MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0364453 6

ORNL-3200
UC-32 – Mathematics and Computers
TID-4500 (16th ed.)

THE TWENTY GRAND PROGRAM FOR THE NUMERICAL SOLUTION OF FEW-GROUP NEUTRON DIFFUSION EQUATIONS IN TWO DIMENSIONS

M. L. Tobias
T. B. Fowler

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

Printed in USA. Price $1.00. Available from the

Office of Technical Services
Department of Commerce
Washington 25, D.C.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

ORNL-3200

UC-32 — Mathematics and Computers
TID-4500 (16th ed.)

Contract No. W-7405-eng-26

REACTOR DIVISION

THE TWENTY GRAND PROGRAM FOR THE NUMERICAL SOLUTION OF FEW-GROUP NEUTRON DIFFUSION EQUATIONS IN TWO DIMENSIONS

M. L. Tobias T. B. Fowler

DATE ISSUED

FEB - 7 1962

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
operated by
UNION CARBIDE CORPORATION
for the
U. S. ATOMIC ENERGY COMMISSION

SYSTEMS LIBRARIES

3 4456 0364453 6

CONTENTS

Abstract 1

Introduction 1

Description of Special Features 2

Scattering from any Group to any Group and Variable Buckling 2

Automatic Handling of Symmetry Conditions 4

Normalization of Fluxes to an Arbitrary Power Level 4

Logarithmic-Derivative or Rod Boundary Conditions 6

Integrals of Dot Products of Flux Gradients 7

Input, Operating Instructions, Sample Problem 7

Instructions for Writing TWENTY GRAND Input 7

Operating Instructions 14

Sample Problem 14

THE TWENTY GRAND PROGRAM FOR THE NUMERICAL SOLUTION OF FEW-GROUP NEUTRON DIFFUSION EQUATIONS IN TWO DIMENSIONS

M. L. Tobias T. B. Fowler

Abstract

The TWENTY GRAND program for the IBM 7090 is capable of solving neutron diffusion problems in cylindrical or slab geometry for one to six groups. Up to 3000 mesh points may be used. Neutron transfer from any group to any other group is permitted. Leakage in the third dimension in X-Y geometry may be treated by a buckling which can vary with region and group. Three types of symmetry conditions may be handled automatically. The zero flux, zero derivative, and logarithmic boundary conditions are available. Normalization of fluxes to an arbitrary input power is allowed. The fission source distribution and the adjoint fluxes and associated integrals may be computed at the user's option. The number of mesh sweeps permitted is stated as input. The average running time in seconds per point per iteration per group is approximately 0.0035.

Introduction

TWENTY GRAND is a program based upon the Equipoise method;[1] it solves the finite difference analogs of the neutron diffusion equations for one to six groups in R-Z and X-Y geometry. The program involves the following special features, which will be discussed in more detail in later sections:

1. Upscattering and downscattering are provided for neutron transfer from any group to any other group.

2. In X-Y geometry, leakage in the third dimension may be taken into account by using a buckling which varies with region and with group.

3. Three types of symmetry conditions may be handled automatically; "single-diagonal," "double-diagonal," and "mirror-diagonal" are the names given to these conditions.

---

[1]M. L. Tobias and T. B. Fowler, EQUIPOISE – An IBM-704 Code for the Solution of Two-Group, Two-Dimensional, Neutron Diffusion Equations in Cylindrical Geometry, ORNL-2967, Oct. 17, 1960.

4. Normalization of fluxes to an arbitrary power level is permitted.

5. The number of mesh sweeps is determined by the user.

In addition to these items, the following features which have been used in earlier Equipoise-type programs are included:

1. Zero flux, zero-derivative, and logarithmic-derivative (rod) boundary conditions may be used.

2. Optional output includes the fission source distribution, the adjoint fluxes, and the following associated integrals for each region

$$\int_R \phi_i \phi_j^* \, dV \qquad i, j = 1, 2, \ldots G$$

and

$$\int_R \nabla\phi_i \cdot \nabla\phi_j^* \, dV \qquad i = 1, 2, \ldots G ,$$

where ϕ and ϕ^* refer to the neutron flux and adjoint flux, respectively.

3. Leakages, absorptions, productions, and eigenvalues are listed.

4. As many as 3000 points may be treated.

Description of Special Features

Scattering from any Group to any Group and Variable Buckling

The special scattering and buckling features are enclosed in braces in the following equation for the neutron balance around an element of volume for the ith neutron group in the slab geometry shown in Fig. 1:

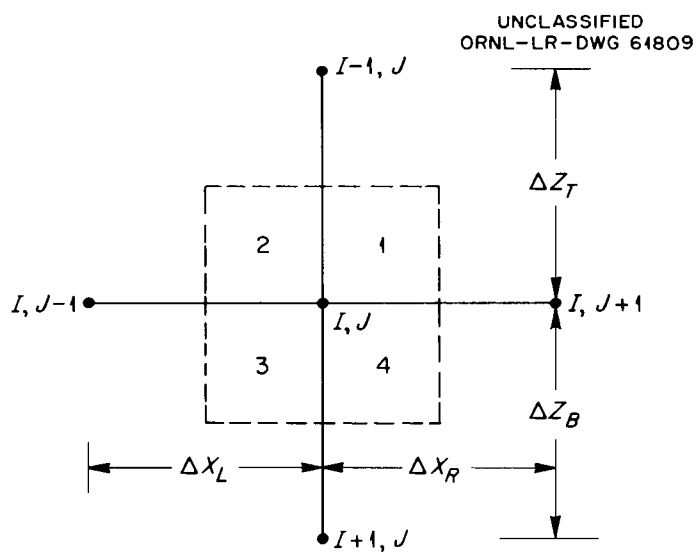

Fig. 1. Diagram of a Typical Mesh Point.

$$D_{1i}[\phi_i(I-1,J) - \phi_i(I,J)]\,\frac{\Delta X_R}{2\Delta Z_T} + \text{similar leakage terms}$$

$$- \left\{ D_{1i}B^2_{1i}\ \phi_i(I,J)\,\frac{\Delta Z_T \Delta X_R}{4} + \text{similar longitudinal leakage terms} \right\}$$

$$- \Sigma_{A1i}\ \phi_i(I,J)\,\frac{\Delta Z_T \Delta X_R}{4} + \text{similar absorption terms}$$

$$- \Sigma_{R1i}\ \phi_i(I,J)\,\frac{\Delta Z_T \Delta X_R}{4} + \text{similar removal terms}$$

$$+ \left\{ \sum_{j \neq i}^{G} \left[f_{1j\rightarrow i}\Sigma_{R1j}\ \phi_j(I,J)\,\frac{\Delta Z_T \Delta X_R}{4} + \text{similar "scattering-in" terms} \right] \right\}$$

$$+ \lambda X_i \left[\sum_{j=1}^{G} \nu\Sigma_{f1j}\ \phi_j(I,J)\,\frac{\Delta Z_T \Delta X_R}{4} + \text{similar source terms} \right] = 0 \qquad (1)$$

The iterative procedure is based upon solving this equation for $\phi_i(I,J)$, except that $\phi_i(I,J)$ is left in the source term. For cylindrical geometry, the surface and volume constants are suitably modified. The symbols used in Eq. 1 have the following meanings:

Notation

B^2_{1i}	Square of group i buckling of area 1 at mesh point (I,J), cm^{-2}
D_{1i}	Group i diffusion coefficient of area 1 at mesh point (I,J), cm
$f_{1j\rightarrow i}$	The fraction of neutrons removed from group j that enter group i from area 1 at mesh point (I,J)
i, j	Subscripts denoting group number
I, J	Coordinates of mesh point (I,J)
ΔX_R	Distance from mesh point (I,J) to mesh point (I,J+1), cm
ΔZ_T	Distance from mesh point (I,J) to mesh point (I-1,J), cm
$\phi_i(I,J)$	Group i flux at mesh point (I,J)
λ	The eigenvalue of the problem; the value by which all $\nu\Sigma_f$'s must be multiplied so that the difference equations will balance

$\nu\Sigma_{f1j}$	The number of neutrons produced per fission times the group j macroscopic fission cross section of area 1 at mesh point (I,J), cm^{-1}
Σ_{A1i}	Group i macroscopic absorption cross section of area 1 at mesh point (I,J), cm^{-1}
Σ_{R1j}	Group j macroscopic removal cross section of area 1 at mesh point (I,J), cm^{-1}
χ_i	The fraction of neutrons produced from fission that are born in group i

Automatic Handling of Symmetry Conditions

By suitable specification of the input it is possible to make the program compute in conformance with the following three types of symmetry conditions:

1. Single diagonal symmetry (square mesh only)

$$\phi(I,J) = \phi(J,I) \quad . \tag{2}$$

2. Double diagonal symmetry (square mesh only)

$$\phi(I,J) = \phi(J,I) \quad ,$$

$$\phi(I,J) = \phi(JMAX-J+1,IMAX-I+1) \quad . \tag{3}$$

3. Mirror diagonal symmetry

$$\phi(I,J) = \phi(IMAX-I+1,JMAX-J+1) \quad , \tag{4}$$

These conditions may be understood by the sketches in Fig. 2.

Normalization of Fluxes to an Arbitrary Power Level

Unless specifically provided for in the input, all answers will be normalized to one source neutron; that is, the output is computed so that the sum of all sources $\nu\ \Sigma_{fi}(I,J)\ \phi_i(I,J)\ \Delta V$ is one neutron per second. By inserting an appropriate constant in the input, the answers may be

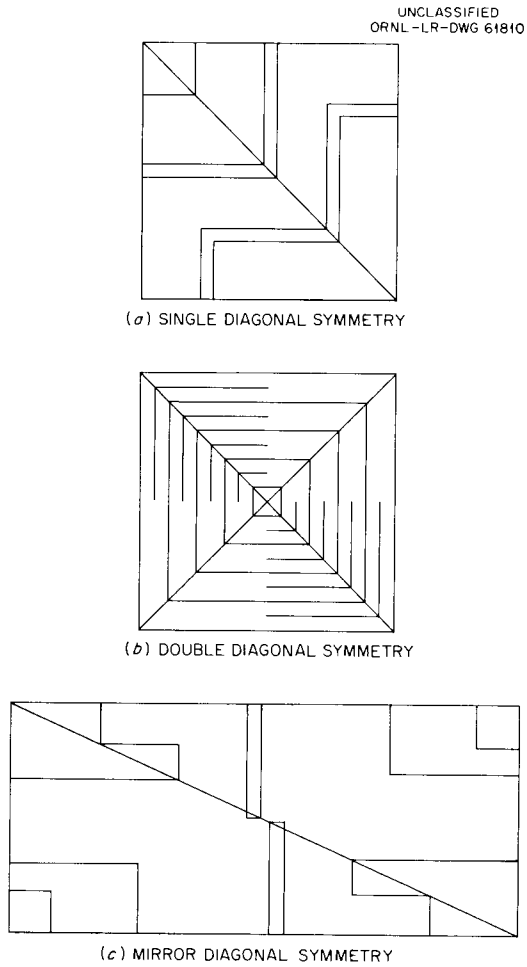

Fig. 2. Sketches of Various Symmetry Conditions that Can Be Handled Automatically.

normalized to any desired power level. If the user assumes that there are 3.3×10^{13} fissions per kilowatt per second and that $\nu = 2.5$, the appropriate constant to be placed in the input for a power of 137 Mw would be:

$$(137)(1000)(2.5)(3.3 \times 10^{13}) = 11.3025 \times 10^{18}$$

(Care must be used if only part of a reactor is being considered. If there were one symmetry boundary, the number above would be divided by 2. Note also that this normalization to a given power corresponds to saying that the reactor is just critical with a fictitious fuel for which the

number of neutrons per fission is $\lambda\nu$, where λ is the eigenvalue computed by the program. There is, of course, no need to introduce λ because it cancels out.)

Logarithmic-Derivative or Rod Boundary Conditions

The finite-difference equivalent of the logarithmic-derivative boundary condition

$$D \frac{d\phi}{d\vec{n}} = -C\phi \tag{5}$$

may be used along the surfaces of "rod regions," which may be placed in the mesh in the same way as any other region (see Fig. 3).

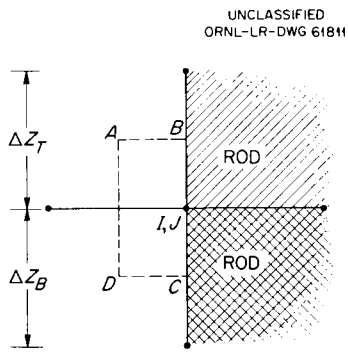

Fig. 3. Element of Volume Bordering on a Rod Region.

The rod region is treated as though it were introducing an absorption cross section rather than a leakage. The diffusion constant in the rod region is made zero for the group or groups considered as rod groups. Slowing down into a rod group is permitted, but there is no removal other than absorption. Leakage into the rod region from the element of volume ABCD of Fig. 3 is handled by introducing terms such as the following into the neutron balance:

$$-\left(C_1 \frac{\Delta Z_T}{2} + C_2 \frac{\Delta Z_B}{2}\right) \phi(I,J) \quad ,$$

where the C's may be regarded as the diffusion constants in the element

ABCD divided by extrapolation distances. Different kinds of rods may adjoin one another along mesh lines.

Integrals of Dot Products of Flux Gradients

The integrals

$$\int \nabla\phi_i \cdot \nabla\phi_i^* \, dV$$

are approximated by computing, over each region, the sum of terms such as the following:

$$\left\{ \left[\frac{\phi_i(I-1,J) - \phi(I,J)}{\Delta Z_T} \right] \left[\frac{\phi_i^*(I-1,J) - \phi^*(I,J)}{\Delta Z_T} \right] + \right.$$

$$\left. + \left[\frac{\phi_i(I,J+1) - \phi_i(I,J)}{\Delta X_R} \right] \left[\frac{\phi_i^*(I,J+1) - \phi_i(I,J)}{\Delta X_R} \right] \right\} \frac{\Delta Z_T \Delta X_R}{4} \quad .$$

This computation is done at the user's option.

Input, Operating Instructions, Sample Problem

Instructions for Writing TWENTY GRAND Input

Figure 4 shows a TWENTY GRAND input form filled in for the sample problem. Given below are the instructions for writing the input. Number formats are in FORTRAN nomenclature and are given in parenthesis immediately following each input number symbol.

Title Card. Column 1 of the title card is left blank. Columns 2 through 72 may contain any desired information and are printed at the top of each page of output.

Control Card 1. Columns 1 through 3, ITMAX(I3) $\leq$ 999: Total number of iterations a problem is to be run. If a problem has not converged before the number of iterations has reached ITMAX, it is terminated automatically and all output is written. Usually problems reach convergence in fewer than 300 iterations.

KEY PUNCHING INSTRUCTIONS:
Punch only those cards which have data in columns 73-80.

TWENTY GRAND INPUT FORM - 1

REQUEST NO.

1	TITLE	73–80
CODE TWENTY GRAND	SAMPLE PROBLEM FOR REPORT	TITLE

ITER (1)	IMAX (4)	JMAX (7)	NR (10)	NC (13)	NG (16)	GI (18)	BI (20)	SI (22)	AI (24)	FI (26)	CI (28)	DI (30)	LB (32)	TB (34)	RB (36)	BB (38)	NORM FACTOR (40)	ε(λ) (50)	ε(φ) (56)	ε(R) (62)	β (68)	(73–80)
300	25	10	8	3	4	-1		1	1				1			1	1.0	.00001	.0001	.0001		CNTRL

XI_1 (1)	XI_2 (6)	XI_3 (11)	XI_4 (16)	XI_5 (21)	XI_6 (26)	B_1^2 (31)	B_2^2 (38)	B_3^2 (45)	B_4^2 (52)	B_5^2 (59)	B_6^2 (66)	(73–80)
0.6	0.2	0.1	0.1			0.002						CNTRL

ΔY (1)	ROW (7)	ΔY (10)	ROW (16)	ΔY (19)	ROW (25)	ΔY (28)	ROW (34)	ΔY (37)	ROW (43)	ΔY (46)	ROW (52)	ΔY (55)	ROW (61)	ΔY (64)	ROW (70)	(73–80)
2.0	4	1.0	22	2.0	25											MESH

Δx (1)	COL (7)	Δx (10)	COL (16)	Δx (19)	COL (25)	Δx (28)	COL (34)	Δx (37)	COL (43)	Δx (46)	COL (52)	Δx (55)	COL (61)	Δx (64)	COL (70)	(73–80)
2.0	2	1.0	3	0.5	5	1.0	10									MESH

COMP. NO. (1)	ROW 1 (4)	ROW 2 (7)	COL 1 (10)	COL 2 (13)	COMP. NO. (20)	ROW 1 (23)	ROW 2 (26)	COL 1 (29)	COL 2 (32)	COMP. NO. (39)	ROW 1 (42)	ROW 2 (45)	COL 1 (48)	COL 2 (51)	COMP. NO. (58)	ROW 1 (61)	ROW 2 (64)	COL 1 (67)	COL 2 (70)	(73–80)
2	1	4	1	3	1	4	10	1	3	3	1	10	3	5	1	4	10	5	7	REG
2	1	4	5	10	1	10	22	1	7	2	4	22	7	10	2	22	25	1	10	REG

Fig. 4. Input for Sample Problem.

KEY PUNCHING INSTRUCTIONS:
Punch only those cards which have data in columns 73 - 80.

TWENTY GRAND INPUT FORM-2

REQUEST NO.

COMP. NO. (1)	GRP NO (4)	D (6)	ΣR (14)	ΣA (23)	νΣf (32)	B^2 (41)	f_1 (48)	f_2 (53)	f_3 (58)	f_4 (63)	f_5 (68)	(73–80)
1	1	1.11	0.0011	0.0011	0.0021		0.6	0.3	0.1			COMP11
1	2	1.12	0.0012	0.0012	0.0022			0.6	0.4			COMP12
1	3	1.13	0.0013	0.0013	0.0023			0.4	0.6			COMP13
1	4	1.14	0.0014	0.0014	0.0024			0.5	0.5			COMP14
2	1	1.21	0.0021	0.0021			0.6	0.3	0.1			COMP21
2	2	1.22	0.0022	0.0022				0.6	0.4			COMP22
2	3	1.23	0.0023	0.0023				0.4	0.6			COMP23
2	4	1.24	0.0024	0.0024				0.5	0.5			COMP24
3	1	1.31	0.0031	0.0031			0.6	0.3	0.1			COMP31
3	2	0.0		0.05								COMP32
3	3	0.0		0.05								COMP33
3	4	1.34	0.0034	0.0041				0.5	0.5			COMP34
												STOP
												STOP

Fig. 4 (continued)

Columns 4 through 6, IMAX(I3) $\leq$ 100: Total number of rows in the mesh. The rows are numbered from top to bottom beginning with 1 and ending with IMAX.

Columns 7 through 9, JMAX(I3) $\leq$ 100: Total number of columns in the mesh. The columns are numbered from left to right beginning with 1 and ending with JMAX. Note that IMAX $\times$ JMAX $\leq$ 3000.

Columns 10 through 12, NR(I3): Total number of rectangular regions that are specified on the region-specification cards (see below). Normally this number must be less than or equal to 100; however, for the adjoint calculation NR $\leq$ 70.

Columns 13 through 15, NC(I3) $\leq$ 50: Total number of compositions that are specified on the composition-specification cards (see below).

Columns 16 through 17, NG(I2) $\leq$ 6: Total number of groups.

Columns 18 through 19, GI(I2): Geometry indicator. For cylindrical geometry write +1; for slab geometry write −1.

Columns 20 through 21, BI(I2): Buckling indicator for slab geometry. A −1 specifies buckling by region (or composition). The bucklings are given on the composition-specification cards. A +1 specifies buckling by group, in which case the bucklings are given on Control Card 2. A 0 or blank specifies a constant buckling, the value of which is written in columns 31 through 37 of control card 2.

Columns 22 through 23, SI(I2): Source indicator. If this number is +1, the source

$$\sum_{i=1}^{G} (\nu\Sigma_f\phi)_i$$

for each of the four quadrants surrounding each mesh point is included in the output. If SI is 0 or blank, the source calculation is skipped.

Columns 24 through 25, AI(I2): Adjoint indicator. If this number is +1, the adjoint calculation is done automatically following the ordinary flux calculation. If AI is 0 or blank the adjoint calculation is skipped.

Columns 26 through 27, FI(I2): Previous flux indicator. If FI is +1, the final flux from the previous problem is used as the initial flux

guess for the present problem. The present problem must have the same mesh and boundary conditions as the previous problem. If FI is 0 or blank, the code supplies an initial flux guess of 100.

Columns 28 through 29, CI(I2): Convergence indicator. If CI is −1, the calculation stops when

$$\left| \frac{\lambda^{t}}{\lambda^{t+10}} - 1 \right| < \epsilon(\lambda) \quad , \tag{6}$$

where λ is the eigenvalue of the problem and t is the iteration number. If CI is +1, the calculation stops when the above condition is met and the following flux convergence condition is satisfied:

$$\left| \frac{\phi_i^{t}(J,J)}{\phi_i^{t+1}(I,J)} - 1 \right|_{max} < \epsilon(\phi) \quad . \tag{7}$$

If CI is 0 or blank, the calculation stops when both the above conditions are met, as well as the residue condition,

$$\left[\sum_i \sum_{I,J} R_i^2(I,J) \right]^{1/2} < \epsilon(R) \quad , \tag{8}$$

where R is the residue per one source neutron calculated from equations such as (1).

Columns 30 through 31, DI(I2): Diagonal symmetry indicator. If this number is +1, the code assumes that the problem has one diagonal symmetry axis passing through mesh point (1,1). A +2 designates two diagonal symmetry axes. A −1 for DI specifies mirror image symmetry, with the symmetry axis passing through mesh point (1,1). If DI is 0 or blank, then no diagonal symmetry axis exists for the problem.

Columns 32 through 33, LB(I2): Left boundary indicator. If LB is 0 or blank, the left boundary of the reactor is a zero flux boundary. If LB is +1, a symmetry boundary is assumed to exist midway between columns 1 and 2.

Columns 34 through 35, TB(I2): Top boundary indicator. If TB is 0 or blank, the top boundary of the reactor is a zero flux boundary. If this number is +1, a symmetry boundary is assumed to exist midway between rows 1 and 2.

Columns 36 through 37, RB(I2): Right boundary indicator. A 0 or blank for this number specifies a zero flux boundary at the right of the reactor. If this number is +1, a symmetry boundary exists midway between columns JMAX-1 and JMAX.

Columns 38 through 39, BB(I2): Bottom boundary indicator. Write 0 or leave blank to specify a zero flux boundary. Write +1 to specify a symmetry boundary midway between rows IMAX-1 and IMAX.

Columns 40 through 49, NORM FACTOR (E10.6): All the fluxes are multiplied by this number and divided by the total source for output.

Columns 50 through 55, $\epsilon(\lambda)$ (E6.3): Convergence criterion for λ convergence condition given by Eq. (6). A value of 10^{-5} is reasonable for this number.

Columns 56 through 61, $\epsilon(\phi)$ (E6.3): Convergence criterion for flux convergence condition given by Eq. (7). A value of 10^{-4} for this number will usually assure reasonable convergence.

Columns 62 through 67, $\epsilon(R)$ (E6.3): Convergence criterion for residue convergence condition given by Eq. (8). This number should be of the order of 10^{-5} for reasonable convergence.

Columns 68 through 72, β(F5.4): Extrapolated Liebmann coefficient. If this number is zero or blank, β is computed by the code. If this number is a positive number between 1 and 2, the value given is used.

<u>Control Card 2</u>. Columns 1 through 5, 6 through 10, 11 through 15, 16 through 20, 21 through 25, 26 through 30; XI_i(F5.4): The fraction of neutrons produced from fission that are born in group i. Note that

$$\sum_{i=1}^{K} XI_i = 1.0 \quad .$$

Columns 31 through 37, 38 through 44, 45 through 51, 52 through 58, 59 through 65, 66 through 72; B_i^2(E7.4): Constant buckling value or

group-dependent buckling values for slab geometry. If the constant buckling option was used (see above), the value is written in columns 31 through 37. The group-dependent buckling values are written in the appropriate columns.

Mesh Specification Cards. In columns 1 through 6, 7 through 9; 10 through 15, 16 through 18; etc., specify ΔY(E6.3) and the row number (I3) up to which this ΔY applies, going from top to bottom of the mesh. Use as many cards as are needed, with each card completely filled through column 72, except possibly the last card. The last number on these cards is equal to IMAX. Repeat as above, supplying values of ΔX(E6.3) and the column number (I3) up to which this ΔX applies, going from left to right of the mesh.

Region Specification Cards. The regions of the reactor are specified as rectangles. For each region specify the composition number (I3), top row number (I3), bottom row number (I3), left column number (I3), and right column number (I3). The compositions are numbered beginning with 1 (see below); however, more than one region may have the same composition number.

Composition Specification Cards. For each different composition number specified above, K composition specification cards are written, where K is the total number of groups. For each card the following numbers are specified.

Columns 1 through 3: Composition number (I3).

Columns 4 through 5: Group number (I2).

Columns 6 through 13, D(E8.5): Diffusion coefficient. Note that if $D = 0$, then $\Sigma_R = \nu\Sigma_f = 0$ and $\Sigma_A = C$. This specifies a rod group.

Columns 14 through 22, Σ_R(E9.6): Macroscopic removal cross section.

Columns 23 through 31, Σ_A(E9.6): Macroscopic absorption cross section.

Columns 32 through 40, $\nu\Sigma_f$(E9.6): ν times macroscopic fission cross section.

Columns 41 through 47, B^2(E7.4): Composition-dependent buckling.

Columns 48 through 52, 53 through 57, 58 through 62, 63 through 67, 68 through 72; f_l^i(F5.4): The fraction of neutrons removed from group i (the group number specified in columns 4 through 5) that enter group l

($i \neq l$) for this composition. The value of l goes from the smallest group number to the largest group number. Note that the number of f's specified is one less than the total number of groups, since no f is given for the group number specified in columns 4 through 5. Also, with reference to Fig. 4, the f's are always specified by beginning in column 48. For example, in specifying group one of a three-group problem, f_1 and f_2 (the f's are labeled f_1, f_2, f_3, f_4, f_5 in Fig. 4) would designate the fraction of removals from group one to groups two and three, respectively. For group two, f_1 and f_2 would be the fraction of removals from group two to groups one and three. In specifying group three, f_1 and f_2 would be the fraction of removals from group three to groups one and two.

The sum of the f's on each card must be 1.0 unless $\Sigma_R = 0$.

Operating Instructions

TWENTY GRAND was programmed to run under control of the IBM-7090 FORTRAN monitor system. A "job" consists of the program deck with the associated monitor control cards followed by the input data for as many cases to be run as desired. Two blank cards following the data deck will stop the calculation. The logical tape numbers used in the code are the following.

1. Tape 9: output
2. Tape 10: input
3. Tape 8: scratch tape needed only for source calculation or adjoint calculation.

One tape is used by the monitor for storage of the program chain links. This tape must be actual tape number B1.

Sample Problem

Figure 5 shows the diagram of the sample problem. It was run as a four-group problem in slab geometry. Figure 6 gives the output.

Note that mesh increments, not total distances, are supplied as input. With reference to Fig. 5, ΔX between columns 5 and 10 is 1 cm, whereas the distance from column 5 to column 10 is 5 cm.

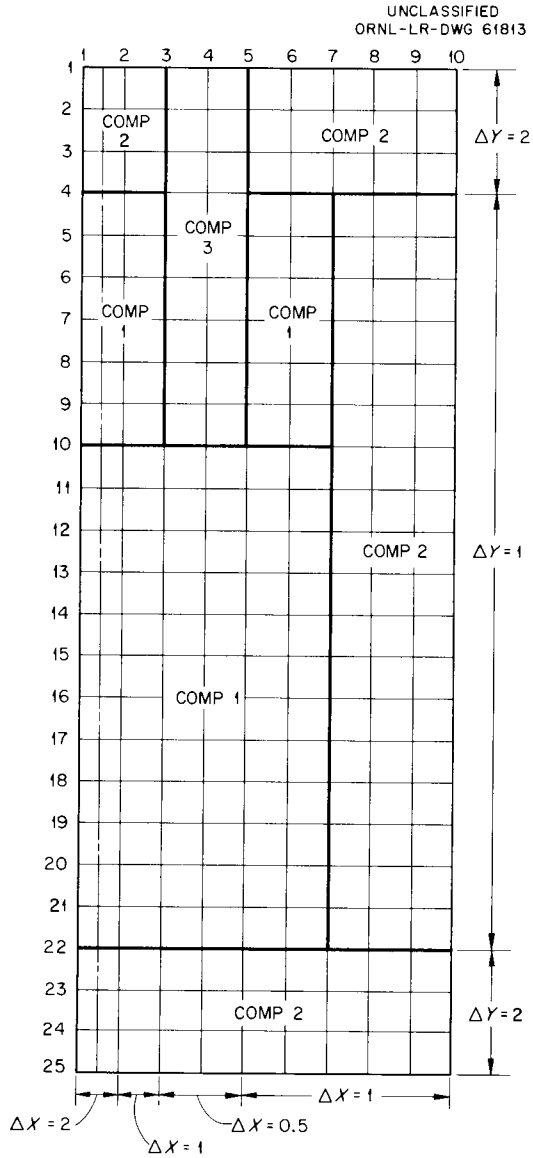

Fig. 5. Diagram of Sample Problem.

```
CODE TWENTY GRAND - SAMPLE PROBLEM

REACTOR SPECIFICATIONS

  25 ROWS    10 COLUMNS    8 REGIONS    3 COMPS    4 GROUPS    XY GEOM    B.C.(L,T,R,B)#1,0,0,1    N.F.# 1.00000E 00

  CHI(K)    0.6000    0.2000    0.1000    0.1000

MESH SPECIFICATIONS

   I  DELTA
   1  2.000    4  1.000   22  2.000   25

   J  DELTA
   1  2.000    2  1.000    3  0.500    5  1.000   10

DIMENSION SPECIFICATIONS

   I   DIST.
   2   2.000    3   4.000    4   6.000    5   7.000    6   8.000    7   9.000    8  10.000    9  11.000   10  12.000
  11  13.000   12  14.000   13  15.000   14  16.000   15  17.000   16  18.000   17  19.000   18  20.000   19  21.000
  20  22.000   21  23.000   22  24.000   23  26.000   24  28.000   25  30.000

   J   DIST.
   2   1.000    3   2.000    4   2.500    5   3.000    6   4.000    7   5.000    8   6.000    9   7.000   10   8.000
```

Fig. 6. Output for Sample Problem.

CODE TWENTY GRAND - SAMPLE PROBLEM

REGION SPECIFICATIONS

REG	IT	IB	JL	JR	CMP	GRP	U	SIGR	SIGA	NUSF	BSQ	F1	F2	F3	F4
1	1	4	1	3	2	1	1.210E 00	2.100E-03	2.100E-03	-0.	2.000E-03	0.	0.600	0.300	0.100
						2	1.220E 00	2.200E-03	2.200E-03	-0.	2.000E-03	-0.	0.	0.600	0.400
						3	1.230E 00	2.300E-03	2.300E-03	-0.	2.000E-03	-0.	0.400	0.	0.600
						4	1.240E 00	2.400E-03	2.400E-03	-0.	2.000E-03	-0.	0.500	0.500	0.
2	4	10	1	3	1	1	1.110E 00	1.100E-03	1.100E-03	2.100E-03	2.000E-03	0.	0.600	0.300	0.100
						2	1.120E 00	1.200E-03	1.200E-03	2.200E-03	2.000E-03	-0.	0.	0.600	0.400
						3	1.130E 00	1.300E-03	1.300E-03	2.300E-03	2.000E-03	-0.	0.400	0.	0.600
						4	1.140E 00	1.400E-03	1.400E-03	2.400E-03	2.000E-03	-0.	0.500	0.500	0.
3	1	10	3	5	3	1	1.310E 00	3.100E-03	3.100E-03	-0.	2.000E-03	0.	0.600	0.300	0.100
						2	0.	-0.	5.000E-02	-0.	2.000E-03	-0.	0.	-0.	-0.
						3	0.	-0.	5.000E-02	-0.	2.000E-03	-0.	-0.	0.	-0.
						4	1.340E 00	3.400E-03	4.100E-03	-0.	2.000E-03	-0.	0.500	0.500	0.
4	4	10	5	7	1	1	1.110E 00	1.100E-03	1.100E-03	2.100E-03	2.000E-03	0.	0.600	0.300	0.100
						2	1.120E 00	1.200E-03	1.200E-03	2.200E-03	2.000E-03	-0.	0.	0.600	0.400
						3	1.130E 00	1.300E-03	1.300E-03	2.300E-03	2.000E-03	-0.	0.400	0.	0.600
						4	1.140E 00	1.400E-03	1.400E-03	2.400E-03	2.000E-03	-0.	0.500	0.500	0.
5	1	4	5	10	2	1	1.210E 00	2.100E-03	2.100E-03	-0.	2.000E-03	0.	0.600	0.300	0.100
						2	1.220E 00	2.200E-03	2.200E-03	-0.	2.000E-03	-0.	0.	0.600	0.400
						3	1.230E 00	2.300E-03	2.300E-03	-0.	2.000E-03	-0.	0.400	0.	0.600
						4	1.240E 00	2.400E-03	2.400E-03	-0.	2.000E-03	-0.	0.500	0.500	0.
6	10	22	1	7	1	1	1.110E 00	1.100E-03	1.100E-03	2.100E-03	2.000E-03	0.	0.600	0.300	0.100
						2	1.120E 00	1.200E-03	1.200E-03	2.200E-03	2.000E-03	-0.	0.	0.600	0.400
						3	1.130E 00	1.300E-03	1.300E-03	2.300E-03	2.000E-03	-0.	0.400	0.	0.600
						4	1.140E 00	1.400E-03	1.400E-03	2.400E-03	2.000E-03	-0.	0.500	0.500	0.
7	4	22	7	10	2	1	1.210E 00	2.100E-03	2.100E-03	-0.	2.000E-03	0.	0.600	0.300	0.100
						2	1.220E 00	2.200E-03	2.200E-03	-0.	2.000E-03	-0.	0.	0.600	0.400
						3	1.230E 00	2.300E-03	2.300E-03	-0.	2.000E-03	-0.	0.400	0.	0.600
						4	1.240E 00	2.400E-03	2.400E-03	-0.	2.000E-03	-0.	0.500	0.500	0.
8	22	25	1	10	2	1	1.210E 00	2.100E-03	2.100E-03	-0.	2.000E-03	0.	0.600	0.300	0.100
						2	1.220E 00	2.200E-03	2.200E-03	-0.	2.000E-03	-0.	0.	0.600	0.400
						3	1.230E 00	2.300E-03	2.300E-03	-0.	2.000E-03	-0.	0.400	0.	0.600
						4	1.240E 00	2.400E-03	2.400E-03	-0.	2.000E-03	-0.	0.500	0.500	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

FLUX CALCULATION BEGINS BETA# 1.7364E 00

IT NO	FLUX CONVR	NU-CRIT CONVR	TOT RESIDUE	MAX RESIDUE	NU-CRITICAL
10	1.1404E-01	1.0000E 00	3.1558E-02	4.9995E-03	4.09722E 01
20	2.3571E-01	2.2999E-01	3.1345E-02	4.0834E-03	3.33112E 01
30	1.2156E-02	1.4841E-03	8.9851E-03	1.5777E-03	3.33607E 01
40	4.8044E-03	4.1302E-03	1.9210E-03	4.4730E-04	3.34990E 01
50	6.1990E-04	7.9259E-04	2.3835E-04	5.6123E-05	3.35256E 01
60	8.0511E-05	1.1065E-04	2.9666E-05	7.1194E-06	3.35293E 01
70	8.7619E-06	1.4238E-05	3.2847E-06	7.4762E-07	3.35298E 01
80	7.3016E-07	1.6242E-06	7.3943E-07	1.1271E-07	3.35298E 01

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

NO.IT.# 80 NU-CRIT# 3.35298E 01 N.F./(TOT PROD)# 8.25541E-03

GROUP 1 FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	4.134E-01	4.134E-01	3.873E-01	3.699E-01	3.491E-01	2.940E-01	2.287E-01	1.562E-01	7.921E-02	0.
3	9.051E-01	9.051E-01	8.446E-01	8.049E-01	7.579E-01	6.351E-01	4.913E-01	3.341E-01	1.689E-01	0.
4	1.578E 00	1.578E 00	1.454E 00	1.378E 00	1.294E 00	1.075E 00	8.182E-01	5.512E-01	2.770E-01	0.
5	2.027E 00	2.027E 00	1.838E 00	1.732E 00	1.629E 00	1.353E 00	1.012E 00	6.749E-01	3.376E-01	0.
6	2.453E 00	2.453E 00	2.215E 00	2.085E 00	1.960E 00	1.625E 00	1.209E 00	8.026E-01	4.003E-01	0.
7	2.859E 00	2.859E 00	2.582E 00	2.430E 00	2.285E 00	1.893E 00	1.405E 00	9.304E-01	4.632E-01	0.
8	3.248E 00	3.248E 00	2.937E 00	2.766E 00	2.602E 00	2.155E 00	1.597E 00	1.055E 00	5.248E-01	0.
9	3.620E 00	3.620E 00	3.284E 00	3.096E 00	2.912E 00	2.409E 00	1.782E 00	1.175E 00	5.835E-01	0.
10	3.972E 00	3.972E 00	3.635E 00	3.427E 00	3.212E 00	2.650E 00	1.954E 00	1.285E 00	6.375E-01	0.
11	4.287E 00	4.287E 00	3.971E 00	3.752E 00	3.495E 00	2.867E 00	2.106E 00	1.382E 00	6.847E-01	0.
12	4.539E 00	4.539E 00	4.219E 00	3.988E 00	3.713E 00	3.040E 00	2.228E 00	1.461E 00	7.229E-01	0.
13	4.715E 00	4.715E 00	4.388E 00	4.149E 00	3.864E 00	3.162E 00	2.316E 00	1.517E 00	7.504E-01	0.
14	4.813E 00	4.813E 00	4.481E 00	4.238E 00	3.947E 00	3.229E 00	2.365E 00	1.548E 00	7.659E-01	0.
15	4.829E 00	4.829E 00	4.497E 00	4.254E 00	3.962E 00	3.242E 00	2.374E 00	1.555E 00	7.688E-01	0.
16	4.763E 00	4.763E 00	4.437E 00	4.197E 00	3.910E 00	3.200E 00	2.344E 00	1.535E 00	7.592E-01	0.
17	4.617E 00	4.617E 00	4.301E 00	4.070E 00	3.792E 00	3.105E 00	2.275E 00	1.490E 00	7.373E-01	0.
18	4.392E 00	4.392E 00	4.093E 00	3.873E 00	3.609E 00	2.958E 00	2.169E 00	1.422E 00	7.037E-01	0.
19	4.092E 00	4.092E 00	3.814E 00	3.611E 00	3.367E 00	2.762E 00	2.029E 00	1.331E 00	6.597E-01	0.
20	3.719E 00	3.719E 00	3.470E 00	3.286E 00	3.066E 00	2.521E 00	1.858E 00	1.223E 00	6.073E-01	0.
21	3.279E 00	3.279E 00	3.062E 00	2.904E 00	2.713E 00	2.240E 00	1.664E 00	1.103E 00	5.496E-01	0.
22	2.776E 00	2.776E 00	2.597E 00	2.466E 00	2.309E 00	1.922E 00	1.460E 00	9.799E-01	4.915E-01	0.
23	2.072E 00	2.072E 00	1.944E 00	1.851E 00	1.739E 00	1.465E 00	1.138E 00	7.754E-01	3.926E-01	0.
24	1.753E 00	1.753E 00	1.648E 00	1.572E 00	1.479E 00	1.252E 00	9.789E-01	6.712E-01	3.411E-01	0.
25	1.753E 00	1.753E 00	1.648E 00	1.572E 00	1.479E 00	1.252E 00	9.789E-01	6.712E-01	3.411E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 2 FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	2.589E-01	2.589E-01	2.511E-01	0.	3.160E-02	3.100E-02	2.677E-02	1.958E-02	1.032E-02	0.
3	5.421E-01	5.421E-01	5.257E-01	0.	7.740E-02	7.570E-02	6.489E-02	4.710E-02	2.469E-02	0.
4	8.759E-01	8.759E-01	8.484E-01	0.	1.602E-01	1.553E-01	1.300E-01	9.244E-02	4.789E-02	0.
5	1.070E 00	1.070E 00	1.035E 00	0.	2.297E-01	2.212E-01	1.799E-01	1.254E-01	6.437E-02	0.
6	1.239E 00	1.239E 00	1.197E 00	0.	3.073E-01	2.951E-01	2.381E-01	1.647E-01	8.413E-02	0.
7	1.376E 00	1.376E 00	1.329E 00	0.	4.012E-01	3.834E-01	3.071E-01	2.112E-01	1.074E-01	0.
8	1.478E 00	1.478E 00	1.424E 00	0.	5.240E-01	4.942E-01	3.901E-01	2.656E-01	1.341E-01	0.
9	1.541E 00	1.541E 00	1.469E 00	0.	7.039E-01	6.375E-01	4.884E-01	3.270E-01	1.636E-01	0.
10	1.569E 00	1.569E 00	1.428E 00	1.244E 00	1.022E 00	8.154E-01	5.954E-01	3.905E-01	1.936E-01	0.
11	1.603E 00	1.603E 00	1.454E 00	1.337E 00	1.205E 00	9.518E-01	6.864E-01	4.467E-01	2.204E-01	0.
12	1.644E 00	1.644E 00	1.508E 00	1.410E 00	1.297E 00	1.040E 00	7.529E-01	4.900E-01	2.416E-01	0.
13	1.677E 00	1.677E 00	1.550E 00	1.459E 00	1.351E 00	1.095E 00	7.964E-01	5.196E-01	2.565E-01	0.
14	1.695E 00	1.695E 00	1.572E 00	1.484E 00	1.379E 00	1.123E 00	8.202E-01	5.365E-01	2.651E-01	0.
15	1.690E 00	1.690E 00	1.572E 00	1.485E 00	1.382E 00	1.129E 00	8.269E-01	5.418E-01	2.681E-01	0.
16	1.662E 00	1.662E 00	1.547E 00	1.463E 00	1.362E 00	1.115E 00	8.181E-01	5.368E-01	2.658E-01	0.
17	1.609E 00	1.609E 00	1.499E 00	1.418E 00	1.321E 00	1.083E 00	7.953E-01	5.223E-01	2.588E-01	0.
18	1.530E 00	1.530E 00	1.426E 00	1.350E 00	1.258E 00	1.032E 00	7.594E-01	4.993E-01	2.476E-01	0.
19	1.428E 00	1.428E 00	1.331E 00	1.261E 00	1.176E 00	9.660E-01	7.119E-01	4.689E-01	2.328E-01	0.
20	1.302E 00	1.302E 00	1.215E 00	1.151E 00	1.074E 00	8.849E-01	6.544E-01	4.324E-01	2.151E-01	0.
21	1.154E 00	1.154E 00	1.078E 00	1.023E 00	9.558E-01	7.907E-01	5.894E-01	3.918E-01	1.957E-01	0.
22	9.863E-01	9.863E-01	9.230E-01	8.767E-01	8.211E-01	6.844E-01	5.211E-01	3.506E-01	1.761E-01	0.
23	7.505E-01	7.505E-01	7.044E-01	6.708E-01	6.305E-01	5.314E-01	4.130E-01	2.818E-01	1.428E-01	0.
24	6.431E-01	6.431E-01	6.047E-01	5.765E-01	5.428E-01	4.597E-01	3.595E-01	2.466E-01	1.253E-01	0.
25	6.431E-01	6.431E-01	6.047E-01	5.765E-01	5.428E-01	4.597E-01	3.595E-01	2.466E-01	1.253E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 3 FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	1.340E-01	1.340E-01	1.300E-01	0.	1.634E-02	1.603E-02	1.384E-02	1.012E-02	5.335E-03	0.
3	2.795E-01	2.795E-01	2.711E-01	0.	3.984E-02	3.896E-02	3.340E-02	2.425E-02	1.272E-02	0.
4	4.489E-01	4.489E-01	4.350E-01	0.	8.186E-02	7.942E-02	6.651E-02	4.737E-02	2.456E-02	0.
5	5.467E-01	5.467E-01	5.288E-01	0.	1.170E-01	1.127E-01	9.184E-02	6.413E-02	3.295E-02	0.
6	6.315E-01	6.315E-01	6.105E-01	0.	1.563E-01	1.501E-01	1.214E-01	8.412E-02	4.301E-02	0.
7	7.006E-01	7.006E-01	6.769E-01	0.	2.039E-01	1.949E-01	1.564E-01	1.078E-01	5.484E-02	0.
8	7.514E-01	7.514E-01	7.243E-01	0.	2.663E-01	2.512E-01	1.986E-01	1.354E-01	6.847E-02	0.
9	7.825E-01	7.825E-01	7.465E-01	0.	3.575E-01	3.239E-01	2.486E-01	1.667E-01	8.350E-02	0.
10	7.962E-01	7.962E-01	7.246E-01	6.312E-01	5.189E-01	4.142E-01	3.029E-01	1.990E-01	9.875E-02	0.
11	8.132E-01	8.132E-01	7.376E-01	6.783E-01	6.113E-01	4.833E-01	3.492E-01	2.276E-01	1.124E-01	0.
12	8.336E-01	8.336E-01	7.647E-01	7.152E-01	6.581E-01	5.282E-01	3.829E-01	2.496E-01	1.232E-01	0.
13	8.505E-01	8.505E-01	7.861E-01	7.399E-01	6.856E-01	5.557E-01	4.051E-01	2.647E-01	1.308E-01	0.
14	8.593E-01	8.593E-01	7.974E-01	7.527E-01	6.995E-01	5.702E-01	4.173E-01	2.734E-01	1.353E-01	0.
15	8.573E-01	8.573E-01	7.973E-01	7.536E-01	7.014E-01	5.735E-01	4.208E-01	2.762E-01	1.368E-01	0.
16	8.434E-01	8.434E-01	7.852E-01	7.427E-01	6.918E-01	5.667E-01	4.166E-01	2.738E-01	1.357E-01	0.
17	8.169E-01	8.169E-01	7.610E-01	7.202E-01	6.712E-01	5.506E-01	4.052E-01	2.666E-01	1.323E-01	0.
18	7.778E-01	7.778E-01	7.251E-01	6.864E-01	6.401E-01	5.256E-01	3.874E-01	2.552E-01	1.267E-01	0.
19	7.267E-01	7.267E-01	6.778E-01	6.420E-01	5.989E-01	4.925E-01	3.637E-01	2.400E-01	1.193E-01	0.
20	6.639E-01	6.639E-01	6.198E-01	5.874E-01	5.485E-01	4.521E-01	3.350E-01	2.217E-01	1.104E-01	0.
21	5.905E-01	5.905E-01	5.519E-01	5.235E-01	4.895E-01	4.053E-01	3.026E-01	2.015E-01	1.007E-01	0.
22	5.074E-01	5.074E-01	4.749E-01	4.511E-01	4.226E-01	3.525E-01	2.687E-01	1.810E-01	9.097E-02	0.
23	3.900E-01	3.900E-01	3.661E-01	3.486E-01	3.277E-01	2.763E-01	2.149E-01	1.467E-01	7.433E-02	0.
24	3.363E-01	3.363E-01	3.162E-01	3.016E-01	2.839E-01	2.405E-01	1.881E-01	1.291E-01	6.561E-02	0.
25	3.363E-01	3.363E-01	3.162E-01	3.016E-01	2.839E-01	2.405E-01	1.881E-01	1.291E-01	6.561E-02	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 4 FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	7.159E-02	7.159E-02	6.689E-02	6.377E-02	.010E-02	5.054E-02	3.929E-02	2.683E-02	1.360E-02	0.
3	1.558E-01	1.558E-01	1.450E-01	1.380E-01	1.298E-01	1.087E-01	8.406E-02	5.716E-02	2.890E-02	0.
4	2.689E-01	2.689E-01	2.474E-01	2.344E-01	2.199E-01	1.826E-01	1.392E-01	9.364E-02	4.719E-02	0.
5	3.433E-01	3.433E-01	3.113E-01	2.933E-01	2.758E-01	2.290E-01	1.716E-01	1.147E-01	5.740E-02	0.
6	4.141E-01	4.141E-01	3.741E-01	3.521E-01	3.310E-01	2.745E-01	2.047E-01	1.361E-01	6.797E-02	0.
7	4.818E-01	4.818E-01	4.353E-01	4.097E-01	3.852E-01	3.193E-01	2.376E-01	1.576E-01	7.858E-02	0.
8	5.466E-01	5.466E-01	4.945E-01	4.658E-01	4.381E-01	3.632E-01	2.698E-01	1.787E-01	8.897E-02	0.
9	6.086E-01	6.086E-01	5.525E-01	5.208E-01	4.899E-01	4.057E-01	3.008E-01	1.988E-01	9.889E-02	0.
10	6.672E-01	6.672E-01	6.110E-01	5.761E-01	5.401E-01	4.461E-01	3.298E-01	2.175E-01	1.080E-01	0.
11	7.198E-01	7.198E-01	6.670E-01	6.303E-01	5.874E-01	4.825E-01	3.554E-01	2.339E-01	1.160E-01	0.
12	7.618E-01	7.618E-01	7.083E-01	6.698E-01	6.239E-01	5.115E-01	3.761E-01	2.472E-01	1.225E-01	0.
13	7.914E-01	7.914E-01	7.367E-01	6.969E-01	6.492E-01	5.321E-01	3.910E-01	2.568E-01	1.272E-01	0.
14	8.079E-01	8.079E-01	7.524E-01	7.119E-01	6.633E-01	5.436E-01	3.994E-01	2.622E-01	1.299E-01	0.
15	8.110E-01	8.110E-01	7.555E-01	7.149E-01	6.662E-01	5.461E-01	4.012E-01	2.634E-01	1.305E-01	0.
16	8.006E-01	8.006E-01	7.460E-01	7.060E-01	6.579E-01	5.395E-01	3.965E-01	2.604E-01	1.290E-01	0.
17	7.769E-01	7.769E-01	7.241E-01	6.853E-01	6.388E-01	5.240E-01	3.853E-01	2.531E-01	1.254E-01	0.
18	7.403E-01	7.403E-01	6.902E-01	6.534E-01	6.092E-01	5.000E-01	3.679E-01	2.419E-01	1.200E-01	0.
19	6.913E-01	6.913E-01	6.448E-01	6.106E-01	5.696E-01	4.681E-01	3.450E-01	2.271E-01	1.128E-01	0.
20	6.307E-01	6.307E-01	5.886E-01	5.578E-01	5.207E-01	4.288E-01	3.171E-01	2.094E-01	1.042E-01	0.
21	5.591E-01	5.591E-01	5.224E-01	4.955E-01	4.632E-01	3.831E-01	2.855E-01	1.897E-01	9.472E-02	0.
22	4.776E-01	4.776E-01	4.470E-01	4.245E-01	3.976E-01	3.314E-01	2.523E-01	1.697E-01	8.521E-02	0.
23	3.628E-01	3.628E-01	3.405E-01	3.242E-01	3.047E-01	2.568E-01	1.996E-01	1.362E-01	6.899E-02	0.
24	3.105E-01	3.105E-01	2.920E-01	2.784E-01	2.621E-01	2.219E-01	1.735E-01	1.190E-01	6.051E-02	0.
25	3.105E-01	3.105E-01	2.920E-01	2.784E-01	2.621E-01	2.219E-01	1.735E-01	1.190E-01	6.051E-02	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP ABSORPTIONS

GROUP-ONE	GROUP-TWO	GROUP-THREE	GROUP-FOUR	TOTAL
6.07368E-01	9.63540E-01	5.00976E-01	1.26401E-01	2.19828E 00

GROUP PRODUCTIONS

GROUP-ONE	GROUP-TWO	GROUP-THREE	GROUP-FOUR	TOTAL
5.67242E-01	2.11147E-01	1.12267E-01	1.09344E-01	10.00000E-01

BOUNDARY LEAKAGES TOTAL# 2.97494E 01

	GROUP-ONE	GROUP-TWO	GROUP-THREE	GROUP-FOUR	TOTAL
LFT	0.	0.	0.	0.	0.
TOP	1.29829E 00	3.76649E-01	1.96470E-01	2.29348E-01	2.10076E 00
RIT	1.66651E 01	5.31529E 00	2.74834E 00	2.91989E 00	2.76486E 01
BOT	0.	0.	0.	0.	0.

AXIAL LEAKAGES

GROUP-ONE	GROUP-TWO	GROUP-THREE	GROUP-FOUR	TOTAL
9.39804E-01	3.15877E-01	1.62741E-01	1.63779E-01	1.58220E 00

REGION ABSORPTIONS

REG	GROUP-ONE	GROUP-TWO	GROUP-THREE	GROUP-FOUR	TOTAL	REG.VOLUME
1	1.73908E-02	1.08193E-02	5.82429E-03	3.41023E-03	3.74447E-02	1.20000E 01
2	3.64899E-02	1.88231E-02	1.03819E-02	7.82888E-03	7.35238E-02	1.20000E 01
3	5.65317E-02	7.57401E-01	3.88504E-01	1.26460E-02	1.21508E 00	1.20000E 01
4	2.45458E-02	5.85440E-03	3.22564E-03	5.27187E-03	3.88977E-02	1.20000E 01
5	1.94245E-02	2.67255E-03	1.43583E-03	3.79407E-03	2.73269E-02	3.00000E 01
6	2.36091E-01	9.04936E-02	4.98474E-02	5.06833E-02	4.27116E-01	6.00000E 01
7	1.05441E-01	3.51701E-02	1.87707E-02	2.04572E-02	1.79839E-01	5.40000E 01
8	1.11453E-01	4.23053E-02	2.29861E-02	2.23089E-02	1.99053E-01	4.00000E 01

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

SOURCE(I,J)

	1		2		3		4		5	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
3	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
4	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	6.919E-03	6.919E-03	6.513E-03	-0.	-0.	-0.	-0.	3.785E-03
5	0.	0.	8.693E-03	8.693E-03	8.099E-03	-0.	-0.	-0.	-0.	4.858E-03
	0.	0.	8.693E-03	8.693E-03	8.099E-03	-0.	-0.	-0.	-0.	4.858E-03
6	0.	0.	1.032E-02	1.032E-02	9.588E-03	-0.	-0.	-0.	-0.	5.947E-03
	0.	0.	1.032E-02	1.032E-02	9.588E-03	-0.	-0.	-0.	-0.	5.947E-03
7	0.	0.	1.180E-02	1.180E-02	1.095E-02	-0.	-0.	-0.	-0.	7.074E-03
	0.	0.	1.180E-02	1.180E-02	1.095E-02	-0.	-0.	-0.	-0.	7.074E-03
8	0.	0.	1.311E-02	1.311E-02	1.215E-02	-0.	-0.	-0.	-0.	8.281E-03
	0.	0.	1.311E-02	1.311E-02	1.215E-02	-0.	-0.	-0.	-0.	8.281E-03
9	0.	0.	1.425E-02	1.425E-02	1.317E-02	-0.	-0.	-0.	-0.	9.661E-03
	0.	0.	1.425E-02	1.425E-02	1.317E-02	-0.	-0.	-0.	-0.	9.661E-03
10	0.	0.	1.522E-02	1.522E-02	1.391E-02	-0.	-0.	-0.	-0.	1.148E-02
	0.	0.	1.522E-02	1.522E-02	1.391E-02	1.391E-02	1.277E-02	1.277E-02	1.148E-02	1.148E-02
11	0.	0.	1.613E-02	1.613E-02	1.484E-02	1.484E-02	1.389E-02	1.389E-02	1.281E-02	1.281E-02
	0.	0.	1.613E-02	1.613E-02	1.484E-02	1.484E-02	1.389E-02	1.389E-02	1.281E-02	1.281E-02
12	0.	0.	1.689E-02	1.689E-02	1.564E-02	1.564E-02	1.473E-02	1.473E-02	1.366E-02	1.366E-02
	0.	0.	1.689E-02	1.689E-02	1.564E-02	1.564E-02	1.473E-02	1.473E-02	1.366E-02	1.366E-02
13	0.	0.	1.745E-02	1.745E-02	1.620E-02	1.620E-02	1.530E-02	1.530E-02	1.422E-02	1.422E-02
	0.	0.	1.745E-02	1.745E-02	1.620E-02	1.620E-02	1.530E-02	1.530E-02	1.422E-02	1.422E-02
14	0.	0.	1.775E-02	1.775E-02	1.651E-02	1.651E-02	1.560E-02	1.560E-02	1.452E-02	1.452E-02
	0.	0.	1.775E-02	1.775E-02	1.651E-02	1.651E-02	1.560E-02	1.560E-02	1.452E-02	1.452E-02

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

SOURCE(I,J)

	1		2		3		4		5	
15	0.	0.	1.778E-02	1.778E-02	1.655E-02	1.655E-02	1.565E-02	1.565E-02	1.457E-02	1.457E-02
	0.	0.	1.778E-02	1.778E-02	1.655E-02	1.655E-02	1.565E-02	1.565E-02	1.457E-02	1.457E-02
16	0.	0.	1.752E-02	1.752E-02	1.632E-02	1.632E-02	1.544E-02	1.544E-02	1.438E-02	1.438E-02
	0.	0.	1.752E-02	1.752E-02	1.632E-02	1.632E-02	1.544E-02	1.544E-02	1.438E-02	1.438E-02
17	0.	0.	1.698E-02	1.698E-02	1.582E-02	1.582E-02	1.497E-02	1.497E-02	1.395E-02	1.395E-02
	0.	0.	1.698E-02	1.698E-02	1.582E-02	1.582E-02	1.497E-02	1.497E-02	1.395E-02	1.395E-02
18	0.	0.	1.616E-02	1.616E-02	1.506E-02	1.506E-02	1.425E-02	1.425E-02	1.328E-02	1.328E-02
	0.	0.	1.616E-02	1.616E-02	1.506E-02	1.506E-02	1.425E-02	1.425E-02	1.328E-02	1.328E-02
19	0.	0.	1.506E-02	1.506E-02	1.405E-02	1.405E-02	1.330E-02	1.330E-02	1.240E-02	1.240E-02
	0.	0.	1.506E-02	1.506E-02	1.405E-02	1.405E-02	1.330E-02	1.330E-02	1.240E-02	1.240E-02
20	0.	0.	1.371E-02	1.371E-02	1.280E-02	1.280E-02	1.212E-02	1.212E-02	1.131E-02	1.131E-02
	0.	0.	1.371E-02	1.371E-02	1.280E-02	1.280E-02	1.212E-02	1.212E-02	1.131E-02	1.131E-02
21	0.	0.	1.212E-02	1.212E-02	1.133E-02	1.133E-02	1.074E-02	1.074E-02	1.004E-02	1.004E-02
	0.	0.	1.212E-02	1.212E-02	1.133E-02	1.133E-02	1.074E-02	1.074E-02	1.004E-02	1.004E-02
22	0.	0.	1.031E-02	1.031E-02	9.650E-03	9.650E-03	9.163E-03	9.163E-03	8.581E-03	8.581E-03
	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
23	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
24	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
	0.	0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

SOURCE(I,J)

	6		7		8		9		10	
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
3	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
4	-0.	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
	3.219E-03	3.219E-03	2.491E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
5	4.136E-03	4.136E-03	3.144E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	4.136E-03	4.136E-03	3.144E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
6	5.066E-03	5.066E-03	3.834E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	5.066E-03	5.066E-03	3.834E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
7	6.034E-03	6.034E-03	4.557E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	6.034E-03	6.034E-03	4.557E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
8	7.063E-03	7.063E-03	5.317E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	7.063E-03	7.063E-03	5.317E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
9	8.181E-03	8.181E-03	6.110E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	8.181E-03	8.181E-03	6.110E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
10	9.383E-03	9.383E-03	6.901E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	9.383E-03	9.383E-03	6.901E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
11	1.038E-02	1.038E-02	7.588E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	1.038E-02	1.038E-02	7.588E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
12	1.111E-02	1.111E-02	8.120E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	1.111E-02	1.111E-02	8.120E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
13	1.160E-02	1.160E-02	8.485E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	1.160E-02	1.160E-02	8.485E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
14	1.187E-02	1.187E-02	8.689E-03	-0.	-0.	-0.	-0.	-0.	0.	0.
	1.187E-02	1.187E-02	8.689E-03	-0.	-0.	-0.	-0.	-0.	0.	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

SOURCE(I,J)

	6		7		8		9		10
15	1.192E-02	1.192E-02	8.736E-03	-0.	-0.	-0.	-0.	0.	0.
	1.192E-02	1.192E-02	8.736E-03	-0.	-0.	-0.	-0.	0.	0.
16	1.177E-02	1.177E-02	8.632E-03	-0.	-0.	-0.	-0.	0.	0.
	1.177E-02	1.177E-02	8.632E-03	-0.	-0.	-0.	-0.	0.	0.
17	1.143E-02	1.143E-02	8.384E-03	-0.	-0.	-0.	-0.	0.	0.
	1.143E-02	1.143E-02	8.384E-03	-0.	-0.	-0.	-0.	0.	0.
18	1.089E-02	1.089E-02	7.999E-03	-0.	-0.	-0.	-0.	0.	0.
	1.089E-02	1.089E-02	7.999E-03	-0.	-0.	-0.	-0.	0.	0.
19	1.018E-02	1.018E-02	7.490E-03	-0.	-0.	-0.	-0.	0.	0.
	1.018E-02	1.018E-02	7.490E-03	-0.	-0.	-0.	-0.	0.	0.
20	9.311E-03	9.311E-03	6.873E-03	-0.	-0.	-0.	-0.	0.	0.
	9.311E-03	9.311E-03	6.873E-03	-0.	-0.	-0.	-0.	0.	0.
21	8.296E-03	8.296E-03	6.173E-03	-0.	-0.	-0.	-0.	0.	0.
	8.296E-03	8.296E-03	6.173E-03	-0.	-0.	-0.	-0.	0.	0.
22	7.147E-03	7.147E-03	5.436E-03	-0.	-0.	-0.	-0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
23	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
24	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
	-0.	-0.	-0.	-0.	-0.	-0.	-0.	0.	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

ADJOINT FLUX CALCULATION BEGINS

IT NO	FLUX CONVR	NU-CRIT CONVR	TOT RESIDUE	MAX RESIDUE	NU-CRITICAL
10	1.4093E-01	0.	1.8226E 00	1.6782E-01	1.00000E 00
20	3.9511E-02	0.	2.7536E-01	3.5659E-02	1.00000E 00
30	5.5441E-03	0.	2.9506E-02	3.3140E-03	1.00000E 00
40	6.6382E-04	0.	3.5094E-03	6.2329E-04	1.00000E 00
50	1.0085E-04	0.	6.5316E-04	1.1430E-04	1.00000E 00
60	1.9238E-05	0.	1.4470E-04	2.2833E-05	1.00000E 00
70	3.9488E-06	0.	4.0099E-05	5.1118E-06	1.00000E 00

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

NO.IT.# 70 NU-CRIT# 1.00000E 00 N.F./(TOT PROD)# 5.71744E-01

GROUP 1 ADJOINT FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	1.610E-01	1.610E-01	1.506E-01	1.437E-01	1.355E-01	1.140E-01	8.866E-02	6.055E-02	3.069E-02	0.
3	3.513E-01	3.513E-01	3.273E-01	3.117E-01	2.933E-01	2.457E-01	1.900E-01	1.292E-01	6.532E-02	0.
4	6.088E-01	6.088E-01	5.605E-01	5.312E-01	4.986E-01	4.141E-01	3.154E-01	2.126E-01	1.069E-01	0.
5	7.795E-01	7.795E-01	7.068E-01	6.661E-01	6.266E-01	5.203E-01	3.896E-01	2.600E-01	1.301E-01	0.
6	9.415E-01	9.415E-01	8.506E-01	8.008E-01	7.530E-01	6.244E-01	4.651E-01	3.090E-01	1.542E-01	0.
7	1.097E 00	1.097E 00	9.905E-01	9.325E-01	8.769E-01	7.268E-01	5.401E-01	3.580E-01	1.784E-01	0.
8	1.245E 00	1.245E 00	1.126E 00	1.061E 00	9.980E-01	8.271E-01	6.136E-01	4.059E-01	2.020E-01	0.
9	1.387E 00	1.387E 00	1.259E 00	1.187E 00	1.116E 00	9.243E-01	6.842E-01	4.518E-01	2.246E-01	0.
10	1.521E 00	1.521E 00	1.393E 00	1.313E 00	1.231E 00	1.016E 00	7.502E-01	4.943E-01	2.454E-01	0.
11	1.642E 00	1.642E 00	1.521E 00	1.437E 00	1.339E 00	1.099E 00	8.086E-01	5.315E-01	2.635E-01	0.
12	1.738E 00	1.738E 00	1.616E 00	1.528E 00	1.423E 00	1.166E 00	8.558E-01	5.617E-01	2.783E-01	0.
13	1.806E 00	1.806E 00	1.681E 00	1.590E 00	1.481E 00	1.212E 00	8.894E-01	5.834E-01	2.889E-01	0.
14	1.844E 00	1.844E 00	1.717E 00	1.624E 00	1.513E 00	1.239E 00	9.085E-01	5.958E-01	2.950E-01	0.
15	1.850E 00	1.850E 00	1.723E 00	1.630E 00	1.519E 00	1.244E 00	9.124E-01	5.983E-01	2.962E-01	0.
16	1.826E 00	1.826E 00	1.701E 00	1.610E 00	1.500E 00	1.229E 00	9.013E-01	5.911E-01	2.927E-01	0.
17	1.771E 00	1.771E 00	1.650E 00	1.562E 00	1.455E 00	1.193E 00	8.753E-01	5.743E-01	2.844E-01	0.
18	1.686E 00	1.686E 00	1.572E 00	1.488E 00	1.387E 00	1.137E 00	8.353E-01	5.485E-01	2.718E-01	0.
19	1.573E 00	1.573E 00	1.467E 00	1.389E 00	1.295E 00	1.063E 00	7.823E-01	5.144E-01	2.551E-01	0.
20	1.433E 00	1.433E 00	1.337E 00	1.267E 00	1.182E 00	9.727E-01	7.180E-01	4.735E-01	2.353E-01	0.
21	1.267E 00	1.267E 00	1.184E 00	1.122E 00	1.049E 00	8.669E-01	6.450E-01	4.281E-01	2.136E-01	0.
22	1.078E 00	1.078E 00	1.009E 00	9.577E-01	8.968E-01	7.470E-01	5.681E-01	3.817E-01	1.916E-01	0.
23	8.124E-01	8.124E-01	7.625E-01	7.260E-01	6.822E-01	5.748E-01	4.466E-01	3.046E-01	1.542E-01	0.
24	6.920E-01	6.920E-01	6.506E-01	6.203E-01	5.839E-01	4.944E-01	3.865E-01	2.651E-01	1.347E-01	0.
25	6.920E-01	6.920E-01	6.506E-01	6.203E-01	5.839E-01	4.944E-01	3.865E-01	2.651E-01	1.347E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 2 ADJOINT FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	2.977E-01	2.977E-01	2.887E-01	0.	3.474E-02	3.409E-02	2.947E-02	2.156E-02	1.136E-02	0.
3	6.241E-01	6.241E-01	6.052E-01	0.	8.622E-02	8.435E-02	7.231E-02	5.247E-02	2.750E-02	0.
4	1.011E 00	1.011E 00	9.791E-01	0.	1.816E-01	1.760E-01	1.470E-01	1.044E-01	5.403E-02	0.
5	1.237E 00	1.237E 00	1.196E 00	0.	2.625E-01	2.526E-01	2.049E-01	1.424E-01	7.300E-02	0.
6	1.433E 00	1.433E 00	1.385E 00	0.	3.525E-01	3.382E-01	2.722E-01	1.878E-01	9.578E-02	0.
7	1.592E 00	1.592E 00	1.538E 00	0.	4.612E-01	4.405E-01	3.521E-01	2.415E-01	1.226E-01	0.
8	1.710E 00	1.710E 00	1.648E 00	0.	6.035E-01	5.688E-01	4.481E-01	3.043E-01	1.535E-01	0.
9	1.783E 00	1.783E 00	1.700E 00	0.	8.119E-01	7.348E-01	5.618E-01	3.753E-01	1.876E-01	0.
10	1.815E 00	1.815E 00	1.651E 00	1.438E 00	1.181E 00	9.408E-01	6.856E-01	4.488E-01	2.222E-01	0.
11	1.854E 00	1.854E 00	1.681E 00	1.545E 00	1.392E 00	1.099E 00	7.908E-01	5.136E-01	2.531E-01	0.
12	1.901E 00	1.901E 00	1.743E 00	1.630E 00	1.499E 00	1.201E 00	8.676E-01	5.636E-01	2.776E-01	0.
13	1.939E 00	1.939E 00	1.792E 00	1.686E 00	1.561E 00	1.263E 00	9.177E-01	5.977E-01	2.947E-01	0.
14	1.959E 00	1.959E 00	1.817E 00	1.714E 00	1.592E 00	1.296E 00	9.450E-01	6.170E-01	3.046E-01	0.
15	1.953E 00	1.953E 00	1.815E 00	1.715E 00	1.595E 00	1.302E 00	9.523E-01	6.229E-01	3.079E-01	0.
16	1.919E 00	1.919E 00	1.786E 00	1.689E 00	1.572E 00	1.286E 00	9.418E-01	6.168E-01	3.051E-01	0.
17	1.856E 00	1.856E 00	1.729E 00	1.635E 00	1.523E 00	1.247E 00	9.147E-01	5.997E-01	2.969E-01	0.
18	1.764E 00	1.764E 00	1.644E 00	1.556E 00	1.450E 00	1.188E 00	8.726E-01	5.727E-01	2.837E-01	0.
19	1.643E 00	1.643E 00	1.532E 00	1.451E 00	1.353E 00	1.110E 00	8.168E-01	5.370E-01	2.663E-01	0.
20	1.495E 00	1.495E 00	1.395E 00	1.322E 00	1.233E 00	1.015E 00	7.493E-01	4.942E-01	2.456E-01	0.
21	1.322E 00	1.322E 00	1.234E 00	1.171E 00	1.094E 00	9.042E-01	6.729E-01	4.466E-01	2.228E-01	0.
22	1.124E 00	1.124E 00	1.052E 00	9.987E-01	9.352E-01	7.789E-01	5.924E-01	3.981E-01	1.998E-01	0.
23	8.468E-01	8.468E-01	7.947E-01	7.566E-01	7.111E-01	5.991E-01	4.654E-01	3.174E-01	1.608E-01	0.
24	7.210E-01	7.210E-01	6.779E-01	6.463E-01	6.084E-01	5.151E-01	4.027E-01	2.762E-01	1.404E-01	0.
25	7.210E-01	7.210E-01	6.779E-01	6.463E-01	6.084E-01	5.151E-01	4.027E-01	2.762E-01	1.404E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 3 ADJOINT FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	3.079E-01	3.079E-01	2.987E-01	0.	3.622E-02	3.554E-02	3.071E-02	2.246E-02	1.184E-02	0.
3	6.456E-01	6.456E-01	6.263E-01	0.	8.978E-02	8.780E-02	7.525E-02	5.459E-02	2.860E-02	0.
4	1.046E 00	1.046E 00	1.014E 00	0.	1.887E-01	1.829E-01	1.528E-01	1.085E-01	5.612E-02	0.
5	1.280E 00	1.280E 00	1.238E 00	0.	2.725E-01	2.622E-01	2.127E-01	1.478E-01	7.577E-02	0.
6	1.483E 00	1.483E 00	1.434E 00	0.	3.658E-01	3.509E-01	2.824E-01	1.948E-01	9.935E-02	0.
7	1.648E 00	1.648E 00	1.593E 00	0.	4.784E-01	4.568E-01	3.650E-01	2.504E-01	1.271E-01	0.
8	1.770E 00	1.770E 00	1.706E 00	0.	6.256E-01	5.895E-01	4.644E-01	3.154E-01	1.590E-01	0.
9	1.845E 00	1.845E 00	1.760E 00	0.	8.411E-01	7.611E-01	5.820E-01	3.887E-01	1.943E-01	0.
10	1.878E 00	1.878E 00	1.709E 00	1.488E 00	1.222E 00	9.741E-01	7.099E-01	4.646E-01	2.300E-01	0.
11	1.919E 00	1.919E 00	1.740E 00	1.599E 00	1.441E 00	1.137E 00	8.187E-01	5.316E-01	2.620E-01	0.
12	1.967E 00	1.967E 00	1.804E 00	1.686E 00	1.551E 00	1.243E 00	8.979E-01	5.832E-01	2.873E-01	0.
13	2.006E 00	2.006E 00	1.854E 00	1.744E 00	1.615E 00	1.307E 00	9.496E-01	6.184E-01	3.049E-01	0.
14	2.026E 00	2.026E 00	1.879E 00	1.773E 00	1.647E 00	1.341E 00	9.778E-01	6.383E-01	3.151E-01	0.
15	2.020E 00	2.020E 00	1.878E 00	1.774E 00	1.650E 00	1.347E 00	9.853E-01	6.444E-01	3.185E-01	0.
16	1.985E 00	1.985E 00	1.847E 00	1.747E 00	1.626E 00	1.330E 00	9.743E-01	6.380E-01	3.156E-01	0.
17	1.920E 00	1.920E 00	1.788E 00	1.691E 00	1.576E 00	1.290E 00	9.462E-01	6.203E-01	3.070E-01	0.
18	1.825E 00	1.825E 00	1.700E 00	1.609E 00	1.499E 00	1.229E 00	9.026E-01	5.923E-01	2.934E-01	0.
19	1.699E 00	1.699E 00	1.584E 00	1.500E 00	1.399E 00	1.148E 00	8.448E-01	5.553E-01	2.754E-01	0.
20	1.546E 00	1.546E 00	1.443E 00	1.367E 00	1.275E 00	1.050E 00	7.749E-01	5.109E-01	2.539E-01	0.
21	1.366E 00	1.366E 00	1.276E 00	1.210E 00	1.131E 00	9.348E-01	6.957E-01	4.616E-01	2.303E-01	0.
22	1.162E 00	1.162E 00	1.087E 00	1.032E 00	9.665E-01	8.051E-01	6.123E-01	4.114E-01	2.065E-01	0.
23	8.745E-01	8.745E-01	8.207E-01	7.814E-01	7.344E-01	6.187E-01	4.807E-01	3.278E-01	1.660E-01	0.
24	7.443E-01	7.443E-01	6.997E-01	6.671E-01	6.280E-01	5.317E-01	4.157E-01	2.851E-01	1.449E-01	0.
25	7.443E-01	7.443E-01	6.997E-01	6.671E-01	6.280E-01	5.317E-01	4.157E-01	2.851E-01	1.449E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

GROUP 4 ADJOINT FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	1.774E-01	1.774E-01	1.658E-01	1.582E-01	1.491E-01	1.255E-01	9.755E-02	6.662E-02	3.377E-02	0.
3	3.873E-01	3.873E-01	3.607E-01	3.434E-01	3.231E-01	2.706E-01	2.093E-01	1.423E-01	7.193E-02	0.
4	6.723E-01	6.723E-01	6.185E-01	5.860E-01	5.499E-01	4.568E-01	3.479E-01	2.344E-01	1.178E-01	0.
5	8.611E-01	8.611E-01	7.804E-01	7.351E-01	6.913E-01	5.742E-01	4.300E-01	2.869E-01	1.436E-01	0.
6	1.040E 00	1.040E 00	9.395E-01	8.840E-01	8.311E-01	6.894E-01	5.136E-01	3.411E-01	1.702E-01	0.
7	1.212E 00	1.212E 00	1.094E 00	1.030E 00	9.682E-01	8.027E-01	5.967E-01	3.953E-01	1.969E-01	0.
8	1.377E 00	1.377E 00	1.245E 00	1.172E 00	1.102E 00	9.138E-01	6.781E-01	4.485E-01	2.232E-01	0.
9	1.534E 00	1.534E 00	1.392E 00	1.311E 00	1.234E 00	1.022E 00	7.566E-01	4.994E-01	2.482E-01	0.
10	1.683E 00	1.683E 00	1.540E 00	1.452E 00	1.361E 00	1.124E 00	8.299E-01	5.465E-01	2.713E-01	0.
11	1.817E 00	1.817E 00	1.683E 00	1.590E 00	1.482E 00	1.216E 00	8.947E-01	5.879E-01	2.914E-01	0.
12	1.923E 00	1.923E 00	1.788E 00	1.690E 00	1.574E 00	1.290E 00	9.471E-01	6.215E-01	3.078E-01	0.
13	1.998E 00	1.998E 00	1.860E 00	1.759E 00	1.639E 00	1.342E 00	9.846E-01	6.456E-01	3.196E-01	0.
14	2.040E 00	2.040E 00	1.900E 00	1.797E 00	1.674E 00	1.371E 00	1.006E 00	6.593E-01	3.263E-01	0.
15	2.048E 00	2.048E 00	1.907E 00	1.804E 00	1.681E 00	1.377E 00	1.010E 00	6.622E-01	3.278E-01	0.
16	2.021E 00	2.021E 00	1.883E 00	1.781E 00	1.660E 00	1.360E 00	9.978E-01	6.542E-01	3.238E-01	0.
17	1.960E 00	1.960E 00	1.826E 00	1.728E 00	1.610E 00	1.320E 00	9.690E-01	6.355E-01	3.147E-01	0.
18	1.866E 00	1.866E 00	1.739E 00	1.646E 00	1.534E 00	1.258E 00	9.246E-01	6.068E-01	3.006E-01	0.
19	1.740E 00	1.740E 00	1.623E 00	1.536E 00	1.433E 00	1.177E 00	8.657E-01	5.690E-01	2.822E-01	0.
20	1.584E 00	1.584E 00	1.479E 00	1.401E 00	1.307E 00	1.076E 00	7.943E-01	5.236E-01	2.602E-01	0.
21	1.401E 00	1.401E 00	1.308E 00	1.241E 00	1.159E 00	9.584E-01	7.132E-01	4.731E-01	2.360E-01	0.
22	1.191E 00	1.191E 00	1.114E 00	1.058E 00	9.908E-01	8.252E-01	6.276E-01	4.216E-01	2.116E-01	0.
23	8.958E-01	8.958E-01	8.407E-01	8.004E-01	7.522E-01	6.338E-01	4.923E-01	3.357E-01	1.700E-01	0.
24	7.620E-01	7.620E-01	7.164E-01	6.830E-01	6.430E-01	5.444E-01	4.256E-01	2.919E-01	1.484E-01	0.
25	7.620E-01	7.620E-01	7.164E-01	6.830E-01	6.430E-01	5.444E-01	4.256E-01	2.919E-01	1.484E-01	0.

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

(FLUX)X(ADJOINT-FLUX) REGION INTEGRALS

REG	F(1)F(K)*	F(2)F(K)*	F(3)F(K)*	F(4)F(K)*	K#1,4
1	3.33684E 00	1.94382E 00	9.99404E-01	5.71119E-01	
	5.79128E 00	3.38019E 00	1.73813E 00	9.91408E-01	
	5.99292E 00	3.49785E 00	1.79863E 00	1.02592E 00	
	3.68152E 00	2.14452E 00	1.10259E 00	6.30109E-01	
2	3.74469E 01	1.72962E 01	8.80068E 00	6.30799E 00	
	5.21609E 01	2.43351E 01	1.23849E 01	8.78886E 00	
	5.39945E 01	2.51908E 01	1.28203E 01	9.09781E 00	
	4.13959E 01	1.91193E 01	9.72831E 00	6.97320E 00	
3	1.56865E 01	0.	0.	2.64646E 00	
	0.	0.	0.	0.	
	0.	0.	0.	0.	
	1.73269E 01	0.	0.	2.92320E 00	
4	1.73859E 01	3.95721E 00	2.01191E 00	2.93191E 00	
	1.18622E 01	2.83744E 00	1.44236E 00	1.99970E 00	
	1.22938E 01	2.94016E 00	1.49458E 00	2.07244E 00	
	1.92065E 01	4.37229E 00	2.22294E 00	3.23894E 00	
5	2.18055E 00	2.89080E-01	1.48297E-01	3.72047E-01	
	8.41492E-01	1.14229E-01	5.85786E-02	1.43513E-01	
	8.75084E-01	1.18774E-01	6.09098E-02	1.49242E-01	
	2.40317E 00	3.18620E-01	1.63450E-01	4.10029E-01	
6	3.11027E 02	1.09441E 02	5.56200E 01	5.24183E 01	
	3.28784E 02	1.15779E 02	5.88398E 01	5.54081E 01	
	3.40100E 02	1.19765E 02	6.08650E 01	5.73151E 01	
	3.44119E 02	1.21085E 02	6.15376E 01	5.79953E 01	
7	2.68257E 01	8.75636E 00	4.46734E 00	4.54999E 00	
	2.61101E 01	8.67073E 00	4.42384E 00	4.42922E 00	
	2.70175E 01	8.97135E 00	4.57722E 00	4.58315E 00	
	2.96743E 01	9.68699E 00	4.94213E 00	5.03315E 00	
8	3.55723E 01	1.28572E 01	6.67362E 00	6.21639E 00	
	3.70787E 01	1.34017E 01	6.95619E 00	6.47961E 00	
	3.82982E 01	1.38424E 01	7.18491E 00	6.69268E 00	
	3.92322E 01	1.41798E 01	7.36006E 00	6.85586E 00	

Fig. 6 (continued)

CODE TWENTY GRAND - SAMPLE PROBLEM

(DEL-FLUX).(ADJOINT DEL-FLUX) REGION INTEGRALS

REG	DF(1)DF(1)*	DF(2)DF(2)*	DF(3)DF(3)*	DF(4)DF(4)*
1	3.29840E-01	2.95591E-01	1.56692E-01	6.19644E-02
2	8.70550E-01	2.54768E-01	1.32525E-01	1.60746E-01
3	6.21464E-01	0.	0.	1.15769E-01
4	1.26783E 00	3.25857E-01	1.70887E-01	2.34595E-01
5	4.39605E-01	2.52982E-02	1.34438E-02	8.25224E-02
6	7.37338E 00	2.91184E 00	1.52151E 00	1.36026E 00
7	8.76698E 00	2.86636E 00	1.51127E 00	1.64213E 00
8	1.79821E 00	6.66097E-01	3.54090E-01	3.41771E-01

Fig. 6 (continued)

ORNL-3200

UC-32 — Mathematics and Computers
TID-4500 (16th ed.)

Internal Distribution

1. L. G. Alexander
2. V. E. Anderson (K-25)
3. S. E. Beall
4. M. Bender
5. L. L. Bennett
6. A. L. Boch
7. W. L. Breazeale
8. R. B. Briggs
9. R. S. Carlsmith
10. W. L. Carter
11. R. D. Cheverton
12. H. C. Claiborne
13. A. L. Colomb
14. R. R. Coveyou
15. J. G. Delene
16. A. C. Downing
17-21. T. B. Fowler
22. A. P. Fraas
23. E. H. Gift
24. D. R. Gilfillan
25. E. E. Gross
26. A. S. Householder
27. W. H. Jordan
28. P. R. Kasten
29. W. E. Kinney
30. J. A. Lane
31. C. E. Larson (K-25)
32. M. P. Lietzke
33. R. N. Lyon
34. H. G. MacPherson
35. W. D. Manly
36. B. Maskowitz (K-25)
37. A. J. Miller
38. E. A. Nephew
39. C. W. Nestor, Jr.
40. C. E. Newlon (K-25)
41. A. M. Perry
42. P. H. Pitkanen
43. C. A. Preskitt
44. B. E. Prince
45. M. W. Rosenthal
46. T. H. Row
47. J. E. Rowe (K-25)
48. H. W. Savage
49. A. W. Savolainen
50. E. G. Silver
51. M. J. Skinner
52. I. Spiewak
53. J. G. Sullivan
54. J. A. Swartout
55-59. M. L. Tobias
60. D. B. Trauger
61. M. E. Tsagaris
62. R. Van Winkle
63. D. R. Vondy
64. D. W. Vroom
65. A. M. Weinberg
66. F. G. Welfare (Y-12)
67. C. E. Winters
68-90. Laboratory Records Department
91. Laboratory Records, LRD-RC
92-93. Central Research Library
94-96. Y-12 Technical Library, Document Reference Section
97-98. Reactor Division Library
99. SHARE Library (K-25)

External Distribution

100. C. P. Bhalla, Westinghouse Electric Corporation, Atomic Power Department, Pittsburgh, Pa.
101. L. R. Blue, Atomics International, Canoga Park, Calif.
102. W. Cartwell, System Analysis and Computation, IBM, Owego, New York

103. R. L. Crowther, Atomic Power Department, General Electric Co., San Jose, Calif.
104. E. M. Gelbard, Westinghouse Electric Corporation, Bettis Plant, Pittsburgh, Pa.
105. D. H. Groelsema, AEC, Washington
106. Haig Iskenderian, Argonne National Laboratory
107. D. Jacobson, Argonne National Laboratory
108. Seymour Jaye, General Atomic, San Diego, Calif.
109. W. B. Lee, Lockheed Nuclear Products, Atlanta, Georgia
110. D. J. Mallon, Allison Division, General Motors Corp., Indianapolis, Indiana
111. T. F. McKiernan, Pratt & Whitney Aircraft, Hartford, Conn.
112. B. H. Mount, Westinghouse Electric Corp. Bettis Plant, Pittsburgh, Pa.
113. W. Sangren, General Atomic, San Diego, Calif.
114. D. M. Shapiro, Internuclear Company, Clayton, Missouri
115. D. W. Thomas, Aerojet-General Nucleonics, San Ramon, Calif.
116. Division of Research and Development, AEC, ORO
117-118. Reactor Division, AEC, ORO
119-726. Given distribution as shown in TID-4500 (16th ed.) under Mathematics and Computers category (75 copies — OTS)