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AVKER: A PROGRAM FOR DETERMINING NEUTRON KERMA FACTORS FOR USE IN ENERGY DEPOSITION CALCULATIONS

M. Solomito, J. J. Ritts,* and H. C. Claiborne

Abstract

The Fortran code AVKER calculates neutron kerma factors which may be used to determine dose or heat generation rates in materials. The program allows the evaluation of the kerma factors for any desired composition that can be made up from elements presently available in the kerma library and for any arbitrary group structure within the energy limits of 19.2 MeV to 0.023 eV.

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Introduction

A knowledge of heat generation rates and dose in materials resulting from neutron interactions is frequently necessary in both design and experimental work. In most applications, these quantities can be estimated by using predetermined neutron kerma factors. Kerma (kinetic energy released in materials) can be calculated with an accuracy limited only by the uncertainties in the nuclear parameters since kerma is concerned only with the energy released at a point rather than the subsequent particle transport and energy deposition. However, for practical purposes the kerma can be taken as equal to the energy deposition at the point of neutron interaction; that is

$$\text{Dose or Heat Generation Rate at } r = \sum_{i=1}^{N} K(E_i)\, \varphi(E_i, \vec{r})$$

where

$\varphi(E_i, r)$ = average neutron flux at r in energy group i (n/cm^2 sec),

$K(E_i)$ = kerma factor for energy group i (watts*/gm)/(n/cm^2 sec),

N = number of energy groups.

The Fortran code AVKER was written to obtain group average kerma factors for various compositions and for any desired energy group structure. The program allows the evaluation of kerma factors for any desired compositions that can be made up from the elements presently available in the kerma library[1] (Table 1). An average value of the kerma factor can then be obtained for any arbitrary group structure with either a flat or 1/E weighting within the limits of 19.2 MeV and 0.023 eV.

This report contains a description of the kerma factor data that is presently available on the kerma library tape which is to be used with the program AVKER. A description of the data card input required to run the program is also given along with a sample problem and a listing of its output.

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*Ergs or rads are used when doses are to be calculated.

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KERMA Library

The total kerma factor for an element is found by summing the average initial kinetic energies imparted to the struck nuclei and the kinetic energies imparted to the charged particles emitted. Therefore the kerma factor for a given element at a given neutron energy is calculated as follows:

$$KF\ (\text{ergs}\cdot\text{b/atom}) = c \sum_j \sigma_j E_j \quad ,$$

where

σ_j = microscopic cross section for reaction j (b/atoms),

E_j = average energy released by reaction j (MeV),

$c = 1.602 \times 10^{-6}$ ergs/MeV.

The methods used to calculate the energy released by each type of reaction are given in ref. 2.

The kerma factors for each of 18 elements is presently available in the KERMA library and each element was calculated as the sum of the contribution from the reactions listed in Table 2. The calculations were performed at 816 discrete neutron energies corresponding to the supergroup-subgroup structure of the 05R code[3] which covers a range from 0.023 eV to 19.2 MeV.

Cross Sections Used

In the kerma library, the cross sections for H, Na, Si, S, K, and Ca were taken from the 05R Library,[4] and the Li-6, Li-7, Be, C, N, O, Mg, Al, Fe and Nb came from ENDF/B.[5] The Cl cross sections were generated by Craven.[6] The authors compiled the P cross sections, mainly for BNL-325[7] and the F cross sections from GAM-II.[8]

Table 1. Kerma Library

I.D. Number	Element
1000	Hydrogen
3001	Lithium-6
3002	Lithium-7
4000	Beryllium
6000	Carbon
7000	Nitrogen
8000	Oxygen
9000	Flourine
11000	Sodium
12000	Magnesium
13000	Aluminum
14000	Silicon
15000	Phosphorus
16000	Sulfur
17000	Chlorine
19000	Potassium
20000	Calcium
26000	Iron
41000	Niobium

Table 2. Reactions Considered in Calculation of Kerma

I.D. Number	Element	Type of Reaction
1000	Hydrogen	Elastic Scattering Neutron Capture
3001	Lithium-6	Elastic Scattering Inelastic Scattering Neutron Capture (n,n',α) $(n,2n,\alpha)$ $(n,p)^a$ (n,α)
3002	Lithium-7	Elastic Scattering Inelastic Scattering Neutron Capture $(n,2n)$ $(n,n'\alpha)$ $(n,2n\alpha)$ $(n,d)^a$
4000	Beryllium	Elastic Scattering Inelastic Scattering Neutron Capture $(n,\alpha)^a$ (n,t) $(n,2n)$
6000	Carbon	Elastic Scattering Inelastic Scattering (n,α) $(n,n'3\alpha)$
7000	Nitrogen	Elastic Scattering Inelastic Scattering Neutron Capture $(n,2n)^b$ (n,p) (n,d) (n,t) (n,α) $(n,2\alpha)$
8000	Oxygen	Elastic Scattering Inelastic Scattering $(n,p)^a$ (n,α)
9000	Flourine	Elastic Scattering Inelastic Scattering Neutron Capture[a] $(n,p)^a$ $(n,\alpha)^a$ $(n,2n)^b$

Table 2 (Cont'd.)

I.D. Number	Element	Type of Reaction
11000	Sodium	Elastic Scattering Inelastic Scattering Neutron Capture[a]
12000	Magnesium	Elastic Scattering Inelastic Scattering Neutron Capture (n,p)[a] (n,α) (n,n'p)
13000	Aluminum	Elastic Scattering Inelastic Scattering Neutron Capture[a] (n,2n) (n,n'p) (n,α)
14000	Silicon	Elastic Scattering Inelastic Scattering
15000	Phosphorus	Elastic Scattering Inelastic Scattering Neutron Capture[a] (n,p)[a] (n,α) (n,2n) (n,n'p)
16000	Sulfur	Elastic Scattering Inelastic Scattering Neutron Capture
17000	Chlorine	Elastic Scattering Neutron Capture (n,p) (n,α)[a]
19000	Potassium	Elastic Scattering Inelastic Scattering Neutron Capture (n,p) (n,α) (n,d) (n,2n)[b] (n,n'α)
20000	Calcium	Elastic Scattering Inelastic Scattering

Table 2 (Cont'd.)

I.D. Number	Element	Type of Reaction
26000	Iron	Elastic Scattering Inelastic Scattering Neutron Capture (n,2n) (n,p)[a] (n,α)
41000	Niobium	Elastic Scattering Inelastic Scattering Neutron Capture (n,p) (n,α)[a] (n,2n)

a. Beta decay after reaction included.
b. Positron decay included.

Input Instructions for AVKER

Card 1 Format (18A4)

72 Columns of Hollerith information, used to title output.

Card 2 Format (3I5)

Column	Variable	Description
1-5	NE	Number of elements in desired composition
6-10	LT	0 Kerma factors will be calculated for this composition at 816 energy points 1 Kerma factors will be calculated for this composition for the desired group structure using a flat weighting 2 Kerma factors will be calculated for this composition for the desired group structure using a 1/E weighting
11-15	NG	Number of groups for which kerma factors are to be calculated (if LT > 0).

Cards 3 Format (I5,E12.5,8A4)

Column	Variable	Description
1-5	IDN(K)	I.D. number of first element in composition as given in Table 1. (Elements must be listed starting with the lowest I.D. number and proceeding to the highest.)
6-17	DEN(K)	Density of first element in composition. (For example, atoms/b-cm or atoms/gm).
18-59	UNIT(K)	Name of first element in composition and/or other type of identification, used to title output.

Note: There must be a card 3 for each element in the composition.

Cards 4 Format (E10.5) (If LT > 0)

Column	Variable	Description
1-10	EG(1)	First energy boundary of desired group structure starting with highest energy (cannot exceed 19.2 MeV)

Cards 4 (cont'd.)

Column	Variable	Description
11-20	EG(2)	Second energy boundary
	.	
	.	
	.	
	EG(NG+1)	Last energy boundary (cannot be less than 0.023 eV).

Note: In addition to the card input data described above, the AVKER code uses a magnetic tape to feed into the fast memory the kerma library data. The tape to be used is a 9-track, high-density tape with one file and is designated as logical 11 in the code.

Acknowledgment

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References

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3. D. C. Irving, R. M. Freestone, Jr., and F. B. K. Kam, 05R, A General-Purpose Monte Carlo Neutron Transport Code, ORNL-3622 (Feb. 1965).

4. D. C. Irving, (05R), Cross Section Library, Memo No. 2, Intra-Laboratory Correspondence, Oak Ridge National Laboratory (1965); this data is available from the Radiation Shielding Information Center, Oak Ridge National Laboratory.

5. H. C. Honeck, ENDF/B, Specifications for an Evaluated Nuclear Data File for Reactor Application, BNL-50066 (T-467), ENDF-102, Brookhaven National Laboratory (May 1966; revised July 1967) (ENDF/B corrected to July 1, 1968).

6. C. W. Craven, Jr., Oak Ridge National Laboratory, private communication.

7. J. R. Stehn et al., Neutron Cross Sections, BNL-325, 2nd Ed., Supplement 2 (1964).

8. ORNL GAM-II Library, unpublished.

APPENDIX I

Sample Problem

Input and Output

CODED BY _____ DATE _____ REQUEST NO. _____

FORTRAN

PROBLEM _____ PROGRAM _____ PAGE _____ OF _____

STATEMENT TYPE | NUMBER | CONT | FORTRAN STATEMENT | IDENTIFICATION

AVKER EXAMPLE PROBLEM - INPUT

```
104 GRØUP KERMA FACTØRS FØR H2O WITH FLAT WEIGHTING                    CARD 1
  2     1  104                                                         CARD 2
1000  0.067       HYDRØGEN                                             CARD 3A
8000  0.0335      ØXYGEN                                               CARD 3B
1.50000 +7 1.34986+7 1.22140+7 1.10517+7 1.00000+7 9.04837+6 8.18731+6 7.40818+6
7.00000 +6 6.70320+6 6.36000+6 6.06531+6 5.48812+6 4.96585+6 4.75000+6 4.49329+6
4.06570 +6 3.67879+6 3.32871+6 3.01194+6 2.72532+6 2.46597+6 2.35000+6 2.23130+6
2.01896 +6 1.82683+6 1.65299+6 1.49569+6 1.35335+6 1.22456+6 1.10803+6 1.00259+6
9.07180 +5 8.20850+5 7.42736+5 6.72055+5 6.08101+5 5.50232+5 4.97871+5 4.50492+5
4.07622 +5 3.68832+5 3.33733+5 3.01974+5 2.73237+5 2.47235+5 2.23708+5 2.02419+5
1.83156 +5 1.65727+5 1.49956+5 1.35686+5 1.22773+5 1.11090+5 8.65169+4 6.73794+4
5.24752 +4 4.08677+4 3.18278+4 2.47875+4 1.93045+4 1.50344+4 1.17088+4 9.11882+3
7.10174 +3 5.53084+3 4.30743+3 3.35463+3 2.61259+3 2.03468+3 1.58461+3 1.23410+3
9.61117 +2 7.48519+2 5.82947+2 4.53999+2 3.53575+2 2.75365+2 2.14454+2 1.67017+2
1.30073 +2 1.01301+2 7.88933+1 6.14421+1 4.78512+1 3.72665+1 2.90232+1 2.26033+1
1.76035 +1 1.37096+1 1.06770+1 8.31529    6.47595    5.04348    3.92786    3.05702
2.38237    1.85539    1.44498    1.12535    8.76425-1  6.82561-1  5.31579-1  4.14000-1
2.2309 -2
```

UCN-1693A (2/66 5-67)

104 GROUP KERMA FACTORS FOR H2O WITH FLAT WEIGHTING

----NUMBER OF ELEMENTS FOR THIS COMPOSITION = 2

ID NUMBER AND CONCETRATION OF ELEMENTS IN COMP.

1000	0.67000E-01	HYDROGEN
8000	0.33500E-01	OXYGEN

KERMA FOR FINE GROUP STRUCTURE

ENERGY	KERMA	ENERGY	KERMA	ENERGY	KERMA	ENERGY	KERMA
0.19208E 08	0.82870E-06	0.19057E 08	0.82609E-06	0.18907E 08	0.82347E-06	0.18756E 08	0.82083E-06
0.18605E 08	0.81819E-06	0.18455E 08	0.81554E-06	0.18304E 08	0.81288E-06	0.18154E 08	0.81021E-06
0.18003E 08	0.80753E-06	0.17852E 08	0.80484E-06	0.17702E 08	0.80214E-06	0.17551E 08	0.79943E-06
0.17400E 08	0.79639E-06	0.17250E 08	0.79316E-06	0.17099E 08	0.78991E-06	0.16948E 08	0.78666E-06
0.16798E 08	0.78339E-06	0.16647E 08	0.78012E-06	0.16496E 08	0.77683E-06	0.16346E 08	0.77353E-06
0.16195E 08	0.77022E-06	0.16044E 08	0.76689E-06	0.15894E 08	0.76356E-06	0.15743E 08	0.76022E-06
0.15592E 08	0.75686E-06	0.15442E 08	0.75350E-06	0.15291E 08	0.75013E-06	0.15140E 08	0.74675E-06
0.14990E 08	0.74272E-06	0.14839E 08	0.73608E-06	0.14689E 08	0.73389E-06	0.14538E 08	0.72589E-06
0.14387E 08	0.71567E-06	0.14237E 08	0.70906E-06	0.14086E 08	0.70244E-06	0.13935E 08	0.69191E-06
0.13785E 08	0.67719E-06	0.13634E 08	0.66287E-06	0.13483E 08	0.65030E-06	0.13333E 08	0.64330E-06
0.13182E 08	0.63702E-06	0.13031E 08	0.63121E-06	0.12881E 08	0.63112E-06	0.12730E 08	0.63289E-06
0.12579E 08	0.63463E-06	0.12429E 08	0.63604E-06	0.12278E 08	0.63642E-06	0.12127E 08	0.63730E-06
0.11977E 08	0.64296E-06	0.11826E 08	0.64869E-06	0.11675E 08	0.64574E-06	0.11525E 08	0.64201E-06
0.11374E 08	0.63560E-06	0.11224E 08	0.63468E-06	0.11073E 08	0.63007E-06	0.10922E 08	0.61905E-06
0.10772E 08	0.61017E-06	0.10621E 08	0.60699E-06	0.10470E 08	0.60677E-06	0.10320E 08	0.60672E-06
0.10169E 08	0.60504E-06	0.10018E 08	0.60025E-06	0.98677E 07	0.59666E-06	0.97170E 07	0.59064E-06
0.96041E 07	0.58540E-06	0.95287E 07	0.58285E-06	0.94534E 07	0.57951E-06	0.93781E 07	0.57608E-06
0.93028E 07	0.57222E-06	0.92274E 07	0.56725E-06	0.91521E 07	0.56687E-06	0.90768E 07	0.56835E-06
0.90015E 07	0.56604E-06	0.89261E 07	0.56005E-06	0.88508E 07	0.56166E-06	0.87755E 07	0.56290E-06
0.87001E 07	0.55827E-06	0.86248E 07	0.55252E-06	0.85495E 07	0.54928E-06	0.84742E 07	0.55009E-06
0.83988E 07	0.55559E-06	0.83235E 07	0.55630E-06	0.82482E 07	0.55662E-06	0.81729E 07	0.55328E-06
0.80975E 07	0.54295E-06	0.80222E 07	0.53314E-06	0.79469E 07	0.53653E-06	0.78716E 07	0.54353E-06
0.77962E 07	0.54834E-06	0.77209E 07	0.54173E-06	0.76456E 07	0.53781E-06	0.75703E 07	0.53523E-06
0.74949E 07	0.53294E-06	0.74196E 07	0.53906E-06	0.73443E 07	0.54365E-06	0.72690E 07	0.55404E-06
0.71936E 07	0.57144E-06	0.71183E 07	0.53333E-06	0.70430E 07	0.52586E-06	0.69676E 07	0.51576E-06
0.68923E 07	0.51343E-06	0.68170E 07	0.52910E-06	0.67417E 07	0.52746E-06	0.66663E 07	0.52452E-06
0.65910E 07	0.52459E-06	0.65157E 07	0.50859E-06	0.64404E 07	0.51693E-06	0.63650E 07	0.52061E-06
0.62897E 07	0.49942E-06	0.62144E 07	0.49776E-06	0.61391E 07	0.49758E-06	0.60637E 07	0.50062E-06
0.59884E 07	0.49764E-06	0.59131E 07	0.51232E-06	0.58378E 07	0.49222E-06	0.57624E 07	0.48816E-06
0.56871E 07	0.49387E-06	0.56118E 07	0.49605E-06	0.55365E 07	0.47931E-06	0.54611E 07	0.46868E-06
0.53858E 07	0.46988E-06	0.53105E 07	0.46867E-06	0.52352E 07	0.47087E-06	0.51598E 07	0.49119E-06
0.50845E 07	0.50571E-06	0.50092E 07	0.47721E-06	0.49338E 07	0.46996E-06	0.48585E 07	0.47933E-06
0.48020E 07	0.46281E-06	0.47644E 07	0.45622E-06	0.47267E 07	0.45491E-06	0.46890E 07	0.45360E-06
0.46514E 07	0.46042E-06	0.46137E 07	0.46205E-06	0.45760E 07	0.45522E-06	0.45384E 07	0.46046E-06
0.45007E 07	0.44614E-06	0.44631E 07	0.44610E-06	0.44254E 07	0.45137E-06	0.43877E 07	0.44828E-06
0.43501E 07	0.45550E-06	0.43124E 07	0.45889E-06	0.42747E 07	0.45122E-06	0.42371E 07	0.45446E-06
0.41994E 07	0.46154E-06	0.41618E 07	0.46091E-06	0.41241E 07	0.44727E-06	0.40864E 07	0.43718E-06
0.40488E 07	0.43462E-06	0.40111E 07	0.43929E-06	0.39734E 07	0.44131E-06	0.39358E 07	0.44098E-06
0.38981E 07	0.43939E-06	0.38605E 07	0.43876E-06	0.38228E 07	0.44242E-06	0.37851E 07	0.46388E-06
0.37475E 07	0.44799E-06	0.37098E 07	0.43926E-06	0.36721E 07	0.43887E-06	0.36345E 07	0.45635E-06
0.35968E 07	0.43475E-06	0.35591E 07	0.43433E-06	0.35215E 07	0.43360E-06	0.34838E 07	0.43233E-06
0.34462E 07	0.43397E-06	0.34085E 07	0.43409E-06	0.33708E 07	0.43393E-06	0.33332E 07	0.43152E-06
0.32955E 07	0.42848E-06	0.32578E 07	0.42185E-06	0.32202E 07	0.41292E-06	0.31825E 07	0.40459E-06

0.31449E	07	0.39959E-06	0.31072E	07	0.39489E-06	0.30695E	07	0.39228E-06	0.30319E	07	0.39036E-06
0.29942E	07	0.38804E-06	0.29565E	07	0.38451E-06	0.29189E	07	0.38086E-06	0.28812E	07	0.37799E-06
0.28436E	07	0.37591E-06	0.28059E	07	0.37382E-06	0.27682E	07	0.37192E-06	0.27306E	07	0.37005E-06
0.26929E	07	0.36815E-06	0.26552E	07	0.36626E-06	0.26176E	07	0.36428E-06	0.25799E	07	0.36222E-06
0.25422E	07	0.35992E-06	0.25046E	07	0.35726E-06	0.24669E	07	0.35348E-06	0.24293E	07	0.34772E-06
0.24010E	07	0.34137E-06	0.23822E	07	0.33707E-06	0.23633E	07	0.33543E-06	0.23445E	07	0.33708E-06
0.23257E	07	0.33976E-06	0.23069E	07	0.34160E-06	0.22880E	07	0.34246E-06	0.22692E	07	0.34253E-06
0.22504E	07	0.34227E-06	0.22315E	07	0.34163E-06	0.22127E	07	0.34092E-06	0.21939E	07	0.34005E-06
0.21750E	07	0.33907E-06	0.21562E	07	0.33805E-06	0.21374E	07	0.33694E-06	0.21185E	07	0.33582E-06
0.20997E	07	0.33468E-06	0.20809E	07	0.33348E-06	0.20620E	07	0.33225E-06	0.20432E	07	0.33099E-06
0.20244E	07	0.32971E-06	0.20055E	07	0.32839E-06	0.19867E	07	0.32696E-06	0.19679E	07	0.32546E-06
0.19491E	07	0.32387E-06	0.19302E	07	0.32261E-06	0.19114E	07	0.32445E-06	0.18926E	07	0.32826E-06
0.18737E	07	0.32444E-06	0.18549E	07	0.32212E-06	0.18361E	07	0.33687E-06	0.18172E	07	0.32361E-06
0.17984E	07	0.31620E-06	0.17796E	07	0.31416E-06	0.17607E	07	0.31243E-06	0.17419E	07	0.31084E-06
0.17231E	07	0.30929E-06	0.17042E	07	0.30777E-06	0.16854E	07	0.30635E-06	0.16666E	07	0.31336E-06
0.16478E	07	0.30491E-06	0.16289E	07	0.30168E-06	0.16101E	07	0.30005E-06	0.15913E	07	0.29847E-06
0.15724E	07	0.29689E-06	0.15536E	07	0.29530E-06	0.15348E	07	0.29371E-06	0.15159E	07	0.29210E-06
0.14971E	07	0.29048E-06	0.14783E	07	0.28884E-06	0.14594E	07	0.28722E-06	0.14406E	07	0.28559E-06
0.14218E	07	0.28391E-06	0.14029E	07	0.28229E-06	0.13841E	07	0.28075E-06	0.13653E	07	0.27980E-06
0.13464E	07	0.27930E-06	0.13276E	07	0.28329E-06	0.13088E	07	0.29052E-06	0.12900E	07	0.28543E-06
0.12711E	07	0.27840E-06	0.12523E	07	0.27446E-06	0.12335E	07	0.27174E-06	0.12146E	07	0.26964E-06
0.12005E	07	0.26817E-06	0.11911E	07	0.26736E-06	0.11817E	07	0.26657E-06	0.11723E	07	0.26579E-06
0.11628E	07	0.26515E-06	0.11534E	07	0.26456E-06	0.11440E	07	0.26396E-06	0.11346E	07	0.26354E-06
0.11252E	07	0.26325E-06	0.11158E	07	0.26293E-06	0.11063E	07	0.26283E-06	0.10969E	07	0.26307E-06
0.10875E	07	0.26328E-06	0.10781E	07	0.26372E-06	0.10687E	07	0.26490E-06	0.10593E	07	0.26607E-06
0.10499E	07	0.26733E-06	0.10404E	07	0.26935E-06	0.10310E	07	0.27156E-06	0.10216E	07	0.27383E-06
0.10122E	07	0.27527E-06	0.10028E	07	0.27591E-06	0.99336E	06	0.27415E-06	0.98395E	06	0.27032E-06
0.97453E	06	0.26552E-06	0.96511E	06	0.26003E-06	0.95570E	06	0.25499E-06	0.94628E	06	0.25057E-06
0.93687E	06	0.24622E-06	0.92745E	06	0.24240E-06	0.91803E	06	0.23964E-06	0.90862E	06	0.23695E-06
0.89920E	06	0.23443E-06	0.88979E	06	0.23246E-06	0.88037E	06	0.23058E-06	0.87096E	06	0.22873E-06
0.86154E	06	0.22713E-06	0.85212E	06	0.22559E-06	0.84271E	06	0.22405E-06	0.83329E	06	0.22262E-06
0.82388E	06	0.22122E-06	0.81446E	06	0.21983E-06	0.80505E	06	0.21847E-06	0.79563E	06	0.21713E-06
0.78621E	06	0.21577E-06	0.77680E	06	0.21442E-06	0.76738E	06	0.21309E-06	0.75797E	06	0.21175E-06
0.74855E	06	0.21041E-06	0.73914E	06	0.20907E-06	0.72972E	06	0.20774E-06	0.72030E	06	0.20639E-06
0.71089E	06	0.20505E-06	0.70147E	06	0.20370E-06	0.69206E	06	0.20234E-06	0.68264E	06	0.20097E-06
0.67323E	06	0.19960E-06	0.66381E	06	0.19822E-06	0.65439E	06	0.19684E-06	0.64498E	06	0.19545E-06
0.63556E	06	0.19405E-06	0.62615E	06	0.19264E-06	0.61673E	06	0.19121E-06	0.60732E	06	0.18977E-06
0.60025E	06	0.18868E-06	0.59555E	06	0.18799E-06	0.59084E	06	0.18729E-06	0.58613E	06	0.18659E-06
0.58142E	06	0.18588E-06	0.57671E	06	0.18517E-06	0.57201E	06	0.18445E-06	0.56730E	06	0.18377E-06
0.56259E	06	0.18311E-06	0.55788E	06	0.18244E-06	0.55317E	06	0.18176E-06	0.54847E	06	0.18108E-06
0.54376E	06	0.18038E-06	0.53905E	06	0.17968E-06	0.53434E	06	0.17897E-06	0.52964E	06	0.17825E-06
0.52493E	06	0.17754E-06	0.52022E	06	0.17693E-06	0.51551E	06	0.17633E-06	0.51080E	06	0.17572E-06
0.50610E	06	0.17525E-06	0.50139E	06	0.17482E-06	0.49668E	06	0.17429E-06	0.49197E	06	0.17402E-06
0.48726E	06	0.17389E-06	0.48256E	06	0.17375E-06	0.47785E	06	0.17395E-06	0.47314E	06	0.17460E-06
0.46843E	06	0.17563E-06	0.46373E	06	0.17743E-06	0.45902E	06	0.17955E-06	0.45431E	06	0.18242E-06
0.44960E	06	0.18547E-06	0.44489E	06	0.18790E-06	0.44019E	06	0.18886E-06	0.43548E	06	0.18793E-06
0.43077E	06	0.18540E-06	0.42606E	06	0.18208E-06	0.42135E	06	0.17833E-06	0.41665E	06	0.17492E-06
0.41194E	06	0.17162E-06	0.40723E	06	0.16872E-06	0.40252E	06	0.16616E-06	0.39781E	06	0.16381E-06
0.39311E	06	0.16187E-06	0.38840E	06	0.15986E-06	0.38369E	06	0.15819E-06	0.37898E	06	0.15653E-06
0.37428E	06	0.15492E-06	0.36957E	06	0.15349E-06	0.36486E	06	0.15207E-06	0.36015E	06	0.15068E-06
0.35544E	06	0.14944E-06	0.35074E	06	0.14823E-06	0.34603E	06	0.14701E-06	0.34132E	06	0.14579E-06
0.33661E	06	0.14457E-06	0.33190E	06	0.14335E-06	0.32720E	06	0.14213E-06	0.32249E	06	0.14090E-06
0.31778E	06	0.13967E-06	0.31307E	06	0.13844E-06	0.30837E	06	0.13720E-06	0.30366E	06	0.13597E-06
0.30013E	06	0.13503E-06	0.29777E	06	0.13442E-06	0.29542E	06	0.13380E-06	0.29306E	06	0.13318E-06
0.29071E	06	0.13255E-06	0.28836E	06	0.13193E-06	0.28600E	06	0.13131E-06	0.28365E	06	0.13068E-06
0.28129E	06	0.13005E-06	0.27894E	06	0.12942E-06	0.27659E	06	0.12879E-06	0.27423E	06	0.12815E-06
0.27188E	06	0.12752E-06	0.26953E	06	0.12688E-06	0.26717E	06	0.12625E-06	0.26482E	06	0.12562E-06
0.26246E	06	0.12498E-06	0.26011E	06	0.12434E-06	0.25776E	06	0.12370E-06	0.25540E	06	0.12306E-06
0.25305E	06	0.12242E-06	0.25069E	06	0.12177E-06	0.24834E	06	0.12111E-06	0.24599E	06	0.12044E-06
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0.21538E 06	0.11148E-06	0.21303E 06	0.11078E-06	0.21068E 06	0.11007E-06	0.20832E 06	0.10936E-06
0.20597E 06	0.10865E-06	0.20362E 06	0.10793E-06	0.20126E 06	0.10721E-06	0.19891E 06	0.10648E-06
0.19655E 06	0.10573E-06	0.19420E 06	0.10498E-06	0.19185E 06	0.10422E-06	0.18949E 06	0.10347E-06
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0.17772E 06	0.99620E-07	0.17537E 06	0.98839E-07	0.17301E 06	0.98054E-07	0.17066E 06	0.97265E-07
0.16831E 06	0.96471E-07	0.16595E 06	0.95673E-07	0.16360E 06	0.94870E-07	0.16124E 06	0.94063E-07
0.15889E 06	0.93251E-07	0.15654E 06	0.92435E-07	0.15418E 06	0.91613E-07	0.15183E 06	0.90787E-07
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0.30454E 05	0.28361E-07	0.29866E 05	0.27913E-07	0.29277E 05	0.27453E-07	0.28689E 05	0.26991E-07
0.28100E 05	0.26527E-07	0.27512E 05	0.26059E-07	0.26923E 05	0.25554E-07	0.26335E 05	0.25045E-07
0.25746E 05	0.24534E-07	0.25158E 05	0.24023E-07	0.24569E 05	0.23517E-07	0.23981E 05	0.23013E-07
0.23392E 05	0.22508E-07	0.22804E 05	0.22001E-07	0.22215E 05	0.21502E-07	0.21627E 05	0.21011E-07
0.21038E 05	0.20519E-07	0.20450E 05	0.20025E-07	0.19861E 05	0.19526E-07	0.19273E 05	0.19017E-07
0.18758E 05	0.18570E-07	0.18464E 05	0.18314E-07	0.18169E 05	0.18057E-07	0.17875E 05	0.17800E-07
0.17581E 05	0.17543E-07	0.17287E 05	0.17273E-07	0.16992E 05	0.17000E-07	0.16698E 05	0.16726E-07
0.16404E 05	0.16451E-07	0.16110E 05	0.16176E-07	0.15815E 05	0.15901E-07	0.15521E 05	0.15626E-07
0.15227E 05	0.15350E-07	0.14933E 05	0.15075E-07	0.14638E 05	0.14803E-07	0.14344E 05	0.14532E-07
0.14050E 05	0.14259E-07	0.13756E 05	0.13986E-07	0.13462E 05	0.13713E-07	0.13167E 05	0.13439E-07
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0.10519E 05	0.10916E-07	0.10225E 05	0.10632E-07	0.99307E 04	0.10349E-07	0.96364E 04	0.10072E-07
0.93790E 04	0.98284E-08	0.92318E 04	0.96892E-08	0.90847E 04	0.95498E-08	0.89376E 04	0.94093E-08
0.87905E 04	0.92678E-08	0.86434E 04	0.91260E-08	0.84962E 04	0.89839E-08	0.83491E 04	0.88417E-08
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0.76135E 04	0.81078E-08	0.74664E 04	0.79570E-08	0.73193E 04	0.78061E-08	0.71721E 04	0.76551E-08
0.70250E 04	0.75039E-08	0.68779E 04	0.73520E-08	0.67308E 04	0.71999E-08	0.65837E 04	0.70476E-08
0.64365E 04	0.68952E-08	0.62894E 04	0.67427E-08	0.61423E 04	0.65900E-08	0.59952E 04	0.64376E-08
0.58481E 04	0.62884E-08	0.57009E 04	0.61392E-08	0.55538E 04	0.59898E-08	0.54067E 04	0.58370E-08
0.52596E 04	0.56823E-08	0.51125E 04	0.55275E-08	0.49653E 04	0.53720E-08	0.48182E 04	0.52150E-08
0.46895E 04	0.50775E-08	0.46159E 04	0.49990E-08	0.45424E 04	0.49204E-08	0.44688E 04	0.48418E-08
0.43952E 04	0.47631E-08	0.43217E 04	0.46845E-08	0.42481E 04	0.46058E-08	0.41746E 04	0.45272E-08
0.41010E 04	0.44485E-08	0.40274E 04	0.43697E-08	0.39539E 04	0.42910E-08	0.38803E 04	0.42123E-08
0.38068E 04	0.41335E-08	0.37332E 04	0.40547E-08	0.36596E 04	0.39759E-08	0.35861E 04	0.38970E-08
0.35125E 04	0.38182E-08	0.34389E 04	0.37393E-08	0.33654E 04	0.36604E-08	0.32918E 04	0.35814E-08
0.32183E 04	0.35025E-08	0.31447E 04	0.34235E-08	0.30711E 04	0.33445E-08	0.29976E 04	0.32655E-08
0.29240E 04	0.31864E-08	0.28505E 04	0.31073E-08	0.27769E 04	0.30282E-08	0.27033E 04	0.29491E-08
0.26298E 04	0.28699E-08	0.25562E 04	0.27907E-08	0.24827E 04	0.27115E-08	0.24091E 04	0.26322E-08
0.23447E 04	0.25628E-08	0.23080E 04	0.25232E-08	0.22712E 04	0.24835E-08	0.22344E 04	0.24438E-08
0.21976E 04	0.24041E-08	0.21608E 04	0.23644E-08	0.21241E 04	0.23247E-08	0.20873E 04	0.22850E-08
0.20505E 04	0.22453E-08	0.20137E 04	0.22056E-08	0.19769E 04	0.21655E-08	0.19402E 04	0.21253E-08
0.19034E 04	0.20851E-08	0.18666E 04	0.20449E-08	0.18298E 04	0.20047E-08	0.17930E 04	0.19645E-08
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0.16091E 04	0.17634E-08	0.15724E 04	0.17232E-08	0.15356E 04	0.16830E-08	0.14988E 04	0.16427E-08
0.14620E 04	0.16025E-08	0.14252E 04	0.15623E-08	0.13885E 04	0.15220E-08	0.13517E 04	0.14818E-08

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0.87813E 03	0.96359E-09	0.84135E 03	0.92332E-09	0.80457E 03	0.88305E-09	0.76779E 03	0.84277E-09
0.73101E 03	0.80249E-09	0.69423E 03	0.76222E-09	0.65745E 03	0.72193E-09	0.62067E 03	0.68164E-09
0.58618E 03	0.64387E-09	0.56779E 03	0.62372E-09	0.54940E 03	0.60357E-09	0.53101E 03	0.58342E-09
0.51262E 03	0.56327E-09	0.49423E 03	0.54312E-09	0.47584E 03	0.52297E-09	0.45745E 03	0.50282E-09
0.43906E 03	0.48266E-09	0.42067E 03	0.46251E-09	0.40228E 03	0.44235E-09	0.38389E 03	0.42219E-09
0.36550E 03	0.40203E-09	0.34711E 03	0.38187E-09	0.32872E 03	0.36171E-09	0.31033E 03	0.34155E-09
0.29309E 03	0.32264E-09	0.28390E 03	0.31256E-09	0.27470E 03	0.30248E-09	0.26551E 03	0.29240E-09
0.25631E 03	0.28231E-09	0.24712E 03	0.27223E-09	0.23792E 03	0.26215E-09	0.22873E 03	0.25206E-09
0.21953E 03	0.24198E-09	0.21034E 03	0.23189E-09	0.20114E 03	0.22181E-09	0.19195E 03	0.21173E-09
0.18275E 03	0.20164E-09	0.17356E 03	0.19156E-09	0.16436E 03	0.18147E-09	0.15517E 03	0.17139E-09
0.14655E 03	0.16194E-09	0.14195E 03	0.15689E-09	0.13735E 03	0.15185E-09	0.13275E 03	0.14681E-09
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0.10977E 03	0.12161E-09	0.10517E 03	0.11657E-09	0.10057E 03	0.11153E-09	0.95973E 02	0.10650E-09
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0.64078E 02	0.71581E-10	0.61779E 02	0.69068E-10	0.59481E 02	0.66556E-10	0.57182E 02	0.64045E-10
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0.36637E 02	0.41667E-10	0.34338E 02	0.39175E-10	0.32039E 02	0.36687E-10	0.29740E 02	0.34203E-10
0.27441E 02	0.31725E-10	0.25143E 02	0.29254E-10	0.22844E 02	0.26792E-10	0.20545E 02	0.24342E-10
0.18318E 02	0.21982E-10	0.17169E 02	0.20771E-10	0.16019E 02	0.19566E-10	0.14870E 02	0.18368E-10
0.13721E 02	0.17178E-10	0.12571E 02	0.15999E-10	0.11422E 02	0.14832E-10	0.10273E 02	0.13682E-10
0.91591E 01	0.12589E-10	0.85845E 01	0.12035E-10	0.80098E 01	0.11489E-10	0.74351E 01	0.10953E-10
0.68604E 01	0.10429E-10	0.62857E 01	0.99206E-11	0.57110E 01	0.94302E-11	0.51363E 01	0.89635E-11
0.45796E 01	0.85444E-11	0.42922E 01	0.83428E-11	0.40049E 01	0.81531E-11	0.37175E 01	0.79768E-11
0.34302E 01	0.78175E-11	0.31428E 01	0.76791E-11	0.28555E 01	0.75677E-11	0.25681E 01	0.74901E-11
0.22858E 01	0.74555E-11	0.21461E 01	0.74578E-11	0.20024E 01	0.74771E-11	0.18588E 01	0.75161E-11
0.17151E 01	0.75794E-11	0.15714E 01	0.76726E-11	0.14277E 01	0.78023E-11	0.12841E 01	0.79788E-11
0.11449E 01	0.82086E-11	0.10012E 01	0.85276E-11	0.85755E 00	0.89908E-11	0.71387E 00	0.96092E-11
0.57245E 00	0.10476E-10	0.50061E 00	0.11079E-10	0.42877E 00	0.11838E-10	0.35694E 00	0.12843E-10
0.28622E 00	0.14210E-10	0.25030E 00	0.15129E-10	0.21439E 00	0.16279E-10	0.17847E 00	0.17774E-10
0.14311E 00	0.19779E-10	0.12515E 00	0.21115E-10	0.10719E 00	0.22780E-10	0.89234E-01	0.24930E-10
0.71556E-01	0.27803E-10	0.62576E-01	0.29712E-10	0.53597E-01	0.32087E-10	0.44617E-01	0.35148E-10
0.35778E-01	0.39230E-10	0.31288E-01	0.41940E-10	0.26798E-01	0.45307E-10	0.22309E-01	0.46898E-10

AVERAGE KERMA VALUES

GROUP NUMBER = 1	AVG. KERMA =	0.70595E-06
GROUP NUMBER = 2	AVG. KERMA =	0.63639E-06
GROUP NUMBER = 3	AVG. KERMA =	0.64002E-06
GROUP NUMBER = 4	AVG. KERMA =	0.60942E-06
GROUP NUMBER = 5	AVG. KERMA =	0.58225E-06
GROUP NUMBER = 6	AVG. KERMA =	0.55723E-06
GROUP NUMBER = 7	AVG. KERMA =	0.54009E-06
GROUP NUMBER = 8	AVG. KERMA =	0.54467E-06
GROUP NUMBER = 9	AVG. KERMA =	0.52169E-06
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GROUP NUMBER = 12	AVG. KERMA =	0.49410E-06
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GROUP NUMBER = 14	AVG. KERMA =	0.46932E-06
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GROUP NUMBER = 16	AVG. KERMA =	0.45181E-06
GROUP NUMBER = 17	AVG. KERMA =	0.44273E-06
GROUP NUMBER = 18	AVG. KERMA =	0.43433E-06
GROUP NUMBER = 19	AVG. KERMA =	0.40671E-06
GROUP NUMBER = 20	AVG. KERMA =	0.37825E-06
GROUP NUMBER = 21	AVG. KERMA =	0.36266E-06
GROUP NUMBER = 22	AVG. KERMA =	0.34324E-06

GROUP NUMBER = 23	AVG. KERMA = 0.34112E-06
GROUP NUMBER = 24	AVG. KERMA = 0.33600E-06
GROUP NUMBER = 25	AVG. KERMA = 0.32625E-06
GROUP NUMBER = 26	AVG. KERMA = 0.31264E-06
GROUP NUMBER = 27	AVG. KERMA = 0.29723E-06
GROUP NUMBER = 28	AVG. KERMA = 0.28433E-06
GROUP NUMBER = 29	AVG. KERMA = 0.28048E-06
GROUP NUMBER = 30	AVG. KERMA = 0.26584E-06
GROUP NUMBER = 31	AVG. KERMA = 0.26791E-06
GROUP NUMBER = 32	AVG. KERMA = 0.25570E-06
GROUP NUMBER = 33	AVG. KERMA = 0.22790E-06
GROUP NUMBER = 34	AVG. KERMA = 0.21515E-06
GROUP NUMBER = 35	AVG. KERMA = 0.20453E-06
GROUP NUMBER = 36	AVG. KERMA = 0.19470E-06
GROUP NUMBER = 37	AVG. KERMA = 0.18556E-06
GROUP NUMBER = 38	AVG. KERMA = 0.17761E-06
GROUP NUMBER = 39	AVG. KERMA = 0.17629E-06
GROUP NUMBER = 40	AVG. KERMA = 0.18176E-06
GROUP NUMBER = 41	AVG. KERMA = 0.16025E-06
GROUP NUMBER = 42	AVG. KERMA = 0.14842E-06
GROUP NUMBER = 43	AVG. KERMA = 0.13968E-06
GROUP NUMBER = 44	AVG. KERMA = 0.13172E-06
GROUP NUMBER = 45	AVG. KERMA = 0.12436E-06
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GROUP NUMBER = 47	AVG. KERMA = 0.11078E-06
GROUP NUMBER = 48	AVG. KERMA = 0.10451E-06
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GROUP NUMBER = 50	AVG. KERMA = 0.92878E-07
GROUP NUMBER = 51	AVG. KERMA = 0.87375E-07
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GROUP NUMBER = 55	AVG. KERMA = 0.58462E-07
GROUP NUMBER = 56	AVG. KERMA = 0.48739E-07
GROUP NUMBER = 57	AVG. KERMA = 0.40200E-07
GROUP NUMBER = 58	AVG. KERMA = 0.32817E-07
GROUP NUMBER = 59	AVG. KERMA = 0.26639E-07
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GROUP NUMBER = 65	AVG. KERMA = 0.67718E-08
GROUP NUMBER = 66	AVG. KERMA = 0.53208E-08
GROUP NUMBER = 67	AVG. KERMA = 0.41593E-08
GROUP NUMBER = 68	AVG. KERMA = 0.32503E-08
GROUP NUMBER = 69	AVG. KERMA = 0.25400E-08
GROUP NUMBER = 70	AVG. KERMA = 0.19826E-08
GROUP NUMBER = 71	AVG. KERMA = 0.15449E-08
GROUP NUMBER = 72	AVG. KERMA = 0.12038E-08
GROUP NUMBER = 73	AVG. KERMA = 0.93806E-09
GROUP NUMBER = 74	AVG. KERMA = 0.73100E-09
GROUP NUMBER = 75	AVG. KERMA = 0.56968E-09
GROUP NUMBER = 76	AVG. KERMA = 0.44400E-09
GROUP NUMBER = 77	AVG. KERMA = 0.34608E-09
GROUP NUMBER = 78	AVG. KERMA = 0.26981E-09
GROUP NUMBER = 79	AVG. KERMA = 0.21040E-09
GROUP NUMBER = 80	AVG. KERMA = 0.16413E-09
GROUP NUMBER = 81	AVG. KERMA = 0.12810E-09
GROUP NUMBER = 82	AVG. KERMA = 0.10006E-09
GROUP NUMBER = 83	AVG. KERMA = 0.78242E-10
GROUP NUMBER = 84	AVG. KERMA = 0.61279E-10

```
GROUP NUMBER = 85       AVG. KERMA =  0.48104E-10
GROUP NUMBER = 86       AVG. KERMA =  0.37886E-10
GROUP NUMBER = 87       AVG. KERMA =  0.29978E-10
GROUP NUMBER = 88       AVG. KERMA =  0.23877E-10
GROUP NUMBER = 89       AVG. KERMA =  0.19191E-10
GROUP NUMBER = 90       AVG. KERMA =  0.15619E-10
GROUP NUMBER = 91       AVG. KERMA =  0.12923E-10
GROUP NUMBER = 92       AVG. KERMA =  0.10923E-10
GROUP NUMBER = 93       AVG. KERMA =  0.94788E-11
GROUP NUMBER = 94       AVG. KERMA =  0.84861E-11
GROUP NUMBER = 95       AVG. KERMA =  0.78602E-11
GROUP NUMBER = 96       AVG. KERMA =  0.75386E-11
GROUP NUMBER = 97       AVG. KERMA =  0.74717E-11
GROUP NUMBER = 98       AVG. KERMA =  0.76315E-11
GROUP NUMBER = 99       AVG. KERMA =  0.79946E-11
GROUP NUMBER =100       AVG. KERMA =  0.85597E-11
GROUP NUMBER =101       AVG. KERMA =  0.93324E-11
GROUP NUMBER =102       AVG. KERMA =  0.10276E-10
GROUP NUMBER =103       AVG. KERMA =  0.11385E-10
GROUP NUMBER =104       AVG. KERMA =  0.18995E-10

IHC002I STOP      0
```

APPENDIX II

Fortran Listing of AVKER

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=60,SOURCE,BCD,NOLIST,DECK,LOAD,MAP,NOEDIT,NOID,NOXREF
                C     PROGRAM AVKER
ISN 0002              DIMENSION   SKER(816,20), TKERM(816), DEN(20), E(816),EG(120),
                     1 TBAR(120), IDN(20), UNIT(20), ID(8), CKER(816), IMD(18)
                C-----THIS PROGRAM MIXES KERMA FOR THE DESIRED COMPOSITION AND AVERAGES
                C     FOR THE DESIRED GROUP STRUCTURE
ISN 0003              READ (5 , 5) IMD
ISN 0004            5 FORMAT (18A4)
ISN 0005              WRITE (6, 6) IMC
ISN 0006            6 FORMAT (1H0,1X,18A4)
ISN 0007              READ (5, 10)  NE, LT, NG
ISN 0008              WRITE (6,11)  NE
ISN 0009           11 FORMAT (47H0----NUMBER OF ELEMENTS FOR THIS COMPOSITION = , I2//)
ISN 0010           10 FORMAT (3I5)
ISN 0011              WRITE (6,14)
ISN 0012           14 FORMAT (49H0 ID NUMBER AND CONCETRATION OF ELEMENTS IN COMP./)
ISN 0013              DO 8 K = 1,NE
ISN 0014              READ (5, 12) IDN(K) ,DEN(K), (UNIT(I), I = 1,8)
ISN 0015           12 FORMAT ( I5, E12.5, 8A4)
ISN 0016              WRITE (6, 15)   IDN(K), DEN(K),(UNIT(I), I =1,8)
ISN 0017           15 FORMAT (1H , I5,5X E12.5,5X,8A4)
ISN 0018            8 CONTINUE
ISN 0019              NTAPE = 11
ISN 0020              REWIND NTAPE
ISN 0021            9 READ (NTAPE) IDNO, INT, IEND, AMASS, (ID(I),I = 1,8)
ISN 0022              IF (IDNO) 50, 50, 22
ISN 0023           22 DO 16  J  =  1, NE
ISN 0024              IF (IDN(J)-IDNO) 16, 18, 16
ISN 0025           16 CONTINUE
ISN 0026              READ (NTAPE)
ISN 0027              GO TO 9
ISN 0028           18 READ (NTAPE) (E(JJ),  CKER(JJ), JJ = 1,IEND)
ISN 0029              DO 20  JJ = 1, IEND
ISN 0030           20 SKER( JJ, J)      =  CKER(JJ)
ISN 0031              IF (IDN(NE) - IDNO) 9, 30, 9
ISN 0032           30 CONTINUE
ISN 0033              CALL MACRO( SKER, TKERM, DEN, E, IEND, NE)
ISN 0034              IF ( LT) 32, 32, 34
ISN 0035           34 MM = NG + 1
ISN 0036              READ(5, 36) (EG(J), J = 1,MM)
ISN 0037           36 FORMAT ( 8E10.5)
ISN 0038              CALL AVKER ( E, TKERM, IEND, EG, TBAR,NG,LT)
ISN 0039              WRITE (6,40)
ISN 0040           40 FORMAT (24H0  AVERAGE KERMA VALUES /)
ISN 0041              WRITE (6, 42) ( J,  TBAR(J),  J = 1,NG)
ISN 0042           42 FORMAT (15H GROUP NUMBER =, I3,5X,14H AVG. KERMA = ,E12.5)
ISN 0043              GO TO 32
ISN 0044           50 WRITE (6, 55)
ISN 0045           55 FORMAT (43H DESIRED KERMA VALUES ARE NOT ON THIS TAPE /)
ISN 0046           32 CONTINUE
ISN 0047              RETURN
ISN 0048              END
```

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=60,SOURCE,BCD,NOLIST,DECK,LOAD,MAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE MACRO (SKER, TKERM, DEN, E, IEND, NE)
ISN 0003            DIMENSION SKER(816,20), TKERM(816), DEN(20), E(816), IDN(20)
ISN 0004          1 DO 2  J = 1, IEND
ISN 0005          2 TKERM(J) = 0.0
ISN 0006            DO 4  K = 1,NE
ISN 0007            DO 4  J = 1,IEND
ISN 0008            TKERM(J) = TKERM(J) +SKER( J,K      )*DEN(K)
ISN 0009          4 CONTINUE
ISN 0010            WRITE (6,8)
ISN 0011          8 FORMAT(34H0  KERMA FOR FINE GROUP STRUCTURE /)
ISN 0012            WRITE (6, 11)
ISN 0013         11 FORMAT (91H0  ENERGY     KERMA        ENERGY     KERMA        ENER
                   1GY     KERMA        ENERGY     KERMA/)
ISN 0014            WRITE (6, 10)  ( E(J), TKERM(J) , J = 1,IEND)
ISN 0015         10 FORMAT (1H0,1X,8E12.5/(2X,8E12.5) )
ISN 0016            RETURN
ISN 0017            END
```

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=60,SOURCE,BCD,NOLIST,DECK,LOAD,MAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE AVKER (E, TKERM, IEND, EG, TBAR, NG, LT)
                C   THIS SUBROUTINE AVERAGES THE KERMA WITH A FLAT WEIGHTING (LT=1)
                C   OR A 1/E WEIGHTING (LT=2)
ISN 0003            DIMENSION E(816), TKERM(816), TBAR(120), EG(120), DUME(120),
                   1 DUMKER(120)
ISN 0004            DO 100 J = 1,NG
ISN 0005            DELE = EG(J) - EG(J+1)
ISN 0006            DU = ALOG(EG(J)/EG(J+1))
ISN 0007            NUM = 0
ISN 0008            DO 20 I = 1,IEND
ISN 0009            IF (E(I).GT.EG(J)) GO TO 20
ISN 0011         16 IF (E(I).LT.EG(J+1)) GO TO 30
ISN 0013         18 NUM = NUM + 1
ISN 0014         20 CONTINUE
ISN 0015         30 KEY = I - NUM
ISN 0016            DUME(1) = EG(J)
ISN 0017            DUMKER(1) = TKERM(KEY-1)-
                   1            ((E(KEY-1)-EG(J))*(TKERM(KEY-1)-TKERM(KEY))) /
                   2            (E(KEY-1)-E(KEY))
ISN 0018            NUM = NUM + 1
ISN 0019            DO 50 K = 2,NUM
ISN 0020            DUME(K) = E(KEY+K-2)
ISN 0021         50 DUMKER(K) = TKERM(KEY+K-2)
ISN 0022            IF (E(I).EQ.EG(J+1)) GO TO 40
ISN 0024         35 NUM = NUM + 1
ISN 0025            DUME(NUM) = EG(J+1)
ISN 0026            DUMKER(NUM) = TKERM(I-1)-
                   1              ((E(I-1)-EG(J+1))*(TKERM(I-1)-TKERM(I))) /
                   2              (E(I-1)-E(I))
ISN 0027         40 CALL TRAP(DUME, DUMKER, NUM, TBAR(J), LT)
ISN 0028            IF (LT.EQ.1) GO TO 45
ISN 0030         48 TBAR(J) = TBAR(J)/DU
ISN 0031            GO TO 100
ISN 0032         45 TBAR(J) = TBAR(J)/DELE
ISN 0033        100 CONTINUE
ISN 0034            RETURN
ISN 0035            END
```

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=00,LINECNT=60,SOURCE,BCD,NOLIST,DECK,LOAD,MAP,NOEDIT,NOID,NOXREF
ISN 0002            SUBROUTINE TRAP(X,Y,NUMB,SUMB,LT)
ISN 0003            DIMENSION X(1),Y(1)
ISN 0004            SUMB=0.0
ISN 0005            J=NUMB-1
ISN 0006            DO 10 I=1,J
ISN 0007            IF (LT.EQ.1) GO TO 40
ISN 0009         50 H = ALOG(X(I)/X(I+1))
ISN 0010            GO TO 8
ISN 0011         40 H=X(I)-X(I+1)
ISN 0012          8 TEMP=H*(Y(I)+Y(I+1))/2.0
ISN 0013         10 SUMB=SUMB+TEMP
ISN 0014            RETURN
ISN 0015            END
```

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