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Design of a shield system for a hyper-pure germanium detector as a stack monitor for use in accident conditions at a nuclear power plant

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DESIGN OF A SHIELD SYSTEM FOR A HYPER-PURE GERMANIUM DETECTOR AS A STACK MONITOR FOR USE IN ACCIDENT CONDITIONS AT A NUCLEAR POWER PLANT

by

Anthony Bruno Petito

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In the Graduate College

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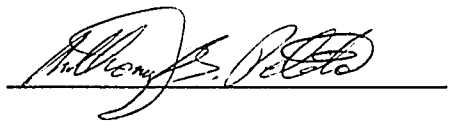
SIGNED: 

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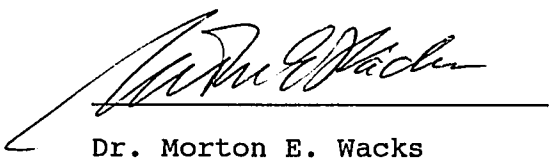

Dr. Morton E. Wacks
Professor of Nuclear Engineering

April 30, 1997
Date

To Mom, Dad and Christine.

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ABSTRACT

Collimator and shield configurations for two high-purity germanium detectors were designed for use during a loss of coolant accident at a boiling water reactor. The detectors will return information concerning stack releases to operators within a 15 minute time frame. Operating parameters for the stack monitors are defined by the United States Nuclear Regulatory Commission (USNRC) and a 24 hour source term generated by ORIGEN2.

A lead collimator 0.4 cm in diameter, 20 cm in length for the high range detector and 2 cm in diameter, 20 cm in length for the low range detector was shown through a Monte Carlo code, MCNP4 to prevent high range detector saturation and provide enough low range detector response so good statistical data on stack releases result.

A lead shield 20 cm thick was shown through MCNP4 to reduce the background radiation interference for both detectors to levels such that the detection of isotopes within the stack effluent is possible as required by the USNRC.

CHAPTER 1

INTRODUCTION

Monitoring of radionuclides released into the environment is a very important task undertaken by all nuclear power plants across the country. While monitoring these releases during normal plant operation is not a problem, it is a very difficult problem when an accident occurs. The extremely high levels of radiation will render even the best detectors useless due to background interference and saturation.

All nuclear reactors have guidelines established by the Nuclear Regulatory Commission (NRC) regarding the expected ranges detectors are to operate within during an accident. For boiling water reactors (BWRs) some detectors are monitoring the effluent released from the secondary containment through the exhaust stack of the plant. The upper end of the detection range is sufficiently high to ensure that virtually all releases from loss of coolant (LOCA) accidents can be monitored.

A collimator is needed to reduce the predicted high radiation levels so the detector can function properly and monitor the stack release. Shielding is needed to reduce the contribution of background radiation which would

interfere with the measurement of the stack effluent radioactivity. It is important to detect a release of radioactivity since it may be the first notification that an accident has occurred. It is also important to be able to measure particular isotopes so their activity can be determined before and as they are released into the environment.

The isotopes that may possibly be released into the environment as a result of a LOCA in a BWR include iodine, krypton and xenon. Although the noble gasses do not pose as great a heath risk as the radioactive iodine, they still are of great concern. Iodine's ability to chemically combine with so many materials makes it very easy to be deposited within the body particularly in the thyroid and gastrointestinal system. Since iodine emits both beta and gamma radiation and has a relatively short half-life a great deal of energy can be deposited internally and therefore this element and its radioisotopes pose a significant health risk.

CHAPTER 2

THEORY AND APPROACH

The general approach to designing the shield configuration is to establish source terms for each end of the detector ranges. The high end of the detection range should represent the worst case in the release scenario and the low end of the detection range the normal plant operating conditions.

The detector efficiency is key in designing the collimator and shield. A high detector efficiency would let a large amount of the gammas present in the source volume to register in the detector. Too many gammas entering the detector in a short period of time will saturate the detector making it useless. To avoid saturation a very small diameter collimator with a long length is needed to significantly reduce the number of gammas reaching the detector. Unfortunately the detector efficiencies are not available for a volume source.

To obtain an efficiency the collimator geometry and detector construction must be modeled so that a Monte Carlo code, MCNP4, can be used to calculate the detector response. This code will generate for its model the percent of initial source particles deposited in the

detector element over an energy spectrum. By knowing the initial gamma energy and quantity in the source and the energy and quantity of the deposited gammas in the detector an efficiency for a specified geometry is defined. Repeated geometry adjustments in the collimator design are made until the gamma response of the detector is at a level that ensures proper operation.

To identify an isotope present within the source volume a high energy gamma distinctive of only that isotope is selected. The number of counts that are recorded by the detector at that particular energy level will be related to the total number of counts deposited by that isotope and the compton scattered photons of higher energy gammas present. The number of counts collected from a particular isotope per unit time allows the activity of that isotope to be determined once the detector efficiency is determined. From a source term where all isotopes activities are given it is possible to relate each isotope activity at a particular time in terms of another. With this relation identifying only one isotope will provide enough information to determine the activity of all isotopes in the source volume.

Finally to ensure that the accident produced background at the detector location does not interfere with the counting of the isotopes a detector shield is designed. This background also makes it impossible to service the detector which must be maintained at cryogenic temperatures. Therefore the system must be self-maintained and cooled.

The effectiveness of the shield was also verified with MCNP4. The shield is considered effective if the background contribution is insignificant compared to the peak being counted. Insignificant is defined as follows, the isotope peak being counted should be at least 10 times larger than the uncertainty in the background contribution through the shield at that particular peak energy.

CHAPTER 3

SYSTEM COMPONENTS AND DESIGN PARAMETERS

3.1 Washington Public Power Supply System

The Washington Public Power Supply System's (WPPSS) Nuclear Plant-2 in Richland, Washington is the basis for this collimator and shield design as the blueprints and Final Safety Analysis Report (FSAR) were available for analysis. BWR source terms have been studied extensively and are well known for loss of coolant accidents.

According to the WPPSS FSAR (Section 15.6.5.5.2.2), the leakage from the primary containment into the secondary is 0.5% of the damaged fuel's fission product inventory per day. Within 24 hours the initial .5% will be uniformly distributed throughout the secondary volume (FSAR: Table 6.2-12 I C) and eventually exhausted through the stack. No dilution of this volume occurs to reduce the activity before it is released to the environment (FSAR: 15.6.5.5.2.2).

The secondary containment volume is 9.91×10^{10} cm^3 and the exhaust rate through the reactor building ventilation system is 3.77×10^7 cm^3/s. At this rate the entire secondary will be completely vented to the environment within 43.75 minutes.

The exhaust stack that the detectors will be mounted

by is next to the secondary containment and they share a common wall. The stack is a rectangular duct 114.3 cm deep and 304.8 cm wide. The secondary containment and the exhaust stack share the 304.8 cm wide wall. When the detector is positioned it will be looking into the stack over a distance of 114.3 cm.

3.2 High-Purity Germanium (HPGe) detector

The detector to be used is a high-purity germanium detector manufactured by EG&G Ortec. It is constructed as a removable capsule that houses the preamplifier electronics and the detector element under the trade name of PopTop™ (Ortec, 1991/92). Figure 1 shows the detector capsule and connection to a liquid nitrogen filled dewar. The system selected is a cooling system based upon expansion of compressed helium rather than liquid nitrogen so service during an accident will not be necessary. The active portion of the capsule is the germanium element found in the end of the capsule.

Unlike lithium drifted detectors (GeLi) the high-purity germanium (HPGe) detectors do not contain any drifted elements and do not have to be at cryogenic temperatures unless operating (Tsoulfanidis, 1983). With GeLi detectors the lithium will drift out of the detector element at room temperature and the PIN junction will be

lost. There is no way to redrift the lithium back into the detector. This forces the GeLi detectors to remain at cryogenic temperatures at all times even when not operating.

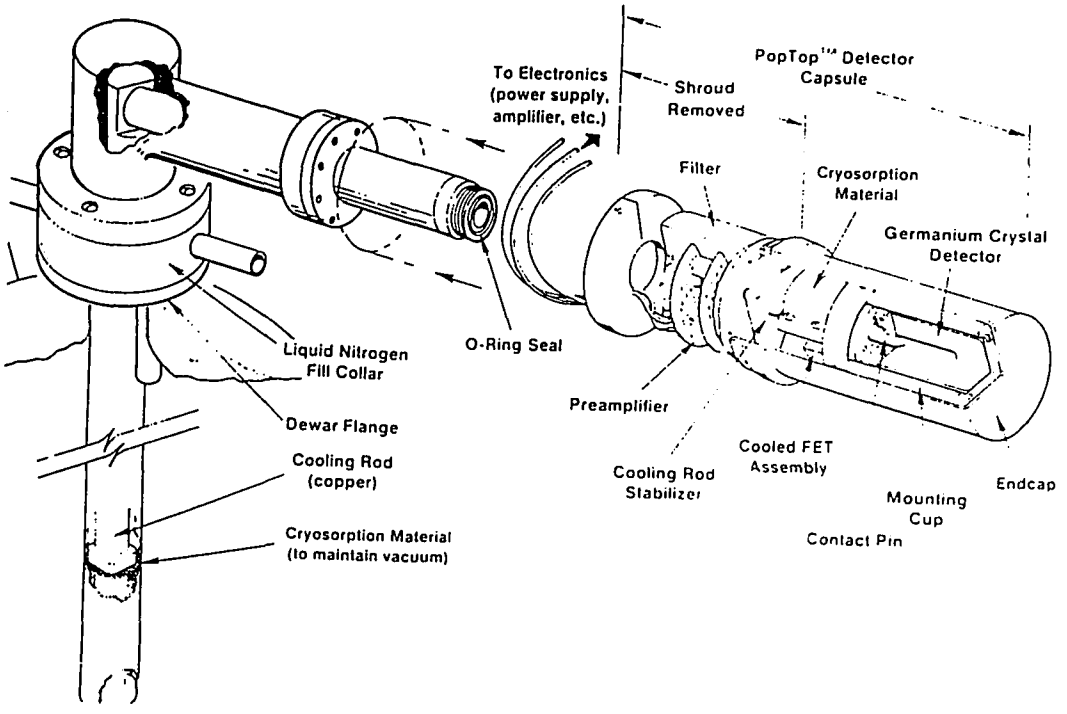

Fig. 1. Sketch of the Ortec HPGe detector and its attachment to a liquid nitrogen filled dewar. Permission obtained from EG&G Ortec to reproduce figure.

This heavy dependence on a cryogenic cooling source is a problem in this stack monitor application. During an accident, replenishment of the liquid nitrogen will not be possible. If the dewar were to run dry the detector would be destroyed. The HPGe could be shut off before the dewar ran dry which would spare the detector.

In either case the loss of a stack monitor during an accident would result. An alternative method of cooling is available and may make service during the accident unnecessary. A refrigeration unit based upon the Solvay cooling cycle is available from Ortec under the trade name Electricool™ (Ortec, 1991/92). Regardless of the method of cooling the detector a connection between the detector element and the cooling supply must exist. This connection must pass through the detector shield and any openings created must be sealed so no secondary containment gases can come in direct contact with the detector element.

Another feature that prompted the selection of the HPGe detector is their high degree of energy resolution. This will be of great importance when the peaks of particular isotopes are identified. The source volume will consist of many different isotopes all emitting gammas of various energies. The better the detector is at distinguishing peaks that have close energy values the more useful the detector system will be to the operators.

3.3 Source Term

The source term for a loss of coolant accident is outlined by the United States Nuclear Regulatory Commission in their regulatory guide 1.3 (Section C 1, 1974) and specified in the WPPSS FSAR (Section 15.6.5.5.1.1). It allows for 100% of the noble gases and 50% of the iodine to become airborne from the damaged fuel. The remaining 50% of the iodine is removed by a combination of plateout and condensation within the secondary. It is only the airborne radioactivity that will ultimately escape into the environment through the exhaust stack.

Calculations regarding which isotopes and how much activity of each is present was produced by an Oak Ridge code Oak Ridge Isotope Generation version 2 (ORIGEN2) and is found in the WPPSS FSAR (Table 15.6-19). These sources identify iodine, krypton and xenon activities for various time periods after the accident. The calculated isotope activities are presented in Tables Ia and Ib.

These activities take into account the additional 0.5% of the fission products released from the fuel each day and the decay the isotopes are undergoing. Figure 2 shows the activity in units of γ/cc*s versus the time in days into the accident.

Since this design must operate during an accident situation it must be based upon the worst case. This is

Table Ia. Secondary containment source terms for a BWR at various times into a loss of coolant accident (LOCA) from ORIGEN2.

Time after LOCA (days)	Halogen Term (γ/cc*s)	Noble Term (γ/cc*s)	Total Term (γ/cc*s)
.04166	3246	4678	7924
.125	6507	8641	15100
.375	9041	13900	22940
1	7200	15000	22200
3	2910	10150	13060
9	1200	4550	5760

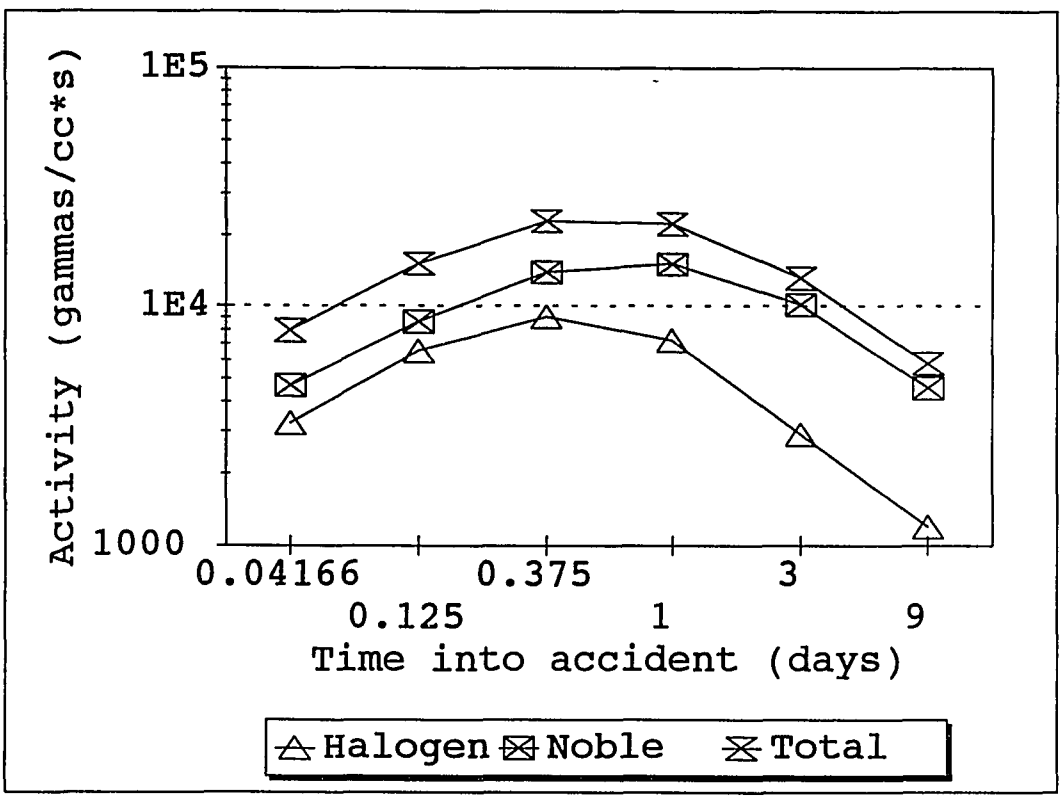

Fig. 2. Graph of source activity verses time into accident.

Table Ib. Source term for the WPPSS BWR 24 hours after a loss of coolant accident (FSAR Table 15.6-19).

Isotope	Activity (Ci) (24hr into LOCA)	Isotope Fraction of Total
I-131	.00617	5.76×10^{-5}
I-132	.00139	1.29×10^{-5}
I-133	.0106	9.90×10^{-5}
I-134	.0009	6.41×10^{-6}
I-135	.00541	5.05×10^{-5}
Kr-83m	.567	.00529
Kr-85m	3.31	.03090
Kr-85	2.67	.02490
Kr-87	1.86	.01730
Kr-88	5.79	.05410
Kr-89	.138	.00128
Xe-131m	.361	.00337
Xe-133m	1.58	.01470
Xe-133	61.0	.57010
Xe-135m	.155	.00144
Xe-135	28.5	.26630
Xe-137	.222	.00207
Xe-138	.848	.00792
Total =	107	1.00

done by selecting the shortest time period after the accident which provides the largest amount of source activity. From Figure 2, 24 hours after the accident provides high enough source activity on which to base the design. According to the WPPSS FSAR (Table 6.2-12 I C) a uniform distribution of the source will exist within the secondary containment 24 hours after the accident.

The ORIGEN2 and FSAR source terms represent the activity present after complete fuel destruction. Since the fuel is completely destroyed the 24 hour case will represent the worst possible case for the WPPSS facility. After 24 hours has elapsed the total source term over the entire energy spectrum is 22200 γ/cc*s. This value is clearly volume dependent and with the secondary containment volume of 9.91×10^{10} cc, the source is now equal to 2.2×10^{15} γ/s within the secondary containment.

The 24 hour ORIGEN2 source term will be the high end of the high range detector term. The low range detector terms will come from the Nuclear Regulatory Commission's regulatory guide 1.97 (Table 2: BWR Variables). Their regulations state that effluent monitoring should begin at 10^{-6} μCi/cc.

Combining the 24 hour source term from ORIGEN2 and the NRC's low range source term a complete detection range is defined. This detection range will cover normal plant

operation through a worst case accident scenario. The detection range is defined from 7.4 x 10^{-2} γ/cc*s through 2.22 x 10^{4} γ/cc*s. Monitoring over this range requires two detectors, one for the high range and one for the low range. An overlap of one decade is incorporated at the high end of the low range and the low end of the high range to prevent the detectors from operating at the less accurate maximum and minimum detection regions. The detection ranges are as follows with the units of μCi/cc are converted to γ/cc*s to be the same as the ORIGEN2 source term units.

Low Range[1]: 4.4 x10^{-2} γ/cc*s to 74 γ/cc*s

High Range[2]: 7.4 γ/cc*s to 2.22 x10^{4} γ/cc*s

3.4 MCNP

The analysis of the collimator and shield's performance was done with a Monte Carlo code MCNP4 made available by Los Alamos National Laboratory. The Monte Carlo Code for Neutron and Photon Transport version 4 (MCNP4) is a general purpose transport code. This code tracks each particle (either gamma or neutron) on a

[1]The low range detector's detection range is defined by the NRC's Regulatory Guide 1.97 (Table 2: BWR variables).

[2]The high end of the high range detector limit used here is defined by the ORIGEN2 source term 24 hours after LOCA.

microscopic level through all of its collisions and will produce output detailing its path. For the gammas being tracked in this study MCNP4 will determine the energy of the gammas that reach and are deposited within the detector element. Any absorption or scatter which results from the gammas passing through the shield or detector housing will also be taken into account when determining how many gammas are deposited within the detector element.

3.5 Design Model

The detector will be viewing the exhaust stack from the secondary containment along the 114.3 cm depth of the stack. Because the stack effluent is traveling up at a rate of 3.77×10^7 cc/s it is assumed that the detector will only see a small portion of the exhaust gasses at any given time. It is further assumed that only the volume contained within the detector element's projection into the stack is the volume the detector will see.

With a stack depth of 114.3 cm the volume the detector sees depends on the collimator dimensions. For the high range detector a source volume of approximately 811 cc is used and for the low range detector a source volume of approximately 2.0×10^4 cc is used. By knowing the activity in units of γ/cc*s for the different detector

ranges and the source volume the detector sees, a calculation of the activity in γ/s that is to be viewed by the detector is made. Table II shows the source term breakdown in γ/s for each case of the four detector ranges over the entire energy spectrum.

The entire geometry and source must be initially defined and put into an input file to be analyzed by MCNP4. This input file's geometry is displayed in Figure 3 and shows (not drawn to scale) the source volume, lead collimator, air gap and the construction of the HPGe detector. Since the program will be calculating the overall gammas being deposited in the germanium element the complete modeling of the detector construction is required for an accurate result. The construction of the detector element was provided by Ortec. The geometry which is constructed of cylindrical elements will accurately model the detector since it is indeed cylindrical. The cylindrical shape will also make construction easier and minimize the weight of the shield without sacrificing the protection.

The design for the detector shield used the same geometry configuration except that the collimator was eliminated and the gap filled with shield material. For both the collimator and shield designs the dimensions of the system were altered repeatedly to achieve the best

TABLE II. Source terms (γ/s) for each of the detector ranges for the defined source volume over the entire energy spectrum.

Energy (MeV)	High End High Range	Low End High Range	High End Low Range	Low End Low Range
.015	2.07×10^{6}	690	1.71×10^{5}	171.9
.025	6.08×10^{5}	201.6	5.02×10^{4}	50.2
.0375	4.37×10^{6}	1455	3.62×10^{5}	362.4
.0575	2.74×10^{5}	91.2	2.27×10^{4}	22.7
.085	3.83×10^{6}	1273.2	3.17×10^{5}	317.1
.125	8.90×10^{4}	29.4	7.32×10^{3}	7.32
.225	2.02×10^{6}	672	1.67×10^{5}	167.4
.375	1.22×10^{6}	406.8	1.01×10^{5}	101.3
.575	2.02×10^{6}	673.8	1.67×10^{5}	167.8
.85	5.56×10^{5}	184.8	4.60×10^{4}	46
1.25	6.02×10^{5}	200.4	4.99×10^{4}	49.9
1.75	1.91×10^{5}	63.6	1.58×10^{4}	15.8
2.25	1.56×10^{5}	51.6	1.28×10^{4}	12.85
2.75	8.84×10^{3}	2.94	7.32×10^{2}	.732
3.5	1.07×10^{3}	.36	89.6	.089
5.0	1.37×10^{2}	.06	14.9	.014
7.0	4.8×10^{-3}	0.0	0.0	0.0
11.0	0.00×10^{0}	0.0	0.0	0.0
Totals =	1.8×10^{7}	6.0×10^{3}	1.5×10^{6}	1.5×10^{3}

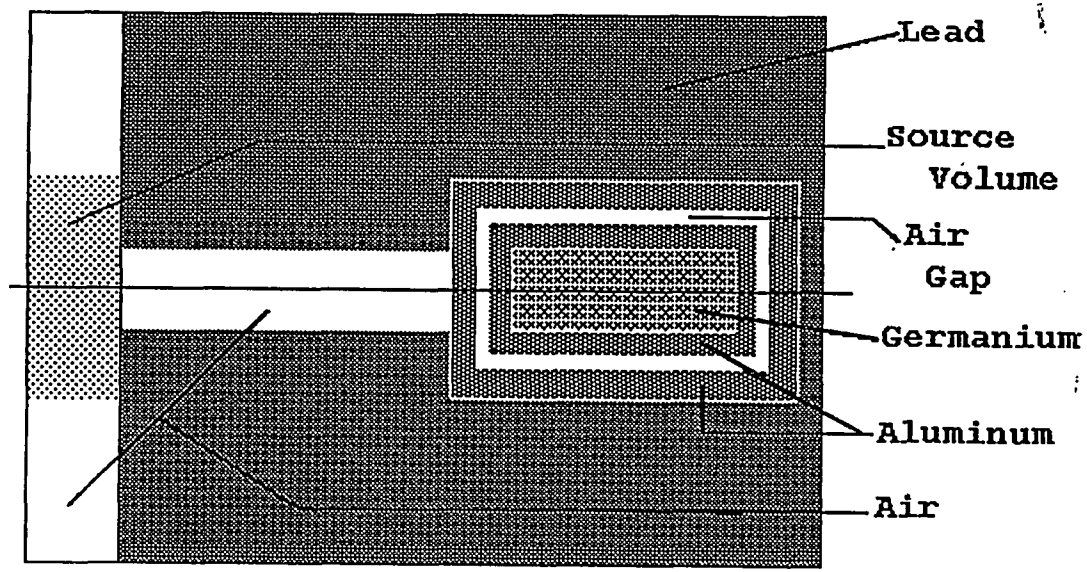

Fig. 3. Sketch of the MCNP4 input file geometry.

reduction and shielding of the source. The complete input and output files used by MCNP4 for the collimator and shield designs are included in Appendices A, B and C.

CHAPTER 4

RESULTS

Results of the MCNP4 runs established that a collimator for the high range detector constructed of lead with a circular opening of diameter 0.4 cm and length of 20 cm would reduce the source activity so the detector is not saturated by the stack effluent expected during a LOCA accident. For the low range detector a collimator constructed of lead with a circular opening of diameter 2 cm and length of 20 cm would allow enough gammas to register within the 15 minute time period to provide good statistical data for the stack effluent during normal facility operating conditions.

The collimator for the high range detector only allowed 1.37% of the gammas present in the 811 cc source volume to register in the detector element over the entire energy spectrum. For the low range detector the collimator allowed 5.32% of the gammas present in the 2.0×10^4 cc source volume to register in the detector element over the entire energy range. Table IIIa shows the fractions generated by MCNP4 of gammas deposited in the high and low range detector elements for each energy group.

Table IIIa. Fractions and errors generated by MCNP4 for the high and low range detector collimators over the entire energy spectrum.

Energy (MeV)	Coll.Frac. High Range	Coll. Error (%)	Coll.Frac. Low Range	Coll. Error (%)
.015	3.17×10^{-4}	17.67	1.61×10^{-3}	7.8
.025	1.98×10^{-4}	22.36	9.52×10^{-4}	10.2
.0375	2.98×10^{-3}	5.76	1.03×10^{-2}	3.0
.0575	2.58×10^{-3}	19.61	1.29×10^{-3}	8.7
.0850	3.84×10^{-3}	5.07	1.44×10^{-2}	2.6
.125	1.98×10^{-4}	22.36	9.22×10^{-4}	10.3
.225	2.03×10^{-3}	6.98	8.41×10^{-3}	3.4
.375	1.40×10^{-3}	8.39	5.35×10^{-3}	4.2
.575	1.36×10^{-3}	8.51	6.07×10^{-3}	4.0
.850	4.96×10^{-4}	14.14	1.84×10^{-3}	7.3
1.25	3.57×10^{-4}	16.66	1.3×10^{-3}	8.7
1.75	1.78×10^{-4}	23.57	4.86×10^{-4}	14.2
2.25	7.93×10^{-5}	35.35	2.08×10^{-4}	21.8
2.75	0.0	0.0	0.0	0.0
3.50	0.0	0.0	0.0	0.0
5.0	0.0	0.0	0.0	0.0
7.0	0.0	0.0	0.0	0.0
11.0	0.0	0.0	0.0	0.0
TOTALS =	1.37×10^{-2}	2.67	5.32×10^{-2}	1.3

The shield which was also constructed of lead to reduce the background term was found to also be 20 cm thick for both the high and low range detectors. Figure 4 is of the collimator and shield design for each detection range. The shield only allowed 2.15×10^{-4}% of the source gammas to register in the detector element. The results of the MCNP4 runs for the shield are presented in Table IIIb.

The cooling equipment will need to pass through the lead shield. As long as 20 cm of lead is surrounding the detector element and no secondary containment or stack effluent air can come in contact with the detector element the detector will monitor the facility stack effluent accurately.

MCNP4 not only produces the fraction of gammas deposited within the detector element but also the error in the fraction of gammas that are deposited. For the high range collimator the error in percent of gammas deposited in the detector element over the entire energy spectrum is 2.67% and for the low range detector the error is 1.3%. The shield error is large but the fraction of gammas that are deposited within the detector is so small that even a 27.7% error will not affect the shield's performance.

With the fraction of gammas deposited in the detector element obtained by MCNP4 and the known initial source values the effectiveness of the collimator and shield can

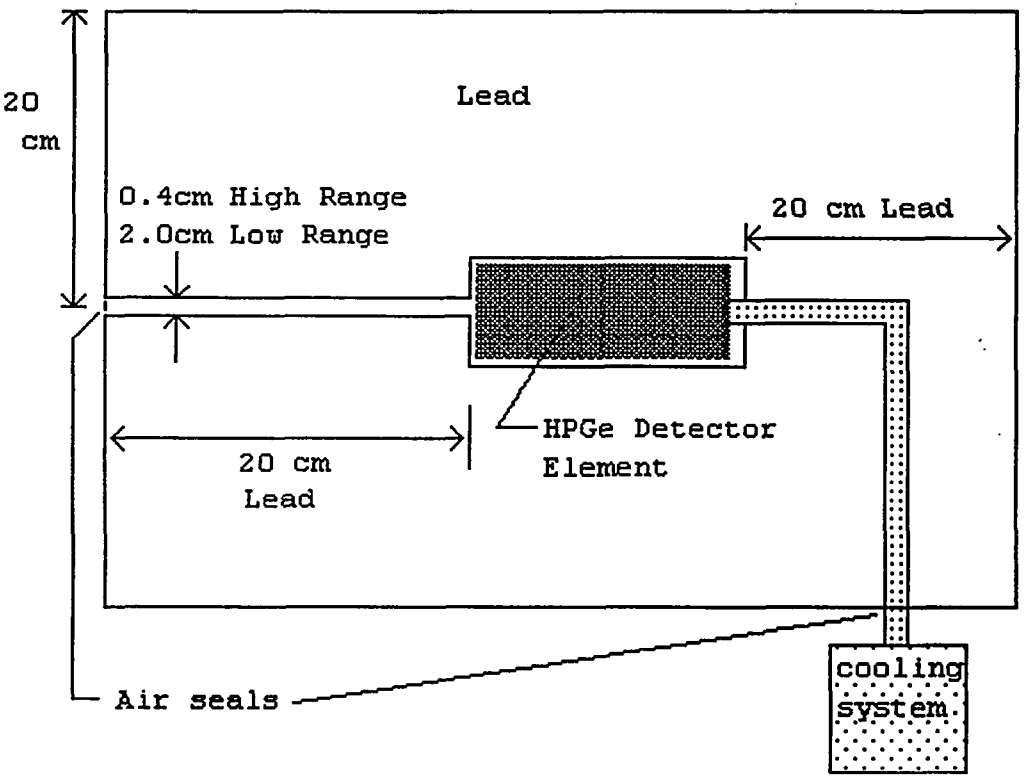

Fig. 4. Sketch of high and low range detector collimator and shield design.

Table IIIb. Fractions and errors generated by MCNP4 for the detector shield over the entire energy spectrum.

Energy (MeV)	Shield Fraction (high; low range)	Shield Error (%)
.015	4.96×10^{-7}	57.7
.025	0.0	0.0
.0375	0.0	0.0
.0575	0.0	0.0
.085	0.0	0.0
.125	0.0	0.0
.225	0.0	0.0
.375	3.30×10^{-7}	70.7
.575	1.65×10^{-7}	100
.85	1.65×10^{-7}	100
1.25	1.65×10^{-7}	100
1.75	6.61×10^{-7}	50
2.25	1.65×10^{-7}	100
2.75	0.0	0.0
3.5	0.0	0.0
5.0	0.0	0.0
7.0	0.0	0.0
11.0	0.0	0.0
Totals =	2.15×10^{-6}	27.73

be determined. For the collimator Table IV presents the detector range, initial source present and the gammas per second that register in the detector element. Table V presents the same information but for the shield design.

Table IV. Reduction in gammas per second from source due to the collimator over the entire energy spectrum.

Detector Ranges	γ/s emitted from Source	γ/s Register in Detector[3]
High Range High End[4]	1.8×10^{7}	2.46×10^{5}
High Range Low End[5]	6.0×10^{3}	82.2
Low Range High End[5]	1.49×10^{6}	7.92×10^{4}
Low Range Low End[5]	1.5×10^{3}	79.8

Table V. Reduction in gammas per second from source due to the shield over the entire energy spectrum.

Detector Ranges	γ/s emitted from Source	γ/s Register in Detector[3]
High Range High End[4]	1.8×10^{7}	38.7
High Range Low End[5]	6.0×10^{3}	1.29×10^{-2}
Low Range High End[5]	1.49×10^{6}	3.21
Low Range Low End[5]	1.5×10^{3}	3.21×10^{-3}

[3]Ortec states detector saturation occurs at 300,000 γ/s.

[4]Defined by ORIGEN2 for 24 hours after a LOCA.

[5]Defined by the NRC's regulatory guide 1.97 (Table 2.BWR variables).

Note the signal from the source through the collimator is more than 6000 times the signal from the background through the shield over the entire energy spectrum of the source. The shield is indeed properly protecting the detector from background interference generated by the source in the secondary containment.

Because the low ends of each detector range source terms are not as large as the high end source terms counting times greater than one second are needed to collect enough counts. A 15 minute count will provide enough counts for the low ends of both detector ranges to produce good statistics. According to Ortec the detector and its electronics can handle approximately 300,000 γ/s before saturation occurs. Since the maximum rate of γ/s is achieved at the high end of the high range detector[6] and is only 2.46×10^5 γ/s no saturation will occur.

To identify the isotopes present in the source volume isotope counting must occur. Krypton-87 because of its 2.97 MeV gamma was selected to be identified. A high energy gamma is desired to avoid as much of the contributions to the peak due to compton scattering from even higher energy gammas as possible. From a review of the known source composition the Kr-87 2.97 MeV gamma is one of the highest energy gammas present. As a result

---

[6]Defined by ORIGEN2 24 hours after the LOCA accident.

little scattering into this peak from higher energy gammas is expected.

The 2.97 MeV gamma of Kr-87 is not as common as other gammas from this isotope. In fact the 2.97 MeV gamma occurs only once in every 2000 gammas emitted (Shirley, 1978). Identification of the Kr-87 isotope from the 2.97 MeV peak will lead to a value of total gammas emitted by Kr-87 since the fraction of Kr-87 with respect to the total source activity is known (WPPSS FSAR Table 15.6-19).

Using the ratios shown in Table VI the gammas present of all other isotopes are found. Having the gammas from each isotope allows for the calculation of the activity present in curies for each isotope. This procedure has been compiled into a spreadsheet[7] which only requires the input of number of counts of the 2.97 MeV gamma to completely determine the source composition in curies. Table VII includes the spreadsheet which presents a source composition for a given number of counts recorded in the 2.97 MeV peak. Identification of different isotopes is possible by adjusting the ratios in Table VI and the spreadsheet in Table VII.

---

[7]Equations used in spreadsheet are found in Appendix D.

Table VI. Ratios of all other source isotopes to Kr-87. Data from WPPSS FSAR Table 15.6-19.

Isotope	Ratio (Iso/Kr-87)	Isotope	Ratio (Iso/Kr-87)
I-131	.00331	Kr-88	3.1129
I-132	.000747	Kr-89	7.4193
I-133	.00569	Xe-131m	.1940
I-134	.000487	Xe-133m	.8494
I-135	.00290	Xe-133	32.7956
Kr-83m	.3048	Xe-135m	.0833
Kr-85m	1.7795	Xe-135	15.3225
Kr-85	1.4838	Xe-137	.1193
Kr-87	1.0	Xe-138	.4559

Table VII. Spreadsheet used to find activity in the secondary for the high range detector. Equations found in App. D.

Isotope to identify: Kr-87

Gamma energy to identify (MeV): 2.97

This energy gamma's probability of occurrence: 0.0005

Total counts in 2.97 MeV channel (gam/s): 10760

Total counts in detector which are from Kr-87 only (gam/s): 2.15E+07

Isotope:	Ratios to Kr-87:	gam / s of isotope:	Activ. of isot in Ci/cc:	Activ. in sec cont.(Ci):
I-131	3.317E-03	7.14E+04	1.19E-09	1.18E+02
I-132	7.473E-04	1.61E+04	2.68E-10	2.66E+01
I-133	5.699E-03	1.23E+05	2.04E-09	2.03E+02
I-134	4.871E-04	1.05E+04	1.75E-10	1.73E+01
I-135	2.909E-03	6.26E+04	1.04E-09	1.03E+02
Kr-83m	3.048E-01	1.417E-08	2.36E-22	2.34E-11
Kr-85m	1.780E+00	3.83E+07	6.38E-07	6.32E+04
Kr-85	1.484E+00	3.19E+07	5.32E-07	5.27E+04
Kr-87	1.000E+00	2.15E+07	3.59E-07	3.55E+04
Kr-88	3.113E+00	6.70E+07	1.12E-06	1.11E+05
Kr-89	7.419E-02	1.60E+06	2.66E-08	2.64E+03
Xe-131m	1.941E-01	4.18E+06	6.96E-08	6.90E+03
Xe-133m	8.495E-01	1.83E+07	3.05E-07	3.02E+04
Xe-133	3.280E+01	7.06E+08	1.18E-05	1.17E+06
Xe-135m	8.333E-02	1.79E+06	2.99E-08	2.96E+03
Xe-135	1.532E+01	3.30E+08	5.49E-06	5.44E+05
Xe-137	1.194E-01	2.57E+06	4.28E-08	4.24E+03
Xe-138	4.559E-01	9.81E+06	1.63E-07	1.62E+04
Total Activity in Secondary Contain. (Ci) =				2.04E+06

Verification of the insignificance of the background term when identifying an isotope is provided by the data in Table VIII. This table compares the source allowed to pass through the collimator into the 2.97 MeV peak of Kr-87 to the contribution of the source from the secondary containment through the shield to the 2.97 MeV peak of Kr-87. With the source passing through the shield composing less than 0.02% of the Kr-87's 2.97 MeV peak it is clear that the shield is quite effective at reducing the background.

Table VIII. Kr-87's 2.97 MeV gamma peak signal through the collimator and shield. Note the low background peak contribution.

Detector Range	Counting Time(min)	Cnts of Peak through Collimator	Cnts of Peak through Shield	Shield Contrib. toward Peak (%)
H. Range High End	15	1.90×10^{3}	0.2995	0.015
H. Range Low End	15	0.6362	9.98×10^{-5}	0.015
Low Range High End	15	613.0	2.48×10^{-2}	0.004
Low Range Low End	15	0.617	2.48×10^{-5}	0.004

CHAPTER 5

CONCLUSIONS

Protecting the high range HPGe detector from the radiation present after a LOCA is possible with a lead shield 20 cm thick. A collimator 0.4 cm in diameter and 20 cm long will reduce the source signal to a level consistent with the detector operating parameters. For the low range detector a collimator 2 cm in diameter, 20 cm long and shield made of lead 20 cm thick is similarly needed. The measure of collimator and shield effectiveness is the reduction of the source activity to prevent saturation of the detector so operators during an accident can evaluate the severity of the situation.

The identification of the Kr-87 isotope requires data about the composition of the source. All calculations performed by Table VII's spreadsheet relied upon the ratios between the activity of Kr-87 and the total activity present in the source and the activity of Kr-87 to all other isotope's activity present in the source. If more accurate data is available about these ratios the identification results and computed source composition will be much more accurate.

The 20 cm of lead shielding has been shown to eliminate any meaningful contribution toward the counting

of Kr-87 or other isotope by the detector from the background contamination in the secondary containment building housing the detector system. The signal received through the collimator is more than 6000 times as strong as the signal through the shield for the high range detector. This is a benefit for counting an isotope in a defined source volume that may not be in abundance. The background could add counts to the peak being counted which would not represent the activity present in the source volume the detector is expected to monitor. By eliminating the background contribution the activity being monitored in the defined source volume is more accurately determined thus the effluent isotopic composition is separated from the secondary containment contamination.

The final system configuration must allow for cooling equipment lines, signal and high voltage leads to be attached to the HPGe. These various cooling and electrical leads will have to penetrate the 20 cm thick lead shield. As long as 20 cm of lead surrounds the detector element and all air gaps are sealed so no secondary containment gases come in contact with the detector element the HPGe should accurately monitor the stack effluent.

APPENDIX A

MCNP4 HIGH RANGE DETECTOR COLLIMATOR

INPUT AND OUTPUT FILES

```
lmcnp     version 4.2m4 ld= 6/30/91
     4/ 8/93 10:20:45

     ************************************************************
     ***************                    probid =    4/ 8/93
     10:20:45
      inp=nplug outp=thesis.H

         1-        detector problem
         2-             1    1    -5.33      -22 20 -21
         3-             2    2    -2.7       -25 23 -24 #1
         4-             3    4    -.0012     -28 26 -27 #1 #2
         5-             4    2    -2.7       -31 28 29 -30
         6-             5    4    -.0012      32 -33 -38
         7-             6    3    -11.3       29 -30 -34 31
         8-             7    0               -35(34:30:-32)
         9-             8    0                35
        10-             9    2    -2.7       -28 27 -30
        11-            10    2    -2.7       -28 29 -26
        12-            11    4    -.0012        33 -36 -37
        13-            12    4    -.0012       36 -29 -37
        14-            13    3    -11.3       33 -29 -34 37
        15-            14    4    -.0012      32 -33 38 -34
        16-
        17-            20   py    135.38
        18-            21   py    142.38
        19-            22   cy    3.5
        20-            23   py    135.33
        21-            24   py    142.43
        22-            25   cy    3.55
        23-            26   py    134.83
        24-            27   py    142.93
        25-            28   cy    3.62
        26-            29   py    134.7
        27-            30   py    143.06
```

```
   28-          31   cy   3.75

   29-          32   py   0.0

   30-          33   py   114.7

   31-          34   cy   23.75

   32-          35   so   300.0

   33-          36   py   117.7

   34-          37   cy   .2

   35-          38   cy   1.5

   36-

   37-       mode p

   38-       imp:p     1 1 1 1 1 1 0 0 1 1 1 1 1 1

   39-       m1   32000      1

   40-       m2   13000      1

   41-       m3   82000      1

   42-       m4   7000  -0.79      8000  -0.21

   43-       sdef erg=d1 pos 0 67.35 0 cel=5 dir=1.0 vec 0
1 0 axs 0 1 0 rad=d2 ext=d3
   44-       si1  0 .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   45-            2.75 3.5 5.0

   46-       sp1  d 0 .115 .0336 .2425 .0152 .2122 .0049
.112 .0678 .1123 .0308 .0334
   47-              .0106 .0086 .00049 .0000597 .00000763

   48-       si2  3.75

   49-       sp2  -21

   50-       si3  67.35

   51-       sp3  -31

   52-       e0   .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   53-            2.75 3.5 5.0 7.0 11.0

   54-       e8   .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   55-            2.75 3.5 5.0 7.0 11.0

   56-       f1:p 27

   57-       f4:p 1 2 3 4 5 6 7 9 10 11 12 13 14

   58-       f8:p 1 2 3 4 5 6 7 8 9 10 11 12 13 14
```

```
   59-        nps  100000

   60-        print     -85  -110

1source                                                  print table
10

 values of defaulted or explicitly defined source
variables

    cel         5.0000E+00
    sur         0.0000E+00
    tme         0.0000E+00
    dir         1.0000E+00
    pos         0.0000E+00    6.7350E+01    0.0000E+00
    x           0.0000E+00
    y           0.0000E+00
    z           0.0000E+00
    axs         0.0000E+00    1.0000E+00    0.0000E+00
    vec         0.0000E+00    1.0000E+00    0.0000E+00
    ccc         0.0000E+00
    nrm         1.0000E+00
    ara         0.0000E+00
    wgt         1.0000E+00
    eff         1.0000E-02
    par         0.0000E+00


 probability distribution   2 for source variable rad
 power law 21:      f(x)=c*abs(x)**k          k =
1.0000E+00


 probability distribution   3 for source variable ext
 exponential function 31:     f(x)=c*exp(k*x)          k =
0.0000E+00


 probability distribution   1 for source variable erg
 unbiased histogram distribution

 source        source           cumulative
probability
  entry         value           probability          of
bin

    1       1.00000E-03        0.000000E+00
0.000000E+00
    2       1.50000E-02        1.082218E-01
1.082218E-01
    3       2.50000E-02        1.420999E-01
3.387812E-02
    4       3.75000E-02        3.866071E-01
2.445072E-01
    5       5.75000E-02        4.019329E-01
1.532581E-02
    6       8.50000E-02        6.158894E-01
```

```
2.139564E-01
    7       1.25000E-01         6.208299E-01
4.940559E-03
    8       2.25000E-01         7.337570E-01
1.129271E-01
    9       3.75000E-01         8.021182E-01
6.836120E-02
   10       5.75000E-01         9.153477E-01
1.132295E-01
   11       8.50000E-01         9.464027E-01
3.105494E-02
   12       1.25000E+00         9.800791E-01
3.367646E-02
   13       1.75000E+00         9.907669E-01
1.068774E-02
   14       2.25000E+00         9.994381E-01
8.671185E-03
   15       2.75000E+00         9.999321E-01
4.940559E-04
   16       3.50000E+00         9.999923E-01
6.019415E-05
   17       5.00000E+00         1.000000E+00
7.693156E-06

     the mean of source distribution   1 is  2.1205E-01

    fraction of energy distribution outside range =
7.6708E-03


 order of sampling source variables.
 cel axs rad ext pos vec dir erg tme
1tally   1
                                                    print table 30
           tally type 1    number of particles crossing a
surface.
           tally for  photons

 surfaces       27


 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1tally   4
```

```
                                                          print table 30
          tally type 4    track length estimate of
particle flux.
          tally for  photons

 warning.  cell    7 of tally   4 has zero importance.

 cells           1       2       3       4       5       6
7       9      10      11      12      13      14

 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
ltally   8
                                                          print table 30
          tally type 8    pulse height distribution.

          tally for  photons

 warning.  cell    7 of tally   8 has zero importance.

 warning.  cell    8 of tally   8 has zero importance.

 warning.  tally   8 needs zero energy bin for negative f8
scores.

 cells           1       2       3       4       5       6
7       8       9      10      11      12      13      14

 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
```

```
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1material composition
                                                    print table 40

 material
  number      component nuclide, atom fraction

     1            32000,  1.00000
     2            13000,  1.00000
     3            82000,  1.00000
     4             7000,  0.81122        8000,  0.18878



 material
  number      component nuclide, mass fraction

     1            32000,  1.00000
     2            13000,  1.00000
     3            82000,  1.00000
     4             7000,  0.79000        8000,  0.21000
1cell volumes and masses
                                                    print table 50

        cell      atom          gram          input
calculated                                reason volume
                   density       density       volume
volume           mass        pieces     not calculated

     1     1  4.41918E-02   5.33000E+00   0.00000E+00
2.69392E+02   1.43586E+03      1
     2     2  6.02616E-02   2.70000E+00   0.00000E+00
1.17111E+01   3.16199E+01      1
     3     3  5.02433E-05   1.20000E-03   0.00000E+00
5.23637E+01   6.28365E-02      1
     4     4  6.02616E-02   2.70000E+00   0.00000E+00
2.51633E+01   6.79408E+01      1
     5     5  5.02433E-05   1.20000E-03   0.00000E+00
8.10767E+02   9.72920E-01      1
     6     6  3.28395E-02   1.13000E+01   0.00000E+00
1.44450E+04   1.63229E+05      1
     7     7  0.00000E+00   0.00000E+00   0.00000E+00
1.12844E+08   0.00000E+00      1
     8     8  0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00      0       infinite
     9     9  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01      1
    10    10  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01      1
    11    11  5.02433E-05   1.20000E-03   0.00000E+00
3.76991E-01   4.52389E-04      1
    12    12  5.02433E-05   1.20000E-03   0.00000E+00
2.13628E+00   2.56354E-03      1
    13    13  3.28395E-02   1.13000E+01   0.00000E+00
3.54386E+04   4.00456E+05      1
    14    14  5.02433E-05   1.20000E-03   0.00000E+00
2.02444E+05   2.42933E+02      1
```

1surface areas

print table 50

surface		input area	calculated area	reason area not calculated
1	20	0.00000E+00	3.84845E+01	
2	21	0.00000E+00	3.84845E+01	
3	22	0.00000E+00	1.53938E+02	
4	23	0.00000E+00	3.95919E+01	
5	24	0.00000E+00	3.95919E+01	
6	25	0.00000E+00	1.58368E+02	
7	26	0.00000E+00	4.11687E+01	
8	27	0.00000E+00	4.11687E+01	
9	28	0.00000E+00	1.90149E+02	
10	29	0.00000E+00	1.77205E+03	
11	30	0.00000E+00	1.77205E+03	
12	31	0.00000E+00	1.96978E+02	
13	32	0.00000E+00	1.77205E+03	
14	33	0.00000E+00	1.77205E+03	
15	34	0.00000E+00	2.13482E+04	
16	35	0.00000E+00	1.13097E+06	
17	36	0.00000E+00	1.25664E-01	
18	37	0.00000E+00	2.51327E+01	
19	38	0.00000E+00	1.08102E+03	

1cells

print table 60

cell	mat	density	atom density	gram density	volume	mass
	pieces		photon importance			
1	1	1	4.41918E-02	5.33000E+00	2.69392E+02	1.43586E+03
		1	1.00000E+00			
2	2	2	6.02616E-02	2.70000E+00	1.17111E+01	3.16199E+01
		1	1.00000E+00			
3	3	4	5.02433E-05	1.20000E-03	5.23637E+01	6.28365E-02
		1	1.00000E+00			

```
     4     4     2  6.02616E-02 2.70000E+00 2.51633E+01
6.79408E+01      1  1.00000E+00

     5     5     4  5.02433E-05 1.20000E-03 8.10767E+02
9.72920E-01      1  1.00000E+00

     6     6     3  3.28395E-02 1.13000E+01 1.44450E+04
1.63229E+05      1  1.00000E+00

     7     7     0  0.00000E+00 0.00000E+00 1.12844E+08
0.00000E+00      1  0.00000E+00

     8     8     0  0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00      0  0.00000E+00

     9     9     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    10    10     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    11    11     4  5.02433E-05 1.20000E-03 3.76991E-01
4.52389E-04      1  1.00000E+00

    12    12     4  5.02433E-05 1.20000E-03 2.13628E+00
2.56354E-03      1  1.00000E+00

    13    13     3  3.28395E-02 1.13000E+01 3.54386E+04
4.00456E+05      1  1.00000E+00

    14    14     4  5.02433E-05 1.20000E-03 2.02444E+05
2.42933E+02      1  1.00000E+00

 total                                      1.13097E+08
5.65493E+05
1surfaces

                                            print table 70
```

surface		trans	type	surface coefficients
1	20		py	1.3538000E+02
2	21		py	1.4238000E+02
3	22		cy	3.5000000E+00
4	23		py	1.3533000E+02
5	24		py	1.4243000E+02
6	25		cy	3.5500000E+00
7	26		py	1.3483000E+02
8	27		py	1.4293000E+02
9	28		cy	3.6200000E+00
10	29		py	1.3470000E+02
11	30		py	1.4306000E+02
12	31		cy	3.7500000E+00
13	32		py	0.0000000E+00
14	33		py	1.1470000E+02
15	34		cy	2.3750000E+01
16	35		so	3.0000000E+02
17	36		py	1.1770000E+02
18	37		cy	2.0000000E-01
19	38		cy	1.5000000E+00

```
    minimum source weight = 9.9233E-01    maximum source
weight = 1.0000E+00

         4 warning messages so far.
1cross-section tables
                                                print table 100

     table    length

                          tables from file 7000.01p2

   7000.01p     389

12/13/82

                          tables from file 8000.01p2

   8000.01p     389

12/13/82

                          tables from file 13000.01p2

  13000.01p     409

12/13/82

                          tables from file 32000.01p2

  32000.01p     457

12/13/82

                          tables from file 82000.01p2

  82000.01p     521

12/13/82

  total        2165

                          tables from file 7000.01e2

   7000.01e     478
                                                    11/16/88

                          tables from file 8000.01e2

   8000.01e     478
                                                    11/16/88

                          tables from file 13000.01e2
```

```
  13000.01e     478
                                                        11/16/88

                        tables from file 32000.01e2

  32000.01e     478
                                                        11/16/88

                        tables from file 82000.01e2

  82000.01e     478
                                                        11/16/88



 use of dynamically allocated storage

     general              467478
     tallies                6596
     bank                   6403
     cross sections         2165

     total                482642

************************************************************
***************
 dump no.  1 on file   runtpw          nps =       0
  ctm =    0.00


         4 warning messages so far.
1problem summary

      run terminated when    100000 particle histories
were done.                                          4/ 8/93
10:36: 7
       detector problem
                                probid =    4/ 8/93
10:20:45
0
 photon creation      tracks      weight        energy
     photon loss          tracks      weight        energy
                                  (per source particle)
                                      (per source particle)

 source               100000    9.9233E-01    2.1281E-01
     escape                3151    3.1268E-02
2.7701E-03

     energy cutoff            0    0.            0.


     time cutoff              0    0.            0.
```

```
 weight window              0     0.              0.
     weight window                0     0.              0.

 cell importance            0     0.              0.
     cell importance              0     0.              0.

 weight cutoff              0     0.              0.
     weight cutoff                0     0.              0.

 energy importance          0     0.              0.
     energy importance            0     0.              0.

 dxtran                     0     0.              0.
     dxtran                       0     0.              0.

 forced collisions          0     0.              0.
     forced collisions            0     0.              0.

 exp. transform             0     0.              0.
     exp. transform               0     0.              0.

 from neutrons              0     0.              0.
     compton scatter              0     0.
5.6013E-02
 bremsstrahlung         25403     2.5208E-01     6.2228E-03
     capture               189864     1.8841E+00
1.8576E-01
 p-annihilation           332     3.2945E-03     1.6965E-03
     pair production          166     1.6473E-03
3.3349E-03
 electron x-rays            0     0.              0.


 1st fluorescence       58106     5.7660E-01     2.6000E-02


 2nd fluorescence        9340     9.2684E-02     1.1406E-03


     total             193181     1.9170E+00     2.4787E-01
         total             193181     1.9170E+00
2.4787E-01

   number of photons banked                          34909
average lifetime, shakes                 cutoffs
   photon tracks per source particle        1.9318E+00
  escape              2.7100E-01            tco   1.0000E+34
   photon collisions per source particle  2.2765E+00
  capture             1.0836E-01            eco   1.0000E-03
   total photon collisions                        227653
  capture or escape 1.1102E-01              wc1   0.0000E+00

  any termination    1.1092E-01             wc2   0.0000E+00

 computer time so far in this run     15.10 minutes
  maximum number ever in bank          8
 computer time in mcrun               12.03 minutes
  bank overflows to backup file        0
 source particles per minute             8.3099E+03
  field length                         0
 random numbers generated                    3540328
```

most random numbers used was 278 in history 92871

range of sampled source weights = 9.9233E-01 to 9.9233E-01

source efficiency = 0.1591 in cell 5

1source distribution frequency tables

print table 170

the expected values below do not include the effect of the rejection loop which samples position.

source distribution 1 for erg

n	source value	weight sampled	weight expected	weight sampled/expected	number sampled	number expected	number sampled/expected
1	1.50000E-02	1.0902E-01	1.0822E-01	1.0074E+00	1.0818E-01	1.0739E-01	1.0074E+00
2	2.50000E-02	3.3820E-02	3.3878E-02	9.9828E-01	3.3561E-02	3.3618E-02	9.9828E-01
3	3.75000E-02	2.4363E-01	2.4451E-01	9.9641E-01	2.4176E-01	2.4263E-01	9.9641E-01
4	5.75000E-02	1.5410E-02	1.5326E-02	1.0055E+00	1.5292E-02	1.5208E-02	1.0055E+00
5	8.50000E-02	2.1377E-01	2.1396E-01	9.9913E-01	2.1213E-01	2.1232E-01	9.9913E-01
6	1.25000E-01	4.8900E-03	4.9406E-03	9.8977E-01	4.8525E-03	4.9027E-03	9.8977E-01
7	2.25000E-01	1.1389E-01	1.1293E-01	1.0085E+00	1.1302E-01	1.1206E-01	1.0085E+00
8	3.75000E-01	6.7350E-02	6.8361E-02	9.8521E-01	6.6833E-02	6.7837E-02	9.8521E-01
9	5.75000E-01	1.1224E-01	1.1323E-01	9.9126E-01	1.1138E-01	1.1236E-01	9.9126E-01
10	8.50000E-01	3.1810E-02	3.1055E-02	1.0243E+00	3.1566E-02	3.0817E-02	1.0243E+00
11	1.25000E+00	3.3750E-02	3.3676E-02	1.0022E+00	3.3491E-02	3.3418E-02	1.0022E+00
12	1.75000E+00	1.1020E-02	1.0688E-02	1.0311E+00	1.0935E-02	1.0606E-02	1.0311E+00
13	2.25000E+00	8.7900E-03	8.6712E-03	1.0137E+00	8.7226E-03	8.6047E-03	1.0137E+00
14	2.75000E+00	4.9000E-04	4.9406E-04	9.9179E-01	4.8624E-04	4.9027E-04	9.9179E-01
15	3.50000E+00	9.0000E-05	6.0194E-05	1.4952E+00	8.9310E-05	5.9732E-05	1.4952E+00
16	5.00000E+00	3.0000E-05	7.6932E-06	3.8996E+00	2.9770E-05	7.6341E-06	3.8996E+00
total		1.0000E+00	1.0000E+00	1.0000E+00	9.9233E-01	9.9233E-01	1.0000E+00

1photon activity in each cell

print table 126

	tracks	population	collisions

```
collisions     number        flux        average
average
        cell    entering                              *
weight      weighted      weighted    track weight    track
mfp
                                                      (per
history)     energy        energy      (relative)     (cm)

     1      1         1396          1532         3244
3.2191E-02   4.9593E-01   4.9593E-01   9.9233E-01
1.9673E+00
     2      2         1671          1443           89
8.8317E-04   2.8318E-01   2.8318E-01   9.9233E-01
2.7220E+00
     3      3         1681          1442            0
0.0000E+00   2.7831E-01   2.7831E-01   9.9233E-01
6.5720E+03
     4      4           98            92            3
2.9770E-05   2.8497E-01   2.8497E-01   9.9233E-01
3.3104E+00
     5      5       102560        100045         6315
6.2666E-02   2.2147E-01   2.2147E-01   9.9233E-01
5.5714E+03
     6      6           90           138          267
2.6495E-03   3.8007E-01   3.8007E-01   9.9233E-01
3.6885E-01
     9      9           69            69            0
0.0000E+00   7.0718E-01   7.0718E-01   9.9233E-01
4.9555E+00
    10     10         1810          1732          383
3.8006E-03   2.4424E-01   2.4424E-01   9.9233E-01
2.3894E+00
    11     11         1988          1982            5
4.9616E-05   2.3573E-01   2.3573E-01   9.9233E-01
5.7151E+03
    12     12         1810          1785            9
8.9310E-05   2.3125E-01   2.3125E-01   9.9233E-01
5.6617E+03
    13     13        92637        127060       217181
2.1552E+00   7.5878E-01   7.5878E-01   9.9233E-01
8.4858E-01
    14     14         3494          3474          157
1.5580E-03   7.0753E-02   7.0753E-02   9.9233E-01
3.6002E+03

     total        209304        240794       227653
2.2591E+00
1photon   weight balance in each cell -- external events
                                                print table
130

        cell    entering        source        energy
time        exiting        total
                                              cutoff
cutoff

     1      1   1.3853E-02   0.0000E+00   0.0000E+00
0.0000E+00  -2.1930E-03   1.1660E-02
     2      2   1.6582E-02   0.0000E+00   0.0000E+00
0.0000E+00  -1.6125E-02   4.5647E-04
     3      3   1.6681E-02   0.0000E+00   0.0000E+00
0.0000E+00  -1.6681E-02   0.0000E+00
```

```
     4     4   9.7248E-04   0.0000E+00   0.0000E+00
0.0000E+00  -9.7248E-04   0.0000E+00
     5     5   2.5404E-02   9.9233E-01   0.0000E+00
0.0000E+00  -9.6440E-01   5.3338E-02
     6     6   8.9310E-04   0.0000E+00   0.0000E+00
0.0000E+00  -5.9540E-05   8.3356E-04
     9     9   6.8471E-04   0.0000E+00   0.0000E+00
0.0000E+00  -6.8471E-04   0.0000E+00
    10    10   1.7961E-02   0.0000E+00   0.0000E+00
0.0000E+00  -1.5262E-02   2.6991E-03
    11    11   1.9728E-02   0.0000E+00   0.0000E+00
0.0000E+00  -1.9678E-02   4.9616E-05
    12    12   1.7961E-02   0.0000E+00   0.0000E+00
0.0000E+00  -1.7902E-02   5.9540E-05
    13    13   9.1926E-01   0.0000E+00   0.0000E+00
0.0000E+00  -2.8539E-02   8.9072E-01
    14    14   3.4672E-02   0.0000E+00   0.0000E+00
0.0000E+00  -3.3432E-02   1.2404E-03

    total     1.0847E+00   9.9233E-01   0.0000E+00
0.0000E+00  -1.1159E+00   9.6106E-01
1photon   weight balance in each cell -- variance
reduction events
print table 130

        cell      weight        cell         weight
energy        dxtran       forced    exponential      total
              window     importance      cutoff
importance                collision    transform

     1     1   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     2     2   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     3     3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4     4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     5     5   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     6     6   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     9     9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10    10   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    11    11   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    12    12   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    13    13   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
```

```
0.0000E+00
    14     14   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00

     total      0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
1photon weight balance in each cell -- physical events
                                              print table
130

        cell      from        brems-     p-annihi-
electron  fluorescence    capture        pair        total
                neutrons    strahlung      lation
x-rays                                 production

     1      1   0.0000E+00   1.4389E-03   0.0000E+00
0.0000E+00   5.3586E-03  -1.8457E-02   0.0000E+00
-1.1660E-02
     2      2   0.0000E+00   2.9770E-05   0.0000E+00
0.0000E+00   1.9847E-05  -5.0609E-04   0.0000E+00
-4.5647E-04
     3      3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4      4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     5      5   0.0000E+00   6.9463E-05   0.0000E+00
0.0000E+00   0.0000E+00  -5.3407E-02   0.0000E+00
-5.3338E-02
     6      6   0.0000E+00   2.8778E-04   0.0000E+00
0.0000E+00   1.1511E-03  -2.2724E-03   0.0000E+00
-8.3356E-04
     9      9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10     10   0.0000E+00   1.9847E-05   0.0000E+00
0.0000E+00   9.9233E-05  -2.8182E-03   0.0000E+00
-2.6991E-03
    11     11   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -4.9616E-05   0.0000E+00
-4.9616E-05
    12     12   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -5.9540E-05   0.0000E+00
-5.9540E-05
    13     13   0.0000E+00   2.5024E-01   3.2945E-03
0.0000E+00   6.6266E-01  -1.8053E+00  -1.6473E-03
-8.9072E-01
    14     14   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -1.2404E-03   0.0000E+00
-1.2404E-03

     total      0.0000E+00   2.5208E-01   3.2945E-03
0.0000E+00   6.6929E-01  -1.8841E+00  -1.6473E-03
-9.6106E-01
1photon activity of each nuclide in each cell, per source
particle                                      print table
140

        cell    nuclides      atom         total
```

collisions		weight lost	total from	weight from	
avg photon					
			fraction	collisions	*
weight		to capture	neutrons	neutrons	
energy					
1	1	32000.01p	1.0000E+00	3244	
3.2191E-02		1.8457E-02	0	0.0000E+00	
0.0000E+00					
2	2	13000.01p	1.0000E+00	89	
8.8317E-04		5.0609E-04	0	0.0000E+00	
0.0000E+00					
3	3	7000.01p	8.1122E-01	0	
0.0000E+00		0.0000E+00	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	0	
0.0000E+00		0.0000E+00	0	0.0000E+00	
0.0000E+00					
4	4	13000.01p	1.0000E+00	3	
2.9770E-05		0.0000E+00	0	0.0000E+00	
0.0000E+00					
5	5	7000.01p	8.1122E-01	4585	
4.5498E-02		3.8234E-02	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	1730	
1.7167E-02		1.5173E-02	0	0.0000E+00	
0.0000E+00					
6	6	82000.01p	1.0000E+00	267	
2.6495E-03		2.2724E-03	0	0.0000E+00	
0.0000E+00					
9	9	13000.01p	1.0000E+00	0	
0.0000E+00		0.0000E+00	0	0.0000E+00	
0.0000E+00					
10	10	13000.01p	1.0000E+00	383	
3.8006E-03		2.8182E-03	0	0.0000E+00	
0.0000E+00					
11	11	7000.01p	8.1122E-01	3	
2.9770E-05		2.9770E-05	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	2	
1.9847E-05		1.9847E-05	0	0.0000E+00	
0.0000E+00					
12	12	7000.01p	8.1122E-01	9	
8.9310E-05		5.9540E-05	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	0	
0.0000E+00		0.0000E+00	0	0.0000E+00	
0.0000E+00					
13	13	82000.01p	1.0000E+00	217181	
2.1552E+00		1.8053E+00	0	0.0000E+00	
0.0000E+00					

```
    14     14     7000.01p  8.1122E-01          103
1.0221E-03     7.7402E-04           0       0.0000E+00
0.0000E+00
                  8000.01p  1.8878E-01           54
5.3586E-04     4.6639E-04           0       0.0000E+00
0.0000E+00

      total                                   227653
2.2591E+00     1.8841E+00           0       0.0000E+00
0.0000E+00


    total over all cells for each nuclide

                  7000.01p                      4700
4.6639E-02     3.9098E-02           0       0.0000E+00
0.0000E+00
                  8000.01p                      1786
1.7723E-02     1.5659E-02           0       0.0000E+00
0.0000E+00
                 13000.01p                       475
4.7136E-03     3.3243E-03           0       0.0000E+00
0.0000E+00
                 32000.01p                      3244
3.2191E-02     1.8457E-02           0       0.0000E+00
0.0000E+00
                 82000.01p                    217448
2.1578E+00     1.8075E+00           0       0.0000E+00
0.0000E+00
1tally   1        nps =   100000
          tally type 1    number of particles crossing a
surface.
          tally for  photons

 surface  27


      energy
    1.5000E-02   0.00000E+00 0.0000
    2.5000E-02   0.00000E+00 0.0000
    3.7500E-02   0.00000E+00 0.0000
    5.7500E-02   0.00000E+00 0.0000
    8.5000E-02   0.00000E+00 0.0000
    1.2500E-01   0.00000E+00 0.0000
    2.2500E-01   5.95398E-05 0.4082
    3.7500E-01   8.93096E-05 0.3333
    5.7500E-01   1.58773E-04 0.2500
    8.5000E-01   1.88543E-04 0.2294
    1.2500E+00   9.92329E-05 0.3162
    1.7500E+00   5.95398E-05 0.4082
    2.2500E+00   1.98466E-05 0.7071
    2.7500E+00   9.92329E-06 1.0000
    3.5000E+00   0.00000E+00 0.0000
    5.0000E+00   0.00000E+00 0.0000
    7.0000E+00   0.00000E+00 0.0000
    1.1000E+01   0.00000E+00 0.0000
      total      6.84707E-04 0.1203

 for the tally-fluctuation-chart bin:
 average tally per history = 6.84707E-04
largest tally in one history = 9.92329E-01
 (largest tally)/(average tally) = 1.44928E+03      nps of
```

```
largest tally =     1043
1tally   4        nps =   100000
          tally type 4    track length estimate of
particle flux.      units   1/cm**2
          tally for  photons

          volumes
                   cell:       1            2            3
          4            5            6            7
                              2.69392E+02  1.17111E+01
5.23637E+01  2.51633E+01  8.10767E+02  1.44450E+04
1.12844E+08
                   cell:       9           10           11
         12           13           14
                              5.35193E+00  5.35193E+00
3.76991E-01  2.13628E+00  3.54386E+04  2.02444E+05

 cell  1


     energy
   1.5000E-02   1.00964E-07 0.0609
   2.5000E-02   4.43998E-09 0.2838
   3.7500E-02   1.97112E-07 0.0849
   5.7500E-02   1.10101E-07 0.1911
   8.5000E-02   2.61662E-06 0.0669
   1.2500E-01   2.95683E-06 0.1174
   2.2500E-01   2.24566E-05 0.0616
   3.7500E-01   2.12673E-05 0.0753
   5.7500E-01   2.18147E-05 0.0851
   8.5000E-01   1.27123E-05 0.1173
   1.2500E+00   7.13835E-06 0.1534
   1.7500E+00   3.15657E-06 0.2320
   2.2500E+00   2.78144E-06 0.2552
   2.7500E+00   2.57852E-07 1.0000
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
   1.1000E+01   0.00000E+00 0.0000
     total      9.75711E-05 0.0461

 cell  2


     energy
   1.5000E-02   1.25142E-07 0.4797
   2.5000E-02   7.66995E-07 0.2423
   3.7500E-02   1.42833E-05 0.0621
   5.7500E-02   1.04123E-06 0.2309
   8.5000E-02   1.77968E-05 0.0535
   1.2500E-01   9.67368E-07 0.2462
   2.2500E-01   1.35691E-05 0.0830
   3.7500E-01   8.84297E-06 0.1047
   5.7500E-01   1.00379E-05 0.0709
   8.5000E-01   4.41036E-06 0.1139
   1.2500E+00   2.82917E-06 0.1351
   1.7500E+00   1.28401E-06 0.2057
   2.2500E+00   1.01104E-06 0.2209
   2.7500E+00   8.47343E-08 1.0000
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
```

1.1000E+01	0.00000E+00	0.0000
total	7.70501E-05	0.0323

cell 3

energy		
1.5000E-02	1.89507E-07	0.7071
2.5000E-02	2.32349E-06	0.2357
3.7500E-02	3.32436E-05	0.0587
5.7500E-02	2.38517E-06	0.2298
8.5000E-02	3.91667E-05	0.0532
1.2500E-01	2.35221E-06	0.2359
2.2500E-01	2.74710E-05	0.0754
3.7500E-01	1.47413E-05	0.0992
5.7500E-01	2.08984E-05	0.0711
8.5000E-01	8.90553E-06	0.1182
1.2500E+00	6.39713E-06	0.1344
1.7500E+00	2.87168E-06	0.2057
2.2500E+00	2.27588E-06	0.2206
2.7500E+00	1.89507E-07	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.63411E-04	0.0297

cell 4

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	5.13817E-08	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	8.07746E-07	0.4205
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	1.99864E-06	0.2746
3.7500E-01	2.58147E-06	0.1826
5.7500E-01	1.04456E-06	0.2450
8.5000E-01	5.13800E-07	0.3622
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.99761E-06	0.1296

cell 5

energy		
1.5000E-02	4.09075E-03	0.0109
2.5000E-02	1.91978E-03	0.0170
3.7500E-02	1.40148E-02	0.0056
5.7500E-02	8.89351E-04	0.0253
8.5000E-02	1.23798E-02	0.0061
1.2500E-01	2.86518E-04	0.0446
2.2500E-01	6.58424E-03	0.0088

3.7500E-01	3.89517E-03	0.0118
5.7500E-01	6.48808E-03	0.0089
8.5000E-01	1.83894E-03	0.0175
1.2500E+00	1.95026E-03	0.0169
1.7500E+00	6.38192E-04	0.0300
2.2500E+00	5.09201E-04	0.0336
2.7500E+00	2.83179E-05	0.1428
3.5000E+00	5.23857E-06	0.3333
5.0000E+00	1.75019E-06	0.5774
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	5.55204E-02	0.0006

cell 6

energy		
1.5000E-02	3.25493E-11	0.2327
2.5000E-02	4.26683E-13	1.0000
3.7500E-02	1.85161E-12	1.0000
5.7500E-02	1.29142E-11	0.7666
8.5000E-02	1.37481E-09	0.1621
1.2500E-01	4.01150E-11	0.7697
2.2500E-01	1.47337E-09	0.2261
3.7500E-01	7.20747E-09	0.2536
5.7500E-01	5.39696E-09	0.2822
8.5000E-01	2.71213E-09	0.6289
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.82526E-08	0.1688

cell 7

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 9

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	1.88391E-06	0.4122
3.7500E-01	2.55680E-06	0.3355
5.7500E-01	4.69587E-06	0.2599
8.5000E-01	5.17581E-06	0.2340
1.2500E+00	2.53415E-06	0.3171
1.7500E+00	1.52019E-06	0.4086
2.2500E+00	4.86659E-07	0.7071
2.7500E+00	2.41040E-07	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.90944E-05	0.1228

cell 10

energy		
1.5000E-02	4.47207E-06	0.1544
2.5000E-02	9.28663E-06	0.1461
3.7500E-02	9.74498E-05	0.0503
5.7500E-02	6.96221E-06	0.2408
8.5000E-02	1.03381E-04	0.0518
1.2500E-01	6.90373E-06	0.2290
2.2500E-01	6.25263E-05	0.0685
3.7500E-01	3.11934E-05	0.0973
5.7500E-01	4.78833E-05	0.0708
8.5000E-01	1.73459E-05	0.1178
1.2500E+00	1.37393E-05	0.1324
1.7500E+00	5.78496E-06	0.2041
2.2500E+00	5.30288E-06	0.2132
2.7500E+00	2.41040E-07	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	4.12472E-04	0.0272

cell 11

energy		
1.5000E-02	9.51299E-03	0.0908
2.5000E-02	4.89596E-03	0.1270
3.7500E-02	3.50030E-02	0.0474
5.7500E-02	1.65831E-03	0.2182
8.5000E-02	3.30125E-02	0.0486
1.2500E-01	8.35752E-04	0.3001
2.2500E-01	1.46080E-02	0.0733
3.7500E-01	9.37726E-03	0.0891
5.7500E-01	1.69428E-02	0.0667
8.5000E-01	6.21131E-03	0.1088
1.2500E+00	4.77997E-03	0.1255

1.7500E+00	2.04062E-03	0.1942
2.2500E+00	1.73728E-03	0.2132
2.7500E+00	7.89670E-05	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.40695E-01	0.0233

cell 12

energy		
1.5000E-02	9.02931E-03	0.0931
2.5000E-02	4.89749E-03	0.1270
3.7500E-02	3.49782E-02	0.0474
5.7500E-02	1.66608E-03	0.2172
8.5000E-02	3.26583E-02	0.0491
1.2500E-01	8.23085E-04	0.3055
2.2500E-01	1.45338E-02	0.0736
3.7500E-01	8.69839E-03	0.0952
5.7500E-01	1.59374E-02	0.0702
8.5000E-01	5.73784E-03	0.1168
1.2500E+00	4.53556E-03	0.1314
1.7500E+00	1.96142E-03	0.2001
2.2500E+00	1.73728E-03	0.2132
2.7500E+00	7.89670E-05	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.37273E-01	0.0238

cell 13

energy		
1.5000E-02	1.41871E-08	0.0064
2.5000E-02	1.64674E-09	0.0208
3.7500E-02	2.50600E-08	0.0088
5.7500E-02	9.09440E-09	0.0278
8.5000E-02	5.01235E-07	0.0058
1.2500E-01	2.66477E-08	0.0308
2.2500E-01	3.33109E-07	0.0116
3.7500E-01	8.57420E-07	0.0132
5.7500E-01	2.36181E-06	0.0121
8.5000E-01	1.30167E-06	0.0209
1.2500E+00	1.62857E-06	0.0229
1.7500E+00	6.79947E-07	0.0393
2.2500E+00	5.15668E-07	0.0476
2.7500E+00	2.89818E-08	0.1892
3.5000E+00	4.73327E-09	0.4008
5.0000E+00	1.73232E-09	0.6315
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	8.29151E-06	0.0090

cell 14

energy		
1.5000E-02	1.74507E-06	0.0363

```
    2.5000E-02   1.10600E-07 0.1332
    3.7500E-02   4.63624E-07 0.0631
    5.7500E-02   1.61202E-07 0.1226
    8.5000E-02   2.52804E-06 0.0299
    1.2500E-01   2.31310E-07 0.1000
    2.2500E-01   4.16901E-07 0.0712
    3.7500E-01   1.57054E-07 0.0989
    5.7500E-01   7.50811E-08 0.1544
    8.5000E-01   6.88639E-09 0.4581
    1.2500E+00   1.64667E-09 0.7006
    1.7500E+00   0.00000E+00 0.0000
    2.2500E+00   0.00000E+00 0.0000
    2.7500E+00   0.00000E+00 0.0000
    3.5000E+00   0.00000E+00 0.0000
    5.0000E+00   0.00000E+00 0.0000
    7.0000E+00   0.00000E+00 0.0000
    1.1000E+01   0.00000E+00 0.0000
      total      5.89742E-06 0.0192

 for the tally-fluctuation-chart bin:
 average tally per history = 2.62848E-02
largest tally in one history = 1.20827E+01
 (largest tally)/(average tally) = 4.59684E+02      nps of
largest tally =    27411
ltally   8        nps =   100000
          tally type 8    pulse height distribution.
           units   number
          tally for  photons

 cell  1


      energy
    1.5000E-02   3.17545E-04 0.1767
    2.5000E-02   1.98466E-04 0.2236
    3.7500E-02   2.98691E-03 0.0576
    5.7500E-02   2.58006E-04 0.1961
    8.5000E-02   3.84031E-03 0.0507
    1.2500E-01   1.98466E-04 0.2236
    2.2500E-01   2.03427E-03 0.0698
    3.7500E-01   1.40911E-03 0.0839
    5.7500E-01   1.36941E-03 0.0851
    8.5000E-01   4.96165E-04 0.1414
    1.2500E+00   3.57239E-04 0.1666
    1.7500E+00   1.78619E-04 0.2357
    2.2500E+00   7.93863E-05 0.3535
    2.7500E+00   0.00000E+00 0.0000
    3.5000E+00   0.00000E+00 0.0000
    5.0000E+00   0.00000E+00 0.0000
    7.0000E+00   0.00000E+00 0.0000
    1.1000E+01   0.00000E+00 0.0000
      total      1.37239E-02 0.0267

 cell  2


      energy
    1.5000E-02   1.37537E-02 0.0267
    2.5000E-02   7.93863E-05 0.3535
    3.7500E-02   2.87775E-04 0.1857
    5.7500E-02   2.97699E-05 0.5773
    8.5000E-02   3.96932E-05 0.5000
```

1.2500E-01	1.98466E-05	0.7071
2.2500E-01	9.92329E-06	1.0000
3.7500E-01	1.98466E-05	0.7071
5.7500E-01	9.92329E-06	1.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	9.92329E-06	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.42598E-02	0.0262

cell 3

energy		
1.5000E-02	1.42796E-02	0.0262
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.42796E-02	0.0262

cell 4

energy		
1.5000E-02	8.93096E-04	0.1054
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	9.92329E-06	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	9.92329E-06	1.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.12943E-04	0.1042

cell 5

energy		
1.5000E-02	9.88022E-01	0.0002
2.5000E-02	1.30987E-03	0.0870
3.7500E-02	1.39918E-03	0.0842
5.7500E-02	3.17545E-04	0.1767
8.5000E-02	2.87775E-04	0.1857
1.2500E-01	2.97699E-04	0.1825
2.2500E-01	3.07622E-04	0.1796
3.7500E-01	1.78619E-04	0.2357
5.7500E-01	8.93096E-05	0.3333
8.5000E-01	9.92329E-05	0.3162
1.2500E+00	9.92329E-06	1.0000
1.7500E+00	9.92329E-06	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.92329E-01	0.0000

cell 6

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	9.92329E-06	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	2.97699E-05	0.5773
1.2500E-01	1.98466E-05	0.7071
2.2500E-01	2.38159E-04	0.2041
3.7500E-01	3.57239E-04	0.1666
5.7500E-01	1.68696E-04	0.2425
8.5000E-01	6.94630E-05	0.3780
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	8.93096E-04	0.1054

cell 7

energy		
1.5000E-02	8.30580E-03	0.0344
2.5000E-02	5.65628E-04	0.1324
3.7500E-02	2.32205E-03	0.0653
5.7500E-02	8.03787E-04	0.1111
8.5000E-02	1.35254E-02	0.0269
1.2500E-01	1.26026E-03	0.0887
2.2500E-01	2.34190E-03	0.0650
3.7500E-01	1.13126E-03	0.0936
5.7500E-01	5.16011E-04	0.1386

8.5000E-01	2.18312E-04	0.2132
1.2500E+00	9.92329E-05	0.3162
1.7500E+00	5.95398E-05	0.4082
2.2500E+00	1.98466E-05	0.7071
2.7500E+00	9.92329E-06	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.11790E-02	0.0176

cell 8

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 9

energy		
1.5000E-02	6.84707E-04	0.1203
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.84707E-04	0.1203

cell 10

energy		
1.5000E-02	1.53712E-02	0.0252
2.5000E-02	4.36625E-04	0.1507
3.7500E-02	1.04195E-03	0.0975
5.7500E-02	3.96932E-05	0.5000
8.5000E-02	1.98466E-04	0.2236
1.2500E-01	2.97699E-05	0.5773
2.2500E-01	2.97699E-05	0.5773
3.7500E-01	9.92329E-06	1.0000
5.7500E-01	9.92329E-06	1.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.71673E-02	0.0238

cell 11

energy		
1.5000E-02	1.96382E-02	0.0223
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	9.92329E-06	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.96481E-02	0.0222

cell 12

energy		
1.5000E-02	1.76833E-02	0.0235
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	9.92329E-06	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	9.92329E-06	1.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000

```
    2.7500E+00    0.00000E+00 0.0000
    3.5000E+00    0.00000E+00 0.0000
    5.0000E+00    0.00000E+00 0.0000
    7.0000E+00    0.00000E+00 0.0000
    1.1000E+01    0.00000E+00 0.0000
      total       1.77032E-02 0.0235

 cell  13


      energy
    1.5000E-02    5.93512E-02 0.0125
    2.5000E-02    3.46621E-02 0.0166
    3.7500E-02    2.28553E-01 0.0058
    5.7500E-02    1.67207E-02 0.0242
    8.5000E-02    2.08727E-01 0.0061
    1.2500E-01    7.66078E-03 0.0359
    2.2500E-01    1.04929E-01 0.0092
    3.7500E-01    6.49976E-02 0.0119
    5.7500E-01    1.07916E-01 0.0091
    8.5000E-01    3.07622E-02 0.0177
    1.2500E+00    3.25682E-02 0.0172
    1.7500E+00    1.07072E-02 0.0303
    2.2500E+00    8.36533E-03 0.0343
    2.7500E+00    4.56471E-04 0.1474
    3.5000E+00    8.93096E-05 0.3333
    5.0000E+00    2.97699E-05 0.5773
    7.0000E+00    0.00000E+00 0.0000
    1.1000E+01    0.00000E+00 0.0000
      total       9.16495E-01 0.0009

 cell  14


      energy
    1.5000E-02    3.43147E-02 0.0167
    2.5000E-02    2.97699E-05 0.5773
    3.7500E-02    9.92329E-06 1.0000
    5.7500E-02    0.00000E+00 0.0000
    8.5000E-02    0.00000E+00 0.0000
    1.2500E-01    0.00000E+00 0.0000
    2.2500E-01    0.00000E+00 0.0000
    3.7500E-01    0.00000E+00 0.0000
    5.7500E-01    0.00000E+00 0.0000
    8.5000E-01    0.00000E+00 0.0000
    1.2500E+00    0.00000E+00 0.0000
    1.7500E+00    0.00000E+00 0.0000
    2.2500E+00    0.00000E+00 0.0000
    2.7500E+00    0.00000E+00 0.0000
    3.5000E+00    0.00000E+00 0.0000
    5.0000E+00    0.00000E+00 0.0000
    7.0000E+00    0.00000E+00 0.0000
    1.1000E+01    0.00000E+00 0.0000
      total       3.43544E-02 0.0167

 for the tally-fluctuation-chart bin:
 average tally per history = 1.37239E-02
largest tally in one history = 9.92329E-01
 (largest tally)/(average tally) = 7.23066E+01      nps of
largest tally =       37
ltally fluctuation charts
```

```
                tally   1                              tally   4
                        tally   8
      nps           mean       error      fom              mean
   error       fom          mean       error      fom
        8000     6.20206E-04 0.4471 5.1E+00
1.18750E-04 0.1432       49         1.40166E-02 0.0934
116
       16000     6.82226E-04 0.3014 5.7E+00
1.13740E-04 0.1054       46         1.36445E-02 0.0670
115
       24000     6.20206E-04 0.2581 5.2E+00
1.02917E-04 0.0896       43         1.37686E-02 0.0544
116
       32000     7.44247E-04 0.2040 6.2E+00
1.05227E-04 0.0780       43         1.38306E-02 0.0470
117
       40000     7.44247E-04 0.1825 6.2E+00
1.04791E-04 0.0697       43         1.39422E-02 0.0419
118
       48000     6.82226E-04 0.1740 5.7E+00
1.02234E-04 0.0644       42         1.38099E-02 0.0384
117
       56000     6.55646E-04 0.1643 5.5E+00
1.01775E-04 0.0604       41         1.37331E-02 0.0357
116
       64000     7.13237E-04 0.1474 6.0E+00
1.02259E-04 0.0562       41         1.39236E-02 0.0331
118
       72000     6.61553E-04 0.1443 5.5E+00
9.78218E-05 0.0538       40         1.38650E-02 0.0313
118
       80000     6.94630E-04 0.1336 5.8E+00
9.81733E-05 0.0511       40         1.39050E-02 0.0297
118
       88000     6.99141E-04 0.1270 5.9E+00
9.74512E-05 0.0491       39         1.38475E-02 0.0283
118
       96000     7.02900E-04 0.1212 5.9E+00
9.70157E-05 0.0472       39         1.38099E-02 0.0272
117
      100000     6.84707E-04 0.1203 5.7E+00
9.75711E-05 0.0461       39         1.37239E-02 0.0267
116


**********************************************************
***************
 dump no.  2 on file   runtpw         nps =  100000
  ctm =   12.03


         4 warning messages so far.


 run terminated when    100000 particle histories were
done.

 mcnp     version 4.2m4  6/30/91                       4/
8/93 10:36: 9                    probid =    4/ 8/93
10:20:45
```

APPENDIX B

MCNP4 LOW RANGE DETECTOR COLLIMATOR

INPUT AND OUTPUT FILES

```
lmcnp     version 4.2m4 ld= 6/30/91
 4/ 8/93  9:58:35

 ************************************************************
 ***************                    probid =    4/ 8/93
 9:58:35
  inp=nplug outp=thesis.L

     1-        detector problem
     2-            1    1    -5.33      -22 20 -21
     3-            2    2    -2.7       -25 23 -24 #1
     4-            3    4    -.0012     -28 26 -27 #1 #2
     5-            4    2    -2.7       -31 28 29 -30
     6-            5    4    -.0012      32 -33 -38
     7-            6    3    -11.3       29 -30 -34 31
     8-            7    0               -35(34:30:-32)
     9-            8    0                35
    10-            9    2    -2.7       -28 27 -30
    11-           10    2    -2.7       -28 29 -26
    12-           11    4    -.0012        33 -36 -37
    13-           12    4    -.0012       36 -29 -37
    14-           13    3    -11.3       33 -29 -34 37
    15-           14    4    -.0012      32 -33 38 -34
    16-
    17-           20   py    135.38
    18-           21   py    142.38
    19-           22   cy    3.5
    20-           23   py    135.33
    21-           24   py    142.43
    22-           25   cy    3.55
    23-           26   py    134.83
    24-           27   py    142.93
    25-           28   cy    3.62
    26-           29   py    134.7
    27-           30   py    143.06
```

```
   28-          31   cy   3.75
   29-          32   py   0.0
   30-          33   py   114.7
   31-          34   cy   23.75
   32-          35   so   300.0
   33-          36   py   117.7
   34-          37   cy   1.0
   35-          38   cy   7.5
   36-
   37-       mode p
   38-       imp:p     1 1 1 1 1 1 0 0 1 1 1 1 1 1
   39-       m1   32000      1
   40-       m2   13000      1
   41-       m3   82000      1
   42-       m4   7000  -0.79     8000  -0.21
   43-       sdef erg=d1 pos 0 67.35 0 cel=5 dir=1.0 vec 0
1 0 axs 0 1 0 rad=d2 ext=d3
   44-       si1  0 .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   45-            2.75 3.5 5.0
   46-       sp1  d 0 .115 .0336 .2425 .0152 .2122 .0049
.112 .0678 .1123 .0308 .0334
   47-              .0106 .0086 .00049 .0000597 .00000763
   48-       si2  3.75
   49-       sp2  -21
   50-       si3  67.35
   51-       sp3  -31
   52-       e0   .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   53-            2.75 3.5 5.0 7.0 11.0
   54-       e8   .015 .025 .0375 .0575 .085 .125 .225
.375 .575 .85 1.25 1.75 2.25
   55-            2.75 3.5 5.0 7.0 11.0
   56-       f1:p 27
   57-       f4:p 1 2 3 4 5 6 7 9 10 11 12 13 14
   58-       f8:p 1 2 3 4 5 6 7 8 9 10 11 12 13 14
```

```
   59-       nps  100000

   60-       print     -85  -110

1source                                                    print table
10

 values of defaulted or explicitly defined source
variables

    cel         5.0000E+00
    sur         0.0000E+00
    tme         0.0000E+00
    dir         1.0000E+00
    pos         0.0000E+00    6.7350E+01    0.0000E+00
    x           0.0000E+00
    y           0.0000E+00
    z           0.0000E+00
    axs         0.0000E+00    1.0000E+00    0.0000E+00
    vec         0.0000E+00    1.0000E+00    0.0000E+00
    ccc         0.0000E+00
    nrm         1.0000E+00
    ara         0.0000E+00
    wgt         1.0000E+00
    eff         1.0000E-02
    par         0.0000E+00


 probability distribution   2 for source variable rad
 power law 21:     f(x)=c*abs(x)**k          k =
1.0000E+00


 probability distribution   3 for source variable ext
 exponential function 31:     f(x)=c*exp(k*x)          k =
0.0000E+00


 probability distribution   1 for source variable erg
 unbiased histogram distribution

 source        source           cumulative
probability
  entry         value           probability           of
bin

    1       1.00000E-03        0.000000E+00
0.000000E+00
    2       1.50000E-02        1.082218E-01
1.082218E-01
    3       2.50000E-02        1.420999E-01
3.387812E-02
    4       3.75000E-02        3.866071E-01
2.445072E-01
    5       5.75000E-02        4.019329E-01
1.532581E-02
    6       8.50000E-02        6.158894E-01
```

```
2.139564E-01
    7       1.25000E-01         6.208299E-01
4.940559E-03
    8       2.25000E-01         7.337570E-01
1.129271E-01
    9       3.75000E-01         8.021182E-01
6.836120E-02
   10       5.75000E-01         9.153477E-01
1.132295E-01
   11       8.50000E-01         9.464027E-01
3.105494E-02
   12       1.25000E+00         9.800791E-01
3.367646E-02
   13       1.75000E+00         9.907669E-01
1.068774E-02
   14       2.25000E+00         9.994381E-01
8.671185E-03
   15       2.75000E+00         9.999321E-01
4.940559E-04
   16       3.50000E+00         9.999923E-01
6.019415E-05
   17       5.00000E+00         1.000000E+00
7.693156E-06

     the mean of source distribution   1 is  2.1205E-01

    fraction of energy distribution outside range =
7.6708E-03


 order of sampling source variables.
 cel axs rad ext pos vec dir erg tme
1tally   1
                                                  print table 30
           tally type 1    number of particles crossing a
surface.
           tally for  photons

 surfaces       27


 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1tally   4
```

```
                                                        print table 30
          tally type 4    track length estimate of
particle flux.
          tally for  photons

 warning.  cell    7 of tally   4 has zero importance.

 cells           1       2       3       4       5       6
7       9      10      11      12      13      14

 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1tally   8
                                                        print table 30
          tally type 8    pulse height distribution.

          tally for  photons

 warning.  cell    7 of tally   8 has zero importance.

 warning.  cell    8 of tally   8 has zero importance.

 warning.  tally   8 needs zero energy bin for negative f8
scores.

 cells           1       2       3       4       5       6
7       8       9      10      11      12      13      14

 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
```

```
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1material composition
                                                    print table 40

 material
  number      component nuclide, atom fraction

     1            32000,  1.00000
     2            13000,  1.00000
     3            82000,  1.00000
     4             7000,  0.81122        8000,  0.18878



 material
  number      component nuclide, mass fraction

     1            32000,  1.00000
     2            13000,  1.00000
     3            82000,  1.00000
     4             7000,  0.79000        8000,  0.21000
1cell volumes and masses
                                                    print table 50

        cell      atom          gram          input
calculated                                 reason volume
                   density       density       volume
volume           mass        pieces     not calculated

     1     1  4.41918E-02   5.33000E+00   0.00000E+00
2.69392E+02   1.43586E+03      1
     2     2  6.02616E-02   2.70000E+00   0.00000E+00
1.17111E+01   3.16199E+01      1
     3     3  5.02433E-05   1.20000E-03   0.00000E+00
5.23637E+01   6.28365E-02      1
     4     4  6.02616E-02   2.70000E+00   0.00000E+00
2.51633E+01   6.79408E+01      1
     5     5  5.02433E-05   1.20000E-03   0.00000E+00
2.02692E+04   2.43230E+01      1
     6     6  3.28395E-02   1.13000E+01   0.00000E+00
1.44450E+04   1.63229E+05      1
     7     7  0.00000E+00   0.00000E+00   0.00000E+00
1.12844E+08   0.00000E+00      1
     8     8  0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00      0       infinite
     9     9  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01      1
    10    10  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01      1
    11    11  5.02433E-05   1.20000E-03   0.00000E+00
9.42478E+00   1.13097E-02      1
    12    12  5.02433E-05   1.20000E-03   0.00000E+00
5.34071E+01   6.40885E-02      1
    13    13  3.28395E-02   1.13000E+01   0.00000E+00
3.53783E+04   3.99774E+05      1
    14    14  5.02433E-05   1.20000E-03   0.00000E+00
1.82986E+05   2.19583E+02      1
```

1surface areas

print table 50

surface		input area	calculated area	reason area not calculated
1	20	0.00000E+00	3.84845E+01	
2	21	0.00000E+00	3.84845E+01	
3	22	0.00000E+00	1.53938E+02	
4	23	0.00000E+00	3.95919E+01	
5	24	0.00000E+00	3.95919E+01	
6	25	0.00000E+00	1.58368E+02	
7	26	0.00000E+00	4.11687E+01	
8	27	0.00000E+00	4.11687E+01	
9	28	0.00000E+00	1.90149E+02	
10	29	0.00000E+00	1.77205E+03	
11	30	0.00000E+00	1.77205E+03	
12	31	0.00000E+00	1.96978E+02	
13	32	0.00000E+00	1.77205E+03	
14	33	0.00000E+00	1.77205E+03	
15	34	0.00000E+00	2.13482E+04	
16	35	0.00000E+00	1.13097E+06	
17	36	0.00000E+00	3.14159E+00	
18	37	0.00000E+00	1.25664E+02	
19	38	0.00000E+00	5.40511E+03	

1cells

print table 60

cell	mat	atom density	gram density	volume	mass	pieces	photon importance
1	1	4.41918E-02	5.33000E+00	2.69392E+02	1.43586E+03	1	1.00000E+00
2	2	6.02616E-02	2.70000E+00	1.17111E+01	3.16199E+01	1	1.00000E+00
3	3	5.02433E-05	1.20000E-03	5.23637E+01	6.28365E-02	1	1.00000E+00

```
     4     4     2  6.02616E-02 2.70000E+00 2.51633E+01
6.79408E+01      1  1.00000E+00

     5     5     4  5.02433E-05 1.20000E-03 2.02692E+04
2.43230E+01      1  1.00000E+00

     6     6     3  3.28395E-02 1.13000E+01 1.44450E+04
1.63229E+05      1  1.00000E+00

     7     7     0  0.00000E+00 0.00000E+00 1.12844E+08
0.00000E+00      1  0.00000E+00

     8     8     0  0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00      0  0.00000E+00

     9     9     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    10    10     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    11    11     4  5.02433E-05 1.20000E-03 9.42478E+00
1.13097E-02      1  1.00000E+00

    12    12     4  5.02433E-05 1.20000E-03 5.34071E+01
6.40885E-02      1  1.00000E+00

    13    13     3  3.28395E-02 1.13000E+01 3.53783E+04
3.99774E+05      1  1.00000E+00

    14    14     4  5.02433E-05 1.20000E-03 1.82986E+05
2.19583E+02      1  1.00000E+00

 total                                      1.13097E+08
5.64812E+05
lsurfaces

                                            print table 70

      surface     trans  type   surface coefficients

    1      20            py    1.3538000E+02
    2      21            py    1.4238000E+02
    3      22            cy    3.5000000E+00
    4      23            py    1.3533000E+02
    5      24            py    1.4243000E+02
    6      25            cy    3.5500000E+00
    7      26            py    1.3483000E+02
    8      27            py    1.4293000E+02
    9      28            cy    3.6200000E+00
   10      29            py    1.3470000E+02
   11      30            py    1.4306000E+02
   12      31            cy    3.7500000E+00
   13      32            py    0.0000000E+00
   14      33            py    1.1470000E+02
   15      34            cy    2.3750000E+01
   16      35            so    3.0000000E+02
   17      36            py    1.1770000E+02
   18      37            cy    1.0000000E+00
   19      38            cy    7.5000000E+00
```

```
    minimum source weight = 9.9233E-01     maximum source
weight = 1.0000E+00

         4 warning messages so far.
1cross-section tables
                                                print table 100

     table     length

                          tables from file 7000.01p2

   7000.01p      389
12/13/82

                          tables from file 8000.01p2

   8000.01p      389
12/13/82

                          tables from file 13000.01p2

  13000.01p      409
12/13/82

                          tables from file 32000.01p2

  32000.01p      457
12/13/82

                          tables from file 82000.01p2

  82000.01p      521
12/13/82
  total         2165

                          tables from file 7000.01e2

   7000.01e      478
                                                11/16/88

                          tables from file 8000.01e2

   8000.01e      478
                                                11/16/88

                          tables from file 13000.01e2
```

```
 13000.01e     478
                                                        11/16/88

                        tables from file 32000.01e2

 32000.01e     478
                                                        11/16/88

                        tables from file 82000.01e2

 82000.01e     478
                                                        11/16/88



 use of dynamically allocated storage

     general              467478
     tallies                6596
     bank                   6403
     cross sections         2165

     total                482642

************************************************************
***************
 dump no.  1 on file   runtpv          nps =       0
  ctm =    0.00


         4 warning messages so far.
1problem summary

      run terminated when    100000 particle histories
were done.                                        4/ 8/93
10:11: 2
       detector problem
                                  probid =    4/ 8/93
9:58:35
0
 photon creation      tracks      weight        energy
     photon loss           tracks      weight        energy
                                  (per source particle)
                                      (per source particle)

 source               100000    9.9233E-01    2.1355E-01
     escape                3253    3.2280E-02
4.3045E-03

     energy cutoff            0    0.            0.


     time cutoff              0    0.            0.
```

```
 weight window              0     0.              0.
     weight window              0     0.              0.

 cell importance            0     0.              0.
     cell importance            0     0.              0.

 weight cutoff              0     0.              0.
     weight cutoff              0     0.              0.

 energy importance          0     0.              0.
     energy importance          0     0.              0.

 dxtran                     0     0.              0.
     dxtran                     0     0.              0.

 forced collisions          0     0.              0.
     forced collisions          0     0.              0.

 exp. transform             0     0.              0.
     exp. transform             0     0.              0.

 from neutrons              0     0.              0.
     compton scatter            0     0.
5.8942E-02
 bremsstrahlung         24574     2.4385E-01     6.1242E-03
     capture               187443     1.8601E+00
1.8142E-01
 p-annihilation           248     2.4610E-03     1.2673E-03
     pair production          124     1.2305E-03
2.4705E-03
 electron x-rays            0     0.             0.


 1st fluorescence       56980     5.6543E-01     2.5102E-02


 2nd fluorescence        9018     8.9488E-02     1.0983E-03


     total             190820     1.8936E+00     2.4714E-01
         total             190820     1.8936E+00
2.4714E-01

   number of photons banked                        33716
average lifetime, shakes                 cutoffs
   photon tracks per source particle        1.9082E+00
  escape              2.6768E-01            tco   1.0000E+34
   photon collisions per source particle  2.2831E+00
  capture             1.1074E-01            eco   1.0000E-03
   total photon collisions                       228314
  capture or escape 1.1341E-01              wc1   0.0000E+00

  any termination    1.1334E-01             wc2   0.0000E+00

 computer time so far in this run     12.10 minutes
  maximum number ever in bank          8
 computer time in mcrun                9.07 minutes
  bank overflows to backup file        0
 source particles per minute             1.1026E+04
  field length                         0
 random numbers generated                    2013686
```

most random numbers used was 179 in history 88308

range of sampled source weights = 9.9233E-01 to 9.9233E-01

source efficiency = 1.0000 in cell 5
1source distribution frequency tables print table 170

the expected values below do not include the effect of the rejection loop which samples position.

source distribution 1 for erg

n	source value	number sampled	number expected	number sampled/expected	weight sampled	weight expected	weight sampled/expected
1	1.50000E-02	1.0757E-01	1.0822E-01	9.9398E-01	1.0674E-01	1.0739E-01	9.9398E-01
2	2.50000E-02	3.3890E-02	3.3878E-02	1.0004E+00	3.3630E-02	3.3618E-02	1.0004E+00
3	3.75000E-02	2.4429E-01	2.4451E-01	9.9911E-01	2.4242E-01	2.4263E-01	9.9911E-01
4	5.75000E-02	1.5250E-02	1.5326E-02	9.9505E-01	1.5133E-02	1.5208E-02	9.9505E-01
5	8.50000E-02	2.1312E-01	2.1396E-01	9.9609E-01	2.1149E-01	2.1232E-01	9.9609E-01
6	1.25000E-01	4.6000E-03	4.9406E-03	9.3107E-01	4.5647E-03	4.9027E-03	9.3107E-01
7	2.25000E-01	1.1399E-01	1.1293E-01	1.0094E+00	1.1312E-01	1.1206E-01	1.0094E+00
8	3.75000E-01	6.7520E-02	6.8361E-02	9.8769E-01	6.7002E-02	6.7837E-02	9.8769E-01
9	5.75000E-01	1.1382E-01	1.1323E-01	1.0052E+00	1.1295E-01	1.1236E-01	1.0052E+00
10	8.50000E-01	3.1290E-02	3.1055E-02	1.0076E+00	3.1050E-02	3.0817E-02	1.0076E+00
11	1.25000E+00	3.4730E-02	3.3676E-02	1.0313E+00	3.4464E-02	3.3418E-02	1.0313E+00
12	1.75000E+00	1.0470E-02	1.0688E-02	9.7963E-01	1.0390E-02	1.0606E-02	9.7963E-01
13	2.25000E+00	8.8400E-03	8.6712E-03	1.0195E+00	8.7722E-03	8.6047E-03	1.0195E+00
14	2.75000E+00	5.5000E-04	4.9406E-04	1.1132E+00	5.4578E-04	4.9027E-04	1.1132E+00
15	3.50000E+00	6.0000E-05	6.0194E-05	9.9677E-01	5.9540E-05	5.9732E-05	9.9677E-01
16	5.00000E+00	1.0000E-05	7.6932E-06	1.2999E+00	9.9233E-06	7.6341E-06	1.2999E+00
total		1.0000E+00	1.0000E+00	1.0000E+00	9.9233E-01	9.9233E-01	1.0000E+00

1photon activity in each cell print table 126

tracks population collisions

```
collisions     number        flux        average
average
        cell    entering                             *
weight     weighted     weighted   track weight   track
mfp
                                                  (per
history)    energy       energy     (relative)     (cm)

     1     1       5401         5952        12780
1.2682E-01   4.7255E-01   4.7255E-01   9.9233E-01
1.9244E+00
     2     2       6534         5599          404
4.0090E-03   2.7880E-01   2.7880E-01   9.9233E-01
2.7413E+00
     3     3       6536         5600            1
9.9233E-06   2.7265E-01   2.7265E-01   9.9233E-01
6.5720E+03
     4     4        394          373           19
1.8854E-04   2.9711E-01   2.9711E-01   9.9233E-01
3.3687E+00
     5     5     102458       100036         6416
6.3668E-02   2.2129E-01   2.2129E-01   9.9233E-01
5.5751E+03
     6     6        366          573         1124
1.1154E-02   4.0740E-01   4.0740E-01   9.9233E-01
4.1473E-01
     9     9        282          284            8
7.9386E-05   6.5749E-01   6.5749E-01   9.9233E-01
4.7711E+00
    10    10       6980         6695         1455
1.4438E-02   2.3643E-01   2.3643E-01   9.9233E-01
2.3842E+00
    11    11       6981         6971            9
8.9310E-05   2.3139E-01   2.3139E-01   9.9233E-01
5.7609E+03
    12    12       7045         6844           53
5.2593E-04   2.2963E-01   2.2963E-01   9.9233E-01
5.7407E+03
    13    13      87842       120461       205966
2.0439E+00   7.6254E-01   7.6254E-01   9.9233E-01
8.5284E-01
    14    14       3173         3165           79
7.8394E-04   7.5098E-02   7.5098E-02   9.9233E-01
3.8247E+03

     total       233992       262553       228314
2.2656E+00
1photon   weight balance in each cell -- external events
                                            print table
130

        cell    entering       source       energy
time       exiting       total
                                            cutoff
cutoff

     1     1   5.3596E-02   0.0000E+00   0.0000E+00
0.0000E+00  -8.9806E-03   4.4615E-02
     2     2   6.4839E-02   0.0000E+00   0.0000E+00
0.0000E+00  -6.2487E-02   2.3518E-03
     3     3   6.4859E-02   0.0000E+00   0.0000E+00
0.0000E+00  -6.4859E-02   0.0000E+00
```

```
     4     4   3.9098E-03   0.0000E+00   0.0000E+00
0.0000E+00  -3.8800E-03   2.9770E-05
     5     5   2.4391E-02   9.9233E-01   0.0000E+00
0.0000E+00  -9.6226E-01   5.4459E-02
     6     6   3.6319E-03   0.0000E+00   0.0000E+00
0.0000E+00  -3.0762E-04   3.3243E-03
     9     9   2.7984E-03   0.0000E+00   0.0000E+00
0.0000E+00  -2.8083E-03  -9.9233E-06
    10    10   6.9265E-02   0.0000E+00   0.0000E+00
0.0000E+00  -5.9242E-02   1.0023E-02
    11    11   6.9274E-02   0.0000E+00   0.0000E+00
0.0000E+00  -6.9185E-02   8.9310E-05
    12    12   6.9910E-02   0.0000E+00   0.0000E+00
0.0000E+00  -6.9602E-02   3.0762E-04
    13    13   8.7168E-01   0.0000E+00   0.0000E+00
0.0000E+00  -2.7448E-02   8.4423E-01
    14    14   3.1487E-02   0.0000E+00   0.0000E+00
0.0000E+00  -3.0861E-02   6.2517E-04

   total      1.3296E+00   9.9233E-01   0.0000E+00
0.0000E+00  -1.3619E+00   9.6005E-01
1photon   weight balance in each cell -- variance
reduction events
print table 130

        cell     weight        cell        weight
energy       dxtran       forced    exponential     total
                window     importance     cutoff
importance                 collision    transform

     1     1   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     2     2   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     3     3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4     4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     5     5   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     6     6   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     9     9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10    10   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    11    11   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    12    12   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    13    13   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
```

```
0.0000E+00
    14    14   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00

     total     0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
1photon weight balance in each cell -- physical events
                                              print table
130

        cell      from        brems-     p-annihi-
electron  fluorescence    capture        pair        total
                neutrons    strahlung      lation
x-rays                                 production

     1     1   0.0000E+00   5.5273E-03   3.9693E-05
0.0000E+00   2.1186E-02  -7.1348E-02  -1.9847E-05
-4.4615E-02
     2     2   0.0000E+00   4.9616E-05   0.0000E+00
0.0000E+00   1.0916E-04  -2.5106E-03   0.0000E+00
-2.3518E-03
     3     3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4     4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -2.9770E-05   0.0000E+00
-2.9770E-05
     5     5   0.0000E+00   3.9693E-05   0.0000E+00
0.0000E+00   0.0000E+00  -5.4499E-02   0.0000E+00
-5.4459E-02
     6     6   0.0000E+00   1.2801E-03   0.0000E+00
0.0000E+00   4.4556E-03  -9.0600E-03   0.0000E+00
-3.3243E-03
     9     9   0.0000E+00   1.9847E-05   0.0000E+00
0.0000E+00   0.0000E+00  -9.9233E-06   0.0000E+00
9.9233E-06
    10    10   0.0000E+00   3.9693E-05   0.0000E+00
0.0000E+00   3.7709E-04  -1.0439E-02   0.0000E+00
-1.0023E-02
    11    11   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -8.9310E-05   0.0000E+00
-8.9310E-05
    12    12   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -3.0762E-04   0.0000E+00
-3.0762E-04
    13    13   0.0000E+00   2.3690E-01   2.4213E-03
0.0000E+00   6.2879E-01  -1.7111E+00  -1.2106E-03
-8.4423E-01
    14    14   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00  -6.2517E-04   0.0000E+00
-6.2517E-04

     total     0.0000E+00   2.4385E-01   2.4610E-03
0.0000E+00   6.5492E-01  -1.8601E+00  -1.2305E-03
-9.6005E-01
1photon activity of each nuclide in each cell, per source
particle                                      print table
140

        cell    nuclides     atom        total
```

collisions		weight lost	total from	weight from	
avg photon					
			fraction	collisions	*
weight		to capture	neutrons	neutrons	
energy					
1	1	32000.01p	1.0000E+00	12780	
1.2682E-01		7.1348E-02	0	0.0000E+00	
0.0000E+00					
2	2	13000.01p	1.0000E+00	404	
4.0090E-03		2.5106E-03	0	0.0000E+00	
0.0000E+00					
3	3	7000.01p	8.1122E-01	1	
9.9233E-06		0.0000E+00	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	0	
0.0000E+00		0.0000E+00	0	0.0000E+00	
0.0000E+00					
4	4	13000.01p	1.0000E+00	19	
1.8854E-04		2.9770E-05	0	0.0000E+00	
0.0000E+00					
5	5	7000.01p	8.1122E-01	4627	
4.5915E-02		3.8651E-02	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	1789	
1.7753E-02		1.5847E-02	0	0.0000E+00	
0.0000E+00					
6	6	82000.01p	1.0000E+00	1124	
1.1154E-02		9.0600E-03	0	0.0000E+00	
0.0000E+00					
9	9	13000.01p	1.0000E+00	8	
7.9386E-05		9.9233E-06	0	0.0000E+00	
0.0000E+00					
10	10	13000.01p	1.0000E+00	1455	
1.4438E-02		1.0439E-02	0	0.0000E+00	
0.0000E+00					
11	11	7000.01p	8.1122E-01	7	
6.9463E-05		6.9463E-05	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	2	
1.9847E-05		1.9847E-05	0	0.0000E+00	
0.0000E+00					
12	12	7000.01p	8.1122E-01	36	
3.5724E-04		2.0839E-04	0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	17	
1.6870E-04		9.9233E-05	0	0.0000E+00	
0.0000E+00					
13	13	82000.01p	1.0000E+00	205966	
2.0439E+00		1.7111E+00	0	0.0000E+00	
0.0000E+00					

```
    14     14     7000.01p  8.1122E-01          57
5.6563E-04     4.6639E-04           0      0.0000E+00
0.0000E+00
                  8000.01p  1.8878E-01          22
2.1831E-04     1.5877E-04           0      0.0000E+00
0.0000E+00

      total                                  228314
2.2656E+00     1.8601E+00           0      0.0000E+00
0.0000E+00


    total over all cells for each nuclide

                  7000.01p                    4728
4.6917E-02     3.9395E-02           0      0.0000E+00
0.0000E+00
                  8000.01p                    1830
1.8160E-02     1.6125E-02           0      0.0000E+00
0.0000E+00
                 13000.01p                    1886
1.8715E-02     1.2990E-02           0      0.0000E+00
0.0000E+00
                 32000.01p                   12780
1.2682E-01     7.1348E-02           0      0.0000E+00
0.0000E+00
                 82000.01p                  207090
2.0550E+00     1.7202E+00           0      0.0000E+00
0.0000E+00
1tally   1        nps =   100000
           tally type 1    number of particles crossing a
surface.
           tally for  photons

 surface  27


      energy
    1.5000E-02   0.00000E+00 0.0000
    2.5000E-02   0.00000E+00 0.0000
    3.7500E-02   0.00000E+00 0.0000
    5.7500E-02   0.00000E+00 0.0000
    8.5000E-02   0.00000E+00 0.0000
    1.2500E-01   1.98466E-05 0.7071
    2.2500E-01   1.58773E-04 0.2500
    3.7500E-01   5.25934E-04 0.1373
    5.7500E-01   8.43480E-04 0.1084
    8.5000E-01   4.06855E-04 0.1561
    1.2500E+00   5.25934E-04 0.1373
    1.7500E+00   2.08389E-04 0.2182
    2.2500E+00   1.38926E-04 0.2672
    2.7500E+00   9.92329E-06 1.0000
    3.5000E+00   0.00000E+00 0.0000
    5.0000E+00   0.00000E+00 0.0000
    7.0000E+00   0.00000E+00 0.0000
    1.1000E+01   0.00000E+00 0.0000
      total      2.83806E-03 0.0599

 for the tally-fluctuation-chart bin:
 average tally per history = 2.83806E-03
largest tally in one history = 1.98466E+00
 (largest tally)/(average tally) = 6.99301E+02      nps of
```

```
largest tally =    41435
ltally   4        nps =   100000
          tally type 4    track length estimate of
particle flux.      units   1/cm**2
          tally for  photons

          volumes
                   cell:       1            2            3
          4            5            6            7
                                2.69392E+02  1.17111E+01
5.23637E+01  2.51633E+01  2.02692E+04  1.44450E+04
1.12844E+08
                   cell:       9           10           11
         12           13           14
                              5.35193E+00  5.35193E+00
9.42478E+00  5.34071E+01  3.53783E+04  1.82986E+05

 cell  1


     energy
   1.5000E-02   4.14828E-07 0.0304
   2.5000E-02   1.63900E-08 0.1415
   3.7500E-02   7.20033E-07 0.0448
   5.7500E-02   3.81674E-07 0.1013
   8.5000E-02   9.65212E-06 0.0375
   1.2500E-01   1.07375E-05 0.0567
   2.2500E-01   9.33586E-05 0.0311
   3.7500E-01   9.42222E-05 0.0376
   5.7500E-01   9.93470E-05 0.0400
   8.5000E-01   3.59022E-05 0.0678
   1.2500E+00   3.46845E-05 0.0726
   1.7500E+00   1.18545E-05 0.1291
   2.2500E+00   7.51445E-06 0.1597
   2.7500E+00   3.08022E-07 0.8528
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
   1.1000E+01   0.00000E+00 0.0000
     total      3.99114E-04 0.0227

 cell  2


     energy
   1.5000E-02   7.85337E-07 0.1875
   2.5000E-02   2.89913E-06 0.1204
   3.7500E-02   5.08196E-05 0.0310
   5.7500E-02   6.71601E-06 0.1136
   8.5000E-02   6.62987E-05 0.0279
   1.2500E-01   5.53189E-06 0.1386
   2.2500E-01   5.45048E-05 0.0473
   3.7500E-01   3.79938E-05 0.0524
   5.7500E-01   4.44132E-05 0.0381
   8.5000E-01   1.28292E-05 0.0664
   1.2500E+00   1.33150E-05 0.0654
   1.7500E+00   3.99848E-06 0.1212
   2.2500E+00   3.23923E-06 0.1338
   2.7500E+00   1.27101E-07 0.7453
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
```

1.1000E+01	0.00000E+00	0.0000
total	3.03472E-04	0.0170

cell 3

energy		
1.5000E-02	4.03960E-07	0.5016
2.5000E-02	9.04259E-06	0.1303
3.7500E-02	1.21639E-04	0.0309
5.7500E-02	1.56964E-05	0.1096
8.5000E-02	1.50428E-04	0.0285
1.2500E-01	1.07599E-05	0.1276
2.2500E-01	1.05390E-04	0.0372
3.7500E-01	6.24162E-05	0.0458
5.7500E-01	9.14387E-05	0.0355
8.5000E-01	2.60279E-05	0.0667
1.2500E+00	2.95455E-05	0.0648
1.7500E+00	8.78390E-06	0.1216
2.2500E+00	7.30950E-06	0.1332
2.7500E+00	2.84261E-07	0.7453
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.39166E-04	0.0150

cell 4

energy		
1.5000E-02	1.97477E-08	0.7533
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	5.28879E-08	0.9863
5.7500E-02	1.56838E-07	0.5774
8.5000E-02	2.82280E-06	0.3803
1.2500E-01	7.22949E-07	0.4139
2.2500E-01	6.95289E-06	0.1242
3.7500E-01	1.11729E-05	0.0781
5.7500E-01	4.75395E-06	0.1541
8.5000E-01	1.57537E-06	0.2175
1.2500E+00	2.73389E-07	0.5843
1.7500E+00	9.97890E-08	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.86035E-05	0.0687

cell 5

energy		
1.5000E-02	1.63249E-04	0.0109
2.5000E-02	7.73341E-05	0.0170
3.7500E-02	5.63651E-04	0.0056
5.7500E-02	3.57371E-05	0.0252
8.5000E-02	5.00678E-04	0.0060
1.2500E-01	1.14397E-05	0.0441
2.2500E-01	2.64899E-04	0.0088

3.7500E-01	1.56510E-04	0.0117
5.7500E-01	2.63345E-04	0.0088
8.5000E-01	7.24372E-05	0.0176
1.2500E+00	8.02831E-05	0.0167
1.7500E+00	2.42631E-05	0.0307
2.2500E+00	2.04995E-05	0.0335
2.7500E+00	1.27302E-06	0.1348
3.5000E+00	1.39386E-07	0.4083
5.0000E+00	2.35022E-08	1.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.23576E-03	0.0006

cell 6

energy		
1.5000E-02	1.67471E-10	0.1031
2.5000E-02	3.32185E-12	0.4678
3.7500E-02	4.75541E-12	0.4921
5.7500E-02	8.89552E-11	0.4321
8.5000E-02	7.53639E-09	0.0891
1.2500E-01	4.21730E-10	0.3183
2.2500E-01	6.30199E-09	0.1278
3.7500E-01	3.42516E-08	0.1110
5.7500E-01	2.98203E-08	0.1732
8.5000E-01	1.68554E-08	0.2950
1.2500E+00	2.01470E-09	0.7991
1.7500E+00	5.19716E-11	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.75186E-08	0.0931

cell 7

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 9

energy		
1.5000E-02	4.69612E-10	1.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	2.35114E-07	1.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	4.95604E-07	0.7072
2.2500E-01	6.49547E-06	0.2970
3.7500E-01	1.73585E-05	0.1530
5.7500E-01	2.51247E-05	0.1222
8.5000E-01	1.09140E-05	0.1594
1.2500E+00	1.32167E-05	0.1375
1.7500E+00	5.16487E-06	0.2184
2.2500E+00	3.17384E-06	0.2769
2.7500E+00	2.41040E-07	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	8.24203E-05	0.0655

cell 10

energy		
1.5000E-02	1.40730E-05	0.0809
2.5000E-02	3.79231E-05	0.0789
3.7500E-02	3.66125E-04	0.0274
5.7500E-02	4.02765E-05	0.0889
8.5000E-02	4.07583E-04	0.0307
1.2500E-01	3.25816E-05	0.1667
2.2500E-01	2.57754E-04	0.0382
3.7500E-01	1.30572E-04	0.0546
5.7500E-01	2.03575E-04	0.0342
8.5000E-01	5.35009E-05	0.0668
1.2500E+00	6.24779E-05	0.0619
1.7500E+00	1.73326E-05	0.1178
2.2500E+00	1.53492E-05	0.1251
2.7500E+00	4.82080E-07	0.7071
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.63961E-03	0.0151

cell 11

energy		
1.5000E-02	1.23174E-03	0.0504
2.5000E-02	7.26533E-04	0.0659
3.7500E-02	5.33453E-03	0.0241
5.7500E-02	3.82923E-04	0.0907
8.5000E-02	4.96305E-03	0.0250
1.2500E-01	8.62396E-05	0.1896
2.2500E-01	2.51063E-03	0.0353
3.7500E-01	1.62659E-03	0.0434
5.7500E-01	2.79209E-03	0.0333
8.5000E-01	7.59163E-04	0.0637
1.2500E+00	8.51785E-04	0.0606

1.7500E+00	2.36131E-04	0.1154
2.2500E+00	2.02156E-04	0.1250
2.7500E+00	6.31736E-06	0.7071
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.17099E-02	0.0116

cell 12

energy		
1.5000E-02	1.16107E-03	0.0517
2.5000E-02	7.25144E-04	0.0658
3.7500E-02	5.31887E-03	0.0242
5.7500E-02	3.91616E-04	0.0889
8.5000E-02	4.88797E-03	0.0252
1.2500E-01	8.77722E-05	0.1840
2.2500E-01	2.50833E-03	0.0352
3.7500E-01	1.53740E-03	0.0452
5.7500E-01	2.69592E-03	0.0340
8.5000E-01	7.16188E-04	0.0659
1.2500E+00	8.32879E-04	0.0612
1.7500E+00	2.31797E-04	0.1159
2.2500E+00	2.03354E-04	0.1244
2.7500E+00	6.31736E-06	0.7071
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.13046E-02	0.0118

cell 13

energy		
1.5000E-02	1.33058E-08	0.0066
2.5000E-02	1.57660E-09	0.0209
3.7500E-02	2.39538E-08	0.0089
5.7500E-02	8.57427E-09	0.0273
8.5000E-02	4.76418E-07	0.0060
1.2500E-01	2.56164E-08	0.0314
2.2500E-01	3.20120E-07	0.0119
3.7500E-01	8.01209E-07	0.0137
5.7500E-01	2.24482E-06	0.0123
8.5000E-01	1.23084E-06	0.0216
1.2500E+00	1.58307E-06	0.0232
1.7500E+00	6.26841E-07	0.0424
2.2500E+00	5.14196E-07	0.0502
2.7500E+00	3.59410E-08	0.1951
3.5000E+00	2.30047E-09	0.6029
5.0000E+00	4.18671E-10	1.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	7.90919E-06	0.0094

cell 14

energy		
1.5000E-02	1.08876E-06	0.0390

```
   2.5000E-02   8.80183E-08 0.1329
   3.7500E-02   3.55769E-07 0.0665
   5.7500E-02   1.18128E-07 0.1188
   8.5000E-02   1.99586E-06 0.0302
   1.2500E-01   2.00405E-07 0.0976
   2.2500E-01   3.48197E-07 0.0711
   3.7500E-01   1.10258E-07 0.1044
   5.7500E-01   5.25821E-08 0.1827
   8.5000E-01   7.40436E-09 0.4400
   1.2500E+00   4.77043E-09 0.5571
   1.7500E+00   0.00000E+00 0.0000
   2.2500E+00   0.00000E+00 0.0000
   2.7500E+00   0.00000E+00 0.0000
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
   1.1000E+01   0.00000E+00 0.0000
     total      4.37015E-06 0.0198

 for the tally-fluctuation-chart bin:
 average tally per history = 1.07518E-01
largest tally in one history = 1.40881E+01
 (largest tally)/(average tally) = 1.31030E+02      nps of
largest tally =    82957
ltally   8        nps =   100000
          tally type 8    pulse height distribution.
           units   number
          tally for  photons

 cell  1


     energy
   1.5000E-02   1.61750E-03 0.0783
   2.5000E-02   9.52636E-04 0.1020
   3.7500E-02   1.03103E-02 0.0309
   5.7500E-02   1.29995E-03 0.0873
   8.5000E-02   1.44086E-02 0.0261
   1.2500E-01   9.22866E-04 0.1036
   2.2500E-01   8.41495E-03 0.0342
   3.7500E-01   5.35858E-03 0.0429
   5.7500E-01   6.07305E-03 0.0403
   8.5000E-01   1.84573E-03 0.0733
   1.2500E+00   1.30987E-03 0.0870
   1.7500E+00   4.86241E-04 0.1428
   2.2500E+00   2.08389E-04 0.2182
   2.7500E+00   0.00000E+00 0.0000
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
   1.1000E+01   0.00000E+00 0.0000
     total      5.32087E-02 0.0133

 cell  2


     energy
   1.5000E-02   5.32385E-02 0.0133
   2.5000E-02   3.47315E-04 0.1690
   3.7500E-02   1.31980E-03 0.0867
   5.7500E-02   7.93863E-05 0.3535
   8.5000E-02   2.18312E-04 0.2132
```

1.2500E-01	1.98466E-05	0.7071
2.2500E-01	9.92329E-05	0.3162
3.7500E-01	7.93863E-05	0.3535
5.7500E-01	9.92329E-06	1.0000
8.5000E-01	9.92329E-06	1.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	9.92329E-06	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	5.54315E-02	0.0130

cell 3

energy		
1.5000E-02	5.54910E-02	0.0130
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	5.54910E-02	0.0130

cell 4

energy		
1.5000E-02	3.59223E-03	0.0525
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	1.98466E-05	0.7071
5.7500E-02	3.96932E-05	0.5000
8.5000E-02	9.92329E-06	1.0000
1.2500E-01	9.92329E-06	1.0000
2.2500E-01	9.92329E-06	1.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	9.92329E-06	1.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.69146E-03	0.0518

cell 5

energy		
1.5000E-02	9.87963E-01	0.0002
2.5000E-02	1.30987E-03	0.0870
3.7500E-02	1.46865E-03	0.0821
5.7500E-02	3.47315E-04	0.1690
8.5000E-02	3.17545E-04	0.1767
1.2500E-01	1.88543E-04	0.2294
2.2500E-01	3.27469E-04	0.1740
3.7500E-01	2.67929E-04	0.1924
5.7500E-01	7.93863E-05	0.3535
8.5000E-01	4.96165E-05	0.4472
1.2500E+00	9.92329E-06	1.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.92329E-01	0.0000

cell 6

energy		
1.5000E-02	8.93096E-05	0.3333
2.5000E-02	1.98466E-05	0.7071
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	2.97699E-05	0.5773
8.5000E-02	8.93096E-05	0.3333
1.2500E-01	1.29003E-04	0.2773
2.2500E-01	8.13710E-04	0.1104
3.7500E-01	1.68696E-03	0.0766
5.7500E-01	5.45781E-04	0.1348
8.5000E-01	1.48849E-04	0.2582
1.2500E+00	2.97699E-05	0.5773
1.7500E+00	9.92329E-06	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.59223E-03	0.0525

cell 7

energy		
1.5000E-02	7.09515E-03	0.0373
2.5000E-02	6.25167E-04	0.1259
3.7500E-02	2.37167E-03	0.0646
5.7500E-02	8.23633E-04	0.1097
8.5000E-02	1.32972E-02	0.0271
1.2500E-01	1.40911E-03	0.0839
2.2500E-01	2.58006E-03	0.0619
3.7500E-01	1.43888E-03	0.0830
5.7500E-01	1.19080E-03	0.0912

8.5000E-01	4.76318E-04	0.1443
1.2500E+00	5.35858E-04	0.1360
1.7500E+00	2.08389E-04	0.2182
2.2500E+00	1.29003E-04	0.2773
2.7500E+00	9.92329E-06	1.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.21912E-02	0.0173

cell 8

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 9

energy		
1.5000E-02	2.73883E-03	0.0601
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	1.98466E-05	0.7071
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	9.92329E-06	1.0000
3.7500E-01	1.98466E-05	0.7071
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	9.92329E-06	1.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.79837E-03	0.0595

cell 10

energy		
1.5000E-02	5.89840E-02	0.0126
2.5000E-02	1.60757E-03	0.0785
3.7500E-02	4.49525E-03	0.0469
5.7500E-02	2.77852E-04	0.1890
8.5000E-02	5.95398E-04	0.1291
1.2500E-01	1.29003E-04	0.2773
2.2500E-01	1.29003E-04	0.2773
3.7500E-01	7.93863E-05	0.3535
5.7500E-01	5.95398E-05	0.4082
8.5000E-01	1.98466E-05	0.7071
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	9.92329E-06	1.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.63868E-02	0.0118

cell 11

energy		
1.5000E-02	6.91653E-02	0.0116
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.91653E-02	0.0116

cell 12

energy		
1.5000E-02	6.78158E-02	0.0117
2.5000E-02	9.92329E-06	1.0000
3.7500E-02	2.97699E-05	0.5773
5.7500E-02	9.92329E-06	1.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	9.92329E-06	1.0000
3.7500E-01	1.98466E-05	0.7071
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	9.92329E-06	1.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000

2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	6.79051E-02	0.0117

cell 13

energy		
1.5000E-02	5.41911E-02	0.0132
2.5000E-02	3.27766E-02	0.0171
3.7500E-02	2.18074E-01	0.0060
5.7500E-02	1.58971E-02	0.0248
8.5000E-02	1.97642E-01	0.0063
1.2500E-01	7.18446E-03	0.0370
2.2500E-01	9.97787E-02	0.0095
3.7500E-01	6.19710E-02	0.0123
5.7500E-01	1.02766E-01	0.0093
8.5000E-01	2.86088E-02	0.0184
1.2500E+00	3.17248E-02	0.0174
1.7500E+00	9.71490E-03	0.0318
2.2500E+00	7.97833E-03	0.0351
2.7500E+00	5.16011E-04	0.1386
3.5000E+00	4.96165E-05	0.4472
5.0000E+00	9.92329E-06	1.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	8.68883E-01	0.0012

cell 14

energy		
1.5000E-02	3.12584E-02	0.0175
2.5000E-02	3.96932E-05	0.5000
3.7500E-02	9.92329E-06	1.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.13080E-02	0.0175

for the tally-fluctuation-chart bin:
average tally per history = 5.32087E-02
largest tally in one history = 9.92329E-01
(largest tally)/(average tally) = 1.86498E+01 nps of
largest tally = 17
ltally fluctuation charts

```
                 tally   1                           tally   4
                         tally   8
        nps          mean      error      fom            mean
   error       fom          mean       error      fom
         8000     2.72891E-03 0.2129       30
4.02274E-04 0.0800      213          5.08569E-02 0.0481
590
        16000     2.66688E-03 0.1523       30
4.06479E-04 0.0558      220          5.19112E-02 0.0336
604
        24000     2.97699E-03 0.1177       33
4.07243E-04 0.0456      220          5.28002E-02 0.0272
616
        32000     2.94598E-03 0.1024       33
4.16581E-04 0.0392      223          5.29656E-02 0.0235
619
        40000     3.00180E-03 0.0908       33
4.02247E-04 0.0357      216          5.21717E-02 0.0212
610
        48000     3.08036E-03 0.0834       33
4.08888E-04 0.0324      218          5.33377E-02 0.0192
625
        56000     3.10103E-03 0.0772       33
4.05969E-04 0.0302      215          5.31073E-02 0.0178
623
        64000     3.03901E-03 0.0728       32
4.06289E-04 0.0282      217          5.34307E-02 0.0166
627
        72000     2.89429E-03 0.0702       31
4.00886E-04 0.0267      215          5.34617E-02 0.0156
627
        80000     2.86535E-03 0.0668       31
3.98675E-04 0.0253      215          5.33873E-02 0.0148
626
        88000     2.86422E-03 0.0636       31
3.98081E-04 0.0242      213          5.30558E-02 0.0142
622
        96000     2.86328E-03 0.0609       31
4.01289E-04 0.0231      215          5.31310E-02 0.0136
623
       100000     2.83806E-03 0.0599       31
3.99114E-04 0.0227      214          5.32087E-02 0.0133
623


**********************************************************
***************
 dump no.  2 on file   runtpv          nps =  100000
  ctm =     9.07


          4 warning messages so far.


 run terminated when     100000 particle histories were
done.

 mcnp     version 4.2m4  6/30/91                       4/
8/93 10:11: 5                    probid =    4/ 8/93
9:58:35
```

APPENDIX C

MCNP4 SHIELD INPUT AND OUTPUT FILES

```
lmcnp     version 4.2m4 ld= 6/30/91
     2/28/93 20:59:33
************************************************************
     *************                    probid =    2/28/93 20:59:33
      inp=shield outp=shld.6ml
1-         shield problem

          2-            1    1    -5.33      -22 20 -21

          3-            2    2    -2.7       -25 23 -24 #1
          4-            3    4    -.0012     -28 26 -27 #1 #2
          5-            4    2    -2.7       -31 28 29 -30
          6-            5    4    -.0012      32 -33 -31
          7-            6    3    -11.3       29 -30 -34 31
          8-            7    0                -35(34:30:-32)
          9-            8    0                 35
         10-            9    2    -2.7       -28 27 -30
         11-           10    2    -2.7       -28 29 -26
         12-           11    3    -11.3        33 -36 -37
         13-           12    3    -11.3       36 -29 -37
         14-           13    3    -11.3       33 -29 -34 37
         15-           14    4    -.0012      32 -33 31 -34
         16-
         17-           20   py   135.38

         18-           21   py   142.38
         19-           22   cy   3.5
         20-           23   py   135.33
         21-           24   py   142.43
         22-           25   cy   3.55
         23-           26   py   134.83
         24-           27   py   142.93
         25-           28   cy   3.62

         26-           29   py   134.7
         27-           30   py   143.06
         28-           31   cy   3.75
         29-           32   py   0.0

         30-           33   py   114.7
         31-           34   cy   23.75
         32-           35   so   300.0
         33-           36   py   117.7

         34-           37   cy   0.25
         35-
         36-       mode p
         37-       imp:p     1 1 1 1 1 1 0 0 1 1 1 1 1 1
         38-       m1   32000      1
         39-       m2   13000      1
         40-       m3   82000      1
         41-       m4   7000  -0.79      8000  -0.21
         42-       sdef erg=d1 pos 0 67.35 0 cel=5 dir=1.0 vec 0 1
    0 axs 0 1 0 rad=d2 ext=d3
         43-       si1  0 .015 .025 .0375 .0575 .085 .125 .225
    .375 .575 .85 1.25 1.75 2.25
         44-            2.75 3.5 5.0

         45-       sp1  d 0 .115 .0336 .2425 .0152 .2122 .0049
    .112 .0678 .1123 .0308 .0334
         46-              .0106 .0086 .00049 .0000597 .00000763
```

```
   47-        si2  3.75

   48-        sp2  -21

   49-        si3  67.35

   50-        sp3  -31

   51-        e0   .015 .025 .0375 .0575 .085 .125 .225 .375
.575 .85 1.25 1.75 2.25
   52-             2.75 3.5 5.0 7.0 11.0

   53-        e8   .015 .025 .0375 .0575 .085 .125 .225 .375
.575 .85 1.25 1.75 2.25
   54-             2.75 3.5 5.0 7.0 11.0

   55-        f1:p 27

   56-        f4:p 1 2 3 4 5 6 7 9 10 11 12 13 14

   57-        f8:p 1 2 3 4 5 6 7 8 9 10 11 12 13 14

   58-        nps  6000000

   59-        print     -85  -110

1source
                                                print table 10

 values of defaulted or explicitly defined source variables

    cel        5.0000E+00
    sur        0.0000E+00
    tme        0.0000E+00
    dir        1.0000E+00
    pos        0.0000E+00   6.7350E+01   0.0000E+00
    x          0.0000E+00
    y          0.0000E+00
    z          0.0000E+00
    axs        0.0000E+00   1.0000E+00   0.0000E+00
    vec        0.0000E+00   1.0000E+00   0.0000E+00
    ccc        0.0000E+00
    nrm        1.0000E+00
    ara        0.0000E+00
    wgt        1.0000E+00
    eff        1.0000E-02
    par        0.0000E+00


 probability distribution   2 for source variable rad
 power law 21:     f(x)=c*abs(x)**k          k = 1.0000E+00


 probability distribution   3 for source variable ext
 exponential function 31:     f(x)=c*exp(k*x)          k =
0.0000E+00


 probability distribution   1 for source variable erg
```

unbiased histogram distribution

source entry	source value	cumulative probability	probability of bin
1	1.00000E-03	0.000000E+00	0.000000E+00
2	1.50000E-02	1.082218E-01	1.082218E-01
3	2.50000E-02	1.420999E-01	3.387812E-02
4	3.75000E-02	3.866071E-01	2.445072E-01
5	5.75000E-02	4.019329E-01	1.532581E-02
6	8.50000E-02	6.158894E-01	2.139564E-01
7	1.25000E-01	6.208299E-01	4.940559E-03
8	2.25000E-01	7.337570E-01	1.129271E-01
9	3.75000E-01	8.021182E-01	6.836120E-02
10	5.75000E-01	9.153477E-01	1.132295E-01
11	8.50000E-01	9.464027E-01	3.105494E-02
12	1.25000E+00	9.800791E-01	3.367646E-02
13	1.75000E+00	9.907669E-01	1.068774E-02
14	2.25000E+00	9.994381E-01	8.671185E-03
15	2.75000E+00	9.999321E-01	4.940559E-04
16	3.50000E+00	9.999923E-01	6.019415E-05
17	5.00000E+00	1.000000E+00	7.693156E-06

the mean of source distribution 1 is 2.1205E-01

fraction of energy distribution outside range = 7.6708E-03

order of sampling source variables.
cel axs rad ext pos vec dir erg tme
1tally 1

print table 30

tally type 1 number of particles crossing a surface.

tally for photons

surfaces 27
energy bins
1.00000E-03 to 1.50000E-02 mev
1.50000E-02 to 2.50000E-02 mev
2.50000E-02 to 3.75000E-02 mev
3.75000E-02 to 5.75000E-02 mev
5.75000E-02 to 8.50000E-02 mev

```
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1tally   4
                                                print table 30
          tally type 4    track length estimate of particle
flux.
          tally for  photons

 warning.  cell    7 of tally   4 has zero importance.

 cells           1      2      3      4      5      6      7
    9     10     11     12     13     14

 energy bins
      1.00000E-03  to  1.50000E-02 mev
      1.50000E-02  to  2.50000E-02 mev
      2.50000E-02  to  3.75000E-02 mev
      3.75000E-02  to  5.75000E-02 mev
      5.75000E-02  to  8.50000E-02 mev
      8.50000E-02  to  1.25000E-01 mev
      1.25000E-01  to  2.25000E-01 mev
      2.25000E-01  to  3.75000E-01 mev
      3.75000E-01  to  5.75000E-01 mev
      5.75000E-01  to  8.50000E-01 mev
      8.50000E-01  to  1.25000E+00 mev
      1.25000E+00  to  1.75000E+00 mev
      1.75000E+00  to  2.25000E+00 mev
      2.25000E+00  to  2.75000E+00 mev
      2.75000E+00  to  3.50000E+00 mev
      3.50000E+00  to  5.00000E+00 mev
      5.00000E+00  to  7.00000E+00 mev
      7.00000E+00  to  1.10000E+01 mev
      total bin
1tally   8
                                                print table 30
          tally type 8    pulse height distribution.

          tally for  photons

 warning.  cell    7 of tally   8 has zero importance.

 warning.  cell    8 of tally   8 has zero importance.

 warning.  tally   8 needs zero energy bin for negative f8
scores.

 cells           1      2      3      4      5      6      7
    8     9     10     11     12     13     14

 energy bins
```

1.00000E-03 to 1.50000E-02 mev
1.50000E-02 to 2.50000E-02 mev
2.50000E-02 to 3.75000E-02 mev
3.75000E-02 to 5.75000E-02 mev
5.75000E-02 to 8.50000E-02 mev
8.50000E-02 to 1.25000E-01 mev
1.25000E-01 to 2.25000E-01 mev
2.25000E-01 to 3.75000E-01 mev
3.75000E-01 to 5.75000E-01 mev
5.75000E-01 to 8.50000E-01 mev
8.50000E-01 to 1.25000E+00 mev
1.25000E+00 to 1.75000E+00 mev
1.75000E+00 to 2.25000E+00 mev
2.25000E+00 to 2.75000E+00 mev
2.75000E+00 to 3.50000E+00 mev
3.50000E+00 to 5.00000E+00 mev
5.00000E+00 to 7.00000E+00 mev
7.00000E+00 to 1.10000E+01 mev
total bin

1material composition

print table 40

material number	component nuclide, atom fraction			
1	32000,	1.00000		
2	13000,	1.00000		
3	82000,	1.00000		
4	7000,	0.81122	8000,	0.18878

material number	component nuclide, mass fraction			
1	32000,	1.00000		
2	13000,	1.00000		
3	82000,	1.00000		
4	7000,	0.79000	8000,	0.21000

1cell volumes and masses

print table 50

	cell	atom density	gram density	input volume	calculated volume	mass	pieces	reason volume not calculated
1	1	4.41918E-02	5.33000E+00	0.00000E+00	2.69392E+02	1.43586E+03	1	
2	2	6.02616E-02	2.70000E+00	0.00000E+00	1.17111E+01	3.16199E+01	1	
3	3	5.02433E-05	1.20000E-03	0.00000E+00	5.23637E+01	6.28365E-02	1	
4	4	6.02616E-02	2.70000E+00	0.00000E+00	2.51633E+01	6.79408E+01	1	
5	5	5.02433E-05	1.20000E-03	0.00000E+00	5.06729E+03	6.08075E+00	1	
6	6	3.28395E-02	1.13000E+01	0.00000E+00	1.44450E+04	1.63229E+05	1	
7	7	0.00000E+00	0.00000E+00	0.00000E+00				

```
1.12844E+08   0.00000E+00       1
      8     8  0.00000E+00   0.00000E+00   0.00000E+00
0.00000E+00   0.00000E+00       0       infinite
      9     9  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01       1
     10    10  6.02616E-02   2.70000E+00   0.00000E+00
5.35193E+00   1.44502E+01       1
     11    11  3.28395E-02   1.13000E+01   0.00000E+00
5.89049E-01   6.65625E+00       1
     12    12  3.28395E-02   1.13000E+01   0.00000E+00
3.33794E+00   3.77187E+01       1
     13    13  3.28395E-02   1.13000E+01   0.00000E+00
3.54372E+04   4.00440E+05       1
     14    14  5.02433E-05   1.20000E-03   0.00000E+00
1.98187E+05   2.37825E+02       1
1surface areas
                                              print table 50

          surface    input        calculated     reason area
                     area           area         not calculated

      1       20  0.00000E+00   3.84845E+01
      2       21  0.00000E+00   3.84845E+01
      3       22  0.00000E+00   1.53938E+02
      4       23  0.00000E+00   3.95919E+01
      5       24  0.00000E+00   3.95919E+01
      6       25  0.00000E+00   1.58368E+02
      7       26  0.00000E+00   4.11687E+01
      8       27  0.00000E+00   4.11687E+01
      9       28  0.00000E+00   1.90149E+02
     10       29  0.00000E+00   1.77205E+03
     11       30  0.00000E+00   1.77205E+03
     12       31  0.00000E+00   2.89953E+03
     13       32  0.00000E+00   1.77205E+03
     14       33  0.00000E+00   1.77205E+03
     15       34  0.00000E+00   2.13482E+04
     16       35  0.00000E+00   1.13097E+06
     17       36  0.00000E+00   1.96350E-01
     18       37  0.00000E+00   3.14159E+01
1cells
                                              print table 60

                          atom          gram
                 photon
         cell   mat     density      density       volume
mass       pieces importance


      1      1     1   4.41918E-02 5.33000E+00 2.69392E+02
1.43586E+03        1   1.00000E+00

      2      2     2   6.02616E-02 2.70000E+00 1.17111E+01
3.16199E+01        1   1.00000E+00

      3      3     4   5.02433E-05 1.20000E-03 5.23637E+01
6.28365E-02        1   1.00000E+00

      4      4     2   6.02616E-02 2.70000E+00 2.51633E+01
6.79408E+01        1   1.00000E+00

      5      5     4   5.02433E-05 1.20000E-03 5.06729E+03
6.08075E+00        1   1.00000E+00
```

```
     6     6     3  3.28395E-02 1.13000E+01 1.44450E+04
1.63229E+05      1  1.00000E+00

     7     7     0  0.00000E+00 0.00000E+00 1.12844E+08
0.00000E+00      1  0.00000E+00

     8     8     0  0.00000E+00 0.00000E+00 0.00000E+00
0.00000E+00      0  0.00000E+00

     9     9     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    10    10     2  6.02616E-02 2.70000E+00 5.35193E+00
1.44502E+01      1  1.00000E+00

    11    11     3  3.28395E-02 1.13000E+01 5.89049E-01
6.65625E+00      1  1.00000E+00

    12    12     3  3.28395E-02 1.13000E+01 3.33794E+00
3.77187E+01      1  1.00000E+00

    13    13     3  3.28395E-02 1.13000E+01 3.54372E+04
4.00440E+05      1  1.00000E+00

    14    14     4  5.02433E-05 1.20000E-03 1.98187E+05
2.37825E+02      1  1.00000E+00


 total                                        1.13097E+08
5.65522E+05
1surfaces
                                          print table 70

       surface     trans  type   surface coefficients

     1      20             py    1.3538000E+02
     2      21             py    1.4238000E+02
     3      22             cy    3.5000000E+00
     4      23             py    1.3533000E+02
     5      24             py    1.4243000E+02
     6      25             cy    3.5500000E+00
     7      26             py    1.3483000E+02
     8      27             py    1.4293000E+02
     9      28             cy    3.6200000E+00
    10      29             py    1.3470000E+02
    11      30             py    1.4306000E+02
    12      31             cy    3.7500000E+00
    13      32             py    0.0000000E+00
    14      33             py    1.1470000E+02
    15      34             cy    2.3750000E+01
    16      35             so    3.0000000E+02
    17      36             py    1.1770000E+02
    18      37             cy    2.5000000E-01

    minimum source weight = 9.9233E-01    maximum source
weight = 1.0000E+00

         4 warning messages so far.
1cross-section tables
                                         print table 100
```

table	length	
		tables from file 7000.01p2
7000.01p	389	
		12/13/82
		tables from file 8000.01p2
8000.01p	389	
		12/13/82
		tables from file 13000.01p2
13000.01p	409	
		12/13/82
		tables from file 32000.01p2
32000.01p	457	
		12/13/82
		tables from file 82000.01p2
82000.01p	521	
		12/13/82
total	2165	
		tables from file 7000.01e2
7000.01e	478	
		11/16/88
		tables from file 8000.01e2
8000.01e	478	
		11/16/88
		tables from file 13000.01e2
13000.01e	478	
		11/16/88
		tables from file 32000.01e2
32000.01e	478	
		11/16/88
		tables from file 82000.01e2
82000.01e	478	

use of dynamically allocated storage

general	467314
tallies	6596
bank	6403
cross sections	2165
total	482478

****
dump no. 1 on file runtpe nps = 0
ctm = 0.00

4 warning messages so far.

****
dump no. 2 on file runtpe nps = 2791449
ctm = 240.02

****
dump no. 3 on file runtpe nps = 5529867
ctm = 480.03

1problem summary

run terminated when 6000000 particle histories were done.
3/ 1/93 5:56:56
shield problem
probid = 2/28/93 20:59:33
0

photon creation / photon loss	tracks / tracks	weight / weight (per source particle)	energy / energy (per source particle)
source	6000000	9.9233E-01	2.1224E-01
escape	190962	3.1583E-02	2.3594E-03
energy cutoff	0	0.	0.
time cutoff	0	0.	0.
weight window	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	0.	0.
weight cutoff	0	0.	0.
energy importance	0	0.	0.

```
   energy importance        0    0.             0.
 dxtran                   0    0.             0.
   dxtran                   0    0.             0.
 forced collisions        0    0.             0.
   forced collisions        0    0.             0.
 exp. transform           0    0.             0.
   exp. transform           0    0.             0.
 from neutrons            0    0.             0.
   compton scatter          0    0.             5.5277E-02
 bremsstrahlung     1551521    2.5660E-01    6.3588E-03
   capture           11432962    1.8909E+00    1.8701E-01
 p-annihilation       17748    2.9353E-03    1.5116E-03
   pair production       8874    1.4677E-03    2.9367E-03
 electron x-rays          0    0.             0.

 1st fluorescence   3492763    5.7766E-01    2.6309E-02

 2nd fluorescence    570766    9.4398E-02    1.1622E-03

     total         11632798    1.9239E+00    2.4758E-01
       total         11632798    1.9239E+00    2.4758E-01

   number of photons banked                    2131161
average lifetime, shakes               cutoffs
   photon tracks per source particle       1.9388E+00
escape             2.7235E-01          tco   1.0000E+34
   photon collisions per source particle  2.2732E+00
capture            1.0771E-01          eco   1.0000E-03
   total photon collisions                     13639287
capture or escape 1.1042E-01          wc1   0.0000E+00

any termination    1.1034E-01          wc2   0.0000E+00

 computer time so far in this run    523.04 minutes
maximum number ever in bank           9
 computer time in mcrun               520.01 minutes
bank overflows to backup file         0
 source particles per minute             1.1538E+04
field length                          0
 random numbers generated                  116080478
most random numbers used was       217 in history   445357

 range of sampled source weights = 9.9233E-01 to 9.9233E-01

 source efficiency = 1.0000  in cell     5
1source distribution frequency tables
                                            print table 170

 the expected values below do not include the effect of the
rejection loop which samples position.


 source distribution   1  for erg

                                              number
                        weight
            source
   n          value          sampled       expected
sampled/expected       sampled        expected
sampled/expected

   1      1.50000E-02      1.0819E-01   1.0822E-01
```

```
9.9968E-01          1.0736E-01   1.0739E-01   9.9968E-01
   2      2.50000E-02      3.3785E-02   3.3878E-02
9.9727E-01          3.3526E-02   3.3618E-02   9.9727E-01
   3      3.75000E-02      2.4441E-01   2.4451E-01
9.9959E-01          2.4253E-01   2.4263E-01   9.9959E-01
   4      5.75000E-02      1.5373E-02   1.5326E-02
1.0031E+00          1.5255E-02   1.5208E-02   1.0031E+00
   5      8.50000E-02      2.1405E-01   2.1396E-01
1.0004E+00          2.1241E-01   2.1232E-01   1.0004E+00
   6      1.25000E-01      4.9562E-03   4.9406E-03
1.0032E+00          4.9181E-03   4.9027E-03   1.0032E+00
   7      2.25000E-01      1.1286E-01   1.1293E-01
9.9937E-01          1.1199E-01   1.1206E-01   9.9937E-01
   8      3.75000E-01      6.8281E-02   6.8361E-02
9.9883E-01          6.7757E-02   6.7837E-02   9.9883E-01
   9      5.75000E-01      1.1331E-01   1.1323E-01
1.0007E+00          1.1244E-01   1.1236E-01   1.0007E+00
  10      8.50000E-01      3.1022E-02   3.1055E-02
9.9893E-01          3.0784E-02   3.0817E-02   9.9893E-01
  11      1.25000E+00      3.3807E-02   3.3676E-02
1.0039E+00          3.3548E-02   3.3418E-02   1.0039E+00
  12      1.75000E+00      1.0756E-02   1.0688E-02
1.0064E+00          1.0674E-02   1.0606E-02   1.0064E+00
  13      2.25000E+00      8.6365E-03   8.6712E-03
9.9600E-01          8.5703E-03   8.6047E-03   9.9600E-01
  14      2.75000E+00      5.0483E-04   4.9406E-04
1.0218E+00          5.0096E-04   4.9027E-04   1.0218E+00
  15      3.50000E+00      5.7833E-05   6.0194E-05
9.6078E-01          5.7390E-05   5.9732E-05   9.6078E-01
  16      5.00000E+00      8.8333E-06   7.6932E-06
1.1482E+00          8.7656E-06   7.6341E-06   1.1482E+00
 total                     1.0000E+00   1.0000E+00
1.0000E+00          9.9233E-01   9.9233E-01   1.0000E+00
1warning.  the following cells are bounded by cells with
photon   importances                             print table
120
 that may be a factor of four or more different.

                               maximum
 minimum
  cell       importance     neighbor      importance    ratio
neighbor       importance    ratio

     9       no data available yet for this cell.
1photon    activity in each cell
                                              print table 126

                  tracks      population   collisions
collisions      number         flux         average
average
        cell    entering                                    *
weight       weighted       weighted    track weight    track mfp
                                                          (per
history)     energy         energy      (relative)      (cm)

     1     1            13             20            44
7.2771E-06   1.0522E+00   1.0522E+00   9.9233E-01
3.0914E+00
     2     2            23             13             0
0.0000E+00   1.1107E+00   1.1107E+00   9.9233E-01
6.1968E+00
     3     3            24             14             0
```

```
0.0000E+00   1.1477E+00   1.1477E+00   9.9233E-01
1.3693E+04
     4     4          10          10           0
0.0000E+00   1.0728E+00   1.0728E+00   9.9233E-01
6.1311E+00
     5     5     6160349     6002433      380098
6.2864E-02   2.2055E-01   2.2055E-01   9.9233E-01
5.5674E+03
     6     6          16          40          81
1.3396E-05   1.1375E+00   1.1375E+00   9.9233E-01
1.3251E+00
     9     9           0           0           0
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10    10          16          14           0
0.0000E+00   1.1589E+00   1.1589E+00   9.9233E-01
6.3100E+00
    11    11       28265       36587       55763
9.2225E-03   7.1528E-01   7.1528E-01   9.9233E-01
7.9568E-01
    12    12        1190        2059        2600
4.3001E-04   1.0969E+00   1.0969E+00   9.9233E-01
1.2333E+00
    13    13     5618813     7738186    13193161
2.1820E+00   7.5890E-01   7.5890E-01   9.9233E-01
8.4980E-01
    14    14      210612      209873        7540
1.2470E-03   7.3379E-02   7.3379E-02   9.9233E-01
3.7670E+03

    total      12019331    13989249    13639287
2.2558E+00
1photon   weight balance in each cell -- external events
                                        print table 130

        cell    entering      source       energy
time       exiting       total
                                         cutoff
cutoff

     1     1   2.1500E-06   0.0000E+00   0.0000E+00
0.0000E+00  -1.6539E-06   4.9616E-07
     2     2   3.8039E-06   0.0000E+00   0.0000E+00
0.0000E+00  -3.8039E-06   0.0000E+00
     3     3   3.9693E-06   0.0000E+00   0.0000E+00
0.0000E+00  -3.9693E-06   0.0000E+00
     4     4   1.6539E-06   0.0000E+00   0.0000E+00
0.0000E+00  -1.6539E-06   0.0000E+00
     5     5   2.6520E-02   9.9233E-01   0.0000E+00
0.0000E+00  -9.6509E-01   5.3759E-02
     6     6   2.6462E-06   0.0000E+00   0.0000E+00
0.0000E+00  -1.6539E-07   2.4808E-06
     9     9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00
    10    10   2.6462E-06   0.0000E+00   0.0000E+00
0.0000E+00  -2.6462E-06   0.0000E+00
    11    11   4.6747E-03   0.0000E+00   0.0000E+00
0.0000E+00  -7.6062E-04   3.9141E-03
    12    12   1.9681E-04   0.0000E+00   0.0000E+00
0.0000E+00  -1.2520E-04   7.1613E-05
    13    13   9.2929E-01   0.0000E+00   0.0000E+00
0.0000E+00  -2.7258E-02   9.0203E-01
```

```
    14    14   3.4833E-02   0.0000E+00   0.0000E+00
0.0000E+00  -3.3861E-02   9.7132E-04

     total     9.9553E-01   9.9233E-01   0.0000E+00
0.0000E+00  -1.0271E+00   9.6075E-01
1photon   weight balance in each cell -- variance reduction
events                                        print table 130

        cell     weight        cell        weight
energy       dxtran       forced    exponential     total
                window     importance     cutoff
importance                 collision    transform

     1     1   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     2     2   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     3     3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4     4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     5     5   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     6     6   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     9     9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10    10   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    11    11   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    12    12   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    13    13   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    14    14   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00

     total     0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
1photon weight balance in each cell -- physical events
                                          print table 130

        cell      from        brems-      p-annihi-
electron  fluorescence    capture        pair        total
               neutrons    strahlung      lation
x-rays                                 production

     1     1   0.0000E+00   1.1577E-06   0.0000E+00
```

```
0.0000E+00   4.9616E-07  -2.1500E-06   0.0000E+00
-4.9616E-07
     2     2   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     3     3   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     4     4   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
     5     5   0.0000E+00   4.2174E-05   9.9233E-07
0.0000E+00   0.0000E+00  -5.3802E-02  -4.9616E-07
-5.3759E-02
     6     6   0.0000E+00   3.3078E-06   0.0000E+00
0.0000E+00   3.4732E-06  -9.2617E-06   0.0000E+00
-2.4808E-06
     9     9   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    10    10   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00   0.0000E+00   0.0000E+00   0.0000E+00
0.0000E+00
    11    11   0.0000E+00   1.0027E-03   1.2239E-05
0.0000E+00   2.8412E-03  -7.7641E-03  -6.1194E-06
-3.9141E-03
    12    12   0.0000E+00   1.2619E-04   3.3078E-06
0.0000E+00   1.2057E-04  -3.2003E-04  -1.6539E-06
-7.1613E-05
    13    13   0.0000E+00   2.5543E-01   2.9188E-03
0.0000E+00   6.6909E-01  -1.8280E+00  -1.4594E-03
-9.0203E-01
    14    14   0.0000E+00   8.2694E-07   0.0000E+00
0.0000E+00   0.0000E+00  -9.7215E-04   0.0000E+00
-9.7132E-04

    total     0.0000E+00   2.5660E-01   2.9353E-03
0.0000E+00   6.7206E-01  -1.8909E+00  -1.4677E-03
-9.6075E-01
1photon activity of each nuclide in each cell, per source
particle                                        print table
140

        cell    nuclides      atom        total
collisions    weight lost    total from   weight from    avg
photon
                             fraction    collisions      *
weight      to capture      neutrons      neutrons
energy

     1     1   32000.01p  1.0000E+00         .    44
7.2771E-06    2.1500E-06            0      0.0000E+00
0.0000E+00

     2     2   13000.01p  1.0000E+00             0
0.0000E+00    0.0000E+00            0      0.0000E+00
0.0000E+00

     3     3    7000.01p  8.1122E-01             0
0.0000E+00    0.0000E+00            0      0.0000E+00
0.0000E+00
               8000.01p  1.8878E-01             0
```

0.0000E+00	0.0000E+00		0	0.0000E+00	
0.0000E+00					
4	4	13000.01p	1.0000E+00	0	
0.0000E+00	0.0000E+00		0	0.0000E+00	
0.0000E+00					
5	5	7000.01p	8.1122E-01	275308	
4.5533E-02	3.8417E-02		0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	104790	
1.7331E-02	1.5385E-02		0	0.0000E+00	
0.0000E+00					
6	6	82000.01p	1.0000E+00	81	
1.3396E-05	9.2617E-06		0	0.0000E+00	
0.0000E+00					
9	9	13000.01p	1.0000E+00	0	
0.0000E+00	0.0000E+00		0	0.0000E+00	
0.0000E+00					
10	10	13000.01p	1.0000E+00	0	
0.0000E+00	0.0000E+00		0	0.0000E+00	
0.0000E+00					
11	11	82000.01p	1.0000E+00	55763	
9.2225E-03	7.7641E-03		0	0.0000E+00	
0.0000E+00					
12	12	82000.01p	1.0000E+00	2600	
4.3001E-04	3.2003E-04		0	0.0000E+00	
0.0000E+00					
13	13	82000.01p	1.0000E+00	13193161	
2.1820E+00	1.8280E+00		0	0.0000E+00	
0.0000E+00					
14	14	7000.01p	8.1122E-01	5451	
9.0153E-04	6.8901E-04		0	0.0000E+00	
0.0000E+00					
		8000.01p	1.8878E-01	2089	
3.4550E-04	2.8314E-04		0	0.0000E+00	
0.0000E+00					
total				13639287	
2.2558E+00	1.8909E+00		0	0.0000E+00	
0.0000E+00					

total over all cells for each nuclide

	7000.01p		280759	
4.6434E-02	3.9106E-02	0	0.0000E+00	
0.0000E+00				
	8000.01p		106879	
1.7677E-02	1.5668E-02	0	0.0000E+00	
0.0000E+00				
	13000.01p		0	
0.0000E+00	0.0000E+00	0	0.0000E+00	
0.0000E+00				
	32000.01p		44	

```
7.2771E-06    2.1500E-06          0       0.0000E+00
0.0000E+00
               82000.01p                 13251605
2.1917E+00    1.8361E+00          0       0.0000E+00
0.0000E+00
1tally   1        nps =  6000000
           tally type 1    number of particles crossing a
surface.
           tally for  photons

 surface  27

     energy
   1.5000E-02   0.00000E+00 0.0000
   2.5000E-02   0.00000E+00 0.0000
   3.7500E-02   0.00000E+00 0.0000
   5.7500E-02   0.00000E+00 0.0000
   8.5000E-02   0.00000E+00 0.0000
   1.2500E-01   0.00000E+00 0.0000
   2.2500E-01   0.00000E+00 0.0000
   3.7500E-01   0.00000E+00 0.0000
   5.7500E-01   0.00000E+00 0.0000
   8.5000E-01   0.00000E+00 0.0000
   1.2500E+00   0.00000E+00 0.0000
   1.7500E+00   0.00000E+00 0.0000
   2.2500E+00   0.00000E+00 0.0000
   2.7500E+00   0.00000E+00 0.0000
   3.5000E+00   0.00000E+00 0.0000
   5.0000E+00   0.00000E+00 0.0000
   7.0000E+00   0.00000E+00 0.0000
   1.1000E+01   0.00000E+00 0.0000
     total      0.00000E+00 0.0000

 for the tally-fluctuation-chart bin:
 average tally per history = 0.00000E+00            largest
tally in one history = 0.00000E+00
 (largest tally)/(average tally) = 1.00000E+00      nps of
largest tally =        0
1tally   4        nps =  6000000
           tally type 4    track length estimate of particle
flux.      units   1/cm**2
           tally for  photons

           volumes
                   cell:       1            2            3
      4            5            6            7
                         2.69392E+02  1.17111E+01
5.23637E+01  2.51633E+01  5.06729E+03  1.44450E+04
1.12844E+08
                   cell:       9            10           11
      12           13           14
                         5.35193E+00  5.35193E+00
5.89049E-01  3.33794E+00  3.54372E+04  1.98187E+05

 cell  1
energy
        1.5000E-02   1.01865E-11 0.6678
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   1.01672E-10 1.0000
        1.2500E-01   5.76616E-10 0.6836
```

```
        2.2500E-01   3.09061E-09 0.6189
        3.7500E-01   4.41974E-09 0.5406
        5.7500E-01   1.90198E-09 0.9020
        8.5000E-01   5.13397E-09 0.6025
        1.2500E+00   6.32676E-09 0.4923
        1.7500E+00   6.86832E-09 0.6698
        2.2500E+00   4.98049E-09 0.7085
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      3.34104E-08 0.3223

     cell  2
energy
        1.5000E-02   0.00000E+00 0.0000
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
        3.7500E-01   5.16077E-09 0.5269
        5.7500E-01   0.00000E+00 0.0000
        8.5000E-01   4.89291E-09 0.6654
        1.2500E+00   8.51990E-09 0.5318
        1.7500E+00   6.64181E-09 0.6987
        2.2500E+00   4.46791E-09 0.7140
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      2.96833E-08 0.3099

     cell  3
energy
        1.5000E-02   0.00000E+00 0.0000
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
        3.7500E-01   6.57301E-09 0.6557
        5.7500E-01   0.00000E+00 0.0000
        8.5000E-01   3.01172E-09 0.6614
        1.2500E+00   1.24626E-08 0.4117
        1.7500E+00   7.64425E-09 0.5171
        2.2500E+00   5.53815E-09 0.5862
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      3.52298E-08 0.2860

     cell  4
energy
        1.5000E-02   0.00000E+00 0.0000
        2.5000E-02   0.00000E+00 0.0000
```

3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	2.73714E-09	0.7385
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	4.86231E-09	0.7642
1.2500E+00	6.71527E-09	0.5938
1.7500E+00	4.52162E-09	1.0000
2.2500E+00	2.80041E-09	1.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.16367E-08	0.3642

cell 5

energy

1.5000E-02	6.51647E-04	0.0014
2.5000E-02	3.08186E-04	0.0022
3.7500E-02	2.25054E-03	0.0007
5.7500E-02	1.42936E-04	0.0033
8.5000E-02	1.99274E-03	0.0008
1.2500E-01	4.74165E-05	0.0056
2.2500E-01	1.04581E-03	0.0011
3.7500E-01	6.32138E-04	0.0015
5.7500E-01	1.04853E-03	0.0011
8.5000E-01	2.87118E-04	0.0023
1.2500E+00	3.12972E-04	0.0022
1.7500E+00	9.96144E-05	0.0039
2.2500E+00	7.99950E-05	0.0044
2.7500E+00	4.67428E-06	0.0182
3.5000E+00	5.35998E-07	0.0537
5.0000E+00	8.17057E-08	0.1374
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	8.90493E-03	0.0001

cell 6

energy

1.5000E-02	2.30508E-13	0.4588
2.5000E-02	2.61507E-14	0.7343
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	5.21238E-12	0.3796
1.2500E-01	1.02968E-12	1.0000
2.2500E-01	2.02480E-13	1.0000
3.7500E-01	1.98886E-11	0.5623
5.7500E-01	2.98788E-11	0.5802
8.5000E-01	5.93599E-11	0.5089
1.2500E+00	1.49565E-10	0.4189
1.7500E+00	1.09583E-10	0.9299
2.2500E+00	7.77299E-11	0.8616
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	4.52706E-10	0.3433

cell 7

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 9

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	0.00000E+00	0.0000

cell 10

energy		
1.5000E-02	0.00000E+00	0.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	1.47898E-08	0.7349
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	4.41393E-09	1.0000
1.2500E+00	2.91785E-08	0.4135
1.7500E+00	1.64642E-08	0.5001
2.2500E+00	1.22442E-08	0.5775
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000

7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	7.70907E-08	0.2974

cell 11

energy

1.5000E-02	3.68468E-06	0.0138
2.5000E-02	4.17948E-07	0.0410
3.7500E-02	6.87363E-06	0.0181
5.7500E-02	2.23039E-06	0.0578
8.5000E-02	1.31681E-04	0.0125
1.2500E-01	6.80995E-06	0.0544
2.2500E-01	8.69557E-05	0.0230
3.7500E-01	2.18415E-04	0.0236
5.7500E-01	6.20978E-04	0.0211
8.5000E-01	3.09763E-04	0.0352
1.2500E+00	3.47833E-04	0.0383
1.7500E+00	1.28393E-04	0.0663
2.2500E+00	1.15695E-04	0.0751
2.7500E+00	7.55586E-06	0.2910
3.5000E+00	8.42315E-07	1.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.98813E-03	0.0137

cell 12

energy

1.5000E-02	2.35726E-08	0.0759
2.5000E-02	4.11473E-09	0.1769
3.7500E-02	5.58719E-09	0.2471
5.7500E-02	1.85641E-08	0.2184
8.5000E-02	7.98162E-07	0.0712
1.2500E-01	8.16472E-08	0.2349
2.2500E-01	4.10319E-07	0.1491
3.7500E-01	1.70271E-06	0.0899
5.7500E-01	5.50031E-06	0.0675
8.5000E-01	8.89935E-06	0.0727
1.2500E+00	1.23537E-05	0.0784
1.7500E+00	7.76852E-06	0.1319
2.2500E+00	7.08034E-06	0.1601
2.7500E+00	3.32632E-07	0.6173
3.5000E+00	5.32441E-08	1.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	4.50328E-05	0.0473

cell 13

energy

1.5000E-02	1.41637E-08	0.0008
2.5000E-02	1.67683E-09	0.0026
3.7500E-02	2.55716E-08	0.0011
5.7500E-02	9.36071E-09	0.0035
8.5000E-02	5.07170E-07	0.0007
1.2500E-01	2.67066E-08	0.0039
2.2500E-01	3.34975E-07	0.0015
3.7500E-01	8.70678E-07	0.0017
5.7500E-01	2.38681E-06	0.0015
8.5000E-01	1.31811E-06	0.0027
1.2500E+00	1.66691E-06	0.0029
1.7500E+00	6.84677E-07	0.0052

```
        2.2500E+00   5.22231E-07 0.0062
        2.7500E+00   3.21635E-08 0.0255
        3.5000E+00   3.31500E-09 0.0743
        5.0000E+00   6.59522E-10 0.2006
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      8.40518E-06 0.0012

     cell  14
energy
        1.5000E-02   1.48827E-06 0.0048
        2.5000E-02   9.83579E-08 0.0175
        3.7500E-02   4.09968E-07 0.0085
        5.7500E-02   1.65857E-07 0.0147
        8.5000E-02   2.54719E-06 0.0038
        1.2500E-01   2.40034E-07 0.0123
        2.2500E-01   4.54041E-07 0.0087
        3.7500E-01   1.46046E-07 0.0124
        5.7500E-01   5.90288E-08 0.0229
        8.5000E-01   7.36640E-09 0.0558
        1.2500E+00   3.14708E-09 0.0883
        1.7500E+00   7.02036E-10 0.1807
        2.2500E+00   1.35266E-10 0.4052
        2.7500E+00   2.73707E-11 1.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      5.62017E-06 0.0025

     for the tally-fluctuation-chart bin:
     average tally per history = 9.00047E-06            largest
    tally in one history = 8.71385E+00
     (largest tally)/(average tally) = 9.68155E+05      nps of
    largest tally =  3499554
    ltally   8        nps =  6000000
               tally type 8    pulse height distribution.
              units   number
               tally for  photons

     cell  1
energy
        1.5000E-02   4.96165E-07 0.5774
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
        3.7500E-01   3.30776E-07 0.7071
        5.7500E-01   1.65388E-07 1.0000
        8.5000E-01   1.65388E-07 1.0000
        1.2500E+00   1.65388E-07 1.0000
        1.7500E+00   6.61553E-07 0.5000
        2.2500E+00   1.65388E-07 1.0000
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      2.15005E-06 0.2773
```

cell 2

energy		
1.5000E-02	2.15005E-06	0.2773
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.15005E-06	0.2773

cell 3

energy		
1.5000E-02	2.31543E-06	0.2673
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.31543E-06	0.2673

cell 4

energy		
1.5000E-02	1.65388E-06	0.3162
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000

7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.65388E-06	0.3162

cell 5

energy

1.5000E-02	9.88032E-01	0.0000
2.5000E-02	1.21230E-03	0.0117
3.7500E-02	1.54324E-03	0.0103
5.7500E-02	3.13411E-04	0.0230
8.5000E-02	3.27799E-04	0.0225
1.2500E-01	2.03427E-04	0.0285
2.2500E-01	3.10930E-04	0.0231
3.7500E-01	2.24763E-04	0.0271
5.7500E-01	7.78978E-05	0.0461
8.5000E-01	4.61433E-05	0.0599
1.2500E+00	2.51390E-05	0.0811
1.7500E+00	1.02541E-05	0.1270
2.2500E+00	1.98466E-06	0.2887
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.92329E-01	0.0000

cell 6

energy

1.5000E-02	1.65388E-07	1.0000
2.5000E-02	0.00000E+00	0.0000
3.7500E-02	0.00000E+00	0.0000
5.7500E-02	0.00000E+00	0.0000
8.5000E-02	0.00000E+00	0.0000
1.2500E-01	0.00000E+00	0.0000
2.2500E-01	0.00000E+00	0.0000
3.7500E-01	3.30776E-07	0.7071
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	6.61553E-07	0.5000
1.2500E+00	9.92329E-07	0.4082
1.7500E+00	1.65388E-07	1.0000
2.2500E+00	3.30776E-07	0.7071
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.64621E-06	0.2500

cell 7

energy

1.5000E-02	7.95898E-03	0.0045
2.5000E-02	5.60997E-04	0.0172
3.7500E-02	2.32370E-03	0.0084
5.7500E-02	9.30474E-04	0.0133
8.5000E-02	1.43435E-02	0.0034
1.2500E-01	1.41903E-03	0.0108
2.2500E-01	2.58303E-03	0.0080
3.7500E-01	1.05319E-03	0.0125
5.7500E-01	2.91745E-04	0.0238
8.5000E-01	2.28236E-05	0.0851
1.2500E+00	5.45781E-06	0.1741
1.7500E+00	3.30776E-07	0.7071

```
        2.2500E+00   0.00000E+00 0.0000
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      3.14932E-02 0.0023

     cell  8

          energy
        1.5000E-02   0.00000E+00 0.0000
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
        3.7500E-01   0.00000E+00 0.0000
        5.7500E-01   0.00000E+00 0.0000
        8.5000E-01   0.00000E+00 0.0000
        1.2500E+00   0.00000E+00 0.0000
        1.7500E+00   0.00000E+00 0.0000
        2.2500E+00   0.00000E+00 0.0000
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      0.00000E+00 0.0000

     cell  9
energy
        1.5000E-02   0.00000E+00 0.0000
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
        3.7500E-01   0.00000E+00 0.0000
        5.7500E-01   0.00000E+00 0.0000
        8.5000E-01   0.00000E+00 0.0000
        1.2500E+00   0.00000E+00 0.0000
        1.7500E+00   0.00000E+00 0.0000
        2.2500E+00   0.00000E+00 0.0000
        2.7500E+00   0.00000E+00 0.0000
        3.5000E+00   0.00000E+00 0.0000
        5.0000E+00   0.00000E+00 0.0000
        7.0000E+00   0.00000E+00 0.0000
        1.1000E+01   0.00000E+00 0.0000
          total      0.00000E+00 0.0000

     cell  10
energy
        1.5000E-02   2.31543E-06 0.2673
        2.5000E-02   0.00000E+00 0.0000
        3.7500E-02   0.00000E+00 0.0000
        5.7500E-02   0.00000E+00 0.0000
        8.5000E-02   0.00000E+00 0.0000
        1.2500E-01   0.00000E+00 0.0000
        2.2500E-01   0.00000E+00 0.0000
```

3.7500E-01	0.00000E+00	0.0000
5.7500E-01	0.00000E+00	0.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	2.31543E-06	0.2673

cell 11

energy

1.5000E-02	4.78799E-04	0.0186
2.5000E-02	1.56457E-04	0.0325
3.7500E-02	1.04244E-03	0.0126
5.7500E-02	9.41059E-05	0.0419
8.5000E-02	1.04310E-03	0.0126
1.2500E-01	8.05441E-05	0.0453
2.2500E-01	5.32881E-04	0.0176
3.7500E-01	4.31002E-04	0.0196
5.7500E-01	5.28415E-04	0.0177
8.5000E-01	1.42068E-04	0.0341
1.2500E+00	8.31903E-05	0.0446
1.7500E+00	2.24928E-05	0.0857
2.2500E+00	9.92329E-06	0.1291
2.7500E+00	4.96165E-07	0.5774
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	4.64592E-03	0.0060

cell 12

energy

1.5000E-02	6.97938E-05	0.0487
2.5000E-02	3.30776E-07	0.7071
3.7500E-02	4.96165E-07	0.5774
5.7500E-02	9.92329E-07	0.4082
8.5000E-02	6.28475E-06	0.1622
1.2500E-01	2.64621E-06	0.2500
2.2500E-01	6.28475E-06	0.1622
3.7500E-01	1.60427E-05	0.1015
5.7500E-01	3.15891E-05	0.0724
8.5000E-01	2.43121E-05	0.0825
1.2500E+00	1.83581E-05	0.0949
1.7500E+00	9.92329E-06	0.1291
2.2500E+00	3.14238E-06	0.2294
2.7500E+00	1.65388E-07	1.0000
3.5000E+00	1.65388E-07	1.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	1.90527E-04	0.0295

cell 13

energy

1.5000E-02	5.95135E-02	0.0016
2.5000E-02	3.50429E-02	0.0021
3.7500E-02	2.32846E-01	0.0007

5.7500E-02	1.69788E-02	0.0031
8.5000E-02	2.11839E-01	0.0008
1.2500E-01	7.60984E-03	0.0046
2.2500E-01	1.04487E-01	0.0012
3.7500E-01	6.71498E-02	0.0015
5.7500E-01	1.10260E-01	0.0012
8.5000E-01	3.05252E-02	0.0023
1.2500E+00	3.31400E-02	0.0022
1.7500E+00	1.06804E-02	0.0039
2.2500E+00	8.30348E-03	0.0044
2.7500E+00	4.82603E-04	0.0185
3.5000E+00	5.52397E-05	0.0547
5.0000E+00	8.76557E-06	0.1374
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	9.28922E-01	0.0001

cell 14
energy

1.5000E-02	3.45402E-02	0.0021
2.5000E-02	2.97699E-05	0.0745
3.7500E-02	1.35618E-05	0.1104
5.7500E-02	5.12703E-06	0.1796
8.5000E-02	6.45014E-06	0.1601
1.2500E-01	2.31543E-06	0.2673
2.2500E-01	3.30776E-07	0.7071
3.7500E-01	0.00000E+00	0.0000
5.7500E-01	1.65388E-07	1.0000
8.5000E-01	0.00000E+00	0.0000
1.2500E+00	0.00000E+00	0.0000
1.7500E+00	0.00000E+00	0.0000
2.2500E+00	0.00000E+00	0.0000
2.7500E+00	0.00000E+00	0.0000
3.5000E+00	0.00000E+00	0.0000
5.0000E+00	0.00000E+00	0.0000
7.0000E+00	0.00000E+00	0.0000
1.1000E+01	0.00000E+00	0.0000
total	3.45979E-02	0.0021

```
 for the tally-fluctuation-chart bin:
 average tally per history = 2.15005E-06          largest
tally in one history = 9.92329E-01
 (largest tally)/(average tally) = 4.61538E+05       nps of
largest tally =    166962
1tally fluctuation charts

               tally   1                              tally   4
                     tally   8
      nps          mean      error      fom              mean
error     fom           mean        error      fom
     512000    0.00000E+00 0.0000 0.0E+00          4.55891E-08
1.0000 2.3E-02        1.93814E-06 1.0000 2.3E-02
    1024000    0.00000E+00 0.0000 0.0E+00          3.43138E-08
0.7443 2.0E-02        1.93814E-06 0.7071 2.3E-02
    1536000    0.00000E+00 0.0000 0.0E+00          2.89830E-08
0.6142 2.0E-02        2.58419E-06 0.5000 3.0E-02
    2048000    0.00000E+00 0.0000 0.0E+00          2.17372E-08
0.6142 1.5E-02        1.93814E-06 0.5000 2.3E-02
    2560000    0.00000E+00 0.0000 0.0E+00          2.44721E-08
0.5237 1.7E-02        1.93814E-06 0.4472 2.3E-02
    3072000    0.00000E+00 0.0000 0.0E+00          2.04180E-08
0.5230 1.4E-02        1.93814E-06 0.4082 2.3E-02
```

```
      3584000    0.00000E+00 0.0000 0.0E+00        3.31098E-08
0.4362 1.7E-02        2.21502E-06 0.3536 2.6E-02
      4096000    0.00000E+00 0.0000 0.0E+00        2.89711E-08
0.4362 1.5E-02        1.93814E-06 0.3536 2.2E-02
      4608000    0.00000E+00 0.0000 0.0E+00        2.75777E-08
0.4127 1.5E-02        1.93814E-06 0.3333 2.2E-02
      5120000    0.00000E+00 0.0000 0.0E+00        2.82347E-08
0.3824 1.5E-02        1.93814E-06 0.3162 2.2E-02
      5632000    0.00000E+00 0.0000 0.0E+00        2.81767E-08
0.3595 1.6E-02        1.93814E-06 0.3015 2.3E-02
      6000000    0.00000E+00 0.0000 0.0E+00        3.34104E-08
0.3223 1.9E-02        2.15005E-06 0.2773 2.5E-02

************************************************************
     ************
      dump no.  4 on file   runtpe          nps = 6000000
     ctm =  520.01
              4 warning messages so far.
      run terminated when   6000000 particle histories were done.

      mcnp     version 4.2m4  6/30/91                        3/
     1/93  5:56:58                    probid =    2/28/93
     20:59:33
```

APPENDIX D

EQUATIONS USED IN TABLE VII'S SPREADSHEET

Equations used in Table VII's spreadsheet:

Total counts in detector from Kr-87 = (Counts from 2.97 MeV peak) / (Prob.of 2.97 MeV γ occurance)

γ/s of isotope = (Isotope ratio to Kr-87) * (Total counts from Kr-87)

Activity of isotope (Ci/cc) = (γ/s of isotope) * (1 dis/ 2 γ) * (1 Ci/ 3.7×10^{10} dis/s) * (1/ souce volume)

Activity of secondary containment(Ci) = (Activity of isotope (Ci/cc)) * (Secondary contain. volume (cc))

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