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IDAHO NATIONAL ENGINEERING LABORATORY

**ETOP 14, A FORTRAN CODE TO PROCESS
ENDF/B DATA INTO THE 68-GROUP
PHROG LIBRARY FORMAT**

PREPARED BY AEROJET NUCLEAR COMPANY FOR
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

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ETOP 14, A FORTRAN CODE TO PROCESS
ENDF/B DATA INTO THE 68-GROUP
PHROG LIBRARY FORMAT

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Date Published - July 1976

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TABLE OF CONTENTS

	<u>Page</u>
I. Introduction	1
II. SR. MAIN and ENDF/B File 1	4
1. SR. ETOP 10	9
2. Processing ENDF/B File 1	12
3. Modification of ENDF/B Data Tape as Part of Input	12
III. Resonance Parameters and File 2	13
1. Treatment of Parameters in SR. TMF2	15
2. S Wave Resonances in the Resolved Resonance Range, SR. RESS	19
3. Construction of Resolved Range Integration Mesh	21
4. S Wave Resonance Equations	29
5. SR. RESO and PHROG Resonance Library	32
6. SR. RESR	32
7. SR. RESU and the Unresolved Resonance Range	32
IV. Pointwise Cross Sections From File 3	46
V. Elastic and Non-Elastic Scattering Matrices	51
1. Elastic Matrices	52
2. First Algorithm for S Wave Scattering Range	55
3. Algorithm 2. ETOG Algorithm in Anisotropic Scattering Range	61
4. Algorithm 3. DAO Algorithm for Non-Elastic Scattering or Elastic Scattering in the Anisotropic Scattering Range	66
5. Numerical Integration for DAO Algorithm	75
6. Accuracy Requirements for the DAO Algorithm	79
7. Renormalization of Non-Elastic Scattering Matrices	83
8. Beryllium n-2n Reaction	87
9. Algorithm 4. Infinite Target Mass Algorithm for Continuum Inelastic and n-2n Scattering Matrices	91

TABLE OF CONTENTS (continued)

	<u>Page</u>
10. Algorithm 5. Smooth Background Scattering Matrix in Isotropic Scattering Range	95
VI. SR. ETOP 80 and PHROG Library Format	101
VII. Input Variable Definitions	114
References	134
Appendix A. Energetics of Non-Elastic Scattering	A-1
Appendix B. Contents of Common Blocks	B-1
Appendix C. Subroutine Bibliography	C-1
Appendix D. Error Stops	D-1
Appendix E. ^{238}U Sample Problem	E-1

Tables

Table 1. PHROG Group Structure (68 groups)	10
Table 2. Values of p_i	44
Table 3. Values of p'_i	44
Table 4. Reaction Types Processed in SR. CROS	47
Table 5. $M^l(A)$	60
Table 6. Elastic Scattering Matrices ^{237}Np , Material 1263, Source Group 3	81
Table 7. Elastic Scattering Matrices ^{12}C , Material 1274, Source Group 7	82

Figures

Figure 1. SR. MAIN	5
Figure 2. Resonance Mesh, First Range	22
Figure 3. Mesh, Region 1 and 2	24
Figure 4. Choice of z_i and p_i for Approximation of $S[f(x)]$ by 5-Point Integration	42
Figure 5. Elastic Scattering Integration Domain	58

	<u>Page</u>
Figure 6. Downscatter Domains of Integration for Algorithm 2.	63
Figure 7. Within Group Domains of Integration	64
Figure 8. Illustration of DAO Algorithm	71
Figure 9. Flat Cross Section Approximation for Background Scattering Cross Section	99
Figure A1. Geometry of CM to LAB Transformation	A-5
Figure A2. Geometry for Double-Valued Region of Hyperbola	A-13
Figure A3. Non-Elastic Hyperbola	A-16

I. INTRODUCTION

ETOP 14 processes neutron cross-section data from the ENDF/B⁽¹⁾ format to the 68-group PHROG⁽²⁾ fast spectrum code. As the program name implies, ETOP 14 has undergone 14 significant revisions from the original version of the ETOG⁽³⁾ code which we received from Westinghouse Nuclear Energy Systems some time in 1967. Many of these revisions merely reflect differences in the PHROG library format over output formats provided by ETOG. Major changes have accompanied modifications in the ENDF/B format and modifications to the PHROG code necessitated by changes in the ENDF/B format. A large number of program changes have been made to increase the program's efficiency and accuracy in treating specific cross sections. Many of these changes parallel similar modifications to the ETOG⁽⁴⁾ code over the years. Much of ETOP 14 is still very similar to ETOG. A large number of auxiliary subroutines used to manipulate ENDF/B data sets are identical to the original subroutines from ETOG testifying to the excellent procedures employed in the original program.

No code the size of ETOP 14 which is tied to the ever changing requirements of cross section formats and accuracy is ever finished. The present version of the program will process all Version 4 ENDF/B formats except the Adler-Adler multilevel resonance formula.⁽¹⁾ A number of approximate treatments of specific cross sections, e.g., p-wave resolved resonances, reflect the fact that PHROG is principally a fast spectrum code for thermal reactor systems. The major limitation in the application of PHROG to fast spectrum systems at present is the inability to self-shield resolved resonances from ENDF/B materials which contain multiple isotope resonance libraries in File 2. The present version of ETOP 14 calculates infinitely dilute capture and fission cross sections and an infinitely dilute elastic scattering matrix for these materials over the resonance range. This limitation will be corrected in the near future. Some reaction cross sections which are only prominent above 10 Mev are ignored by ETOP 14. The code in its present form can be easily extended above 10 Mev. The maximum number of multigroups permitted is 99 even though the PHROG library is presently limited to 68 quarter lethargy groups.

The 14th revision of ETOP involved modifications associated with the calculation of inelastic and n-2n scattering matrices for the large amount of level data in the Version 4 ENDF/B files which is correlated in energy and angle of scattering. The DAO algorithm⁽⁵⁾ which resulted from this analysis also greatly facilitated the calculation of elastic scattering matrices in the anisotropic scattering range. Target recoil is now accurately accounted for with both correlated and uncorrelated non-elastic level cross sections. As a result, both P_0 and P_1 non-elastic scattering matrices are produced for the PHROG library.

A minor change in programming philosophy was incorporated in the new subroutines which were added during this revision. We attempted to communicate through subroutine argument lists as much as possible instead of through COMMON blocks. The existing COMMON blocks were cumbersome to the point where it was becoming difficult to keep track of important subroutine flags and their origin.

The present manuscript assumes a complete familiarity with the ENDF/B format⁽¹⁾ by the reader. No attempt has been made to point out how format differences affect the interpretation of the ENDF/B data sets being read. Only those subroutines and internal flags which affect the data logical flow and accuracy are discussed at length. The discussion in the body of the manuscript follows the program sequence, as data is stripped from an ENDF/B tape, as far as possible. A large number of important subroutines which manipulate ENDF/B data at intermediate stages are not discussed at all. A general discussion of all subroutines internal to ETOP 14 is beyond the scope of the present report. This would be a monumental task.

Many new input flags have been added to the input data list so the problem requestor can control both accuracy and mode of important computation steps. We have attempted to simplify the preparation of input data by including as far as possible standard default values for most input variables. The ^{238}U sample problem is complete. However, a number of other sample input data sheets have been included without the problem output to aid in the preparation of input data. In this respect, one example is worth a thousand words.

With the numerous error correction tapes for existing ENDF/B evaluations appearing from time to time, we have included the CRECT⁽⁶⁾ code as a subroutine in ETOP 14. Revisions of an ENDF/B material may be made along

with an ETOP 14 problem without generating corrected ENDF/B tapes. Existing PHROG library tapes may be edited and printed with the input EDIT option. An auxiliary code⁽⁷⁾ permits the coalescing of two PHROG library tapes over selected materials. Thus, materials from two PHROG library tapes may be combined or deleted at will.

The completed PHROG library is added directly to an old PHROG library tape. Two options are available: the new material may be given a new I.D. and added onto the end of an existing tape or the new material may be assigned an already existing I.D. and replace the old material on the old PHROG tape. If several materials are processed in the same job, they are added onto the end of an existing PHROG tape in the same sequence they are processed.

Two load modules presently exist for ETOP 14. The second load module was required to process ^{12}C , ^{16}O and ^{14}N which contain more than 24 elastic angular distributions from File 4 in individual PHROG groups. This load module requires 54K additional core over the standard load module which can handle all other Version 4 ENDF/B materials.

CPU time for ETOP 14 varies depending on a number of factors. ^{238}U requires 12 minutes, 23 seconds on the IBM 360-75 because of the large number of resolved resonance parameters in File 2. CPU time for materials without resonance libraries depends somewhat on the number of discrete inelastic levels present in the files. Most non-resonant materials require less than 8 minutes CPU time. The program has been written in the Fortran IV language.

II. SR. MAIN AND ENDF/B FILE 1

Overall control of ETOP 14 is maintained in SR. MAIN. In general, four classes of problems may be executed by SR. MAIN controlled by specific input flags. Any number of problems may be stacked for consecutive runs on the same job, but N stacked problems may access no more than 2 ENDF/B tapes mounted on units 11 and 23. The ENDF/B material number to be processed in consecutive runs must be sequenced in the same order as copied on the ENDF/B tape. The four classes of problems controlled by SR. MAIN are:

1. Process a complete cross-section library for one ENDF/B material and add the resultant multigroup library to a PHROG library tape.
2. Process a complete cross-section library for one ENDF/B material, but do not add it to a PHROG library tape.
3. Process a fission spectrum for one ENDF/B material and add it to a PHROG library tape or do not add to a PHROG library tape depending on input flag ISPECA.
4. Perform an edit of an existing PHROG library tape without processing any ENDF/B material data.
Option 4 gives printed listings of selected materials and/or fission spectra from an existing PHROG library tape.

All of these options are controlled by input flags. A simplified flow chart of SR. MAIN is given in Figure 1. In Figure 1, IRUNC is the index for the ENDF/B material being process during the current run. SR. ETOP 10 calls SR. ININ to read the card input data for each material of a sequentially stacked job. When no further card input can be read in SR. ININ, the job end occurs. The input data definitions and format are described in Section VII.

A brief summary of the functions performed in the subroutines called from MAIN is given below.

ETOP 10 calls SR. ININ to read input data cards for each run and sets appropriate control flags depending on the input data. Multi-group boundaries are calculated and the requested weighting spectrum is generated. File 1 of the ENDF/B tape is accessed and the data that is needed is processed.

Figure 1. S.R. MAIN

- ETOP 20 processes the resonance parameter files. Resonance parameters are saved for the PHROG library and a pointwise elastic scattering cross section is saved for the generation of the infinitely dilute elastic scattering matrix in SR. ETOP 40 over the resonance range. Multigroup capture and fission cross sections are generated in the resonance range if resonance parameters for PHROG are not requested, or are not in a format usable by PHROG.
- ETOP 30 processes the pointwise cross sections in ENDF/B file 3 into a multigroup set. Pointwise cross sections needed for generation of elastic and non-elastic scattering matrices in SR. ETOP 40 and ETOP 50 are saved for later use. Control flags are set which control appropriate reaction cross sections later in the program.
- ETOP 40 generates the elastic and non-elastic portions of the multigroup scattering matrices which are correlated in energy and angle of scattering. The scattering matrices are generated in the order that the angular distributions are read sequentially from file 4.
- ETOP 50 generates the non-elastic scattering matrices corresponding to continuum cross sections from file 3. File 5 of the ENDF/B tape is processed for all secondary energy distributions.
- ETOP 80 At the completion of SR. ETOP 50 all cross sections and secondary energy distributions have been processed and saved in designated storage areas. ETOP 80 formats the data for the PHROG library and calls SR. PHED to copy the new material onto the PHROG library tape and print a listing for the new material in PHROG format. SR. ETOP 80 controls the editing of an old PHROG tape if this job is an edit run.

The ENDF/B tape is never rewound during the program. Therefore, stacked runs must be sequenced in the order of the materials on an ENDF/B

tape. Otherwise, a program stop occurs indicating a requested material is out of sequence for the current run.

At any stage in the program the reading of the ENDF/B tape is controlled by 5 SR.'s TMFN (KALL, MWANT).

where KALL = 1 → read an ENDF/B head card.

KALL = 2 → read a data set.

MWANT = MT number of ENDF/B reaction requested.

SR. TMF1 reads file 1 data.

SR. TMF2 reads file 2 data.

SR. TMF3 (I,J) reads file 3 data.

SR. TMF4 (I,J) reads file 4 data.

SR. TMF5 (I,J) reads file 5 data.

When a particular TMFN subroutine is called, the tape is positioned to the head card of the appropriate MWANT reaction type in file number MF by a call to SR. TPOS (MF, MWANT). In this way, undesired reaction types may be skipped since the MT numbers on the ENDF/B tape are listed sequentially in each file. The actual data records are read into COMMON/RECS/ by a call to one of the following subroutines:

SR. LIST reads an ENDF/B LIST record.

SR. TAB1 reads an ENDF/B TAB1 record.

SR. TAB2 reads an ENDF/B TAB2 record.

The type of record to be read is controlled by flags on the head card. These flags are defined in the ENDF/B Formats and Procedures Manual.⁽¹⁾ Each TMFN subroutine is programmed to recognize and interpret the particular ENDF/B control flags and partition and store the data set read accordingly.

COMMON/RECS/ is dimensioned for 12,000 single-precision data words. After data is read from the ENDF/B tape, the control subroutine executes appropriate multigroup operations on the data set. In many cases, the data set must be stored temporarily until such a time that additional data from another file is available for the requirements of a particular algorithm; e.g., the pointwise elastic cross section from File 3 must be saved until the pointwise angular distributions are read from File 4 in SR. ETOP 40.

A large number of additional direct and auxiliary storage areas are available for temporary storage of data sets.

COMMON/DENS/ is dimensioned for 28,000 single-precision data words. COMMON/DENS may be accessed by the following subroutines.

- SR. STORE will transfer a data set from COMMON/RECS/ to a numbered storage location in /DENS/. Unlike COMMON/RECS/, the data set in /DENS/ will be packed between other data sets residing there in a continuous manner without any gaps between data sets. /DENS/ storage is efficient whereas COMMON/RECS/ is general.
- SR. FETCH will transfer a numbered data set from COMMON/DENS/ back into COMMON/RECS/.
- SR. DELETE will delete a numbered data set in COMMON/DENS/ and rearrange the remaining numbered data sets in /DENS/ to eliminate gaps.
- SR. CWAX called from SR. TRIN and SR. ETOP 50 will rearrange the numbered data sets in COMMON/DENS/ to suit the particular requirements for the non-elastic scattering matrices.
- SR. PUTW will restore the numbered data sets in COMMON/DENS/ to their original configuration prior to the call to SR. CWAX.

Multigroup data sets are stored in designated common blocks specifically designed for vectors and matrices. Most of these blocks are not general storage areas but particular to specific subroutines. Tapes and disks are named auxiliary storage units in COMMON/TAPES/. Specific designation of common blocks and tape or disk storage is defined in Appendix B.

A large number of program stops occur at key locations in important subroutines when the program senses numerical errors, format errors or logical errors. In all cases, the error stop is formatted to indicate the subroutine in which the stop occurred, the location in the subroutine and the data and logical explanation for the program stop.

At various locations in the program, important multigroup data sets at stages of partial completion are printed in the output listing so the

problem requester can monitor numerical accuracy and logical consistency in the overall digestion of the ENDF/B data. These output listings are labeled according to kind and intermediate function at the time of printing. Other messages alert the problem requester to the absence of particular ENDF/B data sets or any inconsistency resulting from requested input data flags and ENDF/B data formats.

Subroutine ETOP 10

SR. ETOP 10 performs two functions. The first is to read and digest the card input data and set logical flags based on input options. Preliminary computations are performed which do not require ENDF/B data; e.g., multigroup boundaries are set and the weighting function is generated. The second function is to process the data in File 1 of the ENDF/B tape.

The input data and options defined in Section VII are read in SR. ININ called from SR. ETOP 10. SR. ININ then sorts the input options and sets default values for input options not specifically flagged in the input data. Only a relatively few input options are required in most problems. The rest have default values set automatically in SR. ININ if not specifically named on the input cards. After reading the input data, logical control flags are set which control the overall flow of the program thereafter. The PHROG fast spectrum code is based on 68 quarter lethargy groups defined in Table 1. MAXG is the total number of groups requested for a problem. Five standard options are available to designate the multigroup structure desired. They are controlled by the input flag IEU.

IEU	Multigroup Structure
1	Standard GAM I (PHROG) group structure.
2	Standard GAM II group structure.
4	Standard MUFT-4 group structure.
6	Arbitrary input energy group structure.
7	Arbitrary input lethargy group structure.

MAXG, the total number of groups, is limited to a maximum of 99. IEU = 1 is the default value (Table 1) for normal PHROG processing. We emphasize here that the options on group structure are just that; i.e.,

TABLE 1

PHROG GROUP STRUCTURE (68 GROUPS)

Group Number	Lower Lethargy	Lower Energy (ev)	Group Number	Lower Lethargy	Lower Energy (ev)
1	0.25	7.75×10^6	35	8.75	1.59×10^3
2	0.50	6.07×10^6	36	9.00	1.23×10^3
3	0.75	4.72×10^6	37	9.25	961.1
4	1.00	3.68×10^6	38	9.50	748.5
5	1.25	2.87×10^6	39	9.75	582.9
6	1.50	2.23×10^6	40	10.00	454.0
7	1.75	1.74×10^6	41	10.25	353.6
8	2.00	1.35×10^6	42	10.50	275.4
9	2.25	1.05×10^6	43	10.75	214.5
10	2.50	8.21×10^5	44	11.00	167.0
11	2.75	6.39×10^5	45	11.25	130.1
12	3.00	4.98×10^5	46	11.50	101.3
13	3.25	3.88×10^5	47	11.75	78.9
14	3.50	3.02×10^5	48	12.00	61.4
15	3.75	2.35×10^5	49	12.25	47.9
16	4.00	1.83×10^5	50	12.50	37.3
17	4.25	1.43×10^5	51	12.75	29.0
18	4.50	1.11×10^5	52	13.00	22.6
19	4.75	8.65×10^4	53	13.25	17.6
20	5.00	6.74×10^4	54	13.50	13.7
21	5.25	5.25×10^4	55	13.75	10.68
22	5.50	4.09×10^4	56	14.00	8.32
23	5.75	3.18×10^4	57	14.25	6.48
24	6.00	2.48×10^4	58	14.50	5.04
25	6.25	1.93×10^4	59	14.75	3.93
26	6.50	1.50×10^4	60	15.00	3.06
27	6.75	1.17×10^4	61	15.25	2.38
28	7.00	9.12×10^3	62	15.50	1.86
29	7.25	7.10×10^3	63	15.75	1.44
30	7.50	5.53×10^3	64	16.00	1.125
31	7.75	4.31×10^3	65	16.25	0.876
32	8.00	3.36×10^3	66	16.50	0.683
33	8.25	2.61×10^3	67	16.75	0.532
34	8.50	2.04×10^3	68	17.00	0.414

the multigroup data produced for the output routines is still PHROG type multigroup data, not GAM or MUFT type data. All options to produce multigroup data for code formats other than PHROG have been more or less disabled in ETOP 14.

SR. ETOP 10 calls SR. EU to generate the energy dependent isotropic neutron flux weighting function $W(E)$ used to weight all energy dependent cross sections. The input flag IW determines selection of the weighting function.

IW	Weighting Function
1	$W(E) = \frac{1}{E}$
2	$W(E) = 1.0$
3	Arbitrary input energy dependent function
4	$W(E) = \frac{1}{E}$ joined to a ^{235}U fission spectrum

IW = 4 is the weighting function normally requested for a PHROG library material. The ^{235}U fission spectrum is joined to the C/E flux at EJOIN, where

$$\text{EJOIN} = \text{EZERO} \cdot 2^{-5.0} = 67.4 \text{ kev} \quad (2.1)$$

$$\text{EZERO} = 10 \text{ Mev}$$

Below energy EJOIN,

$$W(E) = \frac{C}{E}, \quad .99 \star .414 \text{ ev} \leq E \leq \text{EJOIN} \quad (2.2)$$

$$\text{where } C = \text{EJOIN} \star W(\text{EJOIN}) \quad (2.3)$$

Above energy EJOIN, $W(E)$ is a ^{235}U fission spectrum given by,

$$W(E) = \sqrt{\frac{4E}{\pi E_0^3}} \cdot 2^{-\frac{E}{E_0}}, \quad \text{EJOIN} \leq E \leq \text{EZERO} \quad (2.4)$$

$$\text{where } E_0 = \text{EZERO} = 1.273 \text{ Mev}$$

The pointwise weight $W(E)$ is stored in COMMON/DENS/, location 1 for use in obtaining weighted cross section integrals. Groupwise integrals of the weight $W(E)$ are stored in ZETA (I), $I = 1, \text{MAXG}$. Groupwise averages of a cross section $\sigma(E)$ are then obtained from

$$\sigma_g = \frac{\int_{E_g}^{E_{g+1}} \sigma(E) W(E) dE}{\text{ZETA}(g)} \quad (2.5)$$

where σ_g is the average cross section for group g .

Processing ENDF/B File 1

A large amount of data, e.g., decay data, fission yields, is contained in File 1 which is extraneous to the neutron cross sections processed by ETOP 14. SR. ETOP 10 calls SR. TMF 1 to read only two data sets in File 1. These are: 1. The hollerith documentation record is read by SR. HOLL and printed for the ETOP 14 output listing. This record does not appear on the PHROG library tape. 2. The number of neutrons per fission $\nu(E)$ is read and saved for processing by SR. CROS. If $\nu(E)$ is a tabular distribution, the TAB1 record is temporarily stored in /DENS/ 3. SR. ETOP 10 then stores the tabular distribution on unit ITP4 for combination with the fission cross section in SR. CROS and subroutines RESS and RESU. The coefficients for an analytic function $\nu(E)$ are stored in COMMON/CONF1/ in the C array. All other data in File 1 is read without processing to position the ENDF/B tape to the head card of File 2.

Modification of ENDF/B Tape Data as Part of Input

SR. CRECT⁽⁶⁾ has been included in ETOP 14. If the input flag ICRECT = 1, 2 has been set, data on an ENDF/B tape may be modified during an ETOP 14 job. The corrections must be made on the first run of a stacked job. The input format for CRECT cards is given in Section VII. If ICRECT = 1, the corrected ENDF/B data tape is a scratch tape. If ICRECT = 2, the corrected ENDF/B tape is saved and no ENDF/B material is processed on this job.

III. RESONANCE PARAMETERS AND FILE 2

The processing procedure for the File 2 resonance parameters depends on the ENDF/B File format as well as on the choice of elastic scattering matrix to be produced in SR. ETOP 40 and SR. FRGOUT called from SR. ETOP 80. The type of elastic scattering matrix produced in the resonance range depends on the input flag IWG discussed in Section V. An option in the PHROG code permits shielding of the elastic scattering matrix by PHROG in the resonance range under certain conditions. These conditions are:

1. Resonance parameters for only a single isotope are present for this material. The present version of PHROG will only calculate resonance cross sections from parameters one isotope at a time. If the File 2 format yields more than one isotope ($NIS > 1$) for a material, then ETOP 14 will calculate the elastic scattering matrix at infinite dilution from File 2 parameters over the resonance range. The capture and fission cross sections will also be calculated from the parameters at infinite dilution.
2. The PHROG code will only shield the elastic scattering matrix in the resonance range for cases where the isotopic mass is greater than 16. This yields only one group downscatter for the quarter lethargy group structure of PHROG. If resonance parameters exist for a material of mass less than 16, ETOP 14 will precalculate an infinitely dilute scattering matrix for the resonance range.

In any event, decisions made in SR. ETOP 20 relative to treatment of resonance parameters may be overridden by the input flag IRES. If $IRES = 1$, no resonance parameter library will be produced for PHROG. All cross sections in the resonance range will be calculated at infinite dilution from the resonance parameters in File 2. If $IRES = 0$, resonance parameter library will be constructed for PHROG provided items 1 and 2 above are satisfied.

If $IRES = 0$, and items 1 and 2 above are satisfied, an independent option exists for the calculation of the elastic scattering matrix depending on the input flag IWG.

- IWG = 1: Calculate an infinitely dilute elastic scattering matrix from the resonance parameters.
- IWG = 2: Do not include the infinitely dilute elastic scattering cross section from s wave resonance parameters in File 2. Calculate only an incomplete scattering matrix from the File 3 smooth background elastic cross section plus contributions from any p wave resonances found in the resolved resonance range in File 2. The resolved p wave resonances are calculated at infinite dilution and added to the File 3 background elastic cross section.
- IWG = 3: Both an infinitely dilute elastic scattering matrix calculated from resonance parameters and an incomplete background scattering matrix (IWG = 2) are calculated for the PHROG library so PHROG will have either option to select from.

Algorithms for the calculation of the elastic scattering matrix are examined in Section V. If IRES = 0 and Items 1 and 2 above are satisfied in SR. ETOP 20, s wave resonance parameters in the resolved resonance range and all resonance parameters from the unresolved resonance range to input group KGTR0P are saved for the PHROG resonance library by SR. RES0. The definition of input group KGTR0P is discussed in Section V. In all other cases, pointwise energy dependent cross sections are constructed at infinite dilution from the resonance parameters in File 2 and integrated to obtain multigroup cross sections over the complete resonance range.

The resonance parameters are read from File 2 to temporary storage locations by SR. TMF2. Conditional flags are then set to determine energy ranges over which resonance parameters are to be converted to infinitely dilute cross sections and energy ranges over which PHROG will calculate shielded cross sections from resonance parameters. The following subroutines are then called from SR. ETOP 20 for the treatment of resonance parameters.

- SR. RESS calculates pointwise infinite dilution capture, fission and elastic scattering cross sections in the resolved resonance range from the resolved resonance parameters which fall in the accepted resolved resonance range for PHROG II. The elastic scattering cross section from negative and thermal energy resonances is also calculated in SR. RESS.
- SR. RESO selects s wave resolved resonance parameters which are to be sent to PHROG. Negative energy and thermal energy (below lower energy bound of resolved resonance range) resonances are sorted out to be processed in SR. RESR.
- SR. RESR calculates average groupwise capture and fission cross sections to be added to the smooth File 3 background cross sections from negative and thermal energy resonances over the resolved resonance range. The pointwise elastic scattering from these resonances was calculated in SR. RESS.
- SR. RESU calculates pointwise infinite dilution capture, fission and elastic scattering cross sections to be integrated over the unresolved resonance range.

Treatment of Parameters in SR. TMF2

SR. TMF2 reads the resonance parameter files and stores the resolved parameters in temporary arrays and stores the unresolved range parameters in the permanent array UQA (IQN). The LRF flag indicates the type of resolved resonance parameters given in the file. For $LRF > 2$ a program stop occurs. This indicates that Adler-Adler or Reich-Moore⁽¹⁾ resolved range multilevel parameters are given in File 2 which cannot be processed by ETOP 14. If $LRF = 2$, Multilevel Breit Wigner resonance parameters are given in File 2 for the resolved range. A warning message is printed indicating that $LRF = 2$ is being reset to 1 where the multilevel parameters will be processed in ETOP 14 and PHROG as Breit Wigner single-level parameters.

Resolved and unresolved energy range limits are stored in appropriate

arrays for use in subroutines RESS, RESO, RESR and RESU.

Resolved p wave resonances are removed from the temporary arrays by SR. PANL (I) for each isotope I and an infinite dilution resonance integral is calculated for each p-wave resonance. The average capture, fission, and compound elastic cross sections determined from the analytic p-wave resonance integrals for each energy group are saved to be added to the smooth background cross sections from File 3. The p-wave resonances are usually very small in the resolved resonance range and are not treated by the present version of PHROG. The average reaction cross section σ_{xg}^1 for a p-wave resonance falling in group g of the resolved range is

$$\sigma_{xg}^1 = \frac{\sum_{I=1}^{NIS} \sum_{J^1} \sum_{r_{J1g}} B_I \frac{\pi}{2} \sigma_0 \frac{\Gamma_{x,r}^1}{E_{rg}}}{\Delta U_g} \quad (3.1)$$

where $\Delta U_g = \ln \left(\frac{E_g}{E_{g-1}} \right) = \int_{E_g}^{E_{g-1}} \frac{dE}{E}$

E_g, E_{g-1} are the group boundaries for group g

$\sum_{r_{J1g}}$ is the sum over all resonances in group g with total p-wave angular momentum J^1 .

B_I is the abundance weight for isotope I

NIS is the number of isotopes for this material

E_{rg} = the p-wave resonance energy in group g

$\Gamma_{x,r}^1$ = p-wave partial resonance width capture, fission and compound elastic scattering for resonance r.

$$\sigma_0 = \frac{4\pi}{k^2} g_J^1 \frac{\Gamma_{n,r}^1}{\Gamma_{T,r}^1}, \text{ capture and fission} \quad (3.2)$$

$$\sigma_0 = \frac{4\pi}{k^2} g_J^1 \frac{\Gamma_{n,r}^1}{\Gamma_{T,r}^1} \cos(2\phi_1) \text{ for compound elastic} \quad (3.3)$$

$(\Gamma_{n,r}^1)^* =$ p-wave neutron width , resonance r

$$(\Gamma_{T,r}^1)^* = \Gamma_{nr}^1 + \Gamma_{\gamma r}^1 + \Gamma_{Fr}^1$$

$$g_J^1 = \frac{2J^1 + 1}{2(2I + 1)} \quad (3.4)$$

$J^1 =$ total angular momentum quantum number of the compound nucleus
for $\ell = 1$.

$I =$ ground state spin of the target nucleus

$$k = 2.196771 \times 10^{-3} \frac{A}{A+1} \sqrt{E_{rg}}$$

$$\phi_1 = \rho - \tan^{-1}(\rho)$$

$$\rho = kR$$

$R =$ the effective scattering radius given in File 2

*Variation of $\Gamma_n^1(E)$ with energy is $\Gamma_n^0 E^{3/2} = \Gamma_n(E_r) * E_r$

This variation is assumed to cancel between Γ_n^1 and Γ_T^1 in Equations (3.2) and (3.3).

Equation (3.1) is an approximate upper limit for the average p-wave resonance cross sections at infinite dilution. The average capture, fission and compound elastic cross section is calculated from Equation (3.1) and added to arrays which will contain the smooth background cross sections from File 3. The p-wave potential scattering cross section is not calculated in SR. PANL (I) but is added at the time the s-wave potential scattering cross section is calculated in SR. RESS. d-wave resonances are ignored in the resolved resonance range. Contributions from p- and d-wave resonances in the unresolved resonance range are calculated in SR. RESU.

SR. PANL (I) also stores the p-wave elastic scattering cross section from Equation (3.1) in two arrays PSCAT (I, 1) and PSCAT (I, 3) to be used in conjunction with Algorithm 5., Section V, for the calculation of the background scattering matrix for input options IWG = 2, 3. The two arrays for group I are,

$$\text{PSCAT (I, 1)} = \text{Contribution from ELO} \rightarrow \frac{\text{ELO}}{\alpha}$$

$$\text{PSCAT (I, 3)} = \text{Contribution from ELO} \rightarrow \text{EHI}$$

where ELO is lower energy bound for group I

EHI is upper energy bound for group I

ELO/α energy bound above which no out of group scattering occurs

$$\alpha = \left(\frac{A - 1}{A + 1} \right)^2$$

where A = target to neutron mass ratio

Discussion of the details of the background elastic scattering matrix for the resonance range is given in Section V. Equation (3.1) gives only average values of cross sections from the p-wave resonances over the energy ranges specified. Thus, the detailed structure of the p-wave resonance elastic scattering cross section does not enter into the pointwise determination of elastic scattering matrices. p-wave resonance contributions are lumped in with the background cross sections from File 3

in the resolved resonance range only. p-wave resonance contributions in the unresolved resonance range are treated in the same way as s-wave resonances.

S-WAVE RESONANCES IN THE RESOLVED RESONANCE RANGE, SR. RESS

Only for the case $IWG = 2$, $IRES = 0$, is it not necessary to determine a detailed pointwise elastic scattering cross section from s-wave resonance parameters over the resolved resonance range. In all other cases, the pointwise elastic scattering cross section must be constructed from s-wave resonance parameters over the complete resolved resonance range in order to determine accurately the elastic scattering matrices. The infinite dilution capture and fission cross sections from s-wave resonance parameters can be obtained with little additional time when the compound elastic scattering cross section is calculated. Thus, SR. RESS calculates average capture and fission cross sections over the resolved resonance range even though not needed in many cases for the PHROG library. These cross sections are printed for information only.

In some materials, hundreds of s-wave resolved resonances are present in File 2 over the resolved resonance range. The generation of a detailed pointwise representation of cross sections from these parameters to produce accurate integrals is a difficult numerical problem when unlimited amounts of core storage are not available. The resonance energies are essentially random numbers as far as the group structure is concerned. Any given group in the resolved range may contain from zero to a score of s-wave resonances arbitrarily spaced at a given time. Thus, a single energy group requires 2000 integration points for the worst cases. Ten or more energy groups with these requirements presents an impossible direct access storage requirement, therefore, SR. RESS disposes of the resolved range s-wave parameters one group at a time.

If more than one isotope is present for a single ENDF/B material, the resonances for NIS isotopes must be recombined and reordered into a single set if a single resonance mesh is to be constructed in one pass for each group. This is accomplished in SR. RESS just before the construction of the groupwise mesh begins. Only the resonance energy E_r and the total width Γ_T are combined and reordered for the construction of the mesh over all isotopic resonances. This reordered set is stored in a temporary storage block. The complete set of resonance parameters ordered by isotope remains in the permanent storage block.

In Section V, Algorithm 1 is used for the calculation of the elastic scattering matrix in the s-wave resonance range. Algorithm 1 requires an integration mesh over two basic energy ranges in each PHROG group.

1. Outscatter range, $EL0 \rightarrow EL0/\alpha$

$$\text{where } \alpha = \left(\frac{A-1}{A+1} \right)^2$$

2. Full scatter range, $EL0 \rightarrow EHI$

where $EL0$ = lower group boundary

EHI = upper group boundary

The basic logic of SR. RESS is to index one PHROG group at a time and process all s-wave resonance parameters over an energy mesh which recognizes these two basic energy ranges for Algorithm 1. The resultant pointwise cross sections from each group are then saved for future usage. The construction of an accurate trapezoidal integration mesh is the principal difficulty considering the wide variety of cases one normally encounters in a single group.

A brief outline of SR. RESS follows.

- A. Index a single PHROG group and set initial flags and range limits. Reorder resonances for all isotopes to a single set.
- B. Determine the number of s-wave resonances falling within the two energy ranges in the group.
- C. Construct an integration mesh over the first range $EL0 \rightarrow EL0/\alpha$.
- D. Construct an integration mesh over the second range $EL0/\alpha \rightarrow EHI$.
- E. Calculate pointwise capture, fission and elastic scatter cross sections from all resonances within the group at each mesh point.

- F. Calculate pointwise capture, fission and elastic scatter cross section tails from all resonances outside the group which nevertheless still contribute to the group.
- G. Integrate the capture and fission cross sections and store.
- H. Save the detailed pointwise elastic scattering cross section from each group for the generation of the elastic scattering matrix using Algorithm 1 in SR. TRAN.
- I. Repeat steps B $\rightarrow$ H. for each PHROG group in the resolved energy range.

When more than one isotope is present in a single material, steps B $\rightarrow$ F require a sum over all isotopes in the material.

Construction of Resolved Range Integration Mesh

Each group is divided into two basic ranges to satisfy Algorithm 1, Section V. The maximum number of mesh points permitted for the whole group is 2000.

NCNT = number of resonances found in group g.

NCRES = number of resonances from $ELO \rightarrow ELO/\alpha$

ICNT = NCNT - NCRES = number of resonances from $ELO/\alpha \rightarrow EHI$

Case 1 NCNT = 0 This Group

Construct a uniformly spaced lethargy mesh over 201 points from ELO to EHI.

Case 2, NCNT $\neq$ 0 This Group

First Range $ELO \rightarrow ELO/\alpha$

The maximum number of mesh points permitted in this range is 288.

Case 3, NCRES = 0

Construct a uniformly spaced lethargy mesh over 100 points from ELO to ELO/α .

Case 4, NCRES $\neq 0$.

Allot each resonance 96 points where $NEP = NCRES * 96$ is the total number of points. If $NEP > 288$, $NEP = 288$. NEP is then divided by $NCRES$ to determine the number of points per resonance IPTS. IPTS is reduced until it is divisible by 6. This corresponds to 6 segments between any two resonances where LPTS is the number of points in each segment.

$$IPTS = 6 * LPTS.$$

The 6 segments between two resonances are marked off in the following way (Figure 2).

Figure 2. Resonance mesh first range.

ELEFT and ERITE are the resonance energies of the two adjacent resonances.

$$EMID = \frac{ERITE + ELEFT}{2.0} \quad (3.5)$$

$$ELG1 = ELEFT + \Gamma_T(LEFT) \quad (3.6)$$

$$ELG2 = ELEFT + 4.0 * \Gamma_T(LEFT) \quad (3.7)$$

$$ERG2 = ERITE - 4.0 * \Gamma_T(RITE) \quad (3.8)$$

$$ERG1 = ERITE - \Gamma_T(RITE) \quad (3.9)$$

where Γ_T is the total width of the resonance.

There are 6 Segments, LPTS uniformly spaced lethargy points in each segment.

Segment Number	Energy Range
1	ELG1 - ELEFT
2	ELG2 - ELG1
3	EMID - ELG2
4	ERG2 - EMID
5	ERG1 - ERG2
6	ERITE - ERG2

(3.10)

In the event either $ELG1, ELG2 \geq EMID$, the first three segments will overlap. Equations (3.6) and (3.7) are then replaced by,

$$ELG2 = \frac{EMID + ELEFT}{2.0} \quad (3.11)$$

$$ELG1 = \frac{ELEFT + ELG2}{2.0} \quad (3.12)$$

In the event either $ERG1, ERG2 \leq EMID$, the last three segments will overlap. Equations (3.8) and (3.9) are replaced by,

$$ERG2 = \frac{EMID + ERITE}{2.0} \quad (3.13)$$

$$ERG1 = \frac{ERG2 + ERITE}{2.0} \quad (3.14)$$

The uniformly spaced lethargy mesh is generated for LPTS points in each segment and stored in BLOCK 1 (MSTAR) where MSTAR is the cumulative number of points. In general, the first and last segments have a more closely spaced mesh than the other segments because they represent the peak of the resonance cross section.

The next righthand resonance in the first range is loaded into ERITE and the last resonance at ERITE becomes ELEFT. The mesh Equations (3.5) through (3.14) are repeated for 6 new segments and the mesh values are added to BLOCK 1 (MSTAR). NCRES resonances are processed in this way in the first range.

Two regions of the first range remain to be defined for Case 4:

- A. The region from ELO to the first NCRES resonance.
- B. The region from the last NCRES resonance to ELO/α .

Figure 3.

Region 1 of First Range

$$ELEFT = ELO \quad (3.15)$$

$$ERITE = E_0(RITE) \quad (3.16)$$

$$EMID = \frac{ELEFT + ERITE}{2.0} \quad (3.17)$$

$$ELG2 = \frac{EMID + ELEFT}{2.0} \quad (3.18)$$

$$ELG1 = \frac{ELEFT + ELG2}{2.0} \quad (3.19)$$

$$ERG1 = ERITE - r_T(RITE) \quad (3.20)$$

$$ERG2 = ERITE - 4.0 * r_T(RITE) \quad (3.21)$$

If $ERG1, ERG2 \leq EMID$, Equations (3.20) and (3.21) are replaced by Equations (3.13) and (3.14). LPTS uniformly spaced lethargy points are placed in each segment defined by Equations (3.15) to (3.21). Region I is the first region in chronological order.

Region 2 of First Range

$$ELG1 = E_0(LEFT) + r_T(LEFT) \quad (3.22)$$

$$ELG2 = E_0(LEFT) + 4.0 * r_T(LEFT) \quad (3.23)$$

$$ERITE = ELO/\alpha \quad (3.24)$$

Region 2 represents the end of range 1. Sixteen equally spaced lethargy points are placed in each of the 3 segments defined by Equations (3.22) through (3.24).

At the completion of the mesh for Region 2 of the first range, BLOCK 1 (MSTAR) contains the complete set of MSTAR mesh points constructed in the first range from ELO to ELO/α . The lethargy mesh is next constructed over the second range from ELO/α to EHI. There are ICNT resonances in this range.

Case 5, ICNT = 0

A uniformly spaced lethargy mesh for 201 points is constructed from E_0/α to EHI and added point by point to BLOCK 1 (MSTAR).

Case 6, ICNT $\neq$ 0

The mesh construction procedure in the second range is repeated verbatim except that the number of mesh points in each segment of this range is different depending on ICNT. The maximum number of mesh points permitted in the second range is:

$$NEP = 1918 - \text{MSTAR (first range)} \quad (3.25)$$

$$1918 = 1998 - 80 \text{ in REGION II.}$$

If NEP is greater than $ICNT * 192$, then, $NEP = ICNT * 192$

$$IPT S = NEP / ICNT \quad (3.26)$$

$$LPTS = IPT S / 6 \quad (3.27)$$

$$IPT S = 6 * LPTS \quad (3.28)$$

Equations (3.26) and (3.27) insure that ICNT, the number of mesh points per resonance, is divisible by 6. There are then LPTS mesh points in each of 6 segments between any two resonances.

Region 1, Second Range

Equations (3.15) through (3.21) are used to construct the mesh using the first resonance in the second range as $E_0(\text{RITE})$, in Figure 3. ELEFT becomes E_0/α .

Region Between ICNT Resonances in the Center of the Range

Equations (3.5) through (3.14) are used to construct the mesh between any two consecutive resonances in the second range. As consecutive pairs of resonances are indexed,

$$E_0(\text{RITE}) \rightarrow E_0(\text{LEFT})$$

$E_0(\text{RITE})$ becomes next resonance. Each new point in the mesh is added to BLOCK 1 (MSTAR) as MSTAR is indexed for LPTS points in each segment. At the completion of all ICNT resonances in this loop, only REGION 2 (Figure 3) of the second range remains where $\text{ERITE} = \text{EHI}$.

Region 2 of Second Range

Equations (3.22) through (3.24) are used to define the three segments from the last resonance in the group to EHI, the group boundary. 80 mesh points are used over this region where points are allotted as:

$$20 \text{ points} \rightarrow E_0(\text{LEFT}), \rightarrow E_0(\text{LEFT}) + \Gamma_T(\text{LEFT}) \quad (3.29)$$

$$20 \text{ points} \rightarrow E_0(\text{LEFT}) + \Gamma_T(\text{LEFT}) \rightarrow E_0(\text{LEFT}) + 4 * \Gamma_T(\text{LEFT}) \quad (3.30)$$

$$40 \text{ points} \rightarrow E_0(\text{LEFT}) + 4 * \Gamma_T(\text{LEFT}) \rightarrow \text{EHI} \quad (3.31)$$

At the completion of this step, BLOCK 1 (MSTAR) contains the complete energy mesh for this group. The mesh may, however, overlap in Region 2 of both the first and second range. A call is made to SR. RESMSH to reorder the mesh over the MSTAR points to insure that the mesh progresses uniformly from ELO to EHI. Mesh points that are out of order are reordered. Any duplicate points are eliminated. This brings SR. RESS to step 3 above.

It remains only to calculate pointwise capture, fission and elastic scatter cross sections over the resonance mesh stored in BLOCK 1 (MSTAR) for this group. The pointwise cross sections are determined in two basic steps:

Step 1. Pointwise cross sections are calculated at every mesh point in BLOCK 1 (MSTAR) for all NCNT resonances which lie within the group and all resonances which lie outside the group but fall within 10 total widths $10 * \Gamma_T(E_0)$ of either group boundary.

Step 2. Resonances which fall outside of energy limits defined as $10 * \Gamma_T(E_0)$ from either group boundary are defined as contributing only resonance tails to this group. They fall into two classes:

- A. Resonances which fall within the resolved resonance range but outside the group limits defined above.
- B. Negative and thermal energy resonances which fall below the lower energy cutoff of the resolved resonance range or which fall below the lower energy boundary of the PHROG group structure even though they are within the ENDF/B resolved resonance range.

All Step 2 resonances are calculated at only every 24th mesh point in the BLOCK 1 (MSTAR) mesh because these resonances only contribute "tails" to the group. The cross section values are stored in a temporary storage location until the fine mesh points between every 24th point are filled in by a call to SR. FILAR which linearly interpolates the cross sections between the calculated mesh points on the coarse mesh. Contributions from these resonances are essentially $1/v$ for the capture and fission cross sections and zero for the compound elastic cross section. The potential scattering cross section over all ℓ states is calculated independently. This procedure saves large amounts of CPU time on the tails of the many s-wave resonances found in File 2.

The compound elastic cross section from Step 2.B is always calculated in SR. RESS on the coarse mesh and linearly interpolated between coarse mesh points in SR. FILAR. The capture and fission cross sections from Step 2.B type resonances are calculated in SR. RESR to be placed in permanent storage arrays for the PHROG library tape. These resonances are eliminated from the PHROG library in SR. RFSO and their contribution to the capture and fission cross section is added to the smooth background cross section from File 3. The compound elastic cross section from Step 2.B type resonances is added to the pointwise elastic cross section used to generate the complete infinitely dilute scattering matrix in SR. TRAN and is also added to the arrays PSCAT (I, 1) and PSCAT (I, 3) used to generate the incomplete background scattering matrix for IWG = 2, 3.

s Wave Resonance Equations

Pointwise values of the s wave capture, $\sigma_C^I(E)$, fission, $\sigma_F^I(E)$ and compound elastic scattering, $\sigma_S^I(E)$ cross sections for isotope I are calculated over the group mesh one isotope at a time. At the completion of the isotope loop, all resonances for a single material have been indexed. The isotopic s wave resonance equations are based on the Breit Wigner single level formula.

$$\sigma_C^I(E) = ABN(I) \frac{\pi}{k^2} \left[\sum_J g_J \sum_r^{NRJ} \frac{\Gamma_{nr} \Gamma_{\gamma r}}{(E-E_r)^2 + \left(\frac{\Gamma_{Tr}}{2}\right)^2} \right]_I \quad (3.32)$$

$$\sigma_F^I(E) = ABN(I) \frac{\pi}{k^2} \left[\sum_J g_J \sum_r^{NRJ} \frac{\Gamma_{nr} \Gamma_{Fr}}{(E-E_r)^2 + \left(\frac{\Gamma_{Tr}}{2}\right)^2} \right]_I \quad (3.33)$$

$$\sigma_S^I(E) = ABN(I) \frac{\pi}{k^2} \left[\sum_J g_J \sum_r^{NRJ} \frac{\left(\Gamma_{nr}^2 \cos 2\phi_0 - 2\Gamma_{nr}(\Gamma_{\gamma r} + \Gamma_{Fr}) \sin^2 \phi_0 + 2(E-E_r)\Gamma_{nr} \sin 2\phi_0 \right)}{(E-E_r)^2 + \left(\frac{\Gamma_{Tr}}{2}\right)^2} \right]_I \quad (3.34)$$

$$\sigma_P^I(E) = ABN(I) \frac{4\pi}{k^2} \left[\sum_{\ell=0}^2 (2\ell+1) \sin^2 \phi_\ell \right]_I \quad (3.35)$$

Equation (3.34) is the compound nucleus elastic scattering cross section with potential-compound interference terms. Equation (3.35) is the smooth potential scattering cross section for isotope I which is calculated and added to the compound elastic cross section in a separate pass in SR. RESS. Interference effects between terms of order ℓ in Equation (3.35) are important in the Mev energy range for intermediate mass materials such as Fe. Evaluation of Equation (3.35) to $\ell = 2$ has been determined to be sufficient for all Version 4 ENDF/B materials. The summation over J is for both s wave spin states in the compound nucleus for each isotope I and the summation over r is for all resonances with total angular momentum J evaluated under Step 1 and Step 2 above. The isotopic dependence of the parameters on the r.h.s. of Equations (3.32) to (3.35) has been suppressed but is implied. The parameters in Equations (3.32) to (3.35) are given by:

$ABN(I)$ is abundance of isotope I

$$k = .002196771 \frac{A}{A+1} \sqrt{E} \quad (3.36)$$

A = Target to neutron mass ratio. For a material with multiple resonance isotopes, A is the minimum mass of all isotopes.

NRJ = Number of resonances with total angular momentum J.

E_r = resonance energy of r^{th} s wave resonance for isotope I.

$$\Gamma_{nr} = \sqrt{\frac{E}{E_r}} \Gamma'_{nr} \quad (3.37)$$

Γ'_{nr} = Neutron width at resonance for r^{th} resonance of isotope I.

$\Gamma_{\gamma r}$ = Radiative capture width for r^{th} resonance of isotope I.

Γ_{Fr} = Fission width for r^{th} resonance of isotope I.

$$\Gamma_{Tr} = \Gamma'_{nr} + \Gamma_{\gamma r} + \Gamma_{Fr} \quad (3.38)$$

= Total width at resonance for r^{th} resonance of isotope I.

$$g_J = \frac{1}{2} \left(\frac{2J + 1}{2I' + 1} \right) \quad (3.39)$$

where J is the total angular momentum quantum number of the r^{th} resonance.

I' is the ground state spin of the target nucleus for isotope I .

$\ell = 0, 1, 2$ = orbital angular momentum quantum number for non-compound potential scattering.

ϕ_ℓ is the phase shift of the potential scattered partial wave with orbital angular momentum ℓ

$$\phi_0 = \rho \quad (3.40)$$

$$\phi_1 = \rho - \tan^{-1} \rho \quad (3.41)$$

$$\phi_2 = \rho - \tan^{-1} \left(\frac{3\rho}{3-\rho^2} \right) \quad (3.42)$$

$$\rho = kR$$

where R is the non-compound (potential scattering length of isotope I in units of 10^{-12} CM) given in File 2.

At the completion of the pointwise cross sections of all resonances for every mesh point in BLOCK 1 (MSTAR), the pointwise elastic scattering cross section is complete for this group except for contributions from the background cross section from File 3. The resonance pointwise elastic scattering cross section is saved on Unit ITP2 until needed in SR. TRAN. The resonance contributions to the capture and fission cross sections are integrated to obtain average values. These averages do not contain contributions from negative and thermal energy resonances, contributions from p wave resonances, or contributions from File 3. The average capture cross section from s wave resonances is temporarily stored in XSMU (g) and the average fission cross section is saved in AGN (g). These and other contributions to the complete cross section will be edited and

recombined in SR. OUT3 at the completion of File 3 processing in SR. CROS. Average values of the potential scattering cross section are stored in GNU (g).

SR. RESO and PHROG Resonance Library

SR. RESO is bypassed if a PHROG s wave resonance parameter library cannot be constructed, e.g., IRES = 1 or NIS > 1. The PHROG library will then contain only the resolved resonance cross sections which were calculated in SR. RESS. If input control and ENDF/B parameters permit passing the s-wave resolved resonance parameters to PHROG, SR. RESO sorts out the negative and thermal energy s-wave resonances and formats the remaining s-wave resolved resonances for the PHROG library. The accepted s-wave resonances are edited to the output listing and stored temporarily until the PHROG library will be constructed in SR. FRGOUT called from SR. ETOP 80. The negative and thermal energy resonances which have been deleted are also edited for information only.

SR. RESR

SR. RESR is called to calculate average groupwise values of the contribution to the capture and fission cross section from negative and thermal energy s-wave resonances which will not be passed to the PHROG library. These average values are edited to the output listing and added into the permanent cross section arrays which will be passed to the PHROG library as smooth cross sections. The compound s-wave elastic scattering contributions from these resonances have already been determined in SR. RESS.

The pointwise cross sections from these resonances are calculated on a mesh of 100 energy points for each resolved resonance range group uniformly spaced in lethargy. The average capture cross section is stored in an array XIN (g) and the average fission cross section is stored in GNU (g).

SR. RESU and the Unresolved Resonance Range

The rules governing the calculation of unresolved range pointwise and average cross sections for PHROG from unresolved range resonance

parameters are similar to those for the resolved range with three exceptions:

1. The construction of the energy mesh for each group is a trivial procedure in the unresolved range in comparison with the resolved resonance range. Only the average fission width exhibits much structure in the case of fissionable materials and even this structure takes the form of relatively smooth behavior over segments of the unresolved range. Twenty-five energy points uniformly spaced in lethargy have been sufficient to obtain accurate integrals for each energy group.
2. Unlike the resolved resonance range, both p wave and d wave unresolved parameters are acceptable to the PHROG code equations. If the PHROG library is to contain an unresolved resonance library, the complete unresolved resonance parameter library from the ENDF/B file is formatted for PHROG without any exceptions or deletions up to the limit of the isotropic scattering range (group KGTR0P).
3. An input flag KGTR0P determines the upper limit of applicability of the unresolved resonance parameter library for PHROG. PHROG will calculate shielded cross sections from the unresolved resonance parameters below in energy, the lower bound of group KGTR0P. Above in energy the lower bound of group KGTR0P, an infinitely dilute scattering matrix is precalculated by ETOP 14 from elastic scattering cross sections generated in SR. RESU. Further significance of KGTR0P is discussed in Section V.

If the input flag IRES = 1 or the number of isotopes NIS for this material is greater than 1, RESU will calculate pointwise cross sections from the unresolved range parameters and delete the ENDF/B unresolved resonance parameter library from the PHROG library. The possibility of shielding the average unresolved resonance cross sections in this case is included as an option for special PHROG libraries using the input variable SIGP. This option is rarely used with ETOP 14 since materials requiring significant shielding send the resonance parameters to the PHROG library

where shielding can be accurately accounted for. The default value of SIGP is 10^7 barns, which corresponds in infinite dilution. If the shielding option is used in ETOP 14, no temperature dependence is included. The shielded cross sections are for room temperatures.

The equations from which the unresolved range pointwise cross sections are generated are derived in reference (8) and are identical to those used in the PHROG II code with the exception of the temperature dependence of $J(\theta, \beta)$. Pointwise capture, $\langle \sigma_C(E) \rangle$, fission $\langle \sigma_F(E) \rangle$ and elastic scattering $\langle \sigma_S(E) \rangle$ cross sections are given for the case of non-fissionable isotopes by (8):

$$\langle \sigma_c(E) \rangle = \sum_{\ell, J} \frac{\frac{\sigma_p \langle r_Y \rangle_{\ell, J}}{\langle D \rangle_{\ell, J} \cos 2\phi_\ell} \int_0^\infty P_n(r) J(\theta, \beta) dr}{1 - \frac{1}{\langle D \rangle_{\ell, J}} \int_0^\infty P_n(r) r_{\ell, J} J(\theta, \beta) dr} \quad (3.44)$$

where

$$P_n(r) dr = \frac{n}{2} \frac{1}{\Gamma^*(\frac{n}{2})} \left(\frac{nr}{2}\right)^{\frac{n}{2} - 1} \exp - \left(\frac{nr}{2}\right) dr \quad (3.45)$$

and $\Gamma^*(\frac{n}{2})$ is the normalized gamma or factorial function.

$$J(\theta, \beta) = \int_0^\infty \frac{\psi(\theta, x)}{\psi(\theta, x) + \beta} dx, \quad \beta = \frac{\sigma_p}{\sigma_0 \cos 2\phi_\ell} \quad (3.46)$$

In PHROG, $J(\theta, \beta)$ is a function of the partial width fluctuation integrals through the dependence of θ and β on the partial widths. The potential plus compound elastic cross section is given by

$$\langle \sigma_s(E) \rangle = \frac{4\pi}{k^2} \sum_{\ell} (2\ell+1) \sin^2 \theta_\ell + \sum_{\ell, J} \frac{\frac{\sigma_p}{\langle D \rangle_{\ell, J} \cos 2\phi_\ell} \left[\int_0^\infty P_n(r) r_{n, \ell, J} J(\theta, \beta) dr - 2 \sin^2 \phi_\ell \int_0^\infty P_n(r) r_{\ell, J}(E) J(\theta, \beta) dr \right]}{1 - \frac{1}{\langle D \rangle_{\ell, J}} \int_0^\infty P_n(r) r_{\ell, J} J(\theta, \beta) dr} \quad (3.47)$$

where it is required that $\sum_J g_{J\mu_{\ell,J}} = 2\ell+1$ and $\mu_{\ell,J}$ is the number of degrees of freedom for the neutron width of a particular J state corresponding to the number of open decay channels for the compound nucleus with total angular momentum J formed with neutrons of angular momentum ℓ .

For fissionable isotopes, statistical fluctuations are present for both the fission width and the neutron width and the equations become^[3]

$$\langle \sigma_c(E) \rangle = \sum_{\ell,J} \frac{\frac{\sigma_p \langle r \rangle_{\ell,J}}{\langle D \rangle_{\ell,J} \cos 2\phi_\ell} \int_0^\infty P_n(r) \int_0^\infty P_k(s) J(\theta, \beta) ds dr}{1 - \frac{1}{\langle D \rangle_{\ell,J}} \int_0^\infty P_n(r) \int_0^\infty P_k(s) r_{\ell,J} J(\theta, \beta) ds dr} \quad (3.48)$$

$$\langle \sigma_f(E) \rangle = \sum_{\ell,J} \frac{\frac{\sigma_p}{\langle D \rangle_{\ell,J} \cos 2\phi_\ell} \int_0^\infty P_n(r) \int_0^\infty P_k(s) s \langle r \rangle_{\ell,J} J(\theta, \beta) ds dr}{1 - \frac{1}{\langle D \rangle_{\ell,J}} \int_0^\infty P_n(r) \int_0^\infty P_k(s) r_{\ell,J} J(\theta, \beta) ds dr} \quad (3.49)$$

$$\begin{aligned} & \frac{\sigma_p}{\langle D \rangle_{\ell,J} \cos 2\phi_\ell} \left[\int_0^\infty P_n(r) r \langle r \rangle_{\ell,J} \int_0^\infty P_k(s) J(\theta, \beta) ds dr \right. \\ & \quad \left. - 2 \sin^2 \phi_\ell \int_0^\infty P_n(r) \int_0^\infty P_k(s) r_{\ell,J} J(\theta, \beta) ds dr \right] \\ \langle \sigma_s(E) \rangle = \sum_{\ell,J} & \frac{\quad}{1 - \frac{1}{\langle D \rangle_{\ell,J}} \int_0^\infty P_n(r) \int_0^\infty P_k(s) r_{\ell,J} J(\theta, \beta) ds dr} \quad (3.50) \end{aligned}$$

If infinitely dilute cross sections are requested, the denominator in each of the above equations is effectively set equal to 1.0 and the numerator is evaluated at $\sigma = 10^7$. In this case, the numerator of Equations (3.48), (3.49), and (3.50) yields a result corresponding to infinite dilution. For other values of θ and β in the PHROG code, $J(\theta, \beta)$ is interpolated from tables and both the numerator and denominator are evaluated.

A complete listing of all the variables used in the above equations as used in SR. RESU is given below.

$\sum_{\ell, J}$ is the summation over all J and ℓ -states of a given isotope

$\langle D \rangle_{\ell, J}$ is the average level spacing for each ℓ, J state of the compound nucleus

$\langle \Gamma(E) \rangle_{\ell, J}$ is the average total width at E for the spin state ℓ, J

$\langle \Gamma(E) \rangle_{\ell, J} = \langle \Gamma_n(E) \rangle_{\ell, J} + \langle \Gamma_f(E) \rangle_{\ell, J} + \langle \Gamma_\gamma(E) \rangle_{\ell, J} + \langle \Gamma_x(E) \rangle_{\ell, J} = \Gamma$

$\langle \Gamma_\gamma(E) \rangle_{\ell, J}$ is the average radiation width at E

$\langle \Gamma_f(E) \rangle_{\ell, J}$ is the average fission width at energy E

$\langle \Gamma_x(E) \rangle_{\ell, J}$ is a partial width permitted in the ENDF/B file for all other extraneous open decay channels, e.g., discrete level inelastic excitation ($\langle \Gamma_x \rangle_{\ell, J}$ is not presently processed by SR. RESU).

$\langle \Gamma_n(E) \rangle_{\ell, J} = \langle \Gamma_n^0(E) \rangle_{\ell, J} \sqrt{E} V_\ell(E) \mu_{\ell, J}$

$\langle \bar{\Gamma}_n^0 \rangle_{\ell, J}$ is the average reduced neutron width

$\mu_{\ell, J}$ is the number of degrees of freedom in the neutron width distribution

$V_\ell(E)$ is the penetrability of the target nucleus for incident neutrons of angular momentum ℓ

$$V_0 = 1.0$$

$$V_1 = \frac{\rho^2}{1 + \rho^2}$$

$$V_2 = \frac{\rho^4}{9.0 + 3.0 \rho^2 + \rho^4}$$

where

$$\rho = ka$$

$$k = .002196771 (A_0/(A_0+1)) \sqrt{E}$$

a, the opaque nucleus channel radius, equals $[0.123 A_0^{1/3} + .08]$ in units of 10^{-12} cm.

ϕ_ℓ is the phase shift and

$$\phi_0 = \hat{\rho}$$

$$\phi_1 = \hat{\rho} - \tan^{-1} \hat{\rho}$$

$$\phi_2 = \hat{\rho} - \tan^{-1} \left(\frac{3\hat{\rho}}{3-\hat{\rho}^2} \right)$$

where $\hat{\rho} = kR_a$

and where

R_a is the noncompound (potential) scattering length of the absorber (in units of 10^{-12} cm.) as given in File 2 of ENDF/B.

The parameters $\langle \Gamma_\gamma(E) \rangle_{\ell,J}$, $\langle \Gamma_f(E) \rangle_{\ell,J}$, $\langle \Gamma_n^0(E) \rangle_{\ell,J}$, and $\langle D \rangle_{\ell,J}$ are either a constant value for a given ℓ, J state or, if tabulated data values are given, are determined at each energy by interpolation.

The fluctuation integrals in Equations (3.48) - (3.50) can be represented as

$$S(f(x)) = \int_0^\infty P_n(r) \int_0^\infty P_k(s) f(x) ds dr, \quad (3.51)$$

where $f(x)$ represents the argument of the integrands.

Equation (3.51) represents integration over the chi-squared distributions used to take into account fluctuations of the fission and neutron width, respectively.

$P_n(r)$ is the chi-squared distribution for the neutron width.

$P_k(s)$ is the chi-squared distribution for the fission width.

r is the ratio of neutron width at E to mean neutron width at E .

s is the ratio of fission width at E to mean fission width at E .

$$J(\theta, \beta) = \int_0^\infty \frac{\psi(\theta, x)}{\psi(\theta, x) + \beta} dx \quad (3.52)$$

is the relative probability of absorption. In SR. RESU, the approximation, $J(\theta, \beta) = \frac{\pi}{2 \sqrt{\beta^2 + \beta}}$, is used if $\beta < 10,000$ for shielding. Otherwise $J(\theta, \beta) = \pi/2\beta$

where
$$\beta = \frac{\sigma_p}{\sigma_0 \cos 2\phi_\ell}$$

σ_p is the effective scattering cross section per absorber atom in the NR approximation input as SIGP.

$$\sigma_p = \sigma_{pa} + \frac{1}{N_a \left(\frac{\bar{\ell}_0}{1-C} \right)} + \sigma_m$$

$$\sigma_{pa} = \sum_{\ell} (2\ell+1) \frac{4\pi}{k^2} \sin^2 \phi_\ell$$

$\bar{\ell}_0$ = is the radius or thickness of the absorber lump

C is the Dancoff pin shadowing factor

σ_m is the sum of the scattering cross sections per absorber atom for all moderators in the absorber lump

N_a is the lump absorber atom density

$$\sigma_0 = 2.6037 \times 10^6 \langle \Gamma_n(E) \rangle g_J \left(\frac{A_0 + 1.0}{A_0} \right)^2 / \langle \Gamma(E) \rangle$$

g_J is the statistical weight for J state levels.

$$g_J = \frac{1}{2} \left(\frac{2J + 1}{2I + 1} \right)$$

J is the total angular momentum quantum number of the compound nucleus

I is the ground state spin of the target nucleus

A_0 is the atomic mass ratio

Integrations over the Chi-Squared Distributions

The integrations over the chi-squared distributions indicated in Equations (3.44) through (3.50) are actually performed using the following approximations. For fissile isotopes,

$$S(f(x)) = \int_0^\infty P_n(r) \int_0^\infty P_k(s) f(x) ds dr = \frac{1}{5 \cdot 10} \sum_{i=1}^{10} \sum_{i'=1}^5 f(p_i, p_{i'}'). \quad (3.53)$$

For nonfissile isotopes there are no fission widths involved so that Equation (3.53) becomes

$$S(f(x)) = \int_0^w P_n(r) f(x) dr = \frac{1}{10} \sum_{i=1}^{10} f(p_i). \quad (3.54)$$

These equations and constants give a 10-point integration with one or two degrees of freedom for the neutron width distributions and a 5-point integration with one to four degrees of freedom for the fission width distribution. A justification for the approximation of the form of Equation (3.54) is given below. The justification for the double integral approximation above is similar. The p_i and p'_i are constants whose values are given in Tables 2 and 3 and which were determined as follows and as described in Appendix A of MC²[9] and in the ERIC-2 code.[10]

Values of z_i are determined such that

$$\int_{z_i}^{z_{i+1}} P_n(x) dx = \frac{1}{N}, \quad (3.55)$$

where P_n is the chi-squared distribution of order n . N is set to 10 for the neutron-width distributions which may be of order 1 or 2 and set to 5 for the fission-width distributions which may be of order 1, 2, 3, or 4. $N-1$ points z_i are involved, besides the points $z_0 = 0$ and $z_N = \infty$.

Within each interval (z_i, z_{i+1}) , average values for x , represented by p_i , are determined using

$$p_{i+1} = N \int_{z_i}^{z_{i+1}} x P_n(x) dx. \quad (3.56)$$

Figure 4 shows these choices of the z_i and p_i .

Figure 4. Choice of z_i and p_i for approximation of $S(f(x))$ by 5-point integration.

Now,

$$S(f) = \int_0^{\infty} P_n(x)f(x)dx = \int_0^{z_1} P_n(x)f(x)dx \\ + \int_{z_1}^{z_2} P_n(x)f(x) + \dots + \int_{z_{N-1}}^{z_{\infty}} P_n(x)f(x)dx$$

so that, by the trapezoidal rule, the following approximation holds.

$$S(f(x)) = f(p_1) \int_0^{z_1} P_n(x)dx + f(p_2) \int_{z_1}^{z_2} P_n(x)dx \\ + \dots + f(p_n) \int_{z_{N-1}}^{z_N} P_n(x)dx.$$

Using Equation (3.55)

$$S(f(x)) = f(p_1) \frac{1}{N} + \dots + f(p_n) \frac{1}{N} = \frac{1}{N} \sum_{i=1}^n f(p_i).$$

Thus,

$$\int_a^b f(x) P_n(x) dx = \frac{1}{N} \sum_{i=1}^N f(p_i). \quad (3.57)$$

TABLE 2⁽⁹⁾VALUES OF p_i

Used for Integration of Neutron-Width
Distributions with One or Two Degrees of Freedom

Index, i	Degrees of Freedom, n		Index, i	Degrees of Freedom, n	
	1	2		1	2
1	0.00525430	0.0517550	6	0.574320	0.800477
2	0.0371740	0.163089	7	0.879486	1.05263
3	0.103133	0.288398	8	1.33502	1.39297
4	0.207850	0.431720	9	2.10558	1.91582
5	0.359875	0.599144	10	4.39230	3.30400

TABLE 3⁽⁹⁾VALUES OF p_i'

Used for Integration of Fission-Width
Distributions with One, Two, Three, or Four Degrees of Freedom

Index, i'	Degrees of Freedom, k			
	1	2	3	4
1	0.0212093	0.107400	0.189269	0.254966
2	0.155477	0.360070	0.476304	0.549072
3	0.467072	0.699863	0.793185	0.82565
4	1.10710	1.22312	1.23576	1.23075
5	3.24914	2.60955	2.30575	2.12265

The pointwise elastic cross sections are weighted by the input weighting function and added to the pointwise resolved resonance cross sections retrieved from unit ITP2. The combined resolved and unresolved weighted pointwise elastic scattering cross section is saved on unit ITPR for the generation of the elastic scattering matrix in SR. TRAN.

The weighted pointwise capture and fission cross sections are integrated to obtain average values one group at a time in the unresolved range and saved in temporary arrays. These cross sections will be discarded if the unresolved range parameters are to be sent to the PHROG library. In this case, the unresolved resonance cross sections are printed in the ETOP 14 output listing for information only at the time of execution.

IV. POINTWISE CROSS SECTIONS FROM FILE 3

With the exception of the resolved and unresolved resonance range, the pointwise cross sections given in File 3 represent the complete reaction cross section. Secondary angular and energy distributions are given in Files 4 and 5, but in every case a reaction cross section must be present in File 3 if secondary distributions are given in Files 4 or 5.

Elastic and non-elastic cross sections from File 3 must be saved in auxiliary storage until angular distributions and/or secondary energy distributions are read from the ENDF/B tape.

SR. CROS reads only reaction types requested from File 3. The data sets are read from the ENDF/B tape by a call to SR. TMF3 (KALL, MWANT) where MWANT is the MT number of the reaction type demanded. Since data sets are read on demand in SR. CROS, any data sets not specifically requested in SR. CROS will be read past without indicating their presence. New reaction types must be specifically programmed into SR. CROS if they are to be processed by ETOP 14.

In the event a reaction type is requested in SR. CROS and is not found on the ENDF/B tape, a message is printed in the output listing indicating its absence and SR. CROS proceeds to the next reaction. For elastic or non-elastic reactions, flags are set in SR. CROS indicating the presence or absence of reaction types for which data is required from Files 4 or 5. Table 4 lists the MT number of the reaction types processed in SR. CROS along with the flags set in SR. CROS which indicate the presence of the data set.

TABLE 4
REACTION TYPES PROCESSED IN SR. CROS

<u>Reaction MT</u>	<u>Type</u>	<u>Flag</u>
2	Elastic	NOXS = 1
4	Total Inelastic	NOXIN = 1
6 } 7 } 8 } 9 }	N2N Level 1st neutron	NF6T9 = # Levels found
16	N2N Continuum	NON2N = 1
18	Fission	NOXF = 1
27	Absorption	NOABS = 1
46 } 47 } 48 } 49 }	N2N Level 2nd neutron	NF4649 = # Levels found
51-90	Level Inelastic	NF3DIS = # Levels found
91	Inelastic Continuum	NF3CON = 1
102	N, γ	NONG = 1
103	N, P	NONP = 1
104	N, D	NOND = 1
105	N, T	NONT = 1
106	N, HE-3	NOHE = 1
107	N, ALPHA	NONA = 1
108	N, 2 ALPHA	NON2A = 1
251	MU BAR	NOMU = 1

In general, the NONX flags in Table 4 set to 2 indicate the absence of the data set from File 3. Exceptions are:

NF6T9 = 0, No N2N levels
 NF4649 = 0, No N2N levels
 NF3DIS = 0, No Inelastic level
 NF3CON = 0, No Inelastic continuum.

Q values from inelastic levels are stored in THETAR (41); Q values from MT = 6-9, 46-49 are stored in QN2N(8) for the discrete N2N levels. Q values from other reactions which are not specifically required for numerical computations are ignored by SR. CROS. MT = 27, absorption cross section is not used in ETOP 14 unless both the n,γ capture cross section and the n,f fission cross section is zero over all groups. In this event, the absorption cross section (MT = 27) is substituted for the capture cross section (MT = 102).

The average elastic scatter contributions from File 3 over the resonance range are added into the arrays PSCAT (KP, 1) and PSCAT (KP, 3) for the determination of the background scatter matrix. These arrays already contain the contributions from resolved p wave resonances and the tails of negative and thermal energy resonances from the last section. The addition of the File 3 elastic cross section over all groups completes these arrays necessary for calculation of the background elastic scattering matrix in Section V, Algorithm 5. The arrays PSCAT (KP, 1) and PSCAT (KP, 2) are printed on the output listing by SR. CROS.

All pointwise cross sections from File 3 except the elastic scattering cross section are integrated over the group structure in SR. CROS and stored in temporary arrays. The pointwise cross section is first combined with the weight $W(E)$ before being integrated over the group structure by a call to SR. GPAV. SR. GPAV averages the weighted cross section over the complete group structure (MAXG groups) and stores the results in the array specified in the argument list. Another subroutine often used to obtain integrals of a TAB1 function over a specified energy range is SR. GRATE. SR. GRATE returns a single integral value over a specified energy range. Both SR. GPAV and SR. GRATE integrate the TAB1 function residing in COMMON/RECS/ at that time.

The fission cross section from File 3 is also combined with the number of neutrons per fission $\nu(E)$ obtained from File 1 and averaged to obtain $\nu\sigma_f$ over the group structure.

The complete set of multigroup average cross sections from Files 2 and 3 is now ready to be listed with the exception of the elastic scattering cross section obtained from the resolved and unresolved

resonance parameters which was saved on unit ITPR. SR. CROS saves the pointwise elastic scattering cross section from File 3 on unit ITPS. The complete elastic scattering cross section is the sum of the File 3 pointwise elastic cross section and the pointwise elastic cross section obtained over the resonance range in SR. RESS and SR. RESU.

The pointwise elastic scattering cross section from units ITPS and unit ITPR are added together in SR. TRAN in Section V. This is accomplished by the first call to SR. GADD which combines the smooth and resonance elastic cross sections one group at a time for the calculation of the elastic scattering matrix. The combined pointwise elastic scattering cross section is then integrated over the group structure to obtain group average values of the complete elastic scattering cross section.

At the completion of this first call to SR. GADD, all multigroup cross sections are edited by a call to SR. OUT3 from SR. TRAN. SR. OUT3 combines appropriate partial cross sections (e.g., absorption is the sum of all neutron capture and fission reactions stored in temporary arrays) and prints in the output listing the complete set of multigroup cross sections. This set contains all cross section contributions from Files 1, 2 and 3 with the exception of the discrete N2N reactions given by MT = 6-9 and 46-49. These level cross sections will not be processed until after the calculation of the elastic scattering matrix. The n-2n cross section printed by SR. OUT3 contains only the continuum n-2n cross section corresponding to MT = 16 from File 3.

SR. CROS prints to the output listing all partial cross sections averaged over the group structure as they are processed from File 3. These average cross section are obtained from Equations (4.1) and (4.2).

$$\bar{\sigma}_{xg} = \frac{\int_{E_g}^{E_{g-1}} \sigma_{nx}(E) W(E) dE}{\int_{E_g}^{E_{g-1}} W(E) dE} \quad (4.1)$$

$$\bar{\nu}\sigma_{Fg} = \frac{\int_{E_g}^{E_{g-1}} \nu(E)\sigma_F(E) W(E)dE}{\int_{E_g}^{E_{g-1}} W(E)dE} \quad (4.2)$$

The pointwise product of the functions in the numerator of Equations (4.1) and (4.2) are obtained from SR. COMB. SR. COMB iterates over the combined mesh for the two functions using the interpolation schemes specified in the ENDF/B files until the product is obtained at the midpoint of the mesh intervals to an accuracy between the input parameters EPSMIN < EPSMAX. Default values of EPSMIN and EPSMAX are .0001 and .065, respectively. When the product of the two functions interpolated to a mesh point is within EPS of the interpolated product function, the mesh is accepted where EPSMIN $\leq$ EPS $\leq$ EPSMAX. If not, EPS is increased and mesh intervals are halved over specified ranges until the criterion is satisfied. If EPS exceeds EPSMAX, a program stop occurs indicating that the product cannot be obtained within an accuracy of EPSMAX.

The total absorption cross section from SR. OUT3 is the multigroup sum of all partial capture and fission cross sections edited from SR. CROS.

V. ELASTIC AND NON-ELASTIC SCATTERING MATRICES

Five general algorithms are available in ETOP 14 for the calculation of multigroup Legendre elastic and non-elastic scattering matrices. They are broken down as follows.

1. ETOG algorithm for elastic scattering matrices in isotropic (CM) energy range.
2. ETOG algorithm for elastic scattering matrices in the anisotropic scattering range.
3. Direct Angular Overlay Algorithm (DAOA) for elastic or non-elastic scattering in the anisotropic scattering range.
4. ETOG algorithm for non-elastic scattering matrices from continuum energy range.
5. Special algorithm for Calculation of Elastic Background Matrix in resonance range.

Only Algorithms 2 and 3 are optional for elastic scattering in the anisotropic scattering range. Control of all elastic scattering matrices is maintained in SR. TRAN. Control of all non-elastic scattering from discrete levels is maintained in SR. TRIN. Control of all non-elastic scattering from a continuum energy range is maintained in SR. ETOP 50.

Flags are set in SR. CROS to indicate the presence and type of elastic and non-elastic cross section data (see Section IV). The pointwise cross sections are then saved on disks for future reference in SR.'s TRAN, TRIN and ETOP 50. The scattering matrices in SR.'s TRAN and TRIN are calculated when the appropriate angular distributions are being read from file 4 of the ENDF/B tape. Scattering matrices are calculated in SR. ETOP 50 when the appropriate secondary energy distributions are being read from file 5 of the ENDF/B tape. Sequential files on the ENDF/B tape in all cases control the order in which particular components of the scattering

matrices are calculated. In general, if data from a file on the ENDF/B tape is out of order for a specific calculation, then it must be saved for future processing. SR. ETOP 40 always calls SR. TRAN first for the calculation of elastic scattering matrices.

1. Elastic Matrices

The first three algorithms are available for the calculation of Legendre moments of the multigroup elastic scattering matrices in SR. TRAN. Only Algorithms 2 and 3 are optional in the anisotropic scattering range. Algorithm 1 is always used for the calculation of elastic scattering matrices in the isotropic (CM) scattering range.

Isotropic Scattering Range

Anisotropic angular data in File 4 is often continued into the resolved and unresolved resonance energy range in the files. In the case of heavy elements (mass > 200), the angular distributions are only slightly anisotropic in the resolved and unresolved energy range. The PHROG code for which the multigroup scattering matrices are prepared can treat only s wave scattering from resolved resonance parameters. In the resolved and unresolved energy ranges, PHROG will shield the resonance cross sections resulting from the parameters. Shielded contributions to the elastic scattering matrices will be calculated for s-wave neutrons only in the resolved and unresolved resonance range by PHROG. ETOP 14 will make a decision as to where to begin calculating the complete unshielded anisotropic scattering matrices on the basis of the input flag KGTR0P.

KGTR0P is the PHROG group number where the first anisotropic source group of the elastic scattering matrix will be calculated in SR. TRAN. All groups below in energy KGTR0P will have only s wave scattering in the elastic scattering matrix. If anisotropic angular data is present in file 4 for energies below group KGTR0P, it will be ignored. KGTR0P is a required input flag. The problem requestor for ETOP 14 must examine the ENDF/B files for a material and make a judicious choice between the merit of shielding the resonance data in PHROG or retaining any anisotropic angular data present on the ENDF/B files and calculating an infinitely dilute scattering matrix above (in energy) group KGTR0P, if KGTR0P is chosen in the resolved or unresolved resonance range.

Several options are then available for the type of elastic scattering matrix calculated by ETOP 14 in the resolved and unresolved resonance range. These resonance range options are controlled by the input flag IWG.

IWG = 1 Create a single complete infinitely dilute elastic scattering matrix in the resolved and unresolved energy range below the lower energy bound of group KGTR0P.

IWG = 2 Create an incomplete background elastic scattering matrix in the resolved and unresolved resonance ranges consisting of only the file 3 elastic background cross section and infinitely dilute contributions from any resolved p-wave resonances in the resolved resonance range plus the tails of negative and thermal energy s-wave resonances.

IWG = 3 Create two separate scattering matrices in the resonance range below, in energy, group KGTR0P. The two elastic scattering matrices will be IWG = 2 and a difference scattering matrix composed of IWG = 1 minus IWG = 2 types. PHROG options will then decide on their useage.

IWG = 4 is meant to be used only in the event there is no angular data present in file 4 for elastic scattering. An infinitely dilute scattering matrix will be calculated in all groups by means of Algorithm 1, instead of Algorithm 2 or 3.

In the event IWG > 1 is chosen for a material with no resonance files, the code will set IWG = 1 internally; however, KGTR0P will always override any angular data if present in file 4. This is true regardless of whether KGTR0P falls within the resonance range or outside. All angular data files may be overridden by setting KGTR0P equal to 1.

Elastic Matrix Equations

The general equation for the calculation of the Legendre moments of the elastic scattering matrix is

$$\sigma_{i,j}^{\ell} = \frac{\int_{E_0(i \rightarrow j)} \phi_{\ell}(E_0) \sigma(E_0) \int_{\beta \in j} P(E_0, \beta) P_{\ell}[\mu_0(\beta)] d\beta dE_0}{\int_{E_i}^{E_{i-1}} \phi_{\ell}(E_0) dE_0} \quad (5.1)$$

where $\sigma_{i,j}^{\ell}$ is the ℓ th Legendre matrix element for neutrons scattering from source group i to sink group j .

$\phi_{\ell}(E_0)$ is the source group Legendre moment of the neutron flux at incident energy E_0 .

$\sigma(E_0)$ is the scattering cross section at incident neutron energy E_0 .

β is the cosine of the scattering angle in either CM (center of mass) or LAB (laboratory) coordinates.

$P(E_0, \beta)$ is the normalized angular scattering probability at incident energy E_0 through an angle whose cosine is β .

$P_{\ell}[\mu_0(\beta)]$ is the ℓ th Legendre polynomial of the cosine of the scattering angle in LAB coordinates μ_0 .

The outer integral in Equation (5.1) is a series of line integrals at each source energy (E_0) over the angular variable β . The inner integral is a single line integral over $\beta \in j$ for each sink group j . In principle, may represent either CM or LAB coordinates for the normalized angular probability given in File 4. Four angular data representations are possible in ENDF/B File 4.

1. $\beta \rightarrow \mu \in \text{CM}$

A. $P(E_0, \mu)$ is a Legendre representation.

$$P(E_0, \mu) = \frac{1}{2} + \sum_{\ell'=1}^{NL'} \frac{2\ell'+1}{2} f_{\ell'}(E_0) P_{\ell'}(\mu)$$

NL' = number of Legendre expansion coefficients $f_{\ell}(E_0)$ at each incident energy E_0 given in File 4

B. $P(E_0, \mu)$ is a two dimensional tabular distribution in CM coordinates.

2. $\beta \rightarrow \mu_0 \in \text{LAB}$

A. $P(E_0, \mu_0)$ is a Legendre representation

$$P(E_0, \mu_0) = \frac{1}{2} + \sum_{\ell=1}^{NL} \frac{2\ell+1}{2} f_{\ell}(E_0) P_{\ell}(\mu_0)$$

NL = number of Legendre expansion coefficients $f_{\ell}(E_0)$ at each incident energy (E_0) given in File 4.

B. $P(E_0, \mu_0)$ is a two dimensional tabular distribution in LAB coordinates.

Normalization of $P(E_0, \beta)$ is such that $\int_{-1}^1 P(E_0, \beta) d\beta = 1$ in all representations.

A large number of strategies⁽¹¹⁾ have been developed over many years for the evaluation of Equation (5.1). The optimum strategy and numerical technique in a given case depends on the energy group structure, the cross section function $\sigma(E_0)$ and the severity of the diffraction pattern represented by $P(E_0, \beta)$. The most difficult numerical problem occurs for $\sigma(E_0)$ containing resonance scattering structure in an energy range where $P(E_0, \beta)$ is highly structured in the cosine of the scattering angle β , and energy group widths are large. Fortunately, this condition only exists for intermediate mass isotopes where the characteristic width of the resonances is also relatively large. For heavy mass isotopes, the angular distributions are generally isotropic in CM coordinates over the resolved resonance range. For this condition the outer integral of Equation (5.1) contains all of the structure and the inner integral reduces to a greatly simplified numerical problem.

2. First Algorithm for s wave Scattering Range

For isotropic scattering (s-wave) in CM coordinates, it is simplest to evaluate $P(E_0, \beta)$ of Equation (5.1) in CM coordinates. In this case,

$P(E_0, \mu) = 0.5$ and the inner integral for sink group j merely consists of mapping $P_\ell[\mu_0(\beta)]$ on the β line between the j group boundaries.

Since the scattering matrix is always calculated in LAB coordinates, $P(E_0, \beta)$ is transformed to LAB coordinates as a function of LAB energy E . The transformation equations are:

$$P(E_0, \mu_0)_{\text{LAB}} d\mu_0 = P(E_0, \mu)_{\text{CM}} d\mu = \frac{1}{2} d\mu \quad (5.2)$$

From conservation of energy and momentum between incident to final neutron energies (see Appendix A) the cosine of the CM scattering angle is given as a function of the final LAB neutron energy.

$$\mu = \frac{1}{2A} \left[\frac{E}{E_0} (A+1)^2 - (A^2+1) \right] \quad (5.3)$$

$$d\mu = \frac{(A+1)^2}{2A} \frac{dE}{E} \quad (5.4)$$

The r.h.s. of Equation (5.2) reduces to

$$P(E_0, \mu) d\mu = \frac{(A+1)^2}{4A} \frac{dE}{E_0} \quad (5.5)$$

where E is the final LAB energy of the neutron. Equation (5.1) becomes

$$\sigma_{i,j}^\ell = \frac{\int_{E_0(i,j)} \phi_\ell(E_0) \sigma(E_0) \frac{(A+1)^2}{4AE_0} \int_{E \in j} P_\ell(\mu_0) dE dE_0}{\int_{E_i}^{E_{i-1}} \phi_\ell(E_0) dE_0} \quad (5.6)$$

μ_0 in Equation (5.6) is related to E through the same momentum-energy balance used in deriving Equation (5.3).

$$\mu_0 = \frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \quad (5.7)$$

Since the ℓ th moment of the flux $\phi_\ell(E_0)$ depends on the transport boundary conditions of the scattering region as well as the energy dependent cross sections, we cannot pre-evaluate the Legendre moment of the flux and will, therefore, use only the isotropic infinite medium flux $\phi_0(E_0)$ derived from a fission source to generate the scattering matrix. Substituting Equation (5.7) into Equation (5.6) and using $\phi_0(E_0)$ as the incident weighting flux, Equation (5.1) becomes

$$\sigma_{ij}^\ell = \frac{\int_{E_0(i \rightarrow j)} \phi_0(E_0) \sigma(E_0) \frac{(A+1)^2}{4AE_0} \int_{E \in j} \text{ times} \quad P_\ell \left[\frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \right] dE dE_0}{\int_{E_i}^{E_{i-1}} \phi_0(E_0) dE_0} \quad (5.8)$$

The limits for the integrals in Equation (5.8) for the general case, $j \neq i$, depend on j and the group structure (see Figure 6).

A graphical illustration of Equation (5.8) is given in Figure 5. For elastic scattering, all scattering domains fall within the energy range $E = \alpha E_0$ to $E = E_0$ where

$$\alpha = \left(\frac{A-1}{A+1} \right)^2 \quad (5.9)$$

Figure 5. Elastic scattering integration domain.

For 0.25 lethargy group widths, ^{16}O is the highest mass isotope which scatters down more than one group. All isotopes with severe resonance structure in the isotropic scattering range scatter down only one group from the source group. In this case, the column sum of the α th moment of the scattering matrix consists of only two groups. From Figure 5, it is observed that the column sum can be obtained from the inner integral between the limits $E = E_0$ to $E = \alpha E_0$, where $E_i \leq E_0 \leq E_{i-1}$. If these limits are substituted into Equation (5.8) for the matrix column sum instead of an individual element, the inner integral of Equation (5.8) may be evaluated analytically for the matrix column sum.

$$\sum_j \sigma_{i,j}^\ell = \frac{\int_{E_i}^{E_{i+1}} \phi_0(E_0) \sigma(E_0) dE_0}{\int_{E_i}^{E_{i+1}} \phi_0(E_0) dE_0} M^\ell(A) \quad (5.10)$$

where, (12)

$$M^\ell(A) = \frac{(A+1)^2}{4AE_0} \int_{\alpha E_0}^{E_0} P_\ell \left[\frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \right] dE \quad (5.11)$$

The outer integral of Equation (5.10) is $\bar{\sigma}_{soi}$, the average of the resonance scattering cross section over the source group. Since the resonance structure is now not convoluted with the rapidly varying higher order Legendre polynomials, the integral to obtain the average cross section is relatively easily obtained. Once the average cross section over the resonance structure is obtained, the ℓ th Legendre moment of the matrix column sum is given by Equation (5.10) as

$$\sum_j \sigma_{i,j}^\ell = \bar{\sigma}_{soi} M^\ell(A), \ell = 0 \rightarrow 3 \quad (5.12)$$

The outscatter group integral for heavy elements is now calculated from Equation (5.8) by Algorithm 2 given in Section V, 3. This is a much simpler numerical problem than the source group term because the outscatter occurs from a very narrow energy range $E_i \leq E_0 \leq \frac{E_i}{\alpha}$ for $A > 100$. Once the outscatter element is evaluated from Equation (5.8), it may be subtracted from Equation (5.12) to obtain the ingroup term which is usually very difficult to evaluate from Equation (5.8) directly.

$$\sigma_{i,i}^\ell = \bar{\sigma}_{soi} M^\ell(A) - \sigma_{i,i+1}^\ell, \ell = 0 \rightarrow 3 \quad (5.13)$$

$M^\ell(A)$ is given in Table 5 to order $\ell = 7$ (ref. 12).

TABLE 5

 $M^l(A)$

l	$M^l(A)$ Equation (5.11)	Hydrogen, $A=1$
0	1	1
1	$\frac{2}{3A}$	$\frac{2}{3}$
2	$\left[5 - 3A^2 - 3 \frac{(A^2-1)^2}{4A} \ln \alpha \right] * \frac{1}{8}$	$\frac{1}{4}$
3	0	0
4	$\left[-14 - \frac{5}{4} (7A^2-1) Z \right] * \frac{1}{24}$	$-\frac{1}{24}$
5	0	0
6	$\left\{ -231A^2 + 93 + \left[\frac{5}{8} 231A^4 - \frac{7}{4} 45A^2 + \frac{35}{8} \right] Z \right\} * \frac{1}{128}$	$\frac{1}{64}$
7	0	0

NOTE: $Z = 5 - 3A^2 - 3 \frac{(A^2-1)^2}{4A} \ln \alpha$

The average scattering cross section $\bar{\sigma}_{\text{soi}}$ is accurately evaluated using the fine numerical integration mesh from SR. RESS. Since the higher order Legendre moments for isotropic scattering are very small, the accuracy of the ingroup term in Equation (5.13) depends upon the accuracy with which the outgroup scattering is calculated by the ETOP algorithm discussed in Section V, 3.

Algorithm 1 is always used in SR. TRAN for energies less than the lower energy bound of group KGTR0P. If IWG = 1 or 3 resonance scattering contributions are calculated from the resonance parameters at infinite dilution in SR. RESS and added to the background elastic cross section from File 3 to obtain $\sigma(E_0)$ before the scattering matrices are calculated. For IWG = 2 or 3, only the background elastic cross section from File 3 is used to construct $\sigma(E_0)$ and ETOP 14 produces an incomplete elastic matrix in the resonance range (See Algorithm 5, Section V, 10).

3. Algorithm 2. ETOP Algorithm in Anisotropic Scattering Range

For energies greater than the lower bound of group KGTR0P, Algorithm 2. is an option for the calculation of the complete elastic scattering matrices in SR. TRAN. In this case $P(E_0, \mu)$ is not isotropic in CM coordinates and the semi-analytic integrals given by Equation (5.11) are no longer possible. Numerical integration of Equation (5.1) is required to obtain the overlays of $P(E_0, \mu)$ in each outscatter group j .

The angular data $P(E_0, \mu)$ is required to be a Legendre representation in CM coordinates.

$$P(E_0, \beta) d\beta = P(E_0, \mu) d\mu \quad (5.14)$$

where

$$P(E_0, \mu) = \frac{1}{2} \sum_{\ell'=0}^{NL'} (2\ell'+1) f_{\ell'}(E_0) P_{\ell'}[\mu(E)] \quad (5.15)$$

and $f_0(E_0) = 1$

If Equations (5.5) and (5.7) are used to transform Equation (5.1) to laboratory energy coordinates we have,

$$\sigma_{i,j}^{\ell} = \frac{\int_{\gamma}^{\delta} \phi_0(E_0) \sigma(E_0) \int_{\lambda}^{\beta} \frac{(A+1)^2}{4AE_0} P_{\ell} \left[\frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \right] \sum_{\ell'=1}^{NL} \left[1 + (2\ell'+1) f_{\ell'}(E_0) P_{\ell'}[\mu(E)] \right] dE dE_0}{\int_{E_i}^{E_{i+1}} \phi_0(E_0) dE_0} \quad (5.16)$$

where $\mu(E)$ in Equation (5.16) is given by Equation (5.3).

$$\mu(E) = \frac{1}{2A} \left[\frac{E}{E_0} (A+1)^2 - (A^2+1) \right] \quad (5.3)$$

The Legendre expansion coefficients $f_{\ell}(E_0)$ are stored in an array YLM(NPE, NLENG) where NPE is the number of uniform lethargy points used as an outer integral integration mesh and NLENG is the maximum number of Legendre coefficients for all angular data sets falling within source group i . Equation (5.16) is transformed to the lethargy variable for both the outer and inner integral.

The strategy employed to evaluate Equation (5.16) is to index group j one group at a time beginning with the source group i and calculate Legendre moments from $\ell = 0$ to $\ell = 3$ for the double integral for each group independently. There are six possible cases for the two-dimensional domains of integration for a downscatter group depending on how the downscatter limit line $E = \alpha E_0$ cuts the group boundaries. The six possible domains of integration are illustrated in Figure 6 for the integration limits⁽³⁾ $\lambda, \beta, \gamma, \delta$ in Equation (5.16) for downscatter. There are 2 cases⁽³⁾ for within group scattering illustrated in Figure 7.

Figure 6. Downscatter domains of integration for Algorithm 2.

Figure 7. Within group domains of integration.

In Figures 6 and 7, cases 4, 5 and 8 require the sum of two double integrals over subregions of the primary domain.⁽³⁾ SR. SINT performs the double integral for subregion 2 of case 8. For all other cases, SR. DINT performs the double integrals in all regions of the indicated domains.

SR. TRAN indexes the source group i one group at a time and determines the logical flow for each outscatter group. The following subroutines are called by TRAN to perform specific functions.

1. SR. GADD is called once at the beginning of each elastic matrix calculation to add the resolved and unresolved elastic resonance scattering cross section which has been saved on unit ITPR to the file 3 elastic cross section saved on unit ITPS. These two elastic components are added together point by point one group at a time and

saved on unit ITPE. Each record on unit ITPE is the combined pointwise elastic cross section for a single group. As TRAN indexes each source group in the loop which calculates the scattering matrix, GADD is called once for each source group to retrieve the scattering cross section saved on unit ITPE. GADD next reads File 4 of the ENDF/B tape to obtain the angular data sets which fall within group i . The angular data sets having energies which fall within group i are stored as Legendre coefficients in CM coordinates in an array $YL(NPIM, NLENG)$. The angular data is interpolated at the upper and lower boundary of each group so the group limits are represented. NPIM is the number of energies at which angular data sets were found in group i including the two group boundaries. NLENG is the maximum number of Legendre coefficients for all angular data sets in group i .

In the event the angular data sets are given in File 4 as tabular distributions, GADD calls SR. LEGEND to manufacture a set of Legendre coefficients for each tabular data set. The transformation matrix given in File 4 is used to transform the Legendre coefficients from LAB to CM coordinates if required.

For energy groups lying below group KGTR0P, the Legendre coefficients of each angular data set are set to 0.0 and a flag ISOTR is set so Algorithm 1 will be used to calculate the scattering matrix for this group instead of Algorithm 2.

2. SR. TRAN next determines the integration limits $\lambda, \beta, \gamma, \delta$ for each outscatter group j and calls SR.'s DINT or SINT to calculate the j matrix element using a Simpson's integration for both variables on a uniform lethargy mesh.
3. Each time DINT or SINT are called, SR. GRID is called to construct a uniform 61-by-61-point lethargy mesh for the outscatter group. The cross section $\sigma(E_0)$ is then interpolated onto the lethargy mesh corresponding to the source energy and the Legendre coefficients stored in $YL(NPIM, NLENG)$ are interpolated onto the lethargy mesh corresponding to the source energy (E_0) and stored in $YLM(61, NLENG)$. DINT or SINT then perform the Simpson's numerical integration for the sink group j and store the result in $P_\ell(j)$ where $\ell = 0, 1, 2, 3$.

4. The complete scattering matrix is then stored on unit ITPS for $\ell = 0, 1$ and unit ITPR for $\ell = 2, 3$ for construction of the PHROG library tape in SR. FRGOUT.

At each integration point on the two-dimensional lethargy mesh, the angular probability $P(E_0, \mu)$ must be constructed from NLENG coefficients stored in YLM (61, NLENG) which is the last term in the numerator of Equation (5.16). $\mu(E)$ is located on the lethargy mesh corresponding to E , Legendre polynomials are constructed to order NLENG and the product $YLM(k, \ell) * P_\ell[\mu(E)]$ summed for NLENG coefficients. This operation is quite time consuming and is one reason for the relatively long computation times of this algorithm. CPU time for the algorithm is consequently a function of how many Legendre expansion coefficients are required to represent $P(E_0, \mu)$ in a particular source group. The fewer the coefficients required, the faster and more accurate the algorithm functions. This algorithm is an option for elastic scattering only in the anisotropic scattering range for energies above KGTR0P if IELAS = 1 in the input data.

4. Algorithm 3. DAO Algorithm for Non-Elastic Scattering or Elastic Scattering in the Anisotropic Scattering Range

Algorithm 2 is not well suited to the calculation of non-elastic scattering matrices in its present form. The principal difficulties are:

1. Angular scattering data must be represented as Legendre expansion coefficients in CM coordinates. Most differential scattering data from ENDF/B for non-elastic scattering is given in LAB coordinates. In addition, many materials contain normalized tabular distributions instead of Legendre coefficients and Algorithm 2 would require the tabular data to be first converted to Legendre expansion coefficients before it could be used. This operation is time consuming and requires a large amount of data manipulation which is extraneous to the principal problem of calculating the scattering matrices. Once Legendre expansion coefficients in LAB coordinates are obtained, they must be transformed to CM coordinates for use in Equations (5.15) and (5.16). The LAB to CM transformation equation for Legendre data is given by

$$W_{\ell'}(E_0) = \sum_{\ell=0}^{NL} T_{\ell\ell'}^{-1}(E_0) W_{\ell}(E_0) \quad (5.17)$$

where $W_{\ell'} = (2\ell'+1)f_{\ell'}(E_0)$

$$W_{\ell} = (2\ell+1)f_{\ell}(E_0)$$

are CM and LAB expansion coefficients, respectively. $f_{\ell}(E_0)$ is the LAB Legendre expansion coefficient obtained from the ENDF/B file directly or manufactured from the ENDF/B tabular distribution by means of

$$f_{\ell}(E_0) = \int_{-1}^1 P(E_0, \mu_0) P_{\ell}(\mu_0) d\mu_0 \quad (5.18)$$

where $P_{\ell}(\mu_0)$ is the ℓ th Legendre polynomial in LAB coordinates.

T is the CM to LAB transformation matrix and its inverse T^{-1} is given by

$$T_{\ell\ell'}^{-1} = \int_{-1}^1 P_{\ell}(\mu_0) \left| \frac{d\mu_0}{d\mu} \right| P_{\ell'}(\mu) d\mu \quad (5.19)$$

where⁽¹⁸⁾

$$\left| \frac{d\mu_0}{d\mu} \right| = \frac{|1 + \gamma\mu|}{(1 + \gamma^2 + 2\gamma\mu)^{3/2}} \quad (5.20)$$

$$\gamma = \frac{1}{A\sqrt{1 + \frac{A+1}{A} \frac{Q}{E_0}}} \quad (5.21)$$

A is target to neutron mass ratio

Q is the nuclear disintegration energy

E_0 is the LAB initial energy of the neutron.

Equations (5.20) and (5.21) are derived in Appendix A. A truncated series approximation to Equation (5.20) yields the following approximate form for the matrix⁽²⁰⁾ T^{-1} , good only for $\gamma < 0.5$.

$$T^{-1} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & \dots \\ -2\gamma & 1 - \frac{1}{5}\gamma^2 & \frac{2}{5}\gamma & \frac{3}{35}\gamma^2 & 0 & 0 & 0 & \dots \\ 3\gamma^2 & -2\gamma & 1 - \frac{9}{7}\gamma^2 & \frac{6}{7}\gamma & \frac{8}{21}\gamma^2 & 0 & 0 & \dots \\ 0 & \frac{16}{5}\gamma^2 & -\frac{12}{5}\gamma & 1 - \frac{14}{5}\gamma^2 & \frac{4}{3}\gamma & \frac{10}{11}\gamma^2 & 0 & \dots \\ 0 & 0 & \frac{30}{7}\gamma^2 & -\frac{20}{7}\gamma & 1 - \frac{370}{77}\gamma^2 & \frac{20}{11}\gamma & \frac{240}{143}\gamma^2 & \dots \\ 0 & 0 & 0 & \frac{40}{7}\gamma^2 & -\frac{10}{3}\gamma & 1 - \frac{95}{13}\gamma^2 & \frac{30}{13}\gamma & \dots \\ 0 & 0 & 0 & 0 & \frac{3185}{429}\gamma^2 & -\frac{42}{11}\gamma & 1 - \frac{567}{55}\gamma^2 & \dots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix} \quad (5.22)$$

Terms in Equation (5.22) involving γ depend on the incident energy of the neutron as well as the Q value of the non-elastic level. For the case of elastic scattering, Q is 0.0 and Equation (5.22) is not energy dependent. Thus, for elastic scattering, Equation (5.22) depends only on the mass of the target nucleus and the transformation matrix is given at the head of the angular data in File 4.

For non-elastic scattering the transformation matrix would have to be constructed at each point on the outer loop integration mesh if Equation (5.16) is used and the data is given in LAB coordinates. This operation would be very time consuming in view of the fact that upwards to 40 individual inelastic scattering levels are permitted for each material in the ENDF/B files.

2. 14 domains of integration are required for non-elastic scattering as opposed to only 8 domains of integration for elastic scattering. Thus, the logic required to map the two-dimensional domains of integration is much more complex than that required for the simpler cases given in Figures 6 and 7.

Once CM Legendre coefficients are obtained for Algorithm 2, then at each point on the integration mesh for Equation (5.16), the differential scattering probability must be reconstructed from

$$P(E_0, \mu) = \frac{1}{2} \left[1 + \sum_{\ell'=1}^{NL'} (2\ell'+1) f_{\ell'}(E_0) P_{\ell'}(\mu) \right] \quad (5.23)$$

CPU time for Algorithm 2 increases substantially as the number of expansion coefficients NL' increases. This is due to the necessity to manufacture the Legendre Polynomials $P_{\ell'}(\mu)$ to NL' order for each point in the integration mesh. It would be more efficient to work with tabular distributions precalculated on the integration mesh than to manufacture the differential data from Legendre expansion coefficients at each mesh point.

The principal aim of the DAO algorithm is to avoid the necessity to manufacture Legendre expansion coefficients from tabular distributions and to avoid the necessity to transform angular data between CM and LAB coordinate systems. If this is possible for non-elastic scattering, then the same algorithm may be applied to elastic scattering since elastic scattering is a limit of the equations for non-elastic scattering.

The first requirement of the DAO algorithm is then to perform the inner integral of Equation (5.1) in the coordinate system the data is given in in File 4 of ENDF/B. Thus, β represents either CM or LAB coordinates.

The inner integral of Equation (5.1) may be performed in β space or transformed to energy coordinates. However, the normalized angular probabilities given in File 4 are given in β space so the inner integral is most easily performed in terms of β .

The second requirement is to avoid the necessity of transforming tabular distributions to Legendre representation. This implies that $P(E_0, \beta)$ on the inner integral mesh will be in the form of a tabular distribution. The angular probability given in File 4 will be linearly interpolated onto the E_0, β integration mesh for a tabular distribution in File 4. If the angular probabilities are given as Legendre expansion coefficients, then $P(E_0, \beta)$ is to be constructed on the β integration mesh by

$$P(E_0, \beta_k) = \frac{1}{2} \left[1 + \sum_{\ell=1}^{NL} (2\ell+1) f_{\ell}(E_0) P_{\ell}(\beta_k) \right] \quad (5.24)$$

The angular probabilities so constructed from File 4 Legendre coefficients are then linearly interpolated onto the E_0 outer integral integration mesh.

A graphical illustration of the double integral given by Equation (5.1) is given in Figure 8 for both the elastic and inelastic scattering domains.

Figure 8. Illustration of DAO algorithm

From Figure 8, the non-elastic domains of integration are bounded by a hyperbola in E_0, E space. The upper bound of the hyperbola is $\beta = +1.0$ and the lower bound is $\beta = -1.0$. For elastic scattering the domains are bounded by two lines where $\beta = +1.0$ corresponds to $E = E_0$ and $\beta = -1.0$ corresponds to $E = \alpha E_0$.

At each incident energy E_0 the inner integral of Equation (5.1) corresponds to a line integral from $\beta = +1.0$ to $\beta = -1.0$. Each individual line integral will overlay outscatter groups falling within the domain $+1.0 \leq \beta \leq -1.0$. Each group receives a contribution from the inner integral proportional to the overlay of $P_\ell(\mu_0)P(E_0, \beta)$. As the outer integral over E_0 in Equation (5.1) is indexed, the domains of integration for each group are automatically mapped by the inner integral. This is a tremendous simplification to the complicated two-dimensional domains of integration for non-elastic scattering since the two-dimensional domains of integration are reduced to one simple loop for the inner integral covering all energy groups falling within $-1.0 \leq \beta \leq +1.0$.

The inner integral will always be performed in the coordinate system for the angular probability given in File 4. Since the Legendre weight $P_\ell(\mu_0)$ in Equation (5.1) always represents LAB coordinates, β is transformed to LAB coordinates at each mesh point to evaluate $P_\ell(\mu_0)$ if β represents CM coordinates. The group boundaries E_j must be located relative to the β mesh depending on the coordinate system also. These Equations are derived in Appendix A and are:

$$(\mu)_{CM} = \frac{\gamma}{2} \left[\frac{E}{E_0} (A+1)^2 - \left(1 + \frac{1}{\gamma^2}\right) \right] \quad (5.25)$$

$$(\mu_0)_{LAB} = \frac{(\mu)_{CM} + \gamma}{\sqrt{1 + \gamma^2 + 2\gamma(\mu)_{CM}}} \quad (5.26)$$

$$\gamma = \frac{1}{A \sqrt{1 + \frac{A+1}{A} \frac{Q}{E_0}}} \rightarrow \frac{1}{A} \text{ elastic} \quad (5.27)$$

where E_0, E are the incident and final energy of the neutron in LAB coordinates respectively and A is the target to neutron mass ratio.

The DAO algorithm then consists of the following steps in brief outline.

1. Generate $P(E_0, \beta)$ on a uniform β mesh depending on the data representation in File 4.

CM $\rightarrow$ LREP = 1

Elastic $\rightarrow$ JTYPE = 1

LAB $\rightarrow$ LREP = 2

Inelastic level $\rightarrow$ JTYPE = 2

N-2N level $\rightarrow$ JTYPE = 3

- A. Tabular Distribution given in File 4.

Interpolate $P(E_0, \beta)$ onto the E_0, β integration mesh.

- B. Legendre representation given in File 4.

$$P(E_0, \beta_k) = \sum_{\ell} \frac{2\ell+1}{2} f_{\ell}(E_0) P_{\ell}(\beta_k) \quad (5.24)$$

Interpolate $P(E_0, \beta_k)$ onto the E_0 integration mesh.

2. Call SR. OUTER to index outer integral integration to $E_0 = E_i$.

3. Call SR. INNER for incident energy E_i .

- A. Obtain maximum and minimum energy bounds corresponding to $\beta = +1.0$ and $\beta = -1.0$, respectively. Locate minimum and maximum energy groups for downscatter.

$$\beta = +1.0 \rightarrow E_{MAX} = \frac{E_i}{(A+1)^2} \left(\frac{\gamma+1}{\gamma} \right)^2, \epsilon j \text{ MIN} \quad (5.28)$$

$$\beta = -1.0 \rightarrow E_{MIN} = \frac{E_i}{(A+1)^2} \left(\frac{\gamma-1}{\gamma} \right)^2, \epsilon j \text{ MAX} \quad (5.29)$$

B. Index all outscatter groups in SR. INNER from j MIN $\rightarrow j$ MAX.

4. Obtain outgroup cuts in β space for two cases depending on LREP.

A. LREP = 1, $\beta \rightarrow$ CM

$$\beta_j = \frac{\gamma}{2} \left[\frac{E_j}{E_i} (A+1)^2 - \left(1 + \frac{1}{\gamma^2}\right) \right] \quad (5.30)$$

$$P_\ell(\mu_0)_k = P_\ell \left[\frac{\beta_k + \gamma}{\sqrt{1 + \gamma^2 + 2\gamma\beta_k}} \right] \quad (5.31)$$

$k \in j$

Add contribution from inner integral to group j for all
 $k \in$ group j .

B. LREP = 2, $\beta \rightarrow$ LAB

$$P_\ell(\mu_0)_k = P_\ell(\beta_k) \quad (5.32)$$

$k \in j$

$$(\mu_j)_{CM} = \frac{\gamma}{2} \left[\frac{E_j}{E_i} (A+1)^2 - \left(1 + \frac{1}{\gamma^2}\right) \right] \quad (5.33)$$

$$\beta_j = \frac{(\mu_j)_{CM} + \gamma}{\sqrt{1 + \gamma^2 + 2\gamma(\mu_j)_{CM}}} \quad (5.34)$$

Add contribution from the inner integral to group j for all
 $k \in$ group j .

5. Cycle j index j MIN $\leq j \leq j$ MAX to obtain all outscatter contributions along a single line integral in SR. INNER.

6. Repeat steps 3-5 for each outer integral mesh point E_i to obtain the complete source group matrix column.

Equations (5.28) and (5.29) are obtained from Equations (5.25) or (5.25) and (5.26) by setting μ or μ_0 to +1.0 or -1.0 and obtaining EMAX or EMIN at these bounds.

The elastic scattering matrix is calculated at step 4 for $\ell = 0, 1, 2$ and 3. The non-elastic matrix is calculated at step 4 for $\ell = 0$ and 1 only. SR. PL is called from SR. INNER at each integration point k to calculate the LAB Legendre polynomials at step 4A or 4B depending on LREP. Legendre polynomials at a single mesh point k are returned from SR. PL in PLXMU (4) at each call. Each call to SR. INNER returns the i matrix column contributions from the inner integral in $ANS(L, K)$, K corresponding to the number of groups downscatter from the source group i .

SR. OUTER then adds $ANS(L, K)$ to the $P_0(j)$, $P_1(j)$, $P_2(j)$ and $P_3(j)$ matrix column for group i . For elastic scattering, the P_0 and P_1 matrices are saved for SR. FRGOUT on Unit ITPS one source group at a time and the P_2 and P_3 matrices are saved on Unit ITPR in SR. TRAN.

For non-elastic scattering SR. TRIN stores the P_0 and P_1 matrices in PMX (ISLOT) and PMX1 (ISLOT). Diagonal elements are stored in DIAG (i) and DIAG1 (i). SR. ETOP 50 then adds in continuum contributions to PMX (ISLOT) and DIAG (i) for the P_0 matrix only since continuum contributions to non-elastic scattering are calculated for essentially infinite target mass.

SR. ETOP 50 calls SR. OUT5 at the completion of all non-elastic matrix calculations for renormalization of each column sum to the average total non-elastic cross section. The P_0 and P_1 non-elastic matrices are saved on Unit ITPR for processing by SR. FRGOUT. The P_2 and P_3 elastic matrices saved on Unit ITPR are written over by the P_0 and P_1 non-elastic matrices since these are presently not used by PHROG.

5. Numerical Integration for DAO Algorithm

SR. OUTER accumulates the outer integral by means of trapezoidal integration on the E_0 mesh in all cases. The outer integral is performed

as a function of E_0 and the inner integral is performed as a function of β in all cases. β is a CM or LAB cosine depending on LREP.

Two numerical integration options are allowed for the inner integral in SR. INNER.

1. Trapezoidal Integral

Trapezoidal integration is a option for the inner integral on a uniform β mesh $-1.0 \leq \beta \leq 1.0$. The number of integration points is controlled by the input variable JMUPTS. JMUPTS may be any integer between 10 → 100. 100 JMUPTS is the maximum permitted in ETOP 14. JMUPTS values of β are stored in PMGRID(100) where PMGRID(1) = 1.0 and PMGRID(JMUPTS) = -1.0. In general when the trapezoidal integral is accumulated in group j in SR. INNER, the group j boundaries β_j will not fall on the PMGRID mesh. The trapezoidal integral is linearly interpolated across the group boundaries from the two adjacent PMGRID mesh points.

2. Gauss Legendre Quadrature Integral

Gauss Legendre Quadrature is an option in SR. INNER for the partial range integrals falling between each outscatter group's boundaries. Only 5, 10 and 16 point Gauss quadrature is permitted controlled by the input variable IGAUSS. When IGAUSS = 0, trapezoidal integration will be used. IGAUSS set to anything other than 0, 5, 10, 16 will cause a program stop in SR. INNER. The designated number of Gauss points are used for the partial range line integrals in each outscatter group j. Each partial range integral in the range $-1/2 \leq \beta' \leq 1/2$ is given by the transformation.⁽¹⁵⁾

$$\beta = (b-a)\beta' + \frac{a+b}{2} \quad (5.35)$$

The partial range integral⁽¹⁵⁾ is then evaluated by Gauss quadrature as

$$\text{ANS}(L,K) = \int_a^b f(\beta) d\beta = \sum_{k=1}^{\text{IGAUSS}} f(\beta_k) H_k \quad (5.36)$$

$$\text{where } \beta_k = (b-a)\beta'_k + \frac{a+b}{2} \quad (5.37)$$

and β'_k are the Gauss points corresponding to the quadrature degree stored in the UGAUS array.

H_k are the Gauss weights stored in the HGAUS array.

and

$$f(\beta_k) = \phi_0(E_i) \sigma_i(E_0) \Delta E_i P_\ell(\mu_0)_k P(E_i, \beta_k) \quad (5.38)$$

If β_k corresponds to CM coordinates in Equation (5.38), $P_\ell(\mu_0)_k$ is first transformed to LAB coordinates by

$$(\mu_0)_k = \frac{\beta_k + \gamma}{1 + \gamma^2 + 2\gamma\beta_k} \quad (5.39)$$

If β_k corresponds to LAB coordinates, $P_\ell(\mu_0)_k = P_\ell(\beta_k)$. Since the Gauss points are symmetric about $\beta' = 0.0$, two terms of the sum in Equation (5.36) are accumulated for each Gauss point corresponding to $\pm |\beta'_k|$. The partial range integral limits, a and b , in Equation (5.36) correspond to the group j cuts given by Equation (5.30) or Equations (5.33) and (5.34) depending on LREP. In this way the DAO algorithm is accommodated to Gauss Quadrature for the inner integral.

$P(E_i, \beta_k)$ in Equation (5.38) must be evaluated at the transformed Gauss points β_k . For either trapezoidal or Gauss integration in SR. INNER, $P(E_0, \beta)$ from File 4 has been linearly interpolated onto the PMGRID mesh in SR. GRIN over JMUPTS for each incident energy E_i on the outer integral energy mesh. The Gauss points β_k , are linearly interpolated between the PMGRID mesh points to evaluate $P(E_i, \beta_k)$ in Equation (5.38). Thus, if Gauss quadrature is requested for the inner integral of Equation (5.1) both IEPNTS and JMUPTS must also be specified in the input for the construction of $P(E_i, \beta_k)$ in SR. POFMU and SR. GRIN. The number of JMUPTS specified has some effect on the accuracy of the Gauss partial range integrals since the Gauss points are linearly interpolated onto the PMGRID mesh for JMUPTS. The finer the mesh, the more accurate will be the Gauss point interpolation.

Construction of $P(E_0, \beta)$ for Algorithm 3

SR. GADD performs the same function for Algorithm 3 as for Algorithm 2 with one exception. The angular data array $YL(NPIM, NLENG)$ read from File 4 of the ENDF/B tape will be reconstructed into a tabular distribution for $NLENG = JMUPTS$ instead of an array containing Legendre expansion coefficients. This is accomplished in SR. GADD by a call to SR. POFMU each time a new angular data set is read from the ENDF/B tape. When Algorithm 3 is requested, SR. OUTER calls SR. GRIN to linearly interpolate the YL array into the $YLM(IEPNTS, JMUPTS)$ array. In the event SR. GRIN finds all angular data sets $YL(NPIM, NLENG)$ are isotropic in a particular energy group, then a flag (IFLAG) is set indicating all data this group is isotropic and the construction of the YLM array is bypassed. SR. INNER sets $YLM = 0.5$ if $IFLAG = 0$. The YLM array is dimensioned $YLM(100, 100)$. The YL array is dimensioned $YL(24, 100)$ for a maximum of 24 angular data sets falling in any one PHROG group including the group boundaries. In the event more than 24 angular data sets are found in File 4 in one PHROG group, a program stop occurs in SR. GADD. A special load module must be used to process these materials where YL has been dimensioned $YL(150, 100)$. This load module must be used for the Version 4 ENDF/B materials ^{16}O , ^{14}N , ^{12}C which contain upwards to 150 angular data sets in specified PHROG groups.

Energy Mesh For DAO Algorithm

1. Elastic Scattering: For materials with a mass > 100 , very few energy points on a uniformly spaced energy mesh fall within the range $ELO \leq E_i \leq ELO/\alpha$ in Figure 8, where outscatter occurs to only one group downscatter. A uniform energy mesh will yield poor accuracy for outscatter matrix elements. The energy mesh is divided into two ranges. The first uses IOUTS points specified in the input between ELO and ELO/α where ELO is the lower energy bound of the group. The second range in Figure 8 between ELO/α and EHI uses $IEPNTS - IOUTS$ uniformly spaced energy points. At least half of the $IEPNTS$ energy mesh should be designated for $IOUTS$ to obtain good accuracy in these cases. The $IOUTS$ variable does not affect the calculation for non-elastic scattering.

2. Non-Elastic Scattering: No special energy mesh can be used to improve accuracy for non-elastic scattering since the Q values of the levels are essentially random numbers as far as the PHROG group boundaries are

concerned. The DAO algorithm always uses a uniformly spaced energy mesh for the non-elastic matrix elements. The calculation of the non-elastic matrix begins at an energy E090 just above the threshold of each level where the integration domain is single valued (see Appendix A).

$$E090 = - \frac{A}{A-1} Q \quad (5.40)$$

This energy corresponds to the point where the hyperbola in Figure 8 just touches the $E = 0$ axis and the neutron scatters at 90° in LAB coordinates with zero exit energy. The extent of the energy range below E090 to the threshold of the level is negligible and the level cross section is also very small. Energies below E090 are neglected in ETOP 14 and the calculation begins at E090. Since the point E090 itself scatters all the way to zero energy, inclusion of E090 will greatly increase the size of the non-elastic matrices without contributing significantly to the physics of the problem. The point E090 is also neglected for the group E090 falls in to reduce the size of the non-elastic matrices.

Each inelastic level is indexed in SR. TRIN independently beginning with MT = 51 through MT = 90. The complete contributions from each level are completed before the next level is indexed. Details for the inelastic matrix are given in Section V, 7.

6. Accuracy Requirements for the DAO Algorithm

It is difficult to state a general rule for required accuracy for trapezoidal vs. Gauss quadrature integration when both elastic and non-elastic matrices are being handled by means of the same algorithm. In general, the angular data for elastic scattering contains more structure than do corresponding cases for non-elastic scattering. Thus, the number of trapezoidal or Gauss points required to obtain accuracy for elastic scattering exceeds the number of points required for non-elastic scattering in the inner integral.

The number of energy points required for the outer integral depends on the amount of structure in the scattering cross section $\sigma(E_0)$ and on the mass of the scattering isotope. Only the energy range above group KGTR0P is processed by the DAO algorithm. For heavy elements, this energy range usually does not contain any resonance structure. Intermediate mass materials

such as Fe, Cr, and Ni present the most difficult cases because of the large amount of elastic resonance structure in the anisotropic scattering range. The non-elastic levels in these cases exhibit only weak structure.

It is safest always to use 100 energy points for important materials regardless of target mass. 10 Gauss points using Gauss Legendre Quadrature has been sufficient to obtain excellent accuracy in all cases tested against competing integration schemes for the inner integral. The P_3 elastic matrix always requires more integration points for the inner integral because of the convolution of the P_3 Legendre polynomial with the angular data. The P_0 matrix elements only require integration over the angular distribution unweighted and are therefore determined to a higher level of accuracy. Since $P(E_0, \beta)$ is a tabular distribution for the DAO algorithm, no knowledge of the order of the equivalent Legendre expansion is retained even for the case where the ENDF/B data was a Legendre representation. For tabular distributions, a knowledge of the order of the distribution would require manufacturing Legendre expansion coefficients.

In cases where 10 Gauss points give excellent accuracy for elastic scattering, 5 Gauss points would usually be more than sufficient for the inelastic matrices of the same material even though 10 Gauss points are used. This is because the angular distributions for inelastic levels show far less structure than does elastic scattering as a rule. Five Gauss points yields poor accuracy for elastic scattering from heavy isotopes in the Mev region. In these cases, 10 Gauss points converge to essentially the same values as 16 Gauss points.

It is recommended that 10 Gauss points always be used for materials of most importance, since the highest order matrices used in PHROG at present are P_1 even though the P_2 and P_3 elastic matrices are calculated. Gauss quadrature is always preferred over trapezoidal integration for the inner integral since it is more efficient. Results for a comparison of algorithm accuracy are given in Tables 6 and 7 for 2 cases, ^{237}Np and ^{12}C , using Version 4 data. The corresponding CPU times on the IBM 360-75 are also included as an aid in evaluating the results. Calculated matrix elements are compared with Algorithm 2 (ETOG) in both cases.

^{237}Np has 9 Legendre coefficients given in CM coordinates in the energy range considered. ^{12}C has 5 Legendre coefficients in CM coordinates.

TABLE 6

ELASTIC SCATTERING MATRICES ^{237}Np MATERIAL 1263 SOURCE GROUP 3

GROUP	P_0		P_1^*	
	3	4	3	4
ETOG	3.767	.04125	8.826	.009875
TRAP 100-60	3.811	.04168	8.972	.01083
TRAP 100-100	3.785	.04154	8.882	.01035
5 GAUSS	3.528	.04104	7.802	.00632
10 GAUSS	3.810	.04158	8.941	.01052
16 GAUSS	3.786	.04153	8.879	.01055

GROUP	P_2^*		P_3^*	
	3	4	3	4
ETOG	12.04	.01442	13.79	.005235
TRAP 100-60	12.32	.01654	14.27	.007388
TRAP 100-100	12.15	.01581	13.97	.006311
5 GAUSS	9.814	.01090	9.653	-.0042
10 GAUSS	12.22	.01567	14.01	.006523
16 GAUSS	12.11	.01560	13.86	.006554

CPU Time (Seconds)/Group

ETOG (Algorithm 2)	5.83
TRAP 100-60	2.23
TRAP 100-100	3.54
5 GAUSS	.670
10 GAUSS	1.073
16 GAUSS	1.506

*NOTE: These matrix elements are each multiplied by the factor $2\ell+1$
 where $\ell = 1, 2, 3$

TABLE 7

ELASTIC SCATTERING MATRICES ^{12}C MATERIAL 1274 SOURCE GROUP 7

Source Group 7				
	P_0	P_1^*	P_2^*	P_3^*
ETOG	.7515	1.329	.6808	.1195
TRAP 100-100	.7532	1.333	.6847	.1230
5 GAUSS	.7531	1.339	.7004	.1379
10 GAUSS	.7532	1.333	.6841	.1213
16 GAUSS	.7532	1.333	.6841	.1213
Sink Group 8				
	P_0	P_1^*	P_2^*	P_3^*
ETOG	.9949	-.7262	-.1881	-.04236
TRAP 100-100	.9909	-.7160	-.1982	-.03888
5 GAUSS	.9920	-.7197	-.1891	-.04288
10 GAUSS	.9909	-.7159	-.1992	-.03688
16 GAUSS	.9909	-.7159	-.1992	-.03687
Sink Group 9				
	P_0	P_1^*	P_2^*	P_3^*
ETOG	.06929	-.1726	.1927	-.1334
TRAP 100-100	.06941	-.1730	.1934	-.1346
5 GAUSS	.06947	-.1729	.1928	-.1332
10 GAUSS	.06930	-.1726	.1927	-.1334
16 GAUSS	.06930	-.1726	.1927	-.1334
CPU Time (Seconds)/Group				
ETOG (Algorithm 2)	3.95			
TRAP 100-100	3.89			
5 GAUSS	.80			
10 GAUSS	1.503			
16 GAUSS	2.33			

*NOTE: These matrix elements are each multiplied by the factor $2\ell+1$
 where $\ell = 1, 2, 3$

It is observed from Tables 6 and 7 that the ETOG Algorithm 2 requires almost twice as much time for ^{237}Np as for ^{12}C even though ^{12}C scatters to three groups. This is due to the fact that ^{237}Np has 9 Legendre coefficients in the angular data file whereas ^{12}C has only 5 Legendre coefficients. The increased computation time for ^{237}Np is required to manufacture the higher order Legendre polynomials at each integration point in the integration mesh. If the angular data had been represented as other than CM Legendre expansion coefficients, the ETOG algorithm would require greatly increased computation time. The DAO algorithm requires essentially the same computation time for any angular data representation.

Results for the inelastic scattering matrices for these two materials give agreement to the fifth digit for all computation schemes listed. This is because the angular data is essentially isotropic for the inelastic scattering in these materials. 5 Gauss points gives excellent accuracy for the inelastic scattering matrices whereas 5 Gauss points yields insufficient accuracy for elastic scattering where the angular distributions for ^{237}Np show 9th order structure.

In judging the accuracy required from any computation algorithm, it must be remembered that a column sum of the matrix is physically no more accurate than the scattering cross section $\sigma(E_0)$ from the source group. Rarely is the elastic scattering cross section more accurate pointwise than ± 3 percent. Thus, for practical application an accuracy of ± 1 percent for the column sum of the P_1 matrix will produce sufficient mathematical accuracy. Any matrix element is no more accurate physically than the pointwise data for the angular distributions which is always less than the cross section $\sigma(E_0)$.

These observations concerning the efficiency of Gauss Legendre quadrature for the partial range integrals in SR. INNER agree with those of other workers.^(16,17) Intercomparison of numerical methods in ETOP 14 is especially useful since the differing numerical techniques share many of the same subroutines in common.

7. Renormalization of Non-elastic Scattering Matrices

The DAO algorithm is used in conjunction with Algorithm 4 for the generation of inelastic scattering matrices. The DAO algorithm calculates

the contributions from inelastic level data which are correlated in energy and angle of scattering. The elastic scattering matrices are calculated with $\sigma(E_0)$ as the pointwise elastic cross section in barns. The inelastic scattering cross section for each level is first converted to the fractional probability of the level relative to the total inelastic cross section by

$$P_r(E_0) = \frac{\sigma_r(E_0)}{\sigma_{IN}(E_0)} \quad (5.41)$$

where

$P_r(E_0)$ = fractional probability of level r

$\sigma_r(E_0)$ = level r cross section in barns

$\sigma_{IN}(E_0)$ = Total inelastic cross section in barns.

The continuum cross section for MT = 91 is also converted to a probability but it is processed in SR. ETOP 50 using Algorithm 4 in the next section. The pointwise probabilities from each level thus sum to 1.0.

$$\sum_r P_r(E_0) = 1.0 \quad (5.42)$$

The inelastic scattering matrix is first calculated using the level probabilities from Equation (5.41) in Equation (5.1) instead of the level cross sections $\sigma_r(E_0)$. Thus a probability matrix is calculated from all levels and continuum contributions in the first pass. A column sum of the probability matrix should then sum to 1.0.

The pointwise level probability for each level is constructed in SR. GOSH one group at a time beginning with group MMIN. MMIN is the PHROG group E090 falls in. The pointwise probability is stored on unit ITPE where each group corresponds to one record. Each inelastic level begins a new cycle. As the calculation of the matrix elements for a given level begins, SR. GADD reads the pointwise level probability from unit ITPE

for a single source group. GADD then reads the angular distributions from File 4 which fall in this source group. SR. OUTER is then called to calculate the probability matrix elements. All inelastic level cross sections are controlled by SR. TRIN. The inelastic algorithm is:

1. At the completion of the elastic scattering matrix controlled by SR. TRAN, SR. TRIN is called.
2. SR. TRIN indexes the level cross sections one level at a time beginning with MT = 51. SR. TRIN next calls SR. GOSH to calculate the level probabilities.
3. SR. GOSH reads the level cross section which has been saved on unit 4 by SR. CROS. GOSH calls SR. COMB to divide the level cross section by the pointwise total inelastic cross section which was stored by SR. CROS in /DENS/storage. The pointwise level probability is saved on unit ITPE where each record corresponds to one PHROG group.
4. SR. TRIN next indexes each PHROG group to begin the calculation of the matrix elements. TRIN calls SR. GADD for each source group.
5. SR. GADD reads the pointwise probability from unit ITPE for this group into COMMON/RECS/. GADD next reads the angular distributions from File 4 of the ENDF/B tape and converts the angular representation into $P(E_0, \beta)$ over the JMUPTS β mesh by a call to SR. FORMU. The angular distributions for this group are stored in the array YL(NPIM, JMUPTS). SR. TRIN next calls SR. OUTER.
6. SR. OUTER calls SR. GRIN to interpolate the level probability onto the IEPNTS energy integration mesh. YL(NPIM, JMUPTS) is then interpolated onto the IEPNTS energy integration mesh as YLM(IEPNTS, JMUPTS). The outer integration is then indexed to the i^{th} point of the energy integration mesh for this source group.
7. For each point of the energy integration mesh, SR. OUTER calls SR. INNER to calculate the complete line integral from $\beta = +1.0$ to

$\beta = -1.0$. SR. INNER calls:

- A. SR. MAXMIN to locate the energy bounds EMAX and EMIN corresponding to $\beta = +1.0$ and $\beta = -1.0$, respectively.
 - B. These energy bounds are next located relative to the outscatter group boundaries by SR. INNER. KMIN and KMAX downscatter groups correspond to EMAX and EMIN, respectively. SR. INNER indexes the outscatter group to K where $KMIN \leq K \leq KMAX$.
 - C. For each new outscatter group, INNER calls SR. MUBOT which determines the energy group boundary in β space corresponding to downscatter group K depending on whether β corresponds to CM or LAB coordinates.
 - D. SR. INNER calls SR. PL to calculate the LAB Legendre polynomials for $\ell = (0, 1, 2, 3, \text{elastic}), (0, 1, \text{non-elastic})$ on the inner integration mesh points depending on whether trapezoidal or Gauss quadrature integration has been requested.
 - E. The contribution to the inner integral in downscatter group K is stored in $ANS(L,K)$. INNER repeats the calculation for each downscatter group $KMIN \leq K \leq KMAX$.
8. SR. OUTER indexes all points on the energy integration mesh for this source group.
 9. At completion of the call to SR. OUTER, SR. TRIN transfers the appropriate matrix elements to $PMX(ISLOT)$ and $PMX1(ISLOT)$ for $\ell = 0, 1$, respectively. Diagonal elements are stored in $DIAG$ and $DIAG1$.
 10. At the completion of all source groups for each level and at the completion of all inelastic levels, SR. ETOP 50 is called to calculate the contribution from continuum level $MT = 91$. Only the P_0 matrix receives a contribution from the continuum cross section. This is also calculated as a probability matrix.

11. After the completion of the continuum contribution to the probability matrix, SR. ETOP 50 calls SR. OUT5 for renormalization of the probability matrix and editing. Renormalization occurs in two steps.
 - A. The column sum for each source group is edited before renormalization to indicate if any serious discrepancies exist. All elements of the probability matrix less than 10^{-4} are set to zero and each column of the P_0 matrix is renormalized to a column sum of 1.0 in SR. RENO. The P_1 probability matrix is renormalized by the same factor.
 - B. SR. RENO is called the second time from SR. OUT5 to multiply the elements of each source group by $XIN(I)$ which is the average total inelastic cross section for group I. $XIN(I)$ was calculated in SR. CROS when the total inelastic cross section was read from File 3 of the ENDF/B tape.
12. The inelastic scattering matrix is saved on unit ITPR for construction of the PHROG library tape in SR. FRGOUT.
13. SR. OUT5 also determines the size of the inelastic scattering matrix, the number of source groups, and the maximum number of groups downscatter. Each source group is assumed to contain elements for the maximum number of groups downscatter from any source group. Thus, some columns of the matrix will contain zero elements. Since there are no contributions to the P_1 matrix from the continuum cross section ($MT = 91$), these elements are all zero.

8. Beryllium n-2n Reaction

A special format in the ENDF/B files has been designated for the ^9Be n-2n reaction. Individual level cross sections are given in File 3 for $MT = 6, 7, 8, 9$ for the first neutron emitted is calculated by the DAO algorithm in the same way as an inelastically scattered neutron. The one difference from an inelastically scattered neutron is that the total n-2n cross section for the first neutron is not given in File 3. Thus, before the DAO algorithm can be applied as outlined in the last section,

the total inelastic cross section must be constructed in SR. TRIN so that the individual level probabilities may be determined as in the case for inelastic scattering. SR. TRIN controls the n-2n reaction for ^9Be . The complete P_0 and P_1 probability matrix for the first neutron emitted is calculated in SR. TRIN.

Level cross sections for the second neutron emitted are given in File 3 for MT = 46 - 49 with corresponding angular distributions given in File 4. However, the second neutron is not correlated in energy and angle of scattering. Separate tabular secondary energy distributions for MT = 46 - 49 are given in File 5. Each secondary neutron emitted in the secondary energy spectrum contains the complete angular distribution given in File 4. The P_1 matrix of the second neutron thus contains the same angular weight $\bar{\mu}_0(E_0)$ for all exit energy groups. A special algorithm is thus required for the second neutron emitted in the reaction. The matrix elements for the second neutron cannot be constructed until the secondary energy distributions are read from File 5. The angular distributions must be processed at the time File 4 is positioned on the ENDF/B tape in SR. TRIN. The ℓ th Legendre moment of the n-2n scattering matrix for the second neutron is given by

$$\sigma_{ij}^{\ell} = \bar{\sigma}_i \sum_r \int_{E_i}^{E_{i-1}} p_r(E_0) \int_{\beta=-1}^{\beta=+1} P_{\ell}[\mu_0(\beta)] p_r(E_0, \beta) d\beta \int_{E_{ej}} G_r(E_0, E) dE dE_0 \quad (5.43)$$

and

$$\bar{\sigma}_i = \frac{\int_{E_i}^{E_{i-1}} \sum_r \sigma_r(E_0) \phi_0(E_0) dE_0}{\int_{E_i}^{E_{i-1}} \phi(E_0) dE_0} \quad (5.44)$$

where $\bar{\sigma}_i$ is the average total n-2n cross section for all four levels.

$\sigma_r(E_0)$ is the n-2n cross section for the r^{th} level.

$\phi_0(E_0)$ is the neutron flux weight in group i .

$$p_r(E_0) = \frac{\sigma_r(E_0)}{\sigma_2(E_0)} \quad (5.45)$$

= probability of scattering from the r^{th} level.

$\sigma_2(E_0)$ = Total pointwise n-2n cross section for the second neutron.

$P_\ell[\mu_0(\beta)]$ is the ℓ th Legendre polynomial of the cosine of the scattering angle β corresponding to CM or LAB coordinates depending on the angular data representation.

$P_r(E_0, \beta)$ is the normalized angular probability distribution given in File 4 for the r^{th} level of the second neutron.

$G_r(E_0, E)$ is the normalized secondary energy distribution given in File 5 for the r^{th} level of the second neutron to final energy E .

A separate integral over β and E is required in Equation (5.43) since the second neutron is uncorrelated in energy and angle of scattering. The total n-2n cross section for the second neutron in Equation (5.44) is the same as the total n-2n cross section for the first neutron. The integral over the β angular distribution may be moved outside the E_0 integral if the angular distributions for each level are only weakly dependent on the incident neutron energy. Equation (5.43) is thus simplified to:

$$\sigma_{ij}^\ell = \bar{\sigma}_i \sum_{r=1}^4 \bar{M}_{r,i}^\ell \int_{E_i}^{E_{i-1}} p_r(E_0) \int_{E_{ej}} G_r(E_0, E) dE dE_0 \quad (5.46)$$

$$\bar{M}_{r,i}^{\ell} = \frac{\int_{E_i}^{E_{i-1}} \sigma_r(E_0) \int_{\beta=-1}^{\beta=+1} P_{\ell}[\mu_0(\beta)] P_r(E_0, \beta) d\beta dE_0}{\int_{E_i}^{E_{i-1}} \sigma_r(E_0) dE_0} \quad (5.47)$$

where $\bar{M}_r^{\ell}$ is the average Legendre moment of the File 4 angular distribution for source group i, level r.

Thus calculation of the Legendre moments $\bar{M}_{ri}^{\ell}$ from the angular distributions given in File 4 is separated from the calculation of the matrix elements in File 5 given by Equation (5.46). The P_1 matrix $\bar{M}_{ri}^1$ are calculated in SR. TRIN and saved in the arrays $P_{11}(I)$, $P_{12}(I)$, $P_{13}(I)$, $P_{14}(I)$ for each level r and each source group I for the second neutron levels. They are then recalled in SR. IMAT at the time of the calculation of the P_0 probability matrix elements given by Equation (5.46)

Since $\bar{M}_{r,i}^0 = 1.0$ the P_0 matrix is unweighted. The P_1 matrix is obtained in SR. IMAT by merely multiplying each P_0 matrix element by the appropriate $\bar{M}_{r,i}^1$ at the time each level and each source group is treated. This procedure greatly simplifies the evaluation of Equation (5.43) since the subroutines to treat the P_0 matrix for the second neutron are identical to the subroutines for the treatment of the continuum inelastic cross section in SR. IMAT with the single exception of the factor $\bar{M}_{r,i}^1$ in Equation (5.46).

The $\bar{M}_{r,i}^1$ are the average LAB cosines of the scattering angle for each level r and each source group i. The values calculated are printed in the ETOP 14 listing at the time they are obtained in SR. TRIN.

Since the probability matrix elements from the second neutron are added to the matrix elements from the first neutron, a column sum of the n-2n matrix before renormalization will add to 2.0 instead of 1.0 as in the case for inelastic scattering described in the last section. Renormalization of the n-2n probability matrix by column to 1.0 in SR. RENO will produce an n-2n matrix for a single neutron. PHROG multiplies each element of the

8

n-2n source term. After renormalization of the probability matrix, SR. RENO multiplies each element of the n-2n probability matrix by the average total n-2n cross section given by Equation (5.44) to produce an n-2n cross section matrix. The P_0 and P_1 n-2n matrices are stored on units ITPE and ITPR for production of the PHROG library in SR. FRGOUT.

Since the inelastic scattering matrices are stored on the same unit and use the same core storage as the n-2n matrices, this version of ETOP 14 will not permit the calculation of both inelastic and $MT = 6 - 9$ and $MT = 46 - 49$ n-2n matrices in a single material. Since this combination of cross section reactions is not anticipated in a single ENDF/B material, this restriction is presently of no consequence. More core storage would be required in the event both inelastic and discrete level n-2n reactions occur in a single ENDF/B material.

9. Algorithm 4. Infinite Target Mass Algorithm for Continuum Inelastic and n-2n Scattering Matrices

Secondary neutrons from continuum cross sections are generally modeled after some form of Weiskopf's Evaporation Model⁽¹³⁾ for the nucleus assuming a very dense level structure for the target nucleus. The secondary neutrons are assumed to evaporate from the compound nucleus in a Maxwellian distribution at a characteristic nuclear temperature $T(E_0)$. In this case $T(E_0)$ is tabulated in File 5 corresponding to LF numbers 7 or 9. The LF flag in File 5 indicates the type of secondary neutron representation. LF = 1 indicates secondary energy distributions are given as a TAB2 record in File 5. SR. IMAT has been programmed to treat⁽¹⁾ LF = 1, 3, 5, 7, 9 and 10 type secondary neutron energy distributions from continuum cross sections. An old ENDF/B secondary neutron specification for discrete level cross sections corresponding to LF = 3 has been retained in SR. IMAT but is seldom used in current ENDF/B version. For LF = 3, no angular distributions are given in File 4 so the secondary neutrons are assumed uncorrelated in energy and scattering angle unless one assumes isotropic scattering in CM coordinates. The options for LF = 3 specification of discrete levels has been retained in ETOP 14 because someone will surely find a use for it one of these days, the way things are going in general.

In all cases for the LF flag, ETOP 14 assumes no target recoil as the secondary neutrons are evaporated from the compound nucleus. This essentially corresponds to isotropic scattering in LAB coordinates for infinite target mass using the DAO algorithm.

In SR. IMAT, the matrix elements for isotropic scattering in LAB coordinates are calculated from

$$\sigma_{i,j}^0 = \bar{\sigma}_i \sum_k \int_{E_i}^{E_{i-1}} p_k(E_0) \int_{E_j}^{E_{j-1}} p_k(E_0, E) dE dE_0 \quad (5.48)$$

and

$$\sum_k p_k(E_0) = 1.0$$

where

$p_k(E_0)$ is the probability of incident neutrons scattering with the type k secondary energy distribution $p_k(E_0, E)$.

$\bar{\sigma}_i$ - average total non-elastic cross section, Equation (5.44)

For MT = 91 inelastic continuum cross sections, $p_k(E_0)$ is first constructed from the cross sections in SR. TMF5 using Equation (5.41) where $k = 1$. In general more than one secondary energy distribution may be given for each incident neutron in File 5. However, for MT = 91 (inelastic continuum) and MT = 16 (n-2n continuum) only one secondary energy distribution in File 5 is permitted for either reaction type.

A probability matrix is first calculated for $\lambda = 0$ neutrons and added to the existing matrix for discrete level cross sections. After renormalization of the probability matrix, the matrix is renormalized to $\bar{\sigma}_i$ as described in the section describing renormalization.

SR. IMAT is programmed to treat the following secondary energy distribution functions corresponding to the LF number given in File 5 of the ENDF/B file.

Secondary Energy Distributions

LF $P_k(E_0, E)$

1 Tabulated Distribution

$P_k(E_0, E)$ Tabulated in File 5

3 Discrete level (Old Format)

$$\delta \left[E - \left(E_0 + \frac{A+1}{A} Q \right) \right]$$

Q given in File 3

5 General Evaporation Spectrum

$g(x)$, Tabulated in File 5

$$x = E/\theta(E_0), \quad 0 \leq E \leq (E_0 - U)$$

$\theta(E_0)$ tabulated in File 5

$$0 \leq E \leq (E_0 - U)$$

7 Simple Fission Spectrum, Maxwellian

$$\frac{\sqrt{E}}{I} e^{-\frac{E}{\theta(E_0)}}$$

$$I = \theta^{3/2} \left[\frac{\sqrt{\pi}}{2} \operatorname{erf}(\sqrt{E_0} - U/\theta) - \frac{(E_0 - U)}{\theta} e^{-\sqrt{(E_0 - U)/\theta}} \right]$$

$$0 \leq E \leq (E_0 - U)$$

$\theta(E_0)$ tabulated in File 5

9 Evaporation spectrum

$$\frac{E \epsilon}{I} e^{-E/\theta(E_0)}$$

$$I = \theta^2 \left[1 - \epsilon \frac{(E_0 - U)}{\theta} + 1 + \frac{E_0 - U}{\theta} \right]$$

$\theta(E_0)$ tabulated in File 5

$$0 \leq E \leq E_0 - U$$

10 Watt spectrum

$$\frac{ab}{\sqrt{4/\pi a^3 b}} \epsilon - \frac{ab}{4} - \frac{E}{a} \sinh(\sqrt{b}E)$$

a, b given in File 5

A secondary E mesh is constructed over the entire energy range. The secondary energy integration mesh is uniform in lethargy over two basic ranges.

$$U \leq 10, \Delta U = \frac{1}{UMESHL} \quad (5.49)$$

$$U < 10, \Delta U = \frac{1}{UMESHH} \quad (5.50)$$

For each incident energy E_0 of the source group, the secondary energy distribution is evaluated at the energies corresponding to the secondary lethargy mesh. The outer integral over the source group is divided into MESHFV uniform energy points per group where MESHFV is an input variable used to control the numerical accuracy of the source group integral. The fractional amount of Equation (5.48) into each sink group j is evaluated as a trapezoidal integral for each MESHFV energy point in the outer integral.

Both UMESHL and UMESHH are input variables to control accuracy of the inner integral in Equation (5.48). Default values of UMESHL and UMESHH are 64.0 and 32.0, respectively. The default values have given sufficient accuracy over a limited number of cases studied. The specification of the secondary integration mesh in terms of lethargy insures that the mesh falls on the group boundaries ($\Delta U = .25$) and that sufficient mesh points will be distributed within each sink group.

LF = 1 specifies a two-dimensional tabulated source to secondary energy distribution in File 5. In this case, the list of secondary energy distributions are interpolated onto the two-dimensional integration mesh by a call to SR. D2 TERP. Only one interpolation scheme each for source energy and secondary energy distributions is permitted. SR. D2 TERP will assume these interpolation schemes to be linear - linear over all energy points given unless specified differently by the input flags LF1INE and LF1INP. Any interpolation scheme may be requested for the source and secondary energies, respectively. Specification of the LF1INE and LF1INP requires examination of the File 5 secondary energy distributions for LF = 1 by the problem requester.

At the completion of the calculation of the inelastic continuum or n-2n continuum matrix elements, SR. ETOP 50 will call SR. OUT5 for renormalization of the scattering matrix and printing as described under Algorithm 3.

SR. IMAT also processes other secondary energy distributions, e.g., fission spectrum using the same integration procedures as describe above.

10. Algorithm 5. Smooth Background Scattering Matrix in Isotropic Scattering Range

When IWG = 2 or 3, an auxilliary background elastic scattering matrix is precalculated by ETOP 14 over the s-wave resonance range. This matrix consists of all non s-wave elastic scattering cross sections from Files 2 and 3 over the group structure falling within the isotropic resonance range determined in Section III. The non s-wave cross sections in these groups fall into 3 categories:

1. Elastic scattering contributions from File 3.

2. Compound elastic cross section contributions from p-wave resonances in the resolved resonance range; p-wave potential scattering not included.
3. Compound elastic contributions from negative energy (bound states) and thermal energy s-wave resonances which fall below the defined PHROG resonance range. These resonances contribute smooth "tails" to the defined resonance range.

All of the above contributions are defined as "smooth" even though p wave resonances are inherently structured. p-wave resonances from the resolved resonance range for heavy mass elements are usually very weak. The integrated cross sections from Equation (3.1) are a very small contribution in comparison with s-wave resonances below 2 or 3 keV. This is the energy range where this approximation is normally applied.

Since the background matrix is for the isotropic scattering range, it may be based on Equation (5.8) Algorithm 1 which reduces to Equation (5.10) for a column sum of the scattering matrix. The within group term is given by Equation (5.13) in terms of the out of group element $\sigma_{i, i+1}^{\ell}$.

$$\sigma_{ii}^{\ell} = \bar{\sigma}_{soi} M^{\ell}(A) - \sigma_{i, i+1}^{\ell}, \ell = 0 \rightarrow 3 \quad (5.13)$$

$M^{\ell}(A)$ is obtained from Table 5 and $\bar{\sigma}_{soi}$ in Equation (5.13) is given by

$$\bar{\sigma}_{soi} = \frac{\int_{E_i}^{E_{i-1}} \phi_0(E_0) \sigma(E_0) dE_0}{\int_{E_i}^{E_{i-1}} \phi_0(E_0) dE_0} \quad (5.51)$$

The out of group scattering term specialized to a single group downscatter ($A > 16$) is taken from Equation (5.8).

$$\sigma_{i, i+1}^{\ell} = \frac{\int_{E_1}^{E_2} \phi_0(E_0) \sigma(E_0) \frac{(A+1)^2}{4AE_0} \int_{\alpha E_0}^{E_i} P_{\ell}[\mu_0(E)] dE dE_0}{\int_{E_i}^{E_{i+1}} \phi_0(E_0) dE_0} \quad (5.52)$$

$$\text{where } \alpha = \left(\frac{A-1}{A+1} \right)^2 \quad (5.53)$$

$$\text{and } \mu_0(E) = \frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \quad (5.7)$$

For the complete scattering matrix, Equation (5.52) was evaluated by means of Algorithm 2 because of the s-wave resonance structure present in $\sigma(E_0)$. This required a very fine integration mesh to evaluate Equation (5.51) in order to use Equation (5.13). Since the background scattering matrix will be devoid of s-wave structure, Equations (5.51) and (5.52) may be reduced to analytic integrals in closed form by the following approximations.

- A. Use only the average background elastic cross section for $\sigma(E_0)$ when evaluating Equation (5.51). This cross section was made up of all contributions from items 1 through 3 above and was stored in PSCAT (i, 3) in subroutines TMF2, RESS and CROS covered in Sections III and IV.
- B. Use only the average background cross section for $\sigma(E_0)$ over the energy range $E_i \rightarrow E_i/\alpha$ when evaluating Equation (5.52). This cross section was stored in PSCAT (i, 1) in subroutines TMF2, RESS and CROS covered in Sections III and IV.

Since $\sigma(E_0)$ is now constant over the specified energy ranges, Equations (5.51) and (5.52) reduce to:

$$\bar{\sigma}_{soi} = \text{PSCAT} (i, 3) \quad (5.54)$$

$$\sigma_{si, i+1}^0 = \frac{\text{PSCAT} (i, 1)}{0.25} \int_{E_1}^{E_2} \frac{1}{E_0} \frac{(A+1)^2}{4AE} \int_{\alpha E_0}^{E_i} dE dE_0 \quad (5.55)$$

$$\sigma_{si, i+1}^1 = \frac{\text{PSCAT} (i, 1)}{0.25} \int_{E_1}^{E_2} \frac{1}{E_0} \frac{(A+1)^2}{4AE} \int_{\alpha E_0}^{E_i} \left[\frac{A+1}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} \right] dE dE_0 \quad (5.56)$$

The neutron flux $\phi_0(E_0)$ in Equations (5.55) and (5.56) is assumed to vary as $1/E_0$. The 0.25 in Equations (5.55) and (5.56) is for a 0.25 lethargy group. The integrations in Equations (5.55) and (5.56) are elementary and yield

$$\sigma_{si, i+1}^0 = \text{PSCAT} (i, 1) * A_0 \quad (5.57)$$

$$\sigma_{si, i+1}^1 = \text{PSCAT} (i, 1) * A_1 \quad (5.58)$$

where

$$A_0 = \frac{4.0}{1-\alpha} \left[E_i \left(\frac{1}{E_1} - \frac{1}{E_2} \right) + \alpha \ln \left(\frac{E_1}{E_2} \right) \right] \quad (5.59)$$

$$A_1 = \frac{4.0}{1-\alpha} \left\{ \frac{A+1}{3} \left[-\frac{2}{3} E_i^{3/2} \left(\frac{1}{E_2^{3/2}} - \frac{1}{E_1^{3/2}} \right) - \alpha^{3/2} \ln \left(\frac{E_2}{E_1} \right) \right] \right. \\ \left. + (A-1) \left[\alpha^{1/2} \ln \left(\frac{E_2}{E_1} \right) + 2E_i^{1/2} \left(\frac{1}{E_2^{1/2}} - \frac{1}{E_1^{1/2}} \right) \right] \right\} \quad (5.60)$$

If the energy group lies entirely within the resonance range, $E_1 = E_i$ and $E_2 = E_i/\alpha$ in Equations (5.59) and (5.60) and these equations may be simplified further. Otherwise, either E_1 or E_2 will be the resonance range lower or upper energy bounds when these bounds fall within the range $E_i \leq E \leq E_i/\alpha$.

Using Equations (5.57) and (5.58) in Equation (5.13), the elements for the background elastic scattering matrix in the isotropic resonance range are:

$$P_0 \text{ Ingroup Element} = \text{PSCAT}(i,3) - A_0 * \text{PSCAT}(i,1) \quad (5.61)$$

$$P_0 \text{ Outgroup Element} = A_0 * \text{PSCAT}(i,1) \quad (5.62)$$

$$P_1 \text{ Ingroup Element} = \frac{2}{3A} \text{PSCAT}(i,3) - A_1 * \text{PSCAT}(i,1) \quad (5.63)$$

$$P_1 \text{ Outgroup Element} = A_1 * \text{PSCAT}(i,1) \quad (5.64)$$

This strategy permits a two step structure for the background elastic scattering cross section in any given group somewhat analogous to the "flat flux approximation" used in two-region heterogeneous resonance theory.⁽¹⁴⁾ Any p-wave resolved resonance falling in the range $E_i/\alpha \leq E_0 \leq E_{i-1}$ is accounted for without approximation since it contributes only to the within group element. A contribution to the within group element is independent of its position in this region (see Figure 9).

Figure 9. Flat Cross Section Approximation for Background Scattering Cross Section.

Contributions from both regions in Figure 9 are added to PSCAT (i,3) which is the average cross section for the group. Only the detailed structure in the outscatter region $E_i \leq E_0 \leq E_i/\alpha$ leads to an approximate evaluation of Equations (5.61) through (5.64). If no p-wave resonance falls within this region, the cross section is already almost flat and the "flat cross section approximation" is quite accurate. Contributions from the s wave resonances and the potential scattering cross section added to the matrix by PHROG will be much larger and completely mask the "flat cross section approximation" used in determining the background scattering matrix. PSCAT (i,3) averages any background structure over the whole group independently of PSCAT (i,1) and follows from the general strategy associated with Algorithm 1.

Outside of the resonance range, the full anisotropic scattering matrix calculated from Algorithm 2 or 3 is added to contributions from Equations (5.61) through (5.64) from the isotropic resonance range. This background matrix is then complete except for s-wave resolved resonance contributions and all contributions from the unresolved range. PHROG will add these contributions from the properly shielded resonance range cross sections.

When IWG = 3, a difference scattering matrix is also calculated and edited to the PHROG library. This difference matrix is obtained by subtracting the complete background scattering matrix, discussed in the last paragraph, from the complete infinitely dilute scattering matrix determined by Algorithm 1 over the resonance range. This matrix will contain only infinitely dilute resonance contributions not present in the background scattering matrix. PHROG will merely add these two scattering matrices together element by element to obtain a complete infinitely dilute matrix if no shielding of the elastic resonance cross section is requested.

The arrays PSCAT (i,1) and PSCAT (i,3) are saved until the construction of the PHROG library tape in SR. FRGOUT discussed in the next section. The background scattering matrix is then calculated using Equations (5.61) to (5.64) by a call to SR. POP1GP from SR. FRGOUT. SR. POP1GP calls SR. AOA1 to evaluate Equations (5.59) and (5.60). The difference scattering matrix is printed in the output listing from SR. PHED by a call to SR. BKSPR. The determination of the integration limits E_1 and E_2 in Equations (5.59) and (5.60) is made by a call to SR. POP1BN.

VI. SR. ETOP 80 AND PHROG LIBRARY FORMAT

Two principal tasks are directed from SR. ETOP 80 depending upon the type of problem being requested by the input data.

- A. If IPRF = 1, an old PHROG library tape is to be edited over selected materials specified by the input data. No new ENDF/B material was processed and SR. MAIN bypassed all computation subroutines to call ETOP 80 directly after reading the input data. ETOP 80 calls SR. PHEDIT to read and print to the output listing selected materials requested in the input from an existing PHROG library tape. The materials requested are read from the old PHROG library tape and printed by a call to SR. PHED from SR. PHEDIT. Any number of materials from the old PHROG library tape may be listed in sequential order in a single problem. At the completion of this loop, the job is terminated.
- B. A single ENDF/B material has been processed in this run. All calculated data has been stored in temporary storage arrays and SR. ETOP 80 calls SR. FRGOUT to format the new cross section data for the PHROG library. SR. FRGOUT then calls SR. PHED to write the new material on the new PHROG library tape at the proper sequential location on the new tape and print an edited listing of the new material to the ETOP 14 output listing.

Item A above is self contained in SR. PHEDIT. Item B can be quite complex when stacked runs are being executed for several new ENDF/B materials and they are being added to an old PHROG library tape. Item B will thus involve several possibilities.

- B1. There is no old PHROG library tape to copy, NITOLD = 0 and IPTIT = 2 in the input data. The new materials from this job will be placed on the new PHROG library tape in the order in which they are processed. Only these new materials will appear on the new library tape.

- B2. IPTIT = 1 and there is an old PHROG library tape to copy. There are NITOLD materials on the old PHROG library tape. All NITOLD materials from the old tape will be copied onto the new library tape. The NITOLD flag is read from the old library tape but it may be incorrect. In this event NITOLD specified in the input data will override the value read from the old tape.

The new materials from this job will be added onto the end of the old PHROG library tape in the sequence they are being processed. For this case (B2) NITOLD materials are first copied onto the new PHROG tape by sequential calls to SR. PCOP from SR. FRGOUT. The titles of the materials copied are printed in the FTOP 14 output listing in the sequence they are copied. IPHRPL is NITOLD + 1 and is the sequence number of the first new material to be added on after the old materials have been copied. IPHRPL is indexed with each new material added and represents the sequence number of each new material being processed in this job. At the completion of the job NMTOT materials will be present on the new PHROG library tape. NMTOT equals NITOLD old materials plus the number of new materials added. Then NMTOT becomes NITOLD on the new PHROG library tape. Each new material is added to the new PHROG library tape by a call to SR. PHED from SR. FRGOUT.

- B3. One new material is to replace one of the old materials on the old PHROG library tape. The new material must be the first ENDF/B material being processed in this job. Second and succeeding ENDF/B materials in this job will be added onto the end of the last material on the old PHROG library tape. The sequence number of the old material being replaced is PHRPL. SR. FRGOUT copies the old materials from the old PHROG tape up to PHRPL by successive calls to SR. PCOP. The PHRPL material on the old PHROG tape is read past but not copied onto the new PHROG tape in its place. SR. FRGOUT then copies old materials from ICURPO to NITOLD by sequentially calling SR. PCOP where ICURPO was the last material copied plus one which is PHRPL + 1. IPHRPL is

now NITOLD + 1 for the second new material being processed in this job which will be added onto the new PHROG tape after the NITOLD material from the old PHROG tape. NMTOT for the new PHROG tape will be one less than NITOLD plus the number of new materials processed during this job. NITOLD on the new PHROG tape will become NMTOT.

- B4. If ISPRF = 1 in the input data, the new material will not be placed on the new PHROG library tape. SR. ETOP 80 will be bypassed. The new material will be processed by ETOP 14 up to SR. ETOP 80 for information only. With this flag, only one run per job is permitted. There will be no old or new PHROG library tape; just data on the ETOP 14 output listing.
- B5. If ISPECA = 1 and the new fission spectrum is to be added to a new PHROG tape onto the end of the fission spectra from the old PHROG tape, SR. PHEDIT is called to copy the old fission spectra and any old materials desired. The EDIT cards (see 51. Input data) must be included to accomplish this in SR. PHEDIT even though this is not strictly an EDIT run. The fission spectrum option functions through the EDIT subroutines (PHEDIT).

For a normal ETOP 14 run adding a new material onto a new PHROG tape, SR. FRGOUT copies old fission spectra and old materials to the new PHROG tape by calls to SR. PCOP. A new fission spectrum is added to a new PHROG tape in SR. PHEDIT. SR. PHEDIT requires the Edit cards (51. in Input description) to also copy any old fission spectra and/or old materials.

NMTOT is always required input for the first material if a new PHROG library tape is to be produced. NMTOT is inserted on the new PHROG library tape as NITOLD on the title card of the new tape. If several stacked runs are being processed and a program stop occurs on any one run, NITOLD on the new PHROG library tape will be screwed up. When this tape is accessed at a later date NITOLD will be incorrect. Therefore, NITOLD is an optional input flag to override the incorrect value on a PHROG library tape. NITOLD must be correct if the proper number of materials are to be copied from the old PHROG library tape to the new PHROG library tape; otherwise everything

gets screwed up in SR. FRGOUT. If NITOLD is correct on the old PHROG library tape, it need not be entered with the input data unless an EDIT RUN is being requested. NITOLD must always be input for edit jobs because it is a DO LOOP limit in SR. PHEDIT.

For each new ENDF/B material to be added to the new PHROG library tape, SR. FRGOUT reads all cross section data from temporary storage locations into the array A (LTOT). LTOT is the total number of words of multigroup cross section data for the PHROG library tape. The A array contains all absorption and fission cross sections and all elastic, inelastic and N2N scattering matrices. Resonance parameters are read directly from temporary storage locations onto the PHROG library tape.

The addition of the P_1 inelastic and n-2n scattering matrices from the DAO algorithm required the following modification of flags for the PHROG library format depending on the NON1 flag set in SR. ETOP 50.

NON1 = 1, 3

LOL(1) = -LOL(1)

A P_1 inelastic matrix is present and it follows the P_0 inelastic matrix in the array A (LTOT). The length of the P_0 and P_1 inelastic matrices is |LOL(1)|.

NON1 = 2, 3

LOL(2) = -LOL(2)

A P_1 n-2n matrix is present and it follows the P_0 n-2n matrix in the array A (LTOT). The length of the P_0 and P_1 n-2n matrix is |LOL(2)|.

Thus, a negative sign for LOL(1) or LOL(2) in the PHROG library indicates to PHROG the presence of a P_1 non-elastic scattering matrix following the P_0 matrix. The length of the P_1 matrix and the number of groups downscatter are the same as for the P_0 matrix. A positive number for LOL(1) or LOL(2) indicates the absence of either P_1 matrix. SR. FRGOUT sets the sign for the LOL array depending on the NON1 flag.

DESCRIPTION OF PHROG CROSS SECTION LIBRARY FORMAT

The data on the PHROG library consists of alphanumeric, integer, and floating point records. The alphanumeric records are used for identification

purposes, the integer data for the most part indicate the number and types of records to be read, and the floating point records make up the actual cross section data.

The initial data records on the tape are used for identification and to indicate the number of materials and fission spectra in the library. Subsequent records describe the cross section data, with similar types of data records being repeated for each material until all materials have been described. The materials are always arranged in the library so that the identification numbers are in ascending order. The cross section data records in the library have been condensed as much as feasible to reduce the processing time. Therefore, the length and number of data records present for a particular material depend on the amount of data required to describe the pertinent cross sections. The minimum number of records in the library for any material is two and the maximum is four.

A detailed description of the arrangement of the data within the library, including the mnemonic names and meanings of the data in the order of their occurrence in the library is found below.

<u>Location in Library</u>	<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
First Record	TAPID(I) (I=1,2)	Alphanumeric title of library (date produced by ETOP)
	AIDT(I) (I=1,10)	Alphanumeric descriptive title of library
	NITL	Number of materials of library
	NFS	Number of source or fission spectra in library

The source or fission spectra records are placed in the library as shown below and are repeated for NFS spectra. The variable MAXG equals 68 for the standard PHROG library, but may be different for libraries created by ETOP for other codes.

Second thru NFS+1 Records	FSN(I) (I=1,18)	Alphanumeric title associated with source spectra
	AFSS(I) (I=1,MAXG)	Fine group values of the source or fission spectra

The cross section data records for each material are arranged as shown below and are repeated for each material.

First Data Record for Material K

<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
BCDW(I) (I=1,19)	Alphanumeric title describing material
NIDAR(1)	The PHROG tape identification number, IDFROG
NIDAR(2)	The atomic number
NIDAR(3)	The atomic weight
NIDAR(4)	The ENDF/B material number
NIDAR(5)	The ENDF/B tape number
NIDAR(6)	The ENDF/B version number
NIDAR(7)	The ETOP version number
NIDAR(8)	Version number of the PHROG library
LTOT	Integer indicating the total number of words of data contained in the cross section vector ADUM
IWA	Absorption reaction flag If IWA=1, absorption cross sections are present.
IWF	Fission reaction flag If IWF=1, fission cross sections and the values of the average number of neutrons per fission are present. (If IWA=0, IWF is ignored.)
IWS	0 => No elastic scattering transfer matrices 1 => Regular elastic scattering transfer matrix is complete (It includes s-wave resolved resonance contribution.) There is no background scattering matrix. 2 => A background elastic scattering matrix is present but it is incomplete. (It does not include the s wave resolved resonance contribution and does not include any unresolved resonance contribution below, in energy, the lower bound of group KGTR0P, the isotropic range limit. 3 => A background elastic scattering matrix is present corresponding to IWS=2. In addition; a difference scattering matrix is present consisting of the difference between the IWS=1 matrix and the IWS=2 matrix over the resonance range. The difference matrix represents all contributions missing from the IWS=2 matrix.

Mnemonic
Name

Description or Function of Data

	<p>4 = A complete elastic scattering transfer matrix will be present. It will be complete (it will contain all contributions to the scattering cross section) but it will be approximate, since it will be calculated for ENDF/B materials which do not contain any secondary elastic angular data. The assumption will have been made that the scattering is isotropic at all energies.</p>
IWR	<p>Resonance parameter data flag</p> <p>If IWR=0, no resonance parameter data are present.</p> <p>If IWR=1, resolved data and GAMI format unresolved data are present.</p> <p>If IWR=2, only resolved data are present and the unresolved calculation will be skipped.</p> <p>If IWR=3, resolved data and ENDF/B unresolved data are present.</p>
KGTR0P	<p>If the isotropic range upper limit is greater than the highest resonance range upper limit, then KGTR0P is the number of the group whose lower boundary in energy is the upper limit of the isotropic scattering range. If not, KGTR0P is equal to one less than the group number of the group containing the highest resonance range upper limit (See INPUT DATA).</p>
LOL(L)	<p>Number of cross section values in list L</p> <p>L=1 => inelastic transfer cross sections</p> <p>L=2 => N,2N transfer cross sections</p> <p>L=3 => P_0 and P_1 elastic transfer cross sections for the regular scattering matrix</p> <p>L=4 => P_2 and P_3 elastic transfer cross sections for the regular scattering matrix</p> <p>NOTE: LOL(1) or LOL(2) negative implies P_1 inelastic or P_1 N2N matrices are also present in addition to P_0 matrices. P_1 matrix in either case follows directly behind the P_0 matrix. The length of either matrix is LOL(1) or LOL(2) . LA and LD vectors apply to both P_0 and P_1 matrix in both cases.</p>

<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
LA(L)	Number of fine groups scattered from in list L starting with the first fine group, i.e., number of the lowest fine group for which scattering reaction of type L is present.
LD(L)	Maximum number of fine groups scattered to in list L, i.e., the maximum number of groups downscattered (this value is constant for all groups in which a scattering reaction is tabulated for a particular material).
(L=1,4)	

Second Data Record for Material K

<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
ADUM(I) (I=1,LTOT)	<p>Vector containing the complete set of microscopic cross sections and values of neutrons produced per fission for material K. All scattering matrices are in this vector.</p> <p>The cross section values, if present, are contained in the vector in the following order:</p> <ol style="list-style-type: none"> 1. If $IWA \geq 1$, the first MAXG (the number of groups used) values are the absorption cross sections starting with group 1. 2. If $IWA \geq 1$, and IWF 1, the next MAXG values are the fission cross sections followed by MAXG values of neutrons produced per fission. 3. If $LOL(1) \geq 1$, the next $LOL(1)$ values are the P_0 inelastic cross sections for transfer from group I to group J. The list starts with I=1 and contains the values for J ranging from 1 to LD(1)+1. Then the values for I=2 with J ranging from 2 to LD(1)+2 are next, etc. until I=LA(1). <p>There are LD(1)+1 values listed for each I, as long as $LD(1)+I \leq MAXG+1$. When $LD(1)+I > MAXG+1$ then only $MAXG+2-I$ values are listed for I.</p> <ol style="list-style-type: none"> 4. If $LOL(1) < 0$ (negative), the next $LOL(1)$ values are the P_1 inelastic cross sections for transfer from group I to group J. The structure of this list is identical to 3. 5. If $LOL(2) \geq 1$, the next $LOL(2)$ values are the $P_0, N, 2N$ cross sections for transfer from group I to group J. The list is ordered as above for the inelastic data.

Mnemonic
Name

Description or Function of Data

6. If $LOL(2) < 0$ (negative), the next $|LOL(2)|$ values are the $P_1, N, 2N$ cross sections for transfer from group I to group J. The structure of this list is identical to 5.
7. If $LOL(3) > 1$, the next $LOL(3)$ values are the isotropic elastic scattering cross sections for transfer from group I to group J followed by the same number of values for the linearly anisotropic component of the elastic scattering cross sections from group I to group J. If $IWS=3$, this is background scattering matrix.
8. If $LOL(4) > 1$, the next $LOL(4)$ values are the P_2 components of the elastic scattering cross sections for transfer from group I to J followed by the P_3 components from group I to group J. If $IWS=3$, this is the background scattering matrix.
9. If $IWS=3$, the next $LOL(3)$ values are the P_0 difference scattering matrix containing only resonance range s-wave contributions at infinite dilution. The structure of this list is identical to 7. This list is followed by $LOL(3)$ P_1 matrix elements.
10. If $IWS=3$, the next $LOL(4)$ values are the P_2 difference matrix elements. The structure of this list is identical to 8. This list is followed by $LOL(4)$ P_3 matrix elements.

Third Data Record for Material K

This record is present only if resolved resonance data are present for material K, i.e., if $IWR \neq 0$.

Mnemonic
Name

Description or Function of Data

NRR	Number of energy levels for which resolved resonance data are given
ECUT	The lower energy limit for the resolved resonance calculation (eV)
EHIR	The upper energy limit for the resolved resonance calculation (eV)
AZERO	The atomic mass number of the material

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<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
SIGPZ	Potential scattering cross section, normally equal to $4\pi R^2$, where R is the scattering length ($\times 10^{-12}$ cm)
EZERO(I)	The energy level at which the I th resolved resonance occurs (eV) where EZERO(I)>EZERO(I+1)
GAMN(I)	The neutron width of the I th resolved resonance (eV)
GMGM(I)	The gamma width of the I th resolved resonance (eV)
GFG(I)	The fission width of the I th resolved resonance (eV)
SPIN(I) (I=1,NRR)	Statistical factor g for the I th resolved resonance

Fourth Data Record for Material K

This record is present only if unresolved resonance data are present for material K, i.e., if IWR $\neq$ 0 and IWR $\neq$ 2.

The record consists of a leading integer word (NUR) indicating the length of the unresolved record followed by a vector containing the data. Both forms of this record are described below.

Arrangement of Data in Vector Using ENDF/B Data

<u>Word Position Number</u>	<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
1	NIS	Number of isotopes in material (presently restricted to 1)
2	ZA	Atomic mass number of material
3	ABN	Relative abundance of this isotope in the material (presently restricted to 1.0)
4	LFW	Fission width flag If LFW=0, fission widths are not present. If LFW=1, fission widths are present.
5	ELQU	Lower limit of unresolved range (eV)
6	EHIU	Upper limit of unresolved range (eV)
7	LRF	Format specification flag (LRF=2 implies format for ENDF/B data)
8	SPIU	Nuclear spin factor, I, of the target nucleus

Word Position Number	Mnemonic Name	Description or Function of Data
9	AA	Scattering length in units of 10^{-12} cm
10	NLSU	Number of λ states present
11	AWRI*	Ratio of the mass of this isotope to that of a neutron
12	LU*	Value of λ
13	NJS*	Number of J states for λ state
14	AJ**	Value of J
15	INT**	Specifies interpolation scheme used if energy dependent parameters are present
16	NE**	Number of points at which energies and resonance parameters are given for this λ state and J state
17	AMUX**	Number of degrees of freedom for distribution of additional widths (if any exist)
18	AMUN**	Number of degrees of freedom for distribution of neutron widths
19	AMUG**	Number of degrees of freedom for distribution of gamma widths
20	AMUF**	Number of degrees of freedom for distribution of fission widths
21	E***	The energy value at which the resonance parameters were evaluated if $NE > 1$ (eV)
22	D***	Mean level spacing (eV)
23	GX***	Average gamma width used to account for all competing events (if any exist) other than scattering, capture, and fission (eV)
24	GNO***	Average reduced neutron width (eV)
25	GG***	Average gamma width (eV)
26	GF***	Average fission width (eV)

*Word positions 11 through 26 are repeated NLSU times for each λ state.

**Word positions 14 through 26 are repeated NJS times for each J state.

***Word positions 21 through 26 are repeated NE times for each energy dependent set of parameters for each J state associated with each λ state.

Arrangement of Data in Vector Using Original GAM-1 Unresolved Data

<u>Mnemonic Name</u>	<u>Description or Function of Data</u>
SMAS	Atomic mass number of material
EC	Lower limit of unresolved range (eV)
DLEV	Mean level spacing (eV)
GAMNO	Average reduced neutron width (eV)
GAMGA	Average gamma width (eV)
GAMFS	Average fission width (eV)
ET	Upper limit or resolved range (eV)
GUNR	Statistical factor g
AA	Scattering length in units of 10^{-12} cm

FORTRAN IV STATEMENTS TO READ CROSS SECTION LIBRARY

The following FORTRAN IV statements will read the PHROG cross section library from tape or a direct access device as the data are presently arranged.

```
      MAXG=68
      READ(LIB,TAPID(1),TAPID(2),(AIDT(I),I=1,10),NITL,NFS
100   DO 100 J=1,NFS
      READ(LIB,(FSN(I),I=1,18),(AFSS(I),I=1,MAXG)
      DO 500 J=1,NITL
      READ(LIB)(BCDW(I),I=1,19),
      * (NIDAR(I),I=1,8),LTOT,IWA,IWF,IWS,IWR,KGTROP
      * (LOL(L),LA(L),LD(L),L=1,4)
      READ(LIB)(ADUM(I),I=1,LTOT)
      IF(IWR)500,500,200
200   READ(LIB)NRR,ECUT,EHIR,AZERO,SIGPZ,
      * (EZERO(I),GAMN(I),GMGM(I),GFG(I),SPIN(I),I=1,NRR)
      IF(IWR-2)300,500,400
300   READ(LIB)NUR,SMAS,EC,DLEV,GAMNO,GAMGA,GAMFS,
      * ET,GUNR,AA
      GO TO 500
400   READ(LIB)NUR,(A(I),I=1,NUR)
500   CONTINUE
```

VII. INPUT VARIABLE DEFINITIONS

The input flags which control ETOP are in the Namelist Input in SR. ININ. For most of these variables, the default values are also in SR. ININ. ININ is called from SR. ETOP 10. ETOP 10 is called from SR. MAIN after initial flags have been set.

We have divided the input flags into three classes here distinguished relative to their importance for normal PHROG library production. The first class are normally always required input to produce a new PHROG tape with standard (more or less) options. The second class of flags produce normal PHROG output with special options mostly controlling various aspects of accuracy in the calculations. The third class of flags are normally used only if the new material is not to be added to a PHROG tape. They are options that are used in debugging to save time or are used only to edit an old PHROG tape. Flags in the first class which are always required input for a normal run are preceded by **. Only those flags which will be different from the default values need be input. The flags may be input in any order, one or several to a card, but each flag must be followed by a comma. The material I.D. is given on the first two cards. The third card contains &NLININ beginning in column 2, the last card is &END beginning in column 2. Problems may be stacked if several materials are to be processed in one job.

I. First Class of Flags required usually for normal ETOP runs which result in a new PHROG library.

**1. MATNO (no default), required for fission spectrum run also.

ENDF/B number of material on ENDF/B tape which is to be processed.

**2. IDTAP (default = 0), required for fission spectrum run also.

ENDF/B tape identification number (e.g., 401)

**3. NMTOT (default = 0), required for fission spectrum run also.

Total number of materials which will be on the new PHROG library tape. It should equal the number of materials on the old PHROG tape (input) plus the number materials to be added onto the end of the old library (not including replacements, see flag No. 14). NMTOT is required on the first run of stacked problems and is ignored on subsequent runs. In the event NMTOT is incorrectly specified on an old PHROG tape, see flag No. 15 which overrides the number of materials on the old tape.

4. IWG (Normal default = 3)

Scattering matrix flag for the type of elastic scattering transfer matrix (matrices) to be produced. It corresponds to the PHROG library variable IWS except that the ENDF/B data present may cause ETOP to modify its value before it is output for PHROG. For example, if there were more than one isotope per material or the atomic weight of the material were less than 16.5, no difference scattering matrix would be produced even if IWS=3. The default value is 3. This not reset for stacked runs.

- 1 = Create a complete infinitely dilute scattering matrix. It will include all scattering contributions. There will not be a background scattering matrix produced.
- 2 = Create an incomplete background scattering matrix which will not include s-wave resolved resonance contribution and not include any unresolved resonance contribution below, in energy, the isotropic range limit (SOTROP).
- 3 = Create an incomplete background elastic scattering matrix over the resonance range corresponding to IWG=2. Also create a difference elastic scattering matrix which will be IWG=1 type minus IWG=2 type. Above and below the resonance range, these matrices will be 0.0. In the resonance range these matrices will contain s wave resonance and potential scattering contributions at infinite dilution. PHROG will then decide how to use these matrices.
- 4 = Sets ISCATA = 1, also sets KGTR0P = -1 when KGTR0P is input as 0. IWG=4 is only meant to be used when no angular data for elastic scattering is present in ENDF/B file 4. The more accurate algorithm 1 equations in SR. TRAN are then used for the calculation of the infinitely dilute elastic scattering matrix at all energies. If angular data is present in File 4, the combination of ISCATA = 1 and KGTR0P = -1 can be used to override the angular data and still produce an isotropic in CM scattering matrix; however, this would never be a production run as the data is then misrepresented.

**5. KGTR0P (default = 0)

KGTR0P is the PHROG group number where the first non-isotropic source group of the elastic scattering matrix will be calculated in SR. TRAN. KGTR0P sets SOTROP in SR. ETOP 10.

$SOTROP = EGRP (MAXG1 - KGTR0P)$

$MAXG1 = 69$ for PHROG

$SOTROP =$ lower energy bound of PHROG group KGTR0P

All elastic matrix elements below energy SOTROP are calculated with the special isotropic range equations in TRAN. If angular distributions exist in ENDF/B file 4 below energy SOTROP, they are ignored by TRAN. Problem requestor must make a judicious choice between value of angular distributions in file 4 or value of shielding resonance scattering data (usually in unresolved range) in PHROG. If it is deemed more important to shield the resonance scattering data in PHROG, then KGTR0P is chosen as the first group where the scattering matrix will be unshielded. Energy groups above SOTROP in energy will include all angular data in file 4 in elastic matrix. Groups below SOTROP in energy will ignore angular data in file 4 but will permit shielding of resonance scattering data by PHROG in these groups if IWG = 2 or 3. KGTR0P flag forces problem requestor to examine ENDF/B files 2 and 4 before running a problem. If no resonance data is present in a material .or. material has several isotopes (infinite dilute scatter matrix will be produced) .or. IWG = 1 or 4 .or. you just do not give a damn .and. you are willing to let SR. TRAN choose the isotropic range limit based on data in file 4: Set KGTR0P = 68. SOTROP will then be .414 eV and SR. TRAN will do the rest. Do not set KGTR0P = -1 as in previous versions of ETOP, SOTROP is then a random number.

****6. IDFR0G (default = 0)**

The PHROG identification number to be placed on the PHROG library for this material. If omitted, a number equal to the identification number of the previous material plus one will be generated. Present maximum value for IDFR0G = 2000.

7. IRFAS0 (default = 0)

The number of ENDF/B card images to be read without checking before starting the search for the requested material. This option allows a reduction in the amount time required to read the ENDF/B tape.

Second Class of Input Required For Special Control of ETOP Producing Normal Output for PHROG

8. NDFB (default = 11)

Logical unit on which the ENDF/B tape is mounted. If two or more problems are stacked and both use different ENDF/B tapes, the first will mount tape on unit 11 if NDFB is not specified. NDFB must be specified as different than 11 for the second problem.

9. ISPEC (default = 0)

0 = no fission spectrum calculation

1 = fission spectrum calculation. If a fission spectrum library is requested, this requires a separate pass by ETOP. No other data is calculated for PHROG library. If fission spectrum is to be added to the new PHROG library, set ISPECA = 1.

10. ISPECA (default = 0)

0 = Do not add a fission spectrum to the PHROG library.

1 = One fission spectrum will be added to the PHROG library. (ISPEC=1 is also required before ISPECA is applicable, so that ETOP will generate the spectrum.) If ISPECA=1, no stacking of runs is allowed. The input required following the &NLININ namelist input are the edit cards followed by a fission spectrum title card which uses columns 1-72. ISPECA=1 is required for any edit runs if fission spectra are to be copied from old PHROG tape. If none are to be copied, ICOPFS(I)=0. See 51 (edit cards) and ISPECA=0.

If ISPEC=1 and ISPECA=0, set ISPRF=1 to skip PHROG library routines completely. If ISPEC=1 and ISPECA=1, set IPRF=0 and include edit cards (51) to copy old fission spectra and any old materials one desires to be copied onto the new PHROG tape. ISPECA=1 always requires complete set of edit cards (51) and title card for new fission spectrum.

11. ICRECT (default = 0), 52 CRECT cards also required.

1 = Call SR. CRECT to make corrections to the ENDF/B data tape during the execution of this problem. See 52 for details. SR. CRECT is called from SR. ININ. The CRECT cards normally directly follow the &END card of the NLININ input. CRECT card formats are normally taken from BNL correction tape listings. Also see sample problems.

2 = Same as 1 except ETOP stops after making corrections to the ENDF/B tape. A new corrected ENDF/B tape is generated for future use. If ICRECT = 1 or 2, the tape containing the corrected ENDF/B data must be mounted and must be an EBCDIC tape and MODE must = 3 (normal default). Also see 52.

12. IPTIT (normal default = 1)

1 = There is an old PHROG tape on unit 13 to be updated.

2 = There is not an old PHROG tape on unit 13 to be updated and the new PHROG tape will contain no old materials. Dummy unit 13, no old fission spectra or materials will be copied.

IPTIT is initialized to 1 on the first run of stacked runs only, otherwise it retains the value from previous runs.

13. IENDFV (default = Version No. of ENDF/B tape)

The version number of the ENDF/B material being processed. It is needed only if the hundreds place of the ENDF/B tape number does not represent the version number.

14. PHRPL (default = 0.0)

PHRPL is the sequence number of the material on the old PHROG tape to be replaced by this ETOP run. If PHRPL = 0.0 or if PHRPL is such that the position of the desired material to be replaced has been passed (which would necessitate a rewind), the new material is added onto the end of the new tape. Also see 3 NMTOT.

NOTE: Only one material may be replaced on the old PHROG tape for each stacked job and it must be the first run on a stacked job. Other runs on a stacked job must be added onto the end of the old PHROG tape. For a job with a single replacement, NMTOT = NITOLD. Otherwise it is NITOLD + the number of additional materials beyond the replacement run.

15. NITOLD (default = NITOLD on old PHROG tape)

NITOLD is required for a fission spectrum run. NITOLD is the number of materials on the old PHROG library tape. This value is also necessary if the number of materials listed on the PHROG library input is incorrect. NITOLD will then override this incorrect value and the new PHROG tape will contain the correct number of materials from the old PHROG tape. Also see 3 NMTOT. Also always required on edit runs, see (51) edit cards.

16. IELAS (default = 2)

IELAS controls SR. TRAN.

1 = Elastic scattering matrix above energy SOTROP (KGTROP) will be calculated by the ETOG algorithm (GRID, DINT, SINT)

2 = Elastic scattering matrix above energy SOTROP (KGTROP) will be calculated by the Direct Angular Overlay Algorithm in TRAN (OUTER, GRIN, INNER, etc.)

17. IEPNTS (default = 100)

IEPNTS is the total number of energy mesh points in the source group for the outer integral in SR. OUTER. IEPNTS are used for both elastic (IELAS=2) and non-elastic matrices. Also see 19, IOUTS if IELAS=2.

18. JMUPTS (default = 60)

JMUPTS is the number of Beta ($\cos \theta$) mesh points for the inner integral in SR. INNER. JMUPTS are used for both elastic (IELAS=2) and non-elastic matrices.

19. IOUTS (default = 60)

IOUTS is the number of energy mesh points assigned to the outscatter portion of the outer integral in SR. GRIN for the elastic matrix if IELAS = 2.

IEPNTS - IOUTS mesh points are assigned to the ingroup portion of the source group. Not used for non-elastic calculation by SR. GRIN.

20. IGAUSS (default = 10)

IGAUSS = 0 means use trapezoidal integration in SR. INNER for DAO algorithm. IGAUSS = 5, 10, 16 means use 5, 10, 16 Gauss points in each outscatter group in SR. INNER. IGAUSS set to other than 0, 5, 10, 16 will cause program stop in SR. INNER. IEPNTS, JUMPTS and IOUTS are also required for Gauss quadrature integration.

21. MESHFV (default = 1 unless LF = 1, then default = 5)

The continuum (MT=91, MT=16) portion of the non-elastic matrix is controlled by SR. ETOP 50. ETOP 50 calls SR. IMAT to calculate the downscatter elements for (LF=1 or LF=9) the secondary neutrons. MESHFV is the number of mesh points used in the source group for the outer integral in IMAT. For important non-elastic scatterers MESHFV should be at least 5.

22. UMESHL (default = 64.0)

UMESHL is number of mesh points for the inner integral (outscatter groups) for outscatter groups below 10.0 groups downscatter. See 21, MESHFV.

23. UMESHH (default = 32.0)

UMESHH is the number of mesh points for the inner integral (outscatter groups) for outscatter groups above 10.0 groups downscatter. See 22, UMESHL.

24. LF1INE (default = 2)

LF1INE is the interpolation scheme to be used for the MESHFV points of the source group in SR. IMAT. See 21, MESHFV.

25. LF1INP (default = 2)

LF1INP is the interpolation scheme to be used for the inner integral to sink groups in SR. IMAT.

For LF = 1 (tabulated secondaries in file 5)

SR. IMAT is presently restricted to a single interpolation scheme for the source and sink groups. LF1INE and LF1INP determine what this interpolation scheme will be.

26. EPSMIN (default = .0001)
Minimum value of EPS for combining two TAB1 functions using SR. COMB.
27. EPSMAX (default = .065)
Maximum value of EPS for combining two TAB1 functions using SR. COMB.
28. SIGP (default = 10.0E + 06, infinite dilution)
Moderator potential scattering cross section per absorber atom for use by ETOP in the unresolved resonance range when: Unresolved data is present for this material but no resonance parameter library is produced by PHROG because e.g., (IWG=1, .or. there is more than one isotope per material, complete matrix is produced). In these cases the user has the option of shielding the cross sections produced from the unresolved range if desired. Used in SR. RESU.
29. SHIELR (default = 1.0)
Old flag for shielding resolved resonances (not used now)
30. IRES (default = 0)
0 = construct resonance parameter cards if possible (one isotope per material)
3 = Calculate equivalent smooth data for all resonance parameters.
IRES = 3 sets IWG = 1 internally.
31. IREW (default = 0)
0 = ENDF/B tape is not rewound by the program.
1 = ENDF/B tape is rewound by the program.
Materials must be listed in order of ENDF/B tape on stacked runs to avoid rewinding ENDF/B tape.
32. IW (default = 1)
1 = Weighting function is 1/E all groups.
2 = Weighting function is 1.0 all groups.
3 = Weighting function is input.
4 = Weighting function is 1/E joined to a ^{235}U fission spectrum at lower bound of PHROG group 20.
53 also required for IW = 3.

III. Special Class of Input Data Which Produces a Non-Standard PHROG Library Which is a No-No Library Or No Library at All (Used for Debugging, To Save Time or Special Edits)

In general one would never add a material using these options to an existing PHROG library unless you think you know what you are doing (doubtful).

33. MAXG (default = 68)

MAXG is the total number of groups for this calculation (maximum is 99 for ETOP). ETOP will produce data for other than the PHROG group structure. However, the type of multigroup data will be PHROG type data. All options to produce MUFT, GAM1, GAM2, ANISN type format data have been more or less disabled in ETOP 14. PHROG type data for other than 68 groups or 68 groups with different energy boundaries can be produced but it should never be added to an existing PHROG library. If this should be attempted, the central processor of the IBM-360 will delete the problem requestor's name from the payroll. Also see 34, IEU.

34. IEU (default = 1)

1 = standard GAM-1 group structure

2 = standard GAM-2 group structure

4 = standard MUFT-4 group structure

6 = Input energy group structure

7 = Input lethargy group structure

See 54 for 6 or 7. Also see 33, MAXG.

35. MODE (first default = 3, reset to 2)

1 ENDF/B tape is binary mode (standard arrangement)

3 ENDF/B tape is BCD mode (standard arrangement)

36. IPRF (default = 0)

0 = Normal ETOP processing is to be done.

1 = The run is to be an editing or copying of the PHROG library. A set of edit cards will be read in following the &NLININ namelist input, (or after the ENDF/B card input if NDFB=5).

See 51, Edit Cards

37. ISPFR (default = 0)

0 = Generate a new PHROG library.

1 = Skip PHROG library output routines.

38. ISCATA (default = 0)

1 = Produce an approximate complete elastic scattering transfer matrix if the ENDF/B material contains elastic scattering data but no secondary elastic angular distributions. The assumption that the scattering is isotropic will be made. If the above conditions hold, the PHROG library variable IWS will be set equal to 4.

Also see 4, IWG.

39. IF30NL (default = 0)

1 = Process ENDF/B File 3 only. (This sets ISPUNR, ISPEL, ISPINL, and ISPN2N equal to 1)

40. ISPOT1 (default = 0)

1 = Skip the weighting function and multigroup structure printout.

2 = Stop after file 2 calculations.

3 = Stop after file 3 calculations.

41. ISPRES (default = 0)

1 = Skip the resolved resonance calculations.

ISPRES = 1 not allowed if ISPEL = 0.

42. ISPUNR (default = 0)

1 = Skip the unresolved resonance calculations.

ISPUNR = 1 not allowed if ISPEL = 0.

43. ISPEL (default = 0)

1 = Skip the elastic matrix calculations.

(This sets NOXS = 2 in SR. CROS)

44. ISPINL (default = 0)

1 = Skip the inelastic matrix calculations.

(This sets NOXIN = 2 in SR. CROS)

45. ISPN2N (default = 0)

1 = Skip the N2N matrix calculations.

(This sets NON2N = 2 in SR. CROS)

46. ISPFL3 (default = 0)

1 = Skip all smooth cross section calculations in File 3 except elastic, inelastic, and N2N.

N = Skip the smooth cross section calculations in File 3 for reaction type (N(N = MT number of reaction, $N \neq 2, 4, 6-9, 16, 46-49, 51-91$, these reactions are covered by other flags above).

NOTE: ISPFL3 flag sometimes reacts unfavorably with other flags above. ISPFL3 = 1 or 18 cannot be used in conjunction with ISPUNR = 1. This produces a stop in SR. CROS for MT = 18 when NU value is to be transferred from DENS storage. NU values are not in DENS with this combination of flags.

47. IPRTLX (default = 0)

1 = Print the inelastic partial matrix for each level and each continuum distribution. These prints all occur before renormalization of the matrix. SR.'s TRIN and ETOP 50 must first be changed in following way. Redimension PMXSV to 4950 and set IPRTLX = 1. Recompile and obtain a new Load Module. In JCL increase XREG by 20K and execute on the new load module. This option was set up this way because it was anticipated that it would be used only occasionally.

48. ICOPY (default = 1)

0 = Do not copy either new or edited old PHROG material onto new PHROG tape in SR. PHED.

1 = Edited (new or old) material will be written on new PHROG tape. If no new PHROG tape is to be generated on either a standard run or an Edit run set ICOPY = 0. Also see 51. If ISPFR = 1, ICOPY not needed.

49. IDOP23 (default = 0)

1 = Place P2 and P3 elastic scattering transfer data on PHROG library. This should not be used until PHROG can handle such data.

0 = No P2 and P3 data is present.

ETOP 14 will not presently execute this option without modification. The P2 and P3 elastic matrices have been wiped out on tape ITPR in SR. OUT5 by the P1 non-elastic matrices. A new tape will

have to be incorporated for the P1 non-elastic matrices before the P2 and P3 elastic matrices can be placed on PHROG tape. This modification involves SR.'s OUT5, FRGOUT, and PHED.

50. NTTL (default = 0) additional title cards

N = Number of cards of additional title card information other than standard PHROG Titles. This set of cards is additional title information to be listed with the program input data in a normal ETOP run. The additional cards follow the &END card of the &NLININ input. Information is written in Cols. 1-80. These cards are read in SR. ININ, label 9003.

51. Additional Edit Cards if IPRF = 1 for EDIT run or if ISPECA = 1 and IPRF = 0.

The following three cards allow the user to produce edited listings of selected PHROG library materials and to copy selected materials from an old PHROG library to a new PHROG library. They follow the &END namelist input cards. A 1 denotes yes; a 0 denotes no. The I indicates the sequence number of the spectra or material. These cards are read in SR. PHEDIT. All 3 sets of cards are required if any single option is chosen. Present limit of sequence number storage in SR. PHEDIT is 1000 for IPRFA and ICOPA cards.
Edit Cards (Format [8011])

Card No.	Name	Description
Card No. 1	ICOPFS(I) I=1,80	Fission spectra to be copied. Requires ISPECA = 1 only if fission spectra are to be copied.
Card No. 2 (Series of cards, as needed)	NPRFA(I), I=1,NITOLD	Materials to be printed. (NITOLD is the number of materials on the old PHROG library.) NITOLD is always required input even if option is not used.
Card No. 3 (Series of cards, as needed)	ICOPA(I), I=1,NITOLD	Materials to be copied. NITOLD is required input even if option is not used. NMTOT also required input for the new PHROG tape. I equals the sequence number of the material on the PHROG library. IDFROG is not used.
Card No. 4	72 COL	Title for new fission spectrum if ISPECA = 1.

If IPRFA(I) materials are to be printed in SR. PHED but none are to be copied to a new PHROG tape, then ICOPY (48) = 0 is required also.

All options above require ICOPY = 1 if new PHROG tape title is to be generated.

NOTE: NITOLD always required if IPRF = 1. NMTOT required for copied materials on new PHROG tape only if ICOPA option is used. Save tape required on Unit FT14 in JCL.

SR. PHEDIT is the mode used to copy a new fission spectra onto a new PHROG tape. Therefore, all Edit cards under 51 above are required to copy old fission spectra and any old materials from the old PHROG tape. Card 4 is also required for the title of the new fission spectrum. The new fission spectrum (only 1 per job) is added onto the end of the old fission spectra copied when ISPECA = 1. NITOLD and NMTOT are also required input data if old materials are to be copied when a new fission spectrum is added.

52. CRECT Cards if ICRECT = 1 or 2

The CRECT cards for the ENDF/B tape follow the &END card of the &NLININ list. As many cards as needed are stacked in the sequence order of the data to be corrected on the ENDF/B tape. Also see 11, ICRECT. CRECT cards are normally taken from a BNL correction tape. Format for CRECT cards is described (reference 6) CRECT card stack begins with a title card for ETOP (see sample problem No. 3). SR. CRECT called from SR. ININ.

ICRECT = 1, Scratch tape required on Unit FT 22

ICRECT = 2, Save tape required on Unit FT 22

53. Card No. 1 (optional)

This is actually a card set and is necessary only if IW=3. The set consists of the desired weighting function as tabulated points plus the interpolation tables defining the interpolation scheme to be used with the tabulated points. The weighting function must be given from low to high in energy. The format of the card set is a standard ENDF/B TAB1 record.

Card 1.1 (44X, 2111)

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	<u>Description</u>
1	45-55	N1	Number of interpolation ranges.
2	56-66	N2	Number of weighting function points.

Card 1.2 (6I11)

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	<u>Description</u>
1	1-11	NBT(1)	Last point number in 1st interpolation range.
2	12-22	JNT(1)	ENDF/B interpolation scheme for 1st range
3	23-33	NBT(2)	Last point number in 2nd interpolation range.
4	34-44	JNT(2)	ENDF/B interpolation scheme for 2nd range.
etc.			
2*N1-1		NBT(N1)	Last point number in N1 interpolation range.
2*N1		JNT(N1)	ENDF/B interpolation scheme for the N1 range.

Card 1.3 (6E11.4)

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	<u>Description</u>
1	1-11	BLOK3(1)	First energy point ($\leq$ lowest energy in group structure.)
2	12-22	BLOK4(1)	Weight at this energy
.			
etc. using N2/6 cards			
.			
2*N2-1		BLOK3(N2)	Last energy point ($\leq$ highest energy in group structure.
2*N2		BLOK4(N2)	Weight at this energy.

54. Card No. 2 (optional)

This is actually a card set and is necessary only if IEU = 6, or 7. The set consists of the desired group structure. If IEU = 6, the set is the energy breakpoints of the structure given from low to high in energy. If IEU = 7, the set is the lethargy breakpoints of the structure given from high to low in lethargy.

Card No. 2.1 (6(E11.4))

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	<u>Description</u>
1	1-11	XX(1)	Group breakpoint number 1.
2	12-22	XX(2)	Group breakpoint number 2.
.			
.			
.			
etc. using (MAXG+1)/6 cards			
.			
.			
MAXG		XX(MAXG)	Group breakpoint number MAXG.
MAXG1		XX(MAXG+1)	Group breakpoint number MAXG+1.

NOTE: If IEU = 6, XX is denoted as EGRP; if IEU = 7,
XX is denoted as UGRP.

2387- Sample Problem
(See Appendix E)

FIELD 1											FIELD 2											FIELD 3											FIELD 4											FIELD 5											FIELD 6											MAT		MF		MT		SEQ. NO.							
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<p>(Sample input - Debug Run. Skip all library output routines, Dummy units 13 and 14. No old Phog tape on unit 13. No new Phog tape on unit 14 Process material to S.R. ETAP 80 and stop.)</p> <p>Time 10 min.</p>																																																																															

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133

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APPENDIX A

ENERGETICS OF NON-ELASTIC SCATTERING

Reference 1 gives the formats for ENDF/B angular distributions of elastic and non-elastic scattered neutrons as a set of normalized probability distributions in the CM or LAB system of coordinates. The basic equations for generating the corresponding scattering matrices are based on the definition of the differential scattering cross section:

$$\sigma(\mu, E) = 2\pi \frac{d\sigma(\Omega, E)}{d\Omega} \quad (A1)$$

$$p(\mu, E) = \frac{\sigma(\mu, E)}{\sigma(E)} = \frac{2\pi}{\sigma(E)} \frac{d\sigma(\Omega, E)}{d\Omega} = \sum_{\ell'=0}^{NL} \frac{2\ell'+1}{2} f_{\ell'}(E) P_{\ell'}(\mu) \quad (A2)$$

and

μ = cosine of scattering angle in either CM or LAB coordinates.

E is the corresponding energy

$\sigma(E)$ is the total scattering cross section for elastic or inelastic scattering

$\sigma(\Omega, E)$ is the differential scattering function.

$f_{\ell'}(E)$ are the angular expansion coefficients at energy E

$P_{\ell'}(\mu)$ are ordinary Legendre polynomials.

Equation (A2) implies that the scattered neutrons possess azimuthal symmetry, i.e., the differential cross section is a function of the polar angle θ only. Such is the case for both elastic and inelastic scattering of neutrons. In the case of inelastic scattering, the ENDF/B formats

require the angular distribution data $f_{\ell}(E)$ to be given in the LAB coordinate system. Elastic scattering gives rise to a considerable simplification for data manipulation since elastic scattered neutron data may be given in either the CM or LAB coordinate system and is always accompanied by a transformation matrix in file 4.

$$f_{\ell}^{\text{CM}}(E) = \sum_{m=0}^{NM} U_{\ell m}^{-1} f_m^{\text{LAB}}(E) \quad (\text{A3})$$

The elastic scattering transformation matrix $U_{\ell m}$ is independent of the incident energy of the neutron and is a function only of the target mass A. The inelastic scattering transformation from CM to LAB is not energy independent and no single transformation matrix exists. This will be evident as the discussion proceeds.

From this point on we will specialize to inelastic scattering and take the elastic limit of the final equations only. However, there is a one to one correspondence between the two at each step of the development with the exception of Equation (A3). It will be helpful to define a new set of variables immediately since none of the references have a consistent notation between them.

θ_0 = LAB scattering angle of neutron

$\mu_0 = \cos \theta_0$

θ = CM scattering angle

$\mu = \cos \theta$

ϕ = LAB scattering angle of target

E_0 = initial energy of neutron in LAB

E = final energy of neutron in LAB

E_2 = final energy of target in LAB

E_1 = relative total energy of colliding particles in CM

Q = net rest mass defect of colliding particles from initial to final values.

$|Q|$ = level excitation energy of the target nucleus.

A = ratio of target mass to neutron mass.

$f_{\ell'}(E_1)$ = Legendre angular expansion coefficient at CM relative energy E_1

$P_{\ell'}(\mu)$ = Legendre polynomial in CM coordinates

$P_{\ell}(\mu_0)$ = Legendre polynomial in LAB coordinates

ℓ' = CM expansion index

ℓ = LAB expansion index

v' = velocity of neutron in CM system

v_1 = velocity of CM in LAB system

All other velocities correspond to the notation for energy given above.

The singly differential scattering cross section is given in CM coordinates as:

$$\sigma_S(E_1, \mu) = \sigma_S(E_1) \sum_{\ell'=0}^{NL'} \frac{2\ell'+1}{2} f_{\ell'}(E_1) P_{\ell'}(\mu) \quad (A4)$$

where NL' is the highest order of CM expansion coefficient given in ENDF/B file 4 at energy E_1 . Equation (A4) may be equated to the corresponding LAB doubly differential scattering cross section since the same number of events occur in each phase space.

$$\sigma(E_0 \rightarrow E, \mu_0) d\mu_0 \delta[E-E(\mu_0)] = \sigma_S(E_1, \mu) d\mu \delta[E-E(\mu)] \quad (A5)$$

$$\sigma(E_0 \rightarrow E, \mu_0) \delta[E-E(\mu_0)] = \sigma_S(E_1, \mu) \left| \frac{d\mu}{d\mu_0} \right| \delta[E-E(\mu)] \quad (A6)$$

The ℓ^{th} Legendre moment of the LAB scattering cross section is given by:

$$\sigma_{\ell}(E_0 \rightarrow E) = \int_{-1}^1 \sigma(E_0 \rightarrow E, \mu_0) \delta[E-E(\mu_0)] P_{\ell}(\mu_0) d\mu_0 \quad (A7)$$

If Equations (A4) and (A6) are substituted into the rhs of Equation (A7)

$$\sigma_{\ell}(E_0 \rightarrow E) = \sigma_S(E_1) \int_{-1}^1 P_{\ell}(\mu_0) \left| \frac{d\mu}{d\mu_0} \right| \delta[E-E(\mu)]$$

$$\text{times} \sum_{\ell'=0}^{NL} \frac{2\ell'+1}{2} f_{\ell'}(E_1) P_{\ell'}(\mu) d\mu_0 \quad (A8)$$

In the ETOP 14 output listings, the scattering matrix elements are $2\ell+1$ times the Legendre moments. $2\ell+1$ is later divided out.

$$\sigma_{\ell}^{\ell}(E_0 \rightarrow E) = (2\ell+1) \sigma_{\ell}(E_0 \rightarrow E) \quad (A9)$$

Thus, the matrix elements generated by Equation (A8) are each multiplied by $2\ell+1$ in the ETOP 14 subroutines.

Equation (A9), where the rhs is given by Equation (A8) cannot be integrated before the transfer function $\left| \frac{d\mu}{d\mu_0} \right|$ is given. Aside from the magnitude of the Legendre coefficients $f_{\ell'}(E_1)$, the transfer function is the only thing that distinguishes elastic from inelastic scattering in Equation (A8).

The transfer function expresses the nature of the transformation from CM to LAB coordinates as a function of the parameters of the collision. The principal difference between elastic and inelastic collisions is that a portion of the available energy in the CM coordinate system is left in the nucleus to be later emitted in the form of a gamma ray. The Q value is the net rest mass defect of the initial to final state particles. If the Q value is negative, the reaction is defined as endoergic. This is the case for inelastic scattering of neutrons. From a momentum and energy balance before and after collision we can obtain the required equations.

Figure A1. Geometry of CM to LAB Transformation

The velocity of the CM is $v_1 = \frac{v_0}{A+1}$. Let v'' be the velocity of the neutron after collision in the CM system, let v' be the velocity of the target in the CM system after collision. The total energy of the colliding particles after collision is equal to the total energy of the colliding particles before collision minus the excitation energy of the nucleus.

CM energy after = CM energy before + Q .

$$\frac{1}{2}(v'')^2 + \frac{1}{2}A(v')^2 = \frac{1}{2} \left(\frac{A}{A+1} \right)^2 v_0^2 + \frac{1}{2}A \frac{v_0^2}{(A+1)^2} + Q \quad (A10)$$

From momentum conservation,

$$v'' = A v'.$$

$$(v'')^2 \left(1 + \frac{1}{A} \right) = \frac{(v_0)^2}{(A+1)^2} \left(A^2 + A + (A+1)^2 \frac{Q}{E_0} \right) \quad (A11)$$

$$v'' = \frac{v_0}{A+1} \sqrt{\frac{A}{A+1} \left(A(A+1) + (A+1)^2 \frac{Q}{E_0} \right)} = \frac{v_0}{A+1} A \sqrt{1 + \frac{A+1}{A} \frac{Q}{E_0}} \quad (A12)$$

Let γ equal the ratio of the velocity of the center of mass to the velocity of the neutron after collision in CM coordinates given by Equation (A12).

$$\gamma = \frac{v_0}{v''} = \frac{1}{A \sqrt{1 + \frac{A+1}{A} \frac{Q}{E_0}}} \quad (A13)$$

From Figure A1, the LAB velocity of the neutron after collision is given by:

$$v^2 = v^2 + (v'')^2 + 2 v v'' \cos \theta \quad (A14)$$

Solving for $\cos \theta$ from Equation (A14) and using Equations (A12) and (A13), we obtain:

$$\mu = \cos \theta = \frac{\gamma}{2} \left[\frac{E}{E_0} (A+1)^2 - \left(1 + \frac{1}{\gamma^2}\right) \right] \quad (A15)$$

Equation (A15) is the basic relationship relating the energy after collision to the CM scattering angle. In order to use Equation (A8), we require $\frac{d\mu}{d\mu_0}$ which is given by Schiff⁽¹⁸⁾ as:

$$\left| \frac{d\mu}{d\mu_0} \right| = \frac{(1 + \gamma^2 + 2\gamma\mu)^{3/2}}{|1 + \gamma\mu|} \quad (A16)$$

where γ is given by Equation (A13).

The l.h.s. of Equation (A8) will be integrated over initial and final energy in order to generate a multigroup scattering matrix. However, if Equation (A16) is used in Equation (A8), the independent variables will be

μ and μ_0 . This would not be as convenient for an energy integration as expressing the r.h.s. of Equation (A8) in terms of energy. This is most easily accomplished by noting

$$\left| \frac{d\mu}{d\mu_0} \right| d\mu_0 = d\mu \quad (A17)$$

where $d\mu$ is then obtained from Equation (A15).

$$\boxed{d\mu = \frac{\gamma}{2} (A+1)^2 \frac{dE}{E_0}} \quad (A18)$$

Using Equations (A17) and (A18) in Equation (A8), Equation (A9) becomes

$$\sigma^\ell(E_0 \rightarrow E) = (2\ell + 1) \sigma_s(E_1) \int_{E_{\min}}^{E_{\max}} \frac{\gamma}{2} \frac{(A+1)^2}{E_0} P_\ell \left[\mu_0(E_0 \rightarrow E) \right] \delta[E - E(\mu)] \text{ times } \sum_{\ell'=0}^{NL'} \frac{2\ell'+1}{2} f_{\ell'}(E_1) P_{\ell'}(\mu) dE \quad (A19)$$

In Equation (A19), E_1 is the total energy of the colliding particles relative to the center of mass and is given by $E_1 = \frac{A}{A+1} E_0$. Thus, $\sigma_s(E_1)$ and $f_{\ell'}(E_1)$ are really functions of E_0 the initial neutron energy.

The integral in Equation (A19) over the delta function expresses the fact that E and the angle of scattering are correlated. There is only one LAB scattering angle possible for each energy E . The integral over the delta function is elementary and is given by,

$$\int_{-\infty}^{\infty} f(x) \delta(x-a) dx = f(a).$$

Equation (A19) now becomes

$$\sigma^{\ell}(E_0 \rightarrow E) = (2\ell+1) \frac{\gamma(A+1)^2}{4E_0} \sigma_S(E_0) P_{\ell}[\mu_0(E_0 \rightarrow E)]$$

$$\text{times } \sum_{\ell'=0}^{NL'} (2\ell'+1) f_{\ell'}(E_0) P_{\ell'}(\mu) \quad (A20)$$

where γ is given by Equation (A13).

If Q in Equation (A13) is set equal to zero, Equations (A15), (A16) and (A20) reduce to Algorithm 2, the limit for elastic scattering. Equation (A20) is in ETOP 14 for elastic scattering where $\gamma = 1/A$, the elastic limit of Equation (A13). Thus, the inelastic scattering matrix can be obtained from the equations for elastic scattering in ETOP 14 by a simple modification of the elastic scattering integrals where $\sigma_S(E_0)$ becomes the cross section for each inelastic level in conjunction with Equation (A13) and the $f_{\ell'}(E_0)$ are obtained from File 4 for that level.

The Q Equation and the Domains of Integration

A scattering matrix is obtained from Equation (A20) by integration over the PHROG group structure from incident to final energy group.

$$\sigma_{i \rightarrow j}^{\ell} = \frac{\int_j dE \int_i W(E_0) \sigma^{\ell}(E_0 \rightarrow E) dE_0}{\int_i W(E_0) dE_0} \quad (A21)$$

where $W(E_0)$ is a weighting function representative of neutron flux variation in the incident group. $\sigma^{\ell}(E_0 \rightarrow E)$ is given by Equation (A20), $\sigma^{\ell}_{i \rightarrow j}$ is the ℓ order matrix element corresponding to group i to j transfer.

Before the integrals in Equation (A21) can be performed, the appropriate domains of integration for inelastic scattering must be found. Because of the excitation energy of the compound nucleus Q , these domains of integration are entirely different from those for elastic scattering.⁽³⁾ The appropriate domains of integration can be obtained from an equation relating the final energy in LAB coordinates to the incident neutron energy and the angle of scattering in the LAB.

Referring to Figure A1 for the CM to LAB transformation, equate energy and momentum before and after collision in LAB coordinates.

$$\text{Energy } E_0 + Q = E + E_2 \quad (\text{A22})$$

$$\text{X Momentum, } \sqrt{2M_0E_0} = \sqrt{2M_3E} \mu_0 + \sqrt{2M_2E_2} \cos \phi \quad (\text{A23})$$

$$\text{Y Momentum, } \sqrt{2M_3E} \sin \theta_0 - \sqrt{2M_2E_2} \sin \phi = 0 \quad (\text{A24})$$

Square Equation (A23) and add it to the square of Equation (A24)

$$M_0E_0 - 2\sqrt{M_0M_3E_0E} \mu_0 + M_3E = M_2E_2 \quad (\text{A25})$$

Eliminate E_2 from Equations (A22) and (A25)

$$Q = \frac{(M_2 + M_3)}{M_2} E - \frac{(M_2 - M_0)}{M_2} E_0 - 2 \frac{\sqrt{M_0M_3E_0E}}{M_2} \mu_0 \quad (\text{A26})$$

where M_0 = projectile mass before collision
 M_1 = target mass before collision
 M_3 = mass of scattered particle after collision
 M_2 = remaining mass of target after collision

Equation (A26) is called the Q equation.⁽¹⁹⁾ It relates the initial and final masses of the colliding particles in LAB coordinates to the initial and final energies and the LAB scattering angle. It is perfectly general and is applicable to charged particle interactions as well as neutron interactions. For Exoergic reactions Q is positive. For Endoergic reactions such as inelastic scattering, Q is negative and represents the excitation energy of the target nucleus. For inelastic scattering, the target nucleus eventually decays to the ground state emitting a net amount of energy |Q| in the form of gamma rays.

If the terms involving E are isolated in Equation (A26), we obtain

$$E - 2 \frac{\sqrt{M_0 M_3} E_0}{M_2 + M_3} \mu_0 = \frac{M_2 Q + (M_2 - M_0) E_0}{M_2 + M_3} \quad (A27)$$

Complete the square in Equation (A27) and solve for $\sqrt{E}$

$$\left(\sqrt{E} - \frac{\sqrt{M_0 M_3} E_0}{M_2 + M_3} \mu_0 \right)^2 = \frac{M_0 M_3 E_0 \mu_0^2}{(M_2 + M_3)^2} + \frac{M_2 Q + (M_2 - M_0) E_0}{M_2 + M_3}$$

$$\sqrt{E} = \frac{\sqrt{M_0 M_3} E_0}{M_2 + M_3} \mu_0 \pm \sqrt{\frac{M_0 M_3 E_0}{(M_2 + M_3)^2} \mu_0^2 + \frac{M_2 Q + (M_2 - M_0) E_0}{M_2 + M_3}} \quad (A28)$$

If Equation (A28) is now specialized to the case of inelastic scattering of neutrons, $M_3 = M_0$, $M_2/M_0 = A$

$$\sqrt{E} = \frac{\sqrt{E_0}}{A+1} \mu_0 \pm \sqrt{\frac{E_0}{(A+1)^2} \mu_0^2 + \frac{A}{(A+1)} Q + \frac{A-1}{A+1} E_0}$$

(A29)

Equation (A29) is a hyperbola in E_0, E space. It is plotted in Figure A3. E is double valued for the same scattering angle in certain regions. At any given scattering angle θ_0 , the reaction is only possible for the argument of the radical positive. The threshold for a given scattering angle occurs when the radical in Equation (A29) becomes zero. This is the initial energy $(E_0)_c$

$$(E_0)_c = \frac{-AQ(A+1)}{(\mu_0)_c^2 + A^2 - 1} \quad (A30)$$

where Q is negative for Endoergic reactions. $(E_0)_c$ has its minimum possible value for $\theta_0 = 0$. This is the threshold of the reaction.

$$(E_0)_{\text{THRES}} = -\frac{A+1}{A} Q \quad (A31)$$

at the threshold,

$$E = \frac{(E_0)_{\text{THRES}}}{(A+1)^2} \quad (A32)$$

This is not the minimum value for E since the radical can still be zero for $0 \leq \mu_0 \leq 1$ given by Equation (A30). For values of $(E_0)_c$ and $(\mu_0)_c$ satisfying Equation (A30), the final neutron energy is given by

$$E = \frac{(E_0) (\mu_0)_c^2}{(A+1)^2} \quad (A33)$$

Equation (A33) is a straight line separating Domains I and II in Figure A3. Equation (A29) is double valued in Domains I and II. The Single valued domain begins for $\mu_0 = 0$ which is for $\theta_0 = 90^\circ$. The first term on the r.h.s. of Equation (A29) is negative $-1 \leq \mu_0 \leq 0$ and only the

positive sign is possible in Domain III for the radical in Equation (A29). Thus, the threshold for Domain III is for $(E_0)_c$ evaluated at $\mu_0 = 0$.

$$(E_0)_{90} = \frac{-AQ}{A-1} \quad (A34)$$

The extent of the region where doubled valued solutions of Equation (A29) are possible is

$$-\frac{A+1}{A} Q \leq E_0 \leq -\frac{A}{A-1} Q.$$

This is a very narrow region for mass numbers > 100 .

Figure A3 is plotted for $A = 5.82$ and $\alpha = .5$. The double valued region is small and little is lost by ignoring it entirely. Thus, in ETOP 14 we will program the solution to Equation (A21) for Domain III only.

The area to be ignored corresponds to the region where the inelastic scattering cross section is very small anyway.

Figure A2 gives the physical interpretation of the double valued region for Equation (A29). In the double valued region, two energies correspond to a single scattering angle in the lab because v'' is less than the velocity of the CM. At $(E_0)_{90}$, the velocity of the CM is just equal to v'' and the double valued region is no longer possible due to geometry.

Double Valued Region $v'' < v_{cm}$

as long as $v'' < v_{cm}$ there are two ways to form vectors to get same LAB angle .

Single Valued Region $v'' > v_{cm}$

Each LAB scattering angle corresponds to only one final LAB velocity.

Figure A2. Geometry for Double Valued Region of Hyperbola

If the mass becomes infinite then the CM velocity of the neutron before collision is the same as its LAB velocity. The final neutron energy is then given by $E = E_0 + Q$. This line is the upper limit for each hyperbola.

The line $\theta_0 = 90^\circ$ is also a straight line given by

$$E = \frac{A-1}{A+1} E_0 + \frac{A}{A+1} Q \quad (A35)$$

and is plotted in Figure A3.

In Domain III, Equation (A29) takes a very simple form at the two limits $\theta_0 = 0$ and $\theta_0 = 180^\circ$.

$$E = \frac{E_0}{(A+1)^2} \left(\frac{\gamma+1}{\gamma} \right)^2, \quad \theta_0 = 0^\circ \quad (A36)$$

$$E = \frac{E_0}{(A+1)^2} \left(\frac{\gamma-1}{\gamma} \right)^2, \quad \theta_0 = 180^\circ \quad (A37)$$

The elastic integration domain may be obtained directly from Equation (A29) by setting $Q = 0$, which makes all equations for inelastic scattering correspond to those for elastic scattering.

If the PHROG group structure is overlayed on Equation (A29), there are 14 possible cases for outgroup scattering in inelastic scattering. In the elastic limit these 14 cases reduce to 8 possibilities given in Figures 6 and 7.

Equation (A20) in conjunction with Equation (A21) requires evaluation of both $P_{\ell}(\mu_0)$ and $P_{\ell}(\mu)$ as a function of initial and final energy throughout the integration. Equation (A15) relates μ to E , E_0 and γ . A corresponding relationship for μ_0 can be obtained from Equation (A29). Square both sides of Equation (A29)

$$E - \frac{2\sqrt{E_0 E}}{A+1} \mu_0 = \frac{A-1}{A+1} E_0 + \frac{A}{A+1} Q$$

$$\mu_0 = \frac{(A+1)}{2} \sqrt{\frac{E}{E_0}} - \frac{A-1}{2} \sqrt{\frac{E_0}{E}} - \frac{A}{2} \frac{Q}{\sqrt{EE_0}} \quad (A38)$$

The elastic limit is obtained from Equation (A38) by setting $Q = 0$. Equation (A38) gives the cosine of the LAB scattering angle in terms of the incident and final energy of the neutron. In the DAO Algorithm, the inner integral is performed in β phase space where β represents either CM(μ) or LAB(μ_0) coordinates. It becomes necessary then to express μ_0 in terms of μ in the event β represents CM coordinates. This relationship is most easily obtained by integrating Equation (A16).

$$\mu_0 = \frac{\mu + \gamma}{\sqrt{1 + \gamma^2 + 2\gamma\mu}} \quad (A39)$$

Equation (A39) represents the point transformation for β from CM to LAB coordinates. For $Q = 0$, Equation (A39) reduces to the familiar transformation equation for elastic scattering.

$$\mu_0 = \frac{A\mu + 1}{\sqrt{1 + A^2 + 2A\mu}} \quad (A40)$$

Figure A3. Non-elastic Hyperbola

$A = 5.82 \quad \alpha = .5 \quad |Q| = 1 \text{ MEV}$

APPENDIX B
COMMON BLOCKS

<u>/TAPES/</u>	literal tape names and data mode
MODE	mode of the ENDF/B library tape (manipulated in ININ)
I05	input tape (set to "5" in ININ)
I06	output print tape (set to "6" in ININ)
I07	output punch tape (set to "7" in ININ)
NDFB	ENDF/B library tape (default value set to 11 in ININ)
ITP1	scratch tape (set to "8" in ININ)
ITP2	scratch tape (set to "9" in ININ)
ITP3	scratch tape (set to "10" in ININ)
ITP4	scratch tape (set to "12" in ININ)
<u>/TAPUSE/</u>	literal tape names
ITPR	contains resonance scattering data (set equal to ITP2 in ININ)
ITPS	contains smooth scattering data (set equal to ITP3 in ININ)
ITPE	contains elastic (resonance plus smooth) scattering data (set equal to ITP4 in ININ)
<u>/RECS/</u>	single record storage
MAT	material number of ENDF/B record
MF	file number of ENDF/B record
MT	reaction type number of ENDF/B record
C1, C2	floating point constants ENDF/B record
L1, L2	integer constants
N1	count of items in a list to follow
N2	count of items in a second list to follow
NBT(150), JNT(150)	general integer storage space (usually contains interpolation tables)

X(6000), Y(6000)	general floating point storage space (usually contain pointwise data, e.g., energies, cross sections)
N1X	maximum length of the NBT and JNT arrays
N2X	maximum length of the X and Y arrays
NS	card sequence number
<u>/DENS/</u>	multi-record, i.e., dense, storage
JMT(60)	record identifier
JAT(60)	record starting location
JTT(60)	record type
JLT(60)	record length
A(28000)	record bulk storage array (0-14,000)
JNS	starting location in the A array of the next record
MNS	the number of records plus one in the A array
JX	maximum length of the portion of the A array presently accessible with S.R.'s STORE, FETCH, DELETE, etc; Set to 12,000 in ININ. Cannot be greater than 14,000.
MX	maximum length of the JMT, JAT, JTT, and JLT arrays (i.e., no more than this number of records allowed) Set to 50 in ININ.
<u>/BLOCK/</u>	Seg. 3 data storage area used only in overlay three
B(2000)	data bulk storage array
<u>/BLOCKS/</u>	Seg. 5 data storage area used only in overlay five
B(1000)	data bulk storage array
<u>/BLOKS/</u>	record length indicators
LBK12	record length variable (usually the number of data pairs listed in X and Y)
LIBK12	record length variable (usually associated with NBT and JNT)
LBK34	record length variable (usually the number of data pairs listed in B)

LIBK34

record length variable (usually associated with NBT and JNT)

/CONF1/

control information associated with File 1

ZA

material (Z,A) designation

AWR

ratio of the mass of the atom (or molecule) to that of the neutron (carbon-12 system)

LRP

flag that indicates whether resolved and/or unresolved resonance parameter are given in File 2

LFI

flag that indicates whether the material is fissionable

LDD

flag that indicates whether radioactive decay data are given for this material

LFP

flag that indicates whether fission product yield data are given for this material

NWD

a count of the number of elements in the Hollerith section

LNU

flag that indicates what representation of $\bar{\nu}(E)$ has been used (polynomial or tabulated)

NC

a count of the number of terms in the polynomial expansion

C(10)

the coefficients of the polynomial (NC are given)

NR1

number of interpolation ranges used to tabulate the values of $\bar{\nu}(E)$

NP1

number of energy points used to tabulate the values of $\bar{\nu}(E)$

/KONTF2/

NIS

number of isotopes in this material

ZAI(7)

the (Z,A) designation for an isotope

ABN(7)

the abundance (weight fraction) of an isotope in this material

LFW(7)

flag that indicates whether average fission widths are given in the unresolved resonance region for this isotope

NER(7)

number of energy ranges given for this isotope

LISR(7), LISRX	resolved scattering calculation indicators
EL(2,7)	lower limit of an energy range
EH(2,7)	upper limit of an energy range
LRU(2,7)	flag that indicates whether this energy range contains data for resolved or unresolved resonance parameters
LRF(2,7)	flag that indicates which representation has been used for this energy range
LISU(7), LISUX	unresolved scattering calculation indicators
SPIR(7)	nuclear spin of the target nucleus (resolved range)
AP(7)	page 4-5 or formats 7.5
NLSR(7)	number of sets of resonance parameters given in this energy range (resolved range). One set each ℓ -state.
CR(7,3)	penetration factor constant (resolved range)
AM(7)	page 4-5 or formats 7.5
LR(7,3)	value of the ℓ -state (resolved range)
NRS(7,3)	number of resolved resonances for a given ℓ -state
SPIU(7)	the nuclear spin I of the target nucleus (unresolved range)
AA(7)	4-5 or 7.5
NLSU(7)	number of ℓ -states given (unresolved range)
CU(7,3)	penetration factor constant (unresolved range)
NEX(7)	number of energy points in fission width Tabulation 4.5 or 7.12
LU(7,3)	value of the ℓ -state (unresolved range)
NJS(7,3)	number of J-states for an ℓ -state
MUF(7,3,4)	number of degrees of freedom used in the fission width distribution 4-6 or 7.13

ELOR	lowest energy (resolved range)
EHIR	highest energy (resolved range)
ELOU	lowest energy (unresolved range)
EHIU	highest energy (unresolved range)
XPOTR	potential scattering - resolved range
XPOTU	potential scattering - unresolved range
LLRR	resolved data indicator
LLRU	unresolved data indicator
LFWX	fission width data indicator
<u>/CONF3/</u>	control information for File 3
LFS	flag that specifies the final excited state of the residual nucleus produced by a particular reaction
NR3	number of energy ranges that are given, A different interpolation scheme may be given for each range
NP3	total number of energy points used to specify the data
<u>/CONF4/</u>	control information for file 4
LVT	flag that specifies whether a transformation matrix is given for elastic scattering
LTT	flag that specifies the type of representation used (Legendre expansion coefficients or normalized probability distribution)
LCT	flag that specifies the frame of reference used (laboratory or center of mass)
NK4	number of elements in the transformation matrix [$NK4 \leq 441$; $NK4 = (NM4 + 1)^2$]
NM4	the maximum order Legendre polynomial that will be required ($NM4 \leq 20$) to describe the angular distributions of elastic scattering in either the center-of-mass or lab system
NRE4	length of E interpolation table
NE4	number of energy values for which angular distributions are given

NL4 highest order Legendre polynomial that is given at each energy ($NL4 \leq 20$), also number of β points in DAO algorithm

NR4 length of interpolation table for tabular distribution

NP4 number of angular points (cosines) used to give the tabulated probability distributions for each energy ($NP4 \leq 101$)

E4 Energy of angular distribution being read from File 4

/CONF5/

NK number of partial energy distributions. There will be one subsection for each partial distribution.

THETA a parameter used to describe the secondary distribution. The definition depends on the energy distribution law (LF) given; units always eV

LF flag that specifies the energy distribution law that is used for a particular subsection (partial energy distribution)

NE count of the number of incident energy points at which tabulated distributions are given. Also the number of points at which THETA(E) is given.

NR5(20) interpolation table length

NP5(20) the count of the number of incident energy points at which $P_K(E_N)$ is given. See 10.4-10.5, formats manual.

EINIT(20) E values in $g(E' \leftarrow E)$ tabulation

AWATT constant "a" in Watt spectrum

BWATT constant "b" in Watt spectrum

LTHET length of theta array

LITHET length of theta interpolation table

LPP length of P list

LIPP length of P interpolation table

LGG length of $g(E'/\theta)$ list

LIGG length of $g(E'/\theta)$ interpolation table

/IN/

INALL	card input control (ETOG)
MATNO	input control flag (see Section VII)
NATID	
IREW	input control flag
EPSMIN	input control flag
EPSMAX	input control flag
SIGP	input control flag

/MOREIN/

XAJIN	input variable, no longer used
KRES	indicator for resonance parameter or smooth data
NAGDS	old variable, no longer used

/OPTION/

IDTAP	input control flag
MCODE	output library format control
MAXG	input control flag
MAXG1	MAXG plus one
MAXG2	MAXG plus two
MINR	lowest group number in resonance region (ETOG)
MINR1	MINR plus one
MINR2	MINR plus two
MAXI	highest source group for inelastic scattering matrices
MAXI1	MAXI plus one
MAXI2	MAXI plus 2
IW	input control flag
IEU	input control flag
IXSR	control for resonance scattering (ETOG)

ISPEC	input control flag
IRES	input control flag
ISGG	control for MUFT Greuling-Goertzel parameter (ETOG)
IN2N	control for n-2n cross section for MUFT (ETOG)
INTO	control for ingroup inelastic scattering for MUFT (ETOG)
IEXT	control for inelastic scattering out of defined matrix (ETOG)
IPUN	control for punched card output (ETOG)

/FLAGS/

File 3 data indicators

KEY	ENDF/B data presence indicator
NOXS	indicates presence of elastic scattering data
MOXIN	indicates presence of inelastic scattering data
NON2N	indicates presence of n-2n scattering data
NOXF	indicates presence of fission cross section
NONG	indicates presence of (n, γ) cross section
NONP	indicates presence of (n,p) cross section
NOND	indicates presence of (n,d) cross section
NONT	indicates presence of (n,t) cross section
NOHE	indicates presence of (n,He ³) cross section
NONA	indicates presence of (n, α) cross section
NON2A	indicates presence of (n,2 α) cross section
NOCAP	indicates presence of absorption cross section
MONU	indicates presence of average cosine of scattering

/CONSTS/

data constants

EZERO	$1.0 * 10^7$ upper bound of group structure
PI	π
HAFPI	$\pi/2$

<u>/GROUPS/</u>	group structure
EGRP(100)	energy boundaries of groups
UGRP(100)	lethargy boundaries of groups
<u>/RESON/</u>	resonance region variables
NRES	number of resolved resonances
NUNR	"acceptable" unresolved resonance indicator
ECUT	energy boundary between resolved and unresolved ranges
DLEV	unresolved mean level spacing
GNOBAR	average unresolved reduced neutron width
GGBAR	average unresolved capture width
CBAR	average unresolved statistical spin factor
GOBAR	average unresolved reduced neutron width
GAFBAR	average unresolved fission width
RFACT	MUFT r factor (ETOG)
SFACT	MUFT s factor (ETOG)
WEAG(250)	resonance statistical spin factor
ER(250)	energy of resolved resonance
GAMN(250)	resolved neutron width
GAMG(250)	resolved capture width
GAMF(250)	resolved fission width
NROIM(250)	NR or NRIA resonance for GAMI
<u>/RESCNT/</u>	resonance indicators
NRIG(99)	group critical resonance indicator
<u>/EXTRAS/</u>	resonance integral variables
CDTEUP	capture resonance integrals due to unresolved parameters for GAMI or GAMII
FDTEIP	fission resonance integral due to unresolved parameters for GAMI or GAMII

G2CASBR	asymmetric contribution to GAMII capture resonance integral below ENDF/B resolved energy region
G2CASIR	asymmetric contribution to GAMII capture resonance integral in ENDF/B resolved energy region
G2FASBR	asymmetric contribution to GAMII fission resonance integral below ENDF/B resolved energy region
G2FASIR	asymmetric contribution to GAMII fission resonance integral in ENDF/B resolved resonance region
RINP	(n,p) resonance integral
RIND	(n,d) resonance integral
RINT	(n,t) resonance integral
RIHE	(n,He ³) resonance integral
RINA	(n, α) resonance integral
RIN2A	(n,2 α) resonance integral
ARRAY(99)	total (resolved or unresolved plus smooth) (n, γ) cross section
<u>/SMOOTH/</u>	multigroup cross sections
XABS(99)	absorption cross section
XFIS(99)	fission cross section
XNU(99)	average number of neutrons per fission
<u>/TRANS/</u>	Seg. 5 elastic scattering calculation variables
AM1	A-1; A = atomic mass
AP1	A+1
ALPLG	$\log(\alpha)$; $\alpha = \left(\frac{A-1}{A+1}\right)^2$
CFAL	1 - α
AL	lower limit for outer integral (algorithm 2)
BU	upper limit for outer integral (algorithm 2)
CL	lower limit for inner integral (algorithm 2)

DU	upper limit for inner integral (algorithm 2)
NUPP1	NLENG + 1
NLENG	highest order of non-zero Legendre expansion coefficients available for a group
A19(20)	$2j+1$; $j = 0, 1, \dots, \text{NLENG}$
FBB(4)	value of inner integral at any energy mesh point
FOLA(4)	$\frac{2\ell+1}{1-\alpha}$; $\ell = 0, 1, 2$
CX(4)	components $\sigma_{j,i}^{\ell}$ of transfer matrix
PLXMU(4)	$P_{\ell}(\mu)$; ℓ th order Legendre polynomial evaluated at μ
PLETA(21)	$P_{\ell}(n)$; ℓ th order Legendre polynomial evaluated at n
PLT1(21)	coefficients in recursion formula for calculation of Legendre polynomials
PLT2(21)	coefficients in recursion formula for calculation of Legendre polynomials
<u>/PARAM/</u>	elastic scattering calculation variables
NPE	number of mesh points for outer integral (algorithm 2)
XNPE	NPE - 1 intervals
NPEP	number of mesh points for inner integral (algorithm 2)
XNPEP	NPEP - 1 intervals
LPEP	number of mesh points for inner integral (algorithm 2 ingroup term)
QLPEP	LPEP - 1 intervals
NPIS	number of energy points for elastic cross section in each group
NPIM	number of energy points for which angular distributions are given in each group
LOR1	highest order of scattering matrix desired plus one
NGROUP	source group number

<u>/PLCOMP/</u>	complete elastic matrix elements each group
P0(100)	P_0 matrix elements
P1(100)	P_1 matrix elements
P2(100)	P_2 matrix elements
P3(100)	P_3 matrix elements
<u>/EXTRA/</u>	matrix column sums
COLUMNS(99)	inelastic or n , $2n$ column sums
<u>/MATXL/</u>	scatter matrix dimensions
LOLIN	total number of elements in inelastic matrix
LAIN	number of source groups from which inelastic scattering occurs
LDIN	maximum number of groups for inelastic downscatter
LOL2N	total number of matrix elements ($n, 2n$) array
LA2N	number of source groups for ($n, 2n$) matrix
LD2N	maximum number of groups for ($n, 2n$) downscatter
LOLP0	total number of elements in P_0 elastic matrix
LAP0	number of source groups for P_0 elastic matrix
LDPO	number of groups for P_0 elastic downscatter
LOLP1	total number of elements in P_1 elastic matrix
LAP1	number of source groups for P_1 elastic matrix
LDP1	number of groups for P_1 elastic downscatter
LOLP	total number of elements in each P_ℓ matrix (GAM II)
LAP	number of source groups from which P_ℓ elastic scattering occurs (GAM II)
LDP	number of groups for P_ℓ elastic downscatter (GAM II)
LOL	total number of elements in composite transfer matrix
LA	number of source groups for composite transfer matrix
LD	number of groups into which composite transfer occurs

<u>/MUFT45/</u>	output card construction variables
NFIL	file number
NCOD	MUFT material number
NGR	group number
NSEQ	sequence number
LAST	matrix column indicator
SIGN(10)	constructed sign
IXP(10)	constructed exponent
FRAC(10)	constructed fraction
<u>/INFO/</u>	information for GAM punched output
ANID(7)	alphanumeric identification for nuclide
NAOC	GAM-I library new addition or change indicator
LTOT	total number of entries in all cross section tables
IWA	absorption cross section presence indicator
IWF	fission cross section presence indicator
IWR	resonance parameter presence indicator
NUM1D	number of one-dimensional arrays present for nuclide
<u>/FILE3/</u>	(output for MUFT File 3) multigroup cross sections
XS(99)	elastic scattering cross section
XC(99)	capture cross section
XIN(99)	inelastic scattering cross section
XF(99)	fission cross section
AGN(99)	isotropic Greuling-Goertzel parameter (age number)
XSMU(99)	anisotropic scattering cross section
GNU(99)	ν , average number of neutrons per fission each group
XSXI(99)	isotropic slowing down power

ETA(99)	anisotropic slowing down power
ZETA(99)	group integral of weighting function
<u>/FILE4/</u>	MUFT group resonance indicator
JRS(99)	number of resonances in group
<u>/FILE5/</u>	non-elastic matrix storage
PMX(4851)	non-elastic P_0 matrix vector
DIAG(99)	diagonal elements of P_0 matrix
PMX1(4851)	non-elastic P_1 matrix vector
DIAG1(99)	diagonal elements of P_1 matrix
XTRA(99)	for renormalization of P_0 matrix
XTRA1(99)	for renormalization of P_1 matrix
<u>/FILE6/</u>	source spectrum
TRUM(99)	source spectrum and temp storage
<u>/TITLES/</u>	
DTE	date of execution this problem
ETIME	time elapsed this step
TTIME	total time to this point
PNAME(2)	name of program
VDAT(2)	date of completion of this version of ETOP
EXPLAN(15)	specific name for this load module
BUNTL(23)	ENDF/B tape title information
TAPTL(20)	ENDF/B tape title information for output listing
IVERS	version number of ETOP load module
LINER	line count for output print control
NPAG	page number for output listing

/OUT/

HDG(200) headings for print of input options, SR. OUT0
I1-I8 control flags for input data print, SR. OUT0

/ANGLR/

IANGLR flag when no elastic angular distribution data is
present in File 4 (set in SR. TRAN)
ISCATA input control flag
IRFAST input control flag
IDOP23 input control flag

/OUTR/

IELAS input control flag
IEPNTS input control flag
JMUPTS input control flag
PMGRID(100) numerical mesh for $\beta(\cos \theta)$ for DAO algorithm
DELMU delta β for trapezoidal PMGRID mesh
IOUTS input control flag
IGAUSS input control flag

/ISOTRP/

SOTROP input control flag
KGTROP input control flag

/VERS4/

PCAP(99) storage for p-wave capture integral
PFIS(99) storage for p-wave fission integral
PSCAT(99,3) storage for background scattering matrix
SHIELR input control flag
SHIELU input control flag
TROPAS nearest group boundary to which isotropic
elastic scattering (CM) ends

EHIRSV	old variable, not used now
ICONDS	input control flag
PBNDRY(3)	old variable not used now
KBNDRY	group containing upper limit of unresolved range

/GLSAD/

NUMRUN	old variable, no longer used
ISPRES	input control flag
ISPUNR	input control flag
IF3ONL	input control flag
ISPFL3	input control flag
ISPEL	input control flag
ISPINL	input control flag
ISPN2N	input control flag
ISPOT1	input control flag
ICRECT	input control flag
IPRTL0	controls printing of individual inelastic matrix elements
NPRTL0	controls printing of individual inelastic matrix elements
IPRTLX	input control flag
IFOPT1	old input flag, no longer used
IFOPT2	old input flag, no longer used
IFOPT3	old input flag, no longer used
ITMF3S	old input flag, no longer used
ISPRCF	input control flag
ISPUCF	old variable, no longer used

/NWINLF/

NF3DIS	number of discrete inelastic levels in File 3
NF3CON	number of inelastic continuum distributions in File 3
NKCNT	count index for inelastic levels
NF35	logical control for inelastic format
NF35IN	logical control for inelastic format
NOXINT	indicates presence of total inelastic cross section
THETAR(41)	inelastic level Q values

/F5MESH/

UMESHL	input control flag
UMESHH	input control flag
LF1INE	input control flag
LF1INP	input control flag
MESHFV	input control flag

/N2N/

NF6T9	number of N2N levels for first neutron
NF4649	number of N2N levels for second neutron
QN2N(8)	n,2n level Q values

/INFLAG/

IWKEEP	temporary storage for IW
MATXX	temporary storage for MAT
MFXX	temporary storage for MF
MTXX	temporary storage for MT

/GNSOP/

IRUNT	old variable no longer used
-------	-----------------------------

NOP1	indicates presence of P_1 elastic matrix
NOP2	indicates presence of P_2 elastic matrix
NOP3	indicates presence of P_3 elastic matrix
XNOP1	dummy variable, never used
XNOP2	dummy variable, never used
XNOP3	dummy variable, never used
IRUNC	sequence number of present problem in a stacked job
 <u>/LOXX/</u>	
LOLXX(4)	number of elements in scattering matrices
LAXX(4)	number of source groups in scattering matrices
LDXX(4)	maximum number of sink groups in scattering matrices
NON1	signifies presence of P_1 non-elastic matrices in SR. ETOP50
 <u>/MAR72/</u>	
POA(300)	storage for P_0 background elastic matrix elements
P1A(300)	storage for P_1 background elastic matrix elements
ICOPFS(80)	storage for input control to copy fission spectra from an old PHROG tape
ALPHA	$[(A-1)/(A+1)]^2$
ELORXX	temp storage for ELOR
EHIRXX	temp storage for EHIR
EHIUXX	temp storage for EHIU
SMELR1	temp storage for p-wave contribution to background elastic matrix
SMELR2	p-wave resonance contribution to background elastic matrix at lower limit of resolved resonance range
SMEHR1	p-wave resonance contribution to background elastic matrix at upper limit of resolved resonance range
SMEHR2	temp storage for p-wave contribution to background elastic matrix

SMEHU1	temp storage for p-wave contribution to background elastic matrix
SMEHU2	temp storage for p-wave contribution to background elastic matrix
KGELOR	group in which lower limit of resolved range occurs
KGEHIR	group in which upper limit of resolved range occurs
KGEHIU	group in which upper limit of unresolved range occurs
IELOR	flag if ELOR is in outscatter range this group
IEHIR	flag if EHIR is in outscatter range this group
IEHIU	flag if EHIU is in outscatter range this group
ICOPY	input control flag
IPRF	input control flag
ISPECA	input control flag
IWG	input control flag
NEWNFS	number of fission spectra to be copied from old PHROG tape to new PHROG tape in SR. PHEDIT
 <u>/PHCOM/</u>	
FROGMT(19)	material description for PHROG library
PTAPID(2)	ID of old PHROG tape
PHRPL	input control flag
NMTOT	input control flag
ICURPO	sequence number of last material processed
IPHRPL	sequence number of processed material for PHROG library
IPTIT	input control flag
ISPR	input control flag
IWS	type elastic scattering matrix in PHROG library
NIDAR(10)	vector describing material in PHROG library
NITOLD	input control flag
NITNEW	number of materials to be written on the new PHROG tape

NTTL	input control flag
 <u>/UCFFRG/</u>	
XCFROG(99)	storage for background absorption cross section for resonance range to be sent to PHROG
XFFROG(99)	storage for background fission cross section for resonance range to be sent to PHROG
 <u>/NOV70/</u>	
IPUNN	old variable, no longer used
TIT3(3)	portion of new PHROG material identification
RAWRI(7)	atomic mass by isotope in resonance range
 <u>/NEWUK/</u>	
IQI	count index for resonance parameter storage in SR. TMF2
IQN	maximum number of resonance parameters stored in UQA
IQNCB	IQN + 3 = additional reserve storage
IQNFB	IQN + 103 = additional reserve storage
IQNF	IQN + 203 = additional reserve storage
UAWRI(7,3)	storage for isotopic atomic weights and constants
IQFG(7)	beginning for count index of unresolved record storage for each isotope
RRLEL	lower limit of resolved resonance range for a PHROG material
 <u>/SEQID/</u>	
IDFROG	input control flag
IDFRSV	temporary storage of material I.D.
 <u>/TOTF/</u>	
RSWCAP(99)	total capture cross section by group, all contributions
RSWFIS(99)	total fission cross section by group, all contributions

/CORR/

A(18)	storage for single ENDF/B card image
MAT	material number
MF	file number
MT	reaction type
MS	sequence number of card image on tape LIBO
MATP	temporary storage for MAT in SR. WCARD
NS	sequence number of card image on tape LIBN
IPX	index for IPT
IPT(100)	storage for operations in SR. CRECT

/CTAPE/

NIN	unit on which ENDF/B corrections are input
NOUT	unit on which ENDF/B corrections are printed to output
LIBO	tape unit for uncorrected ENDF/B tape
LIBN	tape unit for corrected ENDF/B tape

/GO/

	initialization flags for SR. GADD
NET	number of angular data sets read
IREAD	flag for first angular data set read
NREF	index for number of angular data sets each group
EOLD1	energy of previous angular data set read
XOLD1(100)	previous angular data set read
XOLD2(100)	last angular data set read
LDATA	flag for type of angular data

/GCOM/

GSTOR(22000)	general storage area
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APPENDIX C
BIBLIOGRAPHY OF SUBROUTINES

Segment No. 1

MAIN	controls flow of ETOP 14
PAGI	initiates timer, page count, and data
PAGE	controls print of title header for each page of output
TIM	controls print of elapsed time for each page of output
PRININ	reads card input, prints it, then rewinds card input unit
ERR	prints error message
ERROR	prints error message
STORE	transfer numbered set from /RECS/ to /DENS/
FETCH	fetch numbered data set from /DENS/
DELETE	deletes numbered data set in /DENS/
GRATE	integrates a TAB1 function
ECSI	computes integral of $Y(X)$
COMB	combines two TAB1 functions
COMBP	combines one panel of two TAB1 functions
ADD	combining function for addition in COMB
SUB	combining function for subtraction in COMB
MULT	combining function for multiplication in COMB
DIV	combining function for division in COMB
TERP	interpolates between two points
TERP1	interpolates one point
TERP2	forms new table by interpolation
LRIDS	locates a record in /DENS/
FPDS	fetches a point from /DENS/
IPDS	interpolates point in /DENS/
CONT	reads control (CONT) record from ENDF/B tape

Segment No. 1 (cont'd)

LIST	reads LIST record from ENDF/B tape
TAB1	reads TAB1 record from ENDF/B tape
TAB2	reads TAB2 record from ENDF/B tape
TPOS	positions ENDF/B tape to file (MF) and reaction (MT)
SAVE	writes or reads a scratch tape
XTND	extends data array
TERPO	interpolates a data array
GPAV	averages TAB1 function over selected groups
AVRG	averages TAB1 function over a selected energy range
PCOP	copies one material (or the initial records, if IMA=0) from the old PHROG tape to the new PHROG tape. Reads the initial records (Tape I.D. and fission spectra) when IMA=0. If IMA=0, material is skipped; >0 material is copied.
FISPRC	prints the fission spectra and/or copies it, and may add a new one. Arrays input are destroyed from 1 to 18, 1 to MG, respectively
NONZG	determines number of non zero values in an array and their location
OUT5	renormalizes and prints the inelastic and n-2n matrix
RENO	performs renormalization of non-elastic matrices
INF5	initializes file 5 parameters and arrays
CWAX	rearranges numbered data sets in /DENS/ for calculation of non-elastic scattering matrices.

Segment No. 2

ETOP10	controls flow of program in overlay 1
ININ	reads input data and initializes parameters, executes problem end
CRECT	make corrections on an ENDF/B BCD tape
PCRECT	reads and lists card input and stores it on a scratch tape to be reread later. The addition of PCRECT makes the use of the START card mandatory. A title card is now required as the first card. It is suggested that it contain the data set name and the VOL, SER. NO. of the input tape, e.g., L.GLSXXXXX, T9XXXX.

RCARD	read one card from LIB0(11)
WCARD	write card on LIBN, print on NOUT
WCONT	write control card on tape LIBN(22=NDFB), and print on NOUT(4)
OUTO	lists input options selected
OUTPR	prints selected output
ZERO	initializes overlay 1 variables
EU	constructs group structure, weight, and weight averages
ENGT1	generates TAB1 function from function subprogram called
FISS	generating function for fission spectrum
OUT1	prints input options and multigroup structure
TRID	reads ENDF/B tape I.D.
HOL	change integer to 4 digits
TMAT	positions ENDF/B tape to material (MATNO)
HOLL	reads hollerith records from File 1
RMF1	reads ENDF/B File 1

Segment No. 3

ETOP20	controls overlay 2
TMF2	reads ENDF/B data from File 2
PANL	calculates p-wave resolved resonances analytically. Capture and fission group averages go into PCAP and PFIS arrays. According to the group the resonance falls in, scatter is further subdivided into the two ranges per group. ELO to ELO/ALPHA (ECRIT) and ECRIT to EHI
FINDBN	calculate KGELOR, KGEHIR and KGEAIU the groups in which resonance range boundaries fall
FINDGP	uses input variables E, KSTART, and ALPHA plus COMMON to find output variables K, the group index, ILOHI, and KKSU. ILOHI>1 if E is below and =2 if E is above ECRIT

LRF2	reads and stores ENDF/B unresolved data
RESS	calculates pointwise cross sections from resolved resonance
EPRNT	(JUMP) print GNU, the resolved (JUMP = 1) or unresolved (JUMP = 3) resonance potential scattering term (calls NONZ6)
RESMSH	eliminates some mesh points to avoid discontinuity problem, reduce core, and save execution time
FILAR	fills the unfilled portion of YAR from the values at the first point. Every ISK'th point and the last point by interpolation the sets YAR=0.0 at the original, externally calculated points
RESO	prepares resolved resonance parameters for library
RESR	calculates cross sections from negative and thermal energy resonances
RESU	calculates unresolved resonance cross sections
POTSR	calculates the potential scattering term for the first 3 L-states for small values of RHOHAT, p-wave 2D-wave terms are set = 0
CONSCA	presently a dummy subroutine

Segment No. 4

ETOP30	controls overlay 3
CROS	processes cross sections in File 3
TMF3	reads ENDF/B data from File 3
SMBN	calculates and adds to the p-wave contribution. When in the outscatter range, the average XSEC from ELO to range boundary to ECRIT
RESI	calculates resonance integrals from parameters

Segment No. 5

ETOP40	controls overlay 4
TRAN	calculates elastic scattering matrix

GADD	processes angular data from File 4
TMF4	reads ENDF/B data from File 4
POFMU	converts angular distribution data from File 4 to a tabular distribution
LECOM	converts tabular data from File 4 to a Legendre representation
LEGEND	computes Legendre coefficients for SR. LECOM
OUT3:	prints complete set of multigroup cross sections
OUTER	performs outer integral over energy for scattering matrix
GRIN	sets up integration mesh for DAO algorithm
INNER	performs inner angular integral for DAO algorithm
MAXMIN	determines energy bounds of hyperbola for DAO algorithm
MUBOT	determines group cuts for inner integral for DAO algorithm
PL	calculates Legendre polynomials for DAO algorithm
DINT	double integral for ETOG algorithm
GRID	sets up integration mesh for ETOG algorithm
MVAL	calculates point value for inner integral, ETOG algorithm
SINT	calculates first of double integrals for ETOG algorithm
TRIN	controls calculation of non-elastic scattering matrices
GOSH	calculates pointwise scattering probability each group for non-elastic scattering matrix

Segment No. 6

ETOP50	controls overlay 5
RMF5	reads File 5 ENDF/B records
IMAT	calculates continuum non-elastic matrix elements
DZTERP	interpolates a TAB2 record to specified incident and exit energies
PUTW	restores /DENS/ storage to configuration previous to call to SR. CWAX

SPEC	calculates multigroup fission spectrum from ENDF/B data
ETOP80	controls program flow in segment 7. Calls FRGOUT or PHEDIT depending on setting of flags IPRF and ISPECA
FRGOUT	combines all data calculated by ETOP necessary for a new PHROG library material into a single binary array in array A, /DENS/
PFIG	formats elastic scattering matrices for PHROG library
POP1GP	calculates smooth background scattering matrix from the average smooth file 3 plus resolved resonance p-wave over the entire group (KG), PSCAT(KG,3) and the average ingroup from ELO to ELO/ALPHA, PSCAT(KG,1) for MAXG groups
POP1BN	calculates smooth background matrix at resonance range boundaries
AOA1	calculates A0 and A1. The fractions the average scattering from E1 to E2 is to be multiplied by to get the P0 and P1 outscatter term in the isotropic range. From (E1,E2) to the next lower group P0 ingroup = grp. ave. - P0 outgroup, P1 ingroup = (2/3 AWR) * Grp. Ave. - P1 outgroup
POP1	calculates the P0 and P1 ingroup and outgroup isotropic scattering terms using A0, A1
PPMOVE	calculates difference between complete elastic scattering matrix and background matrix and rearranges storage locations for these matrices
FLIPS	rearranges storage locations of resolved resonance parameters
SINUNF	creates a single type of unresolved record for PHROG
PHED	produces an edited listing of a PHROG material. All calls to PHED cause one PHROG material to be printed. If IPRF=0, the data is generated by ETOP SR. FRGOUT. If IPRF=1, data is read from old PHROG input tape. If ICOPY=0, no PHROG output tape is produced.
BKSPR	prints the background scattering matrices
UNRESE	prints PHROG unresolved records to output listing
PHEDIT	sets up loops for printing and/or copying PHROG tape

APPENDIX D

ERROR STOPS

If a program STOP occurs, an error message is printed indicating the reason for the STOP and the subroutine in which the STOP occurs. Certain error stops involve ENDF/B data and its storage. These errors are numbered and printed from subroutines ERR and ERROR. Subroutine ERROR prints only the error number and the control words MAT, MF, MT. Subroutine ERR will print an error number, the subroutine and the statement number where the error occurred and the control words, MAT, MF, MT, C1, C2, L1, L2, N1 and N2. Following is a list of the error numbers, the subroutine which detects the error and an explanation of the error.

<u>Error Number</u>	<u>Detecting Subroutine</u>	<u>Explanation</u>
110	ECSI	Interpolation code out of range
130	TERP2	X(N) not in increasing order
131	TERP2	XP(N) not in increasing order
132	TERP2	Interpolation table incorrect
133	TERP1	Interpolation code not in range 1-5
134	TERP1	$X \leq 0$ cannot be interpolated by logs
135	TERP1	$X1 = X2$, discontinuity
300	STORE	JT not in range 1-6
301	STORE	MA=0 not allowed
302	STORE	Overflow, record will not fit
303	FETCH	MA = 0, record not in /DENS/
308	COMB	Overflow, answer will not fit in /RECS/
309	COMB	MA or MB not in /DENS/
310	COMB	$XL \geq XH$
311	COMB	MA or MB is zero
314	IPDS	Improper interpolation table
315	GRATE	Interpolation table incorrect

APPENDIX E
U²³⁸ Sample Problem

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG
URANIUM-238, REV. 1

DATE OF RUN 12/04/75 PAGE 1

TIME: 0.0 / 0.0 (SEC.)

ENDF/B MAT. NO. = 1262

CORRECTIONS FOR U238 TAPE 409 SER = T99266, IRECT = 1 26-AUG-75
RECT CARD INPUT

2	6	1	1	2	2	3	3	3	5	6	7	7	7
		1	5	2	9	3	5	8	5	6	0	2	5

(KEY CARD COLUMNS)

CORRECT	25	26	
START			TPID
ENDF/B-IV TAPE 409(REV1)			18-NOV-74 409
NEXT			1
GN	1262	1581	DELETE
			2.59000- 2
			1.20000- 3
ON	1262	1606	SET3
			3.26200- 2
			1.20000- 4
GN	1262	3536	SET4
GN	1262	3561	SET4
GN	1262	3566	SET4
GN	1262	3611	SET4
CONTINUE			2

ENDF/B CORRECTOR RUN

TAPE LABELLED				
ENDF/B-IV TAPE 409(REV1)	18-NOV-74	409	0	0

TAPE END CARD WRITTEN ON 22

CORRECTIONS COMPLETED

(ETOP/ 14, 3- 1-75- R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 2

URANIUM-233. REV. 1

TIME: 124.75/ 124.75 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 409

ENDF/B MAT. NO. = 1262

PROGRAM OPTIONS

THE STANDARD 63 GROUP GAM-1 STRUCTURE IS GENERATED INTERNALLY
WEIGHTING FUNCTION IS 1/E JOINED TO A FISSION SPECTRUM

URANIUM-238, REV. 1

TIME: 0.33/ 125.08 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 409

ENDF/B MAT. NO. = 1262

- - ENDF/B - -		- - MULTIGROUP - -		- - - - GROUP INFORMATION - - - -		
TAPE NO.	MATERIAL NO.	CODE	MATERIAL NO.	NUMBER	HIGHEST INELASTIC	LOWEST RESONANCE
409	1262	GAM-2	0	68	68	1
MULTIGROUP STRUCTURE						
GROUP	ENERGY RANGE	LETHARGY RANGE	GROUP	ENERGY RANGE	LETHARGY RANGE	
1	0.778E 07 - 0.1000E 08	0.0 - 0.250	35	0.1585E 04 - 0.2035E 04	8.500 - 8.750	
2	0.6065E 07 - 0.7788E 07	0.250 - 0.500	36	0.1234E 04 - 0.1585E 04	8.750 - 9.000	
3	0.4724E 07 - 0.6065E 07	0.500 - 0.750	37	0.9611E 03 - 0.1234E 04	9.000 - 9.250	
4	0.3679E 07 - 0.4724E 07	0.750 - 1.000	38	0.7485E 03 - 0.9611E 03	9.250 - 9.500	
5	0.2865E 07 - 0.3679E 07	1.000 - 1.250	39	0.5829E 03 - 0.7485E 03	9.500 - 9.750	
6	0.2231E 07 - 0.2865E 07	1.250 - 1.500	40	0.4540E 03 - 0.5829E 03	9.750 - 10.000	
7	0.1738E 07 - 0.2231E 07	1.500 - 1.750	41	0.3536E 03 - 0.4540E 03	10.000 - 10.250	
8	0.1353E 07 - 0.1738E 07	1.750 - 2.000	42	0.2754E 03 - 0.3536E 03	10.250 - 10.500	
9	0.1054E 07 - 0.1353E 07	2.000 - 2.250	43	0.2145E 03 - 0.2754E 03	10.500 - 10.750	
10	0.8209E 06 - 0.1054E 07	2.250 - 2.500	44	0.1670E 03 - 0.2145E 03	10.750 - 11.000	
11	0.6393E 06 - 0.8209E 06	2.500 - 2.750	45	0.1301E 03 - 0.1670E 03	11.000 - 11.250	
12	0.4579E 06 - 0.6393E 06	2.750 - 3.000	46	0.1013E 03 - 0.1301E 03	11.250 - 11.500	
13	0.3877E 06 - 0.4579E 06	3.000 - 3.250	47	0.7889E 02 - 0.1013E 03	11.500 - 11.750	
14	0.3020E 06 - 0.3877E 06	3.250 - 3.500	48	0.6144E 02 - 0.7889E 02	11.750 - 12.000	
15	0.2352E 06 - 0.3020E 06	3.500 - 3.750	49	0.4785E 02 - 0.6144E 02	12.000 - 12.250	
16	0.1832E 06 - 0.2352E 06	3.750 - 4.000	50	0.3727E 02 - 0.4785E 02	12.250 - 12.500	
17	0.1426E 06 - 0.1832E 06	4.000 - 4.250	51	0.2902E 02 - 0.3727E 02	12.500 - 12.750	
18	0.1111E 06 - 0.1426E 06	4.250 - 4.500	52	0.2260E 02 - 0.2902E 02	12.750 - 13.000	
19	0.8652E 05 - 0.1111E 06	4.500 - 4.750	53	0.1760E 02 - 0.2260E 02	13.000 - 13.250	
20	0.6738E 05 - 0.8652E 05	4.750 - 5.000	54	0.1371E 02 - 0.1760E 02	13.250 - 13.500	
21	0.5248E 05 - 0.6738E 05	5.000 - 5.250	55	0.1068E 02 - 0.1371E 02	13.500 - 13.750	
22	0.4087E 05 - 0.5248E 05	5.250 - 5.500	56	0.8315E 01 - 0.1068E 02	13.750 - 14.000	
23	0.3183E 05 - 0.4087E 05	5.500 - 5.750	57	0.6476E 01 - 0.8315E 01	14.000 - 14.250	
24	0.2479E 05 - 0.3183E 05	5.750 - 6.000	58	0.5043E 01 - 0.6476E 01	14.250 - 14.500	
25	0.1930E 05 - 0.2479E 05	6.000 - 6.250	59	0.3928E 01 - 0.5043E 01	14.500 - 14.750	
26	0.1503E 05 - 0.1930E 05	6.250 - 6.500	60	0.3059E 01 - 0.3928E 01	14.750 - 15.000	
27	0.1171E 05 - 0.1503E 05	6.500 - 6.750	61	0.2382E 01 - 0.3059E 01	15.000 - 15.250	
28	0.9119E 04 - 0.1171E 05	6.750 - 7.000	62	0.1855E 01 - 0.2382E 01	15.250 - 15.500	
29	0.7102E 04 - 0.9119E 04	7.000 - 7.250	63	0.1445E 01 - 0.1855E 01	15.500 - 15.750	
30	0.5531E 04 - 0.7102E 04	7.250 - 7.500	64	0.1125E 01 - 0.1445E 01	15.750 - 16.000	
31	0.4307E 04 - 0.5531E 04	7.500 - 7.750	65	0.8764E 00 - 0.1125E 01	16.000 - 16.250	
32	0.3355E 04 - 0.4307E 04	7.750 - 8.000	66	0.6826E 00 - 0.8764E 00	16.250 - 16.500	
33	0.2613E 04 - 0.3355E 04	8.000 - 8.250	67	0.5316E 00 - 0.6826E 00	16.500 - 16.750	
34	0.2035E 04 - 0.2613E 04	8.250 - 8.500	68	0.4140E 00 - 0.5316E 00	16.750 - 17.000	

(ETOP/ 14, 3- 1-75, R. A. GRIMESY : PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 4

URANIUM-238, REV. 1

TIME: 0.13/ 125.22 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 409

ENDF/B MAT. NO. = 1262

WEIGHTING FUNCTION
AS GENERATED AS FOLLOWS

ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT
4.0985E-01	3.1797E-02	6.7379E 04	1.9341E-07	9.2461E 04	2.2215E-07	1.2381E 05	2.5032E-07
2.2354E 05	3.1603E-07	3.0213E 05	3.4059E-07	3.6214E 05	3.5572E-07	4.2214E 05	3.6637E-07
4.8215E 05	3.7352E-07	5.4216E 05	3.7785E-07	6.1717E 05	3.8007E-07	6.9219E 05	3.7947E-07
7.8595E 05	3.7564E-07	8.7971E 05	3.6920E-07	9.9692E 05	3.5846E-07	1.1434E 06	3.4216E-07
1.2266E 05	3.1916E-07	1.7844E 06	2.5835E-07	2.0133E 06	2.2925E-07	2.4711E 06	1.7726E-07
2.8145E 06	1.4446E-07	3.1578E 06	1.1684E-07	3.5870E 06	8.8887E-08	4.0162E 06	6.7136E-08
4.5527E 05	4.6847E-08	5.0892E 06	3.2532E-08	5.7598E 06	2.0436E-08	6.4305E 06	1.2756E-08
7.2688E 06	7.0165E-07	8.1070E 06	3.8359E-09	9.1549E 06	1.7897E-09	1.0100E 07	8.9476E-10

WEIGHTING FUNCTION
INTERPOLATION TABLE

NBT	JNT	NBT	JNT	NBT	JNT	NBT	JNT
2	5	4	5	12	3	19	2
21	3	32	4				

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 5

92-U- 238 URANIUM-238, REV. 1

TIME: 4.71/ 129.93 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

THE (TAPE) DESCRIPTION OF MATERIAL 1262 IS -
92-U- 238 WARD EVAL-SEP73 W.C. PAIK
DIST-AUG74

MF = 1

MT=452

NU-BAR-TOTAL

NORMALIZED TO CF-252. ENERGY DEPENDENCE LINEAR FROM VALUE
OF 2.3195 AT THERMAL TO VALUE OF 2.6275 AT 2.0MEV DATA OF
SOLEILAC (REF. 10) PRIMARY REFERENCE.

MT=454

FISSION PRODUCT YIELD DATA

* * * * *
FISSION PRODUCT YIELD DATA FOR ENDF/B-IV 8/74. RECOMMENDED
VALUES ARE GIVEN FROM THE YIELDS SUBCOMMITTEES OF THE DECAY HEAT
TASK FORCE. MEMBERS OF THE SUBCOMMITTEES INCLUDE W.WALKER(CH),
P.ALIN, N.DUDEY, R.LARSEN, W.MAECK, W.MCELROY, B.RIDER, T.ENGLAND(CH),
A.WAHL AND K.WOLFSBERG. FINAL DIRECT YIELDS WERE GENERATED BY B.
RILER USING METHODS DESCRIBED IN NEDU-12154 REV.1 JAN.74. ENDF/B
FILE PREP. AND MODIFICATIONS WERE MADE BY R.SCHENTER 8/74. PEAK
CHAIN YIELDS ARE GIVEN AS

ELAB=5.00E+05 EV A-YCHAIN(PERCENT)=
882.25, 892.98, 903.35, 913.87, 924.21, 934.84, 944.53, 955.32,
965.29, 975.53, 985.55, 996.25, 1006.13, 1016.58, 1026.79, 1036.34,
1046.44, 1054.21, 1062.75, 1072.13, 1082.03, 1092.36, 1102.10, 1112.56,
1122.01, 1132.15, 1142.96, 1153.11, 1163.89, 1174.14, 1184.93, 1194.83,
1204.75, 1214.00, 1223.61, 1232.71, 1242.26

ELAB=1.40E+07 EV A-YCHAIN(PERCENT)=
882.15, 892.77, 903.11, 913.63, 923.90, 934.39, 944.03, 955.20,
965.01, 975.27, 985.24, 995.71, 1005.52, 1015.70, 1025.66, 1034.53,
1044.51, 1053.52, 1062.43, 1072.00, 1082.14, 1092.33, 1102.10, 1112.49,
1122.27, 1132.65, 1142.69, 1152.64, 1162.10, 1172.86, 1182.99, 1192.62,
1202.43, 1212.43, 1222.82, 1232.44, 1242.15, 1252.74, 1262.09

* * * * *
MT=455
DELAYED NEUTRON YIELDS
BASED ON EVALUATION BY CUX (ANL), VALUES ARE 0.0460
BELOW 4 MEV, DECREASING TO 0.026 FROM 9 TO 20 MEV.

MT=457

RADIOACTIVE DECAY DATA

PREPARED BY C.W.REICH 2/74

REFERENCES Q(ALPHA)- 1973 REVISION OF WAPSTRA-GOVE MASS TABLE.
HALF-LIFE- N.E. HOLDEN. CHART OF THE NUCLIDES (1973)
AND PRIVATE COMMUNICATION (JAN., 1974).

OTHER- Y.A. ELLIS, NUCLEAR DATA B4, NO.6, 635(1970)

NOTE AVG. E-ALPHA = 4255. KEV.

THIS VALUE INCLUDES BOTH THE KINETIC ENERGY OF THE
ALPHA PARTICLE AND THAT OF THE RECOILING NUCLEUS.

NOTE THE INTERNAL-CONVERSION COEFFICIENTS ARE THEORETICAL
VALUES. THE GAMMA-RAY INTENSITIES ARE DERIVED FROM
THESE VALUES, WITH THE REQUIREMENT THAT THE TOTAL
TRANSITION INTENSITY AGREE WITH THAT GIVEN BY THE
ALPHA-PARTICLE BRANCHING DATA.

MF = 2

RESONANCE PARAMETERS

RESOLVED RESONANCE PARAMETERS

F.J. MCCROSSIN (SAVANNAH RIVER LABORATORY) . IN THE EVALUATION RESULTS OF TESTINGS OF PRELIMINARY PARAMETERS ON ISOLATED R00 RESONANCE INTEGRAL CALCULATIONS BY J. HARDY (BETTS ATOMIC POWER LABORATORY) WERE CONSIDERED. COMMENTS BY G. DESAUSSURE (ORNL) AND BY PAIK CONSIDERED IN THE FINAL VALUES.

MT=151 RESOLVED RESONANCES - PARAMETERS INCLUDED FOR 190 S-WAVE AND 220 P-WAVE RESONANCES BASED PRIMARILY ON DATA OF REF 1-7. MEASURED PARAMETERS WERE MODIFIED TO IMPROVE FIT TO POINTWISE CAPTURE MEASUREMENTS OF REF 8. RESOLVED RANGE 1 EV-4 MEV. UNRESOLVED RESONANCES - AVERAGE RADIATION WIDTH=0.0235EV, ENERGY RANGE 4 KEV TO 45 KEV. STATISTICAL FIT TO DATA BY PAIK (REF. 36) SAME TECHNIQUE AS WAS DONE FOR ENDF/B III. AVERAGE S-WAVE LEVEL SPACING=20.0 EV, S-WAVE STRENGTH FUNCTION =1.05E-4 BASED ON EVALUATED RESOLVED RESONANCES. P-WAVE STRENGTH FUNCTION OBTAINED BY ADJUSTING CALCULATION TO THE EVALUATED CAPTURE CROSS SECTION. NEUTRON WIDTHS AND LEVEL SPACING ARE GIVEN AS ENERGY DEPENDENT AT 15 ENERGIES BETWEEN 4.00 AND 45.0 KEV. P-WAVE PENETRATION FACTORS TO BE CALCULATED USING A RADIUS OF 8.4 FERMI PER REVISED ENDF/B FORMATS. THE TECHNIQUE IS ESSENTIALLY SAME AS WAS FOR ENDF/B 3.

MF = 3

MF=3

SMOOTH CROSS SECTIONS

MT=1 BELOW 1 EV FROM REF. 9 EVALUATION (BUT SEE MT=102 BELOW). CROSS SECTIONS BETWEEN 1 EV AND 45 KEV TO BE CALCULATED FROM RESONANCE PARAMETERS WITH FILE 3 BACKGROUND CROSS SECTIONS.

MT=1 BETWEEN 45 AND 100 KEV, FROM REFERENCE 11. BETWEEN 0.1 AND 1.5 MEV, BASED ON DATA OF REFS. 11,12,13. BETWEEN 1.5 AND 4.3 MEV, BASED ON REFERENCE 12. ABOVE 4.3 MEV TO 15 MEV PRIMARY REFERENCES ARE REF. 14 AND HEATON (REF. 15). ABOVE 15 MEV, RECOMMENDED VALUES BY A.B. SMITH AT ANL (REF. 16) WERE USED.

MT=2 SCATTERING CROSS SECTIONS WERE OBTAINED AS DIFFERENCE BETWEEN TOTAL AND NONELASTIC.

MT=3 NONELASTIC BELOW 2.0 MEV OBTAINED AS SUM OF PARTS. THE 2.0 MEV VALUE OF 3.3718 IS BASED ON DIFFERENCE BETWEEN EVALUATED TOTAL AND THE SCATTERING MEASUREMENT OF REF. 17 PLUS ESTIMATED 0.28 FROM DIRECT INTERACTIONS FOR 0.0447 MEV AND 0.148 MEV LEVELS. ABOVE 2.0 MEV, BASED ON REFS. 17 AND 18 TO 7.0 MEV AND REFS. 19 AND 20 ABOVE 7.0 MEV.

MT=4, 51-72 AND 91

THRESHOLD SHAPE BELOW 0.7 MEV MODIFIED AUG 74 FOR MT=4 AND 51. BETWEEN 0.7 AND 2.00 MEV, TOTAL INELASTIC IS COMPLETELY RESOLVED AND OBTAINED AS SUM OF 22 LEVELS BETWEEN 0.0447 AND 1.79 MEV. RESOLVED LEVEL CROSS SECTIONS FROM MEASUREMENTS OF REFERENCE 16.

TOTAL INELASTIC ABOVE 2.0 MEV OBTAINED AS DIFFERENCE BETWEEN NONELASTIC AND SUM OF CAPTURE, FISSION, (N,2N), AND (N,3N) CROSS SECTIONS.

PSEUDO-LEVELS (MT=73 ON AND 91), WERE OBTAINED FROM L. STEWART AND R. HUNTER AT LASL.

MT=16 (N,2N) FROM REFS. 22-24. THESE MEASUREMENTS ARE RELATIVE TO U-238 FISSION AND HAVE BEEN ADJUSTED TO THIS EVALUATION

MT=17 (N,3N) FROM EXTRAPOLATION THROUGH 14 MEV VALUE OF REF. 24

MT=18 FISSION RATIO RELATIVE TO U-235 EVALUATED FROM 0.98 TIMES
LAMPHERE(REF.25) BELOW 2 MEV, REFS. 26 AND 27 BETWEEN 2.0 --
5.4 MEV, AND REFS. 27 AND 28 WITH CORRECTIONS TO REF. 28.
THESE RATIOS ARE IN GOOD AGREEMENT WITH MEASURED VALUES OF
REFERENCES 31 AND 32.
THESE FISSION RATIOS WERE COMBINED WITH THE ENDF/B IV U-235
FISSION CROSS SECTIONS.

MT=102 (N,GAMMA) - METHODS OF REF. 9 USED BELOW 1 EV, BUT VALUE
OF 2.70 B USED AT .0253 EV, RATHER THAN 2.72 B. SMOOTH CROSS
SEC (1 EV-45 KEV) INCLUDE CONTRIBUTIONS FROM (A) BOUND LEVELS
(1-100 EV), (B) UNRESOLVED P-WAVE RESONANCES (.68-4 KEV), AND
(C) A SMALL D-WAVE COMPONENT (10-45 KEV).
BETWEEN 4 AND 100 KEV, BASED ON AVERAGE OF REFS. 38 AND 8.
ABOVE 100 KEV, THE EVALUATION ARE DETERMINED BY FRIESENHANN
(REF.33), RYVES(REF. 34) AND REFERENCE 35.
ABOVE 2 MEV THE EVALUATION BY DEVANEY (REF.37) WAS ADOPTED

MT=251,252,253 CALCULATED FROM LEGENDRE POLYNOMIALS IN FILE 4.
MF = 4

MF=4 LEGENDRE POLYNOMIALS

MT=51,ETC. INELASTIC SCATTERING DISTRIBUTIONS ARE ISOTROPIC

MT=2 ANGULAR DISTRIBUTIONS EVALUATED FROM DATA OF REF. 30.
MF = 5

MF=5 SECONDARY ENERGY DISTRIBUTIONS

MT=16,17 MAXWELLIAN SECONDARY DISTRIBUTIONS ARE SPECIFIED.

MT=18 SIMPLE FISSION SPECTRUM WITH TEMP. = 1.34 MEV AT 2.5 MEV.

MT=91 NUCLEAR TEMP. FOR STATISTICAL INELASTIC FROM REF. 17.

MF = 12-15

PHOTON PRODUCTION DATA GENERATED BY R.J. HOWERTON, LAWRENCE
LIVERMORE LABORATORY.

*****NOTA BENE***** THESE PHOTON PRODUCTION FILES WERE DERIVED
AS DESCRIBED BELOW. THEY ARE DERIVED FROM AND ARE COMPATIBLE
WITH THE NEUTRON FILES OF THIS **REPEAT THIS** EVALUATION.

MT = 102 -- NEUTRON CAPTURE

THE CAPTURE GAMMA-RAY SPECTRUM FOR U-238 HAS BEEN MEASURED
ACCURATELY ONLY AT THERMAL NEUTRON ENERGIES (REF. 39). SOME
MEASUREMENTS HAVE ALSO BEEN MADE IN THE EV AND LOW KEV REGION
(REF. 40). THE LATTER MEASUREMENTS WERE MADE ONLY AT RESONANCE
ENERGIES AND HAVE OTHER PROBLEMS WITH RESPECT TO ENERGY CONSER-
VATION. CONSEQUENTLY, THEY WERE NOT USED FOR THIS EVALUATION.
THE ACCURATE THERMAL MEASUREMENTS WERE USED FROM THE LEAST
NEUTRON ENERGY TO 500 KEV WITH THE MULTIPLICITY ADJUSTED TO
CONSERVE ENERGY. PHOTONS FROM CAPTURE FOR INCIDENT NEUTRON
ENERGIES GREATER THAN 500 KEV WERE INCLUDED IN THE TOTAL PHOTON
PRODUCTION CROSS SECTION AND SPECTRA DISCUSSED BELOW UNDER
MT = 3.

MT = 18 -- NEUTRON INDUCED FISSION

SINCE NO MEASUREMENTS OF THE PHOTONS FROM FISSION OF U-238 HAVE
BEEN MADE, THE U-235 FISSION PHOTON SPECTRUM AND MULTIPLICITY
WERE USED (REF 41). FISSION WAS ENTERED AS A SEPARATE REACTION
FOR INCIDENT NEUTRON ENERGIES LESS THAN 500 KEV. THE MULTIPLICITY
WAS HELD CONSTANT FOR ALL NEUTRON BOMBARDING ENERGIES. ABOVE
500 KEV THE FISSION REACTION WAS INCLUDED IN THE CALCULATION OF
THE TOTAL PHOTON PRODUCTION CROSS SECTION AND SPECTRA ENTERED
UNDER MT = 3 AND DISCUSSED BELOW.

MT = 3 -- DISCRETE PHOTON PRODUCTION

THE FIRST THREE LEVELS IN U-238 CE-EXCITE LARGELY BY INTERNAL CONVERSION AND OTHER ELECTRON PRODUCING PROCESSES. THESE LEVELS PRODUCE VERY LITTLE PHOTON ENERGY AND THAT THAT IS PRODUCED IS NOT GENERALLY DISCRETE. BECAUSE THERE IS NO PROVISION FOR ELECTRON PRODUCTION CROSS SECTIONS IN THE ENDF/B FORMAT, IT WAS ASSUMED FOR THIS EVALUATION THAT THE ENERGY CONTRIBUTIONS FROM THESE THREE LEVELS WAS MANIFESTED IN DISCRETE PHOTONS. THIS IS INCORRECT BUT HAS THE VIRTUE OF CONSERVING ENERGY. WITH THIS ASSUMPTION THE BRANCHING RATIOS WERE TAKEN FROM REFERENCE 42.

MT = 3 -- CONTINUUM PHOTON PRODUCTION

THE CONTINUUM PORTION OF THE PHOTON PRODUCTION WAS BASED ON THE FORMALISM REPORTED IN REFERENCE 43. THIS FORMALISM IS A MODIFICATION OF THAT REPORTED IN REFERENCE 44. THE RESULTS OF THE CALCULATION WERE COMPARED WITH AVAILABLE MEASUREMENTS AND SHOWED SATISFACTORY AGREEMENT (REF. 45,46) IN THE PHOTON ENERGY REGIME FOR WHICH MEASUREMENTS WERE REPORTED (I.E., FOR PHOTON ENERGIES GREATER THAN 750 KEV).

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(ETOP/ 14, 3- 1-75, F. A. GRIMES) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

92-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

DATE OF RUN 12/04/75 PAGE 6

TIME: 5.19/ 135.12 (SEC.)

ENDF/B MAT. NO. = 1262

P-WAVE RESOLVED RESONANCE CONTRIBUTIONS
CALCULATED BY AN ANALYTIC FORMULA

NO POTENTIAL SCATTERING TERM IS INCLUDED

GROUP	CAPTURE	FISSION	SCATTER (EL TO EC)	SCATTER (EC TO EH)	SCATTER (EL TO EH)
32	1.0233E-01	0.0	6.9190E-02	1.3040E-01	1.2625E-01
33	1.0998E-01	0.0	9.9935E-03	2.2803E-C2	2.1935E-02
34	1.2167E-01	0.0	1.5553E-02	1.3481E-02	1.3621E-02
35	1.0990E-01	0.0	9.8069E-03	8.6252E-C3	8.7053E-03
36	1.5626E-01	0.0	5.1628E-03	1.0818E-C2	1.0435E-02
37	2.0334E-01	0.0	9.8852E-03	7.5043E-C3	7.6657E-03
38	1.1723E-01	0.0	3.6007E-03	3.1430E-C3	3.1741E-03
39	1.8663E-01	0.0	4.3406E-04	4.7886E-C3	4.4934E-03
40	9.5572E-02	0.0	0.0	1.5909E-C3	1.4830E-03
41	7.0131E-02	0.0	7.4000E-05	4.7846E-C4	4.5104E-04
42	1.2279E-01	0.0	2.6529E-03	4.9161E-C4	6.3813E-04
43	1.6835E-01	0.0	3.7599E-04	1.0462E-C3	1.0008E-03
44	5.3708E-02	0.0	0.0	7.7378E-C5	7.2133E-05
45	4.6148E-02	0.0	0.0	5.5780E-C5	5.1998E-05
46	3.7060E-02	0.0	0.0	2.0372E-C5	1.8990E-05
47	2.3596E-01	0.0	0.0	7.7873E-C4	7.2594E-04
48	2.2473E-02	0.0	0.0	5.6421E-C6	5.2596E-06
49	4.0404E-03	0.0	0.0	1.1066E-C7	1.0316E-07
50	8.0796E-03	0.0	0.0	3.6882E-C7	3.4381E-07
51	0.0	0.0	0.0	0.0	0.0
52	0.0	0.0	0.0	0.0	0.0
53	4.3392E-02	0.0	0.0	1.9807E-06	1.8464E-06
54	0.0	0.0	0.0	0.0	0.0
55	0.0	0.0	0.0	0.0	0.0
56	2.4643E-01	0.0	0.0	1.7548E-05	1.6358E-05

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

GPAV - KIND = 7 - EPS INCREASED FROM 0.1000E-03 TO 0.5000E-03

1 ETGP/ 14, 3- 1-75, R. A. GRIMESY : PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 7

52-U- 238 URANIUM-238, REV. 1

TIME: 233.38/ 368.49 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

RESOLVED RESONANCE POTENTIAL SCATTERING TERM

GROUP	CROSS SECTION
32	7.4220E 00
33	1.0555E 01
34	1.0564E 01
35	1.0572E 01
36	1.0578E 01
37	1.0582E 01
38	1.0585E 01
39	1.0588E 01
40	1.0590E 01
41	1.0592E 01
42	1.0593E 01
43	1.0594E 01
44	1.0595E 01
45	1.0596E 01
46	1.0596E 01
47	1.0597E 01
48	1.0597E 01
49	1.0597E 01
50	1.0598E 01
51	1.0598E 01
52	1.0598E 01
53	1.0598E 01
54	1.0598E 01
55	1.0598E 01
56	1.0598E 01
57	1.0598E 01
58	1.0598E 01
59	1.0598E 01
60	1.0598E 01
61	1.0598E 01
62	1.0598E 01
63	1.0598E 01
64	1.0598E 01
65	5.0045E 00

92-U- 238 URANIUM-238, REV. 1

TIME: 0.02/ 368.51 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NU. = 1262

RESOLVED
RESONANCE CALCULATION RESULTS

THE RESOLVED SHIELDING FACTOR IS: 1.000E 00

THE FOLLOWING CROSS SECTIONS ARE PRINTED FOR INFORMATION ONLY
 THEY ARE S-WAVE RESOLVED RESONANCE CONTRIBUTIONS WHICH ARE NOT PASSED TO PHROG
 AS PHROG RECALCULATES THEM FROM THE RESONANCE PARAMETERS
 NO POTENTIAL SCATTERING TERM IS INCLUDED HERE

GROUP	CAPTURE	FISSION	SCATTER	GROUP	CAPTURE	FISSION	SCATTER
1	0.0	0.0	0.0	35	1.6530E 00	0.0	1.3526E 01
2	0.0	0.0	0.0	36	1.5317E 00	0.0	6.7084E 00
3	0.0	0.0	0.0	37	2.1232E 00	0.0	1.1198E 01
4	0.0	0.0	0.0	38	2.9853E 00	0.0	7.5288E 00
5	0.0	0.0	0.0	39	3.5220E 00	0.0	8.9799E 00
6	0.0	0.0	0.0	40	3.3728E 00	0.0	3.9101E 00
7	0.0	0.0	0.0	41	2.3856E 00	0.0	1.1123E 00
8	0.0	0.0	0.0	42	4.6265E 00	0.0	5.8195E 00
9	0.0	0.0	0.0	43	6.6389E 00	0.0	8.7285E 00
10	0.0	0.0	0.0	44	1.6143E 01	0.0	8.0232E 01
11	0.0	0.0	0.0	45	2.5155E 00	0.0	-1.4447E 00
12	0.0	0.0	0.0	46	4.5063E 01	0.0	1.0130E 02
13	0.0	0.0	0.0	47	5.1624E 00	0.0	-4.3560E 00
14	0.0	0.0	0.0	48	4.6068E 01	0.0	4.7754E 01
15	0.0	0.0	0.0	49	1.3287E-01	0.0	-2.5111E 00
16	0.0	0.0	0.0	50	3.0691E 00	0.0	9.3683E 00
17	0.0	0.0	0.0	51	1.6922E 02	0.0	1.9097E 02
18	0.0	0.0	0.0	52	7.1971E-01	0.0	-2.3411E 00
19	0.0	0.0	0.0	53	2.4918E 02	0.0	7.5814E 01
20	0.0	0.0	0.0	54	4.4191E-01	0.0	-5.5110E 00
21	0.0	0.0	0.0	55	2.8836E-01	0.0	-4.2853E 00
22	0.0	0.0	0.0	56	6.5097E-01	0.0	-3.2455E 00
23	0.0	0.0	0.0	57	5.1141E 02	0.0	2.9201E 01
24	0.0	0.0	0.0	58	1.1627E 01	0.0	-7.7960E 00
25	0.0	0.0	0.0	59	1.1237E 00	0.0	-5.3558E 00
26	0.0	0.0	0.0	60	6.4492E-01	0.0	-4.8586E 00
27	0.0	0.0	0.0	61	5.1244E-01	0.0	-4.6249E 00
28	0.0	0.0	0.0	62	4.6766E-01	0.0	-4.4876E 00
29	0.0	0.0	0.0	63	4.5914E-01	0.0	-4.3976E 00
30	0.0	0.0	0.0	64	4.7110E-01	0.0	-4.3359E 00
31	0.0	0.0	0.0	65	2.3087E-01	0.0	-2.0316E 00
32	5.6824E-01	0.0	6.0617E 00	66	0.0	0.0	0.0
33	1.1187E 00	0.0	5.7299E 00	67	0.0	0.0	0.0
34	1.3203E 00	0.0	1.0386E 01	68	0.0	0.0	0.0

N2X RESET AT PRESS, 9555

(ETGP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 9

92-U- 238 URANIUM-238, REV. 1

TIME: 0.25/ 368.76 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

RESOLVED
RESONANCE CALCULATION RESULTS
S-WAVE RESONANCES WITHIN THE GROUP STRUCTURE-- TO BE PASSED TO PHROG

NG.	E-ZERC	GAMMA-N	GAMMA-G	GAMMA-F	G-FACTOR	NROIM
1	6.6700E 00	1.5000E-03	2.5600E-02	0.0	1.0000E 00	1
2	2.0900E 01	8.8000E-03	2.6800E-02	0.0	1.0000E 00	1
3	3.6800E 01	3.1100E-02	2.6000E-02	0.0	1.0000E 00	1
4	6.6150E 01	2.5300E-02	2.3500E-02	0.0	1.0000E 00	1
5	8.0740E 01	2.0000E-03	2.3500E-02	0.0	1.0000E 00	2
6	1.0250E 02	7.1000E-02	2.6000E-02	0.0	1.0000E 00	1
7	1.1680E 02	2.8270E-02	2.3500E-02	0.0	1.0000E 00	2
8	1.4560E 02	8.9000E-04	2.3500E-02	0.0	1.0000E 00	2
9	1.6520E 02	3.4000E-03	2.3500E-02	0.0	1.0000E 00	2
10	1.8960E 02	1.6900E-01	2.4700E-02	0.0	1.0000E 00	1
11	2.0840E 02	5.5090E-02	2.3500E-02	0.0	1.0000E 00	2
12	2.3720E 02	2.9110E-02	2.3500E-02	0.0	1.0000E 00	2
13	2.7360E 02	2.7000E-02	2.3100E-02	0.0	1.0000E 00	2
14	2.9100E 02	1.6980E-02	2.3100E-02	0.0	1.0000E 00	2
15	3.1120E 02	1.1000E-03	2.3500E-02	0.0	1.0000E 00	2
16	3.4770E 02	8.3600E-02	2.3500E-02	0.0	1.0000E 00	2
17	3.7680E 02	1.2600E-03	2.3500E-02	0.0	1.0000E 00	2
18	3.9740E 02	6.4000E-03	2.5200E-02	0.0	1.0000E 00	2
19	4.1020E 02	2.0600E-02	2.2600E-02	0.0	1.0000E 00	2
20	4.3370E 02	9.9800E-03	2.3500E-02	0.0	1.0000E 00	2
21	4.5410E 02	4.6000E-04	2.3500E-02	0.0	1.0000E 00	2
22	4.6280E 02	5.5000E-03	2.3500E-02	0.0	1.0000E 00	2
23	4.7830E 02	3.8000E-03	2.3500E-02	0.0	1.0000E 00	2
24	5.1830E 02	5.1600E-02	2.4400E-02	0.0	1.0000E 00	2
25	5.3520E 02	4.7000E-02	2.3500E-02	0.0	1.0000E 00	2
26	5.5590E 02	8.0000E-04	2.3500E-02	0.0	1.0000E 00	2
27	5.7550E 02	4.4100E-02	2.3500E-02	0.0	1.0000E 00	2
28	5.9480E 02	8.5100E-02	2.3100E-02	0.0	1.0000E 00	2
29	6.1980E 02	3.3000E-02	2.3500E-02	0.0	1.0000E 00	2
30	6.2850E 02	6.7000E-03	2.3500E-02	0.0	1.0000E 00	2
31	6.6110E 02	1.3560E-01	2.5100E-02	0.0	1.0000E 00	2
32	6.9290E 02	4.3800E-02	2.4100E-02	0.0	1.0000E 00	2
33	7.0800E 02	2.1000E-02	2.6000E-02	0.0	1.0000E 00	2
34	7.2140E 02	1.2000E-03	2.3500E-02	1.2000E-03	1.0000E 00	2
35	7.3250E 02	2.5000E-03	2.3500E-02	0.0	1.0000E 00	2
36	7.6500E 02	7.6200E-03	2.3500E-02	0.0	1.0000E 00	2
37	7.7930E 02	2.0000E-03	2.3500E-02	0.0	1.0000E 00	2
38	7.9070E 02	6.5300E-03	2.3500E-02	0.0	1.0000E 00	2
39	8.2150E 02	6.6000E-02	2.4000E-02	0.0	1.0000E 00	2
40	8.5060E 02	5.5100E-02	2.3000E-02	0.0	1.0000E 00	2
41	8.5610E 02	8.2700E-02	2.3600E-02	0.0	1.0000E 00	2
42	8.6600E 02	5.7000E-03	2.3500E-02	0.0	1.0000E 00	2
43	9.0450E 02	5.2000E-02	2.6800E-02	0.0	1.0000E 00	2
44	9.2450E 02	1.3900E-02	2.3500E-02	0.0	1.0000E 00	2
45	9.3660E 02	1.3660E-01	2.3600E-02	0.0	1.0000E 00	2
46	9.5800E 02	1.9040E-01	2.2700E-02	0.0	1.0000E 00	2
47	9.9140E 02	3.9000E-01	3.0000E-02	0.0	1.0000E 00	2
48	1.0116E 03	1.5900E-03	2.3500E-02	0.0	1.0000E 00	2

52	1.0990E	03	1.7000E-02	2.2000E-02	0.0	1.0000E	00	2
53	1.1089E	03	2.7000E-02	2.3500E-02	0.0	1.0000E	00	2
54	1.1211E	03	3.0000E-03	2.3500E-02	0.0	1.0000E	00	2
55	1.1404E	03	2.2000E-01	2.3500E-02	0.0	1.0000E	00	2
56	1.1675E	03	8.5000E-03	2.3500E-02	0.0	1.0000E	00	2
57	1.1766E	03	6.0000E-02	2.3500E-02	0.0	1.0000E	00	2
58	1.1945E	03	8.9000E-02	2.3500E-02	0.0	1.0000E	00	2
59	1.2111E	03	5.0000E-03	2.3500E-02	1.2000E-04	1.0000E	00	2
60	1.2449E	03	2.8000E-01	2.3500E-02	0.0	1.0000E	00	2
61	1.2668E	03	2.2100E-02	2.1000E-02	0.0	1.0000E	00	2
62	1.2727E	03	2.7000E-02	2.3500E-02	0.0	1.0000E	00	2
63	1.2981E	03	4.5000E-03	2.3500E-02	0.0	1.0000E	00	2
64	1.3163E	03	4.0000E-03	2.3500E-02	0.0	1.0000E	00	2
65	1.3327E	03	1.6000E-03	2.3500E-02	0.0	1.0000E	00	2
66	1.3932E	03	1.8200E-01	2.3500E-02	0.0	1.0000E	00	2
67	1.4052E	03	7.0000E-02	2.3500E-02	0.0	1.0000E	00	2
68	1.4192E	03	9.0000E-03	2.3500E-02	0.0	1.0000E	00	2
69	1.4274E	03	2.9100E-02	2.6000E-02	0.0	1.0000E	00	2
70	1.4435E	03	1.8000E-02	2.3500E-02	0.0	1.0000E	00	2
71	1.4734E	03	1.2500E-01	2.3500E-02	0.0	1.0000E	00	2
72	1.5223E	03	2.4000E-01	2.3500E-02	0.0	1.0000E	00	2
73	1.5330E	03	4.0000E-04	2.3500E-02	0.0	1.0000E	00	2
74	1.5465E	03	4.0000E-03	2.3500E-02	0.0	1.0000E	00	2
75	1.5660E	03	5.4000E-03	2.3500E-02	0.0	1.0000E	00	2
76	1.5975E	03	3.5500E-01	2.3500E-02	0.0	1.0000E	00	2
77	1.6220E	03	7.0000E-02	2.3500E-02	0.0	1.0000E	00	2
78	1.6374E	03	5.0000E-02	2.3500E-02	0.0	1.0000E	00	2
79	1.6613E	03	1.7000E-01	2.3500E-02	0.0	1.0000E	00	2
80	1.6883E	03	9.2000E-02	2.3500E-02	0.0	1.0000E	00	2
81	1.7090E	03	8.4000E-02	2.8000E-02	0.0	1.0000E	00	2
82	1.7222E	03	1.5000E-02	2.3500E-02	0.0	1.0000E	00	2
83	1.7552E	03	1.0500E-01	2.7000E-02	0.0	1.0000E	00	2
84	1.7821E	03	6.7000E-01	2.3500E-02	0.0	1.0000E	00	2
85	1.7955E	03	3.0000E-03	2.3500E-02	0.0	1.0000E	00	2
86	1.8079E	03	1.4500E-02	2.3500E-02	0.0	1.0000E	00	2
87	1.8455E	03	1.3000E-02	2.3500E-02	0.0	1.0000E	00	2
88	1.8680E	03	2.7000E-03	2.3500E-02	0.0	1.0000E	00	2
89	1.8700E	03	2.7000E-03	2.3500E-02	0.0	1.0000E	00	2
90	1.9024E	03	3.0000E-02	2.3500E-02	0.0	1.0000E	00	2
91	1.9165E	03	2.4900E-02	2.3500E-02	0.0	1.0000E	00	2
92	1.9534E	03	3.7000E-03	2.3500E-02	0.0	1.0000E	00	2
93	1.9686E	03	6.7000E-01	2.5000E-02	0.0	1.0000E	00	2
94	1.9743E	03	5.0000E-01	2.3500E-02	0.0	1.0000E	00	2
95	2.0228E	03	2.1500E-01	2.3500E-02	0.0	1.0000E	00	2
96	2.0298E	03	6.1000E-02	2.3500E-02	0.0	1.0000E	00	2
97	2.0709E	03	3.0000E-03	2.3500E-02	0.0	1.0000E	00	2
98	2.0881E	03	2.7000E-02	2.3500E-02	0.0	1.0000E	00	2
99	2.0959E	03	2.3000E-02	2.3500E-02	0.0	1.0000E	00	2
100	2.1238E	03	3.2000E-03	2.3500E-02	0.0	1.0000E	00	2
101	2.1446E	03	6.2000E-02	2.3500E-02	0.0	1.0000E	00	2
102	2.1522E	03	2.4000E-01	2.3500E-02	0.0	1.0000E	00	2
103	2.1860E	03	6.2000E-01	2.3500E-02	0.0	1.0000E	00	2
104	2.2006E	03	1.2000E-01	2.3500E-02	0.0	1.0000E	00	2
105	2.2170E	03	4.0000E-03	2.3500E-02	0.0	1.0000E	00	2
106	2.2410E	03	1.5000E-03	2.3500E-02	0.0	1.0000E	00	2
107	2.2588E	03	8.6000E-02	2.3500E-02	0.0	1.0000E	00	2
108	2.2670E	03	2.1000E-01	2.3500E-02	0.0	1.0000E	00	2
109	2.2817E	03	1.3500E-01	2.3500E-02	0.0	1.0000E	00	2
110	2.3155E	03	2.1000E-02	2.3500E-02	0.0	1.0000E	00	2
111	2.3390E	03	9.5000E-03	2.3500E-02	0.0	1.0000E	00	2
112	2.3528E	03	4.7000E-02	2.3500E-02	0.0	1.0000E	00	2
113	2.3553E	03	6.1000E-02	2.3500E-02	0.0	1.0000E	00	2
114	2.3914E	03	2.6000E-02	2.3500E-02	0.0	1.0000E	00	2
115	2.4108E	03	4.6000E-03	2.3500E-02	0.0	1.0000E	00	2
116	2.4257E	03	1.3500E-01	2.3500E-02	0.0	1.0000E	00	2
117	2.4455E	03	1.9500E-01	2.3500E-02	0.0	1.0000E	00	2

118	2.4548E	03	1.9000E-02	2.3500E-02	0.0	1.0000E	00	2
119	2.4884E	03	8.8000E-02	2.3500E-02	0.0	1.0000E	00	2
120	2.5207E	03	1.4000E-02	2.3500E-02	0.0	1.0000E	00	2
121	2.5472E	03	5.5000E-01	2.3500E-02	0.0	1.0000E	00	2
122	2.5585E	03	2.3000E-01	2.3500E-02	0.0	1.0000E	00	2
123	2.5799E	03	3.3000E-01	2.3500E-02	0.0	1.0000E	00	2
124	2.5965E	03	6.7000E-01	2.3500E-02	0.0	1.0000E	00	2
125	2.6191E	03	4.5000E-02	2.3500E-02	0.0	1.0000E	00	2
126	2.6217E	03	3.5000E-03	2.3500E-02	0.0	1.0000E	00	2
127	2.6713E	03	2.4000E-01	2.3500E-02	0.0	1.0000E	00	2
128	2.6956E	03	1.9000E-02	2.3500E-02	0.0	1.0000E	00	2
129	2.7165E	03	1.4500E-01	2.3500E-02	0.0	1.0000E	00	2
130	2.7324E	03	1.8000E-03	2.3500E-02	0.0	1.0000E	00	2
131	2.7497E	03	4.5000E-02	2.3500E-02	0.0	1.0000E	00	2
132	2.7616E	03	2.3100E-02	2.3500E-02	0.0	1.0000E	00	2
133	2.7860E	03	1.2100E-02	2.3500E-02	0.0	1.0000E	00	2
134	2.8054E	03	8.0000E-03	2.3500E-02	0.0	1.0000E	00	2
135	2.8280E	03	1.7500E-02	2.3500E-02	0.0	1.0000E	00	2
136	2.8641E	03	1.7500E-01	2.3500E-02	0.0	1.0000E	00	2
137	2.8820E	03	5.5000E-01	2.3500E-02	0.0	1.0000E	00	2
138	2.8963E	03	1.5000E-02	2.3500E-02	0.0	1.0000E	00	2
139	2.9230E	03	3.1000E-02	2.3500E-02	0.0	1.0000E	00	2
140	2.9557E	03	2.1000E-02	2.3500E-02	0.0	1.0000E	00	2
141	2.9658E	03	3.3000E-03	2.3500E-02	0.0	1.0000E	00	2
142	2.9863E	03	5.5000E-03	2.3500E-02	0.0	1.0000E	00	2
143	3.0024E	03	1.1700E-01	2.3500E-02	0.0	1.0000E	00	2
144	3.0151E	03	1.6500E-03	2.3500E-02	0.0	1.0000E	00	2
145	3.0278E	03	1.2500E-01	2.3500E-02	0.0	1.0000E	00	2
146	3.0425E	03	3.5000E-03	2.3500E-02	0.0	1.0000E	00	2
147	3.0581E	03	3.2000E-02	2.3500E-02	0.0	1.0000E	00	2
148	3.1088E	03	1.9000E-01	2.3500E-02	0.0	1.0000E	00	2
149	3.1326E	03	8.0000E-03	2.3500E-02	0.0	1.0000E	00	2
150	3.1461E	03	7.5000E-02	2.3500E-02	0.0	1.0000E	00	2
151	3.1685E	03	1.2000E-02	2.3500E-02	0.0	1.0000E	00	2
152	3.1778E	03	7.4000E-02	2.3500E-02	0.0	1.0000E	00	2
153	3.1861E	03	6.0000E-02	2.3500E-02	0.0	1.0000E	00	2
154	3.2049E	03	7.3000E-02	2.3500E-02	0.0	1.0000E	00	2
155	3.2170E	03	8.0000E-03	2.3500E-02	0.0	1.0000E	00	2
156	3.2249E	03	3.3000E-02	2.3500E-02	0.0	1.0000E	00	2
157	3.2461E	03	2.8000E-02	2.3500E-02	0.0	1.0000E	00	2
158	3.2720E	03	8.0000E-03	2.3500E-02	0.0	1.0000E	00	2
159	3.2782E	03	2.3500E-01	2.3500E-02	0.0	1.0000E	00	2
160	3.2952E	03	8.0000E-03	2.3500E-02	0.0	1.0000E	00	2
161	3.3103E	03	1.2300E-01	2.3500E-02	0.0	1.0000E	00	2
162	3.3202E	03	1.0300E-01	2.3500E-02	0.0	1.0000E	00	2
163	3.3329E	03	7.0000E-02	2.3500E-02	0.0	1.0000E	00	2
164	3.3540E	03	1.0800E-01	2.3500E-02	0.0	1.0000E	00	2
165	3.3883E	03	1.4500E-02	2.3500E-02	0.0	1.0000E	00	2
166	3.4079E	03	1.9000E-01	2.3500E-02	0.0	1.0000E	00	2
167	3.4177E	03	4.1000E-03	2.3500E-02	0.0	1.0000E	00	2
168	3.4353E	03	3.5000E-01	2.3500E-02	0.0	1.0000E	00	2
169	3.4563E	03	5.0000E-01	2.3500E-02	0.0	1.0000E	00	2
170	3.4843E	03	1.0500E-01	2.3500E-02	0.0	1.0000E	00	2
171	3.4933E	03	5.4000E-03	2.3500E-02	0.0	1.0000E	00	2
172	3.5264E	03	5.0000E-03	2.3500E-02	0.0	1.0000E	00	2
173	3.5605E	03	2.2000E-04	2.3500E-02	0.0	1.0000E	00	2
174	3.5727E	03	3.3000E-01	2.3500E-02	0.0	1.0000E	00	2
175	3.5933E	03	4.0000E-02	2.3500E-02	0.0	1.0000E	00	2
176	3.6218E	03	2.0000E-02	2.3500E-02	0.0	1.0000E	00	2
177	3.6283E	03	4.2000E-01	2.3500E-02	0.0	1.0000E	00	2
178	3.6718E	03	7.9000E-03	2.3500E-02	0.0	1.0000E	00	2
179	3.6920E	03	3.2000E-01	2.3500E-02	0.0	1.0000E	00	2
180	3.7159E	03	6.0000E-02	2.3500E-02	0.0	1.0000E	00	2
181	3.7372E	03	1.9500E-01	2.3500E-02	0.0	1.0000E	00	2
182	3.7636E	03	7.2000E-02	2.3500E-02	0.0	1.0000E	00	2
183	3.7808E	03	2.5000E-01	2.3500E-02	0.0	1.0000E	00	2

184	3.8303E 03	1.1000E-02	2.3500E-02	0.0	1.0000E 00	2
185	3.8564E 03	4.9500E-01	2.3500E-02	0.0	1.0000E 00	2
186	3.8721E 03	1.7000E-01	2.3500E-02	0.0	1.0000E 00	2
187	3.9013E 03	2.7000E-01	2.3500E-02	0.0	1.0000E 00	2
188	3.9134E 03	9.0000E-02	2.3500E-02	0.0	1.0000E 00	2
189	3.9390E 03	1.2000E-01	2.3500E-02	0.0	1.0000E 00	2
190	3.9539E 03	1.0500E-01	2.3500E-02	0.0	1.0000E 00	2

ETOP/ 14, 3- 1-75, R. A. GRIMESY ; PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 10

92-U- 238 URANIUM-238, REV. 1

TIME: 0.50/ 369.26 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NDV-74

040900000000

ENDF/B MAT. NO. = 1262

UNRESOLVED
 RESONANCE CALCULATION RESULTS
 THE FOLLOWING CROSS SECTIONS ARE ADDED TO THE SMOOTH VALUES TO ACCOUNT FOR
 UNRESOLVED RESONANCE CONTRIBUTIONS
 THE UNRESOLVED SHIELDING FACTOR IS: 1.000E 00

THE POTENTIAL SCATTERING TERM OVER THREE L-STATES IS INCLUDED HERE

GROUP	CAPTURE	FISSION	SCATTER	GROUP	CAPTURE	FISSION	SCATTER
1	0.0	0.0	0.0	35	0.0	0.0	0.0
2	0.0	0.0	0.0	36	0.0	0.0	0.0
3	0.0	0.0	0.0	37	0.0	0.0	0.0
4	0.0	0.0	0.0	38	0.0	0.0	0.0
5	0.0	0.0	0.0	39	0.0	0.0	0.0
6	0.0	0.0	0.0	40	0.0	0.0	0.0
7	0.0	0.0	0.0	41	0.0	0.0	0.0
8	0.0	0.0	0.0	42	0.0	0.0	0.0
9	0.0	0.0	0.0	43	0.0	0.0	0.0
10	0.0	0.0	0.0	44	0.0	0.0	0.0
11	0.0	0.0	0.0	45	0.0	0.0	0.0
12	0.0	0.0	0.0	46	0.0	0.0	0.0
13	0.0	0.0	0.0	47	0.0	0.0	0.0
14	0.0	0.0	0.0	48	0.0	0.0	0.0
15	0.0	0.0	0.0	49	0.0	0.0	0.0
16	0.0	0.0	0.0	50	0.0	0.0	0.0
17	0.0	0.0	0.0	51	0.0	0.0	0.0
18	0.0	0.0	0.0	52	0.0	0.0	0.0
19	0.0	0.0	0.0	53	0.0	0.0	0.0
20	0.0	0.0	0.0	54	0.0	0.0	0.0
21	0.0	0.0	0.0	55	0.0	0.0	0.0
22	1.3423E-01	0.0	4.7461E 00	56	0.0	0.0	0.0
23	3.8052E-01	0.0	1.2481E 01	57	0.0	0.0	0.0
24	4.3712E-01	0.0	1.2795E 01	58	0.0	0.0	0.0
25	4.9738E-01	0.0	1.3127E 01	59	0.0	0.0	0.0
26	5.6263E-01	0.0	1.3485E 01	60	0.0	0.0	0.0
27	6.2962E-01	0.0	1.3877E 01	61	0.0	0.0	0.0
28	6.9925E-01	0.0	1.4304E 01	62	0.0	0.0	0.0
29	7.6448E-01	0.0	1.4776E 01	63	0.0	0.0	0.0
30	8.8201E-01	0.0	1.5349E 01	64	0.0	0.0	0.0
31	9.9052E-01	0.0	1.5964E 01	65	0.0	0.0	0.0
32	3.1410E-01	0.0	4.8536E 00	66	0.0	0.0	0.0
33	0.0	0.0	0.0	67	0.0	0.0	0.0
34	0.0	0.0	0.0	68	0.0	0.0	0.0

(ETOP/ 14, 3- 1-75- R. A. GRIMES) PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 11

92-U- 238 URANIUM-238. REV. 1

TIME: 24.88/ 394.14 (SEC.)

ENDF/B-IV TAPE 409(REV.1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

UNRESOLVED RESONANCE POTENTIAL SCATTERING TERM

GROUP	CROSS SECTION
22	3.8670E 00
23	1.0156E 01
24	1.0243E 01
25	1.0314E 01
26	1.0372E 01
27	1.0420E 01
28	1.0458E 01
29	1.0488E 01
30	1.0512E 01
31	1.0521E 01
32	3.1221E 00

DATE OF RUN 12/04/75 PAGE 12

TIME: 3.38/ 397.51 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

*** E T O P ***

ENDF/B FILE 3 SMOOTH ELASTIC

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	3.1707E 00	2	3.7773E 00	3	4.4516E 00	4	4.8133E 00	5	4.8151E 00	6	4.5098E 00
7	4.1307E 00	8	4.0343E 00	9	4.4315E 00	10	5.0155E 00	11	5.6781E 00	12	6.4731E 00
13	7.2259E 00	14	8.0582E 00	15	8.8666E 00	16	9.5625E 00	17	1.0180E 01	18	1.0866E 01
19	1.1561E 01	20	1.2071E 01	21	1.2424E 01	22	7.9069E 00	23	2.9994E-01	24	2.7938E-01
25	2.1874E-01	26	1.4152E-01	27	7.1651E-02	28	2.6491E-02	29	1.2229E-03	30	0.0
31	0.0	32	0.0	33	0.0	34	0.0	35	0.0	36	0.0
37	0.0	38	0.0	39	0.0	40	0.0	41	0.0	42	0.0
43	0.0	44	0.0	45	0.0	46	0.0	47	2.6415E-01	48	7.6670E-01
49	1.1587E 00	50	1.4642E 00	51	1.7018E 00	52	1.8870E 00	53	2.0312E 00	54	2.1435E 00
55	2.2310E 00	56	2.2991E 00	57	2.3522E 00	58	2.3935E 00	59	2.4256E 00	60	2.4507E 00
61	2.4703E 00	62	2.4854E 00	63	2.4973E 00	64	2.5066E 00	65	5.8475E 00	66	8.8557E 00
67	8.8790E 00	68	8.8966E 00								

(ETGP/ 14, 3- 1-75, R. A. GRIMES) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

92-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV.1)

18-NOV-74

040900000000

DATE OF RUN 12/04/75 PAGE 13

TIME: 1.98/ 359.49 (SEC.)

ENDF/B MAT. NO. = 1262

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 6
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 16

DATE OF RUN 12/04/75 PAGE 14

TIME: 1.51/ 401.01 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

*** ETOP ***

ENDF,B FILE 3 SMOOTH N,2*N REACTION

GRP	CROSS	SEC	GRP	CROSS	SEC	GRP	CROSS	SEC	GRP	CROSS	SEC	GRP	CROSS	SEC	GRP	CROSS	SEC
1	1.3608E	00	2	3.6017E-01		3	0.0		4	0.0		5	0.0		6	0.0	
7	C.0		8	C.0		9	0.0		10	0.0		11	0.0		12	0.0	
13	0.0		14	0.0		15	0.0		16	0.0		17	0.0		18	0.0	
19	C.0		20	0.0		21	0.0		22	0.0		23	0.0		24	0.0	
25	C.0		26	C.0		27	0.0		28	0.0		29	0.0		30	0.0	
31	0.0		32	0.0		33	0.0		34	0.0		35	0.0		36	0.0	
37	C.0		38	0.0		39	0.0		40	0.0		41	0.0		42	0.0	
43	C.C		44	0.0		45	0.0		46	0.0		47	0.0		48	0.0	
49	C.C		50	0.0		51	C.0		52	0.0		53	0.0		54	0.0	
55	C.C		56	0.0		57	0.0		58	0.0		59	0.0		60	0.0	
61	0.0		62	0.0		63	0.0		64	0.0		65	0.0		66	0.0	
67	0.0		68	0.0													

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/6 DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 15

92-U- 238 URANIUM-238, REV. 1

TIME: 1.26/ 402.27 (SEC.)

ENDF/B-IV TAPE 409 (REV 1)

18-NOV-74 040900000000

ENDF/6 MAT. NO. = 1262

*** ETOP ***

ENDF/3 FILE 3 SMOOTH N,F REACTION

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	9.9099E-01	2	8.5845E-01	3	5.7403E-01	4	5.6318E-01	5	5.4776E-01	6	5.5128E-01
7	5.1893E-01	8	3.0667E-01	9	4.2840E-02	10	1.2523E-02	11	2.0165E-03	12	7.0065E-04
13	1.7075E-04	14	5.3543E-05	15	6.5360E-05	16	5.6432E-05	17	4.9480E-05	18	4.4070E-05
19	4.0389E-05	20	4.0000E-05	21	4.0000E-05	22	4.0000E-05	23	5.8224E-05	24	8.5993E-05
25	8.7000E-05	26	8.7000E-05	27	8.7000E-05	28	7.7425E-05	29	4.9852E-06	30	0.0
31	0.0	32	0.0	33	0.0	34	0.0	35	0.0	36	0.0
37	0.0	38	0.0	39	0.0	40	0.0	41	0.0	42	0.0
43	0.0	44	0.0	45	0.0	46	0.0	47	0.0	48	0.0
49	0.0	50	0.0	51	0.0	52	0.0	53	0.0	54	0.0
55	0.0	56	0.0	57	0.0	58	0.0	59	0.0	60	0.0
61	0.0	62	0.0	63	0.0	64	0.0	65	0.0	66	0.0
67	0.0	68	0.0								

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 27
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 38

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 77
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 91

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 18

S2-U- 238 URANIUM-238, REV. 1

TIME: 0.03/ 406.28 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262.

*** ETOP ***

TOTAL N,GAMMA

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	2.7667E-03	2	4.5672E-03	3	7.5625E-03	4	1.2573E-02	5	2.0850E-02	6	3.3966E-02
7	5.2327E-02	8	7.7042E-02	9	1.0398E-01	10	1.2060E-01	11	1.1954E-01	12	1.1133E-01
13	1.0765E-01	14	1.1044E-01	15	1.2081E-01	16	1.3819E-01	17	1.5310E-01	18	1.7090E-01
19	1.9048E-01	20	2.2434E-01	21	2.9845E-01	22	3.6145E-01	23	4.0434E-01	24	4.5369E-01
25	5.0893E-01	26	5.7087E-01	27	6.3548E-01	28	7.0191E-01	29	7.6461E-01	30	8.8201E-01
31	9.9052E-01	32	1.1127E 00	33	1.3958E 00	34	1.5774E 00	35	1.8609E 00	36	1.7621E 00
37	2.3787E 00	38	3.1196E 00	39	3.7106E 00	40	3.4683E 00	41	2.4557E 00	42	4.7493E 00
43	6.8072E 00	44	1.6157E 01	45	2.5616E 00	46	4.5100E 01	47	5.3992E 00	48	4.6093E 01
49	1.4060E-01	50	3.0818E 00	51	1.6923E 02	52	7.2573E-01	53	2.4923E 02	54	4.4874E-01
55	2.9548E-01	56	9.0520E-01	57	5.1142E 02	58	1.1638E 01	59	1.1359E 00	60	6.5913E-01
61	5.2868E-01	62	4.6651E-01	63	4.8136E-01	64	4.9641E-01	65	5.2502E-01	66	5.6631E-01
67	6.1855E-01	68	6.8261E-01								

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 103
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,P REACTION

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 104
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,D REACTION

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 105
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,T REACTION

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 106
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,HE-3 REACTION

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 107
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,ALPHA REACTION

NO DATA IN FILE 3 FOR MATERIAL 1262, REACTION TYPE 108
TAPE HAS BEEN SEARCHED TO MATERIAL 1262, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,2*ALPHA REACTION

(ETUP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 19

92-U- 238 URANIUM-238, REV. 1

TIME: 0.12/ 408.40 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

P-WAVE RESOLVED RESONANCE CONTRIBUTIONS CALCULATED BY AN ANALYTIC FORMULA
PLUS SMOOTH FILE 3 CONTRIBUTION OVER ALL GROUPS
PLUS SMOOTH CONTRIBUTIONS FROM THERMAL AND NEGATIVE RESONANCES

GROUP	SCATTER (EL TO EC)	SCATTER (EL TO EH)
1	3.3394E 00	3.1707E 00
2	4.0676E 00	3.7773E 00
3	4.6575E 00	4.4516E 00
4	4.8804E 00	4.8133E 00
5	4.7275E 00	4.8151E 00
6	4.2972E 00	4.5098E 00
7	4.0233E 00	4.1207E 00
8	4.1803E 00	4.0343E 00
9	4.7056E 00	4.4315E 00
10	5.2752E 00	5.0155E 00
11	6.0876E 00	5.6781E 00
12	6.8405E 00	6.4731E 00
13	7.6165E 00	7.2255E 00
14	8.4788E 00	8.0582E 00
15	9.2297E 00	8.8666E 00
16	9.8736E 00	9.5625E 00
17	1.0488E 01	1.0180E 01
18	1.1237E 01	1.0866E 01
19	1.1847E 01	1.1561E 01
20	1.2256E 01	1.2071E 01
21	1.2577E 01	1.2424E 01
22	2.9996E-01	7.9065E 00
23	2.9992E-01	2.9594E-01
24	2.4951E-01	2.7938E-01
25	1.8930E-01	2.1674E-01
26	1.0317E-01	1.4152E-01
27	4.7183E-02	7.1651E-02
28	9.9129E-03	2.6491E-02
29	0.0	1.2229E-03
30	0.0	0.0
31	0.0	0.0
32	6.9190E-02	1.2625E-01
33	9.9935E-03	2.1935E-02
34	1.5553E-02	1.3621E-02

(ETGP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

52-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

DATE OF RUN 12/04/75 PAGE 20

TIME: 0.08/ 408.48 (SEC.)

ENDF/B MAT. NO. = 1262

GROUP SCATTER (EL TO EC) SCATTER (EL TO EH)

35	9.8069E-03	8.7053E-03
36	5.1628E-03	1.0435E-02
37	9.8852E-03	7.6657E-03
38	3.6007E-03	3.1741E-03
39	4.3406E-04	4.4934E-03
40	0.0	1.4830E-03
41	7.4000E-05	4.5104E-04
42	2.6529E-03	6.3813E-04
43	3.7599E-04	1.0008E-03
44	0.0	7.2133E-05
45	0.0	5.1998E-05
46	0.0	1.8950E-05
47	5.1880E-01	2.6487E-01
48	5.6569E-01	7.6670E-01
49	1.3137E 00	1.1587E 00
50	1.5848E 00	1.4642E 00
51	1.7959E 00	1.7018E 00
52	1.9603E 00	1.8870E 00
53	2.0883E 00	2.0312E 00
54	2.1880E 00	2.1455E 00
55	2.2657E 00	2.2310E 00
56	2.3262E 00	2.2991E 00
57	2.3733E 00	2.3522E 00
58	2.4099E 00	2.3935E 00
59	2.4385E 00	2.4256E 00
60	2.4608E 00	2.4507E 00
61	2.4781E 00	2.4703E 00
62	2.4915E 00	2.4854E 00
63	2.5021E 00	2.4973E 00
64	2.5103E 00	2.5066E 00
65	8.8407E 00	5.6475E 00
66	8.8679E 00	8.8557E 00
67	8.8879E 00	8.8790E 00
68	8.9033E 00	8.8966E 00

92-U- 23E URANIUM-238, REV. 1

TIME: 52.85/ 461.33 (SEC.)

ENDF/B-IV TAPE 409(REV.1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

MULTI- GROUP	CAPTURE	FISSION	ABSORPTION	SCATTERING	ANISOTROPIC SCATTERING	INELASTIC SCATTERING	N-2N	NEUTRONS PER FISSION
1	2.7667E-03	9.9099E-01	9.9375E-01	3.17C6E C0	2.5649E 00	6.2104E-01	1.3608E 00	1.6429E 00
2	4.5672E-03	8.5845E-01	8.6302E-01	3.7772E C0	3.0422E 00	1.8239E 00	3.6017E-01	3.3750E 00
3	7.5625E-03	5.7403E-01	5.8150E-01	4.4516E C0	3.5827E 00	2.4915E 00	0.0	3.1375E 00
4	1.2573E-02	5.6318E-01	5.7575E-01	4.8133E C0	3.7832E 00	2.5021E 00	0.0	2.9569E 00
5	2.0850E-02	5.4776E-01	5.6851E-01	4.8151E 00	3.5543E 00	2.5093E 00	0.0	2.8183E 00
6	3.3966E-02	5.3128E-01	5.8525E-01	4.5058E C0	2.9659E 00	2.4927E 00	0.0	2.7088E 00
7	5.2327E-02	5.1893E-01	5.7126E-01	4.1306E G0	2.4818E 00	2.5011E 00	0.0	2.6247E 00
8	7.7042E-02	3.0467E-01	3.8371E-01	4.0342E 00	2.1883E 00	2.5859E 00	0.0	2.5626E 00
9	1.0398E-01	4.2840E-02	1.4632E-01	4.4315E G0	2.2320E 00	2.4411E 00	0.0	2.5099E 00
10	1.2060E-01	1.2523E-02	1.3312E-01	5.0155E C0	2.2244E 00	2.1429E 00	0.0	2.4674E 00
11	1.1954E-01	2.0165E-03	1.2155E-01	5.6781E G0	2.2854E 00	1.9492E 00	0.0	2.4350E 00
12	1.1133E-01	7.0065E-04	1.1203E-01	6.4731E C0	2.2597E 00	1.7516E 00	0.0	2.4104E 00
13	1.0765E-01	1.7675E-04	1.0782E-01	7.2257E 00	2.2023E 00	1.5547E 00	0.0	2.3888E 00
14	1.1044E-01	9.3543E-05	1.1054E-01	8.0581E G0	2.1355E 00	1.3508E 00	0.0	2.3733E 00
15	1.2081E-01	6.5560E-05	1.2087E-01	8.8665E 00	2.0169E 00	1.1772E 00	0.0	2.3612E 00
16	1.3819E-01	5.6432E-05	1.3824E-01	9.5623E 00	1.8178E 00	1.0351E 00	0.0	2.3519E 00
17	1.5310E-01	4.9480E-05	1.5315E-01	1.0180E 01	1.6147E 00	8.9582E-01	0.0	2.3449E 00
18	1.7090E-01	4.4070E-05	1.7094E-01	1.0866E 01	1.3924E 00	7.0321E-01	0.0	2.3391E 00
19	1.9048E-01	4.0589E-05	1.9052E-01	1.1561E 01	1.1897E 00	4.7103E-01	0.0	2.3348E 00
20	2.2434E-01	4.0100E-05	2.2438E-01	1.2071E 01	9.8932E-01	2.8676E-01	0.0	2.3314E 00
21	2.9845E-01	4.0100E-05	2.9849E-01	1.2424E 01	6.6971E-01	1.3791E-01	0.0	2.3287E 00
22	3.6145E-01	4.0100E-05	3.6149E-01	1.2653E 01	4.3266E-01	1.8354E-02	0.0	2.3267E 00
23	4.0434E-01	5.8224E-05	4.0440E-01	1.2781E 01	3.2893E-01	0.0	0.0	2.3249E 00
24	4.5365E-01	8.5593E-05	4.5378E-01	1.3075E 01	2.5020E-01	0.0	0.0	2.3238E 00
25	5.0893E-01	8.7100E-05	5.0902E-01	1.3346E 01	1.8085E-01	0.0	0.0	2.3229E 00
26	5.7087E-01	8.7100E-05	5.7096E-01	1.3625E 01	1.2126E-01	0.0	0.0	2.3221E 00
27	6.3548E-01	8.7100E-05	6.3557E-01	1.3951E 01	7.6191E-02	0.0	0.0	2.3216E 00
28	7.0191E-01	7.7425E-05	7.0198E-01	1.4330E 01	4.6452E-02	0.0	0.0	2.3211E 00
29	7.6461E-01	4.9552E-06	7.6461E-01	1.4778E 01	4.1751E-02	0.0	0.0	2.3210E 00
30	8.8201E-01	0.0	8.8201E-01	1.5345E 01	4.3364E-02	0.0	0.0	C.C
31	9.9052E-01	0.0	9.9052E-01	1.5964E 01	4.5102E-02	0.0	0.0	C.C
32	1.1137E 00	0.0	1.1137E 00	1.8535E 01	5.2370E-02	0.0	0.0	C.C
33	1.3958E 00	0.0	1.3958E 00	1.6405E 01	4.6374E-02	0.0	0.0	0.0
34	1.5774E 00	0.0	1.5774E 00	2.1105E 01	5.9639E-02	0.0	0.0	C.C
35	1.8605E 00	0.0	1.8605E 00	2.4203E 01	6.8399E-02	0.0	0.0	C.C

92-U- 238 URANIUM-238, REV. 1

TIME: 0.12/ 461.44 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

MULTI- GROUP	CAPTURE	FISSION	ABSORPTION	SCATTERING	ANISOTROPIC SCATTERING	INELASTIC SCATTERING	N-2N	NEUTRONS PER FISSION
36	1.7621E 00	0.0	1.7621E 00	1.7338E 01	4.8982E-02	0.0	0.0	0.0
37	2.3787E 00	0.0	2.3787E 00	2.1835E 01	6.1685E-02	0.0	0.0	0.0
38	3.1196E 00	0.0	3.1196E 00	1.8176E 01	5.1332E-02	0.0	0.0	0.0
39	3.7106E 00	0.0	3.7106E 00	1.9589E 01	5.5329E-02	0.0	0.0	0.0
40	3.4683E 00	0.0	3.4683E 00	1.4498E 01	4.0958E-02	0.0	0.0	0.0
41	2.4557E 00	0.0	2.4557E 00	1.1715E 01	3.3097E-02	0.0	0.0	0.0
42	4.7493E 00	0.0	4.7493E 00	2.0388E 01	5.7609E-02	0.0	0.0	0.0
43	6.8072E 00	0.0	6.8072E 00	1.9317E 01	5.4571E-02	0.0	0.0	0.0
44	1.6197E 01	0.0	1.6197E 01	9.0895E 01	2.5679E-01	0.0	0.0	0.0
45	2.5616E 00	0.0	2.5616E 00	9.1543E 00	2.5863E-02	0.0	0.0	0.0
46	4.5100E 01	0.0	4.5100E 01	1.1192E 02	3.1622E-01	0.0	0.0	0.0
47	5.3992E 00	0.0	5.3992E 00	6.5835E 00	1.8600E-02	0.0	0.0	0.0
48	4.6093E 01	0.0	4.6093E 01	5.9200E 01	1.6724E-01	0.0	0.0	0.0
49	1.4060E-01	0.0	1.4060E-01	9.2455E 00	2.6122E-02	0.0	0.0	0.0
50	3.0818E 00	0.0	3.0818E 00	2.1430E 01	6.0545E-02	0.0	0.0	0.0
51	1.6923E 02	0.0	1.6923E 02	2.0333E 02	5.7450E-01	0.0	0.0	0.0
52	7.2573E-01	0.0	7.2573E-01	1.0143E 01	2.8656E-02	0.0	0.0	0.0
53	2.4923E 02	0.0	2.4923E 02	8.8591E 01	2.5028E-01	0.0	0.0	0.0
54	4.4874E-01	0.0	4.4874E-01	7.2387E 00	2.0451E-02	0.0	0.0	0.0
55	2.9548E-01	0.0	2.9548E-01	8.5486E 00	2.4152E-02	0.0	0.0	0.0
56	9.0520E-01	0.0	9.0520E-01	9.6521E 00	2.7269E-02	0.0	0.0	0.0
57	5.1142E 02	0.0	5.1142E 02	4.2235E 01	1.1932E-01	0.0	0.0	0.0
58	1.1638E 01	0.0	1.1638E 01	5.2114E 00	1.4723E-02	0.0	0.0	0.0
59	1.1359E 00	0.0	1.1359E 00	7.6775E 00	2.1691E-02	0.0	0.0	0.0
60	6.5913E-01	0.0	6.5913E-01	8.2125E 00	2.3202E-02	0.0	0.0	0.0
61	5.2888E-01	0.0	5.2888E-01	8.4599E 00	2.3901E-02	0.0	0.0	0.0
62	4.8651E-01	0.0	4.8651E-01	8.6112E 00	2.4329E-02	0.0	0.0	0.0
63	4.8136E-01	0.0	4.8136E-01	8.7000E 00	2.4579E-02	0.0	0.0	0.0
64	4.9641E-01	0.0	4.9641E-01	8.7784E 00	2.4801E-02	0.0	0.0	0.0
65	5.2502E-01	0.0	5.2502E-01	8.8259E 00	2.4935E-02	0.0	0.0	0.0
66	5.6631E-01	0.0	5.6631E-01	8.8533E 00	2.5013E-02	0.0	0.0	0.0
67	6.1895E-01	0.0	6.1895E-01	8.8736E 00	2.5070E-02	0.0	0.0	0.0
68	6.8261E-01	0.0	6.8261E-01	8.894CE 00	2.5128E-02	0.0	0.0	0.0

(ETOP/ 14, 3- 1-75, R. A. GIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 23

92-U- 238 URANIUM-238, REV. 1

TIME: 0.10/ 461.54 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

ELASTIC SCATTERING MATRICES

***** BEGINNING OF ISOTROPIC ENERGY RANGE *****

SOURCE GROUP 68

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
68	0.8593E 01	0.8E94E 01	-1.1072E-C4	0.8593E 01	0.3747E 00	0.7537E-01	0.0	0.3747E 00
69	0.3007E 00			0.3007E 00	-0.2993E 00			-0.2993E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
68	0.1194E-02	0.1E97E-03	-1.9113E-04	0.1194E-02	0.1045E-02	0.0	0.0	0.1045E-02
69	-0.1035E-02			-0.1035E-02	-0.1045E-02			-0.1045E-02

SOURCE GROUP 67

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
67	0.8574E 01	0.8E74E 01	-1.3224E-04	0.8574E 01	0.3739E 00	0.7520E-01	-0.1486E-03	0.3739E 00
68	0.3001E 00			0.3001E 00	-0.2987E 00			-0.2987E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
67	0.1175E-02	0.1E93E-03	-1.4567E-04	0.1175E-02	0.1049E-02	0.0	0.0	0.1049E-02
68	-0.1016E-02			-0.1016E-02	-0.1049E-02			-0.1049E-02

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 24

92-U- 238 URANIUM-238, REV. 1

TIME: 2.10/ 463.64 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 66

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
66	0.8554E 01	0.8853E 01	-0.1077E-04	0.8554E 01	0.3728E 00	0.7503E-01	-0.1152E-03	0.3728E 00
67	0.2591E 00			0.2991E 00	-0.2977E 00			-0.2977E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
66	0.1248E-02	0.1590E-03	-0.1373E-03	0.1248E-02	0.1076E-02	0.0	0.0	0.1076E-02
67	-0.1089E-02			-0.1089E-02	-0.1076E-02			-0.1076E-02

SOURCE GROUP 65

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
65	0.8527E 01	0.8826E 01	-0.3242E-04	0.8527E 01	0.3718E 00	0.7479E-01	-0.1793E-03	0.3718E 00
66	0.2984E 00			0.2984E 00	-0.2970E 00			-0.2970E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
65	0.1227E-02	0.1585E-03	-0.9183E-04	0.1227E-02	0.1077E-02	0.0	0.0	0.1077E-02
66	-0.1068E-02			-0.1068E-02	-0.1077E-02			-0.1077E-02

SOURCE GROUP 64

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
64	0.8481E 01	0.8778E 01	-0.3259E-04	0.8481E 01	0.3702E 00	0.7439E-01	-0.1352E-03	0.3702E 00
65	0.2977E 00			0.2977E 00	-0.2958E 00			-0.2958E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
64	0.1862E-02	0.1576E-03	-0.1385E-03	0.1862E-02	0.4937E-05	0.0	0.0	0.4937E-05
65	-0.1704E-02			-0.1704E-02	-0.4937E-05			-0.4937E-05

92-U- 238 URANIUM-238- REV. 1

TIME: 2.00/ 465.64 (SEC.)

ENDF/B-IV TAPE 409(REV1)

13-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 63

SINK	F0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
63	0.8405E 01	0.8700E 01	-0.3239E-04	0.8405E 01	0.3670E 00	0.7373E-01	-0.9095E-04	0.3670E 00
64	0.2549E 00			0.2949E 00	-0.2933E 00			-0.2933E 00

SINK	F2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
63	0.1780E-02	0.1562E-03	-0.1397E-03	0.1780E-02	0.1262E-03	0.0	0.0	0.1262E-03
64	-0.1624E-02			-0.1624E-02	-0.1262E-03			-0.1262E-03

SOURCE GROUP 62

SINK	F0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
62	0.8318E-01	0.8611E 01	-0.4430E-04	0.8318E 01	0.3640E 00	0.7297E-01	-0.1838E-03	0.3640E 00
63	0.2527E 00			0.2527E 00	-0.2911E 00			-0.2911E 00

SINK	F2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
62	0.1740E-02	0.1546E-03	-0.2353E-03	0.1740E-02	0.1440E-03	0.0	0.0	0.1440E-03
63	-0.1585E-02			-0.1585E-02	-0.1440E-03			-0.1440E-03

SOURCE GROUP 61

SINK	F0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
61	0.8171E 01	0.8460E 01	-0.2255E-04	0.8171E 01	0.3586E 00	0.7169E-01	-0.1091E-03	0.3586E 00
62	0.2885E 00			0.2885E 00	-0.2869E 00			-0.2869E 00

SINK	F2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
61	0.1732E-02	0.1519E-03	-0.2395E-03	0.1732E-02	0.1419E-03	0.0	0.0	0.1419E-03
62	-0.1580E-02			-0.1580E-02	-0.1419E-03			-0.1419E-03

(ETGP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROS

DATE OF RUN 12/04/75 PAGE 26

92-U- 238 URANIUM-238, REV. 1

TIME: 1.80/ 467.43 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

04090000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 60

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
60	0.7930E 01	0.8213E 01	-0.2322E-04	0.7930E 01	0.3500E 00	0.6960E-01	-0.1285E-03	0.3500E 00
61	0.2820E 00			0.2820E 00	-0.2804E 00			-0.2804E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
60	0.1732E-02	0.1474E-03	-0.9869E-04	0.1732E-02	0.1387E-03	0.0	0.0	0.1387E-03
61	-0.1585E-02			-0.1585E-02	-0.1387E-03			-0.1387E-03

SOURCE GROUP 59

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
59	0.7407E 01	0.7678E 01	-0.3726E-04	0.7407E 01	0.3338E 00	0.6506E-01	-0.1031E-03	0.3338E 00
60	0.2704E 00			0.2704E 00	-0.2687E 00			-0.2687E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
59	0.1760E-02	0.1378E-03	-0.2111E-03	0.1760E-02	0.1329E-03	0.0	0.0	0.1329E-03
60	-0.1622E-02			-0.1622E-02	-0.1329E-03			-0.1329E-03

SOURCE GROUP 58

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
58	0.4970E 01	0.5211E 01	-0.3660E-04	0.4970E 01	0.2835E 00	0.4416E-01	0.2531E-04	0.2835E 00
59	0.2413E 00			0.2413E 00	-0.2394E 00			-0.2394E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
58	0.2027E-02	0.9357E-04	-0.1555E-03	0.2027E-02	0.1482E-03	0.0	0.0	0.1482E-03
59	-0.1934E-02			-0.1934E-02	-0.1482E-03			-0.1482E-03

52-U- 238 URANIUM-238, REV. 1

TIME: 1.83/ 469.26 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 57

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
57	0.4223E 02	0.4224E 02	-0.3613E-04	0.4223E 02	0.3610E 00	0.3579E 00	-0.9992E-04	0.3610E 00
58	0.1133E-02			0.1133E-02	-0.3108E-02			-0.3108E-02

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
57	-0.3553E-02	0.7583E-03	-0.1535E-03	-0.3553E-02	0.4529E-02	0.0	0.0	0.4529E-02
58	0.4311E-02			0.4311E-02	-0.4529E-02			-0.4529E-02

SOURCE GROUP 56

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
56	0.9298E 01	0.9552E 01	-0.1576E-04	0.9298E 01	0.4330E 00	0.8180E-01	-0.5465E-04	0.4330E 00
57	0.3542E 00			0.3542E 00	-0.3512E 00			-0.3512E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
56	0.3030E-02	0.1753E-03	-0.1260E-03	0.3030E-02	0.1705E-03	0.0	0.0	0.1705E-03
57	-0.2856E-02			-0.2856E-02	-0.1705E-03			-0.1705E-03

SOURCE GROUP 55

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
55	0.8244E 01	0.8549E 01	-0.2231E-04	0.8244E 01	0.3748E 00	0.7244E-01	-0.2931E-03	0.3748E 00
56	0.3044E 00			0.3044E 00	-0.3023E 00			-0.3023E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
55	0.2155E-02	0.1535E-03	-0.9431E-04	0.2155E-02	0.1476E-03	0.0	0.0	0.1476E-03
56	-0.2002E-02			-0.2002E-02	-0.1476E-03			-0.1476E-03

ETOP/ 14, 3- 1-75, R. A. GRIMESY : PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 28

92-U- 23E URANIUM-238, REV. 1

TIME: 1.80/ 471.06 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 54

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
54	0.6568E 01	0.7239E 01	-0.1317E-04	0.6968E 01	0.3303E 00	0.6134E-01	-0.5466E-04	0.3303E 00
55	0.2709E 00			0.2709E 00	-0.2690E 00			-0.2690E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
54	0.1598E-02	0.1300E-03	-0.1120E-03	0.1958E-02	0.1314E-03	0.0	0.0	0.1314E-03
55	-0.1668E-02			-0.1668E-02	-0.1314E-03			-0.1314E-03

SOURCE GROUP 53

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
53	0.8839E 02	0.8859E 02	-0.3445E-04	0.8839E 02	0.9469E 00	0.7508E 00	-0.7145E-04	0.9469E 00
54	0.1990E 00			0.1950E 00	-0.1962E 00			-0.1962E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
53	0.4363E-02	0.1591E-02	-0.2196E-03	0.4363E-02	0.1235E-03	0.0	0.0	0.1235E-03
54	-0.2773E-02			-0.2773E-02	-0.1235E-03			-0.1235E-03

SOURCE GROUP 52

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
52	0.5655E 01	0.1014E 02	-0.1880E-04	0.5655E 01	0.5642E 00	0.8595E-01	-0.9101E-04	0.5642E 00
53	0.4881E 00			0.4881E 00	-0.4782E 00			-0.4782E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
52	0.5536E-02	0.1821E-03	-0.7591E-03	0.5936E-02	0.2601E-03	0.0	0.0	0.2601E-03
53	-0.5754E-02			-0.5754E-02	-0.2601E-03			-0.2601E-03

92-U- 23E URANIUM-238, REV. 1

TIME: 1.88/ 472.94. (SEC.)

ENDF/B-IV TAPE 409(REV.1)

1E-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 51

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
51	0.2031E 03	0.2033E 03	-0.7534E-05	0.2031E 03	0.1975E 01	0.1723E 01	-0.1557E-03	0.1975E 01
52	0.2547E 00			0.2547E 00	-0.2516E 00			-0.2516E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
51	0.6725E-02	0.3651E-02	-0.9567E-04	0.6725E-02	0.1256E-03	0.0	0.0	0.1256E-03
52	-0.3074E-02			-0.3074E-02	-0.1256E-03			-0.1256E-03

SOURCE GROUP 50

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
50	0.1825E 02	0.2113E 02	-0.1424E-03	0.1825E 02	0.2745E 01	0.1816E 00	-0.1785E-03	0.2745E 01
51	0.3183E 01			0.3183E 01	-0.2563E 01			-0.2563E 01

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
50	0.4832E 00	0.3848E-03	-0.1643E-01	0.4832E 00	0.1069E 00	0.0	0.0	0.1069E 00
51	-0.4828E 00			-0.4828E 00	-0.1069E 00			-0.1069E 00

SOURCE GROUP 49

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
49	0.8870E 01	0.9246E 01	-0.2063E-04	0.8870E 01	0.4504E 00	0.7835E-01	-0.9984E-04	0.4504E 00
50	0.3756E 00			0.3756E 00	-0.3721E 00			-0.3721E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
49	0.3690E-02	0.1650E-03	-0.8766E-04	0.3650E-02	0.1707E-03	0.0	0.0	0.1707E-03
50	-0.3524E-02			-0.3524E-02	-0.1707E-03			-0.1707E-03

(ETGF/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 30

92-U- 238 - URANIUM-238, REV. 1

TIME: 1.83/ 474.77 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 48

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
48	0.5899E 02	0.5920E 02	-0.7732E-04	0.5899E 02	0.7070E 00	0.5017E 00	-0.3564E-04	0.7070E 00
49	0.2115E 00			0.2115E 00	-0.2053E 00			-0.2053E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
48	0.7390E-02	0.1063E-02	-0.3149E-03	0.7390E-02	-0.6416E-05	0.0	0.0	-0.6416E-05
49	-0.6327E-02			-0.6327E-02	0.6416E-05			0.6416E-05

SOURCE GROUP 47

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
47	0.6304E 01	0.6584E 01	-0.1449E-04	0.6304E 01	0.3258E 00	0.5579E-01	-0.8013E-04	0.3258E 00
48	0.2792E 00			0.2792E 00	-0.2700E 00			-0.2700E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
47	0.1059E-01	0.1182E-03	-0.3078E-02	0.1059E-01	-0.1612E-02	0.0	0.0	-0.1612E-02
48	-0.1047E-01			-0.1047E-01	0.1612E-02			0.1612E-02

SOURCE GROUP 46

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
46	0.8901E 02	0.1119E 03	-0.2727E-04	0.8901E 02	0.4784E 02	0.9485E 00	-0.2319E-02	0.4784E 02
47	0.2291E 02			0.2291E 02	-0.4689E 02			-0.4689E 02

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
46	-0.2583E 02	0.2009E-02	0.2342E 00	-0.2983E 02	-0.4991E 01	0.0	0.0	-0.4991E 01
47	0.2583E 02			0.2983E 02	0.4991E 01			0.4991E 01

92-U- 238 URANIUM-238, REV. 1

TIME: 1.93/ 476.70 (SEC.)

ENDF/B-IV TAPE 409(REVL)

18-NOV-74 04090C000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 45

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
45	0.8794E 01	0.9154E 01	-0.3125E-04	0.8794E 01	0.4337E 00	0.7758E-01	-0.1441E-03	0.4337E 00
46	0.3601E 00			0.3601E 00	-0.3562E 00			-0.3562E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
45	0.4027E-02	0.1544E-03	-0.1815E-02	0.4027E-02	0.1949E-03	0.0	0.0	0.1949E-03
46	-0.3863E-02			-0.3863E-02	-0.1949E-03			-0.1949E-03

SOURCE GROUP 44

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
44	0.9065E 02	0.9590E 02	-0.3357E-04	0.9065E 02	0.1015E 01	0.7703E 00	-0.1161E-03	0.1015E 01
45	0.2518E 00			0.2518E 00	-0.2448E 00			-0.2448E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
44	0.8020E-02	0.1532E-02	-0.1427E-03	0.8020E-02	0.5565E-03	0.0	0.0	0.5565E-03
45	-0.6388E-02			-0.6388E-02	-0.5565E-03			-0.5565E-03

SOURCE GROUP 43

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
43	0.1882E 02	0.1532E 02	-0.7899E-04	0.1882E 02	0.6480E 00	0.1637E 00	-0.1365E-03	0.6480E 00
44	0.4587E 00			0.4987E 00	-0.4843E 00			-0.4843E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
43	0.1364E-01	0.3468E-03	-0.1049E-02	0.1364E-01	0.1141E-02	0.0	0.0	0.1141E-02
44	-0.1330E-01			-0.1330E-01	-0.1141E-02			-0.1141E-02

(ETCF/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 32

92-U- 238 URANIUM-238, REV. 1

TIME: 1.90/ 478.60 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

04090000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 42

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
42	0.1994E 02	0.2039E 02	-0.7484E-04	0.1994E 02	0.5946E 00	0.1728E 00	-0.1294E-03	0.5946E 00
43	0.4518E 00			0.4518E 00	-0.4218E 00			-0.4218E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
42	0.2317E-01	0.3660E-03	-0.1014E-02	0.2317E-01	0.5571E-02	0.0	0.0	0.5571E-02
43	-0.2280E-01			-0.2280E-01	-0.5571E-02			-0.5571E-02

SOURCE GROUP 41

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
41	0.1127E 02	0.1171E 02	-0.1628E-04	0.1127E 02	0.5296E 00	0.9928E-01	-0.2251E-04	0.5296E 00
42	0.4477E 00			0.4477E 00	-0.4303E 00			-0.4303E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
41	0.1535E-01	0.2103E-03	-0.1557E-02	0.1535E-01	0.2116E-02	0.0	0.0	0.2116E-02
42	-0.1514E-01			-0.1514E-01	-0.2116E-02			-0.2116E-02

SOURCE GROUP 40

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3* μ *SIGS	ERROR	NORMALIZED
40	0.1418E 02	0.1450E 02	-0.1316E-04	0.1418E 02	0.4350E 00	0.1229E 00	-0.8187E-04	0.4350E 00
41	0.3212E 00			0.3212E 00	-0.3122E 00			-0.3122E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
40	0.7735E-02	0.2603E-03	-0.1565E-02	0.7735E-02	-0.1758E-03	0.0	0.0	-0.1758E-03
41	-0.7475E-02			-0.7475E-02	0.1758E-03			0.1758E-03

52-U- 238 URANIUM-238. REV. 1

TIME: 2.05/ 480.65 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NU. = 1262

SOURCE GROUP 39

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
39	0.1929E 02	0.1959E 02	-0.2337E-03	0.1929E 02	0.4301E 00	0.1660E 00	-0.1144E-03	0.4301E 00
40	0.3024E 00			0.3024E 00	-0.2641E 00			-0.2641E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
39	0.3911E-01	0.3517E-03	-0.6620E-03	0.3911E-01	-0.3453E-02	0.0	0.0	-0.3453E-02
40	-0.3876E-01			-0.3876E-01	0.3453E-02			0.3453E-02

SOURCE GROUP 38

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
38	0.1786E 02	0.1818E 02	-0.8395E-04	0.1786E 02	0.4668E 00	0.1540E 00	-0.1306E-03	0.4668E 00
39	0.3172E 00			0.3172E 00	-0.3127E 00			-0.3127E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
38	0.4893E-02	0.5263E-03	-0.2051E-02	0.4893E-02	-0.1429E-03	0.0	0.0	-0.1429E-03
39	-0.4566E-02			-0.4566E-02	0.1429E-03			0.1429E-03

SOURCE GROUP 37

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
37	0.2136E 02	0.2183E 02	-0.1358E-03	0.2136E 02	0.5694E 00	0.1850E 00	-0.1268E-03	0.5694E 00
38	0.4711E 00			0.4711E 00	-0.3844E 00			-0.3844E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
37	0.6124E-01	0.3920E-03	-0.7424E-03	0.6124E-01	0.1745E-01	0.0	0.0	0.1745E-01
38	-0.6094E-01			-0.6094E-01	-0.1745E-01			-0.1745E-01

ETCP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 34

92-U- 238 URANIUM-238, REV. 1

TIME: 2.08/ 482.73 (SEC.)

ENDF/B-IV TAPE 409(REV1)

16-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 36

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
36	0.1568E 02	0.1734E 02	-0.8801E-04	0.1568E 02	0.2678E 01	0.1469E 00	-0.6922E-03	0.2678E 01
37	0.1656E 01			0.1656E 01	-0.2531E 01			-0.2531E 01

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
36	-0.2955E 00	0.3112E-03	0.7712E-02	-0.2955E 00	-0.1253E 01	0.0	0.0	-0.1253E 01
37	0.2958E 00			0.2958E 00	0.1253E 01			0.1253E 01

SOURCE GROUP 35

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
35	0.2282E 02	0.2421E 02	-0.1261E-03	0.2282E 02	0.2204E 01	0.2052E 00	-0.4358E-03	0.2204E 01
36	0.1385E 01			0.1385E 01	-0.1998E 01			-0.1998E 01

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
35	-0.4917E-01	0.4346E-03	0.6696E-03	-0.4917E-01	-0.9837E 00	0.0	0.0	-0.9837E 00
36	0.4961E-01			0.4961E-01	0.9837E 00			0.9837E 00

SOURCE GROUP 34

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
34	0.2065E 02	0.2111E 02	-0.1446E-03	0.2065E 02	0.6042E 00	0.1789E 00	-0.1187E-03	0.6042E 00
35	0.4551E 00			0.4551E 00	-0.4253E 00			-0.4253E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
34	0.2371E-01	0.3789E-03	0.1152E-03	0.2371E-01	0.4660E-02	0.0	0.0	0.4660E-02
35	-0.2334E-01			-0.2334E-01	-0.4660E-02			-0.4660E-02

92-U- 238 URANIUM-238. REV. 1

TIME: 2.11/ 484.94 (SEC.)

ENDF/B-IV TAPE 409(REV.)

18-NOV-74

040900000000

ENDF/E MAT. NO. = 1262

SOURCE GROUP 33

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
33	0.1582E 02	0.1641E 02	-0.9299E-04	0.1582E 02	0.6560E 00	0.1391E 00	-0.1366E-03	0.6560E 00
34	0.5895E 00			0.5855E 00	-0.5169E 00			-0.5169E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
33	0.7638E-01	0.2546E-03	-0.1376E-01	0.7638E-01	0.2790E-01	0.0	0.0	0.2790E-01
34	-0.7609E-01			-0.7609E-01	-0.2750E-01			-0.2790E-01

SOURCE GROUP 32

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
32	0.1813E 02	0.1854E 02	-0.8232E-04	0.1813E 02	0.5305E 00	0.1571E 00	-0.9250E-04	0.5305E 00
33	0.4045E 00			0.4045E 00	-0.3734E 00			-0.3734E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
32	-0.1098E-01	0.3228E-03	-0.4154E-03	-0.1098E-01	0.5109E-01	0.0	0.0	0.5109E-01
33	0.1131E-01			0.1131E-01	-0.5109E-01			-0.5109E-01

SOURCE GROUP 31

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
31	0.1541E 02	0.1596E 02	-0.1195E-04	0.1541E 02	0.6810E 00	0.1353E 00	-0.7435E-04	0.6810E 00
32	0.5491E 00			0.5491E 00	-0.5457E 00			-0.5457E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
31	0.3493E-02	0.2366E-03	-0.1269E-03	0.3498E-02	0.3114E-03	0.0	0.0	0.3114E-03
32	-0.3211E-02			-0.3211E-02	-0.3114E-03			-0.3114E-03

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 36

92-U- 238 URANIUM-238, REV. 1

TIME: 1.93/ 486.77 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 30

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
30	0.1482E 02	0.1535E 02	-0.1243E-04	0.1482E 02	0.6545E 00	0.1301E 00	-0.1547E-03	0.6545E 00
31	0.5275E 00			0.5275E 00	-0.5244E 00			-0.5244E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
30	0.3363E-02	0.2756E-03	-0.7921E-04	0.3363E-02	0.2479E-03	0.0	0.0	0.2479E-03
31	-0.3088E-02			-0.3088E-02	-0.2479E-03			-0.2479E-03

SOURCE GROUP 29

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
29	0.1427E 02	0.1478E 02	-0.1291E-04	0.1427E 02	0.6298E 00	0.1252E 00	-0.1071E-03	0.6298E 00
30	0.5076E 00			0.5076E 00	-0.5046E 00			-0.5046E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
29	0.3165E-02	0.2653E-03	-0.1371E-03	0.3165E-02	0.2995E-03	0.0	0.0	0.2995E-03
30	-0.2900E-02			-0.2900E-02	-0.2995E-03			-0.2995E-03

SOURCE GROUP 28

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
28	0.1384E 02	0.1433E 02	-0.1331E-04	0.1384E 02	0.6086E 00	0.1214E 00	-0.7362E-04	0.6086E 00
29	0.4901E 00			0.4901E 00	-0.4872E 00			-0.4872E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
28	0.3065E-02	0.2573E-03	-0.1131E-03	0.3065E-02	0.2419E-03	0.0	0.0	0.2419E-03
29	-0.2808E-02			-0.2808E-02	-0.2419E-03			-0.2419E-03

52-U- 238 URANIUM-238, REV. 1

TIME: 1.83/ 488.60 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

04090000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 27

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
27	0.1347E 02	0.1395E 02	-0.1357E-04	0.1347E 02	0.5919E 00	0.1182E 00	-0.1229E-03	0.5919E 00
28	0.4764E 00			0.4764E 00	-0.4737E 00			-0.4737E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
27	0.2544E-02	0.2505E-03	-0.2905E-04	0.2544E-02	0.2449E-03	0.0	0.0	0.2449E-03
28	-0.2653E-02			-0.2653E-02	-0.2449E-03			-0.2449E-03

SOURCE GROUP 26

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
26	0.1316E 02	0.1363E 02	-0.1400E-04	0.1316E 02	0.5777E 00	0.1155E 00	-0.1645E-03	0.5777E 00
27	0.4649E 00			0.4649E 00	-0.4622E 00			-0.4622E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
26	0.2894E-02	0.2447E-03	-0.8521E-04	0.2894E-02	0.2864E-03	0.0	0.0	0.2864E-03
27	-0.2650E-02			-0.2650E-02	-0.2864E-03			-0.2864E-03

SOURCE GROUP 25

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
25	0.1289E 02	0.1235E 02	-0.2144E-04	0.1289E 02	0.5652E 00	0.1131E 00	-0.1087E-03	0.5652E 00
26	0.4548E 00			0.4548E 00	-0.4521E 00			-0.4521E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
25	0.2812E-02	0.2296E-03	-0.3057E-04	0.2812E-02	0.2128E-03	0.0	0.0	0.2128E-03
26	-0.2573E-02			-0.2573E-02	-0.2128E-03			-0.2128E-03

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 38

92-U- 238 URANIUM-238, REV. 1

TIME: 1.80/ 490.40 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

SOURCE GROUP 24

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
24	0.1263E 02	0.1307E 02	-0.1459E-04	0.1263E 02	0.5544E 00	0.1108E 00	-0.6052E-04	0.5544E 00
25	0.4462E 00			0.4462E 00	-0.4436E 00			-0.4436E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
24	0.2778E-02	0.2347E-03	-0.1860E-03	0.2778E-02	0.1839E-03	0.0	0.0	0.1839E-03
25	-0.2544E-02			-0.2544E-02	-0.1839E-03			-0.1839E-03

SOURCE GROUP 23

SINK	P0	GROUP AVG	PER CENT	P0	P1	GROUP AVG	PER CENT	P1
GRPS	CALCULATED	SYMM. SCATT.	ERROR	NORMALIZED	CALCULATED	3*MU*SIGS	ERROR	NORMALIZED
23	0.1234E 02	0.1278E 02	-0.1492E-04	0.1234E 02	0.5421E 00	0.1083E 00	-0.1341E-03	0.5421E 00
24	0.4363E 00			0.4363E 00	-0.4338E 00			-0.4338E 00

SINK	P2	GROUP AVG	PER CENT	P2	P3	GROUP AVG	ABSOLUTE	P3
GRPS	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED	CALCULATED	ISOTR. VALUE	ERROR	NORMALIZED
23	0.2694E-02	0.2295E-03	-0.3171E-04	0.2694E-02	0.2375E-03	0.0	0.0	0.2375E-03
24	-0.2464E-02			-0.2464E-02	-0.2375E-03			-0.2375E-03

***** END OF ISOTROPIC ENERGY RANGE *****

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 22 NPIM IS 3

SINK	P0	P1
GRPS	CALCULATED	CALCULATED
22	0.1224E 02	0.1689E 01
23	0.4152E 00	-0.3913E 00

SINK	P2	P3
GRPS	CALCULATED	CALCULATED
22	0.1932E 00	0.3566E-02
23	-0.2168E-01	-0.1960E-02

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

S2-U- 238 URANIUM-238, REV. 1

ENDF/E-IV TAPE 409(REV1)

18-NOV-74

040900000000

DATE OF RUN 12/04/75 PAGE 39

TIME: 3.63/ 494.02 (SEC.)

ENDF/B MAT. NO. = 1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 21 NPIM IS 2

SINK PU
GRPS CALCULATED
21 0.1201E 02
22 0.4078E 00

P1
CALCULATED
0.2385E 01
-0.3761E 00

SINK P2
GRPS CALCULATED
21 0.5310E 00
22 -0.2595E-01

P3
CALCULATED
0.1060E-01
-0.5566E-02

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 20 NPIM IS 3

SINK PU
GRPS CALCULATED
20 0.1175E 02
21 0.3247E 00

P1
CALCULATED
0.3255E 01
-0.2871E 00

SINK P2
GRPS CALCULATED
20 0.1000E 01
21 -0.2473E-01

P3
CALCULATED
0.2286E-01
-0.1303E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 19 NPIM IS 2

SINK PU
GRPS CALCULATED
19 0.1125E 02
20 0.3054E 00

P1
CALCULATED
0.3826E 01
-0.2574E 00

SINK P2
GRPS CALCULATED
19 0.1315E 01
20 -0.2895E-01

P3
CALCULATED
0.3142E-01
-0.1864E-01

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 40

92-U- 238 URANIUM-238, REV. 1

TIME: 4.347 498.37 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 18 NPIM IS 2

SINK P0
GRPS CALCULATED
18 0.1058E 02
19 0.2838E 00

P1
CALCULATED
0.4404E 01
-0.2282E 00

SINK P2
GRPS CALCULATED
18 0.1633E 01
19 -0.3055E-01

P3
CALCULATED
0.4087E-01
-0.2491E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 17 NPIM IS 3

SINK P0
GRPS CALCULATED
17 0.9523E 01
18 0.2573E 00

P1
CALCULATED
0.5037E 01
-0.1926E 00

SINK P2
GRPS CALCULATED
17 0.2054E 01
18 -0.3471E-01

P3
CALCULATED
0.8624E-01
-0.2957E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 16 NPIM IS 2

SINK P0
GRPS CALCULATED
16 0.9327E 01
17 0.2342E 00

P1
CALCULATED
0.5616E 01
-0.1635E 00

SINK P2
GRPS CALCULATED
16 0.2714E 01
17 -0.3272E-01

P3
CALCULATED
0.2728E 00
-0.3578E-01

(EICP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

92-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

DATE OF RUN 12/04/75 PAGE 41

TIME: 4.54/ 502.91 (SEC.)

ENDF/B MAT. NO. = 1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 15 NPIM IS 4

SINK P0
GRPS CALCULATED
15 0.8656E 01
16 0.2115E 00

P1
CALCULATED
0.6187E 01
-0.1361E 00

SINK P2
GRPS CALCULATED
15 0.3391E 01
16 -0.2710E-01

P3
CALCULATED
0.7270E 00
-0.4291E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 14 NPIM IS 2

SINK P0
GRPS CALCULATED
14 0.7672E 01
15 0.1861E 00

P1
CALCULATED
0.6514E 01
-0.1072E 00

SINK P2
GRPS CALCULATED
14 0.3578E 01
15 -0.2535E-01

P3
CALCULATED
0.1286E 01
-0.3841E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 13 NPIM IS 3

SINK P0
GRPS CALCULATED
13 0.7065E 01
14 0.1597E 00

P1
CALCULATED
0.6689E 01
-0.8246E-01

SINK P2
GRPS CALCULATED
13 0.4822E 01
14 -0.2008E-01

P3
CALCULATED
0.1877E 01
-0.4242E-01

(ETGP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA-FOR INPUT TO PHRUG

92-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

DATE OF RUN 12/04/75 PAGE 42

TIME: 4.46/ 507.37 (SEC.)

ENDF/B MAT. NO. =.1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 12 NPIM IS 3

SINK P0
GRPS CALCULATED
12 0.6336E 01
13 0.1375E 00

P1
CALCULATED
0.6851E 01
-0.7072E-01

SINK P2
GRPS CALCULATED
12 0.5683E 01
13 -0.4357E-03

P3
CALCULATED
0.2826E 01
-0.3877E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 11 NPIM IS 3

SINK P0
GRPS CALCULATED
11 0.5565E 01
12 0.1142E 00

P1
CALCULATED
0.6904E 01
-0.4632E-01

SINK P2
GRPS CALCULATED
11 0.6255E 01
12 0.2818E-02

P3
CALCULATED
0.3367E 01
-0.3863E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 10 NPIM IS 4

SINK P0
GRPS CALCULATED
10 0.4523E 01
11 0.9372E-01

P1
CALCULATED
0.6718E 01
-0.4101E-01

SINK P2
GRPS CALCULATED
10 0.7215E 01
11 0.1652E-01

P3
CALCULATED
0.5515E 01
-0.2342E-01

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

92-U- 238 URANIUM-238, REV. 1

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

DATE OF RUN 12/04/75 PAGE 43

TIME: 4.54/ 511.91 (SEC.)

ENDF/B MAT. NO. = 1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 9 NPIM IS 3

SINK P0
GRPS CALCULATED
9 0.4355E 01
10 0.7876E-01

P1
CALCULATED
0.6733E 01
-0.3286E-01

SINK P2
GRPS CALCULATED
9 0.7616E 01
10 0.9730E-02

P3
CALCULATED
0.6885E 01
0.1184E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 8 NPIM IS 3

SINK P0
GRPS CALCULATED
8 0.3572E 01
9 0.6454E-01

P1
CALCULATED
0.6552E 01
-0.2026E-01

SINK P2
GRPS CALCULATED
8 0.7702E 01
9 0.9032E-03

P3
CALCULATED
0.8082E 01
0.2423E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 7 NPIM IS 3

SINK P0
GRPS CALCULATED
7 0.4076E 01
8 0.5855E-01

P1
CALCULATED
0.7468E 01
-0.1326E-01

SINK P2
GRPS CALCULATED
7 0.8543E 01
8 -0.8543E-02

P3
CALCULATED
0.9873E 01
0.2809E-01

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 44

92-U- 238 URANIUM-238, REV. 1

TIME: 4.68/ 516.59 (SEC.)

ENDF/B-IV TAFE 405(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 6 NPIM IS 3

SINK P0
GRPS CALCULATED
6 0.4457E 01
7 0.5712E-01

P1
CALCULATED
0.8916E 01
-0.6887E-02

SINK P2
GRPS CALCULATED
6 0.1130E 02
7 -0.1504E-02

P3
CALCULATED
0.1213E 02
0.1094E-01

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 5 NPIM IS 3

SINK P0
GRPS CALCULATED
5 0.4765E 01
6 0.5272E-01

P1
CALCULATED
0.1066E 02
0.4592E-02

SINK P2
GRPS CALCULATED
5 0.1407E 02
6 0.6561E-02

P3
CALCULATED
0.1579E 02
0.3550E-02

NEW ELASTIC ROUTINE CALL OUTER SOURCE GROUP 4 NPIM IS 3

SINK P0
GRPS CALCULATED
4 0.4775E 01
5 0.4684E-01

P1
CALCULATED
0.1136E 02
0.1252E-01

SINK P2
GRPS CALCULATED
4 0.1556E 02
5 -0.1302E-01

P3
CALCULATED
0.1785E 02
0.1447E-01

DATE OF RUN 12/04/75 PAGE 45

TIME: 4.63/ 521.21 (SEC.)

18-NOV-74 040900000000

ENCLF/B. MAT. NO. = 1262

SINK	PJ
GRPS	CALCULATED
3	0.4446E 01
4	0.4252E-01

P1
CALCULATED
0.1083E 02
0.1671E-01

SINK	P2
GRPS	CALCULATED
3	0.1509E 02
4	0.1564E-01

P3
CALCULATED
0.1771E 02
0.2337E-01

SINK	PJ
GRPS	CALCULATED
2	0.3754E 01
3	0.4121E-01

P1
CALCULATED
0.9264E 01
0.1359E-01

SINK	F2
GRPS	CALCULATED
2	0.1213E 02
3	0.1214E-01

P3
CALCULATED
0.1578E 02
0.2109E-01

SINK	PD
GRPS	CALCULATED
1	0.3203E 01
2	0.3657E-01

P1
CALCULATED
0.7882E 01
0.1179E-01

SINK	P2
GRPS	CALCULATED
1	0.1113E 02
2	6.8800E-02

P3
CALCULATED
0.1353E 02
0.1736E-01

[illegible]

LEVEL NUMBER 52
 GROUP AVERAGE PROBABILITY LEVEL 52 FOR PHRCG GROUPS 1 TO KMIN= 17
 0.0 0.0 0.0 0.0 3.03485E-03 1.30978E-02 3.89928E-02 8.25832E-02 1.62243E-01 2.29235E-01
 2.11017E-01 1.68031E-01 1.24901E-01 9.28877E-02 6.58990E-02 3.82151E-02 1.11718E-02

LEVEL NUMBER 53
 GROUP AVERAGE PROBABILITY LEVEL 53 FOR PHRCG GROUPS 1 TO KMIN= 14
 0.0 0.0 0.0 0.0 2.90097E-03 5.82472E-03 8.73763E-03 1.36963E-02 1.83837E-02 2.14296E-02
 1.76440E-02 1.25969E-02 7.34230E-03 2.10735E-03

LEVEL NUMBER 54
 GROUP AVERAGE PROBABILITY LEVEL 54 FOR PHRCG GROUPS 1 TO KMIN= 11
 0.0 0.0 0.0 0.0 4.50765E-03 1.55433E-02 3.20319E-02 5.88732E-02 1.09571E-01 1.57712E-01
 6.25674E-02

LEVEL NUMBER 55
 GROUP AVERAGE PROBABILITY LEVEL 55 FOR PHRCG GROUPS 1 TO KMIN= 11
 0.0 0.0 0.0 0.0 2.48143E-03 1.17848E-02 2.93521E-02 6.06006E-02 9.67883E-02 9.78664E-02
 1.74232E-02

LEVEL NUMBER 56
 GROUP AVERAGE PROBABILITY LEVEL 56 FOR PHRCG GROUPS 1 TO KMIN= 10
 0.0 0.0 0.0 0.0 2.04406E-03 4.75885E-03 1.00092E-02 2.11097E-02 1.90530E-02 3.42550E-03

LEVEL NUMBER 57
 GROUP AVERAGE PROBABILITY LEVEL 57 FOR PHRCG GROUPS 1 TO KMIN= 10
 0.0 0.0 0.0 0.0 4.48088E-03 1.47297E-02 3.19552E-02 6.08970E-02 7.77866E-02 2.02005E-02

LEVEL NUMBER 58
 GROUP AVERAGE PROBABILITY LEVEL 58 FOR PHRCG GROUPS 1 TO KMIN= 10
 0.0 0.0 0.0 0.0 5.86440E-03 1.44634E-02 2.72767E-02 5.59109E-02 7.60479E-02 1.41284E-02

LEVEL NUMBER 59
 GROUP AVERAGE PROBABILITY LEVEL 59 FOR PHRCG GROUPS 1 TO KMIN= 10
 0.0 0.0 0.0 0.0 4.46302E-03 1.48742E-02 3.78283E-02 6.34022E-02 5.84497E-02 2.49460E-03

LEVEL NUMBER 60
 GROUP AVERAGE PROBABILITY LEVEL 60 FOR PHRCG GROUPS 1 TO KMIN= 10
 0.0 0.0 0.0 0.0 5.89118E-03 1.64217E-02 3.62254E-02 5.80842E-02 4.09861E-02 0.0

LEVEL NUMBER 61
 GROUP AVERAGE PROBABILITY LEVEL 61 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 8.83672E-03 2.52050E-02 5.81215E-02 8.83965E-02 5.34455E-02

LEVEL NUMBER 62
 GROUP AVERAGE PROBABILITY LEVEL 62 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 6.87782E-03 1.97831E-02 4.03236E-02 6.07681E-02 2.04647E-02

LEVEL NUMBER 63
 GROUP AVERAGE PROBABILITY LEVEL 63 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 7.40861E-03 2.20548E-02 4.71336E-02 6.81006E-02 1.86194E-02

LEVEL NUMBER 64
 GROUP AVERAGE PROBABILITY LEVEL 64 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 6.83320E-03 1.86561E-02 4.04618E-02 5.41936E-02 1.04480E-02

LEVEL NUMBER 65
 GROUP AVERAGE PROBABILITY LEVEL 65 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 5.89118E-03 1.65133E-02 3.51406E-02 3.58996E-02 1.78394E-03

LEVEL NUMBER 66
 GROUP AVERAGE PROBABILITY LEVEL 66 FOR PHRCG GROUPS 1 TO KMIN= 9
 0.0 0.0 0.0 0.0 7.45324E-03 2.31818E-02 4.18821E-02 3.20603E-02 0.0

LEVEL NUMBER 67
 GROUP AVERAGE PROBABILITY LEVEL 67 FOR PHRCG GROUPS 1 TO KMIN= 8
 0.0 0.0 0.0 0.0 4.41839E-03 1.26025E-02 2.78536E-02 2.02403E-02

LEVEL NUMBER 68
 GROUP AVERAGE PROBABILITY LEVEL 68 FOR PHRCG GROUPS 1 TO KMIN= 8
 0.0 0.0 0.0 0.0 5.80196E-03 1.25652E-02 2.32587E-02 1.13039E-02

LEVEL NUMBER 69
 GROUP AVERAGE PROBABILITY LEVEL 69 FOR PHRCG GROUPS 1 TO KMIN= 8
 0.0 0.0 0.0 0.0 8.83672E-03 2.45181E-02 4.88179E-02 2.12526E-02

LEVEL NUMBER 70
 GROUP AVERAGE PROBABILITY LEVEL 70 FOR PHRCG GROUPS 1 TO KMIN= 8
 0.0 0.0 0.0 1.38124E-03 2.07976E-02 6.42354E-02 1.10572E-01 2.24084E-02

LEVEL NUMBER 71
 GROUP AVERAGE PROBABILITY LEVEL 71 FOR PHRCG GROUPS 1 TO KMIN= 8
 0.0 0.0 0.30336E-03 3.85912E-02 1.09311E-01 1.55757E-01 1.10529E-01 3.82531E-03

LEVEL NUMBER 72
 GROUP AVERAGE PROBABILITY LEVEL 72 FOR PHRCG GROUPS 1 TO KMIN= 7
 0.0 0.0 0.30336E-03 3.85912E-02 1.07923E-01 1.34580E-01 5.64531E-02

LEVEL NUMBER 73
 GROUP AVERAGE PROBABILITY LEVEL 73 FOR PHRCG GROUPS 1 TO KMIN= 7
 3.12588E-02 7.14787E-03 2.13225E-03 1.03694E-03 0.0 0.0 0.0

LEVEL NUMBER 74
 GROUP AVERAGE PROBABILITY LEVEL 74 FOR PHRCG GROUPS 1 TO KMIN= 5
 3.12588E-02 7.14787E-03 1.97406E-03 0.0 0.0

LEVEL NUMBER 75
 GROUP AVERAGE PROBABILITY LEVEL 75 FOR PHRCG GROUPS 1 TO KMIN= 4
 3.12588E-02 7.07666E-03 1.25200E-03 0.0

LEVEL NUMBER 76
 GROUP AVERAGE PROBABILITY LEVEL 76 FOR PHRCG GROUPS 1 TO KMIN= 3
 3.12588E-02 5.84349E-03 0.0

ENTERING ETOP 50

SCATTERING CROSS SECTIONS ARE GIVEN IN FILE 3 FOR 26 DISCRETE LEVELS

FILE 3, SEC. 51 CONTINUUM CROSS SECTION DATA IS PRESENT

DATE OF RUN 12/04/75 PAGE 46

TIME: 146.13/ 667.35 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

[illegible]

DATE OF RUN 12/04/75 PAGE 47

TIME: 0.42/ 667.76 (SEC.)

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

92-U- 238 URANIUM-238, REV. 1

TIME: 0.10/ 667.86 (SEC.)

ENDF/B-IV IAPC 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

EXIT
GROUP

INELASTIC MATRIX

14 P0	2.4363E-02	9.2516E-02	1.4674E-01	1.4886E-01	1.1400E-01	7.8328E-02	1.6842E-01	2.8983E-01
	2.3148E-01	1.1095E-01	1.1215E-02	7.9676E-02	6.9254E-01	5.3647E-01		
14 P1	0.0	0.0	0.0	0.0	0.0	-3.4097E-03	2.0785E-03	-3.8088E-03
	3.2544E-04	1.3367E-02	-7.0114E-04	-6.0990E-03	-3.1342E-02	4.4003E-02		
15 P0	1.6733E-02	6.4491E-02	1.0375E-01	1.0690E-01	8.3481E-02	4.3187E-02	9.9833E-02	1.7895E-01
	2.0148E-01	1.7092E-01	0.0	1.1865E-02	1.0428E-01	6.9255E-01	3.1947E-01	
15 P1	0.0	0.0	0.0	0.0	0.0	0.0	-4.6246E-03	1.3285E-03
	5.1494E-03	1.2438E-03	0.0	-9.9097E-05	-4.5504E-03	-2.8558E-02	3.8946E-02	
16 P0	1.1187E-02	4.3596E-02	7.0912E-02	7.3562E-02	5.8645E-02	3.0758E-02	5.1827E-02	1.1538E-01
	1.7142E-01	1.3264E-01	0.0	6.9111E-03	5.5317E-04	8.0043E-02	7.8013E-01	9.9654E-02
16 P1	0.0	0.0	0.0	0.0	0.0	0.0	-8.7047E-04	-3.7821E-03
	3.1139E-03	8.1675E-04	0.0	-3.7922E-04	3.6992E-04	-3.9216E-04	-2.8724E-02	3.4243E-02
17 P0	7.3184E-03	2.8774E-02	4.7206E-02	4.9707E-02	3.9884E-02	2.1144E-02	3.3984E-02	5.8552E-02
	1.3725E-01	9.1334E-02	0.0	0.0	5.1961E-03	3.8931E-02	1.5622E-02	7.8189E-01
17 P1	0.0	0.0	0.0	0.0	0.0	0.0	2.5438E-04	-1.5307E-03
	-2.1514E-04	-7.4721E-04	0.0	0.0	-4.7431E-05	-2.5396E-03	2.5133E-03	1.2767E-03
18 P0	4.7683E-03	1.8640E-02	3.0736E-02	3.2658E-02	2.6448E-02	1.4138E-02	2.2576E-02	3.1084E-02
	9.3863E-02	3.5842E-02	3.5825E-02	0.0	3.1756E-03	0.0	3.8471E-02	1.1403E-01
18 P1	0.0	0.0	0.0	0.0	0.0	0.0	-5.1609E-04	-1.1257E-03
	-1.4085E-04	-2.0247E-03	4.1229E-03	0.0	-2.9070E-05	0.0	-2.8842E-04	-2.5985E-02
19 P0	2.9899E-03	1.1900E-02	1.9758E-02	2.1081E-02	1.7196E-02	9.2524E-03	1.1701E-02	1.9088E-02
	5.6577E-02	2.8898E-02	2.9692E-02	0.0	1.9140E-03	0.0	2.3481E-02	1.3274E-03
19 P1	0.0	0.0	0.0	0.0	0.0	0.0	-5.8138E-04	3.6821E-04
	-7.4245E-04	-1.7243E-04	-2.1059E-04	0.0	-1.4498E-05	0.0	-1.2487E-03	1.2368E-03
20 P0	1.8795E-03	7.5121E-03	1.2523E-02	1.3422E-02	1.1010E-02	5.9542E-03	6.7538E-03	1.1175E-02
	3.0905E-02	1.7880E-02	3.1186E-02	0.0	5.7567E-04	6.8261E-04	0.0	1.7706E-02
20 P1	0.0	4.3011E-01	0.0	0.0	0.0	0.0	-5.9388E-05	-5.5114E-04
	-1.2279E-03	2.0773E-04	1.4495E-03	0.0	-1.0334E-04	9.5598E-05	0.0	-1.2530E-04
	0.0	8.7163E-04	0.0	0.0				

DATE OF RUN 12/04/75 PAGE 49

TIME: 0.10/ 667.96 (SEC.)

ENDF/6 MAT. NO. = 1262

INELASTIC MATRIX

21	P0	-1.1722E-03	7.7003E-03	7.8605E-03	8.4542E-03	6.9656E-03	3.7819E-03	4.1087E-03	6.2935E-03
		1.8655E-02	2.3175E-02	2.1710E-02	0.0	0.0	8.2779E-04	0.0	1.1182E-02
		0.0	9.5793E-02	2.4878E-01	0.0	0.0			
21	P1	0.0	0.0	0.0	0.0	0.0	0.0	-1.6122E-04	-1.3211E-04
		-4.0747E-04	-2.4999E-05	-1.7294E-04	0.0	0.0	-5.9965E-06	0.0	-7.9456E-05
		0.0	-1.5897E-02	1.4534E-02	0.0	0.0			
22	P0	7.2655E-04	2.9205E-03	4.8967E-03	5.2810E-03	4.3660E-03	2.3777E-03	2.4544E-03	3.6101E-03
		1.0092E-02	1.0710E-02	1.4017E-02	0.0	0.0	5.1248E-04	0.0	6.9895E-03
		0.0	0.0	2.2064E-01	2.8164E-03	0.0	0.0		
22	P1	0.0	0.0	0.0	0.0	0.0	0.0	-7.4443E-05	-7.9941E-05
		-4.3331E-04	4.2101E-04	-5.7792E-05	0.0	0.0	-5.8924E-06	0.0	-4.5846E-05
		0.0	0.0	-5.6455E-03	4.9191E-03	0.0	0.0		
23	P0	4.4618E-04	1.8063E-03	3.0324E-03	3.2774E-03	2.7167E-03	1.4831E-03	1.5405E-03	2.1605E-03
		5.7805E-03	7.7026E-03	8.8124E-03	0.0	0.0	3.1706E-04	0.0	2.3531E-03
		2.2126E-03	0.0	1.6141E-03	1.3537E-01	0.0	0.0	0.0	
23	P1	0.0	0.0	0.0	0.0	0.0	0.0	2.0667E-05	-1.4033E-04
		-1.3633E-04	-4.4988E-05	-3.4200E-04	0.0	0.0	-3.7446E-06	0.0	-3.7366E-04
		3.4722E-04	0.0	-3.4523E-03	3.1624E-03	0.0	0.0	0.0	
24	P0	2.7544E-04	1.1112E-03	1.8693E-03	2.0235E-03	1.6809E-03	9.1937E-04	8.8385E-04	1.3736E-03
		3.5211E-03	5.1720E-03	5.5058E-03	0.0	0.0	1.9519E-04	0.0	0.0
		3.0050E-03	0.0	0.0	1.0645E-01	0.0	0.0	0.0	0.0
24	P1	0.0	0.0	0.0	0.0	0.0	0.0	-2.4645E-05	-2.7791E-05
		-3.9562E-04	-3.1918E-05	-5.3583E-06	0.0	0.0	-2.3113E-06	0.0	0.0
		-2.9825E-05	0.0	0.0	5.8550E-04	0.0	0.0	0.0	0.0
25	P0	1.6878E-04	6.8175E-04	1.1432E-03	1.2445E-03	1.0355E-03	5.6718E-04	5.2635E-04	8.4232E-04
		2.1683E-03	3.3035E-03	3.4996E-03	0.0	0.0	1.1994E-04	0.0	0.0
		1.8683E-03	0.0	0.0	4.2117E-02	2.5170E-02	0.0	0.0	0.0
		0.0							
25	P1	0.0	0.0	0.0	0.0	0.0	0.0	-1.4868E-04	2.0742E-05
		-6.0309E-06	-1.4326E-04	-2.1554E-06	0.0	0.0	-2.4695E-06	0.0	0.0
		-2.5081E-05	0.0	0.0	-4.8543E-03	3.0432E-03	0.0	0.0	0.0
		0.0							

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 50

52-U- 238 UFANIUM-238, REV. 1

TIME: 0.10/ 668.06 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

EXIT.
GROUP

INELASTIC MATRIX

26 F0	1.0319E-04	4.1721E-04	7.0328E-04	7.6310E-04	6.3570E-04	3.4859E-04	2.8556E-04	5.4908E-04
	1.2309E-03	2.0862E-03	2.2053E-03	0.0	0.0	7.4539E-05	0.0	0.0
	1.1428E-03	0.0	0.0	0.0	3.9888E-02	0.0	0.0	0.0
	0.0	0.0						
26 P1	0.0	0.0	0.0	0.0	0.0	0.0	5.4231E-05	4.3578E-05
	1.5968E-04	2.3574E-05	-1.8462E-05	0.0	0.0	-3.4256E-06	0.0	0.0
	-1.9356E-05	0.0	0.0	0.0	3.2087E-04	0.0	0.0	0.0
	0.0	0.0						
27 F0	6.2980E-05	2.5481E-04	4.2984E-04	4.6677E-04	3.8922E-04	2.1362E-04	1.7699E-04	3.2871E-04
	8.1006E-04	1.2820E-03	1.3731E-03	0.0	0.0	4.4508E-05	0.0	0.0
	7.0697E-04	0.0	0.0	0.0	3.0992E-02	0.0	0.0	0.0
	0.0	0.0	0.0					
27 P1	0.0	0.0	0.0	0.0	0.0	0.0	-2.7899E-05	-5.4078E-05
	4.0292E-05	-9.6546E-05	-1.8234E-04	0.0	0.0	1.4143E-07	0.0	0.0
	-2.1732E-05	0.0	0.0	0.0	3.5739E-04	0.0	0.0	0.0
	0.0	0.0	0.0					
28 P0	3.8385E-05	1.5539E-04	2.6227E-04	2.8498E-04	2.3781E-04	1.3061E-04	1.3381E-04	2.0660E-04
	4.5422E-04	8.0097E-04	8.2281E-04	0.0	0.0	2.7592E-05	0.0	0.0
	4.2755E-04	0.0	0.0	0.0	2.4229E-02	0.0	0.0	0.0
	0.0	0.0	0.0	0.0				
28 P1	0.0	0.0	0.0	0.0	0.0	0.0	8.6616E-06	-2.5476E-05
	-1.1234E-04	-3.5007E-05	1.8408E-06	0.0	0.0	-2.5899E-06	0.0	0.0
	2.5171E-06	0.0	0.0	0.0	3.0174E-05	0.0	0.0	0.0
	0.0	0.0	0.0	0.0				
29 P0	2.3269E-05	9.4647E-05	1.5982E-04	1.7373E-04	1.4507E-04	7.9715E-05	5.5793E-05	1.2662E-04
	2.8075E-04	4.8405E-04	5.0252E-04	0.0	0.0	1.7467E-05	0.0	0.0
	2.6318E-04	0.0	0.0	0.0	1.7539E-02	3.1938E-04	0.0	0.0
	0.0	0.0	0.0	0.0	0.0			
29 P1	0.0	0.0	0.0	0.0	0.0	0.0	4.7769E-05	5.0527E-06
	-8.6727E-05	3.1792E-05	7.7721E-05	0.0	0.0	2.2216E-06	0.0	0.0
	4.4848E-06	0.0	0.0	0.0	-1.0932E-03	3.9172E-04	0.0	0.0
	0.0	0.0	0.0	0.0	0.0			

52-U- 23E URANIUM-238, REV. 1

TIME: 0.07/ 668.13 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

EXIT
GROUP

INELASTIC MATRIX

30 F0	1.4216E-05	5.7555E-05	9.7285E-05	1.0580E-04	8.8379E-05	4.8586E-05	4.8529E-05	7.7155E-05
	1.4342E-04	2.9115E-04	3.0661E-04	0.0	0.0	0.0	0.0	0.0
	1.56E2E-04	0.0	0.0	0.0	8.8860E-05	4.0015E-03	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		
30 F1	0.0	0.0	0.0	0.0	0.0	0.0	-3.9574E-05	-8.4817E-06
	3.1655E-05	-5.6353E-05	-2.4898E-06	0.0	0.0	0.0	0.0	0.0
	-4.7650E-06	0.0	0.0	0.0	-2.3185E-04	6.9964E-05	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		
31 F0	8.6422E-06	3.5023E-05	5.9172E-05	6.4368E-05	5.3791E-05	2.9581E-05	0.0	3.3500E-05
	7.4542E-05	1.8814E-04	1.7686E-04	0.0	0.0	0.0	0.0	0.0
	5.2328E-05	0.0	0.0	0.0	0.0	3.1280E-03	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
31 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-1.7719E-05
	-4.4180E-05	-1.0618E-05	-1.8112E-05	0.0	0.0	0.0	0.0	0.0
	-3.0659E-06	0.0	0.0	0.0	0.0	4.7771E-05	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
32 F0	0.0	2.1285E-05	3.5969E-05	3.9135E-05	3.2714E-05	0.0	2.5452E-05	3.1537E-05
	4.4432E-05	1.0579E-04	1.1455E-04	0.0	0.0	0.0	0.0	0.0
	5.6942E-05	0.0	0.0	0.0	0.0	2.4329E-03	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32 F1	0.0	0.0	0.0	0.0	0.0	0.0	2.4213E-05	1.7439E-05
	-4.7107E-06	2.2684E-05	-7.2299E-05	0.0	0.0	0.0	0.0	0.0
	-3.4660E-07	0.0	0.0	0.0	0.0	4.3551E-05	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33 F0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	3.6422E-05	6.0543E-05	8.0017E-05	0.0	0.0	0.0	0.0	0.0
	3.2739E-05	0.0	0.0	0.0	0.0	1.9008E-03	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0							
33 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1.9196E-05	-7.0484E-06	5.1525E-05	0.0	0.0	0.0	0.0	0.0
	-9.9193E-07	0.0	0.0	0.0	0.0	1.7405E-05	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0							

DATE OF RUN 12/04/75 PAGE 52

TIME: 0.10/ 668.23 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

34	P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	4.8028E-05	3.2625E-05	0.0	0.0	0.0	0.0
		2.0183E-05	0.0	0.0	0.0	0.0	1.4769E-03	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	-3.2334E-05	-5.7884E-05	0.0	0.0	0.0	0.0
		-8.0477E-06	0.0	0.0	0.0	0.0	1.1510E-05	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		9.3743E-06	0.0	0.0	0.0	0.0	1.1434E-03	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		1.3737E-06	0.0	0.0	0.0	0.0	4.5918E-05	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	2.8700E-05	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	8.8832E-04	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	-1.4859E-06	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	-1.4299E-05	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0

DATE OF RUN 12/04/75 PAGE 53

TIME: 0.05/ 668.28 (SEC.)

18-NOV-74

ENC/FB MAT. NO. = 1262

INELASTIC MATRIX

	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	7.1E60E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0		
37 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	3.4E69E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0		
38 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	5.4444E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	2.1E99E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	4.1E70E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	4.7E16E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DATE OF RUN 12/04/75 PAGE 54

TIME: 0.05/ 668.33 (SEC.)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4G P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	3.3159E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4G P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	4.1131E-06	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	2.5719E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	2.7710E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	2.0636E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
42 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	-7.1662E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DATE OF PUN 12/04/75 PAGE 55

TIME: 0.05/ 668.38 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 56

TIME: 0.077 668.45 (SEC.)

18-NÜ V-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 .PAGE 57

TIME: 0.05 / 668.50 (SEC.)

18-NOV-74

040900000300

ENCF/B MAT. NO. = 1262

INELASTIC MATRIX

48 FG	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	1.0545E-04	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	-6.2452E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49 P0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	1.3898E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	-3.7857E-05	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DATE OF RUN 12/04/75 PAGE 58

TIME: 0.03/ 668.53 (SEC.)

18-NÜ V-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 59

TIME: 0.03/ 668.56 (SEC.)

ENCF/B MAT. NO. = 1262

[INELASTIC MATRIX] X

[illegible]

DATE OF RUN 12/04/75 PAGE 60

TIME: 0.05/ 668.61 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF PUN 12/04/75 PAGE 61

TIME: 0.03/ 668.65 (SEC.)

ENLFB MAT. NO. = 1262

INELASTIC MATF.IX

[illegible]

DATE OF RUN 12/04/75 PAGE 62

TIME: 0.07/ 668.71 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 63

TIME: 0.05/ 668.76 (SEC.)

18-NUV-74

040900000000

ENDF;B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 64

TIME: 0.05 / 668.81 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NU. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 65

TIME: 0.077 668.88 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATF.IX

[illegible]

DATE OF PUN 12/04/75 PAGE 66

TIME: 0.05/ 668.93 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 67

TIME: 0.05/ 668.98 (SEC.)

28-NOV-74

040900000000

ENCF/B MAT. NO. = 1262

INELASTIC MATRIX

68 PO

[illegible]

COLUMN SUMS

		COLUMN						
6.2104E-01	1.8239E 00	2.4915E 00	2.5G21E -00	2.5093E 00	2.4927E 00	2.5011E 00	2.5859E 00	
2.4411E 00	2.1429E 00	1.9492E 00	1.7516E 00	1.5547E 00	1.3508E 00	1.1172E 00	1.0351E 00	
8.9582E-01	7.0321E-01	4.7103E-01	2.8676E-01	1.3791E-01	1.8354E-02	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0						

DATE OF RUN 12/04/75 PAGE 68

TIME: 44.88 / 713.86 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

'N, 2N' MATRIX

1	FO	0.0								
1	PI	0.0								
2	FO	0.0	0.0							
2	PI	0.0	0.0							
3	FO	1.2651E-04	0.0	0.0						
3	PI	0.0	0.0	0.0						
4	FO	1.2992E-03	0.0	0.0	0.0					
4	PI	0.0	0.0	0.0	0.0					
5	FO	7.2937E-03	0.0	0.0	0.0	0.0				
5	PI	0.0	0.0	0.0	0.0	0.0				
6	FO	2.5445E-02	1.0577E-05	0.0	0.0	0.0	0.0			
6	PI	0.0	0.0	0.0	0.0	0.0	0.0			
7	FO	6.0928E-02	1.4852E-04	0.0	0.0	0.0	0.0	0.0		
7	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
8	FO	1.0841E-01	1.0398E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	FO	1.5266E-01	4.3207E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0								
9	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0								
10	FO	1.7889E-01	1.1880E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0							
10	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0							
11	FO	1.8150E-01	2.3572E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0						
11	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0						
12	FO	1.6450E-01	3.6167E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0					
12	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0					
13	FO	1.3649E-01	4.5236E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0				
13	PI	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0					

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 69

52-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 713.92 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

EXIT
GROUP

N,2A MATRIX

14 FC	1.0571E-01	4.8451E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 FC	7.7575E-02	4.5802E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 FC	5.4567E-02	3.9253E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17 FC	3.7172E-02	3.1177E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0							
17 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0							
18 FC	2.4674E-02	2.3335E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0						
18 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0						
19 FC	1.6055E-02	1.6674E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0					
19 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0					
20 FC	1.0286E-02	1.1492E-02	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0				
20 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0					

DATE OF RUN 12/04/75 PAGE 70

TIME: 0.08/ 714.01 (SEC.)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

21	P0	6.5108E-03	7.6995E-03	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	P0	4.0823E-03	5.0467E-03	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	P0	2.5410E-03	3.2516E-03	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	P0	1.5725E-03	2.0673E-03	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	P0	9.6889E-04	1.3007E-03	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0
		0.0	0.0	0.0	0.0	0.0	0.0	0.0

(ETOP/ 14, 3- 1-75, R. A. GRIMESY: PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 71

92-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 714.07 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

EXIT
GROUP

N,2N MATRIX

26 P0	5.9489E-04	8.1178E-04	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0						
26 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0						
27 F0	3.6427E-04	5.0345E-04	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0					
27 P1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0					
28 F0	2.2259E-04	3.1065E-04	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0				
28 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0				
29 P0	1.3579E-04	1.9100E-04	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0			
29 F1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0			

DATE OF RUN 12/04/75 PAGE 72

TIME: 0.05/ 714.12 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 73

TIME: 0.07/ 714.19 (SEC.)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATR. 11

[illegible]

DATE OF RUN 12/04/75 PAGE 74

TIME: 0.07/ 714.26 (SEC.)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 75

TIME: 0.05 / 714.31 (SEC.)

18-NOV-74

040900000000

ENDF! 8 MAT. NO. = 1262

N,2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 76

TIME: 0.05/ 714.36 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 77

TIME: 0.07/ 714.42 (SEC.)

18-NOV-74

040903000000

ENDF/B MAT. NO. = 1262

N,2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 78

TIME: 0.05/ 714.47 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 79

TIME: 0.05/ 714.52 (SEC.)

8-NOV-74

04090 C000000

ENCF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 80

TIME: 0.03/ 714.55 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N,2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 81

TIME: 0.071 714.62 (SEC.)

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 82

TIME: 0.03/ 714.65 (SEC.)

18-NOV-74

04090 00000000'

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 83

TIME: 0.07/ 714.72 (SEC.)

18-NOV-74

0409000000000

ENDIF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 84

TIME: 0.05/ 714.77 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N,2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 85

TIME: 0.03/ 714.80 (SEC.)

18-NOV-74 040900000003

ENCF/B MAT. NU. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 86

TIME: 0.07/ 714.87 (SEC.)

18-NOV-74 040900000000

ENDF/8 MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 87

TIME: 0.05/ 714.92 (SEC.)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

[illegible]

DATE OF RUN 12/04/75 PAGE 88

TIME: 0.077 714.99 (SEC.)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

N, 2N MATRIX

68 PO

[illegible]

6d. F1

COLUMN SUMS

[illegible]

52-U- 236 URANIUM-238, REV. 1

TIME: 0.43/ 715.42 (SEC.)

ENDF/B-1V TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

THE FOLLOWING MATERIALS HAVE BEEN COPIED ONTO THE NEW PHROG TAPE (COP) OR REPLACED BY THIS ETOP RUN (REP):

DEUTERIUM	ETOP-PHROG 07/08/71	ENDF/B MAT.1120	SEQ. NO. = 1	ID. = 2	LTOT= 1521	IWR= 0	COP
CARBON-12	ETOP-PHROG 12/16/71	ENDF/B MAT.1140	SEQ. NO. = 2	ID. = 5	LTOT= 510	IWR= 0	COP
THORIUM-232	ETOP-PHROG 07/07/70	ENDF/B MAT.1117	SEQ. NO. = 3	ID. = 6	LTOT= 1256	IWR= 3	COP
PROTACTINIUM-233	ETOP-PHROG 11/14/71	ENDF/B MAT.1119	SEQ. NO. = 4	ID. = 7	LTOT= 1358	IWR= 3	COP
URANIUM-234	ETOP-PHROG 12/14/71	ENDF/B MAT.1043	SEQ. NO. = 5	ID. = 9	LTOT= 1256	IWR= 3	COP
URANIUM-236	ETOP-PHROG 02/12/70	ENDF/B MAT.1046	SEQ. NO. = 6	ID. = 11	LTOT= 1824	IWR= 3	COP
PLUTONIUM-242	ETOP-PHROG 03/14/70	ENDF/B MAT.1055	SEQ. NO. = 7	ID. = 17	LTOT= 1836	IWR= 3	COP
NITROGEN	ETOP-PHROG 07/27/70	ENDF/B MAT.1012	SEQ. NO. = 3	ID. = 22	LTOT= 630	IWR= 0	COP
OXYGEN-16	ETOP-PHROG 03/07/72	ENDF/B MAT.1134	SEQ. NO. = 9	ID. = 23	LTOT= 500	IWR= 0	COP
MAGNESIUM	ETOP-PHROG 07/27/70	ENDF/B MAT.1014	SEQ. NO. = 10	ID. = 24	LTOT= 871	IWR= 0	COP
ALUMINUM-27	ETOP-PHROG 03/02/72	ENDF/B MAT.1135	SEQ. NO. = 11	ID. = 25	LTOT= 490	IWR= 0	COP
SILICON			0 SEQ. NO. = 12	ID. = 26	LTOT= 787	IWR= 0	COP
CELESIUM	ETOP-PHROG 03/07/72	ENDF/B MAT.1121	SEQ. NO. = 13	ID. = 27	LTOT= 736	IWR= 0	COP
MANGANESE-55	ETOP-PHROG 03/02/72	ENDF/B MAT.1019	SEQ. NO. = 14	ID. = 28	LTOT= 844	IWR= 2	COP
IRON	ETOP-PHROG 09/02/71	ENDF/B MAT.1122	SEQ. NO. = 15	ID. = 29	LTOT= 630	IWR= 0	COP
COPPER			0 SEQ. NO. = 16	ID. = 30	LTOT= 985	IWR= 0	COP
NICKEL	ETOP-PHROG 12/16/71	ENDF/B MAT.1123	SEQ. NO. = 17	ID. = 31	LTOT= 572	IWR= 0	COP
ZINC	ETOP-PHROG 10/15/71	ENDF/B MAT.1087	SEQ. NO. = 18	ID. = 32	LTOT= 648	IWR= 0	COP
SELENIUM-82			0 SEQ. NO. = 19	ID. = 33	LTOT= 68	IWR= 0	COP
BROMINE-81			0 SEQ. NO. = 20	ID. = 34	LTOT= 68	IWR= 0	COP
KRYPTON-83			0 SEQ. NO. = 21	ID. = 35	LTOT= 68	IWR= 0	COP
KRYPTON-84			0 SEQ. NO. = 22	ID. = 36	LTOT= 68	IWR= 0	COP
KRYPTON-85			0 SEQ. NO. = 23	ID. = 37	LTOT= 68	IWR= 0	COP
KRYPTON-86			0 SEQ. NO. = 24	ID. = 38	LTOT= 68	IWR= 0	COP
RUBIDIUM-85			0 SEQ. NO. = 25	ID. = 39	LTOT= 68	IWR= 0	COP
RUBIDIUM-87			0 SEQ. NO. = 26	ID. = 40	LTOT= 68	IWR= 0	COP
STRONTIUM-88			0 SEQ. NO. = 27	ID. = 41	LTOT= 68	IWR= 0	COP
STRONTIUM-90			0 SEQ. NO. = 28	ID. = 42	LTOT= 68	IWR= 0	COP
YTRIUM-89			0 SEQ. NO. = 29	ID. = 43	LTOT= 68	IWR= 0	COP
ZIRCONIUM (NATURAL)	ETOP-PHROG 10/01/71	ENDF/B MAT.1143	SEQ. NO. = 30	ID. = 44	LTOT= 684	IWR= 0	COP
ZIRCONIUM-90			0 SEQ. NO. = 31	ID. = 45	LTOT= 640	IWR= 2	COP
ZIRCONIUM-91			0 SEQ. NO. = 32	ID. = 46	LTOT= 640	IWR= 2	COP
ZIRCONIUM-92			0 SEQ. NO. = 33	ID. = 47	LTOT= 640	IWR= 2	COP
ZIRCONIUM-93			0 SEQ. NO. = 34	ID. = 48	LTOT= 68	IWR= 0	COP
ZIRCONIUM-94			0 SEQ. NO. = 35	ID. = 49	LTOT= 640	IWR= 2	COP
ZIRCONIUM-95			0 SEQ. NO. = 36	ID. = 50	LTOT= 640	IWR= 2	COP
MOLYBDENUM-95			0 SEQ. NO. = 37	ID. = 52	LTOT= 68	IWR= 0	COP
MOLYBDENUM-96			0 SEQ. NO. = 38	ID. = 53	LTOT= 68	IWR= 0	COP
MOLYBDENUM-97			0 SEQ. NO. = 39	ID. = 54	LTOT= 68	IWR= 0	COP
MOLYBDENUM-98			0 SEQ. NO. = 40	ID. = 55	LTOT= 68	IWR= 0	COP
MOLYBDENUM-100			0 SEQ. NO. = 41	ID. = 56	LTOT= 68	IWR= 0	COP
TECHNETIUM-99			0 SEQ. NO. = 42	ID. = 57	LTOT= 68	IWR= 0	COP
RUTHENIUM-100			0 SEQ. NO. = 43	ID. = 58	LTOT= 68	IWR= 0	COP
RUTHENIUM-101			0 SEQ. NO. = 44	ID. = 59	LTOT= 68	IWR= 0	COP
RUTHENIUM-102			0 SEQ. NO. = 45	ID. = 60	LTOT= 68	IWR= 0	COP
RUTHENIUM-104			0 SEQ. NO. = 46	ID. = 61	LTOT= 68	IWR= 0	COP
RHOADIUM-103			0 SEQ. NO. = 47	ID. = 62	LTOT= 68	IWR= 0	COP
PALLADIUM-104			0 SEQ. NO. = 48	ID. = 63	LTOT= 68	IWR= 0	COP
PALLADIUM-105			0 SEQ. NO. = 49	ID. = 64	LTOT= 68	IWR= 0	COP
PALLADIUM-106			0 SEQ. NO. = 50	ID. = 65	LTOT= 68	IWR= 0	COP

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 90

92-U- 238 URANIUM-238, REV. 1

TIME: 2.76/ 718.18 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

PALLADIUM-107

PALLADIUM-108

PALLADIUM-110

CADMUM

TELLURIUM-126

TELLURIUM-128

TELLURIUM-130

IODINE-127

IODINE-129

XENON-128

XENON-130

XENON-131

XENON-132

XENON-134

XENON-135

XENON-136

CESIUM-133

CESIUM-135

CESIUM-137

BARIUM-134

BARIUM-136

BARIUM-137

BARIUM-138

LANTHANUM-139

CERIUM-140

CERIUM-142

PRASEODYMIUM-141

NEODYMIUM-142

NEODYMIUM-143

NEODYMIUM-144

NEODYMIUM-145

NEODYMIUM-146

NEODYMIUM-148

NEODYMIUM-150

PROMETHIUM-147

SAMARIUM-147

SAMARIUM-148

SAMARIUM-149

SAMARIUM-150

SAMARIUM-151

SAMARIUM-152

SAMARIUM-154

EUROPIUM-151

EUROPIUM-153

EUROPIUM-154

EUROPIUM-155

GADOLINIUM-154

GADOLINIUM-155

GADOLINIUM-156

GADOLINIUM-157

GADOLINIUM-158

0 SEQ. NO. = 51 ID. = 66 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 52 ID. = 67 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 53 ID. = 68 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 54 ID. = 71 LTOT = 1159 IWR = 0 COP

0 SEQ. NO. = 55 ID. = 77 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 56 ID. = 78 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 57 ID. = 79 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 58 ID. = 80 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 59 ID. = 81 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 60 ID. = 82 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 61 ID. = 83 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 62 ID. = 84 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 63 ID. = 85 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 64 ID. = 86 LTOT = 68 IWR = 0 COP

ETOP-PHROG 07/22/70 ENDF/B MAT.1026

0 SEQ. NO. = 65 ID. = 87 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 66 ID. = 88 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 67 ID. = 89 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 68 ID. = 90 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 69 ID. = 91 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 70 ID. = 92 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 71 ID. = 93 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 72 ID. = 94 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 73 ID. = 95 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 74 ID. = 96 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 75 ID. = 97 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 76 ID. = 98 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 77 ID. = 99 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 78 ID. = 100 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 79 ID. = 101 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 80 ID. = 102 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 81 ID. = 103 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 82 ID. = 104 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 83 ID. = 105 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 84 ID. = 106 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 85 ID. = 107 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 86 ID. = 108 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 87 ID. = 109 LTOT = 68 IWR = 0 COP

ETOP-PHROG 07/22/70 ENDF/B MAT.1027

0 SEQ. NO. = 88 ID. = 110 LTOT = 1204 IWR = 3 COP

0 SEQ. NO. = 89 ID. = 111 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 90 ID. = 112 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 91 ID. = 113 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 92 ID. = 114 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 93 ID. = 115 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 94 ID. = 116 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 95 ID. = 117 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 96 ID. = 118 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 97 ID. = 119 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 98 ID. = 120 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 99 ID. = 121 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 100 ID. = 122 LTOT = 68 IWR = 0 COP

0 SEQ. NO. = 101 ID. = 123 LTOT = 68 IWR = 0 COP

92-U- 238 URANIUM-238, REV. 1

TIME: 0.90/ 719.08 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 04090000000

ENDF/B MAT. NO. = 1262.

TERBIUM-159	0 SEQ. NO. = 102 ID. = 124 LTOT = 68 IWR = 0 COP
GOLD-197	ETOP-PHROG 07/01/70 ENDF/B MAT.1037 SEQ. NO. = 103 ID. = 125 LTOT = 1562 IWR = 3 COP
LEAD	ETOP-PHROG 12/16/71 ENDF/B MAT.1136 SEQ. NO. = 104 ID. = 126 LTOT = 778 IWR = 0 COP
BISMUTH	0 SEQ. NO. = 105 ID. = 127 LTOT = 986 IWR = 0 COP
SIGMA ABS. = (100,000)/V	0 SEQ. NO. = 106 ID. = 128 LTOT = 68 IWR = 0 COP
POTASSIUM 39	0 SEQ. NO. = 107 ID. = 129 LTOT = 430 IWR = 0 COP
BORON-10	ETOP-PHROG 09/30/71 ENDF/B MAT.1155 SEQ. NO. = 108 ID. = 130 LTOT = 717 IWR = 0 COP
PROTACTINIUM-232	0 SEQ. NO. = 109 ID. = 131 LTOT = 476 IWR = 0 COP
PROTACTINIUM-234	0 SEQ. NO. = 110 ID. = 132 LTOT = 476 IWR = 0 COP
URANIUM-232	0 SEQ. NO. = 111 ID. = 133 LTOT = 476 IWR = 0 COP
AMERICIUM-241	ETOP-PHROG 07/22/70 ENDF/B MAT.1056 SEQ. NO. = 112 ID. = 134 LTOT = 1158 IWR = 3 COP
AMERICIUM-243	ETOP-PHROG 07/22/70 ENDF/B MAT.1057 SEQ. NO. = 113 ID. = 135 LTOT = 1096 IWR = 3 COP
LITHIUM (NATURAL)	0 SEQ. NO. = 114 ID. = 138 LTOT = 1302 IWR = 0 COP
LITHIUM-6	ETOP-PHROG 07/27/70 ENDF/B MAT.1005 SEQ. NO. = 115 ID. = 139 LTOT = 830 IWR = 0 COP
LITHIUM-7	ETOP-PHROG 07/27/70 ENDF/B MAT.1006 SEQ. NO. = 116 ID. = 140 LTOT = 930 IWR = 0 COP
SODIUM-23	ETOP-PHROG 12/16/71 ENDF/B MAT.1156 SEQ. NO. = 117 ID. = 141 LTOT = 613 IWR = 2 COP
SULFUR	0 SEQ. NO. = 118 ID. = 143 LTOT = 787 IWR = 0 COP
CHLORINE	0 SEQ. NO. = 119 ID. = 144 LTOT = 781 IWR = 0 COP
POTASSIUM	0 SEQ. NO. = 120 ID. = 145 LTOT = 733 IWR = 0 COP
CALCIUM	0 SEQ. NO. = 121 ID. = 146 LTOT = 781 IWR = 0 COP
TITANIUM	ETOP-PHROG 10/19/71 ENDF/B MAT.1016 SEQ. NO. = 122 ID. = 147 LTOT = 630 IWR = 0 COP
VANADIUM-51	0 SEQ. NO. = 123 ID. = 148 LTOT = 836 IWR = 0 COP
ZINC	0 SEQ. NO. = 124 ID. = 149 LTOT = 920 IWR = 0 COP
NIOBIUM-93	0 SEQ. NO. = 125 ID. = 150 LTOT = 1300 IWR = 0 COP
NIOBIUM-94	0 SEQ. NO. = 126 ID. = 151 LTOT = 68 IWR = 0 COP
IODINE-135	0 SEQ. NO. = 127 ID. = 152 LTOT = 68 IWR = 0 COP
EUROPIUM-156	0 SEQ. NO. = 128 ID. = 153 LTOT = 68 IWR = 0 COP
DYSPROSIUM-164	0 SEQ. NO. = 129 ID. = 154 LTOT = 68 IWR = 0 COP
DYSPROSIUM-165	0 SEQ. NO. = 130 ID. = 155 LTOT = 68 IWR = 0 COP
TANTALUM-181	0 SEQ. NO. = 131 ID. = 156 LTOT = 1240 IWR = 0 COP
TANTALUM-182	0 SEQ. NO. = 132 ID. = 157 LTOT = 68 IWR = 0 COP
TANTALUM-183	0 SEQ. NO. = 133 ID. = 158 LTOT = 68 IWR = 0 COP
TUNGSTEN	0 SEQ. NO. = 134 ID. = 159 LTOT = 1240 IWR = 0 COP
TUNGSTEN-182 (08/22/69, PARTIAL ENDF/B)	0 SEQ. NO. = 135 ID. = 160 LTOT = 980 IWR = 1 COP
TUNGSTEN-183 (08/22/69, PARTIAL ENDF/B)	0 SEQ. NO. = 136 ID. = 161 LTOT = 1108 IWR = 1 COP
TUNGSTEN-184 (08/22/69, PARTIAL ENDF/B)	0 SEQ. NO. = 137 ID. = 162 LTOT = 990 IWR = 1 COP
TUNGSTEN-186 (08/22/69, PARTIAL ENDF/B)	0 SEQ. NO. = 138 ID. = 163 LTOT = 988 IWR = 1 COP
MERCURY (NATURAL)	0 SEQ. NO. = 139 ID. = 164 LTOT = 1396 IWR = 0 COP
MERCURY-196	0 SEQ. NO. = 140 ID. = 165 LTOT = 68 IWR = 0 COP
MERCURY-199	0 SEQ. NO. = 141 ID. = 166 LTOT = 68 IWR = 0 COP
MERCURY-200	0 SEQ. NO. = 142 ID. = 167 LTOT = 68 IWR = 0 COP
MERCURY 201	0 SEQ. NO. = 143 ID. = 168 LTOT = 68 IWR = 0 COP
MERCURY-202	0 SEQ. NO. = 144 ID. = 169 LTOT = 68 IWR = 0 COP
MERCURY-204	0 SEQ. NO. = 145 ID. = 170 LTOT = 68 IWR = 0 COP
URANIUM-233	0 SEQ. NO. = 146 ID. = 176 LTOT = 1464 IWR = 0 COP
THORIUM-232	0 SEQ. NO. = 147 ID. = 179 LTOT = 1340 IWR = 0 COP
CEPHEUS-63	0 SEQ. NO. = 148 ID. = 181 LTOT = 68 IWR = 0 COP
LUTETIUM-175	ETOP-PHROG 11/19/70 ENDF/B MAT.1032 SEQ. NO. = 149 ID. = 182 LTOT = 1019 IWR = 3 COP
LUTETIUM-176	ETOP-PHROG 11/19/70 ENDF/B MAT.1033 SEQ. NO. = 150 ID. = 183 LTOT = 960 IWR = 3 COP
HELIUM	0 SEQ. NO. = 151 ID. = 184 LTOT = 796 IWR = 0 COP
BORON-11	ETOP-PHROG 09/30/71 ENDF/B MAT.1160 SEQ. NO. = 152 ID. = 186 LTOT = 624 IWR = 0 COP

92-U- 238 URANIUM-238, REV. 1

TIME: 3.68/ 722.76 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

THORIUM-233		0	SEQ. NO. = 153	ID. = 187	LTOT = 476	IWR = 0	COP	
THORIUM-234		0	SEQ. NO. = 154	ID. = 188	LTOT = 272	IWR = 0	COP	
URANIUM-239		0	SEQ. NO. = 155	ID. = 189	LTOT = 476	IWR = 0	COP	
HAFNIUM (NATURAL)	ETOP-PHROG 04/15/70	ENDF/B MAT.1034	SEQ. NO. = 156	ID. = 192	LTOT = 340	IWR = 0	COP	
UNIT ABSORPTION			0	SEQ. NO. = 157	ID. = 193	LTOT = 68	IWR = 0	COP
HAFNIUM-174	ETOP-PHROG 06/12/70	ENDF/B MAT.1082	SEQ. NO. = 158	ID. = 194	LTOT = 1062	IWR = 2	COP	
HAFNIUM-177	ETOP-PHROG 06/08/70	ENDF/B MAT.1073	SEQ. NO. = 159	ID. = 195	LTOT = 1428	IWR = 2	COP	
HAFNIUM-178	ETOP-PHROG 06/08/70	ENDF/B MAT.1074	SEQ. NO. = 160	ID. = 196	LTOT = 1479	IWR = 2	COP	
HAFNIUM-179	ETOP-PHROG 06/12/70	ENDF/B MAT.1075	SEQ. NO. = 161	ID. = 197	LTOT = 1003	IWR = 2	COP	
HAFNIUM-180	ETOP-PHROG 06/12/70	ENDF/B MAT.1076	SEQ. NO. = 162	ID. = 198	LTOT = 1062	IWR = 2	COP	
HAFNIUM-176	ETOP-PHROG 06/03/70	ENDF/B MAT.1072	SEQ. NO. = 163	ID. = 199	LTOT = 1479	IWR = 2	COP	
RHENIUM-185	ETOP-PHROG 12/28/70	ENDF/B MAT.1083	SEQ. NO. = 164	ID. = 201	LTOT = 948	IWR = 3	COP	
RHENIUM-187	ETOP-PHROG 11/20/70	ENDF/B MAT.1084	SEQ. NO. = 165	ID. = 202	LTOT = 988	IWR = 3	COP	
MOLYBDENUM	ETOP-PHROG 03/15/72	ENDF/B MAT.1111	SEQ. NO. = 166	ID. = 210	LTOT = 894	IWR = 0	COP	
URANIUM-238	ETOP-PHROG 04/25/72	ENDF/B MAT.1158	SEQ. NO. = 167	ID. = 221	LTOT = 1502	IWR = 3	COP	
PLUTONIUM-239	ETOP-PHROG 04/27/72	ENDF/B MAT.1159	SEQ. NO. = 168	ID. = 222	LTOT = 1729	IWR = 3	COP	
PLUTONIUM-240	ETOP-PHROG 04/27/72	ENDF/B MAT.1105	SEQ. NO. = 169	ID. = 223	LTOT = 1504	IWR = 3	COP	
URANIUM-235	ETOP-PHROG 04/27/72	ENDF/B MAT.1157	SEQ. NO. = 170	ID. = 224	LTOT = 1699	IWR = 3	COP	
CADMIUM-110 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7070	SEQ. NO. = 171	ID. = 225	LTOT = 340	IWR = 0	COP	
CADMIUM-111 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7071	SEQ. NO. = 172	ID. = 226	LTOT = 340	IWR = 0	COP	
CADMIUM-112 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7072	SEQ. NO. = 173	ID. = 227	LTOT = 340	IWR = 0	COP	
CADMIUM-113 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7073	SEQ. NO. = 174	ID. = 228	LTOT = 340	IWR = 0	COP	
CADMIUM-114 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7074	SEQ. NO. = 175	ID. = 229	LTOT = 340	IWR = 0	COP	
CADMIUM-115 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7075	SEQ. NO. = 176	ID. = 230	LTOT = 340	IWR = 0	COP	
CADMIUM-116 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7076	SEQ. NO. = 177	ID. = 231	LTOT = 340	IWR = 0	COP	
INDIUM-115 ALDERMASTON	ETOP-PHROG 05/15/72	ENDF/B MAT.7077	SEQ. NO. = 178	ID. = 232	LTOT = 340	IWR = 0	COP	
SILVER-107	ETOP-PHROG 05/15/72	ENDF/B MAT.1138	SEQ. NO. = 179	ID. = 233	LTOT = 1220	IWR = 2	COP	
SILVER-109	ETOP-PHROG 05/15/72	ENDF/B MAT.1139	SEQ. NO. = 180	ID. = 234	LTOT = 1218	IWR = 2	COP	
PLUTONIUM-238	ETOP-PHROG 05/30/72	ENDF/B MAT.1050	SEQ. NO. = 181	ID. = 235	LTOT = 1446	IWR = 3	COP	
PLUTONIUM-241	ETOP-PHROG 05/30/72	ENDF/B MAT.1106	SEQ. NO. = 182	ID. = 236	LTOT = 1607	IWR = 3	COP	
HYDROGEN	ETOP-PHROG 06/30/72	ENDF/B MAT.1148	SEQ. NO. = 183	ID. = 237	LTOT = 4866	IWR = 0	COP	
BERYLLIUM-9	ETOP-PHROG 07/03/72	ENDF/B MAT.1154	SEQ. NO. = 184	ID. = 238	LTOT = 726	IWR = 0	COP	
CARBON-12	ETOP-PHROG 07/15/72	ENDF/B MAT.1165	SEQ. NO. = 185	ID. = 239	LTOT = 543	IWR = 0	COP	
HAFNIUM-176	ETOP-PHROG 12/28/72	ENDF/B MAT.1072	SEQ. NO. = 186	ID. = 240	LTOT = 1062	IWR = 2	COP	
HAFNIUM-177	ETOP-PHROG 12/28/72	ENDF/B MAT.1073	SEQ. NO. = 187	ID. = 241	LTOT = 1132	IWR = 2	COP	
HAFNIUM-178	ETOP-PHROG 12/30/72	ENDF/B MAT.1074	SEQ. NO. = 188	ID. = 242	LTOT = 1062	IWR = 2	COP	
HAFNIUM-179	ETOP-PHROG 12/30/72	ENDF/B MAT.1075	SEQ. NO. = 189	ID. = 243	LTOT = 1003	IWR = 2	COP	
HAFNIUM-180	ETOP-PHROG 12/30/72	ENDF/B MAT.1076	SEQ. NO. = 190	ID. = 244	LTOT = 1062	IWR = 2	COP	
HAFNIUM-174	ETOP-PHROG 12/30/72	ENDF/B MAT.1082	SEQ. NO. = 191	ID. = 245	LTOT = 1062	IWR = 2	COP	
ZIRCONIUM (NAT) WITH RESONANCES (EXCEPT THER)	ETOP-PHROG 01/15/73	ENDF/B MAT.1143	SEQ. NO. = 192	ID. = 246	LTOT = 684	IWR = 0	COP	
DYSPROSIUM-160	ETOP-PHROG 08/20/73	ENDF/B MAT.7179	SEQ. NO. = 193	ID. = 247	LTOT = 340	IWR = 0	COP	
DYSPROSIUM-161	ETOP-PHROG 08/20/73	ENDF/B MAT.7180	SEQ. NO. = 194	ID. = 248	LTOT = 340	IWR = 0	COP	
DYSPROSIUM-162	ETOP-PHROG 08/20/73	ENDF/B MAT.7181	SEQ. NO. = 195	ID. = 249	LTOT = 340	IWR = 0	COP	
DYSPROSIUM-163	ETOP-PHROG 08/20/73	ENDF/B MAT.7182	SEQ. NO. = 196	ID. = 250	LTOT = 340	IWR = 0	COP	
URANIUM-235	ETOP-PHROG 03/15/75	ENDF/B MAT.1260	SEQ. NO. = 197	ID. = 401	LTOT = 2388	IWR = 2	COP	
URANIUM-235	ETOP-PHROG 03/16/75	ENDF/B MAT.1261	SEQ. NO. = 198	ID. = 402	LTOT = 3884	IWR = 3	COP	
URANIUM-238, REV. 1	ETOP-PHROG 12/01/75	ENDF/B MAT.1262	SEQ. NO. = 199	ID. = 403	LTOT = 2184	IWR = 3	REP	

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 93

92-U- 238 URANIUM-238, REV. 1

TIME: 7.14/ 729.90 (SEC.)

ENDF/B-1V TAPE 409(REV11

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

THE PHROG ID OF THIS MATERIAL IS 403

MATERIAL TITLE

URANIUM-238, REV. 1

ETOP-PHROG 12/04/75 ENDF/B MAT.1262

TOTAL LENGTH OF DATA LIST IS 2184

DATA PRESENT:

ABSORPTION

FISSION

SCATTERING

N-2N

P0,P1 ELASTIC

DIFFERENCE SCATTERING MATRICES

RESONANCE PARAMETER TABLES

NUCLIDE I. C. NUMBER	ATOMIC NUMBER	ATOMIC WEIGHT	ENDF/B MATERIAL NUMBER	ENDF/B TAPE NUMBER	ENDF/B VERSION NUMBER	ETOP VERSION NUMBER	PHROG LIB VERSION NUMBER	NUCLIDE SEQUENCE NUMBER	ISOTROPIC RANGE LIMIT
403	92	238	1262	409	4	14	2	199	22

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 94

92-U- 238 URANIUM-238, REV. 1

TIME: 0.05/ 729.95 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

ABSORPTION CROSS SECTIONS

GROUP	SIGMA-A	GROUP	SIGMA-A
1	9.937532E-01	35	2.079656E-01
2	8.630170E-01	36	2.303816E-01
3	5.815958E-01	37	2.554461E-01
4	5.757480E-01	38	1.302853E-01
5	5.686080E-01	39	1.885990E-01
6	5.852453E-01	40	9.557199E-02
7	5.712603E-01	41	7.013083E-02
8	5.837081E-01	42	1.227921E-01
9	1.468207E-01	43	1.683509E-01
10	1.331239E-01	44	5.370755E-02
11	1.215543E-01	45	4.614786E-02
12	1.120345E-01	46	3.705963E-02
13	1.078191E-01	47	2.368042E-01
14	1.105363E-01	48	2.491748E-02
15	1.208749E-01	49	7.734813E-03
16	1.382425E-01	50	1.274782E-02
17	1.531475E-01	51	5.425986E-03
18	1.709408E-01	52	6.016318E-03
19	1.905160E-01	53	4.986770E-02
20	2.243789E-01	54	6.834298E-03
21	2.984854E-01	55	7.113125E-03
22	2.272522E-01	56	2.542286E-01
23	2.387076E-02	57	9.447608E-03
24	1.665694E-02	58	1.077754E-02
25	1.164196E-02	59	1.224137E-02
26	8.335028E-03	60	1.420338E-02
27	5.944017E-03	61	1.644544E-02
28	2.734320E-03	62	1.884988E-02
29	1.277734E-04	63	2.221905E-02
30	0.0	64	2.531210E-02
31	0.0	65	2.941532E-01
32	2.313817E-01	66	5.663102E-01
33	2.771611E-01	67	6.189456E-01
34	2.570893E-01	68	6.826116E-01

(ETCF/ 14, 3- 1-75, R. A. GIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 95

52-U- 23E URANILM-238, REV. 1

TIME: 0.10/ 730.05 (SEC.)

ENDF/B-IV TAPE 409(FEVL)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

FISSION DATA

GROUP	SIGMA--FISSION	NU	GROUP	SIGMA-FISSION	NU
1	9.909355E-01	3.642868E 00	35	0.0	0.0
2	8.584498E-01	3.375047E 00	36	0.0	0.0
3	5.740333E-01	3.137473E 00	37	0.0	0.0
4	5.631753E-01	2.956851E 00	38	0.0	0.0
5	5.477531E-01	2.818316E 00	39	0.0	0.0
6	5.512831E-01	2.708777E 00	40	0.0	0.0
7	5.189337E-01	2.624683E 00	41	0.0	0.0
8	3.066605E-01	2.562580E 00	42	0.0	0.0
9	4.284021E-02	2.509929E 00	43	0.0	0.0
10	1.252253E-02	2.467403E 00	44	0.0	0.0
11	2.016534E-03	2.435035E 00	45	0.0	0.0
12	7.006458E-04	2.410382E 00	46	0.0	0.0
13	1.707466E-04	2.368844E 00	47	0.0	0.0
14	9.354358E-05	2.373261E 00	48	0.0	0.0
15	6.536052E-05	2.361164E 00	49	0.0	0.0
16	5.643217E-05	2.351907E 00	50	0.0	0.0
17	4.948008E-05	2.344950E 00	51	0.0	0.0
18	4.406919E-05	2.339118E 00	52	0.0	0.0
19	4.038899E-05	2.334788E 00	53	0.0	0.0
20	3.999998E-05	2.331437E 00	54	0.0	0.0
21	4.000001E-05	2.328724E 00	55	0.0	0.0
22	4.000000E-05	2.326686E 00	56	0.0	0.0
23	5.822438E-05	2.324949E 00	57	0.0	0.0
24	8.599350E-05	2.323835E 00	58	0.0	0.0
25	8.700008E-05	2.322893E 00	59	0.0	0.0
26	8.700001E-05	2.322143E 00	60	0.0	0.0
27	8.700011E-05	2.321557E 00	61	0.0	0.0
28	7.742508E-05	2.321134E 00	62	0.0	0.0
29	4.985202E-06	2.321038E 00	63	0.0	0.0
30	0.0	0.0	64	0.0	0.0
31	0.0	0.0	65	0.0	0.0
32	0.0	0.0	66	0.0	0.0
33	0.0	0.0	67	0.0	0.0
34	0.0	0.0	68	0.0	0.0

92-U- 238 URANIUM-238, REV. 1

TIME: 0.08/ 730.13 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

MAXIMUM I = 22

DOWNSCATTERING TO 30 GROUPS

-682 VALUES GIVEN

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP					
I	J	J	J+1	J+2	J+3	J+4	J+5
1	1	2.686687E-03	2.605620E-02	2.838890E-02	2.305898E-02	2.411464E-02	3.794187E-02
1	7	5.651122E-02	6.958938E-02	7.340217E-02	6.858051E-02	5.827475E-02	4.597790E-02
1	13	2.423421E-02	2.436341E-02	1.673781E-02	1.118703E-02	7.318441E-03	4.708298E-03
1	19	2.989882E-03	1.879482E-03	1.172160E-03	7.265471E-04	4.481815E-04	2.754375E-04
1	25	1.687825E-04	1.031925E-04	6.297987E-05	3.838475E-05	2.336944E-05	1.421599E-05
1	31	8.642175E-06					
2	2	2.260672E-04	1.395043E-02	2.759007E-02	5.337201E-02	1.043345E-01	1.615999E-01
2	8	2.122526E-01	2.375984E-01	2.327285E-01	2.056634E-01	1.673137E-01	1.275942E-01
2	14	5.251577E-02	6.449127E-02	4.359610E-02	2.877368E-02	1.863962E-02	1.190038E-02
2	20	7.512141E-03	4.700348E-03	2.920861E-03	1.805348E-03	1.111220E-03	6.817509E-04
2	26	4.172081E-04	2.548138E-04	1.553912E-04	9.464723E-05	5.759520E-05	3.502250E-05
2	32	2.128453E-05					
3	3	2.731143E-03	1.465193E-02	4.991594E-02	1.047937E-01	1.880327E-01	2.692133E-01
3	9	2.214201E-01	3.312428E-01	3.039076E-01	2.546408E-01	1.987504E-01	1.467442E-01
3	15	1.037490E-01	7.091165E-02	4.720604E-02	3.078562E-02	1.975782E-02	1.252297E-02
3	21	7.860504E-03	4.896693E-03	3.032413E-03	1.869296E-03	1.148181E-03	7.032838E-04
3	27	4.298429E-04	2.622721E-04	1.598160E-04	9.728452E-05	5.917231E-05	3.596852E-05
3	33	0.0					
4	4	8.212799E-02	4.172242E-02	1.656266E-01	2.258765E-01	2.135509E-01	2.735296E-01
4	10	2.976276E-01	2.849290E-01	2.467657E-01	1.976106E-01	1.488557E-01	1.069002E-01
4	16	7.396179E-02	4.570691E-02	3.265771E-02	2.108071E-02	1.342176E-02	8.454241E-03
4	22	5.280972E-03	3.277354E-03	2.023638E-03	1.244590E-03	7.631038E-04	4.667691E-04
4	28	2.849770E-04	1.737338E-04	1.057958E-04	6.436781E-05	3.913538E-05	0.0
4	34	0.0					
5	5	1.710837E-01	1.053286E-01	3.125743E-01	4.498114E-01	3.431557E-01	2.304398E-01
5	11	1.978270E-01	1.784989E-01	1.475961E-01	1.139974E-01	8.348083E-02	5.864501E-02
5	17	3.988395E-02	2.644775E-02	1.719580E-02	1.101002E-02	6.965578E-03	4.365951E-03
5	23	2.716710E-03	1.680941E-03	1.035492E-03	6.356973E-04	3.892186E-04	2.378113E-04
5	29	1.450657E-04	8.837919E-05	5.379059E-05	3.271375E-05	0.0	0.0
5	35	0.0					
6	6	2.099338E-01	1.302938E-01	5.122948E-01	4.842775E-01	4.806882E-01	3.431093E-01
6	12	1.898203E-01	1.295075E-01	7.832754E-02	4.318738E-02	3.075833E-02	2.114360E-02
6	18	1.413622E-02	9.252395E-03	5.954184E-03	3.781870E-03	2.377744E-03	1.483100E-03
6	24	9.193723E-04	5.671764E-04	3.485896E-04	2.136192E-04	1.306103E-04	7.971539E-05
6	30	4.858577E-05	2.958058E-05	0.0	0.0	0.0	0.0
6	36	0.0					

S2-U- 23E URANIUM-238, REV. 1

TIME: 0.12/ 730.25 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP						
I	J	J	J+1	J+2	J+3	J+4	J+5	
7	7	2.492676E-01	1.236243E-01	2.402486E-01	4.179859E-01	4.621565E-01	3.633024E-01	
7	13	2.392026E-01	1.684209E-01	9.983283E-02	5.182719E-02	3.398393E-02	2.257644E-02	
7	19	1.170080E-02	6.753813E-03	4.108671E-03	2.454414E-03	1.540492E-03	8.838486E-04	
7	25	5.263523E-04	2.855612E-04	1.769931E-04	1.338053E-04	5.579292E-05	4.852854E-05	
7	31	0.0	2.545197E-05	0.0	0.0	0.0	0.0	
7	37	0.0						
8	8	3.332390E-01	1.890756E-01	1.507171E-01	3.394324E-01	4.237662E-01	4.299805E-01	
8	14	2.898250E-01	1.789543E-01	1.153812E-01	5.855241E-02	3.108427E-02	1.908765E-02	
8	20	1.117457E-02	6.293543E-03	3.610099E-03	2.160490E-03	1.373617E-03	8.423219E-04	
8	26	5.490817E-04	3.287147E-04	2.065984E-04	1.266181E-04	7.715479E-05	3.349992E-05	
8	32	3.153723E-05	0.0	0.0	0.0	0.0	0.0	
8	38	0.0						
9	9	5.961075E-01	4.064131E-01	3.075305E-02	1.978494E-01	2.436608E-01	2.314775E-01	
9	15	2.014849E-01	1.714225E-01	1.372551E-01	9.386778E-02	5.657741E-02	3.090519E-02	
9	21	1.869455E-02	1.009225E-02	5.780544E-03	3.521067E-03	2.188286E-03	1.230869E-03	
9	27	8.100542E-04	4.542246E-04	2.807516E-04	1.434220E-04	7.454172E-05	4.443202E-05	
9	33	3.642244E-05	0.0	0.0	0.0	0.0	0.0	
9	39	0.0						
10	10	8.771707E-01	6.064164E-01	2.542437E-02	0.0	1.109532E-01	1.709249E-01	
10	16	1.326369E-01	9.133369E-02	3.584207E-02	2.889791E-02	1.787958E-02	1.317492E-02	
10	22	1.071048E-02	7.702630E-03	5.171977E-03	3.300485E-03	2.086215E-03	1.281999E-03	
10	28	8.009714E-04	4.840468E-04	2.911515E-04	1.881407E-04	1.057500E-04	6.054337E-05	
10	34	4.802759E-05	0.0	0.0	0.0	0.0	0.0	
10	40	0.0						
11	11	9.927378E-01	7.481814E-01	4.121364E-02	1.121495E-02	0.0	0.0	
11	17	0.0	3.582462E-02	2.969240E-02	3.118614E-02	2.170590E-02	1.401713E-02	
11	23	6.812401E-03	5.905752E-03	3.499646E-03	2.205043E-03	1.373109E-03	8.228056E-04	
11	29	5.025226E-04	3.066142E-04	1.768593E-04	1.145478E-04	8.001698E-05	3.262467E-05	
11	35	0.0	2.870050E-05	0.0	0.0	0.0	0.0	
11	41	0.0						
12	12	9.220222E-01	7.311455E-01	7.967573E-02	1.186486E-02	6.911092E-03	0.0	
12	18	0.0	0.0	0.0	0.0	0.0	0.0	
12	24	0.0	0.0	0.0	0.0	0.0	0.0	
12	30	0.0	0.0	0.0	0.0	0.0	0.0	
12	36	0.0	0.0	0.0	0.0	0.0	0.0	
12	42	0.0						
13	13	7.464134E-01	6.925393E-01	1.042840E-01	5.531688E-04	5.196109E-03	3.175648E-03	
13	19	1.913954E-03	5.756685E-04	0.0	0.0	0.0	0.0	
13	25	0.0	0.0	0.0	0.0	0.0	0.0	

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 98

92-U- 238 URANIUM-238, REV. 1

TIME: 0.12/ 730.36 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP 1 TO GROUP						
1	J	J	J+1	J+2	J+3	J+4	J+5	
13	31	0.0	0.0	0.0	0.0	0.0	0.0	
12	37	0.0	0.0	0.0	0.0	0.0	0.0	
13	43	0.0						
14	14	5.364695E-01	6.925538E-01	8.004278E-02	3.893112E-02	0.0	0.0	
14	20	6.826061E-04	8.277870E-04	5.124793E-04	3.170602E-04	1.951867E-04	1.199377E-04	
14	26	7.453872E-05	4.450776E-05	2.759152E-05	1.746688E-05	0.0	0.0	
14	22	0.0	0.0	0.0	0.0	0.0	0.0	
14	38	0.0	0.0	0.0	0.0	0.0	0.0	
14	44	0.0						
15	15	3.194690E-01	7.801288E-01	1.562206E-02	3.847143E-02	2.348138E-02	0.0	
15	21	0.0	0.0	0.0	0.0	0.0	0.0	
15	27	0.0	0.0	0.0	0.0	0.0	0.0	
15	33	0.0	0.0	0.0	0.0	0.0	0.0	
15	39	0.0	0.0	0.0	0.0	0.0	0.0	
15	45	0.0						
16	16	9.965366E-02	7.818931E-01	1.140330E-01	1.327369E-03	1.770623E-02	1.118215E-02	
16	22	6.985453E-03	2.353114E-03	0.0	0.0	0.0	0.0	
16	28	0.0	0.0	0.0	0.0	0.0	0.0	
16	34	0.0	0.0	0.0	0.0	0.0	0.0	
16	40	0.0	0.0	0.0	0.0	0.0	0.0	
16	46	0.0						
17	17	0.0	5.640932E-01	3.217309E-01	0.0	0.0	0.0	
17	23	2.212612E-03	3.004972E-03	1.868308E-03	1.142802E-03	7.069653E-04	4.275450E-04	
17	29	2.631776E-04	1.568241E-04	9.232790E-05	5.694194E-05	3.273910E-05	2.018275E-05	
17	35	9.374332E-06	0.0	0.0	0.0	0.0	0.0	
17	41	0.0	0.0	0.0	0.0	0.0	0.0	
17	47	0.0						
18	18	0.0	2.273040E-01	4.301097E-01	4.579293E-02	0.0	0.0	
18	24	0.0	0.0	0.0	0.0	0.0	0.0	
18	30	0.0	0.0	0.0	0.0	0.0	0.0	
18	36	0.0	0.0	0.0	0.0	0.0	0.0	
18	42	0.0	0.0	0.0	0.0	0.0	0.0	
18	48	0.0						
19	19	0.0	0.0	2.487763E-01	2.206367E-01	1.614118E-03	0.0	
19	25	0.0	0.0	0.0	0.0	0.0	0.0	
19	31	0.0	0.0	0.0	0.0	0.0	0.0	
19	37	0.0	0.0	0.0	0.0	0.0	0.0	
19	43	0.0	0.0	0.0	0.0	0.0	0.0	
19	49	0.0						

(ETCP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHR3G

DATE OF RUN 12/04/75 PAGE 99

52-U- 238 URANIUM-238, REV. 1

TIME: 0.10/ 730.46 (SEC.)

ENDF/B-IV TAPE 409(REVL)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP						
I	J	J+1	J+2	J+3	J+4	J+5		
20	20	0.0	0.0	2.816376E-C3	1.353669E-01	1.064519E-C1	4.211652E-02	
20	26	0.0	0.0	0.0	0.0	0.0	0.0	
20	32	0.0	0.0	0.0	0.0	0.0	0.0	
20	38	0.0	0.0	0.0	0.0	0.0	0.0	
20	44	0.0	0.0	0.0	0.0	0.0	0.0	
20	50	0.0						
21	21	0.0	0.0	0.0	0.0	2.517346E-C2	3.988777E-02	
21	27	3.099186E-02	2.422864E-02	1.753911E-C2	8.886037E-05	0.0	0.0	
21	33	0.0	0.0	0.0	0.0	0.0	0.0	
21	39	0.0	0.0	0.0	0.0	0.0	0.0	
21	45	0.0	0.0	0.0	0.0	0.0	0.0	
21	51	0.0						
22	22	0.0	0.0	0.0	0.0	0.0	0.0	
22	28	0.0	3.193794E-C4	4.001454E-C3	3.128022E-03	2.432902E-C3	1.900755E-03	
22	34	1.47669E-03	1.143357E-03	8.883209E-C4	7.155985E-04	5.444351E-C4	4.106963E-04	
22	40	5.315E65E-04	2.571859E-C4	2.063563E-C4	1.527148E-04	8.183213E-C5	1.581588E-04	
22	46	1.851309E-05	6.699142E-05	1.054511E-C4	1.389757E-05	0.0	0.0	
22	52	0.0						

ETOP/ 14; 3- 1-75; R. A. GRIMESY J PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 100

92-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 730.53 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

ADDITIONAL P1 INELASTIC SCATTERING MATRIX

MAXIMUM I = 22

DOWNSCATTERING TO 30 GROUPS

-882 VALUES GIVEN

GROUP		TRANSFER CROSS SECTION FROM GROUP 1 TO GROUP						
I	J	J	J+1	J+2	J+3	J+4	J+5	
1	1	8.891707E-04	4.441172E-03	3.618311E-03	1.473178E-03	3.892155E-04	-3.148503E-05	
1	7	0.0	0.0	0.0	0.0	0.0	0.0	
1	13	0.0	0.0	0.0	0.0	0.0	0.0	
1	19	0.0	0.0	0.0	0.0	0.0	0.0	
1	25	0.0	0.0	0.0	0.0	0.0	0.0	
1	31	0.0						
2	2	0.0	1.560367E-03	1.018862E-03	4.601551E-04	6.670570E-04	8.715130E-05	
2	8	2.522011E-05	-1.053769E-05	0.0	0.0	0.0	0.0	
2	14	0.0	0.0	0.0	0.0	0.0	0.0	
2	20	0.0	0.0	0.0	0.0	0.0	0.0	
2	26	0.0	0.0	0.0	0.0	0.0	0.0	
2	32	0.0						
3	3	2.158915E-04	-1.242571E-04	2.823442E-04	-2.382860E-04	2.566668E-05	-1.172114E-05	
3	9	-4.010044E-06	-3.671242E-07	-4.691015E-06	0.0	0.0	0.0	
3	15	0.0	0.0	0.0	0.0	0.0	0.0	
3	21	0.0	0.0	0.0	0.0	0.0	0.0	
3	27	0.0	0.0	0.0	0.0	0.0	0.0	
3	33	0.0						
4	4	1.582189E-03	-7.864507E-04	1.986101E-03	-1.783000E-03	-1.282570E-05	0.0	
4	10	0.0	0.0	0.0	0.0	0.0	0.0	
4	16	0.0	0.0	0.0	0.0	0.0	0.0	
4	22	0.0	0.0	0.0	0.0	0.0	0.0	
4	28	0.0	0.0	0.0	0.0	0.0	0.0	
4	34	0.0						
5	5	2.671669E-03	-2.603752E-04	4.950933E-03	4.524502E-06	-1.607752E-03	-1.891484E-03	
5	11	0.0	0.0	0.0	0.0	0.0	0.0	
5	17	0.0	0.0	0.0	0.0	0.0	0.0	
5	23	0.0	0.0	0.0	0.0	0.0	0.0	
5	29	0.0	0.0	0.0	0.0	0.0	0.0	
5	35	0.0						
6	6	3.194901E-03	3.399093E-05	4.367169E-03	2.533494E-03	2.388517E-03	-1.742956E-03	
6	12	-1.783567E-03	-6.858040E-05	-1.136581E-03	0.0	0.0	0.0	
6	18	0.0	0.0	0.0	0.0	0.0	0.0	
6	24	0.0	0.0	0.0	0.0	0.0	0.0	
6	30	0.0	0.0	0.0	0.0	0.0	0.0	
6	36	0.0						

52-U- 23E URANIUM-238, REV. 1

TIME: 0.12/ 730.65 (SEC.)

ENDF/B-IV TAPE 405 (REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP						
I	J	J	J+1	J+2	J+3	J+4	J+5	
7	7	4.254516E-03	-1.737496E-03	5.990528E-03	3.161023E-03	1.444244E-03	1.226328E-03	
7	13	-6.607204E-04	6.528495E-04	-1.541535E-03	-2.901577E-04	8.47928CE-05	-1.720298E-04	
7	19	-1.537918E-04	-1.979615E-05	-5.373890E-05	-2.481441E-05	6.889115E-06	-8.215075E-06	
7	25	-4.555889E-05	1.807716E-05	-9.299537E-06	2.887212E-06	1.592316E-05	-1.319120E-05	
7	31	0.0	6.071162E-06	0.0	0.0	0.0	0.0	
7	37	0.0						
8	8	6.599213E-03	-5.000614E-03	3.043305E-03	6.141171E-03	3.225541E-03	1.738357E-03	
8	14	-1.269594E-03	4.426467E-04	-1.260706E-03	-5.102195E-04	-3.752422E-04	1.227353E-04	
8	20	-1.837129E-04	-4.403692E-05	-2.664687E-05	-4.677518E-05	-9.263807E-06	6.913852E-06	
8	26	1.452597E-05	-1.802584E-05	-8.491920E-06	1.684236E-06	-2.827231E-06	-5.906219E-06	
8	32	5.513024E-06	0.0	0.0	0.0	0.0	0.0	
8	38	0.0						
9	9	1.326277E-02	-5.879261E-03	1.408061E-03	3.257984E-03	2.368471E-03	1.084814E-04	
9	15	1.716457E-03	1.037973E-03	-7.171324E-05	-4.695133E-05	-2.474822E-04	-4.092862E-04	
9	21	-1.358230E-04	-1.444381E-04	-4.544450E-05	-1.332062E-04	-2.01031CE-06	5.322658E-05	
9	27	1.343058E-05	-3.777948E-05	-2.890913E-05	1.055170E-05	-1.472662E-05	-1.570218E-06	
9	33	6.398594E-06	0.0	0.0	0.0	0.0	0.0	
9	39	0.0						
10	10	1.318397E-02	-1.433058E-02	-3.693325E-04	0.0	4.455622E-03	4.146013E-04	
10	16	2.722500E-04	-2.490715E-04	-6.749160E-04	-5.747676E-05	6.924386E-05	-8.332911E-06	
10	22	1.403374E-04	-1.499597E-05	-1.063948E-05	-4.775244E-05	7.858102E-06	-3.218184E-05	
10	28	-1.166915E-05	1.059730E-05	-1.879781E-05	-3.539202E-06	7.562136E-06	-2.349479E-06	
10	34	-1.177807E-05	0.0	0.0	0.0	0.0	0.0	
10	40	0.0						
11	11	2.319248E-02	-1.425818E-02	-3.341169E-03	-2.337125E-04	0.0	0.0	
11	17	0.0	1.374303E-03	-7.023034E-05	4.831802E-04	-5.764817E-05	-1.926401E-05	
11	23	-1.140014E-04	-1.786101E-06	-7.187991E-07	-6.154136E-06	-6.077846E-05	6.202793E-07	
11	29	2.590704E-05	-8.299351E-07	-6.037230E-06	-2.409981E-05	1.717507E-05	-1.929450E-05	
11	35	0.0	-4.952999E-07	0.0	0.0	0.0	0.0	
11	41	0.0						
12	12	1.799504E-02	-1.051713E-02	-2.032994E-03	-3.303227E-05	-1.264071E-04	0.0	
12	18	0.0	0.0	0.0	0.0	0.0	0.0	
12	24	0.0	0.0	0.0	0.0	0.0	0.0	
12	30	0.0	0.0	0.0	0.0	0.0	0.0	
12	36	0.0	0.0	0.0	0.0	0.0	0.0	
12	42	0.0						
13	13	1.565841E-02	-1.044739E-02	-1.516793E-03	1.233083E-04	-1.581042E-05	-9.690052E-06	
13	19	-4.332676E-06	-3.444700E-05	0.0	0.0	0.0	0.0	
13	25	0.0	0.0	0.0	0.0	0.0	0.0	

(ETCP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 102

92-U- 23E URANIUM-238, REV. 1

TIME: 0.10/ 730.75 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP						
I	J	J	J+1	J+2	J+3	J+4	J+5	
13	31	0.0	0.0	0.0	0.0	0.0	0.0	
13	37	0.0	0.0	0.0	0.0	0.0	0.0	
13	43	0.0						
14	14	1.466773E-02	-9.519428E-03	-1.307190E-04	-8.465201E-04	0.0	0.0	
14	20	3.186593E-05	-1.998821E-06	-1.964127E-06	-1.248198E-06	-7.704344E-07	-8.231569E-07	
14	26	-1.141857E-06	4.714462E-08	-8.635148E-07	7.405412E-07	0.0	0.0	
14	32	0.0	0.0	0.0	0.0	0.0	0.0	
14	38	0.0	0.0	0.0	0.0	0.0	0.0	
14	44	0.0						
15	15	1.298209E-02	-9.574562E-03	8.377796E-04	-9.614004E-05	-4.162325E-04	0.0	
15	21	0.0	0.0	0.0	0.0	0.0	0.0	
15	27	0.0	0.0	0.0	0.0	0.0	0.0	
15	33	0.0	0.0	0.0	0.0	0.0	0.0	
15	39	0.0	0.0	0.0	0.0	0.0	0.0	
15	45	0.0						
16	16	1.141439E-02	-4.255692E-04	-8.661620E-03	4.122569E-04	-4.176769E-05	-2.648549E-05	
16	22	-1.528187E-05	-1.245522E-04	0.0	0.0	0.0	0.0	
16	28	0.0	0.0	0.0	0.0	0.0	0.0	
16	34	0.0	0.0	0.0	0.0	0.0	0.0	
16	40	0.0	0.0	0.0	0.0	0.0	0.0	
16	46	0.0						
17	17	0.0	1.008859E-02	-7.140782E-03	0.0	0.0	0.0	
17	23	1.157390E-04	-9.941645E-06	-8.360468E-06	-6.452028E-06	-7.244021E-06	8.390389E-07	
17	29	1.494925E-06	-1.588344E-06	-1.021983E-06	-1.155344E-07	-3.306432E-07	-2.682579E-06	
17	35	4.579695E-07	0.0	0.0	0.0	0.0	0.0	
17	41	0.0	0.0	0.0	0.0	0.0	0.0	
17	47	0.0						
18	18	0.0	7.489275E-03	2.905435E-04	-5.299047E-03	0.0	0.0	
18	24	0.0	0.0	0.0	0.0	0.0	0.0	
18	30	0.0	0.0	0.0	0.0	0.0	0.0	
18	36	0.0	0.0	0.0	0.0	0.0	0.0	
18	42	0.0	0.0	0.0	0.0	0.0	0.0	
18	48	0.0						
19	19	0.0	0.0	4.844800E-03	-1.881175E-03	-1.150777E-03	0.0	
19	25	0.0	0.0	0.0	0.0	0.0	0.0	
19	31	0.0	0.0	0.0	0.0	0.0	0.0	
19	37	0.0	0.0	0.0	0.0	0.0	0.0	
19	43	0.0	0.0	0.0	0.0	0.0	0.0	
19	49	0.0						

(ETCF/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 103

52-U- 238 URANIUM-238, REV. 1

TIME: 0.10/ 730.85 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

INELASTIC SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP						
I	J	J+1	J+2	J+3	J+4	J+5		
20	20	0.0	0.0	1.639716E-03	1.054123E-03	1.951673E-04	-1.618105E-03	
20	26	0.0	0.0	0.0	0.0	0.0	0.0	
20	32	0.0	0.0	0.0	0.0	0.0	0.0	
20	38	0.0	0.0	0.0	0.0	0.0	0.0	
20	44	0.0	0.0	0.0	0.0	0.0	0.0	
20	50	0.0						
21	21	0.0	0.0	0.0	0.0	1.014400E-03	1.069551E-04	
21	27	1.191313E-04	1.005815E-05	-3.643902E-04	-7.728366E-05	0.0	0.0	
21	33	0.0	0.0	0.0	0.0	0.0	0.0	
21	39	0.0	0.0	0.0	0.0	0.0	0.0	
21	45	0.0	0.0	0.0	0.0	0.0	0.0	
21	51	0.0						
22	22	0.0	0.0	0.0	0.0	0.0	0.0	
22	28	0.0	1.305727E-04	2.332119E-05	1.592371E-05	1.451713E-05	5.801790E-06	
22	34	3.836468E-06	1.530598E-05	-4.766332E-06	1.165641E-05	7.099632E-06	1.577198E-05	
22	40	1.371048E-06	9.236561E-06	-2.388718E-06	1.931835E-05	-3.235205E-05	1.637514E-05	
22	46	-1.639226E-05	4.642454E-05	-2.081736E-05	-1.262222E-05	0.0	0.0	
22	52	0.0						

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 104

92-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 730.91 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

N-2N SCATTERING MATRIX

MAXIMUM I = 2

DOWNSCATTERING TO 35 GROUPS

72 VALUES GIVEN

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP					
I	J	J+1	J+2	J+3	J+4	J+5	
1	1	0.0	0.0	1.269148E-04	1.299224E-03	7.293720E-03	2.544475E-02
1	7	6.092788E-02	1.084055E-01	1.526587E-01	1.788929E-01	1.815019E-01	1.644992E-01
1	13	1.364936E-01	1.057088E-01	7.757545E-02	5.458680E-02	3.717200E-02	2.467421E-02
1	19	1.605528E-02	1.028607E-02	6.510634E-03	4.082315E-03	2.540955E-03	1.572550E-03
1	25	9.688912E-04	5.948909E-04	3.642712E-04	2.225875E-04	1.357881E-04	8.273120E-05
1	31	5.035500E-05	3.062519E-05	1.861472E-05	0.0	0.0	0.0
2	2	0.0	0.0	0.0	0.0	1.097678E-05	1.485158E-04
2	8	1.039826E-03	4.320707E-03	1.187980E-02	2.357166E-02	3.616742E-02	4.533566E-02
2	14	4.649063E-02	4.580219E-02	3.925269E-02	3.117674E-02	2.333465E-02	1.667406E-02
2	20	1.149153E-02	7.699531E-03	5.046666E-03	3.251626E-03	2.067280E-03	1.300702E-03
2	26	8.117773E-04	5.034450E-04	3.106927E-04	1.910048E-04	1.170747E-04	7.159305E-05
2	32	4.370106E-05	2.663808E-05	1.621940E-05	9.867239E-06	5.998836E-06	3.645137E-06

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 105

92-U- 238 URANIUM-238. REV. 1

TIME: 0.05/ 730.96 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

INCOMPLETE P0 AND P1 SCATTERING MATRIX.

INCOMPLETE MATRIX__UNRESOLVED AND S-WAVE RESOLVED RESONANCE CONTRIBUTIONS IN ISOTROPIC RANGE ARE NOT INCLUDED.

MAXIMUM I = 68

DOWNSCATTERING TO 1 GROUPS

272 VALUES GIVEN

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP									
I	J	J+1									
		P0	P1	P0	P1	P0	P1	P0	P1	P0	P1
1	1	3.208210E 00	2.627280E 00	3.856526E-02	3.930461E-03						
2	2	3.794168E 00	3.088105E 00	4.121289E-02	4.530471E-03						
3	2	4.446157E 00	3.608957E 00	4.251613E-02	5.571183E-03						
4	4	4.775222E 00	3.785625E 00	4.684195E-02	4.172914E-03						
5	5	4.765191E 00	3.554945E 00	5.272424E-02	1.530591E-03						
6	6	4.457288E 00	2.971900E 00	5.711938E-02	-2.255549E-03						
7	7	4.075544E 00	2.489452E 00	5.855457E-02	-4.420776E-03						
8	8	3.972404E 00	2.157185E 00	6.453687E-02	-6.752208E-03						
9	9	4.354663E 00	2.244457E 00	7.876360E-02	-1.095242E-02						
10	10	4.923467E 00	2.239205E 00	9.371841E-02	-1.366946E-02						
11	11	5.564666E 00	2.301415E 00	1.141890E-01	-1.544074E-02						
12	12	6.336302E 00	2.283725E 00	1.375046E-01	-2.357254E-02						
13	13	7.065287E 00	2.229536E 00	1.597450E-01	-2.748507E-02						
14	14	7.872371E 00	2.171297E 00	1.860899E-01	-3.571779E-02						
15	15	8.655697E 00	2.062433E 00	2.115217E-01	-4.536738E-02						
16	16	9.326568E 00	1.871997E 00	2.341636E-01	-5.448665E-02						
17	17	9.922679E 00	1.676933E 00	2.572781E-01	-6.421006E-02						
18	18	1.057576E 01	1.468104E 00	2.837918E-01	-7.607782E-02						
19	19	1.125299E 01	1.275175E 00	3.053609E-01	-8.580446E-02						
20	20	1.174723E 01	1.084917E 00	3.246869E-01	-9.569132E-02						
21	21	1.201406E 01	7.949657E-01	4.076199E-01	-1.253667E-01						
22	22	1.223547E 01	5.629988E-01	4.152316E-01	-1.304249E-01						
23	23	2.898023E-01	4.213091E-03	1.013795E-02	-3.365824E-03						
24	24	2.709368E-01	3.593730E-03	8.447316E-03	-2.804529E-03						
25	25	2.123374E-01	2.742305E-03	6.398812E-03	-2.124421E-03						
26	26	1.380511E-01	1.557571E-03	3.487360E-03	-1.157812E-03						
27	27	7.005596E-02	7.318954E-04	1.594859E-03	-5.294972E-04						
28	28	2.615622E-02	1.860779E-04	3.350747E-04	-1.112457E-04						
29	29	1.222871E-03	3.454349E-06	0.0	0.0						
30	30	0.0	0.0	0.0	0.0						
31	31	0.0	0.0	0.0	0.0						
32	32	1.239102E-01	1.133046E-03	2.338747E-03	-7.764697E-04						
33	33	2.159690E-02	1.741109E-04	3.377986E-04	-1.121500E-04						
34	34	1.309567E-02	2.130215E-04	5.257309E-04	-1.745440E-04						
35	35	8.373804E-03	1.346470E-04	3.314924E-04	-1.100563E-04						

ETOP/ 14, 3- 1-75, R. A. GRIMESY I PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 106

92-U- 238 URANIUM-238, REV. 1

TIME: 0.10/ 731.06 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO: = 1262

INCOMPLETE P0 AND P1 SCATTERING MATRIX

GROUP		TRANSFER CROSS SECTION FROM GROUP I TO GROUP							
I	J	J		J+1		J+2			
		P0	P1	P0	P1	P0	P1	P0	P1
36	36	1.026022E-02	8.741466E-05	1.745131E-04	-5.793877E-05				
37	37	7.331554E-03	1.325387E-04	3.341385E-04	-1.109348E-04				
38	38	3.052342E-03	4.937382E-05	1.217094E-04	-4.040780E-05				
39	39	4.478734E-03	1.756405E-05	1.467197E-05	-4.871131E-06				
40	40	1.483035E-03	4.189256E-06	0.0	0.0				
41	41	4.485373E-04	2.104533E-06	2.501324E-06	-8.304460E-07				
42	42	5.484575E-04	3.157467E-05	8.967436E-05	-2.977210E-05				
43	43	9.880476E-04	7.046362E-06	1.270906E-05	-4.219438E-06				
44	44	7.213256E-05	2.037591E-07	0.0	0.0				
45	45	5.199811E-05	1.468835E-07	0.0	0.0				
46	46	1.899041E-05	5.364386E-08	0.0	0.0				
47	47	2.473362E-01	6.570380E-03	1.753654E-02	-5.822174E-03				
48	48	7.340607E-01	1.300309E-02	3.264228E-02	-1.083732E-02				
49	49	1.114326E 00	1.801528E-02	4.440663E-02	-1.474311E-02				
50	50	1.410585E 00	2.192084E-02	5.356865E-02	-1.778492E-02				
51	51	1.641118E 00	2.496120E-02	6.070412E-02	-2.015391E-02				
52	52	1.820714E 00	2.732518E-02	6.626117E-02	-2.199888E-02				
53	53	1.960620E 00	2.917348E-02	7.058907E-02	-2.343575E-02				
54	54	2.069569E 00	3.060578E-02	7.395959E-02	-2.455477E-02				
55	55	2.154396E 00	3.172631E-02	7.658458E-02	-2.542627E-02				
56	56	2.220512E 00	3.259552E-02	7.862872E-02	-2.610493E-02				
57	57	2.271933E 00	3.327779E-02	8.022064E-02	-2.663346E-02				
58	58	2.312035E 00	3.380622E-02	8.146048E-02	-2.704509E-02				
59	59	2.343204E 00	3.421769E-02	8.242649E-02	-2.736580E-02				
60	60	2.367553E 00	3.453837E-02	8.317882E-02	-2.761557E-02				
61	61	2.386507E 00	3.478763E-02	8.376336E-02	-2.780964E-02				
62	62	2.401211E 00	3.498168E-02	8.421886E-02	-2.796087E-02				
63	63	2.412745E 00	3.513350E-02	8.457500E-02	-2.807910E-02				
64	64	2.421729E 00	3.525174E-02	8.485228E-02	-2.817118E-02				
65	65	5.548627E 00	1.157314E-01	2.988340E-01	-9.921360E-02				
66	66	8.554126E 00	1.242537E-01	2.951399E-01	-9.924513E-02				
67	67	8.573559E 00	1.246427E-01	3.000896E-01	-9.957653E-02				
68	68	8.593350E 00	1.248886E-01	3.006592E-01	-9.976494E-02				

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 107

92-U- 238 URANIUM-238, REV. 1

TIME: 0.08/ 731.14 (SEC.)

ENDF/B-IV TAPE 409(REVL)

18-NOV-74

040900000000

ENCF/B MAT. NO. = 1262

P0 AND P1 DIFFERENCE SCATTERING MATRICES

(INCLUDES RESOLVED S-WAVE CONTRIBUTION AND THE UNRESOLVED S AND P WAVE CONTRIBUTION BELOW THE ISOTROPIC RANGE UPPER LIMIT.)

SOURCE GROUP	SINK GROUP	P0	P1	SINK GROUP	P0	P1
1	1	0.0	0.0	2	0.0	0.0
2	2	0.0	0.0	3	0.0	0.0
3	3	0.0	0.0	4	0.0	0.0
4	4	0.0	0.0	5	0.0	0.0
5	5	0.0	0.0	6	0.0	0.0
6	6	0.0	0.0	7	0.0	0.0
7	7	0.0	0.0	8	0.0	0.0
8	8	0.0	0.0	9	0.0	0.0
9	9	0.0	0.0	10	0.0	0.0
10	10	0.0	0.0	11	0.0	0.0
11	11	0.0	0.0	12	0.0	0.0
12	12	0.0	0.0	13	0.0	0.0
13	13	0.0	0.0	14	0.0	0.0
14	14	0.0	0.0	15	0.0	0.0
15	15	0.0	0.0	16	0.0	0.0
16	16	0.0	0.0	17	0.0	0.0
17	17	0.0	0.0	18	0.0	0.0
18	18	0.0	0.0	19	0.0	0.0
19	19	0.0	0.0	20	0.0	0.0
20	20	0.0	0.0	21	0.0	0.0
21	21	0.0	0.0	22	0.0	0.0
22	22	0.0	0.0	23	0.0	0.0
23	23	1.20545E 01	1.76473E-01	24	4.26184E-01	-1.41218E-01
24	24	1.23574E 01	1.81217E-01	25	4.37771E-01	-1.45074E-01
25	25	1.26790E 01	1.85668E-01	26	4.48393E-01	-1.48586E-01
26	26	1.30256E 01	1.91015E-01	27	4.61439E-01	-1.52917E-01
27	27	1.34040E 01	1.96581E-01	28	4.74832E-01	-1.57376E-01
28	28	1.38135E 01	2.02693E-01	29	4.89748E-01	-1.62288E-01
29	29	1.42691E 01	2.09942E-01	30	5.07564E-01	-1.68200E-01
30	30	1.48213E 01	2.18151E-01	31	5.27522E-01	-1.74754E-01
31	31	1.54153E 01	2.27012E-01	32	5.49100E-01	-1.81917E-01
32	32	1.60067E 01	1.75696E-01	33	4.02205E-01	-1.23695E-01
33	33	1.57975E 01	2.18493E-01	34	5.89211E-01	-1.72203E-01
34	34	2.06375E 01	2.01174E-01	35	4.54548E-01	-1.41552E-01

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 108

52-U- 238 URANIUM-238, REV. 1

TIME: 0.12/ 731.26 (SEC.)

ENDF/B-IV TAFE 409(REV1)

18-NUV-74

040900000000

ENDF/B MAT. NO. = 1262

PO AND P1 DIFFERENCE SCATTERING MATRICES

(INCLUDES RESOLVED S-WAVE CONTRIBUTION AND THE UNRESOLVED S AND P WAVE CONTRIBUTION BELOW THE ISOTROPIC RANGE UPPER LIMIT.)

SOURCE GROUP	SINK GROUP	PO	P1	SINK GROUP	PO	P1
35	35	2.28150E 01	7.34370E-01	36	1.38486E 00	-6.66010E-01
36	36	1.56724E 01	8.92672E-01	37	1.65560E 00	-8.43725E-01
37	37	2.13561E 01	1.89671E-01	38	4.70754E-01	-1.28014E-01
38	38	1.78561E 01	1.55543E-01	39	3.17036E-01	-1.04208E-01
39	39	1.92821E 01	1.43366E-01	40	3.02421E-01	-8.80433E-02
40	40	1.41757E 01	1.45005E-01	41	3.21171E-01	-1.04055E-01
41	41	1.12666E 01	1.76528E-01	42	4.47740E-01	-1.43437E-01
42	42	1.99356E 01	1.98171E-01	43	4.51696E-01	-1.40581E-01
43	43	1.88176E 01	2.16009E-01	44	4.98711E-01	-1.61444E-01
44	44	9.06467E 01	3.38377E-01	45	2.51772E-01	-8.16084E-02
45	45	8.79413E 00	1.44578E-01	46	3.60079E-01	-1.18719E-01
46	46	8.90136E 01	1.59470E 01	47	2.29095E 01	-1.56309E 01
47	47	6.05657E 00	1.02040E-01	48	2.61673E-01	-8.41909E-02
48	48	5.82544E 01	2.22668E-01	49	1.78906E-01	-5.76062E-02
49	49	7.75595E 00	1.32131E-01	50	3.31213E-01	-1.09286E-01
50	50	1.68365E 01	8.93033E-01	51	3.12938E 00	-8.36634E-01
51	51	2.01437E 02	6.33276E-01	52	1.94011E-01	-6.37115E-02
52	52	7.83411E 00	1.60723E-01	53	4.21832E-01	-1.37401E-01
53	53	8.64316E 01	2.86465E-01	54	1.28438E-01	-4.19550E-02
54	54	4.89819E 00	7.94972E-02	55	1.96941E-01	-6.51045E-02
55	55	6.08984E 00	5.31940E-02	56	2.27793E-01	-7.53480E-02
56	56	7.07740E 00	1.11736E-01	57	2.75542E-01	-9.09652E-02
57	57	3.95620E 01	8.70633E-02	58	-7.90874E-02	2.55974E-02
58	58	2.65805E 00	6.06993E-02	59	1.59887E-01	-5.27392E-02
59	59	5.06392E 00	7.70421E-02	60	1.87961E-01	-6.22067E-02
60	60	5.56294E 00	8.21259E-02	61	1.98853E-01	-6.58500E-02
61	61	5.78484E 00	8.47450E-02	62	2.04777E-01	-6.78256E-02
62	62	5.91725E 00	8.63627E-02	63	2.08488E-01	-6.90587E-02
63	63	5.95229E 00	8.71951E-02	64	2.10345E-01	-6.96740E-02
64	64	6.05898E 00	8.81611E-02	65	2.12882E-01	-7.04444E-02
65	65	2.97885E 00	8.19409E-03	66	-4.62770E-04	2.19226E-04
66	66	0.0	0.0	67	0.0	0.0
67	67	0.0	0.0	68	0.0	0.0
68	68	0.0	0.0	69	0.0	0.0

92-U- 238 URANIUM-238. REV. 1

TIME: 0.13/ 731.39 (SEC.)

ENDF/B-IV TAPE 409(REV.)

18-NOV-74

040900000303

ENDF/B MAT. NO. = 1262

RESONANCE DATA

XXX RESOLVED REGION XXX

190 RESONANCES ABOVE 5.670E 00 EV

MASS: 2.3800E 02

SIGP: 1.0000E 07

RESOLVED RESONANCE RANGE ENERGY LIMITS:

1.00000E 00

4.0000E 03 EV.

RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE FISSION	STATISTICAL WEIGHT
3.9539E 03	1.0900E-01 2.3500E-02 0.0	1.0000
3.9390E 03	1.3000E-01 2.3500E-02 0.0	1.0000
3.9134E 03	5.0000E-02 2.3500E-02 0.0	1.0000
3.9013E 03	2.7000E-01 2.3500E-02 0.0	1.0000
3.8721E 03	1.7000E-01 2.3500E-02 0.0	1.0000
3.8564E 03	4.9500E-01 2.3500E-02 0.0	1.0000
3.8303E 03	1.1000E-02 2.3500E-02 0.0	1.0000
3.7808E 03	3.5000E-01 2.3500E-02 0.0	1.0000
3.7636E 03	7.2000E-02 2.3500E-02 0.0	1.0000
3.7372E 03	1.9500E-01 2.3500E-02 0.0	1.0000
3.7155E 03	8.0000E-02 2.3500E-02 0.0	1.0000
3.6920E 03	3.2000E-01 2.3500E-02 0.0	1.0000
3.6718E 03	7.9000E-03 2.3500E-02 0.0	1.0000
3.6283E 03	4.2000E-01 2.3500E-02 0.0	1.0000
3.6218E 03	2.0000E-02 2.3500E-02 0.0	1.0000
3.5933E 03	4.0000E-02 2.3500E-02 0.0	1.0000
3.5727E 03	3.3000E-01 2.3500E-02 0.0	1.0000
3.5605E 03	2.2000E-01 2.3500E-02 0.0	1.0000
3.5264E 03	5.0000E-03 2.3500E-02 0.0	1.0000
3.4933E 03	5.4000E-03 2.3500E-02 0.0	1.0000
3.4843E 03	1.0500E-01 2.3500E-02 0.0	1.0000
3.4563E 03	5.0000E-01 2.3500E-02 0.0	1.0000
3.4353E 03	3.5000E-01 2.3500E-02 0.0	1.0000
3.4177E 03	4.1000E-03 2.3500E-02 0.0	1.0000
3.4079E 03	1.9000E-01 2.3500E-02 0.0	1.0000
3.3883E 03	1.4500E-02 2.3500E-02 0.0	1.0000
3.3540E 03	1.0800E-01 2.3500E-02 0.0	1.0000
3.3329E 03	7.0000E-02 2.3500E-02 0.0	1.0000

RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE FISSION	STATISTICAL WEIGHT
3.3202E 03	1.0300E-01 2.3500E-02 0.0	1.0000
3.3103E 03	1.2300E-01 2.3500E-02 0.0	1.0000
3.2952E 03	8.0000E-03 2.3500E-02 0.0	1.0000
3.2782E 03	2.3500E-01 2.3500E-02 0.0	1.0000
3.2720E 03	8.0000E-03 2.3500E-02 0.0	1.0000
3.2481E 03	2.8000E-02 2.3500E-02 0.0	1.0000
3.2249E 03	3.3000E-02 2.3500E-02 0.0	1.0000
3.2170E 03	8.0000E-03 2.3500E-02 0.0	1.0000
3.2049E 03	7.3000E-02 2.3500E-02 0.0	1.0000
3.1881E 03	8.0000E-02 2.3500E-02 0.0	1.0000
3.1778E 03	7.4000E-02 2.3500E-02 0.0	1.0000
3.1685E 03	1.2000E-02 2.3500E-02 0.0	1.0000
3.1481E 03	7.5000E-02 2.3500E-02 0.0	1.0000
3.1326E 03	8.0000E-03 2.3500E-02 0.0	1.0000
3.1088E 03	1.9000E-01 2.3500E-02 0.0	1.0000
3.0581E 03	3.2000E-02 2.3500E-02 0.0	1.0000
3.0425E 03	3.5000E-03 2.3500E-02 0.0	1.0000
3.0278E 03	1.2500E-01 2.3500E-02 0.0	1.0000
3.0151E 03	1.6500E-03 2.3500E-02 0.0	1.0000
3.0024E 03	1.1700E-01 2.3500E-02 0.0	1.0000
2.9863E 03	5.5000E-03 2.3500E-02 0.0	1.0000
2.9658E 03	3.3000E-03 2.3500E-02 0.0	1.0000
2.9557E 03	2.1000E-02 2.3500E-02 0.0	1.0000
2.9330E 03	3.1000E-02 2.3500E-02 0.0	1.0000
2.8963E 03	1.5000E-02 2.3500E-02 0.0	1.0000
2.8820E 03	5.5000E-01 2.3500E-02 0.0	1.0000
2.8641E 03	1.7500E-01 2.3500E-02 0.0	1.0000
2.8280E 03	1.7500E-02 2.3500E-02 0.0	1.0000

92-U- 238 URANIUM-238, REV. 1

TIME: 0.15/ 731.54 (SEC.)

ENDF/B-IV TAPE 409(FEV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

RESONANCE DATA

RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE FISSION	STATISTICAL WEIGHT	RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE FISSION	STATISTICAL WEIGHT
2.8054E 03	8.0000E-03 2.3500E-02 0.0	1.0000	2.2410E 03	1.5000E-03 2.3500E-02 0.0	1.0000
2.7860E 03	1.2100E-02 2.3500E-02 0.0	1.0000	2.2170E 03	4.0000E-03 2.3500E-02 0.0	1.0000
2.7616E 03	2.3100E-02 2.3500E-02 0.0	1.0000	2.2006E 03	1.2000E-01 2.3500E-02 0.0	1.0000
2.7497E 03	4.5000E-02 2.3500E-02 0.0	1.0000	2.1860E 03	6.2000E-01 2.3500E-02 0.0	1.0000
2.7324E 03	1.6000E-03 2.3500E-02 0.0	1.0000	2.1522E 03	2.4000E-01 2.3500E-02 0.0	1.0000
2.7165E 03	1.4500E-01 2.3500E-02 0.0	1.0000	2.1446E 03	6.2000E-02 2.3500E-02 0.0	1.0000
2.6956E 03	1.5000E-02 2.3500E-02 0.0	1.0000	2.1238E 03	3.2000E-03 2.3500E-02 0.0	1.0000
2.6713E 03	2.4000E-01 2.3500E-02 0.0	1.0000	2.0959E 03	2.3000E-02 2.3500E-02 0.0	1.0000
2.6317E 03	3.5000E-03 2.3500E-02 0.0	1.0000	2.0881E 03	2.7000E-02 2.3500E-02 0.0	1.0000
2.6191E 03	4.5000E-02 2.3500E-02 0.0	1.0000	2.0709E 03	3.0000E-03 2.3500E-02 0.0	1.0000
2.5565E 03	6.7000E-01 2.3500E-02 0.0	1.0000	2.0298E 03	6.1000E-02 2.3500E-02 0.0	1.0000
2.5795E 03	3.2000E-01 2.3500E-02 0.0	1.0000	2.0228E 03	2.1500E-01 2.3500E-02 0.0	1.0000
2.5565E 03	2.2000E-01 2.3500E-02 0.0	1.0000	1.9743E 03	5.0000E-01 2.3500E-02 0.0	1.0000
2.5472E 03	5.5000E-01 2.3500E-02 0.0	1.0000	1.9686E 03	6.7000E-01 2.5000E-02 0.0	1.0000
2.5207E 03	1.4000E-02 2.3500E-02 0.0	1.0000	1.9534E 03	3.7000E-03 2.3500E-02 0.0	1.0000
2.4864E 03	8.8000E-02 2.3500E-02 0.0	1.0000	1.9165E 03	2.4900E-02 2.3500E-02 0.0	1.0000
2.4648E 03	1.5000E-02 2.3500E-02 0.0	1.0000	1.9024E 03	3.0000E-02 2.3500E-02 0.0	1.0000
2.4455E 03	1.9500E-01 2.3500E-02 0.0	1.0000	1.8700E 03	2.7000E-03 2.3500E-02 0.0	1.0000
2.4257E 03	1.3500E-01 2.3500E-02 0.0	1.0000	1.8680E 03	2.7000E-03 2.3500E-02 0.0	1.0000
2.4108E 03	4.6000E-03 2.3500E-02 0.0	1.0000	1.8455E 03	1.3000E-02 2.3500E-02 0.0	1.0000
2.3914E 03	2.6000E-02 2.3500E-02 0.0	1.0000	1.8079E 03	1.4500E-02 2.3500E-02 0.0	1.0000
2.3553E 03	6.1000E-02 2.3500E-02 0.0	1.0000	1.7955E 03	3.0000E-03 2.3500E-02 0.0	1.0000
2.3528E 03	4.7000E-02 2.3500E-02 0.0	1.0000	1.7821E 03	6.7000E-01 2.3500E-02 0.0	1.0000
2.3350E 03	9.5000E-03 2.3500E-02 0.0	1.0000	1.7552E 03	1.0500E-01 2.7000E-02 0.0	1.0000
2.3155E 03	2.1000E-02 2.3500E-02 0.0	1.0000	1.7222E 03	1.5000E-02 2.3500E-02 0.0	1.0000
2.2817E 03	1.3500E-01 2.3500E-02 0.0	1.0000	1.7090E 03	8.4000E-02 2.8000E-02 0.0	1.0000
2.2670E 03	2.1000E-01 2.3500E-02 0.0	1.0000	1.6883E 03	9.2000E-02 2.3500E-02 0.0	1.0000
2.2568E 03	6.6000E-02 2.3500E-02 0.0	1.0000	1.6613E 03	1.7000E-01 2.3500E-02 0.0	1.0000

92-U- 236 URANIUM-238, REV. 1

TIME: 0.12/ 731.66 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENCF/B MAT. NO. = 1262

RESONANCE DATA

RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE	FISSION	STATISTICAL WEIGHT	RESONANCE ENERGY	PARTIAL LEVEL WIDTHS NEUTRON CAPTURE	FISSION	STATISTICAL WEIGHT
1.6374E 03	5.0000E-02	2.3500E-02	0.0	1.0294E 03	2.5000E-03	2.3500E-02	0.0
1.6220E 03	7.0000E-02	2.3500E-02	0.0	1.0229E 03	8.3000E-03	2.3500E-02	0.0
1.5975E 03	3.5500E-01	2.3500E-02	0.0	1.0116E 03	1.5900E-03	2.3500E-02	0.0
1.5660E 03	5.4000E-03	2.3500E-02	0.0	9.9140E 02	3.9000E-01	3.0000E-02	0.0
1.5465E 03	4.0000E-03	2.3500E-02	0.0	9.5800E 02	1.9040E-01	2.2700E-02	0.0
1.5330E 03	4.0000E-04	2.3500E-02	0.0	9.3660E 02	1.3660E-01	2.3600E-02	0.0
1.5223E 03	2.4000E-01	2.3500E-02	0.0	9.2450E 02	1.3900E-02	2.3500E-02	0.0
1.4734E 03	1.2500E-01	2.3500E-02	0.0	9.0450E 02	5.2000E-02	2.6800E-02	0.0
1.4425E 03	1.8000E-02	2.3500E-02	0.0	8.6600E 02	5.7000E-03	2.3500E-02	0.0
1.4274E 03	2.9100E-02	2.6000E-02	0.0	8.5610E 02	8.2700E-02	2.3600E-02	0.0
1.4152E 03	9.0000E-03	2.3500E-02	0.0	8.5060E 02	5.5100E-02	2.3000E-02	0.0
1.4052E 03	7.0000E-02	2.3500E-02	0.0	8.2150E 02	6.6000E-02	2.4000E-02	0.0
1.3932E 03	1.8200E-01	2.3500E-02	0.0	7.9070E 02	6.5300E-03	2.3500E-02	0.0
1.3327E 03	1.6000E-03	2.3500E-02	0.0	7.7930E 02	2.0000E-03	2.3500E-02	0.0
1.3163E 03	4.0000E-03	2.3500E-02	0.0	7.6500E 02	7.6200E-03	2.3500E-02	0.0
1.2981E 03	4.5000E-03	2.3500E-02	0.0	7.3250E 02	2.5000E-03	2.3500E-02	0.0
1.2727E 03	2.7000E-02	2.3500E-02	0.0	7.2140E 02	1.2000E-03	2.3500E-02	1.2000E-03
1.2668E 03	2.2100E-02	2.1000E-02	0.0	7.0800E 02	2.1000E-02	2.6000E-02	0.0
1.2449E 03	2.8000E-01	2.3500E-02	0.0	6.9290E 02	4.3800E-02	2.4100E-02	0.0
1.2111E 03	9.0000E-03	2.3500E-02	1.2000E-04	6.6110E 02	1.3560E-01	2.5100E-02	0.0
1.1945E 03	8.9000E-02	2.3500E-02	0.0	6.2850E 02	6.7000E-03	2.3500E-02	0.0
1.1766E 03	6.0000E-02	2.3500E-02	0.0	6.1980E 02	3.3000E-02	2.3500E-02	0.0
1.1675E 03	8.5000E-03	2.3500E-02	0.0	5.9480E 02	8.5100E-02	2.3100E-02	0.0
1.1404E 03	2.2000E-01	2.3500E-02	0.0	5.7990E 02	4.4100E-02	2.3500E-02	0.0
1.1311E 03	3.0000E-03	2.3500E-02	0.0	5.5590E 02	8.0000E-04	2.3500E-02	0.0
1.1089E 03	2.7000E-02	2.3500E-02	0.0	5.3520E 02	4.7000E-02	2.3500E-02	0.0
1.0550E 03	1.7000E-02	2.2000E-02	0.0	5.1830E 02	5.1600E-02	2.4400E-02	0.0
1.0548E 03	8.9000E-02	2.3500E-02	0.0	4.7830E 02	3.8000E-03	2.3500E-02	0.0

ETOP/ 14, 3- 1-75, R. A. GRIMESY, PROCESSES ENDF/B DATA FOR INPUT TO PHRUG

DATE OF RUN 12/04/75 PAGE 112

92-U- 238 URAN-UM-238, REV. 1

TIME: 0.12/ 731.78 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NU. = 1262

RESONANCE DATA

RESONANCE ENERGY	PARTIAL LEVEL WIDTHS			STATISTICAL WEIGHT	RESONANCE ENERGY	PARTIAL LEVEL WIDTHS			STATISTICAL WEIGHT
	NEUTRON	CAPTURE	FISSION			NEUTRON	CAPTURE	FISSION	
4.6280E 02	5.5000E-03	2.3500E-02	0.0	1.0000	2.0840E 02	5.5090E-02	2.3500E-02	0.0	1.0000
4.5410E 02	4.6000E-04	2.3500E-02	0.0	1.0000	1.8960E 02	1.6900E-01	2.4700E-02	0.0	1.0000
4.2370E 02	9.9000E-03	2.3500E-02	0.0	1.0000	1.6520E 02	3.4000E-03	2.3500E-02	0.0	1.0000
4.1020E 02	2.0500E-02	2.2600E-02	0.0	1.0000	1.4560E 02	8.9000E-04	2.3500E-02	0.0	1.0000
3.9740E 02	6.4000E-03	2.5200E-02	0.0	1.0000	1.1680E 02	2.8270E-02	2.3500E-02	0.0	1.0000
3.7660E 02	1.2600E-03	2.3500E-02	0.0	1.0000	1.0250E 02	7.1000E-02	2.6000E-02	0.0	1.0000
3.4770E 02	8.3600E-02	2.3500E-02	0.0	1.0000	8.0740E 01	2.0000E-03	2.3500E-02	0.0	1.0000
3.1120E 02	1.1000E-03	2.3500E-02	0.0	1.0000	6.6150E 01	2.5300E-02	2.3500E-02	0.0	1.0000
2.9100E 02	1.6960E-02	2.3100E-02	0.0	1.0000	3.6800E 01	3.1100E-02	2.6000E-02	0.0	1.0000
2.7360E 02	2.7000E-02	2.3100E-02	0.0	1.0000	2.0900E 01	8.8000E-03	2.6800E-02	0.0	1.0000
2.3720E 02	2.9110E-02	2.3500E-02	0.0	1.0000	6.6700E 00	1.5000E-03	2.5600E-02	0.0	1.0000

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 113

92-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 731.84 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

XXX UNRESOLVED REGION XXX

NUMBER OF ISOTOPES	ATOMIC MASS NUMBER	RELATIVE ABUNDANCE OF ISOTOPE	ARE FISSION WIDTHS GIVEN?	RANGE ENERGY LIMITS	
				LOWER	UPPER
1	238	1.000	NO	4.000E 03	4.500E 04
DATA FORMAT	NUCLEAR SPIN	SCATTERING LENGTH (IN 10**-12 CM.)	NUMBER OF L-STATES		
LRF = 2	0.0	5.1840E-01	2		

(ETOP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 114

92-U- 238 URANIUM-238, REV. 1

TIME: 0.02/ 731.86 (SEC.)

ENDF/B-IV TAPE 409(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

L-STATE VALUE: 0

NO. OF J-STATES FOR THIS L-STATE: 1

ATOMIC WT. (OR CONSTANT FOR VL CALC.) = 2.3601E 02

J-STATE NO. 1

J-STATE VALUE	INTERP. SCHEME	NUMBER OF ENERGY POINTS	NUMBER OF DEGREES OF FREEDOM FOR THE FOLLOWING DISTRIBUTIONS			
			NEUTRON WIDTHS	GAMMA WIDTHS	FISSION WIDTHS	ALL OTHER WIDTHS
0.50	5	15	1	0	0	0
ENERGY	MEAN LEVEL SPACING	AVERAGE REDUCED NEUTRON WIDTH	AVERAGE GAMMA WIDTH	AVERAGE FISSION WIDTH	AVERAGE WIDTH FOR ALL OTHER EVENTS	
4.0000E 03	2.0000E 01	2.1000E-03	2.3500E-02	0.0	0.0	
4.5000E 03	1.9980E 01	2.0979E-03	2.3500E-02	0.0	0.0	
5.0000E 03	1.9950E 01	2.0947E-03	2.3500E-02	0.0	0.0	
5.5000E 03	1.9920E 01	2.0916E-03	2.3500E-02	0.0	0.0	
6.0000E 03	1.9880E 01	2.0874E-03	2.3500E-02	0.0	0.0	
6.5000E 03	1.9840E 01	2.0832E-03	2.3500E-02	0.0	0.0	
7.0000E 03	1.9800E 01	2.0790E-03	2.3500E-02	0.0	0.0	
7.5000E 03	1.9710E 01	2.0695E-03	2.3500E-02	0.0	0.0	
8.0000E 03	1.9610E 01	2.0590E-03	2.3500E-02	0.0	0.0	
8.5000E 03	1.9440E 01	2.0412E-03	2.3500E-02	0.0	0.0	
9.0000E 03	1.9260E 01	2.0223E-03	2.3500E-02	0.0	0.0	
9.5000E 03	1.9090E 01	2.0044E-03	2.3500E-02	0.0	0.0	
1.0000E 04	1.8920E 01	1.9866E-03	2.3500E-02	0.0	0.0	
1.2000E 04	1.8750E 01	1.9687E-03	2.3500E-02	0.0	0.0	
1.5000E 04	1.8590E 01	1.9519E-03	2.3500E-02	0.0	0.0	

(ETUP/ 14, 3- 1-75, R. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 115

92-U- 238 URANIUM-238, REV. 1

TIME: 0.07/ 731.93 (SEC.)

ENDF/B-IV TAPE 405(REV1)

18-NOV-74

040900000000

ENDF/B MAT. NO. = 1262

L-STATE VALUE: 1

NO. OF J-STATES FOR THIS L-STATE: 2

ATOMIC WT. (OR CONSTANT FOR VL CALC.) = 2.3601E 02

J-STATE NO. 1

J-STATE VALUE	INTERP. SCHEME	NUMBER OF ENERGY POINTS	NUMBER OF DEGREES OF FREEDOM FOR THE FOLLOWING DISTRIBUTIONS			
			NEUTRON WIDTHS	GAMMA WIDTHS	FISSION WIDTHS	ALL OTHER WIDTHS
0.50	5	15	1	0	0	0

ENERGY	MEAN LEVEL SPACING	AVERAGE REDUCED NEUTRON WIDTH	AVERAGE GAMMA WIDTH	AVERAGE FISSION WIDTH	AVERAGE WIDTH FOR ALL OTHER EVENTS
4.0000E 03	2.6000E 01	3.0269E-03	2.3500E-02	0.0	0.0
4.5000E 03	1.9930E 01	3.1672E-03	2.3500E-02	0.0	0.0
5.0000E 03	1.9950E 01	3.2424E-03	2.3500E-02	0.0	0.0
6.5000E 03	1.9920E 01	3.2073E-03	2.3500E-02	0.0	0.0
7.5000E 03	1.9880E 01	2.9739E-03	2.3500E-02	0.0	0.0
8.5000E 03	1.9840E 01	2.7591E-03	2.3500E-02	0.0	0.0
1.0000E 04	1.9800E 01	3.0997E-03	2.3500E-02	0.0	0.0
1.2000E 04	1.9710E 01	3.0109E-03	2.3500E-02	0.0	0.0
1.5000E 04	1.9610E 01	3.0544E-03	2.3500E-02	0.0	0.0
2.0000E 04	1.9440E 01	2.9362E-03	2.3500E-02	0.0	0.0
2.5000E 04	1.9260E 01	2.9895E-03	2.3500E-02	0.0	0.0
3.0000E 04	1.9090E 01	2.8398E-03	2.3500E-02	0.0	0.0
3.5000E 04	1.8920E 01	2.7951E-03	2.3500E-02	0.0	0.0
4.0000E 04	1.8750E 01	2.8279E-03	2.3500E-02	0.0	0.0
4.5000E 04	1.8550E 01	2.9299E-03	2.3500E-02	0.0	0.0

92-U- 238 URANIUM-238, REV. 1

TIME: 0.05/ 731.98 (SEC.)

ENDF/B-IV TAPE 40S(REV1)

18-NOV-74 040900000000

ENDF/B MAT. NO. = 1262

J-STATE NC. 2

J-STATE VALU	INTERP. SCHEME	NUMBER OF ENERGY POINTS	NUMBER OF DEGREES OF FREEDOM FOR THE FOLLOWING DISTRIBUTIONS			
			NEUTRON WIDTHS	GAMMA WIDTHS	FISSION WIDTHS	ALL OTHER WIDTHS
1.50	5	15	1	0	0	0

ENERGY	MEAN LEVEL SPACING	AVERAGE REDUCED NEUTRON WIDTH	AVERAGE GAMMA WIDTH	AVERAGE FISSION WIDTH	AVERAGE WIDTH FOR ALL OTHER EVENTS
4.0000E 03	1.0983E 01	1.6622E-03	2.3500E-02	0.0	0.0
4.5000E 03	1.0972E 01	1.7392E-03	2.3500E-02	0.0	0.0
5.0000E 03	1.0955E 01	1.7805E-03	2.3500E-02	0.0	0.0
6.5000E 03	1.0939E 01	1.7613E-03	2.3500E-02	0.0	0.0
7.5000E 03	1.0917E 01	1.6331E-03	2.3500E-02	0.0	0.0
8.5000E 03	1.0895E 01	1.5151E-03	2.3500E-02	0.0	0.0
1.0000E 04	1.0873E 01	1.7022E-03	2.3500E-02	0.0	0.0
1.2000E 04	1.0824E 01	1.6534E-03	2.3500E-02	0.0	0.0
1.5000E 04	1.0769E 01	1.6992E-03	2.3500E-02	0.0	0.0
2.0000E 04	1.0675E 01	1.6124E-03	2.3500E-02	0.0	0.0
2.5000E 04	1.0576E 01	1.6417E-03	2.3500E-02	0.0	0.0
3.0000E 04	1.0483E 01	1.5594E-03	2.3500E-02	0.0	0.0
3.5000E 04	1.0390E 01	1.5349E-03	2.3500E-02	0.0	0.0
4.0000E 04	1.0296E 01	1.5529E-03	2.3500E-02	0.0	0.0
4.5000E 04	1.0209E 01	1.6089E-03	2.3500E-02	0.0	0.0

PLUTONIUM-239	ETOP-PHROG 03/19/75	ENDF/B MAT.1264	SEQ. NO. = 200	ID.= 404	LTOT= 4053	IWR= 3	COP
SODIUM-23	ETOP-PHROG 03/24/75	ENDF/B MAT.1156	SEQ. NO. = 201	ID.= 405	LTOT= 1496	IWR= 2	COP
BORON-10	ETOP-PHROG 03/31/75	ENDF/B MAT.1273	SEQ. NO. = 202	ID.= 406	LTOT= 1880	IWR= 0	COP
CARBON-12	ETOP-PHROG 04/09/75	ENDF/B MAT.1274	SEQ. NO. = 203	ID.= 407	LTOT= 880	IWR= 0	COP
NITROGEN-14	ETOP-PHROG 03/31/75	ENDF/B MAT.1275	SEQ. NO. = 204	ID.= 408	LTOT= 1270	IWR= 0	COP
OXYGEN-16	ETOP-PHROG 03/31/75	ENDF/B MAT.1276	SEQ. NO. = 205	ID.= 409	LTOT= 746	IWR= 0	COP
ALUMINUM-27	ETOP-PHROG 04/05/75	ENDF/B MAT.1193	SEQ. NO. = 206	ID.= 410	LTOT= 1628	IWR= 0	COP
THORIUM-232	ETOP-PHROG 03/29/75	ENDF/B MAT.1296	SEQ. NO. = 207	ID.= 411	LTOT= 3396	IWR= 3	COP
NEPTUNIUM-237	ETOP-PHROG 03/15/75	ENDF/B MAT.1263	SEQ. NO. = 208	ID.= 412	LTOT= 3492	IWR= 3	COP
PLUTONIUM-240	ETOP-PHROG 03/17/75	ENDF/B MAT.1265	SEQ. NO. = 209	ID.= 413	LTOT= 3386	IWR= 3	COP
PLUTONIUM-241	ETOP-PHROG 03/22/75	ENDF/B MAT.1266	SEQ. NO. = 210	ID.= 414	LTOT= 2343	IWR= 3	COP
MANGANESE-55	ETOP-PHROG 04/11/75	ENDF/B MAT.1197	SEQ. NO. = 211	ID.= 415	LTOT= 2516	IWR= 0	COP
NICKEL	ETOP-PHROG 04/02/75	ENDF/B MAT.1190	SEQ. NO. = 212	ID.= 416	LTOT= 1539	IWR= 0	COP
IRON	ETOP-PHROG 04/11/75	ENDF/B MAT.1192	SEQ. NO. = 213	ID.= 417	LTOT= 1628	IWR= 0	COP
CHROMIUM	ETOP-PHROG 04/20/75	ENDF/B MAT.1191	SEQ. NO. = 214	ID.= 418	LTOT= 1098	IWR= 0	COP
FLUORINE-19	ETOP-PHROG 04/08/75	ENDF/B MAT.1277	SEQ. NO. = 215	ID.= 419	LTOT= 2516	IWR= 0	COP
MOLYBDENUM	ETOP-PHROG 04/11/75	ENDF/B MAT.1287	SEQ. NO. = 216	ID.= 420	LTOT= 773	IWR= 0	COP
SILVER-107	ETOP-PHROG 04/05/75	ENDF/B MAT.1138	SEQ. NO. = 217	ID.= 421	LTOT= 1790	IWR= 2	COP
SILVER-109	ETOP-PHROG 04/05/75	ENDF/B MAT.1139	SEQ. NO. = 218	ID.= 422	LTOT= 2926	IWR= 2	COP
TITANIUM	ETOP-PHROG 04/19/75	ENDF/B MAT.1286	SEQ. NO. = 219	ID.= 423	LTOT= 1150	IWR= 0	COP
CADMIUM	ETOP-PHROG 04/22/75	ENDF/B MAT.1281	SEQ. NO. = 220	ID.= 424	LTOT= 1248	IWR= 0	COP
GOLD-197	ETOP-PHROG 04/23/75	ENDF/B MAT.1283	SEQ. NO. = 221	ID.= 425	LTOT= 3018	IWR= 3	COP
LEAD	ETOP-PHROG 04/20/75	ENDF/B MAT.1288	SEQ. NO. = 222	ID.= 426	LTOT= 1768	IWR= 0	COP
LITHIUM-7	ETOP-PHROG 05/02/75	ENDF/B MAT.1272	SEQ. NO. = 223	ID.= 428	LTOT= 2160	IWR= 0	COP

(ETCF/ 14, 3- 1-75, P. A. GRIMESY) PROCESSES ENDF/B DATA FOR INPUT TO PHROG

DATE OF RUN 12/04/75 PAGE 117

TIME: 6.21/ 738.18 (SEC.)

ENCF/B-IV TAPL 409(REV1)

18-NOV-74 040900000000

ENCF/B MAT. NO. = 0

INPUT CARDS AFTER DEFAULTS

END OF DATA WHILE FEADING CARD INPUT


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IEF1421 - STEP WAS EXECUTED - CCND CCODE 0000
IEF2851 TEMP.DAMCLD01 DELETED
IEF2851 VOL SER NOS= CSK004.
IEF2851 SYS75337.T121634.RV000.RAG7#TRA.D4 DELETED
IEF2851 VOL SER NOS= CSK006.
IEF2851 SYS75337.T121634.SV000.RAG7#TRA.R0000713 SYSUUT
IEF2851 VOL SER NOS= SPOL31.
IEF2851 SYS75337.T121634.RV000.RAG7#TRA.D8 DELETED
IEF2851 VOL SER NOS= CSK010.
IEF2851 SYS75337.T121634.RV000.RAG7#TRA.D9 DELETED
IEF2851 VOL SER NOS= CSK011.
IEF2851 SYS75337.T121634.RV000.RAG7#TRA.D10 DELETED
IEF2851 VOL SER NOS= CSK012.
IEF2851 L.RAG0405 KEPT
IEF2851 VOL SER NOS= T99266.
IEF2851 SYS75337.T121634.RV000.RAG7#TRA.D12 DELETED
IEF2851 VOL SER NOS= CSK006.
IEF2851 L.RAGPHRCG KEPT
IEF2851 VOL SER NOS= T99107.
IEF2851 L.RAGPHRGG KEPT
IEF2851 VOL SER NOS= T99033.
IEF2851 SYS75337.T121634.FV000.RAG7#TRA.D22 DELETED
IEF2851 VOL SER NOS= CSK010.
IEF2851 SYS75337.T121634.SV000.RAG7#TRA.R0000714 DELETED
IEF2851 VOL SER NOS= SPGL31.
IEF2851 SYS75337.T123456.10007.RAG7#TRA.S000014G SYSIN
IEF2851 VOL SER NOS= SPCL03.
IEF2851 SYS75337.T123456.10007.RAG7#TRA.S000014O DELETED
IEF2851 VOL SER NOS= SPUL03.
IEF2851 K ODU.T99266.RAG7#TRA.ETCCE.L.RAG0409
IEF3731 STEP JETUGE / START 75338.0049
IEF3741 STEP JETUGE / STOP 75338.0104 CPU 12MIN 20.44SEC MAIN 472K LCS OK
WAIT 0002MIN 12.33SEC SYSIN 000315EC UNUSED CORE 004K EXCPS 003690 SYSHRS .350830
131 000204X;331 000016X;354 000451X;000 000000X;335 000006X;336 000101X;337 000098X;000 000823X;331 000183X;000 000240X
CD1 000239X;335 001321X;354 000000X;136 000008X
IEF2851 TEMP.DAMCLD01 KEPT
IEF2851 VOL SER NOS= CSK004.
IEF3751 JOB /RAG7#TRA/ START 75338.0047
IEF3751 JOB /RAG7#TRA/ STOP 75338.0104 CPU 12MIN 22.56SEC
WAIT 0003MIN 32.74SEC SYSIN 000335EC EXCPS 004450 SYSHRS .353579 DPSU .3535 REL 21.7

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