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Radiation Shielding Information Center
NEUTRON PHYSICS DIVISION

APSAI: A COMPUTER CODE FOR PLOTTING FLUXES AND ABSORPTION DENSITIES GENERATED BY THE ANISN CODE

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COMPUTER CODE ABSTRACT

1. NAME AND TITLE OF CODE

APSAI: Activity Calculations and Plotting of Neutron or Gamma-Ray Spectra from ANISN Calculations Using INTRIGUE-II-C Package.

AUXILIARY ROUTINES

Plotting is carried out using the INTRIGUE-II-C package. CRT and pen-and-ink plotting versions are both possible.

A similar code (CCPLT) can plot neutron and gamma-ray fluxes from ANISN and DOT calculations. The main reason for developing APSAI is that CCPLT can plot only one curve on the same figure and can be used for only one ANISN or DOT case.

APSAI can handle up to 9 different ANISN runs and allow an easy visual comparison between different ones. It can further plot several curves from the same or different runs on the same figure.

2. CONTRIBUTORS

Karadeniz Technical University, Trabzon, Turkey, and the Oak Ridge National Laboratory.

3. CODING LANGUAGE AND COMPUTER

FORTRAN IV; IBM 360.

4. NATURE OF PROBLEM SOLVED

APSAI enables the user to plot fluxes obtained from one or more previous ANISN calculations. It is possible to plot on the same graph output from up to 9 different ANISN runs having the same energy groups, mesh spacing, and geometrical size. Further, the user can plot several geometry- or energy-dependent fluxes on the same figure, often an advantage.

Subroutine ACTIV allows plotting the absorption densities dependent on the x-coordinate. In addition, the damage flux and up to 5 activities at the outer boundary can be calculated.

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Plotting is executed using the INTRIGUE-II-C package which allows both CRT and pen-and-ink plotting.

5. METHOD OF SOLUTION

In order to minimize the core requirement, the fluxes for each ANISN case are read after the previous case is executed. If the fluxes are read from cards, flux cards must be repeated in the input if both energy-and geometry-dependent plots are desired. In order to avoid that, it is advisable to plot the geometry and energy-dependent cases in different runs when the fluxes are read from input cards.

6. RESTRICTIONS AND LIMITATIONS

On account of fixed dimensioning, the number of energy groups must be ≤ 100 and the number of mesh intervals ≤ 150.

The graph paper size is 10" x 14".

Maximum number of different ANISN cases is 9.

Maximum number of curves on each graph is 16.

Maximum number of calculated activites of the outer boundary is 5.

7. TYPICAL RUNNING TIME

For 100 energy groups, 150 mesh points, 6 geometry, 6 energy-dependent curves, and 5 activities from 2 ANISN cases on IBM 360/91, the CPU time was 18 seconds.

8. COMPUTER HARDWARE REQUIREMENTS

APSAI needs approximately 204K bytes of directly addressable core.

9. COMPUTER SOFTWARE REQUIREMENTS

The program is written entirely in FORTRAN IV.

10. REFERENCES:

S. Şahin, "APSAI, Activation Calculations and Plotting of Neutron or Gamma-Ray Spectra from ANISN Calculations Using INTRIGUE-II-C Package," ORNL-TM-4074 (January 1973).

M. B. Emmett, "INTRIGUE-II-C, An IBM 360 Subroutine Package for Making Linear, Logarithmic and Semilogarithmic Graphs Using Either the CALCOMP Pen-and-Ink or Cathode-Ray-Tube Plotter," ORNL-TM-3947 (October 1972).

M. B. Emmett, "INTRIGUE-II, An IBM-360 Subroutine Package for Making Linear, Logarithmic and Semilogarithmic Graphs Using the CALCOMP Plotter," ORNL-4664 (March 1971).

11. CONTENTS OF CODE PACKAGE

The package contains the following items:

a. the referenced document and

b. the source program as BCD card images.

12. HOW TO OBTAIN PACKAGE

Inquiries or requests for the code package may be mailed to

CODES COORDINATOR
Radiation Shielding Information Center
Oak Ridge National Laboratory
Post Office Box X
Oak Ridge, Tennessee 37830

or telephoned to

Area Code 615; 483-8611, extension 3-6944, or to

FTS xx-615-483-6944.

Persons requesting the package should send a reel of magnetic tape to the above address.

13. DATE OF ABSTRACT

January 1973.

ACKNOWLEDGEMENT

The author wishes to thank Karadeniz Technical University for permitting him to come to the Oak Ridge National Laboratory (ORNL) for research work; the Radiation Shielding Information Center for making him welcome here; the Turkish Scientific and Technical Research Council for its financial support of this research work through the post doctoral research fellowship; Mr. F. H. Clark for his encouragement in the development of this program; Mrs. M. B. Emmett for her assistance in the use of the INTRIGUE-II-C package; and Mrs. M. W. Landay for typing this work.

ABSTRACT

APSAI is a program to plot energy or geometry dependent neutron fluxes and absorption densities which were already produced through an ANISN [1] calculation. It permits the plotting of several curves from different cases, which must have the same energy group and mesh interval structure, on the same graph, in order to facilitate a comparison between them. Further, APSAI calculates the damage flux and activities at the outer boundary. APSAI uses the INTRIGUE-II-C [2] package for plotting. Pen-and-ink or cathode-ray-tube (CRT) are both possible.

1. Introduction

A computer code which solves the Boltzmann transport equation normally provides the calculated neutron or gamma-ray fluxes in numerical form. In many instances it is inconvenient to keep this large amount of numerical results. Further, the scientist frequently wishes to have his results in the form of a graph for a better survey and representation of the case. Particularly in a publication or report, it is advisable to give as much information as possible in a compact form; and at times it is necessary to make a comparison between different approximations for solving the problem. When neutron or gamma-ray fluxes are investigated and represented, it is desirable to describe them in graphical form.

ANISN is a multigroup transport code which solves the Boltzmann transport equation in the one-dimensional case [1]. It is used in many research centers throughout the world. It would be advantageous to develop a program which could plot the fluxes after an ANISN calculation. At ORNL there exists a routine (CCPLT) for the purpose of plotting the fluxes of an ANISN run. However, CCPLT can plot only one curve on a graph, and it cannot plot the fluxes from different ANISN runs on the same graph. APSAI was developed to allow the plotting of several curves from different ANISN runs on the same graph. It does not require the fluxes to be recorded on a binary tape (as does CCPLT).

ANISN permits punching the scalar fluxes in a formatted mode by setting ID1 = 2. Changing the punch unit (logical 7) to a magnetic tape allows the information which should be punched to be recorded and saved on this magnetic tape in the punch format.

APSAI reads the fluxes from a magnetic tape prepared as described above. Reading the fluxes from cards is also possible but is not recommended because of the large number of cards.

2. Description of the program

APSAI reads from as many as 9 magnetic tapes from different ANISN calculations those fluxes which the user desires to be plotted on the same graph. All the cases must have the same energy and spatial structure. The geometrical form (plane, cylinder, sphere) need not be the same.

In APSAI only the fluxes from one case are present in the core memory at one time. This enables us to handle several cases with a lower demand on core size.

APSAI allows, in the same run, drawing selected fluxes as functions of energy (on a logarithmic-logarithmic graph) or spatial dimension (x-coordinate, on a semilogarithmic graph) and absorption densities (on a semilogarithmic graph). Either or all of these representations may be obtained depending on the input.

On a geometry-dependent flux-graph, the neutron flux with the highest energy group number (lowest energy) will be indicated as thermal flux. The x-coordinates of the mesh points are calculated internally by giving the boundaries of equidistant regions.

Besides plotting the neutron spectra, APSAI calculates at the outer boundary the damage flux as follows:

The damage flux can be estimated roughly as

$$F_d = \int E \cdot n(E) \cdot dE \qquad (1)$$

for

$$\Phi = n \cdot v \qquad (2)$$

$$E\ [erg] = C \cdot E[eV] = \frac{1}{2} m[\,g\,] \cdot v^2 \left(\frac{cm^2}{s^2}\right) \qquad (3)$$

and

$$C = 1.60206\text{x}10^{-12} \text{ erg/eV} \qquad (4)$$

we can write

$$F_d = \sqrt{\frac{m}{2C}} \int \sqrt{E}\ \Phi(E)dE \qquad (5)$$

where
- E: Neutron energy
- n(E): Neutron density
- Φ: Neutron flux
- m: Mass of neutron
- v: Velocity of neutron

By putting the numerical values of constants in (5) we obtain:

$$F_d = 7.229597\text{x}10^{-7} \int \sqrt{E}\cdot\Phi(E)\cdot dE[\text{eV}/(\text{cm}^2\text{-source neutron})] \qquad (6)$$

or

$$F_d = 1.1582269\text{x}10^{-18} \int \sqrt{E}\cdot\Phi(E)dE[\text{erg}/(\text{cm}^2\text{-source neutron})]. \qquad (7)$$

Further, APSAI calculates at the outer boundary up to 5 activities as

$$A_i = \int \Sigma_i(E)\Phi(E)dE \qquad (8)$$

This enables the user to obtain some conclusions from the neutron spectra outside of the shielding material or outside the reactor.

We may indicate some practical applications of this option:

(a) By shielding or reactor calculations, it may be desired to calculate the detector response at the outer boundary. From the characteristic cross sections of the detector material (for example, (n,p) cross sections for a sulphur detector), APSAI calculates the detector response at the outer boundary.

(b) R. W. Roussin and F. A. R. Schmidt [4] calculated the neutron group dose equivalent rate transmission factors through concrete slabs. By reading these factors (input data set 5), APSAI calculates the neutron and/or gamma-ray dose equivalent rate beyond a concrete slab which follows the reactor or shield region where the fluxes are to be plotted.

For the plotting procedure, APSAI uses the INTRIGUE-II-C package [2]. Hence, it is advisable that the user have the manual for INTRIGUE-II-C and INTRIGUE-II [3]. The same variable names in INTRIGUE-II-C are used in APSAI in order to facilitate handling.

Although INTRIGUE-II-C allows a grid line in the graph, APSAI makes only tic marks of 1/4" on each side of the graph. If the user wishes to draw grid lines in the graph, he has to change the statement

```
     WIDTH = -14.                          MAIN 100
in the APSAI code to
     WIDTH = +14.*
and set in the input
     JTAPE = 0     (See [3].)
```

Titles for the bottom and left side of the graph are imbedded in the program. APSAI allows a title to be written on the top of the graph. It can be written either through an input card (format 18A4), or the title of the ANISN calculation whose fluxes are to be read from the tape with the highest unit number can be utilized (see input description).

In order to avoid too many cycles on the ordinate, the neutron flux has the dimension [neutrons/cm^2-unit lethargy-source neutron]. Since the flux output of ANISN has a different dimension, namely [neutrons/cm^2-source neutron], the fluxes are divided in APSAI by the lethargy difference of the energy boundaries of the corresponding energy group.

APSAI puts point marks on each curve. If it is necessary to draw several flux curves of an ANISN calculation on a graph, it is possible to mark each curve with a different kind of point, which should be selected through input.

The flux curves of the first case will be plotted with a solid line. The flux curves of the following cases will be plotted with a broken line. Each case will have a different number of segments per inch. The x-coordinates of the point marks of different cases will be shifted slightly to be distinguished easily. Further, the user can choose a different

*Also change - sign on MAIN 790 to +

angle of rotation for each symbol. The user must write a text relating to each point and each curve (see input). It appears in the graph as a subtitle. The distances of the first subtitles for points and for curves from the top grid line have to be read through input. The separation of the following subtitles is set to 0.25 inches through the program. There are program checks regarding coordinates of subtitles (see error checks).

Subroutine ACTIV plots absorption densities (semilogarithmic graph) as a function of the x-coordinate. The user has the possibility to plot other functions dependent on the x-coordinate. In this case, he should change the title on the left side of the graph ('ACT1 130' card) in the subroutine ACTIV.

Table 1 shows the input-output unit number for APSAI.

TABLE 1

INPUT-OUTPUT DEVICES

Logical Unit Number	Function
50	Card reader
51	Line printer
10	First magnetic tape drive
9+I	I^{th} magnetic tape drive

3. Restrictions of the program

Graph size is 10" x 14". In order to change these, change the following cards in the program

```
     A(7) = 10.                MAIN 90
and  D7   = 9.6                MAIN 170
     to
     A(7) = height
and  D7   = height - 0.4
further
     WIDTH = -14.              MAIN 100
     to
     WIDTH = -width
```

Minus implies that tic marks are drawn instead of full grid lines. (See [3]).

In changing the size, care should be taken with the subtitles. Because it is possible to draw many curves and to write many subtitles on a graph, a grid line should be avoided.

Because of fixed dimensioning, the maximum number of energy groups is limited to 100, the maximum number of mesh points to 150, and the maximum number of activities to 5. In order to change this, the following change must be made in the program:

The dimensioning of X (mesh points + 1), XM (mesh points + 1), E (energy groups), F (energy group, mesh points), U (energy groups), CR (Nr. of activities, energy groups), ACT (Nr. of activities) on the cards MAIN 20, 30, 40, and XM (mesh points + 1), A1 (mesh points) on the card ACTIV 20. Further, adjust the values of D1, D2, D3, D4, D5, D6, D7 (cards MAIN 110, 120, 130, 140, 150, 160, 170) regarding their effect for dimensioning of the subtitles (Fig. 1, 2, 3).

Further, change the card MAIN 430 to IF(L2.GE.Mesh points + 2) GØ TØ 97.

Maximum number of different cases is 9.

The maximum number of energy groups or mesh points on which the neutron flux should be plotted is not limited. However, APSAI allows not more than 16 curves to be plotted on a graph. If this number is exceeded, the program produces more than one graph, internally allocating the geometry or energy dependent fluxes to several graphs.

4. Error checks

There are three error checks in APSAI. They are

(1) The coordinates of the mesh points are calculated internally. If the number of mesh intervals exceeds 150, the program ends with a message.

(2) The distances for the first subtitle for point marks and curve type explanation have to be read through input. If the subtitles would overwrite each other, the program ends with a message.

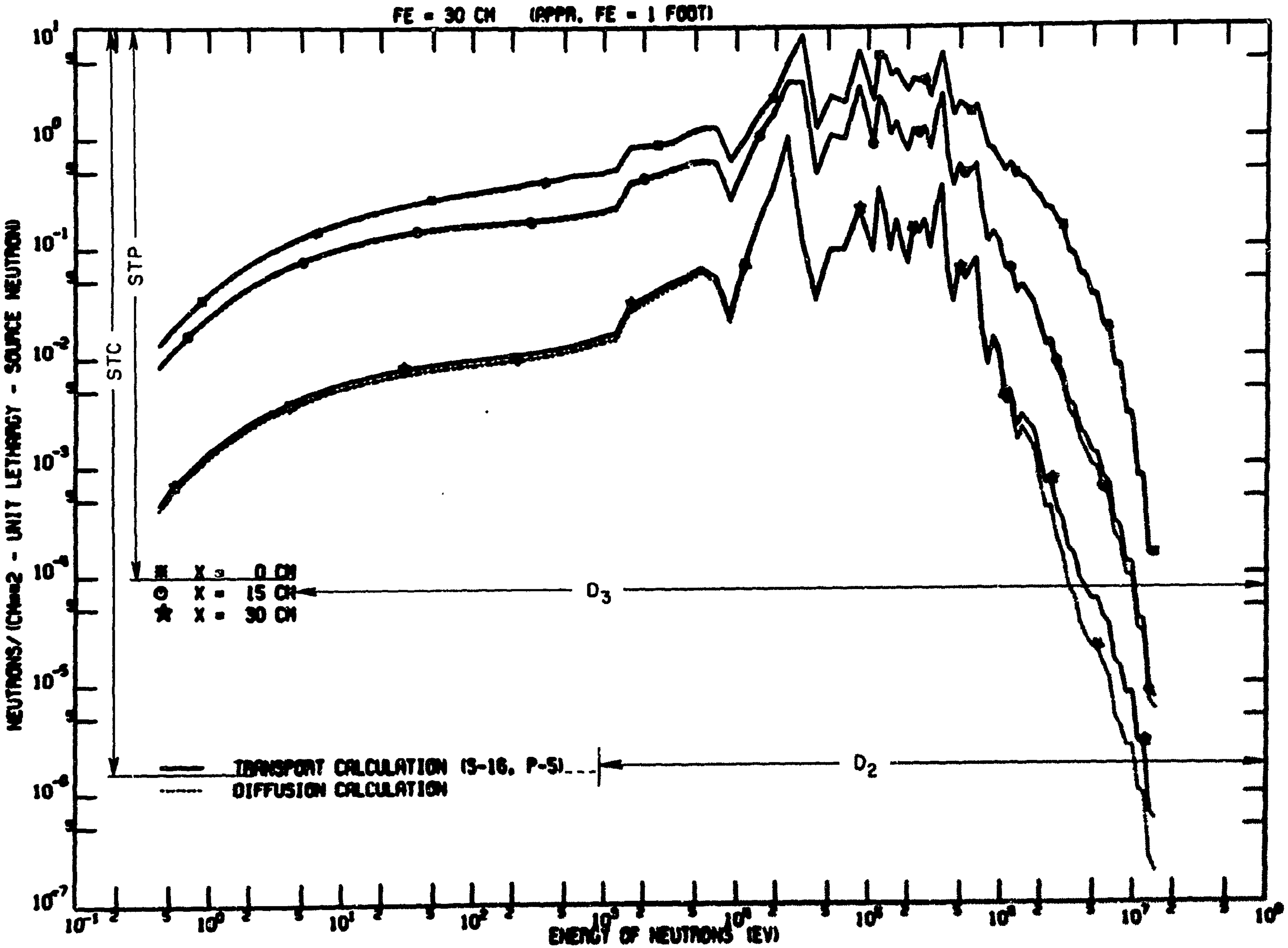


Fig. 1. Differential Neutron Flux (as a function of energy) on Certain Regions.

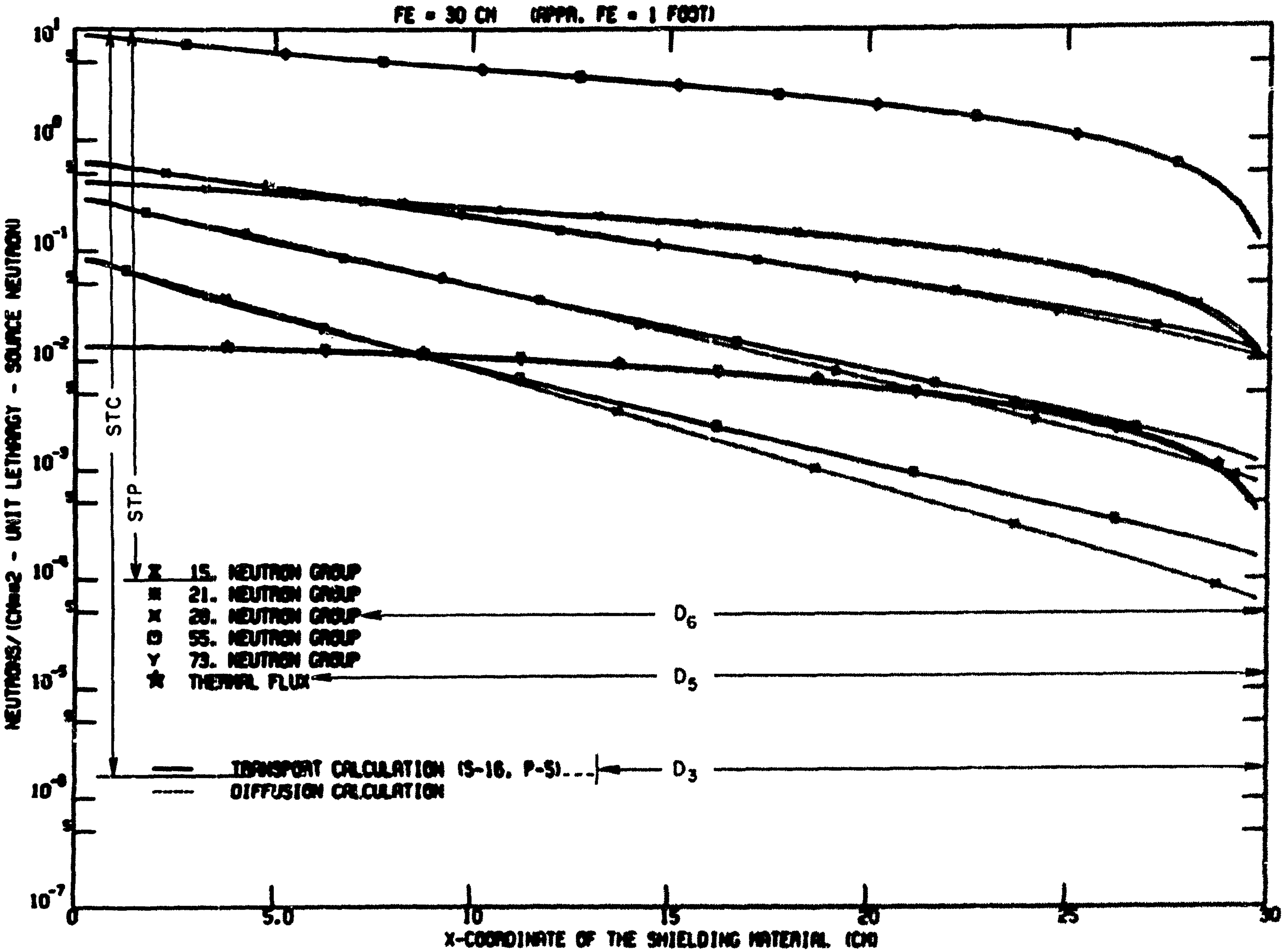


Fig. 2. Neutron Flux as a Function of Position on Certain Energy Groups.

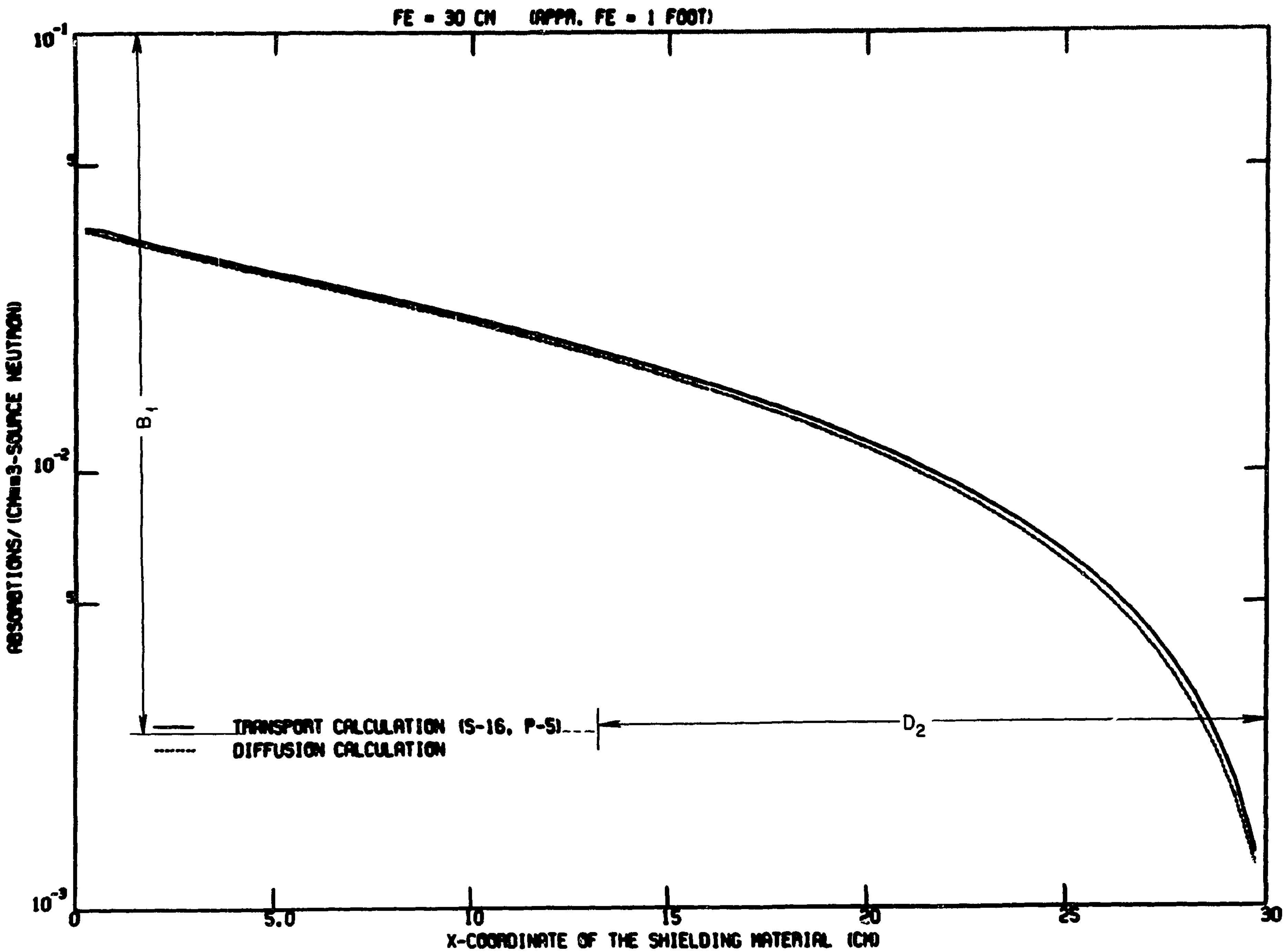


Fig. 3. Neutron Absorption as a Function of Position.

(3) If the subtitles approach the top or bottom line to within less than 0.4", the program ends with a message.

5. Flow charts

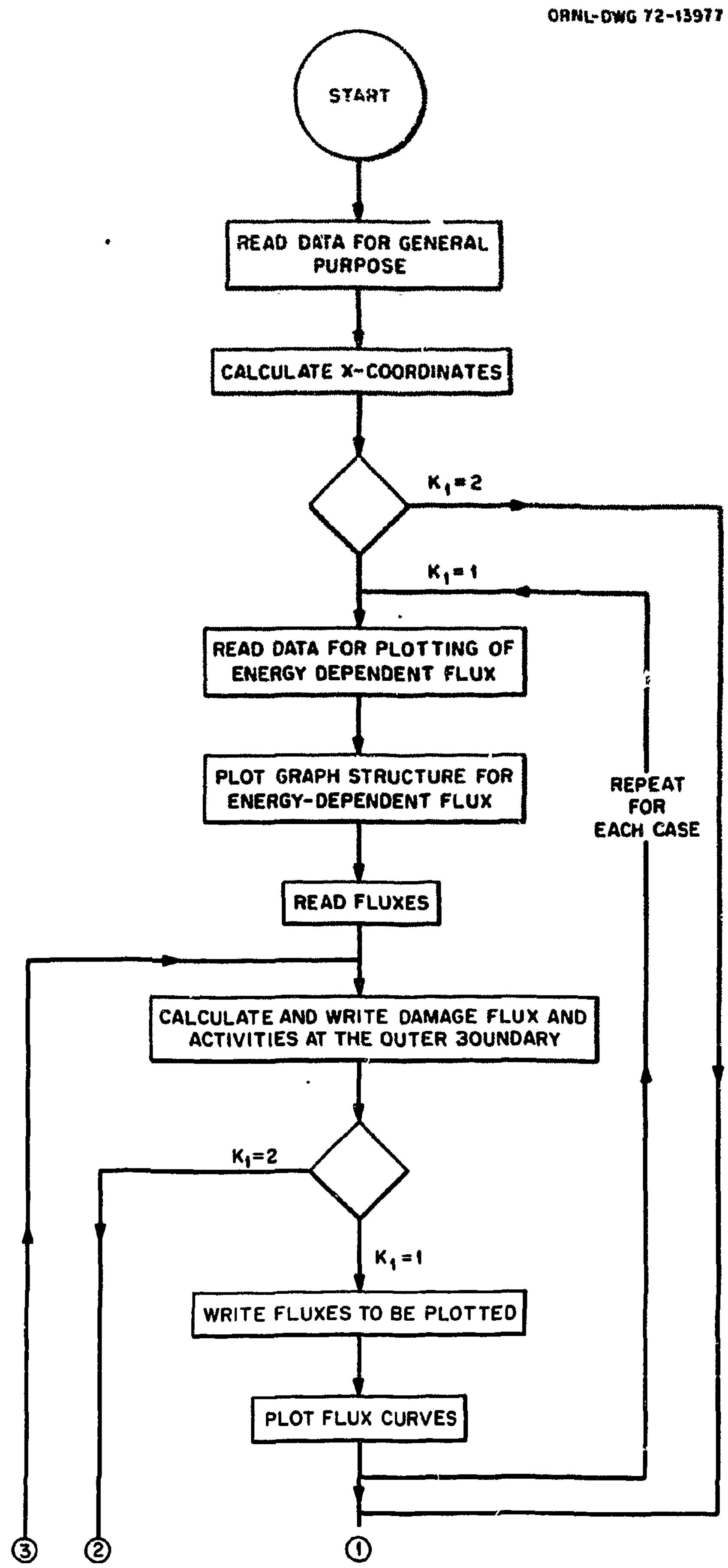
Flow charts of the main routine and subroutine ACTIV are shown on pages 12-14.

6. Input description

In the following input description, the variable names and formats are given as in the program.

Data Set	Max. No. of Cards	Format	Variable Name	Description
1	1	12I6	N	N ≤ 20 Number of interpolation boundaries for x-coordinates. (X=0. must be first boundary)
			NT	NT=1; title for the top of the graph will be taken from ANISN flux tape on the logical unit with the highest number NT=2; title length (NL) and the title (TITL) must be read from cards
			JTAPE	JTAPE=1; pen-and-ink plotting with tic marks on the graph JTAPE=-k; CRT-plotting k: Density of beam recommended value 14≤k≤40
			NCASE	Number of ANISN runs NCASE ≤ 9
			IGM	Number of energy groups IGM ≤ 100
			K1	K1=1 Plot flux as function of energy K1=2 Do not plot flux as function of energy
			K2	K2≤1 Plot flux as a function of x-coordinate K2≥2 Do not plot flux as a function of x-coordinate

Data Set	Max. No. of Cards	Format	Variable Name	Description
			IC	IC=0 Read fluxes from cards IC≥1 Read fluxes from tapes
			LACT	Number of activities to be computed at the outer boundary LACT ≤ 5
			LA	(LA=1) calls subroutine ACTIV for plotting of neutron absorption density
2	2	12I6	(K(I),I=1,N)	Number of interpolation points at the Ith group of the equidistant x-coordinates K1(N)=0
3	4	6(F12.5)	(XS(I),I=1,N)	Values of the boundaries of the x-coordinates normally XS(1)=0.
4	12	6(3X,F9.0)	(E(I),I=1,IGM)	Values of the energy groups in eV E_{max} = E(1)
5(1)	85	6(F12.5)	(CR(J,I),I=1,IGM)	Cross sections for the jth activation at the outer boundary in the Ith energy group
6	1	12I6	MEP	Number of plots of flux versus energy
			MRP	Number of plots of flux versus x-coordinate
7(2)	13	12I6	(NR(I),I=1,MEP)	Numbers of the spatial mesh intervals at which flux curves versus energy are to be plotted
8(2)	13	12I6	(NØX(I),I=1,MEP)	x-coordinates at which flux curves versus energy are to be plotted
9(2,3)	1	6(F12.5) for flux versus energy	STP	Distance in inches from top grid line to bottom of first legend which describes point symbols on the graph



Flow Chart of the Main Program.

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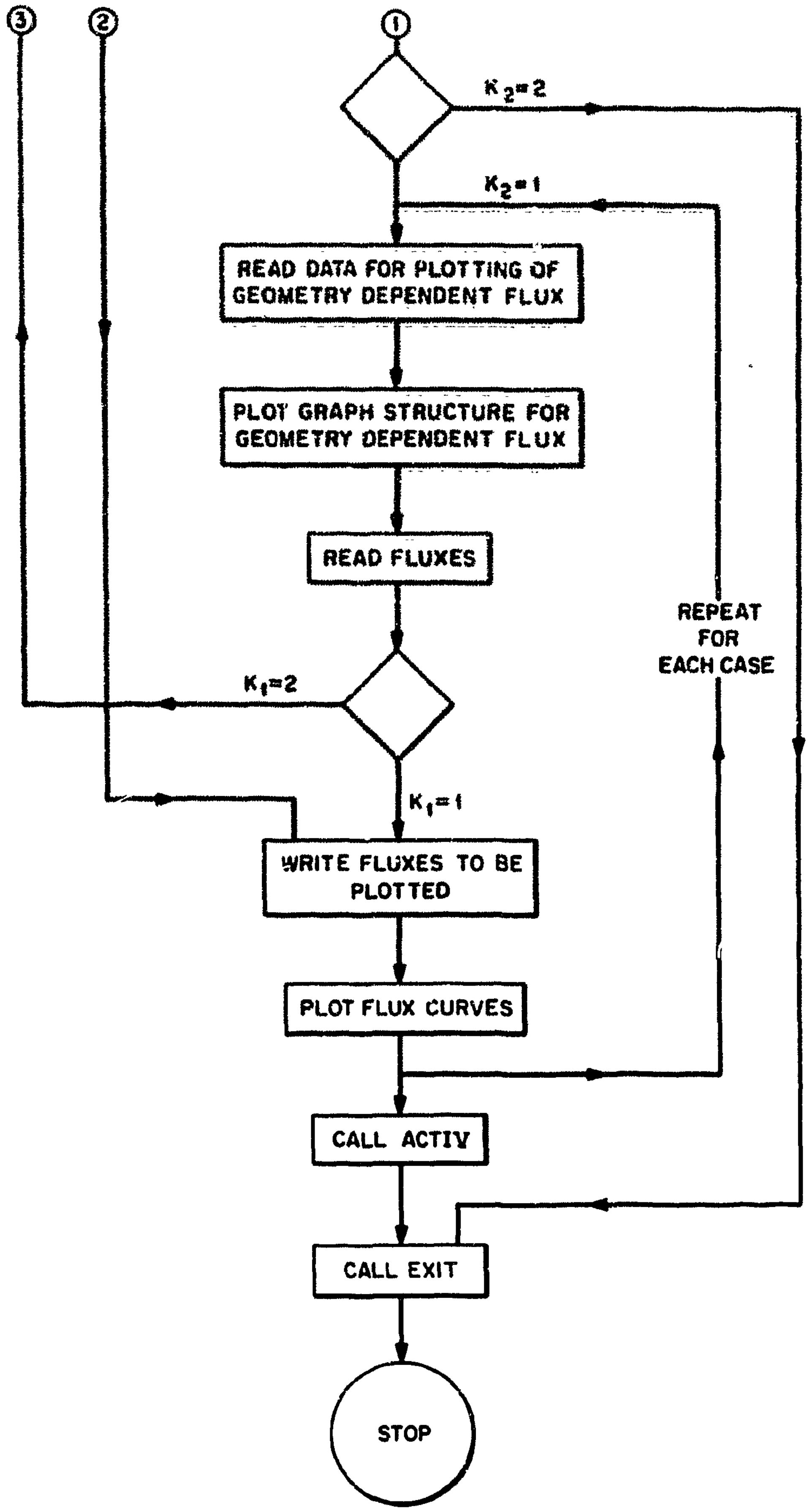
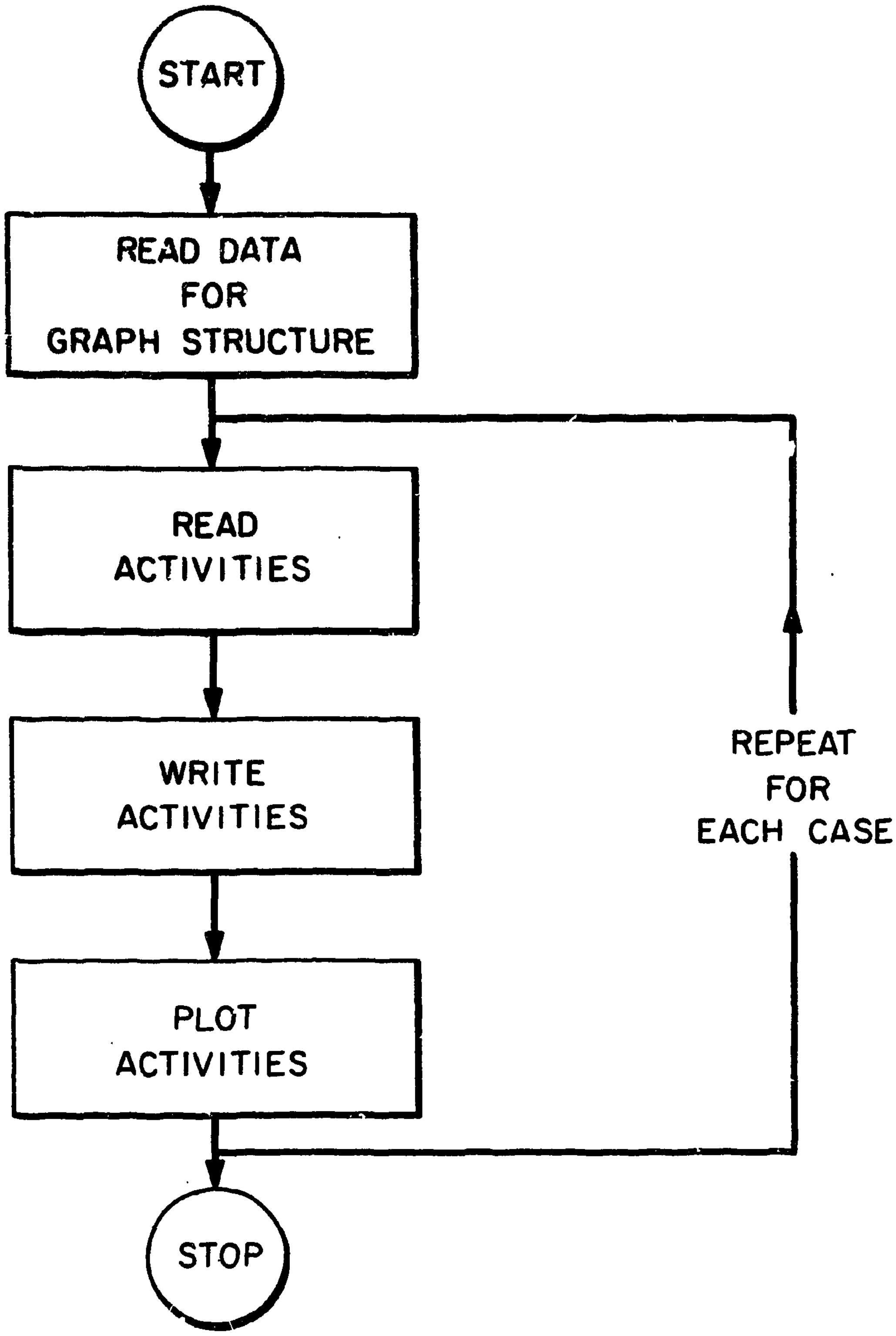


Flow Chart of the Main Program Continued.

ORNL-DWG 72-13975



Flow Chart
of the Subroutine ACTIV

Data Set	Max. No. of Cards	Format	Variable Name	Description
10(2)	2	12I6	(KINDE(I),I=1,ME)	Shape of points for spectrum curves (see INTRIGUE-II [3], page 4) If MEP*NCASE>16 then ME=16/NCASE else ME=MEP
11(2)	1	12I6	NCY	Number of cycles of dependent y-variable (neutron flux)
			ITØFY	Largest exponent of 10 on y-axis; the largest possible value of y is 10^{ITOPY}
			ITØPX	Largest exponent of 10 on energy axis
			NCX	Number of cycles of the independent variable (neutron energy [eV])
12(2)	3	6(F12.5)	(THE(J,I),I=1,ME)	Angles at which the marking points on energy dependent flux curves of the J^{th} case are to be rotated
13(4)*	1	18A4	TITLE	Title card of the ANISN flux output
14(4)*	1	18A4	DUMMY	3* card of the ANISN flux output
15(4)*	2500	6(3X,F9.0)	F(I,J)	Flux cards of the block in ANISN output
16(2)*	1	I5	NL1	Number of Hollerith characters (including blanks) to be read for legend describing curve tracing convention (Recommended value NL1=36)
17(2)*	1	9A4	STIT(I)	Text for the legend of item 16 of the I^{th} case

*Items 12, 13, 14, 15, 16, 17 should be repeated NCASE times successively. Fluxes from cards on this place should be read if only K2≤2 and ME=MEP.

Data Set	Max. No. of Cards	Format	Variable Name	Description
18(5)	1	I5	NL	Number of Hollerith characters to be read for the title on the top grid line NL≤72
19(5)	1	18A4	TITL	Text for the title on the top grid line
20(6)	9	12I6	(NE(I),I=1,MRP)	Numbers of the energy groups at which flux versus x-coordinate should be plotted
21(3,6)	1	6(F12.5)	STP	Distance in inches from top grid line to bottom of first legend which describes point symbols on the graph for flux versus x-coordinate
			STC	Distance in inches from top grid line to bottom of first legend which describes curve tracing convention on the graph for flux versus x-coordinate
22(6)	2	12I6	(KINDR(I),I=1,MR)	Shape of points for geometry dependent flux curves (see INTRIGUE-II [3], p.4) If MRP*NCASE>16 then MR=16/NCASE else MR=MRP
23(6)	1	12I6	NØINT	Number of intervals along x-axis which are terminated by tic marks
24(6)	1	6F(12.5)	DELX	Space between tic marks on x-axis or space between grid lines in units of x-variable
25(7)	1	12I6	NCY	See data set 11
			ITØPY	See data set 11

Data Set	Max. No. of Cards	Format	Variable Name	Description
26(6)*	3	6F(12.5)	(THX(J,I),I=1,MR)	Angles at which the marking points on flux curves versus x-coordinate of the J^{th} case are to be rotated
27(7)*	1	I5	NL1	Number of Hollerith characters including blanks to be read for legend describing curve tracing convention (recommended value NL1=36)
28(7)*	1	9A4	STIT(I)	Text for the legend of item 27 of the I^{th} case
29(8)*	1	18A4	TITLE	Title card of the ANISN flux output
30(8)*	1	18A4	DUMMY	3* card on the ANISN flux output
31(8)*	2500	6(3X,F.9.0)	F(I,J)	Flux cards of the block in ANISN output
32(9)	1	I5	NL	Number of Hollerith characters to be read for the title on the top grid line NL≤72
33(9)	1	18A4	TITL	Text for the title on the top grid line
34(10)	1	12I6	NCY	Number of cycles of dependent y-variable (absorptions/(cm^3-source neutron)] on the graph where absorptions versus x-coordinate are to be plotted
			ITØPY	Largest exponent of 10 on y-axis
35(10,11)	1	F12.5	B1	Distance in inches from top grid line to bottom of first legend which describes curve tracing convention on the graph for absorptions versus x-coordinate
36(10)	225	6(F12.5)	(A1(I);I=1,IM)	Absorption densities IM=Number of mesh intervals along x-axis

*Items 26, 27, 28, 29, 30, 31 should be repeated NCASE times successively. Fluxes from cards on this place should be read only for the case that K1=2 and MR=MRP.

FOOTNOTES:

(1) Read this card only if LACT≥1.
The activation cross sections for all energy groups (I=1,IGM) and for a single activity are recorded as indicated. To record cross sections for the next activity (CR(J+1,I),I=1,IGM), one must begin a new card.

(2) Use this card only if K1=1.

(3) The quantities STP and STC are shown in Fig. 1 and Fig. 2, and they are measured in inches.

(4) Use this card only if K1=1 and IC=0. (Don't put IC=0 if K1=1 and K2≤1).

(5) Use this card only if K1=1 and NT=2.

(6) Use this card only if K2≤1.

(7) Use this card only if K1=2 and K2≤1.

(8) Use this card only if K2≤1 and IC=0. (Don't put IC=0 if K1=1 and K2≤1).

(9) Use this card only if K2≤1, K1=2 and NT=2.

(10) Use this card only if K2≤1 and LA=1.

(11) The quantity B1 is shown in Fig. 3 and measured in inches.

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C     SUMER SAHIN,  APSAI, ACTIVITY CALCULATIONS AND PLOTTING OF NEUTRON
C     OR GAMMA-RAY SPECTRA FROM ANISN CALCULATIONS USING INTRIGUE-II-C
C     PACKAGE, OAK RIDGE NATIONAL LABORATORY, RADIATION SHIELDING
C     INFORMATION CENTER, JANUARY 1973
      DIMENSION A(8),K(20),KINDE(16),KINDR(16),NE(16),NR(16),NOX(16),
     1E(100),THE(9,16),THX(9,16),XS(20),X(151),XM(151),B(16),Y(16),
     2TITLE(18),F(100,150),IDD(9),STIT(9,9),U(100),TITL(18),CR(5,100),
     3ACT(5)
      COMMON N,JTAPE,NCASE,IM,NOINT,NL1,NL
      COMMON IDD
      COMMON WIDTH,XZERO,DELX,XP,XP2,D2
      COMMON A,XM,TITL,STIT
      A(7) = 10.
      WIDTH = -14.
      D1 = 1.
      D2 = 7.8
      D3 = 11.4
      D4 = 0.06667
      D5 = 11.2
      D6 = 10.6
      D7 = 9.6
      READ (50,100) N,NT,JTAPE,NCASE,IGM,K1,K2,IC,LACT,LA
C     K(I) = NUMBER OF INTERPOLATION POINTS
      READ (50,100) (K(I),I=1,N)
C     XS(I) = VALUES OF X-BOUNDARIES
      READ (50,101) (XS(I),I=1,N)
C     E(I) = VALUES OF ENERGY GROUP BOUNDARIES
      READ (50,104) (E(I),I=1,IGM)
C     U(I) = VALUES OF LETHARGY DIFFERENCES PER ENERGY GROUP
      IG = IGM - 1
      DO 77 I = 1,IG
      RF = E(I)/E(I+1)
      U(I) = ALOG(RF)
   77 CONTINUE
      U(IGM) = U(IG)
      IF (LACT - 1) 79,78,78
   78 CONTINUE
C     READ CROSS SECTIONS FOR ACTIVATIONS
      DO 18 J = 1,LACT
   18 READ (50,101) (CR(J,I),I = 1,IGM)
   79 CONTINUE
C * * CALCULATION OF RADIUS MIDPOINTS
      X(1) = XS(1)
      DO 4 I=2,N
      C = K(I-1) + 1
      DX = (XS(I) - XS(I-1))/C
      IF (I-2) 1,1,2
    1 L1 = 2
      L2 = K(1) + 2
      GO TO 3
    2 L1 = L2 + 1
      L2 = L2 + K(I-1) + 1
      IF (L2.GE.152) GO TO 97
    3 DO 4 J=L1,L2
    4 X(J) = X(J-1) + DX
      IM = L2 - 1
      WRITE (51,102)
      DO 5 I=1,IM
      XM(I) = 0.5*(X(I) + X(I+1))
    5 WRITE (51,103) I,XM(I)
C     MEP = NUMBER OF PLOTS FOR NEUTRON FLUX DEPENDENT ON ENERGY
C     MRP = NUMBER OF PLOTS FOR NEUTRON FLUX DEPENDENT ON X-COORDINATE
      READ (50,100) MEP,MRP
      GO TO (80,81),K1
C * * DRAW THE GRAPH FOR NEUTRON SPECTRUM DEPENDENT ON NEUTRON ENERGY
```

```
   80 CONTINUE
      L1 = 1
      ME = MEP
C     NR(I) = IDENTIFICATION NUMBERS OF MIDPOINT POSITIONS FOR PLOTTING
      READ (50,100) (NR(I),I=1,ME)
C     NOX(I) = DISTANCES AT WHICH SPECTRUM IS TO BE PLOTTED
      READ (50,100) (NOX(I),I=1,ME)
  201 IF (ME*NCASE.LE.16) GO TO 200
      ME = 16/NCASE
  200 L2 = L1 + ME - 1
      IF (L1.GT.1) GO TO 205
      READ (50,101) STP,STC
      EP =STP + 0.25*(ME+1)
      EC = STC + 0.25*(NCASE+1)
      IF ((STP.GE.STC.AND.STP.LE.EC).OR.(EP.GE.STC.AND.STP.LE.EC))
     1GO TO 96
      IF (STP.LE.0.4.OR.EP.GE.D7) GO TO 95
      IF (STC.LE.0.4.OR.EC.GE.D7) GO TO 95
C     KINDE(I) = TYPE OF POINTS FOR SPECTRUM PLOTTING
      IF (L1.EQ.1) READ (50,100) (KINDE(I),I=1,ME)
  205 CONTINUE
C     READ DATA FOR GRAPH-STRUCTURE OF SPECTRUM PLOTTING
      READ (50,100) NCY,ITOPY,ITOPX,NCX
      CALL LOGLOG (NCY,ITOPY,ITOPX,NCX,WIDTH,JTAPE,A)
      CALL LETTER (1,23,23HENERGY OF NEUTRONS (EV),A)
      CALL LETTER (2,49,49HNEUTRONS/(CM**2 - UNIT LETHARGY - SOURCE NEUT
     1RON),A)
      CY = NCY
      CX = NCX
      ALFA = CY/A(7)
      BETA = -CX/WIDTH
      G = ITOPY - NCY
      GX = ITOPX - NCX
      EXX1 = GX + BETA*D1
      EXX2 = GX + 1.5*BETA*D1
      XX1 = 10.**EXX1
      XX2 = 10.**EXX2
      DO 7 I=1,ME
      AI = I
      B(I) = STP + 0.25*(AI-1.)
      EX = G + ALFA*(A(7)+0.07-B(I))
      Y(I) = 10.**EX
    7 CALL POINT (1,XX1,Y(I),KINDE(I),0.12,0.,1,A)
      DO 40 ICASE=1,NCASE
      WRITE (51,116)
C     THE(ICASE,I) = ANGLES AT WHICH THE POINTS ON ENERGY DEPENDENT FLUX
C     CURVES OF THE ICASE'TH CALCULATION ARE TO BE ROTATED
      IF (L1.EQ.1) READ (50,101) (THE(ICASE,I),I=1,ME)
      IF (IC-1) 34,36,36
   34 READ (50,105) (TITLE(I),I=1,18)
      READ (50,105) DUMMY
      DO 35 I=1,IGM
   35 READ (50,104) (F(I,J),J=1,IM)
      GO TO 37
   36 NUNIT = 9+ICASE
      REWIND NUNIT
C     READ FLUXES FOR THE I'TH CASE FROM UNIT NUMBER ''9+ICASE''
      READ (NUNIT,105) (TITLE(I),I=1,18)
      READ (NUNIT,105) DUMMY
      DO 41 I=1,IGM
      READ (NUNIT,104) (F(I,J),J=1,IM)
   41 CONTINUE
   37 IDD(ICASE) = 1 + (ICASE-1)*(19-NCASE*ICASE)
      WRITE (51,105) TITLE
      WRITE (51,116)
      AI = ICASE
```

```
      I = ICASE + ME
      B(I) = STC + 0.25*(AI-1.)
      EX = G + ALFA*(A(7)+0.07-B(I))
      Y(I) = 10.**EX
      CALL CURVE (1,XX1,Y(I),IDD(ICASE),A)
      CALL CURVE (2,XX2,Y(I),IDD(ICASE),A)
      CALL HOLLER (NL1,STIT(9,ICASE),50)
      CALL SUBTLE (NL1,STIT(9,ICASE),B(I),D2,A)
   58 CONTINUE
      IF (LACT.LE.0) GO TO 199
      DF = 0.
      DO 19 IAC = 1,LACT
      ACT(IAC) = 0.
      DO 19 J = 1,IGM
      ACT(IAC) = ACT(IAC) + CR(IAC,J)*F(J,IM)
      IF (IAC.EQ.1) DF = DF+ F(J,IM)*SQRT(E(J))
   19 CONTINUE
      DF1 = .72295976*DF/10**6
      DF2 = 1.1582249*DF
      WRITE (51,114) DF1,DF2,(IAC,ACT(IAC),IAC=1,LACT)
      IF (K1.EQ.2) GO TO 59
  199 CONTINUE
      IL = 0
      DO 8 I=L1,L2
      IL = IL + 1
      WRITE (51,116)
      WRITE (51,106) NR(I),XM(NR(I)),ICASE
      WRITE (51,107)
      IF (ICASE-1) 42,42,43
   42 CALL SUBTLE ( 10,10HX =       CM,B(IL),D3,A)
      CALL SUBVAL (4,10,NOX(IL),4H(I3),B(IL),D3,A)
   43 DO 8 J=1,IGM
      F(J,NR(I)) = F(J,NR(I))/U(J)
      WRITE (51,108) J,E(J),F(J,NR(I))
      CALL CURVE (J,E(J),F(J,NR(I)),IDD(ICASE),A)
    8 CONTINUE
      IL = 0
      IG1 = IGM/6
      DO 11 I=L1,L2
      IL = IL + 1
      DO 11 J=I,IGM,IG1
      JD = J + IG1*(ICASE-1)/NCASE
      CALL POINT (1,E(JD),F(JD,NR(I)),KINDE(IL),0.08,THE(ICASE,IL),1,A)
   11 CONTINUE
   40 CONTINUE
      GO TO (60,61),NT
   60 CALL LETTER (0,72,TITLE,A)
      GO TO 62
   61 CALL HOLLER (NL,TITL,50)
      CALL LETTER (0,NL,TITL,A)
   62 CONTINUE
      CALL ADVANC(A)
      L1 = L1 + ME
      ME = MEP - ME
      IF (ME.GT.0) GO TO 201
   81 CONTINUE
      IF (K2.GE.2) GO TO 99
C * * DRAW THE GRAPH FOR NEUTRON FLUX DEPENDENT ON X-COORDINATE
      L1 = 1
      MR = MRP
C     NE(I) = IDENTIFICATION NUMBERS OF ENERGY GROUPS FOR PLOTTING
      READ (50,100) (NE(I),I=1,MR)
  211 IF (MR*NCASE.LE.16) GO TO 210
      MR = 16/NCASE
  210 L2 = L1 + MR - 1
      IF (L1.GT.1) GO TO 215
```

```
      READ (50,101) STP,STC
      EP =STP + 0.25*(MR+1)
      EC = STC + 0.25*(NCASE+1)
      IF ((STP.GE.STC.AND.STP.LE.EC).OR.(EP.GE.STC.AND.STP.LE.EC))
     1GO TO 96
      IF (STP.LE.0.4.OR.EP.GE.D7) GO TO 95
      IF (STC.LE.0.4.OR.EC.GE.D7) GO TO 95
C     KINDR(I) = TYPE OF POINTS FOR GEOMETRY DEPENDENT FLUX PLOTTING
      READ (50,100) (KINDR(I),I=1,MR)
  215 CONTINUE
      READ (50,100) NOINT
      READ (50,101) DELX
      XZERO = XS(1)
      IF (K1.EQ.2) READ (50,100) NCY,ITOPY
      CALL SEMLOG (NCY,ITOPY,XZERO,DELX,NOINT,WIDTH,JTAPE,A)
      CALL LETTER (1,43,43HX-COORDINATE OF THE SHIELDING MATERIAL (CM),A
     1)
      CALL LETTER (2,49,49HNEUTRONS/(CM**2 - UNIT LETHARGY - SOURCE NEUT
     1RON),A)
      V = NOINT
      XP = D4*V*DELX
      XP2 = 1.5*XP
      CY = NCY
      ALFA = CY/A(7)
      G = ITOPY - NCY
      DO 13 I=1,MR
      AI = I
      B(I) = STP + 0.25*(AI-1.)
      EX = G + ALFA*(A(7)+0.07-B(I))
      Y(I) = 10.**EX
   13 CALL POINT (1,XP,Y(I),KINDR(I),0.12,0.0,1,A)
      M1 = MR - 1
      DO 51 I = 1,M1
      CALL SUBTLE (19,19H    . NEUTRON GROUP,B(I),D6,A)
   51 CALL SUBVAL (1,19,NE(I),4H(I3),B(I),D6,A)
      CALL SUBTLE (12,12HTHERMAL FLUX,B(MR),D5,A)
      DO 14 ICASE=1,NCASE
C     THX(ICASE,I) = ANGLES AT WHICH THE POINTS ON GEOMETRY DEPENDENT
C     FLUX CURVES OF THE ICASE'TH CALCULATION ARE TO BE ROTATED
      IF (L1.EQ.1) READ (50,101) (THX(ICASE,I),I=1,MR)
      IDD(ICASE) = 1 + (ICASE-1)*(19-NCASE*ICASE)
      AI = ICASE
      I = ICASE + MR
      B(I) = STC + 0.25*(AI-1.)
      EX = G + ALFA*(A(7)+0.07-B(I))
      Y(I) = 10.**EX
      CALL CURVE (1,XP,Y(I),IDD(ICASE),A)
      CALL CURVE (2,XP2,Y(I),IDD(ICASE),A)
      IF (K1.EQ.2) CALL HOLLER (NL1,STIT(9,ICASE),50)
      CALL SUBTLE (NL1,STIT(9,ICASE),B(I),D2,A)
      IF (IC-1) 25,27,27
   25 READ (50,105) (TITLE(I),I=1,18)
      READ (50,105) DUMMY
      DO 26 I=1,IGM
   26 READ (50,104) (F(I,J),J=1,IM)
      GO TO 28
   27 NUNIT = 9+ICASE
      REWIND NUNIT
      READ (NUNIT,105) TITLE
      READ (NUNIT,105) DUMMY
      DO 71 I=1,IGM
      READ (NUNIT,104) (F(I,J),J=1,IM)
   71 CONTINUE
   28 CONTINUE
      WRITE (51,116)
      WRITE (51,105) TITLE
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```
      IF (LACT.LE.0) GO TO 59
      IF (K1.EQ.2) GO TO 58
   59 CONTINUE
      DO 16 I=L1,L2
      WRITE (51,116)
      WRITE (51,111) NE(I),ICASE
      WRITE (51,112)
      DO 16 J=1,IM
      F(NE(I),J) = F(NE(I),J)/U(NE(I))
      WRITE (51,108) J,XM(J),F(NE(I),J)
      CALL CURVE (J,XM(J),F(NE(I),J),IDD(ICASE),A)
   16 CONTINUE
      IL = 0
      IM1 = IM/6
      DO 14 I=L1,L2
      IL = IL + 1
      I2 = IL + 2
      DO 14 J=I2,IM,IM1
      JD = J + IM1*(ICASE-1)/NCASE
      CALL POINT (1,XM(JD),F(NE(I),JD),KINDR(IL),0.08,THX(ICASE,IL),1,A)
   14 CONTINUE
      GO TO (73,74),NT
   73 CALL LETTER (0,72,TITLE,A)
      GO TO 75
   74 IF (K1.EQ.2) CALL HOLLER (NL,TITL,50)
      CALL LETTER (0,NL,TITL,A)
   75 CONTINUE
      CALL ADVANC(A)
      L1 = L1 + MR
      MR = MRP - MR
      IF (MR.GT.0) GO TO 211
      IF (LA.EQ.1) CALL ACTIV
      GO TO 99
   95 WRITE (51,123)
      GO TO 99
   96 WRITE (51,122)
      GO TO 99
   97 WRITE (51,121)
   99 CONTINUE
      CALL EXIT
  100 FORMAT (12I6)
  101 FORMAT (6(F12.5))
  102 FORMAT (T10,'NUMBER OF X-COORDINATE',T40,'MIDPOINT POSITION (CM)'/
     1)
  103 FORMAT (T10,I8,T40,F12.4)
  104 FORMAT (6(3X,F9.0))
  105 FORMAT (18A4)
  106 FORMAT (T10,'POSITION NUMBER = ',T30,I10,T50,'X-COORDINATE = ',T65
     1,F12.5,T80,'CASE NUMBER = ',T95,I5/)
  107 FORMAT (T5,'GROUP NUMBER',T35,'NEUTRON ENERGY',T60,'NEUTRON FLUX P
     1ER UNIT LETHARGY'/)
  108 FORMAT (T10,I10,T35,E12.5,T60,E12.5)
  111 FORMAT (T10,'ENERGY GROUP NUMBER = ',T40,I10,T60,'CASE NUMBER =',T
     175,I5/)
  112 FORMAT (T10,'NUMBER OF INTERVAL',T40,'X-COORDINATE',T70,'NEUTRON F
     1LUX PER UNIT LETHARGY'/)
  113 FORMAT (T10,I10,T40,F12.5,T70,E12.5)
  114 FORMAT (T5,'DAMAGE FLUX =',T20,E12.5,T35,'EV/(CM**3 - SOURCE NEUTR
     1ON) OR',T68,E12.5,T85,'ERG/(CM**3 - SOURCE NEUTRON)/10**18'/(T5,I5
     2,T12,'TH ACTIVATION =',T30,E12.5))
  116 FORMAT (///1H )
  121 FORMAT (T5,' * * *   DO NOT BE SO CARELESS . . .  YOUR ANISN TAPE
     1 DOES NOT CONTAIN THIS MANY MESH POINTS * * *'/T10,'* * *   TRY AG
     2AIN  WITH MORE CARE OR WRITE YOUR OWN PROGRAM * * *')
  122 FORMAT (T10,' * * * * *  CATION * *  CAUTION * * * * *',T5,' . . .
     1THE SUBTITLES ARE GOING INTO EACHOTHER . . . . .  CHECK THEIR ORDI
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   2NATES CAREFULLY . . . . . . '/T10,' * * *   MORE LUCK BY YOUR NEXT AMAI 3050
   3TTEMPT * * *   '/)                                                 MAI 3060
123 FORMAT (T10,' * * *   STOP MY FRIEND * * *    WHERE ARE YOU TRYINGMAI 3070
   1 TO WRITE * * *'/T5,' * * * * * *  I CAN NOT WRITE ANYTHING OUT OF TMAI 3080
   2HE PAPER * * * * '/T10,' * * *  CHECK THE ORDINATES OF YOUR SUBTIMAI 3090
   3TLES * * *'/)                                                      MAI 3100
    STOP                                                               MAI 3110
    END                                                                MAI 3120
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      SUBROUTINE ACTIV
C     PLOTTING OF ACTIVITIES DEPENDENT ON X-COORDINATE
      DIMENSION A(8),XM(151),TITL(18),STIT(9,9),A1(150),IDD(9)
      COMMON N,JTAPE,NCASE,IM,NOINT,NL1,NL
      COMMON IDD
      COMMON WIDTH,XZERO,DELX,XP,XP2,D2
      COMMON A,XM,TITL,STIT
      READ (50,100) NCY,ITOPY
      READ (50,101) B1
      CALL SEMLOG (NCY,ITOPY,XZERO,DELX,NOINT,WIDTH,JTAPE,A)
      CALL LETTER (0,NL,TITL,A)
      CALL LETTER (1,43,43HX-COORDINATE OF THE SHIELDING MATERIAL (CM),A
     1)
      CALL LETTER (2,34,34HABSORBTIONS/(CM**3-SOURCE NEUTRON),A)
      CY = NCY
      G = ITOPY - NCY
      ALFA = CY/A(7)
      DO 3 ICASE = 1,NCASE
      READ (50,101) (A1(I),I=1,IM)
      EX1 = G + ALFA*(A(7)+0.07-B1)
      Y1 = 10.**EX1
      CALL CURVE (1,XP,Y1,IDD(ICASE),A)
      CALL CURVE (2,XP2,Y1,IDD(ICASE),A)
      CALL SUBTLE (NL1,STIT(9,ICASE),B1,D2,A)
      B1 = B1 + 0.25
      WRITE (51,116)
      WRITE (51,11) ICASE
      DO 1 I=1,IM
      WRITE (51,113) I,XM(I),A1(I)
    1 CALL CURVE (I,XM(I),A1(I),IDD(ICASE),A)
    3 CONTINUE
      CALL ADVANC(A)
   11 FORMAT (T2,'INTERVAL NUMBER',T20,'MIDPOINT POSITION',T45,'ACTIVATI
     1ON OF THE',T65,I3,T70,'TH CASE'/)
  100 FORMAT (12I6)
  101 FORMAT (6(F12.5))
  113 FORMAT (T5,I10,2(10X,E12.5))
  116 FORMAT (///1H )
      RETURN
      END
```

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