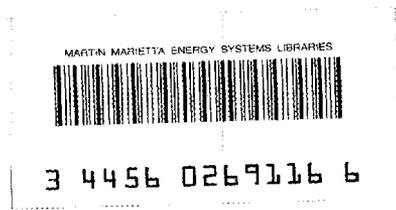


ornl

**OAK RIDGE
NATIONAL
LABORATORY**

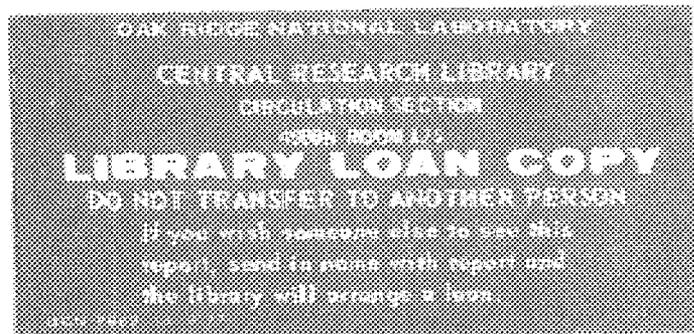
MARTIN MARIETTA



ORNL/TM-10340

A User's Guide to MICAP: A Monte Carlo Ionization Chamber Analysis Package

J. O. Johnson
T. A. Gabriel



OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes--Printed Copy: A13; Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Engineering Physics and Mathematics Division

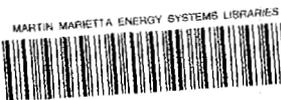
A USER'S GUIDE TO MICAP: A MONTE CARLO IONIZATION
CHAMBER ANALYSIS PACKAGE

J. O. Johnson
T. A. Gabriel

Date Published: January 1988

This Work Sponsored by
Defense Nuclear Agency
Under
Interagency Agreement No. 40-65-65

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400



3 4456 0269116 6

TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	ix
ACKNOWLEDGEMENTS	xi
ABSTRACT	xii
1.0 INTRODUCTION	1
2.0 RDNDF - A CODE FOR READING ENDF/B-FORMATTED DATA FILES.	5
3.0 MICRO - A CODE FOR PROCESSING MICROSCOPIC CROSS SECTION DATA SETS	23
4.0 MACRO - A CODE FOR PRE-MIXING MACROSCOPIC TOTAL CROSS SECTION DATA SETS FOR PROBLEM MIXTURES.	37
5.0 NEUTRON - A CONTINUOUS ENERGY MONTE CARLO CODE FOR TRANSPORTING NEUTRON RADIATION INCIDENT ON AN IONIZATION CHAMBER	45
6.0 RECOMB - A CODE FOR GENERATING RECOMBINATION DATA SETS	117
7.0 HEAVY - A CONTINUOUS ENERGY MONTE CARLO CODE FOR TRANSPORTING RECOIL HEAVY IONS AND CHARGED PARTICLES PRODUCED VIA NEUTRON INTERACTION IN AN IONIZATION CHAMBER.	129
8.0 PECSP - A CODE FOR PROCESSING PHOTON AND ELECTRON CROSS SECTION AND MATERIAL DATA	167
9.0 PHOTPREP - A CODE FOR GENERATING SOURCE INPUT TAPES FOR PROGRAM PHOTON.	201
10.0 PHOTON - A CONTINUOUS ENERGY MONTE CARLO CODE FOR TRANSPORTING PHOTON RADIATION INCIDENT ON AN IONIZATION CHAMBER.	211
REFERENCES	253

APPENDIX A. GENERATION OF POINTWISE CROSS SECTIONS FROM ENDF/B DATA TAPES.	255
1.0 Introduction	257
1.1 RIGEL.	257
1.2 RESND5	260
1.3 LINEAR	262
1.4 SIGMA1	262
1.5 SCAN	264
1.6 Sample Problem	265
APPENDIX B. FIDO INPUT	269

LIST OF TABLES

Table 1.	Subroutine Functions in Program RDNDF	9
Table 2.	Subroutine Functions in Program MICRO	25
Table 3.	Subroutine Functions in Program MACRO	39
Table 4.	Subroutine Functions in Program NEUTRON	53
Table 5.	General Layout of Blank Common in Program NEUTRON	62
Table 6.	Definitions of Variables in Random Walk Blank Common in Program NEUTRON	63
Table 7.	Definitions of Variables in MASS Common in Program NEUTRON	67
Table 8.	Definitions of Variables in CONST Common in Program NEUTRON	68
Table 9.	Definitions of Variables in APOLL Common in Program NEUTRON	69
Table 10.	Definitions of Variables in NUTRON Common in Program NEUTRON	71
Table 11.	Definitions of Variables in GAMMA Common in Program NEUTRON	72
Table 12.	Definitions of Variables in RECOIL Common in Program NEUTRON	73
Table 13.	Definitions of Variables in PAREM Common	74
Table 14.	Definitions of Variables in ORGI Common	76
Table 15.	Definitions of Variables in DBG Common	77
Table 16.	General Layout of Neutron Bank (NBANK Common) in Program NEUTRON	78
Table 17.	General Layout of Secondary Photon Bank (GBANK Common) in Program NEUTRON	79
Table 18.	General Layout of Recoil Heavy Ion and Charged Particle Bank (RBANK Common) in Program NEUTRON	80
Table 19.	Definitions of Subroutine BANKR Arguments for Additional Analysis in Program NEUTRON	81

Table 20.	Combinatorial Geometry Body Data Input Requirements in Program NEUTRON	88
Table 21.	Subroutine Functions in Program RECOMB.	119
Table 22.	Subroutine Functions in Program HEAVY	134
Table 23.	Definitions of Variables in RECOIL Common	137
Table 24.	Definitions of Variables in HPARM Common.	138
Table 25.	Definitions of Variables in NPARM Common.	138
Table 26.	Definitions of Variables in APOLL Common.	139
Table 27.	Definitions of Variables in PAREM Common.	140
Table 28.	Definitions of Variables in ORGI Common	142
Table 29.	Definitions of Variables in DBG Common	143
Table 30.	Combinatorial Geometry Body Data Input Requirements in Program HEAVY	147
Table 31.	Subroutine Functions in Program PECSP	169
Table 32.	Function Purposes in Program PECSP.	170
Table 33.	PECSP Options and Input Specifications.	176
Table 34.	Subroutine Functions in Program PHOTPREP.	204
Table 35.	Information Written on Program PHOTON Input Source Tape	205
Table 36.	Subroutine Functions in Program PHOTON.	218
Table 37.	Definitions of Variables in BOUNDS Common	221
Table 38.	Definitions of Variables in MEDIA Common	221
Table 39.	Definitions of Variables in EPCONT Common	222
Table 40.	Definitions of Variables in MISC Common	223
Table 41.	Definitions of Variables in RANDOM Common	223
Table 42.	Definitions of Variables in STACK Common	224
Table 43.	Definitions of Variables in THRESH Common	225
Table 44.	Definitions of Variables in UPHIOT Common	226

Table 45.	Definitions of Variables in USEFUL Common	226
Table 46.	Definitions of Variables in PAREM Common	227
Table 47.	Definitions of Variables in ORGI Common	229
Table 48.	Definitions of Variables in DBG Common	230
Table 49.	Combinatorial Geometry Body Data Input Requirements in Program PHOTON	231

LIST OF FIGURES

Figure 1.	Simplified Flow Diagram of MICAP - A Monte Carlo Ionization Chamber Analysis Package.	4
Figure 2.	Subroutine Hierarchy in Program RDNDF.	7
Figure 3.	Complete Listing of JCL and Input for RDNDF Sample Problem	16
Figure 4.	Listing of Selected Output from RDNDF Sample Problem	17
Figure 5.	Subroutine Hierarchy in Program MICRO.	24
Figure 6.	Complete Listing of JCL and Input for MICRO Sample Problem	30
Figure 7.	Listing of Selected Output from MICRO Sample Problem	31
Figure 8.	Subroutine Hierarchy in Program MACRO.	38
Figure 9.	Complete Listing of JCL and Input for MACRO Sample Problem	42
Figure 10.	Listing of Selected Output from MACRO Sample Problem	43
Figure 11.	Subroutine Hierarchy in Program NEUTRON.	48
Figure 12.	Complete Listing of JCL and Input for NEUTRON Sample Problem	93
Figure 13.	Listing of Selected Output from NEUTRON Sample Problem	96
Figure 14.	Subroutine Hierarchy in Program RECOMB	118
Figure 15.	Complete Listing of JCL and Input for RECOMB Sample Problem	124
Figure 16.	Listing of Selected Output from RECOMB Sample Problem	125
Figure 17.	Subroutine Hierarchy in Program HEAVY.	132
Figure 18.	Complete Listing of JCL and Input for HEAVY Sample Problem	151

Figure 19.	Listing of Selected Output from HEAVY Sample Problem	154
Figure 20.	Subroutine Hierarchy in Program PECSP.	168
Figure 21.	Complete Listing of JCL and Input for PECSP Sample Problem	184
Figure 22.	Listing of Selected Output from PECSP Sample Problem	185
Figure 23.	Subroutine Hierarchy in Program PHOTPREP	202
Figure 24.	Complete Listing of JCL and Input for PHOTPREP Sample Problem	209
Figure 25.	Subroutine Hierarchy in Program PHOTON	216
Figure 26.	Complete Listing of JCL and Input for PHOTON Sample Problem	235
Figure 27.	Listing of Selected Output from PHOTON Sample Problem	246
Figure A-1.	Schematic Diagram of Pointwise Data Generation with SCAN	266
Figure A-2.	Sample Listing of JCL and Input Used to Generate Pointwise Cross Sections from ENDF/B Data Tapes. .	267

ACKNOWLEDGMENTS

The authors wish to express their sincere appreciation for the many interesting discussions and suggestions contributed by Dr. D. T. Ingersoll, Dr. R. A. Lillie, Dr. R. W. Roussin, Ms. M. B. Emmett, and Mr. M. W. Waddell. The authors are especially indebted to Dr. S. N. Cramer who suggested this project and served as a technical consultant. Special thanks are extended to Angie Alford for typing and preparing the many drafts of this manuscript.

Appreciation is also expressed to Dr. D. E. Bartine, Dr. D. G. Cacuci, and the Engineering Physics and Mathematics Division of the Oak Ridge National Laboratory for providing partial funding of this work. Finally, the authors wish to thank Lt. Cmdr. G. H. Zeman of the Armed Forces Radiobiology Research Institute and Cmdr. Bob Devine of the Defense Nuclear Agency for their strong interest and support of this project.

ABSTRACT

A collection of computer codes entitled MICAP - A Monte Carlo Ionization Chamber Analysis Package has been developed to determine the response of a gas-filled cavity ionization chamber in a mixed neutron and photon radiation environment. In particular, MICAP determines the neutron, photon, and total response of the ionization chamber. The applicability of MICAP encompasses all aspects of mixed field dosimetry analysis including detector design, pre-experimental planning and post-experimental analysis.

The MICAP codes include: RDNDF for reading and processing ENDF/B-formatted cross section files, MICRO for manipulating microscopic cross section data sets, MACRO for creating macroscopic cross section data sets, NEUTRON for transporting neutrons, RECOMB for calculating correction data due to ionization chamber saturation effects, HEAVY for transporting recoil heavy ions and charged particles, PECSP for generating photon and electron cross section and material data sets, PHOTPREP for generating photon source input tapes, and PHOTON for transporting photons and electrons. The codes are generally tailored to provide numerous input options, but whenever possible, default values are supplied which yield adequate results. All of the MICAP codes function independently, and are operational on the ORNL IBM 3033 computer system.

MICAP - A MONTE CARLO IONIZATION CHAMBER ANALYSIS PACKAGE

1.0 INTRODUCTION

There have been three basic methodologies developed for the transport of neutron and photon radiation through matter - diffusion theory, discrete ordinates, and Monte Carlo. Each of these methodologies has been incorporated into sophisticated computer codes applicable to a wide range of problems. The applicability of a methodology to a particular problem is largely dependent on the strengths (or weaknesses) of the methodology and the size and speed of the computer. Diffusion theory and one-dimensional discrete ordinates codes were the early workhorses for radiation transport because of the data requirements and speed of problem execution. As the computer industry developed larger and faster computers, multidimensional discrete ordinates and Monte Carlo codes became economically feasible and viable alternatives to the diffusion theory codes. Furthermore, the evolution of the fast and powerful computers and equally sophisticated computer codes led to an expansion in the applicability of the methodologies employed in radiation transport. This fact coupled with the increased interest in neutron sources in radiation dosimetry led to the development of MICAP - A Monte Carlo Ionization Chamber Analysis Package.

MICAP is designed for determining the response of a gas-filled cavity ionization chamber in a mixed neutron and photon radiation environment. In particular, the code system will determine the neutron, photon, and total response of the ionization chamber. The

applicability of the code system covers all aspects of mixed field dosimetry analysis including detector design, pre-experimental planning and post-experimental analysis.¹ Utilization of MICAP in radiation dosimetry analysis will yield a better understanding of experimental results, and eliminate most of the shortcomings of the methods currently being employed.

The following sections detail the specifics of each module in the MICAP code system. The modules include:

RDNDF Reads ENDF/B-formatted cross section files and processes the data into a suitable form for calculating ionization chamber response characteristics using a continuous Monte Carlo code.

MICRO Manipulates the microscopic cross section data sets created in program RDNDF. In particular, MICRO can combine, copy, or copy and thin data sets.

MACRO Creates a macroscopic total cross section data set for the mixtures in a particular problem.

NEUTRON Transports the neutron source incident on the ionization chamber and generates the recoil heavy ion and charged particle tape and the secondary photon production tape.

RECOMB Calculates the saturation effects which may be present in an ionization chamber. The saturation data curves are applied in the recoil heavy ion and charged particle transport.

HEAVY Transports the recoil heavy ions and charged particles generated in the NEUTRON module. It also incorporates the saturation data (if needed) and determines the ionization

chamber response by recoil heavy ion or charged particle type due to neutrons.

PECSP Generates photon and electron cross section and material data for use in the PHOTON module.

PHOTPREP Generates photon source tapes for input into the PHOTON module.

PHOTON Transports the primary photons incident on the ionization chamber and the secondary photons generated in the NEUTRON module. Determines the ionization chamber response due to photons.

A simplified flow diagram of MICAP is presented in Figure 1.

Each of the modules documented in this report have several special features which are described in the individual sections. Each section includes a brief description of the module, the input requirements, and a sample problem with input and selected outputs shown. For this collection of codes, the general approach has been to provide numerous input options, but whenever possible, default values are supplied which will yield adequate results with a minimum of effort.

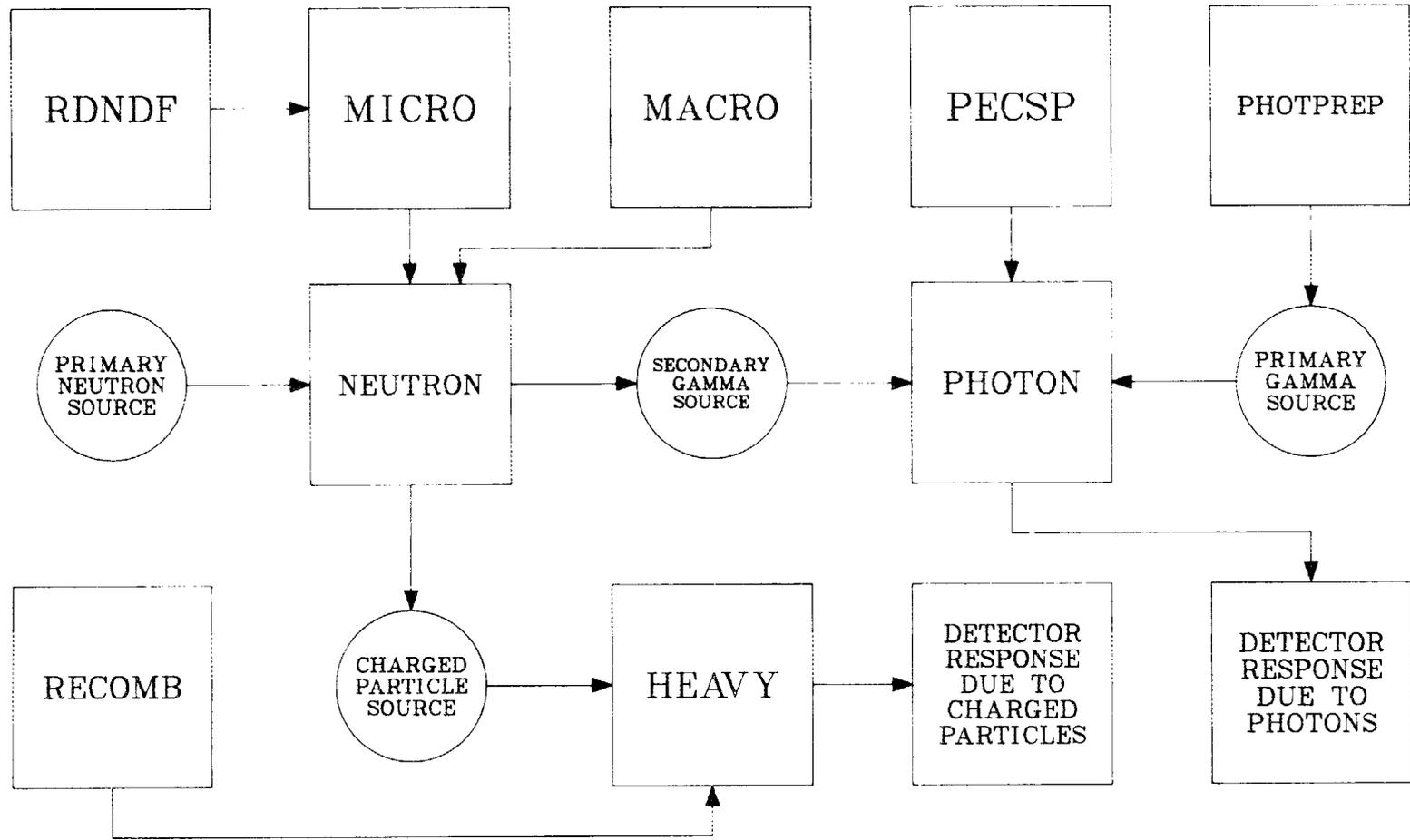


Figure 1. Simplified Flow Diagram of MICAP - A Monte Carlo Ionization Chamber Analysis Package.

2.0 RDNDF - A CODE FOR READING ENDF/B-FORMATTED DATA FILES

2.1 Code Description

The program RDNDF is designed to read ENDF/B-formatted cross section files and process the data into a suitable form for calculating ionization chamber response characteristics using a continuous-energy Monte Carlo program. In particular, the program processes the ENDF/B general information file 1; the neutron data files 3, 4, and 5; and the secondary photon production data files 12, 13, 14, and 15. Program RDNDF assumes the data has already been pre-processed through the RESND5-LINEAR/SIGMA1 program (Appendix A) and that all cross-section data is linearly interpolable over the entire energy range. Because the pre-processing package is structured to be executed for one material at a time, the RDNDF program is also currently limited to processing only one material at a time. Special features of RDNDF include:

1. Processes either binary or BCD formatted data.
2. Stores either $\nu\sigma_f$ or σ_f in the fission cross section position.
3. Utilizes random access devices in the data processing.
4. Calculates an average photon production per neutron interaction table as a function of energy.
5. Calculates a total neutron disappearance table as a function of energy.
6. Processes the neutron angular distribution data into tabulated probability distribution functions.
7. Assumes the secondary photon angular distributions are isotropic.

8. Writes control block records and dictionary records to maintain book-keeping of the sequentially written output file.
9. Allows thinning of the output cross sections and angular distributions.
10. Incorporates multiple options to print portions of the various output files.

To completely understand the contents of the ENDF/B data files and the definitions of the variables written in the output of Files 4, 5, 12, 13, and 15, the user should consult ENDF-102: The Data Formats And Procedures Manual for the Evaluated Nuclear Data File, ENDF/B-V.² The subroutine hierarchy of program RDNDF is shown in Figure 2, and a list of the program subroutines along with their functions is given in Table 1.

2.2 Input Requirements

The following input cards are required in order to execute a RDNDF case. Default values are in brackets ([]).

Card 1: Format (3E12.5,3I6)

TOL	Fractional thinning tolerance for the output microscopic cross sections. [1.00-03]
ANGTOL	Fractional angular tolerance for the output angular distributions. [1.00-02]
TEMP	Cross-section temperature in degrees Kelvin. [0.0]
MODE	Input cross-section data mode (0 - binary; 1 - BCD).
MATNO	ENDF/B material identification number.
NUSIG	Fission cross-section storage flag. (0 - stores $\nu\sigma_F$, 1 - stores σ_F) [0]

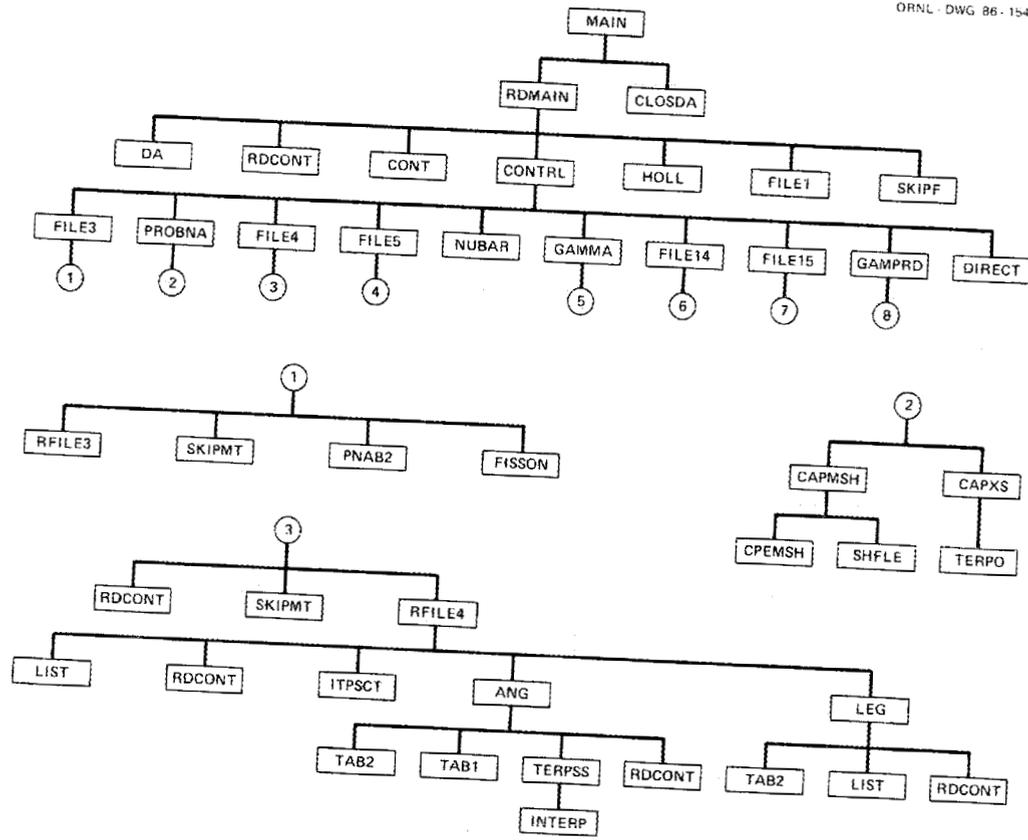
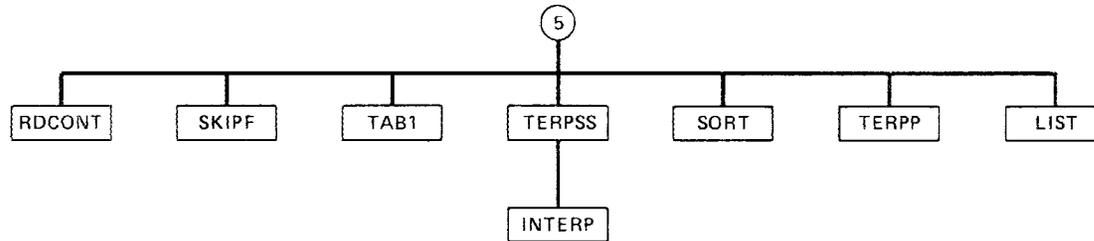
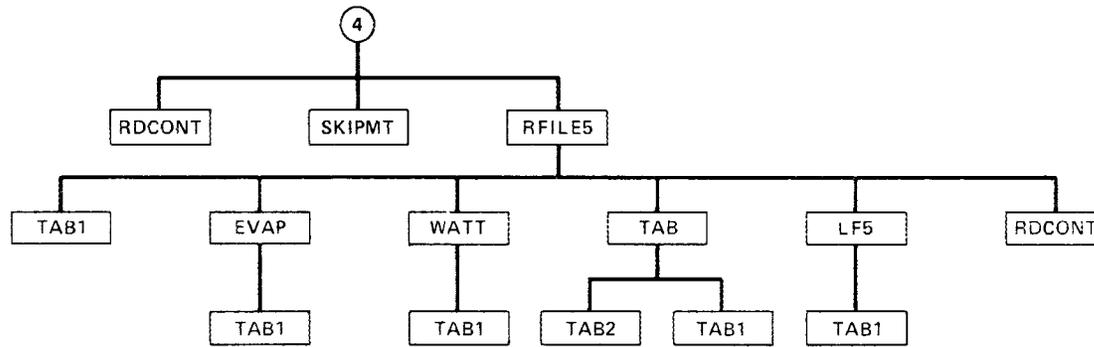


Figure 2. Subroutine Hierarchy in Program RDNDF.



∞

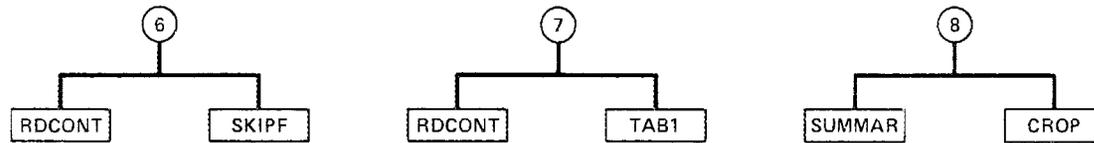


Figure 2. (continued).

Table 1. Subroutine Functions in Program RDNDF

Subroutine	Function
ANG	Reads an ENDF/B File 4 tabulated probability distribution and transformation matrix file to reconstruct the angular distribution probability tables.
CAPMSH	Calculates the energy mesh for the total neutron disappearance array.
CAPXS	Calculates the total neutron disappearance array for the energy mesh calculated in routine CAPMSH.
CONT	Reads an ENDF/B-formatted control record searching for the material number MAT.
CONTRL	The driver routine for reading the ENDF/B files, manipulating the data, and writing the output data set.
CPEMSH	An interpolation routine for calculating the composite energy mesh for the total neutron disappearance array.
CROP	Thins an array using the tolerance TOL.
DIRECT	List out the directory for the output neutron dictionary array (IDICT).
EVAP	Reads an ENDF/B File 5 simple fission spectrum (Maxwellian) or an evaporation spectrum.
FILE1	Reads the $\bar{\nu}$ file from ENDF/B File 1 and writes it to logical unit 9 for future use.
FILE3	Reads the neutron cross section data from ENDF/B File 3 and writes it sequentially to logical unit 8 for future use.
FILE4	Reads the neutron angular distribution data from ENDF/B File 4 and writes it sequentially to logical unit 8 for future use.
FILE5	Reads the neutron secondary energy distribution data from ENDF/B File 5 and writes it sequentially to logical unit 8 for future use.

Table 1. (continued)

Subroutine	Function
FILE14	Reads the photon angular distribution data from ENDF/B File 14.
FILE15	Reads the photon secondary energy distribution data from ENDF/B File 15 and writes it sequentially to logical unit IGAM for future use.
FISSION	Reads the $\bar{\nu}$ data from logical unit 9 and the σ_f cross section from logical unit 8 and constructs $\bar{\nu}\sigma_f$.
GAMMA	Reads the photon production multiplicities from ENDF/B File 12 and the photon production cross sections from ENDF/B File 13. Computes the total photon production cross sections and writes it sequentially to logical unit IGAMP. Writes the partial cross section sets sequentially to logical unit IGAM for future use.
GAMPRD	Computes the average number of photons emitted per collision array.
HOLL	Reads the second and third records of ENDF/B File 1 and the hollerith data section describing the data set evaluation.
INTERP	A general interpolation routine capable of executing the five ENDF/B interpolation schemes.
ITPSCT	Flags the user when a neutron reaction scatters isotropically.
LEG	Reads an ENDF/B File 4 Legendre polynomial coefficient and transformation matrix file to reconstruct the angular distribution probability tables.
LF5	Reads an ENDF/B File 5 general evaporation spectrum.
LIST	Reads ENDF/B formatted LIST records.
MAIN	Initializes the amount of core storage (LEN) used for the data processing and closes the random access units.
NUBAR	Reads the $\bar{\nu}$ array from logical unit 9 and writes it to logical unit 8 for future use.

Table 1. (continued)

Subroutine	Function
PNAB2	Writes ENDF/B MT's 102-114 to logical unit NPNAB for subsequent processing in routine PROBNA.
PROBNA	Reads logical unit NPNAB and calculates the total neutron disappearance array.
RDCONT	Reads ENDF/B formatted CONTROL records.
RDMAIN	Reads the input data and initiates the processing of the ENDF/B files.
RFILE3	The driver routine for processing ENDF/B File 3 data.
RFILE4	The driver routine for processing ENDF/B File 4 data.
RFILE5	The driver routine for processing ENDF/B File 5 data.
SHFLE	Copies an array to another array for future processing.
SKIPF	Reads ENDF/B formatted data to skip an entire file.
SKIPMT	Reads ENDF/B formatted data to skip a particular MT.
SORT	Sorts an array into ascending order.
SUMARR	Sums two arrays of different lengths into a third array.
TAB	Reads ENDF/B formatted TAB records.
TAB1	Reads ENDF/B formatted TAB1 records.
TAB2	Reads ENDF/B formatted TAB2 records.
TERPO	An interpolation routine used in calculating the total neutron disappearance array.
TERPP	An interpolation routine used in calculating the average photon yield per collision.
TERPSS	An interpolation routine used in processing ENDF/B File 15 data.
WATT	Reads an ENDF/B File 5 energy dependent Watt spectrum.

Card 2: Format (8I6)

INN Input card unit. [5]
IOUT Printed output unit. [6]
NPNAB Total neutron disappearance cross-section processing scratch unit. [61]
ISCR Cross-section processing scratch unit. [62]
IGAM Photon production cross-section processing scratch unit. [63]
IGAMP Average photon production cross-section processing scratch unit. [64]
ITAPE Input cross section Library. [60]
OTAPE Output cross section Library. [65]

Card 3: FORMAT (9I6)

NB8 Number of storage blocks for random access unit 8. [400]
NL8 Block size for random access unit 8. [880]
NR8 The associated variable for random access unit 8. [1]
NB9 Number of storage blocks for random access unit 9. [100]
NL9 Block size for random access unit 9. [880]
NR9 The associated variable for random access unit 9. [1]
NB10 Number of storage blocks for random access unit 10. [100]
NL10 Block size for random access unit 10. [880]
NR10 The associated variable for random access unit 10. [1]

Card 4: Format (10I6)

NPRT01 1/0 - Print/Do not print ENDF/B File 1. [0]
NPRT03 1/0 - Print/Do not print ENDF/B File 3. [0]
NPRT04 1/0 - Print/Do not print ENDF/B File 4. [0]
NPRT05 1/0 - Print/Do not print ENDF/B File 5. [0]
NPRTNU 1/0 - Print/Do not print $\bar{\nu}$ array. [0]

NPRTPY 1/0 - Print/Do not print the average photon production per collision array. [0]

NPRTNA 1/0 - Print/Do not print the total neutron disappearance array. [0]

NPRTQA 1/0 - Print/Do not print the ENDF/B reaction Q-value array. [0]

NPRT12 1/0 - Print/Do not print ENDF/B Files 12 and 13. [0]

NPRT13 1/0 - Print/Do not print ENDF/B File 15. [0]

2.3 Input Data Notes

MODE While RDNDF is written to accept either binary or BCD formatted input data files, the pre-processor package only produces BCD data files. Therefore MODE should always be set to 1.

NUSIG The default value is set to zero because the NEUTRON code expects the fission cross section stored as $\bar{\nu}\sigma_f$. Therefore set NUSIG to 0.

NB8,NB9,NB10, The numbers used for these six variables are NL8,NL8,NL10, dependent on the material being processed. A large block size requires fewer blocks and also fewer I/O's. However, for all data sets, large amounts of empty spaces are being transferred. Trial and error is the best way to optimize these values if I/O's become a problem.

NPRTxx Flagging all the print triggers on at once will produce considerable output for large evaluations.

2.4 I/O File Requirements

File	Unit	Description	Required
INN	5	Card Input	Always
IOUT	6	Printed Output	Always
NPNAB	61	Neutron Disappearance Array Scratch Unit	Always
ISCR	62	Cross Section Scratch Unit	Always
IGAM	63	Photon Production Cross Section Scratch Unit	Always
IGAMP	64	Average Photon Production Array Scratch Unit	Always
ITAPE	60	Input Cross Section Library	Always
OTAPE	65	Output Cross Section Library	Always

2.5 JCL Requirements

The job control language (JCL) needed to run a RDNDF case at X-10 is:

```
(Job card, route and jobparm cards)
//RDNDF EXEC PGM=RDNDF,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD SYSOUT=A
//FT08F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
//FT09F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
//FT10F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
(DD Cards for the Input Unit)
(DD Cards for Scratch Units)
(DD Cards for the Output Unit)
//SYSIN DD *
(Input Cards)
/*
//
```

2.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 3 and some selected output is shown in Figure 4. The problem demonstrates the processing of the hydrogen data file with all print triggers turned off.

```

//JOJRDNDF JOB (24337,IO2),'JO JOHNSON 6025',TIME=(0,10)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
/*JOBPARM LINECT=62
//A EXEC PGM=RDNDF,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT08F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
//FT09F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
//FT10F001 DD UNIT=SYSDA,SPACE=(CYL,(4,1)),DCB=(DSORG=DA,RECFM=F)
//FT60F001 DD DSN=MEN.X10.JOJ.HYDROGEN,DISP=SHR
//FT61F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&NPNAB,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//FT62F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&ISCR,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//FT63F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&IGAM,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//FT64F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&IGAMP,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//FT65F001 DD UNIT=3330V,VOL=SER=VINT09,DISP=(NEW,CATLG),
// DSN=MEN.X10.JOJ.RDNDF.H2,SPACE=(TRK,(5,20),RLSE),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//SYSIN DD *
1.00000E-03 1.00000E-02          300.0      1  1301      1
      5      6      61      62      63      64      60      65
400      880      1      100      880      1      100      880      1
      0      0      0      0      0      0      0      0      0      0
/*
//

```

Figure 3. Complete Listing of JCL and Input for RDNDF Sample Problem.

```

      FILE 3 - NEUTRON CROSS SECTIONS
MT=   1  NUMBER OF CROSS SECTIONS= 135
MT=   2  NUMBER OF CROSS SECTIONS= 130
MT= 102  NUMBER OF CROSS SECTIONS= 225
MT= 102  NUMBER OF CROSS SECTIONS= 225  ADDED TO ABSORPTION
MT= 251  SKIPPED
MT= 252  SKIPPED
MT= 253  SKIPPED
MT= 285  SKIPPED

      FILE 4 - ANGULAR DISTRIBUTIONS OF SECONDARY NEUTRONS
MT=   2  NUMBER OF INCIDENT ENERGIES= 14

      FILE 5 - ENERGY DISTRIBUTIONS OF SECONDARY NEUTRONS

      FILE 12 - PHOTON PRODUCTION MULTIPLICITIES AND TRANSITION PROBABILITIES
      -- AND --
      FILE 13 - PHOTON PRODUCTION CROSS SECTIONS
MT= 102  FILE= 12  PHOTON PRODUCTION DATA

      FILE 14 - PHOTON ANGULAR DISTRIBUTIONS
ALL PHOTONS ARE ASSUMED TO SCATTER ACCORDING TO AN ISOTROPIC ANGULAR DISTRIBUTION

A CONTROL BLOCK (ACB)

      NI      LENGTH
      1      2987

B CONTROL BLOCK (BCB)

      IIA  ICB RECNO  IRECNO
      1001      3      13

I CONTROL BLOCK (ICB)

      ISUM      AWR      TEMP      TOL      ANGTOL      UNR FLG
      2987  9.9917E-01  3.0000E+02  1.0000E-03  1.0000E-02      0

      LENGAM      NT      NTS      NQ      THRMLN      LENMAB
      388      1      0      66      0      450

```

Figure 4. Listing of Selected Output from RDNDF Sample Problem.

THE DEFINITIONS OF THE VARIABLES WRITTEN IN THE OUTPUT OF FILES 4, 5, 12, 13, 15, AND NUBAR CAN

BE FOUND IN THE DATA FORMATS AND PROCEDURES MANUAL FOR THE EVALUATED NUCLEAR DATA FILE, ENDF/B-V: ENDF-102

OUTPUT TAPE DICTIONARY (IDICT) FOR ELEMENT 1001

POSITION	LENGTH								
1	270	2	260	3	0	4	0	5	0
6	0	7	0	8	0	9	0	10	0
11	0	12	0	13	0	14	0	15	0
16	0	17	0	18	0	19	0	20	0
21	0	22	0	23	0	24	0	25	0
26	0	27	0	28	0	29	0	30	0
31	0	32	0	33	0	34	0	35	0
36	0	37	0	38	0	39	0	40	0
41	0	42	0	43	0	44	0	45	0
46	0	47	0	48	0	49	0	50	0
51	0	52	0	53	0	54	0	55	450
56	0	57	0	58	0	59	0	60	0
61	0	62	0	63	0	64	0	65	0
66	0	67	350	68	0	69	0	70	0
71	0	72	0	73	0	74	0	75	0
76	0	77	0	78	0	79	0	80	0
81	0	82	0	83	0	84	0	85	0
86	0	87	0	88	0	89	0	90	0
91	0	92	0	93	0	94	0	95	0
96	0	97	0	98	0	99	0	100	0
101	0	102	0	103	0	104	0	105	0
106	0	107	0	108	0	109	0	110	0
111	0	112	0	113	0	114	0	115	0
116	0	117	0	118	0	119	0	120	0
121	0	122	0	123	0	124	0	125	0
126	0	127	0	128	0	129	0	130	0
131	0	132	0	133	0	134	0		

Figure 4. (continued).

DIRECTORY OF THE OUTPUT TAPE DICTIONARY (IDICT)

POSITION 1:	TOTAL CROSS SECTION	(MT= 1)
POSITION 2:	ELASTIC SCATTERING CROSS SECTION	(MT= 2)
POSITION 3:	TOTAL INELASTIC SCATTERING CROSS SECTION	(MT= 4)
POSITION 4:	(N,2N) CROSS SECTION FOR 1ST EXCITED STATE	(MT= 6)
POSITION 5:	(N,2N) CROSS SECTION FOR 2ND EXCITED STATE	(MT= 7)
POSITION 6:	(N,2N) CROSS SECTION FOR 3RD EXCITED STATE	(MT= 8)
POSITION 7:	(N,2N) CROSS SECTION FOR 4TH EXCITED STATE	(MT= 9)
POSITION 8:	TOTAL (N,2N) CROSS SECTION	(MT= 16)
POSITION 9:	TOTAL (N,3N) CROSS SECTION	(MT= 17)
POSITION 10:	TOTAL FISSION CROSS SECTION	(MT= 18)
POSITION 11:	(N,N"A) CROSS SECTION	(MT= 22)
POSITION 12:	(N,2NA) CROSS SECTION	(MT= 24)
POSITION 13:	(N,N"P) CROSS SECTION	(MT= 28)
POSITION 14:	(N,N") CROSS SECTION TO THE 1ST EXCITED STATE	(MT= 51)
POSITION 15:	(N,N") CROSS SECTION TO THE 2ND EXCITED STATE	(MT= 52)
POSITION 16:	(N,N") CROSS SECTION TO THE 3RD EXCITED STATE	(MT= 53)
POSITION 17:	(N,N") CROSS SECTION TO THE 4TH EXCITED STATE	(MT= 54)
POSITION 18:	(N,N") CROSS SECTION TO THE 5TH EXCITED STATE	(MT= 55)
POSITION 19:	(N,N") CROSS SECTION TO THE 6TH EXCITED STATE	(MT= 56)
POSITION 20:	(N,N") CROSS SECTION TO THE 7TH EXCITED STATE	(MT= 57)
POSITION 21:	(N,N") CROSS SECTION TO THE 8TH EXCITED STATE	(MT= 58)
POSITION 22:	(N,N") CROSS SECTION TO THE 9TH EXCITED STATE	(MT= 59)
POSITION 23:	(N,N") CROSS SECTION TO THE 10TH EXCITED STATE	(MT= 60)
POSITION 24:	(N,N") CROSS SECTION TO THE 11TH EXCITED STATE	(MT= 61)
POSITION 25:	(N,N") CROSS SECTION TO THE 12TH EXCITED STATE	(MT= 62)
POSITION 26:	(N,N") CROSS SECTION TO THE 13TH EXCITED STATE	(MT= 63)
POSITION 27:	(N,N") CROSS SECTION TO THE 14TH EXCITED STATE	(MT= 64)
POSITION 28:	(N,N") CROSS SECTION TO THE 15TH EXCITED STATE	(MT= 65)
POSITION 29:	(N,N") CROSS SECTION TO THE 16TH EXCITED STATE	(MT= 66)
POSITION 30:	(N,N") CROSS SECTION TO THE 17TH EXCITED STATE	(MT= 67)
POSITION 31:	(N,N") CROSS SECTION TO THE 18TH EXCITED STATE	(MT= 68)
POSITION 32:	(N,N") CROSS SECTION TO THE 19TH EXCITED STATE	(MT= 69)
POSITION 33:	(N,N") CROSS SECTION TO THE 20TH EXCITED STATE	(MT= 70)
POSITION 34:	(N,N") CROSS SECTION TO THE 21ST EXCITED STATE	(MT= 71)
POSITION 35:	(N,N") CROSS SECTION TO THE 22ND EXCITED STATE	(MT= 72)
POSITION 36:	(N,N") CROSS SECTION TO THE 23RD EXCITED STATE	(MT= 73)
POSITION 37:	(N,N") CROSS SECTION TO THE 24TH EXCITED STATE	(MT= 74)
POSITION 38:	(N,N") CROSS SECTION TO THE 25TH EXCITED STATE	(MT= 75)
POSITION 39:	(N,N") CROSS SECTION TO THE 26TH EXCITED STATE	(MT= 76)
POSITION 40:	(N,N") CROSS SECTION TO THE 27TH EXCITED STATE	(MT= 77)

Figure 4. (continued).

POSITION 41: (N,N") CROSS SECTION TO THE 28TH EXCITED STATE (MT= 78)
 POSITION 42: (N,N") CROSS SECTION TO THE 29TH EXCITED STATE (MT= 79)
 POSITION 43: (N,N") CROSS SECTION TO THE 30TH EXCITED STATE (MT= 80)
 POSITION 44: (N,N") CROSS SECTION TO THE 31ST EXCITED STATE (MT= 81)
 POSITION 45: (N,N") CROSS SECTION TO THE 32ND EXCITED STATE (MT= 82)
 POSITION 46: (N,N") CROSS SECTION TO THE 33RD EXCITED STATE (MT= 83)
 POSITION 47: (N,N") CROSS SECTION TO THE 34TH EXCITED STATE (MT= 84)
 POSITION 48: (N,N") CROSS SECTION TO THE 35TH EXCITED STATE (MT= 85)
 POSITION 49: (N,N") CROSS SECTION TO THE 36TH EXCITED STATE (MT= 86)
 POSITION 50: (N,N") CROSS SECTION TO THE 37TH EXCITED STATE (MT= 87)
 POSITION 51: (N,N") CROSS SECTION TO THE 38TH EXCITED STATE (MT= 88)
 POSITION 52: (N,N") CROSS SECTION TO THE 39TH EXCITED STATE (MT= 89)
 POSITION 53: (N,N") CROSS SECTION TO THE 40TH EXCITED STATE (MT= 90)
 POSITION 54: (N,N") CROSS SECTION TO THE CONTINUUM (MT= 91)
 POSITION 55: (N,G) CROSS SECTION (MT= 102)
 POSITION 56: (N,P) CROSS SECTION (MT= 103)
 POSITION 57: (N,D) CROSS SECTION (MT= 104)
 POSITION 58: (N,T) CROSS SECTION (MT= 105)
 POSITION 59: (N,3HE) CROSS SECTION (MT= 106)
 POSITION 60: (N,A) CROSS SECTION (MT= 107)
 POSITION 61: (N,2A) CROSS SECTION (MT= 108)
 POSITION 62: (N,3A) CROSS SECTION (MT= 109)
 POSITION 63: (N,2P) CROSS SECTION (MT= 111)
 POSITION 64: (N,PA) CROSS SECTION (MT= 112)
 POSITION 65: (N,T2A) CROSS SECTION (MT= 113)
 POSITION 66: (N,D2A) CROSS SECTION (MT= 114)
 POSITION 67: ELASTIC SCATTERING ANGULAR DISTRIBUTION (MT= 2)
 POSITION 68: (N,2N) ANG. DIST. FOR 1ST EXCITED STATE, 1ST N (MT= 6)
 POSITION 69: (N,2N) ANG. DIST. FOR 2ND EXCITED STATE, 1ST N (MT= 7)
 POSITION 70: (N,2N) ANG. DIST. FOR 3RD EXCITED STATE, 1ST N (MT= 8)
 POSITION 71: (N,2N) ANG. DIST. FOR 4TH EXCITED STATE, 1ST N (MT= 9)
 POSITION 72: TOTAL (N,2N) ANGULAR DISTRIBUTION (MT= 16)
 POSITION 73: TOTAL (N,3N) ANGULAR DISTRIBUTION (MT= 17)
 POSITION 74: TOTAL FISSION ANGULAR DISTRIBUTION (MT= 18)
 POSITION 75: (N,N"A) ANGULAR DISTRIBUTION (MT= 22)
 POSITION 76: (N,2NA) ANGULAR DISTRIBUTION (MT= 24)
 POSITION 77: (N,N"P) ANGULAR DISTRIBUTION (MT= 28)
 POSITION 78: (N,2N) ANG. DIST. FOR 1ST EXCITED STATE, 2ND N (MT= 46)
 POSITION 79: (N,2N) ANG. DIST. FOR 2ND EXCITED STATE, 2ND N (MT= 47)
 POSITION 80: (N,2N) ANG. DIST. FOR 3RD EXCITED STATE, 2ND N (MT= 48)

Figure 4. (continued).

POSITION 81: (N,2N) ANG. DIST. FOR 4TH EXCITED STATE, 2ND N (MT= 49)
 POSITION 82: (N,N") ANG. DIST. FOR THE 1ST EXCITED STATE (MT= 51)
 POSITION 83: (N,N") ANG. DIST. FOR THE 2ND EXCITED STATE (MT= 52)
 POSITION 84: (N,N") ANG. DIST. FOR THE 3RD EXCITED STATE (MT= 53)
 POSITION 85: (N,N") ANG. DIST. FOR THE 4TH EXCITED STATE (MT= 54)
 POSITION 86: (N,N") ANG. DIST. FOR THE 5TH EXCITED STATE (MT= 55)
 POSITION 87: (N,N") ANG. DIST. FOR THE 6TH EXCITED STATE (MT= 56)
 POSITION 88: (N,N") ANG. DIST. FOR THE 7TH EXCITED STATE (MT= 57)
 POSITION 89: (N,N") ANG. DIST. FOR THE 8TH EXCITED STATE (MT= 58)
 POSITION 90: (N,N") ANG. DIST. FOR THE 9TH EXCITED STATE (MT= 59)
 POSITION 91: (N,N") ANG. DIST. FOR THE 10TH EXCITED STATE (MT= 60)
 POSITION 92: (N,N") ANG. DIST. FOR THE 11TH EXCITED STATE (MT= 61)
 POSITION 93: (N,N") ANG. DIST. FOR THE 12TH EXCITED STATE (MT= 62)
 POSITION 94: (N,N") ANG. DIST. FOR THE 13TH EXCITED STATE (MT= 63)
 POSITION 95: (N,N") ANG. DIST. FOR THE 14TH EXCITED STATE (MT= 64)
 POSITION 96: (N,N") ANG. DIST. FOR THE 15TH EXCITED STATE (MT= 65)
 POSITION 97: (N,N") ANG. DIST. FOR THE 16TH EXCITED STATE (MT= 66)
 POSITION 98: (N,N") ANG. DIST. FOR THE 17TH EXCITED STATE (MT= 67)
 POSITION 99: (N,N") ANG. DIST. FOR THE 18TH EXCITED STATE (MT= 68)
 POSITION 100: (N,N") ANG. DIST. FOR THE 19TH EXCITED STATE (MT= 69)
 POSITION 101: (N,N") ANG. DIST. FOR THE 20TH EXCITED STATE (MT= 70)
 POSITION 102: (N,N") ANG. DIST. FOR THE 21ST EXCITED STATE (MT= 71)
 POSITION 103: (N,N") ANG. DIST. FOR THE 22ND EXCITED STATE (MT= 72)
 POSITION 104: (N,N") ANG. DIST. FOR THE 23RD EXCITED STATE (MT= 73)
 POSITION 105: (N,N") ANG. DIST. FOR THE 24TH EXCITED STATE (MT= 74)
 POSITION 106: (N,N") ANG. DIST. FOR THE 25TH EXCITED STATE (MT= 75)
 POSITION 107: (N,N") ANG. DIST. FOR THE 26TH EXCITED STATE (MT= 76)
 POSITION 108: (N,N") ANG. DIST. FOR THE 27TH EXCITED STATE (MT= 77)
 POSITION 109: (N,N") ANG. DIST. FOR THE 28TH EXCITED STATE (MT= 78)
 POSITION 110: (N,N") ANG. DIST. FOR THE 29TH EXCITED STATE (MT= 79)
 POSITION 111: (N,N") ANG. DIST. FOR THE 30TH EXCITED STATE (MT= 80)
 POSITION 112: (N,N") ANG. DIST. FOR THE 31ST EXCITED STATE (MT= 81)
 POSITION 113: (N,N") ANG. DIST. FOR THE 32ND EXCITED STATE (MT= 82)
 POSITION 114: (N,N") ANG. DIST. FOR THE 33RD EXCITED STATE (MT= 83)
 POSITION 115: (N,N") ANG. DIST. FOR THE 34TH EXCITED STATE (MT= 84)
 POSITION 116: (N,N") ANG. DIST. FOR THE 35TH EXCITED STATE (MT= 85)
 POSITION 117: (N,N") ANG. DIST. FOR THE 36TH EXCITED STATE (MT= 86)
 POSITION 118: (N,N") ANG. DIST. FOR THE 37TH EXCITED STATE (MT= 87)
 POSITION 119: (N,N") ANG. DIST. FOR THE 38TH EXCITED STATE (MT= 88)
 POSITION 120: (N,N") ANG. DIST. FOR THE 39TH EXCITED STATE (MT= 89)

Figure 4. (continued).

POSITION 121: (N,Nⁿ) ANG. DIST. FOR THE 40TH EXCITED STATE (MT= 90)
 POSITION 122: (N,Nⁿ) ANG. DIST. FOR THE CONTINUUM (MT= 91)
 POSITION 123: TOTAL (N,2N) SECONDARY ENERGY DISTRIBUTION (MT= 16)
 POSITION 124: TOTAL (N,3N) SECONDARY ENERGY DISTRIBUTION (MT= 17)
 POSITION 125: TOTAL FISSION SECONDARY ENERGY DISTRIBUTION (MT= 18)
 POSITION 126: (N,NⁿA) SECONDARY ENERGY DISTRIBUTION (MT= 22)
 POSITION 127: (N,2NA) SECONDARY ENERGY DISTRIBUTION (MT= 24)
 POSITION 128: (N,NⁿP) SECONDARY ENERGY DISTRIBUTION (MT= 28)
 POSITION 129: (N,2N) SEC E DIST FOR 1ST EXCITED STATE, 2ND N (MT= 46)
 POSITION 130: (N,2N) SEC E DIST FOR 2ND EXCITED STATE, 2ND N (MT= 47)
 POSITION 131: (N,2N) SEC E DIST FOR 3RD EXCITED STATE, 2ND N (MT= 48)
 POSITION 132: (N,2N) SEC E DIST FOR 4TH EXCITED STATE, 2ND N (MT= 49)
 POSITION 133: (N,Nⁿ) SEC. ENERGY DIST. FOR THE CONTINUUM (MT= 91)
 POSITION 134: AVERAGE TOTAL NUMBER OF NEUTRONS PER FISSION (MT= 452)

PHOTON PRODUCTION CROSS SECTION DICTIONARY (MTGAM)

REACTION	LENGTH	REACTION	LENGTH	REACTION	LENGTH	REACTION	LENGTH	REACTION	LENGTH
102	460								
POINT XSEC WRITTEN ON UNIT		65	LENGTH=	2987					

Figure 4. (continued).

3.0 MICRO - A CODE FOR PROCESSING MICROSCOPIC CROSS SECTION DATA SETS

3.1 Code Description

The program MICRO is designed to manipulate the cross section data sets created in program RDNDF. As such, MICRO functions as a microscopic cross section utility program. In particular, MICRO can combine two data sets, copy all or part of a data set, or copy a data set and thin the data set prior to output. The particular function MICRO performs is dependent on the input parameter ITYP. Because RDNDF is presently limited to processing one material at a time, the primary use for program MICRO is to combine RDNDF output data sets to form a microscopic cross section library. The maximum number of elements on a data set cannot exceed 50 for the current version of the program. The limiting array is the B Control Block (BCD array).

The subroutine hierarchy of program MICRO is presented in Figure 5. Also, a list of the subroutines used in program MICRO along with their function is given in Table 2.

3.2 Input Requirements

The following input cards are required in order to execute a MICRO case. Default values are in brackets ([]).

Card 1: Format (4I6)

INN Input card unit [5]

IOUT Printed output unit [6]

ITYP Job control parameter.

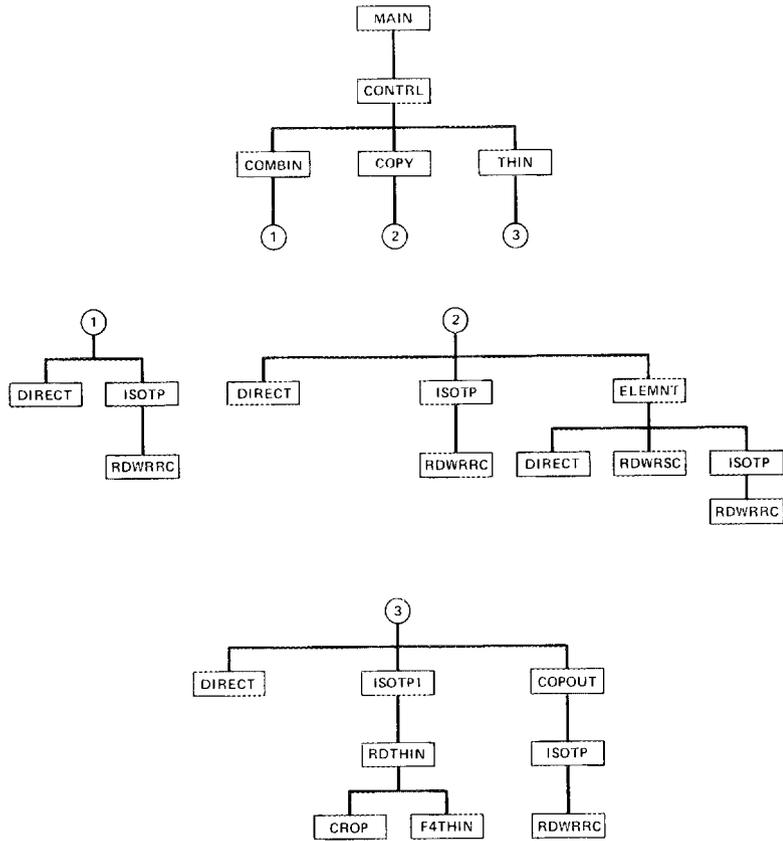


Figure 5. Subroutine Hierarchy in Program MICRO.

Table 2. Subroutine Functions in Program MICRO

Subroutine	Function
COMBIN	Reads in two data sets and combines them into a third data set.
CONTRL	Reads in the input and initiates the utility operation according to the parameter ITYP.
COPOUT	Copies a data set from a scratch logical unit to an output logical unit.
COPY	Copies an entire data set from an input logical unit to an output logical unit.
CROP	Thins an array using the tolerance TOL.
DIRECT	List out the directory for the output neutron cross section dictionary array (IDICT).
ELEMNT	Selectively copies specified elements from an input data set to an output data set.
F4THN	Thins ENDF/B File 4 angular distribution data by excluding some of the incident neutron energies and their associated tabulated distributions.
ISOTP	Reads in the I control block (ICB) and the dictionary (IDICT) for each isotope, and then writes the data set to an output logical unit.
ISOTP1	Reads in the I control block (ICB) and the dictionary (IDICT) for each isotope, initiates thinning and then writes the data to an output logical unit.
MAIN	Initializes the amount of core storage (LEN) used for the utility operation implemented in routine CONTRL.
RDTHIN	Reads in the input data arrays, thins the data, updates the control blocks, and writes the data to the output logical unit.

Table 2. (continued)

Subroutine	Function
RDWRRC	Reads and writes arrays of data from the input logical unit to the output logical unit.
RDWRSC	Reads and writes arrays of data from the input logical unit to a scratch logical unit.
THIN	Copies an input data set to a scratch logical unit, thins the data, and writes the data set to an output logical unit.

- 1 Combine two data sets.
- 2 Copy a data set from one unit to another unit.
- 3 Thin the data set and copy from one unit to another unit.

NPRT 1/0 - Print/Do not print the BUF array [0]

Note: Card 2 will depend on the value ITYP.

Card 2 (ITYP=1): Format (3I6)

ITAPE1 The first input microscopic cross section data set unit.
[60]

ITAPE2 The second input microscopic cross section data set unit.
[61]

ITAPE3 The output combined microscopic cross section data set unit.
[62]

Card 2 (ITYP=2): Format (4I6)

ITAPE1 The input microscopic cross section data set unit. [60]

ISCR Scratch unit used in cross section processing (NELM > 0). [63]

ITAPE3 The output microscopic cross section data set unit. [62]

NELM 0/N - Copy all/Copy N nuclides from unit ITAPE1. [0]

Card(s) 3 (NELM > 0): Format (10I6)

MATNO (I), I=1, NELM The nuclide identification numbers
(in ENDF/B ZA format) to be copied to the output microscopic
cross section data set on unit ITAPE3.

Card 2 (ITYP=3): Format (5I6, E12.4)

ITAPE1 The input microscopic cross section data set unit. [60]

ITAPE2 Scratch unit used in cross section thinning process. [61]

ITAPE3 The thinned output microscopic cross section data set unit.
[62]

ISCR Scratch unit used in cross section processing. [63]

I4THN 1/0 - Thin/Do not thin the ENDF/B File 4 angular distribution
data. [0]

TOL Thinning tolerance for the output microscopic cross sections.
[1.00-03]

3.3 Input Data Notes

NPRT Setting NPRT=1 will print out the first ten values of the data set. This is primarily used to make sure the code is processing the data correctly.

MATNO The nuclide identification numbers are read in the ENDF/B format = 1000*Z + A. Some materials are processed using a MATNO = 1000*Z. Therefore the user should look on the RDNDF output to find the correct MATNO.

I4THN Setting I4THN=1 will thin the ENDF/B file 4 angular distribution data by deleting some of the incident neutron energies and their associated tabulated probability distribution functions. This is a crude form of data reduction and should be used with caution. If more than one interpolation range is given over the range of incident neutron energies, thinning will not be performed.

3.4 I/O File Requirements

File	Unit	Description	Required
INN	5	Card Input	Always
IOUT	6	Printed Output	Always
ITAPE1	60	Input Cross Section Library	Always
ITAPE2	61	Input Cross Section Library	ITYP≠2
ITAPE3	62	Output Cross Section Library	Always
ISCR	63	Scratch Unit for Thinning	ITYP≠1

3.5 JCL Requirements

The job control language (JCL) needed to run a MICRO case at X-10 is:

```
(Job card, route and jobparm cards)
//MICRO EXEC PGM=MICRO,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
(DD cards for input units)
(DD cards for scratch units)
(DD cards for output unit)
//SYSIN DD *
/*
//
```

} As prescribed by ITYP

3.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 6 and some selected output is shown in Figure 7. The problem demonstrates the combination option of the MICRO program by combining the RDNDF hydrogen and carbon data sets on logical units 60 and 61 respectively to form a third output data set on logical unit 62.

```

//JOJMICRO JOB (24337,IO1),'JO JOHNSON 6025',TIME=(0,30)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
/*JOBPARM LINECT=62
//A EXEC PGM=MICRO,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT60F001 DD DSN=MEN.X10.JOJ.RDND.F.H,DISP=SHR
//FT61F001 DD DSN=MEN.X10.JOJ.RDND.F.C,DISP=SHR
//FT62F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=OUT62,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//SYSIN DD *
      5      6      1      0
      60     61     62
/*
//

```

Figure 6. Complete Listing of JCL and Input for MICRO Sample Problem.

DIRECTORY OF THE OUTPUT TAPE DICTIONARY (IDICT)

```

POSITION 1: TOTAL CROSS SECTION (MT= 1 )
POSITION 2: ELASTIC SCATTERING CROSS SECTION (MT= 2 )
POSITION 3: TOTAL INELASTIC SCATTERING CROSS SECTION (MT= 4 )
POSITION 4: (N,2N) CROSS SECTION FOR 1ST EXCITED STATE (MT= 6 )
POSITION 5: (N,2N) CROSS SECTION FOR 2ND EXCITED STATE (MT= 7 )
POSITION 6: (N,2N) CROSS SECTION FOR 3RD EXCITED STATE (MT= 8 )
POSITION 7: (N,2N) CROSS SECTION FOR 4TH EXCITED STATE (MT= 9 )
POSITION 8: TOTAL (N,2N) CROSS SECTION (MT= 16 )
POSITION 9: TOTAL (N,3N) CROSS SECTION (MT= 17 )
POSITION 10: TOTAL FISSION CROSS SECTION (MT= 18 )
POSITION 11: (N,N^A) CROSS SECTION (MT= 22 )
POSITION 12: (N,2NA) CROSS SECTION (MT= 24 )
POSITION 13: (N,N^P) CROSS SECTION (MT= 28 )
POSITION 14: (N,N^1) CROSS SECTION TO THE 1ST EXCITED STATE (MT= 51 )
POSITION 15: (N,N^2) CROSS SECTION TO THE 2ND EXCITED STATE (MT= 52 )
POSITION 16: (N,N^3) CROSS SECTION TO THE 3RD EXCITED STATE (MT= 53 )
POSITION 17: (N,N^4) CROSS SECTION TO THE 4TH EXCITED STATE (MT= 54 )
POSITION 18: (N,N^5) CROSS SECTION TO THE 5TH EXCITED STATE (MT= 55 )
POSITION 19: (N,N^6) CROSS SECTION TO THE 6TH EXCITED STATE (MT= 56 )
POSITION 20: (N,N^7) CROSS SECTION TO THE 7TH EXCITED STATE (MT= 57 )
POSITION 21: (N,N^8) CROSS SECTION TO THE 8TH EXCITED STATE (MT= 58 )
POSITION 22: (N,N^9) CROSS SECTION TO THE 9TH EXCITED STATE (MT= 59 )
POSITION 23: (N,N^10) CROSS SECTION TO THE 10TH EXCITED STATE (MT= 60 )
POSITION 24: (N,N^11) CROSS SECTION TO THE 11TH EXCITED STATE (MT= 61 )
POSITION 25: (N,N^12) CROSS SECTION TO THE 12TH EXCITED STATE (MT= 62 )
POSITION 26: (N,N^13) CROSS SECTION TO THE 13TH EXCITED STATE (MT= 63 )
POSITION 27: (N,N^14) CROSS SECTION TO THE 14TH EXCITED STATE (MT= 64 )
POSITION 28: (N,N^15) CROSS SECTION TO THE 15TH EXCITED STATE (MT= 65 )
POSITION 29: (N,N^16) CROSS SECTION TO THE 16TH EXCITED STATE (MT= 66 )
POSITION 30: (N,N^17) CROSS SECTION TO THE 17TH EXCITED STATE (MT= 67 )
POSITION 31: (N,N^18) CROSS SECTION TO THE 18TH EXCITED STATE (MT= 68 )
POSITION 32: (N,N^19) CROSS SECTION TO THE 19TH EXCITED STATE (MT= 69 )
POSITION 33: (N,N^20) CROSS SECTION TO THE 20TH EXCITED STATE (MT= 70 )
POSITION 34: (N,N^21) CROSS SECTION TO THE 21ST EXCITED STATE (MT= 71 )
POSITION 35: (N,N^22) CROSS SECTION TO THE 22ND EXCITED STATE (MT= 72 )
POSITION 36: (N,N^23) CROSS SECTION TO THE 23RD EXCITED STATE (MT= 73 )
POSITION 37: (N,N^24) CROSS SECTION TO THE 24TH EXCITED STATE (MT= 74 )
POSITION 38: (N,N^25) CROSS SECTION TO THE 25TH EXCITED STATE (MT= 75 )
POSITION 39: (N,N^26) CROSS SECTION TO THE 26TH EXCITED STATE (MT= 76 )
POSITION 40: (N,N^27) CROSS SECTION TO THE 27TH EXCITED STATE (MT= 77 )

```

Figure 7. Listing of Selected Output from MICRO Sample Problem.

POSITION 41: (N,N") CROSS SECTION TO THE 28TH EXCITED STATE (MT= 78)
 POSITION 42: (N,N") CROSS SECTION TO THE 29TH EXCITED STATE (MT= 79)
 POSITION 43: (N,N") CROSS SECTION TO THE 30TH EXCITED STATE (MT= 80)
 POSITION 44: (N,N") CROSS SECTION TO THE 31ST EXCITED STATE (MT= 81)
 POSITION 45: (N,N") CROSS SECTION TO THE 32ND EXCITED STATE (MT= 82)
 POSITION 46: (N,N") CROSS SECTION TO THE 33RD EXCITED STATE (MT= 83)
 POSITION 47: (N,N") CROSS SECTION TO THE 34TH EXCITED STATE (MT= 84)
 POSITION 48: (N,N") CROSS SECTION TO THE 35TH EXCITED STATE (MT= 85)
 POSITION 49: (N,N") CROSS SECTION TO THE 36TH EXCITED STATE (MT= 86)
 POSITION 50: (N,N") CROSS SECTION TO THE 37TH EXCITED STATE (MT= 87)
 POSITION 51: (N,N") CROSS SECTION TO THE 38TH EXCITED STATE (MT= 88)
 POSITION 52: (N,N") CROSS SECTION TO THE 39TH EXCITED STATE (MT= 89)
 POSITION 53: (N,N") CROSS SECTION TO THE 40TH EXCITED STATE (MT= 90)
 POSITION 54: (N,N") CROSS SECTION TO THE CONTINUUM (MT= 91)
 POSITION 55: (N,G) CROSS SECTION (MT= 102)
 POSITION 56: (N,P) CROSS SECTION (MT= 103)
 POSITION 57: (N,D) CROSS SECTION (MT= 104)
 POSITION 58: (N,T) CROSS SECTION (MT= 105)
 POSITION 59: (N,3HE) CROSS SECTION (MT= 106)
 POSITION 60: (N,A) CROSS SECTION (MT= 107)
 POSITION 61: (N,2A) CROSS SECTION (MT= 108)
 POSITION 62: (N,3A) CROSS SECTION (MT= 109)
 POSITION 63: (N,2P) CROSS SECTION (MT= 111)
 POSITION 64: (N,PA) CROSS SECTION (MT= 112)
 POSITION 65: (N,T2A) CROSS SECTION (MT= 113)
 POSITION 66: (N,D2A) CROSS SECTION (MT= 114)
 POSITION 67: ELASTIC SCATTERING ANGULAR DISTRIBUTION (MT= 2)
 POSITION 68: (N,2N) ANG. DIST. FOR 1ST EXCITED STATE, 1ST N (MT= 6)
 POSITION 69: (N,2N) ANG. DIST. FOR 2ND EXCITED STATE, 1ST N (MT= 7)
 POSITION 70: (N,2N) ANG. DIST. FOR 3RD EXCITED STATE, 1ST N (MT= 8)
 POSITION 71: (N,2N) ANG. DIST. FOR 4TH EXCITED STATE, 1ST N (MT= 9)
 POSITION 72: TOTAL (N,2N) ANGULAR DISTRIBUTION (MT= 16)
 POSITION 73: TOTAL (N,3N) ANGULAR DISTRIBUTION (MT= 17)
 POSITION 74: TOTAL FISSION ANGULAR DISTRIBUTION (MT= 18)
 POSITION 75: (N,N"A) ANGULAR DISTRIBUTION (MT= 22)
 POSITION 76: (N,2NA) ANGULAR DISTRIBUTION (MT= 24)
 POSITION 77: (N,N"P) ANGULAR DISTRIBUTION (MT= 28)
 POSITION 78: (N,2N) ANG. DIST. FOR 1ST EXCITED STATE, 2ND N (MT= 46)
 POSITION 79: (N,2N) ANG. DIST. FOR 2ND EXCITED STATE, 2ND N (MT= 47)
 POSITION 80: (N,2N) ANG. DIST. FOR 3RD EXCITED STATE, 2ND N (MT= 48)

Figure 7. (continued).

POSITION 81: (N,2N) ANG. DIST. FOR 4TH EXCITED STATE, 2ND N (MT= 49)
 POSITION 82: (N,N") ANG. DIST. FOR THE 1ST EXCITED STATE (MT= 51)
 POSITION 83: (N,N") ANG. DIST. FOR THE 2ND EXCITED STATE (MT= 52)
 POSITION 84: (N,N") ANG. DIST. FOR THE 3RD EXCITED STATE (MT= 53)
 POSITION 85: (N,N") ANG. DIST. FOR THE 4TH EXCITED STATE (MT= 54)
 POSITION 86: (N,N") ANG. DIST. FOR THE 5TH EXCITED STATE (MT= 55)
 POSITION 87: (N,N") ANG. DIST. FOR THE 6TH EXCITED STATE (MT= 56)
 POSITION 88: (N,N") ANG. DIST. FOR THE 7TH EXCITED STATE (MT= 57)
 POSITION 89: (N,N") ANG. DIST. FOR THE 8TH EXCITED STATE (MT= 58)
 POSITION 90: (N,N") ANG. DIST. FOR THE 9TH EXCITED STATE (MT= 59)
 POSITION 91: (N,N") ANG. DIST. FOR THE 10TH EXCITED STATE (MT= 60)
 POSITION 92: (N,N") ANG. DIST. FOR THE 11TH EXCITED STATE (MT= 61)
 POSITION 93: (N,N") ANG. DIST. FOR THE 12TH EXCITED STATE (MT= 62)
 POSITION 94: (N,N") ANG. DIST. FOR THE 13TH EXCITED STATE (MT= 63)
 POSITION 95: (N,N") ANG. DIST. FOR THE 14TH EXCITED STATE (MT= 64)
 POSITION 96: (N,N") ANG. DIST. FOR THE 15TH EXCITED STATE (MT= 65)
 POSITION 97: (N,N") ANG. DIST. FOR THE 16TH EXCITED STATE (MT= 66)
 POSITION 98: (N,N") ANG. DIST. FOR THE 17TH EXCITED STATE (MT= 67)
 POSITION 99: (N,N") ANG. DIST. FOR THE 18TH EXCITED STATE (MT= 68)
 POSITION 100: (N,N") ANG. DIST. FOR THE 19TH EXCITED STATE (MT= 69)
 POSITION 101: (N,N") ANG. DIST. FOR THE 20TH EXCITED STATE (MT= 70)
 POSITION 102: (N,N") ANG. DIST. FOR THE 21ST EXCITED STATE (MT= 71)
 POSITION 103: (N,N") ANG. DIST. FOR THE 22ND EXCITED STATE (MT= 72)
 POSITION 104: (N,N") ANG. DIST. FOR THE 23RD EXCITED STATE (MT= 73)
 POSITION 105: (N,N") ANG. DIST. FOR THE 24TH EXCITED STATE (MT= 74)
 POSITION 106: (N,N") ANG. DIST. FOR THE 25TH EXCITED STATE (MT= 75)
 POSITION 107: (N,N") ANG. DIST. FOR THE 26TH EXCITED STATE (MT= 76)
 POSITION 108: (N,N") ANG. DIST. FOR THE 27TH EXCITED STATE (MT= 77)
 POSITION 109: (N,N") ANG. DIST. FOR THE 28TH EXCITED STATE (MT= 78)
 POSITION 110: (N,N") ANG. DIST. FOR THE 29TH EXCITED STATE (MT= 79)
 POSITION 111: (N,N") ANG. DIST. FOR THE 30TH EXCITED STATE (MT= 80)
 POSITION 112: (N,N") ANG. DIST. FOR THE 31ST EXCITED STATE (MT= 81)
 POSITION 113: (N,N") ANG. DIST. FOR THE 32ND EXCITED STATE (MT= 82)
 POSITION 114: (N,N") ANG. DIST. FOR THE 33RD EXCITED STATE (MT= 83)
 POSITION 115: (N,N") ANG. DIST. FOR THE 34TH EXCITED STATE (MT= 84)
 POSITION 116: (N,N") ANG. DIST. FOR THE 35TH EXCITED STATE (MT= 85)
 POSITION 117: (N,N") ANG. DIST. FOR THE 36TH EXCITED STATE (MT= 86)
 POSITION 118: (N,N") ANG. DIST. FOR THE 37TH EXCITED STATE (MT= 87)
 POSITION 119: (N,N") ANG. DIST. FOR THE 38TH EXCITED STATE (MT= 88)
 POSITION 120: (N,N") ANG. DIST. FOR THE 39TH EXCITED STATE (MT= 89)

Figure 7. (continued).

POSITION 121: (N,N") ANG. DIST. FOR THE 40TH EXCITED STATE (MT= 90)
 POSITION 122: (N,N") ANG. DIST. FOR THE CONTINUUM (MT= 91)
 POSITION 123: TOTAL (N,2N) SECONDARY ENERGY DISTRIBUTION (MT= 16)
 POSITION 124: TOTAL (N,3N) SECONDARY ENERGY DISTRIBUTION (MT= 17)
 POSITION 125: TOTAL FISSION SECONDARY ENERGY DISTRIBUTION (MT= 18)
 POSITION 126: (N,N"A) SECONDARY ENERGY DISTRIBUTION (MT= 22)
 POSITION 127: (N,2NA) SECONDARY ENERGY DISTRIBUTION (MT= 24)
 POSITION 128: (N,N"P) SECONDARY ENERGY DISTRIBUTION (MT= 28)
 POSITION 129: (N,2N) SEC E DIST FOR 1ST EXCITED STATE, 2ND N (MT= 46)
 POSITION 130: (N,2N) SEC E DIST FOR 2ND EXCITED STATE, 2ND N (MT= 47)
 POSITION 131: (N,2N) SEC E DIST FOR 3RD EXCITED STATE, 2ND N (MT= 48)
 POSITION 132: (N,2N) SEC E DIST FOR 4TH EXCITED STATE, 2ND N (MT= 49)
 POSITION 133: (N,N") SEC. ENERGY DIST. FOR THE CONTINUUM (MT= 91)
 POSITION 134: AVERAGE TOTAL NUMBER OF NEUTRONS PER FISSION (MT= 452)

A CONTROL BLOCK (ACB1)

NI	LENGTH
1	2987

A CONTROL BLOCK (ACB2)

NI	LENGTH
1	19976

A CONTROL BLOCK (ACB)

NI	LENGTH
2	22963

B CONTROL BLOCK (BCB1)

IZA	ICB RECNO	IRECNO
1001	3	13

B CONTROL BLOCK (BCB2)

IZA	ICB RECNO	IRECNO
6000	3	41

B CONTROL BLOCK (BCB)

IZA	ICB RECNO	IRECNO
1001	3	13
5000	16	41

Figure 7. (continued).

I CONTROL BLOCK (ICB)

ISUM	ANR	TEMP	TOL	ANGTOL	UNR FLG
2987	9.9917E-01	3.0000E+02	1.0000E-03	1.0000E-02	0
LENGAM	NT	NTS	NQ	THRMLN	LENNAB
388	1	0	66	0	450

OUTPUT TAPE DICTIONARY (IDICT) FOR ELEMENT 1001

POSITION	LENGTH								
1	270	2	260	3	0	4	0	5	0
6	0	7	0	8	0	9	0	10	0
11	0	12	0	13	0	14	0	15	0
16	0	17	0	18	0	19	0	20	0
21	0	22	0	23	0	24	0	25	0
26	0	27	0	28	0	29	0	30	0
31	0	32	0	33	0	34	0	35	0
36	0	37	0	38	0	39	0	40	0
41	0	42	0	43	0	44	0	45	0
46	0	47	0	48	0	49	0	50	0
51	0	52	0	53	0	54	0	55	450
56	0	57	0	58	0	59	0	60	0
61	0	62	0	63	0	64	0	65	0
66	0	67	350	68	0	69	0	70	0
71	0	72	0	73	0	74	0	75	0
76	0	77	0	78	0	79	0	80	0
81	0	82	0	83	0	84	0	85	0
86	0	87	0	88	0	89	0	90	0
91	0	92	0	93	0	94	0	95	0
96	0	97	0	98	0	99	0	100	0
101	0	102	0	103	0	104	0	105	0
106	0	107	0	108	0	109	0	110	0
111	0	112	0	113	0	114	0	115	0
116	0	117	0	118	0	119	0	120	0
121	0	122	0	123	0	124	0	125	0
126	0	127	0	128	0	129	0	130	0
131	0	132	0	133	0	134	0		

PHOTON PRODUCTION CROSS SECTION DICTIONARY (MTGAM)

REACTION	LENGTH								
102	460								

Figure 7. (continued).

I CONTROL BLOCK (ICB)

ISUM	AWR	TEMP	TOL	ANGTOL	UNR FLG
19976	1.1897E+01	3.0000E+02	1.0000E-03	1.0000E-02	0
LENGAM	NT	NTS	NQ	THRMLN	LENNAB
530	2	0	66	0	476

OUTPUT TAPE DICTIONARY (IDICT) FOR ELEMENT 6000

POSITION	LENGTH								
1	748	2	868	3	232	4	0	5	0
6	0	7	0	8	0	9	0	10	0
11	0	12	0	13	0	14	222	15	22
16	20	17	16	18	16	19	14	20	14
21	12	22	12	23	10	24	8	25	8
26	6	27	6	28	6	29	4	30	4
31	4	32	0	33	0	34	0	35	0
36	0	37	0	38	0	39	0	40	0
41	0	42	0	43	0	44	0	45	0
46	0	47	0	48	0	49	0	50	0
51	0	52	0	53	0	54	20	55	378
56	26	57	24	58	0	59	0	60	74
61	0	62	0	63	0	64	0	65	0
66	0	67	11060	68	0	69	0	70	0
71	0	72	0	73	0	74	0	75	0
76	0	77	0	78	0	79	0	80	0
81	0	82	2298	83	1196	84	236	85	0
86	0	87	0	88	0	89	0	90	0
91	0	92	0	93	0	94	0	95	0
96	0	97	0	98	0	99	0	100	0
101	0	102	0	103	0	104	0	105	0
106	0	107	0	108	0	109	0	110	0
111	0	112	0	113	0	114	0	115	0
116	0	117	0	118	0	119	0	120	0
121	0	122	0	123	0	124	0	125	0
126	0	127	0	128	0	129	0	130	0
131	0	132	0	133	19	134	0		

PHOTON PRODUCTION CROSS SECTION DICTIONARY (MTGAM)

REACTION	LENGTH								
102	782	51	244						

Figure 7. (continued).

4.0 MACRO - A CODE FOR PRE-MIXING MACROSCOPIC TOTAL CROSS SECTION DATA SETS FOR PROBLEM MIXTURES

4.1 Code Description

The program MACRO is designed to read either a RDNDF or MICRO output data set and create the macroscopic total cross sections for the problem mixtures in program NEUTRON. Program NEUTRON also possesses the capability of mixing and thinning the macroscopic total cross sections prior to the random walk. However, this could be expensive for a problem with many isotopes and large cross section sets. Furthermore, mixing cross sections in program NEUTRON could be inefficient if a particular problem is run many times. Therefore MACRO gives the user the option of pre-mixing the macroscopic total cross sections only once for a particular problem.

The subroutine hierarchy of program MACRO is shown in Figure 8. Also, a list of the subroutines used in program MACRO along with their function is given in Table 3.

4.2 Input Requirements

The following input cards and title cards are required in order to execute a MACRO case. Default values are given in brackets ([]).

Card 1: Format (20A4)

TITLE Problem title card

Card 2: Format (5I6)

INN Input card unit. [5]

IOUT Printed output unit. [6]

ITAPE Microscopic cross section input unit. [60]

ORNL - DWG 86 - 15413

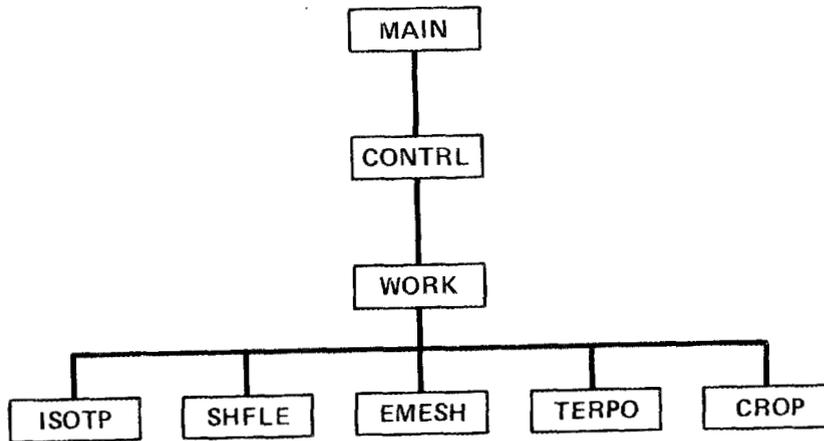


Figure 8. Subroutine Hierarchy in Program MACRO.

Table 3. Subroutine Functions in Program MACRO

Subroutine	Function
CONTRL	Reads in the input, initiates the mixing operation and writes the output.
CROP	Thins an array using the tolerance TOL.
EMESH	An interpolation routine for calculating the composite energy mesh for the mixture.
ISOTP	Reads in the I control block (ICB), the dictionary (IDICTION), and the total cross section for each element in the mixture.
MAIN	Initializes the amount of core storage (LEN) used for the mixing operations.
SHFLE	Copies an array to another array for future processing.
TERPO	An interpolation routine which assumes the data is linearly interpolable.
WORK	The driver routine which performs all the functions necessary to produce the macroscopic mixtures.

OTAPE Macroscopic total cross section output unit. [61]
 ISCR Scratch unit used in cross section processing. [62]
 Card 3: Format (2I6,E12.4)
 NMIX Number of mixtures to be processed
 NPRT 1/0 - Print/Do not print the microscopic total cross sections. [0]
 TOL Thinning tolerance for the output macroscopic mixture cross sections. [1.00-03]

Note: Card 4 repeated NMIX times, is followed each time by Card 5 repeated NELM times.

Card 4: Format (2I6)
 MIXNO Mixture number
 NELM Number of nuclides in mixture MIXNO.

Card 5: Format (I6,E12.4)
 MATNO Nuclide identification number (in ENDF/B 1000*Z + A format) for the nth nuclide in the mixture.
 XAD The atom density (atoms/b-cm) of the nth nuclide in the mixture.

Note: Card 5 is repeated NELM times.

4.3 Input Data Notes

NMIX The number of mixtures should correspond to the number of mixtures in the input data for program NEUTRON.

MIXNO The mixture numbers should correspond to the mixture numbers in the input data for program NEUTRON.

MATNO The nuclide identification numbers are read in the ENDF/B format = 1000*Z + A.

Note: In general, the mixing process in program MACRO should reflect the mixing table in program NEUTRON.

4.4 I/O File Requirements

File	Unit	Description	Required
INN	5	Card Input	Always
IOUT	6	Printed Output	Always
ITAPE	60	Input Microscopic Cross Section Library	Always
OTAPE	61	Output Macroscopic Cross Section Mixture Library	Always
ISCR	62	Scratch Unit	Always

4.5 JCL Requirements

The job control language (JCL) needed to run a MACRO case at X-10 is:

```
(Job card, route and jobparm cards)
//MACRO EXEC PGM=MACRO,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDMME=SYSIN
//FT06F001 DD SYSOUT=A
(DD cards for input unit)
(DD cards for scratch unit)
(DD cards for output unit)
//SYSIN DD *
(Input Data)
/*
//
```

4.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 9 and some selected output is shown in Figure 10. The problem demonstrates the mixing of hydrogen and carbon to create the macroscopic total cross section for an NE102A plastic scintillator.

```

//JOJMACRO JOB (24337,I01),'JO JOHNSON 6025',TIME=(0,30)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
/*JOBPARM LINECT=62
//A EXEC PGM=MACRO,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT60F001 DD DSN=MEN.X10.JOJ.ICOM.MICROS,DISP=SHR
//FT61F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&OTAPE,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//FT62F001 DD UNIT=SYSDA,DISP=(NEW,DELETE),
// DSN=&&ISCR,SPACE=(TRK,(30,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184)
//SYSIN DD *
=MACRO
NE102A POLYVINYLTOLUENE PLASTIC SCINTILLATOR MACROS
      5      6      60      61      62
      1      0  1.0000E-03
      1      2
1001  5.6873E-02
6000  4.7394E-02
/*
//

```

Figure 9. Complete Listing of JCL and Input for MACRO Sample Problem.

MIXTURE NUMBER 1 MACROSCOPIC TOTAL CROSS SECTION ARRAY OF LENGTH 415

ENERGY	XSECT								
1.00000E-05	7.16901E+01	1.15722E-05	6.66445E+01	1.26905E-05	6.36485E+01	1.46858E-05	5.91692E+01	1.64575E-05	5.58956E+01
1.90451E-05	5.19626E+01	2.00000E-05	5.07069E+01	2.31445E-05	4.71396E+01	2.51487E-05	4.52244E+01	2.98627E-05	4.15063E+01
3.45578E-05	3.85874E+01	3.86411E-05	3.64937E+01	4.47164E-05	3.39283E+01	5.00000E-05	3.20868E+01	5.78612E-05	2.98323E+01
6.69584E-05	2.77368E+01	7.07107E-05	2.69953E+01	8.18281E-05	2.51001E+01	9.46934E-05	2.33388E+01	1.00000E-04	2.27130E+01
1.15722E-04	2.11204E+01	1.33917E-04	1.96404E+01	1.41421E-04	1.91145E+01	1.63656E-04	1.77766E+01	1.89387E-04	1.65333E+01
2.00000E-04	1.60930E+01	2.31445E-04	1.49692E+01	2.67833E-04	1.39253E+01	3.16228E-04	1.28276E+01	3.65946E-04	1.19361E+01
4.23482E-04	1.11082E+01	5.00000E-04	1.02380E+01	5.78612E-04	9.53172E+00	6.69584E-04	8.87620E+00	7.74859E-04	8.26796E+00
8.40897E-04	7.94688E+00	1.00000E-03	7.30881E+00	1.15722E-03	6.81440E+00	1.33917E-03	6.35618E+00	1.54972E-03	5.93174E+00
1.79337E-03	5.53872E+00	2.00000E-03	5.26482E+00	2.31445E-03	4.92167E+00	2.67833E-03	4.60446E+00	3.09943E-03	4.31145E+00
3.58674E-03	4.04101E+00	3.97635E-03	3.86285E+00	4.60153E-03	3.62746E+00	5.32500E-03	3.41079E+00	6.16222E-03	3.21159E+00
7.07107E-03	3.03883E+00	8.18281E-03	2.87030E+00	9.46935E-03	2.71604E+00	1.09582E-02	2.57528E+00	1.26810E-02	2.44691E+00
1.46748E-02	2.32992E+00	1.59060E-02	2.27027E+00	1.85502E-02	2.16514E+00	2.13008E-02	2.07936E+00	2.53000E-02	1.98398E+00
2.92778E-02	1.91269E+00	3.38809E-02	1.84877E+00	3.92078E-02	1.79160E+00	4.53723E-02	1.74158E+00	5.25059E-02	1.69730E+00
6.07610E-02	1.65821E+00	7.03142E-02	1.62376E+00	8.13692E-02	1.59419E+00	9.41624E-02	1.56838E+00	1.08967E-01	1.54587E+00
1.45925E-01	1.50915E+00	2.00604E-01	1.47960E+00	2.68643E-01	1.45986E+00	4.16321E-01	1.43911E+00	7.46616E-01	1.42181E+00
1.54948E+00	1.40976E+00	4.47889E+00	1.39891E+00	1.00000E+02	1.38853E+00	1.15722E+04	1.30647E+00	2.50000E+04	1.22392E+00
4.00000E+04	1.14715E+00	5.50000E+04	1.08220E+00	7.00000E+04	1.02648E+00	9.00000E+04	9.63246E-01	1.10000E+05	9.10172E-01
1.30000E+05	8.65060E-01	1.60000E+05	8.07744E-01	1.90000E+05	7.59475E-01	2.20000E+05	7.19251E-01	2.40000E+05	6.96012E-01
2.80000E+05	6.55331E-01	3.20000E+05	6.20456E-01	3.60000E+05	5.90184E-01	4.00000E+05	5.63997E-01	4.60000E+05	5.30318E-01
5.00000E+05	5.10670E-01	5.50000E+05	4.89188E-01	6.00000E+05	4.69809E-01	6.50000E+05	4.52194E-01	7.00000E+05	4.36558E-01
8.00000E+05	4.08752E-01	9.00000E+05	3.85177E-01	1.00000E+06	3.64491E-01	1.10000E+06	3.46701E-01	1.20000E+06	3.30649E-01
1.30000E+06	3.16405E-01	1.37500E+06	3.06724E-01	1.50000E+06	2.91526E-01	1.57500E+06	2.83387E-01	1.70000E+06	2.70644E-01
1.77500E+06	2.63766E-01	1.90000E+06	2.53014E-01	2.00000E+06	2.44953E-01	2.02500E+06	2.43311E-01	2.05000E+06	2.43430E-01
2.05600E+06	2.45195E-01	2.05800E+06	2.46361E-01	2.06000E+06	2.48060E-01	2.06200E+06	2.50574E-01	2.06400E+06	2.54409E-01
2.06500E+06	2.57092E-01	2.06600E+06	2.60502E-01	2.06700E+06	2.64879E-01	2.06800E+06	2.70592E-01	2.06900E+06	2.78119E-01
2.07000E+06	2.88163E-01	2.07100E+06	3.01661E-01	2.07200E+06	3.19790E-01	2.07300E+06	3.43708E-01	2.07400E+06	3.73587E-01
2.07500E+06	4.06674E-01	2.07600E+06	4.35109E-01	2.07700E+06	4.47989E-01	2.07800E+06	4.40029E-01	2.07900E+06	4.16724E-01
2.08000E+06	3.88161E-01	2.08100E+06	3.61367E-01	2.08200E+06	3.39019E-01	2.08300E+06	3.21301E-01	2.08400E+06	3.07475E-01
2.08500E+06	2.96696E-01	2.08600E+06	2.88227E-01	2.08700E+06	2.81493E-01	2.08800E+06	2.76068E-01	2.08900E+06	2.71659E-01
2.09000E+06	2.68012E-01	2.09100E+06	2.64979E-01	2.09300E+06	2.60235E-01	2.09500E+06	2.56724E-01	2.09800E+06	2.52938E-01
2.10200E+06	2.49537E-01	2.10600E+06	2.47205E-01	2.11200E+06	2.44809E-01	2.12000E+06	2.42681E-01	2.14000E+06	2.39497E-01
2.16000E+06	2.37415E-01	2.20000E+06	2.34261E-01	2.28000E+06	2.29646E-01	2.29646E-01	2.24239E-01	2.48000E+06	2.21721E-01
2.56000E+06	2.20229E-01	2.62000E+06	2.20011E-01	2.68000E+06	2.20957E-01	2.72000E+06	2.22418E-01	2.76000E+06	2.24857E-01
2.79000E+06	2.27681E-01	2.80400E+06	2.29714E-01	2.80800E+06	2.30964E-01	2.81000E+06	2.32439E-01	2.81100E+06	2.34010E-01
2.81200E+06	2.37392E-01	2.81300E+06	2.47372E-01	2.81400E+06	2.87712E-01	2.81500E+06	3.67179E-01	2.81600E+06	2.70968E-01
2.81700E+06	2.44837E-01	2.81800E+06	2.38045E-01	2.81900E+06	2.35541E-01	2.82000E+06	2.34412E-01	2.82000E+06	2.33558E-01
2.82600E+06	2.33465E-01	2.84000E+06	2.35752E-01	2.85500E+06	2.39316E-01	2.87000E+06	2.43876E-01	2.88500E+06	2.49735E-01
2.90000E+06	2.57329E-01	2.91500E+06	2.67061E-01	2.93200E+06	2.79728E-01	2.93600E+06	2.82300E-01	2.94000E+06	2.84260E-01
2.94400E+06	2.85223E-01	2.94800E+06	2.84707E-01	2.95200E+06	2.82201E-01	2.95600E+06	2.77252E-01	2.96000E+06	2.69659E-01

43

Figure 10. Listing of Selected Output from MACRO Sample Problem.

2.96400E+06	2.59640E-01	2.96800E+06	2.47904E-01	2.97600E+06	2.23546E-01	2.98000E+06	2.12908E-01	2.98400E+06	2.04081E-01
2.98800E+06	1.97181E-01	2.99200E+06	1.92075E-01	2.99600E+06	1.88495E-01	3.00000E+06	1.86153E-01	3.01000E+06	1.83942E-01
3.02000E+06	1.84652E-01	3.03000E+06	1.86621E-01	3.08000E+06	1.98777E-01	3.10000E+06	2.02983E-01	3.14000E+06	2.10311E-01
3.20000E+06	2.19624E-01	3.26000E+06	2.27870E-01	3.32000E+06	2.34780E-01	3.38000E+06	2.39955E-01	3.42000E+06	2.42225E-01
3.46000E+06	2.43462E-01	3.50000E+06	2.43632E-01	3.56000E+06	2.41998E-01	3.62000E+06	2.38483E-01	3.68000E+06	2.33627E-01
3.78000E+06	2.23584E-01	3.96000E+06	2.04052E-01	4.03000E+06	1.97312E-01	4.08000E+06	1.93623E-01	4.11000E+06	1.92372E-01
4.13000E+06	1.92257E-01	4.15000E+06	1.92994E-01	4.17000E+06	1.94870E-01	4.19000E+06	1.98039E-01	4.23000E+06	2.06741E-01
4.24000E+06	2.08604E-01	4.25000E+06	2.10003E-01	4.26000E+06	2.10824E-01	4.27000E+06	2.11039E-01	4.28000E+06	2.10675E-01
4.30000E+06	2.08569E-01	4.33000E+06	2.03538E-01	4.38000E+06	1.94604E-01	4.42000E+06	1.88558E-01	4.46000E+06	1.83542E-01
4.52000E+06	1.77359E-01	4.58000E+06	1.72247E-01	4.66000E+06	1.66460E-01	4.76000E+06	1.60204E-01	4.82000E+06	1.56709E-01
4.85000E+06	1.55259E-01	4.90000E+06	1.53448E-01	4.91940E+06	1.54198E-01	4.93450E+06	1.60127E-01	4.93550E+06	1.76531E-01
4.93670E+06	1.88138E-01	4.93850E+06	1.86974E-01	4.93950E+06	1.78172E-01	4.94320E+06	1.62831E-01	4.94810E+06	1.56085E-01
4.95460E+06	1.53779E-01	4.95840E+06	1.52702E-01	4.96980E+06	1.51506E-01	5.03000E+06	1.49105E-01	5.20000E+06	1.43150E-01
5.30000E+06	1.40507E-01	5.33000E+06	1.40620E-01	5.33500E+06	1.41291E-01	5.34000E+06	1.44313E-01	5.36200E+06	1.69113E-01
5.37100E+06	1.76487E-01	5.37800E+06	1.68954E-01	5.39000E+06	1.59325E-01	5.40000E+06	1.53743E-01	5.41000E+06	1.49127E-01
5.42000E+06	1.46862E-01	5.44000E+06	1.43537E-01	5.46000E+06	1.41632E-01	5.50000E+06	1.39720E-01	5.70000E+06	1.35548E-01
5.80000E+06	1.34496E-01	6.00000E+06	1.34050E-01	6.12500E+06	1.34158E-01	6.16000E+06	1.34740E-01	6.18000E+06	1.36190E-01
6.21000E+06	1.40867E-01	6.22000E+06	1.42911E-01	6.23000E+06	1.46371E-01	6.24000E+06	1.50804E-01	6.25000E+06	1.59467E-01
6.28500E+06	1.94640E-01	6.29500E+06	1.99263E-01	6.30300E+06	1.94423E-01	6.31000E+06	1.80990E-01	6.32000E+06	1.68319E-01
6.33000E+06	1.59930E-01	6.34000E+06	1.53905E-01	6.37000E+06	1.40598E-01	6.40000E+06	1.31552E-01	6.41000E+06	1.29237E-01
6.42000E+06	1.28151E-01	6.44000E+06	1.28412E-01	6.47000E+06	1.29484E-01	6.49000E+06	1.28824E-01	6.51000E+06	1.25902E-01
6.57000E+06	1.12705E-01	6.58000E+06	1.11193E-01	6.59000E+06	1.10396E-01	6.60000E+06	1.11012E-01	6.64000E+06	1.16562E-01
6.65750E+06	1.17819E-01	6.66500E+06	1.17282E-01	6.68000E+06	1.15022E-01	6.70000E+06	1.13418E-01	7.00000E+06	1.06984E-01
7.10000E+06	1.06278E-01	7.14000E+06	1.06719E-01	7.18000E+06	1.08485E-01	7.20000E+06	1.10033E-01	7.22500E+06	1.12680E-01
7.25000E+06	1.17220E-01	7.27000E+06	1.22278E-01	7.34000E+06	1.48719E-01	7.35000E+06	1.51479E-01	7.37000E+06	1.53694E-01
7.42000E+06	1.54144E-01	7.62000E+06	1.50876E-01	7.65000E+06	1.52080E-01	7.68000E+06	1.56141E-01	7.70000E+06	1.60272E-01
7.72500E+06	1.69570E-01	7.74500E+06	1.78890E-01	7.75000E+06	1.79846E-01	7.77000E+06	1.74619E-01	7.81000E+06	1.66128E-01
7.86000E+06	1.61031E-01	7.93000E+06	1.56930E-01	8.00540E+06	1.55173E-01	8.08000E+06	1.55020E-01	8.10500E+06	1.53678E-01
8.12000E+06	1.51688E-01	8.21000E+06	1.33587E-01	8.24000E+06	1.28893E-01	8.28000E+06	1.24452E-01	8.33000E+06	1.20262E-01
8.40000E+06	1.16214E-01	8.45000E+06	1.14283E-01	8.52000E+06	1.12475E-01	8.70750E+06	1.10642E-01	8.94000E+06	1.09754E-01
8.98000E+06	1.10471E-01	9.00500E+06	1.11757E-01	9.02000E+06	1.14038E-01	9.03000E+06	1.14934E-01	9.08000E+06	1.15402E-01
9.18000E+06	1.19866E-01	9.25000E+06	1.19284E-01	9.30000E+06	1.21390E-01	9.36000E+06	1.18394E-01	9.45000E+06	1.15428E-01
9.56000E+06	1.13216E-01	9.59000E+06	1.13767E-01	9.63000E+06	1.11915E-01	9.64000E+06	1.11866E-01	9.68000E+06	1.14262E-01
9.70000E+06	1.14633E-01	9.74000E+06	1.12781E-01	1.00030E+07	1.09276E-01	1.00530E+07	1.08309E-01	1.01700E+07	1.04564E-01
1.02500E+07	1.03504E-01	1.03000E+07	1.03759E-01	1.05530E+07	1.07539E-01	1.06200E+07	1.10417E-01	1.09400E+07	1.17076E-01
1.10000E+07	1.15165E-01	1.11000E+07	1.17385E-01	1.11700E+07	1.14052E-01	1.14000E+07	1.13184E-01	1.17000E+07	1.09216E-01
1.18000E+07	1.09315E-01	1.19090E+07	1.11313E-01	1.20000E+07	1.13777E-01	1.20530E+07	1.15481E-01	1.21000E+07	1.15107E-01
1.22500E+07	1.09172E-01	1.23000E+07	1.07825E-01	1.24000E+07	1.06551E-01	1.25000E+07	1.05989E-01	1.29900E+07	1.08184E-01
1.31200E+07	1.05914E-01	1.33000E+07	1.04688E-01	1.35400E+07	1.05418E-01	1.37000E+07	1.01968E-01	1.39650E+07	1.01785E-01
1.41820E+07	1.00333E-01	1.44190E+07	1.00029E-01	1.45660E+07	1.00469E-01	1.46940E+07	1.01574E-01	1.47500E+07	1.02478E-01
1.47670E+07	1.02957E-01	1.48120E+07	1.05074E-01	1.48370E+07	1.07042E-01	1.48630E+07	1.07827E-01	1.49270E+07	1.04364E-01
1.50060E+07	1.03832E-01	1.52500E+07	1.04940E-01	1.55530E+07	1.05483E-01	1.60680E+07	1.05812E-01	1.66950E+07	1.03018E-01
1.71380E+07	9.88071E-02	1.73010E+07	9.80371E-02	1.74670E+07	9.79252E-02	1.79010E+07	9.89370E-02	1.82730E+07	9.88780E-02
1.88330E+07	9.79893E-02	1.90530E+07	9.79991E-02	1.91850E+07	9.82891E-02	1.95110E+07	9.98127E-02	2.00000E+07	9.83809E-02

Figure 10. (continued).

5.0 NEUTRON - A CONTINUOUS ENERGY MONTE CARLO CODE FOR TRANSPORTING NEUTRON RADIATION INCIDENT ON AN IONIZATION CHAMBER

5.1 Code Description

The program NEUTRON is a continuous energy and angle Monte Carlo code written specifically for analysis of ionization chamber responses to neutron radiation environments. NEUTRON solves the Boltzmann transport equation using detailed energy and angular data from the ENDF/B-V data base. The approach in program NEUTRON with respect to representing the cross sections is to mirror ENDF/B data to within a prescribed tolerance. The cross sections are represented by vectors of linearly interpolable data-energy pairs. The angular scattering distributions for elastic and discrete inelastic interactions are represented by probability tables. Above the thermal energy region, the scattered neutron energy is determined from exact energy-angle formulas. In the thermal region, the free gas model is employed to obtain the scattered neutron energy. For all continuous energy reactions i.e., continuum inelastic scattering, $(n,2n)$, $(n,3n)$ (n,n',α) , etc., ENDF/B expresses the information in terms of post-collision laboratory energy. Therefore the exact energy-angle formulas cannot be used. Here the neutron exit energy selection is based on the use of ENDF/B-V data as probability tables or an evaporation spectrum. All charged particle production i.e., protons, deuterons, tritons, ^3He ions and alpha particles, from either inelastic scattering or from absorption is assumed isotropic in the laboratory system with the energy determined from a general evaporation spectrum. The recoil

heavy ion and/or charged particle parameters produced at each interaction of the neutron radiation are determined with mass, energy, and momentum balances.

The random walk procedure employed in NEUTRON is based on the integral emergent particle density formalism of the Boltzmann transport equation. This equation introduces the neutron into the system according to the natural source function. The neutron travels to the site of its first collision as determined by the transport kernel. At the collision site, the particular isotope the neutron interacts with is determined. The non-absorption probability array is then used to determine whether a scattering reaction or absorption reaction has occurred. The particular reaction is selected and the exit neutron parameters are determined (if appropriate) from the collision kernel for subsequent transport using the transport kernel. At each collision site, the recoil heavy ion parameters are determined and stored for subsequent transport in the HEAVY code. Furthermore, at each collision site, a check is made to determine if a secondary photon is generated. If applicable, a secondary photon is generated and stored for subsequent transport in the PHOTON code. The transport and collision kernels are applied successively until the neutron is absorbed, escapes, or reaches a specified energy or age cut-off.

NEUTRON represents a unique computational tool in the field of neutron radiation transport. Even though it is specifically written for ionization chamber response analysis, the program is applicable to any problems where charged particle production and secondary

photon production are of interest. Some special features of NEUTRON include:

1. Utilizes all of the data available in ENDF/B-V nuclear data files.
2. Calculates the physics of all partial cross section reactions currently considered in ENDF/B-V.
3. Generalizes the specification of the neutron source through input arrays and/or user supplied subroutines.
4. Incorporates a combinatorial geometry package for detailed geometry modeling.
5. Includes untested programming for splitting, Russian roulette, and exponential transform.
6. Mixes macroscopic total cross sections or reads them in from a MACRO tape.
7. Uses FIDO input for all data arrays except the combinatorial data input.
8. Accesses data arrays through use of the cross section data dictionary array (IDICTIONARY).
9. Incorporates subroutine BANKR to provide additional analysis of the neutron transport processes.
10. Couples to the high energy transport code HETC³ to process neutrons with energies less than 20 MeV generated via transport of high energy particles.

The subroutine hierarchy for program NEUTRON is shown in Figure 11. The following tables (Tables 4 through 19) describe the subroutines along with their functions, the main variables and their storage locations, and the common blocks and their associated variables used in the random walk process employed in program NEUTRON.

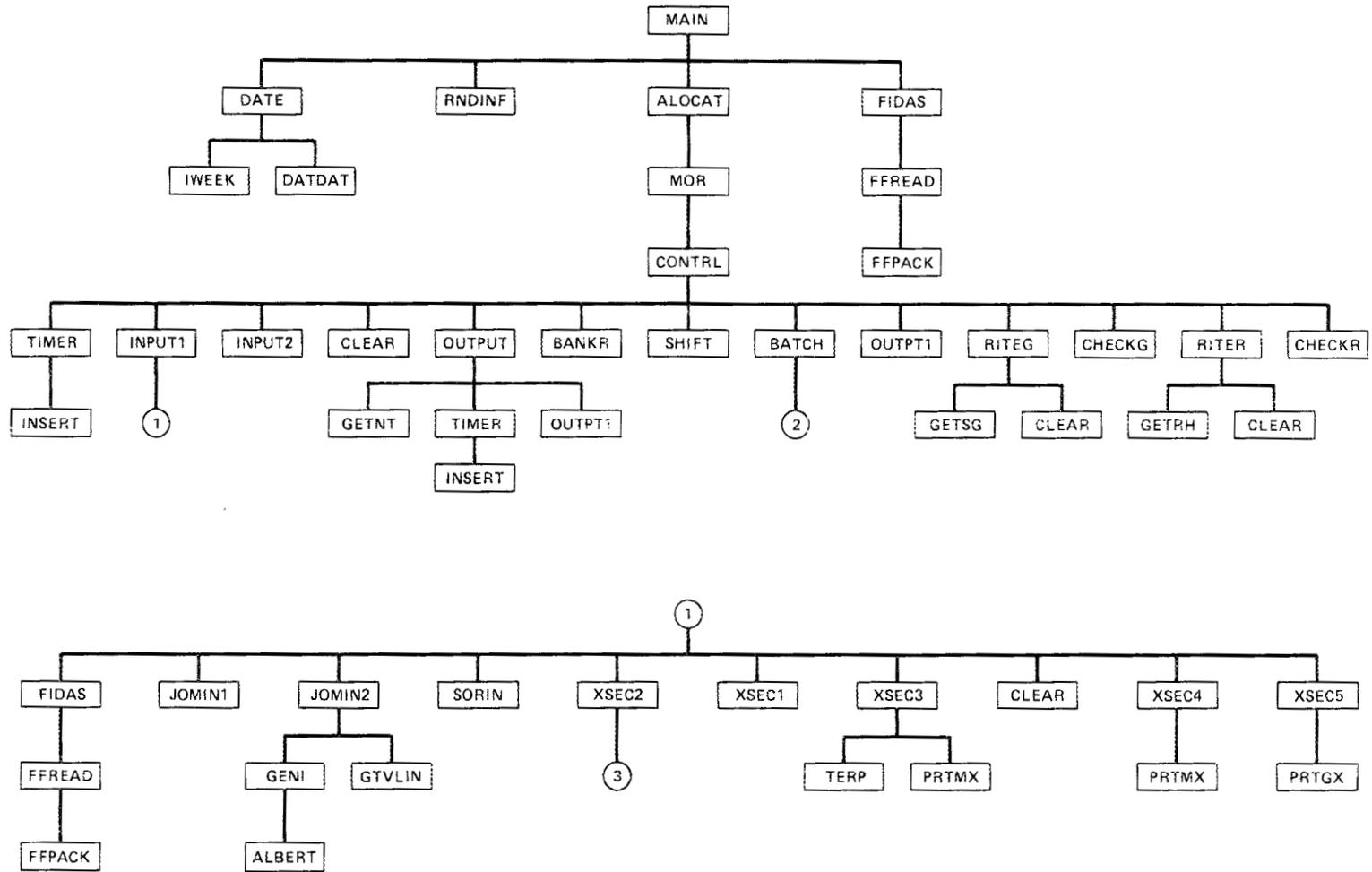


Figure 11. Subroutine Hierarchy in Program NEUTRON.

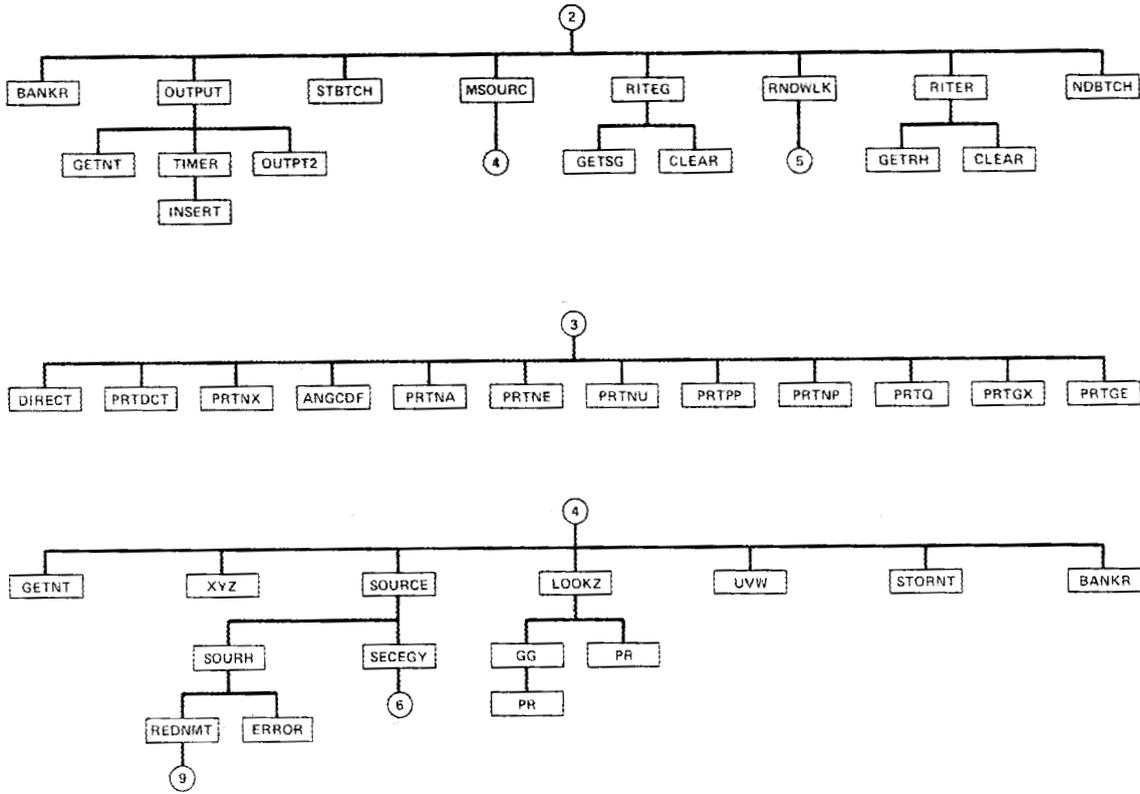


Figure 11. (continued).

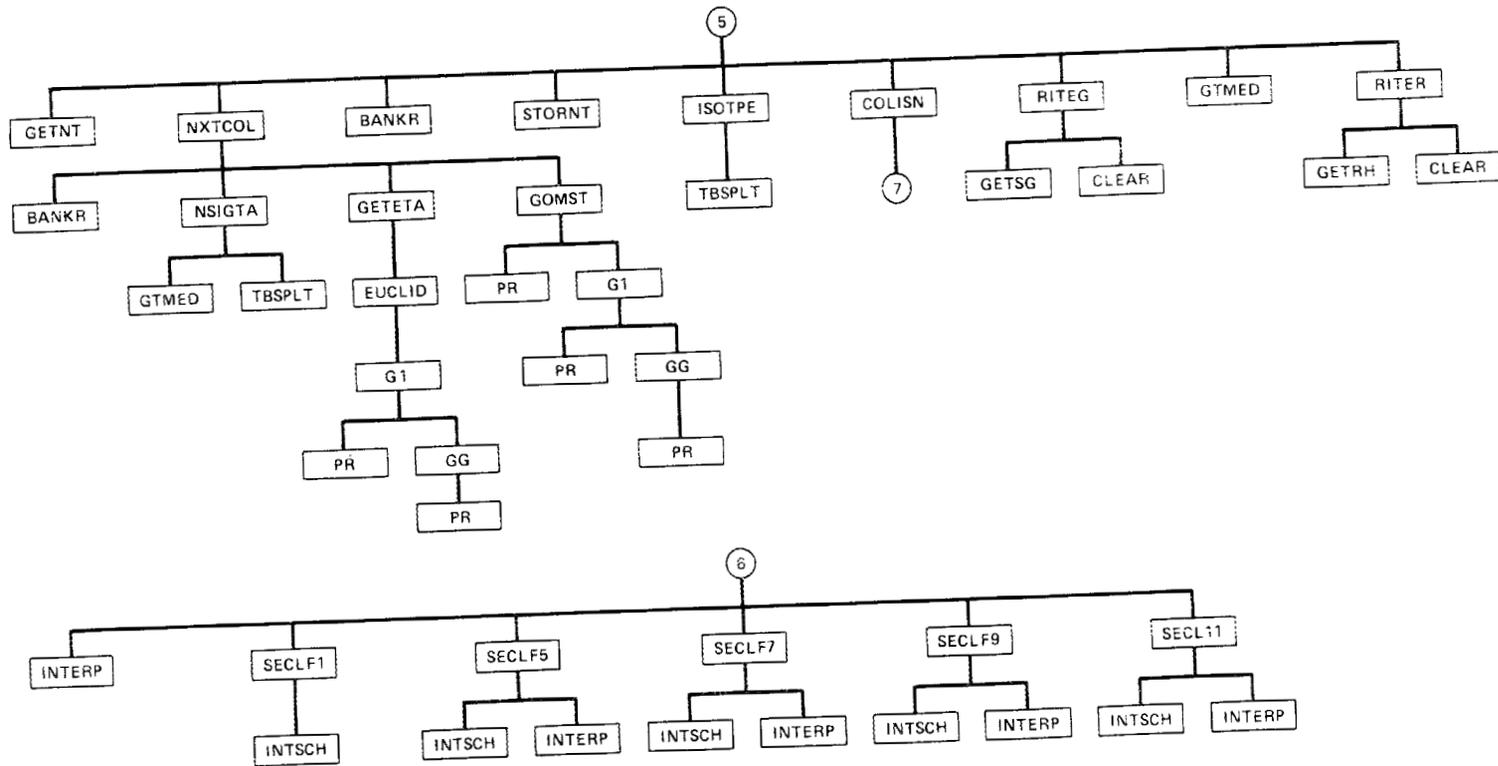


Figure 11. (continued).

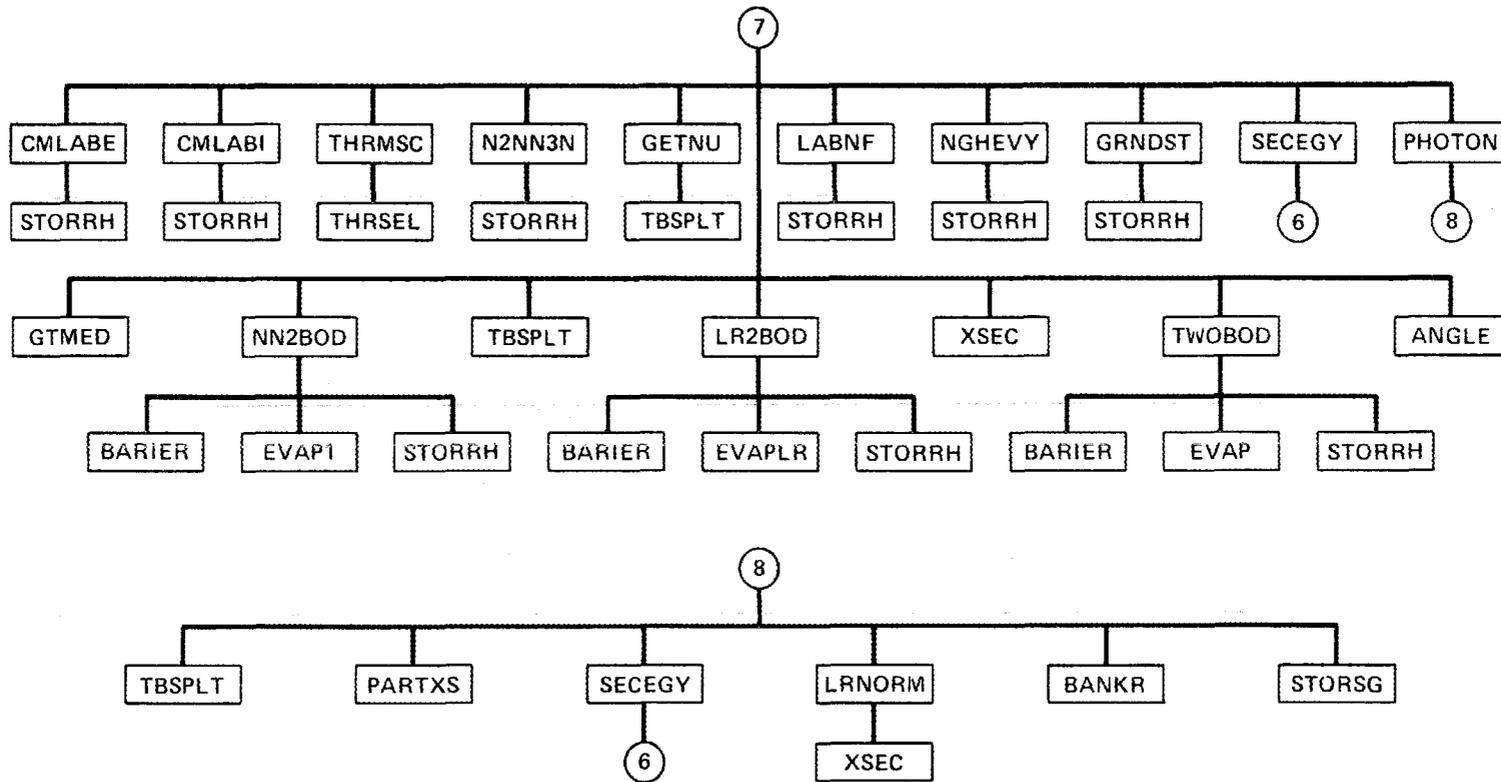


Figure 11. (continued).

Table 4. Subroutine Functions in Program NEUTRON

Subroutine	Function
ALBERT	Processes arbitrary polyhedron body data.
ALOCAT	ASSEMBLER routine which dynamically allocates core storage for problem execution.
ANGLDF	Reads the input angular distribution files and converts them to a normalized cumulative distribution function.
ANGLE	Selects the scattering angle at a collision site.
BANKR	This is a dummy routine usually supplied by the user to perform additional analysis of the data.
BARIER	Calculates the coulomb barrier for a collision involving charged particle emission.
BATCH	Performs the processing of batches of particles during the random walk process.
BFIN	A buffer routine called by routine BUFNMT. This routine is only used at ORNL.
BUFNMT	Initiates the system routines required to read a HETC buffered output tape. This routine is only used at ORNL. (Call from REDNMT if logical unit number of tape ≥ 58).
CHECKG	Checks the contents of the secondary photon production tape by printing the tape contents.
CHECKR	Checks the contents of the recoil heavy ion and charged particle tape by printing the tape contents.
CLEAR	Initializes an array to zero.
CMLABE	Converts the neutron scattering angle from center of mass to laboratory coordinate system and calculates the neutron and recoil heavy ion exit parameters for an elastic scattering reaction.

Table 4. (Continued)

Subroutine	Function
CMLABI	Converts the neutron scattering angle from center of mass to laboratory coordinate system and calculates the neutron and recoil heavy ion exit parameters for an inelastic scattering reaction.
COLISN	Called at each collision to determine the type of collision and the post collision parameters.
CONTRL	The driver routine for the random walk process; calling the input routines, initializing the random walk, and summarizing the run results through calls to the output routines.
DATE	Computes the day, month, date, and year.
DEEBUG	Used to trouble-shoot errors in the program.
DIREC	Function which calculates the cosine of the angle between the flight direction and the most important direction.
DIRECT	List out the directory for the output neutron cross section dictionary array (IDICT).
EUCLID	Determines the number of mean-free-paths between two points in the geometry.
EVAP	Samples an exit energy from an evaporation spectrum for a two-body reaction.
EVAPLR	Samples an exit energy from an evaporation spectrum for a (n,n'x) reaction using ENDF/B LR flags.
EVAP1	Samples an exit energy from an evaporation spectrum for a (n,n'x) reaction.
FFPACK	Used to input a character into a string of characters at a given position.
FFREAD	Acts as a free and fixed field card image translator.

Table 4. (Continued)

Subroutine	Function
FIDAS	Reads free and fixed field input data blocks into arbitrary arrays.
FLTRNF	Random number package written in ASSEMBLER.
GENI	Outputs the geometry input information and places the combinatorial data in the proper storage locations in blank common.
GETETA	Calculates the number of mean-free-paths (η) for the next flight.
GETNT	Has two entry points: GETNT which retrieves values from the neutron bank and stores them in common NUTRON, and STORNT which stores values from common NUTRON into the neutron bank.
GETNU	Selects the average number of neutrons ($\bar{\nu}$) born from a fission reaction.
GETRH	Has two entry points: GETRH which retrieves values from the recoil heavy ion and charged particle bank and stores them in common RECOIL, and STORRH which stores values from common RECOIL into the recoil heavy ion and charged particle bank.
GETSG	Has two entry points: GETSG which retrieves values from the photon bank and stores them in common GAMMA, and STORSG which stores values from common GAMMA into the photon bank.
GG	The workhorse of the combinatorial geometry package - computes distances to intersections for all body types.
GOMST	Determines boundary crossings between the present and next collision site.
GRNDST	Calculates the charged particle and recoil heavy ion parameters for a two body reaction to ground state.
GTMED	Determines the cross section media number corresponding to the geometry media number.

Table 4. (Continued)

Subroutine	Function
GTVLIN	Reads in or calculates the volume of each region in the geometry.
G1	The control routine for the combinatorial geometry package.
INPUT1	Controls the processing of all input data and sets up and initializes all arrays used in the random walk process.
INPUT2	Summarizes the core storage requirements and identifies the array parameters in common POINT.
INSERT	Inserts characters from an array into a character string.
INTERP	A general interpolation routine capable of executing the five ENDF/B interpolation schemes.
INTSCH	Determines the ENDF/B interpolation scheme.
ISOTPE	Determines which isotope in the media has undergone a collision.
IWEEK	Looks up the date and fills in the integer values for MONTH, IDAT, and IYEAR.
JOMIN1	Reads in the geometry data input and calculates the amount of storage needed for the geometry arrays.
JOMIN2	Calculates the beginning locations of the geometry arrays in storage.
LABNF	Calculates the exit parameters for a neutron born from a fission reaction.
LOOKZ	Returns the combinatorial geometry zone of point (X,Y,Z) so tracking can be initialized.
LRNORM	Adjusts the neutron cross section used to calculate photon multiplicity when the inelastic resolved data contains LR-flags designating charged particle emission.

Table 4. (Continued)

Subroutine	Function
LR2BOD	Calculates the charged particle and recoil heavy ion parameters for a two body reaction resulting from the break-up of a nucleus left in an excited state by an inelastic scattering collision designated by an LR-flag.
MAIN	Reads the first FIDAS data block and sets up default values for the input parameters.
MOR	Calls routine CONTRL.
MSOURC	The executive routine for the generation and storage of the source parameters at the start of each batch.
NDBTCH	Called at the end of each batch to perform calculations of batch statistics.
NGHEVY	Calculates the exit parameters for the recoil heavy ion resulting from the (n, γ) reaction.
NN2BOD	Calculates the charged particle and recoil heavy ion parameters for a two body reaction resulting from the break-up of a nucleus left in an excited state by an inelastic scattering collision.
NSIGTA	Determines the macroscopic total cross section for a media.
NXTCOL	Determines the particle spatial coordinates, block and zone number, and age at the next collision site and at every boundary site along the flight path.
N2NN3N	Calculates the neutron and recoil heavy ion exit parameters for a (n,2n) or (n,3n) reaction.
OUTPUT	A multipurpose routine which calculates and prints average source parameters for a batch, calculates and updates batch results, and summarizes results for the counters.

Table 4. (Continued)

Subroutine	Function
OUTPT1	Prints the reaction type number counters and the element collision number counters for the problem.
OUTPT2	Prints the number and weight counters indicating the results of Russian roulette, splitting, and scattering for the problem.
PARTXS	Samples from the photon production partial distribution data to obtain the secondary photon energy from a neutron reaction.
PHOTON	Controls the generation and storage of all secondary photons produced by the neutron reactions.
PR	Called from various locations in the combinatorial geometry package whenever intermediate output or debugging output is required.
PRTDCT	Prints the neutron cross section dictionary (LDICT).
PRTGCB	Prints the photon data control block array (LGCB).
PRTGE	Prints the photon secondary energy distributions.
PRTGX	Prints the secondary photon production partial cross sections.
PRTGXT	Prints the secondary photon production total cross sections.
PRTMX	Prints the macroscopic total cross sections for the mixtures.
PRTNA	Prints the neutron angular distributions.
PRTNE	Prints the neutron secondary energy distributions.

Table 4. (Continued)

Subroutine	Function
PRTNP	Prints the total neutron disappearance array.
PRTNU	Prints the average number of neutrons per fission (ν) array.
PRTNX	Prints the microscopic neutron cross sections.
PRTPP	Prints the average secondary photon production per collision array.
PRTQ	Prints the Q-value, LR-flag, and S-value arrays for the neutron partial reactions.
REDNMT	Reads an output history tape from the HETC code system.
RITEG	Writes the secondary photon output tape for subsequent transport in program PHOTON.
RITER	Writes the recoil heavy ion and charged particle output tape for subsequent transport in program HEAVY.
RNDWLK	Performs the random walk for all particles.
SECEGY	Selects a partial energy distribution from which to sample an exit energy.
SECLF1	Samples an exit energy from a tabulated distribution.
SECLF5	Samples an exit energy from a general evaporation spectrum.
SECLF7	Samples an exit energy from a simple fission spectrum.
SECLF9	Samples an exit energy from an evaporation spectrum.

Table 4. (Continued)

Subroutine	Function
SECL11	Samples an exit energy from an energy dependent Watt spectrum.
SHIFT	Transfers data from one array to another array.
SORIN	Converts the input relative source frequency array to a cumulative distribution function and calculates a biased source spectrum.
SOURCE	Determines the initial parameters for all primary particles.
SOURH	Determines the initial parameters for all primary particles read from an HETC generated source tape.
STBTCH	Initializes arrays to zero used in accumulating analysis quantities during a batch.
TBSPLT	Determines a cross section at a given energy from a cross section versus energy table using a table splitting method.
TERP	Performs linear interpolation.
THRMSC	Controls selection of the neutron exit energy in the thermal range.
THRSEL	Selects neutron exit energy and scattering from $S(\alpha, \beta)$ data.
TIMER	Performs a variety of functions associated with the local and global clocks.
TWOBOD	Calculates the charged particle and recoil heavy ion exit parameters for a two-body collision.
UVW	Used to over-ride the source input direction cosines for a problem.

Table 4. (Continued)

Subroutine	Function
XSEC	Determines a cross section at a given energy from a cross section versus energy table.
XSEC1	Reads the second record off the input microscopic cross section unit and sets up the ICOM array.
XSEC2	Reads the remaining data on logical unit MICROS, selects the elements needed, and stores the microscopic data in core.
XSEC3	Mixes and thins the macroscopic total cross sections according to the mixing table if pre-mixing was not performed.
XSEC4	Reads the premixed macroscopic total cross sections on logical unit MACROS and stores the data in core.
XSEC5	Reads the secondary photon production partial distributions for each reaction listed in the GCB arrays and sums them to create a total secondary photon production array for each reaction.
XYZ	Used to over-ride the source input spatial coordinates for a problem.

Table 5. General Layout of Blank Common
in Program NEUTRON

Starting Location	Variable Name	Length
LFP8	RREL, WTHI, WTLO, WTAV	MAXGP+3*MAXGP*MXREG
LFP9	PATH	MAXGP*MXREG
LFP10	KM	NMIX
LFP11	KE	NMIX
LFP12	RHO	NMIX
LFP13	KZ	NMIX
LFP14	FS	2*NGPFS
LFP15	BFS	NGPFS
LFP16	IN	NMIX
LFP17	ICOM	NNUC
LFP18	IREC	NI
LFP19	Geometry Data	NADD
LFP20	IGAMS	NNUC
LFP21	LGAM	NNUC
LFP22	INABS	NNUC
LFP23	LNAB	NNUC
LFP24	ITHRMS	NNUC
LFP25	LTHRM	NNUC
LFP26	IDICTS	NNR*NNUC
LFP27	LDICT	NNR*NNUC
LFP28	NTX	NNUC
LFP29	NTS	NNUC
LFP30	IGCBS	NGR*NNUC
LFP31	LGCB	NGR*NNUC
LFP32	ISIGTS	MEDIA
LFP33	LSIGT	MEDIA
LFP34	AWR	NNUC
LFP35	Q,LR,QLR	3*NQ*NNUC
LFP36	Current Weight Standards	3*MAXGP*MXREG
LFP37	Splitting and Russian Roulette Counters	8*MAXGP*MXREG
LFP38	Neutron Bank	14*NMOST
LFP39	Photon Bank	13*MOSTG
LFP40	Recoil Heavy Ion and Charged Particle Bank	24*MOSTR
LFP41	NSEI, NAEI	2*NNUC
LFP42	NSCA	24*MEDIA
LFP43	Microscopic Cross Sections	Problem Dependent
LFP44	Macroscopic Cross Sections	Problem Dependent
LFP45	IGCBS2	NGR*NNUC
LFP46	LGCB2	NGR*NNUC
LFP47	Total Microscopic Photon Production Cross Sections	Problem Dependent
LFP48	Next Available Core Location	

Table 6. Definitions of Variables in Random Walk
Blank Common in Program NEUTRON

Variable	Definition
RREL(MAXGP)	Lower energy limits in eV of intervals for constant weight standard.
WTHI(MAXGP,MXREG)	Weight above which splitting is performed.
WTLO(MAXGP,MXREG)	Weight below which Russian Roulette is performed.
WTAV(MAXGP,MXREG)	Weight to be assigned Russian Roulette survivors.
PATH(MAXGP,MXREG)	Exponential transform parameters.
KM(NMIX)	Mixing table medium numbers.
KE(NMIX)	Mixing table element identifiers.
RHO(NMIX)	Mixing table element number densities.
KZ(NMIX)	Mixing table element charge numbers.
FS(NGPFS)	Unbiased source spectrum; unnormalized fraction of source particles in each energy bin - transformed into a cumulative distribution function in routine SORIN.
BFS(NGPFS)	Biased source spectrum; relative importance of each energy group-transformed into a biased cumulative distribution function in routine SORIN.
IN(NMIX)	Mixing table isotope numbers.
ICOM(NNUC)	Microscopic cross section B - control block (BCB) location numbers for the elements used in the problem.
IREC(NI)	Microscopic cross section I - control block (ICB) record numbers on logical unit MICROS.
IGAMS(NNUC)	Starting locations of average photon production arrays.
LGAM(NNUC)	Lengths of average photon production arrays.

Table 6. (Continued)

Variable	Definition
INABS(NNUC)	Starting locations of total neutron disappearance arrays.
LNAB(NNUC)	Lengths of total neutron disappearance arrays.
ITHRMS(NNUC)	Starting locations of thermal scattering data arrays.
LTHRM(NNUC)	Lengths of thermal scattering data arrays.
IDICTS(NNR, NNUC)	Starting locations of microscopic cross section arrays.
LDICT(NNR, NNUC)	Lengths of microscopic cross section arrays.
NTX(NNUC)	Number of secondary photon production cross section arrays.
NTS(NNUC)	Number of secondary photon energy distribution arrays.
IGCBS(NGR, NNUC)	Starting locations of secondary photon production cross section and energy distribution arrays.
LGCB(NGR, NNUC)	Lengths of secondary photon production cross section and energy distribution arrays.
ISIGTS(MEDIA)	Starting locations of macroscopic total cross section arrays.
LSIGT(MEDIA)	Lengths of macroscopic total cross section arrays.
AWR(NNUC)	Atomic mass ratio defined in ENDF/B.
Q(NQ, NNUC)	ENDF/B Q-value array.
LR(NQ, NNUC)	ENDF/B LR-flag array.
QLR(NQ, NNUC)	ENDF/B Q-value associated with the LR-flag.
NSPL(MAXGP, MXREG)	Splitting counter.
WSPL(MAXGP, MXREG)	Weight associated with NSPL i.e., the sum of the weights which have split.

Table 6. (Continued)

Variable	Definition
NOSP(MAXGP, MXREG)	Counter for full bank when splitting was requested.
WNOS(MAXGP, MXREG)	Weight associated with NOSP.
RRKL(MAXGP, MXREG)	Russian roulette death counter.
WRKL(MAXGP, MXREG)	Weight associated with RRKL.
RRSU(MAXGP, MXREG)	Russian roulette survival counter.
WRSU(MAXGP, MXREG)	Weight associated with RRSU.
NSEI(NNUC)	Element scattering collision counter.
NAEI(NNUC)	Element absorption collision counter.
NMT2(MEDIA)	Elastic scattering counter.
NMT4(MEDIA)	Inelastic scattering counter.
NMT16(MEDIA)	(n,2n) reaction counter.
NMT17(MEDIA)	(n,3n) reaction counter.
NMT18(MEDIA)	Fission reaction counter.
NMT22(MEDIA)	(n,n' α) reaction counter.
NMT23(MEDIA)	(n,n' 3α) reaction counter.
NMT24(MEDIA)	(n,2n α) reaction counter.
NMT28(MEDIA)	(n,n'p) reaction counter.
NMT51(MEDIA)	Discrete inelastic scattering counter.
NMT91(MEDIA)	Continuum inelastic scattering counter.
NMT102(MEDIA)	(n, γ) reaction counter.
NMT103(MEDIA)	(n,p) reaction counter.

Table 6. (Continued)

Variable	Definition
NMT104(MEDIA)	(n,d) reaction counter.
NMT105(MEDIA)	(n,t) reaction counter.
NMT106(MEDIA)	(n,He ³) reaction counter.
NMT107(MEDIA)	(n, α) reaction counter.
NMT108(MEDIA)	(n,2 α) reaction counter.
NMT109(MEDIA)	(n,3 α) reaction counter.
NMT111(MEDIA)	(n,2p) reaction counter.
NMT112(MEDIA)	(n,p α) reaction counter.
NMT113(MEDIA)	(n,t2 α) reaction counter.
NMT114(MEDIA)	(n,d2 α) reaction counter.
NSCA(MEDIA)	Total interaction counter.
IGCBS2(NGR,NNUC)	Starting locations of total secondary photon production cross sections.
LGCB2(NGR,NNUC)	Lengths of total secondary photon production cross sections.

Table 7. Definitions of Variables in MASS Common
in Program NEUTRON

Variable	Definition(current values set in MAIN)
ZN	Neutron mass in eV. (9.395124E+08) ^a
ZP	Proton mass in eV. (9.387298E+08)
ZD	Deuteron mass in eV. (1.8760177E+09)
ZT	Triton mass in eV. (2.8092727E+09)
ZHE3	Helium 3 mass in eV. (2.8092539E+09)
ZA	Alpha particle mass in eV. (3.7281883E+09)
AN	Neutron mass in AMU. (1.009062)
AP	Proton mass in AMU. (1.008221)
AD	Deuteron mass in AMU. (2.014894)
AT	Triton mass in AMU. (3.017236)
AHE3	Helium 3 mass in AMU. (3.017215)
AA	Alpha particle mass in AMU. (4.004176)

^aRead as 9.395124 x 10⁸.

Table 8. Definitions of Variables in CONST Common
in Program NEUTRON

Variable	Definition (Current values set in MAIN)
NNR	Number of neutron records per isotope on unit MICROS (134).
NQ	Number of ENDF/B Q-values per isotope on unit MICROS (66).
NGR	Number of photon records per isotope on unit MICROS (60).
NTSTW	Sum of NKILL+NPAST.
NGPREG	Product of number of weight standard groups (MAXGP) and regions (MXREG).
MGPI	Equal to MAXGP+1.
MIM	Equal to (MAXGP+1)*MXREG.
NI	Number of isotopes in data set on unit MICROS.
NNUC	Number of different elements used in the mixing table.
NCOL	Neutron collision counter.

Table 9. Definitions of Variables in APOLL Common
in Program NEUTRON

Variable	Definition
ETA	Number of mean-free-paths between collisions.
ETATH	Distance in centimeters to the next collision if the particle does not encounter a change in total cross section.
ETAUSD	Flight path in mean-free-paths that has been used since the last event.
DEADWT(5)	The summed weights of the particles at death. The four deaths are: Russian roulette, escape, energy, and age limit. The fifth, DEADWT(5), is unused.
XTRA(10)	Used for temporarily storing alphanumeric information on "time used" immediately before printing.
ITERS	Current batch number.
IFR	Switch indicating recoil heavy ion and charge particle bank is full if > 0.
IFG	Switch indicating secondary photon bank is full if > 0.
ITSTR	Switch indicating secondary fissions are to be the source for the next batch if > 0.
NEWNM	Name of last particle in bank.
NGEOM	Length of geometry data arrays.
NMEM	The location of the next particle in the neutron bank to be processed.
NMEMR	The location of the next particle to be stored in the recoil heavy ion and charged particle bank.
NMEMG	The location of the next particle to be stored in the secondary photon bank.
INALB	A switch indicating that an albedo scattering has occurred if > 0.
NDEAD(5)	Number of deaths of each type given in DEADWT.

Table 9. (Continued)

Variable	Definition
NPSCL(13)	An array of counters of events for each batch: (1) sources generated (2) splittings occurring (3) fissions occurring (4) secondary photons generated (5) real collisions (6) albedo scatterings (7) boundary crossings (8) escapes (9) energy cutoffs (10) time cutoffs (11) Russian roulette kills (12) Russian roulette survivals (13) secondary photons not stored because the secondary photon bank was full.

Table 10. Definitions of Variables in NUTRON Common
in Program NEUTRON

Variable	Definition
NAME	Particle first name.
NAMEX	Particle family name.
E	Current energy.
EOLD	Previous energy.
NMED	Medium number at current location.
MEDOLD	Medium number at previous location.
NREG	Region number at current location.
U,V,W	Current direction cosines.
UOLD,VOLD,WOLD	Previous direction cosines.
X,Y,Z	Current location.
XOLD,YOLD,ZOLD	Previous location.
WATE	Current weight.
OLDWT	Previous weight.
WTBC	Weight just before current collision.
BLZNT	Current zone number.
BLZON	Previous zone number.
AGE	Current age.
OLDAGE	Previous age.

Table 11. Definitions of Variables in GAMMA Common
in Program NEUTRON

Variable	Definition
NAMEXG	Particle family name.
MTNG	ENDF/B neutron reaction type number.
NMEDG	Medium number at particle location.
NCOLG	Neutron collision number.
EG	Particle energy.
XG,YG,ZG	Particle location.
UG,VG,WG	Particle direction cosines.
WATEG	Particle weight.
AGEG	Particle age.

Table 12. Definitions of Variables in RECOIL Common
in Program NEUTRON

Variable	Definition
NAMEXR	Particle family name.
MTNR	ENDF/B neutron reaction type number.
NZR	Particle charge.
NCOLR	Neutron collision number.
AR	Particle atomic weight.
ER	Particle energy.
UR,VR,WR	Particle direction cosines.
XR,YR,ZR	Particle location.
WATER	Particle weight.
AGER	Particle age.
ENIR	Pre-collision neutron energy.
UNIR,VNIR,WNIR	Pre-collision neutron direction cosines.
ENOR	Post-collision neutron energy.
UNOR,VNOR,WNOR	Post-collision neutron direction cosines.
WTNR	Neutron weight.
QR	ENDF/B Q-value associated with the neutron reaction type number.

Table 13. Definitions of Variables in PAREM Common

Variable	Definition
XB(3)	Coordinates of the starting point of the present path.
WB(3)	Direction cosines of particle trajectory, (Equal to U,V,W).
WP(3)	Temporary storage of WB(3).
XP(3)	Temporary storage of XB(3).
RIN	Distance to entry calculated in routine GG.
ROUT	Distance to exit calculated in routine GG.
PINF	Machine infinity. (1.00E+20)
DIST	Distance from XB(3) to present point.
IR	Combinatorial zone of present particle position.
IDBG	Set non-zero to initialize a debug printout.
IRPRIM	Next region to be entered after a call of routine G1.
NASC	Body number of last calculated intersection. Set negative to indicate source or collision point not on a body surface.
LSURF	Surface of body NASC where intersection occurred. Positive if particle is entering the body and negative when exiting.
NBO	Body number and a sign used to define zones. Input in zone description as positive when zone is contained in body and as negative if zone is outside body.
LRI	Entry surface calculated in routine GG.
LRO	Exit surface calculated in routine GG.
KLOOP	Trajectory index of present path incremented in routine G1.

Table 13. (continued)

Variable	Definition
LOOP	INEXT of last trajectory calculated for body NBO. If LOOP is equal to KLOOP, routine GG returns immediately with old values in RIN, ROUT, LRI, and LRO.
ITYPE	Body type of body NBO (indicates BOX, SPH, etc.).
NOA	Not used.
JTYL(15)	Alphanumeric title for geometry input.

Table 14. Definitions of Variables in ORGI Common

Variable	Definition
DISTO	Distance from point XB(3) to next scattering point. Used in routine G1 to avoid calculating the next zone if a scattering event occurs before the intersection.
MARKG	Set to 1 in routine G1 if trajectory end point is reached before next intersection, otherwise set to 0.
NMEDG	Zone number IR from a LOOKZ call.
NBLZ	Packed word containing both input zone and code zone numbers.
BLZOLD	Packed word containing input and code zone numbers for the previous collision.

Table 15. Definitions of Variables in DBG Common

Variable	Definition
N	Starting location in MA array of data for zone IRP.
NUM	Ending location in MA array of data for zone IRP.
LOCAT	Location in MA array of address where data for current body is located in the FPD array.
ISAVE	Index in MA array of next body intersected ($N \leq ISAVE \leq NUM$).
INEXT	Pointer to first zone searched in MA array for next body (Equal to $ISAVE + 2$).
IRP	Next zone searched to determine which zone the current body is in.
SMIN	Distance to intersection.
INEX	Pointer to next zone searched in MA array if INEXT is not the zone intersected (Equal to $INEXT + 1$).

Table 16. General Layout of Neutron Bank
(NBANK Common) in Program NEUTRON

Pointer	Variable Name
LNP1	US
LNP2	VS
LNP3	WS
LNP4	XS
LNP5	YS
LNP6	ZS
LNP7	WATES
LNP8	AGES
LNP9	BLZNTS
LNP10	ES
LNP11	NAMES
LNP12	NAMEXS
LNP13	NMEDS
LNP14	NREGS

Table 17. General Layout of Secondary Photon Bank
(GBANK Common) in Program NEUTRON

Pointer	Variable Name
LGP1	EGS
LGP2	XGS
LGP3	YGS
LGP4	ZGS
LGP5	UGS
LGP6	VGS
LGP7	WGS
LGP8	WATEGS
LGP9	AGEGS
LGP10	NAMXGS
LGP11	NCOLGS
LGP12	MTNGS
LGP13	NMEDGS

Table 18. General Layout of Recoil Heavy Ion and Charged Particle Bank (RBANK Common) in Program NEUTRON

Pointer	Variable Name
LRP1	ERS
LRP2	XRS
LRP3	YRS
LRP4	ZRS
LRP5	URS
LRP6	VRS
LRP7	WRS
LRP8	WATERS
LRP9	AGERS
LRP10	ARS
LRP11	NAMXRS
LRP12	NCOLRS
LRP13	MTNRS
LRP14	NZRS
LRP15	ENIRS
LRP16	UNIRS
LRP17	VNIRS
LRP18	WNIRS
LRP19	ENORS
LRP20	UNORS
LRP21	VNORS
LRP22	WNORS
LRP23	WTNRS
LRP24	QRS

Table 19. Definitions of Subroutine BANKR Arguments for
Additional Analysis in Program NEUTRON

BANKR argument	Called from	Location of call in random walk
- 1	CONTRL	After calls to INPUT1 and INPUT2 - to set parameters for new problem.
-2	BATCH	At the beginning of each batch of NSTRT particles.
-3	BATCH	At the end of each batch of NSTRT particles.
-4	CONTRL	At the end of each set of NITS batches - a new problem is about to begin.
1	MSOURC	At a source event.
2	RNDWLK	After a splitting has occurred.
3	COLISN	After a fission has occurred.
4	PHOTON	After a secondary photon has been generated.
5	RNDWLK	After a real collision has occurred - post collision parameters are available.
6	RNDWLK	After an albedo scattering has occurred - post collision parameters are available.
7	NXTCOL	After a boundary crossing has occurred - the track has encountered a new geometry medium other than an albedo or a void media.
8	NXTCOL	After an escape has occurred - the geometry has encountered medium zero.
9	RNDWLK	After the post-collision energy reaches the energy cut-off.
10	RNDWLK	After the post-collision age reaches the age cut-off.
11	RNDWLK	After a Russian roulette kill has occurred.
12	RNDWLK	After a Russian roulette survival has occurred.
13	STORSG	After a secondary photon has been generated but the storage bank is full.

5.2 Input Requirements

The following input arrays and title cards are required in order to execute a NEUTRON case. Default values are in brackets ([]).

CARD 1: FORMAT (20A4)

TITLE Problem title card.

CARD 2: FORMAT (Z12)

RANDOM Starting random number seed.

FIDAS DATA BLOCK 1

1 \$ Array [10 entries]

NCASE Case number for run.

NSTRT Number of particles per batch. (If reading a HETC tape NSTRT must be \geq to the maximum number of 05R Neutrons in any batch.)

NMOST Maximum number of neutrons allowed for in the neutron bank.

NMOSTG Maximum number of secondary photons allowed for in the photon bank.

NMOSTR Maximum number of recoil heavy ions and charged particles allowed for in the recoil heavy ion and charged particle bank.

NITS Number of batches per set. (If reading a HETC tape NITS must be \leq to the number of HETC batches completed.)

NQUIT Number of sets of NITS batches to be run without new input data.

NPHOTN 0/1 - No effect/Print out the contents of the secondary photon production tape.

NHEAVY 0/1 - No effect/Print out the contents of the recoil heavy ion and charged particle production tape.

NSOUR 0/1 - Fixed source problem/Source due to fissions generated in a previous batch.

2 \$ Array [6 entries]

NSPLT 0/1 - No effect/Particle splitting allowed.
NKILL 0/1 - No effect/Russian roulette allowed.
NPAST 0/1 - No effect/Exponential transform invoked.
NOLEAK 0/1 - No effect/Nonleakage option invoked.
IEBIAS 0/1 - No effect/Energy biasing invoked.
MAXGP Number of energy intervals for which Russian roulette, splitting, or exponential transforms are to be performed.

3 \$ Array [6 entries]

MEDIA Number of cross section media.
NMIX Number of mixing operations (element times atom density operations) to be performed.
MXREG Maximum number of regions described by geometry input.
ISOUR 0/1 - Input source distribution/Mono-energetic source with energy equal to ESOUR.
NGPFS Number of energy, probability pairs for which the source spectrum is to be defined.
ISBIAS 0/1 - No effect/source energy biasing invoked.

4 \$ Array [10 entries]

INN Card input unit. [5]
IOUT Printed output unit. [6]
MGEOM Geometry data input scratch unit. [16]
MGAMMA Secondary photon production output unit. [17]
MHEAVY Recoil heavy ion and charged particle production output unit. [18]
MICROS Microscopic cross section input unit. [74]
MACROS Premixed macroscopic total cross section input unit. [75]
MGSCR Secondary photon production scratch unit. [19]
MRSCR Recoil heavy ion production scratch unit. [20]

MHETG HETC output source input unit. [0]

5 \$ Array [8 entries]

IPRTNX 0/1 - No effect/Print neutron microscopic cross sections. [0]

IPRTNA 0/1 - No effect/Print neutron angular distributions. [0]

IPRTNE 0/1 - No effect/Print neutron secondary energy distributions.
[0]

IPRTPP 0/1 - No effect/Print average photon production per collision
array. [0]

IPRTNPF 0/1 - No effect/Print total neutron disappearance array. [0]

IPRTGX 0/1 - No effect/Print secondary photon production microscopic
cross sections. [0]

IPRTGE 0/1 - No effect/Print photon secondary energy distributions.
[0]

IPRTMX 0/1 - No effect/Print mixture macroscopic total cross
sections. [0]

6 * Array [9 entries]

UINP Starting source particle X-direction cosine.

VINP Starting source particle Y-direction cosine.

WINP Starting source particle Z-direction cosine.

XSTRT Starting source particle X-coordinate.

YSTRT Starting source particle Y-coordinate.

ZSTRT Starting source particle Z-coordinate.

WTSTRT Starting source particle weight.

AGSTRT Starting source particle age.

ESOUR Starting source particle energy in eV if ISOUR > 0.

7 * Array [6 entries]

TMAX Maximum c.p.u. time in minutes allowed for problem execution.

TCUT Age in seconds at which particles are retired; if TCUT = 0, no
time kill is performed.

ECUT Energy in eV below which particles are retired; if ECUT = 0, no energy kill is performed.

ETHERM Thermal energy breakpoint in eV to invoke Free Gas Model scattering.

TEMP Temperature in degrees Kelvin used in Free Gas Model, to calculate thermal cross section.

TOL Fractional thinning tolerance used in mixing operations (if MACROS = 0).

T Data Block 1 Terminator

FIDAS DATA BLOCK 2

8 * Array [MAXGP + 3*MAXGP*MXREG] required if NSPLT + NKILL + NPAST > 0.

RREL(I), I = 1,MAXGP, Lower energy limits in eV of energy intervals of constant weight standards.
 (Input in descending order.)

WTHI(I,J), I = 1,MAXGP, Weight above which splitting
 J = 1,MXREG will occur.

WTLO(I,J), I = 1,MAXGP, Weight below which Russian
 J = 1,MXREG roulette is allowed.

WTAV(I,J), I = 1,MAXGP, Weight given those particles
 J = 1,MXREG surviving Russian roulette.

9 * Array [MAXGP*MXREG] required if NSPLIT + NKILL + NPAST > 0.

PATH(I,J), I = 1,MAXGP Path length stretching parameters
 J = 1,MXREG for use in exponential transform.

10 \$ Array [NMIX]

KM(I), I = 1,NMIX Mixing table medium numbers.

11 \$ Array [NMIX]

KE(I), I = 1,NMIX Mixing table element identifiers.

12 * Array [NMIX]

RHO(I), I = 1,NMIX Mixing table atom densities (atoms/b-cm).

13 \$ Array [NMIX]

KZ(I), I = 1,NMIX Mixing table element charge numbers.

14 * Array [2*NGPFS] required if ISOUR = 0.

ES(I),FS(I), I = 1,NGPFS Energy (in eV), probability pairs
of source particles input in ascending energy.

15 * Array [NGPFS] required if ISOUR = 0 and ISBIAS = 1.

BFS(I), I = 1,NGPFS The relative importance of a source
particle at energy ES(I).

T Data Block 2 Terminator

COMBINATORIAL GEOMETRY INPUT INSTRUCTIONS

CARD CGA: Format (2I5,10X,10A6)

IWOPT Option which defines the method by which region volumes
are determined; if

0, volumes set equal to 1,

1, concentric sphere volumes are calculated,

2, slab volumes (1-dim.) are calculated, (not
operational)

3, volumes are input by card.

IDBG If IDBG > 0, subroutine PR is called to print results of
combinatorial geometry calculations during execution. Use only
for debugging.

JTY Alphanumeric title for geometry input (columns 21-80).

CARDS CGB: Format (2X,A3,1X,I4,6D10.3)

ITYPE Specifies body type or END to terminate reading of body
data (for example BOX, RPP, ARB, etc.). Leave blank for
continuation cards.

IALP Body number assigned by user (all input body numbers must
form a sequence set beginning at 1). If left blank, numbers
are assigned sequentially. Either assign all or none of the
numbers. Leave blank for continuation cards.

FPD(I) Real data required for the given body as shown in
Table 20. This data must be in centimeters.

Note: One set of CGB cards is required for each body and for the
END card (see Table 20). Leave columns 1-6 blank on all
continuation cards.

CARDS CGC: Format (2X,A3,I5,9(A2,I5))

IALP IALP must be a nonblank for the first card of each set of cards defining an input zone. If IALP is blank, this card is treated as a continuation of the previous zone card. IALP = END denotes the end of zone description.

NAZ Total number of zones that can be entered upon leaving any of the bodies defined for this input region (some zones may be counted more than once). Leave blank for continuation cards for a given zone. (If $NAZ \leq 0$ on the first card of the zone card set, then it is set to 5.) This is used to allocate blank common. Alternate IIBIAS(I) and JTY(I) for all bodies defining this input zone.

IIBIAS(I) Specify the "OR" operator if required for the JTY(I) body.

JTY(I) Body number with the (+) or (-) sign as required for the zone description.

Note: Input zone specification cards. One set of cards required for each input zone, with input zone numbers being assigned sequentially.

CARDS CGD: Format (14I5)

MRIZ(I) MRIZ(I) is the medium number in which the "Ith" input zone is contained ($I = 1$, to the number of input zones). Region numbers must be sequentially defined from 1.

Cards CGE: Format (14I5)

MMIZ(I) MMIZ(I) is the medium number in which the "Ith" input zone is contained ($I = 1$, to the number of input zones). Medium numbers must be sequentially defined from 1. (Media 0 is used for an external void and media 1000 is used for internal voids.)

Cards CGF: Format (7D10.5) (Omit if IVKOPT \neq 3)

VNOR(I) Volume of the "Ith" region ($I = 1$ to MXREG, the number of regions).

Table 20. Combinatorial Geometry Body Data Input Requirements in Program NEUTRON

Body Type	Card Columns								Number of Cards Needed
	ITYPE 3-5	IALP 7-10	11-20	Real Data Defining Particular Body				61-70	
Box	BOX	IALP is assigned by the user or by the code if left blank.	Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Right Parallelepiped	RPP		Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	1
Sphere	SPH		Vx	Vy	Vz	R	-	-	1
Right Circular Cylinder	RCC		Vx	Vy	Vz	Hx	Hy	H _z	1 of 2
			R	-	-	-	-	-	2 of 2
Right Elliptic Cylinder	REC		Vx	Vy	Vz	Hx	Hy	H _z	1 of 2
			R1x	R1y	R1z	R2x	R2y	R2z	2 of 2
Ellipsoid	ELL		V1x	V1y	V1z	V2x	V2y	V2z	1 of 2
			L	-	-	-	-	-	2 of 2
Truncated Right Cone	TRC		Vx	Vy	Vz	Hx	Hy	H _z	1 of 2
			L1	L2	-	-	-	-	2 of 2
Right Angle Wedge	WED		Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Arbitrary Polyhedron	ARB		V1x	V1y	V1z	V2x	V2y	V2z	1 of 5
			V3x	V3y	V3z	V4x	V4y	V4z	2 of 5
			V5x	V5y	V5z	V6x	V6y	V6z	3 of 5
			V7x	V7y	V7z	V8x	V8y	V8z	4 of 5

Face Descriptions (see note below)

Termination of Body Input Data END

NOTE: Card 5 of the arbitrary polyhedron input contains a four-digit number for each of the six faces of an ARB body. The format is 6D10.3, beginning in column 11. See the ARB write-up in Ref. 4 for an example.

5.3 Input Data Notes

All the input arrays except the title card, random number seed, and the combinatorial geometry input use the FIDO input system. For completeness, a description of FIDO formats and operators is given in Appendix B.

NSTRT When reading a HETC tape, NSTRT must be greater than or equal to the maximum number of O5R neutrons in any batch.

NMOST, NMOSTG, NMOSTR The choice for these three parameters is problem dependent and usually requires a small sample run to optimize available core space. If biasing i.e. Russian roulette, splitting, etc., is not involved, NMOST can be set to NSTRT+1. NMOSTG is determined by the number of secondary photons produced per source neutron. NMOSTR is determined by the number of collisions per source neutron. All three parameters are dependent on available core space. In most problems, multiple scattering will dominate the neutron interaction process, and therefore NMOSTR will determine NMOST, NMOSTG, and subsequently NSTRT.

NITS When reading a HETC tape, NITS must be less than or equal to the number of HETC batches completed.

NPHOTN, NHEAVY These two print triggers are used to check the contents of the secondary photon production and recoil heavy ion and charged particle production tapes. They should be used with caution since large amounts of output are possible.

2\$ Array The contents of this array set up the parameters used in the various biasing schemes present in most Monte Carlo

codes. The programming for these biasing schemes is included in this version of MICAP but has not been tested.

MEDIA This parameter should match the number of media read in from the macroscopic total cross section input unit.

MGSCR, MRSCR These two input/output units are not used in standard problem execution. Therefore job control language (JCL) is not required.

MHETC The current version requires MHETC to be greater than or equal to 58 if a buffered HETC tape is to be processed. IF MHETC is less than 58, a standard FORTRAN I/O tape is read. Typically, MHETC = 59 implies buffered tape and MHETC = 9 implies standard FORTRAN I/O tapes. IF an HETC tape is not being processed be sure MHETC = 0.

5\$ Array Setting any of these parameters to one provides printed output of that portion of the microscopic cross section data set. Caution must be used with some of the flags due to large amounts of output.

UINP, VINP, WINP, UVW These parameters can be over-ridden in subroutine if the problem requires more than a mono-directional source.

XSTRT, YSTRT, ZSTRT These parameters can be over-ridden in subroutine XYZ if the problem requires more than a point source.

10\$, 11\$, 12*, and 13\$ Arrays The mixing table must mirror the mixing operations performed on the pre-mixed macroscopic total cross section data set (if pre-mixing was performed).

14\$ Array The first probability must be equal to zero.

5.4 I/O File Requirements

File	Unit	Description	Required
INN	5	Card Input	Always
IOUT	6	Printed Output	Always
MGEOM	16	Geometry Data Scratch Unit	Always
MGAMMA	17	Secondary Photon Production Output Unit	Always
MHEAVY	18	Recoil Heavy Ion and Charged Particle Production Output Unit	Always
MICROS	74	Microscopic Cross Section Input Unit	Always
MACROS	75	Macroscopic Cross Section Input Unit	IF > 0
MGSCR	19	Secondary Photon Production Scratch Unit	IF > 0
MRSCR	20	Recoil Heavy Ion and Charged Particle Production Scratch Unit	IF > 0
MHETC	9 or 59	HETC Source Input Tape	IF > 0

5.5 JCL Requirements

The job control language (JCL) needed to run a NEUTRON case at X-10 is:

```
(Job card, route and jobparm cards)
//NEUTRON EXEC PGM=NEUTRON,REGION=2048K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
(DD cards for logical units 16, 17, 18, 74)
(DD cards for logical unit 75 if pre-mixing is performed)
(DD cards for logical unit 9 or 59 if a HETC tape is processed)
//SYSIN DD *
(Input Cards)
/*
//
```

5.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 12 and some selected output is shown in Figure 13. The sample problem demonstrates the calculation of an ionization chamber in a ^{252}Cf neutron source field. The problem further demonstrates the user over-ride capability for the input source distribution.

```

//JOJNUTRN JOB (24337,IO2),'JO JOHNSON 6025',TIME=(0,10)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
//A EXEC FORTQCLG,REGION=2048K
//FORT.SYSIN DD *
      SUBROUTINE XYZ(XSTRT,YSTRT,ZSTRT,X,Y,Z)
      DATA XMAX/3.2131/,YMAX/3.2131/,RMAX/3.2131/
20 R=FLTRNF(0)
      X=XMAX-2.0*XMAX*R
      R=FLTRNF(0)
      Y=YMAX-2.0*YMAX*R
      IF((X**2+Y**2).GT.(RMAX**2))GO TO 20
      Z=ZSTRT
      RETURN
      END
/*
//LKED.LMOD DD DSN=X.JOJ24337.PROG,DISP=SHR
//LKED.SYSIN DD *
      INCLUDE LMOD(NEUTRON)
      ENTRY MAIN
//GO.FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT16F001 DD UNIT=SYSDA,DISP=(NEW,KEEP),
// DSN=&&GEOM,SPACE=(TRK,(40,20)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//FT17F001 DD UNIT=SYSDA,DISP=(NEW,KEEP),
// DSN=&&GAMMA,SPACE=(TRK,(50,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//FT18F001 DD UNIT=SYSDA,DISP=(NEW,KEEP),
// DSN=&&HEAVY,SPACE=(TRK,(50,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//FT74F001 DD DSN=MEN.X10.JOJ.ICOM.MICROS,DISP=SHR
//FT75F001 DD DSN=MEN.X10.JOJ.TE50.MACROS,DISP=SHR
//SYSIN DD *
AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
AB54C7879122
1$$ 1001 200 210 100 600 5 1 0 0 0
2$$ 0 0 0 0 0 0
3$$ 6 19 1 0 52 0
4$$ 5 6 16 17 18 74 75 19 20 0
5$$ 0 0 0 0 0 0 0
6** 0.0 0.0 1.0 0.0 0.0 0.0 1.0 0.0 0.0
7** 10.0 0.0 1.00E-05 0.0 300.0 0.001
T
10$$ 1 2 2 2 2 3 3 3 3 3 3 4 4 5 5 5 6 6 6
11$$ 13027 1001 6000 7014 8016 1001 6000 7014 8016 9019 20000
      1001 6000 7014 8016 18000 1001 6000 8016

```

Figure 12. Complete Listing of JCL and Input for NEUTRON Sample Problem.

12** 6.0268-2 6.9367-5 2.6024-5 1.7129-6 1.7438-5
 6.8711-2 4.3416-2 1.7452-3 2.5039-3 6.0758-4 3.0494-4
 4.9054-2 4.9054-2 4.2028-5 1.1275-5 2.5026-7
 4.2061-2 5.0473-2 8.4122-3

13\$\$ 13 1 6 7 8 1 6 7 8 9 20 1 6 7 8 18 1 6 8

14**

1.0000E-11 0.0 1.0000E+03 1.0741E-05 3.0000E+03
 4.5124E-05 5.0000E+03 6.4463E-05 7.0000E+03 7.9202E-05
 1.0000E+04 1.4169E-04 3.0000E+04 1.4497E-03 5.0000E+04
 2.0999E-03 7.0000E+04 2.6145E-03 1.0000E+05 4.7506E-03
 2.0000E+05 2.1850E-02 2.5000E+05 1.3948E-02 3.0000E+05
 1.5266E-02 4.0000E+05 3.2319E-02 5.0000E+05 3.3717E-02
 6.0000E+05 3.4282E-02 7.0000E+05 3.4265E-02 8.0000E+05
 3.3831E-02 1.0000E+06 6.6338E-02 1.2000E+06 6.4040E-02
 1.4000E+06 6.0781E-02 1.5000E+06 2.8991E-02 1.6000E+06
 2.7969E-02 1.8000E+06 5.2706E-02 2.0000E+06 4.8399E-02
 2.2000E+06 4.4196E-02 2.3000E+06 2.0576E-02 2.4000E+06
 1.9597E-02 2.6000E+06 3.6379E-02 2.8000E+06 3.2837E-02
 3.0000E+06 2.9558E-02 3.4000E+06 5.0330E-02 3.7000E+06
 3.1046E-02 4.2000E+06 4.1259E-02 4.6000E+06 2.5342E-02
 5.0000E+06 1.9968E-02 5.5000E+06 1.9036E-02 6.0000E+06
 1.4007E-02 6.5000E+06 1.0195E-02 7.0000E+06 7.3399E-03
 7.5000E+06 5.2700E-03 8.0000E+06 3.7751E-03 8.5000E+06
 2.6983E-03 9.0000E+06 1.9251E-03 9.5000E+06 1.3712E-03
 1.0000E+07 9.7522E-04 1.1000E+07 1.1842E-03 1.2000E+07
 5.9483E-04 1.3000E+07 2.9768E-04 1.4000E+07 1.4848E-04
 1.6000E+07 1.1051E-04 1.8000E+07 2.7117E-05

T

	0	0	AFRRI	50CC	IONIZATION	CHAMBER (0.0CM	BUILD-UP	CAP)
RPP	1	-10.0	10.0	-10.0	10.0	0.0	20.0	
SPH	2	0.0	0.0	10.0	3.2131			
SPH	3	0.0	0.0	10.0	2.49936			
SPH	4	0.0	0.0	10.0	1.50114			
RCC	5	0.0	0.0	10.0	-6.35	0.0	0.0	
		0.15875						
RCC	6	-1.27	0.0	10.0	-1.27	0.0	0.0	
		0.47625						
RCC	7	-2.38125	0.0	10.0	-1.190625	0.0	0.0	
		0.3175						
RCC	8	-2.54	0.0	10.0	-1.666875	0.0	0.0	
		1.74625						
RCC	9	-3.33375	0.0	10.0	-1.349375	0.0	0.0	
		0.635						
RCC	10	-2.460625	0.0	10.0	-0.9525	0.0	0.0	
		0.47625						
RCC	11	-4.524375	0.0	10.0	-0.555625	0.0	0.0	
		0.555625						
RCC	12	-5.000625	0.0	10.0	-0.714375	0.0	0.0	
		0.396875						

Figure 12. (continued).

RCC	13	-4.1275		0.0	10.0	-0.873125		0.0		0.0
		1.666875								
RCC	14	-3.175		0.0	10.0	-1.031875		0.0		0.0
		0.873125								
RCC	15	-2.460625		0.0	10.0	-0.79375		0.0		0.0
		0.635								
RCC	16	-4.60375		0.0	10.0	-1.349375		0.0		0.0
		0.635								
RCC	17	-4.92125		0.0	10.0	-0.47625		0.0		0.0
		1.666875								
RCC	18	-4.60375		0.0	10.0	-1.74625		0.0		0.0
		0.79375								
RCC	19	-5.87375		0.0	10.0	-0.47625		0.0		0.0
		0.635								
RCC	20	-5.000625		0.0	10.0	-0.9525		0.0		0.0
		0.47625								
RCC	21	-2.2225		0.0	10.0	-1.031875		0.0		0.0
		0.873125								
RCC	22	-4.1275		0.0	10.0	-2.2225		0.0		0.0
		1.74625								
RPP	23	-500.0		500.0	-500.0	500.0		-500.0		500.0
END										
AIR	00R	1	-2	-8	-22OR	22	-13	-17		-18
WAL	00R	2	-3	-14	-21OR	8	-14	-21		-22
GAS	00R	3	-4	-6	-15OR	21	-6	-14		-15
COL	00R	4	-5OR	6	-5	-10OR	7	-5		
ROD	0	5								
POL	00R	9	-5	-7	-16OR	10	-5	-7OR	11	-5
	OR	12	-5							
INS	00R	13	-9	-17	-18OR	14	-9	-10OR	15	-10
BRS	0	16	-11	-19	-20					
LUC	00R	19	-5OR	20	-5	-11	-12			
SLV	00R	17	-16OR	18	-9	-16	-19			
VD	0	23	-1							
END										
	1	1	1	1	1	1	1	1	1	1
	5	3	2	3	1	4	6	1	6	1
										0

/*
//

Figure 12. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

1\$ ARRAY 10 ENTRIES READ
2\$ ARRAY 6 ENTRIES READ
3\$ ARRAY 6 ENTRIES READ
4\$ ARRAY 9 ENTRIES READ
5\$ ARRAY 8 ENTRIES READ
6* ARRAY 9 ENTRIES READ
7* ARRAY 6 ENTRIES READ
0T
10\$ ARRAY 19 ENTRIES READ
11\$ ARRAY 19 ENTRIES READ
12* ARRAY 19 ENTRIES READ
13\$ ARRAY 19 ENTRIES READ
14* ARRAY 104 ENTRIES READ
0T

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

1 \$ ARRAY

NCASE	CASE NUMBER FOR RUN	1001
NSTRT	NUMBER OF PARTICLES PER BATCH	200
NMOST	MAXIMUM NUMBER OF NEUTRONS PER BATCH ALLOWED	210
MOSTG	MAXIMUM NUMBER OF SECONDARY PHOTONS PER BATCH ALLOWED	100
MOSTR	MAXIMUM NUMBER OF RECOIL HEAVY IONS PER BATCH ALLOWED	600
NITS	NUMBER OF BATCHES PER SET	5
NQUIT	NUMBER OF SETS OF BATCHES	1
NPHOTN	SECONDARY PHOTON PRODUCTION TAPE CHECK INDICATOR	0
NHEAVY	RECOIL HEAVY ION PRODUCTION TAPE CHECK INDICATOR	0
NSOUR	FIXED SOURCE INDICATOR	0

Figure 13. Listing of Selected Output from NEUTRON Sample Problem.

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
2 \$ ARRAY

WEDNESDAY, AUGUST 27, 1986

NSPLT	SPLITTING INDICATOR	0
NKILL	RUSSIAN ROULETTE INDICATOR	0
NPAST	EXPONENTIAL TRANSFORM INDICATOR	0
NOLEAK	NON-LEAKAGE INDICATOR	0
IEBIAS	ENERGY BIAS INDICATOR	0
MAXGP	NUMBER OF GROUPS FOR RR, SPLITTING, OR EXPPFORM	0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
3 \$ ARRAY

WEDNESDAY, AUGUST 27, 1986

MEDIA	NUMBER OF CROSS SECTION MEDIA	6
NMIX	NUMBER OF MIXING OPERATIONS	19
MXREG	NUMBER OF REGIONS	1
ISOUR	MOMOENERGETIC SOURCE INDICATOR	0
NGPFS	NUMBER OF INPUT SOURCE GROUPS	52
ISBIAS	SOURCE ENERGY BIAS INDICATOR	0

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
4 \$ ARRAY

WEDNESDAY, AUGUST 27, 1986

INN	INPUT UNIT	5
IOUT	PRINTED OUTPUT UNIT	6
MGEOM	GEOMETRY DATA INPUT SCRATCH UNIT	16
MGAMMA	SECONDARY PHOTON OUTPUT UNIT	17
MHEAVY	RECOIL HEAVY ION OUTPUT UNIT	18
MICROS	MICROSCOPIC CROSS SECTION INPUT UNIT	74
MACROS	PREMIXED TOTAL CROSS SECTION INPUT UNIT	75
MGSCR	SECONDARY PHOTON SCRATCH UNIT	19
MRSCR	RECOIL HEAVY ION SCRATCH UNIT	20

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
5 \$ ARRAY

WEDNESDAY, AUGUST 27, 1986

IPRTMX	PRINT NEUTRON CROSS SECTIONS	0
IPRTNA	PRINT NEUTRON ANGULAR DISTRIBUTIONS	0
IPRTNE	PRINT NEUTRON SECONDARY ENERGY DISTRIBUTIONS	0
IPRTPP	PRINT AVERAGE PHOTON PRODUCTION ARRAY	0
IPRTNP	PRINT TOTAL NEUTRON DISAPPEARANCE ARRAY	0
IPRTGX	PRINT PHOTON CROSS SECTIONS	0
IPRTGE	PRINT PHOTON SECONDARY ENERGY DISTRIBUTIONS	0
IPRTMX	PRINT MIXTURE MACROSCOPIC TOTAL CROSS SECTIONS	0

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
6 * ARRAY

WEDNESDAY, AUGUST 27, 1986

UINP	SOURCE X-DIRECTION COSINE	0.0
VINP	SOURCE Y-DIRECTION COSINE	0.0
WINP	SOURCE Z-DIRECTION COSINE	1.0000E+00
XSTRT	SOURCE X-COORDINATE	0.0
YSTRT	SOURCE Y-COORDINATE	0.0
ZSTRT	SOURCE Z-COORDINATE	0.0
WTSTRT	SOURCE PARTICLE WEIGHT	1.0000E+00
AGSTRT	SOURCE AGE	0.0
ESOUR	SOURCE ENERGY	0.0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
7 * ARRAY

WEDNESDAY, AUGUST 27, 1986

TMAX	MAXIMUM IBM CPU TIME	1.0000E+01
TCUT	PARTICLE AGE CUT-OFF	0.0
ECUT	PARTICLE ENERGY CUT-OFF	1.0000E-05
ETHERM	THERMAL ENERGY DEFINITION POINT	0.0
TEMP	TEMPERATURE (DEGREES KELVIN)	3.0000E+02
TOL	THINNING TOLERANCE FOR MIXING	1.0000E-03

CROSS SECTION MIXING TABLE

MEDIUM	ELEMENT	NUMBER DENSITY	Z-NUMBER
1	13027	6.0268E-02	13
2	1001	6.9367E-05	1
2	6000	2.6024E-05	6
2	7014	1.7129E-06	7
2	8016	1.7438E-05	8
3	1001	6.8711E-02	1
3	6000	4.3416E-02	6
3	7014	1.7452E-03	7
3	8016	2.5039E-03	8
3	9019	6.0758E-04	9
3	20000	3.0494E-04	20
4	1001	4.9054E-02	1
4	6000	4.9054E-02	6
5	7014	4.2028E-05	7
5	8016	1.1275E-05	8
5	18000	2.5026E-07	18
6	1001	4.2061E-02	1
6	6000	5.0473E-02	6
6	8016	8.4122E-03	8

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
14 * ARRAY

WEDNESDAY, AUGUST 27, 1986

UNBIASED-UNNORMALIZED SOURCE SPECTRUM

SOURCE ENERGY	UNNORMALIZED FRACTION
1.0000E-11	0.0
1.0000E+03	1.0741E-05
3.0000E+03	4.5124E-05
5.0000E+03	6.4463E-05
.	.
.	.
.	.
1.3000E+07	2.9768E-04
1.4000E+07	1.4848E-04
1.6000E+07	1.1051E-04
1.8000E+07	2.7117E-05

Figure 13. (continued).

NORMALIZED NATURAL SOURCE SPECTRUM

SOURCE ENERGY	NATURAL PROBABILITY
1.0000E-11	0.0
1.0000E+03	1.0741E-05
3.0000E+03	5.5865E-05
5.0000E+03	1.2033E-04
•	•
•	•
•	•
1.3000E+07	9.9971E-01
1.4000E+07	9.9986E-01
1.6000E+07	9.9997E-01
1.8000E+07	1.0000E+00

Figure 13. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

ILOPT = 0 IDBG = 0

BODY DATA

RPP	1	-1.0000000D+01	1.0000000D+01	-1.0000000D+01	1.0000000D+01	0.0	2.0000000D+01	3
SPH	2	0.0	0.0	1.0000000D+01	3.2131000D+00	0.0	0.0	11
SPH	3	0.0	0.0	1.0000000D+01	2.4993600D+00	0.0	0.0	19
SPH	4	0.0	0.0	1.0000000D+01	1.5011400D+00	0.0	0.0	27
RCC	5	0.0	0.0	1.0000000D+01	-6.3500000D+00	0.0	0.0	35
		1.5875000D-01						
RCC	6	-1.2700000D+00	0.0	1.0000000D+01	-1.2700000D+00	0.0	0.0	44
		8.7625000D-01						
RCC	7	-2.3812500D+00	0.0	1.0000000D+01	-1.1906250D+00	0.0	0.0	53
		3.1750000D-01						
RCC	8	-2.5400000D+00	0.0	1.0000000D+01	-1.6668750D+00	0.0	0.0	62
		1.7462500D+00						
RCC	9	-3.3337500D+00	0.0	1.0000000D+01	-1.3493750D+00	0.0	0.0	71
		6.3500000D-01						
RCC	10	-2.4606250D+00	0.0	1.0000000D+01	-9.5250000D-01	0.0	0.0	80
		8.7625000D-01						
RCC	11	-4.5243750D+00	0.0	1.0000000D+01	-5.5562500D-01	0.0	0.0	89
		5.5562500D-01						
RCC	12	-5.0006250D+00	0.0	1.0000000D+01	-7.1437500D-01	0.0	0.0	98
		3.9687500D-01						
RCC	13	-4.1275000D+00	0.0	1.0000000D+01	-8.7312500D-01	0.0	0.0	107
		1.6668750D+00						
RCC	14	-3.1750000D+00	0.0	1.0000000D+01	-1.0318750D+00	0.0	0.0	116
		8.7312500D-01						
RCC	15	-2.4606250D+00	0.0	1.0000000D+01	-7.9375000D-01	0.0	0.0	125
		6.3500000D-01						
RCC	16	-4.6037500D+00	0.0	1.0000000D+01	-1.3493750D+00	0.0	0.0	134
		6.3500000D-01						
RCC	17	-4.9212500D+00	0.0	1.0000000D+01	-4.7625000D-01	0.0	0.0	143
		1.6668750D+00						
RCC	18	-4.6037500D+00	0.0	1.0000000D+01	-1.7462500D+00	0.0	0.0	152
		7.9375000D-01						

Figure 13. (continued).

RCC	19	-5.8737500D+00	0.0	1.0000000D+01	-4.7625000D-01	0.0	0.0	161
		6.3500000D-01						
RCC	20	-5.0006250D+00	0.0	1.0000000D+01	-9.5250000D-01	0.0	0.0	170
		4.7625000D-01						
RCC	21	-2.2225000D+00	0.0	1.0000000D+01	-1.0318750D+00	0.0	0.0	179
		8.7312500D-01						
RCC	22	-4.1275000D+00	0.0	1.0000000D+01	-2.2225000D+00	0.0	0.0	188
		1.7462500D+00						
RPF	23	-5.0000000D+02	5.0000000D+02	-5.0000000D+02	5.0000000D+02	-5.0000000D+02	5.0000000D+02	197
END	24	0.0	0.0	0.0	0.0	0.0	0.0	205

NUMBER OF BODIES 23

LENGTH OF FPD-ARRAY 210

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

INPUT ZONE DATA

AIR	00R	1	-2	-8	-22OR	22	-13	-17	-18	0	Z	1
WAL	00R	2	-3	-14	-21OR	8	-14	-21	-22	0	Z	3
GAS	00R	3	-4	-6	-15OR	21	-6	-14	-15	0	Z	5
COL	00R	4	-5OR	6	-5	-10OR	7	-5	0	0	Z	7
ROD	0	5	0	0	0	0	0	0	0	0	Z	10
POL	00R	9	-5	-7	-16OR	10	-5	-7OR	11	-5	Z	11
	00R	12	-5	0	0	0	0	0	0	0	Z	14
INS	00R	13	-9	-17	-18OR	14	-9	-10OR	15	-10	Z	15
BRS	0	16	-11	-19	-20	0	0	0	0	0	Z	18
LUC	00R	19	-5OR	20	-5	-11	-12	0	0	0	Z	19
SLV	00R	17	-16OR	18	-9	-16	-19	0	0	0	Z	21
VD	0	23	-1	0	0	0	0	0	0	0	Z	23
END	0	0	0	0	0	0	0	0	0	0	Z	24

NUMBER OF INPUT ZONES 11

NUMBER OF CODE ZONES 23

LENGTH OF INTEGER ARRAY 575

Figure 13. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

CODE ZONE	INPUT ZONE	ZONE DATA LOCATIONS	NUMBER OF BODIES	REGION NUMBER	MEDIA NUMBER
1	1	162	4	1	5
2	1	179	4	1	5
3	2	196	4	1	3
4	2	213	4	1	3
5	3	230	4	1	2
6	3	247	4	1	2
7	4	264	2	1	3
8	4	273	3	1	3
9	4	286	2	1	3
10	5	295	1	1	1
11	6	300	4	1	4
12	6	317	3	1	4
13	6	330	2	1	4
14	6	339	2	1	4
15	7	348	4	1	6
16	7	365	3	1	6
17	7	378	2	1	6
18	8	387	4	1	1
19	9	404	2	1	6
20	9	413	4	1	6
21	10	430	2	1	1
22	10	439	4	1	1
23	11	456	2	1	0

Figure 13. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

I	KR1(I)	KR2(I)
1	1	2
2	3	4
3	5	6
4	7	9
5	10	10
6	11	14
7	15	17
8	18	18
9	19	20
10	21	22
11	23	23

MORSE REGION IN INPUT ZONE(I) ARRAY MRIZ(I),I=1,11)

1 1 1 1 1 1 1 1 1 1 1

MORSE MEDIA IN INPUT ZONE(I) ARRAY MMIZ(I),I=1,11)

5 3 2 3 1 4 6 1 6 1 0

OPTION 0 WAS USED IN CALCULATING VOLUMES FOR 1 REGIONS

0-SET VOLUMES = 1, 1-CONCENTRIC SPHERES, 2-SLABS, 3-INPUT VOLUMES.

VOLUMES (CM**) USED IN COLLISION DENSITY AND TRACK LENGTH ESTIMATORS.

REGION 1
VOLUME 1.000D+00

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

TOTAL CORE STORAGE SPACE AVAILABLE=-	433664
LENGTH OF NON CROSS SECTION DATA=-	25959
LENGTH OF GEOMETRY DATA ARRAYS=-	1202
LENGTH OF 1-D CROSS SECTION ARRAYS=-	52378
LENGTH OF ANGULAR DISTRIBUTIONS=-	67914
LENGTH OF SECONDARY ENERGY DISTRIBUTIONS=-	4643
TOTAL LENGTH OF MICROSCOPIC DATA ARRAYS=-	236126
LENGTH OF PHOTON PRODUCTION ARRAYS=-	6912
LENGTH OF NEUTRON DISAPPEARANCE ARRAYS=-	10414
LENGTH OF THERMAL DATA ARRAYS=-	0
LENGTH OF PHOTON CROSS SECTION ARRAYS=-	63771
LENGTH OF PHOTON SECONDARY ENERGY DIST.=	30094
LENGTH OF MIXTURE CROSS SECTION DATA=-	12654
TOTAL LENGTH OF MACROSCOPIC DATA=-	12654

TIME REQUIRED FOR INPUT WAS LESS THAN ONE SECOND.

Figure B-13. (continued).

----- START BATCH NUMBER 2 RANDOM NUMBER= 9EEA505E7F1A -----

AVERAGE SOURCE PARAMETERS FOR THE BATCH

AVERAGE WEIGHT	AVERAGE X-DIRECTION	AVERAGE Y-DIRECTION	AVERAGE Z-DIRECTION	AVERAGE AGE
1.0000E+00	0.0	0.0	1.0000E+00	0.0
AVERAGE ENERGY	AVERAGE X-COORDINATE	AVERAGE Y-COORDINATE	AVERAGE Z-COORDINATE	
2.2724E+06	9.5567E-02	-8.9154E-02	0.0	

SUMMARY COUNTERS OF EVENTS FOR THE BATCH

SOURCES GENERATED	SPLITTINGS OCCURRING	FISSIONS OCCURRING	GAMMA RAYS GENERATED	REAL COLLISIONS	ALBEDO SCATTERINGS	BOUNDARY CROSSINGS
200	0	0	1	291	0	824
PARTICLE ESCAPES	ENERGY CUTOFFS	TIME CUTOFFS	RUSSIAN ROULETTE KILLS	RUSSIAN ROULETTE SURVIVORS	GAMMA RAYS NOT STORED	
199	1	0	0	0	0	

TIME REQUIRED FOR THE PRECEDING BATCH WAS LESS THAN ONE SECOND.

Figure 13. (continued).

APRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

----- START BATCH NUMBER 3 RANDOM NUMBER= 6349FB14FAA -----

AVERAGE SOURCE PARAMETERS FOR THE BATCH

AVERAGE WEIGHT	AVERAGE X-DIRECTION	AVERAGE Y-DIRECTION	AVERAGE Z-DIRECTION	AVERAGE AGE
1.0000E+00	0.0	0.0	1.0000E+00	0.0
AVERAGE ENERGY	AVERAGE X-COORDINATE	AVERAGE Y-COORDINATE	AVERAGE Z-COORDINATE	
1.8533E+06	2.0614E-02	-8.8571E-02	0.0	

SUMMARY COUNTERS OF EVENTS FOR THE BATCH

SOURCES GENERATED	SPLITTINGS OCCURRING	FISSIONS OCCURRING	GAMMA RAYS GENERATED	REAL COLLISIONS	ALBEDO SCATTERINGS	BOUNDARY CROSSINGS
200	0	0	0	317	0	811
PARTICLE ESCAPES	ENERGY CUTOFFS	TIME CUTOFFS	RUSSIAN ROULETTE KILLS	RUSSIAN ROULETTE SURVIVORS	GAMMA RAYS NOT STORED	
199	1	0	0	0	0	

TIME REQUIRED FOR THE PRECEDING BATCH WAS LESS THAN ONE SECOND.

Figure 13. (continued).

----- START BATCH NUMBER 4 RANDOM NUMBER= A18B75BD02EA -----

AVERAGE SOURCE PARAMETERS FOR THE BATCH

AVERAGE WEIGHT	AVERAGE X-DIRECTION	AVERAGE Y-DIRECTION	AVERAGE Z-DIRECTION	AVERAGE AGE
1.0000E+00	0.0	0.0	1.0000E+00	0.0
	AVERAGE ENERGY	AVERAGE X-COORDINATE	AVERAGE Y-COORDINATE	AVERAGE Z-COORDINATE
	2.3333E+06	4.3722E-02	-5.4774E-02	0.0

SUMMARY COUNTERS OF EVENTS FOR THE BATCH

SOURCES GENERATED	SPLITTINGS OCCURRING	FISSIONS OCCURRING	GAMMA RAYS GENERATED	REAL COLLISIONS	ALBEDO SCATTERINGS	BOUNDARY CROSSINGS
200	0	0	1	306	0	845
PARTICLE ESCAPES	ENERGY CUTOFFS	TIME CUTOFFS	RUSSIAN ROULETTE KILLS	RUSSIAN ROULETTE SURVIVORS	GAMMA RAYS NOT STORED	
199	1	0	0	0	0	

TIME REQUIRED FOR THE PRECEDING BATCH WAS LESS THAN ONE SECOND.

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
 ----- START BATCH NUMBER 5

WEDNESDAY, AUGUST 27, 1986
 ----- RANDOM NUMBER= 54AC95A4BACA -----

AVERAGE SOURCE PARAMETERS FOR THE BATCH

AVERAGE WEIGHT	AVERAGE X-DIRECTION	AVERAGE Y-DIRECTION	AVERAGE Z-DIRECTION	AVERAGE AGE
1.0000E+00	0.0	0.0	1.0000E+00	0.0
AVERAGE ENERGY	AVERAGE X-COORDINATE	AVERAGE Y-COORDINATE	AVERAGE Z-COORDINATE	
2.0629E+06	-8.9427E-02	8.1942E-02	0.0	

SUMMARY COUNTERS OF EVENTS FOR THE BATCH

SOURCES GENERATED	SPLITTINGS OCCURRING	FISSIONS OCCURRING	GAMMA RAYS GENERATED	REAL COLLISIONS	ALBEDO SCATTERINGS	BOUNDARY CROSSINGS
200	0	0	1	349	0	854
PARTICLE ESCAPES	ENERGY CUTOFFS	TIME CUTOFFS	RUSSIAN ROULETTE KILLS	RUSSIAN ROULETTE SURVIVORS	GAMMA RAYS NOT STORED	
199	0	0	0	0	0	

TIME REQUIRED FOR THE PRECEDING BATCH WAS LESS THAN ONE SECOND.
 TIME REQUIRED FOR THE PRECEDING 5 BATCHES WAS 4 SECONDS.
 THE NEXT RANDOM NUMBER IS 9AAA0F8F135A

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

NEUTRON DEATHS	NUMBER	WEIGHT
KILLED BY RUSSIAN ROULETTE	0	0.0
ESCAPED THE SYSTEM	994	9.9400E+02
REACHED ENERGY CUTOFF	4	4.0000E+00
REACHED TIME CUTOFF	0	0.0

Figure 13. (continued).

APRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

NUMBER OF INTERACTIONS (BY MEDIUM)
MEDIUM NUMBER

1	4
2	1
3	1514
4	16
5	3
6	27

APRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

SUMMARY REACTION RATE COUNTERS FOR THE RUN

MEDIUM	MT-2 REACTION	MT-4 REACTION	MT-51 REACTION	MT-91 REACTION	MT-18 REACTION
1	3	1	1	0	0
2	1	0	0	0	0
3	1511	1	1	0	0
4	16	0	0	0	0
5	3	0	0	0	0
6	27	0	0	0	0

APRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

SUMMARY REACTION RATE COUNTERS FOR THE RUN

MEDIUM	MT-16 REACTION	MT-17 REACTION	MT-22 REACTION	MT-23 REACTION	MT-24 REACTION	MT-28 REACTION
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

SUMMARY REACTION RATE COUNTERS FOR THE RUN

MEDIUM	MT-102 REACTION	MT-103 REACTION	MT-104 REACTION	MT-105 REACTION	MT-106 REACTION	MT-107 REACTION
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	1	0	0	0	1
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

SUMMARY REACTION RATE COUNTERS FOR THE RUN

MEDIUM	MT-108 REACTION	MT-109 REACTION	MT-111 REACTION	MT-112 REACTION	MT-113 REACTION	MT-114 REACTION
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0

114

Figure 13. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

NUMBER OF SCATTERINGS (BY ELEMENT)

ELEMENT	NUMBER
13027	4
1001	1185
6000	326
7014	18
8016	19
9019	10
20000	1
18000	0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

NUMBER OF ABSORPTIONS (BY ELEMENT)

ELEMENT	NUMBER
13027	0
1001	0
6000	0
7014	1
8016	0
9019	0
20000	1
18000	0

TOTAL CPU TIME FOR THIS PROBLEM WAS 0.08 MINUTES.

Figure 13. (continued).

6.0 RECOMB - A CODE FOR GENERATING RECOMBINATION DATA SETS

6.1 Code Description

The program RECOMB provides a capability for calculating saturation effects present in the ionization chamber. The nonlinearity of the energy deposition i.e., the signal observed, L , is not in direct proportion to the energy deposited due to saturation, is taken into account using Birk's law:⁵

$$\frac{dL}{dx} = \frac{\frac{dE}{dx}}{1 + KB \frac{dE}{dx}} \quad (1)$$

or

$$L(E_2) - L(E_1) = \int_{E_1}^{E_2} \frac{dE}{1 + KB \frac{dE}{dx}}$$

The ionization energy loss, dE/dx , used in evaluating Eq. 1 originates from a code written by Armstrong and Chandler⁶ and corresponds to the ionization energy loss used in calculating the stopping powers and ranges in program HEAVY. Program RECOMB assumes a linear relationship holds between the signal observed and the energy deposited i.e., $L \sim E$, for electrons and positrons. It should be noted that while saturation effects are important, these effects are generally small for the low density media i.e., tissue equivalent gas, CO₂, etc., used in ionization chambers.

The subroutine hierarchy of program RECOMB is shown in Figure 14. Also, a list of the subroutines used in program RECOMB along with their function is given in Table 21.

ORNL - DWG 86 - 15418

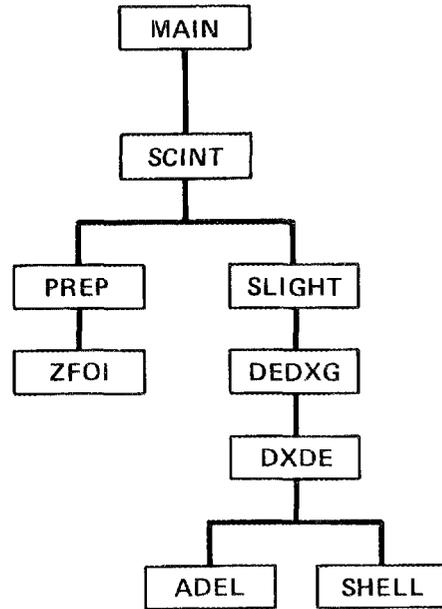


Figure 14. Subroutine Hierarchy in Program RECOMB.

Table 21. Subroutine Functions in Program RECOMB

Subroutine	Function
ADEL	Computes asymptotic density effect correction in the dE/dx equation.
DEDXG	Computes the dE/dx for the charged particles and recoil heavy ions.
DXDE	Incorporates the shell and density effect corrections to the dE/dx equation.
MAIN	Sets the default values for logical units IN, IO, and IPUN equal to 5, 6, and 17 respectively, and calls subroutine SCINT.
PREP	Reads in most of the input and sets up the variables needed in the dE/dx computations.
SCINT	Reads in the rest of the input, and acts as the control subroutine for output.
SHELL	Computes the shell correction in the dE/dx equation.
SLIGHT	Performs the integration of the dE/dx equation to generate the saturation data curves.
ZFOI	Function to yield the ionization potentials for the elements in the media.

6.2 Input Requirements

The following input cards are required in order to execute a RECOMB case. Default values are given in brackets ([]).

Card 1: Format (2E12.4)

EHI Upper energy limit in MeV for which dE/dx will be calculated. [5 x 10¹]

ELOW Lower energy limit in MeV for which dE/dx will be calculated. [1 x 10⁻⁶]

Card 2: Format (2I6)

MXMAT Number of different media. [1]

M2FLG 0/1 - Gas/Solid flag for the active media. [0]

Note: Card 3 repeated MXMAT times, is followed each time by Card 4 repeated NEL times.

Card(s) 3: Format (I6,2E12.4)

NEL The number of nuclide types other than hydrogen in the medium.

DENH The density (atoms/b-cm) of hydrogen in the medium.

AVDEN The average density (gm/cm³) of the medium.

Card(s) 4: Format (3E12.4)

ZZ The charge number of the "nth" nuclide other than hydrogen in the medium.

A The mass number of the "nth" nuclide other than hydrogen in the medium.

DEN The atom density (atoms/b-cm) of the "nth" nuclide other than hydrogen in the medium.

Note: Card 4 is repeated NEL times.

Card 5: Format (3E12.4,3I6)

KB Saturation constant ($\text{gm}/\text{cm}^2/\text{MeV}$) in Birks' law.

EMI Minimum energy in MeV for which light curves are calculated.

EMA Maximum energy in MeV for which light curves are calculated.

NPTS Number of energy points for which light curves are calculated. [500]

NSUB Number of integration points between energy points. [Use 3000]

NOLC Number of light curves generated.

Card(s) 6: Format (2I6,2E12.4)

MED The medium number. [1]

ITYP The type of particle for which the light curves will be calculated.

1 for recoil heavy ions (mass number > 1)

2 for protons

Z The charge number of the recoil heavy ion.

XM The mass number (in amu) of the recoil heavy ion.

Card 7: Blank card

6.3 Input Data Notes

MXMAT Program RECOMB is capable of calculating saturation curves for 16 different media. Program HEAVY, however, expects saturation curves only for the active media and therefore MXMAT should always equal one.

NEL The current array dimensions in Program RECOMB require $NEL \leq 10$.

KB The saturation constant is determined from experimental data. In general, the larger the value of KB, the greater the saturation effects. For $KB = 0$, there are no saturation effects and the signal observed is directly proportional to the energy deposited.

NPTS Program HEAVY requires $NPTS \leq 500$. This yields adequate representation of the saturation curves.

NOLC The number of saturation curves generated is not restricted in program RECOMB. Program HEAVY, however, requires $NOLC \leq 15$. This has been determined to be a sufficient number for ionization chamber calculations. The particle types for which saturation curves are calculated should be input in the following order; protons followed by recoil heavy ions in increasing Z, i.e., P, D, T, ^3He , α , ^{10}B , ^{11}B , . . .

ITYP When the particle type is a proton ($ITYP = 2$), no additional data is needed on that input card.

6.4 I/O File Requirements

File	Unit	Description	Required
IN	5	Card Input	Always
IO	6	Printed Output	Always
IPUN	17	Saturation Curve Output	Always

6.5 JCL Requirements

The job control language (JCL) needed to run a RECOMB case at X-10 is:

```
(Job Card, route and jobparm cards)
//RECOMB EXEC PGM=RECOMB,REGION=1020K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
(DD Cards for Unit 17)
//SYSIN DD *
(Input Cards)
/*
//
```

6.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 15 and some selected output are shown in Figure 16. The problem demonstrates the calculation of saturation curves for two particle types in a NE102A plastic scintillator with $KB = 0.02$. Due to the amount of data printed, only selected portions of the output are shown in Figure 16.

```

//JOJRECOM JOB (24337,IO1),'JO JOHNSON 6025',TIME=(0,30)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
/*JOBPARM LINECT=62
//A EXEC PGM=RECOMB,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT17F001 DD UNIT=3330V,VOL=SER=VINT09,DISP=(NEW,CATLG),
// DSN=MEN.X10.JOJ.KB02.NE102A,SPACE=(TRK,(10,5),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//SYSIN DD *
  5.0000E+01  1.0000E-06
    1      1
    1  5.6873E-02  1.0400E+00
  6.0000E+00  1.2011E+01  4.7394E-02
  2.0000E-02  1.0000E-03  2.0000E+01  500  3000  2
    1      2
    1      1  6.0000E+00  1.2011E+01
(Blank Card)
/*
//

```

Figure 15. Complete Listing of JCL and Input for RECOMB Sample Problem.

```

                                INPUT FOR SUBROUTINE PREP
                                EHI= 5.0000E+01   ELOW= 1.0000E-06
                                THE NUMBER OF DIFFERENT MEDIA (MXMAT)= 1
MEDIUM= 1   NSL= 1   DENH= 5.6873E-02   AVDEN= 1.0400E+00
                                E= 6.0000E+00   A= 1.2011E+01   DEN= 4.7394E-02

```

```

INPUT FOR SCINTILLATION LIGHT CURVES
KB = 2.0000E-02 (GM/CM**2)/MEV
MAXIMUM ENERGY = 2.0000E+01 MEV
MINIMUM ENERGY = 1.0000E-03 MEV
NUMBER OF POINTS = 500
NUMBER OF INTEGRATIONS
BETWEEN ENERGY POINTS = 3000
NUMBER OF LIGHT CURVES = 2

```

Figure 16. Listing of Selected Output from RECOMB Sample Problem.

MEDIUM 1
 PARTICLE TYPE= PROTONS

ENERGY (MEV)	LIGHT (MEV)	F(E) VALUE OF INTEGRAND	DE/DX (MEV/CM)
9.9999931E-04	4.13137488E-04	2.41615176E-01	1.63218262E+02
1.02004502E-03	4.17948235E-04	2.38444149E-01	1.66080414E+02
1.04049197E-03	4.22790879E-04	2.35307336E-01	1.68987595E+02
1.06134778E-03	4.27665422E-04	2.32201219E-01	1.71943726E+02
1.08262245E-03	4.32571862E-04	2.29125798E-01	1.74949570E+02
1.10432412E-03	4.37510666E-04	2.26082861E-01	1.78004166E+02
1.12645980E-03	4.42480901E-04	2.23074615E-01	1.81105850E+02
1.14903995E-03	4.47483268E-04	2.20094264E-01	1.84262375E+02
1.17207225E-03	4.52517765E-04	2.17147291E-01	1.87468796E+02
1.19556603E-03	4.57584858E-04	2.14233041E-01	1.90726303E+02
.	.	.	.
1.67283936E+01	7.26409149E+00	6.21293306E-01	3.16964111E+01
1.70637207E+01	7.47306061E+00	6.25087023E-01	3.11884460E+01
1.74057617E+01	7.68751907E+00	6.28866255E-01	3.06885223E+01
1.77546387E+01	7.90757942E+00	6.32629991E-01	3.01965637E+01
1.81105347E+01	8.13340282E+00	6.36378765E-01	2.97123718E+01
1.84735718E+01	8.36511707E+00	6.40111685E-01	2.92358551E+01
1.88438721E+01	8.60283375E+00	6.43827796E-01	2.87669678E+01
1.92215881E+01	8.84672356E+00	6.47526920E-01	2.83055573E+01
1.96068878E+01	9.09693146E+00	6.51208937E-01	2.78514862E+01
1.99999084E+01	9.35359859E+00	6.54873729E-01	2.74046631E+01

Figure 16. (continued).

MEDIUM 1
 Z= 6.0000E+00 XM= 1.2011E+01

ENERGY (MEV)	LIGHT (MEV)	F(E) VALUE OF INTEGRAND	DE/DX (MEV/CM)
9.99999931E-04	6.08357834E-04	4.20237541E-01	7.17395782E+01
1.02004502E-03	6.16737874E-04	4.15942430E-01	7.30173035E+01
1.04049197E-03	6.25196844E-04	4.11570847E-01	7.43451996E+01
1.06134778E-03	6.33734977E-04	4.07292902E-01	7.56722565E+01
1.08262245E-03	6.42353203E-04	4.02954400E-01	7.70468750E+01
1.10432412E-03	6.51050825E-04	3.98665309E-01	7.84352264E+01
1.12645980E-03	6.59827609E-04	3.94421518E-01	7.98386841E+01
1.14903995E-03	6.68684486E-04	3.90148938E-01	8.12824860E+01
1.17207225E-03	6.77621225E-04	3.85927558E-01	8.27403412E+01
1.19556603E-03	6.86637126E-04	3.81692827E-01	8.42351990E+01
.	.	.	.
1.67283936E+01	1.08962417E-01	7.61986151E-03	6.77226953E+03
1.70637207E+01	1.11527741E-01	7.68239424E-03	6.71672266E+03
1.74057617E+01	1.14166081E-01	7.74606317E-03	6.66108594E+03
1.77546387E+01	1.16879582E-01	7.81086832E-03	6.60539062E+03
1.81105347E+01	1.19670928E-01	7.87683204E-03	6.54963672E+03
1.84735718E+01	1.22542441E-01	7.94398040E-03	6.49383594E+03
1.88438721E+01	1.25496387E-01	8.01231712E-03	6.43800781E+03
1.92215881E+01	1.28535748E-01	8.08187202E-03	6.38215234E+03
1.96068878E+01	1.31663084E-01	8.15265998E-03	6.32628516E+03
1.99999084E+01	1.34881139E-01	8.22471082E-03	6.27041016E+03

*****COMPLETION OF SCINTILLATION LIGHT CURVES*****

Figure 16. (continued).

7.0 HEAVY - A CONTINUOUS ENERGY MONTE CARLO CODE FOR
TRANSPORTING RECOIL HEAVY IONS AND CHARGED PARTICLES
PRODUCED VIA NEUTRON INTERACTION IN AN
IONIZATION CHAMBER

7.1 Code Description

The program HEAVY is a continuous energy Monte Carlo code written specifically for analysis of ionization chamber responses to recoil heavy ions and charged particles produced via neutron interactions. HEAVY solves the Boltzmann transport equation using detailed stopping powers and range/energy tables for the recoil heavy ions and charged particles. There is currently a lack of recoil heavy ion and charged particle cross section data available from ENDF/B or other sources. Therefore, the approach in HEAVY is to represent the physics of the recoil heavy ion and charged particle interaction in the media through the use of stopping powers and range/energy tables for the different types of recoil heavy ions and charged particles generated via the neutron interactions. Employing the stopping powers and range/energy tables in the recoil heavy ion and charged particle transport will yield the ionization energy loss of the recoil heavy ion and charged particle in the media. This energy loss translates directly into charge (or current) deposited in the ionization chamber through the use of the work functions which define the average energy required to produce an ion pair. If the energy deposition behaves nonlinearly i.e., the signal observed is not in direct proportion to the energy deposited due to saturation, then this effect can be accounted for along each recoil heavy ion or charged particle path through the use of the saturation data tables calculated in program RECOMB.

The random walk procedure employed in HEAVY is based on the integral emergent particle density formalism of the Boltzmann transport equation. This formalism introduces the recoil heavy ion or charged particle into the system according to the input source tape written by program NEUTRON. Because there is a lack of recoil heavy ion or charged particle transport cross section data, a small transport cross section (1.0×10^{-10}) is assumed. This assumption will almost always yield the distance to the media boundary along the current particles path calculated by the transport kernel. Also, given the particles energy, the range of the particle in the media is determined from the stopping power and range/energy tables. If the range is less than the distance to the media boundary, the particle is assumed to range out in the media depositing all its energy. If the range is greater than the distance to the media boundary, the fraction of energy deposited in the media is determined from the range/energy tables and the particle is transported to the media boundary with its new energy equal to the old energy less that energy deposited in the media. If saturation effects are found to be significant, the saturation data tables can be applied to yield the energy collected for each particle track. The transport kernel and range/energy tables are applied successively until the particle loses all its energy or escapes the system.

Application of program HEAVY to ionization chamber response analysis yields a detailed description of the detector signal due to neutron interactions. Even though the program is specifically

written for ionization chamber response analysis, the program is applicable to any problem where recoil heavy ion and/or charged particle energy deposition is of interest. Some special features of program HEAVY include:

1. Total energy deposition for all particles with and without transport.
2. Tables of energy deposition results by particle type with and without transport and also with and without saturation effects (if found to be significant).
3. Flexibility in particle types to be considered.
4. Incorporates a combinatorial package for detailed geometry modeling.
5. Incorporates subroutine BANKR to provide additional analysis of the recoil heavy ion transport process.

The subroutine hierarchy for program HEAVY is shown in Figure 17. The following tables (Tables 22 through 29) describe the subroutines along with their functions, and the common blocks and their associated variables used in the random walk process.

7.2 Input Requirements

The following input cards and title cards are required in order to execute a HEAVY case. Default values are in brackets ([]).

Card 1: Format (20A4)

TITLE Problem title card.

Card 2: Format (Z12)

RANDOM Starting random number seed.

Card 3: Format (6I6)

INN Input card unit. [5]

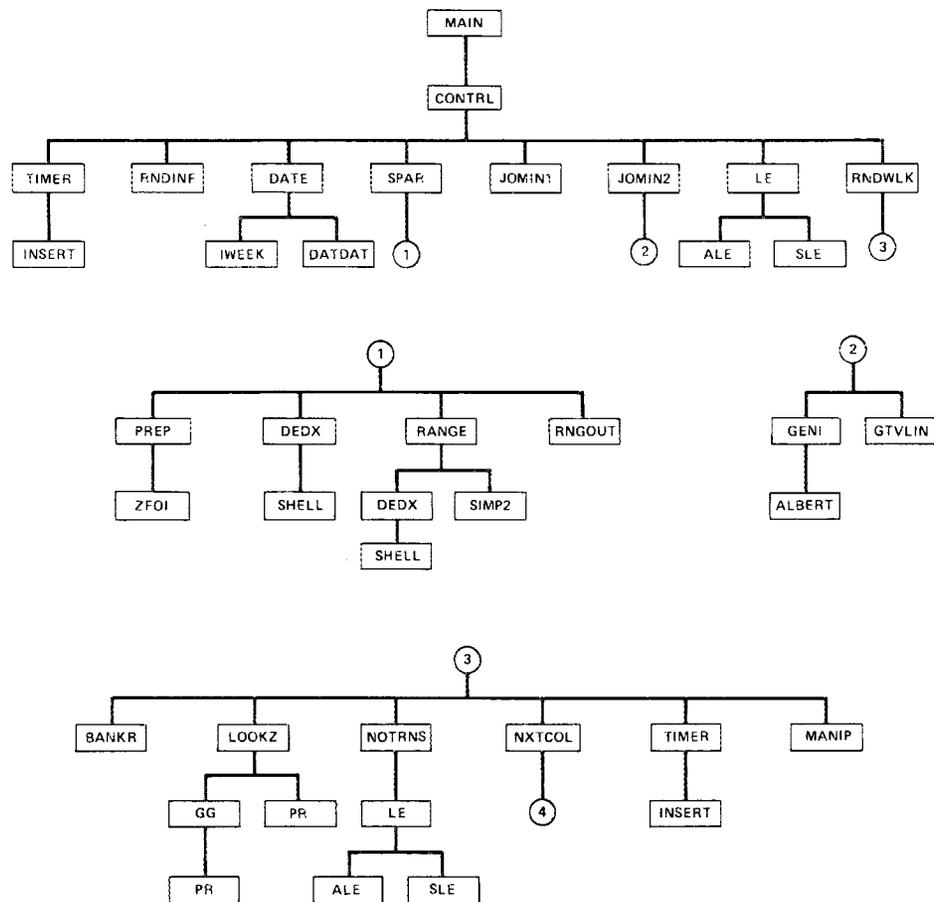


Figure 17. Subroutine Hierarchy in Program HEAVY.

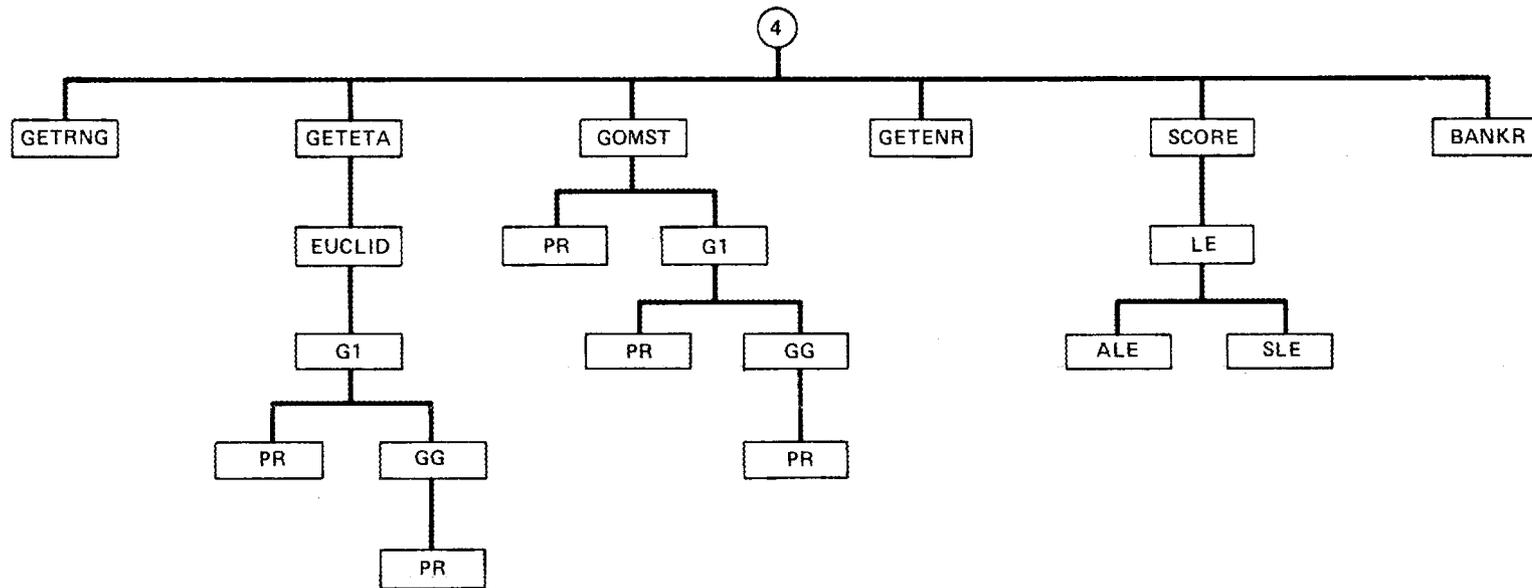


Figure 17. (continued).

Table 22. Subroutine Functions for Program HEAVY

Subroutine	Function
ALBERT	Processes arbitrary polyhedron body data.
ALE	Returns energy detected equal to energy deposited due to no saturation effects.
BANKR	This is a dummy routine usually supplied by the user to perform additional analysis of the data.
CONTRL	Reads in the input, initializes the problem arrays, sets up the storage locations for the data, and begins the processing of the recoil heavy ion and charged particle tape.
DATE	Computes the day, month, date, and year.
DEDX	Computes the dE/dx for the charged particles and recoil heavy ions.
DEEBUG	Used to trouble shoot errors in the program.
EUCLID	Determines the number of mean-free-paths between two points in the geometry.
FLTRNF	Random number package written in ASSEMBLER.
GENI	Outputs the geometry input information and places the combinatorial geometry data in the proper storage locations in blank common.
GETENR	Calculates the energy of a particle given the particles range.
GETETA	Calculates the number of mean-free-paths (η) for the next flight.
GETRNG	Calculates the range of a particle given the particles energy.
GG	The workhorse of the combinatorial geometry package, computes distances to intersections for all body types.

Table 22. (continued)

Subroutine	Function
GOMST	Determines boundary crossings between the present and next collision sites.
GTVLIN	Reads in or calculates the volume of each region in the geometry.
G1	The control routine for the combinatorial geometry package.
INSERT	Inserts characters from an array into a character string.
IWEEK	Function that looks up the data for the user and fills in the values for MONTH, IDATE, and IYEAR.
JOMIN1	Reads in the geometry data input and calculates the amount of storage needed for the geometry arrays.
JOMIN2	Calculates the beginning locations of the geometry arrays in storage.
LE	The controlling routine for determining the energy detected due to saturation effects.
LOOKZ	Returns the combinatorial geometry zone of point (X,Y,Z) so tracking can be initialized.
MAIN	Sets the amount of core storage (LEN) and the length of the analysis arrays (LENSTO) used in the data processing.
MAINP	Performs some analysis on the storage arrays to summarize the response due to the recoil heavy ions and charged particles writes the analysis arrays to unit MSAVE.
NOTRNS	Saves the energy deposited in the active media without transporting the particles.
NXTCOL	Determines the particles spatial coordinates, block and zone number, and age at the next collision site and at every boundary site along the flight path.

Table 22. (continued)

Subroutine	Function
PREP	Reads in the input and sets up the variables used in the routines dedicated to calculating the range/energy data tables.
PR	Called from various locations in the combinatorial geometry package whenever intermediate output or debugging output is required.
RANGE	Computes the ranges of the charged particles and recoil heavy ions.
RNDWLK	Processes the recoil heavy ion input data, performs the random walk for the particles, and prints the output summary tables.
RNGOUT	Prints the table of particles for which stopping powers and ranges are calculated, the proton recoil ranges by media, and the ranges for all particles for the active media.
SCORE	Scores the energy deposited in the active media after transporting the particle.
SHELL	Computes the shell correction in the dE/dx equation.
SIMP2	Performs parabolic integration for even or uneven spacing.
SLE	Reads in the saturation data curves and determines the energy detected given the energy deposited.
SPAR	The control routine for calculating the stopping powers and ranges of the charged particles and recoil heavy ions.
TIMER	Performs a variety of functions associated with the local and global clocks.
ZFOI	Function to yield the ionization potentials for the elements in the media.

Table 23. Definitions of Variables in RECOIL Common

Variable	Definition
NAME	Particles first name.
NAMEX	Particles family name.
E	Current energy.
EOLD	Previous energy.
NMED	Medium number at current location.
MEDOLD	Medium number at previous location.
NREG	Region number at current location.
N,V,W	Current direction cosines.
UOLD,VOLD,WOLD	Previous direction cosines.
X,Y,Z	Current location.
XOLD,YOLD,ZOLD	Previous location.
WATE	Current weight.
OLDWT	Previous weight.
WTBC	Weight just before current collision.
BLZNT	Current zone number.
BLZON	Previous zone number.
AGE	Current age.
OLDAGE	Previous age.

Table 24. Definitions of Variables in HPARM Common

Variable	Definition
NGO	Flag to indicate record type NGO = 1 - not defined NGO = 2 - particle history NGO = 3 - end of batch NGO = 4 - end of run
IQ	Particle type indicator (currently not used)
NCOL	Neutron collision number
NZ	Particle charge
A	Particle atomic weight

Table 25. Definitions of Variables in NPARM Common

Variable	Definition
MT	ENDF/B neutron reaction type number.
ENI	Pre-collision neutron energy.
UNI,VNI,WNI	Pre-collision neutron direction cosines.
ENO	Post-collision neutron energy.
UNO,VNO,WNO	Post-collision neutron direction cosines.
WTN	Neutron weight.
Q	ENDF/B Q-value associated with the neutron reaction type number.

Table 26. Definitions of Variables in APOLL Common

Variable	Definition
ETA	Number of mean-free-paths between collisions.
ETATH	Distance in centimeters to the next collision if the particle does not encounter a change in total cross section.
ETAUSD	Flight path in mean-free-paths that has been used since the last event.
INALB	A switch indicating that an albedo scattering has occurred if > 0 .
NOLEAK	A switch indicating that nonleakage path-length selection is to be used if > 0 .

Table 27. Definitions of Variables in PAREM Common

Variable	Definition
XB(3)	Coordinates of the starting point of the present path.
WB(3)	Direction cosines of particle trajectory, (Equal to U,V,W).
WP(3)	Temporary storage of WB(3).
XP(3)	Temporary storage of XB(3).
RIN	Distance to entry calculated in routine GG.
ROUT	Distance to exit calculated in routine GG.
PINF	Machine infinity. (1.00E+20)
DIST	Distance from XB(3) to present point.
IR	Combinatorial zone of present particle position.
IDBG	Set non-zero to initialize a debug printout.
IRPRIM	Next region to be entered after a call of routine G1.
NASC	Body number of last calculated intersection. Set negative to indicate source or collision point not on a body surface.
LSURF	Surface of body NASC where intersection occurred. Positive if particle is entering the body and negative when exiting.
NBO	Body number and a sign used to define zones. Input in zone description as positive when zone is contained in body and as negative if zone is outside body.
LRI	Entry surface calculated in routine GG.
LRO	Exit surface calculated in routine GG.
KLOOP	Trajectory index of present path incremented in routine G1.

Table 27. (continued)

Variable	Definition
LOOP	INEXT of last trajectory calculated for body NBO. If LOOP is equal to KLOOP, routine GG returns immediately with old values in RIN, ROUT, LRI, and LRO.
ITYPE	Body type of body NBO (indicates BOX, SPH, etc.).
NOA	Not used.
JTY1(15)	Alphanumeric title for geometry input.

Table 28. Definitions of Variables in ORGI Common

Variable	Definition
DISTO	Distance from point XB(3) to next scattering point. Used in routine G1 to avoid calculating the next zone if a scattering event occurs before the intersection.
MARKG	Set to 1 in routine G1 if trajectory end point is reached before next intersection, otherwise set to 0.
NMEDG	Zone number IR from a LOOKZ call.
NBLZ	Packed word containing both input zone and code zone numbers.
BLZOLD	Packed word containing input and code zone numbers for the previous collision.

Table 29. Definitions of Variables in DBG Common

Variable	Definition
N	Starting location in MA array of data for zone IRP.
NUM	Ending location in MA array of data for zone IRP.
LOCAT	Location in MA array of address where data for current body is located in the FPD array.
ISAVE	Index in MA array of next body intersected ($N \leq \text{ISAVE} \leq \text{NUM}$).
INEXT	Pointer to first zone searched in MA array for next body (Equal to $\text{ISAVE} + 2$).
IRP	Next zone searched to determine which zone the current body is in.
SMIN	Distance to intersection.
INEX	Pointer to next zone searched in MA array if INEXT is not the zone intersected (Equal to $\text{INEXT} + 1$).

IOUT Printed output unit. [6]
 MGEOM Geometry data input scratch unit. [16]
 MHEAVY Recoil heavy ion and charged particle tape input unit.
 [18]
 MLIGHT Recombination data input unit. [8]
 MSAVE Output unit for storage of energy deposition arrays.
 [9]
 Card 4: Format (7I6)
 MXMAT Number of different media for which stopping powers and
 ranges are computed. [1]
 MXELMT Maximum number of nuclide types other than hydrogen in
 a medium. [1]
 NPTS Number of energy points used in the stopping power and
 range/energy computations. [50]
 MXITYP Number of particle types in range/energy tables.
 NPRT 1/0 - Print/Do not print the range/energy tables. [0]
 M2FLG 0/1 - Gas/Solid flag for the active media. [0]
 MABC 0/1 - No recombination data/recombination data for the
 active media. [0]

Note: Card 5 repeated MXMAT times, is followed each time by Card 6 repeated NEL times.

Card(s) 5: Format (I6,2E12.4)

NEL The number of nuclide types other than hydrogen in the
 medium.
 DENH The density (atoms/b-cm) of hydrogen in the medium.
 AVDEN The average density (gm/cm³) of the medium.

Card(s) 6: Format (3E12.4)

ZZ The charge number of the "nth" nuclide other than hydrogen
 in the medium.
 A The mass number of the "nth" nuclide other than hydrogen in
 the medium.

DEN The atom density (atoms/b-cm) of the "nth" nuclide other than hydrogen in the medium.

Note: Card 6 is repeated NEL times.

Card 7: Format (2E12.4)

EMIN Minimum energy in MeV for which stopping powers and ranges are computed. (EMIN > 0.0)

EMAX Maximum energy in MeV for which stopping powers and ranges are computed. (EMAX > EMIN)

Card(s) 8: Format (I6,2E12.4)

ITYP The type of particle for which the stopping powers and ranges will be calculated.

1 for recoil heavy ions (mass number > 1)

2 for protons

Z The charge number of the recoil heavy ion.

XM The mass number (in amu) of the recoil heavy ion.

Card 9: Blank card

COMBINATORIAL GEOMETRY INPUT INSTRUCTIONS

CARD CGA: Format (2I5,10X,10A6)

IVOPT Option which defines the method by which region volumes are determined; if

0, volumes set equal to 1,

1, concentric sphere volumes are calculated,

2, slab volumes (1-dim.) are calculated, (not operational)

3, volumes are input by card.

IDBG If IDBG > 0, subroutine PR is called to print results of combinatorial geometry calculations during execution. Use only for debugging.

JTY Alphanumeric title for geometry input (columns 21-80).

CARDS CGB: Format (2X,A3,1X,I4,6D10.3)

ITYPE Specifies body type or END to terminate reading of body data (for example BOX, RPP, ARB, etc.). Leave blank for continuation cards.

IALP Body number assigned by user (all input body numbers must form a sequence set beginning at 1). If left blank, numbers are assigned sequentially. Either assign all or none of the numbers. Leave blank for continuation cards.

FPD(I) Real data required for the given body as shown in Table 30. This data must be in centimeters.

Note: One set of CGB cards is required for each body and for the END card (see Table 30). Leave columns 1-6 blank on all continuation cards.

CARDS CGC: Format (2X,A3,I5,9(A2,I5))

IALP IALP must be a nonblank for the first card of each set of cards defining an input zone. If IALP is blank, this card is treated as a continuation of the previous zone card. IALP = END denotes the end of zone description.

NAZ Total number of zones that can be entered upon leaving any of the bodies defined for this input region (some zones may be counted more than once). Leave blank for continuation cards for a given zone. (If $NAZ \leq 0$ on the first card of the zone card set, then it is set to 5.) This is used to allocate blank common. Alternate IIBIAS(I) and JTY(I) for all bodies defining this input zone.

IIBIAS(I) Specify the "OR" operator if required for the JTY(I) body.

JTY(I) Body number with the (+) or (-) sign as required for the zone description.

Note: Input zone specification cards. One set of cards required for each input zone, with input zone numbers being assigned sequentially.

CARDS CGD: Format (14I5)

MRIZ(I) MRIZ(I) is the medium number in which the "Ith" input zone is contained ($I = 1$, to the number of input zones). Region numbers must be sequentially defined from 1.

CARDS CGE: Format (14I5)

Table 30. Combinatorial Geometry Body Data Input Requirements in Program HEAVY

Body Type	ITYPE 3-5	IALP 7-10	Card Columns						Number of Cards Needed
			11-20	Real Data Defining Particular Body					
			21-30	31-40	41-50	51-60	61-70		
Box	BOX	IALP is assigned by the user or by the code if left blank.	Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
Right Parallelepiped	RPP		H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Sphere	SPH		Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	1
Right Circular Cylinder	RCC		Vx	Vy	Vz	R	-	-	1
Right Elliptic Cylinder	REC		Vx	Vy	Vz	Hx	Hy	Hz	1 of 2
Ellipsoid	ELL		R	-	-	-	-	-	2 of 2
Truncated Right Cone	TRC		Vx	Vy	Vz	Hx	Hy	Hz	1 of 2
Right Angle Wedge	WED		L1	L2	-	-	-	-	2 of 2
Arbitrary Polyhedron	ARB		Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
			V1x	V1y	V1z	V2x	V2y	V2z	1 of 5
			V3x	V3y	V3z	V4x	V4y	V4z	2 of 5
			V5x	V5y	V5z	V6x	V6y	V6z	3 of 5
			V7x	V7y	V7z	V8x	V8y	V8z	4 of 5
			Face Descriptions (see note below)						
Termination of Body Input Data	END								

NOTE: Card 5 of the arbitrary polyhedron input contains a four-digit number for each of the six faces of an ARB body. The format is 6D10.3, beginning in column 11. See the ARB write-up in Ref. 4 for an example.

MMIZ(I) MMIZ(I) is the medium number in which the "Ith" input zone is contained (I = 1, to the number of input zones). Medium numbers must be sequentially defined from 1. (Media 0 is used for an external void and media 1000 is used for internal voids.)

CARDS CGF: Format (7D10.5) (Omit if IVKOPT \neq 3)

VNOR(I) Volume of the "Ith" region (I = 1 to MXREG, the number of regions).

7.3 Input Data Notes

MSAVE Program HEAVY allows for the energy deposition data to be stored in arrays for additional processing if the user requires information from further analysis of the problem. These arrays store the individual contributions (by incident particle type) stacked sequentially. If MSAVE is greater than zero, these arrays will be written to the logical unit designated by the value of MSAVE.

NPTS The default value used in program HEAVY is set to 50. This yields adequate representation of the stopping powers and range/energy data.

NPRT Invoking the print could produce large amounts of output if there are several media and particle types.

MABC Program HEAVY will read in saturation curves produced in program RECOMB for the active media from unit MLIGHT if this parameter is set to one.

EMIN, EMAX The typical energy range used in program HEAVY is EMIN = 0.0 MeV and EMAX = 20.0 MeV.

ITYP The particle types for which stopping powers and range/energy tables are calculated should be input in the

following order; protons followed by recoil heavy ions in increasing Z i.e., P, D, T, ^3He , α , ^{10}B , ^{11}B , There is no limit on the number of particle types program HEAVY can handle. However, if saturation curves produced in program RECOMB are used, the number and order of particle types input in program HEAVY must agree with those input in program RECOMB. When the particle type is a proton (ITYP = 2), no additional data is needed on that input card.

7.4 I/O File Requirements

File	Unit	Description	Required
INN	5	Card Input	Always
IOUT	6	Printed Output	Always
MGEOM	16	Geometry Data Scratch	Always
MHEAVY	18	Recoil Heavy Ion and Charged Particle Tape Input	Always
MLIGHT	8	Recombination Data Input	IF MABC > 0
MSAVE	9	Energy Deposition Data	IF > 0
		Arrays Output	

7.5 JCL Requirements

The job control language (JCL) needed to run a HEAVY case at X-10 is:

```
(Job card, route and jobparm cards)
//HEAVY EXEC PGM=HEAVY,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
(DD Cards for Logical Units 16 and 18)
(DD Cards for Logical Unit 8 if MABC > 0)
(DD Cards for Logical Unit 9 if MSAVE > 0)
//SYSIN DD *
```

(Input Cards)

/*
//

7.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 18 and some selected output are shown in Figure 19. The problem demonstrates the processing of the recoil heavy ion and charged particle tape produced in the sample problem for program NEUTRON. More specifically, the sample problem calculates the ionization chamber response due to the ^{252}Cf neutron source. It was determined from the NEUTRON run output that fifteen different recoil heavy ions and charged particles were produced in the ionization chamber. Therefore stopping powers and range/energy tables were calculated for fifteen particle types. Saturation effects were assumed negligible and therefore not input from unit MLIGHT.

```

//JOJHEAVY JOB (24337,IO2),'JO JOHNSON 6025',TIME=(1,00)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
//A EXEC PGM=HEAVY,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT16F001 DD UNIT=SYSDA,DISP=(NEW,PASS),
// DSN=&&GEOM,SPACE=(TRK,(40,20)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//FT18F001 DD DSN=MEN.X10.JOJ.HEVYSMP,DISP=SHR
//GO.SYSIN DD *
AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
AB54C7879122
      5      6      16      18      0      0
      6      5      100     15      0      0      0
      1          0.0  2.6990E+00
1.3000E+01  2.6982E+01  6.0268E-02
      3  6.9367E-05  1.1378E-03
6.0000E+00  1.2011E+01  2.6024E-05
7.0000E+00  1.4007E+01  1.7129E-06
8.0000E+00  1.5999E+01  1.7438E-05
      5  6.8711E-02  1.1270E+00
6.0000E+00  1.2011E+01  4.3416E-02
7.0000E+00  1.4007E+01  1.7452E-03
8.0000E+00  1.5999E+01  2.5039E-03
9.0000E+00  1.8998E+01  6.0758E-04
2.0000E+01  4.0080E+01  3.0494E-04
      1  4.9054E-02  1.0600E+00
6.0000E+00  1.2011E+01  4.9054E-02
      3          0.0  1.2925E-03
7.0000E+00  1.4007E+01  4.2028E-05
8.0000E+00  1.5999E+01  1.1275E-05
1.8000E+01  3.9948E+01  2.5026E-07
      2  4.2061E-02  1.3000E+00
6.0000E+00  1.2011E+01  5.0473E-02
8.0000E+00  1.5999E+01  8.4122E-03
1.0000E-03  2.0000E+01
      2
      1  1.0000E+00  2.0000E+00
      1  1.0000E+00  3.0000E+00
      1  2.0000E+00  4.0000E+00
      1  4.0000E+00  9.0000E+00
      1  5.0000E+00  1.1000E+01
      1  5.0000E+00  1.2000E+01
      1  6.0000E+00  1.2000E+01
      1  6.0000E+00  1.3000E+01
      1  6.0000E+00  1.4000E+01
      1  7.0000E+00  1.4000E+01

```

Figure 18. Complete Listing of JCL and Input for HEAVY Sample Problem.

1 7.0000E+00 1.5000E+01
 1 7.0000E+00 1.6000E+01
 1 8.0000E+00 1.6000E+01
 1 8.0000E+00 1.7000E+01
 (Blank Card)

0	0	AFRRI	50CC	IONIZATION	CHAMBER (0.0CM	BUILD-UP	CAP)
RPP	1	-10.0	10.0	-10.0	10.0	0.0	20.0
SPH	2	0.0	0.0	10.0	3.2131		
SPH	3	0.0	0.0	10.0	2.49936		
SPH	4	0.0	0.0	10.0	1.50114		
RCC	5	0.0	0.0	10.0	-6.35	0.0	0.0
		0.15875					
RCC	6	-1.27	0.0	10.0	-1.27	0.0	0.0
		0.47625					
RCC	7	-2.38125	0.0	10.0	-1.190625	0.0	0.0
		0.3175					
RCC	8	-2.54	0.0	10.0	-1.666875	0.0	0.0
		1.74625					
RCC	9	-3.33375	0.0	10.0	-1.349375	0.0	0.0
		0.635					
RCC	10	-2.460625	0.0	10.0	-0.9525	0.0	0.0
		0.47625					
RCC	11	-4.524375	0.0	10.0	-0.555625	0.0	0.0
		0.555625					
RCC	12	-5.000625	0.0	10.0	-0.714375	0.0	0.0
		0.396875					
RCC	13	-4.1275	0.0	10.0	-0.873125	0.0	0.0
		1.666875					
RCC	14	-3.175	0.0	10.0	-1.031875	0.0	0.0
		0.873125					
RCC	15	-2.460625	0.0	10.0	-0.79375	0.0	0.0
		0.635					
RCC	16	-4.60375	0.0	10.0	-1.349375	0.0	0.0
		0.635					
RCC	17	-4.92125	0.0	10.0	-0.47625	0.0	0.0
		1.666875					
RCC	18	-4.60375	0.0	10.0	-1.74625	0.0	0.0
		0.79375					
RCC	19	-5.87375	0.0	10.0	-0.47625	0.0	0.0
		0.635					
RCC	20	-5.000625	0.0	10.0	-0.9525	0.0	0.0
		0.47625					
RCC	21	-2.2225	0.0	10.0	-1.031875	0.0	0.0
		0.873125					
RCC	22	-4.1275	0.0	10.0	-2.2225	0.0	0.0
		1.74625					
RPP	23	-500.0	500.0	-500.0	500.0	-500.0	500.0
END							

Figure 18. (continued).

AIR	0OR	1	-2	-8	-22OR	22	-13	-17	-18	
WAL	0OR	2	-3	-14	-21OR	8	-14	-21	-22	
GAS	0OR	3	-4	-6	-15OR	21	-6	-14	-15	
COL	0OR	4	-5OR	6	-5	-10OR	7	-5		
ROD	0	5								
POL	0OR	9	-5	-7	-16OR	10	-5	-7OR	11	-5
	OR	12	-5							
INS	0OR	13	-9	-17	-18OR	14	-9	-10OR	15	-10
BRS	0	16	-11	-19	-20					
LUC	0OR	19	-5OR	20	-5	-11	-12			
SLV	0OR	17	-16OR	18	-9	-16	-19			
VD	0	23	-1							
END										
	1	1	1	1	1	1	1	1	1	1
	5	3	2	3	1	4	6	1	6	1
	/*									
	//									

Figure 18. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

INN	INPUT UNIT	5
IOUT	PRINTED OUTPUT UNIT	6
MGEOM	GEOMETRY DATA INPUT SCRATCH UNIT	16
MHEAVY	RECOIL HEAVY ION INPUT UNIT	18
MLIGHT	LIGHT CURVE INPUT UNIT	0
MSAVE	ENERGY/LIGHT DEPOSITION ARRAYS OUTPUT UNIT	0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

MXMAT	NUMBER OF MEDIA FOR RANGE/ENERGY CALCULATIONS	6
MXELMT	MAXIMUM NUMBER OF ELEMENTS IN ANY MEDIA	5
NPTS	NUMBER OF POINTS IN RANGE/ENERGY TABLES	100
MXITYP	NUMBER OF PARTICLE TYPES IN RANGE/ENERGY TABLES	15
NPRT	1/0 PRINT/NO PRINT RANGE/ENERGY TABLES	0
M2FLG	0/1 GAS/SOLID FLAG FOR THE ACTIVE MEDIA	0
MABC	0/1 NO LIGHT CURVES/READ LIGHT CURVES	0

Figure 19. Listing of Selected Output from HEAVY Sample Problem.

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CP-252 FIELD
 INPUT FOR ROUTINE PREP

THE NUMBER OF DIFFERENT MEDIA (MXMAT)= 6			
MEDIUM=	1	NEL= 1	DENH= 0.0 AVDEN= 2.6990E+00
Z=	1.3000E+01	A= 2.6982E+01	DEN= 6.0268E-02
MEDIUM=	2	NEL= 3	DENH= 6.9367E-05 AVDEN= 1.1378E-03
Z=	6.0000E+00	A= 1.2011E+01	DEN= 2.6024E-05
Z=	7.0000E+00	A= 1.4007E+01	DEN= 1.7129E-06
Z=	8.0000E+00	A= 1.5999E+01	DEN= 1.7438E-05
MEDIUM=	3	NEL= 5	DENH= 6.8711E-02 AVDEN= 1.1270E+00
Z=	6.0000E+00	A= 1.2011E+01	DEN= 4.3416E-02
Z=	7.0000E+00	A= 1.4007E+01	DEN= 1.7452E-03
Z=	8.0000E+00	A= 1.5999E+01	DEN= 2.5039E-03
Z=	9.0000E+00	A= 1.8998E+01	DEN= 6.0758E-04
Z=	2.0000E+01	A= 4.0080E+01	DEN= 3.0494E-04
MEDIUM=	4	NEL= 1	DENH= 4.9054E-02 AVDEN= 1.0600E+00
Z=	6.0000E+00	A= 1.2011E+01	DEN= 4.9054E-02
MEDIUM=	5	NEL= 3	DENH= 0.0 AVDEN= 1.2925E-03
Z=	7.0000E+00	A= 1.4007E+01	DEN= 4.2028E-05
Z=	8.0000E+00	A= 1.5999E+01	DEN= 1.1275E-05
Z=	1.8000E+01	A= 3.9948E+01	DEN= 2.5026E-07
MEDIUM=	6	NEL= 2	DENH= 4.2061E-02 AVDEN= 1.3000E+00
Z=	6.0000E+00	A= 1.2011E+01	DEN= 5.0473E-02
Z=	8.0000E+00	A= 1.5999E+01	DEN= 8.4122E-03

Figure 19. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
 PARTICLES FOR WHICH STOPPING POWERS AND RANGES ARE CALCULATED

WEDNESDAY, AUGUST 27, 1986

TABLE NUMBER	PARTICLE TYPE	CHARGE (Z)	MASS (A)
1	2	1.0000E+00	1.0000E+00
2	1	1.0000E+00	2.0000E+00
3	1	1.0000E+00	3.0000E+00
4	1	2.0000E+00	4.0000E+00
5	1	4.0000E+00	9.0000E+00
6	1	5.0000E+00	1.1000E+01
7	1	5.0000E+00	1.2000E+01
8	1	6.0000E+00	1.2000E+01
9	1	6.0000E+00	1.3000E+01
10	1	6.0000E+00	1.4000E+01
11	1	7.0000E+00	1.4000E+01
12	1	7.0000E+00	1.5000E+01
13	1	7.0000E+00	1.6000E+01
14	1	8.0000E+00	1.6000E+01
15	1	8.0000E+00	1.7000E+01

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

THE PROTON RECOIL RANGE/ENERGY TABLE (BY INPUT GEOMETRY MEDIA)									
ENERGY (EV)	MEDIA 1	MEDIA 2	MEDIA 3	MEDIA 4	MEDIA 5	MEDIA 6	MEDIA	MEDIA	MEDIA
1.0000E+03	7.48033E-06	4.90772E-03	4.82357E-06	5.67090E-06	9.08075E-03	5.34153E-06			
1.10521E+03	7.96031E-06	5.31074E-03	5.22073E-06	6.13106E-06	9.72428E-03	5.76506E-06			
1.22149E+03	8.47015E-06	5.74201E-03	5.64584E-06	6.62346E-06	1.04106E-02	6.21794E-06			
1.35000E+03	9.01146E-06	6.20295E-03	6.10031E-06	7.14975E-06	1.11422E-02	6.70166E-06			
1.49203E+03	9.58605E-06	6.69512E-03	6.58566E-06	7.71172E-06	1.19215E-02	7.21789E-06			
.									
.									
1.09739E+07	7.37115E-02	1.23854E+02	1.26979E-01	1.39502E-01	1.36064E+02	1.18783E-01			
1.21284E+07	8.78560E-02	1.47343E+02	1.51744E-01	1.66459E-01	1.61886E+02	1.41620E-01			
1.34045E+07	1.04743E-01	1.75512E+02	1.81418E-01	1.98761E-01	1.92778E+02	1.68974E-01			
1.48147E+07	1.24911E-01	2.09301E+02	2.16983E-01	2.37474E-01	2.29747E+02	2.01748E-01			
1.63734E+07	1.49003E-01	2.49836E+02	2.59611E-01	2.83876E-01	2.73995E+02	2.41020E-01			
1.80960E+07	1.77790E-01	2.98468E+02	3.10714E-01	3.39502E-01	3.26966E+02	2.88086E-01			
1.99999E+07	2.12193E-01	3.56819E+02	3.71982E-01	4.06192E-01	3.90388E+02	3.44498E-01			

Figure 19. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

RANGE/ENERGY TABLE FOR THE ACTIVE GAS REGION									
ENERGY (EV)	PARTICLE 1	PARTICLE 2	PARTICLE 3	PARTICLE 4	PARTICLE 5	PARTICLE 6	PARTICLE 7	PARTICLE 8	PARTICLE 9
1.00000E+03	4.90772E-03	4.60312E-03	4.19500E-03	1.92399E-03	8.87445E-04	7.32748E-04	7.21529E-04	6.43829E-04	6.35832E-04
1.10521E+03	5.31074E-03	5.04653E-03	4.62946E-03	2.11168E-03	9.64805E-04	7.94143E-04	7.81682E-04	6.95903E-04	6.87202E-04
1.22149E+03	5.74201E-03	5.52912E-03	5.10741E-03	2.31856E-03	1.04952E-03	8.61007E-04	8.47301E-04	7.53039E-04	7.43368E-04
1.35000E+03	6.20295E-03	6.05370E-03	5.63273E-03	2.54652E-03	1.14302E-03	9.34575E-04	9.19499E-04	8.15132E-04	8.04444E-04
1.49203E+03	6.69512E-03	6.62262E-03	6.20807E-03	2.79819E-03	1.24540E-03	1.01498E-03	9.98221E-04	8.83294E-04	8.71592E-04
1.09739E+07	1.23854E+02	7.39389E+01	5.39754E+01	1.13126E+01	2.25466E+00	1.56713E+00	1.54428E+00	1.22192E+00	1.21277E+00
1.21284E+07	1.47343E+02	8.83585E+01	6.44411E+01	1.34154E+01	2.57532E+00	1.76579E+00	1.73633E+00	1.36621E+00	1.35248E+00
1.34045E+07	1.75512E+02	1.05597E+02	7.69623E+01	1.59254E+01	2.94826E+00	1.99761E+00	1.95549E+00	1.53265E+00	1.51441E+00
1.48147E+07	2.09301E+02	1.26205E+02	9.19441E+01	1.89328E+01	3.39215E+00	2.26357E+00	2.21468E+00	1.72550E+00	1.69814E+00
1.63734E+07	2.49836E+02	1.50406E+02	1.09861E+02	2.25282E+01	3.90972E+00	2.57930E+00	2.51217E+00	1.94648E+00	1.91463E+00
1.80960E+07	2.98468E+02	1.78108E+02	1.31285E+02	2.68236E+01	4.52305E+00	2.94370E+00	2.86139E+00	2.20668E+00	2.16169E+00
1.99999E+07	3.56819E+02	2.11147E+02	1.56899E+02	3.19650E+01	5.24788E+00	3.37269E+00	3.26897E+00	2.50515E+00	2.45107E+00

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD

WEDNESDAY, AUGUST 27, 1986

RANGE/ENERGY TABLE FOR THE ACTIVE GAS REGION									
ENERGY (EV)	PARTICLE 10	PARTICLE 11	PARTICLE 12	PARTICLE 13	PARTICLE 14	PARTICLE 15	PARTICLE	PARTICLE	PARTICLE
1.00000E+03	6.28950E-04	5.74720E-04	5.69794E-04	5.65560E-04	5.25337E-04	5.22208E-04			
1.10521E+03	6.79700E-04	6.20101E-04	6.14597E-04	6.09849E-04	5.65704E-04	5.62286E-04			
1.22149E+03	7.35001E-04	6.69323E-04	6.63326E-04	6.58143E-04	6.09770E-04	6.05920E-04			
1.35000E+03	7.95328E-04	7.23251E-04	7.16550E-04	7.10734E-04	6.57412E-04	6.53195E-04			
1.49203E+03	8.61423E-04	7.81736E-04	7.74326E-04	7.67982E-04	7.09625E-04	7.04890E-04			
1.09739E+07	1.20570E+00	1.00251E+00	1.00248E+00	1.00290E+00	8.62612E-01	8.65030E-01			
1.21284E+07	1.34331E+00	1.11304E+00	1.10947E+00	1.10715E+00	9.49984E-01	9.51218E-01			
1.34045E+07	1.49856E+00	1.23716E+00	1.23153E+00	1.22794E+00	1.05011E+00	1.04992E+00			
1.48147E+07	1.67968E+00	1.38111E+00	1.37159E+00	1.36335E+00	1.16330E+00	1.16018E+00			
1.63734E+07	1.88665E+00	1.54513E+00	1.53058E+00	1.52083E+00	1.29246E+00	1.28820E+00			
1.80960E+07	2.12651E+00	1.73429E+00	1.71580E+00	1.69943E+00	1.44056E+00	1.43168E+00			
1.99999E+07	2.40512E+00	1.95315E+00	1.92564E+00	1.90608E+00	1.60894E+00	1.59849E+00			

Figure 19. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

ILOPT = 0 IDBG = 0

BODY DATA

RPP	1	-1.0000000D+01	1.0000000D+01	-1.0000000D+01	1.0000000D+01	0.0	2.0000000D+01	3
SPH	2	0.0	0.0	1.0000000D+01	3.2131000D+00	0.0	0.0	11
SPH	3	0.0	0.0	1.0000000D+01	2.4993600D+00	0.0	0.0	19
SPH	4	0.0	0.0	1.0000000D+01	1.5011400D+00	0.0	0.0	27
RCC	5	0.0	0.0	1.0000000D+01	-6.3500000D+00	0.0	0.0	35
		1.5875000D-01						
RCC	6	-1.2700000D+00	0.0	1.0000000D+01	-1.2700000D+00	0.0	0.0	44
		4.7625000D-01						
RCC	7	-2.3812500D+00	0.0	1.0000000D+01	-1.1906250D+00	0.0	0.0	53
		3.1750000D-01						
RCC	8	-2.5400000D+00	0.0	1.0000000D+01	-1.6668750D+00	0.0	0.0	62
		1.7462500D+00						
RCC	9	-3.3337500D+00	0.0	1.0000000D+01	-1.3493750D+00	0.0	0.0	71
		6.3500000D-01						
RCC	10	-2.4606250D+00	0.0	1.0000000D+01	-9.5250000D-01	0.0	0.0	80
		4.7625000D-01						
RCC	11	-4.5243750D+00	0.0	1.0000000D+01	-5.5562500D-01	0.0	0.0	89
		5.5562500D-01						
RCC	12	-5.0006250D+00	0.0	1.0000000D+01	-7.1437500D-01	0.0	0.0	98
		3.9687500D-01						
RCC	13	-4.1275000D+00	0.0	1.0000000D+01	-8.7312500D-01	0.0	0.0	107
		1.6668750D+00						
RCC	14	-3.1750000D+00	0.0	1.0000000D+01	-1.0318750D+00	0.0	0.0	116
		8.7312500D-01						
RCC	15	-2.4606250D+00	0.0	1.0000000D+01	-7.9375000D-01	0.0	0.0	125
		6.3500000D-01						
RCC	16	-4.6037500D+00	0.0	1.0000000D+01	-1.3493750D+00	0.0	0.0	134
		6.3500000D-01						
RCC	17	-4.9212500D+00	0.0	1.0000000D+01	-4.7625000D-01	0.0	0.0	143
		1.6668750D+00						
RCC	18	-4.6037500D+00	0.0	1.0000000D+01	-1.7462500D+00	0.0	0.0	152
		7.9375000D-01						

Figure 19. (continued).

RCC	19	-5.8737500D+00	0.0	1.0000000D+01	-4.7625000D-01	0.0	0.0	161
		6.3500000D-01						
RCC	20	-5.0006250D+00	0.0	1.0000000D+01	-9.5250000D-01	0.0	0.0	170
		4.7625000D-01						
RCC	21	-2.2225000D+00	0.0	1.0000000D+01	-1.0318750D+00	0.0	0.0	179
		8.7312500D-01						
RCC	22	-4.1275000D+00	0.0	1.0000000D+01	-2.2225000D+00	0.0	0.0	188
		1.7462500D+00						
RPP	23	-5.0000000D+02	5.0000000D+02	-5.0000000D+02	5.0000000D+02	-5.0000000D+02	5.0000000D+02	197
END	24	0.0	0.0	0.0	0.0	0.0	0.0	205

NUMBER OF BODIES 23

LENGTH OF FPD-ARRAY 210

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

INPUT ZONE DATA

AIR	00R	1	-2	-8	-22OR	22	-13	-17	-18	0	Z	1
WAL	00R	2	-3	-14	-21OR	8	-14	-21	-22	0	Z	3
GAS	00R	3	-4	-6	-15OR	21	-6	-14	-15	0	Z	5
COL	00R	4	-5OR	6	-5	-10OR	7	-5	0	0	Z	7
ROD	0	5	0	0	0	0	0	0	0	0	Z	10
POL	00R	9	-5	-7	-16OR	10	-5	-7OR	11	-5	Z	11
	00R	12	-5	0	0	0	0	0	0	0	Z	14
INS	00R	13	-9	-17	-18OR	14	-9	-10OR	15	-10	Z	15
BRS	0	16	-11	-19	-20	0	0	0	0	0	Z	18
LUC	00R	19	-5OR	20	-5	-11	-12	0	0	0	Z	19
SLV	00R	17	-16OR	18	-9	-16	-19	0	0	0	Z	21
VD	0	23	-1	0	0	0	0	0	0	0	Z	23
END	0	0	0	0	0	0	0	0	0	0	Z	24

NUMBER OF INPUT ZONES 11

NUMBER OF CODE ZONES 23

LENGTH OF INTEGER ARRAY 575

Figure 19. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

CODE	ZONE	INPUT ZONE	ZONE DATA LOCATIONS	NUMBER OF BODIES	REGION NUMBER	MEDIA NUMBER
1		1	162	4	1	5
2		1	179	4	1	5
3		2	196	4	1	3
4		2	213	4	1	3
5		3	230	4	1	2
6		3	247	4	1	2
7		4	264	2	1	3
8		4	273	3	1	3
9		4	286	2	1	3
10		5	295	1	1	1
11		6	300	4	1	4
12		6	317	3	1	4
13		6	330	2	1	4
14		6	339	2	1	4
15		7	348	4	1	6
16		7	365	3	1	6
17		7	378	2	1	6
18		8	387	4	1	1
19		9	404	2	1	6
20		9	413	4	1	6
21		10	430	2	1	1
22		10	439	4	1	1
23		11	456	2	1	0

Figure 19. (continued).

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

I	KR1(I)	KR2(I)
1	1	2
2	3	4
3	5	6
4	7	9
5	10	10
6	11	14
7	15	17
8	18	18
9	19	20
10	21	22
11	23	23

MORSE REGION IN INPUT ZONE(I) ARRAY MRIZ(I),I=1,11)

1 1 1 1 1 1 1 1 1 1 1 1

MORSE MEDIA IN INPUT ZONE(I) ARRAY MMIZ(I),I=1,11)

5 3 2 3 1 4 6 1 6 1 0

OPTION 0 WAS USED IN CALCULATING VOLUMES FOR 1 REGIONS

0-SET VOLUMES = 1, 1-CONCENTRIC SPHERES, 2-SLABS, 3-INPUT VOLUMES.

VOLUMES (CM**) USED IN COLLISION DENSITY AND TRACK LENGTH ESTIMATORS.

REGION 1
 VOLUME 1.000D+00
 CORE STORAGE ALLOCATED (LEN) = 100000 CORE STORAGE USED (KLAST) = 92801

TIME REQUIRED FOR INPUT WAS 21 SECONDS.

Figure 19. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
16 NEUTRONS UNDERWENT COLLISIONS IN THE ACTIVE MEDIA

WEDNESDAY, AUGUST 27, 1986

1.21266D+07 EV OF ENERGY WAS DEPOSITED BY THE HEAVY ION RECOILS
RESULTING FROM THESE COLLISIONS (WITH NO TRANSPORT)

23 NEUTRONS TOTAL, UNDERWENT COLLISIONS WHICH DEPOSITED
ENERGY IN THE ACTIVE MEDIA (WITH TRANSPORT)

5.80252D+06 EV OF ENERGY WAS DEPOSITED BY THE HEAVY ION RECOILS
RESULTING FROM THESE COLLISIONS (WITH TRANSPORT)

3.47301D+06 EV OF ENERGY WAS DEPOSITED BY THE HEAVY ION RECOILS
ORIGINATING FROM COLLISIONS IN THE ACTIVE MEDIA

2.32951D+06 EV OF ENERGY WAS DEPOSITED BY THE HEAVY ION RECOILS
ORIGINATING FROM COLLISIONS IN ALL OTHER MEDIA

Figure 19. (continued).

APRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD
16 NEUTRONS UNDERWENT COLLISIONS IN THE ACTIVE MEDIA

WEDNESDAY, AUGUST 27, 1986

1.21266D+07 EV OF LIGHT WAS DEPOSITED BY THE HEAVY ION RECOILS
RESULTING FROM THESE COLLISIONS (WITH NO TRANSPORT)

23 NEUTRONS TOTAL, UNDERWENT COLLISIONS WHICH DEPOSITED
ENERGY IN THE ACTIVE MEDIA (WITH TRANSPORT)

5.80252D+06 EV OF LIGHT WAS DEPOSITED BY THE HEAVY ION RECOILS
RESULTING FROM THESE COLLISIONS (WITH TRANSPORT)

3.47301D+06 EV OF LIGHT WAS DEPOSITED BY THE HEAVY ION RECOILS
ORIGINATING FROM COLLISIONS IN THE ACTIVE MEDIA

2.32951D+06 EV OF LIGHT WAS DEPOSITED BY THE HEAVY ION RECOILS
ORIGINATING FROM COLLISIONS IN ALL OTHER MEDIA

Figure 19. (continued).

AFPRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD WEDNESDAY, AUGUST 27, 1986

SUMMARY OF PARTICLES WHICH DEPOSITED ENERGY IN THE ACTIVE GAS (ENERGY WITH NO TRANSPORT)

TABLE NUMBER	PARTICLE TYPE	CHARGE (Z)	MASS (A)	NUMBER CONTRIBUTING	ENERGY DEPOSITED
1	2	1.0000E+00	1.0000E+00	15	1.18723D+07
2	1	1.0000E+00	2.0000E+00	0	0.0
3	1	1.0000E+00	3.0000E+00	0	0.0
4	1	2.0000E+00	4.0000E+00	0	0.0
5	1	4.0000E+00	9.0000E+00	0	0.0
6	1	5.0000E+00	1.1000E+01	0	0.0
7	1	5.0000E+00	1.2000E+01	0	0.0
8	1	6.0000E+00	1.2000E+01	1	2.54271D+05
9	1	6.0000E+00	1.3000E+01	0	0.0
10	1	6.0000E+00	1.4000E+01	0	0.0
11	1	7.0000E+00	1.4000E+01	0	0.0
12	1	7.0000E+00	1.5000E+01	0	0.0
13	1	7.0000E+00	1.6000E+01	0	0.0
14	1	8.0000E+00	1.6000E+01	0	0.0
15	1	8.0000E+00	1.7000E+01	0	0.0

AFPRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD WEDNESDAY, AUGUST 27, 1986

SUMMARY OF PARTICLES WHICH DEPOSITED ENERGY IN THE ACTIVE GAS (LIGHT ENERGY WITH NO TRANSPORT)

TABLE NUMBER	PARTICLE TYPE	CHARGE (Z)	MASS (A)	NUMBER CONTRIBUTING	ENERGY DEPOSITED
1	2	1.0000E+00	1.0000E+00	15	1.18723D+07
2	1	1.0000E+00	2.0000E+00	0	0.0
3	1	1.0000E+00	3.0000E+00	0	0.0
4	1	2.0000E+00	4.0000E+00	0	0.0
5	1	4.0000E+00	9.0000E+00	0	0.0
6	1	5.0000E+00	1.1000E+01	0	0.0
7	1	5.0000E+00	1.2000E+01	0	0.0
8	1	6.0000E+00	1.2000E+01	1	2.54271D+05
9	1	6.0000E+00	1.3000E+01	0	0.0
10	1	6.0000E+00	1.4000E+01	0	0.0
11	1	7.0000E+00	1.4000E+01	0	0.0
12	1	7.0000E+00	1.5000E+01	0	0.0
13	1	7.0000E+00	1.6000E+01	0	0.0
14	1	8.0000E+00	1.6000E+01	0	0.0
15	1	8.0000E+00	1.7000E+01	0	0.0

Figure 19. (continued).

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD WEDNESDAY, AUGUST 27, 1986

SUMMARY OF PARTICLES WHICH DEPOSITED ENERGY IN THE ACTIVE GAS (ENERGY WITH TRANSPORT)

TABLE NUMBER	PARTICLE TYPE	CHARGE (Z)	MASS (A)	NUMBER CONTRIBUTING	ENERGY DEPOSITED
1	2	1.0000E+00	1.0000E+00	22	5.54825D+06
2	1	1.0000E+00	2.0000E+00	0	0.0
3	1	1.0000E+00	3.0000E+00	0	0.0
4	1	2.0000E+00	4.0000E+00	0	0.0
5	1	4.0000E+00	9.0000E+00	0	0.0
6	1	5.0000E+00	1.1000E+01	0	0.0
7	1	5.0000E+00	1.2000E+01	0	0.0
8	1	6.0000E+00	1.2000E+01	1	2.54271D+05
9	1	6.0000E+00	1.3000E+01	0	0.0
10	1	6.0000E+00	1.4000E+01	0	0.0
11	1	7.0000E+00	1.4000E+01	0	0.0
12	1	7.0000E+00	1.5000E+01	0	0.0
13	1	7.0000E+00	1.6000E+01	0	0.0
14	1	8.0000E+00	1.6000E+01	0	0.0
15	1	8.0000E+00	1.7000E+01	0	0.0

AFRRI 50CC TE-TE IONIZATION CHAMBER IN NBS CF-252 FIELD WEDNESDAY, AUGUST 27, 1986

SUMMARY OF PARTICLES WHICH DEPOSITED ENERGY IN THE ACTIVE GAS (LIGHT ENERGY WITH TRANSPORT)

TABLE NUMBER	PARTICLE TYPE	CHARGE (Z)	MASS (A)	NUMBER CONTRIBUTING	ENERGY DEPOSITED
1	2	1.0000E+00	1.0000E+00	22	5.54825D+06
2	1	1.0000E+00	2.0000E+00	0	0.0
3	1	1.0000E+00	3.0000E+00	0	0.0
4	1	2.0000E+00	4.0000E+00	0	0.0
5	1	4.0000E+00	9.0000E+00	0	0.0
6	1	5.0000E+00	1.1000E+01	0	0.0
7	1	5.0000E+00	1.2000E+01	0	0.0
8	1	6.0000E+00	1.2000E+01	1	2.54271D+05
9	1	6.0000E+00	1.3000E+01	0	0.0
10	1	6.0000E+00	1.4000E+01	0	0.0
11	1	7.0000E+00	1.4000E+01	0	0.0
12	1	7.0000E+00	1.5000E+01	0	0.0
13	1	7.0000E+00	1.6000E+01	0	0.0
14	1	8.0000E+00	1.6000E+01	0	0.0
15	1	8.0000E+00	1.7000E+01	0	0.0

TOTAL CPU TIME FOR THIS PROBLEM WAS 0.65 MINUTES.

Figure 19. (continued).

8.0 PECSP - A CODE FOR PROCESSING PHOTON AND ELECTRON CROSS SECTION AND MATERIAL DATA

8.1 Code Description

The program PECSP is designed to generate cross sections and material data for the PHOTON code, and also to provide options for studying or simulating electromagnetic interactions. For the transport of photons, PECSP generates data for pair production, Compton scattering, and photoelectric processes. For the transport of charged particles (electrons or positrons), PECSP generates data for elastic Coulomb scattering off the nucleus, inelastic scattering off the atomic electrons, bremsstrahlung production, and electron-positron annihilation. These interactions are currently the only ones considered in program PHOTON. The production of the cross sections and material data in PECSP is executed through functionals, i.e., operations whose arguments are functions. Included among these operations are:

1. Fitting of functions using piecewise linear fits
2. Production of print plots of selected functions
3. Evaluation of functions at selected points
4. Selection of energy cutoffs for fitted data
5. Punching of fitted data

Processing the cross sections and material data through functionals avoids the necessity of having a separate call to the associated utility routines for each physical function on which it might be desired to operate.

The program PECSP is equivalent to the PEGS⁷ code. The name was changed to accommodate the program naming convention in MICAP. The subroutine hierarchy of program PECSP is shown in Figure 20. A list of the program subroutines and their functions is given in Table 31 and a list of the program functions and their purpose is given in Table 32. These figures and tables along with the input data table (Table 33) were reproduced from the PEGS manual for completeness.

ORNL DWG 86-15421

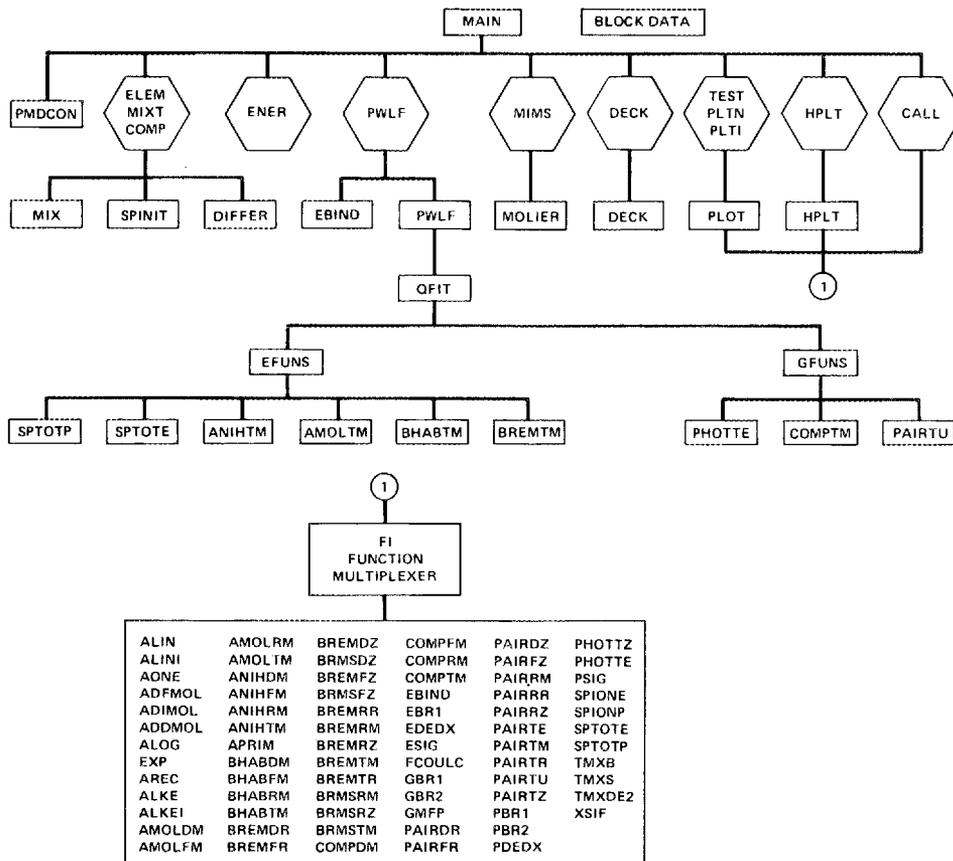


Figure 20. Subroutine Hierarchy in Program PECSP.

Table 31. Subroutine Functions in Program PECSP

Subroutine	Function
DECK	Subprogram to produce a deck of material dependent data (for subsequent use by PHOTON).
DIFFER	Determines the various parameters needed for bremsstrahlung and pair production energy sampling.
EFUNS	Subprogram to compute electron functions to be fit in a way that avoids repetition.
GFUNS	Subprogram to compute photon functions to be fit in a way that avoids repetition.
HPLT	Creates line printer plot comparisons of PHOTON-sampled data (via TESTSR code) and theoretical functions of PECSP.
MIX	Computes Z-dependent parameters that reside in COMMON/MOLVAR/.
MOLIER	Computes material independent multiple scattering data.
PLOT	Subprogram to plot a given function (referenced by number).
PMDCON	Determines the physical, mathematical, and derived constants in a very mnemonic way.
PWLF	Subprogram to piecewise linearly fit up to 10 functions simultaneously on an interval (XL,XU).
SPINIT	Initializes stopping power functions for a particular medium.

Table 32. Function Purposes in Program PECSP

Function	Purpose
AINTP	Linear or log interpolation function.
ALKE	Log of kinetic energy (ALOG(E-RM)), used as a cumulative distribution function for fits and plots.
ALKEI	Inverse of ALKE (EXP(X)+RM).
ALIN	Linear cumulative distribution function for plots (ALIN(X)=X).
ALINI	Inverse of ALIN (same as ALIN). Used as inverse cumulative distribution function in plots.
AONE	Derivative of ALIN (AONE(X)=1). Used as probability density function for plots.
ADFMOL	Appropriate cumulative distribution function for Moller and Bhabba cross sections (ADFMOL(E)=-1/(E-RM)).
ADIMOL	Inverse of ADFMOL.
ADDMOL	Derivative of ADFMOL.
AMOLDM	Moller differential cross section for a mixture of elements.
AMOLFM	"One argument" form of AMOLDM.
AMOLRM	Moller cross section, integrated over some energy range, for a mixture of elements.
AMOLTM	Moller total cross section for a mixture of elements.
ANIHDM	Annihilation differential cross section for a mixture of elements.
ANIHFM	"One argument" form of ANIHDM.
ANIHRM	Annihilation cross section, integrated over some energy range, for a mixture of elements.

Table 32. (continued)

Function	Purpose
ANIHTM	Annihilation total cross section for a mixture of elements.
APRIM	Empirical correction factor in bremsstrahlung cross section.
AREC	Reciprocal function (derivative of $A \log(X)$). Used as probability density function in log plots ($AREC(X)=1/X$).
BHABDM	Bhabha differential cross section for a mixture of elements.
BHABFM	"One argument" form of BHABDM.
BHABRM	Bhabha cross section, integrated over some energy range, for a mixture of elements.
BHABTM	Bhabha total cross section for a mixture of elements.
BREMDR	Bremsstrahlung differential cross section for a "run-time" mixture of elements.
BREMFZ	"One argument" form of BREMDR.
BREMDZ	Bremsstrahlung differential cross section for an element.
BREMFZ	"One argument" form of BREMDZ.
BREMRM	Bremsstrahlung cross section, integrated over some energy range, for a mixture of elements.
BREMRZ	Bremsstrahlung cross section, integrated over some energy range, for a "run-time" mixture of elements.
BREMRZ	Bremsstrahlung cross section, integrated over some energy range, for an element.

Table 32. (continued)

Function	Purpose
BREMTM	Bremsstrahlung total cross section for a mixture of elements.
BREMTR	Bremsstrahlung total cross section for a "run-time" mixture of elements.
BRMSDZ	Soft bremsstrahlung differential cross section for an element.
BRMSFZ	"One argument" form of BRMSDZ.
BRMSRM	Soft bremsstrahlung cross section, integrated over some energy range, for a mixture of elements.
BRMSRZ	Soft bremsstrahlung cross section, integrated over some energy range, for an element.
BRMSTM	Soft bremsstrahlung total cross section for a mixture of elements.
COMPDM	Compton differential cross section for a mixture of elements.
COMPFM	"One argument" form for COMPDM.
COMPRM	Compton cross section, integrated over some energy range, for a mixture of elements.
COMPTM	Compton total cross section for a mixture of elements.
DCADRE	Quadrature routine to integrate $f(x)$ between a and b using cautious Romberg extrapolation.
EBIND	Function to get an average photoelectric binding energy.
EBR1	Function to determine the electron branching ratio (Brem/Total).
EDEDX	Evaluates SPTOTE with cutoffs energies of AE and AP.

Table 32. (continued)

Function	Purpose
ESIG	Determines the total electron interaction cross section (probability per radiation length).
FCOULC	Coulomb correction term in pair production and bremsstrahlung cross sections.
FI	Function multiplexer.
GBR1	Function to determine the gamma-ray branching ration (Pair/Total).
GBR2	Function to determine the gamma-ray branching ratio ((Pair+Compton)/Total).
GMFP	Function to determine the gamma-ray mean free path.
IFUNT	Given PECSP function name, it looks it up in name table and returns the function index. Used by options that specify functions by name.
PAIRDR	Pair production differential cross section for a "run-time" mixture of elements.
PAIRDZ	Pair production differential cross section for an element.
PAIRFR	"One argument" form of PAIRDR.
PAIRFZ	"One argument" form of PAIRDZ.
PAIRRM	Pair production cross section, integrated over some energy range, for a mixture of elements.
PAIRRR	Pair production cross section, integrated over some energy range, for a "run-time" mixture of elements.
PAIRRZ	Pair production cross section, integrated over some energy range, for an element.

Table 32. (continued)

Function	Purpose
PAIRTE	"Empirical" total pair production cross section for a mixture ($\text{SUM}(\text{PZ}(\text{I})) * \text{PAIRTZ}(\text{Z}(\text{I})))$).
PAIRTM	Pair production total cross section for a mixture of elements, obtained by numerical integration of differential cross section.
PAIRTR	Pair production total cross section for a "run-time" mixture of elements.
PAIRTU	Pair production total cross section actually "used". Same as PAIRTE for primary energy less than 50 MeV; otherwise, same as PAIRTM.
PAIRTZ	Computes contribution to empirical pair production total cross section for an element assuming one atom per molecule. It is obtained by log-linear interpolation of Israel-Storm data.
PBR1	Function to determine the positron branching ratio (Brem/Total).
PBR2	Function to determine the positron branching ratio ($(\text{Brem} + \text{Bhabha})/\text{Total}$).
PDEDX	Evaluates SPTOTP with cutoff energies of AE and AP.
PHOTTE	Determines the proper mix of PHOTTZ's for a mixture.
PHOTTZ	Determines the interpolated total photoelectric cross section from tabulated data.
PSIG	Determines the total positron interaction cross section (probability per radiation length).
QD	Driver function for DCADRE, the numerical integration routine.
QFIT	Utility logical function for the piecewise linear fit subroutine, PWLF. It returns .TRUE. if a given partition gives a good fit.

Table 32. (continued)

Function	Purpose
SPIONB	Does the work for SPIONE and SPIONP. One argument tells whether to compute stopping power for electron or positron.
SPIONE	Calculates the stopping power due to ionization for electrons.
SPIONP	Calculates the stopping power due to ionization for positrons.
SPTOTE	Calculates the total stopping power (ionization plus soft bremsstrahlung) for electrons for specified cutoffs.
SPTOTP	Calculates the total stopping power (ionization plus soft bremsstrahlung) for positrons for specified cutoffs.
TMXB	Determines the maximum total step length consistent with Bethe's criterion.
TMXS	Determines the minimum of TMXB and 10 radiation lengths.
TMXDE2	Included for possible future modification purposes ($=\text{TMXB}/(\text{E}^{**2}*\text{BETA}^{**4})$). It might be easier to fit this quantity than to fit TMXB and then apply the denominator in PHOTON as run-time.
XSIF	Function to account for bremsstrahlung and pair production in the field of the atomic electrons.
ZTBL	Given the atomic symbol for an element, it returns the atomic number.

8.2 Input Requirements

The following table summarizes the input cards that are required in order to execute a PECSP case.

Table 33. PECSP Options and Input Specifications

Card	Format	Variables Read	Comments
ELEM1	(4A1)	OPT(1:4)	'ELEM'. Means "select material is an element."
ELEM2	NAMelist/INP/	RHO	Optional. If given, this over-rides the PECSP default density (gm/cm ³) for the element.
		WA(1)	Optional. Atomic weight of element. If given, this over-rides the PECSP default.
ELEM3	(24A1, 6X, 24A1)	MEDIUM (1:24)	Identifier assigned to data set to be produced.
		IDSTRN(1:24)	Optional. Identifier of medium name under which desired Sternheimer coefficients are catalogued in PECSP. If not specified, the identifier in MEDIUM (1:24) is used.
ELEM4	(24(A2, 1X))	ASYM(1)	Atomic symbol for element.
COMP1	(4A1)	OPT(1:4)	'COMP'. Means "select material that is a compound."
COMP2	NAMelist/INP/	NE	Number of elements in compound.
		RHO	Density (gm/cm ³) of compound.
		(PZ(I), I=1, NE)	Relative numbers of atoms in compound.

Table 33. (continued)

Card	Format	Variables Read	Comments
		(WA(I), I=1, NE)	Optional. May be used to over-ride default atomic weights (e.g., to allow for special isotopes).
COMP3	(24A1, 6X, 24A1)	MEDIUM, IDSTRN	Same as ELEM3.
COMP4	(24(A2, 1X))	(ASYM(I), I=1, NE)	Atomic symbols for the atoms in the compound. Duplicates are allowed if several isotopes of the same element are present.
MIXT1	(4A1)	OPT(1:4)	'MIXT'. Means "select material that is a mixture."
MIXT2	NAMelist/INP/	NE	Number of elements in mixture.
		RHO	Density (gm/cm ³) of mixture.
		(RHOZ(I), I=1, NE)	Relative amount of atom in mixture (by weight).
		(WA(I), I=1, NE)	Optional. May be used to over-ride default atomic weights.
MIXT3	(24A1, (6X, 24A1)	MEDIUM, IDSTRN	Same as ELEM3.
MIXT4	(24(A2, 1X))	(ASYM(I), I=1, NE)	Same as COMP4.
ENER1	(4A1)	OPT(1:4)	'ENER'. Means "select energy limits."
ENER2	NAMelist/INP/	AE	Lower cutoff energy (total) for charged particle transport (MeV).

Table 33. (Continued)

Card	Format	Variables Read	Comments
		UE	Upper limit energy (total) for charged particle transport (MeV).
		AP	Lower cutoff energy for photon transport (MeV).
		UP	Upper limit energy for photon transport (MeV).
<p>Note: If the user supplies negative values for the energy limits above, absolute values given will be interpreted as in units of the electron rest mass energy. Thus, AE=-1 is equivalent to AE=0.511 MeV.</p>			
PWLF1	(4A1)	OPT(1:4)	'PWLF'. Means "select piecewise linear fit."
PWLF2	NAMelist/INP/	Note:	The following PWLF parameters are optional and may be over-ridden by the user. The default values (in BLOCK DATA) are indicated below.
		EPE/0.01/	Electron EP parameter.
		EPG/0.01/	Gamma EP parameter.
		ZTHRE(1:8)/8*0./	Electron ZTHR parameter.
		ZTHRG(1:3)/ 0.,.1,0./	Gamma ZTHR parameter.
		ZEPE(1:8)/8*0./	Electron ZEP parameter.
		ZEPG(1:3)/ 0.,.01,0./	Gamma ZEP parameter.
		NIPE/20/	Electron NIP parameter.
		NIPG/20/	Gamma NIP parameter.
		NALE/\$MXEKE/	Electron NIMX parameter.

Table 33. (continued)

Card	Format	Variables Read	Comments
		NALG/\$MXGE/	Gamma NIMX parameter.
DECK1	(4A1)	OPT(1:4)	'DECK'. Means "Punch fit data and other useful parameters."
DECK2	NAMelist/INP/		No parameters.
TEST1	(4A1)	OPT(1:4)	'TEST'. Means "Plot the fitted functions."
TEST2	NAMelist/INP/	NPTS	Optional. Number of points to plot per function (Default=50).
CALL1	(4A1)	OPT(1:4)	'CALL'. Means "Call the designated function and print value."
CALL2	NAMelist/INP/	XP(1:4)	Values for up to four arguments of the function.
CALL3	(6A1)	NAME(1:6)	Name of function to be evaluated.
PLTI1	(4A1)	OPT(1:4)	'PLTI'. Means "Plot function given its index and the index of the distribution function."
PLTI2	NAMelist/INP/	IFUN	The index of the function to be plotted.
		XP(1:4)	Values for the static arguments (parameters).
		IV	Variable telling which argument is to be varied (e.g., IV=2 means plot function vs. its second argument).
		VLO	Lower limit for argument being varied.
		VHI	Upper limit for argument being varied.

Table 33. (continued)

Card	Format	Variables Read	Comments
		NPTS	Number of points to plot.
		IDF	Index of distribution function used to select independent variable.
		MP	May be used to select printer vs. graphic plot output. Not currently operational (i.e., only print plots are produced).
PLTN1	(4A1)	OPT(1:4)	'PLTN'. Means "Plot the named function."
PLTN2	NAMelist/INP/	XP(1:4),IV, VLO,VHI,NPTS, IDF,MD	Same as PLTI2.
PLTN3	(2(6A1))	NAME(1:6)	Name (6 characters) of function to be plotted.
		IDFNAM(1:6)	Name of distribution function to be used.
HPLT1	(4A1)	OPT(1:4)	'HPLT'. Means "Plot histogram to compare the sampled spectrum with the range-integrated and the differential theoretical values."
HPLT2	NAMelist/INP/	EI	Total energy of test particle (MeV).
		ISUB	Variable telling which function is being tested: 1=PAIR 2=COMPT 3=BREMS 4=MOLLER 5=BHABHA 6=ANNIH 7=MSCAT (not implemented).

Table 33. (continued)

Card	Format	Variables Read	Comments
HPLT3	(' TEST DATA FOR ROUTINE=', I2A1, ', SAMPLES=', I10, 'NBINS=', I5)		
		NAMESB(1:12)	Name of subroutine tested.
		NTIMES	Number of samples.
		NBINS	Number of histogram bins.
HPLT4	(' IQI=', I2, ', RNLO, RNHI=', 2F12.8, ', IRNFLG=', I2)		
		IQI	Charge of test particle.
		RNLO, RNHI	Lower and upper limits to random number preceding call to test function.
		IRNFLG	Non-zero means to "apply above limits to preceding random number to test for correlation." Zero value means "don't do this."
HPLT5	(9I8)	NH(1:NBINS)	The sampled data (from TESTSR).
	...etc.		

8.3 Input Data Notes

ELEM This option is used to specify a material which has only one type of atom.

COMP This option is used to specify a material which has more than one type of atom and it is desired to give the proportion by the relative number of atoms.

MIXT This option is similar to the COMP option except the relative atomic portions are given by weight.

ENER This option defines the electron and photon energy interval over which fits to total cross sections and branching ratios are made.

PWLF This option performs simultaneous piecewise linear fits of the electron and photon functions over their respective energy intervals.

DECK This option prints and punches all data that might be of use in program PHOTON.

TEST This option is used as an easy way to obtain plots of all the functions that the PWLF option fits.

CALL This option is used whenever the user desires to have PECSP evaluate a particular function and print out the results.

PLTI and PLTN These options are used to obtain printer plots of any of the functions in the PECSP function table.

8.4 I/O File Requirements

<u>File</u>	<u>Unit</u>	<u>Description</u>	<u>Required</u>
IN	5	Card Input	Always
IO	6	Printed Output	Always
IP	7	Punched Deck	Always
IDAT	8	PHPRNM Data File	Always
ISCR	9	Scratch Unit	Always

8.5 JCL Requirements

The job control language (JCL) needed to run a PECSP case at X-10 is:

```
(Job card, route and jobparm cards)
//PECSP EXEC PGM=PECSP,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FTO5FOO1 DD DDNAME=SYSIN
```

```
//FT06F001 DD SYSOUT=A
(DD Cards for the Output Unit)
//FT08F001 DD DSN=MEN.X10.JOJ.PHPRNM.DATA.LIST,DISP=SHR
(DD Cards for the Scratch Unit)
//SYSIN DD *
(INPUT DATA)
/*
//
```

8.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Figure 21 and some selected output is shown in Figure 22. The problem demonstrates the generation of cross sections and material data for an element, a compound, and a mixture.

```

//JOJPECSP JOB (24337,IO1),'JO JOHNSON 6025',TIME=(3,00)
/*ROUTE PRINT RMT84
//A EXEC PGM=PECSP,REGION=2048K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT07F001 DD UNIT=3330V,VOL=SER=VINT09,DISP=(NEW,CATLG),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200),SPACE=(TRK,(100,20),RLSE),
// DSN=MEN.X10.JOJ.PEGS.OUT
//FT08F001 DD DSN=MEN.X10.JOJ.PHRNM.DATA.LIST,DISP=SHR
//FT09F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=133,BLKSIZE=3458)
//SYSIN DD *
ELEM
  &INP RHO=1.71,WA(1)=12.01115 &END
GRAPHITE
C
ENER
  &INP AE=0.516,UE=15.511,AP=0.001,UP=15.0 &END
PWL
  &INP &END
DECK
  &INP &END
TEST
  &INP &END
MIXT
  &INP NE=6,RHO=1.127,RHOZ=10.2,76.8,5.9,3.6,1.8,1.7 &END
TE PLASTIC
H C O N C A F
ENER
  &INP AE=0.516,UE=15.511,AP=0.001,UP=15.0 &END
PWL
  &INP &END
DECK
  &INP &END
TEST
  &INP &END
COMP
  &INP NE=2,RHO=1.06,PZ(1)=1,PZ(2)=1 &END
POLYSTYRENE
C H
ENER
  &INP AE=0.516,UE=15.511,AP=0.001,UP=15.0 &END
PWL
  &INP &END
DECK
  &INP &END
TEST
  &INP &END
/*
//

```

Figure 21. Complete Listing of JCL and Input for PECSP Sample Problem.

DERIVED CONSTANTS--RADDEG,FSC,FSCI,ERGMEV,R0,RM,RMT2,RMSQ
 5.729576E+01 7.297166E-03 1.370395E+02 1.602099E-06 2.817764E-13 5.110076E-01 1.022015E+00 2.611287E-01
 A22P9= 22.695953,A6680 = 6702.3281

OPT=ELEM
 MEDIUM=GRAPHITE ,STERNHEIMER ID=GRAPHITE
 ATOMIC SYMBOLS ARE: C

NUMBER OF ELEMENTS =		1,DENSITY=	1.71000	(GM/CC)
I	Z(I)	WA(I)	PE(I)	RHOZ(I)
INDEX	PERIODIC	ATOMIC	PROPORTION	PROPORTION
	NUMBER	WEIGHT	BY NUMBER	BY WEIGHT
1	6.00000	12.0112	1.00000	12.0112

Z VARIABLES--WM,EC,ET,EA,EB,EF,EG,ZP
 1.201115E+01 6.000000E+00 4.391060E+01 2.287516E+02 -2.622574E+01 1.010156E-01 -5.972530E-01 -1.146472E-01
 EV,EU,ES,EE,EX,RLC
 -5.995535E-01 -1.150888E-01 4.200000E+01 -5.016924E+01 2.680275E-01 2.486127E+01
 I,XSI,ZEX,FEC,FCOUL,ZE,I=1,NE)
 1 1.318434E+00 4.391060E+01 1.916951E-03 2.300485E-03 4.200000E+01
 EDEN= 5.144471E+23
 BLCC,XCC,TEFF0,XR0= 2.99827E+05 4.82967E+00 6.67177E-05 8.36844E-02

PARAMETERS COMPUTED IN SPINIT.
 IM= .0
 I= 7.800004E-05
 SPC1= 3.260470
 SPC2= -18.26801
 ALIADG= -9.458801
 VPLASM= 6.439741E+15
 STC= -3.149185

Figure 22. Listing of Selected Output from PEGSP Sample Problem.

DIFFERENTIAL CROSS-SECTION DATA,COMMON BREMPF

DL1(6)	DL2(6)	DL3(6)	DL4(6)	DL5(6)	DL6(6)	ALPHI(2)	BPAR(2)	DELCM	DELPOS(2)
0.100132E+01	0.100158E+01	0.100171E+01	0.100132E+01	0.100158E+01	0.100171E+01	0.100132E+01	0.100158E+01	0.100171E+01	0.100171E+01
-0.207536E+00	-0.175728E+00	-0.159389E+00	-0.207638E+00	-0.175816E+00	-0.159470E+00	-0.207638E+00	-0.175816E+00	-0.159470E+00	-0.159470E+00
0.476247E-01	0.338773E-01	0.244636E-01	0.476481E-01	0.338942E-01	0.244759E-01	0.476481E-01	0.338942E-01	0.244759E-01	0.244759E-01
0.997270E+00	0.101529E+01	0.102454E+01	0.997269E+00	0.101530E+01	0.102456E+01	0.997269E+00	0.101530E+01	0.102456E+01	0.102456E+01
-0.222763E+00	-0.226788E+00	-0.228856E+00	-0.222873E+00	-0.226902E+00	-0.228971E+00	-0.222873E+00	-0.226902E+00	-0.228971E+00	-0.228971E+00
0.952000E+00									
0.940894E+00	0.940902E+00	0.853807E+00	0.853805E+00	0.382457E+02	0.227481E+01	0.940894E+00	0.940902E+00	0.853807E+00	0.853805E+00
0.226976E+01									

OPT=ENNR

AE,UE,AP,UP,TE,TET2,TEM,THMOLL

5.1599997E-01 1.5511000E+01 9.9999993E-04 1.5000000E+01 4.9923658E-03 9.9847317E-03 9.7696483E-03 5.2099234E-01

OPT=PWLF

EPWLFNM

EPPE= .100000016E-01,ETHRE= .0
 .0 , .0 , ZEPE= .0 , .0 , .0 , .0 , .0 , .0
 .0 , .0 , .0 , NIPPE= 20,NALE= 150,EPG= .100000016E-01,ETHRG= .0
 .100000024 , .0 , ZEPG= .0 , .100000016E-01, .0 , NIPG= 20,NALG= 200

END

AVERAGE K-IONIZATION ENERGY= 0.000284(MEV)
 NUMBER OF ALLOCATED INTERVALS(= 150) WAS INSUFFICIENT
 TO GET MAXIMUM RELATIVE ERROR LESS THAN 1.00000E-02
 NUMBER OF ALLOCATED INTERVALS(= 200) WAS INSUFFICIENT
 TO GET MAXIMUM RELATIVE ERROR LESS THAN 1.00000E-02

OPT=DECK

ECHO WRITE:MEDIUM,IDSTRN

MEDIUM=GRAPHITE ,STERNCID=GRAPHITE

ECHO WRITE:MTYP,RHO,NE

ELEM,RHO= 1.7100E+00,NE= 1

ECHO WRITE:ASYM(IE),Z(IE),WA(IE),PZ(IE),RHOZ(IE)

ASYM=C ,Z= 6.,A= 12.011,PZ= 1.00000E+00,RHOZ= 1.20112E+01

ECHO WRITE:RLC,AE,AP,UE,UP

2.48613E+01 5.16000E-01 1.00000E-03 1.55110E+01 1.50000E+01

ECHO WRITE:NSGE,NGE,NSEKE,NEKE,NLEKE,NCMP,NRANGE

0 200 0 150 0 0 0

Figure 22. (continued).

```

ECHO WRITE:(DL1(I),DL2(I),DL3(I),DL4(I),DL5(I),DL6(I),I=1,6)
  1.00132E+00 -2.07536E-01  4.76247E-02  9.97270E-01 -2.22763E-01
  9.52000E-01  1.00158E+00 -1.75728E-01  3.38773E-02  1.01529E+00
-2.26788E-01  9.52000E-01  1.00171E+00 -1.59389E-01  2.44636E-02
  1.02454E+00 -2.28856E-01  9.52000E-01  1.00132E+00 -2.07638E-01
  4.76481E-02  9.97269E-01 -2.22873E-01  9.52000E-01  1.00158E+00
-1.75816E-01  3.38942E-02  1.01530E+00 -2.26902E-01  9.52000E-01
  1.00171E+00 -1.59470E-01  2.44759E-02  1.02456E+00 -2.28971E-01
  9.52000E-01
ECHO WRITE:DELCM,(ALPHI(I),SPAR(I),DELPOS(I),I=1,2)
  3.82457E+01  9.40894E-01  8.53807E-01  2.27481E+00  9.40902E-01
  8.53805E-01  2.26976E+00
ECHO WRITE:XRO,TEFFO,BLCC,XCC
  8.36844E-02  6.67177E-05  2.99827E+05  4.82967E+00
ECHO WRITE:BXE,AXE
  1.00021E+02  1.84559E+01
ECHO WRITE:((BFE(I,IFUN),AFE(I,IFUN),IFUN=1,8),I=1,NEKE)
  1.14297E+01  1.62772E+00  1.62845E+05  3.07215E+04 -4.28062E+03
-1.08277E+03 -5.86660E+03 -1.41544E+03  1.00000E+00  0.0
-1.30388E+01 -2.48073E+00  1.08030E+02  2.03631E+01  8.60238E-06
  1.47058E-06  1.14297E+01  1.62772E+00  1.62845E+05  3.07215E+04
-4.28062E+03 -1.08277E+03 -5.86660E+03 -1.41544E+03  1.00000E+00
.
.
.
  5.54220E-01  6.55029E+02  2.79813E+00  5.18680E+01 -1.21376E-01
  5.18584E+01 -1.18560E-01  1.07845E-02  2.48703E-03  1.09873E-02
  2.43774E-03  9.98310E-01  4.23524E-04 -2.01727E+00  9.48379E-01
ECHO WRITE:EBINDA,BXG,AXG
  2.84000E-04  1.43554E+02  2.04920E+01
ECHO WRITE:((BFG(I,IFUN),APG(I,IFUN),IFUN=1,3),I=1,NGE)
  2.35678E-04  3.25618E-05  0.0  0.0  4.66134E-02
  6.27233E-03  2.35678E-04  3.25618E-05  0.0  0.0
  4.66134E-02  6.27233E-03  2.73862E-04  3.81289E-05  0.0
.
.
.
  2.99673E-01  9.99980E-01  1.22142E-06  2.65566E-01  4.15595E-01
-5.02014E-01  3.06923E-01  1.00000E+00  0.0  2.65566E-01
  4.15595E-01 -5.02014E-01  3.06923E-01  1.00000E+00  0.0

```

Figure 22. (continued).

OPT=TEST

PLOT OF FUNCTION ESIG (.516000 : 15.5110)
THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 34.7302

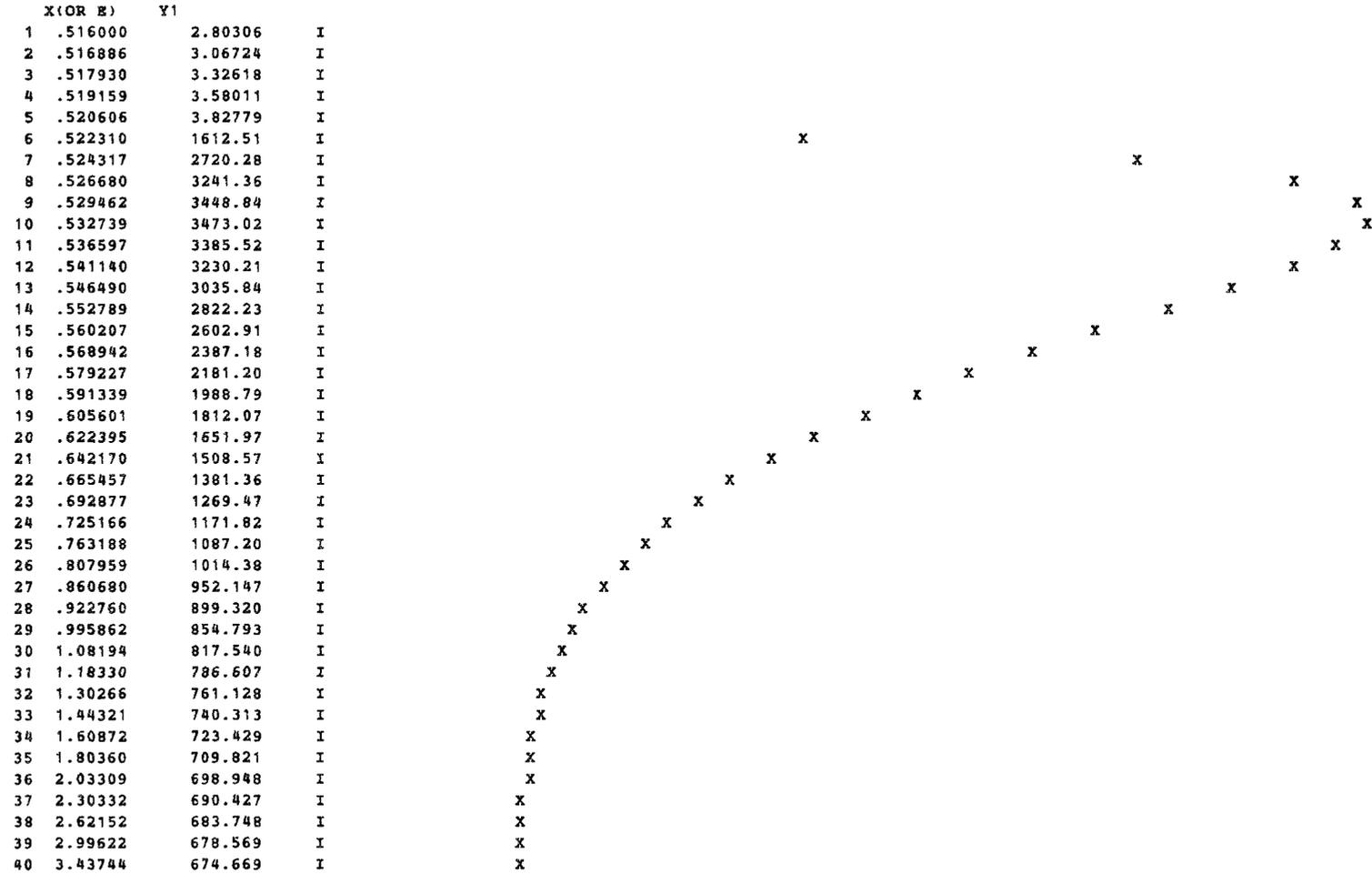


Figure 22. (continued).

PLOT OF FUNCTION PSIG (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 82.1434

X(OR E)	Y1		
1	.516000	25.7913	I
2	.516886	4220.97	I
3	.517930	6613.80	I
4	.519159	7805.73	I
5	.520606	8214.34	I
6	.522310	8128.80	I
7	.524317	7745.27	I
8	.526680	7197.48	I
9	.529462	6573.58	I
10	.532739	5930.21	I
11	.536597	5303.06	I
12	.541140	4713.16	I
13	.546490	4171.50	I
14	.552789	3682.97	I
15	.560207	3248.05	I
16	.568942	2864.78	I
17	.579227	2529.77	I
18	.591339	2238.87	I
19	.605601	1987.63	I
20	.622395	1771.68	I
21	.642170	1586.81	I
22	.665457	1429.17	I
23	.692877	1295.24	I
24	.725166	1181.87	I
25	.763188	1086.28	I
26	.807959	1006.00	I
27	.860680	938.901	I
28	.922760	883.102	I
29	.995862	836.971	I
30	1.08194	799.087	I
31	1.18330	768.207	I
32	1.30266	743.247	I
33	1.44321	723.261	I
34	1.60872	707.399	I
35	1.80360	694.921	I
36	2.03309	685.227	I
37	2.30332	677.890	I
38	2.62152	672.366	I
39	2.99622	668.299	I
40	3.43744	665.445	I

Figure 22. (continued).

PLOT OF FUNCTION EDEDX (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 14.5792

X(OR E)	Y1		
1	.516000	1457.92	I
2	.516886	1288.11	I
3	.517930	1136.96	I
4	.519159	1002.82	I
5	.520606	883.979	I
6	.522310	770.393	I
7	.524317	670.517	I
8	.526680	584.247	I
9	.529462	509.403	I
10	.532739	444.406	I
11	.536597	387.994	I
12	.541140	339.093	I
13	.546490	296.752	I
14	.552789	260.146	I
15	.560207	228.540	I
16	.568942	201.286	I
17	.579227	177.820	I
18	.591339	157.645	I
19	.605601	140.329	I
20	.622395	125.493	I
21	.642170	112.811	I
22	.665457	101.999	I
23	.692877	92.8090	I
24	.725166	85.0290	I
25	.763188	78.4746	I
26	.807959	72.9861	I
27	.860680	68.4257	I
28	.922760	64.6736	I
29	.995862	61.6259	I
30	1.08194	59.1915	I
31	1.18330	57.2907	I
32	1.30266	55.8532	I
33	1.44321	54.8168	I
34	1.60872	54.1262	I
35	1.80360	53.7322	I
36	2.03309	53.5913	I
37	2.30332	53.6647	I
38	2.62152	53.6393	I
39	2.99622	53.1178	I
40	3.43744	52.7155	I

Figure 22. (continued).

PLOT OF FUNCTION PDEDX (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 16.3499

X(O R E)	Y1		
1	.516000	1634.99	I
2	.516886	1415.33	I
3	.517930	1225.26	I
4	.519159	1060.97	I
5	.520606	918.984	I
6	.522310	796.380	I
7	.524317	690.477	I
8	.526680	599.069	I
9	.529462	520.215	I
10	.532739	452.204	I
11	.536597	393.572	I
12	.541140	343.056	I
13	.546490	299.548	I
14	.552789	262.106	I
15	.560207	229.902	I
16	.568942	202.222	I
17	.579227	178.455	I
18	.591339	158.068	I
19	.605601	140.603	I
20	.622395	125.665	I
21	.642170	112.912	I
22	.665457	102.051	I
23	.692877	92.8290	I
24	.725166	85.0279	I
25	.763188	78.4602	I
26	.807959	72.9638	I
27	.860680	68.3992	I
28	.922760	64.6453	I
29	.995862	61.5974	I
30	1.08194	59.1640	I
31	1.18330	57.2647	I
32	1.30266	55.8291	I
33	1.44321	54.7947	I
34	1.60872	54.1062	I
35	1.80360	53.7143	I
36	2.03309	53.5753	I
37	2.30332	53.6506	I
38	2.62152	53.6269	I
39	2.99622	53.1070	I
40	3.43744	52.7060	I

Figure 22. (continued).

PLOT OF FUNCTION EBR1 (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 1.00000E-02

X(OR E)	Y1		
1	.516000	1.00000	I
2	.516886	1.00000	I
3	.517930	1.00000	I
4	.519159	1.00000	I
5	.520606	1.00000	I
6	.522310	2.52325E-03	I
7	.524317	1.58174E-03	I
8	.526680	1.39742E-03	I
9	.529462	1.37693E-03	I
10	.532739	1.42829E-03	I
11	.536597	1.52550E-03	I
12	.541140	1.65970E-03	I
13	.546490	1.82830E-03	I
14	.552789	2.03127E-03	I
15	.560207	2.26994E-03	I
16	.568942	2.54624E-03	I
17	.579227	2.86226E-03	I
18	.591339	3.21999E-03	I
19	.605601	3.62107E-03	I
20	.622395	4.06643E-03	I
21	.642170	4.55613E-03	I
22	.665457	5.08910E-03	I
23	.692877	5.66289E-03	I
24	.725166	6.27356E-03	I
25	.763188	6.91568E-03	I
26	.807959	7.58231E-03	I
27	.860680	8.26507E-03	I
28	.922760	8.95452E-03	I
29	.995862	9.64053E-03	I
30	1.08194	1.03119E-02	IX
31	1.18330	1.09574E-02	IX
32	1.30266	1.15663E-02	IX
33	1.44321	1.21272E-02	IX
34	1.60872	1.25993E-02	IX
35	1.80360	1.29483E-02	IX
36	2.03309	1.31909E-02	IX
37	2.30332	1.34841E-02	IX
38	2.62152	1.37031E-02	IX
39	2.99622	1.38861E-02	IX
40	3.43744	1.41506E-02	IX

X
X
X
X
X

Figure 22. (continued).

PLOT OF FUNCTION PBR1 (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 1.08682E-03

X(OR E)	Y1		
1	.516000	.108682	I
2	.516886	7.26668E-04	I
3	.517930	5.02915E-04	I
4	.519159	4.58652E-04	I
5	.520606	4.65989E-04	I
6	.522310	5.00537E-04	I
7	.524317	5.55535E-04	I
8	.526680	6.29321E-04	I
9	.529462	7.22409E-04	I
10	.532739	8.36478E-04	I
11	.536597	9.73892E-04	I
12	.541140	1.13749E-03	IX
13	.546490	1.33056E-03	IX
14	.552789	1.55654E-03	IX
15	.560207	1.81907E-03	IX
16	.568942	2.12174E-03	IX
17	.579227	2.46788E-03	I X
18	.591339	2.86032E-03	I X
19	.605601	3.30123E-03	I X
20	.622395	3.79168E-03	I X
21	.642170	4.33147E-03	I X
22	.665457	4.91884E-03	I X
23	.692877	5.55022E-03	I X
24	.725166	6.22018E-03	I X
25	.763188	6.92156E-03	I X
26	.807959	7.64548E-03	I X
27	.860680	8.38168E-03	I X
28	.922760	9.11896E-03	I X
29	.995862	9.84582E-03	I X
30	1.08194	1.05500E-02	I X
31	1.18330	1.12198E-02	I X
32	1.30266	1.18445E-02	I X
33	1.44321	1.24131E-02	I X
34	1.60872	1.28848E-02	I X
35	1.80360	1.32259E-02	I X
36	2.03309	1.34550E-02	I X
37	2.30332	1.37334E-02	I X
38	2.62152	1.39350E-02	I X
39	2.99622	1.40995E-02	I X
40	3.43744	1.43467E-02	I X

X

Figure 22. (continued).

PLOT OF FUNCTION PBR2 (.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 9.99454E-03

	X(OR E)	Y1		X
1	.516000	.108682	I	
2	.516886	.994975	I	X
3	.517930	.997040	I	X
4	.519159	.997685	I	X
5	.520606	.997969	I	X
6	.522310	.998104	I	X
7	.524317	.998161	I	X
8	.526680	.998170	I	X
9	.529462	.998147	I	X
10	.532739	.998099	I	X
11	.536597	.998032	I	X
12	.541140	.997947	I	X
13	.546490	.997848	I	X
14	.552789	.997737	I	X
15	.560207	.997615	I	X
16	.568942	.997483	I	X
17	.579227	.997345	I	X
18	.591339	.997202	I	X
19	.605601	.997056	I	X
20	.622395	.996911	I	X
21	.642170	.996771	I	X
22	.665457	.996639	I	X
23	.692877	.996521	I	X
24	.725166	.996421	I	X
25	.763188	.996343	I	X
26	.807959	.996293	I	X
27	.860680	.996274	I	X
28	.922760	.996288	I	X
29	.995862	.996337	I	X
30	1.08194	.996421	I	X
31	1.18330	.996536	I	X
32	1.30266	.996681	I	X
33	1.44321	.996851	I	X
34	1.60872	.997038	I	X
35	1.80360	.997239	I	X
36	2.03309	.997446	I	X
37	2.30332	.997654	I	X
38	2.62152	.997860	I	X
39	2.99622	.998058	I	X
40	3.43744	.998247	I	X

Figure 22. (continued).

```

PLOT OF FUNCTION TMXS ( .516000 : 15.5110 )
THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 5.50984E-03
X(OR E) Y1
1 .516000 8.08512E-07 I
2 .516886 1.07692E-06 I
3 .517930 1.43601E-06 I
4 .519159 1.91664E-06 I
5 .520606 2.56014E-06 I
6 .522310 3.42186E-06 I
7 .524317 4.57584E-06 I
8 .526680 6.12086E-06 I
9 .529462 8.18872E-06 I
10 .532739 1.09547E-05 I
11 .536597 1.46515E-05 I
12 .541140 1.95873E-05 I
13 .546490 2.61684E-05 I
14 .552789 3.49290E-05 I
15 .560207 4.65686E-05 I
16 .568942 6.19978E-05 I
17 .579227 8.23978E-05 I
18 .591339 1.09291E-04 I
19 .605601 1.44629E-04 I
20 .622395 1.90900E-04 I
21 .642170 2.51259E-04 I
22 .665457 3.29688E-04 I
23 .692877 4.31197E-04 I
24 .725166 5.62071E-04 I
25 .763188 7.30202E-04 I
26 .807959 9.45514E-04 I
27 .860680 1.22055E-03 I
28 .922760 1.57124E-03 I
29 .995862 2.01802E-03 I
30 1.08194 2.58729E-03 I
31 1.18330 3.31343E-03 I
32 1.30266 4.24160E-03 I
33 1.44321 5.43143E-03 I
34 1.60872 6.96212E-03 IX
35 1.80360 8.93923E-03 IX
36 2.03309 1.15039E-02 I X
37 2.30332 1.48455E-02 I X
38 2.62152 1.92181E-02 I X
39 2.99622 2.49637E-02 I X
40 3.43744 3.25429E-02 I X

```

Figure 22. (continued).

PLOT OF FUNCTION TXKDE2(.516000 : 15.5110)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM .516000 TO 15.5110
 USING DISTRIBUTION FUNCTION ALKE AND INVERSE DISTRIBUTION FUNCTION ALKEI . EACH X= 1.02361E-04

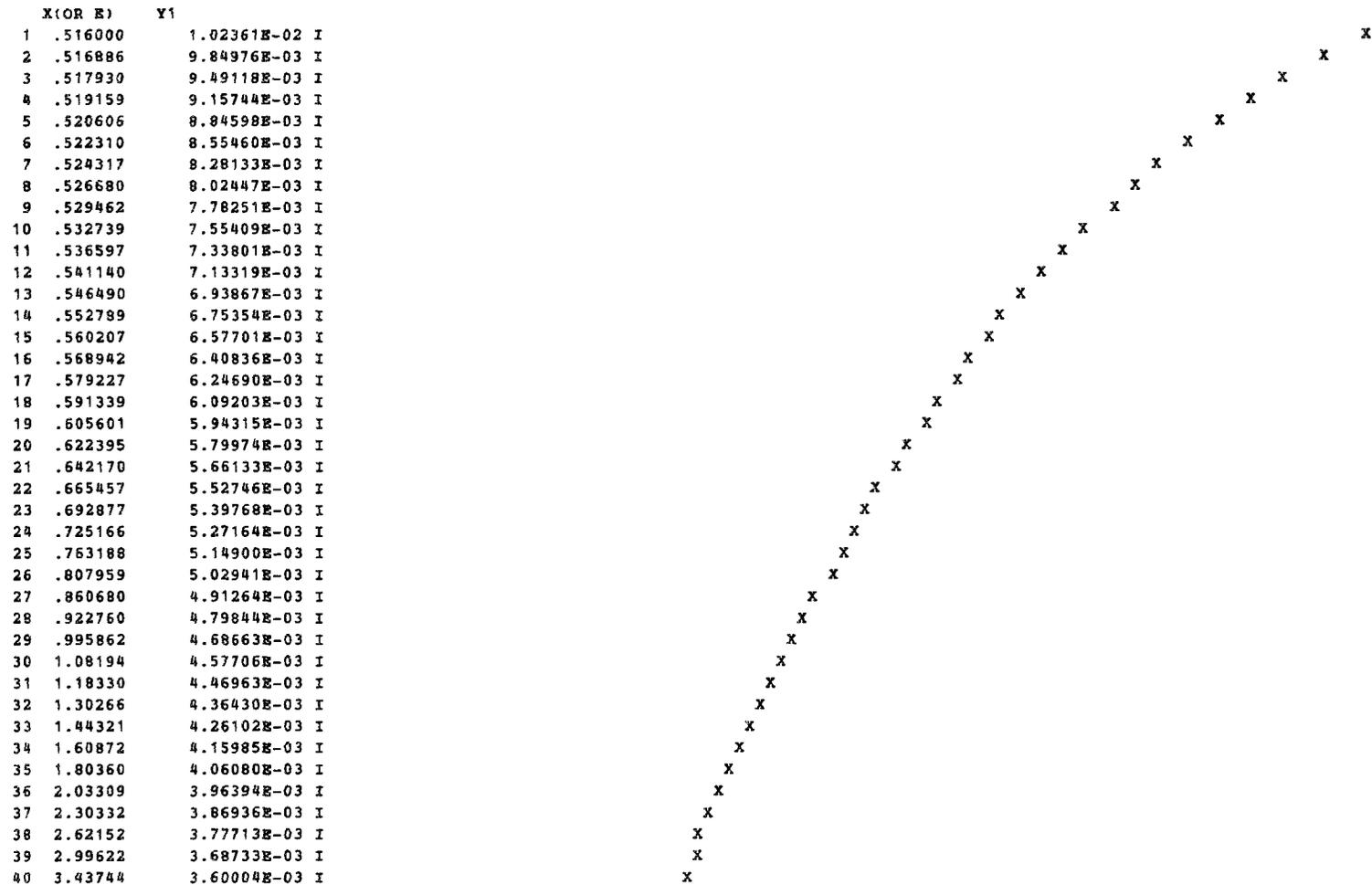


Figure 22. (continued).

PLOT OF FUNCTION GMFP (1.00000E-03 : 15.0000)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM 1.00000E-03 TO 15.0000
 USING DISTRIBUTION FUNCTION ALOG AND INVERSE DISTRIBUTION FUNCTION EXP . EACH X= 1.39104E-02

X(OR E)	Y1			
1	9.99999E-04	1.07491E-05	I	
2	1.21682E-03	1.87689E-05	I	
3	1.48065E-03	3.25473E-05	I	
4	1.80169E-03	5.75340E-05	I	
5	2.19233E-03	1.02972E-04	I	
6	2.66767E-03	1.85065E-04	I	
7	3.24607E-03	3.33026E-04	I	
8	3.94988E-03	6.06448E-04	I	
9	4.80630E-03	1.10586E-03	I	
10	5.84839E-03	2.03792E-03	I	
11	7.11644E-03	3.85484E-03	I	
12	8.65943E-03	7.10190E-03	I	
13	1.05370E-02	1.26556E-02	I	
14	1.28216E-02	2.18450E-02	IX	
15	1.56016E-02	3.57361E-02	I X	
16	1.89843E-02	5.43199E-02	I X	
17	2.31005E-02	7.48160E-02	I X	
18	2.81091E-02	9.43080E-02	I X	
19	3.42038E-02	.110322	I X	
20	4.16198E-02	.122550	I X	
21	5.06438E-02	.131947	I X	
22	6.16244E-02	.139583	I X	
23	7.49859E-02	.146758	I X	
24	9.12442E-02	.154047	I X	
25	.111028	.161929	I X	
26	.135101	.170747	I X	
27	.164393	.180776	I X	
28	.200037	.192384	I X	
29	.243409	.205379	I X	
30	.296185	.220203	I X	
31	.360404	.237061	I X	
32	.438547	.256203	I X	
33	.533633	.277942	I X	
34	.649335	.302674	I X	
35	.790124	.330891	I X	
36	.961438	.363204	I X	
37	1.16990	.400161	I X	
38	1.42355	.442650	I X	
39	1.73221	.490822	I X	
40	2.10779	.545467	I X	

Figure 22. (continued).

PLOT OF FUNCTION GBR1 (1.00000E-03 : 15.0000)
 THE 1ST ARGUMENT IS CHOSEN AT 50 POINTS FROM 1.00000E-03 TO 15.0000
 USING DISTRIBUTION FUNCTION ALOG AND INVERSE DISTRIBUTION FUNCTION EXP . EACH X= 3.29136E-03

	X(OR E)	Y1	
1	9.99999E-04	.0	I
2	1.21682E-03	.0	I
3	1.48065E-03	.0	I
4	1.80169E-03	.0	I
5	2.19233E-03	.0	I
6	2.66767E-03	.0	I
7	3.24607E-03	.0	I
8	3.94988E-03	.0	I
9	4.80630E-03	.0	I
10	5.84839E-03	.0	I
11	7.11644E-03	.0	I
12	8.65943E-03	.0	I
13	1.05370E-02	.0	I
14	1.28216E-02	.0	I
15	1.56016E-02	.0	I
16	1.89843E-02	.0	I
17	2.31005E-02	.0	I
18	2.81091E-02	.0	I
19	3.42038E-02	.0	I
20	4.16198E-02	.0	I
21	5.06438E-02	.0	I
22	6.16244E-02	.0	I
23	7.49859E-02	.0	I
24	9.12442E-02	.0	I
25	.111028	.0	I
26	.135101	.0	I
27	.164393	.0	I
28	.200037	.0	I
29	.243409	.0	I
30	.296185	.0	I
31	.360404	.0	I
32	.438547	.0	I
33	.533633	.0	I
34	.649335	.0	I
35	.790124	.0	I
36	.961438	.0	I
37	1.16990	4.80731E-04	I
38	1.42355	1.30390E-03	I
39	1.73221	4.18662E-03	IX
40	2.10779	9.27795E-03	I X

Figure 22. (continued).

9.0 PHOTPREP - A CODE FOR GENERATING SOURCE INPUT TAPES FOR PROGRAM PHOTON

9.1 Code Description

The program PHOTPREP is designed to generate source tapes for processing in the PHOTON code. The source tape can be generated by either using subroutine SETUP to describe the input source distribution, or by processing a HETC output tape. Program PHOTON is capable of transporting electrons, positrons, or photons.

The information written to a PHOTON source tape is dependent on the user supplied subroutines used in program PHOTON. The user-supplied subroutines given in the program PHOTON sample problem require an unformatted record with 12 input parameters for each source particle. If this record format is changed, the MAIN routine for program PHOTPREP, the RITEG and CHECKG subroutines for program NEUTRON, and the user supplied MAIN routine for program PHOTON will have to be changed.

The subroutine hierarchy for program PHOTPREP is shown in Figure 23. A list of the subroutines used in program PHOTPREP along with their functions is given in Table 34. Finally, the suggested information written on an unformatted PHOTON source tape is shown in Table 35.

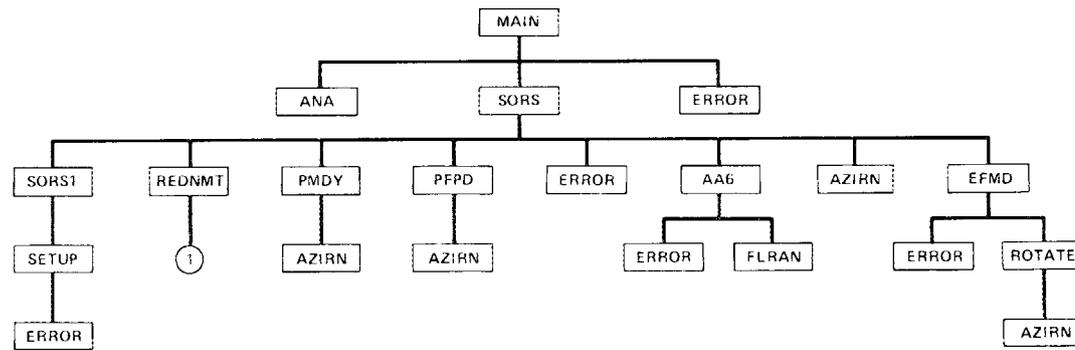


Figure 23. Subroutine Hierarchy in Program PHOTPREP.

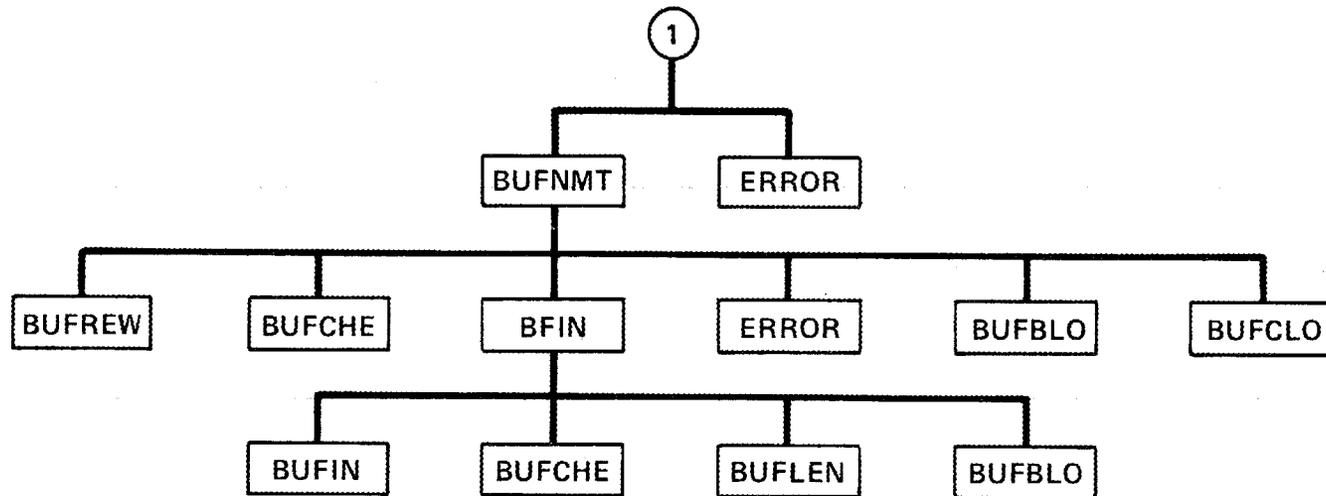


Figure 23. (continued).

Table 34. Subroutine Functions in Program PHOTPREP

Subroutine	Function
AA6	Used with program SPECT (linear or nonlinear) to obtain fission gamma energy. SPECT is part of the CALOR ³ code system.
ANA	User supplied analysis routine for the source.
AZIRN	Selects the azimuthal angle uniformly in theta (θ)
BFIN	A buffer routine called by routine BMFNMT. This routine is only used at ORNL.
BUFNMT	Initiates the system routines required to read a HETC buffered output tape. This routine is only used at ORNL. (Called from REDNMT)
EFMD	Generates electrons (or positrons) from muon decay.
ERROR	Called at various locations in the program to yield a traceback map if an error occurs.
FLRAN	Random number generator written in ASSEMBLER.
MAIN	Reads the input cards, initializes the random number generator, and generates the PHOTON source tape.
PFPD	Generates photons from Pi zero decay.
PMDY	Generates pions from muon decay.
RANFNY	Function to select a random number.
REDNMT	Reads an output history tape from the HETC code system.
ROTATE	Rotates coordinates from relative to fixed coordinate system.
SLFRAF	Function to generate a random number over the interval -1 to +1.
SETUP	Default source parameter routine called from SORS1 to generate source tape for program PHOTON (usually user supplied).
SORS	Generates PHOTON source history tapes from either HETC collision tape or from routine SETUP.
SORS1	Generates the source history tape to be read by program PHOTON.

Table 35. Information Written on Program PHOTON
Input Source Tape

Parameter	Description
NGO	Source Tape Control Parameter NGO = 1 Call Error NGO = 2 Source Particle Information NGO = 3 End of Batch NGO = 4 End of Run
KO	Source Particle Type KO = 1 Positron KO = 0 Photon KO = -1 Electron
E0	Source Particle Energy (MeV)
X0,Y0,Z0	Source Particle Location
U0,V0,W0	Source Particle Direction Cosines
WATE	Source Particle Weight
NOCAS	Source Particle Number
IRI	Source Particle Input Region Number (usually 1.0)

9.2 Input Requirements

The following input cards are required in order to execute a PHOTPREP case. Default values are given in brackets ([]).

Card 1: Format (20A4)

TITLE Problem title card

Card 2: Format (10I5)

NHST Logical unit containing a HETC generated input source.

IN Input card unit.

IO Printed output unit.

ISORS 0/1 - Process a HETC generated input source
tape/generate source using subroutine SETUP

ISORT -1/0/1 - Execute the programming in subroutine SORS to obtain low energy photons and fission photons when processing a HETC generated input source tape./Skip/Execute the programming in subroutine SORS to obtain low energy photons (but not fission photons) when processing a HETC generated input source tape.

ISORU 0/1 - Skip/Execute the programming in subroutine SORS to obtain the electrons and positrons from muon decay when processing a HETC generated input source tape.

ISORV 0/1 - Skip/Execute the programming in subroutine SORS to obtain the electrons from π^- to μ^- decay when processing a HETC generated source tape.

MAXCAS Number of source particles per batch. (IF reading an HETC tape, must equal MAXCAS on HETC tape.)

NT Number of batches of source particles per run.

NPRT Number of generated source particles printed.

Card 3: Format (3Z4)

RANDS(I,I=2,4) Random number seed.

9.3 Input Data Notes

NHST The current version requires NHST to be greater than or equal to 58 if a buffered HETC tape is to be processed. If NHST is less than 58, a standard FORTRAN I/O tape is read. Typically, NHST = 59 implies buffered tape and NHST = 9 implies standard FORTRAN I/O tape.

ISORS For most applications involving ionization chamber analysis, this parameter will be set to one and the source will be generated using subroutine SETUP.

ISORT The current version of subroutine AA6 requires uranium to be the first element (LELEM = 1) in media 3 (NMED = 3) in

order to pick up the fission photons. Therefore, if ISORT = -1, care must be taken by the user if a different material/media setup is used. (The IF test in subroutine AA6 could be changed to accommodate the user's setup).

MAXCAS When processing an HETC tape, this value must equal the value used to produce the HETC tape.

NT When processing an HETC tape, this parameter can be less than the total number of batches processed in HETC.

NPRT A large value for NPRT could produce a significant amount of output. The counter for NPRT loops on the source particle name. Therefore, for HETC runs, there could be many prints per incident source particle.

9.4 I/O File Requirements

File	Unit	Description	Required
IN	5	Card Input	Always
IO	6	Printed Output	Always
ISOR	10	PHOTON Source Output Tape	Always
NHST	59 or 9	HETC Source Input Tape	IF ISORS=0

9.5 JCL Requirements

The job control language (JCL) needed to run a PHOTPREP case at X-10 is:

(Job Card, route and jobparm cards)

```
//PHOTPREP EXEC PGM=PHOTPREP,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
(DD Cards for NHST (if ISORS=0)
(DD Cards for PHOTON source output tape)
//SYSIN DD *
(Input Data)
/*
//
```

9.6 Sample Problem

The JCL and input cards for a separate sample problem for program PHOTPREP is shown in Figure 24 using the default parameters in subroutine SETUP. This sample problem will produce 10 batches of 200 electrons, each with energy equal to 10 MeV, spatial position X,Y,Z equal to 0.0, direction cosines A,B equal to 0.0, G equal to 1.0, particle weight equal to 1.0 and particle region equal to 1.0. A complete listing of the JCL and input cards for a typical sample problem used in ionization chamber analysis is given in conjunction with the PHOTON program sample problem. Likewise, the PHOTPREP selected outputs are shown with the PHOTON selected outputs. The PHOTPREP sample problem generates a PHOTON source tape modeling a mono-directional ^{252}Cf photon source distributed over the face of an ionization chamber using subroutine SETUP. The sample problem generated 10 batches of 200 particles written on logical unit 10 for subsequent use in program PHOTON.

```
//JOJPREP JOB (24337,IO2),'JO JOHNSON 6025',TIME=(1,00)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
//A EXEC PGM=PHOTPREP,REGION=1024K
//STEPLIB DD DSN=X.JOJ24337.PROG,DISP=SHR
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT10F001 DD UNIT=SYSDA,DISP=(NEW,PASS),
// DSN=&&SORS,SPACE=(TRK,(40,20)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//SYSIN DD *
SAMPLE INPUT TO EXECUTE A PHOTPREP CASE
  59   5   6   1   0   0   0 200   10   10
378E26A5A243
/*
//
```

Figure 24. Complete Listing of JCL and Input for PHOTPREP Sample Problem.

10.0 PHOTON - A CONTINUOUS ENERGY MONTE CARLO CODE FOR TRANSPORTING PHOTON RADIATION INCIDENT ON AN IONIZATION CHAMBER

10.1 Code Description

The program PHOTON⁷ is a continuous energy Monte Carlo code that simulates the development of electromagnetic cascade showers in various media. More specifically, PHOTON uses the Boltzmann transport equation to model the physics of photon, electron, and positron transport through matter. The approach in program PHOTON is to use the cross sections and material data produced in program PECSP to simulate the two basic energy loss mechanisms, i.e., collision and radiation, present in an electromagnetic cascade shower. Program PECSP uses theoretical (and sometimes empirical) formulas to compute the physical quantities needed for the shower simulation and prepares them in a suitable format. Presently, pair production, Compton scattering from a "free" electron, and photoelectric processes are the only photon interactions considered in program PHOTON. These processes all have finite cross sections which allow discrete interactions to be simulated. The interactions for electron and positron transport include elastic Coulomb scattering off the nucleus, inelastic scattering off the atomic electrons, bremsstrahlung production, and electron-positron annihilation. The electron and positron processes (except annihilation) all have cross sections which become very large as the energy of the electron or positron approaches zero. The exact values of the total cross sections are not well known and therefore it is not practical to try and simulate every electron or positron interaction. Because these events are considered low momentum

events and do not result in large fluctuations in the electromagnetic shower behavior, they are lumped together and treated in a continuous manner. Program PHOTON (and PECSP) use electron (or positron) and photon cutoff energies given by the variables AE and AP respectively to distinguish between a discrete interaction or an interaction modeled using continuous energy loss formalisms. PHOTON considers any electron or positron interaction that produces low energy electrons (delta-rays) with total energy greater than or equal to AE, or a photon with energy greater than or equal to AP, a discrete event. All other interactions are considered continuous and therefore result in continuous energy loss and direction changes to the electron or positron between discrete interactions.

The random walk procedure employed in PHOTON is based on the integral emergent particle density formalism of the Boltzmann transport equation. The equation introduces the particle into the system according to the natural source function. The particle travels to the site of the first collision as determined by the transport kernel. At the collision site, the particular interaction process is chosen using branching ratios which relate the partial cross section of a particular reaction to that of the total cross section. Once the type of interaction has been selected, the parameters for the product particles are chosen and stored. If there is more than one product particle, the particle with the lowest energy is put on top of the storage array. The transport and collision kernels are applied successively until the particle is

absorbed, escapes, or drops below a predetermined cutoff energy. Once the initial particle has been transported, the product particles resulting from the initial particle interactions are transported in a likewise manner. When the initial particle and all product particles have been transported (including particles resulting from successive generations of product particles) and the storage stack is empty, the simulation of one electromagnetic cascade shower (history) is complete. The entire process is repeated until all batches of histories are transported.

10.2 Code Implementation

The program PHOTON is a modified version of the EGS3⁷ code. As such, the implementation procedures used in program PHOTON follow closely the implementation procedures used in EGS3. The name was changed to accommodate the program naming convention in MICAP.

The program PHOTON consists of two subroutines, HATCH and SHOWER, which the user interacts with through subroutine call statements. These subroutines call the subroutines in program PHOTON which simulate the actual physical processes. These subroutines in turn call other subroutines in program PHOTON including the two user-supplied subroutines, HOWFAR and AUSGAB. Subroutine HOWFAR determines the geometry and subroutine AUSGAB determines the output and scoring. The user communicates with program PHOTON through the use of various Common variables. To use program PHOTON, the user must write a "User Code" consisting of a MAIN program, subroutines HOWFAR and AUSGAB, and any additional auxiliary subroutines the user feels will facilitate the problem

solution. Usually, MAIN will perform any initialization needed for the geometry routine HOWFAR, and set some of the values of certain Common variables used. MAIN then calls subroutine HATCH to perform necessary once-only initialization and read in the cross sections and material data produced by the PECSP program. Once the initialization process is complete, MAIN calls subroutine SHOWER when desired. Each call to SHOWER results in the generation of one history. The arguments to subroutine SHOWER specify the parameters of the incident particle and allow the user flexibility in the choice of source distributions. In summary, the user communicates with program PHOTON through two user-callable subroutines - HATCH and SHOWER, two user-supplied subroutines HOWFAR and AUSGAB, and Common block variables. The sequence of operations needed for the correct operation of program PHOTON is:

1. Pre-HATCH call initialization
2. HATCH call
3. Initialization for HOWFAR
4. Initialization for AUSGAB
5. Determination of Incident Particle Parameters
6. SHOWER call
7. AUSGAB call

Step four may be repeated as often as desired, depending on what type information the user requires.

As stated earlier, the program PHOTON is a modified version of the EGS3 code. A detailed description of the physics used in program PHOTON can be found in Ref. 7. The subroutine hierarchy of

program PHOTON is shown in Fig. 25. A list of the program subroutines and their functions is given in Table 36. The Common Blocks and their associated variables were reproduced from the EGS3 manual for completeness and are presented in Tables 37 through 48.

10.3 Input Requirements

COMBINATORIAL GEOMETRY INPUT INSTRUCTIONS

CARD CGA: Format (2I5,10X,10A6)

IVOPT Option which defines the method by which region volumes are determined; if

0, volumes set equal to 1,

1, concentric sphere volumes are calculated,

2, slab volumes (1-dim.) are calculated, (not operational)

3, volumes are input by card.

IDBG If IDBG > 0, subroutine PR is called to print results of combinatorial geometry calculations during execution. Use only for debugging.

JTY Alphanumeric title for geometry input (columns 21-80).

CARDS CGB: Format (2X,A3,1X,I4,6D10.3)

ITYPE Specifies body type or END to terminate reading of body data (for example BOX, RPP, ARB, etc.). Leave blank for continuation cards.

IALP Body number assigned by user (all input body numbers must form a sequence set beginning at 1). If left blank, numbers are assigned sequentially. Either assign all or none of the numbers. Leave blank for continuation cards.

FPD(I) Real data required for the given body as shown in Table 49. This data must be in centimeters.

Note: One set of CGB cards is required for each body and for the END card (see Table 49). Leave columns 1-6 blank on all continuation cards.

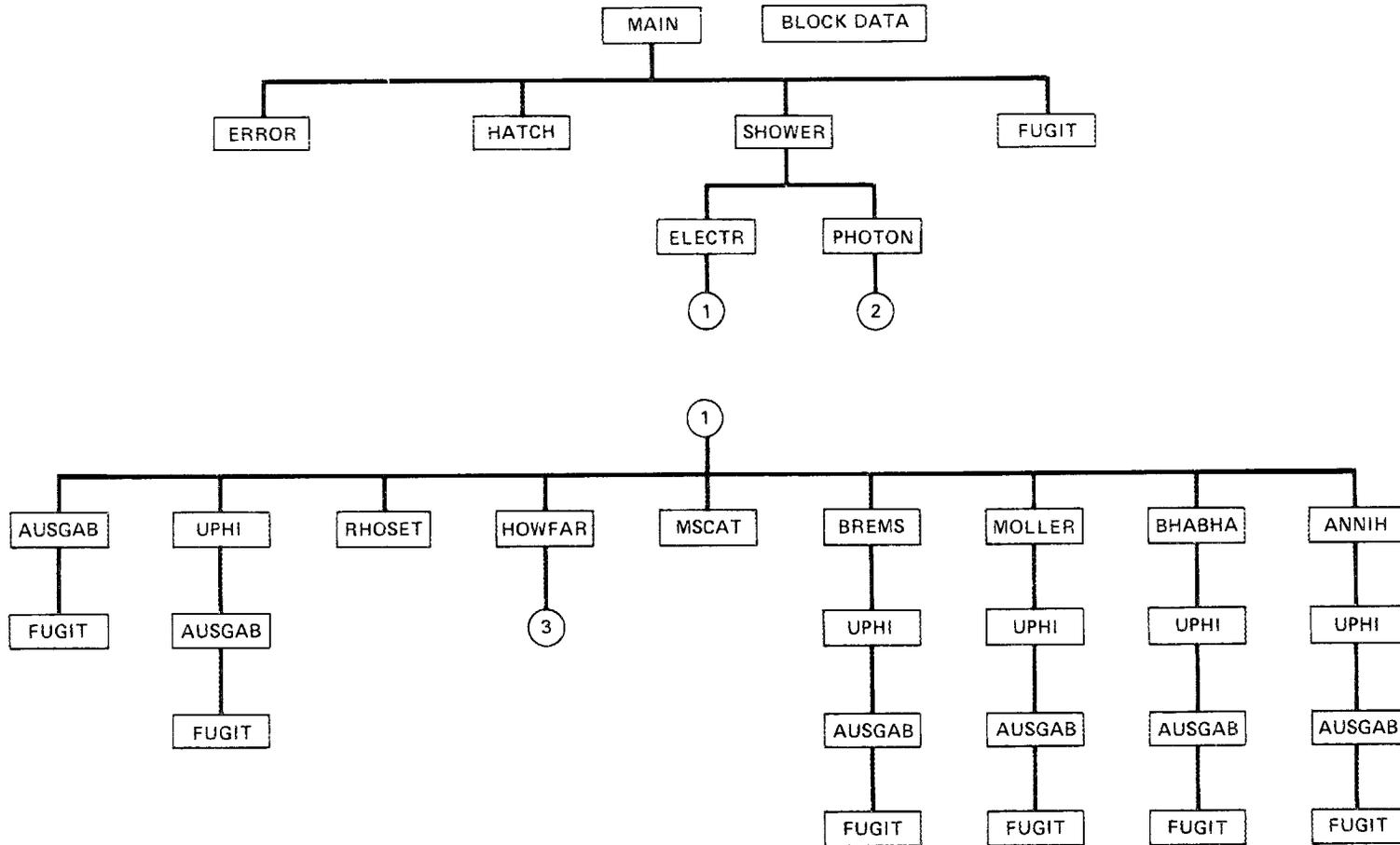


Figure 25. Subroutine Hierarchy in Program PHOTON.

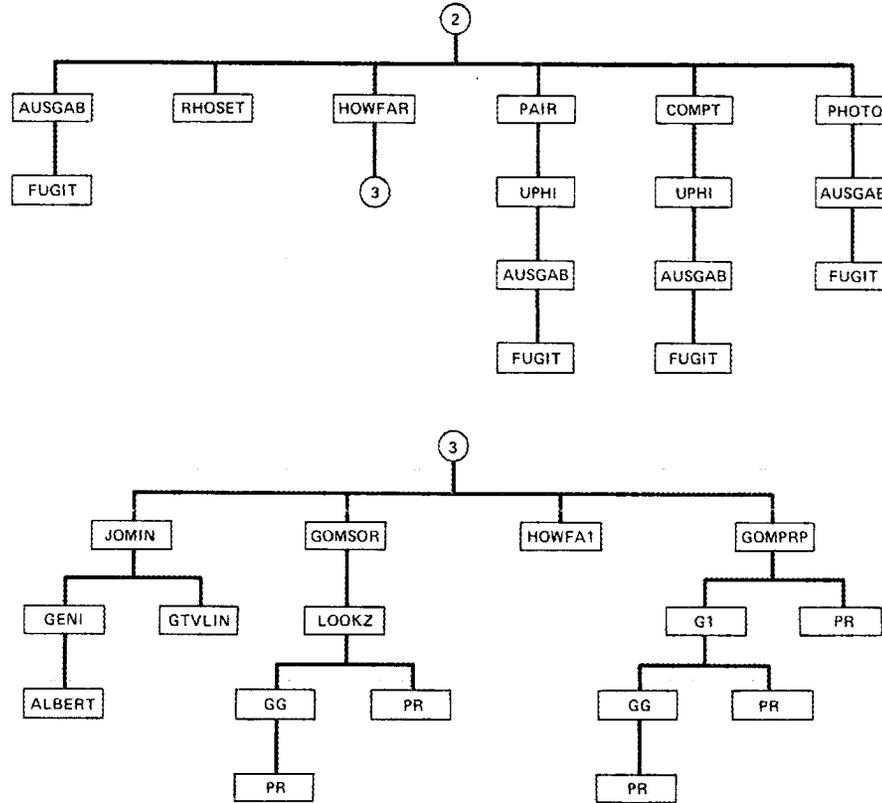


Figure 25. (continued).

Table 36. Subroutine Functions in Program PHOTON

Subroutine	Function
ALBERT	Processes arbitrary polyhedron body data.
ANNIH	Performs physics of two photon electron - positron annihilation.
AUSGAB	User supplied routine which scores and outputs the results.
BHABHA	Performs physics of electron Bhabha scattering with the atomic electrons.
BREMS	Performs physics of electron bremsstrahlung production.
COMPT	Performs physics of photon and electron compton scattering.
ELECTR	The driver routine for the electron and positron random walk processes.
FLRAN	Random number package written in ASSEMBLER.
FUGIT	User supplied routine called from AUSGAB and MAIN to perform scoring.
GENI	Outputs the geometry input information and places the combinatorial geometry data in the proper locations in blank common.
CG	The workhorse of the combinatorial geometry package, computes distances to intersections for all body types.
GOMPRP	Determines the boundary crossings between the present and next collision sites.
GOMSOR	Initializes the particle with respect to the geometry data.
GTVLIN	Reads in or calculates the value of each region in the geometry.
G1	The control routine for the combinatorial geometry package.

Table 36. (continued)

Subroutine	Function
HATCH	Reads in the cross sections and material data processed in PECSP.
HOWFAR	User supplied routine which specifies the geometry and links the geometry to the random walk process.
HOWFAL	User supplied routine called from HOWFAR which determines closest boundary of a media change and sets DNEAR equal to it. This reduces the number of calls to the geometry initialization.
JOMIN	Controls the input of the geometry data, determines the total amount of storage needed and the lengths of the geometry arrays, and initializes the geometry arrays.
LOOKZ	Returns the combinatorial geometry zone of point (X,Y,Z) so tracking can be initialized.
MAIN	User supplied routine which usually sets certain parameters in PHOTON Common blocks, calls HATCH to establish media data, calls HOWFAR to initialize the geometry, calls SHOWER to initiate the cascade, and performs any other user specified functions.
MOLLER	Performs physics of electron Moller scattering with the atomic electrons.
MSCAT	Performs physics of multiple electron scattering.
NORML	Calculates the unit vector normal to combinatorial body NASC.
PAIR	Performs physics of photon pair production.
PHOTO	Performs physics of photon photoelectric effect.

Table 36. (continued)

Subroutine	Function
PHOTON	The driver routine for the photon random walk processes.
PR	Called from various locations in the combinatorial geometry package whenever intermediate output or debugging output is required.
RHOSET	Sets the material density.
SHOWER	Reads in a source particle from the source tape and initiates the random walk process.
UPHI	Stacks the random walk products in the STACK Common block.

Table 37. Definitions of Variables in BOUNDS Common

Variable	Definition
ECUT	Array of regions' charged particle cutoff energies (in MeV).
PCUT	Array of regions' photon cutoff energies (in MeV).
VACDST	Distance to transport in vacuum (default = 1.0E+08).

Table 38. Definitions of Variables in MEDIA Common

Variable	Definition
NMED	Number of media being used (default = 1).
MEDIA	Array containing names of media (default is NaI).
RLC	Array containing radiation lengths of the media (in cm).
RLDU	Array containing radiation lengths of the media in distance units established by DUNIT.
RHO	Array containing density of the media (in gm/cm ³).

Table 39. Definitions of Variables in EPCONT Common

Variable	Definition
EDEP	Energy deposited (in MeV) [Double Precision].
TUSTEP	Total (curved) step length requested.
USTEP	User (straight line) step length requested and granted.
TVSTEP	Actual total (curved) step length to be transported.
VSTEP	Actual (straight line) step length to be transported.
IDISC	User discard request flag. IDISC = 1 means user requests immediate discard, IDISC=-1 means user requests discard after completion of transport, and DISC=0 (default) means no user discard requested.
IROL	Index of previous region.
IRNEW	Index of new region.
EOLD	Charged particle (total) energy at beginning of step (in MeV).
ENEW	Charged particle (total) energy at end of step (in MeV).
BETA	Beta for present particle.
BETA2	Beta squared for present particle.
IAUSFL	Array of flags for turning on various calls to AUSGAB.
EKE	Kinetic energy of charged particle (in MeV).
ELKE	Natural logarithm of EKE.
GLE	Natural logarithm of photon energy.
TSCAT	See Ref. 7.

Table 40. Definitions of Variables in MISC Common

Variable	Definition
MED	Array containing medium index for each region.
DUNIT	The distance unit to be used. DUNIT=1 (default) establishes all distances in cm; whereas, DUNIT=2.54 establishes all distances in inches.
KMPI	FORTTRAN unit number from which to read material data (default=12).
KMPO	FORTTRAN unit number on which to "echo" (e.g., print out) material data (default = 8).
RHOR	Array containing the density for each region (gm/cm^3). If this is different than the default density for the medium for that region, the cross sections and stopping powers are scaled appropriately. The user may also let the density vary continuously by means of the subroutine RHOSSET. CALL RHOSSET (RHOL) should return the local density, RHOL, at the position of the current particle. The default RHOSSET uses $\text{RHOL}=\text{RHOR}(\text{IR}(\text{NP}))$.

Table 41. Definitions of Variables in RANDOM Common

Variable	Definition
IXX	Random number generated seed (default=123456789).

Table 42. Definitions of Variables in STACK Common

Variable	Definition
E	Total energy (in MeV) [Double Precision].
X,Y,Z	Position of particle in units established by DUNIT.
U,V,W	Direction cosines of particles (not necessarily normalized).
DNEAR	A lower bound of distance from (X,Y,Z) to nearest surface of current region.
WT	Statistical weight of current particle (default=1.0). To be used in conjunction with importance sampling as determined by user.
IQ	Integer charge of particle (+1,0,-1).
IR	Index of particle's current region.
NP	The stack pointer, i.e., the particle currently being pointed to. Also, the number of particles on the stack.

Note: This COMMON block contains the information about the particles currently in the shower. All of the above variables are arrays except NP.

Table 43. Definitions of Variables in THRESH Common

Variable	Definition
RMT2	Twice the electron rest mass energy (in MeV).
RMSQ	Electron rest mass energy squared (in MeV-squared).
AP	Array containing PECSP lower photon cutoff energy for each medium (in MeV).
UP	Array containing PECSP upper photon cutoff energy for each medium (in MeV).
AE	Array containing PECSP lower charged particle cutoff energy for each medium (in MeV).
UE	Array containing PECSP upper charged particle cutoff energy for each medium (in MeV).
TE	Same as AE except kinetic energy rather than total energy.
THMOLL	Array containing the Moller threshold energy (THMOLL=AE+TE) for each medium (in MeV).

Table 44. Definitions of Variables in UPHIOT Common

Variable	Definition
THETA	Collision scattering angle (polar).
SINTHE	Sine of THETA.
COSTHE	Cosine of THETA.
SINPHI	Sine of PHI (the azimuthal scattering angle of the collision).
COSPHI	Cosine of PHI.
PI	Pi.
TWOPI	Twice pi.

Table 45. Definitions of Variables in USEFUL Common

Variable	Definition
MEDIUM	Index of current medium. If vacuum, then MEDIUM=0.
MEDOLD	Index of previous medium.
RM	Electron rest mass energy (in MeV).
PRM	"Precision" electron rest mass energy (in MeV) [Double Precision].
PRMT2	Twice PRM [Double Precision].

Table 46. Definitions of Variables in PAREM Common

Variable	Definition
XB(3)	Coordinates of the starting point of the present path.
WB(3)	Direction cosines of particle trajectory, (Equal to U,V,W).
WP(3)	Temporary storage of WB(3).
XP(3)	Temporary storage of XB(3).
RIN	Distance to entry calculated in routine GG.
ROUT	Distance to exit calculated in routine GG.
PINF	Machine infinity. (1.00E+20)
DIST	Distance from XB(3) to present point.
IR	Combinatorial zone of present particle position.
IDBG	Set non-zero to initialize a debug printout.
IRPRIM	Next region to be entered after a call of routine G1.
NASC	Body number of last calculated intersection. Set negative to indicate source or collision point not on a body surface.
LSURF	Surface of body NASC where intersection occurred. Positive if particle is entering the body and negative when exiting.
NBO	Body number and a sign used to define zones. Input in zone description as positive when zone is contained in body and as negative if zone is outside body.
LRI	Entry surface calculated in routine GG.
LRO	Exit surface calculated in routine GG.
KLOOP	Trajectory index of present path incremented in routine G1.

Table 46. (continued)

Variable	Definition
LOOP	INEXT of last trajectory calculated for body NBO. If LOOP is equal to KLOOP, routine GG returns immediately with old values in RIN, ROUT, LRI, and LRO.
ITYPE	Body type of body NBO (indicates BOX, SPH, etc.).
NOA	Not used.

Table 47. Definitions of Variables in ORGI Common

Variable	Definition
DISTO	Distance from point XB(3) to next scattering point. Used in routine G1 to avoid calculating the next zone if a scattering event occurs before the intersection.
MARKG	Set to 1 in routine G1 if trajectory end point is reached before next intersection, otherwise set to 0.
NMEDG	Zone number IR from a LOOKZ call.
NBLZ	Packed word containing both input zone and code zone numbers.
BLZOLD	Packed word containing input and code zone numbers for the previous collision.

Table 48. Definitions of Variables in DBG Common

Variable	Definition
N	Starting location in MA array of data for zone IRP.
NUM	Ending location in MA array of data for zone IRP.
LOCAT	Location in MA array of address where data for current body is located in the FPD array.
ISAVE	Index in MA array of next body intersected ($N \leq \text{ISAVE} \leq \text{NUM}$).
INEXT	Pointer to first zone searched in MA array for next body (Equal to $\text{ISAVE} + 2$).
IRP	Next zone searched to determine which zone the current body is in.
SMIN	Distance to intersection.
INEX	Pointer to next zone searched in MA array if INEXT is not the zone intersected (Equal to $\text{INEXT} + 1$).

Table 49. Combinatorial Geometry Body Data Input Requirements in Program PHOTON

Body Type	Card Columns								Number of Cards Needed
	ITYPE 3-5	IALP 7-10	11-20	Real Data Defining Particular Body					
				21-30	31-40	41-50	51-60	61-70	
Box	BOX	IALP is assigned by the user or by the code if left blank.	Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Right Parallelepiped	RPP		Xmin	Xmax	Ymin	Ymax	Zmin	Zmax	1
Sphere	SPH		Vx	Vy	Vz	R	-	-	1
Right Circular Cylinder	RCC		Vx	Vy	Vz	Hx	Hy	Hx	1 of 2
			R	-	-	-	-	-	2 of 2
Right Elliptic Cylinder	REC		Vx	Vy	Vz	Hx	Hy	Hx	1 of 2
			R1x	R1y	R1z	R2x	R2y	R2z	2 of 2
Ellipsoid	ELL		V1x	V1y	V1z	V2x	V2y	V2z	1 of 2
			L	-	-	-	-	-	2 of 2
Truncated Right Cone	TRC		Vx	Vy	Vz	Hx	Hy	Hx	1 of 2
			L1	L2	-	-	-	-	2 of 2
Right Angle Wedge	WED		Vx	Vy	Vz	H1x	H1y	H1z	1 of 2
			H2x	H2y	H2z	H3x	H3y	H3z	2 of 2
Arbitrary Polyhedron	ARB		V1x	V1y	V1z	V2x	V2y	V2z	1 of 5
			V3x	V3y	V3z	V4x	V4y	V4z	2 of 5
			V5x	V5y	V5z	V6x	V6y	V6z	3 of 5
			V7x	V7y	V7z	V8x	V8y	V8z	4 of 5

Face Descriptions (see note below)

Termination of Body Input Data END

NOTE: Card 5 of the arbitrary polyhedron input contains a four-digit number for each of the six faces of an ARB body. The format is 6D10.3, beginning in column 11. See the ARB write-up in Ref. 4 for an example.

CARDS CGC: Format (2X,A3,I5,9(A2,I5))

IALP IALP must be a nonblank for the first card of each set of cards defining an input zone. If IALP is blank, this card is treated as a continuation of the previous zone card. IALP = END denotes the end of zone description.

NAZ Total number of zones that can be entered upon leaving any of the bodies defined for this input region (some zones may be counted more than once). Leave blank for continuation cards for a given zone. (If $NAZ \leq 0$ on the first card of the zone card set, then it is set to 5.) This is used to allocate blank common. Alternate IIBIAS(I) and JTY(I) for all bodies defining this input zone.

IIBIAS(I) Specify the "OR" operator if required for the JTY(I) body.

JTY(I) Body number with the (+) or (-) sign as required for the zone description.

Note: Input zone specification cards. One set of cards required for each input zone, with input zone numbers being assigned sequentially.

CARDS CGD: Format (14I5)

MRIZ(I) MRIZ(I) is the medium number in which the "Ith" input zone is contained ($I = 1$, to the number of input zones). Region numbers must be sequentially defined from 1.

CARDS CGE: Format (14I5)

MMIZ(I) MMIZ(I) is the medium number in which the "Ith" input zone is contained ($I = 1$, to the number of input zones). Medium numbers must be sequentially defined from 1. (Media 0 is used for an external void and media 1000 is used for internal voids.)

CARDS CGF: Format (7D10.5) (Omit if IVKOPT \neq 3)

VNOR(I) Volume of the "Ith" region ($I = 1$ to MXREG, the number of regions).

10.4 I/O File Requirements

File	Unit	Description	Required
IN	5	Card Input	Always
IO	6	Printed Output	Always
IPUN	7	Punched Output	If user specified
KMPO	8	PECSP Cross Section and Material Data Output Tape	Always
ISOR	10	Source Input Tape	Always
KMPI	12	PECSP Cross Section and Material Data Input Tape	Always
IGEOM	16	Geometry Scratch Unit	Always

10.5 JCL Requirements

The Job Control Language (JCL) needed to run a PHOTON case at X-10 is:

```
(Job card, route and jobparm cards)
//PHOTON EXEC FORTQCLG,REGION=2048K
//FORT.SYSIN DD *
(User supplied subroutines)
/*
//LKED.LMOD DD DSN=X.JOJ24337.PROG, DISP=SHR
//LKED.SYSIN DD *
  INCLUDE LMOD(PHOTON)
  ENTRY MAIN
//GO.FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT07F001 DD SYSOUT=B
(DD cards for input PHOTON source tape on logical unit 10)
(DD cards for input and output PECSP cross section and
material data tape on logical units 12 and 8 respectively)
(DD cards for combinatorial geometry scratch
data on logical unit 16).
//SYSIN DD *
(Input Data Cards)
/*
//
```

10.6 Sample Problem

A complete listing of the JCL and input cards for the sample problem is given in Fig. 26 and some selected output are shown in Fig. 27. The problem demonstrates the generation and processing of a ^{252}Cf photon source distribution incident on an ionization chamber. More specifically, the mono-directional ^{252}Cf distribution is generated in subroutine SETUP of program PHOTPREP and stored on logical unit 10 in the first step of the sample problem.

In the second step, the user supplied subroutines i.e., MAIN, AUSGAB, HOWFAR, etc., are compiled into program PHOTON to transport the ^{252}Cf photon source distribution and obtain the ionization chamber response. This sample problem demonstrates the setup for obtaining the ionization chamber response due to a primary radiation source. If the radiation source is of a secondary nature (e.g. a secondary photon source generated in program NEUTRON), the setup would be exactly the same except the PHOTPREP step would be eliminated, and the source tape would be the one generated by the NEUTRON case.

```

//JOJPHOTN JOB (24337,IO2),'JO JOHNSON 6025',TIME=(1,00)
/*ROUTE PRINT RMT84
/*ROUTE PUNCH RMT84
//A EXEC FORTQCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
      SUBROUTINE SETUP(K,E,X,Y,Z,A,B,G,WT,IRI)
      COMMON/RANDOM/RANDS(4)
      DIMENSION ES(22),PES(22)
      DATA ES/0.01,0.02,0.03,0.045,0.07,0.1,0.15,0.3,0.45,0.7,
1 1.0,1.5,2.0,2.5,3.0,4.0,5.0,6.0,7.0,8.0,10.0,14.0/
      DATA PES/0.0,1.124E-2,2.235E-2,3.878E-2,6.553E-2,9.671E-2,
1 1.463E-1,2.794E-1,3.918E-1,5.415E-1,6.734E-1,8.144E-1,
2 8.946E-1,9.402E-1,9.660E-1,9.891E-1,9.966E-1,9.990E-1,
3 9.998E-1,1.000E+0,1.000E+0,1.000E+0/
      REAL*8 VAL
      DATA XMAX/3.2131/,YMAX/3.2131/,RMAX/3.2131/
      K=0
      CALL FLRAN(RANDS(1),VAL)
      DO 5 I=2,22
      IF(VAL.LE.PES(I))GO TO 7
5 CONTINUE
      CALL ERROR
7 CONTINUE
      CALL FLRAN(RANDS(1),VAL)
      E=ES(I-1)+VAL*(ES(I)-ES(I-1))
10 CALL FLRAN(RANDS(1),VAL)
      X=XMAX-2.0*XMAX*VAL
      CALL FLRAN(RANDS(1),VAL)
      Y=YMAX-2.0*YMAX*VAL
      IF((X**2+Y**2).GT.(RMAX**2))GO TO 10
      Z=0.0
      A=0.0
      B=0.0
      G=1.0
      WT=1.0
      IRI=1
      RETURN
      END
/*
//LKED.LMOD DD DSN=X.JOJ24337.PROC,DISP=SHR
//LKED.SYSIN DD *
      INCLUDE LMOD(PHOTPREP)
      ENTRY MAIN
//GO.FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT10F001 DD UNIT=SYSDA,DISP=(NEW,PASS),

```

Figure 26. Complete Listing of JCL and Input for PHOTON Sample Problem.

```

// DSN=&&SORS,SPACE=(TRK,(40,20)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=6447,BUFL=8184,BUFNO=1)
//SYSIN DD *
  59   5   6   1   0   0   0  200  10
378E26A5A243
/*
//STP2 EXEC FORTQCLG,REGION=2048K
//FORT.SYSPRINT DD DUMMY
//FORT.SYSIN DD *
C   MAIN (TO OVERRIDE ORIGINAL)
    COMMON/GREAT/XMAX,YMAX,ZMAX
    COMMON/MEDIA/NMED,MEDIA(24,10),RLC(10),RLDU(10),RHO(10),MSGE(10),
1  MGE(10),MSEKE(10),MEKE(10),MLEKE(10),MCMFP(10),MRANGE(10)
    COMMON/MISC/KMPI,KMPO,DUNIT,MED(20),RHOR(20)
    COMMON/JUNK/ZCUT(510),ANS(12,510),NUM,J,FRONT,SIDE,BACK
    COMMON/HELPG/NPOLD,IQOLD,NJEFF
    COMMON/EOR/NCASES,NT
    COMMON/BOUNDS/ECUT(20)
    COMMON/PULS/IBO1(100),STO1(20000),IBO2(100),STO2(20000),M,
1  STO3(20000),STO4(20000)
    REAL*8 SUM1,SUM2,SUM3
    INTEGER MEDARR(24,8)
1   /'A','L','U','M','I','N','U','M',16*1H ,
2   'T','E',' ','G','A','S',18*1H ,
3   'T','E',' ','P','L','A','S','T','I','C',14*1H ,
4   'P','O','L','Y','S','T','Y','R','E','N','E',13*1H ,
5   'A','I','R',21*1H ,
6   'M','I','C','A','R','T','A',17*1H ,
7   'L','U','C','I','T','E',18*1H ,
8   'B','R','A','S','S',19*1H /
10010 DO 10011 J=1,24
      MEDIA(J,1)=MEDARR(J,1)
      MEDIA(J,2)=MEDARR(J,2)
      MEDIA(J,3)=MEDARR(J,3)
      MEDIA(J,4)=MEDARR(J,4)
      MEDIA(J,5)=MEDARR(J,5)
      MEDIA(J,6)=MEDARR(J,6)
      MEDIA(J,7)=MEDARR(J,7)
      MEDIA(J,8)=MEDARR(J,8)
10011 CONTINUE
      MED(1)=1
      MED(2)=2
      MED(3)=3
      MED(4)=4
      MED(5)=5
      MED(6)=6
      MED(7)=7
      MED(8)=8
      MED(9)=0

```

} NOTE: MED (I)=I EXCEPT FOR LAST ONE
THEN MED(NMED+1)=0

Figure 26. (continued).

```

M=0
NMED=8
NJEFF=NMED+1
NBATCH=0
FRONT=0. }
BACK=0. } LEAKAGE ENERGY
SIDE=0. }
DO 6618 I=1,80201
6618 IB01(I)=0.
READ(10) NCASES,NT
DO 30 J=1,12
DO 30 I=1,510
30 ANS(J,I)=0.0
I510=1
ZCUT(1)=20.0
CALL HATCH
XMAX=10.0 }
YMAX=10.0 } DEFINES LOW DENSITY AIR BOX SURROUNDING
ZMAX=20.0 } GEOMETRY (SEE SUBROUTINE HOWFAR)
J=1
66 READ(10) NGO,IQI,EI,XI,YI,ZI,UI,VI,WI,WTI,NUM,IRI
IF(NUM.LE.5)
1 WRITE(6,600) NGO,IQI,EI,XI,YI,ZI,UI,VI,WI,WTI,NUM,IRI
600 FORMAT(2I5,8E12.4,2I5)
GO TO (1,2,3,4),NGO
1 CALL ERROR
2 NPOLD=9999
IQOLD=9999
CALL SHOWER(IQI,EI,XI,YI,ZI,UI,VI,WI,IRI,WTI)
GO TO 66
3 NBATCH=NBATCH+1
J=J+1
GO TO 66
4 KK=2
CALL FUGIT(KK,NUM,IARG,DNUM,DNUM,DNUM,DNUM,DNUM,DNUM,DNUM)
IF(NBATCH.NE.NT) CALL ERROR
DO 50 I=1,I510
DO 40 J=1,NBATCH
ANS(J,I)=ANS(J,I)/NCASES
40 ANS(11,I)=ANS(11,I)+ANS(J,I)
50 ANS(11,I)=ANS(11,I)/NBATCH
XBATCH=NBATCH
IF(NBATCH.EQ.1)GO TO 602
DO 60 I=1,I510
DO 70 J=1,NBATCH

```

Figure 26. (continued).

```

70 ANS(12,I)= (ANS(11,I)-ANS(J,I))*2 + ANS(12,I)
   IF(ANS(11,I).EQ.0.0) GO TO 60
   ANS(12,I)= (SQRT(ANS(12,I)/(NBATCH-1)))/ANS(11,I)*100.
   ANS(12,I)=ANS(12,I)/SQRT(XBATCH)
60 CONTINUE
602 WRITE(6,80) (ZCUT(I),ANS(11,I),ANS(12,I),I=1,I510)
80 FORMAT('1','ZCUT=',1PE13.5,5X,'AVERAGE ENERGY DEPOSITED=',
1 1PE13.5,5X,'STANDARD DEVIATION (%)=',1PE13.5)
   NUMBER=NCASES*NBATCH
   FRONT=FRONT/NUMBER
   SIDE=SIDE/NUMBER
   BACK=BACK/NUMBER
   WRITE(6,500)FRONT,SIDE,BACK
500 FORMAT('0','FRONT ENERGY LEAKAGE = ',1PE13.5,5X,
1 'SIDE ENERGY LEAKAGE = ',1PE13.5,5X,'BACK ENERGY LEAKAGE = ',
2 1PE13.5)
   TOTAL=0.
   DO 88 I=1,I510
88 TOTAL=TOTAL+ANS(11,I)
   WRITE(6,90) TOTAL
90 FORMAT('0','AVERAGE ENERGY DEPOSITED=',1PE13.5)
   NB=M
   IT1=0
   IT2=0
   DELC=0.0002
   DELS=0.0002
   DO 6619 I=1,M
   IF(STO2(I).EQ.0.)GO TO 6619
   STO4(I)=STO4(I)+STO3(I)/STO2(I)
   IJ=STO2(I)/DELS
   IJ=IJ+1
   IF(IJ.GT.100)IJ=100
   IT2=IT2+1
   IBO2(IJ)=IBO2(IJ)+1
6619 CONTINUE
   WRITE(6,6671)DELC,DELS,XMAX,YMAX,ZMAX
6671 FORMAT('0','DELC=',1PE13.5,2X,'DELS=',1PE13.5,2X,'XMAX=',
1 1PE13.5,2X,'YMAX=',1PE13.5,2X,'ZMAX=',1PE13.5)
   WRITE(6,6672)
6672 FORMAT('1',6X,'PULSE HEIGHT DISTRIBUTION',/)
   WRITE(6,6673)
6673 FORMAT('0',7X,'BIN',14X,'NUMBER',/)
   WRITE(6,6620)(I,IBO1(I),IBO2(I),I=1,100)
6620 FORMAT(' ',3I10)
   WRITE(6,6620)NB,IT1,IT2
   WRITE(6,6652)
6652 FORMAT('1','CONTRIBUTION BY INCIDENT PARTICLE NUMBER')
WRITE(6,6653)(STO1(I),STO2(I),STO3(I),STO4(I),I=1,NB)

```

Figure 26. (continued).

```

6653 FORMAT(2(1X,F7.0,1X,1PE10.4,1X,1PE10.4,1X,OPF5.3))
      SUM1=0.0
      SUM2=0.0
      SUM3=0.0
      DO 20 I=1,M
      SUM1=SUM1+STO2(I)
      SUM2=SUM2+STO3(I)
      SUM3=SUM3+STO4(I)
20 CONTINUE
      WRITE(6,6654)M,SUM1,SUM2,SUM3
6654 FORMAT(/,' ','NB=',I10,5X,'SUM1=',1PD10.4,5X,'SUM2=',1PD10.4,
1 5X,'SUM3=',1PD10.4,/)
      SUM1=SUM1/M
      SUM2=SUM2/M
      SUM3=SUM3/M
      WRITE(6,6655)SUM1,SUM2,SUM3
6655 FORMAT(' ',18X,'SUM1=',1PD10.4,5X,'SUM2=',1PD10.4,5X,'SUM3=',
1 1PD10.4)
      CALL EXIT
      STOP
      END
      SUBROUTINE AUSGAB(IARG)
      COMMON/GREAT/XMAX,YMAX,ZMAX
      COMMON/STACK/E(40),X(40),Y(40),Z(40),U(40),V(40),W(40),
1 DNEAR(40),WT(40),IQ(40),IR(40),NP
      DOUBLE PRECISION E,X,Y,Z
      COMMON/EPCONT/EDEP,TSTEP,TUSTEP,USTEP,TVSTEP,VSTEP,IDISC,
1 IROLD,IRNEW
      DOUBLE PRECISION EDEP
      COMMON/NEED/MAT
      COMMON/JUNK/ZCUT(510),ANS(12,510),NUM,J,FRONT,SIDE,BACK
      COMMON/USEFUL/PZERO,PRM,PRMT2,RM,EPS,MEDIUM,MEDOLD
      COMMON/JEFF/KILL
      REAL*8 PZERO,PRM,PRMT2
C      IF(IARG.EQ.1) CALL ERROR
      MAT=IR(NP)
      IF(IARG.EQ.3) GO TO 60
      IF(MEDIUM.NE.MAT) CALL ERROR
      IF(IARG.NE.0) GO TO 10
      JJ=0
      ZNEW= Z(NP)+VSTEP*W(NP)
      ZBAR=(ZNEW+Z(NP))/2.
40 IZ=1

```

Figure 26. (continued).

```

30 ANS(J, IZ)=ANS(J, IZ)+EDEP*WT(NP)
   XOLD=X(NP)
   XNEW=X(NP)
   IF(JJ.EQ.0)XNEW=XNEW+U(NP)*VSTEP
   YOLD=Y(NP)
   YNEW=Y(NP)
   IF(JJ.EQ.0)YNEW=YNEW+V(NP)*VSTEP
   ZOLD=Z(NP)
   ZNEW=Z(NP)
   IF(JJ.EQ.0)ZNEW=ZNEW+W(NP)*VSTEP
   IF(EDEP.LE.0.) GO TO 400
   IF(MAT.NE.2)GO TO 400
   KK=1
   TEMP=EDEP*WT(NP)
   CALL FUGIT(KK, NUM, IARG, TEMP, XNEW, YNEW, ZNEW, WT(NP), XOLD, YOLD, ZOLD)
400 CONTINUE
   IF((ABS(XNEW).GT.XMAX).OR.(ABS(YNEW).GT.YMAX))WRITE(6, 50)
1  XOLD, XNEW, YOLD, YNEW, ZOLD, ZNEW
   IF((ABS(XOLD).GT.XMAX).OR.(ABS(YOLD).GT.YMAX))WRITE(6, 50)
1 XOLD, XNEW, YOLD, YNEW, ZOLD, ZNEW
50 FORMAT(' ', 1P6E20.6)
   RETURN
10 ZBAR=Z(NP)
   JJ=1
   GO TO 40
60 EEE=E(NP)
   IF(KILL.NE.0)GO TO 10
   IF(IQ(NP).NE.0)EEE=E(NP)-0.511
   IF(Z(NP).LE.0.01) GO TO 70
   IF(Z(NP).GE.(ZMAX-0.01)) GO TO 80
   SIDE=SIDE+EEE*WT(NP)
   RETURN
70 FRONT=FRONT+EEE*WT(NP)
   RETURN
80 BACK=BACK+EEE*WT(NP)
   RETURN
   END
   SUBROUTINE HOWFAR
   COMMON/GREAT/XMAX, YMAX, ZMAX
   COMMON/STACK/E(40), X(40), Y(40), Z(40), U(40), V(40), W(40),
1  DNEAR(40), WT(40), IQ(40), IR(40), NP
   DOUBLE PRECISION E, GMS, EDEP, X, Y, Z, S
   COMMON/EPCONT/EDEP, TSTEP, TUSTEP, USTEP, TVSTEP, VSTEP, IDISC,
1  IROLD, IRNEW
   COMMON GMS(8000)
   COMMON/HELPG/NPOLD, IQOLD, NJEFF
   COMMON/USEFUL/PZERO, PRM, PRMT2, RM, EPS, MEDIUM
   COMMON/JEFF/KILL
   REAL*8 PZERO, PRM, PRMT2

```

Figure 26. (continued).

```

DATA IST/0/
IF(IST.EQ.1) GO TO 100
NGEOM=1
GMS(1)=NGEOM
IN=5
IO=6
CALL JOMIN(NGEOM,IN,IO)
WRITE(IO,7777) NGEOM
7777 FORMAT(' GEOM REQUIRES',I10,' LOCATIONS')
IF(NGEOM.GT.8000) STOP 101
ESCAP=0.
NMK=9999
IST=1
IKY=0
100 IF(ESCAP.NE.0.) GO TO 300
KILL=0
IF(IQ(NP).GE.0)GO TO 305
C IF((E(NP).LE.0.611).AND.(IR(NP).EQ.1))GO TO 306
GO TO 305
306 IDISC=1
KILL=1
RETURN
305 CONTINUE
101 X1=X(NP)
Y1=Y(NP)
Z1=Z(NP)
UNP=U(NP)
VNP=V(NP)
WNP=W(NP)
XYZDUM=1.E-4
950 X2=X1+UNP*XYZDUM
Y2=Y1+VNP*XYZDUM
Z2=Z1+WNP*XYZDUM
IF(XMAX.LE.ABS(X2)) GO TO 889
IF(YMAX.LE.ABS(Y2)) GO TO 889
IF(ZMAX.LE.ABS(Z2)) GO TO 889
CALL GOMSOR(X2,Y2,Z2,NMED,BLZ)
DNEAR(NP)=0.
IF(NMED.EQ.IR(NP)) GO TO 61
IRNEW=NMED
IF(IQ(NP).EQ.0) GO TO 888
USTEP=-1.E-66
RETURN
888 USTEP=0.
RETURN
61 X2=X1+UNP*USTEP
Y2=Y1+VNP*USTEP
Z2=Z1+WNP*USTEP

```

} METHOD USED FOR PARTICLE ESCAPE

Figure 26. (continued).

```

C      CALL HOWFA1(X(NP),Y(NP),Z(NP),NMED,DNEAR(NP))
      BLZOLD=BLZ
      MEDOLD=NMED
      MARK=1
      CALL GOMPRP(X1,Y1,Z1,UNP,VNP,WNP,NMED,BLZ,MARK,USTEP,S,X2,Y2,Z2)
      IF(NP.NE.NPOLD) IKY=0
      IF(NP.EQ.NPOLD) IKY=IKY+1
      IF(IKY.GT.300) GO TO 805
      NMK=MARK+3
      IQOLD=IQ(NP)
      NPOLD=NP
      GO TO (10,20,30,40),NMK
10    CALL ERROR
20    ESCAP=1.
      USTEP=S
C      IF(USTEP.LE.XYZDUM) USTEP=XYZDUM
      IRNEW=NJEFF
      RETURN
30    USTEP=S
C      IF(USTEP.LE.XYZDUM) USTEP=XYZDUM
      IRNEW=NMED
40    RETURN
300   ESCAP=0.
      IF(IQOLD.NE.IQ(NP)) GO TO 101
      IF(NP.NE.NPOLD) GO TO 101
      IF(IRNEW.NE.NJEFF) GO TO 101
889   IDISC=1
      RETURN
805   X(NP)=X(NP)+XYZDUM*U(NP)
      Y(NP)=Y(NP)+XYZDUM*V(NP)
      Z(NP)=Z(NP)+XYZDUM*W(NP)
      WRITE(6,806)
806   FORMAT(1H,' APPEARS TO BE HUNG-UP  X,Y,Z INCREASED BY 1.E-4 ')
      IKY=0
      GO TO 101
      END
      SUBROUTINE HOWFA1(X,Y,Z,NMED,XYZ)
      REAL*8 X,Y,Z
      RETURN
      END
      SUBROUTINE FUGIT(KK,NUM,IARG,TEMP,XC,YC,ZC,WEIT,X1,Y1,Z1)
      DIMENSION X(20),Y(20),Z(20),XMID(20),YMID(20),ZMID(20)
      DIMENSION RDEL(20),RTRNS(20),WGT(20)
      COMMON/PULS/IBO1(100),STO1(20000),IBO2(100),STO2(20000),M,
1     STO3(20000),STO4(20000)
      COMMON/STACK/EF(40),XF(40),YF(40),ZF(40),UF(40),VF(40),WF(40),
1     DNERF(40),WTF(40),IQF(40),IRF(40),NP1
      DOUBLE PRECISION EF,XF,YF,ZF
      DATA NUMOLD/0/

```

Figure 26. (continued).

```

C      DATA XCNT/0.0/,YCNT/0.0/,ZCNT/10.0/,RCOL/1.50114/,RMX/2.49936/
      IF((IARG.EQ.2).AND.(IQF(NP1).EQ.1))WRITE(6,22)
22  FORMAT(' A POSITRON HAS SLOWED TO REST IN THE ACTIVE MEDIUM')
      IF(IARG.EQ.4)WRITE(6,23)NUM,TEMP,EF(NP1),NP1,IARG
23  FORMAT(' ', 'NUM=', I10, 5X, 'TEMP=', E10.4, 5X, 'EF(NP)=' , E10.4,
1 5X, 'NP=' , I10, 5X, 'IARG=' , I10, /)
      IF((IARG.EQ.2).AND.(IQF(NP1).EQ.1))WRITE(6,21)NUM,TEMP,
1  EF(NP1),NP1
21  FORMAT(' ', 'NUM=', I10, 5X, 'TEMP=', E10.4, 5X, 'EF(NP)=' , E10.4,
1 5X, 'NP=' , I10, /)
      IF((IARG.EQ.2).AND.(IQF(NP1).EQ.1))RETURN
      IF(KK.NE.1)RETURN
      IF(NUMOLD.EQ.NUM)GO TO 20
      M=M+1
      IF(M.GT.20000)RETURN
      STO1(M)=NUM
      NUMOLD=NUM
20  STO2(M)=STO2(M)+TEMP
C      TRKLEN=SQRT((XC-X1)**2+(YC-Y1)**2+(ZC-Z1)**2)
C      NDEL=TRKLEN/1.0+1.01
C      DELTRK=TRKLEN/NDEL
C      DELTMP=TEMP/NDEL
C      X(1)=X1
C      Y(1)=Y1
C      Z(1)=Z1
C      DO 30 I=1,NDEL
C      X(I+1)=X(I)+UF(NP1)*DELTRK
C      Y(I+1)=Y(I)+VF(NP1)*DELTRK
C      Z(I+1)=Z(I)+WF(NP1)*DELTRK
C 30  CONTINUE
C      TMPNEW=0.0
C      DO 40 I=1,NDEL
C      XMID(I)=(X(I+1)+X(I))/2.0
C      YMID(I)=(Y(I+1)+Y(I))/2.0
C      ZMID(I)=(Z(I+1)+Z(I))/2.0
C      RDEL(I)=SQRT((XMID(I)-XCNT)**2+(YMID(I)-YCNT)**2+
1 (ZMID(I)-ZCNT)**2)
C      RTRNS(I)=RDEL(I)-RCOL
C      WGT(I)=RTRNS(I)/(RMX-RCOL)
C      TMPNEW=TMPNEW+WGT(I)*DELTMP
C 40  CONTINUE
C      STO3(M)=STO3(M)+TMPNEW
C      STO3(M)=STO3(M)+TEMP
      RETURN
      END

/*
//LKED.LMOD DD DSN=X.JOJ24337.PROG,DISP=SHR
//LKED.SYSIN DD *

```

Figure 26. (continued).

```

INCLUDE LMOD(PHOTON)
ENTRY MAIN
//GO.FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT07F001 DD SYSOUT=B
//FT08F001 DD DUMMY
//FT12F001 DD DSN=MEN.X10.JOJ.PEGS.AFRRI.CHAMBERS,DISP=SHR
//FT10F001 DD DSN=&&SORS,UNIT=SYSDA,DISP=(OLD,DELETE)
//FT16F001 DD UNIT=SYSDA,SPACE=(TRK,(20,1),RLSE),
// DSN=&&GEOM,DCB=(RECFM=VBS,LRECL=3600,BLKSIZE=3604),
// DISP=(NEW,PASS)
//SYSIN DD *
      0      0      AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)
RPP      1      -10.0      10.0      -10.0      10.0      0.0      20.0
SPH      2      0.0      0.0      10.0      3.2131
SPH      3      0.0      0.0      10.0      2.49936
SPH      4      0.0      0.0      10.0      1.50114
RCC      5      0.0      0.0      10.0      -6.35      0.0      0.0
          0.15875
RCC      6      -1.27      0.0      10.0      -1.27      0.0      0.0
          0.47625
RCC      7      -2.38125      0.0      10.0      -1.190625      0.0      0.0
          0.3175
RCC      8      -2.54      0.0      10.0      -1.666875      0.0      0.0
          1.74625
RCC      9      -3.33375      0.0      10.0      -1.349375      0.0      0.0
          0.635
RCC     10      -2.460625      0.0      10.0      -0.9525      0.0      0.0
          0.47625
RCC     11      -4.524375      0.0      10.0      -0.555625      0.0      0.0
          0.555625
RCC     12      -5.000625      0.0      10.0      -0.714375      0.0      0.0
          0.396875
RCC     13      -4.1275      0.0      10.0      -0.873125      0.0      0.0
          1.666875
RCC     14      -3.175      0.0      10.0      -1.031875      0.0      0.0
          0.873125
RCC     15      -2.460625      0.0      10.0      -0.79375      0.0      0.0
          0.635
RCC     16      -4.60375      0.0      10.0      -1.349375      0.0      0.0
          0.635
RCC     17      -4.92125      0.0      10.0      -0.47625      0.0      0.0
          1.666875
RCC     18      -4.60375      0.0      10.0      -1.74625      0.0      0.0
          0.79375
RCC     19      -5.87375      0.0      10.0      -0.47625      0.0      0.0
          0.635
RCC     20      -5.000625      0.0      10.0      -0.9525      0.0      0.0
          0.47625

```

Figure 26. (continued).

RCC	21	-2.2225		0.0	10.0	-1.031875		0.0	0.0		
		0.873125									
RCC	22	-4.1275		0.0	10.0	-2.2225		0.0	0.0		
		1.74625									
RPP	23	-500.0		500.0	-500.0	500.0		-500.0	500.0		
END											
AIR	0OR	1	-2	-8	-22OR	22	-13	-17	-18		
WAL	0OR	2	-3	-14	-21OR	8	-14	-21	-22		
GAS	0OR	3	-4	-6	-15OR	21	-6	-14	-15		
COL	0OR	4	-5OR	6	-5	-10OR	7	-5			
ROD	0	5									
POL	0OR	9	-5	-7	-16OR	10	-5	-7OR	11	-5	
	OR	12	-5								
INS	0OR	13	-9	-17	-18OR	14	-9	-10OR	15	-10	
BRS	0	16	-11	-19	-20						
LUC	0OR	19	-5OR	20	-5	-11	-12				
SLV	0OR	17	-16OR	18	-9	-16	-19				
VD	0	23	-1								
END											
	1	1	1	1	1	1	1	1	1		
	5	3	2	3	1	4	6	8	7	1	0

/*
//

Figure 26. (continued).

CF-252 PHOTON SOURCE DISTRIBUTION

NHST	IN	IO	ISORS	ISORT	ISORU	ISORV	MAXCAS	NT	NPRT
59	5	6	1	0	0	0	200	10	2

THE STARTING RANDOM NUMBER IS 378E26A5A243

2	0	2.9251E-01	-1.5206E-01	-2.0252E+00	0.0	0.0	0.0	0.0	1.0000E+00	1.0000E+00	1	1
2	0	2.3536E-01	-2.2010E+00	4.7623E-01	0.0	0.0	0.0	0.0	1.0000E+00	1.0000E+00	2	1
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 1												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 2												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 3												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 4												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 5												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 6												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 7												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 8												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 9												
3	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF BATCH 10												
4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0
END OF RUN												

DUNIT REQUESTED&USED ARE: 1.00000E+00 1.00000E+00(CM.)
 EGS SUCCESSFULLY HATCHED FOR 8 MEDIA.

2	0	0.2925E+00	-0.1521E+00	-0.2025E+01	0.0	0.0	0.0	0.0	0.1000E+01	0.1000E+01	1	1
---	---	------------	-------------	-------------	-----	-----	-----	-----	------------	------------	---	---

Figure 27. Listing of Selected Output from PHOTON Sample Problem.

AFRRI 50CC IONIZATION CHAMBER (0.0CM BUILD-UP CAP)

ILOPT = 0 IDBG = 0

BODY DATA								
RPP	1	-0.1000000D+02	0.1000000D+02	-0.1000000D+02	0.1000000D+02	0.0	0.2000000D+02	3
SPH	2	0.0	0.0	0.1000000D+02	0.3213100D+01	0.0	0.0	11
SPH	3	0.0	0.0	0.1000000D+02	0.2499360D+01	0.0	0.0	19
SPH	4	0.0	0.0	0.1000000D+02	0.1501140D+01	0.0	0.0	27
RCC	5	0.0	0.0	0.1000000D+02	-0.6350000D+01	0.0	0.0	35
		0.1587500D+00						
RCC	6	-0.1270000D+01	0.0	0.1000000D+02	-0.1270000D+01	0.0	0.0	44
		0.4762500D+00						
RCC	7	-0.2381250D+01	0.0	0.1000000D+02	-0.1190625D+01	0.0	0.0	53
		0.3175000D+00						
RCC	8	-0.2540000D+01	0.0	0.1000000D+02	-0.1666875D+01	0.0	0.0	62
		0.1746250D+01						
RCC	9	-0.3333750D+01	0.0	0.1000000D+02	-0.1349375D+01	0.0	0.0	71
		0.6350000D+00						
RCC	10	-0.2460625D+01	0.0	0.1000000D+02	-0.9525000D+00	0.0	0.0	80
		0.4762500D+00						
RCC	11	-0.4524375D+01	0.0	0.1000000D+02	-0.5556250D+00	0.0	0.0	89
		0.5556250D+00						
RCC	12	-0.5000625D+01	0.0	0.1000000D+02	-0.7143750D+00	0.0	0.0	98
		0.3968750D+00						
RCC	13	-0.4127500D+01	0.0	0.1000000D+02	-0.8731250D+00	0.0	0.0	107
		0.1666875D+01						
RCC	14	-0.3175000D+01	0.0	0.1000000D+02	-0.1031875D+01	0.0	0.0	116
		0.8731250D+00						
RCC	15	-0.2460625D+01	0.0	0.1000000D+02	-0.7937500D+00	0.0	0.0	125
		0.6350000D+00						
RCC	16	-0.4603750D+01	0.0	0.1000000D+02	-0.1349375D+01	0.0	0.0	134
		0.6350000D+00						
RCC	17	-0.4921250D+01	0.0	0.1000000D+02	-0.4762500D+00	0.0	0.0	143
		0.1666875D+01						
RCC	18	-0.4603750D+01	0.0	0.1000000D+02	-0.1746250D+01	0.0	0.0	152
		0.7937500D+00						

Figure 27. (continued).

```

RCC 19 -0.5873750D+01 0.0          0.1000000D+02 -0.4762500D+00 0.0          0.0          161
        0.6350000D+00
RCC 20 -0.5000625D+01 0.0          0.1000000D+02 -0.9525000D+00 0.0          0.0          170
        0.4762500D+00
RCC 21 -0.2222500D+01 0.0          0.1000000D+02 -0.1031875D+01 0.0          0.0          179
        0.8731250D+00
RCC 22 -0.4127500D+01 0.0          0.1000000D+02 -0.2222500D+01 0.0          0.0          188
        0.1746250D+01
RPP 23 -0.5000000D+03 0.5000000D+03 -0.5000000D+03 0.5000000D+03 -0.5000000D+03 0.5000000D+03 197
END 24 0.0          0.0          0.0          0.0          0.0          205
NUMBER OF BODIES      23
LENGTH OF FPD-ARRAY  210

```

```

                                INPUT ZONE DATA
AIR 00R 1 -2 -8 -22OR 22 -13 -17 -18 0 Z 1
WAL 00R 2 -3 -14 -21OR 8 -14 -21 -22 0 Z 3
GAS 00R 3 -4 -6 -15OR 21 -6 -14 -15 0 Z 5
COL 00R 4 -5OR 6 -5 -10OR 7 -5 0 0 Z 7
ROD 0 5 0 0 0 0 0 0 0 0 Z 10
POL 00R 9 -5 -7 -16OR 10 -5 -7OR 11 -5 Z 11
    00R 12 -5 0 0 0 0 0 0 0 0 Z 14
INS 00R 13 -9 -17 -18OR 14 -9 -10OR 15 -10 Z 15
BRS 0 16 -11 -19 -20 0 0 0 0 0 Z 18
LUC 00R 19 -5OR 20 -5 -11 -12 0 0 0 0 Z 19
SLV 00R 17 -16OR 18 -9 -16 -19 0 0 0 0 Z 21
VD 0 23 -1 0 0 0 0 0 0 0 0 Z 23
END 0 0 0 0 0 0 0 0 0 0 Z 24
NUMBER OF INPUT ZONES 11
NUMBER OF CODE ZONES 23
LENGTH OF INTEGER ARRAY 575

```

Figure 27. (continued).

CODE ZONE	INPUT ZONE	ZONE DATA LOC.	NO. OF BODIES	REGION NO.	MEDIA NO.
1	1	162	4	1	5
2	1	179	4	1	5
3	2	196	4	1	3
4	2	213	4	1	3
5	3	230	4	1	2
6	3	247	4	1	2
7	4	264	2	1	3
8	4	273	3	1	3
9	4	286	2	1	3
10	5	295	1	1	1
11	6	300	4	1	4
12	6	317	3	1	4
13	6	330	2	1	4
14	6	339	2	1	4
15	7	348	4	1	6
16	7	365	3	1	6
17	7	378	2	1	6
18	8	387	4	1	8
19	9	404	2	1	7
20	9	413	4	1	7
21	10	430	2	1	1
22	10	439	4	1	1
23	11	456	2	1	0

I	KR1(I)	KR2(I)
1	1	2
2	3	4
3	5	6
4	7	9
5	10	10
6	11	14
7	15	17
8	18	18
9	19	20
10	21	22
11	23	23

Figure 27. (continued).

```

MORSE REGION IN INPUT ZONE(I) ARRAY  MRIZ(I),I=1,11)

  1  1  1  1  1  1  1  1  1  1  1  1

MORSE MEDIA IN INPUT ZONE(I) ARRAY  MMIZ(I),I=1,11)

  5  3  2  3  1  4  6  8  7  1  0

OPTION 0 WAS USED IN CALCULATING VOLUMES, FOR 1 REGIONS
0-SET VOLUMES = 1, 1-CONCENTRIC SPHERES, 2-SLABS, 3-INPUTVOLUMES.

```

```

VOLUMES (CM**) USED IN COLLISIONS DENSITY AND TRACK LENGTH ESTIMATORS.

REG
1
VOLUME 1.000D+00
GEOM REQUIRES      1180 LOCATIONS
  2  0  0.2354E+00 -0.2201E+01  0.4762E+00  0.0      0.0      0.0      0.1000E+01  0.1000E+01  2  1
  2  0  0.1086E+01 -0.8202E+00 -0.1981E+01  0.0      0.0      0.0      0.1000E+01  0.1000E+01  3  1
  2  0  0.2008E+01  0.2169E+01  0.1531E+01  0.0      0.0      0.0      0.1000E+01  0.1000E+01  4  1
  2  0  0.2891E+00  0.1149E+01  0.1334E+01  0.0      0.0      0.0      0.1000E+01  0.1000E+01  5  1
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  3  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0
  4  0  0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      0  0

ECUT= 2.00000E+01      AVERAGE ENERGY DEPOSITED= 6.64533E-02      STANDARD DEVIATION (%)= 5.23600E+00
FRONT ENERGY LEAKAGE = 5.10789E-03      SIDE ENERGY LEAKAGE = 2.61470E-02      BACK ENERGY LEAKAGE = 8.27765E-01
AVERAGE ENERGY DEPOSITED= 6.64533E-02
DELC= 2.00000E-04      DELS= 2.00000E-04      XMAX= 1.00000E+01      YMAX= 1.00000E+01      ZMAX= 2.00000E+01

```

Figure 27. (continued).

PULSE HEIGHT DISTRIBUTION

BIN	NUMBER	
1	0	0
2	0	0
3	0	1
4	0	0
5	0	0
6	0	0
7	0	1
8	0	0
9	0	0
10	0	1
11	0	0
90	0	0
91	0	0
92	0	1
93	0	0
94	0	0
95	0	0
96	0	0
97	0	0
98	0	0
99	0	0
100	0	0
10	0	10

CONTRIBUTION BY INCIDENT PARTICLE NUMBER

200.	4.1909E-04	4.1909E-04	1.000	289.	6.1043E-03	6.1043E-03	1.000
866.	1.1612E-02	1.1612E-02	1.000	1003.	6.2472E-03	6.2472E-03	1.000
1224.	1.8320E-02	1.8320E-02	1.000	1433.	3.3028E-03	3.3028E-03	1.000
1499.	1.9951E-03	1.9951E-03	1.000	1606.	1.3858E-03	1.3858E-03	1.000
1752.	1.0717E-02	1.0717E-02	1.000	1876.	1.1477E-02	1.1477E-02	1.000
NB=	10	SUM1=7.1580D-02		SUM2=7.1580D-02		SUM3=1.0000D+01	
		SUM1=7.1580D-03		SUM2=7.1580D-03		SUM3=1.0000D+00	

Figure 27. (continued).

LIST OF REFERENCES

1. J. O. Johnson and T. A. Gabriel, "Development and Evaluation of a Monte Carlo Code System for Analysis of Ionization Chamber Responses," ORNL/TM-10196, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., (to be published in 1987).
2. R. Kinsey, "ENDF-102 Data Formats and Procedures for the Evaluated Nuclear Data File, ENDF/B-V," BNL-NCS-50496, Brookhaven Natl. Lab., 1979.
3. T. A. Gabriel, J. D. Amburgey, and B. L. Bishop, "CALOR - A Monte Carlo Program Package for the Design and Analysis of Calorimeter Systems," ORNL/TM-5619, Union Carbide Corporation, Oak Ridge National Lab., 1977.
4. M. B. Emmett, *The MORSE Monte Carlo Radiation Transport Code System*, ORNL-4972, Union Carbide Corp. Nuclear Div., Oak Ridge Natl. Lab., 1975.
5. J. B. Birks, *The Theory and Practice of Scintillation Counting*, The Macmillian Company, New York, 1964.
6. T. W. Armstrong and K. C. Chandler, "SPAR A FORTRAN Program for Computing and Stopping Powers and Ranges for Muons, Charged Pions, Protons, and Heavy Ions," ORNL-4869, Union Carbide Corp. Nuclear Div., Oak Ridge Natl. Lab., 1973.
7. R. L. Ford and W. R. Nelson, *The EGS Code System: Computer Program for the Monte Carlo Simulation of Electromagnetic Cascade Showers*, SLAC-210, Stanford Linear Accelerator Center, 1978.
8. D. E. Cullen, "Program RIGEL," Brookhaven National Laboratory, Upton, New York, Sept. 9, 1970.
9. Odelli Ozer, "RESEND: A Program to Preprocess ENDF/B Materials with Resonance Files into a Pointwise Form," Brookhaven National Laboratory, BNL-17134, November 1973. Correspondence from P. F. Rose to C. R. Weisbin, March 21, 1975. Private communication from NNDC, January 10, 1979.
10. D. E. Cullen, "Program LINEAR (Version 79-1): Linearize Data in the Evaluated Nuclear Data File/Version B (ENDF/B) Format," Lawrence Livermore Laboratory, UCRL-50400, Vol. 17 Part A, Rev 2, October 1979.

11. D. E. Cullen, "Program SIGMA1 (Version 79-1): Doppler Broaden Evaluated Nuclear Data File/Version B (ENDF/B) Format," Lawrence Livermore Laboratory, UCRL-50400, Vol. 17 Part B, Rev 2, October 1979.
12. J. E. White, Oak Ridge National Laboratory, Oak Ridge, Tennessee, letter to J. O. Johnson, Oak Ridge Natl. Lab., Oak Ridge, Tennessee, Marcy 12, 1984.
13. C. R. Weisbin et al., "MINX: A Multigroup Interpretation of Nuclear Cross-Sections from ENDF/B," Los Alamos Scientific Laboratory, LA-6486-MS (September 1976).
14. J. E. White et al., "MINXI5: User's Manual for the ENDF/B-V IBM Version of the MINX Cross Section Processing Program," Oak Ridge Natl. Lab., (to be published).

APPENDIX A

GENERATION OF POINTWISE CROSS SECTIONS
FROM ENDF/B DATA TAPES

APPENDIX A

GENERATION OF POINTWISE CROSS SECTIONS
FROM ENDF/B DATA TAPES

1.0 INTRODUCTION

The program RDNDF is designed to read ENDF/B-V-formatted cross section files and process the data into a suitable form for calculating ionization chamber response characteristics using a continuous Monte Carlo program. To accomplish this objective, the input cross section files must first be processed through a series of pre-processing programs for data in ENDF/B format. Each program has a specific task in converting the raw ENDF/B data into a suitable format for processing in RDNDF. In particular, the pre-processing programs consist of RIGEL⁸, RESND⁹, LINEAR¹⁰, SIGMA¹¹, and SCAN.¹² With the exception of RIGEL, the programs are tied together in the MINXI^{5,13,14} cross section processing package. A brief description of the purpose of each program along with the input instructions needed for accomplishing the above objective are presented below. The interested reader should consult the references for further information.

1.1 RIGEL

Program RIGEL is designed to: selectively or non-selectively retrieve ENDF/B data from up to nine ENDF/B SOURCE tapes; merge the retrieved ENDF/B data onto up to eight ENDF/B RESULT tapes; change the data arrangement from STANDARD arrangement to ALTERNATE or vice

versa; and change the data mode from BCD to Binary or vice versa. All SOURCE tapes must be in the same arrangement (ALTERNATE or STANDARD). Likewise all RESULT tapes must be in the same arrangement. All tapes may be either BCD or Binary mode. RIGEL is normally a single pass program and does not use any scratch unit.

1.1.1.1 Input Requirements

The following input cards are required in order to execute a RIGEL case.

Card 1: Format (4I11)

SOURCE tape arrangement (1 - ALTERNATE, 2 - STANDARD)

RESULT tape arrangement (1 - ALTERNATE, 2 - STANDARD)

ENDF/B tape number for all RESULT tapes (if ≤ 0 , the ENDF/B tape number from the first SOURCE tape is written on all result tapes)

SELECTION OPTION

0 non-selective (all non-duplicate sections are acceptable)

1 (MAT, MF, MT) range

2 (ZA, MF, MT) range

3 (MAT, MF, MT) table

4 (ZA, MF, MT) table

Note: Card 2 will depend on the values of the selection option

Card 2 (Selection Option = 0)

No cards required

Card 2 (Selection Option = 1): Format (6I11) (≤ 0 implies no MAT lower limit)

MAT lower limit

MF lower limit

MT lower limit

MAT upper limit

MF upper limit

MT upper limit

Card 2 (Selection Option = 2): Format (6I11) (≤ 0 implies no limit)

ZA* lower limit

MF lower limit

MT lower limit

ZA upper limit

MF upper limit

MT upper limit

*Integer value in the ENDF/B convention of $1000*Z+A$.

Card(s) 2 (Selection Option = 3): Format (3I11) (≤ 0 implies equality not necessary)

MAT to be retrieved

MF to be retrieved

MT to be retrieved

Note: The number of cards must be less than or equal to 100 and must be followed by a blank card.

Card(s) 2 (Selection Option = 4): Format (3I11) (≤ 0 implies equality not necessary)

ZA to be retrieved

MF to be retrieved

MT to be retrieved

Note: The number of cards must be less than or equal to 100 and must be followed by a blank card.

Card(s) 3: Format (2I11)

SOURCE tape mode (1 - BCD, 2 - Binary)

SOURCE tape unit number

Note: The number of cards must be less than or equal to 9 and must be followed by a blank card.

Card(s) 4: Format (2I11)

RESULT tape mode (1 - BCB, 2 - Binary)

RESULT tape unit number

Note: The number of cards must be less than or equal to 8 and must be followed by a blank card.

Card 5: Format (11A6)

Tape label for all RESULT tapes

Note: If the entire label is blank, the tape label from the first SOURCE tape is written on all RESULT tapes.

1.1.2 I/O File Requirements

The RIGEL program is executed through the AMPX Driver. Because the binary master for ENDF is included in the AMPX catalogued procedures on logical unit 11, the only I/O requirement for a RIGEL case is a logical unit for the RESULT tape. All other I/O logical units (e.g. standard read and write) are included in the AMPX catalogued procedures.

1.2 RESND5

Program RESND5 is designed to reconstruct the energy-dependent neutron total, elastic, capture, and fission cross sections from a combination of resonance parameters and tabulated background cross sections in the ENDF/B format. The cross sections are output in the result file in an ENDF/B format and are linearly interpolable over

the entire energy range. The output includes the original resonance parameters in a form that can be used in Doppler broadening and self-shielding calculations.

1.2.1 Input Requirements

The following card is required in order to execute a RESND5 case.

Card 1: Format (2I5,2E10.4,I10)

MAT1 the starting ENDF/B material number
 MAT2 the ending ENDF/B material number
 ERR the resonance reconstruction tolerance
 AVER the absolute resonance reconstruction tolerance
 IMESH 1/2 - coarse/fine mesh selection

Note: For best results, AVER=1.00E-05 and IMESH=2 are suggested.

1.2.2 I/O File Requirements

File	Unit	Description	Required
INPUT	5	Card Input	Always
OUTPUT	6	Printed Output	Always
ENDFIN	20	Input ENDF/B tape (BCD)	Always
ENDFOT	21	Output ENDF/B tape (BCD)	Always
SCR1	22	Scratch unit	Always
SCR2	23	Scratch unit	Always

1.3 LINEAR

Program LINEAR is designed to convert evaluated cross sections in the ENDF/B format into a tabular form that is subject to linear-linear interpolation in energy and cross section. The program also thins tables of cross sections that are already linearly interpolable. The principal advantage of the program is that it allows subsequent programs to consider only linearly-interpolable data.

1.4 SIGMA1

Program SIGMA1 is designed to Doppler-broaden evaluated cross sections in the ENDF/B format. The program requires the input cross sections to be tabulated as linearly interpolable functions of energy in ENDF/B File 3. The broadened cross sections in this same form replace the original values in the output tape. Furthermore, SIGMA1 has the capability of thinning the broadened cross sections to a specified tolerance.

1.4.1 Input Requirements

LINEAR and SIGMA1 are executed in the same job step. The following cards are required in order to execute a LINEAR/SIGMA1 case.

Card 1: Format (20A4)

TITLE 80 character description of problem

Card 2: Format (6I5)

MAT1 the starting ENDF/B material number

MAT2 the ending ENDF/B material number

NOTAPE a flag which controls various start and restart capabilities

0 or 1 Read a PENDF tape on unit 12 and produce a Doppler broadened tape on unit 21 with all data linearized.

2 Flag used for restarting a SIGMA1 case

LPRINT No effect

NTMP Number of temperatures not counting 0°K

NSIG Number of σ_0 values

Card 3: Format (I5,2E10.0) [Required if NOTAPE=2]

NDONE Number of completed temperatures

RESLO Starting energy (eV) for thinning operation

RESHI Ending energy (eV) for thinning operation

Card 4: Format (4E10.0)

ERR1 Fractional error for resonance reconstruction

ERLIN Fractional error for linearization

ERTHN Fractional error for Doppler thinning

ERINT Fractional error for adaptive integration

Card 5: Format (6E10.0)

TB The NTMP temperatures (°K)

Card 6: Format (6E10.0)

SIGPT The NSIG background dilution cross sections.

1.4.2 I/O File Requirements

File	Unit	Description	Required
INPUT	5	Card Input	Always
OUTPUT	6	Printed Output	Always
SCR1	3	Scratch Unit	Always
SCR2	9	Scratch Unit	Always
ENDFIN	12	Input ENDF/B tape (BCD)	Always
ENDFOT	21	Output ENDF/B tape (BCD)	Always

1.5 SCAN

The program SCAN is used to check the point data files to detect any occurrences of non-physical cross sections and other known abnormalities.

1.5.1 Input Requirements

The following cards are required in order to execute a SCAN case.

Card 1: Format (4I5)

MAT ENDF/B material number

MF ENDF/B file number

NMT Number of reaction types

NTMP Number of temperatures

Card 2: Format (10I5)

MT(I), I=1, NMT Reaction types.

1.5.2 I/O File Requirements

File	Unit	Description	Required
INPUT	5	Card Input	Always
OUTPUT	6	Printed Output	Always
ENDFIN	20	Input ENDF/B tape (BCD)	Always

1.6 SAMPLE PROBLEM

The schematic diagram of the pointwise data generation process (with SCAN) is shown in Figure A-1. A sample listing of the JCL and input used to process ENDF/B files 1 through 15 for material hydrogen is outlined in Figure A-2. The ENDF/B data resides on NE3330 in the binary mode. Since all the modules except RIGEL require BCD data, RIGEL is used to convert the files to BCD formatted data. The output data set consists of two complete evaluations, one at 0°K and the other at 300°K stacked sequentially.

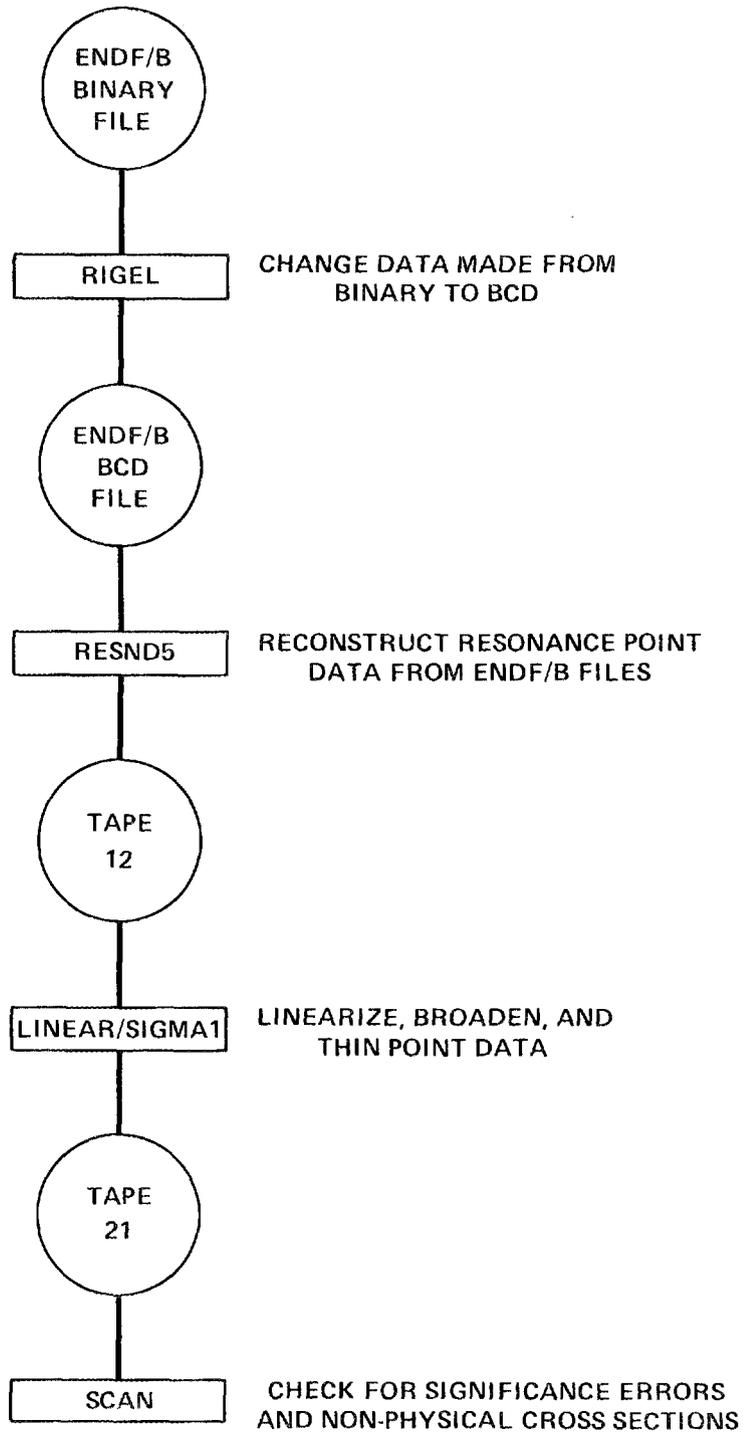


Figure A-1. Schematic Diagram of Pointwise Data Generation with SCAN.

```

//JOJRENDR JOB (24337,IO2),'JO JOHNSON 6025',TIME=(0,10)
/*ROUTE PUNCH RMT84
/*ROUTE PRINT RMT84
/* RUN RIGEL THROUGH AMPX PROCEDURE TO SELECT DATA.
/* OUTPUT FILE WILL BE WRITTEN TO UNIT 60.
//STEP1 EXEC AMPX,PARM.LKED='NOMAP',REGION.GO=1020K,VER=V5
//LKED.ENDFR5 DD DSN=E.BLD00000.RIGEL.HEX,DISP=SHR
//LKED.SYSIN DD *
  INCLUDE ENDFR5
  NAME RIGEL
//GO.FT60F001 DD UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(TRK,(100,20),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=12800),DSN=&&ENDF
//GO.SYSIN DD *
=RIGEL
      2          2          0          1
      1301       1          0         1301         15          0
      2          11
Blank Card
      1          60
Blank Card
Blank Title Card
/*
/* RUN RESND5 TO RECONSTRUCT THE RESONANCE DATA
/* INPUT IS READ FROM UNIT 20 AND OUTPUT IS WRITTEN ON UNIT 21
//STEP2 EXEC FORTQLG,PARM.LKED='NOMAP',LKSIZE=270K,GOSIZE=1020K
//LKED.RESND DD DSN=E.BLD00000.RESEND.QCOM,VOL=SER=ZX0000,DISP=SHR,
// UNIT=3330-1
//LKED.SYSIN DD *
  INCLUDE RESND
//GO.FT20F001 DD DSN=&&ENDF,DISP=(OLD,DELETE)
//GO.FT21F001 DD UNIT=SYSDA,DISP=(NEW,PASS),
// SPACE=(TRK,(100,20),RLSE),
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=12800),DSN=&&TAPE12
//GO.FT22F001 DD UNIT=SYSDA,DISP=(,PASS),SPACE=(CYL,(20,2,5))
//GO.FT23F001 DD UNIT=SYSDA,DISP=(,PASS),SPACE=(CYL,(20,2,5))
//GO.FT05F001 DD *
      1301 1301 0.005          1.0E-05          2
/*
/* RUN LINEAR TO MAKE THE CROSS SECTIONS LINEARLY INTERPOLABLE
/* RUN SIGMA1 TO DOPPLER BROADEN THE RESONANCE CROSS SECTIONS
/* INPUT IS READ FROM UNIT 12 AND OUTPUT IS WRITTEN TO UNIT 21
//STEP3 EXEC FORTQLG,PARM.LKED='NOMAP',LKSIZE=270K,GOSIZE=1020K
//LKED.JEN DD DSN=E.BLD00000.SIGMA1.QCOM,VOL=SER=ZX0000,DISP=SHR,
// UNIT=3330-1
//LKED.SYSIN DD *
  INCLUDE JEN

```

Figure A-2. Sample Listing of JCL and Input Used to Generate Pointwise Cross Sections from ENDF/B Data Tapes.

```

//GO.FT03F001 DD UNIT=SYSDA,SPACE=(TRK,(350,100)),
// DCB=(RECFM=VBS,LRECL=84,BLKSIZE=6384)
//GO.FT09F001 DD UNIT=SYSDA,SPACE=(TRK,(50,10)),
// DCB=(RECFM=VBS,LRECL=X,BLKSIZE=921)
//GO.FT12F001 DD DSN=&&TAPE12,DISP=(OLD,DELETE)
//GO.FT21F001 DD UNIT=3330V,DISP=(NEW,CATLG),
// SPACE=(TRK,(50,50),RLSE),VOL=SER=VINT09,
// DCB=(RECFM=FB,LRECL=80,BLKSIZE=12800),
// DSN=MEN.X10.JOJ.HYDROGEN
//GO.FT05F001 DD *
SAMPLE PROBLEM TO CREATE H (MAT 1301) POINTWISE TAPE
1301 1301 0 1 1 1 0
0.005 0.002 0.002 0.001
3.000E+02
1.000E+10
/*
/** RUN SCAN TO CHECK FOR NON-PHYSICAL CROSS SECTIONS
//STEP4 EXEC FORTQLG,PARM.LKED='NOMAP',REGION=270K
//LKED.PROG DD UNIT=3330V,VOL=SER=VRSIC3,DISP=SHR,
// DSN=JIB.JRK.SCANOBJ
INCLUDE PROG(SCAN)
ENTRY MAIN
//GO.FT20F001 DD DSN=MEN.X10.JOJ.HYDROGEN,DISP=SHR
//GO.FT05F001 DD *
1301 3 3 2
1 2 102
/*
//

```

Figure A-2. (continued).

APPENDIX B

FIDO INPUT

APPENDIX B**FIDO INPUT**

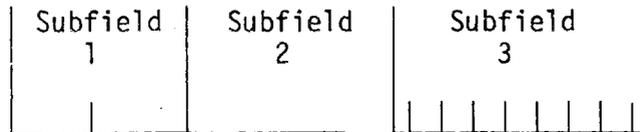
The FIDO input method is especially devised to allow entering or modifying large data arrays with minimum effort. Special advantage is taken of patterns of repetition or symmetry wherever possible. The FIDO system was patterned after the input method used with the FLOCO coding system at Los Alamos and was first applied by Atomics International to the DTF-II code. Since that time, numerous features requested by users have been added, a free-field option has been developed, and the application of FIDO has spread to innumerable codes.

The data are entered in units called "arrays." An array comprises a group of contiguous storage locations which are to be filled with data at one time. These arrays usually correspond on a one-to-one basis with FORTRAN arrays used in the program. A group of one or more arrays read with a single call to the FIDO package forms a "block," and a special delimiter is required to signify the end of each block. Arrays within a block may be read in any order with respect to each other, but an array belonging to one block must not be shifted to another. The same array can be entered repeatedly within the same block. For example, an array could be filled with "0" using a special option, and then a few scattered locations could be changed by reading in a new set of data for that array. If no entries to the arrays in a block are required but the condition requiring the block is met, the delimiter alone satisfies the input requirement.

Three major types of input are available: fixed-field input, free-field input, and user-field input.

Fixed-field Input - Each card is divided into six 12-column data fields, each of which is divided into three subfields. The following sketch illustrates a typical data field. The three subfields always comprise two, one, and nine columns, respectively.

To begin the first array of a block, an array originator field is placed in any field on a card:



Subfield 1: An integer array identifier < 100 specifying the data array to read.

Subfield 2: An array-type indicator -
 "\$" if the array is integer data
 "*" of the array is real data

Subfield 3: Blank

Data are then placed in successive fields until the required number of entries has been accounted for.

In entering data, it is convenient to think of an "index" or "pointer" which is under control of the user, and which specifies the position in the array into which the next data entry is to go. The pointer is always positioned at array location #1 by entering the array originator field. The pointer subsequently moves

according to the data operator chosen. Blank fields are a special case in that they do not cause any data modification and do not move the pointer.

A data field has the following form:

Subfield 1: The data numerator, an integer < 100 . We refer to this entry as N_1 in the following discussion.

Subfield 2: One of the special data operators listed below.

Subfield 3: A nine-character data entry, to be read in F9.0 format. It will be converted to an integer if the array is a "\$" array or if a special array operator such as "Q" is being used. Note that an exponent is permissible but not required. If no decimal is supplied, it is assumed to be immediately to the left of the exponent, if any, otherwise to the right of the last column. This entry is referred to as N_3 in the following discussion.

A list of data operators and their effect on the array being input follows:

"Blank" indicates a single entry of data. The data entry in the third subfield is entered in the location indicated by the pointer, and the pointer is advanced by 1. However, an entirely blank field is ignored.

"+" or "-" indicates exponentiation. The data entry in the third field is entered and multiplied by $10^{\pm N_1}$, where N_1 is the data

numerator in the first subfield, given the sign indicated by the data operator itself. The pointer is advanced by 1. In cases where an exponent is needed, this option allows the entering of more significant figures than the blank option.

"&" has the same effect as "+" on IBM systems.

"R" indicates that the data entry is to be repeated N_1 times. The pointer is advanced by N_1 .

"I" indicates linear interpolation. The data numerator, N_1 , indicates the number of interpolated points to be supplied. The data entry in the third subfield is entered, followed by N_1 interpolated entries equally spaced between that value and the data entry found in the third subfield of the next non-blank field. The pointer is advanced by $N_1 + 1$. The field following an "I" field is then processed normally, according to its own data operator. The "I" entry is especially valuable for specifying a spatial mesh. In "\$" arrays, interpolated values will be rounded to the nearest integer.

"L" indicates logarithmic interpolation. The effect is the same as that of "I" except that the resulting data are evenly separated in log-space. This is especially convenient for specifying an energy mesh.

"Q" is used to repeat sequences of numbers. The length of the sequence is given by the third subfield, N_3 . The sequence of N_3 entries is to be repeated N_1 times. The pointer is advanced by $N_1 * N_3$. If either N_1 or N_3 is 0, then a sequence of $N_1 + N_3$ is repeated one time only, and the pointer is advanced by $N_1 + N_3$. This feature is especially valuable for geometry specification.

"G" has the same effect as "Q", except that the sign of the sequence is changed each time it is entered.

The "N" option has the same effect as "Q", except that the order of the sequence is reversed each time it is entered. This is valuable for the type of symmetry possessed by quadrature coefficients.

"M" has the same effect as N except that the sign of each entry in the sequence is reversed each time the sequence is entered. For example, the entries:

1 2 3 2M2

would be equivalent to:

1 2 3 -3 -2 2 3

This option is also useful in entering quadrature coefficients.

"Z" causes $N_1 + N_3$ locations to be set to 0. The pointer is advanced by $N_1 + N_3$.

"C" causes the position of the last array item entered to be printed. This is the position of the pointer, less 1. The pointer is not moved.

"O" causes the print trigger to be turned on. The trigger is originally off. When the trigger is on, each card image is listed as it is read.

"P" causes the print trigger to be turned off.

"S" indicates that the pointer is to skip N_1 positions leaving those array positions unchanged. If the third subfield is non-blank, that data entry is entered following the skip, and the pointer is advanced by $N_1 + 1$.

"A" moves the pointer to the position N_3 , specified in the third subfield.

"F" fills the remainder of the array with the datum entered in the third subfield.

"E" skips over the remainder of the array. The array length criterion is always satisfied by an "E", no matter how many entries have been specified. No more entries to an array may be given following an "E", except that data entry may be restarted with an "A".

The reading of data to an array is terminated when a new array origin field is supplied, or when the block is terminated. If an incorrect number of positions has been filled, an error edit is given, and a flag is set which will later abort execution of the problem. FIDO then continues with the next array if an array origin was read. Otherwise, it returns control to the calling program.

A block termination consists of a field having "T" in the second subfield. All entries following "T" on a card are ignored, and control is returned from FIDO to the calling program.

Comment cards can be entered within a block by placing a slash (/) in column 1. Then columns 2-80 will be listed, with column 2 being used for printer carriage control. Such cards have no effect on the data array or pointer.

Free-field Input - With free-field input, data are written without fixed restrictions as to field and subfield size and positioning on the card. The options used with fixed-field input are available, although some are slightly restricted in form. In

general, fewer data cards are required for a problem, the interpreting print is easier to read, a card listing is more intelligible, the cards are easier to keypunch, and certain common keypunch errors are tolerated without affecting the problem. Data arrays using fixed- and free-field input can be intermingled at will within a given block.

The concept of three subfields per field is still applicable to free-field input; but if no entry for a field is required, no space for it need be left. Only columns 1-72 may be used, as with fixed-field input.

The array originator field can begin in any position. The array identifiers and type indicators are used as in fixed-field input. The type indicator is entered twice, to designate free-field input (i.e., "\$\$" or "**"). The blank third subfield required in fixed-field input is not required. For example: 31** indicates that array 31, a real-data array, will follow in free-field format.

Data fields may follow the array origin field immediately. The data field entries are identical to the fixed-field entries with the following restrictions:

- (1) Any number of blanks may separate fields, but at least one blank must follow a third subfield entry if one is used.
- (2) If both first and second subfield entries are used, no blanks may separate them, i.e., 24S, but not 24 S.

- (3) Numbers written with exponents must not have imbedded blanks, i.e., 1.0E+4, 1.0E4, 1.0+4, or even 1+4, but not 1.0 E4.
- (4) In third-subfield data entries, only nine digits, including the decimal but not including the exponent field, can be used, i.e., 123456.89E07, but not 123456.789E07.
- (5) The "Z" entry must be of the form: 738Z, not Z738 or 738 Z.
- (6) The "+ or -" data operators are not needed and are not available.
- (7) The "Q, N, and M" entries are restricted: 3Q4, 1N4, or M4, but not 4Q, 4N, or 4M. G is similarly restricted.
- (8) A field must not span two cards.
- (9) All items on a card entered after a slash in any column except the first are ignored.

User-field Input - If the user follows the array identifier in the array originator field with the character "U" or "V", the input format is to be specified by the user. If "U" is specified, the FORTRAN FORMAT to be used must be supplied in columns 1-72 of the next card. The format must be enclosed by the usual parentheses. Then the data for the entire array must follow on successive cards. The rules of ordinary FORTRAN inputs as to exponents, blanks, etc.,

apply. If the array data do not fill the last card, the remainder must be left blank.

"V" has the same effect as "U" except that the format read in the last preceding "U" array is used.

INTERNAL DISTRIBUTION

- | | |
|-----------------------|---|
| 1. R. G. Alsmiller | 28. J. S. Tang |
| 2. J. M. Barnes | 29. M. W. Waddell |
| 3. B. L. Bishop | 30. R. M. Westfall |
| 4. D. G. Cacuci | 31. A. Zucker |
| 5. S. N. Cramer | 32. J. J. Dorning
(Consultant) |
| 6. H. L. Dodds | 33. G. H. Golub
(Consultant) |
| 7. J. D. Drischler | 34. R. Haralick
(Consultant) |
| 8. M. B. Emmett | 35. D. Steiner
(Consultant) |
| 9-13. T. A. Gabriel | 36. Central Research Library |
| 14. D. T. Ingersoll | 37-41. EPMD Reports Office |
| 15-19. J. O. Johnson | 42. ORNL Y-12 Technical Library
Document Reference Section |
| 20. R. A. Lillie | 43-47. Laboratory Records |
| 21. F. C. Maienschein | 48. ORNL Patent Office |
| 22. J. V. Pace III | |
| 23. F. G. Perey | |
| 24. W. A. Rhoades | |
| 25. R. W. Roussin | |
| 26. R. T. Santoro | |
| 27. M. S. Smith | |

EXTERNAL DISTRIBUTION

49. Dr. J. E. Brau, Dept. of Physics, University of Tennessee, Knoxville, Tennessee 37916.
50. Craig Jensen, Dept. of Nuclear Engineering, University of Oklahoma, Norman, Oklahoma 73019.
- 51-81. Technical Information Center.
82. Office of Assistant Manager for Energy Research and Development, Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN 37830.