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A USER'S MANUAL FOR 2DBS,
A DIFFUSION THEORY
SHIELDING CODE

D. R. MARR

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A DIFFUSION THEORY SHIELDING CODE

by

D. R. Marr

Reactor and Plant Technology Department
FFTF Project

February 1970

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D. R. Marr

ABSTRACT

Revisions were made in the two-dimensional, multigroup neutron diffusion code 2DB to facilitate its use in shielding calculations. The revised code, 2DBS, employs the same basic mathematical model. Changes were made (1) to increase the rate of convergence and to improve monitoring and control of the convergence process, particularly for points far from the source; and (2) to incorporate additional versatility in input and output, including linkages to a flux plotting routine. All programming is in FORTRAN-IV.

TABLE OF CONTENTS

I	INTRODUCTION	1
II	SUMMARY.	1
III	DISCUSSION	2
IV	REFERENCES	5
APPENDIX A	2DBS Input Instructions	A-1
APPENDIX B	Condensed Input Guide	B-1
APPENDIX C	2DBS Control Cards.	C-1
APPENDIX D	2DBS Plot Routine	D-1
	Plot Routine Input Instructions	D-3
	Plot Routine Namelist Input	D-4
	Plot Routine Control Cards and Sample Input	D-7
	Plot Routine Notes.	D-8

I. INTRODUCTION

Two dimensional diffusion theory has proven to be an effective and economical method for calculating the performance of in-vessel shields typical of reactors in the LMFBR program. The compactness of such cores often necessitates the 2-d treatment and diffusion theory proves adequate because the exclusion of hydrogenous media from the liquid metal environment relaxes the dependence of the total flux on the high energy scattering treatment where anisotropy is so important.

Additions were made to the available 2-d diffusion code ~~2DB~~⁽¹⁻⁴⁾ to make it more suitable for such shielding work. The new options that were incorporated, along with the corresponding input changes, were deemed sufficient to attach a new name, 2DBS, to the modified code in order to avoid confusion.

II. SUMMARY

No changes were made in the basic mathematical model; however, several features were added which can accelerate flux convergence, particularly for points far from the source. Additional output is also available, including pointwise convergence information, reaction or activation rates; and from a coupled routine, Calcomp plots of the flux, power, fission rate, reaction rates, or spectra.

The features included in 2DBS which affect convergence are the following:

- Line inversion direction is optionally alternated every flux iteration rather than every power iteration.
- The user may set the rebalancing frequency.
- The number of flux iterations can automatically be increased once the power iterations have converged.

- Pointwise flux convergence output is available to indicate whether or not convergence in the region of interest is adequate, thereby obviating the need for further expensive calculations.

Other additions were the following:

- The ability to calculate reaction rates, both pointwise and zonal totals.
- Various portions of the printed output may be suppressed.
- Standard ANISN cross section library tapes may be employed with the code.
- The flux output tape also contains the necessary information for linkage to an auxiliary routine for plotting fluxes, power, fission source rate, reaction rates, and spectra.
- The generalized input accepts an easily remembered alphabetic operation code as well as the numerical form.
- The non-zero fission source requirement was removed for those cases with a fixed source.

III. DISCUSSION

Machine calculation of shielding performance with such codes as 2DB⁽¹⁻⁴⁾ are frequently time consuming and hence expensive. One reason for this is the inherently large size of many shielding problems. Another reason, implicit in shielding, is the need to determine fluxes at points far from the source, points at which the iterative technique is slowly converging. In the latter situation, several ways were found to improve the performance of 2DB.

Typically, shield problems are run in two parts. First, a series of power iterations are made to converge on the core fission source. Little attempt is made to converge the fluxes, except insofar as they determine the fission source. This means that points with little effect on the fission source, such as points far away, are probably poorly converged. Indeed, it would be wasteful of machine time to attempt to converge them every power

iteration. After the fission source convergence has been established, then one power iteration, this time with a large number of flux iterations, is made in order to converge the fluxes. Most of the changes incorporated in 2DBS were to make this latter calculation more efficient. The two part scheme has also been automated in 2DBS so that a new number of flux iterations is used once the power iterations converge.

The solution of the difference equations is most efficient if the line inversion is done in the direction of tightest coupling. Unfortunately, some problems have tight coupling in one direction in some regions and tight coupling in the other direction in other regions. For this reason, 2DB allowed the user to alternate the inversion direction every power iteration. This has been changed in 2DBS to alternation every flux iteration in order that the fluxes as well as the fission source may be converged efficiently.

Overall neutron balance is not inherently maintained in the flux iteration scheme of 2DB; therefore, at intervals, the balance must be restored by rescaling the fluxes. For the types of problems run on 2DB, rebalancing at the beginning of each group calculation was found to be sufficient; however, for the large number of flux iterations frequently involved in shielding problems, more frequent rebalancing is necessary. Accordingly, the frequency of rebalancing is input to 2DBS.

The flux convergence scheme in 2DB (and 2DBS) requires the flux at every point to meet the established criterion. Oftentimes, something less than this is acceptable, namely convergence at all the points of interest. In order to determine if this situation has been reached, 2DBS normally outputs the position and degree of convergence for the worst point for each group, with an optional full display of the convergence degree for each point.

Subsequent to the flux calculation, reaction rates of the following form may be calculated by 2DBS:

$$R = \sum_{i=1,NG} \phi_i \sigma_i$$

where i is the energy index and NG is the number of groups.

By using the appropriate "cross section" for σ_i , one can calculate quantities such as activation rates, power, fission rate, radiation damage rates, instrument responses, secondary gamma production rates, or neutron dose.

Large shield problems can generate several hundred pages of output. Much of this information is not needed in any specific problem, particularly when the user has access to the more compact, edited information now available from an auxiliary plotting routine (see Appendix D). Suppression of various parts of the output has been put under input control.

REFERENCES

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APPENDIX A

2DBS INPUT INSTRUCTIONS

2DBS INPUT INSTRUCTIONS

The following pages describe the input data for 2DBS. Most input is read in via generalized input subroutines. The format for data read in through the generalized input subroutines must adhere to the following form: All cards must contain six data fields of 12 columns each. The last nine columns of each field contain the data, D, associated with the particular field (see exception below); blanks in all nine columns will cause this entire field to be ignored. Columns 2-3 contain an integer, N, from 0 to 99. The first column of each field must contain:

- 0 or blank - no effect ($N = 0$)
- 1 or R - repeat associated entry N times
- 2 or I - do N linear interpolations between associated data entry and succeeding data entry
- 3 or T - terminate reading of this array with previous data entry
- 4 or C - repeat previous D data entries N times (if D is a floating point number, code converts to an integer)
- 5 - ignore this field
- 6 or F - fill the rest of the array with D

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
<u>CARD 1</u> (To run a series of cases, repeat from this card)			
ID (11)	1-66	11A6	Identification card.
MAXT	67-72	I6	Time (minutes) to leave for orderly termination
<u>CARD 2</u>			
A02	1-6	I6	Problem type: = 0, regular calculation, = 1, adjoint calculation.
I04	7-12	16	Eigenvalue type: = 0, sources, = 1, k_{eff} , = 2, time absorption (a),

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
<u>CARD 2</u> (Cont)			
			= 3, concentration (C), = 4, zone thickness (δ), = 5, buckling (B^2).
S02	13-18	I6	Parametric eigenvalue type: = 0, none, = 1, k_{eff} , = 2, α
IGM	19-24	I6	Number of energy groups ($1 \leq N \leq 50$).
NXCM	25-30	I6	Number of downscattering terms.
MCR	31-36	I6	Number of materials (cross sections) from cards .
MTP	37-42	I6	Number of materials from tape.* (Set MTP negative for ANISN cross section tape)
M07	43-48	I6	Initial flux guess: = 0, none, = 1, $X(R)*X(Z)$ from cards, = 2, $X(R,Z,E)$ from cards, = 3, $X(R,Z,E)$ from tape.**
D05	49-54	I6	Maximum number of outer iterations.
G07	55-60	I6	Maximum number of inner iterations per group.
S04	61-66	I6	Trigger for alternating the direction of line inversion = 0, no effect, = 1, alternate directions every inner iteration.

* *Tape H on UNIVAC 1108*

** *Tape E on UNIVAC 1108*

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
NPUN	67-72	I6	Flux dump option: = 0, no punch, = 1, punch flux dump, = 2, punch flux and I2 card, = 3, write flux on tape,*** = 4, write flux on tape and punch I2
<u>CARD 3</u>			
IGE	1-6	I6	Geometry specification: = 0, X-Y, = 1, R-Z, = 2, R- θ .
IM	7-12	I6	Number of radial intervals (≥ 3).
JM	13-18	I6	Number of axial intervals (≥ 3).
IZM	19-24	I6	Number of material zones.
MT	25-30	I6	Total number of materials, including mixes.
M01	31-36	I6	Number of mixture specifications.
B01	37-42	I6	Left boundary condition: = 0, vacuum, = 1, reflective.
B02	43-48	I6	Right boundary condition.
B03	49-54	I6	Top boundary condition: = 0, vacuum, = 1, reflective, = 2, periodic.
B04	55-60	I6	Bottom boundary condition.
IZ	61-66	I6	Number of radial zones (δ option only).
JZ	67-72	I6	Number of axial zones (δ option only).

*** *Tape C on UNIVAC 1208*

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
<u>CARD 4</u>			
NACT	1-6	I6	Number of activations (reaction rates).
NED	7-12	I6	= 0, no effect, = 1, full flux deviations display every outer iteration
NREBL	13-18	I6	= 0, global rebalance at start of group calculation (once per outer iteration). = N, global rebalance every N inners.
NFSUP	19-24	I6	Output array suppression: = 0, no suppression, = 1, suppress group fluxes, = 2, suppress group fluxes, power, fission rate, and activities, = 3, same as 2 plus total flux
NXSEC	25-30	I6	Cross section suppression: = 0, no suppression, = 1, suppression.
NGO7	31-36	I6	Now G07 to use when outer iterations converge.
<u>CARD 5</u>			
EV	1-12	E12	Initial eigenvalue guess. (Used only in search calculations.)
EVM	13-24	E12	Initial eigenvalue modifier. This value' should <u>decrease</u> reactivity-- i.e., $EV + EVM$ should produce a lower reactivity than EV. Since EVM is completely problem dependent no representative values can be given. However, this parameter is rather important, so some thought

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
			should be given to estimating a reasonable value. (Used only in search calculations.)
S03	25-36	E12	Parametric eigenvalue (see third word on Card 2).
BUCK	37-48	E12	Buckling (cm^{-2}). Caution--search (and burnup) calculations that include a buckling term cannot be performed using input cross sections (mixes) directly in zones. Furthermore, a given input mix cannot be used directly in two or more zones in k_{eff} or search problems that have a buckling term. These problems can be avoided by mixing with a density of 1.0. If searching on buckling, BUCK should be zero.
LAL	49-60	E12	Lower limit on $ \lambda-1 $, where $\lambda-1$ is, in essence, the predicted change in the current reactivity. After LAL is reached, the eigenvalue slope is no longer altered. LAL is used only in search calculations. Recommended value $\approx .005$.
LAH	61-72	E12	Upper limit on $ \lambda-1 $. If $ \lambda-1 $ is greater than LAH, LAH rather than $ \lambda-1 $ is used in predicting the new eigenvalue. LAH is used only in search calculations. Recommended value $\approx .5$.
<u>CARD 6</u>			
EPS	1-12	E12	Convergence criterion on the total fission source rate. The maximum

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
			error in k_{eff} is actually about 3xEPS.
EPSA	13-24	E12	Parametric eigenvalue convergence criterion. The eigenvalue is recalculated when $ \lambda^{v+1} - \lambda^v $ is less than EPSA. EPSA is only used in search calculations. Recommended value $\sim 10\text{XEPS}$.
G06	25-36	E12	Flux convergence test (if zero, no test). That is, $\text{Max}(\phi^{v+1} - \phi^v / \phi^v)$.
POD	37-48	E12	Parameter oscillation damper. Ratio of the computed eigenvalue change to the predicted eigenvalue change. POD can be used to accelerate convergence or damp out oscillations. (Used only in search calculations.)
ORF	49-60	E12	Over-relaxation factor. If instabilities arise, reduce ORF. Recommended value ~ 1.6 .
S01	61-72	E12	If X is negative, the total power is normalized to $ X $ Mwt using the conversion factor of 215 Mev/fission. If positive, $X = \text{total source}/k_{\text{eff}}$.
<u>CARD 7</u> (Optional, required if MTP < 0)			
MTT (MTP)		I12(GI)*	ANISN library tape identification numbers.
<u>CARD 8</u> (Optional, required if MCR > 0)			
HOLN(MCR)	1-6	A6	Identification card for first isotope. Name.
ATW(MCR)	7-12	E6	Atomic weight of first isotope (a.m.u.).

* Generalized input format

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
ALAM(MCR)	13-18	E6	Decay constant for first isotope (days ⁻¹ . This value is only used in burnup calculations.
AA(9)	19-72	9A6	Miscellaneous additional identification.
<u>CARD 9</u> (optional, required if MCR >0)			
C(ITL,IGM, MCR)	1-12	E12	Cross section data for first group of first isotope. σ_f (barns).
C(ITL,IGM, MCR)	13-24	E12	σ_a .
C(ITL,IGM, MCR)	25-36	E12	$v\sigma_f$.
C(ITL,IGM, MCR)	37-48	E12	σ_{tr} .
C(ITL,IGM, MCR)	49-60	E12	$\sigma(g \rightarrow g)$
C(ITL,IGM, MCR)	61-72	E12	$\sigma(g-1 \rightarrow g)$.
<u>CARD 10</u> (optional, required if MCR >0)			
C(ITL,IGM, MCR)	1-12	E12	$\sigma(g-2 \rightarrow g)$.
C(ITL,IGM, MCR)	13-24	E12	$\sigma(g-3 \rightarrow g)$.
...			Repeat above sequence for all groups and all isotopes. Data for each new energy group must begin on a new card. The code checks the input data to insure that
			$a_{tr} = a_a + \sum_{g'} a(g \rightarrow g').$
<u>CARD 11</u> (optional, required if MO7 = 1)			
RF(IM)	1-12	E12(GI*)	Initial flux guess for first radial interval.

* Generalized input format

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
RF(IM)	13-24	E12(GI)	Initial flux guess for secondradial interval. This flux profile is used for all energy groups.
...			
<u>CARD 11'</u> (Optional, required if M07 = 1)			
ZF(JM)	1-12	E12(GI)	Initial flux guess for first axial interval.
JF(JM)	13-24	E12(GI)	Initial flux guess for second axial interval. This flux profile is used for all energy groups.
...			
<u>CARD 11"</u> (optional, required if M07 = 2)			
NO(IMJM)	1-12	E12(GI)	Initial flux guess for first mesh point in first group.
NO(IMJM)	13-24	E12(GI)	Initial flux guess for second mesh point in first group. Continue for all mesh points and all energy groups.
...			
<u>CARD 12</u>			
SO(IMJM)	1-12	E12(GI)	External source for first mesh point in first group.
SO(IMJM)	13-24	E12(GI)	External source for second mesh point in first group. Continue for all mesh points.
...			
<u>CARD 12'</u>			
SO(IMJM)	1-12	E12(GI)	External source for first mesh point in second group.
SO(IMJM)	13-24	E12(GI)	External source for second mesh point in second group. Continue for all mesh points.
...			
<u>CARD 12"</u>			
SO(IMJM)	1-12	E12(GI)	Same as above but for group 3. Continue as above, one group per array.
...			
<u>CARD 13</u>			
RO(IM+1)	1-12	E12(GI)	Radial position of first mesh boundary (0.0).

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
RO(IM+1)	13-24	E12(GI)	Radial position of second mesh boundary (cm).
...			
ZO(JM+1)	1-12	E12(GI)	Axial position of first mesh boundary (0.0).
ZO(JM+1)	13-24	E12(GI)	Axial position of second mesh boundary. Dimensions should be in cm for R-Z and X-Y calculations, and in fractions of a circle for R- θ calculations (e.g., 0.5 for 180°).
...			
<u>CARD 15</u>			
MO(IMJM)	1-12	I12(GI)	Zone number for first mesh interval.
MO(IMJM)	13-24	I12(GI)	Zone number for second mesh interval. Mesh intervals are sequence numbered beginning at the lower left and then proceeding through each row in order.
...			
<u>CARD 16</u>			
M2(IZM)	1-12	I12(GI)	Material number for first zone.
M2(IZM)	13-24	I12(GI)	Material number for second zone.
...			
<u>CARD 17</u> (optional, required if BUCK $\neq$ 0 or if IO4 = 5)			
GAM(IZM)	1-12	E12(GI)	Buckling modifier for first zone.
...	13-24	E12(GI)	Buckling modifier for second zone.
<u>CARD 18</u>			
K7(IGM)	1-12	E12(GI)	Fission fraction (spectrum) in first energy group.
K7(IGM)	13-24	E12(GI)	Fission fraction in second energy group.
...			
<u>CARD 19</u>			
V7(IGM)	1-12	E12(GI)	Neutron velocity for first energy group (cm/sec).

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
V7(IGM)	13-24	E12(GI)	Neutron velocity for second energy group.
...			
<u>CARD 20</u> (optional, required if M01>0)			
IO(M01)	1-12	I12(GI)	Material number of Mix 1.
...			
IO(M01)	N-N+11	I12(GI)	Material number of Mix 2.
 <u>CARD 21</u> (Optional, required if M01>0)			
I1(M01)	1-12	I12(GI)	0 (to clear storage area for Mix 1).
I1(M01)	13-24	I12(GI)	Number of first material in Mix 1.
I1(M01)	25-36	I12(GI)	Number of second material in Mix 1.
...			
I1(M01)	N-N+12	I12(GI)	0 (to clear storage area for Mix 2).
I1(M01)	N+13		
	-N+24	I12(GI)	Number of first material in Mix 2.
...			
<u>CARD 22</u> (optional, required if M01>0)			
I2(M01)	1-12	E12(GI)	0
I2(M01)	13-24	E12(GI)	Concentration of first material in Mix 1 (atoms/barn-cm).
I2(M01)	25-36	E12(GI)	Concentration of second material in Mix 1.
...			
<u>CARD 23</u> (optional, required if IO4 = 4)			
R2(IM)	1-12	I12(GI)	Dimensional search zone number for first radial interval.
R2(IM)	13-24	I12(GI)	Dimensional search zone number for second radial interval.
...			
<u>CARD 24</u> (optional, required if IO4 = 4)			
R3(IZ)	1-12	E12(GI)	Dimensional modifier for first (dimensional search) radial zone.
R3(IZ)	13-24	E12(GI)	Dimensional modifier for second radial zone.
...			

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
<u>CARD 25</u> (optional, required if I04 = 4)			
Z2(JM)	1-12	I12(GI)	Dimensional search zone number for first axial interval.
Z2(JM)	13-24	I12(GI)	Dimensional search zone number for second axial interval.
...			
<u>CARD 26</u> (optional, required if I04 = 4)			
Z3(JZ)	1-12	E12(GI)	Dimensional modifier for first axial zone.
Z3(JZ)	13-24	E12(GI)	Dimensional modifier for second axial zone.
...			
<u>CARD 27</u>			
ACTM(NACT)	1-12	I12(GI)	Number of material with the cross section to use in the first reaction rate (activation) calculation.
ACTM(NACT)	13-24	I12(GI)	Number of second activation material.
...			
<u>CARD 28</u>			
ACTP(NACT)	1-12	I12(GI)	Position of cross section, within material ACTM(1) which is to be used in first reaction rate calculation.
ACTP(NACT)	13-24	I12(GI)	Position of cross section, material ACTM(2), second reaction rate.
...			
<u>CARD 29</u> (Burnup Control Card)			
NCON	1-6	I6	Burnup control: = 0, end of problem, read input data for next case. = N, read burnup parameters for N isotopes and take time step of DELT, <0. take time step of DELT.
NPRT	7-12	I6	Print control:

<u>Variable</u>	<u>Columns</u>	<u>Format</u>	<u>Description</u>
			= 0, partial print, = 1, full print.
DELT	13-24	E12	Length of time step (days).
<u>CARD 30</u> (optional, required if NCON > 0)			
MATN(NCON)	1-6	I6	This card contains all burnup parameters for the first burnable isotope. Material sequence number of first burnable isotope.
NBR(NCON)	7-12	I6	Control for breeding ratio calculation: = 0, no effect, = 1, fertile isotope, = 2, fissile isotope.
LD(NCON)	13-18	I6	= 0, no decay source, = N, decay source from burnable isotope N.
LCN(NCON,2)	19-24	I6	= 0, no capture source, = N, capture source from burnable isotope N. See Eq. (5.1).
LCN(NCON,2)	25-30	I6	= 0, no capture source, = N, capture source from burnable isotope N.
LFN(NCON,7)	31-36	I6	= 0, no fission source, = N, fission source from burnable isotope N. See Eq. (5.1).
LFN(NCON,7)	37-48	I6	= 0, no fission source, = N, fission source from burnable isotope N.

...

(Repeat CARD 30 for all burnable isotopes. Repeat from CARD 29 for additional time steps.)

APPENDIX B

CONDENSED INPUT GUIDE

2DBS

6		12		18		24		30		36		42		48		54		60		66		72		78		84	
ID(11) IDENTIFICATION CARD																						HAPT TERMINATION TIME (MIN)					
ADD = 0, REGULAR CALCULATION = 1, ADJOINT CALCULATION		IGM EIGENVALUE TYPE = 0, SOURCE = 1, REFLEX = 2, ABSORP- TION (A) = 3, CONCENT- RATION (C) = 4, ZONE THICK- NESS (S) = 5, BUCKLING (R)		SDP PARAMETRIC EIGENVALUE TYPE = 0, NONE = 1, KEFF = 2, K		IDM NUMBER OF ENERGY GROUPS		NDNM NUMBER OF DOWNS- SCATTERING TERMS		NCB NUMBER OF MATERIALS FROM LAPD		MFE NUMBER OF MATERIALS FROM TAPE (4, 1, 2, 3) AFTER TAPE		MDT FLUX DRESS: = 0, NONE = 1, 8, 16, 32 FROM CASEC = 2, 8, 16, 32 FROM CASEC = 3, 16, 32 FROM TAPE		DDI OUTER ITERATION MAX		DDI INNER ITERATION MAX PER GROUP		SDI INVERSION TRIGGER = 0, NO EFFECT = 1, ALTERNATE DIRECTIONS		NDON FLUX DUMP OPTION = 0, NONE = 1, PUNCH FLUXES = 2, PUNCH FLUXES AND 12 CARD = 3, WRITE TAPE = 4, WRITE TAPE AND PUNCH 12 CARD					
IGM GEOMETRY = 0, 2-D = 1, R-Z = 2, R-θ = 3, 3-D ANGULAR		IM NUMBER OF RADIAL INTERVALS		IM NUMBER OF AXIAL INTERVALS		IM NUMBER OF MATERIAL ZONES		MT TOTAL NUMBER OF MATERIALS INCLUDING MIRRORS		MDI NUMBER OF MIXTURE SPECIFI- CATIONS		MDI LEFT BOUNDARY CONDITION: = 0, VACUUM = 1, REFLECTIVE		MDI RIGHT BOUNDARY CONDITION		MDI TOP BOUNDARY CONDITION = 0, VACUUM = 1, REFLECTIVE = 2, PERIODIC		MDI BOTTOM BOUNDARY CONDITION		IM NUMBER OF RADIAL ZONES (4 OPTION ONLY)		IM NUMBER OF AXIAL ZONES (4 OPTION ONLY)					
NACT NUMBER OF ACTIVATIONS		NFL FLUX DEVIATIONS = 0, NONE = 1, PRINT		NREBL REBALANCING FREQUENCY = 0, NORMAL = 1, EVERY N INVERS		NFSR ARRAY SUPPRESSION = 0, NONE = 1, GROUP FLUXES = 2, PLUS POWER, FISSILE RATIO, ACTIVITIES = 3, PLUS TOTAL FLUX		NKSC CROSS SECTION SUPPRESSION = 0, 92 = 1, 92		NKST NEW SCAT																	
EV FIRST EIGENVALUE DEBT		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER		EV EIGENVALUE MULTIPLIER			
EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION		EV EIGENVALUE CONVERSION CRITERION			

B-2

		6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	
IF(MDI) > 0	●	FIRST MATERIAL TAP ID			SECOND MATERIAL TAP ID			● ● ●									MIT(MTF)
	●	NAME OF 1ST ISOTOPE			ATOMIC WT. OF 1ST ISOTOPE			DECAY CONSTANT OF 1ST ISOTOPE (DAYS ⁻¹)			A(9)			MISCELLANEOUS INFORMATION FOR 1ST ISOTOPE(9A6)			
IF(MDI) > 0	●	CROSS SECTION DATA FOR 1ST ISOTOPE(6K12.5)														C(1TL,IGM,MCR)	
	●	● ● ● (REPEAT ABOVE TWO CARDS FOR EACH ISOTOPE)															
IF(MDI) = 1	●	FLUX GUESS IN FIRST RADIAL INTERVAL			FLUX GUESS IN SECOND RADIAL INTERVAL			● ● ●						RF(1M)			
	●	FLUX GUESS IN FIRST AXIAL INTERVAL			FLUX GUESS IN SECOND AXIAL INTERVAL			● ● ●						ZF(JM)			
IF(MDI) = 2	●	FLUX GUESS IN 1ST MESH INTERVAL FOR GROUP 1			FLUX GUESS IN 2ND MESH INTERVAL FOR GROUP 1			● ● ●						NO(1M1M)			
	●	● ● ● (REPEAT ABOVE CARD FOR ALL GROUPS)														NO(1M1M)	
IF(10M) = 0	●	SOURCE IN 1ST MESH INTERVAL FOR GROUP 1			SOURCE IN 2ND MESH INTERVAL FOR GROUP 1			● ● ●						SO(1M1M)			
	●	● ● ● (REPEAT ABOVE CARD FOR ALL GROUPS)														SO(1M1M)	
	●	1ST RADIAL POINT (0.0)			2ND RADIAL POINT			● ● ●						RO(1M+1)			
	●	1ST AXIAL POINT (0.0)			2ND AXIAL POINT			● ● ●						ZO(JM+1)			
	●	ZONE NUMBER FOR 1ST MESH INTERVAL			ZONE NUMBER FOR 2ND MESH INTERVAL			● ● ●						MO(1M1M)			
	●	MATERIAL NUMBER FOR 1ST ZONE			MATERIAL NUMBER FOR 2ND ZONE			● ● ●						MO(12M)			
IF(BUCK) = 0	●	BUCKLING MODIFIER FOR 1ST ZONE			BUCKLING MODIFIER FOR 2ND ZONE			● ● ●						OAM(12M)			
	●	FISSION FRACTION IN 1ST GROUP			FISSION FRACTION IN 2ND GROUP			● ● ●						KT(10M)			
IF(10M) = 5	●	NEUTRON VELOCITY IN 1ST GROUP			NEUTRON VELOCITY IN 2ND GROUP			● ● ●						VT(10M)			

BNWL-1291

		6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	
IF(MIX1) > 0	●	MATERIAL NUMBER OF MIX 1			MATERIAL NUMBER OF MIX 1			MATERIAL NUMBER OF MIX 1			MATERIAL NUMBER OF MIX 1			MATERIAL NUMBER OF MIX 1			I0(M01)
	●	0			1ST MATERIAL IN MIX 1			2ND MATERIAL IN MIX 1			0			0			I1(M01)
	●	0.0			DENSITY OF 1ST MATERIAL IN MIX 1			DENSITY OF 2ND MATERIAL IN MIX 1			0.0			0			I2(M01)
IF(LOA) = 4	●	ZONE NUMBER FOR 1ST RADIAL INTERVAL			ZONE NUMBER FOR 2ND RADIAL INTERVAL			● ● ●									R2(1M)
	●	MODIFIER FOR 1ST RADIAL ZONE			MODIFIER FOR 2ND RADIAL ZONE			● ● ●									R3(1Z)
	●	ZONE NUMBER FOR 1ST AXIAL INTERVAL			ZONE NUMBER FOR 2ND AXIAL INTERVAL			● ● ●									Z2(1M)
	●	MODIFIER FOR 1ST AXIAL ZONE			MODIFIER FOR 2ND AXIAL ZONE			● ● ●									Z3(1Z)
IF(SACT) > 0	●	MATERIAL FOR 1ST ACTIVATION			MATERIAL FOR 2ND ACTIVATION			● ● ●									ACTN(SACT)
	●	CROSS SECTION POSITION FOR 1ST ACTIVATION			CROSS SECTION POSITION FOR 2ND ACTIVATION			● ● ●									ACTP(SACT)
IF(ISOE) > 0	●	BEGIN = 0, END OF PROBLEM = N, TAKE TIME STEP OF DELT AND READ BURNUP DATA FOR N ISOTOPE. = 0, TAKE TIME STEP OF DELT			SEPT = 0, PARTIAL PRINT = 1, FULL PRINT			DELT LENGTH OF TIME STEP (DAY)									
	●	MATERIAL SEQUENCE NUMBER FOR 1ST BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 1ST BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 1ST BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 1ST BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 1ST BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 2ND BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 2ND BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 2ND BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 2ND BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 2ND BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 3RD BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 3RD BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 3RD BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 3RD BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 3RD BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 4TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 4TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 4TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 4TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 4TH BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 5TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 5TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 5TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 5TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 5TH BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 6TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 6TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 6TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 6TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 6TH BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 7TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 7TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 7TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 7TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 7TH BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 8TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 8TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 8TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 8TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 8TH BURNABLE ISOTOPE			
	●	MATERIAL SEQUENCE NUMBER FOR 9TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 9TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 9TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 9TH BURNABLE ISOTOPE			MATERIAL SEQUENCE NUMBER FOR 9TH BURNABLE ISOTOPE			
● ● ● REPEAT ABOVE CARD FOR ALL BURNABLE ISOTOPES																	

APPENDIX C

2DBS CONTROL CARDS

2DBS CONTROL CARDS

The 2DBS program is maintained on FASTRAND drum file PCF006. The method of securing the program and the necessary control cards at this installation for a typical run with a cross section library type (U1234)* and an output flux tape (U5678)* are shown below. The character V signifies punches 7 and 8 in that column.

```

V   RUN   5,CUBXXX,5,200           NAME
VX= ASG   H=U1234,C=U5678
VN XQT   CUR
IN PCF006
V   XQT   2DBS

```

2DBS DATA

```

V XQT   CUR
TRI   C, H
V FIN

```

* These tape numbers were selected for illustrative purposes only; substitute your own tape numbers.

APPENDIX D

2DBS PLOT ROUTINE

2DBS PLOT ROUTINE

Shield problems typically use many mesh points and many groups. Except for a few integral shielding quantities, this vast amount of information usually needs to be presented to the user in a differential form such as spectra, group flux traverses, and reaction rates as a function of position. The time consuming chore of extracting this sort of information has been automated by the coding of a versatile plot routine for use with the Calcomp plotter. The output tapes from 2DBS as well as the local version of the discrete ordinates transport codes ANISN^{*} and DOT^{**}, contain spatial and energy information along with the scalar fluxes. Editing of this information and plot format are controlled by a small amount of card input to the plot routine.

Plot routine capabilities are the following:

- Zonal maps
- Profiles of:
 1. Group fluxes
 2. Sums of group fluxes
 3. Power density
 4. Fission source rate
 5. Reaction rates

* W. W. Engle, Jr., A User's Manual for ANISN, K-1693, Union Carbide, 1967.

** F. R. Mynatt, A User's Manual for DOT, K-1694, Union Carbide, to be published.

- Comparisons of profiles for up to 5 different 2DBS runs
- Spectra

All coding is in FORTRAN-V^{*} and makes extensive use of variable dimensioning. Multicase efficiency was increased by use of the random access capability of the FH432 magnetic drum storage units. The programming for this feature is modular in nature and could be converted to other storage systems with a moderate effort.

* FORTTRAN V Programmers Reference Manual, UP-4060, UNIVAC, 1966.

PLOT ROUTINE INPUT INSTRUCTIONS

All card input is in NAMELIST format. There is multiple case capability. First card of each case must have the following six characters, starting in column 2 --

\$INPUT

Last card must have, starting in column 2 --

\$END

The primary flux tape should be mounted on logical unit 1 (UNIVAC-1108 Tape C), secondary tapes on any of logical units 2, 3, 4 or 5, or (UNIVAC-1108 Tape E, F, G, or H respectively). Plot tape will be written on Tape D. The angular variable from 2DBS (R, θ) cases is converted internally to degrees upon reading the flux tape so any references to that variable in the plot routine should be in degrees.

The latest version of the plot routine is kept in FASTRAND file PCF006 along with 2DBS. The plot tape is automatically interlocked after the last case. Interlocking of input flux tapes is left to the user.

All input is saved from one case to another so only the changes need to be added in succeeding cases.

PLOT ROUTINE NAMELIST INPUTPLOT SIZE AND SHAPENamelist VariableInput

HEIGHT	If specified, makes ordinate this long in inches, if not specified or zero, it will be set to 6 in.
WIDTH	If specified, makes abscissa this long in inches, if not specified or zero, will be set to 8 in.
SCALE	Scale factor for plot, 1.0 if not input.

NORMALIZATIONNamelist VariableInput

THUX	If nonzero, normalize total flux to THUX at (XNORM, YNORM).
XNORM	
YNORM	

MISCELLANEOUS CONTROLSNamelist VariableInput

NOBND	Set to 1 to suppress plot numbers.
DIMEN	Dimension to be used for all arrays that are limited to ten below. Any other input within this same record will be destroyed, so usually DIMEN will be sole entry in case.
YLIN	Set to 1 to make Y-axis linear.
POWER	Set to 1 to plot power density.
FISSR	Set to 1 to plot fission rate.
HEAD	Heading to replace one from tape.
NTAPE	Set to 1, 2, 3, 4, or 5 for new flux tape on respectively C, E, F, G, or H. If no input, will assume 1(C).
NOXLBL	Set to 1 to suppress X-axis label.
NOYLBL	Set to 1 to suppress Y-axis label.

<u>Namelist Variable</u>	<u>Input</u>																
TSPEC	Spectrum specifier (see table below)																
	<table> <tr> <th>TSPEC</th><th>Plot(s) out</th></tr> <tr> <td>0</td><td>Flux/E, log flux/U, linear flux/U</td></tr> <tr> <td>1</td><td>Flux/E</td></tr> <tr> <td>2</td><td>Log Flux/U</td></tr> <tr> <td>3</td><td>Linear flux/U</td></tr> <tr> <td>4</td><td>Flux/E, log flux/U</td></tr> <tr> <td>5</td><td>Log flux/U, linear flux/U</td></tr> <tr> <td>6</td><td>Flux/E, linear flux/U</td></tr> </table>	TSPEC	Plot(s) out	0	Flux/E, log flux/U, linear flux/U	1	Flux/E	2	Log Flux/U	3	Linear flux/U	4	Flux/E, log flux/U	5	Log flux/U, linear flux/U	6	Flux/E, linear flux/U
TSPEC	Plot(s) out																
0	Flux/E, log flux/U, linear flux/U																
1	Flux/E																
2	Log Flux/U																
3	Linear flux/U																
4	Flux/E, log flux/U																
5	Log flux/U, linear flux/U																
6	Flux/E, linear flux/U																
MAP	Set to 1 to get map of zones.																
NOLIST	Set to 1 to suppress listing of plot points.																
NOGRID	Set to 1 to suppress grid.																

ARRAYS - DIMENSION = 10 OR = DIMEN (SEE ABOVE)

<u>Namelist Variable</u>	<u>Input</u>
LX(I)	Traverses taken at X mesh point numbers LX(I) (or R)
LY(I)	Traverses taken at Y mesh point numbers LY(I) (or Z, Theta)
X(I)	(X,Y) are coordinates of points at which spectra are
Y(I)	wanted.
PLOT1(I)	Beginning group No. for I-TH curve on flux plot No. 1.
PLOT2(I)	Beginning group No. for I-TH curve on flux plot No. 2.
PLOT3(I)	Beginning group No. for I-TH curve on flux plot No. 3.
PLOT4(I)	Beginning group No. for I-TH curve on flux plot No. 4.
PLOT5(I)	Beginning group No. for I-TH curve on flux plot No. 5.
END1(I)	Ending group, I-TH curve, plot 1. If zero, set = PLOT1(I).
END2(I)	Ending group, I-TH curve, plot 2. If zero, set = PLOT2(I).
END3(I)	Ending group, I-TH curve, plot 3. If zero, set = (PLOT3(I)).
END4(I)	Ending group, I-TH curve, plot 4. If zero, set = PLOT4(I).

<u>Namelist Variable</u>	<u>Input</u>
END5(I)	Ending group, I-TH curve, plot 5. If zero, set = PLOT5(I).
ACT1(I)	Activation number for I-TH curve on act. PLOT 1.
ACT2(I)	Activation number for I-TH curve on act. PLOT 2.
ACT3(I)	Activation number for I-TH curve on act. PLOT 3.
ACT4(I)	Activation number for I-TH curve on act. PLOT 4.
ACT5(I)	Activation number for I-TH curve on act. PLOT 5.

COMPARISONS (5 TAPE LIMIT)

<u>Namelist Variable</u>	<u>Input</u>
COMPARE(I)	Number of tapes to compare. For distinguishability you should also input MNEMONICS (see below). Tapes to be compared must have same mesh (IM,JM). Dimensions of the mesh will be read only from the first tape.
MNEMON(I)	One MNEMONIC is assigned to each tape. Input here for each in the form-6HXXXXXX where XXXXXX is the MNEMONIC desired.

ANNOTATION (10 NOTES LIMIT PER CASE)

<u>Namelist Variable</u>	<u>Input</u>
PNO(I)	Plot No. to put note on.
ANGLE(I)	Angle of note.
XCOORD(I)	X-coordinate (in pre-scaled inches) of lower left hand corner of note.
YCOORD(I)	Y-coordinate (in pre-scaled inches) of lower left hand corner of note.
SIZES(I)	Size of characters in note (in pre-scaled inches).
NOTE(I,1)	Note contents (e.g. Note (1,1) = 10H--sodium--)
NOTE(I,2)	Second note (e.g. Note (1,2) = 6H--iron--)
.	
NOTE(I,10)	

PLOT ROUTINECONTROL CARDS AND SAMPLE INPUT

The following is a deck setup with the control cards necessary at this installation and the NAMELIST input cards for plotting the first traverse in the X direction for the first three groups on the first plot, groups four and five on the second, and the flux per unit lethargy spectrum at (100., 326.) on the third. The character V signifies punches 7 and 8 in that column.

```

V  RUN   5,CUBXXX,2,100                      NAME
V  ASG    C=U1234, D=(NH,AT)
V  XQT  CUR
IN  PCF006
V  XQT  PLOT
$INPUT
PLOT1= 1,2,3,PLOT2=4,5,LX=1,X=100.,Y=326.,TSPEC=2,
$END
V  XQT  CUR
TRI C
V  FIN

```

PLOT ROUTINE NOTES

The plot routine will also automatically accept as flux input, output tapes from the one dimensional discrete ordinates transport code ANISN (local version). In that case LY is internally set to one and the problem is thereafter treated as two dimensional with one mesh interval in the transverse direction.

All too frequently, plot tape read errors occur at plotting time causing destruction of a particular plot, usually by what amounts to a shift in origin. Because of the serial nature of the plot information, all subsequent plots would also exhibit this origin shift rendering them unusable. Absolute correction of such a condition is outside the control of the programmer but an attempt is made to reposition the origin before each plot to the proper general area. If plotting on unlined paper, this correction usually is satisfactory. However, if this correction is not suitable and a replot is required, one can specify that the operator start at a particular block on the tape and plot to a specific other block. The necessary information for calculating block numbers is the following:

- The system heading (name, run number, etc.) takes one block.
- Next the zone map, if any, occupies five blocks.
- Each other plot takes twelve blocks.

Thus, plot number N occupies blocks $12(N-1) + 2 + 5$ (MAP) up to, but not including, $12N + 2 + 5$ (MAP).

For use in the spectral plots, the neutron velocity which was input to 2DBS is taken as the upper energy bound of the group.

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