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APPLE-2: An Improved Version of APPLE Code for Plotting Neutron and Gamma Ray Spectra and Reaction Rates

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A computer code APPLE-2 which plots the spatial distribution of energy spectra of multi-group neutron and/or gamma ray fluxes, and reaction rates has been developed. This code is an improved version of the previously developed APPLE code and has the following features:

(1) It plots energy spectra of neutron and/or gamma ray fluxes calculated by ANISN, DOT and MORSE.
(2) It calculates and plots the spatial distribution of neutron and gamma ray fluxes and various types of reaction rates such as nuclear heating rates, operational dose rates, displacement damage rates.
(3) Input data specification is greatly simplified by the use of standard, response libraries and by close coupling with radiation transport calculation codes.
(4) Plotting outputs are given in camera ready form.

Keywords: Plotter, Graphical Display, Neutron Flux, Gamma Ray Flux, Energy Spectra, Reaction Rate, Nuclear Heating Rate, Radiation Transport Calculation, APPLE-2 code

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ＡＰＰＬＥ－２：中性子束とガンマ線束のスペクトルと反応率のプロッターコードＡＰＰＬＥの改良版

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（１９８２年７月１日受理）

中性子束とガンマ線束のエネルギー群スペクトルと反応率の空間分布をプロットする計算コードＡＰＰＬＥ－２を開発した。本コードは以前に開発したＡＰＰＬＥコードの改良版であり以下の特徴を有している。

(1) ＡＮＩＳＮ，ＤＯＴおよびＭＯＲＳＥで計算した中性子束およびガンマ線束のエネルギースペクトルをプロットする。
(2) 中性子束とガンマ線による各種の反応率，例えば核発熱率，運転中の線量率，はじき出し損傷率等の空間分布を計算しプロットする。
(3) 標準的なレスポンスライブラリーの使用と放射線輸送計算コードとの連動により入力法を大巾に簡単にした。
(4) プロット結果をそのままレポート等に利用できる。

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1. Introduction

The APPLE-2 code is an improved version of the APPLE code(1) developed in 1976 for plotting the spatial distribution of the reaction rates and the energy spectra of multi-group neutron flux obtained with one-dimensional discrete ordinates transport code ANISN(2). The APPLE code has been widely used in the nuclear design of fusion devices(3),(4) and analyses(5) of integral experiments in the Japan Atomic Energy Research Institute (JAERI) and elsewhere in Japan(6). The extensive use of the APPLE code made apparent, the complexity of input data preparation and inadequacies of the result such as the difficulty in deriving quantitative information from the overview plot of multigroup neutron flux.

Based on the experiences with the APPLE code, the APPLE-2 code is developed not just as a minor modification of the previous code but as a thoroughly improved code. Additional capabilities of the new code are;

1) to plot the energy spectra of neutron and/or gamma ray fluxes calculated by ANISN(2), DOT(7) and MORSE(8), and
2) to calculate and plot reaction rates using the DOT calculated fluxes.

The input data specification is greatly simplified by modifying the output of the radiation transport codes. Also several standard response libraries for fusion reactor neutronics calculations are made available to the users of the cross section sets such as the GICX40 Set.(9) In addition, all the output graphs are provided in camera ready form.

The function, structure, and input/output descriptions of the code are given in Section 2. Standard response libraries for fusion reactor calculations are described in Section 3. Sufficient number of sample problems are given in Section 4 to demonstrate the versatile application of the code. Some remarks are given in Section 5.

2. APPLE-2 Code

2.1 Functions and Features

The APPLE-2 code has the following functions which are summarized in Table 2.1:

(1) It plots multi-group energy spectra of neutron and/or gamma ray fluxes calculated by ANISN, DOT-3.5 and MORSE.

(2) It gives overview plot of multi-group neutron fluxes calculated by ANISN and DOT-3.5. Scalar neutron flux $\phi(r,E)$ is plotted with the spatial parameter r linearly along the Y-axis, log E along the X-axis and log $\phi(r,E)$ in the Z-axis direction.

(3) It calculates the spatial distribution and region volume intergrated values of reaction rates using scalar flux calculated with ANISN[2] and DOT-3.5[7].

(4) Reaction rate distribution along R or Z direction may be plotted.

(5) Overview plot of reaction rates or scalar fluxes summed over specified groups may be plotted. $R(r_i,z_j)$ or $\phi(r_i,z_j)$ is plotted with spatial parameters r and z along the X- or the Y-axis in an orthogonal coordinate system.

(6) Angular flux calculated by ANISN, $\phi(r,\vec{\Omega},E)$ is rearranged and a shell source at any specified spatial mesh point may be punched out in FIDO format. Thus obtained shell source may be employed in solving deep penetration problems by ANISN, when the entire reactor system is divided into two or more parts and the neutron flux in two adjoining parts are connected by using the shell source.

Notable features of the APPLE-2 code are as follows:

(a) The input data specification is made as simple as possible by making use of the input data required in the radiation transport code. For example, geometry related data in ANISN and DOT are transmitted* to APPLE-2 along with scalar flux data so as to reduce duplicity and errors in reproducing these data.

(b) Most of the input data follow the free form FIDO format developed in the Oak Ridge National Laboratory and used in the ANISN code[2]. Furthermore, the mixture specifying method used in ANISN is also used in APPLE-2.

(c) Libraries for some standard response functions required in fusion reactor nuclear design have been prepared and are made available to users of the 42-group neutron, 21-group gamma ray coupled cross section set GICX40[9]. For fluxes calculated with arbitrary cross sections, response functions must be supplied by card input.

(d) When drawing energy spectra of fluxes calculated with the GICX40 set, there is no need to input energy group structure data as they are built-in in the APPLE-2 code.

(e) Reaction rates calculated with more than one fluxes may be drawn on a graph for comparison.

(f) The graphical outputs are devised so that they may be readily used in reports.

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* Some modification in the ANISN and DOT output is required.

Table 2.1 Functions of the APPLE-2 Code

Functions	Radiation transport codes		
	ANISN	DOT-3.5	MORSE
(1) Neutron and gamma ray energy spectrum plotting, $\phi(E_g)_{r=r_0}$	○	○	○
(2) Overview plotting of the spatial change of energy spectra, $\phi(r_i,E_g)_{z=z_0}$ or $\phi(z_i,E_g)_{r=r_0}$	○	○	—
(3) Reaction rate, $R(r_i)=\sum_g \sigma_{gi}\cdot N_i\cdot\phi(r_i,E_g)$, $R=\sum_i R(r_i)\cdot V_i$ calculation	○	○	—
(4) Reaction rate, $R(r_i)=\sum_g \sigma_{gi}\cdot N_i\cdot\phi(r_i,E_g)$ plotting	○	○	—
(5) Overview plotting of reaction rates or scalar fluxes, $R(r_i,z_j)=\sum_g N_{ij}\cdot\sigma(E_g)\cdot\phi(r_i,z_j,E_g)$ or $\phi(r_i,z_j)=\sum_{g=NL}^{NH}\phi(r_i,z_j,E_g)$	—	○	—
(6) Shell source punchout	○	—	—

2.2 Program Structure and Calculational Flow

The program structure of APPLE-2 is shown in Fig.2.1 together with the Input/Output data flow. As shown in the figure, the APPLE-2 code consists of six major calculational paths which are controlled by the main program APPLE using the identification symbol named IDENT.
The IDENT is always read before any part of the input data.

When IDENT = 'FLUX', scalar flux from ANISN, DOT or MORSE is read together with geometrical data.

When IDENT = 'CROS', response cross sections and mixing input data are read and mixture cross sections are calculated if necessary.

When IDENT = 'RCAL', reaction rate calculation input data are read and reaction rates are calculated.

When IDENT = 'RPLT', calculated reaction rates are plotted.

When IDENT = 'SPEC', neutron or gamma ray scalar flux spectra are plotted.

When IDENT = 'SHEL', shell source is calculated from the angular flux calculated by ANISN.

A job terminates when an input card with IDENT = 'END' is read.

As shown in Fig.2.1 the logical numbers required for input-output files and their uses are:

logical 9 + NON.	scalar fluxes (NON = 1,2,·····10);
logical 5.	standard input;
logical 6.	standard output;
logical 7.	standard punch out;
logical 21.	storage device for writing scalar flux input;
logical 23.	storage device for writing input geometrical data;
logical 24.	storage device for writing input mixture data;

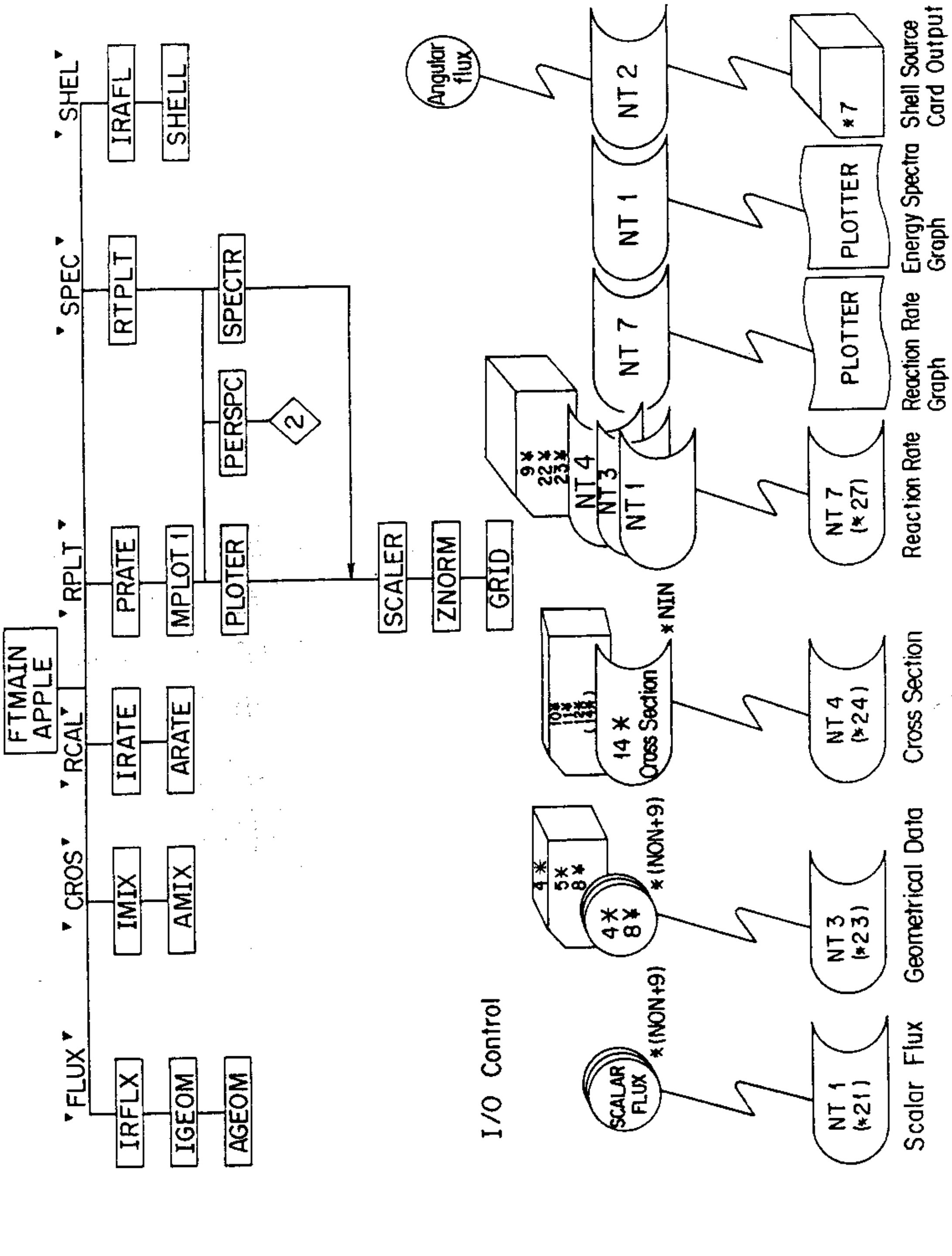


Fig.2.1 Program Structure and Input/Output Data Flow in APPLE-2

Program

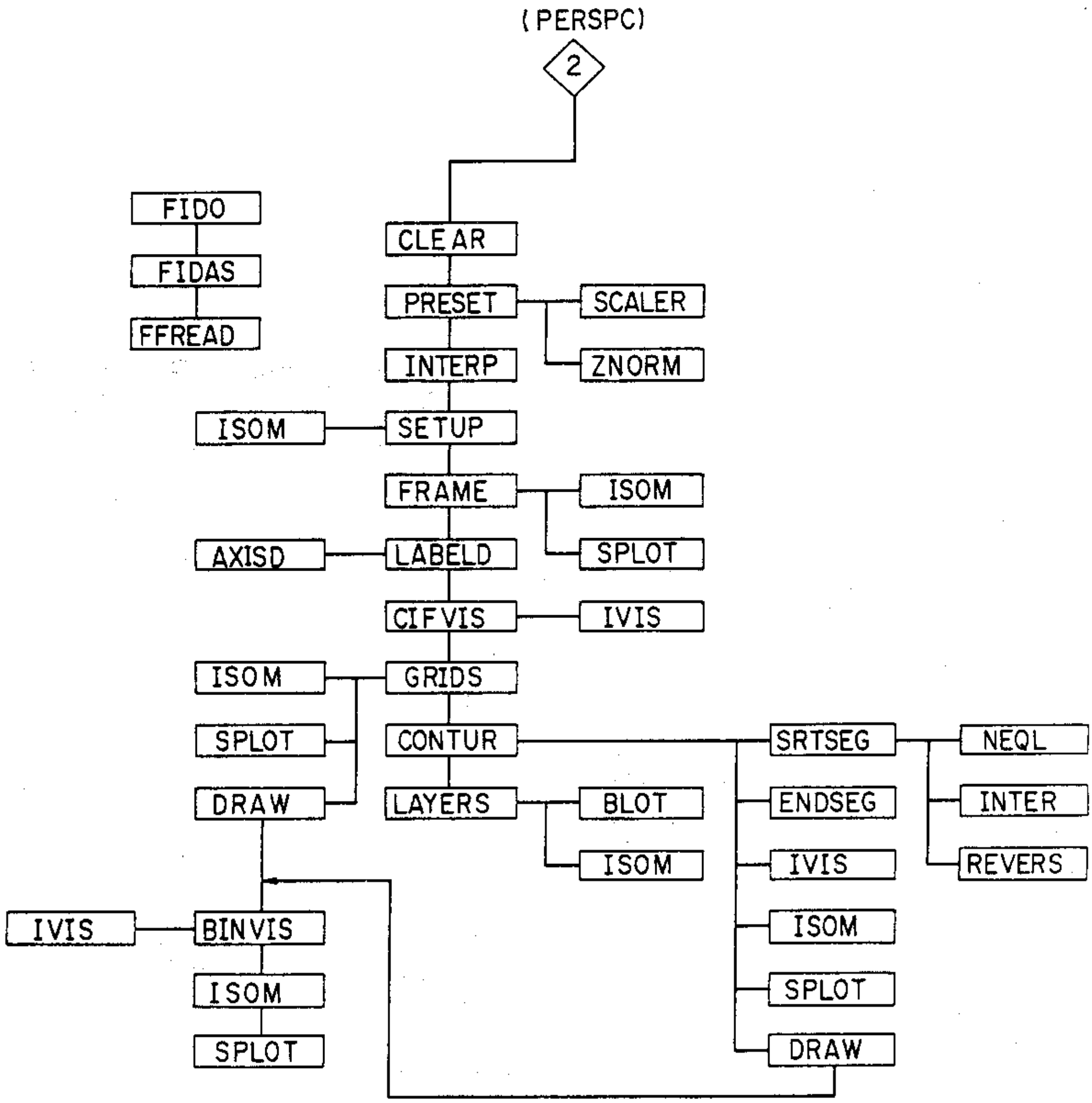


Fig.2.1 Program Structure and Input/Output Data Flow in APPLE-2 Program (continued)

logical 26. storage device for writing input cross sections;

logical 27. storage device for writing reaction rates.

If more than two scalar fluxes are used, the logical numbers 10, 11,·· ···, 20 may be used and specified in the input data.

2.3 Description of subroutines

Brief descriptions of subroutines included in APPLE-2 are as follows:

<u>I/O and control routines</u>

APPLE - the main program which sets blank common size, and controls calculational flow

AGEOM - processes geometrical input data (NT3)

AMIX - mixes cross sections (NT4)

ARATE - calculates reaction rates

AZNAT - writes mixture data

BLOCK DATA - stores standard energy group structures (42N, 100N, 21G, 54G)

CCLEAR - sets elements in array to a certain value

CHAN - transforms dimension of arrays from two to one

CLEAR - same as above

DTFPUN - punches out shell sources in ANISN FIDO format

FFREAD - reads free-form FIDO format[2] cards

FIDAS - same as above

FIDO - same as above

FLTFX - transforms a floating point number to a fixed point number

FTMAIN - sets maximum location and calls the subroutine APPLE

IGEOM - controls geometrical input data

IMIX - controls mixing input data

IRAFL - reads angular flux input data from ANISN output

IRATE - controls reaction rate calculations

IRFLX - reads scalar flux input data from ANISN, DOT or MORSE(NT1)

LOCAT - checks location size

MPLOT1 - controls the plotting of reaction rates

PRATE - sets work array locations for plotting

PUNSH - punches out shell source in ANISN FIDO format

RTPLT - controls the plotting of scalar flux

SHELL - reads and processes angular flux output from ANISN

WOT - writes 1, 2, and 3 dimensional arrays

WOT8 - writes array by 8 columns

General plotting routines

PENSET - exchanges the colour of pens

SCALER - calculates a factor for normalization

ZNORM - normalizes flux value

ENDPLT - ends plotting

Plotting routines for graphic display of reaction rates

GRID - plots grid and titles

LINTYP - plots dotted or dashed lines

PLOTER - plots data and controls calculational flow

REFER - plots reference table

SMOOTH - connects data points with smooth curves

SPECTR - plots scaler flux spectrum

ZUNORM - normalizes plot value

Plotting routines for overview plot of scalar flux

AXISD - plots axes and their titles

BINVIS - calculational routine

BLOT - same as above

CIFVIS - determines hidden parts of grids

CONTUR - plots contour lines

DRAW - control routine

ENDSEG - calculates the end of a contour line

FRAME - draws frames

GRIDS - controls plotting of grids

INTER - interchanges two variables

INTERP - interporates input data to determine the values on square lattice

ISOM - calculates coordinates values

IVIS - determines hidden parts of grids

LABELD - control routine for drawing axes

LAYERS - plots numerical values

NEQL - calculational routine

PERSPC - controls the overview plotting

PRESET - normalizes flux values

REVERS - calculational routine

SETUP - determines maximum and minimum values

SPLOT - plotting routine

SRTSEG - calculational routine

2.4 Variable Descriptions

In the following are described the variables for plotting reaction rates and overview of neutron spectra, which are included in subroutines PLOTER and PERSPC, respectively.

* SUBROUTINE PLOTER

X(NMAX,M) two-dimensional array corresponding to X-axis.

Y(NMAX,M)	two-dimensional array corresponding to Y-axis.
NN(M)	number of data in arrays X and Y
M	number of vectors in X and Y
NMAX	maximum number of data in the vectors in X and Y
NWAY	the option for the scaling
	=1 linear X vs. linear Y
	=2 linear X vs. log Y
	=3 log X vs. linear Y
	=4 log X vs. log Y
BCDY	label for Y-axis
NBCDY	number of letters (characters) in BCDY
BCDX	label for X-axis
NBCDX	number of letters in BCDX
TITLE	main title
NTITLE	number of letters in TITLE
XVECT	=.TRUE. X is one-dimensional array
	=.FALSE. X is two-dimensional array
BOUNDS(M)	BOUNDS(1) minimum value for X-axis
	BOUNDS(2) maximum value for X-axis
	BOUNDS(3) minimum value for Y-axis
	BOUNDS(4) maximum value for Y-axis
XSIZE	length of X-axis
YSIZE	length of Y-axis
NTRA	> 0, points are connected by smooth curves
LOGPO	1 or 3, log scaling is forced on X-axis
	2 , log scaling is forced on Y-axis
LINEIT	> 0, fine grids are drawn
NLABEL	> 0, frame is drawn

NSYMB	< 0, each vector are selectively drawn as continuous line, dashed line, etc.
	=0, only lines are drawn
	> 0, characteristic symbols are assigned to the data points of each vector
	|NSYMB| > 1 Descriptions for each symbol are written on a graph
BCDL(M)	description for each vector
ICENT	< 0, Origin of the coordinate system is set to X = 0.0, Y = 0.0.
	≠ 0, basic coordinate system is drawn

* SUBROUTINE PERSPC

Z(NROW, NCOL)	Z-axis data
X(NCOL)	X-axis data
Y(NROW)	Y-axis data
IV(~)	temporary area
NN(NCOL)	temporary area
IR	number of data for the X-axis
IC	number of data for the Y-axis
THETA	angle (in degrees) down from the Z-axis (see Fig.2.4.5)
PSI	angle (in degrees) around from the X-axis towards the Y-axis (see Fig.2.4.5)
VIEWPT	distance between the view point and the origin of the coordinate system (in cm)
PWIDTH	width of graph (in cm)
PSIZE	length of graph (in cm)
NCONTR	> 0, draw contour lines
IDE	≥ 0, eliminate hidden lines

KROSS	< 0, Z-axis will be placed cross-wise
LGRID	< 0, suppress grid plot of the surface
	> 0, number of grids per 1 scale
NFRAME	< 0, do not draw frame
	= 0, draw only base frame
	> 0, draw full frame
KOLOR	> 0, change colour of the pen
NWAY	Z-axis scaling (1; linear, 2; log)
NWAYX	X-axis scaling
NWAYY	Y-axis scaling
LOGPO	> 0, force log scaling on Z-axis
LOGPOX	> 0, force log scaling on X-axis
LOGPOY	> 0, force log scaling on Y-axis
BCD	title of graph
NBCD	number of letters in title
BCDZ	label for Z-axis
NBCDZ	number of letters in BCDZ
BCDX	label for X-axis
NBCDX	number of letters in BCDX
BCDY	label for Y-axis
NBCDY	number of letters in BCDY

2.5 Input Instructions

The input data for APPLE-2 may be prepared by using corresponding input cards for ANISN/DOT or by using output cards from ANISN or DOT. Either conventional FIDO ($ or *) or free-form ($$ or **) format[3] may be used. Yen symbol ¥ is used in place of dollar symbol $ in the FACOM M-200 computer used in JAERI.

2.5.1 Input card format

1. Card 1 (20A4) TITLE CARD : job title

2. Card 2 (A4,2X,I3) IDENTIFICATION CARD

This card is required before any set of data. This card specifies the data to be input and controls the calculational flow (see Fig.2.1).

IDENT = 'FLUX' ; input scalar flux from ANISN, DOT or MORSE, input geometrical data

= 'CROS' ; input cross section and mixing data

= 'RCAL' ; input reaction rate calculation data

= 'RPLT' ; input reaction rate plotting data

= 'SPEC' ; input energy spectrum plotting data

= 'SHEL' ; input data for the conversion of angular flux into shell source

= 'END' ; terminate the job

NON ; sequence number for same IDENT cards

3. IDENT = 'FLUX' ; Scalar flux and geometrical data input

Card 3.1 (2I3,E12.0)

NXMODE ; input file mode

0 / 1 / 2 / 3 = ANISN / ANISN / DOT / MORSE flux

NXCARD ; 0 / 1 = read geometry data from disk file/card

FNORM ; normalization factor to be multiplied to the input flux (default value = 1.0)

Card 3.2 (5I3) (required only when NXCARD = 1 and MXMODE$\leq$2)

NGROUP ; number of groups

NINTI ; number of radial mesh intervals

NINTJ ; number of axial mesh intervals (enter 1 when NXMODE = 1)

NZONE ; number of zones

IGOM ; geometry type specification

1 / 2 / 3 = slab / cylinder / sphere (NXMODE = 1)

0 / 1 / 2 = R-Z / X-Y / R-THETA (NXMODE = 2)

Cards 3.3 (FIDO format) (required only when NXCARD = 1)

4** [NINTI + 1] radial mesh boundaries

5** [NINTJ + 1] axial mesh boundaries (required when NXMODE = 2)

8¥¥ [NINTI * NINTJ] zone number specification for each mesh point

(set radial directions first as in DOT input)

T

(N.B. Card 3.3 may be copied from corresponding DOT input)

4. IDENT = 'CROS'; Cross section and geometrical data input

Card 4.1 (4I3)

IHM ; length of cross section table

MCR ; number of cross section set

MS ; cross section mixing table length

NIN ; logical file numbers for cross section library, when cross sections are input from cards, NIN equals 0 or 5.

Cards 4.2 (FIDO format)

10¥¥ [MS] ; mixture numbers in mixing table

11¥¥ [MS] ; component numbers in mixing table

12** [MS] ; atom densities in mixing table

T

Cards 4.3 (FIDO format) (required only when NIN = 0 or 5)

14** [IHM * NGROUP * MCR] ; cross sections for reaction rate calculations or response functions

T

5. IDENT = 'RCAL' ; Reaction rate calculation input

Card 5.1 (4I3,E12.0)

NFX ; NFX-th scalar flux data in file NT1 to be used(see Fig.2.1 for NT1)

NGE ; NGE-th geometrical data in file NT3 to be used(see Fig.2.1 for NT3)

ID3 ; number of reaction rates to be calculated

MOPT ; plot option

= 1; reaction rates for each material are plotted

= 2; the sum of the reaction rates is plotted

= 3; both MOPT = 1 and 2 are plotted

CF ; conversion factor to be multiplied to the reaction rates (if not specified CF = 1.0)

Cards 5.2 (FIDO format)

9¥¥ [NZONE] ; material or mixture numbers by zone

22¥¥[ID3] ; material numbers for reaction rate calculations

23¥¥[ID3] ; cross section table positions for reaction rate calculations

Card 5.3 (9A8)

ACT [ID3] ; labels of the reaction rates to be plotted

6. IDENT = 'RPLT' ; reaction rate (or scalar flux)* plotting input

Card 6.1 (2I3,A4)

NPLT(1) ; plot control option

= 1; reaction rate plotting for ANISN

= 2; reaction rate plotting for DOT along a fixed radial row or axial column

= 3; overview plotting of reaction rate for DOT

NPLT(2) ; (required when NPLT(1) $\geq$ 2)

when NPLT(1) = 2, radial or axial mesh point number along which reaction rates are plotted

when NPLT(1) = 3, reaction rate material number for plotting NPLT(2) = 1 ∿ ID3

* Scalar flux is plotted when response function is 1 or 0

TYPE ; (required only when NPLT(1) = 2)

specifies radial or axial plotting type

= 'RADIAL' ; reaction rate is plotted in the axial (Z or θ) direction along NPLT(2)-th radial row (R-Z or R-θ geometry)

= 'Z' ; reaction rate is plotted in the radial direction along NPLT(2)-th axial column (R-Z geometry)

= 'THETA' ; reaction rate is plotted in the radial direction along NPLT(2)-th θ-mesh (R-θ geometry)

= 'X' ; reaction rate is plotted in the Y-direction along NPLT(2)-th X row (X-Y geometry)

= 'Y' ; reaction rate is plotted in the X-direction along NPLT(2)-th Y column (X-Y geometry)

Cards 6.2 (required when NPLT(1) = 1 or 2)

Card 6.2.1 (2F12.4)

XSIZE ; plot size in X-direction, unit in cm. (default value = 15.0)

YSIZE ; plot size in Y-direction, unit in cm. (default value = 20.0)

Card 6.2.2 (20A4) BCDZ ; title heading

Card 6.2.3 (20A4) BCDX ; X-axis title

Card 6.2.4 (20A4) BCDY ; Y-axis title

Card 6.3 (required when NPLT(1) > 2, when overview is plotted)

Card 7.5 described later

Card 7.7 described later

7. IDENT = 'SPEC' ; input data for neutron or gamma ray energy spectrum plotting

Card 7.1 (6I3)

NPLT1 = 2 ; neutron or gamma ray energy spectra plotting at specified mesh points

= 3 ; neutron* energy spectra plotting along radial row or axial column

ISTEPC ; the NON number of scalar flux data for plotting specified in IDENT = FLUX card (same as NFX in card 5.1)

ISTEPR ; the NON number of geometrical data used for plotting (same as NGE in card 5.1)

NORG > 0 ; number of neutron energy groups

< 0 ; number of gamma ray energy groups

NCARD = 0 ; neutron or gamma ray energy group structure in BLOCK DATA will be used (see Section III for built-in structures)

= 1 ; the energy boundaries of groups are input by cards

ID3 ; number of mesh points at which the energy spectra are plotted ($\leq$ 24)

Card 7.2 (2I3) (required when NXMODE = 2 in Card 3.1 or DOT flux spectra are plotted)

MSH ; number of axial column or radial row along which spectra are plotted

MXY = 1 ; spectra is plotted along the radial direction

= 2 ; spectra is plotted along the axial direction

Cards 7.3 (6E12.0) (required when NCARD = 1)

X [ABS(NORG) + 1] ; neutron or gamma ray energy group boundaries from high to low in eV.

Card 7.4 (14I3) (required when NPLT1 = 2)

---

* the program cannot plot overview energy spectra of gamma ray flux in neutron and gamma ray coupled problem.

NSOS [ID3] ; number of mesh points at which energy spectra are plotted

Card 7.5 (6I3,5E12.0) (required when NPLT1 = 3)

1. IDE ≥ 0 ; eliminate hidden lines
   < 0 ; give perspective drawing
2. KROSS < 0 ; place the Z-axis cross-wise
3. LGRID > 0 ; number of grids per 1 scale
   < 0 ; suppress grid plot of the surface
4. NFRAME > 0 ; draw full frame
   $= 0$; draw only base frame
   < 0 ; do not draw frame
5. KOLOR > 0 ; change colour of the pen
6. KONTR ; the range of plotting. If the maximum value is given by 10^N, the values larger than $10^{N-KONTR}$ will be plotted
7. THETA ; angle (in degrees) down from the Z-axis (suggested value 45.0)
8. PSI ; angle (in degrees) around from the X-axis towards the Y-axis (suggested value 45.0)
9. VIEWPT ; distance between viewpoint and the origin of the coordinate system (suggested value 1000.0 cm)
10. PWIDTH ; width of the plot (less than 23.0 cm)
11. PSIZE ; length of the plot (in cm)

Cards 7.6 (required when NPLT1 = 2)

Card 7.6.1 (2F12.4)

XSIZE ; plot size in X-direction (if 0, XSIZE = 15.0 cm)

YSIZE ; plot size in Y-direction (if 0, YSIZE = 20.0 cm)

Card 7.6.2 (20A4)

BCDZ ; title heading

BCDX ; X-axis title

BCDY ; Y-axis title

Card 7.7 (20A4) (required when NPLT1 = 3)

BCD ; title heading for overview plot

8. IDENT = 'SHEL' ; input data for shell source punch out for ANISN calculations

Card 8.1 (3I3)

NGROUP ; number of groups

NINTI ; number of spatial mesh points

NDIR ; number of discrete directions

= ISN + 1 for plane or sphere,

= (ISN * (ISN + 4))/4 for cylinder,

where ISN is the order of S_N used in the angular flux calculation

Card 8.2 (I3)

MBDRY ; the mesh interval number at which the shell source is punched out

Cards 2 ~ 6 may be input repeatedly so as to allow reaction rates plotting in different models on a same graph for comparison. IDENT cards of a kind must be given sequential NON numbers.

IDENT = 'END' card will terminate the job.

2.5.2 Input file record format

The APPLE-2 code reads scalar flux, angular flux, response libraries and other data from files prepared beforehand. The record format of the files are described below.

(a) Scalar flux record format of ANISN output

The output subroutine FINPR of the ANISN code has been slightly modified to transmit relevant data to APPLE-2 together with scalar flux data. The modified portion of the FINPR subroutine is listed in Fig.2.4.1. As shown in the figure, the input parameter ID2 must be made equal to -3 in order to transmit relevant data to APPLE-2. The record format is as follows:

Record 1

IGM ; number of energy groups

IM ; number of spatial mesh intervals

IZM ; number of zones

IGE ; number of geometry type specification

1-slab ; 2-cylinder; 3-sphere

Record 2

RA [IM+1] ; interval boundaries

MA [IM] ; zone numbers by interval

V [IM] ; volumes by interval

Record 3

(XN(J,I),J=1,TM) ; scalar flux in IGM loops

These data are read by subroutine IRFLX of the APPLE-2 code.

(b) Scalar flux record format of DOT output

Subroutines OUTER, TPSAVE and TPXF of the DOT code have been modified to transmit relevant data to APPLE-2 with scalar flux data. The modified portions of the subroutines are listed in Fig.2.4.2. As shown in the figure, the initial portion of the scalar flux data written on NFLSV is modified to transmit the data in the following record format to be read by the subroutine IRFLX of the APPLE-3.

Record 1

IGM ; number of energy groups

IM ; number of radial mesh interval

JM ; number of axial mesh interval

IZM ; number of zones

IGE ; number of geometry type specification

0 / 1 / 2 = R-Z / X-Y / R-THETA

Record 2

RA [IM+1] ; radial interval boundaries

ZA [JM+1] ; axial interval boundaries

MA [IM*JM] ; zone numbers by interval

V [IM*JM] ; volumes by interval

Record 3

((XN(I,J),I=1,IM), J=1,JM) ; scalar flux in IGM loops

(c) Scalar flux record format by MORSE output

The subroutine NRUN of the MORSE-GG code(8) is modified to write the scalar flux of some region (using track length estimator) or some positions (using point detector estimator). The record format of the data read by subroutine IRFLX of the APPLE-2 is as follows:

Recrod 1

NNE ; number of neutron groups

NGROUP ; number of total groups

NINTI ; number of estimators multiplied by 3

Record 2

EFIRST ; the upper bound energy of the first neutron group

EGTOP ; the upper bound energy of the first gamma ray group

Y(I),I=1,NGROUP; the lower bound energy of neutron and gamma ray energy groups from high to low

Record 3

Y(J),J=1,NGROUP ; scalar flux

Record 4

Y(J),J=1,NGROUP ; fractional standard deviation (f.s.d.) of the scalar flux

Records 3 and 4 are in NINTI loops (are read repeatedly for NINTI times).

(d) Angular flux record from ANISN

The angular flux are written by the modified version of the SUMARY subroutine of the ANISN code which is listed in Fig.2.4.4. As shown in Fig.2.4.4, the input parameter ID1 must be made equal to -1 in order to write angular flux on a file for the transmission to APPLE-2.

Record 1 angular flux

(((XND(I,M), I = 1,NINTI + 1), M = 1,NDIR)

Record 1 is in NGROUP loops.

(e) Response function libraries record format

Some standard response function libraries for fusion reactor calculations are provided for the user of the GICX40 cross section set[9] and DLC-2D[10] structured cross section set. The content of the libraries will be described in the next section. The record format of the libraries are as follows:

Record 1 (3I3)

IHM ; length of cross section (response) table

NGP ; number of groups

MCR ; number of cross section set in the library

Record 2 (FIDO format)

14** [IHM * NGP * MCR] ; cross section (or response function values

T ; end of the library

```
      IF(IGMNEW.NE.IGMNEU.AND.JJ1.EQ.1) GO TO 800
      IF(IDAT1.NE.0)REWIND NT3
      IF(IDAT1.EQ.2)REWIND NT1
      IF(NACTPR.EQ.1) CALL ACTPRT(XNXNXN(1),XNXNXN(NXADRS),IM,IGM,ID3,
     *           IZP,IIG,J,I,KK,E2,E3,T3,1)
      IF(ID4.GE.0)GO TO 1
      DO 42 I=1,ID3
   42 CALL PUNSH(T5(1,I),IM)
    1 CONTINUE
      IF(IDAT1.EQ.2)GO TO 26
      IF(ID1.LT.2)GO TO 18
      DO 43 I=1,IGM
   43 CALL PUNSH(XN(1,I),IM)
  160 FORMAT(12A4,8X/1X,2H3*,69X,4HFLUX,3X,1H0)
```

modified portion

```
   18   IF(ID1.GT.-2) GO TO 110
      NFX=10
      REWIND NFX
      IF(ID1.EQ.-2)   GO  TO  104
      WRITE(NFX) IGM,IM,IZM,IGE
  104 CONTINUE
      WRITE(NFX) (RA(I),I=1,IP),(MA(I),I=1,IM),(V(I),I=1,IM)
      DO 105 I=1,IGM
  105 WRITE(NFX) (XN(J,I),J=1,IM)
      WRITE(6,600) IGM,IM,NFX
      REWIND NFX
C  18 WRITE (NOU,170) T
  110 WRITE (NOU,170) T
```

```
C   *** PRINT FLUX IF IN CORE
      WRITE (NOU,60)
   60 FORMAT(12H0 TOTAL FLUX)
      IF(IIBOUD.EQ.1)   REWIND  20
C     IF(IIBOUD.EQ.1) CALL NWSUB4(D(LXND),IP,MM,XNXNXN,IGM,NT4)
      IF(IIBOUD.EQ.1) CALL NWSUB4(D(LXND),IP,MM,XNXNXN,IGM,NT4,D(LW))
      IF(IIBOUD.NE.1)   GO TO 3333
      REWIND 20
      CALL  NWSUB1(XNXNXN,IP,IGM)
      GO TO 3334
 3333 CONTINUE
      CALL WOT(XN,IGM,IM,1,'INT.','GRP.',0)
 3334 CONTINUE
      IF(IISPTM.EQ.1)    CALL  NWSUB2(XN,IP,IGM,IM,XNXNXN)
      CALL  WOTYT(XN,IGM,IM,1,IGMNEU)
      CALL  WOTYT(XN,IGM,IM,IGMNEU+1,IGM)
   19 IF(IDAT1.EQ.1)GO TO 22
C   *** PRINT DIST. SOURCE IF ANY AND IN CORE
      IF(IQM.EQ.0)GO TO 23
      WRITE (NOU,170) T
      WRITE (NOU,70)
   70 FORMAT(20H0 DISTRIBUTED SOURCE)
      CALL WOT(Q,IGM,IM,1,'INT.','GRP.',0)
      GO TO 24
C   *** PRINT SHELL SOURCE IF ANY AND IN CORE
   23 IF(IPM.EQ.0)GO TO 24
      WRITE (NOU,170) T
      IF(IPM.GT.1)GO TO 25
      WRITE (NOU,80) IPP
   80 FORMAT(27H0 SHELL SOURCE IN INTERVAL I3)
      CALL WOT(PA,IGM,MM,1,'ANGL','GRP.',0)
      GO TO  24
   25 WRITE (NOU,90)
   90 FORMAT(14H0 SHELL SOURCE)
      CALL WOT(PA,IM,MM,IGM,'ANGL','INT.','GRP.')
      GO TO 24
```

modified portion

```
   26 IF(ID1.GT.-2)    GO  TO  120
      NFX=10
      REWIND NFX
      IF(ID1.EQ.-2)   GO  TO  114
      WRITE(NFX) IGM,IM,IZM,IGE
  114 CONTINUE
      WRITE(NFX) (RA(I),I=1,IP),(MA(I),I=1,IM),(V(I),I=1,IM)
      DO 115 I=1,IGM
      READ (NT1) (X(J,1),J=1,IM)
      WRITE(NFX) (X(J,1),J=1,IM)
      IF(ISCT.GT.0) READ (NT1)
  115 CONTINUE
      WRITE(6,600) IGM,IM,NFX
      REWIND NT1
      REWIND NFX
  600 FORMAT(1H1////,5X,'*** SCALAR FLUX (',I3,' GROUPS,',I4,
     1  ' INTERVALS ) WAS WRITTEN ON MT=',I3,' ***')
C  26 I02=0
  120 I02=0
```

```
   29 I01=MIN0(IGM-I02,8)
      WRITE (NOU,170) T
      WRITE (NOU,140) I02
  140 FORMAT(32H0 TOTAL FLUX - G=GROUP NO.    N=I3)
      DO 31 I=1,I01
      READ (NT1) (X(J,I),J=1,IM)
   31 IF(ISCT.GT.0)READ (NT1)
      CALL WOT(X,I01,IM,1,'INT.','G=N+',0)
      I03=I01*IM
```

Fig.2.4.1 Modification of Subroutine FINPR of the ANISN Code for the Data Transmission to APPLE-2

```
ISN 00001        SUBROUTINE OUTER (A0,A7,B0,B2,B4,A1,M3,B6,C0,F0,G2,I7,K6,M0,M2,M4,OUTR0010
                1 M5,M6,M7,N2,N4,P2,P4,S0,S2,S4,T7,V0,V7,W0,W1,W2,X0,JMG,X1,X2,Z5, OUTR0020
                2 F2,A5,P3,S3,J3,BSR,BST,E0,E1,E2,E3,E4,E5,E6,E7,F5,F6,F7,ITLP,     OUTR0030
                3 ITMT,IMJMP,NOMAP,ISIZE1,ISIZE2,IGG,ALBDOR,ALBDOT,ALBDOB,IIGM,IMP,OUTR0040
                4 JMP,IMAFLX,JSC,CBAN,IZB,D1,D2,D3,D4,D5,D6,BSL,BSB,ISIZE3,V1,V2,  OUTR0050
                5 V3,V4,V5,NOMG,A)                                                  OUTR0060
           C                                                                        OUTR0070
           C****** OUTER CONTROLS AN OUTER ITERATION, READS DISTRIBUTED SOURCE,     OUTR0080
           C****** BOUNDARY SOURCE(S), FIRST COLLISION SOURCE, AND COMPUTES         OUTR0090
           C****** DOWNSCATTER AND UPSCATTER SOURCES                                OUTR0100
           C                                                                        OUTR0110
ISN 00002        COMMON                                                             OUTR0120
                1 NINP,NOUT,NCR1,NFLUX1,NSCRAT,NAFT,NBSO,NFLSV,NPSO,NZBT,NBFT,NGAM OUTR0130
ISN 00003        COMMON ALA,AV,AVP,AVR,B05,B06,B07,CNT,CTL,CVT,DEN,DENOM,DISCR,     OUTR0140
                1 D01,D02,D03,D04,EQ,EQA,EQB,EQC,EQR,EQS,EVA,EVB,EVP,EVPP,EV1,EV2, OUTR0150
                2 E01,E02,E03,E04,E05,F,GBAR,IAFP,IBB,IBL,IBR,IBT,IFOT,IGEP,IGK,   OUTR0160
                3 IGP,IGV,IG1,IHG,II,IMJM,IP,IT,ITEMP,ITP,IZP,ITEMP1,ITEMP2,JP,K01,OUTR0170
                4 K02,K03,K04,K05,K06,K07,LAP,LAPP,LAR,LC,MBAR,MJMK,ML,MM,MMAFLX,  OUTR0180
                5 MMDN,MMIFLX,MMIM,MMIP,MMJFLX,MMJM,MMLT,MMRT,MMUP,NB,NBAR,NGOTO,  OUTR0190
                6 NOM,NOMA,NUM,PBAR,P02,P07,SBAR,SIM,SIMJM,SJM,SBAR1,SK7,SUMW1,    OUTR0200
                7 SUMW2,TC,TEMP,TI,TEMP1,TEMP2,TEMP3,TEMP4,T06,T10,T11,T12,T15,T16,OUTR0210
                8 T17,UP,UP1,UP2,VBL,VHL,VLL,VNL,VRL,VTL,VVL,V07,V10,V11,V12,V13,  OUTR0220
                9 V14                                                               OUTR0230
ISN 00004        COMMON ID(18),                                                     OUTR0240
                1 A01,A02,A03,A04,IGE,IZM,IM,JM,I04,EV,EVM,EPS,B01,B02,B03,B04,    OUTR0250
                2 M07,FXT,MT,M01,MCR,MTP,IZ,JZ,S02,S03,IGM,IHT,IHS,ITL,S01,M05,M06,OUTR0260
                3 S04,D05,G07,G05,G06,LAL,LAH,POD,EPSA,IAFT,IZC,IMG,ISC,IS2,IS3,   OUTR0270
                4 ITI,IP1,IP2,IP3,IP4,IP5,IB1,IB2,IB3,IB4,IB5,IB6,IZ1,IZ2,IZ3,IZ4, OUTR0280
                5 IZ5,IZ6,J11,J12,J13,J14,J15,J16                                  OUTR0290
ISN 00005        COMMON LLL(2),LC0,LS2,LB2,LB4,LN2,LA0,LA1,LA5,LA7,LB0,LB6,LS3,     OUTR0300
                1 LJ3,LP3,LBSR,LBST,LBSS,LBSL,LBSB,LF0,LF2,LG2,LI0,LI1,LI2,LI3,    OUTR0310
                2 LI7,LK6,LK7,LM0,LM2,LM3,LM4,LM5,LM6,LM7,LN4,LP2,LP4,LR0,LR1,LR2, OUTR0320
                3 LR3,LR4,LR5,LS0,LS4,LT7,LV0,LV7,LW0,LW1,LW2,LZ0,LZ1,LZ2,LZ3,LZ4, OUTR0330
                4 LZ5,LX0,LX1,LX2,LE0,LE1,LE2,LE3,LE4,LE5,LE6,LE7,LF5,LF6,LF7,LM8, OUTR0340
                5 LM9,LABDR,LABDT,LABDB,LJMG,LJSC,LCBAN,LIZB,LD1,LD2,LD3,LD4,LD5,  OUTR0350
                6 LD6,LV1,LV2,LV3,LV4,LV5,LV6,LC1,LC2,LC3,LC4,LC5,LC6,LAST         OUTR0360
ISN 00006        DIMENSION A(1)                                                     OUTR0370
           C                                                                        OUTR0380
ISN 00007        DIMENSION P3(1),JSC(1),E0(1),E1(1),E2(1),E3(1),E4(1),E5(1),E6(1),  OUTR0390
                1 E7(1),F5(1),F6(1),F7(1),JMG(1),X1(1),X2(1),A0(1),A7(1),I7(1),    OUTR0400
                2 K6(1),M2(1),M4(1),M5(1),A1(1),M3(1),M6(1),M7(1),T7(1),V7(1),     OUTR0410
                3 W0(1),W1(1),W2(1),X0(1),Z5(1),B0(1),B2(1),B4(1),B6(1),F0(1),     OUTR0420
                4 G2(1),M0(1),N4(1),P2(1),P4(1),S0(1),S2(1),V0(1),V1(1),V2(1),     OUTR0430
                5 V3(1),V4(1),V5(1),F2(1),A5(1),C0(ITLP,1),BSR(1),BST(1),BSL(1),   OUTR0440
                6 BSB(1),S3(IMJMP,1),J3(IMJMP,K04   ,1),N2(IMJMP,1),S4(IMJMP,1),   OUTR0450
                7 ALBDOR(JMP,1),ALBDOT(IMP,1),ALBDOB(IMP,1),CBAN(IMJMP,1),IZB(1),  OUTR0460
                8 D1(1),D2(1),D3(1),D4(1),D5(1),D6(1),NOMG(1)                      OUTR0470
ISN 00008        INTEGER S02,A02,A03,B01,B02,B03,B04,D05,E04,FXT,GBAR,G07,PBAR,     OUTR0480
                1 SBAR,SBAR1,T15,T16,T17,UP,A04,P02,GOLD                           OUTR0490
ISN 00009        REAL K6,M5,M7,NBAR,N2,N4,NUM,M3,J3                                 OUTR0500
ISN 00010        CALL TIMSTR (1)                                                    OUTR0510
ISN 00011        CALL TIMON (1)                                                     OUTR0520
ISN 00012        CALL REWND(NFLSV)                                                  OUTR0530
ISN 00013        WRITE(NFLSV)  IGM,IM,JM,IZM,IGE                                    2 cards added
ISN 00014        CALL  WANDR4(NFLSV,A(LR0),IP,A(LZ0),JP,A(LM0),IMJM,A(LV0),IMJM,1)
           C
ISN 00015        IF(IZ4.GT.0) CALL REWND(IZ4)                                       OUTR0540
ISN 00016        IF(I04.EQ.6) CALL REWND(NPSO)                                      OUTR0550
ISN 00017        IF(IB5.NE.0 .OR. IB6.NE.0) REWIND NBFT                             OUTR0555
ISN 00018        IGV=1                                                              OUTR0560
           C****** SECTION --24 FIXED SOURCE ******                                 OUTR0570
ISN 00019        UP1=0.0                                                            OUTR0580
ISN 00020    124 CONTINUE                                                           OUTR0590
ISN 00021        K01=A03                                                            OUTR0600
ISN 00022        IF(IB4.NE.1) GO TO 3724                                            OUTR0610
ISN 00023        K01 = I7(IGV)                                                      OUTR0620
ISN 00024        NOMA=(K01*(K01+3))/2                                               OUTR0630
ISN 00025   3724 IF(I04.NE.1) GO TO 3324                                            OUTR0640
ISN 00026   3324 IF(K02)3224,324,3224                                               OUTR0650
ISN 00027   3224 DO 224 I=1,NOM                                                     OUTR0660
ISN 00028        S4(I,1)=0.0                                                        OUTR0670
ISN 00029    224 CONTINUE                                                           OUTR0680
ISN 00030    324 CALL WANDR2(NCR1,C0(1,1),ITL*MT,S2(1),MJMK,2)                      OUTR0690
ISN 00031        IF(I04.NE.6) GO TO 424                                             OUTR0700
ISN 00032        CALL WANDR2(NPSO,S2(1),IMJM,S4(1,1),NOM,2)                         OUTR0710
ISN 00033    424 IF(I04.EQ.0.OR.I04.EQ.6) GO TO 8024                                OUTR0720
ISN 00034        DO 624 I=1,IMJM                                                    OUTR0730
ISN 00035    624 S2(I)=0.                                                           OUTR0740
ISN 00036   8024 IF(IB1.EQ.0.OR.I04.EQ.5) GO TO 724                                 OUTR0750
ISN 00037        DO 8004 L = 1,IB1                                                  OUTR0760
ISN 00038        D1(L) = 0.0                                                        OUTR0770
ISN 00039   8004 CONTINUE                                                           OUTR0780
ISN 00040   8003 DO 8000 IJ=1,IMJM                                                  OUTR0790
ISN 00041        ITEMP=M0(IJ)                                                       OUTR0800
```

Fig.2.4.2 Modification of Subroutines OUTER, TPSAVE, TPXF of the DOT-3.5 Code for the Data Transmission to APPLE-2

```
ISN 00001        SUBROUTINE TPSAVE(N2,IMJM,IGM,IGG,IFOT,J3,NOM,B2,B4,MMIM,MMJM,ITI,
                1 NOMG)
           C
           C****** TPSAVE WRITES SCALAR FLUXES, MOMENTS AND SYSTEM BOUNDARY
           C****** ANGULAR FLUXES ON NFLSV
           C
ISN 00002        COMMON NINP,NOUT,NCR1,NFLUX1,NSCRAT,NAFT,NBSO,NFLSV,NPSO
ISN 00003        DIMENSION  N2(IMJM,IGG),J3(NOM,IGG),B2(9),B4(9),NOMG(1)
ISN 00004        REAL N2,J3
ISN 00005   1234 REWIND NFLUX1
           CRC   REWIND NFLSV                    this statement is deleted
ISN 00006        DO 1236  IIG =1,IGM
ISN 00007        IG1 = IIG
ISN 00008        IF(IFOT.EQ.0) GO TO 1233
ISN 00009        IG1 = 1
ISN 00010        IF(NFLUX1.EQ.NFLSV) GO TO 1237
ISN 00011        CALL WANDR4(NFLUX1,N2(1,IG1),IMJM,J3(1,IG1),NOMG(IIG),B2(1),MMJM,
                1B4(1),MMIM,2)
ISN 00012        GO TO 1235
ISN 00013   1233 CALL WANDR2(NFLUX1,B2(1),MMJM,B4(1),MMIM,2)
ISN 00014   1235 CALL WANDR4 (NFLSV,N2(1,IG1),IMJM,J3(1,IG1),NOM,B2(1),MMJM,B4(1),
                1MMIM,1)
ISN 00015   1236 CONTINUE
ISN 00016   1237 RETURN
ISN 00017        END
```

```
ISN 00001        SUBROUTINE TPXF(NFLUX,NFLUX1,N2,J3,B2,B4,UF,IGRP,FO,FN,N20,J30,
                1 B20,B40,FI,FJ,ICF,IUCF,IK,JK,IKJK,NOM,NOMA,IEDIT,NOUT,NPSO,A)
ISN 00002        COMMON/COPYBU/X(1),LIMX,LBEGIN,LFP,LE,LIGRP,LFN,LFO,LN20,LJ30,
                1 LB20,LB40,LSP,L1,L2,L3,L4,L5,L6,LAST,IA04,IA03,     NOMI,NOMAI,
                2 IB01,IB02,IB03,IB04,JZ1,JZ2,ML,IMK,JMK,IMJMK,IGMA,MMJKI,MMIKI,
                3 IFLUX,IGMI,IA03I,IA04I,ISRCE,IGIXS,DUMBU(4)
ISN 00003        DIMENSION A(1)
ISN 00004        DIMENSION N2(1),J3(IKJK,1),B2(1),B4(1),IGRP(1),FO(1),FN(1),N20(1),
                1 J30(IKJK,1),B20(1),B40(1),FI(IK,1),FJ(JK,1),UF(1),QO(1)
ISN 00005        REAL N2,N20,J3,J30
           C
ISN 00006        IF(ICF.EQ.3)                GO  TO  11
ISN 00007        REWIND  IFLUX
ISN 00008        CALL  WANDRO(IFLUX,2)          this statement is inserted
ISN 00009     11 CONTINUE
ISN 00010        REWIND NFLUX1
ISN 00011        MMJK=IA04*JMK
ISN 00012        MMIK=IA04*IMK
ISN 00013        IF(IUCF.GT.0) CALL WANDRO(NPSO,IGMA)
ISN 00014        DO 12 I=1,IGMA
ISN 00015     12 IF(IGRP(I).LE.0) IGRP(I)=I
           C****** SEARCH FOR FLUX GROUP TO USE ******
ISN 00016        IGOT=0
ISN 00017        DO 100 IIG=1,IGMA
ISN 00018        IGRO=IGRP(IIG)
ISN 00019     80 IF(IGRO.EQ.IGOT) GO TO 90
ISN 00020        IGOT=IGOT+1
```

Fig.2.4.2 Modification of Subroutines OUTER, TPSAVE, TPXF of the DOT-3.5 Code for the Data Transmission to APPLE-2 (Continued)

```
C **      ENERGY WIDTH
        EDELTA = EPREV-E(IEP)
C **      LETHARGY
        RATIOE = EPREV/E(IEP)
        UDELTA = ALOG(RATIOE)
        EPREV  = E(IEP)
  1980  CONTINUE
        DO 1977 I=ID11,ID12,NE
        IF(NFOUT)    1977,1982,1983
C1982  E(I)    = E(I)*EDELTA
  1982  E(I)    = E(I)*EDELTA*FACTR
        GO  TO  1977
  1983  E(I)    = E(I)*EDELTA/UDELTA
  1977  CONTINUE
        WRITE (IO,1070)          (E(I),I=ID11,ID12,NE)
  1070  FORMAT (17X,1P10E10.3)
        DO    1978 I=ID11,ID12,NE
        IF(NFOUT)    1978,1984,1985
  1984  E(I)    = E(I)/EDELTA/FACTR
C1984  E(I)    = E(I)/EDELTA
        GO  TO  1978
  1985  E(I)    = E(I)/EDELTA*UDELTA
  1978  CONTINUE
C * *  OUTPUT FOR FLUX * * *
        J         = ID1
        DO    2030  I=ID11,ID12,NE
        FNE(IE,J) = E(I)
        J         = J+1
  2030  CONTINUE
        ID11      = ID11 + NEND
        ID12      = ID12 + NEND
        WRITE (IO,1080) (E(I),I=ID11,ID12,NE)
  1080  FORMAT (17X,10(F9.3,1X))
        J         = ID1
        DO    2040  I=ID11,ID12,NE
        FSD(IE,J) = E(I)
        J         = J+1
  2040  CONTINUE
        ENE(IE) = E(IEP)
   205  WRITE (IO,1090) E(IEP)
  1090  FORMAT (1X,1PE11.3)
-------------------------------------------------------------------
C * *  PUNCH OUT ENERGY BOUNDARIES * *
        NFX       = 10
        REWIND    NFX
        WRITE(NFX)           NNE,NE,ND
        WRITE(NFX)            EFIRST,EGTOP,(ENE(IE),IE=1,NE)
        DO    2050  ID=1,ND
        WRITE(NFX)           (FNE(IE,ID),IE=1,NE)
        WRITE(NFX)           (FSD(IE,ID),IE=1,NE)
  2050  CONTINUE
        ENDFILE   NFX
        REWIND    NFX
-------------------------------------------------------------------
  2010  FORMAT(12I6)
  2020  FORMAT(6E12.5)
   210  IF (NT)     375,375,215
   215  NRM       = (NRESP-1)/10 + 1
        NTM       = (NT-1)/17 + 1
        IHP       = IH1
C   *   *  OUTPUT SQT AND SQT2 IN THE FOLLOWING LOOP
        DO   275   I=1,ND
        DO   275   INR=1,NRM
        IR1       = (INR-1)*10 + 1
        IF (INR-NRM)      220,225,225
   220  IR2       = IR1 + 9
        GO   TO   230
   225  IR2       = NRESP
   230  DO   275   INT=1,NTM
        IST       = LOCQTE - 19
        WRITE (IO,1100)   IHP,I,(NUMB(IPR),IPR=IST,LOCQTE)
  1100  FORMAT (A1,11HDETECTOR NO,I3,5X,32HRESPONSE(RESPONSE,TIME,DETECTOR
       1),1X,20A4)
        IF (NT-8)        235,235,240
   235  IHP       = IH2
   240  IT1       = (INT-1)*17 + 1
        IF (INT-NTM) 245,250,250
   245  IT2       = IT1 + 16
        GO   TO   255
   250  IT2       = NT
   255  IF (INT-1)       260,260,265
   260  AGS       = E(LOCXD + 4*ND + I)
        GO   TO   270
   265  ISUB      = LOCT + (I-1)*NT + IT1 - 1
        AGS       = E(ISUB)
   270  WRITE (IO,1110) (IR,IR=IR1,IR2)
  1110  FORMAT (4X,9H RESPONSE,10I10)
```

these cards are inserted

Fig.2.4.3 Modification of Subroutine NRUN of the MORSE Code for the Data Transmission to APPLE-2

```
ISN 00001          SUBROUTINE SUMARY(XKI,FD,XN,  VE,W,DSN,MA,MZ,CRX,Q,PA,DF,I2,CA,CF,ANS30040
                  1CT,CS,V,AA,TAB,WD,XND,FXS,FIS,SNN,SFS,OTS,APS,FRT,TXN,DEN,RFL,RCT,ANS30050
                  2RLK,XLL,XLK,XBB,RXN,IG1,I1,IH1,IGM1,M1,IM1)                        ANS30060
              C   *** SUMARY PRINTS ANGULAR FLUXES AND COMPUTES SUMMARY TABLES         ANS30070
ISN 00002          DIMENSION XKI(1),FD(1),XN(I1,1),      VE(1),W(1),DSN(1),MA(1),MZ(1)ANS30080
                  1,CRX(IH1,IGM1,1),Q(I1,1),PA(M1,IM1,1),DF(1),CA(1),CF(1),CT(1),     ANS30090
                  2 CS(1),V(1),AA(1),TAB(1),WD(1),XND(I2,1),FXS(IG1,1),FIS(IG1,1),    ANS30100
                  3 SNN(IG1,1),SFS(IG1,1),OTS(IG1,1),APS(IG1,1),XLK(IG1,1),XBB(IG1,1)ANS30110
                  4,RXN(IG1,1),RFL(IG1,1),RCT(IG1,1),RLK(IG1,1),XLL(IG1,1),FRT(IG1,1)ANS30120
                  5,TXN(IG1,1),DEN(IG1,1)                                             ANS30130
                                                                                      ANS30140
ISN 00003          COMMON /BULKBU/
                  *        D(1),LIM1,LXKI,LFD,LXN,LR,LVE,LW,LDSN,LMA,LMZ,LMB,LMC,LXMD,ANS30150
                  1LMTT,LCRX,LFIX,LFLT,LQ,LPA,LJ5,LRM,LDF,LJ3,LJ4,LIGT,LART,LALFT,    ANS30160
                  2LFGP,LFGG,LEND,LV,LAA,LWD,LMR,LPNC,LXJ,LCH,LCA,LCF,LCT,LCS,LTAB,   ANS30170
                  3LXND,LSA,LSAT,LRAV,LRA,LXNN,LXNE,LXNR,LXNA,LSR,LST,LQG,LFG,LSG,    ANS30180
                  4LXKE,LXNI,LXNO,LT3,LT5,LDA,LDB,LDC,LDS,LB,IGMP,IGMM,IIGG,NERR,IMJTANS30190
                  5,IHG,IMP,MP,NDS,NUS,SDG,SCG,AG,XNLGG,XNLG,SNG,ALA,ASR,EAM,EPG,EQ, ANS30200
                  6E1,E2,E3,E4,E5,E6,E7,E8,E9,E10,E11,E12,E13,E14,E15,E16,E17,E18,E19ANS30210
                  7,E20,ESC,ESM,EVP,EVPP,FTP,IC,ICVT,IGP,IG,IHP,IIC,IIG,IP,IZP,IO1,   ANS30220
                  8IO2,IO3,IO4,IO5,IO6,IO7,IO8,IO9,IO0,JT,LC,MG,MI,ML,MM,NFN,XITR,    ANS30230
                  9XLAP,XLAPP,XLAR,XLA,XNIO,XNII,ZZ1,ZZ2,ZZ3,XNB,XKEP,XKIP,IH,I,K,L, ANS30240
                  AM,J,N,NN,ISV,                                                      ANS30250
                  BID,ITH,ISCT,ISN,IGE,IBL,IBR,IZM,IM,IEVT,IGM,IHT,IHS,IHM,MS,MCR,MTPANS30260
                  C,MT,IDFM,IPVT,IQM,IPM,IPP,IIM,ID1,ID2,ID3,ID4,ICM,IDAT1,IDAT2,IFG,ANS30270
                  DIFLU,IFN,IPRT,IXTR,                                                ANS30280
                  EEV,EVM,EPS,BF,DY,DZ,DFM1,XNF,PV,RYF,XLAL,XLAH,EQL,XNPM,            ANS30290
                  FT(12),NIN,NOU,NT1,NT2,NT3,NT4,NT5,NT6,NT7                          ANS30300
ISN 00004          COMMON/NEWOP1/ IIBOUD,IISPTM,IIANLL,NNNXNN(4),YGRENE(101),         ANS30301
                  *               NOANNO,NOANLL(10),AWSEDR(21)                        ANS30302
ISN 00005          COMMON/NEWOP2/ XNXNXN(30000)                                       ANS30303
               ---------------------------------------------------------------------------  ↑
ISN 00006            IF(ID1.GE.0.OR.ID1.EQ.-2) GO TO 80
ISN 00007          NTX=11                                                    these cards are
ISN 00008          REWIND NTX
ISN 00009          WRITE(6,2220)                                             inserted
ISN 00010     2220 FORMAT(1H1)                                                              ↓
ISN 00011       80 CONTINUE
               ---------------------------------------------------------------------------
                                                                                      ANS30310
ISN 00012          DO 1 IIG=1,IGM                                                     ANS30320
ISN 00013          IIGG=IIG                                                           ANS30330
ISN 00014          READ (NT4)((XND(I,M),I=1,IP),M=1,MM)
               ---------------------------------------------------------------------------  ↑
ISN 00015            IF(ID1.GE.0.OR.ID1.EQ.-2) GO TO 81
ISN 00016          WRITE(NTX)((XND(I,M),I=1,IP),M=1,MM)                      these cards are
ISN 00017          WRITE(6,2222) IIG,NTX,IP,MM
ISN 00018     2222 FORMAT(1H ,5X,'GRP.',I4,'  ANGULAR FLUX WAS WRITTEN ON MT=',I3,5X,  inserted
                 *  '( MESH POINTS =',I4,3X,'DIRECTIONS =',I3,' )')
ISN 00019          GO TO 2                                                                  ↓
ISN 00020       81 CONTINUE
               ---------------------------------------------------------------------------
              C    IF(ID1.EQ.0 .OR. ID1.EQ.2)GO TO 2                                 ANS30340
ISN 00021          IF(ID1.LE.0 .OR. ID1.EQ.2)GO TO 2                                 ANS30350
              C   *** PRINT ANGULAR FLUX                                              ANS30351
ISN 00022          IF(IIG.NE.1)  GO TO 3333                                           ANS30360
ISN 00023          WRITE (NOU,10)IIG                                                  ANS30361
ISN 00024          GO TO 3334                                                         ANS30362
ISN 00025     3333 CONTINUE                                                           ANS30363
ISN 00026          WRITE(NOU,3335) IIG                                                ANS30364
ISN 00027     3335 FORMAT(/////,1X,' FLUX BY ANGLE AND POINT FOR GROUP   ',I3)        ANS30365
ISN 00028     3334 CONTINUE                                                           ANS30370
ISN 00029       10 FORMAT(37H1 FLUX BY ANGLE AND POINT FOR GROUP  I3)                 ANS30371
ISN 00030          IF(IIANLL.EQ.1) GO TO 4444                                         ANS30380
ISN 00031          CALL WOT(XND,MM,IP,1,'PNT.','ANGL',0)                              ANS30381
ISN 00032          GO TO 4445                                                         ANS30382
ISN 00033     4444 CONTINUE                                                           ANS30383
ISN 00034          CALL  NWSUB3(XND,IP,MM,XNXNXN)                                     ANS30384
ISN 00035     4445 CONTINUE                                                           ANS30390
ISN 00036        2 IF(IDAT1.EQ.0)GO TO 3                                              ANS30400
ISN 00037          IIGG=1                                                             ANS30410
ISN 00038          READ (NT3) ((CRX(IH,1,M),IH=1,IHP),M=1,MT)                         ANS30420
ISN 00039          IO1=MP*IMP                                                         ANS30430
ISN 00040          IF(IEVT.EQ.0)READ (NT3) (Q(I,1),I=1,IO1)                           ANS30440
              C   *** COMPUTE SUMMARY TABLES                                          ANS30450
ISN 00041        3 IH=IHM                                                             ANS30460
ISN 00042        4 K=IIG+IHS-IH                                                       ANS30470
ISN 00043          IF(K.LE.0)GO TO 5                                                  ANS30480
ISN 00044          IF(K.GT.IGM)GO TO 6                                                ANS30490
ISN 00045          IF(IDAT1.NE.2)GO TO 7                                              ANS30500
ISN 00046          K=1                                                                ANS30510
ISN 00047          READ (NT1) (XN(I,1),I=1,IM)                                        ANS30520
ISN 00048          IF(ISCT.GT.0)READ (NT1)                                            ANS30530
ISN 00049        7 DO 8 I=1,IM                                                        ANS30540
ISN 00050          J=MA(I)                                                            ANS30550
ISN 00051          L=IABS(MZ(J))                                                      ANS30560
ISN 00052          J=MINO(J,IZM)                                                      ANS30570
ISN 00053          E4=V(I)                                                            ANS30580
ISN 00054          IF(IDFM.GT.0)E4=E4*DF(I)                                           ANS30590
ISN 00055          IF(IH.NE.IHS)GO TO 39
```

Fig.2.4.4 Modification of Subroutine SUMARY of the ANISN Code for Angular Flux Data Transmission

2.5.3 Input Notes and Descriptions

(a) Overview plot of scalar neutron flux

The overview plot mentioned here is the graph of spatial distribution of neutron spectra. For the overview plot, IDENT = FLUX and SPEC input data are necessary. The Z-axis corresponds to values of neutron flux (in log scale), X-axis corresponds to energy (log scale) and Y-axis corresponds to position (linear scale). Origin of the coordinate system will be at the point corresponding to the lowest energy and first mesh point.

As shown in Fig.2.4.5, the angle between Z-axis and the viewpoint vector is THETA and the rotation angle of the plane including viewpoint vector around from the X-axis towards the Y-axis is PSI. For example, if THETA = 0°, the overview from Z-axis direction will be given. By changing the value of PSI, the position of origin, X-axis and Y-axis may be changed. VIEWPT is the distance of the viewpoint from the origin. Suggested values are THETA = 45.0, PSI = 45.0 and VIEWPT = 1000.0.

When the plotting machine allows the exchange of the colour of the pen, pen No.1 (black pen) draws hidden parts of the overview, pen No.2 (red pen) the surface, and pen No.3 (blue pen) the frame and contour lines.

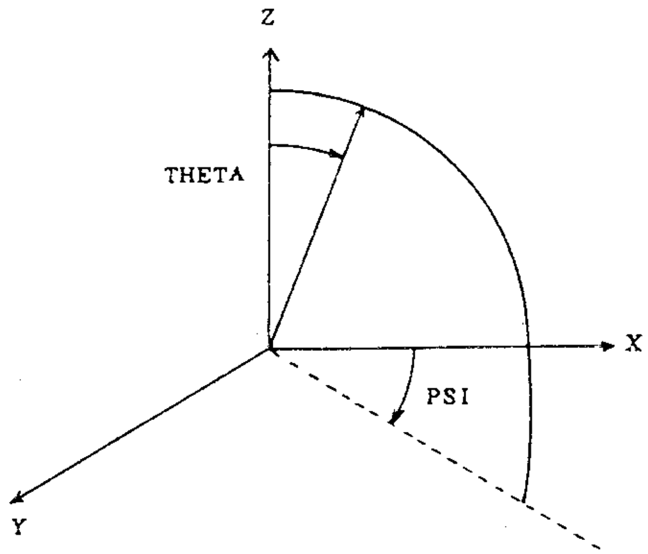


Fig.2.4.5 Angles for Overview Plotting

(b) Calculation and plotting of reaction rates

Reaction rates for each interval, zone and for the whole system are calculated. The plot symbol of reaction rate is given at the midpoint of each interval and the plotted symbols are connected by straight line. The points may be connected by smooth curve by changing NTRA specified in SUBROUTINE MPLOT1 to a positive value.

For the plotting of reaction rates, IDENT = FLUX, CROS, RCAL, RPLT data are required. By repeating IDENT = RCAL input data, any number of reaction rates for different neutron fluxes with same number of energy groups and same number of mesh points, may be plotted on a graph.

The implication of IDENT = CROS data for reading cross section input and making mixing table and IDENT = RCAL data for reaction rate plotting is quite similar to their counter-parts in ANISN. There are following options for choosing the material numbers ID22 for reaction-rates calculations which are input as 22¥ data of IDENT = RCAL.

(i) ID22 > 0,

(a) ID22 ≤ MCR, i.e. when ID22 is equal to one of the component numbers input as 11$ data, the reaction rate for the component element (nuclide)

$$R_i^m = \sum_g \sigma_g^m N^m \phi_{gi}$$

is calculated and plotted. Here,

g ; energy group number,

m ; element number,

i ; spatial mesh number,

σ ; microscopic cross section (14 * data),

N ; atom density (12 * data),

ϕ ; neutron flux.

(b) ID22 > MCR, i.e. when ID22 is equal to one of the mixture number specified as 10¥ data, the reaction rate of the mixture

$$R_i = \sum_m \sum_g \sigma_g^m N^m \phi_{gi}$$

is calculated and plotted.

(ii) ID22 < 0,

$$R_i^m = \sum_g \sigma_g^m \phi_{gi}$$

is calculated and plotted. In this case, $N^m = 1.0$ so that cross section input (14 * data) may be macroscopic.

(c) Restrictions

Variable dimensioning is employed in APPLE. There is no practical limitation in the number of reaction rates to be calculated and plotted on a graph, but a same type of plot symbol will appear for every 17th reaction rate curves.

If a problem requiring larger core size than 50 kW is to be solved, two cards in the FTMAIN routine of APPLE specifying blank common requirements should be changed:

```
COMMON   D(XXXXX)
  LIMM = XXXXX
```

2.6 Output Descriptions

Most of the output list from the APPLE-2 code is self evident and does not need particular explanation. The output are summarized as follows:

(i) List of the input cards.

(ii) Input data are rearranged and explained in more detail. Such as the meaning of the input parameters are described or the zone map is printed for the DOT flux processing.

When a response function library is used, the content list of the library is printed.

(iii) Reaction rate distribution along the specified axial or radial direction and the region integrated values of reaction rate is printed.

(iv) Neutron or gamma ray spectra value to be plotted are listed.

A sample of output listing is shown in Fig.4.3.6.

3. Response Function Libraries for Fusion Reactor Calculations

The nuclear characteristic values required in fusion reactor design are mostly in the form of reaction rate, i.e. the product of neutron or gamma ray flux and response function integrated over energy, or the volume integrated reaction rates.

The four libraries of response functions for fusion reactor calculations provided for the use with the APPLE-2 code are introduced in this Section. The record format of the libraries has been described in 2.4.2(e).

3.1 XS63 Library

This library is in the 42-group netron, 21-group gamma ray energy group structure so that it may be used with the GICX40 cross section set[9]. The group structures of the GICX40 set are given in Tables A.1.1 and A.1.2. The following 17 response functions are stored in this order.

1. Response to obtain 14 MeV neutron flux ($n \cdot cm^{-2} \cdot s^{-1}$)
2. Response to obtain neutron flux with energy greater than 0.1 MeV ($n \cdot cm^{-2} \cdot s^{-1}$)
3. Response to obtain total neutron flux ($n \cdot cm^{-2} \cdot s^{-1}$)
4. Response to obtain total gamma ray flux ($\gamma \cdot cm^{-2} \cdot s^{-1}$)
5. $^{6}Li(n,\alpha)t$ reaction cross section (barn)
6. $^{7}Li(n,n'\alpha)t$ reaction cross section (barn)
7. Displacement damage cross section of SS-316 ($10^{-24} \cdot dpa$)
8. Displacement damage cross section of copper ($10^{-24} \cdot dpa$)
9. Flux to dose conversion factor ($mrem \cdot h^{-1}$)
10. Neutron flux to dose conversion factor ($mrem \cdot h^{-1}$)
11. Gamma ray flux to dose conversion factor ($mR \cdot h^{-1}$)
12. ^{235}U fission cross section (barn)

13. ^{238}U fission cross section (barn)

14. ^{232}Th fission cross section (barn)

15. ^{237}Np fission cross section (barn)

16. $^{58}Ni(n,p)^{58}Co$ reaction cross section (barn)

17. $^{58}Fe(n,\gamma)^{59}Fe$ reaction cross section (barn)

The content of the library is listed in Appendix A.1. The XS63 library is used in the sample problem in 4.1.

3.2 GICXKRMA Library

This library provides kerma factors to be used with the GICX40 cross section set for the nuclear heating calculations. It has neutron and gamma ray kerma factors in 42-group and 21-group structures of the GICX40 set. It also has total kerma factors. Neutron, gamma ray and the total kerma factors are stored for each of the 40 nuclides included in the GICX40 set, in the same order as in the GICX40. The 40 nuclides are listed in Table A.2.1. A part of the library is listed in Appendix A.2. Its use is demonstrated in the sample problem 4.2.

3.3 GFLXDOSE Library

This library includes gamma ray flux to dose rate conversion factors in the 54 group structure (shown in Table A.3.1) of the GROUPIN gamma ray cross section set for decay gamma ray transport calculations. The GROUPIN cross section set is included in the THIDA code system[11] for induced activation calculations. This library is used to calculate and plot the dose rate as shown in the sample problem in 4.3. It is listed in Appendix A.3.

3.4 XS100 Library

The XS100 library includes fission cross sections of ^{235}U, ^{238}U, ^{232}Th and ^{237}Np, and two tritium producing reaction cross sections ^{6}Li(n,α)t and ^{7}Li(n,nα)t. The 100-group neutron energy group structure is the same as the DLC-2D cross section set[10], and is shown in Table A.4.1. This library is used in the analysis of integral experiments conducted in JAERI[5].

4. Sample Problems

Four sample problems are described in this section to demonstrate the versatile capabilities of the APPLE-2 code. They are characterized as follows:

4.1 Sample problem for ANISN flux using XS63 library

4.2 Sample problem for ANISN flux using GICXKRMA library

4.3 Sample problem for DOT flux using GFLXDOSE library

4.4 Sample problem for MORSE energy spectra plotting

4.1 Sample Problem 4.1 for ANISN Flux Using XS63 Library

The sample problem 4.1 gives various nuclear characteristic values, neutron and gamma ray spectra calculated in a simplified model of a fusion reactor shown in Fig.4.1.1. The infinite cylinder model includes a 100 cm radius plasma column surrounded by water layer 100 cm thick. The 14 MeV neutrons are generated uniformly in the plasma region. A 10 cm thick SS316 annulus is placed behind the water layer.

Neutron and gamma ray scalar fluxes in the calculational model were calculated by the ANISN code(2) using the 42-group neutron, 21-group gamma ray cross section set GICX40(9). The scalar fluxes and other relevant data were written on a disk file (or a magnetic tape) by the modified FINPR subroutine (see Fig.2.4.1) for the transmission to the APPLE-2 code.

The input data for this problem is listed in Fig.4.1.2. In the figure, the fifth card shows that a response library containing 17 responses is read from the logical file 1. The XS63 library described in 3.1 is allocated to the logical file 1. The job control cards of this problem by the FACOM M-200 machine in JAERI is shown in Fig.4.1.3.

Operational dose rates, neutron and gamma ray fluxes, radiation damage rates and activation reaction rates in the model are calculated and plotted by the APPLE-2 code. All the results are normalized to unit neutron source. The plotted graphs are shown in Figs.4.1.4 ~ 4.1.6. Neutron and gamma ray energy spectra at three locations are plotted and shown in Figs.4.1.7 and 4.1.8. The overview plot of the neutron spectra is shown in Fig.4.1.9.

4.2 Sample Problem 4.2 for ANISN Flux Using GICXKRMA Library

The sample problem 4.2 gives epoxy dose rate and nuclear heating rate in the calculational model of Fig.4.1.1. Epoxy dose rate is the amount absorbed in an epoxy sample per one year if the sample is brought to the position. One 14 MeV neutron is assumed to be generated every second. Nuclear heating rate is given in the unit of $MeV \cdot cm^{-3} \cdot s^{-1}$.

The input cards for this problem is listed in Fig.4.2.1. The fifth card in the figure shows that a response library containing 40 cross section sets with three components in each set is read from the logical file 3. The GICXKRMA library described in 3.2 is assigned to the logical file 3. Therefore the mixing table begins from 41 in the 10¥¥ data. In the mixing table, the mixtures 41 and 44 corresponds to epoxy and water. Table A.2.1 shows the list of 40 nuclides in the GICXKRMA library which is the same as that of the GICX40 set.

Plotter output of operational dose rate and nuclear heating rate are shown in Figs.4.2.2 and 4.2.3, respectively.

4.3 Sample Problem 4.3 for DOT Flux Using GFLXDOSE Library

The sample problem 4.3 gives the activation dose rate distribution calculated in a disk geometry shown in Fig.4.3.1. The disk is made of lithium oxide (Li_2O) and stainless steel structure. The 14 MeV neutrons are generated from a point source located on the Z axis 20 cm from the disk.

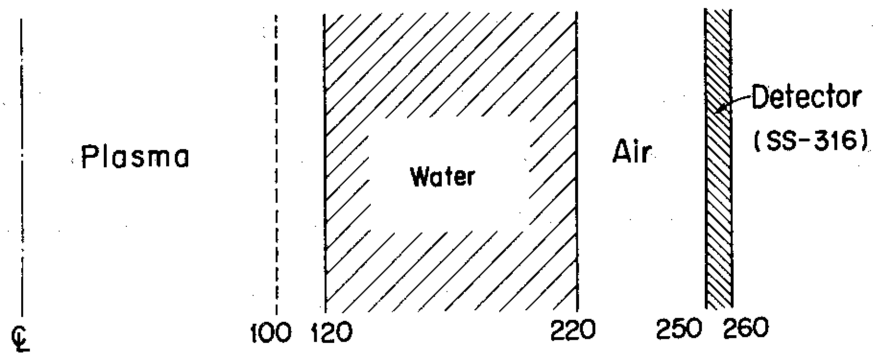
The gamma ray source 1 day after shutdown was obtained using the THIDA code system[11] for activation calculation. Using the source and the 54-Group gamma ray cross section set GROUPIN[11], the gamma ray flux is calculated by the DOT code[7] and stored in a disk file (or a magnetic tape) by the modified subroutines OUTER, TPSAVE and TPXF (see Fig.2.4.2) for the transmission to the APPLE-2 code.

The input data for this problem is listed in Fig.4.3.2. In the figure, the fifth card shows that a response library containing one response is read from the logical file 1, where the GFLXDOSE library described in 3.3 is allocated. The dose rate distribution is calculated and plotted. The dose rate is plotted in the axial direction along R = 13 cm (or the 7th radial mesh interval) and shown in Fig.4.3.3. The overview of the dose rate distribution is shown in Fig.4.3.4. The gamma ray spectra at Z = 23 cm and 39 cm along R = 13 cm are shown in Fig.4.3.5.

The output list for the sample problem 4.3 is given in Fig.4.3.6. The output list rewrites the input data with explanations. The zone map is shown in the second page of the output list. Reaction rates integrated over the whole system, zones and mesh intervals are given from the bottom of the second page of the output. Gamma ray spectra values are listed in the fourth page.

4.4 Sample problem 4.4 for MORSE Flux Energy Spectra Plotting

Neutron and gamma ray energy spectra at four locations calculated by the MORSE code are plotted in this sample. Energy group structure, group fluxes and fractional standard deviation (fsd) values were written by the modified NRUN subroutine of the MORSE code (see Fig.2.4.3). The APPLE-2 code reads these data from the logical file 10 as shown in the second card of the input data list in Fig.4.4.1. The NON value in the IDENT = FLUX card is 1 so the flux data are read from the logical file NON + 9 = 10. The neutron and gamma ray spectra at 4 locations are plotted and are given in Figs.4.4.2 and 4.4.3, respectively. In both figures, the flux values have error bars which denote the extent of statistical deviation (one fsd).



DISTANCE FROM THE PLASMA AXIS (cm)

Fig.4.1.1 A Simplified Model of a Fusion Reactor

```
                 *** APPLE INPUT DATA CARD IMAGE LIST ***
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
 OPERATIONAL DOSE RATE SAMPLE PROBLEM                          <APPLE2>  00000100
FLUX     1                                                               00000110
  1  0                                                                   00000200
CRDS     1                                                               00000300
  1 17 11  1                                                             00000400
10** 3R18 4R19 4R20                                                      00000500
11**  9 10 11   1  2  3  4   7  8 16 17                                  00000600
12** F1 T                                                                00000700
RCAL     1                                                               00000800
  1  1  3  1  1.0                                                        00000900
 9** F18                                                                 00001000
22** 9 10 11                                                             00001100
23** F1   T                                                              00001200
TOTAL    NEUTRON GAMMA                                                   00001300
RPLT     1                                                               00001400
  1                                                                      00001410
 15.0          20.0                                                      00001500
OPERATIONAL DOSE RATE (WATER)                                            00001600
DISTANCE FROM THE PLASMA AXIS (CM)                                       00001700
   MREM PER HOUR      PER  D-T NEUTRON                                   00001800
RCAL     2                                                               00001900
  1  1  4  1  1.0                                                        00002000
 9** F19                                                                 00002100
22** 1  2  3  4                                                          00002200
23** F1   T                                                              00002300
14MEV N..1MEV N.TOTAL N.TOTALGAM                                         00002400
RPLT     2                                                               00002500
  1                                                                      00002510
 15.0          20.0                                                      00002600
NEUTRON AND GAMMA RAY FLUXES (WATER)                                     00002700
DISTANCE FROM THE PLASMA AXIS (CM)                                       00002800
    NEUTRON AND GAMMA FLUX (PER CM**3 SEC)                               00002900
RCAL     3                                                               00003000
  1  1  4  1  1.0                                                        00003100
 9** F20                                                                 00003200
22** 7  8 16 17                                                          00003300
23** F1   T                                                              00003400
SS DPA  CU DPA  NI58NP  FE58NG                                           00003500
RPLT     3                                                               00003600
  1                                                                      00003610
 15.0          20.0                                                      00003700
RADIATION DAMAGE AND ACTIVATION (WATER)                                  00003800
DISTANCE FROM THE PLASMA AXIS (CM)                                       00003900
    DPA RATES AND REACTION RATES                                         00004000
SPEC     1                                                               00004100
  2  1  1 42  0  3                                                       00004200
  4 54105                                                                00004300
 15.0          20.0                                                      00004310
NEUTRON ENERGY SPECTRA (WATER)                                           00004500
     NEUTRON ENERGY (EV)                                                 00004600
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
```

```
                 *** APPLE INPUT DATA CARD IMAGE LIST ***
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
    NEUTRON FLUX PER UNIT LETHARGY                                       00004700
 R=120CM R=170CM R=250CM                                                 00004800
SPEC     2                                                               00004900
  2  1  1-21  0  3                                                       00005000
  4 54105                                                                00005100
 15.0          20.0                                                      00005110
GAMMA    ENERGY SPECTRA (WATER)                                          00005300
      GAMMA    ENERGY (EV)                                               00005400
   GAMMA    FLUX PER UNIT LETHARGY                                       00005500
 R=120CM R=170CM R=250CM                                                 00005600
SPEC     3                                                               00005700
  3  1  1 42  0                                                          00005800
 -1  1 10  1  1  0  45.0        60.0          1000.0        20.0      25.000005900
 NEUTRON ENERGY SPECTRA (WATER)                                          00006000
END      0                                                               00006100
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
```

Fig.4.1.2 Input Data List for Sample Problem 4.1

```
//JCLG JOB
// EXEC JCLG
//SYSIN DD DATA,DLM='++'
// JUSER XXXXXXXX,YA.SEKI,XXXX.XXX
 T.4W.1C.2I.3P.0     GRP OPN
  OPTP PASSWORD=XXXXXXXX
//*******************************************************************/
//*  APPLE: REACTION RATE OR ENERGY SPECTRA PLOTTING.               */
//*   READ FILE.                                                    */
//*    SCALAR FLUX FILE : ANISN OR DOT3.5 OR MORSE                  */
//*    REACTION RATE CROSS SECTION : XS63 OR XS100 OR GICXKRMA      */
//*                               J2372.APPLE.CNTL(APPLE)           */
//*******************************************************************/
//GO   EXEC LMGO,LM='J2372.APPLEPNL'
//FT06F001 DD  DCB=(BLKSIZE=137)
//  EXPAND  DISK,DDN=FT21F001
//  EXPAND  DISK,DDN=FT23F001
//  EXPAND  DISK,DDN=FT24F001
//  EXPAND  DISK,DDN=FT27F001
//  EXPAND  GRNLP,SYSOUT=H
//  EXPAND  DISKTO,DDN=FT10F001,DSN='J2372.SPTR03'
//  EXPAND  DISKTO,DDN=FT01F001,DSN='J2372.APPLE',Q='.DATA(XS63)'
//  EXPAND  DISKTO,DDN=FT02F001,DSN='J2372.APPLE',Q='.DATA(XS100)'
//  EXPAND DISKTO,DDN=FT03F001,DSN='J2372.GICXKRMA'
//  EXPAND  DISKTO,DDN=SYSIN,DSN='J2372.APPLE',Q='.DATA(SS316)'
++
//
```

Fig.4.1.3 List of Job Control Cards for Sample Problem 4.1

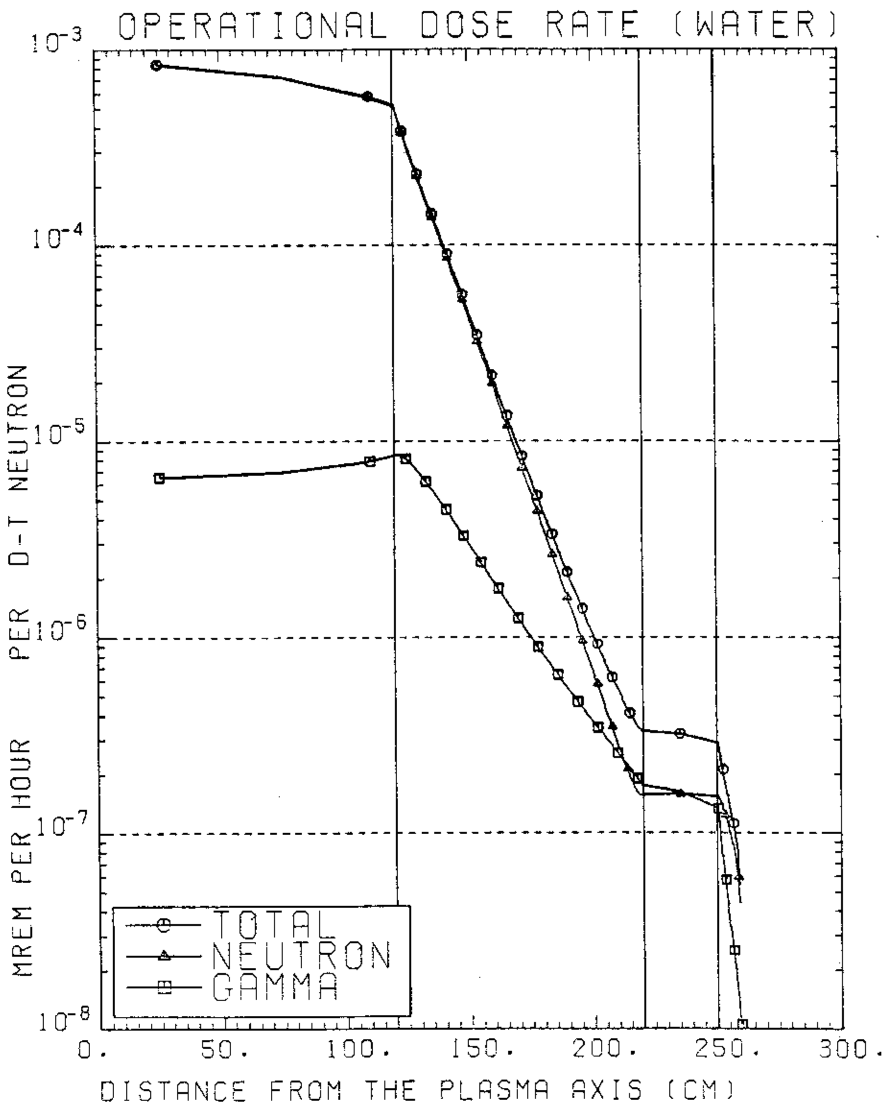


Fig.4.1.4 Plotter Output of Operational Dose Rate

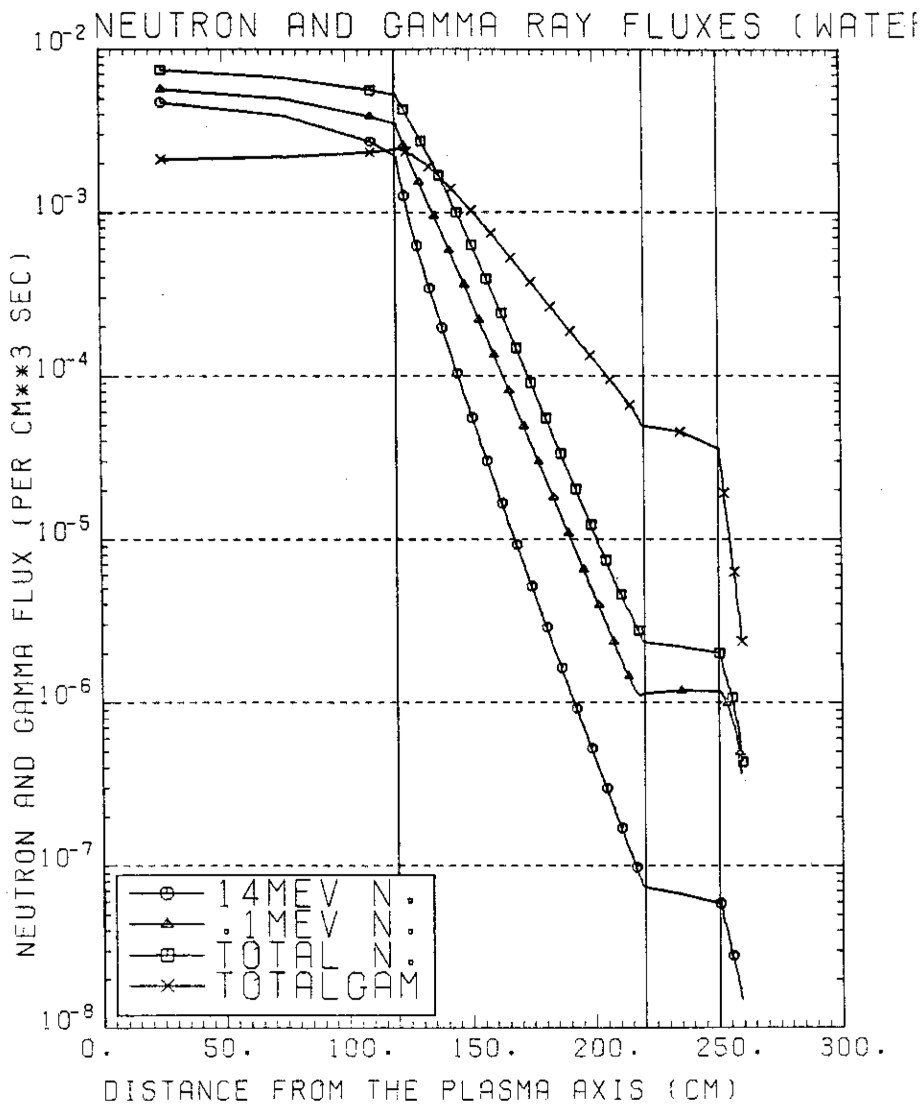


Fig.4.1.5 Plotter Output of Neutron and Gamma Ray Fluxes

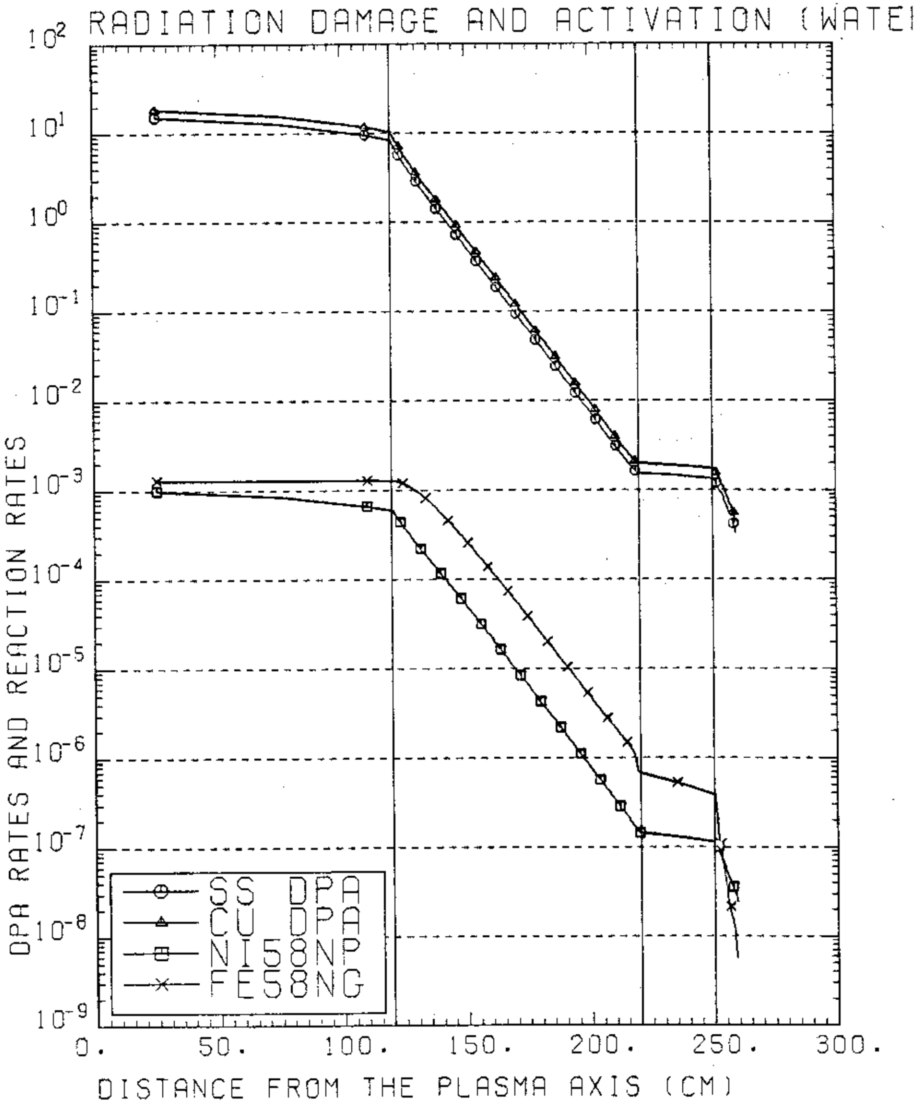


Fig.4.1.6 Plotter Output of Damage Rates and Activation Reaction Rates

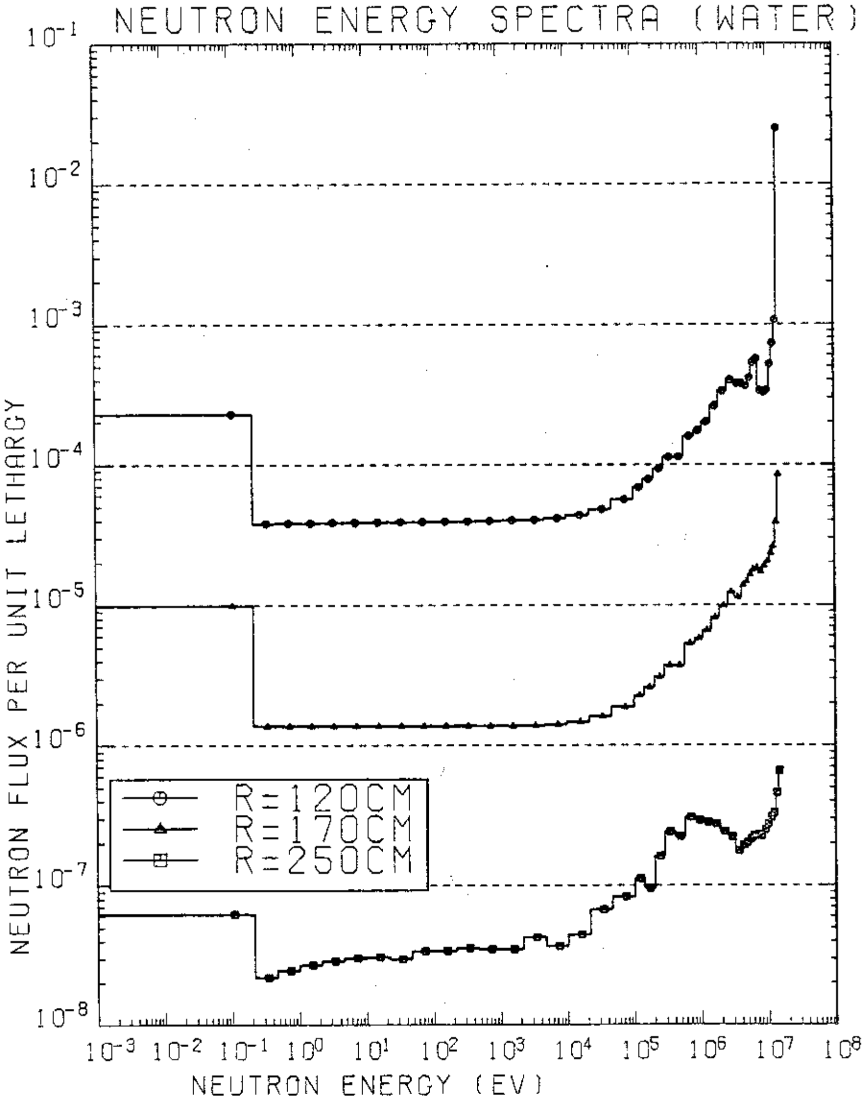


Fig.4.1.7 Plotter Output of Neutron Spectra at 3 Locations

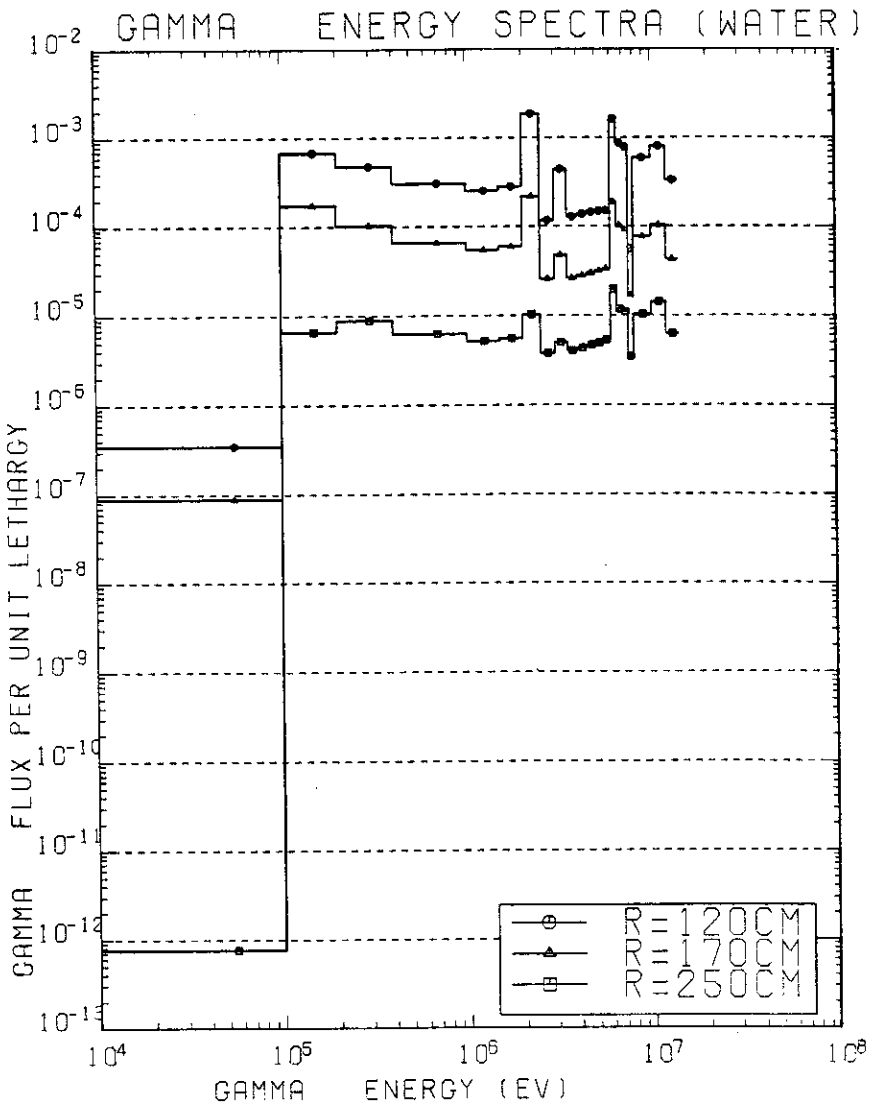


Fig.4.1.8 Plotter Output of Gamma Ray Spectra at 3 Locations

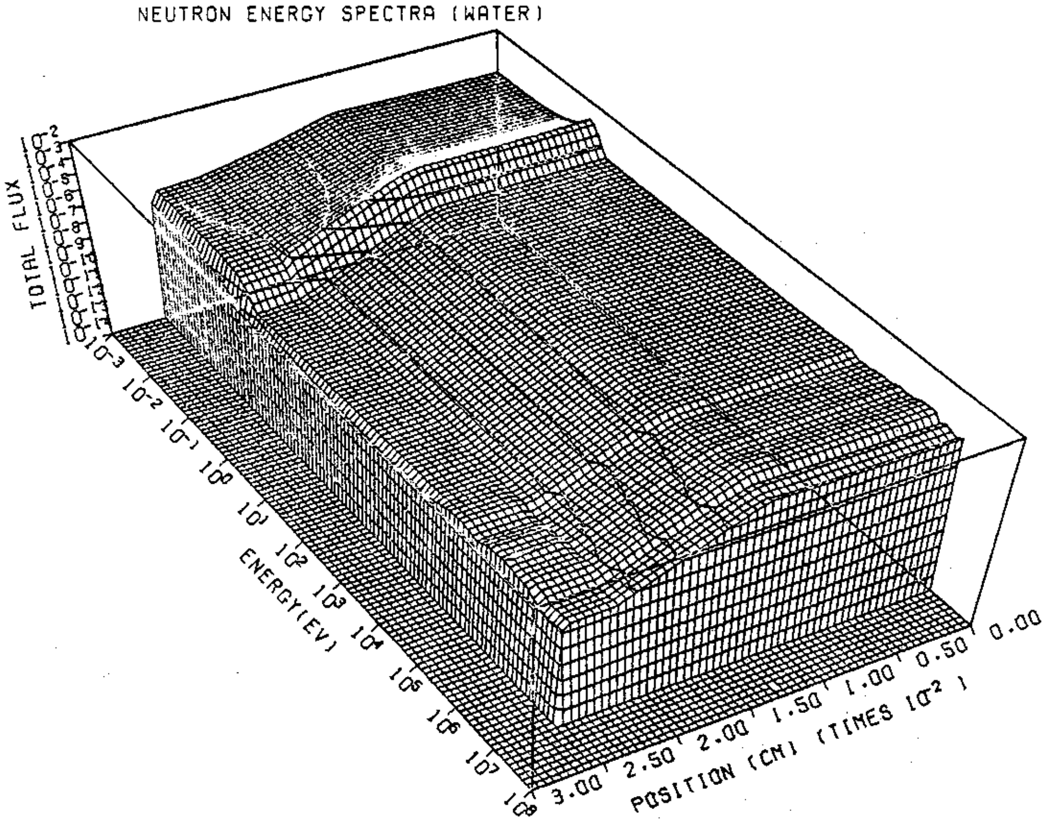


Fig.4.1.9 Overview Plot of Neutron Spectra

```
                    *** APPLE INPUT DATA CARD IMAGE LIST ***
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
  EPOXY DOSE RATE SAMPLE PROBLEM                               <APPLE2>        00000100
FLUX     1                                                                     00000110
  1  0                                                                         00000200
CROS     1                                                                     00000300
  3 40 26   3                                                                  00000400
10** 3R41 3R42 4R43 2R44 45 5R46 8R47                                          00000500
11** 3 4 11 1 2 4 7 8 9 10 4 11 20 4 11 17 27 43 3 4 10 11                     00000600
      17 25 27 39                                                              00000700
12** 3.65-2 7.3-3 4.745-2 5.118-3 6.385-2 3.448-2 1.255-3 1.575-2              00000800
9.848-3 5.909-2 3.35-2 6.7-2 3.296-2 3.391-2 1.331-2 3.031-3 2.394-3           00000810
0.4 6.02-6 4.57-2 7.05-4 1.40-2 3.29-3 5.63-4 2.57-3 1.44-2                    00000820
  T                                                                            00000900
RCAL     1                                                                     00001000
  1  1  3   1 0.50085                                                          00001100
9** F41                                                                        00001200
22** 3R41                                                                      00001300
23** 1 2 3                                                                     00001400
  T                                                                            00001500
NEUTRON GAMMA    TOTAL                                                         00001600
RPLT     1                                                                     00001601
  1                                                                            00001602
  15.0        20.0                                                             00001603
     EPOXY DOSE RATE (WATER)                                                   00001620
  DISTANCE FROM THE PLASMA AXIS (CM)                                           00001630
      DOSE RATE (RAD/YEAR/D-T NEUTRON)                                         00001640
RCAL     2                                                                     00001650
  1  1  6  1                                                                   00001800
9** 41 44 41 43                                                                00001900
22** 3R44 3R43                                                                 00002000
23** 1 2 3    103                                                              00002100
  T                                                                            00002200
NEUTRON GAMMA    TOTAL                                                         00002210
RPLT     2                                                                     00002310
  1                                                                            00003810
  15.0        20.0                                                             00003811
      NUCLEAR HEATING (WATER)                                                  00004000
  DISTANCE FROM THE PLASMA AXIS (CM)                                           00004100
      HEATING RATE (MEV/D-T NEUTRON)                                           00004200
END      0                                                                     00004800
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
```

Fig.4.2.1 Input Data List for Sample Problem 4.2

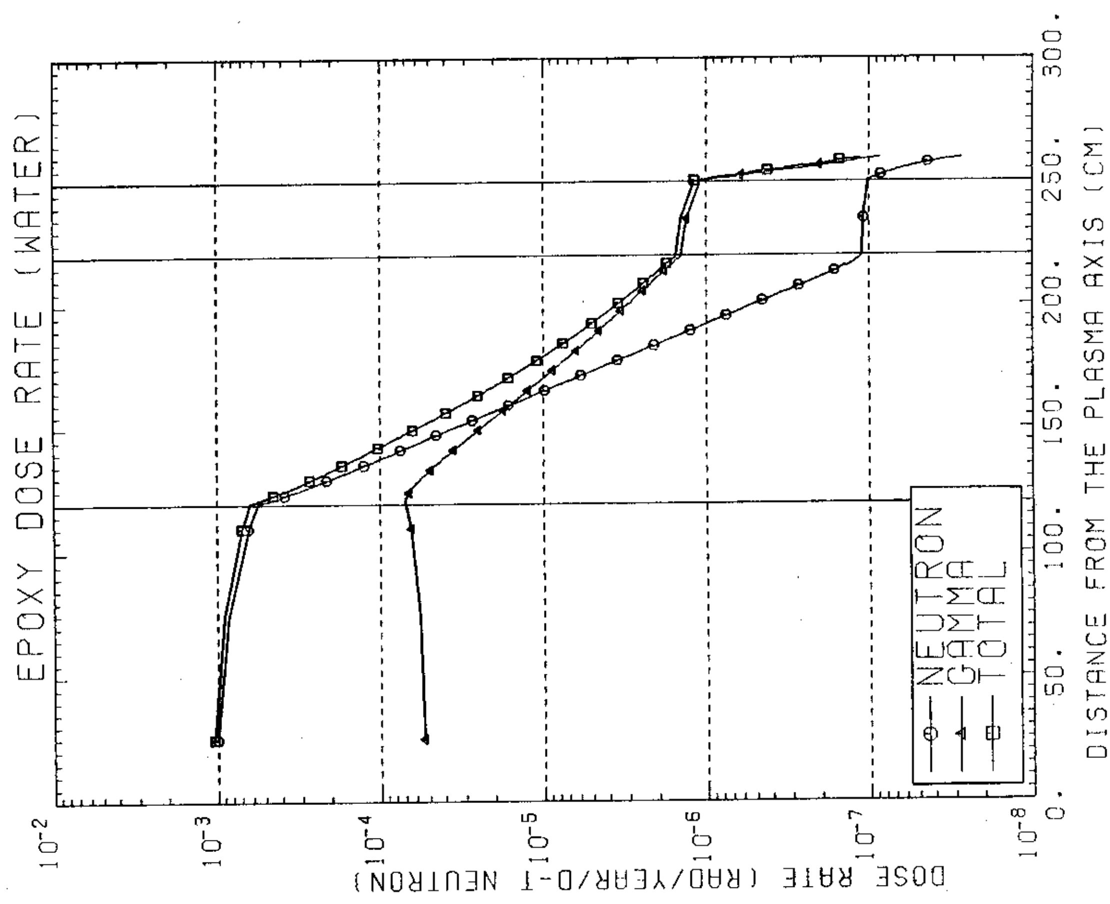


Fig.4.2.2 Plotter Output of Epoxy Dose Rate

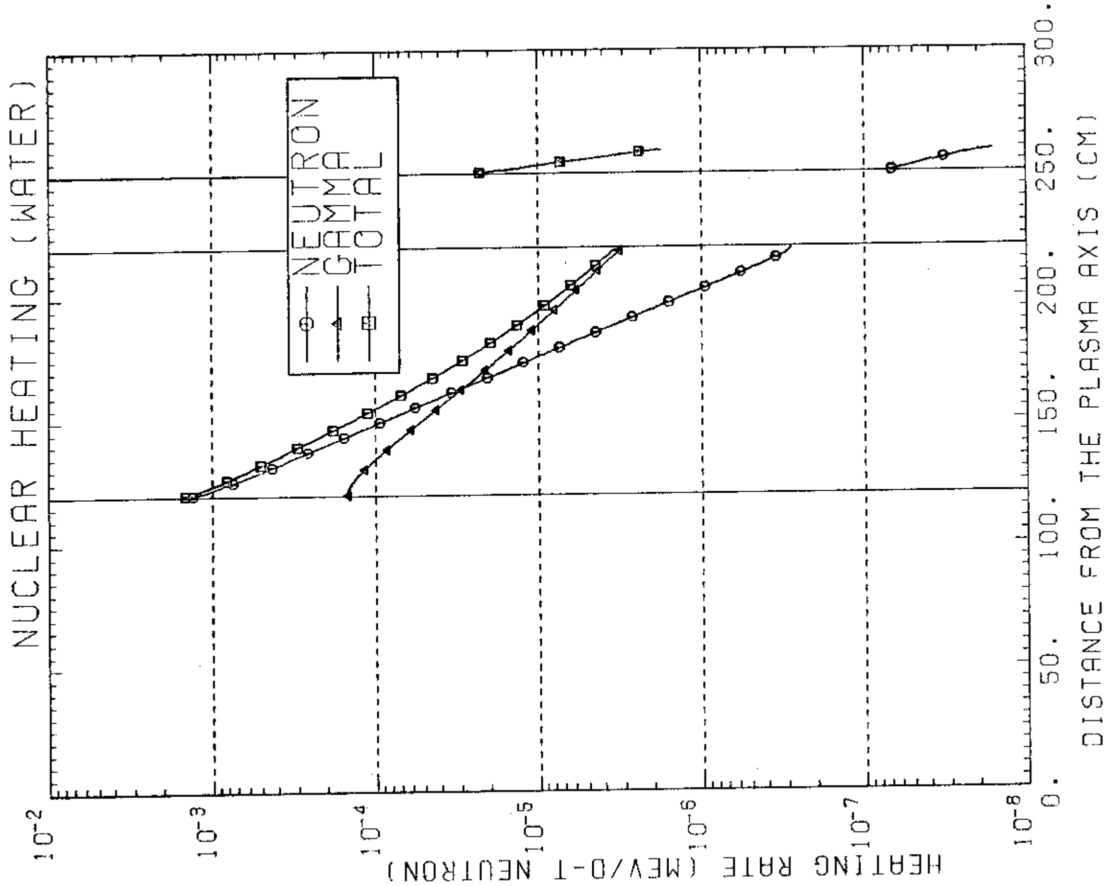


Fig.4.2.3 Plotter Output of Nuclear Heating Rate

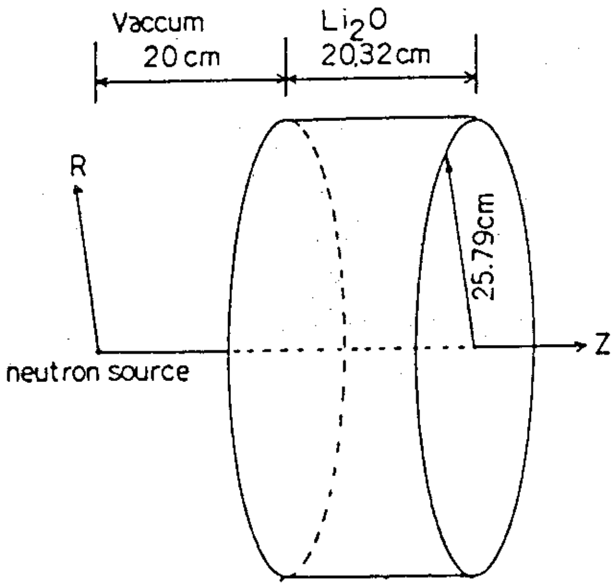


Fig.4.3.1 A Disk Model for Induced Activation Calculation

```
                      *** APPLE INPUT DATA CARD IMAGE LIST ***
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
  *LIU20 RZ - LI2020.32CM P5-S16  1ST SRC                  <APPLE2>      00000100
FLUX     1                                                               00000200
  2  1 1.0                                                               00000300
 54 13 12  2  1                                                          00000400
5**     0.0       0.25    9I20.0     40.0                                00000500
4** 12I0.0      25.79                                                    00000600
8**    39R1   117R2                                                      00000700
  T                                                                      00000800
CROS     1                                                               00000900
  1  1  1  1                                                             00001000
10**  1                                                                  00001100
11**  1                                                                  00001200
12** F1 T                                                                00001300
RCAL     1                                                               00001400
  1  1  1  1  0.0508                                                     00001500
 9** F1                                                                  00001600
22**  1                                                                  00001700
23** F1 T                                                                00001800
1 DAY                                                                    00001900
RPLT     1                                                               00002000
  2  7RADIAL                                                             00002100
 15.0          20.0                                                      00002200
  SHUTDOWN DOSE RATE  (R=13 CM)                                          00002300
DISTANCE FROM MID PLANE (CM)                                             00002400
       DOSE RATE (MREM/HOUR)                                             00002500
RPLT     1                                                               00002600
  3  1                                                                   00002700
 -1  1 10  1  1  0  45.0         60.0         10000.0      20.0       25.000002800
  SHUTDOWN DOSE RATE  (MREM/HOUR)                                        00002900
SPEC     1                                                               00003000
  2  1  1-54  0  2                                                       00003100
  7  2                                                                   00003200
  4 12                                                                   00003300
 15.0          20.0                                                      00003310
 GAMMA RAY  ENERGY SPECTRA (R=13 CM)                                     00003500
    GAMMA   ENERGY (EV)                                                  00003600
  GAMMA   FLUX PER UNIT LETHARGY                                         00003700
Z = 23CMZ = 39CM                                                         00003800
END      0                                                               00004400
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
```

Fig.4.3.2 Input Data List for Sample Problem 4.3

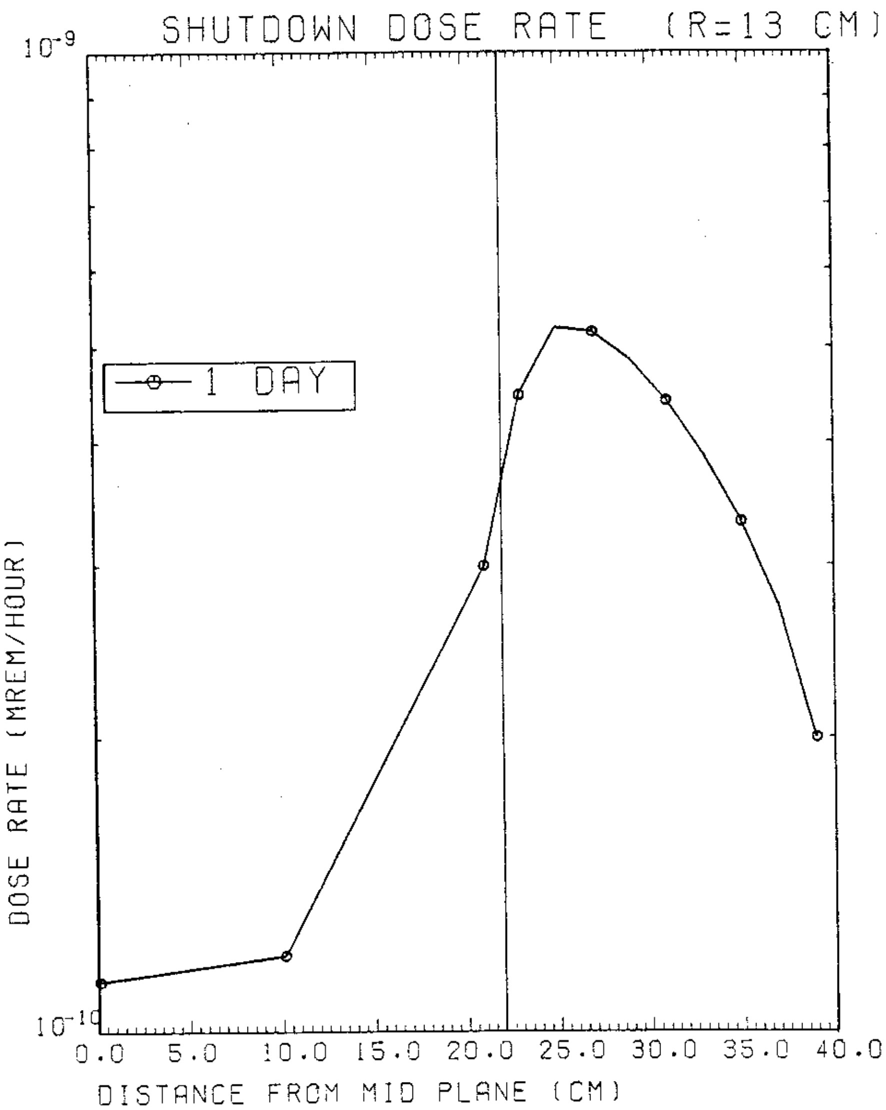


Fig.4.3.3 Plotter Output of the Axial Dose Rate Distribution Along R=13 cm

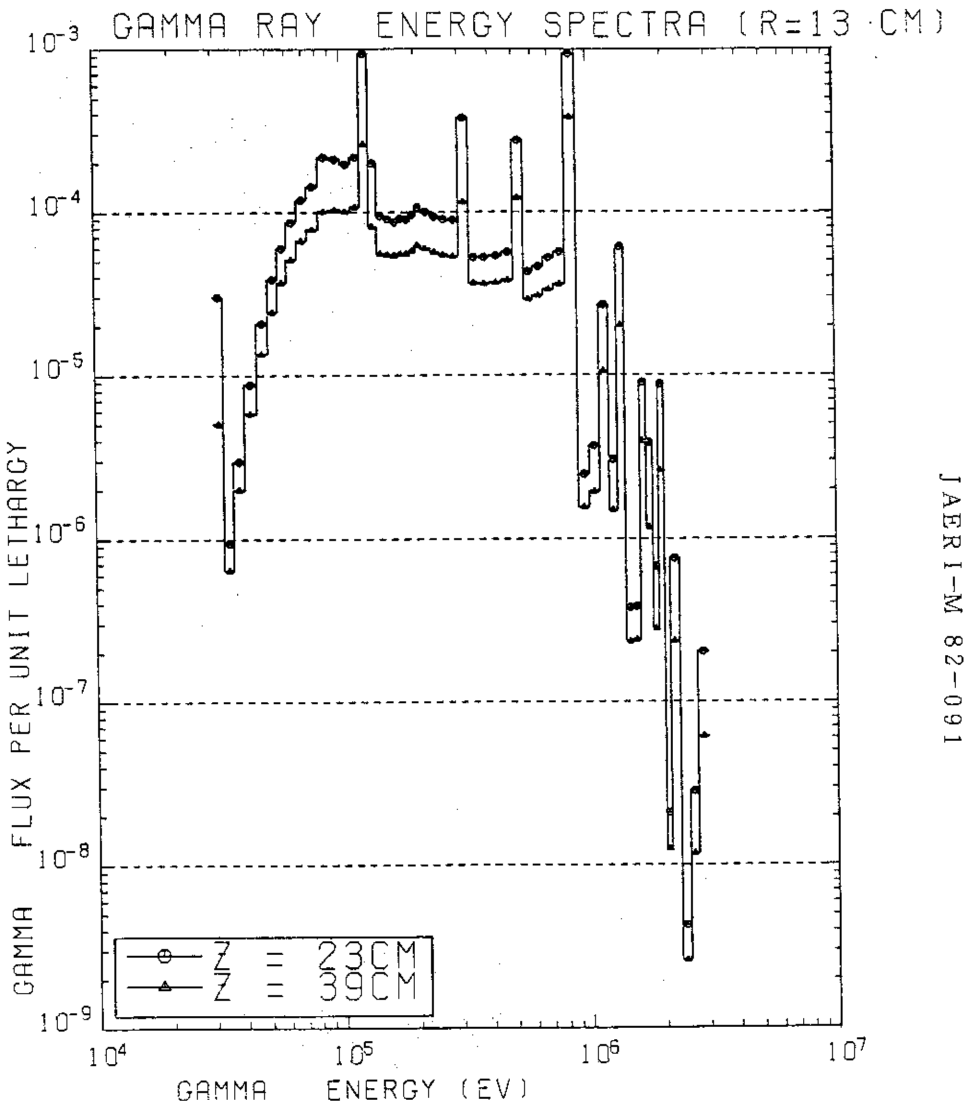


Fig.4.3.5 Plotter Output of Gamma Ray Spectra

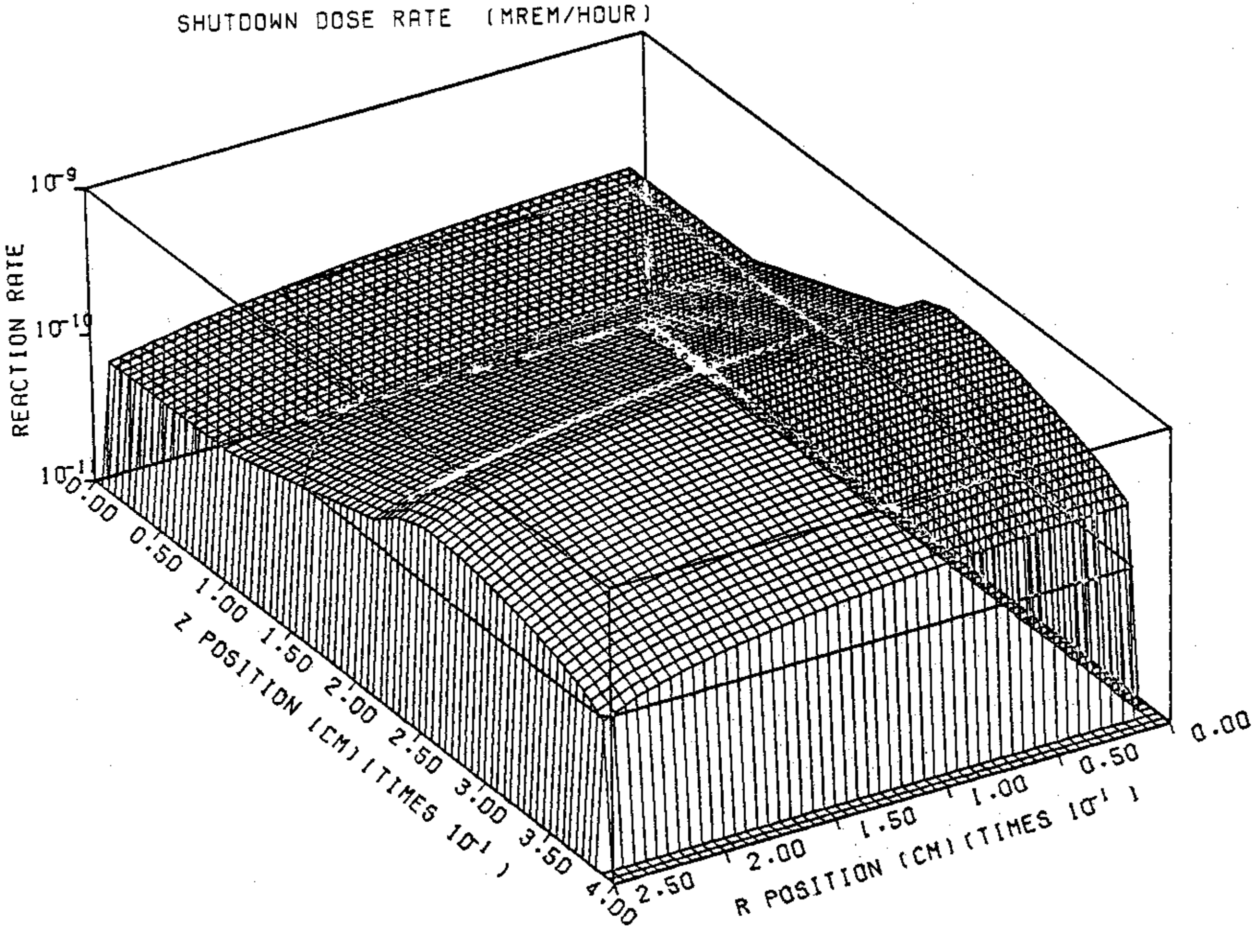


Fig.4.3.4 Overview Plot of Dose Rate Distribution

```
*LIU20 RZ - LI2020.32CM P5-S16  1ST SRC                                  <APPLE2>

READ IDENTIFICATION TYPE.FLUX   FILE  NO.    1

        SCALAR FLUX INPUT MODE
             1/ANISN 2/DOT3.5 3/MORSE                   2
             0/FILE  1/CARD GEOMETRICAL DATA            1
             NORMALIZATION FACTOR                  1.0000E+00

        SCALAR FLUX INPUT PARAMETER
             READ BY UNIT                              10
             NUMBER OF GROUPS                          54
             NUMBER OF RADIAL MESH INTERVAL            13
             NUMBER OF AXIAL  MESH INTERVAL            12
             NUMBER OF ZONE                             2
             NUMBER OF GEOMETRY TYPE                    5

   5* ARRAY      13 ENTRIES READ

   4* ARRAY      14 ENTRIES READ

   8* ARRAY     156 ENTRIES READ

   0T

    RADIAL MESH POINTS   (CM)
        0.0       1.984      3.968      5.952      7.935      9.919     11.903     13.887     15.871     17.855
       19.838    21.822     23.806     25.790

    AXIAL  MESH POINTS   (CM)
        0.0       0.250     20.000     22.000     24.000     26.000     28.000     30.000     32.000     34.000
       36.000    38.000     40.000

   UNCOLLIDED FLUX ZONE MAP - - -


   ZONE NUMBER BY INTERVAL

     12... 2222222222222
     11... 2222222222222
     10... 2222222222222
      9... 2222222222222
      8... 2222222222222
      7... 2222222222222
      6... 2222222222222
      5... 2222222222222
      4... 2222222222222
      3... 1111111111111
      2... 1111111111111
      1... 1111111111111
   YZT
       XPR 1234567890123
           0000000001111

   SYMBOL =  1  2

   NUMBER =   1  2

    READ IDENTIFICATION TYPE.CROS   FILE  NO.    1

      10* ARRAY       1 ENTRIES READ

      11* ARRAY       1 ENTRIES READ

      12* ARRAY       1 ENTRIES READ

      0T
   REACTION NO. 1   CONVERSION FACTOR FOR DOSE RATE (MREM/HOUR)

   14* ARRAY      54 ENTRIES READ

    0T
```

Fig.4.3.6 Output List of Sample Problem 4.3

```
READ IDENTIFICATION TYPE.RCAL    FILE  NO.     1

        NFX     FLUX NO.                        1
        NGE     GEOMETRY NO.                    1
        ID3     TABLE LENGTH                    1
        MOPT    PLOT OPTION                     1
        CF      CONVERSION FACTOR    5.08000E-02

    9* ARRAY        2 ENTRIES READ

   22* ARRAY        1 ENTRIES READ

   23* ARRAY        1 ENTRIES READ

    CT

MATERIAL NAME TABLE
        ACT.     1       1 DAY

TOTAL ACTIVITIES




        ACT.  1
    1  2.73943E-06

ACTIVITIES BY ZONE

  ZONE    ACT.  1
    1  8.32928E-07
    2  1.90742E-06

ACTIVITIES BY INTERVAL

Z-MESH     1    AXIAL     1.25000E-01

R-MESH RADI             1 DAY
    1  9.91921E-01  1.39024E-10
    2  2.97576E+00  1.35624E-10
    3  4.95961E+00  1.32264E-10
    4  6.94345E+00  1.28379E-10
    5  8.92729E+00  1.23815E-10
    6  1.09111E+01  1.18599E-10
    7  1.28950E+01  1.12711E-10
    8  1.48788E+01  1.06248E-10
    9  1.68627E+01  9.92610E-11
   10  1.88465E+01  9.18070E-11
   11  2.08303E+01  8.37607E-11
   12  2.28142E+01  7.37323E-11
   13  2.47980E+01  6.63736E-11
 READ IDENTIFICATION TYPE.RPLT    FILE  NO.     1


     REACTION RATE PLOT OPTION PARAMETERS
          NWAY   =     2
          NTRA   =     0
          LOGPO  =     2
          LINEIT =     1
          NLABEL =     0
          NSYMB  =     2
          ICENT  =     1

  MAIN TITLE(ARATE)   SHUTDOWN DOSE RATE  (R=13 CM)
  X     TITLE        DISTANCE FROM MID PLANE (CM)
  Y     TITLE                DOSE RATE (MREM/HOUR)

          MATERIAL NAME OF PLOT LINE
             1 1 DAY

     ZONE =      1    1    1    2    2    2    2    2    2    2
                 2    2

     ID23 =      1
```

Fig.4.3.6 Output List of Sample Problem 4.3 (continued)

```
   ZONEB=    2.2000E+01

READ IDENTIFICATION TYPE.RPLT    FILE  NO.    1

  OVERVIEW PLOTTING OF REACTION RATES OR SCALAR FLUXES
 MAIN TITLE                 SHUTDOWN DOSE RATE  (MREM/HOUR)
IDE     ELIMINATE HIDDEN LINES                                    -1
KROSS   Z-AXIS WILL BE PLACED CROSS-WISE                           1
LGRID   GRID PLOT OPTION                                          10
NFRAME  FRAME                                                      1
KOLOR   CHANGE COLOUR OF THE PEN                                   1
KONTR   THE RANGE OF PLOTTING (10**N-KONTR)                        0
THETA   ANGLE DOWN FROM THE Z-AXIS                            0.450E+02
PSI  ANGLE AROUND FROM THE X-AXIS TOWARDS THE Y-AXIS          0.600E+02
VIEWPT DISTANCE BETWEEN VIEWPOINT AND ORIGN                   0.100E+05
PWIDTH WIDTH OF THE PLOT                                      0.200E+02
PSIZE  LENGTH OF THE PLOT                                     0.250E+02


READ IDENTIFICATION TYPE.SPEC    FILE. NO.    1

   NEUTRON OR GAMMA ENERGY SPECTRA PLOTTING
 SPECTRA OPTION 2-D OR 3-D        2
 NUMBER OF SCALAR FLUX DATA       1
 NUMBER OF GEOMETRICAL DATA       1
 NEUTRON OR GAMMA GROUPS.       -54
 ENERGY GROUPS READ OPTION        0
 NUMBER OF 2-D MESH POINTS        2
 NUMBER OF GROUPS                    54
 NUMBER OF RADIAL MESH POINTS        13
 NUMBER OF AXIAL  MESH POINTS        12

 2-D SPECTRA MESH POINTS
  4    12

PLOT OPTION PARAMETERS
         NWAY                 4
         NTRA                 0
         LOGPO                3
         LINEIT               1
         NLABEL               0
         NSYMB                2
         ICENT                1

         MAIN TITLE(ARATE)        GAMMA RAY  ENERGY SPECTRA (R=13 CM)
         X     TITLE               GAMMA    ENERGY (EV)
         Y     TITLE               GAMMA    FLUX PER UNIT LETHARGY
         MATERIAL NAME OF PLOT LINE
              Z = 23CM
              Z = 39CM

 DELTA U -- ALOG(E(I)/E(I+1)) ---
       9.531E-02  8.701E-02  1.054E-01  1.178E-01  1.054E-01  9.531E-02  8.701E-02  9.531E-02  1.008E-01
       1.054E-01  1.054E-01  9.531E-02  8.701E-02  8.004E-02  7.411E-02  6.899E-02  6.454E-02  6.062E-02
       5.407E-02  5.129E-02  4.879E-02  9.097E-02  8.338E-02  7.696E-02  1.054E-01  9.531E-02  8.701E-02
       1.178E-01  1.054E-01  9.531E-02  8.701E-02  9.531E-02  1.008E-01  1.040E-01  1.054E-01  1.054E-01
       8.701E-02  8.004E-02  7.411E-02  6.899E-02  6.454E-02  6.062E-02  5.716E-02  5.407E-02  5.129E-02
       9.097E-02  8.338E-02  7.696E-02  1.054E-01
 SCALING OF X-AXIS
    XMIN=   4.000E+00 XMAX=   7.000E+00 DX=   5.080E-01
       3.000E+04  3.300E+04  3.600E+04  4.000E+04  4.500E+04  5.000E+04  5.500E+04  6.000E+04  6.600E+04
       8.100E+04  9.000E+04  1.000E+05  1.100E+05  1.200E+05  1.300E+05  1.400E+05  1.500E+05  1.600E+05
       1.800E+05  1.900E+05  2.000E+05  2.100E+05  2.300E+05  2.500E+05  2.700E+05  3.000E+05  3.300E+05
       4.000E+05  4.500E+05  5.000E+05  5.500E+05  6.000E+05  6.600E+05  7.300E+05  8.100E+05  9.000E+05
       1.100E+06  1.200E+06  1.300E+06  1.400E+06  1.500E+06  1.600E+06  1.700E+06  1.800E+06  1.900E+06
       2.100E+06  2.300E+06  2.500E+06  2.700E+06  3.000E+06

 SCALING OF Y-AXIS
    YMIN=  -9.000E+00 YMAX=  -3.000E+00 DY=   7.620E-01



   1   2.997E-05  9.426E-07  2.967E-06  8.755E-06  2.078E-05  3.863E-05  5.987E-05  8.630E-05  1.182E-04
       2.173E-04  2.103E-04  1.948E-04  2.160E-04  9.365E-04  1.985E-04  9.405E-05  9.036E-05  8.642E-05
       8.963E-05  9.554E-05  1.067E-04  9.991E-05  9.304E-05  8.947E-05  8.868E-05  3.733E-04  5.223E-05
       5.352E-05  5.651E-05  2.741E-04  4.280E-05  4.608E-05  5.203E-05  5.628E-05  9.312E-04  2.474E-06
       2.670E-05  3.048E-06  6.056E-05  3.765E-07  3.811E-07  8.964E-06  3.861E-06  6.788E-07  3.725E-06
       7.553E-07  4.288E-09  2.833E-08  2.021E-07
   2   5.009E-06  6.424E-07  2.000E-06  5.803E-06  1.347E-05  2.434E-05  3.682E-05  5.096E-05  6.636E-05
       1.003E-04  1.024E-04  1.002E-04  1.072E-04  2.598E-04  8.086E-05  5.530E-05  5.444E-05  5.347E-05
       5.515E-05  5.743E-05  6.189E-05  5.944E-05  5.648E-05  5.448E-05  5.326E-05  1.144E-04  3.632E-05
       3.662E-05  3.801E-05  1.218E-04  2.895E-05  3.059E-05  3.334E-05  3.589E-05  3.799E-04  1.560E-06
       1.050E-05  1.486E-06  2.013E-05  2.336E-07  2.406E-07  3.929E-06  1.173E-06  2.810E-07  2.602E-06
       2.366E-07  2.611E-09  1.181E-08  6.145E-08

READ IDENTIFICATION TYPE.END     FILE  NO.    0
 LOCATION REQUESTED ----   50000
 LOCATION USED      ----    9105
 LOCATION UNUSED    ----   40895
*** PLOT  (FPCLS )  *** ICHK =     1
```

Fig.4.3.6 Output List of Sample Problem 4.3 (continued)

```
                  *** APPLE INPUT DATA CARD IMAGE LIST ***
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
 MORSE ENERGY SPECTRA SAMPLE PROBLEM.                               <APPLE2>
FLUX     1
  3
SPEC     1
  2  1  1 28  0  4
  4  5  6  7
  15.0          20.0
 NEUTRON ENERGY SPECTRA
  NEUTRON ENERGY (EV)
 NEUTRON FLUX PER UNIT LETHARGY
 D1       D2       D3       D4
SPEC     2
  2  1  1 -7  0  4
  4  5  6  7
  15.0          20.0
 GAMMA    ENERGY SPECTRA
  GAMMA    ENERGY (EV)
 GAMMA    FLUX PER UNIT LETHARGY
 D1       D2       D3       D4
END      0
----*----1----*----2----*----3----*----4----*----5----*----6----*----7----*----8
```

Fig.4.4.1 Input Data List for Sample Problem 4.4

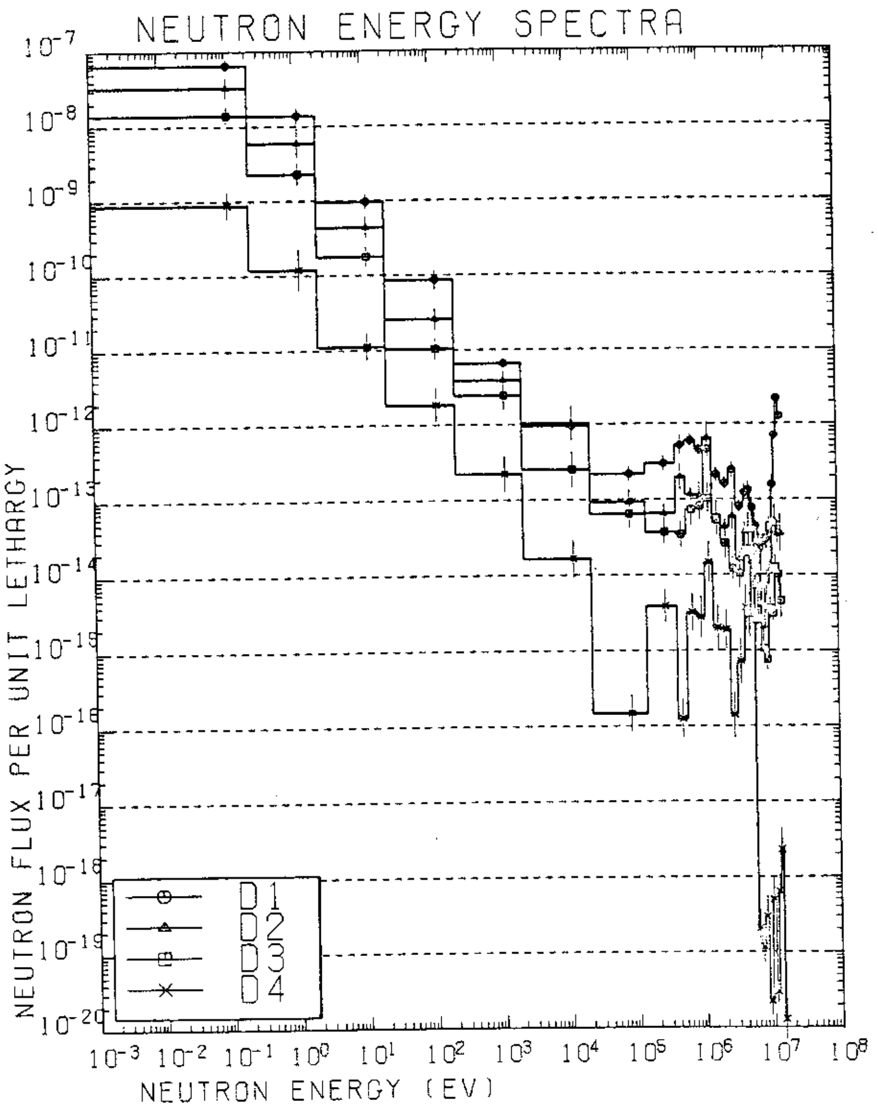


Fig.4.4.2 Plotter Output of Neutron Spectra

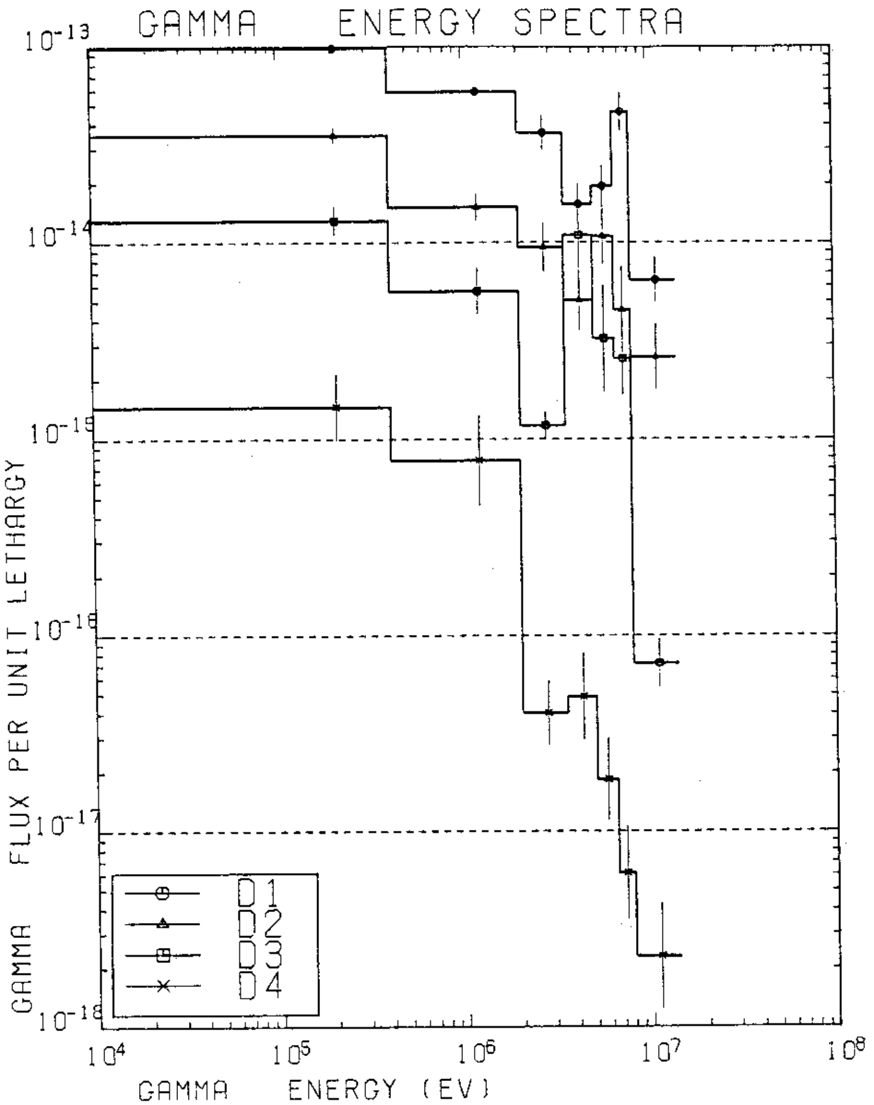


Fig.4.4.3 Plotter Output of Gamma Ray Spectra

5. Concluding Remarks

The main objective for the development of the APPLE-2 code is to simplify the data processing procedure of the fusion reactor neutronics calculations. In order to simplify the input of the code, the output subroutines of radiation transport codes are modified and response libraries compatible with standard cross section sets are provided.

The use of the APPLE-2 code is expected to reduce the manpower required to process the data obtained from ANISN, DOT and MORSE calculations. We hope that such saving in the manpower will off-set the effort required in the development of the APPLE-2 code.

The overview plot routines have been originally obtained from the PERVUE code[12] made by W.G. Price, Jr.

References

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Also as PSR-111/APPLE in RSIC Computer Code Collection, Radiation Shielding Information Center, Oak Ridge National Laboratory (1977)

(2) W.W. Engle, Jr., "A User's Manual for ANISN, A One Dimensional Discrete Ordinates Transport Code With Anisotropic Scattering," K-1693, Oak Ridge National Laboratory (1967)

(3) K. Sako et al., "Engineering Aspects of the JAERI Proposal for INTOR(II)," JAERI-M 8518 (1979)

(4) Y. Seki et al., "Neutronics Design of the Next Tokamak (Swimming Pool Type)," Proc. 3rd Technical Committee Meeting and Workshop on Fusion Reactor Design and Technology, Tokyo, 5-16, October 1981, to be published

(5) Hiroshi Maekawa, Jyo-ichi Kusano and Yasushi Seki, "Response Distributions of ^{6}LiF and ^{7}LiF Thermoluminescence Dosimeters in Lithium Blanket Assemblies," JAERI-M 6811 (1976)

(6) R-Project Design Team, "Reacting Plasma Experiment Facility, Technical Report[II]," Institute of Plasma Physics Nagoya, November (1981) in Japanese

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

(8) E.A. Straker et al., "The MORSE Code — A Multigroup Neutron and Gamma Ray Monte Carlo Transport Code," ORNL-4585 (1970)

(9) Yasushi Seki and Hiromasa Iida, "Coupled 42-Group Neutron and 21-Group Gamma-Ray Cross Section Sets for Fusion Reactor

Calculations," JAERI-M 8818 (1980)

(10) RSIC Data Library Collection, "100-Group Neutron Cross Section Data Based on ENDF/B, DLC-2," Radiation Shielding Information Center, Oak Ridge National Laboratory (1972)

(11) Hiromasa Iida and Masahito Igarashi, "THIDA-Code System for Calculation of the Exposure Dose Rate Around a Fusion Device," JAERI-M 8019 (1978) in Japanese

(12) W.G. Price, Jr., "PERVUE: A Program to Plot Perspective Views of Surfaces," PPPL-1304 (1976)

Appendix List of Response Libraries

Complete lists of XS63, GFLXDOSE and XS100 libraries are given as Tables A.1, A.3 and A.4, respectively. Only the initial part of the GICXKRMA library is listed in Table A.2. Energy group structures and nuclides list are also appended.

Appendix A.1 Complete List of XS63 Library

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1 63 17
14**
' REACTION NO. 1     14 MEV NEUTRON FLUX
   1  62Z
' REACTION NO. 2     NEUTRON FLUX WITH ENERGY GT 0.1 MEV
 24R1  39Z
' REACTION NO. 3     TOTAL NEUTRON FLUX
 42R1  21Z
' REACTION NO. 4     TOTAL GAMMA RAY FLUX
 42Z    21R1
' REACTION NO. 5    LI-6(N,ALPHA)T REACTION RATE
             2.5294-2   2.7750-2   3.0974-2   3.4300-2   3.8447-2
 4.4316-2   5.0658-2   5.8019-2   6.6492-2   7.6484-2   8.7118-2
 9.9839-2   1.2242-1   1.5930-1   2.0238-1   2.3090-1   2.5382-1
 2.6875-1   2.8666-1   3.8706-1   1.059       2.8752      1.2791
 7.2005-1   6.7137-1   8.7341-1   1.2484      1.8176      2.6658
 3.9150      5.7450      8.4442      1.2407+1
 1.8201+1   2.6738+1   3.9271+1
 5.7598+1   8.4605+1   1.2424+2   1.8220+2   2.6760+2   9.4025+2
 21R0.0
' REACTION NO. 6    LI-7(N,N'ALPHA)T REACTION RATE
 3.2338-1   3.5168-1   3.8247-1   4.0062-1   4.1554-1   4.1995-1
 4.2396-1   4.1948-1   3.8405-1   2.9887-1   1.2941-1   4.3060-2
 9.7912-3   1.2312-3 28R0.0
 21R0.0
' REACTION NO. 7    STAINLESS STEEL(SS-316) DISPLACEMENT RATE PER ATOM (DPA)
 2942.5      2848.9      2737.3      2610.0      2465.3      2292.2
 2166.4      2069.3      1963.8      1871.7      1757.7      1642.0
 1412.1      1177.2      865.3       677.6       436.1       351.9
 380.7       362.9       244.4       219.6       241.6       129.5
 110.2       101.1       32.6        26.8        9.9         5.2
 0.14        0.19        0.33        0.36        0.77        0.66
 0.95        1.4         2.0         3.0         4.4         12.3
 21R0.0
' REACTION NO. 8    COPPER DISPLACEMENT RATE PER ATOM (DPA)
 3586.9      3577.5      3636.2      3655.9      3542.5      3253.6
 2897.0      2648.9      2552.0      2367.2      2200.9      1973.3
 1611.5      1236.1       882.0       782.5       697.9       665.6
  584.5       516.1       419.1       349.5       276.5       205.9
  152.0       115.2        65.7        38.9        15.1         9.5
   15.5         1.9         0.25        0.35        0.53        0.78
   0.55         1.7          2.6         3.9         5.7         16.3
 21R0.0
' REACTION NO. 9    TOTAL OF NEUTRON AND GAMMA RAY DOSES (MREM/H)
 17R1.47-1  2R0.115    0.094   2R0.0607  2R0.0354   0.021      0.115
 16R5.42-3   1.19-2     1.03-2     8.79-3     7.86-3     7.49-3     7.12-3
    6.75-3   6.38-3     6.00-3     5.61-3     5.22-3     4.81-3     4.38-3
    3.94-3   3.46-3     2.95-3     2.36-3     1.61-3     7.00-4     2.87-5
    8.49-5
' REACTION NO.10    NEUTRON DOSE (MREM/H)
 17R1.47-1  2R0.115    0.094   2R0.0607  2R0.0354   0.021      0.115
 16R5.42-3 21Z
' REACTION NO.11    GAMMA RAY DOSE (MREM/H)
 42Z
    1.19-2   1.03-2     8.79-3     7.86-3     7.49-3     7.12-3     6.75-3
    6.38-3   6.00-3     5.61-3     5.22-3     4.81-3     4.38-3     3.94-3
    3.46-3   2.95-3     2.36-3     1.61-3     7.00-4     2.87-5     8.49-5
' REACTION NO.12      U-235 FISSION RATE
    2.18     2.046      1.797      1.724      1.769      1.799      1.728
    1.517    1.210      1.069      1.103      1.134      1.181      1.250
    1.276    1.258      1.253      1.188      1.140      1.181      1.234
    1.319    1.418      1.535      1.716      2.022      2.428      3.306
    4.865    6.969      10.65      15.24      20.60      29.88      43.21
    59.65    68.99      15.05      21.31      60.97      144.8      233.5
 21Z
' REACTION NO.13      U-238 FISSION RATE
    1.179    1.083      1.005      .9823      .9777      .9941      .9849
    .9126    .7066      .5693      .5584      .5646      .5553      .5480
    .5416    .3728      5.36-2     1.19-2     1.52-3     2.61-4     9.65-5
    5.98-5   5.04-5     4.29-5     4.00-5     6.54-5     8.70-5     1.54-5
    0.000    7.92-5     5.81-4     32Z
' REACTION NO.14     TH-232 FISSION RATE
    .3715    .3353      .2996      .2831      .2856      .3043      .3318
    .3254    .1728      .1400      .1443      .1440      .1381      .1207
    .1120    8.54-2     9.04-3     46Z
' REACTION NO.15      NP-237 FISSION RATE
    2.384    2.314      2.304      2.341      2.347      2.309      2.233
    2.091    1.670      1.500      1.515      1.544      1.607      1.683
    1.682    1.623      1.550      1.402      .9902      .4308      .1267
    3.07-2   2.34-2     1.85-2     1.43-2     1.09-2     9.64-3     1.06-2
    8.93-3   3.21-2     3.01-2     4.02-2     1.00-1     4.92-3     1.98-1
    1.67-3   6.98-3     6.45-3     7.02-3     2.91-3     7.04-3     5.61-3
 21Z
' REACTION NO.16      NI-58(N,P)CO-58 REACTION RATE
    1.82-1   2.34-1     2.82-1     3.14-1     3.31-1     3.35-1     3.31-1
    3.21-1   3.11-1     2.65-1     2.18-1     1.96-1     1.43-1     7.72-2
    3.11-2   9.56-3     2.57-3     2.95-4     3.15-5     1.38-6     4.32-8
    42Z
' REACTION NO.17      FE-58(N,GAMMA)FE-59 REACTION RATE
    9.13-3   5.14-3     2.89-3     1.63-3     9.49-4     9.11-4     9.38-4
    9.77-4   1.06-3     1.16-3     1.23-3     1.23-3     1.23-3     1.22-3
    1.22-3   1.24-3     1.27-3     1.70-3     2.62-3     2.55-3     2.70-3
    2.87-3   3.26-3     3.95-3     5.30-3     3.72-3     2.32-2     2.82-2
    5.31-4   5.93-4     1.04-3     1.36       7.36-3     1.32-2     2.52-2
    4.28-2   6.75-2     1.03-1     1.53-1     2.27-1     3.34-1     9.58-1
 21Z
T
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Table A.1.1 42-Group Neutron Energy Group Structure

Group	Energy Limits		Mid-Point Energy	
1	15.000 - 13.720	MeV	14.360	MeV
2	13.720 - 12.549		13.135	
3	12.549 - 11.478		12.014	
4	11.478 - 10.500		10.989	
5	10.500 - 9.314		9.907	
6	9.314 - 8.261		8.788	
7	8.261 - 7.328		7.795	
8	7.328 - 6.500		6.914	
9	6.500 - 5.757		6.129	
10	5.757 - 5.099		5.428	
11	5.099 - 4.516		4.808	
12	4.516 - 4.000		4.258	
13	4.000 - 3.162		3.581	
14	3.162 - 2.500		2.831	
15	2.500 - 1.871		2.186	
16	1.871 - 1.400		1.636	
17	1.400 - 1.058		1.229	
18	1.058 - 0.800		0.929	
19	0.800 - 0.566		0.683	
20	0.566 - 0.400		0.483	
21	0.400 - 0.283		0.342	
22	0.283 - 0.200		0.242	
23	0.200 - 0.141		0.171	
24	0.141 - 0.100		0.121	
25	100.0 - 46.5	KeV	73.25	KeV
26	46.5 - 21.5		34.0	
27	21.5 - 10.0		15.75	
28	10.0 - 4.65		7.325	
29	4.65 - 2.15		3.40	
30	2.15 - 1.00		1.575	
31	1.00 - 0.465		0.733	
32	0.465 - 0.215		0.340	
33	0.215 - 0.100		0.158	
34	100.0 - 46.5	eV	73.25	eV
35	46.5 - 21.5		34.0	
36	21.5 - 10.0		15.75	
37	10.0 - 4.65		7.325	
38	4.65 - 2.15		3.40	
39	2.15 - 1.00		1.58	
40	1.00 - 0.465		0.733	
41	0.465 - 0.215		0.340	
42	0.215 - 0.001		0.108	

Table A.1.2 21-Group Gamma-Ray Energy Group Structure

Group	Energy Limits (MeV)	Mid-Point Energy (MeV)
1	14.0 - 12.0	13.0
2	12.0 - 10.0	11.0
3	10.0 - 8.0	9.0
4	8.0 - 7.5	7.75
5	7.5 - 7.0	7.25
6	7.0 - 6.5	6.75
7	6.5 - 6.0	6.25
8	6.0 - 5.5	5.75
9	5.5 - 5.0	5.25
10	5.0 - 4.5	4.75
11	4.5 - 4.0	4.25
12	4.0 - 3.5	3.75
13	3.5 - 3.0	3.25
14	3.0 - 2.5	2.75
15	2.5 - 2.0	2.25
16	2.0 - 1.5	1.75
17	1.5 - 1.0	1.25
18	1.0 - 0.4	0.7
19	0.4 - 0.2	0.3
20	0.2 - 0.1	0.15
21	0.1 - 0.01	0.055

Appendix A.2 Partial List of GICXKRMA Library

3 63 40

14*

0.4426E+01	0.0	0.4426E+01	0.4291E+01	0.0	0.4291E+01
0.4189E+01	0.0	0.4189E+01	0.4086E+01	0.0	0.4086E+01
0.3943E+01	0.0	0.3943E+01	0.3800E+01	0.0	0.3800E+01
0.3616E+01	0.0	0.3616E+01	0.3437E+01	0.0	0.3437E+01
0.3259E+01	0.0	0.3259E+01	0.3113E+01	0.0	0.3113E+01
0.2996E+01	0.0	0.2996E+01	0.2901E+01	0.0	0.2901E+01
0.2617E+01	0.0	0.2617E+01	0.2225E+01	0.0	0.2225E+01
0.2025E+01	0.0	0.2025E+01	0.1855E+01	0.0	0.1855E+01
0.1792E+01	0.0	0.1792E+01	0.1747E+01	0.0	0.1747E+01
0.1742E+01	0.0	0.1742E+01	0.2207E+01	0.0	0.2207E+01
0.5666E+01	0.0	0.5666E+01	0.1479E+02	0.0	0.1479E+02
0.6435E+01	0.0	0.6435E+01	0.3563E+01	0.0	0.3563E+01
0.3274E+01	0.0	0.3274E+01	0.4213E+01	0.0	0.4213E+01
0.5995E+01	0.0	0.5995E+01	0.8713E+01	0.0	0.8713E+01
0.1277E+02	0.0	0.1277E+02	0.1874E+02	0.0	0.1874E+02
0.2750E+02	0.0	0.2750E+02	0.4042E+02	0.0	0.4042E+02
0.5938E+02	0.0	0.5938E+02	0.8711E+02	0.0	0.8711E+02
0.1280E+03	0.0	0.1280E+03	0.1879E+03	0.0	0.1879E+03
0.2757E+03	0.0	0.2757E+03	0.4049E+03	0.0	0.4049E+03
0.5946E+03	0.0	0.5946E+03	0.8720E+03	0.0	0.8720E+03
0.1281E+04	0.0	0.1281E+04	0.2799E+04	0.0	0.2799E+04
0.0	0.1459E+01	0.1459E+01	0.0	0.1313E+01	0.1313E+01
0.0	0.1167E+01	0.1167E+01	0.0	0.1072E+01	0.1072E+01
0.0	0.1033E+01	0.1033E+01	0.0	0.9931E+00	0.9931E+00
0.0	0.9521E+00	0.9521E+00	0.0	0.9096E+00	0.9096E+00
0.0	0.8652E+00	0.8652E+00	0.0	0.8188E+00	0.8188E+00
0.0	0.7702E+00	0.7702E+00	0.0	0.7175E+00	0.7175E+00
0.0	0.6614E+00	0.6614E+00	0.0	0.6000E+00	0.6000E+00
0.0	0.5319E+00	0.5319E+00	0.0	0.4550E+00	0.4550E+00
0.0	0.3665E+00	0.3665E+00	0.0	0.2490E+00	0.2490E+00
0.0	0.1080E+00	0.1080E+00	0.0	0.4322E-01	0.4322E-01
0.0	0.1153E-01	0.1153E-01	0.3359E+01	0.0	0.3359E+01
0.3158E+01	0.0	0.3158E+01	0.3007E+01	0.0	0.3007E+01
0.2856E+01	0.0	0.2856E+01	0.2653E+01	0.0	0.2653E+01
0.2404E+01	0.0	0.2404E+01	0.2209E+01	0.0	0.2209E+01
0.2145E+01	0.0	0.2145E+01	0.2179E+01	0.0	0.2179E+01
0.2133E+01	0.0	0.2133E+01	0.1962E+01	0.0	0.1962E+01
0.1805E+01	0.0	0.1805E+01	0.1418E+01	0.0	0.1418E+01
0.1042E+01	0.0	0.1042E+01	0.7809E+00	0.0	0.7809E+00
0.5738E+00	0.0	0.5738E+00	0.4359E+00	0.0	0.4359E+00
0.3170E+00	0.0	0.3170E+00	0.2049E+00	0.0	0.2049E+00
0.1333E+00	0.0	0.1333E+00	0.1553E+00	0.0	0.1553E+00
0.2640E+00	0.0	0.2640E+00	0.3327E-01	0.0	0.3327E-01
0.2034E-01	0.0	0.2034E-01	0.1316E-01	0.0	0.1316E-01
0.7145E-02	0.0	0.7145E-02	0.4076E-02	0.0	0.4076E-02
0.2660E-02	0.0	0.2660E-02	0.2068E-02	0.0	0.2068E-02
0.2010E-02	0.0	0.2010E-02	0.2409E-02	0.0	0.2409E-02
0.3318E-02	0.0	0.3318E-02	0.4714E-02	0.0	0.4714E-02
0.6759E-02	0.0	0.6759E-02	0.9738E-02	0.0	0.9738E-02
0.1405E-01	0.0	0.1405E-01	0.2049E-01	0.0	0.2049E-01
0.3028E-01	0.0	0.3028E-01	0.4473E-01	0.0	0.4473E-01
0.6570E-01	0.0	0.6570E-01	0.9625E-01	0.0	0.9625E-01
0.2086E+00	0.0	0.2086E+00	0.0	0.1459E+01	0.1459E+01
0.0	0.1313E+01	0.1313E+01	0.0	0.1167E+01	0.1167E+01
0.0	0.1072E+01	0.1072E+01	0.0	0.1033E+01	0.1033E+01
0.0	0.9931E+00	0.9931E+00	0.0	0.9521E+00	0.9521E+00
0.0	0.9096E+00	0.9096E+00	0.0	0.8652E+00	0.8652E+00
0.0	0.8188E+00	0.8188E+00	0.0	0.7702E+00	0.7702E+00
0.0	0.7175E+00	0.7175E+00	0.0	0.6614E+00	0.6614E+00
0.0	0.6000E+00	0.6000E+00	0.0	0.5319E+00	0.5319E+00
0.0	0.4550E+00	0.4550E+00	0.0	0.3665E+00	0.3665E+00
0.0	0.2490E+00	0.2490E+00	0.0	0.1080E+00	0.1080E+00
0.0	0.4322E-01	0.4322E-01	0.0	0.1153E-01	0.1153E-01
0.3389E+01	0.0	0.3389E+01	0.2940E+01	0.0	0.2940E+01
0.2518E+01	0.0	0.2518E+01	0.2208E+01	0.0	0.2208E+01
0.1389E+01	0.0	0.1389E+01	0.1062E+01	0.0	0.1062E+01
0.1414E+01	0.0	0.1414E+01	0.6425E+00	0.0	0.6425E+00
0.8961E+00	0.0	0.8961E+00	0.7202E+00	0.0	0.7202E+00
0.7722E+00	0.0	0.7722E+00	0.8688E+00	0.0	0.8688E+00
0.1210E+01	0.0	0.1210E+01	0.7264E+00	0.0	0.7264E+00
0.5159E+00	0.0	0.5159E+00	0.4217E+00	0.0	0.4217E+00
0.3714E+00	0.0	0.3714E+00	0.3262E+00	0.0	0.3262E+00
0.2757E+00	0.0	0.2757E+00	0.2217E+00	0.0	0.2217E+00
0.1733E+00	0.0	0.1733E+00	0.1322E+00	0.0	0.1322E+00
0.9877E-01	0.0	0.9877E-01	0.7275E-01	0.0	0.7275E-01
0.4435E-01	0.0	0.4435E-01	0.2128E-01	0.0	0.2128E-01
0.1002E-01	0.0	0.1002E-01	0.4696E-02	0.0	0.4696E-02
0.2185E-02	0.0	0.2185E-02	0.1015E-02	0.0	0.1015E-02
0.4723E-03	0.0	0.4723E-03	0.2192E-03	0.0	0.2192E-03
0.1017E-03	0.0	0.1017E-03	0.4733E-04	0.0	0.4733E-04
0.2202E-04	0.0	0.2202E-04	0.1031E-04	0.0	0.1031E-04
0.4942E-05	0.0	0.4942E-05	0.2509E-05	0.0	0.2509E-05
0.1479E-05	0.0	0.1479E-05	0.1148E-05	0.0	0.1148E-05
0.1208E-05	0.0	0.1208E-05	0.2185E-05	0.0	0.2185E-05
0.0	0.3456E+01	0.3456E+01	0.0	0.3023E+01	0.3023E+01
0.0	0.2608E+01	0.2608E+01	0.0	0.2349E+01	0.2349E+01
0.0	0.2245E+01	0.2245E+01	0.0	0.2141E+01	0.2141E+01

Table A.2.1 List of 40 Nuclides Stored in the GICX40 Set

№	Nuclide	MATNO in ENDF/B-3 (4*)	POPOP4 ID Number** for Gamma-ray Producing reactions (n, γ)	(n, n′γ)	others	MT NO for ANISN input P0 ~ P5
1	^{6}Li	1115	30101	40301		1 ~ 6
2	^{7}Li	1116	30101	40301		7 ~ 12
3	^{12}C	1165	60101	60301		13 ~ 18
4	^{16}O	1134	70301	86301	80201, 860601	19 ~ 24
5	^{4}He	1088	30301	40301		25 ~ 30
6	Nb	1164	404101	400301		31 ~ 36
7	Mo	1111	420101	400301		37 ~ 42
8	Cr	1121	240101	240301		43 ~ 48
9	Ni	1123	280101	280301		49 ~ 54
10	Fe	1180	260101	260301		55 ~ 60
11	^{1}H	1148	10101	40301		61 ~ 66
12	^{2}H	1120	13001	40301		67 ~ 72
13	^{3}He	1146	30101	40301		73 ~ 78
14	^{9}Be	1154	40102	40301		79 ~ 84
15	^{10}B	1155	40102	40301	50204	85 ~ 90
16	^{14}N	1133	70102	70301	74401	91 ~ 96
17	^{27}Al	1135	130103	180301		97 ~ 102
18	V	1017	240101	240301		103 ~ 106
19	Cu	1087	290104	280301		109 ~ 114
20	Pb	1136	820102	820301		115 ~ 120
21	^{232}Th	1117	928109	928301	925801	121 ~ 126
22	^{235}U	1157	925101	925301	925801	127 ~ 132
23	^{239}Pu	1159	928109	928301	925801	133 ~ 138
24	^{237}Np	1263*	937101	928301	925801	139 ~ 144
25	Mg	1014	120101 ~~925101~~	~~925301~~		145 ~ 150
26	K	1150	190101	190301	190701	151 ~ 156
27	Ca	1152	200101	200301	200701	157 ~ 162
28	^{11}B	1160*	60101	60301		163 ~ 168
29	Cl	1149*	170101	170301		169 ~ 174
30	Na	1156*	110101	113301		175 ~ 180
31	Cd	1281*	480101	—		181 ~ 186
32	Ta	1285*	730101	740301		187 ~ 192
33	^{182}W	1128*	730103	740301		193 ~ 198
34	^{183}W	1129*	730103	740301		199 ~ 204
35	^{184}W	1130*	730103	740301		205 ~ 210
36	^{186}W	1131*	740103	740301		211 ~ 216
37	F	1277*	90102	86302		217 ~ 222
38	^{238}U	1262*	928109	928301	925801	223 ~ 228
39	Si	1194*	140105	140301		229 ~ 234
40	Ti	1286*	220102	220302		235 ~ 240

* The data in ENDF/B-4 are used.

** ID number used in POPOP4 library has five or six digits. They indicate the following meaning

XXXXXX

- Atomic number
- Last digit of produced nuclide mass number (0 for natural content)
- Reaction types:
  - 1 (n ; γ) radiative capture
  - 2 (n ; α, γ)
  - 3 (n ; n′, γ)
  - 4 (n ; 2n ; γ)
  - 6 (n ; p ; γ)
  - 7 (n ; c. p. , γ)
  - 8 (n ; γ) fission
- Arbitrary number

Appendix A.3 Complete List of GFLXDOSE Library

```
  1 54   1                                                               00007000
 14**                                                                    00007010
' REACTION NO. 1   CONVERSION FACTOR FOR DOSE RATE (MREM/HOUR)           00007020
 0.13266E-03 0.13612E-03 0.12570E-03 0.11531E-03 0.10746E-03 0.10232E-0300007100
 0.97182E-04 0.91994E-04 0.86807E-04 0.81605E-04 0.76397E-04 0.71168E-0400007200
 0.65913E-04 0.60626E-04 0.55299E-04 0.49927E-04 0.44770E-04 0.40115E-0400007300
 0.35973E-04 0.32356E-04 0.29278E-04 0.26468E-04 0.23648E-04 0.20820E-0400007400
 0.18269E-04 0.16288E-04 0.14595E-04 0.12909E-04 0.11513E-04 0.10405E-0400007500
 0.93080E-05 0.84939E-05 0.79561E-05 0.74239E-05 0.68973E-05 0.63776E-0500007600
 0.58663E-05 0.53647E-05 0.48750E-05 0.43997E-05 0.39426E-05 0.35085E-0500007700
 0.31047E-05 0.27578E-05 0.24894E-05 0.22983E-05 0.21809E-05 0.21296E-0500007800
 0.21408E-05 0.22251E-05 0.24143E-05 0.26973E-05 0.30287E-05 0.34423E-0500007900
  T                                                                      00008000
```

Table A.3.1 54-Group Gamma Ray Energy Group Structure

	E(MeV)		E(MeV)
1	3.0 ∿ 2.7	28	0.3 ∿ 0.27
2	2.7 ∿ 2.5	29	0.27 ∿ 0.25
3	2.5 ∿ 2.3	30	0.25 ∿ 0.23
4	2.3 ∿ 2.1	31	0.23 ∿ 0.21
5	2.1 ∿ 2.0	32	0.21 ∿ 0.20
6	2.0 ∿ 1.9	33	0.20 ∿ 0.19
7	1.9 ∿ 1.8	34	0.19 ∿ 0.18
8	1.8 ∿ 1.7	35	0.18 ∿ 0.17
9	1.7 ∿ 1.6	36	0.17 ∿ 0.16
10	1.6 ∿ 1.5	37	0.16 ∿ 0.15
11	1.5 ∿ 1.4	38	0.15 ∿ 0.14
12	1.4 ∿ 1.3	39	0.14 ∿ 0.13
13	1.3 ∿ 1.2	40	0.13 ∿ 0.12
14	1.2 ∿ 1.1	41	0.12 ∿ 0.11
15	1.1 ∿ 1.0	42	0.11 ∿ 0.10
16	1.0 ∿ 0.9	43	0.10 ∿ 0.09
17	0.9 ∿ 0.81	44	0.09 ∿ 0.081
18	0.81 ∿ 0.73	45	0.081 ∿ 0.073
19	0.73 ∿ 0.66	46	0.073 ∿ 0.066
20	0.66 ∿ 0.6	47	0.066 ∿ 0.06
21	0.6 ∿ 0.55	48	0.06 ∿ 0.055
22	0.55 ∿ 0.5	49	0.055 ∿ 0.05
23	0.5 ∿ 0.45	50	0.05 ∿ 0.045
24	0.45 ∿ 0.4	51	0.045 ∿ 0.04
25	0.4 ∿ 0.36	52	0.04 ∿ 0.036
26	0.36 ∿ 0.33	53	0.036 ∿ 0.033
27	0.33 ∿ 0.3	54	0.033 ∿ 0.03

Appendix A.4 Complete List of XS100 Library

```
1100   6                                                                                          00000100
14**                                                                                              00000200
' REACTION NO. 1     U-235 FISSION RATE                                                           00000210
   2.19E+00      1.97E+00      1.74E+00      1.74E+00      1.79E+00      1.80E+0000000300
   1.73E+00      1.56E+00      1.31E+00      1.10E+00      1.08E+00      1.11E+0000000400
   1.13E+00      1.16E+00      1.18E+00      1.21E+00      1.24E+00      1.27E+0000000500
   1.28E+00      1.28E+00      1.27E+00      1.26E+00      1.26E+00      1.25E+0000000600
   1.25E+00      1.25E+00      1.24E+00      1.20E+00      1.16E+00      1.13E+0000000700
   1.13E+00      1.15E+00      1.15E+00      1.16E+00      1.18E+00      1.21E+0000000800
   1.22E+00      1.23E+00      1.25E+00      1.29E+00      1.30E+00      1.31E+0000000900
   1.33E+00      1.37E+00      1.41E+00      1.44E+00      1.48E+00      1.51E+0000001000
   1.54E+00      1.59E+00      1.71E+00      1.84E+00      1.84E+00      1.96E+0000001100
   2.12E+00      2.23E+00      2.36E+00      2.63E+00      2.88E+00      3.08E+0000001200
   3.62E+00      3.99E+00      4.69E+00      5.05E+00      5.52E+00      6.72E+0000001300
   7.28E+00      8.56E+00      8.69E+00      1.21E+01      1.50E+01      1.33E+0100001400
   1.44E+01      2.23E+01      1.97E+01      2.12E+01      2.31E+01      2.35E+0100001500
   2.50E+01      5.62E+01      3.46E+01      6.11E+01      4.39E+01      6.47E+0100001600
   3.14E+01      5.07E+01      9.26E+01      1.29E+01      3.46E+01      5.95E+0000001700
   3.09E+01      1.52E+01      1.40E+01      1.48E+01      3.52E+01      7.97E+0100001800
   5.69E+01      5.66E+01      8.92E+01      4.15E+02                                 00001900
' REACTION NO. 2     U-238 FISSION RATE                                                           00001910
   1.19E+00      1.05E+00      9.91E-01      9.78E-01      9.82E-01      9.96E-0100002000
   9.85E-01      9.34E-01      7.89E-01      6.11E-01      5.60E-01      5.59E-0100002100
   5.64E-01      5.63E-01      5.54E-01      5.44E-01      5.46E-01      5.53E-0100002200
   5.51E-01      5.45E-01      5.16E-01      4.53E-01      3.56E-01      1.90E-0100002300
   5.93E-02      3.56E-02      1.94E-02      1.51E-02      7.05E-03      2.78E-0300002400
   1.49E-03      1.27E-03      7.27E-04      3.40E-04      2.05E-04      1.55E-0400002500
   1.16E-04      9.70E-05      7.98E-05      6.84E-05      6.41E-05      6.01E-0500002600
   5.68E-05      5.39E-05      5.11E-05      4.87E-05      4.64E-05      4.44E-0500002700
   4.25E-05      4.03E-05      4.00E-05      4.00E-05      4.00E-05      5.74E-0500002800
   8.60E-05      8.70E-05      8.70E-05      8.70E-05      7.92E-05      6.02E-0600002900
   0.0           0.0           0.0           0.0           0.0           0.0      00003000
   0.0           0.0           0.0           0.0           0.0           0.0      00003100
   0.0           0.0           0.0           0.0           0.0           0.0      00003200
   0.0           0.0           0.0           0.0           0.0           0.0      00003300
   0.0           0.0           0.0           0.0           0.0           0.0      00003400
   0.0           0.0           0.0           0.0           0.0           0.0      00003500
   0.0           0.0           0.0           0.0                                  00003600
' REACTION NO. 3     TH-232 FISSION RATE                                                          00003610
   3.82E-01      3.21E-01      2.88E-01      2.82E-01      2.90E-01      3.09E-0100003700
   3.31E-01      3.44E-01      2.20E-01      1.38E-01      1.42E-01      1.45E-0100003800
   1.44E-01      1.42E-01      1.38E-01      1.33E-01      1.24E-01      1.12E-0100003900
   1.15E-01      1.18E-01      9.60E-02      8.76E-02      9.62E-02      5.80E-0200004000
   9.96E-03      2.53E-04      0.0           0.0           0.0           0.0      00004100
   0.0           0.0           0.0           0.0           0.0           0.0      00004200
   0.0           0.0           0.0           0.0           0.0           0.0      00004300
   0.0           0.0           0.0           0.0           0.0           0.0      00004400
   0.0           0.0           0.0           0.0           0.0           0.0      00004500
   0.0           0.0           0.0           0.0           0.0           0.0      00004600
   0.0           0.0           0.0           0.0           0.0           0.0      00004700
   0.0           0.0           0.0           0.0           0.0           0.0      00004800
   0.0           0.0           0.0           0.0           0.0           0.0      00004900
   0.0           0.0           0.0           0.0           0.0           0.0      00005000
   0.0           0.0           0.0           0.0           0.0           0.0      00005100
   0.0           0.0           0.0           0.0           0.0           0.0      00005200
   0.0           0.0           0.0           0.0                                  00005300
' REACTION NO. 4     NP-237 FISSION RATE                                                          00005310
   2.37E+00      2.31E+00      2.32E+00      2.35E+00      2.34E+00      2.30E+0000005400
   2.23E+00      2.14E+00      1.81E+00      1.55E+00      1.50E+00      1.52E+0000005500
   1.54E+00      1.57E+00      1.61E+00      1.65E+00      1.68E+00      1.70E+0000005600
   1.69E+00      1.69E+00      1.67E+00      1.64E+00      1.62E+00      1.59E+0000005700
   1.57E+00      1.54E+00      1.50E+00      1.45E+00      1.34E+00      1.21E+0000005800
   1.06E+00      9.07E-01      7.35E-01      5.49E-01      3.89E-01      2.74E-0100005900
   1.88E-01      1.24E-01      7.95E-02      4.94E-02      3.27E-02      2.79E-0200006000
   2.88E-02      2.80E-02      2.41E-02      2.12E-02      1.96E-02      1.88E-0200006100
   1.83E-02      1.72E-02      1.43E-02      1.24E-02      1.23E-02      1.08E-0200006200
   1.01E-02      9.76E-03      9.57E-03      9.61E-03      9.84E-03      1.03E-0200006300
   1.10E-02      1.08E-02      8.19E-03      1.15E-02      5.65E-03      2.99E-0200006400
   1.62E-02      2.81E-02      2.99E-02      3.61E-02      1.76E-02      4.59E-0200006500
   3.14E-02      3.83E-02      1.40E-01      7.57E-02      4.33E-02      2.76E-0300006600
   2.62E-03      1.51E-02      2.94E-01      8.60E-02      2.54E-02      1.88E-0300006700
   1.14E-03      2.03E-03      4.16E-03      3.42E-03      2.31E-02      2.04E-0300006800
   1.45E-02      4.14E-04      1.96E-03      6.78E-03      1.95E-02      1.46E-0300006900
   1.42E-03      3.78E-03      3.82E-02      4.29E-03                                 00007000
' REACTION NO. 5     LI-6 (N,ALPHA)T                                                              00007010
   2.56-2 2.84-2 .0323 .0359 .0401 .0453 .0506 .0566 .0635 .0709                                  00007100
   .0798 .0886 .0991 .112 .125 .137 .154 .178 .194 .205 .213 .222                                 00007200
   .234 .244 .251 .257 .262 .267 .272 .276 .282 .289 .302 .328 .374                               00007300
   .455 .588 .815 1.21 1.93 2.93 3.35 2.66 1.84 1.32 1.02 .857 .760                               00007400
   .699 .655 .648 .684 .742 .820 .914 1.03 1.15 1.30 1.47 1.67 1.88                               00007500
   2.13 2.42 2.74 3.10 3.52 3.99 4.52 5.12 5.81 6.58 7.46 8.45 9.58                               00007600
   10.9 12.3 13.9 15.8 17.9 20.3 23.0 26.1 29.5 33.5 37.9 43.0 48.7                               00007700
   55.2 62.6 70.9 80.4 91.1 103. 162. 133. 150. 170. 193. 218. 833.                               00007800
' REACTION NO. 6     LI-7 (N,NALPHA)T                                                             00007810
   .306 .324 .344 .355 .364 .372 .376 .375 .369 .338 .161 .0912 .0532                             00007900
   .0153  8.504-4 2.916-4 9.886-5 FO      T                                                       00008000
```

Table A.4.1 100-Group Neutron Energy Group Structure

Group	Group Limits E(Top)		E(Low)		E(Mid Point)	
1	1.4918	(+7)*	1.3499	(+7)	1.4208	(+7)
2	1.3499	(+7)	1.2214	(+7)	1.2856	(+7)
3	1.2214	(+7)	1.1052	(+7)	1.1633	(+7)
4	1.1052	(+7)	1.0000	(+7)	1.0526	(+7)
5	1.0000	(+7)	9.0484	(+6)	9.5242	(+6)
6	9.0484	(+6)	8.1873	(+6)	8.6178	(+6)
7	8.1873	(+6)	7.4082	(+6)	7.7977	(+6)
8	7.4082	(+6)	6.7032	(+6)	7.0557	(+6)
9	6.7032	(+6)	6.0653	(+6)	6.3843	(+6)
10	6.0653	(+6)	5.4881	(+6)	5.7767	(+6)
11	5.4881	(+6)	4.9659	(+6)	5.2270	(+6)
12	4.9659	(+6)	4.4933	(+6)	4.7296	(+6)
13	4.4933	(+6)	4.0657	(+6)	4.2795	(+6)
14	4.0657	(+6)	3.6788	(+6)	3.8722	(+6)
15	3.6788	(+6)	3.3287	(+6)	3.5038	(+6)
16	3.3287	(+6)	3.0119	(+6)	3.1703	(+6)
17	3.0119	(+6)	2.7253	(+6)	2.8686	(+6)
18	2.7253	(+6)	2.4660	(+6)	2.5956	(+6)
19	2.4660	(+6)	2.2313	(+6)	2.3486	(+6)
20	2.2313	(+6)	2.0910	(+6)	2.1251	(+6)
21	2.0190	(+6)	1.8268	(+6)	1.9229	(+6)
22	1.8268	(+6)	1.6350	(+6)	1.7399	(+6)
23	1.6530	(+6)	1.4957	(+6)	1.5743	(+6)
24	1.4957	(+6)	1.3534	(+6)	1.4245	(+6)
25	1.3534	(+6)	1.2246	(+6)	1.2890	(+6)
26	1.2246	(+6)	1.1080	(+6)	1.1663	(+6)
27	1.1080	(+6)	1.0026	(+6)	1.0553	(+6)
28	1.0026	(+6)	9.0718	(+5)	9.5488	(+5)
29	9.0718	(+5)	8.2085	(+5)	8.6401	(+5)
30	8.2085	(+5)	7.4274	(+5)	7.8179	(+5)
31	7.4274	(+5)	6.7206	(+5)	7.0740	(+5)
32	6.7206	(+5)	6.0810	(+5)	6.4008	(+5)
33	6.0810	(+5)	5.5023	(+5)	5.7917	(+5)
34	5.5023	(+5)	4.9787	(+5)	5.2405	(+5)
35	4.9787	(+5)	4.5049	(+5)	4.7418	(+5)
36	4.5049	(+5)	4.0762	(+5)	4.2906	(+5)
37	4.0762	(+5)	3.6883	(+5)	3.8827	(+5)
38	3.6883	(+5)	3.3373	(+5)	3.5128	(+5)
39	3.3373	(+5)	3.0197	(+5)	3.1785	(+5)
40	3.0197	(+5)	2.7324	(+5)	2.8761	(+5)
41	2.7324	(+5)	2.4724	(+5)	2.6024	(+5)
42	2.4724	(+5)	2.2371	(+5)	2.3547	(+5)
43	2.2371	(+5)	2.0242	(+5)	2.1306	(+5)
44	2.0242	(+5)	1.8316	(+5)	1.9279	(+5)
45	1.8316	(+5)	1.6573	(+5)	1.7444	(+5)
46	1.6573	(+5)	1.4996	(+5)	1.5784	(+5)
47	1.4996	(+5)	1.3569	(+5)	1.4282	(+5)
48	1.3569	(+5)	1.2277	(+5)	1.2923	(+5)
49	1.2277	(+5)	1.1109	(+5)	1.1693	(+5)
50	1.1109	(+5)	8.6517	(+4)	9.8803	(+4)

Table A.4.1 continued

Group	Group Limits E(Top)		E(Low)		E(Mid Point)	
51	8.6517	(+4)	6.7379	(+4)	7.6948	(+4)
52	6.7379	(+4)	5.2475	(+4)	5.9927	(+4)
53	5.2475	(+4)	4.0868	(+4)	4.6671	(+4)
54	4.0868	(+4)	3.1828	(+4)	3.6348	(+4)
55	3.1828	(+4)	2.4788	(+4)	2.8308	(+4)
56	2.4788	(+4)	1.9305	(+4)	2.2046	(+4)
57	1.9305	(+4)	1.5034	(+4)	1.7169	(+4)
58	1.5034	(+4)	1.1709	(+4)	1.3372	(+4)
59	1.1709	(+4)	9.1188	(+3)	1.0414	(+4)
60	9.1188	(+3)	7.1017	(+3)	8.1103	(+3)
61	7.1017	(+3)	5.5308	(+3)	6.3163	(+3)
62	5.5308	(+3)	4.3074	(+3)	4.9191	(+3)
63	4.3074	(+3)	3.3546	(+3)	3.8310	(+3)
64	3.3546	(+3)	2.6126	(+3)	2.9836	(+3)
65	2.6126	(+3)	2.0347	(+3)	2.3236	(+3)
66	2.0347	(+3)	1.5846	(+3)	1.8096	(+3)
67	1.5846	(+3)	1.2341	(+3)	1.4094	(+3)
68	1.2341	(+3)	9.6112	(+2)	1.0976	(+3)
69	9.6112	(+2)	7.4852	(+2)	8.5482	(+2)
70	7.4852	(+2)	5.8295	(+2)	6.6573	(+2)
71	5.8295	(+2)	4.5733	(+2)	5.1847	(+2)
72	4.5733	(+2)	3.5358	(+2)	4.0379	(+2)
73	3.5358	(+2)	2.7536	(+2)	3.1447	(+2)
74	2.7536	(+2)	2.1445	(+2)	2.4491	(+2)
75	2.1445	(+2)	1.6702	(+2)	1.9074	(+2)
76	1.6702	(+2)	1.3007	(+2)	1.4855	(+2)
77	1.3007	(+2)	1.0130	(+2)	1.1569	(+2)
78	1.0130	(+2)	7.8893	(+1)	9.0097	(+1)
79	7.8893	(+1)	6.1442	(+1)	7.0168	(+1)
80	6.1442	(+1)	4.7851	(+1)	5.4647	(+1)
81	4.7851	(+1)	3.7267	(+1)	4.2559	(+1)
82	3.7267	(+1)	2.9023	(+1)	3.3145	(+1)
83	2.9023	(+1)	2.2603	(+1)	2.5813	(+1)
84	2.2603	(+1)	1.7603	(+1)	2.0103	(+1)
85	1.7603	(+1)	1.3710	(+1)	1.5657	(+1)
86	1.3710	(+1)	1.0677	(+1)	1.2193	(+1)
87	1.0667	(+1)	8.3153	(+0)	9.4962	(+0)
88	8.3153	(+0)	6.4760	(+0)	7.3956	(+0)
89	6.4760	(+0)	5.0435	(+0)	5.7597	(+0)
90	5.0435	(+0)	3.9279	(+0)	4.4857	(+0)
91	3.9279	(+0)	3.0590	(+0)	3.4934	(+0)
92	3.0590	(+0)	2.3824	(+0)	2.7207	(+0)
93	2.3824	(+0)	1.8554	(+0)	2.1189	(+0)
94	1.8554	(+0)	1.4450	(+0)	1.6502	(+0)
95	1.4450	(+0)	1.1254	(+0)	1.2852	(+0)
96	1.1254	(+0)	8.7643	(-1)	1.0009	(+0)
97	8.7643	(-1)	6.8256	(-1)	7.7949	(-1)
98	6.8256	(-1)	5.3158	(-1)	6.0707	(-1)
99	5.3158	(-1)	4.1399	(-1)	4.7279	(-1)
100	4.1399	(-1)	2.5000	(-2)	2.1950	(-1)

*(±n) represents ($10^{\pm n}$)