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PALLAS-2DCY : A CODE FOR DIRECT INTEGRATION OF TRANSPORT EQUATION IN TWO-DIMENSIONAL (R,Z) GEOMETRY

August 1980

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PALLAS-2DCY : A Code for Direct Integration of Transport Equation in Two-Dimensional (R,Z) Geometry

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(Received July 24, 1980)

The PALLAS-2DCY program is the revised version of the old PALLAS-2DCY code which has been designed in 1973 based on a method of direct integration of the Boltzmann transport equation to describe the radiation transport in (r,z) two-dimensional geometry. It has been especially developed for large shielding problems involving the transport of neutrons or photons. The document gives a full description of input and output data, as well as code implementation information and a description of several demonstration problems.

Keywords : Revised PALLAS-2DCY Code, Direct Integration Method, Two-Dimensional (r,z) Geometry, Shielding Problems, Neutron Transport, Photon Transport

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PALLAS-2DCY:
2次元(R,Z)形状における輸送方程式の直接積分コード

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(1980年7月24日受理)

2次元(r, z)形状における放射線輸送を計算するため，ボルツマン輸送方程式を直接積分で解く方法にもとづいて，1973年にPALLAS-2DCYコードが開発されており，本報告はこのコードの改訂版である。本コードは，中性子あるいはγ線の輸送計算のための大きな形状の遮蔽問題を取り扱うために開発されたものである。本報告には，入力データおよび出力データについての十分な記述方法，さらにコードを使用する際の情報や幾つかの例題が記してある。

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1. PROGRAM ABSTRACT

1. Name of Program : PALLAS-2DCY
2. Computer for which designed or operable : FACOM 230/75 and FACOM M-200
3. Nature of physical problem solved : PALLAS-2DCY solves the steady state Boltzmann transport equation in two-dimensional (r,z) geometry. Application is restricted to neutron or photon transport in a fixed-source problem.
4. Method of solution : The method of direct integration of the transport equation is used. in which the equation is integrated along the flight path of particle in the direction of motion at each discrete ordinate direction. Anisotropic scattering is treated precisely using differential scattering cross sections. No iteration and convergence techniques are used for determination of flux.
5. Restriction : About 260K words are required for the total core storage for (55×55) spatial and 28 fixed directional meshes.
6. Typical running time : About 0.0205 sec/spatial mesh/group is required as cpu time on FACOM 230/75.
7. Usual features : Fixed dimensioning is used, so that always 260K core storage is required. Nuclear data for neutron shielding calculation are read in from the PALLAS library tape. Linear attenuation coefficients and pair production coefficients for photon are read in from cards.
8. Machine requirements : Card input, printed output, and scratch data sets may be located on defined external storage device.
9. Language : FORTRAN IV
10. Material available : Input description, source deck for FORTRAN routines and sample problems.

2. Introduction

The PALLAS-2DCY computer programme solves the energy and angular dependent Boltzmann transport equation with general anisotropic scattering in cylindrical geometry. Principal applications are to neutron or gamma-ray transport problems in forward mode. The code is particularly designed and suited to the solution of deep penetration radiation transport problems with external source.

The code has been designed based on a method of direct integration of the transport equation [1)2)], in which the equation is solved by integrating along a flight path of radiation in the direction of motion at each discrete-ordinate angle. The specific features of this method are that (1) the radiation flux is calculated at each energy mesh ($n/cm^2 \cdot sec \cdot (sr) \cdot MeV$) without using any conventional iterative techniques used widely in Sn method for obtaining group flux at each energy group, and (2) the scattering calculations are made directly using the differential scattering cross section for neutron and the Klein-Nishina formula for gamma ray[3)]. Thus a Legendre polynomial expansion approximation used widely in Sn method is not applied to the calculation of radiation scattering. As a result PALLAS-2DCY can provide always positive and physically meaningful angular and scalar fluxes. Besides, (3) no supplementary difference equations are required to obtain a solution to the flux, which makes users free from bothering about choice of such modes as " diamond difference ", " step function " and " weighted difference " equations. By virtue of no usage of average flux, PALLAS-2DCY can be applied to even such problems as violently varied angular and spatial distributions of radiation flux[4)]. In contrast, Two-dimensional Sn codes calculate the transport equation based on the average flux for a cell with each pair of associated cell face fluxes in the five-dimensional finite cells defined in terms of location, direction, and energy phase space variables.

The weak points in the present PALLAS-2DCY code are that (1) it has been written in the fixed dimensioning, which restricts the numbers of energy meshes, material regions, nuclides, angular meshes, spatial meshes to be inputed, and that (2) it is inadequate to deal with a coupled neutron-gamma-ray transport problem because of lack of coupled neutron-gamma nuclear data in the present PALLAS library : The present code can deal with only a neutron or a gamma-ray transport problem. Besides, (3) a subroutine for calculation of neutron monoenergy source problems has not been completed, though gamma-ray monoenergy source problems can be calculated. Since the PALLAS-2DCY calculates the radiation flux based on an assumption of a continuous source energy, a monoenergy source must be dealt with in a special routine. Finally, (4) the present PALLAS-2DCY program is not completed for general use, and for this reason considerable effort should be made for this purpose.

The neutron cross sections required by PALLAS-2DCY are taken from the PALLAS library. On the other hand the gamma-ray cross sections must be prepared by users, in which only linear attenuation coefficients and pair production cross sections may be prepared at all the energy meshes specified by users and gamma-ray scattering cross sections are not required by virtue of direct use of the Klein-Nishina formula.

An analytic first collision source option is not available in the present code. Analytic first collision source options will be available in PALLAS-2DCY-FC code now under development for a variety of source geometries such as a point, line, disk and cylindrical volume sources. The original PALLAS-2DCY code were written for CDC6600 computer in 1973[5] to calculate fast neutron transport in shields. Revisions have been made to the old version so as to calculate thermal neutron and gamma ray transport in shields and also to deal with not only a cylindrical volume source but also various boundary source problems.

3. INFORMATIONS FOR USERS

1) Input Specification

Card 1 Title card PROBLEM (20A4)

Card 2 Control Integers for a PROBLEM

KNDG, KIN, NORF, KTST, MONOE (5I3)

KNDG=1, neutron calculation.
=4, photon calculation.

KIN=0, no effect.
=n, n coupled neutron calculations (data note 1).

NORF=0, reflection boundary condition at the bottom boundary.
>0, no reflection at the bottom boundary.

KTST=0, no effect.
=-1, check of input data read in and no transport calculation.
=1∿3, test calculation up to KTST-th energy mesh.

MONOE=0, no effect.
=10, gamma-ray monoenergy problem (data note 2).

Repeat n times from card 3 if KIN=n>0.

Card 3 JJ, IR, IZ, IUNCL, IFIS, JSAT (6I3)

JJ=number of energy meshes ≤ 25.

IR=number of r-regions ≤ 10.

IZ=number of z-regions ≤ 10.

IUNCL=0.

IFIS=0, source energy spectrum S(E) is read in from cards.
=1, fission spectrum is defined in the program. Do not enter S(E). The fission spectrum is calculated in the program: $S(E)=0.484 \sinh\sqrt{2E}\cdot e^{-E}$ for neutron,
$=14.0 \exp(-1.10E)$ for photon.

JSAT=0, no effect.
=n, calculation starts at n-th energy mesh. Flux calculation up to (n-1)-th energy mesh is omitted.

Card 4 NBND, IBZ1, IBZ2, IBR, LTAP, JOAK, JDTAL (7I3)

NBND=0, cylindrical volume source problem.

=1, point source (data note 3).

=10, boundary flux problem.

IBZ1=z mesh at which top boundary is defined (data note 4).

IBZ2=z mesh at which bottom boundary is defined (data note 4).

IBR=r mesh at which cylindrical surface boundary is defined (data note 4).

LTAP=0, no effect.

=1, boundary fluxes are read in from Tape 22 in which angular fluxes calculated previously have been stored.

JOAK=0, no effect.

=n, print boundary angular fluxes up to n-th energy mesh for check.

JDTAL=0, no effect.

=4, neutron calculation in detailed energy mesh intervals between several MeV and several hundred KeV (data note 5).

Card 5 EMAX, HH, SNORM, RDST (4E10.3)

EMAX=maximum energy in MeV.

HH=0.0 for gamma ray calculation.

=lethargy interval for neutron.

SNORM=source normalization for source volume,

$$\iint S(r,z)\,dr\,dz=\text{SNORM}.$$

RDST=0, no effect.

>0, first radial distance in cm, which is used in the case of NBND=1.

Card 6 MER(n), n=1, IR (10I3)

Number of meshes in n-th radial region (data note 6).

Card 7 RR(n), n=1, IR (8E10.3)

Thickness in cm in n-th radial region.

Card 8 MEZ(n), n=1, IZ (10I3)

Number of meshes in n-th axial region (data note 6).

Card 9 ZZ(n), n=1, IZ (8E10.3)

Thickness in cm in n-th axial region.

Card 10 E(j), j=1, JJ (8E10.3)

Photon energy at j-th energy mesh in MeV. Do not enter them for neutron because neutron energies are defined by an equal lethargy interval:

E(j)=EMAX*EXP((j-1)*HH).

There are five options for Card 11 in accordance with several source problems: Type A is a cylindrical volume source indicated by NBND=0, type B is a point source problem indicated by NBND=1, type C is a top or bottom boundary problem indicated by NBND=10, LTAP=0, IBZ1>0 or IBZ2>1, in which LTAP=0 means that the boundary flux is read in from cards. Type D is also a top or bottom boundary problem indicated by NBND=10, LTAP=1, IBZ1>0 or IBZ2>1, in which LTAP=1 means that the boundary flux is taken from the data stored in a tape. Type E is a cylindrical surface boundary problem indicated by NBND=10, IBR>0.

Type A: NBND=0, the volume source is expressed by

$S(r,z,E)=S(r)*S(z)*S(E)$ $n/cm^3\cdot sec\cdot MeV$.

Card 11-A-1 MSR, MSZ (2I3)

MSR=r-mesh number up to which radial source distribution is read in:

$S(r_n)$ n=1, ---, MSR.

MSZ=z-mesh number up to which axial source distribution is read in:

$S(z_n)$ n=1, ---, MSZ,

Card 11-A-2 RZR, ZZR1, ZZR2 (3E10.3)

RZR=radius of volume source in cm.

ZZR1=top axial distance of cylindrical source in cm.
ZZR2=bottom axial distance of cylindrical source in cm (data note 7).

Card 11-A-3 SR(n), n=1, MSR (8E10.3)
$S(r_n)$, n=1, ---, MSR.

Card 11-A-4 SZ(n), n=1, MSZ (8E10.3)
$S(z_n)$, n=1, ---, MSZ.

Card 11-A-5 SE(j), j=1, JJ (8E10.3)
Source energy spectrum (/MeV) if IFIS=0. Do not enter if IFIS>0.

Type B: NBND=1, a point source option.

Card 11-B-1 MZSC, NSC, LIAG, MZLR (4I3)
MZSC=z-mesh number at which a point source is set.
NSC=z-region number in which a point source is set.
LIAG=radiations are emitted within LIAG-th polar angular mesh.
MZLR=z-mesh number at which the boundary between air and ground is defined for air transport calculation (data note 3).

Card 11-B-2 ZSC (E10.3)
Z distance at which a point source is set.

Card 11-B-3 SE(j), j=1, JJ (8E10.3)
Source spectrum (/MeV) if IFIS=0. Do not enter if IFIS>0.

Type C: NBND=10, LTAP=0, IBR=0, IBZ1>0 or IBZ2>1, the top or bottom boundary flux is expressed by

$$BOUN(\bar{\Omega},r)=S(r,\bar{\Omega})*S(E)\ \ n/cm^2\cdot sr\cdot sec\cdot MeV$$

for $\bar{\Omega}>0$ with respect to Z axis, or

$$BNMZ(\bar{\Omega},r)=S(r,\bar{\Omega})*S(E)\ \ n/cm^2\cdot sr\cdot sec\cdot MeV$$

for $\bar{\Omega}<0$ with respect to Z axis.

Card 11-C-1 LRL, ISOC, ICONT, IXR, IYR (5I3)

LRL=r-mesh number up to which boundary fluxes are read in from cards.

ISOC=0, angular distribution of boundary flux is read in from cards.

=1, isotropic angular distribution is defined in the program.

ICONT=0, radial distribution of boundary flux is read in from cards.

=1, constant radial distribution is assigned in the program.

IXR and IYR; print the boundary fluxes read in at r meshes from IXR through IYR meshes.

Card 11-C-2 SE(j), j=1, JJ (8E10.3)

Source energy spectrum (/MeV) if IFIS=0. Do not enter if IFIS>0.

Card 11-C-3-1 SN(m,ip), ip=ip1, ip2/m=1, LRL (8E10.3)

Angular fluxes at each r mesh up to LRL-th mesh in units of $n/cm^2 \cdot sr \cdot sec \cdot MeV$ if ISOC=ICONT=0.

ip1=1 and ip2=14 for IBZ1>0.

ip1=15 and ip2=28 for IBZ2>0.

Card 11-C-3-2 SN(ip), ip=ip1, ip2 (8E10.3)

Angular fluxes with constant radial distribution if ISOC=0 and ICONT=1.

Card 11-C-3-3 SN(m), m=1, LRL (8E10.3)

Radial distribution with isotropic angular distribution if ISOC=1 and ICONT=0.

Note if ISOC=1 and ICONT=1 do not enter Card 11-C-3.

Type D: NBND=10, LTAP=1, IBR=0, IBZ1>0 or IBZ2>1, the top or bottom boundary flux is taken from the data stored in Tape 22.

Card 11-D-1 LRR, LZZ, LZZ1, LZZ2, LRL, IXR, IYR (7I3)

LRR=total number of r meshes in an old calculation stored in Tape 22.

LZZ=total number of z meshes in an old calculation.

LZZ1=z-mesh number in LZZ meshes at which calculated angular fluxes are picked up for the top boundary fluxes in a new calculation (data note 8).

LZZ2=z-mesh number in LZZ meshes at which calculated fluxes are picked up for the bottom boundary fluxes in a new calculation (data note 8).

LRL=r-mesh number up to which boundary fluxes are defined in a new calculation.

IXR and IYR are the same as defined before.

Card 11-D-2 ROLD(i), i=1, LRR (8E10.3)

R distances in cm at R meshes used in an old calculation.

Type E: NBND=10 and IBR>0, cylindrical surface fluxes are defined at IBR-th radial mesh.

Card 11-E-1 LZL1, LZL2, IXZ, IYZ (4I3)

Boundary fluxes are set at z meshes from LZL2-th through LZL1-th mesh.

Note LZL1>LZL2≥1 (data note 9).

IXZ and IYZ; boundary fluxes are printed at z meshes from IXZ through IYZ-mesh for check.

For LTAP=0,

Card 11-E-2 BOUNR(ip,m), ip=1, IQT/m=LZL2, LZL1 (8E10.3)

Angular distribution at each z mesh in units of $n/cm^2 \cdot sr \cdot sec \cdot MeV$. Repeat from the first through last energy mesh.

For LTAP=1,

Card 11-E-2' LRR, LZZ, LRRL (3I3)

LRR=total number of r meshes in an old calculation.

LZZ=total number of z meshes in an old calculation.

LRRL=r-mesh number in LRR meshes at which calculated angular fluxes are picked up for the surface boundary fluxes in a new calculation (data note 9).

Card 11-E-3' ZOLD(n), n=1 LZZ (20I3)

Z distances in cm at Z meshes in an old calculation.

In addition, in the case of IBZ1>0 and/or IBZ2>1 and LTAP=1, top and/or bottom boundary fluxes must be specified by Card 11-D.

Card 12 LTHAL, LCUT (2I3)

LTHAL=0, no effect.

>0, execute thermal group calculation (data note 10).

LCUT=0, no effect.

=n, termination of iterative thermal group calculations.

Note if KNDG≥3 do not enter this card.

Card 13 EPSRN (E10.3)

Convergence criterion. Do not enter this card if KNDG≥3.

Card 14 NOEL(i,j), j=1, IR/i=1, IZ (10I3)

Number of Nuclides in each material region (data note 11).

Maximum number of nuclides in all the regions of a problem = 16 (fixed).

Card 15 NEK(i,j), j=1 IR/i=1, IZ (10I3)

Numbers of material identification (data note 12).

The input data described below are for nuclear data read in repeatedly every material.

Card 16 MATERIAL (6A4)

Name of material.

For neutron data (KNDG=1),

Card 17 NUCLID, INPTP (2A4, I5)

NUCLID=symbol of nuclide.

INPTP=0, nuclear data are read in from PALLAS library.

>0, nuclear data are read in from cards.

In the case of INPTP=0,

Card 18 MATNO, AMAS, AN(NUC), ICH (I5, 2E10.3, I3)

MATNO=material number (4 digits given in Table 3).

AMAS=mass of nuclide.

AN(NUC)=nuclear density ($\times 10^{24}$).

ICH=0, no effect.

>0, $\sigma_t(E_j)$ and $\sigma_{el}(E_j)$ are read in from cards, by which the data of total and elastic scattering read in from the library are replaced.

In the case of ICH>0,

Card 19 SIGT(j), j=1, JJ (8E10.3)

$\sigma_t(E_j)$, microscopic total cross section at energy E_j (barn).

Card 20 SIGMA(j), j=1, JJ (8E10.3)

$\sigma_{el}(E_j)$, microscopic elastic scattering cross section at E_j (barn).

In the case of INPTP>0,

Card 18 AMAS, AN(NUC) (2E10.3)

Card 19 SIGT(j), j=1, JJ (8E10.3)

Card 20 SIGMA(j), j=1, JJ (8E10.3)

Card 21 LL, JLL (2I3)

LL=order of Legendre polynomial expansion.

JLL=energy-mesh number up to which Legendre expansion coefficients are read in.

Card 22 FMU(j,ℓ),ℓ=1, LL/j=1, JLL (8E10.3)

Legendre expansion coefficient; $f_\ell(E_j)$ (data note 13).

Card 23 INEL (I3)

INEL=0, neither inelastic scattering nor (n,2n) data are read in.

>0, inelastic scattering and/or (n,2n) data are read in.

For INEL>0,

Card 24 JIN, J2N (2I3)

JIN=0, no inelastic scattering data.

=n, inelastic scattering data are read in from cards up to n-th energy mesh;

$\sigma_{in}(E_k, E_j)$, k=1, ---, n/j=1, ---JJ.

J2N=0, no (n,2n) data.

=n, (n,2n) data are read in from cards up to n-th energy mesh;

$\sigma_{n,2n}(E_k, E_j)$, k=1, ---, n/j=1, ---JJ.

Card 25 SN(k,j), k=1, J2N/j=1, JJ (8E10.3)

Slowing down cross section from E_k to E_j energy per MeV due to (n,2n) reaction. Isotropic scattering in the laboratory system is assumed. If J2N=0, do not enter them (data note 14).

Card 26 CIB(k,j), k=1, JIN/j=1, JJ (8E10.3)

Slowing down cross section from E_k to E_j per MeV due to inelastic scattering. Isotropic scattering in the laboratory system is assumed. If JIN=0, do not enter them.

For photon data (KNDG=4).

Card 17 EDN(N1, N2) (E10.3)

Electron density ($\times 10^{24}$) in (N1, N2)-th material region.

Card 18 CRT(N1, N2, j), j=1, JJ (8E10.3)

Linear attenuation coefficient (cm^{-1}) at gamma-ray energy E_j in (N1, N2)-th material region (data note 15).

Card 19 SIGMA(j), j=1, JJ (8E10.3)

Linear pair production coefficient (cm^{-1}) at gamma-ray energy E_j in (N1, N2)-th material region.

Input data specifying external data and output.

Card-01 ITP20, ITP21, KANK, ISKIP, ITP24, ITP29 (6I3)

ITP20=0, no effect.

=J, calculation starts using the old calculated data stored in Tape 20.

ITP21=0, no effect.

= 1, calculated angular fluxes are stored in Tape 21.

KANK=0, no effect.

=1 or 2, if ITP20>0 (data note 16).

ISKIP=0, no effect.

=k, skip k groups from the first group when reading the old data from Tape 20.

ITP24=0, no effect.

=1, calculated reaction rates (or dose rates) are stored in Tape 24.

ITP29=0, no effect.

=1, calculated scalar fluxes are stored in Tape 29.

Card-02 MRK, MZK, MDS, MZDS, IEF, NOR1, NOR2, NOZ1, NOZ2 (9I3)

MRK=0, no angular fluxes are printed.

>0, number of r meshes at which angular fluxes are printed.

MZK=0, no angular fluxes are printed.

>0, number of z meshes at which angular fluxes are printed.

MDS=0, no reaction rates are calculated.

=n, n reaction rates are calculated (maximum number is 15).

MZDS=0, no effect.

>0, currents at MZDS-th z mesh for +z direction and -z direction are printed at all radial meshes.

IEF=0, angular and scalar fluxes are printed in units of $n/cm^2 \cdot sec(sr)MeV$.

=1, energy angular and scalar fluxes are printed in units of $MeV/cm^2 \cdot sec(sr)MeV$.

NOR1=NOR2=NOZ1=NOZ2=0, all the calculated scalar fluxes are printed.

NOR1>0, NOR2>0, NOZ1>0, NOZ2>0, scalar fluxes are printed at r meshes from NOR1-th through NOR2-th and at z meshes from NOZ1-th through NOZ2-th (data note 17).

Card-03 KR(n), n=1, MRK (20I3)

Radial mesh numbers at which angular fluxes are printed if MRK and MZK >0 (data note 18).

Card-04 KZ(n), n=1 MZK (20I3)

Axial mesh numbers at which angular fluxes are printed if MRK and MZK >0 (data note 18).

Card-05 REACT (20A4)

Name of reaction in n-th reaction (or dose rate, for instance mrem/h (data note 19).

Card-06 DOSE(j,n), j=1, JJ (8E10.3)

Reaction cross section (or dose rate conversion factor) at energy E_j in n-th reaction (data note 20).

2) Detailed data notes

(1) Data note 1

The PALLAS neutron transport calculations are usually made based on the nuclear data from the PALLAS library, in which the energy mesh structures are defined depending upon the lethargy width as shown in Table 1. The structure of 0.1 lethargy width is generally used for neutron transport calculations by one-dimensional PALLAS code. For energy structures used in PALLAS two-dimensional neutron calculations, the structure of 0.2 lethargy width is recommended for the energy range of MeV because of a steep gradient in the shape of energy spectrum compared with 1/E. Then the structure of 0.4 lethargy width is used for calculation in the intermediate energy range and the 0.8 lethargy-width structure is used in the low energy range including thermal group. Other combinations of structures can be utilized, for instance the 0.4+0.8 lethargy-width structures or only the 0.8 lethargy-width structure. It should be desirable from the viewpoint of accuracy of calculated result to use the combination of 0.2+0.4+0.8 lethargy-width structures. We present an example of the accuracy of a neutron transport calculation in water. The neutron fluxes in the intermediate and low energy regions including thermal group calculated with the 0.8 lethargy-width structure of 23 energy meshes are underestimated by a factor of approximately 2 compared with those by the combination of the 0.2+0.4+0.8 lethargy-width structures of total 40 energy meshes shown in Fig. 1.

When one uses the series calculation of lethargy-width structures, one should input an integer of 1 or 2 into the KIN; in the case of KIN=2, the structures of 0.2+0.4+0.8 lethargy widths are used, while in the case of KIN=1, the structures of 0.2+0.4 or 0.4+0.8 lethargy widths are used. Concrete examples of combinations in energy-mesh structure are shown in Fig. 1. As seen in the figure the calculated angular fluxes at energy meshes of odd numbers are picked up for use in the next calculation in a series calculation.

(2) Data note 2

Since the PALLAS calculation is made based on the continuous source energy distribution for the purpose of avoiding iterative calculation, it is inevitable to use a special treatment in the calculation of discrete-energy source problems. Thus in the case of a mono-energy source problem one should input as MONOE>0. This routine has not been completed for a neutron monoenergy source in the present code.

(3) Data note 3

As shown in Fig.2 a point monoenergy photon source or a point continuous-energy neutron or photon source is set on a ground surface or at a certain height in air (ZSC cm).

(4) Data note 4

The top, bottom and cylindrical surface boundary conditions are defined as illustrated in Fig.3. In the case of only a top boundary problem, one may input MZZ>IBZ1>0 and IBZ2=IBR=0. In the case of only a bottom boundary problem, one may input MZZ>IBZ2>0 and IBZ2=IBR=0. In the case of only a cylindrical surface problem, one may input MRR>IBR>0 and IBZ1=IBZ2=0. In the case of a top and bottom and cylindrical surface problem, one may input MZZ>IBZ1>IBZ2>0 and MRR>IBR>0. Here MRR and MZZ are respectively the maximum numbers of r and z spatial meshes.

(5) Data note 5

The neutron spectrum becomes to show abrupt increase in the energy region between several MeV and several hundred KeV with increasing penetration distances in heavy materials such as iron. PALLAS calculation with the 0.2 lethargy interval structure, however, underestimates the energy spectrum in this energy region at penetration distances beyond 30cm in an iron shield. This is attributed to the use of too rough lethargy interval compared with that of maximum neutron slowing down in a single elastic scattering. To overcome this difficulty 0.05 lethargy intervals should be desirable in this energy region. Then the 0.2 lethargy interval can be divided equally into four sub-intervals. This may be said to be four iterative calculations in this energy region. If one wants to make the detailed energy mesh calculation for a neutron transport problem with thick heavy materials, one may specify 4 for JDTAL.

(6) Data note 6

An equall spatial mesh interval is defined in each spatial region: n-th radial thickness divided by (MER(n)-1) itervals gives the equal radial mesh interval in n-th region except for first radial region in which its thickness is divided by MER(1) intervals because of no radial mesh assignment at r=0 cm. In PALLAS spatial mesh assignment, two meshes must be assigned at every inner boundary as illustrated in Fig.4.

(7) Data note 7

As depicted in Fig.5 the radius and positions of top and bottom of the cylindrical volume source are specified by input data.

(8) Data note 8

As shown in Fig.6 the angular fluxes calculated previously are picked up at all the radial meshes from first through LRR-th at LZZ1-th z mesh in an old calculation. These fluxes will be used for top boundary fluxes at IBZ1-th z mesh in a new calculation. Since the positions of radial meshes in a new calculation are not necessarily identical with those of an old calculation, the top boundary fluxes will be determined for radial meshes from first through LRL-th in a new calculation by a linear interpolation.

(9) Data note 9

For cylindrical surface boundary fluxes the angular fluxes calculated previously are picked up at all the axial meshes from first through LZZ-th at LRRL-th r mesh in an old calculation. These fluxes will be used for the surface boundary fluxes at axial meshes from LZL2-th through LZL1-th at IBR-th radial mesh as depicted in Fig.7. Since the positions of axial meshes are not necessarily identical in between an old and a new calculations, the surface boundary fluxes will be calculated for axial meshes from LZL2-th through LZL1-th in a new calculation by a log-linear interpolation.

(10) Data note 10

It is inevitable for the thermal neutron flux calculation to use the conventional group calculation using an iteration-convergence technique. For only the case of neutron thermal flux calculation LTHAL has a value larger than zero.

The iterative calculations continue until the following convergence criterion is satisfied for all the spatial meshes defined in a problem:

$$\mathrm{Max}\left\{ \frac{\phi^{n}(\bar{r}) - \phi^{n-1}(\bar{r})}{\phi^{n}(\bar{r})} \right\} < \mathrm{EPSRN},$$

where $\phi^{n}(\bar{r})$ is the scalar flux in n-th iteration.

(11) Data note 11

One of characteristics in the method used in PALLAS code is to deal with as precisely as possible radiation scattering calculations. For this purpose PALLAS executes the scattering calculation for each nuclide. Then one must specify the number of nuclides in each material region. As an ideal way the number of all nuclides included in each material should be specified, which however is not realistic from the point of view of computation time. One of practical ways is to choose the number of main nuclides which contribute considerably to the value of total cross section in each material region. In this limitation the other unimportant nuclides should be assigned to the main nuclides regarding nuclear density.

For instance, atomic compositions of concrete are assumed to be that Si; 0.0141($\times 10^{24}$), Al; 0.00295, Fe; 0.000764, Ca; 0.00294, Mg; 0.000483, Na; 0.000882, H; 0.01223, O; 0.0435. As the input for PALLAS one may chose H, O, Si, Ca and Al as main nuclides in the concrete and use Al and Ca in replacement of respectively Na, Mg and Fe, which results in nuclear densities of 0.01223, 0.0435, 0.004315, 0.0141 and 0.003704 for H, O, Al, Si and Ca, respectively. Note that the order of nuclides to be inputed is that of identification numbers of the PALLAS library given in Table 2.

(12) Data note 12

All the material regions are numbered as illustrated in Fig. 8. In principle at first the numbers 1, 2, ---, 10 are set for (r=1, z=1)-th region, (2,1)-th, ---, (10,1)-th region, and 11, 12, ---, 20 are set for (1,2)-th (2,2)-th, ---, (10,2)-th region, and so on. When the same materials are repeatedly specified in material regions, their identification numbers are replaced by those of the previous same materials as shown in fig. 8.

(13) Data note 13

PALLAS code calculates neutron elastic scattering source using the neutron differential scattering cross section. The neutron differential scattering cross section is calculated in the program based on the data of Legendre expansion coefficients $f_\ell(E_j)$ given in evaluated nuclear data files such as ENDF/B: First, the scattering distribution function $f(E,\mu)$ is calculated by

$$f(E,\mu) = \sum_{\ell=0}^{L} \frac{2\ell+1}{4\pi} f_\ell(E) P_\ell(\mu),$$

where μ is the value of cosine of scattering angle in the center of mass system and L the maximum order given in an evaluated nuclear data file. The maximum number of terms (L_{max}=L+1) is given in Table 3 for each nuclide included in PALLAS library. Then the differential scattering cross section is calculated by

$$\sigma_{el}(\bar{\Omega}'\to\bar{\Omega},E'\to E) = \sigma_{el}(E')f(E',\mu)\delta(\cos\theta-\alpha)\ \frac{(A+1)^2}{2AE'},$$

where $\sigma_{el}(E)$ is the total elastic scattering cross section, θ and α are respectively the scattering angle and its cosine in the laboratory system, and A the mass of nuclide.

(14) Data note 14

Since the neutrons emitted from (n,2n) reaction are twice as many as the incident neutrons, the value of each element in the matrix SN(k,j) is doubled in the program and added to the matrix CIB(k,j).

(15) Data not 15

The gamma-ray nuclear data for PALLAS are used as the linear attenuation coefficient of a material. The data of the linear attenuation coefficient may be taken from reports on photon cross sections such as J.H. Hubbell's compiled data[6], which are given in appendix. The scattering cross section should not be entered, because PALLAS can calculate the gamma ray scattering source by directly use of the Klein-Nishina formula: The comptom scattering source $Q(\bar{r},\bar{\Omega},\lambda)$ is calculated by

$$Q(\bar{r},\bar{\Omega},\lambda) = \int\int n(\bar{r})\ \frac{K(\lambda',\lambda)}{2\pi}\ \delta(1+\lambda'-\lambda-\mu)\ \times\ I(\bar{r},\bar{\Omega}',\lambda')d\bar{\Omega}'d\lambda',$$

where λ is the compton wavelength, given by

$$\lambda = \frac{m_0C^2}{E(\text{MeV})} = \frac{0.511}{E}$$

and m_0C^2 is the electron rest mass energy. Further, $n(\bar{r})$ is the electron density, μ the cosine of scattering angle, $K(\lambda',\lambda)$ and

$I(\bar{r},\bar{\Omega}',\lambda')$ are respectively the scattering kernel derived from Klein-Nishina formula and the energy flux. The relation between the scattering kernel and the Klein-Nishina formula is given by

$$\frac{d\sigma}{d\Omega} \equiv \frac{3}{16\pi}\sigma_T\left(\frac{\lambda'}{\lambda}\right)^2 \left[(\lambda'-\lambda)^2+2(\lambda'-\lambda)+\frac{\lambda'}{\lambda}+\frac{\lambda}{\lambda'}\right]$$

$$= \frac{1}{2\pi}\left(\frac{\lambda'}{\lambda}\right)K(\lambda',\lambda).$$

Then

$$K(\lambda',\lambda) = \frac{3}{8}\sigma_T\left(\frac{\lambda'}{\lambda}\right)\left[(\lambda'-\lambda)^2+2(\lambda'-\lambda)+\frac{\lambda'}{\lambda}+\frac{\lambda}{\lambda'}\right],$$

where

$$\sigma_T = \frac{8\pi}{3}\left(\frac{e^2}{m_0C^2}\right) = 0.665 \text{ barn}.$$

(16) Data note 16

The parameter KANK is used together with ITP20. Consequently, prior to this use the angular fluxes calculated in advance should be stored in Tape 20. In the case of KANK=1, the angular fluxes stored in Tape 20 are transferred one by one in energy mesh into Disk 10. Let the total energy meshes in the previous calculation be JJ', then the next calculation will start at J(=JJ'+1)-th energy mesh. On the other hand in the case of KANK=2, the coupled neutron calculation explained in Data note 1 is made using Tape 20: For instance first calculation was made with the 0.2 lethargy-width structure and then stored in Tape 20. The angular fluxes stored in Tape 20 are transferred alternatively in energy mesh into Disk 10, i.e. the angular fluxes at energy meshes in odd numbers are transferred into Disk 10. Then the new calculation with the 0.4 lethargy-width structure will start at [(JJ'+3)/2]-th energy mesh, when JJ' is the total number of energy meshes in the previous calculation.

(17) Data note 17

These input data are used for limitation of the output list. If NOR1, NOR2, NOZ1 and NOZ2 are zeros, all the calculated scalar fluxes are printed as an output. If NOR1, NOR2, NOZ1 and NOZ2 >0, the calculated scalar fluxes are printed at spatial meshes with respect to the r meshes from NOR1-th through NOR2-th and with respect to the z meshes from NOZ1-th through NOZ2-th.

(18) Data note 18

If MRK>0 and MZK>0, calculated angular fluxes are printed at the (r,z) spatial meshes defined by combinations of (KR(n), KZ(n)), n=1, 2, ---, i.e. at (r,z) spatial meshes of (KR(1), KZ(1)), (KR(1), KZ(2)), ---, (KR(1), KZ(MZK)), (KR(2), KZ(1)), ---, (KR(2), KZ(MZK)), ---, (KR(MRK), KZ(1)), ---, (KR(MRK), KZ(MZK)).

Note that PALLAS angular flux is printed in units of $n/cm^2 \cdot sec \cdot sr \cdot MeV$ for IEF=0 and $MeV/cm^2 . sec \cdot sr \cdot MeV$ for IEF=1. In addition PALLAS scalar flux is printed in units of $n/cm^2 \cdot sec \cdot MeV$ for IEF=0 and $MeV/cm^2 . sec \cdot MeV$ or $n/cm^2 \cdot sec \cdot unit.$ lethargy for IEF=1. Thermal neutron flux is also printed in units of $n/cm^2 \cdot sec \cdot (sr) \cdot MeV$ for IEF=0. If one wants to obtain thermal neutrons below 0.45 eV or thermal group neutrons below 0.45 eV, one may multiply the thermal neutron flux by 0.45×10^{-6} MeV. On the other hand for IEF=1, thermal neutron flux in units of $n/cm^2 \cdot sec \cdot unit$ lethargy is equall to thermal neutrons below 0.45 eV.in units of $n/cm^2 \cdot sec$.

(19) Data note 19

For the dose rate conversion factor, one may prepare the conversion factor from the scalar flux into the dose rate for both neutron and gamma ray even if the calculation is made with IEF=1.

(20) Data note 20

If one want to obtain a variety of reactions such as $^{56}Fe(n,p)$, $^{103}Rh(n,n')$, $^{115}In(n,n')$, $^{32}S(n,p)$, $^{238}U(n,f)$,

$^{237}Np(n,f)$ and $^{197}Au(n,\gamma)$, the order of the reaction data to be inputed should be $^{197}Au(n,\gamma)$, $^{237}Np(n,f)$, $^{103}Rh(n,n')$, $^{238}U(n,f)$, $^{115}In(n,n')$, $^{32}S(n,p)$ and $^{56}Fe(n,p)$ and the values to be inputed for MDS may be 7, 5 and 2, respectively for the 0.2-, 0.4- and 0.8-lethargy-width calculations.

3) External and internal data files

All files used for input, output and scratch data are given in Table 4.

4) Program mnemonic and program variable

Relation of program variables to program mnemonics is given in Table 5.

5) Sample problems

(1) Sample problem 1: Neutron cylindrical volume source problem with a fission source

The input data for this problem are shown in Fig. 9, in which the numbers, 1 through 54, in both sides represent those of the input data cards. The main parameters are 3 energy meshes, 8 radial material regions, 4 axial material regions, reflection at the bottom boundary, the maximum energy of 14.2 MeV and 0.2 lethargy intervals. The constant distribution is assumed for both the radial and axial directions in the cylindrical volume source, composed of four nuclides. The zero numbers in both NOEL(i,j) and NEK(i,j) mean void regions, which is one of characteristic features in PALLAS code: it should be better to deal with air voids and air ducts as vacuum regions. Consequently no nuclide and no scattering are assumed by inputing zeros into NOEL(i,j) and NEK (i,j) as this example. For the input data specifying external data and output, ITP21=1 means that the calculated angular fluxes are stored in Tape 21, and MRK=MZK=3 means that the calculated angular fluxes are printed at (r,z)-spatial meshes composed of respectively 3 meshes on both radial and axial meshes.

The output list of the calculation is shown in Figs.10-1 through 10-4, in which the angular fluxes are printed at the several (r,z)-meshes defined by the input data and the scalar fluxes are also printed at two energy meshes as an example. The angular fluxes are printed in the order of the angular mesh points shown in Fig.11, i.e. the order is Ω_{11}, Ω_{12}, Ω_{21}, Ω_{22}, Ω_{31}, ---, Ω_{41}, ---, Ω_{51}, ---, Ω_{61}, ---, Ω_{71}, Ω_{72}, Ω_{81}, Ω_{82}. Note that both the angular and scalar fluxes are given in units of $n/cm^2\cdot sec\cdot MeV\cdot(sr)$, which are not in units of $n/cm^2\cdot sec\cdot$group-width used widely in Sn calculations. The dose rate distribution expressed in units of mrem/h is to be printed continuously, which is omitted in this example.

(2) Sample problem 2: Neutron boundary flux problem

The calculated angular fluxes for the sample problem 1 are already stored in Tape 21. This sample problem requires this tape which is set this time at Tape 22. In the input card No.4 as shown in Fig. 12, NBND=10, IBZ1=22, IBZ2=0, IBR=11, LTAP=1, JOAK=3 and JDTAL=0 are specified, which means that this problem is a boundary flux problem with a top boundary defined at 22nd z-mesh and with a cylindrical surface boundary defined at 11th r-mesh. Since NBND=10, IBR>0 and LTAP=1, the E option is selected for Card 11 and LZL1=22, IZL2=1, IXZ=15, IYZ=22 are specified. The next input data are LRR=32, IZZ=42 and LRRL=28, which means that the total radial and axial meshes are respectively 32 and 42 in the sample problem 1 and the angular fluxes at 28-th r mesh are picked up for use as the cylindrical surface boundary fluxes in the sample 2 calculation. Since IBZ1>0 in this problem, then Card 11-D option is selected and LRR=32, IZZ=42, IZZ1=38, LZZ2=0, LRL=11, IXR=1 and IYR=3 are specified, which means that the angular fluxes are picked up at 38-th z mesh in the sample

1 calculation for use as the top boundary fluxes in this calculation.

An example of list of boundary condition is shown in Fig. 13, in which BOUN and BOUNR indicate respectively the top and cylindrical surface boundary fluxes. Since the list is controlled by IXR=1 and IYR=3, the top boundary fluxes are printed at r meshes only from 1st through 3rd. On the other hand for the cylindrical surface boundary fluxes, BOUNR's are printed at z meshes from 15-th through 22nd because of control by IXZ=15 and IYZ=22.

The outputs for this calculation are shown in Figs. 14-1 and 14-2, in which the angular and scalar fluxes are printed at two energy meshes. The zero values in the scalar fluxes printed in Fig.14-1 are due to zero inward angular fluxes at the both boundaries.

(3) Sample problem 3: Monoenergy gamma-ray slant incidence problem

This problem is to calculate gamma-ray albedo for iron, then KNDG=4, NORF=10 and MONOE=10 are specified in Card 2 as shown in Fig. 15-1. In order to calculate this problem with a top boundary condition, NBND=10 and IBZ1=1 are specified in Card 4. The gamma-ray energy meshes are specified in Card 10 through 12 for 20 energy meshes. Since NBND=10, IBR=0, IBZ1>0 and LTAP=0, Type C option is selected and LRL=30, ISOC=0, ICONT=1, IXR=IYR=1 are specified in Card 13. As the angular distribution at the top boundary, the angular fluxes are read in from cards, which are specified in Card 17 through 56 for total 20 energy meshes as shown in Figs.15-1 and 15-2. Since this problem is a 1.0 MeV-monoenergy slant incidence, the incident angular flux is defined only at the 2nd polar angle with the radial direction in azimuthal angle at the first energy mesh. Although double iron slabs with each 5 cm thick are taken in this input, of course one iron slab may be adequate. The electron density of iron is specified in

Card 62 as 2.204($\times 10^{24}$), and zero values are inputed in Card 66 through 68 because of no pair production cross sections below 1 MeV. As the input data specifying output, MRK=2, MZK=1, MDS=2, MZDS=1 are inputed by Card 70, in which MZDS=1 means that the current crossing the plane at the first z mesh is printed.

The several examples of calculated results are illustrated in Figs.16-1 through 16-5. Figure 16-1 shows the angular and scalar fluxes for the incident unscattered gamma rays, while Fig.16-2 illustrates those for the scattered gamma rays at the incident energy. Here EDOS is the value of DOSE(J,JM)$\cdot\Delta$E, which is the conversion factor from the flux per MeV into the integrated flux in ΔE MeV. Figure 16-3 shows the backscattered peak angular and scalar fluxes at 0.2 MeV. The calculated responses are printed in Figs. 16-4 and 16-5, in which 'DOSE DISTRIBUTION JM=1' means the total energy fluxes integrated over energy, while 'DOSE DISTRIBUTION JM=2' means the total number fluxes integrated over energy. In addition, 'DOS(+) and DOS(-)' mean the currents respectively to the direction of +z axis (incident direction in this input) and -z axis (reflection direction in this case) for only JM=2 case. The last part of the list is the prints of the total incident currents and reflected currents crossing over the incident plane as well as the total number albedo.

For reference as an example of practical shielding calculations, a list of input data for an analysis of a neutron streaming experiment is presented in Fig. 17. The zeros in the input data in Card 18 through 27 indicate a cylindrical void in shield. The numbers of reaction rates are respectively 10, 4 and 3 for the 0.2-, 0.4- and 0.8-lethargy width calculations. The numbers of energy meshes are respectively 17, 19 and 23 for the 0.2-, 0.4- and 0.8-lethargy width calculations, which indicates a neutron series calculation by a combination of 0.2, 0.4 and 0.8 lethargy intervals.

6. Other notes

One should not apply the present PALLAS-2DCY to such shielding problems as (1) a monoenergy neutron source already mentioned, (2) radiation air transport (or skyshine) problems from distributed sources or from a point source in shielded container, and (3) radiation streaming through various small gaps. The reason is due to no completed subroutine for the first problem and due to appearance of too large ray effects in the calculations of problems (2) and (3). To mitigate these large ray effects, the first collision source option will be added to PALLAS-2DCY-FC code for a variety of source conditions such as point, line, disk and cylindrical sources.

4. ANGULAR MESH POINTS AND NUCLEAR DATA USED IN PALLAS CODE

1) Angular mesh points

The angular variable $\overline{\Omega}$ is represented by discrete-ordinate directional points $\overline{\Omega}_{pq}$ on a unit sphere, in which $\overline{\Omega}_{pq}=\overline{\Omega}(\theta_p,\phi_{pq})$. The θ is the polar angle and the ϕ is the azimuthal angle. In PALLAS calculation, $\omega\equiv\cos\theta$ is used instead of θ (see Figs. 11 and 18). The values for $\overline{\Omega}_{pq}(\omega_p,\phi_{pq})$ fixed in the present code are given in Table 6 for $p\leq4$, since the angular points are distributed symmetrically with respect to the r axis as shown in Fig. 11. Basically any constants can be used for the PALLAS angular quadrature set. The present constants have been calculated in the following manner: First, the center point in each ω_p-range governed by its weight was chosen as the value for ω_p. Second, the center point in each ϕ_{pq}-range governed by its weight was also chosen as the value for ϕ_{pq}, and then the weight for each Ω_{pq} was determined with multiplying the ω_p-weight by the ϕ_{pq}-weight.

One may use the other angular quadrature sets which are defined under the condition of the total 28 mesh points symmetrical with respect to the r axis.

2) Nuclear data for PALLAS

As already mentioned, PALLAS calculates radiation scattering as precisely as possible. For gamma ray scattering the Klein-Nishina formula is directly utilized so that PALLAS calculated angular flux can represent precisely physical phenomena. Then no gamma-ray scattering data are necessary. Nuclear data for gamma ray to be prepared by users are only linear attenuation coefficient and pair production cross section in units of cm^{-1}. These data may be given at the energy mesh points defined by users, the values of which may be obtained by interpolating the data given in Appendix.

For neutron nuclear data the infinite dilution point energy data have been prepared in PALLAS INF library, in which the total cross sections σ_t, σ_c and σ_{el} at all the energy points written in ENDF/B-IV data file were averaged in the energy intervals defined in Table 1. The weighting function for averaging was the fission + 1/E spectrum. All the Legendre expansion coefficients given in ENDF/B-IV file were used for obtaining those at the energy meshes in PALLAS library defined in Table 1. The inelastic slowing down matrix were prepared with use of SUPERTOG code[7).

The effective cross sections used in practical PALLAS calculations have been prepared in PALLAS EFF library for several nuclides, each of which will be used as a single material. For any mixtures one must determine the self-shielding factor for each nuclide in the mixture and multiply the infinite dilution cross section by the factor to obtain the effective cross section for each nuclide.

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Table 1. Energy mesh structures in PALLAS library for PALLAS-2DCY code. 0.2, 0.4 and 0.8 lethargy-width structures are given.

0.2 LETHARGY WIDTH STRUCTURE

GROUP	ENERGY MESH (EV)	UPPER BOUND. (EV)	LOWER BOUND. (EV)
1	1.4200E+07	1.5693E+07	1.2849E+07
2	1.1626E+07	1.2849E+07	1.0520E+07
3	9.5185E+06	1.0520E+07	8.6127E+06
4	7.7931E+06	8.6127E+06	7.0515E+06
5	6.3805E+06	7.0515E+06	5.7733E+06
6	5.2239E+06	5.7733E+06	4.7268E+06
7	4.2770E+06	4.7268E+06	3.8700E+06
8	3.5017E+06	3.8700E+06	3.1684E+06
9	2.8669E+06	3.1685E+06	2.5941E+06
10	2.3472E+06	2.5941E+06	2.1239E+06
11	1.9218E+06	2.1239E+06	1.7389E+06
12	1.5734E+06	1.7389E+06	1.4237E+06
13	1.2882E+06	1.4237E+06	1.1656E+06
14	1.0547E+06	1.1656E+06	9.5432E+05
15	8.6350E+05	9.5432E+05	7.8133E+05
16	7.0698E+05	7.8133E+05	6.3970E+05
17	5.7882E+05	6.3970E+05	5.2374E+05
18	4.7390E+05	5.2374E+05	4.2880E+05
19	3.8800E+05	4.2880E+05	3.5107E+05
20	3.1767E+05	3.5107E+05	2.8744E+05
21	2.6008E+05	2.8744E+05	2.3533E+05
22	2.1294E+05	2.3533E+05	1.9267E+05
23	1.7434E+05	1.9267E+05	1.5775E+05
24	1.4274E+05	1.5775E+05	1.2915E+05
25	1.1686E+05	1.2915E+05	1.0574E+05
26	9.5679E+04	1.0574E+05	8.6574E+04
27	7.8335E+04	8.6574E+04	7.0881E+04
28	6.4135E+04	7.0881E+04	5.8032E+04
29	5.2510E+04	5.8032E+04	4.7513E+04
30	4.2991E+04	4.7513E+04	3.8900E+04
31	3.5198E+04	3.8900E+04	3.1849E+04
32	2.8818E+04	3.1849E+04	2.6076E+04
33	2.3594E+04	2.6076E+04	2.1349E+04
34	1.9317E+04	2.1349E+04	1.7479E+04
35	1.5816E+04	1.7479E+04	1.4311E+04
36	1.2949E+04	1.4311E+04	1.1717E+04
37	1.0602E+04	1.1717E+04	9.5927E+03
38	8.6798E+03	9.5927E+03	7.8538E+03
39	7.1064E+03	7.8538E+03	6.4301E+03
40	5.8182E+03	6.4302E+03	5.2646E+03
41	4.7636E+03	5.2646E+03	4.3103E+03
42	3.9001E+03	4.3103E+03	3.5289E+03
43	3.1931E+03	3.5289E+03	2.8893E+03
44	2.6143E+03	2.8893E+03	2.3655E+03
45	2.1404E+03	2.3655E+03	1.9367E+03
46	1.7524E+03	1.9367E+03	1.5857E+03
47	1.4348E+03	1.5857E+03	1.2982E+03
48	1.1747E+03	1.2982E+03	1.0629E+03
49	9.6175E+02	1.0629E+03	8.7023E+02
50	7.8741E+02	8.7023E+02	7.1248E+02

Table 1. (continued)

0.4 LETHARGY WIDTH STRUCTURE

GROUP	ENERGY MESH (EV)	UPPER BOUND. (EV)	LOWER BOUND. (EV)
1	1.4200E+07	1.7344E+07	1.1626E+07
2	9.5185E+06	1.1626E+07	7.7931E+06
3	6.3805E+06	7.7931E+06	5.2239E+06
4	4.2770E+06	5.2239E+06	3.5017E+06
5	2.8669E+06	3.5017E+06	2.3472E+06
6	1.9218E+06	2.3472E+06	1.5734E+06
7	1.2882E+06	1.5734E+06	1.0547E+06
8	8.6350E+05	1.0547E+06	7.0698E+05
9	5.7882E+05	7.0698E+05	4.7390E+05
10	3.8800E+05	4.7390E+05	3.1767E+05
11	2.6008E+05	3.1767E+05	2.1294E+05
12	1.7434E+05	2.1294E+05	1.4274E+05
13	1.1686E+05	1.4274E+05	9.5679E+04
14	7.8335E+04	9.5679E+04	6.4136E+04
15	5.2510E+04	6.4135E+04	4.2991E+04
16	3.5198E+04	4.2991E+04	2.8818E+04
17	2.3594E+04	2.8818E+04	1.9317E+04
18	1.5816E+04	1.9317E+04	1.2949E+04
19	1.0602E+04	1.2949E+04	8.6798E+03
20	7.1064E+03	8.6798E+03	5.8182E+03
21	4.7636E+03	5.8182E+03	3.9001E+03
22	3.1931E+03	3.9001E+03	2.6143E+03
23	2.1404E+03	2.6143E+03	1.7524E+03
24	1.4348E+03	1.7524E+03	1.1747E+03
25	9.6175E+02	1.1747E+03	7.8741E+02
26	6.4468E+02	7.8741E+02	5.2782E+02
27	4.3214E+02	5.2782E+02	3.5381E+02
28	2.8967E+02	3.5381E+02	2.3716E+02
29	1.9417E+02	2.3716E+02	1.5898E+02
30	1.3016E+02	1.5898E+02	1.0656E+02
31	8.7248E+01	1.0656E+02	7.1433E+01
32	5.8484E+01	7.1433E+01	4.7883E+01
33	3.9203E+01	4.7883E+01	3.2097E+01
34	2.6279E+01	3.2097E+01	2.1515E+01
35	1.7615E+01	2.1515E+01	1.4422E+01
36	1.1808E+01	1.4422E+01	9.6673E+00
37	7.9150E+00	9.6673E+00	6.4802E+00
38	5.3056E+00	6.4802E+00	4.3438E+00
39	3.5564E+00	4.3438E+00	2.9117E+00
40	2.3839E+00	2.9117E+00	1.9518E+00
41	1.5980E+00	1.9518E+00	1.3083E+00
42	1.0712E+00	1.3083E+00	8.7701E-01
43	7.1804E-01	8.7701E-01	5.8788E-01
44	4.8131E-01	5.8787E-01	3.9406E-01
45	3.2263E-01	3.9407E-01	0.0

Table 1. (continued)

0.8 LETHARGY WIDTH STRUCTURE

GROUP	ENERGY MESH (EV)	UPPER BOUND. (EV)	LOWER BOUND. (EV)
1	1.4200E+07	2.1184E+07	9.5185E+06
2	6.3805E+06	9.5185E+06	4.2770E+06
3	2.8669E+06	4.2770E+06	1.9218E+06
4	1.2882E+06	1.9218E+06	8.6350E+05
5	5.7882E+05	8.6350E+05	3.8800E+05
6	2.6008E+05	3.8800E+05	1.7434E+05
7	1.1686E+05	1.7434E+05	7.8335E+04
8	5.2510E+04	7.8335E+04	3.5198E+04
9	2.3594E+04	3.5198E+04	1.5816E+04
10	1.0602E+04	1.5816E+04	7.1064E+03
11	4.7636E+03	7.1064E+03	3.1931E+03
12	2.1404E+03	3.1931E+03	1.4348E+03
13	9.6175E+02	1.4348E+03	6.4468E+02
14	4.3214E+02	6.4468E+02	2.8967E+02
15	1.9417E+02	2.8967E+02	1.3016E+02
16	8.7248E+01	1.3016E+02	5.8484E+01
17	3.9203E+01	5.8484E+01	2.6279E+01
18	1.7615E+01	2.6279E+01	1.1808E+01
19	7.9149E+00	1.1808E+01	5.3055E+00
20	3.5564E+00	5.3055E+00	2.3839E+00
21	1.5980E+00	2.3839E+00	1.0712E+00
22	7.1804E-01	1.0712E+00	4.8131E-01
23	3.2263E-01	4.8131E-01	0.0

Table 2 Identification numbers of PALLAS library

Nuclide	group width in lethargy							
	Δu=0.1		Δu=0.2		Δu=0.4		Δu=0.8	
	No.	ID No	No.	ID No	No.	ID No	No.	ID No
H-1	1	1011	23	2011	45	4011	67	8011
Li-6	2	1036	24	2036	46	4036	68	8036
Li-7	3	1037	25	2037	47	4037	69	8037
B-10	4	1050	26	2050	48	4050	70	8650
B-11	5	1051	27	2051	49	4051	71	8051
C-12	6	1062	28	2062	50	4062	72	8062
N-14	7	1074	29	2074	51	4074	73	8074
O-16	8	1086	30	2086	52	4086	74	8086
Na	9	1113	31	2113	53	4113	75	8113
Mg	10	1120	32	2120	54	4120	76	8120
Al-27	11	1137	33	2137	55	4137	77	8137
Si	12	1140	34	2140	56	4140	78	8140
Ca	13	1200	35	2200	57	4200	79	8200
Cr	14	1240	36	2240	58	4240	80	8240
Mn-55	15	1255	37	2255	59	4255	81	8255
Fe	16	1260	38	2260	60	4260	82	8260
Ni	17	1280	39	2280	61	4280	83	8280
Zr	18	1400	40	2400	62	4400	84	8400
Mo	19	1420	41	2420	63	4420	85	8420
Pb	20	1820	42	2820	64	4820	86	8820
U-235	21	1925	43	2925	65	4925	87	8925
U-238	22	1928	44	2928	66	4928	88	8928

Table 3 Maximum number of terms of Legendre polynomials and the energy group number and the corresponding energy above which the anisotropy of elastic scattering is taken into account.

Nuclide	L_{max} *)	Δu=0.1		Δu=0.2		Δu=0.4		Δu=0.8	
		Grp.**)	E_n **) (eV)	Grp.	E_n (eV)	Grp.	E_n (eV)	Grp.	E_n (eV)
H-1	1	0	1.42+7 †)	0	1.42+7	0	1.42+7	0	1.42+7
Li-6	9	50	1.06+4	37	1.06+4	19	1.06+4	10	1.06+4
Li-7	10	43	2.13+5	22	2.13+5	11	2.60+5	6	2.60+5
B-10	9	46	1.58+5	23	1.74+5	12	1.74+5	6	2.60+5
B-11	9	46	1.58+5	23	1.74+5	12	1.74+5	6	2.60+5
C-12	7	50	1.06+5	37	1.06+4	19	1.06+4	10	1.06+4
N-14	11	26	1.17+6	13	1.29+6	7	1.29+6	4	1.29+6
O-16	11	50	1.06+5	25	1.17+5	13	1.17+5	7	1.17+5
Na	15	50	1.06+5	31	3.52+4	16	3.52+4	8	5.25+4
Mg	16	50	1.06+5	31	3.52+4	16	3.52+4	8	5.25+4
Al-27	11	43	2.13+5	22	2.13+5	11	2.60+5	6	2.60+5
Si	11	50	1.06+5	25	1.17+5	13	1.17+5	7	1.17+5
Ca	11	50	1.06+5	25	1.17+5	13	1.17+5	7	1.17+5
Cr	16	50	1.06+5	48	1.17+3	24	1.43+3	12	2.14+3
Mn-55	16	32	6.40+5	16	7.07+5	8	8.64+5	4	1.29+6
Fe	12	39	3.18+5	20	3.18+5	10	3.88+5	5	5.79+5
Ni	13	50	1.06+5	28	6.41+4	14	7.83+4	7	1.17+5
Zr	16	50	1.06+5	31	3.52+4	16	3.52+4	8	5.25+4
Mo	15	50	1.06+5	25	1.17+5	13	1.17+5	7	1.17+5
Pb	15	41	2.60+5	21	2.60+5	11	2.60+5	6	2.60+5
U-235	16	43	2.13+5	22	2.13+5	11	2.60+5	6	2.60+5
U-238	16	50	1.06+5	35	1.58+4	18	1.58+4	9	2.36+4

*) maximum number of terms of Legendre polynomials.

**) the energy group and the corresponding energy above which the anisotropy of elastic scattering is taken into account.

†) 1.42+7 reads 1.42×10^{7}.

Table 4 PALLAS-2DCY file requirements

Logical unit	Contents	Remarks
1	PALLAS library	Neutron cross sections are read from PALLAS library.
2	Scrach	For working.
3	Calculated data for RS, ZS, PSYS	Data for RS, ZS, PSYS are calculated in Subroutine MISIMA and used in KYOTO.
5	Input	
6	Output	
8	Calculated data WT and GZI	Data for WT and GZI are calculated in Sub. ATAMI and used in NAGOYA.
9	Calculated data for FGM	Data for FGM are calculated in Sub. YOKHAM and used in NAGOYA.
10	Angular fluxes FN	FN for each energy mesh are stored temporally in this unit. Large storage is necessary, for instance (55×55×28).
11	Top boundary fluxes, BOUN	Data are stored in Sub. TOKYO and used in MAIN.
12	Calculated data for CIA	Inelastic scattering matrices CIA are calculated in Sub. YOKHAM and used in NAGOYA.
14	Reaction rates or dose rates	Data are used in Sub. OSAKA
15	Uncollided angular fluxes	
17	Cylindrical surface boundary fluxes, BOUNR	Data are stored in Sub. TOKYO and used in MAIN.
18	Bottom boundary fluxes, BNMZ	Data are stored in Sub. TOKYO and used in MAIN.
19	Scalar fluxes	Data are stored in Sub. OSAKA.
20	Angular fluxes calculated previously	This file is used only when input ITP20>0
21	Calculated angular fluxes for all groups	This file is used only when input ITP21=1.
24	Reaction rates or dose rates	This file is used only when input ITP24>0.
29	Scalar fluxes	This file is used only when input ITP29>0.

Table 5. Relation of program variables to program mnemonics

Program mnemonic	Program variable and remark
WP (IP)	ω_p
WWP (IP)	$\Delta\omega_p$; weight for ω_p
WBP (IP)	Boundary value of $\Delta\omega_p$
WPQ (IPQ)	$\Delta\Omega_{pq}$; weight for angular mesh point
PSY (IP, IPQ)	ϕ_{pq}
PSYB (IP, IPQ)	Boundary value of ϕ_{pq}
AMU (M)	μ_m
WAMU (M)	$\Delta\mu_m$; weight for μ_m
DR (I)	Δr; radial interval in I-th region
DZ (I)	Δz; axial interval in I-th region
CRT (N_1, N_2, J)	$\Sigma_t(r,z,E_j)$; macroscopic total cross section in N_1-z and N_2-r region
RD (M)	r_m; radial distance (cm)
FN (MR, MZ, IPQ)	$I(r_i,z_k,\Omega_{pq})$
SN (MR, MZ, IPQ)	$Q'(r_i,z_k,\Omega_{pq})$
ALPH (M)	α_m
ALHY (M)	α_m for hydrogen
FGM (M, J)	$\Sigma_{el}(r,E_j)f(E_j,\mu_m)$
KMAX (M)	Maximum E_k
KK (M, NONH)	$E_k(\mu_m)$ for nuclide number NONH
SIGMA (J, NUC)	$\Sigma_{el}(r,E_j)$
WT (N, IP, J)	$w_n=\|\psi(\omega_n{}^u,\omega_p,\alpha_m)-\psi(\omega_n{}^l,\omega_p,\alpha_m)\|$
GZI (N, IP, J)	$\cos^{-1}\left(\frac{\alpha_m-\omega_p\omega_n}{\sqrt{(1-\omega_p{}^2)(1-\omega_n{}^2)}}\right)$
RO (NUC)	$\rho=1/A$
RS (M, IP, IPQ)	$\hat{r}_{i-1}=r'$
ZS (M, IP, IPQ)	$\hat{r}_{i-1}=z'$
PSYS (M, IP, IPQ)	$\Omega=\Omega(\omega_p,\phi)$
A (N_1, N_2)	$A(\bar{r},E)$
ION >0	$(\pm r,\ +z)$ direction
<0	$(\pm r,\ -z)$ direction
MUON >0	$(-r,\ \pm z)$ direction
<0	$(+r,\ \pm z)$ direction
MRR	Total number of r meshes
MZZ	Total number of z meshes
CIA (JMK, NONH)	$\frac{\Sigma_{in}(r,E_k\to E_j)\cdot\Delta U}{4\pi}$
GZAI (NUC)	ξ
WAVE (J)	λ_j
DWAVE (J)	$\Delta\lambda_j$
GMU	$\mu=1+\lambda'-\lambda$
ZD (K)	Z_k; axial distance (cm)
ORGN	$(ZZR1+ZZR2)/2$
MRB (N_2)	Boundary mesh numbers in N_2-r region
MZB (N_1)	Boundary mesh numbers in N_1-z region
RB (N_2)	Radial boundary distance
ZB (N_1)	Axial boundary distance
EDN (N_1, N_2)	$n(\bar{r})$; electron density in $(N_1-z,\ N_2-r)$ region
IQT	Total angular meshes
RNEW(M)	Radial distance (cm) for M-th mesh
ZD(M)	Axial distance (cm) for M-th mesh

Table 6 Angular quadrature set for PALLAS-2DCY

p	q	ω	Weight	ϕ	Weight for $\bar{\Omega}pq$
1	1	0.99240	0.015190	0.7854	0.023860
1	2	0.99240	0.015190	2.3562	0.023860
2	1	0.91174	0.14614	0.7854	0.229557
2	2	0.91174	0.14614	2.3562	0.229557
3	1	0.63852	0.40030	0.31416	0.2515165
3	2	0.63852	0.40030	1.09956	0.377275
3	3	0.63852	0.40030	2.04204	0.377275
3	4	0.63852	0.40030	2.82744	0.2515165
4	1	0.219185	0.43837	0.19635	0.172148
4	2	0.219185	0.43837	0.687225	0.258222
4	3	0.219185	0.43837	1.27630	0.258222
4	4	0.219185	0.43837	1.86533	0.258222
4	5	0.219185	0.43837	2.4544	0.258222
4	6	0.219185	0.43837	2.9453	0.172148

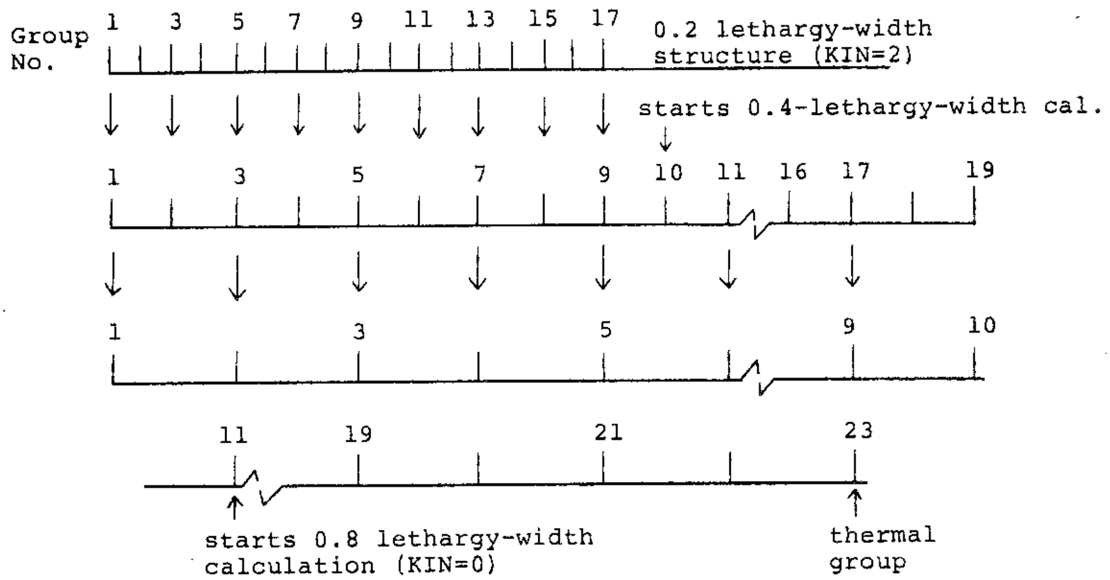


Fig. 1 An example of a series calculation by a combination of energy structures of 0.2, 0.4 and 0.8 lethargy widths (a standard combination is 17 energy meshes of 0.2 lethargy + 19 meshes of 0.4 lethargy width + 23 meshes of 0.8 lethargy width).

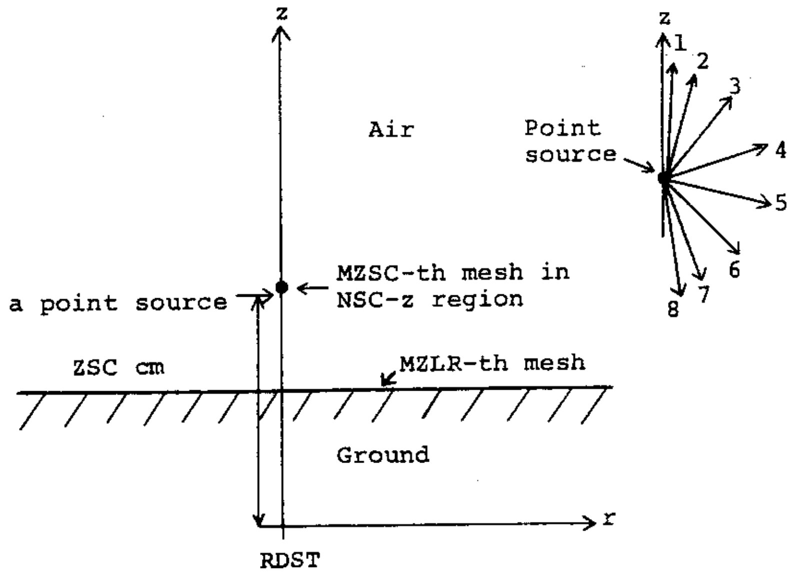


Fig. 2 A point source problem in an air-ground medium

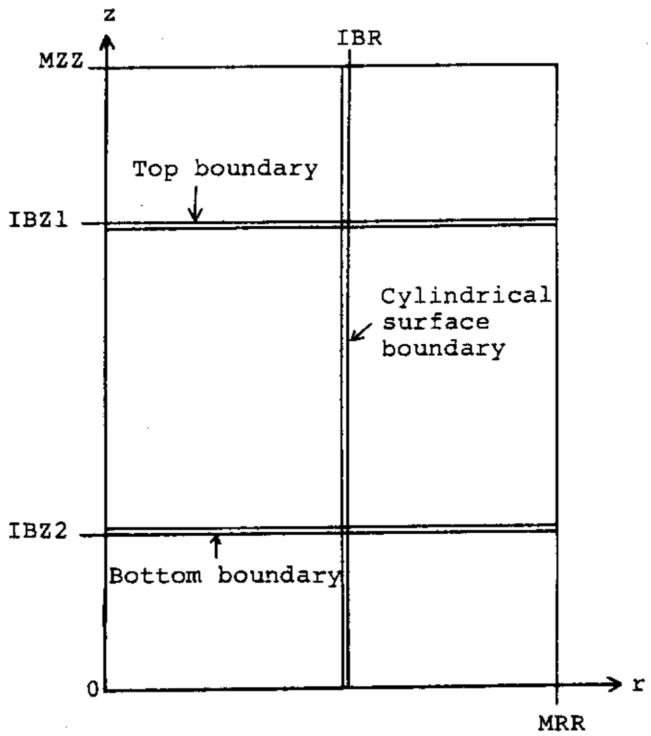


Fig. 3 Top, bottom and cylindrical surface boundary fluxes problem

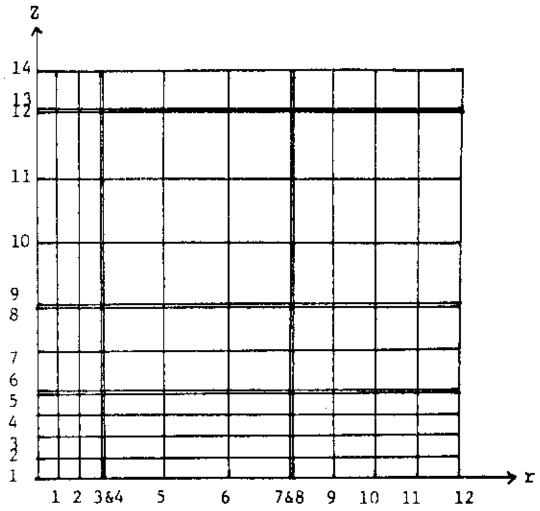


Fig. 4 Spatial mesh assignment

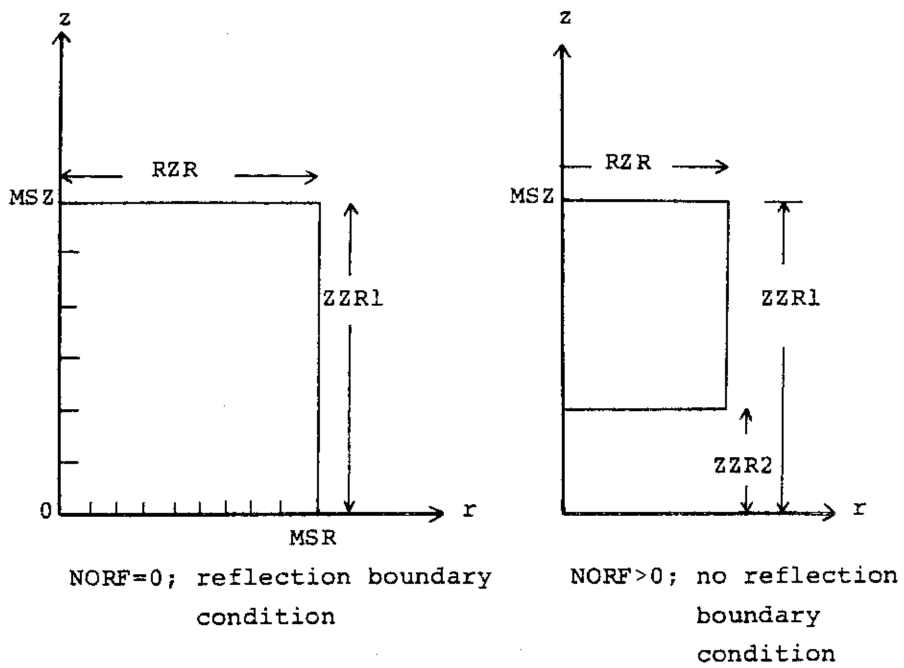
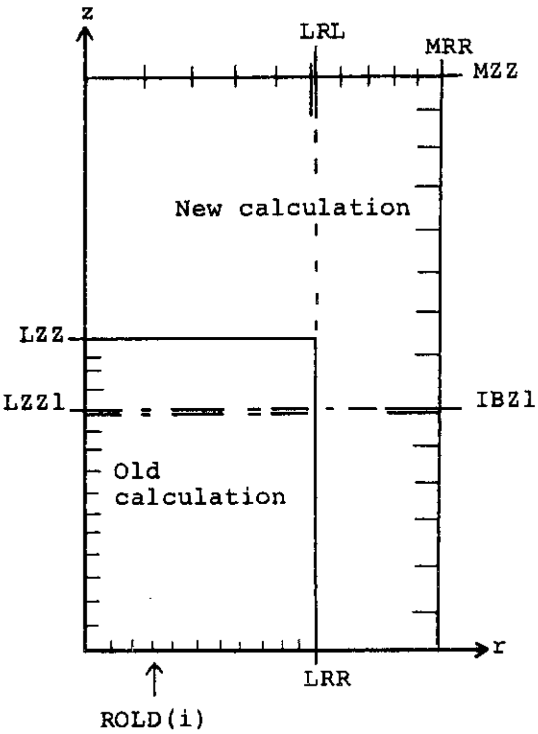


Fig. 5 Cylindrical volume source specification



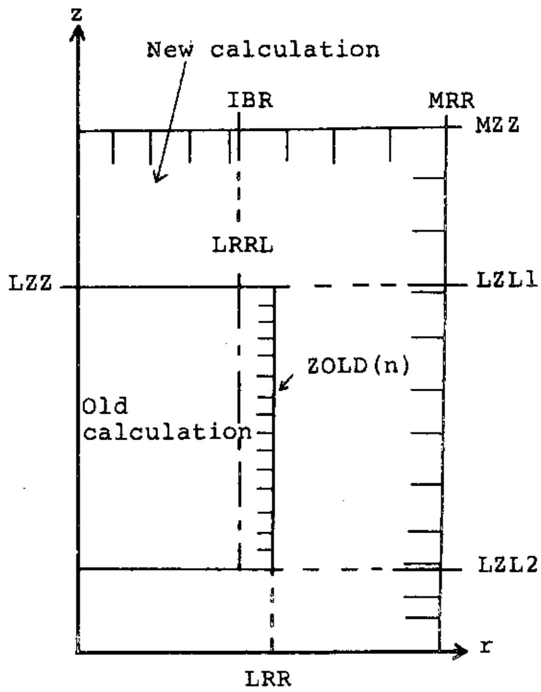


Fig. 6 A new calculation with the top boundary fluxes defined at IBZ1-th axial mesh, which were picked up from IZZ1-th axial mesh in an old calculation

Fig. 7 A new calculation with the cylindrical surface fluxes defined at IBR-th radial mesh in an old calculation

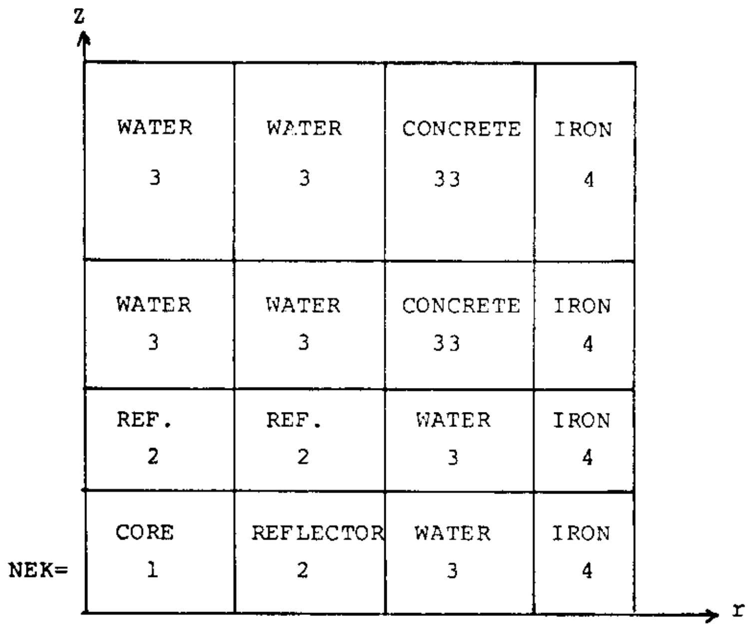


Fig. 8 An example of assignment of identification numbers of material regions

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
NEUTRON CALCULATION SAMPLE PROBLEM  1
  1
  3  8  4  0  1
  0
 14.20      0.2
 10  3  2  6  2  2  5  2
 36.20      7.00      1.250     16.50     1.250     2.60      8.90      14.0
 12 17  4  9
 44.0       60.7      10.20     31.80
 10 12
 36.20      44.0
 2.967E 02 2.967E 02 2.967E 02 2.967E 02 2.967E 02 2.967E 02 2.967E 02 2.967E 02
 2.967E 02 2.967E 02
 1.0        1.00      1.00      1.00      1.00      1.00      1.00      1.00
 1.0        1.00      1.00      1.00
  0  0
 0.0
  4  2  1  1  1  0  1  1
  2  2  1  1  1  0  1  1
  2  2  1  1  1  0  1  1
  1  1  1  1  1  1  1  1
  1  2  3  4  3  0  3  8
  2  2  3  4  3  0  3  8
  2  2  3  3  3  0  3  8
  3  3  3  3  3  3  3  3
PWR FUEL
H
 2011 1.000E 00 4.716E-02
O
 2086 1.600E 01 2.977E-02
FE
 2260 5.585E 01 1.159E-02
U-238
 2928 2.380E 02 3.110E-03
WATER
H
 2011 1.000E 00 6.680E-02
O
 2086 1.600E 01 3.340E-02
IRON
FE
 2260 5.585E 01 8.479E-02
LEAD
PB
 2820 208.00     3.297E-02
AIR
N
 2074 1.400E 01 4.000E-05
  0  1
  3  3  1
  2  4 28
 26 37 38
 DOSE RATE(MREM/H)
 0.1500     0.1490    0.1490    0.1460    0.1470    0.1460    0.1455    0.1450
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....
```

Fig. 9 Input data list for Sample problem 1

```
OUTPUT OF THE COMPUTATION

 RADIATION ENERGY = 1.4200E+01 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

 (R-MESH =  2  Z-MESH = 26)
    1.3360E-04  1.3355E-04  9.0571E-05  6.1339E-05  4.9690E-08  8.8835E-08  1.6974E-08  0.0         0.0         0.0
    5.9168E-31  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH =  2  Z-MESH = 37)
    3.7831E-06  3.7777E-06  1.4308E-06  7.4987E-07  1.2928E-14  2.3849E-14  2.1557E-15  0.0         0.0         0.0
    2.6079E-71  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH =  2  Z-MESH = 38)
    2.1052E-06  2.1013E-06  7.0682E-07  3.3849E-07  1.5431E-15  2.7808E-15  2.6653E-16  0.0         0.0         0.0
    7.7453E-76  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH =  4  Z-MESH = 26)
    1.3360E-04  1.3326E-04  6.8651E-05  5.5419E-05  3.7841E-07  6.3688E-07  2.8496E-09  0.0         1.3384E-29  1.0758E-28
    2.6292E-39  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH =  4  Z-MESH = 37)
    3.7831E-06  3.7007E-06  1.4435E-06  2.2631E-07  1.5525E-13  1.1547E-12  5.4784E-16  0.0         2.9650E-70  2.0931E-69
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH =  4  Z-MESH = 38)
    2.1052E-06  2.0498E-06  7.2694E-07  8.7854E-08  1.8315E-14  1.3337E-13  7.2772E-17  0.0         8.1786E-75  5.7735E-74
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH = 28  Z-MESH = 26)
    6.6977E-17  0.0         5.5669E-08  0.0         5.0263E-06  1.1636E-07  0.0         0.0         5.5165E-13  4.0531E-15
    5.0666E-21  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH = 28  Z-MESH = 37)
    4.4032E-17  0.0         8.8419E-08  0.0         1.6750E-08  1.4007E-09  0.0         0.0         1.8578E-21  4.3996E-33
    5.7547E-32  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
 (R-MESH = 28  Z-MESH = 38)
    3.9270E-17  0.0         4.E940E-08  0.0         7.6311E-09  3.1995E-10  0.0         0.0         1.8937E-22  5.6251E-35
    7.1068E-34  0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
    0.0         0.0         0.0         0.0         0.0         0.0         0.0         0.0
```

Fig. 10-1 Angular flux at 14.2 MeV for Sample problem 1.

SCALAR FLUX - (N/CM**2.SEC.MEV)

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	1.0228E-01	1.0226E-01	1.0221E-01	1.0207E-01	1.0179E-01	1.0128E-01	1.0039E-01	9.8792E-02	9.5727E-02	8.9344E-02
2	1.0204E-01	1.0202E-01	1.0196E-01	1.0184E-01	1.0156E-01	1.0111E-01	1.0026E-01	9.6749E-02	9.5888E-02	8.9994E-02
3	1.0157E-01	1.0155E-01	1.0149E-01	1.0137E-01	1.0114E-01	1.0071E-01	9.9888E-02	9.8390E-02	9.5526E-02	8.9670E-02
4	1.0078E-01	1.0076E-01	1.0070E-01	1.0058E-01	1.0037E-01	9.9978E-02	9.9222E-02	9.7775E-02	9.5028E-02	8.9461E-02
5	9.9520E-02	9.9502E-02	9.9443E-02	9.9327E-02	9.9120E-02	9.8754E-02	9.8087E-02	9.6753E-02	9.4122E-02	8.8832E-02
6	9.7464E-02	9.7448E-02	9.7395E-02	9.7288E-02	9.7096E-02	9.6754E-02	9.6142E-02	9.4995E-02	9.2565E-02	8.7567E-02
7	9.4000E-02	9.3986E-02	9.3940E-02	9.3846E-02	9.3676E-02	9.3371E-02	9.2821E-02	9.1798E-02	8.9799E-02	8.5216E-02
8	8.7808E-02	8.7796E-02	8.7756E-02	8.7676E-02	8.7530E-02	8.7266E-02	8.6793E-02	8.5913E-02	8.4227E-02	8.0706E-02
9	7.5751E-02	7.5741E-02	7.5705E-02	7.5634E-02	7.5505E-02	7.5278E-02	7.4872E-02	7.4131E-02	7.2738E-02	6.9944E-02
10	4.9448E-02	4.9439E-02	4.9406E-02	4.9341E-02	4.9222E-02	4.9015E-02	4.8649E-02	4.7996E-02	4.6794E-02	4.4455E-02
11	4.9448E-02	4.9439E-02	4.9406E-02	4.9341E-02	4.9222E-02	4.9015E-02	4.8649E-02	4.7996E-02	4.6794E-02	4.4455E-02
12	2.2817E-02	2.2805E-02	2.2762E-02	2.2673E-02	2.2503E-02	2.2176E-02	2.1546E-02	2.0928E-02	1.9700E-02	1.8326E-02
13	1.2869E-02	1.2843E-02	1.2677E-02	1.2594E-02	1.2470E-02	1.2286E-02	1.2003E-02	1.1513E-02	1.0871E-02	9.4351E-03
14	1.2869E-02	1.2843E-02	1.2677E-02	1.2594E-02	1.2470E-02	1.2286E-02	1.2003E-02	1.1513E-02	1.0871E-02	9.4351E-03
15	9.2465E-03	9.1971E-03	9.1726E-03	9.1202E-03	9.0359E-03	8.9048E-03	8.6754E-03	8.3473E-03	7.7364E-03	6.7918E-03
16	9.2465E-03	9.1971E-03	9.1726E-03	9.1202E-03	9.0359E-03	8.9048E-03	8.6754E-03	8.3473E-03	7.7364E-03	6.7918E-03
17	4.8837E-03	4.8798E-03	4.8442E-03	4.8220E-03	4.7784E-03	4.7033E-03	4.6093E-03	4.4051E-03	4.0346E-03	3.5868E-03
18	2.7423E-03	2.7380E-03	2.7363E-03	2.7226E-03	2.6929E-03	2.6409E-03	2.5471E-03	2.3875E-03	2.1904E-03	1.9563E-03
19	1.6022E-03	1.6007E-03	1.5945E-03	1.5826E-03	1.5615E-03	1.5171E-03	1.4416E-03	1.3414E-03	1.2539E-03	1.1079E-03
20	9.5452E-04	9.5234E-04	9.4727E-04	9.3566E-04	9.1429E-04	8.7870E-04	8.3051E-04	7.8882E-04	7.3401E-04	6.4089E-04
21	5.7238E-04	5.7186E-04	5.6677E-04	5.5640E-04	5.3648E-04	5.1419E-04	4.9133E-04	4.7188E-04	4.3462E-04	3.7611E-04
22	5.7238E-04	5.7136E-04	5.6677E-04	5.5640E-04	5.3648E-04	5.1419E-04	4.9133E-04	4.7188E-04	4.3462E-04	3.7611E-04
23	4.5474E-04	4.5331E-04	4.4854E-04	4.3913E-04	4.2422E-04	4.0372E-04	3.9036E-04	3.7441E-04	3.4319E-04	2.9630E-04
24	4.5474E-04	4.5331E-04	4.4854E-04	4.3913E-04	4.2422E-04	4.0372E-04	3.9036E-04	3.7441E-04	3.4319E-04	2.9630E-04
25	4.4081E-04	4.3878E-04	4.3221E-04	4.2042E-04	4.0335E-04	3.8860E-04	3.7800E-04	3.6049E-04	3.2769E-04	2.8240E-04
26	4.4081E-04	4.3878E-04	4.3221E-04	4.2042E-04	4.0335E-04	3.8860E-04	3.7800E-04	3.6049E-04	3.2769E-04	2.8240E-04
27	2.9200E-04	2.9031E-04	2.8513E-04	2.7647E-04	2.6694E-04	2.5928E-04	2.5276E-04	2.3970E-04	2.1628E-04	1.8589E-04
28	1.9277E-04	1.9246E-04	1.8862E-04	1.8324E-04	1.7744E-04	1.7432E-04	1.6967E-04	1.5990E-04	1.4329E-04	1.2296E-04
29	1.2679E-04	1.2705E-04	1.2536E-04	1.2215E-04	1.1944E-04	1.1776E-04	1.1424E-04	1.0697E-04	9.5256E-05	8.1693E-05
30	8.5743E-05	8.5179E-05	8.3739E-05	8.1788E-05	8.0555E-05	7.9822E-05	7.7114E-05	7.1740E-05	6.3527E-05	5.4498E-05
31	8.5743E-05	8.5179E-05	8.3739E-05	8.1788E-05	8.0555E-05	7.9822E-05	7.7114E-05	7.1740E-05	6.3527E-05	5.4498E-05
32	6.5051E-05	6.5344E-05	6.6097E-05	6.8022E-05	6.8727E-05	6.7644E-05	6.4008E-05	5.7631E-05	5.0000E-05	4.4195E-05

R	Z 31	Z 32	Z 33	Z 34	Z 35	Z 36	Z 37	Z 38	Z 39	Z 40
1	2.2802E-05	1.6253E-05	1.1528E-05	1.1528E-05	5.8369E-06	2.9405E-06	1.4733E-06	7.3508E-07	3.6561E-07	1.8152E-07
2	2.1465E-05	1.5200E-05	1.0722E-05	1.0722E-05	5.4107E-06	2.7191E-06	1.3620E-06	6.8065E-07	3.3977E-07	1.6956E-07
3	1.9521E-05	1.3750E-05	9.6659E-06	9.6659E-06	4.8729E-06	2.4544E-06	1.2359E-06	6.2277E-07	3.1389E-07	1.5852E-07
4	1.7286E-05	1.2169E-05	8.5717E-06	8.5717E-06	4.3435E-06	2.2060E-06	1.1238E-06	5.7236E-07	2.9285E-07	1.4691E-07
5	1.5192E-05	1.0764E-05	7.6276E-06	7.6276E-06	3.9103E-06	2.0144E-06	1.0320E-06	5.3606E-07	2.7778E-07	1.4474E-07
6	1.3586E-05	9.6419E-06	6.9390E-06	6.9390E-06	3.6136E-06	1.8785E-06	9.8193E-07	5.1273E-07	2.6822E-07	1.4021E-07
7	1.2485E-05	9.0151E-06	6.5161E-06	6.5161E-06	3.4020E-06	1.7801E-06	9.3123E-07	4.8748E-07	2.5511E-07	1.3351E-07
8	1.1717E-05	8.4563E-06	6.1107E-06	6.1107E-06	3.1930E-06	1.6699E-06	8.7402E-07	4.5757E-07	2.3961E-07	1.2549E-07
9	1.1033E-05	7.9523E-06	5.7513E-06	5.7513E-06	3.0065E-06	1.5745E-06	8.2539E-07	4.3299E-07	2.2726E-07	1.1933E-07
10	1.0713E-05	7.6950E-06	5.5656E-06	5.5656E-06	2.9133E-06	1.5285E-06	8.0311E-07	4.2236E-07	2.2226E-07	1.1705E-07
11	1.0713E-05	7.6950E-06	5.5656E-06	5.5656E-06	2.9133E-06	1.5285E-06	8.0311E-07	4.2236E-07	2.2228E-07	1.1705E-07
12	1.0202E-05	7.2759E-06	5.2559E-06	5.2559E-06	2.7546E-06	1.4492E-06	7.6385E-07	4.0308E-07	2.1288E-07	1.1250E-07
13	9.2036E-06	6.5115E-06	4.6340E-06	4.6340E-06	2.3994E-06	1.2627E-06	6.6681E-07	3.5278E-07	1.8669E-07	9.9102E-08
14	9.2036E-06	6.5115E-06	4.6340E-06	4.6340E-06	2.3994E-06	1.2627E-06	6.6681E-07	3.5278E-07	1.8689E-07	9.9102E-08
15	7.0144E-06	4.9302E-06	3.4787E-06	3.4787E-06	2.3252E-06	1.2143E-06	6.3706E-07	3.3559E-07	1.7728E-07	9.3854E-08
16	7.0144E-06	4.9302E-06	3.4787E-06	3.4787E-06	2.3252E-06	1.2143E-06	6.3706E-07	3.3559E-07	1.7728E-07	9.3654E-08
17	4.4524E-06	2.9515E-06	2.0096E-06	2.0096E-06	1.2976E-06	8.6339E-07	5.1033E-07	2.8511E-07	1.5466E-07	8.2494E-08
18	3.1057E-06	1.9696E-06	1.2843E-06	1.2843E-06	7.9345E-07	5.0177E-07	3.2916E-07	2.0594E-07	1.2232E-07	6.9835E-08
19	2.1423E-06	1.3617E-06	8.6912E-07	8.6912E-07	5.2373E-07	3.1849E-07	1.9803E-07	1.2765E-07	8.1640E-08	5.0407E-08
20	1.4430E-06	9.2186E-07	5.9030E-07	5.9030E-07	3.5339E-07	2.1310E-07	1.2873E-07	7.9228E-08	5.0466E-08	3.2334E-08
21	9.4352E-07	6.0608E-07	3.9042E-07	3.9042E-07	2.3523E-07	1.4216E-07	8.6088E-08	5.2001E-08	3.1896E-08	2.0144E-08
22	9.4352E-07	6.0608E-07	3.9042E-07	3.9042E-07	2.3523E-07	1.4216E-07	8.6088E-08	5.2001E-08	3.1898E-08	2.0144E-08
23	7.8759E-07	5.0891E-07	3.2831E-07	3.2831E-07	1.9641E-07	1.2008E-07	7.2757E-08	4.3906E-08	2.6630E-08	1.6513E-08
24	7.8759E-07	5.0891E-07	3.2831E-07	3.2831E-07	1.9641E-07	1.2008E-07	7.2757E-08	4.3906E-08	2.6630E-08	1.6513E-08
25	1.1096E-06	8.3641E-07	6.3337E-07	6.3337E-07	2.1622E-07	1.0487E-07	5.6940E-08	3.2809E-08	1.9398E-08	1.1704E-08
26	1.1096E-06	8.3641E-07	6.3337E-07	6.3337E-07	2.1622E-07	1.0487E-07	5.6940E-08	3.2809E-08	1.9398E-08	1.1704E-08
27	6.7063E-07	4.9053E-07	3.6105E-07	3.6105E-07	2.4636E-07	1.0848E-07	5.4011E-08	2.8319E-08	1.5686E-08	9.0549E-09
28	4.4990E-07	3.1316E-07	2.1990E-07	2.1990E-07	1.4590E-07	9.7617E-08	5.0077E-08	2.6549E-08	1.4024E-08	7.6130E-09
29	3.3451E-07	2.2203E-07	1.4670E-07	1.4670E-07	9.3357E-08	5.8649E-08	3.8689E-08	2.2009E-08	1.2469E-08	6.7961E-09
30	2.6427E-07	1.6924E-07	1.0821E-07	1.0821E-07	6.4154E-08	3.8898E-08	2.3433E-08	1.5335E-08	9.3755E-09	5.6361E-09
31	2.6427E-07	1.6924E-07	1.0821E-07	1.0821E-07	6.4154E-08	3.8898E-08	2.3433E-08	1.5335E-08	9.3755E-09	5.6361E-09
32	1.3818E-06	8.4955E-07	5.2621E-07	5.2621E-07	1.2124E-07	3.9441E-08	1.4117E-08	5.3631E-09	2.0833E-09	8.0920E-10

Fig. 10-2 Scalar flux at 14.2 MeV for Sample problem 1.

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RADIATION ENERGY = 9.5185E+00 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

(R-MESH =  2  Z-MESH = 26)
    2.6747E-03  2.6632E-03  1.8079E-03  1.5713E-03  8.1539E-05  7.1796E-05  5.6342E-05  4.8942E-05  2.0137E-05  1.8177E-05
    2.0645E-05  1.4930E-05  1.4208E-05  1.3833E-05  7.5123E-06  7.3426E-06  6.0293E-06  6.9533E-06  6.3170E-06  5.8528E-06
    3.6696E-06  3.6115E-06  3.4231E-06  3.5251E-06  5.0973E-06  5.1737E-06  4.4552E-06  4.2069E-06
(R-MESH =  2  Z-MESH = 37)
    4.5201E-05  4.4623E-05  1.5490E-05  8.7103E-06  7.9697E-07  6.2069E-07  4.8710E-07  3.8377E-07  1.6082E-07  1.3597E-07
    1.8348E-07  1.1880E-07  1.1788E-07  1.1721E-07  6.9669E-08  6.5128E-08  5.0477E-08  6.9156E-08  6.6757E-08  6.5918E-08
    3.8328E-08  3.5431E-08  3.1694E-08  3.3015E-08  3.4678E-08  3.8126E-08  3.9811E-08  3.6713E-08
(R-MESH =  2  Z-MESH = 38)
    2.2716E-05  2.2523E-05  6.9623E-06  3.7649E-06  3.7544E-07  2.9131E-07  2.2845E-07  1.7680E-07  7.7413E-08  6.6387E-08
    8.9152E-08  5.8609E-08  5.8364E-08  5.8149E-08  3.4205E-08  3.2101E-08  2.4926E-08  3.4277E-08  3.3154E-08  3.2756E-08
    1.8422E-08  1.7075E-08  1.5329E-08  1.5990E-08  1.6832E-08  1.8616E-08  1.9227E-08  1.7723E-08
(R-MESH =  4  Z-MESH = 26)
    2.8445E-03  2.8087E-03  1.7618E-03  9.9477E-04  9.2025E-05  7.5153E-05  4.1289E-05  3.0626E-05  1.8921E-05  1.8459E-05
    1.6306E-05  1.2486E-05  1.1567E-05  1.1008E-05  8.1582E-06  7.1828E-06  5.9667E-06  5.9318E-06  4.9441E-06  3.9451E-06
    3.1066E-06  3.0890E-06  2.6759E-06  3.0680E-06  4.0067E-06  4.5449E-06  3.7293E-06  3.1464E-06
(R-MESH =  4  Z-MESH = 37)
    4.4160E-05  4.2307E-05  1.5691E-05  4.3204E-06  8.8478E-07  5.7437E-07  4.2761E-07  2.5601E-07  1.3703E-07  1.3566E-07
    1.2995E-07  1.0476E-07  1.0547E-07  1.0565E-07  7.0535E-08  6.5815E-08  5.5065E-08  6.1575E-08  5.7801E-08  5.5948E-08
    3.5966E-08  3.2644E-08  2.6278E-08  2.7393E-08  2.8148E-08  3.5997E-08  3.6145E-08  3.0967E-08
(R-MESH =  4  Z-MESH = 38)
    2.2178E-05  2.1150E-05  7.1822E-06  1.9205E-06  4.2644E-07  2.7456E-07  2.0809E-07  1.2064E-07  6.6068E-08  6.5838E-08
    6.6252E-08  5.2527E-08  5.3101E-08  5.3429E-08  3.5060E-08  3.2830E-08  2.7676E-08  3.1045E-08  2.9177E-08  2.8180E-08
    1.7606E-08  1.6071E-08  1.3029E-08  1.3596E-08  1.3988E-08  1.7941E-08  1.7854E-08  1.5313E-08
(R-MESH = 28  Z-MESH = 26)
    6.8007E-06  4.7830E-07  2.3694E-05  4.9616E-07  1.2240E-04  8.0668E-06  3.4440E-07  1.2885E-07  4.7619E-06  3.0374E-06
    3.7469E-07  2.1397E-07  1.1177E-07  6.0696E-08  6.6988E-07  5.8593E-07  2.3460E-07  1.3263E-07  6.7862E-08  7.2246E-08
    2.3179E-07  1.7100E-07  8.6802E-08  9.4860E-08  1.6893E-07  1.1878E-07  1.3134E-07  1.0306E-07
(R-MESH = 28  Z-MESH = 37)
    3.9698E-07  6.9111E-08  3.0389E-06  4.3157E-08  2.9371E-07  9.7164E-08  1.8564E-08  4.4712E-09  1.6993E-08  1.2181E-08
    7.1880E-09  5.3446E-09  4.0872E-09  3.5418E-09  5.6296E-09  4.7713E-09  3.9201E-09  3.3291E-09  2.4877E-09  2.2733E-09
    3.1516E-09  2.7453E-09  1.7181E-09  1.7123E-09  1.5340E-09  2.6942E-09  2.7161E-09  2.0004E-09
(R-MESH = 28  Z-MESH = 38)
    2.7089E-07  5.9170E-08  1.3354E-06  2.5990E-08  1.4121E-07  3.0999E-08  1.1640E-08  2.6604E-09  8.7112E-09  6.2830E-09
    3.3129E-09  2.8349E-09  2.2802E-09  2.0248E-09  3.0178E-09  2.4896E-09  1.9254E-09  1.7139E-09  1.3461E-09  1.2476E-09
    1.6069E-09  1.3677E-09  8.5648E-10  6.8170E-10  7.8607E-10  1.3323E-09  1.3319E-09  9.7352E-10
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Fig. 10-3 Angular flux at 9.5 MeV for Sample problem 1.

K	Z 11	Z 12	Z 13	Z 14	Z 15	Z 16	Z 17	Z 18	Z 19	Z 20
1	2.8635E+00	1.9936E+00	1.9936E+00	1.0471E+00	4.8910E-01	2.6018E-01	1.6652E-01	9.9672E-02	5.8254E-02	3.2334E-02
2	2.9509E+00	1.9695E+00	1.9895E+00	9.5115E-01	4.6633E-01	2.6922E-01	1.5975E-01	9.4225E-02	5.3494E-02	3.0992E-02
3	2.9420E+00	1.9820E+00	1.9820E+00	9.3096E-01	4.6486E-01	2.6516E-01	1.5390E-01	8.6984E-02	5.0497E-02	3.0227E-02
4	2.9454E+00	1.9664E+00	1.9664E+00	8.9400E-01	4.5316E-01	2.5450E-01	1.4200E-01	8.1212E-02	4.8003E-02	2.9141E-02
5	2.9367E+00	1.9458E+00	1.9458E+00	8.5673E-01	4.4035E-01	2.3581E-01	1.3093E-01	7.5592E-02	4.5016E-02	2.7294E-02
6	2.9080E+00	1.9076E+00	1.9076E+00	8.1376E-01	4.0966E-01	2.1481E-01	1.1773E-01	6.6431E-02	4.0751E-02	2.4513E-02
7	2.8451E+00	1.8405E+00	1.8405E+00	7.5398E-01	3.6200E-01	1.8259E-01	1.0240E-01	5.9461E-02	3.5357E-02	2.1361E-02
8	2.7152E+00	1.7137E+00	1.7137E+00	6.4509E-01	2.6670E-01	1.5160E-01	8.6547E-02	5.1017E-02	3.0736E-02	1.8825E-02
9	2.4225E+00	1.4495E+00	1.4495E+00	4.7333E-01	2.3757E-01	1.3206E-01	7.6655E-02	4.5681E-02	2.7784E-02	1.7147E-02
10	1.4912E+00	9.6316E-01	9.6316E-01	4.2140E-01	2.1916E-01	1.2309E-01	7.1884E-02	4.3069E-02	2.6299E-02	1.6272E-02
11	1.4912E+00	9.6316E-01	9.6316E-01	4.2140E-01	2.1916E-01	1.2309E-01	7.1884E-02	4.3069E-02	2.6299E-02	1.6272E-02
12	4.7617E-01	4.2516E-01	4.2516E-01	3.2047E-01	1.8137E-01	1.0567E-01	6.3122E-02	3.6338E-02	2.3666E-02	1.4764E-02
13	2.5040E-01	2.3163E-01	2.3163E-01	1.6467E-01	1.3286E-01	8.2124E-02	5.1501E-02	3.2464E-02	2.0527E-02	1.3031E-02
14	2.5040E-01	2.3163E-01	2.3163E-01	1.6467E-01	1.3286E-01	8.2124E-02	5.1501E-02	3.2464E-02	2.0527E-02	1.3031E-02
15	1.7565E-01	1.6275E-01	1.6275E-01	1.2969E-01	9.1776E-02	6.0982E-02	3.6724E-02	2.4640E-02	1.5671E-02	9.9724E-03
16	1.7565E-01	1.6275E-01	1.6275E-01	1.2969E-01	9.1776E-02	6.0982E-02	3.6724E-02	2.4640E-02	1.5671E-02	9.9724E-03
17	1.0063E-01	9.3984E-02	9.3984E-02	7.7614E-02	5.6621E-02	4.0248E-02	2.7091E-02	1.7569E-02	1.1464E-02	7.4639E-03
18	5.9379E-02	5.5665E-02	5.5665E-02	4.7524E-02	3.5453E-02	2.5765E-02	1.8667E-02	1.2571E-02	8.1847E-03	5.3727E-03
19	3.5688E-02	3.3625E-02	3.3625E-02	2.9420E-02	2.2514E-02	1.6477E-02	1.2375E-02	9.0516E-03	6.0475E-03	3.9100E-03
20	2.1765E-02	2.0593E-02	2.0593E-02	1.8373E-02	1.4422E-02	1.0609E-02	8.0079E-03	6.2026E-03	4.5237E-03	2.9856E-03
21	1.3394E-02	1.2716E-02	1.2716E-02	1.1521E-02	9.2662E-03	6.8717E-03	5.1439E-03	4.0570E-03	3.1892E-03	2.2982E-03
22	1.3394E-02	1.2716E-02	1.2716E-02	1.1521E-02	9.2662E-03	6.8717E-03	5.1439E-03	4.0570E-03	3.1892E-03	2.2982E-03
23	1.0158E-02	9.6540E-03	9.6540E-03	8.7609E-03	7.1665E-03	5.2779E-03	3.9216E-03	3.0759E-03	2.4483E-03	1.8239E-03
24	1.0158E-02	9.6540E-03	9.6540E-03	8.7609E-03	7.1665E-03	5.2779E-03	3.9216E-03	3.0759E-03	2.4483E-03	1.8239E-03
25	9.8428E-03	9.3854E-03	9.3854E-03	8.6381E-03	7.1634E-03	5.4446E-03	4.0847E-03	3.2229E-03	2.6446E-03	2.1093E-03
26	9.8428E-03	9.3854E-03	9.3854E-03	8.6381E-03	7.1634E-03	5.4446E-03	4.0847E-03	3.2229E-03	2.6446E-03	2.1093E-03
27	6.1436E-03	5.5766E-03	5.5766E-03	5.4375E-03	4.5547E-03	3.4732E-03	2.5749E-03	1.9952E-03	1.6353E-03	1.3428E-03
28	3.6715E-03	3.7045E-03	3.7045E-03	3.4465E-03	2.9190E-03	2.2396E-03	1.6473E-03	1.2529E-03	1.0166E-03	8.4666E-04
29	2.4534E-03	2.3503E-03	2.3503E-03	2.1906E-03	1.8792E-03	1.4532E-03	1.0642E-03	7.9511E-04	6.3511E-04	5.3251E-04
30	1.5561E-03	1.4923E-03	1.4923E-03	1.4013E-03	1.2098E-03	9.4406E-04	6.9032E-04	5.0762E-04	3.9766E-04	3.3177E-04
31	1.5561E-03	1.4923E-03	1.4923E-03	1.4013E-03	1.2098E-03	9.4406E-04	6.9032E-04	5.0762E-04	3.9766E-04	3.3177E-04
32	1.2748E-03	1.3334E-03	1.3334E-03	1.2932E-03	1.2079E-03	1.0294E-03	5.1646E-04	6.0927E-04	4.6257E-04	3.7570E-04

K	Z 31	Z 32	Z 33	Z 34	Z 35	Z 36	Z 37	Z 38	Z 39	Z 40
1	4.1623E-04	2.6445E-04	1.9250E-04	1.9250E-04	8.6915E-05	4.0793E-05	1.8727E-05	8.5991E-06	3.9535E-06	1.8217E-06
2	3.9260E-04	2.6606E-04	1.7975E-04	1.7975E-04	6.2545E-05	3.8012E-05	1.7526E-05	8.0863E-06	3.7419E-06	1.7358E-06
3	3.5869E-04	2.4312E-04	1.6452E-04	1.6452E-04	7.5762E-05	3.5093E-05	1.6319E-05	7.6072E-06	3.5557E-06	1.6661E-06
4	3.2308E-04	2.2001E-04	1.4973E-04	1.4973E-04	6.9451E-05	3.2466E-05	1.5250E-05	7.1681E-06	3.3951E-06	1.6066E-06
5	2.9233E-04	2.0055E-04	1.3762E-04	1.3762E-04	6.4346E-05	3.0344E-05	1.4373E-05	6.6272E-06	3.2497E-06	1.5465E-06
6	2.6636E-04	1.8532E-04	1.2766E-04	1.2766E-04	6.0149E-05	2.8516E-05	1.3570E-05	6.4729E-06	3.0926E-06	1.4794E-06
7	2.4660E-04	1.7219E-04	1.1912E-04	1.1912E-04	5.6179E-05	2.6659E-05	1.2732E-05	6.0832E-06	2.9122E-06	1.3959E-06
8	2.3063E-04	1.5966E-04	1.1073E-04	1.1073E-04	5.2292E-05	2.4890E-05	1.1686E-05	5.6928E-06	2.7315E-06	1.3120E-06
9	2.1622E-04	1.4967E-04	1.0388E-04	1.0388E-04	4.9112E-05	2.3415E-05	1.1207E-05	5.3769E-06	2.5872E-06	1.2465E-06
10	2.0740E-04	1.4332E-04	9.9171E-05	9.9171E-05	4.6666E-05	2.2353E-05	1.0714E-05	5.1519E-06	2.4836E-06	1.1998E-06
11	2.0740E-04	1.4332E-04	9.9171E-05	9.9171E-05	4.6666E-05	2.2353E-05	1.0714E-05	5.1519E-06	2.4836E-06	1.1998E-06
12	1.9436E-04	1.3371E-04	9.2191E-05	9.2191E-05	4.3592E-05	2.0851E-05	1.0031E-05	4.8416E-06	2.3433E-06	1.1360E-06
13	1.7740E-04	1.2094E-04	8.2909E-05	8.2909E-05	3.9360E-05	1.8920E-05	9.1314E-06	4.4224E-06	2.1472E-06	1.0444E-06
14	1.7740E-04	1.2094E-04	8.2909E-05	8.2909E-05	3.9360E-05	1.8920E-05	9.1314E-06	4.4224E-06	2.1472E-06	1.0444E-06
15	1.2931E-04	8.7435E-05	5.9472E-05	5.9472E-05	3.7243E-05	1.7960E-05	8.7080E-06	4.2336E-06	2.0623E-06	1.0059E-06
16	1.2931E-04	8.7435E-05	5.9472E-05	5.9472E-05	3.7243E-05	1.7960E-05	8.7080E-06	4.2336E-06	2.0623E-06	1.0059E-06
17	8.4661E-05	5.1491E-05	3.2065E-05	3.2065E-05	1.9991E-05	1.2286E-05	6.6615E-06	3.4434E-06	1.7366E-06	8.6456E-07
18	6.7654E-05	3.7460E-05	2.2004E-05	2.2004E-05	1.2330E-05	7.1919E-06	4.2927E-06	2.4355E-06	1.3241E-06	6.9629E-07
19	5.3236E-05	2.9414E-05	1.6529E-05	1.6529E-05	8.6140E-06	4.8290E-06	2.7300E-06	1.5779E-06	9.0160E-07	5.0358E-07
20	4.0255E-05	2.2496E-05	1.2724E-05	1.2724E-05	6.6747E-06	3.5951E-06	1.9461E-06	1.0731E-06	6.0326E-07	3.4130E-07
21	2.9660E-05	1.6896E-05	9.7826E-06	9.7826E-06	5.2463E-06	2.7399E-06	1.4642E-06	7.8907E-07	4.2953E-07	2.3677E-07
22	2.9660E-05	1.6896E-05	9.7826E-06	9.7826E-06	5.2463E-06	2.7399E-06	1.4642E-06	7.8907E-07	4.2953E-07	2.3677E-07
23	2.6757E-05	1.5702E-05	9.3690E-06	9.3690E-06	4.7208E-06	2.4478E-06	1.3015E-06	6.9962E-07	3.7850E-07	2.0602E-07
24	2.6757E-05	1.5702E-05	9.3690E-06	9.3690E-06	4.7208E-06	2.4478E-06	1.3015E-06	6.9962E-07	3.7850E-07	2.0602E-07
25	5.6766E-05	4.2533E-05	3.1688E-05	3.1688E-05	8.5607E-06	3.1364E-06	1.3323E-06	6.3401E-07	3.2151E-07	1.6901E-07
26	5.6766E-05	4.2533E-05	3.1688E-05	3.1688E-05	8.5607E-06	3.1364E-06	1.3323E-06	6.3401E-07	3.2151E-07	1.6901E-07
27	2.9212E-05	2.1369E-05	1.5526E-05	1.5526E-05	1.0454E-05	3.9386E-06	1.5959E-06	6.8064E-07	3.1337E-07	1.5368E-07
28	1.6710E-05	1.1970E-05	8.5218E-06	8.5218E-06	5.6474E-06	3.7567E-06	1.7157E-06	7.6597E-07	3.3752E-07	1.5353E-07
29	1.0473E-05	7.2518E-06	5.0473E-06	5.0473E-06	3.2549E-06	2.0897E-06	1.3726E-06	7.0988E-07	3.4776E-07	1.6196E-07
30	7.2305E-06	4.8732E-06	3.3368E-06	3.3368E-06	2.0816E-06	1.2690E-06	7.8385E-07	5.0957E-07	2.8676E-07	1.5184E-07
31	7.2305E-06	4.8732E-06	3.3368E-06	3.3368E-06	2.0816E-06	1.2690E-06	7.8385E-07	5.0957E-07	2.8676E-07	1.5184E-07
32	3.4680E-05	2.3722E-05	1.6506E-05	1.6506E-05	4.4096E-06	1.6033E-06	6.4689E-07	2.6314E-07	1.3388E-07	6.6342E-08

Fig. 10-4 Scalar flux at 9.5 MeV for Sample problem 1.

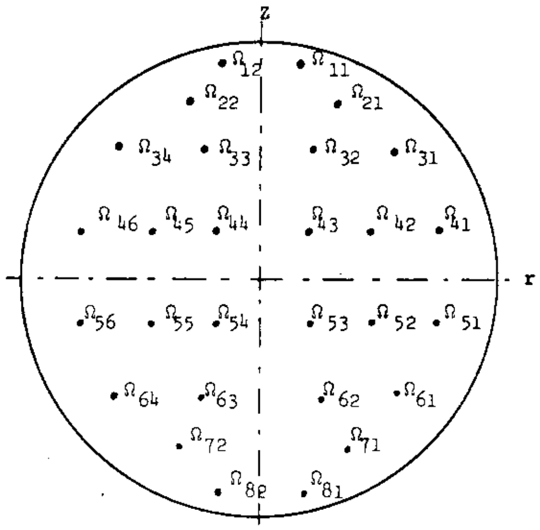

Fig. 11 Angular mesh points and their order in the current PALLAS code.

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
 SAMPLE PROBLEM NO.2 BOUNDARY FLUX PROB.
  1  0  0  0  0
  3  4  3  0  0
 10 22  0 11  1  3  0
 14.20     0.20
 10  3  7 11
 69.25     4.450     30.0      100.0
 21  4 11
130.80     15.90     100.0
 22  1 15 22
 32 42 28
  0.0       4.00      8.00     12.00     16.000    20.000    24.000    28.000
 32.000    36.000    40.000    44.000    44.000    47.794    51.587    55.381
 59.175    62.969    66.762    70.556    74.350    78.144    81.937    85.731
 89.525    93.319    97.112   100.910   104.70    104.70    108.10    111.50
114.90    114.90    118.87    122.85    126.82    130.80    134.77    138.75
142.72    146.70
 32 42 38  0 11  1  3
 3.620      7.240    10.860    14.480    18.100    21.720    25.340    28.960
 32.580    36.200    36.200    39.700    43.200    43.200    44.450    44.450
 47.750    51.050    54.350    57.650    60.950    60.950    62.200    62.200
 64.800    64.800    67.025    69.250    71.475    73.700    73.700    87.700
  0  0
 0.0
  1  1  1  2
  1  1  1  2
  2  2  2  2
  1  1  3  4
  1  1  3  4
  4  4  4  4
 IRON
 FE
 2260 55.85      8.479E-02
 GRAPHITE
 C-12
 2062 12.00      8.030E-02
 AIR
 N-14
 2074 14.0       3.970E-05
 O-16
 2086 16.00      1.061E-05
  0
  3  3  0
 11 21 31
  1 22 30
```

Fig. 12 Input data list for Sample problem 2

```
BOUNDARY  CONDITION
 BOUN  = 2.1053E-06 2.1015E-06 7.0376E-07 3.4963E-07 0.0        0.0        0.0        0.0        0.0        0.0
 BOUN  = 0.0        0.0        0.0        0.0
 BOUN  = 2.1052E-06 2.0567E-06 7.2628E-07 1.0114E-07 0.0        0.0        0.0        0.0        0.0        0.0
 BOUN  = 0.0        0.0        0.0        0.0
 BOUN  = 2.1052E-06 1.7488E-06 7.1973E-07 6.7654E-09 0.0        5.1273E-12 0.0        0.0        0.0        0.0
 BOUN  = 0.0        0.0        0.0        0.0
 BOUNR = 6.8160E-17 0.0        4.5417E-08 0.0        6.5041E-06 1.1977E-07 0.0        0.0        2.4369E-12 1.2785E-13
 BOUNR = 5.8739E-21 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 6.3757E-17 0.0        7.6698E-08 0.0        2.7456E-06 9.8407E-08 0.0        0.0        5.4014E-14 9.9732E-18
 BOUNR = 2.2239E-21 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 5.9362E-17 0.0        1.0548E-07 0.0        1.1290E-06 6.7666E-08 0.0        0.0        1.4270E-15 5.8914E-22
 BOUNR = 1.3607E-22 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 5.5021E-17 0.0        1.4464E-07 0.0        4.5330E-07 4.1909E-08 0.0        0.0        4.3542E-17 8.1340E-25
 BOUNR = 2.9924E-24 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 5.0770E-17 0.0        1.5460E-07 0.0        1.5737E-07 2.2788E-08 0.0        0.0        1.3426E-18 3.1298E-27
 BOUNR = 2.5506E-26 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 4.6282E-17 0.0        1.2220E-07 0.0        3.6135E-08 8.7254E-09 0.0        0.0        1.3984E-20 2.5660E-31
 BOUNR = 5.2749E-30 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 3.9270E-17 0.0        4.8940E-08 0.0        7.6311E-09 3.1995E-10 0.0        0.0        1.8937E-22 5.6251E-35
 BOUNR = 7.1068E-34 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 3.9270E-17 0.0        4.8940E-08 0.0        7.6311E-09 3.1995E-10 0.0        0.0        1.8937E-22 5.6251E-35
 BOUNR = 7.1068E-34 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUNR = 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 BOUN  = 8.9792E-06 8.9107E-06 2.6544E-06 1.2981E-06 6.8403E-08 5.6336E-08 4.5744E-08 3.8975E-08 2.5077E-08 2.2106E-08
 BOUN  = 2.7935E-08 1.7739E-08 1.7328E-08 1.7198E-08
 BOUN  = 8.8821E-06 8.4891E-06 2.8076E-06 5.6072E-07 7.6412E-08 5.1428E-08 4.0712E-08 2.9213E-08 2.1891E-08 2.1603E-08
 BOUN  = 2.0651E-08 1.5626E-08 1.5205E-08 1.5215E-08
 BOUN  = 8.7297E-06 6.6483E-06 2.8294E-06 2.7120E-07 8.0037E-08 4.7331E-08 3.8326E-08 2.5043E-08 1.9247E-08 1.8190E-08
 BOUN  = 1.6428E-08 1.4010E-08 1.3556E-08 1.4230E-08
 BOUNR = 7.5032E-07 3.1525E-08 3.8562E-06 1.4625E-07 3.6528E-05 1.4011E-06 6.8319E-08 2.2216E-08 8.1543E-07 4.6737E-07
 BOUNR = 8.4828E-08 4.6322E-08 2.4073E-08 1.2410E-08 1.0008E-07 8.7456E-08 5.0843E-08 2.7416E-08 1.7279E-08 1.2035E-08
 BOUNR = 4.1909E-08 2.8889E-08 1.8122E-08 1.6424E-08 3.8517E-08 1.9177E-08 3.0015E-08 1.6441E-08
 BOUNR = 4.8803E-07 1.9642E-08 3.2330E-06 7.1632E-08 1.4983E-05 9.4767E-07 3.1194E-08 1.0203E-08 3.5484E-07 2.0664E-07
 BOUNR = 3.9136E-08 2.0737E-08 1.0621E-08 5.6018E-09 5.1732E-08 4.2640E-08 2.3046E-08 1.2166E-08 7.6048E-09 5.3200E-09
 BOUNR = 2.1160E-08 1.3850E-08 8.0238E-09 7.2080E-09 1.6712E-08 8.6678E-09 1.3341E-08 7.4175E-09
 BOUNR = 3.1234E-07 1.3103E-08 2.6458E-06 3.3843E-08 6.0722E-06 5.6408E-07 1.4075E-08 4.6681E-09 1.5452E-07 9.1721E-08
 BOUNR = 1.8661E-08 9.2683E-09 4.6770E-09 2.5718E-09 2.4988E-08 2.0661E-08 1.0939E-08 5.5004E-09 3.3687E-09 2.3783E-09
 BOUNR = 1.0541E-08 7.1009E-09 3.6542E-09 3.2287E-09 7.2335E-09 4.0097E-09 6.0985E-09 3.4530E-09
 BOUNR = 1.8954E-07 9.8940E-09 2.1282E-06 1.7256E-08 2.4425E-06 3.4806E-07 6.9391E-09 2.3216E-09 5.3613E-08 3.4898E-08
 BOUNR = 9.7404E-09 4.4367E-09 2.2173E-09 1.3208E-09 1.2139E-08 1.0012E-08 5.6741E-09 2.8174E-09 1.7458E-09 1.2371E-09
 BOUNR = 5.6181E-09 3.6887E-09 1.7711E-09 1.6190E-09 3.0354E-09 2.0382E-09 2.9441E-09 1.7541E-09
```

Fig. 13 An example of boundary fluxes determined by the interpolation

RADIATION ENERGY = 1.4200E+01 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

(R-MESH = 11 Z-MESH = 1)									
0.0	0.0	4.1621E-14	0.0	4.2593E-05	1.6916E-09	0.0	0.0	1.7738E-04	2.7855E-05
7.4072E-17	0.0	0.0	0.0	1.7738E-04	2.7855E-05	7.4072E-17	0.0	0.0	0.0
4.2593E-05	1.6916E-09	0.0	0.0	4.1621E-14	0.0	0.0	0.0		
(R-MESH = 11 Z-MESH = 22)									
0.0	0.0	4.2940E-08	0.0	7.6511E-09	3.1995E-10	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 11 Z-MESH = 30)									
2.3613E-15	0.0	2.4961E-06	0.0	5.7785E-13	5.0576E-12	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 21 Z-MESH = 1)									
0.0	0.0	0.0	0.0	1.1370E-10	0.0	0.0	0.0	5.5717E-06	2.0653E-07
0.0	0.0	0.0	0.0	5.5717E-06	2.0653E-07	0.0	0.0	0.0	0.0
1.1370E-10	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 21 Z-MESH = 22)									
1.0150E-26	0.0	1.4157E-16	0.0	3.9006E-08	2.5272E-12	0.0	0.0	1.0509E-21	1.0368E-29
4.2251E-34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 21 Z-MESH = 30)									
2.6504E-26	0.0	2.0063E-12	0.0	4.0442E-11	5.1147E-11	0.0	0.0	3.6735E-29	1.7688E-38
1.4482E-36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 31 Z-MESH = 1)									
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3251E-06	1.7156E-08
0.0	0.0	0.0	0.0	2.3251E-06	1.7156E-08	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 31 Z-MESH = 22)									
5.5119E-35	0.0	1.5215E-25	0.0	3.5158E-07	2.8647E-19	0.0	0.0	4.7697E-16	1.9699E-17
1.1213E-22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
(R-MESH = 31 Z-MESH = 30)									
2.6753E-27	0.0	4.7044E-24	0.0	3.1230E-07	7.6060E-17	0.0	0.0	7.4400E-27	2.9737E-34
1.4003E-34	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

R	Z 11	Z 12	Z 13	Z 14	Z 15	Z 16	Z 17	Z 18	Z 19	Z 20
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	2.6696E-05	2.1961E-05	1.4792E-05	7.6271E-06	5.3830E-06	1.4907E-06	6.6739E-07	3.2606E-07	1.6733E-07	8.0866E-08
11	2.6696E-05	2.1961E-05	1.4792E-05	7.6271E-06	5.3830E-06	1.4907E-06	6.6739E-07	3.2606E-07	1.6733E-07	8.0866E-08
12	1.7266E-05	1.4955E-05	1.0663E-05	6.0725E-06	2.6752E-06	1.2637E-06	5.4532E-07	2.3903E-07	1.0873E-07	5.0721E-08
13	1.1212E-05	9.4721E-06	7.4466E-06	4.5919E-06	2.4085E-06	1.0913E-06	4.6959E-07	1.9693E-07	8.3462E-08	3.4498E-08
14	1.1213E-05	9.4721E-06	7.4466E-06	4.5919E-06	2.4083E-06	1.0913E-06	4.6959E-07	1.9693E-07	8.3462E-08	3.4498E-08
15	6.5971E-06	5.4972E-06	4.0141E-06	2.5830E-06	2.1572E-06	1.0795E-06	4.0290E-07	2.0561E-07	8.5216E-08	3.3631E-08
16	3.9784E-06	3.1115E-06	2.5035E-06	2.4216E-06	1.7096E-06	9.6696E-07	4.6417E-07	2.1434E-07	9.0494E-08	3.6916E-08
17	2.4738E-06	1.7534E-06	1.6576E-06	1.5033E-06	1.2037E-06	8.0996E-07	4.5241E-07	2.1716E-07	9.5252E-08	3.9898E-08
18	1.6167E-06	9.5268E-07	9.2369E-07	8.2561E-07	7.7445E-07	5.9202E-07	3.6144E-07	2.0654E-07	9.7455E-08	4.2349E-08
19	1.1512E-06	5.7011E-07	5.2161E-07	5.0640E-07	4.6680E-07	3.5943E-07	2.2847E-07	1.7866E-07	9.4115E-08	4.3734E-08
20	6.5060E-07	3.2654E-07	2.9073E-07	2.2501E-07	2.7214E-07	2.4562E-07	1.9870E-07	1.3942E-07	8.3323E-08	4.2816E-08
21	6.5208E-07	3.3634E-07	2.9070E-07	2.2501E-07	2.7214E-07	2.4563E-07	1.9870E-07	1.3942E-07	8.3323E-08	4.2816E-08
22	1.0916E-06	3.6676E-07	2.0394E-07	2.7747E-07	2.7456E-07	2.6535E-07	2.4316E-07	2.0370E-07	1.5105E-07	9.7474E-08
23	1.2639E-06	4.6332E-07	2.6317E-07	2.6768E-07	2.6719E-07	2.6525E-07	2.5609E-07	2.4020E-07	2.0713E-07	1.6073E-07
24	1.3737E-06	7.2179E-07	2.5294E-07	2.5793E-07	2.5760E-07	2.5607E-07	2.5661E-07	2.5129E-07	2.3689E-07	2.0925E-07
25	1.4119E-06	8.9393E-07	3.2639E-07	2.4566E-07	2.4177E-07	2.4653E-07	2.4969E-07	2.4906E-07	2.4487E-07	2.3333E-07
26	1.3737E-06	9.6914E-07	3.6590E-07	2.2662E-07	2.2737E-07	2.3544E-07	2.3987E-07	2.4162E-07	2.4184E-07	2.3679E-07
27	1.3796E-06	1.0225E-06	4.1074E-07	1.9500E-07	1.9432E-07	2.1326E-07	2.2510E-07	2.3132E-07	2.3428E-07	2.3503E-07
28	1.4032E-06	1.1015E-06	5.5136E-07	1.4145E-07	1.3546E-07	1.7256E-07	1.9893E-07	2.1429E-07	2.2265E-07	2.2690E-07
29	1.4165E-06	1.1754E-06	7.1726E-07	1.0025E-07	5.1142E-08	1.0370E-07	1.5184E-07	1.8364E-07	2.0281E-07	2.1369E-07
30	1.4192E-06	1.2296E-06	8.5636E-07	2.5425E-07	4.2590E-08	2.2110E-08	6.5916E-08	1.2767E-07	1.6666E-07	1.9036E-07
31	1.4142E-06	1.2665E-06	9.6499E-07	4.5467E-07	7.2823E-08	9.9010E-09	1.0767E-08	4.0463E-08	1.0411E-07	1.4844E-07

Fig. 14-1 Angular flux and scalar flux at 14.2 MeV for Sample problem 2

```
RADIATION ENERGY = 9.5185E+00 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

(R-MESH = 11  Z-MESH =  1)
    3.2692E-05  1.1966E-05  5.6285E-05  1.5160E-05  1.5589E-03  4.9091E-05  1.0955E-05  9.6359E-06  6.0219E-03  1.1449E-03
    3.4002E-05  1.2923E-05  9.9973E-06  7.5386E-06  6.0219E-03  1.1449E-03  3.4002E-05  1.2923E-05  9.9973E-06  7.5386E-06
    1.5589E-03  4.9091E-05  1.0955E-05  9.6359E-06  5.6285E-05  1.5160E-05  3.2692E-05  1.1968E-05
(R-MESH = 11  Z-MESH = 22)
    2.7069E-07  5.9170E-08  1.3354E-06  2.5990E-08  1.4121E-07  3.0999E-06  1.1640E-08  2.6604E-09  8.7112E-09  6.2830E-09
    3.3129E-09  2.6349E-09  2.2602E-09  2.0248E-09  3.1349E-09  2.6434E-09  1.9569E-09  1.9499E-09  1.9833E-09  1.7340E-09
    1.7267E-09  1.5135E-09  9.6624E-10  1.0383E-09  8.2295E-10  1.3632E-09  1.4016E-09  1.0114E-09
(R-MESH = 11  Z-MESH = 30)
    1.6225E-08  1.4356E-08  1.5907E-07  6.2502E-09  1.7504E-08  6.0439E-09  2.4746E-09  1.6316E-09  1.4144E-09  7.5093E-10
    3.2422E-10  2.5736E-10  2.1832E-10  1.7675E-10  1.0223E-10  6.0668E-11  2.7209E-11  2.9134E-11  4.1795E-11  3.2633E-11
    1.0438E-11  1.3196E-11  7.3756E-12  1.2452E-11  5.6239E-12  1.1100E-11  1.7108E-11  1.2737E-11
(R-MESH = 21  Z-MESH =  1)
    3.1668E-07  4.7423E-09  1.2143E-06  4.5811E-09  9.9972E-06  1.3546E-06  6.9630E-09  9.7638E-09  2.0213E-04  1.9595E-05
    1.2190E-06  5.6805E-09  5.1766E-09  4.0504E-09  2.0213E-04  1.9595E-05  1.2190E-06  5.6805E-09  5.1766E-09  4.0504E-09
    9.9972E-06  1.3546E-06  8.9530E-09  9.7638E-09  1.2143E-06  4.5811E-09  3.1666E-07  4.7423E-09
(R-MESH = 21  Z-MESH = 22)
    1.2962E-07  7.2687E-09  2.2459E-07  9.2897E-09  1.0578E-06  6.3592E-08  8.1244E-09  3.5501E-09  3.4852E-08  2.0392E-08
    4.8973E-09  5.5509E-10  5.2512E-10  3.9270E-10  2.3666E-09  2.5779E-09  2.4583E-09  2.6534E-10  3.0261E-10  3.0345E-10
    2.1318E-09  2.2719E-09  4.5205E-11  1.0090E-10  2.0656E-09  3.1095E-11  1.5598E-09  2.2102E-11
(R-MESH = 21  Z-MESH = 30)
    5.4734E-08  7.0990E-09  6.5031E-08  8.4660E-09  1.4127E-08  7.0936E-09  3.7449E-09  9.5160E-10  1.8267E-09  7.7539E-10
    3.2465E-10  2.4588E-10  1.7594E-10  1.4450E-10  1.2166E-10  5.1217E-11  1.7529E-11  2.7420E-11  3.6602E-11  4.0702E-11
    1.8924E-11  5.4959E-12  3.8210E-12  5.6228E-12  2.5925E-12  2.6079E-12  4.5747E-12  3.1693E-12
(R-MESH = 31  Z-MESH =  1)
    1.4604E-09  0.0         3.5382E-09  0.0         1.1644E-07  8.1109E-09  0.0         0.0         8.6287E-05  3.6345E-06
    5.3839E-09  0.0         0.0         0.0         8.6287E-05  3.6345E-06  5.3839E-09  0.0         0.0         0.0
    1.1644E-07  8.1109E-09  0.0         0.0         3.5382E-09  0.0         1.4604E-09  0.0
(R-MESH = 31  Z-MESH = 22)
    2.6217E-09  0.0         3.5002E-09  0.0         2.0715E-05  1.6554E-07  0.0         0.0         7.6508E-07  2.1588E-07
    3.0756E-05  0.0         0.0         0.0         6.6258E-10  4.9124E-10  3.9099E-10  0.0         0.0         0.0
    7.8332E-10  7.5759E-10  0.0         0.0         6.5472E-10  0.0         7.4596E-10  0.0
(R-MESH = 31  Z-MESH = 30)
    5.9558E-09  0.0         1.4461E-07  0.0         1.1167E-05  2.8319E-07  0.0         0.0         3.2769E-09  1.9412E-09
    6.4762E-10  0.0         0.0         0.0         1.9911E-10  9.6564E-11  1.1876E-10  0.0         0.0         0.0
    5.4359E-11  7.6324E-11  0.0         0.0         5.2643E-11  0.0         6.0031E-11  0.0
```

SCALAR FLUX - (N/CM**2.SEC.MEV)

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	6.6489E-10	6.5582E-10	6.2975E-10	5.9096E-10	5.4557E-10	4.9472E-10	4.3607E-10	3.7206E-10	3.1068E-10	2.5502E-10
2	1.5928E-09	1.5706E-09	1.5002E-09	1.4147E-09	1.3032E-09	1.1784E-09	1.0241E-09	8.7664E-10	7.2618E-10	5.8938E-10
3	4.6695E-09	4.6107E-09	4.4531E-09	4.1582E-09	3.8203E-09	3.4437E-09	3.0159E-09	2.5497E-09	2.0998E-09	1.6676E-09
4	1.4965E-08	1.4823E-08	1.4319E-08	1.3416E-08	1.2271E-08	1.1017E-08	9.6309E-09	8.1299E-09	6.6698E-09	5.3009E-09
5	5.1096E-08	5.0618E-08	4.8980E-08	4.6033E-08	4.1946E-08	3.7391E-08	3.2543E-08	2.7536E-08	2.2517E-08	1.7550E-08
6	1.8446E-07	1.8229E-07	1.7626E-07	1.6565E-07	1.5177E-07	1.3378E-07	1.1564E-07	9.6173E-08	7.9630E-08	6.0317E-08
7	6.9760E-07	6.8976E-07	6.6627E-07	6.2377E-07	5.7959E-07	5.0897E-07	4.3617E-07	3.6780E-07	2.9357E-07	2.1801E-07
8	2.8301E-06	2.8525E-06	2.7626E-06	2.6010E-06	2.3850E-06	2.0744E-06	1.7704E-06	1.4731E-06	1.1632E-06	8.5606E-07
9	1.4368E-05	1.4214E-05	1.3766E-05	1.2823E-05	1.1600E-05	1.0166E-05	8.6387E-06	7.3422E-06	5.8151E-06	4.0981E-06
10	7.1319E-03	6.9654E-03	6.7133E-03	6.4257E-03	5.8974E-03	4.8784E-03	3.9596E-03	3.5906E-03	2.7927E-03	1.7005E-03
11	7.1319E-03	6.9654E-03	6.7133E-03	6.4257E-03	5.8974E-03	4.8784E-03	3.9596E-03	3.5906E-03	2.7927E-03	1.7005E-03
12	4.4758E-03	4.4058E-03	4.2677E-03	4.1006E-03	3.7355E-03	3.0827E-03	2.5181E-03	2.2878E-03	1.7968E-03	1.1057E-03
13	2.8523E-03	2.8212E-03	2.7534E-03	2.6472E-03	2.3972E-03	1.9752E-03	1.6243E-03	1.4784E-03	1.1723E-03	7.3026E-04
14	2.8523E-03	2.8212E-03	2.7534E-03	2.6472E-03	2.3972E-03	1.9752E-03	1.6243E-03	1.4784E-03	1.1723E-03	7.3026E-04
15	1.7603E-03	1.7550E-03	1.7328E-03	1.6625E-03	1.4876E-03	1.2290E-03	1.0319E-03	9.4586E-04	7.7333E-04	5.0719E-04
16	1.0914E-03	1.0929E-03	1.0850E-03	1.0365E-03	9.1573E-04	7.6365E-04	6.5301E-04	6.0236E-04	5.0479E-04	3.4630E-04
17	6.8475E-04	6.8532E-04	6.7667E-04	6.4429E-04	5.6874E-04	4.7610E-04	4.1363E-04	3.8372E-04	3.2818E-04	2.3412E-04
18	4.2361E-04	4.2256E-04	4.2492E-04	3.9573E-04	3.5164E-04	2.9731E-04	2.6221E-04	2.4456E-04	2.1278E-04	1.5718E-04
19	2.7533E-04	2.7359E-04	2.6602E-04	2.4739E-04	2.1667E-04	1.8536E-04	1.6584E-04	1.5555E-04	1.3736E-04	1.0465E-04
20	1.7397E-04	1.7222E-04	1.6576E-04	1.5232E-04	1.3302E-04	1.1487E-04	1.0414E-04	9.6224E-05	8.7898E-05	6.8853E-05

Fig. 14-2 Angular flux and scalar flux at 9.5 MeV for Sample problem 2

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********************
*                  *
*  INPUT DATA LIST *
*                  *
********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
BERGER-RASO/IRON/THETA=2/
  4  0 10  0 10
 20  1  2  0  0  0
 10  1  0  0
 1.0        0.0        0.0
 30
 20.0
 11  6
 5.0        5.0
 1.0        0.925      0.85       0.775      0.70       0.625      0.55       0.50
 0.45       0.40       0.35       0.30       0.275      0.25       0.2285     0.2035
 0.1765     0.15       0.125      0.10
 30  0  1  1  1
 1.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0
 0.0        0.0        1.0974     0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

Fig.15-1   Input data list for Sample problem 3

```
********************
*                  *
*  INPUT DATA LIST *
*                  *
********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
  1  1
  1  1
  1  1
  1  1
IRON GAMMA
 2.204
 4.6846 -1 4.8673 -1 5.0736 -1 5.3060 -1 5.5679 -1 5.8747 -1 6.2351 -1 6.5159 -1
 6.8479 -1 7.2391 -1 7.7609 -1 8.4102 -1 8.8959 -1 9.4602 -1 1.0025    1.0804
 1.2206    1.4462    1.9111    2.6881
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0   0   0   0   0
  2   1   2   1   0
  5  10
  1
 ENERGY  ALBEDO
 1.0       0.925     0.85      0.775     0.70      0.625     0.55      0.50
 0.45      0.40      0.35      0.30      0.275     0.25      0.2285    0.2035
 0.1785    0.15      0.125     0.10
 NUMBER  ALBEDO
 1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
 1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
 1.0       1.0       1.0       1.0       1.0       1.0       1.0       1.0
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** INPUT DATA END ***
```

Fig.15-2　Input data list for Sample problem 3

```
OUTPUT  OF  THE  COMPUTATION

MONOENERGY (FIRST OUTPUT = UNSCATTERED FLUX , SECOND OUTPUT = SCATTERED FLUX)

RADIATION ENERGY = 1.0000E+00 MEV

ANGULAR FLUX - ( N/CM**2 sec sr)

(R-MESH =  5  Z-MESH =  1)
   0.0        0.0        1.0974E+00  0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0         0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0         0.0        0.0        0.0        0.0        0.0
(R-MESH = 10  Z-MESH =  1)
   0.0        0.0        1.0974E+00  0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0         0.0        0.0        0.0        0.0        0.0        0.0        0.0
   0.0        0.0        0.0         0.0        0.0        0.0        0.0        0.0
EDOS = DOSE(J,JM) * DELTA-E = 1.0000E+00
EDOS = DOSE(J,JM) * DELTA-E = 1.0000E+00
```

SCALAR FLUX - (N/CM**2 SEC)

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	5.0383E-01	3.1422E-01	1.9597E-01	1.2222E-01	7.6221E-02	4.7536E-02	2.9646E-02	1.8489E-02	1.1531E-02	7.1914E-03
2	5.0383E-01	3.5623E-01	2.4525E-01	1.6564E-01	1.1027E-01	7.2604E-02	4.7386E-02	3.0709E-02	1.9788E-02	1.2690E-02
3	5.0383E-01	3.6827E-01	2.6717E-01	1.9162E-01	1.3572E-01	9.4953E-02	6.5670E-02	4.4945E-02	3.0473E-02	2.0489E-02
4	5.0383E-01	3.7395E-01	2.7657E-01	2.0366E-01	1.4909E-01	1.0836E-01	7.8123E-02	5.5845E-02	3.9577E-02	2.7811E-02
5	5.0383E-01	3.7724E-01	2.8189E-01	2.1014E-01	1.5621E-01	1.1572E-01	8.5362E-02	6.2652E-02	4.5724E-02	3.3164E-02
6	5.0383E-01	3.7940E-01	2.8532E-01	2.1425E-01	1.6061E-01	1.2017E-01	8.9709E-02	6.6788E-02	4.9565E-02	3.6647E-02
7	5.0383E-01	3.8092E-01	2.8772E-01	2.1711E-01	1.6364E-01	1.2318E-01	9.2597E-02	6.9495E-02	5.2061E-02	3.8918E-02
8	5.0383E-01	3.8205E-01	2.8950E-01	2.1921E-01	1.6585E-01	1.2537E-01	9.4674E-02	7.1420E-02	5.3813E-02	4.0493E-02
9	5.0383E-01	3.8292E-01	2.9087E-01	2.2082E-01	1.6754E-01	1.2703E-01	9.6247E-02	7.2867E-02	5.5121E-02	4.1659E-02
10	5.0383E-01	3.8361E-01	2.9195E-01	2.2210E-01	1.6887E-01	1.2834E-01	9.7481E-02	7.3999E-02	5.6139E-02	4.2561E-02
11	5.0383E-01	3.8418E-01	2.9284E-01	2.2313E-01	1.6995E-01	1.2940E-01	9.8476E-02	7.4910E-02	5.6956E-02	4.3282E-02
12	5.0383E-01	3.8464E-01	2.9357E-01	2.2399E-01	1.7085E-01	1.3027E-01	9.9296E-02	7.5659E-02	5.7626E-02	4.3873E-02
13	5.0383E-01	3.8504E-01	2.9418E-01	2.2471E-01	1.7160E-01	1.3100E-01	9.9984E-02	7.6286E-02	5.8186E-02	4.4366E-02
14	5.0383E-01	3.8538E-01	2.9471E-01	2.2533E-01	1.7224E-01	1.3163E-01	1.0057E-01	7.6819E-02	5.8662E-02	4.4784E-02
15	5.0383E-01	3.8567E-01	2.9517E-01	2.2586E-01	1.7279E-01	1.3217E-01	1.0107E-01	7.7277E-02	5.9070E-02	4.5143E-02
16	5.0383E-01	3.8592E-01	2.9556E-01	2.2632E-01	1.7327E-01	1.3264E-01	1.0151E-01	7.7676E-02	5.9426E-02	4.5454E-02
17	5.0383E-01	3.8615E-01	2.9591E-01	2.2673E-01	1.7370E-01	1.3305E-01	1.0190E-01	7.8026E-02	5.9737E-02	4.5727E-02
18	5.0383E-01	3.8635E-01	2.9622E-01	2.2709E-01	1.7407E-01	1.3341E-01	1.0224E-01	7.8336E-02	6.0013E-02	4.5969E-02
19	5.0383E-01	3.8652E-01	2.9650E-01	2.2741E-01	1.7441E-01	1.3374E-01	1.0254E-01	7.8612E-02	6.0258E-02	4.6184E-02
20	5.0383E-01	3.8668E-01	2.9675E-01	2.2770E-01	1.7471E-01	1.3403E-01	1.0281E-01	7.8859E-02	6.0478E-02	4.6376E-02
21	5.0383E-01	3.8683E-01	2.9697E-01	2.2797E-01	1.7498E-01	1.3430E-01	1.0306E-01	7.9082E-02	6.0677E-02	4.6550E-02
22	5.0383E-01	3.8696E-01	2.9718E-01	2.2820E-01	1.7523E-01	1.3453E-01	1.0328E-01	7.9285E-02	6.0857E-02	4.6707E-02
23	5.0383E-01	3.8708E-01	2.9736E-01	2.2842E-01	1.7545E-01	1.3475E-01	1.0349E-01	7.9469E-02	6.1020E-02	4.6850E-02
24	5.0383E-01	3.8719E-01	2.9753E-01	2.2862E-01	1.7566E-01	1.3495E-01	1.0367E-01	7.9638E-02	6.1170E-02	4.6981E-02
25	5.0383E-01	3.8729E-01	2.9769E-01	2.2880E-01	1.7584E-01	1.3514E-01	1.0384E-01	7.9792E-02	6.1307E-02	4.7101E-02
26	5.0383E-01	3.8738E-01	2.9783E-01	2.2897E-01	1.7602E-01	1.3530E-01	1.0400E-01	7.9935E-02	6.1434E-02	4.7212E-02
27	5.0383E-01	2.8747E-01	2.9797E-01	2.2912E-01	1.7618E-01	1.3546E-01	1.0415E-01	8.0067E-02	6.1551E-02	4.7314E-02
28	5.0383E-01	3.8755E-01	2.9809E-01	2.2927E-01	1.7633E-01	1.3560E-01	1.0428E-01	8.0189E-02	6.1659E-02	4.7409E-02
29	5.0383E-01	3.8762E-01	2.9820E-01	2.2940E-01	1.7647E-01	1.3574E-01	1.0441E-01	8.0303E-02	6.1760E-02	4.7497E-02
30	5.0383E-01	3.8769E-01	2.9831E-01	2.2953E-01	1.7660E-01	1.3587E-01	1.0452E-01	8.0408E-02	6.1854E-02	4.7579E-02

Fig.16-1 Angular flux and scalar flux for unscattered gamma rays

OUTPUT OF THE COMPUTATION

MONOENERGY (FIRST OUTPUT = UNSCATTERED FLUX , SECOND OUTPUT = SCATTERED FLUX)

RADIATION ENERGY = 1.0000E+00 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

(R-MESH = 5 Z-MESH = 1)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

(R-MESH = 10 Z-MESH = 1)

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

EDOS = DOSE(J,JM) * DELTA-E = 3.7500E-02
EDOS = DOSE(J,JM) * DELTA-E = 3.7500E-02

SCALAR FLUX - (N/CM**2.SEC.MEV)

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	0.0	9.7328E-02	1.2140E-01	1.1357E-01	9.4436E-02	7.3620E-02	5.5097E-02	4.0089E-02	2.8573E-02	2.0048E-02
2	0.0	1.1034E-01	1.5193E-01	1.5392E-01	1.3663E-01	1.1244E-01	8.8064E-02	6.6584E-02	4.9033E-02	3.5376E-02
3	0.0	1.1407E-01	1.6551E-01	1.7606E-01	1.6816E-01	1.4705E-01	1.2205E-01	9.7451E-02	7.5512E-02	5.7116E-02
4	0.0	1.1563E-01	1.7133E-01	1.8924E-01	1.8472E-01	1.6782E-01	1.4519E-01	1.2108E-01	9.6069E-02	7.7528E-02
5	0.0	1.1685E-01	1.7463E-01	1.9527E-01	1.9354E-01	1.7922E-01	1.5864E-01	1.3584E-01	1.1330E-01	9.2450E-02
6	0.0	1.1752E-01	1.7675E-01	1.9909E-01	1.9900E-01	1.8611E-01	1.6672E-01	1.4481E-01	1.2282E-01	1.0216E-01
7	0.0	1.1799E-01	1.7824E-01	2.0174E-01	2.0274E-01	1.9077E-01	1.7209E-01	1.5068E-01	1.2900E-01	1.0849E-01
8	0.0	1.1834E-01	1.7934E-01	2.0370E-01	2.0548E-01	1.9416E-01	1.7595E-01	1.5485E-01	1.3335E-01	1.1288E-01
9	0.0	1.1861E-01	1.8019E-01	2.0519E-01	2.0758E-01	1.9673E-01	1.7887E-01	1.5799E-01	1.3659E-01	1.1613E-01
10	0.0	1.1882E-01	1.8086E-01	2.0636E-01	2.0923E-01	1.9876E-01	1.8116E-01	1.6045E-01	1.3911E-01	1.1865E-01
11	0.0	1.1900E-01	1.8141E-01	2.0734E-01	2.1057E-01	2.0040E-01	1.8301E-01	1.6242E-01	1.4113E-01	1.2066E-01
12	0.0	1.1914E-01	1.8186E-01	2.0814E-01	2.1168E-01	2.0175E-01	1.8454E-01	1.6404E-01	1.4279E-01	1.2230E-01
13	0.0	1.1926E-01	1.8224E-01	2.0881E-01	2.1261E-01	2.0289E-01	1.8582E-01	1.6540E-01	1.4418E-01	1.2368E-01
14	0.0	1.1937E-01	1.8257E-01	2.0938E-01	2.1340E-01	2.0386E-01	1.8690E-01	1.6656E-01	1.4536E-01	1.2484E-01
15	0.0	1.1946E-01	1.8285E-01	2.0988E-01	2.1409E-01	2.0469E-01	1.8784E-01	1.6755E-01	1.4637E-01	1.2584E-01
16	0.0	1.1954E-01	1.8310E-01	2.1031E-01	2.1468E-01	2.0542E-01	1.8866E-01	1.6842E-01	1.4725E-01	1.2671E-01
17	0.0	1.1961E-01	1.8331E-01	2.1069E-01	2.1521E-01	2.0606E-01	1.8937E-01	1.6918E-01	1.4803E-01	1.2747E-01
18	0.0	1.1967E-01	1.8351E-01	2.1102E-01	2.1567E-01	2.0662E-01	1.9000E-01	1.6985E-01	1.4871E-01	1.2815E-01
19	0.0	1.1972E-01	1.8368E-01	2.1132E-01	2.1609E-01	2.0712E-01	1.9057E-01	1.7045E-01	1.4932E-01	1.2875E-01
20	0.0	1.1977E-01	1.8383E-01	2.1159E-01	2.1646E-01	2.0758E-01	1.9108E-01	1.7098E-01	1.4986E-01	1.2928E-01
21	0.0	1.1982E-01	1.8397E-01	2.1183E-01	2.1679E-01	2.0799E-01	1.9153E-01	1.7147E-01	1.5035E-01	1.2977E-01
22	0.0	1.1986E-01	1.8410E-01	2.1205E-01	2.1710E-01	2.0836E-01	1.9195E-01	1.7191E-01	1.5080E-01	1.3021E-01
23	0.0	1.1990E-01	1.8421E-01	2.1226E-01	2.1738E-01	2.0869E-01	1.9233E-01	1.7231E-01	1.5121E-01	1.3060E-01
24	0.0	1.1993E-01	1.8432E-01	2.1244E-01	2.1763E-01	2.0900E-01	1.9267E-01	1.7267E-01	1.5158E-01	1.3097E-01
25	0.0	1.1996E-01	1.8441E-01	2.1261E-01	2.1787E-01	2.0929E-01	1.9299E-01	1.7301E-01	1.5192E-01	1.3130E-01
26	0.0	1.1999E-01	1.8450E-01	2.1277E-01	2.1808E-01	2.0955E-01	1.9328E-01	1.7332E-01	1.5223E-01	1.3161E-01
27	0.0	1.2002E-01	1.8459E-01	2.1291E-01	2.1828E-01	2.0979E-01	1.9355E-01	1.7360E-01	1.5252E-01	1.3190E-01
28	0.0	1.2004E-01	1.8466E-01	2.1304E-01	2.1847E-01	2.1001E-01	1.9380E-01	1.7387E-01	1.5279E-01	1.3216E-01
29	0.0	1.2006E-01	1.8473E-01	2.1317E-01	2.1864E-01	2.1022E-01	1.9404E-01	1.7411E-01	1.5304E-01	1.3241E-01
30	0.0	1.2009E-01	1.8480E-01	2.1328E-01	2.1880E-01	2.1042E-01	1.9425E-01	1.7434E-01	1.5327E-01	1.3263E-01

Fig.16-2 Angular flux and scalar flux for scattered gamma rays at 1.0 MeV.

```
RADIATION ENERGY = 2.0350E-01 MEV

ANGULAR FLUX - (N/CM**2.SEC.MEV.SR)

 (R-MESH =  5  Z-MESH =  1)
    0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
    0.0          0.0          0.0          0.0          2.8650E-02   3.7141E-02   4.5971E-02   4.7688E-02   4.8310E-02   5.0922E-02
    4.6685E-02   6.2384E-02   8.4712E-02   7.6307E-02   1.0866E-01   1.3087E+00   1.0107E-01   1.4712E-01
 (R-MESH = 10  Z-MESH =  1)
    0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0          0.0
    0.0          0.0          0.0          0.0          3.2049E-02   4.0570E-02   4.5696E-02   5.0672E-02   4.9977E-02   5.4906E-02
    5.2647E-02   6.7160E-02   9.2107E-02   8.3864E-02   8.8977E-02   1.3550E+00   1.0973E-01   1.6818E-01
EDOS = DOSE(J,JM) * DELTA-E = 5.0875E-03
EDOS = DOSE(J,JM) * DELTA-E = 2.5000E-02
```

SCALAR FLUX - (N/CM**2.SEC.MEV)

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	8.8665E-01	8.3329E-01	7.6768E-01	6.8820E-01	6.0329E-01	5.2073E-01	4.4437E-01	3.7592E-01	3.1591E-01	2.6378E-01
2	9.1139E-01	9.2015E-01	8.6367E-01	7.7474E-01	6.7684E-01	5.8096E-01	4.9254E-01	4.1382E-01	3.4534E-01	2.8673E-01
3	9.2902E-01	9.7147E-01	9.3516E-01	8.5451E-01	7.5446E-01	6.5116E-01	5.5319E-01	4.6466E-01	3.8711E-01	3.2053E-01
4	9.4361E-01	1.0086E+00	9.8522E-01	9.1337E-01	8.1681E-01	7.1192E-01	6.0932E-01	5.1464E-01	4.3041E-01	3.5733E-01
5	9.5532E-01	1.0357E+00	1.0210E+00	9.5475E-01	8.6208E-01	7.5855E-01	6.5462E-01	5.5689E-01	4.6859E-01	3.9111E-01
6	9.6549E-01	1.0588E+00	1.0468E+00	9.8607E-01	8.9584E-01	7.9380E-01	6.9000E-01	5.9088E-01	5.0021E-01	4.1979E-01
7	9.7450E-01	1.0767E+00	1.0714E+00	1.0111E+00	9.2230E-01	8.2114E-01	7.1764E-01	6.1794E-01	5.2585E-01	4.4348E-01
8	9.8152E-01	1.0902E+00	1.0869E+00	1.0309E+00	9.4330E-01	8.4267E-01	7.3927E-01	6.3929E-01	5.4642E-01	4.6278E-01
9	9.8708E-01	1.1008E+00	1.1028E+00	1.0466E+00	9.6010E-01	8.5986E-01	7.5643E-01	6.5615E-01	5.6278E-01	4.7838E-01
10	9.9154E-01	1.1093E+00	1.1138E+00	1.0591E+00	9.7340E-01	8.7359E-01	7.7019E-01	6.6969E-01	5.7592E-01	4.9093E-01
11	9.9511E-01	1.1160E+00	1.1225E+00	1.0691E+00	9.8415E-01	8.8471E-01	7.8144E-01	6.8079E-01	5.8665E-01	5.0116E-01
12	9.9800E-01	1.1213E+00	1.1296E+00	1.0772E+00	9.9296E-01	8.9368E-01	7.9067E-01	6.8988E-01	5.9542E-01	5.0953E-01
13	1.0004E+00	1.1257E+00	1.1352E+00	1.0838E+00	1.0001E+00	9.0140E-01	7.9828E-01	6.9737E-01	6.0268E-01	5.1646E-01
14	1.0026E+00	1.1292E+00	1.1397E+00	1.0892E+00	1.0060E+00	9.0761E-01	8.0459E-01	7.0362E-01	6.0874E-01	5.2224E-01
15	1.0041E+00	1.1320E+00	1.1435E+00	1.0936E+00	1.0110E+00	9.1282E-01	8.0988E-01	7.0886E-01	6.1383E-01	5.2711E-01
16	1.0053E+00	1.1343E+00	1.1467E+00	1.0974E+00	1.0151E+00	9.1720E-01	8.1433E-01	7.1328E-01	6.1812E-01	5.3121E-01
17	1.0063E+00	1.1362E+00	1.1493E+00	1.1005E+00	1.0186E+00	9.2087E-01	8.1806E-01	7.1697E-01	6.2171E-01	5.3463E-01
18	1.0070E+00	1.1378E+00	1.1515E+00	1.1031E+00	1.0215E+00	9.2388E-01	8.2113E-01	7.2001E-01	6.2465E-01	5.3743E-01
19	1.0075E+00	1.1390E+00	1.1532E+00	1.1052E+00	1.0237E+00	9.2625E-01	8.2352E-01	7.2237E-01	6.2693E-01	5.3960E-01
20	1.0078E+00	1.1398E+00	1.1543E+00	1.1066E+00	1.0253E+00	9.2787E-01	8.2515E-01	7.2397E-01	6.2846E-01	5.4104E-01
21	1.0077E+00	1.1400E+00	1.1548E+00	1.1072E+00	1.0260E+00	9.2855E-01	8.2582E-01	7.2460E-01	6.2904E-01	5.4155E-01
22	1.0070E+00	1.1394E+00	1.1543E+00	1.1066E+00	1.0254E+00	9.2789E-01	8.2514E-01	7.2389E-01	6.2830E-01	5.4074E-01
23	1.0055E+00	1.1376E+00	1.1522E+00	1.1043E+00	1.0228E+00	9.2521E-01	8.2241E-01	7.2115E-01	6.2550E-01	5.3796E-01
24	1.0023E+00	1.1335E+00	1.1474E+00	1.0989E+00	1.0170E+00	9.1926E-01	8.1643E-01	7.1506E-01	6.1948E-01	5.3221E-01
25	9.9625E-01	1.1257E+00	1.1379E+00	1.0884E+00	1.0059E+00	9.0794E-01	8.0479E-01	7.0353E-01	6.0843E-01	5.2191E-01
26	9.8462E-01	1.1101E+00	1.1200E+00	1.0687E+00	9.8542E-01	8.8661E-01	7.8357E-01	6.8316E-01	5.8940E-01	5.0449E-01
27	9.6075E-01	1.0797E+00	1.0849E+00	1.0313E+00	9.4599E-01	8.4720E-01	7.4567E-01	6.4781E-01	5.5721E-01	4.7565E-01
28	9.0461E-01	1.0121E+00	1.0111E+00	9.5296E-01	8.6782E-01	7.7236E-01	6.7629E-01	5.8502E-01	5.0153E-01	4.2733E-01
29	7.3850E-01	8.3017E-01	8.2206E-01	7.6868E-01	6.9533E-01	6.1570E-01	5.3691E-01	4.6293E-01	3.9596E-01	3.3734E-01
30	1.3076E-01	2.0306E-01	2.3184E-01	2.3559E-01	2.2612E-01	2.0941E-01	1.6928E-01	1.6605E-01	1.4720E-01	1.2766E-01

Fig.16-3 Angular flux and scalar flux at 0.2 MeV.

```
RESPONSE FUNCTION
  1.0000E+00  9.2500E-01  8.5000E-01  7.7500E-01  7.0000E-01  6.2500E-01  5.5000E-01  5.0000E-01  4.5000E-01  4.0000E-01
  3.5000E-01  3.0000E-01  2.7500E-01  2.5000E-01  2.2850E-01  2.0350E-01  1.7850E-01  1.5000E-01  1.2500E-01  1.0000E-01

** DOSE DISTRIBUTION **   JM =  1
```

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	5.2752E-01	3.7995E-01	2.7594E-01	2.0236E-01	1.5016E-01	1.1294E-01	8.6078E-02	6.6420E-02	5.1825E-02	4.0811E-02
2	5.2923E-01	4.3895E-01	3.4612E-01	2.6463E-01	2.0025E-01	1.5126E-01	1.1451E-01	8.7099E-02	6.6673E-02	5.1393E-02
3	5.3112E-01	4.5925E-01	3.8282E-01	3.0888E-01	2.4353E-01	1.8960E-01	1.4656E-01	1.1287E-01	8.6792E-02	6.6758E-02
4	5.3261E-01	4.6943E-01	3.9993E-01	3.3218E-01	2.7021E-01	2.1625E-01	1.7125E-01	1.3463E-01	1.0530E-01	8.2041E-02
5	5.3376E-01	4.7584E-01	4.1041E-01	3.4543E-01	2.8600E-01	2.3338E-01	1.8817E-01	1.5046E-01	1.1956E-01	9.4551E-02
6	5.3485E-01	4.8189E-01	4.1795E-01	3.5457E-01	2.9627E-01	2.4464E-01	1.9984E-01	1.6176E-01	1.3006E-01	1.0403E-01
7	5.3597E-01	4.8653E-01	4.2409E-01	3.6163E-01	3.0392E-01	2.5265E-01	2.0815E-01	1.7005E-01	1.3791E-01	1.1123E-01
8	5.3679E-01	4.8969E-01	4.2864E-01	3.6699E-01	3.0971E-01	2.5863E-01	2.1420E-01	1.7612E-01	1.4383E-01	1.1676E-01
9	5.3743E-01	4.9205E-01	4.3213E-01	3.7117E-01	3.1424E-01	2.6333E-01	2.1887E-01	1.8068E-01	1.4828E-01	1.2103E-01
10	5.3793E-01	4.9403E-01	4.3494E-01	3.7443E-01	3.1780E-01	2.6699E-01	2.2253E-01	1.8425E-01	1.5172E-01	1.2431E-01
11	5.3835E-01	4.9547E-01	4.3707E-01	3.7703E-01	3.2066E-01	2.6996E-01	2.2551E-01	1.8716E-01	1.5450E-01	1.2693E-01
12	5.3869E-01	4.9664E-01	4.3888E-01	3.7919E-01	3.2303E-01	2.7242E-01	2.2796E-01	1.8955E-01	1.5676E-01	1.2906E-01
13	5.3905E-01	4.9760E-01	4.4028E-01	3.8093E-01	3.2497E-01	2.7446E-01	2.3000E-01	1.9153E-01	1.5864E-01	1.3082E-01
14	5.3926E-01	4.9836E-01	4.4147E-01	3.8240E-01	3.2660E-01	2.7616E-01	2.3171E-01	1.9319E-01	1.6023E-01	1.3231E-01
15	5.3943E-01	4.9900E-01	4.4247E-01	3.8364E-01	3.2799E-01	2.7763E-01	2.3317E-01	1.9461E-01	1.6158E-01	1.3357E-01
16	5.3956E-01	4.9955E-01	4.4333E-01	3.8471E-01	3.2919E-01	2.7888E-01	2.3443E-01	1.9583E-01	1.6274E-01	1.3466E-01
17	5.3967E-01	5.0002E-01	4.4407E-01	3.8564E-01	3.3024E-01	2.7996E-01	2.3552E-01	1.9689E-01	1.6375E-01	1.3560E-01
18	5.3976E-01	5.0043E-01	4.4474E-01	3.8646E-01	3.3114E-01	2.8091E-01	2.3646E-01	1.9781E-01	1.6463E-01	1.3641E-01
19	5.3982E-01	5.0079E-01	4.4529E-01	3.8717E-01	3.3193E-01	2.8173E-01	2.3728E-01	1.9861E-01	1.6538E-01	1.3712E-01
20	5.3987E-01	5.0108E-01	4.4579E-01	3.8779E-01	3.3261E-01	2.8243E-01	2.3799E-01	1.9929E-01	1.6603E-01	1.3771E-01
21	5.3989E-01	5.0133E-01	4.4619E-01	3.8830E-01	3.3317E-01	2.8302E-01	2.3857E-01	1.9985E-01	1.6656E-01	1.3820E-01
22	5.3987E-01	5.0151E-01	4.4654E-01	3.8870E-01	3.3362E-01	2.8348E-01	2.3902E-01	2.0028E-01	1.6696E-01	1.3854E-01
23	5.3983E-01	5.0163E-01	4.4674E-01	3.8897E-01	3.3390E-01	2.8377E-01	2.3930E-01	2.0055E-01	1.6715E-01	1.3868E-01
24	5.3973E-01	5.0162E-01	4.4680E-01	3.8903E-01	3.3396E-01	2.8382E-01	2.3935E-01	2.0050E-01	1.6703E-01	1.3853E-01
25	5.3952E-01	5.0143E-01	4.4659E-01	3.8878E-01	3.3367E-01	2.8352E-01	2.3889E-01	1.9995E-01	1.6645E-01	1.3794E-01
26	5.3910E-01	5.0089E-01	4.4592E-01	3.8797E-01	3.3282E-01	2.8235E-01	2.3756E-01	1.9857E-01	1.6508E-01	1.3662E-01
27	5.3827E-01	4.9968E-01	4.4435E-01	3.8620E-01	3.3034E-01	2.7955E-01	2.3464E-01	1.9566E-01	1.6228E-01	1.3399E-01
28	5.3659E-01	4.9705E-01	4.4102E-01	3.8107E-01	3.2444E-01	2.7336E-01	2.2850E-01	1.8979E-01	1.5684E-01	1.2907E-01
29	5.3272E-01	4.9096E-01	4.2956E-01	3.6767E-01	3.1051E-01	2.5962E-01	2.1589E-01	1.7840E-01	1.4676E-01	1.2029E-01
30	5.2287E-01	4.6070E-01	3.9486E-01	3.3326E-01	2.7854E-01	2.3115E-01	1.9077E-01	1.5674E-01	1.2829E-01	1.0468E-01

Fig.16-4 Response function for the total energy flux and total energy fluxes integrated over energy

RESPONSE FUNCTION

1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00

** DOSE DISTRIBUTION ** JM = 2

R	Z 1	Z 2	Z 3	Z 4	Z 5	Z 6	Z 7	Z 8	Z 9	Z 10
1	6.1105E-01	5.1040E-01	4.2762E-01	3.3357E-01	2.9023E-01	2.3763E-01	1.9448E-01	1.5917E-01	1.3033E-01	1.0670E-01
2	6.1655E-01	5.8569E-01	5.1275E-01	4.2876E-01	3.5156E-01	2.8567E-01	2.3115E-01	1.8669E-01	1.5077E-01	1.2181E-01
3	6.2272E-01	6.1790E-01	5.6422E-01	4.8887E-01	4.1015E-01	3.3796E-01	2.7541E-01	2.2290E-01	1.7961E-01	1.4434E-01
4	6.2786E-01	6.3673E-01	5.9239E-01	5.2483E-01	4.5017E-01	3.7754E-01	3.1206E-01	2.5536E-01	2.0744E-01	1.6761E-01
5	6.3188E-01	6.4956E-01	6.1118E-01	5.4730E-01	4.7602E-01	4.0511E-01	3.3910E-01	2.8064E-01	2.3026E-01	1.8771E-01
6	6.3561E-01	6.6236E-01	6.2554E-01	5.6380E-01	4.9410E-01	4.2450E-01	3.5899E-01	2.9986E-01	2.4813E-01	2.0387E-01
7	6.3936E-01	6.7249E-01	6.3778E-01	5.7719E-01	5.0821E-01	4.3912E-01	3.7399E-01	3.1469E-01	2.6217E-01	2.1678E-01
8	6.4215E-01	6.7952E-01	6.4701E-01	5.8765E-01	5.1922E-01	4.5036E-01	3.8532E-01	3.2598E-01	2.7313E-01	2.2704E-01
9	6.4429E-01	6.8479E-01	6.5416E-01	5.9583E-01	5.2797E-01	4.5933E-01	3.9418E-01	3.3464E-01	2.8158E-01	2.3515E-01
10	6.4598E-01	6.8917E-01	6.5991E-01	6.0223E-01	5.3480E-01	4.6634E-01	4.0120E-01	3.4152E-01	2.8824E-01	2.4151E-01
11	6.4740E-01	6.9243E-01	6.6421E-01	6.0732E-01	5.4031E-01	4.7204E-01	4.0696E-01	3.4718E-01	2.9369E-01	2.4668E-01
12	6.4854E-01	6.9503E-01	6.6789E-01	6.1154E-01	5.4490E-01	4.7678E-01	4.1169E-01	3.5181E-01	2.9810E-01	2.5085E-01
13	6.4965E-01	6.9714E-01	6.7066E-01	6.1487E-01	5.4858E-01	4.8066E-01	4.1560E-01	3.5562E-01	3.0176E-01	2.5432E-01
14	6.5036E-01	6.9877E-01	6.7295E-01	6.1764E-01	5.5163E-01	4.8387E-01	4.1885E-01	3.5881E-01	3.0483E-01	2.5723E-01
15	6.5090E-01	7.0011E-01	6.7487E-01	6.1995E-01	5.5424E-01	4.8661E-01	4.2159E-01	3.6151E-01	3.0743E-01	2.5969E-01
16	6.5134E-01	7.0123E-01	6.7649E-01	6.2192E-01	5.5643E-01	4.8892E-01	4.2393E-01	3.6381E-01	3.0965E-01	2.6179E-01
17	6.5170E-01	7.0217E-01	6.7786E-01	6.2361E-01	5.5834E-01	4.9090E-01	4.2593E-01	3.6578E-01	3.1154E-01	2.6358E-01
18	6.5198E-01	7.0296E-01	6.7908E-01	6.2507E-01	5.5993E-01	4.9258E-01	4.2763E-01	3.6745E-01	3.1314E-01	2.6509E-01
19	6.5218E-01	7.0364E-01	6.8005E-01	6.2628E-01	5.6128E-01	4.9399E-01	4.2905E-01	3.6884E-01	3.1446E-01	2.6635E-01
20	6.5232E-01	7.0416E-01	6.8086E-01	6.2729E-01	5.6236E-01	4.9511E-01	4.3018E-01	3.6994E-01	3.1553E-01	2.6733E-01
21	6.5235E-01	7.0451E-01	6.8141E-01	6.2799E-01	5.6313E-01	4.9591E-01	4.3097E-01	3.7071E-01	3.1625E-01	2.6800E-01
22	6.5223E-01	7.0465E-01	6.8175E-01	6.2834E-01	5.6350E-01	4.9628E-01	4.3133E-01	3.7105E-01	3.1656E-01	2.6821E-01
23	6.5200E-01	7.0449E-01	6.8160E-01	6.2819E-01	5.6330E-01	4.9605E-01	4.3108E-01	3.7078E-01	3.1617E-01	2.6773E-01
24	6.5146E-01	7.0352E-01	6.8080E-01	6.2720E-01	5.6220E-01	4.9489E-01	4.2991E-01	3.6941E-01	3.1469E-01	2.6626E-01
25	6.5040E-01	7.0228E-01	6.7880E-01	6.2483E-01	5.5961E-01	4.9222E-01	4.2687E-01	3.6622E-01	3.1155E-01	2.6328E-01
26	6.4834E-01	6.9905E-01	6.7465E-01	6.1998E-01	5.5445E-01	4.8628E-01	4.2066E-01	3.6010E-01	3.0571E-01	2.5783E-01
27	6.4430E-01	6.9250E-01	6.6625E-01	6.1055E-01	5.4320E-01	4.7444E-01	4.0891E-01	3.4887E-01	2.9524E-01	2.4828E-01
28	6.3602E-01	6.7878E-01	6.4923E-01	5.8879E-01	5.1998E-01	4.5130E-01	3.8682E-01	3.2838E-01	2.7669E-01	2.3179E-01
29	6.1698E-01	6.4784E-01	6.0379E-01	5.3969E-01	4.7124E-01	4.0529E-01	3.4479E-01	2.9087E-01	2.4377E-01	2.0329E-01
30	5.6919E-01	5.4143E-01	4.8724E-01	4.2600E-01	3.6630E-01	3.1134E-01	2.6240E-01	2.1963E-01	1.8281E-01	1.5150E-01

CURRENT IN UNITS OF DOSE RATE

** DOS(+) **

4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01
4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01
4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01	4.5936E-01

** DOS(-) **

5.4066E-02	5.7867E-02	6.1209E-02	6.3808E-02	6.5820E-02	6.7577E-02	6.9184E-02	7.0410E-02	7.1363E-02	7.2119E-02
7.2746E-02	7.3244E-02	7.3694E-02	7.4017E-02	7.4265E-02	7.4469E-02	7.4639E-02	7.4775E-02	7.4879E-02	7.4954E-02
7.4984E-02	7.4950E-02	7.4855E-02	7.4628E-02	7.4165E-02	7.3249E-02	7.1388E-02	6.7377E-02	5.7336E-02	2.9011E-02

JM = 2
INCIDENT CURRENT = 5.7725E+02
REFLECTED CURRENT = 8.8466E+01
TOTAL ALBEDO = 1.5325E-01

Fig.16-5 Response function for the total number flux and total number fluxes integrated over energy. In addition, number currents and total number current albedo.

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
MIURA NEUTRON EXP. NO.1 CYLN. V010
 1  2  0 -1
17 10  5  0  1
 0
14.1      0.2       7.660E 10
 6  6  2  8  2  3  3  5  2 11
21.06     23.59     1.50      27.195    1.0       8.0       6.0       20.0
 2.0      50.0
 9 26 10  3  5
30.0      120.0     45.0      5.0       20.0
 6  9
21.06     30.0      0.0
1.100E 06 1.040E 06 9.600E 06 6.500E 06 7.150E 06 5.400E 06
1.51      1.49      1.38      1.29      1.120     0.960     0.85      0.73
0.67
 0  0
0.0
 3  2  1  2  1  1  1  0  1  2
 2  2  1  2  1  1  1  0  1  2
 2  2  1  2  2  2  1  0  1  2
 2  2  1  2  2  2  1  1  1  2
 2  2  1  2  2  2  2  2  2  2
 1  2  3  4  5  6  5  0  5  4
 4  4  3  4  5  6  5  0  5  4
 4  4  3  4  4  4  5  6  5  4
 4  4  3  4  4  4  5  5  5  4
 4  4  3  4  4  4  4  4  4  4
   CORE
HY
2011 1.0        0.04577
OXY
2086 16.0       0.02291
AL
2137 27.0       0.01842
REFLECTOR
HY
2011 1.0        0.001638
C-12
2062 12.0       0.07341
AL TANK
AL
2137 27.00      0.06025
WATER
HY
2011 1.0        0.06674
OXY
2086 16.0       0.03337
IRON
FE
2260 55.85      0.08466   10
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

Fig. 17 An example of input data for practical neutron shielding calculation

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
2.596     2.898     3.215     3.495     3.646     3.694     3.648     3.402
3.314     3.119     2.641     2.661     2.356     2.171     2.234     2.171
2.162     4.503     2.736     2.
1.192     1.425     1.709     1.964     2.069     2.110     2.173     2.129
2.305     2.209     2.027     1.963     1.677     1.770     2.120     2.166
1.986     2.883     2.600
LEAD
PB
2820 207.2      0.03296
 0
 0   0 10
     AU7G 0.20
 1.015E-02 1.101E-02 1.192E-02 1.292E-02 1.401E-02 1.516E-02 1.705E-02 2.141E-02
 3.190E-02 4.600E-02 5.976E-02 7.038E-02 7.759E-02 8.285E-02 9.054E-02 1.039E-01
 1.236E-01 1.446E-01 1.694E-01 1.987E-01 2.249E-01 2.493E-01 2.697E-01 2.857E-01
 AU(N,G)+CD 0.20
 9.950E-03 1.079E-02 1.168E-02 1.267E-02 1.375E-02 1.488E-02 1.673E-02 2.099E-02
 3.121E-02 4.493E-02 5.829E-02 6.846E-02 7.533E-02 8.030E-02 8.768E-02 1.006E-01
 1.197E-01 1.401E-01 1.638E-01 1.921E-01 2.175E-01 2.411E-01 2.608E-01 2.763E-01
 CU(N,G) 0.20                                          SAND LIBRARY
 4.023E-27 3.704E-27 3.736E-27 4.051E-27 4.448E-27 4.935E-27 5.464E-27 6.053E-27
 6.656E-27 7.288E-27 7.916E-27 8.613E-27 9.513E-27 1.040E-26 1.109E-26 1.188E-26
 1.292E-26 1.425E-26 1.602E-26 1.823E-26 2.073E-26 2.324E-26 2.607E-26 2.983E-26
IN5N  0.20                                                       ENDF/B-IV
 7.814E-26 1.837E-25 2.673E-25 2.922E-25 3.095E-25 3.178E-25 3.198E-25 3.157E-25
 3.054E-25 2.841E-25 2.508E-25 1.882E-25 1.173E-25 7.037E-26 1.958E-26 1.400E-26
 8.000E-27 3.750E-27 1.250E-27 0.0       0.0       0.0       0.0       0.0
 NI(N,P) 2.79 MEV 0.2
 4.144E-25 5.996E-25 6.579E-25 6.497E-25 6.173E-25 4.615E-25 3.866E-25 2.656E-25
 1.570E-25 8.334E-26 3.438E-26 1.637E-26 7.051E-27 1.826E-27 0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 ZN(4.4 MEV)
 2.201E-25 2.909E-25 2.927E-25 2.637E-25 2.353E-25 1.916E-25 1.430E-25 9.732E-26
 5.733E-26 2.855E-26 8.612E-27 1.236E-27
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
AL-P (5.46 MEV)
 7.941E-26 9.678E-26 1.001E-25 8.011E-26 5.278E-26 2.743E-26 1.168E-26 5.752E-27
 2.885E-26

 MG-24 (N,P) 6.3 MEV
 2.164E-25 1.717E-25 1.277E-25 8.230E-26 1.501E-26


FE6P                                                             ENDF/B-IV
 1.103E-25 9.124E-26 6.064E-26 3.922E-26 1.617E-26 3.088E-27 6.962E-29 6.472E-31
 3.827E-32 0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
AL7A                                                             ENDF/B-IV
 1.239E-25 1.104E-25 7.570E-26 3.242E-26 5.185E-27 8.176E-29 3.963E-32 3.944E-41
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

```
********************
*                  *
*  INPUT DATA LIST *
*                  *
********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
 19 10  5  0  1
 14.1       0.4        7.660E 10
  6  8  2  2  2  3  3  5  2 11
 21.06      23.59      1.56       27.195     1.0        8.0        6.0        20.0
  2.0       50.0
  9 26 10  3  5
 30.0       120.0      45.0       5.0        20.0
  6  9
 21.06      30.0       0.0
 1.100E 06 1.040E 06 9.600E 06 8.500E 06 7.150E 06 5.400E 06
 1.51       1.49       1.38       1.29       1.120      0.980      0.85       0.73
 0.67
  0  0
 0.0
  3  2  1  2  1  1  1  0  1  2
  2  2  1  2  1  1  1  0  1  2
  2  2  1  2  2  2  1  0  1  2
  2  2  1  2  2  2  1  1  1  2
  2  2  1  2  2  2  2  2  2  2
  1  2  3  4  5  6  5  0  5  4
  4  4  3  4  5  6  5  0  5  4
  4  4  3  4  4  4  5  0  5  4
  4  4  3  4  4  4  5  5  5  4
  4  4  3  4  4  4  4  4  4  4
  CORE
 HY
  4011 1.0         0.04577
  OXY
  4086 16.0        0.02291
  AL
  4137 27.0        0.01342
  REFLECTOR
  HY
  4011 1.0         0.001638
  C-12
  4062 12.0        0.07341
 AL TANK
  AL
  4137 27.00       0.06025
  WATER
  HY
  4011 1.0         0.06674
  OXY
  4086 16.0        0.03337
  IRON
  FE
  4260 55.85       0.08466   10
  2.725      3.308      3.638      3.590      3.310      2.811      2.367      2.278
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

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*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
 2.119      2.533      1.905      2.608      2.094      2.984      4.756      9.533
 1.087      2.372      4.928      11.660     6.152      6.593      7.616      8.770
 1.289      1.792      2.069      2.130      2.289      2.000      1.846      2.142
 2.114      2.528      1.899      2.802      2.088      2.975      4.747      9.518
 1.073      2.329      4.917     11.63       6.144      6.588      7.612      8.73
 LEAD
 PB
 4820 207.2      0.03296
  0
  0  0  4
AU7G     WITH SELF SHIELDING     0.4
 1.056   -2 1.226   -2 1.427   -2 1.778   -2 3.359   -2 6.018   -2 7.756   -2 9.163   -2
 1.238E-01 1.704E-01 2.266E-01 2.704E-01 3.028E-01 3.516E-01 4.402E-01 5.403E-01
 6.784   -1 8.735   -1 1.192   +0
AU7G(CD)WITH SELF SHIELDING   0.4
 1.035   -2 1.202   -2 1.400   -2 1.744   -2 3.286   -2 5.866   -2 7.530   -2 8.873   -2
 1.198   -1 1.648   -1 2.191   -1 2.614   -1 2.930   -1 3.403   -1 4.261   -1 5.230   -1
 6.567   -1 8.456   -1 1.155   +0
 CU(N,G) 0.40                                         SAND LIBRARY
 3.983E-27 3.784E-27 4.495E-27 5.510E-27 6.652E-27 7.983E-27 9.560E-27 1.121E-26
 1.309E-26 1.608E-26 2.074E-26 2.616E-26 3.350E-26 3.957E-26 4.708E-26 5.666E-26
 7.375E-26 9.085E-26 2.131E-25 1.705E-24 7.373E-25 3.005E-26 8.140E-25 2.013E-26
IN5N  0.40                                                      ENDF/B-IV
 1.200E-25 2.734E-25 3.111E-25 3.188E-25 3.036E-25 2.422E-25 1.191E-25 2.783E-26
 5.899E-27 1.250E-27 0.0       0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0       0.0        0.0        0.0        0.0        0.0
 23 10  5  0  1
  0
 14.1       0.0        7.060E 10
  6  8  2  8  2  3  3  5  2 11
 21.06      23.59      1.50       27.195     1.0        6.0        6.0        20.0
  2.0       50.0
  9 26 10  3  5
 30.0       120.0      45.0       5.0        20.0
  6  9
 21.06      30.0       0.0
 1.100E 06 1.040E 06 9.600E 06 8.500E 06 7.150E 06 5.400E 06
 1.51       1.49       1.28       1.29       1.120      0.960      0.85       0.73
 0.67
 10 60
 0.01
  3  2  1  2  1  1  1  0  1  2
  2  2  1  2  1  1  1  0  1  2
  2  2  1  2  2  2  1  0  1  2
  2  2  1  2  2  2  1  1  1  2
  2  2  1  2  2  2  2  2  2  2
  1  2  3  4  5  6  5  0  5  4
  4  4  3  4  5  6  5  0  5  4
  4  4  3  4  4  4  5  0  5  4
  4  4  3  4  4  4  5  5  5  4
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
```

```
*********************
*                   *
*  INPUT DATA LIST  *
*                   *
*********************

....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8
  4  4  3  4  4  4  4  4  4  4
 CORE
HY
 8011 1.0         0.04577
 OXY
 8086 16.0        0.02291
 AL
 8137 27.0        0.01842
 REFLECTOR
 HY
 8011 1.0         0.001638
 C-12
 8062 12.0        0.07341
AL TANK
 AL
 8137 27.00       0.06025
 WATER
 HY
 8011 1.0         0.06674
 OXY
 8086 16.0        0.03337
 IRON
 FE
 8260 55.85       0.08466
 LEAD
 PB
 6620 207.2       0.03296
  0
  0  0  3
AU7G     WITH SELF SHIELDING  0.8
 1.158E-02 1.547E-02 3.966E-02 7.826E-02 1.266E-01 2.313E-01 3.100E-01 4.549E-01
 7.093E-01 1.262E 00 2.241E 00 4.221E 00 1.055E 01 1.525E 01 1.207E 01 4.198E 01
 5.112E-01 1.173E 00 2.741E 02 2.443E 02 2.596E 01 2.502E 01 8.441E 01
AU7G(CU)        0.8 WITH SELF SHIELDING
 1.135E-02 1.517E-02 3.675E-02 7.596E-02 1.225E-01 2.237E-01 3.000E-01 4.404E-01
 6.666E-01 1.223E 00 2.174E 00 4.092E 00 1.026E 01 1.324E 01 1.162E 01 4.078E 01
 4.940E-01 1.148E-00 2.675E 02 3.359E 02 2.459E 01 1.770E 01 6.427E-04
 CU(N,G) 0.80                                               SAND LIBRARY
 3.890E-27 4.668E-27 6.928E-27 9.919E-27 1.377E-26 2.171E-26 3.397E-26 4.897E-26
 7.570E-26 8.706E-25 4.075E-25 4.175E-25 1.565E-26 2.611E-24 9.068E-27 1.665E-26
 5.867E-26 9.822E-26 1.910E-25 3.132E-25 5.406E-25 6.328E-25 3.921E-24
....*....1....*....2....*....3....*....4....*....5....*....6....*....7....*....8

*** INPUT DATA END ***
```

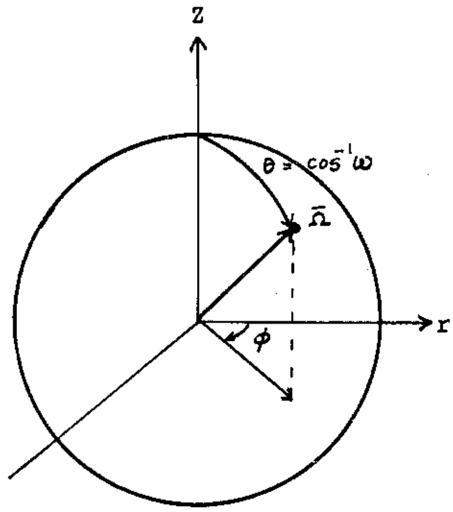

Fig. 18 Moving direction Ω of radiation in PALLAS.

Appendix. Photon cross sections for producing the linear attenuation coefficients and pair production coefficients used for PALLAS-2DCY

The appendix includes the photon cross sections for the main elements and compounds used widely in γ-ray shielding calculations: the data are given in table 1 in the order of boron, carbon, sodium, aluminum, silicon, calcium, iron, copper, tungsten, lead, uranium, water, silicon dioxide, air, concrete, muscle and polyethylene, which are all taken from ref. (6). The linear attenuation coefficients are produced multiplying the total cross sections without coherent (cm^2/g) by the density of material (g/cm^3), while the pair production coefficients in units of cm^{-1} are produced multiplying the pair production cross sections (b/atom) of sum of the nuclear field and electron field by the atomic density (atoms/cm^3), or multiplying the data (cm^2/g) by the density of material (g/cm^3). The densities of materials, atomic densities and electron densities are given in table 2

Table 1 Photon cross sections(6)

BORON, Z=5

Photon energy	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*cm²/g*	*cm²/g*
1.00-02	4.61+00	3.20+00	1.63+01			2.09+01	1.95+01	1.16+00	1.09+00
1.50-02	3.95+00	3.14+00	4.36+00			8.31+00	7.50+00	4.63-01	4.18-01
2.00-02	3.61+00	3.09+00	1.68+00			5.29+00	4.77+00	2.95-01	2.66-01
3.00-02	3.25+00	2.99+00	4.52-01			3.70+00	3.44+00	2.06-01	1.92-01
4.00-02	3.04+00	2.89+00	1.84-01			3.23+00	3.08+00	1.80-01	1.71-01
5.00-02	2.91+00	2.81+00	8.80-02			3.00+00	2.89+00	1.67-01	1.61-01
6.00-02	2.80+00	2.73+00	4.86-02			2.85+00	2.78+00	1.59-01	1.55-01
8.00-02	2.63+00	2.59+00	1.89-02			2.64+00	2.60+00	1.47-01	1.45-01
1.00-01	2.49+00	2.46+00	8.97-03			2.50+00	2.47+00	1.39-01	1.38-01
1.50-01	2.23+00	2.22+00	2.38-03			2.23+00	2.22+00	1.24-01	1.24-01
2.00-01	2.04+00	2.03+00	9.41-04			2.04+00	2.03+00	1.14-01	1.13-01
3.00-01	1.77+00	1.77+00	2.65-04			1.77-00	1.77+00	9.84-02	9.85-02
4.00-01		1.58+00	1.13-04				1.58+00		8.83-02
5.00-01		1.45+00	6.05-05				1.45+00		8.06-02
6.00-01		1.34+00	3.77-05				1.34+00		7.45-02
8.00-01		1.18+00	1.90-05				1.18+00		6.55-02
1.00+00		1.06+00	1.18-05				1.06+00		5.89-02
1.50+00		8.59-01	5.51-06	1.11-03			8.60-01		4.79-02
2.00+00		7.33-01	3.51-06	4.44-03			7.37-01		4.11-02
3.00+00		5.77-01	1.97-06	1.28-02	2.01-04		5.90-01		3.28-02
4.00+00		4.81-01	1.35-06	2.07-02	8.26-04		5.03-01		2.80-02
5.00+00		4.15-01	1.03-06	2.78-02	1.62-03		4.45-01		2.48-02
6.00+00		3.67-01	8.23-07	3.40-02	2.50-03		4.04-01		2.25-02
8.00+00		3.00-01	5.89-07	4.46-02	4.27-03		3.49-01		1.95-02
1.00+01		2.56-01	4.63-07	5.32-02	5.84-03		3.15-01		1.75-02
1.50+01		1.89-01		6.96-02	9.09-03		2.68-01		1.49-02
2.00+01		1.52-01		8.16-02	1.17-02		2.45-01		1.37-02
3.00+01		1.11-01		9.85-02	1.55-02		2.25-01		1.25-02
4.00+01		8.79-02		1.10-01	1.84-02		2.17-01		1.21-02
5.00+01		7.34-02		1.19-01	2.07-02		2.13-01		1.19-02
6.00+01		6.32-02		1.26-01	2.26-02		2.12-01		1.18-02
8.00+01		4.98-02		1.37-01	2.55-02		2.12-01		1.18-02
1.00+02		4.14-02		1.45-01	2.77-02		2.14-01		1.19-02
1.50+02		2.95-02		1.57-01	3.15-02		2.18-01		1.22-02
2.00+02		2.31-02		1.66-01	3.40-02		2.23-01		1.24-02
3.00+02		1.64-02		1.76-01	3.74-02		2.29-01		1.28-02
4.00+02		1.28-02		1.82-01	3.96-02		2.34-01		1.30-02
5.00+02		1.06-02		1.86-01	4.13-02		2.37-01		1.32-02
6.00+02		9.09-03		1.89-01	4.25-02		2.40-01		1.34-02
8.00+02		7.10-03		1.93-01	4.43-02		2.44-01		1.36-02
1.00+03		5.84-03		1.95-01	4.56-02		2.47-01		1.37-02
1.50+03		4.08-03		1.99-01	4.76-02		2.51-01		1.40-02
2.00+03		3.16-03		2.01-01	4.89-02		2.53-01		1.41-02
3.00+03		2.19-03		2.04-01	5.05-02		2.56-01		1.43-02
4.00+03		1.69-03		2.05-01	5.14-02		2.58-01		1.44-02
5.00+03		1.38-03		2.06-01	5.21-02		2.59-01		1.44-02
6.00+03		1.17-03		2.06-01	5.25-02		2.60-01		1.45-02
8.00+03		9.05-04		2.07-01	5.31-02		2.61-01		1.45-02
1.00+04		7.39-04		2.07-01	5.34-02		2.61-01		1.46-02
1.50+04		5.11-04		2.08-01	5.40-02		2.63-01		1.46-02
2.00+04		3.93-04		2.08-01	5.43-02		2.63-01		1.47-02
3.00+04		2.71-04		2.09-01	5.46-02		2.64-01		1.47-02
4.00+04		2.08-04		2.09-01	5.48-02		2.64-01		1.47-02
5.00+04		1.69-04		2.09-01	5.49-02		2.64-01		1.47-02
6.00+04		1.43-04		2.09-01	5.49-02		2.64-01		1.47-02
8.00+04		1.10-04		2.09-01	5.50-02		2.64-01		1.47-02
1.00+05		8.93-05		2.09-01	5.51-02		2.64-01		1.47-02

(b/atom) x .055710 = cm²/g

CARBON, Z=6

Photon energy	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*cm²/g*	*cm²/g*
1.00–02	6.11+00	3.84+00	3.93+01			4.54+01	4.31+01	2.28+00	2.17+00
1.50–02	5.06+00	3.77+00	1.06+01			1.57+01	1.44+01	7.87–01	7.22–01
2.00–02	4.53+00	3.71+00	4.01+00			8.54+00	7.72+00	4.29–01	3.88–01
3.00–02	4.00+00	3.58+00	9.99–01			5.00+00	4.58+00	2.51–01	2.30–01
4.00–02	3.73+00	3.47+00	3.79–01			4.10+00	3.85+00	2.06–01	1.93–01
5.00–02	3.54+00	3.37+00	1.93–01			3.73+00	3.56+00	1.87–01	1.79–01
6.00–02	3.39+00	3.27+00	1.15–01			3.51+00	3.39+00	1.76–01	1.70–01
8.00–02	3.17+00	3.10+00	4.50–02			3.21+00	3.15+00	1.61–01	1.58–01
1.00–01	3.00+00	2.96+00	2.16–02			3.02+00	2.98+00	1.52–01	1.50–01
1.50–01	2.69+00	2.66+00	5.75–03			2.69+00	2.67+00	1.35–01	1.34–01
2.00–01	2.45+00	2.44+00	2.29–03			2.45+00	2.44+00	1.23–01	1.23–01
3.00–01	2.13+00	2.12+00	6.46–04			2.13+00	2.12+00	1.07–01	1.07–01
4.00–01	1.90+00	1.90+00	2.77–04			1.91+00	1.90+00	9.57–02	9.55–02
5.00–01		1.74+00	1.49–04				1.74+00		8.72–02
6.00–01		1.61+00	9.27–05				1.61+00		8.07–02
8.00–01		1.41+00	4.68–05				1.41+00		7.09–02
1.00+00		1.27+00	2.89–05				1.27+00		6.37–02
1.50+00		1.03+00	1.35–05	1.60–03			1.03+00		5.19–02
2.00+00		8.79–01	8.61–06	6.40–03			8.86–01		4.45–02
3.00+00		6.92–01	4.82–06	1.84–02	2.41–04		7.11–01		3.57–02
4.00+00		5.77–01	3.29–06	2.98–02	9.91–04		6.08–01		3.05–02
5.00+00		4.98–01	2.52–06	4.00–02	1.95–03		5.40–01		2.71–02
6.00+00		4.40–01	2.01–06	4.90–02	3.00–03		4.93–01		2.47–02
8.00+00		3.60–01	1.44–06	6.42–02	5.12–03		4.30–01		2.16–02
1.00+01		3.07–01	1.12–06	7.66–02	7.01–03		3.90–01		1.96–02
1.50+01		2.27–01		1.00–01	1.09–02		3.38–01		1.70–02
2.00+01		1.82–01		1.17–01	1.40–02		3.14–01		1.58–02
3.00+01		1.33–01		1.41–01	1.87–02		2.93–01		1.47–02
4.00+01		1.05–01		1.58–01	2.21–02		2.86–01		1.44–02
5.00+01		8.80–02		1.71–01	2.48–02		2.84–01		1.42–02
6.00+01		7.59–02		1.81–01	2.71–02		2.84–01		1.43–02
8.00+01		5.98–02		1.96–01	3.06–02		2.86–01		1.44–02
1.00+02		4.97–02		2.07–01	3.31–02		2.90–01		1.46–02
1.50+02		3.54–02		2.26–01	3.76–02		2.99–01		1.50–02
2.00+02		2.77–02		2.37–01	4.06–02		3.06–01		1.53–02
3.00+02		1.96–02		2.51–01	4.46–02		3.16–01		1.59–02
4.00+02		1.54–02		2.60–01	4.72–02		3.22–01		1.62–02
5.00+02		1.27–02		2.65–01	4.91–02		3.27–01		1.64–02
6.00+02		1.09–02		2.69–01	5.05–02		3.31–01		1.66–02
8.00+02		8.52–03		2.75–01	5.26–02		3.36–01		1.69–02
1.00+03		7.01–03		2.78–01	5.40–02		3.40–01		1.71–02
1.50+03		4.89–03		2.84–01	5.64–02		3.45–01		1.73–02
2.00+03		3.79–03		2.87–01	5.79–02		3.48–01		1.75–02
3.00+03		2.64–03		2.90–01	5.98–02		3.52–01		1.77–02
4.00+03		2.03–03		2.92–01	6.08–02		3.54–01		1.78–02
5.00+03		1.66–03		2.93–01	6.15–02		3.56–01		1.79–02
6.00+03		1.41–03		2.93–01	6.20–02		3.57–01		1.79–02
8.00+03		1.09–03		2.94–01	6.26–02		3.58–01		1.80–02
1.00+04		8.87–04		2.95–01	6.30–02		3.59–01		1.80–02
1.50+04		6.13–04		2.96–01	6.36–02		3.60–01		1.81–02
2.00+04		4.71–04		2.96–01	6.40–02		3.61–01		1.81–02
3.00+04		3.25–04		2.97–01	6.43–02		3.62–01		1.82–02
4.00+04		2.49–04		2.97–01	6.45–02		3.62–01		1.82–02
5.00+04		2.03–04		2.97–01	6.46–02		3.62–01		1.82–02
6.00+04		1.72–04		2.97–01	6.47–02		3.62–01		1.82–02
8.00+04		1.32–04		2.98–01	6.48–02		3.63–01		1.82–02
1.00+05		1.07–04		2.98–01	6.49–02		3.63–01		1.82–02

(b/atom) x .050140 = cm²/g

SODIUM, Z=11

Photon energy,	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	cm²/g	cm²/g
1.00−02	2.19+01	7.04+00	5.69+02			5.91+02	5.76+02	1.55+01	1.51+01
1.50−02	1.49+01	6.92+00	1.60+02			1.75+02	1.67+02	4.58+00	4.37+00
2.00−02	1.18+01	6.80+00	6.48+01			7.66+01	7.16+01	2.01+00	1.88+00
3.00−02	9.11+00	6.57+00	1.78+01			2.69+01	2.44+01	7.05−01	6.39−01
4.00−02	7.90+00	6.37+00	7.18+00			1.51+01	1.35+01	3.95−01	3.55−01
5.00−02	7.19+00	6.18+00	3.53+00			1.07+01	9.71+00	2.81−01	2.54−01
6.00−02	6.73+00	6.00+00	1.99+00			8.72+00	7.99+00	2.28−01	2.09−01
8.00−02	6.11+00	5.69+00	7.92−01			6.90+00	6.48+00	1.81−01	1.70−01
1.00−01	5.69+00	5.42+00	3.85−01			6.08+00	5.80+00	1.59−01	1.52−01
1.50−01	5.01+00	4.88+00	1.06−01			5.11+00	4.99+00	1.34−01	1.31−01
2.00−01	4.54+00	4.47+00	4.29−02			4.58+00	4.51+00	1.20−01	1.18−01
3.00−01	3.92+00	3.89+00	1.24−02			3.93+00	3.90+00	1.03−01	1.02−01
4.00−01	3.50+00	3.48+00	5.31−03			3.50+00	3.49+00	9.18−02	9.14−02
5.00−01	3.19+00	3.18+00	2.86−03			3.19+00	3.18+00	8.36−02	8.34−02
6.00−01	2.95+00	2.94+00	1.78−03			2.95+00	2.95+00	7.74−02	7.72−02
8.00−01		2.59+00	9.01−04				2.59+00		6.78−02
1.00+00		2.33+00	5.58−04				2.33+00		6.09−02
1.50+00		1.89+00	2.61−04	5.46−03			1.90+00		4.97−02
2.00+00		1.61+00	1.67−04	2.16−02			1.63+00		4.28−02
3.00+00		1.27+00	9.25−05	6.19−02	4.43−04		1.33+00		3.49−02
4.00+00		1.06+00	6.28−05	1.00−01	1.82−03		1.16+00		3.04−02
5.00+00		9.14−01	4.79−05	1.34−01	3.57−03		1.05+00		2.76−02
6.00+00		8.08−01	3.82−05	1.64−01	5.49−03		9.77−01		2.56−02
8.00+00		6.61−01	2.73−05	2.15−01	9.40−03		8.85−01		2.32−02
1.00+01		5.63−01	2.14−05	2.56−01	1.28−02		8.31−01		2.18−02
1.50+01		4.16−01		3.34−01	2.00−02		7.70−01		2.02−02
2.00+01		3.34−01		3.90−01	2.57−02		7.50−01		1.96−02
3.00+01		2.43−01		4.69−01	3.42−02		7.47−01		1.96−02
4.00+01		1.93−01		5.24−01	4.05−02		7.58−01		1.99−02
5.00+01		1.61−01		5.65−01	4.55−02		7.72−01		2.02−02
6.00+01		1.39−01		5.98−01	4.94−02		7.87−01		2.06−02
8.00+01		1.10−01		6.47−01	5.53−02		8.12−01		2.13−02
1.00+02		9.11−02		6.82−01	5.98−02		8.33−01		2.18−02
1.50+02		6.48−02		7.39−01	6.75−02		8.72−01		2.28−02
2.00+02		5.08−02		7.74−01	7.27−02		8.97−01		2.35−02
3.00+02		3.60−02		8.14−01	7.95−02		9.30−01		2.44−02
4.00+02		2.82−02		8.38−01	8.38−02		9.50−01		2.49−02
5.00+02		2.34−02		8.53−01	8.69−02		9.64−01		2.52−02
6.00+02		2.00−02		8.65−01	8.92−02		9.74−01		2.55−02
8.00+02		1.56−02		8.79−01	9.26−02		9.87−01		2.59−02
1.00+03		1.28−02		8.88−01	9.50−02		9.96−01		2.61−02
1.50+03		8.97−03		9.03−01	9.89−02		1.01+00		2.65−02
2.00+03		6.94−03		9.10−01	1.01−01		1.02+00		2.67−02
3.00+03		4.83−03		9.18−01	1.04−01		1.03+00		2.69−02
4.00+03		3.73−03		9.23−01	1.05−01		1.03+00		2.70−02
5.00+03		3.05−03		9.26−01	1.06−01		1.04+00		2.71−02
6.00+03		2.58−03		9.28−01	1.07−01		1.04+00		2.72−02
8.00+03		1.99−03		9.30−01	1.08−01		1.04+00		2.72−02
1.00+04		1.63−03		9.31−01	1.08−01		1.04+00		2.73−02
1.50+04		1.12−03		9.34−01	1.09−01		1.04+00		2.74−02
2.00+04		8.64−04		9.36−01	1.10−01		1.05+00		2.74−02
3.00+04		5.96−04		9.36−01	1.10−01		1.05+00		2.74−02
4.00+04		4.57−04		9.37−01	1.10−01		1.05+00		2.75−02
5.00+04		3.72−04		9.38−01	1.11−01		1.05+00		2.75−02
6.00+04		3.15−04		9.38−01	1.11−01		1.05+00		2.75−02
8.00+04		2.41−04		9.38−01	1.11−01		1.05+00		2.75−02
1.00+05		1.96−04		9.38−01	1.11−01		1.05+00		2.75−02

(b/atom) x .02620 = cm²/g

ALUMINUM, Z=13

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent	Total: With coherent	Total: Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*cm²/g*	*cm²/g*
1.00-02	3.04+01	8.32+00	1.15+03			1.18+03	1.16+03	2.63+01	2.58+01
1.50-02	2.03+01	8.17+00	3.35+02			3.55+02	3.43+02	7.93+00	7.66+00
2.00-02	1.57+01	8.03+00	1.37+02			1.53+02	1.45+02	3.41+00	3.24+00
3.00-02	1.17+01	7.77+00	3.85+01			5.02+01	4.63+01	1.12+00	1.03+00
4.00-02	9.89+00	7.52+00	1.55+01			2.54+01	2.30+01	5.67-01	5.14-01
5.00-02	8.88+00	7.30+00	7.65+00			1.65+01	1.49+01	3.69-01	3.34-01
6.00-02	8.22+00	7.09+00	4.33+00			1.25+01	1.14+01	2.80-01	2.55-01
8.00-02	7.38+00	6.72+00	1.73+00			9.11+00	8.45+00	2.03-01	1.89-01
1.00-01	6.83+00	6.41+00	8.45-01			7.67+00	7.25+00	1.71-01	1.62-01
1.50-01	5.96+00	5.77+00	2.33-01			6.19+00	6.00+00	1.38-01	1.34-01
2.00-01	5.39+00	5.28+00	9.53-02			5.49+00	5.38+00	1.22-01	1.20-01
3.00-01	4.64+00	4.60+00	2.76-02			4.67+00	4.62+00	1.04-01	1.03-01
4.00-01	4.14+00	4.12+00	1.19-02			4.15+00	4.13+00	9.27-02	9.22-02
5.00-01	3.78+00	3.76+00	6.43-03			3.78+00	3.77+00	8.44-02	8.41-02
6.00-01	3.49+00	3.48+00	4.02-03			3.49+00	3.48+00	7.80-02	7.77-02
8.00-01	3.06+00	3.06+00	2.04-03			3.06+00	3.06+00	6.84-02	6.83-02
1.00+00	2.75+00	2.75+00	1.26-03			2.75+00	2.75+00	6.13-02	6.14-02
1.50+00		2.23+00	5.89-04	7.68-03			2.24+00		5.00-02
2.00+00		1.91+00	3.73-04	3.03-02			1.94+00		4.32-02
3.00+00		1.50+00	2.07-04	8.65-02	5.23-04		1.59+00		3.54-02
4.00+00		1.25+00	1.41-04	1.40-01	2.15-03		1.39+00		3.11-02
5.00+00		1.08+00	1.07-04	1.87-01	4.22-03		1.27+00		2.84-02
6.00+00		9.54-01	8.53-05	2.29-01	6.49-03		1.19+00		2.66-02
8.00+00		7.81-01	6.09-05	2.99-01	1.11-02		1.09+00		2.44-02
1.00+01		6.65-01	4.76-05	3.57-01	1.52-02		1.04+00		2.31-02
1.50+01		4.92-01		4.65-01	2.36-02		9.80-01		2.19-02
2.00+01		3.95-01		5.43-01	3.03-02		9.68-01		2.16-02
3.00+01		2.88-01		6.52-01	4.04-02		9.81-01		2.19-02
4.00+01		2.29-01		7.29-01	4.79-02		1.01+00		2.24-02
5.00+01		1.91-01		7.86-01	5.36-02		1.03+00		2.30-02
6.00+01		1.64-01		8.31-01	5.81-02		1.05+00		2.35-02
8.00+01		1.30-01		8.98-01	6.51-02		1.09+00		2.44-02
1.00+02		1.08-01		9.46-01	7.03-02		1.12+00		2.51-02
1.50+02		7.66-02		1.02+00	7.93-02		1.18+00		2.63-02
2.00+02		6.01-02		1.07+00	8.53-02		1.21+00		2.71-02
3.00+02		4.26-02		1.13+00	9.31-02		1.26+00		2.82-02
4.00+02		3.33-02		1.16+00	9.81-02		1.29+00		2.88-02
5.00+02		2.76-02		1.18+00	1.02-01		1.31+00		2.92-02
6.00+02		2.36-02		1.19+00	1.04-01		1.32+00		2.95-02
8.00+02		1.85-02		1.22+00	1.08-01		1.34+00		3.00-02
1.00+03		1.52-02		1.23+00	1.11-01		1.35+00		3.02-02
1.50+03		1.06-02		1.25+00	1.15-01		1.37+00		3.07-02
2.00+03		8.21-03		1.26+00	1.18-01		1.38+00		3.09-02
3.00+03		5.71-03		1.27+00	1.21-01		1.40+00		3.12-02
4.00+03		4.40-03		1.28+00	1.22-01		1.40+00		3.13-02
5.00+03		3.60-03		1.28+00	1.23-01		1.41+00		3.14-02
6.00+03		3.05-03		1.28+00	1.24-01		1.41+00		3.15-02
8.00+03		2.35-03		1.29+00	1.25-01		1.41+00		3.16-02
1.00+04		1.92-03		1.29+00	1.26-01		1.42+00		3.16-02
1.50+04		1.33-03		1.29+00	1.27-01		1.42+00		3.17-02
2.00+04		1.02-03		1.29+00	1.27-01		1.42+00		3.17-02
3.00+04		7.04-04		1.30+00	1.28-01		1.42+00		3.18-02
4.00+04		5.40-04		1.30+00	1.28-01		1.43+00		3.18-02
5.00+04		4.40-04		1.30+00	1.28-01		1.43+00		3.18-02
6.00+04		3.72-04		1.30+00	1.28-01		1.43+00		3.18-02
8.00+04		2.85-04		1.30+00	1.28-01		1.43+00		3.18-02
1.00+05		2.32-04		1.30+00	1.28-01		1.43+00		3.19-02

(b/atom) x .022320 = cm²/g

SILICON, Z=14

Photon energy	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	cm²/g	cm²/g
1.00−02	3.50+01	8.97+00	1.56+03			1.59+03	1.57+03	3.42+01	3.36+01
1.50−02	2.34+01	8.80+00	4.56+02			4.79+02	4.65+02	1.03+01	9.97+00
2.00−02	1.78+01	8.65+00	1.87+02			2.05+02	1.96+02	4.39+00	4.19+00
3.00−02	1.31+01	8.36+00	5.29+01			6.60+01	6.13+01	1.41+00	1.31+00
4.00−02	1.10+01	8.10+00	2.15+01			3.25+01	2.96+01	6.96−01	6.35−01
5.00−02	9.79+00	7.86+00	1.06+01			2.04+01	1.85+01	4.37−01	3.96−01
6.00−02	9.01+00	7.64+00	6.00+00			1.50+01	1.36+01	3.22−01	2.92−01
8.00−02	8.04+00	7.24+00	2.42+00			1.05+01	9.66+00	2.24−01	2.07−01
1.00−01	7.41+00	6.90+00	1.19+00			8.60+00	8.09+00	1.84−01	1.73−01
1.50−01	6.44+00	6.21+00	3.29−01			6.77+00	6.54+00	1.45−01	1.40−01
2.00−01	5.82+00	5.69+00	1.34−01			5.96+00	5.82+00	1.28−01	1.25−01
3.00−01	5.01+00	4.95+00	3.91−02			5.05+00	4.99+00	1.08−01	1.07−01
4.00−01	4.47+00	4.43+00	1.69−02			4.49+00	4.45+00	9.62−02	9.54−02
5.00−01	4.07+00	4.05+00	9.15−03			4.08+00	4.06+00	8.75−02	8.70−02
6.00−01	3.76+00	3.75+00	5.72−03			3.77+00	3.75+00	8.08−02	8.05−02
8.00−01	3.29+00	3.29+00	2.89−03			3.30+00	3.29+00	7.07−02	7.06−02
1.00+00		2.96+00	1.79−03				2.96+00		6.35−02
1.50+00		2.40+00	8.36−04	8.94−03			2.41+00		5.18−02
2.00+00		2.05+00	5.30−04	3.52−02			2.09+00		4.48−02
3.00+00		1.61+00	2.93−04	1.00−01	5.63−04		1.72+00		3.68−02
4.00+00		1.35+00	1.99−04	1.62−01	2.31−03		1.51+00		3.24−02
5.00+00		1.16+00	1.42−04	2.17−01	4.54−03		1.38+00		2.97−02
6.00+00		1.03+00	1.21−04	2.67−01	6.99−03		1.30+00		2.79−02
8.00+00		8.41−01	8.61−05	3.47−01	1.20−02		1.20+00		2.57−02
1.00+01		7.16−01	6.74−05	4.13−01	1.63−02		1.15+00		2.46−02
1.50+01		5.30−01		5.38−01	2.55−02		1.09+00		2.34−02
2.00+01		4.25−01		6.28−01	3.27−02		1.09+00		2.33−02
3.00+01		3.10−01		7.55−01	4.35−02		1.11+00		2.38−02
4.00+01		2.46−01		8.43−01	5.16−02		1.14+00		2.45−02
5.00+01		2.05−01		9.13−01	5.76−02		1.18+00		2.52−02
6.00+01		1.77−01		9.61−01	6.25−02		1.20+00		2.57−02
8.00+01		1.40−01		1.04+00	6.99−02		1.25+00		2.67−02
1.00+02		1.16−01		1.09+00	7.55−02		1.28+00		2.75−02
1.50+02		8.25−02		1.18+00	8.51−02		1.35+00		2.89−02
2.00+02		6.47−02		1.24+00	9.16−02		1.39+00		2.99−02
3.00+02		4.58−02		1.30+00	9.98−02		1.45+00		3.10−02
4.00+02		3.59−02		1.34+00	1.05−01		1.48+00		3.17−02
5.00+02		2.97−02		1.36+00	1.09−01		1.50+00		3.22−02
6.00+02		2.55−02		1.38+00	1.12−01		1.52+00		3.25−02
8.00+02		1.99−02		1.40+00	1.16−01		1.54+00		3.30−02
1.00+03		1.63−02		1.42+00	1.19−01		1.55+00		3.33−02
1.50+03		1.14−02		1.44+00	1.23−01		1.58+00		3.38−02
2.00+03		8.84−03		1.45+00	1.26−01		1.59+00		3.41−02
3.00+03		6.15−03		1.47+00	1.29−01		1.60+00		3.44−02
4.00+03		4.74−03		1.47+00	1.31−01		1.61+00		3.45−02
5.00+03		3.88−03		1.48+00	1.32−01		1.61+00		3.46−02
6.00+03		3.29−03		1.48+00	1.33−01		1.62+00		3.47−02
8.00+03		2.53−03		1.49+00	1.34−01		1.62+00		3.48−02
1.00+04		2.07−03		1.49+00	1.34−01		1.63+00		3.48−02
1.50+04		1.43−03		1.49+00	1.35−01		1.63+00		3.49−02
2.00+04		1.10−03		1.49+00	1.36−01		1.63+00		3.50−02
3.00+04		7.58−04		1.50+00	1.36−01		1.63+00		3.50−02
4.00+04		5.82−04		1.50+00	1.37−01		1.64+00		3.51−02
5.00+04		4.74−04		1.50+00	1.37−01		1.64+00		3.51−02
6.00+04		4.01−04		1.50+00	1.37−01		1.64+00		3.51−02
8.00+04		3.07−04		1.50+00	1.37−01		1.64+00		3.51−02
1.00+05		2.50−04		1.50+00	1.37−01		1.64+00		3.51−02

(b/atom) x .021440 = cm²/g

CALCIUM, Z=20

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent	Total: With coherent	Total: Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*cm²/g*	*cm²/g*
1.00−02	6.78+01	1.28+01	6.35+03			6.42+03	6.36+03	9.65+01	9.56+01
1.50−02	4.68+01	1.26+01	1.96+03			2.00+03	1.97+03	3.01+01	2.96+01
2.00−02	3.49+01	1.24+01	8.27+02			8.62+02	8.39+02	1.30+01	1.26+01
3.00−02	2.36+01	1.19+01	2.42+02			2.66+02	2.54+02	3.99+00	3.82+00
4.00−02	1.87+01	1.16+01	9.98+01			1.19+02	1.11+02	1.78+00	1.67+00
5.00−02	1.61+01	1.12+01	5.03+01			6.64+01	6.15+01	9.98−01	9.25−01
6.00−02	1.44+01	1.09+01	2.87+01			4.31+01	3.96+01	6.48−01	5.95−01
8.00−02	1.24+01	1.03+01	1.19+01			2.43+01	2.22+01	3.65−01	3.34−01
1.00−01	1.12+01	9.85+00	5.89+00			1.71+01	1.57+01	2.56−01	2.37−01
1.50−01	9.47+00	8.87+00	1.70+00			1.12+01	1.06+01	1.68−01	1.59−01
2.00−01	8.47+00	8.13+00	7.09−01			9.17+00	8.84+00	1.38−01	1.33−01
3.00−01	7.22+00	7.07+00	2.10−01			7.43+00	7.28+00	1.12−01	1.09−01
4.00−01	6.42+00	6.33+00	9.19−02			6.51+00	6.43+00	9.79−02	9.66−02
5.00−01	5.84+00	5.79+00	4.98−02			5.89+00	5.84+00	8.85−02	8.78−02
6.00−01	5.39+00	5.35+00	3.13−02			5.42+00	5.38+00	8.14−02	8.09−02
8.00−01	4.72+00	4.70+00	1.59−02			4.74+00	4.72+00	7.12−02	7.09−02
1.00+00	4.24+00	4.23+00	9.87−03			4.25+00	4.24+00	6.39−02	6.37−02
1.50+00	3.44+00	3.44+00	4.58−03	1.88−02		3.46+00	3.46+00	5.20−02	5.20−02
2.00+00	2.93+00	2.93+00	2.90−03	7.30−02		3.01+00	3.01+00	4.53−02	4.52−02
3.00+00		2.31+00	1.59−03	2.06−01	8.05−04		2.51+00		3.78−02
4.00+00		1.92+00	1.07−03	3.31−01	3.30−03		2.26+00		3.40−02
5.00+00		1.66+00	8.16−04	4.42−01	6.49−03		2.11+00		3.17−02
6.00+00		1.47+00	6.46−04	5.40−01	9.98−03		2.02+00		3.03−02
8.00+00		1.20+00	4.60−04	7.03−01	1.71−02		1.92+00		2.89−02
1.00+01		1.02+00	3.59−04	8.36−01	2.33−02		1.88+00		2.83−02
1.50+01		7.57−01		1.09+00	3.64−02		1.88+00		2.83−02
2.00+01		6.08−01		1.27+00	4.67−02		1.92+00		2.89−02
3.00+01		4.42−01		1.52+00	6.22−02		2.03+00		3.05−02
4.00+01		3.52−01		1.70+00	7.32−02		2.12+00		3.19−02
5.00+01		2.93−01		1.83+00	8.16−02		2.20+00		3.31−02
6.00+01		2.53−01		1.93+00	8.83−02		2.27+00		3.42−02
8.00+01		1.99−01		2.08+00	9.85−02		2.38+00		3.58−02
1.00+02		1.66−01		2.19+00	1.06−01		2.46+00		3.70−02
1.50+02		1.18−01		2.39+00	1.20−01		2.62+00		3.94−02
2.00+02		9.24−02		2.48+00	1.28−01		2.70+00		4.05−02
3.00+02		6.55−02		2.60+00	1.39−01		2.81+00		4.22−02
4.00+02		5.13−02		2.67+00	1.46−01		2.87+00		4.32−02
5.00+02		4.25−02		2.72+00	1.51−01		2.92+00		4.38−02
6.00+02		3.64−02		2.76+00	1.55−01		2.95+00		4.43−02
8.00+02		2.84−02		2.81+00	1.60−01		2.99+00		4.50−02
1.00+03		2.34−02		2.84+00	1.64−01		3.03+00		4.55−02
1.50+03		1.63−02		2.88+00	1.70−01		3.07+00		4.61−02
2.00+03		1.26−02		2.90+00	1.74−01		3.09+00		4.64−02
3.00+03		8.78−03		2.93+00	1.78−01		3.12+00		4.68−02
4.00+03		6.78−03		2.94+00	1.80−01		3.13+00		4.70−02
5.00+03		5.54−03		2.95+00	1.81−01		3.14+00		4.72−02
6.00+03		4.70−03		2.96+00	1.82−01		3.14+00		4.73−02
8.00+03		3.62−03		2.97+00	1.83−01		3.15+00		4.74−02
1.00+04		2.96−03		2.97+00	1.84−01		3.16+00		4.75−02
1.50+04		2.04−03		2.98+00	1.85−01		3.17+00		4.76−02
2.00+04		1.57−03		2.98+00	1.86−01		3.17+00		4.77−02
3.00+04		1.08−03		2.99+00	1.86−01		3.17+00		4.77−02
4.00+04		8.31−04		2.99+00	1.87−01		3.18+00		4.77−02
5.00+04		6.77−04		2.99+00	1.87−01		3.18+00		4.78−02
6.00+04		5.72−04		2.99+00	1.87−01		3.18+00		4.78−02
8.00+04		4.39−04		2.99+00	1.87−01		3.18+00		4.78−02
1.00+05		3.57−04		2.99+00	1.87−01		3.18+00		4.78−02

(b/atom) x .015030 = cm²/g

IRON, Z=26

Photon energy	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	cm^2/g	cm^2/g
1.00-02	1.23+02	1.67+01	1.59+04			1.60+04	1.59+04	1.73+02	1.72+02
1.50-02	8.05+01	1.63+01	5.15+03			5.23+03	5.17+03	5.64+01	5.57+01
2.00-02	5.98+01	1.61+01	2.31+03			2.37+03	2.33+03	2.55+01	2.51+01
3.00-02	3.89+01	1.55+01	7.15+02			7.54+02	7.31+02	8.13+00	7.88+00
4.00-02	2.94+01	1.50+01	3.06+02			3.35+02	3.21+02	3.62+00	3.46+00
5.00-02	2.43+01	1.46+01	1.56+02			1.80+02	1.71+02	1.94+00	1.84+00
6.00-02	2.12+01	1.42+01	9.04+01			1.12+02	1.05+02	1.20+00	1.13+00
8.00-02	1.76+01	1.34+01	3.76+01			5.52+01	5.10+01	5.95-01	5.50-01
1.00-01	1.54+01	1.28+01	1.89+01			3.43+01	3.17+01	3.70-01	3.42-01
1.50-01	1.27+01	1.15+01	5.52+00			1.82+01	1.71+01	1.96-01	1.84-01
2.00-01	1.12+01	1.06+01	2.33+00			1.35+01	1.29+01	1.46-01	1.39-01
3.00-01	9.50+00	9.19+00	6.98-01			1.02+01	9.89+00	1.10-01	1.07-01
4.00-01	8.41+00	8.24+00	3.09-01			8.72+00	8.54+00	9.40-02	9.21-02
5.00-01	7.62+00	7.52+00	1.69-01			7.79+00	7.69+00	8.40-02	8.29-02
6.00-01	7.03+00	6.96+00	1.07-01			7.14+00	7.06+00	7.69-02	7.62-02
8.00-01	6.15+00	6.11+00	5.44-02			6.21+00	6.17+00	6.69-02	6.65-02
1.00+00	5.52+00	5.50+00	3.38-02			5.55+00	5.53+00	5.99-02	5.96-02
1.50+00	4.48+00	4.47+00	1.56-02	3.32-02		4.53+00	4.51+00	4.88-02	4.87-02
2.00+00		3.81+00	9.81-03	1.26-01			3.95+00		4.25-02
3.00+00		3.00+00	5.35-03	3.50-01	1.05-03		3.35+00		3.62-02
4.00+00		2.50+00	3.61-03	5.61-01	4.30-03		3.07+00		3.31-02
5.00+00		2.16+00	2.73-03	7.46-01	8.44-03		2.92+00		3.14-02
6.00+00		1.91+00	2.16-03	9.08-01	1.30-02		2.83+00		3.05-02
8.00+00		1.56+00	1.53-03	1.18+00	2.22-02		2.77+00		2.98-02
1.00+01		1.33+00	1.19-03	1.40+00	3.04-02		2.76+00		2.98-02
1.50+01		9.84-01	7.00-04	1.82+00	4.73-02		2.85+00		3.07-02
2.00+01		7.90-01	5.00-04	2.13+00	6.07-02		2.98+00		3.21-02
3.00+01		5.75-01		2.55+00	8.06-02		3.20+00		3.45-02
4.00+01		4.57-01		2.84+00	9.45-02		3.39+00		3.65-02
5.00+01		3.81-01		3.06+00	1.05-01		3.54+00		3.82-02
6.00+01		3.29-01		3.22+00	1.13-01		3.67+00		3.95-02
8.00+01		2.59-01		3.48+00	1.27-01		3.86+00		4.16-02
1.00+02		2.15-01		3.65+00	1.36-01		4.01+00		4.32-02
1.50+02		1.53-01		3.94+00	1.53-01		4.25+00		4.58-02
2.00+02		1.20-01		4.12+00	1.64-01		4.40+00		4.75-02
3.00+02		8.51-02		4.32+00	1.78-01		4.58+00		4.94-02
4.00+02		6.67-02		4.44+00	1.86-01		4.69+00		5.06-02
5.00+02		5.52-02		4.52+00	1.92-01		4.77+00		5.14-02
6.00+02		4.73-02		4.57+00	1.97-01		4.82+00		5.19-02
8.00+02		3.69-02		4.65+00	2.04-01		4.89+00		5.27-02
1.00+03		3.04-02		4.69+00	2.09-01		4.93+00		5.32-02
1.50+03		2.12-02		4.77+00	2.16-01		5.00+00		5.39-02
2.00+03		1.64-02		4.80+00	2.20-01		5.04+00		5.43-02
3.00+03		1.14-02		4.84+00	2.24-01		5.08+00		5.48-02
4.00+03		8.81-03		4.86+00	2.26-01		5.10+00		5.50-02
5.00+03		7.20-03		4.88+00	2.28-01		5.11+00		5.51-02
6.00+03		6.11-03		4.89+00	2.29-01		5.13+00		5.52-02
8.00+03		4.71-03		4.90+00	2.31-01		5.14+00		5.54-02
1.00+04		3.84-03		4.91+00	2.31-01		5.14+00		5.55-02
1.50+04		2.66-03		4.92+00	2.33-01		5.16+00		5.56-02
2.00+04		2.04-03		4.93+00	2.33-01		5.16+00		5.56-02
3.00+04		1.41-03		4.93+00	2.34-01		5.17+00		5.57-02
4.00+04		1.08-03		4.93+00	2.35-01		5.17+00		5.57-02
5.00+04		8.80-04		4.94+00	2.35-01		5.17+00		5.58-02
6.00+04		7.44-04		4.94+00	2.35-01		5.17+00		5.58-02
8.00+04		5.70-04		4.94+00	2.35-01		5.17+00		5.58-02
1.00+05		4.64-04		4.94+00	2.36-01		5.17+00		5.58-02

(b/atom) x .010780 = cm^2/g

COPPER, Z=29

Photon energy	Scattering		Photo-electric	Pair production		Total		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent	With coherent	Without coherent
MeV	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	cm²/g	cm²/g
1.00−02	1.66+02	1.86+01	2.35+04			2.37+04	2.35+04	2.24+02	2.23+02
1.50−02	1.06+02	1.82+01	7.72+03			7.83+03	7.74+03	7.42+01	7.33+01
2.00−02	7.70+01	1.79+01	3.46+03			3.54+03	3.48+03	3.35+01	3.30+01
3.00−02	4.92+01	1.73+01	1.11+03			1.15+03	1.12+03	1.09+01	1.06+01
4.00−02	3.64+01	1.68+01	4.80+02			5.16+02	4.97+02	4.89+00	4.71+00
5.00−02	2.96+01	1.63+01	2.47+02			2.77+02	2.63+02	2.62+00	2.50+00
6.00−02	2.55+01	1.58+01	1.45+02			1.71+02	1.61+02	1.62+00	1.52+00
8.00−02	2.07+01	1.50+01	6.08+01			8.14+01	7.58+01	7.72−01	7.18−01
1.00−01	1.79+01	1.43+01	3.08+01			4.87+01	4.51+01	4.61−01	4.27−01
1.50−01	1.45+01	1.29+01	9.04+00			2.36+01	2.19+01	2.23−01	2.08−01
2.00−01	1.27+01	1.18+01	3.80+00			1.65+01	1.56+01	1.57−01	1.48−01
3.00−01	1.07+01	1.02+01	1.15+00			1.18+01	1.14+01	1.12−01	1.08−01
4.00−01	9.42+00	9.19+00	5.12−01			9.93+00	9.70+00	9.41−02	9.19−02
5.00−01	8.54+00	8.39+00	2.81−01			8.82+00	8.67+00	8.36−02	8.22−02
6.00−01	7.86+00	7.76+00	1.77−01			8.04+00	7.94+00	7.62−02	7.52−02
8.00−01	6.87+00	6.82+00	9.11−02			6.96+00	6.91+00	6.60−02	6.55−02
1.00+00	6.16+00	6.13+00	5.65−02			6.22+00	6.19+00	5.89−02	5.86−02
1.50+00	4.99+00	4.98+00	2.61−02	4.23−02		5.06+00	5.05+00	4.80−02	4.79−02
2.00+00	4.25+00	4.25+00	1.63−02	1.58−01		4.43+00	4.43+00	4.20−02	4.19−02
3.00+00	3.35+00	3.34+00	8.88−03	4.38−01	1.17−03	3.79+00	3.79+00	3.60−02	3.59−02
4.00+00		2.79+00	5.96−03	6.98−01	4.79−03		3.50+00		3.32−02
5.00+00		2.41+00	4.50−03	9.28−01	9.41−03		3.35+00		3.18−02
6.00+00		2.13+00	3.56−03	1.13+00	1.45−02		3.28+00		3.10−02
8.00+00		1.74+00	2.52−03	1.46+00	2.48−02		3.23+00		3.06−02
1.00+01		1.48+00	1.95−03	1.74+00	3.39−02		3.25+00		3.08−02
1.50+01		1.10+00	1.20−03	2.25+00	5.27−02		3.41+00		3.23−02
2.00+01		8.81−01	9.00−04	2.63+00	6.77−02		3.58+00		3.39−02
3.00+01		6.41−01	6.00−04	3.15+00	8.97−02		3.89+00		3.68−02
4.00+01		5.10−01	4.00−04	3.51+00	1.05−01		4.13+00		3.91−02
5.00+01		4.25−01		3.78+00	1.17−01		4.32+00		4.10−02
6.00+01		3.67−01		3.99+00	1.26−01		4.48+00		4.25−02
8.00+01		2.89−01		4.30+00	1.41−01		4.73+00		4.48−02
1.00+02		2.40−01		4.52+00	1.51−01		4.91+00		4.65−02
1.50+02		1.71−01		4.87+00	1.70−01		5.21+00		4.94−02
2.00+02		1.34−01		5.08+00	1.82−01		5.39+00		5.11−02
3.00+02		9.50−02		5.32+00	1.97−01		5.61+00		5.32−02
4.00+02		7.44−02		5.46+00	2.06−01		5.74+00		5.44−02
5.00+02		6.16−02		5.55+00	2.13−01		5.83+00		5.52−02
6.00+02		5.27−02		5.62+00	2.18−01		5.89+00		5.58−02
8.00+02		4.12−02		5.71+00	2.25−01		5.97+00		5.66−02
1.00+03		3.39−02		5.77+00	2.30−01		6.03+00		5.72−02
1.50+03		2.37−02		5.85+00	2.38−01		6.11+00		5.79−02
2.00+03		1.83−02		5.89+00	2.42−01		6.15+00		5.83−02
3.00+03		1.27−02		5.94+00	2.47−01		6.20+00		5.88−02
4.00+03		9.83−03		5.97+00	2.49−01		6.23+00		5.90−02
5.00+03		8.03−03		5.98+00	2.51−01		6.24+00		5.91−02
6.00+03		6.81−03		5.99+00	2.52−01		6.25+00		5.93−02
8.00+03		5.25−03		6.01+00	2.54−01		6.26+00		5.94−02
1.00+04		4.29−03		6.01+00	2.55−01		6.27+00		5.95−02
1.50+04		2.96−03		6.03+00	2.56−01		6.29+00		5.96−02
2.00+04		2.28−03		6.03+00	2.57−01		6.29+00		5.96−02
3.00+04		1.57−03		6.05+00	2.58−01		6.31+00		5.98−02
4.00+04		1.21−03		6.05+00	2.58−01		6.31+00		5.98−02
5.00+04		9.82−04		6.05+00	2.58−01		6.31+00		5.98−02
6.00+04		8.30−04		6.05+00	2.58−01		6.31+00		5.98−02
8.00+04		6.36−04		6.05+00	2.59−01		6.31+00		5.98−02
1.00+05		5.18−04		6.05+00	2.59−01		6.31+00		5.98−02

(b/atom) x .009478 = cm²/g

TUNGSTEN, Z=74

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent	Total: With coherent	Total: Without coherent
MeV	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*b/atom*	*cm²/g*	*cm²/g*
1.00–02	1.38+03	4.74+01	2.78+04			2.92+04	2.78+04	9.55+01	9.12+01
1.02–02	1.35+03	4.74+01	2.63+04			2.77+04	2.64+04	9.07+01	8.64+01
L3 1.02–02	1.35+03	4.74+01	7.04+04			7.18+04	7.05+04	2.35+02	2.31+02
1.15–02	1.20+03	4.71+01	5.06+04			5.17+04	5.06+04	1.70+02	1.66+02
L2 1.15–02	1.20+03	4.71+01	7.05+04			7.17+04	7.05+04	2.35+02	2.31+02
1.21–02	1.14+03	4.70+01	6.17+04			6.29+04	6.18+04	2.06+02	2.02+02
L1 1.21–02	1.14+03	4.70+01	7.45+04			7.56+04	7.45+04	2.48+02	2.44+02
1.50–02	8.99+02	4.65+01	4.25+04			4.34+04	4.25+04	1.42+02	1.39+02
2.00–02	6.39+02	4.57+01	1.98+04			2.05+04	1.99+04	6.70+01	6.51+01
3.00–02	3.88+02	4.42+01	6.62+03			7.01+03	6.67+03	2.30+01	2.18+01
4.00–02	2.65+02	4.28+01	3.00+03			3.26+03	3.04+03	1.07+01	9.97+00
5.00–02	1.96+02	4 16+01	1.61+03			1.80+03	1.65+03	5.91+00	5.40+00
6.00–02	1.54+02	4.04+01	9.61+02			1.12+03	1.00+03	3.65+00	3.28+00
6.95–02	1.28+02	3.93+01	6.32+02			7.60+02	6.71+02	2.49+00	2.20+00
K 6.95–02	1.28+02	3.93+01	3.33+03			3.46+03	3.37+03	1.13+01	1.10+01
8.00–02	1.07+02	3.83+01	2.30+03			2.41+03	2.34+03	7.89+00	7.66+00
1.00–01	8.13+01	3.65+01	1.27+03			1.35+03	1.31+03	4.43+00	4.29+00
1.50–01	5.38+01	3.28+01	4.26+02			4.80+02	4.59+02	1.57+00	1.50+00
2.00–01	4.20+01	3.01+01	1.95+02			2.37+02	2.25+02	7.77–01	7.38–01
3.00–01	3.15+01	2.62+01	6.60+01			9.75+01	9.22+01	3.20–01	3.02–01
4.00–01	2.65+01	2.34+01	3.14+01			5.79+01	5.48+01	1.90–01	1.80–01
5.00–01	2.34+01	2.14+01	1.81+01			4.15+01	3.95+01	1.36–01	1.29–01
6.00–01	2.12+01	1.98+01	1.17+01			3.29+01	3.15+01	1.08–01	1.03–01
8.00–01	1.82+01	1.74+01	6.20+00			2.44+01	2.36+01	7.99–02	7.73–02
1.00+00	1.61+01	1.56+01	3.88+00			2.00+01	1.95+01	6.54–02	6.39–02
1.50+00	1.30+01	1.27+01	1.77+00	4.28–01		1.52+01	1.49+01	4.97–02	4.88–02
2.00+00	1.09+01	1.08+01	1.06+00	1.32+00		1.33+01	1.32+01	4.37–02	4.34–02
3.00+00	8.57+00	8.53+00	5.58–01	3.15+00	2.98–03	1.23+01	1.22+01	4.02–02	4.01–02
4.00+00	7.16+00	7.12+00	3.62–01	4.67+00	1.22–02	1.22+01	1.22+01	4.00–02	3.98–02
5.00+00	6.17+00	6.15+00	2.68–01	5.96+00	2.40–02	1.24+01	1.24+01	4.07–02	4.06–02
6.00+00	5.45+00	5.43+00	2.08–01	7.02+00	3.69–02	1.27+01	1.27+01	4.16–02	4.16–02
8.00+00	4.45+00	4.44+00	1.44–01	8.76+00	6.32–02	1.34+01	1.34+01	4.39–02	4.39–02
1.00+01	3.80+00	3.78+00	1.10–01	1.02+01	8.64–02	1.42+01	1.41+01	4.64–02	4.63–02
1.50+01		2.80+00	6.88–02	1.30+01	1.34–01		1.60+01		5.24–02
2.00+01		2.25+00	4.97–02	1.51+01	1.69–01		1.76+01		5.77–02
3.00+01		1.64+00	3.20–02	1.82+01	2.19–01		2.01+01		6.59–02
4.00+01		1.30+00	2.36–02	2.03+01	2.55–01		2.19+01		7.16–02
5.00+01		1.09+00	1.87–02	2.18+01	2.83–01		2.32+01		7.60–02
6.00+01		9.35–01	1.55–02	2.30+01	3.05–01		2.42+01		7.94–02
8.00+01		7.38–01	1.15–02	2.47+01	3.38–01		2.58+01		8.45–02
1.00+02		6.13–01	9.20–03	2.59+01	3.62–01		2.69+01		8.81–02
1.50+02		4.36–01		2.78+01	4.02–01		2.87+01		9.39–02
2.00+02		3.42–01		2.90+01	4.27–01		2.98+01		9.76–02
3.00+02		2.42–01		3.03+01	4.59–01		3.11+01		1.02–01
4.00+02		1.90–01		3.11+01	4.80–01		3.18+01		1.04–01
5.00+02		1.57–01		3.16+01	4.94–01		3.23+01		1.06–01
6.00+02		1.34–01		3.20+01	5.04–01		3.26+01		1.07–01
8.00+02		1.05–01		3.24+01	5.18–01		3.31+01		1.08–01
1.00+03		8.64–02		3.27+01	5.27–01		3.34+01		1.09–01
1.50+03		6.04–02		3.32+01	5.40–01		3.38+01		1.11–01
2.00+03		4.67–02		3.34+01	5.48–01		3.40+01		1.11–01
3.00+03		3.25–02		3.37+01	5.56–01		3.43+01		1.12–01
4.00+03		2.51–02		3.38+01	5.60–01		3.44+01		1.13–01
5.00+03		2.05–02		3.39+01	5.63–01		3.45+01		1.13–01
6.00+03		1.74–02		3.40+01	5.65–01		3.45+01		1.13–01
8.00+03		1.34–02		3.40+01	5.68–01		3.46+01		1.13–01
1.00+04		1.09–02		3.41+01	5.70–01		3.47+01		1.14–01
1.50+04		7.56–03		3.41+01	5.72–01		3.47+01		1.14–01
2.00+04		5.81–03		3.42+01	5.73–01		3.48+01		1.14–01
3.00+04		4.01–03		3.42+01	5.75–01		3.48+01		1.14–01
4.00+04		3.08–03		3.42+01	5.76–01		3.48+01		1.14–01
5.00+04		2.51–03		3.43+01	5.76–01		3.48+01		1.14–01
6.00+04		2.12–03		3.43+01	5.76–01		3.48+01		1.14–01
8.00+04		1.62–03		3.43+01	5.77–01		3.48+01		1.14–01
1.00+05		1.32–03		3.43+01	5.77–01		3.48+01		1.14–01

(b/atom) x .003276 = cm²/g

LEAD, Z=82

	Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent	Total: With coherent	Total: Without coherent
	MeV	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	cm²/g	cm²/g
	1.00-02	1.73+03	5.25+01	4.40+04			4.57+04	4.41+04	1.33+02	1.28+02
	1.30-02	1.34+03	5.19+01	2.20+04			2.33+04	2.20+04	6.78+01	6.41+01
L_3	1.30-02	1.34+03	5.19+01	5.58+04			5.71+04	5.59+04	1.66+02	1.62+02
	1.50-02	1.15+03	5.16+01	3.84+04			3.96+04	3.85+04	1.15+02	1.12+02
	1.52-02	1.13+03	5.15+01	3.75+04			3.86+04	3.76+04	1.12+02	1.09+02
L_2	1.52-02	1.13+03	5.15+01	4.90+04			5.01+04	4.91+04	1.46+02	1.43+02
	1.59-02	1.08+03	5.14+01	4.35+04			4.46+04	4.36+04	1.30+02	1.27+02
L_1	1.59-02	1.08+03	5.14+01	5.29+04			5.40+04	5.29+04	1.57+02	1.54+02
	2.00-02	8.17+02	5.07+01	2.86+04			2.95+04	2.87+04	8.57+01	8.34+01
	3.00-02	4.91+02	4.90+01	9.71+03			1.02+04	9.76+03	2.97+01	2.84+01
	4.00-02	3.36+02	4.75+01	4.47+03			4.81+03	4.52+03	1.40+01	1.31+01
	5.00-02	2.48+02	4.60+01	2.44+03			2.68+03	2.48+03	7.81+00	7.22+00
	6.00-02	1.94+02	4.47+01	1.48+03			1.67+03	1.52+03	4.87+00	4.43+00
	8.00-02	1.32+02	4.24+01	6.70+02			8.03+02	7.13+02	2.33+00	2.07+00
	8.80-02	1.16+02	4.16+01	5.15+02			6.31+02	5.56+02	1.83+00	1.62+00
K	8.80-02	1.16+02	4.16+01	2.45+03			2.56+03	2.49+03	7.45+00	7.23+00
	1.00-01	9.93+01	4.04+01	1.76+03			1.86+03	1.80+03	5.40+00	5.23+00
	1.50-01	6.39+01	3.64+01	6.14+02			6.78+02	6.51+02	1.97+00	1.89+00
	2.00-01	4.92+01	3.33+01	2.92+02			3.41+02	3.25+02	9.91-01	9.45-01
	3.00-01	3.61+01	2.90+01	1.03+02			1.39+02	1.32+02	4.04-01	3.83-01
	4.00-01	3.00+01	2.60+01	4.96+01			7.96+01	7.56+01	2.31-01	2.20-01
	5.00-01	2.63+01	2.37+01	2.92+01			5.55+01	5.29+01	1.61-01	1.54-01
	6.00-01	2.37+01	2.19+01	1.92+01			4.29+01	4.11+01	1.25-01	1.20-01
	8.00-01	2.03+01	1.93+01	1.02+01			3.04+01	2.95+01	8.85-02	8.56-02
	1.00+00	1.79+01	1.73+01	6.39+00			2.43+01	2.37+01	7.08-02	6.90-02
	1.50+00	1.43+01	1.41+01	2.89+00	5.66-01		1.78+01	1.75+01	5.17-02	5.10-02
	2.00+00	1.22+01	1.20+01	1.77+00	1.70+00		1.57+01	1.55+01	4.55-02	4.50-02
	3.00+00	9.51+00	9.46+00	9.14-01	3.94+00	3.30-03	1.44+01	1.43+01	4.18-02	4.16-02
	4.00+00	7.94+00	7.89+00	5.89-01	5.77+00	1.35-02	1.43+01	1.43+01	4.16-02	4.14-02
	5.00+00	6.84+00	6.81+00	4.34-01	7.30+00	2.66-02	1.46+01	1.46+01	4.24-02	4.24-02
	6.00+00	6.04+00	6.02+00	3.36-01	8.54+00	4.09-02	1.50+01	1.49+01	4.35-02	4.34-02
	8.00+00	4.93+00	4.92+00	2.31-01	1.05+01	7.00-02	1.58+01	1.58+01	4.59-02	4.59-02
	1.00+01	4.20+00	4.19+00	1.78-01	1.22+01	9.57-02	1.67+01	1.67+01	4.84-02	4.84-02
	1.50+01		3.10+00	1.12-01	1.55+01	1.48-01		1.89+01		5.48-02
	2.00+01		2.49+00	8.10-02	1.81+01	1.86-01		2.09+01		6.06-02
	3.00+01		1.81+00	5.20-02	2.18+01	2.42-01		2.39+01		6.96-02
	4.00+01		1.44+00	3.80-02	2.43+01	2.81-01		2.60+01		7.57-02
	5.00+01		1.20+00	3.00-02	2.61+01	3.11-01		2.77+01		8.04-02
	6.00+01		1.04+00	2.50-02	2.75+01	3.35-01		2.89+01		8.41-02
	8.00+01		8.18-01	1.80-02	2.96+01	3.71-01		3.08+01		8.96-02
	1.00+02		6.79-01	1.41-02	3.10+01	3.97-01		3.21+01		9.34-02
	1.50+02		4.83-01		3.33+01	4.41-01		3.43+01		9.96-02
	2.00+02		3.79-01		3.48+01	4.68-01		3.56+01		1.03-01
	3.00+02		2.69-01		3.64+01	5.03-01		3.71+01		1.08-01
	4.00+02		2.10-01		3.73+01	5.25-01		3.80+01		1.11-01
	5.00+02		1.74-01		3.79+01	5.40-01		3.86+01		1.12-01
	6.00+02		1.49-01		3.83+01	5.51-01		3.90+01		1.13-01
	8.00+02		1.16-01		3.89+01	5.66-01		3.96+01		1.15-01
	1.00+03		9.58-02		3.92+01	5.76-01		3.99+01		1.16-01
	1.50+03		6.69-02		3.98+01	5.90-01		4.04+01		1.18-01
	2.00+03		5.18-02		4.00+01	5.98-01		4.07+01		1.18-01
	3.00+03		3.60-02		4.04+01	6.07-01		4.10+01		1.19-01
	4.00+03		2.78-02		4.05+01	6.12-01		4.12+01		1.20-01
	5.00+03		2.27-02		4.06+01	6.15-01		4.13+01		1.20-01
	6.00+03		1.93-02		4.07+01	6.17-01		4.13+01		1.20-01
	8.00+03		1.48-02		4.08+01	6.20-01		4.14+01		1.20-01
	1.00+04		1.21-02		4.09+01	6.21-01		4.15+01		1.21-01
	1.50+04		8.37-03		4.09+01	6.24-01		4.16+01		1.21-01
	2.00+04		6.44-03		4.10+01	6.25-01		4.16+01		1.21-01
	3.00+04		4.44-03		4.10+01	6.27-01		4.16+01		1.21-01
	4.00+04		3.41-03		4.10+01	6.28-01		4.17+01		1.21-01
	5.00+04		2.78-03		4.11+01	6.28-01		4.17+01		1.21-01
	6.00+04		2.35-03		4.11+01	6.28-01		4.17+01		1.21-01
	8.00+04		1.80-03		4.11+01	6.29-01		4.17+01		1.21-01
	1.00+05		1.46-03		4.11+01	6.29-01		4.17+01		1.21-01

(b/atom) x .002907 = cm²/g

URANIUM, Z=92

	Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent	Total: With coherent	Total: Without coherent
	MeV	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	b/atom	cm²/g	cm²/g
	1.00-02	2.17+03	5.89+01	6.84+04			7.05+04	6.84+04	1.78+02	1.73+02
	1.50-02	1.47+03	5.79+01	2.38+04			2.53+04	2.38+04	6.39+01	6.03+01
	1.72-02	1.27+03	5.74+01	1.68+04			1.81+04	1.69+04	4.58+01	4.28+01
L_3	1.72-02	1.27+03	5.74+01	4.06+04			4.19+04	4.07+04	1.06+02	1.03+02
	2.00-02	1.07+03	5.68+01	2.70+04			2.81+04	2.71+04	7.10+01	6.85+01
	2.09-02	1.01+03	5.67+01	2.38+04			2.48+04	2.38+04	6.27+01	6.03+01
L_2	2.09-02	1.01+03	5.67+01	3.38+04			3.48+04	3.38+04	8.80+01	8.56+01
	2.18-02	9.61+02	5.65+01	3.06+04			3.15+04	3.06+04	7.98+01	7.75+01
L_1	2.18-02	9.61+02	5.65+01	3.53+04			3.63+04	3.54+04	9.18+01	8.95+01
	3.00-02	6.36+02	5.50+01	1.56+04			1.62+04	1.56+04	4.10+01	3.96+01
	4.00-02	4.36+02	5.32+01	7.35+03			7.79+03	7.40+03	1.97+01	1.87+01
	5.00-02	3.22+02	5.16+01	4.07+03			4.39+03	4.12+03	1.11+01	1.04+01
	6.00-02	2.51+02	5.02+01	2.50+03			2.75+03	2.55+03	6.96+00	6.45+00
	8.00-02	1.68+02	4.76+01	1.16+03			1.32+03	1.20+03	3.35+00	3.04+00
	1.00-01	1.25+02	4.53+01	6.31+02			7.56+02	6.77+02	1.91+00	1.71+00
	1.16-01	1.05+02	4.38+01	4.26+02			5.31+02	4.70+02	1.34+00	1.19+00
K	1.16-01	1.05+02	4.38+01	1.82+03			1.92+03	1.86+03	4.86+00	4.71+00
	1.50-01	7.80+01	4.08+01	9.36+02			1.01+03	9.77+02	2.56+00	2.47+00
	2.00-01	5.88+01	3.74+01	4.48+02			5.07+02	4.85+02	1.28+00	1.23+00
	3.00-01	4.21+01	3.25+01	1.59+02			2.01+02	1.92+02	5.09-01	4.85-01
	4.00-01	3.45+01	2.91+01	7.87+01			1.13+02	1.08+02	2.86-01	2.73-01
	5.00-01	3.01+01	2.66+01	4.64+01			7.65+01	7.30+01	1.93-01	1.85-01
	6.00-01	2.70+01	2.46+01	3.06+01			5.76+01	5.52+01	1.46-01	1.40-01
	8.00-01	2.29+01	2.16+01	1.65+01			3.94+01	3.81+01	9.97-02	9.64-02
	1.00+00	2.03+01	1.94+01	1.04+01			3.07+01	2.98+01	7.76-02	7.54-02
	1.50+00	1.61+01	1.58+01	4.73+00	7.77-01		2.17+01	2.13+01	5.48-02	5.39-02
	2.00+00	1.37+01	1.35+01	2.84+00	2.26+00		1.88+01	1.86+01	4.75-02	4.70-02
	3.00+00	1.07+01	1.06+01	1.49+00	5.09+00	3.70-03	1.73+01	1.72+01	4.38-02	4.35-02
	4.00+00	8.91+00	8.85+00	9.58-01	7.32+00	1.52-02	1.72+01	1.71+01	4.35-02	4.34-02
	5.00+00	7.68+00	7.64+00	7.02-01	9.16+00	2.99-02	1.76+01	1.75+01	4.45-02	4.44-02
	6.00+00	6.78+00	6.75+00	5.43-01	1.06+01	4.59-02	1.80+01	1.80+01	4.55-02	4.54-02
	8.00+00	5.55+00	5.52+00	3.75-01	1.30+01	7.86-02	1.90+01	1.89+01	4.80-02	4.79-02
	1.00+01	4.72+00	4.71+00	2.88-01	1.49+01	1.07-01	2.00+01	2.00+01	5.06-02	5.06-02
	1.50+01		3.48+00	1.80-01	1.88+01	1.65-01		2.27+01		5.73-02
	2.00+01		2.80+00	1.31-01	2.20+01	2.08-01		2.51+01		6.36-02
	3.00+01		2.04+00	8.50-02	2.66+01	2.69-01		2.90+01		7.33-02
	4.00+01		1.62+00	6.20-02	2.96+01	3.13-01		3.16+01		7.99-02
	5.00+01		1.35+00	5.00-02	3.18+01	3.46-01		3.36+01		8.50-02
	6.00+01		1.16+00	4.00-02	3.36+01	3.73-01		3.51+01		8.89-02
	8.00+01		9.17-01	3.00-02	3.61+01	4.12-01		3.75+01		9.48-02
	1.00+02		7.62-01	2.40-02	3.77+01	4.41-01		3.89+01		9.84-02
	1.50+02		5.42-01		4.07+01	4.89-01		4.17+01		1.06-01
	2.00+02		4.25-01		4.24+01	5.19-01		4.34+01		1.10-01
	3.00+02		3.01-01		4.44+01	5.57-01		4.53+01		1.15-01
	4.00+02		2.36-01		4.56+01	5.81-01		4.64+01		1.17-01
	5.00+02		1.95-01		4.63+01	5.98-01		4.71+01		1.19-01
	6.00+02		1.67-01		4.69+01	6.09-01		4.76+01		1.21-01
	8.00+02		1.31-01		4.75+01	6.25-01		4.83+01		1.22-01
	1.00+03		1.07-01		4.80+01	6.36-01		4.88+01		1.23-01
	1.50+03		7.50-02		4.87+01	6.51-01		4.94+01		1.25-01
	2.00+03		5.81-02		4.90+01	6.60-01		4.97+01		1.26-01
	3.00+03		4.04-02		4.94+01	6.69-01		5.01+01		1.27-01
	4.00+03		3.12-02		4.96+01	6.74-01		5.03+01		1.27-01
	5.00+03		2.55-02		4.97+01	6.78-01		5.04+01		1.28-01
	6.00+03		2.16-02		4.98+01	6.80-01		5.05+01		1.28-01
	8.00+03		1.67-02		5.00+01	6.83-01		5.07+01		1.28-01
	1.00+04		1.36-02		5.00+01	6.85-01		5.07+01		1.28-01
	1.50+04		9.40-03		5.01+01	6.88-01		5.08+01		1.29-01
	2.00+04		7.22-03		5.02+01	6.89-01		5.09+01		1.29-01
	3.00+04		4.98-03		5.02+01	6.91-01		5.09+01		1.29-01
	4.00+04		3.83-03		5.03+01	6.92-01		5.10+01		1.29-01
	5.00+04		3.11-03		5.03+01	6.92-01		5.10+01		1.29-01
	6.00+04		2.63-03		5.03+01	6.92-01		5.10+01		1.29-01
	8.00+04		2.02-03		5.03+01	6.93-01		5.10+01		1.29-01
	1.00+05		1.64-03		5.04+01	6.93-01		5.11+01		1.29-01

(b/atom) x .002530 = cm²/g

WATER, H_2O

Photon energy	Scattering With coherent	Scattering Without coherent	Photo-electric	Pair production Nuclear field	Pair production Electron field	Total With coherent	Total Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00−02	3.97−01	2.14−01	4.78+00			5.18+00	4.99+00
1.50−02	3.09−01	2.10−01	1.27+00			1.58+00	1.48+00
2.00−02	2.70−01	2.07−01	5.05−01			7.75−01	7.11−01
3.00−02	2.32−01	2.00−01	1.38−01			3.70−01	3.38−01
4.00−02	2.13−01	1.93−01	5.48−02			2.67−01	2.48−01
5.00−02	2.00−01	1.88−01	2.67−02			2.27−01	2.14−01
6.00−02	1.91−01	1.82−01	1.50−02			2.06−01	1.97−01
8.00−02	1.78−01	1.73−01	5.95−03			1.84−01	1.79−01
1.00−01	1.68−01	1.65−01	2.85−03			1.71−01	1.68−01
1.50−01	1.50−01	1.48−01	7.76−04			1.51−01	1.49−01
2.00−01	1.37−01	1.36−01	3.11−04			1.37−01	1.36−01
3.00−01	1.19−01	1.18−01	8.86−05			1.19−01	1.18−01
4.00−01	1.06−01	1.06−01	3.78−05			1.06−01	1.06−01
5.00−01	9.68−02	9.67−02	2.04−05			9.68−02	9.67−02
6.00−01	8.96−02	8.95−02	1.28−05			8.96−02	8.95−02
8.00−01		7.86−02	6.42−06				7.86−02
1.00+00		7.06−02	3.98−06				7.07−02
1.50+00		5.74−02	1.86−06	9.86−05			5.75−02
2.00+00		4.90−02	1.18−06	3.93−04			4.94−02
3.00+00		3.85−02	6.62−07	1.13−03	1.34−05		3.97−02
4.00+00		3.22−02	4.51−07	1.83−03	5.52−05		3.40−02
5.00+00		2.78−02	3.44−07	2.45−03	1.09−04		3.03−02
6.00+00		2.45−02	2.75−07	3.00−03	1.67−04		2.77−02
8.00+00		2.01−02	1.97−07	3.93−03	2.86−04		2.43−02
1.00+01		1.71−02	1.54−07	4.69−03	3.90−04		2.22−02
1.50+01		1.27−02		6.11−03	6.08−04		1.94−02
2.00+01		1.02−02		7.16−03	7.80−04		1.81−02
3.00+01		7.40−03		8.63−03	1.04−03		1.71−02
4.00+01		5.88−03		9.63−03	1.23−03		1.67−02
5.00+01		4.91−03		1.04−02	1.38−03		1.67−02
6.00+01		4.22−03		1.10−02	1.51−03		1.67−02
8.00+01		3.33−03		1.19−02	1.70−03		1.70−02
1.00+02		2.77−03		1.26−02	1.84−03		1.72−02
1.50+02		1.97−03		1.37−02	2.09−03		1.78−02
2.00+02		1.54−03		1.44−02	2.26−03		1.82−02
3.00+02		1.09−03		1.52−02	2.48−03		1.88−02
4.00+02		8.57−04		1.57−02	2.62−03		1.92−02
5.00+02		7.10−04		1.60−02	2.73−03		1.95−02
6.00+02		6.08−04		1.63−02	2.80−03		1.97−02
8.00+02		4.75−04		1.66−02	2.92−03		2.00−02
1.00+03		3.90−04		1.68−02	3.00−03		2.02−02
1.50+03		2.73−04		1.71−02	3.12−03		2.05−02
2.00+03		2.11−04		1.72−02	3.20−03		2.06−02
3.00+03		1.47−04		1.74−02	3.30−03		2.08−02
4.00+03		1.13−04		1.75−02	3.35−03		2.10−02
5.00+03		9.26−05		1.76−02	3.38−03		2.10−02
6.00+03		7.86−05		1.76−02	3.40−03		2.11−02
8.00+03		6.05−05		1.77−02	3.43−03		2.11−02
1.00+04		4.94−05		1.77−02	3.45−03		2.12−02
1.50+04		3.41−05		1.77−02	3.48−03		2.13−02
2.00+04		2.62−05		1.78−02	3.50−03		2.13−02
3.00+04		1.81−05		1.78−02	3.52−03		2.13−02
4.00+04		1.39−05		1.78−02	3.52−03		2.13−02
5.00+04		1.13−05		1.78−02	3.53−03		2.13−02
6.00+04		9.57−06		1.78−02	3.53−03		2.14−02
8.00+04		7.33−06		1.78−02	3.54−03		2.14−02
1.00+05		5.97−06		1.78−02	3.54−03		2.14−02

SILICON DIOXIDE, SiO_2

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00−02	5.64−01	1.93−01	1.85+01			1.90+01	1.87+01
1.50−02	3.95−01	1.89−01	5.33+00			5.73+00	5.52+00
2.00−02	3.16−01	1.86−01	2.18+00			2.49+00	2.36+00
3.00−02	2.46−01	1.80−01	6.13−01			8.59−01	7.93−01
4.00−02	2.14−01	1.74−01	2.48−01			4.63−01	4.22−01
5.00−02	1.96−01	1.69−01	1.22−01			3.18−01	2.91−01
6.00−02	1.83−01	1.64−01	6.91−02			2.52−01	2.33−01
8.00−02	1.67−01	1.56−01	2.78−02			1.94−01	1.83−01
1.00−01	1.55−01	1.48−01	1.36−02			1.69−01	1.62−01
1.50−01	1.37−01	1.33−01	3.76−03			1.40−01	1.37−01
2.00−01	1.24−01	1.22−01	1.53−03			1.26−01	1.24−01
3.00−01	1.07−01	1.06−01	4.45−04			1.08−01	1.07−01
4.00−01	9.57−02	9.52−02	1.92−04			9.59−02	9.54−02
5.00−01	8.73−02	8.70−02	1.04−04			8.74−02	8.71−02
6.00−01	8.07−02	8.05−02	6.50−05			8.08−02	8.05−02
8.00−01		7.07−02	3.28−05				7.07−02
1.00+00		6.36−02	2.03−05				6.36−02
1.50+00		5.16−02	9.49−06	1.47−04			5.18−02
2.00+00		4.41−02	6.02−06	5.81−04			4.47−02
3.00+00		3.47−02	3.33−06	1.66−03	1.21−05		3.63−02
4.00+00		2.89−02	2.26−06	2.69−03	4.97−05		3.17−02
5.00+00		2.50−02	1.63−06	3.60−03	9.76−05		2.87−02
6.00+00		2.21−02	1.38−06	4.42−03	1.50−04		2.66−02
8.00+00		1.81−02	9.81−07	5.76−03	2.57−04		2.41−02
1.00+01		1.54−02	7.68−07	6.86−03	3.51−04		2.26−02
1.50+01		1.14−02		8.94−03	5.47−04		2.09−02
2.00+01		9.14−03		1.05−02	7.02−04		2.03−02
3.00+01		6.65−03		1.26−02	9.35−04		2.02−02
4.00+01		5.28−03		1.40−02	1.11−03		2.04−02
5.00+01		4.41−03		1.52−02	1.24−03		2.08−02
6.00+01		3.80−03		1.60−02	1.35−03		2.12−02
8.00+01		3.00−03		1.73−02	1.51−03		2.18−02
1.00+02		2.49−03		1.83−02	1.64−03		2.24−02
1.50+02		1.77−03		1.98−02	1.85−03		2.34−02
2.00+02		1.39−03		2.07−02	1.99−03		2.41−02
3.00+02		9.85−04		2.19−02	2.18−03		2.50−02
4.00+02		7.71−04		2.25−02	2.30−03		2.56−02
5.00+02		6.39−04		2.29−02	2.38−03		2.60−02
6.00+02		5.47−04		2.33−02	2.45−03		2.62−02
8.00+02		4.27−04		2.37−02	2.54−03		2.66−02
1.00+03		3.51−04		2.39−02	2.61−03		2.69−02
1.50+03		2.45−04		2.43−02	2.71−03		2.73−02
2.00+03		1.90−04		2.45−02	2.78−03		2.75−02
3.00+03		1.32−04		2.48−02	2.85−03		2.78−02
4.00+03		1.02−04		2.49−02	2.89−03		2.79−02
5.00+03		8.33−05		2.50−02	2.92−03		2.80−02
6.00+03		7.06−05		2.50−02	2.94−03		2.81−02
8.00+03		5.44−05		2.51−02	2.97−03		2.81−02
1.00+04		4.44−05		2.52−02	2.98−03		2.82−02
1.50+04		3.07−05		2.52−02	3.01−03		2.83−02
2.00+04		2.36−05		2.53−02	3.02−03		2.83−02
3.00+04		1.63−05		2.53−02	3.03−03		2.83−02
4.00+04		1.25−05		2.53−02	3.04−03		2.84−02
5.00+04		1.02−05		2.53−02	3.04−03		2.84−02
6.00+04		8.60−06		2.53−02	3.05−03		2.84−02
8.00+04		6.60−06		2.53−02	3.05−03		2.84−02
1.00+05		5.37−06		2.54−02	3.05−03		2.84−02

AIR, NBS Handbook 85(1964) Composition

Photon energy	Scattering		Photo-electric	Pair production		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00–02	3.64–01	1.93–01	4.63+00			4.99+00	4.82+00
1.50–02	2.85–01	1.89–01	1.27+00			1.55+00	1.45+00
2.00–02	2.47–01	1.86–01	5.05–01			7.52–01	6.91–01
3.00–02	2.11–01	1.80–01	1.39–01			3.49–01	3.18–01
4.00–02	1.93–01	1.74–01	5.53–02			2.48–01	2.29–01
5.00–02	1.81–01	1.69–01	2.70–02			2.08–01	1.96–01
6.00–02	1.73–01	1.64–01	1.52–02			1.88–01	1.79–01
8.00–02	1.61–01	1.56–01	6.06–03			1.67–01	1.62–01
1.00–01	1.51–01	1.48–01	2.94–03			1.54–01	1.51–01
1.50–01	1.35–01	1.33–01	8.05–04			1.36–01	1.34–01
2.00–01	1.23–01	1.22–01	3.24–04			1.23–01	1.23–01
3.00–01	1.07–01	1.06–01	9.30–05			1.07–01	1.06–01
4.00–01	9.53–02	9.52–02	3.99–05			9.54–02	9.53–02
5.00–01	8.70–02	8.70–02	2.15–05			8.70–02	8.70–02
6.00–01	8.05–02	8.04–02	1.34–05			8.05–02	8.05–02
8.00–01		7.07–02	6.79–06				7.07–02
1.00+00		6.36–02	4.20–06				6.36–02
1.50+00		5.17–02	1.96–06	9.89–05			5.18–02
2.00+00		4.41–02	1.25–06	3.94–04			4.45–02
3.00+00		3.47–02	6.97–07	1.13–03	1.21–05		3.58–02
4.00+00		2.89–02	4.73–07	1.83–03	4.97–05		3.08–02
5.00+00		2.50–02	3.61–07	2.46–03	9.76–05		2.75–02
6.00+00		2.21–02	2.88–07	3.01–03	1.50–04		2.52–02
8.00+00		1.81–02	2.06–07	3.94–03	2.57–04		2.23–02
1.00+01		1.54–02	1.61–07	~~4.70–03~~	~~3.51–04~~		2.04–02
1.50+01		1.14–02		6.14–03	5.47–04		1.81–02
2.00+01		9.14–03		7.18–03	7.02–04		1.70–02
3.00+01		6.65–03		8.65–03	9.35–04		1.62–02
4.00+01		5.28–03		9.67–03	1.11–03		1.61–02
5.00+01		4.41–03		1.04–02	1.24–03		1.61–02
6.00+01		3.80–03		1.11–02	1.36–03		1.62–02
8.00+01		3.00–03		1.20–02	1.53–03		1.65–02
1.00+02		2.55–03		1.26–02	1.65–03		1.68–02
1.50+02		1.77–03		1.38–02	1.87–03		1.74–02
2.00+02		1.39–03		1.45–02	2.02–03		1.79–02
3.00+02		9.85–04		1.53–02	2.22–03		1.85–02
4.00+02		7.71–04		1.58–02	2.34–03		1.89–02
5.00+02		6.38–04		1.61–02	2.43–03		1.92–02
6.00+02		5.47–04		1.63–02	2.50–03		1.94–02
8.00+02		4.27–04		1.67–02	2.60–03		1.97–02
1.00+03		3.51–04		1.69–02	2.67–03		1.99–02
1.50+03		2.45–04		1.72–02	2.79–03		2.02–02
2.00+03		1.90–04		1.73–02	2.86–03		2.04–02
3.00+03		1.32–04		1.75–02	2.95–03		2.06–02
4.00+03		1.02–04		1.76–02	2.99–03		2.07–02
5.00+03		8.33–05		1.77–02	3.02–03		2.08–02
6.00+03		7.07–05		1.77–02	3.05–03		2.08–02
8.00+03		5.44–05		1.78–02	3.08–03		2.09–02
1.00+04		4.44–05		1.78–02	3.10–03		2.09–02
1.50+04		3.07–05		1.78–02	3.12–03		2.10–02
2.00+04		2.36–05		1.79–02	3.14–03		2.10–02
3.00+04		1.63–05		1.79–02	3.15–03		2.11–02
4.00+04		1.25–05		1.79–02	3.16–03		2.11–02
5.00+04		1.02–05		1.79–02	3.17–03		2.11–02
6.00+04		8.60–06		1.79–02	3.17–03		2.11–02
8.00+04		6.60–06		1.79–02	3.18–03		2.11–02
1.00+05		5.37–06		1.79–02	3.18–03		2.11–02

CONCRETE, Grodstein – McGinnies Composition

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00−02	6.00−01	1.93−01	2.63+01			2.69+01	2.65+01
1.50−02	4.21−01	1.89−01	7.82+00			8.24+00	8.01+00
2.00−02	3.34−01	1.86−01	3.26+00			3.59+00	3.45+00
3.00−02	2.56−01	1.80−01	9.38−01			1.19+00	1.12+00
4.00−02	2.20−01	1.74−01	3.84−01			6.05−01	5.59−01
5.00−02	2.00−01	1.69−01	1.92−01			3.92−01	3.61−01
6.00−02	1.86−01	1.64−01	1.09−01			2.95−01	2.73−01
8.00−02	1.69−01	1.56−01	4.45−02			2.13−01	2.00−01
1.00−01	1.57−01	1.48−01	2.19−02			1.79−01	1.70−01
1.50−01	1.37−01	1.34−01	6.20−03			1.44−01	1.40−01
2.00−01	1.25−01	1.22−01	2.56−03			1.27−01	1.25−01
3.00−01	1.07−01	1.07−01	7.52−04			1.08−01	1.07−01
4.00−01	9.60−02	9.54−02	3.27−04			9.63−02	9.58−02
5.00−01	8.75−02	8.72−02	1.77−04			8.77−02	8.73−02
6.00−01	8.09−02	8.06−02	1.11−04			8.10−02	8.07−02
8.00−01	7.09−02	7.08−02	5.64−05			7.09−02	7.09−02
1.00+00		6.37−02	3.50−05				6.37−02
1.50+00		5.18−02	1.63−05	1.58−04			5.19−02
2.00+00		4.42−02	1.03−05	6.22−04			4.48−02
3.00+00		3.47−02	5.67−06	1.77−03	1.21−05		3.65−02
4.00+00		2.90−02	3.84−06	2.87−03	4.98−05		3.19−02
5.00+00		2.50−02	2.86−06	3.84−03	9.78−05		2.90−02
6.00+00		2.21−02	2.32−06	4.70−03	1.50−04		2.70−02
8.00+00		1.81−02	1.65−06	6.13−03	2.57−04		2.45−02
1.00+01		1.54−02	1.29−06	7.31−03	3.52−04		2.31−02
1.50+01		1.14−02	9.21−08	9.52−03	5.48−04		2.15−02
2.00+01		9.15−03	6.58−08	1.11−02	7.03−04		2.10−02
3.00+01		6.67−03		1.34−02	9.37−04		2.10−02
4.00+01		5.30−03		1.49−02	1.11−03		2.13−02
5.00+01		4.42−03		1.61−02	1.24−03		2.18−02
6.00+01		3.81−03		1.70−02	1.35−03		2.22−02
8.00+01		3.00−03		1.84−02	1.51−03		2.29−02
1.00+02		2.49−03		1.94−02	1.64−03		2.35−02
1.50+02		1.78−03		2.11−02	1.85−03		2.47−02
2.00+02		1.39−03		2.20−02	1.99−03		2.54−02
3.00+02		9.87−04		2.32−02	2.18−03		2.64−02
4.00+02		7.73−04		2.39−02	2.30−03		2.69−02
5.00+02		6.40−04		2.43−02	2.38−03		2.73−02
6.00+02		5.48−04		2.47−02	2.44−03		2.76−02
8.00+02		4.28−04		2.51−02	2.54−03		2.81−02
1.00+03		3.52−04		2.54−02	2.60−03		2.83−02
1.50+03		2.46−04		2.58−02	2.71−03		2.87−02
2.00+03		1.90−04		2.60−02	2.77−03		2.90−02
3.00+03		1.32−04		2.63−02	2.85−03		2.92−02
4.00+03		1.02−04		2.64−02	2.89−03		2.94−02
5.00+03		8.35−05		2.65−02	2.92−03		2.95−02
6.00+03		7.08−05		2.65−02	2.93−03		2.95−02
8.00+03		5.45−05		2.66−02	2.96−03		2.96−02
1.00+04		4.45−05		2.67−02	2.97−03		2.97−02
1.50+04		3.08−05		2.67−02	3.00−03		2.98−02
2.00+04		2.37−05		2.68−02	3.01−03		2.98−02
3.00+04		1.63−05		2.68−02	3.02−03		2.98−02
4.00+04		1.25−05		2.68−02	3.03−03		2.99−02
5.00+04		1.02−05		2.68−02	3.03−03		2.99−02
6.00+04		8.62−06		2.68−02	3.04−03		2.99−02
8.00+04		6.61−06		2.68−02	3.04−03		2.99−02
1.00+05		5.38−06		2.69−02	3.04−03		2.99−02

MUSCLE, Striated, NBS Handbook 85(1964) Composition

Photon energy	Scattering		Photo-electric	Pair production		Total	
	With coherent	Without coherent		Nuclear field	Electron field	With coherent	Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00-02	3.89-01	2.12-01	4.88+00			5.27+00	5.09+00
1.50-02	3.05-01	2.08-01	1.32+00			1.63+00	1.53+00
2.00-02	2.66-01	2.05-01	5.26-01			7.93-01	7.31-01
3.00-02	2.29-01	1.98-01	1.44-01			3.73-01	3.42-01
4.00-02	2.10-01	1.92-01	5.73-02			2.68-01	2.49-01
5.00-02	1.98-01	1.86-01	2.81-02			2.27-01	2.14-01
6.00-02	1.90-01	1.81-01	1.58-02			2.05-01	1.97-01
8.00-02	1.76-01	1.71-01	6.31-03			1.83-01	1.78-01
1.00-01	1.67-01	1.63-01	3.04-03			1.70-01	1.66-01
1.50-01	1.49-01	1.47-01	8.32-04			1.49-01	1.48-01
2.00-01	1.35-01	1.35-01	3.35-04			1.36-01	1.35-01
3.00-01	1.18-01	1.17-01	9.59-05			1.18-01	1.17-01
4.00-01	1.05-01	1.05-01	4.11-05			1.05-01	1.05-01
5.00-01	9.59-02	9.58-02	2.22-05			9.60-02	9.59-02
6.00-01	8.88-02	8.87-02	1.39-05			8.88-02	8.87-02
8.00-01		7.79-02	6.99-06				7.79-02
1.00+00		7.00-02	4.33-06				7.00-02
1.50+00		5.69-02	2.03-06	9.69-05			5.70-02
2.00+00		4.86-02	1.29-06	3.86-04			4.89-02
3.00+00		3.82-02	7.18-07	1.11-03	1.33-05		3.93-02
4.00+00		3.19-02	4.89-07	1.80-03	5.47-05		3.37-02
5.00+00		2.75-02	3.73-07	2.41-03	1.08-04		3.00-02
6.00+00		2.43-02	2.97-07	2.95-03	1.65-04		2.74-02
8.00+00		1.99-02	2.13-07	3.86-03	2.83-04		2.40-02
1.00+01		1.69-02	1.66-07	4.60-03	3.87-04		2.19-02
1.50+01		1.25-02		6.00-03	6.03-04		1.92-02
2.00+01		1.01-02		7.03-03	7.73-04		1.79-02
3.00+01		7.33-03		8.47-03	1.03-03		1.68-02
4.00+01		5.82-03		9.46-03	1.22-03		1.65-02
5.00+01		4.86-03		1.02-02	1.37-03		1.64-02
6.00+01		4.19-03		1.08-02	1.49-03		1.65-02
8.00+01		3.30-03		1.17-02	1.68-03		1.67-02
1.00+02		2.75-03		1.24-02	1.82-03		1.70-02
1.50+02		1.95-03		1.35-02	2.07-03		1.75-02
2.00+02		1.53-03		1.42-02	2.24-03		1.79-02
3.00+02		1.09-03		1.50-02	2.46-03		1.85-02
4.00+02		8.50-04		1.54-02	2.60-03		1.89-02
5.00+02		7.04-04		1.58-02	2.70-03		1.92-02
6.00+02		6.02-04		1.60-02	2.78-03		1.94-02
8.00+02		4.70-04		1.63-02	2.89-03		1.97-02
1.00+03		3.87-04		1.65-02	2.97-03		1.99-02
1.50+03		2.70-04		1.68-02	3.10-03		2.02-02
2.00+03		2.09-04		1.69-02	3.18-03		2.03-02
3.00+03		1.46-04		1.71-02	3.27-03		2.05-02
4.00+03		1.12-04		1.72-02	3.32-03		2.06-02
5.00+03		9.18-05		1.73-02	3.36-03		2.07-02
6.00+03		7.79-05		1.73-02	3.38-03		2.08-02
8.00+03		6.00-05		1.74-02	3.41-03		2.08-02
1.00+04		4.90-05		1.74-02	3.43-03		2.09-02
1.50+04		3.38-05		1.74-02	3.46-03		2.09-02
2.00+04		2.60-05		1.75-02	3.48-03		2.10-02
3.00+04		1.79-05		1.75-02	3.49-03		2.10-02
4.00+04		1.38-05		1.75-02	3.50-03		2.10-02
5.00+04		1.12-05		1.75-02	3.51-03		2.10-02
6.00+04		9.48-06		1.75-02	3.51-03		2.10-02
8.00+04		7.27-06		1.75-02	3.52-03		2.10-02
1.00+05		5.91-06		1.75-02	3.52-03		2.11-02

POLYETHYLENE, $(CH_2)_n$

Photon energy	Scattering: With coherent	Scattering: Without coherent	Photo-electric	Pair production: Nuclear field	Pair production: Electron field	Total: With coherent	Total: Without coherent
MeV	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g	cm²/g
1.00−02	3.18−01	2.20−01	1.69+00			2.01+00	1.91+00
1.50−02	2.72−01	2.16−01	4.56−01			7.28−01	6.72−01
2.00−02	2.48−01	2.13−01	1.73−01			4.20−01	3.85−01
3.00−02	2.23−01	2.06−01	4.30−02			2.66−01	2.49−01
4.00−02	2.10−01	1.99−01	1.63−02			2.26−01	2.15−01
5.00−02	2.00−01	1.93−01	8.30−03			2.09−01	2.01−01
6.00−02	1.93−01	1.88−01	4.95−03			1.98−01	1.93−01
8.00−02	1.81−01	1.78−01	1.94−03			1.83−01	1.80−01
1.00−01	1.71−01	1.69−01	9.29−04			1.72−01	1.70−01
1.50−01	1.54−01	1.53−01	2.47−04			1.54−01	1.53−01
2.00−01		1.40−01	9.85−05				1.40−01
3.00−01		1.22−01	2.78−05				1.22−01
4.00−01		1.09−01	1.19−05				1.09−01
5.00−01		9.95−02	6.41−06				9.95−02
6.00−01		9.21−02	3.99−06				9.21−02
8.00−01		8.09−02	2.01−06				8.09−02
1.00+00		7.27−02	1.24−06				7.27−02
1.50+00		5.91−02	5.81−07	7.28−05			5.92−02
2.00+00		5.04−02	3.70−07	2.91−04			5.07−02
3.00+00		3.96−02	2.07−07	8.35−04	1.38−05		4.05−02
4.00+00		3.31−02	1.42−07	1.35−03	5.68−05		3.45−02
5.00+00		2.86−02	1.08−07	1.82−03	1.12−04		3.05−02
6.00+00		2.53−02	8.65−08	2.23−03	1.72−04		2.77−02
8.00+00		2.07−02	6.20−08	2.92−03	2.94−04		2.39−02
1.00+01		1.76−02	4.82−08	3.48−03	4.02−04		2.15−02
1.50+01		1.30−02		4.55−03	6.26−04		1.82−02
2.00+01		1.05−02		5.33−03	8.03−04		1.66−02
3.00+01		7.61−03		6.42−03	1.07−03		1.51−02
4.00+01		6.05−03		7.19−03	1.27−03		1.45−02
5.00+01		5.05−03		7.76−03	1.42−03		1.42−02
6.00+01		4.35−03		8.22−03	1.55−03		1.41−02
8.00+01		3.43−03		8.91−03	1.75−03		1.41−02
1.00+02		2.85−03		9.42−03	1.90−03		1.42−02
1.50+02		2.03−03		1.03−02	2.17−03		1.45−02
2.00+02		1.59−03		1.08−02	2.34−03		1.47−02
3.00+02		1.13−03		1.15−02	2.58−03		1.52−02
4.00+02		8.82−04		1.19−02	2.73−03		1.55−02
5.00+02		7.30−04		1.21−02	2.85−03		1.57−02
6.00+02		6.25−04		1.23−02	2.93−03		1.59−02
8.00+02		4.88−04		1.26−02	3.05−03		1.61−02
1.00+03		4.02−04		1.27−02	3.14−03		1.63−02
1.50+03		2.81−04		1.30−02	3.28−03		1.65−02
2.00+03		2.17−04		1.31−02	3.36−03		1.67−02
3.00+03		1.51−04		1.33−02	3.46−03		1.69−02
4.00+03		1.17−04		1.33−02	3.52−03		1.70−02
5.00+03		9.53−05		1.34−02	3.56−03		1.70−02
6.00+03		8.08−05		1.34−02	3.59−03		1.71−02
8.00+03		6.23−05		1.35−02	3.62−03		1.72−02
1.00+04		5.08−05		1.35−02	3.64−03		1.72−02
1.50+04		3.51−05		1.35−02	3.68−03		1.73−02
2.00+04		2.70−05		1.36−02	3.70−03		1.73−02
3.00+04		1.86−05		1.36−02	3.72−03		1.73−02
4.00+04		1.43−05		1.36−02	3.73−03		1.73−02
5.00+04		1.16−05		1.36−02	3.73−03		1.73−02
6.00+04		9.84−06		1.36−02	3.74−03		1.74−02
8.00+04		7.55−06		1.36−02	3.74−03		1.74−02
1.00+05		6.14−06		1.36−02	3.75−03		1.74−02

Table 2 Density of material, atomic and electron densities

Atomic number and material	Mass	Density (g/cm^3)	Atomic density (/cm^3)	Electron density (/cm^3)
5 B	10.82	2.45	0.1364	0.682
6 C	12.01	1.60	0.0803	0.4818
11 Na	23	0.971	0.0254	0.2794
13 Al	27	2.7	0.0602	0.7826
14 Si	28.1	2.42	0.0522	0.7308
20 Ca	40.1	1.55	0.0233	0.466
26 Fe	55.85	7.86	0.0848	2.205
29 Cu	63.54	8.94	0.0847	2.456
74 W	183.86	19.3	0.0632	4.677
82 Pb	207.2	11.34	0.03296	2.703
92 U	238.1	18.9	0.04783	4.400
Water		1.0		0.3345
SiO_2				
Air(20°C)		1.205-3*		3.628-4*
Concrete		2.25		0.6869
Muscle				
Polythylene		0.92		0.3166

* 1.205×10^{-3}