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EQUIPOISE-3: A TWO-DIMENSIONAL, TWO-GROUP, NEUTRON DIFFUSION CODE FOR THE IBM-7090 COMPUTER

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EQUIPOISE-3: A TWO-DIMENSIONAL, TWO-GROUP, NEUTRON DIFFUSION CODE FOR THE IBM-7090 COMPUTER

T. B. Fowler M. L. Tobias

Abstract

EQUIPOISE-3 is an IBM-7090 FORTRAN programmed code for the solution of two-group, two-dimensional, neutron diffusion equations. A maximum of 2100 mesh points may be used, and the code will solve problems in either rectangular or cylindrical geometry. Logarithmic derivative boundary conditions are allowed, and removal of neutrons from both groups is permitted. Adjoint fluxes with the associated flux—adjoint flux regional integrals may be calculated automatically if desired. A constant buckling, group-dependent buckling, or region-dependent buckling may be specified for rectangular geometry.

This program is intended to fill the need for a rapid two-dimensional calculation suitable for survey calculations. During the iterative part of the computations, all operations are carried out in the core memory. The magnetic tape memory is used only for input, output, and program storage. The running time for a 1000-point problem requiring 100 iterations would be about 3 min.

Introduction

EQUIPOISE-3, the program described in this report, is an extension of the code EQUIPOISE-2.[1-3] The maximum number of mesh points has been increased to 2100 (from 1444), and the code will handle rectangular geometry as well as cylindrical geometry. Removal of neutrons from the thermal group to the fast group is permitted, and the rod (logarithmic

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[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.

[2]M. L. Tobias and T. B. Fowler, Adjoint Flux Computation and Other Additions and Improvements to the EQUIPOISE Program; The Three-Dimensional Prototype Program, WHIRLAWAY, ORNL CF-60-8-10, August 10, 1960.

[3]T. B. Fowler and M. L. Tobias, EQUIPOISE-2: A Two-Dimensional, Two-Group, Neutron-Diffusion Code for the IBM-7090 Computer, ORNL CF-60-11-67, November 21, 1960.

derivative) boundary condition has been incorporated. The buckling for rectangular geometry may be specified as constant, group dependent, or region dependent. The adjoint flux option has been retained. In addition to computing the flux-adjoint flux region integrals, the code will also calculate the integrals of the dot products of the gradients of the group fluxes and their adjoints. The distribution of materials and the mesh spacing is arbitrary, subject to the condition that the maximum number of mesh spaces in either direction is limited to 100. The maximum number of compositions is limited to 50, and the maximum number of regions is limited to 100. The boundary conditions of zero flux or zero current may be applied to each of the four boundaries. A special mesh sweep procedure is used for problems having one or two diagonal symmetry axes or problems having mirror image symmetry.

The running time is about 0.0017 sec per point per iteration. With the exception of input, output, and program storage, no tapes are used during the calculation. The code was programmed in FORTRAN language to be run under control of the IBM-7090 FORTRAN Monitor System.[4]

Basic Difference Equations – Calculational Procedure

The simple five-point-difference equations used to describe the neutron diffusion group equations are, at each point:

$$\begin{bmatrix} A1_k(I,J)\ [\Phi_k(I-1,J) - \Phi_k(I,J)] \\ +A2_k(I,J)\ [\Phi_k(I+1,J) - \Phi_k(I,J)] \\ +A3_k(I,J)\ [\Phi_k(I,J+1) - \Phi_k(I,J)] \\ +A4_k(I,J)\ [\Phi_k(I,J-1) - \Phi_k(I,J)] \end{bmatrix} + A5_{3-k}(I,J)\ \Phi_{3-k}(I,J) -$$

$$-A6_k(I,J)\ \Phi_k(I,J) + \chi_k \lambda \sum_k A7_k(I,J)\ \Phi_k(I,J) = 0 \quad , \qquad k = 1,2 \qquad (1)$$

(All symbols are defined in the Notation section).

[4]IBM-7090 FORTRAN Monitor Reference Manual, Form C28-6065.

Given a set of positive fluxes and a set of boundary conditions, Eqs. (1) are summed for all internal points. If the resulting equation is solved for λ, the result may be interpreted as follows:

$$\lambda = \frac{\text{neutrons leaked plus neutrons absorbed}}{\text{neutrons produced}} .$$

Thus, λ can be regarded as the inverse of a static multiplication constant. This value of λ is inserted into the equations and a new set of fluxes is computed. With this new set of fluxes, a new λ is computed, and the process is repeated until it converges. The output fluxes are normalized to an arbitrary power, which is specified as the input.

For points associated with a "rod region," the fluxes are not defined, but satisfy

$$D \frac{d\Phi}{dx} = -E\Phi \quad . \tag{2}$$

The constants $A1_k$, $A2_k$, $A3_k$, $A4_k$, $A5_k$, and $A7_k$ in Eqs. (1) all become zero and $A6_k$ is replaced by $A6'_k$. In this case, with reference to Fig. 1, the leakage from point 1 to point 2 is expressed by

$$\text{Leakage} = E\Phi(1)\left(u\,\frac{\Delta Y_T}{2} + u\,\frac{\Delta Y_B}{2}\right) , \tag{3}$$

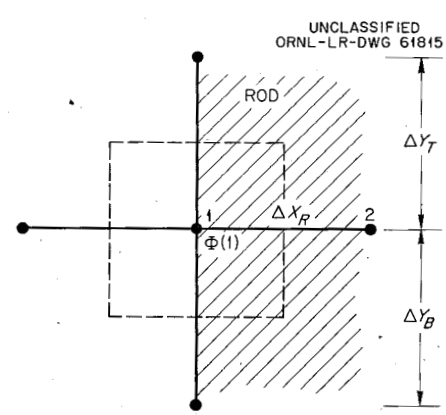

Fig. 1. Schematic of "Rod Region."

where E may be regarded as the diffusion constant divided by the extrapolation distance.

The calculational procedure indicated above is accelerated by the use of the "extrapolated Liebmann process:"[5]

$$\Phi_{EL}^{t+1} = (1 - \beta)\Phi_{EL}^{t} + \beta\Phi_{OL}^{t+1} \quad , \tag{4}$$

where β is a number between 1 and 2 and Φ_{OL}^{t+1} represents the flux values calculated by the ordinary Liebmann process. The following empirical formula is used to estimate β:

$$\beta = 2 - (2)^{1/2}\left[\left(\frac{\pi}{m}\right)^2 + j\left(\frac{2.405}{n}\right)^2 + (1 - j)\left(\frac{\pi}{n}\right)^2\right]^{1/2} \quad . \tag{5}$$

For cylindrical geometry, j is equal to 1 and is equal to 0 for rectangular geometry; m and n are the number of mesh intervals in the Y (or axial) direction and the X (or radial) direction, respectively. If either the top or bottom boundary of the reactor is a symmetry boundary, m is doubled; if both the top and bottom boundaries are symmetry boundaries, m is equal to ∞. The same holds true for n, considering the left and right boundaries of the reactor. For a cell problem, i.e., four symmetry boundaries, β is set equal to 1.9. If a negative flux should be calculated for some $\beta > 1$, it is destroyed, and a new value is generated based upon a new β halfway between 1 and the original estimate. If necessary, this process is repeated until the flux at that point is positive. The original value of β is restored after completion of a ten-iteration cycle. If a problem has not converged after one-half the total number of iterations specified (see Appendix B), a new β halfway between 1 and the original estimate is computed. The value of β is set equal to 1 at two-thirds the total number of iterations and remains at that value for the duration of the calculation.

---

[5]S. P. Frankel, Convergence Rates of Iterative Treatments of Partial Differential Equations, Mathematical Tables and Other Aids to Computation 4, 65–75 (1950).

Convergence Criteria

There are three convergence options available. The calculation stops when

$$\left| \frac{\lambda^{t-10}}{\lambda^{t}} - 1 \right| < \epsilon_{\lambda} \quad , \tag{6}$$

when the above condition is met as well as the flux convergence condition

$$\left| \frac{\Phi^{t}}{\Phi^{t-1}} - 1 \right|_{max} < \epsilon_{\Phi} \quad , \tag{7}$$

or when both the above conditions are met as well as the residue condition

$$\frac{\left[\sum_{k} \sum_{I,J} R_{k}^{2}(I,J) \right]^{1/2}}{\lambda \sum_{k} \sum_{I,J} A7_{k}(I,J) \; \Phi_{k}(I,J)} < \epsilon_{R} \quad . \tag{8}$$

Also, if a problem has not converged after the specified total number of iterations, it is terminated automatically.

Computation of Adjoint Fluxes and Integrals and the Source Calculation

If the "adjoint flux" option is used (see Appendix B), the problem is first solved in the ordinary way and all output is written. The appropriate interchange of group constants "across the diagonal" is then made and the adjoint fluxes are computed with a fixed value of λ equal to the value calculated. The adjoint problem is done in about one-third the time required by the ordinary problem. The adjoint flux distribution is printed as well as the following integrals, calculated region by region:

$$\int \Phi_k \Phi_l^* \, dV \quad , \qquad k = 1, 2 \text{ with fixed } l; \; l = 1, 2$$

and (9)

$$\int \nabla\Phi_k \cdot \nabla\Phi_k^* \, dV \quad , \qquad k = 1, 2 \quad .$$

For the adjoint calculation, only the flux convergence condition is tested. It is given by

$$\frac{\rho_{max} - \rho_{min}}{\frac{1}{2}(\rho_{max} + \rho_{min})} < \epsilon_\Phi \quad , \tag{10}$$

where

$$\rho = \frac{\Phi^t}{\Phi^{t-1}} \quad .$$

If the source option is used, the output will include the following:

$$\left[\sum_{k=1}^{K} (\nu\Sigma_f\Phi)_k \right]_N \quad , \tag{11}$$

where N represents the four quadrants surrounding each mesh point.

Notation

$A1_k$ $\qquad \frac{1}{2\Delta Y_T} (pD_{k1} \, \Delta X_R + qD_{k2} \, \Delta X_L)$

$A2_k$ $\qquad \frac{1}{2\Delta Y_B} (qD_{k3} \, \Delta X_L + pD_{k4} \, \Delta X_R)$

$A3_k$ $\qquad \frac{1}{2\Delta X_R} (rD_{k1} \, \Delta Y_T + rD_{k4} \, \Delta Y_B)$

$A4_k$ $\qquad \frac{1}{2\Delta X_L} (sD_{k2} \, \Delta Y_T + sD_{k3} \, \Delta Y_B)$

$A5_k$	$\Sigma_{Rk}\left[p\left(\frac{\Delta X_R\,\Delta Y_T + \Delta X_R\,\Delta Y_B}{4}\right) + q\left(\frac{\Delta X_L\,\Delta Y_T + \Delta X_L\,\Delta Y_B}{4}\right)\right]$
$A6_k$	$\left[\Sigma_{Ak} + \Sigma_{Rk} + (DB^2)_k\right]\left[p\left(\frac{\Delta X_R\,\Delta Y_T + \Delta X_R\,\Delta Y_B}{4}\right) + q\left(\frac{\Delta X_L\,\Delta Y_T + \Delta X_L\,\Delta Y_B}{4}\right)\right]$
$A6_k'$	$E\left(p\,\frac{\Delta X_R}{2} + q\,\frac{\Delta X_L}{2} + u\,\frac{\Delta Y_T}{2} + u\,\frac{\Delta Y_B}{2}\right)$
$A7_k$	$\nu\Sigma_{fk}\left[p\left(\frac{\Delta X_R\,\Delta Y_T + \Delta X_R\,\Delta Y_B}{4}\right) + q\left(\frac{\Delta X_L\,\Delta Y_T + \Delta X_L\,\Delta Y_B}{4}\right)\right]$
D_{kN}	Group k diffusion coefficient, cm, for the Nth quadrant surrounding a mesh point
$(DB^2)_k$	Group k diffusion coefficient times perpendicular buckling squared
E	Rod group constant
I, J	Denotes the Ith row and Jth column of the mesh
m, n	The number of axial and radial increments in the mesh, respectively
p	$\pi\left[2X(J) + \frac{\Delta X_R}{2}\right]$ for cylindrical geometry
	1 for rectangular geometry
q	$\pi\left[2X(J) - \frac{\Delta X_L}{2}\right]$ for cylindrical geometry
	1 for rectangular geometry
r	$\pi\left[2X(J) + \Delta X_R\right]$ for cylindrical geometry
	1 for rectangular geometry
$R_k(I,J)$	Residue at mesh point I, J and group k calculated from Eqs. (1)

s	$\pi\left[2X(J) - \Delta X_L\right]$	for cylindrical geometry
	1	for rectangular geometry
u	$2\pi X(J)$	for cylindrical geometry
	1	for rectangular geometry

$X, \Delta X$	Distance from left boundary or left axis of symmetry and mesh increment in the X direction (or radial direction for cylindrical geometry), respectively, cm
$Y, \Delta Y$	Distance from top boundary or top axis of symmetry and mesh increment in the Y direction (or axial direction for cylindrical geometry), respectively, cm
k, l	Subscripts denoting kth or lth group
L,R,T,B	Subscripts denoting left, right, top, bottom, respectively
t, t'	Superscripts denoting iteration number (sweep through all groups)
β	Extrapolated Liebmann coefficient
$\epsilon_\lambda, \epsilon_\Phi, \epsilon_R$	Convergence criteria
$\Phi_k^t(I,J)$	Group k flux at mesh point (I,J) and iteration number t
λ	A number by which all $\nu\Sigma f$'s must be multiplied so that the difference equations balance. An over-all value can be obtained by summing all the equations.
$\lambda_{max}, \lambda_{min}$	The largest and smallest values of λ, respectively, calculated at particular mesh points
ν	The number of neutrons produced per fission
Σ_{Ak}	Group k macroscopic absorption cross section, cm^{-1}
Σ_{Rk}	Group k macroscopic removal cross section, cm^{-1}
$\nu\Sigma_{fk}$	ν times group k macroscopic fission cross section, cm^{-1}
χ_k	Fraction of neutrons produced from fission that are born in group k

Appendix A. STRUCTURE OF THE CODE, MONITOR SYSTEM OPERATION

Program Links

EQUIPOISE-3 was programmed in FORTRAN language in a series of chain links which are written on a program tape by the Monitor System at execution time. Table A.1 below lists the program chain links and the function of each. The numbers in parentheses indicate the serial number of the link and the tape on which it is written.

Table A.1. Program Chain Links

Chain Link	Function
CHAIN (1,1)	Reads input and sets up initial conditions
CHAIN (2,1)	Calculates group constants
CHAIN (3,1)	Does the flux iteration calculation
CHAIN (4,1)	Calculates group and region absorptions
CHAIN (5,1)	Writes flux distribution, neutron balance, source, and flux-adjoint flux region integrals on output tape
CHAIN (6,1)	Calculates source
CHAIN (7,1)	Calculates flux-adjoint flux region integrals

Tape Assignment

EQUIPOISE-3 uses one input tape, one output tape, and one scratch tape if the source option or the adjoint option is used. The Monitor System requires one tape, and actual tape number B-1 is used to store the program. Table A.2 gives the logical tape numbers (with the actual tape number required for the program tape) that are referred to in the code, with the function of each tape.

Table A.2. Tapes Required for EQUIPOISE-3

Logical Tape No.	Actual Tape No.	Function
		System tape
	B-1	Program tape
8		Scratch tape, needed only for source calculations or adjoint calculations
9		Output tape
10		Input tape

IBM-7090 FORTRAN Monitor System Operations

For the IBM-7090 FORTRAN monitor, the DSU Channel-Unit Table[6] relating the logical tape numbers to the actual tape numbers must be supplied by the user and put with each chain link as a binary deck. The machine operating instructions are those given in reference 4. A "job" consists of the program deck, with all necessary control cards, followed by the input data decks; it is loaded on the input tape for processing by the Monitor System. The output should be listed on 14-in. × 11-in. paper under program control.

[6]IBM-709 FORTRAN Operations Reference Manual, Form C28-6066-1.

Appendix B. INPUT PREPARATION, SAMPLE PROBLEM, AND OUTPUT

Input Data Cards

Figure B.1 shows the input data forms filled out for the sample problem. Columns 73-80 may be used for card identification. There are five types of data cards required for input to EQUIPOISE-3: (1) title card, (2) control cards, (3) mesh-specification cards, (4) region-specification cards, (5) composition-specification cards. Given below are the instructions for writing EQUIPOISE-3 input. Note that the number formats are described in FORTRAN nomenclature and are given in parentheses immediately following the input number symbol.

Title Card. The first column 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 output.

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

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

Columns 7 through 9, JMAX(I3) $\leq$ 100: Total number of columns. The columns in the mesh are numbered from left to right beginning with 1. Note that it is necessary that IMAX $\times$ JMAX $\leq$ 2100.

Columns 10 through 12, NR(I3) $\leq$ 100: Total number of rectangular regions that are specified by the region-specification cards (see below).

Columns 13 through 15, NC(I3) $\leq$ 50: Number of compositions specified by the composition-specification cards (see below).

Columns 16 through 17, GI(I2): Geometry indicator. A +1 for this number specifies cylindrical geometry; a 0 or blank specifies rectangular geometry.

Columns 18 through 19, BI(I2): Buckling indicator. If this number is 0, a constant buckling is specified. If this number is +1, the buckling is specified by groups; if this number is +2, the buckling is specified

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

EQUIPOISE-3 INPUT FORM-I

REQUEST NO.

1	TITLE	73 80
CODE EQUIPOISE-3	SAMPLE PROBLEM FOR REPORT	TITLE

ITER (1)	IMAX (4)	JMAX (7)	NR (10)	.NC (13)	GI (16)	BI (18)	SI (20)	AI (22)	FI (24)	CI (26)	DI (28)	LB (30)	TB (32)	RB (34)	BB (36)	NORM FACTOR (38)	ε(λ) (48)	ε(φ) (55)	ε(R) (62)	β (69)	(73)
300	25	10	8	3		1	1	1		3		1				1.0	+15	.00001	.00001	0.0001	CNTRL

XI_1 (1)	XI_2 (7)	B_1^2 (13)	B_2^2 (21)	
1.0		0.003	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. B.1. Input for Sample Problem.

EQUIPOISE – 3 FORM – 2

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

REQUEST NO.

COMP. NO. (1)	GRP. NO. (4)	D (7)	Σ_R (17)	Σ_A (27)	$\nu\Sigma_f$ (37)	B^2 (47)		(73–80)
1	1	1.5	0.0051	0.00111	0.0021			COMP11
1	2	1.31		0.00112	0.0022			COMP12
2	1	1.52	0.0052	0.00211				COMP21
2	2	1.32	0.0032	0.00222				COMP22
3	1	1.53	0.0053	0.00311				COMP31
3	2			0.5				COMP32
								STOP
								STOP

Fig. B.1 (continued)

by composition. Constant and group-dependent buckling is specified on control card 2. Composition-dependent buckling is specified on the composition-specification cards. For cylindrical geometry, write 0 or leave blank.

Columns 20 through 21, SI(I2): Source indicator. If this number is +1, the source,

$$\left[\sum_{k=1} (\nu\Sigma_f\Phi)_k\right]_N \quad , \qquad N = 1, 2, 3, 4 \quad , \qquad \text{(B.1)}$$

is computed for output at each mesh point. If SI is 0, the source calculation is skipped.

Columns 22 through 23, AI(I2): Adjoint indicator. If AI is +1, the adjoint fluxes and associated flux—adjoint flux integrals will be computed following the flux calculation. If AI is 0, the adjoint flux calculation is skipped.

Columns 24 through 25, FI(I2): Previous-flux indicator. If this number is +1, the flux distribution from the preceding case is used as the initial flux guess for the present case. The present case must have the same number of rows and columns and the same boundary conditions as the preceding case. If this number is 0, the initial flux guess is supplied by the code.

Columns 26 through 27, CI(I2): Convergence indicator. If CI is +1, the problem converges only on nu-critical (λ), Eq. (6). If CI is +2, the problem converges on nu-critical and the flux, Eq. (7). If CI is +3, the problem converges on nu-critical, flux, and the total residue, Eq. (8).

Columns 28 through 29, DI(I2): Diagonal symmetry indicator. For problems with no diagonal symmetry, this number is 0 or blank. DI is +1 for problems having one diagonal symmetry axis passing through point (1,1). A +2 for this number indicates two diagonal symmetry axes. A +3 for DI indicates mirror image symmetry. These diagonal symmetry conditions are illustrated by the sketches of Fig. B.2. The points where the fluxes are equal are indicated by O and □.

48.43
192
144
3064

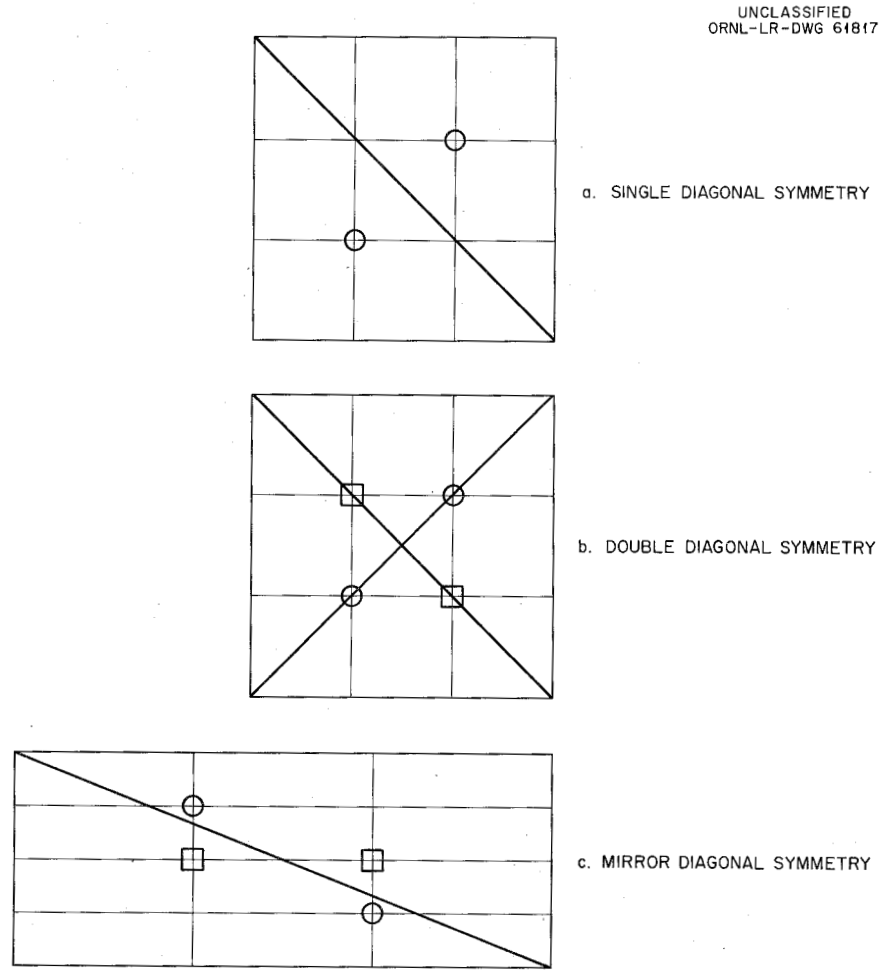

Fig. B.2. Symmetry Conditions.

Columns 30 through 31, LB(I2): Left-boundary indicator. The left, top, right, and bottom boundaries may be either zero-flux boundaries or symmetry boundaries. If this number is +1, a symmetry boundary is assumed to exist midway between columns one and two. If LB is 0, column one is assumed to be a zero-flux boundary. For cylindrical geometry, LB must be +1.

Columns 32 through 33, TB(I2): Top boundary indicator. If this number is +1, a symmetry boundary is assumed to exist midway between rows one and two; if 0, row one is assumed to be a zero-flux boundary.

Columns 34 through 35, RB(I2): Right boundary indicator. If this number is +1, a symmetry boundary is assumed to exist midway between columns JMAX-1 and JMAX; if 0, column JMAX is assumed to be a zero-flux boundary.

Columns 36 through 37, BB(I2): Bottom boundary indicator. If BB is +1, a symmetry boundary is assumed to exist midway between rows IMAX-1 and IMAX; if 0, row IMAX is assumed to be a zero-flux boundary.

Columns 38 through 47, NORM FACTOR (E10.6): Normalization factor. The output fluxes are normalized by multiplying each flux by the normalization factor and dividing by the total source. For example, if w is the total reactor power in megawatts, μ the number of fissions per megawatt-second, and ν the number of neutrons produced per fission, then the normalization factor would be $w \times \mu \times \nu \times f$, where f is the part of the reactor considered in the calculation and is either 1, 1/2, or 1/4, depending upon whether there were 0, 1, or 2 symmetry boundaries. If NORM FACTOR is 0 or blank, the code uses 1.0 for this number.

Columns 48 through 54, 55 through 61, and 62 through 68; ϵ_λ, ϵ_Φ, ϵ_R (E7.4): The convergence criteria referred to in Eqs. (6), (7), and (8). Numbers of the order of 10^{-5} for ϵ_λ, 10^{-4} for ϵ_Φ, and 10^{-5} for ϵ_R will assure convergence for most problems.

Columns 69 through 72, β (F4.3): Extrapolated Liebmann coefficient. If this number is 0 or blank, the code calculates β from Eq. (5). If this number has a value between 1 and 2, the code uses the number specified.

Control Card 2. Columns 1 through 6, XI_1 (F6.5): The fraction of neutrons produced from fission that are born in group one.

Columns 7 through 12, XI_2 (F6.5): The fraction of neutrons produced from fission that are born in group two. Note that XI_1 plus XI_2 must equal 1.0.

Columns 13 through 20, B_1^2 (E8.5): If BI (control card 1) is 0, the value of the constant buckling is specified here for rectangular geometry. If BI is +1, the group one buckling is specified. Note that B^2 may be zero.

Columns 21 through 28, B_2^2 (E8.5): Group two buckling.

Mesh-Specification Cards. Described below are the two types of cards required to specify the mesh: (1) cards giving the ΔY's and row numbers and (2) cards giving the ΔX's and the column numbers, in that order.

1. In columns 1 through 6, 7 through 9; 10 through 15, 16 through 18; etc., supply a value of ΔY(E6.3) and the row number (I3) up to which

this ΔY applies, going from top to bottom in the mesh. Use as many cards as are needed. Each card, except possibly the last, should be completely filled through column 72. The last number on these cards is equal to IMAX.

2. In columns 1 through 6, 7 through 9; 10 through 15, 16 through 18; etc., supply a value of ΔX(E6.3) and the column number (I3) up to which this ΔX applies, going from left to right in the mesh. Use as many cards as are needed. The last number on these cards is equal to JMAX.

Region-Specification Cards. The regions are specified as rectangles with a composition number assigned to each region. The number of regions specified must completely cover the mesh and must be equal to the value of NR given on control card 1. The regions may be specified in any order with each card, except possibly the last specifying four regions.

In columns 1 through 3, 4 through 6, 7 through 9, 10 through 12, 13 through 15; 20 through 22, 23 through 25, 26 through 28, 29 through 31, 32 through 34, etc., give, respectively, the composition number (I3) that applies to that region (see below), the upper-row number (I3) of the region, the bottom-row number (I3) of the region, the left-column number (I3) of the region, the right-column number (I3) of the region.

Composition-Specification Cards. The different compositions of the reactor are numbered consecutively beginning with 1. Each composition-specification card specifies a composition number, a group number, and the nuclear constants and buckling for that composition and group. The number of composition-specification cards must equal 2 NC (control card 1), and may be written in any order.

Columns 1 through 3: Composition number (I3).

Columns 4 through 6: Group number (I3).

Columns 7 through 16, D(E10.7): Diffusion coefficient. If D = 0, then $\Sigma_R = \nu\Sigma_f = B^2 = 0$ and $\Sigma_A = E$. This specifies a "rod-group."

Columns 17 through 26, Σ_R(E10.7): Macroscopic removal cross section. Neutrons may be removed from either group to the other group.

Columns 27 through 36, Σ_A(E10.7): Macroscopic absorption cross section.

Columns 37 through 46, $\nu\Sigma_f$(E10.7): ν times macroscopic fission cross section.

Columns 47 through 56, B^2(E10.7): Composition-dependent buckling.

Deck Makeup

EQUIPOISE-3 will run as many cases as desired, with no stops between cases, simply by stacking the input data decks; however, two blank cards should follow the last input deck.

Sample Problem

Figure B.3 shows the diagram of the reactor. It was run in rectangular geometry with constant buckling. There is an axis of symmetry midway between columns 1 and 2. The reactor is broken up into 8 regions and there are 3 different material compositions which are cited in Table B.1.

Table B.1. Properties of Compositions in Sample Problem

Composition	Group	D	Σ_R	Σ_A	$\nu\Sigma_f$
1	1	1.51	0.0051	0.0011	0.0021
	2	1.31	0	0.0012	0.0022
2	1	1.52	0.0052	0.0021	0
	2	1.32	0.0032	0.0022	0
3	1	1.53	0.0053	0.0031	0
	2	0	0	0.5	0

Note that mesh increments, not total distances, are supplied as input. With reference to Fig. B.3, ΔX between columns 5 and 10 is 1 cm, whereas the distance from column 5 to column 10 is 5 cm.

Figure B.1 shows the standard EQUIPOISE-3 input forms filled out according to the instructions given in previous paragraphs.

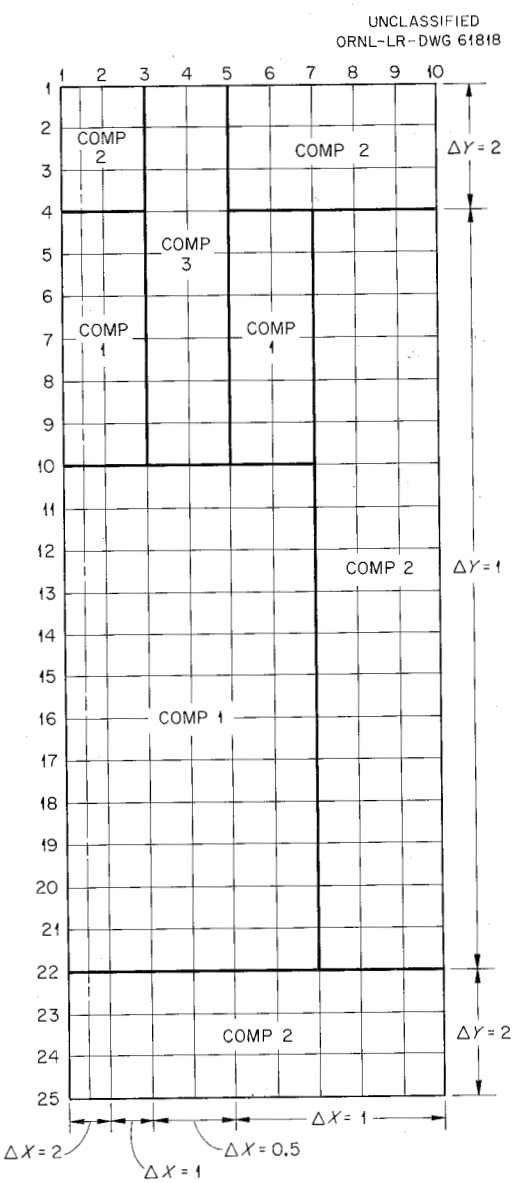

Fig. B.3. Diagram of Reactor in Sample Problem.

Output

Figure B.4 shows the output for the sample problem. This output consists of the items shown below.

1. Title.
2. Reactor specifications.
3. Mesh specifications.
4. Reactor dimensions.

```
CODE EQUIPOISE - 3   SAMPLE PROBLEM FOR REPORT

REACTOR SPECIFICATIONS

  25 ROWS   10 COLUMNS   8 REGIONS   3 COMPS   2 GROUPS   XY GEOM   B.C.(L,T,R,B)#1,0,0,0   N.F.#10.00000E 14

  CHI1# 1.0000   CHI2#-0.

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. B.4. Output for Sample Problem.

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

REGION SPECIFICATIONS

REG	I1	I2	J1	J2	COMP	GROUP	D	SIGR	SIGA	NUSF	B SQ
1	1	4	1	3	2	1	1.520E 00	5.200E-03	2.100E-03	-0.	3.000E-03
						2	1.320E 00	3.200E-03	2.200E-03	-0.	2.000E-03
2	4	10	1	3	1	1	1.500E 00	5.100E-03	1.100E-03	2.100E-03	3.000E-03
						2	1.310E 00	-0.	1.200E-03	2.200E-03	2.000E-03
3	1	10	3	5	3	1	1.530E 00	5.300E-03	3.100E-03	-0.	3.000E-03
						2	-0.	-0.	5.000E-01	-0.	2.000E-03
4	4	10	5	7	1	1	1.500E 00	5.100E-03	1.100E-03	2.100E-03	3.000E-03
						2	1.310E 00	-0.	1.200E-03	2.200E-03	2.000E-03
5	1	4	5	10	2	1	1.520E 00	5.200E-03	2.100E-03	-0.	3.000E-03
						2	1.320E 00	3.200E-03	2.200E-03	-0.	2.000E-03
6	10	22	1	7	1	1	1.500E 00	5.100E-03	1.100E-03	2.100E-03	3.000E-03
						2	1.310E 00	-0.	1.200E-03	2.200E-03	2.000E-03
7	4	22	7	10	2	1	1.520E 00	5.200E-03	2.100E-03	-0.	3.000E-03
						2	1.320E 00	3.200E-03	2.200E-03	-0.	2.000E-03
8	22	25	1	10	2	1	1.520E 00	5.200E-03	2.100E-03	-0.	3.000E-03
						2	1.320E 00	3.200E-03	2.200E-03	-0.	2.000E-03

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

FLUX CALCULATION BEGINS BETA# 1.6915E 00

IT NO	FLUX CONVR	NU-CRIT CONVR	TOT RESIDUE	MAX RESIDUE	NU-CRITICAL
10	5.5502E-02	1.0000E 00	4.3874E-02	7.9872E-03	5.93048E 01
20	1.5938E-02	2.5630E-01	3.8263E-02	5.8997E-03	4.72060E 01
30	1.3660E-02	1.2589E-03	1.5107E-02	2.5143E-03	4.71466E 01
40	6.9387E-03	5.9832E-03	4.6234E-03	9.5961E-04	4.74304E 01
50	1.6092E-03	2.2308E-03	1.0696E-03	2.2549E-04	4.75365E 01
60	3.6079E-04	5.2705E-04	2.3556E-04	5.0159E-05	4.75615E 01
70	7.7724E-05	1.1655E-04	5.0884E-05	1.0805E-05	4.75671E 01
80	1.6630E-05	2.5146E-05	1.1011E-05	2.2829E-06	4.75683E 01
90	3.4422E-06	5.4389E-06	2.5277E-06	4.2498E-07	4.75685E 01

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

NO.IT.# 90 NU-CRIT# 4.75685E 01 N.F./(TOT PROD)# 1.69855E 13

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	7.166E 14	7.166E 14	6.724E 14	6.407E 14	6.029E 14	5.097E 14	3.979E 14	2.725E 14	1.383E 14	0.
3	1.573E 15	1.573E 15	1.472E 15	1.400E 15	1.316E 15	1.110E 15	8.629E 14	5.882E 14	2.977E 14	0.
4	2.749E 15	2.749E 15	2.545E 15	2.410E 15	2.263E 15	1.907E 15	1.466E 15	9.858E 14	4.948E 14	0.
5	3.488E 15	3.488E 15	3.198E 15	3.014E 15	2.836E 15	2.397E 15	1.824E 15	1.212E 15	6.050E 14	0.
6	4.205E 15	4.205E 15	3.845E 15	3.619E 15	3.404E 15	2.875E 15	2.180E 15	1.442E 15	7.181E 14	0.
7	4.903E 15	4.903E 15	4.480E 15	4.215E 15	3.963E 15	3.343E 15	2.530E 15	1.671E 15	8.304E 14	0.
8	5.580E 15	5.580E 15	5.101E 15	4.800E 15	4.511E 15	3.800E 15	2.871E 15	1.892E 15	9.395E 14	0.
9	6.230E 15	6.230E 15	5.711E 15	5.376E 15	5.050E 15	4.243E 15	3.197E 15	2.103E 15	1.043E 15	0.
10	6.841E 15	6.841E 15	6.318E 15	5.965E 15	5.589E 15	4.663E 15	3.499E 15	2.295E 15	1.136E 15	0.
11	7.374E 15	7.374E 15	6.863E 15	6.500E 15	6.074E 15	5.032E 15	3.760E 15	2.461E 15	1.217E 15	0.
12	7.787E 15	7.787E 15	7.264E 15	6.884E 15	6.430E 15	5.315E 15	3.963E 15	2.590E 15	1.279E 15	0.
13	8.058E 15	8.058E 15	7.522E 15	7.130E 15	6.660E 15	5.501E 15	4.098E 15	2.675E 15	1.321E 15	0.
14	8.179E 15	8.179E 15	7.636E 15	7.239E 15	6.761E 15	5.583E 15	4.157E 15	2.712E 15	1.339E 15	0.
15	8.143E 15	8.143E 15	7.604E 15	7.208E 15	6.733E 15	5.559E 15	4.138E 15	2.699E 15	1.332E 15	0.
16	7.951E 15	7.951E 15	7.425E 15	7.038E 15	6.574E 15	5.428E 15	4.040E 15	2.635E 15	1.300E 15	0.
17	7.604E 15	7.604E 15	7.101E 15	6.732E 15	6.289E 15	5.193E 15	3.865E 15	2.521E 15	1.244E 15	0.
18	7.109E 15	7.109E 15	6.640E 15	6.295E 15	5.881E 15	4.858E 15	3.617E 15	2.360E 15	1.165E 15	0.
19	6.474E 15	6.474E 15	6.048E 15	5.735E 15	5.359E 15	4.429E 15	3.300E 15	2.155E 15	1.065E 15	0.
20	5.709E 15	5.709E 15	5.335E 15	5.061E 15	4.731E 15	3.915E 15	2.923E 15	1.913E 15	9.461E 14	0.
21	4.828E 15	4.828E 15	4.514E 15	4.284E 15	4.008E 15	3.325E 15	2.495E 15	1.641E 15	8.143E 14	0.
22	3.845E 15	3.845E 15	3.598E 15	3.418E 15	3.201E 15	2.668E 15	2.030E 15	1.354E 15	6.766E 14	0.
23	2.209E 15	2.209E 15	2.071E 15	1.971E 15	1.851E 15	1.556E 15	1.205E 15	8.180E 14	4.129E 14	0.
24	1.007E 15	1.007E 15	9.457E 14	9.008E 14	8.471E 14	7.150E 14	5.570E 14	3.806E 14	1.930E 14	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

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	2.371E 13	2.371E 13	1.836E 13	0.	8.789E 12	1.078E 13	1.037E 13	8.045E 12	4.368E 12	0.
3	5.095E 13	5.095E 13	3.946E 13	0.	1.904E 13	2.333E 13	2.244E 13	1.738E 13	9.431E 12	0.
4	8.528E 13	8.528E 13	6.599E 13	0.	3.241E 13	3.970E 13	3.811E 13	2.945E 13	1.595E 13	0.
5	1.064E 14	1.064E 14	8.220E 13	0.	4.110E 13	5.038E 13	4.825E 13	3.720E 13	2.012E 13	0.
6	1.303E 14	1.303E 14	1.007E 14	0.	5.166E 13	6.330E 13	6.043E 13	4.645E 13	2.506E 13	0.
7	1.579E 14	1.579E 14	1.221E 14	0.	6.530E 13	7.970E 13	7.555E 13	5.768E 13	3.099E 13	0.
8	1.908E 14	1.908E 14	1.480E 14	0.	8.474E 13	1.019E 14	9.488E 13	7.153E 13	3.814E 13	0.
9	2.311E 14	2.311E 14	1.817E 14	0.	1.173E 14	1.337E 14	1.199E 14	8.838E 13	4.659E 13	0.
10	2.807E 14	2.807E 14	2.336E 14	2.115E 14	1.873E 14	1.796E 14	1.507E 14	1.078E 14	5.601E 13	0.
11	3.359E 14	3.559E 14	3.042E 14	2.853E 14	2.656E 14	2.289E 14	1.829E 14	1.276E 14	6.554E 13	0.
12	3.845E 14	3.845E 14	3.569E 14	3.383E 14	3.172E 14	2.688E 14	2.109E 14	1.454E 14	7.413E 13	0.
13	4.223E 14	4.223E 14	3.951E 14	3.757E 14	3.530E 14	2.981E 14	2.326E 14	1.594E 14	8.104E 13	0.
14	4.481E 14	4.481E 14	4.203E 14	4.002E 14	3.762E 14	3.176E 14	2.473E 14	1.692E 14	8.588E 13	0.
15	4.619E 14	4.619E 14	4.337E 14	4.131E 14	3.885E 14	3.280E 14	2.552E 14	1.745E 14	8.852E 13	0.
16	4.642E 14	4.642E 14	4.360E 14	4.154E 14	3.907E 14	3.299E 14	2.567E 14	1.755E 14	8.901E 13	0.
17	4.556E 14	4.556E 14	4.281E 14	4.079E 14	3.837E 14	3.240E 14	2.522E 14	1.724E 14	8.744E 13	0.
18	4.371E 14	4.371E 14	4.108E 14	3.914E 14	3.682E 14	3.111E 14	2.421E 14	1.656E 14	8.398E 13	0.
19	4.099E 14	4.099E 14	3.852E 14	3.671E 14	3.454E 14	2.919E 14	2.273E 14	1.554E 14	7.887E 13	0.
20	3.750E 14	3.750E 14	3.525E 14	3.360E 14	3.162E 14	2.673E 14	2.083E 14	1.425E 14	7.233E 13	0.
21	3.341E 14	3.341E 14	3.141E 14	2.994E 14	2.818E 14	2.384E 14	1.859E 14	1.273E 14	6.466E 13	0.
22	2.886E 14	2.886E 14	2.714E 14	2.588E 14	2.437E 14	2.063E 14	1.612E 14	1.105E 14	5.617E 13	0.
23	1.919E 14	1.919E 14	1.805E 14	1.722E 14	1.622E 14	1.376E 14	1.078E 14	7.402E 13	3.766E 13	0.
24	9.525E 13	9.525E 13	8.966E 13	8.555E 13	8.062E 13	6.842E 13	5.365E 13	3.688E 13	1.878E 13	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

GROUP ABSORPTIONS

GROUP-ONE	GROUP-TWO	TOTAL
9.49781E 14	1.08588E 15	2.03566E 15

GROUP PRODUCTIONS

GROUP-ONE	GROUP-TWO	TOTAL
9.48612E 14	5.13876E 13	10.00000E 14

BOUNDARY LEAKAGES TOTAL# 4.24966E 16

	GROUP-ONE	GROUP-TWO	TOTAL
LFT	0.	0.	0.
TOP	2.79252E 15	5.45804E 13	2.84710E 15
RIT	3.36455E 16	1.76482E 15	3.54103E 16
BOT	3.91505E 15	3.24118E 14	4.23917E 15

AXIAL LEAKAGES

GROUP-ONE	GROUP-TWO	TOTAL
2.94827E 15	8.80124E 13	3.03629E 15

REGION ABSORPTIONS

REG	GROUP-ONE	GROUP-TWO	TOTAL	REG.VOLUME
1	3.02610E 13	9.73973E 11	3.12349E 13	1.20000E 01
2	6.29035E 13	2.26947E 12	6.51730E 13	1.20000E 01
3	9.82679E 13	1.03550E 15	1.13377E 15	1.20000E 01
4	4.32629E 13	1.22425E 12	4.44871E 13	1.20000E 01
5	3.41410E 13	8.35004E 11	3.49760E 13	3.00000E 01
6	3.90726E 14	2.45359E 13	4.15262E 14	6.00000E 01
7	1.80872E 14	1.07660E 13	1.91638E 14	5.40000E 01
8	1.09347E 14	9.77050E 12	1.19118E 14	4.80000E 01

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

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.	5.961E 12	5.961E 12	5.490E 12	-0.	-0.	-0.	-0.	4.824E 12
5	0.	0.	7.559E 12	7.559E 12	6.897E 12	-0.	-0.	-0.	-0.	6.046E 12
	0.	0.	7.559E 12	7.559E 12	6.897E 12	-0.	-0.	-0.	-0.	6.046E 12
6	0.	0.	9.117E 12	9.117E 12	8.296E 12	-0.	-0.	-0.	-0.	7.261E 12
	0.	0.	9.117E 12	9.117E 12	8.296E 12	-0.	-0.	-0.	-0.	7.261E 12
7	0.	0.	1.064E 13	1.064E 13	9.677E 12	-0.	-0.	-0.	-0.	8.465E 12
	0.	0.	1.064E 13	1.064E 13	9.677E 12	-0.	-0.	-0.	-0.	8.465E 12
8	0.	0.	1.214E 13	1.214E 13	1.104E 13	-0.	-0.	-0.	-0.	9.659E 12
	0.	0.	1.214E 13	1.214E 13	1.104E 13	-0.	-0.	-0.	-0.	9.659E 12
9	0.	0.	1.359E 13	1.359E 13	1.239E 13	-0.	-0.	-0.	-0.	1.086E 13
	0.	0.	1.359E 13	1.359E 13	1.239E 13	-0.	-0.	-0.	-0.	1.086E 13
10	0.	0.	1.498E 13	1.498E 13	1.378E 13	-0.	-0.	-0.	-0.	1.215E 13
	0.	0.	1.498E 13	1.498E 13	1.378E 13	1.378E 13	1.299E 13	1.299E 13	1.215E 13	1.215E 13
11	0.	0.	1.623E 13	1.623E 13	1.508E 13	1.508E 13	1.428E 13	1.428E 13	1.334E 13	1.334E 13
	0.	0.	1.623E 13	1.623E 13	1.508E 13	1.508E 13	1.428E 13	1.428E 13	1.334E 13	1.334E 13
12	0.	0.	1.720E 13	1.720E 13	1.604E 13	1.604E 13	1.520E 13	1.520E 13	1.420E 13	1.420E 13
	0.	0.	1.720E 13	1.720E 13	1.604E 13	1.604E 13	1.520E 13	1.520E 13	1.420E 13	1.420E 13
13	0.	0.	1.785E 13	1.785E 13	1.667E 13	1.667E 13	1.580E 13	1.580E 13	1.476E 13	1.476E 13
	0.	0.	1.785E 13	1.785E 13	1.667E 13	1.667E 13	1.580E 13	1.580E 13	1.476E 13	1.476E 13
14	0.	0.	1.816E 13	1.816E 13	1.696E 13	1.696E 13	1.608E 13	1.608E 13	1.503E 13	1.503E 13
	0.	0.	1.816E 13	1.816E 13	1.696E 13	1.696E 13	1.608E 13	1.608E 13	1.503E 13	1.503E 13

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

SOURCE(I,J)

	1		2		3		4		5	
15	0.	0.	1.812E 13	1.812E 13	1.692E 13	1.692E 13	1.605E 13	1.605E 13	1.499E 13	1.499E 13
	0.	0.	1.812E 13	1.812E 13	1.692E 13	1.692E 13	1.605E 13	1.605E 13	1.499E 13	1.499E 13
16	0.	0.	1.772E 13	1.772E 13	1.655E 13	1.655E 13	1.569E 13	1.569E 13	1.467E 13	1.467E 13
	0.	0.	1.772E 13	1.772E 13	1.655E 13	1.655E 13	1.569E 13	1.569E 13	1.467E 13	1.467E 13
17	0.	0.	1.697E 13	1.697E 13	1.585E 13	1.585E 13	1.504E 13	1.504E 13	1.405E 13	1.405E 13
	0.	0.	1.697E 13	1.697E 13	1.585E 13	1.585E 13	1.504E 13	1.504E 13	1.405E 13	1.405E 13
18	0.	0.	1.589E 13	1.589E 13	1.485E 13	1.485E 13	1.408E 13	1.408E 13	1.316E 13	1.316E 13
	0.	0.	1.589E 13	1.589E 13	1.485E 13	1.485E 13	1.408E 13	1.408E 13	1.316E 13	1.316E 13
19	0.	0.	1.450E 13	1.450E 13	1.355E 13	1.355E 13	1.285E 13	1.285E 13	1.201E 13	1.201E 13
	0.	0.	1.450E 13	1.450E 13	1.355E 13	1.355E 13	1.285E 13	1.285E 13	1.201E 13	1.201E 13
20	0.	0.	1.281E 13	1.281E 13	1.198E 13	1.198E 13	1.137E 13	1.137E 13	1.063E 13	1.063E 13
	0.	0.	1.281E 13	1.281E 13	1.198E 13	1.198E 13	1.137E 13	1.137E 13	1.063E 13	1.063E 13
21	0.	0.	1.087E 13	1.087E 13	1.017E 13	1.017E 13	9.656E 12	9.656E 12	9.037E 12	9.037E 12
	0.	0.	1.087E 13	1.087E 13	1.017E 13	1.017E 13	9.656E 12	9.656E 12	9.037E 12	9.037E 12
22	0.	0.	8.709E 12	8.709E 12	8.153E 12	8.153E 12	7.746E 12	7.746E 12	7.258E 12	7.258E 12
	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. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

SOURCE(I,J)

	6	7	8	9	10
1	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.
2	-0.	-0.	-0.	-0.	0.
	-0.	-0.	-0.	-0.	0.
3	-0.	-0.	-0.	-0.	0.
	-0.	-0.	-0.	-0.	0.
4	-0.	-0.	-0.	-0.	0.
	4.092E 12	4.092E 12	3.163E 12-0.	-0.	0.
5	5.144E 12	5.144E 12	3.936E 12-0.	-0.	0.
	5.144E 12	5.144E 12	3.936E 12-0.	-0.	0.
6	6.176E 12	6.176E 12	4.711E 12-0.	-0.	0.
	6.176E 12	6.176E 12	4.711E 12-0.	-0.	0.
7	7.196E 12	7.196E 12	5.480E 12-0.	-0.	0.
	7.196E 12	7.196E 12	5.480E 12-0.	-0.	0.
8	8.205E 12	8.205E 12	6.238E 12-0.	-0.	0.
	8.205E 12	8.205E 12	6.238E 12-0.	-0.	0.
9	9.204E 12	9.204E 12	6.977E 12-0.	-0.	0.
	9.204E 12	9.204E 12	6.977E 12-0.	-0.	0.
10	1.019E 13	1.019E 13	7.679E 12-0.	-0.	0.
	1.019E 13	1.019E 13	7.679E 12-0.	-0.	0.
11	1.107E 13	1.107E 13	8.299E 12-0.	-0.	0.
	1.107E 13	1.107E 13	8.299E 12-0.	-0.	0.
12	1.175E 13	1.175E 13	8.787E 12-0.	-0.	0.
	1.175E 13	1.175E 13	8.787E 12-0.	-0.	0.
13	1.221E 13	1.221E 13	9.117E 12-0.	-0.	0.
	1.221E 13	1.221E 13	9.117E 12-0.	-0.	0.
14	1.242E 13	1.242E 13	9.273E 12-0.	-0.	0.
	1.242E 13	1.242E 13	9.273E 12-0.	-0.	0.

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

SOURCE(I,J)

	6	7	8	9	10				
15	1.239E 13	1.239E 13	9.251E 12	-0.	-0.	-0.	-0.	0.	0.
	1.239E 13	1.239E 13	9.251E 12	-0.	-0.	-0.	-0.	0.	0.
16	1.212E 13	1.212E 13	9.049E 12	-0.	-0.	-0.	-0.	0.	0.
	1.212E 13	1.212E 13	9.049E 12	-0.	-0.	-0.	-0.	0.	0.
17	1.162E 13	1.162E 13	8.672E 12	-0.	-0.	-0.	-0.	0.	0.
	1.162E 13	1.162E 13	8.672E 12	-0.	-0.	-0.	-0.	0.	0.
18	1.089E 13	1.089E 13	8.129E 12	-0.	-0.	-0.	-0.	0.	0.
	1.089E 13	1.089E 13	8.129E 12	-0.	-0.	-0.	-0.	0.	0.
19	9.943E 12	9.943E 12	7.431E 12	-0.	-0.	-0.	-0.	0.	0.
	9.943E 12	9.943E 12	7.431E 12	-0.	-0.	-0.	-0.	0.	0.
20	8.809E 12	8.809E 12	6.596E 12	-0.	-0.	-0.	-0.	0.	0.
	8.809E 12	8.809E 12	6.596E 12	-0.	-0.	-0.	-0.	0.	0.
21	7.507E 12	7.507E 12	5.648E 12	-0.	-0.	-0.	-0.	0.	0.
	7.507E 12	7.507E 12	5.648E 12	-0.	-0.	-0.	-0.	0.	0.
22	6.057E 12	6.057E 12	4.619E 12	-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. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

ADJOINT FLUX CALCULATION BEGINS

LT NC	FLUX CONVR	NU-CRIT CONVR	TOT RESIDUE	MAX RESIDUE	NU-CRITICAL
10	3.3829E-03	0.	2.5833E 00	4.4539E-01	1.00000E 00
20	2.1898E-03	0.	2.7080E-01	4.8712E-02	1.00000E 00
30	1.1016E-03	0.	3.1843E-02	4.4510E-03	1.00000E 00
40	3.5192E-04	0.	6.7548E-03	1.1612E-03	1.00000E 00
50	9.9968E-05	0.	1.7539E-03	3.2758E-04	1.00000E 00
60	2.7664E-05	0.	4.7483E-04	9.1866E-05	1.00000E 00
70	7.5326E-06	0.	1.3808E-04	2.7187E-05	1.00000E 00
80	2.1383E-06	0.	6.6721E-05	9.4108E-06	1.00000E 00

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

NO.IT.# 80 NU-CRIT# 1.00000E 00 N.F./(TOT PROD)# 5.56474E-01

GROUP 1 ADJCINT FLUX

	1	2	3	4	5	6	7	8	9	10
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	3.843E 14	3.843E 14	3.604E 14	3.433E 14	3.230E 14	2.731E 14	2.132E 14	1.460E 14	7.416E 13	0.
3	8.427E 14	8.427E 14	7.879E 14	7.493E 14	7.041E 14	5.940E 14	4.620E 14	3.151E 14	1.595E 14	0.
4	1.469E 15	1.469E 15	1.360E 15	1.287E 15	1.209E 15	1.019E 15	7.840E 14	5.276E 14	2.650E 14	0.
5	1.861E 15	1.861E 15	1.707E 15	1.609E 15	1.514E 15	1.280E 15	9.746E 14	6.483E 14	3.239E 14	0.
6	2.242E 15	2.242E 15	2.051E 15	1.931E 15	1.816E 15	1.534E 15	1.165E 15	7.715E 14	3.844E 14	0.
7	2.613E 15	2.613E 15	2.388E 15	2.248E 15	2.113E 15	1.784E 15	1.352E 15	8.937E 14	4.446E 14	0.
8	2.973E 15	2.973E 15	2.719E 15	2.559E 15	2.405E 15	2.027E 15	1.534E 15	1.012E 15	5.032E 14	0.
9	3.319E 15	3.319E 15	3.043E 15	2.865E 15	2.692E 15	2.263E 15	1.708E 15	1.125E 15	5.587E 14	0.
10	3.644E 15	3.644E 15	3.366E 15	3.178E 15	2.979E 15	2.487E 15	1.870E 15	1.229E 15	6.093E 14	0.
11	3.927E 15	3.927E 15	3.656E 15	3.463E 15	3.237E 15	2.684E 15	2.010E 15	1.318E 15	6.527E 14	0.
12	4.146E 15	4.146E 15	3.869E 15	3.667E 15	3.427E 15	2.836E 15	2.119E 15	1.388E 15	6.866E 14	0.
13	4.291E 15	4.291E 15	4.007E 15	3.799E 15	3.549E 15	2.935E 15	2.191E 15	1.434E 15	7.092E 14	0.
14	4.355E 15	4.355E 15	4.068E 15	3.857E 15	3.604E 15	2.979E 15	2.223E 15	1.455E 15	7.192E 14	0.
15	4.337E 15	4.337E 15	4.051E 15	3.841E 15	3.589E 15	2.967E 15	2.214E 15	1.448E 15	7.160E 14	0.
16	4.236E 15	4.236E 15	3.957E 15	3.752E 15	3.506E 15	2.898E 15	2.163E 15	1.415E 15	6.995E 14	0.
17	4.053E 15	4.053E 15	3.787E 15	3.591E 15	3.356E 15	2.774E 15	2.071E 15	1.355E 15	6.699E 14	0.
18	3.792E 15	3.792E 15	3.543E 15	3.360E 15	3.141E 15	2.597E 15	1.939E 15	1.269E 15	6.278E 14	0.
19	3.457E 15	3.457E 15	3.231E 15	3.065E 15	2.865E 15	2.371E 15	1.772E 15	1.161E 15	5.744E 14	0.
20	3.054E 15	3.054E 15	2.855E 15	2.709E 15	2.534E 15	2.100E 15	1.572E 15	1.032E 15	5.114E 14	0.
21	2.591E 15	2.591E 15	2.423E 15	2.301E 15	2.153E 15	1.788E 15	1.345E 15	8.876E 14	4.413E 14	0.
22	2.074E 15	2.074E 15	1.942E 15	1.845E 15	1.729E 15	1.443E 15	1.100E 15	7.352E 14	3.678E 14	0.
23	1.205E 15	1.205E 15	1.130E 15	1.075E 15	1.010E 15	8.497E 14	6.585E 14	4.476E 14	2.261E 14	0.
24	5.532E 14	5.532E 14	5.196E 14	4.950E 14	4.655E 14	3.931E 14	3.064E 14	2.095E 14	1.063E 14	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

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	1.191E 14	1.191E 14	9.154E 13	0.	2.723E 13	3.434E 13	3.392E 13	2.672E 13	1.462E 13	0.
3	3.107E 14	3.107E 14	2.390E 14	0.	7.762E 13	9.698E 13	9.374E 13	7.223E 13	3.898E 13	0.
4	6.931E 14	6.931E 14	5.346E 14	0.	2.033E 14	2.467E 14	2.244E 14	1.634E 14	8.568E 13	0.
5	9.881E 14	9.881E 14	7.641E 14	0.	3.190E 14	3.797E 14	3.324E 14	2.337E 14	1.208E 14	0.
6	1.287E 15	1.287E 15	9.949E 14	0.	4.368E 14	5.196E 14	4.537E 14	3.179E 14	1.637E 14	0.
7	1.604E 15	1.604E 15	1.241E 15	0.	5.784E 14	6.873E 14	6.001E 14	4.206E 14	2.162E 14	0.
8	1.960E 15	1.960E 15	1.520E 15	0.	7.767E 14	9.106E 14	7.871E 14	5.487E 14	2.807E 14	0.
9	2.377E 15	2.377E 15	1.866E 15	0.	1.110E 15	1.232E 15	1.031E 15	7.071E 14	3.583E 14	0.
10	2.878E 15	2.878E 15	2.376E 15	2.120E 15	1.836E 15	1.698E 15	1.335E 15	8.919E 14	4.461E 14	0.
11	3.429E 15	3.429E 15	3.077E 15	2.862E 15	2.633E 15	2.196E 15	1.652E 15	1.082E 15	5.356E 14	0.
12	3.912E 15	3.912E 15	3.601E 15	3.390E 15	3.149E 15	2.592E 15	1.925E 15	1.250E 15	6.161E 14	0.
13	4.281E 15	4.281E 15	3.976E 15	3.758E 15	3.500E 15	2.879E 15	2.133E 15	1.383E 15	6.804E 14	0.
14	4.525E 15	4.525E 15	4.214E 15	3.990E 15	3.721E 15	3.063E 15	2.271E 15	1.473E 15	7.248E 14	0.
15	4.640E 15	4.640E 15	4.327E 15	4.099E 15	3.826E 15	3.152E 15	2.340E 15	1.520E 15	7.481E 14	0.
16	4.630E 15	4.630E 15	4.321E 15	4.095E 15	3.823E 15	3.153E 15	2.343E 15	1.524E 15	7.505E 14	0.
17	4.502E 15	4.502E 15	4.203E 15	3.984E 15	3.721E 15	3.071E 15	2.285E 15	1.487E 15	7.330E 14	0.
18	4.263E 15	4.263E 15	3.981E 15	3.774E 15	3.525E 15	2.912E 15	2.169E 15	1.413E 15	6.971E 14	0.
19	3.920E 15	3.920E 15	3.662E 15	3.473E 15	3.245E 15	2.683E 15	2.001E 15	1.306E 15	6.448E 14	0.
20	3.485E 15	3.485E 15	3.258E 15	3.090E 15	2.889E 15	2.392E 15	1.788E 15	1.170E 15	5.786E 14	0.
21	2.969E 15	2.969E 15	2.776E 15	2.635E 15	2.466E 15	2.047E 15	1.538E 15	1.012E 15	5.020E 14	0.
22	2.382E 15	2.382E 15	2.229E 15	2.118E 15	1.984E 15	1.654E 15	1.260E 15	8.406E 14	4.200E 14	0.
23	1.383E 15	1.383E 15	1.297E 15	1.234E 15	1.159E 15	9.744E 14	7.548E 14	5.127E 14	2.588E 14	0.
24	6.348E 14	6.348E 14	5.961E 14	5.678E 14	5.340E 14	4.508E 14	3.513E 14	2.401E 14	1.217E 14	0.
25	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

(FLUX)X(ADJOINT-FLUX) REGION INTEGRALS

REG	F(1)F(K)*	F(2)F(K)*	K#1,2
1	1.39940E 31	4.26649E 29	
	5.67431E 30	1.73379E 29	
2	1.54551E 32	5.23193E 30	
	9.91092E 31	3.41075E 30	
3	6.58044E 31	0.	
	0.	0.	
4	7.47342E 31	1.97519E 30	
	3.27466E 31	9.39936E 29	
5	9.36288E 30	2.01666E 29	
	1.91736E 30	4.35185E 28	
6	1.19541E 33	6.77784E 31	
	1.23498E 33	7.09558E 31	
7	1.10450E 32	6.33752E 30	
	1.01655E 32	6.14947E 30	
8	5.79476E 31	4.74692E 30	
	6.64934E 31	5.44681E 30	

Fig. B.4 (continued)

CODE EQUIPOISE - 3 SAMPLE PROBLEM FOR REPORT

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

REG	DF(1)DF(1)*	DF(2)DF(2)*
1	1.38866E 30	2.40400E 28
2	3.42164E 30	2.27018E 29
3	2.62689E 30	0.
4	4.91743E 30	1.06940E 29
5	1.89056E 30	1.03182E 28
6	2.87822E 31	1.85524E 30
7	3.64382E 31	1.99386E 30
8	7.73585E 30	6.73992E 29

Fig. B.4 (continued)

5. Region and composition specifications.
6. The value of the extrapolated Liebmann coefficient.
7. Convergence levels at every tenth iteration consisting of flux convergence [Eq. (7)], nu-critical convergence [Eq. (6)], and residue convergence [Eq. (8)]. Also reported at every tenth iteration are the maximum residue and the value of nu-critical (λ).
8. The normalized group flux values at every point.
9. A neutron balance list calculated from the printed-out fluxes.
10. A summary of the group absorptions by region, and the region volumes.
11. The source density (B.1) at each quadrant of each mesh point.
12. A summary of convergence levels for the adjoint calculation.
13. The group adjoint-flux values at each point.
14. The flux times adjoint-flux region integrals, calculated region by region. For two regions, the print-out would be as follows:

Region	F(1)F(K)*	F(2)F(K)*	K = 1,2
1	$\int \Phi_1 \Phi_1^* \, dv$	$\int \Phi_2 \Phi_1^* \, dv$	
	$\int \Phi_1 \Phi_2^* \, dv$	$\int \Phi_2 \Phi_2^* \, dv$	
2	$\int \Phi_1 \Phi_1^* \, dv$	$\int \Phi_2 \Phi_1^* \, dv$	
	$\int \Phi_1 \Phi_2^* \, dv$	$\int \Phi_2 \Phi_2^* \, dv$	

15. The region integrals of the dot products of the gradients of the flux and the adjoint flux. For two regions, the print-out would be as follows:

Region	DF(1)DF(1)*	DF(2)DF(2)*
1	$\int \nabla \Phi_1 \cdot \nabla \Phi_1^* \, dv$	$\int \nabla \Phi_2 \cdot \nabla \Phi_2^* \, dv$
2	$\int \nabla \Phi_1 \cdot \nabla \Phi_1^* \, dv$	$\int \nabla \Phi_2 \cdot \nabla \Phi_2^* \, dv$

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