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G^3: A General Purpose Gamma-Ray Scattering Program

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Richard E. Malenfant

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ABSTRACT

GGG (G^3) is the generic designation for a series of computer programs that enable the user to estimate gamma-ray scattering from a point source to a series of point detectors. Program output includes detector response due to each source energy, as well as a grouping by scattered energy in addition to a simple, direct beam result. Although G^3 is basically a single-scatter program, it also includes a correction for multiple scattering by applying a buildup factor for the path segment between the point of scatter and the detector point. Results are recorded with and without the buildup factor. Surfaces, defined by quadratic equations, are used to provide for a full three-dimensional description of the physical geometry. G^3 evaluates scattering effects in those situations where more exact techniques are not economical.

I. THE PROGRAM

A. Introduction

The General Geometry Gas (GGG or G^3) code is the generic name for a series of computer programs that were originated at the Los Alamos Scientific Laboratory (LASL) for the IBM 7090/7094 and CDC-6600 computers. G^3 can also be used with the IBM-704 and Stretch, the IBM 7030. Many versions of G^3 have been made available, and the nomenclature and some identifying features of the various versions are given in Table I.

The original G^3 program was prepared on the basis of the successful QAD geometry routine.[1] As such, it includes a more complex geometry in a gamma-scattering program than that allowed by the GAS code.* G^3 can be used to estimate gamma scattering in a heterogeneous three-dimensional space, whereas the use of GAS is limited to gamma scattering in a homogeneous region of cylindrical symmetry with spherically shielded point isotropic source and detector, both on the axis of symmetry. Cross sections for all materials are computed by a semi-empirical fit in mass number (Z) and energy.

G^3 evaluates the uncollided flux at specified scatter points and multiplies it by the product of the differential cross section for scattering toward the detector point and the number of electrons in the elemental volume associated with the scatter point, which is assumed to be at the center of the elemental volume. Attenuation through materials between the scatter point and the detector point is characteristic of the degraded energy as determined by the incident energy, the scattering angle, and the angle-energy relationships.

*Unpublished data by Bob E. Watt of LASL who originated the program, and J. R. Streetman of LASL who modified it.

TABLE I

SOME VERSIONS OF G^3 AND THEIR SPECIFIC CHARACTERISTICS

Version	Characteristics
G-31	First operational version with semiempirical fit for photoelectric and pair-production cross sections.
G-32	Direct beam calculation and print-out added to G-31
G-33	Correction of G-32's erroneous calculation of scattering when the scatter grid is specified in spherical coordinates and the azimuthal angle sine is negative.
G-34	Cross sections determined by linear interpolation of tabular data rather than by semiempirical fit.
G-35	Coherent scattering removed from tabular cross sections--version most often used.
DG-35	G-35 with intermediate storage on disk rather than on magnetic tape.
G-36	CDC-6600 version using extended core (ECS) for intermediate storage and tabular buildup data interpolated with a bicubic spline.
G-36A	Same as G-36 except for use of disk rather than ECS.
G-36ED	By input option, this version allows the selection of either disk or ECS for intermediate storage.

Detector response is recorded as a function of incident and scattered energy both with and without application of build-up on the path between the scatter point and the dose point. Conversion factors can be used to obtain results in any desired units.

Arrival intensities, energies, and incident-direction cosines are stored to eliminate recalculation for subsequent detector locations.

B. Equations

Figure 1 is a graphic version of the terms used in the description below.

The uncollided flux arriving at the scatter point along the incident leg is

$$\phi(E) = \frac{S(E)}{4\pi\rho^2} \exp\left(-\sum_{m_o} \mu_{m_o} \rho_{m_o}\right), \qquad (1)$$

where

m_o = material index

$\phi(E)$ = the incident uncollided flux, photons/cm^2-sec

$S(E)$ = the isotropic source strength, photons/sec

ρ = the total source-scatter point separation distance, cm

μ_{m_o} = the linear attenuation coefficient of the material traversed going from source to scatter point, cm^{-1}

ρ_{m_o} = the distance through the m_o material, cm.

The scattered photon energy as a function of initial energy and angle of scatter is

$$E' = \frac{E}{1 + \frac{E}{0.511}(1 - \cos\theta)}, \qquad (2)$$

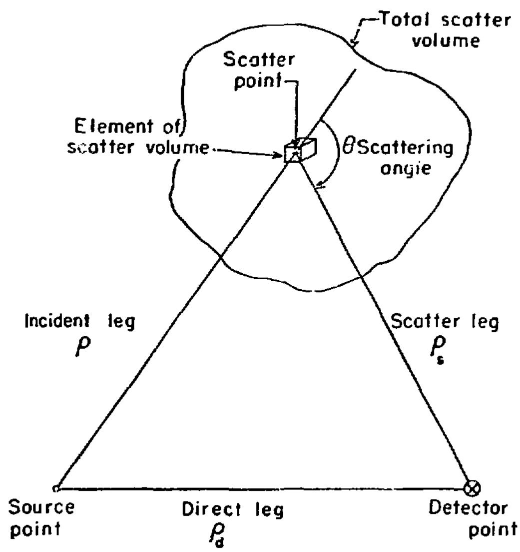

Fig. 1. Geometry definition.

where

E' = scattered photon energy, MeV

E = incident energy, MeV

θ = the scattering angle.

The Klein-Nishina differential-scattering cross section per electron is given by[2]

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{r_o^2}{2} \frac{(1 + \cos^2\theta)}{[1 + \alpha_o (1 - \cos\theta)]^3} \left\{1 + \frac{\alpha_o^2 (1 - \cos\theta)^2}{(1 + \cos^2\theta)\ [1 + \alpha_o (1 - \cos\theta)]}\right\} \quad (3)$$

where

r_o = classical electron radius, 2.818×10^{-13} cm

α_o = $E/m_oc^2 = E/0.511$

$\frac{d\sigma}{d\Omega}(E,\theta)$ = the cross section in cm^2/electron for scattering an incident photon of energy E through an angle θ into a unit solid angle, $1/4\pi$ sr.

Scattering is calculated at the geometric center of each elemental scatter volume and is characteristic of the materials at that point even if other materials are contained elsewhere within the volume. The number of electrons associated with the scatter point is

$$N = 0.6023 \times 10^{24}\left(\sum_{m_o} \frac{\theta_{m_o} Z_{m_o}}{A_{m_o}}\right) \Delta V \quad (4)$$

where

θ_{m_o} = the density of the material at the scatter point, g/cm^3

Z_{m_o} = the atomic number, hence the number of electrons per nucleus of the m_o material

A_{m_o} = the atomic mass of the m_o material

ΔV = the volume element associated with the scatter point as computed in the coordinate system in which the scatter grid is defined.

In all cases, elemental densities must be used.

In Eq. (5), the detector response without buildup on the scatter leg is given by

$$D_1(E) = \frac{S_1(E)K(E')k_s}{4\pi\rho_s^2} \exp\left(-\sum_{m_o} \mu'_{m_o} \rho_{s'_{m_o}}\right) \quad (5)$$

where

$S_1(E)$ = the equivalent isotropic point source intensity of the radiation scattered in the direction of the detector, and

$$S_1(E) = 4\pi\ \phi(E)\ N \frac{d\sigma}{d\Omega}(E) \quad (6)$$

$K(E')$ = a flux-to-dose factor

ρ_s = the scatter point-detector separation distance measured along the scattered leg, cm

μ'_{m_o} = the linear attenuation coefficient of the m_o material for the scattered energy, cm^{-1}

$\rho_{s'_{m_o}}$ = the distance through the m_o material along the scatter leg, cm

k_s = a multiplicative constant used to take advantage of symmetry.

$$x = \sum_{m_o} \mu'_{m_o} \rho_{s'_{m_o}}$$

The buildup factor in G-36 is obtained from a two-dimensional (E and x) interpolation of tabular data. The two-dimensional bicubic spline by Jordan* was incorporated into the program by LASL's J. R. Streetman. Versions G-33 and DG-35 use the approximation to water point-isotropic dose buildup given by the following expressions, which were taken from the original GAS code.

For E > 1.801 MeV

$$B(E,x) = 1 + \left(0.8 - 0.214\ \ln \frac{E}{1.801}\right) x^s \quad (7)$$

For E ≤ 1.801 MeV

$$B(E,x) = 1 + 0.8\ x^s, \quad (8)$$

where

$$s = 1.44 + 0.0239\ E + 0.625\ \ln\left(0.19 + \frac{1.0005}{E}\right) \quad (9)$$

and

$$x = \sum_{m_o} \mu'_{m_o} \rho_{s'_{m_o}} . \quad (10)$$

*LASL internal document by T. L. Jordan, LASL subroutine E104.

Buildup data in the current version of G-36 were calculated for air (78.084 vol% N, 20.946 vol% O, 0.033 vol% CO_2, and 0.934 vol% Ar) with the DTF-IV transport program.[3] Because of the nature of buildup factors, we suggest that users of the program incorporate their own values. Buildup factors in the literature will generally not suffice because gamma rays from 0.5 to 10 MeV can scatter to energies lower than those for which data are available. In FORTRAN terms, data are stored in the linear array BU for energies in array ETBL (monotonic increasing) and for attenuation lengths in MUTBL. In the present version of G-36, there are 10 entries in ETBL and 8 in MUTBL, resulting in 80 entries in BU. Any change in the number of data points or any changes to the data will require appropriate changes in the dimension statement of the arrays and the calls to the subroutines SPL2D1 and SPL202 in ATTEN.

G^3 also computes a direct beam response without buildup, i.e.,

$$D_2(E) = \frac{S(E)K(E)}{4\pi\rho_d^2} \exp\left[-\sum_{m_o} \mu_{m_o} \rho_{m_o}\right] . \qquad (11)$$

The direct beam response with buildup is also calculated as

$$D_2(E) = B(E,x)\ D_2(E,\rho) . \qquad (12)$$

In Eqs. (11) and (12), all quantities are as previously defined except that they are evaluated along the direct leg shown in Fig. 1.

When Eqs. (1) and (5) are combined, the G^3 calculation of the scattered radiation for each source-point scatter-point detector-point is

C. Geometry

Equation (15) and its reduced forms, Eqs. (16) through (20) define unique boundary surfaces determined by the coefficients and constants A, B, C, x_o, y_o, z_o, and k, when r equals zero. The index, s, associated with each equation identifies the equation type.

$$s = 1 \quad Ax^2 + xx_o + By^2 + yy_o + Cz^2 + zz_o - k = r \qquad (15)$$

$$s = 2 \quad A(x - x_o)^2 + B(y - y_o)^2 + C(z - z_o) - k = r \qquad (16)$$

$$s = 3 \quad (x - x_o)^2 + (y - y_o)^2 - k = r \qquad (17)$$

$$s = 4 \quad x - k = r \qquad (18)$$

$$s = 5 \quad y - k = r \qquad (19)$$

$$s = 6 \quad z - k = r \qquad (20)$$

A zone, or region of homogeneous composition, is defined by listing the surfaces (up to and including six) that bound it. The variable, r, relates any point in space to the surface. For each surface bounding the zone, there is a sense index, j, that has a value of either +1 or -1. The value is chosen so that the product of j and r(x', y', z') is negative if the point (x', y', z') lies "inside" the zone. Conversely, if the point (x', y', z') lies "outside" the zone, $j \cdot r(x', y', z') > 0$. Each j must be chosen in accord with the type of bounding surface. If the bounding surface is closed (i.e., sphere, ellipsoid, etc.), a region inside the surface would have j = +1 and a region outside the surface

$$D_1(E) = \frac{4\pi S(E)K(E')N\,k_s}{(4\pi\rho^2)(4\pi\rho_s^2)} \frac{d\sigma}{d\Omega} \exp\left[-\left(\sum_{m_o} \mu_{m_o}\rho_{m_o}\right)-\left(\sum_{m_o} \mu'_{m_o}\rho_{s',m_o}\right)\right] , \qquad (13)$$

and

$$D_1(E) = B(E,x)D_1(E) .$$

would have $j = -1$. An open bounding surface (i.e., cylinder, paraboloid, elliptical cylinder, cone, etc.) would have $j = +1$ for a region between the surface and the axis of the figure, and $j = -1$ for all other space. In a right-handed coordinate system, a planar bounding surface defined by Eqs. (18) through (20) would have $j = +1$ for a region to the negative (left) side of the plane and $j = -1$ for a region to the positive (right) side.

A single bounding surface can be used in the definition of many zones. To minimize input, each surface used in a problem is identified by a boundary number, λ. The zone definition includes the number of bounding surfaces, B_O, for the zone; an indication of an "inside zone" [sign $(B_O) = +$] or an "outside zone" [sign $(B_O) = -$]; and the composition, h, within the zone. Also included are the surface sign index and the boundary numbers $(j.\lambda)$ of the zone's bounding surfaces, and, for each boundary number, the zone number, P, in which the program will initiate the cyclical search procedure to determine the zone entered as the boundary is crossed.

Although a problem will run correctly with any ordering of zones and boundaries for each zone, machine-time savings can be effected by taking advantage of program logic to establish the order. Define a bordering set to be all zones that can be entered immediately upon leaving a zone across a given boundary. Machine time can be saved if the bordering set contains two or more zones that are numbered consecutively (or as close thereto as possible), and if the P associated with the adjacent zone and the common boundary is specified as the lowest numbered zone in the set. In addition, specification of the simple boundary types ($s = 4$ to 6) before the more complex boundary types in the list for each zone will generally also save time. These points will not be elaborated upon with a list of conditions and exceptions, because experience with the program will provide the user with the familiarity to tailor particular calculations expeditiously.

Computing time can sometimes be saved by using outside zones so that the program will not search for additional boundary crossings for points within such a zone. Because of the reentrant nature of many scattering calculations, the outside zones feature must be used with care to avoid having the program ignore portions of the geometry.

Reference 1 gives a more complete discussion of the geometry routines.

D. <u>The Scatter Grid</u>

The scattering volume is described independently of the geometry description of the problem with the restriction that the coordinate sets must have a common origin. For convenience, the scatter grid description can be specified in a rectangular, cylindrical, or spherical coordinate system. The relationship between the three systems is shown in Fig. 2.

Scatter "boxes," or small volumes for performing the numerical integration over the scatter region are specified by listing the coordinates of the divisions of the region on the respective axes in the system chosen. Nonuniform divisions are often used. Each coordinate can have up to 20 increments thus providing for as many as 8000 scatter boxes.

The geometry can be specified in such a way that simplification of the scatter

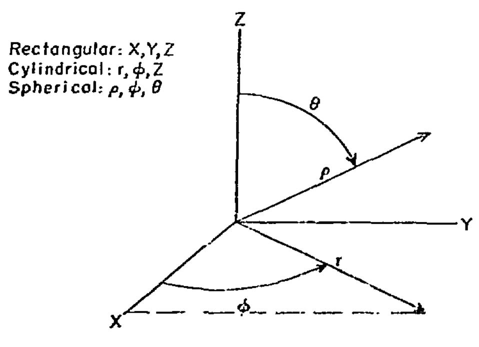

Fig. 2. Relationships of coordinate systems.

grid is possible. For example, to mock up the effect of the collimator of a collimated source, it is easiest to specify the geometry with the source point at the origin and restrict integration of the scatter grid. However, to mock up the effect of the collimator of a collimated detector, it is easiest to locate the detector at the origin and restrict integration. In both cases, a spherical coordinate system would be most useful for defining the scatter grid.

E. Cross Sections

All cross sections used in the calculation are incorporated into the program deck. With the exception of the Compton differential cross section, which is calculated analytically, Eq. (3), all cross sections are linearly interpolated from tables taken from LA-3753.[4] The present program incorporates 20 energy-group cross sections for all 92 elements. The energy grid used is given in Table II.

TABLE II

ENERGY GRID FOR CROSS SECTIONS

Energy (MeV)	
0.05	0.8
0.06	1.0
0.08	1.5
0.1	2.0
0.15	3.0
0.2	4.0
0.3	5.0
0.4	6.0
0.5	8.0
0.6	10.0

This grid should be satisfactory for most calculations made with the program. If another grid should be required, new cross sections must be provided for all elements. Cross sections entered should be total linear-attenuation coefficients, without coherent scatter, in units of cm^2/g.

Linear interpolation was chosen instead of a more exotic scheme because it was sufficiently accurate with the fine energy grid used and it caused no difficulty near the discontinuities of the photoelect absorption edges.

F. Source Terms

The program input requires a set of point isotropic source terms in units of photons/sec and, in a one-to-one correspon ence, a set of discrete energies in MeV. The listings must be in increasing order c energy for correct interpolation of attenu tion coefficients and conversion factors. The units of the source term must be photo sec (as opposed to, for example, MeV/sec) because only these units will be handled correctly when the scattered flux is calculated from the differential cross sectio in the program. Presently, a maximum of 20 energy groups can be accommodated, although a reassembly with revised dimension statements can readily be made to change this number.

G. Detector Bins and Conversion Factors

Detector response to the scattered radiation is sorted into four listings--source energy, with and without buildup on the scattered leg, and scattered energy, with and without buildup on the scattered leg. The energy grouping of the source energies is determined by the source energy grid and that of the scattered energies is specified completely independent of the source energies, both in the values of and in the number of entries. As with the source term, G^3 is set up to handle this grid correctly only if the list runs from low to high energies in a monotonic sequence.

The basic units of the output are photon fluxes (photons/cm^2-sec). For convenience, a set of conversion factors can be applied to these values to yield, for example, mR/h. Conversion factors are listed in a one-to-one correspondence with the listing of detector energy bins. We use linear interpolation in energy to determine the factor to be applied to a particular scattered energy.

H. Output

The machine printout consists of

1. A listing of the input values.

2. The direct beam response, including the conversion factor for the source energy applied, both with and without buildup, for each energy group of the source, and for the sum over all source energies. These quantities are listed in tables headed "minimum direct" (for the value without buildup) and "maximum direct" (for the value with buildup).

3. The scattered response, including the conversion factor for the scattered energies applied, both with and without buildup on the scattered leg, for each energy group of the source, and for the sum over all source energies. Values are listed in tables headed "minimum scatter" and "maximum scatter," defined as before.

4. The scattered response, including the conversion factor for the scattered energy applied, both with and without buildup on the scattered leg, sorted according to the scattered energy group structure provided as input. Sums are not listed as they are the same as those in item 3 above.

5. A tabulation of minimum direct plus maximum scatter by source energy, and the total of these values.

II. OPERATIONAL USE

A. Numerical Integration

The scatter from the small volumes specified for the numerical integration is assumed to take place at the center of each "box." As such, the results of a particular calculation may be affected by the size selected or the total range specified for the integration. There are no simple rules for specifying the box size in all cases. However, it seems obvious that the scatter grid should be such that there is only a small range of scattering angles across the extent of each important box and that the boxes should be small in relation to the mean free path of the scattered photons.

Usually it is desirable to check the effect of both box size and range (where applicable) by rerunning the calculation with different values.

B. The Buildup Factor

The three basic assumptions incorporated into G^3 with respect to the buildup factor are (1) the general use of point isotropic buildup factors for application to effectively nonisotropic sources, (2) the application of buildup only to the scatter leg, and (3) the use of a single medium buildup factor.

The effect of the first assumption is to overcalculate buildup for forward scattering and undercalculate for backward scattering. Generally, the error is a monotonic increasing function of incident energy. A polar plot of the differential-scattering cross section ($d\sigma/d\theta = 2\pi \sin\theta \, d\sigma/d\Omega$) is given in Fig. 3 to aid in the evaluation of the effect of this assumption. The highly nonisotropic nature of the scattering is apparent.

Application of buildup only to the scatter leg is correct for most cases. For example, consider the use of G^3 to calculate scattering in an infinite medium. Figure 4 indicates some possible scattering paths. The contribution to the dose arriving at the detector from the multiple scatter (point 1 to point 3 to point 2 to the detector) would be accounted for by the buildup factor applied to the dose

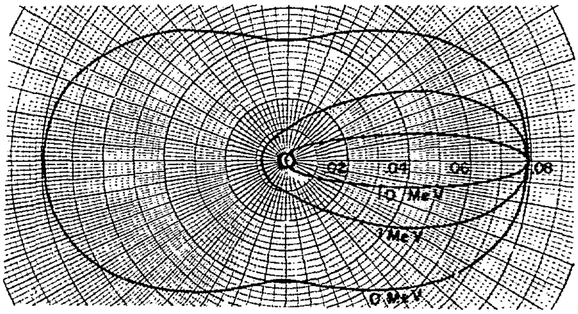

Fig. 3. dσ/dΩ as a function of θ, the scattering angle barns/electron-steradian.

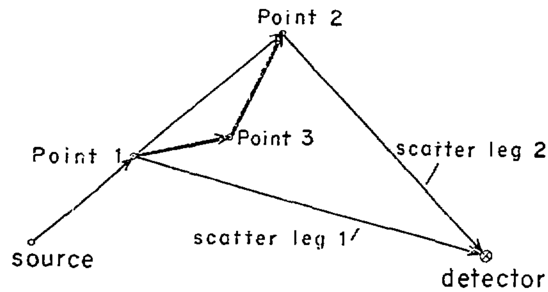

Fig. 4. Possible multiple scattering paths.

contribution scattered at point 1 along scatter leg 1. To apply a buildup factor along the incident leg to scatter point 2, as well as along the scatter leg from point 1, would, in effect, be to count this scatter twice. In situations of integration over the significant volume of an infinite-homogeneous medium, application of the buildup factor only on the scatter leg is correct. For finite or structured media, however, the approximation may or may not be the more correct. However, because one loses all information of arrival direction and energy after application of a buildup factor, and because the buildup for the scattered energy is generally larger than that for the incident energy, the most reasonable approach and that consistent with the infinite medium case seems to be the application of buildup only on the scatter leg.

The third assumption was made because general multimedia buildup factors do not exist. G^3 was designed to provide an economical calculational tool to assist in evaluating complex radiation problems.

III. CONDENSED INPUT

A. Variable Names and Format

Set 1 - Title or identification of the problem, any alphanumeric information (12A6), one card,

Set 2 - Control data 8(I5,I4), one card,

- geom (NGEOM) - specifies scattering geometry
  - 1 - rectangular
  - 2 - cylindrical
  - 3 - spherical
- L (LU) - number of X_1, r_2, or ρ_3 divisions in scattering volume $1 \leq L \leq 20$
- M (MU) - number of y_1, ϕ_2, or ϕ_3 divisions in scattering volume $1 \leq M \leq 20$
- N (NU) - number of Z_1, Z_2, or θ_3 divisions in scattering volume $1 \leq N \leq 20$
- Mo (MAT) - number of elements, $1 \leq Mo \leq 20$
- H (NCMP) - number of compositions, $1 \leq H \leq 20$
- I (NINC) - number of source energy groups, $1 \leq I \leq 30$
- J (NSC) - number of energy bin entries, $1 \leq J \leq 30$
- G (NREG) - number of regions, $1 \leq G \leq 50$

B (NB) - number of bounding surfaces, $1 \leq B \leq 50$

G_s (NZSϕ) - region where source point is located

IFD (IFDISK) - specifies either disk or ECS storage
0 if ECS is used, and 1 if disk is used

Set 3 - x_1, r_2, or ρ_3 divisions 8E9.4 Int(L/8) + 1 cards

Set 4 - y_1, ϕ_2, or ϕ_3 divisions 8E9.4 Int(M/8) + 1 cards

Set 5 - z_1, Z_2, or θ_3 divisions 8E9.4 Int(N/8) + 1 cards

Set 6 - Region description 8(I5,I4) G cards

- Bo (NBNDZN) - number of boundaries of the region
- h (NCMPZN) - composition in the region described
- $\pm\lambda$ ($\pm$LED) - j.λ for the first boundary to consider for this zone
- p (NTRYZN) - the zone that is likely to be entered by crossing boundary λ from the zone

(There are Bo pairs of ($\pm\lambda$, p) for each zone.)

Set 7 - Boundary description I5,I4,7E9.4 B cards

- λ (I) - boundary number
- S (NEQBD) - boundary type number
- A (ABD), B (BBD), C (CBD), x_0 (XOBD), y_0 (YOBD), z_0 (ZOBD), k (DBD) — boundary equation coefficients as required

Set 8 - Composition Matrix 8E9.4 H[Int(Mo/8)+1]* cards

- $\theta_{i,j}$ (COMP) - the densities in g/cm^3 of the ith composition (rows) and the jth element (columns)

Set 9 - Element atomic numbers 8E9.4 Int(Mo/8)+1 cards

- Z (ZMAT) - element atomic numbers in the same order as the columns in Set 8, must be floating point integer

Set 10 - Element atomic weights 8E9.4 Int(Mo/8)+1 cards

- A (AMAT) - element atomic weights in the order as on Set 8

Set 11 - Source energies 8E9.4 Int(I/8)+1 cards

- E_i (EINC) - source energies in MeV, input in ascending order of energy

Set 12 - Source group intensities 8E9.4 Int(I/8)+1 cards

- S_i (SINC) - gamma group intensities in photons/sec in same order as Set 11

Set 13 - Scattered energy group bounds 8E9.4 Int(J/8)+1 cards

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*The function Int(X) equals the greatest integer less than X. For example, Int(1.01) = 1, Int(.9) = 0, and Int(1.0) = 0.

E_j (ESC) - lower bounds for each scattered group, input in ascending order of energy. A lower bound of zero should not be entered for the first group as this is understood.

Set 14 - Conversion factors 8E9.4 Int(J/8)+1 cards

K_j (CONV) - units conversion factors in one-to-one correspondence with E_j

Set 15 - Constants

ε (EPSLN) - a small number used in region testing

δ (FUDGE) - a small number used in geometry routines, must be greater than ε

k_s (SFACT) - the symmetry factor

Set 16 - Source location 3E9.4,2(I5,I4) one card

x_s (XSO), y_s (YSO), z_s (ZSO) - source coordinates consistent with coordinate system specified by n

n (NCOORD) - coordinate system specification, 1 cartesian, 2 cylindrical, 3 spherical

n_1 (N1), n_2 (N2) - a distance print will be obtained for the n_1 through the n_2 source - scatter point rays

Set 17 - Receiver locations 3E9.4,2(I5,I4) any number of cards

x_r (XRC), y_r (YRC), z_r (ZRC) - the detector coordinates consistent with coordinate system specified by n

n (NCOORD) - coordinate system specification, 1 cartesian, 2 cylindrical, 3 spherical

n_1 (N1), n_2 (N2) a distance print will be obtained for the n_1 through the n_2 scatter point - detector point rays

Set 18 - Last card 3E9.4,2(I5,I4) one card

$n < 0$ - denotes end of problem, i.e., NCOORD < 0

Set 19 - Final card

STOP - STOP written in columns 1-4 with columns 5-6 blank, denotes end of problem set

---

B. Input Format Sheet

Figure 5 is a schematic representation of the program input.

IV. SAMPLE PROBLEMS

Two sample problems are described and illustrated by calculation. In each case, a sketch of the real geometry is given along with the geometry as prepared for the calculation.

A. Sample Problem 1

Case 1. Air scattering into a collimated detector. The physical geometry and calculated geometries are shown in Fig. 6. For this calculation, and for many of a similar nature, it is not necessary to mock up the entire geometry. By restricting the integration over the scattering region to that volume defined by an extension of the conical collimator, only one physical zone

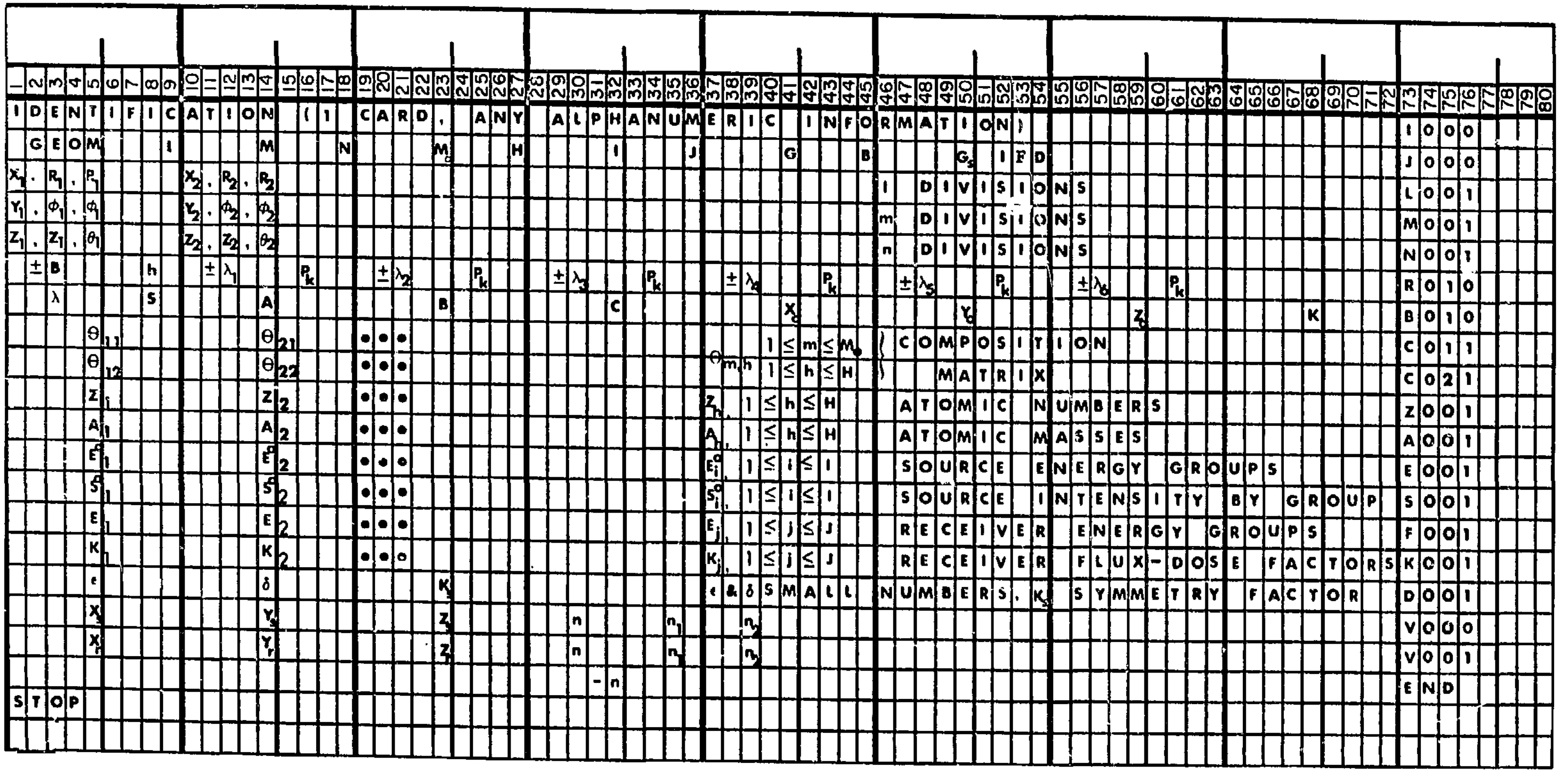

Fig. 5. Input format.

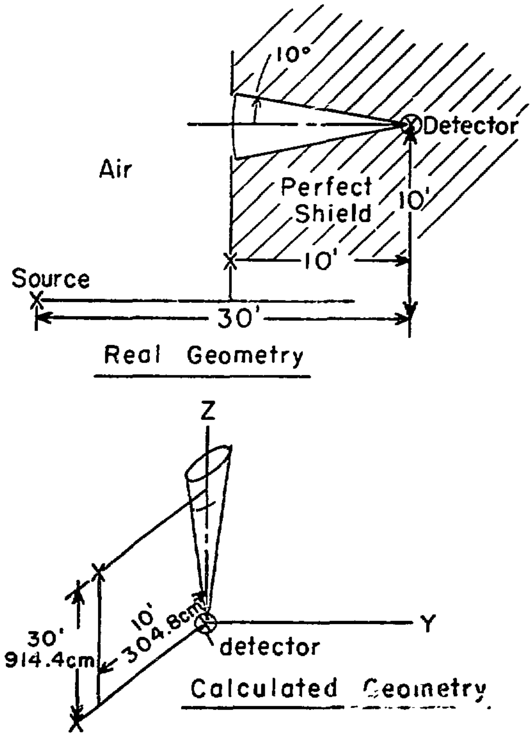

Fig. 6. Real and calculated geometry for Case 1.

need be described. It must contain the source point, all scatter points, and all detector points.

For the present calculation, let us consider this zone to be the semi-infinite region of space on the positive side of a plane perpendicular to the x-axis and intersecting it at -1000. The necessary boundary can be defined by the equation

$$x + 1000 = 0.$$

This is described by an equation of Type 4 (Eq. 18) with k = -1000. The scattering medium will be air with a density of 0.00125 g/cm^3 and a composition of 76.5 wt% nitrogen and 23.5 wt% oxygen. These two materials are specified by listing as input the atomic numbers and atomic masses.

	Nitrogen (Material 1)	Oxygen (Material 2)
Atomic number	7.0	8.0
Atomic mass	14.0067	15.9994

The composition, air, would then be specified by listing the physical density of each constituent, that is,

ρ(nitrogen) = 0.00095625

ρ(oxygen) = 0.00029375.

The zone could be described as

number of boundaries, -1; 1 boundary, outside zone;

composition, 1;

sign index and boundary, -1; refer back to Sec. I.C for the sign of j.

No zone for search need be specified because this is an outside zone. Consider the source to be a megacurie of ^{60}Co, i.e., 3.7 x 10^{16} disintegrations per second. Then the energies and their associated photon strengths are

E	Strength
1.7 MeV	3.7 x 10^{16} photons/sec
1.33 MeV	3.7 x 10^{16} photons/sec

A reasonably detailed scatter bin structure and a set of conversion factors to give results in R/h are given below.

E_j	K_j
0.05	1.295/-7
0.06	1.188/-7
0.08	1.30/-7
0.10	1.596/-7
0.15	2.592/-7
0.20	3.708/-7
0.30	5.958/-7
0.40	8.148/-7
0.50	1.0215/-7
0.60	1.2222/-7
0.80	1.5928/-6
1.00	1.923/-6
1.50	2.652/-6

A scatter grid, defined in spherical coordinates, is given below.

ρ	φ	θ
307.2	0	0
335.28	0.78539	0.087266
365.76	1.5708	0.17453
396.24	2.3562	
441.96	3.14159	
487.68		
533.40		
579.12		
640.08		
701.04		
762.00		
822.96		
883.92		
975.36		
1200.0		
1500.0		
2000.0		

The control card would then have the following entries.

G	3
L	16
M	4
N	2
M_o	2
H	1
I	2
J	13
G	1
B	1
g_s	1
ISD	1

A listing of the cards is given in Table III. The program listing is given in Appendix A.

B. Sample Problem 2

Case 2. Air scattering from a collimated source. This problem represents an attempt to calculate with G^3 the air scattering from a monodirectional-monoenergetic beam source into a series of detectors. This problem has been calculated with Monte Carlo by Lynch, Benoit, Johnson, and Zerby.[5] We will assume the case of a 2-MeV source directed at 30° to the line joining the source and detector with detectors located 5, 10, 20, 40, 65, and 100 ft from the source. (Problem numbers 623, 523, and 423 in Vol. 5, and problems 323, 223, and 123 in Vol. 4 of ORNL-2292.) Because the model used in ORNL-2292 used a monodirectional source whereas G^3 uses an isotropic source, a relationship between the source strength, E, and the solid angle subtended by the scatter region employed for the G^3 calculation will have to be derived for normalization. For the selected problems, Lynch et al. tabulated response values in R/h, per source photon per second. If the scatter volume is defined by an angular aperture, θ, the solid angle at the source is given by

$$2\pi(1 - \cos\theta) .$$

For a source of strength E/photons/sec to deliver 1 photon/sec into this scatter region, E must be assigned the value

$$\frac{4\pi}{2\pi(1 - \cos\theta)} .$$

For the particular problem, choose θ as 1° (0.017453 rad), hence $E = 1.3132 \times 10^4$ photons/sec.

Figure 7 shows both the conceived and calculated geometries. This problem, as in Case 1, can be considered as a single region. In fact, the same geometry description, compositions, and materials can be used as in Case 1.

Scatter boxes. Boundaries of the scatter boxes are listed as for Case 1.

TABLE III

SAMPLE PROBLEM 1, INPUT

```
SAMPLE PROBLEM 001, AIR SCATTERING INTO COLLIMATED DETECTOR              I000001
   3  16   4   2    2   1    2  13    1   1    1   1                      J000001
 307.2    335.28   365.76   396.24   441.96   487.68   533.40   579.12   L001001
 640.08   701.04   762.00   822.96   883.92   975.36   1200.0   1500.0   L002001
 2000.0                                                                   L003001
 0.0      0.78539  1.5708   2.3562   3.14159                              M001001
 0.0      0.087266 0.17453                                                N001001
  -1   1   -1                                                             R010001
   1   4                                                       -1000.0    B010001
 95625-04 29375-04                                                        C011001
 7.0      8.0                                                             Z001001
 14.0067  15.9994                                                         A001001
 1.17     1.33                                                            001001
 37    +16 37    +16                                                      S001001
 0.05     0.06     0.08     0.10     0.15     0.20     0.30     0.40     F001001
 0.50     0.60     0.80     1.00     1.50                                 F002001
 1295 -07 1188 -07 1300 -07 1596 -07 2592 -07 3708 -07 5958 -07 8148 -07K001001
 10215-06 12222-06 15928-06 1923 -06 2652 -06                             K002001
 0.01     1.0      2.0                                                    D000001
 304.8    0.0      914.1                                                  V000001
 0.0      0.0      0.0                                                    V001001
                                                                          END
```

ρ	ρ	ϕ	θ
0	1800	0	
50	2100	6.2832	+0.017453
100	2500		
200	3000		
300	3500		
450	4000		
600	5000		
900	6000		
1200	7000		
1500	8000		

The scatter energy bins and conversion factors are listed below. Because the source energy is 2.0 MeV, the largest possible scatter energy is 2.0 MeV.

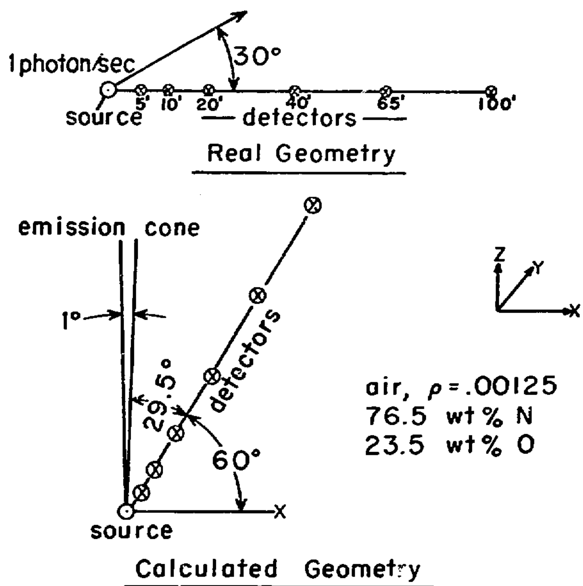

Fig. 7. Real and calculated geometry for Sample Problem 2.

E_j	K_j (R/h/photon/cm^2-sec)	E_j	K_j (R/h/photon/cm^2-sec)
0.05	1.295/-7	0.5	1.0215/-6
0.06	1.188/-7	0.6	1.2222/-6
0.08	1.30/-7	0.8	1.5928/-6
0.1	1.596/-7	1.0	1.923/-6
0.15	2.592/-7	1.5	2.652/-6
0.2	3.708/-7	2.0	3.272/-6
0.3	5.958/-7		
0.4	8.148/-7		

TABLE IV

SAMPLE PROBLEM 2, INPUT

```
SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE                   I000002
   3  19    1     1     2     1     1  14     1     1     1     1           J000002
0.0       50.0      100.0     200.0     300.0     450.0     600.C     900.0 L001002
1200.0    1500.0    1800.0    2100.0    2500.0    3000.0    3500.0   4000.0 L002002
5000.0    6000.0    7000.0    8000.0                                        L003002
0.0       6.2832                                                            M001002
0.0       .017453                                                           N001002
  -1   1   -1                                                               R010002
   1   4                                                          -1000.0   B010002
95625-04  29406-04                                                          C011002
7.0       8.0                                                               Z001002
14.0067   15.9994                                                           A001002
2.0                                                                         E001002
13132+04                                                                    S001002
.05       .06       .08       .1        .15       .2        .3        .4    E001002
.5        .6        .8        1.0       1.5       2.0                       E002002
1295 -07  1188 -07  13   -07  1596 -07  2592 -07  3708 -07  5958 -07  8148 -07K001002
10215-06  12222-06  15928-06  1923 -06  2652 -06  3272 -06                  K002002
.01       1.0       1.0                                                     D000002
0.0       0.0       0.0            1  60                                    V000002
75.04     0.0       132.64                                                  V001002
150.09    0.0       265.29                                                  V002002
300.18    0.0       530.57                                                  V003002
600.36    0.0       1061.1                                                  V004002
975.58    0.0       1724.4                                                  V005002
1500.9    0.0       2652.9                                                  V006002
                                                                            END
```

```
SAMPLE PROBLEM 002A, AIR SCATTERING FROM COLLIMATED SOURCE, RANGE CHECK I000002A
   3  12    1     1     2     1     1  14     1     1     1     1           J000002A
8000.0    9000.0    10000.0   11000.0   12000.0   13000.0   14000.0  15000.0 L001002A
16000.0   17000.0   18000.0   19000.0   20000.0                             L002002A
0.0       6.2832                                                            M001002A
0.0       .017453                                                           N001002A
  -1   1   -1                                                               R010002A
   1   4                                                          -1000.0   B010002A
95625-04  29406-04                                                          C011002A
7.0       8.0                                                               Z001002A
14.0067   15.9994                                                           A001002A
2.0                                                                         E001002A
13132+04                                                                    S001002A
.05       .06       .08       .1        .15       .2        .3        .4    E001002A
.5        .6        .8        1.0       1.5       2.0                       E002002A
1295 -07  1188 -07  13   -07  1596 -07  2592 -07  3708 -07  5958 -07  8148 -07K001002A
10215-06  12222-06  15928-06  1923 -06  2652 -06  3272 -06                  K002002A
.01       1.0       1.0                                                     D000002A
0.0       0.0       0.0                                                     V000002A
75.04     0.0       132.64                                                  V001002A
150.09    0.0       265.29                                                  V002002A
300.18    0.0       530.57                                                  V003002A
600.36    0.0       1061.1                                                  V004002A
975.58    0.0       1724.4                                                  V005002A
1500.9    0.0       2652.9                                                  V006002A
                                                                            END
```

Source and detector locations

	x	y	z	Comment (ft)
Source	0.0	0.0	0.0	
Detectors	75.04	0.0	132.64	5
	150.09	0.0	265.29	10
	300.18	0.0	530.57	20
	600.36	0.0	1061.1	40
	975.58	0.0	1724.4	65
	1500.9	0.0	2652.9	100

Control data

Quantity	Value	Comments
G	3	Scatter region described in spherical coordinates
L	20	20 radial divisions
M	1	1 division on ϕ
N	1	1 division on θ
M_O	2	2 materials
H	1	1 composition
I	1	1 source group
J	14	14 scatter bins
G	1	1 zone
B	1	1 boundary
g_s	1	source is in zone 1

Checks on the numerical integration effects can often be performed quite readily with G^3. Here it might be suspected that the range of integration on ρ is inadequate, particularly for the most distant detector points. A second calculation (Table IV) was carried out to extend the numerical integration on ρ from 8000 to 20,000 cm. Results of these calculations are listed in Table V along with results from ORNL-2292 for comparison.

The machine output is given in Appendix B.

ACKNOWLEDGMENT

G^3 was suggested by the GAS code developed by Bob E. Watt, and modified by J. R. Streetman of LASL. The program itself was originally prepared for the computer and checked out by Martin Kellogg of LASL. Subsequent modifications were made by J. R. Streetman and a number of users at other installations, particularly Jerry Lahti of Lewis Research Center and George Anno of NUS Corporation.

TABLE V

COMPARISON OF G^3 CALCULATION WITH ORNL-2292 RESULTS[a]

Distance (ft)	Case 002	Case 002A	Total	ORNL-2292
5	1.5476/-13	3.0692/-17	1.5479/-13	1.33/-13
10	7.2972/-14	3.1716/-17	7.3004/-14	6.68/-14
20	3.4424/-14	3.3874/-17	3.4458/-14	3.35/-14
40	1.6049/-14	3.8661/-17	1.6088/-14	1.63/-14
65	9.2965/-15	4.5643/-17	9.3421/-15	9.86/-15
100	5.6394/-15	5.7589/-17	5.6970/-15	6.09/-15

[a]Values are R/h per source photon/sec.

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2. R. D. Evans, The Atomic Nucleus (McGraw-Hill Book Company, NY, 1955), p. 683.

3. K. D. Lathrop, "DTF-IV, FORTRAN-IV Program for Solving the Multigroup Transport Equation with Anisotropic Scattering," Los Alamos Scientific Laboratory report LA-3373 (November 1965).

4. E. Storm and H. I. Israel, "Photon Cross Sections from 0.001 to 100 MeV for Elements 1 through 100," Los Alamos Scientific Laboratory report LA-3753 (November 1967).

5. R. E. Lynch, J. V. Benoit, W. P. Johnson, and C. D. Zerby, "A Monte Carlo Calculation of Air-Scattered Gamma Rays," Oak Ridge National Laboratory report ORNL-2292 (February 1958).

APPENDIX A

G^3 LISTING

```
      PROGRAM G36ED(INPUT,TAPE5=INPUT,OUTPUT,TAPE6=OUTPUT,TAPE13)
C     CDC 6600 VERSION FOR EITHER DISK OR ECS STORAGE
      COMMON NGEOM,LU,MU,NU,MAT,NCMP,NINC,NSC,NREG,NB,NZSO,IFD,UU(4),ID(
     1 12),XR(21),YPH(21),ZTH(21),FL(20),FM(20),FN(20),NBNDZN(50),NCMPZN(
     2 50),LBD(6,50),NTRYZN(6,50),NEQBD(50),ABD(50),BBD(50),CBD(50),X0BD(
     3 50),Y0BD(50),Z0BD(50),DBD(50),COMP(20,40),ZMAT(20),AMAT(20),EINC(3
     4 0),CINC(30),SINC(30),ESC(31),ES(31),CONV(31),EPSLN,FUDGE,ZZZ(80) ,S
     5 FACT
      COMMON /DATA/ NAME(100),ENRG(20),XSECO(20,100)
      COMMON /LOGIC/ PRINT,DLEG,INITL
      LOGICAL PRINT,DLEG,INITL
      COMMON /WESC/ NZR,XRC,YRC,ZRC,ALPHA,BETA,GAMMA,SSCC(30)
      COMMON /RESC/ NZSOR,XS,YS,ZS,ALPHAS,BETAS,GAMMAS,SSC(30)
      COMMON /ATNLNG/ SMAT(20),SSO,A(30),AU(30),IERR
      DIMENSION COSM(20), SINM(20), COSN(20), SINN(20), GDOSE(30), GDOSU
     1 (30), BDOSE(31), BDOSU(31), CR(30), RATIO(30)
      DIMENSION CDIR(30), DIR(30), DIRU(30), DSD(30)
      DATA INITL/.TRUE./,PTIME/0./
C
      CALL SECOND (STIME)
1     LOCECS=0
      INITL=.TRUE.
      CALL INPT
      IFDISK=IFD
      READ (5,54) XSO,YSO,ZSO,NCOORD,NDUM,N1,N2
      IF (NCOORD.EQ.0) NCOORD=1
      IF (NCOORD.LT.0) GO TO 1
      GO TO (4,3,2), NCOORD
2     XXSO=XSO*SIN(ZSO)
      YYSO=XXSO*SIN(YSO)
      ZSO=XSO*COS(ZSO)
      XSO=XXSO
      YSO=YYSO
      GO TO 4
3     XXSO=XSO*COS(YSO)
      YSO=XSO*SIN(YSO)
      XSO=XXSO
4     NS=1
      IF(IFDISK)411,411,412
  411 NINCP7=NINC+7
      M=LU*MU*NU*NINCP7
      IF (M .LT. 2000) M = 2000
      M = (M + 511) / 512
      WRITE (6,64) M
```

```
  412 DO 5 M=1,MAT
 5      SMAT(M)=1. 0
        CALL ATTEN (EINC)
        INITL=. FALSE.
        DLEG=. TRUE.
        NRC=0
        LINES=60
        LININC=NINC+ NSC+ 10
        NSC1=NSC+ 1
        DO 6 J=1,NSC
 6      RATIO(J)=(CONV(J+ 1)- CONV(J))/(ESC(J+ 1)- ESC(J))
        DO 9 I=1,NINC
        DO 7 J=1,NSC
        DIFF2=EINC(I)- ESC(J+ 1)
        IF (DIFF2) 8,8,7
 7      CONTINUE
        CDIR(I)=CONV(NSC1)
        GO TO 9
 8      CDIR(I)=CONV(J+ 1)+ RATIO(J)*DIFF2
 9      CONTINUE
        GO TO (14,12,10), NGEOM
 10     DO 11 N=1,NU
        COSN(N)=COS(ZTH(N))
 11     SINN(N)=SIN(ZTH(N))
 12     DO 13 M=1,MU
        COSM(M)=COS(YPH(M))
 13     SINM(M)=SIN(YPH(M))
C
 14     DO 27 L=1,LU
        DO 27 M=1,MU
        FLM=FL(L)*FM(M)
        DO 27 N=1,NU
        GO TO (17,16,15), NGEOM
 15     XRC=XR(L)*SINN(N)
        YRC=XRC*SINM(M)
        XRC=XRC*COSM(M)
        ZRC=XR(L)*COSN(N)
        GO TO 19
 16     XRC=XR(L)*COSM(M)
        YRC=XR(L)*SINM(M)
        GO TO 18
 17     XRC=XR(L)
        YRC=YPH(M)
 18     ZRC=ZTH(N)
 19     IF (N1- NS) 20,21,23
 20     IF (NS- N2) 22,22,23
 21     WRITE (6,56) ID
 22     WRITE (6,55) XSO,YSO,ZSO,XRC,YRC,ZRC,L,M,N
        PRINT=. TRUE.
 23     CALL LENGTH (XSO,YSO,ZSO)
        IF (IERR. GT. 0) GO TO 52
        IF (NCMPZN(NZR). LE. 0) GO TO 26
        J=NCMPZN(NZR)
```

```
      ELECT=0. 0
      DO 24 K=1,MAT
 24   ELECT=ELECT+ ZMAT(K)/AMAT(K)*COMP(K,J)
      ELECT=ELECT*. 6023
      CALL ATTEN (EINC)
      DO 25 I=1,NINC
 25   SSCC(I)=SINC(I)*FLM*FN(N)*A(I)*ELECT
      IF (IFDISK)26,26,261
 26   CALL ECWR (NZR,LOCECS,7,NERR)
      LOCECS=LOCECS+ 7
      IF (NERR. NE. 0) CALL ECSABT (LOCECS)
      CALL ECWR (SSCC,LOCECS,NINC,NERR)
      LOCECS=LOCECS+ NINC
      IF (NERR. NE. 0) CALL ECSABT (LOCECS)
      GO TO 27
 261  WRITE(13)NZR,XRC,YRC,ZRC,ALPHA,BETA,GAMMA,(SSCC(K),K=1,NINC)
 27   NS=NS+ 1
C
      PRINT=. FALSE.
      DLEG=. FALSE.
 28   LOCECS=0
      IF (IFDISK)282,282,281
 281  REWIND 13
 282  READ (5,54) XRC,YRC,ZRC,NCOORD,NDUM,N1,N2
      IF (NCOORD. EQ. 0) NCOORD=1
      IF (NCOORD. LT. 0) GO TO 1
      GO TO (31,30,29), NCOORD
 29   XXRC=XRC*SIN(ZRC)
      YYRC=XXRC*SIN(YRC)
      XXRC=XXRC*COS(YRC)
      ZRC=XRC*COS(ZRC)
      XRC=XXRC
      YRC=YYRC
      GO TO 31
 30   XXRC=XRC*COS(YRC)
      YRC=XRC*SIN(YRC)
      XRC=XXRC
 31   CALL LENGTH (XSO,YSO,ZSO)
      IF (IERR) 32,32,52
 32   CALL ATTEN (EINC)
      TDIR=0. 0
      TDIRU=0. 0
      DO 33 I=1,NINC
      DIR(I)=SINC(I)*CDIR(I)
      DIRU(I)=DIR(I)*AU(I)/12. 566371
      DIR(I)=DIR(I)*A(I)/12. 566371
      TDIR=TDIR+ DIR(I)
 33   TDIRU=TDIRU+ DIRU(I)
      NS=1
      NRC=NRC+ 1
      DO 34 I=1,NINC
      GDOSE(I)=0. 0
 34   GDOSU(I)=0. 0
```

```
      DO 35 I=1,NSC1
      BDOSE(I)=0. 0
35    BDOSU(I)=0. 0
C
      DO 48 L=1,LU
      DO 48 M=1,MU
      DO 48 N=1,NU
      IF (IFDISK)351,351,352
351   CALL ECRD (NZSOR,LOCECS,NINCP7,NERR)
      LOCECS=LOCECS+ NINCP7
      IF (NERR. NE. 0) CALL ECSABT (LOCECS)
      GO TO 353
352   READ(13)NZSOR,XS,YS,ZS,ALPHAS,BETAS,GAMMAS,(SSC(K),K=1,NINC)
353   NZSO=NZSOR
      IF (N1- NS) 36,37,39
36    IF (NS- N2) 38,38,39
37    WRITE (6,56) ID
      LINES=60
38    WRITE (6,55) XS,YS,ZS,XRC,YRC,ZRC,L,M,N
      PRINT=. TRUE.
39    IF (NCMPZN(NZSO). LE. 0) GO TO 48
      CALL LENGTH (XS,YS,ZS)
      IF (IERR. GT. 0) GO TO 52
      SCOS=ALPHAS*ALPHA+ BETAS*BETA+ GAMMAS*GAMMA
      CSCOS=1. 0- SCOS
      SCOS2=SCOS**2- 1. 0
      DO 40 I=1,NINC
      CR(I)=1. 0+ CINC(I)*CSCOS
40    ES(I)=EINC(I)/CR(I)
      CALL ATTEN (ES)
      JL=1
      ASSIGN 41 TO II
      DO 47 I=1,NINC
      GO TO II, (41,46)
41    DO 42 J=JL,NSC
      DIFF2=ESC(J+ 1)- ES(I)
      IF (DIFF2) 42,43,44
42    CONTINUE
      ASSIGN 46 TO II
      J=NSC1
      CON=CONV(J)
      GO TO 46
43    CON=CONV(J+ 1)
      GO TO 45
44    CON=CONV(J+ 1)- RATIO(J)*DIFF2
45    JL=J
46    DS=. 03971*(1. 0/CR(I))**2*(CR(I)+ (1. 0/CR(I))+ SCOS2)*SSC(I)*CON
      GD=DS*A(I)
      GDU=DS*AU(I)
      GDOSE(I)=GDOSE(I)+ GD
      GDOSU(I)=GDOSU(I)+ GDU
      BDOSE(J)=BDOSE(J)+ GD
47    BDOSU(J)=BDOSU(J)+ GDU
48    NS=NS+ 1
```

```
C
      TDOSE=0. 0
      TDOSU=0. 0
      DO 49 I=1,NINC
      GDOSE(I)=GDOSE(I)*SFACT
      GDOSU(I)=GDOSU(I)*SFACT
      DSD(I)=GDOSU(I)+ DIR(I)
      TDOSE=TDOSE+ GDOSE(I)
49    TDOSU=TDOSU+ GDOSU(I)
      TDSD=TDOSU+ TDIR
      DO 50 I=1,NSC1
      BDOSU(I)=BDOSU(I)*SFACT
50    BDOSE(I)=BDOSE(I)*SFACT
      LINES=LINES+ LININC
      IF (LINES. LE. 59) GO TO 51
      WRITE (6,56) ID
      LINES=LININC
51    WRITE (6,57) NRC,XRC,YRC,ZRC
      WRITE (6,63) XSO,YSO,ZSO
      WRITE (6,58)
      WRITE (6,59) (I,EINC(I),SINC(I),DIR(I),DIRU(I),GDOSE(I),GDOSU(I),D
     1 SD(I),I,I=1,NINC)
      WRITE (6,62) TDIR,TDIRU,TDOSE,TDOSU,TDSD
      WRITE (6,60)
      WRITE (6,61) (I,ESC(I),CONV(I),BDOSE(I),BDOSU(I),I,I=1,NSC1)
      CALL SECOND (TIME)
      TIME=TIME- STIME
      PTIME=TIME- PTIME
      WRITE (6,65) PTIME,TIME
      PTIME=TIME
      GO TO 28
52    IF (DLEG) WRITE (6,55) XSO,YSO,ZSO,XRC,YRC,ZRC,L,M,N,IERR
      IF (. NOT. DLEG) WRITE (6,55) XS,YS,ZS,XRC,YRC,ZRC,L,M,N,IERR
53    READ (5,54) XRC,YRC,ZRC,NCOORD
      IF (NCOORD) 1,53,53
C
54    FORMAT (3E9. 4,2(I5,I4))
55    FORMAT (*0FROM*1P3E12. 4,* TO*3E12. 4,3I3,I7,* TYPE GEOMETRY ERROR. *
     1 )
56    FORMAT (6H1       12A6)
57    FORMAT (1H0I9,6X2HX=1PE12. 4,4X2HY=E12. 4,4X2HZ=E12. 4)
58    FORMAT (103H0      GROUP    ENERGY    SOURCE    MIN DIRECT   MAX
     1 DIRECT  MIN SCATTR  MAX SCATTR  MIND+ MAXSC  GROUP)
59    FORMAT (I10,2X1P7E12. 4,I5)
60    FORMAT (66H0       BIN    LOWER EDGE     FACTOR   MIN SCATTR MAX S
     1 CATTR   BIN)
61    FORMAT (I10,2X1P4E12. 4,I5)
62    FORMAT (12H0      TOTALS24X1P5E12. 4)
63    FORMAT (16H       SOURCE    ,2HX=1PE12. 4,4X2HY=E12. 4,4X2HZ=E12. 4)
64    FORMAT (/1X,O4,*K ECS FIELD LENGTH NEEDED. COLS. 50 TO 53 OF JOB
     Q CARD. *)
65    FORMAT (/* CP TIME FOR THIS DETECTOR POINT WAS*,F8. 3,/F10. 3,* SECO
     1 NDS EXECUTION CP TIME SO FAR. *)
```

```
      END
      SUBROUTINE INPT
C
      DIMENSION NAM(20)
      COMMON NGEOM,LU,MU,NU,MAT,NCMP,NINC,NSC,NREG,NB,NZSO,IFD,UU(4),ID(
     1 12),XR(21),YPH(21),ZTH(21),FL(20),FM(20),FN(20),NBNDZN(50),NCMPZN(
     2 50),LBD(6,50),NTRYZN(6,50),NEQBD(50),ABD(50),BBD(50),CBD(50),XOBD(
     3 50),Y0BD(50),Z0BD(50),DBD(50),COMP(20,40),ZMAT(20),AMAT(20),EINC(3
     4 0),CINC(30),SINC(30),ESC(31),ES(31),CONV(31),EPSLN,FUDGE,ZZZ(80),S
     5 FACT
      COMMON /DATA/ NAME(100),ENRG(20),XSECO(20,100)
      DIMENSION NCONT(16)
      EQUIVALENCE (NCONT(1),NGEOM)
C
C
C
C                READ INPUT
C
      READ (5,8) ID
      IF (ID(1). EQ. 4HSTOP) STOP
      READ (5,9) NCONT
      IU=LU+ 1
      JU=MU+ 1
      KU=NU+ 1
      READ (5,10) (XR(I),I=1,IU)
      READ (5,10) (YPH(I),I=1,JU)
      READ (5,10) (ZTH(I),I=1,KU)
C
      DO 1 I=1,NREG
      READ (5,9) K,NCMPZN(I),(LBD(J,I),NTRYZN(J,I),J=1,K)
1     NBNDZN(I)=K
      READ (5,11) (I,(NEQBD(I),ABD(I),BBD(I),CBD(I),X0BD(I),Y0BD(I),Z0BD
     1 (I),DBD(I)),J=1,NB)
C
      DO 2 I=1,NCMP
2     READ (5,10) (COMP(J,I),J=1,MAT)
      READ (5,10) (ZMAT(I),I=1,MAT)
      READ (5,10) (AMAT(I),I=1,MAT)
C
      READ (5,10) (EINC(I),I=1,NINC)
      READ (5,10) (SINC(I),I=1,NINC)
      READ (5,10) (ESC(I+ 1),I=1,NSC)
      READ (5,10) (CONV(I+ 1),I=1,NSC)
      ESC(1)=0. 0
      CONV(1)=CONV(2)
      READ (5,10) EPSLN,FUDGE,SFACT
      SFACT=SFACT/12. 566371
      DO 3 I=1,NINC
3     CINC(I)=EINC(I)/0. 51099
      IV=NSC+ 1
      DO 4 I=1,IV
4     ES(I)=ESC(I)/. 51099
C
```

```
C
C                PRINT INPUT
C
      WRITE (6,18) ID
      WRITE (6,19) NCONT
      WRITE (6,12) (XR(I),I=1,JU)
      WRITE (6,13) (YPH(I),I=1,JU)
      WRITE (6,14) (ZTH(I),I=1,KU)
      CALL GEOM
      WRITE (6,12) (XR(I),I=1,LU)
      WRITE (6,13) (YPH(I),I=1,MU)
      WRITE (6,14) (ZTH(I),I=1,NU)
      WRITE (6,15) (FL(I),I=1,LU)
      WRITE (6,16) (FM(I),I=1,MU)
      WRITE (6,17) (FN(I),I=1,NU)
C
      WRITE (6,18) ID
      WRITE (6,20)
      DO 5 I=1,NREG
      K=NBNDZN(I)
5     WRITE (6,21) I,K,NCMPZN(I),(LBD(J,I),NTRYZN(J,I),J=1,K)
      WRITE (6,18) ID
      WRITE (6,22)
      WRITE (6,23) (I,NEQBD(I),ABD(I),BBD(I),CBD(I),X0BD(I),Y0BD(I),Z0BD
     1 (I),DBD(I),I=1,NB)
C
      DO 6 I=1,MAT
      K=ZMAT(I)
6     NAM(I)=NAME(K)
      DO 7 I=1,MAT,9
      WRITE (6,18) ID
      K=MIN0(MAT,I+ 8)
      WRITE (6,24) (J,J=I,K)
      WRITE (6,27) (NAM(J),J=I,K)
      WRITE (6,25) (AMAT(J),J=I,K)
      DO 7 L=1,NCMP
7     WRITE (6,26) L,(COMP(J,L),J=I,K)
      RETURN
C
8     FORMAT (12A6)
9     FORMAT (8(I5,I4))
10    FORMAT (8E9. 4)
11    FORMAT (I5,I4,7E9. 4)
12    FORMAT (12H0 X OR      R1P8E12. 4/(12X8E12. 4))
13    FORMAT (12H0 Y OR    PHI1P8E12. 4/(12X8E12. 4))
14    FORMAT (12H0 Z OR THETA1P8E12. 4/(12X8E12. 4))
15    FORMAT (12H0        F(L)1P8E12. 4/(12X8E12. 4))
16    FORMAT (12H0        F(M)1P8E12. 4/(12X8E12. 4))
17    FORMAT (12H0        F(N)1P8E12. 4/(12X8E12. 4))
18    FORMAT (6H1      12A6)
19    FORMAT (13H      CONTROL16I6)
20    FORMAT (91H0  ZONE  BNDS  COMP  BND1   PK1  BND2  PK2  BND3  PK3
     1  BND4   PK4  BND5   PK5  BND6   PK6//)
```

```
21    FORMAT (15I6)
22    FORMAT (92H0   BND      EQ         A            B            C          X
     1 0           Y0            Z0             K//)
23    FORMAT (2I6,1P7E12. 4)
24    FORMAT (15H0   COMP     MAT,I5,8I12)
25    FORMAT (12H          A      1P9E12. 4)
26    FORMAT (I6,6X1P9E12. 4)
27    FORMAT (1H  ,17X,A2,8(10X,A2))
      END
      SUBROUTINE GEOM
C
      COMMON NGEOM,LU,MU,NU,MAT,NCMP,NINC,NSC,NREG,NB,NZSO,IFD,UU(4),ID(
     1 12),XR(21),YPH(21),ZTH(21),FL(20),FM(20),FN(20),NBNDZN(50),NCMPZN(
     2 50),LBD(6,50),NTRYZN(6,50),NEQBD(50),ABD(50),BBD(50),CBD(50),X0BD(
     3 50),Y0BD(50),Z0BD(50),DBD(50),COMP(20,40),ZMAT(20),AMAT(20),EINC(3
     4 0),CINC(30),SINC(30),ESC(31),ES(31),CONV(31),EPSLN,FUDGE,ZZZ(80),S
     5 FACT
C
      DO 4 I=1,LU
      GO TO (1,2,3), NGEOM
1     FL(I)=XR(I+ 1)- XR(I)
      GO TO 4
2     FL(I)=(XR(I+ 1)**2- XR(I)**2)/2. 0
      GO TO 4
3     FL(I)=(XR(I+ 1)**3- XR(I)**3)/3. 0
4     XR(I)=(XR(I+ 1)+ XR(I))/2. 0
      DO 5 I=1,MU
      FM(I)=YPH(I+ 1)- YPH(I)
5     YPH(I)=(YPH(I+ 1)+ YPH(I))/2. 0
      DO 8 I=1,NU
      GO TO (6,6,7), NGEOM
6     FN(I)=ZTH(I+ 1)- ZTH(I)
      GO TO 8
7     FN(I)=COS(ZTH(I))- COS(ZTH(I+ 1))
8     ZTH(I)=(ZTH(I+ 1)+ ZTH(I))/2. 0
      RETURN
      END
      SUBROUTINE LENGTH (XSO,YSO,ZSO)
      COMMON NGEOM,LU,MU,NU,MAT,NCMP,NINC,NSC,NREG,NB,NZSO,IFD,UU(4),ID(
     1 12),XR(21),YPH(21),ZTH(21),FL(20),FM(20),FN(20),NBNDZN(50),NCMPZN(
     2 50),LBD(6,50),NTRYZN(6,50),NEQBD(50),ABD(50),BBD(50),CBD(50),X0BD(
     3 50),Y0BD(50),Z0BD(50),DBD(50),COMP(20,40),ZMAT(20),AMAT(20),EINC(3
     4 0),CINC(30),SINC(30),ESC(31),ES(31),CONV(31),EPSLN,FUDGE,ZZZ(80),S
     5 FACT
      COMMON /ATNLNG/ SMAT(20),SSO,A(30),AU(30),IERR
      COMMON /LOGIC/ PRINT,DLEG,INITL
      LOGICAL PRINT,DLEG,INITL
      LOGICAL NOTALL
      COMMON /WESC/ NZR,XRC,YRC,ZRC,ALPHA,BETA,GAMMA,SSCC(30)
      COMMON /RESC/ NZSOR,XS,YS,ZS,ALPHAS,BETAS,GAMMAS,SSC(30)
      DIMENSION R(6)
C
C
```

```
 1      IF (PRINT) WRITE (6,37)
        DO 2 M=1,MAT
 2      SMAT(M)=0. 0
        X=XSO
        Y=YSO
        Z=ZSO
        ALPHA=XRC- X
        BETA=YRC- Y
        GAMMA=ZRC- Z
        SRC=SQRT(ALPHA**2+ BETA**2+ GAMMA**2)
        ALPHA=ALPHA/SRC
        BETA=BETA/SRC
        GAMMA=GAMMA/SRC
        SSO=SRC
        SMIN=FUDGE
        NP=NZSO
 3      NOTALL=. FALSE.
        X=X+ ALPHA*SMIN
        Y=Y+ BETA*SMIN
        Z=Z+ GAMMA*SMIN
        SRC=SRC- SMIN
        IL=NP
        IU=NREG
 4      DO 13 I=IL,IU
        JU=IABS(NBNDZN(I))
        DO 12 J=1,JU
        KSIN=LBD(J,I)
        K=IABS(LBD(J,I))
        IF (K. EQ. 0) K=1
        NEQ=NEQBD(K)
        GO TO (5,6,7,8,9,10), NEQ
 5      R(J)=X*(ABD(K)*X+ X0BD(K))+ Y*(BBD(K)*Y+ Y0BD(K))+ Z*(CBD(K)*Z+ Z0BD(K)
      1 )- DBD(K)
        GO TO 11
 6      XT=X- X0BD(K)
        YT=Y- Y0BD(K)
        ZT=Z- Z0BD(K)
        R(J)=ABD(K)*XT*XT+ BBD(K)*YT*YT+ CBD(K)*ZT*ZT- DBD(K)
        GO TO 11
 7      XT=X- X0BD(K)
        YT=Y- Y0BD(K)
        R(J)=XT*XT+ YT*YT- DBD(K)
        GO TO 11
 8      R(J)=X- DBD(K)
        GO TO 11
 9      R(J)=Y- DBD(K)
        GO TO 11
10      R(J)=Z- DBD(K)
11      IF (FLOAT(LBD(J,I))*R(J). GE. 0. ) GO TO 13
12      CONTINUE
        GO TO 15
13      CONTINUE
        IF (IU. LT. NP) GO TO 14
```

```
      IL=1
      IU=NP-1
      GO TO 4
 14   IERR=1
      PRINT=.NOT.PRINT
      IF (PRINT) GO TO 1
      GO TO 36
C
 15   SMIN=SRC
      KK=0
      IF (NBNDZN(I).LE.0) GO TO 34
      DO 33 J=1,JU
      KSIN=LBD(J,I)
      K=IABS(LBD(J,I))
      IF (K.EQ.0) K=1
      NEQ=NEQBD(K)
      GO TO (16,17,19,20,21,22), NEQ
 16   E=(X*ABD(K)+.5*X0BD(K))*ALPHA+(Y*BBD(K)+.5*Y0BD(K))*BETA+(Z*CBD(K)
     1 +.5*Z0BD(K))*GAMMA
      GO TO 18
 17   E=ABD(K)*ALPHA*(X-X0BD(K))+BBD(K)*BETA*(Y-Y0BD(K))+CBD(K)*GAMMA*(Z
     1 -Z0BD(K))
 18   H=ABD(K)*ALPHA**2+BBD(K)*BETA**2+CBD(K)*GAMMA**2
      GO TO 23
 19   E=ALPHA*(X-X0BD(K))+BETA*(Y-Y0BD(K))
      H=1.0-GAMMA**2
      GO TO 23
 20   IF (ALPHA.EQ.0.) GO TO 33
      SBD=-R(J)/ALPHA
      IF (SBD) 33,25,32
 21   IF (BETA.EQ.0.) GO TO 33
      SBD=-R(J)/BETA
      IF (SBD) 33,25,32
 22   IF (GAMMA.EQ.0.) GO TO 33
      SBD=-R(J)/GAMMA
      IF (SBD) 33,25,32
 23   IF (H.GE.0.0) GO TO 24
      H=-H
      E=-E
      R(J)=-R(J)
      KSIN=-KSIN
 24   IF (H.GT.EPSLN) GO TO 27
      IF (R(J).NE.0.0) GO TO 26
 25   IERR=2
C     THE POINT IS ON A BOUNDARY.
      PRINT=.NOT.PRINT
      IF (PRINT) GO TO 1
      GO TO 36
 26   IF (ABS(E).LE.EPSLN) GO TO 33
      SBD=-.5*R(J)/E
      IF (SBD.LE.0.0) GO TO 33
      GO TO 32
 27   IF (R(J)) 28,25,29
```

```
28    IF (H*SMIN**2+ 2. 0*E*SMIN+ R(J). LE. 0. 0) GO TO 33
      QUAD=E**2- H*R(J)
      GO TO 30
29    IF (E. GE. 0. 0) GO TO 33
      QUAD=E**2- H*R(J)
      IF (QUAD. LE. EPSLN) GO TO 33
30    IF (KSIN. LT. 0) GO TO 31
      SBD=(- E+ SQRT(QUAD))/H
      GO TO 32
31    SBD=(- E- SQRT(QUAD))/H
32    IF (SBD. GE. SMIN) GO TO 33
      NOTALL=. TRUE.
      SMIN=SBD
      KK=K
      NP=NTRYZN(J,I)
33    CONTINUE
C
34    SMIN=SMIN+ FUDGE
      IF (PRINT) WRITE (6,38) I,KK,SMIN,X,Y,Z
      N=NCMPZN(I)
      DO 35 M=1,MAT
35    SMAT(M)=SMAT(M)+ SMIN*COMP(M,N)
      IF (NOTALL) GO TO 3
      IERR=0
36    PRINT=. FALSE.
      NZR=I
      NOTALL=. FALSE.
      RETURN
C
37    FORMAT (67H0    ZONE      BOUNDARY     DISTANCE          X         Y
     1              Z)
38    FORMAT (2(I7,5X),1P4E12. 4)
      END
      SUBROUTINE ATTEN (E)
      COMMON NGEOM,LU,MU,NU,MAT,NCMP,NINC,NSC,NREG,NB,NZSO,IFD,UU(4),ID(
     1 12),XR(21),YPH(21),ZTH(21),FL(20),FM(20),FN(20),NBNDZN(50),NCMPZN(
     2 50),LBD(6,50),NTRYZN(6,50),NEQBD(50),ABD(50),BBD(50),CBD(50),X0BD(
     3 50),Y0BD(50),Z0BD(50),DBD(50),COMP(20,40),ZMAT(20),AMAT(20),EINC(3
     4 0),CINC(30),SINC(30),ESC(31),ES(31),CONV(31),EPSLN,FUDGE,ZZZ(80),S
     5 FACT
      COMMON /DATA/ NAME(100),ENRG(20),XSECO(20,100)
      COMMON /ATNLNG/ SMAT(20),SSO,A(30),AU(30),IERR
      COMMON /LOGIC/ PRINT,DLEG,INITL
      LOGICAL PRINT,DLEG,INITL
      LOGICAL FIRST
      DIMENSION E(30), XSEC(19,20), SLOPE(19,20), XSECI(30,20)
      DIMENSION BU(10,8), FX(10,8), FY(10,8), FXY(10,8), T1(10,8), T2(10
     1 ,8), T3(10,8), ETBL(10), MUTBL(8), IBD(6)
      DATA IBD/3,5*1/
      DATA ETBL/. 137,. 237,. 5,1. ,2. ,3. ,4. ,6. ,8. ,10. /
      DATA MUTBL/0. ,1. ,2. ,4. ,7. ,10. ,15. ,20. /
      DATA BU/10*1. ,3. 94,3. 48,2. 48,2. 06,1. 76,1. 62,1. 53,1. 41,1. 35,1. 30,
     1 7. 18,6. 70,4. 70,3. 50,2. 65,2. 30,2. 05,1. 80,1. 65,1. 55,
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```
     2 14. 9,14. 5,11. 5,6. 85,4. 65,3. 80,3. 30,2. 60,2. 10,1. 97,
     3 31. 1,35. 6,27. 7,12. 9,7. 7,5. 35,4. 37,3. 39,2. 91,2. 63,
     4 54. 8,64. 0,52. 7,20. 4,10. ,7. 35,5. 85,4. 36,3. 67,3. 26,
     5 117. 7,138. 4,112. 8,31. 6,17. 1,10. 7,8. 34,6. 28,4. 85,4. 26,
     6 219. 0,248. 0,202. 0,73. 2,24. 2,14. 3,10. 7,7. 35,5. 94,5. 19/
      DATA FX/80*0. /,FY/80*0. /,FXY/80*0. /
      DATA FIRST/. TRUE. /
      IFDISK=IFD
      IF (INITL) GO TO 6
      IF (DLEG) GO TO 3
1     DO 2 I=1,NINC
      CALL SEARCH (E(I),ENRG,19,NE,T1)
      EDIF=E(I)- ENRG(NE)
      DO 2 M=1,MAT
2     IF (SMAT(M). GT. 0. ) XSECI(I,M)=XSEC(NE,M)+ SLOPE(NE,M)*EDIF
      IF (INITL) RETURN
3     RCSSQ=1. /SSO**2
      DO 5 I=1,NINC
      RELX=0.
      DO 4 M=1,MAT
4     RELX=RELX+ SMAT(M)*XSECI(I,M)
      A(I)=EXP(- RELX)*RCSSQ
5     IF (. NOT. DLEG) AU(I)=A(I)*SPL2D2(RELX,E(I),8,MUTBL,10,ETBL,BU,FX,F
     1 Y,FXY,10,0,0)
      RETURN
6     IF (FIRST) CALL SPL2D1 (8,MUTBL,10,ETBL,BU,FX,FY,FXY,10,IBD,T1,T2,
     1 T3)
      FIRST=. FALSE.
      IF (IFDISK)61,61,62
   61 CALL ECWR(XSECO,0,2000,NERR)
      IF (NERR. NE. 0) CALL ECSABT (0)
      GO TO 62
   62 DO 7 M=1,MAT
      J=IFIX(ZMAT(M))
      IF (IFDISK)63,63,64
   63 LOCECS=20*(J- 1)
      CALL ECRD (XSEC(1,M),LOCECS,20,NERR)
      IF (NERR. NE. 0)CALL ECSABT (LOCECS)
      GO TO 65
   64 DO 641 N=1,19
      SLOPE(N,M)=(XSECO(N+ 1,J)- XSECO(N,J))/(ENRG(N+ 1)- ENRG(N))
  641 XSEC(N,M)=XSECO(N,J)
      GO TO 7
   65 DO 66 N=1,19
   66 SLOPE(N,M)=(XSEC(N+ 1,M)- XSEC(N,M))/(ENRG(N+ 1)- ENRG(N))
7     CONTINUE
      GO TO 1
      END
      BLOCK DATA
      COMMON /DATA/ NAME(100),ENRG(20),XSECO(20,100)
      DATA (NAME(I),I=1,100)/2H H,2HHE,2HLI,2HBE,2H B,2H C,2H N,2H O,2H
     1 F,2HNE,2HNA,2HMG,2HAL,2HSI,2H P,2H S,2HCL,2HAR,2H K,2HCA,2HSC,2HTI
     2 ,2H V,2HCR,2HMN,2HFE,2HCO,2HNI,2HCU,2HZN,2HGA,2HGE,2HAS,2HSE,2HBR,
```

```
3 2HKR,2HRB,2HSR,2H Y,2HZR,2HNB,2HMO,2HTC,2HRU,2HRH,2HPD,2HAG,2HCD,2
4 HIN,2HSN,2HSB,2HTE,2H I,2HXE,2HCS,2HBA,2HLA,2HCE,2HPR,2HND,2HPM,2H
5 SM,2HEU,2HGD,2HTB,2HDY,2HHO,2HER,2HTM,2HYB,2HLU,2HHF,2HTA,2H W,2HR
6 E,2HOS,2HIR,2HPT,2HAU,2HHG,2HTL,2HPB,2HBI,2HPO,2HAT,2HRN,2HFR,2HRA
7 ,2HAC,2HTH,2HPA,2H U,2HNP,2HPU,2HAM,2HCM,2HBK,2HCF,2HES,2HFM/
  DATA (ENRG(I),I=1,20)/. 05,. 06,. 08,. 1,. 15,. 2,. 3,. 4,. 5,. 6,. 8,1. ,1. 5,
1 2. ,3. ,4. ,5. ,6. ,8. ,10. /
  DATA(XSECO(I),I=1,20)/  . 335,. 326,. 309,. 295,. 265,. 243,. 212,. 189,.
1 173,. 160,. 140,. 126,. 103,. 0876,. 0691,. 0579,. 0502,. 0446,. 0371,. 0321/
  DATA(XSECO(I),I=21,40)/  . 1688,. 1640,. 1560,. 1480,. 1330,. 1220,. 1060
1 ,. 0953,. 0870,. 0805,. 0707,. 0635,. 0516,. 0442,. 0349,. 0295,. 0257,. 0231
2 ,. 0194,. 0169/
  DATA(XSECO(I),I=41,60)/  . 1469,. 1423,. 1347,. 1268,. 1150,. 1060,. 0921
1 ,. 0825,. 0754,. 0696,. 0612,. 0550,. 0447,. 0382,. 0304,. 0257,. 0225,. 0203
2 ,. 0172,. 0152/
  DATA(XSECO(I),I=61,80)/  . 151,. 146,. 138,. 132,. 119,. 109,. 0945,. 0847
1 ,. 0773,. 0715,. 0628,. 0565,. 0459,. 0394,. 0313,. 0266,. 0234,. 0211,. 018,
2 . 0161/
  DATA(XSECO(I),I=81,100)/ . 1608,. 1536,. 1463,. 1380,. 1237,. 1139,. 0985
1 ,. 0881,. 0805,. 0745,. 0654,. 0588,. 0478,. 0410,. 0321,. 0279,. 0247,. 0224
2 ,. 0193,. 0175/
  DATA(XSECO(I),I=101,120)/. 178,. 169,. 157,. 149,. 134,. 122,. 106,. 0953,
1 . 087,. 0805,. 0707,. 0636,. 0518,. 0444,. 0356,. 0304,. 027,. 0245,. 0213,. 0
2 194/
  DATA(XSECO(I),I=121,140)/. 185,. 173,. 159,. 15,. 134,. 123,. 106,. 0955,.
1 0869,. 0805,. 0707,. 0636,. 0517,. 0445,. 0357,. 0306,. 0273,. 0249,. 0218,.
2 02/
  DATA(XSECO(I),I=141,160)/. 197,. 18,. 162,. 151,. 134,. 123,. 107,. 0953,.
1 087,. 0806,. 0708,. 0636,. 0518,. 0445,. 0359,. 0309,. 0276,. 0254,. 0224,. 0
2 206/
  DATA(XSECO(I),I=161,180)/. 1987,. 1786,. 1565,. 1448,. 1275,. 1780,. 1016
1 ,. 0905,. 0826,. 0762,. 0670,. 0602,. 0491,. 0422,. 0342,. 0296,. 0266,. 0245
2 ,. 0218,. 0203/
  DATA(XSECO(I),I=181,200)/ . 231,. 1992,. 1688,. 1536,. 1337,. 1226,. 1054
1 ,. 0947,. 0863,. 0797,. 0701,. 0630,. 0514,. 0442,. 0359,. 0312,. 0281,. 0260
2 ,. 0233,. 0218/
  DATA(XSECO(I),I=201,220)/ . 248,. 206,. 168,. 151,. 13,. 118,. 102,. 0912,
1 . 0833,. 077,. 0676,. 0608,. 0496,. 0427,. 0348,. 0303,. 0274,. 0254,. 0229,.
2 0215/
  DATA(XSECO(I),I=221,240)/ . 293,. 232,. 181,. 16,. 135,. 122,. 106,. 0944,
1 . 086,. 0795,. 0699,. 0627,. 0512,. 0442,. 036,. 0315,. 0286,. 0266,. 0242,. 0
2 228/
  DATA(XSECO(I),I=241,260)/ . 326,. 248,. 186,. 161,. 134,. 12,. 103,. 0922,
1 . 084,. 0777,. 0683,. 0614,. 05,. 0432,. 0353,. 031,. 0282,. 0264,. 0241,. 022
2 9/
  DATA(XSECO(I),I=261,280)/ . 389,. 288,. 205,. 172,. 139,. 125,. 107,. 0954
1 ,. 0869,. 0802,. 0706,. 0635,. 0517,. 0447,. 0367,. 0323,. 0296,. 0277,. 0254
2 ,. 0243/
  DATA(XSECO(I),I=281,300)/ . 432,. 311,. 211,. 174,. 137,. 122,. 104,. 0928
1 ,. 0846,. 078,. 0685,. 0617,. 0502,. 0436,. 0358,. 0316,. 029,. 0273,. 0252,.
2 0242/
  DATA(XSECO(I),I=301,320)/ . 518,. 363,. 234,. 188,. 144,. 127,. 108,. 0958
1 ,. 0874,. 0806,. 0707,. 0635,. 0519,. 0448,. 0371,. 0328,. 0302,. 0284,. 0266
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 2 ,. 0255/
   DATA(XSECO(I),I=321,340)/ . 584,. 3957,. 2451,. 1902,. 1403,. 1223,. 1033
 1 ,. 0922,. 0839,. 0775,. 0680,. 0609,. 0498,. 0432,. 0358,. 0318,. 0295,. 0280
 2 ,. 0262,. 0252/
   DATA(XSECO(I),I=341,360)/ . 629,. 420,. 249,. 188,. 135,. 117,. 0977,. 086
 1 7,. 079,. 073,. 0638,. 0573,. 0468,. 0407,. 0338,. 0301,. 0279,. 0266,. 0248,
 2 . 0241/
   DATA(XSECO(I),I=361,380)/ . 782,. 514,. 293,. 215,. 149,. 127,. 106,. 0936
 1 ,. 0852,. 0786,. 0689,. 0618,. 0505,. 0438,. 0365,. 0327,. 0305,. 0289,. 0274
 2 ,. 0267/
   DATA(XSECO(I),I=381,400)/ . 929,. 597,. 33,. 238,. 158,. 132,. 109,. 0965,
 1 . 0876,. 0809,. 0708,. 0634,. 0518,. 0451,. 0376,. 0338,. 0316,. 0302,. 0285,
 2 . 028/
   DATA(XSECO(I),I=401,420)/ . 999,. 6317,. 3387,. 2377,. 1507,. 1247,. 1025
 1 ,. 0902,. 0819,. 0755,. 0662,. 0593,. 0484,. 0421,. 0353,. 0318,. 0299,. 0287
 2 ,. 0273,. 0267/
   DATA(XSECO(I),I=421,440)/ 1. 125,. 7062,. 3677,. 2517,. 1531,. 1253,. 101
 1 ,. 0892,. 0809,. 0745,. 0653,. 0586,. 0478,. 0416,. 0350,. 0316,. 0298,. 0287
 2 ,. 0274,. 0269/
   DATA(XSECO(I),I=441,460)/ 1. 250,. 7850,. 3999,. 2661,. 1565,. 1249,. 100
 1 ,. 0880,. 0797,. 0734,. 0642,. 0576,. 0470,. 0410,. 0345,. 0313,. 0296,. 0285
 2 ,. 0274,. 0270/
   DATA(XSECO(I),I=461,480)/ 1. 443,. 9005,. 4516,. 2930,. 1665,. 1302,. 103
 1 ,. 0904,. 0817,. 0751,. 0657,. 0589,. 0482,. 0419,. 0354,. 0322,. 0305,. 0295
 2 ,. 0285,. 0282/
   DATA(XSECO(I),I=481,500)/ 1. 599,. 9942,. 4925,. 3108,. 1709,. 1318,. 102
 1 ,. 0895,. 0807,. 0742,. 0648,. 0582,. 0474,. 0414,. 0351,. 0320,. 0304,. 0295
 2 ,. 0286,. 0283/
   DATA(XSECO(I),I=501,520)/ 1. 83,1. 13,. 555,. 344,. 183,. 138,. 106,. 0919
 1 ,. 0828,. 0762,. 0664,. 0595,. 0485,. 0424,. 036,. 033,. 0313,. 0304,. 0295,.
 2 0294/
   DATA(XSECO(I),I=521,540)/ 2. 01,1. 235,. 5999,. 3669,. 1880,. 1387,. 1052
 1 ,. 0910,. 0817,. 0750,. 0655,. 0588,. 0479,. 0419,. 0356,. 0327,. 0312,. 0304
 2 ,. 0297,. 0296/
   DATA(XSECO(I),I=541,560)/ 2. 32,1. 427,. 6832,. 4127,. 2550,. 1488,. 1108
 1 ,. 0951,. 0854,. 0783,. 0682,. 0611,. 0499,. 0437,. 0372,. 0343,. 0329,. 0320
 2 ,. 0314,. 0314/
   DATA(XSECO(I),I=561,580)/ 2. 45,1. 51,. 713,. 427,. 206,. 147,. 108,. 0916
 1 ,. 082,. 0751,. 0654,. 0585,. 0476,. 0418,. 0357,. 033,. 0316,. 0309,. 0303,.
 2 0305/
   DATA(XSECO(I),I=581,600)/ 2. 71,1. 661,. 7773,. 4630,. 2182,. 1519,. 1095
 1 ,. 0927,. 0827,. 0756,. 0659,. 0590,. 0481,. 0427,. 0362,. 0335,. 0322,. 0316
 2 ,. 0312,. 0313/
   DATA(XSECO(I),I=601,620)/ 2. 88,1. 768,. 8150,. 4841,. 2228,. 1527,. 1074
 1 ,. 0904,. 0806,. 0734,. 0639,. 0571,. 0467,. 0410,. 0353,. 0327,. 0315,. 0309
 2 ,. 0307,. 0309/
   DATA(XSECO(I),I=621,640)/ 3. 12,1. 905,. 8876,. 5194,. 2320,. 1562,. 1031
 1 ,. 0904,. 0802,. 0731,. 0634,. 0568,. 0463,. 0407,. 0351,. 0327,. 0315,. 0310
 2 ,. 0308,. 0311/
   DATA(XSECO(I),I=641,660)/ 3. 39,2. 08,. 9606,. 5592,. 2440,. 1617,. 1099,
 1 . 0910,. 0806,. 0733,. 0636,. 0568,. 0464,. 0407,. 0353,. 0329,. 0318,. 0313,
 2 . 0313,. 0316/
   DATA(XSECO(I),I=661,680)/ 3. 62,2. 20,1. 029,. 5586,. 2515,. 1634,. 1087,
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 1 .0897,.0792,.0720,.0623,.0556,.0454,.0399,.0346,.0324,.0315,.0310,
 2 .0310,.0314/
   DATA(XSECO(I),I=681,700)/ 3.99,2.43,1.135,.6436,.2691,.1727,.1124,
 1 .0922,.0810,.0735,.0635,.0567,.0462,.0406,.0354,.0332,.0323,.0318,
 2 .0320,.0325/
   DATA(XSECO(I),I=701,720)/ 4.24,2.56,1.203,.6791,.2785,.1753,.1122,
 1 .0913,.0800,.0727,.0625,.0557,.0454,.0400,.0349,.0329,.0320,.0317,
 2 .0318,.0324/
   DATA(XSECO(I),I=721,740)/ 4.60,2.79,1.309,.7335,.2963,.1826,.1149,
 1 .0928,.0811,.0732,.0630,.0562,.0458,.0404,.0353,.0333,.0325,.0322,
 2 .0325,.0331/
   DATA(XSECO(I),I=741,760)/ 4.96,3.03,1.406,.7882,.3122,.1900,.1176,
 1 .0941,.0817,.0736,.0633,.0564,.0459,.0405,.0355,.0336,.0329,.0326,
 2 .0330,.0337/
   DATA(XSECO(I),I=761,780)/ 5.40,3.29,1.542,.8555,.3328,.2002,.1212,
 1 .0960,.0832,.0743,.0642,.0572,.0465,.0411,.0361,.0343,.0336,.0334,
 2 .0338,.0346/
   DATA(XSECO(I),I=781,800)/ 5.78,3.52,1.658,.9100,.3517,.2085,.1239,
 1 .0978,.0839,.0752,.0644,.0573,.0466,.0412,.0363,.0345,.0339,.0337,
 2 .0343,.0351/
   DATA(XSECO(I),I=801,820)/ 6.23,3.80,1.764,.9820,.3724,.2178,.1275,
 1 .0996,.0850,.0766,.0650,.0578,.0470,.0416,.0367,.0350,.0344,.0343,
 2 .0349,.0359/
   DATA(XSECO(I),I=821,840)/ 6.62,4.04,1.86,1.03,.389,.225,.13,.0998,
 1 .0851,.0761,.0648,.0575,.0467,.0414,.0365,.0349,.0344,.034,.0349,
 2 .0359/
   DATA(XSECO(I),I=841,860)/ 7.02,4.28,1.958,1.089,.4065,.2328,.1310,
 1 .1003,.0851,.0757,.0646,.0573,.0465,.0412,.0365,.0349,.0345,.0344,
 2 .0353,.0363/
   DATA(XSECO(I),I=861,880)/ 7.43,4.54,2.075,1.156,.4274,.2411,.1327,
 1 .1011,.0855,.0759,.0645,.0571,.0464,.0411,.0365,.0351,.0347,.0347,
 2 .0356,.0367/
   DATA(XSECO(I),I=881,900)/ 7.99,4.89,2.220,1.243,.4548,.2543,.1373,
 1 .1039,.0872,.0773,.0655,.0579,.0470,.0417,.0371,.0357,.0354,.0354,
 2 .0364,.0376/
   DATA(XSECO(I),I=901,920)/ 8.39,5.12,2.330,1.301,.4710,.2608,.1391,
 1 .1048,.0869,.0767,.0648,.0573,.0464,.0413,.0368,.0354,.0352,.0353,
 2 .0363,.0375/
   DATA(XSECO(I),I=921,940)/ 8.97,5.49,2.50,1.388,.5014,.2759,.1447,.
 1 1076,.0886,.0781,.0659,.0582,.0470,.0418,.0374,.0361,.0359,.0360,.
 2 0371,.0384/
   DATA(XSECO(I),I=941,960)/ 9.31,5.71,2.59,1.437,.5168,.2816,.1455,.
 1 1065,.0878,.0771,.0648,.0571,.0462,.0410,.0368,.0356,.0355,.0357,.
 2 0368,.0382/
   DATA(XSECO(I),I=961,980)/ 9.85,6.02,2.75,1.515,.5436,.2940,.1492,.
 1 1083,.0887,.0778,.0652,.0574,.0464,.0412,.0370,.0359,.0358,.0360,.
 2 0372,.0387/
   DATA(XSECO(I),I=981,1000)/10.2,6.28,2.87,1.58,.563,.303,.153,.109,
 1 .0886,.0776,.0647,.0568,.0459,.0408,.0367,.0355,.0355,.0358,.0368,
 2 .0383/
   DATA(XSECO(I),I=1001,1020)/10.7,6.57,3.01,1.650,.5980,.3150,.1557,
 1 .1101,.0892,.0780,.0647,.0568,.0458,.0407,.0367,.0357,.0357,.0361,
 2 .0374,.0389/
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      DATA(XSECO(I),I=1021,1040)/11. 0,6. 75,3. 10,1. 700,. 6040,. 3191,. 1557,
     1 . 1090,. 0879,. 0767,. 0633,. 0555,. 0447,. 0397,. 0359,. 0350,. 0351,. 0354,
     2 . 0367,. 0383/
      DATA(XSECO(I),I=1041,1060)/12. ,7. 26,3. 34,1. 83,. 648,. 339,. 165,. 114,
     1 . 0913,. 0792,. 0653,. 0571,. 046,. 0409,. 037,. 036,. 0361,. 0365,. 0377,. 03
     2 94/
      DATA(XSECO(I),I=1061,1080)/12. 1,7. 47,3. 46,1. 905,. 6640,. 3471,. 1679,
     1 . 1146,. 0910,. 0787,. 0647,. 0565,. 0453,. 0404,. 0366,. 0358,. 0360,. 0365,
     2 . 0379,. 0396/
      DATA(XSECO(I),I=1081,1100)/12. 6,7. 88,3. 67,2. 012,. 7000,. 3642,. 1745,
     1 . 1174,. 0929,. 0800,. 0655,. 0572,. 0458,. 0408,. 0371,. 0363,. 0366,. 0371,
     2 . 0385,. 0403/
      DATA(XSECO(I),I=1101,1120)/13. 1,8. 16,3. 79,2. 079,. 7180,. 3719,. 1763,
     1 . 1174,. 0928,. 0798,. 0650,. 0566,. 0453,. 0404,. 0367,. 0360,. 0363,. 0369,
     2 . 0384,. 0402/
      DATA(XSECO(I),I=1121,1140)/13. 7,8. 55,4. 00,2. 195,. 7560,. 3891,. 1839,
     1 . 1211,. 0947,. 0812,. 0659,. 0573,. 0458,. 0408,. 0372,. 0365,. 0369,. 0375,
     2 . 0390,. 0409/
      DATA(XSECO(I),I=1141,1160)/14. 3,8. 99,4. 22,2. 312,. 7990,. 4081,. 1869,
     1 . 1249,. 0973,. 0828,. 0670,. 0582,. 0464,. 0414,. 0377,. 0370,. 0375,. 0382,
     2 . 0398,. 0417/
      DATA(XSECO(I),I=1161,1180)/15. 1,9. 45,4. 49,2. 460,. 8440,. 4281,. 1989,
     1 . 1286,. 0991,. 0847,. 0683,. 0591,. 0470,. 0420,. 0383,. 0377,. 0383,. 0390,
     2 . 0407,. 0427/
      DATA(XSECO(I),I=1181,1200)/15. 6,9. 75,4. 64,2. 560,. 8720,. 4425,. 2037,
     1 . 1304,. 1000,. 0852,. 0684,. 0591,. 0469,. 0419,. 0383,. 0378,. 0384,. 0391,
     2 . 0408,. 0429/
      DATA(XSECO(I),I=1201,1220)/16. 2,10. 14,4. 84,2. 66,. 910,. 4578,. 2093,.
     1 1322,. 1019,. 0861,. 0688,. 0594,. 0470,. 0420,. 0384,. 0380,. 0386,. 0394,.
     2 0411,. 0432/
      DATA(XSECO(I),I=1221,1240)/16. 5,10. 44,5. 02,2. 76,. 940,. 4723,. 2140,.
     1 1351,. 1028,. 0867,. 0690,. 0594,. 0469,. 0419,. 0384,. 0380,. 0387,. 0395,.
     2 0412,. 0434/
      DATA(XSECO(I),I=1241,1260)/17. 2,10. 83,5. 24,2. 90,. 986,. 4924,. 2216,.
     1 1388,. 1047,. 0882,. 0700,. 0601,. 0474,. 0424,. 0389,. 0385,. 0393,. 0401,.
     2 0419,. 0441/
      DATA(XSECO(I),I=1261,1280)/2. 6,10. 93,5. 35,2. 96,1. 015,. 5031,. 2245,.
     1 1397,. 1056,. 0880,. 0695,. 0596,. 0469,. 0419,. 0385,. 0382,. 0390,. 0398,.
     2 0416,. 0439/
      DATA(XSECO(I),I=1281,1300)/2. 6,11. 32,5. 57,3. 09,1. 054,. 5233,. 2311,.
     1 1455,. 1075,. 0893,. 0702,. 0600,. 0472,. 0421,. 0388,. 0384,. 0393,. 0402,.
     2 0420,. 0443/
      DATA(XSECO(I),I=1301,1320)/2. 8,11. 52,5. 76,3. 20,1. 093,. 5407,. 2368,.
     1 1454,. 1084,. 0900,. 0706,. 0602,. 0471,. 0422,. 0389,. 0385,. 0395,. 0404,.
     2 0422,. 0446/
      DATA(XSECO(I),I=1321,1340)/2. 9,11. 80,5. 98,3. 32,1. 131,. 5599,. 2434,.
     1 1492,. 1103,. 0914,. 0713,. 0607,. 0474,. 0424,. 0391,. 0388,. 0398,. 0408,.
     2 0426,. 0450/
      DATA(XSECO(I),I=1341,1360)/3. 1,12. 10,6. 21,3. 45,1. 180,. 5791,. 2510,.
     1 1530,. 1121,. 0928,. 0720,. 0612,. 0477,. 0427,. 0394,. 0392,. 0402,. 0412,.
     2 0431,. 0455/
      DATA(XSECO(I),I=1361,1380)/3. 2,12. 39,6. 42,3. 58,1. 228,. 6012,. 2586,.
     1 1568,. 1150,. 0943,. 0729,. 0618,. 0481,. 0430,. 0397,. 0395,. 0406,. 0416,.
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     2 0435,.0460/
       DATA(XSECO(I),I=1381,1400)/3.3,2.01,6.60,3.70,1.257,.6177,.263,.15
     1 96,.1159,.0951,.0732,.0620,.0481,.0428,.0398,.0396,.0406,.0417,.04
     2 36,.0462/
       DATA(XSECO(I),I=1401,1420)/3.5,2.13,6.88,3.83,1.315,.6430,.2719,.1
     1 634,.1188,.0966,.0743,.0627,.0486,.0433,.0402,.04,.0411,.0421,.044
     2 1,.0467/
       DATA(XSECO(I),I=1421,1440)/3.6,2.19,7.04,3.92,1.354,.6620,.2777,.1
     1 662,.1206,.0975,.0747,.0628,.0485,.0433,.0402,.0401,.0411,.0422,.0
     2 442,.0469/
       DATA(XSECO(I),I=1441,1460)/3.8,2.26,7.29,4.08,1.402,.6850,.2853,.1
     1 700,.1225,.0994,.0757,.0635,.0489,.0436,.0404,.0405,.0415,.0426,.0
     2 447,.0474/
       DATA(XSECO(I),I=1461,1480)/3.9,2.34,7.49,4.21,1.44,.708,.293,.174,
     1 .125,.101,.0763,.064,.0492,.0437,.0405,.0402,.0409,.0418,.0438,.04
     2 65/
       DATA(XSECO(I),I=1481,1500)/4.1,2.43,7.72,4.35,1.500,.729,.3005,.17
     1 87,.1272,.1022,.0774,.0645,.0494,.0441,.0409,.0409,.0421,.0431,.04
     2 53,.0481/
       DATA(XSECO(I),I=1501,1520)/4.3,2.50,7.92,4.46,1.539,.750,.3063,.18
     1 15,.1291,.1032,.0778,.0647,.0495,.0440,.0409,.0410,.0421,.0431,.04
     2 54,.0482/
       DATA(XSECO(I),I=1521,1540)/4.4,2.60,8.14,4.61,1.587,.771,.3140,.18
     1 62,.1310,.1051,.0787,.0652,.0496,.0443,.0411,.0412,.0423,.0433,.04
     2 56,.0485/
       DATA(XSECO(I),I=1541,1560)/4.6,2.71,8.61,4.75,1.64,.795,.324,.191,
     1 .135,.107,.08,.0659,.0501,.0445,.0414,.0411,.0418,.0427,.0448,.047
     2 7/
       DATA(XSECO(I),I=1561,1580)/4.8,2.83,1.31,4.91,1.694,.825,.3331,.19
     1 57,.1377,.1098,.0811,.0668,.0506,.0451,.0419,.0421,.0432,.0442,.04
     2 66,.0495/
       DATA(XSECO(I),I=1581,1600)/4.9,2.94,1.34,5.05,1.742,.848,.3398,.19
     1 95,.1396,.1108,.0819,.0673,.0508,.0452,.0421,.0423,.0433,.0443,.04
     2 68,.0497/
       DATA(XSECO(I),I=1601,1620)/5.0,3.01,1.36,5.16,1.8,.866,.346,.204,.
     1 143,.112,.0824,.0675,.0508,.0452,.042,.0416,.0423,.0433,.0454,.048
     2 4/
       DATA(XSECO(I),I=1621,1640)/5.2,3.15,1.41,5.29,1.84,.896,.356,.208,
     1 .145,.114,.0836,.0684,.0512,.0457,.0421,.042,.0426,.0436,.0459,.04
     2 89/
       DATA(XSECO(I),I=1641,1660)/5.4,3.29,1.46,5.46,1.908,.924,.3667,.21
     1 40,.1482,.1165,.0850,.0694,.0518,.0461,.0429,.0432,.0442,.0450,.04
     2 77,.0507/
       DATA(XSECO(I),I=1661,1680)/5.6,3.42,1.54,5.66,1.975,.962,.3772,.22
     1 07,.1530,.1193,.0871,.0707,.0527,.0468,.0435,.0439,.0448,.0457,.04
     2 84,.0515/
       DATA(XSECO(I),I=1681,1700)/5.9,3.58,1.62,5.87,2.053,1.001,.3916,.2
     1 284,.1577,.1232,.0891,.0722,.0536,.0476,.0442,.0446,.0456,.0464,.0
     2 492,.0523/
       DATA(XSECO(I),I=1701,1720)/5.8,3.57,1.62,5.79,2.025,.982,.3861,.22
     1 46,.1549,.1203,.0868,.0701,.0519,.0460,.0428,.0432,.0441,.0449,.04
     2 76,.0507/
       DATA(XSECO(I),I=1721,1740)/6.1,3.65,1.68,.920,2.103,1.02,.3986,.23
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1 23,.1587,.1241,.0887,.0716,.0528,.0467,.0434,.0438,.0448,.0455,.04
2 83,.0514/
  DATA(XSECO(I),I=1741,1760)/6.3,3.79,1.72,.930,2.161,1.039,.4103,.2
1 371,.1626,.1261,.0900,.0723,.0531,.0470,.0436,.0440,.0448,.0458,.0
2 485,.0517/
  DATA(XSECO(I),I=1761,1780)/6.5,3.90,1.80,.970,2.239,1.078,.4227,.2
1 448,.1674,.1299,.0921,.0738,.0540,.0477,.0443,.0446,.0456,.0456,.0
2 492,.0524/
  DATA(XSECO(I),I=1781,1800)/6.7,4.06,1.82,1.00,2.269,1.097,.4307,.2
1 478,.1693,.1309,.0925,.0739,.0539,.0476,.0442,.0444,.0452,.0464,.0
2 490,.0522/
  DATA(XSECO(I),I=1801,1820)/7.0,4.23,1.90,1.05,2.376,1.146,.4489,.2
1 583,.1760,.1357,.0954,.0762,.0553,.0488,.0452,.0454,.0464,.0475,.0
2 501,.0534/
  DATA(XSECO(I),I=1821,1840)/7.2,4.28,1.93,1.06,2.42,1.17,.452,.259,
1 .176,.136,.0952,.0757,.0548,.0484,.0445,.044,.0446,.0455,.0479,.05
2 11/
  END
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APPENDIX B

SAMPLE PROBLEMS

```
   SAMPLE PROBLEM 001. AIR SCATTERING INTO COLLIMATED DETECTOR
   CONTROL       3    16     4     2     2     1     2    13     1     1     1     1    -0    -0    -0    -0

X OR      R  3.0720E+02  3.3528E+02  3.6576E+02  3.9624E+02  4.4196E+02  4.8768E+02  5.3340E+02  5.7912E+02
             6.4008E+02  7.0104E+02  7.6200E+02  8.2296E+02  8.8392E+02  9.7536E+02  1.2000E+03  1.5000E+03
             2.0000E+03

Y OR    PHI  0.          7.8539E-01  1.5708E+00  2.3562E+00  3.1416E+00

Z OR THETA   0.          8.7266E-02  1.7453E-01

X OR      R  3.2124E+02  3.5052E+02  3.8100E+02  4.1910E+02  4.6482E+02  5.1054E+02  5.5626E+02  6.0960E+02
             6.7056E+02  7.3152E+02  7.9248E+02  8.5344E+02  9.2964E+02  1.0877E+03  1.3500E+03  1.7500E+03

Y OR    PHI  3.9269E-01  1.1781E+00  1.9635E+00  2.7489E+00

Z OR THETA   4.3633E-02  1.3090E-01

       F(L)  2.8996E+06  3.7473E+06  4.4269E+06  8.0384E+06  9.8861E+06  1.1925E+07  1.4159E+07  2.2672E+07
             2.7430E+07  3.2640E+07  3.8303E+07  4.4420E+07  7.9089E+07  2.6670E+08  5.4900E+08  1.5417E+09

       F(M)  7.8539E-01  7.8541E-01  7.8540E-01  7.8539E-01

       F(N)  3.8053E-03  1.1386E-02


    SAMPLE PROBLEM 001. AIR SCATTERING INTO COLLIMATED DETECTOR
  ZONE   BNDS   COMP   BND1   PK1  BND2   PK2  BND3   PK3  BND4   PK4  BND5   PK5  BND6   PK6

    1     -1      1     -1     -0


     SAMPLE PROBLEM 001. AIR SCATTERING INTO COLLIMATED DETECTOR
  BND    EQ       A          B          C          X0         Y0         Z0          K

   1      4  -0.        -0.        -0.        -0.        -0.        -0.        -1.0000E+03
```

SAMPLE PROBLEM 001, AIR SCATTERING INTO COLLIMATED DETECTOR

COMP	MAT.	1	2
		N	O
A		1.4007E+01	1.5999E+01
1		9.5625E-04	2.9375E-04

ZONE	BOUNDARY	DISTANCE	X	Y	Z
1	0	6.6137E+02	3.0436E+02	8.1077E-03	9.1350E+02

SAMPLE PROBLEM 001, AIR SCATTERING INTO COLLIMATED DETECTOR

1	X= 0.	Y= 0.	Z= 0.
SOURCE	X= 3.0480E+02	Y= 0.	Z= 9.1440E+02

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	1.1700E+00	3.7000E+16	6.4037E+03	6.4563E+03	1.2614E+01	1.2852E+01	6.4165E+03	1
2	1.3300E+00	3.7000E+16	7.1243E+03	7.1740E+03	1.2670E+01	1.2886E+01	7.1372E+03	2
TOTALS			1.3528E+04	1.3630E+04	2.5284E+01	2.5738E+01	1.3554E+04	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	2.1911E+00	2.4547E+00	7
8	3.0000E-01	5.9580E-07	1.6182E+00	1.6783E+00	8
9	4.0000E-01	8.1480E-07	1.4951E+00	1.5258E+00	9
10	5.0000E-01	1.0215E-06	1.9345E+00	1.9597E+00	10
11	6.0000E-01	1.2222E-06	6.5798E+00	6.6235E+00	11
12	8.0000E-01	1.5928E-06	7.9663E+00	7.9910E+00	12
13	1.0000E+00	1.9230E-06	3.4990E+00	3.5051E+00	13
14	1.5000E+00	2.6520E-06	0.	0.	14

CP TIME FOR THIS DETECTOR POINT WAS .844
.844 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE

CONTROL	3	19	1	1	2	1	1	14	1	1	1	1	-0	-0	-0	-0

X OR R	0.	5.0000E+01	1.0000E+02	2.0000E+02	3.0000E+02	4.5000E+02	6.0000E+02	9.0000E+02
	1.2000E+03	1.5000E+03	1.8000E+03	2.1000E+03	2.5000E+03	3.0000E+03	3.5000E+03	4.0000E+03
	5.0000E+03	6.0000E+03	7.0000E+03	8.0000E+03				
Y OR PHI	0.	6.2832E+00						
Z OR THETA	0.	1.7453E-02						
X OR R	2.5000E+01	7.5000E+01	1.5000E+02	2.5000E+02	3.7500E+02	5.2500E+02	7.5000E+02	1.0500E+03
	1.3500E+03	1.6500E+03	1.9500E+03	2.3000E+03	2.7500E+03	3.2500E+03	3.7500E+03	4.5000E+03
	5.5000E+03	6.5000E+03	7.5000E+03					
Y OR PHI	3.1416E+00							
Z OR THETA	8.7265E-03							
F(L)	4.1667E+04	2.9167E+05	2.3333E+06	6.3333E+06	2.1375E+07	4.1625E+07	1.7100E+08	3.3300E+08
	5.4900E+08	8.1900E+08	1.1430E+09	2.1213E+09	3.7917E+09	5.2917E+09	7.0417E+09	2.0333E+10
	3.0333E+10	4.2333E+10	5.6333E+10					
F(M)	6.2832E+00							
F(N)	1.5230E-04							

SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE

ZONE	BNDS	COMP	BND1	PK1	BND2	PK2	BND3	PK3	BND4	PK4	BND5	PK5	BND6	PK6
1	-1	1	-1	-0										

SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE

BND	EQ	A	B	C	X0	Y0	Z0	K
1	4	-0.	-0.	-0.	-0.	-0.	-0.	-1.0000E+03

SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE

COMP	MAT.	1	2
		N	O
A		1.4007E+01	1.5999E+01
1		9.5625E-04	2.9406E-04

SAMPLE PROBLEM 002, AIR SCATTERING FROM COLLIMATED SOURCE

1	X=	7.6200E+01	Y=	0.	Z=	1.3198E+02
SOURCE	X=	0.	Y=	0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	1.4598E-07	1.4599E-07	1.5452E-13	1.5476E-13	1.4598E-07	1
TOTALS			1.4598E-07	1.4599E-07	1.5452E-13	1.5476E-13	1.4598E-07	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	7.5078E-15	7.7185E-15	7
8	3.0000E-01	5.9580E-07	2.4645E-14	2.4653E-14	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	4.3919E-14	4.3925E-14	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	7.8451E-14	7.8464E-14	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .186
1.030 SECONDS EXECUTION CP TIME SO FAR.

2	X=	1.5240E+02	Y=	0.	Z=	2.6396E+02
SOURCE	X=	0.	Y=	0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	3.6187E-08	3.6200E-08	7.2720E-14	7.2972E-14	3.6187E-08	1
TOTALS			3.6187E-08	3.6200E-08	7.2720E-14	7.2972E-14	3.6187E-08	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	6.9238E-15	7.1346E-15	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	9.7757E-15	9.7837E-15	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	2.1679E-14	2.1691E-14	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	3.4341E-14	3.4363E-14	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .084
1.114 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002. AIR SCATTERING FROM COLLIMATED SOURCE

3	X= 3.0400E+02	Y= 0.	Z= 5.2793E+02
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	8.9062E-09	8.9189E-09	3.4143E-14	3.4424E-14	8.9062E-09	1
TOTALS			8.9062E-09	8.9189E-09	3.4143E-14	3.4424E-14	8.9062E-09	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	3.2098E-15	3.4133E-15	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	3.1422E-15	3.1534E-15	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	6.1131E-15	6.1266E-15	11
12	8.0000E-01	1.5928E-06	5.8838E-15	5.8961E-15	12
13	1.0000E+00	1.9230E-06	1.5794E-14	1.5834E-14	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .090
1.204 SECONDS EXECUTION CP TIME SO FAR.

4	X= 6.0960E+02	Y= 0.	Z= 1.0559E+03
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	2.1494E-09	2.1616E-09	1.5720E-14	1.6049E-14	2.1494E-09	1
TOTALS			2.1494E-09	2.1616E-09	1.5720E-14	1.6049E-14	2.1494E-09	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	7.9528E-16	9.6479E-16	7
8	3.0000E-01	5.9580E-07	6.5907E-16	6.7708E-16	8
9	4.0000E-01	8.1480E-07	1.4631E-15	1.4839E-15	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	2.8738E-15	2.8991E-15	11
12	8.0000E-01	1.5928E-06	4.3656E-15	4.4028E-15	12
13	1.0000E+00	1.9230E-06	5.5636E-15	5.6217E-15	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .088
1.292 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002. AIR SCATTERING FROM COLLIMATED SOURCE

5	X=	9.9060E+02	Y= 0.	Z=	1.7158E+03
SOURCE	X=	0.	Y= 0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	7.8020E-10	7.9162E-10	8.9201E-15	9.2965E-15	7.8021E-10	1
TOTALS			7.8020E-10	7.9162E-10	8.9201E-15	9.2965E-15	7.8021E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	6.1101E-16	7.6925E-16	7
8	3.0000E-01	5.9580E-07	3.3874E-16	3.5609E-16	8
9	4.0000E-01	8.1480E-07	5.5477E-16	5.7396E-16	9
10	5.0000E-01	1.0215E-06	8.5591E-16	8.7736E-16	10
11	6.0000E-01	1.2222E-06	1.2079E-15	1.2338E-15	11
12	8.0000E-01	1.5928E-06	1.5483E-15	1.5821E-15	12
13	1.0000E+00	1.9230E-06	3.8035E-15	3.9040E-15	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .088
1.380 SECONDS EXECUTION CP TIME SO FAR.

6	X=	1.5240E+03	Y= 0.	Z=	2.6396E+03
SOURCE	X=	0.	Y= 0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	3.1064E-10	3.2113E-10	5.2173E-15	5.6394E-15	3.1064E-10	1
TOTALS			3.1064E-10	3.2113E-10	5.2173E-15	5.6394E-15	3.1064E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	2.3355E-16	3.4691E-16	7
8	3.0000E-01	5.9580E-07	4.3573E-16	4.8521E-16	8
9	4.0000E-01	8.1480E-07	3.5482E-16	3.7844E-16	9
10	5.0000E-01	1.0215E-06	3.6385E-16	3.8358E-16	10
11	6.0000E-01	1.2222E-06	4.5312E-16	4.7571E-16	11
12	8.0000E-01	1.5928E-06	1.1684E-15	1.2250E-15	12
13	1.0000E+00	1.9230E-06	2.2098E-15	2.3445E-15	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .090
1.470 SECONDS EXECUTION CP TIME SO FAR.

```
SAMPLE PROBLEM 002A. AIR SCATTERING FROM COLLIMATED SOURCE. RANGE CHECK
CONTROL      3   12    1    1    2    1    1   14    1    1    1    1   -0   -0   -0   -0

X OR       R  8.0000E+03  9.0000E+03  1.0000E+04  1.1000E+04  1.2000E+04  1.3000E+04  1.4000E+04  1.5000E+04
              1.6000E+04  1.7000E+04  1.8000E+04  1.9000E+04  2.0000E+04

Y OR     PHI  0.          6.2832E+00

Z OR   THETA  0.          1.7453E-02

X OR       R  8.5000E+03  9.5000E+03  1.0500E+04  1.1500E+04  1.2500E+04  1.3500E+04  1.4500E+04  1.5500E+04
              1.6500E+04  1.7500E+04  1.8500E+04  1.9500E+04

Y OR     PHI  3.1416E+00

Z OR   THETA  8.7265E-03

        F(L)  7.2333E+10  9.0333E+10  1.1033E+11  1.3233E+11  1.5633E+11  1.8233E+11  2.1033E+11  2.4033E+11
              2.7233E+11  3.0633E+11  3.4233E+11  3.8033E+11

        F(M)  6.2832E+00

        F(N)  1.5230E-04


SAMPLE PROBLEM 002A. AIR SCATTERING FROM COLLIMATED SOURCE. RANGE CHECK
ZONE  BNDS  COMP  BND1  PK1  BND2  PK2  BND3  PK3  BND4  PK4  BND5  PK5  BND6  PK6

  1    -1     1    -1   -0


SAMPLE PROBLEM 002A. AIR SCATTERING FROM COLLIMATED SOURCE. RANGE CHECK
BND   EQ      A          B          C          X0         Y0         Z0         K

  1    4  -0.        -0.        -0.        -0.        -0.        -0.        -1.0000E+03


SAMPLE PROBLEM 002A. AIR SCATTERING FROM COLLIMATED SOURCE. RANGE CHECK
COMP    MAT.     1           2
                 N           O
   A       1.4007E+01  1.5999E+01
  1        9.5625E-06  2.9406E-04
```

SAMPLE PROBLEM 002A. AIR SCATTERING FROM COLLIMATED SOURCE, RANGE CHECK

1	X=	7.6200E+01	Y= 0.	Z=	1.3198E+02
SOURCE	X=	0.	Y= 0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	1.4598E-07	1.4599E-07	5.7587E-18	3.0692E-17	1.4598E-07	1
TOTALS			1.4598E-07	1.4599E-07	5.7587E-18	3.0692E-17	1.4598E-07	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	5.7587E-18	3.0692E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .154
1.624 SECONDS EXECUTION CP TIME SO FAR.

2	X=	1.5240E+02	Y= 0.	Z=	2.6396E+02
SOURCE	X=	0.	Y= 0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	3.6187E-08	3.6200E-08	6.0279E-18	3.1716E-17	3.6187E-08	1
TOTALS			3.6187E-08	3.6200E-08	6.0279E-18	3.1716E-17	3.6187E-08	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	6.0279E-18	3.1716E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .076
1.700 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002A, AIR SCATTERING FROM COLLIMATED SOURCE, RANGE CHECK

3	X= 3.0400E+02	Y= 0.	Z= 5.2793E+02
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	8.9062E-09	8.9189E-09	6.6091E-18	3.3874E-17	8.9062E-09	1
TOTALS			8.9062E-09	8.9189E-09	6.6091E-18	3.3874E-17	8.9062E-09	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	6.6091E-18	3.3874E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .070
1.770 SECONDS EXECUTION CP TIME SO FAR.

4	X= 6.0960E+02	Y= 0.	Z= 1.0559E+03
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	2.1494E-09	2.1616E-09	7.9662E-18	3.8661E-17	2.1494E-09	1
TOTALS			2.1494E-09	2.1616E-09	7.9662E-18	3.8661E-17	2.1494E-09	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	7.9662E-18	3.8661E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .066
1.836 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002A, AIR SCATTERING FROM COLLIMATED SOURCE, RANGE CHECK

5	X=	9.9060E+02	Y=	0.	Z=	1.7158E+03
SOURCE	X=	0.	Y=	0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	7.8020E-10	7.9162E-10	1.0111E-17	4.5643E-17	7.8020E-10	1
TOTALS			7.8020E-10	7.9162E-10	1.0111E-17	4.5643E-17	7.8020E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	1.0111E-17	4.5643E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .068
1.904 SECONDS EXECUTION CP TIME SO FAR.

6	X=	1.5240E+03	Y=	0.	Z=	2.6396E+03
SOURCE	X=	0.	Y=	0.	Z=	0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	3.1064E-10	3.2113E-10	1.4233E-17	5.7589E-17	3.1064E-10	1
TOTALS			3.1064E-10	3.2113E-10	1.4233E-17	5.7589E-17	3.1064E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	1.4233E-17	5.7589E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .070
1.974 SECONDS EXECUTION CP TIME SO FAR.

SAMPLE PROBLEM 002A, AIR SCATTERING FROM COLLIMATED SOURCE, RANGE CHECK

5	X= 9.9060E+02	Y= 0.	Z= 1.7158E+03
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	7.8020E-10	7.9162E-10	1.0111E-17	4.5643E-17	7.8020E-10	1
TOTALS			7.8020E-10	7.9162E-10	1.0111E-17	4.5643E-17	7.8020E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	1.0111E-17	4.5643E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .068
1.904 SECONDS EXECUTION CP TIME SO FAR.

6	X= 1.5240E+03	Y= 0.	Z= 2.6396E+03
SOURCE	X= 0.	Y= 0.	Z= 0.

GROUP	ENERGY	SOURCE	MIN DIRECT	MAX DIRECT	MIN SCATTR	MAX SCATTR	MIND+MAXSC	GROUP
1	2.0000E+00	1.3132E+04	3.1064E-10	3.2113E-10	1.4233E-17	5.7589E-17	3.1064E-10	1
TOTALS			3.1064E-10	3.2113E-10	1.4233E-17	5.7589E-17	3.1064E-10	

BIN	LOWER EDGE	FACTOR	MIN SCATTR	MAX SCATTR	BIN
1	0.	1.2950E-07	0.	0.	1
2	5.0000E-02	1.2950E-07	0.	0.	2
3	6.0000E-02	1.1880E-07	0.	0.	3
4	8.0000E-02	1.3000E-07	0.	0.	4
5	1.0000E-01	1.5960E-07	0.	0.	5
6	1.5000E-01	2.5920E-07	0.	0.	6
7	2.0000E-01	3.7080E-07	1.4233E-17	5.7589E-17	7
8	3.0000E-01	5.9580E-07	0.	0.	8
9	4.0000E-01	8.1480E-07	0.	0.	9
10	5.0000E-01	1.0215E-06	0.	0.	10
11	6.0000E-01	1.2222E-06	0.	0.	11
12	8.0000E-01	1.5928E-06	0.	0.	12
13	1.0000E+00	1.9230E-06	0.	0.	13
14	1.5000E+00	2.6520E-06	0.	0.	14
15	2.0000E+00	3.2720E-06	0.	0.	15

CP TIME FOR THIS DETECTOR POINT WAS .070
1.974 SECONDS EXECUTION CP TIME SO FAR.