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Calculation of Thermal Neutron Diffusion Length and Group Cross Sections: The GLEN Program

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by

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CALCULATION OF THERMAL NEUTRON DIFFUSION LENGTH AND GROUP CROSS SECTIONS: THE GLEN PROGRAM

by

W. W. Clendenin

ABSTRACT

The FORTRAN-IV program GLEN has been developed to obtain thermal neutron scattering cross sections for transport calculations, and to determine the diffusion length for thermalized neutrons. Cross section values are computed using the results of TOR for a fine mesh of initial and final energies and angles of deflection, and are used to obtain the coefficients in a Legendre polynomial expansion. The total cross section, transport cross section, and similar integral parameters are obtained by numerical integration over the energy mesh. Fine mesh cross sections are used for calculation of the diffusion length, both in diffusion theory and in a P_{11} approximation. Neutron spectra are computed corresponding to an epithermal source and a buckling for thermal neutrons, or optionally a Maxwell distribution is used for the scalar flux. Flux-weighted group cross sections based on these spectra are calculated. The printed results include transfer cross sections and may be used in a few-group Legendre polynomial treatment or in transport calculations based on the S_n method. Card output is provided in the format of cross section input for S_n programs.

I. INTRODUCTION.

The functions of the FORTRAN-IV program GLEN are to obtain values of the double differential scattering cross section[1] $\sigma(E_o \to E,\theta,T)$ for thermal neutrons, to evaluate the total scattering cross section and thermal neutron diffusion length from these, and to calculate flux-weighted group average cross sections for a few-group treatment of thermal neutrons. The scattering cross sections are obtained from the mesh values of the function $s(R_n,\epsilon_m)$ calculated by the TOR program.[1]

The cross section $\sigma(E_o \to E,\theta,T)$ may be written in the form

$$\sigma(E_o \to E,\theta,T) = \sigma_o(E_o \to E,\theta,T) + \sigma_1(E_o \to E,\theta,T), \qquad (1)$$

where $\sigma_o(E_o \to E,\theta,T)$ is an elastic scattering term, and all inelastic scattering is included in the term $\sigma_1(E_o \to E,\theta,T)$. The cross section $\sigma_1(E_o \to E,\theta,T)$ is given in terms of $s(R,\epsilon)$ as

$$\sigma_1(E_o \to E,\theta,T) = (\sigma_b/4\pi)(E/E_o)^{\frac{1}{2}} s(R,\epsilon). \qquad (2)$$

Here σ_b is the bound cross section of the atom comprising the moderator, and the parameters of $s(R,\epsilon)$ are

$$R = (m/M)(E_o + E - 2E_o^{\frac{1}{2}}E^{\frac{1}{2}} \cos\theta), \qquad (3)$$

$$\epsilon = E - E_o, \qquad (4)$$

where (m/M) is the ratio of neutron mass to atomic mass. The cross section $\sigma_1(E_o \to E,\theta,T)$ is obtained

for particular values of E_o, E, θ by interpolating $s(R,\epsilon)$ for R,ϵ given by Eqs. (3) and (4) from the mesh values $s(R_n,\epsilon_m)$.

It is convenient to treat the cross section $\sigma_1(E_o \to E,\theta,T)$ by means of the familiar expansion in Legendre polynomials

$$\sigma_1(E_o \to E,\theta,T) = (4\pi)^{-1}\sum_{\ell}(2\ell+1)\sigma_1^{(\ell)}(E_o \to E)P_\ell(\cos\theta). \tag{5}$$

The expansion coefficients are given by

$$\sigma_1^{(\ell)}(E_o \to E) = 2\pi \int_o^{\pi} P_\ell(\cos\theta)\sigma_1(E_o \to E,\theta,T)\sin\theta d\theta. \tag{6}$$

For $\ell = 0,1,2,3$ these coefficients are evaluated by the numerical calculation of the integrals described in Section II. This evaluation is carried out for a fine mesh of energy values E_n. A maximum of 87 values of E_n, specified as input, is provided for. The part of the total scattering cross section corresponding to $\sigma_1(E_o \to E,\theta,T)$, designated $\sigma_o^{in}(E_o)$, is the integral of $\sigma_1^{(o)}(E_o \to E)$ over all final energies E, evaluated by trapezoid rule integration.

The elastic scattering cross section $\sigma_o(E_o \to E,\theta,T)$ depends on the type of moderator being considered. For a monatomic gas, an option specified in GLEN by a value 0 for the indicator IDEN, this cross section vanishes for all E_o. For a crystalline material, specified in GLEN by IDEN > 0, it is possible either to have $\sigma_o(E_o \to E,\theta,T)$ computed internally in the incoherent approximation, or to read in values obtained from another program. The control indicator INSELR, when set to 1, reads in values of the coefficients $\sigma_o^{el}(E_o)$ and $\sigma_1^{el}(E_o)$ of the Legendre polynomial expansion

$$\sigma_o(E_o \to E,\theta,T) = (4\pi)^{-1}\sum_{\ell}(2\ell+1)\sigma_\ell^{el}(E_o)\delta(E-E_o)P_\ell(\cos\theta). \tag{7}$$

For INSELR = 0, no elastic cross sections are read in. An input energy parameter E_b, designated BRGLIM, is used to control the internal computation. For $E_o > E_b$, values of $\sigma_\ell^{el}(E_o)$ corresponding to the incoherent approximation are calculated. By setting E_b, the incoherent approximation may be used for all or part of the values E_o.

Based on the moderator cross sections obtained as outlined above, macroscopic cross sections for the fine energy group-structure are obtained for each composition specified. The composition is made up of the moderator and a maximum of four heavy non-moderating isotopes. All number densities are specified as input. For each composition, a diffusion length of the mixture is calculated in two approximations, one the diffusion approximation, and the second a P_{11} approximation. In both cases the diffusion length is computed as an eigenvalue using Gauss-Seidel iteration,[2] and verified by calculating residuals. The formulation of these calculations is given in Section IV.

Three optional means of determining a scalar flux for the flux-weighted averages are provided in GLEN. When the indicator NSPEC is set to 1, a hardened spectrum corresponding to a scattering-in source from epithermal energies and macroscopic absorption and buckling is used. For NSPEC = 0, a Maxwell distribution is used. When NSPEC = - 1, the scalar flux is read in. In each case higher order flux components are calculated, based on the transport equation, for $\ell = 1,2,3$. For each isotope of the composition values of the group scattering, absorption, fission, and transfer cross sections are obtained for $\ell = 0,1,2,3$. These are punched in the format required as input for DTF-IV,[3] as well as printed out. In addition, macroscopic scattering, absorption, fission, and transfer cross sections are printed. Section V describes the calculation of group cross sections.

The detailed input and output of the GLEN program are described in Sections VI and VII.

II. LEGENDRE POLYNOMIAL EXPANSIONS OF CROSS SECTIONS.

The calculation of cross sections is carried out for the mesh of energy values E_n, designated ENERGY(N), N = 1, NENERG ≤ 87. Both the initial energy E_o and final energy E are taken from this energy mesh. A convenient means of handling the differential cross section $\sigma_1(E_o \to E,\theta,T)$ is to expand it in Legendre polynomials of $\cos\theta$, as in Eq. (5). The expansion coefficients $\sigma_1^{(\ell)}(E_o \to E)$ are obtained by determining $\sigma_1(E_o \to E,\theta,T)$ on an internally specified mesh of $\cos\theta$, COSMU(NMU), NMU = 1, NMUM1, and carrying out numerically the integration indicated in Eq. (6). For particular values E_o, E, and $\cos\theta$, the parameters R and ϵ are given by Eqs. (3) and (4). The value of $s(R,\epsilon)$ is obtained from the mesh values $s(R_n,\epsilon_m)$

punched by the TOR program[1] as part of the input for GLEN. For this mesh the interpolation formula is

$$s(R,\epsilon) = s(R,\epsilon_m) + \left\{(\epsilon-\epsilon_m)\Big/\left(A_\epsilon^{m-1}h_\epsilon\right)\right\}\left\{s(R,\epsilon_{m+1}) - s(R,\epsilon_m)\right\} + \left\{(\epsilon-\epsilon_m)\Big/\left(A_\epsilon^{2m-1}h_\epsilon^{\,2}\right)\right\}\left\{(\epsilon-\epsilon_{m+1})\Big/(1+A_\epsilon)\right\}\left\{s(R,\epsilon_{m+2}) - (1+A_\epsilon)s(R,\epsilon_{m+1}) + A_\epsilon s(R,\epsilon_m)\right\}. \quad (8)$$

Here

$$s(R,\epsilon_m) = s(R_n,\epsilon_m) + \left\{(R-R_n)/\left(A_R^{n-1}h_R\right)\right\}\left\{s(R_{n+1},\epsilon_m) - s(R_n,\epsilon_m)\right\} + \left\{(R-R_n)/\left(A_R^{2n-1}h_R^{\,2}\right)\right\}\left\{(R-R_{n+1})/(1+A_R)\right\}\left\{s(R_{n+2},\epsilon_m) - (1+A_R)s(R_{n+1},\epsilon_m) + A_R s(R_n,\epsilon_m)\right\}. \quad (9)$$

The cross section $\sigma_1(E_o\to E,\theta,T)$ is given in terms of $s(R,\epsilon)$ by Eq. (2).

The mesh of values of cos θ, COSMU(NMU), has been chosen to correspond to Gauss integrations using the five-point formula over eight subintervals of the interval $-1. \le \cos\theta \le 1.$ The subintervals are

$$\begin{aligned} -1. &\le \cos\theta \le -.8,\\ -.8 &\le \cos\theta \le -.4,\\ -.4 &\le \cos\theta \le .0,\\ .0 &\le \cos\theta \le .4,\\ .4 &\le \cos\theta \le .7,\\ .7 &\le \cos\theta \le .85,\\ .85 &\le \cos\theta \le .95,\\ .95 &\le \cos\theta \le 1. \end{aligned}$$

As a check, the integrals of Eq. (6) are also calculated using three-point Gauss integration. If the values do not agree within a fractional criterion set internally, the energies E_o and E, the result of the five-point integration, and the fractional difference between the two integrations are printed out. The identification of these is

ℓ	Criterion	Five-point integration	Fractional difference
0	.01	SIGL0T	FRCDF0
1	.02	SIGL1T	FRCDF1
2	.04	SIGL2T	FRCDF2
3	.08	SIGL3T	FRCDF3

The results of the five-point integration are taken to be the values of the coefficients $\sigma_1^{(\ell)}(E_o\to E)$ designated in the code as SIGL0(NINI,NFIN), SIGL1 (NINI,NFIN), SIGL2(NINI,NFIN), SIGL3(NINI,NFIN) for ℓ = 0,1,2,3 respectively. The corresponding initial energy E_o is ENERGY(NINI) and the final energy E is ENERGY(NFIN).

The numerical integration described is used in GLEN to calculate values of $\sigma_1^{(\ell)}(E_o\to E)$ for $E_o \ge E$. The remaining values are obtained from these by use of the detailed balance condition,

$$E_o \exp(-E_o/T)\sigma_1^{(\ell)}(E_o\to E) = E\exp(-E/T)\sigma_1^{(\ell)}(E\to E_o). \quad (10)$$

Values of $s(R,\epsilon)$ for $\epsilon < 0$ are needed for the numerical integration. If the table of input values has $\epsilon > 0$, it is replaced through the detailed balance condition by values for $\epsilon < 0$.

The energy integrals $\sigma_\ell^{in}(E_o)$ given by

$$\sigma_\ell^{in}(E_o) = \int_o^{E_1}\sigma_1^{(\ell)}(E_o\to E)dE \quad (11)$$

are evaluated by trapezoid rule integration. Here E_1 is the upper limit of the thermal energy range, designated ENERGY(1) in the convention ENERGY(N) > ENERGY(N+1). The integrals $\sigma_\ell^{in}(E_o)$ are designated SINP0(N), SINP1(N), SINP2(N), SINP3(N), N = 1, NENERG for ℓ = 0,1,2,3 respectively. The quantity $\sigma_o^{in}(E_o)$ is the total inelastic scattering cross section.

For the elastic cross section $\sigma_o(E_o\to E,\theta,T)$, the expansion coefficients of Eq. (7) are given by

$$\sigma_\ell^{el}(E_o)\delta(E-E_o) = 2\pi\int_o^{\pi}\sigma_o(E_o\to E,\theta,T)P_\ell(\cos\theta)\sin\theta\,d\theta. \quad (12)$$

For crystalline scattering, the incoherent approximation to $\sigma_o(E_o\to E,\theta,T)$, corrected for the Bragg limit E_b, is

$$\sigma_o(E_o\to E,\theta,T) = \begin{cases} 0, & E_o \le E_b,\\ (\sigma_b/4\pi)\exp\{-R\gamma(0)\}\delta(E-E_o), & E_o > E_b. \end{cases} \quad (13)$$

The functional value γ(0), designated GAMO, is calculated by the TOR program[1] and is part of the output of this program punched as input for GLEN. For $E_o > E_b$ the expansion coefficients $\sigma_o^{el}(E_o)$ and $\sigma_1^{el}(E_o)$ are

$$\sigma_o^{el}(E_o) = \sigma_b[\{1-\exp(-2a)\}/2a], \quad (14)$$

$$\sigma_1^{el}(E_o) = \sigma_b[\{\exp(-2a)-1+a+a.\exp(-2a)\}/2a^2], \quad (15)$$

where the parameter a is

$$a = 2(m/M)E_o\gamma(0). \quad (16)$$

For INSELR = 1, values are read in for $\sigma_o^{el}(E_o)$, designated SELPO(N), and for $\sigma_1^{el}(E_o)$, designated SELP1(N), for N = 1, NENERG. For INSELR = 0, SELPO(N) and SELP1(N) are set to 0. For $E_o > E_b$, ENERGY(N) > BRGLIM in the GLEN notation, the values of Eq. (14) and Eq. (15) are added to SELPO(N) and SELP1(N) respectively. Thus the incoherent approximation may be used for all E_n by setting INSELR = 0 and setting E_b equal to the physical Bragg limit of the crystal (.00175 ev. for graphite and .0062 ev. for beryllium). Or it may be used only for $E_o > E_b$ where E_b is an energy above the physical Bragg limit. In the latter case, the values read in for $E_o > E_b$ should be 0.

Because of the proportionality to $\delta(E-E_o)$ of $\sigma_o(E_o \to E,\theta,T)$ of Eq. (7), the energy integrals for $\sigma_o(E_o \to E,\theta,T)$ corresponding to Eq. (11) are simply $\sigma_\ell^{el}(E_o)$. Consequently, the total scattering cross section is

$$\sigma_{tot}(E_o) = \sigma_o^{in}(E_o) + \sigma_o^{el}(E_o). \quad (17)$$

The usual transport cross section is

$$\sigma_{tr\ 1}(E_o) = \sigma_{tot}(E_o) - \sigma_1^{in}(E_o) - \sigma_1^{el}(E_o). \quad (18)$$

Two additional transport cross sections are

$$\sigma_{tr\ 2}(E_o) = \sigma_{tot}(E_o) - \sigma_2^{in}(E_o),$$
$$\sigma_{tr\ 3}(E_o) = \sigma_{tot}(E_o) - \sigma_3^{in}(E_o). \quad (19)$$

In the program, the four cross sections $\sigma_{tot}(E_o)$, $\sigma_{tr\ 1}(E_o)$, $\sigma_{tr\ 2}(E_o)$, $\sigma_{tr\ 3}(E_o)$, designated STOT(N), STR1(N), STR2(N), STR3(N) respectively are calculated for N = 1, NENERG.

The cross sections of Eq. (6), Eq. (11), Eq. (12), and Eqs. (17) ··· (19) are printed out. The detailed output is described in Section VII.

III. TRANSPORT EQUATION.

Each of the compositions treated consists of the moderator and from one to four heavy nonmoderating isotopes. For the moderator the number density n_o, designated ENODMO, is read in. If the absorption cross section $\sigma_A^{(o)}(E_n)$ has a 1/v dependence, the code, with indicator INDAMO set to 0, will compute the values of $\sigma_A^{(o)}(E_n)$, designated SIGAMO(N) for N = 1, NENERG. These correspond to the value SIABMO of the absorption cross section at energy ENABMO. Alternatively, with the indicator INDAMO set to 1, the values of SIGAMO(N) are read in.

For each of the heavy nonmoderating isotopes, numbered by NISO = 1, NISOMA ≤ 4, the parameters INDAIS(NISO), INDFIS(NISO), ENODIS(NISO), SIGSIS (NISO), SIP1IS(NISO) are read in. The quantity SIGSIS(NISO) is the scattering cross section $\sigma_s^{(i)}$, and SIP1IS(NISO) is the product $\bar{\omega}^{(i)}\sigma_s^{(i)}$ of scattering cross section and average cosine $\bar{\omega}^{(i)}$ in the scattering process. The isotope number density n_i is ENODIS(NISO). The parameters INDAIS(NISO) and INDFIS(NISO) are indicators analogous to INDAMO for the isotope absorption cross section $\sigma_A^{(i)}(E_n)$ and the isotope fission product $\nu^{(i)}\sigma_F^{(i)}(E_n)$ respectively.

Two forms of the transport equation are solved for each composition. The first corresponds to the usual measurement of diffusion length in which the flux in a one-dimensional plane geometry is proportional to exp(-x/L) with L the diffusion length. The transport equation for the steady state case has the form

$$\vec{\nabla}\cdot\{\vec{\Omega}\Phi(\vec{r},E,\vec{\Omega})\} + \{\Sigma_A(E) + \Sigma_s(E)\}\Phi(\vec{r},E,\vec{\Omega})$$
$$= S(\vec{r},E,\vec{\Omega}) + \iint \Sigma(E_o \to E,\vec{\Omega}_o\cdot\vec{\Omega})\Phi(\vec{r},E_o,\vec{\Omega}_o)dE_o d\vec{\Omega}_o. \quad (20)$$

Here $\Phi(\vec{r},E,\vec{\Omega})$ is the directional flux in the direction with unit vector $\vec{\Omega}$, $\Sigma_A(E)$ and $\Sigma_s(E)$ are the macroscopic absorption and scattering cross sections, $\Sigma(E_o \to E,\vec{\Omega}_o\cdot\vec{\Omega})$ is the macroscopic transfer cross section, and $S(\vec{r},E,\vec{\Omega})$ is the external source.

In the spherical harmonics approximation, both the transfer cross section and the flux are expanded in Legendre polynomials, the transfer cross section being given by

$$\Sigma(E_o \to E,\vec{\Omega}_o\cdot\vec{\Omega}) = (4\pi)^{-1}\sum_\ell (2\ell+1)\Sigma_\ell(E_o \to E)P_\ell(\vec{\Omega}_o\cdot\vec{\Omega}). \quad (21)$$

For plane geometry, the flux expansion is

$$\Phi(\vec{r},E,\vec{\Omega}) = (4\pi)^{-1}\sum_\ell (2\ell+1)\phi_\ell(x,E)P_\ell(\mu), \quad (22)$$

where μ is the cosine of the angle with the x-axis. Substitution of (21) and (22) into (20) leads to the

well-known system of equations

$$\frac{\ell+1}{2\ell+1}\frac{\partial\phi_{\ell+1}(x,E)}{\partial x}+\frac{\ell}{2\ell+1}\frac{\partial\phi_{\ell-1}(x,E)}{\partial x}+\{\Sigma_A(E)+\Sigma_s(E)\}\phi_\ell(x,E)=S_\ell(x,E)+\int\Sigma_\ell(E_o\to E)\phi_\ell(x,E_o)dE_o. \tag{23}$$

For a particular composition, the macroscopic cross sections corresponding to energy E_n are given by

$$\Sigma_A(E_n)=n_o\sigma_A^{(o)}(E_n)+\sum_i n_i\sigma_A^{(i)}(E_n), \tag{24}$$

$$\Sigma_s(E_n)=n_o\sigma_{tot}(E_n)+\sum_i n_i\sigma_s^{(i)}, \tag{25}$$

$$\Sigma_\ell(E_j\to E_n)=n_o\left\{\sigma_1^{(\ell)}(E_j\to E_n)+\sigma_\ell^{el}(E_n)\delta(E_j-E_n)\right\}+\sum_i n_i\sigma_s^{(i)}\bar{P}_\ell^{(i)}\delta(E_j-E_n). \tag{26}$$

Here $\sigma_s^{(i)}\bar{P}_o^{(i)}=\sigma_s^{(i)}$, $\sigma_s^{(i)}\bar{P}_1^{(i)}=\sigma_s^{(i)}\bar{\mu}^{(i)}$. The cross sections $\sigma_s^{(i)}\bar{P}_\ell^{(i)}$ and $\sigma_\ell^{el}(E_n)$ for $\ell\geq 2$ have been neglected. The value of $\Sigma_A(E_n)$ corresponding to ENERGY(N) is designated SMAABS(N) and the analogous value of $\Sigma_s(E_n)$ is designated SMASCT(N).

For subsequent solution of the transport equation it is useful to define the transport cross sections

$$\text{SMATR0(N)}:\Sigma_{tr\ 0}(E_n)=n_o\sigma_{tot}(E_n)+\Sigma_A(E_n), \tag{27}$$

$$\text{SMATR1(N)}:\Sigma_{tr\ 1}(E_n)=n_o\sigma_{tr\ 1}(E_n)+\sum_i n_i\sigma_s^{(i)}(1-\bar{P}_1^{(i)})+\Sigma_A(E_n), \tag{28}$$

$$\text{SMATR2(N)}:\Sigma_{tr\ 2}(E_n)=n_o\sigma_{tr\ 2}(E_n)+\sum_i n_i\sigma_s^{(i)}+\Sigma_A(E_n), \tag{29}$$

$$\text{SMATR3(N)}:\Sigma_{tr\ 3}(E_n)=n_o\sigma_{tr\ 3}(E_n)+\sum_i n_i\sigma_s^{(i)}+\Sigma_A(E_n). \tag{30}$$

The usual diffusion coefficient is

$$\text{DIFCOF(N)}:\ D(E_n)=1/\{3\Sigma_{tr\ 1}(E_n)\}. \tag{31}$$

For a solution corresponding to moderation from epithermal energies, the source term $S_o(E_n)$ is taken to be

$$\text{SOURCE(N)}:\ S_o(E_n)=n_o\sigma_1^{(o)}(E_1\to E_n). \tag{32}$$

Finally, the macroscopic parameter corresponding to the fission product is

$$\text{SMAFIS(N)}:\Sigma_F(E_n)=\sum_i n_i\nu^{(i)}\sigma_F^{(i)}(E_n). \tag{33}$$

IV. CALCULATION OF DIFFUSION LENGTH.

For the diffusion length calculation, Eq. (23) is solved for values E_n, ENERGY(N), of the energy mesh. Each of the Legendre components $\phi_\ell(x,E)$ is assumed to have the spatial dependence exp(-x/L),

$$\phi_\ell(x,E)=f_\ell(E)\exp(-x/L). \tag{34}$$

The scattering-in integral on the right side of the equation is approximated with the trapezoid rule and the external source $S_\ell(x,E)$ is set to 0 for each ℓ. The differential-integral equation (23) is thus reduced to the system of linear equations,

$$-\frac{1}{L}\left\{\frac{\ell+1}{2\ell+1}f_{\ell+1}(E_n)+\frac{\ell}{2\ell+1}f_{\ell-1}(E_n)\right\}+\{\Sigma_A(E_n)+\Sigma_s(E_n)\}f_\ell(E_n)=\sum_{j=1}^{N}A_\ell^{j\to n}f_\ell(E_j). \tag{35}$$

Here

$$A_\ell^{j\to n}=n_oC_\ell^{j\to n}+\left\{n_o\sigma_\ell^{el}(E_n)+\sum_i n_i\sigma_s^{(i)}\bar{P}_\ell^{(i)}\right\}\delta_j^{\ n}, \tag{36}$$

where $\delta_j^{\ n}$ is the Kronecker delta. The coefficients $C_\ell^{j\to n}$ are given by

$$C_\ell^{1\to n}=\tfrac{1}{2}(E_1-E_2)\sigma_1^{(\ell)}(E_1\to E_n),$$
$$C_\ell^{j\to n}=\tfrac{1}{2}(E_{j-1}-E_{j+1})\sigma_1^{(\ell)}(E_j\to E_n),\ j=2,\ldots N. \tag{37}$$

The parameter N of Eq. (37) is identical with NENERG, the number of energies E_n, and use has been made of the facts that $E_{N+1}=0$ and $\sigma_1^{(\ell)}(0\to E_n)f_\ell(0)=0$.

Two principal approximations to the system of equations (35) are used. The first is based on the usual diffusion theory. If $f_1(E_j)$ is approximated by the Maxwell distribution $E_j\exp(-E_j/T)$, then the detailed balance condition on $\sigma_1^{(\ell)}(E_o\to E)$ implies that

$$\sum_{j=1}^{N}C_1^{j\to n}f_1(E_j)=\sigma_1^{in}(E_n)f_1(E_n). \tag{38}$$

If $f_\ell(E_n)$ for $\ell \geq 2$ are neglected, Eqs. (35) reduce to

$$f_1(E_n) = D(E_n)f_o(E_n)/L, \tag{39}$$

$$-D(E_n)f_o(E_n)/L^2 + \left\{\Sigma_{tr\ o}(E_n) - n_o\sigma_o^{el}(E_n)\right\}f_o(E_n) = n_o \sum_{j=1}^{N} C_o^{j\to n} f_o(E_j). \tag{40}$$

Integrating Eq. (40) over energy by the trapezoid rule, one obtains

$$L^2 = \frac{\sum_{n=1}^{N} \frac{1}{2}(E_n - E_{n+1})\{D(E_n)f_o(E_n) + D(E_{n+1})f_o(E_{n+1})\}}{\sum_{n=1}^{N} \frac{1}{2}(E_n - E_{n+1})\{\Sigma_A(E_n)f_o(E_n) + \Sigma_A(E_{n+1})f_o(E_{n+1})\}}. \tag{41}$$

It is easily verified that in this integration the total scattering-out given by a sum over $n_o\sigma_o^{in}(E_n)f_o(E_n)$ analogous to those in Eq. (41) is numerically, as well as physically, exactly equal to the scattering-in given by a sum over the right side of Eq. (40). The values of the integrands $D(E_{N+1})f_o(E_{N+1})$ and $\Sigma_A(E_{N+1})f_o(E_{N+1})$ at $E_n = E_{N+1}$ vanish since $f_o(E)$ vanishes as E near $E = E_{N+1} = 0$.

To solve Eq. (40) a method based on Gauss-Seidel iteration,[2] and previously used[4] in connection with determining pulse decay constants, has been utilized. As a preliminary, a value of L^2 is obtained from Eq. (41) using a Maxwell distribution for $f_o(E_n)$. Using this parameter, one iteration of Gauss-Seidel type is carried out. The new values of $f_o(E_n)$ are used in Eq. (41) to obtain a new value of L^2, and the process is repeated. This type of iteration is continued until two successive values of L agree within an internally set criterion corresponding to a fractional difference of .00001. To verify that a solution has been obtained, a residual equal to the ratio of the difference between the left and right sides of Eq. (40) to the difference between the left side and $n_o C_o^{n\to n} f_o(E_n)$ is computed for each value of E_n. In the program, the values of L obtained in successive iterations are designated by DIFLGT(NDFLIT) and the values of $f_o(E_n)$ by DFLFO(N).

Using the final value of $f_o(E_n)$ calculated by iterative solution of Eq. (40), a corrected value of L is obtained including the terms for $\ell = 2$ and $\ell = 3$. If the right side of Eq. (35) is approximated for $\ell = 2$ and $\ell = 3$ using an evaluation of the kind used in connection with $\ell = 1$ in Eq. (38), the equation for $\ell = 3$ becomes a simple algebraic equation which may be solved for $f_3(E_n)$ in terms of $f_2(E_n)$. Similarly, the equation for $\ell = 2$ may be solved for $f_2(E_n)$ in terms of $f_1(E_n)$. When $f_2(E_n)$ is included in Eq. (35) for $\ell = 1$, one arrives at equations similar to Eqs. (39) and (40) except that $D(E_n)$ is replaced by $D_3(E_n)$ where

$$D_3(E_n) = 1\Big/\left[3\left\{\Sigma_{tr\ 1}(E_n) - \frac{(4/15)L^{-2}}{\Sigma_{tr\ 2}(E_n) - \frac{(9/35)L^{-2}}{\Sigma_{tr\ 3}(E_n)}}\right\}\right]. \tag{42}$$

The value of L is computed from Eq. (41) using $D_3(E_n)$ in place of $D(E_n)$. This value, L_{final}, is listed as the DIFFUSION LENGTH in the printout and designated as DFLGFI in the program. The printout TRANSPORT CORRECTION, designated TRCORR, is the quantity $(L_{final}-L)/L_{final}$ where L is the last value of DIFLGT(NDFLIT) obtained in the iterative process. For the printout, the scalar flux $f_o(E_n)$ is normalized to unity over the interval $0 \leq E_n \leq E_1$, and compared with a similarly normalized Maxwell distribution.

The corrected diffusion length DFLGFI can be expected to be more accurate than the spectrum values DFLFO(N) since the ratio of integrals in Eq. (41) varies by less corresponding to a spectrum change than the spectrum itself. However, it is desirable both to obtain a more accurate spectrum and to confirm the value of the diffusion length. Consequently, the diffusion length is also calculated in the P_{11} approximation. For improved accuracy the approximation of Eq. (38) is not made for $C_1^{j\to n}$ but only for $C_2^{j\to n}$, $C_3^{j\to n}$, ... With $D(E_n)$ replaced by $D_{11}(E_n)$, the P_{11} approximation is expressed by Eqs. (39) and (40) where $D_{11}(E_n)$ is given by the expression

$$D_{11}(E_n) = 1\Big/\left[3\left\{\Sigma_{tr\ 1}(E_n) + n_o\sigma_1^{in}(E_n) - n_o \sum_{j=1}^{N} C_1^{j\to n} f_1(E_j)/f_1(E_n) - F\right\}\right]. \tag{43}$$

Here the parameter F represents the P_{11} correction[4] to diffusion theory and is given by the continued fraction

$$F = \cfrac{(4/15)L^{-2}}{\Sigma_{tr\,2}(E_n) - \cfrac{Y_2}{X_3 - \cfrac{Y_3}{X_4 - \cfrac{Y_4}{X_5 - \cdots}}}}, \quad (44)$$

where

$$X_k = \Sigma_{tr\,3}(E_n), \quad (45)$$

$$Y_k = [(k+1)^2/\{4(k+1)^2-1\}]L^{-2}, \quad (46)$$

and terms have been included in Eq. (44) through Y_{10}/X_{11}.

The method used for solving Eq. (40) in the diffusion theory case is also used for the P_{11} approximation, with the addition that flux values $f_1(E_n)$ from the previous iteration are used to compute $D_{11}(E_n)$ prior to each Gauss-Seidel iteration. The initial value used for L in the P_{11} calculation is DFLGFI; the initial scalar flux $f_o(E_n)$ is a Maxwell distribution and the initial neutron current $f_1(E_n)$ is obtained from Eq. (39) using $D(E_n)$. The first step is to compute $D_{11}(E_n)$ using these values. In the P_{11} calculation, $f_o(E_n)$ is designated DF11FO(N) and $f_1(E_n)$ is designated DF11F1(N). The convergence test for this calculation is based on $f_o(E_n)$; convergence is attained when the fractional difference between successive iterates is less than the internally set value .001 for each n. To verify the solution, a residual is computed for each E_n as the ratio of the difference between the left and right sides of Eq. (40) to the sum of the left side and the term $n_o\sigma_o^{el}(E_n)f_o(E_n)$.

The value of L, designated DFLP11, computed from the last iterate of $f_o(E_n)$ is printed out as P11 DIFFUSION LENGTH. The ratio (DFLP11-DIFLGT(NDFLIT))/DFLP11, where DIFLGT(NDFLIT) is the last value obtained in the diffusion approximation, is designated as P11COR and printed out as P11 CORRECTION. For printing, the scalar flux $f_o(E_n)$ is normalized to unity over $0 \le E_n \le E_1$, $f_1(E_n)$ is given by Eq. (39) with $D_{11}(E_n)$ in place of $D(E_n)$, and a Maxwell distribution normalized in the same way as $f_o(E_n)$ is printed for comparison. Values of the residuals are printed for each E_n. The values of $D_{11}(E_n)$, designated DFCO11(N), used in the final P_{11} iteration are printed out together with the values of $D(E_n)$, designated DIFCOF(N).

V. GROUP CROSS SECTIONS.

The neutron spectrum used to obtain flux-weighted group cross sections is also based on Eq. (23). The geometrical parameter K, designated BUCKLE, is used to imply the form of solution. For $K \ge 0$, the scalar flux is of the form cos Bx $f_o(E)$ where $B = K^{\frac{1}{2}}$. In this case the remaining Legendre components have the form

$$\phi_{2\ell}(x,E) = \cos Bx\, f_{2\ell}(E),$$
$$\phi_{2\ell+1}(x,E) = \sin Bx\, f_{2\ell+1}(E). \quad (47)$$

For the P_3 approximation, neglecting $\phi_\ell(x,E)$ for $\ell \ge 4$, and making the diagonalizing approximation of Eq. (38) for $C_1^{j\to n}$, $C_2^{j\to n}$, $C_3^{j\to n}$, the spherical harmonics equations become

$$D_K(E_n)Kf_o(E_n) + \Sigma_{tr\,0}(E_n)f_o(E_n)$$
$$= S_o(E_n) + n_o\left[\sum_{j=1}^{N} C_o^{j\to n} f_o(E_j) + \sigma_o^{el}(E_n)f_o(E_n)\right], \quad (48)$$

$$f_1(E_n) = D_K(E_n)Bf_o(E_n), \quad (49)$$

$$f_2(E_n) = \frac{-(2/5)Bf_1(E_n)}{\Sigma_{tr\,2}(E_n) + \dfrac{(9/35)K}{\Sigma_{tr\,3}(E_n)}}, \quad (50)$$

$$f_3(E_n) = \frac{(3/7)Bf_2(E_n)}{\Sigma_{tr\,3}(E_n)}. \quad (51)$$

Here the effective diffusion coefficient $D_K(E_n)$, designated DFCFB2(N), is

$$D_K(E_n) = 1\Big/\left[3\left\{\Sigma_{tr\,1}(E_n) + \frac{(4/15)K}{\Sigma_{tr\,2}(E_n) + \dfrac{(9/35)K}{\Sigma_{tr\,3}(E_n)}}\right\}\right]. \quad (52)$$

In the limit $K \to 0$, the formulas are modified only to the extent of considering $f_1(E_n)/B$, etc., so that in Eqs. (48) ... (52) K is set equal to 0, and B is set equal to 1.

For $K < 0$, the Legendre components of the directional flux have the form

$$\phi_\ell(x,E) = \exp(-\varkappa x)f_\ell(E), \quad (53)$$

where $\varkappa$ is $(-K)^{\frac{1}{2}}$. In the P_3 approximation, Eqs. (48) and (52) have the same form as in the case $K \geq 0$. In Eqs. (49) and (51) the parameter B is replaced by $\varkappa$, and in Eq. (50) the parameter (-B) is replaced by $\varkappa$.

It should be pointed out that Eq. (48) expresses the P_3 approximation for a broader class of geometries,[4] including the sphere and infinite cylinder.

Three options are available in GLEN for the determination of the scalar flux $f_o(E_n)$, designated B2F(1,N). When the spectrum indicator NSPEC is set to 1, $f_o(E_n)$ is computed from Eq. (48) by Gauss-Seidel iteration. Starting values are given by a Maxwell distribution normalized to the source $S_o(E_n)$, i.e. such that

$$\int_o^{E_1} \{D_K(E)K+\Sigma_A(E)\} f_o(E)dE = \int_o^{E_1} S_o(E)dE. \qquad (54)$$

The magnitude of the source term $S_o(E_n)$ is arbitrary but its energy dependence corresponds to scattering from energies above E_1 to thermal energies E_n, $E_n \leq E_1$. This energy dependence is approximated by taking $S_o(E_n)$ to be $n_o\sigma_1^{(o)}(E_1 \to E_n)$. Values of $S_\ell(x,E)$ of Eq. (23) for $\ell \geq 1$ have been neglected. The source term $S_o(x,E)$ has been taken to be a product function with energy dependence designated by $S_o(E_n)$ and the same spatial dependence as $\phi_o(x,E)$.

An acceleration technique, in which the values for the p-th iteration, $f_o^{(p)}(E_n)$, are replaced as follows,

$$f_o^{(p)}(E_n) \to f_o^{(p)}(E_n) + .6\left\{f_o^{(p)}(E_n) - f_o^{(p-1)}(E_n)\right\}, \qquad (55)$$

is used in the Gauss-Seidel iteration. The convergence criterion for the iteration sequence is

$$|1 - f_o^{(p-1)}(E_n)/f_o^{(p)}(E_n)| \leq 10^{-5}, \qquad (56)$$

for each E_n. When convergence has been reached, as indicated by this criterion, a residual is computed for each E_n given by the ratio of the difference between left and right sides of Eq. (48) to the left side less the term $n_o\left\{C_o^{n\to n}+\sigma_o^{el}(E_n)\right\}f_o(E_n)$.

With $f_o(E_n)$ determined by the Gauss-Seidel iteration, the remaining components $f_1(E_n)$ ... $f_3(E_n)$ are given by Eqs. (49) ... (51). For K = 0, or K < 0, these equations are modified as described above.

When NSPEC is set to 0, $f_o(E_n)$ is given by a Maxwell distribution normalized according to Eq. (54). The components $f_1(E_n)$ ... $f_3(E_n)$ are given by Eqs. (49) ... (51) as in the previous case. The residuals are set equal to 0.

When NSPEC is set to - 1, the scalar flux spectrum $f_o(E_n)$ is read in. The remaining components $f_1(E_n)$ ... $f_3(E_n)$ are obtained from Eqs. (49) ... (51) as in the previous two cases. The residuals are set to 0.

The components $f_o(E_n)$ ... $f_3(E_n)$, designated B2F(1,N) ... B2F(4,N) respectively are printed for each E_n, together with the residuals. The number of iterations required in the accelerated Gauss-Seidel iteration is also printed. For a Maxwell distribution or a spectrum read in, this number is set to 1.

An integration of Eq. (23) over energy groups is the basis for the few-group edits of cross sections to be used in transport codes. For flux components $\phi_\ell(x,E)$ of the form of Eq. (47) or Eq. (53) the spatial dependence of Eq. (23) is a common factor for each value of ℓ. For the energy group m, corresponding to energy interval $E_{m+1} \leq E \leq E_m$, the group flux components are given by

$$\text{FGPF(L,MFG)} \equiv F_\ell^{(m)} = \int_{E_{m+1}}^{E_m} f_\ell(E)dE. \qquad (57)$$

Similarly the moderator scattering cross section for the group is

$$\text{QMOFGP(L,MFG)} \equiv q_\ell^{(m)} = \left\{F_\ell^{(m)}\right\}^{-1} \int_{E_{m+1}}^{E_m} \sigma_{tot}(E)f_\ell(E)dE. \qquad (58)$$

The corresponding group scattering cross section for the i-th isotope is just the value $\sigma_s^{(i)}$, since this is energy independent. The group absorption cross sections for the moderator, and the nonmoderating isotopes are, similarly,

$$\text{RMOFGP(L,MFG)} \equiv r_\ell^{(m)} = \left\{F_\ell^{(m)}\right\}^{-1} \int_{E_{m+1}}^{E_m} \sigma_A^{(o)}(E)f_\ell(E)dE, \qquad (59)$$

$$\text{RISFGP(NISO,L,MFG)} \equiv r_{i,\ell}^{(m)}$$

$$= \left\{F_\ell^{(m)}\right\}^{-1} \int_{E_{m+1}}^{E_m} \sigma_A^{(i)}(E) f_\ell(E)\,dE. \qquad (60)$$

For $\ell = 0$, the group value of $\nu^{(i)}\sigma_F^{(i)}(E)$ is

$$\text{FISFGP(NISO,MFG)} \equiv w_i^{(m)}$$

$$= \left\{F_\ell^{(m)}\right\}^{-1} \int_{E_{m+1}}^{E_m} \nu^{(i)}\sigma_F^{(i)}(E) f_o(E)\,dE. \qquad (61)$$

The scattering in term of Eq. (23) is made up in part of elastic terms which yield averages similar to those of Eq. (58). For $\ell = 0$ and $\ell = 1$ the group cross sections corresponding to $\sigma_\ell^{el}(E)$ are

$$s_\ell^{(m)} = \left\{F_\ell^{(m)}\right\}^{-1} \int_{E_{m+1}}^{E_m} \sigma_\ell^{el}(E) f_\ell(E)\,dE. \qquad (62)$$

These cross sections are designated SELOFG(MFG) and SEL1FG(MFG) for $\ell = 0$ and $\ell = 1$ respectively. The corresponding elastic terms for isotopes are just the terms $\sigma_s^{(i)}\overline{P}_\ell^{(i)}$ of Eq. (26), since these are energy independent. For the inelastic part of the scattering in integral the group cross section for scattering from the k-th group to the m-th group is

$$t_\ell^{k\to m} = \left\{F_\ell^{(k)}\right\}^{-1} \int_{E_{m+1}}^{E_m} dE \int_{E_{k+1}}^{E_k} \sigma_1^{(\ell)}(E_o \to E) f_\ell(E_o)\,dE_o. \qquad (63)$$

The whole scattering in term $p_\ell^{k\to m}$ for the moderator is the sum of (62) and (63),

$$\text{PMOFG(L,KFG,MFG)} \equiv p_\ell^{k\to m} = t_\ell^{k\to m} + s_\ell^{(m)}\delta_k{}^m, \qquad (64)$$

where $\delta_k{}^m$, the Kronecker delta, is 1 for k = m, and 0 for $k \neq m$.

The integrals of Eqs. (57) ... (63) are evaluated by trapezoid rule integration. Based on the index JPRBNO, two types of edits of the moderator and isotope cross sections are provided. Both are based on the format for the code DTF-IV.[3] For JPRBNO ≥ 0, transfer cross sections from each thermal group to every other thermal group are included. The format of these cross sections is

σ^a	$r_\ell^{(m)}$	$r_{i,\ell}^{(m)}$
$\nu\sigma^f$	0	$\begin{cases} w_i^{(m)} & \text{if } \ell = 0 \\ 0 & \text{if } \ell > 0 \end{cases}$
σ	$q_\ell^{(m)} + r_\ell^{(m)}$	$\sigma_s^{(i)} + r_{i,\ell}^{(m)}$
σ^{up}	$\sum_{k<m} p_\ell^{m\to k}$	0
⋮	⋮	⋮
$\sigma^{g\leftarrow g+2}$	$p_\ell^{m+2\to m}$	0
$\sigma_s^{g\leftarrow g+1}$	$p_\ell^{m+1\to m}$	0
$\sigma_s^{g\leftarrow g}$	$p_\ell^{m\to m}$	$\sigma_s^{(i)}\overline{P}_\ell^{(i)}$
$\sigma_s^{g\leftarrow g-1}$	$p_\ell^{m-1\to m}$	0
$\sigma_s^{g\leftarrow g-2}$	$p_\ell^{m-2\to m}$	0
⋮	⋮	⋮

(65)

The column on the left of Eq. (65) is in the DTF notation (IA-3373, p. 54); the second and third columns in the notation of Eqs. (58) ... (64). The order in which the cross sections are punched begins with moderator cross sections for $\ell = 0$ in the succession $m = 1, m_{max}$ where $m_{max} \equiv$ NFGP. This is followed by values for $m = 1, m_{max}$ for $\ell = 1,2,3$ successively. A similar sequence is followed for isotope 1, and subsequently for the remaining isotopes in order. In agreement with the DTF-IV input format a header card appears before the part of the deck referring to a given value of ℓ, and is used to print JPRBNO, the number NMIX of the composition being treated, the label MODERATOR or the number of the isotope, and the value of ℓ. The cross section values are also printed out, with the sole difference that a heading identifying the moderator or isotope, the value of ℓ, and the group is inserted before the cross section values for each group.

For JPRBNO < 0, the values of the scattering in terms $p_\ell^{k\to m}$ of Eq. (65) are modified so that the form includes only scattering in from the four groups above and the four groups below the group being considered, i.e. for $m-4 \le k \le m+4$. The total cross sections are preserved by making the replacements

$$p_\ell^{m-4\to m} \longrightarrow p_\ell^{m-4\to m} + p_\ell^{m-4\to m+1} + \cdots + p_\ell^{m-4\to m_{max}}, \quad m \geq 5, \tag{66}$$

$$p_\ell^{m+4\to m} \longrightarrow p_\ell^{m+4\to m} + p_\ell^{m+4\to m-1} + \cdots + p_\ell^{m+4\to 1}, \quad m \leq m_{max}-4. \tag{67}$$

Physically, these replacements correspond to altering the transfer cross sections so that down-scattering below the fourth lower group is put into the fourth lower group, and similarly for up-scattering. When the replacements are made, all of the scattering from each thermal group to all others is included so that the total scattering cross section is unchanged for each group. The modified table of values of $p_\ell^{k\to m}$ corresponding to Eq. (65) has only the nine elements for $m-4 \leq k \leq m+4$. The similar table for the heavy nonmoderating isotopes also has nine elements, with only the element corresponding to elastic scattering different from 0. Values of the cross section table integers of DTF-IV for the two cases are

JPRBNO ≥ 0	JPRBNO < 0
IHT = 3	IHT = 3
IHS = $m_{max} + 4$	IHS = 9
IHM = $2m_{max} + 3$	IHM = 13.

(68)

A second difference for the JPRBNO < 0 case is that an input parameter, STRAND, which is the $\ell = 0$ transfer cross section to the highest energy thermal group ($m = 1$) from the group immediately above it, is punched in the correct position after the $p_o^{1\to 1}$ cross section. The two systems coalesce if $m_{max} \leq 4$, and in this case a negative JPRBNO is changed to its absolute value in treating the first mixture, and for NMIX ≥ 2 the value of STRAND should be omitted from the input.

Macroscopic cross sections are also edited and printed by GLEN. The macroscopic group cross sections for scattering, absorption, and transfer respectively are

$$\text{QMACFG(L,MFG)} \equiv Q_\ell^{(m)} = n_o q_\ell^{(m)} + \sum_i n_i \sigma_s^{(i)}, \tag{69}$$

$$\text{RMACFG(L,MFG)} \equiv R_\ell^{(m)} = n_o r_\ell^{(m)} + \sum_i n_i r_{i,\ell}^{(m)}, \tag{70}$$

$$\text{PMACFG(L,KFG,MFG)} \equiv P_\ell^{k\to m} = n_o p_\ell^{k\to m} + \delta_k^m \left(\sum_i n_i \sigma_s^{(i)} \overline{P}_\ell^{(i)} \right). \tag{71}$$

In addition, the macroscopic fission cross section and source are given by

$$\text{FMACFG(MFG)} \equiv W^{(m)} = \sum_i n_i w_i^{(m)}, \tag{72}$$

$$\text{SRCFGP(MFG)} \equiv S_o^{(m)} = n_o \int_{E_{m+1}}^{E_m} \sigma_1^{(o)}(E_1 \to E) dE, \tag{73}$$

where the integral of Eq. (73) is evaluated by trapezoid rule integration. The group fluxes $F_\ell^{(m)}$ of Eq. (57) and the group parameters of Eqs. (69) ... (73) are printed out.

As a verification of the edited parameters, check quantities based on the integration of Eq. (23) over energy are used. In terms of the macroscopic few-group parameters, these integrals appear as sums. Since the total scattering out must be identical with the total scattering in, the relation

$$\sum_m Q_o^{(m)} F_o^{(m)} = \sum_m \sum_k P_o^{k\to m} F_o^{(k)}, \tag{74}$$

holds for any scalar flux values $F_o^{(m)}$. For the case NSPEC = 1, and K ≥ 0, the scalar flux cos Bx $f_o(E)$ is a solution of Eq. (23), and the flux components obey the equation

$$B \sum_m F_1^{(m)} + \sum_m R_o^{(m)} F_o^{(m)} \approx \sum_m S_o^{(m)} \tag{75}$$

to the degree of approximation of the iterative method used in solving Eq. (48). For K < 0, B in Eq. (75) is replaced by $-\kappa$. For NSPEC = 0, the normalization of Eq. (54) assures that Eq. (75) will be obeyed exactly. When NSPEC = -1, the scalar flux is used as read in and there is no necessary relation between the left and right sides of Eq. (75). Since the higher flux components $f_1(E_n)$, $f_2(E_n)$, $f_3(E_n)$ are given by the approximations of Eqs. (49), (50), and (51) to Eq. (23), these components, for K ≥ 0, obey approximately the relationships

$$-B\left\{\frac{2}{3}\sum_m F_2^{(m)} + \frac{1}{3}\sum_m F_o^{(m)}\right\} + \sum_m Q_1^{(m)} F_1^{(m)} + \sum_m R_1^{(m)} F_1^{(m)} \approx \sum_m \sum_k P_1^{k\to m} F_1^{(k)}, \tag{76}$$

$$B\left\{\frac{3}{5}\sum_m F_3^{(m)} + \frac{2}{5}\sum_m F_1^{(m)}\right\} + \sum_m Q_2^{(m)}F_2^{(m)} + \sum_m R_2^{(m)}F_2^{(m)} \approx \sum_m \sum_k P_2^{k\to m}F_2^{(k)}, \quad (77)$$

$$-B\left\{\frac{3}{7}\sum_m F_2^{(m)}\right\} + \sum_m Q_3^{(m)}F_3^{(m)} + \sum_m R_3^{(m)}F_3^{(m)} \approx \sum_m \sum_k P_3^{k\to m}F_3^{(k)}. \quad (78)$$

In practice the approximation of obtaining flux components by means of the diagonalized form corresponding to Eq. (38) is accurate enough that the agreement of the two sides of Eqs. (76), (77), (78) is usually to the eight significant figures printed. For $K < 0$, B of Eqs. (76) and (78) is replaced by $\varkappa$, and B of Eq. (77) is replaced by $-\varkappa$. The check quantities of the left and right sides of Eqs. (74) ··· (78) are printed out by comparable pairs in the left-right and also in the numerical order of these equations, under the title CHECK SUMS.

VI. INPUT FOR GLEN.

1. Title card — 12 A 6

Card output from TOR:

2. IDEN, TEMPEN, GAMO — I 10, 2 E 20.8
3. AFAREC, HREC, AFAEPS, HEPS — 4 E 20.8
4. NLIM — I 10
5. REC(N), N = 1, NLIM — 4 E 19.8
6. MLIM — I 9
7. EPS(M), M = 1, MLIM — 4 E 18.8
8. NPROD — I 8
9. SKE(N,M), N = 1, NLIM, M = 1, MLIM — 5 E 15.8

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10. JPRBNO (Identification no. used in card output, ≤ 5 digits) — I 10
11. NENERG (No. multigroup energies, ≤ 87) — I 10
12. ENERGY(N), N = 1, NENERG (Multigroup energies, $E_n > E_{n+1} > .0$) — 4 E 20.8
13. FACMAS (m/M ≤ 1.) — E 20.8
14. SIGBND ($\sigma_b > .0$) — E 20.8
15. INSELR (0 or 1), BRGLIM — I 10, E 20.8
    a. If INSELR = 1, read in
       SELP0(N), N = 1, NENERG — 4 E 20.8
       SELP1(N), N = 1, NENERG — 4 E 20.8
       } Additive elastic cross sections
    b. For INSELR = 0 go directly to 16. below
    c. BRGLIM is the Bragg limit of the crystal, e.g. .0062 ev. for beryllium, and .00175 ev. for graphite
16. NFGP (No. few groups, ≤ 20) — I 10
17. ENFEGP(N), N = 1, NFGP (few-group energies, subset of 12., $E_k > E_{k+1} > .0$) — 4 E 20.8
18. NMIXMA (No. mixtures of isotopes, 1 ≤ NMIXMA ≤ 10) — I 10

Following are for each mixture:

19. INDAMO, ENODMO (Moderator absorption indicator INDAMO (0 or 1) and number density ENODMO ≥ .0) — I 10, E 20.8
    a. If INDAMO = 0, read in ENABMO, SIABMO (Energy ENABMO > .0 for which moderator absorption cross section is SIABMO ≥ .0) — 2 E 20.8
    b. If INDAMO = 1, read in SIGAMO(N), N = 1, NENERG (Moderator absorption cross section ≥ .0) — 4 E 20.8
20. NISOMA (No. additional isotopes, 1 ≤ NISOMA ≤ 4) — I 10
21. For NISO = 1, NISOMA read in for each isotope INDAIS(NISO), INDFIS (NISO), ENODIS(NISO), SIGSIS(NISO), SIP1IS(NISO) (Absorption indicator INDAIS (0 or 1) and fission indicator INDFIS (0 or 1), number density ENODIS ≥ .0, scattering cross section SIGSIS ≥ .0, product of scattering cross section and average cosine SIP1IS) — 2 I 10, 3 E 20.8

22. For NISO = 1, NISOMA
    a. If INDAIS(NISO) = 0, read in ENABIS(NISO), SIABIS(NISO) (Energy ENABIS > .0 for which isotope absorption cross section is SIABIS ≥ .0) 2 E 20.8
    b. If INDAIS(NISO) = 1, read in SIGAIS(NISO,N), N = 1, NENERG (Isotope absorption cross section ≥ .0) 4 E 20.8
    c. If INDFIS(NISO) = 0, read in ENFIIS(NISO), SIFIIS(NISO) (Energy ENFIIS > .0 for which value of $\nu\sigma_f$ for isotope is SIFIIS ≥ .0) 2 E 20.8
    d. If INDFIS(NISO) = 1, read in SIGFIS(NISO,N), N = 1, NENERG (Product $\nu\sigma_f$ ≥ .0 of isotope fission cross section σ_f and average number ν of neutrons per fission) 4 E 20.8
23. BUCKLE (Buckling) E 20.8
24. NSPEC (Spectrum indicator, 1, 0, or -1) I 10
    a. If NSPEC = 1 hardened spectra corresponding to the macroscopic absorption and buckling will be computed
    b. If NSPEC = 0 the scalar flux will be set equal to a Maxwell distribution
    c. If NSPEC = -1 the scalar flux B2F(1,N), N = 1, NENERG is to be read in after 25. below 4 E 20.8
25. STRAND E 20.8
    Omitted for JPRBNO ≥ 0. For JPRBNO < 0, microscopic transfer cross section into highest energy thermal group from group immediately above it

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Points to be noted about the input:

1) Cross sections and number densities are to be in compatible units, e.g. cross sections in barns and number densities in multiples of 10^{24} atoms/cm^3.
2) Buckling is in units cm^{-2}.
3) Mass ratio FACMAS is ratio of neutron mass to nuclide mass.
4) Energies are input in the order from highest to lowest. Energy dependent quantities read in, e.g. cross sections or scalar flux, have the same order. The energy .0 is not read in, but is always assumed to be the lower bound of energy integrals over the lowest range. Energies for TOR and for GLEN must be in the same units, e.g. electron volts.
5) An absorption or fission cross section may be read in by setting the corresponding indicator equal to 1. Or if the energy dependence is 1/v, the indicator may be set equal to 0, and the code will then compute values for all energies, e.g. of the absorption cross section corresponding to the value SIABIS at the energy ENABIS.
6) The quantity averaged is the product $\nu\sigma_f$, rather than σ_f.
7) The few group energies, ENFEGP(N), are a subset of the multigroup energies, ENERGY(N), and every value ENFEGP(N) must also appear as a value ENERGY(N).
8) Note that the program assumes the presence of at least one additional isotope besides the moderator. If no other isotope is present in the physical problem, input for an artificial isotope having number density .0 should be used.

VII. GLEN OUTPUT.

1. Following the title card, check quantities are printed out by the main program.

   The formal output of the code is divided into two parts. The first part consists of printed output of moderator cross section parameters and is carried out by the subroutine GLNRIT. The second part is carried out by the subroutine GLPRNT for each of the mixtures, up to a maximum of ten mixtures. A printout of results for each mixture is given. In addition, the group cross sections for each isotope in the mixture are punched in the format of the cross section input of DTF-IV.

- -

Printout of input parameters:

2. IDEN, TEMPEN, GAMO
3. NENERG
4. ENERGY(N), N = 1, NENERG

5. FACMAS
6. SIGBND

---

7. EINI(NINI), EFIN(NFIN), SIGLO(NINI, NFIN), SIGL1(NINI, NFIN), SIGL2(NINI, NFIN) SIGL3(NINI, NFIN), for NINI = 1, NENERG and NFIN = 1, NENERG. The parameters EINI and EFIN are the initial energy E_o and final energy E respectively of the neutron in the laboratory system. The cross section parameters SIGLO---SIGL3 are the expansion coefficients $\sigma_1^{(0)}(E_o \to E) \cdots \sigma_1^{(3)}(E_o \to E)$ of the double differential scattering cross section $\sigma_1(E_o \to E,\theta,T)$ in a Legendre polynomial expansion, $\sigma_1(E_o \to E,\theta,T) = (4\pi)^{-1}\sum_{\ell}(2\ell+1)\sigma_1^{(\ell)}(E_o \to E)P_\ell(\cos\theta)$. Here $\sigma_1(E_o \to E,\theta,T)$ is the part of the cross section which includes inelastic scattering.
8. ENERGY(N), SELPO(N), SELP1(N) for N = 1, NENERG. The parameters SELPO(N) and SELP1(N) are the expansion coefficients $\sigma_o^{el}(E_o)$ and $\sigma_1^{el}(E_o)$ of the pure elastic double differential scattering cross section $\sigma_o(E_o \to E,\theta,T)$ in the Legendre polynomial expansion $\sigma_o(E_o \to E,\theta,T) = (4\pi)^{-1}\sum_{\ell}(2\ell+1)\sigma_\ell^{el}(E_o)\delta(E-E_o)P_\ell(\cos\theta)$.
9. ENERGY(N), SINPO(N), SINP1(N), SINP2(N), SINP3(N), N = 1, NENERG. The parameters SINPO(N)---SINP3(N) are the integrals over final energy E of the cross sections $\sigma_1^{(0)}(E_o \to E) \cdots \sigma_1^{(3)}(E_o \to E)$ respectively.
10. ENERGY(N), STOT(N), STR1(N), STR2(N), STR3(N), N = 1, NENERG. The parameter STOT(N) is the total scattering cross section $\sigma_{tot}(E_o)$ which is the sum of SINPO(N) and SELPO(N). The remaining parameters are the transport cross sections
    STR1(N) = STOT(N) - SINP1(N) - SELP1(N)
    STR2(N) = STOT(N) - SINP2(N)
    STR3(N) = STOT(N) - SINP3(N).
11. Under the heading ANALYTIC MONATOMIC GAS CROSS SECTIONS, analytically computed values of the monatomic gas analogues of $\sigma_1^{(0)}(E_o \to E)$ and $\sigma_1^{(1)}(E_o \to E)$ are printed. These correspond to the values of TEMPEN, FACMAS and SIGBND. The order of printing is initial energy, final energy, $\ell = 0$ component, $\ell = 1$ component. These are computed and printed only if the GLEN instruction C TO OMIT CALCULATION OF ANALYTIC CHECK IN GLEN near the end of the main program is changed to CALL GLMOCK.

For each mixture the output below is printed.

Input parameters and absorption and fission cross sections:

12. NFGP
13. ENFEGP(N), N = 1, NFGP
14. INDAMO, ENODMO
15. If INDAMO = 0, ENABMO, SIABMO
16. SIGAMO(N), N = 1, NENERG. Moderator absorption cross section.
17. NISOMA
18. INDAIS(NISO), INDFIS(NISO), ENODIS(NISO), SIGSIS(NISO), SIPlIS(NISO), for NISO = 1, NISOMA
19. If INDAIS(NISO) = 0, NISO, ENABIS(NISO), SIABIS(NISO), for NISO = 1, NISOMA
20. If INDFIS(NISO) = 0, NISO, ENFIIS(NISO), SIFIIS(NISO), for NISO = 1, NISOMA
21. N, SIGAIS(NISO,N), N = 1, NENERG for NISO = 1, NISOMA. Absorption cross section for each isotope.
22. N, SIGFIS(NISO,N), N = 1, NENERG for NISO = 1, NISOMA. Product $\nu\sigma_f$ for each isotope.
23. BUCKLE
24. Corresponding to the three possible values of NSPEC, an indication of the type of neutron spectrum used to obtain group averages is printed:

NSPEC	Legend
1	HARDENED NEUTRON SPECTRUM
0	MAXWELL NEUTRON SPECTRUM
-1	NEUTRON SPECTRUM READ IN

Macroscopic cross sections:

25. These cross sections are defined in terms of the moderator and isotope cross sections and number densities of 10...22:

For N = 1, NENERG:

SMASCT(N) = ENODMO* STOT(N) + (ENODIS(NISO)* SIGSIS (NISO), NISO = 1, NISOMA)

SMAABS(N) = ENODMO* SIGAMO(N) + (ENODIS(NISO)* SIGAIS(NISO,N), NISO = 1, NISOMA)

SMAFIS(N) = (ENODIS(NISO)* SIGFIS(NISO,N), NISO = 1, NISOMA)

SMATR0(N) = ENODMO* STOT(N) + SMAABS(N)

SMATR1(N) = ENODMO* STR1(N) + SMAABS(N) + (ENODIS(NISO)* (SIGSIS(NISO) - SIP1IS(NISO)), NISO = 1, NISOMA)

SMATR2(N) = ENODMO* STR2(N) + SMAABS(N) + (ENODIS(NISO) *SIGSIS(NISO), NISO = 1, NISOMA)

SMATR3(N) = ENODMO* STR3(N) + SMAABS(N) + (ENODIS(NISO) *SIGSIS(NISO), NISO = 1, NISOMA)

The parameter SMASCT(N) is the macroscopic scattering cross section for the mixture including the moderator and all additional isotopes. Similarly, SMAABS(N) is the macroscopic absorption cross section for the mixture, and SMAFIS(N) is the macroscopic fission cross section multiplied by the average number of neutrons per fission. The remaining parameters are transport cross sections.

- -

Diffusion coefficient and source:

26. Diffusion coefficient DIFCOF(N) and isotropic source SOURCE(N) defined by:

DIFCOF(N) = 1./(3.* SMATR1(N))

SOURCE(N) = ENODMO* SIGLO (1, N)

for N = 1, NENERG

- -

Values from diffusion approximation calculation:

27. Diffusion length DFLGFI including a transport correction TRCORR based on the P_3 approximation.

28. The sequence of eigenvalues for the diffusion length obtained in the iterative process used to calculate this quantity. It should be noted that no transport correction is included in these eigenvalues.

29. For N = 1, NENERG the neutron spectrum (isotropic component) DFLFO(N) obtained in the diffusion length calculation normalized according to $\int_0^{E_1} \varphi_0(E)\, dE = 1.$, where E_1 is ENERGY(1).

For comparison the Maxwell distribution SPMANO(N) normalized according to the same convention. A residual DFLRSD(N) which expresses the accuracy with which the spectrum DFLFO(N) satisfies the integral equation which implies the diffusion length. To assure that the iterative process used in solving this equation has converged to a physically significant result, it should be verified that all values of DFLRSD(N) are small in magnitude, usually less than 10^{-3}, and that all values of DFLFO(N) are non-negative.

- -

Values from P_{11} diffusion length calculation:

30. In the P_{11} approximation the diffusion length DFLP11, and the P_{11} correction P11COR to the diffusion approximation.

31. The sequence of eigenvalues for the P_{11} diffusion length.

32. For N = 1, NENERG the isotropic neutron spectrum DF11FO(N) normalized as in 29. above, and the corresponding $\ell = 1$ spectrum component DF11F1(N). For comparison with DF11FO(N) the normalized Maxwell distribution SPMANO(N) is printed. The residuals DF11RS(N) are printed and the criterion that these are small, usually less than 10^{-3}, should be verified to assure that a converged solution has been obtained. In addition, for a physically significant solution both DF11FO(N) and DF11F1(N) must be non-negative for all N. The values of the P_{11} diffusion coefficient DFCO11(N) used in the last iteration are printed, together with the values of the diffusion approximation coefficient DIFCOF(N) for comparison.

- -

Buckling spectra:

33. Values for N = 1, NENERG of neutron spectra corresponding to the macroscopic cross sections of 25. and the buckling of 23. The values for the isotropic ($\ell = 0$) component are determined according to the value of NSPEC as follows: 1) for NSPEC = 1, a hardened neutron spectrum is calculated corresponding to SOURCE(N); 2) for NSPEC = 0, the scalar flux is set equal to a Maxwell distribution; 3) for NSPEC = -1, the scalar flux is read in. In all three cases the spectra for $\ell = 1, 2, 3$ are those implied by the transport equation to correspond to the specified scalar flux. For the hardened neutron

spectrum the accuracy of the solution obtained by Gauss-Seidel iteration is specified by a residual B2RSD(N). For complete convergence each of the values of this quantity should be less than 10^{-5}. For the Maxwell distribution and the read-in spectrum the residual is set to 0.

The buckling spectra are used in obtaining the flux-weighted few-group averages. It should be pointed out that for items 1. through 33. in the GLEN output, energy dependent quantities are point quantities referring to one of the multigroup energies, e.g. SMASCT(N) is the macroscopic scattering cross section corresponding to ENERGY(N). However, for items following 33. energy dependent quantities are few-group averages.

34. The number NB2IT of iterations in obtaining the buckling spectra. For the Maxwell distribution and the read-in spectrum this is 1. For the hardened spectrum it is < 500 for complete convergence.

- -

35. The isotope edits for input to DTF are punched and also printed out. The order of the quantities is that for cross section input for DTF-IV (IA-3373, p. 54). For each energy group the cross sections are in the order: σ^a, $\nu\sigma^f$, σ, σ^{up}, . . . $\sigma_s^{g+2\to g}$, $\sigma_s^{g+1\to g}$, $\sigma_s^{g\to g}$, $\sigma_s^{g-1\to g}$, $\sigma_s^{g-2\to g}$, ... Two optional forms of punched edit are available. For JPRBNO ≥ 0, the punched edit includes transfer cross sections from each thermal group to all other thermal groups, and no provision is made for any epithermal group. This is intended for problems which involve only thermal neutrons with a source specified externally. The energy dependence of the source for the few-group structure used is given in 36. below. For this option the total cross section σ is always in position 3, (IHT = 3), the diagonal transfer cross section is in position NFGP + 4, (IHS = NFGP + 4), and the length of the table is 2* NFGP + 3, (IHM = 2* NFGP + 3).

The second option, for JPRBNO < 0, uses a standard thirteen-element table (IHM = 13) with transfer cross sections specified only in the sequence $\sigma_s^{g+4\to g}, \ldots \sigma_s^{g\to g}, \ldots \sigma_s^{g-4\to g}$. The end cross sections in this sequence, $\sigma_s^{g+4\to g}$ and $\sigma_s^{g-4\to g}$, are corrected so that the total scattering-out cross section from a group, $\sum_{g'} \sigma_s^{g\to g'}$, is equal to the total cross section σ. In this option the total cross section is again in position 3, (IHT = 3), and the diagonal transfer cross section in position 9, (IHS = 9).

For both options, the cards are punched in order of groups starting with the first (highest energy group). In the card output, all cross sections for all groups (IGM = NFGP) are punched in format 1P6E12.4 in a continuous set of numbers, totalling IGM* IHM. This format is called for by DTF and the card deck is to be used intact as DTF input. The printed output is in the same order and differs only in having a title card which specifies the group number printed before the cross sections for that group. In agreement with the DTF format, a header card precedes the IGM* IHM set of numbers and carries the following information: the identification number JPRBNO, the number NMIX of the mixture being treated, identification of the isotope either as the moderator or as one of the numbered isotopes (isotope 1 through isotope 4), and the value of ℓ. The order of these identification numbers is also the order of the loops used in specifying output: for each mixture (mixture 1 through mixture 10) the moderator cross sections for $\ell = 0$ are punched, then successively those for ℓ = 1, 2, 3. Next the cross sections for isotope 1 are punched in the order ℓ = 0, 1, 2, 3. Following this the cross sections for isotopes 2, 3, and 4 are punched in similar fashion.

The deck for a mixture may be used intact as input for DTF but four remarks should be made. First, at the beginning of each mixture two additional identification cards are punched, one a repeat of the title card and the second a card giving the mixture number NMIX. These are to be removed before the deck is used as input. Second, the program automatically punches values

for ℓ = 0, 1, 2, 3. If the higher anisotropic components for ℓ = 2, 3, are not wanted in the DTF problem, these parts of the deck, indicated by the header cards, can be excised. Third, the GLEN code requires the formal presence of at least one additional isotope, isotope 1. If there is no additional physical isotope, this will be a dummy, corresponding to zero number density and with meaningless cross sections. In this case the part of the deck for isotope 1 should be excised.

Fourth, it will usually be the option with JPRBNO < 0 that is used for problems involving all energies. In this case the cards for groups higher in energy than the highest thermal group must be inserted for each value of ℓ. This can be done directly if the number of such higher energy groups is a multiple of 6 (for the standard few-group structure, this number is 12, and the condition is met). Otherwise, since DTF requires cross section input in a continuous sequence for all groups, it is necessary to read the card output from GLEN into the machine and construct a new continuous array. The following read instructions may be used to read the GLEN card output for each ℓ:

```
READ (10, 1) ((CS(I, M), I = 1, 13), M = 1,
     NFGP)
1 FORMAT (1P6E12.4)
```

The input parameter STRAND is inserted in the card output for the highest energy thermal group as the transfer cross section into this group from the group immediately above it for ℓ = 0. This is the only transfer cross section from epithermal to thermal groups included in the punched edit.

36. Few-group macroscopic cross sections corresponding to the number densities ENODMO and ENODIS (NISO), NISO = 1, NISOMA, and to the isotopic cross sections in 35. The fluxes printed are energy-integrated values for each group of the buckling spectra of 33. which correspond to the expansion of the flux for plane geometry in Legendre polynomials. The cross sections are flux-weighted averages for each group corresponding to the Legendre polynomial expansion of the transport equation. The scattering-in integral becomes a sum in the few-group approximation used and the transfer cross sections are given. It should be noted that the fission cross section given is the group average of the product $\nu\sigma_f$ for ℓ = 0. Similarly the source dependence is for the isotropic source (ℓ = 0).

37. Check sums, summed over all energy groups. The first pair of numbers listed represent the total scattering-out and total scattering-in, and these numbers should be identical to all the figures printed in every case. The third, fourth, and fifth pairs of numbers represent the agreement of the higher order anisotropic scattering-in integrals with the net neutron losses and these should be approximately equal in each case. The second pair of numbers represents the agreement of the absorption and leakage with the isotropic source. For hardened spectra (NSPEC = 1) there should be approximate agreement. For the Maxwell distribution (NSPEC = 0) the spectrum is normalized to the source and the numbers should agree to all the figures printed. For a read-in spectrum (NSPEC = -1) no necessary relation exists between the second pair of numbers.

APPENDIX

The program has been compiled and run on the CDC 6600. The core storage requirement is approximately 55,600.

REFERENCES

1. W. W. Clendenin, LA-3823, Los Alamos Laboratory Report, "Calculation of Thermal Neutron Scattering Cross Sections for Crystalline Materials: the TOR Program" (1967).
2. R. S. Varga, Matrix Iterative Analysis, Prentice-Hall, Inc., Englewood Cliffs, N.J. (1962).
3. K. D. Lathrop, LA-3373, Los Alamos Laboratory Report, "DTF-IV, a FORTRAN-IV Program for Solving the Multigroup Transport Equation with Anisotropic Scattering" (1965).
4. W. W. Clendenin, Nucl. Sci. Eng. 18, 351 (1964).

```
                PROGRAM GLEN(INPUT,TAPE10=INPUT,
               1OUTPUT,TAPE9=OUTPUT,
               2PUNCH,TAPE11=PUNCH)
          $IBFTC GLEN     DECK
000003          COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
               1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSP1,
               2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
               3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
               4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
               5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
               6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
               7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
               8STOT(90),STR1(90),STR2(90),STR3(90)
000003          COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
               1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
               2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
               3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
               4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
               5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
               6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
               7DFCOFI(90),DFLGFT,TRCORR,DFLRSD(90),
               8DFCF82(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000003          COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
               1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
               2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
               3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
               4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
               5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
               6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
               7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000003          COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000003          COMMON DFC011(87)
000003          READ(10,1)(AFIELD(J),J=1,12)
000015        1 FORMAT(12A6)
000015          WRITE(9,801)
000021      801 FORMAT(2H1 )
000021          WRITE(9,1)(AFIELD(J),J=1,12)
000033          READ(10,901)IDEN,TEMPEN,GAM0
000045      901 FORMAT(I10,2E20.8)
000045        2 FORMAT(4E20.8)
000045          READ(10,2)AFAREC,HREC,AFAEPS,HEPS
000061          READ(10,3)NLIM
000067        3 FORMAT(I10)
000067          READ(10,4)(REC(N),N=1,NLIM)
000102        4 FORMAT(4E19.8)
000102          READ(10,5)MLIM
000110        5 FORMAT(I9)
000110          READ(10,6)(EPS(M),M=1,MLIM)
000123        6 FORMAT(4E18.8)
000123          READ(10,7)NPROD
000131        7 FORMAT(I8)
000131          DO 8 N=1,NLIM
000133        8 READ(10,9)(SKE(N,M),M=1,MLIM)
000152        9 FORMAT(5E15.8)
000152          WRITE(9,902)SKE(1,1),SKE(2,1),SKE(NLIM,MLIM)
000166      902 FORMAT(10H0SKE(1,1)=,F15.8,10H SKE(2,1)=,E15.8,
               116H SKE(NLIM,MLIM)=,E15.8)
000166          READ(10,3)JPRBNO
000174          ININCK=0
000175          READ(10,3)NENERG
000203          IF(NENERG-87)12,12,10
000206       10 WRITE(9,11)
000212       11 FORMAT(17H0NENERG TOO LARGE)
000212          ININCK=1
000213       12 IF(NENERG)13,13,15
000215       13 WRITE(9,14)
000221       14 FORMAT(20H0NENERG NOT POSITIVE)
000221          ININCK=1+ININCK
000223       15 READ(10,2)(ENERGY(N),N=1,NENERG)
000236          GLNCMP=ENERGY(NENERG)
```

```
000240          IF(GLNCMP)951,951,953
000241      951 WRITE(9,952)
000245      952 FORMAT(28H0LAST ENERGY LESS/EQUAL ZERO)
000245          ININCK=1+ININCK
000247      953 NRGLS1=NENERG-1
000251          DO 18 N=1,NRGLS1
000253          GLNCMP=ENERGY(N)-ENERGY(N+1)
000255          IF(GLNCMP)16,16,18
000257       16 NOUT=N+1
000261          WRITE(9,17)NOUT
000267       17 FORMAT(8H0ENERGY(,I3,15H ) OUT OF ORDER)
000267          ININCK=1+ININCK
000271       18 CONTINUE
000274          READ(10,2)FACMAS
000301          IF(FACMAS)19,19,21
000303       19 WRITE(9,20)
000307       20 FORMAT(23H0FACMAS LESS/EQUAL ZERO)
000307          ININCK=1+ININCK
000311       21 IF(FACMAS-1.)24,24,22
000314       22 WRITE(9,23)
000320       23 FORMAT(24H0FACMAS GREATER THAN ONE)
000320          ININCK=1+ININCK
000322       24 READ(10,2)SIGBND
000330          IF(SIGBND)25,25,27
000332       25 WRITE(9,26)
000336       26 FORMAT(23H0SIGBND LESS/EQUAL ZERO)
000336          ININCK=1+ININCK
000340       27 SBD4PI=SIGBND/12.566371
000342          READ(10,901)INSELR,BRGLIM
000352          IF(INSELR)30,32,29
000354       29 IF(INSELR-1)30,32,30
000356       30 WRITE(9,31)
000362       31 FORMAT(17H0INSELR INCORRECT)
000362          ININCK=1+ININCK
000364       32 IF(INSELR)37,37,33
000366       33 READ(10,2)(SELP0(N),N=1,NENERG)
000401          DO 36 N=1,NENERG
000403          GLNCMP=SELP0(N)
000405          IF(GLNCMP)34,36,36
000406       34 WRITE(9,35)N
000414       35 FORMAT(7H0SELP0(,I3,11H ) NEGATIVE)
000414          ININCK=1+ININCK
000416       36 CONTINUE
000421          READ(10,2)(SELP1(N),N=1,NENERG)
000433          GO TO 39
000434       37 DO 38 N=1,NENERG
000436          SELP0(N)=.0
000437       38 SELP1(N)=.0
000442       39 IF(ININCK)40,50,40
000443       40 WRITE(9,41)ININCK
000451       41 FORMAT(32H0INPUT THRU SELP1 CHECKED. ABOVE.
                1I3,31H ERRORS FOUND. PROBLEM STOPPED.)
000451          STOP
000453       50 NPRSIG=1
000454          CALL GLNFIR
000455          DO 51 NINI=1,NENERG
000457       51 EINI(NINI)=ENERGY(NINI)
000463          DO 52 NFIN=1,NENERG
000465       52 EFIN(NFIN)=ENERGY(NFIN)
000471          DO 80 NINI=1,NENERG
000473          DO 79 NFIN=NINI,NENERG
000474          DO 55 NMU=1,NMUMAX
000475          GLNREC=FACMAS*(EINI(NINI)+EFIN(NFIN)
               1-2.*((EINI(NINI)*EFIN(NFIN))**.5)*COSMU(NMU))
000510          GLNEPS=EFIN(NFIN)-EINI(NINI)
000513          CALL GLNINT
000514          IF(NPRSIG)53,55,55
000516       53 WRITE(9,54)NINI,NFIN,NMU,EINI(NINI),
               1EFIN(NFIN),COSMU(NMU),SIGSCT(NMU)
000540       54 FORMAT(6H0NINI=,I3,6H NFIN=,I3,5H NMU=,I3,
               16H EINI=,E15.8,6H EFIN=,E15.8,7H COSMU=,E15.8,
               2AH SIGSCT=,E15.8)
```

```
000540       55 CONTINUE
000543       56 SIGL0T=.0
000544          SIGL1T=.0
000545          SIGL2T=.0
000546          SIGL3T=.0
000547       57 DO 58 NMU=1,NMUM1
000551          SIGMUL=SIGSCT(NMU)*WATE(NMU)
000553          SIGL0T=SIGL0T+SIGMUL
000555          SIGL1T=SIGL1T+SIGMUL*COSMU(NMU)
000557          SIGL2T=SIGL2T+SIGMUL*(3.*(COSMU(NMU)**2)-1.)
000565       58 SIGL3T=SIGL3T+SIGMUL*(5.*(COSMU(NMU)**3)
              1-3.*COSMU(NMU))
000576       59 SIGL0C=.0
000577          SIGL1C=.0
000600          SIGL2C=.0
000601          SIGL3C=.0
000602       60 DO 61 NMU=NMUM2,NMUM3
000604          SIGMUL=SIGSCT(NMU)*WATE(NMU)
000606          SIGL0C=SIGL0C+SIGMUL
000610          SIGL1C=SIGL1C+SIGMUL*COSMU(NMU)
000612          SIGL2C=SIGL2C+SIGMUL*(3.*(COSMU(NMU)**2)-1.)
000620       61 SIGL3C=SIGL3C+SIGMUL*(5.*(COSMU(NMU)**3)
              1-3.*COSMU(NMU))
000631       62 SIMUCK(3)=.08888888*SIGSCT(3)
000633          SIMUCK(8)=.17777778*SIGSCT(8)
000635          SIMUCK(13)=.17777778*SIGSCT(13)
000637          SIMUCK(18)=.17777778*SIGSCT(18)
000641          SIMUCK(23)=.13333334*SIGSCT(23)
000643          SIMUCK(28)=.06666666*SIGSCT(28)
000645          SIMUCK(33)=.04444444*SIGSCT(33)
000647          SIMUCK(38)=.02222222*SIGSCT(38)
000651          DO 621 NMUCK=3,38,5
000653          SIGL0C=SIGL0C+SIMUCK(NMUCK)
000655          SIGL1C=SIGL1C+SIMUCK(NMUCK)*COSMU(NMUCK)
000660          SIGL2C=SIGL2C+SIMUCK(NMUCK)
              1*(3.*(COSMU(NMUCK)**2)-1.)
000666      621 SIGL3C=SIGL3C+SIMUCK(NMUCK)
              1*(5.*(COSMU(NMUCK)**3)-3.*COSMU(NMUCK))
000676          IF(ABS(SIGL0T)-1.E-06)66,66,63
000701       63 FRCDF0=ABS(1.-SIGL0C/SIGL0T)
000705          IF(FRCDF0-.01)66,66,64
000707       64 WRITE(9,65)NINI,NFIN,EINI(NINI),EFIN(NFIN),SIGL0T,FRCDF0
000727       65 FORMAT(6H0NINI=,I3,6H NFIN=,I3,6H EINI=,E15.8,
              16H EFIN=,E15.8,8H SIGL0T=,E15.8,8H FRCDF0=,E15.8)
000727       66 SIGL0(NINI,NFIN)=6.2831853*SIGL0T
000734          IF(ABS(SIGL1T)-1.E-06)70,70,67
000740       67 FRCDF1=ABS(1.-SIGL1C/SIGL1T)
000744          IF(FRCDF1-.02)70,70,68
000746       68 WRITE(9,69)NINI,NFIN,EINI(NINI),EFIN(NFIN),SIGL1T,FRCDF1
000766       69 FORMAT(6H0NINI=,I3,6H NFIN=,I3,6H EINI=,E15.8,
              16H EFIN=,E15.8,8H SIGL1T=,E15.8,8H FRCDF1=,E15.8)
000766       70 SIGL1(NINI,NFIN)=6.2831853*SIGL1T
000773          IF(ABS(SIGL2T)-1.E-06)74,74,71
000777       71 FRCDF2=ABS(1.-SIGL2C/SIGL2T)
001003          IF(FRCDF2-.04)74,74,72
001005       72 WRITE(9,73)NINI,NFIN,EINI(NINI),EFIN(NFIN),SIGL2T,FRCDF2
001025       73 FORMAT(6H0NINI=,I3,6H NFIN=,I3,6H EINI=,E15.8,
              16H EFIN=,E15.8,8H SIGL2T=,E15.8,8H FRCDF2=,E15.8)
001025       74 SIGL2(NINI,NFIN)=3.1415927*SIGL2T
001032          IF(ABS(SIGL3T)-1.E-06)78,78,75
001036       75 FRCDF3=ABS(1.-SIGL3C/SIGL3T)
001042          IF(FRCDF3-.08)78,78,76
001044       76 WRITE(9,77)NINI,NFIN,EINI(NINI),EFIN(NFIN),SIGL3T,FRCDF3
001064       77 FORMAT(6H0NINI=,I3,6H NFIN=,I3,6H EINI=,E15.8,
              16H EFIN=,E15.8,8H SIGL3T=,E15.8,8H FRCDF3=,E15.8)
001064       78 SIGL3(NINI,NFIN)=3.1415927*SIGL3T
001071       79 CONTINUE
001074       80 CONTINUE
001076          DO 82 NINI=2,NENERG
001077          NINLS1=NINI-1
001101          DO 81 NFIN=1,NINLS1
```

```
001102          DBFACT=(EFIN(NFIN)/EINI(NINI))*EXP((EINI(NINI)
               1-EFIN(NFIN))/TEMPEN)
001115          SIGL0(NINI,NFIN)=DBFACT*SIGL0(NFIN,NINI)
001122          SIGL1(NINI,NFIN)=DBFACT*SIGL1(NFIN,NINI)
001126          SIGL2(NINI,NFIN)=DBFACT*SIGL2(NFIN,NINI)
001132          SIGL3(NINI,NFIN)=DBFACT*SIGL3(NFIN,NINI)
001136       81 CONTINUE
001140       82 CONTINUE
001142          IF(IDEN)821,89,821
001143      821 DO 88 N=1,NENERG
001145          GLNCMP=ENERGY(N)-BRGLIM
001147          IF(GLNCMP)88,88,822
001151      822 AELSTC=2.*FACMAS*GAM0*ENERGY(N)
001155          IF(AELSTC-.0001)83,83,84
001157       83 SELP0(N)=SELP0(N)+SIGBND
001162          GO TO 85
001162       84 SELP0(N)=SELP0(N)
               1+.5*SIGBND*(1.-EXP(-2.*AELSTC))/AELSTC
001175       85 IF(AELSTC-.03)86,86,87
001200       86 SELP1(N)=SELP1(N)+SIGBND*AELSTC*(1.-AELSTC)/3.
001207          GO TO 88
001210       87 SELP1(N)=SELP1(N)
               1+.5*SIGBND*((1.+AELSTC)*EXP(-2.*AELSTC)+AELSTC-1.)
               2/(AELSTC**2)
001226       88 CONTINUE
001231       89 NERGP1=NENERG+1
001233          ENERGY(NERGP1)=.0
001234          EINI(NERGP1)=.0
001235          EFIN(NERGP1)=.0
001236          DO 91 N=1,NENERG
001240          ENWT1=.5*(ENERGY(1)-ENERGY(2))
001243          SINP0(N)=ENWT1*SIGL0(N,1)
001245          SINP1(N)=ENWT1*SIGL1(N,1)
001247          SINP2(N)=ENWT1*SIGL2(N,1)
001250          SINP3(N)=ENWT1*SIGL3(N,1)
001252          DO 90 J=2,NENERG
001253          ENWT2=.5*(ENERGY(J-1)-ENERGY(J+1))
001256          SINP0(N)=SINP0(N)+ENWT2*SIGL0(N,J)
001264          SINP1(N)=SINP1(N)+ENWT2*SIGL1(N,J)
001267          SINP2(N)=SINP2(N)+ENWT2*SIGL2(N,J)
001273       90 SINP3(N)=SINP3(N)+ENWT2*SIGL3(N,J)
001300          STOT(N)=SINP0(N)+SELP0(N)
001303          STR1(N)=STOT(N)-SINP1(N)-SELP1(N)
001306          STR2(N)=STOT(N)-SINP2(N)
001311       91 STR3(N)=STOT(N)-SINP3(N)
001315          CALL GLNRIT
            C     TO OMIT CALCULATION OF ANALYTIC CHECK IN GLEN
001316          CALL GLFEGP
001317          STOP
001321          END
```

```
          $IBFTC GLN1     DECK
                 SUBROUTINE GLNFIR
000002           COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
                1NENERG,FACMAS,SIGBND,SBD4PI,ARECP1,AEPSP1,
                2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
                3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
                4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
                5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
                6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
                7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
                8STOT(90),STR1(90),STR2(90),STR3(90)
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000002          COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
                1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
                2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
                3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
                4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
                5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
                6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
                7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
                8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002          COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
                1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
                2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
                3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
                4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
                5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
                6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
                7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002          COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002          COMMON DFCO11(87)
000002        1 ARECP1=AFAREC+1.
000004          AEPSP1=AFAEPS+1.
000006          ARP1H2=ARECP1*(HREC**2)
000010          AEP1H2=AEPSP1*(HEPS**2)
000012        2 NLIMP1=NLIM+1
000014          MLIMP1=MLIM+1
000016        3 DO 4 M=1,MLIMP1
000020        4 SKE(NLIMP1,M)=.0
000027        5 DO 6 N=1,NLIM
000031        6 SKE(N,MLIMP1)=.0
000040        7 COSMU(1)=-.99061798
000042          COSMU(2)=-.95384693
000043          COSMU(3)=-.9
000045          COSMU(4)=-.84615307
000046          COSMU(5)=-.80938202
000050          COSMU(6)=-.78123597
000051          COSMU(7)=-.70769386
000053          COSMU(8)=-.6
000054          COSMU(9)=-.49230614
000056          COSMU(10)=-.41876403
000057          COSMU(11)=-.38123597
000061          COSMU(12)=-.30769386
000062          COSMU(13)=-.2
000064          COSMU(14)=-.09230614
000065          COSMU(15)=-.01876403
000067          COSMU(16)=.01876403
000070          COSMU(17)=.09230614
000072          COSMU(18)=.2
000073          COSMU(19)=.30769386
000075          COSMU(20)=.38123597
000076          COSMU(21)=.41407302
000100          COSMU(22)=.46922960
000101          COSMU(23)=.55
000103          COSMU(24)=.63077040
000104          COSMU(25)=.68592698
000106          COSMU(26)=.70703651
000107          COSMU(27)=.73461480
000111          COSMU(28)=.775
000112          COSMU(29)=.81538520
000114          COSMU(30)=.84296349
000115          COSMU(31)=.85469101
000117          COSMU(32)=.87307653
000120          COSMU(33)=.90
000122          COSMU(34)=.92692347
000123          COSMU(35)=.94530899
000125          COSMU(36)=.95234550
000126          COSMU(37)=.96153827
000130          COSMU(38)=.975
000131          COSMU(39)=.98846173
000133          COSMU(40)=.99765450
000134          WATE(1)=.02369269
000136          WATE(2)=.04786287
```

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000137          WATE(3)=.05688888
000141          WATE(4)=.04786287
000142          WATE(5)=.02369269
000143          WATE(6)=.04738537
000145          WATE(7)=.09572574
000146          WATE(8)=.11377778
000150          WATE(9)=.09572574
000151          WATE(10)=.04738537
000152          WATE(11)=.04738537
000153          WATE(12)=.09572574
000154          WATE(13)=.11377778
000155          WATE(14)=.09572574
000156          WATE(15)=.04738537
000157          WATE(16)=.04738537
000160          WATE(17)=.09572574
000161          WATE(18)=.11377778
000162          WATE(19)=.09572574
000163          WATE(20)=.04738537
000164          WATE(21)=.03553903
000165          WATE(22)=.07179430
000167          WATE(23)=.08533334
000170          WATE(24)=.07179430
000172          WATE(25)=.03553903
000173          WATE(26)=.01776952
000174          WATE(27)=.03589715
000176          WATE(28)=.04266666
000177          WATE(29)=.03589715
000201          WATE(30)=.01776952
000202          WATE(31)=.01184635
000203          WATE(32)=.02393143
000205          WATE(33)=.02844444
000206          WATE(34)=.02393143
000210          WATE(35)=.01184635
000211          WATE(36)=.00592317
000212          WATE(37)=.01196572
000214          WATE(38)=.01422222
000215          WATE(39)=.01196572
000216          WATE(40)=.00592317
000217          COSMU(41)=-.97745967
000221          COSMU(42)=-.82254033
000222          COSMU(43)=-.75491934
000224          COSMU(44)=-.44508066
000225          COSMU(45)=-.35491934
000227          COSMU(46)=-.04508066
000230          COSMU(47)=.04508066
000232          COSMU(48)=.35491934
000233          COSMU(49)=.43381050
000235          COSMU(50)=.66618950
000236          COSMU(51)=.71690525
000240          COSMU(52)=.83309475
000241          COSMU(53)=.86127017
000243          COSMU(54)=.93872983
000244          COSMU(55)=.95563508
000246          COSMU(56)=.99436492
000247          WATE(41)=.05555556
000251          WATE(42)=.05555556
000252          WATE(43)=.11111111
000253          WATE(44)=.11111111
000255          WATE(45)=.11111111
000256          WATE(46)=.11111111
000260          WATE(47)=.11111111
000261          WATE(48)=.11111111
000263          WATE(49)=.08333333
000264          WATE(50)=.08333333
000266          WATE(51)=.04166667
000267          WATE(52)=.04166667
000271          WATE(53)=.02777778
000272          WATE(54)=.02777778
000273          WATE(55)=.01388889
000274          WATE(56)=.01388889
000275          NMUMAX=56
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```
000276          NMUM1=40
000277          NMUM2=41
000300          NMUM3=56
000301        8 IF(HEPS)12,12,9
000303        9 DO 10 N=1,NLIM
000305          DO 10 M=1,MLIM
000306       10 SKE(N,M)=(EXP(EPS(M)/TEMPEN))*SKE(N,M)
000325          HEPS=-HEPS
000326          DO 11 M=1,MLIM
000327       11 EPS(M)=-EPS(M)
000334       12 RETURN
000335          END
```

```
        $IBFTC GLN2     DECK
               SUBROUTINE GLNINT
000002         COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
              1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSPI,
              2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
              3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
              4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
              5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
              6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
              7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
              8STOT(90),STR1(90),STR2(90),STR3(90)
000002         COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
              1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
              2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
              3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
              4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
              5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
              6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
              7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
              8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002         COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
              1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
              2SELOFG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
              3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
              4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
              5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
              6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
              7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002         COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002         COMMON DFCO11(87)
000002       1 N=2
000003       2 GLNCMP=REC(N)
000006       3 IF(GLNREC-GLNCMP)4,4,5
000011       4 NGLN=N-1
000013         GO TO 8
000014       5 IF(N-NLIM)6,7,7
000017       6 N=N+1
000021         GO TO 2
000021       7 SIGSCT(NMU)=.0
000023         RETURN
000024       8 M=2
000025         ABGLNP=ABS(GLNEPS)
000027       9 GLNCMP=ABS(EPS(M))
000032      10 IF(ABGLNP-GLNCMP)11,11,12
000035      11 MGLN=M-1
000037         GO TO 15
000040      12 IF(M-MLIM)13,14,14
000043      13 M=M+1
000045         GO TO 9
000045      14 SIGSCT(NMU)=.0
000047         RETURN
```

```
000050       15 IF(IDEN)20,16,20
000051       16 IF(NGLN-1)17,17,20
000054       17 IF(GLNREC)18,18,19
000056       18 SIGSCT(NMU)=.0
000060          RETURN
000061       19 AMT1=1./((12.566371*GLNREC*TEMPEN)**.5)
000067          AMT2=(GLNEPS+GLNREC)**2
000071          AMT3=4.*GLNREC*TEMPEN
000074          SIGSCT(NMU)=(SBD4PI)*((EFIN(NFIN)/EINI(NINI))**.5)
               1*AMT1*EXP(-AMT2/AMT3)
000112          RETURN
000112       20 NGLNL1=NGLN-1
000114          NGL2L1=2*NGLN-1
000117       21 GLCF0=GLNREC-REC(NGLN)
000122          GLCF1=GLCF0/(HREC*(AFAREC**NGLNL1))
000130          GLCF2=GLCF0*(GLNREC-REC(NGLN+1))
               1/(ARP1H2*(AFAREC**NGL2L1))
000140       22 SGLN0=SKE(NGLN,MGLN)+GLCF1*(SKE(NGLN+1,MGLN)
               1-SKE(NGLN,MGLN))+GLCF2*(SKE(NGLN+2,MGLN)
               2-ARECP1*SKE(NGLN+1,MGLN)+AFAREC*SKE(NGLN,MGLN))
000162          SGLN1=SKE(NGLN,MGLN+1)+GLCF1*(SKE(NGLN+1,MGLN+1)
               1-SKE(NGLN,MGLN+1))+GLCF2*(SKE(NGLN+2,MGLN+1)
               2-ARECP1*SKE(NGLN+1,MGLN+1)+AFAREC*SKE(NGLN,MGLN+1))
000200          SGLN2=SKE(NGLN,MGLN+2)+GLCF1*(SKE(NGLN+1,MGLN+2)
               1-SKE(NGLN,MGLN+2))+GLCF2*(SKE(NGLN+2,MGLN+2)
               2-ARECP1*SKE(NGLN+1,MGLN+2)+AFAREC*SKE(NGLN,MGLN+2))
000215       23 MGLNL1=MGLN-1
000217          MGL2L1=2*MGLN-1
000222       24 GLCF10=GLNEPS-EPS(MGLN)
000225          GLCF11=GLCF10/(HEPS*(AFAEPS**MGLNL1))
000233          GLCF12=GLCF10*(GLNEPS-EPS(MGLN+1))
               1/(AEP1H2*(AFAEPS**MGL2L1))
000243       25 SGLN=SGLN0
               1+GLCF11*(SGLN1-SGLN0)
               2+GLCF12*(SGLN2-AEPSP1*SGLN1+AFAEPS*SGLN0)
000257          IF(SGLN)27,28,28
000260       27 SGLN=.0
000261       28 SIGSCT(NMU)=(SBD4PI)*((EFIN(NFIN)/EINI(NINI))**.5)
               1*SGLN
000273          RETURN
000274          END
```

```
$IBFTC GLN3     DECK
          SUBROUTINE GLNRIT
000002    COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
         1NENERG,FACMAS,SIGRND,SBD4PI,ARECP1,AEPSP1,
         2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
         3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
         4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
         5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
         6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
         7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
         8STOT(90),STR1(90),STR2(90),STR3(90)
000002    COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
         1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
         2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
         3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
         4RUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
         5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
         6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMAN0(90),
         7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
         8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002    COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
         1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
         2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
         3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
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     4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
     5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
     6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
     7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002       COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002       COMMON DFCO11(87)
000002       WRITE(9,1)IDEN,TEMPEN,GAM0
000014     1 FORMAT(6H0IDEN=,I3,8H TEMPEN=,E15.8,6H GAM0=,E15.8)
000014       WRITE(9,2)NENERG
000022     2 FORMAT(8H0NENERG=,I3)
000022       WRITE(9,3)
000026     3 FORMAT(14H0 N      ENERGY)
000026       WRITE(9,4)(N,ENERGY(N),N=1,NENERG)
000043     4 FORMAT(I3,E15.8)
000043       WRITE(9,5)FACMAS
000051     5 FORMAT(8H0FACMAS=,E15.8)
000051       WRITE(9,6)SIGBND
000057     6 FORMAT(8H0SIGBND=,E15.8)
000057       WRITE(9,7)
000063     7 FORMAT(101H0NINI NFIN      EINI            EFIN            SIGL0
     1          SIGL1            SIGL2            SIGL3)
000063       DO 8 NINI=1,NENERG
000065     8 WRITE(9,9)(NINI,NFIN,EINI(NINI),EFIN(NFIN),
     1SIGL0(NINI,NFIN),SIGL1(NINI,NFIN),SIGL2(NINI,NFIN),
     2SIGL3(NINI,NFIN),NFIN=1,NENERG)
000133     9 FORMAT(2I5,6E16.8)
000133       WRITE(9,10)
000136    10 FORMAT(46H0 N      ENERGY            SELP0            SELP1)
000136       WRITE(9,11)(N,ENERGY(N),SELP0(N),SELP1(N),N=1,NENERG)
000161    11 FORMAT(I3,3E16.8)
000161       WRITE(9,12)
000165    12 FORMAT(78H0 N      ENERGY            SINP0            SINP1
     1 SINP2            SINP3)
000165       WRITE(9,13)(N,ENERGY(N),SINP0(N),SINP1(N),
     1SINP2(N),SINP3(N),N=1,NENERG)
000216    13 FORMAT(I3,5E16.8)
000216       WRITE(9,14)
000222    14 FORMAT(77H0 N      ENERGY            STOT             STR1
     1 STR2            STR3)
000222       WRITE(9,13)(N,ENERGY(N),STOT(N),STR1(N),
     1STR2(N),STR3(N),N=1,NENERG)
000253       RETURN
000254       END
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$IBFTC GLN4     DECK
       SUBROUTINE GLFEGP
000002       COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
     1NENERG,FACMAS,SIGBND,SBD4PI,ARECP1,AEPSP1,
     2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
     3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
     4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
     5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
     6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
     7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
     8STOT(90),STR1(90),STR2(90),STR3(90)
000002       COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAM0,ENODM0,
     1ENABM0,SIABM0,SIGAM0(90),NISOMA,NISO,
     2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
     3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
     4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
     5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
     6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMAN0(90),
     7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
     8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002       COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
     1FGPF(4,20),GMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
     2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
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     3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
     4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
     5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
     6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
     7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002       COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002       COMMON DFC011(87)
000002       ININCK=0
000003       READ(10,7)NFGP
000011       IF(NFGP-20)902,902,900
000014   900 WRITE(9,901)
000020   901 FORMAT(20H0NFGP EXCEEDS TWENTY)
000020       ININCK=ININCK+1
000022   902 IF(NFGP)910,910,912
000024   910 WRITE(9,911)
000030   911 FORMAT(18H0NFGP NOT POSITIVE)
000030       ININCK=ININCK+1
000032   912 READ(10,1)(ENFEGP(N),N=1,NFGP)
000045     1 FORMAT(4E20.8)
000045       DO 6 N=1,NFGP
000047       INFGCK=0
000050       DO 2 J=1,NENERG
000052       GLNCMP=ENFEGP(N)-ENERGY(J)
000056       IF(GLNCMP)2,3,2
000057     2 INFGCK=INFGCK+1
000063       GO TO 903
000064     3 INFGCK=0
000065   903 IF(INFGCK)4,6,4
000066     4 WRITE(9,5)N
000074     5 FORMAT(8H0ENFEGP(,I3,12H ) INCORRECT)
000074       ININCK=ININCK+1
000076     6 CONTINUE
000101       DO 908 N=2,NFGP
000102       GLNCMP=ENFEGP(N-1)-ENFEGP(N)
000105       IF(GLNCMP)906,906,908
000107   906 WRITE(9,907)N
000115   907 FORMAT(8H0ENFEGP(,I3,15H ) OUT OF ORDER)
000115       ININCK=ININCK+1
000117   908 CONTINUE
000122       READ(10,7)NMIXMA
000127     7 FORMAT(8I10)
000127       IF(NMIXMA)8,8,10
000131     8 WRITE(9,9)
000135     9 FORMAT(17H0NMIXMA INCORRECT)
000135       ININCK=ININCK+1
000137    10 IF(NMIXMA-10)12,12,11
000142    11 WRITE(9,9)
000146       ININCK=ININCK+1
000150    12 IF(ININCK)13,15,13
000151    13 WRITE(9,14)ININCK
000157    14 FORMAT(57H0FEW GROUP ENERGIES AND NUMBER OF MIXTURES CHECKED, ABOV
     1E,I3,31H ERRORS FOUND, PROBLEM STOPPED.)
000157       STOP
000161    15 NMIX=1
000162    16 ININCK=0
000163       READ(10,17)INDAMO,ENODMO
000173    17 FORMAT(I10,3E20.8)
000173       IF(INDAMO)18,22,20
000175    18 WRITE(9,19)
000201    19 FORMAT(48H0MODERATOR SIGA READ INDICATOR INDAMO INCORRECT.)
000201       ININCK=ININCK+1
000203       GO TO 22
000203    20 IF(INDAMO-1)21,22,21
000205    21 WRITE(9,19)
000211       ININCK=ININCK+1
000213    22 IF(ENODMO)23,25,25
000215    23 WRITE(9,24)
000221    24 FORMAT(42H0MODERATOR NUMBER DENSITY ENODMO NEGATIVE.)
000221       ININCK=ININCK+1
000223    25 IF(INDAMO)26,26,35
000225    26 READ(10,1)ENABMO,STABMO
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000235       27 IF(ENABMO)28,28,30
000237       28 WRITE(9,29)
000243       29 FORMAT(21H0ENABMO NOT POSITIVE.)
000243          ININCK=ININCK+1
000245       30 IF(SIABMO)31,33,33
000247       31 WRITE(9,32)
000253       32 FORMAT(17H0SIABMO NEGATIVE.)
000253          ININCK=ININCK+1
000255       33 DO 34 N=1,NENERG
000257       34 SIGAMO(N)=SIABMO*((ENABMO/ENERGY(N))**.5)
000270          GO TO 39
000271       35 READ(10,1)(SIGAMO(N),N=1,NENERG)
000304          DO 38 N=1,NENERG
000306          GLNCMP=SIGAMO(N)
000310          IF(GLNCMP)36,38,38
000311       36 WRITE(9,37)N
000317       37 FORMAT(8H0SIGAMO(,I3,12H ) NEGATIVE.)
000317          ININCK=ININCK+1
000321       38 CONTINUE
000324       39 READ(10,7)NISOMA
000332          IF(NISOMA)40,40,42
000334       40 WRITE(9,41)
000340       41 FORMAT(33H0NUMBER ISOTOPES NISOMA INCORRECT)
000340          ININCK=ININCK+1
000342       42 IF(NISOMA-4)44,44,43
000345       43 WRITE(9,41)
000351          ININCK=ININCK+1
000353       44 READ(10,45)(INDAIS(NISO),INDFIS(NISO),ENODIS(NISO),
             1SIGSIS(NISO),SIP1IS(NISO),NISO=1,NISOMA)
000402       45 FORMAT(2I10,3E20.8)
000402          DO 89 NISO=1,NISOMA
000404          JTEST=INDAIS(NISO)
000406          IF(JTEST)46,50,48
000407       46 WRITE(9,47)NISO
000415       47 FORMAT(36H0ISOTOPE SIGA READ INDICATOR INDAIS(,I3,
               112H ) INCORRECT)
000415          ININCK=ININCK+1
000417          GO TO 50
000417       48 IF(JTEST-1)49,50,49
000421       49 WRITE(9,47)NISO
000427          ININCK=ININCK+1
000431       50 JTEST=INDFIS(NISO)
000434          IF(JTEST)51,55,53
000435       51 WRITE(9,52)NISO
000443       52 FORMAT(36H0ISOTOPE SIGF READ INDICATOR INDFIS(,I3,
               112H ) INCORRECT)
000443          ININCK=ININCK+1
000445       53 IF(JTEST-1)54,55,54
000447       54 WRITE(9,52)NISO
000455          ININCK=ININCK+1
000457       55 GLNCMP=ENODIS(NISO)
000462          IF(GLNCMP)56,58,58
000463       56 WRITE(9,57)NISO
000471       57 FORMAT(31H0ISOTOPE NUMBER DENSITY ENODIS(,I3,
               111H ) NEGATIVE)
000471          ININCK=ININCK+1
000473       58 GLNCMP=SIGSIS(NISO)
000476          IF(GLNCMP)59,61,61
000477       59 WRITE(9,60)NISO
000505       60 FORMAT(41H0ISOTOPE SCATTERING CROSS SECTION SIGSIS(,I3,
               111H ) NEGATIVE)
000505          ININCK=ININCK+1
000507       61 JTEST=INDAIS(NISO)
000512          IF(JTEST)62,62,71
000513       62 READ(10,1)ENABIS(NISO),SIABIS(NISO)
000525       63 GLNCMP=ENABIS(NISO)
000530          IF(GLNCMP)64,64,66
000531       64 WRITE(9,65)NISO
000537       65 FORMAT(8H0ENABIS(,I3,15H ) NOT POSITIVE)
000537          ININCK=ININCK+1
000541       66 GLNCMP=SIABIS(NISO)
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000544          IF(GLNCMP)67,69,69
000545       67 WRITE(9,68)NISO
000553       68 FORMAT(8H0SIABIS(,I3,11H ) NEGATIVE)
000553          ININCK=ININCK+1
000555       69 DO 70 N=1,NENERG
000557       70 SIGAIS(NISO,N)=SIABIS(NISO)*((ENABIS(NISO)
                1/ENERGY(N))**.5)
000576          GO TO 75
000577       71 READ(10,1)(SIGAIS(NISO,N),N=1,NENERG)
000614          DO 74 N=1,NENERG
000616          GLNCMP=SIGAIS(NISO,N)
000622          IF(GLNCMP)72,74,74
000623       72 WRITE(9,73)NISO,N
000633       73 FORMAT(8H0SIGAIS(,I3,2H ,,I3,11H ) NEGATIVE)
000633          ININCK=ININCK+1
000635       74 CONTINUE
000640       75 JTEST=INDFIS(NISO)
000643          IF(JTEST)76,76,85
000644       76 READ(10,1)ENFIIS(NISO),SIFIIS(NISO)
000656       77 GLNCMP=ENFIIS(NISO)
000661          IF(GLNCMP)78,78,80
000662       78 WRITE(9,79)NISO
000670       79 FORMAT(8H0ENFIIS(,I3,15H ) NOT POSITIVE)
000670          ININCK=ININCK+1
000672       80 GLNCMP=SIFIIS(NISO)
000675          IF(GLNCMP)81,83,83
000676       81 WRITE(9,82)NISO
000704       82 FORMAT(8H0SIFIIS(,I3,11H ) NEGATIVE)
000704          ININCK=ININCK+1
000706       83 DO 84 N=1,NENERG
000710       84 SIGFIS(NISO,N)=SIFIIS(NISO)*((ENFIIS(NISO)
                1/ENERGY(N))**.5)
000727          GO TO 89
000730       85 READ(10,1)(SIGFIS(NISO,N),N=1,NENERG)
000745          DO 88 N=1,NENERG
000747          GLNCMP=SIGFIS(NISO,N)
000753          IF(GLNCMP)86,88,88
000754       86 WRITE(9,87)NISO,N
000764       87 FORMAT(8H0SIGFIS(,I3,2H ,,I3,11H ) NEGATIVE)
000764          ININCK=ININCK+1
000766       88 CONTINUE
000771       89 CONTINUE
000774          READ(10,1)BUCKLE
001001          READ(10,7)NSPEC
001007          IF(NSPEC)90,94,92
001011       90 IF(NSPEC+1)190,94,190
001013      190 WRITE(9,91)
001017       91 FORMAT(35H0SPECTRUM INDICATOR NSPEC INCORRECT)
001017          ININCK=ININCK+1
001021          GO TO 94
001021       92 IF(NSPEC-1)93,94,93
001023       93 WRITE(9,91)
001027          ININCK=ININCK+1
001031       94 IF(JPRBNO)941,942,942
001033      941 READ(10,1)STRAND
001041      942 IF(ININCK)95,99,95
001042       95 WRITE(9,96)NMIX,ININCK
001052       96 FORMAT(18H0INPUT FOR MIXTURE,I3,
                115H CHECKED, ABOVE,I3,
                231H ERRORS FOUND, MIXTURE SKIPPED.)
001052          IF(NMIX-NMIXMA)97,98,98
001055       97 NMIX=NMIX+1
001057          GO TO 18
001057       98 RETURN
001060       99 DO 100 N=1,NENERG
001062      100 SOURCE(N)=ENODMO*SIGL0(1,N)
001073          DO 101 N=1,NENERG
001074      101 SIGL0(1,N)=.5*(ENERGY(1)-ENERGY(2))*SIGL0(1,N)
001106          SIGL0(1,1)=SIGL0(1,1)+SELP0(1)
001110          DO 102 J=2,NENERG
001111          ENWT=.5*(ENERGY(J-1)-ENERGY(J+1))
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```
001115          DO 102 N=1,NENERG
001116      102 SIGL0(J,N)=ENWT*SIGL0(J,N)
001127          DO 103 J=2,NENERG
001131      103 SIGL0(J,J)=SIGL0(J,J)+SELP0(J)
001142      104 AD0SIS=.0
001143          DO 105 NISO=1,NISOMA
001145      105 AD0SIS=AD0SIS+ENODIS(NISO)*SIGSIS(NISO)
001153          DO 106 N=1,NENERG
001155      106 SMASCT(N)=ENODMO*STOT(N)+AD0SIS
001163      107 DO 108 N=1,NENERG
001165          SMAABS(N)=ENODMO*SIGAMO(N)
001170          DO 108 NISO=1,NISOMA
001172      108 SMAABS(N)=SMAABS(N)+ENODIS(NISO)*SIGAIS(NISO,N)
001207      109 DO 110 N=1,NENERG
001211          SMAFIS(N)=.0
001213          DO 110 NISO=1,NISOMA
001214      110 SMAFIS(N)=SMAFIS(N)+ENODIS(NISO)*SIGFIS(NISO,N)
001231          DO 111 N=1,NENERG
001232      111 SMATR0(N)=ENODMO*STOT(N)+SMAABS(N)
001241      112 AD1SIS=.0
001242          DO 113 NISO=1,NISOMA
001244      113 AD1SIS=AD1SIS+ENODIS(NISO)*SIP1IS(NISO)
001252          DFAD10=AD0SIS-AD1SIS
001254          DO 114 N=1,NENERG
001256          SMATR1(N)=ENODMO*STR1(N)+DFAD10+SMAABS(N)
001264          SMATR2(N)=ENODMO*STR2(N)+AD0SIS+SMAABS(N)
001271          SMATR3(N)=ENODMO*STR3(N)+AD0SIS+SMAABS(N)
001275      114 DIFCOF(N)=1./(3.*SMATR1(N))
001303          CALL GLSPEC
001304          CALL GLEDIT
001305          IF(NMIX-NMIXMA)115,116,116
001310      115 NMIX=NMIX+1
001312          GO TO 16
001312      116 WRITE(9,117)NMIXMA
001320      117 FORMAT(4H0ALL,I3,34H MIXTURES COMPLETED. END OF PRINT.)
001320          RETURN
001321          END
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        $IBFTC GLNS     DECK
               SUBROUTINE GLSPEC
000002         COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
              1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSPI,
              2ARPIH2,AEPIH2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
              3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
              4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
              5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
              6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
              7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
              8STOT(90),STR1(90),STR2(90),STR3(90)
000002         COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
              1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
              2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
              3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
              4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
              5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
              6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
              7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
              8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002         COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
              1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
              2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
              3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
              4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
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     5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
     6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
     7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002       COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002       COMMON DFCO11(87)
000002       DO 1 N=1,NENERG
000004       DFLF0(N)=ENERGY(N)*EXP(-ENERGY(N)/TEMPEN)
000015     1 SPMAN0(N)=DFLF0(N)
000022       CALL GLDFL
000023       IF(RCDFL2)21,21,2
000025     2 DIFLGT(1)=SQRT(1./RCDFL2)
000032       NDFLIT=2
000033     3 ENUM=.0
000034       DO 4 J=2,NENERG
000036     4 ENUM=ENUM+SIGL0(J,1)*DFLF0(J)
000046       ENUM=ENUM*ENODM0
000050       EDEN=SMATR0(1)-DIFCOF(1)*RCDFL2-ENODM0*SIGL0(1,1)
000055       DFLF0(1)=ENUM/EDEN
000056     5 NRGLS1=NENERG-1
000060       DO 8 N=2,NRGLS1
000062       NLS1=N-1
000064       NPL1=N+1
000065       ENUM=.0
000066       DO 6 J=1,NLS1
000067     6 ENUM=ENUM+SIGL0(J,N)*DFLF0(J)
000101       DO 7 J=NPL1,NENERG
000103     7 ENUM=ENUM+SIGL0(J,N)*DFLF0(J)
000115       ENUM=ENUM*ENODM0
000117       EDEN=SMATR0(N)-DIFCOF(N)*RCDFL2-ENODM0*SIGL0(N,N)
000130     8 DFLF0(N)=ENUM/EDEN
000135       ENUM=.0
000135       DO 9 J=1,NRGLS1
000137     9 ENUM=ENUM+SIGL0(J,NENERG)*DFLF0(J)
000151       ENUM=ENUM*ENODM0
000153       EDEN=SMATR0(NENERG)-DIFCOF(NENERG)*RCDFL2
            1-ENODM0*SIGL0(NENERG,NENERG)
000164    10 DFLF0(NENERG)=ENUM/EDEN
000167       CALL GLDFL
000170    11 DIFLGT(NDFLIT)=SQRT(1./RCDFL2)
000177       NITLS1=NDFLIT-1
000201    12 GLNCMP=ABS(1.-DIFLGT(NITLS1)/DIFLGT(NDFLIT))
000207       IF(GLNCMP-.00001)15,15,13
000211    13 IF(NDFLIT-50)14,15,15
000214    14 NDFLIT=NDFLIT+1
000216       GO TO 3
000216    15 RDFCF1=.26666667*RCDFL2
000220       RDFCF2=.25714286*RCDFL2
000222       DO 16 N=1,NENERG
000223    16 DFCOFI(N)=1./(3.*(SMATR1(N)-RDFCF1
            1/(SMATR2(N)-RDFCF2/SMATR3(N))))
000237       ENWT1=(ENERGY(1)-ENERGY(2))*DFLF0(1)
000242       ENUM=ENWT1*SMAABS(1)
000244       EDEN=ENWT1*DFCOFI(1)
000246       ESPNOR=ENWT1
000247       EMANOR=(ENERGY(1)-ENERGY(2))*SPMAN0(1)
000252       DO 17 N=2,NENERG
000253       ENWT2=(ENERGY(N-1)-ENERGY(N+1))*DFLF0(N)
000257       ENUM=ENUM+ENWT2*SMAABS(N)
000262       EDEN=EDEN+ENWT2*DFCOFI(N)
000265       ESPNOR=ESPNOR+ENWT2
000267    17 EMANOR=EMANOR+(ENERGY(N-1)-ENERGY(N+1))*SPMAN0(N)
000276       ESPNOR=.5*ESPNOR
000277       EMANOR=.5*EMANOR
000300       DFLGFI=SQRT(EDEN/ENUM)
000305       TRCORR=(DFLGFI-DIFLGT(NDFLIT))/DFLGFI
000310       DO 18 N=1,NENERG
000311       DFLF0(N)=DFLF0(N)/ESPNOR
000314    18 SPMAN0(N)=SPMAN0(N)/EMANOR
000320       DO 20 N=1,NENERG
000322       RSDRT=.0
000323       DO 19 J=1,NENERG
```

```
000325       19 RSDRT=RSDRT+SIGL0(J,N)*DFLF0(J)
000337          RSDRT=RSDRT-SIGL0(N,N)*DFLF0(N)
000345          RSDRT=ENODMO*RSDRT
000346          RSDLT=(SMATR0(N)-DIFCOF(N)*RCDFL2
               1-ENODMO*SIGL0(N,N))*DFLF0(N)
000360       20 DFLRSD(N)=(RSDLT-RSDRT)/RSDLT
000365          DO 201 N=1,NENERG
000367          DF11F0(N)=SPMANO(N)
000372      201 DF11F1(N)=DIFCOF(N)*DF11F0(N)/DFLGFI
000400          NDF11=NDFLIT+1
000402          DIFLGT(NDF11)=DFLGFI
000404          DFIN=1./DFLGFI
000406          DFINSQ=1./(DFLGFI**2)
000407      202 DO 203 N=1,NENERG
000411          FGINGD(N)=.5*(ENERGY(1)-ENERGY(2))*SIGL1(1,N)*DF11F1(1)
000421          DO 2021 J=2,NENERG
000422     2021 FGINGD(N)=FGINGD(N)+.5*(ENERGY(J-1)-ENERGY(J+1))
               1*SIGL1(J,N)*DF11F1(J)
000442      203 DFC011(N)=.333333/(SMATR1(N)+ENODMO*(SINP1(N)-FGINGD(N)/DF11F1(N))
               1-.26666667*DFINSQ/(SMATR2(N)-.25714286*DFINSQ/(SMATR3(N)
               2-.25396825*DFINSQ/(SMATR3(N)
               3-.25252525*DFINSQ/(SMATR3(N)
               4-.25174825*DFINSQ/(SMATR3(N)
               5-.25128205*DFINSQ/(SMATR3(N)
               6-.25098039*DFINSQ/(SMATR3(N)
               7-.25077399*DFINSQ/(SMATR3(N)
               8-.25062657*DFINSQ/(SMATR3(N)
               9-.25051760*DFINSQ/(SMATR3(N))))))))))
000520          D11R=.0
000521          DO 205 N=1,NENERG
000522          ENUM=.0
000523          DO 204 J=1,NENERG
000525      204 ENUM=ENUM+SIGL0(J,N)*DF11F0(J)
000537          ENUM=ENUM-SIGL0(N,N)*DF11F0(N)
000545          ENUM=ENODMO*ENUM
000546          EDEN=SMATR0(N)-DFINSQ*DFC011(N)-ENODMO*SIGL0(N,N)
000556          GLNCMP=ABS((DF11F0(N)-ENUM/EDEN)/DF11F0(N))
000563          IF(GLNCMP-D11R)205,205,2041
000565     2041 D11R=GLNCMP
000567      205 DF11F0(N)=ENUM/EDEN
000575          DO 208 N=1,NENERG
000576      208 DF11F1(N)=DFIN*DFC011(N)*DF11F0(N)
000605          ENWT1=ENERGY(1)-ENERGY(2)
000607          ENUM=ENWT1*SMAABS(1)*DF11F0(1)
000611          EDEN=ENWT1*DFC011(1)*DF11F0(1)
000613          DO 209 N=2,NENERG
000615          ENWT2=ENERGY(N-1)-ENERGY(N+1)
000620          ENUM=ENUM+ENWT2*SMAABS(N)*DF11F0(N)
000624      209 EDEN=EDEN+ENWT2*DFC011(N)*DF11F0(N)
000632          NDF11=NDF11+1
000634          DIFLGT(NDF11)=SQRT(EDEN/ENUM)
000642          IF(D11R-.001)212,212,210
000644      210 IF(NDF11-100)211,212,212
000647      211 DFIN=1./DIFLGT(NDF11)
000652          DFINSQ=DFIN**2
000653          GO TO 202
000654      212 DFLP11=DIFLGT(NDF11)
000657          P11COR=(DFLP11-DIFLGT(NDFLIT))/DFLP11
000662          ENORM=(ENERGY(1)-ENERGY(2))*DF11F0(1)
000665          DO 213 N=2,NENERG
000666      213 ENORM=ENORM+(ENERGY(N-1)-ENERGY(N+1))*DF11F0(N)
000675          ENORM=.5*ENORM
000677          DO 214 N=1,NENERG
000700          DF11F0(N)=DF11F0(N)/ENORM
000703      214 DF11F1(N)=DF11F1(N)/ENORM
000707          DFIN=1./DIFLGT(NDF11)
000712          DO 216 N=1,NENERG
000713          RSDRT=.0
000714          DO 215 J=1,NENERG
000716      215 RSDRT=RSDRT+SIGL0(J,N)*DF11F0(J)
000730          RSDRT=ENODMO*RSDRT
000731          RSDLT=SMATR0(N)*DF11F0(N)-DFIN*DF11F1(N)
```

```
000737      216 DF11RS(N)=(RSDLT-RSDRT)/RSDLT
000745          GO TO 25
000745       21 NDFLIT=1
000746          DIFLGT(1)=.0
000747          DFLGFI=.0
000750          TRCORR=.0
000751          NDF11=2
000752          DIFLGT(2)=.0
000753          DFLP11=.0
000754          P11COR=.0
000755          DO 22 N=1,NENERG
000756          DFLF0(N)=.0
000760          DF11F0(N)=.0
000761          DF11F1(N)=.0
000763          DF11RS(N)=.0
000764          DFC011(N)=.0
000766       22 DFLRSD(N)=.0
000771          EMANOR=(ENERGY(1)-ENERGY(2))*SPMANO(1)
000774          DO 23 N=2,NENERG
000776       23 EMANOR=EMANOR+(ENERGY(N-1)-ENERGY(N+1))*SPMANO(N)
001005          EMANOR=.5*EMANOR
001007          DO 24 N=1,NENERG
001010       24 SPMANO(N)=SPMANO(N)/EMANOR
001015       25 B2CF1=.26666667*BUCKLE
001017          B2CF2=.25714286*BUCKLE
001021          DO 26 N=1,NENERG
001022       26 DFCFB2(N)=1./(3.*(SMATR1(N)+B2CF1/(SMATR2(N)
                1+B2CF2/SMATR3(N))))
001036       27 EDEN=(ENERGY(1)-ENERGY(2))*(BUCKLE*DFCFB2(1)
                1+SMAABS(1))*SPMANO(1)
001044          DO 28 N=2,NENERG
001045       28 EDEN=EDEN+(ENERGY(N-1)-ENERGY(N+1))*(BUCKLE*DFCFB2(N)
                1+SMAABS(N))*SPMANO(N)
001060          EDEN=.5*EDEN
001061          ANORSP=ENODMO*SINP0(1)/EDEN
001064          DO 29 N=1,NENERG
001065          B2F(1,N)=ANORSP*SPMANO(N)
001072       29 B2FOLD(N)=B2F(1,N)
001077          NB2IT=1
001100          IF(NSPEC)431,44,291
001102      291 NB2IT=2
001103       30 ENUM=.0
001104          DO 31 J=2,NENERG
001106       31 ENUM=ENUM+SIGL0(J,1)*B2F(1,J)
001120          ENUM=ENUM*ENODMO+SOURCE(1)
001123          EDEN=SMATR0(1)+DFCFB2(1)*BUCKLE-ENODMO*SIGL0(1,1)
001127          B2F(1,1)=ENUM/EDEN
001131          DO 34 N=2,NRGLS1
001132          NLS1=N-1
001134          NPL1=N+1
001135          ENUM=.0
001136          DO 32 J=1,NLS1
001137       32 ENUM=ENUM+SIGL0(J,N)*B2F(1,J)
001153          DO 33 J=NPL1,NENERG
001155       33 ENUM=ENUM+SIGL0(J,N)*B2F(1,J)
001171          ENUM=ENUM*ENODMO+SOURCE(N)
001174          EDEN=SMATR0(N)+DFCFB2(N)*BUCKLE-ENODMO*SIGL0(N,N)
001205       34 B2F(1,N)=ENUM/EDEN
001214          ENUM=.0
001214          DO 35 J=1,NRGLS1
001216       35 ENUM=ENUM+SIGL0(J,NENERG)*B2F(1,J)
001232          ENUM=ENUM*ENODMO+SOURCE(NENERG)
001235          EDEN=SMATR0(NENERG)+DFCFB2(NENERG)*BUCKLE
                1-ENODMO*SIGL0(NENERG,NENERG)
001246          B2F(1,NENERG)=ENUM/EDEN
001253          INSPCK=0
001253          DO 37 N=1,NENERG
001255          GLNCMP=ABS(1.-B2FOLD(N)/B2F(1,N))
001264          IF(GLNCMP-.00001)37,37,36
001266       36 INSPCK=INSPCK+1
001270       37 CONTINUE
```

```
001273          IF(INSPCK)38,41,38
001274       38 IF(NB2IT-500)39,41,41
001277       39 NB2IT=NB2IT+1
          C     TO ACCELERATE BUCKLING SPECTRUM CONVERGENCE IN GLEN
001301          DO 391 N=1,NENERG
001302      391 B2F(1,N)=B2F(1,N)+.6*(B2F(1,N)-B2FOLD(N))
001315          DO 40 N=1,NENERG
001317       40 B2FOLD(N)=B2F(1,N)
001330          GO TO 30
001330       41 DO 43 N=1,NENERG
001332          RSDRT=.0
001333          DO 42 J=1,NENERG
001335       42 RSDRT=RSDRT+SIGL0(J,N)*B2F(1,J)
001351          RSDRT=RSDRT-SIGL0(N,N)*B2F(1,N)
001361          RSDRT=ENODMO*RSDRT+SOURCE(N)
001364          RSDLT=(SMATR0(N)+DFCFB2(N)*BUCKLE
                1-ENODMO*SIGL0(N,N))*B2F(1,N)
001400       43 B2RSD(N)=(RSDLT-RSDRT)/RSDLT
001405          GO TO 451
001406      431 READ(10,432)(B2F(1,N),N=1,NENERG)
001423      432 FORMAT(4E20.8)
001423          DO 433 N=1,NENERG
001425      433 B2RSD(N)=.0
001431          GO TO 451
001432       44 DO 45 N=1,NENERG
001434       45 B2RSD(N)=.0
001440      451 BUCLAB=ABS(BUCKLE)
001442          IF(BUCKLE)452,46,47
001443      452 BUFAC0=SQRT(BUCLAB)
001446          BUFAC1=BUFAC0
001447          GO TO 48
001447       46 BUFAC0=1.
001451          BUFAC1=-1.
001452          GO TO 48
001453       47 BUFAC0=SQRT(BUCLAB)
001456          BUFAC1=-BUFAC0
001457       48 DO 49 N=1,NENERG
001461          B2F(2,N)=BUFAC0*DFCFB2(N)*B2F(1,N)
001471          B2F(3,N)=.4*BUFAC1*B2F(2,N)/(SMATR2(N)
                1+B2CF2/SMATR3(N))
001502       49 B2F(4,N)=.42857143*BUFAC0*B2F(3,N)/SMATR3(N)
001512          SIGL0(1,1)=SIGL0(1,1)-SELP0(1)
001514          DO 50 N=1,NENERG
001516       50 SIGL0(1,N)=2.*SIGL0(1,N)/(ENERGY(1)-ENERGY(2))
001530          DO 51 N=2,NENERG
001531       51 SIGL0(N,N)=SIGL0(N,N)-SELP0(N)
001542          DO 52 J=2,NENERG
001544          ENWT=.5*(ENERGY(J-1)-ENERGY(J+1))
001550          DO 52 N=1,NENERG
001551       52 SIGL0(J,N)=SIGL0(J,N)/ENWT
001562          RETURN
001563          END
```

```
          $IBFTC GLN6     DECK
                 SUBROUTINE GLDFL
000002           COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
                1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSPI,
                2ARPIH2,AEPIH2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
                3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
                4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
                5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
                6GAMO,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
                7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
                8STOT(90),STR1(90),STR2(90),STR3(90)
```

```
000002          COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
                1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
                2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIPIIS(4),
                3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
                4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
                5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
                6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
                7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
                8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002          COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
                1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
                2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
                3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
                4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
                5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
                6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
                7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002          COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002          COMMON DFC011(87)
000002        1 ENWT1=(ENERGY(1)-ENERGY(2))*DFLF0(1)
000005          ENUM=ENWT1*SMAABS(1)
000007          EDEN=ENWT1*DIFCOF(1)
000011          DO 2 N=2,NENERG
000012          ENWT2=(ENERGY(N-1)-ENERGY(N+1))*DFLF0(N)
000016          ENUM=ENUM+ENWT2*SMAABS(N)
000021        2 EDEN=EDEN+ENWT2*DIFCOF(N)
000026          RCDFL2=ENUM/EDEN
000030          RETURN
000030          END
```

```
SIBFTC GLNT     DECK
          SUBROUTINE GLEDIT
000002          COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
                1NENERG,FACMAS,SIGBND,SRD4PI,ARECPI,AEPSPI,
                2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
                3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
                4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
                5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
                6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
                7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
                8STOT(90),STR1(90),STR2(90),STR3(90)
000002          COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
                1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
                2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIPIIS(4),
                3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
                4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
                5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
                6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
                7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
                8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002          COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
                1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
                2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
                3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
                4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
                5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
                6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
                7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002          COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002          COMMON DFC011(87)
000002          CALL GLNTIN
000003        1 DO 4 L=1,4
000005          DO 2 N=1,NENERG
000006        2 FGINGD(N)=B2F(L,N)
```

```
000017          FGINGD(NENERG+1)=.0
000020          DO 3 MFG=1,NFGP
000021          CALL GLINTE
000022        3 FGPF(L,MFG)=FGPEIN
000032        4 CONTINUE
000034        5 DO 8 L=1,4
000036          DO 6 N=1,NENERG
000037        6 FGINGD(N)=STOT(N)*B2F(L,N)
000051          FGINGD(NENERG+1)=.0
000052          DO 7 MFG=1,NFGP
000053          CALL GLINTE
000054        7 QMOFGP(L,MFG)=FGPEIN/FGPF(L,MFG)
000066        8 CONTINUE
000070        9 DO 12 L=1,4
000072          DO 10 N=1,NENERG
000073       10 FGINGD(N)=SIGAMO(N)*B2F(L,N)
000105          FGINGD(NENERG+1)=.0
000106          DO 11 MFG=1,NFGP
000107          CALL GLINTE
000110       11 RMOFGP(L,MFG)=FGPEIN/FGPF(L,MFG)
000122       12 CONTINUE
000124       13 DO 16 NISO=1,NISOMA
000126          DO 16 L=1,4
000127          DO 14 N=1,NENERG
000130       14 FGINGD(N)=SIGAIS(NISO,N)*B2F(L,N)
000144          FGINGD(NENERG+1)=.0
000145          DO 15 MFG=1,NFGP
000146          CALL GLINTE
000147       15 RISFGP(NISO,L,MFG)=FGPEIN/FGPF(L,MFG)
000164       16 CONTINUE
000170       17 DO 18 N=1,NENERG
000172       18 FGINGD(N)=SELP0(N)*B2F(1,N)
000204          FGINGD(NENERG+1)=.0
000205          DO 19 MFG=1,NFGP
000206          CALL GLINTE
000207       19 SEL0FG(MFG)=FGPEIN/FGPF(1,MFG)
000216       20 DO 21 N=1,NENERG
000220       21 FGINGD(N)=SELP1(N)*B2F(2,N)
000232          FGINGD(NENERG+1)=.0
000233          DO 22 MFG=1,NFGP
000234          CALL GLINTE
000235       22 SEL1FG(MFG)=FGPEIN/FGPF(2,MFG)
000244       23 DO 24 L=1,4
000246       24 B2F(L,NENERG+1)=.0
000254          NRGPL1=NENERG+1
000256          DO 241 J=1,NENERG
000257          SIGL0(J,NRGPL1)=.0
000263          SIGL1(J,NRGPL1)=.0
000265          SIGL2(J,NRGPL1)=.0
000266      241 SIGL3(J,NRGPL1)=.0
000272          DO 34 M=1,NFGP
000274          DO 34 K=1,NFGP
000275          DO 25 N=1,NRGPL1
000276          GLNCMP=ENFEGP(K)-ENERGY(N)
000302          IF(GLNCMP)25,26,26
000303       25 CONTINUE
000306       26 NFGPK1=N
000310          DO 27 N=1,NRGPL1
000311          GLNCMP=ENFEGP(K+1)-ENERGY(N)
000314          IF(GLNCMP)27,28,28
000316       27 CONTINUE
000321       28 NFGPK2=N-1
000323          DO 29 N=1,NRGPL1
000325          GLNCMP=ENFEGP(M)-ENERGY(N)
000331          IF(GLNCMP)29,30,30
000332       29 CONTINUE
000335       30 NFGPM1=N
000337          DO 31 N=1,NRGPL1
000340          GLNCMP=ENFEGP(M+1)-ENERGY(N)
000343          IF(GLNCMP)31,32,32
000345       31 CONTINUE
```

```
000350      32 NFGPM2=N-1
000352         PMOFG(1,K,M)=.0
000360         PMOFG(2,K,M)=.0
000365         PMOFG(3,K,M)=.0
000371         PMOFG(4,K,M)=.0
000376         DO 33 N=NFGPM1,NFGPM2
000400         DO 33 J=NFGPK1,NFGPK2
000402         ENWT=(ENERGY(N)-ENERGY(N+1))*(ENERGY(J)-ENERGY(J+1))
000410         PMOFG(1,K,M)=PMOFG(1,K,M)+ENWT
              1*(B2F(1,J)*(SIGL0(J,N)+SIGL0(J,N+1))
              2+B2F(1,J+1)*(SIGL0(J+1,N)+SIGL0(J+1,N+1)))
000437         PMOFG(2,K,M)=PMOFG(2,K,M)+ENWT
              1*(B2F(2,J)*(SIGL1(J,N)+SIGL1(J,N+1))
              2+B2F(2,J+1)*(SIGL1(J+1,N)+SIGL1(J+1,N+1)))
000463         PMOFG(3,K,M)=PMOFG(3,K,M)+ENWT
              1*(B2F(3,J)*(SIGL2(J,N)+SIGL2(J,N+1))
              2+B2F(3,J+1)*(SIGL2(J+1,N)+SIGL2(J+1,N+1)))
000507      33 PMOFG(4,K,M)=PMOFG(4,K,M)+ENWT
              1*(B2F(4,J)*(SIGL3(J,N)+SIGL3(J,N+1))
              2+B2F(4,J+1)*(SIGL3(J+1,N)+SIGL3(J+1,N+1)))
000540         PMOFG(1,K,M)=.25*PMOFG(1,K,M)/FGPF(1,K)
000551         PMOFG(2,K,M)=.25*PMOFG(2,K,M)/FGPF(2,K)
000555         PMOFG(3,K,M)=.25*PMOFG(3,K,M)/FGPF(3,K)
000561      34 PMOFG(4,K,M)=.25*PMOFG(4,K,M)/FGPF(4,K)
000571         DO 35 K=1,NFGP
000572         PMOFG(1,K,K)=PMOFG(1,K,K)+SEL0FG(K)
000601      35 PMOFG(2,K,K)=PMOFG(2,K,K)+SEL1FG(K)
000613      36 DO 39 NISO=1,NISOMA
000615         DO 37 N=1,NENERG
000616      37 FGINGD(N)=SIGFIS(NISO,N)*B2F(1,N)
000632         FGINGD(NENERG+1)=.0
000633         DO 38 MFG=1,NFGP
000634         CALL GLINTE
000635      38 FISFGP(NISO,MFG)=FGPEIN/FGPF(1,MFG)
000647      39 CONTINUE
000651      40 DO 41 N=1,NENERG
000653      41 FGINGD(N)=SOURCE(N)
000650         FGINGD(NENERG+1)=.0
000661         DO 42 MFG=1,NFGP
000663         CALL GLINTE
000664      42 SRCFGP(MFG)=FGPEIN
000671      43 SCISA0=.0
000672         SCISA1=.0
000673         DO 44 NISO=1,NISOMA
000674         SCISA0=SCISA0+ENODIS(NISO)*SIGSIS(NISO)
000700      44 SCISA1=SCISA1+ENODIS(NISO)*SIP1IS(NISO)
000706         DO 45 L=1,4
000710         DO 45 M=1,NFGP
000711      45 QMACFG(L,M)=ENODMO*QMOFGP(L,M)+SCISA0
000727         DO 46 L=1,4
000730         DO 46 M=1,NFGP
000731         RMACFG(L,M)=ENODMO*RMOFGP(L,M)
000740         DO 46 NISO=1,NISOMA
000741      46 RMACFG(L,M)=RMACFG(L,M)+ENODIS(NISO)
              1*RISFGP(NISO,L,M)
000764         DO 47 L=1,4
000765         DO 47 K=1,NFGP
000766         DO 47 M=1,NFGP
000767      47 PMACFG(L,K,M)=ENODMO*PMOFG(L,K,M)
001011         DO 48 K=1,NFGP
001012      48 PMACFG(1,K,K)=PMACFG(1,K,K)+SCISA0
001024         DO 49 K=1,NFGP
001025      49 PMACFG(2,K,K)=PMACFG(2,K,K)+SCISA1
001037         DO 50 M=1,NFGP
001040         FMACFG(M)=.0
001042         DO 50 NISO=1,NISOMA
001043      50 FMACFG(M)=FMACFG(M)+ENODIS(NISO)*FISFGP(NISO,M)
001060         DO 53 L=1,4
001061         FSUM(L)=.0
001063         QSUM(L)=.0
001064         RSUM(L)=.0
```

```
001066          PSUM(L)=.0
001067          DO 52 M=1,NFGP
001071          FSUM(L)=FSUM(L)+FGPF(L,M)
001077          QSUM(L)=QSUM(L)+QMACFG(L,M)*FGPF(L,M)
001106          RSUM(L)=RSUM(L)+RMACFG(L,M)*FGPF(L,M)
001113          DO 51 K=1,NFGP
001115       51 PSUM(L)=PSUM(L)+PMACFG(L,K,M)*FGPF(L,K)
001133       52 CONTINUE
001135       53 CONTINUE
001137       54 BUCLAB=ABS(BUCKLE)
001141          BUFAC1=-SQRT(BUCLAB)
001144          IF(BUCKLE)55,56,56
001146       55 BUFAC0=BUFAC1
001150          GO TO 57
001150       56 BUFAC0=-BUFAC1
001152       57 CKIDL=QSUM(1)
001154          CKIDR=PSUM(1)
001155          CKSU0L=BUFAC0*FSUM(2)+RSUM(1)
001160          CKSU0R=.0
001161          DO 58 M=1,NFGP
001162       58 CKSU0R=CKSU0R+SRCFGP(M)
001167          CKSU1L=BUFAC1*(2.*FSUM(3)+FSUM(1))/3.
                1+QSUM(2)+RSUM(2)
001176          CKSU1R=PSUM(2)
001177          CKSU2L=BUFAC0*(.6*FSUM(4)+.4*FSUM(2))
                1+QSUM(3)+RSUM(3)
001206          CKSU2R=PSUM(3)
001210          CKSU3L=BUFAC1*.42857143*FSUM(3)
                1+QSUM(4)+RSUM(4)
001215          CKSU3R=PSUM(4)
001216          IF(BUCKLE)60,59,60
001217       59 CKSU1L=CKSU1L-FSUM(1)/3.
001222          CKSU2L=CKSU2L+.4*FSUM(2)
001225          CKSU3L=CKSU3L-.42857143*FSUM(3)
001230       60 CALL GLPRNT
001231          RETURN
001232          END
```

```
        $IBFTC GLNB     DECK
               SUBROUTINE GLNTIN
000002         COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
              1NENERG,FACMAS,SIGBND,SBD4PI,ARECP1,AEPSP1,
              2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
              3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
              4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
              5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
              6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
              7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
              8STOT(90),STR1(90),STR2(90),STR3(90)
000002         COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
              1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
              2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
              3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
              4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
              5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
              6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
              7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
              8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002         COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
              1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
              2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
```

```
     3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
     4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
     5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
     6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
     7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002       COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002       COMMON DFCO11(87)
000002       NRGPL1=NENERG+1
000004       NFGPL1=NFGP+1
000006       ENFEGP(NFGPL1)=.0
000010       DO 3 MFG=1,NFGPL1
000011       DO 1 N=1,NRGPL1
000012       GLNCMP=ENFEGP(MFG)-ENERGY(N)
000016       IF(GLNCMP)1,2,2
000017     1 CONTINUE
000022     2 NFGPL(MFG)=N
000025     3 CONTINUE
000027       DO 4 N=1,NENERG
000031     4 ENINWT(N)=ENERGY(N)-ENERGY(N+1)
000037       RETURN
000037       END
```

```
$IBFTC GLN9     DECK
       SUBROUTINE GLINTE
000002       COMMON NLIM,MLIM,TEMPFN,AFAREC,HREC,AFAEPS,HEPS,
     1NENERG,FACMAS,SIGBND,SBD4PI,ARECP1,AEPSP1,
     2ARP1H2,AEP1H2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
     3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
     4NIN1,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
     5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
     6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
     7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
     8STOT(90),STR1(90),STR2(90),STR3(90)
000002       COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
     1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
     2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
     3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
     4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
     5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
     6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
     7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
     8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002       COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
     1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
     2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
     3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
     4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
     5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
     6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
     7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002       COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002       COMMON DFCO11(87)
000002       NFGPL1=NFGPL(MFG)
000005       NFGPL2=NFGPL(MFG+1)-1
000007       FGPEIN=.0
000010       DO 1 N=NFGPL1,NFGPL2
000012     1 FGPEIN=FGPEIN+ENINWT(N)*(FGINGD(N)
      1+FGINGD(N+1))
000021       FGPEIN=.5*FGPEIN
000023       RETURN
000023       END
```

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      $IBFTC GL10    DECK
            SUBROUTINE GLPRNT
000002      COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
           1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSPI,
           2ARPIH2,AEPIH2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
           3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
           4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
           5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
           6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
           7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
           8STOT(90),STR1(90),STR2(90),STR3(90)
000002      COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
           1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
           2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
           3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
           4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
           5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
           6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
           7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
           8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002      COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
           1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
           2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
           3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
           4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
           5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
           6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
           7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002      COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002      COMMON DFCO11(87)
000002       1 WRITE(9,2)NMIX
000010       2 FORMAT(8H1MIXTURE,I3,21H FEW GROUP PARAMETERS)
000010         WRITE(9,3)NFGP
000016       3 FORMAT(48HONUMBER NFGP OF FEW GROUP ENERGIES ENFEGP, NFGP=,I3)
000016         WRITE(9,4)
000022       4 FORMAT(15H0NFG      ENFEGP)
000022         WRITE(9,901)(N,ENFEGP(N),N=1,NFGP)
000037     901 FORMAT(I4,E16.8)
000037       5 FORMAT(I4,7E16.8)
000037         WRITE(9,6)INDAMO,ENODMO
000047       6 FORMAT(33H0MODERATOR SIGA INDICATOR INDAMO=,I3,
            133H MODERATOR NUMBER DENSITY ENODMO=,E15.8)
000047         IF(INDAMO)7,7,9
000051       7 WRITE(9,8)ENABMO,SIABMO
000061       8 FORMAT(8H0ENABMO=,E15.8,8H SIABMO=,E15.8)
000061       9 WRITE(9,10)
000065      10 FORMAT(15H0  N      SIGAMO)
000065         WRITE(9,901)(N,SIGAMO(N),N=1,NENERG)
000102         WRITE(9,11)NISOMA
000110      11 FORMAT(35H0NUMBER ADDITIONAL ISOTOPES NISOMA=,I3)
000110         WRITE(9,12)
000114      12 FORMAT(113H0ISOTOPE SIGA INDICATOR, SIGF INDICATOR, NUMBER DENSITY
           1, P0 SCATTERING CROSS SECTION, P1 SCATTERING CROSS SECTION)
000114         WRITE(9,13)
000120      13 FORMAT(73H  INDAIS    INDFIS          ENODIS                SIGSIS
           1          SIP1IS)
000120         WRITE(9,14)(INDAIS(NISO),INDFIS(NISO),ENODIS(NISO),
           1SIGSIS(NISO),SIP1IS(NISO),NISO=1,NISOMA)
000147      14 FORMAT(I8,I10,E22.8,E20.8,E20.8)
000147         DO 17 NISO=1,NISOMA
000151         JTEST=INDAIS(NISO)
000153         IF(JTEST)15,15,17
000154      15 WRITE(9,16)NISO,ENABIS(NISO),SIABIS(NISO)
000170      16 FORMAT(6H0NISO=,I3,8H ENABIS=,E15.8,8H SIABIS=,E15.8)
000170      17 CONTINUE
000173         DO 20 NISO=1,NISOMA
000174         JTEST=INDFIS(NISO)
000176         IF(JTEST)18,18,20
000177      18 WRITE(9,19)NISO,ENFIIS(NISO),SIFIIS(NISO)
000213      19 FORMAT(6H0NISO=,I3,8H ENFIIS=,E15.8,8H SIFIIS=,E15.8)
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```
000213       20 CONTINUE
000216          DO 22 NISO=1,NISOMA
000217          WRITE(9,21)NISO
000224       21 FORMAT(14H0  N   SIGAIS(,I2,2H ))
000224       22 WRITE(9,901)(N,SIGAIS(NISO,N),N=1,NENERG)
000246          DO 24 NISO=1,NISOMA
000247          WRITE(9,23)NISO
000254       23 FORMAT(14H0  N   SIGFIS(,I2,2H ))
000254       24 WRITE(9,901)(N,SIGFIS(NISO,N),N=1,NENERG)
000276          WRITE(9,25)BUCKLE
000303       25 FORMAT(10H0BUCKLING=,E15.8)
000303          IF(NSPEC)251,26,28
000305      251 WRITE(9,252)NSPEC
000313      252 FORMAT(33H0NEUTRON SPECTRUM READ IN. NSPEC=,I2)
000313          GO TO 30
000314       26 WRITE(9,27)NSPEC
000322       27 FORMAT(33H0MAXWELL NEUTRON SPECTRUM. NSPEC=,I2)
000322          GO TO 30
000323       28 WRITE(9,29)NSPEC
000331       29 FORMAT(34H0HARDENED NEUTRON SPECTRUM. NSPEC=,I2)
000331       30 WRITE(9,31)
000335       31 FORMAT(51H1MACROSCOPIC CROSS SECTIONS FOR MULTIGROUP ENERGIES)
000335          WRITE(9,32)
000341       32 FORMAT(111H   N      SMASCT           SMAABS           SMAFIS
                1  SMATR0          SMATR1          SMATR2          SMATR3)
000341          WRITE(9,5)(N,SMASCT(N),SMAABS(N),SMAFIS(N),
                1SMATR0(N),SMATR1(N),SMATR2(N),SMATR3(N),N=1,NENERG)
000400          WRITE(9,34)
000404       34 FORMAT(57H0DIFFUSION COEFFICIENT AND SOURCE FOR MULTIGROUP ENERGIE
                1S)
000404          WRITE(9,35)
000410       35 FORMAT(47H   N      ENERGY          DIFCOF          SOURCE)
000410          WRITE(9,902)(N,ENERGY(N),DIFCOF(N),SOURCE(N),N=1,NENERG)
000433      902 FORMAT(I4,3E16.8)
000433          WRITE(9,36)
000437       36 FORMAT(29H1DIFFUSION LENGTH CALCULATION)
000437          WRITE(9,37)DFLGFI,TRCORR
000447       37 FORMAT(18H0DIFFUSION LENGTH=,E15.8,
                122H TRANSPORT CORRECTION=,E15.8)
000447          WRITE(9,38)
000453       38 FORMAT(24H0SEQUENCE OF EIGENVALUES)
000453          WRITE(9,39)
000457       39 FORMAT(18H NO.   DIFF. LGTH.)
000457          WRITE(9,901)(N,DIFLGT(N),N=1,NDFLIT)
000474          WRITE(9,40)
000500       40 FORMAT(64H0  N      ENERGY          SPECTRUM          MAXWELL
                1RESIDUAL)
000500          WRITE(9,903)(N,ENERGY(N),DFLF0(N),SPMAN0(N),DFLRSD(N),N=1,NENERG)
000526      903 FORMAT(I4,4E16.8)
000526          WRITE(9,401)DFLP11,P11COR
000536      401 FORMAT(22H0P11 DIFFUSION LENGTH=,E16.8,
                116H P11 CORRECTION=,E16.8)
000536          WRITE(9,402)
000542      402 FORMAT(16H0P11 EIGENVALUES)
000542          WRITE(9,39)
000546          NDTPL1=NDFLIT+1
000550          WRITE(9,901)(N,DIFLGT(N),N=NDTPL1,NDF11)
000565          WRITE(9,404)
000571      403 FORMAT(111H  N      ENERGY            F0              F1
                1 MAXWELL          RESIDUAL          DFCO11          DIFCOF)
000571      404 FORMAT(12H0P11 SPECTRA)
000571          WRITE(9,403)
000575          WRITE(9,405)(N,ENERGY(N),DF11F0(N),DF11F1(N),
                1SPMAN0(N),DF11RS(N),DFCO11(N),DIFCOF(N),N=1,NENERG)
000634      405 FORMAT(I4,7E16.8)
000634          WRITE(9,41)
000640       41 FORMAT(18H1 BUCKLING SPECTRA)
000640          WRITE(9,42)
000644       42 FORMAT(96H   N      ENERGY            L=0             L=1
                1   L=2             L=3          RESIDUAL)
000644          WRITE(9,904)(N,ENERGY(N),B2F(1,N),B2F(2,N),
```

```
     1R2F(3,N),B2F(4,N),B2RSD(N),N=1,NENERG)
000702  404 FORMAT(I4,6E16.8)
000702      WRITE(9,421)NB2IT
000710  421 FORMAT(19H0NUMBER ITERATIONS=,I4)
000710      ZERO=.0
000711      WRITE(9,43)NMIX
000717   43 FORMAT(26H1ISOTOPE EDITS FOR MIXTURE,I2)
000717      WRITE(11,44)(AFIELD(J),J=1,12)
000731   44 FORMAT(12A6)
000731      WRITE(11,45)NMIX
000737   45 FORMAT(6H NMIX=,I4)
000737      IF(NFGP-4)441,441,442
000742  441 JPRBNO=IABS(JPRBNO)
000744  442 LIMPR1=NFGP-4
000746      LIMPR2=NFGP+4
000747      DO 50 L=1,4
000751      LPRT=L-1
000753      WRITE(11,451)JPRBNO,NMIX,LPRT
000764  451 FORMAT(8H JPRBNO=,I5,8H   NMIX=,I1,12H   MODERATOR,
     1 5H   L=,I1)
000764      DO 491 MFG=1,NFGP
000766      SSMPRT(MFG)=.0
000770      DO 46 KFG=1,MFG
000771   46 SSMPRT(MFG)=SSMPRT(MFG)+PMOFG(L,MFG,KFG)
001004      SSMPRT(MFG)=SSMPRT(MFG)-PMOFG(L,MFG,MFG)
001013      WRITE(9,47)LPRT,MFG
001023   47 FORMAT(14H0MODERATOR, L=,I2,9H , GROUP=,I3)
001023      NFGPM2=NFGP+NFGP-1
001025      DO 471 KFG=1,40
001027  471 PPRT(KFG,MFG)=.0
001035      DO 48 KFG=1,NFGP
001036      KPFG=NFGP-KFG+MFG
001041   48 PPRT(KPFG,MFG)=PMOFG(L,KFG,MFG)
001053      SPRTOT(MFG)=QMOFGP(L,MFG)+RMOFGP(L,MFG)
001062      IF(JPRBNO)482,481,481
001063  481 WRITE(9,49)RMOFGP(L,MFG),ZERO,SPRTOT(MFG),
     1SSMPRT(MFG),(PPRT(KPFG,MFG),KPFG=1,NFGPM2)
001115      GO TO 491
001116  482 IF(MFG-5)485,483,483
001121  483 PPRT(NFGP+4,MFG)=.0
001126      LIM1=MFG
001126      LIM2=NFGP
001127      DO 484 NRNINT=LIM1,LIM2
001131  484 PPRT(NFGP+4,MFG)=PPRT(NFGP+4,MFG)+PMOFG(L,MFG-4,NRNINT)
001146  485 IF(MFG+4-NFGP)486,486,488
001151  486 PPRT(NFGP-4,MFG)=.0
001156      DO 487 NRNINT=1,MFG
001157  487 PPRT(NFGP-4,MFG)=PPRT(NFGP-4,MFG)+PMOFG(L,MFG+4,NRNINT)
001174  488 IF(L-1)490,490,511
001177  490 IF(MFG-1)510,510,511
001202  510 PPRT(NFGP+1,MFG)=STRAND
001207  511 WRITE(9,49)RMOFGP(L,MFG),ZERO,SPRTOT(MFG),
     1SSMPRT(MFG),(PPRT(KPFG,MFG),KPFG=LIMPR1,LIMPR2)
001241   49 FORMAT(1P6E12.4)
001241  491 CONTINUE
001244      IF(JPRBNO)513,512,512
001245  512 WRITE(11,49)(RMOFGP(L,MFG),ZERO,SPRTOT(MFG),
     1SSMPRT(MFG),(PPRT(KPFG,MFG),KPFG=1,NFGPM2),MFG=1,NFGP)
001302      GO TO 50
001303  513 WRITE(11,49)(RMOFGP(L,MFG),ZERO,SPRTOT(MFG),
     1SSMPRT(MFG),(PPRT(KPFG,MFG),KPFG=LIMPR1,LIMPR2),
     2MFG=1,NFGP)
001340   50 CONTINUE
001342      DO 561 NISO=1,NISOMA
001344      DO 561 L=1,4
001345      LPRT=L-1
001347      WRITE(11,501)JPRBNO,NMIX,NISO,LPRT
001362  501 FORMAT(8H JPRBNO=,I5,8H   NMIX=,I1,11H   ISOTOPE=,I1,
     1 5H   L=,I1)
001362      DO 56 MFG=1,NFGP
001364      WRITE(9,51)NISO,LPRT,MFG
```

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001375       51 FORMAT(8H0ISOTOPE,I2,5H . L=,I2,9H . GROUP=,I3)
001375          NFGPM2=NFGP+NFGP-1
001377          DO 52 KPFG=1,NFGPM2
001401       52 PPRT(KPFG,MFG)=.0
001410          FISPRT(MFG)=.0
001412          SPRTOT(MFG)=SIGSIS(NISO)+RISFGP(NISO,L,MFG)
001422          IF(L-1)53,53,54
001424       53 PPRT(NFGP,MFG)=PPRT(NFGP,MFG)+SIGSIS(NISO)
001433          FISPRT(MFG)=FISFGP(NISO,MFG)
001437          GO TO 551
001440       54 IF(L-2)55,55,551
001443       55 PPRT(NFGP,MFG)=PPRT(NFGP,MFG)+SIP1IS(NISO)
001452      551 IF(JPRBNO)553,552,552
001454      552 WRITE(9,49)RISFGP(NISO,L,MFG),FISPRT(MFG),
               1SPRTOT(MFG),ZERO,(PPRT(KPFG,MFG),KPFG=1,NFGPM2)
001510          GO TO 56
001511      553 WRITE(9,49)RISFGP(NISO,L,MFG),FISPRT(MFG),
               1SPRTOT(MFG),ZERO,(PPRT(KPFG,MFG),KPFG=LIMPR1,LIMPR2)
001545       56 CONTINUE
001550          IF(JPRBNO)555,554,554
001551      554 WRITE(11,49)(RISFGP(NISO,L,MFG),FISPRT(MFG),
               1SPRTOT(MFG),ZERO,(PPRT(KPFG,MFG),KPFG=1,NFGPM2),
               2MFG=1,NFGP)
001610          GO TO 561
001611      555 WRITE(11,49)(RISFGP(NISO,L,MFG),FISPRT(MFG),
               1SPRTOT(MFG),ZERO,(PPRT(KPFG,MFG),KPFG=LIMPR1,LIMPR2),
               2MFG=1,NFGP)
001650      561 CONTINUE
001655       57 FORMAT(I8,E20.8,3E16.8)
001655          WRITE(9,58)
001660       58 FORMAT(33H1FEW GROUP MACROSCOPIC PARAMETERS)
001660          WRITE(9,59)
001664       59 FORMAT(7H0FLUXES)
001664          WRITE(9,60)
001670       60 FORMAT(70H     GROUP           L=0             L=1             L=2
               1          L=3)
001670          WRITE(9,57)(M,FGPF(1,M),FGPF(2,M),FGPF(3,M),
               1FGPF(4,M),M=1,NFGP)
001720          WRITE(9,61)
001724       61 FORMAT(26H0SCATTERING CROSS SECTIONS)
001724          WRITE(9,60)
001730          WRITE(9,57)(M,QMACFG(1,M),QMACFG(2,M),
               1QMACFG(3,M),QMACFG(4,M),M=1,NFGP)
001760          WRITE(9,62)
001764       62 FORMAT(26H0ABSORPTION CROSS SECTIONS)
001764          WRITE(9,60)
001770          WRITE(9,57)(M,RMACFG(1,M),RMACFG(2,M),
               1RMACFG(3,M),RMACFG(4,M),M=1,NFGP)
002020          WRITE(9,63)
002024       63 FORMAT(30H0GROUP TRANSFER CROSS SECTIONS)
002024          DO 66 K=1,NFGP
002026          WRITE(9,64)K
002033       64 FORMAT(15H0INITIAL GROUP=,I3)
002033          WRITE(9,65)
002037       65 FORMAT(70H FINAL GROUP       L=0             L=1             L=2
               1          L=3)
002037       66 WRITE(9,57)(M,PMACFG(1,K,M),PMACFG(2,K,M),
               1PMACFG(3,K,M),PMACFG(4,K,M),M=1,NFGP)
002100          WRITE(9,67)
002103       67 FORMAT(23H0FISSION CROSS SECTIONS)
002103          WRITE(9,68)
002107       68 FORMAT(22H     GROUP           L=0)
002107          WRITE(9,905)(M,FMACFG(M),M=1,NFGP)
002124      905 FORMAT(I4,E16.8)
002124          WRITE(9,69)
002130       69 FORMAT(25H0SOURCE ENERGY DEPENDENCE)
002130          WRITE(9,68)
002134          WRITE(9,905)(M,SRCFGP(M),M=1,NFGP)
002151          WRITE(9,70)
002155       70 FORMAT(11H1CHECK SUMS)
002155          WRITE(9,71)CKIDL,CKIDR
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002165       71 FORMAT(2E16.8)
002165          WRITE(9,71)CKSU0L,CKSU0R
002175          WRITE(9,71)CKSU1L,CKSU1R
002205          WRITE(9,71)CKSU2L,CKSU2R
002215          WRITE(9,71)CKSU3L,CKSU3R
002225          WRITE(9,72)NMIX
002233       72 FORMAT(28H0END OF PRINTOUT FOR MIXTURE,I3)
002233          RETURN
002234          END
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          $IBFTC GL11
                SUBROUTINE GLMOCK
000002          COMMON NLIM,MLIM,TEMPEN,AFAREC,HREC,AFAEPS,HEPS,
                1NENERG,FACMAS,SIGBND,SBD4PI,ARECPI,AEPSPI,
                2ARPIH2,AEPIH2,COSMU(60),WATE(60),SIGSCT(60),SIMUCK(38),
                3NMUMAX,NMUM1,NMUM2,NMUM3,GLNREC,GLNEPS,
                4NINI,NFIN,NMU,REC(50),EPS(50),SKE(51,51),
                5IDEN,ENERGY(91),EINI(91),EFIN(91),AFIELD(12),
                6GAM0,SIGL0(87,88),SIGL1(87,88),SIGL2(87,88),SIGL3(87,88),
                7SELP0(90),SELP1(90),SINP0(90),SINP1(90),SINP2(90),SINP3(90),
                8STOT(90),STR1(90),STR2(90),STR3(90)
000002          COMMON NFGP,ENFEGP(21),NMIXMA,NMIX,INDAMO,ENODMO,
                1ENABMO,SIABMO,SIGAMO(90),NISOMA,NISO,
                2INDAIS(4),INDFIS(4),ENODIS(4),SIGSIS(4),SIP1IS(4),
                3ENABIS(4),SIABIS(4),SIGAIS(4,90),ENFIIS(4),SIFIIS(4),SIGFIS(4,90),
                4BUCKLE,NSPEC,SMASCT(90),SMAABS(90),SMAFIS(90),SOURCE(90),
                5SMATR0(90),SMATR1(90),SMATR2(90),SMATR3(90),DIFCOF(90),
                6NDFLIT,DIFLGT(100),RCDFL2,DFLF0(90),SPMANO(90),
                7DFCOFI(90),DFLGFI,TRCORR,DFLRSD(90),
                8DFCFB2(90),B2F(4,91),B2F0LD(90),NB2IT,B2RSD(90)
000002          COMMON MFG,FGINGD(91),FGPEIN,NFGPL(21),ENINWT(90),
                1FGPF(4,20),QMOFGP(4,20),RMOFGP(4,20),RISFGP(4,4,20),
                2SEL0FG(20),SEL1FG(20),PMOFG(4,20,20),FISFGP(4,20),
                3SRCFGP(20),QMACFG(4,20),RMACFG(4,20),PMACFG(4,20,20),
                4FMACFG(20),FSUM(4),QSUM(4),RSUM(4),PSUM(4),
                5CKIDL,CKIDR,CKSU0L,CKSU0R,CKSU1L,CKSU1R,
                6CKSU2L,CKSU2R,CKSU3L,CKSU3R,JPRBNO,STRAND,
                7SSMPRT(20),SPRTOT(20),FISPRT(20),PPRT(40,20)
000002          COMMON NDF11,DFLP11,P11COR,DF11F0(87),DF11F1(87),DF11RS(87)
000002          COMMON DFCO11(87)
000002          PCK=.3275911
000004          A1CK=.2548296
000005          A2CK=-.2844967
000007          A3CK=1.4214137
000010          A4CK=-1.4531520
000012          A5CK=1.0614054
000013          FACK=.5/(FACMAS**.5)
000020          FCMD1=1.-FACMAS
000022          FCMS2=1.+FACMAS
000023          WRITE(9,1)
000027        1 FORMAT(38H0ANALYTIC MONATOMIC GAS CROSS SECTIONS)
000027        2 DO 12 NINI=1,NENERG
000031          ZPCK=SQRT(EINI(NINI)/TEMPEN)
000036          ZPCK2=ZPCK*ZPCK
000037          SIGFAC=(.125*SIGBND)/(FACMAS*EINI(NINI))
000043        3 DO 12 NFIN=NINI,NENERG
000045        4 ZCK=SQRT(EFIN(NFIN)/TEMPEN)
000053          ZCK2=ZCK*ZCK
000054          Y1CK=FACK*(FCMD1*ZPCK+FCMS2*ZCK)
000060          Y2CK=FACK*(FCMD1*ZPCK-FCMS2*ZCK)
000064          Y3CK=FACK*(FCMS2*ZPCK-FCMD1*ZCK)
000070          Y4CK=FACK*(FCMS2*ZPCK+FCMD1*ZCK)
000074          Y1CK2=Y1CK*Y1CK
000075          Y2CK2=Y2CK*Y2CK
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```
000077          Y3CK2=Y3CK*Y3CK
000100          Y4CK2=Y4CK*Y4CK
000102          EXFC1=EXP(-Y1CK2)
000106          EXFC2=EXP(-Y2CK2)
000112          EXFC3=EXP(-Y3CK2)
000116          EXFC4=EXP(-Y4CK2)
000122          EXZPZ3=EXP(ZPCK2-ZCK2-Y3CK2)
000127          EXZPZ4=EXP(ZPCK2-ZCK2-Y4CK2)
000134        5 IF(Y2CK-2.7)6,6,7
000137        6 T1CK=1./(1.+PCK*ABS(Y1CK))
000144          T1CK2=T1CK*T1CK
000145          T1CK3=T1CK*T1CK2
000146          T1CK4=T1CK*T1CK3
000147          T1CK5=T1CK*T1CK4
000151          ERF1CK=(Y1CK/ABS(Y1CK))*(1.-(A1CK*T1CK
               1+A2CK*T1CK2+A3CK*T1CK3+A4CK*T1CK4
               2+A5CK*T1CK5)*EXFC1)
000166          T2CK=1./(1.+PCK*ABS(Y2CK))
000172          T2CK2=T2CK*T2CK
000173          T2CK3=T2CK*T2CK2
000174          T2CK4=T2CK*T2CK3
000175          T2CK5=T2CK*T2CK4
000177          ERF2CK=(Y2CK/ABS(Y2CK))*(1.-(A1CK*T2CK
               1+A2CK*T2CK2+A3CK*T2CK3+A4CK*T2CK4
               2+A5CK*T2CK5)*EXFC2)
000214          DIF12=ERF1CK-ERF2CK
000216          GO TO 8
000216        7 PA1CK=2.*Y1CK2
000220          PA1CK2=PA1CK*PA1CK
000221          PA1CK3=PA1CK*PA1CK2
000222          ERF1CK=-(.56418958/Y1CK)*(1.-1./PA1CK
               1+3./PA1CK2-15./PA1CK3)
               2*EXFC1
000232          PA2CK=2.*Y2CK2
000234          PA2CK2=PA2CK*PA2CK
000235          PA2CK3=PA2CK*PA2CK2
000238          ERF2CK=-(.56418958/Y2CK)*(1.-1./PA2CK
               1+3./PA2CK2-15./PA2CK3)
               2*EXFC2
000246          DIF12=ERF1CK-ERF2CK
000250        8 IF(Y3CK-2.7)9,9,10
000253        9 T3CK=1./(1.+PCK*ABS(Y3CK))
000260          T3CK2=T3CK*T3CK
000261          T3CK3=T3CK*T3CK2
000262          T3CK4=T3CK*T3CK3
000263          T3CK5=T3CK*T3CK4
000265          ERF3CK=(Y3CK/ABS(Y3CK))*(1.-(A1CK*T3CK
               1+A2CK*T3CK2+A3CK*T3CK3+A4CK*T3CK4
               2+A5CK*T3CK5)*EXFC3)
000302          T4CK=1./(1.+PCK*ABS(Y4CK))
000306          T4CK2=T4CK*T4CK
000307          T4CK3=T4CK*T4CK2
000310          T4CK4=T4CK*T4CK3
000311          T4CK5=T4CK*T4CK4
000313          ERF4CK=(Y4CK/ABS(Y4CK))*(1.-(A1CK*T4CK
               1+A2CK*T4CK2+A3CK*T4CK3+A4CK*T4CK4
               2+A5CK*T4CK5)*EXFC4)
000330          DIF34=(ERF3CK-ERF4CK)*EXP(ZPCK2-ZCK2)
000336          GO TO 11
000337       10 PA3CK=2.*Y3CK2
000341          PA3CK2=PA3CK*PA3CK
000342          PA3CK3=PA3CK*PA3CK2
000343          ERF3CK=-(.56418958/Y3CK)*(1.-1./PA3CK
               1+3./PA3CK2-15./PA3CK3)
               2*EXZPZ3
000353          PA4CK=2.*Y4CK2
000355          PA4CK2=PA4CK*PA4CK
000356          PA4CK3=PA4CK*PA4CK2
000357          ERF4CK=-(.56418958/Y4CK)*(1.-1./PA4CK
               1+3./PA4CK2-15./PA4CK3)
               2*EXZPZ4
```

```
000367          DIF34=ERF3CK-ERF4CK
000371       11 SIG0CK=SIGFAC*(DIF12+DIF34)
000374          ZDZPCK=ZCK/ZPCK
000376          ZZPICK=1./(ZCK*ZPCK)
000400          C1CK=.5*(FCMS2*ZDZPCK-FCMD1/ZDZPCK)
                1-ZZPICK
000405          D1CK=.5*(FCMS2/ZDZPCK-FCMD1*ZDZPCK)
                1-ZZPICK
000412          SIG1CK=(SIGFAC/FACMAS)
                1*(C1CK*DIF12+D1CK*DIF34
                2+1.12837?2*ZZPICK*(Y1CK*EXFC1-Y2CK*EXFC2
                3+Y3CK*EXZPZ3-Y4CK*EXZPZ4))
000432       12 WRITE(9,14)NINI,NFIN,EINI(NINI),EFIN(NFIN),
                1SIG0CK,SIG1CK
000460       14 FORMAT(2I5,4E16.8)
000460          RETURN
000460          END
```