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RIFF RAFF,
A Program for Computation of
Resonance Integrals in a Two-region Cell

by

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RIFF RAFF,
A Program for Computation of Resonance
Integrals in a Two-region Cell

by

P. H. Kier

ABSTRACT

A method of computing resonance absorption by a rod in a two-region cylindricalized cell that is not based on the assumption of an asymptotic neutron source distribution is developed and used to write a FORTRAN program RIFF RAFF (RP 359X), for the CDC-3600. An energy range of interest is divided into extremely narrow intervals of equal lethargy width. For each interval, the source distribution in each region is taken to be a three-term polynomial. By using this form for the source and the assumption that neutrons enter the rod isotropically, the reaction rates and the flux distribution for the interval are obtained. The reaction rates are accumulated over specified energy intervals to obtain resonance integrals; the flux distribution is used to obtain the source distribution for intervals at lower energies.

RIFF RAFF allows for ten materials in each region. There can be four resonance absorbers in the rod, each having 60 resonances. The nonresonance materials can have $1/v$ absorption cross sections, with the restriction that for the moderator, the macroscopic absorption cross section must be small compared to the scattering cross section. The running time for a problem with 20 resonances and 4000 fine groups is about 2 min.

I. INTRODUCTION

A. The Standard Approximations and Their Limitations

The standard methods of computing resonance absorption for lattices are based upon the narrow-resonance approximation in the moderator (NRM) and the flat-source approximation in the fuel lump. The NRM approximation implies that neutrons are scattered into a resonance energy band from energies for which the neutron flux in the moderator is unperturbed by absorption in the lump. Thus the neutron source in the moderator is assumed to have the form of the asymptotic neutron flux, spatially uniform and

constant in lethargy. The assumption is excellent when resonances are widely spaced and the moderator is hydrogenous, but it will introduce significant error for several situations of interest. One case in which the NRM approximation is unjustified is when a resonance is not narrow compared to the average lethargy gain per collision with the principal scatterer in the moderator (e.g. the low-lying resonances of U^{238} with a graphite moderator), since the scattering of neutrons from one energy to another within the same resonance energy band is appreciable. The NRM approximation is also poor when there is appreciable scattering from one resonance energy band to another such as will occur for the closely spaced resonances of fissile nuclide or for mixtures of resonance-absorbing materials.

Use of the NRM approximation and the flat-flux approximation has persisted because of the tremendous simplifications they allow in the calculation of resonance integrals. Resonances are treated as isolated, and their absorption is obtained without knowledge of the details of the neutron-flux distribution at resonance energies. If, in addition, Wigner's rational approximation is used for the magnitude of the flat flux in the fuel lump, a heterogeneous system is reduced to an equivalent homogeneous system.^{1,2}

B. Methods Not Based on the NRM Approximation

The Monte Carlo procedure³ provided the first method of computing resonance absorption that was not based on the NRM approximation. Monte Carlo can treat complex geometric configurations with few assumptions, but it consumes considerable computer time and yields neither resonance integrals nor flux distributions. Corngold⁴ was the first to develop an analytical formulation for resonance absorption that is not based on the usual assumptions. By taking the space-angle moments of the angular flux in an infinite, regular slab lattice, he derived an expression for the resonance escape probability that includes curvature of the flux in the fuel slabs and lethargy-dependent but flat fluxes in the moderator. Berg,⁵ by using an iterative solution to the integral equation for the source in the moderator, also finds the effect of the lethargy dependence of a uniform source in the moderator on resonance absorption. Iijima⁶ improves upon Berg's procedure by iteratively solving the coupled integral equations for the neutron flux in the moderator and in the fuel. He applies the method to find the effect of the depletion of the source in the moderator on absorption by wide, isolated resonances for plane geometry.

Within recent years, several semianalytical methods have been developed expressly for solution on a high-speed digital computer that include the effects of the space and lethargy dependence of the neutron source. Kier⁷ treats absorption by wide or overlapping resonances in large slab cells. Driggers's method⁸ divides a cylindricalized cell into annular regions within which the flux is flat. His code inputs cross-section data numerically and limits either the detail or the energy range of a calculation. Lewis⁹ has

developed a method based on the integral Boltzmann equation that uses Lagrangian interpolation polynomials to evaluate the transport kernel. The perfect reflection boundary condition at the surface of the cylindrical cell should limit the accuracy of his method when treating small cells.

This report presents a method of computing resonance absorption and neutron-flux distributions in a two-region cylindricalized cell at epithermal energies. The method is quite versatile and can be used to treat large or small cells with equal facility. The energy mesh can be made fine enough to treat Doppler effects and the energy range of interest for fast reactors. The method, which is presented in Part II, has been used to write a program, RIFF RAFF, for the CDC-3600. The program is described in Part III, and a sample calculation to illustrate use of the program is given in Part IV. (Derivations of expressions for escape and transmission probabilities for the moderator and for the rod are given in Appendixes A and B, respectively. Appendix C gives the listing of the FORTRAN source program.)

II. THEORY

We shall consider a two-region cylindricalized cell for which the central rod contains resonance-absorbing materials. Since the NRM approximation is not made, it is necessary to determine the neutron-flux distribution in the cell as a function of energy. Since the resonance cross section is a rapidly varying function of energy, the flux distribution will be also.

An energy range of interest will be divided into many narrow groups of equal lethargy width. To describe the rapid variation of the flux distribution at resonance energies adequately, the groups must be extremely narrow. We shall specify that the groups are narrow compared to the maximum lethargy gain per collision with the heaviest of nuclides. Consequently, we can assume that a neutron will have only one collision per group, which will either result in its being absorbed or scattered to a lower group. Since a neutron will have only one collision per group, it is appropriate to use a transport theory formulation based on first-flight escape probabilities in treating a group. An unwanted consequence of using such narrow groups is that a program based on this formulation must do the computations for a group extremely rapidly since otherwise excessive computer time would be consumed.

We shall consider only epithermal energies, for which materials normally used as moderators have constant scattering cross sections and small absorption cross sections. The total cross section of the moderator will be taken as constant when considering escape probabilities. If we also assume that the flux entering or leaving the rod is isotropic, and that the neutron source for a group has the form

$$S(r) = \sum_n S_n F_n(r), \quad (1)$$

where S_n are group-dependent constants and $F_n(r)$ are functions of the radial coordinate, we need compute the escape probability for the component of the source in the moderator distributed as $F_n(r)$ only once. The probability of neutrons from $F_n(r)$ being absorbed upon entering the rod is then the product of the escape probability from the moderator and the collision probability in the rod for an isotropic surface flux (cosine surface source).

The assumption that neutrons enter the rod isotropically is quite good due to the geometric properties of rods. It is made with success by Amouyal and Benoist¹⁰ in their treatment of thermal utilization. Cady¹¹ has shown that the escape probability for an incident surface flux is only weakly dependent upon its angular distribution.

Three other assumptions are basic to the method:

- (1) Scattering is isotropic in the laboratory system of coordinates.
- (2) Neutrons leaving the cell are returned isotropically.
- (3) The neutron flux is asymptotic above the energy range of the calculation.

The first assumption appears to be necessary if the method is to be tractable, the second assumption has been found¹² to be a suitable boundary condition for small circularized cells, and the third assumption is good since the energy ranges of interest are far below the energies at which neutrons are born.

The neutron source distribution for a group will be taken as a three-term polynomial in each region:

$$S_i(r) = \sum_{n=0}^2 S_{in} \left(\frac{r}{a} \right)^{2n}, \quad i = \begin{cases} 0, & \text{rod;} \\ 1, & \text{moderator;} \end{cases} \quad (2)$$

where a is the radius of the rod and S_{in} are group-dependent coefficients.

That the collision probability for the source shape assumed in Eq. (2) closely approximates the collision probability for a true source shape with large curvature was checked as follows. Castle *et al.*¹³ computed the collision probability in a rod of radius R when the cross section of the rod is Σ for a source distributed as $I_0(\kappa R)$. This shape was approximated by a three-term polynomial by requiring that

$$S(R) = I_0(\kappa R),$$

$$S(0) = I_0(0),$$

and

$$\int S(r) r dr = \int I_0(\kappa r) r dr.$$

A case where there is a large curvature is when $\kappa R \approx 2$ when $\Sigma R \approx 0.5$. For this case, the polynomial approximation yielded a collision probability of 0.390, as compared to 0.392 for the modified Bessel function.

With the source shape given by Eq. (2), the collision rate in the rod is given by

$$R_{\text{col}} = S_s(1 - p_s) + \sum_{n=0}^2 (1 - p_n) S'_{\text{on}}, \quad (3)$$

where S_s , the rate with which neutrons impinge upon the surface of the rod is

$$\begin{aligned} S_s &= \sum_{n=0}^2 P_{\text{an}} S'_{\text{ln}} + T_{\text{ba}} \sum_{n=0}^2 (P_{\text{bn}} S'_{\text{ln}} + p_n T_{\text{ab}} S'_{\text{on}} + P_{\text{an}} p_s T_{\text{ab}} S'_{\text{ln}}) \\ &\quad \times \sum_{j=0}^{\infty} (T_{\text{bb}} + T_{\text{ba}} T_{\text{ab}} p_s)^j \\ &= \sum_{n=0}^2 \left\{ P_{\text{an}} S'_{\text{ln}} + \frac{T_{\text{ba}} [p_n T_{\text{ab}} S'_{\text{on}} + (P_{\text{bn}} + P_{\text{an}} p_s T_{\text{ab}}) S'_{\text{ln}}]}{1 - T_{\text{bb}} - T_{\text{ba}} T_{\text{ab}} p_s} \right\}, \quad (4) \end{aligned}$$

where

P_{xn} = first-flight probability of escape through the surface of the moderator at x for neutrons scattered into the group in the moderator distributed as $(r/a)^{2n}$;

T_{xy} = probability that neutrons entering the moderator isotropically through its surface at x escape through the surface at y without suffering an intervening collision;

p_n = first-flight escape probability from rod for neutrons scattered into the group in the rod distributed as $(r/a)^{2n}$;

p_s = probability that neutrons impinging upon the surface of the rod isotropically escape from the rod without suffering an intervening collision;

b = outer radius of the moderator;

$$S'_{on} = \frac{\pi a^2}{n+1} S_{on};$$

$$S'_{ln} = \frac{\pi a^2}{n+1} \left\{ (b/a)^{2n+2} - 1 \right\} S_{ln}. \quad (5)$$

The first summation in Eq. (4) represents neutrons from the slowing-down source in the moderator that impinge upon the rod's surface directly after escaping from the moderator; the second summation represents neutrons that impinge upon the rod's surface after having left the cell and being returned isotropically one or more times. The reaction rate for process z in material j is simply

$$R_{Zj} = R_{col} \frac{\Sigma_{zj}}{\Sigma_{rod}}. \quad (6)$$

In this model, the P_{xn} and T_{xy} are independent of group because the total cross section of the moderator is assumed to be constant. Expressions for P_{xn} and T_{xy} are derived in Appendix A. The probabilities p_n and p_s are dependent only on the radius of the rod since the groups are so narrow that there are not multiple collisions within a group. Since p_n and p_s depend upon the total cross section of the rod, they are group-dependent. Cady¹⁴ has derived exact expressions for these probabilities.

For the neutron source to have the form given in Eq. (2), the flux must have the same form:

$$\phi_i(r) = \sum_{n=0}^2 \phi_{in} \left(\frac{r}{a} \right)^{2n}, \quad \begin{array}{l} i = 0, \text{ rod;} \\ i = 1, \text{ moderator;} \end{array} \quad (7)$$

where ϕ_{in} are group-dependent coefficients. By taking the spatial moments of the flux that results from a particular source distribution, Cady has been able to obtain ϕ_{on} in the form

$$\phi_{on} = c_n S_s + \sum_{j=0}^2 c_{nj} S_{oj}, \quad (8)$$

where

c_{nj} = contribution to flux coefficient ϕ_{on} from source neutrons distributed as $(r/a)^{2j}$,

and

c_n = contribution to flux coefficient ϕ_{on} from isotropic surface flux.

The c_n and c_{nj} are group-dependent since they depend upon the radius of the rod in mean free paths.

Thus far we have shown how the flux distribution and the reaction rates in the rod for a group are obtained from the slowing-down source distribution and the cross sections for materials in the rod. We must still obtain the flux distribution in the moderator, i.e., the ϕ_{1n} . At this point, there is enough information known for a group to determine the ϕ_{1n} by requiring the flux in the moderator to satisfy certain conditions. The following three conditions are used to obtain three simultaneous equations involving the ϕ_{1n} :

1. Equality of the fluxes at the interface:

$$\phi_1(a) = \phi_0(a). \quad (9a)$$

2. Neutron conservation; since each collision removes a neutron from the group, the collision rate in the group must equal the rate at which neutrons are scattered into the group, or

$$\Sigma_{\text{mod}} \int_{\text{mod}} \phi_1(r) dV = \int_{\text{mod}} S_1(r) dV + \int_{\text{rod}} S_0(r) dV - R_{\text{col}}. \quad (9b)$$

3. The derivative of $\phi_1(r)$ vanishes at the surface of the cell:

$$\frac{d}{dr} \phi_1(b) = 0. \quad (9c)$$

Thus far we have assumed that the neutron source distribution for the group is known. Since we do not assume an asymptotic source, the source is dependent upon the flux in those groups from which neutrons can be scattered into the current group. A source component for the k^{th} group is

$$S_k^{\text{in}} = \sum_{j=1}^J \sum_{\ell=1}^{L_j} P_{\ell j} \Sigma_{s_{k-\ell,j}} \phi_{k-\ell}^{\text{in}}, \quad (10)$$

where

$P_{\ell j} \equiv$ probability that a neutron is scattered down ℓ groups in a scattering collision with material j ;

$\Sigma_{s_{k-\ell,j}} \equiv$ macroscopic scattering cross section of material j in group $k - \ell$;

$L_j \equiv$ maximum number of groups a neutron can be down-scattered in a collision with an atom of material j ;

and

$\phi_{k-\ell}^{\text{in}}$ flux component in group $k - \ell$.

Equation (10) would be an extremely time-consuming expression to use because a neutron can be scattered through so many groups. Under the assumption of isotropic scattering, $P_{\ell j}$ has the form

$$P_{\ell j} = \frac{1}{1 - \alpha_j} e^{-(\ell-1)\Delta u} (1 - e^{-\Delta u}) \Delta u, \quad (11)$$

where Δu is the lethargy width of a group, and $(1 - \alpha_j)$ is the maximum fractional energy loss. From Eq. (11), we see that $P_{\ell} = e^{-\Delta u} P_{\ell-1}$, which allows us to reduce Eq. (10) to the much simpler form,

$$S_k^{\text{in}} = \sum_{j=1}^J P_{1j} \Sigma_{s_{k-1,j}} \phi_{k-1}^{\text{in}} + e^{-\Delta u} \left\{ S_{k-1}^{\text{in}} - \sum_{j=1}^J P_{Lj} \Sigma_{s_{k-Lj-1,j}} \phi_{k-Lj-1}^{\text{in}} \right\}. \quad (12)$$

It is impossible to store all the fluxes necessary for exact evaluation of the last term of Eq. (12) for light materials such as hydrogen or deuterium. Therefore, for materials that can scatter neutrons through more groups than the number for which information is stored, we shall use the asymptotic flux for ϕ_{k-L-1} . RIFF RAFF stores information for 600 groups. For energies below 100 eV, we can use a Δu such that this approximation is made only for materials lighter than carbon.

To summarize the treatment of a fine group, Eq. (12) is used to obtain the source distribution for a group. Then the cross sections, escape probabilities, and flux-source coefficients are obtained for the rod. Equations (3), (5), and (6) are then used to obtain the reaction rates; the flux distribution in the rod is obtained from Eq. (8), and the flux distribution in the moderator is obtained by solving Eqs. (9a), (9b), and (9c) for the ϕ_{1n} . We have now obtained the quantities of interest for the group and can repeat this procedure for the next group. We assume that the flux is asymptotic above the energy range being considered. With this assumption, we can work down in energy, group by group, without iteration, until the entire energy range of interest is covered. The reaction rates can be accumulated over specified energy intervals and can then be used to compute either resonance integrals or effective cross sections.

The resonance integral is defined as that cross section which, when multiplied by the flux that would be present in the absence of the resonance, ϕ_{∞} , gives the true reaction rate. Thus the resonance integral for process z in material j is

$$I_{zj} = R_{zj} / \phi_{\infty} N_j V_{\text{rod}}, \quad (13)$$

where N_j is the atom density of material j , and V_{rod} is the volume of the rod. The effective cross section, σ_{zj} , is defined in terms of the actual flux and is related to the reaction rate as follows:

$$\sigma_{zj} = R_{zi}/N_j \left\{ \iint_{cell} \phi(r, u) dV du \right\}. \quad (14)$$

The resonance escape probability can be easily obtained from this formulation. It is given by

$$p = 1 - \frac{\sum_j R_{aj}}{\int_{cell} q(E_0, r) dV}, \quad (15)$$

where $q(E_0, r)$, the slowing density at the energy at which the calculation begins, is

$$q(E_0, r) = \phi_\infty \sum_i \xi_i \Sigma_{si}, \quad (16)$$

where ξ_i is the average lethargy gain received by a neutron in a collision with an atom of material i .

This theory has been used to write a program, RIFF RAFF, for the CDC-3600 which computes resonance integrals and flux distributions at epithermal energies. The RIFF RAFF program is described in Part III.

III. THE RIFF RAFF PROGRAM

The theory developed in Part II has been used to construct a program for the CDC-3600 to compute resonance absorption by a rod in a two-region cylindrical cell. The program is written in 3600 FORTRAN.¹⁵ In this part, the input information necessary for operation of the program will be given, then the quantities computed and printed will be described, and finally the organization of the program will be discussed.

A. Input

<u>Card</u>	<u>FORMAT</u>	<u>Variables</u>	<u>Description</u>
1	9A8		Problem identification
2	4E12.6	A,	Radius of fuel rod in cm

<u>Card</u>	<u>FORMAT</u>	<u>Variables</u>	<u>Description</u>
2 (contd.)		B, TEMP, DELTA	Outer radius of moderator in cm Temperature in rod in °K, TEMP > 0 Width of fine groups in lethargy units, DELTA < 2×10^{-3}
3	6I6	NRØD, NMØD, NRESAB, NGP, NFLUX, MØRE	No. of materials in rod, $0 < \text{NRØD} \leq 10$ No. of materials in moderator, $0 < \text{NMØD} \leq 10$ No. of resonance absorbing nuclides in rod, $0 < \text{NRESAB} \leq 4$ No. of broad groups, $0 < \text{NGP} \leq 25$ Flux and collision density distribution printed for every NFLUX th fine group; if NFLUX ≤ 0, no flux edit If last problem in batch submitted, MØRE > 0; otherwise MØRE ≤ 0
4	6E12.6	(ENGP(I), I=1,NGP+1)	ENGP(I) is the upper energy of the I th broad group in eV. ENGP(NGP+1) is the lower energy of NGP th group; ENGP(I) > ENGP(I+1)
5	A6,4E12.6	(MATMØD(I), AMASSM(I), ADENM(I), SIGPM(I), SIGAM(I), I=1,NMØD)	Material identification of I th material in moderator Atomic mass of I th material in amu Atom density of I th material in units of $10^{24}/\text{cm}^3$ Scattering cross section of I th material in barns 2200-m/sec value of 1/v absorption cross section of I th material in barns
6	A6,5E12.6,I6	MATRØD(I), AMASSR(I), ADENR(I), SIGPR(I),	Material identification of I th material in rod Atomic mass of I th material in amu Atom density of I th material in units of $10^{24}/\text{cm}^3$ Potential scattering cross section in barns

<u>Card</u>	<u>FORMAT</u>	<u>Variables</u>	<u>Description</u>
6 (contd.)		SIGA22(I),	2200-m/sec value of $1/v$ absorption cross section in barns for nonresonance materials; constant background-absorption cross section in barns for resonance material
		SIGF22(I),	2200-m/sec value of $1/v$ fission cross section in barns for nonresonance materials; constant background-fission cross section in barns for resonance material
		NRES(I)	No. of resonances for I^{th} material, $0 \leq \text{NRES}(I) \leq 60$; $\text{NRES}(I) > 0$ for $I \leq \text{NRESAB}$

Note: Materials should be ordered such that resonance materials are read in first. SIGA22(I) and SIGF22(I) should be zero if resonances of material I are resolved for the energy range of the calculation. If $\text{NRES}(I) > 0$, read in resonance parameters for material I (card 7) next; otherwise, read in card 6 for next material.

7	6E12.6	(ER(I,J),	Resonance energy of J^{th} resonance in eV
		GAMNUT(I,J),	Neutron width of J^{th} resonance evaluated at ER(I,J) in eV
		GAMRAD(I,J),	Radiation width of J^{th} resonance in eV
		GAMFIS(I,J),	Fission width of J^{th} resonance in eV
		G(I,J),	Statistical spin factor of J^{th} resonance
		XNAT(I,J),	If $\text{XNAT}(I,J) > 2 (E - E_r)/\Gamma $, Doppler-broadened line shapes are used for contribution of resonance to cross sections for group; otherwise, natural line shapes are used
		J=1,NRES(I))	

B. Output

RIFF RAFF computes reaction rates based upon a normalization of an asymptotic neutron flux per unit lethargy of unity above the energy range of the calculation. The reaction rates can then be related to the resonance integral by use of Eq. (13), to the effective cross section by use of Eq. (14), or to the nonabsorption probability by use of Eq. (15).

For each broad group, the following quantities are computed and printed:

1. Integrals over region and the lethargy extent of the broad group of reaction rates for absorption, fission, and scattering for each material in the rod, and reaction rates for absorption and scattering for each material in the moderator.
2. Total reaction rates for absorption, fission, and scattering in the rod, and total reaction rates for absorption and scattering in the moderator.
3. Integrals over the lethargy extent of the broad group of reaction rates for absorption and fission at the surface of the rod for each material in the rod.
4. Resonance integrals for absorption (capture + fission) and for fission for each resonance absorber in the rod in barns.
5. Probability that neutrons slowed down past the maximum energy of the energy range of the calculation are absorbed in the broad group.
6. Integrals over region, and the lethargy extent of the broad group of the computed neutron flux and the asymptotic neutron flux in both the fuel rod and the moderator.
7. Integrals over region, and the lethargy extent of the broad group of the computed collision density in the fuel rod.

In addition to these broad, group-dependent quantities, RIFF RAFF prints the following quantities:

8. Resonance integrals for absorption, and fission for each resonance absorber, for the entire energy range of the calculation.
9. Probability that neutrons slowed down past the maximum energy of the energy range of the calculation are not absorbed in the energy range.
10. The neutron flux at seven points in the cell, and the collision density at four points in the fuel rod for every n^{th} group, where n is an input parameter.

C. Organization of the RIFF RAFF Program

RIFF RAFF consists of a main program and ten subroutines. The block diagram of the program is shown in Fig. 1, and the complete listing of the source program is given in Appendix C. The function of each subroutine is given below.

Fig. 1. Block Diagram of the RIFF RAFF Program

are used to obtain the microscopic resonance scattering, absorption, and fission cross sections for a material for a fine group:

$$\sigma_s = \sum_{k=1}^K \left\{ \frac{\sigma_{ok} \Gamma_{nk}}{\Gamma_k} \Psi(\xi, x) + \sqrt{\sigma_p \sigma_{ok} g_k \Gamma_{nk} / \Gamma_k} \chi(\xi, x) \right\}; \quad (16)$$

$$\sigma_a = \sum_{k=1}^K \sqrt{\frac{|E_k|}{E}} \frac{\Gamma_{\gamma k} + \Gamma_{fk}}{\Gamma_k} \sigma_{ok} \Psi(\xi, x); \quad (17)$$

$$\sigma_f = \sum_{k=1}^K \sqrt{\frac{|E_k|}{E}} \frac{\Gamma_{fk}}{\Gamma_k} \sigma_{ok} \Psi(\xi, x); \quad (18)$$

where

$E \equiv$ average energy of fine group (eV),

$E_k \equiv$ energy of k^{th} resonance (eV),

Γ_{nk} , $\Gamma_{\gamma k}$, Γ_{fk} and $\Gamma_k \equiv$ neutron, radiation, fission, and total width of k^{th} resonance (eV),

1. INPUT--reads in input information and then prints this information after calling DATA and ESCAPE.

2. DATA--computes group-independent parameters.

3. ESCAPE--computes escape probabilities and transmission probabilities for the moderator using the expressions developed in Appendix A. Weddle's Rule¹⁶ is used to integrate numerically over ϕ .

4. KI--computes the Bickley functions, $Ki_n(x)$, using the rational expansions of Gargantini and Pomentale¹⁷ for $Ki_2(x)$ and $Ki_3(x)$.

5. SOURCE--computes the neutron source distribution for a fine group from use of Eq. (12).

6. XSECT--computes the cross sections for a fine group in the moderator and the fuel. The following expressions

$$x \equiv 2(E - E_k)/\Gamma_k,$$

$$\xi \equiv (A\Gamma_k^2/4EkT)^{1/2},$$

$$A \equiv \text{atomic mass (amu)},$$

$$kT \equiv \text{material temperature (eV)},$$

and

$\Psi(\xi, x)$ and $\chi(\xi, x) \equiv$ symmetric and antisymmetric, Doppler-broadened, line-shape functions.

7. W--O'Shea and Thacher's¹⁸ subroutine for computing the real and the imaginary parts of the complex probability integral, $W(z)$, where $z = \xi x/2 + i \xi/2$ and $\Psi(\xi, x) = (\xi\sqrt{\pi}/2) \operatorname{Re}\{W(z)\}$; $\chi(\xi, x) = \xi\sqrt{\pi} \operatorname{Im}\{W(z)\}$.

8. GRØUP--After calling RØD to obtain the escape probabilities and source-flux coefficients, c_{ij} , for a group, GRØUP computes the reaction rates in the rod [Eqs. (3) and (6)], the flux distribution in the rod [Eq. (8)], and the flux distribution in the moderator from the solution of Eqs. (9a), (9b), and (9c). GRØUP also accumulates the fluxes and reaction rates over a broad group.

9. RØD--Supplies the values of the escape probabilities (p_n and p_s) and source-flux coefficients (c_{ij}) for use by GRØUP. These quantities are functions only of the thickness of the rod in mean free paths, z . For $z < 0.3$, they are computed from small argument expansions of the form

$$c_{ij}(z) = Tcv1_{ij}z - (Tcv2_{ij} - Tcv3_{ij}\ln z)z^2 - (Tcv4_{ij} - Tcv5_{ij}\ln z)z^4; \quad (19)$$

$$p_n(z) = 1 - Tep1_n z + (Tep2_n - 0.5\ln z)z^2 + (Tep3_n - Tep4_n\ln z)z^4; \quad (20)$$

where the $Tcvk_{ij}$ and the $Tepk_n$ are stored in RØD by the use of DATA statements.

For large arguments, $z > 8.09$, the quantities are computed from asymptotic expansions of the form

$$c_{ij}(z) = j\delta_{ij} + \sum_{k=1}^K Tcv_{ijk}/z^k; \quad (21)$$

$$p_n(z) = \sum_{k=1}^K Tpv_nk/z^k; \quad (22)$$

where Tcv_{ijk} and Tpv_nk are stored in RØD by the use of DATA statements, and K is dependent upon z .

For intermediate arguments ($0.30 < z < 8.09$), values of p_n , p_s , and c_{ij} are stored in various subroutines on DATA cards. The intervals between tabulated values are as follows:

<u>Range of Mean Free Path z</u>	<u>Interval between Tabulated Values, Δz</u>
0.3-0.53	0.005
0.53-1.01	0.01
1.01-2.17	0.02
2.17-8.09	0.04

Newton's three-point forward-difference formula¹⁹ is used for interpolation. Thus, if $z = z_i + p\Delta z$,

$$f(z) = \rho_0 f(z_i) + \rho_1 f(z_{i+1}) + \rho_2 f(z_{i+2}), \quad (23)$$

where

$$\rho_0 = 1 - p(3 - p)/2; \quad \rho_1 = p(2 - p); \quad \rho_2 = p(p - 1)/2.$$

The values of p_n , p_s , and c_{ij} were calculated with the FLUX program; the listing of this program is included in Appendix C.

10. $\emptyset$ UTPUT --prints the quantities of interest that have been computed.

IV. SAMPLE CALCULATION

To illustrate the use of RIFF RAFF, the input for three problems will be given to show the effect of overlapping on the resonance integral of the 21.84-eV and 23.48-eV resonances of Th^{232} for an oxide rod in a water-moderated cell.

In the first problem, both resonances are present; in the second problem, only the 23.48-eV resonance is present; and in the third problem, only the 21.84-eV resonance is present. The difference between the sum of the resonance integrals in the second and third problems and that in the first shows the error that would be introduced by treating these resonances as being isolated. In Table I, the input for the three problems is given; in Table II, those pages of the output on which resonance integrals are printed are given. From Table II, we see that the overlapping effect reduced the resonance integral of the two resonances by approximately 3% for this particular cell. The three problems used 50 sec on the CDC-3600.

704 INPUT DATA

FORM I

TABLE I. Input for Sample Calculation

COST CODE _____

PROGRAM RIFF RAFF										PROBLEM SAMPLE										ORIGINATOR KIER										DATE										PAGE 1 OF 2																																							
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1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9	0										
EFFECT OF VERLAP ON RI										OF TW TH-2										3.2 RES. H ₂ O										OXIDE CELL										BOTH RES.																																							
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FORM I

TABLE I (Contd.)

COST CODE _____

PROGRAM RIFF RAFF

PROBLEM SAMPLE

ORIGINATOR KIER

DATE _____

PAGE 2 OF 2

[illegible]

TABLE II. The Effect of Overlapping on the Resonance Integral of the 23.48-eV and 21.84-eV Resonances of Th232 for a 1-cm-diam ThO₂ Rod in a Cell with $V_{H_2O}/V_{ThO_2} = 3$

EFFECT OF OVERLAP ON RI OF TWO TH-232 RES., H2O-OXIDE CELL BOTH RES.			
EFFECTIVE RESONANCE INTEGRALS IN BARNS			
MATERIAL	GROUP	ABSORPTION	FISSION
TH 232	1	4.7565+000	0.0000+000
TH 232	TOTAL	4.7565+000	0.0000+000

EFFECT OF OVERLAP ON RI OF TWO TH-232 RES, H2O-OXIDE CELL 23.48EV RES,			
EFFECTIVE RESONANCE INTEGRALS IN BARNS			
MATERIAL	GROUP	ABSORPTION	FISSION
TH 232	1	2.5801+000	0.0000+000
TH 232	TOTAL	2.5801+000	0.0000+000

EFFECT OF OVERLAP ON RI OF TWO TH-232 RES, H2O-OXIDE CELL 21.84EV RES.			
EFFECTIVE RESONANCE INTEGRALS IN BARNS			
MATERIAL	GROUP	ABSORPTION	FISSION
TH 232	1	2.3130+000	0.0000+000
TH 232	TOTAL	2.3130+000	0.0000+000

APPENDIX A

Escape Probabilities and Transmission Probabilities for the Moderator

Let us first consider the probability of escape through the inner surface of the moderator for anisotropic source distributed as $(R/a)^{2n}$. With reference to Fig. A-1,

$$\begin{aligned}
 P_{an} &= 4 \int_0^{\pi/2} \int_0^{\pi/2} \int_0^{r_{\max}} \Phi_n(r, \theta, \phi) (r^2 \sin \theta \, dr d\theta d\phi) e^{-\Sigma r} \int_0^{2\pi} \left(\frac{\sin \theta \cos \phi}{4\pi r^2} \right) a \, d\alpha \\
 &= 2a \int_0^{\pi/2} \int_0^{\pi/2} \int_0^{r_{\max}} \Phi_n(r, \theta, \phi) e^{-\Sigma r} \sin^2 \theta \cos \phi \, dr d\theta d\phi,
 \end{aligned} \tag{A-1}$$

where $\overline{QP} = r \sin \theta$, and $\Phi_n(r, \theta, \phi)$ is the probability that neutrons in the source distributed as $(R/a)^{2n}$ have coordinates (r, θ, ϕ) . We can easily find $\Phi_n(R)$ and then use the law of cosines to obtain $\Phi_n(r, \theta, \phi)$. First,

$$\begin{aligned}
 \Phi_n(R) &= \frac{(R/a)^{2n}}{2\pi \int_a^b dR R (R/a)^{2n}} \\
 &= \frac{(n+1) R^{2n}}{\pi (b^{2n+2} - a^{2n+2})}.
 \end{aligned} \tag{A-2}$$

From the law of cosines,

$$R^2 = a^2 + 2ar \sin \theta \cos \phi + r^2 \sin^2 \theta. \tag{A-3}$$

Therefore,

$$\Phi_n(r, \theta, \phi) = \frac{(n+1)[a^2 + 2ar \sin \theta \cos \phi + r^2 \sin^2 \theta]^n}{\pi (b^{2n+2} - a^{2n+2})}. \tag{A-4}$$

The law of cosines is also used to obtain $r_{\max}$, which occurs when $R = b$:

$$r_{\max} = [-a \cos \phi + \sqrt{b^2 - a^2 \sin^2 \phi}] \csc \theta = f(\phi) \csc \theta \tag{A-5}$$

By substituting Eqs. (A-4) and (A-5) into Eq. (A-1), we obtain

$$\begin{aligned}
 P_{an} &= \frac{2(n+1)a}{\pi (b^{2n+2} - a^{2n+2})} \int_0^{\pi/2} \int_0^{\pi/2} \int_0^{f(\phi) \csc \theta} (a^2 + 2ar \sin \theta \cos \phi + r^2 \sin^2 \theta)^n e^{-\Sigma r} \\
 &\quad \cdot \sin^2 \theta \cos \phi \, dr d\theta d\phi.
 \end{aligned} \tag{A-6}$$

The integration over r is performed easily. The integration over θ can be put into compact form by introducing Bickley functions, $Ki_n(x)$, which can be defined as

$$Ki_n(x) = \int_0^{\pi/2} e^{-x \csc \theta} \sin^{n-1} \theta d\theta. \quad (A-7)$$

When we perform the integrations, the following expressions are obtained for the P_{an} of interest:

$$P_{a0} = \frac{2a}{\pi(b^2 - a^2)\Sigma} \left[\frac{\pi}{4} - \int_0^{\pi/2} d\phi \cos \phi Ki_3 \{ \Sigma f(\phi) \} \right]; \quad (A-8)$$

$$P_{a1} = \frac{4a}{\pi(b^4 - a^4)\Sigma} \left[\pi \left(\frac{a^2}{4} + \frac{a}{3\Sigma} + \frac{3}{8\Sigma^2} \right) - \int_0^{\pi/2} d\phi \cos \phi \left\{ b^2 Ki_3 \{ \Sigma f(\phi) \} \right. \right. \\ \left. \left. + \frac{h(\phi)}{\Sigma} Ki_4 \{ \Sigma f(\phi) \} + \frac{2}{\Sigma^2} Ki_5 \{ \Sigma f(\phi) \} \right\} \right]; \quad (A-9)$$

$$P_{a2} = \frac{6a}{\pi(b^6 - a^6)\Sigma} \left[\pi \left(\frac{a^4}{4} + \frac{2a^3}{3\Sigma} + \frac{7a^2}{4\Sigma^2} + \frac{16a}{5\Sigma^3} + \frac{15}{4\Sigma^4} \right) - \int_0^{\pi/2} d\phi \cos \phi \left\{ b^4 Ki_3 \{ \Sigma f(\phi) \} \right. \right. \\ \left. \left. + \frac{2b^2 h(\phi)}{\Sigma} Ki_4 \{ \Sigma f(\phi) \} + \frac{4[3b^2 - 2a^2 \sin^2 \phi]}{\Sigma^2} Ki_5 \{ \Sigma f(\phi) \} \right. \right. \\ \left. \left. + \frac{12h(\phi)}{\Sigma^3} Ki_6 \{ \Sigma f(\phi) \} + \frac{24}{\Sigma^4} Ki_7 \{ \Sigma f(\phi) \} \right\} \right]; \quad (A-10)$$

where

$$h(\phi) = 2\sqrt{b^2 - a^2 \sin^2 \phi}.$$

Now let us consider the probabilities of escape through the outer surface of the moderator at b . With reference to Fig. A-2,

$$P_{bn} = 4 \int_0^{\pi/2} \int_0^{\pi/2} \int_0^{r_{\max}} \Phi_n(r, \theta, \phi') (r^2 \sin \theta dr d\theta d\phi') e^{-\Sigma r} \int_0^{2\pi} \left(\frac{\sin \theta \cos \phi'}{4\pi r^2} \right) b d\alpha \\ = 2b \int_0^{\pi/2} \int_0^{\pi/2} \int_0^{r_{\max}} \Phi_n(r, \theta, \phi') e^{-\Sigma r} \sin^2 \theta \cos \phi' dr d\theta d\phi', \quad (A-11)$$

where now, from the law of cosines,

$$R^2 = b^2 - 2br \sin \theta \cos \phi' + r^2 \sin^2 \theta, \quad (\text{A-12})$$

Fig. A-2. Projection of Neutron Path on Plane Perpendicular to Axis of Cylinder for Derivation of P_{bn}

and therefore

$$\Phi_n(r, \theta, \phi') = \frac{n+1}{\pi(b^{2n+2} - a^{2n+2})} [b^2 - 2br \sin \theta \cos \phi' + r^2 \sin^2 \theta]^n. \quad (\text{A-13})$$

As can be seen from Fig. A-2, the form of $r_{\max}$ depends upon ϕ' .

When $\phi' \leq \sin^{-1} a/b$, $r_{\max}$ is obtained from the law of cosines for $R = a$:

$$\begin{aligned} r_{\max} &= [b \cos \phi' - \sqrt{a^2 - b^2 \sin^2 \phi'}] \csc \theta \\ &= g(\phi') \csc \theta. \end{aligned} \quad (\text{A-14})$$

When $\phi' \geq \sin^{-1} a/b$, $r_{\max}$ is obtained from the law of cosines for $R = b$:

$$r_{\max} = 2b \cos \phi' \csc \theta = \gamma(\phi') \csc \theta. \quad (\text{A-15})$$

By substituting Eqs. (A-13), (A-14), and (A-15) into Eq. (A-11), we obtain

$$\begin{aligned} P_{bn} &= \frac{2(n+1)b}{\pi(b^{2n+2} - a^{2n+2})} \left[\int_0^{\sin^{-1}(a/b)} d\phi' \int_0^{\pi/2} d\theta \int_0^{g(\phi') \csc \theta} (b^2 - 2br \sin \theta \cos \phi' \right. \\ &\quad \left. + r^2 \sin^2 \theta)^n e^{-\Sigma r} \sin^2 \theta \cos \phi' dr + \int_{\sin^{-1}(a/b)}^{\pi/2} d\phi' \int_0^{\pi/2} d\theta \int_0^{\gamma(\phi') \csc \theta} \right. \\ &\quad \left. (b^2 - 2br \sin \theta \cos \phi' + r^2 \sin^2 \theta)^n e^{-\Sigma r} \sin^2 \theta \cos \phi' dr \right]. \end{aligned} \quad (\text{A-16})$$

As before, we perform the integrations over r and θ . Then we make the transformation $\sin \phi = (b/a) \sin \phi'$, which allows us to express the P_{bn} in terms of integrals over ϕ between 0 and $\pi/2$. The P_{bn} of interest becomes

$$P_{b0} = \frac{2b}{\pi(b^2 - a^2)\Sigma} \left\{ \frac{\pi}{4} - \int_0^{\pi/2} d\phi \cos \phi \left[\text{Ki}_3\{\Sigma \gamma(\phi)\} - \frac{a}{b} \text{Ki}_3\{\Sigma h(\phi)\} + \frac{a}{b} \text{Ki}_3\{\Sigma f(\phi)\} \right] \right\}; \quad (\text{A-17})$$

$$P_{b1} = \frac{4b}{\pi(b^4 - a^4)\Sigma} \left\{ \pi \left(\frac{b^2}{4} - \frac{b}{3\Sigma} + \frac{3}{8\Sigma^2} \right) - \int_0^{\pi/2} d\phi \cos \phi \left[\frac{a^3}{b} \text{Ki}_3\{\Sigma f(\phi)\} \right. \right. \\ \left. \left. + b^2 \text{Ki}_3\{\Sigma \gamma(\phi)\} - ab \text{Ki}_3\{\Sigma h(\phi)\} - \frac{\gamma(\phi)}{\Sigma} \left[\frac{a^2}{b^2} \text{Ki}_4\{\Sigma f(\phi)\} - \text{Ki}_4\{\Sigma \gamma(\phi)\} \right] \right. \right. \\ \left. \left. - \frac{a}{b\Sigma} h(\phi) \text{Ki}_4\{\Sigma h(\phi)\} + \frac{2a}{b\Sigma^2} \left[\text{Ki}_5\{\Sigma f(\phi)\} - \text{Ki}_5\{\Sigma h(\phi)\} \right] + \frac{2}{\Sigma^2} \text{Ki}_5\{\Sigma \gamma(\phi)\} \right] \right\}; \quad (\text{A-18})$$

$$P_{b2} = \frac{6b}{\pi(b^6 - a^6)\Sigma} \left\{ \pi \left(\frac{b^4}{4} - \frac{2b^3}{3\Sigma} + \frac{7b^2}{4\Sigma^2} - \frac{16b}{5\Sigma^3} + \frac{15}{4\Sigma^4} \right) - \int_0^{\pi/2} d\phi \cos \phi \left[\frac{a^5}{b} \text{Ki}_3\{\Sigma f(\phi)\} \right. \right. \\ \left. \left. + ab^3 \text{Ki}_3\{\Sigma \gamma(\phi)\} - b^4 \text{Ki}_3\{\Sigma h(\phi)\} - \frac{2}{\Sigma} \left[\frac{a^4}{b^2} \gamma(\phi) \text{Ki}_4\{\Sigma f(\phi)\} - b^2 \gamma(\phi) \text{Ki}_4\{\Sigma \gamma(\phi)\} \right. \right. \right. \\ \left. \left. + abh(\phi) \text{Ki}_4\{\Sigma h(\phi)\} \right] + \frac{4}{\Sigma^2} \left[\frac{a^3}{b} (1 + 2 \cos^2 \phi) \text{Ki}_5\{\Sigma f(\phi)\} - b^2 (1 + 2 \cos^2 \phi) \text{Ki}_5\{\Sigma \gamma(\phi)\} \right. \right. \\ \left. \left. + [3b^2 - 2a^2 \sin^2 \phi] \text{Ki}_5\{\Sigma h(\phi)\} \right] - \frac{12}{\Sigma^3} \left[\frac{a^2}{b^2} \gamma(\phi) \text{Ki}_6\{\Sigma f(\phi)\} - \gamma(\phi) \text{Ki}_6\{\Sigma \gamma(\phi)\} \right. \right. \\ \left. \left. + \frac{a}{b} h(\phi) \text{Ki}_6\{\Sigma h(\phi)\} \right] + \frac{24}{\Sigma^4} \left[\frac{a}{b} \text{Ki}_7\{\Sigma f(\phi)\} + \text{Ki}_7\{\Sigma \gamma(\phi)\} - \frac{a}{b} \text{Ki}_7\{\Sigma h(\phi)\} \right] \right\}. \quad (\text{A-19})$$

Fig. A-3. Projection of Neutron Path on Plane Perpendicular to Axis of Cylinder for Derivation of T_{ab}

Now let us consider the probabilities that neutrons that enter the moderator at x traverse the moderator without having a collision to leave at y . Neutrons entering the moderator through its inner surface leave through the surface at b . With reference to Fig. A-3,

$$T_{ab} = \frac{\int_0^{\pi/2} \int_0^{\pi/2} \cos \phi \sin^2 \theta e^{-\Sigma r} d\theta d\phi}{\int_0^{\pi/2} \int_0^{\pi/2} \cos \phi \sin^2 \phi d\theta d\phi} \\ = \frac{4}{\pi} \int_0^{\pi/2} \int_0^{\pi/2} \cos \phi \sin^2 \theta e^{-\Sigma r} d\theta d\phi. \quad (\text{A-20})$$

From the law of cosines,

$$r = \left(-a \cos \phi + \sqrt{b^2 - a^2 \sin^2 \phi} \right) \csc \theta = f(\phi) \csc \theta.$$

Therefore, by performing the integration over θ , we obtain

$$T_{ab} = \frac{4}{\pi} \int_0^{\pi/2} d\phi \cos \phi \text{Ki}_3\{\Sigma f(\phi)\}. \quad (\text{A-21})$$

Neutrons entering the moderator through its outer surface at b can leave the moderator through either the inner or the outer surface. With reference to Fig. A-4, the probability of leaving through the inner surface is

Fig. A-4. Projection of Neutron Path on Plane Perpendicular to Axis of Cylinder for Derivation of T_{ba}

$$T_{ba} = \frac{4}{\pi} \int_0^{\sin^{-1}(a/b)} \int_0^{\pi/2} \cos \phi' \sin^2 \theta e^{-\Sigma r} d\theta d\phi', \quad (\text{A-22})$$

where

$$r = \left(b \cos \phi' - \sqrt{a^2 - b^2 \sin^2 \phi'} \right) \csc \theta.$$

By integrating over θ and transforming from ϕ' to ϕ as before, we obtain

$$T_{ba} = \frac{4}{\pi} \frac{a}{b} \int_0^{\pi/2} d\phi \cos \phi \text{Ki}_3\{\Sigma f(\phi)\} = \frac{a}{b} T_{ab}. \quad (\text{A-23})$$

With reference to Fig. A-5, the probability that neutrons entering isotropically at b leave the moderator at b without suffering an intervening collision is

$$\begin{aligned} T_{bb} &= \frac{4}{\pi} \int_{\sin^{-1}(a/b)}^{\pi/2} \int_0^{\pi/2} \cos \phi' \sin^2 \theta e^{-\Sigma r} d\theta d\phi' \\ &= \frac{4}{\pi} \int_0^{\pi/2} \int_0^{\pi/2} \cos \phi' \sin^2 \theta e^{-\Sigma r} d\theta d\phi' \\ &\quad - \frac{4}{\pi} \int_0^{\sin^{-1}(a/b)} \int_0^{\pi/2} \cos \phi' \sin^2 \theta e^{-\Sigma r} d\theta d\phi', \end{aligned} \quad (\text{A-24})$$

where now $r = 2b \cos \phi' \csc \theta = \gamma(\phi') \csc \theta$. Performing the integrations over θ and transforming ϕ' as before, we obtain

$$T_{bb} = \frac{4}{\pi} \int_0^{\pi/2} d\phi \cos \phi \left[Ki_3\{\Sigma \gamma(\phi)\} - \frac{a}{b} Ki_3\{\Sigma h(\phi)\} \right]. \quad (A-25)$$

Fig. A-5
Projection of Neutron Path on
Plane Perpendicular to Axis of
Cylinder for Derivation of T_{bb}

APPENDIX B

The Escape Probabilities and Source-flux Coefficients for the Rod

The escape probabilities (p_s, p_n) and the source-flux coefficients (c_i, c_{ij}) were obtained from Cady's cylindrical-moments method.¹⁴ The starting point of Cady's work is Peierl's integral equation for the nondirectional flux,

$$\phi(\mathbf{r}) = \phi_u(\mathbf{r}) + (\Sigma_s/4\pi) \int d\mathbf{r}' \frac{e^{-\Sigma |\mathbf{r}-\mathbf{r}'|}}{|\mathbf{r}-\mathbf{r}'|} \phi(\mathbf{r}'). \quad (\text{B-1})$$

For a rod characterized by its radius in mean free paths, $X = \Sigma a$, and mean number of secondaries per collision, $c = \Sigma_s/\Sigma$, Eq. (B-1) becomes

$$L(\phi) = \phi(\chi) - c \int_0^X d\xi \xi \phi(\xi) K(\chi|\xi) - \phi_u(\chi) = 0, \quad (\text{B-2})$$

where χ is the dimensionless radial variable, and $K(\chi|\xi)$ is the symmetric first collision kernel,

$$K(\chi|\xi) = \begin{cases} \int_1^\infty ds I_0(\xi_s) K_0(\chi s), & \xi < \chi < X; \\ \int_1^\infty ds I_0(\xi_s) K_0(\chi s), & \chi < \xi < X. \end{cases} \quad (\text{B-3})$$

$K(\chi|\xi)$ is normalized so that $\Sigma K(\chi|\xi)/2\pi$ gives the flux at χ for a cylindrical shell source of $\ln/\text{cm-sec}$ at ξ ; $\phi_u(\chi)$ is the uncollided flux from inhomogeneous sources.

To obtain the source-flux coefficients, we assume a solution of the form

$$\tilde{\phi} = \frac{2S}{X} \sum_{n=0}^2 c_{2n} \left(\frac{r}{a}\right)^{2n}, \quad (\text{B-4})$$

where S is the number of neutrons in the source divided by time and the surface area of the rod. To obtain the c_n , we require that the following three spatial moments of Eq. (B-2) vanish:

$$\int_0^X d\chi \chi^{2i+1} L\{\tilde{\phi}(\chi)\} = 0, \quad i = 0, 1, 2. \quad (\text{B-5})$$

Introducing the cylindrical moments,

$$M_{2i,2j}(X) = \frac{2i + 2j + 2}{X^{2i+2j+2}} \int_0^X dX X^{2j+1} \int_0^X d\xi \xi^{2j+1} K(\xi|X), \quad (B-6)$$

and the moments of the uncollided flux,

$$m_{2j}(X) = \frac{1}{SX^{2j+1}} \int_0^X dX X^{2j+1} \phi_u(X), \quad (B-7)$$

Eq. (B-5) can be written as the following matrix equation:

$$\begin{bmatrix} (1 - c M_{00}) & \frac{1}{2} (1 - c M_{02}) & \frac{1}{3} (1 - c M_{04}) \\ \frac{1}{2} (1 - c M_{02}) & \frac{1}{3} (1 - c M_{22}) & \frac{1}{4} (1 - c M_{24}) \\ \frac{1}{3} (1 - c M_{04}) & \frac{1}{4} (1 - c M_{24}) & \frac{1}{5} (1 - c M_{44}) \end{bmatrix} \begin{bmatrix} c_0 \\ c_2 \\ c_4 \end{bmatrix} = \begin{bmatrix} m_0 \\ m_2 \\ m_4 \end{bmatrix}. \quad (B-8)$$

The source-flux coefficients are obtained by inverting this equation. Because the width of a group is so small in our treatment, in each collision a neutron will be scattered to some lower group, $c = 0$. The moments of the uncollided flux for the four sources are

$$\text{Surface, } S_s: \quad m_0 = 2X(1 - M_{00}), \quad m_2 = X(1 - M_{02}), \quad m_4 = 2X(1 - M_{04})/3;$$

$$\text{Uniform, } S'_{00}: \quad m_0 = M_{00}, \quad m_2 = M_{02}/2, \quad m_4 = M_{04}/3;$$

$$\text{Second Power, } S'_{02}: \quad m_0 = M_{02}, \quad m_2 = 2M_{22}/3, \quad m_4 = M_{24}/2;$$

$$\text{Fourth Power, } S'_{04}: \quad m_0 = M_{04}, \quad m_2 = 3M_{24}/4, \quad m_4 = 3M_{44}/5.$$

The first-flight escape probability is given by

$$P = 1 - \frac{1}{XS} \int_0^X dX X \phi_u(X). \quad (B-9)$$

For the sources of interest, Eq. (B-9) has the following solutions:

$$\text{Surface: } P = 1 - 2X(1 - M_{00}), \quad \text{Second Power: } P = 1 - M_{02},$$

$$\text{Uniform: } P = 1 - M_{00}, \quad \text{Fourth Power: } P = 1 - M_{04}.$$

The cylindrical moments $M_{2m,2n}(X)$ can be expressed as the difference of two functions $A_{2m,2n}(X)$ and $B_{2m,2n}(X)$, where

$$A_{2m,2n}(X) = \sum_{i=0}^n \left(\frac{m+n+1}{m+n+1-i} \right) \frac{f_{ni}^2}{(2i+1) X^{2i}}; \quad (\text{B-10})$$

$$B_{2m,2n}(X) = (2m+2n+2) \sum_{i=0}^n f_{ni} \sum_{j=0}^m f_{mj} (-1)^j F_{j+1,i+1}(X); \quad (\text{B-11})$$

$$f_{ni} = \frac{(2)^i n!}{(n-i)!}; \quad (\text{B-12})$$

and

$$F_{ij}(X) = X \int_X^{\infty} \frac{dz}{z^{i+j}} I_i(z) K_j(z). \quad (\text{B-13})$$

Explicit expressions for the $F_{ij}(X)$ (Table X) and the $M_{2m,2n}(X)$ in terms of the $F_{ij}(X)$ (Table XI) are given in Ref. 14.

APPENDIX C

Listing of the RIFF RAFF Source Deck

PROGRAM RIFFRAFF						RIFF	000
	COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),					COMR	1
X	TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),					COMR	2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),					COMR	3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),					COMR	4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),					COMR	5
X	HS(150),T23(155),H23(150),TCV23(7),TPV2(7),					COMR	6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),					COMR	7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),					COMR	8
X	H3(150),T33(155),H33(150),TCV33(7),PHI2(3)					COMR	9
	COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD,					COM1	1
X	XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,					COM1	2
X	XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,					COM1	3
X	MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,					COM1	4
X	NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,					COM1	5
X	AB,AB2,PLROD(10),SIGPMH(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,					COM1	6
X	Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,					COM1	7
X	Z4,BA,P1ROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,					COM1	8
X	NRESAB,P1MOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,					COM1	9
X	SDD,B2,PHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,MGP,					COM1	10
X	NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,					COM1	11
X	AMASSM(10)					COM1	12
	COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),					COM2	1
X	XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),					COM2	2
X	R(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),					COM2	3
X	CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),					COM2	4
X	SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)					COM2	5
	DATA(H21=						
X	0.20964492,	0.20566969,	0.20169715,	0.19773079,	0.19377381,	H21	1
X	0.18982920,	0.18589969,	0.18198780,	0.17809588,	0.17422605,	H21	6
X	0.17038030,	0.16656041,	0.16276804,	0.15900469,	0.15527173,	H21	11
X	0.15157040,	0.14790183,	0.14426703,	0.14066690,	0.13710227,	H21	16
X	0.13357386,	0.13008230,	0.12662814,	0.12321189,	0.11983394,	H21	21
X	0.11649465,	0.11319432,	0.10993317,	0.10671139,	0.10352911,	H21	26
X	0.10038642,	0.09728337,	0.09421995,	0.09119614,	0.08821188,	H21	31
X	0.08526707,	0.08236159,	0.07949528,	0.07666797,	0.07387946,	H21	36
X	0.07112952,	0.06841793,	0.06574442,	0.06310871,	0.06051053,	H21	41
X	0.05794956,	0.05542550,	0.05293801,	0.05048677,	0.04807142,	H21	46
X	0.04569161,	0.04334699,	0.04103718,	0.03876182,	0.03652053,	H21	51
X	0.03431292,	0.03213861,	0.02999722,	0.02788836,	0.02581163,	H21	56
X	0.02376664,	0.02175299,	0.01977030,	0.01781816,	0.01589619,	H21	61
X	0.01400399,	0.01214117,	0.01030733,	0.00850210,	0.00672507,	H21	66
X	0.00497586,	0.00325410,	0.00155939,	-0.00010864,	-0.00175039,	H21	71
X	-0.00336614,	-0.00495637,	-0.00652140,	-0.00806159,	-0.00957731,	H21	76
X	-0.01106892,	-0.01253676,	-0.01398118,	-0.01540254,	-0.01680117,	H21	81
X	-0.01817740,	-0.01953158,	-0.02086403,	-0.02217508,	-0.02346505,	H21	86
X	-0.02473426,	-0.02598303,	-0.02721165,	-0.02842045,	-0.02960971,	H21	91
X	-0.03077975,	-0.03193084,	-0.03306329,	-0.03417738,	-0.03527339,	H21	96
X	-0.03635160,	-0.03741228,	-0.03845570,	-0.03948214,	-0.04049185,	H21	101
X	-0.04148509,	-0.04246211,	-0.04342318,	-0.04436853,	-0.04529841,	H21	106
X	-0.04621306,	-0.04711272,	-0.04799762,	-0.04886798,	-0.04972404,	H21	111
X	-0.05056602,	-0.05139414,	-0.05220861,	-0.05300965,	-0.05379746,	H21	116
X	-0.05457225,	-0.05533423,	-0.05608359,	-0.05682053,	-0.05754524,	H21	121
X	-0.05825791,	-0.05895874,	-0.05964790,	-0.06032558,	-0.06099195,	H21	126
X	-0.06164720,	-0.06229149,	-0.06292499,	-0.06354788,	-0.06416031,	H21	131
X	-0.06476245,	-0.06535446,	-0.06593649,	-0.06650871,	-0.06707126,	H21	136
X	-0.06762428,	-0.06816794,	-0.06870237,	-0.06922772,	-0.06974413,	H21	141
X	-0.07025172,	-0.07075065,	-0.07124104,	-0.07172303,	-0.07219674,	H21	146
	DATA(H22=						
X	1.86785574,	1.89207699,	1.91590612,	1.93934632,	1.96240091,	H22	1
X	1.98507331,	2.00736709,	2.02928589,	2.05083348,	2.07201368,	H22	6
X	2.09283040,	2.11328764,	2.13338944,	2.15313988,	2.17254314,	H22	11

X	2.19160338,	2.21032484,	2.22871177,	2.24676844,	2.26449915,	H22	16
X	2.28190820,	2.29899993,	2.31577863,	2.33224864,	2.34841428,	H22	21
X	2.36427986,	2.37984968,	2.39512802,	2.41011916,	2.42482736,	H22	26
X	2.43925683,	2.45341178,	2.46729641,	2.48091484,	2.49427121,	H22	31
X	2.50736960,	2.52021406,	2.53280862,	2.54515724,	2.55726388,	H22	36
X	2.56913244,	2.58076678,	2.59217073,	2.60334806,	2.61430251,	H22	41
X	2.62503778,	2.63555751,	2.64586531,	2.65596475,	2.66585933,	H22	46
X	2.67555254,	2.68504778,	2.69434845,	2.70345787,	2.71237933,	H22	51
X	2.72111606,	2.72967128,	2.73804812,	2.74624969,	2.75427904,	H22	56
X	2.76213919,	2.76983310,	2.77736369,	2.78473385,	2.79194639,	H22	61
X	2.79900412,	2.80590978,	2.81266606,	2.81927562,	2.82574108,	H22	66
X	2.83206502,	2.83824995,	2.84429837,	2.85021274,	2.85599545,	H22	71
X	2.86164888,	2.86717534,	2.87257715,	2.87785653,	2.88301571,	H22	76
X	2.88805686,	2.89298211,	2.89779357,	2.90249330,	2.90708334,	H22	81
X	2.91156567,	2.91594225,	2.92021501,	2.92438583,	2.92845659,	H22	86
X	2.93242910,	2.93630515,	2.94008650,	2.94377490,	2.94737204,	H22	91
X	2.95087957,	2.95429915,	2.95763239,	2.96088086,	2.96404612,	H22	96
X	2.96712970,	2.97013309,	2.97305776,	2.97590517,	2.97867671,	H22	101
X	2.98137379,	2.98399779,	2.98655003,	2.98903184,	2.99144451,	H22	106
X	2.99378931,	2.99606750,	2.99828029,	3.00042890,	3.00251450,	H22	111
X	3.00453824,	3.00650127,	3.00840472,	3.01024967,	3.01203720,	H22	116
X	3.01376837,	3.01544423,	3.01706578,	3.01863403,	3.02014996,	H22	121
X	3.02161454,	3.02302872,	3.02439343,	3.02570957,	3.02697805,	H22	126
X	3.02819974,	3.02937551,	3.03050621,	3.03159267,	3.03263571,	H22	131
X	3.03363612,	3.03459471,	3.03551223,	3.03638946,	3.03722714,	H22	136
X	3.03802600,	3.03878675,	3.03951012,	3.04019677,	3.04084741,	H22	141
X	3.04146269,	3.04204328,	3.04258981,	3.04310293,	3.04358324,	H22	146

DATA(H23=

X	-1.29487000,	-1.30873999,	-1.32230623,	-1.33557269,	-1.34854339,	H23	1
X	-1.36122234,	-1.37361355,	-1.38572105,	-1.39754885,	-1.40910100,	H23	6
X	-1.42038148,	-1.43139431,	-1.44214349,	-1.45263300,	-1.46286680,	H23	11
X	-1.47284886,	-1.48258308,	-1.49207340,	-1.50132368,	-1.51033779,	H23	16
X	-1.51911956,	-1.52767280,	-1.53600127,	-1.54410873,	-1.55199889,	H23	21
X	-1.55967542,	-1.56714196,	-1.57440212,	-1.58145947,	-1.58831754,	H23	26
X	-1.59497984,	-1.60144980,	-1.60773087,	-1.61382639,	-1.61973973,	H23	31
X	-1.62547416,	-1.63103295,	-1.63641930,	-1.64163638,	-1.64668734,	H23	36
X	-1.65157525,	-1.65630315,	-1.66087406,	-1.66529092,	-1.66955666,	H23	41
X	-1.67367415,	-1.67764622,	-1.68147567,	-1.68516524,	-1.68871764,	H23	46
X	-1.69213554,	-1.69542155,	-1.69857826,	-1.70160822,	-1.70451391,	H23	51
X	-1.70729781,	-1.70996233,	-1.71250986,	-1.71494273,	-1.71726324,	H23	56
X	-1.71947367,	-1.72157623,	-1.72357311,	-1.72546647,	-1.72725841,	H23	61
X	-1.72895101,	-1.73054632,	-1.73204633,	-1.73345301,	-1.73476830,	H23	66
X	-1.73599410,	-1.73713228,	-1.73818466,	-1.73915304,	-1.74003920,	H23	71
X	-1.74084486,	-1.74157174,	-1.74222149,	-1.74279576,	-1.74329616,	H23	76
X	-1.74372428,	-1.74408165,	-1.74436981,	-1.74459025,	-1.74474443,	H23	81
X	-1.74483380,	-1.74485975,	-1.74482368,	-1.74472694,	-1.74457088,	H23	86
X	-1.74435678,	-1.74408593,	-1.74375960,	-1.74337901,	-1.74294538,	H23	91
X	-1.74245988,	-1.74192368,	-1.74133793,	-1.74070373,	-1.74002220,	H23	96
X	-1.73929439,	-1.73852136,	-1.73770416,	-1.73684379,	-1.73594124,	H23	101
X	-1.73499749,	-1.73401350,	-1.73299020,	-1.73192850,	-1.73082931,	H23	106
X	-1.72969351,	-1.72852196,	-1.72731551,	-1.72607498,	-1.72480121,	H23	111
X	-1.72349497,	-1.72215705,	-1.72078822,	-1.71938923,	-1.71796082,	H23	116
X	-1.71650370,	-1.71501858,	-1.71350616,	-1.71196711,	-1.71040210,	H23	121
X	-1.70881177,	-1.70719678,	-1.70555775,	-1.70389527,	-1.70220997,	H23	126
X	-1.70050242,	-1.69877320,	-1.69702288,	-1.69525202,	-1.69346115,	H23	131
X	-1.69165080,	-1.68982151,	-1.68797376,	-1.68610807,	-1.68422493,	H23	136
X	-1.68232481,	-1.68040819,	-1.67847553,	-1.67652727,	-1.67456386,	H23	141
X	-1.67258573,	-1.67059330,	-1.66858700,	-1.66656723,	-1.66453438,	H23	146

1 CALL INPUT

MU=0

NIX=0

KGP=1

RIFF 010

RIFF 020

RIFF 030

RIFF 040

INIT=1	RIFF 050
5 DO 10 I=1,NROD	RIFF 060
RRAR(I,KGP)=0.	RIFF 070
RRSR(I,KGP)=0.	RIFF 080
RRFR(I,KGP)=0.	RIFF 090
RRASUR(I,KGP)=0.	RIFF 100
10 RRFSUR(I,KGP)=0.	RIFF 110
DO 15 II=1,NMOD	RIFF 120
RRAM(II,KGP)=0.	RIFF 130
15 RRSN(II,KGP)=0.	RIFF 140
DO 20 J=1,3	RIFF 150
TFLUXR(J,KGP)=0.	RIFF 160
20 TFLUXM(J,KGP)=0.	RIFF 170
CPERT(KGP)=0.	RIFF 180
IGP=INIT	RIFF 190
25 CALL SOURCE	RIFF 200
CALL XSECT	RIFF 210
CALL GROUP	RIFF 220
IF (NU-LARGE)60,60,30	RIFF 230
30 IF(NFLUX)55,55,35	RIFF 240
35 DO 50 K=1,NU,NFLUX	RIFF 250
DO 40 KK=1,4	RIFF 260
FLUX(KK)=FLUXR(K,1)+RADSQ(KK)*(FLUXR(K,2)+RADSQ(KK)*FLUXR(K,3))	RIFF 270
40 CDEN(KK)=SIGMAC(K)*FLUX(KK)	RIFF 280
DO 45 KA=5,7	RIFF 290
45 FLUX(KA)=FLUXM(K,1)+RADSQ(KA)*(FLUXM(K,2)+RADSQ(KA)*FLUXM(K,3))	RIFF 300
PRINT 301,ENERGY(K),(FLUX(KB),KB=1,7)	RIFF 310
50 PRINT 302,(CDEN(KC),KC=1,4)	RIFF 320
301 FORMAT(/8E16.4)	RIFF 330
302 FORMAT(16X,4E16.4)	RIFF 340
55 IF(NIX)60,60,95	RIFF 350
60 IF(IGP-MGP(KGP))65,70,70	RIFF 360
65 IGP=IGP+1	RIFF 370
GO TO 25	RIFF 380
70 RAP(KGP)=0.	RIFF 390
DO 75 L=1,NROD	RIFF 400
RRAR(L,KGP)=RRAR(L,KGP)*DELTA	RIFF 410
RAP(KGP)=RAP(KGP)+RRAR(L,KGP)	RIFF 400
RRFR(L,KGP)=RRFR(L,KGP)*DELTA	RIFF 430
RRSR(L,KGP)=RRSR(L,KGP)*DELTA	RIFF 440
RRASUR(L,KGP)=RRASUR(L,KGP)*DELTA	RIFF 450
75 RRFSUR(L,KGP)=RRFSUR(L,KGP)*DELTA	RIFF 460
DO 80 M=1,NMOD	RIFF 470
RRAM(M,KGP)=RRAM(M,KGP)*DELTA	RIFF 480
RRSM(M,KGP)=RRSM(M,KGP)*DELTA	RIFF 490
80 RAP(KGP)=RAP(KGP)+RRAM(M,KGP)	RIFF 500
CPERT(KGP)=CPERT(KGP)*DELTA	RIFF 510
IF(KGP-NGP)85,90,90	RIFF 520
85 INIT=MGP(KGP)+1	RIFF 530
KGP=KGP+1	RIFF 540
GO TO 5	RIFF 550
90 NIX=10	RIFF 560
GO TO 30	RIFF 570
95 CALL OUTPUT	RIFF 580
IF(MORE)1,1,100	RIFF 590
100 END	RIFF 600

COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),	COMR	1
X TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),	COMR	2
X T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),	COMR	3
X T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),	COMR	4
X T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),	COMR	5
X HS(150),T23(155),H23(150),TCV23(7),TPV2(7),	COMR	6
X H1(150),T31(155),H31(150),TCV31(7),TPV3(7),	COMR	7
X H2(150),T32(155),H32(150),TCV32(7),TPS(7),	COMR	8
X H3(150),T33(155),H33(150),TCV33(7),PHIZ(3)	COMR	9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NRD,	COM1	1
XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,	COM1	2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,	COM1	3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,	COM1	4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,	COM1	5
X AB,AB2,PLROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,	COM1	6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,	COM1	7
X Z4,BA,P1ROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,	COM1	8
X NRESAB,P1MOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,	COM1	9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,	COM1	10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,	COM1	11
X AMASSM(10)	COM1	12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),	COM2	1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),	COM2	2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),	COM2	3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),	COM2	4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)	COM2	5
DATA(T12=		
X -0.06966166, -0.07047355, -0.07127480, -0.07206545, -0.07284554, T12		1
X -0.07361512, -0.07437422, -0.07512290, -0.07586118, -0.07658914, T12		6
X -0.07730680, -0.07801420, -0.07871140, -0.07939843, -0.08007535, T12		11
X -0.08074219, -0.08139899, -0.08204582, -0.08268270, -0.08330969, T12		16
X -0.08392683, -0.08453416, -0.08513172, -0.08571958, -0.08629776, T12		21
X -0.08686631, -0.08742529, -0.08797472, -0.08851467, -0.08904516, T12		26
X -0.08956626, -0.09007800, -0.09058042, -0.09107358, -0.09155752, T12		31
X -0.09203229, -0.09249792, -0.09295447, -0.09340197, -0.09384048, T12		36
X -0.09427004, -0.09469069, -0.09510248, -0.09550545, -0.09589965, T12		41
X -0.09666192, -0.09738963, -0.09808315, -0.09874283, -0.09936904, T12		46
X -0.09996211, -0.10052240, -0.10105028, -0.10154608, -0.10201016, T12		51
X -0.10244286, -0.10284454, -0.10321553, -0.10355619, -0.10386685, T12		56
X -0.10414785, -0.10439954, -0.10462224, -0.10481631, -0.10498207, T12		61
X -0.10511985, -0.10522999, -0.10531281, -0.10536863, -0.10539780, T12		66
X -0.10540062, -0.10537742, -0.10532852, -0.10525423, -0.10515488, T12		71
X -0.10503076, -0.10488220, -0.10470951, -0.10451298, -0.10429294, T12		76
X -0.10404967, -0.10378347, -0.10349466, -0.10318351, -0.10285033, T12		81
X -0.10249542, -0.10211905, -0.10172152, -0.10130311, -0.10086410, T12		86
X -0.10040479, -0.09992543, -0.09942632, -0.09890772, -0.09836991, T12		91
X -0.09890772, -0.09781317, -0.09664391, -0.09540207, -0.09408973, T12		96
X -0.09270893, -0.09126168, -0.08974995, -0.08817570, -0.08654082, T12		101
X -0.08484718, -0.08309662, -0.08129093, -0.07943191, -0.07752126, T12		106
X -0.07556070, -0.07355189, -0.07149648, -0.06939607, -0.06725222, T12		111
X -0.06506648, -0.06284036, -0.06057534, -0.05827285, -0.05593434, T12		116
X -0.05356117, -0.05115471, -0.04871629, -0.04624722, -0.04374875, T12		121
X -0.04122215, -0.03866862, -0.03608936, -0.03348554, -0.03085829, T12		126
X -0.02820873, -0.02553794, -0.02284698, -0.02013691, -0.01740872, T12		131
X -0.01466341, -0.01190194, -0.00912528, -0.00633432, -0.00352998, T12		136
X -0.00071313, 0.00211538, 0.00495470, 0.00780402, 0.01066255, T12		141
X 0.01352951, 0.01640414, 0.01928572, 0.02217352, 0.02506684, T12		146
X 0.02796500, 0.03086734, 0.03377322, 0.03668199, 0.03959306, T12		151
DATA(T13=		
X -0.06853148, -0.06967166, -0.07081172, -0.07195164, -0.07309143, T13		1
X -0.07423108, -0.07537058, -0.07650993, -0.07764914, -0.07878818, T13		6
X -0.07992706, -0.08106578, -0.08220432, -0.08334270, -0.08448089, T13		11

X	-0.08561890,	-0.08675673,	-0.08789436,	-0.08903179,	-0.09016904,	T13	16
X	-0.09130606,	-0.09244289,	-0.09357950,	-0.09471588,	-0.09585205,	T13	21
X	-0.09698799,	-0.09812369,	-0.09925917,	-0.10039439,	-0.10152937,	T13	26
X	-0.10266410,	-0.10379858,	-0.10493279,	-0.10606673,	-0.10720041,	T13	31
X	-0.10833380,	-0.10946692,	-0.11059975,	-0.11173229,	-0.11286454,	T13	36
X	-0.11399648,	-0.11512812,	-0.11625945,	-0.11739046,	-0.11852115,	T13	41
X	-0.12078155,	-0.12304060,	-0.12529826,	-0.12755450,	-0.12980926,	T13	46
X	-0.13206252,	-0.13431422,	-0.13656433,	-0.13881279,	-0.14105957,	T13	51
X	-0.14330463,	-0.14554792,	-0.14778941,	-0.15002904,	-0.15226677,	T13	56
X	-0.15450256,	-0.15673638,	-0.15896817,	-0.16119788,	-0.16342549,	T13	61
X	-0.16565094,	-0.16787420,	-0.17009521,	-0.17231394,	-0.17453034,	T13	66
X	-0.17674438,	-0.17895600,	-0.18116516,	-0.18337183,	-0.18557595,	T13	71
X	-0.18777750,	-0.18997641,	-0.19217266,	-0.19436621,	-0.19655699,	T13	76
X	-0.19874499,	-0.20093015,	-0.20311244,	-0.20529180,	-0.20746822,	T13	81
X	-0.20964162,	-0.21181200,	-0.21397929,	-0.21614346,	-0.21830447,	T13	86
X	-0.22046228,	-0.22261686,	-0.22476816,	-0.22691614,	-0.22906076,	T13	91
X	-0.22691614,	-0.23120199,	-0.23547411,	-0.23973221,	-0.24397598,	T13	96
X	-0.24820513,	-0.25241937,	-0.25661842,	-0.26080200,	-0.26496984,	T13	101
X	-0.26912167,	-0.27325723,	-0.27737626,	-0.28147851,	-0.28556374,	T13	106
X	-0.28963170,	-0.29368216,	-0.29771489,	-0.30172966,	-0.30572627,	T13	111
X	-0.30970448,	-0.31366411,	-0.31760494,	-0.32152678,	-0.32542944,	T13	116
X	-0.32931275,	-0.33317651,	-0.33702056,	-0.34084473,	-0.34464886,	T13	121
X	-0.34843279,	-0.35219638,	-0.35593947,	-0.35966193,	-0.36336362,	T13	126
X	-0.36704443,	-0.37070421,	-0.37434286,	-0.37796025,	-0.38155630,	T13	131
X	-0.38513088,	-0.38868391,	-0.39221529,	-0.39572494,	-0.39921277,	T13	136
X	-0.40267870,	-0.40612267,	-0.40954460,	-0.41294443,	-0.41632210,	T13	141
X	-0.41967756,	-0.42301075,	-0.42632164,	-0.42961017,	-0.43287632,	T13	146
X	-0.43612004,	-0.43934132,	-0.44254012,	-0.44571642,	-0.44887021,	T13	151

DATA(T21=

X	0.19102009,	0.19298408,	0.19492001,	0.19682822,	0.19870909,	T21	1
X	0.20056295,	0.20239016,	0.20419103,	0.20596591,	0.20771513,	T21	6
X	0.20943898,	0.21113780,	0.21281187,	0.21446152,	0.21608704,	T21	11
X	0.21768871,	0.21926682,	0.22082166,	0.22235351,	0.22386262,	T21	16
X	0.22534929,	0.22681377,	0.22825632,	0.22967720,	0.23107666,	T21	21
X	0.23245495,	0.23381231,	0.23514898,	0.23646521,	0.23776122,	T21	26
X	0.23903726,	0.24029353,	0.24153028,	0.24274772,	0.24394606,	T21	31
X	0.24512553,	0.24628633,	0.24742867,	0.24855276,	0.24965880,	T21	36
X	0.25074699,	0.25181752,	0.25287061,	0.25390643,	0.25492516,	T21	41
X	0.25691216,	0.25883308,	0.26068932,	0.26248230,	0.26421337,	T21	46
X	0.26588384,	0.26749502,	0.26904815,	0.27054446,	0.27198516,	T21	51
X	0.27337141,	0.27470435,	0.27598510,	0.27721474,	0.27839434,	T21	56
X	0.27952494,	0.28060755,	0.28164317,	0.28263276,	0.28357727,	T21	61
X	0.28447764,	0.28533476,	0.28614952,	0.28692280,	0.28765544,	T21	66
X	0.28834827,	0.28900211,	0.28961775,	0.29019597,	0.29073753,	T21	71
X	0.29124319,	0.29171366,	0.29214968,	0.29255194,	0.29292112,	T21	76
X	0.29325791,	0.29356296,	0.29383691,	0.29408041,	0.29429407,	T21	81
X	0.29447850,	0.29463429,	0.29476204,	0.29486232,	0.29493568,	T21	86
X	0.29498268,	0.29500386,	0.29499974,	0.29497086,	0.29491771,	T21	91
X	0.29497086,	0.29484080,	0.29461764,	0.29430520,	0.29390714,	T21	96
X	0.29342699,	0.29286815,	0.29223390,	0.29152739,	0.29075166,	T21	101
X	0.28990964,	0.28900414,	0.28803790,	0.28701352,	0.28593354,	T21	106
X	0.28480040,	0.28361643,	0.28238392,	0.28110503,	0.27978189,	T21	111
X	0.27841653,	0.27701090,	0.27556690,	0.27408635,	0.27257102,	T21	116
X	0.27102261,	0.26944275,	0.26783304,	0.26619498,	0.26453007,	T21	121
X	0.26283972,	0.26112531,	0.25938815,	0.25762954,	0.25585069,	T21	126
X	0.25405281,	0.25223704,	0.25040448,	0.24855622,	0.24669327,	T21	131
X	0.24481665,	0.24292730,	0.24102615,	0.23911410,	0.23719202,	T21	136
X	0.23526073,	0.23332103,	0.23137370,	0.22941949,	0.22745912,	T21	141
X	0.22549327,	0.22352262,	0.22154782,	0.21956948,	0.21758819,	T21	146
X	0.21560455,	0.21361911,	0.21163239,	0.20964492,	0.20765720,	T21	151

SUBROUTINE OUTPUT

PRINT 401, (TITLE(II), II=1,9)

OUT 000

OUT 010

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401 FORMAT(1H1,30X,9A8///30X,22HREACTION RATES IN CELL //45X,17HVOLUMEOUT 020
X INTEGRATED,38X,17HAT SURFACE OF ROD/20H MATERIAL GROUP,10X, OUT 030
X10HSCATTERING,2(10X,10HABSORPTION,13X,7HFISSION) ) OUT 040
REP=1, OUT 050
DO 5 II=1,NRESAB OUT 060
TOTAL1(II)=0, OUT 070
TOTAL2(II)=0, OUT 080
5 CDEN(II)=1./(VR(1)*ADENR(II)) OUT 090
DO 30 I=1,NGP OUT 100
RAP(I)=RAP(I)/SDD OUT 110
REP=REP-RAP(I) OUT 120
TPHIR(I)=0, OUT 130
TPHIM(I)=0, OUT 140
DO 10 JJ=1,3 OUT 150
TPHIR(I) =TPHIR(I) +VR(JJ)*TFLUXR(JJ,I)*DELTA OUT 160
TPHIM(I) =TPHIM(I) +VM(JJ)*TFLUXM(JJ,I)*DELTA OUT 170
PA(JJ)=0, OUT 180
10 PB(JJ)=0, OUT 190
DO 20 J=1,NROD OUT 200
PRINT 402,MATROD(J),I,RRSR(J,I),RRAR(J,I),RRFR(J,I),RRASUR(J,I), OUT 210
X RRSUR(J,I) OUT 220
402 FORMAT(4X,A6,I10,5E20,4) OUT 230
PA(1)=PA(1)+RRSR(J,I) OUT 240
PA(2)=PA(2)+RRAR(J,I) OUT 250
PA(3)=PA(3)+RRFR(J,I) OUT 260
IF(J=NRESAB)15,15,20 OUT 270
15 RRAR(J,I)=CDEN(J)*RRAR(J,I) OUT 280
RRFR(J,I)=CDEN(J)*RRFR(J,I) OUT 290
TOTAL1(J)=TOTAL1(J)+RRAR(J,I) OUT 300
TOTAL2(J)=TOTAL2(J)+RRFR(J,I) OUT 310
20 CONTINUE OUT 320
PRINT 403,I,(PA(IJ),IJ=1,3) OUT 330
403 FORMAT(//10H TOTAL ROD,I10,3E20,4//) OUT 340
DO 25 K=1,NMOD OUT 350
PB(1)=PB(1)+RRSM(K,I) OUT 360
PB(2)=PB(2)+RRAM(K,I) OUT 370
25 PRINT 404,MATMOD(K),I,RRSM(K,I),RRAM(K,I) OUT 380
404 FORMAT(4X,A6,I10,2E20,4) OUT 390
PRINT 405,I,PB(1),PB(2) OUT 400
405 FORMAT(//16H TOTAL MODERATOR,I4,2E20,4//) OUT 410
30 CONTINUE OUT 420
PRINT 406,(TITLE(IT),IT=1,9) OUT 430
406 FORMAT(1H1,30X,9A8///50X,38HEFFECTIVE RESONANCE INTEGRALS IN BARN,OUT 440
X/22X,8HMATERIAL,5X,5HGROUP,10X,10HABSORPTION,13X,7HFISSION) OUT 450
DO 40 K=1,NRESAB OUT 460
DO 35 M=1,NGP OUT 470
35 PRINT 407,MATROD(K),M,RRAR(K,M),RRFR(K,M) OUT 480
40 PRINT 408,MATROD(K),TOTAL1(K),TOTAL2(K) OUT 490
407 FORMAT(24X,A6,I10,2E20,4) OUT 500
408 FORMAT(//24X,A6,5X,5HTOTAL,2E20,4//) OUT 510
PRINT 409,(TITLE(LL),LL=1,9) OUT 520
409 FORMAT(1H1,30X,9A8///46X,14HFLUX INTEGRALS,30X,27HPERTURBED COLLISQUY 530
XION DENSITY/32X,3HROD,35X,9HMODERATOR,11X,15HINTEGRAL IN ROD,15X, OUT 540
X10HABSORPTION/5X,5HGROUP,2(11X,9HPERTURBED,10X,10HASYPOTIC),29X,OUT 550
X11HPROBABILITY) OUT 560
DO 60 N=1,NGP OUT 570
IF(N=1)45,45,50 OUT 580
45 F=FLOATF(MGP(N))*DELTA OUT 590
GO TO 55 OUT 600
50 F=FLOATF(MGP(N)-MGP(N-1))*DELTA OUT 610
55 Z2=VR(1)*F OUT 620
Z4=VM(1)*F OUT 630
60 PRINT 411,N,TPHIR(N),Z2,TPHIM(N),Z4,CPERT(N),RAP(N) OUT 640
411 FORMAT(5X,I5,6E20,4) OUT 650
PRINT 412,REP OUT 660
412 FORMAT(///40X,34HTOTAL NON-ABSORPTION PROBABILITY =,F7,5) OUT 670
RETURN OUT 680
END OUT 690

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SUBROUTINE ROD

COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),	COMR	1
X TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),	COMR	2
X T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),	COMR	3
X T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),	COMR	4
X T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),	COMR	5
X HS(150),T23(155),H23(150),TCV23(7),TPV2(7),	COMR	6
X H1(150),T31(155),H31(150),TCV31(7),TPV3(7),	COMR	7
X H2(150),T32(155),H32(150),TCV32(7),TPS(7),	COMR	8
X H3(150),T33(155),H33(150),TCV33(7),PHIZ(3)	COMR	9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD,	COM1	1
XS(3),TAB,SIGPR(10),SIGF22(10),LRD(10),CDEN(4),SIGMAC(600),NMOD,	COM1	2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,	COM1	3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,	COM1	4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,	COM1	5
X AB,AB2,PLROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,	COM1	6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,	COM1	7
X Z4,BA,P1ROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,	COM1	8
X NRESAB,P1MOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,	COM1	9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,	COM1	10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,	COM1	11
X AMASSM(10)	COM1	12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),	COM2	1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),	COM2	2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),	COM2	3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),	COM2	4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)	COM2	5
DATA(TS =		
X 0.57010597, 0.56507400, 0.56009424, 0.55516607, 0.55028886, TS		1
X 0.54546199, 0.54068485, 0.53595685, 0.53127740, 0.52664591, TS		6
X 0.52206181, 0.51752454, 0.51303355, 0.50858828, 0.50418820, TS		11
X 0.49983277, 0.49552148, 0.49125379, 0.48702921, 0.48284724, TS		16
X 0.47870737, 0.47460911, 0.47055200, 0.46653554, 0.46255928, TS		21
X 0.45862275, 0.45472549, 0.45086706, 0.44704701, 0.44326491, TS		26
X 0.43952032, 0.43581282, 0.43214199, 0.42850741, 0.42490867, TS		31
X 0.42134538, 0.41781713, 0.41432353, 0.41086419, 0.40743873, TS		36
X 0.40404677, 0.40068795, 0.39736188, 0.39406821, 0.39080659, TS		41
X 0.38437804, 0.37807346, 0.37189014, 0.36582544, 0.35987680, TS		46
X 0.35404169, 0.34831767, 0.34270236, 0.33719343, 0.33178860, TS		51
X 0.32648566, 0.32128245, 0.31617685, 0.31116680, 0.30625029, TS		56
X 0.30142537, 0.29669011, 0.29204264, 0.28748113, 0.28300380, TS		61
X 0.27860890, 0.27429473, 0.27005964, 0.26590198, 0.26182018, TS		66
X 0.25781268, 0.25387797, 0.25001457, 0.24622102, 0.24249591, TS		71
X 0.23883786, 0.23524552, 0.23171756, 0.22825270, 0.22484966, TS		76
X 0.22150721, 0.21822415, 0.21499928, 0.21183147, 0.20871957, TS		81
X 0.20566248, 0.20265912, 0.19970842, 0.19680937, 0.19396094, TS		86
X 0.19116214, 0.18841200, 0.18570958, 0.18305395, 0.18044419, TS		91
X 0.18305395, 0.17787943, 0.17288141, 0.16805314, 0.16338818, TS		96
X 0.15888033, 0.15452366, 0.15031249, 0.14624136, 0.14230505, TS		101
X 0.13849853, 0.13481700, 0.13125584, 0.12781062, 0.12447709, TS		106
X 0.12125117, 0.11812894, 0.11510663, 0.11218063, 0.10934748, TS		111
X 0.10660383, 0.10394649, 0.10137237, 0.09887852, 0.09646209, TS		116
X 0.09412035, 0.09185067, 0.08965053, 0.08751750, 0.08544923, TS		121
X 0.08344349, 0.08149810, 0.07961099, 0.07778016, 0.07600368, TS		126
X 0.07427968, 0.07260640, 0.07098211, 0.06940516, 0.06787394, TS		131
X 0.06638694, 0.06494267, 0.06353970, 0.06217667, 0.06085226, TS		136
X 0.05956518, 0.05831422, 0.05709820, 0.05591596, 0.05476642, TS		141
X 0.05364852, 0.05256123, 0.05150356, 0.05047458, 0.04947336, TS		146
X 0.04849902, 0.04755071, 0.04662760, 0.04572890, 0.04485385, TS		151
DATA(T1 =		
X 0.71649005, 0.71299345, 0.70952541, 0.70608560, 0.70267365, T1		1
X 0.69928924, 0.69593204, 0.69260171, 0.68929795, 0.68602043, T1		6

X	0.68276884,	0.67954290,	0.67634230,	0.67316674,	0.67001595,	T1	11
X	0.66688964,	0.66378753,	0.66070936,	0.65765485,	0.65462375,	T1	16
X	0.65161579,	0.64863072,	0.64566830,	0.64272826,	0.63981038,	T1	21
X	0.63691441,	0.63404012,	0.63118728,	0.62835567,	0.62554504,	T1	26
X	0.62275520,	0.61998591,	0.61723697,	0.61450816,	0.61179929,	T1	31
X	0.60911013,	0.60644049,	0.60379018,	0.60115899,	0.59854674,	T1	36
X	0.59595323,	0.59337827,	0.59082168,	0.58828329,	0.58576290,	T1	41
X	0.58077544,	0.57585791,	0.57100896,	0.56622728,	0.56151158,	T1	46
X	0.55686061,	0.55227316,	0.54774803,	0.54328407,	0.53888016,	T1	51
X	0.53453519,	0.53024809,	0.52601781,	0.52184333,	0.51772366,	T1	56
X	0.51365782,	0.50964485,	0.50568383,	0.50177385,	0.49791403,	T1	61
X	0.49410349,	0.49034140,	0.48662691,	0.48295922,	0.47933755,	T1	66
X	0.47576110,	0.47222913,	0.46874090,	0.46529567,	0.46189274,	T1	71
X	0.45853141,	0.45521100,	0.45193085,	0.44869029,	0.44548870,	T1	76
X	0.44232545,	0.43919992,	0.43611151,	0.43305963,	0.43004371,	T1	81
X	0.42706318,	0.42411749,	0.42120609,	0.41832845,	0.41548405,	T1	86
X	0.41267238,	0.40989293,	0.40714521,	0.40442874,	0.40174304,	T1	91
X	0.40442874,	0.39908766,	0.39386600,	0.38876021,	0.38376689,	T1	96
X	0.37888273,	0.37410457,	0.36942935,	0.36485412,	0.36037603,	T1	101
X	0.35599234,	0.35170041,	0.34749766,	0.34338164,	0.33934996,	T1	106
X	0.33540032,	0.33153047,	0.32773829,	0.32402167,	0.32037860,	T1	111
X	0.31680715,	0.31330542,	0.30987160,	0.30650391,	0.30320064,	T1	116
X	0.29996015,	0.29678083,	0.29366112,	0.29059952,	0.28759458,	T1	121
X	0.28464488,	0.28174905,	0.27890576,	0.27611372,	0.27337169,	T1	126
X	0.27067845,	0.26803283,	0.26543368,	0.26287990,	0.26037041,	T1	131
X	0.25790416,	0.25548013,	0.25309738,	0.25075490,	0.24845178,	T1	136
X	0.24618713,	0.24396005,	0.24176969,	0.23961524,	0.23749587,	T1	141
X	0.23541082,	0.23335930,	0.23134059,	0.22935397,	0.22739872,	T1	146
X	0.22547417,	0.22357965,	0.22171451,	0.21987813,	0.21806990,	T1	151
DATA(TEPV1= .13333333E+01, .12444444E+01, .11961904E+01)							
DATA(TEPV2= .682965760E+00, .641299090E+00, .620465760E+00)							
DATA(TEPV3= .534440000E-01, .591650000E-01, .619410000E+01)							
DATA(TEPV4= .416666667E-01, .486111111E-01, .520833333E+01)							
DATA(TCV1= .156190476E+01, .102433862E+01, .884502164E+00, D TCV1							
X	=.304761924E+00, .101587301E+01, .100663781E+01,					D	TCV1
X	=.228571430E+00, .863492064E+00, .574891775E+00,					D	TCV1
DATA(TCV2= .807965746E+00, .682965770E+00, .637132419E+00, D TCV2							
X	=.250000000E+00, .000000000E+00, .500000000E-01,					D	TCV2
X	.000000000E+00, -.125000000E+00, -.125000000E+00,					D	TCV2
DATA(TCV3= .500000000E+00, .500000000E+00, .500000000E+00, D TCV3							
X	.000000000E+00, .000000000E+00, .000000000E+00,					D	TCV3
X	.000000000E+00, .000000000E+00, .000000000E+00,					D	TCV3
DATA(TCV4= .354245000E-01, .448291000E-01, .491585800E-01, D TCV4							
X	.394602480E-01, .298305280E-01, .260605800E-01,					D	TCV4
X	=.520833333E-01, -.173611000E-02, -.743994000E-03,					D	TCV4
DATA(TCV5= .208333333E-01, .277777778E-01, .312500000E-01, D TCV5							
X	.416666667E-01, .416666667E-01, .416666667E-01,					D	TCV5
X	.000000000E+00, .000000000E+00, .000000000E+00,					D	TCV5
DATA(TPS= .00000000E+00, .18750000E+00, .00000000E+00, .1171876E+00 D TPS							
X	.00000000E+00, .3845214E+01, .00000000E+00,					D	TPS
DATA(TPV1= .50000000E+00, .00000000E+00, .93750000E-01, .00000000E+00 D TPV1							
X	=.5859375E-01, .00000000E+00, .1922607E-01,					D	TPV1
DATA(TPV2= .10000000E+01, .13333333E+01, .13125000E+01, .00000000E+00 D TPV2							
X	=.7421875E+00, .00000000E+00, .9997558E+00,					D	TPV2
DATA(TPV3= .15000000E+01, .40000000E+01, .1021875E+02, .19500000E+02 D TPV3							
X	.2044930E+02, .00000000E+00, .1472700E+02,					D	TPV3
DATA(TCV11= .15000000E+01, .16000000E+02, .7771875E+02, .19200000E+03 D TCV11							
X	=.2173242E+03, .00000000E+00, .1310065E+03,					D	TCV11
DATA(TCV12= .12000000E+02, .11200000E+03, .48375000E+03, .11520000E+04 D TCV12							
X	.1296094E+04, .00000000E+00, .7945752E+03,					D	TCV12
DATA(TCV13= .15000000E+02, .12000000E+03, .4921875E+03, .11520000E+04 D TCV13							
X	=.1291992E+04, .00000000E+00, .7994200E+03,					D	TCV13

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DATA(TCV21=, .3000000E+02, .3066667E+02, -, .1119375E+03, .1920000E+03 D TCV21
X      , .8574218E+02, .0000000E+00, -, .4645790E+03) D TCV21
DATA(TCV22= .2400000E+02, -, .1920000E+03, .6675000E+03, -, .1152000E+04 D TCV22
X      , .5550000E+03, .0000000E+00, .2707646E+04) D TCV22
DATA(TCV23=, .3000000E+02, .2000000E+03, -, .6693750E+03, .1152000E+04 D TCV23
X      , .5730469E+03, .0000000E+00, -, .2664734E+04) D TCV23
DATA(TCV31=, .4500000E+01, .3600000E+02, -, .1206562E+03, .2112000E+03 D TCV31
X      , .1865040E+03, .0000000E+00, .4551580E+03) D TCV31
DATA(TCV32= .3600000E+02, -, .2240000E+03, .6952500E+03, -, .1152000E+04 D TCV32
X      , .9107812E+03, .0000000E+00, -, .2073647E+04) D TCV32
DATA(TCV33=, .4500000E+02, .2400000E+03, -, .7115625E+03, .1152000E+04 D TCV33
X      , .8680080E+03, .0000000E+00, .1800150E+04) D TCV33
IF(Z=,3)100,100,10 ROD 010
10 IF(Z=8.09)200,300,300 ROD 020
100 F=LOGF(Z) ROD 030
Z2=Z**2 ROD 040
Z4=Z2**2 ROD 050
DO 150 I=1,3 ROD 060
EPV(I)=1, -TEPV1(I)*Z+(TEPV2(I)-.5*F)*Z2+(TEPV3(I)-TEPV4(I)*F)*Z4 ROD 070
DO 150 J=1,3 ROD 080
150 CV(I,J)=TCV1(I,J)*Z-(TCV2(I,J)-TCV3(I,J)*F)*Z2-(TCV4(I,J)-TCV5(I, ROD 090
1 J)*F)*Z4 ROD 100
EPS=1.-2.*Z*EPV(1) ROD 110
GO TO 400 ROD 120
300 F=1. ROD 130
CV(1,1)=1. ROD 140
CV(1,2)=0. ROD 150
CV(1,3)=0. ROD 160
CV(2,1)=0. ROD 170
CV(2,2)=2. ROD 180
CV(2,3)=0. ROD 190
CV(3,1)=0. ROD 200
CV(3,2)=0. ROD 210
CV(3,3)=3. ROD 220
EPV(1)=0. ROD 230
EPV(2)=0. ROD 240
EPV(3)=0. ROD 250
EPS=0. ROD 260
MAX=3.+40./Z ROD 270
IF(MAX=7)320,320,310 ROD 280
310 MAX=7 ROD 290
320 DO 350 K=1,MAX ROD 300
F=F/Z ROD 310
CV(1,1)=CV(1,1)+F*TCV11(K) ROD 320
CV(1,2)=CV(1,2)+F*TCV12(K) ROD 330
CV(1,3)=CV(1,3)+F*TCV13(K) ROD 340
CV(2,1)=CV(2,1)+F*TCV21(K) ROD 350
CV(2,2)=CV(2,2)+F*TCV22(K) ROD 360
CV(2,3)=CV(2,3)+F*TCV23(K) ROD 370
CV(3,1)=CV(3,1)+F*TCV31(K) ROD 380
CV(3,2)=CV(3,2)+F*TCV32(K) ROD 390
CV(3,3)=CV(3,3)+F*TCV33(K) ROD 400
EPV(1)=EPV(1)+F*TPV1(K) ROD 410
EPV(2)=EPV(2)+F*TPV2(K) ROD 420
EPV(3)=EPV(3)+F*TPV3(K) ROD 430
350 EPS=EPS+F*TPS(K) ROD 440
GO TO 400 ROD 450
200 IF(Z=1.01)210,220,220 ROD 690
210 IF(Z=.53)230,240,240 ROD 460
220 IF(Z=2.17)250,250,260 ROD 470
230 INDEX=200.+Z*59. ROD 480
PP=200.*Z*59.-FLOATF(INDEX) ROD 490

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	GO TO 270	ROD	500
240	INDEX=100.*Z-7.	ROD	510
	PP=100.*Z-7.-FLOATF(INDEX)	ROD	520
	GO TO 270	ROD	530
250	INDEX=50.*Z+45.5	ROD	540
	PP=50.*Z+45.5-FLOATF(INDEX)	ROD	550
	GO TO 270	ROD	560
260	INDEX=25.*Z+53.25	ROD	570
	PP=25.*Z+53.25-FLOATF(INDEX)	ROD	580
270	INDEX1=INDEX+1	ROD	640
	INDEX2=INDEX+2	ROD	650
	PPZ=1.-.5*PP*(3.-PP)	ROD	660
	PP1=PP*(2.-PP)	ROD	670
	PP2=.5*PP*(PP-1.)	ROD	680
	IF(Z-2.17)280,290,290	ROD	690
280	EPV(1)=PPZ*T1(INDEX)+PP1*T1(INDEX1)+PP2*T1(INDEX2)	ROD	700
	EPV(2)=PPZ*T2(INDEX)+PP1*T2(INDEX1)+PP2*T2(INDEX2)	ROD	710
	EPV(3)=PPZ*T3(INDEX)+PP1*T3(INDEX1)+PP2*T3(INDEX2)	ROD	720
	EPS =PPZ*TS(INDEX)+PP1*TS(INDEX1)+PP2*TS(INDEX2)	ROD	730
	CV(1,1)=PPZ*T11(INDEX)+PP1*T11(INDEX1)+PP2*T11(INDEX2)	ROD	740
	CV(1,2)=PPZ*T12(INDEX)+PP1*T12(INDEX1)+PP2*T12(INDEX2)	ROD	750
	CV(1,3)=PPZ*T13(INDEX)+PP1*T13(INDEX1)+PP2*T13(INDEX2)	ROD	760
	CV(2,1)=PPZ*T21(INDEX)+PP1*T21(INDEX1)+PP2*T21(INDEX2)	ROD	770
	CV(2,2)=PPZ*T22(INDEX)+PP1*T22(INDEX1)+PP2*T22(INDEX2)	ROD	780
	CV(2,3)=PPZ*T23(INDEX)+PP1*T23(INDEX1)+PP2*T23(INDEX2)	ROD	790
	CV(3,1)=PPZ*T31(INDEX)+PP1*T31(INDEX1)+PP2*T31(INDEX2)	ROD	800
	CV(3,2)=PPZ*T32(INDEX)+PP1*T32(INDEX1)+PP2*T32(INDEX2)	ROD	810
	CV(3,3)=PPZ*T33(INDEX)+PP1*T33(INDEX1)+PP2*T33(INDEX2)	ROD	820
	GO TO 400	ROD	830
290	EPV(1)=PPZ*H1(INDEX)+PP1*H1(INDEX1)+PP2*H1(INDEX2)	ROD	840
	EPV(2)=PPZ*H2(INDEX)+PP1*H2(INDEX1)+PP2*H2(INDEX2)	ROD	850
	EPV(3)=PPZ*H3(INDEX)+PP1*H3(INDEX1)+PP2*H3(INDEX2)	ROD	860
	EPS =PPZ*HS(INDEX)+PP1*HS(INDEX1)+PP2*HS(INDEX2)	ROD	870
	CV(1,1)=PPZ*H11(INDEX)+PP1*H11(INDEX1)+PP2*H11(INDEX2)	ROD	880
	CV(1,2)=PPZ*H12(INDEX)+PP1*H12(INDEX1)+PP2*H12(INDEX2)	ROD	890
	CV(1,3)=PPZ*H13(INDEX)+PP1*H13(INDEX1)+PP2*H13(INDEX2)	ROD	900
	CV(2,1)=PPZ*H21(INDEX)+PP1*H21(INDEX1)+PP2*H21(INDEX2)	ROD	910
	CV(2,2)=PPZ*H22(INDEX)+PP1*H22(INDEX1)+PP2*H22(INDEX2)	ROD	920
	CV(2,3)=PPZ*H23(INDEX)+PP1*H23(INDEX1)+PP2*H23(INDEX2)	ROD	930
	CV(3,1)=PPZ*H31(INDEX)+PP1*H31(INDEX1)+PP2*H31(INDEX2)	ROD	940
	CV(3,2)=PPZ*H32(INDEX)+PP1*H32(INDEX1)+PP2*H32(INDEX2)	ROD	950
	CV(3,3)=PPZ*H33(INDEX)+PP1*H33(INDEX1)+PP2*H33(INDEX2)	ROD	960
400	RETURN	ROD	970
	END	ROD	980

SUBROUTINE SOURCE										SOUR	010
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),										COMR	1
X	TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),									COMR	2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),									COMR	3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),									COMR	4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),									COMR	5
X	HS(150),T23(155),H23(150),TCV23(7),TPV2(7),									COMR	6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),									COMR	7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),									COMR	8
X	H3(150),T33(155),H33(150),TCV33(7),PHIZ(3)									COMR	9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD,										COM1	1
XS(3),TAB,SIGPR(10),SIGF22(10),LRMD(10),CDEN(4),SIGMAC(600),NMROD,										COM1	2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,										COM1	3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,										COM1	4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,										COM1	5
X AB,AB2,PLROD(10),SIGPMM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,										COM1	6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,										COM1	7
X Z4,BA,P1ROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,										COM1	8
X NRESAB,P1MOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,										COM1	9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,										COM1	10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,										COM1	11
X AMASSM(10)										COM1	12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),										COM2	1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),										COM2	2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),										COM2	3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),										COM2	4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)										COM2	5
DATA(T32=											
X	0.29686530,	0.30170743,	0.30653763,	0.31139086,	0.31621955,	T32	1				
X	0.32104762,	0.32587483,	0.33069448,	0.33550401,	0.34031981,	T32	6				
X	0.34512855,	0.34993158,	0.35473277,	0.35952542,	0.36431748,	T32	11				
X	0.36910487,	0.37388496,	0.37866093,	0.38343434,	0.38820463,	T32	16				
X	0.39296311,	0.39772354,	0.40247610,	0.40722749,	0.41197098,	T32	21				
X	0.41671324,	0.42144642,	0.42617797,	0.43090304,	0.43562404,	T32	26				
X	0.44033860,	0.44505370,	0.44975686,	0.45445955,	0.45915604,	T32	31				
X	0.46384733,	0.46853216,	0.47321464,	0.47789075,	0.48256171,	T32	36				
X	0.48722696,	0.49188751,	0.49654163,	0.50119250,	0.50583753,	T32	41				
X	0.51511137,	0.52436327,	0.53359297,	0.54280209,	0.55198857,	T32	46				
X	0.56115305,	0.57029416,	0.57941270,	0.58850959,	0.59758201,	T32	51				
X	0.60663133,	0.61565764,	0.62465981,	0.63363776,	0.64259242,	T32	56				
X	0.65152231,	0.66042792,	0.66930847,	0.67816469,	0.68699590,	T32	61				
X	0.69580187,	0.70458237,	0.71333708,	0.72206690,	0.73077061,	T32	66				
X	0.73944824,	0.74810009,	0.75672512,	0.76532404,	0.77389640,	T32	71				
X	0.78244216,	0.79096090,	0.79945302,	0.80791779,	0.81635542,	T32	76				
X	0.82476567,	0.83314848,	0.84150360,	0.84983122,	0.85813082,	T32	81				
X	0.86640271,	0.87464633,	0.88286203,	0.89104926,	0.89920829,	T32	86				
X	0.90733878,	0.91544080,	0.92351426,	0.93155890,	0.93957481,	T32	91				
X	0.93155895,	0.94756175,	0.96344872,	0.97921920,	0.99487262,	T32	96				
X	1.01040838,	1.02582612,	1.04112522,	1.05630527,	1.07136602,	T32	101				
X	1.08630693,	1.10112792,	1.11582855,	1.13040859,	1.14486789,	T32	106				
X	1.15920622,	1.17342347,	1.18751950,	1.20149428,	1.21534769,	T32	111				
X	1.22907975,	1.24269044,	1.25617983,	1.26954795,	1.28279492,	T32	116				
X	1.29592084,	1.30892584,	1.32181003,	1.33457368,	1.34721697,	T32	121				
X	1.35974013,	1.37214340,	1.38442705,	1.39659140,	1.40863675,	T32	126				
X	1.42056341,	1.43237176,	1.44406213,	1.45563497,	1.46709062,	T32	131				
X	1.47842952,	1.48965210,	1.50075881,	1.51175012,	1.52262649,	T32	136				
X	1.53338843,	1.54403641,	1.55457097,	1.56499264,	1.57530195,	T32	141				
X	1.58549942,	1.59558565,	1.60556119,	1.61542662,	1.62518252,	T32	146				
X	1.63482949,	1.64436816,	1.65379911,	1.66312295,	1.67234034,	T32	151				
DATA(T33=											
X	-0.16121393,	-0.16370736,	-0.16618659,	-0.16868663,	-0.17115994,	T33	1				
X	-0.17363047,	-0.17609800,	-0.17855588,	-0.18100157,	-0.18345148,	T33	6				

X	-0.18589236,	-0.18832554,	-0.19075494,	-0.19317390,	-0.19559040,	T33	11
X	-0.19800038,	-0.20040125,	-0.20279621,	-0.20518687,	-0.20757271,	T33	16
X	-0.20994503,	-0.21231766,	-0.21468080,	-0.21704117,	-0.21939207,	T33	21
X	-0.22174023,	-0.22407781,	-0.22641229,	-0.22873885,	-0.23105994,	T33	26
X	-0.23337321,	-0.23568568,	-0.23798491,	-0.24028237,	-0.24257237,	T33	31
X	-0.24485596,	-0.24713190,	-0.24940433,	-0.25166926,	-0.25392792,	T33	36
X	-0.25617981,	-0.25842595,	-0.26066465,	-0.26289912,	-0.26512679,	T33	41
X	-0.26956316,	-0.27397413,	-0.27835965,	-0.28272158,	-0.28705807,	T33	46
X	-0.29137000,	-0.29565621,	-0.29991772,	-0.30415568,	-0.30836748,	T33	51
X	-0.31255469,	-0.31671762,	-0.32085534,	-0.32496799,	-0.32905670,	T33	56
X	-0.33312018,	-0.33715913,	-0.34117297,	-0.34516261,	-0.34912757,	T33	61
X	-0.35306781,	-0.35698329,	-0.36087387,	-0.36474063,	-0.36858254,	T33	66
X	-0.37239979,	-0.37619289,	-0.37996094,	-0.38370484,	-0.38742430,	T33	71
X	-0.39111944,	-0.39479002,	-0.39843659,	-0.40205860,	-0.40565640,	T33	76
X	-0.40922989,	-0.41277919,	-0.41630420,	-0.41980523,	-0.42328194,	T33	81
X	-0.42673477,	-0.43016329,	-0.43356801,	-0.43694851,	-0.44030519,	T33	86
X	-0.44363784,	-0.44694669,	-0.45023174,	-0.45349288,	-0.45673031,	T33	91
X	-0.45349292,	-0.45994393,	-0.46630019,	-0.47256200,	-0.47872969,	T33	96
X	-0.48480352,	-0.49078401,	-0.49667134,	-0.50246590,	-0.50816819,	T33	101
X	-0.51377840,	-0.51929716,	-0.52472471,	-0.53006146,	-0.53530788,	T33	106
X	-0.54046435,	-0.54553133,	-0.55050922,	-0.55539852,	-0.56019961,	T33	111
X	-0.56491301,	-0.56953912,	-0.57407847,	-0.57853150,	-0.58289872,	T33	116
X	-0.58718060,	-0.59137764,	-0.59549027,	-0.59951909,	-0.60346457,	T33	121
X	-0.60732722,	-0.61110754,	-0.61480607,	-0.61842334,	-0.62195987,	T33	126
X	-0.62541618,	-0.62879283,	-0.63209034,	-0.63530928,	-0.63845017,	T33	131
X	-0.64151356,	-0.64450001,	-0.64741008,	-0.65024431,	-0.65300328,	T33	136
X	-0.65568755,	-0.65829766,	-0.66083418,	-0.66329770,	-0.66568878,	T33	141
X	-0.66800796,	-0.67025585,	-0.67243299,	-0.67453998,	-0.67657736,	T33	146
X	-0.67854573,	-0.68044566,	-0.68227773,	-0.68404248,	-0.68574053,	T33	151
DATA(HS :							
X	0.04572890,	0.04400171,	0.04236331,	0.04080829,	0.03933161,	HS	1
X	0.03792855,	0.03659473,	0.03532605,	0.03411867,	0.03296903,	HS	6
X	0.03187378,	0.03082979,	0.02983415,	0.02888413,	0.02797716,	HS	11
X	0.02711085,	0.02628295,	0.02549137,	0.02473412,	0.02400936,	HS	16
X	0.02331536,	0.02265049,	0.02201321,	0.02140209,	0.02081578,	HS	21
X	0.02025300,	0.01971257,	0.01919336,	0.01869430,	0.01821441,	HS	26
X	0.01775275,	0.01730842,	0.01688059,	0.01646849,	0.01607135,	HS	31
X	0.01568849,	0.01531923,	0.01496296,	0.01461908,	0.01428702,	HS	36
X	0.01396627,	0.01365631,	0.01335668,	0.01306693,	0.01278661,	HS	41
X	0.01251535,	0.01225274,	0.01199843,	0.01175207,	0.01151333,	HS	46
X	0.01128191,	0.01105750,	0.01083983,	0.01062862,	0.01042362,	HS	51
X	0.01022460,	0.01003131,	0.00984354,	0.00966108,	0.00948373,	HS	56
X	0.00931130,	0.00914361,	0.00898048,	0.00882174,	0.00866725,	HS	61
X	0.00851684,	0.00837039,	0.00822773,	0.00808875,	0.00795331,	HS	66
X	0.00782130,	0.00769260,	0.00756710,	0.00744469,	0.00732527,	HS	71
X	0.00720874,	0.00709501,	0.00698399,	0.00687559,	0.00676973,	HS	76
X	0.00666633,	0.00656532,	0.00646660,	0.00637014,	0.00627584,	HS	81
X	0.00618364,	0.00609349,	0.00600532,	0.00591907,	0.00583469,	HS	86
X	0.00575211,	0.00567130,	0.00559220,	0.00551477,	0.00543894,	HS	91
X	0.00536469,	0.00529196,	0.00522071,	0.00515092,	0.00508252,	HS	96
X	0.00501549,	0.00494979,	0.00488539,	0.00482225,	0.00476033,	HS	101
X	0.00469960,	0.00464005,	0.00458163,	0.00452431,	0.00446807,	HS	106
X	0.00441288,	0.00435872,	0.00430555,	0.00425336,	0.00420212,	HS	111
X	0.00415180,	0.00410240,	0.00405387,	0.00400621,	0.00395939,	HS	116
X	0.00391339,	0.00386818,	0.00382378,	0.00378013,	0.00373722,	HS	121
X	0.00369505,	0.00365360,	0.00361284,	0.00357276,	0.00353336,	HS	126
X	0.00349459,	0.00345648,	0.00341898,	0.00338210,	0.00334582,	HS	131
X	0.00331010,	0.00327497,	0.00324040,	0.00320638,	0.00317289,	HS	136
X	0.00313992,	0.00310747,	0.00307552,	0.00304407,	0.00301309,	HS	141
X	0.00298259,	0.00295255,	0.00292296,	0.00289383,	0.00286511,	HS	146
IF (IGP-1) 10,10,20							SOURCE20
10 NU=1							SOUR 021

DO 11 I=1,3	SOUR 030
S(I)=0.	SOUR 040
11 Q(I)=0.	SOUR 050
DO 12 IA=1,NROD	SOUR 060
12 S(1)=S(1)+SIGPMR(IA)	SOUR 080
DO 13 IB=1,NMOD	SOUR 090
13 Q(1)=Q(1)+SIGPMM(IB)	SOUR 110
GO TO 200	SOUR 120
20 MU=(IGP-MU-2)/LARGE	SOUR 130
NU=IGP-MU*(LARGE+1)	SOUR 140
DO 60 J=1,3	SOUR 150
S(J)=S(J)*EXDU	SOUR 160
DO 60 K=1,NROD	SOUR 170
S(J)=S(J)+PIROD(K)+PHIROD(J)*SIGS(K)	SOUR 180
IF(LROD(K)-LARGE)30,30,25	SOUR 190
25 S(J)=S(J)-PLROD(K)+PHIZ(J)*SIGPMR(K)	SOUR 200
GO TO 60	SOUR 210
30 JP=IGP-LROD(K)-1	SOUR 220
IF(JP)25,25,35	SOUR 230
35 IF(MU)40,40,45	SOUR 240
40 IF(K-NRESAB)42,42,44	SOUR 250
42 S(J)=S(J)-PLROD(K)+FLUXR(JP,J)*SIGSS(JP,K)	SOUR 251
GO TO 60	SOUR 252
44 S(J)=S(J)-PLROD(K)+FLUXR(JP,J)*SIGPMR(K)	SOUR 253
GO TO 60	SOUR 260
45 KAPPA=NU+LARGE-LROD(K)	SOUR 270
LAMBDA=KAPPA-LARGE-1	SOUR 280
IF(LAMBDA)55,55,50	SOUR 290
50 KAPPA=LAMBDA	SOUR 300
55 IF(K-NRESAB)57,57,59	SOUR 310
57 S(J)=S(J)-PLROD(K)+FLUXR(KAPPA,J)*SIGSS(KAPPA,K)	SOUR 311
GO TO 60	SOUR 312
59 S(J)=S(J)-PLROD(K)+FLUXR(KAPPA,J)*SIGPMR(K)	SOUR 313
60 CONTINUE	SOUR 320
DO 100 L=1,3	SOUR 330
Q(L)=Q(L)*EXDU	SOUR 340
DO 100 M=1,NMOD	SOUR 350
Q(L)=Q(L)+PLMOD(M)+PHIMOD(L)*SIGPMM(M)	SOUR 360
IF(LMOD(M)-LARGE)70,70,65	SOUR 370
65 Q(L)=Q(L)-PLMOD(M)+PHIZ(L)*SIGPMM(M)	SOUR 380
GO TO 100	SOUR 390
70 JP=IGP-LMOD(M)-1	SOUR 400
IF(JP)65,65,75	SOUR 410
75 IF(MU)80,80,85	SOUR 420
80 Q(L)=Q(L)-PLMOD(M)+FLUXM(JP,L)*SIGPMM(M)	SOUR 430
GO TO 100	SOUR 440
85 KAPPA=NU+LARGE-LMOD(M)	SOUR 450
LAMBDA=KAPPA-LARGE-1	SOUR 460
IF(LAMBDA)95,95,90	SOUR 470
90 KAPPA=LAMBDA	SOUR 480
95 Q(L)=Q(L)-PLMOD(M)+FLUXM(KAPPA,L)*SIGPMM(M)	SOUR 490
100 CONTINUE	SOUR 500
200 RETURN	SOUR 510
END	SOUR 520

SUBROUTINE ESCAPE

ESCAPE01

COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),	COMR	1
X TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),	COMR	2
X T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),	COMR	3
X T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),	COMR	4
X T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),	COMR	5
X HS(150),T23(155),H23(150),TCV23(7),TPV2(7),	COMR	6
X H1(150),T31(155),H31(150),TCV31(7),TPV3(7),	COMR	7
X H2(150),T32(155),H32(150),TCV32(7),TPS(7),	COMR	8
X H3(150),T33(155),H33(150),TCV33(7),PHI2(3)	COMR	9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD,	COM1	1
XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,	COM1	2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,	COM1	3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,	COM1	4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,	COM1	5
X AB,AB2,PIROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,	COM1	6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,	COM1	7
X Z4,BA,PIROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,	COM1	8
X NRESAB,PIMOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,	COM1	9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,	COM1	10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,	COM1	11
X AMASSM(10)	COM1	12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),	COM2	1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),	COM2	2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),	COM2	3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),	COM2	4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)	COM2	5
DATA(T22=		
X 0.30410574, 0.30914600, 0.31418460, 0.31922164, 0.32425697, T22		1
X 0.32929060, 0.33432250, 0.33935263, 0.34438095, 0.34940739, T22		6
X 0.35443200, 0.35945466, 0.36447541, 0.36949418, 0.37451091, T22		11
X 0.37952558, 0.38453816, 0.38954863, 0.39455694, 0.39956307, T22		16
X 0.40456695, 0.40956856, 0.41456791, 0.41956490, 0.42455952, T22		21
X 0.42955175, 0.43454154, 0.43952889, 0.44451370, 0.44949598, T22		26
X 0.45447569, 0.45945281, 0.46442726, 0.46939907, 0.47436815, T22		31
X 0.47933449, 0.48429805, 0.48925882, 0.49421674, 0.49917177, T22		36
X 0.50412391, 0.50907311, 0.51401931, 0.51896252, 0.52390271, T22		41
X 0.53377381, 0.54363236, 0.55347811, 0.56331081, 0.57313021, T22		46
X 0.58293604, 0.59272806, 0.60250603, 0.61226971, 0.62201885, T22		51
X 0.63175322, 0.64147259, 0.65117671, 0.66086533, 0.67053828, T22		56
X 0.68019529, 0.68983615, 0.69946065, 0.70906855, 0.71865966, T22		61
X 0.72823374, 0.73779061, 0.74733002, 0.75685181, 0.76635576, T22		66
X 0.77584168, 0.78530935, 0.79475860, 0.80418923, 0.81360105, T22		71
X 0.82299389, 0.83236755, 0.84172187, 0.85105664, 0.86037172, T22		76
X 0.86966691, 0.87894205, 0.88819700, 0.89743157, 0.90664560, T22		81
X 0.91583894, 0.92501142, 0.93416292, 0.94329325, 0.95240230, T22		86
X 0.96148989, 0.97055590, 0.97960019, 0.98862263, 0.99762306, T22		91
X 0.98862263, 1.00660138, 1.02449111, 1.04229082, 1.05999957, T22		96
X 1.07761641, 1.09514049, 1.11257094, 1.12990697, 1.14714782, T22		101
X 1.16429275, 1.18134108, 1.19829214, 1.21514532, 1.23190004, T22		106
X 1.24855574, 1.26511189, 1.28156803, 1.29792370, 1.31417847, T22		111
X 1.33033195, 1.34638378, 1.36233363, 1.37818122, 1.39392624, T22		116
X 1.40956847, 1.42510768, 1.44054367, 1.45587631, 1.47110541, T22		121
X 1.48623089, 1.50125264, 1.51617060, 1.53098471, 1.54569496, T22		126
X 1.56030134, 1.57480388, 1.58920261, 1.60349759, 1.61768890, T22		131
X 1.63177664, 1.64576091, 1.65964187, 1.67341965, 1.68709443, T22		136
X 1.70066639, 1.71413573, 1.72750266, 1.74076741, 1.75393024, T22		141
X 1.76699140, 1.77995115, 1.79280980, 1.80556762, 1.81822494, T22		146
X 1.83078207, 1.84323935, 1.85559713, 1.86785574, 1.88001557, T22		151
DATA(T23=		
X -0.24778559, -0.25172419, -0.25565644, -0.25958247, -0.26350217, T23		1
X -0.26741560, -0.27132273, -0.27522359, -0.27911817, -0.28300640, T23		6

X	-0.28688840,	-0.29076406,	-0.29463349,	-0.29849662,	-0.30235343,	T23	11
X	-0.30620394,	-0.31004816,	-0.31388610,	-0.31771773,	-0.32154309,	T23	16
X	-0.32536212,	-0.32917486,	-0.33298132,	-0.33678147,	-0.34057531,	T23	21
X	-0.34436286,	-0.34814410,	-0.35191907,	-0.35568770,	-0.35945005,	T23	26
X	-0.36320608,	-0.36695583,	-0.37069926,	-0.37443641,	-0.37816723,	T23	31
X	-0.38189175,	-0.38560995,	-0.38932188,	-0.39302748,	-0.39672677,	T23	36
X	-0.40041976,	-0.40410645,	-0.40778681,	-0.41146087,	-0.41512865,	T23	41
X	-0.42244525,	-0.42973661,	-0.43700273,	-0.44424364,	-0.45145931,	T23	46
X	-0.45864973,	-0.46581492,	-0.47295487,	-0.48006961,	-0.48715910,	T23	51
X	-0.49422337,	-0.50126242,	-0.50827626,	-0.51526485,	-0.52222824,	T23	56
X	-0.52916642,	-0.53607940,	-0.54296718,	-0.54982977,	-0.55666718,	T23	61
X	-0.56347940,	-0.57026646,	-0.57702834,	-0.58376508,	-0.59047667,	T23	66
X	-0.59716313,	-0.60382446,	-0.61046067,	-0.61707179,	-0.62365780,	T23	71
X	-0.63021875,	-0.63675463,	-0.64326546,	-0.64975124,	-0.65621201,	T23	76
X	-0.66264776,	-0.66905851,	-0.67544430,	-0.68180513,	-0.68814101,	T23	81
X	-0.69445197,	-0.70073801,	-0.70699919,	-0.71323548,	-0.71944693,	T23	86
X	-0.72563354,	-0.73179536,	-0.73793239,	-0.74404466,	-0.75013220,	T23	91
X	-0.74404467,	-0.751619502,	-0.76824660,	-0.78019962,	-0.79205429,	T23	96
X	-0.80381081,	-0.81546942,	-0.82703035,	-0.83849384,	-0.84986013,	T23	101
X	-0.86112949,	-0.87230219,	-0.88337849,	-0.89435870,	-0.90524308,	T23	106
X	-0.91603194,	-0.92672559,	-0.93732434,	-0.94782851,	-0.95823844,	T23	111
X	-0.96855444,	-0.97877687,	-0.98890608,	-0.99894242,	-1.00888625,	T23	116
X	-1.01873794,	-1.02849786,	-1.03816640,	-1.04774395,	-1.05723080,	T23	121
X	-1.06662760,	-1.07593452,	-1.08515205,	-1.09428058,	-1.10332056,	T23	126
X	-1.11227238,	-1.12113649,	-1.12991333,	-1.13860331,	-1.14720689,	T23	131
X	-1.15572452,	-1.16415663,	-1.17250368,	-1.18076613,	-1.18894443,	T23	136
X	-1.19703906,	-1.20505047,	-1.21297913,	-1.22082552,	-1.22859012,	T23	141
X	-1.23627339,	-1.24387582,	-1.25139789,	-1.25884008,	-1.26620289,	T23	146
X	-1.27348679,	-1.28069228,	-1.28781985,	-1.29487000,	-1.30184321,	T23	151
DATA(T31):							
X	0.15312480,	0.15452446,	0.15589948,	0.15724438,	0.15856745,	T31	1
X	0.15986503,	0.16113750,	0.16238630,	0.16361217,	0.16481270,	T31	6
X	0.16599042,	0.16714540,	0.16827730,	0.16938753,	0.17049504,	T31	11
X	0.17154080,	0.17258553,	0.17360896,	0.17461111,	0.17559234,	T31	16
X	0.17655434,	0.17749508,	0.17841646,	0.17931758,	0.18019984,	T31	21
X	0.18106233,	0.18190663,	0.18273170,	0.18353859,	0.18433213,	T31	26
X	0.18509791,	0.18585001,	0.18658572,	0.18730332,	0.18800400,	T31	31
X	0.18868778,	0.18933507,	0.19000539,	0.19063961,	0.19125772,	T31	36
X	0.19185999,	0.19244646,	0.19301758,	0.19357302,	0.19411338,	T31	41
X	0.19514938,	0.19612693,	0.19704744,	0.19791196,	0.19872209,	T31	46
X	0.19947900,	0.20018411,	0.20083847,	0.20144310,	0.20199957,	T31	51
X	0.20250876,	0.20297172,	0.20338968,	0.20376366,	0.20409451,	T31	56
X	0.20438344,	0.20463132,	0.20483918,	0.20500782,	0.20513823,	T31	61
X	0.20523129,	0.20528790,	0.20530891,	0.20529499,	0.20524712,	T31	66
X	0.20516606,	0.20505250,	0.20490735,	0.20473121,	0.20452485,	T31	71
X	0.20428897,	0.20402430,	0.20373142,	0.20341111,	0.20306395,	T31	76
X	0.20269060,	0.20229166,	0.20186778,	0.20141948,	0.20094742,	T31	81
X	0.20045210,	0.19993415,	0.19939404,	0.19883239,	0.19824965,	T31	86
X	0.19764638,	0.19702305,	0.19638015,	0.19571820,	0.19503764,	T31	91
X	0.19571820,	0.19433896,	0.19288897,	0.19137174,	0.18979067,	T31	96
X	0.18814899,	0.18644979,	0.18469609,	0.18289075,	0.18103653,	T31	101
X	0.17913609,	0.17719194,	0.17520656,	0.17318230,	0.17112141,	T31	106
X	0.16902606,	0.16689835,	0.16474028,	0.16255377,	0.16034070,	T31	111
X	0.15810283,	0.15584188,	0.15355949,	0.15125726,	0.14893670,	T31	116
X	0.14659927,	0.14424639,	0.14187940,	0.13949960,	0.13710824,	T31	121
X	0.13470651,	0.13229588,	0.12987654,	0.12745046,	0.12501835,	T31	126
X	0.12258121,	0.12013996,	0.11769552,	0.11524875,	0.11280048,	T31	131
X	0.11035151,	0.10790261,	0.10545451,	0.10300791,	0.10056350,	T31	136
X	0.09812191,	0.09568377,	0.09324966,	0.09082017,	0.08839582,	T31	141
X	0.08597716,	0.08356465,	0.08115880,	0.07876005,	0.07636883,	T31	146
X	0.07398557,	0.07161064,	0.06924445,	0.06688733,	0.06453965,	T31	151
TAU=1./SIGMA						ESCAPE02	

ATAU=A*TAU	ESCAPE09
BTAU=B*TAU	ESCAPE10
TAU2=TAU*TAU	ESCAPE11
R7=1.57079632*TAU/VM(1)	ESCAPE16
R2=2.*TAU/(A2*VM(2))	ESCAPE17
R4=2.*TAU/(VM(3)*A2*A2)	ESCAPE18
PA(2)=3.141592653*(.25*A2+.333333333*ATAU+.375*TAU2)	ESCAPE19
PB(2)=3.141592653*(.25*B2+.333333333*BTAU+.375*TAU2)	ESCAPE20
PA(3)=3.141592653*(A2*(.25*A2+.666666666*ATAU+1.75*TAU2)+TAU2*(3.2	ESCAPE21
1 *ATAU+3.75*TAU2))	ESCAPE22
PB(3)=3.141592653*(B2*(.25*B2-.666666666*BTAU+1.75*TAU2)-TAU2*(3.2	ESCAPE23
1 *BTAU-3.75*TAU2))	ESCAPE24
TAB=0.	ESCAPE25
TBB=0.	ESCAPE26
DO 100 K=1,8	ESCAPE27
DO 100 J=1,7	ESCAPE28
WEIGHT=.9817477E=02	ESCAPE29
GO TO(30,20,40,10,40,20,40)J	ESCAPE30
10 WEIGHT=WEIGHT+.9817477E=02	ESCAPE31
20 WEIGHT=WEIGHT+.39269908E=01	ESCAPE32
GO TO 40	ESCAPE33
30 IF(K-J)40,40,50	ESCAPE34
40 GG=6*K+J=7	ESCAPE35
ANGLE=.327249234E=01*GG	ESCAPE36
Y=COSF(ANGLE)	ESCAPE37
Y2=Y*Y	ESCAPE38
FY3=B*Y	ESCAPE39
FY2=SQRTF(B2-A2*(1.-Y2))	ESCAPE40
FY1=FY2-A*Y	ESCAPE41
CALL KI(BICK1,SIGMA*FY1,7)	ESCAPE42
XTAB=Y*BICK1(3)	ESCAPE43
CALL KI(BICK2,2.*SIGMA*FY2,7)	ESCAPE44
XPA2=Y*(B2*BICK1(3)+2.*TAU*(FY2*BICK1(4)+TAU*BICK1(5)))	ESCAPE45
CALL KI(BICK3,2.*SIGMA*FY3,7)	ESCAPE46
XTBB=Y*(BICK3(3)-AB*BICK2(3))	ESCAPE47
Z2=3.*B2=2.*A2*(1.-Y2)	ESCAPE48
Z4=1.+2.*Y2	ESCAPE49
XPA4=Y*(B2*B2*BICK1(3)+4.*TAU*(B2*FY2*BICK1(4)+TAU*(Z2*BICK1(5)+	ESCAPE50
1 6.*TAU*(FY2*BICK1(6)+TAU*BICK1(7))))	ESCAPE51
XPB2=Y*(A2*AB*BICK1(3)+B2*(BICK3(3)-AB*BICK2(3))-2.*TAU*(FY3*(AB2	ESCAPE52
1 *BICK1(4)-BICK3(4))+AB*FY2*BICK2(4)-TAU*(AB*(BICK1(5)-BICK2(5)	ESCAPE53
2)*BICK3(5))))	ESCAPE54
XPB4=Y*(A2*A2*AB*BICK1(3)+B2*B2*(BICK3(3)-AB*BICK2(3))-4.*TAU*(FY3	ESCAPE55
1 *(AB2*A2*BICK1(4)-B2*BICK3(4))+A*B*FY2*BICK2(4)+TAU*(Z4*(A2	ESCAPE56
2 *AB*BICK1(5)+B2*BICK3(5))-AB*Z2*BICK2(5)-6.*TAU*(FY3*(AB2*	ESCAPE57
3 BICK1(6)-BICK3(6))+AB*FY2*BICK2(6)-TAU*(BICK3(7)+AB*(BICK1(7)	ESCAPE58
4 *BICK2(7))))))	ESCAPE59
50 TAB=TAB+WEIGHT*XTAB	ESCAPE60
TBB=TBB+WEIGHT*XTBB	ESCAPE61
PA(2)=PA(2)*WEIGHT*XPA2	ESCAPE62
PB(2)=PB(2)*WEIGHT*XPB2	ESCAPE63
PA(3)=PA(3)*WEIGHT*XPA4	ESCAPE64
PB(3)=PB(3)*WEIGHT*XPB4	ESCAPE65
100 CONTINUE	ESCAPE66
TAB=1.273239544*TAB	ESCAPE67
TBB=1.273239544*TBB	ESCAPE68
TBA=AB*TAB	ESCAPE69
PA(1)=RZ*A*(1.-TAB)	ESCAPE70
PB(1)=RZ*B*(1.-TBB-TBA)	ESCAPE71
PA(2)=R2*A*PA(2)	ESCAPE72
PB(2)=R2*B*PB(2)	ESCAPE73
PA(3)=R4*A*PA(3)	ESCAPE74
PB(3)=R4*B*B*PB(3)	E **PE7
RETURN	ESCAPE76
END	ESCAPE77

SUBROUTINE INPUT										INPUT 00
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),										COMR 1
X	TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),									COMR 2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),									COMR 3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),									COMR 4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),									COMR 5
X	H5(150),T23(155),H23(150),TCV23(7),TPV2(7),									COMR 6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),									COMR 7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),									COMR 8
X	H3(150),T33(155),H33(150),TCV33(7),PHI2(3)									COMR 9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NRD,										COM1 1
X	S(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,									COM1 2
X	Q(3),TBB,SIGA M(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,									COM1
X	MU,TBA,ADENH(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,									COM1 4
X	NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,									COM1 5
X	AB,AB2,PIROD(10),SIGPMH(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,									COM1 6
X	Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,									COM1 7
X	Z4,BA,PIROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,									COM1 8
X	NRESAB,PIMOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,									COM1 9
X	SDD,B2,TPHIR(25)8 H+ M+X HXB++2 4+X+ 0 4+XC ---+48M++ 2+7 8 + +4									
X	NAB,A2,TPHIM(25)80YT+ 3+X H8 ++288 H80Y0 # H80 ---+80 --+8 ++78 + +									1
X	AMASSM(10)									COM1 12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),										COM2 1
X	ER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),									COM2 2
X	G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),									COM2 3
X	CV(3,3),FLUXM#600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),									COM2
X	SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)									COM2 5
DATA(H11=										
X	0.91035301, 0.91312504, 0.91575691, 0.91825530, 0.92062657, H11									1
X	0.92287676, 0.925 1628 H 2 66 Y H 28 6 8 H 77 Y H 1									
X	0.93250307, H 4 8 08 H 5686878 H 7 5 4 8 H 854 658 H1									1
X	0.93985522, H 4 76 8 H 42 72 8 H 43 8 8 H 444 7 8 H1									
X	0.94542058, 0.9463544 8 H 4 2 88 H 8 28 H 88 88 H 1									2
X	0.94958176, 0.95027322, 0.95092284, 0.95153261, 0.95210442, H11									26
X	0.95264006, 0.95314127, 0.95360968, 0.95404686, 0.95445431, H11									31
X	0.95483346, 0.95518567, 0.95551225, 0.95581443, 0.95609340, H11									36
X	0.95635030, 0.95658620, 0.95680215, 0.95699913, 0.95717807, H11									41
X	0.95733988, 0. 5 48 4 = H 528 H 7 8 H 8 2 8 H 1									
X	0.95792075, 0.95799653, 0.95806044, 0.95811311, 0.95815512, H11									51
X	0.95818705, 0.95820944, 0.95822281, 0.95822765, 0.95822443, H11									56
X	0.95821361, 0.95819562, 0.95817086, 0.95813974, 0.95810262, H11									61
X	0.95805986, 0.95801182, 0.95795880, 0.95790113, 0.95783910, H11									66
X	0.95777299, 0.95770308, 0.95762963, 0.95755287, 0.95747305, H11									71
X	0.95739039, 0.95730510, 0.95721739, 0.95712745, 0.95703547, H11									76
X	0.95694162, 0.95684607, 0.95674899, 0.95665052, 0.95655081, H11									81
X	0.95644999, 0.95634821, 0.95624559, 0.95614223, 0.95603827, H11									86
X	0.95593380, 0.95582893, 0.95572376, 0.95561837, 0.95551286, H11									91
X	0.95540731, 0.95530180, 0.95519640, 0.95509118, 0.95498622, H11									96
X	0.95488157, 0.95477729, 0.95467345, 0.95457010, 0.95446728, H11									101
X	0.95436504, 0.95426344, 0.95416250, 0.95406229, 0.95396282, H11									106
X	0.95386413, 0.95376627, 0.95366925, 0.95357312, 0.95347789, H11									111
X	0.95338359, 0.95329024, 0.95319788, 0.95310651, 0.95301615, H11									116
X	0.95292683, 0.95283856, 0.95275136, 0.95266523, 0.95258019, H11									121
X	0.95249625, 0.95241342, 0.95233171, 0.95225113, 0.95217169, H11									126
X	0.95209338, 0.95201622, 0.95194021, 0.95186535, 0.95179165, H11									131
X	0.95171911, 0.95164773, 0.95157751, 0.95150845, 0.95144055, H11									136
X	0.95137381, 0.95130823, 0.95124380, 0.95118053, 0.95111841, H11									141
X	0.95105744, 0.95099761, 0.95093893, 0.95088138, 0.95082496, H11									146
DATA(H12=										
X	0.03668199, 0.04250583, 0.04833414, 0.05416248, 0.05998664, H12									1
X	0.06580264, 0.07160673, 0.07739538, 0.08316523, 0.08891317, H12									6
X	0.09463623, 0.10033164, 0.10599681, 0.11162930, 0.11722684, H12									11

X	0.12278731,	0.12830871,	0.13378921,	0.13922709,	0.14462078,	H12	16
X	0.14996879,	0.15526977,	0.16052248,	0.16572577,	0.17087860,	H12	21
X	0.17598002,	0.18102917,	0.18602527,	0.19096762,	0.19585561,	H12	26
X	0.20068868,	0.20546636,	0.21018824,	0.21485395,	0.21946321,	H12	31
X	0.22401579,	0.22851149,	0.23295019,	0.23733180,	0.24165626,	H12	36
X	0.24592358,	0.25013380,	0.25428700,	0.25838327,	0.26242277,	H12	41
X	0.26640567,	0.27033218,	0.27420251,	0.27801693,	0.28177572,	H12	46
X	0.28547918,	0.28912764,	0.29272142,	0.29626090,	0.29974645,	H12	51
X	0.30317847,	0.30655735,	0.30988353,	0.31315742,	0.31637948,	H12	56
X	0.31955016,	0.32266991,	0.32573922,	0.32875856,	0.33172841,	H12	61
X	0.33464927,	0.33752162,	0.34034599,	0.34312286,	0.34585275,	H12	66
X	0.34853617,	0.35117363,	0.35376566,	0.35631276,	0.35881545,	H12	71
X	0.36127427,	0.36368972,	0.36606232,	0.36839260,	0.37068106,	H12	76
X	0.37292824,	0.37513463,	0.37730075,	0.37942713,	0.38151425,	H12	81
X	0.38356263,	0.38557278,	0.38754519,	0.38948037,	0.39137879,	H12	86
X	0.39324097,	0.39506738,	0.39685851,	0.39861483,	0.40033683,	H12	91
X	0.40202497,	0.40367973,	0.40530156,	0.40689092,	0.40844828,	H12	96
X	0.40997407,	0.41146876,	0.41293277,	0.41436655,	0.41577052,	H12	101
X	0.41714512,	0.41849077,	0.41980788,	0.42109687,	0.42235815,	H12	106
X	0.42359213,	0.42479919,	0.42597974,	0.42713417,	0.42826286,	H12	111
X	0.42936620,	0.43044455,	0.43149829,	0.43252779,	0.43353341,	H12	116
X	0.43451550,	0.43547442,	0.43641052,	0.43732414,	0.43821561,	H12	121
X	0.43908528,	0.43993347,	0.44076051,	0.44156672,	0.44235243,	H12	126
X	0.44311792,	0.44386353,	0.44458955,	0.44529628,	0.44598402,	H12	131
X	0.44665306,	0.44730368,	0.44793618,	0.44855083,	0.44914790,	H12	136
X	0.44972767,	0.45029040,	0.45083637,	0.45136582,	0.45187902,	H12	141
X	0.45237621,	0.45285766,	0.45332359,	0.45377426,	0.45420991,	H12	146

DATA(H13=

X	-0.44571643,	-0.45200148,	-0.45819640,	-0.46430113,	-0.47031572,	H13	1
X	-0.47624023,	-0.48207478,	-0.48781957,	-0.49347481,	-0.49904077,	H13	6
X	-0.50451775,	-0.50990613,	-0.51520629,	-0.52041865,	-0.52554369,	H13	11
X	-0.53058190,	-0.53553381,	-0.54039997,	-0.54518098,	-0.54987744,	H13	16
X	-0.55449000,	-0.55901931,	-0.56346605,	-0.56783093,	-0.57211466,	H13	21
X	-0.57631799,	-0.58044165,	-0.58448642,	-0.58845308,	-0.59234242,	H13	26
X	-0.59615525,	-0.59989237,	-0.60355460,	-0.60714278,	-0.61065775,	H13	31
X	-0.61410033,	-0.61747139,	-0.62077177,	-0.62400232,	-0.62716390,	H13	36
X	-0.63025738,	-0.63328360,	-0.63624344,	-0.63913774,	-0.64196737,	H13	41
X	-0.64473319,	-0.64743606,	-0.65007683,	-0.65265634,	-0.65517546,	H13	46
X	-0.65763502,	-0.66003586,	-0.66237882,	-0.66466473,	-0.66689442,	H13	51
X	-0.66906870,	-0.67118840,	-0.67325432,	-0.67526727,	-0.67722804,	H13	56
X	-0.67913741,	-0.68099619,	-0.68280514,	-0.68456502,	-0.68627661,	H13	61
X	-0.68794065,	-0.68955789,	-0.69112907,	-0.69265493,	-0.69413618,	H13	66
X	-0.69557354,	-0.69696772,	-0.69831941,	-0.69962931,	-0.70089810,	H13	71
X	-0.70212646,	-0.70331504,	-0.70446452,	-0.70557553,	-0.70664872,	H13	76
X	-0.70768472,	-0.70868416,	-0.70964765,	-0.71057581,	-0.71146923,	H13	81
X	-0.71232850,	-0.71315421,	-0.71394694,	-0.71470725,	-0.71543570,	H13	86
X	-0.71613285,	-0.71679923,	-0.71743539,	-0.71804185,	-0.71861913,	H13	91
X	-0.71916775,	-0.71968821,	-0.72018102,	-0.72064665,	-0.72108559,	H13	96
X	-0.72149832,	-0.72188531,	-0.72224702,	-0.72258389,	-0.72289639,	H13	101
X	-0.72318495,	-0.72345000,	-0.72369198,	-0.72391129,	-0.72410835,	H13	106
X	-0.72428358,	-0.72443736,	-0.72457010,	-0.72468218,	-0.72477399,	H13	111
X	-0.72484589,	-0.72489826,	-0.72493146,	-0.72494585,	-0.72494178,	H13	116
X	-0.72491980,	-0.72487964,	-0.72482224,	-0.72474773,	-0.72465643,	H13	121
X	-0.72454867,	-0.72442475,	-0.72428498,	-0.72412966,	-0.72395911,	H13	126
X	-0.72377359,	-0.72357341,	-0.72335884,	-0.72313017,	-0.72288767,	H13	131
X	-0.72263161,	-0.72236224,	-0.72207985,	-0.72178466,	-0.72147695,	H13	136
X	-0.72115695,	-0.72082491,	-0.72048108,	-0.72012567,	-0.71975892,	H13	141
X	-0.71938107,	-0.71899233,	-0.71859292,	-0.71818306,	-0.71776296,	H13	146

READ 101,(TITLE(I),I=1,9),A,B,TEMP,DELTA	INPUT 01
101 FORMAT(9A8/4E12.6)	INPUT 02
READ 102,NROD,NMOD,NRESAB,NGP,NFLUX,MORE	INPUT 03
102 FORMAT(6I6)	INPUT 04

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      NGP1=NGP+1                                INPUT 05
      READ 103,(ENGP(II),II=1,NGP1)              INPUT 06
103  FORMAT(6E12.6)                             INPUT 07
      READ 104,(MATMOD(J),AMASSM(J),ADENM(J),SIGPM(J),SIGAM(J),J=1,NMQD) INPUT 08
104  FORMAT(A6,4E12.6)                           INPUT 09
      DO 10 K=1,NROD                             INPUT 10
      READ 105,MATROD(K),AMASSR(K),ADENR(K),SIGPR(K),SIGA22(K),SIGF22(K) INPUT 11
      X      ,NRES(K)                             INPUT 12
105  FORMAT(A6,5E12.6,I6)                         INPUT 13
      IF (NRES(K))10,10,5                         INPUT 14
      5  NRESK=NRES(K)                             INPUT 15
      READ 103,(ER(K,KK),GAMNUT(K,KK),GAMRAD(K,KK),GAMFIS(K,KK),G(K,KK), INPUT 16
      X      ,XNAT(K,KK),KK=1,NRESK)             INPUT 17
10  CONTINUE                                     INPUT 18
      CALL DATA                                  INPUT 19
      CALL ESCAPE                                 INPUT 20
      DO 15 L=1,NGP                               INPUT 21
15  MGP(L)=LOGF(ENGP(L)/ENGP(L+1))/DELTA          INPUT 22
      PRINT 201,(TITLE(IK),IK=1,9),A,B,TEMP,DELTA,MGP(NGP),NGP      INPUT 23
201  FORMAT(1H1, / 30X,9A8, //20X,15H RADIUS OF ROD =,E12.5,24H      RADINPUT 24
      1IUS OF CELL =,E12.5,27H      TEMPERATURE OF ROD =,E12.5//20X,22H INPUT 25
      2IDTH OF FINE GROUPS =,E12.5,21H NO. OF FINE GROUPS =,15,7X,23H NO INPUT 26
      3. OF BROAD GROUPS =,13 ///120H      NUMBER OF BROAD GROUP      INPUT 27
      4  MAXIMUM ENERGY OF GROUP      MINIMUM ENERGY OF GROUP      NINPUT 28
      5UMBER OF FINE GROUPS)          INPUT 29
      PRINT 202,1,ENGP(1),ENGP(2),MGP(1)          INPUT 30
      IF (NGP-1)30,30,20                        INPUT 31
20  DO 25 IJ=2,NGP                              INPUT 32
      NFGP=MGP(IJ)-MGP(IJ-1)                    INPUT 33
25  PRINT 202,IJ,ENGP(IJ),ENGP(IJ+1),NFGP        INPUT 34
202  FORMAT(25X,15,2(15X,E15.4),24X,I6)          INPUT 35
30  PRINT 203                                    INPUT 36
203  FORMAT(///50X,20H MODERATOR PARAMETERS/20X,90H MATERIAL      ATOINPUT 37
      1M DENSITY      ATOMIC MASS      SIGMA P (BARNS)      SIGMA A(2200MINPUT 38
      2/S)      )          INPUT 39
      PRINT 204,(MATMOD(JI),ADENM(JI),AMASSM(JI),SIGPM(JI),SIGAM(JI), INPUT 40
      X      ,JI=1,NMQD)          INPUT 41
204  FORMAT(24X,A6,4(5X,E15.4))                  INPUT 42
      PRINT 205                                  INPUT 43
205  FORMAT(///50X,14H ROD PARAMETERS/8X,8H MATERIAL,4X,12H ATOM DENSITY, INPUT 44
      X5X,11H ATOMIC MASS,9X,7HSIGMA P,5X,11H1/V SIGMA A,5X,27H1/V SIGMA FINPUT 45
      X NO. RESONANCES )          INPUT 46
      PRINT 206,(MATROD(L),ADENR(L),AMASSR(L),SIGPR(L),SIGA22(L),SIGF22(L) INPUT 47
      XL),NRES(L),L=1,NROD)          INPUT 48
206  FORMAT(10X,A6,5E16.4,10X,I6)                INPUT 49
      PRINT 207                                  INPUT 50
207  FORMAT(1H1//50X,20H RESONANCE PARAMETERS//10X,116H MATERIAL PEAK EINPUT 51
      XENERGY(EV)      GAMMA N (EV)      GAMMA GAMMA (EV)      GAMMA F (EV) INPUT 52
      XSPIN FACTOR (G)      X(NATURAL) )          INPUT 53
      DO 35 M=1,NRESAB                          INPUT 54
      MA=NRES(M)                                INPUT 55
35  PRINT 208,(MATROD(M),ER(M,N),GAMNUT(M,N),GAMRAD(M,N),GAMFIS(M,N), INPUT 56
      X      ,G(M,N),XNAT(M,N),N=1,MA)          INPUT 57
208  FORMAT(12X,A6,6E18.4)                       INPUT 58
      IF(NFLUX)50,50,40                         INPUT 59
40  PRINT 209,NFLUX,(RAD(MM),MM=1,7)             INPUT 60
209  FORMAT(1H1,25X,64H FLUX DISTRIBUTION IN CELL AND COLLISION DENSITY INPUT 61
      XIN ROD FOR EVERY,13,8H TH GROUP//37X,36H DISTANCE FROM ROD AXIS/RADI INPUT 62
      XUS OF ROD//10X,6H ENERGY,7E16.4)        INPUT 63
50  RETURN                                       INPUT 64
      END                                       INPUT 65

```

SUBROUTINE GROUP				GROUP 01
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),				COMR 1
X	TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),			COMR 2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),			COMR 3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),			COMR 4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),			COMR 5
X	HS(150),T23(155),H23(150),TCV23(7),TPV2(7),			COMR 6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),			COMR 7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),			COMR 8
X	H3(150),T33(155),H33(150),TCV33(7),PHIZ(3)			COMR 9
COMMON/1/SIGPM(10),SIGA22(10),LMD(10),FLUX(7),ENERGY(600),NROD,				COM1 1
XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,				COM1 2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,				COM1 3
X	MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,			COM1 4
X	NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,			COM1 5
X	AB,AB2,PLROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,			COM1 6
X	Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,			COM1 7
X	Z4,BA,P1ROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,			COM1 8
X	NRESAB,P1MOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,			COM1 9
X	SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,			COM1 10
X	NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,			COM1 11
X	AMASSM(10)			COM1 12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),				COM2 1
X	ER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),			COM2 2
X	G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),			COM2 3
X	CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),			COM2 4
X	SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)			COM2 5
DATA(H31=				
X	0.06688733, 0.06220171, 0.05755633, 0.05295350, 0.04839528, H31			1
X	0.04388355, 0.03941998, 0.03500605, 0.03064308, 0.02633221, H31			6
X	0.02207446, 0.01787071, 0.01372169, 0.00962802, 0.00559024, H31			11
X	0.00160874, -0.00231615, -0.00618419, -0.00999523, -0.01374920, H31			16
X	-0.01744609, -0.02108595, -0.02466890, -0.02819511, -0.03166478, H31			21
X	-0.03507819, -0.03843565, -0.04173748, -0.04498409, -0.04817586, H31			26
X	-0.05131325, -0.05439672, -0.05742676, -0.06040388, -0.06332894, H31			31
X	-0.06620150, -0.06902311, -0.07179402, -0.07451482, -0.07718610, H31			36
X	-0.07980848, -0.08238256, -0.08490897, -0.08738834, -0.08982129, H31			41
X	-0.09220846, -0.09455049, -0.09684801, -0.09910166, -0.10131207, H31			46
X	-0.10347989, -0.10560574, -0.10769025, -0.10973407, -0.11173781, H31			51
X	-0.11370209, -0.11562754, -0.11751477, -0.11936438, -0.12117699, H31			56
X	-0.12295319, -0.12469357, -0.12639872, -0.12806923, -0.12970566, H31			61
X	-0.13130859, -0.13287858, -0.13441618, -0.13592195, -0.13739641, H31			66
X	-0.13884012, -0.14025360, -0.14163736, -0.14299192, -0.14431779, H31			71
X	-0.14561547, -0.14688545, -0.14812821, -0.14934423, -0.15053399, H31			76
X	-0.15169794, -0.15283655, -0.15395026, -0.15503951, -0.15610475, H31			81
X	-0.15714639, -0.15816487, -0.15916059, -0.16013396, -0.16108539, H31			86
X	-0.16201527, -0.16292398, -0.16381192, -0.16467945, -0.16552694, H31			91
X	-0.16635477, -0.16716327, -0.16795281, -0.16872373, -0.16947636, H31			96
X	-0.17021105, -0.17092811, -0.17162786, -0.17231063, -0.17297672, H31			101
X	-0.17362644, -0.17426008, -0.17487794, -0.17548031, -0.17606747, H31			106
X	-0.17663970, -0.17719727, -0.17774046, -0.17826952, -0.17878471, H31			111
X	-0.17928629, -0.17977451, -0.18024960, -0.18071183, -0.18116141, H31			116
X	-0.18159858, -0.18202357, -0.18243660, -0.18283790, -0.18322767, H31			121
X	-0.18360614, -0.18397350, -0.18432996, -0.18467572, -0.18501098, H31			126
X	-0.18533593, -0.18565077, -0.18595567, -0.18625081, -0.18653639, H31			131
X	-0.18681257, -0.18707953, -0.18733744, -0.18758646, -0.18782675, H31			136
X	-0.18805849, -0.18828182, -0.18849690, -0.18870388, -0.18890291, H31			141
X	-0.18909414, -0.18927771, -0.18945376, -0.18962243, -0.18978386, H31			146
DATA(H32=				
X	1.66312296, 1.68145190, 1.69936007, 1.71685266, 1.73393492, H32			1
X	1.75061223, 1.76688996, 1.78277360, 1.79826863, 1.81338063, H32			6
X	1.82811516, 1.84247781, 1.85647421, 1.87010998, 1.88339075, H32			11

X	1.89632214,	1.90890977,	1.92115922,	1.93307610,	1.94466596,	H32	16
X	1.95593435,	1.96688674,	1.97752861,	1.98786541,	1.99790251,	H32	21
X	2.00764525,	2.01709894,	2.02626883,	2.03516012,	2.04377796,	H32	26
X	2.05212743,	2.06021357,	2.06804137,	2.07561573,	2.08294151,	H32	31
X	2.09002352,	2.09686648,	2.10347507,	2.10985391,	2.11600752,	H32	36
X	2.12194040,	2.12765694,	2.13316152,	2.13845840,	2.14355181,	H32	41
X	2.14844590,	2.15314476,	2.15765241,	2.16197281,	2.16610985,	H32	46
X	2.17006736,	2.17384910,	2.17745877,	2.18090002,	2.18417642,	H32	51
X	2.18729147,	2.19024863,	2.19305129,	2.19570277,	2.19820635,	H32	56
X	2.20056523,	2.20278257,	2.20486145,	2.20680491,	2.20861594,	H32	61
X	2.21029744,	2.21185229,	2.21328332,	2.21459327,	2.21578483,	H32	66
X	2.21686070,	2.21782344,	2.21867562,	2.21941975,	2.22005827,	H32	71
X	2.22059360,	2.22102808,	2.22136404,	2.22160372,	2.22174937,	H32	76
X	2.22180315,	2.22176720,	2.22164358,	2.22143438,	2.22114158,	H32	81
X	2.22076714,	2.22031300,	2.21978103,	2.21917309,	2.21849098,	H32	86
X	2.21773647,	2.21691131,	2.21601718,	2.21505576,	2.21402866,	H32	91
X	2.21293750,	2.21178381,	2.21056916,	2.20929501,	2.20796285,	H32	96
X	2.20657411,	2.20513019,	2.20363248,	2.20208231,	2.20048101,	H32	101
X	2.19882986,	2.19713014,	2.19538307,	2.19358988,	2.19175173,	H32	106
X	2.18986980,	2.18794521,	2.18597909,	2.18397252,	2.18192555,	H32	111
X	2.17984224,	2.17772060,	2.17556263,	2.17336929,	2.17114157,	H32	116
X	2.16888039,	2.16658664,	2.16426125,	2.16190507,	2.15951898,	H32	121
X	2.15710380,	2.15466035,	2.15218945,	2.14969187,	2.14716838,	H32	126
X	2.14461974,	2.14204668,	2.13944992,	2.13683016,	2.13418809,	H32	131
X	2.13152439,	2.12883972,	2.12613472,	2.12341003,	2.12066624,	H32	136
X	2.11790399,	2.11512384,	2.11232638,	2.10951219,	2.10668180,	H32	141
X	2.10383576,	2.10097459,	2.09809882,	2.09520896,	2.09230548,	H32	146

DATA(H33=

X	-0.68404249,	-0.68737242,	-0.69044008,	-0.69325003,	-0.69580687,	H33	1
X	-0.69811518,	-0.70017950,	-0.70200438,	-0.70359432,	-0.70495383,	H33	6
X	-0.70608738,	-0.70699939,	-0.70769427,	-0.70817641,	-0.70845014,	H33	11
X	-0.70851975,	-0.70838951,	-0.70806362,	-0.70754629,	-0.70684162,	H33	16
X	-0.70595372,	-0.70488662,	-0.70364431,	-0.70223075,	-0.70064981,	H33	21
X	-0.69890535,	-0.69700115,	-0.69494097,	-0.69272849,	-0.69036735,	H33	26
X	-0.68786111,	-0.68521334,	-0.68242749,	-0.67950700,	-0.67645521,	H33	31
X	-0.67327547,	-0.66997101,	-0.66654506,	-0.66300077,	-0.65934123,	H33	36
X	-0.65556950,	-0.65168855,	-0.64770135,	-0.64361078,	-0.63941966,	H33	41
X	-0.63513080,	-0.63074690,	-0.62627067,	-0.62170473,	-0.61705166,	H33	46
X	-0.61231400,	-0.60749421,	-0.60259474,	-0.59761799,	-0.59256627,	H33	51
X	-0.58744189,	-0.58224707,	-0.57698405,	-0.57165495,	-0.56626190,	H33	56
X	-0.56080694,	-0.55529213,	-0.54971942,	-0.54409075,	-0.53840804,	H33	61
X	-0.53267312,	-0.52688781,	-0.52105390,	-0.51517311,	-0.50924716,	H33	66
X	-0.50327770,	-0.49726634,	-0.49121469,	-0.48512430,	-0.47899668,	H33	71
X	-0.47283333,	-0.46663567,	-0.46040515,	-0.45414313,	-0.44785097,	H33	76
X	-0.44152999,	-0.43518149,	-0.42880671,	-0.42240689,	-0.41598324,	H33	81
X	-0.40953692,	-0.40304908,	-0.39658084,	-0.39007327,	-0.38354747,	H33	86
X	-0.37700445,	-0.37044523,	-0.36387081,	-0.35728213,	-0.35068015,	H33	91
X	-0.34406578,	-0.33743992,	-0.33080343,	-0.32415717,	-0.31750197,	H33	96
X	-0.31083863,	-0.30416794,	-0.29749067,	-0.29080757,	-0.28411936,	H33	101
X	-0.27742675,	-0.27073044,	-0.26403110,	-0.25732938,	-0.25062593,	H33	106
X	-0.24392135,	-0.23721627,	-0.23051127,	-0.22380692,	-0.21710378,	H33	111
X	-0.21040239,	-0.20370328,	-0.19700697,	-0.19031395,	-0.18362471,	H33	116
X	-0.17693973,	-0.17025946,	-0.16358435,	-0.15691483,	-0.15025133,	H33	121
X	-0.14359425,	-0.13694400,	-0.13030096,	-0.12366551,	-0.11703800,	H33	126
X	-0.11041881,	-0.10380826,	-0.09720669,	-0.09061442,	-0.08403178,	H33	131
X	-0.07745906,	-0.07089656,	-0.06438457,	-0.05780336,	-0.05127320,	H33	136
X	-0.04475436,	-0.03824707,	-0.03175160,	-0.02526817,	-0.01879701,	H33	141
X	-0.01233834,	-0.00589239,	0.00054065,	0.00696058,	0.01336720,	H33	146

Z=A*SIGTOT

GROUP 02

CALL ROD

GROUP 03

REFLEC=TBA/(1.-TBB-TBA*TAB*EPS)

GROUP 04

COLROD=0.

GROUP 05

TOTSOR=0,	GROUP 06
SURSOR=0,	GROUP 07
DO 10 I=1,3	GROUP 08
SM=VM(I)*Q(I)	GROUP 09
SR=VR(I)*S(I)	GROUP 10
TOTSOR=TOTSOR+SM*SR	GROUP 11
ENTER=TAB*EPV(I)*SR+SM*(PB(I)+PA(I)*EPS*TAB)	GROUP 111
COLROD=COLROD+SR*(1.-EPV(I))	GROUP 211
10 SURSOR=SURSOR+SM*PA(I)+REFLEC*ENTER	GROUP 12
COLROD=COLROD+SURSOR*(1.-EPS)	GROUP 13
COLMOD=TOTSOR-COLROD	GROUP 113
DO 30 K=1,3	GROUP 14
PHIROD(K)=(S(1)-2.*Z*SURSOR/VR(1))*CV(1,K)	GROUP 114
DO 20 J=2,3	GROUP 15
DEM=J	GROUP 115
20 PHIROD(K)=PHIROD(K)+S(J)*CV(J,K)/DEM	GROUP 16
IF(K=1)21,21,25	GROUP 17
21 PHIROD(K)=PHIROD(K)+2.*Z*SURSOR/VR(1)	GROUP 18
25 PHIROD(K)=PHIROD(K)/SIGTOT	GROUP 19
30 CONTINUE	GROUP 20
Z2=PHIROD(1)+PHIROD(2)+PHIROD(3)	GROUP 21
PHIM=COLMOD/SIGMOD	GROUP 121
PHIMOD(3)=U*(VM(1)+Z2-PHIM)	GROUP 22
PHIMOD(2)=-2.*BA2*PHIMOD(3)	GROUP 23
PHIMOD(1)=Z2-PHIMOD(2)-PHIMOD(3)	GROUP 24
CPERT(KGP)=CPERT(KGP)+COLROD	GROUP 25
ENERGY(NU)=E	GROUP 26
SIGMAC(NU)=SIGTOT	GROUP 27
DO 35 KK=1,3	GROUP 28
FLUXR(NU,KK)=PHIROD(KK)	GROUP 29
FLUXM(NU,KK)=PHIMOD(KK)	GROUP 30
TFLUXR(KK,KGP)=TFLUXR(KK,KGP)+PHIROD(KK)	GROUP 31
35 TFLUXM(KK,KGP)=TFLUXM(KK,KGP)+PHIMOD(KK)	GROUP 32
PHIR=COLROD/SIGTOT	GROUP 33
DO 40 L=1,NROD	GROUP 34
RRAR(L,KGP)=RRAR(L,KGP)+PHIR*SIGA(L)	GROUP 35
RRFR(L,KGP)=RRFR(L,KGP)+PHIR*SIGX(L)	GROUP 36
RRSR(L,KGP)=RRSR(L,KGP)+PHIR*SIGS(L)	GROUP 37
RRASUR(L,KGP)=RRASUR(L,KGP)+Z2*SIGA(L)	GROUP 38
40 RRFSUR(L,KGP)=RRFSUR(L,KGP)+Z2*SIGX(L)	GROUP 39
DO 45 M=1,NMOD	GROUP 40
RRAM(M,KGP)=RRAM(M,KGP)+PHIM*SMOD(M)	GROUP 41
45 RRSMM(M,KGP)=RRSM(M,KGP)+PHIM*SIGPM(M)	GROUP 42
DO 50 N=1,NRESAB	GROUP 43
50 SIGSS(NU,N)=SIGS(N)	GROUP 44
RETURN	GROUP 45
END	GROUP 46

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SUBROUTINE W
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3), COMR 1
X      T8(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3), COMR 2
X      T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3), COMR 3
X      T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3), COMR 4
X      T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3), COMR 5
X      H8(150),T23(155),H23(150),TCV23(7),TPV2(7), COMR 6
X      H1(150),T31(155),H31(150),TCV31(7),TPV3(7), COMR 7
X      H2(150),T32(155),H32(150),TCV32(7),TPS(7), COMR 8
X      H3(150),T33(155),H33(150),TCV33(7),PHIZ(3) COMR 9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD, COM1 1
XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD, COM1 2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR, COM1 3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM, COM1 4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ, COM1 5
X AB,AB2,PIROD(10),SIGPMM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW, COM1 6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ, COM1 7
X Z4,BA,PIROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW, COM1 8
X NRESAB,PIMOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP, COM1 9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP, COM1 10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP, COM1 11
X AMASSM(10) COM1 12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25), COM2 1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25), COM2 2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60), COM2 3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60), COM2 4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60) COM2 5
DIMENSION X(12),Y(12),AA(11),BB(11)
EQUIVALENCE
1(RBK,AJP),(RNKM1,C),
2(RAK,TEMP4),(RNKM2,AQ),(AIBK,AK),(AINKM1,D),
3(RNK,TEMPC),(AINKM2,BQ),(AINK,TEMPD),(RDKM1,AM),
4(RDKM2,GQ),(AIDKM1,EL),(RDK,TEMPPM),(AIDKM2,H),
5(AIDK,TEML)
DATA(X=
X .1000000E 01, .4444444E-01, .5442176E-02, .2119093E-02,
X .1126194E-02, .6983402E-03, .4752903E-03, .3443545E-03,
X .2609611E-03, .2045830E-03, .1646905E-03, .1354280E-03),
X(Y=
X -.3333333E 00, .4761904E-01, .1298701E-01, .6060606E-02,
X .3508772E-02, .2288329E-02, .1610305E-02, .1194743E-02,
X .9216589E-03, .7326007E-03, .5963029E-03, .4948045E-03),
X(AA=
X .2000000E 01, .1200000E 02, .3000000E 02,
X -.5600000E 02, .9000000E 02, .1320000E 03, .1820000E 03,
X -.2400000E 03, .3060000E 03, .3800000E 03, .4620000E 03),
X(BB=
X .5000000E 01, .9000000E 01, .1300000E 02,
X .1700000E 02, .2100000E 02, .2500000E 02, .2900000E 02,
X .3300000E 02, .3700000E 02, .4100000E 02, .4500000E 02)
27 R2=REZ*REZ
A12=AIMZ*AIMZ
ABREZ=ABSF(REZ)
IF(ABREZ+1.25*AIMZ-5.0)102,102,100
100 IF(ABREZ+1.1*AIMZ-6.6)117,117,116
101 IF(ABREZ+1.43333*AIMZ-4.3)119,119,118
102 IF(ABREZ+1.863636*AIMZ-4.1)111,111,104
103 IF(AIMZ-1.5)110,120,120
104 IF(AIMZ-1.4)115,115,101
105 IF(ABREZ+1.07317*AIMZ-4.4)119,119,118
106 IF(ABREZ-2.7)127,128,128
107 IF(ABREZ-3.1)106,108,108

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108 IF(ABREZ=3.4)129,130,130
109 IF(R2+1.18*AI2-5.76)103,107,107
110 IF(R2+1.7227*AI2-4.41)125,126,126
111 IF(R2+1.71*AI2-2.89)113,109,109
112 IF(R2+1.69*AI2-1.69)123,124,124
113 IF(R2+2.0408*AI2-1.0)114,112,112
114 IF(R2+1.5625*AI2-.25)121,122,122
115 IF(ABREZ+1.43333*AIMZ-4.3)120,120,105
116 NMAX=1
    GO TO 15
117 NMAX=2
    GO TO 15
118 NMAX=3
    GO TO 15
119 NMAX=4
    GO TO 15
120 NMAX=6
    GO TO 15
121 NMAX=2
    GO TO 20
122 NMAX=3
    GO TO 20
123 NMAX=4
    GO TO 20
124 NMAX=5
    GO TO 20
125 NMAX=6
    GO TO 20
126 NMAX=7
    GO TO 20
127 NMAX=8
    GO TO 20
128 NMAX=9
    GO TO 20
129 NMAX=10
    GO TO 20
130 NMAX=11
C WA IS OBTAINED FROM ASYMPTOTIC SERIES
15 RV=2.*(R2-AI2)
   AIBK=4.*REZ*AIMZ
   AIDKM1=AIBK
   AIDKM2=0.
   AINKM2=0.
   RNKM2=0.
   TEMPM=0.
   TEMEL=0.
   RDKM2=1.
   RNKM1=-1.12837917*AIMZ
   AINKM1=1.12837917*REZ
   RDKM1=RV+1.
   DO11K=1,NMAX
   RAK=AA(K)
   RBK=RV-BB(K)
   RNK=RBK*RNKM1+RAK*RNKM2+AIBK*AINKM1
   AINK=RBK*AINKM1+RAK*AINKM2+AIBK*RNKM1
   AIDK=RBK*AIDKM1+RAK*AIDKM2+AIBK*RDKM1
   RDK=RBK*RDKM1+RAK*RDKM2+AIBK*AIDKM1
   RNKM2=RNKM1
   AINKM2=AINKM1
   RDKM2=RDKM1
   AIDKM2=AIDKM1
   RNKM1=RNK

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      AINKM1=AINK
      RDKM1=RDK
11  AIDKM1=AIDK
12  AMAGN=RDK*RDK+AIDK*AIDK
      REW=(RNK*RDK+AINK*AIDK)/AMAGN
      AIMW=(RDK*AINK-AIDK*RNK)/AMAGN
65  RETURN
C WT IS OBTAINED FROM TAYLOR SERIES
20  TEMP1=R2*AI2
      TEMP2=2.*TEMP1*TEMP1
      AJ=(R2-AI2)/TEMP2
      AK=2.*REZ*AIMZ/TEMP2
      C=0.
      BQ=0.
      D=0.
      GQ=0.
      H=0.
      EL=0.
      AQ=1.
      AM=1.
      EXPON=EXPF(TEMP2*AJ)
      EXPC=EXPON*COSF(TEMP2*AK)
      EXPS=-EXPON*SINF(TEMP2*AK)
      DO13K=1,NMAX
      TEMP4=X(K)
      AJP=AJ+Y(K)
      RNK=RBK*RNKM1+RAK*RNKM2-AIBK*AINKM1
      AINK=RBK*AINKM1+RAK*AINKM2-AIBK*RNKM1
      AIDK=RBK*AIDKM1+RAK*AIDKM2-AIBK*RDKM1
      RDK=RBK*RDKM1+RAK*RDKM2-AIBK*AIDKM1
      RNKM2=RNKM1
      AINKM2=AINKM1
      RDKM2=RDKM1
      AIDKM2=AIDKM1
      RNKM1=RNK
      AINKM1=AINK
      RDKM1=RDK
13  AIDKM1=AIDK
6  TEMP7=(AM*AM+EL*EL)*1.7724539
      REF=(AIMZ*(C*AM+D*EL)-REZ*(AM*D-C*EL))/
1  TEMP7/TEMP1
      AIMF=(AIMZ*(AM*D-C*EL)+REZ*(C*AM+D*EL)
1  )/TEMP7/TEMP1
      REW=EXPC*REF
      AIMW=EXPS*AIMF
64  RETURN
      END

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SUBROUTINE XSECT					XSECT	00
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),					COMR	1
X	T8(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),				COMR	2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),				COMR	3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),				COMR	4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),				COMR	5
X	HS(150),T23(155),H23(150),TCV23(7),TPV2(7),				COMR	6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),				COMR	7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),				COMR	8
X	H3(150),T33(155),H33(150),TCV33(7),PHI2(3)				COMR	9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NROD,					COM1	1
X	S(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,				COM1	2
X	XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,				COM1	3
X	MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,				COM1	4
X	NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,				COM1	5
X	AB,AB2,PIROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,				COM1	6
X	Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,				COM1	7
X	Z4,BA,PIROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,				COM1	8
X	NRESAB,PIMOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,				COM1	9
X	SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,KGP,				COM1	10
X	NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,				COM1	11
X	AMASSM(10)				COM1	12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),					COM2	1
X	ER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),				COM2	2
X	G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),				COM2	3
X	CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),				COM2	4
X	SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)				COM2	5
DATA(T2 =						
X	0.73952224,	0.73635098,	0.73320650,	0.73008845,	0.72699648, T2	1
X	0.72393028,	0.72088951,	0.71787385,	0.71488300,	0.71191665, T2	6
X	0.70897449,	0.70605623,	0.70316158,	0.70029026,	0.69744199, T2	11
X	0.69461648,	0.69181348,	0.68903272,	0.68627394,	0.68353687, T2	16
X	0.68082127,	0.67812690,	0.67545350,	0.67280084,	0.67016868, T2	21
X	0.66755680,	0.66496496,	0.66239293,	0.65984051,	0.65730747, T2	26
X	0.65479359,	0.65229867,	0.64982251,	0.64736488,	0.64492561, T2	31
X	0.64250448,	0.64010130,	0.63771588,	0.63534803,	0.63299757, T2	36
X	0.63066431,	0.62834807,	0.62604867,	0.62376594,	0.62149970, T2	41
X	0.61701601,	0.61259628,	0.60823920,	0.60394350,	0.59970797, T2	46
X	0.59553138,	0.59141259,	0.58735046,	0.58334389,	0.57939178, T2	51
X	0.57549311,	0.57164683,	0.56785197,	0.56410754,	0.56041260, T2	56
X	0.55676622,	0.55316750,	0.54961557,	0.54610955,	0.54264862, T2	61
X	0.53923196,	0.53585876,	0.53252825,	0.52923965,	0.52599224, T2	66
X	0.52278527,	0.51961803,	0.51648984,	0.51340001,	0.51034787, T2	71
X	0.50773327,	0.50435410,	0.50141121,	0.49850349,	0.49563036, T2	76
X	0.49279122,	0.48998552,	0.48721269,	0.48447219,	0.48176347, T2	81
X	0.47908603,	0.47643933,	0.47382289,	0.47123622,	0.46867882, T2	86
X	0.46615022,	0.46364998,	0.46117762,	0.45873272,	0.45631482, T2	91
X	0.45873272,	0.45392352,	0.44921900,	0.44461593,	0.44011117, T2	96
X	0.43570174,	0.43138475,	0.42715741,	0.42301707,	0.41896114, T2	101
X	0.41498715,	0.41109271,	0.40727553,	0.40353338,	0.39986413, T2	106
X	0.39626572,	0.39273615,	0.38927351,	0.38587596,	0.38254169, T2	111
X	0.37926898,	0.37605617,	0.37290164,	0.36980384,	0.36676127, T2	116
X	0.36377247,	0.36083603,	0.35795059,	0.35511485,	0.35232752, T2	121
X	0.34958737,	0.34689321,	0.34424390,	0.34163830,	0.33907535, T2	126
X	0.33655398,	0.33407319,	0.33163199,	0.32922943,	0.32686458, T2	131
X	0.32453654,	0.32224446,	0.31998747,	0.31776478,	0.31557558, T2	136
X	0.31341910,	0.31129460,	0.30920134,	0.30713864,	0.30510580, T2	141
X	0.30310216,	0.30112707,	0.29917991,	0.29726008,	0.29536696, T2	146
X	0.29350001,	0.29165864,	0.28984233,	0.28805054,	0.28628276, T2	151
DATA(T3 =						
X	0.75218052,	0.74919094,	0.74622724,	0.74328906,	0.74037609, T3	1
X	0.73748798,	0.73462442,	0.73178509,	0.72896968,	0.72617789, T3	6

1 DO 5 IK=1,NROD	XSECT 02
SIGA22(IK)=ADENR(IK)*SIGA22(IK)	XSECT 03
5 SIGF22(IK)=ADENR(IK)*SIGF22(IK)	XSECT 04
DO 10 IM=1,NMOD	XSECT 05
10 SIGAM(IM)=ADENM(IM)*SIGAM(IM)	XSECT 06
E=.5*ENGP(1)*(1.+EXDU)	XSECT 07
DEL=.5*V	XSECT 08
FDEL=1.+5*DEL*(1.+75*DEL*(1.-5*DEL))	XSECT 09
GO TO 30	XSECT 10
15 FDEL=1.+5*V*(1.+75*V*(1.-5*V))	XSECT 11
20 E=E*EXDU	XSECT 12
30 SIGTOT=0.	XSECT 13
XMOD=XMOD*FDEL	XSECT 14
DO 80 I=1,NROD	XSECT 15
IF(I=NRESAB)40,40,35	XSECT 16
35 SIGA(I)=XMOD*SIGA22(I)	XSECT116
SIGX(I)=XMOD*SIGF22(I)	XSECT 17
GO TO 70	XSECT117
40 SIGS(I)=0.	XSECT 18
SIGA(I)=SIGA22(I)	XSECT 19
SIGX(I)=SIGF22(I)	XSECT 20
XZETA(I)=XZETA(I)*FDEL	XSECT 20
NRESI=NRES(I)	XSECT120
DO 60 J=1,NRESI	XSECT 21
XROD(I,J)=XROD(I,J)*FDEL	XSECT 22
X=2.*(E-ER(I,J))/GAMMA(I,J)	XSECT 23
IF(ABSF(X)-XNAT(I,J))45,45,50	XSECT 24
45 ZETA=GAMMA(I,J)*XZETA(I)	XSECT 25
AIMZ=.5*ZETA	XSECT 26
REZ=X*AIMZ	XSECT 27
CALL W	XSECT 28
PSI=.88623*ZETA*REW	XSECT 29
CHI=1.77246*AIMW*ZETA	XSECT 30
GO TO 55	XSECT 31
50 PSI=1./(1.+X**2)	XSECT 32
CHI=2.*X*PSI	XSECT 33
55 F=PSI*SIGZ(I,J)	XSECT 34
SIGA(I)=SIGA(I)+F*XROD(I,J)*(GAMFIS(I,J)+GAMRAD(I,J))	XSECT 35
SIGX(I)=SIGX(I)+F*XROD(I,J)*GAMFIS(I,J)	XSECT 36
60 SIGS(I)=SIGS(I)+F*(GAMNUT(I,J)+SIGIN(I,J)*CHI)	XSECT 37
SIGS(I)=SIGS(I)+SIGPMR(I)	XSECT 38
GO TO 80	XSECT 39
70 SIGS(I)=SIGPMR(I)	XSECT 40
80 SIGTOT=SIGTOT+SIGA(I)+SIGS(I)	XSECT 41
SIGMOD=0.	XSECT 42
DO 90 K=1,NMOD	XSECT 43
SMOD(K)=XMOD*SIGAM(K)	XSECT 44
90 SIGMOD=SIGMOD+SIGPMH(K)*SMOD(K)	XSECT 45
RETURN	XSECT 46
END	XSECT 47

SUBROUTINE DATA										DATA 000
COMMON/RODDATA/T11(155),H11(150),TCV11(7),TEPV1(3),TCV1(3,3),										COMR 1
X	TS(155),T12(155),H12(150),TCV12(7),TEPV2(3),TCV2(3,3),									COMR 2
X	T1(155),T13(155),H13(150),TCV13(7),TEPV3(3),TCV3(3,3),									COMR 3
X	T2(155),T21(155),H21(150),TCV21(7),TEPV4(3),TCV4(3,3),									COMR 4
X	T3(155),T22(155),H22(150),TCV22(7),TPV1(7),TCV5(3,3),									COMR 5
X	HS(150),T23(155),H23(150),TCV23(7),TPV2(7),									COMR 6
X	H1(150),T31(155),H31(150),TCV31(7),TPV3(7),									COMR 7
X	H2(150),T32(155),H32(150),TCV32(7),TPS(7),									COMR 8
X	H3(150),T33(155),H33(150),TCV33(7),PHIZ(3)									COMR 9
COMMON/1/SIGPM(10),SIGA22(10),LMOD(10),FLUX(7),ENERGY(600),NR0D,										COM1 1
XS(3),TAB,SIGPR(10),SIGF22(10),LROD(10),CDEN(4),SIGMAC(600),NMOD,										COM1 2
XQ(3),TBB,SIGAM(10),MATROD(10),SIGA(10),NRES(4),F,TOTAL1(4),NABR,										COM1 3
X MU,TBA,ADENM(10),MATMOD(10),SIGX(10),MGP(25),U,TOTAL2(4),NABM,										COM1 4
X NU,BA2,ADENR(10),SIGPMR(10),SIGS(10),RAP(25),VV,XZETA(4),AIMZ,										COM1 5
X AB,AB2,PIROD(10),SIGPM(10),SMOD(10),RAD(7),DELTA,LARGE,AIMW,										COM1 6
X Z2,EPS,PLMOD(10),AMASSR(10),ENGP(26),EPV(3),NFLUX,SIGMA,REZ,										COM1 7
X Z4,BA,PIROD(10),CPERT(25),BICK1(7),A,PA(3),SIGTOT,TEMP,REW,										COM1 8
X NRESAB,PIMOD(10),PHIROD(3),BICK2(7),B,PB(3),SIGMOD,EXDU,NGP,										COM1 9
X SDD,B2,TPHIR(25),PHIMOD(3),BICK3(7),E,VR(3),COLROD,MORE,MGP,										COM1 10
X NAB,A2,TPHIM(25),V,TITLE(9),RADSQ(7),Z,VM(3),COLMOD,XMOD,IGP,										COM1 11
X AMASSM(10)										COM1 12
COMMON/2/RRASUR(10,25),RRAR(10,25),GAMNUT(4,60),TFLUXR(3,25),										COM2 1
XER(4,60),RRFSUR(10,25),RRSR(10,25),GAMRAD(4,60),TFLUXM(3,25),										COM2 2
X G(4,60),FLUXR(600,3),RRFR(10,25),GAMFIS(4,60),XROD(4,60),										COM2 3
X CV(3,3),FLUXM(600,3),RRAM(10,25),GAMMA(4,60),XNAT(4,60),										COM2 4
X SIGSS(600,4),RRSM(10,25),SIGIN(4,60),SIGZ(4,60)										COM2 5
DATA(H1 =										
X	0.21987813,	0.21628921,	0.21280815,	0.20943050,	0.20615202,	H1	1			
X	0.20296866,	0.19987661,	0.19687223,	0.19395207,	0.19111284,	H1	6			
X	0.18635141,	0.18566479,	0.18305016,	0.18050481,	0.17802616,	H1	11			
X	0.17561176,	0.17325926,	0.17096643,	0.16873112,	0.16655130,	H1	16			
X	0.16442502,	0.16235042,	0.16032570,	0.15834918,	0.15641920,	H1	21			
X	0.15453423,	0.15269275,	0.15089333,	0.14913460,	0.14741525,	H1	26			
X	0.14573401,	0.14408967,	0.14248107,	0.14090709,	0.13936666,	H1	31			
X	0.13785876,	0.13638238,	0.13493658,	0.13352045,	0.13213311,	H1	36			
X	0.13077370,	0.12944143,	0.12813550,	0.12685515,	0.12559967,	H1	41			
X	0.12436834,	0.12316051,	0.12197550,	0.12081271,	0.11967151,	H1	46			
X	0.11855133,	0.11745160,	0.11637179,	0.11531135,	0.11426979,	H1	51			
X	0.11324661,	0.11224135,	0.11125353,	0.11028273,	0.10932851,	H1	56			
X	0.10839045,	0.10746816,	0.10656124,	0.10566932,	0.10479205,	H1	61			
X	0.10392905,	0.10308000,	0.10224456,	0.10142242,	0.10061325,	H1	66			
X	0.09981677,	0.09903267,	0.09826068,	0.09750052,	0.09675192,	H1	71			
X	0.09601463,	0.09528839,	0.09457295,	0.09386809,	0.09317357,	H1	76			
X	0.09248917,	0.09181467,	0.09114985,	0.09049452,	0.08984848,	H1	81			
X	0.08921152,	0.08858347,	0.08796413,	0.08735333,	0.08675090,	H1	86			
X	0.08615666,	0.08557046,	0.08499212,	0.08442150,	0.08385844,	H1	91			
X	0.08330279,	0.08275441,	0.08221316,	0.08167891,	0.08115151,	H1	96			
X	0.08063084,	0.08011676,	0.07960917,	0.07910793,	0.07861293,	H1	101			
X	0.07812405,	0.07764118,	0.07716422,	0.07669304,	0.07622756,	H1	106			
X	0.07576767,	0.07531326,	0.07486424,	0.07442053,	0.07398201,	H1	111			
X	0.07354861,	0.07312024,	0.07269680,	0.07227821,	0.07186440,	H1	116			
X	0.07145528,	0.07105077,	0.07065080,	0.07025528,	0.06986415,	H1	121			
X	0.06947733,	0.06909476,	0.06871636,	0.06834206,	0.06797180,	H1	126			
X	0.06760552,	0.06724315,	0.06688463,	0.06652990,	0.06617890,	H1	131			
X	0.06583157,	0.06548785,	0.06514769,	0.06481103,	0.06447782,	H1	136			
X	0.06414801,	0.06382155,	0.06349837,	0.06317845,	0.06286172,	H1	141			
X	0.06254814,	0.06223767,	0.06193025,	0.06162585,	0.06132441,	H1	146			
DATA(H2 =										
X	0.28805054,	0.28453848,	0.28111853,	0.27778695,	0.27454020,	H2	1			
X	0.27137492,	0.26828795,	0.26527627,	0.26233700,	0.25946744,	H2	6			
X	0.25666499,	0.25392721,	0.25125174,	0.24863637,	0.24607897,	H2	11

XMOD=SQRTF(.0253/ENGP(1))	DATA 040
AB=A/B	DATA 050
BA=B/A	DATA 060
BA2=BA**2	DATA 070
AB2=AB**2	DATA 080
A2=A**2	DATA 090
B2=B**2	DATA 100
DO 5 I=1,3	DATA 110
VR(I)=3.14159265*A2/FLOATF(I)	DATA 120
5 VM(I)=VR(I)*(BA2**I-1)	DATA 130
RAD(1)=0.	DATA 140
RAD(2)=.33333333	DATA 150
RAD(3)=.66666666	DATA 160
RAD(4)=1.	DATA 170
RAD(5)=RAD(3)+RAD(2)*BA	DATA 180
RAD(6)=RAD(2)+RAD(3)*BA	DATA 190
RAD(7)=BA	DATA 200
DO 10 J=1,7	DATA 210
10 RADSQ(J)=RAD(J)**2	DATA 220
VV=3.46668E-04*ENGP(1)*TEMP	DATA 230
V=DELTA*(1.-.5*DELTA*(1.-(DELTA/3.)*(1.-.25*DELTA)))	DATA 240
EXDU=1.-V	DATA 250
U=1./(2.*BA2*(VM(2)-VM(1))+VM(1)=VM(3))	DATA 260
DO 40 K=1,NMOD	DATA 270
SIGPMM(K)=ADENM(K)*SIGPM(K)	DATA 280
SIGMA=SIGMA+ADENM(K)*(SIGPM(K)+XMOD*SIGAM(K))	DATA 290
IF(AMASSM(K)=1.1)15,15,20	DATA 300
15 LMOD(K)=500000	DATA 310
BETA=1.	DATA 320
UMAX=20.	DATA 330
GO TO 25	DATA 340
20 LMOD(K)=2.*LOGF(1.+2./(AMASSM(K)=1.))/DELTA	DATA 350
UMAX=DELTA*FLOATF(LMOD(K))	DATA 360
BETA=1./(1.-EXP(-UMAX))	DATA 370
25 P1MOD(K)=BETA*V	DATA 380
PLMOD(K)=(BETA-1.)*V	DATA 390
SDD=SDD+SIGPMM(K)*(1.-(BETA-1.)*UMAX)+VM(1)	DATA 400
IF(LMOD(K)=600)30,40,40	DATA 410
30 IF(LMOD(K)=LARGE)40,40,35	DATA 420
35 LARGE=LMOD(K)	DATA 430
40 CONTINUE	DATA 440
DO 85 L=1,NROD	DATA 450
SIGPMR(L)=ADENR(L)*SIGPR(L)	DATA 460
IF(AMASSR(L)=1.1)45,45,50	DATA 470
45 LROD(L)=500000	DATA 480
BETA=1.	DATA 490
UMAX=20.	DATA 500
GO TO 55	DATA 510
50 LROD(L)=2.*LOGF(1.+2./(AMASSR(L)=1.))/DELTA	DATA 520
UMAX=DELTA*FLOATF(LROD(L))	DATA 530
BETA=1./(1.-EXP(-UMAX))	DATA 540
55 P1ROD(L)=BETA*V	DATA 550
PLROD(L)=(BETA-1.)*V	DATA 560
SDD=SDD+VR(1)*SIGPMR(L)*(1.-(BETA-1.)*UMAX)	DATA 570
IF(LROD(L)=600)60,70,70	DATA 580
60 IF(LROD(L)=LARGE)70,70,65	DATA 590
65 LARGE=LROD(L)	DATA 600
70 IF(L=NRESAB)75,75,85	DATA 610
75 XZETA(L)=SQRTF(AMASSR(L)/VV)	DATA 620
NRESL=NRES(L)	DATA 625
DO 80 M=1,NRESL	DATA 630
XROD(L,M)=SQRTF(ABSF(ER(L,M))/ENGP(1))	DATA 640
GAMMA(L,M)=GAMNUT(L,M)+GAMRAD(L,M)+GAMFIS(L,M)	DATA 650
SIGZ(L,M)=2.62E+06*G(L,M)+GAMNUT(L,M)/(ABSF(ER(L,M))*GAMMA(L,M)	DATA 660
X **2)*ADENR(L)	DATA 670
80 SIGIN(L,M)=SQRTF(SIGPMR(L)*G(L,M)+SIGZ(L,M)*GAMNUT(L,M))	DATA 680
85 CONTINUE	DATA 690
RETURN	DATA 700
END	DATA 710

SUBROUTINE KI(Z,X,K)	KI	010
DIMENSION Z(10),TN3(7),TD3(7),TN2(7),TD2(7),TN1(6),TD1(6),TZ(6)	KI	020
DATA(TN3=.3869326747E+01, .2384938852E+02, .4462802315E+02,	KI	030
1 .2946275617E+02, .7112371513E+01, .5229698829E+00,	KI	040
2 .0000000000E+00)	KI	050
DATA(TD3=.5056885587E+01, .3415217325E+02, .7972442010E+02,	KI	060
1 .7879235420E+02, .3481496948E+02, .6561524932E+01,	KI	070
2 .4172698269E+00)	KI	080
DATA(TN2=.2031025486E+00, .4557657076E+01, .2402730460E+02,	KI	090
1 .3564815114E+02, .1580553881E+02, .1866032641E+01,	KI	100
2 .0000000000E+00)	KI	110
DATA(TD2=.2045502170E+00, .4771899521E+01, .2864849162E+02,	KI	120
1 .5850777370E+02, .4746853418E+02, .1503011023E+02,	KI	130
2 .1488882521E+01)	KI	140
DATA(TN1=.3333333333E+00, .5000000000E-01, .3968253960E+02,	KI	150
1 .1929012340E-03, .6313131313E-05, .1838500000E+06)	KI	160
DATA(TD1=.7561176680E+00, .1122784335E+01, .1398974810E+01,	KI	170
1 .1617228779E+01, .1797026760E+01, .1949707411E+01)	KI	180
DATA(TZ= -.783235800E-01, .218956800E-01, -.106244600E+01,	KI	190
1 .587872000E-02, -.251540000E-02, .532080000E+03)	KI	200
IF(X)10,10,30	KI	210
10 Z(1)=1.570796327	KI	220
Z(2)=1.0	KI	230
Z(3)=.785398163	KI	240
20 IF(K=3)200,200,100	KI	250
30 IF(X=30.)50,40,40	KI	260
40 ASYMP=EXP(-X)*SQRTF(1.570796/X)	KI	270
Z(1)=ASYMP*(1.-(.625-1.00781/X)/X)	KI	280
Z(2)=ASYMP*(1.-(1.125-2.69531/X)/X)	KI	290
Z(3)=ASYMP*(1.-(1.625-5.13281/X)/X)	KI	300
GO TO 20	KI	310
50 F=1.	KI	320
FR=EXP(-X)*SQRTF(1.+X)	KI	330
SN3=.132356142E+00	KI	340
SD3=.168521747E+00	KI	350
SN2=.135285215E-02	KI	360
SD2=.135285226E-02	KI	370
DO 60 I=1,7	KI	380
F=F*X	KI	390
SN3=SN3+TN3(I)*F	KI	400
SD3=SD3+TD3(I)*F	KI	410
SN2=SN2+TN2(I)*F	KI	420
60 SD2=SD2+TD2(I)*F	KI	430
Z(3)=FR*SN3/SD3	KI	440
Z(2)=FR*SN2/SD2	KI	450
IF(X=2.)70,80,80	KI	460
70 F=.25*X*X	KI	470
Q=LOGF(.5*X)	KI	480
Z(1)=1.57076326-X*(.42278335=Q)	KI	490
FR=X	KI	500
DO 75 J=1,6	KI	510
FR=FR*F	KI	520
75 Z(1)=Z(1)-FR*(TN1(J)*(TD1(J)-Q))	KI	530
GO TO 20	KI	540
80 F=1.	KI	550
ZERO=1.25331414	KI	560
DO 90 L=1,6	KI	570
F=2.*F/X	KI	580
90 ZERO=ZERO+TZ(L)*F	KI	590
ZERO=ZERO*EXP(-X)/SQRTF(X)	KI	600
Z(1)=2.*Z(3)-X*(ZERO-Z(2))	KI	610
GO TO 20	KI	620
100 DO 150 M=4,K	KI	630
R1=M=1	KI	640
R2=M=2	KI	650
150 Z(M)=(R2*Z(M-2)+X*(Z(M-3)-Z(M-1)))/R1	KI	660
200 RETURN	KI	670
END	KI	680

```

PROGRAM FLUX
  DIMENSION ZI(4),ZK(4),EZI(40),EZK(40),CV(3,3),C11(10),C12(10),
X    C13(10),C21(10),C22(10),C23(10),C31(10),C32(10),C33(10),X(10),
X    XMZZ(10),XM2Z(10),XM4Z(10),XM22(10),XM42(10),XM44(10)
1 READ 101,Z,DX,MORE
  L=1
  X(L)=Z
5 A=X(L)
101 FORMAT(2E12.6,I6)
201 FORMAT(1H1,50X,16H FLUX COEFFICIENTS//9X,118HX      CV(1,1)      CV(
X1,2)      CV(1,3)      CV(2,1)      CV(2,2)      CV(2,3)      CV(3
X,1)      CV(3,2)      CV(3,3))
202 FORMAT(F10.4,9E13.5)
203 FORMAT(///50X,8H MOMENTS//9X,1HX,14X,6HM(0,0),14X,6HM(0,2),14X,6H
XM(0,4),14X,6HM(2,2),14X,6HM(2,4),14X,6HM(4,4))
204 FORMAT(F10.4,6E20.5)
  CALL BES1(A,,0,3,EZI,4)
  XPLUS=EXPF(A)
  XMINUS=EXPF(-A)
  CALL BESK(A,,0,3,EZK,4)
  DO 250 K=1,4
    ZI(K)=XPLUS*EZI(K)
250 ZK(K)=XMINUS*EZK(K)
    CV(1,1)=9.*QZZ-18.*Q2Z+10.*Q4Z
    CV(1,2)=-12.*(3.*QZZ-8.*Q2Z+5.*Q4Z)
    CV(1,3)=30.*(QZZ-3.*Q2Z+2.*Q4Z)
    CV(2,1)=9.*Q2Z-24.*Q22+15.*Q42
    CV(2,2)=-36.*Q2Z+128.*Q22-90.*Q42
    CV(2,3)=30.*(Q2Z-4.*Q22+3.*Q42)
    CV(3,1)=9.*(Q4Z-3.*Q42+2.*Q44)
    CV(3,2)=-36.*(Q4Z-4.*Q42+3.*Q44)
    CV(3,3)=30.*(Q4Z-4.5*Q42+3.6*Q44)
    C11(L)=CV(1,1)
    C12(L)=CV(1,2)
    C13(L)=CV(1,3)
    C21(L)=CV(2,1)
    C22(L)=CV(2,2)
    C23(L)=CV(2,3)
    C31(L)=CV(3,1)
    C32(L)=CV(3,2)
    C33(L)=CV(3,3)
    XMZZ(L)=QZZ
    XM2Z(L)=Q2Z
    XM4Z(L)=Q4Z
    XM22(L)=Q22
    XM42(L)=Q42
    XM44(L)=Q44
    IF(L=10) 10,20,20
10 L=L+1
  X(L)=X(L-1)+DX
  GO TO 5
20 PRINT 201
  PRINT 202,(X(J),C11(J),C12(J),C13(J),C21(J),C22(J),C23(J),C31(J),
X    C32(J),C33(J),J=1,10)
  PRINT 203
  PRINT 204,(X(M),XMZZ(M),XM2Z(M),XM4Z(M),XM22(M),XM42(M),XM44(M),
X    M=1,10)
  IF(MORE) 1,1,100
100 END

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REFERENCES

1. L. W. Nordheim, Theory of Resonance Absorption, Proc. Symp. Applied Math., Am. Math. Soc. 11, 58-88, Providence (1961).
2. J. Chernick and R. Vernon, Some Refinements in the Calculation of Resonance Integrals, Nucl. Sci. Eng. 4, 649, 672 (1958).
3. R. D. Richtmyer, R. Van Norton, and R. Wolfe, The Monte Carlo Calculation of Resonance Capture in Reactor Lattices, Second Intern. Conf. on Peaceful Uses of Atomic Energy, Geneva, P/2489, 16, 180-186 (1958).
4. N. Corngold, Resonance Escape Probability in Slab Lattices, BNL-445 (1956); J. Nucl. Energy 4, 293-304 (1957).
5. J. O. Berg, Resonance Integrals in Tight Lattices, Nukleonik 5, 345-349 (1963).
6. S. Iijima, Resonance Absorption and the Resonance Disadvantage Factor, Nucl. Sci. Eng. 17, 42-46 (1963).
7. P. H. Kier, The Effect of a Non-Asymptotic Neutron Source on Resonance Absorption in Slab Lattices, Sc.D. thesis, Nucl. Engr. Dept., MIT (1963) unpublished.
8. F. E. Driggers, A Method of Calculating Neutron Absorptions and Flux Spectra at Epithermal Energies, CRRP-1197 (1964).
9. E. E. Lewis, A Boltzmann Integral Equation Treatment of Resonance Absorption in Reactor Lattices, Ph.D. thesis, Univ. of Ill. (1964) unpublished; Trans. Am. Nucl. Soc. 7, 29-30 (1964).
10. A. Amouyal and P. Benoist, New Method of the Determination of the Thermal Utilization Factor of a Cell, CEA-571 (1956).
11. K. B. Cady, Neutron Transport in Cylindrical Rods, Ph.D. thesis, Nucl. Engr. Dept., MIT (1963).
12. R. Simms, I. Kaplan, T. J. Thompson, and D. D. Lanning, Failure of the Cell Cylindricalization Approximation in Closely Packed Uranium/Heavy Water Lattices, Trans. Am. Nucl. Soc. 7, No. 1, 9 (1964).
13. H. Castle, H. W. Ibser, G. Sacher, and A. M. Weinberg, The Effect of Fast Fission on k, CP-644 (1943); A. M. Weinberg and E. P. Wigner, Physical Theory of Neutron Chain Reactors, The University of Chicago Press, Chicago (1958), p. 711.

14. K. B. Cady and M. Clark, Neutron Transport in Cylindrical Rods, Nucl. Sci. Eng. 18, 491-507 (1964).
15. 3600 Computer System FORTRAN/Preliminary Reference Manual, Control Data Corp. (1964).
16. F. B. Hildebrand, Introduction to Numerical Analyses, McGraw-Hill Book Co., Inc., New York (1956), p. 160.
17. I. Gargantini and T. Pomentale, Rational Chebyshev Approximation to the Bessel Function Integrals $K_i(x)$, Comm. ACM 7, 727-730 (1964).
18. D. M. O'Shea and H. C. Thacher, Jr., Computation of Resonance Line Shape Functions, Trans. Am. Nucl. Soc. 6, No. 1, 36-37 (1963).
19. M. Abramowitz and I. A. Stegun (Eds.), Handbook of Mathematical Functions, U. S. Government Printing Office, Washington, D. C. (1964), Chap. 25.