N(3).EQ.1.AND.N(4).EQ.0) GO TO 2
      IF (N(1).EQ.1.AND.N(2).EQ.0.AND.N(3).EQ.0.AND.N(4).EQ.1) GO TO 1
      IF (N(1).EQ.0.AND.N(2).EQ.1.AND.N(3).EQ.1.AND.N(4).EQ.0) GO TO 2
      IF (N(1).EQ.0.AND.N(2).EQ.1.AND.N(3).EQ.0.AND.N(4).EQ.1) GO TO 2
      IF (N(1).EQ.0.AND.N(2).EQ.0.AND.N(3).EQ.1.AND.N(4).EQ.1) GO TO 2
      IF (N(1).EQ.0.AND.N(2).EQ.1.AND.N(3).EQ.1.AND.N(4).EQ.1) GO TO 2
      IF (N(1).EQ.1.AND.N(2).EQ.0.AND.N(3).EQ.1.AND.N(4).EQ.1) GO TO 1
      IF (N(1).EQ.1.AND.N(2).EQ.1.AND.N(3).EQ.1.AND.N(4).EQ.0) GO TO 1
      IF (N(1).EQ.1.AND.N(2).EQ.1.AND.N(3).EQ.0.AND.N(4).EQ.1) GO TO 1
      IF (N(1).EQ.1.AND.N(2).EQ.1.AND.N(3).EQ.1.AND.N(4).EQ.1) MMM=2
    1 ACEFT=ACEFT*2.5
      IF (KONTE.EQ.3) ACEFT=ACEFT*0.59
      IF (KONTE.EQ.2) DEL=0.1
      IF (KONTE.EQ.3) DEL=1.0
      GO TO 172
    2 ACEFT=ACEFT/2.0
```

```
      GO TO 172
    3 ACEFT=ACEFT/1.5
  172 CEFT(1)=ACEFT
      JUMP=2
      IF (KONTE.GT.NMODE) CEFT(1)=CEFT(1)/3.0
      IFOUND=1
      GO TO (10,71),MMM
   71 RETURN
      END
      SUBROUTINE MUDONE(SKIP)
      INTEGER SKIP
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      GO TO (10,15),SKIP
   10 CALL DATA
C
C     SET INITIAL PARAMETERS
C
      INDEX=1
      NUMBER=1
   11 ACEFT=CEFT(1)
   15 IHUNT=-1
   26 KQUIT=0
      KPRINT=1
      KCOND=KSTOR
   20 ISOLV=0
      REWIND NSCR
      IT=-1
      H=1.
      KH=1
      ISTOP=1
      IREG=1
      KINDM=NPTS
   30 IF(NREG-1) 40,40,50
   40 KIND=NPTS
      GO TO 60
   50 KIND=IND(1
```

```
   60 CALL SET
   70 IF(KQUIT) 80,80,430
   80 CALL START
   90 IF(KQUIT) 100,100,430
  100 CALL CONDIT(MARSTP-1,MARSTP)
  110 IF(KH) 120,120,170
C
C      BACKWARD MARCH
C
  120 IF(KQUIT) 130,130,150
  130 IF(ISTOP) 400,400,140
  140 LOLIM=3
      MARSTP=MNDEX-ISTOP+2
      GO TO 260
C
C      CONDIT FAILED RESET FREQUENCY OF CONDITIONING
C
  150 KCOND=KCOND-1
      KQUIT=0
  160 IF(KCOND-1) 165,165,20
  165 CALL YEGADS(3,KSTOR,0)
      GO TO 430
C
C      FORWARD MARCH
C
  170 IF(KQUIT) 200,200,180
  180 MARSTP=MARSTP-1
      KQUIT=0
      MNDEX=MNDEX-1
  190 IF(MARSTP-2) 195,195,100
  195 CALL YEGADS(4,MNDEX,0)
      GO TO 430
C
C      NUMBER OF STEPS TO NEXT CONDITIONING
C
  200 IF(IT) 220,210,210
  210 LOLIM=3
      MARSTP=3+KBCO
      IT=1
      GO TO 260
  220 LOLIM=3
      MARSTP=2+KCOND
  230 IF(MNDEX+MARSTP+KBCO-NPTS) 260,250,240
  240 MARSTP=NPTS-MNDEX-KBCO
  250 IT=0
  260 CALL MARCH(1)
  270 IF(IT) 100,100,280
  280 GO TO (290,310),IFOUND
  290 CALL EVAL(MARSTP-KBCO+1)
      CALL ZERO
      CALL OUTPUT(1)
      IFOUND=IFOUND
  300 GO TO (305,310),IFOUND
  305 IF(INDEX-INDEXM) 20,430,430
  310 GO TO (380,320),IFUNCT
```

```
C
C
C     START BACKWARD MARCH
C
  320 IT=0
  330 IF(NREG-1) 340,340,350
  340 KIND=1
      GO TO 360
  350 KIND=IND(NREG-1)
  360 CALL RESTRT
  370 IF(KQUIT) 100,100,150
  380 IF(INDEX-INDEXM) 390,430,430
  390 IF(NUMBER-NUMAX) 395,430,430
  395 IFOUND=1
      GO TO (396,397),KCHO
  396 RAD(KREG)=RAD(KREG)+DEL
      GO TO 15
  397 CEFT(KREG)=CEFT(KREG)+DEL
      GO TO 15
  400 RETURN
  430 GO TO (440,10),MORE
  440 CALL EXIT
      END
      SUBROUTINE MUDTWO
C
C     CALCULATE EIGENFUNCTION
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      CALL FUNCT
      CALL OUTPUT(2)
      GO TO (20,10),KPOW
   10 CALL POWER
      CALL OUTPUT(3)
   20 RETURN
      END
      SUBROUTINE DATA
C
```

```
C     READS ALL INPUT
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      READ (1,270) (POW(I),I=1,18)
      WRITE (3,300) (POW(I),I=1,18)
      READ (1,280) NREG,NFCT,NOG,NPTS,KCOND,IFOUND,IFUNCT,INDEXM,NUMAX,
     2KPOW,MORE,KAPP,KBCI,KBCO,KREG,KCHO,KHUNT,IA,K1,K2,K3,KG,KGA,KNA,
     3NMODE,KNORM,NPTZ,NREGZ,KNR,KNZ,KNG,MPOW,KGEL
      READ (1,280) (INDZ(I),I=1,NREGZ)
      KSTOR=KCOND
      READ (1,280) (IND(I),I=1,NREG)
      READ (1,290) RRO,RZO
      READ (1,290) (RADZ(I),I=1,NREGZ)
   10 GO TO (20,30),K1
   20 READ (1,290) (RAD(I),I=1,NREG)
      READ (1,290) (CEFT(I),I=1,NREG)
      READ (1,290) (GNU(I),I=1,NREG)
      READ (1,290) EPA,EPB,DEL,EPC
      IF(EPC) 25,25,30
   25 EPC=0.1*EPA
   30 A=IA
   40 IF(KAPP) 50,60,70
   50 NA=NFCT
      NB=NFCT
      GO TO 80
   60 NA=NOG
      NB=NOG
      GO TO 80
   70 NA=NOG
      NB=NFCT
C
C     COMMENT CARDS
C
   80 READ (1,270) (Y(I),I=1,18)
      WRITE (3,310) (Y(I),I=1,18)
      READ (1,270) (Y(I),I=1,18)
      WRITE (3,310) (Y(I),I=1,18)
```

```
      WRITE (3,330)
   90 DO 100 J=1,NOG
      READ (1,270) (Y(I),I=1,18)
  100 WRITE (3,320) (Y(I),I=1,18)
  110 IF(KAPP) 120,180,180
C
C     VARIATION I
C
  120 READ (1,290) (((SSIGA(I,J,K),I=1,NA),J=1,NA),K=1,NREG)
      READ (1,290) (((RSIGA(I,J,K),I=1,NA),J=1,NA),K=1,NREG)
      READ (1,290) (((FSIGA(I,J,K),I=1,NA),J=1,NA),K=1,NREG)
      READ (1,290) ((FSIG(I,J),I=1,NOG),J=1,NREG)
      READ (1,290) (((DA(I,J,K),I=1,NA),J=1,NA),K=1,NREG)
      READ (1,290) ((ZA(I,J),I=1,NOG),J=1,NA)
      READ (1,290) (WA(I),I=1,NOG)
      READ (1,290) ((GAMA(I,J),I=1,NA),J=1,NA)
      READ (1,290) ((EXTPA(I,J),I=1,NA),J=1,NA)
  130 DO 160 I=1,NA
  140 DO 150 J=1,NA
  150 Z(I,J)=0.
  160 Z(I,I)=1.
  170 RETURN
C
C     NORMAL MARCH-OUT AND VARIATION II
C
  180 READ (1,290) (((SSIG(I,J,K),I=1,NA),J=1,NA),K=1,NREG)
      READ (1,290) ((RSIG(I,J),I=1,NA),J=1,NREG)
      READ (1,290) ((FSIG(I,J),I=1,NA),J=1,NREG)
      READ (1,290) ((F(I,J),I=1,NA), J=1,NREG)
      READ (1,290) ((BUCK(I,J),I=1,NA),J=1,NREG)
      READ (1,290) ((D(I,J),I=1,NA), J=1,NREG)
      READ (1,290) (GAM(I),I=1,NA)
      READ (1,290) (EXTP(I),I=1,NA)
  190 IF(KAPP) 200,200,250
  200 DO 230 I=1,NA
  210 DO 220 J=1,NA
  220 Z(I,J)=0.
  230 Z(I,I)=1.
  240 RETURN
  250 READ (1,290) (WA(I),I=1,NA)
      READ (1,290) (WB(I),I=1,NA)
      READ (1,290) ((Z(I,J),I=1,NA), J=1,NB)
  260 RETURN
  270 FORMAT (1X 18A4)
  280 FORMAT (20I3)
  290 FORMAT (15X 4E15.8)
  300 FORMAT (1H1 18A4)
  310 FORMAT (1H0 18A4)
  320 FORMAT (1H  18A4)
  330 FORMAT (1H )
      END
      SUBROUTINE SET
C
C     CALCULATES P MATRIX
      NORMAL MARCH-OUT AND VARIATION II
```

```
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
   10 IF(INDEX-1) 30,30,20
   20 GO TO (30,100),KCHO
   30 RHO(1)=RAD(1)/IND(1)
   40 IF(NREG-1) 70,70,50
   50 DO 60 I=2,NREG
   60 RHO(I)=RAD(I)/(IND(I)-IND(I-1))
   70 DO 90 I=1,NREG
   75 IF(RHO(I)) 80,80,90
   80 CALL YEGADS(1,I,2)
      GO TO 230
   90 CONTINUE
  100 IF(KAPP) 110,240,240
C
C     VARIATION I
C
  110 DO 220 K=1,NREG
      X=RHO(K)*RHO(K)
      G=GNU(K)*CEFT(K)
  120 DO 140 I=1,NA
  130 DO 140 J=1,NA
      TEMPA(I,J)=RSIGA(I,J,K)-SSIGA(I,J,K)-G*FSIGA(I,J,K)
  140 S(I,J)=DA(I,J,K)
      CALL DETINV(1,2)
  150 IF(KQUIT) 160,160,230
  160 DO 200 I=1,NA
  170 DO 200 J=1,NA
      P(I,J,K)=0.
  180 DO 190 L=1,NA
  190 P(I,J,K)=P(I,J,K)+T(I,L)*TEMPA(L,J)
  200 P(I,J,K)=X*P(I,J,K)
  210 DO 220 I=1,NA
  220 P(I,I,K)=2.+P(I,I,K)
  230 RETURN
C
C     NORMAL MARCH-OUT AND VARIATION II
```

```
C
  240 DO 340 K=1,NREG
      G=GNU(K)*CEFT(K)
      X=RHO(K)*RHO(K)
  250 DO 270 I=1,NA
  260 DO 270 J=1,NA
  270 P(I,J,K)=-SSIG(I,J,K)-G*F(I,K)*FSIG(J,K)
  280 DO 290 I=1,NA
  290 P(I,I,K)=RSIG(I,K)+D(I,K)*BUCK(I,K)+P(I,I,K)
  300 DO 320 I=1,NA
  310 DO 320 J=1,NA
  320 P(I,J,K)=(X*P(I,J,K))/D(I,K)
  330 DO 340 I=1,NA
  340 P(I,I,K)=2.+P(I,I,K)
  350 RETURN
   16 FORMAT (20I3)
   17 FORMAT (15X 4E15.8)
      END
      SUBROUTINE START
C
C     BEGIN MARCH
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      MNDEX=1
   10 IF(KAPP) 20,20,50
   20 DO 40 I=1,NA
   30 DO 40 J=1,NA
   40 PSI(I,J,1)=Z(I,J)
      GO TO 80
   50 DO 70 I=1,NA
   60 DO 70 J=1,NB
   70 PSI(I,J,1)=WA(I)*Z(I,J)
   80 GO TO (90,190),KBCI
C
C     PHI(0) = 0
C
```

```
   90 X=2*MNDEX
      ALPHA=X/(X+A)
  100 DO 130 I=1,NA
  110 DO 130 J=1,NB
      PSI(I,J,2)=0.
  120 DO 130 L=1,NA
  130 PSI(I,J,2)=PSI(I,J,2)+ALPHA*P(I,L,1)*PSI(L,J,1)
      MNDEX=2
      X=2*MNDEX
      ALPHA=X/(X+A)
      BETA=(X-A)/(X+A)
  140 DO 170 I=1,NA
  150 DO 170 J=1,NB
      PSI(I,J,3)=-BETA*PSI(I,J,1)
  160 DO 170 L=1,NA
  170 PSI(I,J,3)=PSI(I,J,3)+ALPHA*P(I,L,1)*PSI(L,J,2)
      MARSTP=3
  180 RETURN
C
C     D(PHI(0))/DR = 0
C
  190 DO 220 I=1,NA
  200 DO 210 J=1,NA
  210 S(I,J)=P(I,J,1)
  220 S(I,I)=S(I,I)-2.
      X=1./(2.*(1.+A))
  230 DO 260 I=1,NA
  240 DO 250 J=1,NA
  250 S(I,J)=X*S(I,J)
  260 S(I,I)=S(I,I)+1.
      CALL DETINV(1,3)
  270 IF(KQUIT) 280,280,330
  280 X=2*MNDEX
      ALPHA=X/(X+A)
      BETA=(X-A)/(X+A)
  290 DO 320 I=1,NA
  300 DO 320 J=1,NB
      PSI(I,J,2)=0.
  310 DO 320 L=1,NA
  320 PSI(I,J,2)=PSI(I,J,2)+(ALPHA*P(I,L,1)-BETA*T(I,L))*PSI(L,J,1)
      MARSTP=2
  330 RETURN
      END
      SUBROUTINE DETINV(M,I1)
C
C     INVERTS S TO GIVE T OR EVALUATES DETERMINANT(S)
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
```

```
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      BIG=1.E25
      GO TO (2,2,1,2,2,1,1,2,2,1,1,2,2,2,2),I1
    1 NC=NA
      GO TO 10
    2 NC=NB
   10 GO TO (20,70),M
C
C     UNIT MATRIX NEEDED FOR INVERSION
C
   20 DO 40 I=1,NC
   30 DO 40 J=1,NC
   40 TEMP(I,J)=0.
   50 DO 60 I=1,NC
   60 TEMP(I,I)=1.
   70 IF(ABS(S(1,1))-EPB)80,80,130
   80 GO TO (90,110),M
   90 CALL YEGADS(2,1,I1)
  100 RETURN
  110 DT=0.
  120 RETURN
C
C     CROUT REDUCTION
C
  130 IF(NC-1) 160,160,140
  140 DO 150 I=2,NC
  150 S(1,I)=S(1,I)/S(1,1)
  160 GO TO (170,180),M
  170 TEMP(1,1)=TEMP(1,1)/S(1,1)
  180 IF(NC-1) 370,370,185
  185 DO 360 K=2,NC
      IMIN=K-1
  190 DO 200 I=1,IMIN
  200 S(K,K)=S(K,K)-S(K,I)*S(I,K)
  210 IF(ABS(S(K,K))-EPB)220,220,250
  220 GO TO (230,240),M
  230 CALL YEGADS(2,K,I1)
      GO TO 460
  240 DT=0.
      GO TO 540
  250 IMAX=K+1
  260 IF(NC-IMAX) 310,270,270
  270 DO 300 I=IMAX,NC
  280 DO 290 J=1,IMIN
     4FSIGA(10,10,3),DA(10,
```

```
      S(I,K)=S(I,K)-S(I,J)*S(J,K)
  290 S(K,I)=S(K,I)-S(K,J)*S(J,I)
  300 S(K,I)=S(K,I)/S(K,K)
  310 GO TO (320,360),M
  320 DO 350 I=1,K
  330 DO 340 J=1,IMIN
  340 TEMP(K,I)=TEMP(K,I)-S(K,J)*TEMP(J,I)
  350 TEMP(K,I)=TEMP(K,I)/S(K,K)
  360 CONTINUE
  370 GO TO (380,470),M
C
C     INVERSE MATRIX
C
  380 DO 390 J=1,NC
  390 T(NC,J)=TEMP(NC,J)
  400 IF(NC-1) 460,460,420
  420 DO 450 K=2,NC
      IMIN=NC+1-K
      IMAX=IMIN+1
  430 DO 450 J=1,NC
      T(IMIN,J)=TEMP(IMIN,J)
  440 DO 450 I=IMAX,NC
  450 T(IMIN,J)=T(IMIN,J)-S(IMIN,I)*T(I,J)
  460 RETURN
C
C     DETERMINANT
C
  470 DT=S(1,1)/10.
  480 IF(NC-1) 540,540,500
  500 DO 530 I=2,NC
      DT=DT*S(I,I)/10.
  510 IF(ABS(DT)-BIG)530,530,520
  520 DT=SIGN(BIG,DT)
  530 CONTINUE
  540 RETURN
      END
      SUBROUTINE CONDIT(N,M)
C
C     CONDITIONING TRANSFORMATION
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
```

```
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
   10 IF(KAPP) 20,20,50
   20 DO 40 I=1,NA
   30 DO 40 J=1,NA
      S(I,J)=PSI(I,J,M)
   40 TEMPA(I,J)=PSI(I,J,N)
      GO TO 90
   50 DO 80 I=1,NB
   60 DO 80 J=1,NB
      S(I,J)=0.
      TEMPA(I,J)=0.
   70 DO 80 K=1,NA
      S(I,J)=S(I,J)+Z(K,I)*WB(K)*PSI(K,J,M)
   80 TEMPA(I,J)=TEMPA(I,J)+Z(K,I)*WB(K)*PSI(K,J,N)
   90 CALL DETINV(1,5)
  100 IF(KQUIT) 110,110,210
  110 IF(H) 270,120,120
C
C     FORWARD MARCH
C
  120 ISOLV=ISOLV+1
      KSOLV(ISOLV)=MNDEX+1
  130 DO 160 I=1,NB
  140 DO 160 J=1,NB
      FRWD(I,J)=0
  150 DO 160 K=1,NB
  160 FRWD(I,J)=FRWD(I,J)+TEMPA(I,K)*T(K,J)
      WRITE(NSCR) FRWD
  170 IF(KAPP) 180,180,220
  180 DO 200 I=1,NA
  190 DO 200 J=1,NA
      PSI(I,J,1)=FRWD(I,J)
  200 PSI(I,J,2)=Z(I,J)
  210 RETURN
  220 DO 250 I=1,NA
  230 DO 250 J=1,NB
      PSI(I,J,1)=0.
      PSI(I,J,2)=WA(I)*Z(I,J)
  240 DO 250 K=1,NB
  250 PSI(I,J,1)=PSI(I,J,1)+WA(I)*Z(I,K)*FRWD(K,J)
  260 RETURN
C
C     BACKWARD MARCH
C
  270 DO 300 I=1,NB
  280 DO 300 J=1,NB
      BKWD(I,J)=0
  290 DO 300 K=1,NB
  300 BKWD(I,J)=BKWD(I,J)+TEMPA(I,K)*T(K,J)
      WRITE (NSCR) BKWD
  310 IF(KAPP) 320,320,350
      CALL DETINV(1,6)
```

```
  320 DO 340 I=1,NA
  330 DO 340 J=1,NA
      PSI(I,J,1)=BKWD(I,J)
  340 PSI(I,J,2)=Z(I,J)
      GO TO 390
  350 DO 380 I=1,NA
  360 DO 380 J=1,NB
      PSI(I,J,1)=0.
      PSI(I,J,2)=WA(I)*Z(I,J)
  370 DO 380 K=1,NB
  380 PSI(I,J,1)=PSI(I,J,1)+WA(I)*Z(I,K)*BKWD(K,J)
  390 ISOLV=ISOLV-1
  400 IF(ISOLV) 410,410,420
  410 ISTOP=0
      GO TO 430
  420 ISTOP=KSOLV(ISOLV)
  430 RETURN
      END
      SUBROUTINE CROSS(KL,KR,K,KFOP)
C
C     MARCH ACROSS BOUNDARY
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      KA=K+1
      KB=K-1
      X=0.
      KTEMP=(KL+KR)/2
      DO 1 I=1,KTEMP
    1 X=X+RAD(I)
      XA=0.5*H*A*RHO(KR)
      ALPHA=X/(X+XA)
      BETA=(X-0.5*A*H*RHO(KL))/(X+XA)
   10 IF(KAPP) 20,100,100
   20 DO 40 I=1,NA
   30 DO 40 J=1,NA
   40 S(I,J)=DA(I,J,KR)
      CALL DETINV(1,6)
```

```
   50 IF(KQUIT) 60,60,300
   60 DO 90 I=1,NA
   70 DO 90 J=1,NA
      TEMP(I,J)=0.
   80 DO 90 L=1,NA
   90 TEMP(I,J)=TEMP(I,J)+T(I,L)*DA(L,J,KL)
      GO TO 150
  100 DO 120 I=1,NA
  110 DO 120 J=1,NA
  120 TEMP(I,J)=0.
  130 DO 140 I=1,NA
  140 TEMP(I,I)=D(I,KL)/D(I,KR)
  150 X=RHO(KR)/RHO(KL)
      XA=BETA*X
      Q=ALPHA/2.
      QQ=(BETA-ALPHA)*X
      QQQ=1.-ALPHA
  160 DO 205 I=1,NA
  170 DO 200 J=1,NA
      S(I,J)=0.
  180 DO 190 L=1,NA
  190 S(I,J)=S(I,J)+X*TEMP(I,L)*P(L,J,KL)
      T(I,J)=XA*TEMP(I,J)
  200 S(I,J)=Q*(P(I,J,KR)+S(I,J))+QQ*TEMP(I,J)
  205 S(I,I)=S(I,I)+QQQ
  210 GO TO (220,270),KFOP
C
C     EXPANSION VECTORS
C
  220 DO 250 I=1,NA
  230 DO 250 J=1,NB
      PSI(I,J,KA)=0.
  240 DO 250 L=1,NA
  250 PSI(I,J,KA)=PSI(I,J,KA)+S(I,L)*PSI(L,J,K)-T(I,L)*PSI(L,J,KB)
      GO TO 300
C
C     EIGENFUNCTION
C
  270 KA=MNDEX+KH
      KB=MNDEX-KH
  275 DO 290 I=1,NA
      PHI(I,KA)=0.
  280 DO 290 L=1,NA
  290 PHI(I,KA)=PHI(I,KA)+S(I,L)*PHI(L,MNDEX)-T(I,L)*PHI(L,KB)
  300 RETURN
      END
      SUBROUTINE MARCH(M)
C
C     MARCH BETWEEN POINTS OF CONDITIONING
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
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```
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      IREG=IREG
   10 DO 240 J=LOLIM,MARSTP
      MNDEX=MNDEX+KH
      BETA=BET(IREG)
C
C     TEST FOR BOUNDARY CROSSING
C
   20 IF(MNDEX-KIND) 150,30,150
   30 IF(KINDM-KIND) 50,40,50
   40 IT=J-1
      GO TO 250
   50 CALL CROSS(IREG,IREG+KH,J-1,M)
   60 IF(KQUIT) 70,70,250
   70 IREG=IREG+KH
      KROSS=KROSS+1
   80 IF(KH) 90,90,120
   90 IF(IREG-1) 100,100,110
  100 KIND=1
      GO TO 240
  110 KIND=IND(IREG-1)
      GO TO 240
  120 KIND=IND(IREG)
  130 IF(NREG-IREG) 140,140,240
  140 KIND=KIND+KBCO-1
      GO TO 240
  150 GO TO (191,160),M
C
C     EIGENFUNCTION
C
  160 KA=MNDEX+KH
      KB=MNDEX-KH
  170 DO 190 I=1,NA
      PHI(I,KA)=-BETA*PHI(I,KB)
  180 DO 190 K=1,NA
  190 PHI(I,KA)=PHI(I,KA)+ALPHA*P(I,K,IREG)*PHI(K,MNDEX)
      GO TO 240
C
C     EXPANSION VECTORS
C
  191 DO 192 I=1,NA
```

```
      DO 192 K=1,NA
  192 TEMP(I,K)=ALPHA*P(I,K,IREG)
  200 DO 230 I=1,NA
  210 DO 230 K=1,NB
      PSI(I,K,J)=-BETA*PSI(I,K,J-2)
  220 DO 230 L=1,NA
  230 PSI(I,K,J)=PSI(I,K,J)+TEMP(I,L)*PSI(L,K,J-1)
  240 CONTINUE
  250 RETURN
      END
      FUNCTION BET(M)
C
C     ALPHA AND BETA
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
   10 IF(IA) 20,20,30
   20 ALPHA=1.
      BET=1.
      GO TO 80
   30 GO TO (40,50,60),M
   40 X=MNDEX
      GO TO 70
   50 X=RAD(1)/RHO(2)+MNDEX-IND(1)
      GO TO 70
   60 X=(RAD(1)+RAD(2))/RHO(3)+MNDEX-IND(2)
   70 XA=0.5*H*A
      ALPHA=X/(X+XA)
      BET=(X-XA)/(X+XA)
   80 RETURN
      END
      SUBROUTINE EVAL(M)
C
C     SET UP MATRIX FOR DETERMINANT EVALUATION
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
```

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     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
   10 GO TO (20,100),KBCO
C
C      PHI(M) = 0
C
   20 IF(KAPP) 30,30,60
   30 DO 50 I=1,NA
   40 DO 50 J=1,NA
   50 S(I,J)=PSI(I,J,M)
      GO TO 290
   60 DO 90 I=1,NB
   70 DO 90 J=1,NB
      S(I,J)=0.
   80 DO 90 K=1,NA
   90 S(I,J)=S(I,J)+Z(K,I)*WB(K)*PSI(K,J,M)
      GO TO 290
C
C      GAM*PHI(M) + EXTP*D(PHI(M))/DE = 0
C
  100 X=1./(2.*RHO(NREG))
  110 IF(KAPP) 120,190,220
  120 DO 140 I=1,NA
  130 DO 140 J=1,NA
  140 TEMP(I,J)=X*(PSI(I,J,M+1)-PSI(I,J,M-1))
  150 DO 180 I=1,NA
  160 DO 180 J=1,NA
      S(I,J)=0.
  170 DO 180 K=1,NA
  180 S(I,J)=S(I,J)+GAMA(I,K)*PSI(K,J,M)+EXTPA(I,K)*TEMP(K,J)
      GO TO 290
  190 DO 210 I=1,NA
  200 DO 210 J=1,NA
  210 S(I,J)=GAM(I)*PSI(I,J,M)+X*EXTP(I)*(PSI(I,J,M+1)-PSI(I,J,M-1))
      GO TO 290
  220 DO 240 I=1,NA
  230 DO 240 J=1,NB
  240 TEMP(I,J)=GAM(I)*PSI(I,J,M)+X*EXTP(I)*(PSI(I,J,M+1)-PSI(I,J,M-1))
  250 DO 280 I=1,NB
  260 DO 280 J=1,NB
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      S(I,J)=0.
  270 DO 280 K=1,NA
  280 S(I,J)=S(I,J)+WB(K)*Z(K,I)*TEMP(K,J)
  290 CALL DETINV(2,8)
  300 RETURN
      END
      SUBROUTINE ZERO
C
C     SEARCH FOR DETERMINANT EQUAL ZERO
C     THREE POINT INTERPOLATION
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      KB=1
   10 GO TO (20,70),KHUNT
C
C     NO SEARCH
C
   20 GO TO (30,40),KCHO
   30 V(1)=RAD(KREG)
      RAD(KREG)=RAD(KREG)+DEL
      GO TO 50
   40 V(1)=CEFT(KREG)
      CEFT(KREG)=CEFT(KREG)+DEL
   50 INDEX=INDEX+1
   60 RETURN
C
C     SEARCH
C
   70 IF(DT) 90,80,100
   80 GO TO (85,86),KCHO
   85 V(1)=RAD(KREG)
      GO TO 210
   86 V(1)=CEFT(KREG)
      GO TO 210
   90 KB=2
  100 IF(IHUNT) 105,195,250
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```
  105 GO TO (110,120),KCHO
  110 V(KB)=RAD(KREG)
      GO TO 125
  120 V(KB)=CEFT(KREG)
  125 V(KB+3)=DT
  130 IF(IHUNT) 140,150,250
  140 DTO=DT
      IHUNT=0
      GO TO 20
  150 X=1.
      X=SIGN(X,DTO)
      XA=1.
      XA=SIGN(XA,DT)
C
C     TEST FOR PROPER CHANGE IN SIGN
C
  160 IF(X*XA) 170,180,140
  170 IF(XA) 180,180,140
  180 IHUNT=1
  190 VV=0.5*(V(1)+V(2))
  200 IF(ABS((V(1)-V(2))/VV)-EPA)210,210,220
  210 IFOUND=2
      NUMBER=NUMBER+1
  220 GO TO (230,240),KCHO
  230 RAD(KREG)=VV
      GO TO 60
  240 CEFT(KREG)=VV
      GO TO 60
  250 V(3)=V(KB)
      V(6)=V(KB+3)
      GO TO (260,270),KCHO
  260 V(KB)=RAD(KREG)
      GO TO 280
  270 V(KB)=CEFT(KREG)
  280 V(KB+3)=DT
      H=V(4)*V(5)*V(6)
      VV=0
      DO 1020 I=4,6
      PP=V(I)
      DO 1010 J=4,6
      IF(I-J) 1000,1010,1000
 1000 PP=PP*(V(I)-V(J))
 1010 CONTINUE
      IF(EPA*ABS(PP)-ABS(H)) 190,190,1020
 1020 VV=VV+H*V(I-3)/PP
 1040 IF(V(2)-VV) 190,190,290
  290 IF(VV-V(1)) 190,190,200
      END
      SUBROUTINE RESTRT
C
C     BEGIN BACKWARD MARCH
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
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      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      KH=-1
      H=-1.
      MNDEX=IND(NREG)
   10 IF(KAPP) 20,20,50
   20 DO 40 I=1,NA
   30 DO 40 J=1,NA
   40 PSI(I,J,1)=Z(I,J)
      GO TO 80
   50 DO 70 I=1,NA
   60 DO 70 J=1,NB
   70 PSI(I,J,1)=WA(I)*Z(I,J)
   80 GO TO (90,140),KBCO
C
C     PHI(M) = 0
C
   90 MNDEX=MNDEX-1
      BETA=BET(NREG)
  100 DO 130 I=1,NA
  110 DO 130 J=1,NB
      PSI(I,J,2)=0.
  120 DO 130 K=1,NA
  130 PSI(I,J,2)=PSI(I,J,2)+ALPHA*P(I,K,NREG)*PSI(K,J,1)
      GO TO 440
C
C     GAM*PHI(M) + EXTP*D(PHI(M))/DE = 0
C
  140 BETA=BET(NREG)
      X=1./(2.*RHO(NREG))
  150 IF(KAPP) 160,210,210
  160 DO 200 I=1,NA
  170 DO 200 J=1,NA
      S(I,J)=0.
  180 DO 190 K=1,NA
  190 S(I,J)=S(I,J)+EXTPA(I,K)*P(K,J,NREG)
  200 S(I,J)=ALPHA*X*S(I,J)+BETA*GAMA(I,J)
      GO TO 250
  210 DO 240 I=1,NA
  220 DO 230 J=1,NA
```

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  230 S(I,J)=X*ALPHA*EXTP(I)*P(I,J,NREG)
  240 S(I,I)=S(I,I)+BETA*GAM(I)
  250 CALL DETINV(1,10)
  260 IF(KQUIT) 265,265,470
  265 X=(1.+BETA)*X
  270 IF(KAPP) 280,330,330
  280 DO 320 I=1,NA
  290 DO 320 J=1,NA
      TEMP(I,J)=0.
  300 DO 310 K=1,NA
  310 TEMP(I,J)=TEMP(I,J)+T(I,K)*EXTPA(K,J)
  320 TEMP(I,J)=X*TEMP(I,J)
      GO TO 360
  330 DO 350 I=1,NA
  340 DO 350 J=1,NA
  350 TEMP(I,J)=X*EXTP(J)*T(I,J)
  360 MNDEX=MNDEX-1
      BETA=BET(NREG)
  370 DO 390 I=1,NA
  380 DO 390 J=1,NA
  390 S(I,J)=ALPHA*P(I,J,NREG)-BETA*TEMP(I,J)
  400 DO 430 I=1,NA
  410 DO 430 J=1,NA
      PSI(I,J,2)=0.
  420 DO 430 K=1,NA
  430 PSI(I,J,2)=PSI(I,J,2)+S(I,K)*PSI(K,J,1)
  440 ISOLVM=ISOLV
      MARSTP=MNDEX+2-KSOLV(ISOLV)
      LOLIM=3
      IREG=NREG
  450 IF(MARSTP-LOLIM) 470,460,460
  460 CALL MARCH(1)
  470 RETURN
      END
      SUBROUTINE FUNCT
C
C     SOLVES FOR EIGENFUNCTION
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
```

```
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      IREG=NREG
      KEND=NPTS+1
   10 DO 520 J=1,ISOLVM
C
C     MARCH FORWARD TO LAST VALUE OF PHI
C
      K=ISOLVM+1-J
      H=1.
      KH=1
      N=KSOLV(K)
      CALL HOSIEQ(1,K)
   20 IF(IREG-1) 50,50,30
   30 IF(N-IND(IREG-1)) 40,40,50
   40 IREG=IREG-1
      GO TO 20
   50 MNDEX=N-1
      MARSTP=KEND-N+1
      LOLIM=3
   60 IF(MARSTP-LOLIM) 110,70,70
   70 KROSS=0
      KIND=IND(IREG)
   80 IF(NREG-IREG) 90,90,100
   90 KIND=KIND+KBCO-1
  100 CALL MARCH(2)
  101 IF(KQUIT) 109,109,1000
  109 IREG=IREG-KROSS
  110 IF(J-1) 300,300,120
  120 IF(KEND-N) 130,130,140
  130 KN=N
      GO TO 145
  140 KN=KEND-1
  145 KEND=KN+1
  150 DO 180 I=1,NREG
  160 IF(KEND-IND(I)) 180,170,180
  170 KA=I
      GO TO 190
  180 CONTINUE
      KA=IREG+KROSS
      IF(KN-IND(KA)) 186,182,186
  182 KA=KA+1
  186 KB=KN+1
      KC=KN+2
      KD=KN
      KH=-1
      H=-1.
      GO TO 200
  190 KB=KN
      KC=KN-1
      KD=KN+1
      KH=1
      H=1.
C
```

```
C       MATCH
C
  200 MNDEX=KB
      BETA=BET(KA)
      DO 220 L=1,NA
      Y(L)=-BETA*PHI(L,KC)
  210 DO 220 I=1,NA
  220 Y(L)=Y(L)+ALPHA*P(L,I,KA)*PHI(I,KB)
      IF(KH) 222,221,221
  221 CM=PHI(KG,KD)/Y(KG)
      GO TO 229
  222 CM=Y(KG)/PHI(KG,KD)
  229 LOLIM=N-1
      X=((1+KH)*CM+1-KH)/2
  240 DO 250 I=1,NA
      Y(I)=X*Y(I)
  230 DO 250 L=LOLIM,KN
  250 PHI(I,L)=CM*PHI(I,L)
      DO 255 I=1,NA
  255 Y(I)=(Y(I)-PHI(I,KD))*100./PHI(I,KD)
C
C       WRITE MATCH ERROR
C
      WRITE (3,1010) KN,KG
      WRITE (3,1020) (Y(I),I=1,NA)
  300 DO 310 I=1,NA
  310 V(I)=PHI(I,N)
C
C       MARCH BACKWARD HALFWAY TO NEXT POINT OF CONDITIONING
C
      H=-1.
      KH=-1
      CALL HOSIEQ(2,K)
  320 IF(K-1) 330,330,340
  330 KEND=1
      GO TO 350
  340 KEND=N-1-(KSOLV(K)-KSOLV(K-1))/2
  350 LOLIM=3
      MARSTP=1+N-KEND
  360 IF(MARSTP-LOLIM) 430,370,370
  370 MNDEX=N
      KROSS=0
  380 IF(IREG-1) 390,390,400
  390 KIND=1
      GO TO 410
  400 KIND=IND(IREG-1)
  410 CALL MARCH(2)
  420 IF(KQUIT) 430,430,1000
  430 IREG=IREG
      LOLIM=KEND
      CM=V(KG)/PHI(KG,N)
      MARSTP=N-1
  440 DO 470 I=1,NA
  450 DO 460 L=LOLIM,MARSTP
  460 PHI(I,L)=CM*PHI(I,L)
```

```
  470 PHI(I,N)=V(I)
  520 CONTINUE
      KH=1
      H=1.
C
C     PHI(0)
C
  530 IF(A-1.2) 660,660,540
C
C     SPHERE
C
  540 DO 570 I=1,NA
  550 DO 560 J=1,NA
  560 S(I,J)=P(I,J,1)
  570 S(I,I)=S(I,I)-2.
  580 DO 610 I=1,NA
  590 DO 600 J=1,NA
  600 S(I,J)=S(I,J)/6.
  610 S(I,I)=S(I,I)+1.
      CALL DETINV(1,11)
  620 IF(KQUIT) 630,630,1000
  630 DO 650 I=1,NA
      PHIC(I)=0.
  640 DO 650 J=1,NA
  650 PHIC(I)=PHIC(I)+T(I,J)*PHI(J,1)
      GO TO 700
C
C     CYLINDER OR SLAB
C
  660 ALPHA=2./(2.-A)
      BETA=(2.+A)/(2.-A)
  670 DO 690 I=1,NA
      PHIC(I)=-BETA*PHI(I,2)
  680 DO 690 J=1,NA
  690 PHIC(I)=PHIC(I)+ALPHA*P(I,J,1)*PHI(J,1)
  700 IF(KAPP) 710,900,900
C
C     VARIATION I  CALCULATION OF PHI FROM EXPANSION COEFFICIENTS
C
  710 GO TO (2790,720),KBCO
  720 X=1./(2.*RHO(NREG))
  730 DO 750 I=1,NA
      Y(I)=0.
  740 DO 750 J=1,NA
  750 Y(I)=Y(I)+GAMA(I,J)*PHI(J,NPTS-1)+EXTPA(I,J)*(PHI(J,NPTS)-PHI(J,
     2NPTS-2))*X
 2790 DO 2810 I=1,NREG
      KA=IND(I)
      MNDEX=KA
      BETA=BET(I)
      X=BETA+1.
      DO 2800 J=1,NA
      V(J)=-X*PHI(J,KA-1)
      DO 2800 L=1,NA
```

```
 2800 V(J)=V(J)+ALPHA*P(J,L,I)*PHI(L,KA)
      X=0.5/RHO(I)
      DO 2810 J=1,NA
      CURR(J,I)=0.
      DO 2810 L=1,NA
 2810 CURR(J,I)=CURR(J,I)-DA(J,L,I)*V(L)*X
      GO TO 940
C
C     NORMALIZE TO PHI(KGA,KNA) = 1.
C
  900 GO TO (2940,910),KBCO
  910 X=1./(2.*RHO(NREG))
  920 DO 930 I=1,NA
  930 Y(I)=GAM(I)*PHI(I,NPTS-1)+X*EXTP(I)*(PHI(I,NPTS)-PHI(I,NPTS-2))
 2940 DO 2960 I=1,NREG
      KA=IND(I)
      MNDEX=KA
      BETA=BET(I)
      X=BETA+1.
      DO 2950 J=1,NA
      V(J)=-X*PHI(J,KA-1)
      DO 2950 L=1,NA
 2950 V(J)=V(J)+ALPHA*P(J,L,I)*PHI(L,KA)
      X=0.5/RHO(I)
      DO 2960 J=1,NA
 2960 CURR(J,I)=-X*D(J,I)*V(J)
  940 IF(KNA) 942,942,946
  942 CM=1./PHIC(KGA)
      GO TO 950
  946 CM=1./PHI(KGA,KNA)
  950 DO 990 I=1,NA
      Y(I)=CM*Y(I)
      PHIC(I)=CM*PHIC(I)
  960 DO 970 J=1,NREG
  970 CURR(I,J)=CM*CURR(I,J)
  980 DO 990 J=1,NPTS
  990 PHI(I,J)=CM*PHI(I,J)
 1000 RETURN
 1010 FORMAT (1H0 14X 42HHERE IS THE PERCENT ERROR FOR MATCH AT X = I3,
     215H FOR Y MATCH AT I3, 1H.)
 1020 FORMAT (1H0 14X 4E15.8)
      END
      SUBROUTINE HOSIEQ(M,K)
C
C     SOLVES (S-I)Y = 0
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
```

```
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      REWIND NSCR
      DO 2 I=1,K
    2 READ (NSCR) FRWD
      KK=K+1
      KKK=2*ISOLVM+1-K
      DO 8 I=KK,KKK
    8 READ (NSCR) BKWD
   10 GO TO (20,90),M
C
C     FORWARD MARCH
C
   20 IF(K-ISOLVM) 40,30,30
   30 WRITE (3,610)
   40 DO 80 I=1,NB
   50 DO 75 J=1,NB
      S(I,J)=0.
   60 DO 70 L=1,NB
   70 S(I,J)=S(I,J)+FRWD(I,L)*BKWD(L,J)
   75 T(I,J)=S(I,J)
   80 S(I,I)=S(I,I)-1.
      GO TO 140
C
C     BACKWARD MARCH
C
   90 DO 130 I=1,NB
  100 DO 125 J=1,NB
      S(I,J)=0.
  110 DO 120 L=1,NB
  120 S(I,J)=S(I,J)+BKWD(I,L)*FRWD(L,J)
  125 T(I,J)=S(I,J)
  130 S(I,I)=S(I,I)-1.
  140 IF(NB-1) 150,150,160
  150 Y(1)=1.
      GO TO 400
C
C     WILKINSON@S METHOD
C
  160 DO 270 I=2,NB
      KA=I-1
  170 DO 270 J=1,KA
  180 IF(S(I,J)) 190,270,190
  190 IF(ABS(S(J,J))-ABS(S(I,J)))210,200,200
  200 X=S(I,J)/S(J,J)
      GO TO 240
[illegible] Y(I)=X*Y(I)
```

```
  210 X=S(J,J)/S(I,J)
  220 DO 230 L=1,NB
      XA=S(J,L)
      S(J,L)=S(I,L)
  230 S(I,L)=XA
  240 KB=J+1
  250 DO 260 L=KB,NB
  260 S(I,L)=S(I,L)-X*S(J,L)
  270 CONTINUE
      XA=S(NB,NB)
      Y(NB)=1.
  280 DO 350 I=2,NB
      KB=NB-I+1
      X=0.
      KA=NB-I+2
  290 DO 295 L=KA,NB
  295 X=X+S(KB,L)*Y(L)
  300 IF(ABS(S(KB,KB))-1.E-10)310,310,340
  310 Y(KB)=1.
      XA=0.
  320 DO 330 J=KA,NB
  330 Y(J)=0.
      GO TO 350
  340 Y(KB)=(XA-X)/S(KB,KB)
  350 CONTINUE
      IF(K3) 359,359,890
C
C     ITERATION TO REDUCE ERROR
C
  890 DO 1000 L=1,K3
      DO 960 I=1,NB
      Y(I)=0.
      KA=I-1
      KB=I+1
      IF(ABS(T(I,I)-1.)-EPB)960,960,900
  900 IF(KA) 930,930,910
  910 DO 920 J=1,KA
  920 Y(I)=Y(I)+T(I,J)*Y(J)
  930 IF(KB-NB) 940,940,955
  940 DO 950 J=KB,NB
  950 Y(I)=Y(I)+T(I,J)*Y(J)
  955 Y(I)=Y(I)/(1.-T(I,I))
  960 CONTINUE
      X=ABS(Y(1))
      XA=1.
      XA=SIGN(XA,Y(1))
      DO 980 I=2,NB
      IF(X-ABS(Y(I)))970,980,980
  970 X=ABS(Y(I))
      XA=1.
      XA=SIGN(XA,Y(I))
  980 CONTINUE
      X=XA/X
      DO 990 I=1,NB
  990 Y(I)=X*Y(I)
```

```
 1000 CONTINUE
      GO TO 400
C
C     NORMALIZE TO MAXIMUM VALUE OF Y = 1.
C
  359 X=ABS(Y(1))
      XA=1.
      XA=SIGN(XA,Y(1))
  360 DO 390 I=2,NB
  370 IF(X-ABS(Y(I)))380,390,390
  380 X=ABS(Y(I))
      XA=1.
      XA=SIGN(XA,Y(I))
  390 CONTINUE
      X=XA/X
      DO 395 I=1,NB
  395 Y(I)=X*Y(I)
C
C     PHI(J) AND PHI(J-1)
C
  400 GO TO (410,500),M
C
C     FORWARD MARCH
C
  410 KA=KSOLV(K)-1
      KB=KA+1
  420 IF(KAPP) 430,430,460
  430 DO 450 I=1,NA
      PHI(I,KA)=Y(I)
      PHI(I,KB)=0.
  440 DO 450 J=1,NA
  450 PHI(I,KB)=PHI(I,KB)+BKWD(I,J)*Y(J)
      GO TO 590
  460 DO 490 I=1,NA
      PHI(I,KA)=0.
      PHI(I,KB)=0.
  470 DO 490 J=1,NB
      PHI(I,KA)=PHI(I,KA)+WA(I)*Z(I,J)*Y(J)
  480 DO 490 L=1,NB
  490 PHI(I,KB)=PHI(I,KB)+WA(I)*Z(I,J)*BKWD(J,L)*Y(L)
      GO TO 590
C
C     BACKWARD MARCH
C
  500 KA=KSOLV(K)
      KB=KA-1
  510 IF(KAPP) 520,520,550
  520 DO 540 I=1,NA
      PHI(I,KA)=Y(I)
      PHI(I,KB)=0.
  530 DO 540 J=1,NA
  540 PHI(I,KB)=PHI(I,KB)+FRWD(I,J)*Y(J)
      GO TO 590
  550 DO 580 I=1,NA
```

```
      PHI(I,KA)=0.
      PHI(I,KB)=0.
  560 DO 580 J=1,NB
      PHI(I,KA)=PHI(I,KA)+WA(I)*Z(I,J)*Y(J)
  570 DO 580 L=1,NB
  580 PHI(I,KB)=PHI(I,KB)+WA(I)*Z(I,J)*FRWD(J,L)*Y(L)
  590 WRITE (3,620) KA
      WRITE (3,630) (Y(I),I=1,NA)
  600 RETURN
  610 FORMAT (1H1 19X 51HTHE EXPANSION COEFFICIENTS ARE GIVEN FOR THE RA
     2DIAL / 15X 21HMESH POINT INDICATED.)
  620 FORMAT (1H0 14X 24HTHE RADIAL MESH POINT IS , I3)
  630 FORMAT (1H  14X, 4E15.8)
      END
      SUBROUTINE POWER
C
C     CALCULATES POWER AS (FSIG,PHI)
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      IREG=1
      PI=3.1415926536
   10 IF(IA-1) 20,30,40
   20 XA=1.
      GO TO 50
   30 XA=2.*PI
      GO TO 50
   40 XA=4.*PI/3.
   50 POWC=0.
      IA=IA+1
   60 DO 70 I=1,NOG
   70 POWC=POWC+PHIC(I)*FSIG(I,1)
      XTA=XA*((RHO(1)/2.)**(IA))
      XT=XTA*POWC
      MARSTP=IND(1)-1
      KA=IND(1)
      LOLIM=1
   80 X=XA*(RHO(IREG)**(IA))
```

```
  90 DO 120 I=LOLIM,MARSTP
     XB=X*((I+0.5)**IA-(I-0.5)**IA)
     POW(I)=0.
 100 DO 110 J=1,NOG
 110 POW(I)=POW(I)+PHI(J,I)*FSIG(J,IREG)
     XT=XT+XB*POW(I)
 120 XTA=XTA+XB
 130 XB=X*(KA**IA-(KA-0.5)**IA)
     XTA=XTA+XB
     POW(KA)=0.
 140 DO 150 I=1,NOG
 150 POW(KA)=POW(KA)+XB*PHI(I,KA)*FSIG(I,IREG)
     IREG=IREG+1
 160 IF(NREG-IREG) 210,170,170
 170 X=XA*((RHO(IREG))**(IA))
     XC=X*((KA+0.5)**IA-KA**IA)
     XTA=XTA+XC
 180 DO 190 I=1,NOG
 190 POW(KA)=POW(KA)+XC*PHI(I,KA)*FSIG(I,IREG)
     XT=XT+POW(KA)
     POW(KA)=POW(KA)/(XB+XC)
     LOLIM=IND(IREG-1)+1
     KA=IND(IREG)
     MARSTP=IND(IREG)-1
 200 IF(MARSTP-LOLIM) 130,90,90
 210 XT=XT+POW(KA)
     POW(KA)=POW(KA)/XB
     POWAVG=XT/XTA
     POWCAV=POWC/POWAVG
     IA=IA-1
 220 RETURN
     END
     SUBROUTINE OUTPUT(M)
C
C    WRITE RESULTS
C
     INTEGER Q
     DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
    3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
    5DOG(2)
     COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
    2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
    3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
    5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
    6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
    7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
    8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
    9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
     COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
    2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
    3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
    4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
    5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
     EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     EIGENFUNCTION
```

```
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      Q=K2
   10 GO TO (20,260),KPRINT
C
C     GENERAL INFORMATION
C
   20 KPRINT=2
   30 IF(IA-1) 40,50,60
   40 WRITE (Q,570)
      GO TO 70
   50 WRITE (Q,580)
      GO TO 70
   60 WRITE (Q,590)
   70 IF(KAPP) 80,90,100
   80 WRITE (Q,600)
      GO TO 110
   90 WRITE (Q,610)
      GO TO 110
  100 WRITE (Q,620)
  110 GO TO (120,130),KBCI
  120 WRITE (Q,630)
      GO TO 140
  130 WRITE (Q,640)
  140 GO TO (150,160),KBCO
  150 WRITE (Q,650)
      GO TO 170
  160 WRITE (Q,660)
  170 WRITE (Q,670) NREG,NA,NPTS
  180 GO TO (190,260,260),M
  190 WRITE (Q,680) KCOND,EPA
      WRITE (Q,690)
      WRITE (Q,700)
      X=0.
  200 DO 210 I=1,NREG
      XA=1./CEFT(I)
      X=X+RAD(I)
  210 WRITE (Q,710) I,XA,IND(I),X
  220 GO TO (230,240),KCHO
  230 WRITE (Q,720) KREG
      WRITE (Q,700)
  235 WRITE (Q,740) V(KB),DT
      GO TO 250
  240 WRITE (Q,730) KREG
      WRITE (Q,700)
  245 XA=1./V(KB)
      WRITE (Q,740) XA,DT
  250 RETURN
  260 GO TO (270,290,490),M
C
C     EIGENVALUE AND DETERMINANT
C
  270 GO TO (235,245),KCHO
C
C     EIGENFUNCTION
```

```
C
  290 WRITE (Q,750)
      WRITE (Q,690)
      WRITE (Q,700)
      X=0.
  300 DO 310 I=1,NREG
      X=X+RAD(I)
      XA=1./CEFT(I)
  310 WRITE (Q,710) I,XA,IND(I),X
      WRITE (Q,680) KCOND,EPA
      WRITE (Q,760)
      WRITE (Q,700)
      X=0.
  320 DO 330 I=1,NA
  330 WRITE (Q,770) X,I,PHIC(I)
      IREG=1
      WRITE (Q,700)
  340 DO 405 J=1,NPTS
  350 IF(J-IND(IREG)) 380,380,360
  360 IF(NREG-IREG) 380,380,370
  370 IREG=IREG+1
  380 X=X+RHO(IREG)
  390 DO 400 I=1,NA
  400 WRITE (Q,770) X,I,PHI(I,J)
  405 WRITE (Q,700)
      WRITE (Q,780)
  410 DO 435 I=1,NREG
  420 DO 430 J=1,NA
  430 WRITE (Q,790) I,J,CURR(J,I)
  435 WRITE (Q,700)
  440 GO TO (480,450),KBCO
  450 WRITE (Q,800)
      WRITE (Q,700)
  460 DO 470 I=1,NA
  470 WRITE (Q,810) I,Y(I)
  480 RETURN
C
C     POWER
C
  490 WRITE (Q,820)
      WRITE (Q,830) XT
      WRITE (Q,840) POWAVG
      WRITE (Q,850) POWCAV
      WRITE (Q,860)
      X=0.
      WRITE (Q,700)
      WRITE (Q,870) X,POWC
      IREG=1
  500 DO 550 I=1,NPTS
  510 IF(I-IND(IREG)) 540,540,520
  520 IF(IREG-NREG) 530,540,540
  530 IREG=IREG+1
  540 X=X+RHO(IREG)
  550 WRITE (Q,870) X,POW(I)
```

```
560 RETURN
570 FORMAT (1H1 19X 36HTHE REACTOR BEING STUDIED IS A SLAB.)
580 FORMAT (1H1 19X 40HTHE REACTOR BEING STUDIED IS A CYLINDER.)
590 FORMAT (1H1 19X 38HTHE REACTOR BEING STUDIED IS A SPHERE.)
600 FORMAT (1H0 19X 54HTHE COEFFICIENTS OF AN INCOMPLETE SET OF FUNCTI
   2ONS ARE / 1H  14X 18HUSED IN THE MARCH.)
610 FORMAT (1H0 19X 49HA COMPLETE SET OF FUNCTIONS IS USED IN THE MARC
   2H.)
620 FORMAT (1H0 19X 52HAN INCOMPLETE SET OF FUNCTIONS IS USED IN THE M
   2ARCH.)
630 FORMAT (1H0 19X 53HTHE INNER BOUNDARY CONDITION IS THE FLUX EQUALS
   2 ZERO.)
640 FORMAT (1H0 19X 51HTHE INNER BOUNDARY CONDITION IS THE GRADIENT OF
   2 THE / 1H  14X 17HFLUX EQUALS ZERO.)
650 FORMAT (1H0 19X 47HTHE OUTER BOUNDARY CONDITION IS THE HOMOGENEOUS
   2 / 1H  14X 14HDIRICHLET ONE.)
660 FORMAT (1H0 19X 47HTHE OUTER BOUNDARY CONDITION IS THE HOMOGENEOUS
   2 / 1H  14X 10HMIXED ONE.)
670 FORMAT (1H0 19X 28HTHE NUMBER OF REGIONS EQUALS I3, 22H, THE NUMBE
   2R OF GROUPS / 1H  14X 6HEQUALS I3, 39H, AND THE NUMBER OF SPACE PO
   3INTS EQUALS I3, 1H.)
680 FORMAT (1H0 19X 36HTHE FREQUENCY OF CONDITIONING EQUALS I2, 19H AN
   2D EPSILON EQUALS / 1H  14X E10.3, 1H.)
690 FORMAT (1H0 14X 6HREGION 12X 5HK-EFF 12X 8HLAST PT. 10X 9HRADIUS-C
   2M)
700 FORMAT (1H )
710 FORMAT (1H  17X I1, 13X F9.6, 13X I3, 12X F9.5)
720 FORMAT (1H0 22X 7HRADIUS( I1, 4H)-CM 20X 11HDETERMINANT)
730 FORMAT (1H0 24X 6HK-EFF( I1, 1H) 22X 11HDETERMINANT)
740 FORMAT (1H  21X E15.8, 16X E15.8)
750 FORMAT (1H1)
760 FORMAT (1H0 17X 9HRADIUS-CM 13X 5HGROUP 12X 16HFLUX-N/SQ CM/SEC)
770 FORMAT (1H  17X F9.5, 15X I2, 14X E15.8)
780 FORMAT (1H0 17X 6HREGION 13X 5HGROUP 11X 19HCURRENT-N/SQ CM/SEC)
790 FORMAT (1H  20X I1, 17X I2, 14X E15.8)
800 FORMAT (1H0 28X 5HGROUP 19X 18HBOUNDARY CONDITION)
810 FORMAT (1H  26X I2, 22X E15.8)
820 FORMAT (1H1 19X 53HPOWER IS IN FISSIONS/SECOND SUBJECT TO THE FLUX
   2 SCALE / 1H  14X 32HFACTOR.  1 UNIT = 1 FISSION/SEC.)
830 FORMAT (1H0 19X 13HTOTAL POWER =  20X E15.8, 7H UNITS.)
840 FORMAT (1H0 19X 23HAVERAGE POWER DENSITY = 10X E15.8, 10H UNITS/CC
   2.)
850 FORMAT (1H0 19X 33HCENTER TO AVERAGE POWER DENSITY = E15.8, 1H.)
860 FORMAT (1H0 23X 9HRADIUS-CM 16X 22HPOWER DENSITY-UNITS/CC)
870 FORMAT (1H  23X F9.5, 19X E15.8)
    END
    SUBROUTINE YEGADS(N1,N2,N3)
C
C   WRITES ERROR MESSAGES
C
    DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
   3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
   5DOG(2)
    COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
   2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
```

```
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      KQUIT=1
   10 GO TO (20,30,40,50),N1
   20 WRITE (3,70) N2
      GO TO 60
   30 WRITE (3,80) N2,N3
      GO TO 60
   40 WRITE (3,90) N2
      GO TO 60
   50 WRITE (3,100) N2
   60 RETURN
   70 FORMAT (1HO 19X 25HRHO IS NEGATIVE IN REGION I2, 1H.)
   80 FORMAT (1HO 19X 32HMATRIX INVERSION FAILED AT POINT I3, 22H.  THE
     2INVERTED MATRIX / 1H  14X 18HWAS FOR SUBROUTINE I3, 1H.)
   90 FORMAT (1HO 19X 27HKCOND WAS REDUCED TO 1 FROM I3, 22HBY REPEATED
     2FAILURE OF / 1H  14X 21HCONDIT ON MARCH BACK.)
  100 FORMAT (1HO 19X 28HMARSTP WAS REDUCED TO 2 NEAR I3, 22HBY REPEATED
     2 FAILURE OF / 1H  14X 24HCONDIT ON MARCH FORWARD.)
      END
      SUBROUTINE CALCRS
C     DATA PREPARATION FOR 2-D FLUX SYNTHESIS
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),N(10),
     4FI(20,20,3),R(90),RP(90),AA(20,20,3),B(10,3),G(10,10,3),C(10,100),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      COMMON R,RP,FUD,DUF(10,10)
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
      R(J)=X
```

```
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      NPT=NPTS
      ALPHA=IA
      GO TO (20,10),KGEL
   10 NN=NPTS+1
      DO 11 I=1,NN
      DO 11 J=1,NOG
      DO 11 K=1,NMODE
   11 PHIA(J,I,K)=FLX(J,I,K)
   20 CONTINUE
      DO 50 K=1,NREG
      DO 50 I=1,NOG
      DO 40 J=1,NOG
   40 FI(I,J,K)=F(I,K)*FSIG(J,K)
   50 RSIG(I,K)=RSIG(I,K)+D(I,K)*BUCK(I,K)
   60 IF(IA-1) 70,90,130
C
C     SLAB
C
   70 BETA=1.
      DO 80 I=1,NPT
      R(I)=1.
   80 RP(I)=1.
      GO TO 160
C
C     CYLINDER
C
   90 BETA=6.28318531
      R(1)=0.
      RP(1)=0.0
      LOW=2
      KU=IND(1)
      DO 120 I=1,NREG
      DO 100 J=LOW,KU
      R(J)=RHO(I)+R(J-1)
  100 RP(J)=BETA*R(J)
      IF(NREG-I) 120,120,110
  110 LOW=KU+1
      KU=IND(I+1)
  120 CONTINUE
      GO TO 160
C
C     SPHERE
C
  130 BETA=4.18879020
      X=0.
      R(1)=0.
      RP(1)=0.0
      LOW=2
      KU=IND(1)
      DO 160 I=1,NREG
      DO 140 J=LOW,KU
      X=X+RHO(I)
      R(J)=X
```

```
  140 RP(J)=BETA*X*X
      IF(NREG-I) 160,160,150
  150 LOW=KU+1
      KU=IND(I+1)
  160 CONTINUE
      GO TO (190,220),KNORM
  190 CALL VOLINT(FI,D,FSIGA,1,1)
      DO 210 K=1,NMODE
      X=FSIGA(K,K,1)
      XA=1.
      XA=SIGN(XA,X)
      X=SQRT(ABS(X))
      X=1./X
      XA=XA*X
      DO 210 I=1,NOG
      DO 200 J=1,NPT
      PHIA(I,J,K)=XA*PHIA(I,J,K)
  200 FLX(I,J,K)=X*FLX(I,J,K)
      DO 210 J=1,NREG
  210 CURRN(I,J,K)=X*CURRN(I,J,K)
  220 CONTINUE
      CALL VOLINT(FI,D,FSIGA,1,2)
      CALL VOLINT(FI,RSIG,RSIGA,2,3)
      CALL VOLINT(FI,D,DA,3,4)
      CALL VOLINT(SSIG,D,SSIGA,1,5)
      GO TO (300,240),KBCO
  240 DO 250 K=1,NREG
      DO 250 I=1,NOG
  250 RSIG(I,K)=GAM(I)
      CALL VOLINT(FI,RSIG,GAMA,3,1)
      DO 1 I=1,NMODE
      DO 1 J=1,NMODE
    1 GAMA(I,J)=DUF(I,J)
      DO 260 J=1,NREG
      DO 260 I=1,NOG
  260 RSIG(I,J)=EXTP(I)
      CALL VOLINT(FI,RSIG,EXTPA,3,1)
      DO 2 I=1,NMODE
      DO 2 J=1,NMODE
    2 EXTPA(I,J)=DUF(I,J)
  300 RETURN
      END
      SUBROUTINE VOLINT(AA,B,G,KHCO,KKK)
C
C     EVALUATE INTEGRAL OVER PHIA*AA*FLX
C
      DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
     3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),
     4FI(20,20,3),R(90),RP(90),AA(20,20,3),B(10,3),G(10,10,3),C(10,100),
     5DOG(2)
      COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
     2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
      GO TO (10,110,190),KHCO
```

```
   6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
   7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
   8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
   9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
    COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
   2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
   3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
   4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
   5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
    COMMON R,RP,FUD,DUF(10,10)
    EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
   5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
   6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
    DO 240 KK=1,NREGZ
    IF (KK.EQ.2) GO TO 11
    GO TO 6
 11 GO TO (6,22,33,33,22),KKK
 22 DO 21 MM=1,NREG
    DO 21 NN=1,NOG
    DO 21 JJ=1,NOG
 21 AA(NN,JJ,MM)=AA(NN,JJ,2)
    GO TO 6
 33 DO 32 MM=1,NREG
    DO 32 JJ=1,NOG
 32 B(JJ,MM)=B(JJ,2)
  6 DO 240 N=1,NMODE
    DO 240 M=1,NMODE
    GO TO (10,60,60),KHCO
 10 DO 50 I=1,NREG
    KU=IND(I)
    IF(I-1) 20,20,30
 20 LOW=1
    GO TO 40
 30 LOW=IND(I-1)
 40 JJ=LOW-1
    DO 50 J=LOW,KU
    II=J-JJ
    S(II,I)=0.
    DO 50 K=1,NOG
    DO 50 L=1,NOG
 50 S(II,I)=S(II,I)+PHIA(K,J,N)*AA(K,L,I)*FLX(L,J,M)
    GO TO 190
 60 DO 100 I=1,NREG
    KU=IND(I)
    IF(I-1) 70,70,80
 70 LOW=1
    GO TO 90
 80 LOW=IND(I-1)
 90 JJ=LOW-1
    DO 100 J=LOW,KU
    II=J-JJ
    S(II,I)=0.
    DO 100 K=1,NOG
100 S(II,I)=S(II,I)+PHIA(K,J,N)*B(K,I)*FLX(K,J,M)
    GO TO (10,110,190),KHCO
```

```
110 DO 180 I=1,NREG
    X=1./(RHO(I)*RHO(I))
    KU=IND(I)-1
    IF(I-1) 120,120,140
120 LOW=2
    XA=2.*X*(1.+ALPHA)
    DO 130 J=1,NOG
130 S(1,1)=S(1,1)-PHIA(J,1,N)*D(J,1)*(FLX(J,2,M)-FLX(J,1,M))*XA
    GO TO 160
140 LOW=IND(I-1)+1
    DO 150 J=1,NOG
150 S(1,I)=S(1,I)-PHIA(J,LOW-1,N)*(D(J,I)*2.*X*(FLX(J,LOW,M)-FLX(J,LOW
   2-1,M))+(2./RHO(I)-ALPHA/R(LOW-1))*CURRN(J,I-1,M))
160 JJ=LOW-2
    XA=ALPHA/(2.*RHO(I))
    DO 170 J=LOW,KU
    II=J-JJ
    DO 170 K=1,NOG
170 S(II,I)=S(II,I)-PHIA(K,J,N)*D(K,I)*(X*(FLX(K,J+1,M)+FLX(K,J-1,M)-
   22.*FLX(K,J,M))+(XA/R(J))*(FLX(K,J+1,M)-FLX(K,J-1,M)))
    II=IND(I)-JJ
    DO 180 J=1,NOG
180 S(II,I)=S(II,I)-PHIA(J,KU+1,N)*(X*2.*D(J,I)*(FLX(J,KU,M)-FLX(J,KU+
   21,M))-(2./RHO(I)+ALPHA/R(KU+1))*CURRN(J,I,M))
190 G(N,M,KK)=0.0
    DUF(N,M)=0.0
    DO 240 I=1,NREG
    KU=IND(I)-1
    IF(I-1) 200,200,210
200 LOW=2
    GO TO 220
210 LOW=IND(I-1)+1
220 JJ=LOW-2
    X=RP(LOW-1)*S(1,I)
    DO 230 J=LOW,KU,2
    II=J-JJ
230 X=X+4.*RP(J)*S(II,I)+2.*RP(J+1)*S(II+1,I)
    II=KU+1-JJ
    X=X-RP(KU+1)*S(II,I)
    X=X*RHO(I)/3.
    DUF(N,M)=DUF(N,M)+X
240 G(N,M,KK)=G(N,M,KK)+X
250 RETURN
    END
    SUBROUTINE TWOSYN
C
C   COMBINE EXPANSION COEFFICIENTS AND TRIAL FUNCTIONS
C
    DIMENSION PHI(10,50),RHOZ(3),FISIG(10,3,3),ZZ(100),
   3PHIC(20),BKWD(20,20),FRWD(20,20),CURR(20,3),POW(190),
   4FI(20,20,3),R(100),RP(100),AA(20,20,3),B(20,3),G(8,8,3),C(8,100),
   5PHE(10,50)
    COMMON IND(3),RAD(3),CEFT(3),GNU(3),SSIG(20,20,3),RSIGA(10,10,3),
   2FSIG(20,3),Z(20,20),WA(20),WB(20),GAMA(10,10),EXTPA(10,10),
    DO 30 J=1,NPTR
```

```
     3P(20,20,3),T(20,20),S(60,20),TEMP(20,20),TEMPA(20,20),RHO(3),
     5PSI(10,10,10),Y(20),V(20),KSOLV(20),IHUNT,KQUIT,KPRINT,NUMBER,KCON
     6D,KSTOR,ISOLV,IT,H,KH,ISTOP,IREG,KINDM,NPTS,NREG,KREG,KIND,
     7MARSTP,LOLIM,MNDEX,KBCO,KBCI,IFOUND,IFUNCT,INDEX,INDEXM,NUMAX,
     8KPOW,MORE,NFCT,NOG,KAPP,KCHO,KHUNT,IA,K1,EPA,EPB,DEL,A,NA,NB,X,
     9XA,XB,KA,KB,KC,KD,KN,XC,ALPHA,BETA,DT,DTO,ISOLVM,KROSS,KEND,K2
      COMMON K3,KG,KGA,KNA,BKWD,FRWD,NSCR,NMODE,ACEFT,EPC,KNORM,
     2PHIA(10, 50,6),FLX(10, 50,6),CURRN(10,3,6),RADZ(3),RRO,RZO,NPTZ,
     3INDZ(3),NREGZ,KNG,KNR,KNZ,IHOP,SSIGA(10,10,3),RSIG(10,3),F(10,3),
     4FSIGA(10,10,3),DA(10,10,3),D(10,3),GAM(10),BUCK(10,3),EXTP(10),
     5ZA(10,10),BCEFT(2,8),NREGR,NPTR,INDR(3),RHOR(3),MPOW,KGEL
      EQUIVALENCE (PSI(1),PHI(1)),(PSI(501),PHIC(1)),(TEMPA(1),POW(1)),
     5(TEMPA(191),POWC),(TEMPA(192),POWAVG),(TEMPA(193),POWCAV),
     6(TEMPA(194),XT),(TEMPA(195),XTA),(PSI(521),CURR(1))
      WRITE (3,1100)
      XXA=1.0/CEFT(1)
      WRITE (3,1090) XXA
      NPHE=5
      NPTZ=NPTZ+2-KBCO
      NPTR=NPTR+2-KBCO
      DO 1 I=1,NMODE
      C(I,1)=PHIC(I)
      DO 1 J=2,NPTZ
    1 C(I,J)=PHI(I,J-1)
      RHOZ(1)=RADZ(1)/INDZ(1)
      IF (NREGZ-1) 76,76,51
   51 DO 61 I=2,NREGZ
   61 RHOZ(I)=RADZ(I)/(INDZ(I)-INDZ(I-1))
   76 DO 91 I=1,NREGZ
      IF (RHOZ(I)) 81,81,91
   81 CALL YEGADS(1,I,2)
   91 CONTINUE
      DO 72 K=1,NREGZ
      DO 72 J=1,NREGR
      DO 72 I=1,NOG
   72 FISIG(I,J,K)=FSIG(I,J)
C
C     FLUX=SUM(A*TRIAL FUNCTIONS)
C
      DO 21 K=1,NPTZ
      DO 20 I=1,NOG
      DO 20 J=1,NPTR
      PHE(I,J)=FLX(I,J,1)*C(1,K)
      DO 20 L=2,NMODE
   20 PHE(I,J)=PHE(I,J)+FLX(I,J,L)*C(L,K)
   21 WRITE (NPHE'K) PHE
C
C     NORMALIZATION
C
      READ (NPHE'KNZ) PHE
      X=1.0/PHE(KNG,KNR)
      DO 31 K=1,NPTZ
      READ (NPHE'K) PHE
      DO 30 I=1,NOG
      DO 30 J=1,NPTR
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```
   30 PHE(I,J)=X*PHE(I,J)
   31 WRITE (NPHE'K) PHE
      R(1)=RRO
      LOW=2
      KU=INDR(1)+1
      DO 60 I=1,NREGR
      DO 40 J=LOW,KU
   40 R(J)=R(J-1)+RHOR(I)
      IF(NREGR-I) 60,60,50
   50 LOW=KU+1
      KU=INDR(I+1)+1
   60 CONTINUE
      ZZ(1)=RZO
      LOW=2
      KU=INDZ(1)+1
      DO 90 I=1,NREGZ
      DO 70 J=LOW,KU
   70 ZZ(J)=ZZ(J-1)+RHOZ(I)
      IF(NREGZ-I) 90,90,80
   80 LOW=KU+1
      KU=INDZ(I+1)+1
   90 CONTINUE
      IPR=1
   95 DO 180 I=1,NOG
      IPAGE=1
      KCK=0
      LOW=1
      KU=26
  105 IF(NPTZ-KU) 100,100,110
  100 KCK=1
      KU=NPTZ
  110 GO TO (111,112,113),IPR
  111 PRINT 1040, I,IPAGE
      GO TO 114
  112 PRINT 1070, I,IPAGE
      GO TO 114
  113 PRINT 1080, IPAGE
  114 KCQ=0
      LOWR=1
      KUR=6
  115 IF(NPTR-KUR) 120,120,130
  120 KCQ=1
      KUR=NPTR
  130 PRINT 1050, (R(K),K=LOWR,KUR)
      DO 140 K=LOW,KU
      READ (NPHE'K) PHE
C
C     PRINT FLUX
C
  140 WRITE (3,1060) ZZ(K),(PHE(I,J),J=LOWR,KUR)
      IF(KCQ) 150,150,160
  150 LOWR=KUR+1
      KUR=KUR+6
      IPAGE=IPAGE+1
  160 RETURN
```

```
      GO TO (151,152,153),IPR
  151 PRINT 1040, I,IPAGE
      GO TO 115
  152 PRINT 1070, I,IPAGE
      GO TO 115
  153 PRINT 1080, IPAGE
      GO TO 115
  160 IF(KCK) 170,170,180
  170 LOW=KU+1
      KU=KU+26
      IPAGE=IPAGE+1
      GO TO 105
  180 CONTINUE
      NPTZ=NPTZ-2+KBCO
      NPTR=NPTR-2+KBCO
      IF (MPOW.EQ.1) GO TO 260
      GO TO (181,240,260),IPR
  181 LOW=1
      KU=INDZ(1)
      DO 230 I=1,NREGZ
      LOWR=1
      KUR=INDR(1)
      DO 210 J=1,NREGR
      DO 191 K=LOW,KU
      READ (NPHE'K) PHE
      DO 190 L=LOWR,KUR
      DO 190 N=1,NOG
  190 PHE(N,L)=FISIG(N,J,I)*PHE(N,L)
  191 WRITE (NPHE'K) PHE
      IF(NREGR-J) 210,210,200
  200 LOWR=KUR+1
      KUR=INDR(J+1)
  210 CONTINUE
      IF(NREGZ-I) 230,230,220
  220 LOW=KU+1
      KU=INDZ(K+1)
  230 CONTINUE
      IPR=2
      GO TO 95
  240 DO 251 K=1,NPTZ
      READ (NPHE'K) PHE
      DO 250 I=2,NOG
      DO 250 J=1,NPTR
  250 PHE(1,J)=PHE(1,J)+PHE(I,J)
  251 WRITE (NPHE'K) PHE
      READ (NPHE'KNZ) PHE
      X=1.0/PHE(1,KNR)
      DO 256 K=1,NPTZ
      READ (NPHE'K) PHE
      DO 255 I=1,NPTR
  255 PHE(1,I)=X*PHE(1,I)
  256 WRITE (NPHE'K) PHE
      IPR=3
      GO TO 95
  260 RETURN
```

```
1000 FORMAT (72H
    2                   )
1010 FORMAT (20I3)
1020 FORMAT (5E15.8)
1030 FORMAT (58X E15.8)
1040 FORMAT (///54X 5HGROUP I2, 5H FLUX 37X 4HPAGE I3/)
1050 FORMAT (/18X 6(2X 3HR = F9.5, 3X)/)
1060 FORMAT (2X 3HZ = F9.5, 1X 6(2X E15.8))
1070 FORMAT (50X 5HGROUP I2, 14H POWER DENSITY 32X 4HPAGE I3)
1025 FORMAT (6E13.8)
1080 FORMAT (50X 19HTOTAL POWER DENSITY 34X 4HPAGE I3)
1090 FORMAT (1H0 24X 'K-EFFECTIVE = ' F9.6/)
1100 FORMAT ('1')
     END
```

2. SAMPLE INPUT FOR THE MUD-SYN CODE

```
          PROBLEM NUMBER THREE     TOTALLY REFLECTED CYLINDER
  2  2  2 30  5  1  2170  1  1  1  0  2  1  1  2  2  1  1  3
  0  1  1  0  3  2 47  2  1  1  1  1  1
 42 47
 26 30
ORIGIN
RADZ            1.0        E 02 5.0        E 00
RADR            5.5        E 01 5.0        E 00
                1.136           1.0
                1.0             1.0
                1.0        E-05 1.0        E-05 0.01
              THE REACTOR IS A CYLINDER
            THE NUMBER OF GROUPS EQUALS TWO
            GROUP ONE IS THE FAST GROUP
            GROUP TWO IS THE THERMAL GROUP
SSIG            0.              0.46       E-02 0.              0.
                0.              0.66       E-02 0.              0.
RSIG            0.72       E-02 0.66       E-02 0.67       E-02 0.14       E-02
FSIG            0.18       E-02 0.1        E-01 0.              0.
CHI             1.              0.              1.              0.
BUCK            0.              0.              0.              0.
D               0.93            0.9             0.9             0.9
GAM             0.              0.              0.              0.
EXTP            0.              0.              0.              0.
```

3. SAMPLE OUTPUT FOR THE MUD-SYN CODE

K-EFFECTIVE = 0.842993

GROUP 1 FLUX — PAGE 1

	R = 0.0	R = 2.11538	R = 4.23077	R = 6.34615	R = 8.46154	R = 10.57692
Z = 0.0	0.99999976E 00	0.99735212E 00	0.98949051E 00	0.97667336E 00	0.95939243E 00	0.93820125E 00
Z = 2.38095	0.99972409E 00	0.99707657E 00	0.98921514E 00	0.97639347E 00	0.95911831E 00	0.93792820E 00
Z = 4.76190	0.99875408E 00	0.99610901E 00	0.98825455E 00	0.97544956E 00	0.95818514E 00	0.93701434E 00
Z = 7.14286	0.99648082E 00	0.99384153E 00	0.98600453E 00	0.97322792E 00	0.95600170E 00	0.93487793E 00
Z = 9.52381	0.99290621E 00	0.99027598E 00	0.98246610E 00	0.96973366E 00	0.95256716E 00	0.93151665E 00
Z = 11.90476	0.98800081E 00	0.98538375E 00	0.97761261E 00	0.96494323E 00	0.94786197E 00	0.92691588E 00
Z = 14.28571	0.98179513E 00	0.97919452E 00	0.97147250E 00	0.95888311E 00	0.94190961E 00	0.92109573E 00
Z = 16.66666	0.97430396E 00	0.97172320E 00	0.96406001E 00	0.95156676E 00	0.93472278E 00	0.91406763E 00
Z = 19.04761	0.96554416E 00	0.96298653E 00	0.95539206E 00	0.94301081E 00	0.92631769E 00	0.90584779E 00
Z = 21.42856	0.95552617E 00	0.95299482E 00	0.94547838E 00	0.93322432E 00	0.91670287E 00	0.89644349E 00
Z = 23.80951	0.94423521E 00	0.94173384E 00	0.93430614E 00	0.92219710E 00	0.90587097E 00	0.88585114E 00
Z = 26.19046	0.93170249E 00	0.92923433E 00	0.92190540E 00	0.90995705E 00	0.89384782E 00	0.87409383E 00
Z = 28.57141	0.91794634E 00	0.91551453E 00	0.90829390E 00	0.89652210E 00	0.88065064E 00	0.86118835E 00
Z = 30.95236	0.90298450E 00	0.90059239E 00	0.89348930E 00	0.88190931E 00	0.86629653E 00	0.84715140E 00
Z = 33.33331	0.88685274E 00	0.88450325E 00	0.87752646E 00	0.86615235E 00	0.85081744E 00	0.83201283E 00
Z = 35.71426	0.86954485E 00	0.86724114E 00	0.86040050E 00	0.84924829E 00	0.83421242E 00	0.81577456E 00
Z = 38.09521	0.85109532E 00	0.84884048E 00	0.84214473E 00	0.83122897E 00	0.81651175E 00	0.79846483E 00
Z = 40.47617	0.83152413E 00	0.82932097E 00	0.82277936E 00	0.81211448E 00	0.79773569E 00	0.78010380E 00
Z = 42.85712	0.81085032E 00	0.80870199E 00	0.80232316E 00	0.79192370E 00	0.77790266E 00	0.76070946E 00
Z = 45.23807	0.78913033E 00	0.78703952E 00	0.78083122E 00	0.77070999E 00	0.75706404E 00	0.74033076E 00
Z = 47.61902	0.76637173E 00	0.76434118E 00	0.75831175E 00	0.74848199E 00	0.73522913E 00	0.71897793E 00
Z = 49.99997	0.74260628E 00	0.74063861E 00	0.73479587E 00	0.72527051E 00	0.71242797E 00	0.69667995E 00
Z = 52.38092	0.71786070E 00	0.71595854E 00	0.71031046E 00	0.70110232E 00	0.68868762E 00	0.67346430E 00
Z = 54.76187	0.69215375E 00	0.69031979E 00	0.68487418E 00	0.67599630E 00	0.66402668E 00	0.64934909E 00
Z = 57.14282	0.66556418E 00	0.66380054E 00	0.65856373E 00	0.65002644E 00	0.63851595E 00	0.62440139E 00
Z = 59.52377	0.63810152E 00	0.63641053E 00	0.63138944E 00	0.62320375E 00	0.61216742E 00	0.59863436E 00

GROUP 1 FLUX — PAGE 2

	R = 12.69230	R = 14.80769	R = 16.92307	R = 19.03844	R = 21.15381	R = 23.26918
Z = 0.0	0.91375738E 00	0.88674778E 00	0.85783345E 00	0.82761240E 00	0.79656589E 00	0.76502866E 00
Z = 2.38095	0.91348606E 00	0.88647884E 00	0.85756773E 00	0.82735085E 00	0.79630959E 00	0.76477867E 00
Z = 4.76190	0.91259462E 00	0.88561231E 00	0.85672790E 00	0.82653922E 00	0.79552710E 00	0.76402622E 00
Z = 7.14285	0.91051245E 00	0.88359010E 00	0.85477024E 00	0.82464921E 00	0.79370677E 00	0.76227689E 00
Z = 9.52381	0.90723592E 00	0.88040757E 00	0.85168850E 00	0.82167321E 00	0.79084003E 00	0.75952178E 00
Z = 11.90476	0.90275556E 00	0.87606019E 00	0.84748340E 00	0.81761682E 00	0.78693628E 00	0.75577283E 00
Z = 14.28571	0.89708769E 00	0.87056059E 00	0.84216386E 00	0.81248540E 00	0.78199786E 00	0.75103045E 00
Z = 16.66666	0.89024287E 00	0.86391813E 00	0.83573806E 00	0.80628598E 00	0.77603102E 00	0.74529982E 00
Z = 19.04761	0.88223654E 00	0.85614794E 00	0.82822073E 00	0.79903293E 00	0.76904953E 00	0.73859429E 00
Z = 21.42856	0.87307531E 00	0.84725535E 00	0.81961602E 00	0.79072934E 00	0.76105583E 00	0.73091573E 00
Z = 23.80951	0.86275917E 00	0.83724451E 00	0.80993181E 00	0.78138661E 00	0.75206381E 00	0.72227985E 00
Z = 26.19046	0.85130852E 00	0.82613266E 00	0.79918271E 00	0.77101654E 00	0.74208289E 00	0.71269429E 00
Z = 28.57141	0.83873963E 00	0.81393546E 00	0.78738344E 00	0.75963312E 00	0.73112667E 00	0.70217204E 00
Z = 30.95236	0.82506841E 00	0.80066842E 00	0.77454919E 00	0.74725109E 00	0.71920925E 00	0.69072646E 00

Z = 33.33331	0.81032288E 00	0.78635728E 00	0.76070321E 00	0.73389167E 00	0.70634985E 00	0.67837524E 00
Z = 35.71426	0.79450768E 00	0.77100962E 00	0.74585593E 00	0.71956736E 00	0.69256294E 00	0.66513413E 00
Z = 38.09521	0.77764881E 00	0.75464898E 00	0.73002863E 00	0.70429760E 00	0.67786586E 00	0.65101892E 00
Z = 40.47617	0.75976634E 00	0.73729527E 00	0.71324104E 00	0.68810159E 00	0.66227758E 00	0.63604796E 00
Z = 42.85712	0.74087799E 00	0.71896601E 00	0.69551021E 00	0.67099607E 00	0.64581436E 00	0.62023693E 00
Z = 45.23807	0.72102994E 00	0.69970423E 00	0.67687607E 00	0.65301812E 00	0.62851048E 00	0.60361797E 00
Z = 47.61902	0.70023316E 00	0.67952198E 00	0.65735167E 00	0.63418126E 00	0.61037999E 00	0.58620512E 00
Z = 49.99997	0.67851567E 00	0.65844601E 00	0.63696235E 00	0.61450988E 00	0.59144622E 00	0.56802064E 00
Z = 52.38092	0.65590513E 00	0.63650393E 00	0.61573613E 00	0.59403151E 00	0.57173634E 00	0.54909116E 00
Z = 54.76187	0.63241941E 00	0.61371369E 00	0.59369016E 00	0.57276344E 00	0.55126703E 00	0.52943307E 00
Z = 57.14282	0.60812122E 00	0.59013325E 00	0.57087815E 00	0.55075467E 00	0.53008354E 00	0.50908804E 00
Z = 59.52377	0.58302492E 00	0.56577814E 00	0.54731655E 00	0.52802253E 00	0.50820363E 00	0.48807400E 00

GROUP 1 FLUX

	R = 25.38455	R = 27.49992	R = 29.61530	R = 31.73067	R = 33.84604	R = 35.96141
Z = 0.0	0.73316914E 00	0.70098239E 00	0.66830802E 00	0.63485038E 00	0.60021716E 00	0.56396770E 00
Z = 2.38095	0.73292667E 00	0.70074886E 00	0.66808450E 00	0.63463825E 00	0.60001749E 00	0.56378168E 00
Z = 4.76190	0.73220485E 00	0.70005810E 00	0.66742581E 00	0.63401252E 00	0.59942615E 00	0.56322634E 00
Z = 7.14286	0.73052764E 00	0.69845402E 00	0.66589630E 00	0.63255954E 00	0.59805268E 00	0.56193632E 00
Z = 9.52381	0.72788578E 00	0.69592714E 00	0.66348678E 00	0.63027072E 00	0.59588921E 00	0.55990422E 00
Z = 11.90476	0.72429311E 00	0.69249237E 00	0.66021204E 00	0.62715983E 00	0.59294784E 00	0.55714023E 00
Z = 14.28571	0.71974850E 00	0.68814743E 00	0.65606964E 00	0.62322468E 00	0.58922714E 00	0.55364394E 00
Z = 16.66666	0.71425647E 00	0.68289649E 00	0.65106344E 00	0.61846906E 00	0.58473080E 00	0.54941905E 00
Z = 19.04761	0.70783001E 00	0.67675185E 00	0.64520502E 00	0.61290389E 00	0.57946932E 00	0.54447550E 00
Z = 21.42856	0.70047015E 00	0.66971451E 00	0.63849550E 00	0.60653037E 00	0.57344395E 00	0.53881466E 00
Z = 23.80951	0.69219404E 00	0.66180182E 00	0.63095158E 00	0.59936404E 00	0.56666839E 00	0.53244811E 00
Z = 26.19046	0.68300778E 00	0.65301883E 00	0.62257802E 00	0.59140956E 00	0.55914772E 00	0.52538151E 00
Z = 28.57141	0.67292374E 00	0.64337754E 00	0.61338615E 00	0.58267778E 00	0.55089217E 00	0.51762438E 00
Z = 30.95236	0.66195488E 00	0.63289022E 00	0.60338759E 00	0.57317984E 00	0.54191232E 00	0.50918674E 00
Z = 33.33331	0.65011746E 00	0.62157220E 00	0.59259707E 00	0.56292975E 00	0.53222179E 00	0.50008208E 00
Z = 35.71426	0.63742769E 00	0.60943943E 00	0.58102989E 00	0.55194157E 00	0.52183312E 00	0.49032068E 00
Z = 38.09521	0.62390023E 00	0.59650582E 00	0.56869900E 00	0.54022795E 00	0.51075858E 00	0.47991496E 00
Z = 40.47617	0.60955280E 00	0.58278823E 00	0.55562091E 00	0.52780455E 00	0.49901271E 00	0.46887851E 00
Z = 42.85712	0.59440058E 00	0.56830144E 00	0.54180938E 00	0.51468444E 00	0.48660815E 00	0.45722282E 00
Z = 45.23807	0.57847351E 00	0.55307353E 00	0.52729130E 00	0.50089329E 00	0.47356957E 00	0.44497180E 00
Z = 47.61902	0.56178570E 00	0.53711826E 00	0.51207972E 00	0.48644316E 00	0.45990771E 00	0.43213516E 00
Z = 49.99997	0.54435831E 00	0.52045584E 00	0.49619389E 00	0.47135276E 00	0.44564056E 00	0.41872984E 00
Z = 52.38092	0.52621734E 00	0.50311130E 00	0.47965777E 00	0.45564443E 00	0.43078917E 00	0.40477526E 00
Z = 54.76187	0.50737840E 00	0.48509979E 00	0.46248591E 00	0.43933213E 00	0.41536659E 00	0.39028364E 00
Z = 57.14282	0.48788053E 00	0.46645772E 00	0.44471288E 00	0.42244911E 00	0.39940476E 00	0.37528610E 00
Z = 59.52377	0.46774125E 00	0.44720250E 00	0.42635506E 00	0.40501028E 00	0.38291734E 00	0.35979468E 00

GROUP 1 FLUX

	R = 38.07678	R = 40.19215	R = 42.30753	R = 44.42290	R = 46.53827	R = 48.65364
Z = 0.0	0.52566218E 00	0.48491985E 00	0.44143677E 00	0.39505965E 00	0.34580159E 00	0.29385775E 00
Z = 2.38095	0.52549064E 00	0.48476356E 00	0.44129670E 00	0.39493608E 00	0.34569502E 00	0.29376829E 00
Z = 4.76190	0.52497345E 00	0.48428702E 00	0.44086337E 00	0.39454871E 00	0.34535635E 00	0.29349087E 00
Z = 7.14286	0.52377158E 00	0.48317879E 00	0.43985504E 00	0.39364678E 00	0.34456724E 00	0.29281062E 00
Z = 9.52381	0.52187854E 00	0.48143345E 00	0.43826735E 00	0.39222682E 00	0.34332514E 00	0.29175568E 00
Z = 11.90476	0.51930195E 00	0.47905642E 00	0.43610299E 00	0.39028966E 00	0.34162939E 00	0.29031450E 00

Z = 14.28571	0.51604277E 00	0.47604948E 00	0.43336535E 00	0.38783944E 00	0.33948427E 00	0.28849149E 00
Z = 16.66666	0.51210475E 00	0.47241658E 00	0.43005812E 00	0.38487953E 00	0.33689344E 00	0.28628975E 00
Z = 19.04761	0.50749707E 00	0.46816623E 00	0.42618912E 00	0.38141716E 00	0.33386290E 00	0.28371453E 00
Z = 21.42856	0.50222152E 00	0.46330035E 00	0.42176038E 00	0.37745446E 00	0.33039486E 00	0.28076786E 00
Z = 23.80951	0.49628723E 00	0.45782584E 00	0.41677660E 00	0.37299407E 00	0.32649046E 00	0.27744991E 00
Z = 26.19046	0.48970038E 00	0.45174932E 00	0.41124475E 00	0.36804330E 00	0.32215685E 00	0.27376717E 00
Z = 28.57141	0.48247010E 00	0.44507933E 00	0.40517271E 00	0.36260903E 00	0.31740016E 00	0.26972491E 00
Z = 30.95236	0.47460544E 00	0.43782419E 00	0.39856809E 00	0.35669822E 00	0.31222618E 00	0.26532817E 00
Z = 33.33331	0.46611983E 00	0.42999697E 00	0.39144337E 00	0.35032272E 00	0.30664611E 00	0.26058662E 00
Z = 35.71426	0.45702147E 00	0.42160362E 00	0.38380277E 00	0.34348470E 00	0.30066073E 00	0.25550026E 00
Z = 38.09521	0.44732255E 00	0.41265649E 00	0.37565792E 00	0.33619553E 00	0.29428047E 00	0.25007844E 00
Z = 40.47617	0.43703556E 00	0.40316671E 00	0.36701900E 00	0.32846415E 00	0.28751296E 00	0.24432743E 00
Z = 42.85712	0.42617124E 00	0.39314413E 00	0.35789484E 00	0.32029837E 00	0.28036505E 00	0.23825300E 00
Z = 45.23807	0.41475254E 00	0.38261062E 00	0.34830606E 00	0.31171715E 00	0.27285391E 00	0.23187029E 00
Z = 47.61902	0.40278786E 00	0.37157339E 00	0.33825856E 00	0.30272532E 00	0.26498336E 00	0.22518206E 00
Z = 49.99997	0.39029318E 00	0.36004734E 00	0.32776630E 00	0.29333550E 00	0.25676441E 00	0.21819782E 00
Z = 52.38092	0.37728631E 00	0.34804851E 00	0.31684327E 00	0.28355998E 00	0.24820775E 00	0.21092629E 00
Z = 54.76187	0.36377853E 00	0.33558708E 00	0.30549890E 00	0.27340698E 00	0.23932022E 00	0.20337355E 00
Z = 57.14282	0.34979993E 00	0.32269228E 00	0.29376048E 00	0.26290208E 00	0.23012537E 00	0.19556004E 00
Z = 59.52377	0.33536088E 00	0.30937266E 00	0.28163540E 00	0.25205112E 00	0.22062749E 00	0.18748903E 00

GROUP 1 FLUX PAGE 5

	R = 50.76901	R = 52.88438	R = 54.99976	R = 56.24976	R = 57.49976	R = 58.74976
Z = 0.0	0.23959398E 00	0.18354768E 00	0.12638438E 00	0.92487454E-01	0.60405802E-01	0.29708762E-01
Z = 2.38095	0.23952186E 00	0.18349290E 00	0.12634677E 00	0.92459977E-01	0.60387827E-01	0.29699929E-01
Z = 4.76190	0.23928773E 00	0.18331361E 00	0.12622339E 00	0.92369616E-01	0.60328834E-01	0.29670913E-01
Z = 7.14286	0.23874146E 00	0.18289518E 00	0.12593526E 00	0.92158854E-01	0.60191162E-01	0.29603206E-01
Z = 9.52381	0.23788178E 00	0.18223691E 00	0.12548208E 00	0.91827273E-01	0.59974533E-01	0.29496659E-01
Z = 11.90476	0.23670655E 00	0.18133652E 00	0.12486207E 00	0.91373444E-01	0.59678219E-01	0.29350925E-01
Z = 14.28571	0.23522002E 00	0.18019760E 00	0.12407798E 00	0.90799630E-01	0.59303399E-01	0.29166583E-01
Z = 16.66666	0.23342484E 00	0.17882246E 00	0.12313098E 00	0.90106666E-01	0.58850806E-01	0.28943989E-01
Z = 19.04761	0.23132527E 00	0.17721397E 00	0.12202340E 00	0.89296222E-01	0.58321480E-01	0.28683655E-01
Z = 21.42856	0.22892308E 00	0.17537391E 00	0.12075651E 00	0.88368952E-01	0.57715934E-01	0.28385837E-01
Z = 23.80951	0.22621775E 00	0.17330134E 00	0.11932945E 00	0.87324679E-01	0.57033852E-01	0.28050371E-01
Z = 26.19046	0.22321504E 00	0.17100102E 00	0.11774546E 00	0.86165607E-01	0.56276791E-01	0.27678039E-01
Z = 28.57141	0.21991909E 00	0.16847605E 00	0.11600685E 00	0.84893286E-01	0.55445828E-01	0.27269349E-01
Z = 30.95236	0.21633428E 00	0.16572976E 00	0.11411583E 00	0.83509386E-01	0.54542016E-01	0.26824843E-01
Z = 33.33331	0.21246856E 00	0.16276849E 00	0.11207688E 00	0.82017303E-01	0.53567465E-01	0.26345536E-01
Z = 35.71426	0.20832139E 00	0.15959150E 00	0.10988921E 00	0.80416441E-01	0.52521907E-01	0.25831308E-01
Z = 38.09521	0.20390075E 00	0.15620488E 00	0.10755742E 00	0.78709960E-01	0.51407389E-01	0.25283165E-01
Z = 40.47617	0.19921172E 00	0.15261275E 00	0.10508388E 00	0.76899946E-01	0.50225187E-01	0.24701737E-01
Z = 42.85712	0.19425893E 00	0.14881843E 00	0.10247135E 00	0.74988008E-01	0.48976470E-01	0.24087593E-01
Z = 45.23807	0.18905491E 00	0.14483178E 00	0.99726260E-01	0.72979271E-01	0.47664464E-01	0.23442321E-01
Z = 47.61902	0.18360168E 00	0.14065427E 00	0.96849680E-01	0.70874155E-01	0.46289623E-01	0.22766151E-01
Z = 49.99997	0.17790729E 00	0.13629186E 00	0.93845904E-01	0.68676114E-01	0.44853974E-01	0.22060070E-01
Z = 52.38092	0.17197847E 00	0.13174987E 00	0.90718627E-01	0.66387415E-01	0.43359220E-01	0.21324918E-01
Z = 54.76187	0.16582018E 00	0.12703210E 00	0.87469995E-01	0.64010203E-01	0.41806567E-01	0.20561289E-01
Z = 57.14282	0.15944964E 00	0.12215179E 00	0.84109664E-01	0.61551120E-01	0.40200457E-01	0.19771375E-01
Z = 59.52377	0.15286911E 00	0.11711067E 00	0.80638468E-01	0.59010949E-01	0.38541414E-01	0.18955428E-01

GROUP 1 FLUX PAGE 6

	R = 59.99976
Z = 0.0	-0.11065526E-06
Z = 2.38095	-0.11062173E-06
Z = 4.76190	-0.11051338E-06
Z = 7.14286	-0.11026106E-06
Z = 9.52381	-0.10986389E-06
Z = 11.90476	-0.10932115E-06
Z = 14.28571	-0.10863459E-06
Z = 16.66666	-0.10780553E-06
Z = 19.04761	-0.10683584E-06
Z = 21.42856	-0.10572626E-06
Z = 23.80951	-0.10447684E-06
Z = 26.19046	-0.10308997E-06
Z = 28.57141	-0.10156782E-06
Z = 30.95236	-0.99912199E-07
Z = 33.33331	-0.98126748E-07
Z = 35.71426	-0.96211465E-07
Z = 38.09521	-0.94169764E-07
Z = 40.47617	-0.92004143E-07
Z = 42.85712	-0.89716764E-07
Z = 45.23807	-0.87313254E-07
Z = 47.61902	-0.84794692E-07
Z = 49.99997	-0.82164718E-07
Z = 52.38092	-0.79426570E-07
Z = 54.76187	-0.76582523E-07
Z = 57.14282	-0.73640251E-07
Z = 59.52377	-0.70601061E-07

GROUP 1 FLUX

	R = 0.0	R = 2.11538	R = 4.23077	R = 6.34615	R = 8.46154	R = 10.57692
Z = 61.90472	0.60980242E 00	0.60818619E 00	0.60338730E 00	0.59556377E 00	0.58501571E 00	0.57208151E 00
Z = 64.28568	0.58069402E 00	0.57915497E 00	0.57458490E 00	0.56713456E 00	0.55708975E 00	0.54477245E 00
Z = 66.66663	0.55079067E 00	0.54933101E 00	0.54499668E 00	0.53793067E 00	0.52840400E 00	0.51672214E 00
Z = 69.04758	0.52019936E 00	0.51882070E 00	0.51472700E 00	0.50805318E 00	0.49905521E 00	0.48802173E 00
Z = 71.42853	0.48893225E 00	0.48763627E 00	0.48378795E 00	0.47751427E 00	0.46905595E 00	0.45868421E 00
Z = 73.80948	0.45702571E 00	0.45581406E 00	0.45221615E 00	0.44635063E 00	0.43844259E 00	0.42874575E 00
Z = 76.19043	0.42450845E 00	0.42338288E 00	0.42004055E 00	0.41459179E 00	0.40724570E 00	0.39823788E 00
Z = 78.57138	0.39138430E 00	0.39034677E 00	0.38726586E 00	0.38224328E 00	0.37547177E 00	0.36716837E 00
Z = 80.95233	0.35779810E 00	0.35684949E 00	0.35403264E 00	0.34944040E 00	0.34324920E 00	0.33565742E 00
Z = 83.33328	0.32375228E 00	0.32289362E 00	0.32034391E 00	0.31618720E 00	0.31058306E 00	0.30371147E 00
Z = 85.71423	0.28928542E 00	0.28851771E 00	0.28623813E 00	0.28252202E 00	0.27751189E 00	0.27136880E 00
Z = 88.09518	0.25442696E 00	0.25375152E 00	0.25174588E 00	0.24847615E 00	0.24406815E 00	0.23866338E 00
Z = 90.47614	0.21914488E 00	0.21856350E 00	0.21683717E 00	0.21402276E 00	0.21022826E 00	0.20557564E 00
Z = 92.85709	0.18367541E 00	0.18318766E 00	0.18173903E 00	0.17937756E 00	0.17619395E 00	0.17229062E 00
Z = 95.23804	0.14797539E 00	0.14758164E 00	0.14641273E 00	0.14450711E 00	0.14193833E 00	0.13878906E 00
Z = 97.61899	0.11208808E 00	0.11178887E 00	0.11090058E 00	0.10945272E 00	0.10750115E 00	0.10510892E 00
Z = 99.99994	0.76052189E-01	0.75847924E-01	0.75241685E-01	0.74253619E-01	0.72922111E-01	0.71290493E-01
Z =100.99994	0.60921367E-01	0.60760066E-01	0.60281016E-01	0.59499722E-01	0.58445718E-01	0.57152230E-01
Z =101.99994	0.45824539E-01	0.45702886E-01	0.45341589E-01	0.44752281E-01	0.43957170E-01	0.42981204E-01
Z =102.99994	0.30761868E-01	0.30679606E-01	0.30435294E-01	0.30036766E-01	0.29498924E-01	0.28838601E-01
Z =103.99994	0.15374731E-01	0.15333652E-01	0.15211646E-01	0.15012607E-01	0.14743999E-01	0.14414202E-01
Z =104.99994	-0.56275741E-07	-0.56191723E-07	-0.55940102E-07	-0.55521518E-07	-0.54942088E-07	-0.54204914E-07

	R = 12.69230	R = 14.80769	R = 16.92307	R = 19.03844	R = 21.15381	R = 23.26918
Z = 61.90472	0.55716300E 00	0.54067969E 00	0.52303553E 00	0.50459599E 00	0.48565519E 00	0.46641755E 00
Z = 64.28568	0.53056550E 00	0.51486868E 00	0.49806631E 00	0.48050660E 00	0.46246952E 00	0.44414997E 00
Z = 66.66663	0.50324792E 00	0.48836046E 00	0.47242445E 00	0.45576978E 00	0.43866235E 00	0.42128670E 00
Z = 69.04758	0.47529542E 00	0.46123421E 00	0.44618285E 00	0.43045288E 00	0.41429520E 00	0.39788425E 00
Z = 71.42853	0.44672132E 00	0.43350375E 00	0.41935551E 00	0.40456975E 00	0.38938218E 00	0.37395692E 00
Z = 73.80948	0.41756141E 00	0.40520430E 00	0.39197743E 00	0.37815481E 00	0.36395699E 00	0.34953749E 00
Z = 76.19043	0.38784844E 00	0.37636960E 00	0.36408287E 00	0.35124796E 00	0.33805460E 00	0.32466060E 00
Z = 78.57138	0.35759127E 00	0.34700972E 00	0.33568323E 00	0.32384652E 00	0.31168830E 00	0.29934001E 00
Z = 80.95233	0.32690102E 00	0.31722653E 00	0.30687112E 00	0.29604930E 00	0.28493369E 00	0.27364463E 00
Z = 83.33328	0.29578590E 00	0.28702962E 00	0.27765721E 00	0.26786309E 00	0.25780368E 00	0.24758762E 00
Z = 85.71423	0.26428378E 00	0.25645638E 00	0.24807864E 00	0.23932457E 00	0.23033404E 00	0.22120416E 00
Z = 88.09518	0.23242986E 00	0.22554356E 00	0.21817338E 00	0.21047240E 00	0.20256364E 00	0.19453293E 00
Z = 90.47614	0.20020968E 00	0.19428104E 00	0.18793565E 00	0.18130487E 00	0.17449450E 00	0.16757852E 00
Z = 92.85709	0.16778910E 00	0.16281635E 00	0.15749454E 00	0.15193427E 00	0.14622456E 00	0.14042729E 00
Z = 95.23804	0.13515753E 00	0.13114643E 00	0.12685448E 00	0.12237108E 00	0.11776829E 00	0.11309594E 00
Z = 97.61899	0.10235095E 00	0.99305511E-01	0.96047997E-01	0.92646360E-01	0.89155674E-01	0.85613966E-01
Z = 99.99994	0.69410145E-01	0.67334712E-01	0.65116107E-01	0.62801003E-01	0.60427144E-01	0.58020696E-01
Z =100.99994	0.55658780E-01	0.54006733E-01	0.52235957E-01	0.50382670E-01	0.48476167E-01	0.46537098E-01
Z =101.99994	0.41854132E-01	0.40607061E-01	0.39270025E-01	0.37870340E-01	0.36430173E-01	0.34965198E-01
Z =102.99994	0.28075803E-01	0.27231533E-01	0.26326086E-01	0.25377985E-01	0.24402313E-01	0.23409870E-01
Z =103.99994	0.14033206E-01	0.13611495E-01	0.13159189E-01	0.12685534E-01	0.12198050E-01	0.11702139E-01
Z =104.99994	-0.53314814E-07	-0.52276480E-07	-0.51093910E-07	-0.49770904E-07	-0.48309602E-07	-0.46711154E-07

	R = 25.38455	R = 27.49992	R = 29.61530	R = 31.73067	R = 33.84604	R = 35.96141
Z = 61.90472	0.44698638E 00	0.42735839E 00	0.40743595E 00	0.38703841E 00	0.36592609E 00	0.34382987E 00
Z = 64.28568	0.42564613E 00	0.40695512E 00	0.38798368E 00	0.36855984E 00	0.34845561E 00	0.32741439E 00
Z = 66.66663	0.40373582E 00	0.38600719E 00	0.36801243E 00	0.34958833E 00	0.33051860E 00	0.31056005E 00
Z = 69.04758	0.38130808E 00	0.36456406E 00	0.34756869E 00	0.33016801E 00	0.31215769E 00	0.29330790E 00
Z = 71.42853	0.35837668E 00	0.34263915E 00	0.32666564E 00	0.31031156E 00	0.29338461E 00	0.27566898E 00
Z = 73.80948	0.33497345E 00	0.32026285E 00	0.30533236E 00	0.29004633E 00	0.27422523E 00	0.25766730E 00
Z = 76.19043	0.31113255E 00	0.29746860E 00	0.28360045E 00	0.26940238E 00	0.25470752E 00	0.23932809E 00
Z = 78.57138	0.28686780E 00	0.27426982E 00	0.26148331E 00	0.24839222E 00	0.23484278E 00	0.22066218E 00
Z = 80.95233	0.26224250E 00	0.25072557E 00	0.23903650E 00	0.22706932E 00	0.21468323E 00	0.20172018E 00
Z = 83.33328	0.23727000E 00	0.22684890E 00	0.21627271E 00	0.20544523E 00	0.19423920E 00	0.18251139E 00
Z = 85.71423	0.21198416E 00	0.20267266E 00	0.19322318E 00	0.18354994E 00	0.17353874E 00	0.16306198E 00
Z = 88.09518	0.18642330E 00	0.17823368E 00	0.16992331E 00	0.16141641E 00	0.15261281E 00	0.14339983E 00
Z = 90.47614	0.16059387E 00	0.15353954E 00	0.14638042E 00	0.13905162E 00	0.13146675E 00	0.12352884E 00
Z = 92.85709	0.13457358E 00	0.12866277E 00	0.12266505E 00	0.11652583E 00	0.11017257E 00	0.10352373E 00
Z = 95.23804	0.10837954E 00	0.10361814E 00	0.98787904E-01	0.93844712E-01	0.88729858E-01	0.83377421E-01
Z = 97.61899	0.82040429E-01	0.78434765E-01	0.74778557E-01	0.71038246E-01	0.67169070E-01	0.63120782E-01
Z = 99.99994	0.55594895E-01	0.53149439E-01	0.50671849E-01	0.48138998E-01	0.45520153E-01	0.42780738E-01
Z =100.99994	0.44576220E-01	0.42593997E-01	0.40581640E-01	0.38522266E-01	0.36393218E-01	0.34168899E-01
Z =101.99994	0.33483725E-01	0.31986337E-01	0.30466698E-01	0.28912399E-01	0.27306676E-01	0.25630541E-01
Z =102.99994	0.22406526E-01	0.21393005E-01	0.20365383E-01	0.19315679E-01	0.18232968E-01	0.17104786E-01
Z =103.99994	0.11200715E-01	0.10694150E-01	0.10180481E-01	0.96557215E-02	0.91144219E-02	0.85503682E-02
Z =104.99994	-0.44975465E-07	-0.43101231E-07	-0.41086782E-07	-0.38930256E-07	-0.36630368E-07	-0.34187273E-07

GROUP 1 FLUX

	R = 38.07678	R = 40.19215	R = 42.30753	R = 44.42290	R = 46.53827	R = 48.65364
Z = 61.90472	0.32048082E 00	0.29564619E 00	0.26914024E 00	0.24086899E 00	0.21083993E 00	0.17917198E 00
Z = 64.28568	0.30518031E 00	0.28153151E 00	0.25629115E 00	0.22936970E 00	0.20077443E 00	0.17061830E 00
Z = 66.66663	0.28946984E 00	0.26703793E 00	0.24309647E 00	0.21756053E 00	0.19043708E 00	0.16183335E 00
Z = 69.04758	0.27338946E 00	0.25220382E 00	0.22959244E 00	0.20547521E 00	0.17985845E 00	0.15284383E 00
Z = 71.42853	0.25694895E 00	0.23703790E 00	0.21578687E 00	0.19312036E 00	0.16904449E 00	0.14365435E 00
Z = 73.80948	0.24017054E 00	0.22156054E 00	0.20169801E 00	0.18051213E 00	0.15800875E 00	0.13427669E 00
Z = 76.19043	0.22307706E 00	0.20579195E 00	0.18734330E 00	0.16766554E 00	0.14676392E 00	0.12472093E 00
Z = 78.57138	0.20567775E 00	0.18973988E 00	0.17272949E 00	0.15458596E 00	0.13531423E 00	0.11499047E 00
Z = 80.95233	0.18802243E 00	0.17345315E 00	0.15790319E 00	0.14131743E 00	0.12370020E 00	0.10512108E 00
Z = 83.33329	0.17011887E 00	0.15693790E 00	0.14286965E 00	0.12786388E 00	0.11192453E 00	0.95114648E-01
Z = 85.71423	0.15199143E 00	0.14021641E 00	0.12764847E 00	0.11424267E 00	0.10000241E 00	0.84983826E-01
Z = 88.09518	0.13366491E 00	0.12331045E 00	0.11225861E 00	0.10046977E 00	0.87946892E-01	0.74739397E-01
Z = 90.47614	0.11514127E 00	0.10622025E 00	0.96698463E-01	0.86542249E-01	0.75754225E-01	0.64376950E-01
Z = 92.85709	0.96498013E-01	0.89024723E-01	0.81047714E-01	0.72538018E-01	0.63498020E-01	0.53963114E-01
Z = 95.23804	0.77721596E-01	0.71705341E-01	0.65282762E-01	0.58430810E-01	0.51150776E-01	0.43471396E-01
Z = 97.61899	0.58842957E-01	0.54292005E-01	0.49432982E-01	0.44247936E-01	0.38737800E-01	0.32924142E-01
Z = 99.99994	0.39886121E-01	0.36806219E-01	0.33516850E-01	0.30005455E-01	0.26272397E-01	0.22332158E-01
Z =100.99994	0.31823665E-01	0.29335313E-01	0.26686113E-01	0.23867179E-01	0.20879421E-01	0.17734479E-01
Z =101.99994	0.23864940E-01	0.21993350E-01	0.20002559E-01	0.17885927E-01	0.15644100E-01	0.13285723E-01
Z =102.99994	0.15918594E-01	0.14663465E-01	0.13330635E-01	0.11915646E-01	0.10418862E-01	0.88458918E-02
Z =103.99994	0.79573095E-02	0.73297843E-02	0.66634342E-02	0.59560426E-02	0.52077845E-02	0.44214875E-02
Z =104.99994	-0.31603140E-07	-0.28882752E-07	-0.26033984E-07	-0.23068427E-07	-0.20001490E-07	-0.16852333E-07

GROUP 1 FLUX

	R = 50.76901	R = 52.88438	R = 54.99976	R = 56.24976	R = 57.49976	R = 58.74976
Z = 61.90472	0.14608800E 00	0.11191589E 00	0.77061594E-01	0.56393381E-01	0.36831819E-01	0.18114615E-01
Z = 64.28568	0.13911384E 00	0.10657310E 00	0.73382735E-01	0.53701226E-01	0.35073508E-01	0.17249849E-01
Z = 66.66663	0.13195080E 00	0.10108548E 00	0.69604099E-01	0.50936028E-01	0.33267502E-01	0.16361605E-01
Z = 69.04758	0.12462127E 00	0.95470428E-01	0.65737844E-01	0.48106678E-01	0.31419583E-01	0.15452772E-01
Z = 71.42853	0.11712885E 00	0.89730799E-01	0.61785787E-01	0.45214556E-01	0.29530670E-01	0.14523767E-01
Z = 73.80948	0.10948312E 00	0.83873749E-01	0.57752818E-01	0.42263255E-01	0.27603105E-01	0.13575755E-01
Z = 76.19043	0.10169202E 00	0.77905059E-01	0.53643014E-01	0.39255716E-01	0.25638815E-01	0.12609672E-01
Z = 78.57138	0.93757808E-01	0.71826696E-01	0.49457580E-01	0.36192838E-01	0.23638375E-01	0.11625819E-01
Z = 80.95233	0.85710943E-01	0.65662146E-01	0.45212887E-01	0.33086587E-01	0.21609612E-01	0.10628033E-01
Z = 83.33328	0.77552557E-01	0.59412369E-01	0.40909506E-01	0.29937398E-01	0.19552801E-01	0.96164532E-02
Z = 85.71423	0.69292903E-01	0.53085048E-01	0.36552794E-01	0.26749171E-01	0.17470501E-01	0.85923336E-02
Z = 88.09518	0.60940325E-01	0.46686254E-01	0.32146819E-01	0.23524899E-01	0.15364651E-01	0.75566359E-02
Z = 90.47614	0.52490462E-01	0.40212516E-01	0.27689099E-01	0.20262759E-01	0.13234075E-01	0.65087751E-02
Z = 92.85709	0.44000506E-01	0.33709038E-01	0.23211166E-01	0.16985826E-01	0.11093836E-01	0.54561608E-02
Z = 95.23804	0.35446752E-01	0.27156491E-01	0.18699400E-01	0.13684135E-01	0.89374222E-02	0.43956004E-02
Z = 97.61899	0.26847918E-01	0.20569533E-01	0.14163960E-01	0.10365125E-01	0.67696944E-02	0.33294749E-02
Z = 99.99994	0.18212490E-01	0.13954472E-01	0.96091554E-02	0.70319325E-02	0.45927167E-02	0.22587925E-02
Z =100.99994	0.14454059E-01	0.11069983E-01	0.76216236E-02	0.55774637E-02	0.36427758E-02	0.17915892E-02
Z =101.99994	0.10826927E-01	0.82913786E-02	0.57083927E-02	0.41773766E-02	0.27283435E-02	0.13418533E-02
Z =102.99994	0.72073042E-02	0.55186674E-02	0.37992608E-02	0.27802796E-02	0.18158646E-02	0.89307805E-03
Z =103.99994	0.36024251E-02	0.27583700E-02	0.18989588E-02	0.13896481E-02	0.90761110E-03	0.44638081E-03
Z =104.99994	-0.13642939E-07	-0.10398534E-07	-0.71459958E-08	-0.52293956E-08	-0.34154413E-08	-0.16797814E-08

	R = 59.99976
Z = 61.90472	-0.67469216E-07
Z = 64.28568	-0.64248297E-07
Z = 66.66663	-0.60940124E-07
Z = 69.04758	-0.57555038E-07
Z = 71.42853	-0.54094695E-07
Z = 73.80948	-0.50563493E-07
Z = 76.19043	-0.46965155E-07
Z = 78.57138	-0.43300950E-07
Z = 80.95233	-0.39584513E-07
Z = 83.33328	-0.35816537E-07
Z = 85.71423	-0.32001793E-07
Z = 88.09518	-0.28144097E-07
Z = 90.47614	-0.24241746E-07
Z = 92.85709	-0.20321053E-07
Z = 95.23804	-0.16370521E-07
Z = 97.61899	-0.12399159E-07
Z = 99.99994	-0.84108400E-08
Z =100.99994	-0.66692678E-08
Z =101.99994	-0.49936446E-08
Z =102.99994	-0.33214567E-08
Z =103.99994	-0.16601720E-08
Z =104.99994	0.63102159E-14

GROUP 2 FLUX PAGE 1

	R = 0.0	R = 2.11538	R = 4.23077	R = 6.34615	R = 8.46154	R = 10.57692
Z = 0.0	0.56396747E 00	0.56290454E 00	0.55965763E 00	0.55428326E 00	0.54690492E 00	0.53760213E 00
Z = 2.38095	0.56379837E 00	0.56273556E 00	0.55948925E 00	0.55411583E 00	0.54673886E 00	0.53743780E 00
Z = 4.76190	0.56324768E 00	0.56218576E 00	0.55894262E 00	0.55357432E 00	0.54620427E 00	0.53691202E 00
Z = 7.14286	0.56196207E 00	0.56090260E 00	0.55766672E 00	0.55231047E 00	0.54495710E 00	0.53568572E 00
Z = 9.52381	0.55993891E 00	0.55888325E 00	0.55565876E 00	0.55032146E 00	0.54299402E 00	0.53375554E 00
Z = 11.90476	0.55717373E 00	0.55612320E 00	0.55291480E 00	0.54760391E 00	0.54031265E 00	0.53111988E 00
Z = 14.28571	0.55367571E 00	0.55263186E 00	0.54944354E 00	0.54416603E 00	0.53692079E 00	0.52778584E 00
Z = 16.66666	0.54945099E 00	0.54841512E 00	0.54525113E 00	0.54001397E 00	0.53282392E 00	0.52375865E 00
Z = 19.04761	0.54450935E 00	0.54348284E 00	0.54034716E 00	0.53515697E 00	0.52803159E 00	0.51904780E 00
Z = 21.42856	0.53885454E 00	0.53783852E 00	0.53473532E 00	0.52959883E 00	0.52254701E 00	0.51365614E 00
Z = 23.80951	0.53248739E 00	0.53148347E 00	0.52841693E 00	0.52334118E 00	0.51637268E 00	0.50758684E 00
Z = 26.19046	0.52542019E 00	0.52442956E 00	0.52140373E 00	0.51639527E 00	0.50951940E 00	0.50085020E 00
Z = 28.57141	0.51766270E 00	0.51668668E 00	0.51370555E 00	0.50877106E 00	0.50199676E 00	0.49345547E 00
Z = 30.95236	0.50922489E 00	0.50826478E 00	0.50533229E 00	0.50047821E 00	0.49381423E 00	0.48541218E 00
Z = 33.33331	0.50012374E 00	0.49918067E 00	0.49630052E 00	0.49153292E 00	0.48498785E 00	0.47673571E 00
Z = 35.71426	0.49036258E 00	0.48943800E 00	0.48661393E 00	0.48193949E 00	0.47552204E 00	0.46743089E 00
Z = 38.09521	0.47995734E 00	0.47905236E 00	0.47628814E 00	0.47171289E 00	0.46543157E 00	0.45751202E 00
Z = 40.47617	0.46892041E 00	0.46803623E 00	0.46533561E 00	0.46086544E 00	0.45472854E 00	0.44699115E 00
Z = 42.85712	0.45726275E 00	0.45640063E 00	0.45376712E 00	0.44940817E 00	0.44342387E 00	0.43587887E 00
Z = 45.23807	0.44501257E 00	0.44417340E 00	0.44161046E 00	0.43736821E 00	0.43154418E 00	0.42420119E 00
Z = 47.61902	0.43217671E 00	0.43136185E 00	0.42887276E 00	0.42475277E 00	0.41909665E 00	0.41196531E 00
Z = 49.99997	0.41877270E 00	0.41798300E 00	0.41557109E 00	0.41157883E 00	0.40609789E 00	0.39918762E 00
Z = 52.38092	0.40481758E 00	0.40405428E 00	0.40172261E 00	0.39786339E 00	0.39256513E 00	0.38588506E 00
Z = 54.76187	0.39032263E 00	0.38958657E 00	0.38733858E 00	0.38361746E 00	0.37850910E 00	0.37206835E 00
Z = 57.14282	0.37532580E 00	0.37461805E 00	0.37245631E 00	0.36887819E 00	0.36396587E 00	0.35777247E 00
Z = 59.52377	0.35983628E 00	0.35915774E 00	0.35708511E 00	0.35365450E 00	0.34894472E 00	0.34300673E 00

	R = 12.69230	R = 14.80769	R = 16.92307	R = 19.03844	R = 21.15381	R = 23.26918
Z = 0.0	0.52652085E 00	0.51380259E 00	0.49958479E 00	0.48400396E 00	0.46717703E 00	0.44920164E 00
Z = 2.38095	0.52635878E 00	0.51364326E 00	0.49942863E 00	0.48385155E 00	0.46702886E 00	0.44905829E 00
Z = 4.76190	0.52584362E 00	0.51314014E 00	0.49893916E 00	0.48337704E 00	0.46657056E 00	0.44861734E 00
Z = 7.14286	0.52464223E 00	0.51196748E 00	0.49779868E 00	0.48227179E 00	0.46550351E 00	0.44759113E 00
Z = 9.52381	0.52275127E 00	0.51012158E 00	0.49600321E 00	0.48053175E 00	0.46382338E 00	0.44597518E 00
Z = 11.90476	0.52017009E 00	0.50760287E 00	0.49355429E 00	0.47815919E 00	0.46153355E 00	0.44377351E 00
Z = 14.28571	0.51690483E 00	0.50441658E 00	0.49045640E 00	0.47515810E 00	0.45863682E 00	0.44098830E 00
Z = 16.66666	0.51296073E 00	0.50056779E 00	0.48671395E 00	0.47153246E 00	0.45513719E 00	0.43762332E 00
Z = 19.04761	0.50834674E 00	0.49606508E 00	0.48233587E 00	0.46729070E 00	0.45104283E 00	0.43368638E 00
Z = 21.42856	0.50306587E 00	0.49091130E 00	0.47732413E 00	0.46243501E 00	0.44635552E 00	0.42917913E 00
Z = 23.80951	0.49712181E 00	0.48511089E 00	0.47168434E 00	0.45697105E 00	0.44108164E 00	0.42410809E 00
Z = 26.19046	0.49052399E 00	0.47867250E 00	0.46542418E 00	0.45090616E 00	0.43522763E 00	0.41847944E 00
Z = 28.57141	0.48328167E 00	0.47160530E 00	0.45855254E 00	0.44424886E 00	0.42880177E 00	0.41230094E 00
Z = 30.95236	0.47540426E 00	0.46391809E 00	0.45107806E 00	0.43700755E 00	0.42181224E 00	0.40558034E 00
Z = 33.33331	0.46690643E 00	0.45562518E 00	0.44301438E 00	0.42919505E 00	0.41427118E 00	0.39832920E 00
Z = 35.71426	0.45779330E 00	0.44673228E 00	0.43436760E 00	0.42081791E 00	0.40618527E 00	0.39055431E 00
Z = 38.09521	0.44807887E 00	0.43725246E 00	0.42515010E 00	0.41188788E 00	0.39756560E 00	0.38226634E 00
Z = 40.47617	0.43777484E 00	0.42719740E 00	0.41537327E 00	0.40241599E 00	0.38842309E 00	0.37347567E 00
Z = 42.85712	0.42689192E 00	0.41657746E 00	0.40504736E 00	0.39241230E 00	0.37876725E 00	0.36419141E 00
Z = 45.23807	0.41545480E 00	0.40541649E 00	0.39419514E 00	0.38189852E 00	0.36861897E 00	0.35443360E 00
Z = 47.61902	0.40347111E 00	0.39372230E 00	0.38282454E 00	0.37088233E 00	0.35798568E 00	0.34420943E 00
Z = 49.99997	0.39095670E 00	0.38151008E 00	0.37095010E 00	0.35937822E 00	0.34688145E 00	0.33353239E 00
Z = 52.38092	0.37792838E 00	0.36879641E 00	0.35858834E 00	0.34740198E 00	0.33532166E 00	0.32241744E 00
Z = 54.76187	0.36439675E 00	0.35559195E 00	0.34574950E 00	0.33496380E 00	0.32331610E 00	0.31087387E 00
Z = 57.14282	0.35039538E 00	0.34192872E 00	0.33246428E 00	0.32209289E 00	0.31089264E 00	0.29892838E 00
Z = 59.52377	0.33593386E 00	0.32781643E 00	0.31874228E 00	0.30879873E 00	0.29806054E 00	0.28658992E 00

	R = 25.38455	R = 27.49992	R = 29.61530	R = 31.73067	R = 33.84604	R = 35.96141
Z = 0.0	0.43015236E 00	0.41007906E 00	0.38901383E 00	0.36696720E 00	0.34394425E 00	0.31994867E 00
Z = 2.38095	0.43001437E 00	0.40994704E 00	0.38888824E 00	0.36684865E 00	0.34383309E 00	0.31984532E 00
Z = 4.76190	0.42959201E 00	0.40954423E 00	0.38850594E 00	0.36648798E 00	0.34349501E 00	0.31953096E 00
Z = 7.14286	0.42860907E 00	0.40860695E 00	0.38761681E 00	0.36564922E 00	0.34270889E 00	0.31879956E 00
Z = 9.52381	0.42706126E 00	0.40713108E 00	0.38621658E 00	0.36432827E 00	0.34147084E 00	0.31764799E 00
Z = 11.90476	0.42495292E 00	0.40512127E 00	0.38431001E 00	0.36252970E 00	0.33978498E 00	0.31607980E 00
Z = 14.28571	0.42228591E 00	0.40257877E 00	0.38189811E 00	0.36025447E 00	0.33765256E 00	0.31409603E 00
Z = 16.66666	0.41906369E 00	0.39950681E 00	0.37898397E 00	0.35750544E 00	0.33507603E 00	0.31169921E 00
Z = 19.04761	0.41529357E 00	0.39591265E 00	0.37557429E 00	0.35428900E 00	0.33206129E 00	0.30889481E 00
Z = 21.42856	0.41097730E 00	0.39179754E 00	0.37167054E 00	0.35060638E 00	0.32860982E 00	0.30568421E 00
Z = 23.80951	0.40612131E 00	0.38716817E 00	0.36727899E 00	0.34646374E 00	0.32472700E 00	0.30207229E 00
Z = 26.19046	0.40073144E 00	0.38202977E 00	0.36240453E 00	0.34186554E 00	0.32041723E 00	0.29806316E 00
Z = 28.57141	0.39481485E 00	0.37638932E 00	0.35705388E 00	0.33681804E 00	0.31568640E 00	0.29366243E 00
Z = 30.95236	0.38837928E 00	0.37025410E 00	0.35123378E 00	0.33132780E 00	0.31054062E 00	0.28887552E 00
Z = 33.33331	0.38143551E 00	0.36363423E 00	0.34495389E 00	0.32540381E 00	0.30498844E 00	0.28371078E 00
Z = 35.71426	0.37399036E 00	0.35653651E 00	0.33822083E 00	0.31905228E 00	0.29903537E 00	0.27817303E 00
Z = 38.09521	0.36605376E 00	0.34897029E 00	0.33104318E 00	0.31228149E 00	0.29268932E 00	0.27226973E 00
Z = 40.47617	0.35763592E 00	0.34094530E 00	0.32343042E 00	0.30510014E 00	0.28595853E 00	0.26600850E 00

Z = 42.85712	0.34874552E 00	0.33246976E 00	0.31539035E 00	0.29751569E 00	0.27884990E 00	0.25939572E 00
Z = 45.23807	0.33940136E 00	0.32356167E 00	0.30693990E 00	0.28954417E 00	0.27137846E 00	0.25244564E 00
Z = 47.61902	0.32961076E 00	0.31422794E 00	0.29808551E 00	0.28119165E 00	0.26355004E 00	0.24516326E 00
Z = 49.99997	0.31938648E 00	0.30448073E 00	0.28883910E 00	0.27246910E 00	0.25537467E 00	0.23755836E 00
Z = 52.38092	0.30874282E 00	0.29433382E 00	0.27921337E 00	0.26338905E 00	0.24686420E 00	0.22964162E 00
Z = 54.76187	0.29768908E 00	0.28379601E 00	0.26921684E 00	0.25395906E 00	0.23802590E 00	0.22141987E 00
Z = 57.14282	0.28625005E 00	0.27289075E 00	0.25887179E 00	0.24420035E 00	0.22887939E 00	0.21291161E 00
Z = 59.52377	0.27443480E 00	0.26162673E 00	0.24818647E 00	0.23412049E 00	0.21943194E 00	0.20412326E 00

GROUP 2 FLUX

	R = 38.07679	R = 40.19215	R = 42.30753	R = 44.42290	R = 46.53827	R = 48.65364
Z = 0.0	0.29499322E 00	0.26910812E 00	0.24235010E 00	0.21480566E 00	0.18660152E 00	0.15790552E 00
Z = 2.38095	0.29489815E 00	0.26902169E 00	0.24227262E 00	0.21473718E 00	0.18654233E 00	0.15785569E 00
Z = 4.76190	0.29460835E 00	0.26875734E 00	0.24203455E 00	0.21452630E 00	0.18635911E 00	0.15770066E 00
Z = 7.14286	0.29393411E 00	0.26814234E 00	0.24148077E 00	0.21403557E 00	0.18593287E 00	0.15734011E 00
Z = 9.52381	0.29287243E 00	0.26717395E 00	0.24060875E 00	0.21326286E 00	0.18526179E 00	0.15677226E 00
Z = 11.90476	0.29142648E 00	0.26585484E 00	0.23942077E 00	0.21220982E 00	0.18434697E 00	0.15599811E 00
Z = 14.28571	0.28959739E 00	0.26418620E 00	0.23791802E 00	0.21087778E 00	0.18318975E 00	0.15501881E 00
Z = 16.66666	0.28738749E 00	0.26217020E 00	0.23610252E 00	0.20926851E 00	0.18179184E 00	0.15383589E 00
Z = 19.04761	0.28480196E 00	0.25981152E 00	0.23397833E 00	0.20738584E 00	0.18015635E 00	0.15245193E 00
Z = 21.42856	0.28184175E 00	0.25711113E 00	0.23154670E 00	0.20523059E 00	0.17828417E 00	0.15086776E 00
Z = 23.80951	0.27851152E 00	0.25407314E 00	0.22881061E 00	0.20280558E 00	0.17617756E 00	0.14908504E 00
Z = 26.19046	0.27481508E 00	0.25070101E 00	0.22577381E 00	0.20011389E 00	0.17383927E 00	0.14710629E 00
Z = 28.57141	0.27075756E 00	0.24699956E 00	0.22244030E 00	0.19715917E 00	0.17127258E 00	0.14493430E 00
Z = 30.95236	0.26634401E 00	0.24297327E 00	0.21881443E 00	0.19394535E 00	0.16848063E 00	0.14257169E 00
Z = 33.33331	0.26158226E 00	0.23862940E 00	0.21490252E 00	0.19047821E 00	0.16546881E 00	0.14002311E 00
Z = 35.71426	0.25647640E 00	0.23397160E 00	0.21070784E 00	0.18676031E 00	0.16223902E 00	0.13729000E 00
Z = 38.09521	0.25103360E 00	0.22900629E 00	0.20623636E 00	0.18279701E 00	0.15879613E 00	0.13437659E 00
Z = 40.47617	0.24526066E 00	0.22373992E 00	0.20149356E 00	0.17859328E 00	0.15514439E 00	0.13128638E 00
Z = 42.85712	0.23916364E 00	0.21817791E 00	0.19648457E 00	0.17415357E 00	0.15128756E 00	0.12802261E 00
Z = 45.23807	0.23275566E 00	0.21233225E 00	0.19122022E 00	0.16948748E 00	0.14723414E 00	0.12459260E 00
Z = 47.61902	0.22604132E 00	0.20620716E 00	0.18570411E 00	0.16459835E 00	0.14298689E 00	0.12099856E 00
Z = 49.99997	0.21902961E 00	0.19981068E 00	0.17994368E 00	0.15949267E 00	0.13855171E 00	0.11724532E 00
Z = 52.38092	0.21173036E 00	0.19315189E 00	0.17394698E 00	0.15417755E 00	0.13393438E 00	0.11333811E 00
Z = 54.76187	0.20414978E 00	0.18623639E 00	0.16771901E 00	0.14865732E 00	0.12913901E 00	0.10928005E 00
Z = 57.14282	0.19630522E 00	0.17908025E 00	0.16127449E 00	0.14294523E 00	0.12417692E 00	0.10508114E 00
Z = 59.52377	0.18820238E 00	0.17168850E 00	0.15461773E 00	0.13704515E 00	0.11905152E 00	0.10074401E 00

GROUP 2 FLUX

	R = 50.76901	R = 52.88438	R = 54.99976	R = 56.24976	R = 57.49976	R = 58.74976
Z = 0.0	0.12892312E 00	0.99899709E-01	0.71112573E-01	0.53823162E-01	0.35998818E-01	0.17956365E-01
Z = 2.38095	0.12888253E 00	0.99868357E-01	0.71090341E-01	0.53806316E-01	0.35987560E-01	0.17950758E-01
Z = 4.76190	0.12875611E 00	0.99770427E-01	0.71020603E-01	0.53753551E-01	0.35952270E-01	0.17933156E-01
Z = 7.14286	0.12846160E 00	0.99542201E-01	0.70858240E-01	0.53630669E-01	0.35870086E-01	0.17892160E-01
Z = 9.52381	0.12799817E 00	0.99183142E-01	0.70602655E-01	0.53437211E-01	0.35740700E-01	0.17827623E-01
Z = 11.90476	0.12736607E 00	0.98693252E-01	0.70253968E-01	0.53173307E-01	0.35564192E-01	0.17739575E-01
Z = 14.28571	0.12656647E 00	0.98073781E-01	0.69812894E-01	0.52839488E-01	0.35340920E-01	0.17628208E-01
Z = 16.66666	0.12560064E 00	0.97325265E-01	0.69280148E-01	0.52436255E-01	0.35071220E-01	0.17493688E-01
Z = 19.04761	0.12447065E 00	0.96449733E-01	0.68656921E-01	0.51964540E-01	0.34755722E-01	0.17336313E-01
Z = 21.42856	0.12317735E 00	0.95447600E-01	0.67943573E-01	0.51424645E-01	0.34394622E-01	0.17156195E-01

Z = 23.80951	0.12172186E 00	0.94319701E-01	0.67140758E-01	0.50816976E-01	0.33988189E-01	0.16953461E-01
Z = 26.19046	0.12010628E 00	0.93067884E-01	0.66249549E-01	0.50142486E-01	0.33537067E-01	0.16728446E-01
Z = 28.57141	0.11833292E 00	0.91693759E-01	0.65271378E-01	0.49402129E-01	0.33041894E-01	0.16481444E-01
Z = 30.95236	0.11640400E 00	0.90199113E-01	0.64207494E-01	0.48596840E-01	0.32503288E-01	0.16212787E-01
Z = 33.33331	0.11432320E 00	0.88586807E-01	0.63059747E-01	0.47728203E-01	0.31922318E-01	0.15922997E-01
Z = 35.71426	0.11209178E 00	0.86857677E-01	0.61828975E-01	0.46796598E-01	0.31299230E-01	0.15612200E-01
Z = 38.09521	0.10971314E 00	0.85014403E-01	0.60516894E-01	0.45803528E-01	0.30635025E-01	0.15280891E-01
Z = 40.47617	0.10719001E 00	0.83059430E-01	0.59125215E-01	0.44750202E-01	0.29930525E-01	0.14929485E-01
Z = 42.85712	0.10452527E 00	0.80994546E-01	0.57655334E-01	0.43637697E-01	0.29186435E-01	0.14558326E-01
Z = 45.23807	0.10172480E 00	0.78824520E-01	0.56110658E-01	0.42468574E-01	0.28404489E-01	0.14168292E-01
Z = 47.61902	0.98790407E-01	0.76550782E-01	0.54492094E-01	0.41243527E-01	0.27585134E-01	0.13759594E-01
Z = 49.99997	0.95726073E-01	0.74176192E-01	0.52801870E-01	0.39964244E-01	0.26729509E-01	0.13332803E-01
Z = 52.38092	0.92536032E-01	0.71704388E-01	0.51042233E-01	0.38632426E-01	0.25838740E-01	0.12888480E-01
Z = 54.76187	0.89222848E-01	0.69136977E-01	0.49214650E-01	0.37249178E-01	0.24913572E-01	0.12427002E-01
Z = 57.14282	0.85794508E-01	0.66480577E-01	0.47323696E-01	0.35817973E-01	0.23956336E-01	0.11949528E-01
Z = 59.52377	0.82253456E-01	0.63736618E-01	0.45370460E-01	0.34339625E-01	0.22967566E-01	0.11456326E-01

GROUP 2 FLUX

	R = 59.99976
Z = 0.0	0.10036337E-06
Z = 2.38095	0.10033148E-06
Z = 4.76190	0.10023297E-06
Z = 7.14286	0.10000366E-06
Z = 9.52381	0.99642648E-07
Z = 11.90476	0.99150611E-07
Z = 14.28571	0.98528119E-07
Z = 16.66666	0.97776308E-07
Z = 19.04761	0.96896599E-07
Z = 21.42856	0.95889732E-07
Z = 23.80951	0.94756615E-07
Z = 26.19046	0.93498954E-07
Z = 28.57141	0.92118398E-07
Z = 30.95236	0.90616822E-07
Z = 33.33331	0.88996956E-07
Z = 35.71426	0.87259764E-07
Z = 38.09521	0.85408033E-07
Z = 40.47617	0.83443922E-07
Z = 42.85712	0.81369478E-07
Z = 45.23807	0.79189363E-07
Z = 47.61902	0.76905053E-07
Z = 49.99997	0.74519562E-07
Z = 52.38092	0.72036130E-07
Z = 54.76187	0.69456974E-07
Z = 57.14282	0.66788118E-07
Z = 59.52377	0.64031440E-07

GROUP 2 FLUX

	R = 0.0	R = 2.11538	R = 4.23077	R = 6.34615	R = 8.46154	R = 10.57692
Z = 61.90472	0.34387410E 00	0.34322560E 00	0.34124494E 00	0.33796626E 00	0.33346522E 00	0.32779026E 00
Z = 64.28568	0.32745838E 00	0.32684088E 00	0.32495451E 00	0.32183242E 00	0.31754607E 00	0.31214201E 00
Z = 66.66663	0.31059855E 00	0.31001282E 00	0.30822372E 00	0.30526251E 00	0.30119705E 00	0.29607153E 00

Z = 69.04758	0.29334635E 00	0.29279310E 00	0.29110336E 00	0.28830653E 00	0.28446692E 00	0.27962589E 00
Z = 71.42853	0.27571023E 00	0.27519023E 00	0.27360195E 00	0.27097303E 00	0.26736397E 00	0.26281363E 00
Z = 73.80948	0.25771248E 00	0.25722629E 00	0.25574166E 00	0.25328404E 00	0.24991018E 00	0.24565661E 00
Z = 76.19043	0.23937374E 00	0.23892212E 00	0.23754299E 00	0.23526013E 00	0.23212624E 00	0.22817510E 00
Z = 78.57138	0.22069985E 00	0.22028351E 00	0.21901202E 00	0.21690756E 00	0.21401834E 00	0.21037579E 00
Z = 80.95233	0.20175797E 00	0.20137739E 00	0.20021498E 00	0.19829094E 00	0.19564962E 00	0.19231945E 00
Z = 83.33328	0.18255341E 00	0.18220901E 00	0.18115699E 00	0.17941582E 00	0.17702556E 00	0.17401177E 00
Z = 85.71423	0.16310990E 00	0.16280204E 00	0.16186190E 00	0.16030562E 00	0.15816939E 00	0.15547609E 00
Z = 88.09518	0.14344954E 00	0.14317876E 00	0.14235175E 00	0.14098287E 00	0.13910371E 00	0.13673460E 00
Z = 90.47614	0.12356454E 00	0.12333143E 00	0.12261927E 00	0.12144047E 00	0.11982232E 00	0.11778212E 00
Z = 92.85709	0.10355592E 00	0.10336041E 00	0.10276335E 00	0.10177505E 00	0.10041827E 00	0.98707855E-01
Z = 95.23804	0.83415568E-01	0.83257854E-01	0.82776546E-01	0.81979871E-01	0.80886185E-01	0.79507470E-01
Z = 97.61899	0.63166857E-01	0.63047349E-01	0.62682331E-01	0.62078193E-01	0.61248876E-01	0.60203541E-01
Z = 99.99994	0.42835344E-01	0.42754043E-01	0.42505778E-01	0.42094938E-01	0.41531093E-01	0.40820524E-01
Z =100.99994	0.34326304E-01	0.34261283E-01	0.34062698E-01	0.33733971E-01	0.33282593E-01	0.32713383E-01
Z =101.99994	0.25803994E-01	0.25754951E-01	0.25605187E-01	0.25357276E-01	0.25016867E-01	0.24587605E-01
Z =102.99994	0.17297644E-01	0.17264515E-01	0.17163377E-01	0.16995978E-01	0.16766123E-01	0.16476311E-01
Z =103.99994	0.86460039E-02	0.86294487E-02	0.85789189E-02	0.84952749E-02	0.83804280E-02	0.82356185E-02
Z =104.99994	-0.32996393E-07	-0.32947021E-07	-0.32794560E-07	-0.32539656E-07	-0.32185383E-07	-0.31730941E-07

GROUP 2 FLUX

	R = 12.69230	R = 14.80769	R = 16.92307	R = 19.03844	R = 21.15381	R = 23.26918
Z = 61.90472	0.32103091E 00	0.31327319E 00	0.30460137E 00	0.29509860E 00	0.28483653E 00	0.27387464E 00
Z = 64.28568	0.30570513E 00	0.29831773E 00	0.29005975E 00	0.28101057E 00	0.27123827E 00	0.26079965E 00
Z = 66.66663	0.28996617E 00	0.28295934E 00	0.27512681E 00	0.26654369E 00	0.25727481E 00	0.24737364E 00
Z = 69.04758	0.27385962E 00	0.26724184E 00	0.25984424E 00	0.25173783E 00	0.24298358E 00	0.23363233E 00
Z = 71.42853	0.25739378E 00	0.25117356E 00	0.24422032E 00	0.23660094E 00	0.22837287E 00	0.21958363E 00
Z = 73.80948	0.24059010E 00	0.23477536E 00	0.22827560E 00	0.22115332E 00	0.21346188E 00	0.20524621E 00
Z = 76.19043	0.22346890E 00	0.21806777E 00	0.21203035E 00	0.20541465E 00	0.19827044E 00	0.19063920E 00
Z = 78.57138	0.20603704E 00	0.20105761E 00	0.19549143E 00	0.18939209E 00	0.18280554E 00	0.17576981E 00
Z = 80.95233	0.18835282E 00	0.18380052E 00	0.17871195E 00	0.17313588E 00	0.16711432E 00	0.16068232E 00
Z = 83.33328	0.17042232E 00	0.16630280E 00	0.16169804E 00	0.15665233E 00	0.15120363E 00	0.14538360E 00
Z = 85.71423	0.15226817E 00	0.14858675E 00	0.14447176E 00	0.13996285E 00	0.13509405E 00	0.12989348E 00
Z = 88.09518	0.13391298E 00	0.13067479E 00	0.12705529E 00	0.12308949E 00	0.11880708E 00	0.11423326E 00
Z = 90.47614	0.11535215E 00	0.11256337E 00	0.10944623E 00	0.10603064E 00	0.10234225E 00	0.98402679E-01
Z = 92.85709	0.96670687E-01	0.94332933E-01	0.91720045E-01	0.88857114E-01	0.85765719E-01	0.82464099E-01
Z = 95.23804	0.77865601E-01	0.75981498E-01	0.73875844E-01	0.71568966E-01	0.69078267E-01	0.66418350E-01
Z = 97.61899	0.58958787E-01	0.57530664E-01	0.55934846E-01	0.54186321E-01	0.52299876E-01	0.50285067E-01
Z = 99.99994	0.39974596E-01	0.39004333E-01	0.37920471E-01	0.36733624E-01	0.35452895E-01	0.34085855E-01
Z =100.99994	0.32035239E-01	0.31256769E-01	0.30386388E-01	0.29432476E-01	0.28402269E-01	0.27301863E-01
Z =101.99994	0.24076205E-01	0.23489174E-01	0.22832882E-01	0.22113681E-01	0.21337077E-01	0.20507719E-01
Z =102.99994	0.16131088E-01	0.15734881E-01	0.15292037E-01	0.14806908E-01	0.14283258E-01	0.13724320E-01
Z =103.99994	0.80631189E-02	0.78651309E-02	0.76438338E-02	0.74013881E-02	0.71396865E-02	0.68603344E-02
Z =104.99994	-0.31178672E-07	-0.30530245E-07	-0.29787270E-07	-0.28951892E-07	-0.28026054E-07	-0.27011946E-07

GROUP 2 FLUX

	R = 25.38455	R = 27.49992	R = 29.61530	R = 31.73067	R = 33.84604	R = 35.96141
Z = 61.90472	0.26225853E 00	0.25001872E 00	0.23717463E 00	0.22373271E 00	0.20969599E 00	0.19506651E 00
Z = 64.28568	0.24973804E 00	0.23808247E 00	0.22585154E 00	0.21305138E 00	0.19968468E 00	0.18575370E 00
Z = 66.66663	0.23688161E 00	0.22582620E 00	0.21422493E 00	0.20208365E 00	0.18940502E 00	0.17619115E 00

Z = 69.04758	0.22372305E 00	0.21328163E 00	0.20232481E 00	0.19085795E 00	0.17888367E 00	0.16640371E 00
Z = 71.42853	0.21026993E 00	0.20045632E 00	0.19015807E 00	0.17938089E 00	0.16812658E 00	0.15639722E 00
Z = 73.80948	0.19654047E 00	0.18736726E 00	0.17774147E 00	0.16766787E 00	0.15714854E 00	0.14618504E 00
Z = 76.19043	0.18255293E 00	0.17403245E 00	0.16509169E 00	0.15573490E 00	0.14596421E 00	0.13578099E 00
Z = 78.57138	0.16831428E 00	0.16045856E 00	0.15221518E 00	0.14358813E 00	0.13457948E 00	0.12519044E 00
Z = 80.95233	0.15386671E 00	0.14668518E 00	0.13914931E 00	0.13126278E 00	0.12302738E 00	0.11444432E 00
Z = 83.33328	0.13921654E 00	0.13271856E 00	0.12590003E 00	0.11876434E 00	0.11131316E 00	0.10354739E 00
Z = 85.71423	0.12438315E 00	0.11857718E 00	0.11248505E 00	0.10610962E 00	0.99452376E-01	0.92514217E-01
Z = 88.09518	0.10938686E 00	0.10428065E 00	0.98922849E-01	0.93315959E-01	0.87461352E-01	0.81359744E-01
Z = 90.47614	0.94228089E-01	0.89829683E-01	0.85214376E-01	0.80384433E-01	0.75340986E-01	0.70084751E-01
Z = 92.85709	0.78965783E-01	0.75279951E-01	0.71412563E-01	0.67365408E-01	0.63139498E-01	0.58735244E-01
Z = 95.23804	0.63600242E-01	0.60631502E-01	0.57516579E-01	0.54257091E-01	0.50853673E-01	0.47306724E-01
Z = 97.61899	0.48150841E-01	0.45902781E-01	0.43544449E-01	0.41076928E-01	0.38500641E-01	0.35815828E-01
Z = 99.99994	0.32638256E-01	0.31113908E-01	0.29515192E-01	0.27842801E-01	0.26096940E-01	0.24277706E-01
Z =100.99994	0.26136015E-01	0.24907980E-01	0.23619983E-01	0.22272941E-01	0.20867430E-01	0.19403931E-01
Z =101.99994	0.19629233E-01	0.18704176E-01	0.17734274E-01	0.16720291E-01	0.15662737E-01	0.14562022E-01
Z =102.99994	0.13132628E-01	0.12509979E-01	0.11857644E-01	0.11176229E-01	0.10466140E-01	0.97277276E-02
Z =103.99994	0.65645948E-02	0.62533766E-02	0.59273094E-02	0.55866838E-02	0.52317306E-02	0.48626103E-02
Z =104.99994	-0.25911977E-07	-0.24728735E-07	-0.23465365E-07	-0.22125203E-07	-0.20712402E-07	-0.19231873E-07

GROUP 2 FLUX

	R = 38.07678	R = 40.19215	R = 42.30753	R = 44.42290	R = 46.53827	R = 48.65364
Z = 61.90472	0.17985213E 00	0.16407096E 00	0.14775771E 00	0.13096482E 00	0.11376959E 00	0.96274316E-01
Z = 64.28568	0.17126566E 00	0.15623790E 00	0.14070344E 00	0.12471235E 00	0.10833812E 00	0.91678143E-01
Z = 66.66663	0.16244882E 00	0.14819473E 00	0.13345993E 00	0.11829197E 00	0.10276055E 00	0.86958230E-01
Z = 69.04758	0.15342480E 00	0.13996249E 00	0.12604618E 00	0.11172086E 00	0.97052276E-01	0.82127750E-01
Z = 71.42853	0.14419883E 00	0.13154614E 00	0.11846679E 00	0.10500282E 00	0.91216505E-01	0.77189445E-01
Z = 73.80948	0.13478333E 00	0.12295693E 00	0.11073172E 00	0.98146975E-01	0.85260808E-01	0.72149634E-01
Z = 76.19043	0.12519079E 00	0.11420602E 00	0.10285091E 00	0.91161966E-01	0.79192936E-01	0.67014933E-01
Z = 78.57138	0.11542606E 00	0.10529804E 00	0.94828427E-01	0.84051073E-01	0.73015571E-01	0.61787512E-01
Z = 80.95233	0.10551816E 00	0.96259594E-01	0.86688697E-01	0.76836526E-01	0.66748261E-01	0.56484006E-01
Z = 83.33328	0.95471263E-01	0.87094307E-01	0.78434885E-01	0.69520831E-01	0.60393356E-01	0.51106375E-01
Z = 85.71423	0.85298777E-01	0.77814579E-01	0.70078015E-01	0.62114064E-01	0.53959079E-01	0.45661658E-01
Z = 88.09518	0.75014353E-01	0.68432629E-01	0.61629064E-01	0.54625295E-01	0.47453605E-01	0.40156621E-01
Z = 90.47614	0.64618409E-01	0.58948665E-01	0.53087637E-01	0.47054298E-01	0.40876381E-01	0.34590617E-01
Z = 92.85709	0.54154865E-01	0.49403829E-01	0.44492457E-01	0.39436523E-01	0.34259245E-01	0.28991401E-01
Z = 95.23804	0.43618012E-01	0.39791841E-01	0.35836473E-01	0.31764589E-01	0.27594849E-01	0.23352034E-01
Z = 97.61899	0.33023741E-01	0.30127574E-01	0.27133517E-01	0.24051104E-01	0.20894427E-01	0.17682236E-01
Z = 99.99994	0.22385839E-01	0.20423416E-01	0.18394545E-01	0.16305633E-01	0.14166169E-01	0.11988845E-01
Z =100.99994	0.17883450E-01	0.16307991E-01	0.14681112E-01	0.13008125E-01	0.11296675E-01	0.95568672E-02
Z =101.99994	0.13418961E-01	0.12235064E-01	0.11013042E-01	0.97568557E-02	0.84722526E-02	0.71667545E-02
Z =102.99994	0.89615732E-02	0.81687272E-02	0.73510073E-02	0.65110475E-02	0.56526475E-02	0.47807880E-02
Z =103.99994	0.44796169E-02	0.40832832E-02	0.36745172E-02	0.32546343E-02	0.28255379E-02	0.23897190E-02
Z =104.99994	-0.17689434E-07	-0.16091811E-07	-0.14447085E-07	-0.12764179E-07	-0.11053299E-07	-0.93258556E-08

GROUP 2 FLUX

	R = 50.76901	R = 52.88438	R = 54.99976	R = 56.24976	R = 57.49976	R = 58.74976
Z = 61.90472	0.78604162E-01	0.60909014E-01	0.43357614E-01	0.32816172E-01	0.21948624E-01	0.10948077E-01
Z = 64.28568	0.74851632E-01	0.58001172E-01	0.41287694E-01	0.31249505E-01	0.20900786E-01	0.10425407E-01
Z = 66.66663	0.70997894E-01	0.55015028E-01	0.39162010E-01	0.29640630E-01	0.19824710E-01	0.98886564E-02

Z = 69.04758	0.67054033E-01	0.51958989E-01	0.36986597E-01	0.27994122E-01	0.18723462E-01	0.93393475E-02
Z = 71.42853	0.63022196E-01	0.48834756E-01	0.34762662E-01	0.26310887E-01	0.17597660E-01	0.87777972E-02
Z = 73.80948	0.58907583E-01	0.45646429E-01	0.32493092E-01	0.24593126E-01	0.16448770E-01	0.82047172E-02
Z = 76.19043	0.54715253E-01	0.42397887E-01	0.30180648E-01	0.22842899E-01	0.15278149E-01	0.76208152E-02
Z = 78.57138	0.50447118E-01	0.39090544E-01	0.27826317E-01	0.21060966E-01	0.14086328E-01	0.70263222E-02
Z = 80.95233	0.46117041E-01	0.35735268E-01	0.25437895E-01	0.19753243E-01	0.12877256E-01	0.64232349E-02
Z = 83.33328	0.41726485E-01	0.32333147E-01	0.23016151E-01	0.17420296E-01	0.11651322E-01	0.58117360E-02
Z = 85.71423	0.37281182E-01	0.28888624E-01	0.20564228E-01	0.15564516E-01	0.10410115E-01	0.51926151E-02
Z = 88.09518	0.32786559E-01	0.25405847E-01	0.18085048E-01	0.13688102E-01	0.91551021E-02	0.45666136E-02
Z = 90.47614	0.28241977E-01	0.21884236E-01	0.15578158E-01	0.11790692E-01	0.78860335E-02	0.39335936E-02
Z = 92.85709	0.23670685E-01	0.18342182E-01	0.13056867E-01	0.98824166E-02	0.66097304E-02	0.32969757E-02
Z = 95.23804	0.19066494E-01	0.14774576E-01	0.10517344E-01	0.79603456E-02	0.53241886E-02	0.26557420E-02
Z = 97.61899	0.14437508E-01	0.11187781E-01	0.79641752E-02	0.60279444E-02	0.40317439E-02	0.20110670E-02
Z = 99.99994	0.97892247E-02	0.75860098E-02	0.54003373E-02	0.40874667E-02	0.27338983E-02	0.13636956E-02
Z =100.99994	0.78009814E-02	0.60436800E-02	0.43014959E-02	0.32554576E-02	0.21772615E-02	0.10859978E-02
Z =101.99994	0.58495365E-02	0.45315363E-02	0.32250953E-02	0.24407539E-02	0.16323582E-02	0.81419689E-03
Z =102.99994	0.39015352E-02	0.30220954E-02	0.21506210E-02	0.16275193E-02	0.10884404E-02	0.54288935E-03
Z =103.99994	0.19502058E-02	0.15106069E-02	0.10749933E-02	0.81351888E-03	0.54405862E-03	0.27136365E-03
Z =104.99994	-0.75941422E-08	-0.58715450E-08	-0.41722288E-08	-0.31552279E-08	-0.21091331E-08	-0.10516970E-08

GROUP 2 FLUX PAGE 12

	R = 59.99976
Z = 61.90472	0.61190633E-07
Z = 64.28568	0.58269308E-07
Z = 66.66663	0.55269449E-07
Z = 69.04758	0.52199230E-07
Z = 71.42853	0.49060425E-07
Z = 73.80948	0.45857188E-07
Z = 76.19043	0.42593559E-07
Z = 78.57138	0.39271082E-07
Z = 80.95233	0.35900229E-07
Z = 83.33328	0.32482198E-07
Z = 85.71423	0.29021528E-07
Z = 88.09518	0.25522542E-07
Z = 90.47614	0.21984974E-07
Z = 92.85709	0.18426388E-07
Z = 95.23804	0.14842030E-07
Z = 97.61899	0.11238317E-07
Z = 99.99994	0.76195725E-08
Z =100.99994	0.60699428E-08
Z =101.99994	0.45504862E-08
Z =102.99994	0.30336433E-08
Z =103.99994	0.15163999E-08
Z =104.99994	-0.59357054E-14

VITA

William Ray Heldenbrand was born on June 17, 1946, near Kidder, Missouri. He received his primary and secondary education in the public schools of Winston, Missouri. He was married to Patricia Jean Heldenbrand in 1966. He received a Bachelor of Science Degree in Physics and Mathematics from Central Missouri State College in May, 1968.

He entered the Graduate School of the University of Missouri-Rolla in June, 1968, and has held an Atomic Energy Commission Traineeship for the period August, 1968, to May, 1969.