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ETOM-1: A FORTRAN IV PROGRAM TO PROCESS DATA FROM THE ENDF/B FILE TO THE MUFT FORMAT

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PHYSICS (TID-4500)

ETOM-1 - A FORTRAN IV PROGRAM TO PROCESS DATA FROM THE ENDF/B FILE TO THE MUFT FORMAT

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ABSTRACT

ETOM-1 is a digital computer program which processes basic nuclear data in the ENDF/B format and produces library data for the MUFT or P1MG programs. ETOM-1 is written entirely in ASA standard FORTRAN and is designed to be computer independent. Along with printed results, the output includes punched cards in the format appropriate to the desired library.

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1.0 INTRODUCTION

1.1 General Background

Most nuclear reactor programs require basic data in some form. The primary data needed for the physics programs, e.g., diffusion, depletion, transport, spectrum, shielding, etc., are neutron cross sections. This data is normally required as a program dependent library, the construction of which requires a basic evaluation of the cross sections. This evaluation should consider all experimentally measured data and the theories associated with it, the theories to fill the gaps where there is no experimental data and a careful examination of any existing libraries. Considering that a library may consist of 60 or more isotopes, this is an enormous task. Moreover it is a continuing task because there is an ever increasing volume of new data, new theories, new program requirements, and discovered deficiencies in older libraries.

Since most installations have only one or two persons responsible for library construction and maintenance, it is impossible for each installation to do a complete and correct evaluation. In the past the urgent need and shortage of time and manpower forced each laboratory to improvise as best it could. At times only a partial literature search was done, hence the best data may have been missed. Frequently existing libraries (or large sections thereof) were blindly used solely because they were available. Sometimes they were good; sometimes they were not.

This also led to an internal installation inconsistency. The basic data in one program might be different from that in another. This made program comparisons meaningless and provided a strong possibility of error if programs were used together in some integrated scheme.

But even more frustrating was the fact that a large duplication of effort existed. Many installations were doing evaluations but, because their results appeared in various forms, it was difficult to achieve effective communication and exchange of the results.

Recognizing these problems, the Division of Reactor Development and Technology (DRDT) of the Atomic Energy Commission (AEC) has enbarked on a plan involving the cooperative efforts of fifteen participating laboratories. The purpose of this effort is to produce a set of current evaluated data and to provide the necessary computer programs to effectively use and process that data.

The mechanism of the cooperative effort is through a Cross Section Evaluation Working Group (CSEWG) composed of members from the participating laboratories and coordinated by the National Neutron Cross Section Center at the Brookhaven National Laboratory. This is a working group initially concerned with the first set of data and computer programs but ultimately involved in a continuing effort to test, update, and refine the data and improve and extend the programs.

This data is known as the Evaluated Nuclear Data File (ENDF) and exists as two forms, ENDF/A (reference 6) and ENDF/B (reference 7). The A form allows duplication and fragmentation of evaluated data while the B form requires a complete and unique representation of each isotope. Since it is complete and self-consistent, the ENDF/B form is most useful for the construction of program libraries. Hence most of the computer programs process data in the ENDF/B form.

This report is a description of one of the processing programs, ETOM-1, which produces MUFT 4 (reference 2), MUFT 5 (reference 3), or PLMG (reference 4) library decks from the ENDF/B. (The name, ETOM, is the mnemonic for ENDF/B TO MUFT).

1.2 Prior Work

Before the initiation of the AEC effort, several laboratories had already started their own effort to construct an evaluated detailed cross section data file from which libraries could be constructed. The Bettis Atomic Power Laboratory was developing the ROC-1 (Repository of Cross Sections) system (reference 8). They also had developed some processing programs to use with the system. One such program, RAM-1 (reference 1), was used to process data from ROC-1 to produce decks for the MILC library used by MUFT 5 and P3MG (reference 5). Inasmuch as it deals with the same conceptual problem, ETOM-1 is based on RAM-1. It is hoped that the experience gained by RAM-1 users will be reflected in ETOM-1 such that it will be less restrictive yet retain the essential value of RAM-1.

1.3 Preliminary Version

A preliminary version of ETOM-1, designated ETOM, was distributed to the CSEWG participating laboratories in April, 1967. It was intended that ETOM be used to gain familiarity with the program and also to uncover any problems associated with its use on different computers. ETOM was deficient in that it had no low energy resonance treatment, it had an approximate 1/E weighting scheme and it performed only trapezoidal integrations. ETOM-1 is a logical extension of ETOM and does not have these deficiencies; hence, it is more accurate and less restrictive.

Many of the "general purpose retrieval subroutines" (reference 10) for the ENDF/B system written by H. C. Honeck are incorporated in ETOM-1, but were not in ETOM. These subroutines enable two tabular functions to be accurately combined and they also provide for exact (according to the specified interpolation schemes) integration of the functions. They also facilitate in the internal

generation of a weighting function and provide the mechanism by which the 1/E weighting can be made exact. The incorporation of these subroutines required substantial restructuring and some rewriting and modification of the program. Hence no attempt was made to periodically communicate the changes to the CSEWG. However when outright errors were discovered in ETOM, the corrections were sent to BNL for distribution to the CSEWG.

2.0 PROGRAM DESCRIPTION

2.1 General Information

In the remainder of the report, a limited knowledge of the MUFT codes and the ENDF/B structure is assumed. Some ENDF/B notation will be referred to without a detailed explanation. Likewise the meanings of the MUFT parameters will not be explained in detail but only the means of calculating them will be described.

The MUFT library quantities are a fixed requirement of the MUFT program; hence this serves as a defining constraint for ETOM-1. Where it is apparent that different procedures could be used to calculate the quantities, input options are provided to permit flexibility in the use of the ETOM-1 program.

The following notation is used in subsequent sections. A quantity without an argument (e.g., σ_{nn}) will denote a group averaged value. A quantity with an argument (e.g., $\sigma_{nn}(E)$) will represent a detailed energy description.

Obviously, average values are frequently needed by the program; they are usually calculated as

$$\sigma = \frac{\int \sigma(E)\, W(E)\, dE}{\int W(E)\, dE} \quad .$$

Here the integral is taken over the appropriate energy range (usually the multigroup) and W(E) is the weighting function which may be 1/E, constant at a value of 1.0, input, or a combination of 1/E joined to a fission spectrum. The present version of the program does the integration by using the specified interpolation schemes associated with the cross sections and the weighting function.

2.2 Smooth Cross Sections

The information required for MUFT file 3 is 8 sets of data consisting of multigroup cross sections, slowing down parameters, and the average number of neutrons per fission. The fission neutron yield is obtained from ENDF/B file 1 while most of the other needed data is in ENDF/B file 3. If the resonance representation requires a contribution to the smooth cross sections, data from ENDF/B file 2 will also be used.

2.2.1 Symmetric Scattering

The basic symmetric scattering is calculated as

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

where

$\sigma_{nn}(E)$ is obtained from ENDF/B file 3, MT=2.

If certain options are selected, a contribution may be added to the smooth symmetric scattering to account for resonance scattering (see sections 2.3 and 2.4), or ingroup inelastic scattering (see section 2.5). In addition to its use in calculating σ_{nn}, $\sigma_{nn}(E)$ is saved on a scratch tape for possible later use by the program (e.g., to calculate $\mu\sigma_{nn}$).

2.2.2 Smooth Capture

The basic smooth capture is calculated as

$$\sigma_{nc} = \sigma_{n\gamma} + \sigma_{np} + \sigma_{nd} + \sigma_{nt} + \sigma_{nHe3} + \sigma_{n\alpha} + \sigma_{n2\alpha}$$

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

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

where

σ_{nx} is obtained from ENDF/B file 3 tabulation.

For x = γ, the tabulation is MT = 102,

x = p, MT = 103

x = d, MT = 104

x = t, MT = 105

x = He^3, MT = 106

x = α, MT = 107

x = 2α, MT = 108

If certain resonance conditions exist, a resonance contribution will be added to the smooth capture (see sections 2.3 and 2.4).

2.2.3 Inelastic Scattering

The basic inelastic scattering is calculated as

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

where

$\sigma_{nn'}(E)$ is obtained from ENDF/B file 3, MT=4.

If certain options are selected, this quantity may be modified to account for ingroup inelastic scattering (see sections 3.4.12) or the n,2n treatment (see section 2.2.9). In addition to its use here, $\sigma_{nn'}(E)$ is saved for further use in the construction of the inelastic scattering probability matrix.

2.2.4 Smooth Fission

The basic smooth fission is calculated as

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

where $\sigma_{nf}(E)$ is obtained from ENDF/B file 3, MT=18.

If certain resonance conditions exist, a resonance contribution will be added to the smooth fission (see sections 2.3 and 2.4). If certain n,2n treatment options are selected, a contribution may be added to the smooth fission (see section 2.2.9).

2.2.5 Anisotropic Scattering

The anisotropic scattering is calculated as

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

where $\mu(E)$ is obtained from ENDF/B file 3, MT=251 and $\sigma_{nn}(E)$ is retrieved from the scratch tape. Note that the product $\mu(E)\, \sigma_{nn}(E)$ is formed before the integration is done.

If there is no $\mu(E)$ data on the ENDF/B tape then

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

where A is the atomic mass ratio, AWR, obtained from ENDF/B file 1.

2.2.6 Neutrons Per Fission

The average number of neutrons per fission is calculated as

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

where

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

and $\nu(E)$ is obtained from ENDF/B file 1, MT=452.

Note that the product is formed before the integration is done. If $\nu(E)$ is expressed as a polynomial, the product is formed by calculating ν at each E value in the $\sigma_{nf}(E)$ mesh. If a tabulation of $\nu(E)$ is given, the two tabulations ($\nu(E)$ and $\sigma_{nf}(E)$) are combined in the usual way.

If certain n,2n treatment options are selected, an adjustment to ν will be made (see section 2.2.9). If resonance fission widths are present (resolved or unresolved), then for the groups which contain ENDF/B resonance information, ν is calculated as

$$\nu = \frac{\int \nu(E)\,\frac{dE}{E}}{\int \frac{dE}{E}}$$

This is not a serious approximation since ν is very nearly constant over the resonance region and a detailed calculation of σ_{nf} from resonance parameters is not justified.

2.2.7 Isotropic Greuling Goertzel Parameters

This is called the "age number" by MUFT and may be calculated as

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

where $\gamma(E)$ is obtained from ENDF/B file 3, MT=253. If ENDF/B data is not present for MT=253, or by selecting an input option, the "age number" is calculated as

$$\gamma = 0.5 \quad \Delta u$$

where Δu is the group lethargy width.

2.2.8 Isotropic Slowing Down Power

The isotropic slowing down power is calculated as

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

where $\xi(E)$ is obtained from ENDF/B file 3, MT=252, and $\sigma_{nn}(E)$ is retrieved from the scratch tape. Note that the product $\xi(E)\, \sigma_{nn}(E)$ is formed before the integration is done. If there is no $\xi(E)$ data on the ENDF/B tape then

$$\xi\, \sigma_{nn} = \frac{2}{A + \frac{2}{3}} \quad \sigma_{nn}$$

where A is the atomic mass ratio, AWR, obtained from ENDF/B file 1.

2.2.9 Treatment of the n-2n Reaction

Since MUFT has no explicit treatment of the n-2n reaction, 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 3.4.11 for further detail.

2.3 Resolved Resonance Treatment

MUFT has an explicit treatment for resolved resonances. This treatment requires factors involving the resonance parameters rather than the parameters themselves. For each resolved resonance the MUFT library requires

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

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

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

The r and m factors constitute MUFT file 4. If $\Gamma_f \neq 0$, the α factors are also part of file 4 of MUFT 4. (For MUFT 5, the α factors are called MUFT file 5). ETOM-1 calculates these parameters and determines the proper group for each resolved resonance.

There is a MUFT restriction of a maximum of 8 resonances in any one group. If this restriction is exceeded, certain options are provided to treat the "extra" resonances. In all options the "extra"

resonances are those which contribute least to the infinite dilute resonance integral. For details of the options see section 3.4.8.

The MUFT treatment implicitly assumes that the entire resonance effect is in the multigroup where the resonance peak occurs. Thus, resonances below the multigroup energy structure (thermal and negative energy resonances) are not handled as explicit resonances by MUFT. Hence ETOM-1 treats these resonances separately. The cross sections due to these resonances are calculated at 100 equal lethargy spaced points in each resolved resonance group. These values are then averaged with the weighting function to get the contribution which is added to the smooth cross sections. In calculating the cross section, the Breit-Wigner single level formulation is used:

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

where R is designated as AP in ENDF/B

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

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

where

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

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

ETOM-1 contains an optional treatment of the resonance scattering (see section 3.4.14). If the scattering cross section is to be taken as the potential scattering, then σ_n is not calculated in the low resonance treatment.

If the resolved resonance scattering is to be added to the smooth scattering cross section, some care must be taken in the calculation. Simply taking a mesh of equal lethargy spacing would very likely miss an entire resonance or its principal contribution. Therefore, a fine mesh has to be constructed for each group. The spacing of the mesh is variable and depends on the resonances contained in the group. This fine mesh is presently constructed by considering the N resonances within the group plus the nearest one on each side of the group. Each interior resonance is then allotted 400/(N+1) points. Half of the allotted points go from $(E_o - \frac{\Gamma}{2})$ to $(E_o + \frac{\Gamma}{2})$ with equal energy spacing. The other half (also with equal energy spacing) go from $E_o \pm \frac{\Gamma}{2}$ to the mid-point between resonances. The two resonances on each side of the group, are each allotted 200/(N+1) points, half of which go from E_o to $E_o \pm \frac{\Gamma}{2}$ and the other half from $E_o \pm \frac{\Gamma}{2}$ to the midpoint. The complete mesh is thus taken from the peak of the first resonance below the group to the peak of the first resonance above the group. Once this mesh is constructed, the resonance scattering cross section is calculated at each point as the sum over all resonances (not just those in the group) using the above formula for σ_n. This fine mesh representation is then averaged with the weighting function to produce the resonance scattering contribution which is added to the smooth scattering cross section.

2.4 Unresolved Resonance Treatment

There is no special treatment of unresolved resonance information in MUFT. Since unresolved data may be given in ENDF/B, ETOM-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 (ref. 9)

*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.

where effective resonance cross sections are evaluated at discrete energy points, E*, in the unresolved region.

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

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

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

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

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 ETOM-1 is not primarily a mixture dependent program, there is no way for ETOM-1 to calculate σ_p internally. Hence, the quantity $(\sigma_p - 4\pi R^2)$ is designated as an input item. (ETOM-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. The temperature and actual heterogeneous effects should be accounted for by the use of the L-factor in MUFT.

ETOM-1 calculates the capture, fission and scattering cross sections at 100 equal lethargy spaced 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.

2.5 Inelastic Matrix 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 (ref. 7, page 12.4) that inelastic data be given as discrete levels (LF=3) plus a Maxwellian distribution (LF=8 or 9), ETOM-1 will handle LF = 3,6,7,8,9, and 10. The other distributions (LF = 1,2,4, and 5) are simply 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

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

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

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

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

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

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

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

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

Thus the product is the desired result; namely

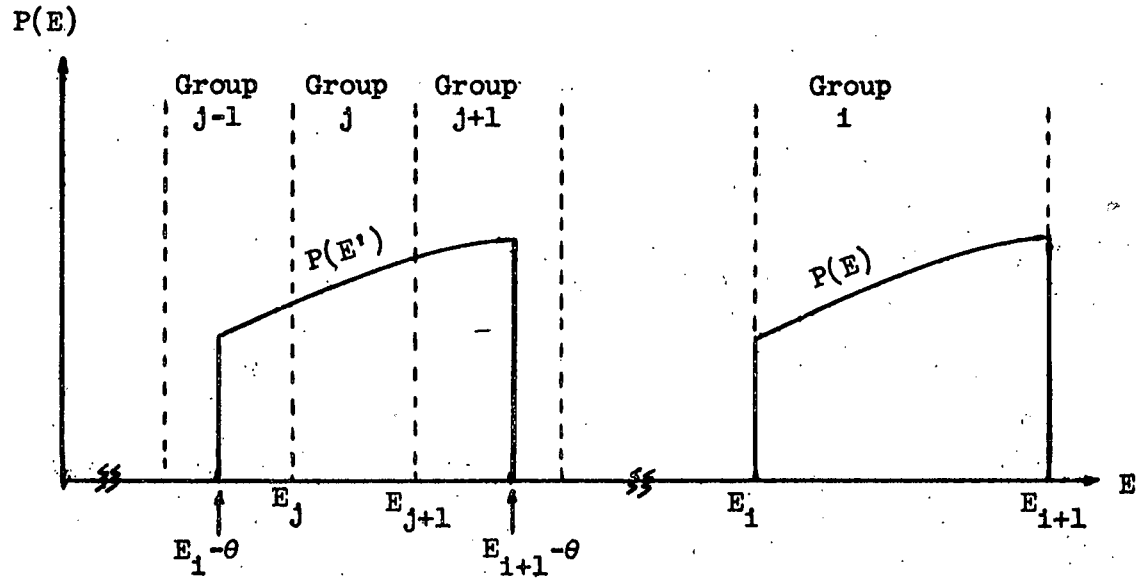
$$\sigma_{in}^{i} * P_{in}^{i \to j} = \frac{\int \sigma_{in}(E)\, W(E)\, dE}{\int W(E)\, dE} * \frac{\int P_{in}^{i \to j}(E)\, \sigma_{in}(E)\, W(E)\, dE}{\int \sigma_{in}(E)\, W(E)\, dE}$$

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

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:



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, $P_{in}^{i \rightarrow j}$, is then calculated as:

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

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

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

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

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

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

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

The preceding descriptions are for each LF subsection of the secondary energy distribution. All subsections are combined to 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, ingroup scattering (see section 3.4.12) and out of matrix scattering (see section 3.4.13), the renormalization is essential.

2.6 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, ETOM-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, ETOM-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.)

3.0 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

ETOM-1 is a program to process data from the ENDF/B file and produce library decks for MUFT 4 or MUFT 5. The output from ETOM-1 consists of printed tabulations of the data and 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 Multigroup Restrictions

1) Maximum number of multigroups - 99
2) Maximum number of resonances per group - 8
   (NOTE: This is a MUFT restriction, not at ETOM limit)
3) Maximum total number of resolved resonances - 250
4) Maximum inelastic group number - 99
5) Minimum resonance group number - 1

3.2.2 ENDF/B Data Restrictions

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 - 50.

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 - 3
4) Maximum number of points in the fission width tabulation - (900)/(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 - 50.

3.2.2.4 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 total number of points in all $g(E' \leftarrow E)$ tabulations per subsection - 2000.
4) Maximum number of interpolation ranges for E per subsection - 10.
5) Maximum number of interpolation ranges for $g(E' \leftarrow E)$ per subsection - 30.
6) Maximum number of points in the g(x) tabulation per subsection - 2000 for LF=4; - 1000 for LF=5.
7) Maximum number of interpolation ranges for g(x) per subsection - 20 for LF=4; - 10 for LF=5.
8) Maximum number of points in the θ(E) tabulation per subsection - 1000.
9) Maximum number of interpolation ranges for θ(E) per subsection - 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 - 50.

3.3 Input Description

In the following input list, the various items are described and the columns to be used for each item 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 next section.

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

Item	Cols.	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 ETOM-1 1 = ENDF/B tape is rewound by ETOM-1
5	41-50	EPSMIN	Minimum value of epsilon for combining two TAB 1 functions
6	51-60	EPSMAX	Maximum value of epsilon for combining two TAB 1 functions
7	61-70	SIGP	Non-resonance isotope potential scattering cross section per absorber atom. i.e., $SIGP = \left(\frac{\Sigma_p}{N} - 4\pi R^2\right)$ where Σ_p is the mixture macroscopic potential cross section, N is the resonance isotope number density and $4\pi R^2$ is the resonance isotope potential scattering.

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

Item	Cols.	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 1.0 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.
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	Cols.	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	Out of defined matrix inelastic scattering 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 interpolation tables defining the interpolation scheme to be used with the tabulated points. The weighting function must be given from low to high in energy. The format of the card set is a standard ENDF/B TAB 1 record.

Card 4.1 (44X, 2I11)

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

Card 4.2 - .... (6I11)

Item	Cols.	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.
⋮			
etc.			
2*N1-1		NBT(N1)	Last point number in N1 interpolation range.
2*N1		JNT(N1)	Interpolation scheme for the N1 range.

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

Item	Cols.	Name	Description
1	1-11	BLOK3(1)	First energy point ($\leq$ lowest energy in group structure).
2	12-22	BLOK4(1)	Weight at this energy.
⋮			
etc. using N2/3 cards			
⋮			
2*N2-1		BLOK3(N2)	Last energy point ($\geq$ highest energy in group structure
2*N2		BLOK4(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 consists of the desired group structure. If IEU=6, the set is the energy breakpoints of the structure given from low to high in energy. If IEU=7, the set is the lethargy breakpoints of the structure given from high to low in lethargy.

Card 5.1 (6E11.4)

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

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

3.4 Available Options

3.4.1 Read input option (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 with the first case (INALL=1) and subsequent cases need only the first card (INALL=0).

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

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

3.4.4 Multigroup code option (MCODE). Since the actual processing is the same for both MUFT 4 and MUFT 5, this option merely controls the output card format.

3.4.5 Multigroup structure option (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.

3.4.6 Weighting function option (IW). This option permits the weighting functions to be 1/E, 1.0, input or a combination of 1/E joined to a U-235 fission spectrum. Other built-in functions can be easily added in the future.

3.4.7 Spectrum calculation option (ISPEC). ETOM-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).

3.4.8 Resolved resonance treatment (IRES). Since MUFT permits only 8 resolved resonances per group, some provision must be made for those groups which have more than 8 resolved resonances. Two choices are provided.

For IRES=1: All m values are calculated. The 8 largest m resonances 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.

(The relationship preserves the infinite dilute resonance integral values).

For IRES=2: All m values are calculated. The 7 largest m resonances are kept and included in the MUFT resonance file. A pseudo-resonance is constructed as the 8th and included in the MUFT resonance file. The m, r, and α factors for this pseudo-resonance are calculated as

$$m_8 = \Sigma\, m$$

$$r_8 = \left(\frac{m_8}{\Sigma\, (\frac{m}{\sqrt{r}})} \right)^2$$

$$\alpha_8 m_8 = \Sigma\, m\, (\frac{\Gamma_f}{\Gamma_\gamma + \Gamma_f})$$

where the sums are over all non-kept resonances.

3.4.9 Output punch option (IPUN). This option merely selects whether or not the results should be punched out on cards. The output cards are in the correct format for direct use in constructing a MUFT 4 library or a MUFT 5 (MILC) library.

3.4.10 Greuling-Goertzel parameter option (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.

3.4.11 n-2n cross section option (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 and 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

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

3.4.12 Ingroup inelastic scattering option (INTO). MUFT does not permit ingroup inelastic scattering, hence three options are provided.

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 and reducing the inelastic accordingly.

3.4.13 Out of defined matrix inelastic scattering (IEXT). The limits of the inelastic matrix are defined by MAXI. Since there may be some inelastic scatter to groups greater than MAXI, three options are provided for treating this scatter.

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).

3.4.14 Resonance scattering option. Physically the scattering consists of a smooth part and a resonance part. MUFT has no explicit treatment of resonance scattering. Scattering is only present 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 results. Likewise, if the total ENDF/B description is used, i.e.,

*** Private communication with D. R. Harris, BAPL and C. Lubitz, KAPL.

smooth and resonance or smooth only depending on the ENDF/B control parameter (LIS), the resonance part may not be ignored. Hence three options are provided:

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

For IXSR=1: Over all groups containing 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: Over all groups containing 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.

3.5 Problem Stacking Procedure

ETOM is designed to sequentially process 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.

3.6 Sample Problem Input

The sample problem processes the data for ENDF/B material number 1051 (reference 12) and produces a MUFT-4 deck. The 1051 data is that present on ENDF/B tape (identification number) 115 with one exception. Card number 900 was corrected by changing the first entry from $1.0*10^{-4}$ to $8.0*10^{3}$ and the fourth entry from 0.0 to 1.0, thus making $p_1(E)$ double values (0.0 and 1.0) at the threshold energy $8.0*10^{3}$. This correction is necessary to assure the proper unit probability. That is, using the notation on page 9.1 of reference 7, the following should be true*:

$$\sum_{k=1}^{NK} p_k(E) \begin{cases} = 1.0 \text{ for all E where } \sigma(E) \neq 0.0 \\ \\ = 0.0 \text{ for all E where } \sigma(E) = 0.0 \end{cases}$$

Material 1051 is Pu-239 and was chosen because its resonance representation shows several of the features of ETOM-1. The sample input sheet is given on the next page.

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* It is suggested that this condition should be included as part of the data checking code CHECKER (reference 13).

WESTINGHOUSE
FORM 32950

CODING FORM [redacted]

TITLE SAMPLE PROBLEM FOR WCAP 3688-1 / ENDF 113 ANALYST DANNELS - KUSNER DATE APRIL 1968

JOB NO. MATERIAL 1051 PU-239 LS. NO. _____ LABEL 73—76 _____ SHEET 1 OF 1

SYMBOL		OR		ADDRESS, TAG, DECREMENT	REMARKS	NO.
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		77 78 79 80
1	1	1051		21 1 .0001 .0026 1.0E+07		
115		3		4 54 4 4 0 1 1 11		
26		25		3 2 3 3 2		

35

3.7 Sample Problem Output

The sample problem was run on a CDC-6600 using the SCOPE 2.0 operating system. The output is on the following pages and is self explanatory.

*** ETOM ***

MUFT 4 FILE 21 HAS BEEN CREATED FROM ENDF/B MATERIAL 1051 ON TAPE 115

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

THE STANDARD 54 GROUP MUFT STRUCTURE IS GENERATED INTERNALLY

WEIGHTING FUNCTION IS 1/E JOINED TO A FISSION SPECTRUM

EXTRA RESONANCES ARE ADDED TO SMOOTH CROSS SECTION

THE GRUELING-GOERTZEL PARAMETER IS TAKEN EQUAL TO HALF THE GROUP LETHARGY WIDTH

THE N-2N CROSS SECTION IS ADDED HALF TO FISSION, HALF TO INELASTIC

THE INGROUP INELASTIC SCATTERING IS ADDED TO THE SMOOTH SCATTERING

THE EXCESS SCATTER IS LUMPED INTO THE HIGHEST GROUP

THE RESONANCE SCATTERING IS TAKEN = TO VALUE IN IST GROUP ABOVE RESONANCE REGION

- - ENDF/B - -		- - MULTIGROUP - -		- - - - - GROUP INFORMATION - - - - -		
TAPE NO.	MATERIAL NO.	CODE	MATERIAL NO.	NUMBER	HIGHEST INELASTIC	LOWEST RESONANCE
115	1051	MUFT-4	21	54	25	26

MULTIGROUP STRUCTURE

GROUP	ENERGY RANGE	LETHARGY RANGE	GROUP	ENERGY RANGE	LETHARGY RANGE
1	7.7880E+06 - 1.0000E+07	0.000 - .250	28	1.2341E+03 - 2.0347E+03	8.500 - 9.000
2	6.0653E+06 - 7.7880E+06	.250 - .500	29	7.4852E+02 - 1.2341E+03	9.000 - 9.500
3	4.7237E+06 - 6.0653E+06	.500 - .750	30	4.5400E+02 - 7.4852E+02	9.500 - 10.000
4	3.6788E+06 - 4.7237E+06	.750 - 1.000	31	2.7536E+02 - 4.5400E+02	10.000 - 10.500
5	2.8650E+06 - 3.6788E+06	1.000 - 1.250	32	1.6702E+02 - 2.7536E+02	10.500 - 11.000
6	2.2313E+06 - 2.8650E+06	1.250 - 1.500	33	1.3007E+02 - 1.6702E+02	11.000 - 11.250
7	1.7377E+06 - 2.2313E+06	1.500 - 1.750	34	1.0130E+02 - 1.3007E+02	11.250 - 11.500
8	1.3534E+06 - 1.7377E+06	1.750 - 2.000	35	7.8893E+01 - 1.0130E+02	11.500 - 11.750
9	1.0540E+06 - 1.3534E+06	2.000 - 2.250	36	6.1442E+01 - 7.8893E+01	11.750 - 12.000
10	8.2085E+05 - 1.0540E+06	2.250 - 2.500	37	4.7851E+01 - 6.1442E+01	12.000 - 12.250
11	6.3928E+05 - 8.2085E+05	2.500 - 2.750	38	3.7267E+01 - 4.7851E+01	12.250 - 12.500
12	4.9787E+05 - 6.3928E+05	2.750 - 3.000	39	2.9023E+01 - 3.7267E+01	12.500 - 12.750
13	3.8774E+05 - 4.9787E+05	3.000 - 3.250	40	2.2603E+01 - 2.9023E+01	12.750 - 13.000
14	3.0197E+05 - 3.8774E+05	3.250 - 3.500	41	1.7603E+01 - 2.2603E+01	13.000 - 13.250
15	2.3518E+05 - 3.0197E+05	3.500 - 3.750	42	1.3710E+01 - 1.7603E+01	13.250 - 13.500
16	1.8316E+05 - 2.3518E+05	3.750 - 4.000	43	1.0677E+01 - 1.3710E+01	13.500 - 13.750
17	1.4264E+05 - 1.8316E+05	4.000 - 4.250	44	8.3153E+00 - 1.0677E+01	13.750 - 14.000
18	1.1109E+05 - 1.4264E+05	4.250 - 4.500	45	6.4760E+00 - 8.3153E+00	14.000 - 14.250
19	8.6517E+04 - 1.1109E+05	4.500 - 4.750	46	5.0435E+00 - 6.4760E+00	14.250 - 14.500
20	6.7379E+04 - 8.6517E+04	4.750 - 5.000	47	3.9279E+00 - 5.0435E+00	14.500 - 14.750
21	4.0868E+04 - 6.7379E+04	5.000 - 5.500	48	3.0590E+00 - 3.9279E+00	14.750 - 15.000
22	2.4788E+04 - 4.0868E+04	5.500 - 6.000	49	2.3824E+00 - 3.0590E+00	15.000 - 15.250
23	1.5034E+04 - 2.4788E+04	6.000 - 6.500	50	1.8554E+00 - 2.3824E+00	15.250 - 15.500
24	9.1188E+03 - 1.5034E+04	6.500 - 7.000	51	1.4395E+00 - 1.8554E+00	15.500 - 15.754
25	5.5308E+03 - 9.1188E+03	7.000 - 7.500	52	1.1254E+00 - 1.4395E+00	15.754 - 16.000
26	3.3546E+03 - 5.5308E+03	7.500 - 8.000	53	8.3368E-01 - 1.1254E+00	16.000 - 16.300
27	2.0347E+03 - 3.3546E+03	8.000 - 8.500	54	6.2481E-01 - 8.3368E-01	16.300 - 16.588

*** ETOM ***

WEIGHTING FUNCTION
IS GENERATED AS FOLLOWS

ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT	ENERGY	WEIGHT
61.8564E-02	63.8353E-06	67.3795E+03	19.3415E-08	92.4610E+03	22.2151E-08	12.3813E+04	25.0816E-08
23.3545E+04	31.6025E-08	30.2127E+04	34.0592E-08	36.2137E+04	35.5715E-08	42.2146E+04	36.6374E-08
48.2156E+04	37.3521E-08	54.2165E+04	37.7845E-08	61.7177E+04	38.0069E-08	69.2189E+04	37.9471E-08
78.5954E+04	37.5644E-08	87.9719E+04	36.9199E-08	99.6925E+04	35.8455E-08	11.4343E+05	34.2158E-08
13.2657E+05	31.9159E-08	17.8440E+05	25.8342E-08	20.1332E+05	22.9249E-08	24.7116E+05	17.7258E-08
28.1454E+05	14.4449E-08	31.5791E+05	11.6833E-08	35.8714E+05	88.8802E-09	40.1636E+05	67.1297E-09
45.5289E+05	46.8923E-09	50.8941E+05	32.5275E-09	57.6007E+05	20.4329E-09	64.3073E+05	12.7481E-09
72.6906E+05	70.1541E-10	81.0738E+05	38.3489E-10	91.5528E+05	17.8915E-10	10.1000E+06	89.4694E-11

WEIGHTING FUNCTION
INTERPOLATION TABLE

NBT	JNT	NBT	JNT	NBT	JNT	NBT	JNT
2	5	4	5	12	3	19	2
21	3	32	4				

*** ETOM ***

```
THE (TAPE) DESCRIPTION OF MATERIAL  1051 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, 17, AND 18 VALUES - ABOVE 3 MEV SMOOTH AGREES WITH CURVE IN REF 19.

MT=27 SUM OF FISSION AND (N,GAMMA) CROSS SECTIONS

MT=102 OBTAINED FROM FISSION CROSS SECTIONS AND ALPHA VALUES IN THE FOLLOWING WAYS - FROM 1 EV TO 30 KEV (N,GAMMA) FROM SMOOTH FISSION AND STATISTICAL S-WAVE ALPHA VALUE, SMOOTH SUPPLEMENTS RESONANCE CONTRIBUTION - FROM 30 KEV TO 100 KEV ALPHA DETERMINED FROM SMOOTH PLUS RESONANCE (N,GAMMA) OVER SMOOTH PLUS RESONANCE FISSION MADE TO AGREE WITH LINE THRU HOPKINS-DIVEN AND ORNL MEASURED VALUES, REF 20,21 - FROM 100 KEV TO 2 MEV SMOOTH (N,GAMMA) FROM SMOOTH FISSION AND ALPHA VALUES FROM REF 20,21 - ABOVE 2MEV CROSS SECTION IS ZERO

MT=251,252,253 MU-BAR(L-SYSTEM), XI, GAMMA CALCULATED BY CHAD

MF=4 ANGULAR DISTRIBUTIONS

MT=2 COEFFICIENTS IN C OF M AND TRANSFORMATION MATRIX GIVEN FOR 20 TH ORDER LEGENDRE POLYNOMIAL EXPANSION DATA FROM A1, REF 10

MF=5 ENERGY DISTRIBUTIONS

MT=4 FRACTIONS OF TOTAL INELASTIC CONTRIBUTED BY EACH OF 13 LEVELS UP TO 2 MEV - DISTRIBUTION ABOVE 2 MEV GIVEN BY EVAPORATION MODEL WITH ENERGY DEPENDENT TEMPERATURE - DATA FROM REF 11

MT=16,17 DISTRIBUTION GIVEN BY EVAPORATION MODEL WITH TEMPERATURES SLIGHTLY SMALLER THAN INELASTIC VALUES

MT=18 DISTRIBUTION GIVEN BY MAXWELLIAN WITH T=1.41 MEV, ACCORDING TO REF 22

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*** ETOM ***

RESOLVED
RESONANCE CALCULATION RESULTS

NO.	E-ZERO	GAMMA-N	GAMMA-G	GAMMA-F	GROUP	M	R	ALPHA
0	-12.0000E-01	84.5000E-05	39.0000E-03	20.1000E-02	0	0.	0.	0.
0	29.6000E-02	23.0000E-05	38.6000E-03	55.4000E-03	0	0.	0.	0.
1	78.3000E-01	87.0000E-05	40.6000E-03	41.5000E-03	45	27.6521E+00	26.0957E+02	50.5481E-02
2	10.9300E+00	18.2000E-04	31.5000E-03	14.6700E-02	43	29.6981E+00	18.0313E+02	82.3232E-02
3	11.9000E+00	10.7000E-04	40.9000E-03	22.0000E-03	43	14.6310E+00	27.2173E+02	34.9762E-02
4	14.2800E+00	55.0000E-05	38.7000E-03	52.5000E-03	42	52.7965E-01	82.1727E+01	57.5658E-02
5	14.6800E+00	22.0000E-04	38.7000E-03	31.7000E-03	42	19.4947E+00	39.4191E+02	45.0284E-02
6	15.5000E+00	23.7000E-04	38.7000E-03	76.0500E-02	42	64.5636E-01	12.4847E+01	95.1577E-02
7	17.6000E+00	16.0000E-04	39.1000E-03	46.3000E-03	42	99.8490E-01	20.1993E+02	54.2155E-02
8	22.2000E+00	22.3000E-04	31.3000E-03	75.0000E-03	41	87.2756E-01	17.8524E+02	70.5550E-02
9	23.9000E+00	87.0000E-05	38.7000E-03	37.1000E-03	40	29.6536E-01	92.4379E+01	48.9446E-02
10	26.2000E+00	17.8000E-04	38.7000E-03	35.7000E-03	40	49.8723E-01	17.1522E+02	47.9839E-02
11	27.3000E+00	13.0000E-05	38.7000E-03	28.0000E-04	40	34.2429E-02	22.4557E+01	67.4699E-03
12	32.3000E+00	86.0000E-05	38.7000E-03	18.9000E-02	39	53.9070E-02	76.1811E+00	83.0040E-02
13	35.3000E+00	31.0000E-05	38.7000E-03	41.0000E-04	39	48.6394E-02	39.8277E+01	95.7944E-03
14	41.4000E+00	60.7000E-04	59.2000E-03	10.7000E-03	38	64.1702E-01	34.9697E+02	15.3076E-02
15	44.5000E+00	63.4000E-04	27.8000E-03	42.0000E-04	38	52.6232E-01	61.0781E+02	13.1250E-02
16	47.6000E+00	54.0000E-04	38.7000E-03	30.1000E-02	38	15.4000E-01	21.2413E+01	88.6076E-02
17	49.8500E+00	44.0000E-05	59.8000E-03	75.0000E-02	37	11.6165E-02	71.4705E-01	92.6155E-02
18	50.2200E+00	30.4000E-04	41.3000E-03	11.2000E-03	37	22.4380E-01	20.2887E+02	21.3333E-02
19	52.6000E+00	10.0500E-03	39.3000E-03	77.0000E-04	37	58.9314E-01	54.3347E+02	16.3830E-02
20	55.7900E+00	14.3000E-04	26.0000E-03	22.0000E-03	37	87.8586E-02	99.1631E+01	45.8333E-02
21	57.6000E+00	17.0000E-03	38.7000E-03	54.6000E-02	37	32.6848E-01	31.2888E+01	93.3812E-02
22	58.0000E+00	12.0000E-03	38.7000E-03	80.5000E-02	37	23.0877E-01	15.6490E+01	95.4131E-02
23	59.3900E+00	55.9000E-04	48.6000E-03	13.3000E-02	37	30.2781E-01	96.0637E+01	73.2379E-02
24	61.1000E+00	22.4000E-03	38.7000E-03	20.0000E-01	37	38.9591E-01	11.5492E+01	98.1017E-02
25	63.4000E+00	19.4000E-04	38.7000E-03	13.9000E-03	36	91.6651E-02	10.6556E+02	26.4259E-02
26	65.9600E+00	12.5000E-03	22.4000E-03	77.0000E-03	36	50.2592E-01	29.6255E+02	77.4648E-02
27	74.3100E+00	32.7000E-04	36.6000E-03	29.5000E-03	36	11.1120E-01	11.9033E+02	44.6293E-02
28	75.2100E+00	22.1000E-03	44.9000E-03	95.0000E-03	36	66.4437E-01	30.8471E+02	67.9056E-02
29	82.0000E+00	62.0000E-04	38.7000E-03	15.0000E-01	35	60.2846E-02	31.9978E+00	97.4849E-02
30	85.3000E+00	86.7000E-04	38.7000E-03	20.0000E-01	35	77.8874E-02	32.4504E+00	98.1017E-02
31	85.6000E+00	30.7000E-04	38.7000E-03	21.6700E-02	35	81.5289E-02	27.0007E+01	84.8473E-02

32	90.9000E+00	24.7000E-04	38.7000E-03	11.4600E-02
33	95.5000E+00	93.4000E-05	38.7000E-03	23.0000E-02
34	96.0000E+00	92.0000E-04	38.7000E-03	14.0000E-01
35	97.6000E+00	18.0000E-04	38.7000E-03	36.0000E-02
36	99.0000E+00	93.5000E-04	38.7000E-03	20.0000E-01
37	10.1200E+01	56.0000E-05	38.7000E-03	31.1000E-02
38	10.3000E+01	17.4000E-04	38.7000E-03	83.7000E-03
39	10.5400E+01	58.7000E-04	38.7000E-03	10.2500E-02
40	10.6800E+01	80.0000E-04	34.9000E-03	33.1000E-03
41	11.0400E+01	93.3000E-05	38.7000E-03	31.0000E-04
42	11.6100E+01	33.4000E-04	27.0000E-03	18.8000E-02
43	11.8900E+01	14.7000E-03	52.3000E-03	65.7000E-03
44	12.1000E+01	28.0000E-04	38.7000E-03	35.3000E-03
45	12.3400E+01	53.0000E-05	23.1000E-03	51.0000E-03
46	12.6300E+01	18.7000E-04	50.0000E-03	32.2000E-03
47	12.7600E+01	53.0000E-05	38.7000E-03	21.5000E-02
48	13.1900E+01	34.8000E-03	38.7000E-03	37.4000E-01
49	13.3800E+01	53.4000E-04	27.6000E-03	11.4000E-03
50	13.5400E+01	40.0000E-05	38.7000E-03	92.7000E-03
51	13.6800E+01	32.0000E-04	38.7000E-03	26.5000E-03
52	14.3200E+01	73.3000E-04	38.7000E-03	53.4000E-03
53	14.6300E+01	78.4000E-04	54.2000E-03	14.2000E-03
54	14.8000E+01	13.3000E-04	38.7000E-03	91.0000E-04
55	14.9400E+01	14.7000E-04	51.3000E-03	36.5000E-03
56	15.7000E+01	34.8000E-03	38.7000E-03	70.4000E-02
57	16.0900E+01	60.0000E-04	38.7000E-03	50.8000E-02
58	16.4400E+01	25.4000E-03	40.2000E-03	11.8000E-03
59	16.6900E+01	57.0000E-04	38.7000E-03	47.7000E-03
60	17.0500E+01	88.0000E-04	38.7000E-03	12.6000E-01
61	17.5800E+01	21.0000E-04	32.9000E-03	43.9000E-03
62	17.7100E+01	39.0000E-04	62.2000E-03	70.0000E-04
63	17.8800E+01	13.0000E-04	38.7000E-03	14.6000E-03
64	18.5100E+01	14.0000E-03	38.7000E-03	17.5000E-01
65	19.0300E+01	16.0000E-04	38.7000E-03	11.8900E-02
66	19.5100E+01	49.6000E-03	38.7000E-03	33.7000E-02
67	19.6400E+01	50.7000E-04	58.5000E-03	68.9000E-03
68	19.9200E+01	89.5000E-04	21.6000E-03	12.5000E-02
69	20.3600E+01	18.7000E-03	38.7000E-03	29.8000E-02
70	20.7100E+01	67.0000E-04	38.7000E-03	11.3000E-03

35	57.9346E-02	33.8079E+01	74.7554E-02	
35	20.0976E-02	71.1823E+00	85.5973E-02	
35	65.1127E-02	43.1717E+00	97.3101E-02	
35	12.3483E-02	30.0921E+00	90.2935E-02	
35	62.3366E-02	30.1327E+00	98.1017E-02	
35	35.8361E-03	10.3541E+00	88.9334E-02	
34	31.8460E-02	26.4229E+01	68.3824E-02	
34	99.9028E-02	71.5969E+01	72.5921E-02	
34	12.3581E-01	17.3664E+02	48.6765E-02	
34	14.7457E-02	38.0954E+01	74.1627E-03	
34	48.0504E-02	25.5503E+01	87.4419E-02	
34	18.2085E-01	16.3150E+02	55.6780E-02	
34	36.2884E-02	57.1732E+01	47.7027E-02	
34	68.0551E-03	11.2528E+01	68.8259E-02	
34	22.5723E-02	33.9108E+01	39.1727E-02	
34	63.9703E-03	32.1072E+00	84.7458E-02	
33	13.0106E-01	45.0006E+00	98.9758E-02	
33	51.6664E-02	15.5908E+02	29.2308E-02	
33	42.8364E-03	44.0064E+00	70.5479E-02	
33	32.0981E-02	64.1962E+01	40.6442E-02	
33	65.2034E-02	93.9066E+01	57.9805E-02	
33	64.7159E-02	12.4186E+02	20.7602E-02	
33	11.6337E-02	35.0457E+01	19.0377E-02	
33	12.7560E-02	21.3482E+01	41.5718E-02	
33	88.5283E-02	17.8764E+01	94.7893E-02	
33	15.0483E-02	43.8081E+00	92.9212E-02	
33	12.4338E-01	26.4097E+02	22.6923E-02	
33	37.8030E-02	68.5052E+01	55.2083E-02	
32	19.7374E-02	25.7379E+00	97.0201E-02	
32	13.0249E-02	29.0214E+01	57.1615E-02	
32	23.1807E-02	56.1601E+01	10.1156E-02	
32	78.1723E-03	25.5993E+01	27.3921E-02	
32	26.6145E-02	27.3276E+00	97.8364E-02	
32	86.1323E-03	10.2958E+01	75.4442E-02	
32	75.5617E-02	34.6628E+01	89.6992E-02	
32	24.8936E-02	36.9072E+01	54.0816E-02	
32	41.8619E-02	53.6090E+01	85.2660E-02	
32	84.1632E-02	48.2150E+01	88.5061E-02	
32	27.1276E-02	99.0852E+01	22.6000E-02	

71	21.6300E+01	64.0000E-04	38.7000E-03	21.7000E-03	32	24.3578E-02	78.8711E+01	35.9272E-02
72	22.2800E+01	30.7000E-04	38.7000E-03	51.7000E-03	32	11.7792E-02	28.0774E+01	57.1903E-02
73	23.1100E+01	10.1000E-03	38.7000E-03	12.1000E-03	32	31.0655E-02	11.7886E+02	23.8189E-02
74	23.4000E+01	90.7000E-04	38.7000E-03	19.7000E-03	32	28.2350E-02	97.9249E+01	33.7329E-02
75	23.8700E+01	52.0000E-04	38.7000E-03	68.5000E-03	32	17.1410E-02	36.4018E+01	63.8993E-02
76	24.2600E+01	57.0000E-04	38.7000E-03	52.7000E-03	32	17.9527E-02	44.8541E+01	57.6586E-02
77	24.8500E+01	14.7000E-03	38.7000E-03	34.3000E-03	32	39.0210E-02	11.0567E+02	46.9863E-02
78	25.0900E+01	24.0000E-03	38.7000E-03	15.3000E-03	32	51.9780E-02	16.7196E+02	28.3333E-02
79	26.1800E+01	84.8000E-03	38.7000E-03	63.2000E-01	32	80.1479E-02	32.5642E+00	99.3914E-02
80	26.9200E+01	17.2000E-03	38.7000E-03	33.3000E-02	32	14.8909E-02	10.3076E+01	89.5884E-02
81	27.2300E+01	24.0000E-03	38.7000E-03	15.3000E-03	32	44.1291E-02	15.4056E+02	28.3333E-02
82	27.5200E+01	28.0000E-03	38.7000E-03	29.9000E-02	32	67.2322E-02	50.5942E+01	88.5401E-02
83	27.9100E+01	78.6000E-04	38.7000E-03	19.5000E-03	31	17.5064E-02	73.9637E+01	33.5052E-02
84	28.2500E+01	24.0000E-03	38.7000E-03	53.0000E-04	31	38.3203E-02	15.9198E+02	12.0455E-02
85	29.1800E+01	14.0000E-03	38.7000E-03	30.4000E-02	31	10.3695E-02	84.8281E+00	88.7073E-02
86	29.6000E+01	30.7000E-04	38.7000E-03	84.7000E-03	31	67.3536E-03	15.5185E+01	69.1388E-02
87	29.8100E+01	10.0000E-03	38.7000E-03	46.3000E-03	31	19.8281E-02	62.2186E+01	54.4706E-02

*** ETOM ***

RESOLVED
RESONANCE CALCULATION RESULTS
THE FOLLOWING CROSS SECTIONS ARE ADDED TO THE SMOOTH VALUES TO ACCOUNT FOR SURPLUS (MORE THAN 8 PER GROUP) RESONANCES AND/OR RESOLVED RESONANCE SCATTERING

GROUP	CAPTURE	FISSION	SCATTER	GROUP	CAPTURE	FISSION	SCATTER
1	0.	0.	0.	28	0.	0.	0.
2	0.	0.	0.	29	0.	0.	0.
3	0.	0.	0.	30	0.	0.	0.
4	0.	0.	0.	31	0.	0.	0.
5	0.	0.	0.	32	45.9167E-01	47.2080E-01	0.
6	0.	0.	0.	33	12.0631E-01	15.4081E-01	0.
7	0.	0.	0.	34	19.4614E-02	53.4926E-02	0.
8	0.	0.	0.	35	24.9182E-03	20.0247E-02	0.
9	0.	0.	0.	36	0.	0.	0.
10	0.	0.	0.	37	0.	0.	0.
11	0.	0.	0.	38	0.	0.	0.
12	0.	0.	0.	39	0.	0.	0.
13	0.	0.	0.	40	0.	0.	0.
14	0.	0.	0.	41	0.	0.	0.
15	0.	0.	0.	42	0.	0.	0.
16	0.	0.	0.	43	0.	0.	0.
17	0.	0.	0.	44	0.	0.	0.
18	0.	0.	0.	45	0.	0.	0.
19	0.	0.	0.	46	0.	0.	0.
20	0.	0.	0.	47	0.	0.	0.
21	0.	0.	0.	48	0.	0.	0.
22	0.	0.	0.	49	0.	0.	0.
23	0.	0.	0.	50	0.	0.	0.
24	0.	0.	0.	51	0.	0.	0.
25	0.	0.	0.	52	0.	0.	0.
26	0.	0.	0.	53	0.	0.	0.
27	0.	0.	0.	54	0.	0.	0.

*** ETOM ***

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.	28	0.	0.	0.
2	0.	0.	0.	29	0.	0.	0.
3	0.	0.	0.	30	0.	0.	0.
4	0.	0.	0.	31	18.6578E-07	85.4415E-07	0.
5	0.	0.	0.	32	26.7382E-06	12.2390E-05	0.
6	0.	0.	0.	33	66.0817E-06	30.2290E-05	0.
7	0.	0.	0.	34	12.2996E-05	56.2296E-05	0.
8	0.	0.	0.	35	22.8693E-05	10.4467E-04	0.
9	0.	0.	0.	36	42.4656E-05	19.3782E-04	0.
10	0.	0.	0.	37	78.7214E-05	35.8749E-04	0.
11	0.	0.	0.	38	14.5622E-04	66.2485E-04	0.
12	0.	0.	0.	39	26.8660E-04	12.1950E-03	0.
13	0.	0.	0.	40	49.4002E-04	22.3590E-03	0.
14	0.	0.	0.	41	90.4606E-04	40.7890E-03	0.
15	0.	0.	0.	42	16.4810E-03	73.9483E-03	0.
16	0.	0.	0.	43	29.8429E-03	13.3038E-02	0.
17	0.	0.	0.	44	53.6450E-03	23.7120E-02	0.
18	0.	0.	0.	45	95.6243E-03	41.7892E-02	0.
19	0.	0.	0.	46	16.8855E-02	72.6795E-02	0.
20	0.	0.	0.	47	29.5248E-02	12.4502E-01	0.
21	0.	0.	0.	48	51.1480E-02	20.9743E-01	0.
22	0.	0.	0.	49	87.9957E-02	34.7253E-01	0.
23	0.	0.	0.	50	15.1148E-01	56.5609E-01	0.
24	0.	0.	0.	51	26.2996E-01	91.3719E-01	0.
25	0.	0.	0.	52	46.7217E-01	14.6779E+00	0.
26	0.	0.	0.	53	29.4595E-01	84.6825E-01	0.
27	0.	0.	0.	54	0.	0.	0.

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.	28	32.7071E-01	51.3012E-01	0.
2	0.	0.	0.	29	45.1724E-01	67.7574E-01	0.
3	0.	0.	0.	30	61.7512E-01	89.1693E-01	0.
4	0.	0.	0.	31	69.3883E-01	97.3137E-01	0.
5	0.	0.	0.	32	0.	0.	0.
6	0.	0.	0.	33	0.	0.	0.
7	0.	0.	0.	34	0.	0.	0.
8	0.	0.	0.	35	0.	0.	0.
9	0.	0.	0.	36	0.	0.	0.
10	0.	0.	0.	37	0.	0.	0.
11	0.	0.	0.	38	0.	0.	0.
12	0.	0.	0.	39	0.	0.	0.
13	0.	0.	0.	40	0.	0.	0.
14	0.	0.	0.	41	0.	0.	0.
15	0.	0.	0.	42	0.	0.	0.
16	0.	0.	0.	43	0.	0.	0.
17	0.	0.	0.	44	0.	0.	0.
18	0.	0.	0.	45	0.	0.	0.
19	58.3476E-03	38.1513E-02	0.	46	0.	0.	0.
20	13.2674E-02	76.8476E-02	0.	47	0.	0.	0.
21	19.4442E-02	89.3941E-02	0.	48	0.	0.	0.
22	31.9666E-02	10.8462E-01	0.	49	0.	0.	0.
23	50.5784E-02	13.4536E-01	0.	50	0.	0.	0.
24	76.9970E-02	17.1649E-01	0.	51	0.	0.	0.
25	11.3811E-01	22.3358E-01	0.	52	0.	0.	0.
26	16.4564E-01	29.3689E-01	0.	53	0.	0.	0.
27	23.4036E-01	38.7437E-01	0.	54	0.	0.	0.

*** ETOM ***

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	6.5449E-08	8	9.3919E-03	9	3.3006E-02	10	5.6545E-02	11	7.7329E-02	12	1.0018E-01
13	1.2190E-01	14	1.4762E-01	15	1.7169E-01	16	1.8828E-01	17	2.0395E-01	18	2.1409E-01
19	1.6197E-01	20	8.8401E-02	21	9.8619E-02	22	1.8497E-01	23	2.2773E-01	24	2.0457E-01
25	9.4175E-02	26	-7.4252E-02	27	-2.0681E-01	28	-3.4022E-01	29	-5.5005E-01	30	3.6171E-01
31	-1.2370E+00	32	2.8852E-01	33	0.	34	0.	35	0.	36	0.
37	0.	38	0.	39	0.	40	0.	41	0.	42	0.
43	0.	44	4.6557E-02	45	1.9677E-01	46	3.2742E-01	47	4.5210E-01	48	4.4843E-01
49	1.1785E+00	50	2.7895E+00	51	4.0571E+00	52	5.0374E+00	53	1.1870E+01	54	2.8257E+01

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 103
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,P REACTION

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 104
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,D REACTION

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 105
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,T REACTION

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 106
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,HE-3 REACTION

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 107
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,ALPHA REACTION

NO DATA IN FILE 3 FOR MATERIAL 1051, REACTION TYPE 108
TAPE HAS BEEN SEARCHED TO MATERIAL 1051, FILE 3, REACTION TYPE 251
CONSEQUENTLY, THERE IS NO N,2*ALPHA REACTION

*** ETOM ***

MULTI-GROUP	SYMMETRIC SCATTERING	SMOOTH CAPTURE	INELASTIC SCATTERING	SMOOTH FISSION	ANISOTROPIC SCATTERING	NEUTRONS PER FISSION	ISOTROPIC G-G	ISOTROPIC SLOW-DOWN
1	32.3603E-01	10.0000E-11	92.4752E-02	24.7284E-01	26.6723E-01	39.4966E-01	12.5000E-02	52.6744E-04
2	40.6484E-01	10.0000E-11	13.3855E-01	20.8239E-01	32.1489E-01	37.4630E-01	12.5000E-02	73.9242E-04
3	44.6528E-01	10.0000E-11	15.1632E-01	18.7295E-01	34.7788E-01	35.8510E-01	12.5000E-02	85.5117E-04
4	45.0573E-01	10.0000E-11	13.7142E-01	19.2083E-01	34.4070E-01	34.3071E-01	12.5000E-02	92.0160E-04
5	45.7012E-01	10.0000E-11	12.3088E-01	19.8214E-01	32.4455E-01	33.0914E-01	12.5000E-02	11.3350E-03
6	44.9482E-01	10.0000E-11	11.6624E-01	20.3407E-01	29.3049E-01	32.1237E-01	12.5000E-02	13.2863E-03
7	43.0708E-01	65.4494E-09	10.8608E-01	19.8397E-01	23.6571E-01	31.3822E-01	12.5000E-02	16.4302E-03
8	42.2985E-01	93.9187E-04	99.1606E-02	18.6718E-01	19.3672E-01	30.7963E-01	12.5000E-02	19.3883E-03
9	43.6421E-01	33.0061E-03	89.7212E-02	17.9384E-01	18.6683E-01	30.3502E-01	12.5000E-02	21.0993E-03
10	46.4583E-01	56.5448E-03	78.7396E-02	17.2077E-01	20.0524E-01	29.9678E-01	12.5000E-02	22.3023E-03
11	51.5520E-01	77.3294E-03	76.1606E-02	16.5496E-01	20.7259E-01	29.6874E-01	12.5000E-02	24.0251E-03
12	57.5200E-01	10.0177E-02	73.6866E-02	15.9454E-01	20.7531E-01	29.4708E-01	12.5000E-02	31.0361E-03
13	65.3271E-01	12.1896E-02	67.1887E-02	15.1354E-01	21.0414E-01	29.3011E-01	12.5000E-02	37.3780E-03
14	73.0857E-01	14.7621E-02	56.8850E-02	14.8963E-01	21.8340E-01	29.1690E-01	12.5000E-02	43.2526E-03
15	79.4889E-01	17.1685E-02	48.1307E-02	14.8001E-01	22.3807E-01	29.0645E-01	12.5000E-02	48.2005E-03
16	86.3827E-01	18.8284E-02	43.1878E-02	14.8185E-01	17.1112E-01	28.9845E-01	12.5000E-02	58.4620E-03
17	91.5295E-01	20.3947E-02	37.9471E-02	15.0798E-01	13.3712E-01	28.9220E-01	12.5000E-02	65.9561E-03
18	95.0418E-01	21.4090E-02	33.9122E-02	15.2412E-01	10.2406E-01	28.8746E-01	12.5000E-02	71.5604E-03
19	95.0418E-01	22.0319E-02	30.2910E-02	15.3230E-01	74.8329E-02	28.8334E-01	12.5000E-02	73.8902E-03
20	95.0418E-01	22.1075E-02	27.1743E-02	14.7851E-01	56.9314E-02	28.8039E-01	12.5000E-02	75.3979E-03
21	95.0418E-01	29.3060E-02	24.5536E-02	14.6089E-01	38.5307E-02	28.7731E-01	25.0000E-02	76.9520E-03
22	95.0418E-01	50.4632E-02	22.7168E-02	16.0636E-01	23.9862E-02	28.7443E-01	25.0000E-02	78.1790E-03
23	95.0418E-01	73.3514E-02	20.3483E-02	18.1871E-01	15.5995E-02	28.7269E-01	25.0000E-02	78.8849E-03
24	95.0418E-01	97.4538E-02	13.2565E-02	20.7896E-01	10.5134E-02	28.7163E-01	25.0000E-02	79.3148E-03
25	95.0418E-01	12.3229E-01	84.9180E-04	24.1063E-01	74.2922E-03	28.7099E-01	25.0000E-02	79.5762E-03
26	95.0418E-01	15.7139E-01	0.	28.0929E-01	55.5799E-03	28.7060E-01	25.0000E-02	79.7311E-03
27	95.0418E-01	21.3355E-01	0.	35.2949E-01	44.2305E-03	28.7036E-01	25.0000E-02	79.8288E-03
28	95.0418E-01	29.3049E-01	0.	45.7512E-01	37.3468E-03	28.7022E-01	25.0000E-02	79.8880E-03
29	95.0418E-01	39.6719E-01	0.	59.5646E-01	33.1718E-03	28.7013E-01	25.0000E-02	79.9239E-03
30	95.0418E-01	65.3682E-01	0.	94.2569E-01	30.6392E-03	28.7008E-01	25.0000E-02	79.9457E-03
31	95.0418E-01	57.0183E-01	0.	86.4310E-01	29.1034E-03	28.7005E-01	25.0000E-02	79.9589E-03
32	95.0418E-01	48.8042E-01	0.	71.7556E-01	28.1717E-03	28.7003E-01	25.0000E-02	79.9670E-03
33	95.0418E-01	12.0637E-01	0.	15.4111E-01	27.7073E-03	28.7002E-01	12.5000E-02	79.9711E-03
34	95.0418E-01	19.4737E-02	0.	63.5489E-02	27.4921E-03	28.7002E-01	12.5000E-02	79.9729E-03
35	95.0418E-01	25.1469E-03	0.	20.1292E-02	27.3245E-03	28.7001E-01	12.5000E-02	79.9743E-03

*** ETOM ***

MULTI-GROUP	SYMMETRIC SCATTERING	SMOOTH CAPTURE	INELASTIC SCATTERING	SMOOTH FISSION	ANISOTROPIC SCATTERING	NEUTRONS PER FISSION	ISOTROPIC G-G	ISOTROPIC SLOW-DOWN
36	95.0418E-01	42.4656E-05	0.	19.3782E-04	27.1939E-03	28.7001E-01	12.5000E-02	79.9754E-03
37	95.0418E-01	78.7214E-05	0.	35.8749E-04	27.0923E-03	28.7001E-01	12.5000E-02	79.9763E-03
38	95.0418E-01	14.5622E-04	0.	66.2485E-04	27.0145E-03	28.7001E-01	12.5000E-02	79.9770E-03
39	95.0418E-01	26.8660E-04	0.	12.1950E-03	26.9526E-03	28.7000E-01	12.5000E-02	79.9775E-03
40	95.0418E-01	49.4002E-04	0.	22.3590E-03	26.9044E-03	28.7000E-01	12.5000E-02	79.9779E-03
41	95.0418E-01	90.4606E-04	0.	40.7890E-03	26.8668E-03	28.7000E-01	12.5000E-02	79.9782E-03
42	95.0418E-01	16.4810E-03	0.	73.9483E-03	26.8376E-03	28.7000E-01	12.5000E-02	79.9784E-03
43	95.0418E-01	29.8429E-03	0.	13.3038E-02	26.8148E-03	28.7000E-01	12.5000E-02	79.9786E-03
44	95.0418E-01	10.0202E-02	0.	95.1000E-02	26.7971E-03	28.7000E-01	12.5000E-02	79.9788E-03
45	95.0418E-01	29.2396E-02	0.	34.3505E-01	26.7833E-03	28.7000E-01	12.5000E-02	79.9789E-03
46	95.0418E-01	49.6270E-02	0.	54.3855E-01	26.7725E-03	28.7000E-01	12.5000E-02	79.9790E-03
47	95.0418E-01	74.7343E-02	0.	68.6701E-01	26.7641E-03	28.7000E-01	12.5000E-02	79.9791E-03
48	95.0418E-01	95.9906E-02	0.	86.6486E-01	26.7576E-03	28.7000E-01	12.5000E-02	79.9791E-03
49	95.0418E-01	20.5850E-01	0.	11.1188E+00	26.7525E-03	28.7000E-01	12.5000E-02	79.9792E-03
50	95.0418E-01	43.0098E-01	0.	14.4523E+00	26.7486E-03	28.7000E-01	12.5000E-02	79.9792E-03
51	95.0418E-01	66.8710E-01	0.	19.0086E+00	26.7455E-03	28.7000E-01	12.6900E-02	79.9792E-03
52	95.0418E-01	97.0961E-01	0.	25.4371E+00	26.7431E-03	28.7000E-01	12.3100E-02	79.9792E-03
53	95.0418E-01	14.8163E+00	0.	38.2610E+00	26.7411E-03	28.7000E-01	15.0000E-02	79.9793E-03
54	13.2362E+00	28.2572E+00	0.	67.5921E+00	37.2391E-03	28.7000E-01	14.4200E-02	11.1384E-02

INELASTIC SCATTERING PROBABILITY MATRIX
BEFORE RENORMALIZATION

EXIT GROUP								
2	56.6664E-05							
3	36.5145E-04	15.0749E-04						
4	14.2074E-03	74.8623E-04	35.6376E-04					
5	37.0851E-03	23.7004E-03	13.9620E-03	78.4312E-04				
6	70.6278E-03	52.5628E-03	36.6436E-03	24.4970E-03	15.5291E-03			
7	10.4927E-02	88.0385E-03	70.0875E-03	53.7526E-03	39.4551E-03	30.1748E-03		
8	12.8234E-02	11.8225E-02	10.4477E-02	89.2774E-03	73.5500E-03	61.8698E-03	45.9845E-03	
9	13.4460E-02	13.3472E-02	12.8024E-02	11.9094E-02	10.7464E-02	97.4148E-03	84.3188E-03	83.0214E-03
10	12.5045E-02	13.1521E-02	13.4519E-02	13.3763E-02	12.9618E-02	12.4613E-02	24.1485E-02	58.0289E-03
	24.3471E-02							
11	10.5869E-02	11.6506E-02	12.5303E-02	13.1273E-02	13.4516E-02	13.5423E-02	19.0952E-02	20.8586E-02
	68.4406E-03	32.2166E-02						
12	83.2917E-03	94.9601E-03	10.6223E-02	11.5918E-02	12.4051E-02	12.9519E-02	59.6420E-03	31.4834E-02
	60.8675E-04	16.8358E-02	30.1867E-02					
13	61.8801E-03	72.5239E-03	83.6534E-03	94.2463E-03	10.4400E-02	11.2086E-02	10.0647E-02	16.0945E-02
	11.6307E-02	24.8272E-04	16.7600E-02	40.8960E-02				
14	43.9619E-03	52.6459E-03	62.1970E-03	71.8393E-03	81.7322E-03	89.7054E-03	87.3284E-03	11.5782E-02
	80.7044E-03	0.	10.8859E-02	22.6654E-03	25.5826E-02			
15	30.1614E-03	36.7315E-03	44.2139E-03	52.0701E-03	60.4881E-03	67.5416E-03	62.8953E-03	0.
	15.7288E-02	0.	0.	11.6923E-02	74.2829E-04	32.4250E-02		
16	20.1377E-03	24.8478E-03	30.3486E-03	36.2868E-03	42.8441E-03	48.4871E-03	34.3076E-03	10.4734E-03
	86.7410E-03	17.0030E-03	0.	86.6685E-03	34.5737E-03	16.2216E-03	35.7625E-02	
17	13.1631E-03	16.4087E-03	20.2702E-03	24.5245E-03	29.3257E-03	33.5377E-03	30.9862E-03	14.5239E-03
	38.7352E-03	28.2626E-03	0.	14.0868E-03	51.5114E-03	49.9013E-04	52.7691E-03	31.0118E-02
18	84.6304E-04	10.6341E-03	13.2535E-03	16.1835E-03	19.5440E-03	22.5344E-03	20.3734E-03	89.0633E-04
	23.4427E-03	17.4649E-03	0.	0.	39.6870E-03	50.6214E-05	33.4536E-04	12.4278E-02
	23.2055E-02							
19	53.7156E-04	67.9154E-04	85.2307E-04	10.4823E-03	12.7568E-03	14.8027E-03	13.0013E-03	54.4905E-04
	14.3950E-03	10.7524E-03	0.	24.5343E-05	17.9212E-03	15.5943E-03	26.9492E-04	54.7458E-04
	15.6274E-02	20.7269E-02						
20	33.7532E-04	42.8827E-04	54.1060E-04	66.9168E-04	81.9276E-04	95.5396E-04	82.1274E-04	33.2772E-04
	88.1675E-04	65.9965E-04	0.	0.	72.5410E-04	17.1653E-03	15.2975E-04	46.4152E-05
	31.0215E-03	10.1140E-02	28.8473E-02					
21	34.0852E-04	43.5167E-04	55.2056E-04	68.6644E-04	84.5802E-04	99.1303E-04	83.4583E-04	32.6530E-04
	86.7768E-04	65.0998E-04	0.	0.	47.7027E-04	23.1670E-03	0.	29.4722E-04
	93.7862E-05	99.8055E-03	70.3528E-03	39.9328E-02				

INELASTIC SCATTERING PROBABILITY MATRIX
BEFORE RENORMALIZATION

EXIT GROUP								
22	12.9853E-04	16.6577E-04	21.2446E-04	26.5702E-04	32.9234E-04	38.7766E-04	32.0169E-04	12.0958E-04
	32.2435E-04	24.2435E-04	0.	0.	84.5799E-05	10.5987E-03	0.	14.1466E-04
	0.	61.5198E-04	59.3565E-03	20.1731E-03	30.1852E-02			
23	48.7943E-05	62.7757E-05	80.3202E-05	10.0793E-04	12.5344E-04	14.8067E-04	12.0869E-04	44.6866E-05
	11.9347E-04	89.8619E-05	0.	0.	31.6131E-05	37.6158E-04	29.7377E-05	34.6427E-05
	27.3332E-05	0.	78.5667E-04	30.5601E-03	0.	49.7506E-02		
24	18.1830E-05	23.4342E-05	30.0424E-05	37.7765E-05	47.0809E-05	55.7168E-05	45.1757E-05	16.4816E-05
	44.0696E-05	33.2113E-05	0.	0.	11.7448E-05	40.5444E-05	14.6644E-04	0.
	28.0958E-05	0.	24.3302E-04	10.4304E-03	13.8196E-04	0.	60.6524E-02	
25	67.4156E-06	86.9783E-06	11.1637E-05	14.0551E-05	17.5401E-05	20.7802E-05	16.7805E-05	60.7264E-06
	16.2492E-05	12.2520E-05	0.	0.	43.4644E-06	15.0222E-05	54.3928E-05	0.
	10.4821E-05	0.	0.	15.4020E-04	30.0867E-04	0.	21.3716E-02	25.4168E-02

MAIN DIAGONAL ELEMENTS (INGROUP SCATTER)

36.9921E-06	13.1027E-05	39.9635E-05	11.1595E-04	27.3162E-04	65.8280E-04	63.9843E-04	10.9370E-03
14.1801E-02	41.6483E-02	42.1683E-02	35.0426E-02	57.9650E-02	58.3068E-02	57.9408E-02	55.4971E-02
57.9023E-02	58.5635E-02	57.1511E-02	53.7023E-02	69.1946E-02	50.2494E-02	17.9748E-02	0.
0.							

SCATTER OUT OF MATRIX RANGE

39.4743E-06	50.9715E-06	65.4831E-06	82.5226E-06	10.3091E-05	12.2240E-05	10.0998E-05	35.6496E-06
45.3510E-06	13.6023E-05	0.	0.	25.4192E-06	88.1094E-06	31.9029E-05	0.
61.7181E-06	0.	0.	91.7727E-05	18.0571E-04	0.	0.	74.5832E-02

COLUMN SUMS
BEFORE RENORMALIZATION

10.0000E-01	10.0000E-01	99.9997E-02	99.9996E-02	10.0000E-01	10.0000E-01	10.0001E-01	99.9997E-02
99.9974E-02	99.9995E-02	10.0001E-01	99.9981E-02	99.9970E-02	99.9966E-02	99.9999E-02	10.0001E-01
10.0003E-01	10.0000E-01	99.9983E-02	99.9972E-02	99.9994E-02	10.0000E-01	99.9989E-02	10.0000E-01

INELASTIC SCATTERING PROBABILITY MATRIX
AFTER RENORMALIZATION

EXIT GROUP								
2	56.6685E-05							
3	36.5159E-04	15.0769E-04						
4	14.2079E-03	74.8721E-04	35.6520E-04					
5	37.0864E-03	23.7035E-03	13.9677E-03	78.5191E-04				
6	70.6304E-03	52.5697E-03	36.6584E-03	24.5244E-03	15.5716E-03			
7	10.4931E-02	88.0501E-03	70.1157E-03	53.8128E-03	39.5632E-03	30.3746E-03		
8	12.8239E-02	11.8241E-02	10.4519E-02	89.3775E-03	73.7595E-03	62.2795E-03	46.2802E-03	
9	13.4465E-02	13.3490E-02	12.8075E-02	11.9233E-02	10.7758E-02	98.0598E-03	84.8610E-03	83.9396E-03
10	12.5050E-02	13.1538E-02	13.4573E-02	13.3913E-02	12.9973E-02	12.5438E-02	24.3038E-02	58.6707E-03
	28.3709E-02							
11	10.5873E-02	11.6521E-02	12.5354E-02	13.1420E-02	13.4865E-02	13.6320E-02	19.2180E-02	21.0893E-02
	79.7515E-03	55.2115E-02						
12	83.2948E-03	94.9725E-03	10.8245E-02	11.6048E-02	12.4431E-02	13.0377E-02	60.0255E-03	31.8316E-02
	70.9268E-04	28.8525E-02	52.1967E-02					
13	61.8823E-03	72.5334E-03	83.6871E-03	94.3520E-03	10.4686E-02	11.2828E-02	10.1294E-02	16.2725E-02
	13.5529E-02	42.5479E-04	28.9801E-02	62.9609E-02				
14	43.9636E-03	52.6528E-03	62.2221E-03	71.9194E-03	81.9561E-03	90.2994E-03	87.8899E-03	11.7062E-02
	94.0420E-03	0.	18.8231E-02	34.8937E-03	60.8645E-02			
15	30.1625E-03	36.7363E-03	44.2317E-03	52.1285E-03	60.6538E-03	67.9889E-03	63.2997E-03	0.
	18.3283E-02	0.	0.	18.0005E-02	17.6729E-03	77.7767E-02		
16	20.1385E-03	24.8511E-03	30.3608E-03	36.3275E-03	42.9615E-03	48.8082E-03	34.5282E-03	10.5892E-03
	10.1076E-02	29.1391E-03	0.	13.3428E-02	82.2557E-03	38.9101E-03	85.0292E-02	
17	13.1636E-03	16.4108E-03	20.2783E-03	24.5520E-03	29.4060E-03	33.7598E-03	31.1855E-03	14.6846E-03
	45.1368E-03	48.4353E-03	0.	21.6868E-03	12.2553E-02	11.9697E-03	12.5464E-02	69.6827E-02
18	84.6336E-04	10.6355E-03	13.2588E-03	16.2016E-03	19.5976E-03	22.6837E-03	20.5044E-03	90.0484E-04
	27.3170E-03	29.9306E-03	0.	0.	94.4210E-03	12.1424E-04	79.5395E-04	27.9249E-02
	55.1188E-02							
19	53.7176E-04	67.9243E-04	85.2650E-04	10.4940E-03	12.7918E-03	14.9007E-03	13.0849E-03	55.0932E-04
	16.7740E-03	18.4270E-03	0.	37.7710E-05	42.6371E-03	37.4056E-03	64.0746E-04	12.3012E-03
	37.1189E-02	50.0207E-02						
20	33.7545E-04	42.8883E-04	54.1278E-04	66.9918E-04	82.1520E-04	96.1723E-04	82.6554E-04	33.6453E-04
	10.2739E-03	11.3102E-03	0.	0.	17.2585E-03	41.1738E-03	36.3715E-04	10.4294E-04
	73.6838E-03	24.4083E-02	67.3260E-02					
21	34.0864E-04	43.5224E-04	55.2278E-04	68.7414E-04	84.8119E-04	99.7868E-04	83.9949E-04	33.0141E-04
	10.1118E-03	11.1565E-03	0.	0.	11.3491E-03	55.5700E-03	0.	66.2233E-04
	22.2766E-04	24.0863E-02	16.4194E-02	86.2573E-02				

*** ETOM ***

INELASTIC SCATTERING PROBABILITY MATRIX
AFTER RENORMALIZATION

EXIT GROUP								
22	12.9858E-04	16.6599E-04	21.2531E-04	26.6000E-04	33.0136E-04	39.0334E-04	32.2227E-04	12.2296E-04
	37.5723E-04	41.5476E-04	0.	0.	20.1227E-04	25.4227E-03	0.	31.7870E-04
	0.	14.8467E-03	13.8531E-02	43.5751E-03	97.9885E-02			
23	48.7961E-05	62.7840E-05	80.3526E-05	10.0906E-04	12.5687E-04	14.9048E-04	12.1647E-04	45.1809E-05
	13.9071E-04	15.4002E-04	0.	0.	75.2119E-05	90.2277E-04	70.7044E-05	77.8413E-05
	64.9232E-05	0.	18.3365E-03	66.0118E-03	0.	10.0000E-01		
24	18.1836E-05	23.4373E-05	30.0544E-05	37.8189E-05	47.2099E-05	56.0857E-05	45.4661E-05	16.6639E-05
	51.3529E-05	56.9161E-05	0.	0.	27.9424E-05	97.2525E-05	34.8661E-04	0.
	66.7346E-05	0.	56.7837E-04	22.5303E-03	44.8616E-04	0.	73.9447E-02	
25	10.6894E-05	13.7968E-05	17.7192E-05	22.3324E-05	27.9256E-05	33.2228E-05	27.0531E-05	97.4419E-06
	24.2193E-05	44.3081E-05	0.	0.	15.3893E-05	57.1678E-05	20.5177E-04	0.
	39.5573E-05	0.	0.	53.0927E-04	15.6286E-03	0.	26.0553E-02	10.0000E-01

COLUMN SUMS
AFTER RENORMALIZATION

10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01
10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01
10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01	10.0000E-01

*** ETOM ***

MUFT FILE 3 HAS BEEN CHANGED DUE TO RENORMALIZATION OPTION INTO=3
THE REVISED FILE IS AS FOLLOWS

MULTI-GROUP	SYMMETRIC SCATTERING	SMOOTH CAPTURE	INELASTIC SCATTERING	SMOOTH FISSION	ANISOTROPIC SCATTERING	NEUTRONS PER FISSION	ISOTROPIC G-G	ISOTROPIC SLOW-DOWN
1	32.3606E-01	10.0000E-11	92.4717E-02	24.7284E-01	26.6726E-01	39.4966E-01	12.5000E-02	52.6770E-04
2	40.6501E-01	10.0000E-11	13.3837E-01	20.8239E-01	32.1503E-01	37.4630E-01	12.5000E-02	73.9274E-04
3	44.6589E-01	10.0000E-11	15.1571E-01	18.7295E-01	34.7836E-01	35.8510E-01	12.5000E-02	85.5233E-04
4	45.0726E-01	10.0000E-11	13.6989E-01	19.2083E-01	34.4187E-01	34.3071E-01	12.5000E-02	92.0473E-04
5	45.7349E-01	10.0000E-11	12.2752E-01	19.8214E-01	32.4693E-01	33.0914E-01	12.5000E-02	11.3433E-03
6	45.0250E-01	10.0000E-11	11.5857E-01	20.3407E-01	29.3549E-01	32.1237E-01	12.5000E-02	13.3089E-03
7	43.1403E-01	65.4494E-09	10.7913E-01	19.8397E-01	23.6952E-01	31.3822E-01	12.5000E-02	16.4567E-03
8	42.4069E-01	93.9187E-04	98.0760E-02	18.6718E-01	19.4149E-01	30.7963E-01	12.5000E-02	19.4380E-03
9	44.9143E-01	33.0061E-03	76.9987E-02	17.9384E-01	19.2125E-01	30.3502E-01	12.5000E-02	21.7144E-03
10	49.7376E-01	56.5448E-03	45.9459E-02	17.2077E-01	21.4672E-01	29.9678E-01	12.5000E-02	23.8766E-03
11	54.7635E-01	77.3294E-03	44.0450E-02	16.5496E-01	22.0171E-01	29.6874E-01	12.5000E-02	27.6464E-03
12	60.1023E-01	10.0177E-02	47.8602E-02	15.9454E-01	21.6847E-01	29.4708E-01	12.5000E-02	32.4294E-03
13	69.2217E-01	12.1896E-02	28.2428E-02	15.1354E-01	22.2958E-01	29.3011E-01	12.5000E-02	39.6064E-03
14	76.4025E-01	14.7621E-02	23.7176E-02	14.8963E-01	22.8249E-01	29.1690E-01	12.5000E-02	45.2155E-03
15	82.2776E-01	17.1685E-02	20.2434E-02	14.3001E-01	23.1659E-01	29.0645E-01	12.5000E-02	49.8916E-03
16	88.7795E-01	18.8284E-02	19.2198E-02	14.2185E-01	17.5860E-01	28.9845E-01	12.5000E-02	60.0841E-03
17	93.7268E-01	20.3947E-02	15.9748E-02	15.0798E-01	13.6922E-01	28.9220E-01	12.5000E-02	67.5394E-03
18	97.0278E-01	21.4090E-02	14.0520E-02	15.2412E-01	10.4546E-01	28.8746E-01	12.5000E-02	73.0558E-03
19	96.7730E-01	22.0319E-02	12.9794E-02	15.3230E-01	76.1960E-02	28.8334E-01	12.5000E-02	75.2361E-03
20	96.5011E-01	22.1075E-02	12.5811E-02	14.7851E-01	57.8055E-02	28.8039E-01	12.5000E-02	76.5556E-03
21	96.7408E-01	29.3060E-02	75.6363E-03	14.6089E-01	39.2195E-02	28.7731E-01	25.0000E-02	78.3276E-03
22	96.1833E-01	50.4632E-02	11.3018E-02	16.0636E-01	24.2743E-02	28.7443E-01	25.0000E-02	79.1180E-03
23	95.4076E-01	73.3514E-02	16.6907E-02	18.1871E-01	15.6596E-02	28.7269E-01	25.0000E-02	79.1885E-03
24	95.0418E-01	97.4538E-02	13.2565E-02	20.7896E-01	10.5134E-02	28.7163E-01	25.0000E-02	79.3148E-03
25	95.0418E-01	12.3229E-01	84.9180E-04	24.1063E-01	74.2922E-03	28.7099E-01	25.0000E-02	79.5762E-03
26	95.0418E-01	15.7139E-01	0.	28.0929E-01	55.5799E-03	28.7060E-01	25.0000E-02	79.7311E-03
27	95.0418E-01	21.3355E-01	0.	35.2949E-01	44.2305E-03	28.7036E-01	25.0000E-02	79.8288E-03
28	95.0418E-01	29.3049E-01	0.	45.7512E-01	37.3468E-03	28.7022E-01	25.0000E-02	79.8880E-03
29	95.0418E-01	39.6719E-01	0.	59.5646E-01	33.1718E-03	28.7013E-01	25.0000E-02	79.9239E-03
30	95.0418E-01	65.3682E-01	0.	94.2569E-01	30.6392E-03	28.7008E-01	25.0000E-02	79.9457E-03
31	95.0418E-01	57.0183E-01	0.	86.4310E-01	29.1034E-03	28.7005E-01	25.0000E-02	79.9589E-03
32	95.0418E-01	48.8042E-01	0.	71.7556E-01	28.1717E-03	28.7003E-01	25.0000E-02	79.9670E-03
33	95.0418E-01	12.0637E-01	0.	15.4111E-01	27.7073E-03	28.7002E-01	12.5000E-02	79.9711E-03
34	95.0418E-01	19.4737E-02	0.	63.5489E-02	27.4921E-03	28.7002E-01	12.5000E-02	79.9729E-03
35	95.0418E-01	25.1469E-03	0.	20.1292E-02	27.3245E-03	28.7001E-01	12.5000E-02	79.9743E-03

*** ETOM ***

MULTI-GROUP	SYMMETRIC SCATTERING	SMOOTH CAPTURE	INELASTIC SCATTERING	SMOOTH FISSION	ANISOTROPIC SCATTERING	NEUTRONS PER FISSION	ISOTROPIC G-G	ISOTROPIC SLOW-DOWN
36	95.0418E-01	42.4656E-05	0.	19.3782E-04	27.1939E-03	28.7001E-01	12.5000E-02	79.9754E-03
37	95.0418E-01	78.7214E-05	0.	35.8749E-04	27.0923E-03	28.7001E-01	12.5000E-02	79.9763E-03
38	95.0418E-01	14.5622E-04	0.	66.2485E-04	27.0145E-03	28.7001E-01	12.5000E-02	79.9770E-03
39	95.0418E-01	26.8660E-04	0.	12.1950E-03	26.9526E-03	28.7000E-01	12.5000E-02	79.9775E-03
40	95.0418E-01	49.4002E-04	0.	22.3590E-03	26.9044E-03	28.7000E-01	12.5000E-02	79.9779E-03
41	95.0418E-01	90.4606E-04	0.	40.7890E-03	26.8668E-03	28.7000E-01	12.5000E-02	79.9782E-03
42	95.0418E-01	16.4810E-03	0.	73.9483E-03	26.8376E-03	28.7000E-01	12.5000E-02	79.9784E-03
43	95.0418E-01	29.8429E-03	0.	13.3038E-02	26.8146E-03	28.7000E-01	12.5000E-02	79.9786E-03
44	95.0418E-01	10.0202E-02	0.	95.1000E-02	26.7971E-03	28.7000E-01	12.5000E-02	79.9788E-03
45	95.0418E-01	29.2396E-02	0.	34.3505E-01	26.7833E-03	28.7000E-01	12.5000E-02	79.9789E-03
46	95.0418E-01	49.4270E-02	0.	54.3855E-01	26.7725E-03	28.7000E-01	12.5000E-02	79.9790E-03
47	95.0418E-01	74.7343E-02	0.	68.6701E-01	26.7641E-03	28.7000E-01	12.5000E-02	79.9791E-03
48	95.0418E-01	95.9906E-02	0.	86.6486E-01	26.7576E-03	28.7000E-01	12.5000E-02	79.9791E-03
49	95.0418E-01	20.5850E-01	0.	11.1188E+00	26.7525E-03	28.7000E-01	12.5000E-02	79.9792E-03
50	95.0418E-01	43.0098E-01	0.	14.4523E+00	26.7486E-03	28.7000E-01	12.5000E-02	79.9792E-03
51	95.0418E-01	66.8710E-01	0.	19.0086E+00	26.7455E-03	28.7000E-01	12.6900E-02	79.9792E-03
52	95.0418E-01	97.0961E-01	0.	25.4371E+00	26.7431E-03	28.7000E-01	12.3100E-02	79.9792E-03
53	95.0418E-01	14.8163E+00	0.	38.2610E+00	26.7411E-03	28.7000E-01	15.0000E-02	79.9793E-03
54	13.2362E+00	28.2572E+00	0.	67.5921E+00	37.2391E-03	28.7000E-01	14.4200E-02	11.1384E-02

THE FOLLOWING CARDS HAVE BEEN GENERATED AND PUNCHED


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+3+21+01+5132360+4110000+5092471+5124728+5012500+5126672+5139406+4852677
+3+21+02+5140650+0000000+5113383+5120823+5012500+5132150+5137463+4873927
+3+21+03+5144658+4110000+5115157+5118729+5012500+5134783+5135851+4885523
+3+21+04+5145072+4110000+5113698+5119203+5012500+5134418+5134307+4892047
+3+21+05+5145734+4110000+5112275+5119821+5012500+5132469+5133091+4911343
+3+21+06+5145024+4110000+5111585+5120340+5012500+5129354+5132123+4913308
+3+21+07+5143140+4365449+5110791+5119839+5012500+5123695+5131382+4916456
+3+21+08+5142406+4893918+5098074+5118671+5012500+5119416+5130796+4919437
+3+21+09+5144914+4933006+5076998+5117938+5012500+5119212+5130350+4921714
+3+21+10+5149737+4956544+5045945+5117207+5012500+5121467+5129967+4923676
+3+21+11+5154763+4977329+5044044+5116549+5012500+5122017+5129687+4927646
+3+21+12+5160102+5010017+5047866+5115945+5012500+5121684+5129470+4932429
+3+21+13+5169221+5012189+5028242+5115135+5012500+5122295+5129301+4935615
+3+21+14+5176402+5014762+5023717+5114896+5012500+5122824+5129169+4945215
+3+21+15+5182277+5017168+5020243+5114800+5012500+5123165+5129064+4949691
+3+21+16+5188779+5018828+5019219+5114818+5012500+5117585+5128984+4960084
+3+21+17+5193726+5020394+5015974+5115079+5012500+5113692+5128921+4967539
+3+21+18+5197027+5021408+5014052+5115241+5012500+5110454+5128874+4973055
+3+21+19+5196772+5022031+5012979+5115322+5012500+5076196+5128833+4975236
+3+21+20+5196501+5022107+5012581+5114795+5012500+5057805+5128803+4976555
+3+21+21+5196740+5029306+4975638+5114608+5025000+5039219+5128773+4978327
+3+21+22+5196183+5050463+5011301+5116063+5025000+5024274+5128744+4979118
+3+21+23+5195407+5073351+5016690+5118187+5025000+5015659+5128726+4979188
+3+21+24+5195041+5097453+5013256+5120789+5025000+5010513+5128716+4979314
+3+21+25+5195041+5112322+4884918+5124106+5025000+4974292+5128709+4979576
+3+21+26+5195041+5115713+0000000+5128092+5025000+4955579+5128705+4979731
+3+21+27+5195041+5121335+0000000+5135294+5025000+4944230+5128703+4979828
+3+21+28+5195041+5129304+0000000+5145751+5025000+4937346+5128702+4979888
+3+21+29+5195041+5139671+0000000+5159564+5025000+4933171+5128701+4979923
+3+21+30+5195041+5165368+0000000+5194256+5025000+4930639+5128700+4979945
+3+21+31+5195041+5157018+0000000+5180430+5025000+4929103+5128700+4979958
+3+21+32+5195041+5148804+0000000+5171755+5025000+4928171+5128700+4979965
+3+21+33+5195041+5112063+0000000+5115411+5012500+4927707+5128700+4979971
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+3+21+34+5195041+5019473+0000000+5063548+5012500+4927492+5128700+4979972
+3+21+35+5195041+4925146+0000000+5020129+5012500+4927324+5128700+4979974
+3+21+36+5195041+4742465+0000000+4819378+5012500+4927193+5128700+4979975
+3+21+37+5195041+4778721+0000000+4835874+5012500+4927092+5128700+4979976
+3+21+38+5195041+4814562+0000000+4866248+5012500+4927014+5128700+4979976
+3+21+39+5195041+4826865+0000000+4912195+5012500+4926952+5128700+4979977
+3+21+40+5195041+4849400+0000000+4922358+5012500+4926904+5128700+4979977
+3+21+41+5195041+4890460+0000000+4940789+5012500+4926866+5128700+4979978
+3+21+42+5195041+4916481+0000000+4973948+5012500+4926837+5128700+4979978
+3+21+43+5195041+4929842+0000000+5013303+5012500+4926814+5128700+4979978
+3+21+44+5195041+5010020+0000000+5095099+5012500+4926797+5128700+4979978
+3+21+45+5195041+5029239+0000000+5134350+5012500+4926783+5128700+4979978
+3+21+46+5195041+5049627+0000000+5154385+5012500+4926772+5128700+4979978
+3+21+47+5195041+5074734+0000000+5168670+5012500+4926764+5128700+4979979
+3+21+48+5195041+5095990+0000000+5186648+5012500+4926757+5128700+4979979
+3+21+49+5195041+5120584+0000000+5211118+5012500+4926752+5128700+4979979
+3+21+50+5195041+5143009+0000000+5214452+5012500+4926748+5128700+4979979
+3+21+51+5195041+5166870+0000000+5219008+5012690+4926745+5128700+4979979
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+5+21+03+4836515+4815076+0000000+0000000+0000000+0000000+0000000+0000000
```

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```
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*5*21*25*4739557*0000000*0000000*4853092*4915628*0000000*5026055*5110000
```

4.0 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 likely 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. In any case, adequate storage remains to handle any foreseeable contingency.

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 ETOM-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 is first read into these blocks before processing. When data is manipulated, it is done in the blocks. The blocks also serve as temporary space for some processed results before they are output. These blocks are the device which permits the general purpose subroutines to be self-contained. At present there are 4 floating point blocks, two of length 4000 and 2 of length 1000. Associated with each of the four is a fixed point block of length 50.

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 only read forward. Thus the data is processed in the order it appears on the ENDF/B tape not in the order it is required by MUFT.

Because of this some data must be saved from the time it is first encountered on the library tape until such time as it is 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 is stored in /DENS/. 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 library cards as part of the output. Hence when MUFT library data is produced, it is stored and then recalled in the last part of the program when the cards are constructed and punched.

4.2 Labeled COMMON Variables

Insofar as practical, the ENDF/B notation has been retained for variable names. Hence more detailed explanations of the variables may be found in references 7 and 10. Connected with the ENDF/B data are control parameters to further define and describe the various sections of the ENDF/B information. Hence, note that in addition to the large storage areas /RECS/ and /DENS/, there are common blocks which contain control variables for each ENDF/B file, /CONTF1/-/CONTF5/. The blocks /FILE3/-/FILE6/ and /MUFT45/ are used to store the MUFT variables generated by the program. Other blocks are self-explanatory. In the following 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
IO5	input tape
IO6	output print tape
IO7	output punch tape
NDFB	ENDF/B library tape
ITP1-ITP4	scratch tapes
/TAPUSE/	tape use literal
ITPR	resonance scattering data (not used at present)
ITPS	smooth scattering data
ITPE	elastic (resonance plus smooth) scattering data (not used at present)

/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
X,Y,B,	general floating point storage space
N1X	maximum length of the NBT and JNT arrays
N2X	maximum length of the X and Y arrays
NS	card sequence number

/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

(DIMENSION, EQUIVALENCE, AND /BLOKS/) - general storage space

BLOK1-BLOK4	general use floating point storage
IBLK1-IBLK4	general use fixed point storage
LBK12	control variable (usually the number of data pairs listed in BLOK1 and BLOK2)
LBK34	same as LBK12 but usually associated with BLOK3 and BLOK4.
LIBK12, LIBK34	same as above but associated with IBLK1-IBLK4.

*This common block is part of the package of Retrieval Subroutines for the ENDF/B System written by H. C. Honeck (Ref. 10). In ETOM-1, some of the array dimensions have been changed.

/CONTF1/	control information associated with file 1
ZA	material (Z,A) designation
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	nu representation indicator
NC	number of nu polynomial terms
C	nu polynomial coefficients
NR1	interpolation table length
NP1	data list length
/CONTF2/	control information - file 2
NIS	no. of isotopes
ZAI	isotope (Z,A) designation
ABN	abundance
LFW	fission width indicator
NER	number of energy ranges
LISR, LISRX	resolved scattering calculation indicator
EL	range lower energy limit
EH	range higher energy limit
LRU	data type indicator
LRF	resonance formula indicator
LISU, LISUX	unresolved scattering calculation indicator
SPIR	nuclear spin - resolved
AP, AM, AA	scattering length
NLSR	number of ℓ states - resolved
CR	penetration factor constant - resolved
LR	ℓ - resolved
NRS	number of resonances
SPIU	nuclear spin - unresolved

NLSU	number of ℓ states - unresolved
CU	penetration factor constant - unresolved
NEX	number of points in fission width tabulation
LU	ℓ - unresolved
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
XPOTU	potential scattering - unresolved
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

/CONTF5/	control information - file 5
NK	number of representations (subsections)
THETA	θ
LF	function representation indicator
NE	number of E values in g tabulation
NR5	interpolation table length
NP5	data list length
EINIT	E values in g tabulation
AWATT	constant "a" in Watt spectrum
BWATT	constant "b" in Watt spectrum
LTHET	length of theta array
LITHET	length of theta interpolation tables

LPP	length of P list
LIPP	length of P interpolation tables
LGG	length of g list
LIGG	length of g interpolation tables
/IN/	basic input (see input description)
/OPTION/	input options (see input description)
MAXG1	MAXG+1
MAXG2	MAXT+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 indicator
NOXIN	inelastic scattering cross section indicator
NON2N	n-2n cross section indicator
/CONSTS/	data constants
EZERO	$1.0 * 10^{7}$
PI	π
HAFPI	$\pi/2$
/GROUPS/	group structure
EGRP	energy structure
UGRP	lethargy structure

/FILE3/	output for MUFT file 3
XS	symmetric scattering
XC	smooth capture
XIN	inelastic scattering
XF	fission
AGN	isotropic Greuling-Goertzel parameter (age number)
XSMU	anisotropic scattering
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
JRS	no. of resonances in group
R	MUFT r factor
EM	MUFT m factor
ALFA	MUFT α factor

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* NOTE: Various notation is used for the isotropic and anisotropic Greuling-Goertzel and slowing down parameters. The following table may be helpful.

QUANTITY	MUFT 4 Ref. 2	MUFT 5 Ref. 3	PIMG Ref. 4	"TAPE 5" Ref. 11	ENDF/B MT Ref. 7
Isotropic Slowing Down	$\xi\sigma_o$	ξ_o	$\xi\sigma_s$	$\xi\sigma_s$	252(ξ)
Anisotropic Slowing Down		ξ_1	$\eta\sigma_s$	$\eta\sigma_s$	-
Isotropic Greuling-Goertzel	λ	λ_o	γ	λ_o	253( )
Anisotropic Greuling-Goertzel		λ_1	ζ	λ_1,ζ	-

/FILE5/	output for MUFT file 5
PMX	probability matrix
DIAG	ingroup scatter
XTRA	out of matrix scatter
/FILE6/	output for MUFT file 6
TRUM	source spectrum
/MUFT45/	output card construction variable
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

4.3 Overlay Structure and Routine List

Following is a list of the programs, subroutines, and functions used by ETOM-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	control flow of main program
ERR	print error message
ERROR	print error message*
STORE	store record in dense storage*
FETCH	fetch record from dense storage*
DELETE	delete record from dense storage*
ECSI	compute integral of y(x)*
GRATE	integrate TAB1 function*
COMBP	combine one panel of two TAB1 functions*
COMB	combine two TAB1 functions*
ADD	combining function for addition*
SUB	combining function for subtraction*
MULT	combining function for multiplication*
DIV	combining function for division*
TERP	interpolate between two points*
TERP1	interpolate one point*
TERP2	form new table by interpolation*
LRIDS	locate record in dense storage*
FPDS	fetch point from dense storage*
IPDS	interpolate point in dense storage*
GENT1	generate TAB1 function*
FISS	generating function for fission spectrum*
HOLL	read hollerith material description
CONT	read control (CONT) record
LIST	read LIST record
TAB1	read TAB1 record
TAB2	read TAB2 record
TPOS	position ENDF/B tape to file (MF) and reaction (MT)
XTND	extend data array
SAVE	write or read a scratch tape
TERPO	interpolate a data array
GPAV	average over selected groups
AVRG	average over a selected range
OUT3	print output (file 3 data)

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* This subroutine (or function) is part of the package of Retrieval Subroutines for the ENDF/B System written by H. C. Honeck (Ref. 10).

Overlay (1,0)

ETOM10	control flow of program in overlay (1,0)
ININ	read input
ZERO	initialize
EU	construct group structure, weight, and weight averages
TRID	read ENDF/B tape I.D.
TMAT	position ENDF/B tape to material (MAT)
TMF1	read ENDF/B file 1
OUT1	print output (input)

Overlay (2,0)

ETOM20	control flow of program in overlay (2,0)
TMF2	read ENDF/B file 2
RESS	calculate resolved resonance scattering
RESR	calculate resolved resonance parameters and low resonance effect
RESU	calculate unresolved resonance contribution

Overlay (3,0)

ETOM30	control flow of program in overlay (3,0)
TMF3	read ENDF/B file 3
CROS	calculate smooth cross sections

Overlay (5,0)

ETOM50	control flow of program in overlay (5,0)
TMF5	read ENDF/B file 5
IMAT	calculate contribution to inelastic matrix
CWAX	combine weight and cross section
PUTW	restore weight to proper place
OUT5	print output (file 5 data)
RENO	renormalize inelastic matrix
SPEC	calculate source (fission) spectrum
POUT	punch output
XSP4	construct output card

4.4 Error Stops

If certain errors are detected, an error message will be printed. Some messages are printed directly from the routine where 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.

5.0 ENVIRONMENT INFORMATION

ETOM-1 as distributed requires approximately $43{,}000_{10}$ locations and uses one scratch tape in addition to the mounted library tape. It also requires standard system input, output, and punch units. Since the program is entirely in FORTRAN 4, it should compile and execute properly on any configuration meeting these requirements.

Most of the development of the program was done on a CDC 6600 using the SCOPE 2.0 operating system. However it has also run successfully on the IBM 360/75 (using ASP), the UNIVAC 1108, and the CDC 6600 (using SCOPE 3.1).

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