WCAP-3845-1
ENDF 114

ETOG-1, A FORTRAN IV Program to Process Data from the ENDF/B File to the MUFT, GAM and ANISN Formats

Westinghouse Atomic Power Divisions

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Program Written by:

D. E. Kusner
R. A. Dannels

Report Written by:

D. E. Kusner
S. Kellman

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APPROVED: Robert A. Dannels

Robert A. Dannels, Manager
Programming Development

Westinghouse Electric Corporation
Nuclear Energy Systems
P. O. Box 355
Pittsburgh, Pennsylvania 15230

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ABSTRACT

ETOG-1, an extension of the ETOM-1 program, processes basic nuclear data in the ENDF/B format and produces the data required for the generation of MUFT, GAM-I, GAM-II, and ANISN libraries. ETOG-1 is written entirely in ASA standard FORTRAN, and is designed to be computer independent. In addition to printed results, the output includes punched cards in the format appropriate for the generation of the desired library.

CHAPTER 1

INTRODUCTION

In order to permit users of the GAM-I[1], GAM-II[2], and ANISN[3] programs to generate library data from the Evaluated Nuclear Data File, the ETOM-1[4] program has been extended. An improved treatment of the resolved resonance region has been incorporated, and routines have been added to calculate, edit, and punch in the appropriate format the multigroup transfer matrices required by these codes.

For completeness, sections of the ETOM-1 report, Reference 4, are reproduced here.

CHAPTER 2

PROGRAM DESCRIPTION

2.1 GENERAL INFORMATION

Detailed descriptions of the codes for which libraries may be generated are given in References 1-4. Here, a limited knowledge of the structure of these programs, in addition to the ENDF/B system, is assumed.

As in Reference 4, the following notation is used in this report. A quantity with an argument, e.g., $\sigma_{nn}(E)$, represents the magnitude of that quantity at a particular energy E, while the quantity without an argument, e.g., $\sigma_{n,n'}$ denotes a group-averaged value.

Average cross sections are calculated as

$$\sigma = \frac{\int \sigma(E)\ W(E)\ dE}{\int W(E)\ dE}, \tag{2.1}$$

where the integral extends over the appropriate energy interval. W(E), the weighting function, may vary as 1/E, may be constant, may be entered as input, or may be expressed as a combination of 1/E joined to a fission spectrum. In combining the cross sections and weighting function and performing the integration, the program makes use of the specified interpolation schemes.

Data in ENDF/B Files 1, 2, 3, 4 and 5 are employed in generating the multigroup cross sections, slowing down and fission parameters, transfer matrices, and spectra required by MUFT, GAM and ANISN*.

2.2 TREATMENT OF SMOOTH DATA

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* The version of ANISN for which ETOG-1 prepares library data is that used at Battelle-Northwest. The authors are indebted to K. Stewart of Batelle-Northwest for providing them with the routines which punch and edit the library data for ANISN.

2.2.1 Elastic Scattering Cross Section

The group-averaged symmetric scattering cross section, σ_{nn}, is computed by use of Equation (2.1), where $\sigma_{nn}(E)$ is obtained from ENDF/B File 3, reaction type MT = 2. If necessary, σ_{nn} is modified to account for resonance scattering. In the production of data for the MUFT library, the only library treated that explicitly requires the elastic scattering cross section, the handling of resonance scattering is determined by one of three available options. (See Section 3.3.4.13). For GAM and ANISN library data, $\sigma_{nn}(E)$ is required only in order to establish the elastic scatter transfer matrix; resonance scattering cross sections are calculated by use of the single level Breit-Wigner formula, as discussed in Section 2.3, and added to $\sigma_{nn}(E)$.

In the generation of a MUFT library, the option also exists for the addition of the in-group inelastic scattering cross section to σ_{nn}.

The composite $\sigma_{nn}(E)$ is written on a scratch tape for later use by the program, e.g., in the calculation of the transfer matrix.

2.2.2 Capture Cross Section

The smooth capture cross section is calculated as the sum,

$$\sigma_{nc} = \sigma_{n\gamma} + \sigma_{np} + \sigma_{nd} + \sigma_{nt} + \sigma_{nHe^3} + \sigma_{n\alpha} + \sigma_{n2\alpha}. \tag{2.2}$$

Each of the averaged quantities, σ_{nx}, is calculated as

$$\sigma_{nx} = \frac{\int \sigma_{nx}(E)\, W(E)\, dE}{\int W(E)\, dE} \tag{2.3}$$

where $\sigma_{nx}(E)$ is obtained from the ENDF/B File 3 tabulation. For x = γ, p, d, t, He^3, α, and 2α, respectively, the tabulation is that for reaction type MT = 102, 103, 104, 105, 106, 107, and 108.

If required, a resonance contribution is added to the smooth capture cross

sections. When resonance cross sections are calculated from parameters given in ENDF/B File 2, corrections must be made to σ_{nc} depending upon the code for which the data is being produced, and the particular options chosen. For MUFT and GAM-I libraries, contributions are added to σ_{nc} to account for the asymmetric tails which are not calculated by the codes from the resonance parameters supplied to them; in the groups below the lower bound of the resonance region as defined in ENDF/B File 2, the contributions to σ_{nc} due to the symmetric resolved resonances are subtracted from the smooth values given in ENDF/B File 3. For GAM-II, the entire contribution to σ_{nc} from the resolved resonances are subtracted from the smooth values in File 3 in the groups below the ENDF/B-defined resonance region. Finally, for ANISN resonance cross sections are converted to equivalent smooth data.

It should be noted here that for the GAM-II program, the components of the parasitic capture cross section, i.e., reaction types MT = 102 to 108, are required for use in editing results and are punched as part of ETOG output.

2.2.3 Inelastic Scattering Cross Section

The inelastic scattering cross section is calculated as

$$\sigma_{nn'} = \frac{\int \sigma_{nn'}(E)\, W(E)\, dE}{\int W(E)\, dE} \tag{2.4}$$

where $\sigma_{nn'}(E)$ is obtained from ENDF/B File 3, reaction type MT = 4. The cross section $\sigma_{nn'}$ is required for the generation of a MUFT library, but does not appear explicitly in GAM or ANISN. The energy-dependent $\sigma_{nn'}(E)$ is saved on tape for further use in the construction of the inelastic scattering transfer matrix.

In the case of MUFT, options exist whereby $\sigma_{nn'}$ is modified to account for the treatment of the in-group inelastic scattering, inelastic scattering out of the range of the defined matrix, or the n,2n reaction.

2.2.4 (n,2n) Cross Section

The (n,2n) cross section is calculated as

$$\sigma_{n,2n} = \frac{\int \sigma_{n,2n}(E)\ W(E)\ dE}{\int W(E)\ dE} \tag{2.5}$$

where $\sigma_{n,2n}(E)$ is obtained from ENDF/B File 3, MT = 16.

The (n,2n) reaction is not treated explicitly in MUFT or ANISN. In the generation of MUFT data, three input options are provided for the user. The reaction may be treated as all fission, as all inelastic scattering, or as half fission and half inelastic scattering. In all cases, appropriate adjustments are made to the smooth cross sections and ν values. (See Section 3.3.4.10 for further detail).

For GAM, the (n,2n) transfer matrix is established explicitly, as described in Section 2.4.3. In the generation of ANISN data, elements of the matrix are added to the appropriate elements of the composite isotropic transfer matrix; $\sigma_{n,2n}$ is subtracted groupwise from the absorption cross section to preserve the neutron balance.*

2.2.5 Fission Cross Section

The smooth fission cross section is calculated as

$$\sigma_{nf} = \frac{\int \sigma_{nf}(E)\ W(E)\ dE}{\int W(E)\ dE} \tag{2.6}$$

where $\sigma_{nf}(E)$ is obtained from ENDF/B, File 3, reaction type MT=18. If required, a resonance contribution is added to the smooth fission cross section. When explicit resonance parameters are given in ENDF/B File 2, corrections similar to those discussed in Section 2.2.2 under smooth capture, are made to σ_{nf}.

Also, an option exists for the addition of the (n,2n) cross section to σ_{nf} in the generation of MUFT library data.

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* K. B. Stewart, Pacific Northwest Laboratory, personal communication, July, 1969.

2.2.6 Neutrons Per Fission

Outside the resonance region, the average number of neutrons per fission is calculated as

$$\nu = \frac{(\nu\sigma_{nf})}{\sigma_{nf}}$$

where

$$(\nu\sigma_{nf}) = \frac{\int (\nu(E)\ \sigma_{nf}(E)\ )\ W(E)\ dE}{\int W(E)\ dE} \tag{2.7}$$

and $\nu(E)$ is obtained from ENDF/B File 1, MT = 452. If $\nu(E)$ is expressed as a polynomial, the product in the integrand is formed after calculating ν at each energy point in the $\sigma_{nf}(E)$ mesh. If a tabulation of $\nu(E)$ is given, the two functions, $\nu(E)$ and $\sigma_{nf}(E)$ are combined by use of the ENDF service routines.

In the resonance region, ν is calculated as

$$\nu = \frac{\int \nu(E)\ W(E)\ dE}{\int W(E)\ dE} \tag{2.8}$$

This is a valid approximation since ν is nearly constant over the resonance region, and the detailed numerical integration of Equation (2.7) is not justified.

Note that in the generation of MUFT library data, ν may be modified to account for the (n,2n) reaction.

2.2.7 Additional Parameters Generated for MUFT Library

Three additional multigroup quantities are required for the creation of a MUFT library tape, i.e., the anisotropic scattering cross section, isotropic Greuling-Goertzel parameter, and isotropic slowing down power.

The anisotropic elastic scattering cross section is calculated as

$$\mu\sigma_{nn} = \frac{\int (\mu(E)\ \sigma_{nn}(E)\ )\ W(E)\ dE}{\int W(E)\ dE} \tag{2.9}$$

where $\mu(E)$ is obtained from ENDF/B File 3, MT = 251, and $\sigma_{nn}(E)$ is retrieved from the tape on which it was stored. If no $\mu(E)$ data is given on the ENDF/B tape, then

$$\mu\sigma_{nn} = \frac{2}{3A}\ \sigma_{nn} \tag{2.10}$$

where A is the atomic mass ratio, AWR, obtained from the tape.

The isotropic Greuling-Goertzel parameter, or age number as it is called in MUFT, may be calculated as

$$\gamma = \frac{\int \gamma(E)\ W(E)\ dE}{\int W(E)\ dE} \tag{2.11}$$

where $\gamma(E)$ is obtained from ENDF/B File 3, MT = 253. If no such data is present, or if an input option is selected, the age number is calculated as[5]

$$\gamma = \frac{\Delta u}{2} \tag{2.12}$$

where Δu is the group lethargy width.

The isotropic slowing down power is calculated as

$$\xi\ \sigma_{nn} = \frac{\int (\xi(E)\ \sigma_{nn}(E)\ )\ W(E)\ dE}{\int W(E)\ dE} \tag{2.13}$$

where $\xi(E)$ is obtained from ENDF/B File 3, MT = 252, and $\sigma_{nn}(E)$ is retrieved from the tape on which it was stored. If there is no $\xi(E)$ data on the ENDF/B tape, then

$$\xi\sigma_{nn} = \frac{2}{A + \frac{2}{3}} \sigma_{nn} \tag{2.14}$$

where A is the atomic mass ratio, AWR, obtained from the tape.

2.3 RESONANCE TREATMENT

While ANISN requires only composite multigroup cross sections, MUFT and GAM have explicit resonance treatments.

2.3.1 MUFT Requirements

2.3.1.1 Resolved Resonance Region

For each resolved resonance treated, the MUFT library requires

$$r = \frac{\sigma_o (\Gamma_\gamma + \Gamma_f)}{\Gamma}$$

$$m = \frac{\sigma_o (\Gamma_\gamma + \Gamma_f)}{E_o} \tag{2.15}$$

$$\alpha = \frac{\Gamma_f}{\Gamma_\gamma + \Gamma_f}$$

ETOG-1 calculates these factors, and determines the proper group for each resolved resonance.

The MUFT treatment implicitly assumes that the entire effect of a resonance is felt in the multigroup in which its peak occurs. Therefore, the contri-

butions of each resonance to all groups below the lower bound of the resonance region, as defined in ENDF/B File 2, must be subtracted from the smooth capture and fission cross sections which already include the contributions. Since only the symmetric resonance is treated, it is necessary to subtract only the symmetric tail. Similarly, in each group in the resolved resonance range, where r, m and α factors have been generated, the asymmetric tail due to each resonance must be added to smooth capture and fission cross sections. If the cross sections have been computed on the fine mesh discussed in Section 2.3.4, the asymmetric tails are calculated in each group affected using that mesh, and are properly weighted, before being averaged over the group. If the fine mesh has not been established, the contributions are calculated at 100 points, equally spaced in lethargy, in each group affected before being averaged. The symmetric tails are always calculated at 100 points equally spaced in lethargy in the group affected before being averaged.

Resonances below the resolved region as defined in ENDF/B (i.e., at thermal and negative energies) are not handled as explicit resonances by MUFT, and ETOG treats them separately. Pointwise capture, fission and optionally, scattering, cross sections due to these resonances are calculated at 100 points, equally spaced in lethargy, in each group containing resolved resonances. Then these values, properly weighted, are averaged over the group to obtain the contributions which are added to the smooth cross sections.

The s-wave cross sections are calculated by use of the Breit-Wigner single level formula:

$$\sigma_n = 4\pi R^2 + \frac{1}{1+x^2}\,\frac{\sigma_o \Gamma_n}{\Gamma} + \frac{2x}{1+x^2}\sqrt{\frac{(4\pi R^2)\,\sigma_o g\,\Gamma_n}{\Gamma}} \qquad (2.16)$$

where R is designated as AP in ENDF/B and

$$\sigma_\gamma = \frac{\sigma_o \Gamma_\gamma}{\Gamma}\,\frac{1}{1+x^2}\sqrt{\frac{|E_o|}{E}}$$

$$\sigma_f = \frac{\sigma_o \Gamma_f}{\Gamma}\,\frac{1}{1+x^2}\sqrt{\frac{|E_o|}{E}}\ .$$

The quantities σ_o and x are defined as

$$\sigma_o = \frac{(2.6037 * 10^6)\ \Gamma_n g}{|E_o|\ \Gamma} * \left(\frac{A+1.008665}{A}\right)^2$$

$$x = \frac{(E-E_o)}{\Gamma/2}$$

P-wave cross sections, converted to equivalent smooth data, are computed by use of the Breit-Wigner formulae given in Appendix C of Reference 7.

A number of options exist for the treatment of resolved resonances during the generation of MUFT library data. For example, since the number of resonances in any one group is restricted to eight in MUFT, options are provided for treatment of any "extra" resonances if more than eight occur.

In addition, ETOG permits a number of options for treatment of resolved resonance scattering which is not handled explicitly in MUFT. Scattering is present only in the MUFT smooth cross section file. Although no general statement can be made about the correct way to represent resonance scattering in the MUFT library, two limiting cases can be cited.* For materials that are primarily resonance absorbers, the resonance scattering should be ignored. For materials that are primarily resonance scatterers, the resonance scattering should be included as part of the MUFT "smooth" scattering cross section file. Mathematically in the ENDF/B format structure, there is a smooth part (ENDF/B file 3) and a resonance part (ENDF/B file 2). However the mathematical representation may not be the physical one. For example, the constraint of Breit-Wigner representation of resonances may require the mathematical smooth cross section to be negative! So if one wants to ignore the resonance scattering, there is a problem. The use of only ENDF/B file 3 may produce erroneous

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* D. R. Harris, Bettis Atomic Laboratory and C. Lubitz, Knolls Atomic Power Laboratory, personal communication.

results. Likewise, if the total ENDF/B description is used, the resonance part may not be ignored. Hence three options are provided in which the resonance scattering cross section may be computed from the ENDF/B representation, may be taken as the potential scattering cross section, or may be taken as the value in the first group above the resonance region.

2.3.1.2 Unresolved Resonance Region

There is no special treatment of unresolved resonance information in MUFT. Since unresolved data may be given in ENDF/B, ETOG-1 constructs effective smooth cross sections over the unresolved range. The method employed is the same as that used by the Argonne* program MC^2 (Reference 11) where effective resonance cross sections are evaluated at discrete energy points, E*, in the unresolved region.

In MC^2, the effective unresolved resonance capture cross section at energy E* is calculated as

$$\sigma_c(E^*) = \sum \frac{\frac{\sigma_p \Gamma_\gamma}{\bar{D}} \int_0^\infty P_n(r) \int_0^\infty P_k(s) \int_0^\infty \frac{\psi}{\psi+\beta}\, dx\, ds\, dr}{1 - \frac{1}{\bar{D}} \int_0^\infty P_n(r) \int_0^\infty P_k(s)\, \Gamma \int_0^\infty \frac{\psi}{\psi+\beta}\, dx\, ds\, dr}, \qquad (2.17)$$

where the sum is taken over all J states for all ℓ states. This equation is for fissile isotopes; for fertile isotopes the $P_k(s)$ integral does not appear. A similar equation is used to calculate the fission cross section.

Since ETOG-1 does not permit a temperature dependence, a zero temperature is assumed. Thus,

$$\int_0^\infty \frac{\psi}{\psi+\beta}\, dx = \frac{\pi/2}{\sqrt{\beta\,(1+\beta)}}. \qquad (2.18)$$

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* The authors are grateful to Dr. Bert Toppel of ANL for graciously providing them with the MC^2 subroutine UNRES for reference during the programming of ETOM-1 and ETOG-1.

β is defined as σ_p/σ_o where σ_o is the resonance peak cross section and σ_p is the macroscopic potential scattering cross section for the mixture per absorber atom. Since ETOG-1 is not primarily a mixture dependent program, there is no way for ETOG-1 to calculate σ_p internally. Hence, the quantity $(\sigma_p - 4\pi R^2)$ is designated as an input item. (ETOG-1 adds $4\pi R^2$ to the input value to obtain the σ_p used in the calculation). This provides the user with the flexibility of selecting a value of σ_p which is typical for his applications. Note that this σ_p only affects the unresolved resonance treatment.

ETOG-1 calculates the capture, fission and scattering cross sections at 100 equally spaced lethargy points for each multigroup in the unresolved region. These values are then averaged with the weighting function to provide the unresolved resonance contributions which are added to the smooth cross sections.

2.3.2 GAM Requirements

2.3.2.1 GAM-I

In the resolved energy range, the GAM-I library requires for each resonance the parameters E_o, Γ_n, Γ_γ, Γ_f, and an index, L, indicating whether the narrow resonance or narrow resonance-infinite mass approximation is to be used. The latter parameter is established by a test on the practical width of the resonance.[6] ETOG-1 outputs s-wave resonance parameters only and converts all higher wave resonances to equivalent smooth capture and fission cross section data. In the unresolved range, single values of parameters $\langle D \rangle$, $\langle \Gamma_n^o \rangle$, $\langle \Gamma_\gamma \rangle$, $\langle \Gamma_f \rangle$, in addition to the lower bound of the range, E_ℓ, are required. Tables of these quantities are established directly from the ENDF/B data, File 2.

The particular set of values of unresolved resonance parameters punched depends upon input quantity, XAJIN, which is the spin of the compound nucleus for a given ℓ state in the unresolved region. This input quantity must correspond to a value of J given in File 2, reaction type 151. If XAJIN does not correspond to a value of J in the ENDF/B file, all unresolved resonance paramters are converted to equivalent smooth capture, fission, and scattering cross sections.

Tables of smooth absorption and fission cross sections are set up by use of ENDF/B File 3 data. Corrections to account for the treatments of symmetric

and asymmetric tails, and of resonances at negative and thermal energies are made in the same manner as for the MUFT library.

Also required for the library is the number of neutrons produced per fission, which is read from File 1 data.

2.3.2.2 GAM-II

In the resolved resonance range GAM-II requires for each resonance, parameters E_o, Γ_n, Γ_γ, Γ_f, and g. Factors r, used to determine the mesh spacing for the numerical integration yielding the collision density, and S used to determine the upper limit for the integration yielding the absorption resonance integral, are also necessary, as is the potential scattering cross section, σ_{po}. ETOG sets r equal to 0.0, S equal to 5.0, and σ_{po} equal to $4\pi R^2$, where R is the resolved range scattering length given in ENDF/B File 2. In the unresolved range, parameters $\langle D \rangle$, $\langle \Gamma_n^o \rangle$, $\langle \Gamma_\gamma \rangle$, $\langle \Gamma_f \rangle$ and $\bar{g}$ are required together with a table of energies at which the unresolved resonance function J (See Reference 2) should be calculated. The first entry in the latter table is the cut-off energy, E_ℓ, and the following entries coincide with the fine group boundaries. The last entry in the table is the upper bound of the specified unresolved resonance range. Again, as in GAM-I, the particular set of (five) unresolved resonance parameters punched depends upon input quantity, XAJIN. If the value of XAJIN does not correspond to a value of J in ENDF/B File 2, all unresolved resonance parameters are converted to equivalent smooth data.

GAM-II utilizes the asymmetric Breit-Wigner formula; therefore the contributions of the resolved resonances to any group below the lower bound of the resonance region must be subtracted from the smooth capture and fission cross sections of ENDF/B File 3. Thermal and negative energy resonances are treated as they are in MUFT and GAM-I, that is, by adding their contributions, properly weighted and averaged, to the smooth contribution in each group.

2.3.3 ANISN Requirements

As required by ANISN, the ETOG-1 program prepares group-averaged total, absorption, and fission (times ν) cross sections, in addition to a composite (cross

section) transfer matrix. Tables of σ_{nc}, σ_{nf}, $\sigma_{n\gamma}$ and $\sigma_{n\alpha}$ are transmitted as activity cross sections.

Cross sections must be generated from the resonance parameters if they exist in File 2 of ENDF/B, i.e., input option IRES = 3 must be selected. (See Section 3.3.1) As in GAM-II, the cross sections are generated in the specified resonance region by use of the asymmetric Breit-Wigner formula, with tail contributions in the appropriate energy group. Therefore, no corrections are necessary. Negative and thermal energy resonance contributions are calculated, properly weighted, and averaged over each group in the resonance region. The group-averaged values obtained from the resonance calculation are added to the appropriate group-averaged smooth values obtained from ENDF/B File 3. The pointwise (weighted) scattering cross-sections are stored on tape for later use in generating the transfer matrix.

2.3.4 Pointwise Resolved Resonance Cross Sections

In a number of cases, pointwise cross sections must be calculated in the resolved range, e.g., when resonance cross sections are to be added to the smooth contribution for the generation of a MUFT library, and when GAM or ANISN transfer matrices are to be generated (See Section 2.4). In these cases, detailed descriptions of the energy variation of the cross sections are necessary in order to compute accurately group-averaged cross sections, or components of the transfer matrices. For this reason the cross sections are calculated on a variable fine mesh which depends upon the resonance structure within each group and employs a maximum of 1000 points per group.

Presently the fine mesh is constructed by considering all resonances within the group and placing a large number of points around each peak in order to describe adequately the rapidly changing cross section. For each group, a special attempt is made to describe the cross-section over a sufficiently fine mesh from E_b, the lowest energy of the group, to $E_b\left(\frac{A-1}{A+1}\right)^2$; then full advantage may be taken of techniques developed to calculate the elements of the transfer matrix at energies at which the angular distribution of elastic scattering is isotropic in the center of mass system. Where necessary the cross sections, properly weighted,

are averaged over the group, and the (weighted) scattering cross section is written on tape for later use in generating the elastic transfer matrix.

2.4 TRANSFER MATRICES

The libraries handled by ETOG-1 require a number of transfer matrices. For MUFT, an inelastic scattering probability matrix must be generated; for GAM, separate elastic scattering, inelastic scattering, and (n,2n) cross section matrices must be created; and for ANISN only a composite cross section transfer matrix is needed.

2.4.1 Inelastic Scattering

2.4.1.1 MUFT Treatment

MUFT requires an inelastic scattering probability matrix as MUFT 4 File 5 (MUFT 5, File 6). Since the requirement is for a probability (rather than a cross section)matrix, all of the necessary information is contained in ENDF/B, File 5. There are 10 ENDF/B defined representations of secondary energy distributions. Although it was suggested (Reference 7, page 12.4) that inelastic data be given as discrete levels (LF = 3) plus a Maxwellian distribution (LF = 8 or 9), ETOG-1 will handle LF = 3, 6, 7, 8, 9, and 10. The other distributions (LF = 1, 2, 3, and 5) are ignored by the current version of the program.

During execution, MUFT forms the inelastic scattering cross section matrix as the product of the inelastic scattering cross section and the inelastic scattering probability matrix. The elements, $\sigma_{in}^{i\to j}$, of this cross section matrix are used in the MUFT calculation. These (averaged value) matrix elements should be formed as

$$\sigma_{in}^{i\to j} = \frac{\int \sigma_{in}^{i\to j}(E)\, W(E)\, dE}{\int W(E)\, dE} = \frac{\int P_{in}^{i\to j}(E)\, \sigma_{in}(E)\, W(E)\, dE}{\int W(E)\, dE} . \qquad (2.19)$$

But $\sigma_{in}^{i\to j}$ is calculated in MUFT as

$$\sigma_{in}^{i\to j} = \sigma_{in}^{i} * P_{in}^{i\to j} \tag{2.20}$$

and σ_{in}^{i} is calculated by ETOG-1 as

$$\sigma_{in} = \frac{\int \sigma_{in}(E)\, W(E)\, dE}{\int W(E)\, dE} . \tag{2.21}$$

Hence $P_{in}^{i\to j}$ is calculated by ETOG-1 as

$$P_{in}^{i\to j} = \frac{\int P_{in}^{i\to j}(E)\, \sigma_{in}(E)\, W(E)\, dE}{\int \sigma_{in}(E)\, W(E)\, dE} \tag{2.22}$$

Thus the product is the desired result; namely,

$$\sigma_{in}^{i} * P_{in}^{i\to j} = \frac{\int \sigma_{in}(E)\, W(E)\, dE}{\int W(E)\, dE} * \frac{\int P_{in}^{i\to j}(E)\, \sigma_{in}(E)\, W(E)\, dE}{\int \sigma_{in}(E)\, W(E)\, dE} \tag{2.23}$$

$$= \frac{\int P_{in}^{i\to j}(E)\, \sigma_{in}(E)\, W(E)\, dE}{\int W(E)\, dE}$$

Slightly different procedures are needed for the different (LF) representations in the ENDF/B File 5 data.

For LF = 3, an average probability of inelastic scattering from the source group is calculated. A linear mapping is made to take P(E) to P(E'), and then the fractional amount in each sink group is computed.

Consider the following figure:

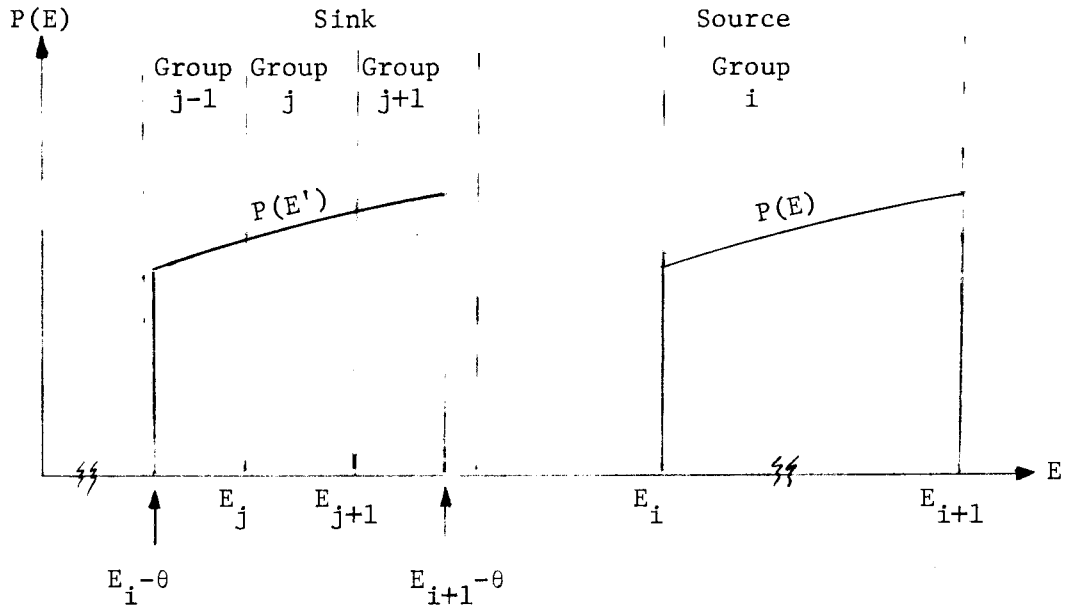

FIGURE 1

In the figure note that P(E') is obtained from P(E) by a linear mapping using the relationship $E' = E-\theta$. The contribution to the probability matrix element, $P_{in}^{i\to j}$, is then calculated as:

$$P_{in}^{i\to j} = \frac{\int_{E_i}^{E_{i+1}} [P(E)\ \sigma_{in}(E)]\ W(E)\ dE}{\int_{E_i}^{E_{i+1}} [\sigma_{in}(E)\ W(E)]\ dE} * \frac{\int_{E_j}^{E_{j+1}} P(E')\ dE'}{\int_{E_i-\theta}^{E_{i+1}-\theta} P(E')\ dE'} \qquad (2.24)$$

For LF = 6, 8, or 10, an E' mesh is constructed to cover the entire energy range; the appropriate (LF) function, f(E), is calculated over this range, and the fractional amount in each sink group computed. The contribution to the probability matrix element, $P_{in}^{i\to j}$, is then calculated as

$$P_{in}^{i\to j} = \frac{\int_{E_i}^{E_{i+1}} P(E)\ [\sigma_{in}(E)\ W(E)]\ dE}{\int_{E_i}^{E_{i+1}} [\sigma_{in}(E)\ W(E)]\ dE} * \frac{\int_{E_j}^{E_{j+1}} f(E)\ dE}{\int_{\text{all groups}} f(E)\ dE} \qquad (2.25)$$

For LF = 7 or 9, a value of θ averaged over the source group is used in the functional calculation. The rest of the calculation is the same as for LF = 6, 8, or 10. Thus,

$$\theta = \frac{\int \theta(E) \frac{dE}{E}}{\int \frac{dE}{E}} \tag{2.26}$$

and the contribution to the probability matrix element, $P_{in}^{i\to j}$, is then calculated as:

$$P_{in}^{i\to j} = \frac{\int_{E_i}^{E_{i+1}} P(E)\,[\sigma_{in}(E)\,W(E)]\,dE}{\int_{E_i}^{E_{i+1}} [\sigma_{in}(E)\,W(E)]\,dE} * \frac{\int_{E_j}^{E_{j+1}} f(E,\theta)\,dE}{\int_{\text{all groups}} f(E,\theta)\,dE} \tag{2.27}$$

All LF subsections describing the secondary energy distribution of inelastically scattered neutrons form the probability matrix. Thus, each element of the matrix is the sum of contributions from one or more LF subsections. It is a MUFT requirement that the final inelastic probability matrix be exactly normalized to unity. Hence after the matrix is completed, it is renormalized to satisfy this requirement. In principle, this renormalization is not necessary since the ENDF/B distributions are normalized to unity. However due to calculational round-off errors, and treatment of ingroup scattering and out of matrix scattering, the renormalization is essential.

2.4.1.2 GAM and ANISN Requirements

The treatment is the same as that described in the preceding section, with the additional feature that the product

$$\sigma_{in}^{i\to j} = \sigma_{in}^{i} * P_{in}^{i\to j} \tag{2.28}$$

is formed by ETOG-1. In the generation of ANISN data, the inelastic transfer cross sections are added to the isotropic (P_o) elastic transfer cross sections.

2.4.2 Elastic Scattering

The calculation of the elastic scattering matrix is based loosely on program TRANSFER[8], which has been re-written extensively.

The differential cross section for scattering events in dE and $d\Omega$ which result in neutrons in dE' and $d\Omega'$, per unit solid angle, is expressed in terms of a Legendre polynomial expansion,

$$\sigma_s(E', \underline{\Omega}'; E, \underline{\Omega}) = \frac{1}{4\pi} \sum_{\ell=0}^{N} S_\ell(E',E)\, P_\ell(\mu)\, \left|\frac{d\mu}{d\underline{\Omega}}\right| \tag{2.29}$$

where $\mu = \underline{\Omega} \cdot \underline{\Omega}'$ is the cosine of the angle of scatter in the lab system. If the equation is multiplied by $P_k(\mu)$ and integrated over μ, the resulting expression for the energy transfer coefficient $S_\ell(E',E)$ is:

$$S_\ell(E',E) = 4\pi \left|\frac{d\underline{\Omega}}{d\mu}\right| \frac{2\ell+1}{2} \int_{-1}^{1} d\mu\, P_\ell(\mu)\sigma_s(E',\underline{\Omega}'; E,\underline{\Omega}) \tag{2.30}$$

If now the energy condition for elastic scattering is introduced into the cross section as a delta function, and the cross section is expressed, as generally reported, in terms of a Legendre expansion in the center of mass system, then

$$\sigma_s(E',\underline{\Omega}'; E,\underline{\Omega}) = \frac{\sigma_s(E)}{4\pi} \sum_{k=0}^{J} (2k+1) f_k(E) P_k(\eta) \left|\frac{d\eta}{d\underline{\Omega}}\right| \delta\left[E'-E+\frac{(1-\alpha)}{2}E-\frac{(1-\alpha)}{2}E\eta\right] \tag{2.31}$$

where

$\eta = \dfrac{(A^2-1+\mu^2)^{1/2} \quad \mu-1+\mu^2}{A}$, the cosine of the angle of scatter in the center of mass system.

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

$f_k(E)$ = the Legendre expansion coefficients of the angular distribution of scattering in the center of the mass system.

Substitution of Equation (2.31) into (2.30), followed by integration, leads to[9]

$$S_\ell(E',E) = \frac{2\ell+1}{(1-\alpha)E}\ \sigma_s(E)\ P_\ell(\mu) \sum_{k=0}^{J} (2k+1) f_k(E)\ P_k(\eta). \tag{2.32}$$

The elements of the transfer matrix, of order ℓ, for scatter from group i to j are defined as

$$\sigma^{\ell}_{j,i} = \frac{\int_i dE' \int_j dE\ W(E)\ S_\ell(E',E)}{\int_i dE\ W(E)} \tag{2.33}$$

$$= \frac{2\ell+1}{1-\alpha} \frac{\int_\gamma^\delta dE' \int_\lambda^\beta dE\ \sigma_s(E)\ W(E)\ P_\ell(\mu) \sum_{k=0}^{J} (2k+1)\ f_k(E)\ P_k(\eta)}{\int_\gamma^\delta W(E)\ dE}$$

where γ,δ are the limits of group i and
λ,β are the limits of group j.

The cross section is retrieved from tape, and after transformation to lethargy the integration is performed numerically by use of Simpson's rule. The limits of the integrals in Equation (2.33), depend on the relative position of the group limits and the atomic mass of the scatterer. Since scattering to energy E' can occur from energies $E = E'/\alpha$ to $E = E'$ only, the limits of integration may be determined by inspection of Figure 2 in which the line $E' = E/\alpha$ is drawn in the six possible ways it can cross the rectangle.

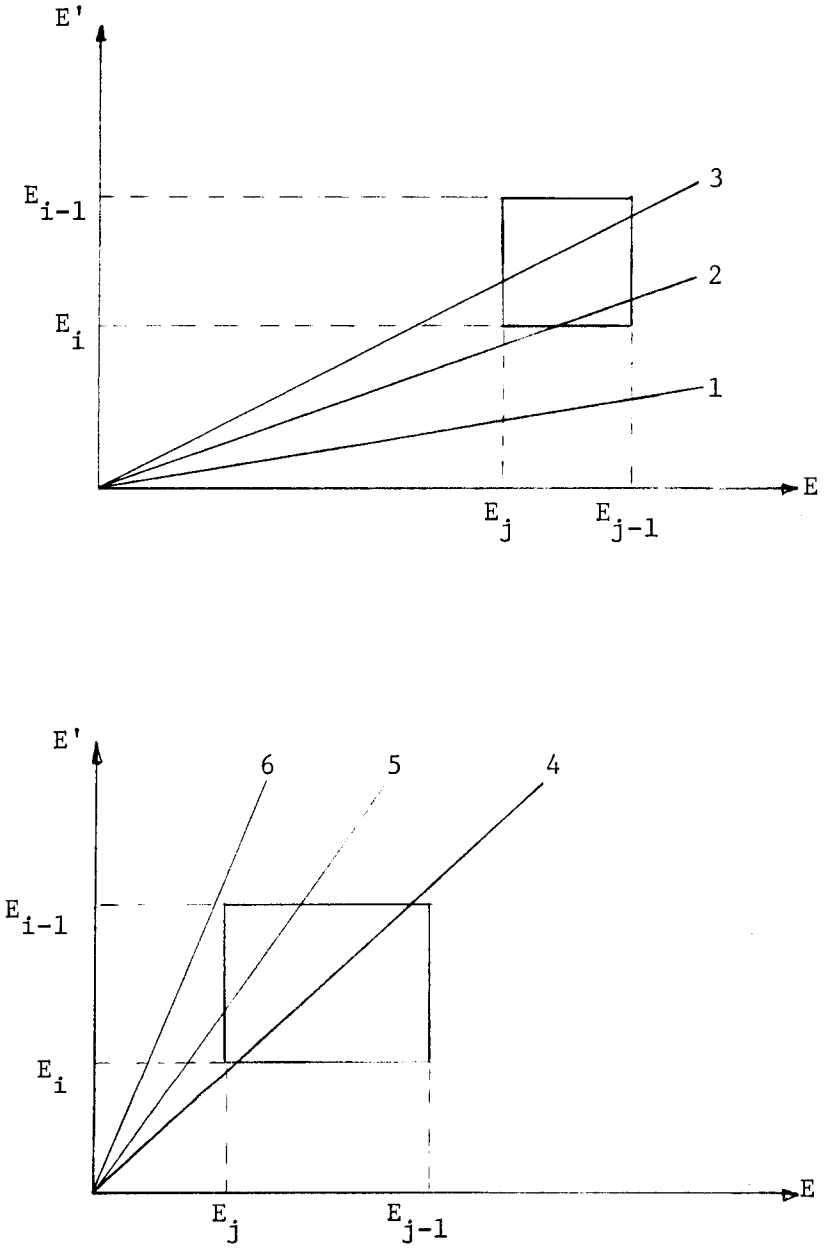

Figure 2

For out-of-group scattering (j = i) the limits in the six possible cases are listed in the following table.

TABLE 1

For $i \neq j$,

(1)	$\alpha E_i > E_j$	$\alpha E_i \geq E_{j-1}$	Integral is zero
	$\alpha E_{i-1} > E_j$	$\alpha E_{i-1} > E_{j-1}$	
(2)	$\alpha E_i \geq E_j$	$\alpha E_i < E_{j-1}$	$\beta = E_{j-1}$, $\delta = E/\alpha$, $\lambda = \alpha E_i$, $\gamma = E_i$
	$\alpha E_{i-1} > E_j$	$\alpha E_{i-1} \geq E_{j-1}$	
(3)	$\alpha E_i \leq E_j$	$\alpha E_i < E_{j-1}$	$\beta = E_{j-1}$, $\delta = E/\alpha$, $\lambda = E_j$, $\gamma = E_i$
	$\alpha E_{i-1} > E_j$	$\alpha E_{i-1} \geq E_{j-1}$	
(4)	$\alpha E_i \geq E_j$	$\alpha E_i < E_{j-1}$	Integral is the sum of two double integrals: $\beta_1 = E_{j-1}$, $\delta_1 = E_{i-1}$, $\lambda_1 = \alpha E_{i-1}$, $\gamma_1 = E_i$; $\beta_2 = \alpha E_{i-1}$, $\delta_2 = E/\alpha$, $\lambda_2 = \alpha E_i$, $\gamma_2 = E_i$
	$\alpha E_{i-1} > E_j$	$\alpha E_{i-1} \leq E_{j-1}$	
(5)	$\alpha E_i \leq E_j$	$\alpha E_i < E_{j-1}$	Integral is the sum of two double integrals: $\beta_1 = \alpha E_{i-1}$, $\delta_1 = E/\alpha$, $\lambda_1 = E_j$, $\gamma_1 = E_i$; $\beta_2 = E_{j-1}$, $\delta_2 = E_{i-1}$, $\lambda_2 = \alpha E_{i-1}$, $\gamma_2 = E_i$
	$\alpha E_{i-1} > E_j$	$\alpha E_{i-1} \leq E_{j-1}$	

TABLE 1 (continued)

(6)	$\alpha E_i < E_j$	$\alpha E_i < E_{j-1}$	$\beta = E_{j-1}$	$\delta = E_{i-1}$
	$\alpha E_{i-1} \leq E_j$	$\alpha E_{i-1} < E_{j-1}$	$\lambda = E_j$	$\gamma = E_i$

There are two possible cases for in-group (j = i) scattering in which the limits of the integration are listed in Table 2 below.

TABLE 2

For i = j

(7)	$\alpha E_{j-1} \leq E_j$	$\beta = E_{j-1}$	$\delta = E_{j-1}$
		$\lambda = E_j$	$\gamma = E$
(8)	$\alpha E_{j-1} > E_j$	Integral is the sum of two double integrals	
		$\beta_1 = \alpha E_{j-1}$	$\delta_1 = E/\alpha$
		$\lambda_1 = E_j$	$\gamma_1 = E$
		$\beta_2 = E_{j-1}$	$\delta_2 = E_{j-1}$
		$\lambda_2 = \alpha E_{j-1}$	$\gamma_2 = E$

An investigation of the rate of convergence of the integrals as a function of the number of intervals in the integration indicated that 60 intervals in both the inner and outer integrations were adequate. It must be noted, however, that the scheme is not quite adequate for the calculation of matrix elements of order greater than 1 at low energies at which the scattering is isotropic in the center of mass system; these elements are small, generally less than 10^{-3}, and are the results of subtractions of terms of the same order of magnitude. For this reason, when scattering to only one group below the source group occurs, a technique suggested by R. Grimesey is adopted.

For energies at which the scattering is isotropic in the center of mass system the integrals in Equation (2.33), when summed over all sink groups, may be evaluated analytically[10], that is,

$$\begin{aligned}
\sum \sigma^0_{j,i} &= \bar{\sigma}_i, \quad \text{the average scattering cross section in group i.} \\
\sum \sigma^1_{j,i} &= \overline{\mu\sigma}_i = \frac{2}{3A}\bar{\sigma}_i \\
\sum \sigma^2_{j,i} &= \frac{\bar{\sigma}_i}{8}\left[\, 5-3A^2 - \frac{3(A^2-1)}{4A} \ln\alpha \,\right] \\
\sum \sigma^3_{j,i} &= 0
\end{aligned} \tag{2.34}$$

The philosophy of the calculation for this special case is to divide the integration over the source group into 2 parts, one extending from E_{i-1} to E_i/α and the other from E_i/α to E_i. The latter bounds correspond to the generally small range which contributes to out-of-group scattering. Then the out-of-group term is calculated quite accurately as described above, and the in-group term is computed by use of relationships (2.34).

2.4.3 (n,2n) Reaction

For the GAM and ANISN libraries, the treatment of the (n,2n) reaction is the same as that of inelastic scattering, that is, $P^{i\to j}_{n,2n}$ is computed and the product

$$\sigma^{i\to j}_{n,2n} = \sigma^{i}_{n,2n} * P^{i\to j}_{n,2n}$$

is formed. In the generation of ANISN data, the (n,2n) transfer cross section elements are added to the corresponding isotropic transfer cross sections.

2.5 SOURCE SPECTRUM

A source spectrum is required as part of a MUFT library and is present as MUFT 4 File 6 or as MUFT 5 File 7. The source is usually taken to be the secondary energy distribution of fission neutrons. Hence it is obtained from ENDF/B File 5, MT = 18. The current version, ETOG-1, will only process an energy distribution represented simply by, or as a combination of, a simple fission spectrum (LF = 6), a Maxwellian distribution (LF = 8), or a Watt spectrum (LF = 10). The other defined distributions, LF = 1, 2, 3, 4, 5, 7 and 9 are not accepted and an error message is printed by the program.

Using the representation specified in the ENDF/B library, ETOG-1 calculates the source at each point of a mesh covering an energy range from 20 Mev to the lowest energy in the multigroup structure. The mesh spacing is 1/64 lethargy unit from the lowest lethargy to 10.0 and 1/32 lethargy unit above 10.0. Thus the curve is represented by nearly 1000 points. The integral of this curve over each group is then computed and the results normalized to a unit source. For the source calculation, the top energy of the first group is taken as 20 Mev, hence the "upper tail" of the spectrum is included in group 1. Finally the source in each group is divided by the lethargy width of the group since MUFT requires the source to be in neutrons per lethargy unit. (For group 1 the correct lethargy width is used, not the width to 20 Mev.)

CHAPTER 3

EXECUTION INFORMATION AND PROCEDURES

This section is written so as to be reasonably self-contained in order to provide sufficient information to run problems with the program. The intent is that this section will provide the program user with a code running prescription. The other sections of the report should be consulted where further details are required.

3.1 SUMMARY DESCRIPTION

ETOG-1 is a program which processes information from the ENDF/B file and produces data decks required for the generation of libraries for the MUFT-4, MUFT-5, GAM-I, GAM-II and ANISN codes. The output of ETOG-1 consists of printed tabulations of the data in addition to cards punched in the proper format.

3.2 LIMITATIONS

Due to the finite storage capacity of the computer, certain limitations are necessary. It is felt that these restrictions are not presently confining. The program is constructed such that these limitations can be easily relaxed to accomodate future needs.

3.2.1 Restrictions Placed on Multigroups by ETOG-1

1) Maximum number of multigroups - 99
2) Maximum number of resolved resonances - 250
3) Maximum number of sets of Legendre coefficients per group - 100
4) Maximum number of points allowed in the inner and outer integrals of the equation used to calculate the elements of the transfer matrix, $\sigma^{\ell}_{j,i}$ - 100 (The code presently uses 60 intervals in both the inner and outer integrals.)

The following is a MUFT restriction and not an ETOG-1 limitation:

5) Maximum number of resonances per group - 8

3.2.2 Restrictions Placed on ENDF/B Data by ETOG-1

3.2.2.1 File 1 - General Information

1) ν representation by a polynomial:
   Maximum number of coefficients - 10.

2) ν representation by a tabulation:
   Maximum number of tabulated points - 4000
   Maximum number of interpolation ranges - 100

3.2.2.2 File 2 - Resonance Parameters

1) Maximum number of isotopes - 6
2) Maximum number of ℓ states - 3
3) Maximum number of J states per ℓ state - 4
4) Maximum number of points in the fission width tabulation - 1000 / total number of states.

3.2.2.3 File 3 - Smooth Cross Sections

1) Maximum number of points in all File 3 tabulations - 4000
2) Maximum number of interpolation ranges in all File 3 tabulations - 100

3.2.2.4 File 4 - Secondary Angular Distributions

1) Maximum number of Legendre coefficients per energy value - 24
2) Maximum number of points in the transformation matrix - 1000
3) Maximum number of points in angular distribution tabulation - 4000
4) Maximum number of interpolation ranges for angular distribution tabulation - 100

3.2.2.5 File 5 - Secondary Energy Distribution

1) Maximum number of points in the P(E) tabulation - 1000 for LF = 1, 4, 5; 2000 for LF = 7, 9; 3000 for LF = 2, 3, 6, 8, 10
2) Maximum number of interpolation ranges for P(E) - 10 for LF = 1, 4, 5; 20 for LF = 7, 9; 30 for LF = 2, 3, 6, 8, 10

3) Maximum number of points in $g(E' \leftarrow E)$ tabulation - 2000
4) Maximum number of interpolation ranges for E in obtaining $g(E' \leftarrow E)$ - 10
5) Maximum number of interpolation ranges for E' in obtaining $g(E' \leftarrow E)$ - 10
6) Maximum number of points in g(x) tabulation - 2000 for LF = 4;
   1000 for LF = 5
7) Maximum number of interpolation ranges for g(x) - 20 for LF = 4;
   10 for LF = 5
8) Maximum number of points in $\theta(E)$ tabulation - 1000
9) Maximum number of interpolation ranges for $\theta(E)$ - 10

3.2.3 Input Option Restrictions

1) Maximum number of points in input weighting function tabulation - 4000
2) Maximum number of interpolation ranges for the input weighting function tabulation - 100

3.3 INPUT FORMAT

For reasons of clarity, the discussion of the input format for GAM and ANISN is separated from that for MUFT. Duplicate descriptions appear where necessary.

In the following input lists the various items are described and the columns to be used for each item are designated. Standard FORTRAN input is used. For added convenience, the actual program formats and symbols are also listed. The various options are more fully described in the section following the input description.

3.3.1 Input Description for GAM-I, GAM-II, and ANISN

Card No. 1 (5I5, 5X, 4E10.0)

Item	Columns	Name	Description
1	1-5	INALL	0 = only card 1 is read
			1 = all input cards are read
2	6-10	MATNO	ENDF/B tape material number
3	11-15	MATID	Multigroup material identification number

Item	Columns	Name	Description
4	16-20	IREW	0 = ENDF/B tape is not rewound by the program 1 = ENDF/B tape is rewound by the program
5	21-25	NAGDS	0 = ANISN transfer cross sections for all possible sink groups are punched for each source group ≠0 = ANISN transfer cross sections for NAGDS sink groups are punched for each source group; i.e., downscatter is truncated after NAGDS groups below the given group
6	31-40	XAJIN	The J (spin) value for which unresolved resonance parameter cards are desired (if possible)
7	41-50	EPSMIN	Minimum value of epsilon for combining two TAB1 functions
8	51-60	EPSMAX	Maximum value of epsilon for combining two TAB1 functions
9	61-70	SIGP	Potential scattering cross section (per absorber atom), of non-resonance isotopes for use in unresolved resonance treatment, i.e., $SIGP = \left(\frac{\Sigma_p}{N} - 4\pi R^2\right)$ where Σ_p is the macroscopic potential scattering cross section of the mixture, and N is the number density and $4\pi R^2$ is the potential scattering cross section of the resonance isotope.

Card No. 2 (9I5, 20X, I5)

Item	Columns	Name	Description
1	1-5	IDTAP	ENDF/B tape identification number
2	6-10	MODE	1 = ENDF/B tape is binary mode (standard arrangement) 3 = ENDF/B tape is BCD mode (standard arrangement)
3	11-15	MCODE	1 = multigroup code is GAM-I 2 = multigroup code is GAM-II
4	16-20	MAXG	Number of multigroups
5	21-25	IEU	1 = standard GAM-I group structure 2 = standard GAM-II group structure 6 = input energy group structure 7 = input lethargy group structure
6	26-30	IW	1 = weighting function is 1/E

Item	Columns	Name	Description
			2 = weighting function is constant
			3 = weighting function is input
			4 = weighting function is 1/E joined to a fission spectrum
7	31-35	ISPEC	0 = no spectrum calculation
			1 = spectrum calculation
8	36-40	IRES	0 = construct resonance parameter cards if possible
			3 = calculate equivalent smooth data for all resonance parameters.
9	41-45	IPUN	0 = no punched output
			1 = punched output
			2 = punched output in ANISN format
10	66-70	NDFB	Logical unit on which the ENDF/B library tape is mounted (if = 0, NDFB is set = 11)

Card No. 3 (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 tables defining the interpolation schemes to be used with those points. The weighting function must be given in order of increasing energy. The format of the card set is a standard ENDF/B TAB1 record.

Card 3.1 (44X, 2I11)

Item	Columns	Name	Description
1	45-55	N1	Number of interpolation ranges
2	56-66	N2	Number of weighting function points

Card 3.2 - ... (6I11)

Item	Columns	Name	Description
1	1-11	NBT(1)	Last point number in 1st interpolation range
2	12-22	JNT(1)	Interpolation scheme for 1st range
3	23-33	NBT(2)	Last point number in 2nd interpolation range

Item	Columns	Name	Description
4	34-44	JNT(2)	Interpolation scheme for 2nd range
⋮			
2*N1-1		NBT(N1)	Last point number in N1th interpolation range
2*N1		JNT(N1)	Interpolation scheme for the N1th range

Card 3.3 - ... (6E11.4)

Item	Columns	Name	Description
1	1-11	X(1)	First energy point ($\leq$ lowest energy in group structure)
2	12-22	Y(1)	Weight at this energy
⋮			
2*N2-1		X(N2)	Last energy point ($\geq$ highest energy in group structure)
2*N2		Y(N2)	Weight at this energy

Card No. 4 (optional)

This is actually a card set and is necessary only if IEU = 6 or 7. The set defines the desired group structure. If IEU = 6, the set contains the multigroup energy breakpoints given in order of increasing energy. If IEU = 7, the set contains the multigroup lethargy breakpoints given in order of decreasing lethargy.

Card 4.1 - ... (6E11.4)

Item	Columns	Name	Description
1	1-11	XX(1)	Energy or lethargy of breakpoint number 1
2	12-22	XX(2)	Energy or lethargy of breakpoint number 2
⋮			
MAXG		XX(MAXG)	Energy or lethargy of breakpoint number MAXG
MAXG+1		XX(MAXG+1)	Energy or lethargy of breakpoint number MAXG+1

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

3.3.2 Available Options for GAM and ANISN

3.3.2.1 Input (INALL)

This option is designed to facilitate stacked cases where several materials are to be processed in the same way. Complete input is necessary only for the first case (INALL = 1) and subsequent cases need only the first card (INALL = 0).

3.3.2.2 Tape Rewind (IREW)

This option provides running efficiency by permitting a single pass over the ENDF/B tape during the processing of a stack of cases. The first case should request a tape rewind (IREW = 1) but subsequent cases should not (IREW = 0).

3.3.2.3 Unresolved Resonance Parameter (XAJIN)

This option allows a particular set of unresolved resonance parameters to be output explicitly. All other sets of unresolved resonance parameters are converted to equivalent smooth data. The J (spin) value entered as input must correspond to a J state existing in the ENDF/B file. In some cases a J state equal to 0 exists; therefore caution must be used in setting J = 0.

3.3.2.4 Tape Mode (MODE)

The ENDF/B tape may be either in the binary (MODE = 1) or BCD (MODE = 3) mode. For compactness and running efficiency it is recommended that the binary mode be used where possible.

3.3.2.5 Multigroup Structure (IEU)

This option allows the standard 68 group GAM-I or 99 group GAM-II structure to be internally generated. Different structures may be entered as input in either energy or lethargy units.

3.3.2.6 Weighting Function (IW)

This option permits the weighting functions to be 1/E, constant, pointwise

input or a combination of 1/E joined to a U-235 fission spectrum. Other built-in functions can be added easily in the future.

3.3.2.7 Spectrum Calculation (ISPEC)

ETOG-1 will do either a general cross section deck calculation or a spectrum deck calculation. Both cannot be done simultaneously. Hence this option selects which calculation is to be done. If both are desired, two cases must be run (and the tape rewound before the second case).

3.3.2.8 Resolved Resonance Parameters (IRES)

This option allows resolved resonance parameters to be output explicitly for the GAM codes or permits equivalent smooth data to be generated from the resonance parameters.* In certain cases this option will be overridden internally (See Section 2.3).

3.3.2.9 Punched Cards (IPUN)

This option allows cards to be punched in the proper format if desired. If cards in the ANISN format are desired rather than the GAM-II format, IPUN is set equal to 2.*

3.3.3 Input Description for MUFT-4 and MUFT-5

Card No. 1 (4I5, 20X, 3E10.0)

Item	Columns	Name	Description
1	1-5	INALL	0 = only card number 1 is read
			1 = all input cards are read
2	6-10	MATNO	ENDF/B tape material number
3	11-15	MATID	Multigroup material identification number
4	16-20	IREW	0 = ENDF/B tape is not rewound by ETOG-1
			1 = ENDF/B tape is rewound by ETOG-1

* In order to obtain library data for ANISN, ETOG-1 should be run to produce GAM-II library data; however, the IPUN option should be set to output ANISN data and the IRES option should be set to convert all resonance parameters to equivalent smooth capture and fission data.

Item	Columns	Name	Description
5	41-50	EPSMIN	Minimum value of epsilon for combining two TAB1 functions
6	51-60	EPSMAX	Maximum value of epsilon for combining two TAB1 functions
7	61-70	SIGP	Potential scattering cross section (per abosrber atom) of non-resonance isotopes for use in unresolved resonance treatment, i.e., $$SIGP = \left(\frac{\Sigma_p}{N} - 4\pi R^2 \right)$$ where Σ_p is the macroscopic potential cross section of the mixture, and N is the number density and $4\pi R^2$ is the potential scattering cross section of the resonance isotope.

Card No. 2 (9I5, 20X, I5)

Item	Columns	Name	Description
1	1-5	IDTAP	ENDF/B tape identification number
2	6-10	MODE	1 = ENDF/B tape is binary mode (standard arrangement) 3 = ENDF/B tape is BCD mode (standard arrangement)
3	11-15	MCODE	4 = multigroup code is MUFT 4 5 = multigroup code is MUFT 5
4	16-20	MAXG	Number of multigroups
5	21-25	IEU	4 = standard MUFT 54 group structure 6 = input energy group structure 7 = input lethargy group structure
6	26-30	IW	1 = weighting function is 1/E 2 = weighting function is constant 3 = weighting function is input 4 = weighting function is 1/E joined to a fission spectrum
7	31-35	ISPEC	0 = no spectrum calculation 1 = spectrum calculation
8	36-40	IRES	1 = add extra resonances to smooth cross section 2 = use extra resonances to form a pseudo-resonance
9	41-45	IPUN	0 = no punched output 1 = punched output

Item	Columns	Name	Description
10	66-70	NDFB	Logical unit on which the ENDF/B library tape is mounted (if = 0, NDFB is set = 11).

Card No. 3 (7I5)

Item	Columns	Name	Description
1	1-5	MINR	Lowest group number in resonance region
2	6-10	MAXI	Highest group number in inelastic region
3	11-15	ISGG	Greuling-Goertzel parameter 1 = calculated from ENDF/B tape 3 = taken equal to 0.5* Δu
4	16-20	IN2N	n-2n cross section 1 = added to fission 2 = half added to fission; half to inelastic 3 = added to inelastic
5	21-25	INTO	Ingroup inelastic scattering 1 = distributed over all inelastic groups 2 = lumped into adjacent (lowest) group 3 = added to smooth scattering
6	26-30	IEXT	Inelastic scattering out of defined matrix 1 = distributed over all inelastic groups 2 = lumped into adjacent (lowest) group 3 = lumped into last (highest) group
7	31-35	IXSR	Resonance scattering 0 = calculated from ENDF/B tape and added to smooth 1 = taken as $4\pi R^2$ over ENDF/B defined resonance region 2 = taken to be equal to the value in the first group above the resonance region

Card No. 4

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 tables defining the interpolation shcemes to be used with those points. The weighting function

must be given in order of increasing energy. The format of the card set is a standard ENDF/B TAB1 record.

Card 4.1 (44X, 2I11)

Item	Columns	Name	Description
1	45-55	N1	Number of interpolation ranges
2	56-66	N2	Number of weighting function points

Card 4.2 ... (6I11)

Item	Columns	Name	Description
1	1-11	NBT(1)	Last point number in 1st interpolation range
2	12-22	JNT(1)	Interpolation scheme for 1st range
3	23-33	NBT(2)	Last point number in 2nd interpolation range
4	34-44	JNT(2)	Interpolation scheme for 2nd range
⋮			
2*N1-1		NBT(N1)	Last point number in N1th interpolation range
2*N1		JNT(N1)	Interpolation scheme for the N1th range

Card 4.3 .... (6E11.4)

Item	Columns	Name	Description
1	1-11	X(1)	First energy point ($\leq$ lowest energy in group structure)
2	12-22	Y(1)	Weight at this energy
⋮			
2*N2-1		X(N2)	Last energy point ($\geq$ highest energy in group structure)
2*N2		Y(N2)	Weight at this energy

Card No. 5

This is actually a card set and is necessary only if IEU = 6 or 7. The set defines the desired group structure. If IEU = 6, the set contains the multigroup energy breakpoints given in order of increasing energy. If IEU = 7, the set contains the multigroup lethargy breakpoints given in order of decreasing lethargy.

Card 5.1 (6E11.4)

Item	Columns	Name	Description
1	1-11	XX(1)	Energy or lethargy of breakpoint number 1
2	12-22	XX(2)	Energy or lethargy of breakpoint number 2
⋮			
MAXG		XX(MAXG)	Energy or lethargy of breakpoint number MAXG
MAXG+1		XX(MAXG+1)	Energy or lethargy breakpoint number MAXG+1

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

3.3.4 Available Options for MUFT

3.3.4.1 Input (INALL)

This option is designed to facilitate stacked cases where several materials are to be processed in the same way. Complete input is necessary only for the first case (INALL = 1) and subsequent cases need only the first card (INALL = 0).

3.3.4.2 Tape Rewind (IREW)

This option provides running efficiency by permitting a single pass over the ENDF/B tape during the processing of a stack of cases. The first case should request a tape rewind (IREW = 1) but subsequent cases should not (IREW = 0).

3.3.4.3 Tape Mode (MODE)

The ENDF/B tape may be either in the binary (MODE = 1) or BCD (MODE = 3) mode. For compactness and running efficiency it is recommended that the binary mode be used where possible.

3.3.4.4 Multigroup Structure (IEU)

This option permits the standard 54 group MUFT structure to be internally generated or allows the structure to be input in either energy or lethargy units.

3.3.4.5 Weighting Function (IW)

This option permits the weighting functions to be 1/E, constant, pointwise input or a combination of 1/E joined to a U-235 fission spectrum. Other built-in functions can be added easily in the future.

3.3.4.6 Spectrum Calculation (ISPEC)

ETOG-1 will do either a general cross section deck calculation or a spectrum deck calculation. Both cannot be done simultaneously. Hence this option selects which calculation is to be done. If both are desired, two cases must be run (and the tape rewound before the second case).

3.3.4.7 Resolved Resonance Treatment (IRES)

Since MUFT permits only eight resolved resonances per group, some provision must be made for those groups which have more than eight resolved resonances. Two choices are provided:

For IRES = 1: All m values are calculated. The eight resonances with the largest m values are kept and included in the MUFT resonance file. The other resonances are treated as effective smooth cross sections and added to the MUFT smooth cross section file according to the relationships

$$\Delta u * \sigma_{nc} = \frac{\pi}{2} m\left(\frac{\Gamma_\gamma}{\Gamma_\gamma + \Gamma_f}\right)$$

$$\Delta u * \sigma_{nf} = \frac{\pi}{2} m\left(\frac{\Gamma_f}{\Gamma_\gamma + \Gamma_f}\right)$$

where Δu = group lethargy width and

σ_{nc} = effective smooth capture cross section

σ_{nf} = effective smooth fission cross section

Note: These relationships preserve the infinite dilute resonance integral values.

For IRES = 2: All m values are calculated. The seven resonances with the

largest m values are kept and included in the MUFT resonance file. A pseudo-resonance is constructed as the eighth and included in the MUFT resonance file. The m, r, and α factors for this pseudo-resonance are calculated as

$$m_8 = \sum m$$

$$r_8 = \left[\frac{m_8}{\sum \left(\frac{m}{\sqrt{r}} \right)} \right]^2$$

$$\alpha_8 m_8 = \sum m \left(\frac{\Gamma_f}{\Gamma_\gamma + \Gamma_f} \right)$$

where the sums are over all non-kept resonances.

3.3.4.8 Output Punch (IPUN)

This option permits the punching of the results on cards, if deisred. The output cards are in the correct format for direct use in constructing a MUFT-4 or MUFT-5 library.

3.3.4.9 Greuling-Goertzel Parameter (ISGG)

This option permits the Greuling-Goertzel parameter to be calculated directly from the ENDF/B tape or to be taken equal to half the group lethargy width.

3.3.4.10 (n,2n) Cross Section (IN2N)

Three choices are provided for the treatment of the (n,2n) reaction.

For IN2N = 1: The (n,2n) cross section is treated as fission (with a ν value of 2) and added to the smooth fission; ν is adjusted accordingly.

$$\sigma_f = \sigma_f + \sigma_{n,2n}$$

$$\nu = \frac{\nu^* \sigma_f + 2.0 * \sigma_{n,2n}}{\sigma_f + \sigma_{n,2n}}$$

For IN2N = 2: The (n,2n) reaction is treated as half fission (with a ν value of 1) and half inelastic scattering.

$$\sigma_f = \sigma_f + 0.5 * \sigma_{n,2n}$$

$$\sigma_{in} = \sigma_{in} + 0.5 * \sigma_{n,2n}$$

$$\nu = \frac{\nu * \sigma_f + 1.0 * 0.5 * \sigma_{n,2n}}{\sigma_f + 0.5 * \sigma_{n,2n}}$$

For IN2N = 3: The (n,2n) reaction is treated as inelastic scattering and added to the smooth inelastic value.

$$\sigma_{in} = \sigma_{in} + \sigma_{n,2n}$$

3.3.4.11 Ingroup Inelastic Scattering Cross Section (INTO)

Since MUFT does not permit ingroup inelastic scattering, three options are provided for its treatment.

For INTO = 1: The ingroup scatter is distributed over all defined sink groups in proportion to the inelastic scattering probabilities.

For INTO = 2: The ingroup scatter is lumped into the adjacent group (i.e., the first off-diagonal element).

For INTO = 3: The ingroup scatter is treated as elastic scattering by adding the ingroup scatter to the smooth elastic cross section and reducing the inelastic cross section accordingly.

3.3.4.12 Inelastic Scattering Out of Defined Matrix (IEXT)

The limits of the inelastic matrix are defined by MAXI. Since there may be some inelastic scatter to group numbers greater than MAXI, three options are provided for treating this case.

For IEXT = 1: The excess scatter is distributed over all defined sink groups

in proportion to the inelastic scattering probabilities.

For IEXT = 2: The excess scatter is lumped into the lowest group (i.e., the first off diagonal element).

For IEXT = 3: The excess scatter is lumped into the highest group (MAXI).

3.3.4.13 Resonance Scattering Option (IXSR)

MUFT has no explicit treatment of resonance scattering. Hence three options are provided:

For IXSR = 0: The scattering cross section is used completely according to the ENDF/B representation.

For IXSR = 1: For all groups within the ENDF/B-defined resonance region (both resolved and unresolved), the scattering cross section is taken as the potential scattering cross section ($4\pi R^2$).

For IXSR = 2: For all groups within the ENDF/B-defined resonance region (both resolved and unresolved), the scattering cross section is taken to be equal to the value in the first group above the resonance region.

3.3.5 Problem Stacking Procedure

ETOG-1 is designed to process sequentially any number of materials during one run. Normally the first material request (via Card No. 1) will be accompanied by all input data (set INALL = 1) and the ENDF/B tape will be rewound by the program (set IREW = 1). Subsequent material requests will only require Card No. 1 (set INALL = 0) and the ENDF/B tape will not be rewound by the program (set IREW = 0). Since the ENDF/B tape is not rewound, the material requests should be in ascending order according to ENDF/B material number (MATNO on Card No. 1). On subsequent material

requests additional input is necessary only if it differs from the initial material request. Likewise the tape should only be rewound if the same material is to be processed twice. (For example, if both a cross section deck and spectrum deck is required).

For maximum efficiency, however, the tape should not be rewound and two separate runs may be more efficient than a single run with frequent rewinds.

3.3.6 Sample Problem Input

The sample problem processes the information for ENDF/B material number 1051 (Reference 15) and produces a data deck for generation of a GAM-II library.

The 1051 data is that present on ENDF/B tape (identification number) 115 with several exceptions. Slight changes were made to File 3 and File 4 data to assure that $\mu(E)$ and the secondary elastic scattering angular distribution were isotropic at energies below 10 Kev. Card Nos. 681, 682, 683, 808, and 809 were corrected. One card was inserted after Card No. 682, and two were inserted after Card No. 811. Images of the corrected data cards appear in the table below.

```
  0.0          0.0        0           0        1          40    1051  3  251  681
   40            2                                            1051  3  251  682
1.0-5    2.81294-3   1.0-3    2.81294-3   1.0+3   2.81294-3    1051  3  251  682A
1.0+4    2.81294-3   5.0+4    3.73177-2   1.0+5   7.89562-2    1051  3  251  683
  0.0          0.0        0           0        1          38    1051  4    2  808
   38            2                                            1051  4    2  809
  0.0       1.0E+4        0           0        1           0    1051  4    2  811A
  0.0          0.0        0           0        0           0    1051  4    2  811B
```

Material 1051 is Pu-239 and was chosen because its resonance representation

shows several of the features of ETOG-1. The sample input sheet is given on the next page.

3.4 OUTPUT FORMAT

3.4.1 Printed Output

The output edit lists the material being processed, the ENDF/B tape being read, and the input options selected. Tables of groupwise energy and lethargy bounds are given, as well as File 1 data read from ENDF/B. If resonance parameters (resolved and unresolved) are listed in ENDF/B File 2, these quantities are printed; groupwise corrections to resonance cross sections, which depend on the library to be generated, follow. File 3 data for each reaction type processed is edited as groupwise cross sections. Before composite group cross sections are tabulated (excluding the contributions calculated from resonance parameters by the codes for which the library data are intended) infinitely dilute resonance integrals for parasitic capture and fission reactions are printed. Headings are self-explanatory.

If elastic scattering matrices are established, the results are printed next. In the energy range in which the scattering is isotropic in the center of mass system the sum of contributions to $\sigma^{\ell}_{j,i}$ from all sink groups j is compared with the expected values given by Equation (2.34), and a percentage error is computed. The results are normalized to these expected values. Note that these equations alone are used to determine the values of matrix elements for two-group scatter. These tables are followed by the inelastic scattering and (n,2n) matrices, if they exist. Both probability and cross section matrices, before and after renormalization, are

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FORTRAN CODING FORM

TITLE SAMPLE PROBLEM FOR WCAP-3845-1 ANALYST _____ DATE JAN 1970

JOB NO. MATERIAL 1051 PU-239 L.S. NO. _____ LABEL (73–76) _____ SHEET 1 OF 1

1 2 3 4 5	6	7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72	NO. 77 78 79 80
1		1051 21 1 0.0 0.0001 0.0026 1.0E+07	
115		3 2 99 2 4 0 0 1 11	

edited. Finally, images of cards punched for use by the library generators are printed.

3.4.2 Punched Card Output

3.4.2.1 Punched Card Format for MUFT-4

ETOG-1 produces punched cards for use in generating library data for MUFT-4 Files 3, 4, 5 and 6, as described in Reference 12. All floating point numbers are punched in excess-50 format; both fixed and floating point numbers have their signs in the column preceding the exponent. Only columns 1-72 of any card are used for data. Consequently, the ENDF/B material number is punched in columns 74-77 of each card. Cards for each material are sequenced in columns 78-80.

Column 2 of each card designates the file into which the information given is to be placed. Output cards for MUFT-4 File 3 contain microscopic cross sections, slowing down parameters, and fission product parameters in the following format:

Card No. 1

Columns	Variable Name	Information
4-5	MATID	Element number
7-8	NGR	Group number
9-16	XS	Total scattering cross section
17-24	XC	Smooth capture cross section
25-32	XIN	Total inelastic scattering cross section
33-40	XF	Smooth fission cross section

Columns	Variable Name(s)	Information
41-48	AGN	Isotropic Greuling-Goertzel parameter (age number)
49-56	XSMU	Anisotropic scattering cross section
57-64	GNU	Number of neutrons per fission
65-72	XSXI	Isotropic slowing down power

Card No. 1 is punched for each output energy group.

Card for MUFT-4 File 4 contain resonance parameters in the following format:

Card No. 2

Columns	Variable Name(s)	Information
4-5	MATID	Element number
7-8	JRS	Number ($\leq$ 8) of r-factors* on card, for group n
9-16	R	$r_{n,1}$
17-24	R	$r_{n,2}$
⋮		⋮
65-72	R	$r_{n,JRS}$

Card No. 3

Columns	Variable Name(s)	Information
4-5	MATID	Element number
7-8	JRS	Number ($\leq$ 8) of m-factors* on card, for group n (same as number of r-factors)
9-16	EM	$m_{n,1}$
17-24	EM	$m_{n,2}$
⋮		⋮
65-72	EM	$m_{n,JRS}$

---

* Defined in Section 2.3.1

Card Nos. 2 and 3 are repeated for each energy group n as specified in the input deck, i.e., for n = MINR to n = MAXG.

Card No. 4

Columns	Variable Name(s)	Information
4-5	MATID	Element number
7-8	JRS	Number ($\leq$ 8) of α-factors* on card, for group n
9-16	ALFA	$\alpha_{n,1}$
17-24	ALFA	$\alpha_{n,2}$
⋮		⋮
65-72	ALFA	$\alpha_{n,JRS}$

If fission-to-absorption ratios exist, one Card No. 4 is punched for each group n as specified in the input deck, i.e., for n = MINR to n = MAXG.

Cards for MUFT-4 File 5 contain the inelastic scattering cross sections, σ_{in}^{i}, and the inelastic scattering probability matrix elements $P_{in}^{i\rightarrow j}$ in the following formats:

Card No. 5

Columns	Variable Name(s)	Information
4-5	MATID	Element number
7-8		Group number, i, of first σ_{in} on card
9-16	XIN(i)	σ_{in}^{i}
17-24	XIN(i+1)	σ_{in}^{i+1}
⋮		⋮
65-72	XIN(i+7)	σ_{in}^{i+7}

Card (set) No. 5 is repeated until all output groups are specified.

---

* Defined in Section 2.3.1

Card No. 6

Columns	Information
4-5	Element number
7-8	Group number, j, to which inelastic scattering is occurring
9-16	$P_{in}^{1\rightarrow j}$
17-24	$P_{in}^{2\rightarrow j}$
⋮	⋮
65-72	$P_{in}^{8\rightarrow j}$
⋮	⋮

where $P_{in}^{i\rightarrow j}$ is the probability of inelastic scattering from the i^{th} group to the j^{th} group.

Card (set) No. 6 is repeated for each of the specified groups, i.e., for j = 2 to j = MAXI.

Output cards for MUFT-4 File 6 contain source spectra in the following format:

Card No. 7

Columns	Variable Name(s)	Information
4-5	MATID	Source spectrum number
9-16	TRUM(1)	$\bar{X}_1$
17-24	TRUM(2)	$\bar{X}_2$
⋮		⋮
65-72	TRUM(8)	$\bar{X}_8$
⋮		⋮

Card No. 7 is repeated until the fractional source, $\bar{X}_i$, in each output energy group i has been specified.

3.4.2.2 Punched Card Format for MUFT-5

ETOG-1 produces punched cards for use in generating library data for MUFT-5

Files 3, 4, 5, 6 and 7, as described in Reference 13. All data is punched in excess-0 format. The sign of the fraction appears only when it is negative and, in this case, the number of significant digits in the fraction is reduced by one. There is a maximum of eight data fields, 7 columns in length, per card; data fields are separated by commas. Only columns 9-80 are used for data. Consequently the ENDF/B material number is punched in columns 1-4 and the cards for each material are sequenced in columns 5-7.

Column 9 of each card designates the file into which the information given is to be placed. Output cards for MUFT-5 File 3 contain microscopic cross sections, slowing down parameters, and fission product parameters in the following formats:

Card No. 1

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14	NGR	Group number
16	NSEQ	Sequence number (=1)
18-24	XS	Total scattering cross section
26-32	XC	Smooth capture cross section
34-40	XIN	Total inelastic scattering cross section
42-48	XF	Smooth fission cross section
50-56	XSMU	Anisotropic scattering cross section

Card No. 2

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14	NGR	Group number
16	NSEQ	Sequence number (=2)
18-24	GNU	Number of neutrons per fission
26-32	AGN	Isotropic Greuling-Goertzel parameter (age number)
34-40	XSXI	Isotropic slowing down power
42-48		Anisotropic Greuling-Goertzel parameter (not produced by ETOG-1)

Columns	Variable Name(s)	Information
50-56		Anisotropic slowing down power (not produced by ETOG-1)

Card Nos. 1 and 2 are repeated for each output energy group.

Cards for MUFT-5 File 4 contain resonance absorption parameters in the following formats:

Card No. 3

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14	NGR	Group number
16	NSEQ	Sequence number (=1)
18-24	R	$r_{n,1}$
26-32	R	$r_{n,2}$
⋮		⋮
74-80	R	$r_{n,8}$

Card No. 4

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14	NGR	Group number
16	NSEQ	Sequence number (=2)
18-24	EM	$m_{n,1}$
26-32	EM	$m_{n,2}$
⋮		⋮
74-80	EM	$m_{n,8}$

Card Nos. 3 and 4 are repeated for each specified group n, i.e., for n = MINR to n = MAXG.

Cards for MUFT-5 File 5 contain fission-to-absorption ratios in the following format:

Card No. 5

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14	NGR	Group number
16	NSEQ	Sequence number (=0)
18-24	ALFA	$\alpha_{n,1}$
26-32	ALFA	$\alpha_{n,2}$
⋮		⋮
74-80	ALFA	$\alpha_{n,8}$

If fission-to-absorption ratios exist, one Card No. 5 is punched for each group n as specified in the input deck, i.e., for n = MINR to n = MAXG.

Cards for MUFT-5 File 6 contain the inelastic scattering cross sections σ_{in}^{i} and the inelastic scattering probability matrix elements, $P_{in}^{i\rightarrow j}$, in the following formats:

Card No. 6

Columns	Variable Name(s)	Information
10-12	MATID	Element number
13-14		Group number, i, of first σ_{in} on card
16	NSEQ	Sequence number (=0)
18-24	XIN(i)	σ_{in}^{i}
26-32	XIN(i+1)	σ_{in}^{i+1}
⋮		⋮
74-80	XIN(i+7)	σ_{in}^{i+7}

Card (set) No. 6 is repeated until all output groups are specified.

Card No. 7

Columns	Information
10-12	Element number
13-14	Group number, j, to which inelastic scattering is occurring
16	Sequence number

Columns	Information
18-24	$P_{in}^{1\rightarrow j}$
26-32	$P_{in}^{2\rightarrow j}$
⋮	⋮
74-80	$P_{in}^{8\rightarrow j}$
⋮	⋮

where $P_{in}^{i\rightarrow j}$ is the probability of inelastic scattering from the i^{th} group to the j^{th} group.

The sequence numbers, starting with 1, increase by 1 on each succeeding card until all the elements of the j^{th} row of the matrix are punched. The sequence number starts at 1 again for the next row as Card (set) No. 7 is repeated for the next group specified, i.e., for j = 2 to j = MAXI.

Output cards for MUFT-5 File 7 contain source spectra in the following format:

Card No. 8

Columns	Variable Name(s)	Information
10-12	MATID	Spectrum number
13-14		Group number, i of first $\bar{X}$ on card
16	NSEQ	Sequence number (=0)
18-24	TRUM(i)	$\bar{X}_i$
26-32	TRUM(i+1)	$\bar{X}_{i+1}$
⋮		
74-80	TRUM(i+7)	$\bar{X}_{i+7}$

Card No. 8 is repeated until the fractional source, $\bar{X}_i$, in each output energy group i has been specified.

3.4.2.3 Punched Card Format for GAM-I*

The cards produced by ETOG-1 for use in generating library information for

---

* The format discussed above was derived from a private communication with G. Joanou and J. Dudek.

GAM-I contain data in columns 1-72 only. Consequently, the ENDF/B material number is punched in columns 73-76, and the cards for each material are sequenced in columns 77-80.

It should be noted that ETOG-1 does not produce Card Nos. 1, 2, 3, 4, 5 and 8 which are required by the GAM-I library updating (or generating) program. These cards are reserved for descriptive information which must be specified by the user when a particular library is generated. The remaining cards are punched in the following formats:

Card Nos. 6 and 7 are punched only when a fission spectrum calculation is performed by ETOG-1; in this case, the only cards in the output deck are Card Nos. 6 and 7.

Card No. 6

Columns	Information
1-72	Alphanumeric information giving ENDF/B material number and tape number from which microscopic data was taken.

Card No. 7

Columns	Variable Name(s)	Information
1-12	TRUM(1)	$\bar{X}_1$
13-24	TRUM(2)	$\bar{X}_2$
⋮		⋮
61-72	TRUM(6)	$\bar{X}_6$
⋮		⋮

Card No. 7 is repeated until the fractional source $\bar{X}_i$ in each output energy group i has been specified.

Card No. 9

Columns	Variable Name	Information
1-12	MATID	Element number
13-24	NAOC	1 = an addition will be made to the GAM-I

Columns		Information
		library (ETOG-1 always punches 1) 2 = a change will be made to the GAM-I library

Card No. 10

Columns	Variable Name	Information
1-24	ANID	Alphanumeric information giving ENDF/B material number and tape number from which microscopic data was taken

Card No. 11

Columns	Variable Name	Information
1-12	MATID	Element number
13-24	LTOT	Total number of entries in P_o, P_1, inelastic and (n,2n) matrices, and in the σ_f, σ_a, and ν tables
25-36	IWA	0 = no absorption cross sections appear 1 = absorption cross sections appear
37-48	IWF	0 = no fission cross sections appear 1 = fission cross sections appear
49-60	IWR	0 = no resonance parameters appear 1 = only absorption resonance parameters appear 2 = absorption and fission resonance parameters appear

Card No. 12

Columns	Variable Name	Information
1-12	LOLIN	Total number of elements in inelastic matrix
13-24	LAIN	Number of source groups from which inelastic scattering occurs
25-36	LDIN	Maximum number of sink groups into which inelastic downscattering occurs.

Card No. 13

Columns	Variable Name	Information
1-12	LOL2N	Total number of elements in (n,2n) matrix
13-24	LA2N	Number of source groups from which (n,2n) transfer occurs
25-36	LD2N	Maximum number of sink groups into which (n,2n) transfer occurs

Card No. 14

Columns	Variable Name	Information
1-12	LOLP0	Total number of elements in P_o matrix
13-24	LAP0	Number of source groups from which P_o elastic scattering occurs
25-36	LDP0	Maximum number of sink groups into which P_o downscattering occurs

Card No. 15

Columns	Variable Name	Information
1-12	LOLP1	Total number of elements in P_1 matrix
13-24	LAP1	Number of source groups from which P_1 elastic scattering occurs
25-36	LDP1	Maximum number of sink groups in which P_1 downscattering occurs

Card No. 16 (Exists in output deck only if IWA = 1)

Columns	Variable Name	Information
1-12	XABS(1)	σ_a^1
13-24	XABS(2)	σ_a^2
⋮		⋮
61-72	XABS(6)	σ_a^6
⋮		⋮

Card No. 16 is repeated until the absorption cross section, σ_a^i, is specified for all groups i.

Card No. 17 (Exists in output deck only if IWF = 1)

Columns	Variable Name	Information
1-12	XFIS(1)	σ_f^1
13-24	XFIS(2)	σ_f^2
⋮		⋮
61-72	XFIS(6)	σ_f^6
⋮		⋮

Card No. 17 is repeated until the fission cross section σ_f^i is specified for all groups i.

Card No. 18 (Exists in output deck only if IWF = 1)

Columns	Variable Name	Information
1-12	XNU(1)	ν_1
13-24	XNU(2)	ν_2
⋮		⋮
61-72	XNU(6)	ν_6
⋮		⋮

Card No. 18 is repeated until the average number of neutrons per fission, ν_i, is specified for all groups i.

Card No. 19 (Exists in output deck only if LOLIN > 0)

Columns	Information
1-12	$\sigma_{in}^{1\to1}$
13-24	$\sigma_{in}^{1\to2}$
⋮	⋮
61-72	$\sigma_{in}^{1\to6}$
⋮	⋮

where $\sigma_{in}^{i\to j}$ represents the cross section for inelastic scattering from group

i to group j. Card (set) No. 19 is repeated until the ingroup cross section and LDIN sink group cross sections are specified for each of the LAIN source groups.*

Card No. 20 (Exists in output deck only if LOL2N > 0)

Columns	Information
1-12	$\sigma_{n,2n}^{1\to1}$
13-24	$\sigma_{n,2n}^{1\to2}$
⋮	⋮
61-72	$\sigma_{n,2n}^{1\to6}$
⋮	⋮

where $\sigma_{n,2n}^{i\to j}$ represents the (n,2n) cross section for transfer from group i to group j. Card (set) No. 20 is repeated until the ingroup cross section and LD2N sink group cross sections are specified for each of the LA2N source groups.

Card (Set) No. 21 (Exists in output deck only if LOLP0 - LOLP1 > 0)

Card No. 21.1

Columns	Information
13-24	$\sigma_{1,1}^{0}$
25-36	$\sigma_{1,1}^{1}$
⋮	⋮

---

* In the case of k macroscopic output energy groups, note that transfer in the inelastic, (n,2n), and P_n elastic matrices is terminated at sink group k+1 for every source group for which i+j > k+1.

Card No. 21.2

Columns	Information
13-24	$\sigma^{0}_{2,1}$
25-36	$\sigma^{1}_{2,1}$
⋮	⋮

Card No. 21.N

Columns	Information
13-24	$\sigma^{0}_{N,1}$
25-36	$\sigma^{1}_{N,1}$
⋮	⋮

where $N \leq K+1$ and K is the number of macroscopic energy groups.

Card No. 21.N+1

Columns	Information
13-24	$\sigma^{0}_{2,2}$
25-36	$\sigma^{1}_{2,2}$
⋮	⋮

where $\sigma^{\ell}_{j,i}$ represents the element of the elastic scattering matrix, of order ℓ, for transfer from group i to group j.

Card (Set) No. 21 is repeated until the ingroup elements and LDPO(=LDP1) sink group elements are specified for each of the LAPO(=LAP1) source groups.

Card No. 22 (Exists in output deck only if IWR > 0)

Columns	Variable Name(s)	Information
1-12	NRES	Number of resolved resonances
13-24	IAMAS	Atomic mass number
25-36	ECUT	Cut-off energy separating resolved and unresolved regions
37-48	DLEV	Unresolved energy level spacing

Columns	Variable Name(s)	Information
49-60	GNOBAR	$\langle\Gamma_n^0\rangle$, average unresolved neutron width
61-72	GGBAR	$\langle\Gamma_\gamma\rangle$, average unresolved capture width

Card No. 23 (Exists in output deck only if IWR > 0)

Columns	Variable Name(s)	Information
1-12	ER	Energy, E_o, of I^{th} resolved resonance
13-24	GAMN	Γ_n, neutron width of this resonance
25-36	GAMF	Γ_γ, capture width of this resonance
37-48	NROIM	1 = this resonance is treated by narrow resonance approximation 2 = this resonance is treated by infinite mass approximation

Card No. 23 is repeated for each resolved resonance.

If fission parameters exist, Card No. 22 and (Set) No. 23 are repeated for fission, i.e.,

Card No. 24 (Exists in output deck only if IWR = 2)

Columns	Variable Name(s)	Information
1-12	NRES	Number of resolved resonances
13-24	IAMAS	Atomic mass number
25-36	ECUT	Cut-off energy separating resolved and unresolved regions
37-48	DLEV	Unresolved energy level spacing
49-60	GNOBAR	$\langle\Gamma_n^0\rangle$, average unresolved scattering width
61-72	GAFBAR	$\langle\Gamma_f\rangle$, average unresolved fission width

Card No. 25 (Exists in output deck only if IWR = 2)

Columns	Variable Name(s)	Information
1-12	ER	Energy, E_o, of I^{th} resolved resonance
13-24	GAMN	Γ_n, neutron width of this resonance
25-36	GAMF	Γ_f, fission width of this resonance

Columns	Variable Name(s)	Information
37-48	NROIM	1 = this resonance is treated by narrow resonance approximation 2 = this resonance is treated by infinite mass approximation

Card No. 25 is repeated for each resolved resonance.

3.4.2.4 Punched Card Format for GAM-II

ETOG-1 produces punched cards for use in generating library data for GAM-II as described in Reference 2. Only columns 1-72 of any card are used for data. Consequently, the ENDF/B material number is punched in columns 73-76, and the cards for each material are sequenced in columns 77-80.

It must be noted that ETOG-1 does not produce the first eight cards required by the GAM-II library updating (or generating) program. The remaining cards are punched in the following formats.

Card No. 9

Columns	Variable Name(s)	Information
1-72	ANID	Alphanumeric information giving ENDF/B material number and tape number from which microscopic data was taken.

Card No. 10

Columns	Variable Name(s)	Information
1-12	MATID	Element number
13-24	NRES	Number of resolved resonances
25-36	NUNR	Number of unresolved resonances (NUNR must equal the number of energies at which the unresolved resonance functions $\bar{J}$ are to be calculated (See Card No. 14)

If NRES = 0, cards 11-14 do not appear in the output deck.

Card No. 11

Columns	Variable Name(s)	Information
1-12	AMAS	Atomic mass number
13-24	XPOTR	Potential scattering cross section (per absorber atom) of the absorber
25-36	GBAR	<g>, average statistical spin factor in unresolved range
37-48	NRES	Number of resolved resonances
49-60	SFACT	S-factor to determine upper limit of integration yielding absorption resonance integral (ETOG-1 arbitrarily sets SFACT = 5.0)
61-72	DLEV	<D>, average energy level spacing in unresolved range

Card No. 12

Columns	Variable Name(s)	Information
1-12	GOBAR	$\langle\Gamma_n^0\rangle$, average unresolved neutron width
13-24	GGBAR	$\langle\Gamma_\gamma\rangle$, average unresolved capture width
25-36	GAFBAR	$\langle\Gamma_f\rangle$, average unresolved fission width

Card No. 13

Columns	Variable Name(s)	Information
1-12	ER	Energy, E_o, of I^{th} resolved resonance
13-24	GAMN	Γ_n, neutron width for this resonance
25-36	GAMG	Γ_γ, capture width for this resonance
37-48	GAMF	Γ_f, fission width for this resonance
49-60	RFACT	r-factor to determine mesh size for numerical integration yielding collision density (ETOG-1 arbitrarily sets RFACT = 0.0)
61-72	WEAG	g, statistical spin factor for this resonance

Card No. 13 is repeated for each resolved resonance.

If NUNR = 0, Card No. 14 does not appear in the output deck.

Card No. 14

Columns	Variable Name(s)	Information
1-12	EFORJ	Energies at which the unresolved resonance functions $\bar{J}$ are to be calculated. The first and last energies are the lowest and highest energies, respectively, in the unresolved range as defined in ENDF/B File 2 for the isotope. The intermediate energies are the GAM-II fine group boundaries which fall between these limits.
13-24	EFORJ	
⋮	⋮	

Card No. 14 is repeated until all such energies are specified.

Card (Set) Nos. 15, 16, 17, 18, and 19 are not produced by ETOG-1. These cards are needed only when the tape being generated is updated from an existing library tape and consequently, must be supplied by the user.

Card Nos. 20 and 21 are punched only when a fission spectrum calculation is performed by ETOG-1. In this case the only cards in the output deck are Card Nos. 20 and 21.

Card No. 20

Columns	Information
1-72	Alphanumeric information giving ENDF/B material number and tape number from which microscopic data was taken.

Card No. 21

Columns	Variable Name(s)	Information
1-12	TRUM(1)	$\bar{X}_1$
13-24	TRUM(2)	$\bar{X}_2$
⋮		⋮
61-72	TRUM(6)	$\bar{X}_6$

Card No. 21 is repeated until the fractional source, $\bar{X}_i$, for each output energy group i has been specified.

Card No. 22

Columns	Variable Name(s)	Information
1-72	ANID	Alphanumeric information giving ENDF/B material number and tape number from which microscopic data was taken.

Card No. 23

Columns	Variable Name(s)	Information
1-12	MATID	Element number
13-24	NRES	Number of resolved resonances
25-36	NUNR	Number of unresolved resonances
37-48	LOLP	Total number of elements in P_ℓ matrix (All P_ℓ matrices are of equal size)
49-60	LAP	Number of source groups from which P_ℓ elastic scattering occurs.
61-72	LDP	Maximum number of groups (including in-group) to which P_ℓ downscattering occurs.

Card No. 24

Columns	Variable Name(s)	Information
1-12	LOLIN	Total number of elements in inelastic matrix
13-24	LAIN	Number of source groups from which inelastic scattering occurs
25-36	LDIN	Maximum number of groups (including in-group) to which inelastic downscattering occurs
37-48	LOL2N	Total number of elements in (n,2n) matrix
49-60	LA2N	Number of source groups from which (n,2n) transfer occurs
61-72	LD2N	Maximum number of groups (including in-group) to which (n,2n) transfer occurs.

Card No. 25

Columns	Variable Name(s)	Information
1-12	IWF	0 = this nuclide is not fissionable 1 = this nuclide is fissionable

Columns	Variable Name(s)	Information
13-24	NUM1D	The number of one-dimensional arrays present for the nuclide (e.g., the parasitic absorption, fission, (n,γ), (n,p) cross section and ν arrays)
25-36	LOL	Total number of elements in transfer matrix, i.e., total number of elements in the composite matrix formed from the sum of the P_ℓ, inelastic, and (n,2n) matrices
37-48	LA	Maximum number of source groups from which transfer can occur, i.e., maximum of LAP, LAIN, and LA2N
49-60	LD	Maximum number of groups (including in-group) to which transfer can occur, i.e., maximum of LDP, LDIN, and LD2N
61-72	LTOT	Number of records for this nuclide*

Card No. 26

Column	Variable Name(s)	Information
1-12	AMAS	Atomic mass number

Card No. 27

Columns	Information
1-22	Identification for the one-dimensional array which is punched on Card No. 28.

Card No. 28

Columns	Information
1-12	1st element of the one-dimensional array

---

* Number of records = 1+1 (if any one-dimensional array exists) +6 (if P_ℓ matrices exist) +1 (if inelastic matrix exists) +1 (if (n,2n) matrix exists) +1 (if any of the P_ℓ, inelastic or (n,2n) matrices exist).

Columns	Information
13-24	2nd element of the one-dimensional array
⋮	⋮

Card No. 28 is repeated until all elements of the one-dimensional array are specified.

Card No. 27 and Card (Set) No. 28 are repeated for each of the one-dimensional arrays which is to be punched (NUM1D).

If LOLP $\neq$ 0, Card (Set) Nos. 29-32 are punched for the P_0, P_1, P_2 and P_3 matrices.

Card (Set) No. 29

Card 29.1

Columns	Information
1-12	$\sigma^0_{1,1}$
13-24	$\sigma^0_{2,1}$
⋮	⋮
61-72	$\sigma^0_{6,1}$
⋮	⋮

Card 29.N

Columns	Information
1-12	⋮
13-24	
⋮	$\sigma^0_{N,1}$

where $N \leq K + 1$ and K is the number of macroscopic energy groups.

Card 29.N+1

Columns	Information
1-12	$\sigma^{0}_{1,2}$
13-24	$\sigma^{0}_{2,2}$
⋮	⋮

where $\sigma^{\ell}_{j,i}$ represents the element of the elastic scattering matrix of order ℓ for transfer from group i to group j. Card (Set) No. 29 is repeated until LDP sink group elements are specified for each of the LAP source groups.*

The format of Card (Set) Nos. 30, 31 and 32 is the same as that of Card (Set) No. 29, where $\sigma^{0}_{j,i}$ is replaced by $\sigma^{1}_{j,i}$, $\sigma^{2}_{j,i}$, and $\sigma^{3}_{j,i}$ respectively.

Card (Set) No. 33 (Exists in the output deck only if LOLIN > 0)

Columns	Information
1-12	$\sigma^{1\to1}_{in}$
13-24	$\sigma^{1\to2}_{in}$
⋮	⋮
61-72	$\sigma^{1\to6}_{in}$
⋮	⋮

where $\sigma^{i\to j}_{in}$ represents the cross section for inelastic scattering from group i to group j. Card (Set) No. 33 is repeated until LDIN sink group cross sections are specified for each of the LAIN source groups.

Card No. 34 (Exists in the output deck only if LOL2N > 0)

Columns	Information
1-12	$\sigma^{1\to1}_{n,2n}$

---

* In the case of k macroscopic output energy groups note that transfer in the inelastic, (n,2n) and P_{ℓ} elastic matrices is terminated at sink group k + 1 for every source group for which i + j > k + 1.

Columns	Information
13-24	$\sigma_{n,2n}^{1\to2}$
⋮	⋮
61-72	$\sigma_{n,2n}^{1\to6}$
⋮	⋮

where $\sigma_{n,2n}^{i\to j}$ represents the (n,2n) cross section for transfer from group i to group j. Card (Set) No. 34 is repeated until LD2N sink group cross sections are specified for each of the LA2N source groups.

3.4.2.5 Punched Card Format for ANISN

Punched cards containing multigroup cross sections as required by ANISN (described in Reference 3) are produced by ETOG-1. Only columns 1-72 of any card are used for data; consequently, the ENDF/B material number is punched in columns 73-76 and the cards for each material are sequenced in columns 77-80.

ANISN expects a table of cross sections for each input energy group. Each output data card consists of six twelve-column data fields where each data field consists of three subfields of two, one, and nine columns respectively. The contents of the first two subfields define the operation to be performed on the data contained in the third subfield. ETOG-1 uses only the repeat option; i.e., the first subfield will contain an R which signifies that the data in the third subfield is to be entered in the next N locations of the cross section table. (ETOG-1 applies the repeat operation only to the number 0.0). Thus the location of a particular cross section on an output data card depends upon the number and location of zeros in the table.

For each energy group, j, the following cross sections are produced in the designated locations.

Location	Variable(s)	Information
1	XNGAM	(n,γ) cross section for group j

Location	Variable(s)	Information
2	XNALP	(n,α) cross section for group j
3	XC	Parasitic capture cross section for group j
4	XFIS	Fission cross section for group j
5	XABS	Absorption cross section for group j
6	XNU	$\nu\sigma_f$ for group j
7	XTOT	Total cross section for group j
8		$\sigma^{\ell}_{j,j}$
9		$\sigma^{\ell}_{j,j-1}$
10		$\sigma^{\ell}_{j,j-2}$
11		
⋮		⋮
N		$\sigma^{\ell}_{j,j-NAGDS}$

where $\sigma^{\ell}_{j,i}$ represents the element of the composite transfer matrix, of order ℓ, for transfer from group i to group j. Cross sections of a given order ℓ, starting with $\ell=0$, are punched for all energy groups j, one group at a time.

The (n,γ), (n,α), parasitic capture, fission and absorption cross sections as well as $\nu\sigma_f$ are set to zero for higher order cross sections, i.e., for $\ell=1$, 2, and 3.

Note that ETOG-1 does not produce any upscatter components and the maximum order of scatter is P_3. As indicated in the concluding section of this report (Chapter 6), work must be done on the present version of subroutine TRANSFER in the code to produce reliable higher order scattering components.

3.4.3 Sample Problem Output

The sample problem, described in Section 3.3.6, was run on a CDC-6600 computer using the SCOPE 3.1 operating system. Selected pages of the printed output appear in the following pages in order to indicate to the user the format of the available output.

*** ETOG ***

GAM 2 FILE 21 HAS BEEN CREATED FROM ENDF/B MATERIAL 1051 ON TAPE 115

THE DECK HAS BEEN CREATED USING THE ETOG OPTIONS LISTED BELOW.

THE STANDARD 99 GROUP GAM-2 STRUCTURE IS GENERATED INTERNALLY

WEIGHTING FUNCTION IS 1/E JOINED TO A FISSION SPECTRUM

RESONANCE PARAMETER CARDS ARE CONSTRUCTED IF POSSIBLE

THE RESONANCE SCATTERING IS CALCULATED FROM ENDF/B TAPE AND ADDED TO SMOOTH

*** ETOG ***

ENDF/B TAPE NO.	ENDF/B MATERIAL NO.	MULTIGROUP CODE	MULTIGROUP MATERIAL NO.	GROUP INFORMATION NUMBER	HIGHEST INELASTIC	LOWEST RESONANCE
115	1051	GAM-2	21	99	99	1

MULTIGROUP STRUCTURE

GROUP	ENERGY RANGE	LETHARGY RANGE	GROUP	ENERGY RANGE	LETHARGY RANGE
1	1.3499E+07 - 1.4918E+07	-.400 - -.300	37	3.6883E+05 - 4.0762E+05	3.200 - 3.300
2	1.2214E+07 - 1.3499E+07	-.300 - -.200	38	3.3373E+05 - 3.6883E+05	3.300 - 3.400
3	1.1052E+07 - 1.2214E+07	-.200 - -.100	39	3.0197E+05 - 3.3373E+05	3.400 - 3.500
4	1.0000E+07 - 1.1052E+07	-.100 - 0.000	40	2.7324E+05 - 3.0197E+05	3.500 - 3.600
5	9.0484E+06 - 1.0000E+07	0.000 - .100	41	2.4724E+05 - 2.7324E+05	3.600 - 3.700
6	8.1873E+06 - 9.0484E+06	.100 - .200	42	2.2371E+05 - 2.4724E+05	3.700 - 3.800
7	7.4082E+06 - 8.1873E+06	.200 - .300	43	2.0242E+05 - 2.2371E+05	3.800 - 3.900
8	6.7032E+06 - 7.4082E+06	.300 - .400	44	1.8316E+05 - 2.0242E+05	3.900 - 4.000
9	6.0653E+06 - 6.7032E+06	.400 - .500	45	1.6573E+05 - 1.8316E+05	4.000 - 4.100
10	5.4881E+06 - 6.0653E+06	.500 - .600	46	1.4996E+05 - 1.6573E+05	4.100 - 4.200
11	4.9659E+06 - 5.4881E+06	.600 - .700	47	1.3569E+05 - 1.4996E+05	4.200 - 4.300
12	4.4933E+06 - 4.9659E+06	.700 - .800	48	1.2277E+05 - 1.3569E+05	4.300 - 4.400
13	4.0657E+06 - 4.4933E+06	.800 - .900	49	1.1109E+05 - 1.2277E+05	4.400 - 4.500
14	3.6788E+06 - 4.0657E+06	.900 - 1.000	50	8.6517E+04 - 1.1109E+05	4.500 - 4.750
15	3.3287E+06 - 3.6788E+06	1.000 - 1.100	51	6.7379E+04 - 8.6517E+04	4.750 - 5.000
16	3.0119E+06 - 3.3287E+06	1.100 - 1.200	52	5.2475E+04 - 6.7379E+04	5.000 - 5.250
17	2.7253E+06 - 3.0119E+06	1.200 - 1.300	53	4.0868E+04 - 5.2475E+04	5.250 - 5.500
18	2.4660E+06 - 2.7253E+06	1.300 - 1.400	54	3.1828E+04 - 4.0868E+04	5.500 - 5.750
19	2.2313E+06 - 2.4660E+06	1.400 - 1.500	55	2.4788E+04 - 3.1828E+04	5.750 - 6.000
20	2.0190E+06 - 2.2313E+06	1.500 - 1.600	56	1.9305E+04 - 2.4788E+04	6.000 - 6.250
21	1.8268E+06 - 2.0190E+06	1.600 - 1.700	57	1.5034E+04 - 1.9305E+04	6.250 - 6.500
22	1.6530E+06 - 1.8268E+06	1.700 - 1.800	58	1.1709E+04 - 1.5034E+04	6.500 - 6.750
23	1.4957E+06 - 1.6530E+06	1.800 - 1.900	59	9.1188E+03 - 1.1709E+04	6.750 - 7.000
24	1.3534E+06 - 1.4957E+06	1.900 - 2.000	60	7.1017E+03 - 9.1188E+03	7.000 - 7.250
25	1.2246E+06 - 1.3534E+06	2.000 - 2.100	61	5.5308E+03 - 7.1017E+03	7.250 - 7.500
26	1.1080E+06 - 1.2246E+06	2.100 - 2.200	62	4.3074E+03 - 5.5308E+03	7.500 - 7.750
27	1.0026E+06 - 1.1080E+06	2.200 - 2.300	63	3.3546E+03 - 4.3074E+03	7.750 - 8.000
28	9.0718E+05 - 1.0026E+06	2.300 - 2.400	64	2.6126E+03 - 3.3546E+03	8.000 - 8.250
29	8.2085E+05 - 9.0718E+05	2.400 - 2.500	65	2.0347E+03 - 2.6126E+03	8.250 - 8.500
30	7.4274E+05 - 8.2085E+05	2.500 - 2.600	66	1.5846E+03 - 2.0347E+03	8.500 - 8.750
31	6.7206E+05 - 7.4274E+05	2.600 - 2.700	67	1.2341E+03 - 1.5846E+03	8.750 - 9.000
32	6.0810E+05 - 6.7206E+05	2.700 - 2.800	68	9.6112E+02 - 1.2341E+03	9.000 - 9.250
33	5.5023E+05 - 6.0810E+05	2.800 - 2.900	69	7.4852E+02 - 9.6112E+02	9.250 - 9.500
34	4.9787E+05 - 5.5023E+05	2.900 - 3.000	70	5.8295E+02 - 7.4852E+02	9.500 - 9.750
35	4.5049E+05 - 4.9787E+05	3.000 - 3.100	71	4.5400E+02 - 5.8295E+02	9.750 - 10.000
36	4.0762E+05 - 4.5049E+05	3.100 - 3.200	72	3.5358E+02 - 4.5400E+02	10.000 - 10.250

*** ETOG ***

73	2.7536E+02 - 3.5358E+02	10.250 - 10.500
74	2.1445E+02 - 2.7536E+02	10.500 - 10.750
75	1.6702E+02 - 2.1445E+02	10.750 - 11.000
76	1.3007E+02 - 1.6702E+02	11.000 - 11.250
77	1.0130E+02 - 1.3007E+02	11.250 - 11.500
78	7.8893E+01 - 1.0130E+02	11.500 - 11.750
79	6.1442E+01 - 7.8893E+01	11.750 - 12.000
80	4.7851E+01 - 6.1442E+01	12.000 - 12.250
81	3.7267E+01 - 4.7851E+01	12.250 - 12.500
82	2.9023E+01 - 3.7267E+01	12.500 - 12.750
83	2.2603E+01 - 2.9023E+01	12.750 - 13.000
84	1.7603E+01 - 2.2603E+01	13.000 - 13.250
85	1.3710E+01 - 1.7603E+01	13.250 - 13.500
86	1.0677E+01 - 1.3710E+01	13.500 - 13.750
87	8.3153E+00 - 1.0677E+01	13.750 - 14.000
88	6.4760E+00 - 8.3153E+00	14.000 - 14.250
89	5.0435E+00 - 6.4760E+00	14.250 - 14.500
90	3.9279E+00 - 5.0435E+00	14.500 - 14.750
91	3.0590E+00 - 3.9279E+00	14.750 - 15.000
92	2.3824E+00 - 3.0590E+00	15.000 - 15.250
93	1.8554E+00 - 2.3824E+00	15.250 - 15.500
94	1.4450E+00 - 1.8554E+00	15.500 - 15.750
95	1.1254E+00 - 1.4450E+00	15.750 - 16.000
96	8.7642E-01 - 1.1254E+00	16.000 - 16.250
97	6.8256E-01 - 8.7642E-01	16.250 - 16.500
98	5.3158E-01 - 6.8256E-01	16.500 - 16.750
99	4.1399E-01 - 5.3158E-01	16.750 - 17.000

*** ETOG ***

WEIGHTING FUNCTION
IS GENERATED AS FOLLOWS

ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT
40.9854E-02	11.4163E+06	67.3795E+03	69.4425E+00	95.5046E+03	96.2779E+00	12.3630E+04	12.1907E+01
23.6130E+04	21.3146E+01	29.2380E+04	25.2514E+01	34.8630E+04	28.8079E+01	40.4881E+04	32.0098E+01
47.5193E+04	35.5499E+01	54.5506E+04	38.6172E+01	61.5819E+04	41.2521E+01	68.6132E+04	43.4923E+01
77.4022E+04	45.7904E+01	86.1913E+04	47.5882E+01	97.1777E+04	49.2177E+01	11.0911E+05	50.4286E+01
12.8077E+05	50.8874E+01	17.9575E+05	47.6097E+01	20.2106E+05	44.8913E+01	26.9698E+05	35.2262E+01
30.3494E+05	30.3977E+01	33.7290E+05	25.9057E+01	37.9535E+05	20.9181E+01	42.1780E+05	16.6815E+01
47.4586E+05	12.3968E+01	52.7392E+05	90.9864E+00	59.3400E+05	60.9536E+00	65.9407E+05	40.3288E+00
74.1917E+05	23.7317E+00	82.4427E+05	13.7923E+00	92.7564E+05	69.0189E-01	10.3070E+06	34.1111E-01
11.5962E+06	13.9397E-01	12.8854E+06	56.2615E-02	14.4970E+06	17.8487E-02	15.0674E+06	11.8507E-02

WEIGHTING FUNCTION
INTERPOLATION TABLE

NBT	JNT	NBT	JNT	NBT	JNT	NBT	JNT
2	5	4	5	14	3	19	2
20	3	36	4				

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THE (TAPE) DESCRIPTION OF MATERIAL  1151 IS -
    PLUTONIUM 239.  ENDF/B.  OCTOBER.1966.
   PLUTONIUM-239   ENDF/B   DESCRIPTION OF EVALUATION AND SOURCES
       FOUND IN GEAP-5272, EVALUATION AND COMPILATION OF PU-239
       CROSS SECTION DATA FOR ENDF/B FILES, BY P. GREEBLER, P. ALINE,
       B. A. HUTCHINS, DECEMBER, 1966
   MF=1           GENERAL INFORMATION
       ATOMIC MASS = 237.00 BASED ON NEUTRON MASS OF 1.008665 AMU-
         REF.1
     MT=452, NU = 2.87 + 0.135E(MEV) - THERMAL VALUE FROM REF 2-
       SLOPE BASED ON REF 3,4.
     MT=453, RADIOACTIVE DECAY DATA FROM REF 1
   MF=2           RESONANCE PARAMETERS
     MT=151. RESOLVED PARAMETERS TO 300 EV FOR 89 LEVELS -MODIFIED
       FROM COMPILATION IN REF 5 USING DATA FROM REF 6,7.
       UNRESOLVED S-WAVE RESONANCE PARAMETERS WITH SPIN DEPENDENT
       FISSION WIDTHS FROM 300EV TO 100 KEV. STATISTICAL PARAMETERS
       BASED ON SCHMIDT, REF 5.
       SPIN INDEPENDENT SCATTERING RADIUS GIVES 10.3 B POT SCAT.
       RESONANCE PARAMETERS MUST BE USED FOR FISSION, CAPTURE, TOTAL,
       AND ELASTIC SCATTERING FROM 1EV TO 100 KEV
   MF=3           SMOOTH  DATA
     THERMAL NEUTRON DATA --  0.001 TO 1.0 EV
       MT=1,2,18,27,102 - ENERGY DEPENDENCE BASED ON EVALUATION BY
         LEONARD, REF 8- 2200 M/SEC NORMALIZATION OF WESTCOTT,
         REF 9 - ALL CROSS SECTION CONTRIBUTIONS INCLUDED IN SMOOTH
         DATA.
       MT=4,16,17,251,252,253 - VALUES BELOW 1 EV SET AT ZERO.
     EPI-THERMAL AND FAST NEUTRON DATA -- 1.0 EV TO 15 MEV
       MT=1 TOTAL VALUES EQUAL SUM OF PARTIAL CROSS SECTIONS
       MT=2 ELASTIC SCATTERING VALUES FROM AI, REF 10 - RESONANCE
         AND POTENTIAL SCATTERING NOT INCLUDED FROM 1 EV TO 100 KEV
       MT=4 SUM OF 13 DISCRETE LEVEL CROSS SECTIONS UP TO 2 MEV -
         CONTINUUM CROSS SECTIONS ABOVE 2 MEV - DATA FROM REF
         11
       MT=16,17 DATA FROM PEARLSTEIN, REF 12
       MT=18 FROM 200 TO 300 EV, SMOOTH DATA SUPPLEMENTS RESONANCE
         CROSS SECTIONS TO AGREE WITH PETREL DATA, REF 13 - FROM
         300 EV TO 3 KEV SMOOTH SUPPLEMENTS RESONANCE CONTRIBUTION
         TO AGREE WITH PETREL, REF 13, AND JAMES, REF 14, FISSION
         DATA AND UTTLEY VARIATIONS IN STRENGTH FUNCTION, REF 15 -
         FROM 3 TO 100 KEV SMOOTH SUPPLEMENTS RESONANCE DATA TO
         AGREE WITH DAVEY RECOMMENDATION, REF 16, AND WHITE DATA,
         REF 17 - FROM 100 KEV TO 3 MEV SMOOTH FOLLOWS REF 16,
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*** ETOG ***

RESOLVED
RESONANCE CALCULATION RESULTS
RESOLVED (THERMAL AND NEGATIVE ENERGY) RESONANCES BELOW GROUP STRUCTURE

NO.	E-ZERO	GAMMA-N	GAMMA-G	GAMMA-F	G-FACTOR	NROIM
0	-12.0000E-01	84.5000E-05	39.0000E-03	20.1000E-02	75.0000E-02	1
0	29.6000E-02	23.0000E-05	38.6000E-03	55.4000E-03	25.0000E-02	1

*** ETOG ***

RESOLVED
RESONANCE CALCULATION RESULTS
ACCEPTED RESONANCES - GAM PARAMETERS PRODUCED

NO.	E-ZERO	GAMMA-N	GAMMA-G	GAMMA-F	G-FACTOR	NROIM
1	78.3000E-01	87.0000E-05	40.6000E-03	41.5000E-03	75.0000E-02	1
2	10.9300E+00	18.2000E-04	31.5000E-03	14.6700E-02	75.0000E-02	1
3	11.9000E+00	10.7000E-04	40.9000E-03	22.0000E-03	75.0000E-02	1
4	14.2800E+00	55.0000E-05	38.7000E-03	52.5000E-03	75.0000E-02	1
5	14.6800E+00	22.0000E-04	38.7000E-03	31.7000E-03	75.0000E-02	1
6	15.5000E+00	23.7000E-04	38.7000E-03	76.0500E-02	25.0000E-02	1
7	17.6000E+00	16.0000E-04	39.1000E-03	46.3000E-03	75.0000E-02	1
8	22.2000E+00	22.3000E-04	31.3000E-03	75.0000E-03	75.0000E-02	1
9	23.9000E+00	87.0000E-05	38.7000E-03	37.1000E-03	75.0000E-02	1
10	26.2000E+00	17.8000E-04	38.7000E-03	35.7000E-03	75.0000E-02	1
11	27.3000E+00	13.0000E-05	38.7000E-03	28.0000E-04	75.0000E-02	2
12	32.3000E+00	86.0000E-05	38.7000E-03	18.9000E-02	25.0000E-02	1
13	35.3000E+00	31.0000E-05	38.7000E-03	41.0000E-04	75.0000E-02	2
14	41.4000E+00	60.7000E-04	59.2000E-03	10.7000E-03	75.0000E-02	1
15	44.5000E+00	63.4000E-04	27.8000E-03	42.0000E-04	75.0000E-02	1
16	47.6000E+00	54.0000E-04	38.7000E-03	30.1000E-02	25.0000E-02	1
17	49.8500E+00	44.0000E-05	59.8000E-03	75.0000E-02	25.0000E-02	2
18	50.2200E+00	30.4000E-04	41.3000E-03	11.2000E-03	75.0000E-02	2
19	52.6000E+00	10.0500E-03	39.3000E-03	77.0000E-04	75.0000E-02	1
20	55.7900E+00	14.3000E-04	26.0000E-03	22.0000E-03	75.0000E-02	2
21	57.6000E+00	17.0000E-03	38.7000E-03	54.6000E-02	25.0000E-02	1
22	58.0000E+00	12.0000E-03	38.7000E-03	80.5000E-02	25.0000E-02	1
23	59.3900E+00	55.9000E-04	48.6000E-03	13.3000E-02	75.0000E-02	1
24	61.1000E+00	22.4000E-03	38.7000E-03	20.0000E-01	25.0000E-02	1
25	63.4000E+00	19.4000E-04	38.7000E-03	13.9000E-03	75.0000E-02	2
26	65.9600E+00	12.5000E-03	22.4000E-03	77.0000E-03	75.0000E-02	1
27	74.3100E+00	32.7000E-04	36.6000E-03	29.5000E-03	75.0000E-02	2
28	75.2100E+00	22.1000E-03	44.9000E-03	95.0000E-03	75.0000E-02	1
29	82.0000E+00	62.0000E-04	38.7000E-03	15.0000E-01	25.0000E-02	1
30	85.3000E+00	86.7000E-04	38.7000E-03	20.0000E-01	25.0000E-02	1
31	85.6000E+00	30.7000E-04	38.7000E-03	21.6700E-02	75.0000E-02	2
32	90.9000E+00	24.7000E-04	38.7000E-03	11.4600E-02	75.0000E-02	2
33	95.5000E+00	93.4000E-05	38.7000E-03	23.0000E-02	75.0000E-02	2
34	96.0000E+00	92.0000E-04	38.7000E-03	14.0000E-01	25.0000E-02	1
35	97.6000E+00	18.0000E-04	38.7000E-03	36.0000E-02	25.0000E-02	2
36	99.0000E+00	93.5000E-04	38.7000E-03	20.0000E-01	25.0000E-02	1
37	10.1200E+01	56.0000E-05	38.7000E-03	31.1000E-02	25.0000E-02	2
38	10.3000E+01	17.4000E-04	38.7000E-03	83.7000E-03	75.0000E-02	2
39	10.5400E+01	58.7000E-04	38.7000E-03	10.2500E-02	75.0000E-02	2

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*** ETOG ***

UNRESOLVED
RESONANCE CALCULATION RESULTS
GAM PARAMETERS

L	J	AV SPIN	AV D	AV GAM-N-0	AV GAM GAM	AV GAM-F
0	0.0	25.0000E-02	87.8000E-01	94.0000E-05	38.7000E-03	0.

RESOLVED
RESONANCE CALCULATION RESULTS
THE FOLLOWING CROSS SECTIONS ARE ADDED TO THE SMOOTH VALUES TO ACCOUNT FOR
RESOLVED (THERMAL AND NEGATIVE ENERGY) RESONANCES BELOW GROUP STRUCTURE

GROUP	CAPTURE	FISSION	SCATTER	GROUP	CAPTURE	FISSION	SCATTER
1	0.	0.	0.	51	0.	0.	0.
2	0.	0.	0.	52	0.	0.	0.
3	0.	0.	0.	53	0.	0.	0.
4	0.	0.	0.	54	0.	0.	0.
5	0.	0.	0.	55	0.	0.	0.
6	0.	0.	0.	56	0.	0.	0.
7	0.	0.	0.	57	0.	0.	0.
8	0.	0.	0.	58	0.	0.	0.
9	0.	0.	0.	59	0.	0.	0.
10	0.	0.	0.	60	0.	0.	0.
11	0.	0.	0.	61	0.	0.	0.
12	0.	0.	0.	62	0.	0.	0.
13	0.	0.	0.	63	0.	0.	0.
14	0.	0.	0.	64	0.	0.	0.
15	0.	0.	0.	65	0.	0.	0.
16	0.	0.	0.	66	0.	0.	0.
17	0.	0.	0.	67	0.	0.	0.
18	0.	0.	0.	68	0.	0.	0.
19	0.	0.	0.	69	0.	0.	0.
20	0.	0.	0.	70	0.	0.	0.
21	0.	0.	0.	71	0.	0.	0.
22	0.	0.	0.	72	0.	0.	0.
23	0.	0.	0.	73	41.5610E-07	19.0322E-06	42.3701E-04
24	0.	0.	0.	74	19.1525E-06	87.6870E-06	14.6278E-03
25	0.	0.	0.	75	35.6994E-06	16.3383E-05	18.7635E-03
26	0.	0.	0.	76	66.4995E-06	30.4136E-05	24.0653E-03
27	0.	0.	0.	77	12.3771E-05	56.5624E-05	30.8441E-03
28	0.	0.	0.	78	23.0125E-05	10.5118E-04	39.5204E-03
29	0.	0.	0.	79	42.7296E-05	19.4930E-04	50.6066E-03
30	0.	0.	0.	80	79.2064E-05	36.0942E-04	64.7461E-03
31	0.	0.	0.	81	14.6509E-04	66.6481E-04	82.7706E-03
32	0.	0.	0.	82	27.0273E-04	12.3673E-03	10.5664E-02
33	0.	0.	0.	83	49.6919E-04	22.4886E-03	13.4710E-02
34	0.	0.	0.	84	90.9834E-04	41.0191E-03	17.1329E-02
35	0.	0.	0.	85	16.5739E-03	74.3514E-03	21.7519E-02
36	0.	0.	0.	86	30.0061E-03	13.3733E-02	27.5179E-02
37	0.	0.	0.	87	53.9289E-03	23.9289E-02	34.6816E-02
38	0.	0.	0.	88	96.1103E-03	41.9830E-02	43.5777E-02
39	0.	0.	0.	89	16.9689E-02	72.9944E-02	54.4007E-02

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*** ETOG ***

RESOLVED
RESONANCE CALCULATION RESULTS

THE FOLLOWING CROSS SECTIONS ARE SUBTRACTED FROM THE SMOOTH VALUES BELOW THE ENDF/B RESOLVED RANGE
TO AVOID COUNTING THE ASYMMETRIC PART OF THE BREIT-WIGNER FORMULA TWICE.
IT IS IMPLICITLY CONTAINED WITHIN THE ENDF/B (FILE 3) SMOOTH DATA AND EXPLICITLY CALCULATED BY GAM-2.

GROUP	CAPTURE	FISSION	GROUP	CAPTURE	FISSION	GROUP	CAPTURE	FISSION
1	0.	0.	34	0.	0.	67	0.	0.
2	0.	0.	35	0.	0.	68	0.	0.
3	0.	0.	36	0.	0.	69	0.	0.
4	0.	0.	37	0.	0.	70	0.	0.
5	0.	0.	38	0.	0.	71	0.	0.
6	0.	0.	39	0.	0.	72	0.	0.
7	0.	0.	40	0.	0.	73	0.	0.
8	0.	0.	41	0.	0.	74	0.	0.
9	0.	0.	42	0.	0.	75	0.	0.
10	0.	0.	43	0.	0.	76	0.	0.
11	0.	0.	44	0.	0.	77	0.	0.
12	0.	0.	45	0.	0.	78	0.	0.
13	0.	0.	46	0.	0.	79	0.	0.
14	0.	0.	47	0.	0.	80	0.	0.
15	0.	0.	48	0.	0.	81	0.	0.
16	0.	0.	49	0.	0.	82	0.	0.
17	0.	0.	50	0.	0.	83	0.	0.
18	0.	0.	51	0.	0.	84	0.	0.
19	0.	0.	52	0.	0.	85	0.	0.
20	0.	0.	53	0.	0.	86	0.	0.
21	0.	0.	54	0.	0.	87	0.	0.
22	0.	0.	55	0.	0.	88	0.	0.
23	0.	0.	56	0.	0.	89	0.	0.
24	0.	0.	57	0.	0.	90	0.	0.
25	0.	0.	58	0.	0.	91	0.	0.
26	0.	0.	59	0.	0.	92	0.	0.
27	0.	0.	60	0.	0.	93	0.	0.
28	0.	0.	61	0.	0.	94	0.	0.
29	0.	0.	62	0.	0.	95	0.	0.
30	0.	0.	63	0.	0.	96	21.0237E-02	83.4317E-02
31	0.	0.	64	0.	0.	97	44.2714E-02	17.5839E-01
32	0.	0.	65	0.	0.	98	50.5761E-02	20.0944E-01
33	0.	0.	66	0.	0.	99	57.8370E-02	22.9695E-01

*** ETOG ***

RESOLVED
RESONANCE CALCULATION RESULTS

THE FOLLOWING CROSS SECTIONS ARE SUBTRACTED FROM THE SMOOTH VALUES BELOW THE ENDF/B RESOLVED RANGE
TO AVOID COUNTING THE SYMMETRIC PART OF THE BREIT-WIGNER FORMULA TWICE.
IT IS IMPLICITLY CONTAINED WITHIN THE ENDF/B (FILE 3) SMOOTH DATA AND EXPLICITLY CALCULATED BY GAM-2.

GROUP	CAPTURE	FISSION	GROUP	CAPTURE	FISSION	GROUP	CAPTURE	FISSION
1	0.	0.	34	0.	0.	67	0.	0.
2	0.	0.	35	0.	0.	68	0.	0.
3	0.	0.	36	0.	0.	69	0.	0.
4	0.	0.	37	0.	0.	70	0.	0.
5	0.	0.	38	0.	0.	71	0.	0.
6	0.	0.	39	0.	0.	72	0.	0.
7	0.	0.	40	0.	0.	73	0.	0.
8	0.	0.	41	0.	0.	74	0.	0.
9	0.	0.	42	0.	0.	75	0.	0.
10	0.	0.	43	0.	0.	76	0.	0.
11	0.	0.	44	0.	0.	77	0.	0.
12	0.	0.	45	0.	0.	78	0.	0.
13	0.	0.	46	0.	0.	79	0.	0.
14	0.	0.	47	0.	0.	80	0.	0.
15	0.	0.	48	0.	0.	81	0.	0.
16	0.	0.	49	0.	0.	82	0.	0.
17	0.	0.	50	0.	0.	83	0.	0.
18	0.	0.	51	0.	0.	84	0.	0.
19	0.	0.	52	0.	0.	85	0.	0.
20	0.	0.	53	0.	0.	86	0.	0.
21	0.	0.	54	0.	0.	87	0.	0.
22	0.	0.	55	0.	0.	88	0.	0.
23	0.	0.	56	0.	0.	89	0.	0.
24	0.	0.	57	0.	0.	90	0.	0.
25	0.	0.	58	0.	0.	91	0.	0.
26	0.	0.	59	0.	0.	92	0.	0.
27	0.	0.	60	0.	0.	93	0.	0.
28	0.	0.	61	0.	0.	94	0.	0.
29	0.	0.	62	0.	0.	95	0.	0.
30	0.	0.	63	0.	0.	96	72.1279E-03	20.8712E-02
31	0.	0.	64	0.	0.	97	13.3169E-02	38.8131E-02
32	0.	0.	65	0.	0.	98	12.8908E-02	37.8620E-02
33	0.	0.	66	0.	0.	99	12.5756E-02	37.1528E-02

*** ETOE ***

UNRESOLVED
RESONANCE CALCULATION RESULTS
THE FOLLOWING CROSS SECTIONS ARE ADDED TO THE SMOOTH VALUES TO ACCOUNT FOR
UNRESOLVED RESONANCE CONTRIBUTIONS

GROUP	CAPTURE	FISSION	SCATTER	GROUP	CAPTURE	FISSION	SCATTER
1	0.	0.	0.	51	12.1917E-02	77.9748E-02	10.9745E+00
2	0.	0.	0.	52	15.9095E-02	86.7796E-02	11.0695E+00
3	0.	0.	0.	53	20.6281E-02	95.4850E-02	11.1739E+00
4	0.	0.	0.	54	26.5949E-02	10.5075E-01	11.2897E+00
5	0.	0.	0.	55	33.9528E-02	11.6141E-01	11.4121E+00
6	0.	0.	0.	56	42.8373E-02	12.8275E-01	11.5403E+00
7	0.	0.	0.	57	53.4230E-02	14.5049E-01	11.6719E+00
8	0.	0.	0.	58	66.1002E-02	16.3589E-01	11.8055E+00
9	0.	0.	0.	59	80.9305E-02	18.5881E-01	11.9419E+00
10	0.	0.	0.	60	98.5489E-02	21.1786E-01	12.0805E+00
11	0.	0.	0.	61	11.9324E-01	24.1950E-01	12.2211E+00
12	0.	0.	0.	62	14.3701E-01	27.7057E-01	12.3629E+00
13	0.	0.	0.	63	17.2272E-01	31.7681E-01	12.5054E+00
14	0.	0.	0.	64	20.5854E-01	36.4204E-01	12.6500E+00
15	0.	0.	0.	65	24.4853E-01	41.8072E-01	12.7927E+00
16	0.	0.	0.	66	28.9808E-01	48.0680E-01	12.9310E+00
17	0.	0.	0.	67	34.2010E-01	55.3349E-01	13.0679E+00
18	0.	0.	0.	68	40.2584E-01	63.4114E-01	13.2031E+00
19	0.	0.	0.	69	47.2635E-01	72.7431E-01	13.3355E+00
20	0.	0.	0.	70	55.3471E-01	83.3824E-01	13.4644E+00
21	0.	0.	0.	71	64.6480E-01	95.5133E-01	13.5887E+00
22	0.	0.	0.	72	75.3285E-01	10.9335E+00	13.7079E+00
23	0.	0.	0.	73	56.1009E-01	80.3012E-01	90.7468E-01
24	0.	0.	0.	74	0.	0.	0.
25	0.	0.	0.	75	0.	0.	0.
26	0.	0.	0.	76	0.	0.	0.
27	0.	0.	0.	77	0.	0.	0.
28	0.	0.	0.	78	0.	0.	0.
29	0.	0.	0.	79	0.	0.	0.
30	0.	0.	0.	80	0.	0.	0.
31	0.	0.	0.	81	0.	0.	0.
32	0.	0.	0.	82	0.	0.	0.
33	0.	0.	0.	83	0.	0.	0.
34	0.	0.	0.	84	0.	0.	0.
35	0.	0.	0.	85	0.	0.	0.
36	0.	0.	0.	86	0.	0.	0.
37	0.	0.	0.	87	0.	0.	0.
38	0.	0.	0.	88	0.	0.	0.
39	0.	0.	0.	89	0.	0.	0.

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*** ERROR ***

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	3.0216E+00	2	2.9736E+00	3	2.9277E+00	4	2.9266E+00	5	3.0271E+00	6	3.2214E+00
7	3.5332E+00	8	3.9584E+00	9	4.2459E+00	10	4.4215E+00	11	4.4771E+00	12	4.5000E+00
13	4.5000E+00	14	4.5124E+00	15	4.5466E+00	16	4.5815E+00	17	4.5745E+00	18	4.5194E+00
19	4.4420E+00	20	4.3526E+00	21	4.2860E+00	22	4.2508E+00	23	4.2163E+00	24	4.2374E+00
25	4.3101E+00	26	4.3841E+00	27	4.4593E+00	28	4.5874E+00	29	4.8030E+00	30	5.0302E+00
31	5.1918E+00	32	5.4289E+00	33	5.6937E+00	34	5.9671E+00	35	6.2814E+00	36	6.6380E+00
37	6.9766E+00	38	7.2499E+00	39	7.5317E+00	40	7.7902E+00	41	8.0099E+00	42	8.2818E+00
43	8.5952E+00	44	8.8605E+00	45	9.0333E+00	46	9.2087E+00	47	9.3582E+00	48	9.4798E+00
49	9.6036E+00	50	4.5186E+00	51	-2.3419E-01	52	-1.4808E-01	53	-8.2146E-02	54	-3.0797E-02
55	-1.0703E-03	56	0.	57	0.	58	0.	59	0.	60	0.
61	0.	62	0.	63	0.	64	0.	65	0.	66	0.
67	0.	68	0.	69	0.	70	0.	71	0.	72	0.
73	0.	74	0.	75	0.	76	0.	77	0.	78	0.
79	0.	80	0.	81	0.	82	0.	83	0.	84	1.0622E-01
85	7.5220E-01	86	1.3378E+00	87	1.6851E+00	88	1.7000E+00	89	1.7000E+00	90	1.7000E+00
91	1.7000E+00	92	1.7000E+00	93	1.7000E+00	94	1.7000E+00	95	1.7000E+00	96	7.4156E+00
97	1.3023E+01	98	1.4005E+01	99	1.6086E+01						

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*** EIOG ***

ENDF/B FILE 3 SMOOTH N,GAMMA REACTION

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	1.0000E-10	2	1.0000E-10	3	1.0000E-10	4	1.0000E-10	5	1.0000E-10	6	1.0000E-10
7	1.0000E-10	8	1.0000E-10	9	1.0000E-10	10	1.0000E-10	11	1.0000E-10	12	1.0000E-10
13	1.0000E-10	14	1.0000E-10	15	1.0000E-10	16	1.0000E-10	17	1.0000E-10	18	1.0000E-10
19	1.0000E-10	20	1.0000E-10	21	5.8968E-09	22	4.3254E-06	23	3.1507E-03	24	2.0693E-02
25	2.6875E-02	26	3.4904E-02	27	4.5330E-02	28	5.5421E-02	29	6.2362E-02	30	6.9582E-02
31	8.0548E-02	32	9.0994E-02	33	9.9624E-02	34	1.0461E-01	35	1.1312E-01	36	1.2552E-01
37	1.3729E-01	38	1.4576E-01	39	1.5462E-01	40	1.6442E-01	41	1.7535E-01	42	1.8261E-01
43	1.8709E-01	44	1.9245E-01	45	1.9924E-01	46	2.0628E-01	47	2.1117E-01	48	2.1360E-01
49	2.1608E-01	50	1.6365E-01	51	8.8640E-02	52	8.3717E-02	53	1.1621E-01	54	1.6669E-01
55	2.0650E-01	56	2.2584E-01	57	2.3000E-01	58	2.1720E-01	59	1.8955E-01	60	1.2936E-01
61	5.2588E-02	62	-3.9221E-02	63	-1.1576E-01	64	-1.7630E-01	65	-2.4281E-01	66	-3.1201E-01
67	-3.7354E-01	68	-2.2255E-01	69	-9.3926E-01	70	-1.7872E+00	71	2.7761E+00	72	-1.9932E+00
73	-3.8060E-01	74	4.3865E-01	75	1.1165E-01	76	0.	77	0.	78	0.
79	0.	80	0.	81	0.	82	0.	83	0.	84	0.
85	0.	86	0.	87	4.8056E-02	88	1.9820E-01	89	3.2879E-01	90	4.5324E-01
91	4.4755E-01	92	1.1971E+00	93	2.8042E+00	94	4.0607E+00	95	5.0396E+00	96	1.0950E+01
97	2.3952E+01	98	4.7739E+01	99	1.4389E+02						

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*** EIOG ***

ENDF/B FILE 2 RESONANCE CONTRIBUTION TO N,GAMMA

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	0.	2	0.	3	0.	4	0.	5	0.	6	0.
7	0.	8	0.	9	0.	10	0.	11	0.	12	0.
13	0.	14	0.	15	0.	16	0.	17	0.	18	0.
19	0.	20	0.	21	0.	22	0.	23	0.	24	0.
25	0.	26	0.	27	0.	28	0.	29	0.	30	0.
31	0.	32	0.	33	0.	34	0.	35	0.	36	0.
37	0.	38	0.	39	0.	40	0.	41	0.	42	0.
43	0.	44	0.	45	0.	46	0.	47	0.	48	0.
49	0.	50	5.8029E-02	51	1.2971E-01	52	1.6839E-01	53	2.1728E-01	54	2.7892E-01
55	3.5481E-01	56	4.4634E-01	57	5.5530E-01	58	6.8568E-01	59	8.3814E-01	60	1.0191E+00
61	1.2324E+00	62	1.4825E+00	63	1.7755E+00	64	2.1197E+00	65	2.5193E+00	66	2.9798E+00
67	3.5143E+00	68	4.1342E+00	69	4.8510E+00	70	5.6778E+00	71	6.6289E+00	72	7.7208E+00
73	1.0015E+01	74	1.2861E+01	75	6.0385E+00	76	1.7777E+01	77	1.4874E+01	78	2.3598E+00
79	2.8445E+01	80	5.2982E+01	81	6.2375E+01	82	3.4045E+00	83	2.7774E+01	84	2.8956E+01
85	9.6629E+01	86	8.7883E+01	87	5.9914E+00	88	8.3224E+01	89	1.2164E+00	90	8.8768E-01
91	9.9678E-01	92	1.3339E+00	93	1.9678E+00	94	3.0993E+00	95	5.1729E+00	96	3.6134E+00
97	0.	98	0.	99	0.						

*** FIDO ***

TOTAL N.GAMMA

GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC	GRP	CROSS SEC
1	1.0000E-10	2	1.0000E-10	3	1.0000E-10	4	1.0000E-10	5	1.0000E-10	6	1.0000E-10
7	1.0000E-10	8	1.0000E-10	9	1.0000E-10	10	1.0000E-10	11	1.0000E-10	12	1.0000E-10
13	1.0000E-10	14	1.0000E-10	15	1.0000E-10	16	1.0000E-10	17	1.0000E-10	18	1.0000E-10
19	1.0000E-10	20	1.0000E-10	21	5.8968E-09	22	4.3254E-06	23	3.1507E-03	24	2.0693E-02
25	2.6875E-02	26	3.4904E-02	27	4.5330E-02	28	5.5421E-02	29	6.2362E-02	30	6.9582E-02
31	8.0548E-02	32	9.0994E-02	33	9.9624E-02	34	1.0461E-01	35	1.1312E-01	36	1.2552E-01
37	1.3729E-01	38	1.4576E-01	39	1.5462E-01	40	1.6442E-01	41	1.7535E-01	42	1.8261E-01
43	1.8709E-01	44	1.9245E-01	45	1.9924E-01	46	2.0628E-01	47	2.1117E-01	48	2.1360E-01
49	2.1608E-01	50	2.2168E-01	51	2.1835E-01	52	2.5211E-01	53	3.3348E-01	54	4.4561E-01
55	5.6131E-01	56	6.7218E-01	57	7.8530E-01	58	9.0288E-01	59	1.0277E+00	60	1.1485E+00
61	1.2850E+00	62	1.4433E+00	63	1.6598E+00	64	1.9434E+00	65	2.2765E+00	66	2.6677E+00
67	3.1407E+00	68	3.9117E+00	69	3.9117E+00	70	3.8906E+00	71	9.4049E+00	72	5.7277E+00
73	9.6341E+00	74	1.3300E+01	75	6.1501E+00	76	1.7777E+01	77	1.4874E+01	78	2.3598E+00
79	2.8445E+01	80	5.2982E+01	81	6.2375E+01	82	3.4045E+00	83	2.7774E+01	84	2.8956E+01
85	9.6629E+01	86	8.7883E+01	87	6.0394E+00	88	8.3423E+01	89	1.5452E+00	90	1.3409E+00
91	1.4443E+00	92	2.5310E+00	93	4.7720E+00	94	7.1600E+00	95	1.0213E+01	96	1.4564E+01
97	2.3952E+01	98	4.7739E+01	99	1.4389E+02						

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*** ETOG ***

INFINITELY DILUTE RESONANCE INTEGRALS

N.GAMMA= 2.1264E+02 BARNS

N.GAMMA= 2.1258E+02 BARNS (AS CALCULATED FROM TOTAL N.GAMMA GROUP AVERAGED VALUES)

FISSION= 3.6999E+02 BARNS

N.P= 0. BARNS

N.D= 0. BARNS

N.T= 0. BARNS

N.HE-3= 0. BARNS

N.ALPHA= 0. BARNS

N.2*ALPHA= 0. BARNS

ABSORPTION= 5.8262E+02 BARNS

*** ETOG ***

MULTI-GROUP	CAPTURE	FISSION	ABSORPTION	SCATTERING	ANISOTROPIC SCATTERING	INELASTIC SCATTERING	N-2N	NEUTRONS PER FISSION
1	10.0000E-11	26.5477E-01	26.5477E-01	30.2160E-01	15.3665E-01	17.0512E-02	97.6929E-03	47.7300E-01
2	10.0000E-11	25.8215E-01	25.8215E-01	29.7355E-01	27.0758E-01	28.1615E-02	15.0049E-02	45.9365E-01
3	10.0000E-11	25.1733E-01	25.1733E-01	29.2765E-01	25.9294E-01	41.3413E-02	15.8209E-02	44.3070E-01
4	10.0000E-11	24.5730E-01	24.5730E-01	29.2663E-01	25.2578E-01	57.6238E-02	15.4843E-02	42.8343E-01
5	10.0000E-11	24.2000E-01	24.2000E-01	30.2714E-01	25.5054E-01	72.3309E-02	14.9286E-02	41.4961E-01
6	10.0000E-11	24.1162E-01	24.1162E-01	32.2146E-01	26.5450E-01	85.6952E-02	13.8321E-02	40.2892E-01
7	10.0000E-11	23.2435E-01	23.2435E-01	35.3318E-01	28.5195E-01	10.1477E-01	11.6163E-02	39.2001E-01
8	10.0000E-11	21.1408E-01	21.1408E-01	39.5842E-01	31.3915E-01	12.2064E-01	80.9485E-03	38.2056E-01
9	10.0000E-11	19.5429E-01	19.5429E-01	42.4505E-01	33.4002E-01	14.2828E-01	35.8719E-03	37.3121E-01
10	10.0000E-11	18.7072E-01	18.7072E-01	44.2147E-01	34.5911E-01	15.4406E-01	30.8718E-04	36.4906E-01
11	10.0000E-11	18.7007E-01	18.7007E-01	44.7712E-01	34.8451E-01	15.1728E-01	0.	35.7517E-01
12	10.0000E-11	18.8556E-01	18.8556E-01	45.0000E-01	34.8582E-01	14.6075E-01	0.	35.0908E-01
13	10.0000E-11	19.1237E-01	19.1237E-01	45.0000E-01	34.7041E-01	13.9367E-01	0.	34.4869E-01
14	10.0000E-11	19.3829E-01	19.3829E-01	45.1243E-01	34.0107E-01	13.2659E-01	0.	33.9353E-01
15	10.0000E-11	19.6247E-01	19.6247E-01	45.4669E-01	33.1079E-01	12.6311E-01	0.	33.4610E-01
16	10.0000E-11	19.8686E-01	19.8686E-01	45.8150E-01	32.3039E-01	12.2091E-01	0.	32.9954E-01
17	10.0000E-11	20.1269E-01	20.1269E-01	45.7446E-01	31.2963E-01	11.9238E-01	0.	32.5761E-01
18	10.0000E-11	20.3952E-01	20.3952E-01	45.1938E-01	30.0499E-01	11.7577E-01	0.	32.2097E-01
19	10.0000E-11	20.3571E-01	20.3571E-01	44.4180E-01	27.8376E-01	11.4721E-01	0.	31.8789E-01
20	10.0000E-11	20.1338E-01	20.1338E-01	43.5251E-01	25.2427E-01	11.1133E-01	0.	31.5768E-01
21	58.9678E-10	19.7820E-01	19.7820E-01	42.8600E-01	23.0683E-01	10.6859E-01	0.	31.3056E-01
22	43.2543E-07	19.2557E-01	19.2557E-01	42.5093E-01	21.3073E-01	10.7157E-01	0.	31.0705E-01
23	31.5070E-04	18.7407E-01	18.7722E-01	42.1626E-01	19.7209E-01	10.0637E-01	0.	30.8372E-01
24	20.6927E-03	18.3676E-01	18.5746E-01	42.3734E-01	18.2170E-01	93.4939E-02	0.	30.6372E-01
25	26.8750E-03	18.1179E-01	18.3867E-01	43.1011E-01	18.2073E-01	90.9038E-02	0.	30.4702E-01
26	34.9039E-03	17.8730E-01	18.2220E-01	43.8439E-01	18.7372E-01	90.9628E-02	0.	30.3040E-01
27	45.3301E-03	17.6281E-01	18.0814E-01	44.5937E-01	19.7264E-01	83.0334E-02	0.	30.1397E-01
28	55.4210E-03	17.2784E-01	17.8326E-01	45.8741E-01	20.4382E-01	79.2996E-02	0.	29.9909E-01
29	62.3618E-03	16.9318E-01	17.5554E-01	48.0294E-01	19.7103E-01	76.6395E-02	0.	29.8683E-01
30	69.5824E-03	16.7252E-01	17.4210E-01	50.3008E-01	20.7483E-01	76.2152E-02	0.	29.7572E-01
31	80.5485E-03	16.4499E-01	17.2554E-01	51.9172E-01	19.9948E-01	76.3473E-02	0.	29.6541E-01
32	90.9937E-03	16.3423E-01	17.2522E-01	54.2883E-01	22.1346E-01	75.3050E-02	0.	29.5671E-01
33	99.6240E-03	16.0964E-01	17.0926E-01	56.9367E-01	21.3141E-01	73.9693E-02	0.	29.4841E-01
34	10.4611E-02	15.5521E-01	16.5982E-01	59.6713E-01	19.3527E-01	72.6283E-02	0.	29.4100E-01
35	11.3115E-02	15.2288E-01	16.3599E-01	62.8147E-01	20.7210E-01	69.9325E-02	0.	29.3432E-01

*** ETOE ***

MULTI-GROUP	CAPTURE	FISSION	ABSORPTION	SCATTERING	ANISOTROPIC SCATTERING	INELASTIC SCATTERING	N-2N	NEUTRONS PER FISSION
36	12.5522E-02	15.0943E-01	16.3495E-01	66.3797E-01	21.2259E-01	66.0286E-02	0.	29.2827E-01
37	13.7292E-02	14.9809E-01	16.3538E-01	69.7651E-01	21.2202E-01	62.0444E-02	0.	29.2266E-01
38	14.5763E-02	14.9097E-01	16.3674E-01	72.4985E-01	20.9764E-01	57.7077E-02	0.	29.1792E-01
39	15.4625E-02	14.8410E-01	16.3873E-01	75.3157E-01	23.3939E-01	53.4702E-02	0.	29.1310E-01
40	16.4422E-02	14.8002E-01	16.4444E-01	77.9005E-01	24.0744E-01	49.6427E-02	0.	29.0896E-01
41	17.5347E-02	14.8000E-01	16.5535E-01	80.1002E-01	21.6075E-01	47.4073E-02	0.	29.0533E-01
42	18.2614E-02	14.8000E-01	16.6261E-01	82.8162E-01	19.3819E-01	45.5068E-02	0.	29.0195E-01
43	18.7095E-02	14.8000E-01	16.6709E-01	85.9500E-01	17.3532E-01	43.6040E-02	0.	28.9895E-01
44	19.2449E-02	14.8510E-01	16.7755E-01	88.6036E-01	15.7577E-01	41.5680E-02	0.	28.9615E-01
45	19.9238E-02	14.9880E-01	16.9804E-01	90.3316E-01	14.3004E-01	39.3040E-02	0.	28.9380E-01
46	20.6284E-02	15.1274E-01	17.1902E-01	92.0861E-01	12.9508E-01	37.2643E-02	0.	28.9146E-01
47	21.1167E-02	15.2116E-01	17.3232E-01	93.5815E-01	11.6650E-01	35.6792E-02	0.	28.8947E-01
48	21.3602E-02	15.2362E-01	17.3722E-01	94.7972E-01	10.4452E-01	34.2002E-02	0.	28.8780E-01
49	21.6080E-02	15.2613E-01	17.4221E-01	96.0364E-01	93.2147E-02	32.7184E-02	0.	28.8611E-01
50	21.7944E-02	15.5665E-01	17.7459E-01	10.1944E+00	80.2447E-02	30.3242E-02	0.	28.8334E-01
51	21.0557E-02	14.9117E-01	17.0172E-01	10.7396E+00	64.4864E-02	27.2020E-02	0.	28.8039E-01
52	24.2812E-02	14.5959E-01	17.0240E-01	10.9197E+00	49.4757E-02	25.0078E-02	0.	28.7809E-01
53	32.2487E-02	14.9242E-01	18.1491E-01	11.0904E+00	37.9481E-02	24.0131E-02	0.	28.7630E-01
54	43.2636E-02	15.7715E-01	20.0978E-01	11.2579E+00	28.5592E-02	23.1799E-02	0.	28.7491E-01
55	54.6028E-02	16.7763E-01	22.2366E-01	11.4076E+00	21.0725E-02	22.1709E-02	0.	28.7382E-01
56	65.4213E-02	17.8454E-01	24.3875E-01	11.5403E+00	15.1185E-02	21.1497E-02	0.	28.7298E-01
57	76.4230E-02	19.0209E-01	26.6632E-01	11.6719E+00	10.4078E-02	19.4069E-02	0.	28.7232E-01
58	87.8205E-02	20.2965E-01	29.0786E-01	11.8055E+00	66.8030E-03	15.7873E-02	0.	28.7181E-01
59	99.8852E-02	21.8424E-01	31.8309E-01	11.9419E+00	38.9804E-03	10.2559E-02	0.	28.7141E-01
60	11.1484E-01	23.4847E-01	34.6331E-01	12.0805E+00	33.9816E-03	15.3568E-03	0.	28.7109E-01
61	12.4583E-01	25.3311E-01	37.7893E-01	12.2211E+00	34.3774E-03	0.	0.	28.7085E-01
62	13.9779E-01	27.1350E-01	41.1129E-01	12.3629E+00	34.7760E-03	0.	0.	28.7066E-01
63	16.0696E-01	29.6635E-01	45.7332E-01	12.5054E+00	35.1771E-03	0.	0.	28.7052E-01
64	18.8224E-01	33.3415E-01	52.1639E-01	12.6500E+00	35.5838E-03	0.	0.	28.7040E-01
65	22.0571E-01	37.9184E-01	59.9755E-01	12.7927E+00	35.9850E-03	0.	0.	28.7031E-01
66	25.8606E-01	42.9674E-01	68.8281E-01	12.9310E+00	36.3742E-03	0.	0.	28.7024E-01
67	30.4655E-01	49.1551E-01	79.6206E-01	13.0679E+00	36.7591E-03	0.	0.	28.7019E-01
68	38.0329E-01	59.9411E-01	97.9740E-01	13.2031E+00	37.1395E-03	0.	0.	28.7015E-01
69	37.8709E-01	58.9405E-01	96.8114E-01	13.3355E+00	37.5119E-03	0.	0.	28.7012E-01
70	37.4751E-01	57.5554E-01	95.0304E-01	13.4644E+00	37.8744E-03	0.	0.	28.7009E-01

*** ETOG ***

MULTI-GROUP	CAPTURE	FISSION	ABSORPTION	SCATTERING	ANISOTROPIC SCATTERING	INELASTIC SCATTERING	N-2N	NEUTRONS PER FISSION
71	92.4085E-01	13.5335E+00	22.7744E+00	13.5887E+00	38.2242E-03	0.	0.	28.7007E-01
72	55.3970E-01	81.2741E-01	13.6671E+00	13.7079E+00	38.5595E-03	0.	0.	28.7005E-01
73	52.2950E-01	89.4663E-01	14.1761E+00	15.9060E+00	44.7426E-03	0.	0.	28.7004E-01
74	43.8673E-02	37.9586E-01	42.3453E-01	16.2117E+00	45.6026E-03	0.	0.	28.7003E-01
75	11.1681E-02	86.5414E-02	97.7095E-02	12.7161E+00	35.7697E-03	0.	0.	28.7003E-01
76	66.4995E-06	30.4196E-05	37.0696E-05	16.2469E+00	45.7014E-03	0.	0.	28.7002E-01
77	12.3771E-05	56.5824E-05	68.9595E-05	13.0771E+00	36.7851E-03	0.	0.	28.7002E-01
78	23.0125E-05	10.5118E-04	12.8130E-04	11.0673E+00	31.1316E-03	0.	0.	28.7001E-01
79	42.7296E-05	19.4980E-04	23.7709E-04	21.9768E+00	61.8194E-03	0.	0.	28.7001E-01
80	79.2064E-05	36.0942E-04	44.0148E-04	18.8542E+00	53.0357E-03	0.	0.	28.7001E-01
81	14.6509E-04	66.6481E-04	81.2990E-04	17.1273E+00	48.1780E-03	0.	0.	28.7001E-01
82	27.0273E-04	12.2673E-03	14.9700E-03	83.3022E-01	23.4324E-03	0.	0.	28.7000E-01
83	49.6919E-04	22.4886E-03	27.4578E-03	10.7049E+00	30.1123E-03	0.	0.	28.7000E-01
84	90.9834E-04	41.0191E-03	50.1175E-03	11.5642E+00	32.5295E-03	0.	0.	28.7000E-01
85	16.5739E-03	74.3514E-03	90.9252E-03	13.7021E+00	38.5430E-03	0.	0.	28.7000E-01
86	30.0061E-03	13.3733E-02	16.3739E-02	13.1193E+00	36.9039E-03	0.	0.	28.7000E-01
87	10.1985E-02	97.5152E-02	10.7714E-01	81.3879E-01	22.8939E-03	0.	0.	28.7000E-01
88	29.4305E-02	34.5882E-01	37.5313E-01	10.0158E+00	28.1739E-03	0.	0.	28.7000E-01
89	49.8482E-02	54.5266E-01	59.5115E-01	89.7757E-01	25.2534E-03	0.	0.	28.7000E-01
90	74.9928E-02	68.8126E-01	76.3119E-01	95.4988E-01	26.8632E-03	0.	0.	28.7000E-01
91	96.1578E-02	86.8252E-01	96.4409E-01	99.3349E-01	27.9423E-03	0.	0.	28.7000E-01
92	20.8179E-01	11.1449E+00	13.2266E+00	10.2561E+00	28.8499E-03	0.	0.	28.7000E-01
93	43.2499E-01	14.4843E+00	18.8093E+00	10.5699E+00	29.7325E-03	0.	0.	28.7000E-01
94	66.9837E-01	19.0188E+00	25.7171E+00	10.9024E+00	30.6679E-03	0.	0.	28.7000E-01
95	97.2339E-01	25.4791E+00	35.2025E+00	11.2797E+00	31.7292E-03	0.	0.	28.7000E-01
96	14.0375E+00	35.5663E+00	49.6039E+00	12.0934E+00	34.0181E-03	0.	0.	28.7000E-01
97	23.3760E+00	56.3048E+00	79.6808E+00	13.0228E+00	36.6322E-03	0.	0.	28.7000E-01
98	47.1040E+00	10.6882E+01	15.3986E+01	14.0049E+00	39.3949E-03	0.	0.	28.7000E-01
99	14.3183E+01	28.5362E+01	42.8545E+01	16.0861E+00	45.2492E-03	0.	0.	28.7000E-01

*** ETOG ***

ELASTIC SCATTERING MATRICES

***** BEGINNING OF ISOTROPIC ENERGY RANGE *****

SOURCE GROUP 99

SINK GRPS	P0 CALCULATED	GROUP AVG SYMM. SCATT.	PER CENT ERROR	P0 NORMALIZED	P1 CALCULATED	GROUP AVG 3*MU*SIGS	PER CENT ERROR	P1 NORMALIZED
99	1.5484E+01	1.6086E+01	-1.4135E-12	1.5484E+01	7.3211E-01	1.3575E-01	-4.9071E-13	7.3211E-01
100	6.0193E-01			6.0193E-01	-5.9636E-01			-5.9636E-01

SINK GRPS	P2 CALCULATED	GROUP AVG ISOTR. VALUE	PER CENT ERROR	P2 NORMALIZED	P3 CALCULATED	GROUP AVG ISOTR. VALUE	ABSOLUTE ERROR	P3 NORMALIZED
99	5.8202E-03	2.8713E-04	-7.1745E-12	5.8202E-03	1.5837E-04	0.	0.	1.5837E-04
100	-5.5331E-03			-5.5331E-03	-1.5837E-04			-1.5837E-04

SOURCE GROUP 98

SINK GRPS	P0 CALCULATED	GROUP AVG SYMM. SCATT.	PER CENT ERROR	P0 NORMALIZED	P1 CALCULATED	GROUP AVG 3*MU*SIGS	PER CENT ERROR	P1 NORMALIZED
98	1.3510E+01	1.4005E+01	-8.1177E-13	1.3510E+01	6.0968E-01	1.1819E-01	-1.6909E-12	6.0968E-01
99	4.9500E-01			4.9500E-01	-4.9150E-01			-4.9150E-01

SINK GRPS	P2 CALCULATED	GROUP AVG ISOTR. VALUE	PER CENT ERROR	P2 NORMALIZED	P3 CALCULATED	GROUP AVG ISOTR. VALUE	ABSOLUTE ERROR	P3 NORMALIZED
98	3.7254E-03	2.4998E-04	-6.5058E-12	3.7254E-03	1.1205E-04	0.	0.	1.1205E-04
99	-3.4754E-03			-3.4754E-03	-1.1205E-04			-1.1205E-04

SOURCE GROUP 97

SINK GRPS	P0 CALCULATED	GROUP AVG SYMM. SCATT.	PER CENT ERROR	P0 NORMALIZED	P1 CALCULATED	GROUP AVG 3*MU*SIGS	PER CENT ERROR	P1 NORMALIZED

SINK GRPS	P2 CALCULATED	GROUP AVG ISOTR. VALUE	PER CENT ERROR	P2 NORMALIZED	P3 CALCULATED	GROUP AVG ISOTR. VALUE	ABSOLUTE ERROR	P3 NORMALIZED
62	2.6153E-03	2.2067E-04	-2.9479E-12	2.6153E-03	9.1733E-05	0.	0.	9.1733E-05
63	-2.3946E-03			-2.3946E-03	-9.1733E-05			-9.1733E-05

SOURCE GROUP 61

SINK GRPS	P0 CALCULATED	GROUP AVG SYMM. SCATT.	PER CENT ERROR	P0 NORMALIZED	P1 CALCULATED	GROUP AVG 3*MU*SIGS	PER CENT ERROR	P1 NORMALIZED
61	1.1808E+01	1.2221E+01	-4.4512E-13	1.1808E+01	5.1439E-01	1.0313E-01	-2.5836E-12	5.1439E-01
62	4.1365E-01			4.1365E-01	-4.1126E-01			-4.1126E-01

SINK GRPS	P2 CALCULATED	GROUP AVG ISOTR. VALUE	PER CENT ERROR	P2 NORMALIZED	P3 CALCULATED	GROUP AVG ISOTR. VALUE	ABSOLUTE ERROR	P3 NORMALIZED
61	2.5856E-03	2.1814E-04	-8.4494E-12	2.5856E-03	9.0685E-05	0.	0.	9.0685E-05
62	-2.3675E-03			-2.3675E-03	-9.0685E-05			-9.0685E-05

SOURCE GROUP 60

SINK GRPS	P0 CALCULATED	GROUP AVG SYMM. SCATT.	PER CENT ERROR	P0 NORMALIZED	P1 CALCULATED	GROUP AVG 3*MU*SIGS	PER CENT ERROR	P1 NORMALIZED
60	1.1672E+01	1.2080E+01	-9.4108E-13	1.1672E+01	5.0848E-01	1.0195E-01	-3.9205E-12	5.0848E-01
61	4.0889E-01			4.0889E-01	-4.0654E-01			-4.0654E-01

SINK GRPS	P2 CALCULATED	GROUP AVG ISOTR. VALUE	PER CENT ERROR	P2 NORMALIZED	P3 CALCULATED	GROUP AVG ISOTR. VALUE	ABSOLUTE ERROR	P3 NORMALIZED
60	2.5561E-03	2.1563E-04	-5.0281E-12	2.5561E-03	8.9643E-05	0.	0.	8.9643E-05
61	-2.3405E-03			-2.3405E-03	-8.9643E-05			-8.9643E-05

***** END OF ISOTROPIC ENERGY RANGE *****

SOURCE GROUP 59

SINK GRPS	P0 CALCULATED	P1 CALCULATED
59	1.1538E+01	5.1880E-01

60	4.0413E-01	-4.0185E-01

SINK GRPS	P2 CALCULATED	P3 CALCULATED
59	1.3748E-02	-5.2708E-03
60	-2.3129E-03	-8.8608E-05

SOURCE GROUP 58

SINK GRPS	P0 CALCULATED	P1 CALCULATED
58	1.1407E+01	5.9636E-01
59	3.9895E-01	-3.9593E-01

SINK GRPS	P2 CALCULATED	P3 CALCULATED
58	7.2024E-02	-3.1153E-02
59	-1.9883E-03	-1.8262E-03

SOURCE GROUP 57

SINK GRPS	P0 CALCULATED	P1 CALCULATED
57	1.1279E+01	7.0119E-01
58	3.9324E-01	-3.8893E-01

SINK GRPS	P2 CALCULATED	P3 CALCULATED
57	1.4956E-01	-6.4808E-02
58	-1.3976E-03	-5.0373E-03

SOURCE GROUP 56

SINK GRPS	P0 CALCULATED	P1 CALCULATED

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SINK GRPS	P0 CALCULATED	P1 CALCULATED
3	2.8830E+00	7.4451E+00
4	5.2511E-02	3.3229E-02

SINK GRPS	P2 CALCULATED	P3 CALCULATED
3	1.0626E+01	1.2760E+01
4	2.1454E-02	1.8693E-02

SOURCE GROUP 2

SINK GRPS	P0 CALCULATED	P1 CALCULATED
2	2.9352E+00	7.7147E+00
3	5.0104E-02	3.8651E-02

SINK GRPS	P2 CALCULATED	P3 CALCULATED
2	1.1103E+01	1.3374E+01
3	2.7167E-02	1.4293E-02

SOURCE GROUP 1

SINK GRPS	P0 CALCULATED	P1 CALCULATED
1	2.9905E+00	7.9885E+00
2	4.6628E-02	4.4885E-02

SINK GRPS	P2 CALCULATED	P3 CALCULATED
1	1.1545E+01	1.3997E+01
2	3.3927E-02	8.6975E-03

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*** ETOG ***

INELASTIC SCATTERING PROBABILITY MATRIX
BEFORE RENORMALIZATION

EXIT GROUP										
1	47.4491E-08									
2	29.2347E-07	77.9101E-08								
3	10.8692E-06	52.0524E-07	16.2233E-07							
4	35.0372E-06	18.1785E-06	92.9945E-07	33.3759E-07						
5	99.2754E-06	55.3882E-06	30.4946E-06	16.6238E-06	54.1847E-07					
6	25.0241E-05	14.9121E-05	87.7563E-06	51.1573E-06	29.1462E-06	10.6243E-06				
7	56.7198E-05	35.8784E-05	22.4280E-05	13.8934E-05	84.2783E-06	49.3734E-06	20.0641E-06			
8	11.6795E-04	77.9873E-05	51.4939E-05	33.7061E-05	21.6428E-05	13.4658E-05	81.6687E-06	30.0662E-06		
9	22.0409E-04	15.4567E-04	10.7248E-04	73.7948E-05	49.8897E-05	32.7807E-05	21.0438E-05	13.2543E-05	53.2549E-06	
10	38.4378E-04	28.1799E-04	20.4518E-04	14.7238E-04	10.4301E-04	72.0060E-05	48.6690E-05	32.3260E-05	20.4979E-05	73.7792E-06
11	62.4067E-04	47.6313E-04	36.0056E-04	27.0065E-04	19.9582E-04	14.4099E-04	10.2053E-04	71.1270E-05	47.5534E-05	31.4347E-05
12	94.9602E-04	75.1682E-04	58.9566E-04	45.8946E-04	35.2424E-04	26.4992E-04	19.5781E-04	14.2536E-04	99.9768E-05	69.3840E-05
13	13.6265E-03	11.1485E-03	90.4131E-04	72.7908E-04	57.8722E-04	45.1453E-04	34.6580E-04	26.2498E-04	19.2301E-04	13.9476E-04
14	18.5405E-03	15.6295E-03	13.0648E-03	10.8439E-03	88.9704E-04	71.7558E-04	57.0337E-04	44.7720E-04	34.1165E-04	25.7536E-04
15	24.0413E-03	20.8230E-03	17.8899E-03	15.2644E-03	12.8860E-03	10.7112E-03	87.8565E-04	71.2424E-04	56.2591E-04	44.0341E-04
16	29.8442E-03	26.4910E-03	23.3316E-03	20.4115E-03	17.6817E-03	15.1048E-03	12.7476E-03	10.6453E-03	86.8258E-04	70.2248E-04
17	35.6133E-03	32.3219E-03	29.1141E-03	26.0535E-03	23.1029E-03	20.2305E-03	17.5198E-03	15.0250E-03	12.6188E-03	10.5139E-03
18	41.0059E-03	37.9720E-03	34.9069E-03	31.8843E-03	28.8784E-03	25.8612E-03	22.9257E-03	20.1408E-03	17.3699E-03	14.8671E-03
19	45.7112E-03	43.1049E-03	40.3642E-03	37.5509E-03	34.6771E-03	31.6909E-03	28.6945E-03	25.7652E-03	22.7603E-03	19.9615E-03
20	49.4853E-03	47.4414E-03	45.1703E-03	42.7444E-03	40.1546E-03	37.3774E-03	34.4981E-03	31.5946E-03	28.5234E-03	25.5740E-03

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*** ETOG ***

INELASTIC MATRIX

EXIT GROUP									
1	0.								
2	0.	0.							
3	18.5339E-07	0.	0.						
4	59.7443E-07	51.1945E-07	0.	0.					
5	16.9281E-06	15.5985E-06	12.6073E-06	95.7950E-07	0.				
6	42.6704E-06	41.9956E-06	36.2806E-06	29.4795E-06	21.0824E-06	91.0477E-07			
7	96.7168E-06	10.1041E-05	92.7233E-06	80.0612E-06	60.9613E-06	42.3117E-06	20.3607E-06		
8	19.9156E-05	21.9629E-05	21.2889E-05	19.4232E-05	15.6550E-05	11.5398E-05	82.8762E-06	36.7007E-06	
9	37.5834E-05	43.5294E-05	44.3391E-05	42.5244E-05	36.0868E-05	28.0921E-05	21.3550E-05	16.1790E-05	
	76.0645E-06								
10	65.5429E-05	79.3605E-05	84.5530E-05	84.8462E-05	75.4446E-05	61.7072E-05	49.3886E-05	39.4591E-05	
	29.2774E-05	11.3922E-05							
11	10.6414E-04	13.4140E-04	14.8857E-04	15.5626E-04	14.4364E-04	12.3489E-04	10.3562E-04	86.8220E-05	
	67.9211E-05	48.5381E-05	19.8641E-05						
12	16.1923E-04	21.1689E-04	24.3742E-04	26.4468E-04	25.4920E-04	22.7091E-04	19.8676E-04	17.3988E-04	
	14.2798E-04	10.7135E-04	73.1578E-05	32.7626E-05					
13	23.2354E-04	31.3966E-04	37.3792E-04	41.9459E-04	41.8609E-04	38.6883E-04	35.1705E-04	32.0421E-04	
	27.4666E-04	21.5364E-04	15.3581E-04	10.5731E-04	41.6668E-05				
14	31.6147E-04	44.0160E-04	54.0134E-04	62.4883E-04	64.3552E-04	61.4928E-04	57.8769E-04	54.6514E-04	
	48.7290E-04	39.7658E-04	29.4942E-04	21.1449E-04	14.8569E-04	65.7072E-05			
15	40.9944E-04	58.6420E-04	73.9614E-04	87.9613E-04	93.2085E-04	91.7917E-04	89.1555E-04	86.9629E-04	
	80.3555E-04	67.9927E-04	52.2578E-04	38.8664E-04	28.3544E-04	20.4082E-04	77.7982E-05		
16	50.8894E-04	74.6043E-04	96.4588E-04	11.7622E-03	12.7898E-03	12.9444E-03	12.9361E-03	12.9943E-03	
	12.4014E-03	10.8434E-03	86.0717E-04	66.1819E-04	49.9549E-04	37.2341E-04	27.2502E-04	12.0644E-04	
17	60.7267E-04	91.0251E-04	12.0365E-03	15.0134E-03	16.7111E-03	17.3370E-03	17.7788E-03	18.3405E-03	
	18.0236E-03	16.2344E-03	13.2684E-03	10.5145E-03	81.8516E-04	62.9708E-04	47.6582E-04	36.5600E-04	
	18.9361E-04								
18	69.9221E-04	10.6937E-03	14.4314E-03	18.3734E-03	20.8887E-03	22.1624E-03	23.2646E-03	24.5852E-03	
	24.8096E-03	22.9562E-03	19.2654E-03	15.6896E-03	12.5599E-03	99.4389E-04	77.5812E-04	61.3326E-04	
	50.1508E-04	23.6392E-04							
19	77.9454E-04	12.1398E-03	16.4876E-03	21.6440E-03	25.0831E-03	27.1583E-03	29.1187E-03	31.4506E-03	
	32.5088E-03	30.8224E-03	26.4942E-03	22.1170E-03	18.1591E-03	14.7553E-03	11.8332E-03	96.1329E-04	
	80.4970E-04	70.0145E-04	36.7843E-04						
20	84.3808E-04	13.3605E-03	18.4746E-03	24.6316E-03	29.0451E-03	32.0314E-03	35.0081E-03	38.5664E-03	
	40.7402E-03	39.4886E-03	34.4883E-03	29.6132E-03	24.8778E-03	20.4958E-03	17.0145E-03	14.1696E-03	
	12.1232E-03	10.7305E-03	94.3574E-04	42.1309E-04					

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*** ETOG ***

N-2N PROBABILITY MATRIX
BEFORE RENORMALIZATION

EXIT GROUP								
1	19.0534E-08							
2	12.7460E-07	39.5392E-08						
3	51.7977E-07	28.0134E-07	10.1854E-07					
4	18.0992E-06	10.4597E-06	60.8605E-07	18.7233E-07				
5	55.1731E-06	33.8619E-06	20.8995E-06	98.3518E-07	31.7772E-07			
6	14.8607E-05	96.3189E-06	62.7130E-06	32.0585E-06	17.9179E-06	65.9165E-07		
7	35.7688E-05	24.3581E-05	16.6469E-05	91.7245E-06	54.6725E-06	31.9972E-06	13.0429E-06	
8	77.7770E-05	55.3931E-05	39.5575E-05	23.3302E-05	14.7416E-05	91.5943E-06	55.2947E-06	20.2767E-06
9	15.4200E-04	11.4373E-04	84.9941E-05	53.3141E-05	35.5166E-05	23.2969E-05	14.8876E-05	92.6397E-06
	37.3109E-06							
10	28.1213E-04	21.6400E-04	16.6721E-04	11.0586E-04	77.2868E-05	53.2494E-05	35.8298E-05	23.5339E-05
	14.8501E-05	55.2803E-06						
11	47.5450E-04	37.8274E-04	30.1120E-04	21.0103E-04	15.3356E-04	11.0473E-04	77.8918E-05	53.7310E-05
	35.7521E-05	24.1749E-05	0.					
12	75.0501E-04	61.5417E-04	50.4619E-04	36.8611E-04	27.9850E-04	20.9895E-04	15.4396E-04	11.1340E-04
	77.7332E-05	55.0153E-05	0.	0.				
13	11.1335E-03	93.8279E-04	79.0278E-04	60.1767E-04	47.3448E-04	36.8325E-04	28.1540E-04	21.1366E-04
	15.4140E-04	11.3699E-04	0.	0.	0.			
14	15.6115E-03	13.4868E-03	11.6388E-03	92.0236E-04	74.7771E-04	60.1329E-04	47.5910E-04	37.0555E-04
	28.1110E-04	21.5274E-04	0.	0.	0.	0.		
15	20.8027E-03	18.3794E-03	16.2141E-03	13.2643E-03	11.0984E-03	91.9672E-04	75.1154E-04	60.4506E-04
	47.5289E-04	37.6547E-04	0.	0.	0.	0.	0.	
16	26.4695E-03	23.8662E-03	21.4784E-03	18.1217E-03	15.5698E-03	13.2575E-03	11.1417E-03	92.3883E-04
	75.0321E-04	61.3009E-04	0.	0.	0.	0.	0.	0.
17	32.3004E-03	29.6645E-03	27.1828E-03	23.5847E-03	20.7555E-03	18.1134E-03	15.6212E-03	13.3091E-03
	11.1307E-03	93.5066E-04	0.	0.	0.	0.	0.	0.
	0.							
18	37.9518E-03	35.4405E-03	33.0108E-03	29.3755E-03	26.4196E-03	23.8762E-03	20.8140E-03	18.1739E-03
	15.6087E-03	13.4477E-03	0.	0.	0.	0.	0.	0.
	0.	0.						
19	43.0891E-03	40.8495E-03	38.6162E-03	35.1602E-03	32.2506E-03	29.3663E-03	26.4811E-03	23.6419E-03
	20.7996E-03	18.3342E-03	0.	0.	0.	0.	0.	0.
	0.	0.	0.					
20	47.4271E-03	45.5804E-03	43.6696E-03	40.5950E-03	37.9049E-03	35.1515E-03	32.3122E-03	29.4342E-03
	26.4663E-03	23.8170E-03	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.				

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*** ETOG ***

N,2N MATRIX

EXIT GROUP									
1	0.								
2	0.	0.							
3	0.	0.	0.						
4	17.6820E-07	15.6945E-07	0.	0.					
5	53.9014E-07	50.8089E-07	33.0657E-07	0.	0.				
6	14.5181E-06	14.4524E-06	99.2202E-07	49.6419E-07	26.7498E-07	0.			
7	34.9444E-06	36.5488E-06	26.3375E-06	14.2034E-06	81.6209E-07	44.2600E-07	15.1514E-07		
8	75.9843E-06	83.1160E-06	62.5851E-06	36.1264E-06	22.0078E-06	12.4697E-06	64.2336E-07	16.4140E-07	
9	15.0646E-05	17.1615E-05	13.4472E-05	82.5558E-06	53.0229E-06	32.2254E-06	17.2944E-06	74.9920E-07	
	13.3844E-07								
10	27.4732E-05	32.4703E-05	26.3774E-05	17.1240E-05	11.5382E-05	73.4570E-06	41.6221E-06	19.0508E-06	
	53.2713E-07	17.0665E-08							
11	46.4491E-05	56.7591E-05	47.4411E-05	32.5340E-05	22.8946E-05	15.2811E-05	90.4837E-06	43.4954E-06	
	12.8253E-06	74.6344E-08	0.						
12	73.3203E-05	92.3418E-05	79.8373E-05	57.0787E-05	41.7790E-05	29.0337E-05	17.9356E-05	90.1303E-06	
	27.8850E-06	16.9847E-07	0.	0.					
13	10.8768E-04	14.0787E-04	12.5032E-04	93.1824E-05	70.6813E-05	50.9483E-05	32.7053E-05	17.1101E-05	
	55.2940E-06	35.1018E-07	0.	0.	0.				
14	15.2517E-04	20.2366E-04	18.4141E-04	14.2497E-04	11.1635E-04	83.1786E-05	55.2846E-05	29.9965E-05	
	10.0842E-05	66.4607E-07	0.	0.	0.	0.			
15	20.3232E-04	27.5778E-04	25.6528E-04	20.5395E-04	16.5688E-04	12.7213E-04	87.2585E-05	48.9349E-05	
	17.0499E-05	11.6250E-06	0.	0.	0.	0.	0.		
16	25.8594E-04	35.8107E-04	33.9816E-04	28.0611E-04	23.2442E-04	18.3383E-04	12.9429E-04	74.7885E-05	
	26.9160E-05	18.9252E-06	0.	0.	0.	0.	0.	0.	
17	31.5559E-04	44.5109E-04	43.0067E-04	36.5204E-04	30.9860E-04	25.0553E-04	18.1465E-04	10.7737E-04	
	39.9289E-05	28.8680E-06	0.	0.	0.	0.	0.	0.	
	0.								
18	37.0771E-04	53.1777E-04	52.2273E-04	45.4874E-04	39.4420E-04	32.4117E-04	24.1788E-04	14.7118E-04	
	55.9928E-05	41.5147E-06	0.	0.	0.	0.	0.	0.	
	0.	0.							
19	42.0960E-04	61.2938E-04	61.0958E-04	54.4449E-04	48.1471E-04	40.4209E-04	30.7621E-04	19.1381E-04	
	74.6138E-05	56.6025E-06	0.	0.	0.	0.	0.	0.	
	0.	0.	0.						
20	46.3339E-04	68.3923E-04	69.0909E-04	62.8606E-04	56.5884E-04	48.6232E-04	37.5358E-04	23.8270E-04	
	94.9416E-05	73.5295E-06	0.	0.	0.	0.	0.	0.	
	0.	0.	0.	0.					

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*** ETOG ***

THE FOLLOWING CARDS HAVE BEEN PUNCHED

```
ENDF/B TAPE NO.= 115     MATERIAL NO.= 1051                                    1051    1
 2.10000E+01 8.70000E+01 2.50000E+01                                           1051    2
 2.36999E+02 1.00000E+07 2.50000E-01 8.70000E+01 5.00000E+00 8.78000E+001051    3
 9.40000E-04 3.87000E-02 0.                                                    1051    4
 7.83000E+00 8.70000E-04 4.06000E-02 4.15000E-02 0.          7.50000E-011051    5
 1.09300E+01 1.82000E-03 3.15000E-02 1.44700E-01 0.          7.50000E-011051    6
 1.19000E+01 1.07000E-03 4.09000E-02 2.20000E-02 0.          7.50000E-011051    7
 1.42800E+01 5.50000E-04 3.87000E-02 5.25000E-02 0.          7.50000E-011051    8
 1.46800E+01 2.20000E-03 3.87000E-02 3.17000E-02 0.          7.50000E-011051    9
 1.55000E+01 2.37000E-03 3.87000E-02 7.60500E-01 0.          2.50000E-011051   10
 1.76000E+01 1.60000E-03 3.91000E-02 4.63000E-02 0.          7.50000E-011051   11
 2.22000E+01 2.23000E-03 3.13000E-02 7.50000E-02 0.          7.50000E-011051   12
 2.39000E+01 8.70000E-04 3.87000E-02 3.71000E-02 0.          7.50000E-011051   13
 2.62000E+01 1.78000E-03 3.87000E-02 3.57000E-02 0.          7.50000E-011051   14
 2.73000E+01 1.30000E-04 3.87000E-02 2.80000E-03 0.          7.50000E-011051   15
 3.23000E+01 8.60000E-04 3.87000E-02 1.89000E-01 0.          2.50000E-011051   16
 3.53000E+01 3.10000E-04 3.87000E-02 4.10000E-03 0.          7.50000E-011051   17
 4.14000E+01 6.07000E-03 5.92000E-02 1.07000E-02 0.          7.50000E-011051   18
 4.45000E+01 6.34000E-03 2.78000E-02 4.20000E-03 0.          7.50000E-011051   19
 4.76000E+01 5.40000E-03 3.87000E-02 3.01000E-01 0.          2.50000E-011051   20
 4.98500E+01 4.40000E-04 5.98000E-02 7.50000E-01 0.          2.50000E-011051   21
 5.02200E+01 3.04000E-03 4.13000E-02 1.12000E-02 0.          7.50000E-011051   22
 5.26000E+01 1.00500E-02 3.93000E-02 7.70000E-03 0.          7.50000E-011051   23
 5.57900E+01 1.43000E-03 2.60000E-02 2.20000E-02 0.          7.50000E-011051   24
 5.76000E+01 1.70000E-02 3.87000E-02 5.46000E-01 0.          2.50000E-011051   25
 5.80000E+01 1.20000E-02 3.87000E-02 8.05000E-01 0.          2.50000E-011051   26
 5.93900E+01 5.59000E-03 4.86000E-02 1.33000E-01 0.          7.50000E-011051   27
 6.11000E+01 2.24000E-02 3.87000E-02 2.00000E+00 0.          2.50000E-011051   28
 6.34000E+01 1.94000E-03 3.87000E-02 1.39000E-02 0.          7.50000E-011051   29
 6.59600E+01 1.25000E-02 2.24000E-02 7.70000E-02 0.          7.50000E-011051   30
 7.43100E+01 3.27000E-03 3.66000E-02 2.95000E-02 0.          7.50000E-011051   31
 7.52100E+01 2.21000E-02 4.49000E-02 9.50000E-02 0.          7.50000E-011051   32
 8.20000E+01 6.20000E-03 3.87000E-02 1.50000E+00 0.          2.50000E-011051   33
 8.53000E+01 8.67000E-03 3.87000E-02 2.00000E+00 0.          2.50000E-011051   34
 8.56000E+01 3.07000E-03 3.87000E-02 2.16700E-01 0.          7.50000E-011051   35
 9.09000E+01 2.47000E-03 3.87000E-02 1.14600E-01 0.          7.50000E-011051   36
 9.55000E+01 9.34000E-04 3.87000E-02 2.30000E-01 0.          7.50000E-011051   37
 9.60000E+01 9.20000E-03 3.87000E-02 1.40000E+00 0.          2.50000E-011051   38
 9.76000E+01 1.80000E-03 3.87000E-02 3.60000E-01 0.          2.50000E-011051   39
 9.90000E+01 9.35000E-03 3.87000E-02 2.00000E+00 0.          2.50000E-011051   40
 1.01200E+02 5.60000E-04 3.87000E-02 3.11000E-01 0.          2.50000E-011051   41
 1.03000E+02 1.74000E-03 3.87000E-02 8.37000E-02 0.          7.50000E-011051   42
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5.63048E+01 1.06882E+02 2.85362E+02 0.          0.          0.          1051 137
  NU-SIGMA FISSION                                                      1051 138
4.77300E+00 4.59365E+00 4.43070E+00 4.28343E+00 4.14961E+00 4.02892E+001051 139
3.92001E+00 3.82056E+00 3.73121E+00 3.64906E+00 3.57517E+00 3.50908E+001051 140
3.44869E+00 3.39353E+00 3.34610E+00 3.29954E+00 3.25761E+00 3.22097E+001051 141
3.18789E+00 3.15768E+00 3.13056E+00 3.10706E+00 3.08372E+00 3.06372E+001051 142
3.04702E+00 3.03040E+00 3.01397E+00 2.99909E+00 2.98683E+00 2.97572E+001051 143
2.96541E+00 2.95671E+00 2.94841E+00 2.94100E+00 2.93432E+00 2.92827E+001051 144
2.92266E+00 2.91792E+00 2.91310E+00 2.90894E+00 2.90533E+00 2.90195E+001051 145
2.89895E+00 2.89615E+00 2.89380E+00 2.89146E+00 2.88947E+00 2.88780E+001051 146
2.88611E+00 2.88334E+00 2.88039E+00 2.87809E+00 2.87630E+00 2.87491E+001051 147
2.87382E+00 2.87298E+00 2.87232E+00 2.87181E+00 2.87141E+00 2.87109E+001051 148
2.87085E+00 2.87066E+00 2.87052E+00 2.87040E+00 2.87031E+00 2.87024E+001051 149
2.87019E+00 2.87015E+00 2.87012E+00 2.87009E+00 2.87007E+00 2.87005E+001051 150
2.87004E+00 2.87003E+00 2.87003E+00 2.87002E+00 2.87002E+00 2.87001E+001051 151
2.87001E+00 2.87001E+00 2.87001E+00 2.87000E+00 2.87000E+00 2.87000E+001051 152
2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+001051 153
2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+00 2.87000E+001051 154
2.87000E+00 2.87000E+00 2.87000E+00 0.          0.          0.          1051 155
      N,GAMMA                                                           1051 156
1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-101051 157
1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-101051 158
1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-10 1.00000E-101051 159
1.00000E-10 1.00000E-10 5.89678E-09 4.32543E-06 3.15070E-03 2.06927E-021051 160
2.68750E-02 3.49039E-02 4.53301E-02 5.54210E-02 6.23618E-02 6.95824E-021051 161
8.05485E-02 9.09937E-02 9.96240E-02 1.04611E-01 1.13115E-01 1.25522E-011051 162
1.37292E-01 1.45763E-01 1.54625E-01 1.64422E-01 1.75347E-01 1.82614E-011051 163
1.87095E-01 1.92449E-01 1.99238E-01 2.06284E-01 2.11167E-01 2.13602E-011051 164
2.16080E-01 2.21679E-01 2.18351E-01 2.52109E-01 3.33481E-01 4.45611E-011051 165
5.61310E-01 6.72176E-01 7.85304E-01 9.02881E-01 1.02769E+00 1.14848E+001051 166
1.28500E+00 1.44332E+00 1.65978E+00 1.94342E+00 2.27646E+00 2.66774E+001051 167
3.14072E+00 3.91169E+00 3.91172E+00 3.89059E+00 9.40495E+00 5.72767E+001051 168
9.63408E+00 1.33000E+01 6.15011E+00 1.77765E+01 1.48741E+01 2.35977E+001051 169
2.84446E+01 5.29816E+01 6.23749E+01 3.40446E+00 2.77737E+01 2.89562E+011051 170
9.66288E+01 8.78835E+01 6.03944E+00 8.34226E+01 1.54518E+00 1.34092E+001051 171
1.44434E+00 2.53100E+00 4.77197E+00 7.15997E+00 1.02125E+01 1.45635E+011051 172
2.39518E+01 4.77387E+01 1.43887E+02 0.          0.          0.          1051 173
2.99051E+00 4.66284E-02 2.93518E+00 5.01042E-02 2.88305E+00 5.25110E-021051 174
2.87513E+00 5.60817E-02 2.96770E+00 6.10750E-02 3.15217E+00 6.80251E-021051 175
3.45096E+00 7.78406E-02 3.86410E+00 8.69445E-02 4.14599E+00 9.24338E-021051 176
4.32233E+00 9.41500E-02 4.37868E+00 9.51642E-02 4.40330E+00 9.50085E-021051 177
4.40442E+00 9.52811E-02 4.40779E+00 1.04895E-01 4.43305E+00 1.13864E-011051 178
4.45979E+00 1.21885E-01 4.44774E+00 1.26849E-01 4.38832E+00 1.31120E-011051 179
4.29571E+00 1.40104E-01 4.19381E+00 1.58725E-01 4.11720E+00 1.68848E-011051 180
4.07322E+00 1.77747E-01 4.02924E+00 1.87044E-01 4.03202E+00 2.05338E-011051 181
4.10915E+00 2.00954E-01 4.18269E+00 2.01716E-01 4.25896E+00 2.00440E-011051 182
4.37803E+00 2.04376E-01 4.56573E+00 2.37218E-01 4.78734E+00 2.42747E-011051 183
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CHAPTER 4

PROGRAMMER'S INFORMATION

This section contains many of the internal details of the program. The intent is that this section will provide the programmer with information that will prove helpful for making additions or modifications and also assist in making the program operational at other installations.

4.1 GENERAL PROGRAM DESIGN PHILOSOPHY

This program was written with the assumption that it would be used at many installations with a variety of computing machinery. Also it is not primarily a production program but one that will simply be used from time to time to generate new libraries or update old ones. Hence a basic aim was to produce straightforward, clear programming that would be readily understood. The program is entirely in ASA standard FORTRAN (FORTRAN IV) and uses no programming tricks and takes no advantage of any particular hardware or software. Also in the spirit of simplicity, variable dimensioning was not used.

The program was written with the expectation that there will be future additions and modifications. Some of these are anticipated with statement allocations and comments. Others are already wholly or partially included.

The main program is simply a series of tests and calls. It is quite straightforward and serves as a gross flow diagram. The flow is in a straight line with few deviations; hence, segmenting is readily accomplished. The program as distributed is segmented according to the overlay structure given in Section 4.3.

Many of the subroutines used by the program may be useful in other (present and future) codes connected with the ENDF/B system. Hence an attempt has been made to write these routines with general use in mind and they are self-contained (or nearly so). Some ETOG-1 subroutines may be replaced by similar routines from other ENDF/B codes when they become available.

Most of the data handling is done with large common storage blocks. All tape data are first read into these blocks before processing. Data manipulation is performed in these blocks. The blocks also serve as temporary storage for some processed results before final editing. These blocks are the device which permits the general purpose subroutines to be self-contained. At present there are 2 floating point blocks of length 4000. Associated with these are 2 fixed point blocks of length 100.

The logical flow of the program is designed so that the ENDF/B library tape will be scanned only once. Hence, the library tape is never backspaced, and is read forward only. Therefore, some data must be saved from the time they are first encountered on the library tape until such time as they are needed by the program. One such example is the scattering cross section which is saved on scratch tape ITPS and used at various times in the program. Certain other data are stored in /DENS/ of length 10000. For example, due to the frequency of the need, the weighting function (if other than constant) is stored as the first record in /DENS/.

The program will optionally produce MUFT-4, MUFT-5, GAM-I, GAM-II or ANISN library cards as part of the output. Therefore, after library data have been generated, they are stored and then recalled in the last part of the program when the cards are constructed and punched.

4.2 LABELED COMMON VARIABLES

The ENDF/B notation has been retained for variable names when possible. Hence more detailed explanations of the variables may be found in Reference 7. Connected with the ENDF/B data are control paramters to further define and describe the various sections of the ENDF/B information. Therefore, note that in addition to the large storage areas /RECS/ and /DENS/, there are common blocks /CONTF1/-/CONTF5/. The blocks /FILE3/-/FILE6/ are used to store the required information generated by the program. Other blocks are self-explanatory. In the following section, the labeled COMMON block name is given first and its general category described. The variables in

the block are then described in the same order as they appear in the block.

/TAPES/	literal tape names and data mode
MODE	mode of the ENDF/B library tape
I05	input tape
I06	output print tape
I07	output punch tape
NDFB	ENDF/B library tape
ITP1-ITP4	scratch tapes
/TAPUSE/	literal tape names
ITPR	contains resonance scattering data
ITPS	contains smooth scattering data
ITPE	contains elastic (resonance plus smooth) scattering data
/RECS/	single record storage*
MAT	material number
MF	file number
MT	reaction type number
C1, C2	floating point constants
L1, L2	integer constants (usually test numbers)
N1	count of items in a list to follow
N2	count of items in a second list to follow
NBT, JNT	general integer storage space (usually contain interpolation tables)
X,Y	general floating point storage space (usually contain point-wise data)
N1X	maximum length of the NBT and JNT arrays
N2X	maximum length of the X and Y arrays
NS	card sequence number

* This common block is part of the package of Retrieval Subroutines for the ENDF/B System written by H. C. Honeck (Reference 14). In ETOG-1, some of the array dimensions have been changed.

/DENS/	dense (multi-record) storage*
JMT	record identifier
JAT	record starting location
JTT	record type
JLT	record length
A	record bulk storage array
JNS, MNS	pointers for next record
JX	maximum length of the A array
MX	maximum length of the JMT, JAT, JTT, and JLT arrays
/BLOCK/	data storage area within an overlay (information in this area cannot be retrieved or manipulated within another overlay)
B	data bulk storage array
/BLOCKS/	data storage area within an overlay (information in this area cannot be retrieved or manipulated within another overlay)
B	data bulk storage array
/BLOKS/	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)
/CONTF1/	control information associated with File 1
ZA	material (Z,A) designation

* This common block is part of the package of Retrieval Subroutines for the ENDF/B System written by H. C. Honeck (Reference 14). In ETOG-1, some of the array dimensions have been changed.

AWR	atomic weight ratio
LRP	resonance indicator
LFI	fissile indicator
LDD	radioactive decay indicator
LFP	fission product indicator
NWD	number of (computer) words in material description
LNU	ν representation indicator
NC	number of ν polynomial terms
C	ν polynomial coefficients
NR1	interpolation table length
NP1	data list length

/CONTF2/	control information - File 2
NIS	number of isotopes
ZAI	isotope (Z,A) designation
ABN	abundance of isotope
LFW	fission width indicator
NER	number of energy ranges for isotope
LISR, LISRX	resolved scattering calculation indicators
EL	lower energy limit of a range
EH	higher energy limit of a range
LRU	data type indicator
LRF	resonance formula indicator
LISU, LISUX	unresolved scattering calculation indicators
SPIR	nuclear spin-resolved range
AP, AM, AA	scattering lengths
NLSR	number of ℓ states - resolved range
CR	penetration factor constant - resolved range
LR	ℓ - resolved range
NRS	number of resonances
SPIU	nuclear spin - unresolved range
NLSU	number of ℓ states - unresolved range
CU	penetration factor constant - unresolved range
NEX	number of points in fission width tabulation

LU	ℓ - unresolved region
NJS	number of J states
MUF	number of degrees of freedom in fission width tabulation
ELOR	lowest energy - resolved region
EHIR	highest energy - resolved region
ELOU	lowest energy - unresolved region
EHIU	highest energy - unresolved region
XPOTR	potential scattering - resolved region
XPOTU	potential scattering - unresolved region
LLRR	resolved data indicator
LLRU	unresolved data indicator
LFWX	fission width data indicator

/CONTF3/	control information - File 3
LFS	final state number
NR3	interpolation table length
NP3	data list length

/CONTF4/	control information - File 4
LVT	transformation matrix indicator
LTT	data form indicator
LCT	coordinate system indicator
NK4	number of elements in transformation matrix
NM4	number of columns in transformation matrix minus one
NRE4	length of E interpolation table
NE4	number of energy values
NL4	order of Legendre polynomial
NR4	length of interpolation table for tabulation
NP4	number of points in tabulation
E4	energy values at which secondary energy distributions are given

/CONTF5/	control information - File 5
NK	number of representations (subsections)

THETA	θ
LF	function representation indicator
NE	number of E values in $g(E' \leftarrow E)$ tabulation
NR5	interpolation table length
NP5	data list length
EINIT	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/ basic input (see input description)

/MOREIN/ input options (see input description)

KRES	resonance parameter or equivalent smooth data indicator for stacked cases

/OPTION/ input options (see input description)

MAXG1	MAXG+1
MAXG2	MAXG+2
MINR1	MINR+1
MINR2	MINR+2
MAXI1	MAXI+1
MAXI2	MAXI+2

/FLAGS/ program control indicators

KEY	data presence indicator
NOXS	elastic scattering cross section presence indicator
NOXIN	inelastic scattering cross section presence indicator

NON2N	n-2n cross section presence indicator
NOXF	fission cross section presence indicator
NONG	(n,γ) cross section presence indicator
NONP	(n,p) cross section presence indicator
NOND	(n,d) cross section presence indicator
NONT	(n,t) cross section presence indicator
NOHE	(n,He^3) cross section presence indicator
NONA	(n,α) cross section presence indicator
NON2A	$(n,2\alpha)$ cross section presence indicator
NOCAP	absorption cross section presence indicator
NOMU	$\bar{\mu}_\ell$ (average cosine of the scattering angle) presence indicator

/CONSTS/	data constants
EZERO	$1.0 * 10^7$
PI	π
HAFPI	$\pi/2$

/GROUPS/	group structure
EGRP	energy structure
UGRP	lethargy structure

/RESON/	resonance region variables
NRES	number of resolved resonances
NUNR	"acceptable" set of unresolved resonance parameters indicator
ECUT	cutoff energy between resolved and unresolved ranges
DLEV	unresolved mean level spacing
GNOBAR	average unresolved resonance reduced neutron width
GGBAR	average unresolved resonance capture width
GBAR	average unresolved resonance statistical spin factor
GOBAR	average unresolved resonance reduced neutron width
GAFBAR	average unresolved resonance fission width
RFACT	GAM-II r-factor
SFACT	GAM-II S-factor

WEAG	resonance statistical spin factor
ER	energy of resolved resonance
GAMN	resolved resonance neutron width
GAMG	resolved resonance capture width
GAMF	resolved resonance fission width
NROIM	narrow resonance or infinite mass approximation indicator
/RESCNT/	resonance indicator
NRIG	group critical resonance indicator
/EXTRAS/	resonance integral variables
CDTEUP	capture resonance integral due to the explicit unresolved parameters output for GAM-I or GAM-II
FDTEUP	fission resonance integral due to the explicit unresolved parameters output for GAM-I or GAM-II
G2CASBR	asymmetric contribution to GAM-II capture resonance integral below ENDF/B resolved energy region due to resolved resonances output for GAM-II
G2CASIR	asymmetric contribution to GAM-II capture resonance integral in ENDF/B resolved energy region due to resolved resonances output for GAM-II
G2FASBR	asymmetric contribution to GAM-II fission resonance integral below ENDF/B resolved energy region due to resolved resonances output for GAM-II
G2FASIR	asymmetric contribution to GAM-II fission resonance integral in ENDF/B resolved energy region due to resolved resonances output for GAM-II
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	$(n,2\alpha)$ resonance integral
ARRAY	total (resolved or unresolved plus smooth) (n,γ) cross section

/SMOOTH/	multigroup cross sections
XABS	absorption cross section
XFIS	fission cross section
XNU	average number of neutrons per fission
/TRANS/	elastic scattering calculation variables
AM1	A-1; A = atomic mass
AP1	A+1
ALPLG	log (α); $\alpha = \left(\frac{A-1}{A+1}\right)^2$
CFAL	1-α
AL	lower limit for outer integral
BU	upper limit for outer integral
CL	lower limit for inner integral
DU	upper limit for inner integral
NUPP1	NLENG+1
NLENG	highest order of non-zero Legendre expansion coefficients available for a group
A19	$2j + 1$; $j = 0, 1, \ldots$ NLENG
FBB	value of inner integral at any energy mesh point
FOLA	$\frac{2\ell+1}{1-\alpha}$; $\ell = 0, 1, 2, \ldots$
CX	components, $\sigma^{\ell}_{j,i}$, of transfer matrix
PLXMU	$P_{\ell}(\mu)$; ℓth order Legendre polynomial evaluated at μ
PLETA	$P_{\ell}(\eta)$; ℓth order Legendre polynomial evaluated at η
PLT1	coefficients in recursion formula for calculation of Legendre polynomials
PLT2	coefficients in recursion formula for calculation of Legendre polynomials
/PARAM/	elastic scattering calculation variables
NPE	number of mesh points used in calculating outer integral
XNPE	NPE-1; number of intervals used in calculating outer integral

NPEP	number of mesh points used in calculating inner integral
XNPEP	NPEP-1; number of intervals used in calculating inner integral
LPEP	number of mesh points used in calculating inner integral (in-group component only)
QLPEP	LPEP-1; number of intervals used in calculating inner integral (in-group component only)
NPIS	number of energy points for which elastic scattering cross sections are calculated for a particular group
NPIM	number of energy points for which Legendre expansion coefficients are calculated for a particular group
LOR1	highest order of scattering matrix desired plus one
NGROUP	source group number
/PLCOMP/	final elastic scattering matrix elements
P0	P_0 matrix elements for a particular source group
P1	P_1 matrix elements for a particular source group
P2	P_2 matrix elements for a particular source group
P3	P_3 matrix elements for a particular source group
/EXTRA/	matrix column sums
COLUMS	matrix column sums (e.g., inelastic and (n,2n))
/MATXL/	matrix dimensions
LOLIN	total number of elements in the inelastic matrix
LAIN	number of source groups from which inelastic scattering occurs
LDIN	number of groups into which inelastic downscattering occurs
LOL2N	total number of elements in the (n,2n) array
LA2N	number of source groups from which (n,2n) transfer occurs
LD2N	number of groups into which (n,2n) transfer occurs
LOLP0	total number of elements in P_0 matrix (GAM-I)
LAP0	number of source groups from which P_0 elastic scattering occurs (GAM-I)
LDP0	number of groups into which P_0 downscattering occurs (GAM-I)
LOLP1	total number of elements in P_1 matrix (GAM-I)
LAP1	number of source groups from which P_1 elastic scattering occurs (GAM-I)

LDP1	number of groups into which P_1 downscattering occurs (GAM-I)
LOLP	total number of elements in each P_ℓ, i.e., P_0, P_1, P_2, and P_3, matrix (GAM-II)
LAP	number of source groups from which P_ℓ elastic scattering occurs (GAM-II)
LDP	number of groups into which P_ℓ downscattering occurs (GAM-II)
LOL	total number of elements in composite transfer matrix
LA	number of source groups from which composite transfer occurs
LD	number of groups into which composite transfer occurs

/MUFT45/	output card construction variables
NFIL	file number
NCOD	MUFT material number
NGR	group number
NSEQ	sequence number
LAST	matrix column indicator
SIGN	constructed sign
IXP	constructed exponent
FRAC	constructed fraction

/INFO/	information for GAM punched output
ANID	alphanumeric identification for nuclide
NAOC	GAM-I library new addition or change indicator
LTOT	total number of entries in P_0, P_1, inelastic, and (n,2n) matrices and in the σ_f, σ_a, and ν tables
IWA	absorption cross section presence indicator
IWF	fission cross section presence indicator
IWR	resonance parameter presence indicator
NUMID	number of one-dimensional arrays present for nuclide

/ANISN/	
NC	card sequence number
NF	field number indicator

NUM	number of elements in array
KT	array element counter
IX	first subfield; integer or blank
JX	second subfield; operation indicator
FX	third subfield; numerical data
/FILE3/	(output for MUFT File 3) multigroup cross sections, slowing down and fission product parameters
XS	scattering cross section
XC	capture cross section
XIN	inelastic scattering cross section
XF	fission cross section
AGN	isotropic Greuling-Goertzel parameter (age number)
XSMU	anisotropic scattering cross section
GNU	ν
XSXI	isotropic slowing down power
ETA	anisotropic slowing down power
ZETA	anisotropic Greuling-Goertzel parameter (also used to store the group integral of the weight)
/FILE4/	(output for MUFT File 4) MUFT group resonance indicator
JRS	number of resonances in group
/FILE5/	(output for MUFT File 5) inelastic and (n,2n) matrices
PMX	probability and/or cross section matrix
DIAG	ingroup scatter
XTRA	out of matrix scatter
/FILE6/	(output for MUFT File 6) source spectrum
TRUM	source spectrum (also used for temporary storage)

4.3 OVERLAY STRUCTURE AND ROUTINE LIST

Following is a list of the programs, subroutines, and functions used by ETOG-1.

A brief summary of the purpose of each is included. The order of the list is the same as that of the physical deck. It is arranged by program segment; hence, this list also serves as the overlay structure description.

Overlay (0,0)

FLOW	controls flow of main program
ERR	prints error message
ERROR	prints error message*
STORE	stores record in dense storage*
FETCH	fetches record from dense storage*
DELETE	deletes record from dense storage*
ECSI	computes integral of y(x)*
GRATE	integrates TAB1 function*
COMB	combines two TAB1 functions*
COMBP	combines one panel of two TAB1 functions*
ADD	combining function for addition*
SUB	combining function for subtraction*
MULT	combining function for multiplication*
DIV	combining function for division*
TERP	interpolates between two points*
TERP1	interpolates one point*
TERP2	forms new table by interpolation*
LRIDS	locates record in dense storage*
FPDS	fetches point from dense storage*
LPDS	interpolates point in dense storage*
HOLL	reads hollerith material description
CONT	reads control (CONT) record
LIST	reads LIST record
TAB1	reads TAB1 record
TAB2	reads TAB2 record
TPOS	positions ENDF/B tape to file (MF) and reaction (MT)
XTND	extends data array
SAVE	writes or reads a scratch tape
TERPO	interpolates a data array

* This subroutine (or function) is part of the package of Retrieval Subroutines for the ENDF/B System written by H. C. Honeck (Reference 14).

GPAV	averages over selected groups
AVRG	averages over a selected energy range
OUT3	prints output (File 3 data)
XSP4	converts data to excess-50 format, punches MUFT-4 and MUFT-5

Overlay (1,0)

ETOG10	controls flow of program in overlay (1,0)
ININ	reads input
OUT0	lists input options selected
ZERO	initializes variables
EU	constructs group structure, weight, and weight averages
GENT1	generates TAB1 function
FISS	generating function for fission spectrum
TRID	reads ENDF/B tape I.D.
TMAT	positions ENDF/B tape to material (MAT)
TMF1	reads ENDF/B File 1
OUT1	prints output (input)

Overlay (2,0)

ETOG20	controls flow of program in overlay (2,0)
TMF2	reads ENDF/B File 2
RES0	calculates resonance parameters for GAM-I and GAM-II
RESS	calculates resolved resonance scattering
FACTR	calculates penetration and shift factors and phase shift
RESR	calculates resolved resonance parameters and low resonance effect
RESU	calculates unresolved resonance contribution

Overlay (3,0)

ETOG30	controls flow of program in overlay (3,0)
TMF3	reads ENDF/B File 3
CROS	calculates smooth cross sections
RESI	calculates infinitely dilute resonance integrals

Overlay (4,0)

ETOG40	controls flow of program in overlay (4,0)
TRAN	controls calculation of transfer elements, prints elastic scattering matrices

GRID	sets up lethargy mesh for integration
MVAL	evaluates inner integrand at an energy mesh value
DINT	performs double integration for matrix element
SINT	performs double integration for in-group matrix element (special case)
GADD	retrieves scattering cross sections and Legendre coefficients
TMF4	reads ENDF/B File 4
LECOM	establishes Legendre coefficients in center-of-mass coordinate system
LEGEND	fits Legendre coefficients to tabulated angular distributions

Overlay (5,0)

ETOG50	controls flow of program in overlay (5,0)
INF5	initializes File 5
TMF5	reads ENDF/B File 5
IMAT	calculates contributions to inelastic matrix
CWAX	combines weight and cross section
PUTW	restores weight to proper place
OUT5	prints output (File 5 data)
RENO	renormalizes inelastic matrix
SPEC	calculates source (fission) spectrum

Overlay (6,0)

ETOG60	controls flow of program in overlay (6,0)
POUT	punches output for MUFT
GOUT	prints and punches output for GAM

Overlay (7,0)

ETOG70	controls flow of program in overlay (7,0)
ANOUT	prints output for ANISN
ANPUN	punches output for ANISN
ANPUNF	punches last card

4.4 ERROR STOPS

If certain errors are detected, an error message will be printed. Some messages are printed directly by the routine in which they are detected.

Others are printed by one of the error printing subroutines. 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. Subroutine ERROR prints only the error number and the control words, MAT, MF, and MT. Following is a list of the error numbers, the subroutine which detects the error and an explanation of the error.

Error Number	Detecting Subroutine	Explanation
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

CHAPTER 5

ENVIRONMENT INFORMATION

The amount of core storage required by ETOG-1, associated system library functions, and the SCOPE 3.1 operating system is approximately $55{,}000_{10}$ locations. ETOG-1 uses four scratch tapes in addition to the mounted library tape. It also requires standard system input, output, and punch units. The program, written entirely in FORTRAN IV, should compile and execute properly on any configuration meeting these requirements.

CHAPTER 6
COMMENTS AND CONCLUSIONS

As indicated in the report, the present version of ETOG handles the job for which it was written quite well. However, suggestions may be made as to possible improvements in a future version of the code, particularly the generation of higher order terms of the elastic scattering transfer matrix. Where the analytic behavior of the cross section and weighting function is known it might be possible to include a semi-analytic treatment of the integrals. When pointwise resonance cross sections are generated, a test on linearity of points in the table might be incorporated to determine the interpolation scheme required between points and thus permit more accurate integration. Although the running time of the program will be increased appreciably, it is expected that cross sections generated for a given material will be valid for a year, perhaps; therefore, running time should not be the primary consideration.

In addition, modification of the current version of the code is required to permit treatment of a number of high energy reactions such as (n,3n), (n,n')α, (n,n')2α, etc. Presently, if cross sections above 10 Mev are required, the user should examine ENDF/B File 3 to determine whether this shortcoming will affect his output results.

Finally, comments should be made about modifications required to permit the handling of altered ENDF/B formats. Currently, in the resolved resonance region, only the Breit-Wigner single-level formula is assumed to hold. In the unresolved region, neutron and gamma widths are assumed to be energy-independent, while the fission widths may be tabulated as a function of energy. Also the total inelastic cross section, i.e., MT=4, is treated while components of the cross section, i.e., MT=5-15, are not handled. A considerable effort is required to extend the capabilities of the current version of the code.

CHAPTER 7

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