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Institut für Neutronenphysik und Reaktortechnik
Projekt Schneller Brüter

HEXAGA—II
A Two-dimensional Multi-group Neutron Diffusion Programme for a Uniform Triangular Mesh with Arbitrary Group Scattering for the IBM/370-168 Computer

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H E X A G A - II
A TWO-DIMENSIONAL MULTI-GROUP NEUTRON DIFFUSION PROGRAMME FOR A UNIFORM TRIANGULAR MESH WITH ARBITRARY GROUP SCATTERING FOR THE IBM/370-168 COMPUTER

by

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Summary

This report presents the AGA two-sweep iterative methods belonging to the family of factorization techniques in their practical application in the HEXAGA-II two-dimensional programme to obtain the numerical solution to the multi-group, time-independent, (real and/or adjoint) neutron diffusion equations for a fine uniform triangular mesh. An arbitrary group scattering model is permitted.

The report written for the users provides the description of input and output. The use of HEXAGA-II is illustrated by two sample reactor problems.

HEXAGA II - Ein Rechenprogramm für die IBM-Anlage/370-168 zur Lösung der Multigruppen-Neutronen-Diffusionsgleichung in 2 Raumdimensionen für regelmäßige Dreiecksmaschengitter mit beliebiger Neutronenstreuung über die Energiegruppen

Zusammenfassung

Der Bericht enthält die Beschreibung der "AGA Two Sweep Iterative Methods", die zur Familie der Faktorisierungsverfahren gehören, und ihre Anwendung im Rechenprogramm HEXAGA-II für zwei Raumdimensionen. HEXAGA-II liefert die numerische Lösung der zeitunabhängigen Multigruppen-Neutronendiffusionsgleichungen für feine, regelmäßige Dreiecksmaschengitter für den reellen und den adjungierten Neutronenfluß. Im Rahmen des betrachteten Modells können die Neutronen beliebig über die Energiegruppen gestreut werden.

Der Bericht ist für die Benutzer von HEXAGA-II zusammengestellt und enthält die Beschreibungen der Programm-Ein- und Ausgabe. Zwei Sample Probleme für Reaktorberechnungen sollen die Anwendung von HEXAGA-II verdeutlichen.

Streszczenie

W raporcie przedstawiono dwuprzebiegowe metody iteracyjne AGA, należące do rodziny technik faktoryzacyjnych, w ich praktycznym zastosowaniu w dwuwymiarowym programie HEXAGA-II dostarczającym numerycznego rozwiązania wielogrupowych, czasowo niezależnych (rzeczywistych i/albo sprzężonych) równań dyfuzji neutronów w drobnej jednorodnej siatce trójkątnej. Możliwe jest stosowanie dowolnego modelu rozpraszania neutronów.

Raport ten, przeznaczony dla użytkowników, zawiera opis inputu i outputu. Użycie programu HEXAGA-II jest zilustrowane dwoma przykładami problemów reaktorowych.

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CONTENTS

I. INTRODUCTION

This report describes both the numerical methods utilized in the HEXAGA-II programme and the use of the programme.

Over a uniform triangular mesh imposed upon a parallelogram area HEXAGA-II finds a discrete numerical (both real and adjoint) solution to the multi-group, time-independent neutron diffusion equations for a heterogeneous reactor. It was developed originally under Polish-Bulgarian collaboration /3/. The first version of HEXAGA-II was written by the author and M. Manolova +) (for the CDC CYBER-72 computer at the Institute of Nuclear Research, Swierk, Otwock, Poland) for a uniform hexagonal mesh imposed upon a 120 degree rhombus as one third of a reactor by means of the 120 degree rotationally symmetrical boundary conditions on the rhombus boundaries adjacent to the remaining part of a reactor and logarithmic boundary conditions on two external boundaries.

The present version of HEXAGA-II implemented on an IBM-370/168 computer is extended to a uniform triangular mesh imposed upon an arbitrary 120 degree parallelogram area with logarithmic boundary conditions on four external boundaries; it is now more flexible than the former programme. This programme, which has been especially adjusted to calculate large reactor problems, is written in FORTRAN-IV with dynamic storage allocation by applying the XTAREA assembly language subroutine /4/.

These are the main features of the programme:

1. Use of a uniform triangular mesh with a constant mesh width over the reactor.
2. Up to 40,000 mesh points are allowed.

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3. Up to 40 neutron energy groups (independent of the number of mesh points) are possible.
4. An arbitrary group scattering matrix and fission transfer from each group into any other can be handled.
5. Problems may be specified with external logarithmic derivative boundary conditions given groupwise and pointwise.

HEXAGA-II makes use of the AGA two-sweep iterative method recently proposed for multidimensional reactor calculations /1/. The application of the AGA method, which is part of the family of factorization methods, leads to an increasing rate of convergence for inner spatial flux iterations. In order to accelerate the rate of convergence in HEXAGA-II even further, two independent techniques based on a successive overrelaxation process are applied: the Single SOR and Double SOR methods /1/. The latter method turned out has to be particularly effective for large reactor problems with a fine mesh. A special strategy of outer-inner iterations realized in HEXAGA-II consists of a fixed number (given in input data) of inner iterations for all neutron groups in a given outer iteration. It will be described in Chapter III.

A four-energy group problem with about 20,000 mesh points representing a model of the SNR 300 reactor as a typical fast reactor requires about 8 minutes of CPU time and 1000 K core storage on the IBM-370/168 computer with the following convergence criteria: $\varepsilon_{k_{eff}} \leq 10^{-6}$ and $\varepsilon_{\phi} \leq 10^{-5}$.

II. THE MATHEMATICAL MODEL

1. The Multi-Group Neutron Diffusion Equation

HEXAGA-II provides an approximation to the solution of the following multi-group, time independent, neutron diffusion equations

$$-\nabla D_g(\underline{x})\nabla\phi_g(\underline{x}) + \Sigma_g^T(\underline{x})\phi_g(\underline{x}) = S_g(\underline{x}) \qquad (1)$$

$$S_g(\underline{x}) = \frac{\chi_g}{k_{eff}} \sum_{g'=1}^{G} \nu\Sigma_{g'}^F(\underline{x})\phi_g(\underline{x}) + \sum_{\substack{g'=1 \\ g'\neq g}}^{G} \Sigma_{g'\to g}^S(\underline{x})\phi_{g'}(\underline{x}) \qquad (1a)$$

for $g = 1,2, \ldots, G$

where g - group index

- $\underline{x}$ - spatial point
- ∇ - gradient operator
- ϕ_g - neutron flux
- D_g - diffusion coefficient
- Σ_g^T - macroscopic total removal cross section
- $\nu\Sigma_g^F$ - macroscopic fission production cross section
- $\Sigma_{g'\to g}^S$ - macroscopic scattering cross section from group g' to group g
- χ_g - value of fission spectrum
- k_{eff} - effective multiplication factor

These equations are supplemented by group-dependent logarithmic boundary conditions at the external boundaries of the reactor

$$\frac{1}{\phi_g(\underline{x})} \frac{\partial\phi_g(\underline{x})}{\partial n} = -\frac{\alpha_g(\underline{x})}{D_g(\underline{x})} \qquad (2)$$

where α_g is a non-negative constant and the derivative is taken normal to the boundary outward to the reactor.

The adjoint solution required for supplementary perturbation calculations is made in HEXAGA-II with a little extra effort devoted to the algorithm for the real solution. In fact, it is only necessary to transpose the scattering matrix and invert the order in which the group equations are solved, interchanging the roles of the fission spectrum fractions, χ_g, and the fission production cross section terms $\nu\Sigma_g^F$, in each equation.

As the real system is defined by Eqs. (1 and 1a) the corresponding adjoint system can be written in the following form

$$-\nabla D_g(\underline{x})\nabla\phi_g^*(\underline{x}) + \Sigma_g^T(\underline{x})\phi_g^*(\underline{x}) = S_g^*(\underline{x}) \qquad (1^*)$$

$$S_g^*(\underline{x}) = \frac{1}{k_{eff}}\,\nu\Sigma_g^F(\underline{x}) \sum_{g'=1}^{G} \chi_{g'}\phi_{g'}(\underline{x}) + \sum_{\substack{g'=1 \\ g'\neq g}}^{G} \Sigma_{g\to g'}^S(\underline{x})\phi_{g'}^*(\underline{x}) \qquad (1^*a)$$

for $g = G, G-1, \ldots\ldots, 1$
where ϕ_g^* is adjoint neutron flux.

2. The Geometrical Representation

The solution is approximated over a parallelogram area that is composed of uniform triangular elementary subregions. The uniform grid of mesh lines is imposed upon this parallelogram area (see Fig. 1). The constant distance between mesh lines is chosen such that the boundaries of the area and the interfaces determining subregions (containing elementary triangles with the same material compositions) coincide exactly with the mesh lines. Both axes x and v in the assumed oblique coordinate system coincide with the boundary lines of the parallelogram area of the solution.

The discrete solution of Eq. (1) (and/or Eq. (1*)) consists of the effective multiplication factor and of values approximating (real and/or adjoint) neutron flux and fission sources at the points of intersections of the mesh lines called mesh points.

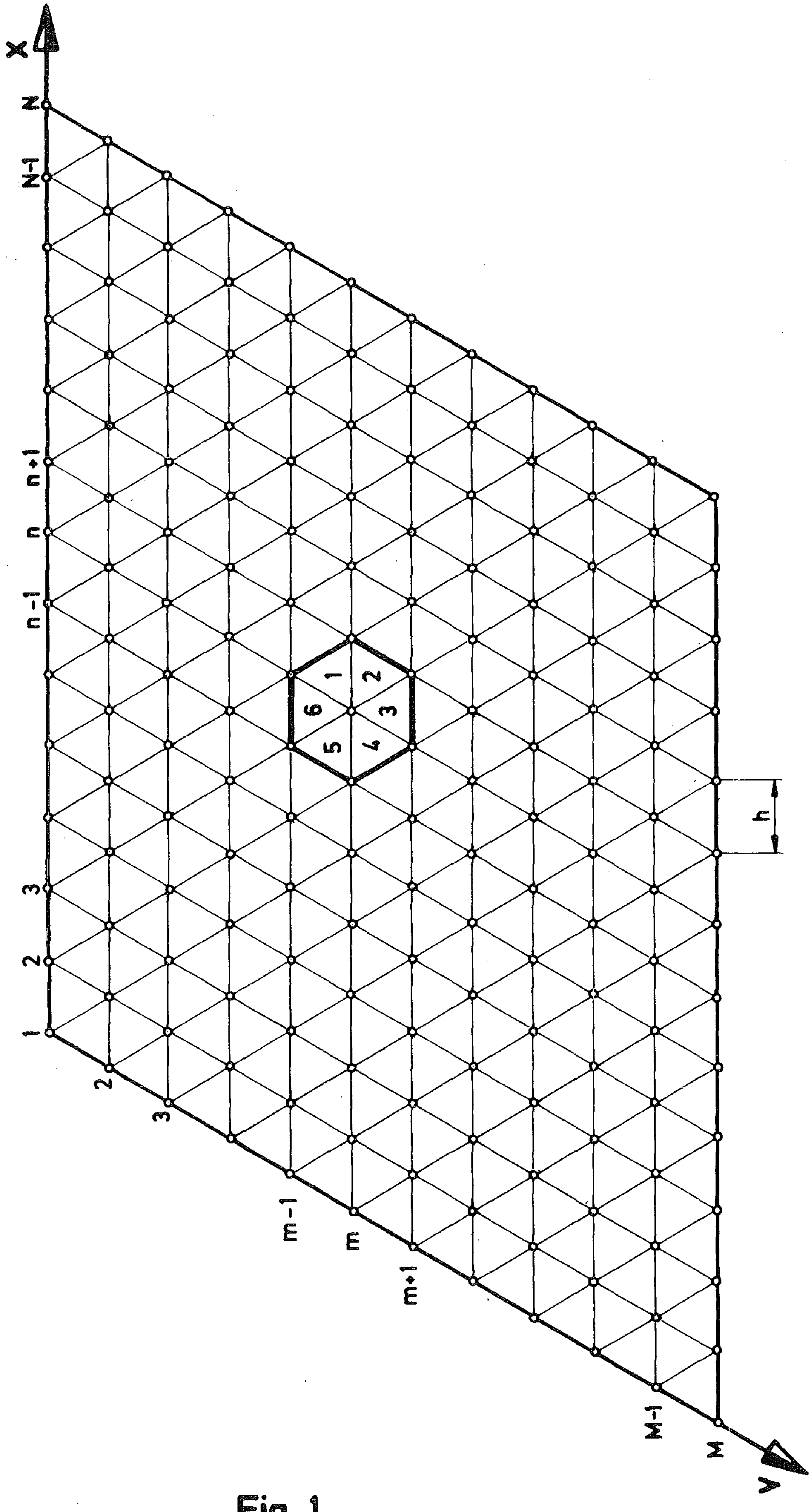


Fig. 1

3. Difference Equations

To obtain a solution, Eq. (1) is approximated by seven-point difference equations at mesh points. Consider the mesh point (m,n) at the intersection of two mesh lines m and n, as illustrated in Fig. 1. It is assumed that the smallest homogeneous diffusion region has the form of a triangle representing one material composition. Therefore, the following difference expression for a given group, g, is used at the corner point between six different triangles numbered from 1 to 6, as in Fig. 1.

$$k_n^m \phi_n^m = c_n^m + e_n^m \phi_{n-1}^m + l_n^m \phi_{n-1}^{m-1} + g_n^m \phi_n^{m-1} + \phi_{n+1}^{m+1} + u_n^m \phi_n^{m+1} + w_n^m \phi_{n+1}^m \tag{3}$$

where $k_n^m = \frac{2}{a} \sum_{i=1}^{6} (D_i + \frac{h^2}{4} \Sigma_i^T)$

$$e_n^m = \frac{1}{a} (D_4 + D_5)$$

$$l_n^m = \frac{1}{a} (D_5 + D_6)$$

$$g_n^m = \frac{1}{a} (D_6 + D_1)$$

$$u_n^m = \frac{1}{a} (D_3 + D_4)$$

$$w_n^m = \frac{1}{a} (D_1 + D_2)$$

$$c_n^m = \frac{6h^2}{a} \{ \frac{\chi_g}{k_{eff}} \sum_{g'=1}^{G} \left[(\sum_{i=1}^{6} \nu\Sigma_i^F)_{g'} (\phi_n^m)_{g'} \right] + \sum_{\substack{g'=1 \\ g' \neq g}}^{G} \left[(\sum_{i=1}^{6} \Sigma_{g'\to g,i}^S)_{g'} (\phi_n^m)_{g'} \right] \}$$

$a = D_2 + D_3$

h - is spacing of the uniform triangular mesh.

Eq. (3) is normalized such that the coefficient with ϕ_{n+1}^{m+1} equals unity. Similar difference equations are used at the mesh points lying on the external boundaries; the term $\frac{2\sqrt{3}}{a}$ h α_n^m is added to k_n^m, where α_n^m is defined by Eq. (2), whereas the other coefficients of the difference equations (Eq. (3)) are calculated with appropriate modifications.

III. THE METHOD OF SOLUTION

A new approach to the numerical solution of the multidimensional neutron diffusion equation has recently been proposed by the author /1/. The method of solution used in HEXAGA-II is an application of this so-called AGA two-sweep iterative method.

Accepting the conventional scheme of fission source iterations one must repeatedly solve the inhomogeneous two-dimensional difference equations for G groups

$$A_g \phi_g = c_g, \qquad g = 1,2,\dots G \tag{4}$$

where A_g is a non-singular matrix sxs and s is equal to the total number of mesh points, that is, s = MxN. In this matrix notation, the matrix A_g contains the difference coefficients of Eq. (3), the components of the vector c_g are the coefficients, c_n^m, of Eq. (3) and ϕ_g is the solution vector in a given group, g. Thus, the discrete solution of Eq. (1) consists of a series of outer iterations, each of them running over all energy groups. The fission sources are recalculated before each outer iteration, and the scattering sources before each group calculation. In each energy group, the inner iterations to solve Eq. (4) can be repeated I times. In HEXAGA-II the value of I, specified in the input, is fixed for all energy groups in a given outer iteration.

To solve Eq. (4), the AGA two-sweep iterative method is employed with the application of either the Single SOR or Double SOR process /1/. It will be described in the next sections of this Chapter.

1. A General Iteration Scheme

The non-singular sxs matrix A_g of Eq. (4) can be expressed in the following form (suppressing index g)

$$A = M - N \tag{5}$$

where M and N are also sxs matrices. If M is non-singular, we say that this expression represents a splitting of A, and associated with this splitting is an iterative method

$$M\phi^{(j+1)} = N\phi^{(j)} + c, \quad j \geq 0 \tag{6}$$

$$\phi^{(j+1)} = M^{-1}N\phi^{(j)} + M^{-1}c, \quad j \geq 0 \tag{7}$$

where j denotes the iteration index and a guess is made of the inital vector $\phi^{(0)}$. The above equations represent the general scheme of the iterative method and $M^{-1}N$ is the iteration matrix associated with this method.

Particular iterative methods differ in the choice of the matrices M and N. For a given iterative method, $\phi^{(j+1)}$ tends to ϕ (the exact solution of Eq. (4)) with $j \to \infty$ for all $\phi^{(0)}$ if, and only if, the spectral radius $\rho(M^{-1}N)$ of the iteration matrix $M^{-1}N$ is less than unity /2/. Moreover, the smaller the spectral radius of the iteration matrix, the better is the convergence asymptotically of a given iterative method.
Let us define the sxs matrix $A = (a_{i,j})$ of Eq. (4) as a sum of the following sxs matrices

$$A = K - L - U \tag{8}$$

where

$$K = (k_{i,j}) = \text{diag}\,\{A_g\} \geq 0, \qquad k_{i,j} = \begin{cases} a_{i,j} & \text{for } i = j \\ 0 & \text{for } i \neq j \end{cases}$$

$$L = (l_{i,j}) \geq 0 \qquad l_{i,j} = \begin{cases} -a_{i,j} & \text{for } i > j \\ 0 & \text{for } i < j \end{cases}$$

$$U = (u_{i,j}) \geq 0 \qquad u_{i,j} = \begin{cases} 0 & \text{for } i \geq j \\ -a_{i,j} & \text{for } i < j \end{cases}$$

Thus, K, L and U are diagonal, strictly lower triangular and strictly upper triangular matrices, respectively.

Referring to Eq. (3) we have the following interpretation of the matrix A: The coefficients k_n^m are the entries of the positive main diagonal of K; e_n^m, l_n^m and g_n^m are respectively the entries of the three non-negative diagonals of L; and u_n^m, w_n^m and units are respectively the entries of the three non-negative diagonals of U. For the above interpretation of the matrix A it was assumed that the numbering of mesh points in the mesh grid shown in Fig. 1 increases successively along every mesh line in the axial direction x, and successively from a given mesh line to the next one in the axial direction of v. Since A is an irreducibly diagonally dominant matrix satisfying the definition (8), $A^{-1} > 0$ /2/.

With the above definition of A the classical iterative methods are represented by the following splittings.

a) <u>The point Jacobi method</u>

$$A = M_J - N_J, \quad M_J = K \text{ and } N_J = L + U$$

$$\mathcal{B} = K^{-1}(L+U) \geq 0 \tag{9}$$

b) <u>The point Gauss-Seidel method</u>

$$A = M_G - N_G, \quad M_G = K - L \text{ and } N_G = U$$

$$\mathcal{L}_1 = (I-K^{-1}L)^{-1}K^{-1}U \geq 0 \tag{10}$$

where $\mathcal{B}$ and $\mathcal{L}_1$ are iteration matrices, respectively, in these methods.

2. The AGA Two-Sweep Iterative Method

The non-singular sxs matrix A of Eq. (4) can be expressed as follows:

$$A = K - P - (L+H) - (U+Q) + P + H + Q \tag{11}$$

on the assumption that P, H and Q are diagonal, strictly lower triangular and strictly upper triangular non-negative sxs matrices, respectively.

We assume that the diagonal matrices $K = (k_{i,j})$ and $P = (p_{i,j})$ satisfy the following condition

$$K \geq P \geq 0 \tag{12}$$

where $k_{i,j} > p_{i,j} \geq 0$ for all $1 \leq i \leq s$, so that

$$D = K - P \geq 0 \tag{13}$$

is a non-singular non-negative matrix and Eq. (11) can be written equivalently as

$$A = D - (L+H) - (U+Q) + P + H + Q \tag{14}$$

We apply the following identity

$$D - (L+H) - (U+Q) \equiv [I - (L+H)D^{-1}]D[I - D^{-1}(U+Q)] - (L+H)D^{-1}(U+Q) \tag{15}$$

with the following required relation

$$(L+H)D^{-1}(U+Q) = P + H + Q + T \tag{16}$$

where P is the main diagonal of $(L+H)D^{-1}(U+Q)$, that is

$$P = \text{diag}\,\{(L+H)D^{-1}(U+Q)\} \tag{17}$$

and H + Q + T has zero entries on the main diagonal and its off-main diagonal entries are those of $(L+H)D^{-1}(U+Q)$.

Using the above relations we get

$$A = \left[I - (L+H)D^{-1}\right]D\left[I - D^{-1}(U+Q)\right] - T \equiv M_A - N_A \tag{18}$$

where

$$M_A = \left[I - (L+H)D^{-1}\right]D\left[I - D^{-1}(U+Q)\right] \text{ and } N_A = T \tag{19}$$

The iterative method associated with this splitting can be written as follows

$$\phi^{(j+1)} = \left[I - D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - (L+H)D^{-1}\right]^{-1}T\phi^{(j)} + \\ + \left[I - D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - (L+H)D^{-1}\right]^{-1}c, \quad j \geq 0 \tag{20}$$

and

$$\mathcal{A}_1 = \left[I - D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - (L+H)D^{-1}\right]^{-1} T \geq 0 \tag{21}$$

is the iteration matrix for this method.

This method can easily be implemented by applying the two-sweep procedure (for any initial vector $\phi^{(0)}$) which eliminates the calculation procedure for the inversion of triangular matrices. Let us multiply (20) on the left by $\left[I-D^{-1}(U+Q)\right]$ and shift $D^{-1}(U+Q)\phi$ on the right hand-side; we obtain

$$\phi^{(j+1)} = D^{-1}\{(U+Q)\phi^{(j+1)} + \left[I - (L+H)D^{-1}\right]^{-1}(T\phi^{(j)}+c)\}.$$

Denoting

$$\beta^{(j+1)} = \left[I - (L+H)D^{-1}\right]^{-1}(T\phi^{(j)}+c)$$

and again multiplying this expression on the left by $\left[I-(L+H)D^{-1}\right]$ we finally have

$$\left.\begin{aligned} \beta^{(j+1)} &= (L+H)D^{-1}\beta^{(j+1)} + T\phi^{(j)} + c, \\ \phi^{(j+1)} &= D^{-1}\left[(U+Q)\phi^{(j+1)} + \beta^{(j+1)}\right], \; j \geq 0 \end{aligned}\right\} \qquad (22)$$

Since $(L+H)D^{-1}$ and $D^{-1}(U+Q)$ are lower and upper strictly triangular matrices, respectively, successive components of $\beta^{(j+1)}$ can be calculated recursively for increasing indices in the forward elimination sweep and successive components of $\phi^{(j+1)}$ can be calculated recursively for decreasing indices in the backward substitution sweep.

This method is called the AGA two-sweep iterative method and the matrix $\mathcal{A}_1$, defined in Eq. (21), the AGA matrix associated with the matrix A of Eq. (4).

The AGA method represented by Eqs. (22) is a general form of the two-sweep iterative methods. Special versions of the AGA method differ in the choice of the matrices H and Q, where D, P and T are the resultant matrices.

Finally, it should be mentioned that when A is an irreducibly diagonally dominant matrix satisfying Def. (8), the following inequality (proved in Reference 1) is valid

$$0 < \rho\ (\mathcal{A}_1) < \rho\ (\mathcal{L}_1) < 1 \qquad (23)$$

Moreover, Beauwens /5/ proved that in this case matrix D has always positive diagonal entries.

The application of the successive overrelaxation process in the AGA method and a certain choice of the relaxation factor reduces the spectral radius of the iteration matrix, which in many cases results in a considerable acceleration of convergence. A process of this kind can be applied to one or both sweeps simultaneously. Both cases are described in the next sections.

3. The AGA Single Successive Overrelaxation Two-Sweep Iterative Method (the AGA Single SOR Method)

Using the overrelaxation process to the backward substitution sweep, we directly obtain from the two-sweep Equations (22).

$$\left.\begin{aligned} \beta^{(j+1)} &= (L+H)D^{-1}\beta^{(j+1)} + T\phi^{(j)} + c \\ \phi^{(j+1)} &= \omega D^{-1}\left[(U+Q)\phi^{(j+1)} + \beta^{(j+1)}\right] - (\omega-1)\phi^{(j)}, \quad j \geq 0 \end{aligned}\right\} \qquad (24)$$

and by analogy to Eq. (20)

$$\phi^{(j+1)} = \left[I - \omega D^{-1}(U+Q)\right]^{-1}\{\omega D^{-1}\left[I - (L+H)D^{-1}\right]^{-1}T - (\omega-1)I\}\phi^{(j)} +$$

$$+ \omega\left[I - \omega D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - (L+H)D^{-1}\right]^{-1}c, \quad j \geq 0 \qquad (25)$$

for any initial vector $\phi^{(0)}$.

For brevity's sake we shall call this method the AGA single SOR method and the matrix,

$$\mathcal{A}_\omega = \left[I - \omega D^{-1}(U+Q)\right]^{-1}\{\omega D^{-1}\left[I - (L+H)D^{-1}\right]^{-1}T - (\omega-1)I\}, \qquad (26)$$

the AGA single SOR matrix. Assuming $\omega = 1$ we see that this method reduces exactly to the AGA method expressed by Eq. (20) and $\mathcal{A}_{\omega=1} = \mathcal{A}_1$.

The question now arises whether there exists any value of the relaxation factor, ω, which minimizes the spectral radius $\rho(\mathcal{A}_\omega)$. It has been proved /1/ that $\omega = 1$ minimizes $\rho(\mathcal{A}_\omega)$ for the range $0 < \omega \leq 1$. This suggests that the use of ω greater than unity would decrease the spectral radius $\rho(\mathcal{A}_\omega)$. Unfortunately, there is no exact formula for an optimum value of ω which gives the minimum of $\rho(\mathcal{A}_\omega)$ in the general case. However, it has been observed experimentally that there is an optimum value, $\bar{\omega}$, greater than unity, and the following inequality is fulfilled:

$$1 < \bar{\omega} < \omega_{max} < 2 \tag{27}$$

where ω_{max} is the value of ω for which the spectral radius of $\mathcal{R}_{\omega_{max}}$ equals unity.

It was observed in many numerical examples that in the case of a triangular geometry, $\omega_{max} \approx 1.33$.

4. The AGA Double Successive Overrelaxation Two-Sweep Iterative Method (the AGA Double SOR Method)

We can use the overrelaxation process simultaneously to both sweep equations of AGA method Eqs. (22), that is

$$\left.\begin{aligned} \beta^{(j+1)} &= \Omega_\beta\left[(L+H)D^{-1}\beta^{(j+1)} + T\phi^{(j)} + c\right] - (\Omega_\beta-1)\beta^{(j)} \\ \phi^{(j+1)} &= \Omega_\phi D^{-1}\left[(U+Q)\phi^{(j+1)} + \beta^{(j+1)}\right] - (\Omega_\phi-1)\phi^{(j)}, \quad j \geq 0 \end{aligned}\right\} \tag{28}$$

for any initial vectors $\phi^{(0)}$ and $\beta^{(0)}$.

The above equations can be condensed to the following iteration scheme

$$\phi^{(j+1)} = \mathcal{H}_{\Omega_\beta\Omega_\phi}\phi^{(j)} - \mathcal{P}_{\Omega_\beta\Omega_\phi}\phi^{(j-1)} + m, \quad j > 0 \tag{29}$$

where the iteration matrices $\mathcal{H}_{\Omega_\beta\Omega_\phi}$ and $\mathcal{P}_{\Omega_\beta\Omega_\phi}$ and the vector m have the following form

$$\begin{aligned} \mathcal{H}_{\Omega_\beta\Omega_\phi} = {} & \left[I - \Omega_\phi D^{-1}(U+Q)\right]^{-1}\{D^{-1}\left[I - \Omega_\beta(L+H)D^{-1}\right]^{-1}\left[\Omega_\beta\Omega_\phi T \right. \\ & \left. - (\Omega_\beta-1)D\left[I - \Omega_\phi D^{-1}(U+Q)\right]\right] - (\Omega_\phi-1)I\} \end{aligned} \tag{30}$$

$$\mathcal{P}_{\Omega_\beta\Omega_\phi} = (\Omega_\beta-1)(\Omega_\phi-1)\left[I - \Omega_\phi D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - \Omega_\beta(L+H)D^{-1}\right]^{-1} \tag{31}$$

$$m = \Omega_\beta\Omega_\phi\left[I - \Omega_\phi D^{-1}(U+Q)\right]^{-1}D^{-1}\left[I - \Omega_\beta(1+H)D^{-1}\right]^{-1}c \tag{32}$$

For brevity's sake we shall call this method the AGA double SOR method. With $\Omega_\beta = 1$, this method reduces to the AGA single SOR method; and

$$\mathcal{M}_{\Omega_\beta=1,\Omega_\phi} = \mathcal{A}_{\omega=\Omega_\phi} \text{ and } \mathcal{N}_{\Omega_\beta=1,\Omega_\phi} = 0.$$

In reactor calculations it was observed that this method, with the proper choice of relaxation parameters Ω_β and Ω_ϕ, converges faster than the AGA single SOR method and is more effective for large reactor problems with a fine mesh. The best results are obtained when the following relation holds:

$$\Omega_\beta = \Omega_\phi = \bar{\Omega} \approx 1 + \frac{(\bar{\omega}-1)}{2} \qquad (33)$$

where $\bar{\omega}$ is the optimum relaxation factor in the AGA single SOR method.

It should be mentioned that a special subroutine for estimating a priori the optimum $\bar{\Omega}$ is included in HEXAGA-II. This estimate of $\bar{\Omega}$ is based on an empirical formula giving a good approximation of the optimum $\bar{\Omega}$ for the problems considered up to now (see Section 7 of this Chapter).

5. Derivation of Recursive Formulae Used in HEXAGA-II

In this section the derivation of the recursive formulae for the version of the AGA two-sweep iterative method taken in HEXAGA-II is shown.

We postulate the following formula for the backward substitution sweep at the mesh point (m,n) (see Fig. 1)

$$\phi_n^m = \frac{\beta_n^m + \phi_{n+1}^{m+1} + U_n^m \phi_n^{m+1} + W_n^m \phi_{n+1}^m}{D_n^m} \qquad (34)$$

The corresponding formula at the mesh point (n-1,n-1) can be written as follows

$$\phi_{n-1}^{m-1} = \frac{\beta_{n-1}^{m-1} + \phi_n^m + U_{n-1}^{m-1}\phi_{n-1}^m + W_{n-1}^{m-1}\phi_n^{m-1}}{D_{n-1}^{m-1}}$$

Substituting this formula in the difference equation (3) we have

$$\left(k_n^m - \frac{l_n^m}{D_{n-1}^{m-1}}\right) \phi_n^m = c_n^m + \frac{l_n^m}{D_{n-1}^{m-1}} \beta_{n-1}^{m-1} + \left(e_n^m + \frac{l_n^m}{D_{n-1}^{m-1}} U_{n-1}^{m-1}\right) \phi_{m-1}^m +$$

$$+ \left(g_n^m + \frac{l_n^m}{D_{n-1}^{m-1}} W_{n-1}^{m-1}\right) \phi_n^{m-1} + \phi_{n+1}^{m+1} + u_n^m \phi_n^{m+1} + w_n^m \phi_{n+1}^m$$

Again writing the formulae for ϕ_{n-1}^m and ϕ_n^{m-1}, that is, at the mesh points (m,n-1) and (m-1,n) (according to Eq. (34) and substituting them in the last equation and introducing an iteration index, j, we finally obtain the following recursive formulae

$$\left.\begin{aligned} (\beta_n^m)^{(j+1)} &= c_n^m + L_n^m(\beta_{n-1}^{m-1})^{(j+1)} + E_n^m\left[(\beta_{n-1}^m)^{(j+1)} + U_{n-1}^m(\phi_{n-1}^{m+1})^{(j)}\right] + \\ &\quad + G_n^m\left[(\beta_n^{m-1})^{(j+1)} + W_n^{m-1}(\phi_{n+1}^{m-1})^{(j)}\right] \\ (\phi_n^m)^{(j+1)} &= \frac{(\beta_n^m)^{(j+1)} + (\phi_{n+1}^{m+1})^{(j+1)} + U_n^m(\phi_n^{m+1})^{(j+1)} + W_n^m(\phi_{n+1}^m)^{(j+1)}}{D_n^m} \qquad j \geq 0 \end{aligned}\right\} \quad (35)$$

where

$$L_n^m = l_n^m / D_{n-1}^{m-1}$$

$$E_n^m = (e_n^m + L_n^m U_{n-1}^{m-1}) / D_{n-1}^m$$

$$G_n^m = (g_n^m + L_n^m W_{n-1}^{m-1}) / D_n^{m-1}$$

$$D_n^m = k_n^m - L_n^m - E_n^m W_{n-1}^m - G_n^m U_n^{m-1}$$

$$U_n^m = u_n^m + E_n^m$$

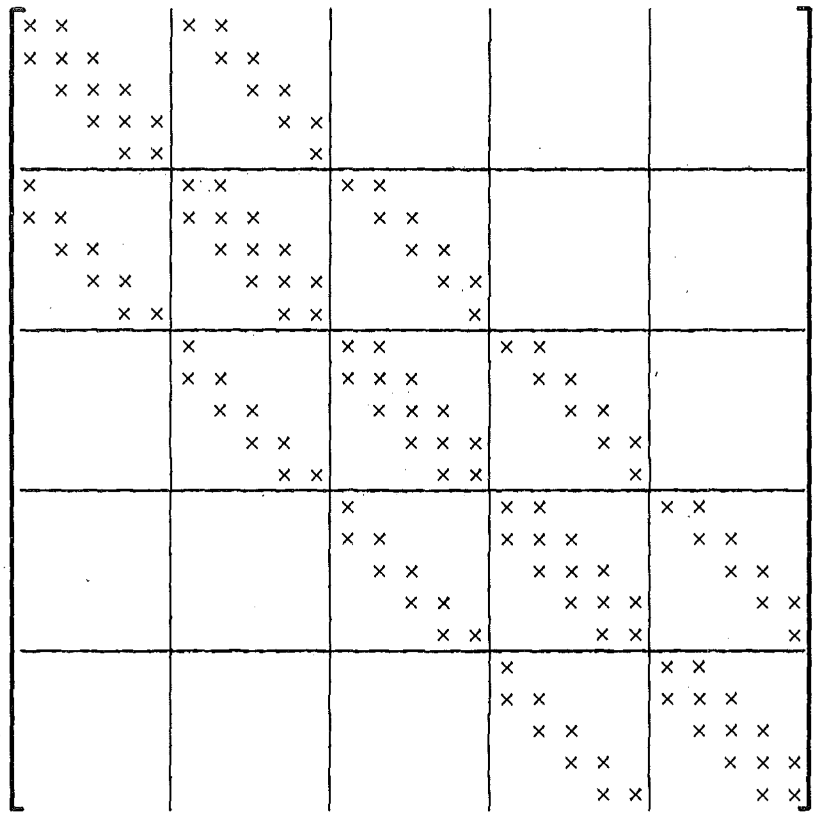
$$W_n^m = w_n^m + G_n^m$$

The above recursive formulae represent the version of the AGA two-sweep iterative method, defined by the two-sweep equations (22), which is taken in HEXAGA-II. Thus, for a given iteration j+1 and an energy group g the values of β are calculated recursively in the forward elimination sweep for successively increasing mesh indices m and n (m=1, n=1,2,...N; m=2, n=1,2,...N, etc.) using the values of ϕ from iteration j. With calculated values of β existing in all mesh points, the values of ϕ are calculated recursively in the backward substitution sweep for successively decreasing mesh indices m and n (m=M, n=N, N-1,...1; m=M-1, n=N,N-1,...1,etc.). The values of coefficients L, E, G, U and W are calculated (also recursively for successively increasing mesh indices m and n) only once for all mesh points and all energy groups and stored for the whole iteration process.

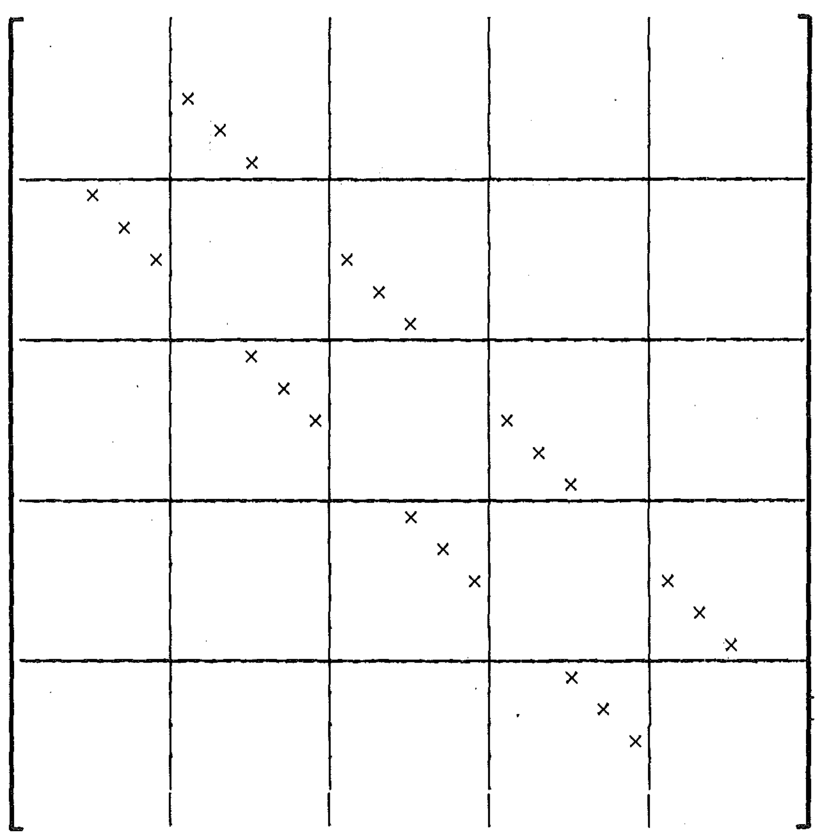
Similar recursive formulae can be derived in the same way for the mesh points belonging to outer boundaries. However, in this case some terms of Eqs. (35) must disappear according to a given outer boundary.

By relating Eq. (35) to the matrix notation of the AGA two-sweep iterative method defined by Eqs. (22) we can give the following interpretation of difference coefficients of Eqs. (35) under the assumption that the indices of the components of both vectors β and ϕ, i, are related to the mesh indices m and n by the following formula: $i = (m-1)N + n$ (where N is the number of mesh points in x-direction, see Fig. 1). Thus, coefficients $L_n^m U_{n-1}^{m-1}$ and $L_n^m W_{n-1}^{m-1}$ are the respective entries of two non-negative subdiagonals of the matrix H coinciding with the non-negative subdiagonals of the matrix L. Coefficients E_n^m and G_n^m are the respective entries of two non-negative superdiagonals of the matrix Q coinciding with the non-negative superdiagonals of the matrix U. D_n^m are the entries of the diagonal matrix D, and terms $L_n^m + E_n^m W_{n-1}^m + G_n^m U_n^{m-1}$ are the entries of the diagonal matrix P. Coefficients $E_n^m U_{n-1}^m$ and $G_n^m W_n^{m-1}$ are the respective entries of two diagonals of the matrix T located symmetrically with respect to the main diagonal. The pictures of matrices A, H, Q and T (where non-zero entries are marked by crosses) are shown for the example in which M=N=5.

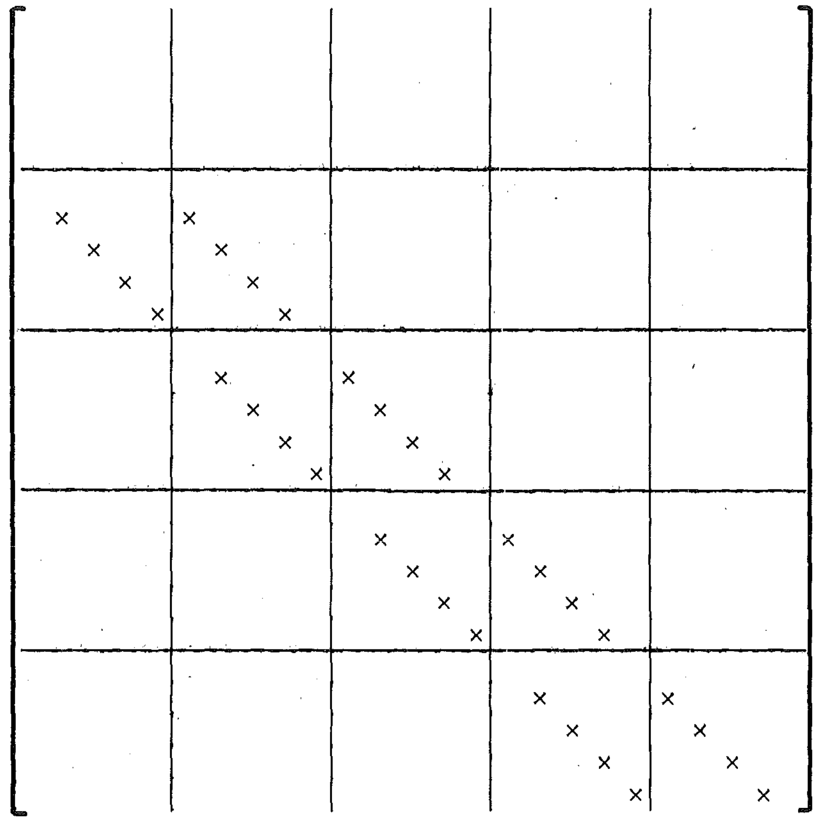
A = K-L-U =



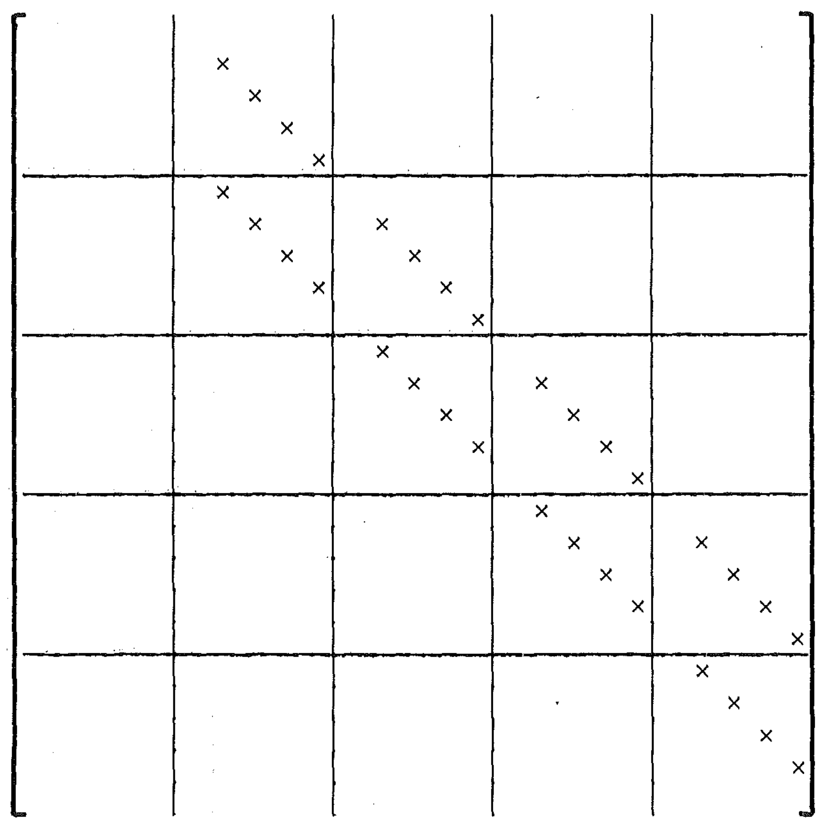
T =



H =



Q =



For the AGA single SOR and the AGA double SOR method, the corresponding recursive formulae have the following forms:

For the AGA single SOR method:

$$\left.\begin{aligned}
(\beta_n^m)^{(j+1)} &= c_n^m + L_n^m(\beta_{n-1}^{m-1})^{(j+1)} + E_n^m\left[(\beta_{n-1}^m)^{(j+1)} + U_{n-1}^m(\phi_{n-1}^{m+1})^{(j)}\right] + \\
&\quad + G_n^m\left[(\beta_n^{m-1})^{(j+1)} + W_n^{m-1}(\phi_{n+1}^{m-1})^{(j)}\right] \\
(\phi_n^m)^{(j+1)} &= \frac{\omega}{D_n^m}\left[(\beta_n^m)^{(j+1)} + (\phi_{n+1}^{m+1})^{(j+1)} + U_n^m(\phi_n^{m+1})^{(j+1)} + \right. \\
&\quad \left. + W_n^m(\phi_{n+1}^m)^{(j+1)}\right] - (\omega-1)\phi^{(j)}, \qquad j \geq 0
\end{aligned}\right\} \quad (36)$$

For the AGA double SOR method:

$$\left.\begin{aligned}
(\beta_n^m)^{(j+1)} &= \Omega_\beta\{c_n^m + L_n^m(\beta_{n-1}^{m-1})^{(j+1)} + E_n^m\left[(\beta_{n-1}^m)^{(j+1)} + U_{n-1}^m(\phi_{n-1}^{m+1})^{(j)}\right] + \\
&\quad + G_n^m\left[(\beta_n^{m-1})^{(j+1)} + W_n^{m-1}(\phi_{n+1}^{m-1})^{(j)}\right]\} - (\Omega_\beta-1)(\beta_n^m)^{(j)} \\
(\phi_n^m)^{(j+1)} &= \frac{\Omega_\phi}{D_n^m}\left[(\beta_n^m)^{(j+1)} + (\phi_{n+1}^{m+1})^{(j+1)} + U_n^m(\phi_n^{m+1})^{(j+1)} + \right. \\
&\quad \left. + W_n^m(\phi_{n+1}^m)^{(j+1)}\right] - (\Omega_\phi-1)(\phi_n^m)^{(j)}, \quad j \geq 0
\end{aligned}\right\} \quad (37)$$

Finally, it should be mentioned that these methods require more arithmetic operations per mesh point compared with the point SOR method. In the case of HEXAGA-II, the AGA single SOR method needs 10 multiplications and 8 additions per mesh point; the AGA double SOR method needs 12 multiplications and 10 additions per mesh point whereas, in the point SOR method, these numbers are 8 and 7, respectively.

6. The Iteration Process

A special strategy of outer-inner iterations is used in HEXAGA-II, in which a number of inner iterations, I, given as an input value ($1 \leq I \leq 8$), are fixed for all energy groups, G, in a given outer iteration. The scattering sources are recalculated after each group calculation, that is, after I inner iterations each. The fission sources S_n^m and k_{eff} are recalculated after each outer iteration, j, that is,

$$(S_n^m)^{(j)} = \sum_{g=1}^{G} \left[\nu\Sigma_g^f (\phi_n^m)_g^{(j)} \right] \tag{38}$$

and

$$k_{eff}^{(j)} = \int_V S^{(j)} dv \tag{39}$$

where the integration of sources in HEXAGA-II is approximated by the trapezoidal method. For the next outer iteration, j+1 new sources $(S_n^m)_*^{(j+1)}$ are renormalized as follows

$$(S_n^m)_*^{(j+1)} = \frac{1}{k_{eff}^{(j)}} (S_n^m)^{(j)} \tag{40}$$

To start the iteration process, a zero initial guess is made for vectors $\beta^{(0)}$ and $\phi^{(0)}$ (all components of both vectors $\beta^{(0)}$ and $\phi^{(0)}$ are set equal to zero in all energy groups). For the calculation of initial sources $S^{(0)}$ a flat flux ϕ, which is the same in all energy groups, is taken for the whole core region. It has been observed that such initial guesses for both vectors $\phi^{(0)}$, $\beta^{(0)}$ and $S^{(0)}$ minimize the number of outer iterations in most reactor problems.

The outer iteration index, j, coincides with the inner iteration index, I, only for I=1. For I>1, the inner iterations for spatial flux performed by the two-sweep equations (either Eqs. (36) or Eqs. (37) are repeated I times for every energy group, g (g=1,...G). Thus, for any convergent iteration process up to the outer iteration j_o the total number of inner iterations is equal to $j_o \cdot I \cdot G$. It has been observed in all problems considered up to now that using a few inner iterations per outer iteration ($1 \leq I \leq 3$) provides the minimum time of a central processor unit (CPU), and very often the best results are obtained for 2 or 3 inner iterations per outer iteration.

The iterative process continues until the following convergence criteria are fulfilled:

- Either the maximum number of outer iterations has been reached

$$j = j_{max},$$

- or the following inequalities are satisfied:

$$\left| \frac{k_{eff}^{(j+1)} - k_{eff}^{(j)}}{k_{eff}^{(j+1)}} \right| < \varepsilon_k \qquad (42)$$

and

$$\left| \frac{\phi_{(I)}^{(j+1)} - \phi_{(I-1)}^{(j+1)}}{\phi_{(I)}^{(j+1)}} \right| < \varepsilon_\phi \qquad (43)$$

for all energy-space mesh points, where values of j_{max}, I, ε_k and ε_ϕ are specified in the input data. In the case where I=1, $\phi_{(I-1)}^{(j+1)}$ is replaced by $\phi_{(I)}^{(j)}$.

7. The Method of Estimating Optimum Relaxation Factors

A special subroutine for estimating optimum relaxation factors before starting the iteration process is applied in HEXAGA-II. This estimate, which provides a good approximation of optimum relaxation factors, is based on an empirical formula derived from the analysis of numerical results obtained up to now. The following relations hold for both methods:

1. The AGA single SOR method

$$\bar{\omega} = 1. + 0.315\rho(\mathfrak{A}) \qquad (44)$$

2. The AGA double SOR method

$$\bar{\Omega} = \Omega_\beta = \Omega_\phi = 1.19/(1.19 - 0.19\rho(\mathfrak{A})) \qquad (45)$$

where

$$\rho(\mathfrak{A}) = \max_{1 \le g \le G} \rho(\mathfrak{A}_{g,\omega=1}) \qquad (46)$$

The time of the estimate of $\bar{\omega}$ or $\bar{\Omega}$ by the programme amounts to a few percent of the total time of calculation for a given reactor problem. Since the AGA single SOR method turned out to be less effective than the AGA double SOR method, the latter is applied in HEXAGA-II.

Finally, it should be noted that the exact estimate of optimum relaxation factors is a very important problem and difficult to solve both in HEXAGA-II and in other diffusion programmes. Unfortunately, there are no theoretical considerations which would allow to predict these factors a priori for the AGA method. However, the above empirical formulae provide a good approximation of optimum relaxation factors for the majority of reactor problems. The values of $\bar{\Omega}$ evaluated by Eq. (45) are very close to the optimum value of Ω_{opt} for large reactor problems with 20000 - 40000 mesh points. For smaller problems these values of $\bar{\Omega}$ can sometimes be slightly underestimated which, in the effect, results in an increase in CPU time by about 10 to 20 percent. However, even with such underestimate of Ω_{opt}, CPU time is many times less than it would be if improper values of Ω had been used. Moreover, for the overestimated values of Ω_{opt} non-convergence can be obtained in HEXAGA-II.

IV. INPUT DESCRIPTION

The HEXAGA-II input data prepared mainly in the form of a card deck consist of a series of input variables describing, for a given reactor problem, successively its size, the distribution of material compositions in the mesh, material composition group constant and parameters determining the iteration process. HEXAGA-II also offers the possibility of transmission of cross sections extracted from an SIGMN Block /6/ stored on an external file; this feature is due to G. Buckel of INR (Karlsruhe Nuclear Research Center).

Though HEXAGA-II is a code for a triangular geometry, the description of the material distribution inside the mesh is given in the input basically as for a hexagonal geometry. That is, six adjacent triangles are grouped in one hexagon. The layout of the reactor must be enclosed by a parallelogram. The left upper corner of this parallelogram is taken as the origin of an oblique coordinate system x - v (see Fig. 1). Now a mesh of regular hexagons is superimposed upon this parallelogram. The boundaries of the parallelogram cut some hexagons in pieces. These cut hexagons are also referred to as hexagons in the following text. As illustrated in Figs. 2, 3 and 4, there are three possibilities for choosing the location of hexagons relative to the origin of the coordinate system. These three arrangements of the hexagonal mesh will be called the 1st, 2nd and 3rd spatial models, corresponding to Figs. 2, 3 and 4, respectively.

In this hexagonal description of the triangular mesh we specify, line by line, from top to bottom, only the indices x and v of hexagon centers coinciding with mesh points of these lines. If there are ununiform hexagons, that is, hexagons containing more than one material composition, one has to create a new composition number for this type of material arrangement and to indicate this number in the input together with a specification of the material compositions corresponding to the six triangles.

To simplify the preparation of HEXAGA-II input data an auxiliary programme INPREP is available. It prints the arrangement of hexagons in the parallelogram mesh for any example considered and furnishes information

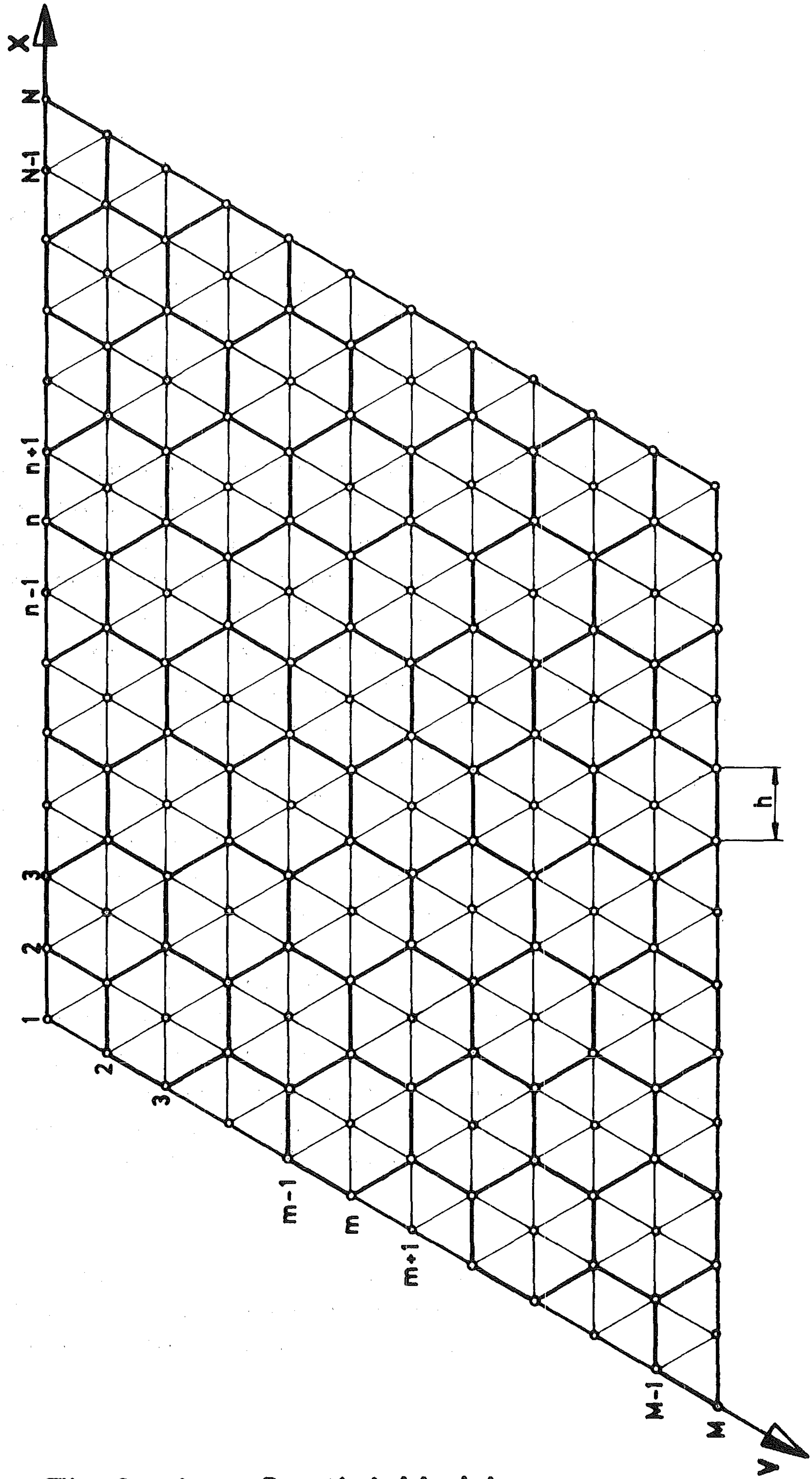


Fig. 2 1-st Spatial Model

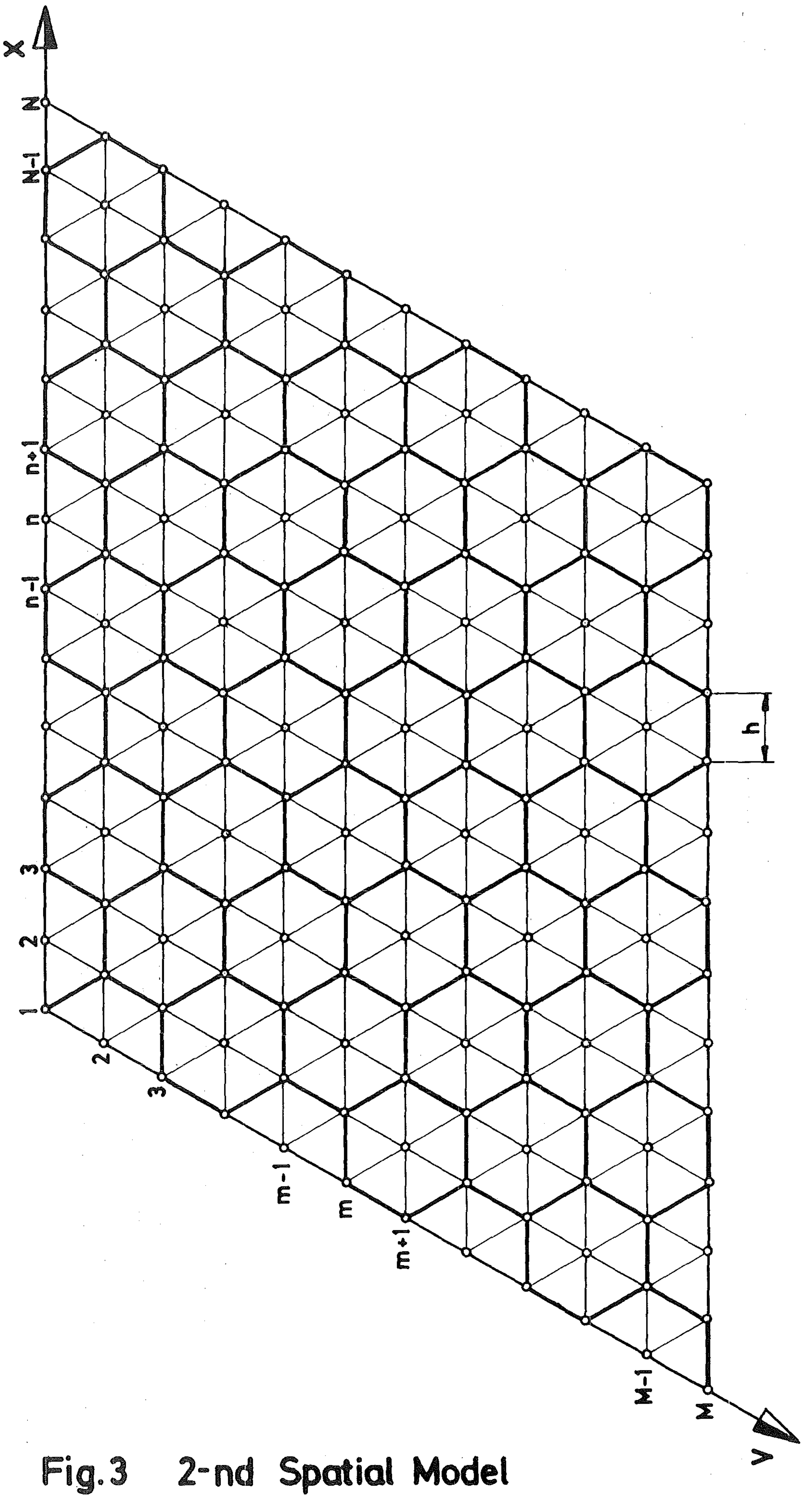


Fig. 3 2-nd Spatial Model

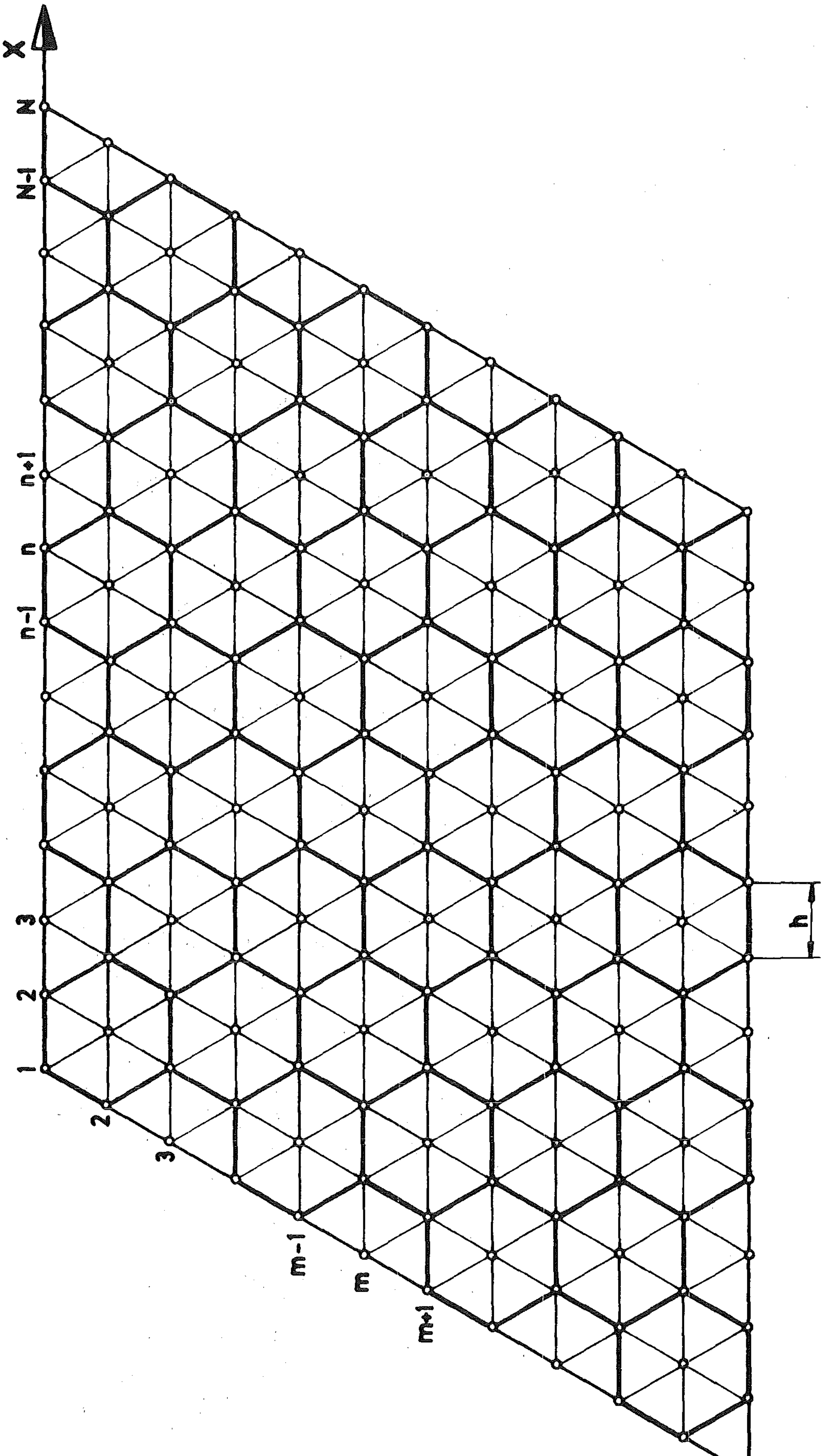


Fig. 4 3-d Spatial Model

about computer storage requirements. The use of this programme is described in Appendix.

It should be mentioned that there is the possibility with HEXAGA-II to calculate a sequence of reactor problems with optional forms of output and storage of results.

The two sample problems presented in this report provide a good illustration of the possibilities of HEXAGA-II input data.

In the table below, formats and the meaning of input variables together with comments on their use are described in the sequence in which they occur in particular cards (or card sets).

Input Card Description

Card (or Card set) number	Format	Name	Description
1/	(10A8)	Title card	(80 alphanumerical characters are permitted)
2/	(16I4,F11.5)	NOM	Spatial model number, 1 ≤ NOM ≤ 3, depending on the location of hexagons at the origin of the coordinate oblique system x - v; the value of NOM corresponds to one of the spatial model numbers represented in Figs. 2, 3 and 4.
		M	Number of mesh lines parallel to the axes x.
		N	Number of mesh lines parallel to the axes v.
		NOG	Number of energy groups, 2 ≤ NOG ≤ 40.
		MDS	Maximum number of energy groups throughout which neutrons are downscattered, 1 ≤ MDS ≤ NOG - 1.
		NOTHG	Number of thermal groups, 1 ≤ NOTHG ≤ NOG - 1.
		NOC	Number of different material compositions, NOC ≤ 999.
		NOFC	Number of different fissionable material compositions, NOFC ≤ NOC (if macroscopic cross sections are transferred from SIGMN block: NOFC = NOC).

NBASIC — Basic material composition number, $0 \leq NBASIC \leq NOC$. Dependent on the value of NBASIC, there are two possibilities for the description of the distribution of material compositions in the mesh (see explanations on card 3).

NOUH — Number of hexagons with different material compositions, $NOUH \leq NOC$.

NOH — Number of all different (uniform and non-uniform) hexagons, $NOH \geq NOUH$.
Note: In a uniform hexagon, all triangles have the same material composition; in a non-uniform hexagon, triangles may have different material compositions. Hexagons cut by the outer boundaries are counted as full hexagons and their triangles lying outside outer boundary can be specified by an arbitrary material composition.

NLC — Left boundary condition indicator.

NTC — Top boundary condition indicator.

NRC — Right boundary condition indicator.

NBC — Bottom boundary condition indicator.
These indicators may have one of the following values:
0 - corresponds to zero flux
1 - corresponds to zero current
2 - corresponds to a logarithmic derivative boundary condition where the parameter α of

Eq. (1a) is taken to be constant along the corresponding outer boundary.

3 - corresponds to a logarithmic derivative boundary condition, but the parameter α is given pointwise for the corresponding outer boundary.

Note: Parameters α, if any, are specified groupwise after the specification of group constants.

NAD $0 \leq$ NAD ≤ 2

0 - real flux calculation only

1 - both real and adjoint flux calculations

2 - adjoint flux calculation only.

H   Mesh width given in centimeters.

3/   The data specifying the location of material compositions in the hexagonal description of the mesh must be provided according to the value of NBASIC; if NBASIC = 0, continue with card set number 3/1'/.

3/1/   If $1 \leq$ NBASIC $\leq$ NOC, all hexagons must be uniform, NOH = NOUH = NOC.
Material composition NBASIC is assumed in all locations of the mesh that are not specified otherwise in the card subset below.
For j = 1, NOC - 1 the whole sequence from 3/1/1/ to 3/1/3/ must be indicated as follows

3/1/1/   (2I4)   NSP   Material composition number $1 \leq$ NSP $\leq$ NOC and NSP $\neq$ NBASIC given in an arbitrary order.

		NL	Number of mesh lines parallel to the x-axes which pass through centers of hexagons containing material composition NSP. For i = 1, ...NL 3/1/2/ and 3/1/3/ must be indicated.
3/1/2/	(214)	LNR	Index number of one of these NL mesh lines.
		NP	Number of points on this mesh line LNR coinciding with the centers of hexagons containing composition NSP.
3/1/3/	(2014)	NCR(NP)	Array of the point indices (on the mesh line LNR) coinciding with the centers of hexagons containing composition NSP.

After completion of the material distribution, the input continues with card set 4.

3/1'/ (2014)

If NBASIC = 0, all hexagons in the mesh are specified by their centers linewise from top to bottom. The input of each mesh line is treated as one card set. NOUH $\leq$ NOC.
If NOH = NOUH, the hexagon composition numbers correspond to the material composition numbers NSP.
If NOH > NOUH, new hexagon composition numbers NH (NH > NOC) have to be created for each type of non-uniform hexagon and each of them must be specified additionally in card set 3/1'/1/.

3/1'/1/ (614,I6)

If NOH > NOUH, the material composition numbers of six triangles (corresponding to the order of triangles shown in Fig. 1) for each non-uniform hexagon must be given followed by the newly created hexagonal type of composition number NH, NH = NOUH + 1, NOUH + 2, . . . NOH.

4/ Group constant specifications must be provided for each material composition. Two possibilities are allowed:

a) Input as a card deck or from an external file stored in the card image format. Mixing of these two input forms is allowed.
b) Transmission of group constants from a SIGMN block /6/, stored on an external file. In this case, bucklings must be given according to 4/2'/-4/4'/.

4/1/	(2I4)	INCS	Indicator for reading in group constants = 1 - group constants given as a card deck. < 0 - group constants given on an external file in card image format with data set reference number |INCS| and |INCS| > 1. = 0 - group constants must be transformed from SIGMN block.
		NSP	- material composition number, $1 \leq NSP \leq NOC$, if INCS $\neq$ 0 - data reference number of SIGMN block, if INCS = 0.

If INCS = 0, turn to card sets 4/2'/...4/4'/.

4/2/	(6E13.6)	DIF(NOG)	Array of diffusion coefficients D_g for all energy groups.

4/3/ SIGT (NOG) Array of macroscopic total removal cross sections Σ_g^T for all energy groups

$$\Sigma_g^T = \Sigma_g^A + \sum_{\substack{g'=1 \\ g'\neq g}}^{G} \Sigma_{g\to g'}^S + D_g B^2$$

where

Σ_g^A - macroscopic absorption cross section

$\Sigma_{g\to g'}^S$ -macroscopic scattering cross section from group g to g'.

B - transverse buckling

4/4/ If a given value of NSP corresponds to a fissionable material composition, that is, NSP $\leq$ NOFC, two arrays for $\nu\Sigma^F$ and χ must be specified. It should be noticed that all fissionable material compositions must be denoted by the numbers from 1 to NOFC. For NSP > NOFC, both arrays are omitted in the input. However, if a given material composition is in reality unfissionable but was declared a fissionable composition, zero values of $\nu\Sigma_g^F$ and values of χ with $\sum_1^G \chi_g = 1$ must be specified for all energy groups in the input.

4/4/1/ NUSIGF(NOG) Array of macroscopic production fission cross sections $\nu\Sigma_g^F$ for all energy groups.

4/4/2/ CHI(NOG) Array of fission source fractions χ_g for all energy groups.

4/5/ SIGDS(NOG-1,MDS) Array of macroscopic downscattering cross sections $\Sigma_{g\to g'}^{ds}$, whose values for MDS > 1 are specified as follows:

4/5/1/ $\Sigma^{ds}_{1\to 2}, \Sigma^{ds}_{1\to 3}, \ldots\ldots \Sigma^{ds}_{1\to MDS+1}$

4/5/2/ $\Sigma^{ds}_{2\to 3}, \Sigma^{ds}_{2\to 4}, \ldots\ldots \Sigma^{ds}_{2\to MDS+2}$

4/5/NOG-2/ $\Sigma^{ds}_{NOG-2\to NOG-1}, \Sigma^{ds}_{NOG-2\to NOG}$

4/5/NOG-1/ $\Sigma^{ds}_{NOG-1\to NOG}$.

4/6/ If there is more than one thermal group, NOTHG > 1, we must provide the following triangular array:

SIGUS(NOTHG-1, NOTHG-1) Array of macroscopic upscattering cross sections $\Sigma^{us}_{g'\to g}$ whose values in a general case are specified as follows:

4/6/1/ $\Sigma^{us}_{I+1\to I}, \Sigma^{us}_{I+2\to I}, \ldots\ldots \Sigma^{us}_{NOG\to I}$

4/6/2/ $\Sigma^{us}_{I+2\to I+1}, \Sigma^{us}_{I+3\to I+1}, \ldots \Sigma^{us}_{NOG\to I+1}$

4/6/NOTHG-2/ $\Sigma^{us}_{NOG-1\to NOG-2}, \Sigma^{us}_{NOG\to NOG-2}$

4/6/NOTHG-1/ $\Sigma^{us}_{NOG\to NOG-1}$

where I = NOG - NOTHG + 1

Note: The above sequence of data beginning from 4/1/ must be repeated NOC times, that is, for each material composition. However, if |INCS| > 1, the data from 4/2/ to 4/6/ are omitted for this composition in the card deck, because they are stored on an external file with the data set number equal to |INCS|.

Turn to 5/

4/2'/	(I4)	IBUCK	Buckling indicator = 1 - uniform buckling = 2 - material dependent buckling = 3 - group dependent buckling = 4 - group and material dependent buckling.
4/3'/	(I4)	MX	= 1 for IBUCK = 1 = NOC for IBUCK = 2 or IBUCK = 4 = NOG for IBUCK = 3.
4/4'/	(6E13.6)	B2(MX)	Values of B^2.

Note: If IBUCK = 4, card 4/3'/ and 4/4'/ must be repeated NOG times.

5/

If at least one of the values of NLC, NTC, NRC and NBC is $\geq$ 2, we specify the parameters α of Eq. (1a) as follows:

If NLC = 2,

5/1/	(E11.5)	PARL	Parameter α constant along the left outer boundary.

If NLC = 3,

5/1'/	(7E11.5)	ALFAL(M)	Array of parameters α for all mesh points along the left outer boundary.

If NTC = 2,

5/2/	(E11.5)	PART	Parameter α constant along the top outer boundary.

If NTC = 3,

5/2'/	(7E11.5)	ALFAT(N)	Array of parameters α for all mesh points along the top outer boundary.

		If NRC = 2,	
5/3/	(E11.5)	PARR	Parameter α constant along the right outer boundary.
		IF NRC = 3,	
5/3'/	(7E11.5)	ALFAR(M)	Array of parameters α for all mesh points along the right outer boundary.
		If NBC = 2,	
5/4/	(E11.5)	PARB	Parameter α constant along the bottom outer boundary.
		If NBC = 3,	
5/4'/	(7E11.5)	ALFAB(N)	Array of parameters α for all mesh points along the bottom outer boundary.

Note: This sequence of data beginning from 5/1/, if it exists, must be repeated successively for all energy groups.

6/	(4I4, 2F8.4 2E9.1, 2I4)	INIT	= 0 - fluxes and sources are not stored on an external file. = 1 - first fluxes and next sources are stored on the external file with data set reference number 21. = 2 - only fluxes are stored on the external file with data set reference number 21.
		MAXO	Maximum number of outer iterations,
		MAXI	Maximum number of inner iterations, $1 \leq MAXI \leq 8$.
		MINI	Minimum number of inner iterations, $1 \leq MINI \leq 8$.

Note: If MAXI = MINI, the number of inner iterations equal to MAXI is performed in all outer iterations. For MAXI > MINI, the following strategy is used: In the first MAXI - MINI outer iterations the number of inner iterations (fixed for all energy groups) is decreased by one from outer to outer iteration starting with MAXI. This is continued until the number of inner iterations reaches the value of MINI; then this number of inner iterations is fixed for the remaining outer iterations.

OMB	Relaxation factor Ω_β (see explanations given below for NOMEGA).
OMF	Relaxation factor Ω_ϕ (see explanations given below for NOMEGA).
EPS	Point convergence criterion for neutron flux (see Eq. (43)).
EPL	Convergence criterion for k_{eff} (see Eq. (42)).
NOMEGA	= 0 - values of Ω_β and Ω_ϕ specified in the input are used in the iteration process. = 2 - values of Ω_β and Ω_ϕ are calculated by programme for the iteration process independent of their values specified in the input.

NCON = 0 - fluxes and sources are printed without starting a new problem.

= 1 - fluxes and sources are printed and then reading of a new problem is started.

= 2 - printing of fluxes and sources is omitted in the output, but a new problem is started.

V. OUTPUT DESCRIPTION

The output of HEXAGA-II (for a printer with 132 characters per line) begins with the title information and the list of parameters describing a given reactor problem. Next, the picture of the reactor in the form of a parallelogram area is printed. The corners of hexagons are marked by stars and numbers printed inside each hexagon describe the type of material composition. Each type of material composition is specified for each type of hexagon behind the picture of the reactor. A table of group constants for all material compositions is included. If logarithmic boundary conditions are used, the values of the parameters α for all mesh points in each energy group are printed.

If optimum relaxation factors are estimated by the programme, the following information is printed: The preliminary estimate of the energy group in which the spectral radius reaches a maximum, the calculation of this spectral radius performed by the power method, and the values of Ω_β (OMEGAB) and Ω_ϕ (OMEGAF) evaluated by means of the empirical formula given in Chapter III.

During the iteration process, the values of relaxation factors Ω_β and Ω_ϕ, the eigenvalue k_{eff} and its relative error, and the maximum relative error of the neutron flux in inner iterations are printed for each outer iteration. The printing of neutron fluxes and sources is the last optional output information.

The sample problems presented in this report provide an illustration of the output form.

VI. PROGRAMMING INFORMATION

1. Description of the HEXAGA-II Programme

HEXAGA-II consists of six main subroutines

INPUT
MATREL
REORD
EIGEN
ITERAT
ADITER

wich are called by the main programme in the above sequence.

INPUT provides the description of problem to be solved and prints the distribution of material compositions in the parallelogram area represented by a hexagonal mesh.

In MATREL, coefficients of Eq. (3 and 35) are calculated, that is, the coefficients of difference equations, coefficients used with the calculation of scattering and fission terms, and coefficients of recursive formulae used in the two-sweep equations (35).

REORD reorders all records on external files in a sequence suitable for the iteration processes executed in EIGEN, ITERAT and ADITER.

EIGEN provides the estimate of the relaxation parameter based on the empirical formula (45) with the calculation of the spectral radius $\rho(\mathcal{H})$ by means of the power method.

In ITERAT, the real system of difference equations is solved by means of the AGA Double SOR two-sweep iteration method.

In ADITER, the adjoint system of difference equations is solved also by means of the AGA Double SOR two-sweep iteration method.

HEXAGA-II uses eight external files with dataset reference numbers 12, 13, 14, 15, 16, 17, 18 and 20 for real flux calculations and two auxiliary files 22 and 23 for adjoint flux calculations. In the case of storage of neutron fluxes and fission sources and/or adjoint fluxes, file 21 is used.

The above files used in ITERAT or ADITER serve as stores of the following data:

File 12 - coefficients used in the recurrence formulae of the AGA method (Eqs. (35)).

File 13 - coefficients used with the calculation of scattering terms and fission sources (vector c in Eq. 8).

File 14 - components of β (for former or current outer iteration).

File 15 - components of ϕ (for former or current outer iteration).

File 16 - components of β (for current or former outer iteration).

File 17 - components of ϕ (for current or former outer iteration).

File 18 - fission sources (for former or current outer iteration).

File 20 - fission sources (for current or former outer iteration).

Files 14, 16, 15, 17 and 18, 20 are used in the flip-flop form. In the case of adjoint calculations, the data stored on files 12 and 13 are reordered and restored on files 22 and 23, respectively.

2. Memory Requirements

HEXAGA-II is a module of the INR programme library NUSYS at the computer center of GfK, Karlsruhe. With a (mild) overlay structure, this module takes 60 K bytes of fast memory. Up to now it has been impossible to translate the source deck of HEXAGA-II with the FORTRAN IV H-Ext. Compiler (of the IBM/360-system) into a correctly working load module. So the above value corresponds to the version translated with the FORTRAN IV G1 Compiler. Without overlay the module occupies 90 K bytes of core region.

For any special case considered one has to take into account further storage requirements for

(a) dynamic storage: 36 time the number of mesh points in bytes,

(b) buffers: 16 buffers for real flux calculations,
20 buffers for adjoint flux calculations
2 additional buffers, if fluxes and/or sources have to be stored.
The sizes of the buffers depend (for the IBM/360 and IBM/370

systems, respectively) on the DCB subparameter BLKSIZE on the DD-(Data-Definition) cards for each file /7/ (see also sample problems).

3. External File Space Requirements

For data storage a space has to be reserved on particular external files. This space can be calculated for each file as follows:

File 12: $S_{12} = 24\times NOG\times(M\times N+1)$

File 13: $S_{13} = 8\times NOG\times(M\times N+1)$
$+ 2\times MDS\times(2\times NOG-MDS-1)\times(M\times N+2\times M)$
$+ 2\times NOTHG\times(NOTHG-1)\times(M\times N+2\times M)$

File 14: $S_{14} = \max \{8\times NOG\times(M\times N+1);$
$2\times MDS\times(2\times NOG-MDS-1)\times(M\times N+2\times M)\}$

File 15: $S_{15} = \max \{8\times NOG\times(M\times N+1);$
$2\times NOTHG\times(NOTHG-1)\times(M\times N+2\times M)\}$

File 16: $S_{16} = \max \{4\times NOG\times(M\times M+1);$
$2\times MDS\times(2\times NOG-MDS-1)\times(M\times N+2\times M);$
$2\times NOTHG\times(NOTHG-1)\times(M\times N+2\times M)\}$

File 17: $S_{17} = S_{16}$

File 18: $S_{18} = 4\times(M\times N+1)$

File 20: $S_{20} = S_{18}$

File 21: $S_{21} = 4\times(2\times NOG+1)\times(M\times N+1)$

File 22: $S_{22} = S_{12}$

File 23: $S_{23} = S_{13}$

The values of S are expressed in bytes and M, N, NOG, MDS and NOTHG denote the number of mesh points in the x direction, the number of mesh points in the v direction (see Fig. 1), the number of energy groups, the maximum number of energy groups throughout which neutrons are downscattered and the number of thermal groups, respectively.

VII. NUMERICAL EXAMPLES

HEXAGA-II is illustrated by two four-group sample problems, B1 and B2, both based on a fast reactor problem similar to the prototype breeder reactor SNR-300.

Both sample problems represent the same physical configuration of the reactor and have the same group constants; they differ only in the step-size of the discretization mesh. The area of solution is restricted to one third of the reactor with the following boundary conditions: on the left and top boundaries the current is equal to zero, and on the right and bottom boundaries the logarithmic derivative boundary condition is taken.

In the sample problem B1 with the triangular mesh the step width equals 6.4665 cm, all hexagons are uniform and the total number of mesh points amounts to 324. In the sample problem B2 the mesh step corresponds to the mesh step of B1 divided by the factor of 2. This twofold decrease of the mesh step results in 1225 mesh points and the simultaneous appearance of some number of non-uniform hexagons in the mesh of B2.

Both sample problems are illustrated by job cards, external file specifications, input data sheets and the printout of the output.

Sample Problem B1

Real and adjoint flux calculations with the full printout of results.
One inner iteration per outer iteration is assumed.
In the case of using IBM/370-168 computer the following data
were obtained:

CPU time: 42.4 sec
Total costs: 30.98 DM

DATENKARTEN

Programm HEXAGA-II SAMPLE PROBLEM B1 Datum ______ Name ____________ Blatt-Nr. _____

```
//........JØB CARD..............
// REGIØN=300K,TIME=2
/*FØRMAT PR,DDNAME=FT06F001,ØVFL=ØN
// EXEC FGG,LIB=NUSYS,NAME=HEXAGA
//SYSIN DD *
//G.FT12F001 DD UNIT=SYSDA,SPACE=(7294,5),DCB=(BLKSIZE=7294,RECFM=VBS)
//G.FT13F001 DD UNIT=SYSDA,SPACE=(7294,3),DCB=*.FT12F001
//G.FT14F001 DD UNIT=SYSDA,SPACE=(7294,2),DCB=*.FT12F001
//G.FT15F001 DD UNIT=SYSDA,SPACE=(7294,2),DCB=*.FT12F001
//G.FT16F001 DD UNIT=SYSDA,SPACE=(7294,2),DCB=*.FT12F001
//G.FT17F001 DD UNIT=SYSDA,SPACE=(7294,2),DCB=*.FT12F001
//G.FT18F001 DD UNIT=SYSDA,SPACE=(7294,1),DCB=*.FT12F001
//G.FT20F001 DD UNIT=SYSDA,SPACE=(7294,1),DCB=*.FT12F001
//G.FT21F001 DD UNIT=SYSDA,SPACE=(7294,5),DCB=*.FT12F001
//G.FT22F001 DD UNIT=SYSDA,SPACE=(7294,3),DCB=*.FT12F001
//G.SYSIN DD *
```

DATENKARTEN

Programm: HEXAGA-II SAMPLE PROBLEM B1 Datum ______ Name ____________ Blatt-Nr. 1

INPUT DATA

```
1/
          SAMPLE PROBLEM B1
2/
   1  18  18   4   3   1   5   3   0   5   5   1   1   2   2   1     6.46650
3/1'/
   1   1   1   2   2   3
   1   1   1   2   3   3
   1   1   1   4   2   3
   1   1   5   1   2   3
   1   1   1   2   3   3
   1   1   1   2   2   3
   1   5   1   1   2   3
   1   1   1   2   3   3
   1   1   1   4   2   3
   2   1   1   2   2   3
   4   2   4   2   3   3
```

DATENKARTEN

Programm ____ Datum ____ Name ____ Blatt-Nr. 2

```
  2   2   2   2   2   3
  2   2   2   2   2   3
  2   2   2   2   3   3
  3   3   3   3   3   3
  3   3   3   3   3   3
  3   3   3   3   3   3
  3   3   3   3   3   3
4/
  1   1
 .287629E+01  .157085E+01  .722486E+00  .964199E+00
 .282040E-01  .527470E-02  .176120E-01  .265460E-01
 .118780E-01  .532520E-02  .104710E-04  .266110E-01
 .768000E+00  .232000E+00 0.           0.
 .235070E-01  .407910E-05  .444830E-07
 .161530E-02  .423090E-07
 .468380E-02
```

DATENKARTEN

Programm ____________ Datum ______ Name ____________ Blatt-Nr. 3

1 2			
.287654E+01	.157136E+01	.712708E+00	.942978E+00
.287820E-01	.604910E-02	.195100E-01	.337140E-01
.149430E-01	.768870E-02	.148090E-01	.381590E-01
.768000E+00	.232000E+00	0.	0.
.232620E-01	.464510E-05	.499680E-07	
.157180E-02	.407240E-07		
.434140E-02			
1 3			
.228561E+01	.117193E+01	.632475E+00	.818357E+00
.359590E-01	.588550E-02	.160410E-01	.133490E-01
.774270E-02	.108250E-03	.297420E-03	.846870E-03
.768000E+00	.232000E+00	0.	0.
.320710E-01	.388800E-05	.450390E-07	
.277760E-02	.900180E-07		
.589710E-02			

DATENKARTEN

Programm ______ Datum ______ Name ______ Blatt-Nr. 4

```
  1    4
.250307E+01  .131468E+01  .574277E+00  .615369E+00
.248140E-01  .164120E-01  .721220E-01  .168680E-00
.229460E-01  .103200E-05  .104890E-07
.376870E-02  .703610E-11
.868150E-02
  1    5
.461642E+01  .290183E+01  .102118E+01  .172963E+01
.131590E-01  .145590E-02  .460010E-02  .786600E-03
.129420E-01  .687800E-06  .699030E-08
.128710E-02  .436330E-11
.345330E-02
5/
.46948E+00
.46948E+00
.46948E+00
```

DATENKARTEN

Programm ________ Datum ______ Name ______ Blatt-Nr. 5

```
.46948E+00
.46948E+00
.46948E+00
.46948E+00
.46948E+00
6/
  0 100   1   1 1.0000 1.0000 1.0E-05 1.0E-06  2  0
```

```
H E X A G A - II   WRITTEN BY ZBIGNIEW WOZNICKI,   FEB. 1975

                SAMPLE PROBLEM  B1

          1 TYPE OF HEXAGONAL MESH ARRANGEMENT

      324 MESH POINTS

        4 NEUTRON  GR.

        1 THERMAL GR.

        3 NEUTRON GR. THROUGHOUT WHICH NEUTRONS ARE DOWN-SCATTERED

        5 MATERIAL COMP.

        3 FISSIONABLE COMP.

   6.4665 CM - MESH STEP

          OUTER BOUNDARY COND:  LEFT   - FLUX DERIVATIVE EQUAL TO ZERO
                                TOP    - FLUX DERIVATIVE EQUAL TO ZERO
                                RIGHT  - LOGARITHMIC
                                BOTTOM - LOGARITHMIC
```

THE LOCATION OF HEXAGONS

```
                      1   3   5   7   9  11  13  15  17
                     / / / / / / / / / / / / / / / / / /

                 1-  1 * * 1 * * 1 * * 2 * * 2 * * 3 * *
                  -  * * 1 * * 1 * * 1 * * 2 * * 3 * * 3
               3-  * 1 * * 1 * * 1 * * 4 * * 2 * * 3 *
                -  1 * * 1 * * 5 * * 1 * * 2 * * 3 * *
             5-  * * 1 * * 1 * * 1 * * 2 * * 3 * * 3
              -  * 1 * * 1 * * 1 * * 2 * * 2 * * 3 *
           7-  1 * * 5 * * 1 * * 1 * * 2 * * 3 * *
            -  * * 1 * * 1 * * 1 * * 2 * * 3 * * 3
         9-  * 1 * * 1 * * 1 * * 4 * * 2 * * 3 *
          -  2 * * 1 * * 1 * * 2 * * 2 * * 3 * *
      11-  * * 4 * * 2 * * 4 * * 2 * * 3 * * 3
        -  * 2 * * 2 * * 2 * * 2 * * 2 * * 3 *
    13-  2 * * 2 * * 2 * * 2 * * 2 * * 3 * *
      -  * * 2 * * 2 * * 2 * * 2 * * 3 * * 3
  15-  * 3 * * 3 * * 3 * * 3 * * 3 * * 3 *
    -  3 * * 3 * * 3 * * 3 * * 3 * * 3 * *
17-  * * 3 * * 3 * * 3 * * 3 * * 3 * * 3
  -  * 3 * * 3 * * 3 * * 3 * * 3 * * 3 *
```

THE MATERIAL SPECIFICATION OF HEXAGONS

```
          * * * * * * * *
         * *           * *
        *   *    T6   *   *
       *     *       *     *
      *       *     *       *
     *    T5   *   *   T1    *
    *           * *           *
   * * * * * * *HNR* * * * * * *
    *           * *           *
     *    T4   *   *   T2    *
      *       *     *       *
       *     *       *     *
        *   *    T3   *   *
         * *           * *
          * * * * * * * *
```

HNR	T1	T2	T3	T4	T5	T6
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5

MATERIAL SPECIFICATION

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
1	G				
	1	2.87679E+00	2.82040E-02	1.18780E-02	7.68000E-01
	2	1.57085E+00	5.27470E-03	5.32520E-03	2.32000E-01
	3	7.22486E-01	1.76120E-02	1.04710E-02	0.0
	4	9.64199E-01	2.65460E-02	2.66110E-02	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.35970E-02	4.07910E-06	4.44930E-08
2	1.61530E-03	4.23C90E-08	
3	4.68380E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
2	G				
	1	2.87654E+00	2.87820E-02	1.49430E-02	7.68000E-01
	2	1.57136E+00	6.04910E-03	7.68870E-03	2.32000E-01
	3	7.12708E-01	1.95100E-02	1.48090E-02	0.0
	4	9.42978E-01	3.37140E-02	3.81590E-02	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.32620E-02	4.64510E-06	4.99680E-08
2	1.57180E-03	4.07240E-08	
3	4.34140E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
3	G				
	1	2.28561E+00	3.59590E-02	7.74270E-03	7.68000E-01
	2	1.17193E+00	5.88550E-03	1.08250E-04	2.32000E-C1
	3	6.32475E-01	1.60410E-02	2.97420E-04	0.0
	4	8.18357E-01	1.33490E-02	8.46870E-04	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	3.20710E-02	3.88800E-06	4.50390E-08
2	2.77760E-03	9.00180E-08	
3	5.89710E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
4	G				
	1	2.50307E+00	2.48140E-02	0.0	0.0
	2	1.31468E+00	1.64120E-02	0.0	0.0
	3	5.74277E-01	7.21220E-02	0.0	0.0
	4	6.15369E-01	1.68680E-01	0.0	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.29460E-02	1.03200E-06	1.04890E-08
2	3.76870E-03	7.03610E-12	
3	8.68150E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
5	G				
	1	4.61642E+00	1.31590E-02	0.0	0.0
	2	2.90183E+00	1.45590E-03	0.0	0.0
	3	1.02118E+00	4.60010E-03	0.0	0.0
	4	1.72963E+00	7.86600E-04	0.0	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	1.29420E-02	6.87800E-07	6.99030E-09
2	1.28710E-03	4.36330E-12	
3	3.45330E-03		

LOGARITHMIC BOUNDARY CONDITION PARAMETERS

GR NR	PT NR	LEFT	TOP	RIGHT	BOTTOM
1					
	1			4.6948E-01	4.6948E-01
	2			4.6948E-01	4.6948E-01
	3			4.6948E-01	4.6948E-01
	4			4.6948E-01	4.6948E-01
	5			4.6948E-01	4.6948E-01
	6			4.6948E-01	4.6948E-01
	7			4.6948E-01	4.6948E-01
	8			4.6948E-01	4.6948E-01
	9			4.6948E-01	4.6948E-01
	10			4.6948E-01	4.6948E-01
	11			4.6948E-01	4.6948E-01
	12			4.6948E-01	4.6948E-01
	13			4.6948E-01	4.6948E-01
	14			4.6948E-01	4.6948E-01
	15			4.6948E-01	4.6948E-01
	16			4.6948E-01	4.6948E-01
	17			4.6948E-01	4.6948E-01
	18			4.6948E-01	4.6948E-01
2					
	1			4.6948E-01	4.6948E-01
	2			4.6948E-01	4.6948E-01
	3			4.6948E-01	4.6948E-01
	4			4.6948E-01	4.6948E-01
	5			4.6948E-01	4.6948E-01
	6			4.6948E-01	4.6948E-01
	7			4.6948E-01	4.6948E-01
	8			4.6948E-01	4.6948E-01
	9			4.6948E-01	4.6948E-01
	10			4.6948E-01	4.6948E-01
	11			4.6948E-01	4.6948E-01
	12			4.6948E-01	4.6948E-01
	13			4.6948E-01	4.6948E-01
	14			4.6948E-01	4.6948E-01
	15			4.6948E-01	4.6948E-01
	16			4.6948E-01	4.6948E-01
	17			4.6948E-01	4.6948E-01
	18			4.6948E-01	4.6948E-01
3					
	1			4.6948E-01	4.6948E-01
	2			4.6948E-01	4.6948E-01
	3			4.6948E-01	4.6948E-01
	4			4.6948E-01	4.6948E-01
	5			4.6948E-01	4.6948E-01
	6			4.6948E-01	4.6948E-01
	7			4.6948E-01	4.6948E-01
	8			4.6948E-01	4.6948E-01
	9			4.6948E-01	4.6948E-01
	10			4.6948E-01	4.6948E-01
	11			4.6948E-01	4.6948E-01
	12			4.6948E-01	4.6948E-01
	13			4.6948E-01	4.6948E-01
	14			4.6948E-01	4.6948E-01
	15			4.6948E-01	4.6948E-01
	16			4.6948E-01	4.6948E-01
	17			4.6948E-01	4.6948E-01
	18			4.6948E-01	4.6948E-01

4

1	4.6948E-01	4.6948E-01
2	4.6948E-01	4.6948E-01
3	4.6948E-01	4.6948E-01
4	4.6948E-01	4.6948E-01
5	4.6948E-01	4.6948E-01
6	4.6948E-01	4.6948E-01
7	4.6948E-01	4.6948E-01
8	4.6948E-01	4.6948E-01
9	4.6948E-01	4.6948E-01
10	4.6948E-01	4.6948E-01
11	4.6948E-01	4.6948E-01
12	4.6948E-01	4.6948E-01
13	4.6948E-01	4.6948E-01
14	4.6948E-01	4.6948E-01
15	4.6948E-01	4.6948E-01
16	4.6948E-01	4.6948E-01
17	4.6948E-01	4.6948E-01
18	4.6948E-01	4.6948E-01

THE ESTIMATION OF OPTIMUM OMEGA

NG	NORM
1	0.374871
2	0.589447
3	0.165770
4	0.166291

NG	IT	NI	ER	ER/ER
2	1	0.589447	0.967253	0.967253
2	2	0.645163	-0.094522	-0.097722
2	3	0.663563	-0.028520	0.301726
2	4	0.673531	-0.015021	0.526701
2	5	0.679565	-0.008959	0.596407
2	6	0.683284	-0.005472	0.610815
2	7	0.685576	-0.003354	0.612931
2	8	0.686981	-0.002048	0.610748
2	9	0.687834	-0.001240	0.605214
2	10	0.688350	-0.000751	0.605385
2	11	0.688659	-0.000447	0.595934
2	12	0.688841	-0.000264	0.590618
2	13	0.688949	-0.000155	0.588448
2	14	0.689010	-0.000089	0.570552

OMEGAB=1.1236 OMEGAF=1.1236

ITERATION PROCESS

FLUX CONV IN
INNER ITERS --> 1

IT NR	OMEGAB	OMEGAF	K-EFF	K-EFF CONV.	GR NR	
1	1.1236	1.1236	0.810501	5.1775E+02	1	1.00E+00
					2	1.00E+00
					3	1.00E+00
					4	1.00E+00
2	1.1236	1.1236	1.089722	2.5623E-01	1	3.84E+00
					2	5.04E-01
					3	6.27E-01
					4	9.67E-01
3	1.1236	1.1236	1.098463	7.9579E-03	1	5.58E-01
					2	2.67E-01
					3	3.59E-01
					4	5.34E-01
4	1.1236	1.1236	1.088725	8.9436E-03	1	3.11E-01
					2	1.98E-01
					3	2.74E-01
					4	3.41E-01
5	1.1236	1.1236	1.096784	7.3475E-03	1	1.29E-01
					2	1.28E-01
					3	7.06E-02
					4	6.01E-02
6	1.1236	1.1236	1.107114	9.3307E-03	1	5.99E-02
					2	5.54E-02
					3	3.99E-02
					4	3.27E-02
7	1.1236	1.1236	1.114005	6.1861E-03	1	3.45E-02
					2	2.86E-02
					3	2.25E-02
					4	1.75E-02
8	1.1236	1.1236	1.117773	3.3710E-03	1	1.93E-02
					2	1.53E-02
					3	1.12E-02
					4	8.79E-03
9	1.1236	1.1236	1.119725	1.7435E-03	1	1.09E-02
					2	7.91E-03
					3	5.83E-03
					4	4.47E-03
10	1.1236	1.1236	1.120701	8.7059E-04	1	5.28E-03
					2	4.04E-03
					3	2.91E-03
					4	2.50E-03
11	1.1236	1.1236	1.121181	4.2790E-04	1	2.96E-03
					2	2.05E-03
					3	1.50E-03
					4	1.14E-03
12	1.1236	1.1236	1.121419	2.1261E-04	1	1.48E-03
					2	1.06E-03
					3	7.64E-04

					4	5.54E-04
13	1.1236	1.1236	1.121544	1.1140E-04	1	7.45E-04
					2	5.34E-04
					3	3.87E-04
					4	2.91E-04
14	1.1236	1.1236	1.121609	5.7876E-05	1	3.78E-04
					2	2.74E-04
					3	1.99E-04
					4	1.44E-04
15	1.1236	1.1236	1.121638	2.6405E-05	1	1.89E-04
					2	1.36E-04
					3	9.73E-05
					4	7.06E-05
16	1.1236	1.1236	1.121654	1.3649E-05	1	9.35E-05
					2	7.10E-05
					3	5.17E-05
					4	3.96E-05
17	1.1236	1.1236	1.121664	9.3579E-06	1	4.58E-05
					2	3.56E-05
					3	2.63E-05
					4	2.10E-05
18	1.1236	1.1236	1.121667	2.5630E-06	1	2.38E-05
					2	1.76E-05
					3	1.24E-05
					4	1.05E-05
19	1.1236	1.1236	1.121671	3.4571E-06	1	1.14E-05
					2	9.89E-06
					3	7.57E-06
					4	7.93E-06
20	1.1236	1.1236	1.121671	0.0	1	7.63E-06
					2	5.72E-06
					3	4.77E-06
					4	5.72E-06

1 FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	6.0389E-03	5.9802E-03	5.8052E-03	5.5235E-03	5.1729E-03	4.7955E-03	4.3816E-03	3.9027E-03	3.4129E-03	2.9999E-03
2	5.9802E-03	5.9802E-03	5.8622E-03	5.6242E-03	5.2775E-03	4.9030E-03	4.5417E-03	4.1198E-03	3.5986E-03	3.0240E-03
3	5.8052E-03	5.8622E-03	5.8052E-03	5.6242E-03	5.2906E-03	4.7717E-03	4.4820E-03	4.2475E-03	3.8134E-03	3.1849E-03
4	5.5235E-03	5.6242E-03	5.6242E-03	5.5235E-03	5.2775E-03	4.7717E-03	4.3663E-03	4.2354E-03	3.9897E-03	3.5568E-03
5	5.1729E-03	5.2775E-03	5.2906E-03	5.2775E-03	5.1730E-03	4.9030E-03	4.4820E-03	4.2354E-03	4.0517E-03	3.8064E-03
6	4.7955E-03	4.9030E-03	4.7717E-03	4.7717E-03	4.9030E-03	4.7955E-03	4.5417E-03	4.2475E-03	3.9897E-03	3.8064E-03
7	4.3816E-03	4.5417E-03	4.4820E-03	4.3663E-03	4.4820E-03	4.5417E-03	4.3816E-03	4.1199E-03	3.8134E-03	3.5568E-03
8	3.9027E-03	4.1199E-03	4.2475E-03	4.2354E-03	4.2354E-03	4.2475E-03	4.1199E-03	3.9027E-03	3.5986E-03	3.1849E-03
9	3.4129E-03	3.5986E-03	3.8134E-03	3.9897E-03	4.0517E-03	3.9897E-03	3.8134E-03	3.5986E-03	3.4129E-03	3.0240E-03
10	2.9999E-03	3.0240E-03	3.1849E-03	3.5568E-03	3.8064E-03	3.8064E-03	3.5568E-03	3.1849E-03	3.0240E-03	2.9999E-03
11	2.6448E-03	2.6463E-03	2.5418E-03	3.0045E-03	3.4400E-03	3.6054E-03	3.4400E-03	3.0045E-03	2.5418E-03	2.6463E-03
12	2.2679E-03	2.4164E-03	2.3936E-03	2.5779E-03	2.9805E-03	3.1949E-03	3.1949E-03	2.9805E-03	2.5779E-03	2.3936E-03
13	1.7338E-03	1.9836E-03	2.1191E-03	2.2431E-03	2.4511E-03	2.6368E-03	2.6981E-03	2.6368E-03	2.4511E-03	2.2431E-03
14	1.0224E-03	1.3551E-03	1.5801E-03	1.6503E-03	1.7841E-03	1.9672E-03	1.9775E-03	1.9775E-03	1.9672E-03	1.7841E-03
15	4.5877E-04	6.5171E-04	9.0733E-04	1.0053E-03	9.8341E-04	1.1755E-03	1.2258E-03	1.1198E-03	1.2258E-03	1.1755E-03
16	2.0518E-04	2.9707E-04	4.0202E-04	4.8596E-04	5.2392E-04	5.6770E-04	6.1450E-04	6.1528E-04	6.1528E-04	6.1450E-04
17	8.5646E-05	1.2853E-04	1.7582E-04	2.2029E-04	2.5213E-04	2.7493E-04	2.9564E-04	3.0739E-04	3.0939E-04	3.0739E-04
18	2.8717E-05	4.5696E-05	6.4646E-05	8.3772E-05	9.9835E-05	1.1162E-04	1.2086E-04	1.2761E-04	1.3061E-04	1.3061E-04

	11	12	13	14	15	16	17	18
1	2.6448E-03	2.2679E-03	1.7338E-03	1.0224E-03	4.5876E-04	2.0518E-04	8.5646E-05	2.8717E-05
2	2.6463E-03	2.4164E-03	1.9836E-03	1.3551E-03	6.5171E-04	2.9707E-04	1.2852E-04	4.5695E-05
3	2.5418E-03	2.3936E-03	2.1191E-03	1.5801E-03	9.0733E-04	4.0201E-04	1.7582E-04	6.4646E-05
4	3.0045E-03	2.5779E-03	2.2431E-03	1.6503E-03	1.0053E-03	4.8596E-04	2.2029E-04	8.3772E-05
5	3.4400E-03	2.9805E-03	2.4511E-03	1.7841E-03	9.8341E-04	5.2391E-04	2.5213E-04	9.9835E-05
6	3.6054E-03	3.1949E-03	2.6368E-03	1.9672E-03	1.1755E-03	5.6770E-04	2.7493E-04	1.1162E-04
7	3.4400E-03	3.1949E-03	2.6981E-03	1.9775E-03	1.2258E-03	6.1450E-04	2.9564E-04	1.2086E-04
8	3.0045E-03	2.9805E-03	2.6368E-03	1.9775E-03	1.1198E-03	6.1528E-04	3.0739E-04	1.2761E-04
9	2.5418E-03	2.5779E-03	2.4511E-03	1.9672E-03	1.2258E-03	6.1528E-04	3.0939E-04	1.3061E-04
10	2.6463E-03	2.3936E-03	2.2431E-03	1.7841E-03	1.1755E-03	6.1450E-04	3.0739E-04	1.3061E-04
11	2.6448E-03	2.4164E-03	2.1191E-03	1.6503E-03	9.8341E-04	5.6770E-04	2.9564E-04	1.2761E-04
12	2.4164E-03	2.2679E-03	1.9836E-03	1.5801E-03	1.0053E-03	5.2392E-04	2.7493E-04	1.2086E-04
13	2.1191E-03	1.9836E-03	1.7338E-03	1.3551E-03	9.0733E-04	4.8596E-04	2.5213E-04	1.1162E-04
14	1.6503E-03	1.5801E-03	1.3551E-03	1.0224E-03	6.5171E-04	4.0201E-04	2.2029E-04	9.9834E-05
15	9.8341E-04	1.0053E-03	9.0733E-04	6.5171E-04	4.5877E-04	2.9707E-04	1.7582E-04	8.3772E-05
16	5.6770E-04	5.2392E-04	4.8596E-04	4.0202E-04	2.9707E-04	2.0518E-04	1.2852E-04	6.4646E-05
17	2.9564E-04	2.7493E-04	2.5213E-04	2.2029E-04	1.7582E-04	1.2852E-04	8.5646E-05	4.5695E-05
18	1.2761E-04	1.2086E-04	1.1162E-04	9.9835E-05	8.3772E-05	6.4646E-05	4.5695E-05	2.8717E-05

2 FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	3.0079E-02	2.9811E-02	2.9021E-02	2.7757E-02	2.6130E-02	2.4210E-02	2.1917E-02	1.9179E-02	1.6113E-02	1.3327E-02
2	2.9811E-02	2.9811E-02	2.9280E-02	2.8235E-02	2.6742E-02	2.5001E-02	2.2987E-02	2.0493E-02	1.7496E-02	1.4096E-02
3	2.9021E-02	2.9280E-02	2.9021E-02	2.8235E-02	2.6907E-02	2.5076E-02	2.3633E-02	2.1511E-02	1.8771E-02	1.5317E-02
4	2.7757E-02	2.8235E-02	2.8235E-02	2.7757E-02	2.6742E-02	2.5076E-02	2.3754E-02	2.2314E-02	1.9782E-02	1.6989E-02
5	2.6130E-02	2.6742E-02	2.6907E-02	2.6742E-02	2.6130E-02	2.5001E-02	2.3633E-02	2.2314E-02	2.0168E-02	1.7864E-02
6	2.4210E-02	2.5001E-02	2.5076E-02	2.5076E-02	2.5001E-02	2.4210E-02	2.2987E-02	2.1511E-02	1.9782E-02	1.7864E-02
7	2.1917E-02	2.2987E-02	2.3633E-02	2.3754E-02	2.3633E-02	2.2987E-02	2.1917E-02	2.0493E-02	1.8771E-02	1.6990E-02
8	1.9179E-02	2.0493E-02	2.1511E-02	2.2314E-02	2.2314E-02	2.1511E-02	2.0493E-02	1.9179E-02	1.7496E-02	1.5317E-02
9	1.6113E-02	1.7496E-02	1.8771E-02	1.9782E-02	2.0168E-02	1.9782E-02	1.8771E-02	1.7496E-02	1.6113E-02	1.4096E-02
10	1.3327E-02	1.4096E-02	1.5317E-02	1.6990E-02	1.7864E-02	1.7864E-02	1.6990E-02	1.5317E-02	1.4096E-02	1.3327E-02
11	1.1347E-02	1.1684E-02	1.1735E-02	1.3782E-02	1.5382E-02	1.5858E-02	1.5382E-02	1.3782E-02	1.1735E-02	1.1684E-02
12	9.7350E-03	1.0377E-02	1.0525E-02	1.1413E-02	1.2949E-02	1.3737E-02	1.3737E-02	1.2949E-02	1.1413E-02	1.0525E-02
13	7.9701E-03	8.7797E-03	9.3697E-03	9.9988E-03	1.0827E-02	1.1558E-02	1.1838E-02	1.1558E-02	1.0827E-02	9.9988E-03
14	6.0381E-03	6.9802E-03	7.5984E-03	8.2514E-03	8.8932E-03	9.3515E-03	9.7706E-03	9.7706E-03	9.3515E-03	8.8932E-03
15	3.8211E-03	4.7348E-03	5.6260E-03	6.1486E-03	6.4982E-03	7.1106E-03	7.3925E-03	7.3218E-03	7.3925E-03	7.1106E-03
16	2.1461E-03	2.8210E-03	3.4300E-03	3.9183E-03	4.2651E-03	4.5824E-03	4.8438E-03	4.9393E-03	4.9393E-03	4.8438E-03
17	9.4707E-04	1.3841E-03	1.7568E-03	2.0720E-03	2.3189E-03	2.5144E-03	2.6736E-03	2.7728E-03	2.8026E-03	2.7728E-03
18	2.0014E-04	3.5488E-04	4.8012E-04	5.8624E-04	6.7310E-04	7.4162E-04	7.9618E-04	8.3565E-04	8.5546E-04	8.5546E-04

	11	12	13	14	15	16	17	18
1	1.1347E-02	9.7350E-03	7.9701E-03	6.0381E-03	3.8211E-03	2.1461E-03	9.4707E-04	2.0014E-04
2	1.1684E-02	1.0377E-02	8.7797E-03	6.9802E-03	4.7348E-03	2.8210E-03	1.3841E-03	3.5488E-04
3	1.1735E-02	1.0525E-02	9.3697E-03	7.5984E-03	5.6259E-03	3.4300E-03	1.7568E-03	4.8011E-04
4	1.3782E-02	1.1413E-02	9.9988E-03	8.2514E-03	6.1486E-03	3.9183E-03	2.0720E-03	5.8624E-04
5	1.5382E-02	1.2949E-02	1.0827E-02	8.8932E-03	6.4982E-03	4.2651E-03	2.3189E-03	6.7310E-04
6	1.5858E-02	1.3737E-02	1.1558E-02	9.3515E-03	7.1106E-03	4.5824E-03	2.5144E-03	7.4162E-04
7	1.5382E-02	1.3737E-02	1.1838E-02	9.7706E-03	7.3925E-03	4.8438E-03	2.6736E-03	7.9618E-04
8	1.3782E-02	1.2949E-02	1.1558E-02	9.7706E-03	7.3217E-03	4.9393E-03	2.7728E-03	8.3564E-04
9	1.1735E-02	1.1413E-02	1.0827E-02	9.3515E-03	7.3925E-03	4.9393E-03	2.8026E-03	8.5546E-04
10	1.1684E-02	1.0525E-02	9.9988E-03	8.8932E-03	7.1106E-03	4.8438E-03	2.7728E-03	8.5546E-04
11	1.1347E-02	1.0377E-02	9.3697E-03	8.2514E-03	6.4982E-03	4.5824E-03	2.6736E-03	8.3564E-04
12	1.0377E-02	9.7350E-03	8.7797E-03	7.5984E-03	6.1486E-03	4.2651E-03	2.5144E-03	7.9618E-04
13	9.3697E-03	8.7797E-03	7.9701E-03	6.9802E-03	5.6260E-03	3.9183E-03	2.3189E-03	7.4162E-04
14	8.2514E-03	7.5984E-03	6.9802E-03	6.0381E-03	4.7348E-03	3.4300E-03	2.0720E-03	6.7310E-04
15	6.4982E-03	6.1486E-03	5.6260E-03	4.7348E-03	3.8211E-03	2.8210E-03	1.7568E-03	5.8624E-04
16	4.5824E-03	4.2651E-03	3.9183E-03	3.4300E-03	2.8210E-03	2.1461E-03	1.3841E-03	4.8011E-04
17	2.6736E-03	2.5144E-03	2.3189E-03	2.0720E-03	1.7568E-03	1.3841E-03	9.4707E-04	3.5488E-04
18	8.3564E-04	7.9618E-04	7.4162E-04	6.7310E-04	5.8624E-04	4.8011E-04	3.5488E-04	2.0014E-04

3 FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	2.6806E-03	2.6604E-03	2.6024E-03	2.5129E-03	2.3885E-03	2.2101E-03	1.9674E-03	1.6652E-03	1.3042E-03	9.9360E-04
2	2.6603E-03	2.6603E-03	2.6217E-03	2.5526E-03	2.4647E-03	2.3322E-03	2.1115E-03	1.8194E-03	1.4678E-03	1.0242E-03
3	2.6024E-03	2.6217E-03	2.6024E-03	2.5526E-03	2.5025E-03	2.5160E-03	2.3605E-03	1.9829E-03	1.6286E-03	1.1546E-03
4	2.5129E-03	2.5526E-03	2.5526E-03	2.5129E-03	2.4647E-03	2.5160E-03	2.5556E-03	2.2123E-03	1.7790E-03	1.4242E-03
5	2.3885E-03	2.4647E-03	2.5025E-03	2.4647E-03	2.3885E-03	2.3322E-03	2.3605E-03	2.2123E-03	1.8421E-03	1.5285E-03
6	2.2101E-03	2.3322E-03	2.5160E-03	2.5160E-03	2.3322E-03	2.2101E-03	2.1115E-03	1.9829E-03	1.7790E-03	1.5285E-03
7	1.9674E-03	2.1115E-03	2.3605E-03	2.5556E-03	2.3605E-03	2.1115E-03	1.9674E-03	1.8194E-03	1.6286E-03	1.4242E-03
8	1.6652E-03	1.8194E-03	1.9829E-03	2.2123E-03	2.2123E-03	1.9829E-03	1.8194E-03	1.6652E-03	1.4678E-03	1.1546E-03
9	1.3043E-03	1.4678E-03	1.6286E-03	1.7790E-03	1.8421E-03	1.7790E-03	1.6286E-03	1.4678E-03	1.3042E-03	1.0242E-03
10	9.9360E-04	1.0242E-03	1.1546E-03	1.4242E-03	1.5285E-03	1.5285E-03	1.4242E-03	1.1546E-03	1.0242E-03	9.9359E-04
11	8.4756E-04	8.1134E-04	7.4796E-04	1.0067E-03	1.2414E-03	1.2877E-03	1.2414E-03	1.0067E-03	7.4795E-04	8.1133E-04
12	7.7151E-04	7.9108E-04	7.4033E-04	8.1163E-04	1.0106E-03	1.1013E-03	1.1013E-03	1.0106E-03	8.1163E-04	7.4032E-04
13	7.0777E-04	7.3435E-04	7.6328E-04	8.1079E-04	8.8432E-04	9.6091E-04	9.9517E-04	9.6091E-04	8.8431E-04	8.1079E-04
14	7.0122E-04	7.0862E-04	7.0944E-04	8.0730E-04	8.6602E-04	8.6568E-04	9.5837E-04	9.5837E-04	8.6568E-04	8.6602E-04
15	5.6244E-04	6.4552E-04	6.7561E-04	7.3385E-04	8.3246E-04	8.4046E-04	8.7602E-04	9.3711E-04	8.7602E-04	8.4047E-04
16	3.4585E-04	4.3928E-04	5.0839E-04	5.6415E-04	6.1887E-04	6.6220E-04	6.9101E-04	7.1369E-04	7.1369E-04	6.9101E-04
17	1.5063E-04	2.2118E-04	2.7391E-04	3.1568E-04	3.5045E-04	3.7954E-04	4.0181E-04	4.1663E-04	4.2220E-04	4.1663E-04
18	1.9054E-05	3.7609E-05	5.0388E-05	6.0256E-05	6.8245E-05	7.4847E-05	8.0140E-05	8.3956E-05	8.6022E-05	8.6022E-05

	11	12	13	14	15	16	17	18
1	8.4756E-04	7.7151E-04	7.0777E-04	7.0122E-04	5.6244E-04	3.4585E-04	1.5063E-04	1.9053E-05
2	8.1134E-04	7.9108E-04	7.3435E-04	7.0861E-04	6.4552E-04	4.3928E-04	2.2118E-04	3.7609E-05
3	7.4795E-04	7.4032E-04	7.6328E-04	7.0944E-04	6.7561E-04	5.0839E-04	2.7391E-04	5.0388E-05
4	1.0067E-03	8.1163E-04	8.1079E-04	8.0730E-04	7.3385E-04	5.6415E-04	3.1568E-04	6.0256E-05
5	1.2414E-03	1.0106E-03	8.8431E-04	8.6602E-04	8.3246E-04	6.1887E-04	3.5045E-04	6.8245E-05
6	1.2877E-03	1.1013E-03	9.6090E-04	8.6568E-04	8.4046E-04	6.6220E-04	3.7954E-04	7.4847E-05
7	1.2414E-03	1.1013E-03	9.9517E-04	9.5837E-04	8.7601E-04	6.9101E-04	4.0181E-04	8.0140E-05
8	1.0067E-03	1.0106E-03	9.6091E-04	9.5837E-04	9.3710E-04	7.1369E-04	4.1663E-04	8.3955E-05
9	7.4795E-04	8.1163E-04	8.8432E-04	8.6568E-04	8.7602E-04	7.1368E-04	4.2220E-04	8.6022E-05
10	8.1133E-04	7.4032E-04	8.1079E-04	8.6602E-04	8.4046E-04	6.9101E-04	4.1663E-04	8.6022E-05
11	8.4756E-04	7.9108E-04	7.6328E-04	8.0730E-04	8.3246E-04	6.6220E-04	4.0181E-04	8.3955E-05
12	7.9108E-04	7.7151E-04	7.3435E-04	7.0944E-04	7.3385E-04	6.1887E-04	3.7954E-04	8.0140E-05
13	7.6328E-04	7.3435E-04	7.0777E-04	7.0861E-04	6.7561E-04	5.6415E-04	3.5045E-04	7.4847E-05
14	8.0730E-04	7.0944E-04	7.0861E-04	7.0122E-04	6.4552E-04	5.0839E-04	3.1568E-04	6.8245E-05
15	8.3246E-04	7.3385E-04	6.7561E-04	6.4552E-04	5.6244E-04	4.3928E-04	2.7391E-04	6.0256E-05
16	6.6220E-04	6.1887E-04	5.6415E-04	5.0839E-04	4.3928E-04	3.4585E-04	2.2118E-04	5.0388E-05
17	4.0181E-04	3.7954E-04	3.5045E-04	3.1568E-04	2.7391E-04	2.2118E-04	1.5063E-04	3.7609E-05
18	8.3955E-05	8.0140E-05	7.4847E-05	6.8245E-05	6.0256E-05	5.0388E-05	3.7609E-05	1.9053E-05

4 FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	4.6470E-04	4.6231E-04	4.5591E-04	4.4647E-04	4.2977E-04	3.9624E-04	3.4239E-04	2.7134E-04	1.8269E-04	1.1389E-04
2	4.6231E-04	4.6231E-04	4.5814E-04	4.5233E-04	4.4685E-04	4.2825E-04	3.7978E-04	3.0946E-04	2.2261E-04	1.0935E-04
3	4.5591E-04	4.5814E-04	4.5591E-04	4.5233E-04	4.5756E-04	4.8730E-04	4.5845E-04	3.5625E-04	2.6436E-04	1.3557E-04
4	4.4647E-04	4.5233E-04	4.5233E-04	4.4647E-04	4.4685E-04	4.8730E-04	5.0922E-04	4.2914E-04	3.0723E-04	2.1532E-04
5	4.2977E-04	4.4685E-04	4.5756E-04	4.4685E-04	4.2977E-04	4.2825E-04	4.5845E-04	4.2914E-04	3.2565E-04	2.4108E-04
6	3.9624E-04	4.2825E-04	4.8730E-04	4.8730E-04	4.2825E-04	3.9624E-04	3.7978E-04	3.5625E-04	3.0723E-04	2.4108E-04
7	3.4238E-04	3.7978E-04	4.5845E-04	5.0922E-04	4.5845E-04	3.7978E-04	3.4238E-04	3.0946E-04	2.6436E-04	2.1532E-04
8	2.7134E-04	3.0946E-04	3.5625E-04	4.2914E-04	4.2914E-04	3.5625E-04	3.0946E-04	2.7134E-04	2.2261E-04	1.3557E-04
9	1.8269E-04	2.2261E-04	2.6436E-04	3.0723E-04	3.2565E-04	3.0723E-04	2.6436E-04	2.2261E-04	1.8269E-04	1.0935E-04
10	1.1389E-04	1.0935E-04	1.3557E-04	2.1532E-04	2.4108E-04	2.4108E-04	2.1532E-04	1.3557E-04	1.0935E-04	1.1389E-04
11	9.7681E-05	7.6368E-05	5.3716E-05	1.0888E-04	1.7261E-04	1.8187E-04	1.7261E-04	1.0888E-04	5.3716E-05	7.6368E-05
12	1.0207E-04	9.5824E-05	7.2292E-05	8.1528E-05	1.2929E-04	1.4990E-04	1.4990E-04	1.2929E-04	8.1528E-05	7.2292E-05
13	1.1424E-04	1.0745E-04	1.0549E-04	1.1009E-04	1.2268E-04	1.3824E-04	1.4560E-04	1.3824E-04	1.2268E-04	1.1009E-04
14	1.5316E-04	1.3352E-04	1.2246E-04	1.4092E-04	1.5032E-04	1.4628E-04	1.6819E-04	1.6819E-04	1.4628E-04	1.5032E-04
15	1.5986E-04	1.6703E-04	1.5389E-04	1.6323E-04	1.9447E-04	1.8415E-04	1.9214E-04	2.1829E-04	1.9214E-04	1.8415E-04
16	1.1192E-04	1.3466E-04	1.4617E-04	1.5555E-04	1.7010E-04	1.8074E-04	1.8637E-04	1.9439E-04	1.9439E-04	1.8637E-04
17	5.2147E-05	7.4182E-05	8.8001E-05	9.7624E-05	1.0641E-04	1.1450E-04	1.2043E-04	1.2473E-04	1.2667E-04	1.2473E-04
18	7.9806E-06	1.4943E-05	1.9339E-05	2.2259E-05	2.4543E-05	2.6591E-05	2.8288E-05	2.9527E-05	3.0264E-05	3.0264E-05

	11	12	13	14	15	16	17	18
1	9.7681E-05	1.0207E-04	1.1424E-04	1.5316E-04	1.5986E-04	1.1192E-04	5.2147E-05	7.9805E-06
2	7.6368E-05	9.5823E-05	1.0745E-04	1.3352E-04	1.6703E-04	1.3466E-04	7.4182E-05	1.4943E-05
3	5.3716E-05	7.2292E-05	1.0549E-04	1.2246E-04	1.5389E-04	1.4617E-04	8.8001E-05	1.9339E-05
4	1.0888E-04	8.1528E-05	1.1009E-04	1.4092E-04	1.6323E-04	1.5555E-04	9.7623E-05	2.2259E-05
5	1.7261E-04	1.2929E-04	1.2268E-04	1.5032E-04	1.9447E-04	1.7010E-04	1.0641E-04	2.4543E-05
6	1.8187E-04	1.4990E-04	1.3824E-04	1.4628E-04	1.8415E-04	1.8074E-04	1.1450E-04	2.6591E-05
7	1.7261E-04	1.4990E-04	1.4560E-04	1.6819E-04	1.9214E-04	1.8637E-04	1.2043E-04	2.8288E-05
8	1.0888E-04	1.2929E-04	1.3824E-04	1.6819E-04	2.1829E-04	1.9439E-04	1.2473E-04	2.9527E-05
9	5.3716E-05	8.1528E-05	1.2268E-04	1.4628E-04	1.9214E-04	1.9439E-04	1.2667E-04	3.0264E-05
10	7.6368E-05	7.2292E-05	1.1009E-04	1.5032E-04	1.8415E-04	1.8637E-04	1.2473E-04	3.0264E-05
11	9.7680E-05	9.5823E-05	1.0549E-04	1.4092E-04	1.9447E-04	1.8074E-04	1.2043E-04	2.9527E-05
12	9.5823E-05	1.0207E-04	1.0745E-04	1.2246E-04	1.6323E-04	1.7010E-04	1.1450E-04	2.8288E-05
13	1.0549E-04	1.0745E-04	1.1424E-04	1.3352E-04	1.5389E-04	1.5555E-04	1.0641E-04	2.6591E-05
14	1.4092E-04	1.2246E-04	1.3352E-04	1.5316E-04	1.6703E-04	1.4617E-04	9.7623E-05	2.4543E-05
15	1.9447E-04	1.6323E-04	1.5389E-04	1.6703E-04	1.5986E-04	1.3466E-04	8.8001E-05	2.2259E-05
16	1.8074E-04	1.7010E-04	1.5555E-04	1.4617E-04	1.3466E-04	1.1192E-04	7.4181E-05	1.9339E-05
17	1.2043E-04	1.1450E-04	1.0641E-04	9.7623E-05	8.8001E-05	7.4181E-05	5.2147E-05	1.4943E-05
18	2.9527E-05	2.8288E-05	2.6591E-05	2.4543E-05	2.2259E-05	1.9339E-05	1.4943E-05	7.9805E-06

SOURCES

	1	2	3	4	5	6	7	8	9	10
1	2.7234E-04	2.6994E-04	2.6288E-04	2.5161E-04	2.3704E-04	2.1957E-04	1.9847E-04	1.7315E-04	1.6364E-04	1.6636E-04
2	2.6994E-04	2.6994E-04	2.6520E-04	2.5592E-04	2.4279E-04	2.2719E-04	2.0858E-04	1.8535E-04	1.5720E-04	9.9177E-05
3	2.6288E-04	2.6520E-04	2.6288E-04	2.5592E-04	2.4451E-04	1.5302E-04	1.4400E-04	1.9524E-04	1.6934E-04	9.0061E-05
4	2.5161E-04	2.5592E-04	2.5592E-04	2.5161E-04	2.4279E-04	1.5302E-04	0.0	1.3581E-04	1.7954E-04	1.5336E-04
5	2.3704E-04	2.4279E-04	2.4451E-04	2.4279E-04	2.3704E-04	2.2719E-04	1.4400E-04	1.3581E-04	1.8348E-04	1.8386E-04
6	2.1957E-04	2.2719E-04	1.5302E-04	1.5302E-04	2.2719E-04	2.1957E-04	2.0858E-04	1.9524E-04	1.7954E-04	1.8386E-04
7	1.9847E-04	2.0858E-04	1.4400E-04	0.0	1.4400E-04	2.0858E-04	1.9847E-04	1.8535E-04	1.6934E-04	1.5336E-04
8	1.7315E-04	1.8535E-04	1.9524E-04	1.3581E-04	1.3581E-04	1.9524E-04	1.8535E-04	1.7315E-04	1.5720E-04	9.0061E-05
9	1.6364E-04	1.5720E-04	1.6934E-04	1.7954E-04	1.8348E-04	1.7954E-04	1.6934E-04	1.5720E-04	1.6364E-04	9.9177E-05
10	1.6636E-04	9.9177E-05	9.0061E-05	1.5336E-04	1.8386E-04	1.8386E-04	1.5336E-04	9.0061E-05	9.9177E-05	1.6636E-04
11	1.4304E-04	9.6206E-05	0.0	9.7483E-05	1.7655E-04	2.0182E-04	1.7655E-04	9.7483E-05	0.0	9.6206E-05
12	1.2406E-04	1.3127E-04	8.6943E-05	9.4266E-05	1.6400E-04	1.7539E-04	1.7539E-04	1.6400E-04	9.4266E-05	8.6943E-05
13	1.0203E-04	1.1212E-04	1.1904E-04	1.2660E-04	1.3765E-04	1.4778E-04	1.5163E-04	1.4778E-04	1.3765E-04	1.2660E-04
14	3.1916E-05	6.3529E-05	9.7212E-05	7.4968E-05	8.0786E-05	1.1970E-04	8.9121E-05	8.9121E-05	1.1970E-04	8.0786E-05
15	4.2684E-06	5.8920E-06	2.9541E-05	3.2335E-05	8.7299E-06	3.7422E-05	3.8964E-05	9.9263E-06	3.8964E-05	3.7422E-05
16	2.0186E-06	2.8502E-06	3.7590E-06	4.4863E-06	4.8463E-06	5.2416E-06	5.6456E-06	5.6755E-06	5.6755E-06	5.6456E-06
17	8.5461E-07	1.2736E-06	1.7075E-06	2.1065E-06	2.3975E-06	2.6108E-06	2.8000E-06	2.9098E-06	2.9317E-06	2.9098E-06
18	2.5644E-07	4.1606E-07	5.8387E-07	7.4886E-07	8.8693E-07	9.8927E-07	1.0697E-06	1.1285E-06	1.1551E-06	1.1551E-06

	11	12	13	14	15	16	17	18
1	1.4304E-04	1.2406E-04	1.0203E-04	3.1916E-05	4.2684E-06	2.0186E-06	8.5461E-07	2.5644E-07
2	9.6206E-05	1.3127E-04	1.1212E-04	6.3529E-05	5.8920E-06	2.8502E-06	1.2736E-06	4.1606E-07
3	0.0	8.6943E-05	1.1903E-04	9.7212E-05	2.9541E-05	3.7590E-06	1.7075E-06	5.8387E-07
4	9.7483E-05	9.4266E-05	1.2660E-04	7.4968E-05	3.2335E-05	4.4863E-06	2.1065E-06	7.4886E-07
5	1.7655E-04	1.6400E-04	1.3765E-04	8.0786E-05	8.7299E-06	4.8463E-06	2.3975E-06	8.8693E-07
6	2.0182E-04	1.7539E-04	1.4778E-04	1.1970E-04	3.7421E-05	5.2416E-06	2.6108E-06	9.8926E-07
7	1.7655E-04	1.7539E-04	1.5163E-04	8.9121E-05	3.8964E-05	5.6456E-06	2.8000E-06	1.0697E-06
8	9.7483E-05	1.6400E-04	1.4778E-04	8.9121E-05	9.9263E-06	5.6755E-06	2.9098E-06	1.1285E-06
9	0.0	9.4266E-05	1.3765E-04	1.1970E-04	3.8964E-05	5.6755E-06	2.9317E-06	1.1551E-06
10	9.6206E-05	8.6943E-05	1.2660E-04	8.0786E-05	3.7422E-05	5.6456E-06	2.9098E-06	1.1551E-06
11	1.4304E-04	1.3127E-04	1.1904E-04	7.4968E-05	8.7299E-06	5.2416E-06	2.8000E-06	1.1285E-06
12	1.3127E-04	1.2406E-04	1.1212E-04	9.7212E-05	3.2335E-05	4.8463E-06	2.6108E-06	1.0697E-06
13	1.1904E-04	1.1212E-04	1.0203E-04	6.3529E-05	2.9541E-05	4.4863E-06	2.3975E-06	9.8926E-07
14	7.4968E-05	9.7212E-05	6.3529E-05	3.1916E-05	5.8920E-06	3.7590E-06	2.1065E-06	8.8693E-07
15	8.7299E-06	3.2335E-05	2.9541E-05	5.8920E-06	4.2684E-06	2.8502E-06	1.7075E-06	7.4886E-07
16	5.2416E-06	4.8463E-06	4.4863E-06	3.7590E-06	2.8502E-06	2.0186E-06	1.2736E-06	5.8387E-07
17	2.8000E-06	2.6108E-06	2.3975E-06	2.1065E-06	1.7075E-06	1.2736E-06	8.5461E-07	4.1606E-07
18	1.1285E-06	1.0697E-06	9.8926E-07	8.8693E-07	7.4886E-07	5.8387E-07	4.1606E-07	2.5644E-07

ITERATION PROCESS (ADJOINT CALCULATIONS)

IT NR	OMEGAB	OMEGAF	K-EFF	K-EFF CONV.	GR NR	FLUX CONV IN INNER ITERS --> 1
1	1.1236	1.1236	0.675060	1.5502E+04	4	1.00E+00
					3	1.00E+00
					2	1.00E+00
					1	1.00E+00
2	1.1236	1.1236	1.019657	3.3795E-01	4	2.55E+00
					3	3.79E+00
					2	7.55E-01
					1	1.29E+00
3	1.1236	1.1236	1.087386	6.2286E-02	4	6.24E-01
					3	8.76E-01
					2	3.55E-01
					1	2.48E-01
4	1.1236	1.1236	1.088963	1.4477E-03	4	5.92E-01
					3	5.49E-01
					2	1.35E-01
					1	1.30E-01
5	1.1236	1.1236	1.094199	4.7858E-03	4	1.02E-01
					3	1.66E-01
					2	9.12E-02
					1	8.88E-02
6	1.1236	1.1236	1.104280	9.1285E-03	4	9.82E-02
					3	1.42E-01
					2	7.66E-02
					1	5.54E-02
7	1.1236	1.1236	1.112272	7.1860E-03	4	4.31E-02
					3	3.36E-02
					2	3.45E-02
					1	3.03E-02
8	1.1236	1.1236	1.116875	4.1208E-03	4	2.08E-02
					3	1.92E-02
					2	1.94E-02
					1	1.61E-02
9	1.1236	1.1236	1.119236	2.1098E-03	4	1.14E-02
					3	1.04E-02
					2	1.03E-02
					1	8.35E-03
10	1.1236	1.1236	1.120432	1.0674E-03	4	6.31E-03
					3	5.77E-03
					2	5.40E-03
					1	4.34E-03
11	1.1236	1.1236	1.121037	5.3936E-04	4	3.41E-03
					3	3.12E-03
					2	2.78E-03
					1	2.25E-03
12	1.1236	1.1236	1.121345	2.7472E-04	4	1.81E-03
					3	1.65E-03
					2	1.44E-03

					1	1.17E-03
13	1.1236	1.1236	1.121504	1.4204E-04	4	9.30E-04
					3	8.47E-04
					2	7.40E-04
					1	5.98E-04
14	1.1236	1.1236	1.121586	7.3135E-05	4	4.75E-04
					3	4.31E-04
					2	3.79E-04
					1	3.07E-04
15	1.1236	1.1236	1.121625	3.4869E-05	4	2.41E-04
					3	2.19E-04
					2	1.94E-04
					1	1.54E-04
16	1.1236	1.1236	1.121647	1.9610E-05	4	1.19E-04
					3	1.09E-04
					2	9.94E-05
					1	8.11E-05
17	1.1236	1.1236	1.121660	1.1921E-05	4	6.10E-05
					3	5.53E-05
					2	4.99E-05
					1	4.10E-05
18	1.1236	1.1236	1.121665	4.2915E-06	4	3.43E-05
					3	3.15E-05
					2	2.55E-05
					1	1.91E-05
19	1.1236	1.1236	1.121668	2.5630E-06	4	1.43E-05
					3	1.34E-05
					2	1.23E-05
					1	1.06E-05
20	1.1236	1.1236	1.121668	0.0	4	1.05E-05
					3	1.05E-05
					2	7.63E-06
					1	5.72E-06
21	1.1236	1.1236	1.121669	8.9407E-07	4	6.08E-06
					3	6.14E-06
					2	4.77E-06
					1	4.29E-06

4 ADJOINT FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	2.1172E-04	2.0980E-04	2.0407E-04	1.9486E-04	1.8301E-04	1.6896E-04	1.5128E-04	1.2703E-04	9.6336E-05	7.5501E-05
2	2.0980E-04	2.0980E-04	2.0595E-04	1.9829E-04	1.8720E-04	1.7435E-04	1.5944E-04	1.3863E-04	1.0554E-04	5.0809E-05
3	2.0407E-04	2.0595E-04	2.0407E-04	1.9829E-04	1.8816E-04	1.7334E-04	1.6259E-04	1.4750E-04	1.2019E-04	5.5559E-05
4	1.9486E-04	1.9829E-04	1.9829E-04	1.9486E-04	1.8720E-04	1.7334E-04	1.6219E-04	1.5297E-04	1.3514E-04	1.0577E-04
5	1.8301E-04	1.8720E-04	1.8816E-04	1.8720E-04	1.8301E-04	1.7435E-04	1.6259E-04	1.5297E-04	1.4030E-04	1.2651E-04
6	1.6896E-04	1.7435E-04	1.7334E-04	1.7334E-04	1.7435E-04	1.6896E-04	1.5944E-04	1.4750E-04	1.3514E-04	1.2651E-04
7	1.5128E-04	1.5944E-04	1.6259E-04	1.6220E-04	1.6259E-04	1.5944E-04	1.5128E-04	1.3863E-04	1.2019E-04	1.0577E-04
8	1.2703E-04	1.3863E-04	1.4750E-04	1.5297E-04	1.5297E-04	1.4750E-04	1.3863E-04	1.2703E-04	1.0554E-04	5.5559E-05
9	9.6337E-05	1.0554E-04	1.2019E-04	1.3514E-04	1.4030E-04	1.3514E-04	1.2019E-04	1.0554E-04	9.6337E-05	5.0810E-05
10	7.5501E-05	5.0810E-05	5.5559E-05	1.0577E-04	1.2651E-04	1.2651E-04	1.0577E-04	5.5559E-05	5.0810E-05	7.5501E-05
11	7.2455E-05	4.3395E-05	1.2346E-05	5.2685E-05	1.0669E-04	1.1891E-04	1.0669E-04	5.2685E-05	1.2346E-05	4.3395E-05
12	7.1377E-05	6.8237E-05	3.9795E-05	4.4094E-05	8.7725E-05	1.0443E-04	1.0443E-04	8.7725E-05	4.4094E-05	3.9795E-05
13	5.8140E-05	6.4491E-05	6.3939E-05	6.4284E-05	7.4897E-05	8.6506E-05	9.0102E-05	8.6506E-05	7.4896E-05	6.4284E-05
14	3.3941E-05	4.5485E-05	5.2831E-05	5.2927E-05	5.7305E-05	6.5803E-05	6.6164E-05	6.6164E-05	6.5803E-05	5.7305E-05
15	1.4539E-05	2.1047E-05	3.0017E-05	3.2890E-05	3.1067E-05	3.8405E-05	4.0478E-05	3.6319E-05	4.0478E-05	3.8405E-05
16	6.1063E-06	9.1005E-06	1.2531E-05	1.5178E-05	1.6127E-05	1.7481E-05	1.9173E-05	1.9183E-05	1.9183E-05	1.9173E-05
17	2.1618E-06	3.4930E-06	4.8925E-06	6.1780E-06	7.0329E-06	7.6272E-06	8.2438E-06	8.6110E-06	8.6658E-06	8.6110E-06
18	3.2603E-07	6.4558E-07	9.5556E-07	1.2570E-06	1.4988E-06	1.6660E-06	1.8036E-06	1.9132E-06	1.9619E-06	1.9619E-06

	11	12	13	14	15	16	17	18
1	7.2454E-05	7.1377E-05	5.8140E-05	3.3941E-05	1.4539E-05	6.1063E-06	2.1618E-06	3.2603E-07
2	4.3395E-05	6.8237E-05	6.4491E-05	4.5485E-05	2.1047E-05	9.1005E-06	3.4930E-06	6.4558E-07
3	1.2346E-05	3.9795E-05	6.3939E-05	5.2831E-05	3.0017E-05	1.2531E-05	4.8925E-06	9.5555E-07
4	5.2685E-05	4.4094E-05	6.4284E-05	5.2926E-05	3.2890E-05	1.5178E-05	6.1780E-06	1.2570E-06
5	1.0669E-04	8.7725E-05	7.4896E-05	5.7305E-05	3.1067E-05	1.6127E-05	7.0329E-06	1.4988E-06
6	1.1891E-04	1.0443E-04	8.6506E-05	6.5803E-05	3.8405E-05	1.7481E-05	7.6271E-06	1.6660E-06
7	1.0669E-04	1.0443E-04	9.0102E-05	6.6163E-05	4.0478E-05	1.9173E-05	8.2438E-06	1.8036E-06
8	5.2685E-05	8.7725E-05	8.6506E-05	6.6163E-05	3.6319E-05	1.9183E-05	8.6110E-06	1.9132E-06
9	1.2346E-05	4.4094E-05	7.4896E-05	6.5803E-05	4.0478E-05	1.9183E-05	8.6657E-06	1.9619E-06
10	4.3395E-05	3.9795E-05	6.4284E-05	5.7305E-05	3.8405E-05	1.9173E-05	8.6110E-06	1.9619E-06
11	7.2454E-05	6.8236E-05	6.3939E-05	5.2926E-05	3.1067E-05	1.7481E-05	8.2438E-06	1.9132E-06
12	6.8236E-05	7.1377E-05	6.4491E-05	5.2831E-05	3.2890E-05	1.6127E-05	7.6271E-06	1.8036E-06
13	6.3939E-05	6.4491E-05	5.8140E-05	4.5485E-05	3.0017E-05	1.5178E-05	7.0329E-06	1.6660E-06
14	5.2926E-05	5.2831E-05	4.5485E-05	3.3941E-05	2.1047E-05	1.2531E-05	6.1780E-06	1.4988E-06
15	3.1067E-05	3.2890E-05	3.0017E-05	2.1047E-05	1.4539E-05	9.1004E-06	4.8925E-06	1.2570E-06
16	1.7481E-05	1.6127E-05	1.5178E-05	1.2531E-05	9.1004E-06	6.1062E-06	3.4930E-06	9.5555E-07
17	8.2438E-06	7.6271E-06	7.0329E-06	6.1780E-06	4.8925E-06	3.4930E-06	2.1618E-06	6.4558E-07
18	1.9132E-06	1.8036E-06	1.6660E-06	1.4988E-06	1.2570E-06	9.5555E-07	6.4558E-07	3.2603E-07

3 ADJOINT FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	1.7942E-04	1.7778E-04	1.7291E-04	1.6506E-04	1.5485E-04	1.4261E-04	1.2718E-04	1.0653E-04	8.1623E-05	6.4420E-05
2	1.7778E-04	1.7778E-04	1.7450E-04	1.6800E-04	1.5858E-04	1.4743E-04	1.3432E-04	1.1645E-04	8.9876E-05	5.1379E-05
3	1.7291E-04	1.7450E-04	1.7291E-04	1.6800E-04	1.5951E-04	1.4736E-04	1.3720E-04	1.2401E-04	1.0180E-04	5.6815E-05
4	1.6506E-04	1.6800E-04	1.6800E-04	1.6506E-04	1.5858E-04	1.4736E-04	1.3687E-04	1.2819E-04	1.1361E-04	9.0464E-05
5	1.5485E-04	1.5858E-04	1.5951E-04	1.5858E-04	1.5485E-04	1.4743E-04	1.3720E-04	1.2819E-04	1.1782E-04	1.0630E-04
6	1.4261E-04	1.4743E-04	1.4736E-04	1.4736E-04	1.4743E-04	1.4261E-04	1.3432E-04	1.2401E-04	1.1361E-04	1.0630E-04
7	1.2718E-04	1.3432E-04	1.3720E-04	1.3687E-04	1.3720E-04	1.3432E-04	1.2718E-04	1.1645E-04	1.0180E-04	9.0464E-05
8	1.0653E-04	1.1645E-04	1.2401E-04	1.2819E-04	1.2819E-04	1.2401E-04	1.1645E-04	1.0653E-04	8.9876E-05	5.6815E-05
9	8.1623E-05	8.9876E-05	1.0180E-04	1.1361E-04	1.1782E-04	1.1361E-04	1.0180E-04	8.9876E-05	8.1623E-05	5.1379E-05
10	6.4420E-05	5.1380E-05	5.6816E-05	9.0464E-05	1.0630E-04	1.0630E-04	9.0464E-05	5.6815E-05	5.1379E-05	6.4420E-05
11	6.0796E-05	4.3487E-05	2.1713E-05	5.3534E-05	9.0238E-05	9.9819E-05	9.0238E-05	5.3534E-05	2.1713E-05	4.3487E-05
12	5.8990E-05	5.7251E-05	3.9971E-05	4.4419E-05	7.4429E-05	8.7615E-05	8.7615E-05	7.4429E-05	4.4419E-05	3.9970E-05
13	4.7707E-05	5.3113E-05	5.3091E-05	5.3901E-05	6.2616E-05	7.2122E-05	7.5205E-05	7.2122E-05	6.2615E-05	5.3900E-05
14	2.7655E-05	3.7011E-05	4.3088E-05	4.3242E-05	4.6945E-05	5.4112E-05	5.4572E-05	5.4572E-05	5.4112E-05	4.6945E-05
15	1.2168E-05	1.7466E-05	2.4331E-05	2.6718E-05	2.5807E-05	3.1333E-05	3.3135E-05	3.0357E-05	3.3135E-05	3.1333E-05
16	5.1548E-06	7.6596E-06	1.0449E-05	1.2601E-05	1.3475E-05	1.4628E-05	1.6007E-05	1.6112E-05	1.6112E-05	1.6007E-05
17	1.7873E-06	2.9151E-06	4.0742E-06	5.1295E-06	5.8446E-06	6.3535E-06	6.8709E-06	7.1883E-06	7.2462E-06	7.1883E-06
18	2.1380E-07	4.4450E-07	6.6039E-07	8.6761E-07	1.0341E-06	1.1509E-06	1.2477E-06	1.3252E-06	1.3608E-06	1.3608E-06

	11	12	13	14	15	16	17	18
1	6.0796E-05	5.8990E-05	4.7707E-05	2.7655E-05	1.2168E-05	5.1548E-06	1.7873E-06	2.1380E-07
2	4.3487E-05	5.7251E-05	5.3112E-05	3.7011E-05	1.7466E-05	7.6596E-06	2.9151E-06	4.4450E-07
3	2.1713E-05	3.9970E-05	5.3091E-05	4.3088E-05	2.4331E-05	1.0449E-05	4.0742E-06	6.6039E-07
4	5.3534E-05	4.4419E-05	5.3900E-05	4.3242E-05	2.6718E-05	1.2601E-05	5.1295E-06	8.6761E-07
5	9.0238E-05	7.4429E-05	6.2615E-05	4.6945E-05	2.5807E-05	1.3475E-05	5.8445E-06	1.0341E-06
6	9.9818E-05	8.7615E-05	7.2122E-05	5.4112E-05	3.1333E-05	1.4628E-05	6.3535E-06	1.1509E-06
7	9.0238E-05	8.7615E-05	7.5205E-05	5.4572E-05	3.3134E-05	1.6007E-05	6.8709E-06	1.2477E-06
8	5.3534E-05	7.4429E-05	7.2122E-05	5.4572E-05	3.0357E-05	1.6112E-05	7.1883E-06	1.3252E-06
9	2.1713E-05	4.4419E-05	6.2615E-05	5.4112E-05	3.3134E-05	1.6112E-05	7.2461E-06	1.3608E-06
10	4.3487E-05	3.9970E-05	5.3900E-05	4.6945E-05	3.1333E-05	1.6007E-05	7.1883E-06	1.3608E-06
11	6.0796E-05	5.7250E-05	5.3091E-05	4.3242E-05	2.5807E-05	1.4628E-05	6.8709E-06	1.3252E-06
12	5.7250E-05	5.8990E-05	5.3112E-05	4.3088E-05	2.6718E-05	1.3475E-05	6.3535E-06	1.2477E-06
13	5.3091E-05	5.3112E-05	4.7707E-05	3.7011E-05	2.4331E-05	1.2601E-05	5.8445E-06	1.1509E-06
14	4.3242E-05	4.3088E-05	3.7011E-05	2.7655E-05	1.7466E-05	1.0449E-05	5.1295E-06	1.0341E-06
15	2.5807E-05	2.6718E-05	2.4331E-05	1.7466E-05	1.2168E-05	7.6596E-06	4.0742E-06	8.6761E-07
16	1.4628E-05	1.3475E-05	1.2601E-05	1.0449E-05	7.6596E-06	5.1548E-06	2.9151E-06	6.6039E-07
17	6.8709E-06	6.3535E-06	5.8445E-06	5.1295E-06	4.0742E-06	2.9151E-06	1.7873E-06	4.4450E-07
18	1.3252E-06	1.2477E-06	1.1509E-06	1.0341E-06	8.6761E-07	6.6039E-07	4.4450E-07	2.1380E-07

2 ADJOINT FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	2.1831E-04	2.1632E-04	2.1043E-04	2.0100E-04	1.8894E-04	1.7493E-04	1.5836E-04	1.3857E-04	1.1682E-04	9.7847E-05
2	2.1632E-04	2.1632E-04	2.1236E-04	2.0452E-04	1.9328E-04	1.8039E-04	1.6591E-04	1.4801E-04	1.2619E-04	1.0142E-04
3	2.1043E-04	2.1236E-04	2.1043E-04	2.0452E-04	1.9435E-04	1.7990E-04	1.6946E-04	1.5515E-04	1.3556E-04	1.0965E-04
4	2.0100E-04	2.0452E-04	2.0452E-04	2.0100E-04	1.9328E-04	1.7990E-04	1.6956E-04	1.6010E-04	1.4329E-04	1.2349E-04
5	1.8894E-04	1.9328E-04	1.9435E-04	1.9328E-04	1.8894E-04	1.8039E-04	1.6946E-04	1.6010E-04	1.4623E-04	1.3124E-04
6	1.7493E-04	1.8039E-04	1.7990E-04	1.7990E-04	1.8039E-04	1.7493E-04	1.6591E-04	1.5515E-04	1.4329E-04	1.3124E-04
7	1.5836E-04	1.6591E-04	1.6946E-04	1.6956E-04	1.6946E-04	1.6591E-04	1.5836E-04	1.4801E-04	1.3556E-04	1.2349E-04
8	1.3857E-04	1.4801E-04	1.5515E-04	1.6010E-04	1.6010E-04	1.5515E-04	1.4801E-04	1.3857E-04	1.2619E-04	1.0965E-04
9	1.1682E-04	1.2619E-04	1.3556E-04	1.4329E-04	1.4623E-04	1.4329E-04	1.3556E-04	1.2619E-04	1.1682E-04	1.0142E-04
10	9.7847E-05	1.0142E-04	1.0965E-04	1.2349E-04	1.3125E-04	1.3125E-04	1.2349E-04	1.0965E-04	1.0142E-04	9.7847E-05
11	8.4497E-05	8.5226E-05	8.2663E-05	1.0005E-04	1.1422E-04	1.1875E-04	1.1422E-04	1.0005E-04	8.2662E-05	8.5226E-05
12	7.3007E-05	7.7402E-05	7.6948E-05	8.3502E-05	9.6733E-05	1.0356E-04	1.0355E-04	9.6733E-05	8.3502E-05	7.6948E-05
13	5.8754E-05	6.5333E-05	6.9470E-05	7.3837E-05	8.0503E-05	8.6567E-05	8.8796E-05	8.6567E-05	8.0502E-05	7.3837E-05
14	4.1670E-05	4.9878E-05	5.5190E-05	5.9247E-05	6.3990E-05	6.8307E-05	7.0815E-05	7.0815E-05	6.8307E-05	6.3990E-05
15	2.4321E-05	3.1043E-05	3.8288E-05	4.1926E-05	4.3446E-05	4.8710E-05	5.0755E-05	4.9280E-05	5.0755E-05	4.8710E-05
16	1.2996E-05	1.7436E-05	2.1650E-05	2.5003E-05	2.7143E-05	2.9236E-05	3.1104E-05	3.1621E-05	3.1621E-05	3.1104E-05
17	5.5535E-06	8.2334E-06	1.0608E-05	1.2647E-05	1.4203E-05	1.5415E-05	1.6441E-05	1.7076E-05	1.7252E-05	1.7076E-05
18	1.1589E-06	2.0706E-06	2.8375E-06	3.5029E-06	4.0463E-06	4.4675E-06	4.8052E-06	5.0535E-06	5.1762E-06	5.1762E-06

	11	12	13	14	15	16	17	18
1	8.4496E-05	7.3007E-05	5.8753E-05	4.1669E-05	2.4321E-05	1.2996E-05	5.5535E-06	1.1589E-06
2	8.5226E-05	7.7402E-05	6.5333E-05	4.9878E-05	3.1043E-05	1.7436E-05	8.2334E-06	2.0706E-06
3	8.2662E-05	7.6948E-05	6.9469E-05	5.5189E-05	3.8288E-05	2.1650E-05	1.0608E-05	2.8375E-06
4	1.0005E-04	8.3502E-05	7.3837E-05	5.9247E-05	4.1926E-05	2.5003E-05	1.2647E-05	3.5029E-06
5	1.1422E-04	9.6733E-05	8.0502E-05	6.3990E-05	4.3446E-05	2.7143E-05	1.4203E-05	4.0463E-06
6	1.1875E-04	1.0355E-04	8.6567E-05	6.8306E-05	4.8709E-05	2.9236E-05	1.5415E-05	4.4675E-06
7	1.1422E-04	1.0355E-04	8.8796E-05	7.0814E-05	5.0755E-05	3.1104E-05	1.6441E-05	4.8052E-06
8	1.0005E-04	9.6733E-05	8.6567E-05	7.0814E-05	4.9280E-05	3.1621E-05	1.7076E-05	5.0535E-06
9	8.2662E-05	8.3502E-05	8.0502E-05	6.8306E-05	5.0755E-05	3.1621E-05	1.7252E-05	5.1762E-06
10	8.5226E-05	7.6948E-05	7.3837E-05	6.3990E-05	4.8709E-05	3.1104E-05	1.7076E-05	5.1762E-06
11	8.4496E-05	7.7402E-05	6.9469E-05	5.9247E-05	4.3446E-05	2.9236E-05	1.6441E-05	5.0535E-06
12	7.7402E-05	7.3007E-05	6.5333E-05	5.5189E-05	4.1926E-05	2.7143E-05	1.5415E-05	4.8052E-06
13	6.9469E-05	6.5333E-05	5.8753E-05	4.9878E-05	3.8288E-05	2.5003E-05	1.4203E-05	4.4675E-06
14	5.9247E-05	5.5189E-05	4.9878E-05	4.1669E-05	3.1043E-05	2.1650E-05	1.2647E-05	4.0462E-06
15	4.3446E-05	4.1926E-05	3.8288E-05	3.1043E-05	2.4321E-05	1.7436E-05	1.0608E-05	3.5029E-06
16	2.9236E-05	2.7143E-05	2.5003E-05	2.1650E-05	1.7436E-05	1.2996E-05	8.2333E-06	2.8375E-06
17	1.6441E-05	1.5415E-05	1.4203E-05	1.2647E-05	1.0608E-05	8.2333E-06	5.5535E-06	2.0706E-06
18	5.0535E-06	4.8052E-06	4.4675E-06	4.0463E-06	3.5029E-06	2.8375E-06	2.0706E-06	1.1589E-06

1 ADJOINT FLUX GROUP

	1	2	3	4	5	6	7	8	9	10
1	2.5228E-04	2.5001E-04	2.4329E-04	2.3256E-04	2.1893E-04	2.0339E-04	1.8566E-04	1.6532E-04	1.4357E-04	1.2300E-04
2	2.5001E-04	2.5001E-04	2.4549E-04	2.3656E-04	2.2380E-04	2.0925E-04	1.9344E-04	1.7482E-04	1.5334E-04	1.3053E-04
3	2.4329E-04	2.4549E-04	2.4329E-04	2.3656E-04	2.2499E-04	2.0864E-04	1.9638E-04	1.8153E-04	1.6203E-04	1.3921E-04
4	2.3256E-04	2.3656E-04	2.3656E-04	2.3256E-04	2.2380E-04	2.0864E-04	1.9592E-04	1.8535E-04	1.6846E-04	1.4875E-04
5	2.1893E-04	2.2380E-04	2.2499E-04	2.2380E-04	2.1893E-04	2.0925E-04	1.9638E-04	1.8535E-04	1.7084E-04	1.5455E-04
6	2.0339E-04	2.0925E-04	2.0864E-04	2.0864E-04	2.0925E-04	2.0339E-04	1.9344E-04	1.8153E-04	1.6846E-04	1.5455E-04
7	1.8566E-04	1.9344E-04	1.9638E-04	1.9592E-04	1.9638E-04	1.9344E-04	1.8566E-04	1.7482E-04	1.6203E-04	1.4875E-04
8	1.6532E-04	1.7482E-04	1.8153E-04	1.8535E-04	1.8535E-04	1.8153E-04	1.7482E-04	1.6532E-04	1.5334E-04	1.3921E-04
9	1.4357E-04	1.5334E-04	1.6203E-04	1.6846E-04	1.7084E-04	1.6846E-04	1.6203E-04	1.5334E-04	1.4357E-04	1.3053E-04
10	1.2300E-04	1.3053E-04	1.3921E-04	1.4875E-04	1.5455E-04	1.5455E-04	1.4875E-04	1.3921E-04	1.3053E-04	1.2300E-04
11	1.0513E-04	1.1087E-04	1.1509E-04	1.2692E-04	1.3623E-04	1.3957E-04	1.3623E-04	1.2692E-04	1.1509E-04	1.1087E-04
12	8.8585E-05	9.5724E-05	9.9867E-05	1.0716E-04	1.1680E-04	1.2202E-04	1.2202E-04	1.1680E-04	1.0716E-04	9.9866E-05
13	7.0838E-05	7.8981E-05	8.5152E-05	9.0999E-05	9.7450E-05	1.0269E-04	1.0464E-04	1.0269E-04	9.7450E-05	9.0998E-05
14	5.1742E-05	6.0815E-05	6.7174E-05	7.2684E-05	7.8050E-05	8.2150E-05	8.4859E-05	8.4859E-05	8.2150E-05	7.8049E-05
15	3.2359E-05	4.0213E-05	4.8103E-05	5.2764E-05	5.5550E-05	6.0777E-05	6.3050E-05	6.2199E-05	6.3049E-05	6.0777E-05
16	1.8522E-05	2.4106E-05	2.9295E-05	3.3509E-05	3.6472E-05	3.9139E-05	4.1322E-05	4.2084E-05	4.2083E-05	4.1321E-05
17	8.9743E-06	1.2582E-05	1.5834E-05	1.8644E-05	2.0862E-05	2.2610E-05	2.4016E-05	2.4886E-05	2.5146E-05	2.4886E-05
18	3.0743E-06	4.7521E-06	6.2772E-06	7.6215E-06	8.7390E-06	9.6252E-06	1.0325E-05	1.0826E-05	1.1077E-05	1.1077E-05

	11	12	13	14	15	16	17	18
1	1.0513E-04	8.8584E-05	7.0838E-05	5.1742E-05	3.2359E-05	1.8522E-05	8.9742E-06	3.0742E-06
2	1.1087E-04	9.5724E-05	7.8981E-05	6.0815E-05	4.0212E-05	2.4106E-05	1.2582E-05	4.7521E-06
3	1.1509E-04	9.9866E-05	8.5151E-05	6.7174E-05	4.8103E-05	2.9295E-05	1.5834E-05	6.2772E-06
4	1.2692E-04	1.0716E-04	9.0998E-05	7.2684E-05	5.2763E-05	3.3509E-05	1.8644E-05	7.6214E-06
5	1.3623E-04	1.1680E-04	9.7450E-05	7.8049E-05	5.5550E-05	3.6472E-05	2.0862E-05	8.7390E-06
6	1.3957E-04	1.2202E-04	1.0269E-04	8.2150E-05	6.0777E-05	3.9139E-05	2.2610E-05	9.6252E-06
7	1.3623E-04	1.2202E-04	1.0464E-04	8.4859E-05	6.3049E-05	4.1321E-05	2.4016E-05	1.0325E-05
8	1.2692E-04	1.1680E-04	1.0269E-04	8.4859E-05	6.2199E-05	4.2083E-05	2.4885E-05	1.0826E-05
9	1.1509E-04	1.0716E-04	9.7450E-05	8.2150E-05	6.3049E-05	4.2083E-05	2.5146E-05	1.1077E-05
10	1.1087E-04	9.9866E-05	9.0998E-05	7.8049E-05	6.0777E-05	4.1321E-05	2.4885E-05	1.1077E-05
11	1.0513E-04	9.5724E-05	8.5151E-05	7.2684E-05	5.5550E-05	3.9139E-05	2.4016E-05	1.0826E-05
12	9.5724E-05	8.8584E-05	7.8981E-05	6.7174E-05	5.2763E-05	3.6472E-05	2.2610E-05	1.0325E-05
13	8.5151E-05	7.8981E-05	7.0838E-05	6.0814E-05	4.8103E-05	3.3509E-05	2.0862E-05	9.6252E-06
14	7.2684E-05	6.7174E-05	6.0814E-05	5.1742E-05	4.0212E-05	2.9295E-05	1.8644E-05	8.7390E-06
15	5.5550E-05	5.2763E-05	4.8103E-05	4.0212E-05	3.2359E-05	2.4106E-05	1.5834E-05	7.6214E-06
16	3.9139E-05	3.6472E-05	3.3509E-05	2.9295E-05	2.4106E-05	1.8522E-05	1.2581E-05	6.2772E-06
17	2.4016E-05	2.2610E-05	2.0862E-05	1.8644E-05	1.5834E-05	1.2581E-05	8.9742E-06	4.7521E-06
18	1.0826E-05	1.0325E-05	9.6252E-06	8.7390E-06	7.6214E-06	6.2772E-06	4.7521E-06	3.0742E-06

Sample Problem B2

Only flux calculations without the printing of fluxes and sources. The following strategy is assumed in the iteration process: five inner iterations, in the first outer iteration, four inner iterations in the second outer iteration, three inner iterations in the third outer iteration, and two inner iterations in the next outer iteration. In the case of using IBM/370-168 computer the following data were obtained:

CPU time: 58.72 sec
Total costs: 41.53 DM

DATENKARTEN

Programm HEXAGA-II SAMPLE PROBLEM B2 Datum ______ Name ____________ Blatt-Nr. ______

```
//......   JØB CARD..........
// REGIØN=300K,TIME=1
/*FØRMAT PR,DDNAME=FT06F001,ØVFL=ØN
// EXEC FGG,LIB=NUSYS,NAME=HEXAGA
//SYSIN DD *
//G.FT12F001 DD UNIT=SYSDA,SPACE=(7294,17),DCB=(BLKSIZE=7294,RECFM=VBS)
//G.FT13F001 DD UNIT=SYSDA,SPACE=(7294,10),DCB=*.FT12F001
//G.FT14F001 DD UNIT=SYSDA,SPACE=(7294,6),DCB=*.FT12F001
//G.FT15F001 DD UNIT=SYSDA,SPACE=(7294,6),DCB=*.FT12F001
//G.FT16F001 DD UNIT=SYSDA,SPACE=(7294,5),DCB=*.FT12F001
//G.FT17F001 DD UNIT=SYSDA,SPACE=(7294,5),DCB=*.FT12F001
//G.FT18F001 DD UNIT=SYSDA,SPACE=(7294,1),DCB=*.FT12F001
//G.FT20F001 DD UNIT=SYSDA,SPACE=(7294,1),DCB=*.FT12F001
//G.SYSIN DD *
```

DATENKARTEN

Programm HEXAGA-II SAMPLE PROBLEM B2 Datum ______ Name ____________ Blatt-Nr. 1

INPUT DATA

```
1/
          SAMPLE PROBLEM B2
2/
  2  35  35  4  3  1  5  3  0  5  21  1  1  2  2  0  3.23325
3/11/
  1  1  1  1  1  9  2  2  2  3  3  3
  1  1  1  1  1  1  2  2  2  3  3  3
  1  1  1  1  1  1  17  2  20  3  3
  1  1  1  1  1  1  4  2  2  3  3  3
  1  1  1  1  6  1  11  4  2  2  3  3
  1  1  1  5  1  1  4  2  2  3  3
  1  1  1  8  5  1  1  16  2  21  3  3
  1  1  1  1  5  1  1  2  2  3  3  3
  1  1  1  1  7  1  12  2  20  3  3
  1  1  1  1  1  1  2  2  2  3  3  3
  1  1  6  1  1  1  9  2  2  2  3  3
```

DATENKARTEN

Programm ______ Datum ______ Name ______ Blatt-Nr. 2

1	5	1	1	1	1	2	2	2	3	3	
1	6	5	1	1	1	1	2	2	21	3	3
1	1	5	1	1	1	1	2	2	3	3	3
1	1	7	1	1	1	13	2	20	3	3	
1	1	1	1	1	1	4	2	2	3	3	3
10	1	1	1	1	1	14	4	2	2	3	3
1	1	1	1	1	2	4	2	2	3	3	
2	15	1	10	1	13	2	16	2	21	3	3
2	4	1	2	1	4	2	2	2	3	3	3
18	4	12	2	14	4	2	2	20	3	3	
2	4	2	2	2	4	2	2	2	3	3	3
2	2	16	2	2	2	16	2	2	2	3	3
2	2	2	2	2	2	2	2	2	3	3	
2	2	2	2	2	2	2	2	2	21	3	3
2	2	2	2	2	2	2	2	2	3	3	3
19	2	19	2	19	2	19	2	21	3	3	

DATENKARTEN

Programm ________ Datum ________ Name ________ Blatt-Nr. 3

3	2	3	2	3	2	3	2	3	3	3	3
3	3	21	3	21	3	21	3	21	3	3	3
3	3	3	3	3	3	3	3	3	3	3	
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	
3	3	3	3	3	3	3	3	3	3	3	3
3	3	3	3	3	3	3	3	3	3	3	3
3/1'/1/											
1	1	5	5	1	1	6					
1	1	1	1	5	5	7					
5	5	1	1	1	1	8					
2	2	1	1	1	1	9					
1	1	2	2	1	1	10					
4	4	1	1	1	1	11					
2	2	2	2	1	1	12					

DATENKARTEN

Programm ______ Datum ______ Name ______ Blatt-Nr. 4

```
         10        20        30        40        50        60        70        80
  2  2  4  4  1  1  13
  4  4  2  2  1  1  14
  1  1  4  4  1  1  15
  2  2  2  2  4  4  16
  2  2  4  4  2  2  17
  4  4  2  2  2  2  18
  2  2  3  3  2  2  19
  3  3  2  2  2  2  20
  3  3  3  3  2  2  21
4/
          THE SAME DATA AS IN SAMPLE PROBLEM 1
5/
          THE SAME DATA AS IN SAMPLE PROBLEM 1
6/
  0.100  5  2  1.0000  1.0000  1.0E-05  1.0E-06  2  2
```

H E X A G A - II WRITTEN BY ZBIGNIEW WOZNICKI, FEB. 1975

SAMPLE PROBLEM B2

2 TYPE OF HEXAGONAL MESH ARRANGEMENT

1225 MESH POINTS

4 NEUTRON GR.

1 THERMAL GR.

3 NEUTRON GR. THROUGHOUT WHICH NEUTRONS ARE DOWN-SCATTERED

5 MATERIAL COMP.

3 FISSIONABLE COMP.

3.2332 CM - MESH STEP

```
OUTER BOUNDARY COND:  LEFT   - FLUX DERIVATIVE EQUAL TO ZERO
                      TOP    - FLUX DERIVATIVE EQUAL TO ZERO
                      RIGHT  - LOGARITHMIC
                      BOTTOM - LOGARITHMIC
```

THE LOCATION OF HEXAGONS

```
                1   3   5   7   9  11  13  15  17  19  21  23  25  27  29  31  33  35
                / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / / /

           1-  * 1 * * 1 * * 1 * * 1 * * 1 * * 9 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3
            -  1 * * 1 * * 1 * * 1 * * 1 * * 1 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3 *
          3-  * * 1 * * 1 * * 1 * * 1 * * 1 * * 1 * *17 * * 2 * *20 * * 3 * * 3 * *
          -  * 1 * * 1 * * 1 * * 1 * * 1 * * 1 * * 4 * * 2 * * 2 * * 3 * * 3 * * 3
        5-  1 * * 1 * * 1 * * 1 * * 6 * * 1 * *11 * * 4 * * 2 * * 2 * * 3 * * 3 *
        -  * * 1 * * 1 * * 1 * * 5 * * 1 * * 1 * * 4 * * 2 * * 2 * * 3 * * 3 * *
      7-  * 1 * * 1 * * 1 * * 8 * * 5 * * 1 * * 1 * *16 * * 2 * *21 * * 3 * * 3
      -  1 * * 1 * * 1 * * 1 * * 5 * * 1 * * 1 * * 2 * * 2 * * 3 * * 3 * * 3 *
    9-  * * 1 * * 1 * * 1 * * 1 * * 7 * * 1 * *12 * * 2 * *20 * * 3 * * 3 * *
    -  * 1 * * 1 * * 1 * * 1 * * 1 * * 1 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3
  11-  1 * * 1 * * 6 * * 1 * * 1 * * 1 * * 9 * * 2 * * 2 * * 2 * * 3 * * 3 *
  -  * * 1 * * 5 * * 1 * * 1 * * 1 * * 1 * * 2 * * 2 * * 2 * * 3 * * 3 * *
 13-  * 1 * * 8 * * 5 * * 1 * * 1 * * 1 * * 1 * * 2 * * 2 * *21 * * 3 * * 3
 -  1 * * 1 * * 5 * * 1 * * 1 * * 1 * * 1 * * 2 * * 2 * * 3 * * 3 * * 3 *
15-  * * 1 * * 1 * * 7 * * 1 * * 1 * * 1 * *13 * * 2 * *20 * * 3 * * 3 * *
-  * 1 * * 1 * * 1 * * 1 * * 1 * * 1 * * 4 * * 2 * * 2 * * 3 * * 3 * * 3
17- 10 * * 1 * * 1 * * 1 * * 1 * * 1 * *14 * * 4 * * 2 * * 2 * * 3 * * 3 *
-  * * 1 * * 1 * * 1 * * 1 * * 1 * * 2 * * 4 * * 2 * * 2 * * 3 * * 3 * *
19-  * 2 * *15 * * 1 * *10 * * 1 * *13 * * 2 * *16 * * 2 * *21 * * 3 * * 3
-  2 * * 4 * * 1 * * 2 * * 1 * * 4 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3 *
21-  * *18 * * 4 * *12 * * 2 * *14 * * 4 * * 2 * * 2 * *20 * * 3 * * 3 * *
-  * 2 * * 4 * * 2 * * 2 * * 2 * * 4 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3
23-  2 * * 2 * *16 * * 2 * * 2 * * 2 * *16 * * 2 * * 2 * * 2 * * 3 * * 3 *
-  * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 3 * * 3 * *
25-  * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * *21 * * 3 * * 3
-  2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 2 * * 3 * * 3 * * 3 *
27-  * *19 * * 2 * *19 * * 2 * *19 * * 2 * *19 * * 2 * *21 * * 3 * * 3 * *
-  * 3 * * 2 * * 3 * * 2 * * 3 * * 2 * * 3 * * 2 * * 3 * * 3 * * 3 * * 3
29-  3 * * 3 * *21 * * 3 * *21 * * 3 * *21 * * 3 * *21 * * 3 * * 3 * * 3 *
-  * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * *
31-  * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3
-  3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 *
33-  * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * *
-  * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3
35-  3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 * * 3 *
```

THE MATERIAL SPECIFICATION OF HEXAGONS

```
            * * * * * * * *
           * *           * *
          *   *    T6    *   *
         *     *        *     *
        *       *      *       *
       *    T5   *    *   T1    *
      *           * *            *
     * * * * * * *HNR* * * * * * *
      *           * *            *
       *    T4   *    *   T2    *
        *       *      *       *
         *     *        *     *
          *   *    T3    *   *
           * *           * *
            * * * * * * * *
```

HNR	T1	T2	T3	T4	T5	T6
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	1	1	5	5	1	1
7	1	1	1	1	5	5
8	5	5	1	1	1	1
9	2	2	1	1	1	1
10	1	1	2	2	1	1
11	4	4	1	1	1	1
12	2	2	2	2	1	1
13	2	2	4	4	1	1
14	4	4	2	2	1	1
15	1	1	4	4	1	1
16	2	2	2	2	4	4
17	2	2	4	4	2	2
18	4	4	2	2	2	2
19	2	2	3	3	2	2
20	3	3	2	2	2	2
21	3	3	3	3	2	2

MATERIAL SPECIFICATION

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
1	G				
	1	2.87679E+00	2.82040E-02	1.18780E-02	7.68000E-01
	2	1.57085E+00	5.27470E-03	5.32520E-03	2.32000E-01
	3	7.22486E-01	1.76120E-02	1.04710E-02	0.0
	4	9.64199E-01	2.65460E-02	2.66110E-02	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.35970E-02	4.07910E-06	4.44930E-08
2	1.61530E-03	4.23090E-08	
3	4.68380E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
2	G				
	1	2.87654E+00	2.87820E-02	1.49430E-02	7.68000E-01
	2	1.57136E+00	6.04910E-03	7.68870E-03	2.32000E-01
	3	7.12708E-01	1.95100E-02	1.48090E-02	0.0
	4	9.42978E-01	3.37140E-02	3.81590E-02	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.32620E-02	4.64510E-06	4.99680E-08
2	1.57180E-03	4.07240E-08	
3	4.34140E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
3	G				
	1	2.28561E+00	3.59590E-02	7.74270E-03	7.68000E-01
	2	1.17193E+00	5.88550E-03	1.08250E-04	2.32000E-01
	3	6.32475E-01	1.60410E-02	2.97420E-04	0.0
	4	8.18357E-01	1.33490E-02	8.46870E-04	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	3.20710E-02	3.88800E-06	4.50390E-08
2	2.77760E-03	9.00180E-08	
3	5.89710E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
4	G				
	1	2.50307E+00	2.48140E-02	0.0	0.0
	2	1.31468E+00	1.64120E-02	0.0	0.0
	3	5.74277E-01	7.21220E-02	0.0	0.0
	4	6.15369E-01	1.68680E-01	0.0	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	2.29460E-02	1.03200E-06	1.04890E-08
2	3.76870E-03	7.03610E-12	
3	8.68150E-03		

COMP	GR NR	DIF	SIGT	NUSIGF	CHI
5	G				
	1	4.61642E+00	1.31590E-02	0.0	0.0
	2	2.90183E+00	1.45590E-03	0.0	0.0
	3	1.02118E+00	4.60010E-03	0.0	0.0
	4	1.72963E+00	7.86600E-04	0.0	0.0

SIGDS

G	G-->G+1	G-->G+2	G-->G+3
1	1.29420E-02	6.87800E-07	6.99030E-09
2	1.28710E-03	4.36330E-12	
3	3.45330E-03		

LOGARITHMIC BOUNDARY CONDITION PARAMETERS

GR NR	PT NR	LEFT	TOP	RIGHT	BOTTOM
1					
	1			4.6948E-01	4.6948E-01
	2			4.6948E-01	4.6948E-01
	3			4.6948E-01	4.6948E-01
	4			4.6948E-01	4.6948E-01
	5			4.6948E-01	4.6948E-01
	6			4.6948E-01	4.6948E-01
	7			4.6948E-01	4.6948E-01
	8			4.6948E-01	4.6948E-01
	9			4.6948E-01	4.6948E-01
	10			4.6948E-01	4.6948E-01
	11			4.6948E-01	4.6948E-01
	12			4.6948E-01	4.6948E-01
	13			4.6948E-01	4.6948E-01
	14			4.6948E-01	4.6948E-01
	15			4.6948E-01	4.6948E-01
	16			4.6948E-01	4.6948E-01
	17			4.6948E-01	4.6948E-01
	18			4.6948E-01	4.6948E-01
	19			4.6948E-01	4.6948E-01
	20			4.6948E-01	4.6948E-01
	21			4.6948E-01	4.6948E-01
	22			4.6948E-01	4.6948E-01
	23			4.6948E-01	4.6948E-01
	24			4.6948E-01	4.6948E-01
	25			4.6948E-01	4.6948E-01
	26			4.6948E-01	4.6948E-01
	27			4.6948E-01	4.6948E-01
	28			4.6948E-01	4.6948E-01
	29			4.6948E-01	4.6948E-01
	30			4.6948E-01	4.6948E-01
	31			4.6948E-01	4.6948E-01
	32			4.6948E-01	4.6948E-01
	33			4.6948E-01	4.6948E-01
	34			4.6948E-01	4.6948E-01
	35			4.6948E-01	4.6948E-01
2					
	1			4.6948E-01	4.6948E-01
	2			4.6948E-01	4.6948E-01
	3			4.6948E-01	4.6948E-01
	4			4.6948E-01	4.6948E-01
	5			4.6948E-01	4.6948E-01
	6			4.6948E-01	4.6948E-01
	7			4.6948E-01	4.6948E-01
	8			4.6948E-01	4.6948E-01
	9			4.6948E-01	4.6948E-01
	10			4.6948E-01	4.6948E-01
	11			4.6948E-01	4.6948E-01
	12			4.6948E-01	4.6948E-01
	13			4.6948E-01	4.6948E-01
	14			4.6948E-01	4.6948E-01
	15			4.6948E-01	4.6948E-01
	16			4.6948E-01	4.6948E-01
	17			4.6948E-01	4.6948E-01
	18			4.6948E-01	4.6948E-01
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	20			4.6948E-01	4.6948E-01
	21			4.6948E-01	4.6948E-01

	22	4.6948E-01	4.6948E-01
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	24	4.6948E-01	4.6948E-01
	25	4.6948E-01	4.6948E-01
	26	4.6948E-01	4.6948E-01
	27	4.6948E-01	4.6948E-01
	28	4.6948E-01	4.6948E-01
	29	4.6948E-01	4.6948E-01
	30	4.6948E-01	4.6948E-01
	31	4.6948E-01	4.6948E-01
	32	4.6948E-01	4.6948E-01
	33	4.6948E-01	4.6948E-01
	34	4.6948E-01	4.6948E-01
	35	4.6948E-01	4.6948E-01
3			
	1	4.6948E-01	4.6948E-01
	2	4.6948E-01	4.6948E-01
	3	4.6948E-01	4.6948E-01
	4	4.6948E-01	4.6948E-01
	5	4.6948E-01	4.6948E-01
	6	4.6948E-01	4.6948E-01
	7	4.6948E-01	4.6948E-01
	8	4.6948E-01	4.6948E-01
	9	4.6948E-01	4.6948E-01
	10	4.6948E-01	4.6948E-01
	11	4.6948E-01	4.6948E-01
	12	4.6948E-01	4.6948E-01
	13	4.6948E-01	4.6948E-01
	14	4.6948E-01	4.6948E-01
	15	4.6948E-01	4.6948E-01
	16	4.6948E-01	4.6948E-01
	17	4.6948E-01	4.6948E-01
	18	4.6948E-01	4.6948E-01
	19	4.6948E-01	4.6948E-01
	20	4.6948E-01	4.6948E-01
	21	4.6948E-01	4.6948E-01
	22	4.6948E-01	4.6948E-01
	23	4.6948E-01	4.6948E-01
	24	4.6948E-01	4.6948E-01
	25	4.6948E-01	4.6948E-01
	26	4.6948E-01	4.6948E-01
	27	4.6948E-01	4.6948E-01
	28	4.6948E-01	4.6948E-01
	29	4.6948E-01	4.6948E-01
	30	4.6948E-01	4.6948E-01
	31	4.6948E-01	4.6948E-01
	32	4.6948E-01	4.6948E-01
	33	4.6948E-01	4.6948E-01
	34	4.6948E-01	4.6948E-01
	35	4.6948E-01	4.6948E-01
4			
	1	4.6948E-01	4.6948E-01
	2	4.6948E-01	4.6948E-01
	3	4.6948E-01	4.6948E-01
	4	4.6948E-01	4.6948E-01
	5	4.6948E-01	4.6948E-01
	6	4.6948E-01	4.6948E-01
	7	4.6948E-01	4.6948E-01
	8	4.6948E-01	4.6948E-01
	9	4.6948E-01	4.6948E-01
	10	4.6948E-01	4.6948E-01
	11	4.6948E-01	4.6948E-01
	12	4.6948E-01	4.6948E-01
	13	4.6948E-01	4.6948E-01

14	4.6948E-01	4.6948E-01
15	4.6948E-01	4.6948E-01
16	4.6948E-01	4.6948E-01
17	4.6948E-01	4.6948E-01
18	4.6948E-01	4.6948E-01
19	4.6948E-01	4.6948E-01
20	4.6948E-01	4.6948E-01
21	4.6948E-01	4.6948E-01
22	4.6948E-01	4.6948E-01
23	4.6948E-01	4.6948E-01
24	4.6948E-01	4.6948E-01
25	4.6948E-01	4.6948E-01
26	4.6948E-01	4.6948E-01
27	4.6948E-01	4.6948E-01
28	4.6948E-01	4.6948E-01
29	4.6948E-01	4.6948E-01
30	4.6948E-01	4.6948E-01
31	4.6948E-01	4.6948E-01
32	4.6948E-01	4.6948E-01
33	4.6948E-01	4.6948E-01
34	4.6948E-01	4.6948E-01
35	4.6948E-01	4.6948E-01

THE ESTIMATION OF OPTIMUM OMEGA

NG	NORM
1	0.719727
2	0.836721
3	0.511508
4	0.509477

NG	IT	NI	ER	ER/ER
2	1	0.836721	0.976094	0.976094
2	2	0.867133	-0.036346	-0.037237
2	3	0.876614	-0.010933	0.300798
2	4	0.882126	-0.006288	0.575105
2	5	0.885935	-0.004317	0.686637
2	6	0.888813	-0.003247	0.752154
2	7	0.891101	-0.002574	0.792658
2	8	0.892983	-0.002111	0.820304
2	9	0.894562	-0.001768	0.837398
2	10	0.895904	-0.001499	0.847896
2	11	0.897055	-0.001285	0.856870
2	12	0.898047	-0.001105	0.860431
2	13	0.898902	-0.000952	0.861087
2	14	0.899643	-0.000824	0.865731
2	15	0.900285	-0.000713	0.865741
2	16	0.900840	-0.000616	0.863636
2	17	0.901321	-0.000533	0.865325
2	18	0.901739	-0.000463	0.869410
2	19	0.902099	-0.000399	0.860082
2	20	0.902412	-0.000346	0.868421
2	21	0.902683	-0.000299	0.865014
2	22	0.902916	-0.000258	0.863057
2	23	0.903119	-0.000224	0.867159
2	24	0.903293	-0.000192	0.855319
2	25	0.903445	-0.000168	0.875622
2	26	0.903576	-0.000144	0.857955
2	27	0.903689	-0.000125	0.867550
2	28	0.903786	-0.000107	0.854962
2	29	0.903870	-0.000093	0.875000

OMEGAB=1.1687   OMEGAF=1.1687

ITERATION PROCESS

IT NR	OMEGAB	OMEGAF	K-EFF	K-EFF CONV.	GR NR	FLUX CONV IN INNER ITERS --> 1	2	3	4	5
1	1.1687	1.1687	1.099779	3.8126E+02	1	1.00E+00	6.25E-01	2.33E-01	1.99E-01	1.89E-01
					2	1.00E+00	6.52E-01	3.72E-01	2.19E-01	1.02E-01
					3	1.00E+00	5.97E-01	4.57E-01	2.46E-01	9.63E-02
					4	1.00E+00	6.73E-01	3.86E-01	2.41E-01	1.36E-01
2	1.1687	1.1687	1.093054	6.1522E-03	1	4.64E+00	1.09E+00	4.12E-01	1.79E-01	
					2	4.61E-01	2.35E-01	1.26E-01	5.67E-02	
					3	8.95E-01	3.48E-01	1.40E-01	7.22E-02	
					4	4.21E-01	1.86E-01	8.01E-02	4.98E-02	
3	1.1687	1.1687	1.092194	7.8678E-04	1	2.92E-01	2.36E-01	1.40E-01		
					2	8.08E-02	6.54E-02	4.10E-02		
					3	2.59E-01	1.08E-01	5.40E-02		
					4	2.19E-01	1.16E-01	4.97E-02		
4	1.1687	1.1687	1.103693	1.0419E-02	1	1.14E-01	4.92E-02			
					2	4.17E-02	2.68E-02			
					3	7.11E-02	2.08E-02			
					4	7.98E-02	1.97E-02			
5	1.1687	1.1687	1.114928	1.0077E-02	1	6.14E-02	6.56E-02			
					2	2.98E-02	2.09E-02			
					3	4.80E-02	1.63E-02			
					4	4.35E-02	1.78E-02			
6	1.1687	1.1687	1.120794	5.2339E-03	1	2.40E-02	1.99E-02			
					2	1.65E-02	9.82E-03			
					3	2.45E-02	4.34E-03			
					4	1.97E-02	4.47E-03			
7	1.1687	1.1687	1.123072	2.0278E-03	1	1.26E-02	1.26E-02			
					2	7.90E-03	4.37E-03			
					3	1.14E-02	3.15E-03			
					4	9.63E-03	2.89E-03			
8	1.1687	1.1687	1.123827	6.7210E-04	1	6.27E-03	5.34E-03			
					2	3.48E-03	2.02E-03			
					3	4.71E-03	1.39E-03			
					4	3.57E-03	8.89E-04			
9	1.1687	1.1687	1.124104	2.4688E-04	1	2.81E-03	2.25E-03			
					2	1.48E-03	8.09E-04			
					3	2.01E-03	6.54E-04			
					4	1.65E-03	4.06E-04			
10	1.1687	1.1687	1.124236	1.1712E-04	1	1.34E-03	1.27E-03			
					2	6.22E-04	3.46E-04			
					3	8.58E-04	2.76E-04			
					4	6.91E-04	1.55E-04			
11	1.1687	1.1687	1.124329	8.2314E-05	1	8.64E-04	6.74E-04			
					2	2.72E-04	1.57E-04			
					3	3.70E-04	1.24E-04			
					4	3.00E-04	7.53E-05			
12	1.1687	1.1687	1.124377	4.3273E-05	1	5.42E-04	3.31E-04			
					2	1.17E-04	6.81E-05			
					3	1.45E-04	4.96E-05			

					4	1.15E-04	3.72E-05
13	1.1687	1.1687	1.124383	5.1260E-06	1	3.12E-04	1.73E-04
					2	4.71E-05	2.69E-05
					3	5.34E-05	2.96E-05
					4	4.77E-05	2.86E-05
14	1.1687	1.1687	1.124372	8.5831E-06	1	1.75E-04	8.89E-05
					2	2.57E-05	1.72E-05
					3	3.05E-05	1.72E-05
					4	2.19E-05	2.00E-05
15	1.1687	1.1687	1.124375	2.5630E-06	1	8.96E-05	5.69E-05
					2	1.72E-05	8.88E-06
					3	8.46E-06	4.65E-06
					4	1.02E-05	7.27E-06
16	1.1687	1.1687	1.124377	1.7285E-06	1	4.01E-05	3.26E-05
					2	8.46E-06	6.68E-06
					3	7.33E-06	3.81E-06
					4	6.85E-06	2.98E-06
17	1.1687	1.1687	1.124378	8.9407E-07	1	2.38E-05	1.44E-05
					2	5.72E-06	5.36E-06
					3	4.23E-06	2.92E-06
					4	4.23E-06	1.97E-06
18	1.1687	1.1687	1.124378	0.0	1	1.24E-05	8.40E-06
					2	3.87E-06	3.99E-06
					3	3.81E-06	4.47E-06
					4	3.58E-06	2.86E-06

VIII. APPENDIX:

Description of the INPREP Programme

The INPREP-II programme, written in FORTRAN IV and available in a card deck for IBM/370-168 computer, is intended as an auxiliary programme allowing to simplify considerably the preparation of that part of the HEXAGA-II input data which is concerned with the specification of material compositions inside a triangular mesh.

As input data INPREP-II uses only the first two cards of the HEXAGA-II input data, that is, card numbers 1/ and 2/ (see Chapter IV) where the value of NOH (number of all different hexagons) is ignored by the programme.

In the INPREP output, the picture of empty hexagonal mesh bounded by a parallelogram area of a given reactor problem is printed according to the value of NOM given in the input. In other words, INPREP-II provides the same picture of mesh (called "THE LOCATION OF HEXAGONS") as HEXAGA-II, but without the specification of material composition numbers representing particular hexagons in the mesh. However, these numbers can now be written by the user according to the material arrangement of a given reactor problem. With such specification of material compositions in the mesh prepared in advance it is possible in an easy way to prepare input cards for HEXAGA-II.

Moreover, INPREP-II in the output provides the specification of space (in bytes) which must be reserved on particular files used by HEXAGA-II.

The maximum CPU time amounts to a few seconds and a standard core region is sufficient (122 K). As an illustration of INPREP the output for sample problem B2, completed by hand writing, is presented.

I N P R E P - II WRITTEN BY ZBIGNIEW WOZNICKI, FEB. 1975

SAMPLE PROBLEM B2

2 TYPE OF HEXAGONAL MESH ARRANGEMENT

1225 MESH POINTS

4 NEUTRON GR.

1 THERMAL GR.

3 NEUTRON GR. THROUGHOUT WHICH NEUTRONS ARE DOWN-SCATTERED

5 MATERIAL COMP.

3 FISSIONABLE COMP.

0.0 CM - MESH STEP

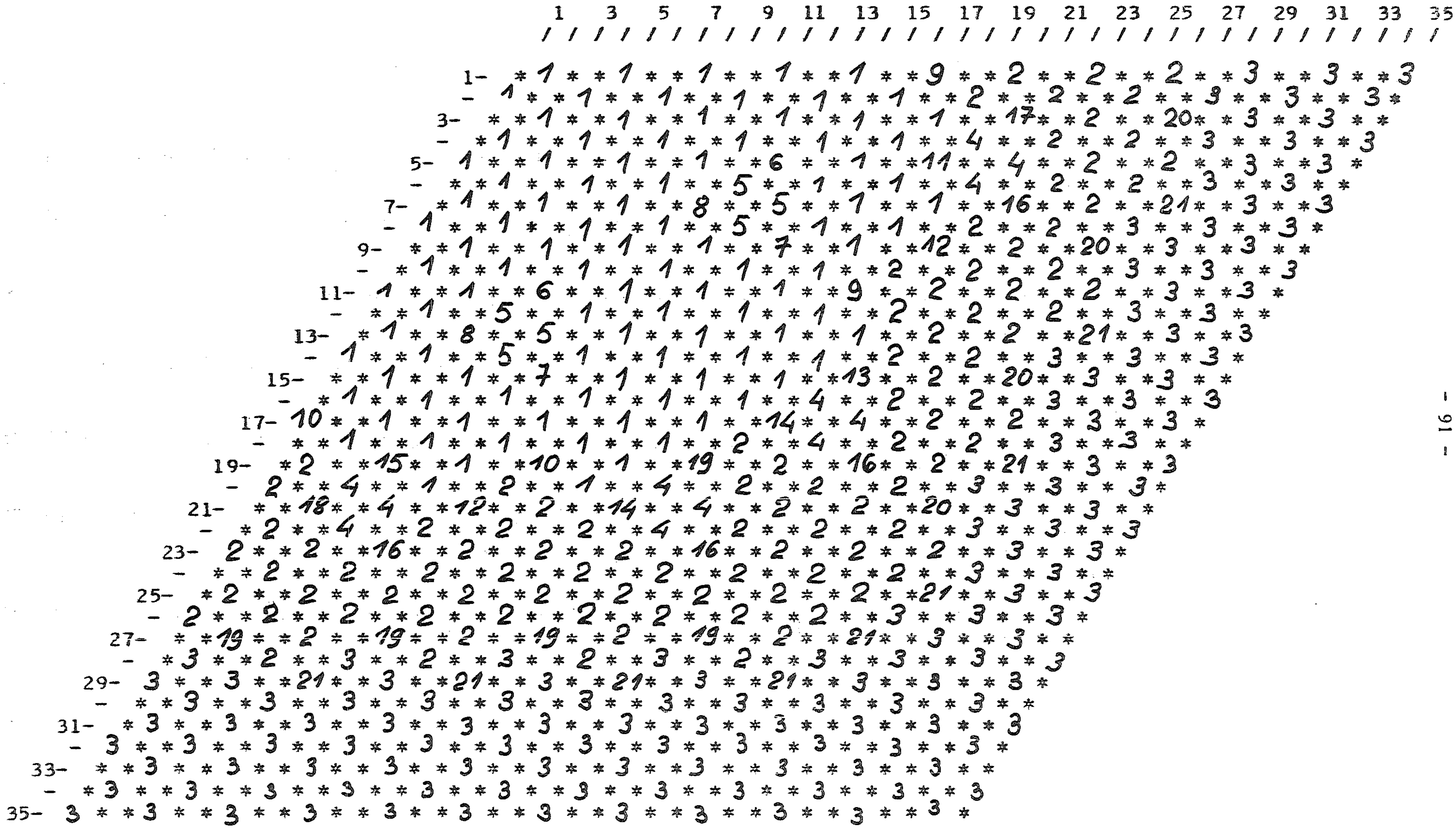
OUTER BOUNDARY COND: LEFT - FLUX DERIVATIVE EQUAL TO ZERO
TOP - FLUX DERIVATIVE EQUAL TO ZERO
RIGHT - LOGARITHMIC
BOTTOM - LOGARITHMIC

THE DETERMINATION OF DISC SPACE

FILE NR	SPACE IN BYTES
12	117696
13	70336
14	39232
15	39232
16	31104
17	31104
18	4904
20	4904
21	44136
22	117696
23	70336

DIMENSION SPACE: 16520 BYTES

THE LOCATION OF HEXAGONS



THE MATERIAL SPECIFICATION OF HEXAGONS

```
          * * * * * * * *
         * *           * *
        *   *    T6   *   *
       *     *       *     *
      *       *     *       *
     *   T5    *   *   T1    *
    *           * *           *
   * * * * * * *HNR* * * * * * *
    *           * *           *
     *   T4    *   *   T2    *
      *       *     *       *
       *     *       *     *
        *   *    T3   *   *
         * *           * *
          * * * * * * * *
```

HNR	T1	T2	T3	T4	T5	T6
1	1	1	1	1	1	1
2	2	2	2	2	2	2
3	3	3	3	3	3	3
4	4	4	4	4	4	4
5	5	5	5	5	5	5
6	1	1	5	5	1	1
7	1	1	1	1	5	5
8	5	5	1	1	1	1
9	2	2	1	1	1	1
10	1	1	2	2	1	1
11	4	4	1	1	1	1
12	2	2	2	2	1	1
13	2	2	4	4	1	1
14	4	4	2	2	1	1
15	1	1	4	4	1	1
16	2	2	2	2	4	4
17	2	2	4	4	2	2
18	4	4	2	2	2	2
19	2	2	3	3	2	2
20	3	3	2	2	2	2
21	3	3	3	3	2	2

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