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WHIRLAWAY – A THREE-DIMENSIONAL, TWO-GROUP NEUTRON DIFFUSION CODE FOR THE IBM 7090 COMPUTER

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OAK RIDGE NATIONAL LABORATORY
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Errata

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Page 2, line 8 (last term of Eq. 1) –

Change

$$+ \chi_k \lambda \left[\sum_{j=1}^{8} \nu\Sigma f_1(j)\, V_j + \sum_{j=1}^{8} \nu\Sigma f_2(j)\, V_j \right] = 0 .$$

To

$$+ \chi_k \lambda \left[\sum_{j=1}^{8} \nu\Sigma f_1(j)\, \phi_1(I,J,K)\, V_j + \sum_{j=1}^{8} \nu\Sigma f_2(j)\, \phi_2(I,J,K)\, V_j \right] = 0 .$$

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WHIRLAWAY – A THREE-DIMENSIONAL, TWO-GROUP NEUTRON DIFFUSION CODE FOR THE IBM 7090 COMPUTER

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ABSTRACT

WHIRLAWAY is an IBM 7090 FORTRAN programmed code for the solution of two-group neutron diffusion equations in *xyz* geometry. The code was designed to run under control of the IBM 7090 FORTRAN Monitor System on a machine with at least six tape units. The maximum number of mesh points is limited to 12,750. Arbitrary distributions of materials and mesh spacing are permitted. The boundary conditions are either zero flux or zero current at each of the six faces of the reactor, and the code will, if desired, compute the adjoint-flux and associated flux–adjoint-flux region integrals that are necessary for perturbation calculations. Computation time is approximately 0.006 sec per point iteration. Normally, running times are about 2 to 3 hr for a 10,000-point problem.

INTRODUCTION

The iterative procedure used in WHIRLAWAY is the same simple approach as that used in the two-dimensional code, EQUIPOISE,[1] and has proved to be even more powerful in three dimensions. The number of iterations required to reach the same degree of convergence in three dimensions is considerably less than that required for a like problem in two dimensions. As yet, no proofs exist that the process will converge to the desired answer, but no difficulties have been encountered.

WHIRLAWAY uses no tapes for storage of group constants. All necessary constants are computed as needed as the calculation progresses. This approach has proved to be at least as fast as the alternative procedure of calculating all the group constants at the beginning of a case and reading them from tape as they are needed. One tape is needed to store the flux distribution if the adjoint calculation is being done; five tapes are needed for input, output, program, and Monitor System.

COMPUTATIONAL METHOD AND DIFFERENCE EQUATIONS

The simple computational procedure used in WHIRLAWAY is identical in principle to that described in detail in ref 1.

With reference to Fig. 1, the three-dimensional difference equations that are solved in the code are, at each mesh point:

---

[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).

$$
\begin{aligned}
&[\Phi_k(I+1,J,K) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AR_i \right] \\
&+ [\Phi_k(I-1,J,K) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AL_i \right] \\
&+ [\Phi_k(I,J+1,K) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AO_i \right] \\
&+ [\Phi_k(I,J-1,K) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AI_i \right] \\
&+ [\Phi_k(I,J,K+1) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AT_i \right] \\
&+ [\Phi_k(I,J,K-1) - \Phi_k(I,J,K)] \left[\sum_{i=1}^{4} D_k(j)\, AB_i \right] \\
&+ \Phi_{k-1}(I,J,K) \left[\sum_{j=1}^{8} \Sigma R_{k-1}(j)\, V_j \right] - \Phi_k(I,J,K) \left\{ \sum_{j=1}^{8} [\Sigma A_k(j) + \Sigma R_k(j)]\, V_j \right\} \\
&+ \chi_k \lambda \left[\sum_{j=1}^{8} \nu \Sigma f_1(j)\, V_j + \sum_{j=1}^{8} \nu \Sigma f_2(j)\, V_j \right] = 0 . \qquad (1)
\end{aligned}
$$

Note that ΣR_0 and ΣR_2 are both zero because there is no slowing-down into group 1, nor is there any out of group 2.

NOTATION

AR_i	Area of quarter-face i to the right of mesh point (I,J,K), cm^2
AL_i	Area of quarter-face i to the left of mesh point (I,J,K), cm^2
AO_i	Area of quarter-face i in the "out" direction from mesh point (I,J,K), cm^2
AI_i	Area of quarter-face i in the "in" direction from mesh point (I,J,K), cm^2
AT_i	Area of quarter-face i above mesh point (I,J,K), cm^2
AB_i	Area of quarter-face i below mesh point (I,J,K), cm^2
$D_k(j)$	Group k diffusion coefficient of octant j surrounding mesh point (I,J,K), cm
i	Denotes quarter-face surrounding mesh point (I,J,K)
I,J,K	Denotes the coordinates of a mesh point
j	Denotes octant surrounding mesh point (I,J,K)
k	Subscript denoting the group number

V_j	Volume of octant j surrounding mesh point (I,J,K), cm^3
$X(I)$	Distance from the origin to mesh plane I, cm
$Y(J)$	Distance from the origin to mesh plane J, cm
$Z(K)$	Distance from the origin to mesh plane K, cm
$\Phi_k(I,J,K)$	Group k flux at mesh point (I,J,K)
λ	The eigenvalue of the problem; the value by which all the $\nu\Sigma_f$'s must be multiplied so that the difference equations will balance
$\nu\Sigma f_k(j)$	The number of neutrons produced per fission times the macroscopic fission cross section of group k in octant j, cm^{-1}
$\Sigma A_k(j)$	Macroscopic absorption cross section of group k and octant j, cm^{-1}
$\Sigma R_k(j)$	Macroscopic removal cross section of group k and octant j, cm^{-1}
χ_k	The fraction of neutrons produced from fission that are born in group k

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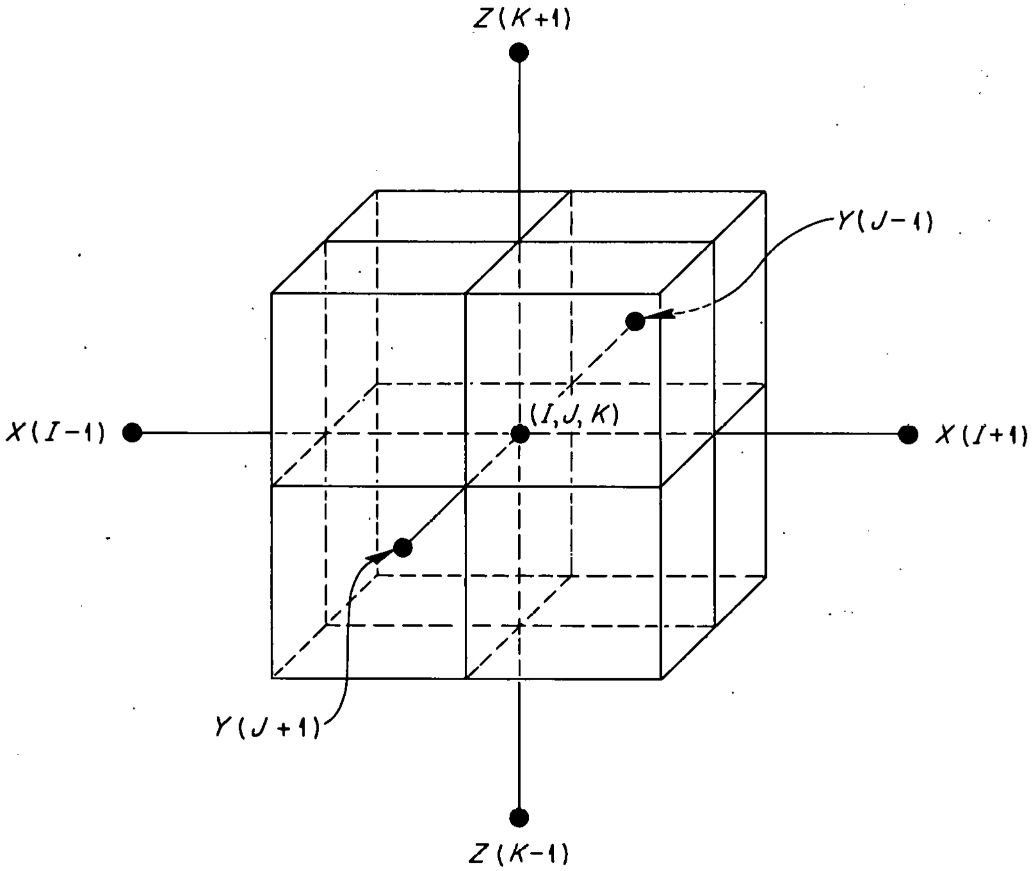

Fig. 1. Schematic of Mesh at Point (I,J,K).

Appendix A

INPUT PREPARATION AND OPERATING INSTRUCTIONS

Input Data Cards. – Figure B.2 shows an input data form filled out for the sample problem. Given below are the instructions for writing WHIRLAWAY 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. The contents of this card are printed at the top of each page of output.

Control Card. – Columns 1–3, IMAX(I3) $\leqq$ 999: total number of mesh planes in the x direction. The x direction runs from left to right, with the left plane being number 1 and the right plane being number IMAX.

Columns 4–6, JMAX(I3) $\leqq$ 999: total number of mesh planes in the y direction. The y direction runs from "in" to "out," with the innermost plane designated as number 1 and the outermost plane designated as plane number JMAX.

Columns 7–9, KMAX(I3) $\leqq$ 999: total number of mesh planes in the z direction. The z direction runs from bottom to top, with plane 1 being the bottom boundary of the reactor and plane KMAX being the top plane of the reactor. Note that IMAX × JMAX × KMAX $\leqq$ 12,750.

Columns 10–18, NORM FACTOR (E9.5): normalization factor. The converged fluxes at each mesh point are divided by

$$\sum_{I,J,K} \left[\sum_{j=1}^{8} \nu\Sigma f_1(j)\, \Phi_1(I,J,K)\, V_j + \sum_{j=1}^{8} \nu\Sigma f_2(j)\, \Phi_2(I,J,K)\, V_j \right] , \tag{A.1}$$

the total neutron source, and multiplied by the normalization factor. Use of this factor enables the user to make the output fluxes correspond to any arbitrary power level. For example, let W be the total reactor power in megawatts, ν the number of neutrons produced per fission, and μ the number of fissions per megawatt-second. Then the normalization factor would be $\nu \times \mu \times W \times F$, where F is the fraction of the whole reactor that is considered in the calculation. If the reactor had three symmetry boundaries, F would be $\frac{1}{8}$. For a reactor with one symmetry boundary, F would be $\frac{1}{2}$.

If this item is omitted, the program treats the normalization factor as 1.0.

Columns 19–20, GI(I2): geometry indicator. This number is not used. WHIRLAWAY considers only xyz geometry at present.

Columns 21–22, SI(I2): source indicator. If this number is +1, the source,

$$(\nu\Sigma f_1 \Phi_1 + \nu\Sigma f_2 \Phi_2)_j , \tag{A.2}$$

is computed for output at each mesh point, where $j = 1, \ldots , 8$. If SI is 0, the source calculation is skipped.

Columns 23–24, AI(I2): adjoint indicator. If this number is +1, the adjoint-flux and the flux–adjoint-flux region integrals are computed following the regular calculation. If AI is 0, the adjoint-flux calculation is not done.

Columns 25–26, FI(I2): previous-flux indicator. If this number is +1, the flux distribution from the preceding case is used as the initial flux for the present case. Restrictions are that the present case must have the same number of divisions in the x, y, and z directions and the same boundary conditions as the previous case. If this number is 0, the code supplies the initial flux guess.

Columns 27–28, CI(I2): convergence indicator. If this number is 0, the calculation stops when

$$\left| \frac{\lambda_{n-10}}{\lambda_n} - 1 \right| < \epsilon , \tag{A.3}$$

where n is the iteration number and ϵ is the convergence criterion (see below). The over-all eigenvalue of the problem is λ.

If CI is +1, the calculation stops when the above condition is met, as well as the flux convergence condition

$$\left| \frac{\Phi_n}{\Phi_{n+1}} - 1 \right|_{\max} < \epsilon , \tag{A.4}$$

where Φ_n is the flux at a point at iteration n and Φ_{n+1} is the flux at the same point at iteration $n + 1$. For the adjoint calculation, only the flux convergence condition is tested; it is given by

$$\frac{\rho_{\max} - \rho_{\min}}{\frac{1}{2}(\rho_{\max} + \rho_{\min})} < \epsilon , \tag{A.5}$$

where $\rho = \Phi_n/\Phi_{n+1}$.

If CI is −1, the calculation stops when the flux condition [Eq. (A.4)] is met, as well as the point-λ convergence condition

$$\frac{\lambda_{pt}^{\max} - \lambda_{pt}^{\min}}{\lambda} < \epsilon , \tag{A.6}$$

where $\lambda_{pt}^{\max}$ and $\lambda_{pt}^{\min}$ are the maximum and minimum values of λ, respectively, calculated according to Eq. (1) at each mesh point (pt). If a problem has not reached convergence after 300 iterations, it is automatically terminated by the code.

Columns 29–30, LB(I2): left boundary indicator. If this number is 0, the left boundary plane of the reactor is considered as a zero-flux boundary. If this number is +1, a symmetry boundary is assumed to exist midway between planes $I = 1$ and $I = 2$.

Columns 31–32, RB(I2): right boundary indicator. If this number is 0, the right boundary plane of the reactor is considered as a zero-flux boundary; if +1, a symmetry boundary is assumed to exist midway between planes $I =$ IMAX-1 AND $I =$ IMAX.

Columns 33–34, IB(I2): "in" boundary indicator. If this number is 0, the innermost boundary is a zero-flux boundary; if +1, a symmetry boundary exists midway between planes $J = 1$ and $J = 2$.

Columns 35–36, OB(I2): "out" boundary indicator. If this number is 0, the outermost boundary is a zero-flux boundary; if +1, a symmetry boundary exists midway between planes J = JMAX-1 and J = JMAX.

Columns 37–38, BB(I2): bottom boundary indicator. If BB is 0, the bottom boundary of the reactor is a zero-flux boundary; if +1, a symmetry boundary exists midway between planes $K = 1$ and $K = 2$.

Columns 39–40, TB(I2): top boundary indicator. If TB is 0, the top boundary of the reactor is a zero-flux boundary; if +1, a symmetry boundary plane is assumed to exist midway between planes K = KMAX-1 and K = KMAX.

Columns 41–46, $\chi 1_1$(E6.3): the fraction of neutrons produced from fission that are born in group 1.

Columns 47–52, $\chi 1_2$(E6.3): the fraction of neutrons produced from fission that are born in group 2.

Columns 53–58, β_1(E6.3): extrapolated Liebmann coefficient for group 1. If this number is 0, β_1 is computed by the code; if it is not 0, the code uses the value specified. If β is to be calculated by the code, the following empirical formula is used:

$$\beta = 2 - \sqrt{2}\left[\left(\frac{\pi}{p}\right)^2 + \left(\frac{\pi}{q}\right)^2 + \left(\frac{\pi}{r}\right)^2\right]^{1/2} , \tag{A.7}$$

where p, q, and r are the number of mesh increments in the x, y, and z directions, respectively. If one of a pair of opposite surfaces is a symmetry boundary, the corresponding number of mesh increments is doubled. If both opposite surfaces are symmetry boundaries, the corresponding number of mesh increments is made ∞.

If a problem has not converged after 150 iterations, a new β is calculated by

$$\beta_{\text{new}} = \frac{\beta_{\text{old}} + 1}{2} , \tag{A.8}$$

and β is set to 1 at 200 iterations.

Columns 59–64, β_2(E6.3): same as β_1 except for group 2.

Columns 65–72, ϵ(E8.5): convergence criterion.

Mesh Specification Cards. – Described below are the three types of cards required to specify the mesh: (1) cards giving the ΔX's and I numbers, (2) cards giving the ΔY's and J numbers, and (3) cards specifying the ΔZ's and K numbers.

1. In columns 1–6 and 7–9, 10–15 and 16–18, etc., supply a value of ΔX(E6.3) and the value of I(I3) up to which this ΔX applies, going from left to right of the mesh. Use as many cards as needed, with each card, except possibly the last, being completely filled through column 72. The last number on these cards is equal to IMAX.
2. In columns 1–6 and 7–9, 10–15 and 16–18, etc., supply a value of ΔY(E6.3) and the value of J(I3) up to which this ΔY applies, going from "in" to "out" of the mesh. The last number on these cards is equal to JMAX.

3. In columns 1–6 and 7–9, 10–15 and 16–18, etc., supply a value of ΔZ(E6.3) and the value of K(I3) up to which this ΔZ applies, going from bottom to top of the mesh. The last number on these cards is equal to KMAX.

Region Specification Cards. – The regions are specified as parallelopipeds, with each card completely specifying one region, for as many regions as are needed to fill the mesh. The region-specification cards may be in any order. However, the regions must be numbered consecutively. **One card with the number 99 punched in columns 1 and 2 must follow the last region-specification card.**

Columns 1–2, RG(I2)	Region number
Columns 3–5, I1(I3)	Left I coordinate of the region
Columns 6–8, I2(I3)	Right I coordinate of the region
Columns 9–11, J1(I3)	"In" J coordinate of the region
Columns 12–14, J2(I3)	"Out" J coordinate of the region
Columns 15–17, K1(I3)	Bottom K coordinate of the region
Columns 18–20, K2(I3)	Top K coordinate of the region
Columns 21–26, D_1(E6.3)	Group 1 diffusion coefficient
Columns 27–32, D_2(E6.3)	Group 2 diffusion coefficient
Columns 33–40, ΣR_1(E8.5)	Group 1 macroscopic removal cross section
Columns 41–48, ΣA_1(E8.5)	Group 1 macroscopic absorption cross section
Columns 49–56, ΣA_2(E8.5)	Group 2 macroscopic absorption cross section
Columns 57–64, $\nu\Sigma f_1$(E8.5)	Group 1, ν times the macroscopic fission cross section
Columns 65–72, $\nu\Sigma f_2$(E8.5)	Group 2, ν times the macroscopic fission cross section

Operation Instructions. – WHIRLAWAY consists of nine CHAIN links which are distributed on two tapes by the Monitor System at execution time. The DSU Channel-Unit Table, which relates the logical tape numbers to the actual tape number, must be supplied to each CHAIN link by the user. Table A.1 gives the logical tape numbers used in the code and, in the case of the program tape, the actual tape numbers that must be used.

Table A.1. Tapes Required for WHIRLAWAY

Logical Tape Number	Actual Tape Number	Function
8		Scratch tape for adjoint calculation only
9		Output tape
10		Input tape
	B1	Program tape
	B2	Program tape
		System tape

The operating instructions are those given in ref 2; a "job" consists of the program deck with all necessary monitor control cards followed by the data decks for as many cases to be run as desired. Two blank cards should follow the last input data deck. The output tape should be listed under program control on 14- by 11-in. paper.

Appendix B

SAMPLE PROBLEM

The configuration of the sample problem is shown in Fig. B.1; the input data are given in Fig. B.2; Fig. B.3 gives the output. The problem ran in 8.4 min. Note that mesh increments are specified as input, not total distances. The mesh increment from plane two to plane five in the X direction is 2 cm, and the distance is 6 cm.

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[2] *IBM-7090 FORTRAN Reference Manual,* Form C28-6065.

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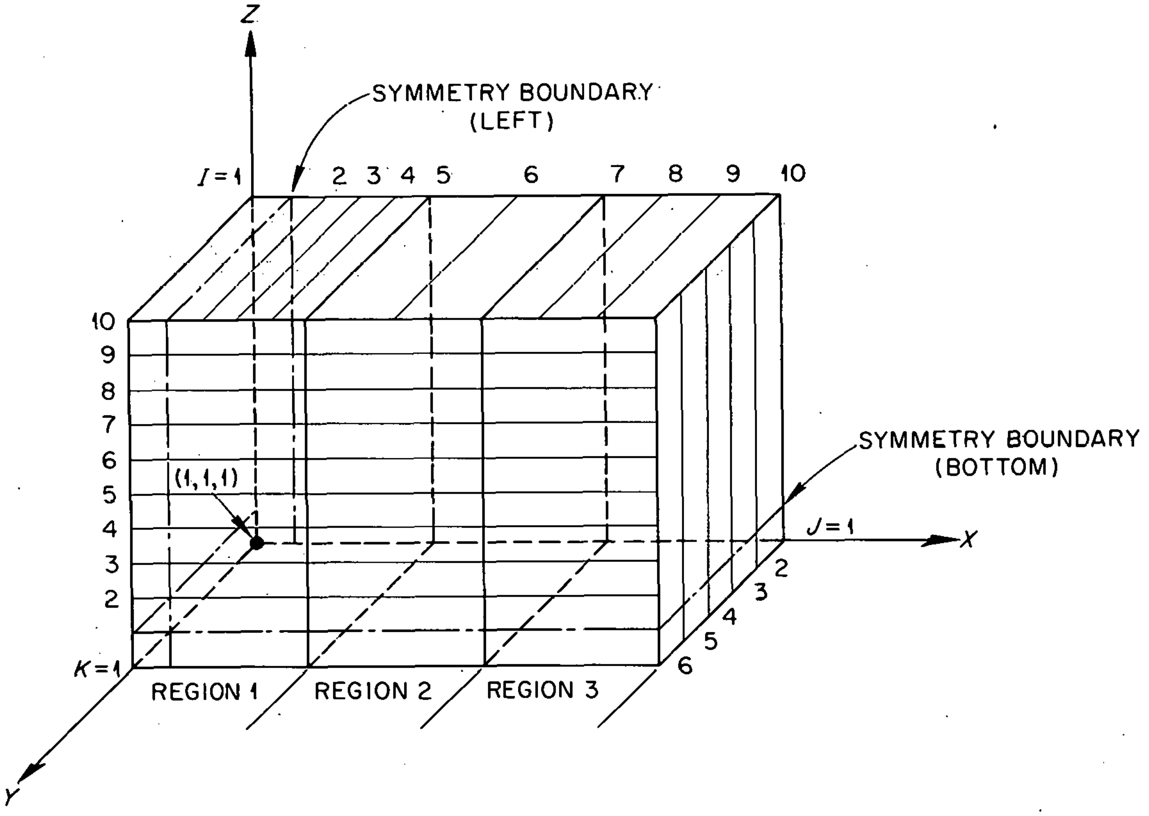

Fig. B.1. Diagram of Sample Problem.

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

WHIRLAWAY INPUT FORM

REQUEST NO.

TITLE 1	73–80
WHIRLAWAY SAMPLE PROBLEM FOR REPORT	ID 01

IMAX 1	JMAX 4	KMAX 7	NORM FACTOR 10	GI 19	SI 21	AI 23	FI 25	CI 27	LB 29	RB 31	IB 33	OB 35	BB 37	TB 39	XI_1 41	XI_2 47	β_1 53	β_2 59	ϵ 65	73–80
10	6	10	1.0		1	1		-1	1				1		1.0				0.001	CNTRL 02

Δx 1	I 7	Δx 10	I 16	Δx 19	I 25	Δx 28	I 34	Δx 37	I 43	Δx 46	I 52	Δx 55	I 61	Δx 64	I 70	73–80
4.0	2	2.0	5	4.0	7	3.0	10									MESH 03

ΔY 1	J 7	ΔY 10	J 16	ΔY 19	J 25	ΔY 28	J 34	ΔY 37	J 43	ΔY 46	J 52	ΔY 55	J 61	ΔY 64	J 70	73–80
3.0	6															MESH 04

Δz 1	K 7	Δz 10	K 16	Δz 19	K 25	Δz 28	K 34	Δz 37	K 43	Δz 46	K 52	Δz 55	K 61	Δz 64	K 70	73–80
4.0	2	2.0	10													MESH 05

RG 1	I1 3	I2 6	J1 9	J2 12	K1 15	K2 18	D_1 21	D_2 27	ΣR_1 33	ΣA_1 41	ΣA_2 49	$\nu\Sigma f_1$ 57	$\nu\Sigma f_2$ 65	73–80
1	1	6	1	6	1	10	1.5	1.2	0.0033	0.0012	0.0047	0.004	0.063	REG 06
2	6	8	1	6	1	10	1.7	1.13	0.0052	0.0007	0.0063	0.0004	0.025	REG 07
3	8	10	1	6	1	10	1.2	0.87	0.0067	0.00052	0.008			REG 08
99														END 09
														STOP 10
														STOP 11

Fig. B.2. Input Data for Sample Problem.

The output (Fig. B.3) consists of the items shown below:

1. Title.
2. Reactor specifications.
3. Mesh specifications.
4. Dimension specifications.
5. Region specifications.
6. The values of the extrapolated Liebmann coefficients.
7. Flux convergence [Eq. (A.4)], point-λ convergence [Eq. (A.6)], total-λ convergence [Eq. (A.3)], total residue, and λ (labeled NU-CRITICAL) at every tenth iteration. The total residue is calculated as the square root of the sum of the squares of the residues (summed over all points and groups) divided by the total source [Eq. (A.1)].
8. The normalized flux values for each group at each mesh point.
9. A neutron-balance list calculated from the printed-out fluxes.
10. A summary of the region-integrated group absorptions and the region volumes.
11. The source density [Eq. (A.2)] at each octant of each internal mesh point.
12. A summary of convergence levels for the adjoint calculation.
13. The normalized adjoint-flux values at each mesh point.
14. The flux times the adjoint-flux region integrals and the region integrals of the dot products of the gradients of the flux and the adjoint flux.

For one region, the printout would be as follows:

REG	PHI(1)XPHI(K)*	PHI(2)XPHI(K)*	DELPHI(K)·DELPHI(K)*	$K = 1, 2$
1	$\int \Phi_1 \Phi_1{}^* dv$	$\int \Phi_2 \Phi_1{}^* dv$	$\int \nabla\Phi_1 \cdot \nabla\Phi_1{}^* dv$	
	$\int \Phi_1 \Phi_2{}^* dv$	$\int \Phi_2 \Phi_2{}^* dv$	$\int \nabla\Phi_2 \cdot \nabla\Phi_2{}^* dv$	

Fig. B.3. WHIRLAWAY Sample Problem.

```
WHIRLAWAY SAMPLE PROBLEN FOR REPORT

REACTCR SPECIFICATIONS

 IMAX 10  JMAX  6  KMAX 10  N.F. 1.0000E 00   BND COND(L,R,I,O,B,T) 1,0,0,0,1,0  XI1 1.000  X12-0.     EPI 10.000E-04

MESH SPECIFICATIONS

   I   DELX
   1  4.000   2  2.000   5  4.000   7  3.000  10

   J   DELY
   1  3.000   6

   K   DELZ
   1  4.000   2  2.000  10

DIMENSION SPECIFICATIONS

    I   DIST.
    2   2.000     3    4.000     4    6.000     5    8.000     6  12.000     7  16.000     8  19.000     9  22.000    10  25.000

    J   DIST.
    2   3.000     3    6.000     4    9.000     5  12.000     6  15.000

    K   DIST.
    2   2.000     3    4.000     4    6.000     5    8.000     6  10.000     7  12.000     8  14.000     9  16.000    10  18.000

REGION SPECIFICATIONS

 REG    I1   I2  J1   J2  K1  K2      D1           D2         SIGR1       SIGA1       SIGA2      NUSIGF1     NUSIGF2
   1     1    6   1    6   1  10  1.500E 00   1.200E 00   3.300E-03   1.200E-03   4.700E-03   4.000E-03   6.300E-02
   2     6    8   1    6   1  10  1.700E 00   1.130E 00   5.200E-03   7.000E-04   6.300E-03   4.000E-04   2.500E-02
   3     8   10   1    6   1  10  1.200E 00   8.700E-01   6.700E-03   5.200E-04   8.000E-03   0.          0.


       WHIRLAWAY SAMPLE PROBLEM FOR REPORT


       FLUX CALCULATION BEGINS     BETAF# 1.0376E 00  BETAS# 1.0376E 00

        IT NC      FLUX CCNVR     PT LAMDA CONVR     TOT LAMDA CONVR     TOT RESIDUE                        NU-CRITICAL
          10       1.6257E-01       7.3534E-02         1.0000E 00         5.2357E-03                        8.137153E 00
          20       6.4815E-02       3.5451E-02         3.0469E-01         1.9415E-03                        1.170291E 01
          30       2.0239E-02       1.1715E-02         1.0127E-01         4.9873E-04                        1.302157E 01
          40       5.5618E-03       3.4427E-03         2.4268E-02         1.1213E-04                        1.334544E 01
          50       1.4763E-03       9.6896E-04         5.1891E-03         2.4159E-05                        1.341506E 01
          60       3.9160E-04       2.7550E-04         1.0501E-03         5.0984E-06                        1.342916E 01


  WHIRLAWAY SAMPLE PROBLEM FOR REPORT


   FAST FLUX(I, 6,K)

   K  I    1          2          3          4          5          6          7          8          9          10

  10    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   9    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   8    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   7    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   6    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   5    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   4    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   3    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   2    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   1    0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
```

Fig. B.3 (continued).

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 FAST FLUX(I, 5,K)
 K  I    1          2          3          4          5          6          7          8          9         10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  1.324E-02  1.324E-02  1.258E-02  1.149E-02  9.980E-03  5.711E-03  2.834E-03  1.639E-03  6.543E-04  0.
 8  2.609E-02  2.609E-02  2.479E-02  2.263E-02  1.966E-02  1.125E-02  5.582E-03  3.227E-03  1.289E-03  0.
 7  3.813E-02  3.813E-02  3.623E-02  3.309E-02  2.873E-02  1.644E-02  8.160E-03  4.718E-03  1.884E-03  0.
 6  4.902E-02  4.902E-02  4.657E-02  4.253E-02  3.694E-02  2.114E-02  1.049E-02  6.065E-03  2.422E-03  0.
 5  5.841E-02  5.841E-02  5.550E-02  5.068E-02  4.402E-02  2.519E-02  1.250E-02  7.228E-03  2.886E-03  0.
 4  6.602E-02  6.602E-02  6.273E-02  5.729E-02  4.975E-02  2.847E-02  1.413E-02  8.170E-03  3.263E-03  0.
 3  7.163E-02  7.163E-02  6.806E-02  6.216E-02  5.398E-02  3.089E-02  1.533E-02  8.864E-03  3.540E-03  0.
 2  7.505E-02  7.505E-02  7.131E-02  6.513E-02  5.656E-02  3.237E-02  1.606E-02  9.288E-03  3.709E-03  0.
 1  7.505E-02  7.505E-02  7.131E-02  6.513E-02  5.656E-02  3.237E-02  1.606E-02  9.288E-03  3.709E-03  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 FAST FLUX(I, 4,K)
 K  I    1          2          3          4          5          6          7          8          9         10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  2.143E-02  2.143E-02  2.036E-02  1.860E-02  1.615E-02  9.240E-03  4.586E-03  2.651E-03  1.059E-03  0.
 8  4.221E-02  4.221E-02  4.010E-02  3.662E-02  3.181E-02  1.820E-02  9.033E-03  5.222E-03  2.085E-03  0.
 7  6.170E-02  6.170E-02  5.862E-02  5.354E-02  4.649E-02  2.661E-02  1.320E-02  7.635E-03  3.049E-03  0.
 6  7.931E-02  7.931E-02  7.536E-02  6.882E-02  5.977E-02  3.420E-02  1.697E-02  9.815E-03  3.919E-03  0.
 5  9.451E-02  9.451E-02  8.980E-02  8.201E-02  7.122E-02  4.076E-02  2.023E-02  1.170E-02  4.671E-03  0.
 4  1.068E-01  1.068E-01  1.015E-01  9.270E-02  8.051E-02  4.607E-02  2.287E-02  1.322E-02  5.280E-03  0.
 3  1.159E-01  1.159E-01  1.101E-01  1.006E-01  8.734E-02  4.998E-02  2.481E-02  1.434E-02  5.728E-03  0.
 2  1.214E-01  1.214E-01  1.154E-01  1.054E-01  9.152E-02  5.237E-02  2.599E-02  1.503E-02  6.002E-03  0.
 1  1.214E-01  1.214E-01  1.154E-01  1.054E-01  9.152E-02  5.237E-02  2.599E-02  1.503E-02  6.002E-03  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 FAST FLUX(I, 3,K)
 K  I    1          2          3          4          5          6          7          8          9         10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  2.143E-02  2.143E-02  2.036E-02  1.860E-02  1.615E-02  9.241E-03  4.586E-03  2.652E-03  1.059E-03  0.
 8  4.221E-02  4.221E-02  4.010E-02  3.663E-02  3.181E-02  1.820E-02  9.033E-03  5.223E-03  2.086E-03  0.
 7  6.170E-02  6.170E-02  5.862E-02  5.354E-02  4.650E-02  2.661E-02  1.321E-02  7.635E-03  3.049E-03  0.
 6  7.931E-02  7.931E-02  7.536E-02  6.882E-02  5.977E-02  3.420E-02  1.698E-02  9.815E-03  3.920E-03  0.
 5  9.451E-02  9.451E-02  8.980E-02  8.201E-02  7.122E-02  4.076E-02  2.023E-02  1.170E-02  4.671E-03  0.
 4  1.068E-01  1.068E-01  1.015E-01  9.270E-02  8.051E-02  4.607E-02  2.287E-02  1.322E-02  5.280E-03  0.
 3  1.159E-01  1.159E-01  1.101E-01  1.006E-01  8.734E-02  4.998E-02  2.481E-02  1.434E-02  5.728E-03  0.
 2  1.214E-01  1.214E-01  1.154E-01  1.054E-01  9.152E-02  5.237E-02  2.600E-02  1.503E-02  6.002E-03  0.
 1  1.214E-01  1.214E-01  1.154E-01  1.054E-01  9.152E-02  5.237E-02  2.600E-02  1.503E-02  6.002E-03  0.
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 FAST FLUX(I, 2,K)
 K  I   1          2          3          4          5          6          7          8          9          10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  1.324E-02  1.324E-02  1.258E-02  1.149E-02  9.981E-03  5.711E-03  2.835E-03  1.639E-03  6.545E-04  0.
 8  2.609E-02  2.609E-02  2.479E-02  2.264E-02  1.966E-02  1.125E-02  5.583E-03  3.228E-03  1.289E-03  0.
 7  3.813E-02  3.813E-02  3.623E-02  3.309E-02  2.874E-02  1.644E-02  8.162E-03  4.719E-03  1.885E-03  0.
 6  4.902E-02  4.902E-02  4.657E-02  4.254E-02  3.694E-02  2.114E-02  1.049E-02  6.067E-03  2.423E-03  0.
 5  5.841E-02  5.841E-02  5.550E-02  5.069E-02  4.402E-02  2.519E-02  1.250E-02  7.230E-03  2.887E-03  0.
 4  6.602E-02  6.602E-02  6.273E-02  5.729E-02  4.976E-02  2.848E-02  1.413E-02  8.173E-03  3.264E-03  0.
 3  7.163E-02  7.163E-02  6.806E-02  6.216E-02  5.398E-02  3.089E-02  1.533E-02  8.866E-03  3.541E-03  0.
 2  7.505E-02  7.505E-02  7.131E-02  6.513E-02  5.656E-02  3.237E-02  1.607E-02  9.290E-03  3.710E-03  0.
 1  7.505E-02  7.505E-02  7.131E-02  6.513E-02  5.656E-02  3.237E-02  1.607E-02  9.290E-03  3.710E-03  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 FAST FLUX(I, 1,K)
 K  I   1          2          3          4          5          6          7          8          9          10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 8  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 7  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 6  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 5  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 4  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 3  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 2  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 1  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 6,K)
 K  I   1          2          3          4          5          6          7          8          9          10
10  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 8  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 7  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 6  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 5  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 4  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 3  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 2  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 1  0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 5,K)
 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   6.004E-04  6.004E-04  5.762E-04  5.377E-04  4.889E-04  3.782E-04  2.583E-04  1.821E-04  8.979E-05  0.
 8   1.183E-03  1.183E-03  1.135E-03  1.059E-03  9.629E-04  7.448E-04  5.087E-04  3.586E-04  1.769E-04  0.
 7   1.729E-03  1.729E-03  1.659E-03  1.548E-03  1.408E-03  1.089E-03  7.437E-04  5.243E-04  2.586E-04  0.
 6   2.222E-03  2.222E-03  2.133E-03  1.990E-03  1.810E-03  1.400E-03  9.561E-04  6.740E-04  3.324E-04  0.
 5   2.648E-03  2.648E-03  2.541E-03  2.372E-03  2.156E-03  1.668E-03  1.139E-03  8.032E-04  3.961E-04  0.
 4   2.994E-03  2.994E-03  2.873E-03  2.681E-03  2.438E-03  1.886E-03  1.288E-03  9.079E-04  4.478E-04  0.
 3   3.248E-03  3.248E-03  3.117E-03  2.909E-03  2.645E-03  2.046E-03  1.397E-03  9.850E-04  4.858E-04  0.
 2   3.403E-03  3.403E-03  3.266E-03  3.048E-03  2.771E-03  2.144E-03  1.464E-03  1.032E-03  5.090E-04  0.
 1   3.403E-03  3.403E-03  3.266E-03  3.048E-03  2.771E-03  2.144E-03  1.464E-03  1.032E-03  5.090E-04  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 4,K)
 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   9.715E-04  9.715E-04  9.323E-04  8.701E-04  7.911E-04  6.119E-04  4.179E-04  2.946E-04  1.453E-04  0.
 8   1.914E-03  1.914E-03  1.836E-03  1.714E-03  1.558E-03  1.205E-03  8.232E-04  5.803E-04  2.862E-04  0.
 7   2.797E-03  2.797E-03  2.684E-03  2.505E-03  2.278E-03  1.762E-03  1.203E-03  8.484E-04  4.184E-04  0.
 6   3.596E-03  3.596E-03  3.451E-03  3.221E-03  2.928E-03  2.265E-03  1.547E-03  1.091E-03  5.379E-04  0.
 5   4.285E-03  4.285E-03  4.112E-03  3.838E-03  3.489E-03  2.699E-03  1.844E-03  1.300E-03  6.411E-04  0.
 4   4.844E-03  4.844E-03  4.648E-03  4.339E-03  3.944E-03  3.051E-03  2.084E-03  1.469E-03  7.247E-04  0.
 3   5.255E-03  5.255E-03  5.043E-03  4.707E-03  4.279E-03  3.310E-03  2.261E-03  1.594E-03  7.862E-04  0.
 2   5.506E-03  5.506E-03  5.284E-03  4.932E-03  4.484E-03  3.469E-03  2.369E-03  1.670E-03  8.238E-04  0.
 1   5.506E-03  5.506E-03  5.284E-03  4.932E-03  4.484E-03  3.469E-03  2.369E-03  1.670E-03  8.238E-04  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 3,K)
 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   9.716E-04  9.716C-04  9.324E-04  8.702E-04  7.911E-04  6.120E-04  4.180E-04  2.946E-04  1.453E-04  0.
 8   1.914E-03  1.914E-03  1.836E-03  1.714E-03  1.558E-03  1.205E-03  8.233E-04  5.804E-04  2.863E-04  0.
 7   2.798E-03  2.798E-03  2.685E-03  2.506E-03  2.278E-03  1.762E-03  1.204E-03  8.485E-04  4.185E-04  0.
 6   3.596E-03  3.596E-03  3.451E-03  3.221E-03  2.928E-03  2.265E-03  1.547E-03  1.091E-03  5.380E-04  0.
 5   4.286E-03  4.286E-03  4.113E-03  3.838E-03  3.490E-03  2.700E-03  1.844E-03  1.300E-03  6.412E-04  0.
 4   4.844E-03  4.844E-03  4.649E-03  4.339E-03  3.945E-03  3.052E-03  2.085E-03  1.470E-03  7.248E-04  0.
 3   5.255E-03  5.255E-03  5.043E-03  4.707E-03  4.280E-03  3.311E-03  2.262E-03  1.594E-03  7.863E-04  0.
 2   5.507E-03  5.507E-03  5.284E-03  4.932E-03  4.484E-03  3.469E-03  2.370E-03  1.670E-03  8.239E-04  0.
 1   5.507E-03  5.507E-03  5.284E-03  4.932E-03  4.484E-03  3.469E-03  2.370E-03  1.670E-03  8.239E-04  0.
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 2,K)
 K  I   1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   6.005E-04  6.005E-04  5.763E-04  5.379E-04  4.890E-04  3.783E-04  2.584E-04  1.821E-04  8.983E-05  0.
 8   1.183E-03  1.183E-03  1.135E-03  1.059E-03  9.631E-04  7.451E-04  5.089E-04  3.588E-04  1.769E-04  0.
 7   1.729E-03  1.729E-03  1.659E-03  1.549E-03  1.408E-03  1.089E-03  7.440E-04  5.245E-04  2.587E-04  0.
 6   2.223E-03  2.223E-03  2.133E-03  1.991E-03  1.810E-03  1.400E-03  9.565E-04  6.743E-04  3.326E-04  0.
 5   2.649E-03  2.649E-03  2.542E-03  2.372E-03  2.157E-03  1.669E-03  1.140E-03  8.036E-04  3.963E-04  0.
 4   2.994E-03  2.994E-03  2.873E-03  2.682E-03  2.438E-03  1.886E-03  1.289E-03  9.084E-04  4.480E-04  0.
 3   3.248E-03  3.248E-03  3.117E-03  2.909E-03  2.645E-03  2.046E-03  1.398E-03  9.855E-04  4.861E-04  0.
 2   3.404E-03  3.404E-03  3.266E-03  3.049E-03  2.772E-03  2.144E-03  1.465E-03  1.033E-03  5.093E-04  0.
 1   3.404E-03  3.404E-03  3.266E-03  3.049E-03  2.772E-03  2.144E-03  1.465E-03  1.033E-03  5.093E-04  0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SLOW FLUX(I, 1,K)
 K  I   1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 8   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 7   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 6   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 5   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 4   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 3   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 2   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 1   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

   WHIRLAWAY SAMPLE PROBLEM FOR REPORT

   TOTAL NEUTRON BALANCE

    FAST ABSORPTION   SLOW ABSORPTION   FAST PRODUCTION   SLOW PRODUCTION   FAST LEAKAGE   SLOW LEAKAGE
     1.796585E-01      4.739558E-02      5.434502E-01      4.565498E-01     1.265026E 01   5.518459E-01
   REGION ABSORPTIONS AND VOLUMES

    REG   FAST ABSORPTION   SLOW ABSORPTION     VOLUME
     1    1.600868E-01      3.033664E-02      3.240000E 03
     2    1.719823E-02      1.257728E-02      1.890000E 03
     3    2.373498E-03      4.481678E-03      1.620000E 03
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SCURCE(I,J,K,L)

   (I,J,K)    L     1           2           3           4           5           6           7           8
 ( 2, 2, 2)     5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04
 ( 3, 2, 2)     4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04
 ( 4, 2, 2)     4.526E-04   4.526E-04   4.526E-04   4.526E-04   4.526E-04   4.526E-04   4.526E-04   4.526E-04
 ( 5, 2, 2)     4.009E-04   4.009E-04   4.009E-04   4.009E-04   4.009E-04   4.009E-04   4.009E-04   4.009E-04
 ( 6, 2, 2)     6.655E-05   2.646E-04   2.646E-04   6.655E-05   6.655E-05   2.646E-04   2.646E-04   6.655E-05
 ( 7, 2, 2)     4.304E-05   4.304E-05   4.304E-05   4.304E-05   4.304E-05   4.304E-05   4.304E-05   4.304E-05
 ( 8, 2, 2)     0.          2.953E-05   2.953E-05   0.          0.          2.953E-05   2.953E-05   0.
 ( 9, 2, 2)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 3, 2)     8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04
 ( 3, 3, 2)     7.945E-04   7.945E-04   7.945E-04   7.945E-04   7.945E-04   7.945E-04   7.945E-04   7.945E-04
 ( 4, 3, 2)     7.323E-04   7.323E-04   7.323E-04   7.323E-04   7.323E-04   7.323E-04   7.323E-04   7.323E-04
 ( 5, 3, 2)     6.486E-04   6.486E-04   6.486E-04   6.486E-04   6.486E-04   6.486E-04   6.486E-04   6.486E-04
 ( 6, 3, 2)     1.077E-04   4.280E-04   4.280E-04   1.077E-04   1.077E-04   4.280E-04   4.280E-04   1.077E-04
 ( 7, 3, 2)     6.964E-05   6.964E-05   6.964E-05   6.964E-05   6.964E-05   6.964E-05   6.964E-05   6.964E-05
 ( 8, 3, 2)     0.          4.777E-05   4.777E-05   0.          0.          4.777E-05   4.777E-05   0.
 ( 9, 3, 2)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 4, 2)     8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04   8.327E-04
 ( 3, 4, 2)     7.944E-04   7.944E-04   7.944E-04   7.944E-04   7.944E-04   7.944E-04   7.944E-04   7.944E-04
 ( 4, 4, 2)     7.322E-04   7.322E-04   7.322E-04   7.322E-04   7.322E-04   7.322E-04   7.322E-04   7.322E-04
 ( 5, 4, 2)     6.485E-04   6.485E-04   6.485E-04   6.485E-04   6.485E-04   6.485E-04   6.485E-04   6.485E-04
 ( 6, 4, 2)     1.077E-04   4.280E-04   4.280E-04   1.077E-04   1.077E-04   4.280E-04   4.280E-04   1.077E-04
 ( 7, 4, 2)     6.963E-05   6.963E-05   6.963E-05   6.963E-05   6.963E-05   6.963E-05   6.963E-05   6.963E-05
 ( 8, 4, 2)     0.          4.777E-05   4.777E-05   0.          0.          4.777E-05   4.777E-05   0.
 ( 9, 4, 2)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 5, 2)     5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04   5.146E-04
 ( 3, 5, 2)     4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04   4.910E-04
 ( 4, 5, 2)     4.525E-04   4.525E-04   4.525E-04   4.525E-04   4.525E-04   4.525E-04   4.525E-04   4.525E-04
 ( 5, 5, 2)     4.008E-04   4.008E-04   4.008E-04   4.008E-04   4.008E-04   4.008E-04   4.008E-04   4.008E-04
 ( 6, 5, 2)     6.654E-05   2.645E-04   2.645E-04   6.654E-05   6.654E-05   2.645E-04   2.645E-04   6.654E-05
 ( 7, 5, 2)     4.303E-05   4.303E-05   4.303E-05   4.303E-05   4.303E-05   4.303E-05   4.303E-05   4.303E-05
 ( 8, 5, 2)     0.          2.952E-05   2.952E-05   0.          0.          2.952E-05   2.952E-05   0.
 ( 9, 5, 2)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 2, 3)     4.911E-04   4.911E-04   4.911E-04   4.911E-04   4.911E-04   4.911E-04   4.911E-04   4.911E-04
 ( 3, 2, 3)     4.686E-04   4.686E-04   4.686E-04   4.686E-04   4.686E-04   4.686E-04   4.686E-04   4.686E-04
 ( 4, 2, 3)     4.319E-04   4.319E-04   4.319E-04   4.319E-04   4.319E-04   4.319E-04   4.319E-04   4.319E-04
 ( 5, 2, 3)     3.826E-04   3.826E-04   3.826E-04   3.826E-04   3.826E-04   3.826E-04   3.826E-04   3.826E-04
 ( 6, 2, 3)     6.352E-05   2.525E-04   2.525E-04   6.352E-05   6.352E-05   2.525E-04   2.525E-04   6.352E-05
 ( 7, 2, 3)     4.108E-05   4.108E-05   4.108E-05   4.108E-05   4.108E-05   4.108E-05   4.108E-05   4.108E-05
 ( 8, 2, 3)     0.          2.818E-05   2.818E-05   0.          0.          2.818E-05   2.818E-05   0.
 ( 9, 2, 3)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 3, 3)     7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04
 ( 3, 3, 3)     7.582E-04   7.582E-04   7.582E-04   7.582E-04   7.582E-04   7.582E-04   7.582E-04   7.582E-04
 ( 4, 3, 3)     6.988E-04   6.988E-04   6.988E-04   6.988E-04   6.988E-04   6.988E-04   6.988E-04   6.988E-04
 ( 5, 3, 3)     6.190E-04   6.190E-04   6.190E-04   6.190E-04   6.190E-04   6.190E-04   6.190E-04   6.190E-04
 ( 6, 3, 3)     1.028E-04   4.085E-04   4.085E-04   1.028E-04   1.028E-04   4.085E-04   4.085E-04   1.028E-04
 ( 7, 3, 3)     6.646E-05   6.646E-05   6.646E-05   6.646E-05   6.646E-05   6.646E-05   6.646E-05   6.646E-05
 ( 8, 3, 3)     0.          4.560E-05   4.560E-05   0.          0.          4.560E-05   4.560E-05   0.
 ( 9, 3, 3)     0.          0.          0.          0.          0.          0.          0.          0.
 ( 2, 4, 3)     7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04   7.947E-04
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SOURCE(I,J,K,L)

   (I,J,K)   L      1           2           3           4           5           6           7           8
  ( 5, 4, 6)     4.235E-04   4.235E-04   4.235E-04   4.235E-04   4.235E-04   4.235E-04   4.235E-04   4.235E-04
  ( 6, 4, 6)     7.031E-05   2.795E-04   2.795E-04   7.031E-05   7.031E-05   2.795E-04   2.795E-04   7.031E-05
  ( 7, 4, 6)     4.547E-05   4.547E-05   4.547E-05   4.547E-05   4.547E-05   4.547E-05   4.547E-05   4.547E-05
  ( 8, 4, 6)     0.          3.119E-05   3.119E-05   0.          0.          3.119E-05   3.119E-05   0.
  ( 9, 4, 6)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 5, 6)     3.361E-04   3.361E-04   3.361E-04   3.361E-04   3.361E-04   3.361E-04   3.361E-04   3.361E-04
  ( 3, 5, 6)     3.206E-04   3.206E-04   3.206E-04   3.206E-04   3.206E-04   3.206E-04   3.206E-04   3.206E-04
  ( 4, 5, 6)     2.955E-04   2.955E-04   2.955E-04   2.955E-04   2.955E-04   2.955E-04   2.955E-04   2.955E-04
  ( 5, 5, 6)     2.618E-04   2.618E-04   2.618E-04   2.618E-04   2.618E-04   2.618E-04   2.618E-04   2.618E-04
  ( 6, 5, 6)     4.345E-05   1.727E-04   1.727E-04   4.345E-05   4.345E-05   1.727E-04   1.727E-04   4.345E-05
  ( 7, 5, 6)     2.810E-05   2.810E-05   2.810E-05   2.810E-05   2.810E-05   2.810E-05   2.810E-05   2.810E-05
  ( 8, 5, 6)     0.          1.928E-05   1.928E-05   0.          0.          1.928E-05   1.928E-05   0.
  ( 9, 5, 6)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 2, 7)     2.615E-04   2.615E-04   2.615E-04   2.615E-04   2.615E-04   2.615E-04   2.615E-04   2.615E-04
  ( 3, 2, 7)     2.495E-04   2.495E-04   2.495E-04   2.495E-04   2.495E-04   2.495E-04   2.495E-04   2.495E-04
  ( 4, 2, 7)     2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04
  ( 5, 2, 7)     2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04
  ( 6, 2, 7)     3.381E-05   1.344E-04   1.344E-04   3.381E-05   3.381E-05   1.344E-04   1.344E-04   3.381E-05
  ( 7, 2, 7)     2.187E-05   2.187E-05   2.187E-05   2.187E-05   2.187E-05   2.187E-05   2.187E-05   2.187E-05
  ( 8, 2, 7)     0.          1.500E-05   1.500E-05   0.          0.          1.500E-05   1.500E-05   0.
  ( 9, 2, 7)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 3, 7)     4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04
  ( 3, 3, 7)     4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04
  ( 4, 3, 7)     3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04
  ( 5, 3, 7)     3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04
  ( 6, 3, 7)     5.470E-05   2.174E-04   2.174E-04   5.470E-05   5.470E-05   2.174E-04   2.174E-04   5.470E-05
  ( 7, 3, 7)     3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05
  ( 8, 3, 7)     0.          2.427E-05   2.427E-05   0.          0.          2.427E-05   2.427E-05   0.
  ( 9, 3, 7)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 4, 7)     4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04   4.230E-04
  ( 3, 4, 7)     4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04   4.036E-04
  ( 4, 4, 7)     3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04   3.720E-04
  ( 5, 4, 7)     3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04   3.295E-04
  ( 6, 4, 7)     5.469E-05   2.174E-04   2.174E-04   5.469E-05   5.469E-05   2.174E-04   2.174E-04   5.469E-05
  ( 7, 4, 7)     3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05   3.537E-05
  ( 8, 4, 7)     0.          2.426E-05   2.426E-05   0.          0.          2.426E-05   2.426E-05   0.
  ( 9, 4, 7)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 5, 7)     2.614E-04   2.614E-04   2.614E-04   2.614E-04   2.614E-04   2.614E-04   2.614E-04   2.614E-04
  ( 3, 5, 7)     2.494E-04   2.494E-04   2.494E-04   2.494E-04   2.494E-04   2.494E-04   2.494E-04   2.494E-04
  ( 4, 5, 7)     2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04   2.299E-04
  ( 5, 5, 7)     2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04   2.036E-04
  ( 6, 5, 7)     3.380E-05   1.344E-04   1.344E-04   3.380E-05   3.380E-05   1.344E-04   1.344E-04   3.380E-05
  ( 7, 5, 7)     2.186E-05   2.186E-05   2.186E-05   2.186E-05   2.186E-05   2.186E-05   2.186E-05   2.186E-05
  ( 8, 5, 7)     0.          1.499E-05   1.499E-05   0.          0.          1.499E-05   1.499E-05   0.
  ( 9, 5, 7)     0.          0.          0.          0.          0.          0.          0.          0.
  ( 2, 2, 8)     1.789E-04   1.789E-04   1.789E-04   1.789E-04   1.789E-04   1.789E-04   1.789E-04   1.789E-04
  ( 3, 2, 8)     1.707E-04   1.707E-04   1.707E-04   1.707E-04   1.707E-04   1.707E-04   1.707E-04   1.707E-04
  ( 4, 2, 8)     1.573E-04   1.573E-04   1.573E-04   1.573E-04   1.573E-04   1.573E-04   1.573E-04   1.573E-04
  ( 5, 2, 8)     1.393E-04   1.393E-04   1.393E-04   1.393E-04   1.393E-04   1.393E-04   1.393E-04   1.393E-04
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SOURCE(I,J,K,L)

   (I,J,K)    L     1          2          3          4          5          6          7          8
  ( 4, 2, 5)     3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04
  ( 5, 2, 5)     3.120E-04  3.120E-04  3.120E-04  3.120E-04  3.120E-04  3.120E-04  3.120E-04  3.120E-04
  ( 6, 2, 5)     5.179E-05  2.059E-04  2.059E-04  5.179E-05  5.179E-05  2.059E-04  2.059E-04  5.179E-05
  ( 7, 2, 5)     3.350E-05  3.350E-05  3.350E-05  3.350E-05  3.350E-05  3.350E-05  3.350E-05  3.350E-05
  ( 8, 2, 5)     0.         2.298E-05  2.298E-05  0.         0.         2.298E-05  2.298E-05  0.
  ( 9, 2, 5)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 3, 5)     6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04
  ( 3, 3, 5)     6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04
  ( 4, 3, 5)     5.699E-04  5.699E-04  5.699E-04  5.699E-04  5.699E-04  5.699E-04  5.699E-04  5.699E-04
  ( 5, 3, 5)     5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04
  ( 6, 3, 5)     8.379E-05  3.331E-04  3.331E-04  8.379E-05  8.379E-05  3.331E-04  3.331E-04  8.379E-05
  ( 7, 3, 5)     5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05
  ( 8, 3, 5)     0.         3.718E-05  3.718E-05  0.         0.         3.718E-05  3.718E-05  0.
  ( 9, 3, 5)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 4, 5)     6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04  6.480E-04
  ( 3, 4, 5)     6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04  6.183E-04
  ( 4, 4, 5)     5.698E-04  5.698E-04  5.698E-04  5.698E-04  5.698E-04  5.698E-04  5.698E-04  5.698E-04
  ( 5, 4, 5)     5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04  5.047E-04
  ( 6, 4, 5)     8.379E-05  3.331E-04  3.331E-04  8.379E-05  8.379E-05  3.331E-04  3.331E-04  8.379E-05
  ( 7, 4, 5)     5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05  5.419E-05
  ( 8, 4, 5)     0.         3.717E-05  3.717E-05  0.         0.         3.717E-05  3.717E-05  0.
  ( 9, 4, 5)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 5, 5)     4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04
  ( 3, 5, 5)     3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04
  ( 4, 5, 5)     3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04  3.522E-04
  ( 5, 5, 5)     3.119E-04  3.119E-04  3.119E-04  3.119E-04  3.119E-04  3.119E-04  3.119E-04  3.119E-04
  ( 6, 5, 5)     5.178E-05  2.058E-04  2.058E-04  5.178E-05  5.178E-05  2.058E-04  2.058E-04  5.178E-05
  ( 7, 5, 5)     3.348E-05  3.348E-05  3.348E-05  3.348E-05  3.348E-05  3.348E-05  3.348E-05  3.348E-05
  ( 8, 5, 5)     0.         2.297E-05  2.297E-05  0.         0.         2.297E-05  2.297E-05  0.
  ( 9, 5, 5)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 2, 6)     3.361E-04  3.361E-04  3.361E-04  3.361E-04  3.361E-04  3.361E-04  3.361E-04  3.361E-04
  ( 3, 2, 6)     3.207E-04  3.207E-04  3.207E-04  3.207E-04  3.207E-04  3.207E-04  3.207E-04  3.207E-04
  ( 4, 2, 6)     2.956E-04  2.956E-04  2.956E-04  2.956E-04  2.956E-04  2.956E-04  2.956E-04  2.956E-04
  ( 5, 2, 6)     2.618E-04  2.618E-04  2.618E-04  2.618E-04  2.618E-04  2.618E-04  2.618E-04  2.618E-04
  ( 6, 2, 6)     4.346E-05  1.728E-04  1.728E-04  4.346E-05  4.346E-05  1.728E-04  1.728E-04  4.346E-05
  ( 7, 2, 6)     2.811E-05  2.811E-05  2.811E-05  2.811E-05  2.811E-05  2.811E-05  2.811E-05  2.811E-05
  ( 8, 2, 6)     0.         1.928E-05  1.928E-05  0.         0.         1.928E-05  1.928E-05  0.
  ( 9, 2, 6)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 3, 6)     5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04
  ( 3, 3, 6)     5.189E-04  5.189E-04  5.189E-04  5.189E-04  5.189E-04  5.189E-04  5.189E-04  5.189E-04
  ( 4, 3, 6)     4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04
  ( 5, 3, 6)     4.236E-04  4.236E-04  4.236E-04  4.236E-04  4.236E-04  4.236E-04  4.236E-04  4.236E-04
  ( 6, 3, 6)     7.032E-05  2.795E-04  2.795E-04  7.032E-05  7.032E-05  2.795E-04  2.795E-04  7.032E-05
  ( 7, 3, 6)     4.548E-05  4.548E-05  4.548E-05  4.548E-05  4.548E-05  4.548E-05  4.548E-05  4.548E-05
  ( 8, 3, 6)     0.         3.120E-05  3.120E-05  0.         0.         3.120E-05  3.120E-05  0.
  ( 9, 3, 6)     0.         0.         0.         0.         0.         0.         0.         0.
  ( 2, 4, 6)     5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04  5.438E-04
  ( 3, 4, 6)     5.188E-04  5.188E-04  5.188E-04  5.188E-04  5.188E-04  5.188E-04  5.188E-04  5.188E-04
  ( 4, 4, 6)     4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04  4.782E-04
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Fig. B.3 (continued).

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 SOURCE(I,J,K,L)

   (I,J,K)    L      1          2          3          4          5          6          7          8
 ( 3, 4, 3)     7.582E-04  7.582E-04  7.582E-04  7.582E-04  7.582E-04  7.582E-04  7.582E-04  7.582E-04
 ( 4, 4, 3)     6.988E-04  6.988E-04  6.988E-04  6.988E-04  6.988E-04  6.988E-04  6.988E-04  6.988E-04
 ( 5, 4, 3)     6.190E-04  6.190E-04  6.190E-04  6.190E-04  6.190E-04  6.190E-04  6.190E-04  6.190E-04
 ( 6, 4, 3)     1.028E-04  4.085E-04  4.085E-04  1.028E-04  1.028E-04  4.085E-04  4.085E-04  1.028E-04
 ( 7, 4, 3)     6.645E-05  6.645E-05  6.645E-05  6.645E-05  6.645E-05  6.645E-05  6.645E-05  6.645E-05
 ( 8, 4, 3)     0.         4.559E-05  4.559E-05  0.         0.         4.559E-05  4.559E-05  0.
 ( 9, 4, 3)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 5, 3)     4.911E-04  4.911E-04  4.911E-04  4.911E-04  4.911E-04  4.911E-04  4.911E-04  4.911E-04
 ( 3, 5, 3)     4.686E-04  4.686E-04  4.686E-04  4.686E-04  4.686E-04  4.686E-04  4.686E-04  4.686E-04
 ( 4, 5, 3)     4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04
 ( 5, 5, 3)     3.825E-04  3.825E-04  3.825E-04  3.825E-04  3.825E-04  3.825E-04  3.825E-04  3.825E-04
 ( 6, 5, 3)     6.350E-05  2.524E-04  2.524E-04  6.350E-05  6.350E-05  2.524E-04  2.524E-04  6.350E-05
 ( 7, 5, 3)     4.106E-05  4.106E-05  4.106E-05  4.106E-05  4.106E-05  4.106E-05  4.106E-05  4.106E-05
 ( 8, 5, 3)     0.         2.817E-05  2.817E-05  0.         0.         2.817E-05  2.817E-05  0.
 ( 9, 5, 3)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 2, 4)     4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04
 ( 3, 2, 4)     4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04
 ( 4, 2, 4)     3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04
 ( 5, 2, 4)     3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04
 ( 6, 2, 4)     5.855E-05  2.327E-04  2.327E-04  5.855E-05  5.855E-05  2.327E-04  2.327E-04  5.855E-05
 ( 7, 2, 4)     3.787E-05  3.787E-05  3.787E-05  3.787E-05  3.787E-05  3.787E-05  3.787E-05  3.787E-05
 ( 8, 2, 4)     0.         2.598E-05  2.598E-05  0.         0.         2.598E-05  2.598E-05  0.
 ( 9, 2, 4)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 3, 4)     7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04
 ( 3, 3, 4)     6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04
 ( 4, 3, 4)     6.442E-04  6.442E-04  6.442E-04  6.442E-04  6.442E-04  6.442E-04  6.442E-04  6.442E-04
 ( 5, 3, 4)     5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04
 ( 6, 3, 4)     9.472E-05  3.765E-04  3.765E-04  9.472E-05  9.472E-05  3.765E-04  3.765E-04  9.472E-05
 ( 7, 3, 4)     6.126E-05  6.126E-05  6.126E-05  6.126E-05  6.126E-05  6.126E-05  6.126E-05  6.126E-05
 ( 8, 3, 4)     0.         4.203E-05  4.203E-05  0.         0.         4.203E-05  4.203E-05  0.
 ( 9, 3, 4)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 4, 4)     7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04  7.325E-04
 ( 3, 4, 4)     6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04  6.989E-04
 ( 4, 4, 4)     6.441E-04  6.441E-04  6.441E-04  6.441E-04  6.441E-04  6.441E-04  6.441E-04  6.441E-04
 ( 5, 4, 4)     5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04  5.705E-04
 ( 6, 4, 4)     9.471E-05  3.765E-04  3.765E-04  9.471E-05  9.471E-05  3.765E-04  3.765E-04  9.471E-05
 ( 7, 4, 4)     6.125E-05  6.125E-05  6.125E-05  6.125E-05  6.125E-05  6.125E-05  6.125E-05  6.125E-05
 ( 8, 4, 4)     0.         4.202E-05  4.202E-05  0.         0.         4.202E-05  4.202E-05  0.
 ( 9, 4, 4)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 5, 4)     4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04  4.527E-04
 ( 3, 5, 4)     4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04  4.319E-04
 ( 4, 5, 4)     3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04  3.981E-04
 ( 5, 5, 4)     3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04  3.526E-04
 ( 6, 5, 4)     5.853E-05  2.327E-04  2.327E-04  5.853E-05  5.853E-05  2.327E-04  2.327E-04  5.853E-05
 ( 7, 5, 4)     3.785E-05  3.785E-05  3.785E-05  3.785E-05  3.785E-05  3.785E-05  3.785E-05  3.785E-05
 ( 8, 5, 4)     0.         2.597E-05  2.597E-05  0.         0.         2.597E-05  2.597E-05  0.
 ( 9, 5, 4)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 2, 5)     4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04  4.005E-04
 ( 3, 2, 5)     3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04  3.821E-04
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT


 SOURCE(I,J,K,L)

   (I,J,K)   L     1          2          3          4          5          6          7          8
 ( 6, 2, 8)     2.313E-05  9.194E-05  9.194E-05  2.313E-05  2.313E-05  9.194E-05  9.194E-05  2.313E-05
 ( 7, 2, 8)     1.496E-05  1.496E-05  1.496E-05  1.496E-05  1.496E-05  1.496E-05  1.496E-05  1.496E-05
 ( 8, 2, 8)     0.         1.026E-05  1.026E-05  0.         0.         1.026E-05  1.026E-05  0.
 ( 9, 2, 8)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 3, 8)     2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04
 ( 3, 3, 8)     2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04
 ( 4, 3, 8)     2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04
 ( 5, 3, 8)     2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04
 ( 6, 3, 8)     3.742E-05  1.487E-04  1.487E-04  3.742E-05  3.742E-05  1.487E-04  1.487E-04  3.742E-05
 ( 7, 3, 8)     2.420E-05  2.420E-05  2.420E-05  2.420E-05  2.420E-05  2.420E-05  2.420E-05  2.420E-05
 ( 8, 3, 8)     0.         1.660E-05  1.660E-05  0.         0.         1.660E-05  1.660E-05  0.
 ( 9, 3, 8)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 4, 8)     2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04  2.894E-04
 ( 3, 4, 8)     2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04  2.761E-04
 ( 4, 4. 8)     2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04  2.545E-04
 ( 5, 4, 8)     2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04  2.254E-04
 ( 6, 4, 8)     3.741E-05  1.487E-04  1.487E-04  3.741E-05  3.741E-05  1.487E-04  1.487E-04  3.741E-05
 ( 7, 4, 8)     2.419E-05  2.419E-05  2.419E-05  2.419E-05  2.419E-05  2.419E-05  2.419E-05  2.419E-05
 ( 8, 4, 8)     0.         1.660E-05  1.660E-05  0.         0.         1.660E-05  1.660E-05  0.
 ( 9, 4, 8)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 5, 8)     1.788E-04  1.788E-04  1.788E-04  1.788E-04  1.788E-04  1.788E-04  1.788E-04  1.788E-04
 ( 3, 5, 8)     1.706E-04  1.706E-04  1.706E-04  1.706E-04  1.706E-04  1.706E-04  1.706E-04  1.706E-04
 ( 4, 5, 8)     1.573E-04  1.573E-04  1.573E-04  1.573E-04  1.573E-04  1.573E-04  1.573E-04  1.573E-04
 ( 5, 5, 8)     1.393E-04  1.393E-04  1.393E-04  1.393E-04  1.393E-04  1.393E-04  1.393E-04  1.393E-04
 ( 6, 5, 8)     2.312E-05  9.192E-05  9.192E-05  2.312E-05  2.312E-05  9.192E-05  9.192E-05  2.312E-05
 ( 7, 5, 8)     1.495E-05  1.495E-05  1.495E-05  1.495E-05  1.495E-05  1.495E-05  1.495E-05  1.495E-05
 ( 8, 5, 8)     0.         1.026E-05  1.026E-05  0.         0.         1.026E-05  1.026E-05  0.
 ( 9, 5, 8)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 2, 9)     9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05
 ( 3, 2, 9)     8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05
 ( 4, 2, 9)     7.986E-05  7.986E-05  7.986E-05  7.986E-05  7.986E-05  7.986E-05  7.986E-05  7.986E-05
 ( 5, 2, 9)     7.073E-05  7.073E-05  7.073E-05  7.073E-05  7.073E-05  7.073E-05  7.073E-05  7.073E-05
 ( 6, 2, 9)     1.174E-05  4.668E-05  4.668E-05  1.174E-05  1.174E-05  4.668E-05  4.668E-05  1.174E-05
 ( 7, 2, 9)     7.593E-06  7.593E-06  7.593E-06  7.593E-06  7.593E-06  7.593E-06  7.593E-06  7.593E-06
 ( 8, 2, 9)     0.         5.209E-06  5.209E-06  0.         0.         5.209E-06  5.209E-06  0.
 ( 9, 2, 9)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 3, 9)     1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04
 ( 3, 3, 9)     1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04
 ( 4, 3, 9)     1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04
 ( 5, 3, 9)     1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04
 ( 6, 3, 9)     1.900E-05  7.552E-05  7.552E-05  1.900E-05  1.900E-05  7.552E-05  7.552E-05  1.900E-05
 ( 7, 3, 9)     1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05
 ( 8, 3, 9)     0.         8.427E-06  8.427E-06  0.         0.         8.427E-06  8.427E-06  0.
 ( 9, 3, 9)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 4, 9)     1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04  1.469E-04
 ( 3, 4, 9)     1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04  1.402E-04
 ( 4, 4, 9)     1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04  1.292E-04
 ( 5, 4, 9)     1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04  1.144E-04
 ( 6, 4, 9)     1.899E-05  7.551E-05  7.551E-05  1.899E-05  1.899E-05  7.551E-05  7.551E-05  1.899E-05


WHIRLAWAY SAMPLE PROBLEM FOR REPORT


 SOURCE(I,J,K,L)

   (I,J,K)   L     1          2          3          4          5          6          7          8
 ( 7, 4, 9)     1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05  1.228E-05
 ( 8, 4, 9)     0.         8.426E-06  8.426E-06  0.         0.         8.426E-06  8.426E-06  0.
 ( 9, 4, 9)     0.         0.         0.         0.         0.         0.         0.         0.
 ( 2, 5, 9)     9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05  9.081E-05
 ( 3, 5, 9)     8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05  8.664E-05
 ( 4, 5, 9)     7.985E-05  7.985E-05  7.985E-05  7.985E-05  7.985E-05  7.985E-05  7.985E-05  7.985E-05
 ( 5, 5, 9)     7.072E-05  7.072E-05  7.072E-05  7.072E-05  7.072E-05  7.072E-05  7.072E-05  7.072E-05
 ( 6, 5, 9)     1.174E-05  4.667E-05  4.667E-05  1.174E-05  1.174E-05  4.667E-05  4.667E-05  1.174E-05
 ( 7, 5, 9)     7.590E-06  7.590E-06  7.590E-06  7.590E-06  7.590E-06  7.590E-06  7.590E-06  7.590E-06
 ( 8, 5, 9)     0.         5.207E-06  5.207E-06  0.         0.         5.207E-06  5.207E-06  0.
 ( 9, 5, 9)     0.         0.         0.         0.         0.         0.         0.         0.
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Fig. B.3 (continued).

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 WHIRLAWAY SAMPLE PROBLEM FOR REPORT


 ADJOINT FLUX CALCULATION BEGINS

  IT NC     FLUX CONVR    PT LAMDA CONVR    TOT LAMDA CONVR    TOT RESIDUE                    NU-CRITICAL
    10      1.0809E-01      0.                0.                 1.8625E-03                   1.000000E 00
    20      1.9828E-02      0.                0.                 2.1774E-04                   1.000000E 00
    30      4.7228E-03      0.                0.                 3.4804E-05                   1.000000E 00
    40      1.4036E-03      0.                0.                 8.9807E-06                   1.000000E 00
    50      4.1608E-04      0.                0.                 3.0375E-06                   1.000000E 00

WHIRLAWAY SAMPLE PROBLEM FOR REPORT


 ADJOINT FAST FLUX(I, 6,K)

 K  I    1          2          3          4          5          6          7          8          9          10

10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 9   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 8   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 7   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 6   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 5   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 4   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 3   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 2   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 1   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT


 ADJOINT FAST FLUX(I, 5,K)

 K  I    1          2          3          4          5          6          7          8          9          10

10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.

 9   1.252E-04  1.252E-04  1.193E-04  1.096E-04  9.658E-05  6.154E-05  3.553E-05  2.348E-05  1.096E-05  0.

 8   2.465E-04  2.465E-04  2.349E-04  2.159E-04  1.902E-04  1.212E-04  6.997E-05  4.624E-05  2.158E-05  0.

 7   3.604E-04  3.604E-04  3.434E-04  3.156E-04  2.781E-04  1.772E-04  1.023E-04  6.759E-05  3.154E-05  0.

 6   4.633E-04  4.633E-04  4.414E-04  4.058E-04  3.574E-04  2.277E-04  1.315E-04  8.688E-05  4.054E-05  0.

 5   5.521E-04  5.521E-04  5.260E-04  4.835E-04  4.259E-04  2.714E-04  1.567E-04  1.035E-04  4.831E-05  0.

 4   6.241E-04  6.241E-04  5.946E-04  5.466E-04  4.815E-04  3.068E-04  1.771E-04  1.170E-04  5.461E-05  0.

 3   6.771E-04  6.771E-04  6.451E-04  5.930E-04  5.224E-04  3.328E-04  1.921E-04  1.270E-04  5.924E-05  0.

 2   7.094E-04  7.094E-04  6.760E-04  6.214E-04  5.474E-04  3.487E-04  2.013E-04  1.330E-04  6.208E-05  0.

 1   7.094E-04  7.094E-04  6.760E-04  6.214E-04  5.474E-04  3.487E-04  2.013E-04  1.330E-04  6.208E-05  0.
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Fig. B.3 (continued).

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WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT FAST FLUX(I, 4,K)
 K  I   1           2           3           4           5           6           7           8           9           10
10   0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9   2.025E-04   2.025E-04   1.930E-04   1.774E-04   1.563E-04   9.956E-05   5.748E-05   3.798E-05   1.773E-05   0.
 8   3.989E-04   3.989E-04   3.801E-04   3.494E-04   3.078E-04   1.961E-04   1.132E-04   7.481E-05   3.491E-05   0.
 7   5.831E-04   5.831E-04   5.556E-04   5.107E-04   4.499E-04   2.866E-04   1.655E-04   1.093E-04   5.103E-05   0.
 6   7.496E-04   7.496E-04   7.143E-04   6.565E-04   5.784E-04   3.685E-04   2.127E-04   1.406E-04   6.559E-05   0.
 5   8.933E-04   8.933E-04   8.512E-04   7.824E-04   6.892E-04   4.391E-04   2.535E-04   1.675E-04   7.815E-05   0.
 4   1.010E-03   1.010E-03   9.622E-04   8.844E-04   7.791E-04   4.963E-04   2.865E-04   1.893E-04   8.834E-05   0.
 3   1.096E-03   1.096E-03   1.044E-03   9.595E-04   8.452E-04   5.385E-04   3.108E-04   2.054E-04   9.584E-05   0.
 2   1.148E-03   1.148E-03   1.094E-03   1.005E-03   8.857E-04   5.642E-04   3.257E-04   2.152E-04   1.004E-04   0.
 1   1.148E-03   1.148E-03   1.094E-03   1.005E-03   8.857E-04   5.642E-04   3.257E-04   2.152E-04   1.004E-04   0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT FAST FLUX(I, 3,K)
 K  I   1           2           3           4           5           6           7           8           9           10
10   0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9   2.025E-04   2.025E-04   1.930E-04   1.774E-04   1.563E-04   9.956E-05   5.747E-05   3.798E-05   1.772E-05   0.
 8   3.989E-04   3.989E-04   3.801E-04   3.494E-04   3.078E-04   1.961E-04   1.132E-04   7.480E-05   3.490E-05   0.
 7   5.831E-04   5.831E-04   5.557E-04   5.107E-04   4.499E-04   2.866E-04   1.655E-04   1.093E-04   5.102E-05   0.
 6   7.497E-04   7.497E-04   7.143E-04   6.566E-04   5.784E-04   3.685E-04   2.127E-04   1.405E-04   6.558E-05   0.
 5   8.933E-04   8.933E-04   8.512E-04   7.824E-04   6.892E-04   4.391E-04   2.534E-04   1.675E-04   7.814E-05   0.
 4   1.010E-03   1.010E-03   9.622E-04   8.844E-04   7.791E-04   4.963E-04   2.865E-04   1.893E-04   8.833E-05   0.
 3   1.096E-03   1.096E-03   1.044E-03   9.595E-04   8.452E-04   5.385E-04   3.108E-04   2.054E-04   9.583E-05   0.
 2   1.148E-03   1.148E-03   1.094E-03   1.005E-03   8.857E-04   5.642E-04   3.257E-04   2.152E-04   1.004E-04   0.
 1   1.148E-03   1.148E-03   1.094E-03   1.005E-03   8.857E-04   5.642E-04   3.257E-04   2.152E-04   1.004E-04   0.

WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT FAST FLUX(I, 2,K)
 K  I   1           2           3           4           5           6           7           8           9           10
10   0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9   1.252E-04   1.252E-04   1.193E-04   1.096E-04   9.658E-05   6.153E-05   3.552E-05   2.347E-05   1.095E-05   0.
 8   2.465E-04   2.465E-04   2.349E-04   2.159E-04   1.902E-04   1.212E-04   6.995E-05   4.622E-05   2.157E-05   0.
 7   3.604E-04   3.604E-04   3.434E-04   3.157E-04   2.781E-04   1.771E-04   1.022E-04   6.756E-05   3.153E-05   0.
 6   4.633E-04   4.633E-04   4.415E-04   4.058E-04   3.574E-04   2.277E-04   1.314E-04   8.685E-05   4.052E-05   0.
 5   5.521E-04   5.521E-04   5.261E-04   4.836E-04   4.259E-04   2.713E-04   1.566E-04   1.035E-04   4.829E-05   0.
 4   6.241E-04   6.241E-04   5.947E-04   5.466E-04   4.815E-04   3.067E-04   1.770E-04   1.170E-04   5.458E-05   0.
 3   6.771E-04   6.771E-04   6.452E-04   5.930E-04   5.224E-04   3.328E-04   1.921E-04   1.269E-04   5.922E-05   0.
 2   7.095E-04   7.095E-04   6.761E-04   6.214E-04   5.474E-04   3.487E-04   2.013E-04   1.330E-04   6.205E-05   0.
 1   7.095E-04   7.095E-04   6.761E-04   6.214E-04   5.474E-04   3.487E-04   2.013E-04   1.330E-04   6.205E-05   0.
```

Fig. B.3 (continued).

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT FAST FLUX(I, 1,K)

 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 8   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 7   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 6   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 5   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 4   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 3   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 2   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 1   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
```

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 6,K)

 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 8   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 7   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 6   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 5   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 4   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 3   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 2   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 1   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
```

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 5,K)

 K  I    1          2          3          4          5          6          7          8          9          10
10   0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
 9   1.426E-03  1.426E-03  1.358E-03  1.247E-03  1.095E-03  6.849E-04  3.532E-04  2.001E-04  7.899E-05  0.
 8   2.808E-03  2.808E-03  2.675E-03  2.455E-03  2.157E-03  1.349E-03  6.957E-04  3.941E-04  1.556E-04  0.
 7   4.106E-03  4.106E-03  3.910E-03  3.589E-03  3.154E-03  1.972E-03  1.017E-03  5.761E-04  2.274E-04  0.
 6   5.278E-03  5.278E-03  5.026E-03  4.614E-03  4.054E-03  2.535E-03  1.307E-03  7.406E-04  2.923E-04  0.
 5   6.289E-03  6.289E-03  5.989E-03  5.499E-03  4.831E-03  3.021E-03  1.558E-03  8.825E-04  3.483E-04  0.
 4   7.109E-03  7.109E-03  6.770E-03  6.216E-03  5.461E-03  3.414E-03  1.761E-03  9.975E-04  3.937E-04  0.
 3   7.713E-03  7.713E-03  7.345E-03  6.743E-03  5.925E-03  3.704E-03  1.910E-03  1.082E-03  4.271E-04  0.
 2   8.082E-03  8.082E-03  7.697E-03  7.066E-03  6.208E-03  3.882E-03  2.002E-03  1.134E-03  4.476E-04  0.
 1   8.082E-03  8.082E-03  7.697E-03  7.066E-03  6.208E-03  3.882E-03  2.002E-03  1.134E-03  4.476E-04  0.
```

Fig. B.3 (continued).

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 4,K)
 K  I     1           2           3           4           5           6           7           8           9          10
10  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9  2.307E-03   2.307E-03   2.197E-03   2.017E-03   1.772E-03   1.108E-03   5.715E-04   3.238E-04   1.278E-04   0.
 8  4.544E-03   4.544E-03   4.328E-03   3.973E-03   3.491E-03   2.183E-03   1.126E-03   6.377E-04   2.517E-04   0.
 7  6.643E-03   6.643E-03   6.326E-03   5.808E-03   5.103E-03   3.191E-03   1.645E-03   9.321E-04   3.679E-04   0.
 6  8.540E-03   8.540E-03   8.133E-03   7.466E-03   6.560E-03   4.101E-03   2.115E-03   1.198E-03   4.729E-04   0.
 5  1.018E-02   1.018E-02   9.691E-03   8.897E-03   7.817E-03   4.887E-03   2.520E-03   1.428E-03   5.635E-04   0.
 4  1.150E-02   1.150E-02   1.096E-02   1.006E-02   8.836E-03   5.525E-03   2.849E-03   1.614E-03   6.370E-04   0.
 3  1.248E-02   1.248E-02   1.189E-02   1.091E-02   9.586E-03   5.994E-03   3.091E-03   1.751E-03   6.911E-04   0.
 2  1.308E-02   1.308E-02   1.245E-02   1.143E-02   1.004E-02   6.280E-03   3.239E-03   1.835E-03   7.241E-04   0.
 1  1.308E-02   1.308E-02   1.245E-02   1.143E-02   1.004E-02   6.280E-03   3.239E-03   1.835E-03   7.241E-04   0.
```

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 3,K)
 K  I     1           2           3           4           5           6           7           8           9          10
10  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9  2.307E-03   2.307E-03   2.197E-03   2.017E-03   1.772E-03   1.108E-03   5.715E-04   3.238E-04   1.278E-04   0.
 8  4.544E-03   4.544E-03   4.328E-03   3.973E-03   3.491E-03   2.183E-03   1.126E-03   6.376E-04   2.517E-04   0.
 7  6.643E-03   6.643E-03   6.327E-03   5.808E-03   5.103E-03   3.190E-03   1.645E-03   9.320E-04   3.679E-04   0.
 6  8.540E-03   8.540E-03   8.133E-03   7.466E-03   6.560E-03   4.101E-03   2.115E-03   1.198E-03   4.729E-04   0.
 5  1.018E-02   1.018E-02   9.692E-03   8.897E-03   7.817E-03   4.887E-03   2.520E-03   1.428E-03   5.634E-04   0.
 4  1.150E-02   1.150E-02   1.096E-02   1.006E-02   8.836E-03   5.524E-03   2.849E-03   1.614E-03   6.369E-04   0.
 3  1.248E-02   1.248E-02   1.189E-02   1.091E-02   9.586E-03   5.994E-03   3.091E-03   1.751E-03   6.910E-04   0.
 2  1.308E-02   1.308E-02   1.245E-02   1.143E-02   1.004E-02   6.280E-03   3.239E-03   1.835E-03   7.241E-04   0.
 1  1.308E-02   1.308E-02   1.245E-02   1.143E-02   1.004E-02   6.280E-03   3.239E-03   1.835E-03   7.241E-04   0.
```

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 2,K)
 K  I     1           2           3           4           5           6           7           8           9          10
10  0.          0.          0.          0.          0.          0.          0.          0.          0.          0.
 9  1.426E-03   1.426E-03   1.358E-03   1.247E-03   1.095E-03   6.849E-04   3.532E-04   2.001E-04   7.897E-05   0.
 8  2.809E-03   2.809E-03   2.675E-03   2.456E-03   2.157E-03   1.349E-03   6.956E-04   3.940E-04   1.555E-04   0.
 7  4.106E-03   4.106E-03   3.910E-03   3.590E-03   3.154E-03   1.972E-03   1.017E-03   5.760E-04   2.273E-04   0.
 6  5.278E-03   5.278E-03   5.026E-03   4.614E-03   4.054E-03   2.535E-03   1.307E-03   7.404E-04   2.922E-04   0.
 5  6.290E-03   6.290E-03   5.990E-03   5.499E-03   4.831E-03   3.020E-03   1.557E-03   8.822E-04   3.482E-04   0.
 4  7.110E-03   7.110E-03   6.771E-03   6.216E-03   5.461E-03   3.414E-03   1.760E-03   9.973E-04   3.936E-04   0.
 3  7.714E-03   7.714E-03   7.346E-03   6.744E-03   5.925E-03   3.704E-03   1.910E-03   1.082E-03   4.270E-04   0.
 2  8.083E-03   8.083E-03   7.697E-03   7.066E-03   6.208E-03   3.881E-03   2.001E-03   1.134E-03   4.474E-04   0.
 1  8.083E-03   8.083E-03   7.697E-03   7.066E-03   6.208E-03   3.881E-03   2.001E-03   1.134E-03   4.474E-04   0.
```

Fig. B.3 (continued).

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

 ADJOINT SLOW FLUX(I, 1,K)

 K  I   1         2         3         4         5         6         7         8         9        10
10  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 9  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 8  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 7  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 6  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 5  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 4  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 3  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 2  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
 1  0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
```

```
WHIRLAWAY SAMPLE PROBLEM FOR REPORT

(FLUX)X(ADJOINT FLUX) REGION INTEGRALS

 REG    PHI(1)XPHI(K)*    PHI(2)XPHI(K)*    DELPHI(K)XDELPHI(K)*   K#1,2
   1     9.090635E-02      4.317399E-03        7.078119E-03
         1.033031E 00      4.903836E-02        3.700013E-03

   2     7.180329E-03      5.489473E-04        6.096975E-04
         7.625474E-02      5.756491E-03        4.494544E-04

   3     5.110133E-04      6.041580E-05        8.124323E-05
         4.173925E-03      4.900008E-04        7.681295E-05
```

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ORNL-3150
Addendum

WHIRLAWAY – A THREE-DIMENSIONAL, TWO-GROUP NEUTRON DIFFUSION CODE FOR THE IBM 7090 COMPUTER

T. B. Fowler M. L. Tobias

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ORNL-3150 – ADDENDUM

WHIRLAWAY – A THREE-DIMENSIONAL, TWO-GROUP NEUTRON DIFFUSION CODE FOR THE IBM-7090 COMPUTER

T. B. Fowler M. L. Tobias

ABSTRACT

By making certain changes in two of the chain links of the WHIRLAWAY code, it may be used to calculate the flux distribution with a fixed source in one region. The eigenvalue is kept at unity. While regions with flux-dependent sources are permitted, they must not be adjacent to the one fixed-source region. Corrected values for the sample problem given in ORNL-3150 are also included.

INTRODUCTION

Since the code WHIRLAWAY was written, the problem arose of using the code for calculating the flux distribution in a reactor, assuming a constant source in one region. This calculation may be done by making some changes in the first two chain links of WHIRLAWAY. The original code should continue to be used for ordinary calculations.

The changes described here permit a constant source in one region of the reactor to be specified as input. The flux distribution is then computed for a critical reactor ($k = 1$). A variable source may appear in other regions.

The running time for this calculation may be longer than the time required for the ordinary calculation since it appears that more iterations are required to resolve the flux.

CHANGES IN THE CODE

In the first chain link of WHIRLAWAY, FORTRAN statement number 157 should be replaced by the following statements:

```
157  IL(1) = II(1,NGEM)
     IL(2) = II(2,NGEM)
     JL(1) = JJ(1,NGEM)
     JL(2) = JJ(2,NGEM)
     KL(1) = KK(1,NGEM)
     KL(2) = KK(2,NGEM)
     WRITE OUTPUT TAPE 9, 1019, NGEM
1019 FØRMAT (8HO REGIØN13,26H IS A CØNST. SØURCE REGIØN)
     WRITE ØUTPUT TAPE 9, 1004
```

Assuming that the second chain-link deck is listed with 58 lines per page (beginning with the comment card), the following FORTRAN changes should be made in the second chain link:

1. The fifth statement from the bottom of page 1 of the code (NTAM1 = JMAX*KMAX) should be replaced by the following FORTRAN statements:

```
     IF(I-IL(1))2006,2000,2000
2000 IF(I-IL(2))2001,2001,2006
2001 IF(J-JL(1))2006,2002,2002
2002 IF(J-JL(2))2003,2003,2006
2003 IF(K-KL(1))2006,2004,2004
2004 IF(K-KL(2))2005,2005,2006
2005 IJCSO  = 1
     GO TO 2007
2006 IJCSO  = 0
2007 NTAM1 = JMAX*KMAX
```

2. Statement number 901 (page 2 of the code) and the three statements immediately following (up to but not including statement number 902) should be replaced by the following FORTRAN statements:

```
 901 TEMR1 = X11
     IF(IJCSO)3006,3006,3005
3005 TMF3  = A9
     TMF4  = A10
     GO TO 3007
3006 TMF3  = P1(N)*A9
     TMF4  = P2(N)*A10
3007 TEMR2 = 0.0
```

3. Statement number 904 and the two statements immediately following (up to but not including statement number 905) should be replaced by the following statements:

```
     TEMR3 = X12
     IF(IJCSO)4006,4006,4005
4005 TMS3  = A9
     GO TO 4007
4006 TMS3  = TMFF*A9
4007 TMS4  = TMFF*B7
```

4. The two statements (GR2P = GR2P + TMSF*A10, and GR2A = GR2A + TMSF*B8) which are the eleventh and twelfth statements from the bottom of page 2 of the code should be replaced by:

```
     IF(IJCSØ)5006,5006,5005
5005 GR2P  = GR2P + A10
     GØ TØ 5007
5006 GR2P  = GR2P + TMSF*A10
5007 GR2A  = GR2A + TMSF*B8
```

5. The eleven FORTRAN statements on page 3 of the code, beginning with the statement just preceding statement number 909 (IF(NADJJ)910,910,909) and ending with the statement following statement number 910 (T22 = TMFF*(TMF2 + A8)), should be replaced by:

```
 910 IF(IJCSØ)6006,6006,6005
6005 T11  =  TMS3 + A10
     GØ TØ 6007
6006 T11  =  TMS3 + TMSF*A10
6007 T22  =  TMFF*(TMF2 + A8)
```

6. The twelve statements beginning with the statement just preceding statement number 999 (IF(DENF + DENS)999,911,999) and ending with 911 (including the continuation card) should be replaced by the following statement (note that the second line is the continuation card):

```
911  RSTØT = RSTØT + (TMF1 + DENF + T44 - T22 +
    1TMS1 + T55 + DENS - T33)**2
```

7. The seventh statement from the bottom of page 3 of the code (IF(NADJJ)125,125,129) should be removed.

8. The fourth statement from the bottom of page 3 of the code should be replaced by:

```
VERGL = 0.0
```

9. The six statements on page 4 of the code, beginning with statement number 129 and ending with the statement following statement number 130, should be replaced by:

```
130  RSTØT  = SQRTF(RSTØT)/(XLAMDA*(GR1P + GR2P))
     PHINØR = GR1P + GR2P
```

INPUT AND OUTPUT CHANGES AND RESTRICTIONS

The region number for which the constant source is to be specified is written in columns 19–20 of the control card. The constant source (specified as neutrons produced/cm^3-sec) is given in place of $\nu\Sigma f_1$ (fast) and $\nu\Sigma f_2$ (thermal) on the region-specification card describing the constant-source region. All other input remains unchanged.

The point λ convergence condition is not calculated and will be reported as zero on output. The value of λ (reported as NU-CRITICAL) is calculated but not used in solving for the flux. At convergence, λ should be close to 1.0. The fluxes are not normalized for output in this calculation. If the source output option is used, the source reported for the points in the constant-source region will be incorrect. The input source ($\nu\Sigma f_1$ and $\nu\Sigma f_2$) will have been multiplied by the point fluxes in this region.

Only one constant-source region may be specified, and this region must not be adjacent to a variable-source region. Also, the adjoint calculation should not be specified.

CORRECTED VALUES FOR SAMPLE PROBLEM GIVEN IN ORNL-3150

The last column of numbers in the sample problem (see Fig. B.3 on p 25) are incorrect. The correct values are:

```
DELPHI(K)XDELPHI(K)*
   4.901340E-03
   2.570613E-03

   5.110480E-04
   3.773587E-04

   6.749514E-05
   6.382378E-05
```