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THE QAD-BSA POINT-KERNEL SHIELDING CODE

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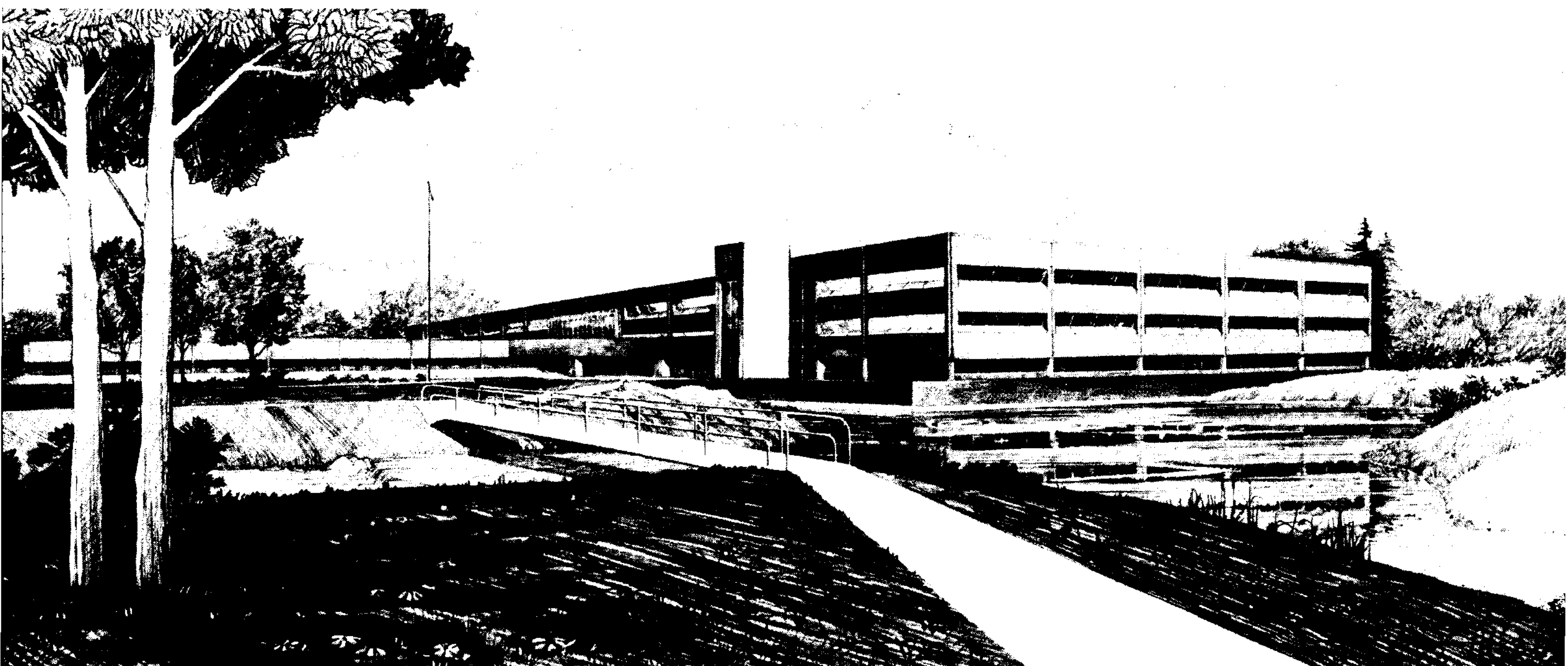

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ABSTRACT

QAD-BSA, a three-dimensional, point-kernel shielding code, calculates photon dose rates and heating rates using exponental attenuation and infinite medium buildup factors. Calculational provisions include estimates of fast neutron penetration using the moments method. Included geometry routines can describe complicated source and shield geometries. An internal library contains data for many frequently used structural and shielding materials, enabling the code to solve most problems with only source strengths and problem geometry required as input. This code adapts especially well to problems requiring multiple sources and sources with asymmetrical geometry. In addition to being edited separately, the total interaction rates from many sources may be edited at each detector point. Calculated photon interaction rates agree closely with those obtained using another point-kernel code (QAD-P5A), and an S_n transport code (SCAMP).

ACKNOWLEDGEMENT

R. E. Malanfant and D. M. Peterson of Los Alamos Scientific Laboratory developed the basic coding QAD-BSA, including several features that differentiate it from previous versions of QAD.

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THE QAD-BSA POINT-KERNEL SHIELDING CODE

1. INTRODUCTION

Adapted for use on CDC computers, the QAD-BSA code solves three-dimensional shielding and heating problems. Photon problems are solved by calculating the uncollided flux (assuming exponential attenuation) and then multiplying the flux by the appropriate infinite medium buildup factor.[1] Included neutron removal cross sections[2] for 17 materials and neutron moments[3,4] for three reference materials permit approximate solutions of short-range fission-neutron shielding problems using the moments method.[5]

Versatile geometry routines enable accurate description of complicated sources and hardware. An internal library contains attenuation and heating coefficients for most materials used in radiation shields and reactor components. Library data for up to four materials may be input at execution time. Calculations with the photon energy group structure built into the coding optimize convenience, but this group structure can be changed at execution time to permit use of photon sources with different energy-group boundaries.

Change cases require a minimum of additional input. Results may be edited after each case, and the sums of heating rates and dose rates for selected cases can be edited at the end of the problem. Dose rates are edited in millirem per hour and heating rates in watts per gram.

QAD-BSA originates from the earlier QAD codes[6,7] and incorporates many of their most convenient features. Data for the internal library were obtained from the original author[8], a modification of one of the earlier QAD codes[7], and published photon interaction data.[9,10] The description of the code given in the following sections makes liberal use of material from the basic QAD document.[6]

The internal library and the ease with which change cases can be run suit the code to the occasional user, to scoping calculations, and to some heating calculations in complicated in-core tests.

2. POINT-KERNEL CALCULATIONS

The following equation computes the dose rate or heating rate, D, produced at a detector by a point source of monoenergetic photons in an infinite homogeneous medium:

$$D = \frac{S\ C\ B\ \exp(-d\mu)}{4\pi\rho^2} \tag{1}$$

where:

S	=	source strength of a point source
C	=	conversion factor for heating or dose rate
B	=	buildup factor for the infinite homogeneous medium
$d\mu$	=	linear attenuation coefficient
ρ	=	distance from source to detector.

This expression yields approximate solutions for very simple problems. For most practical shielding problems, which are usually more complex, this equation must be generalized to describe finite sources and shields and to provide a distribution of photon energies. The generalization represents a finite source by many point sources and selects an appropriate buildup factor and effective gamma energies. The generalized equation (Section 2.1) yields values of heating and dose rates comparable to values calculated by more sophisticated and costly methods (e.g., S_n and Monte Carlo codes).

2.1 Photon Calculations

The generalized equation used in QAD-BSA for photon calculations is

$$D = \sum_i D_i = \sum_{i,j,k,l} \frac{S_{i,j,k,l}\ C_i\ B_i}{4\pi\rho^2_{j,k,l}} \exp\left[-\sum\sum h_{n,j,k,l}\ d_{m,n}\ \mu_{m,i}\right] \tag{2}$$

i = index specifying the photon energy group

D_i = detector response for the ith photon group

j,k,l = indices defining the source volume element for which the calculation is being performed (j^{th} point of first coordinate, k^{th} point of second coordinate, and l^{th} point of third coordinate)

$S_{i,j,k,l}$ = source strength of photon group i in volume element (j,k,l)

C_i = conversion factor for photon group (to output units)

B_i = buildup factor for photon energy group (at x_i attenuation meanfree paths $B_i = b_0 + b_i x_i + b_2 x_i^2 + b_3 x_i^3$)

$\rho j,k,l$ = distance from source point (j,k,l) to detector point

n,j,k,l = path length through the n^{th} composition along the source-detector line ($\rho_{j,k,l}$)

$d_{m,n}$ = density of material m in composition n

$\mu_{m,i}$ = photon attenuation coefficient of material m for photon group i.

Separating a finite source into many small-volume elements gives discrete representation of that finite source. Each volume element is identified by the subscripts (j,k,l) in Equation (2). Input cards K through P define these volume elements.)

Gamma attenuation coefficients in the internal library originated in published data[9,10] and previous compilations of attenuation coefficients available in codes described in References 6 and 7. Data from Reference 9 provide coefficients for calculation of heating by photons. Coding and coefficients for the calculation of buildup factors were taken from QAD-P5A.[7] Photon flux-to-dose and neutron flux-to-dose rate coefficients were calculated from data in ANISI/ANS-6.1-1977.[11]

2.2 Neutron Moments Calculations

The program includes provisions for estimating neutron dose rates and heating rates using the moments method described in Reference 5. Calculations are based on published neutron moments data[3,4] for beryllium, water, and carbon, and neutron removal cross sections[2] for seventeen materials. In order to use this method in QAD-BSA it is assumed that the number flux from a point-isotropic source penetrating a series of regions of diverse materials may be estimated from the number flux resulting from some equivalent penetration in an infinite homogeneous medium. The equivalent penetration is based on equal numbers of relaxation lengths calculated from energy-independent removal cross sections. The application of this method to neutron problems fails to give the consistent results obtained in the photon calculations. Its use can be justified only by comparison with calculations by more exact methods . Reference 6 contains a more extended discussion of this method.

3. APPLICABILITY OF QAD-BSA

QAD-BSA offers an improved alternate to QAD-P5A[7] (now in general use at INEL). The restrictions inherent in the point-kernel method apply equally to both codes.

The following features make QAD-BSA more convenient to use than QAD-P5A for problems with complex geometry or many different sources;

(a) It is very simple to run a series of change cases, particularly those in which only the source spectrum and/or source geometry are changed. Each additional case requires only a few cards.

(b) At the option of the user, the program sums dose rates from some or all of a series of change cases. This eliminates laborious hand tabulation of the total dose rate.

(c) The origin of the axes used to describe the source may be translated with respect to the basic problem axes. This enables the code to locate cylindrical or spherical sources (as well as sources described in cartesian coordinates) anywhere in the system without having to redescribe the complete system.

(d) Discontinuous or irregularly shaped sources may be defined by setting a flag that causes the code to ignore source points outside specified regions of interest.

(e) An internal library provides gamma heating conversion factors for 18 materials (e.g., aluminum, iron, and uranium).

(f) As many as 140 boundaries and 107 regions may be used, depending on the types of boundaries and regions. As many as 15 boundaries may be used for a single region.

(g) As many as 10 source spectra may be used for a single case. This option is particularly useful for calculating dose rates from the same geometrical source at different decay times.

(h) Output may be renormalized. This option eliminates the need for hand calculations when output is desired in more than one set of units.

The internal library includes photon attenuation coefficients for only 40 materials. The user may, however, substitute different attenuation, photon heating, and neutron heating coefficients for hydrogen, beryllium, boron and/or carbon. This option increases code flexibility.

4. CODE VALIDATION

Predicted heating rates for a test in the Power Burst Facility were perviously calculated[12] using both QAD-BSA and a one-dimensional S_n transport code (SCAMP)[13], with the same photon sources. Figure 1 gives the results of these two calculations. The agreement of the two methods supports the validity of the point-kernel method for calculating heating by photons. The method is applicable to problems with complex geometry for which a multidimensional S_n or Monte Carlo transport code would otherwise be required.

With identical library data, sources, and geometries, QAD-BSA and QAD-P5A should give identical results. Only insignificant differences result from the minor differences in library data. Several previously solved problems verify the essential equivalence of results from the two codes. For example, both codes calculated the first sample problem (see Section 6); Table 1 gives the results.

5. INPUT INSTRUCTIONS

CARD A: TITLE AND TIME LIMIT (11A6,I4,2X)

Column	Variable	Entry (Read by QINPUT)
1-66	HD(1-11)	Title. Any BCD information
67-70	HD(12)	Time Limit. After the number of seconds specified here the data already calculated will be summed and the problem terminated "manually". (Default = 9999)

FOR "NORMAL" OPERATION A PRESET GAMMA ENERGY GROUP STRUCTURE AND MATERIALS FROM THE INTERNAL LIBRARY ARE USED. INSTRUCTIONS FOR CHANGING THE ENERGY GROUP STRUCTURE AND LIBRARY ARE GIVEN AS "SUPPLEMENTAL INPUT" AT THE END OF THIS SECTION.

CARD B: MISCELLANEOUS INTEGER CONTROL DATA [9I2,6(I5,I4)]

Column	Variable	Entry (Read by QINPUT)
1-2	NOSPEC	Number of Source Gamma Spectra This determines the number of gamma spectra to be read in on cards Q and R. (If this entry is omitted or zero a default spectrum of 86 milliwatts appropriate for equilibrium conditions in a highly enriched thermal reactor at 1 watt power is used.) NOSPEC $\leq$ 10.
3-4	NSS	Source Geometry and Spectra Control 0 means both source geometry and source spectra will be used from the previous case, so cards F through R are not required. 1 means the source geometry will be calculated using data from cards F through P, but the default spectrum or the spectra from the previous case will be used. Cards Q and R will be omitted. 2 means the source geometry will be obtained from the previous case (cards F through P omitted), but the source spectra will be input on cards Q and R. 3 means source geometry will be input on cards F through P and source spectra on cards Q and R.
5-6	IX	Summed Data Flag 0 means the results of this case will not be included in the summed data at the end of the problem. 1 means the results of this case will be included in the final sum of the data. (MTOTAL (Cols 11-12) must also be non-zero if IX=1.)
7-8	NBLD	Buildup Factor 1 H_2O dose 2 Al dose 3 Fe dose 4 Pb dose 5 H_2O energy absorption 6 Al energy absorption 7 Fe energy absorption 8 Pb energy absorption

Column	Variable	Entry
9-10	LISPEC	Spectra Edit Control for Each Case 0 causes the contribution to dose and heating rates to be edited for each energy group in source spectra. 1 causes only the total dose and heating rates to be edited. (MTOTAL must also be non-zero if LISPEC=1.)
11-12	MTOTAL	Data Edit Control 0 eliminates sums of data and individual case final edits 1 edits sums of data and identifies the sums with the first detector coordinate (r, x, or ρ for cylindrical, cartesian, or spherical coordinate systems, respectively) and HDTTL from Cards W. (Coordinate numbers are given on p. 10.) 2 edits sums (identified by coordinate 3 and HDTTL). 3 edits sums (identified by coordinate 2 and HDTTL). 4 edits sums (identified by coordinates 1 and 3, and HDTTL). 5 edits sums (identified by coordinates 1 and 2, and HDTTL). 6 edits sums (identified by coordiantes 3 and 2, and HDTTL). 7 edits sums (identified by all coordinates: 1, 3, and 2).
13-14	LP	Card Punch Control 0 eliminates all punched card output. 1 causes the following cards to be punched <u>if</u> the data on the cards is input or calculated: 0 card contains problem ID. 1 card contains detector coordinates and ID. 2 card contains gamma fluxes and data for iron. 3 card contains data for heating in other materials. 4 card contains neutron data from first reference material. 5 card contains neutron data from second material. 6 card contains neutron data from third material.
15-16	LINDEX	Special Debug Ray Trace Control (see note) 0 eliminates all of the special ray traces. 1 gives zone-boundary trace if most probable zone is missed. 2 gives zone-boundary trace for all source-detector pairs. (Note: entries other than 0 should be used with care since a large amount of output may be produced.)
17-18	IESPLN	Geometry Parameter Control 0 means use default values of EPSLN, FUDGE, and FUDGFR. 1 requires card V be input to define EPSLN, FUDGE, and FUDGFR.
19-23	NREG	Number of Zones If zones are unchanged from the previous case, enter the negative of the number of zones and omit cards S. The number of zones is limited by the requirement that $\sum_{i=1}^{NREG} (3+2B_i) \leq 700,$ where B_i is the number of boundaries used to describe the i^{th} zone. (The absolute maximum is 140.)

Column	Variable	Entry
24-27	NBOUND	Number of Boundaries If boundaries are unchanged from the previous case enter the negative of the number of boundaries and omit cards T. The number of boundaries is limited by the requirement that $\sum_{i=1}^{NBOUND} (2+M_i) \leq 500,$ where M_i is the number of coefficients for the i^{th} boundary. M_i = 7 for boundary types 1 and 2, M_i = 3 for boundary type 3, and M_i = 1 for boundary types 4, 5, and 6. (The absolute maximum is 107.)
28-32	NCOMP	Number of Compositions If compositions are unchanged from the previous case enter the negative of the number of compositions and omit cards U. The number of compositions is limited by the requirement that NCOMP*MAT$\leq$400.
33-36	MAT	Number of Attenuating Materials If the same materials are used as in the previous case enter the negative of the number of materials and omit card C. The maximum number of materials allowed is 20.
37-41	NRGY	Highest Numbered Gamma Energy Group Used (See input description for card Q for energy groups.)
42-45	NGINT	Number of Extra Gamma Heating Calculations +10 Heating in iron is always calculated. If no additional gamma heating calculations are desired enter 0 here and omit card D. If gamma heating is desired for the same materials as in the previous case enter the number of extra calculations and omit card D. (Maximum extra calculations = 3.)
46-50	INEUT	Number of Neutron Reference Materials 0 means no neutron calculations will be done $1 \leq$ INEUT ≤ 3 means neutron calculations will be done with 1, 2, or 3 reference materials. (The neutron reference materials available are C, Be, and H_2O.)
51-54	NNINT	Number of Extra Neutron Heating Calculations +10 Omit or enter 0 if INEUT (previous entry) is 0. Heating in iron is always calculated if INEUT>0. If $11 \leq$ NNINT ≤ 13, card E must be included. If the same materials are used as in the previous problem, enter the number of extra heating calculations and omit card E.

55-59	NSET(13)	First Source Point for Which Ray Will be Traced
60-63	NSET(14)	Last Source Point for Which Ray Will be Traced
64-68	NSET(15)	Increment Between Source Points (Note: the ray traces specified here by NSET(13-15) are not the special debug traces specified by LINDEX in Cols. 15-16.) If NSET(13)=NSET(14)=NSET(15)=0, no ray traces are edited.
69-72	IGP	Gamma Group Number to be Used to Calculate Relaxation Length (Default = 14)

CARD C GAMMA ATTENUATION MATERIAL ID'S: [8(I5,I4)]
[MAT entries (none if MAT < 0)]

Column	Variable	Entry
1-5	NOAT(1)	ID of First Gamma Attenuation Material
6-9	NOAT(2)	ID of Second Gamma Attenuation Material
10-14	NOAT(3)	ID of Third Gamma Attenuation Material
etc.	etc.	etc.[(Number of Entries is MAT (Cols. 33-36, Card B)]

The internal library contains gamma attenuation coefficients (cm^2/g) for the following materials:

NOAT	Material	NOAT	Material	NOAT	Material
1	Hydrogen	24	Chromium	71	Lutetium*
3	Lithium	25	Manganese*	72	Hafnium*
4	Beryllium	26	Iron	73	Tantalum*
5	Boron	27	Cobalt*	74	Tungsten
6	Carbon	28	Nickel	79	Gold*
8	Oxygen	29	Copper	82	Lead
11	Sodium	40	Zirconium	90	Thorium*
12	Magnesium	41	Niobium	92	Uranium
13	Aluminum	42	Molybdenum	94	Plutonium*
14	Silicon	47	Silver*	100	Air
16	Sulfur	48	Cadmium	101	Water
19	Potassium	50	Tin*	102	Lithium Hydride
20	Calcium*	60	Neodymium*		
22	Titanium	70	Yttrium*		

*The internal library does not contain neutron removal cross sections for these materials. They will contribute nothing to neutron attenuation.

CARD D: GAMMA HEATING MATERIAL ID'S [8(I5,I4)]
[NGINT-10 entries (none if NGINT $\leq$ 0)]

Column	Variable	Entry
1-5	NOFHG(1)	ID of First Gamma Heating Material (in addition to iron)
6-9	NOFHG(2)	ID of Second Gamma Heating Material (in addition to iron)
10-14	NOFHG(3)	ID of Third Gamma Heating Material (in addition to iron)

The internal library contains gamma heating coefficients [(w/g)/(MeV/cm^2·s)] for the following materials:

NOFHG	Material	NOFHG	Material	NOFHG	Material
1	Hydrogen	26	Iron	92	Uranium
3	Lithium	29	Copper	101	Water
4	Beryllium	40	Zirconium	103	ZrH
5	Boron	42	Molybdenum	270	UO_2
6	Carbon	74	Tungsten		
8	Oxygen	82	Lead		
11	Sodium				
13	Aluminum				

CARD E: NEUTRON HEATING MATERIAL ID'S [8(I5,I4)]
[NNINT-10 entries (none if NNINT = 0)]

Cols	Entry	
1-5	ID of First Neutron Heating Material	NOFHN(1)
6-9	ID of Second Neutron Heating Material	NOFHN(2)
10-14	ID of Third Neutron Heating Material	NOFHN(3)

The internal library contains neutron heating coefficients (w/g)/(neutron/cm^2·s) for the following materials:

NOFHN	Material	NOFHN	Material	NOFHN	Material
1	Hydrogen	6	Carbon	40	Zirconium
4	Beryllium	13	Aluminum	101	Water
5	Boron	26	Iron	103	ZrH

CARD F: SOURCE GEOMETRY [8(I5,I4)]
(Omit if NSS=0 or 2)

Note: The "first", "second", and "third" coordinates are defined below for source and detector input instructions.

Type of Geometry	First Coordinate	Second Coordinate	Third Coordinate
cylinder	r	z	ϕ
cartesian	x	z	y
spherical	ρ	θ	ϕ

Column	Variable	Entry (Read by SOURCE)
1-5	NSSET(1)	Number of Source Intervals Along the First Coordinate Axis
6-9	NSSET(2)	Number of Source Intervals Along the Second Coordinate Axis
10-14	NSSET(3)	Number of Source Intervals Along the Third Coordinate Axis
15-18	NSSET(4)	Source Intensity Code* for the First Axis
19-23	NSSET(5)	Source Intensity Code* for the Second Axis
24-27	NSSET(6)	Source Intensity Code* for the Third Axis *(0=flat, 1=cosin, 2=arbitrary; See cards H, L, N, and P)
28-32	NSSET(7)	Source Geometry Type (0 = cylindrical, 1 = cartesian, 2 = spherical)
33-36	NSSET(8)	Angular Input Form (0 = radians, 1 = degrees)
37-41	NSSET(9)	Most probable source zone
42-45	NSSET(10)	Source Geometry Origin [0 = (0,0,0), 1 = coordinates from Card J]
46-50	NSSET(11)	Number of Source Renormalization Parameters ($\leq$ 5) (Parameters will be entered on Cards I.)
51-54	NSSET(12)	Detector Response Flag 0 means detector response is due to all source points. 0 < NSSET(12) $\leq$ 6 means detector response will be due only to source points in zones listed on Card G.

CARD G: ALLOWED SOURCE ZONES [8(I5,I4)]
[Required only if NSSET(12) on Card F > 0]

Column	Variable	Entries (Read by SOURCE)
1-5	ISFRAC(1)	First Allowed Source Zone
6-9	ISFRAC(2)	Second Allowed Source Zone
etc.	etc.	(Up to 6 entries of allowed source zones.)

CARD H: SOURCE INTENSITY AND COSINE COEFFICIENTS (8E9.4)
(Omit if NSS = 0 or 2 on Card B)

Column	Variable	Entries (Read by SOURCE
1-9	ASO	Total Source Power (Multiplies entries on Cards Q)
10-18	XISO(1,1)	First Cosine Coefficient for First Coordinate*
19-27	XISO(2,1)	Second Cosine Coefficient for First Coordinate*
28-36	XISO(1,2)	First Cosine Coefficient for Second Coordinate*
37-45	XISO(2,2)	Second Cosine Coefficient for Second Coordinate*
46-54	XISO(1,3)	First Cosine Coefficient for Third Coordinate*
55-63	XISO(2,3)	Second Cosine Coefficient for Third Coordinate*
64-72	BSO	Auxiliary Source Normalizer (Defaults to 1.0)

*This entry is omitted unless a cosine distribution is specified by the applicable flag [NSSET(4) or NSSET(5) or NSSET(6) on Card G].
e.g., for cartesian coordinates the source strength at (X,Z,Y) is
Source Strength (X,Z,Y) = ASO·BSO·COS[XISO(1,1)(X-XISO(2,1)]
·COS[XISO(1,2)(Z - XISO(2,2)]·COS[XISO(1,3)(Y - XISO(2,3)]

CARD(S) I: SOURCE RENORMALIZATION (E9.4,3X,10A6)
[Required only if NSSET (11) > 0 on Card F]

Column	Variable	Entry (Read by SOURCE)
1-9	SNORM(1)	First Renormalization Factor
13-72	HDSN(J,1)	Title for First Renormalized Output (optional)
etc.	etc.	NSSET(11) Cards ($\leq$ 5) are Required

CARD J: ORIGIN OF SOURCE COORDINATES (3E9.4)
[Required only if NSSET (10) = 1 on Card F]

Column	Variable	Entry (Read by SOURCE. Input units are centimeters.)
1-9	STCORD(1)	X Coordinate of Origin of Source Coordinate System
10-18	STCORD(3)	Z Coordinate of Origin of Source Coordinate System
19-27	STCORD(2)	Y Coordinate of Origin of Source Coordinate System

CARDS K THROUGH P: SOURCE DIVISION POINTS AND INTENSITIES (8E9.4)

Card	Variable	Entry (Read by SOURCE. Input units are centimeters.)
K	C(I)	Enter source division points for the first coordinate. NSSET(1) + 1 entries are required. (See Card F for NSSET.)
L	F(I)	Required only if NSSET(4) = 2 on Card F. Enter arbitrary weight factor for each value of C(I) on Cards K. (These weight factors do not need to be normalized.)
M	C(I)	Enter source division points for the second coordinate. NSSET(2) + 1 entries are required. (See Card F.)
N	F(I)	Required only if NSSET(5) = 2 on Card F. Enter weight factor for each entry on Card M.
O	C(I)	Enter source division points for the third coordinate. NSSET(3) + 1 entires are required (See Card F).
P	F(I)	Required only if NSSET(6) = 2 on Card F. Enter weight factor for each entry on Card O.

CARD Q(1) GAMMA SPECTRUM TITLE CARD (I5,I4,E9.4,5A10,A4)
(Omit if NOSPEC = 0, or NSS = 0 or 1 on Card B.)

Column	Variable	Entry (Read by QINPUT)
1-5	LIMSPC(1,1)	First Energy Group in the Gamma Spectrum
6-9	LIMSPC(2,1)	Last Energy Group in the Gamma Spectrum
10-18	SPECNM(1)	Normalization factor. All source strengths entered on Cards R(1) are multiplied by this factor. (default = 1.0)
19-68	HDSPEC(J,1)	Any BCD Data. To be printed with edit of spectrum. (J=1,5)
69-72	HDSPEC(6,1)	Enter DISK to read gamma spectrum from logical unit 13 instead of from cards R(1).

NOTE: Unless the gamma group structure has been modified the gamma sources (Cards Q and R) are input in the default energy structure shown below. The normal units are MeV/s, but watts or some other power units can be used if a conversion factor is entered as ASO or BSO on Card H, or SPECNM on Card Q. If NOSPEC = 0 on Card B, a default spectrum of 20 groups with a total power of 0.086 watts is used. (This spectrum is suitable for equilibrium operation of a highly enriched light water reactor at 1.0 watt. The default gamma group structure must be used.)

Gp	Average Photon Energy (MeV)	Upper Energy of Gp (MeV)	Gp	Average Photon Energy (MeV)	Upper Energy of Gp (MeV)	Gp	Average Photon Energy (MeV)	Upper Energy of Gp (MeV)
1	9.00	10.00	10	2.00	2.26	19	0.40	0.46
2	7.00	8.00	11	1.70	1.86	20	0.30	0.36
3	5.90	6.50	12	1.45	1.56	21	2.23	2.23
4	5.10	5.50	13	1.25	1.36	22	4.496	4.496
5	4.45	4.75	14	1.00	1.16	23	3.68	3.68
6	4.00	4.25	15	0.83	0.91	24	1.45	1.45
7	3.50	3.75	16	0.70	0.76	25	4.45	4.45
8	3.00	3.25	17	0.60	0.66	26	3.40	3.40
9	2.50	2.76	18	0.50	0.56	27	6.80	6.80

CARD R(1): GAMMA SOURCE SPECTRUM (see Note above) (8E9.4)
[Omit if Card Q(1) is omitted, or if HDSPEC(6,1) = DISK on Card Q]

Column	Variable	Entry (Read by QINPUT)
1-9	SPEC(1,1)	Group LIMSPC(1,1) of first spectrum (in MeV/s).
10-18	SPEC(2,1)	Group LIMSPC(1,1) + 1 of first spectrum (in MeV/s).

etc., through group LIMSPC (2,1).

CARDS Q(I) and R(I): ADDITIONAL GAMMA SPECTRA TITLES AND SOURCES

(Input additional sets of Cards Q and R to a total of NOSPEC sets.)

CARDS S: ZONE DESCRIPTIONS - NREG CARDS ARE REQUIRED (8(I5,I4)
(Omit if NREG < 0)

Column	Variable	Entry (Read by QINPUT)
1-5	NZN(1)	Number of Boundaries Defining Zone ($\leq$ 15)
6-9	NZN(2)	Zone Composition Number. (0 may be used for a void.)
10-14	NZN(3)	Signed Boundary Number (see Reference 3 for examples)*
15-18	NZN(4)	Most Probable Zone of Entry After Ray Crosses NZN(3)
19-24	NZN(5)	Signed Boundary Number
25-27	NZN(6)	Most Probable Zone of Entry After Ray Crosses NZN(5).
etc.	etc.	Continue alternating boundary numbers and most probable zone of entries until NZN(1) pairs are entered. If more than 7 boundaries are used continue the alternating boundary-zone entries starting in columns 1-5 of the next card.

*To determine the sign of the boundary through which the ray will leave a zone set K = K-S in the appropriate boundary equation of Card T and insert coordinates of a point within the zone. Solve the equation for S. The boundary must have the same sign as S.

CARDS T: BOUNDARY DESCRIPTIONS - NBOUND Cards Required (I5,I4,7E9.4)
(Omit if NBOUND < 0)

Column	Variable	Entry (Read by QINPUT)
1-5	JI*	Boundary Number*
6-9	NEQ	Boundary Type
10-18	BNDT(1)	=K*
19-27	BNDT(2)	=A*
28-36	BNDT(3)	=B*
37-45	BNDT(4)	=C*
46-54	BNDT(5)	$=X_0$
55-63	BNDT(6)	$=Y_0$
64-72	BNDT(7)	$=Z_0$

Boundaries Descriptions

Type	Equation
1	$Ax^2+By^2+Cz^2+X_ox + Y_oy + Z_oz = K$
2	$A(x-x_o)^2+B(y-y_o)^2+C(z-z_o)^2=K$
3	$(x-x_o)^2+(y-y_o)^2=K$
4	$x=K$
5	$y=K$
6	$z=K$

*If JI is set equal to the negative of the boundary number for boundary types 1, 2, or 3 the square roots of parameters A, B, C, and K are entered.

CARDS U: COMPOSITIONS. NCOMP Compositions Required (8E9.4)
(Omit if NCOMP < 0)

Column	Variable	Entry (Read by QINPUT)
1-9	COMP(1)	Density (g/cm^3) of material NOAT(1) from Card C.
10-18	COMP(2)	Density (g/cm^3) of material NOAT(2) from Card C.
etc.	etc.	Continue on successive cards until values for MAT materials are entered.

Repeat for each of the NCOMP compositions

CARD V: RAY TRACE PARAMETERS (8E9.4)
(Required only if IESPLN=1)

Column	Variable	Entry (Read by QINPUT)
1-9	EPSLN	Equation test parameter (default = 10^{-5})
10-18	FUDGE	Boundary test parameter (default = 0.02)
19-27	FUDGFR	FUDGE multiplier for geometry error cases (default = 2)

CARDS W: DETECTOR COORDINATES AND ID'S (3E9.4,2(I5,I4),9X,3A6)
(Omit if NRCOPT = -2 (Cols. 28-32 on Card X))

Column	Variable	Entry (Read by QADBS7) [3E9.4,2(I5,I4),9X,3A6]
1-9	RRC	First Coordinate of first detector (r,x, or ρ)
10-18	ZRC	Second Coordinate of first detector (z, z, or Θ)
19-27	PHIRC	Third coordinate of first detector (ϕ, Y, or ϕ)
28-32	NRCOPT	0 means use cylindrical coordinates (r,z,ϕ) for this detector point and input angle in radians. 1 means use cartesian coordinates (x,z,y) for this detector point. 2 means use spherical coordinates (ρ,Θ,ϕ) for this detector point and input angles in radians. 3 means use cylindrical coordinates with angles in degrees 4 means use spherical coordinates with angles in degrees

Column	Variable	Entry (Read by QADBS7)
33-36	NGPF	First Source Point for Which Ray Will be Traced*
37-41	NGPL	Last Source Point for Which Ray Will be Traced*
42-45	NGPI	Increment Between Source Points*
46-54	9X	No Entry
55-72	HDTTL	Any BCD Identification of Detector Point

*Overrides NSET(13-15) on Card B, for This Detector Point

CARD X: END CARD (3E9.4,2(I5,I4),9X,3A6)

Column	Variable	Entry (Read by QADBS7)
1-27	27x	No Entry
28-32	NRCOPT	End Flag -1 means the current case is finished and data for the next case, if any, will be read. -2 means the same except detector points from the previous case will be used for the current case.

SUPPLEMENTAL INPUT INSTRUCTIONS:

The gamma energy group structure given following the input description for Card Q(1) may be changed for a problem. Limited modification of the internal library is also permitted. These changes can be made only at the beginning of problem execution (i.e., all change cases must use the same group structure and material library as the original case). Both group structure and materials may be changed.

Up to 30 gamma energy groups may be defined. Attenuation, dose rate, and gamma heating coefficients for the new groups are obtained by linear interpolation between values for the default group structure for energies between 0.3 and 9.0 MeV. For group energies outside this range the new coefficients are calculated by linear extrapolation.

Library material data can be modified only for material ID's, 1(hydrogen), 4(beryllium), 5(boron), and 6(carbon). To use this option the coefficients for a new material (e.g., concrete) are entered for the first 20 groups of the default group structure.

To change the gamma group structure or internal library the following cards are used instead of Card A, for the first case only.

CARD A1: TITLE, TIME LIMIT, AND MODIFICATION FLAGS (11A6,I4,I1,I1)

Column	Variable	Entry (Read by QADBS7)
1-66	HD(1-11)	Title. Any BCD Information
67-70	HD(12)	Time Limit.
71	MODMATL	= 0, means the no changes will be made in the library = 1, means the internal library will be modified
72	MODNRGY	= 0, means the default energy group structure will be used. = 1, means changes will be made in the energy group structure

CARD A2: INTEGER DATA FOR DATA MODIFICATIONS [8(I5,I4)]

Column	Variable	Entry (Read by CONVERT)
1-5	NRGY	Number of gamma groups in the modified structure ($\leq$30).
6-9	NMATL	Number of materials for which the internal library data are to be modified ($\leq$4).
10-14 15-18 19-23 24-27	NMTL(1) NMTL(2) NMTL(3) NMTL(4)	Material ID's for which modified data are to be inserted. These ID's are restricted to 1, 4, 5, and 6 (NMATL values).

CARDS A3,A4: DATA TO MODIFY GAMMA GROUP STRUCTURE
(Omit if MODNRGY = 0)

Card(s)	Variable	Entry (Read by CONVERT)
A3	WDTH	Enter the total gamma energy range in columns 1-12.
	WDTHG	Enter NRGY pairs of energies describing the new gamma group structure, using 12 columns for each pair of values. (12A6).
A4	EBAR	Enter NRGY values of the effective gamma energies for the modified group structure (8E9.4).

CARDS A5-A7: DATA TO MODIFY INTERNAL LIBRARY* (8E9.4)
(Omit if MODMATL = 0)

Card(s)	Variable	Data (Read by CONVERT)*
A5(1)	XSECO(I,K)	Enter gamma attenuation coefficients for NMTL(1) for the first 20 average group energies of the default energy group structure. The units are cm^2/gm.

Card(s)	Variable	Data (Read by CONVERT) (continued)
A6(1)	WTGO(I,K)	Enter gamma flux-to-heating coefficients for NMTL(1) for the first 20 average group energies of the default energy group structure. The units are (watts/g)/(MeV/$cm^2 \cdot s$).
A7(1)	WTN(I,K)	Enter neutron flux-to-heating coefficients for NMTL(1) for the 10 neutron groups in the internal library. (The effective neutron energies are 12.08, 8.1, 5,43, 3.64, 2.44, 1.63, 1.10, 0.73, 0.49, and 0.33 MeV.). Units are (watts/g)/(neutron/$cm^2 \cdot s$)
A5(i) A6(i) A7(i)	XSECO(I,K) WTGO(I,K) WTN(I,K)	Repeat sets of cards A5, A6, and A7 until NMATL sets have been read in.

*Non-Zero values of XSECO(I,K), WTGO(I,K), and WTN(I,K) are required only if they are to be used in the calculations, but dummy cards must be inserted if coefficients are not entered.

6. SAMPLE PROBLEMS

Input is included for two sample problems. The first problem is a simple cylindrical lead cask with concrete walls on two sides. The cross section of the problem geometry at y = 0 is shown in Figure 2. Input cards are listed in Appendix A and the output in Appendix B.

The second sample problem demonstrates many of the options available in QAD-BSA. Library data and photon energy group structure are modified. The sources are shifted away from the problem geometry origin (and restricted to region 2 in the second case). Two photon sources are used for each case. Neutron calculations are done. The problem geometry is shown in Figure 2 and the input data is listed in Appendix A.

TABLE 1. COMPARISON OF CALCULATIONS WITH QAD-BSA AND QAD-P5A*

Detector Location			Direct Beam $\left(\frac{\text{Photons}}{\text{cm}^2\cdot\text{sec}}\right)$		Dose Rate (w/Buildup) $\left(\frac{\text{millirem}}{\text{hr}}\right)$	
X(cm)	Y(cm)	Z(cm)	QAD-BSA	QAD-P5A	QAD-BSA	QAD-P5A
220.1	0.0	65.	2.213+7	2.218+7	1.447+5	1.449+5
-15.	0.0	100.	1.557+9	1.557+9	8.567+6	8.567+6
-420.1	0.0	35.	6.600+6	6.615+6	4.284+4	4.290+4
0.0	0.0	-20.1	4.900+8	4.911+8	3.117+6	3.121+6

*For sample problem shown in Figure 2.

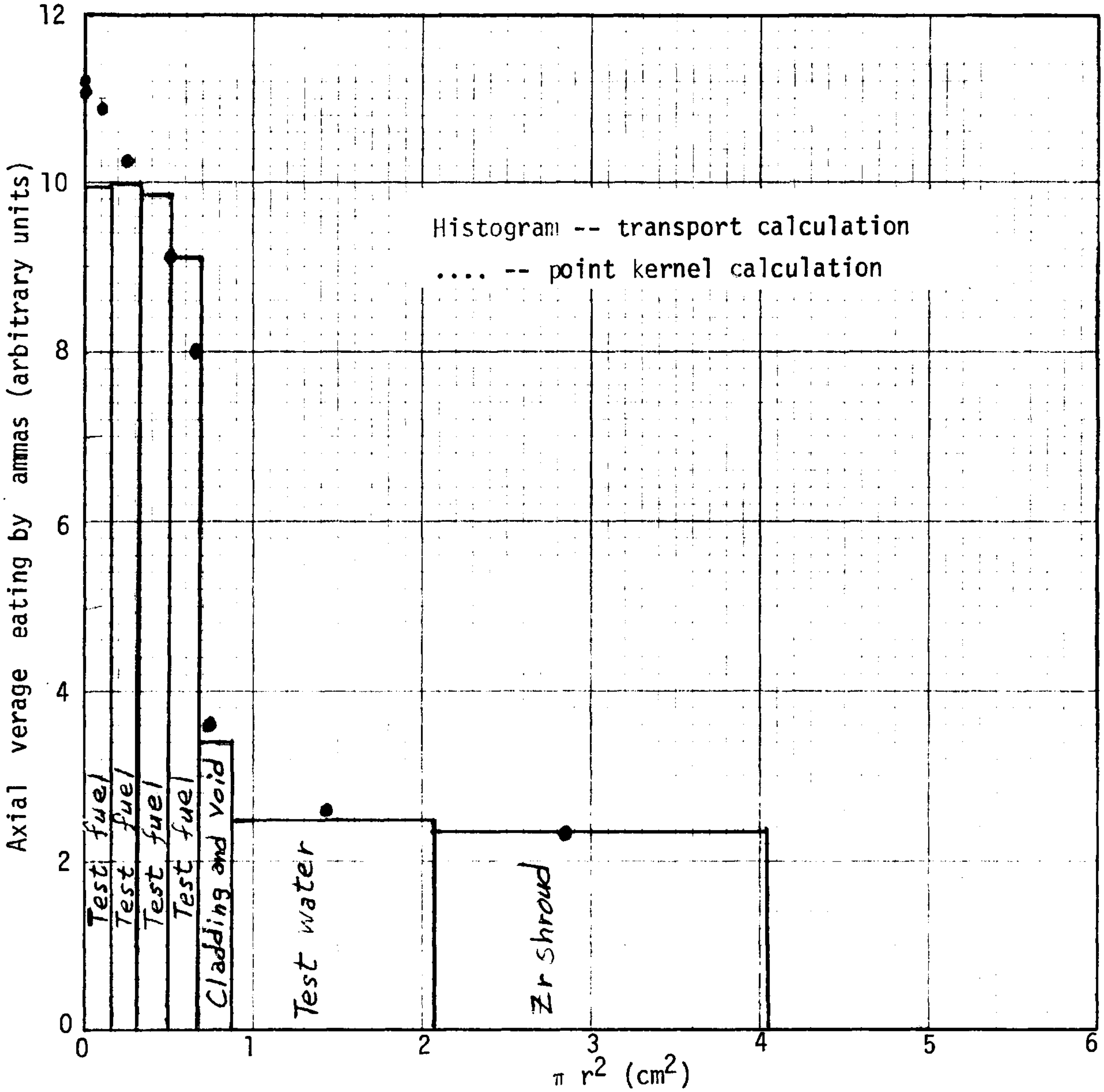

Figure 1. Comparison of Results Obtained with S_n-transport and Point-Kernel Codes for a Single-Rod Test in the PBF.

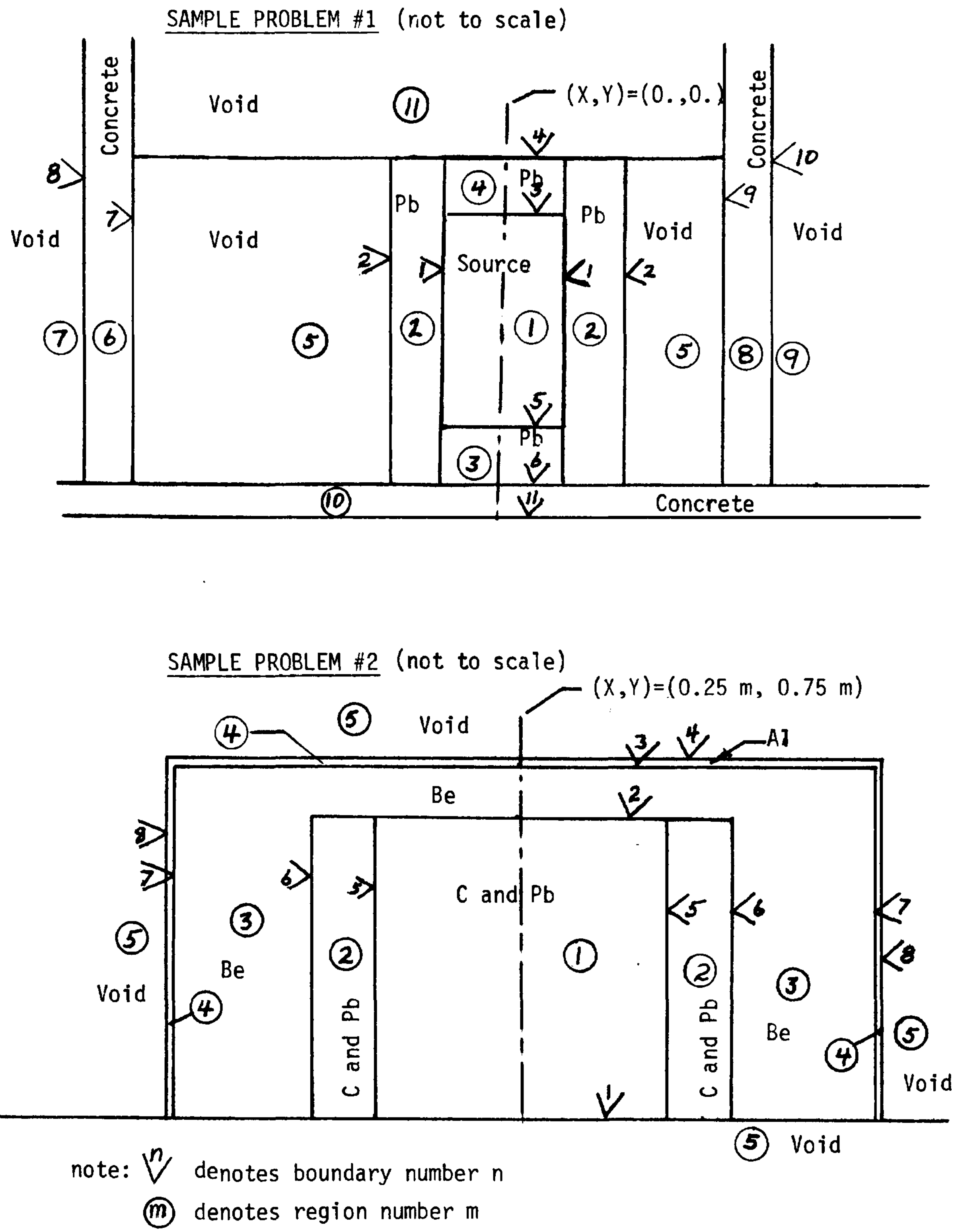

Figure 2. Geometries of Sample Problems.

7. REFERENCES

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APPENDIX A

INPUT FOR SAMPLE PROBLEMS

SHORT SAMPLE PROBLEM

```
TEY0A,P2,T037,STANY.     QAD-BSA SHORT SAMPLE(MTOTAL=1)
ACCOUNT,3220,11TNCC001,TD2.
ATTACH,QADBSAABS,ID=TEY.
QADBSAA.
EXIT,U.
REWIND,INPUT.
COPYSBF.

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A               25
 1 3 1 4 0 7 0 0 0   12   11     4   10     9   11     0    0    1    1    1    CARD B
   92    8   62   12   13   14    26   11    20    1                            CARD C
   82                                                                            CARD D
    4    5    8    0    0    0     0    1     1    0     0    0                  CARD F
1.0                                                                              CARD H
.0         5.        8.        9.        10.                                     CARD K
15.        25.       35.       45.       55.       65.1                          CARD M
.0         45.       90.       135.      180.      225.      270.      315.      CARD 01
360.                                                                             CARD 02
    5    9   1.0        SOURCE IN CASK                                           CARD Q
 1.0   +16 2.0   +16 3.0   +16 4.0   +16 5.0   +16                               CARD R
    3    1    +1    2    +3    4    -5    3                                      CARD S1
    4    2    -1    1    +2    5    -6   10    +4   11                           CARD S2
    3    2    -6   10    +1    2    +5    1                                      CARD S3
    3    2    -3    1    +1    2    +4   11                                      CARD S4
    3    4    -2    2    +9    8    -7    6                                      CARD S5
    3    3    -8    7    -6   10    +7    5                                      CARD S6
    2    4    -5   10    +8    6                                                 CARD S7
    3    3    -9    5    -6   10   +10    9                                      CARD S8
    2    4   -10    8    -6   10                                                 CARD S9
    2    3    +5    2   -11   12                                                 CARD S10
    3    4    -4    2    +9    8    -7    6                                      CARD S11
    1    4   +11   10                                                            CARD S12
   -1    3 10.                                                                   CA94 T1
   -2    3 25.                                                                   CARD T2
    3    6 65.                                                                   CARD T3
    4    6 80.                                                                   CARD T4
    5    6 15.                                                                   CARD T5
    6    6 0.                                                                    CARD T6
    7    4 -400.                                                                 CARD T7
    8    4 -420.                                                                 CARD T8
    9    4 200.                                                                  CARD T9
   10    4 220.                                                                  CARD T10
   11    5 -20.1                                                                 CA94 T11
 .00223     .00445                                                               CARD U1A
 .0                                                                              CARD U1B
 .0                   11.35                                                      CARD U2A
 .0                                                                              CARD U2B
 .0         1.159     .0        .006      .110      .733      .029      .040     CARD U3A
 .194       .0131                                                                CARD U3B
 .0                                                                              CARD U4A
 .0                                                                              CARD U4B
220.1       65.0      0.0          1
-15.        100.      0.0          1
-420.       35.       0.0          1
0.0         -20.1     0.0          1
                                  -1                                             CARD X
```

GENERAL SAMPLE PROBLEM

```
QAD-ESA SAMPLE PROBLEM (SHIFTED SOURCE,NEW ENERGIES,ETC)                    2511CARD A1
   16   1    5                                                                   CARD A2
.04740  .04475  .04350  .04270  .04227  .04200  .04205  .04210                  CARD A5A
.04397  .04577  .04900  .05292  .05980  .05840  .06132  .09880                  CARD A5B
.11400  .14500  .20000  .35000                                                  CARD A5C
6.0990-156.2950-155.9930-155.6710-155.4470-155.2870-155.0780-154.8660-15CARD A6A
4.7930-154.6540-154.5220-154.9620-155.3190-156.4400-157.9500-151.0320-14CARD A6B
1.1620-141.5920-142.4790-144.7100-14                                            CARD A6C
                                                                                CARD A7A
                                                                                CARD A7B
10.-.10      10.-9.       9.-8.        8.-7.        7.-6.        6.-5.          CARD A3A
5.-4.        4.-3.        3.-2.        2.-1.        1.-.9        .9-.8          CARD A3B
 .8-.7        .7-.6        .6-.5        .5-.4        .4-.1                      CARD A3C
9.5      8.5      7.5      6.5      5.5      4.5      3.5      2.5              CARD A4A
1.5      .95      .85      .75      .65      .55      .45      .25              CARD A4B
 2 3 1 4 0 2 0 0 0   5   8   3   4   20  13   3  12   1  10   5  14
   4   6  13  12                                                                  C
  13   4   6                                                                      D
  13  40 101
   3   2   2   0   1   0   0   1   1   1   1   0                                  F
 1.0        0.0       0.0      .5235 -02 25.0                               S
 5.0        RENORMALIZED TO  5.0                                                 I
 250.0      0.0       750.0                                                        J
 0.0        10.0      20.0      30.0      40.0      50.0                         K
 0.0        20.0      30.0      40.0      45.0      50.0                         M
 0.0        60.0      120.0     160.0                                            D
   3     6   0.3456 1.0+05  MEV IN EACH SOURCE GROUP (SRCE #1)              Q
 1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+0    1.0+05      R
   1    16   0.3456 1.0+05  MEV IN EACH SOURCE GROUP (SRCE #4)               C
 1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+0    1.0+05      R
 1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+05   1.0+0    1.0+05        R
   3   1  -1   5   2   3   5   2                                            S1
   4   1  -1   5   2   3   6   3  -5   1                                    S2
   3   2  -1   5   3   4   7   4                                            S3
   3   3  -1   5   4   5   8   5                                            S4
  -1   0                                                                    S5
   1   6                                                                    T1
   2   6  50.0                                                              T2
   3   6  60.0                                                              B      3
   4   6  61.0                                                              B      4
  -5   3  20.0                                 250.0     750.0              B      5
  -6   3  50.0                                 250.0     750.0                     6
  -7   3  60.0                                 250.0     750.0              B      7
  -8   3  61.0                                 250.0     750.0              B      0
          1.30               0.5                                            C*     1
 1.70                                                                       C*     2
                    2.70                                                    C*     3
 250.0      55.0      750.0      1                     DETECTOR ONE          V 1
 250.0      250.0     750.0      1                     LAST DETECTOR
                                -1                                           LAST CO.
QAD-ESA SAMPLE PROBLEM #2B                                                   CARD A
 2 1 1 5 0 7 0 0 0   -5   -8   -3   -4   20   3   3   2   1  10   5  14
     5   2   2   0    1    0    0    1    1   1   0   1
     2
 1.0        0.0       0.0      5235 -02 25.0                                S
 25.        0.        75.
 0.0        10.0      20.0      30.0      40.0      50.0                     R
 0.0        20.0      30.0      40.0      45.0      50.0                     Z
 0.0        60.0      120.0     160.0                                        P
                                -2                                           REPEAT

***********          1EYQUAL  //// END OF LIST ////
***********          1EYQUAL  //// END OF LIST ////
```

APPENDIX B

OUTPUT FOR SHORT SAMPLE PROBLEM

```
QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A                  25    12/22/80    18.46.09.    TEY 9/80

    SOURCE OPTION    3                       TOTALS LIST OPTION     7   GROUP RESULTS ARE PRINTED

NUMBER OF ZONES            12   NUMBER OF PHOTON ENERGY GROUPS          9   GEOMETRY PRINT PARAMETERS    1 (FIRST)
          BOUNDARIES       11             PHOTON INTEGRALS              1                                1 (LAST)
          COMPOSITIONS      4             NEUTRON REFERENCE MATERIALS   0                                1 (DELTA)
          MATERIALS        10             NEUTRON INTEGRALS             0                               14 (PHOTON GRP)
                                                                                 NO SPECIAL DEBUG TRACE

ALL REGION, BOUNDARY, COMPOSITION, AND MATERIAL DATA READ IN


SOURCE POWER  1.0000E+00     SOURCE NORMALIZER  1.0000E+00     NUMBER OF RESULT RENORMALIZERS    0

    CYLINDRIC SOURCE GEOMETRY      ANGLES INPUT IN DEGREES       MOST PROBABLE SOURCE ZONE  1

                     NUMBER      INTENSITY        INTENSITY FUNCTION COEFFICIENTS
                    OF POINTS      INDEX

      R COORDINATE     4          1  (FLAT)              0.            0.
      Z COORDINATE     5          1  (FLAT)              0.            0.
    PHI COORDINATE     8          1  (FLAT)              0.            0.

 THE ORIGIN OF THE SOURCE POINT COORDINATE SYSTEM IS AT  X =  0.          Y =  0.          Z =  0.
    ( IN TERMS OF THE GEOMETRY COORDINATE SYSTEM )

                        1            2            3            4
      R COORDINATE   2.5000E+00   6.5000E+00   8.5000E+00   9.5000E+00
        INTENSITY    2.5000E-01   3.9000E-01   1.7000E-01   1.9000E-01
        BOUNDARY     0.           5.0000E+00   8.0000E+00   9.0000E+00   1.0000E+01

                        5            6            7            8            9
      Z COORDINATE   2.0000E+01   3.0000E+01   4.0000E+01   5.0000E+01   6.0000E+01
        INTENSITY    2.0000E-01   2.0000E-01   2.0000E-01   2.0000E-01   2.0000E-01
        BOUNDARY     1.5000E+01   2.5000E+01   3.5000E+01   4.5000E+01   5.5000E+01   6.5000E+01

                       10           11           12           13           14           15           16           17
    PHI COORDINATE   3.9270E-01   1.1781E+00   1.9635E+00   2.7489E+00   3.5343E+00   4.3197E+00   5.1051E+00   5.8905E+00
        INTENSITY    1.2500E-01   1.2500E-01   1.2500E-01   1.2500E-01   1.2500E-01   1.2500E-01   1.2500E-01   1.2500E-01
        BOUNDARY     0.           4.5000E+01   9.0000E+01   1.3500E+02   1.8000E+02   2.2500E+02   2.7000E+02   3.1500E+02   3.6000E+02
                              SOURCE IN CASK
      5     9  1.0000E+00     1.0000E+16   2.0000E+16   3.0000E+16   4.0000E+16   5.0000E+16
```

ZONE PARAMETERS

ZONE NO	NU BNDS	COMP NO,	BND NO	PROB ZONE	BND NO	PROB ZONE	BND NO	PROB ZONE	BND NO	PROB ZONE	BND NO	PROB ZONE	BND NO	PROB ZONE
1	3	1	1	2	3	4	-5	3						
2	4	2	-1	1	2	5	-6	10	4	11				
3	3	2	-6	10	1	2	5	1						
4	3	2	-3	1	1	2	4	11						
5	3	4	-2	2	9	8	-7	6						
6	3	3	-8	7	-6	10	7	5						
7	2	4	-6	10	8	6								
8	3	3	-9	5	-6	10	10	9						
9	2	4	-10	8	-5	10								
10	2	3	6	2	-11	12								
11	3	4	-4	2	9	8	-7	6						
12	1	4	11	10										

599 ZONE ARRAY STORAGE SPACES LEFT

BOUNDARY EQUATION PARAMETERS

NO	TYPE	K	A	B	C	XO	YO	ZO
1	3 (INPUT)	1.0000E+02 1.0000E+01	1.0000E 00	1.0000E 00		0.	0.	
2	3 (INPUT)	6.2500E+02 2.5000E+01	1.0000E 00	1.0000E 00		0.	0.	
3	6	6.5000E+01						
4	6	8.0000E+01						
5	6	1.5000E+01						
6	6	0.						
7	4	-4.0000E+02						
8	4	-4.2000E+02						
9	4	2.0000E+02						
10	4	2.2000E+02						
11	6	-2.0000E+01						

462 BOUNDARY ARRAY STORAGE SPACES LEFT

COMPOSITION MATRIX

COMP/MAT	92	8	82	12	13	14	26	11	20
1	2.2300E-03	4.4600E-03	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	1.1350E+01	0.	0.	0.	0.	0.	0.
3	0.	1.1590E+00	0.	6.0000E-03	1.1000E-01	7.3300E-01	2.9000E-02	4.0000E-02	1.9400E-01
4	0.	0.	0.	0.	0.	0.	0.	0.	0.

COMPOSITION MATRIX

COMP/MAT	1
1	0.
2	0.
3	1.3100E-02
4	0.

360 COMPOSITION ARRAY STORAGE SPACES LEFT

ATTENUATION COEFFICIENTS

PHOTON GRP	ENERGY	92	8	82	12	13	14	26	11
1	9.0000E+00	4.9500E-02	2.1500E-02	4.7400E-02	2.3500E-02	2.3500E-02	2.4850E-02	2.9400E-02	2.2200E-02
2	7.0000E+00	4.8100E-02	2.3700E-02	4.4750E-02	2.5400E-02	2.5200E-02	2.6550E-02	2.9700E-02	2.4200E-02
3	5.9000E+00	4.6900E-02	2.5100E-02	4.3500E-02	2.6600E-02	2.6500E-02	2.7890E-02	3.0500E-02	2.5600E-02
4	5.1000E+00	4.5800E-02	2.7800E-02	4.2700E-02	2.8400E-02	2.8300E-02	2.9410E-02	3.1300E-02	2.7200E-02
5	4.4500E+00	4.5200E-02	2.9200E-02	4.2270E-02	3.0200E-02	2.9600E-02	3.1080E-02	3.2200E-02	2.8900E-02
6	4.0000E+00	4.4900E-02	3.0900E-02	4.2000E-02	3.1500E-02	3.1000E-02	3.2300E-02	3.3000E-02	3.0300E-02
7	3.5000E+00	4.4500E-02	3.3000E-02	4.2050E-02	3.3750E-01	3.3000E-02	3.4500E-02	3.4100E-02	3.2200E-02
8	3.0000E+00	4.4700E-02	3.5900E-02	4.2100E-02	3.6000E-02	3.5300E-02	3.6700E-02	3.6000E-02	3.4800E-02
9	2.5000E+00	4.5500E-02	3.9600E-02	4.3900E-02	4.0100E-02	3.8500E-02	4.0700E-02	3.8700E-02	3.8300E-02

ATTENUATION COEFFICIENTS

PHOTON GRP	ENERGY	20	1
1	9.0000E+00	2.6250E-02	3.4600E-02
2	7.0000E+00	2.9350E-02	4.0900E-02
3	5.9000E+00	3.0340E-02	4.5200E-02
4	5.1000E+00	3.1460E-02	4.9600E-02
5	4.4500E+00	3.2810E-02	5.4400E-02
6	4.0000E+00	3.3600E-02	5.7900E-02
7	3.5000E+00	3.5700E-02	6.3500E-02
8	3.0000E+00	3.7600E-02	6.9100E-02
9	2.5000E+00	4.1350E-02	7.8400E-02

GAMMA DATA

GRP	ENERGY	CONVERSION	IRON ABS	COEF FOR BUILDUP OPTION NO. 4			
1	9.0000E+00	9.7455E-04	3.9370E-15	9.6369E-01	1.7110E-01	-2.1271E-02	4.0869E-03
2	7.0000E+00	1.0420E-03	3.7970E-15	1.0004E+00	1.8934E-01	-9.7212E-03	3.7523E-03
3	5.9000E+00	1.0992E-03	3.7000E-15	1.0037E+00	1.9339E-01	3.9970E-04	2.7739E-03
4	5.1000E+00	1.1562E-03	3.6570E-15	9.9781E-01	2.0858E-01	6.7274E-03	1.8699E-03
5	4.4500E+00	1.2089E-03	3.6250E-15	9.9254E-01	2.3390E-01	1.0096E-02	1.0521E-03
6	4.0000E+00	1.2364E-03	3.5930E-15	9.9351E-01	2.5870E-01	1.1135E-02	7.1922E-04
7	3.5000E+00	1.3219E-03	3.5540E-15	9.9132E-01	2.9184E-01	1.0844E-02	3.3846E-04
8	3.0000E+00	1.3971E-03	3.5830E-15	9.9548E-01	3.2757E-01	8.9459E-03	9.0227E-05
9	2.5000E+00	1.4886E-03	3.6520E-15	1.0026E+00	3.6026E-01	5.4705E-03	-1.1431E-05

GAMMA RAY AND NEUTRON WEIGHTING FACTORS

1	6.6490E-15
2	6.2960E-15
3	5.9430E-15
4	5.6710E-15
5	5.4470E-15
6	5.2870E-15
7	5.0780E-15
8	4.8860E-15
9	4.7900E-15
10	

***** SETUP TIME .14 SEC

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 1 COORDINATES X = 220.1000 X = 220.1000
Y = 0.0000 Y = 0.0000
Z = 55.0000 Z = 65.0000

GEOMETRY PRINT FOR PSEUDO SOURCE POINT AT THE SOURCE CENTER

SOURCE COORDINATES: (X,Y,Z)=(0. ,0. , .4000E+02)
DIRECTION COSINES: (X,Y,Z)=(.9936E+00,0. , .1129E+00)
CYLINDRIC RADIUS 0.
SOURCE-DETECTOR DISTANCE .2215E+03
EPSILON .1000E-05 DELTA .2000E-01 FUDGE FACTOR .2000E+01 FUDGE .2000E-01

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	1	1.0064E+01	1.0064E+01	1.0000E+01	0.	4.1136E+01	1.0000E+01	5.3640E-03	1.8742E-03
2	2	1.5096E+01	2.5161E+01	2.5000E+01	0.	4.2840E+01	2.5000E+01	1.0680E+01	1.8742E-03
5	9	1.7613E+02	2.0129E+02	2.0000E+02	0.	6.2717E+01	2.0000E+02	1.0680E+01	1.8742E-03
8	10	2.0129E+01	2.2141E+02	2.2000E+02	0.	6.4989E+01	2.2000E+02	1.3381E+01	1.1321E+00
9	0	1.0064E-01	2.2152E+02	2.2010E+02	0.	6.5000E+01	2.2010E+02	1.3381E+01	1.1321E+00

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 1 COORDINATES X = 220.1000 X = 220.1000
Y = 0.0000 Y = 0.0000
Z = 55.0000 Z = 65.0000

R PHI Z
SOURCE POINT INDEX 1 1 1 (INDICES INCREASE IN THE ORDER Z, R, PHI)
SOURCE COORDINATES: (X,Y,Z)=(.2310E+01, .9567E+00, .2000E+02)
DIRECTION COSINES: (X,Y,Z)=(.9793E+00,-.4302E-02, .2023E+00)
CYLINDRIC RADIUS .2500E+01
SOURCE-DETECTOR DISTANCE .2224E+03
EPSILON .1000E-05 DELTA .2000E-01 FUDGE FACTOR .2000E+01 FUDGE .2000E-01

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	1	7.8092E+00	7.8092E+00	9.9573E+00	9.2311E-01	2.1580E+01	1.0000E+01	4.1621E-03	1.4543E-03
2	2	1.5346E+01	2.3155E+01	2.4985E+01	8.5710E-01	2.4685E+01	2.5000E+01	1.0855E+01	1.4543E-03
5	9	1.7871E+02	2.0187E+02	2.0000E+02	8.8295E-02	6.0847E+01	2.0000E+02	1.0855E+01	1.4543E-03
8	10	2.0423E+01	2.2229E+02	2.2000E+02	4.3928E-04	6.4979E+01	2.2000E+02	1.3596E+01	1.1482E+00
9	0	1.0211E-01	2.2239E+02	2.2010E+02	4.3576E-15	6.5000E+01	2.2010E+02	1.3596E+01	1.1482E+00

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 1 COORDINATES X 220.1000 Y 0.0000 Z 65.0000

SOURCE IN CASK

PHOTON RELAXATION LENGTHS FOR 1.0 MEV MAX 0.0000(SOURCE POINT 0 0 0) MIN*********(SOURCE POINT 0 0 0)
MEAN BUILDUP FACTOR 4.8105

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	ENERGY FLUX DIRECT BEAM (MEV PER SQ CM SEC)	ENERGY FLUX WITH BUILDUP (MEV PER SQ CM SEC)	DOSE RATE DIRECT BEAM (MILLIREM PER HOUR)	DOSE RATE WITH BUILDUP (MILLIREM PER HOUR)	HEATING RATES IN IRON DIRECT BEAM (WATTS PER GRAM)	HEATING RATES IN IRON WITH BUILDUP (WATTS PER GRAM)
TOTAL	3.1945	10.00-0.26	2.2127E+07	1.0644E+08	3.0037E+04	1.4468E+05	7.9586E-08	3.8289E-07
W/BU	3.2062							
5	4.4500	4.75-4.25	2.0139E+06	9.4509E+06	2.4346E+03	1.1425E+04	7.3003E-09	3.4260E-08
6	4.0000	4.25-3.75	3.9498E+06	1.8564E+07	4.9705E+03	2.3351E+04	1.4192E-08	6.5701E-08
7	3.5000	3.75 3.25	5.1356E+06	2.4559E+07	6.7879E+03	3.2464E+04	1.8250E-08	8.7282E-08
8	3.0000	3.25-2.76	6.2572E+06	3.0127E+07	6.7419E+03	4.2091E+04	2.2420E-08	1.0795E-07
9	2.5000	2.76-2.26	4.7712E+06	2.3741E+07	7.1024E+03	3.5341E+04	1.7424E-08	8.6701E-08

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	HEATING RATE IN LEAD DIRECT BEAM (WATTS PER GM)	HEATING RATE IN LEAD WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)
TOTAL		10.00-0.26	1.1135E-07	5.3526E-07				
5	4.4500	4.75-4.25	1.0970E-08	5.1479E-08				
6	4.0000	4.25-3.75	2.0883E-08	9.8148E-08				
7	3.5000	3.75 3.25	2.6075E-08	1.2471E-07				
8	3.0000	3.25-2.76	3.0573E-08	1.4720E-07				
9	2.5000	2.76-2.26	2.2854E-08	1.1372E-07				

***** DETECTOR TIME .09 SEC

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

```
RECEIVER NUMBER  2  COORDINATES     X =      -15.0000          X =      -15.0000
                                    Y =        0.0000          Y =        0.0000
                                    Z =      100.0000          Z =      100.0000

            GEOMETRY PRINT FOR PSEUDO SOURCE POINT AT THE SOURCE CENTER

          SOURCE COORDINATES: (X,Y,Z)=(0.          ,0.          , .4000E+02)
          DIRECTION COSINES: (X,Y,Z)=(-.2425E+00,0.          , .9701E+00)
             CYLINDRIC RADIUS       0.
      SOURCE-DETECTOR DISTANCE      .6185E+02
   EPSILON   .1000E-05      DELTA   .2000E-01      FUDGE FACTOR   .2000E+01      FUDGE   .2000E-01
```

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	3	2.5769E+01	2.5769E+01	-6.2500E+00	0.	6.5000E+01	6.2500E+00	1.3734E-02	4.7990E-03
4	4	1.5462E+01	4.1231E+01	-1.0000E+01	0.	8.0000E+01	1.0000E+01	1.0947E+01	4.7990E-03
11	0	2.0616E+01	6.1647E+01	-1.5000E+01	0.	1.0000E+02	1.5000E+01	1.0947E+01	4.7990E-03

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

```
RECEIVER NUMBER  2  COORDINATES     X =      -15.0000          X =      -15.0000
                                    Y =        0.0000          Y =        0.0000
                                    Z =      100.0000          Z =      100.0000

                                           R            PHI           Z
          SOURCE POINT INDEX               1             1            1       (INDICES INCREASE IN THE ORDER   Z, R, PHI)
          SOURCE COORDINATES: (X,Y,Z)=( .2310E+01, .9567E+00, .2000E+02)
           DIRECTION COSINES: (X,Y,Z)=(-.2115E+00,-.1169E-01, .9773E+00)
             CYLINDRIC RADIUS       .2500E+01
      SOURCE-DETECTOR DISTANCE      .8186E+02
   EPSILON   .1000E-05      DELTA   .2000E-01      FUDGE FACTOR   .2000E+01      FUDGE   .2000E-01
```

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	3	4.6044E+01	4.6044E+01	-7.4270E+00	4.1856E-01	6.5000E+01	7.4388E+00	2.4540E-02	8.5747E-03
4	1	1.2149E+01	5.8194E+01	-9.9962E+00	2.7656E-01	7.6874E+01	1.0000E+01	8.6155E+00	8.5747E-03
2	4	3.1987E+00	6.1393E+01	-1.0673E+01	2.3918E-01	8.0000E+01	1.0675E+01	1.0877E+01	8.5747E-03
11	0	2.0464E+01	8.1857E+01	-1.5000E+01	7.9936E-15	1.0000E+02	1.5000E+01	1.0877E+01	8.5747E-03

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 2 COORDINATES X -15.0000 Y 0.0000 Z 100.0000

SOURCE IN CASK

PHOTON RELAXATION LENGTHS FOR 1.0 MEV MAX 0.0000(SOURCE POINT 0 0 0) MIN**********(SOURCE POINT 0 0 0)
MEAN BUILDUP FACTOR 4.0030

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	ENERGY FLUX DIRECT BEAM (MEV PER SQ CM SEC)	ENERGY FLUX WITH BUILDUP (MEV PER SQ CM SEC)	DOSE RATE DIRECT BEAM (MILLIREM PER HOUR)	DOSE RATE WITH BUILDUP (MILLIREM PER HOUR)	HEATING RATES IN IRON DIRECT BEAM (WATTS PER GRAM)	HEATING RATES IN IRON WITH BUILDUP (WATTS PER GRAM)
TOTAL	3.1057	10.00-0.26	1.5567E+09	6.2392E+09	2.1336E+06	6.5658E+06	5.6031E-05	2.2461E-05
W/BU	3.1220							
5	4.4500	4.75-4.25	1.1063E+08	4.2536E+08	1.3374E+05	5.1422E+05	4.0104E-07	1.5419E-06
6	4.0000	4.25-3.75	2.3219E+08	8.9983E+08	2.9218E+05	1.1323E+06	8.3425E-07	3.2331E-06
7	3.5000	3.75 3.25	3.4512E+08	1.3635E+09	4.5621E+05	1.8024E+06	1.2256E-06	4.8459E-06
8	3.0000	3.25-2.76	4.5594E+08	1.8302E+09	6.3699E+05	2.5570E+06	1.6336E-06	6.5576E-06
9	2.5000	2.76-2.26	4.1281E+08	1.7203E+09	6.1451E+05	2.6609E+06	1.5076E-06	6.2827E-06

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	HEATING RATE IN LEAD DIRECT BEAM (WATTS PER GM)	HEATING RATE IN LEAD WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)
TOTAL		10.00-0.26	7.7878E-06	3.1181E-05				
5	4.4500	4.75-4.25	6.0261E-07	2.3170E-06				
6	4.0000	4.25-3.75	1.2276E-06	4.7574E-06				
7	3.5000	3.75 3.25	1.7525E-06	6.9238E-06				
8	3.0000	3.25-2.76	2.2277E-06	6.9423E-06				
9	2.5000	2.76-2.26	1.9774E-06	8.2404E-06				

***** DETECTOR TIME .07 SEC

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QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER  3  COORDINATES      X =     -420.0000          X =     -420.0000
                                     Y =        0.0000          Y =        0.0000
                                     Z =       35.0000          Z =       35.0000

          GEOMETRY PRINT FOR PSEUDO SOURCE POINT AT THE SOURCE CENTER

          SOURCE COORDINATES: (X,Y,Z)=(0.          ,0.          , .4000E+02)
           DIRECTION COSINES: (X,Y,Z)=(-.9999E+00,0.           ,-.1190E-01)
             CYLINDRIC RADIUS          0.
     SOURCE-DETECTOR DISTANCE          .4200E+03
 EPSILON    .1000E-05        DELTA    .2000E-01     FUDGE FACTOR    .2000E+01        FUDGE    .2000E-01

   GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE
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ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	1	1.0001E+01	1.0001E+01	-1.0000E+01	0.	3.9881E+01	1.0000E+01	5.3301E-03	1.8624E-03
2	2	1.5001E+01	2.5002E+01	-2.5000E+01	0.	3.9702E+01	2.5000E+01	1.0613E+01	1.8624E-03
5	-7	3.7503E+02	4.0003E+02	-4.0000E+02	0.	3.5238E+01	4.0000E+02	1.0613E+01	1.8624E-03
6	-8	2.0001E+01	4.2003E+02	-4.2000E+02	0.	3.5000E+01	4.2000E+02	1.3297E+01	1.1249E+00
7	0	1.1551E-12	4.2003E+02	-4.2000E+02	0.	3.5000E+01	4.2000E+02	1.3297E+01	1.1249E+00


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QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER  3  COORDINATES      X =     -420.0000          X =     -420.0000
                                     Y =        0.0000          Y =        0.0000
                                     Z =       35.0000          Z =       35.0000

                                           R            PHI            Z
           SOURCE POINT INDEX              1             1             1        (INDICES INCREASE IN THE ORDER   Z, R, PHI)
           SOURCE COORDINATES: (X,Y,Z)=( .2310E+01, .9567E+00, .2000E+02)
            DIRECTION COSINES: (X,Y,Z)=(-.9994E+00,-.2264E-02, .3550E-01)
             CYLINDRIC RADIUS          .2500E+01
     SOURCE-DETECTOR DISTANCE          .4226E+03
 EPSILON    .1000E-05        DELTA    .2000E-01     FUDGE FACTOR    .2000E+01        FUDGE    .2000E-01

   GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE
```

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	1	1.2274E+01	1.2274E+01	-9.9568E+00	9.2892E-01	2.0436E+01	1.0000E+01	6.5418E-03	2.2858E-03
2	2	1.5037E+01	2.7311E+01	-2.4984E+01	8.9488E-01	2.0969E+01	2.5000E+01	1.0639E+01	2.2858E-03
5	-7	3.7525E+02	4.0256E+02	-4.0000E+02	4.5308E-02	3.4290E+01	4.0000E+02	1.0639E+01	2.2858E-03
6	-8	2.0013E+01	4.2258E+02	-4.2000E+02	3.5527E-15	3.5000E+01	4.2000E+02	1.3325E+01	1.1260E+00
7	0	8.1402E-13	4.2258E+02	-4.2000E+02	1.7187E-15	3.5000E+01	4.2000E+02	1.3325E+01	1.1260E+00

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 3 COORDINATES X -420.0000 Y 0.0000 Z 35.0000

SOURCE IN CASK

PHOTON RELAXATION LENGTHS FOR 1.0 MEV MAX 0.0000(SOURCE POINT 0 0 0) MIN*********(SOURCE POINT 0 0 0)
MEAN BUILDUP FACTOR 4.7747

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	ENERGY FLUX DIRECT BEAM (MEV PER SQ CM SEC)	ENERGY FLUX WITH BUILDUP (MEV PER SQ CM SEC)	DOSE RATE DIRECT BEAM (MILLIREM PER HOUR)	DOSE RATE WITH BUILDUP (MILLIREM PER HOUR)	HEATING RATES IN IRON DIRECT BEAM (WATTS PER GRAM)	HEATING RATES IN IRON WITH BUILDUP (WATTS PER GRAM)
TOTAL	3.1929	10.00-0.26	6.6034E+06	3.1529E+07	8.9651E+03	4.2864E+04	2.3751E-08	1.1342E-07
W/BU	3.2051							
5	4.4500	4.75-4.25	5.9981E+05	2.7887E+06	7.2511E+02	3.3712E+03	2.1743E-09	1.0109E-08
6	4.0000	4.25-3.75	1.1706E+06	5.4829E+06	1.4806E+03	6.8997E+03	4.2275E-09	1.9700E-08
7	3.5000	3.75 3.25	1.5312E+06	7.2558E+06	2.0241E+03	9.6060E+03	5.4419E-09	2.5826E-08
8	3.0000	3.25-2.76	1.8671E+06	8.9271E+06	2.6085E+03	1.2472E+04	6.6898E-09	3.1986E-08
9	2.5000	2.76-2.26	1.4287E+06	7.0539E+06	2.1268E+03	1.0515E+04	5.2176E-09	2.5797E-08

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	HEATING RATE IN LEAD DIRECT BEAM (WATTS PER GM)	HEATING RATE IN LEAD WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)
TOTAL		10.00-0.26	3.3229E-08	1.5853E-07				
5	4.4500	4.75-4.25	3.2672E-09	1.5190E-08				
5	4.0000	4.25-3.75	6.2207E-09	2.8988E-08				
7	3.5000	3.75 3.25	7.7755E-09	3.6901E-08				
8	3.0000	3.25-2.76	9.1226E-09	4.3618E-08				
9	2.5000	2.76-2.26	6.8434E-09	3.3836E-08				

***** DETECTOR TIME .08 SEC

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

```
RECEIVER NUMBER   4   COORDINATES      X =        0.0000          X =        0.0000
                                       Y =        0.0000          Y =        0.0000
                                       Z =      -20.1000          Z =      -20.1000
```

GEOMETRY PRINT FOR PSEUDO SOURCE POINT AT THE SOURCE CENTER

```
         SOURCE COORDINATES: (X,Y,Z)=(0.          ,0.          , .4000E+02)
          DIRECTION COSINES: (X,Y,Z)=(0.          ,0.          ,-.1000E+01)
            CYLINDRIC RADIUS      0.
    SOURCE-DETECTOR DISTANCE      .6010E+02
EPSILON    .1000E-05        DELTA   .2000E-01      FUDGE FACTOR   .2000E+01       FUDGE   .2000E-01
```

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	-5	2.5000E+01	2.5000E+01	0.	0.	1.5000E+01	0.	1.3324E-02	4.6557E-03
3	-6	1.5000E+01	4.0000E+01	0.	0.	0.	0.	1.0620E+01	4.6557E-03
10	-11	2.0000E+01	6.0000E+01	0.	0.	-2.0000E+01	0.	1.3304E+01	1.1276E+00
12	0	1.0000E-01	6.0100E+01	0.	0.	-2.0100E+01	0.	1.3304E+01	1.1276E+00

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

```
RECEIVER NUMBER   4   COORDINATES      X =        0.0000          X =        0.0000
                                       Y =        0.0000          Y =        0.0000
                                       Z =      -20.1000          Z =      -20.1000

                                         R                PHI            Z
          SOURCE POINT INDEX             1                 1             1          (INDICES INCREASE IN THE ORDER   Z, R, PHI)
         SOURCE COORDINATES: (X,Y,Z)=( .2310E+01, .9567E+00, .2000E+02)
          DIRECTION COSINES: (X,Y,Z)=(-.5749E-01,-.2381E-01,-.9981E+00)
            CYLINDRIC RADIUS      .2500E+01
    SOURCE-DETECTOR DISTANCE      .4018E+02
EPSILON    .1000E-05        DELTA   .2000E-01      FUDGE FACTOR   .2000E+01       FUDGE   .2000E-01
```

GEOMETRY PARAMETERS EVALUATED ON LEAVING ZONE

ZONE NO	BND NO	DISTANCE THRU ZONE	DISTANCE FROM SOURCE	COORDINATES X	COORDINATES Y	COORDINATES Z	CYL RADIUS	TOTAL RELAXATION LENGTH GAMMA	TOTAL RELAXATION LENGTH NEUTRON
1	-5	5.0097E+00	5.0097E+00	2.0217E+00	8.3742E-01	1.5000E+01	2.1883E+00	2.6700E-03	9.3294E-04
3	-6	1.5029E+01	2.0039E+01	1.1577E+00	4.7955E-01	5.6843E-14	1.2531E+00	1.0530E+01	9.3294E-04
10	-11	2.0039E+01	4.0078E+01	5.7598E-03	2.3858E-03	-2.0000E+01	6.2344E-03	1.3319E+01	1.1261E+00
12	0	1.0019E-01	4.0178E+01	2.9976E-15	3.5041E-15	-2.0100E+01	4.6114E-15	1.3319E+01	1.1261E+00

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

RECEIVER NUMBER 4 COORDINATES X 0.0000 Y 0.0000 Z -20.1000

SOURCE IN CASK

PHOTON RELAXATION LENGTHS FOR 1.0 MEV MAX 0.0000(SOURCE POINT 0 0 0) MIN*********(SOURCE POINT 0 0 0)
MEAN BUILDUP FACTOR 4.6782

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	ENERGY FLUX DIRECT BEAM (MEV PER SQ CM SEC)	ENERGY FLUX WITH BUILDUP (MEV PER SQ CM SEC)	DOSE RATE DIRECT BEAM (MILLIREM PER HOUR)	DOSE RATE WITH BUILDUP (MILLIREM PER HOUR)	HEATING RATES IN IRON DIRECT BEAM (WATTS PER GRAM)	HEATING RATES IN IRON WITH BUILDUP (WATTS PER GRAM)
TOTAL	3.1902	10.00-0.26	4.6998E+08	2.2923E+09	6.6528E+05	3.1172E+06	1.7624E-06	8.2460E-06
W/BU	3.2044							
5	4.4500	4.75-4.25	4.4566E+07	2.0173E+08	5.3876E+04	2.4387E+05	1.6155E-07	7.3126E-07
6	4.0000	4.25-3.75	8.7260E+07	3.9693E+08	1.0981E+05	4.9949E+05	3.1353E-07	1.4262E-06
7	3.5000	3.75 3.25	1.1345E+08	5.2706E+08	1.4997E+05	6.9673E+05	4.0319E-07	1.8732E-06
8	3.0000	3.25-2.76	1.3825E+08	6.4872E+08	1.9315E+05	9.0633E+05	4.9535E-07	2.3244E-06
9	2.5000	2.76-2.26	1.0646E+08	5.0781E+08	1.5847E+05	7.7082E+05	3.8878E-07	1.8911E-06

GRP NO	MEAN ENERGY MEV	ENERGY GROUP LIMITS MEV	HEATING RATE IN LEAD DIRECT BEAM (WATTS PER GM)	HEATING RATE IN LEAD WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)	HEATING RATE DIRECT BEAM (WATTS PER GM)	HEATING RATE WITH BUILDUP (WATTS PER GM)
TOTAL		10.00-0.26	2.4656E-05	1.1524E-05				
5	4.4500	4.75-4.25	2.4275E-07	1.0988E-06				
6	4.0000	4.25-3.75	4.6135E-07	2.0986E-06				
7	3.5000	3.75 3.25	5.7609E-07	2.6764E-06				
8	3.0000	3.25-2.76	6.7550E-07	3.1697E-06				
9	2.5000	2.76-2.26	5.0993E-07	2.4803E-06				

***** DETECTOR TIME .07 SEC

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

1 SOURCE IN CASK

**** NO SOURCE RENORMALIZATION

COORDINATES			ENERGY FLUX MEV PER SQ CM SEC	DOSE RATE MILLIREM PER HOUR	HEATING RATE IN IRON WATTS PER GM	HEATING RATE IN LEAD WATTS PER GM
BUILTUP GAMMA RAY DATA						
2.201E+02	0.	6.500E+01	1.0644E+08	1.4468E+05	3.8289E-07	5.3526E-07
-1.500E+01	0.	1.000E+02	6.2392E+09	8.5668E+06	2.2461E-05	3.1181E-05
-4.200E+02	0.	3.500E+01	3.1529E+07	4.2864E+04	1.1342E-07	1.6853E-07
0.	0.	-2.010E+01	2.2923E+09	3.1172E+06	8.2460E-06	1.1524E-05

QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

1 SOURCE IN CASK

**** NO SOURCE RENORMALIZATION

COORDINATES			ENERGY FLUX MEV PER SQ CM SEC	DOSE RATE MILLIREM PER HOUR	HEATING RATE IN IRON WATTS PER GM	HEATING RATE IN LEAD WATTS PER GM
DIRECT BEAM GAMMA RAY DATA						
2.201E+02	0.	6.500E+01	2.2127E+07	3.0037E+04	7.9586E-08	1.1135E-07
-1.500E+01	0.	1.000E+02	1.5567E+09	2.1336E+06	5.6031E-06	7.7878E-06
-4.200E+02	0.	3.500E+01	6.6034E+06	8.9651E+03	2.3751E-08	3.3229E-08
0.	0.	-2.010E+01	4.8998E+08	6.6528E+05	1.7624E-06	2.4656E-06

*****END PRINT TIME .01 SEC

***** PROBLEM TIME .46 SEC

SUM PRINT FOR 1 PROBLEMS

1 QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

**** NO SOURCE RENORMALIZATION

COORDINATES			ENERGY FLUX MEV PER SQ CM SEC	DOSE RATE MILLIREM PER HOUR	HEATING RATE IN IRON WATTS PER GM	HEATING RATE IN LEAD WATTS PER GM
BUILDUP GAMMA RAY DATA						
2.201E+02	0.	6.500E+01	1.0644E+08	1.4468E+05	3.8289E-07	5.3526E-07
-1.500E+01	0.	1.000E+02	6.2392E+09	8.5668E+06	2.2461E-05	3.1181E-05
-4.200E+02	0.	3.500E+01	3.1529E+07	4.2864E+04	1.1342E-07	1.5853E-07
0.	0.	-2.010E+01	2.2923E+09	3.1172E+06	8.2460E-06	1.1524E-05

SUM PRINT FOR 1 PROBLEMS

1 QAD-BSA SHORT SAMPLE PROBLEM,PB CASK(MTOTAL=7) CARD A

**** NO SOURCE RENORMALIZATION

COORDINATES			ENERGY FLUX MEV PER SQ CM SEC	DOSE RATE MILLIREM PER HOUR	HEATING RATE IN IRON WATTS PER GM	HEATING RATE IN LEAD WATTS PER GM
DIRECT BEAM GAMMA RAY DATA						
2.2[illegible]+02	0.	6.500E+01	2.2127E+07	3.0037E+04	7.9586E-08	1.1135E-07
-1.500E+01	0.	1.000E+02	1.5557E+09	2.1336E+06	5.6031E-06	7.7878E-06
-4.200E+02	0.	3.500E+01	6.6034E+06	6.9651E+03	2.3751E-08	3.3229E-08
0.	0.	-2.010E+01	4.8998E+08	6.6528E+05	1.7624E-06	2.4656E-06

*****EXECUTION TIME .66 SEC