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A General Dimensional Neutron Diffusion Calculation Code: ADC

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A FORTRAN computer program ADC is developed for the FACOM 230-75 computer to be capable of solving eigenvalue problems of neutron diffusion equation in one, two and three spatial dimensions. The available coordinate systems are orthogonal (X), (X, Y), (X, Y, Z) and cylindrical (R, Z), (R, θ), (R, θ, Z). The outer boundary condition for the neutron flux can be chosen to be symmetric, zero flux or log-derivative condition. The present program can be used also for obtaining the adjoint flux.

Keywords: Neutron Diffusion Equation, Eigenvalue, Three-Dimensional Calculation, Neutron Flux, Adjoint Flux, Computer Code, Boundary Conditions, Orthogonal Coordinates, Cylindrical Coordinates

* Present Division : Division of Reactor Safety Evaluation

1, 2, 3 次元中性子拡散コード：ADC

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1，2および3次元空間における中性子拡散方程式の固有値問題を解くための計算プログラムADCを電算機 FACOM 230-75 用として開発した．適用可能な座標系は，直交座標（X），（X，Y），（X，Y，Z）および，円筒座標（R，Z），（R，θ），（R，θ，Z）である．中性子束に対する外部境界条件としては，対称条件，零中性子束条件または対数微分条件のいずれかを選ぶことができる．このプログラムで随伴中性子束もまた計算できる．

* 現在，安全解析部

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1. Introduction

A computer program for solving the multi-group neutron diffusion equation is one of the widely used programs for reactor physics and reactor design calculations. With the development of large scale computers, complex calculations of neutron flux distribution in a reactor core such as burn-up calculations have become feasible by performing directly three-dimensional calculations.

The three-dimensional diffusion codes, such as CITATION[1] and 3DB[2] have been developed in a way that the programming depends on the inherent function of the digital cmputer system to be applied. The CITATION code requires large fast core memories for the calculation of a large scale BWR core. On the other hand, the 3DB code requires less fast core memories than the CITATION, but it requires longer compution time on the FACOM 230-75 because of using scratch disk units many times for iteration processes.

The general dimensional diffusion equation program ADC for FACOM 230-75 is therefore developed for resolving the above drawbacks. This program permits an effective use of the available core memory by using two step FORTRAN job. At the first step, the size of common area and the program flow paths are arranged to be adequate for the problem to bo solved. These functions are called variable common arrangement and flow path control. At the next step, the main program and following sub-programs are compiled according to the generated program flow paths. If the storage required by the problem to be solved exceeds the size of available fast memory, scratch units are used.

The finite difference diffusion equation as well as its adjoint equation is solved by either of the following two iterative methods. One is a double loop iteration method with inner iteration and outer iteration, where the difference equation of each energy group is solved by inner iteration using pointwise or linewise relaxation method. After the inner iteration is converged, the eigenvalue is obtained by outer iteration. The other is a one-through iteration method which is similar to EQUIPOISE[3] method. For achieving a rapid convergence of the above iteration process, the initial guess flux can be constructed from a synthesis in our program.

The program ADC solves the eigenvalue problems of neutron diffusion equation and its adjoint equation in one-, two-, or three-dimensions. Either symmetric, zero flux or log-derivative condition is chosen at outside boundaries. Internal control rod boundary conditions are also permitted to be used. Various options are available to print out the neutron flux distribution averaged over the specified regions. This computer code is programed in FORTRAN IV for the FACOM 230-75 computer.

2. Main Feature of ADC Code

The main features of the general dimensional diffusion calculation code ADC are summarized as follows;

1) Computer : The code is programmed to be effectively used on the FACOM 230-75 computer. However it can easily be made usable on any other computers having at least 64K word storage.

2) Equation to be solved : The multi-group neutron diffusion problem may be solved to obtain the eigenvalue in one-, two- or three-dimensional geometry using finite difference formulation of diffusion theory.

3) Geometry : Rectangular (X), (X, Y), (X, Y, Z) or cylindrical (r), (r, z), (r, θ), (r, θ, z).

4) Boundary condition : Zero flux, reflective flux or flux with logarithmic derivative.

5) Method of calculating the pointwise flux : Either successive over-relaxation, or successive line-over-relaxation method may be selected by the user.

6) Method of fission source iteration : Either successive over-relaxation or Tchebysheff polynominal method may be selected by the user.

7) Flux convergence criteria : Pointwise flux ratio.

8) Eigenvalue convergence criteria : Either pointwise source ratio or integral source ratio. (The latter can be used only if one-through iteration method is selected by the user.)

9) Restrictions on the complexity of the problem : As variable common and program flow path control are set, there are few restrictions on the complexity of the problem. The storage of data is allocated dynamically depending on the number of energy groups and mesh intervals. If storage required by the problem exceeds the available fast memory, this program uses scratch units automatically. Therefore, the execution time is dependent strongly on the storage requirement of the problem.

10) Flux guess for a three-dimensional calculation : Flux guess can be synthesized in the program so as to shorten the computation time by using the results of two-dimensional calculation in an appropriate X-Y or R-θ plane and one-dimensional calculation in an appropriate axial direction specified by the user. Hence, the total execution time is drastically reduced compared to that when the flat flux guess is used as a user's option.

11) Programming language : FACOM 230-75 FORTRAN-IV language.

12) Computer system : FACOM 230-75 with FORTRAN-IV H-level compiler.

3. Details of the Method

The multi-group neutron diffusion equation is approximated to obtain a set of finite-difference equations expressing neutron balance over a finite volume element. The diffusion approximation to neutron transport equation at a location, r, and in a discrete energy group, g, is expressed by the following differential equation (1), in which a perpendicular buckling term may be allowed if required. The fission source neutron distribution function, χ, is assumed to be only energy dependent, and the slowing-down source is assumed to come from only the next higher energy group.

$$-D_g(r)\nabla^2\Phi_g(r)+(\Sigma_{a,g}(r)+\Sigma_{r,g}(r)+D_g(r)B^2)\phi_g(r)$$
$$=\chi_g\Sigma_{g'}\frac{\nu\Sigma_{f,g'}(r)\phi_{g'}(r)}{k_{eff}}+\Sigma_{r,g-1}(r)\phi_{g-1}(r);\ g=1,2,\cdots\cdots G, \quad (1)$$

where

∇^2 = Laplacian differential operator : $\frac{\partial^2}{\partial X^2}+\frac{\partial^2}{\partial Y^2}+\frac{\partial^2}{\partial Z^2}$ in slab geometry, (cm^{-2}),

$\phi_g(r)$ = Neutron flux at location, r, and in energy group, g, (n/sec-cm^2),

$\Sigma_{a,g}(r)$ = Macroscopic absorption cross section. (cm^{-1}),

$\Sigma_{r,g}(r)$ = Macroscopic slowing down cross section from energy group g to $(g+1)$, (cm^{-1}),

$D_g(r)$ = Diffusion coefficient,

B_g^2 = Buckling term to account for the effect of the neutron leakage to the perpendicular direction, if necessary, (cm^{-2}),

$\nu\Sigma_{f,g}(r)$ = Macroscopic emission cross section (ν is the number of neutrons emitted by a fission and Σ_f is the fission cross section), (cm^{-1}),

χ_g = Fission neutron energy spectrum ($\sum_g \chi_g=1.0$),

k_{eff} = Effective multiplication factor, or the largest eigenvalue of the equation.

3.1 Formulation of difference equations

To obtain the spatial difference equations, the spatial mesh points are assigned in the center of three-dimensional mesh volumes. For fewer dimensions, the mesh interval in the undefined dimensions is treated as infinite and the associated terms to the undefined dimensions cancel out of the difference equations.

Equation (1) is integrated over a single mesh volume. For the (I, J, K) mesh point at the position $X=X_i$, $Y=Y_j$ and $Z=Z_k$, the X integration is performed from $X_i-\frac{\Delta X_i}{2}$ to $X_i+\frac{\Delta X_i}{2}$, the Y integration from $Y_j-\frac{\Delta Y_j}{2}$ to $Y_j+\frac{\Delta Y_j}{2}$ and the Z integration from $Z_k-\frac{\Delta Z_k}{2}$ to $Z_k+\frac{\Delta Z_k}{2}$. **Figure 1** presents a three-dimensional sketch showing the location of mesh point (I, J, K) and the surrounding six locations in the slab geometry.

The leakage terms are modified first by transforming the volume integral of the Laplacian to a surface integral by using the Green's theorem:

$$\int D\nabla^2\phi dv=\int D\nabla\phi\cdot dA \quad . \tag{2}$$

The neutron leakage from (I, J, K) to (I, J, K-1) through the top surface of an area of $|dA|=\Delta X_i\Delta Y_j$ is approximated as follows. Let ϕ_s be the flux at the surface of the mesh (I, J, K). Then, we have

$$D_{i,j,k}[\phi_{i,j,k}-\phi_s]\frac{\Delta X_i\Delta Y_j}{\frac{\Delta Z_k}{2}}=D_{i,j,k-1}[\phi_s-\phi_{i,j,k-1}]\frac{\Delta X_i\Delta Y_j}{\frac{\Delta Z_{k-1}}{2}}$$

where $D_{i,j,k}$ and $D_{i,j,k-1}$ are the diffusion coefficients at (I, J, K) and (I, J, K−1), respectively. Eliminating ϕ_s from the above equations, we get

$$\begin{aligned}[\int D\nabla\phi\cdot dA]_{z\_}&=\frac{2\Delta X_i\Delta Y_j}{\frac{\Delta Z_r}{D_{i,j,k-1}}+\frac{\Delta Z_{r-1}}{D_{i,j,k}}}(\phi_{i,j,k}-\phi_{i,j,k-1})\\&=\frac{D_{i,j,k-1}\cdot A_{i,j,k-1}}{l_{i,j,k-1}}(\phi_{i,j,k}-\phi_{i,j,k-1}) \quad .\end{aligned} \tag{3}$$

where $l_{i,j,k-1}$ is $(\Delta Z_r/D_{i,j,k-1}+\Delta Z_{r-1}/D_{i,j,k})\cdot D_{i,j,k-1}/2$.

Since the factors which are multiplied to the flux difference are simply constructed by material and geometrical constants, Eq. (3) can be reduced to the form

$$L(Z\_)=C_{i,j,k,z\_}(\phi_{i,j,k}-\phi_{i,j,k-1}) \quad . \tag{4}$$

The leakage from the whole element is then given by

$$\begin{aligned}&L(Z\_)+L(Z_+)+L(X\_)+L(X_+)+L(Y\_)+L(Y_+)\\&=\phi_{i,j,k}(C_{i,j,k,z\_}+C_{i,j,k,z_+}+C_{i,j,k,x\_}+C_{i,j,k,x_+}+C_{i,j,k,y\_}+C_{i,j,k,y_+})\\&\quad-C_{i,j,k,z\_}\phi_{i,j,k-1}-C_{i,j,k,z_+}\phi_{i,j,k+1}-C_{i,j,k,x\_}\phi_{i-1j,k}-C_{i,j,k,x_+}\phi_{i,j,k}\\&\quad-C_{i,j,k,y\_}\phi_{i,j-1,k}-C_{i,j,k,y_+}\phi_{i,j+1,k} \quad .\end{aligned} \tag{5}$$

The destruction and production terms of Eq. (1) are obtained by performing simply the integration over the mesh volume. The destruction term is given by

$$\Sigma_{t,g,i,j,k}V_{i,j,k}\phi_{i,j,k} \quad . \tag{6}$$

The production (source) term is given by

$$S_{g,i,j,k}V_{i,j,k} \quad , \tag{7}$$

where

$$\Delta X_i\Delta Y_i\Delta Z_i=V_{i,j,k} \quad ,$$

$$\Sigma_{t,g}(r)=\Sigma_{a,g}(r)+\Sigma_{r,g}(r)+D_g(r)B^2 \quad ,$$

$$S_g(r)=\chi_g\sum_{g'=1}^{N}\frac{\nu\Sigma_{f,g'}(r)\phi_{g'}(r)}{k_{eff}}+\Sigma_{r,g-1}(r)\phi_{g-1}(r) \quad .$$

Thus, the volume integration of equation (1) arround mesh point 0 (see **Fig. 1**) leads to the expression (8) where, for simplicity, the group indices are omitted.

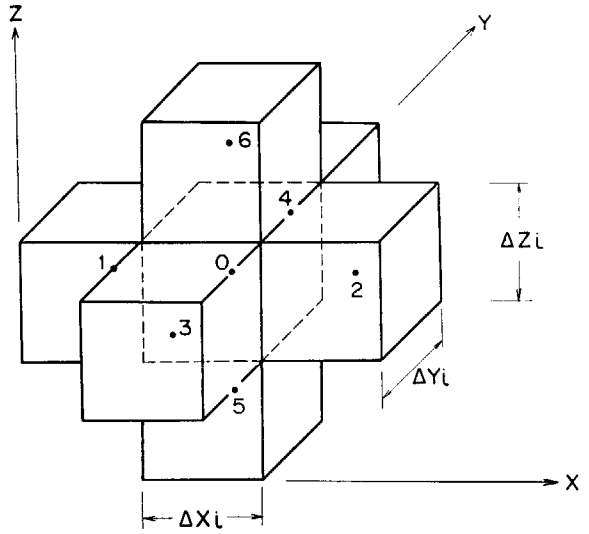

Fig. 1. Three dimensional mesh description in X-Y-Z geometry.

$$\sum_{k=1}^{6} C_k(\phi_k-\phi_0)-\Sigma_{t,0}\phi_0 V_0=S_0V_0 \quad . \tag{8}$$

The neutron balance equation (8) forms the simultaneous finite difference equations for each energy group.

Finally, equation (8) is modified into a convenient form for performing the flux iteration .

$$-C_7\phi_0+\sum_{k=1}^{6} C_k\phi_k=S_0V_0 \quad , \tag{9}$$

where

$$C_7=(\Sigma_{t,0}V_0+\sum_{k=1}^{6} C_k) \quad .$$

3.2 Boundary conditions

For the zero gradient boundary condition, the associated constant, $C_{i,j,k,s}$ is set to zero. For the logarithmic derivative boundary condition at an external or internal boundary, the flux slope within the finite difference volume element is assumed to be constant. The boundary condition to be satisfied at the element surface is therefore

$$-\frac{D}{\phi_s}\frac{\partial\phi}{\partial X}\Big|_s=C_s \quad , \tag{10}$$

where C_s is a specified constant .

Let ϕ_i be the internal flux, ϕ_s be the boundary flux and Δ be the interval from the internal point to the boundary. A linear approximation of flux within the element gives

$$-\frac{\partial\phi}{\partial X}\Big|_s=\frac{\phi_i-\phi_s}{\Delta} \quad , \quad \text{or}$$

$$-\frac{D_i}{\phi_s}\frac{\partial\phi}{\partial X}\Big|_s=\frac{D_i}{\Delta\phi_s}(\phi_i-\phi_s)=C_s \quad .$$

Denoting the surface area as A_n, the boundary leakage from one surface of a volume element is given by

$$L_{S,N}=-D_iA_n\frac{\partial\phi}{\partial X}\Big|_b=\frac{A_n\phi_i}{(\frac{1}{C_s}+\frac{\Delta}{D_i})} \quad , \tag{11}$$

which gives the required constant for Eq. (5). The external leakage is considered to be the net loss from the system, but the leakage into an internal black absorber is accounted for as absorption in the region.

For the periodic boundary condition, the flux values at the mesh points on the edges in symmetry are set equal. On the other hand, for the zero-flux boundary condition, the flux values at the mesh points on the boundary are set zero (see **Fig. 2**).

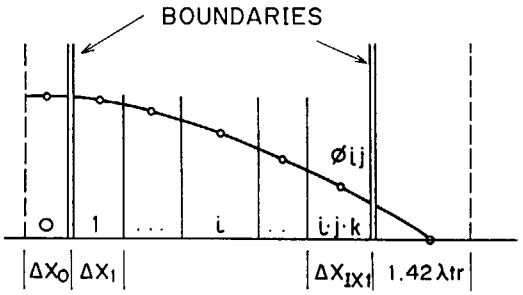

Fig. 2. Schematic diagram of one dimensional mesh points

3.3 Iterative procedure for finite difference equations

The multi-group diffusion equation (1) can be written in the following matrix form:

$$(\boldsymbol{M}-\boldsymbol{\Sigma})\phi=\frac{1}{k_{eff}}F\phi \tag{12}$$

by defining the flux vector as

$$\phi=\begin{pmatrix}\phi_1(r)\\ \phi_2(r)\\ \cdot\\ \cdot\\ \cdot\\ \phi_N(r)\end{pmatrix}$$

and the operator matrices as follows:

$$\boldsymbol{M}=\begin{pmatrix}-\nabla\cdot D_1\nabla+\Sigma_{T1} & 0 & 0\\ 0 & -\nabla\cdot D_2\nabla+\Sigma_{T2} & 0\\ \cdot & \ddots & \cdot\\ \cdot & & \cdot\\ \cdot & & 0\\ 0 & & -\nabla\cdot D_N\nabla+\Sigma_{TN}\end{pmatrix},$$

$$\Sigma = \begin{bmatrix} 0, & 0,\ldots\ldots\ldots\ldots,0 \\ \Sigma_{r,1}, & 0,\ldots\ldots\ldots\ldots,0 \\ 0, & \Sigma_{r,2} \quad \ddots \\ \vdots & \vdots \quad\quad \ddots \\ 0, & 0,\ldots\ldots\ldots,\Sigma_{r,N-1},0 \end{bmatrix},$$

$$F = \begin{bmatrix} \chi_1\nu\Sigma_{f1}, & \chi_1\nu\Sigma_{f2},\ldots\ldots\ldots,\chi_1\nu\Sigma_{fN} \\ \chi_2\nu\Sigma_{f1}, & \chi_2\nu\Sigma_{f2},\ldots\ldots\ldots,\chi_2\nu\Sigma_{fN} \\ \vdots & \vdots \\ \chi_N\nu\Sigma_{f1}, & \chi_N\nu\Sigma_{f2},\ldots\ldots\ldots,\chi_N\nu\Sigma_{fN} \end{bmatrix}.$$

In the finite difference approximation shown in the preceding section, Eq. (12) is converted to a set of algebraic equations:

$$A\phi=\frac{1}{k_{eff}}F\phi \quad , \tag{13}$$

where A is the algebraic matrix operator, which contains the diffusion, scattering and loss operators. As the largest eigenvalue of Eq. (13) is physically significant, the solution to Eq. (13) is expressed as

$$k_{eff}\phi=A^{-1}F\phi \quad . \tag{14}$$

For obtaining the solution of Fq. (13), it is necessary to invert the matrix A. For most problems of interest, however A is too large to invert. In a case which involve for instance, 10,000 space-energy points, the matrix A contains 100,000,000 elements, which are far too many numbers to handle efficiently with present generation computers. Thus in the ADC program, two matrix iterative techniques, either of which may be selected by user's option, are prepared for solving Eq. (13).

Inner and outer iteration

The values of neutron flux as for all energy groups are initially guessed and the fission neutron source for the first iteration is calculated using this flux guess. The fission neutron source for the m-th iteration is defined by

$$S^{(m)}_{i,j,k}=\sum_{g=1}^{N}\nu\Sigma_{fg,i,j,k}\phi^{(m-1)}_{g,i,j,k}V_{i,j,k} \quad , \tag{15}$$

where $\phi^{(m-1)}_{g,i,j,k}$ is the (m−1)-st iteration flux of the g-th group at mesh point (I, J, K). With this fission neutron source, $X_g S^{(m)}_{i,j,k}$, one can obtain a set of multi-group fluxes, beginning at the first group and carrying on down to the thermal (N-th) group. As the slowing-down source in Eq. (7) depends on the fluxes, it is updated every time of iterations by using the newest flux values. This iterative process is called as the inner iteration and is performed by the subroutine INNER1 or INNER2.

The finite difference equation (9) is rewritten in the matrix form:

$$A_g\phi_g=S_g \quad , \tag{16}$$

where flux and source vectors are defined by

$$\phi_g = \begin{Bmatrix} \phi_{g,1,1,1} \\ \phi_{g,2,1,1} \\ \vdots \\ \phi_{g,Nx,1,1} \\ \phi_{g,1,2,1} \\ \vdots \\ \phi_{g,Nx,2,1} \\ \vdots \\ \phi_{g,1,Ny,1} \\ \vdots \\ \phi_{g,Nx,Ny,Nz} \end{Bmatrix}, \qquad S_g = \begin{Bmatrix} S_{g,1,1,1} \\ S_{g,2,1,1} \\ \vdots \\ S_{g,Nx,1,1} \\ S_{g,1,2,1} \\ \vdots \\ S_{g,Nx,2,1} \\ \vdots \\ S_{g,1,Ny,1} \\ \vdots \\ S_{g,Nx,Ny,Nz} \end{Bmatrix}.$$

The pointwise neutron source $S_{g,i,j,k}$, which consists of fission and slowing-down source at the mesh point (I, J, K) in the g-th group, is the m-th element of the vector S_g with

$$m = i + (j-1)N_x + (k-1)N_xN_y \quad ,$$

where N_x, N_y and N_z are the maximum numbers of mesh points along X, Y and Z axes, respectively. In a similar fashion, the matrix A_g is constructed with elements $A_{i,j}$ defined by

$$\left.\begin{aligned} A_{m,m} &= -C_{7,i,j,k} \quad , \\ A_{m,m+1} &= C_{2,i,j,k} \quad , \\ A_{m,m+Nx} &= C_{3,i,j,k} \quad , \\ A_{m,m-Nx} &= C_{4,i,j,k} \quad , \\ A_{m,m+NxNy} &= C_{5,i,j,k} \quad , \\ A_{m,m-NxNy} &= C_{6,i,j,k} \quad . \end{aligned}\right\} \tag{17}$$

The inner iteration process is accelerated by successive over-relaxation (SOR) or successive line over-relaxation (SLOR) method. The iterative scheme of SOR is represened as

$$\phi^{(m)}_{i,j,k} = (1-\omega)\phi^{(m-1)}_{i,j,k} + \frac{\omega}{C_{7,i,j,k}}\{C_{1,i,j,k}\phi^{(m)}_{i-1,j,k} + C_{2,i,j,k}\phi^{(m-1)}_{i+1,j,k} + C_{3,i,j,k}\phi^{(m)}_{i,j-1,k}$$

$$+ C_{4,i,j,k}\phi^{(m-1)}_{i,j+1,k} + C_{5,i,j,k}\phi^{(m)}_{i,j,k-1} + C_{6,i,j,k}\phi^{(m-1)}_{i,j,k+1} - S_{i,j,k}\} \quad , \tag{18}$$

which is rewritten in the matrix form:

$$\phi^{(m)}_g = (\boldsymbol{I} - \omega L_g)^{-1}\{(1-\omega)\boldsymbol{I} + \omega U_g\}\phi^{(m-1)}_g + \omega(\boldsymbol{I} - \omega L_g)^{-1}S_g \quad , \tag{19}$$

where $L_g = D_g^{-1}F_g$, $U_g = D_g^{-1}F_g$, $A_g = D_g - \boldsymbol{E}_g - F_g$. The D_g is a diagonal matrix, and $\boldsymbol{E}_g$ and F_g are strictly lower and upper triangular matrices, respectively. Futhermore, $\boldsymbol{I}$ is a unit matrix and ω is a relaxation factor ($1<\omega<2$). On the other hand, applying simultaneous extrapolation to all points on the line as follows;

$$\phi^{(m)}_{i,j,k} = \phi^{(m-1)}_{i,j,k}(1-\omega) + \omega\phi'^{(m)}_{i,j,k} \quad , \tag{20}$$

the iteration scheme of SLOR is represented as

$$C_{1,i,j,k}\phi'^{(m)}_{i-1,j,k} + C_{2,i,j,k}\phi'^{(m)}_{i+1,j,k} - C_{7,i,j,k}\phi'^{(m)}_{i,j,k}$$

$$=S_{i,j,k}-C(_{3,i,j,k}\phi^{(m)}_{i,j-1,k}+C_{4,i,j,k}\phi^{(m-1)}_{i,j+1,k}+C_{5,i,j,k}\phi^{(m)}_{i,j,k-1}+C_{6,i,j,k}\phi^{(m-1)}_{i,j,k}) \quad . \quad (21)$$

The solution of Eq. (21) involves the well-known problem of inverting a tri-diagonal matrix by Gauss reduction technique.

The convergence rate of an iterative process depends on the relaxation factor. In the case of SOR of SLOR method, the spectral radius, ρ, of the point or block Jacobian matrix (e. g. for SOR, the point Jacobian matrix is $L+U$) is needed to determine the optimum relaxation factor;

$$\omega=\frac{2}{1+\sqrt{1-\rho^2}} \quad . \quad (22)$$

For estimating ρ by using the m-th iteration flux, $\phi^{(m)}_{g,i,j,k}$, which is in dependent on the source vector S_g, the source vector is set to zero and the power iteration for finding the largest eigenvalue of Jacobian matrix is performed in advance of the inner iteration process. However, since fairly time consuming iterations are required for estimating ρ, the total running time is not always reduced with the use of the calculated optimum relaxation factor. Thus, in ADC program, choice is permitted whether the constant relaxation factor is given by user's experience or the optimum factor is computed from the simplified spectral radius, ρ, of the Jacobian matrix. In the case of SOR, this spectral radius is given[4] by

$$\rho=\frac{1}{N}\sum_{n=1}^{N}\cos\left(\frac{\pi}{I_n+1}\right) \quad , \quad (23)$$

where N is the number of dimensions and I_n is the number of mesh intervals in the n-th direction. In the case of SLOR, we omit, from the summation in Eq. (23), the dimension along which the line relaxation is done to give

$$\rho=\frac{1}{N-1}\sum_{n=1}^{N-1}\cos\left(\frac{\pi}{I_n+1}\right) \quad . \quad (24)$$

The inner iteration is repeated until the following convergence criterion is satisfied.

$$\max_{i,j,k}\left|\frac{\phi^{(m)}_{g,i,j,k}}{\phi^{(m-1)}_{g,i,j,k}}-1\right|<\varepsilon_1 \quad , \quad (25)$$

where ε_1 is an input parameter.

After the inner iteration is converged, the fission source is updated with the converged neutron flux. This process is called as the outer iteration and is performed by the subroutine OUTER. This iteration process can be accelerated by either Tchebysheff extrapolation or over-relaxation method. An operation on Eq. (14) with the matrix F gives

$$K_{eff}S=\boldsymbol{P}S \quad , \quad (26)$$

where S is the fission source vector and $\boldsymbol{P}$ is the matrix FA^{-1}. The fission source vector for the m-th iteration is given by

$$S^{(m)}=\boldsymbol{P}S^{(m-1)} \quad , \quad (27)$$

where $S^{(m-1)}$ is the (m−1)-st iteration fission source. The eigenvalue, and its upper and lower bounds at the m-th iteration are defined respectively as follows[5]:

$$K^{(m)}_{eff}=\sum_{i,j,k}S^{(m)}_{i,j,k}\frac{\sum_{i,j,k}S^{(m)}_{i,j,k}\cdot S^{(m)}_{i,j,k}}{\sum_{i,j,k}S^{(m)}_{i,j,k}\cdot S^{(m-1)}_{i,j,k}} \quad , \quad (28)$$

$$\bar{K}^{(m)}_{eff}=\max_{i,j,k}\left\{\frac{S^{(m)}_{i,j,k}}{S^{(m-1)}_{i,j,k}}\right\}\cdot\sum_{i,j,k}S^{(m-1)}_{i,j,k} \quad , \quad (29)$$

$$\underline{K}_{eff}=\underset{i,j,k}{\mathrm{Min}}\left\{\frac{S^{(m)}_{i,j,k}}{S^{(m-1)}_{i,j,k}}\right\}\cdot\sum_{i,j,k}S^{(m-1)}_{i,j,k} \quad . \tag{30}$$

If the convergence criterion (with an input parameter ε_2)

$$\frac{\bar{K}^{(m)}_{eff}-\underline{K}^{(m)}_{eff}}{2\cdot K^{(m)}_{eff}}<\varepsilon_2 \tag{31}$$

is not satisfied, the extrapolated neutron source $S^{*(m)}_{i,j,k}$ after the m-th iteration is calculated by either of the following two formulae, Eqs. (32) and (35). If a Tchebysheff polynominal extrapolation is selected by user's option, $S^{*(m)}_{i,j,k}$ is given by

$$S^{*(m)}_{i,j,k}=\frac{S^{(m)}_{i,j,k}}{\sum_{i,j,k}S^{(m)}_{i,j,k}}+\alpha\left\{\frac{S^{(m)}_{i,j,k}}{\sum_{i,j,k}S^{(m)}_{i,j,k}}-\frac{S^{(m-1)}_{i,j,k}}{\sum_{i,j,k}S^{(m-1)}_{i,j,k}}\right\} \quad , \tag{32}$$

in which α is given by

$$\alpha^{(n)}_{i}=\frac{\{\lambda_1+\lambda_N+(\lambda_1-\lambda_N)\cos\frac{2i+1}{2n}\pi\}}{\{2\lambda_0-\lambda_1-\lambda_N-(\lambda_1-\lambda_N)\cos\frac{2i+1}{2n}\pi\}} \quad , \tag{33}$$

where λ_0, λ_1 and λ_N are the largest, the second and the least eigenvalues of the matrix $\boldsymbol{P}$. The eigenvalue λ_N is assumed to be zero and the dominant ratio, λ_1/λ_0, is approximated by

$$\frac{\lambda_1}{\lambda_0}=1-\frac{\sum_g R^{(m)}_g}{\sum_g R^{(m-1)}_g} \quad , \tag{34}$$

where the residual R_g is defined by

$$R^{(m)}_g=\sum_{i,j,k}\left(\phi^{(m)}_{g,i,j,k}-\phi^{(m-1)}_{g,i,j,k}\right)^2 \quad .$$

If an over-relaxation method is selected by user's option, $S^{*(m)}_{i,j,k}$ is given by

$$S^{*(m)}_{i,j,k}=(1-\omega)\frac{S^{(m-1)}_{i,j,k}}{\sum_{i,j,k}S^{(m-1)}_{i,j,k}}+\omega\cdot\frac{S^{(m)}_{i,j,k}}{\sum_{i,j,k}S^{(m)}_{i,j,k}}, \tag{35}$$

where ω is a relaxation factor calculated by the formula

$$\omega=\{\underline{\omega}_m+\bar{\omega}_m\}/2 \quad , \tag{36}$$

where $\underline{\omega}_m$ and $\bar{\omega}_m$ are defined respectively by

$$\underline{\omega}_m=\frac{2}{1+\sqrt{1-\underset{i,j,k}{\mathrm{Max}}\left\{\frac{S^{(m)}_{i,j,k}}{S^{(m-1)}_{i,j,k}}\right\}}} \quad , \quad \bar{\omega}_m=\frac{2}{1+\sqrt{1-\underset{i,j,k}{\mathrm{Min}}\left\{\frac{S^{(m)}_{i,j,k}}{S^{(m-1)}_{i,j,k}}\right\}}} \quad ,$$

or ω may be specified by input data.

One-through-iteration

The iterative technique described below is similar to that used in the EQUIPOISE program. In this method the convergence of neutron fluxes at all space-energy points is tested at the end of one-through iterative step. This iterative process may be described as

$$\phi^{(m)}=B^{(m)}\phi^{(m-1)} \quad , \tag{37}$$

where $\phi^{(m)}$ is the flux vector for m-th iteration and defined by

$$\phi^{(m)}=\begin{pmatrix}\phi_1^{(m)}\\ \phi_2^{(m)}\\ \cdot\\ \cdot\\ \phi_g^{(m)}\\ \cdot\\ \cdot\\ \phi_N^{(m)}\end{pmatrix}$$

where $\phi_g^{(m)}$ is the subvector shown in Eq. (16), and $B^{(m)}$ is the iteration matrix which is varied with iteration because the fission source is re-normalized at the end of a sweep through all mesh points and all groups. The matrix form of Eq. (37) is applicable in both cases of point and line relaxation method. For example, if point relaxation is used according to Eq. (18), the subvector of any g-th group for the m-th iteration $\phi_g^{(m)}$ is given by

$$\phi_g^{(m)}=(I-\omega L_g)^{-1}\{(1-\omega)I+\omega U_g\}\phi_g^{(m-1)}+\omega(I-\omega L_g)^{-1}$$
$$\left\{\frac{1}{K_{eff}^{(m)}}\sum_{g'=1}^{N}F_{gg'}\phi_{g'}^{(m-1)}+\Sigma_{r,g-1}\phi_{g-1}^{(m)}\right\}\quad , \tag{38}$$

where $K_{eff}^{(m)}$ is given by

$$K_{eff}^{(m)}=\sum_{g=1}^{N}\sum_{g'=1}^{N}F_{gg'}\phi_{g'}^{(m-1)}\quad . \tag{39}$$

Equation (38) can also be written in the matrix form as shown in Eq. (37). The most straightfoward method for solving Eq. (38) is basically the power method, which is applicable to any matrix whose largest eigenvalue is unique. For $B^{(m)}$ with such a form as the discrete approximation matrix to neutron diffusion operator, its spectral radius is bounded[6] by

$$\min_{g,i,j,k}\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}<\rho(B^{(m)})<\max_{g,i,j,k}\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}\quad , \tag{40}$$

where $\phi_{g,i,j,k}^{(m)}$ is the m-th iteration flux of the g-th group at the mesh point (I, J, K) and $\rho(B^{(m)})$ is the spectral radius of $B^{(m)}$. The $\rho(B^{(m)})$ must tend to unity as the iteration proceeds because of the fission source renormalization. When the flux convergence criterion (with an input parameter ε_1)

$$\left|\max_{g,i,j,k}\left(\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}\right)-1\right|<\varepsilon_1,\quad \left|\min_{g,i,j,k}\left(\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}\right)-1\right|<\varepsilon_1 \tag{41}$$

is satisfied, the iterative process is terminated. The eigenvalue at the m-th iteration is estimated by Eq. (39). For accelerating this process, an extrapolation factor is applied to all of the space-energy pointwise flux values individually. It is convenient for obtaining the extrapolation factor to use the eigenvalues, $\lambda_n^{(m)}$ and eigen-functions, $\psi_n^{(m)}$ defined by the equation

$$\lambda_n^{(m)}\psi_n^{(m)}=B^{(m)}\psi_n^{(m)}\qquad (m=1,2,\ldots..)\quad , \tag{42}$$

where the $\lambda_n^{(m)}$ are ordered such that $\lambda_0^{(m)}>\lambda_1^{(m)}>\cdots\cdots$.

Equation (42) leads to the extrapolation form[6]:

$$\phi^{(\infty)}=\phi^{(m)}+\alpha^{(m)}(\phi^{(m)}-\phi^{(m-1)})\quad ,$$
$$\alpha^{(m)}=\lambda_0^{(m)}/(1-\lambda_0^{(m)})\quad , \tag{43}$$

the $\alpha^{(m)}$ being called an extrapolation factor. The $\lambda_o^{(m)}$ is estimated by

$$\lambda_o^{(m)}=\frac{1}{2}\left\{\max_{g,i,j,k}\left(\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}\right)+\min_{g,i,j,k}\left(\frac{\phi_{g,i,j,k}^{(m)}}{\phi_{g,i,j,k}^{(m-1)}}\right)\right\}\quad . \tag{44}$$

This extrapolation is not applied to the first I_m iterations and after I_m-th iteration, the change

of the extrapolation factor is tested every L_m iterations. The I_m and L_m are specified as input data and the extrapolation criterion is given by

$$\left| \frac{\alpha^{(m)}}{\alpha^{(m-1)}} - 1 \right| < \varepsilon_2 \quad . \tag{45}$$

3.4 Adjoint flux problem

The multi-group diffusion equation (12) can be rewritten as

$$M\phi - \Sigma\phi - \frac{1}{K_{eff}} F\phi = L\phi = 0 \quad , \tag{46}$$

where the matrix elements of the operator L are

$$L_{gg} = -\nabla D_g \nabla + \Sigma_{tg} - \frac{\chi_g}{K_{eff}} \nu\Sigma_{fg} \quad ,$$

$$L_{g,g-1} = -\Sigma_{g-1,g} - \frac{\chi_g}{K_{eff}} \nu\Sigma_{f,g-1} \quad ,$$

$$L_{g,g'} = -\frac{\chi_g}{K_{eff}} \nu\Sigma_{f,g'} \quad (g' \neq g \text{ or } g-1), \quad (g, g' = 1, 2, \cdots\cdots N) \quad .$$

The adjoint operator L^* to Eq. (46) and its solution, i.e., the adjoint flux $\phi*$ must satisfy the following relation:

$$[\phi^* \cdot L\phi] = [\phi \cdot L^*\phi^*] \quad . \tag{47}$$

Therefore, we get

$$-\nabla D_g \nabla \phi_g^* + \Sigma_{tg}\phi_g^* = \Sigma_{g,g+1}\phi_g^*{}_{g+1} + \frac{\nu\Sigma_{fg}}{\lambda} \sum_g \chi_g \phi_g^*, \quad (g = 1, 2, \cdots\cdots N) \quad , \tag{48}$$

or in the matrix representation,

$$L^*\phi^* = 0 \quad ,$$

where $L^*$is the transposed operator of L.

The calculation of the adjoint flux distribution is perfo rmed by the user's option in desending order of g (g=N, N−1, ……2, 1).

4. Program Usage

4.1 Variable common and program flow path control

The required core memories are depend sensitively on the problem to be solved, since the ADC program solves either one- two- or three-dimensional problem, optionally. Ordinarily, by the use of variable dimensioning, the program permits the optimum use of available storage. However, the compilers do not allow variable dimensions in the main program, and hence a fixed common length must be occupied prior to the program loading.

Since the program flow path depends on the problem to be solved, for an effective use of the core storage, the subroutines which are unnecessary for solving the problem should be unloaded and the "CALL" statement calling such subroutines in the main program should also be deleted. Formelly, in these cases, the overlay structure was changed, but for multi-process computers, the occupation of unnecessary core memory or loading of unnecessary subroutines is not economical.

The ADC program has eliminated these demerits by using two-step Fortran job. A common area and program flow path required for solving a particular problem are generated every time before the execution starts. This improved flowchart is shown in **Fig. 3.**

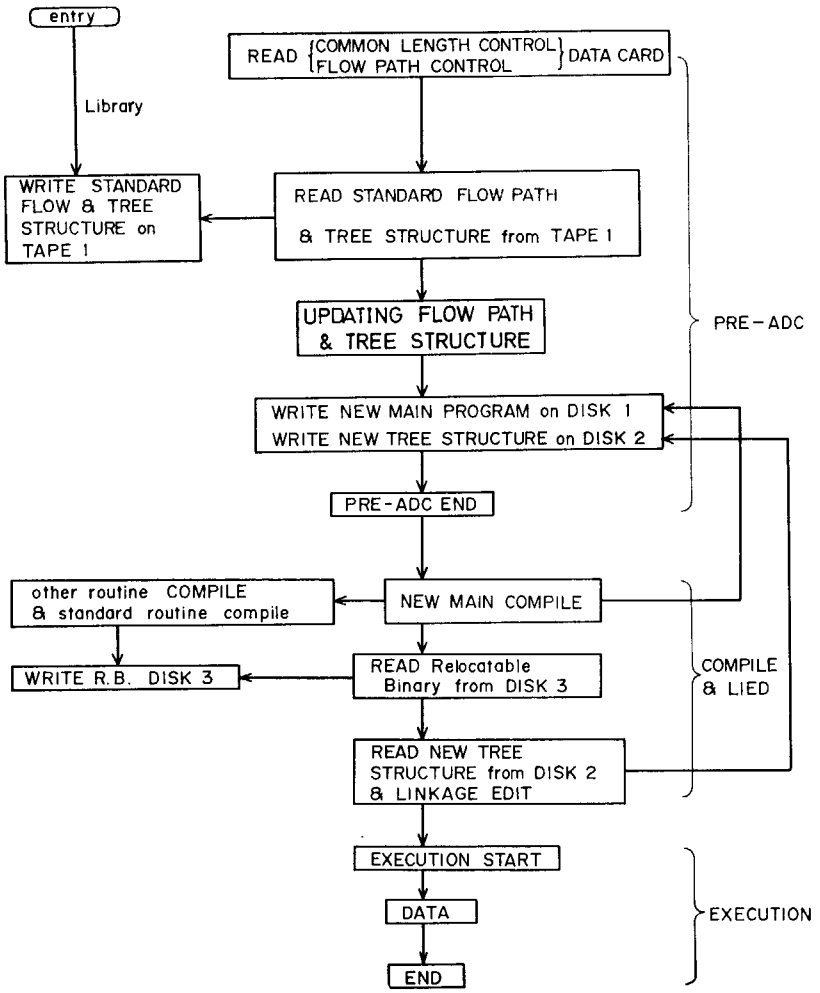

Fig. 3. Flow for variable common and path control.

In pre-ADC, the input data are read in with INPUT CARD O to INPUT GARD 7 (see Section 4.3.A) for the determination of COMMON length and flow path control. The standard main program of ADC is read from a library tape and updated according to the input data from pre-ADC, and hence the tree structure is generated for the linkage edit corresponding to the new flow path. The BCD image of the new main program and tree structure are saved in DISK 1 and DISK 2, respectively. Next, the new main program and other subroutines are compiled and the linkage edit is made according to new tree structure. After reading the remaining input data (see Section 4.3.B), the execution starts. The ADC program can be used also with a fixed common length for a 64K words machine as usual.

4.2 Standard program flow and required core memory

The standard ADC code, the main program of which has a fixed common length, is divided into five segments as shown in **Fig. 4**. **Table 1** lists the functions of ADC subroutines. Each stage of the program fits in a computer having at least 64K words core storage, and uses 5 scratch tapes depending on the problem to be solved. **Table 2** gives the logical tape numbers that are referred to in the program and the functions of the tapes.

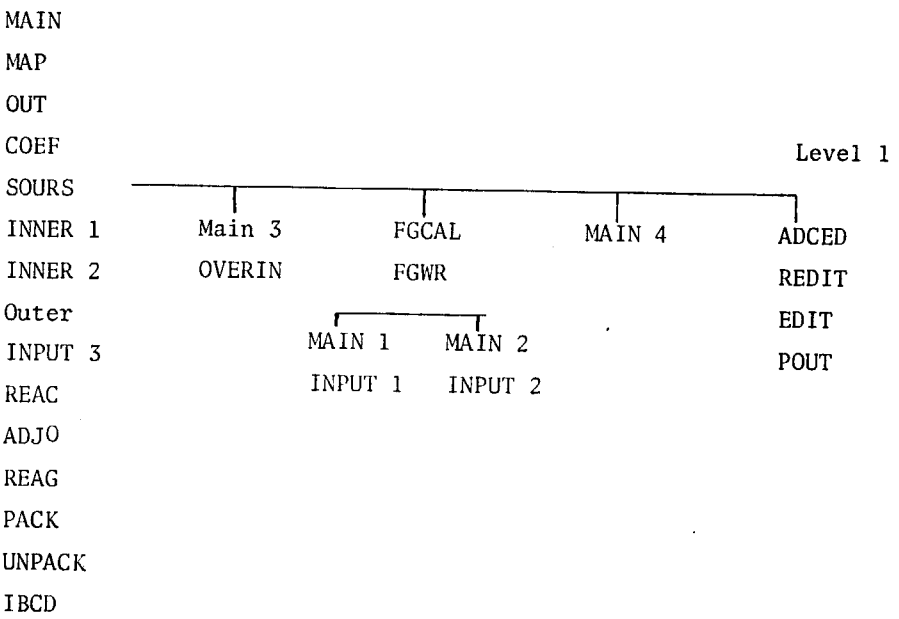

Fig. 4. Overlay structure for general dimensional code ADC.

Table 1 ADC subroutines

Name	Function	Called From
MAIN	Allocated total core storage and control all problem input	
MAP	Writes material map	MAIN 4, MAIN 3 MAIN 2, REDIT
OUT	Writes pointwise flux and pointwise power distribution	MAIN 4, MAIN 3 MAIN 2
COEF	Calculates coefficient for difference equation	MAIN 4, MAIN 3 MAIN 2
SOURS	Calculates fission source and slowing down sources	MAIN 3, MAIN 2
INNER 1	Calculates flux distribution by point over-relaxation method	MAIN 3, MAIN 2

INNER 2	Calculates flux distribution by line over-relaxation method	
Outer	Calculates new fission source distribution	MAIN 3, MAIN 4
INPUT 1	Input data for one dimensional calculation	MAIN 1
INPUT 2	Input data for two dimensional calculation	MAIN 2
INPUT 3	Input data for three dimensional calculation	MAIN 3, MAIN 4
REAC	Calculates gross neutron balance	MAIN 4, MAIN 2
ADJO	Inter change cross section for adjoint flux calculation	MAIN 1, MAIN 2, MAIN 3, MAIN 4
MAIN 1	Control for one dimensional calculation	MAIN FGCAL
MAIN 2	Control for two dimensional calculation	MAIN FGCAL
MAIN 3	Control for three dimensional calculation by inner and outer iteration	MAIN
MAIN 4	Control for three dimensional calculatron by one loop iteration	MAIN
OVERIN	Calculates optimum over relaxation factor	MAIN 3
ADCED	Control for editing and allocating core storage	MAIN
REDIT	Region editing	ADCED
EDIT	Calculates regionwise neutron balance	ADCED
POUT	Writes pointwise quantities	ADCED
REAG PACK UNPACK IBCD	Subroutines for reading input data in free format	INPUT 3 INPUT 2 INPUT 1 REDIT
FGCAL	Synthesized flux guess for three dimensional calculation	MAIN
FGWR	writes flux guess on tape of unit 3	FGCAL

Table 2 Tape and disk required for ADC.

Logical Number	Use
1	Disk-scratch
2	Disk-scratch
3	Tape or Disk・・・Flux dump
4	Disk-scratch
8	Disk-scratch

The execution time required to solve a problem is very dependent on the problem itself. The use of a large capacity storage without using scratch units is best to achieve the minimum execution time. However, as the core capacity is limited, an efficient use of auxiliary hardware with sophisticated software is necessary to reduce the required core memory. In a sample problem shown in the appendix with X-Y-Z geometry of 3840 mesh points and three energy groups, the amount of the required core memory for the ADC code is 108K words, on the other hand for the CITATION code, is 207K words. This result shows that the way of the selection of common area and program flow path of the ADC code is effective to reduce the required core memory. In this case, the execution time for the ADC is 79 sec and that for the CITATION is 77sec.

4.3 Detailed input specification

Except for the control parameters, the cross sections, spatial flux guess and all other floating point numbers are read into the ADC program in the free format via generalized subroutine REAG. The

subroutine REAG for FACOM 230-75 converts BCD information to integer or floating point binary information. Three conversion types of reading N floating numbers, N integer numbers, and $4*N_1$ characters, N_2 integers and N_3 floating point numbers are allowed by corresponding subroutines. [6]

A typical example of the function of this subroutine is described for the following three punched cards;

```
105, 318, −14, 1.5E−3 3.12E−3/ THIS IS A COMMENT
2(1.0,1.5) 3(0)/
1.0, 5*0.1, 2*−0.2/
```

The subroutine will convert BCD number 105 and 318 to their binary integer equivalents. In a similar fashion −14 will be converted to a negative binary integer, and 1.5E −3 will be converted to 0.0015. Data punched on a card may be delimited by blank column or comma. The slash (/) indicates the end of the BCD field to be converted, and the remainder of the card can be used for comments. If no slash is present, 72 columns of a card are scanned and the next card is read.

The second card indicates that the data 1.0 and 1.5 in the first parentheses and 0 in the second are repeated twice and three times, respectively, and therefore it is equivalent with a card punched as 1.0, 1.5, 1.0, 1.5, 0,0,0/. The last card indicates that the first word is 1.0, the second word 0.1 is successively accumulated five times to the previous word and the last word −0.2, twice. Therefore it is equivalent with a card punched as 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.3, 1.1/.

The format for the control parameters (CARD 0 ∽CARD 7) must be 12I6 for integer, 6E12.5 for floating point data and 18A4 for job title and comments. The input data from CARD 0 to CARD 7 are used for determination of COMMON length and flow path control.

4.3.A. Input of control information for ADC

Word Number on Card	Name of Variable	Comments
JOB TITLE CARD ..... CARD 0		
	TITL	User must punch an asterisk sign (*) in the first column, which is used to identify a title card. The information punched in the remaining columns will be printed at the top of page of output.
CONTROL INTEGERS ..... CARD 1		
1	IDISN	Problem dimension 1/2/3 one dimension/two dimension/three dimension.
2	IGEOM	Geometry 1/2/3/4/5 slab X-Y-Z, X-Y, X/cylinder R-Z-θ/cylinder R-Z/cylinder R-θ/cylinder R.
3	NGMAX	Number of energy groups.
4	MAT	Total number of materials for which cross sections are to be supplied.
5	IADJ	Adjoint calculation option −1/0/1 adjont only/regular calculation only/regular and adjoint calculaton.
6	NFGES1	Input option of regular flux guess read from card. = 0 Flat = −1 From logical unit 3 tape = −2 If IDISN=2 or 1, flux calculation in previous case is used. If IDISN=3, the flux guess is synthesized from one and two dimensional calculation in the code.
7	NEGES2	Input option of adjoint flux guess same as NFGES1.
8	IFOUT	Flux output option of IFOUT=1, out put to logical unit 3 tape.

9	NCASE	Option for running a series of case 3/2/1/0/−1/−2 more case with fine edit/end of batch with fine edit/more case/end of batch/a series output in tape are re-edited/out-put of selected case in tape are re-edited. If NCASE <0, CARD 0, CARD 1 and edit input are required.

CONTROL INTEGER ·····CARD 2

1	IX1	Number of intervals in the X or R direction.
2	IY1	Number of intervals in the Y, Z or θ direction.
3	IZ1	Number of intervals in the Z direction

CONTROL INTEGER ·····Required only if IDISN=3 ·····CARD 3

1	MZL	Number of X-Y or R-θ layer for different material map identification.
2	MZC	Number of X-Y or R-θ layers with fission source.
3	NFLUX	Number of X-Y or R-θ layers for flux value in core storage NFLUX $\leq$ IZi, usually equal to IZl.
4	NCOEF	Number of X-Y or R-θ layers for difference equation coefficients value in core storage. 0/1/N coefficients value of all layers are in core/coefficients are calculated at each iteration step/coefficients of N layers are in core, other coefficients are in tape at each iteration step, those are read from tape.

CONTROL INTEGERS·····CARD 4

1	IOUTSC	Outer iteration option 0/1/3 over-relaxation/Tchebysheff extrapolation/One-loop iteration, this option is used only if IDISN=3.
2	ITOMAX	Maximum number of outer iteration counts. If IOUTSC=3, maximum number of one-loop iteration counts.

CONTROL FLOATING POINT DATA ·····CARD 5

1	OMEGA1	Used only if IOUTSC=0, outer loop over relaxation factor.
2	EPS3	Outer Loop Convergence Criteria Recommended if IOUTSC=0, or 1 EPS3=10^{-4} and if IOUTSC=3, EPS=10^{-6}.

CONTROL INTEGER ·····Required only if IDISN=2, or 3 ·····CARD 6

1	INITSC	Inner iteration option 0/1/2/3/4/5/ point relaxation/ X-line relaxation/Y-line relaxation/point relaxation factor is calculated in code/X-line relaxation factor is calculated in code/ Y-line relaxation factor is calculated in code/. Recommended that if IDISN=2, INITSC=1, if IDISN=3, IOUTSC=0, INITSC=4 or 5, and if IDISN=3, IOUTSC=1, INITSC=1or 4.
2	ITIN1	Used only if IDISN=2, or if IDISN=3, IOUTSC=1 or 0. Maximum number of X-Y or R-θ layers inner iteration counts.
3	ITIN2	Used only if IDISN=3, IOUTSC=1 or 0. Maximum number of XYZ inner iteration counts.
4	LCMX	Used only if IOUTSC=3. Number of one-loop iteration for testing extrapolation factor.
5	ITDM	Used only if IOUTSC=3. Minimum delay between extrapolation.

CONTROL FLOATING POINT DATA··· Required only if IDISN-2 or 3 ·····CARD 7

1	OMEGA2	Used only if INITSC=0, 1, 6. Inner loop over relaxation factor $1 \leq$ OMEGA2 < 2.
2	EPS1	Used only if IDISN=2. Convergence criteria of X-Y, R-θ, or

		R-Z layers. Recommended value 10^{-4}.
3	EPS2	Used only if IDISN=3. Convergence criteria of X-Y-Z or R-θ-Z inner loop. Recommended value 10^{-4}.
4	EPS4	Used only if IOUTSC=3. Extrapolation criteria. Recommended value 0.05.

4.3.B. Input of remaining data for ADC

All the following data are read by the subroutione REAG. We denote these format by I for integer and E for floating-point number.

Block Name and Dimension	Format	Number of Entries	Comments
XAI(I)	E	NGMAX	Fission spectrum.
IBOUND(I)	I	IDISN*2	Boundary condition 1/0/−1 reflective/Vacuum/by derivative $D\phi'/\phi$. IBOUND(1); if IGEOM=1 left boundary, if IGEOM−2,3,4 or 5 center boundary of R. IBOUND(2); if IGEOM=1 right bounbary, if IGEOM−2,3,4 or 5 outer boundary of R. IBOUND(3); if IGEOM=1 back boundary, if IGEOM=2,4 θ-direction boundary. If full circular or periodic boundary, IBOUND(3)=−2; if IGEOM=3 top boundary of Z. IBOUND(4); if IGEOM=1 front boundary, if IGEOM=2,4 θ-direction boundary, if IGEOM=3 bottom boundary of Z. IBOUND(5); top boundary of Z. IBOUND(6); bottom boundary of Z.
BO(I)	I		Log derivative data. Number of entries is summation of numbers of IBOUND(I)=−1 boundary.
MZID(IZl)	I	IZl	Required only if IDISN=3. Material layer map number of first X-Y or R-θ plane. Material layer map number of second X-Y or R-θ plane. • • • Material layer map number of IZlth X-Y or R-θ plane, (e.g. if MZL=2, IZl=4, MZID(i) are 1,1,2,2/two layers of all may have the same material map specification as 1, remaining layers are specified as 2).
MZCD(IZl)	I	IZl	Required only if IDISN=3. 0/1 layer with no fission source/layer with fission source, (e.g. if MZC=2, IZl=4, MZCD(i) are 0,0,1,1/two layers have no fission source specifications as 0).
Material number			Material identification number.

			Number of entries depends on IDISN.
NREG(IX1, IY1, MZL)	I		If IDISN=3, MZL blocks data are required and each block has IX1*IY1 entries. The first block is material number for first material layer, the first data read in is the first X or R-line, as follow second X-line, X line number must be ascending order. The second block is material number for second material layer. . . . The MZL the block is material number for MZLth material layer, (e. g. if IX1=4, IY1=4, IZ1=4, MZL=2 first and second plane material map 1 1 1 1 →X 1 1 1 1 ↓ 2 2 2 2 Y 2 2 2 2 third and forth plane material map. 1 1 1 1 →X 1 1 1 1 ↓ 2 2 1 1 Y 2 2 1 1 In this example map, two block data are required, the first 8(1), 8 (2)/and the second 8(1), 2(2, 2, 1, 1)/).
NREG(IX1, IY1)	I	IX1*IY1	If IDIZN=2, IX1*IY1 entries the first data read in is first X or R line, as follow second line, line number must be ascending order. The scheme for these data read in is same as one layer of three dimension.
NREG(IX1)	I	IX1	If IDISN=1 material number around each mesh point.
DX(IX1)	E	IX1	X or R direction mesh interval.
DY(IY1)	E	IYO	Y, Z or θ direction mesh interval required only if IDISN $\geqq$ 2.
DZ(IZ1)	E	IZ1	Z direction mesh inteval required only if IDISN=3.
Cross Section	E		If IDISN=1 or 2, NGMAX*MAT blocks data are required and each block has six entries. First material, 1st energy group, $D_1^{(1)}$, $\Sigma_{a1}^{(1)}$, $\Sigma_{R1}^{(1)}$, $\nu\Sigma_{f1}^{(1)}$, $\nu_1^{(1)}$, $B_1^{2\,(1)}$ first material 2nd energy group, $D_2^{(1)}$, $\Sigma_{a2}^{(1)}$, $\Sigma_{R2}^{(1)}$, $\nu\Sigma_{f2}^{(1)}$, $\nu_2^{(1)}$, $B_2^{2\,(2)}$ . . . first material NGMAXth energy group, second material 1st energy group, .

			.
			.
			D; diffusion coefficient, Σ_a; absorption, Σ_R; removal, Σ_f; fission, ν; nue value, B^2; transverse buckling. If IDISN=3, NGMAX*MAT blocks data are required. Each block has five entries. (no buckling data)
			$D_1^{(1)}$, $\Sigma_{a1}^{(1)}$, $\Sigma_{R1}^{(1)}$, ν $\Sigma_{f1}^{(1)}$, $\nu_1^{(1)}$
			If $D_i^{(1)}$ is input zero, this specifies a rod group for this material. The rod group constant $C_r=D\phi'/\phi$ is input in the place of Σ_a, and Σ_R, ν Σ_f, ν and B^2 must be input zero.
NR(NFGES1) or NF(NFGES2)	I	NFGES1 or NFGES2	Input flux guess option. Required only if IDISN=3, NFGES1 or NFGES2 $>$ 0. NF(1); from 1st X-Y or R-θ plane to NF(1)th plane, group dependent same flux guess is used. NF(2); from NF(1)+1th plane to NF(2)th plane, group dependent same flux guess is used.
			.
			.
			.
			NF(NFGES1) : from NF(NFGES1−1)+1th plane to NF (NFGES1) {=IZ1}th plane, group dependent same flux guess is used.
Input Flux Guess	E		Number of entries depends on IDISN. Required only if NFGES1 or NFGES2 $>$ 0.
FLUX(IX1, IY1, NGMAX, NFGES1) or FLUX (IX1, IY1, NGMAX, NEGES2)			If IDISN=3, NFGES1*NGMAX blocks data are required. Each block has IX1*IY1 entries. First block, first group, first X-line second group, second X-line . . . . . . 2nd block, first group, first X-line second group, second X-line . . . . . .
FLUX(IX1, IY1, NGMAX)	E		If IDISN=2, NFGES1 or 2 $>$ 0, NGMAX blocks data are required. Each block has IX1*IY1 entries. The order of flux guess read in is same as case of IDISN=3.
FLUX (IX1, NGMAX)			If IDISN=1, NFGES1 or 2 $>$ 0, NGMAX blocks, data are required. Each block has IX1*IY1 entries.
IA (3)	I	3	If IDISN=3 and NFGES1 or NFGES2=−2 following three integers data are required for flux guess synthesized. IA (1): X or R direction mesh point number for appropriate Z-axis one dimensional calculation. IA (2): Y or θ direction mesh point number for appropriate

Z-axis one dimensional calculation.

IA (3) : X-Y or R-θ plane number for appropriate two dimensional calculation.

4.3.C. Input of control number for ADC-Edit

Following data are required only if NCASE≠0 or ≠1 and IDISN≠1

Number Word on Card	Name of Variable	Comment
EDIT TITLE CARD····· Required only if NCASE=3, =2, or=−2····· CARD 0		
	TINPUT	The job title of previous case selected to re-edit. This card must be completely same as the JOB TITLE CARD.
CONTROL INTEGER ····· CARD 1		
1	NRMAX	Number of edit region.
2	NFR	Number of flux ratio edit ($\phi_g/\phi_{g'}$). if NFR=0, no edit.
3	NBETA	Number of groups of edit regionwise flux to be normalized. If NBETA=0, normalization factor is total power.
4	NPO	Option of point power normalization factor to be read. 0/1 specified by code/edit regionwise specified by input.
5	MZE	Used only if IDISN=3. Number of X-Y or R-θ layers with different edit region layer map.
CONTROL FLOATING POINT DATA ····· CARD 2		
1	PT	Total power (watt), if PT=1.0, point power normalization factor is average power.
2	PCONV	Power conversion factor (Watt/fission/SEC).

4.3.D. Input of remaining data for ADC-Edit

The following data are read by the subroutine REAG. The formats denoted by I and E mean integer and floating point number, respectively.

Block Name and Dimension	Format	Number of Entries	Comment
NFR(NFR*2)	I	NFR*2	Required only if NFR > 0. Energy group number for flux ratio calculation (e.g. if NGMAX=4, NFR=2). 1, 4, 2, 4/ In this example, ϕ_1/ϕ_4, ϕ_2/ϕ_4 pointwise two ratios are calculated)
IG1(NBETA)	I	NBETA	Required only if NBETA > 0. Energy group number to be normalized (e.g. if NBETA=2, NGMAX=4). 3, 4/ In this example, 3rd group, 4th group fluxes are normalized by input specifications. (Other group fluxes are normalized by total power.)
BETAF(NBETA, NRMAX)	E		Required only if NBETA > 0. NBETA blocks data are required. Each block has NRMAX entries. 1st block; IG1(1)th group flux normalization factor. 2nd block; IG1(2)th group flux normalization factor. ⋮

			NBETAth block IG1 (NBETA) th group flux normalizationfactor. Flux would be normalized pointwise and edit regionwise.
BETAP	E	NRMAX	Edit region wise power density normalization factor. Required only if NPO≠0.
MZED(IZ1)	I	IZ1	Required only if IDISN=3. Edit layer map number of each X-Y or R-plane. These data are read in same scheme as ADC input MZID (IZ1).
Edit region number			Edit region identification number. Number of entries depends on IDISN.
NREGE(IX1, IY1, MZE)	I		If IDISN=3, MZE blocks data are required. Each block has IX1*IY1 entries.
NREGE (IX1, IY1)	I		If IDISN=2, IX1*IY1 entries. These data are read in same scheme as ADC input NREG.

4.4 Output information

Output data of "ADC" consist of two parts, normal edit quantities and optional regionwise edit quantities. Varieties of integrated and averaged values for specified mesh-regions, which are not always identical with material regions, are edited by the edit segment ADCED.

The follwing is the list of normal output quantities. All pointwise edit data are normalized so that total fission source equals to unity.

(1) All the input is printed immediately after read-in.
(2) The two dimensional material map by integer numbers. (for three dimensional problem, multiple maps corresponding to all X-Y or R-θ planes)
(3) Eigenvalue convergence status at each iteration.
(4) Gross neutron balance.
(5) Pointwise group flux.
(6) Pointwise power density.

The following quantities are edited optionally if the user requires the integrated and averaged values in edit-regions or the re-editing of the result saved in tape.

(1) All the input of "ADCED" is printed immediately after the reading.
(2) The two dimensional edit-region by integer numbers (for three dimensional problem, multiple maps corresponding to all X-Y or R-θ planes).
(3) Pointwise edit
  (a) Pointwise flux $\phi_{g,i,j,k}$
  Renormalized by the formula
  $$\phi_{g,i,j,k}=\beta_g(NR)\phi'_{g,i,j,k}$$
if NBETA=0, $\beta^{-1}=\sum_g\int_v \frac{\mathrm{PCONV}}{\nu_g}\nu_g \Sigma_{fg}\phi_g dv/PT$ is constant.
If NBETA $>$ 0, β_g (NR) is specified by input for the edit-region for each energy group
where NR : edit-region number
  PCONV : conversion factor to power
  PT : total power
  (b) Pointwise flux ratio $\alpha_{NFR,i,j,k}$
  $$\alpha_{NFR,i,j,k}=\phi'_{g,i,j,k}/\phi'_{g',i,j,k}$$
where neutron group number g is specified by input.
  (c) Pointwise power $P_{i,j,k}$

$$P_{i,j,k}=\Sigma_g \frac{\mathrm{PCONV}}{\nu_g} * \mathrm{BETAP}\ (NR)\ * \nu_g \Sigma_{fg} \phi'_{g,i,j,k}$$

where if NPO=0, BETAP (NR)=1 constant

if NPO≧1 BETAP (NR) : edit-regionwise power

Normalization factors are specified by input.

$$\text{if PT=1. 0,}\quad P_{i,j,k}=\sum_g \frac{1}{\nu_g} \nu_g \Sigma_{fg} \phi'_g / \sum_g \int_V \frac{1}{\nu_g} \nu_g \Sigma_{fg} \phi'_g dv$$

(4) Integral edit

Integrals are calculated only for edit-regions specified by input. The following quantities are edited for each group and for the sum over the groups.

(a) Neutron leakage

$$L_{NR,g}=-\int_{SNR} D_{g,i,j,k} \nabla \phi'_{g,i,j,k} ds$$

Rod leakage and DB^2 leakage are also edited.

(b) Neutron absorption

$$A_{NR,g}=\int_{v_{NR}} \Sigma_{a,g,i,j,k} \phi'_{g,i,j,k} dv$$

(c) Neutron removal

$$R_{NR,g}=\int_{v_{NR}} \Sigma_{R,g,i,j,k} \phi'_{g,i,j,k} dv$$

(d) Neutron source

$$F_{NR,g}=X_g \Sigma_{g'} \int \nu_g \Sigma_{fg',i,j,k} \phi'_{g',i,j,k} dv$$

These quantities are renormalized so that total neutron source; $\sum_{NR} \sum_g F_{NR,g}$ equals to unity.

(e) Region averaged flux $\overline{\phi}_{NR,g}$

$$\overline{\phi}_{NR,g}=\int_{v_{NR}} \phi_{g,i,j,k} dv / v_{NR}$$

All of the flux integrals and averages are multiplied by the normalization factor.

(f) Region averaged power, P_{NR}

$$P_{NR}=\int_{v_{NR}} P_{i,j,k} dv / v_{NR}$$

$P_{i,j,k}$ are pointwise power as shown previously.

(g) Regionwise k_{NR}^{∞}

$$k_{NR}^{\infty}=\sum_g F_{NR,g} / \sum_g A_{NR,g}$$

(h) Edit-region volume

$$v_{NR}=\int_{v_{NR}} \Sigma_{EV}\ v_{i,j,k}$$

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Calculations in Two and Three Dimensions, *Nucl. Sci. Eng.*, 12(4) 513-518 (1962)

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Appendix: Sample Input and Output

The following pages show the input data and computer output for 3-group, 2-material, eigenvalue problem in X-Y-Z geometry (see Figure A-1). The problem requires about 79 seconds to run.

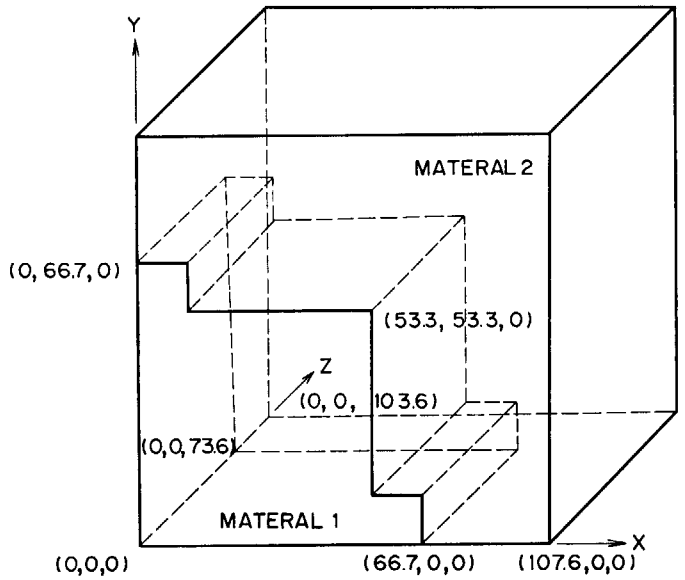

Fig. A-1. Diagram of sample problem.

Sample Input and Sample Output

```
 IDENT=JOB

00010 ¥NO  T555,T.2C.4W.2P.0
00020 ¥GJOB  3111446,YO.NAITO,525.10,BWR.ACE,SMF=CLS
00030 ¥HRUN MADC,J1446.MADCEB,OUT=500,SYSOUT=CLS,NAME=2
00040 ¥DISKTO   F01,(J1446.ADCLIB(SORCELIB))
00050 ¥LIBEDISK F02,TEMP1
00060 ¥SORTFDD  F04,TEMP,J1446.TEMP2,,,PASS,9,F,80,1200
00070 ¥SORTFDD  F08,TEMP,J1446.TEMP,,,PASS,9,F,80,1200
00080 ¥DATA
00090 *******INPUT  DATA**********
00100 ¥HFORT TFNAME=J1446.TEMP,SYSOUT=CLS
00110 ¥HLIED.A RFNAME=J1446.ADCRB,EDIT=YES,PROGNAME=ADC3,SYSOUT=CLS
00120         ,RBSPC=300,DIRCT=200,EBTRK=200
00130 ¥LIBEDISK SYSIN,J1446.TEMP2
00140 ¥HRUN ADC3,OUT=500,SYSOUT=CLS
00150 ¥DISK  F01
00160 ¥DISK  F02
00170 ¥LIBEDISK  F09,TEMP1
00180 ¥DISK  F03
00190 ¥DISK  F04
00200 ¥DISK  F08
00210 ¥JEND

#

 IDENT=000

00010 ¥NO NAIT,  T.6C.4W.3P.0
00020 ¥GJOB  3111446,YO.NAITO,525.10,SMF=CLS
00030 ¥HRUN MADC,J1446.MADCEB,OUT=500,SYSOUT=CLS,NAME=2
00040 ¥DISKTO  F01,J1446.ADCLIB
00050 ¥LIBEDISK F02,TEMP1
00060 ¥FD F05.001,FILE=(CATLG,J1446.ADCDATA(DATA4))
00070 ¥LIBEDISK F04,TEMP2
00080 ¥SORTFDD F08,TEMP,J2304.TEMP,,,PASS,9,F,80,1200
00090 ¥HFORT TFNAME=J2304.TEMP,SYSOUT=CLS
00100 ¥HLIED RFNAME=J1446.ADCRB,EDIT=YES,PROGNAME=ADC3,SYSOUT=CLS
00110         ,RBSPC=300,DIRCT=200,EBTRK=200
00120 ¥HRUN ADC3,OUT=500,SYSOUT=CLS
00130 ¥DISK F01
00140 ¥DISK F02
00150 ¥LIBEDISK F09,TEMP1
00160 ¥DISK F03
00170 ¥DISK F04
00180 ¥DISK F08
00190 ¥JEND
```

```
1

                ***ADC CALCU*** *       ADC  X-Y-Z  SAMPLE  PROBLEM
IDISK     1/2/3/=ONE/TWO/THREE DIMENSIONAL CALCU.                                   3
IGEOM     1/2/3/4/5/=SLAB X,XY,XYZ/CYLINDER,R THETA,Z/R,Z/R,THETA/R/                 1
NGMAX     TOTAL NUMBER OF ENERGY GROUPS                                             3
MAT       TOTAL NUMBER OF COMPOSITION                                               2
IADJ      1/0/-1=NEUTRON FLUX AND ADJOINT FLUX/NEUTRON FLUX ONLY/ADJOINT FLUX ONLY/ 0
NFGES1    .GT.0/0/-1/-2=READ CARDS/FLAT/READ UNIT3/NO READ/ NEUTRON FLUX GUESS      0
NFGES2    .GT.0/0/-1/-2=READ CARDS/FLAT/READ UNIT3/NO READ/ ADJOINT FLUX GUESS      0
IFOUT     IF NOT ZERO  WRITE FLUX OUTPUT ON UNIT 3                                  1
NCASE     1/0=MORE CASE/END CASE                                                    1
IX1       TOTAL NUMBER OF X OR R DIRECTIONAL MESH POINTS                           16
IY1       TOTAL NUMBER OF Y OR THETA DIRECTIONAL MESH POINTS                       16
IZ1       TOTAL NUMBER OF Z DIRECTIONAL MESH POINTS                                15
MZL       TOTAL NUMBER OF XY LAYERS WITH DIFFERENT COMPOSITION MAP I.D.             2
MZC       TOTAL NUMBER OF XY LAYERS WITH FISSION SOURCE                            10
NFLUX     TOTAL NUMBER OF XY LAYERS FOR FLUX IN CORE STORAGE                       15
NCOEF     TOTAL NUMBER OF XY LAYERS FOR DIFFERENCE EW. COEFFICENT IN CORE STORAGE
          IF ZERO  ALL IS INCORE                                                    0
IOUTSC    OUTER ITERATION SCHEME 0/1/2/3/=OVER RELAXATION/TCHEBYSHEFF EXTRA./DUM/NOT ACC./  3
INITSC    INNER ITERATION SCHEME 0/1/2/3/4/5/6/7                                    1
ITOMAX    MAXIMUM NUMBER OF OUTER ITERATION COUNTS                                100
ITIN1     MAXIMUM NUMBER OF INNER ITERATION COUNTS IN XY LAYERS OR R,THETA/RZ LAYERS  1
ITIN2     MAXIMUM NUMBER OF INNER ITERATION COUNTS IN XYZ OR R,THETA,Z               1
LCMX      NUMBER OF ITERATION FOR TESTING OVER RELAXATION FACTOR                    5
ITDM      MINIMUM DELAY BETWEEN EXTRAPOLATION                                      50
OMEGA1    OUTER LOOP OVER RELAXATION FACTOR                                 0.0
OMEGA2    INNER LOOP OVER RELAXATION FACTOR                                 0.12500E+01
EPS1      XY LAYER INNER LOOP CONVERGENCE CRITERIA                          0.10000E-03
EPS2      XYZ INNER LOOP CONVERGENCE CRITERIA                               0.10000E-03
EPS3      OUTER LOOP CONVERGENCE CRITERIA                                   0.50000E-06
EPS4      EXTRAPOLATION CRITERIA                                            0.50000E-01
                          CORE USED  108015  WITHIN  108015      16      45

1

0         F,SPECTR
          0.10000E+01 0.0         0.0
0         BOUNDARY
                    1         0         0         1         0         1
0         Z MAT ID
                    1         1         1         1         1         2         2         2         2         2
                    2         2         2         2         2
```

Z COREID
XY MATID
XY MATID

```
                    2         2         2         2         1         1         1         1         1         1
                    1         1         2         2         2         2         2         2         2         2
                    1         1         1         1         1         1         1         1         2         2
                    2         2         2         2         2         2         1         1         1         1
                    1         1         1         1         2         2         2         2         2         2
                    2         2         2         2         1         1         1         1         1         1
                    2         2         2         2         2         2         2         2         2         2
                    1         1         1         1         1         1
0          X MESHWD
           0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
           0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0          Y MESHWD
           0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
           0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0          Z MESHWD
           0.80000E+01 0.80000E+01 0.80000E+01 0.80000E+01 0.80000E+01 0.74700E+01 0.74700E+01 0.74700E+01 0.74700E+01 0.74700E+01
           0.74700E+01 0.74700E+01 0.74700E+01 0.74700E+01 0.74700E+01
1


           CROSS SECTION      EG GROUP      DIFU COE      SGMAA          SIGTR          NUSIGF         NU VALUE
           MAT NUMB.      1
                                  1        0.22432E+01  0.56400E-03  0.54889E-01  0.0            0.0
                                  2        0.77642E+00  0.72000E-03  0.11476E+00  0.0            0.0
                                  3        0.23702E+00  0.10161E-01  0.0          0.0            0.0
           MAT NUMB.      2
                                  1        0.17916E+01  0.27610E-02  0.34931E-01  0.32561E-02  0.26000E+01
                                  2        0.87917E+00  0.17109E-01  0.53684E-01  0.97048E-02  0.24300E+01
                                  3        0.46215E+00  0.60230E-01  0.0          0.85206E-01  0.24300E+01
1THIS MAP  TO  Z  MESH POINT NO
      1  2  3  4  5
0X  DIRECTION MESH WIDTH
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0Y  DIRECTION MESH WIDTH
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0    X 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
    Y
    0  ***************************************************
       * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    1  *                                                 *
       * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    2  *                                                 *
       * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    3  *                                                 *
       * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
```

```
     4  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     5  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     6  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     7  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     8  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     9  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    10  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    11  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    12  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    13  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    14  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    15  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
    16  ****************************************************
1THIS MAP  TO  Z  MESH POINT NO
       6  7  8  9 10 11 12 13 14 15
0X  DIRECTION MESH WIDTH
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0Y  DIRECTION MESH WIDTH
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01 0.68300E+01
0    X 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
     Y
     0  ****************************************************
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     1  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     2  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     3  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     4  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     5  *                                                  *
        * 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
     6  *******                                           *
        * 2  2* 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
```

```
   7  *     *                                                 *
      * 2  2* 1  1  1  1  1  1  1  1  1  1  1  1  1  1  1  1*
   8  *     ********************                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
   9  *                        *                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
  10  *                        *                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
  11  *                        *                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
  12  *                        *                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
  13  *                        *                              *
      * 2  2  2  2  2  2  2  2* 1  1  1  1  1  1  1  1  1*
  14  *                        ********                       *
      * 2  2  2  2  2  2  2  2  2  2  2* 1  1  1  1  1  1*
  15  *                                 *                     *
      * 2  2  2  2  2  2  2  2  2  2  2* 1  1  1  1  1  1*
  16  ***************************************************
1
```

1 IT.COUNT	EIGEN CONV.	EIGENVALUE	ACC.PARAMETER	FRMIN	FRMAX	FLUX CHANGE
1	0.14766611E+00	0.85233389E+00	0.10000000E+01	0.11721666E+00	0.31075073E+01	0.75312108E+01
2	0.95008914E-02	0.84423596E+00	0.10000000E+01	0.26397814E+00	0.12817900E+01	0.27881925E+01
3	0.45917962E-01	0.88300155E+00	0.10000000E+01	0.36334762E+00	0.11638608E+01	0.17521854E+01
4	0.49151233E-01	0.92640217E+00	0.10000000E+01	0.42107404E+00	0.11350726E+01	0.13748792E+01
5	0.38768906E-01	0.96231776E+00	0.10000000E+01	0.45895467E+00	0.11131678E+01	0.11788644E+01
6	0.28378918E-01	0.98962730E+00	0.10000000E+01	0.48094036E+00	0.10918636E+01	0.10792599E+01
7	0.36231138E-01	0.10254826E+01	0.12500000E+01	0.59522806E-01	0.11672423E+01	0.15800283E+02
8	0.16426371E-01	0.10423276E+01	0.12500000E+01	0.11157748E+00	0.42928636E+01	0.79623816E+01
9	0.11306169E-01	0.10541123E+01	0.12500000E+01	0.22208065E+00	0.13103919E+01	0.35028687E+01
10	0.85568789E-02	0.10631322E+01	0.12500000E+01	0.27031530E+00	0.11080035E+01	0.26993837E+01
11	0.65805042E-02	0.10701282E+01	0.12500000E+01	0.30117121E+00	0.10564814E+01	0.23203706E+01
12	0.52024167E-02	0.10755954E+01	0.12500000E+01	0.32668220E+00	0.10466080E+01	0.20610789E+01
13	0.41916256E-02	0.10802043E+01	0.12500000E+01	0.35409945E+00	0.10391292E+01	0.18240654E+01
14	0.34287156E-02	0.10839081E+01	0.12500000E+01	0.39601752E+00	0.10324360E+01	0.15251408E+01
15	0.28365749E-02	0.10869826E+01	0.12500000E+01	0.41306008E+00	0.10271634E+01	0.14209553E+01
16	0.23667315E-02	0.10895552E+01	0.12500000E+01	0.42626286E+00	0.10227593E+01	0.13459703E+01
17	0.19872040E-02	0.10917204E+01	0.12500000E+01	0.45853092E+00	0.10191194E+01	0.11808780E+01
18	0.16754177E-02	0.10935495E+01	0.12500000E+01	0.51948309E+00	0.10161209E+01	0.92499045E+00
19	0.14169566E-02	0.10950990E+01	0.12500000E+01	0.60792851E+00	0.10137433E+01	0.64493023E+00
20	0.12003943E-02	0.10964136E+01	0.12500000E+01	0.70835127E+00	0.10117261E+01	0.41172897E+00
21	0.10182787E-02	0.10975300E+01	0.12500000E+01	0.79299094E+00	0.10100133E+01	0.26104847E+00
22	0.86376852E-03	0.10984780E+01	0.12500000E+01	0.84813982E+00	0.10086307E+01	0.17905087E+00
23	0.73309483E-03	0.10992833E+01	0.12500000E+01	0.88340372E+00	0.10074926E+01	0.13198527E+00
24	0.62186488E-03	0.10999669E+01	0.12500000E+01	0.90657093E+00	0.10065377E+01	0.10305766E+00
25	0.52746279E-03	0.11005471E+01	0.12500000E+01	0.92179571E+00	0.10057695E+01	0.84839063E-01

26	0.44673137E-03	0.11010388E+01	0.12500000E+01	0.93281060E+00	0.10051265E+01	0.72028970E-01
27	0.37916099E-03	0.11014562E+01	0.12500000E+01	0.94106644E+00	0.10047188E+01	0.62624225E-01
28	0.32068196E-03	0.11018094E+01	0.12500000E+01	0.94802757E+00	0.10045848E+01	0.54821647E-01
29	0.27170246E-03	0.11021088E+01	0.12500000E+01	0.95452151E+00	0.10044530E+01	0.47645337E-01
30	0.22985004E-03	0.11023621E+01	0.12500000E+01	0.95983316E+00	0.10043275E+01	0.41847731E-01
31	0.19462472E-03	0.11025767E+01	0.12500000E+01	0.96441846E+00	0.10042201E+01	0.36894303E-01
32	0.16471904E-03	0.11027583E+01	0.12500000E+01	0.96846376E+00	0.10041097E+01	0.32563163E-01
33	0.13950437E-03	0.11029121E+01	0.12500000E+01	0.97206570E+00	0.10039403E+01	0.28737040E-01
34	0.11784069E-03	0.11030421E+01	0.12500000E+01	0.97527832E+00	0.10037314E+01	0.25348337E-01
35	0.99994730E-04	0.11031524E+01	0.12500000E+01	0.97815548E+00	0.10034998E+01	0.22332365E-01
36	0.84612864E-04	0.11032457E+01	0.12500000E+01	0.98072788E+00	0.10032562E+01	0.19650831E-01
37	0.72071531E-04	0.11033252E+01	0.12500000E+01	0.98303376E+00	0.10030122E+01	0.17259055E-01
38	0.61018683E-04	0.11033926E+01	0.12500000E+01	0.98509280E+00	0.10027869E+01	0.15132786E-01
39	0.51993708E-04	0.11034499E+01	0.12500000E+01	0.98693365E+00	0.10025641E+01	0.13239349E-01
40	0.43996547E-04	0.11034985E+01	0.12500000E+01	0.98856813E+00	0.10023482E+01	0.11564065E-01
41	0.37728955E-04	0.11035401E+01	0.12500000E+01	0.99001728E+00	0.10021418E+01	0.10083364E-01
42	0.32002241E-04	0.11035754E+01	0.12500000E+01	0.99129604E+00	0.10019470E+01	0.87803786E-02
43	0.27707369E-04	0.11036060E+01	0.12500000E+01	0.99242175E+00	0.10017646E+01	0.76361282E-02
44	0.23439902E-04	0.11036319E+01	0.12500000E+01	0.99340972E+00	0.10015951E+01	0.66340029E-02
45	0.20117881E-04	0.11036541E+01	0.12500000E+01	0.99427448E+00	0.10014386E+01	0.57584863E-02
46	0.17228122E-04	0.11036731E+01	0.12500000E+01	0.99502948E+00	0.10012950E+01	0.49953496E-02
47	0.15148614E-04	0.11036898E+01	0.12500000E+01	0.99568720E+00	0.10011638E+01	0.43314741E-02
48	0.12772158E-04	0.11037039E+01	0.12500000E+01	0.99625915E+00	0.10010442E+01	0.37548931E-02
49	0.11232881E-04	0.11037163E+01	0.12500000E+01	0.99675579E+00	0.10009356E+01	0.32547621E-02
50	0.94776371E-05	0.11037268E+01	0.12500000E+01	0.99718629E+00	0.10008373E+01	0.28216569E-02
51	0.85594932E-05	0.11037362E+01	0.12500000E+01	0.99755922E+00	0.10007485E+01	0.24467474E-02
52	0.74523728E-05	0.11037444E+01	0.12575453E+01	0.99786900E+00	0.10006737E+01	0.21355537E-02
53	0.50762219E-05	0.11037501E+01	0.11467890E+01	0.99831256E+00	0.10005360E+01	0.16902943E-02
54	0.47251727E-05	0.11037553E+01	0.11467890E+01	0.99853471E+00	0.10004764E+01	0.14674471E-02
55	0.43471434E-05	0.11037601E+01	0.11467890E+01	0.99871859E+00	0.10004313E+01	0.12830519E-02
56	0.37531053E-05	0.11037642E+01	0.11467890E+01	0.99887359E+00	0.10003890E+01	0.11276770E-02
57	0.34020629E-05	0.11037680E+01	0.11467890E+01	0.99900642E+00	0.10003513E+01	0.99456933E-03
58	0.29430673E-05	0.11037712E+01	0.11467890E+01	0.99912189E+00	0.10003169E+01	0.87888417E-03
59	0.26080533E-05	0.11037743E+01	0.11467890E+01	0.99922250E+00	0.10002863E+01	0.77809808E-03
60	0.25110456E-05	0.11037771E+01	0.11467890E+01	0.99931072E+00	0.10002542E+01	0.68975901E-03
61	0.19440223E-05	0.11037792E+01	0.11467890E+01	0.99938826E+00	0.10002249E+01	0.61210802E-03
62	0.19980210E-05	0.11037814E+01	0.11467890E+01	0.99945638E+00	0.10001968E+01	0.54392358E-03
63	0.19980241E-05	0.11037836E+01	0.11467890E+01	0.99951655E+00	0.10001773E+01	0.48368182E-03
64	0.15930169E-05	0.11037854E+01	0.11467890E+01	0.99956955E+00	0.10001598E+01	0.43062941E-03
65	0.15120151E-05	0.11037871E+01	0.11467890E+01	0.99961650E+00	0.10001445E+01	0.38365008E-03
66	0.13230047E-05	0.11037885E+01	0.11467890E+01	0.99965768E+00	0.10001310E+01	0.34223971E-03
67	0.11610069E-05	0.11037898E+01	0.11467890E+01	0.99969527E+00	0.10001189E+01	0.30452592E-03
68	0.10800143E-05	0.11037910E+01	0.11467890E+01	0.99973044E+00	0.10001080E+01	0.26963970E-03
69	0.91800183E-06	0.11037920E+01	0.11467890E+01	0.99976191E+00	0.10000983E+01	0.23814039E-03
70	0.12150097E-05	0.11037934E+01	0.11467890E+01	0.99978927E+00	0.10000894E+01	0.21078209E-03
71	0.94500741E-06	0.11037944E+01	0.11467890E+01	0.99981286E+00	0.10000813E+01	0.18718014E-03
			EXTRAPOLATION IS DONE	RATIO= 0.89864571E+00	EXTRA FACTOR= 0.88663809E+01	
72	0.56700466E-06	0.11037950E+01	0.10000000E+01	0.99985439E+00	0.10000627E+01	0.14563278E-03

73	0.70200667E-06	0.11037954E+01	0.12500000E+01	0.99961856E+00	0.10000635E+01	0.18147107E-03
74	0.70200761E-06	0.11037966E+01	0.12500000E+01	0.99985045E+00	0.10000713E+01	0.14957512E-03
75	0.91800618E-06	0.11037976E+01	0.12500000E+01	0.99986652E+00	0.10000640E+01	0.13349697E-03
76	0.56700790E-06	0.11037982E+01	0.12500000E+01	0.99988037E+00	0.10000568E+01	0.11964378E-03
77	0.54000748E-06	0.11037988E+01	0.12500000E+01	0.99989277E+00	0.10000509E+01	0.10724042E-03
78	0.51300104E-06	0.11037994E+01	0.12500000E+01	0.99990408E+00	0.10000458E+01	0.95933146E-04
79	0.59400226E-06	0.11038000E+01	0.12500000E+01	0.99991407E+00	0.10000446E+01	0.85935670E-04
80	0.56700539E-06	0.11038007E+01	0.12500000E+01	0.99992301E+00	0.10000457E+01	0.77000313E-04
81	0.21600573E-06	0.11038009E+01	0.12500000E+01	0.99993084E+00	0.10000408E+01	0.69163129E-04

1 GROSS NEUTRON BALANCE

ENERGY GR.	LEFT LEAK	RIGHT LEAK	BACK LEAK	FRONT LEAK	TOP LEAK	BOTTOM LEAK	LOGDRI LEAK
1	0.0	0.25917E-04	0.25911E-04	0.0	0.69947E-04	0.0	0.0
2	0.0	0.78192E-05	0.78174E-05	0.0	0.20562E-04	0.0	0.0
3	0.0	0.57858E-04	0.57845E-04	0.0	0.14423E-03	0.0	0.0
SUM	0.0	0.91594E-04	0.91573E-04	0.0	0.23474E-03	0.0	0.0

ENERGY GR.	ABSORPTIONS	OUT-SCATTER	SOURCE	IN-SCATTER	TOTAL LOSSES	TOTAL GAINS	PROD/ABSORP
1	0.67521E-01	0.93236E+00	0.10000E+01	0.0	0.10000E+01	0.10000E+01	0.14810E+02
2	0.20034E+00	0.73198E+00	0.0	0.93236E+00	0.93236E+00	0.93236E+00	0.46539E+01
3	0.73172E+00	0.0	0.0	0.73198E+00	0.73198E+00	0.73198E+00	0.10004E+01
SUM	0.99958E+00	0.26643E+01	0.10000E+01	0.16643E+01	0.26643E+01	0.26643E+01	0.11043E+01

LEAKAGE 0.41790868E-03 TOTAL ABSORP 0.99958199E+00 TOTAL PRODUCTION 0.11038011E+01 K EFFECTIVE 0.11038012E+01

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0 1 GROUP FLUX, Z POSITION 0.40000E+01

Y		X 3.415E+00 (1)	1.025E+01 (2)	1.708E+01 (3)	2.391E+01 (4)	3.074E+01 (5)	3.757E+01 (6)	4.440E+01 (7)	5.123E+01 (8)	5.806E+01 (9)	6.489E+01 (10)
3.415E+00	1	4.001E-10	3.707E-10	3.204E-10	2.619E-10	2.054E-10	1.563E-10	1.158E-10	8.305E-11	5.726E-11	3.769E-11
1.025E+01	2	1.002E-09	9.264E-10	7.981E-10	6.525E-10	5.099E-10	3.886E-10	2.882E-10	2.067E-10	1.420E-10	9.278E-11
1.708E+01	3	2.215E-09	2.044E-09	1.755E-09	1.428E-09	1.121E-09	8.571E-10	6.379E-10	4.577E-10	3.129E-10	2.023E-10
2.391E+01	4	4.595E-09	4.235E-09	3.632E-09	2.958E-09	2.333E-09	1.796E-09	1.344E-09	9.652E-10	6.561E-10	4.192E-10
3.074E+01	5	8.938E-09	8.246E-09	7.086E-09	5.804E-09	4.621E-09	3.595E-09	2.710E-09	1.949E-09	1.316E-09	8.292E-10
3.757E+01	6	1.611E-08	1.492E-08	1.292E-08	1.071E-08	8.659E-09	6.829E-09	5.194E-09	3.738E-09	2.505E-09	1.556E-09
4.440E+01	7	2.656E-08	2.480E-08	2.160E-08	1.844E-08	1.520E-08	1.218E-08	9.349E-09	6.736E-09	4.477E-09	2.739E-09
5.123E+01	8	3.984E-08	3.765E-08	3.363E-08	2.934E-08	2.472E-08	2.012E-08	1.558E-08	1.123E-08	7.410E-09	4.477E-09
5.806E+01	9	5.502E-08	5.263E-08	4.852E-08	4.267E-08	3.680E-08	3.034E-08	2.366E-08	1.710E-08	1.123E-08	6.736E-09
6.489E+01	10	7.084E-08	6.833E-08	6.365E-08	5.734E-08	4.987E-08	4.152E-08	3.261E-08	2.366E-08	1.558E-08	9.349E-09
7.172E+01	11	8.615E-08	8.350E-08	7.844E-08	7.134E-08	6.258E-08	5.250E-08	4.152E-08	3.034E-08	2.012E-08	1.218E-08
7.855E+01	12	1.000E-07	9.723E-08	9.177E-08	8.396E-08	7.410E-08	6.228E-08	4.987E-08	3.680E-08	2.472E-08	1.520E-08
8.537E+01	13	1.119E-07	1.089E-07	1.031E-07	9.467E-08	8.396E-08	7.134E-08	5.735E-08	4.287E-08	2.935E-08	1.844E-08

9.220E+01	14	1.211E-07	1.180E-07	1.119E-07	1.031E-07	9.178E-08	7.644E-08	6.365E-08	4.832E-08	3.384E-08	2.180E-08
9.903E+01	15	1.275E-07	1.243E-07	1.180E-07	1.089E-07	9.723E-08	8.350E-08	6.833E-08	5.263E-08	3.765E-08	2.480E-08
1.059E+02	16	1.308E-07	1.275E-07	1.211E-07	1.119E-07	1.000E-07	8.615E-08	7.064E-08	5.502E-08	3.984E-08	2.656E-08

0 1 GROUP FLUX, Z POSITION 0.40000E+01

X	7.172E+01	7.855E+01	8.537E+01	9.220E+01	9.903E+01	1.059E+02
	11	12	13	14	15	16
Y						
3.415E+00 1	2.359E-11	1.405E-11	7.962E-12	4.297E-12	2.179E-12	9.548E-13
1.025E+01 2	5.746E-11	3.376E-11	1.887E-11	1.004E-11	5.023E-12	2.179E-12
1.708E+01 3	1.235E-10	7.131E-11	3.911E-11	2.042E-11	1.004E-11	4.297E-12
2.391E+01 4	2.516E-10	1.424E-10	7.649E-11	3.911E-11	1.887E-11	7.962E-12
3.074E+01 5	4.886E-10	2.710E-10	1.424E-10	7.131E-11	3.376E-11	1.404E-11
3.757E+01 6	8.996E-10	4.886E-10	2.516E-10	1.235E-10	5.746E-11	2.359E-11
4.440E+01 7	1.556E-09	8.292E-10	4.192E-10	2.023E-10	9.278E-11	3.769E-11
5.123E+01 8	2.505E-09	1.316E-09	6.561E-10	3.129E-10	1.420E-10	5.726E-11
5.806E+01 9	3.738E-09	1.949E-09	9.652E-10	4.577E-10	2.067E-10	8.305E-11
6.489E+01 10	5.194E-09	2.710E-09	1.344E-09	6.379E-10	2.882E-10	1.158E-10
7.172E+01 11	6.830E-09	3.595E-09	1.796E-09	8.572E-10	3.886E-10	1.564E-10
7.855E+01 12	8.660E-09	4.621E-09	2.333E-09	1.121E-09	5.100E-10	2.054E-10
8.537E+01 13	1.072E-08	5.805E-09	2.958E-09	1.428E-09	6.505E-10	2.619E-10
9.220E+01 14	1.292E-08	7.087E-09	3.633E-09	1.756E-09	7.982E-10	3.205E-10
9.903E+01 15	1.492E-08	8.246E-09	4.236E-09	2.044E-09	9.266E-10	3.708E-10
1.059E+02 16	1.611E-08	8.939E-09	4.596E-09	2.215E-09	1.002E-09	4.002E-10

0 2 GROUP FLUX, Z POSITION 0.40000E+01

X	3.415E+00	1.025E+01	1.708E+01	2.391E+01	3.074E+01	3.757E+01	4.440E+01	5.123E+01	5.806E+01	6.489E+01
	1	2	3	4	5	6	7	8	9	10
Y										
3.415E+00 1	2.053E-10	1.902E-10	1.643E-10	1.343E-10	1.053E-10	8.014E-11	5.934E-11	4.257E-11	2.934E-11	1.931E-11
1.025E+01 2	5.442E-10	5.031E-10	4.333E-10	3.531E-10	2.767E-10	2.109E-10	1.564E-10	1.122E-10	7.704E-11	5.032E-11
1.708E+01 3	1.207E-09	1.113E-09	9.559E-10	7.775E-10	6.101E-10	4.665E-10	3.471E-10	2.490E-10	1.702E-10	1.101E-10
2.391E+01 4	2.505E-09	2.309E-09	1.979E-09	1.611E-09	1.270E-09	9.780E-10	7.318E-10	5.255E-10	3.571E-10	2.281E-10
3.074E+01 5	4.875E-09	4.497E-09	3.863E-09	3.164E-09	2.518E-09	1.959E-09	1.476E-09	1.061E-09	7.166E-10	4.515E-10
3.757E+01 6	8.790E-09	8.141E-09	7.047E-09	5.843E-09	4.721E-09	3.723E-09	2.831E-09	2.037E-09	1.365E-09	8.474E-10
4.440E+01 7	1.450E-08	1.354E-08	1.190E-08	1.006E-08	8.293E-09	6.644E-09	5.099E-09	3.673E-09	2.441E-09	1.493E-09
5.123E+01 8	2.175E-08	2.056E-08	1.847E-08	1.602E-08	1.349E-08	1.098E-08	8.499E-09	6.128E-09	4.042E-09	2.441E-09
5.806E+01 9	3.005E-08	2.874E-08	2.638E-08	2.341E-08	2.009E-08	1.656E-08	1.292E-08	9.332E-09	6.128E-09	3.673E-09
6.489E+01 10	3.869E-08	3.732E-08	3.476E-08	3.132E-08	2.723E-08	2.267E-08	1.780E-08	1.292E-08	8.500E-09	5.099E-09
7.172E+01 11	4.705E-08	4.561E-08	4.284E-08	3.896E-08	3.418E-08	2.867E-08	2.267E-08	1.656E-08	1.098E-08	6.644E-09

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0 2 GROUP FLUX, Z POSITION 0.40000E+01

X	3.415E+00	1.025E+01	1.708E+01	2.391E+01	3.074E+01	3.757E+01	4.440E+01	5.123E+01	5.806E+01	6.489E+01
	1	2	3	4	5	6	7	8	9	10
Y										
7.855E+01 12	5.464E-08	5.311E-08	5.012E-08	4.585E-08	4.047E-08	3.418E-08	2.723E-08	2.009E-08	1.349E-08	8.294E-09
8.537E+01 13	6.110E-08	5.947E-08	5.630E-08	5.170E-08	4.586E-08	3.896E-08	3.132E-08	2.341E-08	1.602E-08	1.006E-08
9.220E+01 14	6.616E-08	6.447E-08	6.114E-08	5.630E-08	5.013E-08	4.284E-08	3.476E-08	2.639E-08	1.847E-08	1.190E-08

9.903E+01	15	6.964E-08	6.790E-08	6.447E-08	5.947E-08	5.311E-08	4.561E-08	3.732E-08	2.874E-08	2.056E-08	1.354E-08
1.059E+02	16	7.141E-08	6.964E-08	6.616E-08	6.110E-08	5.464E-08	4.705E-08	3.869E-08	3.005E-08	2.175E-08	1.450E-08

0 2 GROUP FLUX, Z POSITION 0.40000E+01

X	7.172E+01	7.855E+01	8.537E+01	9.220E+01	9.903E+01	1.059E+02
	11	12	13	14	15	16
Y						
3.415E+00 1	1.208E-11	7.191E-12	4.075E-12	2.198E-12	1.111E-12	4.603E-13
1.025E+01 2	3.116E-11	1.830E-11	1.023E-11	5.438E-12	2.713E-12	1.111E-12
1.708E+01 3	6.717E-11	3.878E-11	2.126E-11	1.109E-11	5.438E-12	2.198E-12
2.391E+01 4	1.369E-10	7.747E-11	4.160E-11	2.126E-11	1.023E-11	4.075E-12
3.074E+01 5	2.660E-10	1.474E-10	7.747E-11	3.877E-11	1.830E-11	7.190E-12
3.757E+01 6	4.896E-10	2.660E-10	1.369E-10	6.717E-11	3.116E-11	1.208E-11
4.440E+01 7	8.474E-10	4.515E-10	2.281E-10	1.101E-10	5.032E-11	1.931E-11
5.123E+01 8	1.365E-09	7.166E-10	3.572E-10	1.702E-10	7.704E-11	2.934E-11
5.806E+01 9	2.038E-09	1.061E-09	5.255E-10	2.490E-10	1.122E-10	4.257E-11
6.489E+01 10	2.831E-09	1.477E-09	7.319E-10	3.472E-10	1.564E-10	5.934E-11
7.172E+01 11	3.723E-09	1.959E-09	9.781E-10	4.665E-10	2.109E-10	8.015E-11
7.855E+01 12	4.721E-09	2.518E-09	1.271E-09	6.101E-10	2.768E-10	1.053E-10
8.537E+01 13	5.844E-09	3.164E-09	1.612E-09	7.776E-10	3.531E-10	1.343E-10
9.220E+01 14	7.048E-09	3.864E-09	1.979E-09	9.560E-10	4.334E-10	1.644E-10
9.903E+01 15	8.141E-09	4.497E-09	2.309E-09	1.113E-09	5.031E-10	1.902E-10
1.059E+02 16	8.791E-09	4.875E-09	2.505E-09	1.207E-09	5.442E-10	2.053E-10

0 3 GROUP FLUX, Z POSITION 0.40000E+01

X	3.415E+00	1.025E+01	1.708E+01	2.391E+01	3.074E+01	3.757E+01	4.440E+01	5.123E+01	5.806E+01	6.489E+01
	1	2	3	4	5	6	7	8	9	10
Y										
3.415E+00 1	3.448E-09	3.199E-09	2.772E-09	2.272E-09	1.788E-09	1.364E-09	1.012E-09	7.272E-10	5.017E-10	3.303E-10
1.025E+01 2	1.083E-08	1.004E-08	8.682E-09	7.110E-09	5.598E-09	4.279E-09	3.181E-09	2.286E-09	1.573E-09	1.030E-09
1.708E+01 3	2.418E-08	2.239E-08	1.934E-08	1.584E-08	1.250E-08	9.597E-09	7.162E-09	5.151E-09	3.531E-09	2.291E-09
2.391E+01 4	4.940E-08	4.573E-08	3.954E-08	3.248E-08	2.579E-08	1.994E-08	1.497E-08	1.078E-08	7.358E-09	4.724E-09
3.074E+01 5	9.408E-08	8.728E-08	7.578E-08	6.273E-08	5.032E-08	3.933E-08	2.975E-08	2.147E-08	1.458E-08	9.253E-09
3.757E+01 6	1.659E-07	1.546E-07	1.355E-07	1.137E-07	9.256E-08	7.332E-08	5.595E-08	4.046E-08	2.733E-08	1.714E-08
4.440E+01 7	2.685E-07	2.523E-07	2.244E-07	1.918E-07	1.591E-07	1.279E-07	9.853E-08	7.141E-08	4.798E-08	2.977E-08
5.123E+01 8	3.987E-07	3.784E-07	3.428E-07	2.993E-07	2.532E-07	2.066E-07	1.604E-07	1.166E-07	7.801E-08	4.798E-08
5.806E+01 9	5.476E-07	5.249E-07	4.836E-07	4.303E-07	3.701E-07	3.057E-07	2.392E-07	1.744E-07	1.166E-07	7.141E-08
6.489E+01 10	7.034E-07	6.789E-07	6.332E-07	5.711E-07	4.971E-07	4.144E-07	3.267E-07	2.392E-07	1.605E-07	9.853E-08
7.172E+01 11	8.545E-07	8.284E-07	7.785E-07	7.083E-07	6.217E-07	5.222E-07	4.145E-07	3.057E-07	2.066E-07	1.280E-07
7.855E+01 12	9.919E-07	9.641E-07	9.101E-07	8.328E-07	7.353E-07	6.217E-07	4.971E-07	3.701E-07	2.532E-07	1.591E-07
8.537E+01 13	1.109E-06	1.080E-06	1.022E-06	9.387E-07	8.328E-07	7.083E-07	5.711E-07	4.304E-07	2.993E-07	1.918E-07
9.220E+01 14	1.201E-06	1.170E-06	1.110E-06	1.022E-06	9.101E-07	7.785E-07	6.332E-07	4.836E-07	3.428E-07	2.244E-07
9.903E+01 15	1.264E-06	1.232E-06	1.170E-06	1.080E-06	9.641E-07	8.284E-07	6.789E-07	5.249E-07	3.785E-07	2.523E-07
1.059E+02 16	1.296E-06	1.264E-06	1.201E-06	1.109E-06	9.919E-07	8.545E-07	7.034E-07	5.476E-07	3.987E-07	2.685E-07

0 3 GROUP FLUX, Z POSITION 0.40000E+01

X	7.172E+01	7.855E+01	8.537E+01	9.220E+01	9.903E+01	1.059E+02
	11	12	13	14	15	16
Y						
3.415E+00 1	2.066E-10	1.229E-10	6.949E-11	3.726E-11	1.832E-11	6.296E-12

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3 GROUP FLUX, Z POSITION 0.40000E+01

Y		X 7.172E+01 (11)	7.855E+01 (12)	8.537E+01 (13)	9.220E+01 (14)	9.903E+01 (15)	1.059E+02 (16)
1.025E+01	2	6.387E-10	3.758E-10	2.100E-10	1.113E-10	5.406E-11	1.832E-11
1.708E+01	3	1.403E-09	8.128E-10	4.467E-10	2.326E-10	1.113E-10	3.726E-11
2.391E+01	4	2.850E-09	1.622E-09	8.742E-10	4.467E-10	2.100E-10	6.948E-11
3.074E+01	5	5.495E-09	3.063E-09	1.622E-09	8.128E-10	3.758E-10	1.229E-10
3.757E+01	6	1.002E-08	5.495E-09	2.850E-09	1.403E-09	6.387E-10	2.066E-10
4.440E+01	7	1.714E-08	9.253E-09	4.724E-09	2.291E-09	1.030E-09	3.303E-10
5.123E+01	8	2.733E-08	1.458E-08	7.358E-09	3.531E-09	1.573E-09	5.017E-10
5.806E+01	9	4.046E-08	2.147E-08	1.078E-08	5.151E-09	2.236E-09	7.272E-10
6.489E+01	10	5.595E-08	2.975E-08	1.497E-08	7.162E-09	3.181E-09	1.012E-09
7.172E+01	11	7.333E-08	3.933E-08	1.994E-08	9.598E-09	4.280E-09	1.364E-09
7.855E+01	12	9.257E-08	5.033E-08	2.579E-08	1.250E-08	5.598E-09	1.788E-09
8.537E+01	13	1.137E-07	6.274E-08	3.248E-08	1.584E-08	7.111E-09	2.273E-09
9.220E+01	14	1.355E-07	7.579E-08	3.954E-08	1.934E-08	8.683E-09	2.772E-09
9.903E+01	15	1.546E-07	8.729E-08	4.574E-08	2.239E-08	1.004E-08	3.199E-09
1.059E+02	16	1.659E-07	9.409E-08	4.940E-08	2.418E-08	1.083E-08	3.449E-09

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