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DAC2, A Two-Dimensional S_n Perturbation Code

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DAC2, A Two-Dimensional S_n Perturbation Code

by

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DAC2, A TWO-DIMENSIONAL S_n PERTURBATION CODE

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G. C. Hopkins

ABSTRACT

DAC2 uses angular fluxes from the 2DF S_n code to calculate reactivity perturbations, effective delayed neutron fractions, and generation times in reactors. In addition to the fluxes, input to DAC2 consists of the input deck to 2DF and the perturbation specifications, each of which is described.

I. INTRODUCTION

In the calculation of reactor parameters such as neutron generation time, effective delayed neutron fractions, and reactivity feedback coefficients, noniterative perturbation techniques are more computationally economic than comparable iterative S_n methods. Moreover, this economy increases as the number of space dimensions used in the computations increases. With the increased emphasis on two-dimensional static reactor calculations, the need has arisen for a two-dimensional perturbation code. To this end, DAC2 was written.

DAC2 was built up from, and is very computationally similar to, the one-dimensional S_n perturbation code DAC1. Therefore, one is referred to the DAC1 report¹ for perturbation theory development and formulas. Pertinent formulas, having algorithms in DAC2, will be repeated in this report.

The S_n perturbation calculations performed by DAC2 require the regular and adjoint angular fluxes created by the two-dimensional S_n code 2DF. A special version of 2DF is available, which puts out these fluxes. Although there is no report available for 2DF, it is the two-dimensional version of DTF-IV, for which there is a report.²

II. PERTURBATION FORMULAS

In the development from the multigroup transport equation to the space-independent kinetic equations, three parameters are defined ($\bar{\beta}_1$, Λ , and ρ); these are calculated by DAC2 as described below.

The effective delayed neutron fractions, $\bar{\beta}_1$, are determined by

$$\bar{\beta}_1 = \frac{1}{K\bar{F}} \sum_k v_k \left[\sum_g \phi_{gk} \sum_Y (v\mu_f)_{gk}^Y \beta_1^Y \right] \left(\sum_g \phi_{gk}^* f_g^1 \right); \quad (1)$$

the prompt neutron generation time, Λ , is defined as

$$\Lambda = \frac{1}{\bar{F}} \sum_k v_k \sum_g \frac{1}{v_g} \phi_{gi}; \quad (2)$$

and the reactivity ρ is broken into three parts

$$\rho = I_f + I_S - I_T. \quad (3)$$

In Eqs. (1) through (3),

K is the effective multiplication,

v_k is the volume element associated with mesh point k ,

ϕ_{gk} is the total flux in group g , point k ,

ϕ_{gk}^* is the adjoint total flux, group g, point k,
 ν is the number of neutrons released per fission,
 μ_f is the macroscopic fission cross section,
 γ is the isotope designator,
 β_i^γ is the delayed neutron fraction for delayed neutron group i and isotope γ ,
 f_g^i is the fraction of delayed group i neutrons released in prompt group g, and
 v_g is the average speed of neutrons in group g.

The other quantities are a normalization factor

$$F = \sum_k v_k \sum_\gamma \left[\sum_g \phi_{gk} \frac{(\nu\mu_f)_{gk}}{K} \right] \cdot \left[\sum_g \phi_{gk}^* \left[(1 - \beta^\gamma) \chi_g^\gamma + \sum_i \beta_i^\gamma f_i^1 \right] \right], \quad (4)$$

where χ_g^γ is the fraction of the prompt neutrons from fission of isotope γ released in group g;

$$J_{gk} = \int \psi_{gk}(\Omega) \psi_{gk}^*(\Omega) d\Omega,$$

is the transport weighting integral;

$$I_f = \frac{1}{F} \sum_k v_k \sum_\gamma \left[\sum_g \phi_{gk} \frac{\delta(\nu\mu_f)_{gk}^\gamma}{K} \right] \cdot \left[\sum_g \phi_{gk}^* \left[(1 - \beta^\gamma) \chi_g^\gamma + \sum_i \beta_i^\gamma f_i^1 \right] \right], \quad (5)$$

where $\delta(\nu\mu_f)$ represents changes (perturbations) in the fission cross section;

$$I_s = \frac{1}{F} \sum_k v_k \sum_{gg'} \phi_{gk}^* \phi_{g'k} \delta \mu_{g'gk}, \quad (6)$$

where $\delta \mu_{g'gk}$ represents changes in the scattering matrix; and

$$I_T = \frac{1}{F} \sum_k v_k J_{gk} \delta \mu_{Tgk}, \quad (7)$$

where $\delta \mu_{Tgk}$ represents changes in the transport cross section.

In DAC2, the transport weighting integral,

J_{gk} , is calculated using the regular and adjoint discrete angular fluxes, ψ_{gkn} and ψ_{gkn}^* , respectively, put out by the special version of 2DF.

$$J_{gk} = \sum_n w_n \psi_{gkn} \psi_{gkn}^*, \quad (8)$$

where w_n is the S_n weight for direction n, and n' is the reflected direction.

In addition, there is an option to compute the reactivity associated with perturbing the buckling height from DY to DY' :

$$\rho = \sum_k v_k \sum_g \frac{J_{gk}}{F} \mu_{Tgk} \frac{\pi^2}{3} \cdot \left[\left(DY' \mu_{Tgk} + XT \right)^{-2} - \left(DY \mu_{Tgk} + XT \right)^{-2} \right], \quad (9)$$

where $XT = 1.4208$ provides for extrapolation distances.

III. DAC2 INPUT

The input to DAC2 consists of the entire 2DF input deck, perturbation data, and angular fluxes. The 2DF input is listed in the appendix. The only change necessary is to substitute the converged eigenvalue for the initial eigenvalue guess, EV, on card 3. The 2DF data is followed immediately by the perturbation data. The first card, in 6I6, E12.5 format, contains the perturbation control words ITP, NFI, NDG, NPM, NPE, NPR, DYP where ITP is the type of perturbation (0/1/2 = density/cross section/both), the next five integers specify the number of fissionable isotopes, delayed groups, perturbation mixture specifications, elements, and zones, respectively, and DYP is the perturbed buckling height, if a buckling perturbation calculation is desired. If not, it should be zero.

The remaining input, except for any cross sections, is entered using the special data formats described in the appendix following card 11. The first four arrays refer to fissionable isotope data

MFI(γ), $\gamma = 1$, NFI - fissionable isotope numbers

(($\chi(g, \gamma)$), $g = 1, IGM$), $\gamma = 1, NFI$) - fission fractions

(($f(g, i)$), $g = 1, IGM$, $i = 1, NDG$) - delayed fractions

(($\beta(i, \gamma)$), $i = 1, NDG$, $\gamma = 1, NFI$) - delayed neutron abundances.

If the number of perturbation elements, NPM, is zero, no additional input is required.

The next two arrays are perturbation region data.

((MPA(I,J), I = 1,IM), J = 1,JM) - perturbation zone numbers
(MPZ(K), K = 1,NPR) - perturbation material numbers.

Next, the mixture data is read.

(MP(K), K = 1,NPM) - mixture numbers
(MPC(K), K = 1,NPM) - mixture commands
(XDE(K), K = 1,NPM) - mixture densities - unperturbed
(XDEP(K), K = 1,NPM) - mixture densities - perturbed.

The perturbed mixture densities, XDEP, are not read in, of course, if ITP = 1. Cross-section sets for additional elements, not contained in the 2DF input, are entered at this point, if desired, in a

6E12.5 format. Finally, if ITP is 1 or 2, the perturbed cross-section sets, for NPE elements, are read in.

The regular and adjoint angular fluxes should be copied to the disk files TAPE1 and TAPE2, respectively, before execution. The ordering of these fluxes, as output by 2DF, is complicated. Therefore, if another code is used to generate the fluxes, the subroutine SORT should be checked, and revised if necessary, to ensure proper ordering.

APPENDIX

INPUT INSTRUCTIONS FOR 2DF*

The enclosed material describes the input for the FORTRAN two-dimensional code, 2DF. Although this code is based on the earlier Floco versions DDK and DDF, the input to those codes is different from the input to 2DF. Similarly, the FORTRAN code TWOTRAN (x,y)³ requires different input.

In the following pages, input data is listed and described in exactly the order in which it is entered in the code. In 2DF input, data are divided into three categories:

1. A title card (72A1),
2. Input control integers (3X,I9) and input control floating point numbers (E12.4) intermixed on cards 2 through 11, and

3. Problem dependent data on subsequent cards. In 2DF input, the same special formats for reading problem data and the same algorithms for mixing cross sections are used as in the 1DF code. In addition, the same algorithm is used to search for criticality in alpha, concentration and delta calculations as is used in 1DF. Cross-section formats are also the same in 1DF and 2DF.

*Obtained from a private communication by K. D. Lathrop.

<u>No. of Word on Card</u>	<u>Variable</u>	<u>Format</u>	<u>Comments</u>
<u>Card 1</u>			
All	ID	72A1	Problem Identification Card which may contain any alpha-numeric characters desired. A '1' in column one will restore the page before writing the information contained in the card.

<u>No. of Word on Card</u>	<u>Variable</u>	<u>Format</u>	<u>Comments</u>
<u>CONTROL DATA</u>			
<u>Card 2</u>			
1	A01	3X,I9	Dimension: 2 only
2	A02	3X,I9	Theory: 0 = Regular 1 = Adjoint: The flux guess and source must be input in reverse order in terms of groups. The output fluxes are printed in reverse order.
3	A03	3X,I9	Scattering: 0 = Isotropic 1 = Anisotropic, first order only.
4	A04	3X,I9	Quadrature: Order of the SN approximation. These values can be obtained from the code by setting the value negative and omitting the card input. The order must always be even. See problem data items M5, 7, and W0 below.
5	A05	3X,I9	Geometry: 0 = X Y 1 = R Z 2 = R θ , Input of θ is in revolutions instead of degrees or radians.
6	I2M	3X,I9	Number of Zones: Normally each area of different material composition is a different zone but a region of homogeneous composition may be divided into several zones to obtain detailed balance tables.
<u>Card 3</u>			
1	IM	3X,I9	Number of Radial Intervals. See problem data item R0 below.
2	JM	3X,I9	Number of Axial Intervals. See problem data item Z0 below.
3	I2VT	3X,I9	Eigenvalue Type: 0 = Q - Source Calculation 1 = K - K-Effective (Criticality) Calculation 2 = α - Alpha (Time Absorption) Calculation 3 = C - Concentration Calculation 4 = δ - Delta (Zone Thickness) Calculation
4	EV	E12.4	Initial Eigenvalue Guess: (Typical Values are 1.0 for C calculations and 0.0 for all the rest).
5	EVM	E12.4	Eigenvalue Modifier: (Typical values are: 0.0 for Q and K calculations; 0.01 for alpha calculations; ± 0.2 for C calculations; and ± 0.1 for delta calculations).
6	EPS	E12.4	Overall Convergence Criterion: (Typical Value is 10^{-4}).
<u>Card 4</u>			
1	B01	3X,I9	Left Boundary Condition: 0 = Vacuum 1 = Reflective 2 = Periodic 3 = White
2	B02	3X,I9	Right Boundary Condition: Same options as B01.
3	B03	3X,I9	Top Boundary Condition: Same options as B01.
4	B04	3X,I9	Bottom Boundary Condition: Same options as B01.
5	M07	3X,I9	Restart and Flux Input Options: For the first four options, the flux is input from cards as follows: 0-Input a value for each group, X_g , which will be used for that group, in each interval, i.e., $\phi_g(i,j) = X_g$.

<u>No. of Word on Card</u>	<u>Variable</u>	<u>Format</u>	<u>Comments</u>
			1-Input IGM blocks of values, each IM*JM long, $X_g(i,j)$, i.e., $\phi_g(i,j) = X_g(i,j)$.
			2-Input is a value for each group, X_g , followed by a block of values, one for each interval, $Y(i,j)$, i.e., $\phi_g(i,j) = X_g * Y(i,j)$.
			3-Input a value for each group, X_g ; a value for each radial interval, $Y(i)$; and a value for each axial interval, $Z(j)$, i.e., $\phi_g(i,j) = X_g * Y(i) * Z(j)$.
			For the next four options, the input is from tape, as follows:
			4-(Not currently used by code.)
			5-Enter problem restart dump on unit 7 for continuation of the problem. The only card inputs allowed are the eleven parameter cards from the problem with this indicator (M07) changed to 5.
			6-Enter problem restart dump on unit 7, but only the flux will be used from it. All other input must be from cards.
			7-Enter flux on tape (instead of cards) on unit 7. This flux must be IGM blocks, each IM by JM in length. All other input must be from cards.
6	FXT	3X,I9	Use Negative Source Check? 0 = No 1 = Yes. Test: The source is checked at each point and in each group. If source is negative, problem is terminated.
<u>Card 5</u>			
1	MT	3X,I9	Total Number of Materials, Including Mixtures.
2	MO1	3X,I9	Number of mixture specifications. (Zero must be the first specification for each material. In the case of anisotropic materials, the anisotropic part must be in a separate mixture, which also must begin with a zero.) See problem data items I0, I1, and I2 below.
3	MCR	3X,I9	Number of Cross Section Blocks Input from Cards.
4	MTP	3X,I9	Number of Cross Section Blocks Input from Library. (Not currently used by the code.)
5	IZ	3X,I9	Number of Radial Zone Modifiers (used for Delta Option Only). See problem data items R2 and R3 below.
6	JZ	3X,I9	Number of Axial Zone Modifiers (used for Delta Option Only). See problem data items Z2 and Z3 below.
<u>Card 6</u>			
1	S02	3X,I9	Parametric Eigenvalue Type: 0 = None 1 = K-effective for sub- or supercritical system. Enter desired value of k_{eff} in S03 below. 2 = Alpha calculation for $\exp(\alpha + \alpha_0)$ time dependence where α_0 is S03.
2	S03	E12.4	Parametric Eigenvalue.
3	IGM	3X,I9	Number of Energy Groups.
4	IHT	3X,I9	Position of Sigma Total in Cross-Section Table.
5	IHS	3X,I9	Position of Sigma Self Scatter in Cross-Section Table.
6	ITL	3X,I9	Cross-Section Table Length.

<u>No. of Word on Card</u>	<u>Variable</u>	<u>Format</u>	<u>Comments</u>
<u>Card 7</u>			
1	S01	E12.4	Normalization Factor. Normally 1.0 but not used if zero.
2	M05	3X,I9	Not Used - Leave Blank or Zero.
3	M06	3X,I9	Source Input Options: (For Source Problems (IEVT = 0) only). The Input is always from cards according to the following: 0 = Input is a value for each group, X_g , which will be used in each interval, i.e., $Q_g(i,j) = X_g$. 1 = Input is IGM blocks of values, each IM * JM long, $X_g(i,j)$, i.e., $Q_g(i,j) = X_g(i,j)$. 2 = Input is a value for each group, X_g , followed by a value for each interval, $Y(i,j)$, i.e., $Q_g(i,j) = X_g * Y(i,j)$. 3 = Input is a value for each group, X_g , a value for each radial interval, $Y(i)$, and a value for each axial inter- val, $Z(j)$, i.e., $Q_g(i,j) = X_g * Y(i) * Z(j)$.
4	S04	3X,I9	Not used - Leave Blank.
5	D05	3X,I9	Maximum Number of Outer Iterations. (Suggested value 50.) (If running time limitation is object, use ITIMOF below.)
6	G07	3X,I9	Maximum Number of Inner Iterations per Group. (Suggested value: 10 to 20.) If this limit is imposed, a message is printed in the flux summary.
<u>Card 8</u>			
1	G05	E12.4	Use Neutron Balance Test? 0 = No G05 = Limit for Test. TEST: If the neutron balance becomes larger than the limit G05, the problem is terminated.
2	G06	E12.4	Use Inner Pointwise Flux Test? 0 = No G06 = Limit for Test. TEST: For each point, the ratio of the present flux to the previous flux at that point must differ from 1 by less than G06, or the problem will return for more inner iterations, that is, $\left 1 - \frac{N}{NP} \right \leq G06$ N = Present Flux NP = Previous Flux.
3	LAL	E12.4	Lower Limit on Lambda. Used in search options. (Suggested value: 0.01.) See instructions for usage of LAL, LAH, POD, and EPSA on pages 105 and 106 in LA-3373.
4	LAH	E12.4	Upper Limit on Lambda. Used in search options. (Suggested value: 0.5.)
5	POD	E12.4	New Parameter Modifier. (Or Parameter Oscillation Damper.) (Suggested value: 1.0 except for IEVT = 2, then use 0.5.)
6	EPSA	E12.4	Convergence precision used in criticality searches (IEVT > 1). First value of k_{eff} is obtained to a precision EPS. Second and subsequent values in the search are obtained to a preci- sion EPSA. Suggested value for EPSA is 10*EPS.
<u>Card 9</u>			
1	NOACP	3X,I9	Are Activity Prints Desired? 0 = No N = Total number of Positions in Cross-Section Table for which Prints are desired. (See note at top of next page.)

<u>No. of Word on Card</u>	<u>Variable</u>	<u>Format</u>	<u>Comments</u>
2	NOACN	3X,I9	Nuclides for which Activity Prints are Desired? 0 = None M = Total number of Materials for which Prints are desired. Note: N different activities will be computed for each of M different materials. See problem data items I6 and I4 below.
3	INDZR	3X,I9	Print Zone Summary by Region? 0 = No 1 = Yes. The print here is by region and by group for all groups and totals. Included are: Q-Source, Fissions, In-Scatter, Self-Scatter, Horizontal Leakage Absorptions, Out-Scatter, Right Leakage, Vertical Leakage, Top Leakage, Net Leakage, Neutron Balance.
4	IPFLX	3X,I9	Punch Fluxes on Cards? 0 = Yes 1 = No. This is the standard flux restart format (MO7 = 1).
5	IPCUR	3X,I9	Punch Currents on Cards? 0 = No 1 = Yes.
6	IDMTPS	3X,I9	Prepare a Special Dump Tape at the end of the problem? 0 = Yes 1 = No. This can be used as a flux input (Tape 7) for other problems if the number of groups and of intervals are the same. (MO7 = 6.) See item MO7 above.

Card 10

1	INEG	3X,I9	Use Negative Flux Fix-up? 0 = No 1 = Yes. TEST: If flux becomes negative and source is positive, the code maintains neutron balance but obtains a positive flux by changing the difference scheme.
2	ITIMOF	3X,I9	Time Limit in Seconds. If this is greater than zero, a group restart dump will be taken after the last inner iteration before the time limit, which assumes that there is enough time for this. We recommend that it be set 5 to 10 min less than CP time requested on long-running problems.
3	IPNTF	3X,I9	Print Input Fluxes: 0 = No 1 = Yes. <u>Not operational currently.</u> Input fluxes are always printed.
4	IPNTQ	3X,I9	Print Input Q Source: 0 = No 1 = Yes. <u>Not operational currently.</u> Input Q Source is always printed.
5	IPNTX	3X,I9	Print Input Cross Sections: 0 = No 1 = Yes. <u>Not operational currently.</u> Input Cross Sections are always printed.
6	ICKCX	3X,I9	Check Cross-Section Input for Consistency? 0 = No 1 = Yes. TEST: The code checks the value given for sigma absorption against the value computed by the following relation: $\sigma_a = \sigma_t - \sigma_{gg} - \sum_{g=1}^G \sigma_{g'g} + \sigma_g$

If the difference is greater than EPS, the problem is terminated. No check is made if sigma total = 0 for the first group (i.e., for anisotropic materials).

Card 11

1	NOFILM	3X,I9	Plot Fluxes on Film? 0 = No 1 = Yes.
			If yes, a three dimensional plot of the fluxes by group is obtained on film.
2	DBSQC	E12.4	Extrapolation distance (normally 1.42089216).
3	DBSQH	E12.4	Total Buckling Height. When different from zero, the absorption and total cross sections are modified by adding to them the following function:

$$\left(\frac{\pi}{\sigma_t * DBSQH + DBSQC} \right)^2 * \frac{\sigma_t}{3.0}$$

SPECIAL DATA FORMATS

The 2DF Data Input, in general, follows the format developed for 1DF(DTF-IV). With the exception of the Cross Sections, all data are read in one of two special formats: S(E) [6(I1,I2,E9.4)], for reading floating point numbers; and S(I)[6(I1, I2,I9)], for reading integers. In these formats, the first integer (I1) indicates the option, as described below, and the second integer (I2) indicates the number of times it is to be applied.

I1

Option

2	Place I2 linear interpolants between the word in this data field and the one following. (Not allowed for integers.)
3	Terminate reading of data block. A 3 <u>must</u> follow last word of each data block.
4	Fill the remainder of the data block with the information in the data field.
5	Repeat information in the data field I2*10 times.
9	Skip to next card. Indicates the end of data to be read from this card.

I1 Option

0 (or blank)	No special action taken -- Code reads data field as is.
1	Repeat information in the data field I2 times.

PROBLEM DATA

Block Name	Format	Number of Entries	Comments
I3	S(I)	MTP	Identification numbers of cross-section blocks to be read from Tape. If all cross sections are from cards, this block is omitted.
CO	(6E12.4)	MCR	Cross-Section Blocks on Cards where MCR is the number of blocks. The first card in each block is the heading card that identifies the nuclide, and gives any other information desired, in alpha-numeric characters (72A1 format). This is followed by the tables for the energy groups, beginning with the highest and ending with the lowest. At the end of each table (using as many cards as needed), the table for the next group follows immediately on the same card, if space remains. The organization of the cross-section table is described under CARD 6 of the parameters. The number of cards in each cross-section block is (IGM*ITL+5)/6 (Integer Arithmetic). If none of the cross sections are from cards, this block would be omitted. The cross-section format is described on pages 53 and 54 of LA-3373.

PROBLEM DATA

<u>Block Name</u>	<u>Format</u>	<u>Number of Entries</u>	<u>Comments</u>												
NO	S(E)	VARIES	Flux The length of this block depends on the option chosen in Parameter M07 (Card 4) as follows: <table><tr><th><u>Option</u></th><th><u>Length</u></th></tr><tr><td>0</td><td>IGM</td></tr><tr><td>1</td><td>IGM blocks of IM * JM each</td></tr><tr><td>2</td><td>IGM + IM * JM</td></tr><tr><td>3</td><td>IGM + IM + JM</td></tr><tr><td>4 through 7</td><td>Flux is taken from tape.</td></tr></table>	<u>Option</u>	<u>Length</u>	0	IGM	1	IGM blocks of IM * JM each	2	IGM + IM * JM	3	IGM + IM + JM	4 through 7	Flux is taken from tape.
<u>Option</u>	<u>Length</u>														
0	IGM														
1	IGM blocks of IM * JM each														
2	IGM + IM * JM														
3	IGM + IM + JM														
4 through 7	Flux is taken from tape.														
QO	S(E)	VARIES	Distributed Source. This block is included for problems of IEVT = 0 only. The length of the block depends on the option chosen in Parameter M06 (Card 7), as follows: <table><tr><th><u>Option</u></th><th><u>Length</u></th></tr><tr><td>0</td><td>IGM</td></tr><tr><td>1</td><td>IGM blocks of IM * JM</td></tr><tr><td>2</td><td>IGM + IM * JM</td></tr><tr><td>3</td><td>IGM + IM + JM.</td></tr></table>	<u>Option</u>	<u>Length</u>	0	IGM	1	IGM blocks of IM * JM	2	IGM + IM * JM	3	IGM + IM + JM.		
<u>Option</u>	<u>Length</u>														
0	IGM														
1	IGM blocks of IM * JM														
2	IGM + IM * JM														
3	IGM + IM + JM.														
RO	S(E)	IM + 1	Lengths (cm) of Space Mesh Boundaries in the radial direction (Radii). The entries must be ordered by magnitude. They must begin with 0.0 except in x-y geometry. Evenly spaced intervals between any two points can be calculated by the code by using Option 2 described in the introduction.												
ZO	S(E)	JM + 1	Lengths (cm) of Space Mesh Boundaries in the axial direction. All directions for the RO block apply here also.												
MO	S(I)	IM * JM	Number of the zone to which each interval determined by the RO and ZO blocks belongs. For the first ZO interval, the zone numbers for all intervals in the radial dimension (IM values) must be given in order, from left to right; for the second axial interval, zone numbers for the entire length of the radial dimension are given; and so forth. (See sample diagram at end of the data listing.)												
M2	S(I)	IZM	Material Numbers or Mixtures that are contained in each zone. Each separate zone or region must be assigned a number for the material, or mixture of input materials, contained in it. Where two or more zones have exactly the same materials in the same proportions, they may be assigned the same material number. However, the numbers must be ordered according to zones in terms of the M0 block.												
K7	S(E)	IGM	Fission Spectrum. These are ordered by group, beginning with the highest energy group (g = 1).												
V7	S(E)	IGM	Velocities for each group. Same ordering as K7.												
M5	S(E)	MM	Quadrature Eta Directions. Conditional on A04<0. See note below for length and order of entries.												
M7	S(E)	MM	Quadrature Mu Directions. Conditional for A04<0. See note below for length and order of entries.												
WO	S(E)	MM	Quadrature Weights. Conditional on A04<0. For the blocks M5, M7, and WO, the length MM is determined by the following: $MM = (A04 * (A04 + 4))/2 .$ If A04 is negative, the three blocks will be furnished by the code and the cards must be omitted. Each M5 value is repeated for a negative-to-positive M7 block. In each set of M7 values, the first is for initialization and the corresponding weight (WO) is 0.0. The set of SN constants must fulfill the following conditions:												

PROBLEM DATA

Block Name	Format	Number of Entries	Comments																																																																				
$\sum_{m=1}^{MM} W O_m * M5_m = 0, \quad \sum_{m=1}^{MM} W O_m * M7_m = 0, \quad \sum_{m=1}^{MM} W O_m = 1$																																																																							
A sample set of constants are given below for A04 = 4. Here all WO are equal but this is not true for A04 > 4.																																																																							
			<table> <tr> <th>I</th><th>WO</th><th>M5</th><th>M7</th></tr> <tr><td>1</td><td>0.</td><td>-.33333330E+00</td><td>-.94280930E+00</td></tr> <tr><td>2</td><td>.83333320E-01</td><td>-.33333330E+00</td><td>-.88191700E+00</td></tr> <tr><td>3</td><td>.83333320E-01</td><td>-.33333330E+00</td><td>-.33333330E+00</td></tr> <tr><td>4</td><td>.83333320E-01</td><td>-.33333330E+00</td><td>.33333330E+00</td></tr> <tr><td>5</td><td>.83333320E-01</td><td>-.33333330E+00</td><td>.88191700E+00</td></tr> <tr><td>6</td><td>0.</td><td>-.88191700E+00</td><td>-.47140450E+00</td></tr> <tr><td>7</td><td>.83333320E-01</td><td>-.88191700E+00</td><td>-.33333330E+00</td></tr> <tr><td>8</td><td>.83333320E-01</td><td>-.88191700E+00</td><td>.33333330E+00</td></tr> <tr><td>9</td><td>0.</td><td>.33333330E+00</td><td>-.94280930E+00</td></tr> <tr><td>10</td><td>.83333320E-01</td><td>.33333330E+00</td><td>-.88191700E+00</td></tr> <tr><td>11</td><td>.83333320E-01</td><td>.33333330E+00</td><td>-.33333330E+00</td></tr> <tr><td>12</td><td>.83333320E-01</td><td>.33333330E+00</td><td>.33333330E+00</td></tr> <tr><td>13</td><td>.83333320E-01</td><td>.33333330E+00</td><td>.88191700E+00</td></tr> <tr><td>14</td><td>0.</td><td>.88191700E+00</td><td>-.47140450E+00</td></tr> <tr><td>15</td><td>.83333320E-01</td><td>.88191700E+00</td><td>-.33333330E+00</td></tr> <tr><td>16</td><td>.83333320E-01</td><td>.88191700E+00</td><td>.33333330E+00</td></tr> </table>	I	WO	M5	M7	1	0.	-.33333330E+00	-.94280930E+00	2	.83333320E-01	-.33333330E+00	-.88191700E+00	3	.83333320E-01	-.33333330E+00	-.33333330E+00	4	.83333320E-01	-.33333330E+00	.33333330E+00	5	.83333320E-01	-.33333330E+00	.88191700E+00	6	0.	-.88191700E+00	-.47140450E+00	7	.83333320E-01	-.88191700E+00	-.33333330E+00	8	.83333320E-01	-.88191700E+00	.33333330E+00	9	0.	.33333330E+00	-.94280930E+00	10	.83333320E-01	.33333330E+00	-.88191700E+00	11	.83333320E-01	.33333330E+00	-.33333330E+00	12	.83333320E-01	.33333330E+00	.33333330E+00	13	.83333320E-01	.33333330E+00	.88191700E+00	14	0.	.88191700E+00	-.47140450E+00	15	.83333320E-01	.88191700E+00	-.33333330E+00	16	.83333320E-01	.88191700E+00	.33333330E+00
I	WO	M5	M7																																																																				
1	0.	-.33333330E+00	-.94280930E+00																																																																				
2	.83333320E-01	-.33333330E+00	-.88191700E+00																																																																				
3	.83333320E-01	-.33333330E+00	-.33333330E+00																																																																				
4	.83333320E-01	-.33333330E+00	.33333330E+00																																																																				
5	.83333320E-01	-.33333330E+00	.88191700E+00																																																																				
6	0.	-.88191700E+00	-.47140450E+00																																																																				
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9	0.	.33333330E+00	-.94280930E+00																																																																				
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16	.83333320E-01	.88191700E+00	.33333330E+00																																																																				
I0	S(I)	MO1	Numbers labeling the cross-section mixture blocks.																																																																				
I1	S(I)	MO1	Numbers indicating which input materials are to be used to make each mixture.																																																																				
I2	S(E)	MO1	Atomic densities (times 10^{24} , since input cross sections are assumed to be in b). The first value must be 0.0, corresponding to the 0 in the I1 table, followed by the density for each input material in the order given in the I1 table. (In the case of concentration searches, a zero here and in the corresponding positions in I1, will cause the value of the mixture to be multiplied by the eigenvalue until the concentration gives a critical value - if this is possible.)																																																																				
R2	S(I)	IM	Radial Numbers. These are used only in Delta Calculations (IEVT = 4). They indicate which radial zone each interval is in. Within each of these zones, radii are increased or decreased by the same radial modifier.																																																																				
R3	S(E)	IZ	Radial Modifiers. These are the factors used with the Radial Numbers to achieve the increase or decrease in size. A new radius (RA) is calculated from the initial value (R) from $R A_{i+1} = R A_i + (R_{i+1} - R_i)(1 + EV * R3_k)$ in the kth radial zone.																																																																				
Z2	S(I)	JM	Axial Numbers. These are used in the same manner as the R2 block except in the axial direction.																																																																				
Z3	S(E)	JZ	Axial Modifiers. These are used in the same manner as the R3 block except in the axial direction.																																																																				
I6	S(I)	NOACP	Activity Positions from the Cross Section Tables ($\leq$ ITL).																																																																				
I4	S(I)	NOACN	Nuclides for which activities are desired ($\leq$ MT).																																																																				

DATA

The four blocks RO, ZO, MO, and M2 describe the geometric arrangement of the various regions, or zones, and the materials contained in them. Each separate region must be completely specified by zone (MO) and material (M2) numbers as well as by boundaries in the radial (RO) and axial (ZO) directions. Each boundary of each region in both directions must be identified in the RO or ZO block.

Note in Diagram I that the radial boundaries, 0.0, 2.0, and 3.0, and the axial boundaries, 0.0, 3.0, and 4.0 are needed to specify the nonrectangular portion of Zone 1. All portions of a zone need not be contiguous (note the separated portions of Zone 1), nor do zones need to be numbered in any particular order.

Assigning zone numbers in the pattern of Diagram I results in Diagram II (which would be printed by the code). The zone numbers must be given in a specific order and a zone number must be given for each interval in each direction.* Note that where boundaries are to be interpolated (between radial boundaries 5.0 and 6.0; axial boundaries 0.0 and 3.0, 5.0, and 7.0), zone numbers must be given for the intervals to be formed by the interpolated boundaries even though they are not specified initially.

*The zone number block must begin at the smallest radial and axial boundaries, giving all the radial intervals in order for the first axial interval, and then all, (from smallest radial boundary to largest) for the second axial interval, and so forth. In preparing input this would mean starting at *a* and going to *b*; then from *c* to *d*, and so forth).

Diagram I

e	3	3	3	1	1	1	2	f
.	3	3	3	4	4	4	2	.
.	3	3	3	4	4	4	2	.
.	3	3	3	1	1	1	2	.
.	1	3	3	1	1	1	2	.
c	1	1	3	1	1	1	2	d
a	1	1	3	1	1	1	2	b

Diagram II

The M2 block contains the identification number of the nuclide in each zone. If mixtures are made, the numbers assigned to the mixtures must be greater than the number of input cross section blocks. These input blocks are assigned identification numbers in the order in which they are read. For example, if three cross sections are read in, in the example of Diagram 1, the mixtures in the four zones can be assigned numbers 4, 5, 6, and 7 in any order desired. A diagram showing which material is in which interval is printed by the code.

In the case of anisotropic materials, a separate mixture is made for the anisotropic portion. Space must be left after the isotropic mixture for the anisotropic mixture. To indicate this, the identification number in the M2 Table is made negative. In the above example, if the material in Zone 1 had an anisotropic component, we would need 4, 5, 6, 7, and 8 to number the mixtures. If we assign 4 to Zone 1, 5 automatically becomes the anisotropic part and the table would be as shown below

Comparison of M2 Tables for:

Zone	All Isotropic Materials	One Anisotropic Material in Zone 1
1	4	-4
2	5	6
3	6	7
4	7	8

REFERENCES

1. B. M. Carmichael, "DAC1, a One-Dimensional S_n Perturbation Code," LA-4342, Los Alamos Scientific Laboratory (1970).
2. K. D. Lathrop, "DTF-IV, a FORTRAN-IV Program for Solving the Multigroup Transport Equation with Anisotropic Scattering," LA-3373, Los Alamos Scientific Laboratory (1965).
3. K. D. Lathrop and F. W. Brinkley, "Theory and Use of the General-Geometry TWOTRAN Program," LA-4432, Los Alamos Scientific Laboratory (1970).