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RABID: An Integral Transport-theory Code
for Neutron Slowing Down in Slab Cells

by

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ABSTRACT

This report consists of the theory behind the methods used in the RABID code to solve the integral transport equation in slab geometry for cells with repeating boundary conditions, together with a user's guide, sample problems, and code listings. Space- and lethargy-dependent slowing-down sources are used with cross sections obtained by the single-level Breit-Wigner formalism for s- and p-wave resonances, to calculate resonance absorption, broad-group average fluxes and cross sections, and foil reaction rates.

RABID is coded in FORTRAN-IV for the IBM/360-75. A core requirement of 420 k bytes permits up to 300 resonances, 20 materials having resonances, 10 materials without resonances, 30 regions in the cell, and 25 broad groups.

I. INTRODUCTION

A tractable approach to the computation of resonance absorption, average neutron fluxes, and group cross sections for multiplate fast-reactor cells of the ZPR type has been developed by Kier and Robba.¹ Their technique, described here as the "RABBLE Method," assumes that the neutron currents at plate interfaces can be resolved into two components: one with a cosine angular distribution, the other with a cosine-squared angular distribution. This assumption enables the definition of transmission probabilities for these current components and, together with escape probabilities for spatially flat isotropic sources, leads to a simple solution of the spatial part of the integral transport equation.

A more accurate treatment of the spatial dependence of neutron flux is possible if one makes no assumptions about the angular distribution of the interface currents. Instead, the integral transport equation is solved "exactly" by the RABID code under the assumption that the slowing-down source is spatially linear, rather than flat as in RABBLE.

Initially, RABID consisted of the RABBLE code with a completely changed collision-rate calculation. Major evolutionary changes and

improvements have since affected virtually every section of code taken from RABBLE. For example, input/output subroutines have been changed to deal with foil calculations and transverse bucklings. Changes in the cross-section subroutines now permit p-wave resonances in addition to s-waves. The slowing-down-source calculation now accounts for ingroup scattering and uses much more effective storage of scattering rates to reduce or eliminate errors in the source contribution from fine groups one scattering interval distant. These and other topics will be developed at greater length.

II. THEORY

A. Integral Transport Equation

The integral form of the Boltzmann transport equation in a source-free infinite medium is

$$\phi(\vec{r}, u) = \iiint d\vec{r}' \int_0^u \frac{du' F_s(u', \vec{r}') P(u' \rightarrow u) \exp[-\Sigma_t(u, \vec{r})|\vec{r} - \vec{r}'|]}{4\pi|\vec{r} - \vec{r}'|^2}, \quad (1)$$

where the scattering rate at lethargy u' and space point $\vec{r}'$ is

$$F_s(u', \vec{r}') = \Sigma_s(u') \phi(\vec{r}', u'). \quad (2)$$

The probability per unit lethargy that a neutron is scattered from u' to u is

$$P(u' \rightarrow u) = \begin{cases} \frac{1}{1-\alpha} e^{-(u-u')}, & u \geq u' \geq u - \epsilon, \\ 0, & u' < u - \epsilon, \end{cases} \quad (3)$$

where

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

and A is the ratio of target nuclide mass to neutron mass.

Equation 1 can be reduced to one-dimensional form for infinite slab geometry by integrating over the other two spatial coordinates as follows:

$$\begin{aligned}
& \iiint \frac{d\vec{r}' F_s(u', \vec{r}') \exp[-\Sigma_t(u, \vec{r}') |\vec{r} - \vec{r}'|]}{4\pi |\vec{r} - \vec{r}'|^2} \\
&= \int dx' F_s(u', x') \int_0^\infty \frac{2\pi r dr \exp[-\Sigma_t(u, \vec{r}') (r^2 + |x - x'|^2)^{1/2}]}{4\pi (r^2 + |x - x'|^2)} \\
&= \int dx' F_s(u', x) \int_1^\infty \exp[-\Sigma_t(u) |x - x'| t] dt/t \\
&= \frac{1}{2} \int dx' F_s(u', x') E_1[\Sigma_t(u) |x - x'|], \tag{4}
\end{aligned}$$

where the scattering source now depends only on x' and u' , and the exponential integral functions are²

$$E_n(Z) \equiv \int_1^\infty \exp(-Zt) dt/t^n. \tag{5}$$

Equation 1 now becomes

$$\phi(x, u) = \frac{1}{2} \int dx' \int_0^u du' F_s(u', x') P(u' \rightarrow u) E_1[\Sigma_t(u) |x - x'|]. \tag{6}$$

The following similar equation for the neutron current can be obtained:

$$\vec{J}(x, u) = \frac{1}{2} \int dx' \int_0^u du' F_s(u', x') P(u' \rightarrow u) E_2[\Sigma_t(u) |x - x'|]. \tag{7}$$

The lethargy dependence must now be converted from a continuous function to a multigroup formalism in which the group lethargy width is very narrow ($\Delta u \lesssim 10^{-3}$). Now define

$$\phi_\ell(x) \Delta u = \int_{u_{\ell \min}}^{u_{\ell \max}} \phi(x, u') du', \tag{8}$$

$$f_{s\ell}(x') \Delta u = \int_{u_{\ell \min}}^{u_{\ell \max}} du' F_s(u', x'), \tag{9}$$

(where $u_{\ell \min}$ and $u_{\ell \max}$ are lower and upper lethargy bounds, respectively, corresponding to group ℓ),

$$\begin{aligned}
P_\ell \Delta u &= \frac{1}{1-\alpha} \int_{u_0}^{u_0+\Delta u} du \int_{u_0-\ell\Delta u}^{u_0-(\ell-1)\Delta u} du' e^{-(u-u')} \\
&= \frac{(1-e^{-\Delta u})^2}{1-\alpha} e^{-(\ell-1)\Delta u}, \quad \ell = 1, 2, \dots, L,
\end{aligned} \tag{10}$$

and

$$P_s \Delta u = \frac{1}{1-\alpha} \int_{u_0}^{u_0+\Delta u} du \int_{u_0}^u du' e^{-(u-u')} = \frac{1}{1-\alpha} (\Delta u - 1 + e^{-\Delta u}). \tag{11}$$

Let $L = \epsilon/\Delta u$ be an integral number of groups (by a minor adjustment to the mass ratio A , if necessary). Then the slowing-down source in group k from all other groups is

$$S_{0k}(x') = \sum_{\ell=1}^L f_{sk-\ell}(x') P_\ell \Delta u - \alpha \sum_{sk-\ell} \phi_{k-L} P_s \Delta u, \tag{12}$$

and the ingroup (self-scatter) source is

$$S_{sk}(x') = \sum_{sk} \phi_k P_s \Delta u,$$

where $P_s \Delta u$ is the probability for self-scatter. Some of the neutrons scattered in group $k-L$ cannot reach group k , leading to the term

$$\alpha \sum_{sk-L} \phi_{k-L} P_s \Delta u.$$

Now Eqs. 6 and 7 become

$$\phi_k(x) = \frac{1}{2} \int dx' \left[\sum_{\ell=1}^L f_{sk-\ell}(x') P_\ell \Delta u + \sum_{sk} \phi_k P_s \Delta u \right] E_1(\sum_{tk} |x - x'|) \tag{13}$$

and

$$\vec{J}_k(x) = \frac{1}{2} \int dx' \left[\sum_{\ell=1}^L f_{sk-\ell}(x') P_\ell \Delta u + \sum_{sk} \phi_k P_s \Delta u \right] E_2(\sum_{tk} |x - x'|). \tag{14}$$

B. Collision Rates

The collision rate within a plate is the difference between the uncollided current in and the uncollided current out. For example, the current at τ mean free paths beyond a plate of optical thickness τ_1 is

$$\vec{J}(\tau, \tau_1) = \frac{1}{2} \int_0^{\tau_1} dx' [S_0(x') + S_S(x')] E_2(\tau + \Sigma_{t1} x'). \quad (15)$$

Since the self-scatter term is never more than 1 or 2% of the total source, it is a good approximation to assume that both source components have the same x' -dependence; that is,

$$S(x') = S_0(x') + S_S(x') = \bar{S} + (x' - t_1/2) \Delta S/t_1. \quad (16)$$

Then,

$$\begin{aligned} \vec{J}(\tau, \tau_1) &= \frac{1}{2} \int_0^{\tau_1} dx' S(x') E_2(\tau + \Sigma_{t1} x') = \frac{\bar{S}}{2\tau_1} [E_3(\tau) - E_3(\tau + \tau_1)] \\ &+ \frac{\Delta S}{2\tau_1} \left\{ [E_3(\tau) + E_3(\tau_1 + \tau)]/2 - \frac{1}{\tau_1} [E_4(\tau) - E_4(\tau_1 + \tau)] \right\}. \end{aligned} \quad (17)$$

To obtain the collision rate in plate 2 due to the source in plate 1, in which τ mean free paths separate the plates, one evaluates Eq. 17 at both sides of plate 2:

$$\vec{CR}(1 \rightarrow 2) = \vec{J}(\tau, \tau_1) - \vec{J}(\tau + \tau_2, \tau_1). \quad (18)$$

Assuming an array of unit cells which repeat to infinity in both directions (periodic boundary conditions), the contribution by all plates of type 1 (in a given direction--the superscript arrow denotes this direction) is

$$\vec{CR}_\infty(1 \rightarrow 2) = \sum_{m=0}^{\infty} [\vec{J}(\tau + mh, \tau_1) - \vec{J}(\tau + \tau_2 + mh, \tau_1)], \quad (19)$$

where h is the optical thickness of the unit cell. The average collided flux is

$$\phi = CR/\Sigma_t. \quad (20)$$

Equation 19 evaluated in forward and backward directions yields collision probabilities in an N-region unit cell of the form

$$\underline{P} = \begin{pmatrix} P_{11} & P_{21} & \dots & P_{N1} \\ P_{12} & P_{22} & \dots & P_{N2} \\ \vdots & \vdots & \ddots & \vdots \\ P_{1N} & P_{2N} & \dots & P_{NN} \end{pmatrix},$$

where $P_{ij} = [\vec{CR}_\infty(i \rightarrow j) + \overleftarrow{CR}_\infty(j \leftarrow i)]/S_i$.

With sources and collision rates written as vectors, the transport equation becomes

$$\vec{CR} = \underline{P}[\vec{S}_0 + \underline{R}\vec{CR}], \quad (21)$$

where $\underline{R}$ is a diagonal matrix

$$\underline{R} = \begin{pmatrix} \left(\frac{\Sigma_s P_s}{\Sigma_t} \right)_1 & & 0 \\ & \ddots & \\ 0 & & \left(\frac{\Sigma_s P_s}{\Sigma_t} \right)_N \end{pmatrix}.$$

Solving Eq. 21, we obtain

$$\vec{CR} = [\underline{P}^{-1} - \underline{R}]^{-1} \vec{S}_0. \quad (22)$$

RABID uses MATINV³--a standard ANL System/360 Library Subroutine--to perform the matrix inversions shown in Eq. 22. This routine is very fast, relative to the time involved in calculating the $\underline{P}$ matrix. Computation time increases only a few percent, relative to an approximate method of solving Eq. 21 which bypasses the matrix inversions. For completeness, the approximate method formerly used will now be described.

A simple but reasonable approximation is to solve Eq. 21 using an estimate of $\vec{CR}$ on the right-hand side. In general, the variation of collision rates from fine group $k-1$ to fine group k is a few percent or less. Also, the ingroup-scattered source contribution is very small. Equation 21 is approximated as follows:

$$\vec{CR}_k \approx \vec{CR}_{k-1}, \text{ in right-hand side;} \quad (23)$$

$$\vec{CR}_k = \underline{P}[\vec{S}_{0k} + \underline{R}\vec{CR}_{k-1}] = \underline{P}\vec{S}'_k. \quad (24)$$

Now correct the source using the best estimate available for $\vec{CR}_k$,

$$\vec{S} - \vec{S}' \approx \underline{R}(\vec{CR}' - \vec{CR}_{k-1}). \quad (25)$$

This accounts for single ingroup scattering collisions. Multiple ingroup scattering collisions lead to

$$\vec{S} - \vec{S}' \approx \underline{R}(\underline{I} - \underline{R})^{-1} (\vec{CR}' - \vec{CR}_{k-1}). \quad (26)$$

The increment to the collision-rate vector is also $\vec{S} - \vec{S}'$, if one ignores the spatial transfer of this very small correction. The collision-rate vector becomes

$$\vec{CR}_k \approx \vec{CR}_k' + \vec{S} - \vec{S}'. \quad (27)$$

In the limiting case of one-region (homogeneous) problems, the exact solution of Eq. 22 is

$$CR_k = S_{0k}/(1 - R), \quad (28)$$

which is also obtained by the approximate method.

We have seen that this approximation method is exact for homogeneous problems. Its basic fault for heterogeneous problems is the errors in the spatial transfer of ingroup-scattered neutrons. In the rather extreme example of a binary cell consisting of a heavy-atom absorber plate and a light-atom moderator plate, the flux in the absorber plate was overestimated by about 1% when it was optically thin. Physically, most of the ingroup-scattered neutrons were produced by collisions in the absorber plate and should have suffered their next collision in the optically thick moderator plate. However, in the approximation method, the ingroup-scattered neutrons tended to remain in the absorber plate, giving too high a flux there.

To represent neutron losses by leakage from a finite-sized system with buckling B^2 , one need only scale the collision-probability matrix $\underline{P}$ by a nonleakage probability, PNL. A reasonable definition of PNL is obtained as follows:

$$PNL_k = \frac{\langle \Sigma_t \rangle_k}{\langle \Sigma_t \rangle_k + \langle D \rangle_k B^2}, \quad (29)$$

where k is the fine-group index, A_i is the thickness of region i ,

$$\langle \Sigma_t \rangle_k = \frac{\sum_{i=1}^{KREG} (\Sigma_{tk} \phi_k A)_i}{\sum_{i=1}^{KREG} (\phi_k A)_i}, \quad (30)$$

the flux-volume-weighted total macroscopic cross section for the unit cell,

$$\langle \Sigma_t \rangle_k \approx \frac{\sum_{i=1}^{KREG} (\Sigma_{tk} \phi_{k-1} A)_i}{\sum_{i=1}^{KREG} (\phi_{k-1} A)_i}, \quad (31)$$

and

$$\langle D \rangle_k = \left[\frac{3 \sum_{m=1}^{KCOMP} A_m \sum_{j=1}^{KMAT} N_{jm} \sigma_{tj} \left(\frac{\sigma_{aj}}{\sigma_{sj}} + 1 - \bar{\mu}_{oj} \right)}{\sum_{m=1}^{KCOMP} A_m} \right]^{-1} \quad (32)$$

This prescription for the diffusion coefficient comes from Weinberg and Wigner.⁴ Hopefully, a better recipe for $\langle D \rangle$ can be found, for example, by using a transport-theory code, which will account for leakage parallel and perpendicular to the plates in slab geometry. Meanwhile, note that PNL is rather insensitive to errors in $\langle D \rangle$, for large systems. Also, group-averaged cross sections will in general be quite insensitive to $\langle D \rangle$. Provision has been made to use broad-group-dependent bucklings in finite systems.

C. Slowing-down Source

The slowing-down source would be very time-consuming to calculate directly because hundreds or even thousands of fine-group scattering rates contribute. Using the property that $P_\ell = e^{-\Delta u} P_{\ell-1}$, we can obtain the following recursion relation:

$$S_k = e^{-\Delta u} S_{k-1} + (P_1 - e^{-\Delta u} P_s) [(\Sigma_s \phi)_{k-1} - \alpha (\Sigma_s \phi)_{k-L-1}] + P_s [(\Sigma_s \phi)_k - \alpha (\Sigma_s \phi)_{k-L}]. \quad (33)$$

Equation 33 is written for a single material in a given region. Generalization to many materials and regions requires that Eq. 33 be evaluated in a given region for all isotopes, as P_1 , P_s , and α are material-dependent, while $\Sigma_s \phi$ depends both on material and region. However, all we need to solve Eq. 21 are the $\vec{S}_0$ vector elements,

$$S_{0k} = S_k - P_s (\Sigma_s \phi)_k. \quad (34)$$

All components of S_{0k} are known, as $(\Sigma_s \phi)_{k-1}$ is the previous fine-group scattering rate, $(\Sigma_s \phi)_{k-L}$ is obtained by parabolic interpolation from a table of scattering rates for each material/region pair, and $(\Sigma_s \phi)_{k-L-1}$ is the previous interpolated value of $(\Sigma_s \phi)_{(k-1)-L}$. After Eq. 21 has been solved by performing the matrix manipulations of Eq. 22, the fluxes can be found by using Eq. 20. Then the term $P_s (\Sigma_s \phi)_k$ is calculated and S_k follows from Eq. 34.

D. Deletion of Ingroup Scattering

The matrix inversions of Eq. 22 can be eliminated (saving a few percent of computer time) by introducing the assumption that ingroup scattering does not occur. That is, $P_s = 0$. To conserve neutrons, P_ℓ as defined in Eq. 10 must be slightly altered. The sum of the downscatter probabilities must remain unity. Noting that

$$\sum_{\ell=1}^L P_\ell = 1 - e^{-\Delta u} \neq 1, \quad (35)$$

we see that dividing P_ℓ by $1 - e^{-\Delta u}$ will conserve neutrons when ingroup scattering has zero probability. In that case,

$$P'_\ell \Delta u \equiv P_\ell \Delta u / (1 - e^{-\Delta u}) = \frac{1 - e^{-\Delta u}}{1 - \alpha} e^{-(\ell-1)\Delta u}, \quad \ell = 1, 2, \dots, L. \quad (36)$$

The user can decide whether to include ingroup scattering by his choice of the value for the input variable KS. An exhaustive study has not been made to establish how important this choice is. Certainly in many typical problems, where $L \approx 100$, one can safely ignore ingroup scattering. Problems for which $L < 100$ should be examined using both options before arbitrarily ignoring ingroup scattering.

III. STORAGE OF SCATTERING RATES

In the past, RABBLE¹ and RABID have been known to generate absorption probabilities in excess of unity, and slowing-down sources less than zero. These events were the result of overapproximations in calculating the slowing-down sources. Originally, scattering rates were stored for each material (isotope or element) of each composition (which might be spatially averaged over several regions), lethargy-averaged over each intermediate group. Removing the spatial averaging eased the problem somewhat. Then a better system of lethargy-averaging was devised for RABID which gave further improvements by better utilizing the memory space available. The intermediate group size no longer was involved; instead, a lethargy width was optimally chosen for each material.

At this point, 200 scattering rates were retained--enough to eliminate lethargy averaging for heavy materials. The latest development is to retain a variable number of scattering rates. This number is problem-dependent and is automatically chosen to be as large as possible. The method eliminates waste storage formerly reserved for zero-density materials and space for extra materials not in use.

To give an example, suppose one had a two-composition problem with 10 regions (five of each composition), where one composition had four materials, and the other had two. A total of 30 plate/material combinations* are involved in the slowing-down-source calculation. Each one will have $[40,000/30]_{\text{integer}} = 1333$ words, versus 200 in the previous method. Hence, lethargy averaging need not be performed at all in many problems and is over a narrower lethargy range if required. Also, it is now possible to solve a problem with 30 compositions, 20 isotopes, and 300 resonances using only 420 k bytes. For a homogeneous problem using KMAT materials, the space per material is $(40,000/\text{KMAT})_{\text{integer}}$.

The scattering rate $(\Sigma_s \phi)_{k-L}$ is required by Eq. 33 for each region/material pair. Tables of scattering rates are stored for each pair at equal lethargy intervals within a given broad group. (They vary with broad groups because the fine-group width Δu is broad-group dependent.) The lethargy interval is selected automatically to maximize the number of tabular entries between group k and group $k-L$, consistent with memory available. This is equivalent to choosing an interval width that is the smallest possible integral multiple of the fine-group width, and storing the average scattering rate over the interval.

It is not necessary to use the same Δu throughout a problem to maintain a prescribed level of numerical accuracy. The Doppler width,

$$w = \left(\frac{4EkT}{A} \right)^{1/2},$$

determines Δu by the empirical rule, $\Delta u \leq w/4E$. At lower energies, Δu can be increased. Then an interpolation scheme is necessary to extract $(\Sigma_s \phi)_{k-L}$ from the table, since the group boundaries extrapolated back from group k will not in general match up with the group boundaries previously used when the scattering rates were stored.

The "bookkeeping" involved in storing scattering rates is rather complicated. The following discussion (not at all needed by, nor recommended for, the casual user) is for a fixed table size of 200 entries. The code now uses a generalized table size of NOX entries for NISO plate/material pairs ($\text{NOX} = 40,000/\text{NISO} - 1$).

At this point, let us define the parameters involved in FORTRAN-coding the method:

J = isotope number,

IBG = broad group number of fine group k ,

*Each plate/material combination is defined as a nonzero-density material in a given plate.

N = broad group number of fine group $k - L$,
 I = region number,
 K = composition number,
 $USTR(IBG)$ = lower lethargy bound of broad group IBG ,
 $DUSTR(IBG)$ = lethargy width of broad group IBG ,
 $MULT(J,N)$ = multiplicity, or number of fine groups per averaging interval,
 $INUI(J,N)$ = number of first averaging interval in broad group N for isotope J ,
 $INUF(J,N)$ = number of last averaging interval in broad group N for isotope J ,
 LM = number of averaging interval containing group $k - L$,
 $M = LM \text{ (Modulo } 200\text{)},$
 Q = lethargy at center of fine group $k - L$,
 U = lethargy at upper end of fine group k ,
 $UMAX(J,IBG)$ = ϵ for isotope J in broad group IBG rounded to closest integral multiple of the fine-group lethargy width,
 $JNU(J)$ = number of interval currently being incremented for isotope J ,
 $JMULT(J)$ = number of fine-group scattering rates currently included in averaging interval $JNU(J)$,
 $UIGP$ = intermediate-group lethargy width,
 $UFGP$ = fine-group lethargy width,
 and
 PL = fraction of averaging interval from center of interval LM to point Q .

Using these definitions, we obtain

$$MULT(J,IBG) = [1 + UMAX(J,IBG)/(UFGP*173)]_{\text{integer}} \quad (37)$$

Although 200 values of scattering rates will be retained, one must account for the one currently being incremented which is unavailable for use, and also allow for an extra interval for the three-point interpolation scheme beyond fine group $k - L$. Also, extra intervals are required for 25 broad-group boundaries. Then,

$$SCAT(J,I,JNU(J)) = \sum_{\ell=1}^{MULT(J,N)} (\Sigma_s \phi)_{\ell,I} / MULT(J,N). \quad (38)$$

Figure 1 illustrates the method for $MULT(J,N) = 2$ and $MULT(J,IBG) = 3$.

Fig. 1. Details of Scattering-rate Storage and Retrieval

$$\left. \begin{aligned} PL &= INUI(J,N) + (Q - USTR(N)) / (UFGP_N * MULT(J,N)) - 0.5 \\ LM &= [PL + 0.5]_{\text{integer}} \\ PL &= PL - LM. \end{aligned} \right\} \quad (39)$$

The scattering rate at point Q is obtained from the Lagrange three-point formula

$$f(x_0 + ph) \approx \frac{p(p-1)}{2} f_{-1} + (1-p^2) f_0 + \frac{p(p+1)}{2} f_1. \quad (40)$$

where $f(x) = \sum_s \phi(u)$, $PL = p$, and f_0 is $\langle \sum_s \phi \rangle$ at the center of averaging interval LM.

In many problems, a fine-group width of 10^{-4} lethargy units is adequately small. The following table indicates the worth of retaining scattering rates by this method for a fine-group width of 10^{-4} , for a fixed table length of 200.

<u>Atomic Weight</u>	<u>ϵ</u>	<u>No. of Fine Groups per Averaging Interval</u>
>202	<0.0198	1
101 < A < 202	0.0198 < ϵ < 0.0396	2
67 < A < 101	0.0396 < ϵ < 0.0584	3
51 < A < 67	0.0584 < ϵ < 0.0792	4
40 < A < 51	0.0792 < ϵ < 0.0990	5
33 < A < 40	0.0990 < ϵ < 0.1188	6
29 < A < 33		7
25 < A < 29		8
23 < A < 25		9
20 < A < 23		10

Although light isotopes require several fine groups per averaging interval, the effect of errors due to averaging in scattering rates is reduced because the relative size of the source correction varies roughly as the atomic weight. Equivalently, the number of fine groups in the range ϵ roughly varies inversely with atomic weight. Another helpful condition arises from the fact that resonances tend to be broader for lighter isotopes, which permits a wider averaging interval for the same accuracy.

IV. FOILS BETWEEN REGIONS

A standard experiment on ZPR-type fast-reactor mockups is that of determining relative reaction rates within a unit cell by means of "small" (in both thickness and diameter) foils placed between the plates. It is reasonable to assume that the foils have essentially no effect on the neutron-flux distribution in a typical unit cell. Using this assumption, one can obtain the following collision rate in the foil by evaluating Eq. 18 at both sides of the foil (τ_f mean free paths thick):

$$\overrightarrow{CR}(1 \rightarrow \text{foil}) = \overrightarrow{J}(\tau, \tau_1) - \overrightarrow{J}(\tau + \tau_f, \tau_1). \quad (41)$$

Again, assuming an array of unit cells which repeat to infinity in both directions, the contribution by all plates of type 1 in a given direction is

$$\overrightarrow{CR}_{\infty}(1 \rightarrow \text{foil}) = \sum_{m=0}^{\infty} [\vec{J}(\tau + mh, \tau_1) - \vec{J}(\tau + \tau_f + mh, \tau_1)]. \quad (42)$$

The assumption that the foil has no effect on the cell means that the optical thickness of the unit cell h does not include τ_f and that there is no slowing-down source in the foil. Also, the optical thickness τ between plate 1 and the foil does not include contributions by foils at interfaces.

V. RESONANCE CROSS SECTIONS

The RABBLE¹ cross-section generation routine XSECT has been modified to account for the dependence of s-wave cross sections on scatterer mass number. The factor in the Breit-Wigner formula of $\pi\lambda^2$ was assumed to be 2.62×10^6 b/eV in RABBLE, good enough for most resonant materials (heavy atomic weights). It is now more correctly calculated as $2.60385 \times 10^6 \left(1 + \frac{1}{A}\right)^2$ b/eV, where A is the scatterer mass number. The s-wave resonance cross sections are

$$\sigma_s^s = \sigma_0^s \frac{\Gamma_n^s}{\Gamma^s} \Psi(\xi, x) + \left(\frac{\sigma_p \sigma_0 g_J^s \Gamma_n}{\Gamma^s} \right)^{1/2} \chi(\xi, x) \quad (43)$$

and

$$\sigma_a^s = \sigma_0^s \sqrt{\frac{|E_0|}{E}} \frac{\Gamma_f^s + \Gamma_\gamma^s}{\Gamma^s} \Psi(\xi, x), \quad (44)$$

where

$$\begin{aligned} \sigma_0^s &= \text{peak height of s-wave resonance} \\ &= \frac{2.60385 \times 10^6}{|E_0|} \left(1 + \frac{1}{A}\right)^2 g_J^s \frac{\Gamma_n^s}{\Gamma^s}, \end{aligned}$$

$$x = \frac{2}{\Gamma^s} (E - E_0),$$

$$\Gamma^s = \Gamma_\gamma^s + \Gamma_f^s + \Gamma_n^s,$$

$$\xi = \Gamma^s / \Delta; \quad \Delta = 2 \left(\frac{kTE}{A} \right)^{1/2}; \quad g_J^s = \frac{2J+1}{2(2I+1)},$$

J = total spin of compound nucleus,

I = spin of target nucleus,

E = neutron energy (in laboratory), eV,

E_0 = resonance energy (in laboratory), eV,

and

σ_p = potential scattering cross section.

Further modifications now permit treatment of p-wave resonances as follows:⁵

$$\sigma_s^p = \sigma_0^p \frac{\Gamma_n^p}{\Gamma^p} \sqrt{\frac{|E_0|}{E}} \left\{ \Psi(\xi, x) + \frac{\Gamma^p}{2E_0} \chi(\xi, x) + \left(\frac{\Gamma^p}{2E_0} \right)^2 [1 - \Psi(\xi, x)] \right\}, \quad (45)$$

$$\sigma_f^p = \sigma_0^p \frac{\Gamma_f^p}{\Gamma^p} \sqrt{\frac{|E_0|}{E}} \left[\Psi(\xi, x) + \frac{\Gamma^p}{4E_0} \chi(\xi, x) \right], \quad (46)$$

$$\sigma_\gamma^p = \sigma_0^p \frac{\Gamma_\gamma^p}{\Gamma^p} \sqrt{\frac{|E_0|}{E}} \left[\Psi(\xi, x) + \frac{\Gamma^p}{4E_0} \chi(\xi, x) \right], \quad (47)$$

and

$$\sigma_a^p = \sigma_f^p + \sigma_\gamma^p, \quad (48)$$

where

σ_0^p = peak height of p-wave resonance

$$= \frac{2.60385 \times 10^6}{|E_0|} \left(1 + \frac{1}{A} \right)^2 g_J^p \frac{\Gamma_n^p}{\Gamma^p},$$

$$x = \frac{2}{\Gamma^p} (E - E_0),$$

$$\Gamma^p = \Gamma_\gamma^p + \Gamma_f^p + \Gamma_n^p,$$

$$\xi = \Gamma^p / \Delta; \quad \Delta = 2 \left(\frac{kTE}{A} \right)^{1/2}; \quad g_J^p = \frac{(2J+1)}{2(2I+1)},$$

J = total spin of compound nucleus,

I = spin of target nucleus,

E = neutron energy (in laboratory), eV,

E_0 = resonance energy (in laboratory), eV,

$$\Gamma_n^p = \Gamma_n^0 \sqrt{E_0} v_1(E_0),$$

$$v_1(E_0) = \frac{\sigma_p E_0}{2.60385 \times 10^6 \left(1 + \frac{1}{A} \right)^2 + \sigma_p E_0} = \text{p-wave penetration factor},$$

Γ_n^0 = reduced neutron width,

and

σ_p = potential scattering cross section.

Doppler-broadened line-shape functions Ψ and χ are obtained from the complex probability integral W as follows:

$$\Psi(\xi, x) = \frac{\xi \sqrt{\pi}}{2} \operatorname{Re} W\left(\frac{\xi x}{2}, \frac{\xi}{2}\right), \quad (49)$$

and

$$\chi(\xi, x) = \xi \sqrt{\pi} \operatorname{Im} W\left(\frac{\xi x}{2}, \frac{\xi}{2}\right). \quad (50)$$

Values of $\operatorname{Re} W$ and $\operatorname{Im} W$ are obtained from subroutine QUICKW.⁶

VI. OUTPUT EDIT

As explained in the Introduction, much of the RABBLE code was initially used in RABID and modified as necessary. The output edit is composed of all the normal RABBLE output plus resonance integrals, special output for foils at interfaces in the unit cell, the execution time, and a table showing the number of fine groups used to lethargy-average scattering rates for each material in each broad group. The edited quantities will now be defined, after the nomenclature is established.

<u>Variable</u>	<u>Definition</u>
k	Fine-group index
I	Intermediate- or broad-group index
i	Region index
j	Material index
ℓ	Interface index ($\ell = 1$ at right of first region)
m	Composition index
n	Foil-composition index
ϕ_{ik}	Spatially integrated flux per unit lethargy in fine group k and region i
${}_z R_{ik}^j$	$= \phi_{ik} \sum_z {}^j \Delta u =$ reaction rate for process z (f = fission, a = absorption, s = scattering) in fine group k integrated over region i

<u>Variable</u>	<u>Definition</u>
Δu	Fine-group lethargy width
A_i	Thickness of region i (cm)
ΔU_I	Lethargy width of intermediate or broad group I
u_I	Lower lethargy bound of group I
x_m	Left boundary of composition m ($x_1 = 0$)
N_{jm}	Atom number density of material j in composition m

A. Regional Average Flux

$$\bar{\phi}_{iI} = \frac{\int_{u_I}^{u_{I+1}} \phi_i(u) du}{A_i \int_{u_I}^{u_{I+1}} du} \approx \frac{\sum_k \phi_{ik} \Delta u}{A_i \Delta U_I}. \quad (51)$$

B. Composition-averaged Flux

$$\bar{\phi}_{mI} = \frac{\int_{x_m}^{x_{m+1}} dx \int_{u_I}^{u_{I+1}} \phi(u, x) du}{\int_{x_m}^{x_{m+1}} dx \int_{u_I}^{u_{I+1}} du} \approx \frac{\sum_i \bar{\phi}_{iI}}{\sum_i i}. \quad (52)$$

C. Cell-averaged Flux

$$\bar{\phi}_I = \frac{\int_0^\infty dx \int_{u_I}^{u_{I+1}} \phi(u, x) du}{\int_0^\infty dx \int_{u_I}^{u_{I+1}} du} \approx \frac{\sum_m \bar{\phi}_{mI} A_m}{\sum_m A_m}. \quad (53)$$

D. Composition-averaged Microscopic Cross Section for Process z

$${}_z \bar{\sigma}_{mI}^j = \frac{\int_{x_m}^{x_{m+1}} dx \int_{u_I}^{u_{I+1}} \Sigma_z^j(u) \phi(u, x) du}{N_{jm} \int_{x_m}^{x_{m+1}} dx \int_{u_I}^{u_{I+1}} \phi(u, x) du} \approx \frac{\sum_i \sum_k {}_z R_{ik}^j}{N_{jm} \sum_i \sum_k \phi_{ik}}. \quad (54)$$

E. Cell-averaged Macroscopic Cross Section for Process z

$${}_z\bar{\Sigma}_I = \frac{\int_0^\infty dx \int_{u_I}^{u_{I+1}} \phi(u, x) {}_z\Sigma(u, x) du}{\int_0^\infty dx \int_{u_I}^{u_{I+1}} \phi(u, x) du} \approx \frac{\sum_j \sum_i \sum_k {}_zR_{ik}^j}{\sum_i \sum_k \phi_{ik}}. \quad (55)$$

In the above five definitions, $\sum_k$ is over all fine groups within Group I, $\sum_i$ is over all regions in the composition m, and $\sum_j$ is over all materials.

F. Resonance Integral for Process z

The resonance integral is defined as that cross section which, when multiplied by the flux that would be present in the absence of resonances, ϕ_∞ , gives the true reaction rate. The normalization used assumes $\phi_\infty = 1$.

$${}_z(RI)_{mI}^j \phi_\infty = \frac{\int_{x_m}^{x_{m+1}} dx \int_{u_I}^{u_{I+1}} {}_z\Sigma^j(u) \phi(u, x) du}{N_{jm} A_m} \approx {}_z\bar{\Sigma}_{mI}^j \bar{\phi}_{mI} \Delta U_I. \quad (56)$$

The symbols printed out are RA and RF for absorption and fission resonance integrals. Scattering resonance integrals are not printed but can be calculated as shown.

G. Accumulated Absorption Probability for a Broad Group

$$RAP = \frac{\int_0^\infty dx \int_{u_I}^{u_{I+1}} \phi(u, x) {}_a\Sigma(u, x) du}{SDD} \approx \frac{\sum_j \sum_i \sum_k aR_{ik}^j}{SDD}, \quad (57)$$

where the slowing-down density at the lethargy corresponding to the start of the problem is

$$SDD = \phi_\infty \sum_m A_m \sum_j N_{jm} \xi_j \sigma_p^j \quad (58)$$

and

$$\xi = 1 - \frac{\alpha}{1 - \alpha} \epsilon. \quad (59)$$

H. Foil Resonance Integral for Process z

Microscopic average foil cross sections are not calculated; hence, microscopic resonance integrals for foils can only be obtained if the foil consists of just one material. In that case,

$$z(RI)_{nI}^{\ell j} \phi_{\infty} = \frac{\int_{u_I}^{u_{I+1}} z \Sigma^n(u) \phi_{\ell}^n(u) du}{N_{jn} A_n} \approx z \bar{\Sigma}_{\ell I}^n \bar{\phi}_{\ell I}^n \Delta U_I / N_{jn}. \quad (60)$$

The quantity edited is $z \bar{\Sigma}_{\ell I}^n \bar{\phi}_{\ell I}^n \Delta U_I$. The flux incident upon all foils is the same. Although it is not edited directly, one can obtain it by defining an optically thin foil (say $\tau < 10^{-4}$ mean free paths) for which $\sigma_a = \sigma_f = 0$ and σ_s is independent of energy. Then the broad-group-average flux ϕ_{inc} incident upon foils can be extracted from

$$RS(F) = \Sigma_s \phi_{inc} \Delta U_I. \quad (61)$$

VII. INPUT PREPARATION

A. Choice of Group Sizes

The intermediate-group size no longer has any effect on the slowing-down source (it did in RABBLE¹), but is still involved in calculating resonance cross sections. If the energy at the peak of a resonance lies within a given intermediate group, it automatically is included, regardless of the magnitude of the cross section. If not within the given intermediate group, it is included only if $\sigma_t > \text{TEST}$ (an input variable) at either end of the intermediate group. Thus, to save running time, the user should use a small intermediate-group size if he specifies $\text{TEST} > 0$. For example, 0 01 lethargy unit is reasonable.

The choice of fine-group size $\Delta u_I = \text{UIGP}/\text{NFI}(I)$ can be placed on a consistent basis by comparison with the Doppler width

$$w = \sqrt{\frac{4E_0 k T}{A}}, \quad (62)$$

where E_0 is the resonance energy, k is Boltzmann's constant (8.6164×10^{-5} eV/°K), T is the temperature, and A is the mass number of the resonant material. A satisfactory rule of thumb is to choose Δu_I so that $\Delta u_I \leq w/4E$.

B. Input Description for RABID

The following overall restrictions must be observed:

<u>Parameter</u>	<u>Range</u>
Regions	$1 \leq KREG \leq 30$
Materials	$1 \leq KMAT \leq 20$
Resonant materials	$1 \leq KRES \leq 20$
Compositions	$1 \leq KCOMP \leq 30$
Resonances	$1 \leq \sum_{J=1}^{KRES} NRES(J) \leq 300$
Intermediate groups	$1 \leq KGP \leq 1000$
Broad groups	$1 \leq KBG \leq 25$

<u>Card</u>	<u>Format</u>	<u>Variable</u>	<u>Description</u>
1	18A4	(TITLE(I), I=1,18)	Problem identification
2	10I6	KREG	No. of regions; $1 \leq KREG \leq 30$.
		KMAT	No. of materials; $1 \leq KMAT \leq 20$.
		KCOMP	No. of compositions; $1 \leq KCOMP \leq 30$.
		KRES	No. of resonant materials; $1 \leq KRES \leq 20$.
		KGP	No. of intermediate groups; $1 \leq KGP \leq 1000$.
		KBG	No. of broad groups; $1 \leq KBG \leq 25$.
		NOPT	NOPT = 0, homogeneous; $1 \leq NOPT \leq 3$, normal, heterogeneous; NOPT = 4, special case with resonance interference term $\chi(\xi, x)$ set to zero. If KREG = 1, the result is homogeneous anyway.
		NTEMP	If all compositions at the same temperature, NTEMP = 1; otherwise, NTEMP = III. III = KCOMP + KFOIL ≤ 35 .
		NPRINT	If NPRINT > 0, edit of intermediate group output is omitted. If NPRINT < 0, fine-group fluxes and intermediate-group output are printed. MORE = 0 for the first problem in a batch.
		MORE	If the last problem in a batch, MORE > 0 gives elegant stop. Otherwise, an "end of data set" error will terminate the run. MORE < 0 denotes the next problem to be a modification problem.*

*A modification problem is one in which some input variables from the preceding problem need modification, while the other input variables remain fixed. Any or all input variables may be changed using the NAMELIST feature of FORTRAN-IV.⁷ The NAMELIST name is MOD. This convenient input feature results in considerable savings in cards and labor needed to run a sequence of closely related problems. A new title card (type-1) is assumed to precede the NAMELIST input for a modification problem.

<u>Card</u>	<u>Format</u>	<u>Variable</u>	<u>Description</u>
3	12I6	(NIB(I),	No. of intermediate groups in Ith broad group; $1 \leq \text{NIB(I)} \leq 100$, and $\sum \text{NIB(I)} = \text{KGP}$.
		NFI(I), I=1, KBG)	No. of fine groups per intermediate group in Ith broad group, chosen such that $\text{UIGP}/\text{NFI(I)} \leq 10^{-3}$.
4	3E12.6,4I6	UIGP	Lethargy width of intermediate group.
		ENGP(1)	Maximum energy of the range covered in the calculation (eV).
		TEST	A resonance contributes to the cross sections for fine groups within an intermediate group if (a) the resonance energy lies within the intermediate group, or (b) the resonance cross section at either the upper or lower energy limit of the intermediate group exceeds TEST (barns).
		KFOIL	No. of foils to edit interface fluxes and average cross sections; $0 \leq \text{KFOIL} \leq 5$. Computation time is minimized by handling a problem with several foils in a single run as opposed to several runs, each with a single foil.
		KBSQ	If $\text{KBSQ} > 0$, read type-5 cards for the broad-group transverse bucklings. If $\text{KBSQ} \leq 0$, omit type-5 cards.
		KS	$\text{KS} > 0$ deletes ingroup scattering by adjusting group-transfer probabilities.
5	5E12.6	(BSQ(I), I=1, KBG)	Broad-group transverse bucklings.
		(TEMP (I), I=1, III)	Temperature of Ith composition ($^{\circ}\text{K}$), if $I \leq \text{KCOMP}$. Temperature of foil $I - \text{KCOMP}$ otherwise. $\text{III} = \text{KCOMP} + \text{KFOIL} \leq 35$.
7	5(I2,E10.4)	(NINT(I),	No. of regions into which Ith composition is divided, if $I \leq \text{KCOMP}$. Not used if $I > \text{KCOMP}$.
		RMAX(I),	Outer boundary of Ith composition, if $I \leq \text{KCOMP}$.
		I=1, III)	Thickness of foil $I - \text{KCOMP}$, if $I > \text{KCOMP}$ (cm).
8	A6,I6,4E12.6	(NUCLID(I),	Identification of Ith material.
		NRES(I),	No. of resonances for Ith material; $\sum \text{NRES(I)} \leq 300$. If $I > \text{KRES}$, $\text{NRES(I)} = 0$.
		AMU(I),	Atomic weight of Ith material (AMU).
		SIGPOT(I),	Potential scattering cross section of Ith material (b).

<u>Card</u>	<u>Format</u>	<u>Variable</u>	<u>Description</u>
		SIGA22(I),	2200-m/sec (0.0253 eV) value of $1/v$ absorption cross section for resonant materials. Constant-background absorption cross section for resonant materials (b).
		SIGF22(I), I=1,KMAT)	2200-m/sec (0.0253-eV) value of $1/v$ fission cross section for nonresonant materials. Constant-background fission cross section for resonant materials (b).
9	5E12.6	(DEN(I,J), J=1,III)	Atom density of material I in composition J, if $I \leq KCOMP$. If $I > KCOMP$, atom density of material I in foil $I - KCOMP$ ($10^{24}/\text{cm}^3$).

NOTE: Materials must be ordered so that information for resonant materials is read first. If $NRES(I) > 0$, read in cards 10 for the resonances of material I next; if $NRES(I) = 0$, read in card 8 for material $I + 1$ next.

10	5E12.6	(ER(J), GN(J), GR(J), GF(J), G(J), J=1,NRES(I))	Energy of Jth resonance (eV). Neutron width of Jth resonance at ER(J) (eV). Radiation width of Jth resonance (eV). Fission width of Jth resonance (eV). Statistical spin factor. $g = \frac{2J' + 1}{2(2I' + 1)}$, where J' is the spin of the compound nucleus and I' is the spin of the target nucleus. For s-waves, $G(J) \geq 0$. To denote a p-wave, tag a minus sign on G(J).
11	6E12.5	(SIGA22(I), SIGF22(I), I=1,KRES)	If $KB \neq 0$, KBG sets of type-11 cards are required. Constant-background absorption cross section for resonant materials, for a given broad group. Constant-background fission cross section for resonant materials, for a given broad group.

C. Error Messages

Only a few consistency checks on input parameters are performed. A few calculated quantities are checked to see if they are physically reasonable. If they are not, the problem may be aborted, or some corrective action taken. Listed below are the checks and decisions made by the code.

1. RATES

a. $KREG < 0$ sets $IERR = 1$, prints *****KREG****, and returns to MAIN, where the problem is aborted. Input for the next problem is then processed.

b. Optical thicknesses TAU are checked. $TAU < 0$ sets IERR = 1, prints K, TAU(K), IBGP, and IFGP, followed by *****PROBLEM ABORTED. Control returns to MAIN, which aborts the problem. Input for the next problem is then processed.

c. Collision rates are inspected. If $CR < 0$, the $\vec{CR}$ vector and the $\underline{P}$ matrix are printed followed by the message NEG. COLL. RATE ZEROED OUT. Then SOURCE(I), TQ(I), DS(I), TAU(I), and ITRY(I) are printed out for $1 \leq I \leq KREG$. The $\vec{CR}$ are renormalized so that the smallest value is zero and neutron conservation is maintained. A gross error in calculating $\underline{P}$ is required for this error.

2. SOARCE

a. SOURCE < 0 prints I, SOURCE(I), and energy E. The problem continues using

$$SOURCE(I) = \sum_{j=1}^{KMAT} DS1(J)*PHI(I)*SL(J,LREG(I))$$

= downscatter contribution from previous group.

3. INPUT

a. $KREG \neq \sum_{K=1}^{KCOMP} NINT(K)$ prints KREG NOT CONSISTENT

WITH NINT, and problem is aborted. Input for the next problem is read.

b. LAST(KRES) > 300 prints > 300 RESONANCES, and problem is aborted. Input for the next problem is read.

c. $\sum_{I=1}^{KBG} \neq KGP$ prints their values. KGP is reset to the

smaller value and printed. Problem is aborted if $KGP > 1000$ or $KGP \leq 0$; then input for next problem is read.

4. MATINV

DETERM = 0 implies MATINV is trying to invert a singular matrix. It immediately returns to RATES, which does not check for failure.

D. Timing Considerations

The most important factors influencing the computer time (CPU time) required are the number of regions, the number of foils, the unit-cell

optical thickness, and the number of fine groups. The basic quantity the user wants to know is calculational speed, in fine groups per minute (since total time varies directly with the number of fine groups). Table I gives an estimate which should be within $\pm 20\%$ for typical problems having a unit-cell optical thickness >0.2 mean free path. The time per fine group needed to obtain region collision rates and fluxes is

$$t_{\phi} \approx 0.01\{2.368 + N[-0.582 + N(0.24 - 0.00094N)]\} \text{ (sec)}, \quad N \geq 2. \quad (63)$$

The time per fine group needed to obtain interface collision rates for a foil is

$$t_f \approx 0.01\{1.463 + N[-1.092 + N(0.407 - 0.0071N)]\} \text{ (sec)}, \quad N \geq 2. \quad (64)$$

In Eqs. 63 and 64, N is the number of regions. Then the total time per fine group is

$$t_{\text{total}} = t_{\phi} + t_f * K_{\text{FOIL}}. \quad (65)$$

TABLE I. Calculational Speed (all compositions at same temperature)

No. of Regions	No. of Fine Groups per Minute			No. of Regions	No. of Fine Groups per Minute		
	No Foils	One Foil	Two Foils		No Foils	One Foil	Two Foils
1	43,000	37,700	33,800	11	250	133	73
2	2,780	2,000	1,560	12	215	95	62
3	2,180	1,360	990	13	180	82	53
4	1,570	860	595	14	155	71	46
5	1,120	565	380	15	135	62	40
6	820	390	260	16	119	55	36
7	620	285	185	18	94	44	29
8	480	215	140	20	76	37	24
9	375	170	110	25	49	25	17
10	305	137	89	30	34	19	13

Homogeneous problems are a special case. For these, a single-material problem gave

$$t_{\text{total}} = 0.0014 + 0.00036M \text{ (sec)}, \quad (66)$$

Equations 63-66 are for all compositions at the same temperature. Times will increase if more than one temperature is involved, or for greater complexity in terms of numbers of resonances and materials. Conversely, some problems with large N may be quicker because fine groups for which the unit cell optical thickness is large (on a resonance peak) have essentially uncoupled regions. RABID assumes that regions more than nine mean free paths apart are totally uncoupled.

APPENDIX A

Numerical Methods Used to Obtain Collision Rates

1. Introduction

Integral transport theory was used in Section II to derive plate-to-plate collision probabilities in infinite slab geometry as used in the RABID code. The "exact" analytic expressions derived involve many infinite sums of the exponential integral functions²

$$E_n(z) = \int_1^\infty e^{-zt} dt/t^n, \quad n \geq 0. \quad (A.1)$$

A needed related function is

$$\alpha_n(z) = \int_1^\infty t^n e^{-zt} dt, \quad n \geq 0. \quad (A.2)$$

The sum we wish to evaluate numerically for a unit cell of optical thickness h is

$$S_n(z, h) = \int_1^\infty \frac{e^{-zt} dt}{(1 - e^{-ht}) t^n} = \sum_{k=0}^\infty E_n(z + kh), \quad n > 0. \quad (A.3)$$

A very fast, accurate method for calculating $S_n(z, h)$ has been derived on the basis of special Gaussian quadrature formulas. That is, let

$$\int_1^\infty \exp(-x) f(x) dx/x^n = \sum_{i=1}^M w_{i,n} f(t_{i,n}) + R_M(z) \quad (A.4)$$

and

$$\int_1^\infty g(x) dx/x^n = \sum_{i=1}^M [w_{i,n} \exp(t_{i,n})] g(t_{i,n}) + R_M(z), \quad (A.5)$$

where $R_M(z)$ is the remainder (or error in the M th order quadrature), $f(x)$ is an arbitrary function, $g(x) = e^{-x}f(x)$, and $w_{i,n}$ and $t_{i,n}$ are quadrature weights and nodes, respectively. The quadratures are exact if $f(x)$ is a polynomial of degree less than or equal to $2M - 1$. One obtains

$$S_n(z, h) \approx \sum_{i=1}^M \left[\frac{w_{i,n} \exp(t_{i,n})}{1 - \exp(-ht_{i,n})} \right] \exp(-zt_{i,n}). \quad (A.6)$$

In this application, h remains constant for a given fine group. A useful method of evaluating exponential integrals also results from Eq. A.5:

$$E_n(x) \approx \sum_{i=1}^M [w_{i,n} \exp(t_{i,n})] \exp(-xt_{i,n}).$$

The methods used to evaluate the nodes $t_{i,n}$, weights $w_{i,n}$, and $w_{i,n} \exp(t_{i,n})$ of Eqs. A.4 and A.5 are discussed in Sections 2 and 3 below. Tables of results to 16 significant figures for $n = 0(1)10$ and $M = 2(1)10$ have been published.⁸

2. The Equations To Be Solved

The construction of the quadrature formulas of order M follows the method used by Chandrasekhar.⁹ Given a weighting function $t^{-n} \exp(-t)$, define its ℓ th moment over $[1, \infty]$ to be

$$\alpha_{n,\ell} = \int_1^\infty t^{\ell-n} \exp(-t) dt, \quad \ell = 0, 1, \dots, 2M - 1. \quad (\text{A.7})$$

We require that

$$\alpha_{n,\ell} = \sum_{i=1}^M w_i t_i^\ell, \quad \ell = 0, 1, \dots, 2M - 1. \quad (\text{A.8})$$

Equations A.8 are a nonlinear system of $2M$ equations in the $2M$ unknowns w_i and t_i . To solve Eqs. A.8, form the sums

$$\alpha_{n,i+M} + \sum_{\ell=0}^M c_\ell \alpha_{n,i+\ell}, \quad i = 0, 1, \dots, M - 1, \quad (\text{A.9})$$

where the c_ℓ 's are undetermined constants. Use of Eqs. A.8 in Eq. A.9 gives

$$\sum_{j=1}^M w_j t_j^i \left(t_j^M + \sum_{\ell=0}^{M-1} c_\ell t_j^\ell \right), \quad i = 0, 1, \dots, M - 1. \quad (\text{A.10})$$

The c_ℓ 's can now be defined as the unique solution to

$$\alpha_{n,i+M} + \sum_{\ell=0}^{M-1} c_\ell \alpha_{n,i+\ell} = 0, \quad i = 0, 1, \dots, M - 1. \quad (\text{A.11})$$

Then, from Eq. A.10,

$$t_j^M + \sum_{\ell=0}^{M-1} c_\ell t_j^\ell = 0, \quad j = 1, \dots, M.$$

The nodes t_i are the roots of

$$F(t) = t^M + \sum_{\ell=0}^{M-1} c_\ell t^\ell = 0. \quad (\text{A.12})$$

The weights w_i are obtained from any M of Eqs. A.8 upon insertion of the t_i .

3. Computational Methods and Results

All computations were carried out on a CDC-1604 computer with 25-digit accuracy. The fundamental quantities required accurately are the moments

$$\begin{aligned} \alpha_{n,\ell} &= \int_1^\infty \exp(-t) dt / t^{n-\ell} \\ &= E_{n-\ell}(1), \quad \text{if } n - \ell > 0, \\ &= \exp(-1), \quad \text{if } n - \ell = 0, \\ &= \exp(-1) + (\ell - n) \alpha_{n,\ell-1}, \quad \text{if } n - \ell < 0. \end{aligned} \quad (\text{A.13})$$

First $E_1(1)$ was evaluated to 25S from the series

$$E_1(x) = -(\gamma + \ln x) + x - \frac{x^2}{2 \cdot 2!} + \frac{x^3}{3 \cdot 3!} - \dots,$$

including terms up to the 30th power. Then the recursion relation $E_n(x) = [\exp(-x) - x E_{n-1}(x)] / (n-1)$ was used to generate other $E_n(1)$. Less than one significant figure is lost in $E_{10}(1)$, and this loss is not important because the α_ℓ differ by 7 to 17 orders of magnitude at low and high ℓ , depending on M (as shown in Table II). The magnitude range is less for smaller M .

Equations A.11 have a symmetric matrix of coefficients. The square-root method¹⁰ was used to solve Eqs. A.11. The roots of Eq. A.12 were obtained by Newton's method of linear interpolation. Ten refinements in each root were performed to ensure accuracy to the limitations of the computer. The first M of Eqs. A.8 were then solved by the Gauss elimination method.

TABLE II. The Moments $\alpha_{n,l} = \int_1^\infty \exp(-t) dt/t^{n-l}$

$n - l$	$\alpha_{n,l}$	$n - l$	$\alpha_{n,l}$
10	3.63939940314164016341645E-02	-5	1.19928697821890196840141E 02
9	4.03334948886947068880430E-02	-6	7.19940066372512623362440E 02
8	4.52114820618846664911801E-02	-7	5.03994834404875980585868E 03
7	5.13990667382496561572632E-02	-8	4.03199546318312498891910E 04
6	5.94850407419443846519443E-02	-9	3.62879959565922420445041E 05
5	7.04542374617203983358024E-02	-10	3.62879996353866537589273E 06
4	8.60624913245607282523142E-02	-11	3.99167999668047603062623E 07
3	1.09691967197760136838582E-01	-12	4.79001599969536564846590E 08
2	1.48495506775922047918360E-01	-13	6.22702079997185478417712E 09
1	2.19383934395520273677164E-01	-14	8.71782911999738464196511E 10
0	3.67879441171442321595524E-01	-15	1.30767436799997557573594E 12
-1	7.35758882342884643191047E-01	-16	2.09227898879999770912162E 13
-2	1.83939720585721160797762E 00	-17	3.55687428095999978430116E 14
-3	5.88607105874307714552938E 00	-18	6.40237370572799997962153E 15
-4	2.39121636761437509037090E 01	-19	1.21645100408831999980688E 17

The accuracy of the results for $M = 4$ and 8 for $n = 0$ was confirmed by comparison with the work of Rabinowitz and Weiss.¹¹ The nodes are identical to all 18S of their tables. The weights also agree to all 18S upon scaling their results by a factor of $e = 2.718 \dots$ (corresponding to the change of variables: $t = x - 1$). A similar check with Abramowitz and Stegun¹² for $M = 2$ and 10 for $n = 0$ indicated a difference of at most a half-digit in the 12th and last place of their tables. The number of accurate significant figures obtained is approximately $20 - 0.4n$. For uniformity, the tabled values have been rounded to 16 figures.

4. Optically Thin Unit Cells

The Gaussian quadratures derived here are least accurate for either z or h small (say, < 0.1). Also, the error increases as z or h approaches zero and as M decreases. A complementary numerical technique has been derived which rapidly becomes more accurate as h decreases. The Euler-MacLaurin summation formula¹³ leads to

$$\begin{aligned}
 S_n(z, h) = & E_{n+1}(z)/h + E_n(z)/2 + hE_{n-1}(z)/12 \\
 & - h^3E_{n-3}(z)/720 + h^5E_{n-5}(z)/30,240 \\
 & - h^7E_{n-7}(z)/1,209,600 + h^9E_{n-9}(z)/47,900,160 - \dots, \quad (A.14)
 \end{aligned}$$

where $E_{n-\ell}(z)$ is replaced by $\alpha_{\ell-n}(z)$ if $n - \ell < 0$. The truncation error of the series in Eq. A.14 is less than the absolute value of the first neglected term for h sufficiently small.

Much simpler expressions can be obtained using the recursion relation

$$E_n(z) = [e^{-z} - zE_{n-1}(z)]/(n-1) \quad (\text{A.15})$$

and the definition

$$E_0(z) = e^{-z}/z. \quad (\text{A.16})$$

For example,

$$S_2(z, h) \approx \frac{1}{2} \{ \exp(-z) [1/h + h/6z - h^3(1+z)/360z^2] + E_2(z)(1 - z/h - h/6z) \} + h^5/5040z^4 \quad (\text{A.17})$$

$$|\text{error}| < h^7 \alpha_5(z)/1,209,600 < h^7/10,080z^6.$$

$$S_3(z, h) \approx \frac{1}{12} \{ \exp(-z) [(4-2z)/h + 3 - (h^3/60z)(1 - [h^2/(21z^2)]) \cdot [1 + z + z^2/2]] \} + E_2(z)(h - 3z + 2z^2/h) \quad (\text{A.18})$$

$$|\text{error}| < h^7 \alpha_4(z)/1,209,600 < h^7/50,400z^5.$$

$$S_4(z, h) \approx \frac{1}{12} \left\{ \exp(-z) \left[\frac{3-z}{h} + 2 + h^3(1-z)/60z^2 \right] + E_3(z)(z^2/h + h - 2z - h^3/30z^2) \right\} \quad (\text{A.19})$$

$$|\text{error}| < h^5 \alpha_1(z)/30,240 < h^5/30,240z^2.$$

Equations A.17-19 require $z \geq h$ for accuracy. Equation A.17 in particular benefits by the restriction $z \geq 2h$. For small arguments, $E_2(z)$ and $E_3(z)$ are quickly obtained from series expansions.

Another numerical difficulty arises for optically thin plates, such as thin foils. The collision rate in the foil involves taking the difference $S_{n+1}(z, h) - S_{n+1}(z + \Delta, h)$, where Δ is very small. In this case, all numerical accuracy is eventually lost for Δ sufficiently small. A Taylor series expansion about $z + \Delta/2$ yields

$$E_{n+1}(z - \Delta/2) - E_{n+1}(z + \Delta/2) = \Delta [E_n(z) + \Delta^2 E_{n-2}(z)/24 + \Delta^4 E_{n-4}(z)/1920 + \dots], \quad (\text{A.20})$$

where again $\alpha_{\ell-n}(z)$ is substituted for $E_{n-\ell}(z)$ if $n - \ell < 0$. Equation A.20 is a rapidly convergent expansion for $\Delta < 0.01$, which improves in accuracy as $\Delta \rightarrow 0$. It also leads to easy numerical evaluation via the Gaussian quadrature of Eq. A.6:

$$S_{n+1}(z, h) - S_{n+1}(z + \Delta, h) \approx \Delta \sum_{i=1}^M \left[\frac{w_{i,n} \exp(t_{i,n})}{1 - \exp(-ht_{i,n})} \right] \exp[-(z + \Delta/2) t_{i,n}] \\ \cdot (1 + \Delta^2 t_{i,n}^2/24 + \Delta^4 t_{i,n}^4/1920), \quad \Delta < 0.01. \quad (\text{A.21})$$

The given numerical techniques are all in use in several codes such as RABID, and in versions of the perturbation-theory heterogeneity-effect codes CALHET¹⁴ and CALHET-2.¹⁵

APPENDIX B

Coding Description

RABID consists of the main program and 22 subprograms, about half of which are small functions or subroutines that return a single calculated number. This diversity of special subprograms is required in order to optimize computation speed and numerical accuracy over several ranges of arguments. The logical connections between the various parts of RABID are shown in Fig. 2. Calls to subprograms are represented by traveling down the connecting links; returns go in the opposite direction. Most of the program uses common blocks of storage to save running time by eliminating or minimizing lists of formal parameters. As a result, duplication of variable names is also minimized. It is coded entirely in the FORTRAN IV language.^{7,16} The purpose of each subprogram is described briefly below.

Fig. 2. Subroutine Hierarchy in RABID

1. MAIN

The main program (MAIN) controls the logical sequence of much of the code. At the start of the first problem in a batch, subroutine TABLE is called. Also, the tables of real and imaginary parts of the complex probability integral W are transferred from a data set on the disc to the TR and TI arrays in core storage. Succeeding problems in a batch assume all tables are available. Numerous variables are initialized after subroutines INPUT, DATA, SYM, and RESTES have been called and executed. The main loop is $\text{DO } 45 \text{ IBGP} = 1, \text{ KGP}$ (card 78), which runs over all intermediate groups. Within this is another loop over fine groups: $\text{DO } 22 \text{ IFGP} = 1, \text{ N}$ (card 103). Subroutines SOARCE, XSECT, and RATES are cycled through in the inner loop. Also within this loop, reaction rates, integral fluxes, and scattering rates are accumulated and stored. Subroutine OUTPUT is called from inside the outer loop.

2. TABLE

The exponential integrals $E_3(Z)$ and $E_4(Z)$ are obtained from two polynomial and rational approximations (Ref. 12, 5.1.53 and 5.1.56, p. 231). Values are tabulated for Z as follows: 0(0.01)2(0.02)4(0.08)6.4. For $1 \leq I \leq 331$, $TAB(I)$ is E_3 while $TAB(I+331)$ is E_4 . Functions $E3$ and $E4$ use these tables.

3. INPUT

All required card input is read, $DATA$ is called, and problem specifications are printed. SYM is called, followed by a consistency check on KGP and $NIB(I)$.

4. DATA

Space allocations for scattering rates are determined, ingroup-scatter and downscatter probabilities are calculated, and constants related to cross sections and geometry are evaluated.

5. SYM

The unit cell is scanned for region symmetries. Symmetric-region number pairs are stored in array $ISYM$ to be used by $RATES$ to ensure symmetry in collision rates. Slight round-off and numerical errors tend to accumulate if not kept in check. $ISYM$ is printed, unless there are no symmetric regions.

6. RESTES

The name is a six-character truncation of $RESTEST$ from $RABBLE$. This subprogram determines which resonances are to be included when calculating cross sections for the fine groups in any intermediate group. The resonance contributes if

- a. The resonance energy lies within the intermediate group, or
- b. The resonance cross sections at either the upper or lower energy limit of the intermediate group exceeds the input parameter $TEST$.

7. QUICKW

$ReW(\xi x/2, \xi/2)$ and $ImW(\xi x/2, \xi/2)$ are obtained by six-point interpolation within two 62×62 tables (TR and TI) or from rational approximations if the arguments of W are outside the tables.⁶

8. SOARCE

The source for the first fine group in a problem is obtained under the assumption that $\phi(u) = \phi_\infty$ for u less than the lethargy at the start of the problem. The source in Region i is

$$SI(I) = A_i \sum_j N_{ji} \sigma_p^j. \quad (B.1)$$

The source is calculated from Eq. 30, which is equivalent to Eq. 12 for all other fine groups. Numerical round-off is controlled by keeping all increments to the source in a separate array called DS. Hence the total source in Region i is $SI(I) + DS(I)$.

9. XSECT

Section V gives the equations for s- and p-wave resonance cross sections and $\Psi(\xi, x)$ and $\chi(\xi, x)$, which are evaluated using $\text{Re}W(\xi x/2, \xi/2)$ and $\text{Im}W(\xi x/2, \xi/2)$ from QUICKW. Macroscopic cross sections are obtained for each material in each composition, for each fine group.

10. RATES

The primary purpose of RATES is to produce the collision-rate vector $\underline{CR}$ by solving Eq. 22. It also produces an interface collision-rate vector for each foil. Many auxiliary calculations are required before the collision probability matrix $\underline{P}$ is evaluated. For example, the non-leakage probability is found from Eqs. 29-32. Optical thicknesses τ_i are obtained for regions and the unit cell, h . Fourth-order quadrature weights are found from Eq. A.6, for $S_3(z, h)$ and $S_4(z, h)$.

The spatially flat slowing-down source is linearized in compositions having more than one region. If the linear component exceeds 1% of the flat source strength, it is retained. Otherwise, it is dropped. A further test requires the linear component of the current leaving a source region to exceed 1% of the flat-component current in order to be retained. These measures save computer time on negligible effects.

Uncollided neutron currents from flat source components are followed from left to right across the unit cell. Given a flat source strength of PNL in region i , the collision rate in region j is found from Eqs. 17-20. Reciprocity is used to find the collision rate in region i from a flat source in region j . Collision rates due to linear source components are calculated by following currents in both directions across the unit cell. The collision rate in the "last" region ($i + \text{KREG} - 1$) is found from neutron conservation. Hence $\text{KREG}(\text{KREG} - 1)$ collision probabilities need be obtained to account

for flat source components, with twice this number to account for linear source components, because reciprocity does not apply.

After $\overrightarrow{CR}$ and $\overrightarrow{\phi}$ are obtained, the ingroup scattering contribution to the source, $\overrightarrow{\Sigma_s P_s \phi}$, is obtained. Numerical round-off is controlled by dropping the total increment to the source from group $k - 1$ to k if its magnitude is less than 0.5×10^{-6} times $\overrightarrow{S}_c$.

11. OUTPUT

Intermediate- and broad-group average fluxes and cross sections defined in Section VI are printed if requested.

12. E2

The following series expansion is evaluated:

$$E2(x) \approx 1 - x(1 - \gamma - \ln x) - \frac{x^2}{1 \cdot 2!} + \frac{x^3}{2 \cdot 3!} - \frac{x^4}{3 \cdot 4!}, \quad 0 \leq x \leq 0.6. \quad (B.2)$$

13. E3

Linear interpolation within tables of $E_3(z)$ stored by TABLE is used to obtain $E_3(x)$, for $0 \leq x \leq 6.4$, with error $< 0.01\%$. For $x > 6.4$, the following asymptotic approximation is used:

$$E_3(x) = e^{-x} \left\{ 1 + \frac{3}{D} [1 + (3 - 2x)/D] \right\} / (x + 3), \quad (B.3)$$

where

$$D = (x + 3)^2.$$

The error is 1/30% or less.

14. E4

Linear interpolation within tables of $E_4(z)$ stored by TABLE is used to obtain $E_4(x)$, for $0 \leq x \leq 6.4$, with error $< 0.01\%$. For $x > 6.4$, the following asymptotic approximation is used:

$$E_4(x) = e^{-x} \left\{ 1 + \frac{4}{D} [1 + (4 - 2x)/D] \right\} / (x + 4), \quad (B.4)$$

where

$$D = (x + 4)^2.$$

The error is 1/30% or less.

15. PE3

For $x < 0.6$, $E_3(x)$ is evaluated from the expansion

$$E_3(x) \approx \frac{1}{2} - x + \frac{x^2}{2} (1.5 - \gamma - \ln x) + \frac{x^3}{3!} - \frac{x^4}{2 \cdot 4!} + \frac{x^5}{3 \cdot 5!} - \frac{x^6}{4 \cdot 6!}. \quad (B.5)$$

The error is $\leq 1.1 \times 10^{-6}$. For $x \geq 0.6$, E3 is called.

16. PFUNC

The probability of escape without a collision from a slab of optical thickness x is (for a flat or linear source)

$$P = [0.5 - E_3(x)]/x. \quad (B.6)$$

If $x \geq 0.6$, $E_3(x)$ is obtained from E3; otherwise, the following double-precision series expansion is used:

$$0.5 - E_3(x) \approx +x - \frac{x^2}{2} (1.5 - \gamma - \ln x) - \frac{x^3}{3!} + \frac{x^4}{2 \cdot 4!} - \frac{x^5}{3 \cdot 5!} + \frac{x^6}{4 \cdot 6!} - \frac{x^7}{4 \cdot 7!}. \quad (B.7)$$

The error is $\leq 7 \times 10^{-8}$. High accuracy is needed to give good results for very thin slabs.

17. XTRAP

$$S_3(z, h) \approx \sum_{i=1}^M w_{i,3} e^{-zt_{i,3}} + C(z, h). \quad (B.8)$$

$$C(z, h) = (0.004126 + 0.00628e^{-19.6h}) e^{-18.2z}, \quad z < 0.3$$

$$= 0, \quad z \geq 0.3. \quad (B.9)$$

The M index lies between 1 and 4, depending on z .

18. XTRAP4

$$S_4(z, h) \approx \sum_{i=1}^M w_{i,4} e^{-zt_{i,4}} \quad (B.10)$$

The M index lies between 1 and 4, depending on z .

19. YZ3

Numerous options are exercised to maximize both speed and accuracy in evaluating a difference of the infinite sums of exponential integrals.

a. $\Delta > 0.01$ ($\Delta = z - y$)

(1) $h \leq 0.2$

$$S_3(y, h) - S_3(z, h) \approx EZ3(y, h) - EZ3(z, h). \quad (B.11)$$

(2) $h > 0.2$

$$S_3(y, h) - S_3(z, h) \approx \sum_{i=1}^M w_{i,3} (e^{-yt_{i,3}} - e^{-zt_{i,3}}) + C(y, h) - C(z, h). \quad (B.12)$$

See XTRAP for C and M.

b. $\Delta \leq 0.01$

(1) $\Delta < 0.0001$

From Eq. A.20,

$$S_3(y, h) - S_3(z, h) \approx \Delta S_2(y + \Delta/2, h). \quad (B.13)$$

The first few terms of $S_2(y + \Delta/2, h)$ are found "exactly" using $E2(z)$ for $z < 0.6$.

For $z \geq 0.6$, from Eq. A.21,

$$S_3(y, h) - S_3(z, h) \approx \Delta \sum_{i=1}^4 w_{i,2} [1 + u(1 + 0.0125u)] e^{-qt_{i,2}}, \quad (B.14)$$

where $u = \Delta^2 t_{i,2}^2 / 24$, and $q = y + \Delta/2$.

(2) $0.0001 \leq \Delta \leq 0.01$

Function PFUNC is used to get accurate differences in $E_3(y) - E_3(y + \Delta)$ as follows:

$$PFUNC(x) = (0.5 - E_3(x))/x. \quad (B.15)$$

$$\begin{aligned} \therefore E_3(x) - E_3(x+\Delta) &= (x+\Delta) \text{PFUNC}(x+\Delta) - x \text{PFUNC}(x) \\ &= x(\text{PFUNC}(x+\Delta) - \text{PFUNC}(x)) + \Delta \text{PFUNC}(x). \end{aligned} \quad (\text{B.16})$$

In this way, ℓ exact terms are found for

$$0 \leq \ell < \left(\frac{0.6 - y - \Delta}{h} \right)_{\text{truncated integer}}$$

Then the remainder of $S_3(y, h) - S_3(z, h)$ is found from Eq. B.14.

20. YZ4

This routine is much like YZ3, but is inherently more accurate because $S_4(z, h)$ is easier to sum than $S_3(z, h)$. Less numerical effort is justified since YZ4 is only involved in relatively small effects from linear source components. The options are:

$$\text{a. } \underline{\Delta > 0.01} \ (\Delta = z - y)$$

$$(1) \ \underline{h \leq 0.3}$$

$$S_4(y, h) - S_4(z, h) \approx \text{EZ4}(y, h) - \text{EZ4}(z, h). \quad (\text{B.17})$$

$$(2) \ \underline{h > 0.3}$$

$$S_4(y, h) - S_4(z, h) \approx \sum_{i=1}^M w_{i,4} \left[e^{-y t_{i,4}} - e^{-z t_{i,4}} \right]. \quad (\text{B.18})$$

$1 \leq M \leq 4$, depending on y .

$$\text{b. } \underline{\Delta < 0.01}$$

$$S_4(y, h) - S_4(z, h) \approx \Delta \left\{ \sum_{i=1}^4 w_{i,3} [1 + u(1 + 0.0125u)] e^{-q t_{i,3}} + C(q, h) \right\}. \quad (\text{B.19})$$

where $u = \Delta^2 t_{1,3}^2 / 24$ and $q = y + \Delta/2$. See XTRAP for $C(q, h)$.

21. EZ3

Equation A.18 gives

$$S_3(z, h) \approx E_3(z) + E_3(z+h) + S_3(z+2h, h).$$

In other words, two exact terms are calculated before summing the series to infinity.

22. EZ4

Equation A.19 gives

$$S_4(z, h) \approx E_4(z, + S_4(z+h, h).$$

In other words, a single exact term is calculated before summing the series to infinity.

23. MATINV

This is a standard ANL System/360 Library Subroutine,³ which performs matrix inversions. Numerical accuracy is maximized by pivoting on the largest element during reduction to a triangular system.

APPENDIX C

Listing of RABID

```
//APOKAEBK JOB (R,P26010,45,X00011),APO,CLASS=A,PRTY=8
// EXEC FTNHCLX,XREG=420K,CARDS=BCD,OPT=2,TIME=4
//C.SYSIN DD *
```

C	PROGRAM RABID	RAB	1
	CI *MON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	RAB	2
X	PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	RAB	3
X	SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DS1(20),	RAB	4
X	DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	RAB	5
	COMMON/QW/REZ,AIMZ,REW,AIMW, TRI(62,62),TI(62,62)	RAB	6
	COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	RAB	7
X	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	RAB	8
X	GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	RAB	9
X	SIGMIN(300), SIG(30),	RAB	10
X	SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	RAB	11
	COMMON/B/ UIGP, CR(30),RAD(35),	RAB	12
X	RATIO(30),DIFX(30), SPP(30),SPN(30),	RAB	13
X	AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	RAB	14
X	XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	RAB	15
X	V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	RAB	16
	COMMON/C/	RAB	17
X	XAREAT,AREAT,RMAX(30),	RAB	18
X	ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	RAB	19
X	XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	RAB	20
X	XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	RAB	21
X	GX2(10),GW2(10),WW2(10),	RAB	22
X	DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	RAB	23
X	GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	RAB	24
	COMMON/D/KI,KRES,NTEMP,INCLUD(300),	RAB	25
X	NEXT(20),LAST(20),NRES(20),INDEX, KS,	RAB	26
X	NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	RAB	27
X	IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	RAB	28
X	NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	RAB	29
X	INU1(20,25),INU2(20,25),NOX,NISO,KBSQ	RAB	30
	REAL*8 NUCLID	RAB	31
	DIMENSION DS(30),SOR(30),SI(30)	RAB	32
	DIMENSION LOC(20,30)	RAB	33
	REAL*8 TIME,DS,SOR,SI	RAB	34
	REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	RAB	35
X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	RAB	36
	REAL*8 DPS	RAB	37
	CALL TABLE	RAB	38
	READ(8) ((TR(I,J),I=1,62), J=1,62)	RAB	39
	READ(8) ((TI(I,J),I=1,62), J=1,62)	RAB	40
	MORE=0	RAB	41
1	CALL TIMSET	RAB	42
	IERR=0	RAB	43
	CALL INPUT	RAB	44
	IBG=1	RAB	45
	JBG=1	RAB	46
	NXN=NISO*NOX	RAB	47
	DO 11 I=1,NISC	RAB	48
11	SCAT(I)=0.	RAB	49
	JI=0	RAB	50
	DO 12 I=1,KREG	RAB	51
C	FLAT FLUX FOR FIRST NON-LEAKAGE CALCULATION	RAB	52
	PHI(I)=1.	RAB	53

M=LREG(I)	RAB	54
DO 12 J=1,KMAT	RAB	55
IF(DEN(J,M))13,12,13	RAB	56
13 JI=JI+1	RAB	57
LOC(J,I)=JI	RAB	58
12 CONTINUE	RAB	59
ACS=0.000	RAB	60
FCS=0.000	RAB	61
SCS=0.000	RAB	62
PHITOT=0.000	RAB	63
DO 2 I=1,KREG	RAB	64
2 PHIRT(I)=0.	RAB	65
DO 5 I=1,KCOMP	RAB	66
PHICT(I)=0.	RAB	67
DO 5 J=1,KMAT	RAB	68
RIAC(J,I)=0.0	RAB	69
RIFC(J,I)=0.0	RAB	70
5 RISC(J,I)=0.	RAB	71
DO 6 I=1,KPEG	RAB	72
DO 6 K=1,KFOIL	RAB	73
AF(I,K)=0.	RAB	74
SSF(I,K)=0.	RAB	75
6 FF(I,K)=0.	RAB	76
DO 45 IBGP=1,KGP	RAB	77
IF(IBGP-1)8,8,9	RAB	78
8 DO 7 J=1,KMAT	RAB	79
DSL(J)=P1(J,IBG)+PS(J,IBG)*(V(IBG)-1.000)	RAB	80
DSMAX(J)=ALP(J,IBG)*DSL(J)	RAB	81
UPS(J)=PS(J,IBG)	RAB	82
DSL(J)=ALP(J,IBG)*DPS(J)	RAB	83
7 CONTINUE	RAB	84
IF(KB.EQ.0) GO TO 9	RAB	85
IF(IBG.EQ. 1) GO TO 9	RAB	86
READ(5,110) (SIGA22(I),SIGF22(I),I=1,KRES)	RAB	87
110 FORMAT(6E12.5)	RAB	88
WRITE(6,111) (I,SIGA22(I),SIGF22(I),I=1,KRES)	RAB	89
111 FORMAT(///' REVISION OF BACKGROUND CROSS SECTIONS FOR NEXT BROAD	RAB	90
GROUP'/' MATERIAL',3X,'SIGA22(I)',6X,'SIGF22(I)'/(16,4X,2E12.5))	RAB	91
9 CALL RESTES	RAB	92
ACSGP=0.000	RAB	93
FCSGP=0.000	RAB	94
SCSGP=0.000	RAB	95
PHIT=0.000	RAB	96
MU=(IBGP-1)/100	RAB	97
NU=IBGP-100*MU	RAB	98
DO 10 J=1,KCUMP	RAB	99
FLUXCP(J,NU)=0.	RAB	100
DO 10 K=1,KMAT	RAB	101
SIGABG (K,J)=0.00	RAB	102
SIGFBG(K,J)=0.000	RAB	103
10 SIGSBG (K,J)=0.00	RAB	104
DO 15 J=1,KREG	RAB	105
15 FLUX(J,NU)=0.	RAB	106
N=NF1(IBG)	RAB	107
DO 22 IFGP=1,N	RAB	108
CALL SOURCE(IERR,DS,SOR,SI)	RAB	109

IF(IERR)16,16,1	RAB 110
C IERR GRTE 0 ABORTS PROBLEM	RAB 111
16 CALL KATES(IERR,DS,SOR,SI)	RAB 112
JI=0	RAB 113
IF(IERR)17,17,1	RAB 114
17 DO 20 I=1,KREG	RAB 115
201 M=LREG(I)	RAB 116
PHI(I)=CR(I)/SIG(M)	RAB 117
FLUX(I,NU)=FLUX(I,NU)+PHI(I)	RAB 118
DO 24 J=1,KMAT	RAB 119
IF(DEN(J,M))29,24,29	RAB 120
29 JI=JI+1	RAB 121
SCAT(JI+JNU(J))=SCAT(JI+JNU(J))+PHI(I)*SS(J,M)	RAB 122
SL(J,M)=SS(J,M)	RAB 123
SIGABG(J,M)=SIGABG(J,M)+PHI(I)*SA(J,M)	RAB 124
SIGFBG(J,M)=SIGFBG(J,M)+PHI(I)*SF(J,M)	RAB 125
SIGSBG(J,M)=SIGSBG(J,M)+PHI(I)*SS(J,M)	RAB 126
24 CONTINUE	RAB 127
IF(KFOIL)20,20,27	RAB 128
27 DO 26 K=1,KFOIL	RAB 129
DO 26 J=1,KMAT	RAB 130
AF(I,K)=AF(I,K)+TT(I,K)*SA(J,KCOMP+K)	RAB 131
SSF(I,K)=SSF(I,K)+TT(I,K)*SS(J,KCOMP+K)	RAB 132
26 FF(I,K)=FF(I,K)+TT(I,K)*SF(J,KCOMP+K)	RAB 133
20 CONTINUE	RAB 134
DO 30 J=1,KMAT	RAB 135
JMULT(J)=JMULT(J)+1	RAB 136
IF(JMULT(J)-MULT(J,18G))30,31,31	RAB 137
31 JMULT(J)=0	RAB 138
DK=1.0/MULT(J,18G)	RAB 139
JJJ=JNU(J)	RAB 140
JNU(J)=JNU(J)+NISO	RAB 141
IF(JNU(J)-NXN)34,34,33	RAB 142
33 JNU(J)=0	RAB 143
34 DO 32 I=1,KREG	RAB 144
IF(DEN(I,LREG(I)))35,32,35	RAB 145
35 SCAT(LOC(J,I)+JJJ)=SCAT(LOC(J,I)+JJJ)*DK	RAB 146
SCAT(LOC(J,I)+JNU(J))=0.	RAB 147
32 CONTINUE	RAB 148
30 CONTINUE	RAB 149
IF(NPRINT)21,22,22	RAB 150
21 WRITE(6,101)(PHI(I),I=1,KREG)	RAB 151
C NPRINT LESS ZEKU GIVES FINE GROUP FLUX OUTPUT	RAB 152
101 FORMAT(1H,7HPHI(I)=,(8E14.7))	RAB 153
22 CONTINUE	RAB 154
DO 25 I=1,KREG	RAB 155
M=LREG(I)	RAB 156
PHIRT(I)=PHIRT(I)+FLUX(I,NU)	RAB 157
FLUXCP(M,NU)=FLUXCP(M,NU)+FLUX(I,NU)	RAB 158
25 PHICT(M)=PHICT(M)+FLUX(I,NU)	RAB 159
DO 40 I=1,KCOMP	RAB 160
PHIT=PHIT+FLUXCP(I,NU)	RAB 161
DO 40 J=1,KMAT	RAB 162
RIAC(J,I)=RIAC(J,I)+SIGABG(J,I)	RAB 163
RIFC(J,I)=RIFC(J,I)+SIGFBG(J,I)	RAB 164
RISC(J,I)=RISC(J,I)+SIGSBG(J,I)	RAB 165

ACSGP=ACSGP+SIGABG (J,I)	RAB 166
FCSGP=FCSGP+SIGFBG (J,I)	RAB 167
40 SCSGP=SCSGP+SIGSBG (J,I)	RAB 168
PHITOT=PHITOT+PHIT	RAB 169
ACS=ACS+ACSGP	RAB 170
FCS=FCS+FCSGP	RAB 171
SCS=SCS+SCSGP	RAB 172
IF(JBG-NIB(1BG))144,60,60	RAB 173
60 DO 62 J=1,KMAT	RAB 174
IF(JMULT(J))62,62,69	RAB 175
69 JJJ=JNU(J)+NISO	RAB 176
IF(JJJ-NXN)70,70,71	RAB 177
71 JJJ=0	RAB 178
70 DO 63 I=1,KREG	RAB 179
IF(DEN(J,LREG(I))) 172,63,72	RAB 180
72 NXX=LUC(J,I)+JNU(J)	RAB 181
SCAT(NXX)=SCAT(NXX)/JMULT(J)	RAB 182
SCAT(LDC(J,I)+JJJ)=0.	RAB 183
63 CONTINUE	RAB 184
JNU(J)=JJJ	RAB 185
62 CONTINUE	RAB 186
44 CALL OUTPUT	RAB 187
45 CONTINUE	RAB 188
CALL TIME(TIME)	RAB 189
WRITE(6,100) TIME	RAB 190
100 FORMAT(1H0,6H TIME=,F10.3,5H SEC.)	RAB 191
GO TO 1	RAB 192
END	RAB 193
SUBROUTINE INPUT	INP 1
COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	INP 2
X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	INP 3
X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	INP 4
X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	INP 5
COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	INP 6
COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	INP 7
XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	INP 8
X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	INP 9
X SIGMIN(300), SIG(30),	INP 10
X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	INP 11
COMMON/B/ UIGP, CR(30),RAD(35),	INP 12
X RAT10(30),DIFX(30), SPP(30),SPN(30),	INP 13
X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	INP 14
XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	INP 15
X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	INP 16
COMMON/C/	INP 17
X XAREAT,AREAT,RMAX(30),	INP 18
X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	INP 19
X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	INP 20
X SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	INP 21
XGX2(10),GW2(10),HW2(10),	INP 22
X OR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	INP 23
X GW4(10),HW3(10),HW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	INP 24
COMMON/D/KI,KRES,NTEMP,INCLUD(300),	INP 25
X NEXT(20),LAST(20),NRES(20),INDEX, KS,	INP 26
X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	INP 27
X 18GP,1FGP,1BG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	INP 28

X	NFI(25),TITLE(18),KB	,MULT(20,25),JNU(20),JMULT(20),	INP	29
X	INUI(20,25),INUF(20,25),NOX,NISO,KBSQ		INP	30
	REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,		INP	31
X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGF8G,SIGSBG,P1,PS,ALP,DSL		INP	32
	REAL*8 DPS		INP	33
	REAL*8 NUCLID		INP	34
	NAMLIST/MOD/TITLE,KREG,KMAT,KCOMP,KRES,KGP,KBG,NOPT,NTEMP,NPRINT,		INP	35
X	MURE,NIB,NFI,UIGP,ENGP,TEST,KFOIL,KBSQ,KS,BSQ,TEMP,NINT,RMAX,		INP	36
X	NUCLID,NRES,AMU,SIGPOT,SIGA22,SIGF22,DEN,ER,GN,GR,GF,G,KB		INP	37
	IF(MORE)80,1,90		INP	38
1	READ(5,101) (TITLE(I),I=1,18)		INP	39
101	FORMAT(18A4)		INP	40
	READ(5,102) KREG,KMAT,KCOMP,KRES,KGP,KBG,NOPT,NTEMP,NPRINT,MORE		INP	41
102	FORMAT(12I6)		INP	42
	READ(5,102) (NIB(I),NFI(I),I=1,KBG)		INP	43
	READ(5,107) UIGP,ENGP(1),TEST,KFOIL,KBSQ,KS,KB		INP	44
107	FORMAT(3E12.6,4I6)		INP	45
	III=KFOIL+KCOMP		INP	46
	IF(KBSQ)71,71,70		INP	47
70	READ(5,106) (BSQ(I),I=1,KBG)		INP	48
	GO TO 72		INP	49
71	DO 73 I=1,KBG		INP	50
73	BSQ(I)=0.		INP	51
72	READ(5,103) (TEMP(I),I=1,III)		INP	52
103	FORMAT(5E12.6)		INP	53
	READ(5,104) (NINT(I),RMAX(I),I=1,III)		INP	54
104	FORMAT(5(I2,E10.4))		INP	55
	DO 10 I=1,KMAT		INP	56
	READ(5,105)NUCLID(I),NRES(I),AMU(I),SIGPOT(I),SIGA22(I),SIGF22(I)		INP	57
105	FORMAT(A6,I6,4E12.6)		INP	58
	READ(5,106) (DEN(I,J),J=1,III)		INP	59
106	FORMAT(5E12.6)		INP	60
	IF(NRES(I))10,10,5		INP	61
5	IF(I-1)6,6,7		INP	62
6	NEXT(I)=1		INP	63
	LAST(I)=NRES(I)		INP	64
	GO TO 8		INP	65
7	NEXT(I)=LAST(I-1)+1		INP	66
	LAST(I)=LAST(I-1)+NRES(I)		INP	67
8	N=NEXT(I)		INP	68
	L=LAST(I)		INP	69
	DO 9 J=N,L		INP	70
9	READ(5,106) ER(J),GN(J),GR(J),GF(J),G(J)		INP	71
10	CONTINUE		INP	72
1000	CALL DATA		INP	73
	WRITE(6,201) (TITLE(I),I=1,18),KREG,KMAT,KCOMP,KRES,KBG,UIGP,		INP	74
X	KGP,TEST,NOPT,KFOIL		INP	75
201	FORMAT(1H1,6H KRID,/,		INP	76
1	2X,18A4///10X,18HNO. CELL REGIONS =,13,29X,15HNO. MATERI		INP	77
	XALS =,13/10X,18HNO. COMPOSITIONS =,13,29X,24HNO. RESONANT MATERIAL		INP	78
	XS =,12/10X,18HNO. BROAD GROUPS =,13,29X,29HLETHARGY WIDTH INTER. GINP		INP	79
	XROUP =,E12.6/10X,25HNO. INTERMEDIATE GROUPS =,14,21X,16HRESONANCE		INP	80
	XTEST =,E10.3,8H (BARNS),6H NOPT=,12,7H KFOIL=,12,/) INP		INP	81
	IF(KS)12,12,11		INP	82
11	WRITE(6,220)		INP	83
220	FORMAT(/, ' SCATTERING TRANSFER PROBABILITIES ADJUSTED TO REMOVE IINP		INP	84

XN-GROUP SCATTERING')	INP	85
12 IF(V11)13,30,13	INP	86
13 WRITE(6,225)	INP	87
225 FORMAT(/,' RESONANT MATERIALS HAVE BROAD-GROUP-DEPENDENT ABSORPTION	INP	88
XN AND FISSION CROSS SECTIONS')	INP	89
30 WRITE (6,205)	INP	90
205 FORMAT(///2X,46HREGION/COMPOSITION/OUTER DIMENSION/TEMPERATURE/)	INP	91
DU 35 I=1,KREG	INP	92
NX(I)=I	INP	93
35 XTEMP(I)=TEMP(LREG(I))	INP	94
WRITE (6,206) (NX(I),I=1,KREG)	INP	95
WRITE (6,206) (LREG(I),I=1,KREG)	INP	96
WRITE (6,207) (RAD(I),I=1,KREG)	INP	97
WRITE (6,208) (XTEMP(I),I=1,KREG)	INP	98
206 FORMAT(15I8)	INP	99
207 FORMAT(15F8.5)	INP	100
208 FORMAT(15F8.2)	INP	101
IF(KFOIL)39,39,36	INP	102
36 WRITE(6,230) (1,LREG(KREG+I),RMAX(KCOMP+I),	INP	103
TEMP(KCOMP+I),I=1,KFOIL)	INP	104
230 FORMAT(///5H FOIL,2X,11HCOMPOSITION,7X,9HTHICKNESS,4X,11HTEMPERATURE,	INP	105
XRE/(15,7X,16,6X,E12.5,F10.3))	INP	106
39 WRITE (6,209)	INP	107
209 FORMAT(///2X,14H MATERIAL RES.,8X,40HMASS SIG POT SIG A 1/V	INP	108
X SIG F 1/V)	INP	109
DO 40 I=1,KMAT	INP	110
40 WRITE (6,210) NUCLID(I),NRES(I),AMU(I),SIGPOT(I),SIGA22(I),	INP	111
X SIGF22(I)	INP	112
210 FORMAT(1H ,A6,17,6X,4E12.5)	INP	113
DU 400 I=1,KMAT	INP	114
400 WRITE (6,401) I , (DEN(I,J),J=1,111)	INP	115
401 FORMAT(1H0,7HISOTOPE, 15,/, (10E12.5))	INP	116
WRITE (6,211)	INP	117
211 FORMAT(///1H ,11HBROAD GROUP,4X,17HNO. INTER. GROUPS,4X,20HNO. FIN	INP	118
XE GP/INFER GP,4X,19HMAXIMUM ENERGY (EV),4X,19HMINIMUM ENERGY (EV),	INP	119
X 4X,8HBUCKLING)	INP	120
N=1	INP	121
M=N+NIB(1)	INP	122
DO 45 I=1,KBG	INP	123
WRITE (6,212) I,NIB(I),NFI (I),ENGP(N),ENGP(M),BSQ(I)	INP	124
N=M	INP	125
45 M=N+NIB(I+1)	INP	126
212 FORMAT(6X,15,2(17X,15),3(7X,E15.4))	INP	127
WRITE(6,240) (I,I=1,KBG)	INP	128
240 FORMAT(1H1,82H NUMBER OF FINE GROUPS USED TO LETHARGY-AVERAGE SCAT	INP	129
TERING RATES FOR EACH MATERIAL///17H BROAD GROUP NO.=,2514)	INP	130
DO 46 J=1,KMAT	INP	131
WRITE(6,241) NUCLID(J), (MULT(J,I),I=1,KBG)	INP	132
241 FORMAT(1H0,5X,A6,5X,25I4)	INP	133
46 CONTINUE	INP	134
PRINT 213	INP	135
213 FORMAT(1H1/50X,20HRESONANCE PARAMETERS//12X,8H MATERIAL,10X,10HENER	INP	136
XGY(EV),8X,12HGAMMA N (EV),4X,16HGAMMA GAMMA (EV),8X,12HGAMMA F (E	INP	137
X),16X,1HG)	INP	138
DO 50 I=1,KRES	INP	139
N=NEXT(I)	INP	140

L=LAST(I)	INP	141
50 WRITE (6,214) (NUCLID(I),ER(J),GN(J),GR(J),GF(J),G(J),J=N,L)	INP	142
214 FORMAT(14X,A6,5E20.5)	INP	143
CALL SYM(ISYM,DEN,AREA,KMAT,KREG,LREG)	INP	144
ISUM=0	INP	145
DO 55 I=1,KBG	INP	146
55 ISUM=ISUM+NIB(I)	INP	147
IF(ISUM-KGP)56,57,56	INP	148
56 WRITE(6,215) KGP,ISUM	INP	149
ISUM=MIN0(KGP,ISUM)	INP	150
215 FORMAT(/9H ***KGP=,I4,9H RESET TO,I4)	INP	151
KGP=ISUM	INP	152
57 IF(KGP-1000)59,59,58	INP	153
58 WRITE(6,216)	INP	154
216 FORMAT(/21H ***KGP EXCEEDS 1000)	INP	155
GO TO 1	INP	156
59 IF(KGP)1,1,60	INP	157
60 RETURN	INP	158
C MODIFICATION PROBLEM USING NAMELIST FEATURE OF FORTRAN IV	INP	159
NO READ(5,101) (TITLE(I),I=1,18)	INP	160
READ(5,MOD)	INP	161
GO TO 1000	INP	162
90 STOP	INP	163
END	INP	164
SUBROUTINE RATES(IEHR,DDS,SOR,SI)	RTS	1
COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	RTS	2
X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,RTS	RTS	3
X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	RTS	4
X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	RTS	5
COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),Ti(62,62)	RTS	6
COMMON/A/ F1V,SL(20,30),TEST, SIGP(20,30),XZETA(20,30),	RTS	7
XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	RTS	8
X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	RTS	9
X SIGMIN(300), SIG(30),	RTS	10
X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	RTS	11
COMMON/B/ UIGP, CR(30),RAD(35),	RTS	12
X RATID(30),DIFX(30), SPP(30),SPN(30),	RTS	13
X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	RTS	14
XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	RTS	15
X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	RTS	16
COMMON/C/	RTS	17
X XAREAT,AREAT,RMAX(30),	RTS	18
X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	RTS	19
X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	RTS	20
XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	RTS	21
XGX2(10),GW2(10),WW2(10),	RTS	22
X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	RTS	23
X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	RTS	24
COMMON/D/K1,KRES,NTEMP,INCLUD(300),	RTS	25
X NEXT(20),LAST(20),NRES(20),INDEX,KS,	RTS	26
X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	RTS	27
X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	RTS	28
X NFI(25),TITLE(18),KB MULT(20,25),JNU(20),JMULT(20),	RTS	29
X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	RTS	30
REAL*8 NUCLID	RTS	31
REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	RTS	32

X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,PI,PS,ALP,DSL	RTS	33
	REAL*8 DPS,DDS,SUR,SI	RTS	34
	REAL*8 DEL,QQ,PFUNC	RTS	35
	DIMENSION Q(30), TAU(35), TTAU(30),TQ(60),T(30)	RTS	36
	DIMENSION RR(30)	RTS	37
	DIMENSION SI(30),DS(30),ITRY(30),PIJ(30,30),K(30),DDS(30),SOR(30)	RTS	38
	EQUIVALENCE (KREG,II)	RTS	39
	PNL=1.	RTS	40
	IF(KBSQ)15,15,5	RTS	41
C	FIND NON-LEAKAGE PROBABILITY PNL	RTS	42
C	ASSUME D IS 1/(3SIGMA TOT) WHERE SIGMA TOT IS FLUX-WTD	RTS	43
5	V1=0.	RTS	44
	V2=0.	RTS	45
	DO 10 I=1,KREG	RTS	46
	V2=V2+PHI(I)	RTS	47
10	V1=V1+PHI(I)*SIG(LREG(I))	RTS	48
	V1=V1/V2	RTS	49
	D=0.	RTS	50
	DO 11 K=1,KCUMP	RTS	51
	D=D+SIGTR(K)*AREAC(K)	RTS	52
11	CONTINUE	RTS	53
	D=KMAX(KCUMP)/(3.*D)	RTS	54
	PNL=V1/(V1+D*B5Q(18G))	RTS	55
15	IF(II-1)20,30,80	RTS	56
20	WRITE (6,25)	RTS	57
25	FORMAT(10H ***KREG**)	RTS	58
	IERR=1	RTS	59
	RETURN	RTS	60
30	CONTINUE	RTS	61
	R(1) = 0.0	RTS	62
	CR(1) = SOURCE(1)	RTS	63
	IF (1BGP.EQ.1.AND.1FGP.EQ.1) GO TO 60	RTS	64
	CR(1)=CR(1)*PNL	RTS	65
	IF(KS.GT.0) GO TO 41	RTS	66
	DO 40 J=1,KMAT	RTS	67
	IF (DEN(J,1)) 35,40,35	RTS	68
35	R(1) = R(1) + DPS(J) * SS(J,1)	RTS	69
40	CONTINUE	RTS	70
	R(1) = R(1)/SIG(1)	RTS	71
41	CR(1)=PNL*SOURCE(1)/(1.-R(1))	RTS	72
	QQ= SUR(1)+R(1)*CR(1)	RTS	73
C	CHECK IF SOURCE CORRECTION LESS THAN ROUNDOFF	RTS	74
	IF(SOURCE(1))45,55,45	RTS	75
45	IF(DABS(QQ/SOURCE(1))-0.5D-06)50,50,55	RTS	76
50	QQ=0.0D0	RTS	77
55	DDS(1)=DDS(1)+QQ	RTS	78
	SOURCE(1)=(SI(1)+DDS(1))*PNL	RTS	79
60	IF(KFOIL)75,75,65	RTS	80
65	DO 70 L=1,KFOIL	RTS	81
	DEL=SIG (L+1)*AREA(L+1)	RTS	82
	ZZ=DEL*PFUNC(DEL)	RTS	83
	TT(1,L) = ZZ * SOURCE(1)/(DEL * SIG(1) * (1.0 - R(1)))	RTS	84
70	CONTINUE	RTS	85
75	RETURN	RTS	86
80	I2=II-2	RTS	87
	TOT=0.	RTS	88

JJJ=KREG+KFOIL	RTS	89
DO 115 K=1,JJJ	RTS	90
TAU(K)=SIG (LREG(K))*AREA(K)	RTS	91
IF(TAU(K))85,95,95	RTS	92
85 WRITE(6,90) K,TAU(K),IBCP,IFGP	RTS	93
90 FORMAT(5H TAU(,12,2H)=,E12.5,17H INTERMEDIATE GR.,13,2X,9H FINE GR	RTS	94
1.,13,/,21H *****PRUBLEM ABORTED)	RTS	95
IERR=1	RTS	96
RETURN	RTS	97
95 IF(K-1)100,100,115	RTS	98
100 TTAU(K)=0.0	RTS	99
IF(TAU(K))110,110,105	RTS	100
105 TTAU(K)=1./TAU(K)	RTS	101
110 Q(K)=0.5*SOURCE(K)*PNL	RTS	102
TQ(K)=TTAU(K)*Q(K)	RTS	103
TQ(K+1)=TQ(K)	RTS	104
TOT=TOT+TAU(K)	RTS	105
115 CONTINUE	RTS	106
L=0	RTS	107
DO 145 I=1,KCOMP	RTS	108
IF(NINT(I)-1)120,120,125	RTS	109
120 DS(L+1)=0.	RTS	110
ITRY(L+1)=0	RTS	111
L=L+1	RTS	112
GO TO 145	RTS	113
125 M=NINT(I)-1	RTS	114
IF(M-2)140,130,130	RTS	115
130 DO 135 J=2,M	RTS	116
135 DS(L+J)=0.5*(TQ(L+J+1)-TQ(L+J-1))	RTS	117
140 DS(L+M+1)=(TQ(L+M+1)-TQ(L+M))	RTS	118
DS(L+1)= (TQ(L+2)-TQ(L+1))	RTS	119
L=L+NINT(I)	RTS	120
145 CONTINUE	RTS	121
DO 150 I=1,11	RTS	122
Q(I) = 0.5	RTS	123
TQ(I) = TQ(I)/SOURCE(I)	RTS	124
DS(I) = DS(I)/SOURCE(I)	RTS	125
150 CONTINUE	RTS	126
DO 175 I=1,11	RTS	127
DO SELF-ABSORPTION ONLY	RTS	128
M=I+1	RTS	129
QQ=TAU(I)	RTS	130
P(I)=PFUNC(QQ)	RTS	131
WORK(I)=TAU(I)	RTS	132
WORK(M)=TAU(I)	RTS	133
ITRY(I)=0	RTS	134
IF(TQ(I))160,155,160	RTS	135
155 IF(ABS(DS(I))-0.000001)170,170,165	RTS	136
160 IF(ABS(DS(I)/TQ(I))-.01)170,170,165	RTS	137
165 ITRY(I)=1	RTS	138
GO TO 175	RTS	139
170 DS(I)=0.	RTS	140
175 CONTINUE	RTS	141
DO 180 I=1,4	RTS	142
WW2(I)=GW2(I)/(1.- EXP(TOT*GX2(I)))	RTS	143
WW3(I)=GW3(I)/(1.- EXP(TOT*GX3(I)))	RTS	144

	HW4(I)=GW4(I)/(1.- EXP(TOT*GX4(I)))	RTS	145
180	CONTINUE	RTS	146
	XC=.004126+.00628* EXP(-19.8*TOT)	RTS	147
	ASSIGN 295 TO JSWCH	RTS	148
	ASSIGN 360 TO JRSWCH	RTS	149
	IF(TOT-4.5)190,190,185	RTS	150
185	ASSIGN 285 TO JSWCH	RTS	151
	ASSIGN 350 TO JRSWCH	RTS	152
C	DO NEIGHBOUR AND SAME CELL CONTRIBUTIONS	RTS	153
C	BY CALCULATING CURRENT IN - CURRENT OUT	RTS	154
190	V1=TOT	RTS	155
	V2=TOT	RTS	156
	CALL XTRAP	RTS	157
	A1=V7	RTS	158
	CALL XTRAP4	RTS	159
	A3=V8	RTS	160
	AA1=A1+0.5	RTS	161
C		RTS	162
	DO 195 IR=1,II	RTS	163
	RR(IR) = 0.0	RTS	164
	DO 195 JR=1,II	RTS	165
195	PIJ (IR,JR) = 0.0	RTS	166
C		RTS	167
	DO 420 I=1,II	RTS	168
	NN=II+I-1	RTS	169
	IR=II+I-1	RTS	170
	MM=II+IR	RTS	171
	X6=0.	RTS	172
	F7=0.	RTS	173
	X8=0.	RTS	174
	FS=TQ(I)	RTS	175
	V4=TAU(I)	RTS	176
	X1=TOT + TAU(I)	RTS	177
	IF(TAU(I)-.01)200,200,205	RTS	178
200	V3=TOT	RTS	179
	CALL YZ3	RTS	180
	A2=V9	RTS	181
	GO TO 210	RTS	182
205	V3=2.*TOT	RTS	183
	CALL YZ3	RTS	184
	PT=PE3(TOT)	RTS	185
	A2=V9+PT-PE3(X1)	RTS	186
210	X2=TOT+TAU(IR)	RTS	187
	X3=TOT-TAU(I)	RTS	188
	FIN=Q(I)*(P(I) + A2*TTAU(I))	RTS	189
	F9=0.	RTS	190
	V3=0.0	RTS	191
	ASSIGN 330 TO ISWCH	RTS	192
	IF(ITRY(I))235,235,215	RTS	193
215	ASSIGN 325 TO ISWCH	RTS	194
	DFS=DS(I)	RTS	195
	V1=TAU(I)	RTS	196
	V4=TAU(I)	RTS	197
	CALL XTRAP	RTS	198
	CALL YZ4	RTS	199
	F9=DFS*(0.5*(AA1+V7)-1TAU(I)*V10)	RTS	200

IF(FIN)220,230,220	RTS 201
220 IF(ABS(F9/FIN)-.01)225,225,230	RTS 202
225 ASSIGN 330 TO ISWCH	RTS 203
F9=0.	RTS 204
GO TO 235	RTS 205
230 V1=X3	RTS 206
V2=X3+TUT	RTS 207
CALL XTRAP	RTS 208
CALL XTRAP4	RTS 209
V8=V8+E4(X3)	RTS 210
F7=DFS*(0.5*(V7+A1)-TTAU(I)*(V8-A3))	RTS 211
235 X6=0.	RTS 212
X4=TOT-TAU(IR)	RTS 213
V1=X2	RTS 214
V1=X2	RTS 215
CALL XTRAP	RTS 216
BIN=0.	RTS 217
BOUFL=0.	RTS 218
ASSIGN 380 TO IRSWCH	RTS 219
IF(ITRY(IR))260,260,240	RTS 220
240 ASSIGN 365 TO IRSWCH	RTS 221
V1=TOT+TAU(IR)	RTS 222
CALL XTRAP	RTS 223
BIN=Q(IR)*(P(IR)+(A1-V7)*TTAU(IR))	RTS 224
DSR=DS(IR)	RTS 225
V1=TAU(IR)	RTS 226
V4=TAU(IR)	RTS 227
CALL XTRAP	RTS 228
CALL YZ4	RTS 229
X6=DSR*(0.5*(A1+V7)-TTAU(IR)*V10)	RTS 230
IF(BIN)245,255,245	RTS 231
245 IF(ABS(X6/BIN)-.01)250,250,255	RTS 232
250 ASSIGN 380 TO IRSWCH	RTS 233
GO TO 260	RTS 234
255 BIN=-X6	RTS 235
V1=X4	RTS 236
V2=X4+TUT	RTS 237
CALL XTRAP	RTS 238
CALL XTRAP4	RTS 239
V8=V8+E4(X4)	RTS 240
BOUFL=-	RTS 241
1 DSR*(0.5*(V7+A1)-TTAU(IR)*(V8-A3))	RTS 242
260 V4=TAU(I)	RTS 243
IF(TAU(I)-.01)265,265,270	RTS 244
265 V3=X3	RTS 245
CALL YZ3	RTS 246
FOUFL=FS*V9	RTS 247
GO TO 275	RTS 248
270 V3=X3+TOT	RTS 249
CALL YZ3	RTS 250
FOUFL=FS*(V9+PE3(X3)-PT)	RTS 251
275 CONTINUE	RTS 252
PIJ(I,I)=2.*(Q(I)*(1.-P(I))+FOUFL-FS*A2) + PIJ(I,I)	RTS 253
C THIS IS RR(I) FROM I-TH PLATE IN ALL UNIT CELLS AND IS NOT	RTS 254
C CONTRIBUTED TO BY LINEAR SOURCE TERM, BY SYMMETRY	RTS 255
X1=WORK(I)	RTS 256

X2=WORK(IR)	RTS 257
X5=WORK(NN)	RTS 258
V3=0.	RTS 259
IF(I2)335,335,280	RTS 260
280 CONTINUE	RTS 261
C	RTS 262
C	RTS 263
DO 335 K=1,I2	RTS 264
J=I+K	RTS 265
IF (J.GT.II) J = J - II	RTS 266
GO TO JSWCH,(295,285)	RTS 267
285 IF(V3-9.)295,290,290	RTS 268
290 PIJ(I,J) = PIJ(I,J) + FIN	RTS 269
PIJ(J,I) = PIJ(J,I) + FIN * TQ(J)/TQ(I)	RTS 270
FIN=FOUTL	RTS 271
GO TO 340	RTS 272
295 V4=WORK(J)	RTS 273
THICK=X1	RTS 274
IF(X1-V4)300,300,305	RTS 275
300 V4=X1	RTS 276
THICK=WORK(J)	RTS 277
305 IF(V4-.1)310,310,315	RTS 278
310 CALL YZ3	RTS 279
C1=V9	RTS 280
V3=V3+THICK	RTS 281
CALL YZ3	RTS 282
C1=FS*(C1-V9)	RTS 283
FOUT=FIN-C1	RTS 284
PIJ(I,J) = PIJ(I,J) + C1	RTS 285
PIJ(J,I) = PIJ(J,I) + C1 * TQ(J)/TQ(I)	RTS 286
V3=V3+WORK(J)-THICK	RTS 287
GO TO ISWCH,(330,325)	RTS 288
315 V3=V3+WORK(J)	RTS 289
V4=X1	RTS 290
CALL YZ3	RTS 291
FOUT=FS*V9	RTS 292
320 PIJ(I,J) = PIJ(I,J) + FIN - FOUT	RTS 293
PIJ(J,I) = PIJ(J,I) + (FIN-FOUT) * TQ(J)/TQ(I)	RTS 294
GO TO ISWCH,(330,325)	RTS 295
325 V1=V3	RTS 296
CALL XTRAP	RTS 297
X9=V7	RTS 298
V1=V3+V4	RTS 299
CALL XTRAP	RTS 300
X9=0.5*(X9+V7)	RTS 301
CALL YZ4	RTS 302
ABC=DFS*(X9-TTAU(I)*V10)	RTS 303
PIJ(I,J) = PIJ(I,J) + F9 - ABC	RTS 304
F9=ABC	RTS 305
330 FIN=FOUT	RTS 306
335 CONTINUE	RTS 307
C	RTS 308
340 V3=0.	RTS 309
IF (I2)370,370,345	RTS 310
345 CONTINUE	RTS 311
C	RTS 312

257	C		RTS	313
258		DO 370 K=1,12	RTS	314
259		M=MM-K	RTS	315
260		IF (M.GT.II) M = M - II	RTS	316
261		V3=V3+WORK(M)	RTS	317
262		GO TO JRSWCH,(360,350)	RTS	318
263	350	IF(V3-9.)360,355,355	RTS	319
264	355	PIJ(IR,M)=PIJ(IR,M) + BIN	RTS	320
265		GO TO 380	RTS	321
266	360	V4= X2	RTS	322
267		GO TO IRSWCH,(380,365)	RTS	323
268	365	V1=V3	RTS	324
269		CALL XTRAP	RTS	325
270		X10=V7	RTS	326
271		V1=V3+V4	RTS	327
272		CALL XTRAP	RTS	328
273		X10=0.5*(X10+V7)	RTS	329
274		CALL YZ4	RTS	330
275		BOUT= -DSR*(X10-TTAU(IR)*V10)	RTS	331
276		PIJ(IR,M)=PIJ(IR,M) + BIN - BOUT	RTS	332
277		BIN=BOUT	RTS	333
278	370	CONTINUE	RTS	334
279	C		RTS	335
280	375	CONTINUE	RTS	336
281		PIJ(IR,I) = PIJ(IR,I) + BIN - BOUTL	RTS	337
282	380	V3=TOT-X1-X5	RTS	338
283		V4=X1	RTS	339
284		THICK=X5	RTS	340
285		IF(X5-X1)385,390,390	RTS	341
286	385	V4=X5	RTS	342
287		THICK=X1	RTS	343
288	390	IF(V4-.01)395,395,400	RTS	344
289	395	CALL YZ3	RTS	345
290		C1=V9	RTS	346
291		V3=V3+THICK	RTS	347
292		CALL YZ3	RTS	348
293		C1=FS*(C1-V9)	RTS	349
294		GO TO 405	RTS	350
295	400	C1=F IN-FOU TL	RTS	351
296	405	CONTINUE	RTS	352
297		IF (NN.GT.II) NN = NN - II	RTS	353
298		PIJ(I,NN) = PIJ(I,NN) + C1 + F9 - F7	RTS	354
299		PIJ(NN,I) = PIJ(NN,I) + C1 * TQ(NN)/TQ(I)	RTS	355
300	C		RTS	356
301		NDX=0	RTS	357
302		R(I) = 0.0	RTS	358
303		IF(KS.GT.0) GO TO 420	RTS	359
304		M = LREG(II)	RTS	360
305		DO 415 J=1,KMAT	RTS	361
306		IF (DEN(J,M)) 410,415,410	RTS	362
307	410	R(I) = R(I) + DPS(J) * SS(J,M)	RTS	363
308	415	CONTINUE	RTS	364
309		R(I) = R(I)/SIG(M)	RTS	365
310	420	CONTINUE	RTS	366
311	C		RTS	367
312	C		RTS	368

C	IF(KS.GT.0) GO TO 430	RTS 369
	IF(1BGP.EQ.1.AND.1FGP.EQ.1) GO TO 430	RTS 370
	CALL MATINV (PIJ,II,RR ,0,DETERM,30)	RTS 371
C		RTS 372
	DO 425 L=1,II	RTS 373
	PIJ(L,L) = PIJ(L,L) - R(L)	RTS 374
425	CONTINUE	RTS 375
C		RTS 376
	CALL MATINV (PIJ,II,RR ,0,DETERM,30)	RTS 377
C		RTS 378
		RTS 379
430	DO 435 K=1,II	RTS 380
	CR(K) = 0.0	RTS 381
	DO 435 KK=1,II	RTS 382
	CR(K) = CR(K) + PIJ(KK,K) * SOURCE(KK)	RTS 383
435	CONTINUE	RTS 384
	DO 437 I=1,KREG,2	RTS 385
	IF(1SYM(I))438,438,436	RTS 386
436	AVG=0.5*(CR(1SYM(I))+CR(1SYM(I+1)))	RTS 387
	CR(1SYM(I))=AVG	RTS 388
	CR(1SYM(I+1))=AVG	RTS 389
437	CONTINUE	RTS 390
438	CONTINUE	RTS 391
C		RTS 392
	DO 460 I=1,II	RTS 393
	IF(1BGP.EQ.1.AND.1FGP.EQ.1) GO TO 455	RTS 394
	QQ=R(I)*CR(I)+SOR(I)	RTS 395
C	CHECK IF SOURCE CORRECTION LESS THAN ROUNDOFF	RTS 396
	IF(SOURCE(I))440,450,440	RTS 397
440	IF(1ABS(QQ/SOURCE(I))-50D-06)445,445,450	RTS 398
445	QQ=0.0D0	RTS 399
450	DDS(I)=DDS(I)+QQ	RTS 400
	SOURCE(I)=(SI(I)+DDS(I))*PNL	RTS 401
455	TQ(I)=0.5*SOURCE(I)*1TAU(I)	RTS 402
	DS(I)=DS(I)*SOURCE(I)	RTS 403
460	CONTINUE	RTS 404
C		RTS 405
C		RTS 406
	DO 475 K=1,II	RTS 407
	M=II+K	RTS 408
	DO 465 L=1,KFOIL	RTS 409
	IT(K,L)=0.	RTS 410
	IT(M,L)=0.	RTS 411
465	CONTINUE	RTS 412
	IF(CR(K))470,475,475	RTS 413
470	NDX=1	RTS 414
475	CONTINUE	RTS 415
	IF(NDX)530,530,480	RTS 416
480	WRITE (6,485) (CR(I),I=1,II)	RTS 417
485	FORMAT(1H0,(5E17.8))	RTS 418
	DO 490 J=1,II	RTS 419
490	WRITE (6,485) (PIJ(I,J),I=1,II)	RTS 420
	WRITE (6,495) (SOURCE(I),TQ(I),DS(I),TAU(I),1TRY(I),I=1,II)	RTS 421
495	FORMAT(1H0,26HNEG. COLL. RATE ZEROED OUT,/, (4E20.8,15))	RTS 422
	V3=1.0E+30	RTS 423
	V1=0.	RTS 424

	V2=0.	RTS	425
	DO 505 I=1,KREG	RTS	426
	V1=V1+SOURCE(I)	RTS	427
	V2=V2+CR(I)	RTS	428
	IF(CR(I)-V3)500,505,505	RTS	429
500	V3=CR(I)	RTS	430
505	CONTINUE	RTS	431
	V2=V2-KREG*V3	RTS	432
	V1=V1/V2	RTS	433
	DO 510 I=1,KREG	RTS	434
	CR(I)=V1*(CR(I)-V3)	RTS	435
510	CONTINUE	RTS	436
C	THIS NORMALISES TO SUM(CR(I)-SOURCE(I))=0.	RTS	437
C	AND SETS MINIMUM COLLISION RATE TO ZERO	RTS	438
530	IF(KFOIL)610,610,535	RTS	439
C	BEGIN FOIL CALCULATIONS	RTS	440
535	DO 600 I=1,KREG	RTS	441
	X1=WORK(I)	RTS	442
	FS=TQ(I)	RTS	443
	DFS=DS(I)	RTS	444
	V3=0.	RTS	445
	IR=II+1-I	RTS	446
	SR=TQ(IR)	RTS	447
	USR=DS(IR)	RTS	448
	MM=II+IR	RTS	449
	DO 565 K=1,KREG	RTS	450
	J=I+K	RTS	451
	DO 560 L=1,KFOIL	RTS	452
	V4= TAU(II+L)	RTS	453
	CALL YZ3	RTS	454
	X2=V9	RTS	455
	X10=0.	RTS	456
	IF(DFS)540,545,540	RTS	457
540	CALL YZ4	RTS	458
	X10=V10	RTS	459
545	V3=V3+X1	RTS	460
	CALL YZ3	RTS	461
	X3=V9	RTS	462
	V10=0.	RTS	463
	IF(DFS)550,555,550	RTS	464
550	CALL YZ4	RTS	465
555	V3=V3-X1	RTS	466
	TT(J-1,L)=TT(J-1,L)+FS*(X2-X3)+DFS*((X2+X3)*.5-TTAU(I)*(X10-V10))	RTS	467
560	CONTINUE	RTS	468
	V3=V3+WORK(J)	RTS	469
565	CONTINUE	RTS	470
	X1=WORK(IR)	RTS	471
	V3=0.	RTS	472
	DO 595 K=1,KREG	RTS	473
	M=MM-K	RTS	474
	DO 590 L=1,KFOIL	RTS	475
	V4= TAU(II+L)	RTS	476
	CALL YZ3	RTS	477
	X2=V9	RTS	478
	X10=0.	RTS	479
	IF(DSR)570,575,570	RTS	480

425	570 CALL YZ4	RTS	481
426	X10=V10	RTS	482
427	575 V3=V3+X1	RTS	483
428	CALL YZ3	RTS	484
429	X3=V9	RTS	485
430	V10=0.	RTS	486
431	IF(DSR)580,585,580	RTS	487
432	580 CALL YZ4	RTS	488
433	585 V3=V3-X1	RTS	489
434	TT(M,L)=TT(M,L)+SR*(X2-X3)-DSR*((X2+X3)*.5-TTAU(IR)*(X10-V10))	RTS	490
435	590 CONTINUE	RTS	491
436	V3=V3+WURK(M)	RTS	492
437	595 CONTINUE	RTS	493
438	600 CONTINUE	RTS	494
439	DO 605 L=1,KFOIL	RTS	495
440	DO 605 I=1,KREG	RTS	496
441	TT(I,L)=(TT(I,L)+TT(I+KREG,L))/TAU (II+L)	RTS	497
442	605 CONTINUE	RTS	498
443	610 RETURN	RTS	499
444	END	RTS	500
445	SUBROUTINE DATA	DAT	1
446	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),PI(20,25),	DAT	2
447	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	DAT	3
448	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	DAT	4
449	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	DAT	5
450	COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	DAT	6
451	COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	DAT	7
452	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	DAT	8
453	X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	DAT	9
454	X SIGMIN(300), SIG(30),	DAT	10
455	X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WURK(60),PI(30)	DAT	11
456	COMMON/B/ UIGP, CR(30),RAD(35),	DAT	12
457	X RATIO(30),DIFX(30), SPP(30),SPN(30),	DAT	13
458	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	DAT	14
459	X TAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	DAT	15
460	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	DAT	16
461	COMMON/C/	DAT	17
462	X XAREAT,AREAT,RMAX(30),	DAT	18
463	X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	DAT	19
464	X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	DAT	20
465	X SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	DAT	21
466	XGX2(10),GW2(10),WW2(10),	DAT	22
467	X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	DAT	23
468	X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	DAT	24
469	COMMON/D/KI,KRES,NTEMP,INCLUD(300),	DAT	25
470	X NEXT(20),LAST(20),NRES(20),INDEX, KS,	DAT	26
471	X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	DAT	27
472	X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	DAT	28
473	X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	DAT	29
474	X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	DAT	30
475	REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	DAT	31
476	X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,PI,PS,ALP	DAT	32
477	REAL*8 DSL,DPS	DAT	33
478	REAL*8 NUCLID	DAT	34
479	REAL*8 VT,BETA,UARG	DAT	35
480	GX2(1)=-1.177891426	DAT	36

481	GX2(2)=-2.077191119	DAT	37
482	GX2(3)=-4.163318952	DAT	38
483	GX2(4)=-8.243369530	DAT	39
484	GW2(1)=.341652502	DAT	40
485	GW2(2)=.324695119	DAT	41
486	GW2(3)=.166569908	DAT	42
487	GW2(4)=.0832491983	DAT	43
488	GX3(1)=-1.13889383	DAT	44
489	GX3(2)=-1.85532327	DAT	45
490	GX3(3)=-3.61600813	DAT	46
491	GX3(4)=-7.28316919	DAT	47
492	GW3(1)=.251036872	DAT	48
493	GW3(2)=.178254373	DAT	49
494	GW3(3)=.0531086307	DAT	50
495	GW3(4)=.0134690502	DAT	51
496	GX4(1)=-1.11147228	DAT	52
497	GX4(2)=-1.68851498	DAT	53
498	GX4(3)=-3.15938155	DAT	54
499	GX4(4)=-6.41012357	DAT	55
500	GW4(1)=.194827289	DAT	56
	GW4(2)=.113795599	DAT	57
1	GW4(3)=.0215903023	DAT	58
2	GW4(4)=.00280124126	DAT	59
3	PI=3.14159265	DAT	60
4	FIV=SQRT(0.6253/ENGP(1))	DAT	61
5	XNFB=1./NFI(1)	DAT	62
6	DO 200 J=1,KMAT	DAT	63
7	200 BARMU(J)=.6666667/AMU(J)	DAT	64
8	NISU=0	DAT	65
9	DO 2 K=1,KCOMP	DAT	66
10	DO 2 J=1,KMAT	DAT	67
11	I=(DEN(J,K))3,2,3	DAT	68
12	3 NISU=NISU+NINT(K)	DAT	69
13	2 CONTINUE	DAT	70
14	NOX=40000/NISU-1	DAT	71
15	DO 35 I=1,KBG	DAT	72
16	UFGP=UIGP/NFI(I)	DAT	73
17	EXDU=DEXP(-UFGP)	DAT	74
18	V(I)=1.000-EXDU	DAT	75
19	C DELETION OF INGROUP SCATTERING PROBABILITY AND	DAT	76
20	C REDEFINITION OF DOWNSCATTER PROBABILITIES TO CONSERVE NEUTRONS	DAT	77
21	VT=V(I)*V(I)/UFGP	DAT	78
22	IF(KS.GT.0) VT=V(I)	DAT	79
23	DO 35 J=1,KMAT	DAT	80
24	IF(AMU(J)-1.1)5,5,10	DAT	81
25	5 UMAX(J,I)=20.000	DAT	82
26	GO TO 15	DAT	83
27	10 UARG=1.000+2.000/(AMU(J)-1.)	DAT	84
28	UMAX(J,I)=2.000*DLOG(UARG)	DAT	85
29	C ROUND TO NEAREST INTEGER MULTIPLE	DAT	86
30	15 LUMAX=UMAX(J,I)/UFGP + .5	DAT	87
31	C MULT IS THE NUMBER OF FINE GROUPS AVERAGED OVER FOR SCAT	DAT	88
32	MULT(J,I)=1+LUMAX/(NOX-26)	DAT	89
33	C NEED AN EXTRA INTERVAL FOR 3RD INTERPOLATION POINT AND ONE FOR	DAT	90
34	C CHANGING CURRENT INTERVAL AND 25 FOR BROAD GROUP BOUNDS	DAT	91
35	UMAX(J,I)=UFGP*DFLOAT(LUMAX)	DAT	92
36			

37	ALP(J,I)=DEXP(-UMAX(J,I))	DAT	93
38	IF(I-2)1,30,30	DAT	94
39	1 IF(J-KRES)20,20,30	DAT	95
40	20 DO 25 K=1,NTEMP	DAT	96
41	25 XZETA(J,K)=SQRT (AMU(J)/(3.46668E-04*ENGP(1)*TEMP(K)))	DAT	97
42	N=NEXT(J)	DAT	98
43	L=LAST(J)	DAT	99
44	A2 = 1.0 + 1.0/AMU(J)	DAT	100
45	A4 = A2 * A2	DAT	101
46	DO 27 K=N,L	DAT	102
47	AER=ABS (ER(K))	DAT	103
48	XRES(K)=SQRT (AER/ENGP(1))	DAT	104
49	GAMMA(K)=GN(K)+GR(K)+GF(K)	DAT	105
50	SIGZ(K)=2.60385E+06 * A4 * G(K) * GN(K)/(AER * GAMMA(K)**2)	DAT	106
51	IF (G(K).GE.0.0) GO TO 26	DAT	107
52	SIGZ(K) = 2.60385E+06 * A4 * (-G(K)) * GN(K)/(AER * GAMMA(K))	DAT	108
53	26 ABSS=ABS (SIGPOT(J)*G(K)*SIGZ(K)*GN(K))	DAT	109
54	27 SIGIN(K)=SQRT (ABSS)	DAT	110
55	30 BETA=1.000/(1.000-ALP(J,I))	DAT	111
56	P1(J,I)=BETA*VT	DAT	112
57	PS(J,I)=BETA*(UFGP-V(I))/UFGP	DAT	113
58	IF(KS.GT.0) PS(J,I)=0.000	DAT	114
59	35 CONTINUE	DAT	115
60	USTR(1)=0.	DAT	116
61	DUSTR(1)=UIGP*N(B(1))	DAT	117
62	DO 36 J=1,KMAT	DAT	118
63	JNU(J)=0	DAT	119
64	JMULT(J)=0	DAT	120
65	INUI(J,1)=1	DAT	121
66	INUF(J,1)=INUI(J,1)+(NIB(1)*NFI(1)-1)/MULT(J,1)	DAT	122
67	36 CONTINUE	DAT	123
68	IF(KBG-1)38,38,37	DAT	124
69	37 DO 39 I=2,KBG	DAT	125
70	DUSTR(I)= NIB(I)*UIGP	DAT	126
71	USTR(I)=USTR(I-1)+DUSTR(I-1)	DAT	127
72	DO 39 J=1,KMAT	DAT	128
73	INUI(J,I)=INUF(J,I-1)+1	DAT	129
74	INUF(J,I)=INUI(J,I)+(NIB(I)*NFI(I)-1)/MULT(J,I)	DAT	130
75	39 CONTINUE	DAT	131
76	38 Z=UIGP	DAT	132
77	DO 40 I=1,KGP	DAT	133
78	ENGP(I+1)=ENGP(I)*EXP(-Z)	DAT	134
79	40 Z=Z+UIGP	DAT	135
80	IF(KREG-1)100,100,41	DAT	136
81	41 IF(NOPT)100,100,43	DAT	137
82	100 AREA(1)=1.0	DAT	138
83	XAREA(1)=XNFB	DAT	139
84	LREG(1)=1	DAT	140
85	AREAC(1)=1.0	DAT	141
86	XAREAC(1)=XNFB	DAT	142
87	RAD(1)=1.0	DAT	143
88	AREAT=1.0	DAT	144
89	XAREAT=XNFB	DAT	145
90	GO TO 95	DAT	146
91	43 MINT(1)=NINT(1)	DAT	147
92	DR(1)=RMAX(1)/FLOAT (NINT(1))	DAT	148

DO 45 I=2,KCOMP	DAT 149
DR(I)=(RMAX(I)-RMAX(I-1))/FLOAT (NINT(I))	DAT 150
45 MINT(I)=MINT(I-1)+NINT(I)	DAT 151
I=1	DAT 152
RAD(1)=DR(1)	DAT 153
AREA(1)=RAD(1)	DAT 154
LREG(1)=1	DAT 155
DO 60 J=2,KREG	DAT 156
IF(J-MINT(I))55,55,50	DAT 157
50 I=I+1	DAT 158
55 LREG(J)=I	DAT 159
AREA(J)=DR(I)	DAT 160
60 RAD(J)=RAD(J-1)+DR(I)	DAT 161
80 AREAT=RMAX(KCOMP)	DAT 162
XAREAT=XNFB/AREAT	DAT 163
AREAC(1)=RMAX(1)	DAT 164
XAREAC(1)=XNFB/AREAC(1)	DAT 165
XAREA(1)=XNFB/AREA(1)	DAT 166
DO 85 I=2,KREG	DAT 167
85 XAREA(I)=XNFB/AREA(I)	DAT 168
DO 90 J=2,KCOMP	DAT 169
AREAC(J)=RMAX(J)-RMAX(J-1)	DAT 170
90 XAREAC(J)=XNFB/AREAC(J)	DAT 171
95 IF(KFOIL)96,96,119	DAT 172
119 DO 120 I=1,KFOIL	DAT 173
LREG(KREG+I)=KCOMP+I	DAT 174
AREA(KREG+I)=RMAX(KCOMP+I)	DAT 175
120 CONTINUE	DAT 176
96 RETURN	DAT 177
END	DAT 178
SUBROUTINE SGARCE(IERR,DS,SQR,SI)	SOA 1
COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),PI(20,25),	SOA 2
X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	SOA 3
X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DS1(20),	SOA 4
X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	SOA 5
COMMON/QW/REZ,AIMZ,REH,AIMW, TR(62,62),TI(62,62)	SOA 6
COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	SOA 7
XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	SOA 8
X GR(300),EK(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	SOA 9
X SIGMIN(300), SIG(30),	SOA 10
X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	SOA 11
COMMON/B/ UIGP, CR(30),RAD(35),	SOA 12
X RATIO(30),DIFX(30), SPP(30),SPN(30),	SOA 13
X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	SOA 14
XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	SOA 15
X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	SOA 16
COMMON/C/	SOA 17
X XAREAT,AREAT,RMAX(30),	SOA 18
X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	SOA 19
X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	SOA 20
XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	SOA 21
XGX2(10),GW2(10),WW2(10),	SOA 22
X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	SOA 23
X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	SOA 24
COMMON/D/KI,KRES,NTEMP,INCLUD(300),	SOA 25
X NEXT(20),LAST(20),NRES(20),INDEX, KS,	SOA 26

X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	SOA	27
X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	SOA	28
X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	SOA	29
X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	SOA	30
DIMENSION DS(30),SI(30),SOR(30)	SOA	31
REAL*8 NUCLID	SOA	32
REAL*8 DS,SI,SOUR,PL,Q,7,XS,U,XNFI,SOR	SOA	33
REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	SOA	34
X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	SOA	35
REAL*8 DPS	SOA	36
XNFI=1.000/NFI(1BG)	SOA	37
UFGP=UIGP*XNFI	SOA	38
EXDU=1.000-V(1BG)	SOA	39
IF(1BGP-1)5,5,35	SOA	40
5 IF(1FGP-1)10,10,35	SOA	41
10 U=UFGP	SOA	42
NUX1=NOX+1	SOA	43
NXN=NOX*NISO	SOA	44
SDD=0.000	SOA	45
KAP=0.000	SOA	46
DO 25 I=1,KMAT	SOA	47
Z=1.000/(1.000-DEXP(-UMAX(I,1BG)))	SOA	48
DO 25 J=1,III	SOA	49
IF(I-KRES)20,20,15	SOA	50
15 SA(I,J)=DEN(I,J)*SIGA22(I)	SOA	51
SF(I,J)=DEN(I,J)*SIGF22(I)	SOA	52
20 SIGP(I,J)=DEN(I,J)*SIGPOT(I)	SOA	53
IF(J-KCOMP)24,24,25	SOA	54
24 SDD=SDD+SIGP(I,J)*AREAC(J)*(1.000-(Z-1.000)*UMAX(I,1BG))	SOA	55
25 CONTINUE	SOA	56
DO 31 I=1,KREG	SOA	57
SI(I)=0.00+CO	SOA	58
DS(I)=0.00+00	SOA	59
SOR(I)=0.000	SOA	60
K=LREG(I)	SOA	61
DO 30 J=1,KMAT	SOA	62
SCL(J,I)=SIGP(J,K)*AREA(I)	SOA	63
30 SI(I)=SI(I)+SIGP(J,K)*AREA(I)	SOA	64
31 SOURCE(I)=SI(I)	SOA	65
INDEX=1	SOA	66
CALL XSECT(IERR)	SOA	67
GO TO 100	SOA	68
35 IF(JBG-2)40,36,36	SOA	69
36 INDEX=4	SOA	70
GO TO 60	SOA	71
40 IF(1FGP-2)45,41,36	SOA	72
41 INDEX=2	SOA	73
GO TO 55	SOA	74
45 IF(1BG-2)46,47,47	SOA	75
46 INDEX=1	SOA	76
GO TO 55	SOA	77
47 INDEX=3	SOA	78
55 XS=-V(1BG)	SOA	79
L=1BG	SOA	80
60 CALL XSECT(IERR)	SOA	81
JI=0	SOA	82

DO 95 I=1,KREG	SOA 83
K=LREG(I)	SOA 84
SOUR=(SI(I)+DS(I))*XS	SOA 85
DO 98 J=1,KMAT	SOA 86
IF(DEN(J,K))61,98,61	SOA 87
61 SOUR=SOUR+PHI(I)*(SL(J,K)*DSI(J))	SOA 88
X -SCL(J,I)*DSMAX(J)	SOA 89
JI=JI+1	SOA 90
Q=U-UMAX(J,IBG)-0.5D0*UFGP	SOA 91
N=1	SOA 92
UU=DUSTR(1)	SOA 93
IF(Q-1.0D-8)90,90,64	SOA 94
64 Q=Q-1.0D-8	SOA 95
66 IF(Q-UU)70,70,67	SOA 96
67 N=N+1	SOA 97
UU=UU+DUSTR(N)	SOA 98
GO TO 66	SOA 99
70 PL=-.5+INUI(J,N)+(Q-USTR(N))*NFI(N)/(UIGP*MULT(J,N))	SOA 100
LM=PL+.5	SOA 101
MM=(LM-1)/NOXI	SOA 102
M=NISO*(LM-NOXI*MM-1)	SOA 103
PL=PL-LM	SOA 104
ML=M-NISO	SOA 105
IF(ML)200,201,201	SOA 106
200 ML=NXN	SOA 107
201 MH=M+NISO	SOA 108
IF(MH-NXN)203,203,202	SOA 109
202 MH=0	SOA 110
203 XL=SCAT(JI+ML)	SOA 111
XO=SCAT(JI+M)	SOA 112
XH=SCAT(JI+MH)	SOA 113
IF(LM-INUI(J,N)-1)261,230,230	SOA 114
C THIS IS SPECIAL CASE AT START OF A BROAD GROUP	SOA 115
261 IF(INUF(J,N)-LM)221,210,221	SOA 116
C THIS IS NOT INTERPOLATION AT ALL	SOA 117
210 VVV=XO	SOA 118
GO TO 75	SOA 119
C 2-POINT INTERPOLATION ON 2 HIGH POINTS	SOA 120
221 VVV=(1.-PL)*XO + PL*XH	SOA 121
GO TO 75	SOA 122
230 IF(INUF(J,N)-LM)241,232,241	SOA 123
C USE 2 LOW POINTS	SOA 124
232 PL=PL+1.	SOA 125
VVV=(1.-PL)*XL+PL*XO	SOA 126
GO TO 75	SOA 127
C NORMAL 3-POINT INTERPOLATION	SOA 128
241 VVV=0.5*PL*(PL-1.)*XL + (1.-PL*PL)*XO +0.5*PL*(1.+PL)*XH	SOA 129
75 SOUR=SOUR-VVV*DSL(J)	SOA 130
SCL(J,I)=VVV	SOA 131
GO TO 98	SOA 132
90 SOUR=SOUR-DSL(J)*SCL(J,I)	SOA 133
98 CONTINUE	SOA 134
SOURCE(I)=SI(I)+DS(I)+SOUR	SOA 135
SOR(I)=SOUR	SOA 136
95 CONTINUE	SOA 137
DO 96 I=1,KREG	SOA 138

IF(SOURCE(I))97,96,96	SOA	139
97 E=ENGP(I)*DEXP(-U)	SOA	140
PRINT 102,I,SOURCE(I),E	SOA	141
102 FORMAT(8H SOURCE(I,2,2H)=,E15.8,2X,22HRESET TO 1 DOWNSCATTER,2X,	SOA	142
X 2HE=E13.5)	SOA	143
SOURCE(I)=0.	SOA	144
K=LREG(I)	SOA	145
DO 961 J=1,KMAT	SOA	146
IF(DEN(J,K))962,961,962	SOA	147
962 SOURCE(I)=DS1(J)*PHI(I)*SL(J,K) +SOURCE(I)	SOA	148
961 CONTINUE	SOA	149
DS(I)=SOURCE(I)-SI(I)	SOA	150
96 CONTINUE	SOA	151
100 U=U+UFGP	SOA	152
RETURN	SOA	153
END	SOA	154
SUBROUTINE YZ3	YZ3	1
COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	YZ3	2
X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,YZ3	YZ3	3
X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DS1(20),	YZ3	4
X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	YZ3	5
COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	YZ3	6
COMMON/A/ F1V,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	YZ3	7
XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	YZ3	8
X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	YZ3	9
X SIGMIN(300), SIG(30),	YZ3	10
X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	YZ3	11
COMMON/B/ UIGP, CR(30),RAD(35),	YZ3	12
X RAT(10(30),DIFX(30), SPP(30),SPN(30),	YZ3	13
X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	YZ3	14
XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	YZ3	15
X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	YZ3	16
COMMON/C/	YZ3	17
X XAREAT,AREAT,RMAX(30),	YZ3	18
X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	YZ3	19
X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	YZ3	20
X SIGIR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	YZ3	21
XGX2(10),GW2(10),WW2(10),	YZ3	22
X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	YZ3	23
X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	YZ3	24
COMMON/D/KI,KRES,NTEMP,INCLUDI300),	YZ3	25
X NEXT(20),LAST(20),NRES(20),INDEX, KS,	YZ3	26
X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	YZ3	27
X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	YZ3	28
X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	YZ3	29
X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	YZ3	30
REAL*8 NUCLID	YZ3	31
REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	YZ3	32
X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	YZ3	33
REAL*8 DPS	YZ3	34
REAL*8 B,PFZ,PFUNC,C	YZ3	35
EQUIVALENCE (V3, Y),(V4, DEL)	YZ3	36
V9=0.	YZ3	37
A=Y	YZ3	38
IF(DEL-.01)18,18,15	YZ3	39
18 IF(DEL-.0001)40,50,50	YZ3	40

OA 139	40 DEL2=0.	YZ3 41
OA 140	DIF=0.	YZ3 42
OA 141	41 IF(A-.6)42,11,11	YZ3 43
OA 142	42 DIF=DIF+E2(A)*DEL	YZ3 44
OA 143	A=A+TUT	YZ3 45
OA 144	GO TO 41	YZ3 46
OA 145	50 DEL2=.0416666667*DEL*DEL	YZ3 47
OA 146	DIF=0.	YZ3 48
OA 147	B=A+DEL	YZ3 49
OA 148	19 IF(B-.6)10,11,11	YZ3 50
OA 149	10 PFZ=PFUNC(B)	YZ3 51
OA 150	C=A	YZ3 52
OA 151	DIF=DIF+C*(PFZ-PFUNC(C))+DEL*PFZ	YZ3 53
OA 152	A=A+TUT	YZ3 54
OA 153	B=A+DEL	YZ3 55
OA 154	GO TO 19	YZ3 56
Z3 1	11 Q= A+0.5*DEL	YZ3 57
Z3 2	DO 12 I=1,4	YZ3 58
Z3 3	U=GX2(I)*GX2(I)*DEL2	YZ3 59
Z3 4	V9=V9+WW2(I)*(1.+U*(1.+0.125*U))* EXP(Q*GX2(I))	YZ3 60
Z3 5	12 CONTINUE	YZ3 61
Z3 6	V9=V9*DEL +DIF	YZ3 62
Z3 7	RETURN	YZ3 63
Z3 8	15 Z=Y+DEL	YZ3 64
Z3 9	IF(1UT-.2)30,30,31	YZ3 65
Z3 10	30 V9=EZ3(Y,TOT)-EZ3(Z,TOT)	YZ3 66
Z3 11	RETURN	YZ3 67
Z3 12	31 IF(Y-.3)7,8,8	YZ3 68
Z3 13	8 IF(Y-3.16)20,20,21	YZ3 69
Z3 14	20 M=0.633*(7.89-Y)	YZ3 70
Z3 15	GO TO 22	YZ3 71
Z3 16	21 M=1.+6.2/Y	YZ3 72
Z3 17	GO TO 22	YZ3 73
Z3 18	7 V9 =XC* EXP(-18.2*Y)	YZ3 74
Z3 19	M=4	YZ3 75
Z3 20	IF(Z-.3)9,22,22	YZ3 76
Z3 21	9 V9 =V9 -XC* EXP(-18.2*Z)	YZ3 77
Z3 22	22 DO 1 I=1,M	YZ3 78
Z3 23	V9 =V9 +WW3(I)*(EXP(Y*GX3(I)) - EXP(Z*GX3(I)))	YZ3 79
Z3 24	1 CONTINUE	YZ3 80
Z3 25	2 RETURN	YZ3 81
Z3 26	END	YZ3 82
Z3 27	SUBROUTINE YZ4	YZ4 1
Z3 28	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	YZ4 2
Z3 29	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,YZ4 3	
Z3 30	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DS1(20),	YZ4 4
Z3 31	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	YZ4 5
Z3 32	COMMON/QW/REZ,AIMZ,REN,AIMW, TR(62,62),TI(62,62)	YZ4 6
Z3 33	COMMON/A/ FIV,SL(20,30),TEST, SIGP(20,30),XZETA(20,30),	YZ4 7
Z3 34	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	YZ4 8
Z3 35	X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	YZ4 9
Z3 36	X SIGMIN(300), SIG(30),	YZ4 10
Z3 37	X SIGA22(20),SIGF22(20), XN,XC,ETCT,TOT3,WORK(60),P(30)	YZ4 11
Z3 38	COMMON/B/ UIGP, CR(30),RAD(35),	YZ4 12
Z3 39	X RATIO(30),DIFX(30), SPP(30),SPN(30),	YZ4 13
Z3 40	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	YZ4 14

41	XTAB(662),TOT,TT(60,5),	AF(30,5),FF(30,5),	YZ4	15
42	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)		YZ4	16
43	COMMON/C/		YZ4	17
44	X XAREAT,AREAT,RMAX(30),		YZ4	18
45	X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),		YZ4	19
46	X XTEMP(30),	PHICT(30),PHI(30),PFLUX(30),	YZ4	20
47	X SIGTR(30),BARMU(30),	AMU(20),SIGPUT(20),AREAC(30),XAREAC(30),	YZ4	21
48	X GX2(10),GW2(10),WW2(10),		YZ4	22
49	X DK(30),XAREA(30),PHIRT(30),	GX3(10),GX4(10),GW3(10),	YZ4	23
50	X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10		YZ4	24
51	COMMON/D/KI,KRES,NTEMP,INCLUD(300),		YZ4	25
52	X NEXT(20),LAST(20),NRES(20),INDEX,KS,		YZ4	26
53	X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,		YZ4	27
54	X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),		YZ4	28
55	X NF1(25),TITLE(18),KB	MULT(20,25),JNU(20),JMUL(20),	YZ4	29
56	X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ		YZ4	30
57	REAL*8 NUCLID		YZ4	31
58	REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,		YZ4	32
59	X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SICSBG,PI,PS,ALP,DSL		YZ4	33
60	REAL*8 DPS		YZ4	34
61	EQUIVALENCE (V3, Y),(V4, DEL)		YZ4	35
62	V10=0.		YZ4	36
63	IF(DEL-.01)11,11,15		YZ4	37
64	11 Q=Y+0.5*DEL		YZ4	38
65	DEL2=.0416666667*DEL*DEL		YZ4	39
66	DO 12 I=1,4		YZ4	40
67	W=GX3(I)*GX3(I)*DEL2		YZ4	41
68	V10=V10+WW3(I)*(1.+W*(1.+0.0125*W))* EXP(Q*GX3(I))		YZ4	42
69	12 CONTINUE		YZ4	43
70	IF(Q-.3)13,14,14		YZ4	44
71	13 V10=V10+XC* EXP(-18.2*Q)		YZ4	45
72	14 V10=V10*DEL		YZ4	46
73	RETURN		YZ4	47
74	15 Z=Y+DEL		YZ4	48
75	IF(TOT-.3)3,3,4		YZ4	49
76	3 V10=EZ4(Y,TOT)-EZ4(Z,TOT)		YZ4	50
77	RETURN		YZ4	51
78	4 IF(Y-3.64)20,20,21		YZ4	52
79	20 M=0.549*(9.10-Y)		YZ4	53
80	GO TO 22		YZ4	54
81	21 M=1.+6.81/Y		YZ4	55
82	22 DO 1 I=1,M		YZ4	56
1	V10=V10+WW4(I)*(EXP(Y*GX4(I)) - EXP(Z*GX4(I)))		YZ4	57
2	1 CONTINUE		YZ4	58
3	2 RETURN		YZ4	59
4	END		YZ4	60
5	SUBROUTINE XSECT(IERR)		XSE	1
6	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),PI(20,25),		XSE	2
7	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,		XSE	3
8	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DS1(20),		XSE	4
9	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)		XSE	5
10	COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)		XSE	6
11	COMMON/A/ F1V,SL(20,30), TEST,	SIGP(20,30),XZETA(20,30),	XSE	7
12	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),		XSE	8
13	X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),		XSE	9
14	X SIGMIN(300), SIG(30),		XSE	10

15	X	SIGA22(20),SIGF22(20),	XN,XC,ETOT,TOT3,WORK(60),P(30)	XSE	11
16		COMMON/B/	UIGP,	CR(30),RAD(35),	XSE
17	X	RATIO(30),DIFX(30),	SPP(30),SPN(30),	XSE	13
18	X	AREA(35),	FLUX(30,100),FLUXCP(30,100),SCAT(40000),	XSE	14
19	X	TAB(662),TOT,TI(60,5),	AF(30,5),FF(30,5),	XSE	15
20	X	V11,V12,V13,SSF(30,5),	USTR(25),DUSTR(25)	XSE	16
21		COMMON/C/		XSE	17
22	X	XAREAT,AKEAT,RMAX(30),		XSE	18
23	X	ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),		XSE	19
24	X	XTMP(30),	PHICT(30),PHI(30),PFLUX(30),	XSE	20
25	X	SIGTR(30),BARMU(30),	AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	XSE	21
26	X	GX2(10),GW2(10),WW2(10),		XSE	22
27	X	DR(30),XAREA(30),PHIRT(30),	GX3(10),GX4(10),GW3(10),	XSE	23
28	X	GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10		XSE	24
29		COMMON/D/K1,KRES,NTEMP,INCLUD(300),		XSE	25
30	X	NEXT(20),LAST(20),NRES(20),INDEX,KS,		XSE	26
31	X	NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,		XSE	27
32	X	IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),		XSE	28
33	X	NFI(25),TITLE(18),KB	MULT(20,25),JNU(20),JMUL(20),	XSE	29
34	X	INUI(20,25),INUF(20,25),NOX,NISO,KBSQ		XSE	30
35	REAL*8	UFGP,V,EXDU,UMAX,DS1,DSMAX,SGURCE,SDD,ACS,FCS,SCS,PHITOT,		XSE	31
36	X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,PI,PS,ALP		XSE	32
37	REAL*8	DSL,DPS,E		XSE	33
38	REAL*8	NUCLID		XSE	34
39	GO TO	(3,10,6,20),INDEX		XSE	35
40	3	E=0.5*ENGP(1)*(1.0+EXDU)		XSE	36
41		Z=0.5*V(IBG)		XSE	37
42	DO 4	J=1,III		XSE	38
43	DO 4	I=1,KMAT		XSE	39
44	SA(I,J)=SA(I,J)*F1V			XSE	40
45	4	SF(I,J)=SF(I,J)*F1V		XSE	41
46	GO TO	15		XSE	42
47	6	E=.5*E*(EXDU+1.-V(IBG-1))		XSE	43
48		Z=0.5*(V(IBG)+V(IBG-1))		XSE	44
49	GO TO	15		XSE	45
50	10	E=E*EXDU		XSE	46
51		Z=V(IBG)		XSE	47
52	15	FDEL=1.+5*Z*(1.+75*Z*(1.+5.*Z/6.))		XSE	48
53	GO TO	25		XSE	49
54	20	E=E*EXDU		XSE	50
55	25	XYZ=1.77246		XSE	51
56		IF(NOPT-4)70,71,71		XSE	52
57	71	XYZ=0.		XSE	53
58	70	DO 40 I=1,KRES		XSE	54
59	C	NOPT GREATER 3 IMPLIES NO INTERFERENCE TERM CHI		XSE	55
60		DO 40 J=1,NTEMP		XSE	56
1		XZETA(I,J)=XZETA(I,J)*FDEL		XSE	57
2		SA(I,J)=SIGA22(I)		XSE	58
3		SF(I,J)=SIGF22(I)		XSE	59
4		SS(I,J)=0.		XSE	60
5		N=NEXT(I)		XSE	61
6		L=LAST(I)		XSE	62
7		DO 40 K=N,L		XSE	63
8		IF(J-1)30,30,35		XSE	64
9	30	XRES(K)=XRES(K)*FDEL		XSE	65
10	35	IF(INCLUD(K)-IBGP)40,36,40		XSE	66

11	36	X=2.*(E-ER(K))/GAMMA(K)	XSE	67
12		ZETA=GAMMA(K)*XZEIA(I,J)	XSE	68
13		AIMZ=.5*ZETA	XSE	69
14		REZ=X*AIMZ	XSE	70
15		CALL QUICKW	XSE	71
16		PSI=.88623*ZETA*REW	XSE	72
17		CHI=XYZ*ZETA*AIMW	XSE	73
18	C		XSE	74
19		IF (G(K).LT.0.0) GO TO 39	XSE	75
20	C		XSE	76
21		F=PSI*SIGZ(K)	XSE	77
22		SA(I,J)=SA(I,J)+F*XRES(K)*(GF(K)+GR(K))	XSE	78
23		SF(I,J)=SF(I,J)+F*XRES(K)*GF(K)	XSE	79
24		SS(I,J)=SS(I,J)+F*GN(K)+CHI*SIGIN(K)	XSE	80
25		GO TO 40	XSE	81
26	C		XSE	82
27	39	CONTINUE	XSE	83
28		F1 = PSI + (GAMMA(K) * CHI / (4.0 * ER(K)))	XSE	84
29		GO2 = GAMMA(K) / (2.0 * ER(K))	XSE	85
30		F2 = PSI + GO2 * (CHI + GO2 * (1.0-PSI))	XSE	86
31		SA(I,J)= SA(I,J) + F1 * XRES(K) * SIGZ(K) * (GR(K)+GF(K))/GAMMA(K)	XSE	87
32		SF(I,J) = SF(I,J) + F1 * XRES(K) * SIGZ(K) * GF(K)/GAMMA(K)	XSE	88
33		SS(I,J) = SS(I,J) + F2 * SIGZ(K) * GN(K)/GAMMA(K)	XSE	89
34	C		XSE	90
35	40	CONTINUE	XSE	91
36		DO 66 M=1,III	XSE	92
37		J=III+1-M	XSE	93
38		SIG(J)=0.	XSE	94
39		SIGTR(J)=0.	XSE	95
40		DO 66 I=1,KMAT	XSE	96
41		IF (I-KRES)45,45,60	XSE	97
42	45	IF (INTMP-1)50,50,55	XSE	98
43	50	SA(I,J)=DEN(I,J)*SA(I,1)	XSE	99
44		SF(I,J)=DEN(I,J)*SF(I,1)	XSE	100
45		SS(I,J)=DEN(I,J)*SS(I,1)+SIGP(I,J)	XSE	101
46		GO TO 90	XSE	102
47	55	SA(I,J)=DEN(I,J)*SA(I,J)	XSE	103
48		SF(I,J)=DEN(I,J)*SF(I,J)	XSE	104
49		SS(I,J)=DEN(I,J)*SS(I,J)+SIGP(I,J)	XSE	105
50	90	IF(SS(I,J)-.05DO*SIGP(I,J))92,65,65	XSE	106
51	C	92 WRITE (6,100) I,J,SS(I,J),E	XSE	107
52		92 CONTINUE	XSE	108
53	100	FORMAT(34H SCATTERING CROSS SECTION <.05SIGP, 4H SS(I,12,1H,12,2H)	XSE	109
54		I=,E12.5,7HENERGY=,E12.5)	XSE	110
55		SS(I,J)=0.05DO*SIGP(I,J)	XSE	111
56		GO TO 65	XSE	112
57	60	SA(I,J)=SA(I,J)*FDEL	XSE	113
58		SF(I,J)=SF(I,J)*FDEL	XSE	114
59		SS(I,J)=SIGP(I,J)	XSE	115
60	65	SIG(J)=SIG(J)+SA(I,J)+SS(I,J)	XSE	116
61		X=0.	XSE	117
62		IF(SS(I,J).NE.0.) X=SA(I,J)/SS(I,J)	XSE	118
63		SIGTR(J)=SIGTR(J)+ (SA(I,J)+SS(I,J))*(X+1.-BARMU(I))	XSE	119
64	66	CONTINUE	XSE	120
65		RETURN	XSE	121
66		END	XSE	122

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67 SUBROUTINE RESTES RES 1
68 COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25), RES 2
69 X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP, RES 3
70 X SCSPG,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20), RES 4
71 X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25) RES 5
72 COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62) RES 6
73 COMMON/A/ F1V,SL(20,30), TEST, SIGP(20,30),XZETA(20,30), RES 7
74 XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300), RES 8
75 X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300), RES 9
76 X SIGMIN(300), SIG(30), RES 10
77 X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30) RES 11
78 COMMON/B/ UIGP, CR(30),RAD(35), RES 12
79 X RATIO(30),DIFX(30), SPP(30),SPN(30), RES 13
80 X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000), RES 14
81 XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5), RES 15
82 X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25) RES 16
83 COMMON/C/ RES 17
84 X XAREAT,AREAT,RMAX(30), RES 18
85 X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30), RES 19
86 X XTEMP(30), PHICT(30),PHI(30),PFLUX(30), RES 20
87 X SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30), RES 21
88 XGX2(10),GW2(10),WW2(10), RES 22
89 X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10), RES 23
90 X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10 RES 24
91 COMMON/D/KI,KRES,NTEMP,INCLUD(300), RES 25
92 X NEXT(20),LAST(20),NRES(20),INDEX, KS, RES 26
93 X NU,NOPT,ISYM(30),I1,KFQIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE, RES 27
94 X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30), RES 28
95 X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20), RES 29
96 X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ RES 30
97 REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT, RES 31
98 X PHIT,ACSGP,FCSGP,SCSPG,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL RES 32
99 REAL*8 UPS RES 33
100 REAL*8 NUCLID RES 34
101 DO 50 I=1,KRES RES 35
102 N=NEXT(I) RES 36
103 L=LAST(I) RES 37
104 DO 50 J=N,L RES 38
105 IF(IGP-2)5,15,15 RES 39
106 5 INCLUD (J)=0. RES 40
107 X=2.*(ENGP(1)-ER(J))/GAMMA(J) RES 41
108 ZETA=GAMMA(J)*XZETA(1,1) RES 42
109 AIMZ=0.5*ZETA RES 43
110 REZ=X*AIMZ RES 44
111 CALL QUICKW RES 45
112 PSI=0.88623*ZETA*REW RES 46
113 CHI=1.77246*ZETA*AIMW RES 47
114 IF(G(J).LT.0.0) GO TO 6 RES 48
115 C S-WAVE RES 49
116 SIGM=PSI*SIGZ(J)*(GN(J)+XRES(J)*(GF(J)+GR(J))) +CHI*SIGIN(J) RES 50
117 GO TO 7 RES 51
118 C P-WAVE RES 52
119 F1=PSI*(GAMMA(J)*CHI/(4.0*ER(J))) RES 53
120 GO2=GAMMA(J)/(2.0*ER(J)) RES 54
121 F2=PSI+GO2*(CHI+GO2*(1.0-PSI)) RES 55
122 SIGM=SIGZ(J)*(F1*XRES(J)*(GR(J)+GF(J))+F2*GN(J))/GAMMA(J) RES 56

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1	7 SIGM= ABS(SIGM)	RES	57
2	IF(SIGM-TEST)25,10,10	RES	58
3	10 INCLUD (J)=IBGP	RES	59
4	GO TO 25	RES	60
5	15 IF(SIGMIN(J)-TEST)25,20,20	RES	61
6	20 INCLUD (J)=IBGP	RES	62
7	25 K=IBGP+1	RES	63
8	X=2.0*(ENGP(K)-ER(J))/GAMMA(J)	RES	64
9	AIMZ=.5*GAMMA(J)* SQRT(AMU(I)/(3.46668E-04*ENGP(K)*TEMP(1)))	RES	65
10	REZ=X*AIMZ	RES	66
11	CALL QUICKW	RES	67
12	Z=1.77246*AIMZ*REW	RES	68
13	Y=3.54492*AIMZ*AIMW	RES	69
14	C Z=PSI, Y=CHI	RES	70
15	W= SQRT(ABS(ER(J))/ENGP(K))	RES	71
16	IF(G(J).LT.0.0) GO TO 26	RES	72
17	C S-WAVE	RES	73
18	SIGMIN(J)=SIGZ(J)*Z*(GN(J)+W*(GF(J)+GR(J))) + Y*SIGIN(J)	RES	74
19	GO TO 27	RES	75
20	C P-WAVE	RES	76
21	26 F1=Z+ GAMMA(J)*Y/(4.0*ER(J))	RES	77
22	GUZ=GAMMA(J)/(2.0*ER(J))	RES	78
23	F2=Z+G02*(Y+G02*(1.0-Z))	RES	79
24	SIGMIN(J)=SIGZ(J)*(F1*W*(GR(J)+GF(J)) + F2*GN(J))/GAMMA(J)	RES	80
25	27 SIGMIN(J)= ABS(SIGMIN(J))	RES	81
26	IF(SIGMIN(J)-TEST)35,30,30	RES	82
27	30 INCLUD(J)=IBGP	RES	83
28	GO TO 50	RES	84
29	35 IF(ENGP(IBGP)-ER(J))50,40,40	RES	85
30	40 IF(ENGP(K)-ER(J))45,45,50	RES	86
31	45 INCLUD (J)=IBGP	RES	87
32	50 CONTINUE	RES	88
33	RETURN	RES	89
34	END	RES	90
35	SUBROUTINE OUTPUT	OUT	1
36	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	OUT	2
37	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	OUT	3
38	X SCSGP,KAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	OUT	4
39	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	OUT	5
40	COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	OUT	6
41	COMMON/A/ F1V,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	OUT	7
42	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	OUT	8
43	X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	OUT	9
44	X SIGMIN(300), SIG(30),	OUT	10
45	X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	OUT	11
46	COMMON/B/ UIGP, CR(30),RAD(35),	OUT	12
47	X RATIG(30),DIFX(30), SPP(30),SPN(30),	OUT	13
48	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	OUT	14
49	XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	OUT	15
50	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	OUT	16
51	COMMON/C/	OUT	17
52	X XAREAT,AREAT,RMAX(30),	OUT	18
53	X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	OUT	19
54	X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	OUT	20
55	XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	OUT	21
56	XGX2(10),GW2(10),WW2(10),	OUT	22

57	X	DR(30),XAREA(30),PHIRT(30),	GX3(10),GX4(10),GW3(10),	OUT	23
58	X	GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10		OUT	24
59		CUMUN/D/KI,KRES,NTEMP,INCLUD(300),		OUT	25
60	X	NEXT(20),LAST(20),NRES(20),INDEX,KS,		OUT	26
61	X	NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,		OUT	27
62	X	IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),		OUT	28
63	X	NFI(25),TITLE(18),KB	MULT(20,25),JNU(20),JMULT(20),	OUT	29
64	X	INUI(20,25),INUF(20,25),NOX,NISO,KBSQ		OUT	30
65		REAL*8 NUCLID		OUT	31
66		REAL*8 UFGP,V,EXDU,UMAX,DS1,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,		OUT	32
67	X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL		OUT	33
68		REAL*8 DPS		OUT	34
69		DIMENSION LLLL(20)		OUT	35
70		RAP=RAP+ACSGP*UFGP/SDD		OUT	36
71		ZZ=1./NFI(18G)		OUT	37
72		IF(18G-2)1,65,65		OUT	38
73	65	IF(18G-2)70,1,1		OUT	39
74	70	W=FLOAT(NFI(18G-1))/FLOAT(NFI(18G))		OUT	40
75		XAREAT=W*XAREAT		OUT	41
76		DO 75 I=1,KCOMP		OUT	42
77	75	XAREAC(I)=W*XAREAC(I)		OUT	43
78		DO 80 I=1,KREG		OUT	44
79	80	XAREA(I)=W*XAREA(I)		OUT	45
80		1 JBG=IBGP+1		OUT	46
81		IF(NPRINT)2,2,10		OUT	47
82	2	WRITE(6,101)IBGP,ENGP(18G),ENGP(JBG)		OUT	48
83	101	FORMAT(1H0,2X,5HGROUP,14,E18.5,6H EV TO,E12.5,3H EV/)		OUT	49
84		WRITE(6,110)		OUT	50
85		ACSGP=ACSGP/PHIT		OUT	51
86		FCSGP=FCSGP/PHIT		OUT	52
87		SCSGP=SCSGP/PHIT		OUT	53
88		PHIT=PHIT*XAREAT		OUT	54
89		WRITE(6,102)ACSGP,FCSGP,SCSGP,PHIT		OUT	55
90	102	FORMAT(24X,4HCELL,18X,4D18.5//17X,11HCOMPOSITION,10X,8HMATERIAL)		OUT	56
1		DO 5 I=1,KCOMP		OUT	57
2		ZZ=FLUXCP(I,NU)*XAREAC(I)		OUT	58
3		WRITE(6,103)1,ZZ		OUT	59
4	103	FORMAT(26X,12,72X,E18.5)		OUT	60
5		DO 5 J=1,KMAT		OUT	61
6		ZY=0.		OUT	62
7		IF(DEN(J,I))16,5,16		OUT	63
8	16	ZY=1./(DEN(J,I)*FLUXCP(I,NU))		OUT	64
9	17	SIGABG(J,I)=ZY*SIGABG(J,I)		OUT	65
10		SIGFBG(J,I)=ZY*SIGFBG(J,I)		OUT	66
11		SIGSBG(J,I)=ZY*SIGSBG(J,I)		OUT	67
12		WRITE(6,1104)NUCLID(J),SIGABG(J,I),SIGFBG(J,I),SIGSBG(J,I)		OUT	68
13	5	CONTINUE		OUT	69
14	1104	FORMAT(40X,A6,3D18.5)		OUT	70
15	104	FORMAT(4H RA=,E12.5,5X,3H RF=,E12.5,4X,A6,3E18.5)		OUT	71
16	10	IF(JBG-NIB(18G))15,20,20		OUT	72
17	15	JBG=JBG+1		OUT	73
18		GO TO 60		OUT	74
19	20	LBGP=JBG-NIB(18G)		OUT	75
20		XNIB=NIB(18G)		OUT	76
21		WRITE(6,105)(TITLE(I),I=1,18),IBG,ENGP(LBGP),ENGP(JBG)		OUT	77
22	105	FORMAT(1H1,2X,18A4///20X,23HSUMMARY FOR BROAD GROUP,13,	5X, OUT	78	

	X E12.5,6H EV TO,E12.5,3H EV//)	OUT	79
23	WRITE (6,110)	OUT	80
24	110 FORMAT(21X,7HAVERAGE,29X,7HSIGMA A,11X,7HSIGMA F,11X,7HSIGMA S,	OUT	81
25	X14X,4HFLUX/)	OUT	82
26	ACS=ACS/PHITOT	OUT	83
27	FCS=FCS/PHITOT	OUT	84
28	SCS=SCS/PHITOT	OUT	85
29	PHITOT=PHITOT*XAREAT/XNIB	OUT	86
30	WRITE (6,102) ACS,FCS,SCS,PHITOT	OUT	87
31	DO 25 I=1,KCOMP	OUT	88
32	ZZ=PHICT(I)*XAREAC(I)/XNIB	OUT	89
33	WRITE (6,103) I,ZZ	OUT	90
34	DO 25 J=1,KMAT	OUT	91
35	ZY=0.	OUT	92
36	IF(DEN(J,I))27,25,27	OUT	93
37	27 ZY=1./(DEN(J,I)*PHICT(I))	OUT	94
38	28 RIAC(J,I)=ZY*RIAC(J,I)	OUT	95
39	RIFC(J,I)=ZY*RIFC(J,I)	OUT	96
40	RISC(J,I)=ZY*RISC(J,I)	OUT	97
41	RA=RIAC(J,I)*ZZ*UIGP*NIB(1BG)	OUT	98
42	RF=RIFC(J,I)*ZZ*UIGP*NIB(1BG)	OUT	99
43	WRITE (6,104) RA,RF,NUCLID(J),RIAC(J,I),RIFC(J,I),RISC(J,I)	OUT	100
44	25 CONTINUE	OUT	101
45	WRITE (6,111) RAP	OUT	102
46	111 FORMAT(////10X,35HCUMULATIVE ABSORPTION PROBABILITY =,D13.6)	OUT	103
47	MIN=1	OUT	104
48	MNO=KREG	OUT	105
49	26 MAX=MINO (MNO,16) + MIN-1	OUT	106
50	WRITE (6,106) 1BG,(NX(I),I=MIN,MAX)	OUT	107
51	106 FORMAT(1H1,//20X,50HREGIONAL INTERMEDIATE GROUP FLUXES FOR BROAD	GOUT	108
52	GROUP,14, //9X,5HLOWER,/,16X,16I6)	OUT	109
53	WRITE (6,107) (LREG(I),I=MIN,MAX)	OUT	110
54	107 FORMAT(3X,10HENERGY(EV),/,16X,16I6)	OUT	111
55	DO 35 I=LBGP,1BGP	OUT	112
56	MM=I+1	OUT	113
57	M=(I-1)/100	OUT	114
58	N=I-100*M	OUT	115
59	DO 30 J=MIN,MAX	OUT	116
60	30 LLLL(J)=XAREA(J)*FLUX(J,N)*10000.+ 0.5	OUT	117
61	35 WRITE (6,108) I,ENGP(MM),(LLLL(J),J=MIN,MAX)	OUT	118
62	108 FORMAT(1H ,14,E12.5,16I6)	OUT	119
63	DO 40 I=MIN,MAX	OUT	120
64	40 LLLL(I)=10000.*XAREA(I)*PHIRT(I)/XNIB+0.5	OUT	121
65	WRITE (6,109) (LLLL(I),I=MIN,MAX)	OUT	122
66	109 FORMAT(1H ,2X,7HAVERAGE,7X,16I6)	OUT	123
67	IF(KFOIL)50,50,210	OUT	124
68	210 ZZ=1.0/(NIB(1BG)*NFI(1BG))	OUT	125
69	DO 42 K=1,KFCIL	OUT	126
70	DO 41 I=1,KREG	OUT	127
71	AF(I,K)=AF(I,K)*ZZ	OUT	128
72	SSF(I,K)=SSF(I,K)*ZZ	OUT	129
73	41 FF(I,K)=FF(I,K)*ZZ	OUT	130
74	WRITE(6,120) K,(I,AF(I,K),FF(I,K),SSF(I,K),I=1,KREG)	OUT	131
75	120 FORMAT(///,5H FOIL,13,/,	OUT	132
76	110H INTERFACE, 11H RA(F) ,3X,7HRF(F) ,4X,7HRS(F) ,	OUT	133
77	2 /(4X,12,4X,3E12.5))	OUT	134

79	42 CONTINUE	OUT	135
80	50 PHITOT=0.000	OUT	136
81	ACS=0.000	OUT	137
82	FCS=0.000	OUT	138
83	SCS=0.000	OUT	139
84	DO 53 I=1,KREG	OUT	140
85	53 PHIRT(I)=0.	OUT	141
86	DO 55 I=1,KCOMP	OUT	142
87	PHICT(I)=0.	OUT	143
88	DO 55 J=1,KMAT	OUT	144
89	RIAC(J,I)=0.	OUT	145
90	RIFC(J,I)=0.	OUT	146
91	55 RISC(J,I)=0.	OUT	147
92	IBG=IBG+1	OUT	148
93	JBG=1	OUT	149
94	DO 56 I=1,KREG	OUT	150
95	DO 56 K=1,KFGIL	OUT	151
96	AF(I,K)=0.	OUT	152
97	FF(I,K)=0.	OUT	153
98	56 CONTINUE	OUT	154
99	60 RETURN	OUT	155
00	END	OUT	156
01	SUBROUTINE XTRAP	XT	1
02	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	XT	2
03	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	XT	3
04	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	XT	4
05	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	XT	5
06	COMMON/QW/REZ,AIMZ,KEW,AIMW, TR(62,62),TI(62,62)	XT	6
07	COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	XT	7
08	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	XT	8
09	X GK(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	XT	9
10	X SIGMIN(300), SIG(30),	XT	10
11	X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	XT	11
12	COMMON/B/ UIGP, CR(30),RAD(35),	XT	12
13	X RATIO(30),DIFX(30), SPP(30),SPN(30),	XT	13
14	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	XT	14
15	XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	XT	15
16	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	XT	16
17	COMMON/C/	XT	17
18	X XAREAT,AREAT,RMAX(30),	XT	18
19	X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	XT	19
20	X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	XT	20
21	X SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	XT	21
22	XGX2(10),GW2(10),WW2(10),	XT	22
23	X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	XT	23
24	X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	XT	24
25	COMMON/D/KI,KRES,NTEMP,INCLUD(300),	XT	25
26	X NEXT(20),LAST(20),NRES(20),INDEX, KS,	XT	26
27	X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	XT	27
28	X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	XT	28
29	X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	XT	29
30	X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	XT	30
31	REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	XT	31
32	X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	XT	32
33	REAL*8 DPS	XT	33
34	REAL*8 NUCLID	XT	34

5	EQUIVALENCE (X,V1)	XT	35
6	V7=0.	XT	36
7	IF(X-.3)5,6,6	XT	37
8	5 V7 = XC* EXP(-18.2*X)	XT	38
9	M=4	XT	39
0	GO TO 22	XT	40
1	6 IF(X-3.16)20,20,21	XT	41
2	20 M=0.633*(7.89-X)	XT	42
3	GO TO 22	XT	43
4	21 M=1.+6.2/X	XT	44
5	22 DO 1 I=1,M	XT	45
6	V7 =V7 +WW3(I)* EXP(X*GX3(I))	XT	46
7	1 CONTINUE	XT	47
8	2 RETURN	XT	48
9	END	XT	49
0	SUBROUTINE XTRAP4	XT4	1
1	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	XT4	2
2	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	XT4	3
3	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	XT4	4
4	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	XT4	5
5	COMMON/CW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	XT4	6
6	COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	XT4	7
7	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	XT4	8
8	X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	XT4	9
9	X SIGMIN(300), SIG(30),	XT4	10
0	X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	XT4	11
1	COMMON/B/ UIGP, CR(30),RAD(35),	XT4	12
2	X RATIO(30),DIFX(30), SPP(30),SPN(30),	XT4	13
3	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	XT4	14
4	XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	XT4	15
5	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	XT4	16
6	COMMON/C/	XT4	17
7	X XAREAT,AREAT,RMAX(30),	XT4	18
8	X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	XT4	19
9	X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	XT4	20
0	X SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	XT4	21
1	XGX2(10),GW2(10),WW2(10),	XT4	22
2	X OR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	XT4	23
3	X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	XT4	24
4	COMMON/D/K1,KRES,NTEMP,INCLUD(300),	XT4	25
5	X NEXT(20),LAST(20),NRES(20),INDEX, KS,	XT4	26
6	X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	XT4	27
7	X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	XT4	28
8	X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),	XT4	29
9	X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	XT4	30
0	REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	XT4	31
1	X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	XT4	32
2	REAL*8 DPS	XT4	33
3	REAL*8 NUCLID	XT4	34
4	EQUIVALENCE (X,V2)	XT4	35
5	V8=0.	XT4	36
6	IF(X-3.64)20,20,21	XT4	37
7	20 M=0.549*(9.10-X)	XT4	38
8	GO TO 22	XT4	39
9	21 M=1.+6.81/X	XT4	40
0	22 DO 1 I=1,M	XT4	41

5	1	V8	=V8	+WW4(I)* EXP(X*GX4(I))	XT4	42
6	2	RETURN			XT4	43
7		END			XT4	44
8		FUNCTION E3(X)			E3	1
9		COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),			E3	2
0	X	PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,			E3	3
1	X	SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),			E3	4
2	X	DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)			E3	5
3		COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)			E3	6
4		COMMON/A/ F1V,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),			E3	7
5	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),				E3	8
6	X	GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),			E3	9
7	X	SIGMIN(300), SIG(30),			E3	10
8	X	SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)			E3	11
9		COMMON/B/ UIGP, CR(30),RAD(35),			E3	12
0	X	RATIO(30),DIFX(30), SPP(30),SPN(30),			E3	13
1	X	AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),			E3	14
2	XTAB(662),IOT,TT(60,5), AF(30,5),FF(30,5),				E3	15
3	X	V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)			E3	16
4		COMMON/C/			E3	17
5	X	XAREAT,AREAT,RMAX(30),			E3	18
6	X	ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),			E3	19
7	X	XTEMP(30), PHICT(30),PHI(30),PFLUX(30),			E3	20
8	X	SIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),			E3	21
9	XGX2(10),GW2(10),WW2(10),				E3	22
0	X	DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),			E3	23
1	X	GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10			E3	24
2		COMMON/D/KI,KRES,NTEMP,INCLUD(300),			E3	25
3	X	NEXT(20),LAST(20),NRES(20),INDEX, KS,			E3	26
4	X	NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,			E3	27
5	X	IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),			E3	28
6	X	NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMUL(20),			E3	29
7	X	INUI(20,25),INUF(20,25),NOX,NISO,KBSQ			E3	30
8		REAL*8 NUCLID			E3	31
9		REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,			E3	32
0	X	PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL			E3	33
1		REAL*8 DPS			E3	34
2		IF(X-2.)70,70,30			E3	35
3	30	IF(X-4.)71,71,31			E3	36
4	31	IF(X-6.)111,111,160			E3	37
5	160	D=(X+3.)*2.			E3	38
6		E3= EXP(-X)*(1.+(3./D)*(1.+(3.-2.*X)/D))/(X+3.)			E3	39
7	C	ERROR IS 1/30 PERCENT OR LESS			E3	40
8		RETURN			E3	41
9	70	XX=100.*X+1			E3	42
0		NFDEL=XX			E3	43
1		F1=XX-NFDEL			E3	44
2		E3=TAB(NFDEL)+(TAB(NFDEL+1)-TAB(NFDEL))*F1			E3	45
3		RETURN			E3	46
4	71	XX=50.*X+101			E3	47
5		NFDEL=XX			E3	48
6		F1=XX-NFDEL			E3	49
7	112	E3=TAB(NFDEL)+(TAB(NFDEL+1)-TAB(NFDEL))*F1			E3	50
8		RETURN			E3	51
9	111	XX=X*12.5+251			E3	52
0		NFDEL=XX			E3	53

F1=XX-NFDEL	E3	54
GU TO 112	E3	55
END	E3	56
FUNCTION E4(X)	E4	1
COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	E4	2
X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	E4	3
X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	E4	4
X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	E4	5
COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	E4	6
COMMON/A/ FIV,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	E4	7
XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	E4	8
X GR(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	E4	9
X SIGMIN(300), SIG(30),	E4	10
X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	E4	11
COMMON/B/ UIGP, CR(30),RAD(35),	E4	12
X RATIO(30),DIFX(30), SPP(30),SPN(30),	E4	13
X AKEA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	E4	14
XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	E4	15
X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	E4	16
COMMON/C/	E4	17
X XAREAT,AREAT,RMAX(30),	E4	18
X ENGP(1001),RIAC(20,30),RIFC(20,30),RISC(20,30),TEMP(30),	E4	19
X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	E4	20
XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	E4	21
XGX2(10),GW2(10),WW2(10),	E4	22
X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	E4	23
X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	E4	24
COMMON/D/K1,KRES,NTEMP,INCLUD(300),	E4	25
X NEXT(20),LAST(20),NRES(20),INDEX, KS,	E4	26
X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	E4	27
X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	E4	28
X NFI(25),TITLE(18),KB ,MULT(20,25),JNU(20),JMULT(20),	E4	29
X INUI(20,25),INUF(20,25),NUX,NISO,KBSQ	E4	30
REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	E4	31
X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	E4	32
REAL*8 DPS	E4	33
REAL*8 NUCLID	E4	34
IF(X-2.)70,70,30	E4	35
30 IF(X-4.)71,71,31	E4	36
31 IF(X-6.4)111,111,160	E4	37
160 D=(X+4.)*2.	E4	38
E4= EXP(-X)*(1.+(4./D)*(1.+(4.-2.*X)/D))/(X+4.)	E4	39
RETURN	E4	40
C ERROR IS 1/30 PERCENT OR LESS	E4	41
70 XX=100.*X+332	E4	42
NFDEL=XX	E4	43
F1=XX-NFDEL	E4	44
E4=TAB(NFDEL)+(TAB(NFDEL+1)-TAB(NFDEL))*F1	E4	45
RETURN	E4	46
71 XX=50.*X+432	E4	47
NFDEL=XX	E4	48
F1=XX-NFDEL	E4	49
112 E4=TAB(NFDEL)+(TAB(NFDEL+1)-TAB(NFDEL))*F1	E4	50
RETURN	E4	51
111 XX=X*12.5+582	E4	52
NFDEL=XX	E4	53

3	54	F1=XX-NFDEL	E4	54
3	55	GO TO 112	E4	55
3	56	END	E4	56
4	1	SUBROUTINE TABLE	TAB	1
4	2	COMMON/E/NUCLID(20),UFGP,V(25),EXDU,UMAX(20,25),P1(20,25),	TAB	2
4	3	X PS(20,25),SOURCE(30),SDD,ACS,FCS,SCS,PHITOT,PHIT,ACSGP,FCSGP,	TAB	3
4	4	X SCSGP,RAP,SIGABG(20,30),SIGFBG(20,30),SIGSBG(20,30),DSL(20),	TAB	4
4	5	X DSMAX(20),ALP(20,25),SCL(20,30),DSL(20),DPS(20),BSQ(25)	TAB	5
4	6	COMMON/QW/REZ,AIMZ,REW,AIMW, TR(62,62),TI(62,62)	TAB	6
4	7	COMMON/A/ F1V,SL(20,30), TEST, SIGP(20,30),XZETA(20,30),	TAB	7
4	8	XSA(20,30),SF(20,30),SS(20,30),DEN(20,30),G(300),GN(300),GF(300),	TAB	8
4	9	X GK(300),ER(300),XRES(300),SIGZ(300),GAMMA(300),SIGIN(300),	TAB	9
4	10	X SIGMIN(300), SIG(30),	TAB	10
4	11	X SIGA22(20),SIGF22(20), XN,XC,ETOT,TOT3,WORK(60),P(30)	TAB	11
4	12	COMMON/B/ UIGP, CR(30),RAD(35),	TAB	12
4	13	X RATIO(30),DIFX(30), SPP(30),SPN(30),	TAB	13
4	14	X AREA(35), FLUX(30,100),FLUXCP(30,100),SCAT(40000),	TAB	14
4	15	XTAB(662),TOT,TT(60,5), AF(30,5),FF(30,5),	TAB	15
4	16	X V11,V12,V13,SSF(30,5),USTR(25),DUSTR(25)	TAB	16
4	17	COMMON/C/	TAB	17
4	18	X XAREAT,AREAT,RMAX(30),	TAB	18
4	19	X ENGP(1001),KIAC(20,30),KIFC(20,30),RISC(20,30),TEMP(30),	TAB	19
4	20	X XTEMP(30), PHICT(30),PHI(30),PFLUX(30),	TAB	20
4	21	XSIGTR(30),BARMU(30), AMU(20),SIGPOT(20),AREAC(30),XAREAC(30),	TAB	21
4	22	XGX2(10),GW2(10),WW2(10),	TAB	22
4	23	X DR(30),XAREA(30),PHIRT(30), GX3(10),GX4(10),GW3(10),	TAB	23
4	24	X GW4(10),WW3(10),WW4(10),V1,V2,V3,V4,V5,V6,V7,V8,V9,V10	TAB	24
4	25	COMMON/D/KI,KRES,NTEMP,INCLUD(300),	TAB	25
4	26	X NEXT(20),LAST(20),NRES(20),INDEX, KS,	TAB	26
4	27	X NU,NOPT,ISYM(30),III,KFOIL,KREG,KMAT,KCOMP,KGP,KBG,NPRINT,MORE,	TAB	27
4	28	X IBGP,IFGP,IBG,JBG,NIB(25),NINT(30),MINT(30),LREG(35),NX(30),	TAB	28
4	29	X NFI(25),TITLE(18),K8 ,MULT(20,25),JNU(20),JMULT(20),	TAB	29
4	30	X INUI(20,25),INUF(20,25),NOX,NISO,KBSQ	TAB	30
4	31	REAL*8 UFGP,V,EXDU,UMAX,DSL,DSMAX,SOURCE,SDD,ACS,FCS,SCS,PHITOT,	TAB	31
4	32	X PHIT,ACSGP,FCSGP,SCSGP,RAP,SIGABG,SIGFBG,SIGSBG,P1,PS,ALP,DSL	TAB	32
4	33	REAL*8 DPS	TAB	33
4	34	REAL*8 NUCLID	TAB	34
4	35	FORM TABLES	TAB	35
4	36	1 DO 110 I=1,331	TAB	36
4	37	IF(I-201)450,450,400	TAB	37
4	38	450 ZZZZ=(I-1)*.01+.0000000001	TAB	38
4	39	GO TO 500	TAB	39
4	40	400 IF(I-301)650,650,600	TAB	40
4	41	650 ZZZZ=(I-101)*.02	TAB	41
4	42	GO TO 500	TAB	42
4	43	600 ZZZZ=(I-251)*.08	TAB	43
4	44	500 IF(ZZZZ-1.)115,115,120	TAB	44
4	45	115 TAB(I) =-.57721566+.99999193*ZZZZ-.24991055*ZZZZ**2+.05519968*	TAB	45
4	46	1ZZZZ**3-.00976004*ZZZZ**4+.00107857*ZZZZ**5-ALOG(ZZZZ)	TAB	46
4	47	GO TO 116	TAB	47
4	48	120 TAB(I) =(EXP(-ZZZZ)/ZZZZ)*(ZZZZ**4+8.573328740*ZZZZ**3+	TAB	48
4	49	1 18.05901697*ZZZZ**2+8.634760892*ZZZZ+.2677737343)/(ZZZZ**4+	TAB	49
4	50	2 9.573322345*ZZZZ**3 +25.63295615*ZZZZ**2+21.09965308*ZZZZ+	TAB	50
4	51	3 3.958496923)	TAB	51
4	52	116 E2= EXP(-ZZZZ)-ZZZZ*TAB(I)	TAB	52
4	53	TAB(I)=0.5*(EXP(-ZZZZ)-ZZZZ*E2)	TAB	53

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      TAB(I+331)=0.33333333*( EXP(-ZZZZ)-ZZZZ*TAB(I))
C      TAB(I) IS E3 WHILE TAB(I+331) IS E4
110  CONTINUE
      RETURN
      END
      FUNCTION EZ3(P,H)
      A=P+H
      Z=A+H
      Z2=Z*Z
      H2=H*H
      FF2=(H2*H/(1260.*Z))*(21.-H2*(1.+Z*(1.+0.5*Z))/Z2)
      EZ3=PE3(P) +PE3(A)+
X    .08333333333*( EXP(-Z)*(((4.-2.*Z)/H)+3.-FF2)
X    + E2(Z)*(H-3.*Z+(2.*Z2/H)))
      RETURN
      END
      FUNCTION EZ4(P,H)
      Z=P+H
      HZ=H*(H/Z)**2
      EZ4=.08333333333*( EXP(-Z)*((3.-Z)/H + 2.
1    +PE3(Z)*(Z*Z/H+H-2.*Z-HZ/30.))+E4(P)
      RETURN
      END
      FUNCTION E2(Q)
C      USED BY EZ3 FOR SMALL Q
      DIMENSION A(5)
      DATA
X    A/1.,0.,-.5, .08333333333,-.013888888889/
      X=Q+1.0E-20
      A(2)=-.4227843351+ALOG(X)
      E2=A(5)*X
      DO 11 K=1,3
      L=5-K
      E2=(E2+A(L))*X
11  CONTINUE
      E2=E2+A(1)
      RETURN
      END
C      FUNCTION PE3(S)
      USED BY EZ3 FOR SMALL S
      DIMENSION B(7)
      DATA
X    B/.5,-1.,0.,0.1666666667,-.02083333333, .002777777778,
X    -.000347222222/
      IF(S-.6)2,1,1
1    PE3=E3(S)
      RETURN
C      E3 TABLES FOR LESS THAN .6 NOT REQUIRED NOW
2    X=S+1.0E-20
      B(3)=-(-.9227843351+ALOG(X))/2.
      PE3=B(7)*X
      DO 11 K=1,5
      L=7-K
      PE3=(PE3+B(L))*X
11  CONTINUE
      PE3=PE3+B(1)

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TAB 54
TAB 55
TAB 56
TAB 57
TAB 58
EZ3 1
EZ3 2
EZ3 3
EZ3 4
EZ3 5
EZ3 6
EZ3 7
EZ3 8
EZ3 9
EZ3 10
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EZ4 1
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E2 10
E2 11
E2 12
E2 13
E2 14
E2 15
PE3 1
PE3 2
PE3 3
PE3 4
PE3 5
PE3 6
PE3 7
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PE3 11
PE3 12
PE3 13
PE3 14
PE3 15
PE3 16
PE3 17
PE3 18

54	RETURN	PE3	19
55	END	PE3	20
56	FUNCTION PFUNC(S)	PFU	1
57	IMPLICIT REAL*8(A-H,U-Z)	PFU	2
58	REAL*4 E3,T	PFU	3
1	DIMENSION B(8)	PFU	4
2	DATA	PFU	5
3	X 8/.5D0,-1.D0,0.D0,.1666666666667D0,-.0208333333333D0,	PFU	6
4	X.0027777777777778D0,-.0003472222222222,.00003968253968D0/	PFU	7
5	IF(S-.6)2,1,1	PFU	8
6	1 !=S	PFU	9
7	PFUNC=(.5-E3(T))/T	PFU	10
8	RETURN	PFU	11
9	2 IF(S)3,4,4	PFU	12
10	3 S=0.0D0	PFU	13
11	4 X=S+1.0D-20	PFU	14
1	B(3)=-(-.9227843350985D0+DLOG(X))* .5D0	PFU	15
2	PE3=B(8)*X	PFU	16
3	DO 11 K=1,6	PFU	17
4	L=8-K	PFU	18
5	PE3=(PE3+B(L))*X	PFU	19
6	11 CONTINUE	PFU	20
7	PFUNC=-PE3/X	PFU	21
1	RETURN	PFU	22
2	END	PFU	23
3	SUBROUTINE SYM(ISYM,DEN,AREA,KMAT,KREG,LREG)	SYM	1
4	DIMENSION ISYM(30),LREG(35),DEN(20,30),AREA(35)	SYM	2
5	DO 1 I=1,KREG	SYM	3
6	1 ISYM(I)=0	SYM	4
7	K=1	SYM	5
8	M=KREG-1	SYM	6
9	IF(M)62,62,2	SYM	7
10	2 DO 60 I=1,M	SYM	8
11	IJ=I+1	SYM	9
12	DO 60 J=IJ,KREG	SYM	10
13	II=I	SYM	11
14	JJ=J	SYM	12
15	10 DO 15 L=1,KMAT	SYM	13
1	TI=AREA(II)*DEN(L,LREG(II))	SYM	14
2	TJ=AREA(JJ)*DEN(L,LREG(JJ))	SYM	15
3	IF(TI-TJ)11,15,11	SYM	16
4	11 TI=AMAX1(TI,TJ)	SYM	17
5	IF((ABS(TI-TJ))/TI-1.0E-6)15,15,60	SYM	18
6	15 CONTINUE	SYM	19
7	IF(II-KREG)30,20,20	SYM	20
8	20 II=0	SYM	21
9	30 IF(JJ-1140,40,50	SYM	22
10	40 JJ=KREG+1	SYM	23
11	50 II=II+1	SYM	24
12	JJ=JJ-1	SYM	25
13	IF(1-II)10,70,10	SYM	26
14	70 ISYM(K)=I	SYM	27
15	ISYM(K+1)=J	SYM	28
16	K=K+2	SYM	29
17	60 CONTINUE	SYM	30
18	K=K-1	SYM	31

19	IF(K)62,62,61	SYM	32
20	61 WRITE(6,100) (ISYM(KK),KK=1,K)	SYM	33
1	100 FORMAT(/,42H THE FOLLOWING PAIRS ARE SYMMETRIC REGIONS,/, (20I6))	SYM	34
2	GO TO 63	SYM	35
3	62 WRITE (6,101)	SYM	36
4	101 FORMAT(/,21H NO SYMMETRIC REGIONS)	SYM	37
5	63 RETURN	SYM	38
6	END	SYM	39
7	SUBROUTINE MATINV (A,N,B,M,DETERM,NMAX)	MAT	1
8	C	MAT	2
9	C MATRIX INVERSION WITH ACCOMPANYING SOLUTION OF LINEAR EQUATIONS	MAT	3
10	C	MAT	4
11	C**** REMOVE NEXT STATEMENT IN SINGLE PRECISION VERSION	MAT	5
12	C IMPLICIT REAL*8 (A-H,O-Z)	MAT	6
13	REAL*4 PIVOT	MAT	7
14	DIMENSION A(NMAX,N),B(NMAX,M)	MAT	8
15	COMMON /F402/PIVOT(100),INDEX(100)	MAT	9
16	C	MAT	10
17	C INITIALIZE DETERMINANT AND PIVOT ELEMENT ARRAY	MAT	11
18	C	MAT	12
19	DETERM = 1.0	MAT	13
20	DO 20 I=1,N	MAT	14
21	PIVOT (I) = 0.0	MAT	15
22	20 CONTINUE	MAT	16
23	C	MAT	17
1	C PERFORM SUCCESSIVE PIVOT OPERATIONS (GRAND LOOP)	MAT	18
2	C	MAT	19
3	C	MAT	20
4	DO 550 I=1,N	MAT	21
5	C	MAT	22
6	C SEARCH FOR PIVOT ELEMENT AND EXTEND DETERMINANT PARTIAL PRODUCT	MAT	23
7	C	MAT	24
8	AMAX = 0.0	MAT	25
9	DO 105 J=1,N	MAT	26
10	IF (PIVOT(J).NE.0.0) GO TO 105	MAT	27
11	DO 100 K=1,N	MAT	28
12	IF (PIVOT(K).NE.0.0) GO TO 100	MAT	29
13	TEMP = ABS(A(J,K))	MAT	30
14	IF (TEMP.LT.AMAX) GO TO 100	MAT	31
15	IROW = J	MAT	32
16	ICOLUM = K	MAT	33
17	AMAX = TEMP	MAT	34
18	100 CONTINUE	MAT	35
19	105 CONTINUE	MAT	36
20	INDEX(I) = 4096*IROW+ICOLUM	MAT	37
21	J = IROW	MAT	38
22	AMAX = A(J,ICOLUM)	MAT	39
23	DETERM = AMAX * DETERM	MAT	40
24	C	MAT	41
25	C RETURN IF MATRIX IS SINGULAR (ZERO PIVOT) AFTER COLUMN INTERCHANGE	MAT	42
26	C	MAT	43
27	IF (DETERM.EQ.0.0) GO TO 600	MAT	44
28	C	MAT	45
29	PIVOT(ICOLUM) = AMAX	MAT	46
30	C	MAT	47
31	C INTERCHANGE ROWS TO PUT PIVOT ELEMENT ON DIAGONAL	MAT	48
32	C		

32	IF (IROW.EQ.ICOLUM) GO TO 260	MAT	49
33	DETERM = -DETERM	MAT	50
34	DO 200 K=1,N	MAT	51
35	SWAP = A(J,K)	MAT	52
36	A(J,K) = A(ICOLUM,K)	MAT	53
37	A(ICOLUM,K) = SWAP	MAT	54
38	200 CONTINUE	MAT	55
39	IF (M.LE.0) GO TO 260	MAT	56
1	DO 250 K=1,M	MAT	57
2	SWAP = B(J,K)	MAT	58
3	B(J,K) = B(ICOLUM,K)	MAT	59
4	B(ICOLUM,K) = SWAP	MAT	60
5	250 CONTINUE	MAT	61
6	C	MAT	62
7	C DIVIDE PIVOT ROW BY PIVOT ELEMENT	MAT	63
8	C	MAT	64
9	260 K = ICOLUM	MAT	65
10	A(ICOLUM,K) = 1.0	MAT	66
11	DO 350 K=1,N	MAT	67
12	A(ICOLUM,K) = A(ICOLUM,K)/AMAX	MAT	68
13	350 CONTINUE	MAT	69
14	IF (M.LE.0) GO TO 380	MAT	70
15	DO 370 K=1,M	MAT	71
16	B(ICOLUM,K) = B(ICOLUM,K)/AMAX	MAT	72
17	370 CONTINUE	MAT	73
18	C	MAT	74
19	C REDUCE NON-PIVOT ROWS	MAT	75
20	380 DO 550 J=1,N	MAT	76
21	IF (J.EQ.ICOLUM) GO TO 550	MAT	77
22	T = A(J,ICOLUM)	MAT	78
23	A(J,ICOLUM) = 0.0	MAT	79
24	DO 450 K=1,N	MAT	80
25	A(J,K) = A(J,K)-A(ICOLUM,K)*T	MAT	81
26	450 CONTINUE	MAT	82
27	IF (M.LE.0) GO TO 550	MAT	83
28	DO 500 K=1,M	MAT	84
29	B(J,K) = B(J,K)-B(ICOLUM,K)*T	MAT	85
30	500 CONTINUE	MAT	86
31	550 CONTINUE	MAT	87
32	C	MAT	88
33	C INTERCHANGE COLUMNS AFTER ALL PIVOT OPERATIONS HAVE BEEN PERFORMED	MAT	89
34	C	MAT	90
35	600 DO 710 I=1,N	MAT	91
36	I1 = N+1-I	MAT	92
37	K = INDEX(I1)/4096	MAT	93
38	ICOLUM = INDEX(I1)-4095*K	MAT	94
39	IF (K.EQ.ICOLUM) GO TO 710	MAT	95
40	DO 705 J=1,N	MAT	96
41	SWAP = A(J,K)	MAT	97
42	A(J,K) = A(J,ICOLUM)	MAT	98
43	A(J,ICOLUM) = SWAP	MAT	99
44	705 CONTINUE	MAT	100
45	710 CONTINUE	MAT	101
46	C	MAT	102
47	RETURN	MAT	103
48	END	MAT	104

SUBROUTINE QUICKW	QKW	1
COMMON/QW/AX,Y,REW,AIMW,TR(62,62),TI(62,62)	QKW	2
X=AX	QKW	3
TEST=X*X+Y*Y	QKW	4
IF (TEST.LT.36.) GO TO 10	QKW	5
IF (TEST.LT.144.) GO TO 2	QKW	6
IF (TEST.LT.10000.) GO TO 3	QKW	7
A1=0.5641896/TEST	QKW	8
REW=Y*A1	QKW	9
AIMW=X*A1	QKW	10
RETURN	QKW	11
10 AKI=SIGN(1.0,AX)	QKW	12
X=ABS(AX)	QKW	13
II=X*10.	QKW	14
JJ=Y*10.	QKW	15
I=II+2	QKW	16
J=JJ+2	QKW	17
N=J-1	QKW	18
P=10.*X-II	QKW	19
Q=10.*Y-JJ	QKW	20
15 P2=P*P	QKW	21
Q2=Q*Q	QKW	22
PQ=P*Q	QKW	23
HP=.5*P	QKW	24
HQ=.5*Q	QKW	25
HQ2=.5*Q2	QKW	26
HP2=.5*P2	QKW	27
A1=HQ2-HQ	QKW	28
A2=HP2-HP	QKW	29
A3=1.+PQ-P2-G2	QKW	30
A4=HP2-PQ+HP	QKW	31
A5=HQ2-PQ+HQ	QKW	32
REW=A1*TR(I,N)+A2*TR(I-1,J)+A3*TR(I,J)+A4*TR(I+1,J)+A5*TR(I,J+1)	QKW	33
1+PQ*TR(I+1,J+1)	QKW	34
5 AIMW=AKI*(	QKW	35
1 A1*TI(I,N)+A2*TI(I-1,J)+A3*TI(I,J)+A4*TI(I+1,J)+A5*TI(I,J+1)	QKW	36
2)+PQ*TI(I+1,J+1))	QKW	37
RETURN	QKW	38
2 A1=(X+Y)*(X-Y)	QKW	39
A2=2.*X*Y	QKW	40
A3=A2*A2	QKW	41
A4=A1-.2752551	QKW	42
A5=A1-2.724745	QKW	43
D1=.5124242/(A4*A4+A3)	QKW	44
D2=.05176536/(A5*A5+A3)	QKW	45
D12A2=(D1+D2)*A2	QKW	46
DADA=D1*A4+D2*A5	QKW	47
REW=D12A2*X-Y*DADA	QKW	48
7 AIMW=D12A2*Y+X*DADA	QKW	49
RETURN	QKW	50
3 A1=2.*(X+Y)*(X-Y)	QKW	51
A2=4.*X*Y	QKW	52
A22=A2*A2	QKW	53
A4=A1-1.	QKW	54
A42=A4*A4	QKW	55
U1=1.1283792/(A42+A22)	QKW	56

1	REW=D1*(A2*X-A4*Y)	QKW	57
2	AIMW=1.1283792/(A4*X+A2*Y)	QKW	58
3	C SECOND TERM OF THE CONTINUED FRACTION	QKW	59
4	A5=A42- 4.*A4-A22-2.	QKW	60
5	A52=A5*A5	QKW	61
6	A6=A2*(A4+A4-4.)	QKW	62
7	A62=A6*A6	QKW	63
8	D1= 1./ (A52+A62)	QKW	64
9	A1=1. +(A5+A5)*D1	QKW	65
10	A2=D1*(A6+A6)	QKW	66
11	REW=REW*A1+AIMW*A2	QKW	67
12	AIMW=AIMW*A1-REW*A2	QKW	68
13	RETURN	QKW	69
14	END	QKW	70
15	//L.SYSLMOD DD DSN=TEMP.APORABID(RABIDA1),DISP=(NEW,CATLG),UNIT=DKTEMP		
16	//X.FT05F001 DD DDNAME=SYSIN		
17	//X.FT06F001 DD SYSOUT=A,DCB=(RECFM=FBA,LRECL=132,BLKSIZE=1584),	X	
18	// SPACE=(1584,(60,60))		
19	//X.FT08F001 DD DSN=TEMP.GLGATRTI,DISP=SHR,UNIT=DKTEMP,	X	
20	// DCB=(RECFM=VB,LRECL=500,BLKSIZE=5004),SPACE=(TRK,(5,1))		
21	//X.SYSIN DD *		

APPENDIX D

Sample Problems

1. Description of Problems

The first problem is the simplest possible case: homogeneous, one material, one resonance, and no absorption (obtained by setting $G = 0$ for the resonance, and zero background-absorption cross section). Physically, the flux must remain constant at unity. The output intermediate-group fluxes are scaled by 10,000 and rounded to the closest integral value.

The unit cell for the second problem consists of two compositions, each subdivided into four regions. Composition 1 is ^{238}U , and composition 2 is ^{12}C . An infinitely thin ^{238}U foil will sample interface conditions.

The third problem is a representation of the core of ZPR-3 Assemblies 53 and 54. The compositions are:

- a. Drawer + matrix + matrix + drawer
- b. Four carbon plates
- c. Cladding
- d. ZPR fuel plate
- e. Cladding
- f. Six carbon plates
- g. Cladding
- h. SEFOR fuel plate
- i. Cladding
- j. Three carbon plates

This case is one of a series of problems designed to calculate ^{238}U capture rates across the cell at positions corresponding to those used in an activation-foil scan. The activation-foil scan experiment and the procedure used to calculate the scan will now be described briefly with a comparison of results.

In the experiments, depleted-uranium foils were irradiated in the cell locations as shown in Fig. 3. The foils were counted by a Ge(Li) gamma-ray spectrometer. The activations were obtained from three gamma rays (209.8, 228.2, and 277.6 keV) which follow the beta decay of ^{239}Np . The experimental errors of $\pm 1.5\%$ include a $\pm 0.4\%$ contribution from statistics.

Fig. 3. ^{238}U In-cell Capture Rates in ZPR-3 Assemblies 53 and 54. ANL Neg. No. Id-103-A11290.

Heterogeneously self-shielded, 23-epithermal-group neutron cross sections generated by MC^2 were used by the TESS transport code in a one-dimensional, double S_{12} cell calculation. The amplitude variation exhibited by this calculation was clearly too small, because the self-shielding of each foil was inadequately accounted for.

Essentially "exact" calculations of the reaction rates in each foil were obtained from the integral transport code RABID. Uranium-238 capture cross sections in the energy range from 24.8 to 3.35 keV (a span of 8 MC^2 fine groups, each 0.25 lethargy unit wide) were obtained from statistically generated resolved resonance sequences for (ℓ, J) states of $(\frac{1}{2}, 0)$, $(\frac{1}{2}, 1)$, and $(\frac{3}{2}, 1)$. The Schmidt tabulation was used for both the unresolved and the resolved resonance parameters. The resonance sequences were centered on each MC^2 fine group. Resolved ^{238}U resonances were used from 3.35 keV down to 13.7 eV. Resolved resonances for aluminum, iron, chromium, and nickel were used over 24.8 keV to 13.7 eV. Smooth cross sections for ^{239}Pu were used down to 275 eV, below which resolved resonance parameters were used. Similarly, ^{240}Pu was accounted for by smooth cross sections above 130 eV, and resolved resonances below. Fine-group fluxes

from an ultrafine-group homogeneous MC² calculation were used to weight the RABID foil reaction rates. Above 24.8 keV, the spatial flux was very flat, the self-shielding of each foil became uniform, and the contribution to the total capture rate was about 28%. The RABID calculations are the same (to within 0.3%) whether a spatially flat flux is assumed above 24.8 keV, or if TESS spatial fluxes are used to weight the foil activations. Also, the contribution by neutrons below 13.7 eV is negligible. The amplitude variation shown by this calculation would be expected to increase slightly if resonance sequences were used above 24.8 keV, but not enough to display the experimental variation.

It is concluded that broad-group transport calculations of ²³⁸U capture rates in foils are rather inadequate and that "exact" RABID calculations agree fairly well with experiment. Uncertainties in ²³⁸U resonance parameters may explain those differences remaining between theory and experiment. Also, "scatter" in the experimental data indicates that the errors assigned to them may be too small.

2. Input for Sample Problems

HOMOGENEOUS TEST--NO ABSORPTION OR LEAKAGE. FLUX MUST STA. FLAT.										1
1	1	1	1	30	1	3	1	1		2
30	50									3
.02		1000.		0.		0	0			4
300.										5
1	1.									6
A-200		1	200.	1.		0.				7
1.										8
10000.		.01		.01		.00		0.		9
PLATE, FOIL EQUIVALENCE THEORY CHECK 1/8 IN U-238 1 IN C 8 REGION										1
8	2	2	1	5	1	4	1	1	0	2
5	50									3
0.01		2613.0		0.01		1	1			4
.001										5
293.0		293.0		293.0		293.0				6
4	.3175	4	2.8575		1.000E-10					7
U 238		66	238.		10.6					8
.042		0.		1.						9
1245.		.23		.0246		0.		1.		10
1267.		.027		.0246		0.		1.		11
1273.		.029		.0246		0.		1.		12
1299.		.0036		.0246		0.		1.		13
1317.		.0047		.0246		0.		1.		14
1336.		.0015		.0246		0.		1.		15
1393.		.17		.0246		0.		1.		16
1405.		.082		.0246		0.		1.		17
1420.		.011		.0246		0.		1.		18
1428.		.034		.0246		0.		1.		19
1444.		.023		.0246		0.		1.		20
1474.		.0805		.0246		0.		1.		21
1523.		.21		.0246		0.		1.		22
1546.		.002		.0246		0.		1.		23
1550.		.002		.0246		0.		1.		24
1565.		.0024		.0246		0.		1.		25
1623.		.09		.0246		0.		1.		26
1638.		.0404		.0246		0.		1.		27
1662.		.16		.0246		0.		1.		28
1688.		.07		.0246		0.		1.		29
1709.		.05		.0246		0.		1.		30
1723.		.014		.0246		0.		1.		31
1756.		.07		.0246		0.		1.		32
1782.		.5		.0246		0.		1.		33
1798.		.0021		.0246		0.		1.		34
1808.		.017		.0246		0.		1.		35
1846.		.0133		.0246		0.		1.		36
1902.		.0209		.0246		0.		1.		37
1917.		.0219		.0246		0.		1.		38
1969.		.577		.0246		0.		1.		39
1975.		.467		.0246		0.		1.		40
2024.		.202		.0246		0.		1.		41
2031.		.0496		.0246		0.		1.		42
2089.		.0137		.0246		0.		1.		43
2097.		.0101		.0246		0.		1.		44
2124.		.0046		.0246		0.		1.		45
2146.		.0347		.0246		0.		1.		46
2153.		.1760		.0246		0.		1.		47

2172.	.C023	.0246	0.	1.	48
2186.	.365	.0246	0.	1.	49
2194.	.C023	.0246	0.	1.	50
2201.	.113	.0246	0.	1.	51
2230.	.C047	.0246	0.	1.	52
2236.	.C^47	.0246	0.	1.	53
2242.	.C014	.0246	0.	1.	54
2259.	.0656	.0246	0.	1.	55
2266.	.145	.0246	0.	1.	56
2281.	.11	.0246	0.	1.	57
2289.	.C024	.0246	0.	1.	58
2302.	.C0096	.0246	0.	1.	59
2316.	.C0144	.0246	0.	1.	60
2337.	.C0483	.0246	0.	1.	61
2352.	.063	.0246	0.	1.	62
2356.	.0631	.0246	0.	1.	63
2393.	.C0112	.0246	0.	1.	64
2410.	.C0441	.0246	0.	1.	65
2427.	.C813	.0246	0.	1.	66
2446.	.111	.0246	0.	1.	67
2454.	.C0247	.0246	0.	1.	68
2490.	.C549	.0246	0.	1.	69
2521.	.C1	.0246	0.	1.	70
2549.	.343	.0246	0.	1.	71
2559.	.217	.0246	0.	1.	72
2581.	.244	.0246	0.	1.	73
2599.	.561	.0246	0.	1.	74
2604.	.C025	.0246	0.	1.	75
C 12	0	12.	4.7		76
0.	.C75	0.			77
U-238 FUILS IN LPR-3 ASSY 53 C-17 RESONANCE SET-02					1
12	9	10	5	10	1
10	12				3
.C008457	21967.5	0.001	1		4
300.	300.	300.	300.	300.	5
300.	300.	300.	300.	300.	6
300.					7
1 .4661	1 1.7361	1 1.76658	1 2.02312	1 2.0536	8
3 3.9586	1 3.98908	1 4.56312	1 4.5936	1 5.5461	9
0.0127					10
U-238	20	238.	10.6	0.0	0.0
0.0		0.0	0.0	0.0	0.0
0.0		0.0	0.0308768	0.0	0.0
C.0476					14
2.17871E 04	8.70641E-04	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.17964E 04	2.60020E-02	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18056E 04	1.60871E-04	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18149E 04	4.23203E-03	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18241E 04	9.03192E-03	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18334E 04	5.57224E-03	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18426E 04	2.20094E-03	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18519E 04	2.11191E-02	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18611E 04	7.17102E-03	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18704E 04	3.26603E-02	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18796E 04	1.90628E-05	2.46000E-02	0.0	-2.00000E 00	1 1 2
2.18889E 04	5.65034E-02	2.46000E-02	0.0	-2.00000E 00	1 1 2

48	2.18981E	04	3.13407E-03	2.46000E-02	0.0	-2.00000E	00	1	1	2	27
49	2.19074E	04	1.72296E-02	2.46000E-02	0.0	-2.00000E	00	1	1	2	28
50	2.19166E	04	1.13291E-02	2.46000E-02	0.0	-2.00000E	00	1	1	2	29
51	2.19259E	04	4.19695E-02	2.46000E-02	0.0	-2.00000E	00	1	1	2	30
52	2.19351E	04	1.40241E-02	2.46000E-02	0.0	-2.00000E	00	1	1	2	31
53	2.19444E	04	4.47596E-04	2.46000E-02	0.0	-2.00000E	00	1	1	2	32
54	2.19536E	04	9.06997E-02	2.46000E-02	0.0	-2.00000E	00	1	1	2	33
55	2.19629E	04	1.46722E-03	2.46000E-02	0.0	-2.00000E	00	1	1	2	34
56	AL	2	27.	1.4.	0.0018	0.0					35
57					.002936						36
58	0.0		0.0	0.0	0.0	0.0					37
59											38
60	5.90600E	03	2.00000E	01	0.0	0.0	4.16700E-01				39
61	3.50400E	04	1.50000E	03	0.0	0.0	5.83300E-01				40
62	FE	6	55.8500		5.22	0.0	0.0				41
63	0.035370		0.0	0.061970		0.0	0.061970				42
64	0.		.06197	0.	.06197						43
65											44
66	1.15000E	03	5.60000E-02	6.73000E-01		0.0	9.16800E-01				45
67	3.90000E	03	2.20000E	02	1.0	0.0	2.17000E-02				46
68	6.00000E	03	4.20000E	02	1.7	0.0	2.17000E-02				47
69	8.00000E	03	1.00000E	03	3.0	0.0	5.84000E-02				48
70	2.70000E	04	0.0	6.0		0.0	2.17000E-02				49
71	2.83000E	04	1.67000E	03	1.5	0.0	9.16800E-01				50
72	CR	5	52.01	3.71		0.0	0.0				51
73	0.00880		0.0	0.015410		0.0	0.01541				52
74	0.		.01541	0.	.01541						53
75											54
76	4.25000E	03	1.00000E	02	0.0	0.0	5.96000E-02				55
77	6.60000E	03	1.70000E	03	3.0	0.0	4.31000E-02				56
1	2.35000E	04	4.90000E	02	0.0	0.0	2.38000E-02				57
2	2.65000E	04	5.00000E	02	0.0	0.0	2.38000E-02				58
3	2.87000E	04	5.10000E	02	0.0	0.0	4.31000E-02				59
4	NI	4	58.7	6.57		0.0	0.0				60
5	0.00385		0.0	0.00675		0.0	.00675				61
6	0.		.00675	0.	.00675						62
7											63
8	4.60000E	03	1.30000E	03	0.0	0.0	3.66000E-02				64
9	1.25000E	04	2.60000E	03	0.0	0.0	2.61600E-01				65
10	1.55000E	04	1.54000E	03	0.0	0.0	6.77600E-01				66
11	2.87000E	04	1.11000E	03	0.0	0.0	2.61600E-01				67
12	PU-240	0	240.00	13.180		199.00	0.0				68
13	0.0		0.0	0.0	0.00135160		0.0				69
14	0.0		0.0	6.62280E-04		0.0	0.0				70
15											71
16	PU-239	0	239.00	10.320		662.00	0.0				72
17	0.0		0.0	0.0	0.0284290		0.0				73
18	0.0		0.0	7.07625E-03		0.0	0.0				74
19											75
20	MU	0	96.000	7.0000		69.400	0.0				76
21	0.										77
22	0.		0.	.002463							78
23	0.										79
24	C	0	12.	4.7							80
25	0.		.08183	0.	0.	0.					81
26	.08183		0.	0.	0.	.08183					82
	0.										83

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3. Output from Sample Problems

RAB10

HOMOGENEOUS TEST--NO ABSORPTION OR LEAKAGE. FLUX MUST STAY FLAT.

NO. CELL REGIONS = 1
NO. COMPOSITIONS = 1
NO. BROAD GROUPS = 1
NO. INTERMEDIATE GROUPS = 30

NO. MATERIALS = 1
NO. RESONANT MATERIALS = 1
LETHARGY WIDTH INTER. GROUP = 0.200000E-01
RESONANCE TEST = 0.0 (BARNs) NOPT= 3 KFOIL= 0

RESONANT MATERIALS HAVE BROAD-GROUP-DEPENDENT ABSORPTION AND FISSION CROSS SECTIONS

REGION/COMPOSITION/OUTER DIMENSION/TEMPERATURE

1
1
1.00000
300.00

MATERIAL RES. MASS SIG POT SIG A 1/V SIG F 1/V
A-200 1 0.20000E 03 0.10000E 01 0.0 0.0

ISOTOPE 1
0.10000E 01

BROAD GROUP	NO. INTER. GROUPS	NO. FINE GP/INTER GP	MAXIMUM ENERGY (EV)	MINIMUM ENERGY (EV)	BUCKLING
1	30	50	0.1000E 04	0.5488E 03	0.0

NUMBER OF FINE GROUPS USED TO LETHARGY-AVERAGE SCATTERING RATES FOR EACH MATERIAL

BROAD GROUP NO.= 1
A-200 1

RESONANCE PARAMETERS

MATERIAL	ENERGY (EV)	GAMMA N (EV)	GAMMA GAMMA (EV)	GAMMA F (EV)	G
A-200	0.10000E 05	0.10000E-01	0.10000E-01	0.0	0.0

NO SYMMETRIC REGIONS

HOMOGENEOUS TEST--NO ABSORPTION OR LEAKAGE. FLUX MUST STAY FLAT.

SUMMARY FOR BROAD GROUP 1		0.10000E 04 EV TO 0.54881E 03 EV			
AVERAGE		SIGMA A	SIGMA F	SIGMA S	FLUX
CELL		0.0	0.0	0.10000D 01	0.99999D 00
COMPOSITION	MATERIAL				
1					
RA= 0.0	KF= 0.0	A-200	0.0	0.0	0.99999E 00
				0.10000E 01	

CUMULATIVE ABSORPTION PROBABILITY = 0.0

REGIONAL INTERMEDIATE GROUP FLUXES FOR BROAD GROUP 1

LOWER
ENERGY (EV)

	1
1	0.98020E 03 10000
2	0.96079E 03 10000
3	0.94176E 03 10000
4	0.92312E 03 10000
5	0.90484E 03 10000
6	0.88692E 03 10000
7	0.86936E 03 10000
8	0.85214E 03 10000
9	0.83527E 03 10000
10	0.81873E 03 10000
11	0.80252E 03 10000
12	0.78663E 03 10000
13	0.77105E 03 10000
14	0.75578E 03 10000
15	0.74082E 03 10000
16	0.72615E 03 10000
17	0.71177E 03 10000
18	0.69768E 03 10000
19	0.68386E 03 10000
20	0.67032E 03 10000
21	0.65705E 03 10000
22	0.64404E 03 10000
23	0.63128E 03 10000
24	0.61878E 03 10000
25	0.60653E 03 10000
26	0.59452E 03 10000
27	0.58275E 03 10000
28	0.57121E 03 10000
29	0.55990E 03 10000
30	0.54881E 03 10000
AVERAGE	10000

TIME= 2.213 SEC.

RABID
 PLATE, FOIL EQUIVALENCE THEORY CHECK 1/8 IN U-238 1 IN C 8 REGION

NO. CELL REGIONS = 8
 NO. COMPOSITIONS = 2
 NO. BROAD GROUPS = 1
 NO. INTERMEDIATE GROUPS = 5

NO. MATERIALS = 2
 NO. RESONANT MATERIALS = 1
 LETHARGY WIDTH INTER. GROUP = 0.100000E-01
 RESONANCE TEST = 0.100E-01 (BARNs) NOPT = 4 KFOIL = 1

RESONANT MATERIALS HAVE BROAD-GROUP-DEPENDENT ABSORPTION AND FISSION CROSS SECTIONS

REGION/COMPOSITION/OUTER DIMENSION/TEMPERATURE

1	2	3	4	5	6	7	8
1	1	1	1	2	2	2	2
0.07937	0.15875	0.23812	0.31750	0.95250	1.58750	2.22250	2.85750
293.00	293.00	293.00	293.00	293.00	293.00	293.00	293.00

FOIL COMPOSITION	THICKNESS	TEMPERATURE
1 3	0.10000E-09	293.000

MATERIAL	RES.	MASS	SIG POT	SIG A 1/V	SIG F 1/V
U 238	66	0.23800E 03	0.10600E 02	0.0	0.0
C 12	0	0.12000E 02	0.47000E 01	0.0	0.0

ISOTOPE 1
 0.42000E-01 0.0 0.10000E 01

ISOTOPE 2
 0.0 0.75000E-01 0.0

BROAD GROUP	NO. INTER. GROUPS	NO. FINE GP/INTER GP	MAXIMUM ENERGY (EV)	MINIMUM ENERGY (EV)	BUCKLING
1	5	50	0.2613E 04	0.2486E 04	0.1000E-02

NUMBER OF FINE GROUPS USED TO LETHARGY-AVERAGE SCATTERING RATES FOR EACH MATERIAL

BROAD GROUP NO.	
1	
U 238	1
C 12	1

RESONANCE PARAMETERS

MATERIAL	ENERGY(EV)	GAMMA N (EV)	GAMMA GAMMA (EV)	GAMMA F (EV)	G
U 238	0.12450E 04	0.2300E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.12670E 04	0.2700E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.12730E 04	0.2900E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.12990E 04	0.3600E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.13170E 04	0.4700E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.13360E 04	0.1500E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.13930E 04	0.1700E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.14050E 04	0.8200E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.14200E 04	0.1100E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.14280E 04	0.3400E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.14440E 04	0.2300E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.14740E 04	0.8050E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.15230E 04	0.2100E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.15460E 04	0.2000E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.15500E 04	0.2400E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.15650E 04	0.9000E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.16230E 04	0.4040E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.16380E 04	0.1600E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.16620E 04	0.7000E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.16880E 04	0.5000E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.17090E 04	0.1400E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.17230E 04	0.7000E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.17560E 04	0.5000E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.17820E 04	0.2100E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.17980E 04	0.1700E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.18080E 04	0.1330E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.18460E 04	0.2090E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.19020E 04	0.2190E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.19170E 04	0.5770E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.19690E 04	0.4670E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.19750E 04	0.2020E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.20240E 04	0.4960E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.20310E 04	0.1370E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.20890E 04	0.1010E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.20970E 04	0.4600E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.21240E 04	0.3470E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.21460E 04	0.1760E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.21530E 04	0.2300E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.21720E 04	0.3650E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.21860E 04	0.2300E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.21940E 04	0.2300E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.22010E 04	0.1130E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.22300E 04	0.4700E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.22360E 04	0.4700E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.22420E 04	0.1400E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.22590E 04	0.6560E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.22660E 04	0.14500E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.22810E 04	0.1100E 00	0.24600E-01	0.0	0.1000E 01
U 238	0.22890E 04	0.2400E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.23020E 04	0.9600E-03	0.24600E-01	0.0	0.1000E 01
U 238	0.23160E 04	0.1440E-01	0.24600E-01	0.0	0.1000E 01
U 238	0.23370E 04	0.4830E-02	0.24600E-01	0.0	0.1000E 01
U 238	0.23520E 04	0.6300E-01	0.24600E-01	0.0	0.1000E 01

U 238	0.23560E 04	0.63100E-01	0.24600E-01	0.0	0.10000E 01
U 238	0.23930E 04	0.11200E-01	0.24600E-01	0.0	0.10000E 01
U 238	0.24100E 04	0.44100E-02	0.24600E-01	0.0	0.10000E 01
U 238	0.24270E 04	0.81300E-01	0.24600E-01	0.0	0.10000E 01
U 238	0.24460E 04	0.11100E 00	0.24600E-01	0.0	0.10000E 01
U 238	0.24540E 04	0.24700E-02	0.24600E-01	0.0	0.10000E 01
U 238	0.24900E 04	0.54900E-01	0.24600E-01	0.0	0.10000E 01
U 238	0.25210E 04	0.10000E-01	0.24600E-01	0.0	0.10000E 01
U 238	0.25490E 04	0.34300E 00	0.24600E-01	0.0	0.10000E 01
U 238	0.25590E 04	0.21700E 00	0.24600E-01	0.0	0.10000E 01
U 238	0.25810E 04	0.24400E 00	0.24600E-01	0.0	0.10000E 01
U 238	0.25990E 04	0.56100E 00	0.24600E-01	0.0	0.10000E 01
U 238	0.26040E 04	0.25000E-02	0.24600E-01	0.0	0.10000E 01

THE FOLLOWING PAIRS ARE SYMMETRIC REGIONS

1 4 2 3 5 8 6 7

PLATE, FOIL EQUIVALENCE THEORY CHECK 1/8 IN U-238 1 IN C 8 REGION

SUMMARY FOR BROAD GROUP 1 0.26130E 04 EV TO 0.24856E 04 EV

AVERAGE		SIGMA A		SIGMA F		SIGMA S		FLUX	
CELL		0.29647D-02		0.0		0.38710D 00		0.98211D 00	
COMPOSITION		MATERIAL							
1		U 238		0.64542E 00		0.15926E 02		0.96669E 00	
RA= 0.31196E-01	RF= 0.0			0.0				0.98403E 00	
2		C 12		0.0		0.47000E 01			
RA= 0.0	RF= 0.0			0.0					

CUMULATIVE ABSORPTION PROBABILITY = 0.291976D-02

REGIONAL INTERMEDIATE GROUP FLUXES FOR BROAD GROUP 1

LOWER		1	2	3	4	5	6	7	8
ENERGY (EV)		1	1	1	1	2	2	2	2
1	0.25870E 04	8549	8325	8325	8549	9157	9337	9337	9157
2	0.25613E 04	9987	9822	9822	9987	9999	9941	9941	9999
3	0.25358E 04	9068	8799	8799	9068	9445	9510	9510	9445
4	0.25105E 04	11144	11168	11168	11144	10685	10464	10464	10685
5	0.24856E 04	9913	9897	9897	9913	9934	9932	9932	9934
AVERAGE		9732	9602	9602	9732	9844	9837	9837	9844

FOIL 1

INTERFACE	RA(F)	RF(F)	RS(F)
1	0.59221E 00	0.0	0.14942E 02
2	0.54922E 00	0.0	0.14359E 02
3	0.59221E 00	0.0	0.14942E 02
4	0.88561E 00	0.0	0.19195E 02
5	0.10821E 01	0.0	0.21627E 02
6	0.11212E 01	0.0	0.22132E 02
7	0.10821E 01	0.0	0.21627E 02
8	0.88561E 00	0.0	0.19195E 02

TIME= 73.332 SEC.

RABID

U-238 FOILS IN ZPR-3 ASSY 53

C-17

RESONANCE SET-02

NO. CELL REGIONS = 12
 NO. COMPOSITIONS = 10
 NO. BROAD GROUPS = 1
 NO. INTERMEDIATE GROUPS = 10

NO. MATERIALS = 9
 NO. RESONANT MATERIALS = 5
 LETHARGY WIDTH INTER. GROUP = 0.845700E-03
 RESONANCE TEST = 0.100E-02 (BARNs) NOPT= 3 KFOIL= 1

RESONANT MATERIALS HAVE BROAD-GROUP-DEPENDENT ABSORPTION AND FISSION CROSS SECTIONS

REGION/COMPOSITION/OUTER DIMENSION/TEMPERATURE

1	2	3	4	5	6	7	8	9	10	11	12
0.46610	1.73610	1.76658	2.02312	2.05360	2.68860	3.32360	3.95860	3.98908	4.56312	4.59360	5.54610
300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00	300.00

FOIL	COMPOSITION	THICKNESS	TEMPERATURE
1	11	0.12700E-01	300.000

MATERIAL	RES.	MASS	SIG POT	SIG A 1/V	SIG F 1/V
U-238	20	0.23800E 03	0.10600E 02	0.0	0.0
AL	2	0.27000E 02	0.14000E 01	0.18000E-02	0.0
FE	6	0.55850E 02	0.52200E 01	0.0	0.0
CR	5	0.52010E 02	0.37100E 01	0.0	0.0
NI	4	0.58700E 02	0.65700E 01	0.0	0.0
PU-240	0	0.24000E 03	0.13180E 02	0.19900E 03	0.0
PU-239	0	0.23900E 03	0.10320E 02	0.66200E 03	0.0
MO	0	0.96000E 02	0.70000E 01	0.69400E 02	0.0
C	0	0.12000E 02	0.47000E 01	0.0	0.0

ISOTOPE	1	2	3	4
0.0	0.0	0.0	0.0	0.0
0.47600E-01	0.0	0.0	0.0	0.0
ISOTOPE	2	3	4	
0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	
ISOTOPE	3	4		
0.35370E-01	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	
ISOTOPE	4			
0.08000E-02	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	

ISOTOPE	5							
0.38500E-02	0.0	0.67500E-02	0.0	0.67500E-02	0.0	0.67500E-02	0.0	0.67500E-02
0.0								
ISOTOPE	6							
0.0	0.0	0.0	0.13516E-02	0.0	0.0	0.0	0.66228E-03	0.0
0.0								
ISOTOPE	7							
0.0	0.0	0.0	0.28429E-01	0.0	0.0	0.0	0.70762E-02	0.0
0.0								
ISOTOPE	8							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.24630E-02	0.0
0.0								
ISOTOPE	9							
0.0	0.81830E-01	0.0	0.0	0.0	0.81830E-01	0.0	0.0	0.81830E-01
0.0								

BROAD GROUP	NO. INTER. GROUPS	NO. FINE GP/INTER GP	MAXIMUM ENERGY (EV)	MINIMUM ENERGY (EV)	BUCKLING
1	10	12	0.2197E 05	0.2178E 05	0.0

NUMBER OF FINE GROUPS USED TO LETHARGY-AVERAGE SCATTERING RATES FOR EACH MATERIAL

BROAD GROUP NO. =	1
U-238	1
AL	2
FE	1
CR	1
NI	1
PU-240	1
PU-239	1
MO	1
C	4

RESONANCE PARAMETERS

MATERIAL	ENERGY(EV)	GAMMA N (EV)	GAMMA	GAMMA (EV)	GAMMA F (EV)	G
U-238	0.21787E 05	0.87064E-03	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21796E 05	0.26002E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21806E 05	0.16087E-03	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21815E 05	0.42320E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21824E 05	0.90319E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21833E 05	0.55722E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21843E 05	0.22009E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21852E 05	0.21119E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21861E 05	0.71710E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21870E 05	0.32660E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21880E 05	0.19063E-04	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21889E 05	0.56503E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21898E 05	0.31341E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21907E 05	0.17230E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21917E 05	0.11329E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21926E 05	0.41969E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21935E 05	0.14024E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21944E 05	0.44760E-03	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21954E 05	0.90709E-01	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
U-238	0.21963E 05	0.14672E-02	0.24600E-01	0.24600E-01	0.0	-0.20000E 01
AL	0.59060E 04	0.20000E 02	0.0	0.0	0.0	0.41670E 00
AL	0.35040E 05	0.15000E 04	0.0	0.0	0.0	0.58330E 00
FE	0.11500E 04	0.56000E-01	0.67300E 00	0.67300E 00	0.0	0.91680E 00
FE	0.39000E 04	0.22000E 03	0.10000E 01	0.10000E 01	0.0	0.21700E-01
FE	0.60000E 04	0.42000E 03	0.17000E 01	0.17000E 01	0.0	0.21700E-01
FE	0.80000E 04	0.10300E 04	0.30000E 01	0.30000E 01	0.0	0.58400E-01
FE	0.27000E 05	0.0	0.60000E 01	0.60000E 01	0.0	0.21700E-01
FE	0.28300E 05	0.16700E 04	0.15000E 01	0.15000E 01	0.0	0.91680E 00
CR	0.42500E 04	0.10000E 03	0.0	0.0	0.0	0.59600E-01
CR	0.66000E 04	0.17000E 04	0.30000E 01	0.30000E 01	0.0	0.43100E-01
CR	0.23500E 05	0.49000E 03	0.0	0.0	0.0	0.23800E-01
CR	0.26500E 05	0.50000E 03	0.0	0.0	0.0	0.23800E-01
CR	0.28700E 05	0.51000E 03	0.0	0.0	0.0	0.43100E-01
NI	0.46000E 04	0.13000E 04	0.0	0.0	0.0	0.36600E-01
NI	0.12500E 05	0.26000E 04	0.0	0.0	0.0	0.26160E 00
NI	0.15500E 05	0.15400E 04	0.0	0.0	0.0	0.67760E 00
NI	0.28700E 05	0.11100E 04	0.0	0.0	0.0	0.26160E 00

NO SYMMETRIC REGIONS

SUMMARY FOR BROAD GROUP 1

0.21968E 05 EV TO 0.21783E 05 EV

AVERAGE		SIGMA A		SIGMA F		SIGMA S		FLUX
CELL		0.24082D-02		0.0		0.36450D 00		0.10212D 01
COMPOSITION		MATERIAL						
1								0.10688E 01
RA= 0.13867E-04	RF= 0.0	FE	0.15342E-02	0.0	0.16921E 01			
RA= 0.47774E-06	RF= 0.0	CR	0.52855E-04	0.0	0.37863E 01			
RA= 0.0	RF= 0.0	NI	0.0	0.0	0.16769E 02			
2								0.10252E 01
RA= 0.0	RF= 0.0	C	0.0	0.0	0.47000E 01			
3								0.10217E 01
RA= 0.13256E-04	RF= 0.0	FE	0.15341E-02	0.0	0.16922E 01			
RA= 0.45671E-06	RF= 0.0	CR	0.52856E-04	0.0	0.37863E 01			
RA= 0.0	RF= 0.0	NI	0.0	0.0	0.16770E 02			
4								0.10142E 01
RA= 0.15469E-04	RF= 0.0	AL	0.18000E-02	0.0	0.86361E 00			
RA= 0.15390E-02	RF= 0.0	PU-240	0.21400E 00	0.0	0.13180E 02			
RA= 0.61179E-02	RF= 0.0	PU-239	0.71190E 00	0.0	0.10320E 02			
5								0.10202E 01
RA= 0.13236E-04	RF= 0.0	FE	0.15341E-02	0.0	0.16922E 01			
RA= 0.45602E-06	RF= 0.0	CR	0.52856E-04	0.0	0.37863E 01			
RA= 0.0	RF= 0.0	NI	0.0	0.0	0.16770E 02			
6								0.10099E 01
RA= 0.0	RF= 0.0	C	0.0	0.0	0.47000E 01			
7								0.10140E 01
RA= 0.13155E-04	RF= 0.0	FE	0.15340E-02	0.0	0.16923E 01			
RA= 0.45327E-06	RF= 0.0	CR	0.52858E-04	0.0	0.37863E 01			
RA= 0.0	RF= 0.0	NI	0.0	0.0	0.16770E 02			
8								0.10061E 01
RA= 0.24576E-02	RF= 0.0	U-238	0.28885E 00	0.0	0.10992E 02			
RA= 0.18208E-02	RF= 0.0	PU-240	0.21400E 00	0.0	0.13180E 02			
RA= 0.50570E-02	RF= 0.0	PU-239	0.71190E 00	0.0	0.10320E 02			
RA= 0.63499E-03	RF= 0.0	MO	0.74632E-01	0.0	0.70000E 01			
9								0.10189E 01
RA= 0.13219E-04	RF= 0.0	FE	0.15340E-02	0.0	0.16922E 01			
RA= 0.45548E-06	RF= 0.0	CR	0.52858E-04	0.0	0.37863E 01			
RA= 0.0	RF= 0.0	NI	0.0	0.0	0.16770E 02			
10								0.10262E 01
RA= 0.0	RF= 0.0	C	0.0	0.0	0.47000E 01			

CUMULATIVE ABSORPTION PROBABILITY = 0.444990D-03

REGIONAL INTERMEDIATE GROUP FLUXES FOR BROAD GROUP 1

LOWER		1	2	3	4	5	6	7	8	9	10	11	12
ENERGY(EV)		1	2	3	4	5	6	6	6	7	8	9	10
1	0.21949E 05	10671	10217	10186	10125	10169	10077	10024	9973	9967	9827	10022	10175
2	0.21930E 05	10744	10278	10242	10183	10226	10142	10113	10125	10199	10129	10250	10304
3	0.21912E 05	10692	10243	10209	10151	10193	10107	10067	10047	10077	9976	10129	10234
4	0.21893E 05	10718	10268	10232	10175	10217	10135	10106	10115	10182	10112	10232	10290
5	0.21875E 05	10668	10234	10201	10145	10185	10103	10064	10043	10072	9972	10122	10225
6	0.21856E 05	10677	10245	10211	10156	10196	10116	10083	10076	10122	10039	10171	10251
7	0.21838E 05	10685	10257	10222	10168	10207	10130	10103	10112	10177	10112	10225	10279
8	0.21819E 05	10685	10261	10226	10173	10211	10137	10113	10130	10205	10149	10252	10292
9	0.21801E 05	10686	10267	10231	10180	10217	10144	10125	10151	10237	10193	10283	10308
10	0.21783E 05	10651	10244	10210	10160	10196	10123	10096	10103	10162	10098	10208	10263
AVERAGE		10688	10252	10217	10162	10202	10121	10090	10087	10140	10061	10189	10262

FOIL 1			
INTERFACE	RA(F)	RF(F)	RS(F)
1	0.14441E-01	0.0	0.54269E 00
2	0.13937E-01	0.0	0.52334E 00
3	0.13929E-01	0.0	0.52304E 00
4	0.13908E-01	0.0	0.52232E 00
5	0.13912E-01	0.0	0.52247E 00
6	0.13789E-01	0.0	0.51829E 00
7	0.13737E-01	0.0	0.51745E 00
8	0.13682E-01	0.0	0.51894E 00
9	0.13663E-01	0.0	0.51863E 00
10	0.13733E-01	0.0	0.52111E 00
11	0.13756E-01	0.0	0.52159E 00
12	0.14430E-01	0.0	0.54254E 00

TIME= 69.339 SEC.

APPENDIX E Glossary of Symbols

1. Mathematical Symbols

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>														
Γ^x	V	-	Total width of resonance ($x = s$ for s-waves, $x = p$ for p-waves).														
Γ_z	V	-	Neutron width for process z ($z = \gamma, f$, and n for capture, fission, and scattering, respectively).														
Γ_n^p	V	-	$\Gamma_n^0 \sqrt{E_0} v_1(E_0)$, where Γ_n^0 is the reduced neutron width and $v_1(E_0) = \frac{\sigma_p E_0}{2.60385 \times 10^6 \left(1 + \frac{1}{A}\right)^2 + \sigma_p E_0} = \text{p-wave penetration factor.}$														
Δ	A.4	A.20	Foil optical thickness.														
Δ	V	-	$2\left(\frac{kTE}{A}\right)^{1/2}$ = Doppler width of a resonance at energy E ; k is Boltzmann's constant.														
ΔU_I	VI	-	Lethargy width of intermediate or broad group I.														
ΔS	II.B	16	Spatially linear slowing-down source component														
Δu	II.A	8	Lethargy width of a fine group.														
Σ_z	II.A	-	Macroscopic neutron cross section for process z .														
<table><tr><th><u>Process</u></th><th><u>z</u></th></tr><tr><td>Absorption</td><td>a</td></tr><tr><td>Capture</td><td>c</td></tr><tr><td>Fission</td><td>f</td></tr><tr><td>Scattering</td><td>s</td></tr><tr><td>Total</td><td>t</td></tr><tr><td>Potential scattering</td><td>p</td></tr></table>				<u>Process</u>	<u>z</u>	Absorption	a	Capture	c	Fission	f	Scattering	s	Total	t	Potential scattering	p
<u>Process</u>	<u>z</u>																
Absorption	a																
Capture	c																
Fission	f																
Scattering	s																
Total	t																
Potential scattering	p																
${}_z \bar{\Sigma}_I$	VI.E	55	Cell-averaged macroscopic cross section for process z .														

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>														
${}_z\bar{\Sigma}_{l1}^n$	VI.H	60	Average macroscopic cross section for process z in group I, for foil n at interface l .														
α	II.A	3	$\left(\frac{A-1}{A+1}\right)^2$, where A is the ratio of target nuclide mass to neutron mass.														
$\alpha_n(z)$	A.1	A.2	$\int_1^\infty t^n e^{-zt} dt, \quad n \geq 0.$														
$\alpha_{n,l}$	A.1	A.7	$\int_1^\infty t^{\ell-n} e^{-t} dt = \ell\text{th moment of } e^{-t}/t^n \text{ weighting function.}$														
γ	B.12	B.2	Euler's constant = 0.5772156649...														
ϵ	II.A	-	$2 \ell n \frac{A+1}{A-1} = \text{maximum lethargy increment upon elastic scattering.}$														
ξ	V	43	$\Gamma/\Delta; \Delta = 2\left(\frac{kTE}{A}\right)^{1/2} = \text{Doppler width.}$														
ξ	VI.G	59	Average lethargy increment for an elastic scattering collision.														
$\bar{\mu}_{0j}$	II.B	32	$2/(3A)$ for material j .														
σ_0^x	V	-	Peak value of resonance cross section, barns ($x = s$ or p for s - or p -waves).														
σ_z	V	-	Microscopic neutron cross section for process z (barns).														
<table><tr><th><u>Process</u></th><th><u>z</u></th></tr><tr><td>Absorption</td><td>a</td></tr><tr><td>Capture</td><td>c</td></tr><tr><td>Fission</td><td>f</td></tr><tr><td>Scattering</td><td>s</td></tr><tr><td>Total</td><td>t</td></tr><tr><td>Potential scattering</td><td>p</td></tr></table>				<u>Process</u>	<u>z</u>	Absorption	a	Capture	c	Fission	f	Scattering	s	Total	t	Potential scattering	p
<u>Process</u>	<u>z</u>																
Absorption	a																
Capture	c																
Fission	f																
Scattering	s																
Total	t																
Potential scattering	p																
${}_z\bar{\sigma}_{ml}^j$	VI.F	56	Composition-averaged microscopic cross section for process z .														

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>
$\phi(\vec{r}, u)$	II.A	1	Neutron flux per unit lethargy at space point $\vec{r}$ and lethargy u .
$\phi(x, u)$	II.A	6	Neutron flux per unit lethargy at space point x and lethargy u (one-dimensional slab geometry).
$\phi_\ell(x)$	II.A	8	Average neutron flux per unit lethargy at space point x in lethargy group ℓ .
ϕ_{ik}	VI	-	Spatially integrated flux per unit lethargy in fine group k and region i .
$\bar{\phi}_{\ell I}^n$	VI.H	60	Average neutron flux per unit lethargy integrated over foil n in broad group I at interface ℓ .
ϕ_∞	VI	-	Neutron flux per unit lethargy that would be present in the absence of resonances, far from neutron sources. The code assumes $\phi_\infty = 1$.
ϕ_{inc}	VI.H	61	Neutron flux per unit lethargy incident upon a foil.
$\bar{\phi}_I$	VI.C	53	Cell-averaged flux in intermediate or broad group I .
$\bar{\phi}_{iI}$	VI.A	51	Regional average flux in intermediate or broad group I .
$\bar{\phi}_{mI}$	VI.B	52	Composition-averaged flux in intermediate or broad group I .
$\chi(\xi, x)$	V	50	Antisymmetric Doppler-broadened line-shape function.
$\Psi(\xi, x)$	V	49	Symmetrical Doppler-broadened line-shape function.
A	II.A	-	Ratio of target nuclide mass to neutron mass (elastic scattering).
A_i	II.B	30	Thickness of region i (cm).
B^2	II.B	29	Buckling of finite medium for nonleakage probability.

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>
$C(z, h)$	B.17	B.9	Approximate error correction for $S_2(z, h)$ for $z < 0.3$.
$\overrightarrow{CR}(1 \rightarrow 2)$	II.B	18	Collision rate in region 2 due to a neutron source in region 1, for neutrons proceeding to the right.
$\overrightarrow{CR}_\infty(1 \rightarrow 2)$	II.B	19	Collision rate in region 2 due to neutron sources in all type 1 regions for an infinitely repeating array of unit cells, for neutrons proceeding to the right.
$\langle D \rangle_k$	II.B	32	Cell-averaged diffusion coefficient for neutron leakage from finite systems.
E	V	44	Neutron energy (in laboratory), eV.
E_0	V	44	Resonance energy (in laboratory), eV.
E_n	II.A	5	Exponential integral function of order $n \geq 0$.
$F_S(u', \vec{r}')$	II.A	2	Scattering rate at lethargy u' and space point $\vec{r}'$.
$\vec{J}(x, u)$	II.A	7	Neutron current/unit lethargy at space point x and lethargy u .
$\vec{J}(\tau, \tau_1)$	II.B	17	Neutron current at τ mean free paths beyond a source region of optical thickness τ_1 .
L	II.A	12	$= \epsilon/\Delta u$ = number of fine groups that contribute to slowing-down source from elastic scattering (not including ingroup scattering).
N_{jm}	VI.D	54	Atom number density of material j in composition m .
$P(u' \rightarrow u)$	II.A	3	Probability of elastic scattering from lethargy u' to u .
$\underline{P}$	II.B	21	P_{ij} is probability of a neutron born in region i suffering its next collision in region j .
P_ℓ	II.A	10	Probability of elastic scattering from group $k - \ell$ to k ; $1 < \ell < \epsilon/\Delta u$.

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>
P_s	II.A	11	Probability of ingroup elastic scattering.
$\underline{R}$	II.B	22	$R_{ij} = (\sum_s P_s / \sum_t)_{ij}$, $i = j$, $= 0$, $i \neq j$.
$R_M(z)$	A.1	A.4	Remainder of Mth-order Gauss quadrature.
${}_z R_{ik}^j$	VI.D	54	$(\phi_{ik})_z \Sigma^{jk} \Delta u$ = reaction rate for process z in fine group k and material j integrated over region i .
RAP	VI.G	57	Accumulated absorption probability.
${}_z RI_{mI}^j$	VI.F	56	Resonance integral for process z in material j , in composition m and group I .
${}_z RI_{nI}^{\ell j}$	VI.H	60	Resonance integral for process z in material j , in group I , in foil n , at interface ℓ .
$\bar{S}$	II.B	16	Spatially flat slowing-down source component.
$S(x')$	II.B	16	Total elastic scattering source at space point x' .
$S_n(z, h)$	A.1	A.3	$\sum_{k=0}^{\infty} E_n(z + kh)$, $n \geq 0$.
$S_{sk}(x')$	II.A	-	Ingroup elastic scattering source in group k at space point x' .
$S_{0k}(x')$	II.A	12	Slowing-down source in group k at space point x' from all groups $k - \ell$, $1 \leq \ell \leq L$.
SDD	VI.G	58	Slowing-down density at the lethargy corresponding to the start of the problem.
$W(z)$	V	49	Complex probability integral, where $z = u + iv$.
$f_{s\ell}(x')$	II.A	9	Average scattering rate per unit lethargy in group ℓ at space point x' .
g_J	V	43	$\frac{2J+1}{2(2I+1)}$, where J = total spin of compound nucleus and I is spin of target nucleus.

<u>Symbol</u>	<u>Section</u>	<u>Equation</u>	<u>Definition</u>
h	II.B	19	Optical thickness of unit cell.
t_l	II.B	15	Thickness of source region l (cm)
$t_{i,n}$	A.1	A.4	Gaussian quadrature abscissas of order M , $1 \leq i \leq M$, for exponential integral function of order n .
u_l	VI.A	51	Lower lethargy bound of group l .
x	V	43	$2(E - E_0)/\Gamma$.
x_m	VI.B	52	Left boundary of composition m ($x_1 = 0$).
w	III	-	$= \left(\frac{4EkT}{A} \right)^{1/2}$ = Doppler width of a resonance at energy E ; k is Boltzmann's constant.
$w_{i,n}$	A.1	A.4	Gaussian quadrature weights of order M , $1 \leq i \leq M$, for exponential integral function of order n .

2. Code Symbols

QUANTITIES DENOTED BY * ARE INPUT VARIABLES

ABC	LINEAR SOURCE COMPONENT CURRENT LEAVING A REGION FROM RIGHT
ACS	BROAD GROUP AVERAGE ABSORPTION CROSS SECTION FOR CELL
ACSGP	INTERMEDIATE GROUP AVERAGE ABSORPTION CROSS SECTION FOR CELL
AF	BROAD GROUP AVERAGE FOIL MACROSCOPIC ABSORPTION CROSS SECTION
AIMW	IMAGINARY PART OF COMPLEX PROBABILITY INTEGRAL W(Z)
AIMZ	IMAGINARY PART OF ARGUMENT FOR COMPLEX PROBABILITY INTEGRAL W(Z)
ALP	$\text{ALPHA} = ((A-1)/(A+1))^{*2}$
AMU	* MATERIAL MASS (UNITS OF NEUTRON MASS)
AREA	REGION THICKNESS
AREAC	THICKNESS OF COMPOSITION
AREAT	TOTAL THICKNESS OF UNIT CELL
AX	REZ (QUICKW)
BARMU	AVERAGE COSINE OF SCATTERING ANGLE, $2/(3A)$
BIN	BACK DIRECTION LINEAR SOURCE CURRENT ENTERING ON RIGHT
BOUT	BACK DIRECTION LINEAR SOURCE CURRENT LEAVING ON LEFT
BOUTL	LAST VALUE OF BOUT NEEDED
BSQ	* BUCKLING FOR NEUTRON LEAKAGE FROM FINITE SYSTEMS
CR	COLLISION RATE VECTOR
D	DIFFUSION COEFFICIENT FOR CELL
CDS	DS IN RATES
DEN	* MATERIAL ATOM DENSITY MATRIX (10**24 ATOMS/BARN-CM)
DETERM	DETERMINANT OF MATRIX INVERTED BY MATINV
DFS	FORWARD LINEAR SOURCE COMPONENT (LEFT TO RIGHT) (RATES)
DIFX	NOT USED
DPS	PS
DR	REGION THICKNESS
DS	SUM OF ALL CORRECTIONS TO SOURCE IN GROUP K COMPARED TO ASYMPTOTIC VALUE ENTERING PROBLEM FROM ABOVE
DS	LINEAR SOURCE COMPONENT (RATES)
USL	ALP*PS
DSMAX	RECURSION COEFFICIENT FOR ELASTIC SCATTERING FROM GROUP K-1-L TO K
CSR	REVERSE DIRECTION LINEAR SOURCE COMPONENT (RIGHT TO LEFT) (RATES)
DSI	RECURSION COEFFICIENT FOR ELASTIC SCATTERING FROM GROUP K-1 TO K
DISTR	BROAD GROUP LEITHARGY WIDTH
ENGP	UPPER ENERGY BOUND (EV) OF INTERMEDIATE GROUPS (* ENGP(1))
ER	* RESONANCE ENERGY (EV)
ETUT	NOT USED
EXDU	DEXP(-UFGP)
FCS	BROAD GROUP AVERAGE FISSION CROSS SECTION FOR CELL
FCSGP	INTERMEDIATE GROUP AVERAGE FISSION CROSS SECTION FOR CELL
FF	BROAD GROUP AVERAGE FOIL MACROSCOPIC FISSION CROSS SECTION
FFF	BROAD GROUP AVERAGE FOIL FLUX
FFLUX	INTERMEDIATE GROUP AVERAGE FOIL FLUX
FIN	FLAT SOURCE COMPONENT CURRENT ENTERING A REGION FROM LEFT
FLUX	INTERMEDIATE GROUP AVERAGE FLUX IN A REGION
FLUXCP	INTERMEDIATE GROUP AVERAGE FLUX IN A COMPOSITION
FOUT	FLAT SOURCE COMPONENT CURRENT LEAVING A REGION FROM RIGHT
FOUTL	LAST VALUE OF FOUT NEEDED
FS	FORWARD FLAT COMPONENT SOURCE (CURRENT TO RIGHT) (RATES)
FIV	$\text{SQRT}(1.0253/\text{ENGP}(1))$

F9 LINEAR SOURCE COMPONENT CURRENT ENTERING A REGION FROM LEFT
 G * STATISTICAL SPIN FACTOR FOR A RESONANCE
 GAMMA TOTAL WIDTH (EV) OF A RESONANCE
 GF * FISSION WIDTH (EV) FOR A RESONANCE
 GN * NEUTRON WIDTH (EV) FOR A RESONANCE
 GR * RADIATION WIDTH (EV) FOR A RESONANCE
 GW2 GAUSS QUADRATURE WEIGHTS FOR E2
 GW3 GAUSS QUADRATURE WEIGHTS FOR E3
 GW4 GAUSS QUADRATURE WEIGHTS FOR E4
 GX2 GAUSS QUADRATURE ABSCISSAS*(I-1) FOR E2
 GX3 GAUSS QUADRATURE ABSCISSAS*(I-1) FOR E3
 GX4 GAUSS QUADRATURE ABSCISSAS*(I-1) FOR E4
 IBG BROAD GROUP NUMBER
 IBGP INTERMEDIATE GROUP NUMBER
 IERR ERROR INDICATOR IF POSITIVE (FOR SOURCE,RATES,AND XSECT)
 IFGP FINE GROUP NUMBER (WITHIN AN INTERMEDIATE GROUP)
 II KREG
 III KFOIL+KCCMP
 INCLUD SET TO IBGP AT START OF INT. GR. IBGP IF THIS RESONANCE TO BE INCLUDED
 IN RESONANT CROSS SECTION CALCULATIONS FOR THIS INT. GROUP.
 ZERO IF THIS RESONANCE IS NOT IMPORTANT.
 INDEX 1=FIRST FINE GROUP IN FIRST INTERMEDIATE GROUP
 2=2ND FINE GROUP IN ANY BROAD GROUP
 3=FIRST FINE GROUP IN ANY BUT FIRST BROAD GROUP
 4=NOT FIRST INTERMEDIATE GROUP IN ANY BROAD GROUP
 INUF NUMBER OF LAST SCATTERING RATE AVERAGING INTERVAL IN A BROAD GROUP
 INU1 NUMBER OF FIRST SCATTERING RATE AVERAGING INTERVAL IN A BROAD GROUP
 ISYM NON-ZERO PAIRS ARE SYMMETRIC REGION NUMBERS
 ITRY POSITIVE IF LINEAR SOURCE TERMS PRESENT AND TO BE INCLUDED (RATES)
 JBG INTERMEDIATE GROUP NUMBER WITHIN A BROAD GROUP
 JMULT FINE GROUP COUNTER FOR AVERAGING SCATTERING RATES
 JNU POSITION COUNTER IN SCATTERING RATE TABLE SCAT (UNITS OF NISO)
 KB * >0 IMPLIES THAT BROAD GROUP DEPENDENT SMOOTH BACKGROUND CROSS
 SECTIONS ARE TO BE READ FOR FIRST KRES MATERIALS
 KBG * NUMBER OF BROAD GROUPS
 KHSQ * SWITCH TO INPUT BUCKLINGS IF >0 ELSE SET BUCKLINGS TO ZERO
 KCCMP * NUMBER OF COMPOSITIONS
 KFOIL * NUMBER OF FOILS (MINUS SIGN TAG SAYS LAST IS INFINITELY THIN)
 KGP * NUMBER OF INTERMEDIATE GROUPS
 KMAT * NUMBER OF MATERIALS (MATERIAL=ISOTOPE OR COLLECTION OF ISOTOPES)
 KREG * NUMBER OF REGIONS
 KRES * NUMBER OF RESONANT MATERIALS
 KS * >0 IMPLIES THAT THE ELASTIC SCATTERING PROBABILITIES ARE TO BE
 MODIFIED TO REMOVE INGROUP SCATTERING. INGROUP SCATTERING IS
 INCLUDED OTHERWISE
 LAST LAST RESONANCE OF A MATERIAL IS AT THIS LOCATION IN RESONANCE LIST
 LLLL SCALED INTERMEDIATE GROUP FLUXES ROUNDED TO NEAREST INTEGER(OUTPUT)
 LUC SEQUENCE NUMBER OF NON-ZERO ATOM DENSITY MATERIAL/REGION PAIRS
 OBTAINED IN MAIN BY OUTER LOOP OVER REGIONS AND INNER LOOP OVER MATS.
 LREG COMPOSITION NUMBER FOR A REGION
 MH INDEX OF SCATTERING RATE 1 ABOVE MO (SOURCE)
 MINT NUMBER OF LAST REGION IN A COMPOSITION
 ML INDEX OF SCATTERING RATE 1 BELOW MO (SOURCE)
 MU INDEX OF SCATTERING RATE CLOSEST TO FINE GROUP K-L (SOURCE)
 MORE * >0 IMPLIES THIS IS LAST PROBLEM, OTHERWISE ADDITIONAL INPUT IS READ
 MULT MULTIPLICITY, OR NUMBER OF FINE GROUPS USED TO AVERAGE SCATTERING RATE

NDX IF COLLISION RATE FOUND TO BE NEGATIVE, NDX IS SET TO 1 TO INITIATE
 SPECIAL OUTPUT AND RENORMALIZATION OF COLL. RATES TO CONSERVE NEUTRONS
 AND BE NON-NEGATIVE (MINIMUM SET TO ZERO)
 NEXT FIRST RESONANCE OF A MATERIAL IS AT THIS LOCATION IN RESONANCE LIST
 NFI * NUMBER OF FINE GROUPS PER INTERMEDIATE GR. IN A BROAD GROUP
 NIB * NUMBER OF INTERMEDIATE GROUPS PER BROAD GROUP
 NINT * NUMBER OF REGIONS PER COMPOSITION (EQUAL THICKNESS)
 NISU NUMBER OF REGION/MATERIAL PAIRS WITH NON-ZERO ATOM DENSITY
 NUPT * NOT POSITIVE IMPLIES A HOMOGENEOUS 1 REGION PROBLEM
 POSITIVE IMPLIES A HETEROGENEOUS MULTI-REGION PROBLEM
 >3 IMPLIES NO INTERFERENCE TERM CHI IN RESONANT CROSS SECTIONS
 NCX 40000/NISU-1
 AUX1 NCX+1
 NPRINT * <0 GIVES FINE GROUP FLUX OUTPUT AND INTERMEDIATE GROUP OUTPUT
 =0 GIVES INTERMEDIATE GROUP OUTPUT
 >0 SUPPRESSES ALL OUTPUT FOR FINE AND INTERMEDIATE GROUPS
 NRES * NUMBER OF RESONANCES FOR A MATERIAL
 NTEMP * NUMBER OF DIFFERENT TEMPERATURES
 NU INTERMEDIATE GROUP NUMBER (MODULO 100)
 NUCLID * ALPHAMERIC NAME FOR MATERIAL (ISOTOPE OR COLLECTION OF ISOTOPES)
 NX REGION NUMBER
 NXN NOX*NISC
 P PROBABILITY OF ESCAPE WITHOUT A COLLISION FROM A REGION
 PFLUX NOT USED
 PHI SPATIALLY INTEGRATED FINE GROUP FLUX IN GROUP K
 PHIC BROAD GROUP AVERAGE FLUX IN COMPOSITION
 PHIR BROAD GROUP AVERAGE REGION FLUXES
 PHIT INTERMEDIATE GROUP AVERAGE FLUX FOR CELL
 PHITOT BROAD GROUP AVERAGE FLUX FOR CELL
 PIJ MATRIX TO BE INVERTED BY MATINV. IF IT IS THE COLLISION PROBABILITY
 MATRIX, THEN PIJ(I,J) IS TRANSFER PROBABILITY FROM I TO J
 PL INTERPOLATION INTERVAL FRACTION FOR SCATTERING RATE AT K-L
 PNL NON-LEAKAGE PROBABILITY (RATES)
 PS INGROUP ELASTIC SCATTERING TRANSFER PROBABILITY
 P1 MAJOR COMPONENT OF ELASTIC TRANSFER PROBABILITY FROM GROUP K-1 TO K
 Q .5*SOURCE*PNL (RATES)
 C LETHARGY AT MIDPOINT OF FINE GROUP K-L (SOURCE)
 R DPS*SS (RATES)
 RA BROAD GROUP RESONANCE INTEGRAL FOR ABSORPTION
 RA(F) BROAD GROUP RESONANCE INTEGRAL FOR FOIL ABSORPTION
 RAD DISTANCE FROM LEFT BOUNDARY OF CELL TO RIGHT BOUNDARY OF REGION
 RAP CUMULATIVE ABSORPTION PROBABILITY
 RATIO NOT USED
 REW REAL PART OF COMPLEX PROBABILITY INTEGRAL W(Z)
 REZ REAL PART OF ARGUMENT FOR COMPLEX PROBABILITY INTEGRAL W(Z)
 RF BROAD GROUP RESONANCE INTEGRAL FOR FISSION
 RF(F) BROAD GROUP RESONANCE INTEGRAL FOR FOIL FISSION
 RIAC BROAD GROUP AVERAGE MICROSCOPIC CROSS SECTION FOR ABSORPTION
 RIFC BROAD GROUP AVERAGE MICROSCOPIC CROSS SECTION FOR FISSION
 RISC BROAD GROUP AVERAGE MICROSCOPIC CROSS SECTION FOR SCATTERING
 RMAX * DISTANCE FROM LEFT BOUNDARY OF CELL TO RIGHT BOUNDARY OF COMPOSITION
 SA MACROSCOPIC ABSORPTION CROSS SECTION IN FINE GROUP K
 SCAT TABLE OF SCATTERING RATES FOR EACH MATERIAL/REGION PAIR
 SCL ELASTIC SCATTERING RATE FROM GROUP K-1-L TO K
 SCS BROAD GROUP AVERAGE SCATTERING CROSS SECTION FOR CELL
 SCSGP INTERMEDIATE GROUP AVERAGE SCATTERING CROSS SECTION FOR CELL

SDD SLOWING DOWN DENSITY ENTERING PROBLEM FROM ABOVE IN ENERGY
 SF MACROSCOPIC FISSION CROSS SECTION IN FINE GROUP K
 SI ASYMPTOTIC SLOWING DOWN SOURCE ABOVE PROBLEM
 SIG TOTAL MICROSCOPIC CROSS SECTION IN GROUP K
 SIGABG INTERMEDIATE GROUP AVERAGE ABSORPTION CROSS SECTION
 SIGA22 * FLAT BACKGROUND ABSORPTION CROSS SECTION FOR RESONANT MATERIALS.
 .0253 EV 1/V ABSORPTION CROSS SECTION FOR NON-RESONANT MATERIALS
 SIGFBG INTERMEDIATE GROUP AVERAGE FISSION CROSS SECTION
 SIGF22 * FLAT BACKGROUND FISSION CROSS SECTION FOR RESONANT MATERIALS.
 .0253 EV 1/V FISSION CROSS SECTION FOR NON-RESONANT MATERIALS
 SIGIN S-WAVE INTERFERENCE CONTRIBUTION TO SCATTERING CROSS SECTION=SIGIN*CHI
 SIGMIN RESONANCE CROSS SECTION TO BE COMPARED TO TEST
 SIGP MACROSCOPIC POTENTIAL SCATTERING CROSS SECTION
 SIGPOT * MATERIAL POTENTIAL SCATTERING CROSS SECTION
 SIGS8G INTERMEDIATE GROUP AVERAGE SCATTERING CROSS SECTION
 SIGTR MACROSCOPIC TRANSPORT CROSS SECTION FOR A COMPOSITION
 SL SCATTERING CROSS SECTION IN GROUP K-1
 SUK SUM OF ALL DIFFERENCES BETWEEN SOURCE IN GROUP K-1 AND THAT IN GROUP K
 MINUS INGROUP SCATTERING CONTRIBUTION IN GROUP K
 SOURCE SLOWING DOWN SOURCE IN GROUP K
 SPN NOT USED
 SPV NOT USED
 SS MACROSCOPIC SCATTERING CROSS SECTION IN FINE GROUP K
 SSF BROAD GROUP AVERAGE FOIL MACROSCOPIC SCATTERING CROSS SECTION
 TAB E3 AND E4 TABLES
 TAJ REGION OPTICAL THICKNESS (RATES)
 TEMP * TEMPERATURE OF COMPOSITION (DEGREES KELVIN)
 TEST * VALUE OF RESONANT CROSS SECTION TO BE EXCEEDED IF RESONANCE IS TO BE
 INCLUDED IN FINE GROUP FLUX CALCULATIONS WITHIN AN INTERMEDIATE GROUP
 (THE RESONANCE IS AUTOMATICALLY INCLUDED IF IT LIES WITHIN THE INTER-
 MEDIATE GROUP)
 TI TABLE OF IMAGINARY PART OF W(Z)
 TITLE * ALPHAMERIC TITLE OF PROBLEM
 TOT OPTICAL THICKNESS OF UNIT CELL(H)
 TOT3 NOT USED
 TC Q/REGION OPTICAL THICKNESS
 TR TABLE OF REAL PART OF W(Z)
 TI FOIL COLLISION RATE IN FINE GROUP K
 ITAU 1/REGION OPTICAL THICKNESS
 U UPPER LETHARGY BOUND OF FINE GROUP K (SCARCE)
 UFGP FINE GROUP LETHARGY WIDTH
 UIGP * INTERMEDIATE GROUP LETHARGY WIDTH
 UMAX UPPER LETHARGY BOUND OF BROAD GROUP
 USTR LOWER LETHARGY BOUND OF A BROAD GROUP (U=0 AT E=ENGP(1))
 V 1.-EXDU
 V1 ARGUMENT OF S3(V1,H) IN XTRAP
 V2 ARGUMENT OF S4(V2,H) IN XTRAP4
 V3 Y, IN YZ3 AND YZ4, FOR SUMMING E3 AND E4 FUNCTIONS
 V4 DELTA, WHERE Z=Y+V4, IN YZ3 AND YZ4
 V5 NOT USED
 V6 NOT USED
 V7 S3(V1,H) IN XTRAP
 V8 S4(V2,H)
 V9 S3(Y,H)-S3(Z,H)
 V10 S4(Y,H)-S4(Z,H)
 V11 NOT USED

VI2	NOT USED
VI3	NOT USED
W0KK	DOUBLE LENGTH OPTICAL THICKNESS VECTOR
W0Z	GAUSS QUADRATURE WEIGHTS FOR S2(Z,H)
W03	GAUSS QUADRATURE WEIGHTS FOR S3(Z,H)
W04	GAUSS QUADRATURE WEIGHTS FOR S4(Z,H)
XAREAL	XNFB/AREAC
XAREAT	XNFB/AREAT
XC	.004126+.00628*EXP(-19.8*TOT)
XN	NOT USED
XNFB	1/NF1(1BG)
XRES	SQRT(ER/ENERGY OF GROUP K)
XTEMP	TEMPERATURE OF REGION (DEGREES KELVIN)
Y	ATM2 (QUICKW)
Y	ARGUMENT IN S3(Y,H) OR S4(Y,H) IN Y23 AND Y24
Z	ARGUMENT IN S3(Z,H) OR S4(Z,H) IN Y23 AND Y24

REFERENCES

1. P. H. Kier and A. A. Robba RABBLE. A Program for Computation of Resonance Absorption in Multiregion Reactor Cells. ANL-7326 (April 1967)
2. G. Placek, The Functions $E_n(x) = \int_1^\infty \exp(-xu)u^{-n} du$ N.B.S. Appl. Math. Series, No. 37, U.S.G.P.O., Washington (1954).
3. Burton S. Garbow Matrix Inversion with Accompanying Solution of Linear Equations, ANL F402S (Dec 1967).
4. Alvin M. Weinberg and Eugene P. Wigner, The Physical Theory of Neutron Chain Reactors. p. 196, The University of Chicago Press, Chicago (1959).
5. C. R. Adkins, T. E. Murley, and M. W. Dyos, A Detailed Method for Calculating the Low Energy Multigroup Cross Sections and the Doppler Coefficient in a Fast Reactor, Nucl. Sci. Eng. 36, 336-350 (1969).
6. B. J. Toppel, A. L. Rago, and D. M. O'Shea, MC². A Code to Calculate Multigroup Cross Sections, ANL-7318, p. 23 (June 1967).
7. IBM System/360 FORTRAN IV Language, Form C28-6515-7. Eighth Edition International Business Machines Corp., New York, pp. 47-49 (Oct 1968).
8. Arne P. Olson Gaussian Quadratures for $\int_1^\infty \exp(-x)f(x) dx/x^m$ and $\int_1^\infty g(x) dx/x^m$, Math. Comput. 23(106), p. 447 (1969)
9. S. Chandrasekhar, Radiative Transfer, pp. 57-60, Dover Publications, New York (1960).
10. V. N. Faddeeva, Computational Methods of Linear Algebra, pp. 81-85, Dover Publications, New York (1959).
11. Philip Rabinowitz and George Weiss, Tables of Abscissas and Weights for Numerical Evaluation of Integrals of the Form $\int_0^\infty e^{-x}x^n f(x) dx$. Mathematical Tables and Other Aids to Computation 13, pp. 285-294 (1959).
12. Milton Abramowitz and Irene A. Stegun (Editors), Handbook of Mathematical Functions, Fifth Edition 55, p. 923, U.S.G.P.O., Washington (1966).

13. Ibid., p. 886.
14. F. L. Fillmore and L. D. Felten, The CALHET Heterogeneous Perturbation Theory Code and Application to ZPR-3-48, AI-67-91 (Aug 1967).
15. F. L. Fillmore, The CALHET-2 Heterogeneous Perturbation Theory Code and Application to ZPR-3-48, AI-69-13 (March 1969).
16. IBM System/360 Operating System Job Control Language, Form C28-6539-8, Ninth Edition, International Business Machines Corp., New York (Nov 1968).