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User's Guide and Description of the Perturbation Code Modules DGRAD and TPERT

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COMPUTER SCIENCES DIVISION

USER'S GUIDE AND DESCRIPTION OF THE PERTURBATION CODE MODULES DGRAD AND TPERT*

E. T. Tomlinson and R. A. Lillie**

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DEPARTMENT OF ENERGY

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ABSTRACT

Two code modules, TPERT and DGRAD, are described, which when used in conjunction with the DOT IV discrete ordinate neutron transport code provide the user with the capability of performing perturbation calculations. The modules and their input are described. A sample problem is presented to aid in executing these modules.

1. INTRODUCTION

The movement and/or replacement of one material by another in a reactor core will cause a change in the system multiplication factor, k_{eff}. The magnitude of this change can be calculated either directly by recalculation of k_{eff} for the perturbed system or through the use of perturbation techniques. The methods incorporated in the code modules described in this report include first-order and exact perturbation theory based on both transport and diffusion theory approximations to the neutron transport equation. These modules were written as ancillary codes to the DOT IV discrete ordinates transport code. All input to these models is done using the free-form input routine FIDO.

2. TPERT

A perturbation code, TPERT, has been written to obtain exact and first-order reactivity changes. The purpose of this section is to provide a brief review of the expressions evaluated by TPERT and to

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provide a detailed description of the required input. TPERT couples with VIP[1] which generates adjoint-forward flux tables, i.e., $\phi^*\phi$ tables, using DOT-III[2] scalar flux tape information. (A slight modification of VIP will allow the use of DOT-IV scalar flux tapes.)[3] The general scheme consists of passing the spatially integrated $\phi^*\phi$ tables from VIP into TPERT which in turn folds the $\phi^*\phi$ tables with the pertinent cross section changes.

The reactivity associated with a change in reactor composition, i.e., a perturbation, may be obtained from:

$$\Delta\rho = \langle\phi^*,(\Delta F/k-\Delta\Sigma+\Delta S)\phi'\rangle/\langle\phi^*,F'\phi'\rangle \qquad (1)$$

where

$\Delta\rho$ = reactivity change

ΔF = change in fission operator

$\Delta\Sigma$ = change in total cross section operator

ΔS = change in scattering operator

k = unperturbed state eigenvalue

ϕ^* = unperturbed adjoint flux

ϕ' = perturbed forward flux

$F' = F + \Delta F$ = perturbed fission operator.

The brackets, i.e., $\langle\ \rangle$, in Equation (1) indicate integration over space, energy and angle. Equation (1) is normally called the exact perturbation equation since there are no approximations employed in its development. The first-order, or linear, approximation to Equation (1) may be obtained by simply substituting the unperturbed forward fiux ϕ and the unperturbed fission operator F for ϕ' and F', respectively.

This yields:

$$\Delta\rho = \langle\phi^*,(\Delta F/k-\Delta\Sigma+\Delta s)\phi\rangle/\langle\phi^*,F\phi\rangle \ . \qquad (2)$$

The evaluation of the integrals in Equations (1) and (2) is carried out in two steps. The first step is performed by VIP and results in the generation of (L+1), where L is the order of scattering anisotropy, $\phi^*\phi$ tables for each region in which material changes occur or in which fissionable nuclides appear. These tables are ordered in a manner similar to ANISN formatted cross-section tables.

The terms which fold with the total cross section in TPERT are located in position IHT. These terms have the form[4]:

$$T_g = -\sum_{L}\sum_{\ell=0}^{L}\sum_{m=0}^{\ell}(-1)^{\ell+1}(2\ell+1)j^*_{\ell,m,i,g}\ j_{\ell,m,i,g}\ V_i \qquad (3)$$

where

$j^*_{\ell,m,i,g}$ = the DOT ℓm^{th} adjoint flux moment in space cell i and group g

$j_{\ell,m,i,g}$ = the DOT forward flux moment.

V_i = volume of i^{th} space cell.

The terms which fold with the scattering and fission operators are stored in positions IHS through IHS+G-1 where G represents the total number of groups. These terms have the form[4]:

$$T_{\ell,g,g'} = \sum_{\ell}\sum_{m}(-1)^{\ell+1}j^*_{\ell,m,i,g}\ j_{\ell,m,g'}\ V_i \ . \qquad (4)$$

For a given group g, the subscript g′ may take on two values. In positions IHS through IHS+g-1:

$$g' = g-k+1 \text{ for } k=1,\ldots,g$$

and in positions IHS+g through IHS+G-1:

$$g' = k \text{ for } k=g+1\ldots,G \ .$$

The second step in the evaluation of the integrals in Equations (1) and (2) is carried out by TPERT. This step consists of folding the terms represented by Equations (3) and (4) with the appropriate cross-section changes for each region. The folding process is described by the following:

$$\left\langle \phi^*, \frac{\Delta F}{k} \phi \right\rangle_r = \sum_g \sum_{g'} \chi_g \frac{\Delta \nu \Sigma_{fg'}}{k} T_{o,g,g'} \ , \tag{5a}$$

$$-\left\langle \phi^*, \Delta\Sigma\phi \right\rangle_r = \sum_g \Delta\Sigma_{Tg} T_g \ , \tag{5b}$$

and

$$\left\langle \phi^*, \Delta S\phi \right\rangle_r = \sum_g \sum_{g'} \sum_{\ell} \Delta\Sigma_{s\ell,g'\to g} T_{\ell,g,g'} \tag{5b}$$

where

χ_g = fraction of fission neutrons born in group g,

$\Delta\nu\Sigma_{fg'}$ = change in nu times the fission cross section in group g

$\Delta\Sigma_{Tg}$ = change in total cross section in group g,

$\Delta\Sigma_{s\ell,g'\to g}$ = change in ℓ^{th} order scattering coefficient for scattering from group g′ to group g.

In Equations (5), the subscript r has been introduced to denote different material regions. The perturbation denominators, i.e., $\langle\phi^*,F'\phi'\rangle$ and $\langle\phi^*,F\phi\rangle$ are evaluated by simply substituting $\nu\Sigma_{f'g'}$ or $\nu\Sigma_{fg'}$ into Equation (5a) for $\Delta\nu\Sigma_{fg'}$. Summing the region contributions to $\Delta\rho$ completes the reactivity calculation.

TPERT INPUT

Title Card (18A4)

1$$ IHT - Position of total cross section

IHS - Position of self-scatter cross section

ITL - Cross-section table length

IGM - Number of energy groups

NR - Number of "VIP" regions (see Note 1)

ISCT - Order of scattering anisotropy

NMAT - Number of P_0 materials from tape (see Note 2)

NTAB - Logical unit number of VIP $\phi^*\phi$ tables

NCR - Logical unit number of cross-section tape

NDCR - Direct access logical unit number for cross-section storage (see Note 3)

NSRT - Logical unit for scratch disk (diffusion only)

JFLAG = 0 - use perturbed $\nu\Sigma_f$ denominator

1 - use unperturbed $\nu\Sigma_f$ denominator

ITOD = 0 - transport calculation (see Note 8)

1 - diffusion calculation

Terminate data block 1 with a T.

2** CHI (IGM) - Fission spectrum

3** VELS (IGM) - Group inverse velocities - fill with 1.0's if inverse velocity folding is not desired (see Note 7)

4$$ MATID (NMAT)- Cross-section tape ID's for P_0 materials.

Arrays 5$$ through 10** apply to the following relationships for a given VIP region:

Σ unperturbed = U1*Σ_1+U2*Σ_2

Σ perturbed = P1*Σ_1+P2*Σ_2

5$$ MAT1 (NR) - P_0 material numbers on direct access storage for Σ_1 cross sections by VIP region - use negative number if region has fissionable material but no perturbation.

6** U1 (NR) - Unperturbed multiplier for Σ_1 by VIP region

7** P1 (NR) - Perturbed multiplier for Σ_1 by VIP region

8$$ MAT2 (NR) - P_0 material numbers on direct access storage for Σ_2 cross sections by VIP region - use a zero if only Σ_1 occurs in a region

9** U2 (NR) - Unperturbed multiplier for Σ_2 by VIP region

10** P2 (NR) - Perturbed multiplier for Σ_2 by VIP region

11** EIG - Unperturbed K_{eff}

BETA - Total delayed neutron fraction

DNORM - Perturbation integral denominator - enter 0.0 if code is to calculate

Terminate data block 2 with a T.

Note 1: Each region which contains a perturbation, i.e., change in cross section, or which contains fissionable material is a VIP region.

Note 2: TPERT, as presently programmed, will only accept cross sections in ANISN library format - either on tape or disk.

Note 3: Direct access is used to store the cross sections in the same order as the ID's in the 4$$ array, e.g., if the ID of material M corresponds to the Nth entry in the 4$$ array, the P_0 number for this material is N in the 5$$ and 8$$ arrays.

Note 4: The number of words needed in COMMON/DATA in TPERT main is given by:

$$(3+2*ITL)*IGM+NMAT*(ISCT+2)+10*NR+40$$

Note 5: The number of tracks needed on logical unit NDCR is given by:

$$((ITL*IGM-1)/1800+1)*NMAT*(ISCT+1)$$

Note 6: To run multiple cases, simply supply a new title card and change the appropriate arrays. Be sure to include a terminator, e.g., T for both data blocks.

Note 7: TPERT will evaluate the quantity $\langle \phi^*, \frac{1}{v} \phi \rangle$ which is useful in certain time-dependent reactivity calculations.

Note 8: To run diffusion cases, it is necessary to set ISCT=1 in VIP and input the flux tapes generated by DGRAD.

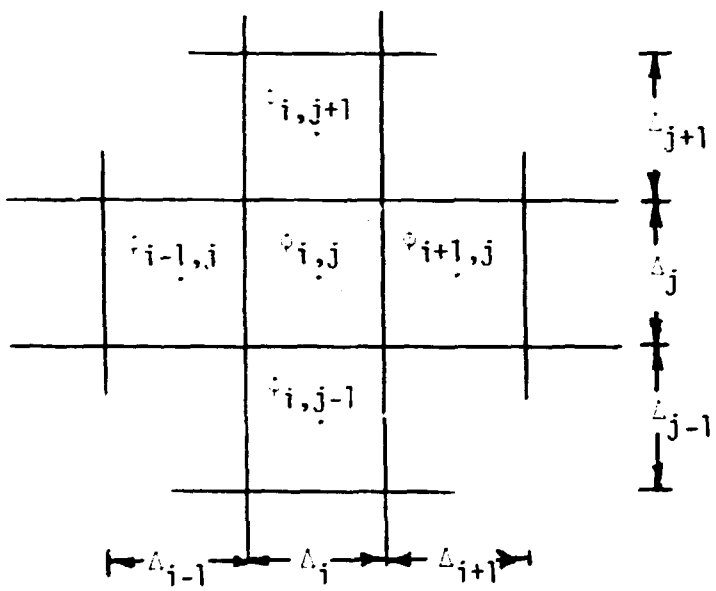
3. DGRAD

A module, DGRAD, was written to calculate the directional flux gradients from DOT III[2] diffusion theory flux tapes. DOT-IV[5] scalar flux tapes can also be used if they are preprocessed in the RTFLUM[6] module of the DOS[5] system. The module, DGRAD, in conjunction with VIP[3] and TPERT will allow the use of diffusion theory fluxes to obtain exact and first-order perturbation reactivity changes.

In order to calculate the reactivity associated with changes in reactor compositions using diffusion theory, it is necessary to fold not only the scalar fluxes with the appropriate cross sections, but also the average flux gradients with the diffusion coefficients. Since DOT

diffusion theory does not directly calculate these gradients, it was necessary to calculate the needed quantities external to the DOT code.

Consider the typical mesh cell with cell-centered fluxes



The flux on the left boundary of cell i, j, ϕ_{BL} can be calculated if the current across this boundary is assumed to be continuous.

$$2\, D_{i-1,j}\, \frac{\phi_{BL} - \phi_{i-1,j}}{\Delta_{i-1}} = 2\, D_{i,j}\, \frac{\phi_{i,j} - \phi_{BL}}{\Delta_i}$$

where $D_{i,j}$ is the diffusion coefficient for cell i,j. Solving for ϕ_{BL}

$$\phi_{BL} = \frac{D_{i,j}\, \phi_{i,j}\, \Delta_{i-1} + D_{i-1,j}\, \phi_{i-1,j} \Delta_i}{D_{i-1,j}\, \Delta_i + D_{i,j}\, \Delta_{i-1}} \quad .$$

Similarly for the right boundary

$$\phi_{BR} = \frac{D_{i+1,j}\,\phi_{i+1,j}\,\Delta_i + D_{i,j}\,\phi_{i,j}\,\Delta_{i+1}}{D_{i,j}\,\Delta_{i+1} + D_{i+1,j}\,\Delta_i} \quad .$$

The R direction gradient can then be obtained as follows

$$\nabla^R \phi_{i,j} = \frac{\phi_{BR} - \phi_{BL}}{\Delta_i} \quad .$$

Similar arguments are used for the calculation of the Z direction gradients.

On the outer boundaries of the problem the following conditions are imposed

For reflected boundaries at

i=1	$\phi_{0,j} = \phi_{i,j}$	j=1	$\phi_{i,0} = \phi_{i,1}$
	$\Delta_{0,j} = \Delta_{i,j}$		$\Delta_{i,0} = \Delta_{i,1}$
	$D_{0,j} = D_{1,j}$		$D_{i,0} = D_{i,1}$
i=IM	$\phi_{IM+1,j} = \phi_{IM,j}$	j=JM	$\phi_{i,JM+1} = \phi_{i,JM}$
	$\Delta_{IM+1,j} = \phi_{IM,j}$		$\Delta_{i,JM+1} = \Delta_{i,JM}$
	$D_{IM+1,j} = D_{IM,j}$		$D_{i,JM+1} = D_{i,JM}$

For non-return boundaries the flux is assumed to equal zero at the extrapolated boundary

i=1	$\phi_{0,j} = 0.0$	j=1	$\phi_{i,0} = 0.0$
	$\Delta_{0,j} = 1.42089/\Sigma_{TR}$		$\Delta_{i,0} = 1.42089/\Sigma_{TR}$
	$D_{0,j} = D_{i,j}$		$D_{i,0} = D_{i,1}$

i=IM	$\Sigma_{IM+1,j}$	= 0.0	j=JM	$\Sigma_{i,JM+1}$	= 0.0
	$\Delta_{IM+1,j}$	= 1.42089/Σ_{TR}		$\Delta_{i,JM+1}$	= 1.42089/Σ_{TR}
	$D_{IM+1,j}$	= $D_{IM,j}$		$D_{i,JM+1}$	= $D_{i,JM}$

DGRAD INPUT

Title Card (20A4)

1SS IFLX - 0/1 Forward/Adjoint
IM - No. of Radial Intervals
JM - No. of Axial Intervals
MZ - No. of Material Zones
ITL - Cross-Section Table Length
IHT - Position of the Transport Cross Section
MT - Total Number of Materials
IGM - No. of Energy Groups
IBL - Left Boundary Condition 0=VAC 1=REF
IBR - Right Boundary Condition
IBT - Top Boundary Condition
IBB - Bottom Boundary Condition
IP1 - 0/1 Diffusion/Hybrid Output (see Note 2)
NIN - Flux Input Unit
NOUT - Flux Output Unit
NSEC - Cross-Section Input Unit
ISCRT - Scratch Unit
IPRT - 0/1 Print/No Print Flux and Gradients

Data Block must be terminated with a T.

4** (IM+1) Radial Boundaries
5** (JM+1) Axial Boundaries
6$$ (IM*JM) Zone Number By Interval
7$$ (MZ) Material By Zone

Data Block must be terminated with a T.

Note 1. To run multiple simply supply a new title card and input all the arrays and T's.

Note 2. If IP1 is set equal to zero the scalar flux and the flux gradients are output for the TPERT diffusion perturbation calculation. If IP1 is set equal to 1 the scalar flux and the partial currents are output for the VIP transport integral calculation. VIP is then run as if it were doing a normal P_1 transport problem. The latter option allows for including the P_1 scattering effects and implicit calculation of neutron leakage worths.

REFERENCES

1. R. L. Childs, "VIF, A Computer Program Using Two-Dimensional Discrete Ordinates Transport Calculations for Cross Section Sensitivity Analysis," UCCND/CSD-1 (to be published).

2. W. A. Rhoades and F. R. Mynatt, *The DOT III Two-Dimensional Discrete Ordinates Transport Code*, ORNL/TM-4280, 1973.

3. R. L. Childs, personal communication, 1977.

4. R. L. Childs, D. E. Bartine and W. W. Engle, Jr., "Perturbation Theory and Sensitivity Analysis for Two-Dimensional Shielding Calculations," *Trans. Am. Nucl. Soc.*, 21:543, June 1975.

5. W. A. Rhoades, personal communication, 1977.

APPENDIX

SAMPLE PROBLEM

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FORWARD GRADIENTS

DGRAD

```
1$ ARRAY      18 ENTRIES READ
CT
                  0 0/1 FORWARD/ADJOINT
                 96 NO. OF RADIAL INTERVALS
                 83 NO. OF AXIAL INTERVALS
                128 NO. OF MATERIAL ZONES
                 14 X-SEC TABLE LENGTH
                  5 POSITION OF TRANSPORT X-SEC
                 18 TOTAL NO. OF MATERIALS
                  9 NO. OF ENERGY GROUPS
                  1 LEFT BOUNDARY CONDITION 0=VAC 1=REF
                  0 RIGHT BOUNDARY CONDITION
                  0 TOP BOUNDARY CONDITION
                  0 BOTTOM BOUNDARY CONDITION
                  1 0/1 DIFFUSION/P1 OUTPUT
                  1 FLUX INPUT UNIT
                  2 FLUX OUTPUT UNIT
                  3 CROSS SECTION INPUT UNIT
                  4 SCRATCH UNIT NUMBER
                  1 PRINT/NO PRINT
4$ ARRAY      99 ENTRIES READ <- RADIAL INTERVAL BOUNDARIES
5$ ARRAY      84 ENTRIES READ <- AXIAL INTERVAL BOUNDARIES
6$ ARRAY    8134 ENTRIES READ <- ZONE NUMBER BY INTERVAL
7$ ARRAY     128 ENTRIES READ <- MATERIAL NUMBER BY ZONE
01
              32905 WORDS NECESSARY  35000 WORDS AVAILABLE
    FLUX FOR GROUP   1 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   2 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   3 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   4 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   5 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   6 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   7 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   8 HAS BEEN WRITTEN ON UNIT NOUT
    FLUX FOR GROUP   9 HAS BEEN WRITTEN ON UNIT NOUT
```

1$ ARRAY 18 ENTRIES READ

0T

DGRAD

```
     1 0/1 FORWARD/ADJOINT
    98 NO. OF RADIAL INTERVALS
    83 NO. OF AXIAL INTERVALS
   126 NO. OF MATERIAL ZONES
    14 X-SEC TABLE LENGTH
     5 POSITION OF TRANSPORT X-SEC
    18 TOTAL NO. OF MATERIALS
     9 NO. OF ENERGY GROUPS
     1 LEFT BOUNDARY CONDITION 0=VAC 1=REF
     0 RIGHT BOUNDARY CONDITION
     0 TOP BOUNDARY CONDITION
     0 BOTTOM BOUNDARY CONDITION
     1 0/1 DIFFUSION/PI OUTPUT
    10 FLUX INPUT UNIT
    11 FLUX OUTPUT UNIT
     3 CROSS SECTION INPUT UNIT
     4 SCRATCH UNIT NUMBER
     1 PRINT/NO PRINT
```

4* ARRAY 99 ENTRIES READ

5* ARRAY 84 ENTRIES READ

6$ ARRAY 8134 ENTRIES READ

7$ ARRAY 126 ENTRIES READ

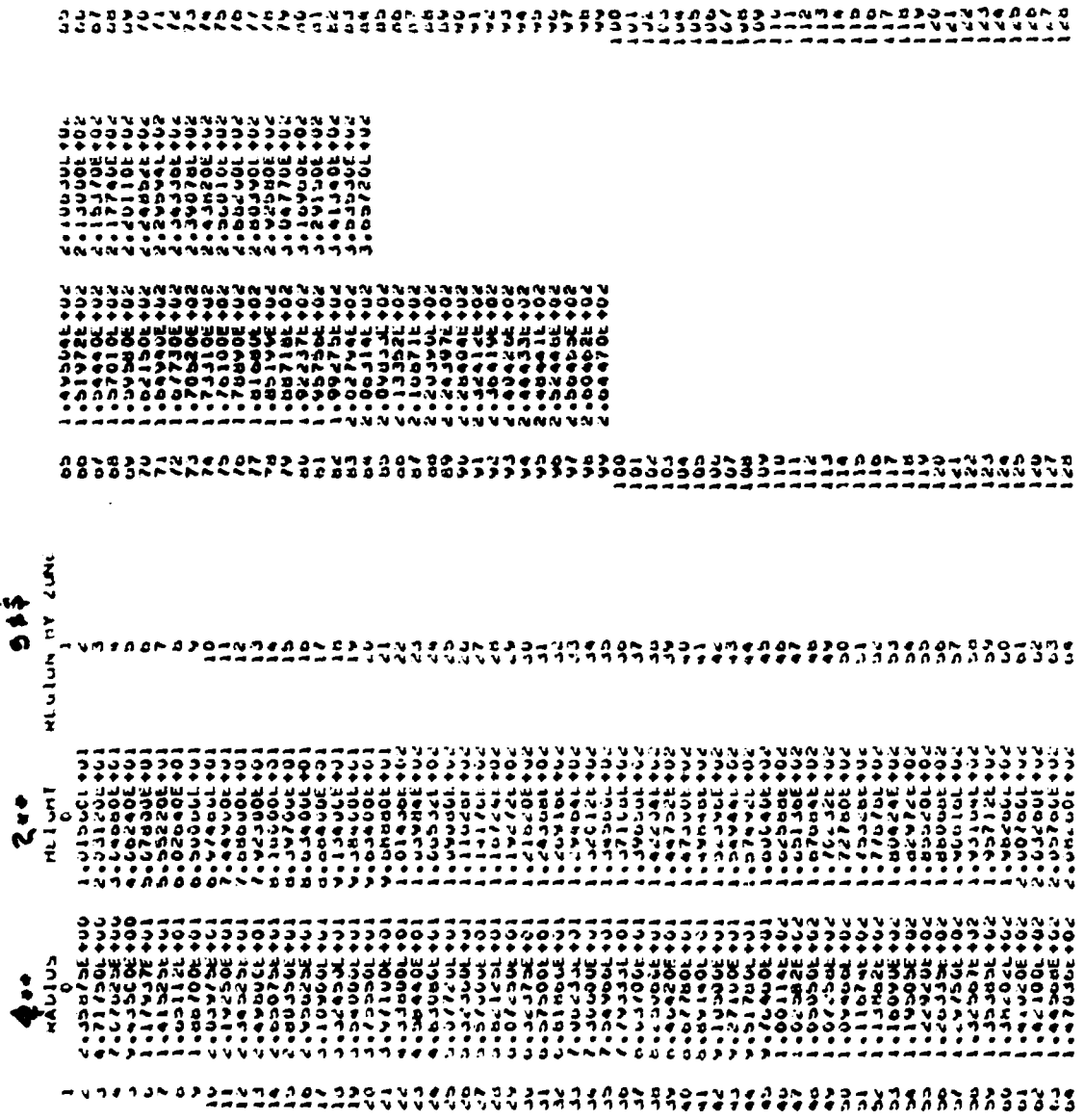
01

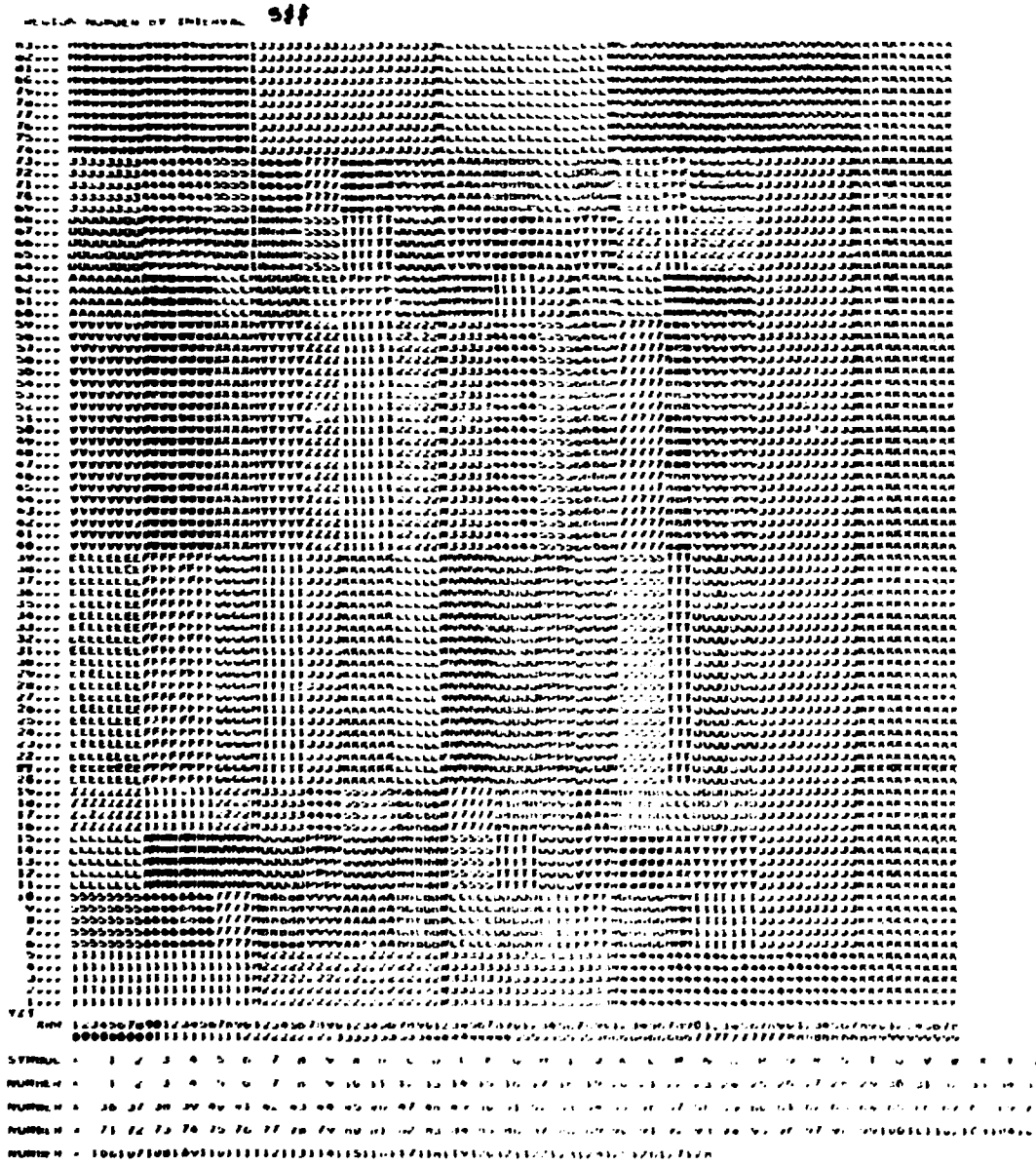
```
                32905 WORDS NECESSARY  35000 WORDS AVAILABLE
     FLUX FOR GROUP   1 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   2 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   3 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   4 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   5 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   6 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   7 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   8 HAS BEEN WRITTEN ON UNIT NOUT
     FLUX FOR GROUP   9 HAS BEEN WRITTEN ON UNIT NOUT

IHC0021 STOP 123
```

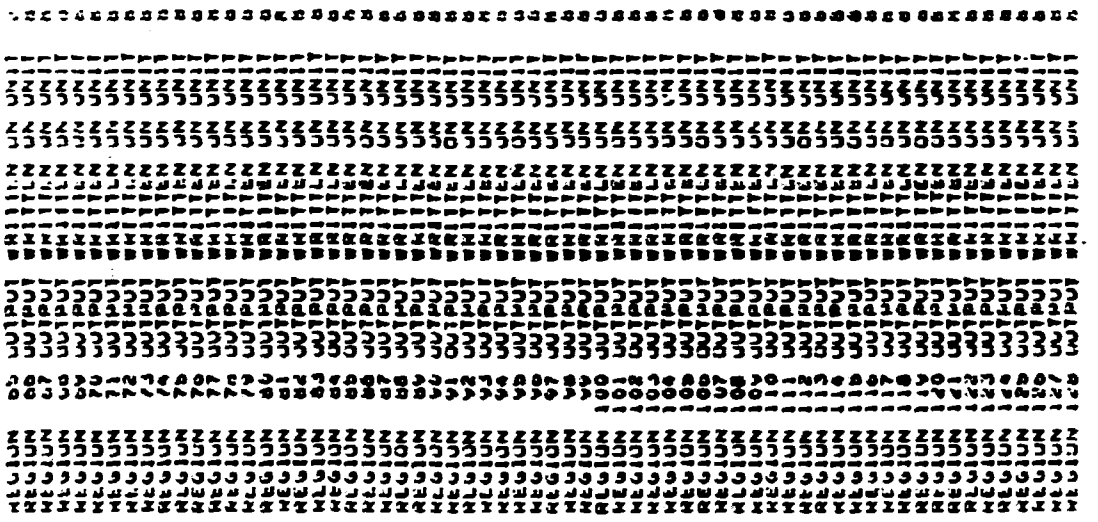
```
VIP FOR R-Z DISRUPTED CORE ANALYSIS

 1$ ARRAY      11 ENTRIES READ

 2$ ARRAY      10 ENTRIES READ

 0T
```

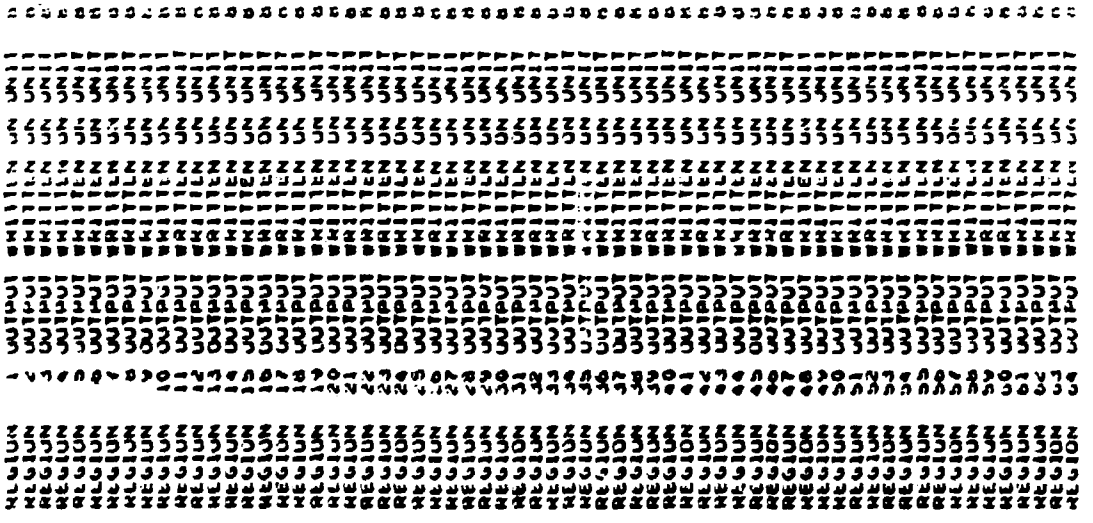
VIP

```
CONTROL PARAMETERS

    1    ID    -- PROBLEM IDENTIFICATION NUMBER (MUST BE POSITIVE)
   98    IM    -- NUMBER OF RADIAL INTERVALS
   83    JM    -- NUMBER OF AXIAL INTERVALS
  128    IZM   -- NUMBER OF ZONES (LARGEST ENTRY IN THE 8$ OR 9$ ARRAY)
    1    ISCT  -- MAXIMUM ORDER OF LEGENDRE EXPANSION (MUST NOT EXCEED A03 IN DOT INPUT)
    9    IGM   -- NUMBER OF ENERGY GROUPS
    1    IGE   -- 0/1/2  X-Y / R-Z / R-THETA GEOMETRY
    5    IMT   -- TABLE POSITION OF TOTAL CROSS SECTION IN SWANLAKE PROBLEM
   14    ITC   -- CROSS SECTION TABLE LENGTH IN SWANLAKE PROBLEM
    2    IFISS -- 1/2 NONFISSION SWANLAKE / FISSION SWANLAKE
    0    IPRT  -- 0/N  NO EFFECT / PRINT THE (PHI*)(PHI) MATRIX FOR REGIONS 1 THROUGH N.

INPUT/OUTPUT PARAMETERS

    0    NUF   -- 0/N NO EFFECT / READ UNCOLLIDED FORWARD FLUX MOMENTS FROM UNIT N.
    0    NUA   -- 0/N NO EFFECT / READ UNCOLLIDED ADJOINT FLUX MOMENTS FROM UNIT N.
    1    NFF   -- LOGICAL UNIT FOR THE FORWARD SCALAR FLUX TAPE
    2    NAF   -- LOGICAL UNIT FOR THE ADJOINT SCALAR FLUX TAPE
    8    NTP   -- OUTPUT UNIT FOR THE (PHI*)(PHI) TAPE
    5    NIN   -- INPUT UNIT (NORMALLY 5)
    6    NOU   -- OUTPUT UNIT (NORMALLY 6)
30000    LBL   -- BLKSIZE IN THE FBSAM OD STATEMENTS
   10    NBL   -- MAXIMUM NUMBER OF BLOCKS PER LOGICAL RECORD (FBSAM UNITS ONLY)
    1    NERC  -- 0/1 FOLLOW FBSAM ERROR PROCEDURES / IGNORE FBSAM I/O ERRORS


THE MESH IS DIVIDED INTO     5 BLOCKS
    86404 STORAGE LOCATIONS USED

   2$ ARRAY      84 ENTRIES READ

   4$ ARRAY      99 ENTRIES READ

   8$ ARRAY    6134 ENTRIES READ

   9$ ARRAY     128 ENTRIES READ

   0T
```









CASE 4 EXACT P1 PERT

TPERT

1S ARRAY 13 ENTRIES READ

0T

2* ARRAY 9 ENTRIES READ

3* ARRAY 9 ENTRIES READ

4S ARRAY 17 ENTRIES READ

5S ARRAY 128 ENTRIES READ

6* ARRAY 128 ENTRIES READ

7* ARRAY 128 ENTRIES READ

8S ARRAY 128 ENTRIES READ

9* ARRAY 128 ENTRIES READ

10* ARRAY 128 ENTRIES READ

11* ARRAY 3 ENTRIES READ

0T

CASE 4 EXACT P1 PERT

INPUT CONSTANTS

IHT	POSITION OF TOTAL CROSS SECTION	5
IHS	POSITION OF SELF-SCATTER CROSS SECTION	6
ITL	CROSS SECTION TABLE LENGTH	14
IGM	NUMBER OF ENERGY GROUPS	9
NR	NUMBER OF VIP MATERIAL REGIONS	128
ISCT	ORDER OF SCATTERING ANISOTROPY	1
NMAT	NUMBER OF PG INPUT MATERIALS	17

NTAB	LOGICAL UNIT NUMBER OF VIP PHI-PHI* VOLUME INTEGRATED TABLES	1
NCR	LOGICAL UNIT NUMBER OF INPUT CROSS SECTION LIBRARY	5
NUCR	DIRECT ACCESS LOGICAL UNIT NUMBER FOR CROSS SECTION STORAGE	15
NSRT	SCRATCH DISK UNIT NUMBER	16

JFLAG	0/1 = USE PERTURBED DENUMINATOR/UNPERTURBED DENUMINATOR	0
ITDD	0/1 = TRANSPORT CALCULATION/DIFFUSION CALCULATION	0

GROUP	2** CHI	3** VELOCITY	4** MATERIAL	4** MATID	11** EIG/BETA/UNORM
1	3.3125E-02	1.0000E 00	1	1	9.0343E-01
2	6.2725E-01	1.0000E 00	2	5	3.4000E-03
3	2.0881E-01	1.0000E 00	3	9	0
4	1.2709E-01	1.0000E 00	4	13	
5	3.6430E-03	1.0000E 00	5	17	
6	2.7874E-05	1.0000E 00	6	21	
7	6.0861E-05	1.0000E 00	7	25	
8	4.6874E-07	1.0000E 00	8	29	
9	1.4529E-11	1.0000E 00	9	33	
10			10	37	
11			11	41	
12			12	45	
13			13	49	
14			14	53	
15			15	57	
16			16	61	
17			17	65	

60	7	1.0000E 00	0	7	0	1.0000E 00
61	9	1.0000E 00	0	9	0	1.0000E 00
62	6	1.0000E 00	0	6	0	1.0000E 00
63	7	1.0000E 00	0	7	0	1.0000E 00
64	9	1.0000E 00	0	9	0	1.0000E 00
65	7	1.0000E 00	0	7	0	1.0000E 00
66	9	1.0000E 00	0	17	0	1.0000E 00
67	7	1.0000E 00	0	19	0	1.0000E 00
68	9	1.0000E 00	0	17	0	1.0000E 00
69	7	1.0000E 00	0	12	0	1.0000E 00
70	9	1.0000E 00	0	9	0	1.0000E 00
71	7	1.0000E 00	0	12	0	1.0000E 00
72	9	1.0000E 00	0	9	0	1.0000E 00
73	7	1.0000E 00	0	10	0	1.0000E 00
74	9	1.0000E 00	0	9	0	1.0000E 00
75	7	1.0000E 00	0	7	0	1.0000E 00
76	9	1.0000E 00	0	9	0	1.0000E 00
77	7	1.0000E 00	0	7	0	1.0000E 00
78	9	1.0000E 00	0	9	0	1.0000E 00
79	7	1.0000E 00	0	7	0	1.0000E 00
80	9	1.0000E 00	0	17	0	1.0000E 00
81	7	1.0000E 00	0	12	0	1.0000E 00
82	9	1.0000E 00	0	17	0	1.0000E 00
83	7	1.0000E 00	0	12	0	1.0000E 00
84	9	1.0000E 00	0	9	0	1.0000E 00
85	7	1.0000E 00	0	12	0	1.0000E 00
86	9	1.0000E 00	0	9	0	1.0000E 00
87	7	1.0000E 00	0	10	0	1.0000E 00
88	9	1.0000E 00	0	9	0	1.0000E 00
89	7	1.0000E 00	0	7	0	1.0000E 00
90	9	1.0000E 00	0	9	0	1.0000E 00
91	7	1.0000E 00	0	7	0	1.0000E 00
92	9	1.0000E 00	0	9	0	1.0000E 00
93	7	1.0000E 00	0	7	0	1.0000E 00
94	9	1.0000E 00	0	9	0	1.0000E 00
95	8	1.0000E 00	0	16	0	1.0000E 00
96	9	1.0000E 00	0	9	0	1.0000E 00
97	8	1.0000E 00	0	13	0	1.0000E 00
98	9	1.0000E 00	0	9	0	1.0000E 00
99	8	1.0000E 00	0	13	0	1.0000E 00
100	9	1.0000E 00	0	9	0	1.0000E 00
101	8	1.0000E 00	0	11	0	1.0000E 00
102	9	1.0000E 00	0	9	0	1.0000E 00
103	8	1.0000E 00	0	8	0	1.0000E 00
104	9	1.0000E 00	0	9	0	1.0000E 00
105	8	1.0000E 00	0	8	0	1.0000E 00
106	9	1.0000E 00	0	9	0	1.0000E 00
107	8	1.0000E 00	0	8	0	1.0000E 00
108	9	1.0000E 00	0	9	0	1.0000E 00
109	8	1.0000E 00	0	8	0	1.0000E 00
110	9	1.0000E 00	0	9	0	1.0000E 00
111	8	1.0000E 00	0	8	0	1.0000E 00
112	9	1.0000E 00	0	9	0	1.0000E 00
113	8	1.0000E 00	0	8	0	1.0000E 00
114	9	1.0000E 00	0	9	0	1.0000E 00
115	8	1.0000E 00	0	8	0	1.0000E 00
116	9	1.0000E 00	0	9	0	1.0000E 00
117	8	1.0000E 00	0	8	0	1.0000E 00
118	9	1.0000E 00	0	9	0	1.0000E 00
119	8	1.0000E 00	0	8	0	1.0000E 00
120	9	1.0000E 00	0	9	0	1.0000E 00
121	8	1.0000E 00	0	8	0	1.0000E 00
122	4	1.0000E 00	0	4	0	1.0000E 00
123	5	1.0000E 00	0	5	0	1.0000E 00
124	4	1.0000E 00	0	4	0	1.0000E 00
125	5	1.0000E 00	0	5	0	1.0000E 00
126	4	1.0000E 00	0	4	0	1.0000E 00
127	5	1.0000E 00	0	5	0	1.0000E 00
128	4	1.0000E 00	0	4	0	1.0000E 00

1770 WORDS OF COMMON NEEDED, 10000 WORDS WERE AVAILABLE

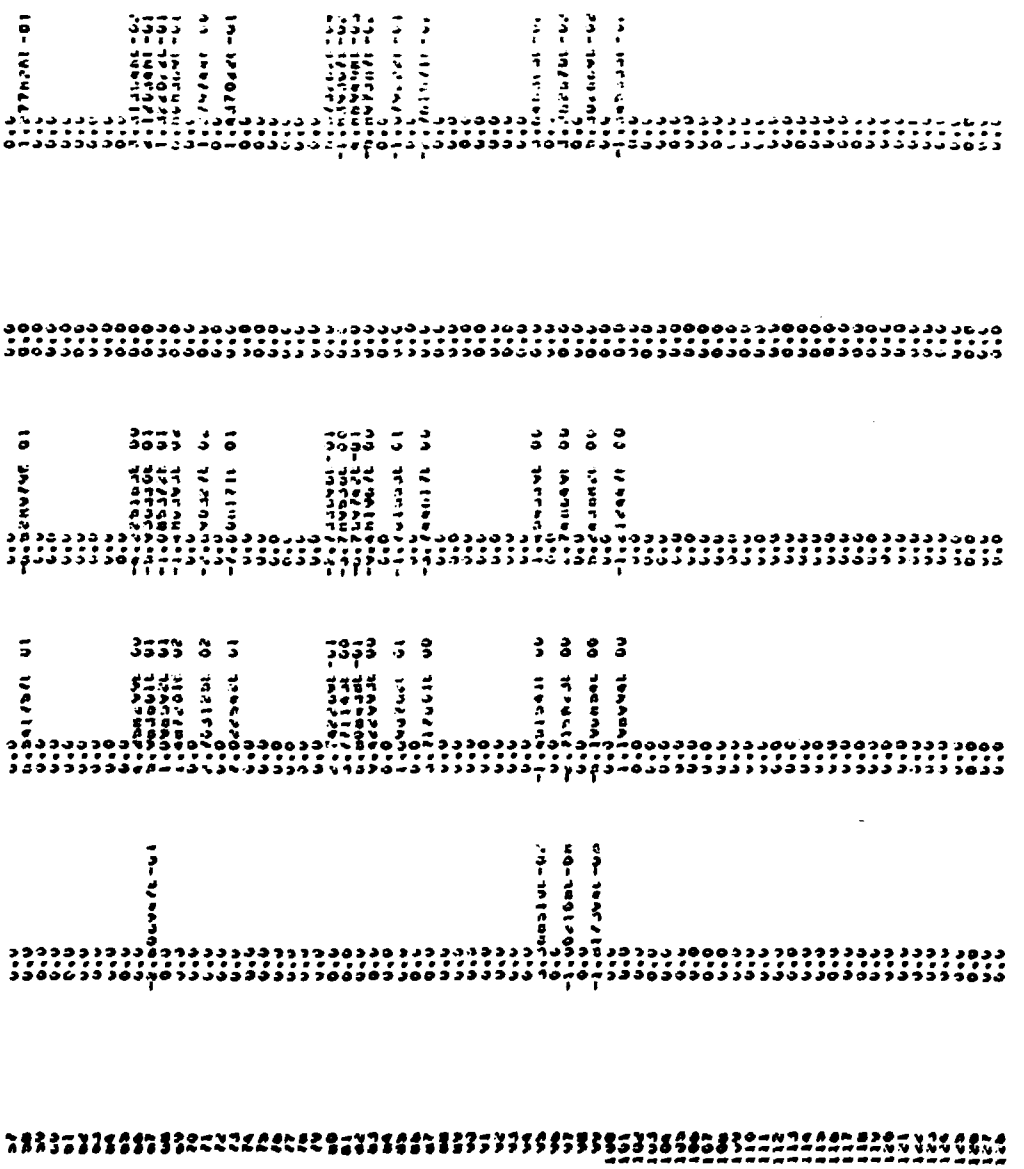
REACTIVITY CONTRIBUTION DUE TO CHANGE IN FISSION CROSS SECTION = -6.501374E-09
REACTIVITY CONTRIBUTION DUE TO CHANGE IN TOTAL CROSS SECTION = 1.963034E-05
REACTIVITY CONTRIBUTION DUE TO CHANGE IN SCATTERING CROSS SECTION = -1.977310E-05
REACTIVITY CONTRIBUTION DUE TO CHANGE IN DIFFUSION COEFFICIENT = 0.0

PERTURBATION INTEGRAL DENOMINATOR = 3.744993E-08

TOTAL REACTIVITY CHANGE (DOLLARS) = 1.302670E 00

INTEGRAL OVER INVERSE VELOCITY = 4.721234E-06

REGION OR INTERVAL NO.	DELTA NUSIGF WORTH	DELTA SIGT OR SIGR WORTH	DELTA SIGS INSCAT WORTH	DELTA DIFF COEF WORTH	TOTAL REGION OR INTERVAL WORTH
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	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0
31	0.0	0.0	0.0	0.0	0.0
32	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0	0.0
41	0.0	0.0	0.0	0.0	0.0
42	0.0	0.0	0.0	0.0	0.0
43	0.0	0.0	0.0	0.0	0.0
44	0.0	0.0	0.0	0.0	0.0
45	0.0	0.0	0.0	0.0	0.0
46	0.0	0.0	0.0	0.0	0.0
47	0.0	0.0	0.0	0.0	0.0
48	0.0	0.0	0.0	0.0	0.0
49	0.0	0.0	0.0	0.0	0.0
50	0.0	-1.4675795E 01	1.4535006E 01	0.0	-1.4007896E-01
51	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0
53	0.0	-3.0865771E 01	3.6475058E 01	0.0	-3.0764706E-01
54	0.0	0.0	0.0	0.0	0.0
55	0.0	-7.3311192E 01	7.2620797E 01	0.0	-6.6493676E-01
56	0.0	0.0	0.0	0.0	0.0



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