

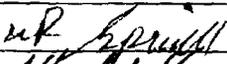
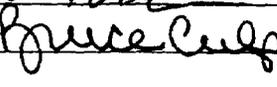
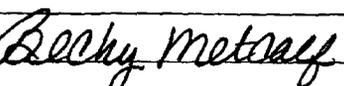
Engineering Design File

ETR Reactor Vessel Source Term and External Dose Rates

**Idaho
Cleanup
Project**

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ETR Reactor Vessel Source Term and External Dose Rates

1. PURPOSE

The purpose of this EDF is to estimate the source term of the ETR reactor based on dose measurements performed inside of the reactor and internal surface contamination surveys.

2. INTRODUCTION

On July 19, 2005 thirteen sets of TLD chips (LiF) were placed inside the ETR Rabbit (see Figure 1). The Rabbit is located at approximately the O-3 location on Figure 2. The Rabbit is a sample tube allowing test samples to be delivered to the reactor core area during operation. The Rabbit tube extends down just outside of the Aluminum reflector to the top surface of the grid plate (see Figure 3). The TLDs were oriented such that the first TLD was located 2 inches above the grid plate with the other TLD chips sets at 2 foot intervals throughout the Rabbit tube. The TLD chips were exposed in the core for a period of 5 minutes. Additionally, on September of 2005, a sample of loose surface contamination was removed from the primary system at a heat exchange low point drain. This sample was sent to an off-site lab for analysis. The lab results were then analyzed and converted to Ci/cm^2 for the contaminated surfaces in EDF 6291 (reference 1), "Radiological Characterization of the ETR Complex Internal Surfaces".

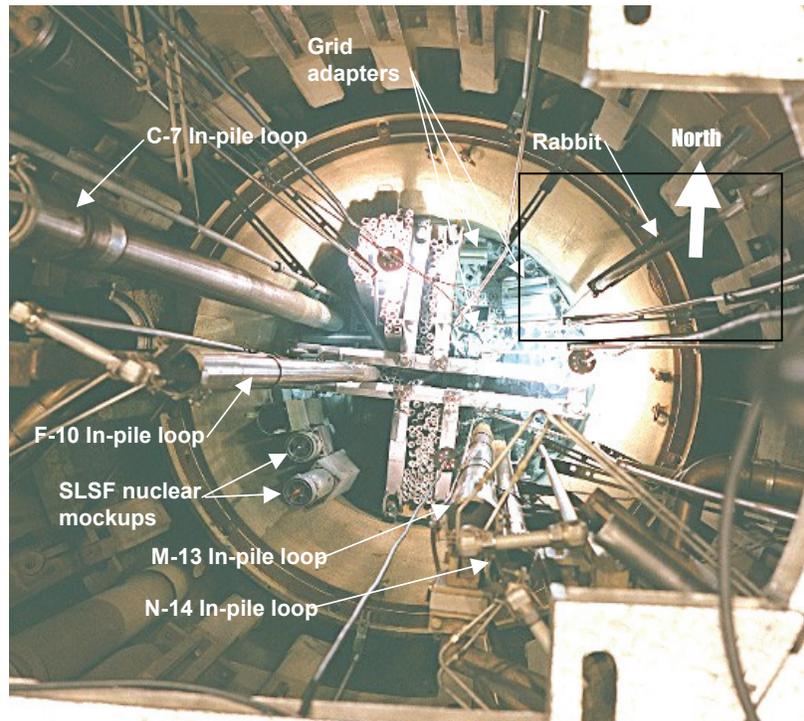


Figure 1. Photograph of the ETR core from above showing Rabbit location.

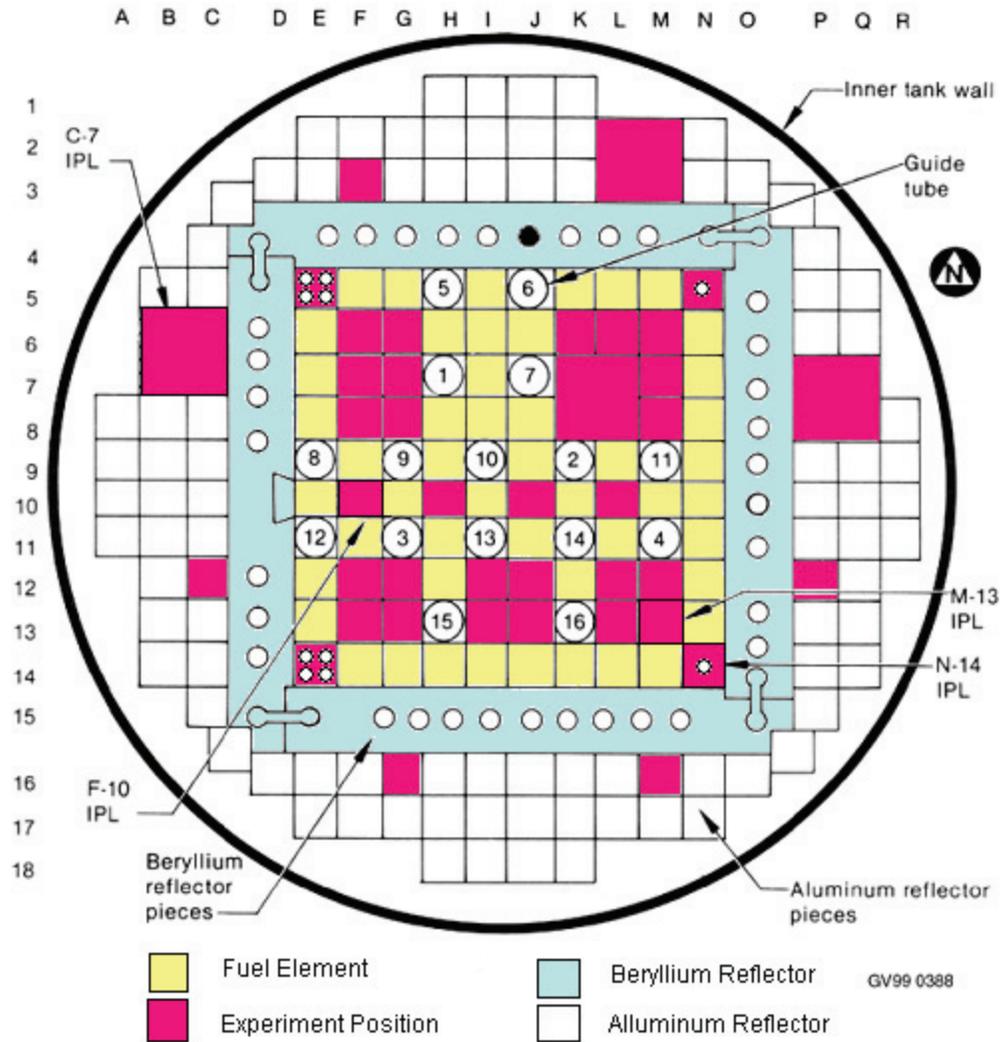


Figure 2. Locations inside the reactor core.

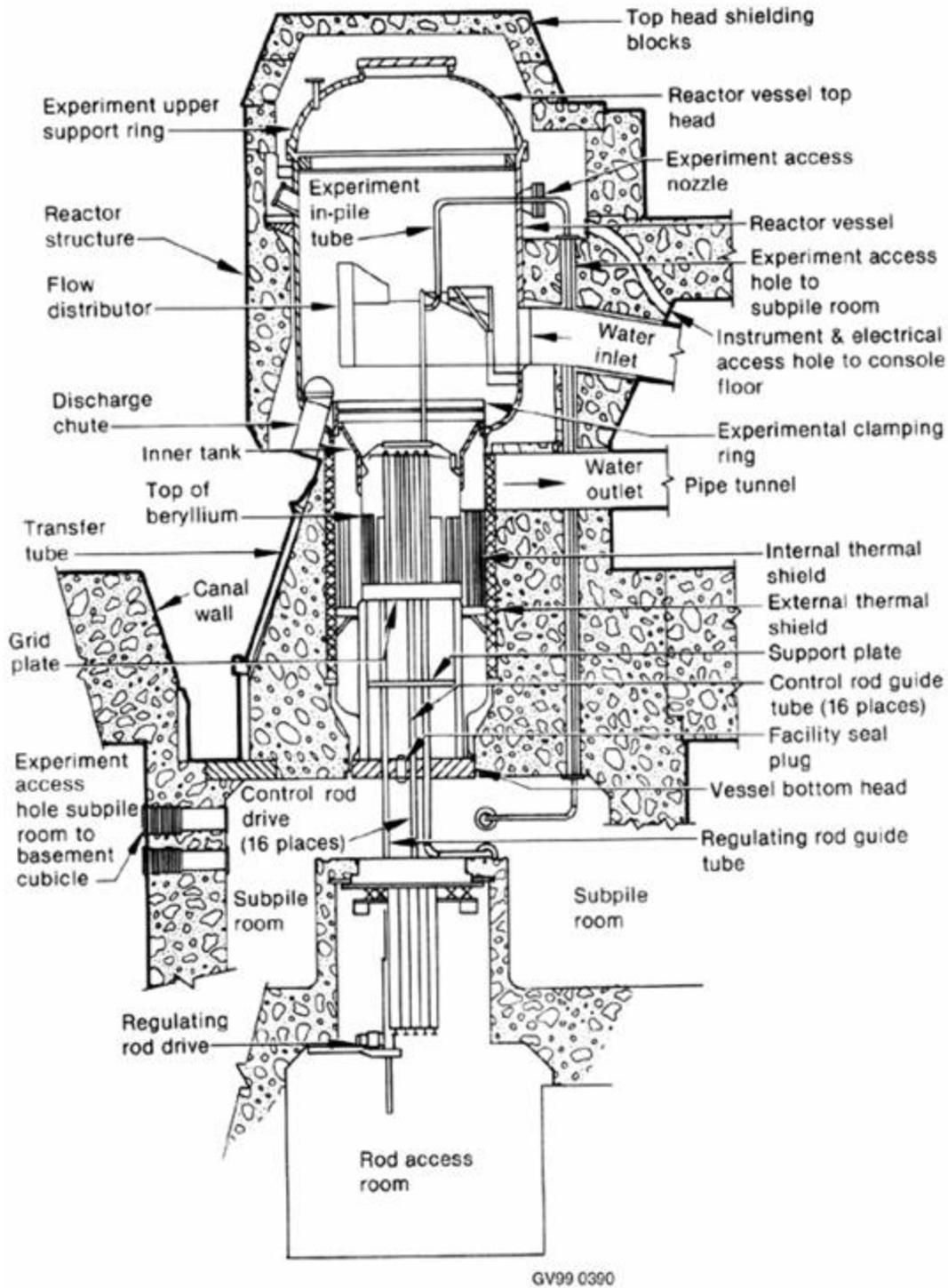


Figure 3. Cross section showing the major elements making up the ETR.

3. ANALYTICAL DATA

Table 1 contains the TLD results provided by R. Perry of the Dosimetry organization. The “Final Results” are in mR for a 5 minute exposure time. The results were then converted to mR/hr.

Table 1. TLD Results.

Station #	Final Results (Mr)	Inside Rabbit Tube (mR/h)
1	41694	5.003E+05
2	40722	4.887E+05
3	4780	5.736E+04
4	1800	2.160E+04
5	620	7.440E+03
6	219	2.628E+03
7	208	2.496E+03
8	83	9.960E+02
9	23	2.760E+02
10	2	2.400E+01
11	1	1.200E+01
12	2	2.400E+01
13	2	2.400E+01

Table 2 shows the various radionuclides and the relative ratios (scaled to Co-60) of the radionuclides as presented in EDF-6958 (Reference 2).

Table 2. EDF 6958, ETR radionuclides and Scaling Factors.

Isotope	Reactor Totals (Ci/Ci)	Isotope	Reactor Totals (Ci/Ci)	Isotope	Reactor Totals (Ci/Ci)
H-3	1.67E+01	I-129	2.15E-09	U-235	1.29E-10
Be-10	1.89E-04	Cs-134	1.49E-06	U-236	3.67E-10
C-14	6.74E-03	Cs-137	1.37E-03	U-238	4.33E-09
Cl-36	6.40E-05	Ce-144	1.15E-12	Np-237	1.09E-09
Mn-54	1.63E-09	Eu-152	9.23E-05	Pu-238	4.24E-05
Ni-59	6.72E-02	Eu-154	5.31E-04	Pu-239	9.21E-06
Co-60	1.00E+00	Pb-210	3.50E-14	Pu-240	1.13E-05
Ni-63	1.23E+01	Ra-226	5.65E-14	Pu-241	9.21E-04
Zn-65	8.68E-14	Ac-227	5.14E-10	Pu-242	1.44E-07
Sr-90	4.29E-04	Th-228	9.10E-08	Pu-244	1.36E-13
Nb-94	2.45E-03	Th-229	6.10E-10	Am-241	9.21E-05

Table 2. (continued).

Isotope	Reactor Totals (Ci/Ci)	Isotope	Reactor Totals (Ci/Ci)	Isotope	Reactor Totals (Ci/Ci)
Tc-99	3.22E-06	Th-230	5.95E-12	Am-243	1.40E-06
Ru-103	0.00E+00	Th-232	1.04E-09	Cm-243	2.56E-07
Ru-106	1.59E-10	Pa-231	7.53E-10	Cm-244	1.62E-04
Ag-108m	1.23E-04	U-232	8.76E-08	Cm-245	3.07E-08
Ag-110m	3.75E-14	U-233	1.73E-07	Cm-246	3.39E-08
Sb-125	3.35E-06	U-234	1.56E-08	Cm-247	2.39E-13
				Cm-248	4.29E-12

Table 3 shows the radionuclides determined to be in the primary system surface contamination and the area specific activity values for these radionuclides as presented in EDF 6291.

Table 3. EDF 6291 Values.

Nuclide	Area Specific Activity (Ci/cm ²)
Am241	1.1E-12
C14	1.8E-12
Co60	3.2E-09
Cs137	2.3E-11
Fe55	4.4E-09
Ni59	8.2E-11
Ni63	7.8E-09
Pu238	1.3E-12
Pu239	2.0E-12
Sr90	2.1E-11
U233	1.9E-13
U235	5.2E-15

4. METHODS AND ASSUMPTIONS

TLD STATIONS:

For the modeling of the reactor in this EDF, the activated portion of the reactor was divided up into different regions and modeled in MicroShield (Reference 5) separately. These regions (referred to as stations) were defined by the locations of the TLD chips that were placed in the Rabbit tube. The first set of TLD chips were placed 2" above the grid plate at the bottom of the core (Station 1). The model for this region included the volume from the bottom surface of the grid plate to a location halfway between Station 1 and Station 2 (or 1' above station 1). The other regions were each of 2' in height representing the volume from 1' below the TLD station to 1' above the TLD station. All of the stations were

cylindrical volumes with a radius of 26.5" (the approximate distance from the centerline of the core to the TLD chips).

ASSUMPTIONS:

The following assumptions were used in the development of the MicroShield models used to determine the vessel source term:

- The relative ratios (scaling factors) between the various radionuclides presented in EDF-6958 are assumed to be exact and representative of the materials in the vessel.

As stated in EDF-6958, there is uncertainty in the alloy composition for the precursor element that neutron activates to the isotope of concern (e.g., Mo is in stainless steel and Mo98 + n transmutes to Tc99; so Mo is the precursor for Tc99). Often, reported assay data indicate upper limits on impurities, and these were usually used. However, there is no guarantee that the impurities included in that process really are there. There is uncertainty in the computer code to accurately predict the isotope inventory (due to uncertainties in decay or cross-section data and mathematical models in the code) and there are uncertainties associated with the way the power history data were modeled. Since it is not feasible to sample all of the materials in the vessel, the EDF-6958 values are used.

- The modeled activated volumes associated with the TLD stations are assumed to account for all of the activity associated with the vessel.

The 26.5 inch radius used in the models is the approximate distance from the reactor centerline to the rabbit tube location. Remaining Items contained in this 26.5 inch radius include the grid plate, beryllium and aluminum reflectors, In-pile tubes, control rod poisons sections and other control rod components. Based on the EDF-6958 data, these components represent ~96% of the reactor total activity. The inner tank accounts for effectively all of the remaining 4% of the reactor activity.

In the model, the activity of the inner tank was modeled as if it existed within the 26.5 radius. The inside edge of the inner tank is ~ 4.6" from the rabbit tube and contributed dose to the TLD stations. The modeling of the tank activity as if it existed inside of the 26.5 radius is considered valid for the following reason: For two cylinders (one with an inside radius of 31.1" and the other with an outside radius of 21.9" so that the distance from the nearest edge to the measurement point is 4.6") of the same thickness and activity, the dose rate at the measurement point is approximately equal.

Additionally, while 13 sets of TLD chips were inserted into the rabbit tube, only the first 7 were used to determine the reactor source term. Per EDF-6958, only those materials within ~ 1m of the core edge experience significant (in terms of total source term) activation. There are no significantly activated structures below the grid plate and these below grid plate materials were modeled as if they were included in the first station. Above the grid plate, this activated section (the core area plus 1 m above the core) was monitored by the TLD chips placed in stations 1 thru 4. The source term determined from these TLD locations represents 98.8% of the total calculated vessel source term.

The total exposure rate at TLD station point 5 could not be attributed to the dose that would have been generated there due to the source term at station point 4. For this reason, a source term was determined for station point 5 based on the measured dose minus the dose due to the source term at station point 4. The source term determined at station 5 represented only 0.7% of the reactor activity.

The same was true for stations 6 and 7. The source terms determined for these locations, based on the measured dose minus the dose contribution from the source term directly below the station point, represented ~0.25% of the total reactor activity for each station.

The dose rate at station point 8, once the dose due to the source term at station point 7 was subtracted, was insignificant and thus produced an insignificant contribution to the total source term. Additionally, the dose measured at station points 9-13 produced an insignificant contribution to the source term and were neglected.

- The materials in the vessel are assumed to attenuate gamma radiation the same as iron with a 5.38 g/cc density.

The vessel was constructed of many different materials (Beryllium, Nickel, Stainless Steel, etc.) with the most abundant material being stainless steel. For the models, the activated materials were modeled as if their gamma attenuation was similar to that of iron (the main component in stainless steel). The density of the source term used in the model was based on the density of stainless steel obtained from MatWeb.com (reference 3). The density was reduced by the metal to water (now air) ratio listed in the Fundamentals in the Operation of Nuclear Test Reactors, Vol. 3 Engineering Test Reactor Design and Operation manual (reference 4). This calculation was performed by multiplying the stainless steel density by the ratio as follows: $8.03 \text{ g/cc} * .67 = 5.38 \text{ g/cc}$.

The modeling of the reactor as iron with a uniform density is considered conservative. Station 1 contains the most metal in its modeled volume. This modeled volume consists of the grid plate, portions of the beryllium and aluminum reflectors, portions of the control rods, and portions of the in-pile tubes. The total volume of station 1 is 0.875 m^3 ($53,456 \text{ in}^3$). The estimated component masses and volumes in this station are as follows:

- Grid plate – 0.489 m^3 component volume, 0.285 m^3 material volume, 2,213 kg. Component density (accounting for holes in the grid plate) = $2215 \text{ kg}/0.489 \text{ m}^3 = 4.53 \text{ g/cm}^3$.
- Be reflector – 0.133 m^3 component volume, 0.102 m^3 material volume, 188 kg. Component density (accounting for holes) = $188 \text{ kg}/0.133 \text{ m}^3 = 1.41 \text{ g cm}^3$.
- Al reflector – 0.469 m^3 component volume, 0.392 m^3 material volume, 1088 kg. Component density (accounting for holes) = $1088 \text{ kg}/0.469 \text{ m}^3 = 2.319 \text{ g/cm}^3$.
- Black Control Rods – 0.009 m^3 component volume, 0.0034 m^3 material volume, 27.3 kg. Component density = $27.3 \text{ kg}/.009 \text{ m}^3 = 3 \text{ g/cm}^3$.
- Grey Control Rods – 0.028 m^3 component volume, 0.01 m^3 material volume, 78.8 kg. Component density = $78.8 \text{ kg}/ 0.028 \text{ m}^3 = 2.81 \text{ g/cm}^3$.
- Control Rod Tubes – 0.053 m^3 component volume, 0.016 m^3 material volume, 30 kg. Component density = $30 \text{ kg}/0.053 \text{ m}^3 = 0.56 \text{ g/cm}^3$.
- (4) In-pile tubes (assumed to be 2.5" SCH 160) – 0.0096 m^3 component volume, 0.001 m^3 material volume, 8.4 kg. Component density = $8.4 \text{ kg}/.0096 \text{ m}^3 = 0.875 \text{ g/cm}^3$.

The combined density of station 1 as a whole is $3633.5 \text{ kg}/0.875 \text{ m}^3 = 4.15 \text{ g/cm}^3$.

The assumed density value of 5.38 g/cm^3 for each station is greater than that of any of the individual components and is greater than the density of station 1 taken as a whole.

The gamma attenuation of a material is described by the following equation:

$$I = bI_o e^{-(\mu / \rho)(\rho)(x)}$$

Where:

I_o = Original radiation exposure rate

I = Attenuated exposure rate

μ/ρ = mass attenuation coefficient

ρ = absorber density

x = absorber thickness

b = buildup factor.

For a given material, increasing the density value in the above equation results in a lower attenuated exposure rate (more gammas are attenuated) for a given original radiation exposure rate and absorber thickness. Additionally, if more gammas are attenuated by the higher density shield medium, a higher original exposure rate (i.e. a higher activity source term) is required to produce the same attenuated exposure rate.

In the model, the calculated dose from the source term directly below the TLD station point was subtracted from the measured TLD result (ie the dose from the source term at TLD station point 1 was determined at station point 2 and this dose was subtracted from the measured dose at station 2). The use of the higher density attenuator in the model resulted in a dose being subtracted that was smaller than if the lower density attenuator was used. This results in a higher activity source term being determined. For example, the source term at station point 2 was determined based on a dose rate of 487,044 mR/hr ($488,664 \text{ mR/hr} - 1,620 \text{ mR/hr}$). If the lower density material was used, the source term would have been based on a dose rate of 486,344 mR/hr ($488,664 \text{ mR/hr} - 2,230 \text{ mR/hr}$).

Additionally, in the model, the attenuating medium was assumed to be iron. The only other material of significant quantity in station point 1 is aluminum. The MicroShield model was re-run using Aluminum with a density of 5.38 g/cm^3 as the attenuator. The source term, with aluminum as the attenuator, produced a source term that was lower than if iron was used (for the same dose rate).

- The it is assumed that all dose measured by the TLD chips at station 1 was from the volume of material in the model for station 1 and received no added dose from the activated volumes of the other stations.
- The surface contamination on the vessel internal surfaces is assumed to have the same area specific activity (Ci/cm^2) values as that determined in EDF-6291 for the primary system.

The sample point in EDF-6291 was a low point drain from a primary heat exchanger where impurities in the primary system water would have collected; the sample contained radionuclides associated with fission/fuel (Cs-137, Sr-90, Am-241, Pu-238, Pu-239, U-233, & U235) and radionuclides associated with activation (Co-60, C-14, Fe-55, Ni-59, Ni-63) indicating that the contamination came from or passed through the reactor and were then deposited on piping surfaces; during reactor operation, the same water flowed through the reactor as the primary system; and the primary system did contain an ion exchanger used to remove activity from the primary coolant. However, less than 1% of primary system flow was through the ion exchanger.

The process history of the reactor states that after the fuel was removed, the reactor was rinsed and horizontal surfaces vacuumed. The surface contamination should be no greater than that in the primary system piping

METHODOLOGY

The following methodology was used to determine the reactor source term:

1. A MicroShield model was created for TLD station 1.

- The geometry of this station was a cylindrical volume of 26.5" radius. The height of the volume for station 1 was equivalent to the distance from below the grid plate to 1' above the TLD location.
- The radionuclides used in the model are those shown in Table 2 above. The initial activity value for each radionuclide was based on 1 Ci of Co-60 and the scaling factors in Table 2. For example, the initial activity of Ni-63 used in the model with a Table 2 scaling factor of 1.23E01 to Co-60 was determined as presented below:

$$Ni63_Activity = 1.23 * 10^1 * 1Ci = 123Ci$$

- A dose rate was determined at the TLD measurement location based on the initial source term.
- The concentrations of each radionuclide were then adjusted (while maintaining the ratios between individual quantities constant) until a dose rate equal to that measured by the TLD chips was obtained.
- Based on this corrected source term, a dose rate at the TLD location for station 2 was determined.

2. A MicroShield model was created for the remaining TLD stations.

- The geometry of the remaining stations were also cylindrical volumes all of 26.5" radius. The height of the volumes for these stations were 2' (the TLDs were placed in the rabbit tube in 2' intervals and each station was defined as including the volume from 1' below to 1' above the TLD measurement location).
- The radionuclides and activity values used each model are the same as those used for station 1.
- A dose rate was determined at the TLD measurement location of the station based on the initial source term.

- The concentrations of each radionuclide were then adjusted (while maintaining the ratios between individual quantities constant) until a dose rate equal to that measured by the TLD chips, less the dose rate contributed by the station source term directly below the modeled station, was obtained. For example, the dose rate measured by the TLD chips at station 2 was 4.887E05 mR/hr; the dose received by the chips from the activated volume of station 1 was 1.619E03 mR/hr. Thus, the dose rate used for the source term determination of station 2 was (4.887E05 – 1.619E03) mR/hr or 4.871E05 mR/hr.
 - Once a source term was determined for the station, a dose rate at the TLD location directly above was determined (to be subtracted from the TLD results as shown in the example above).
 - After determining a source term for each station, the source terms were summed to give a total vessel source term.
3. Using the above calculated vessel source term value and the percent activity values and component radionuclide scaling factors determined in EDF-6958 (and are repeated in Attachment 2), the activity of each component in the vessel was determined as presented in the example below.

This example calculates the tritium (H-3) in the Be reflector. This same methodology was used to calculate the activity values for each radionuclide in each component in the vessel.

The total activity of the reactor presented in the results section below is 59,273 Ci. The percentage of activity that the Be reflector contributes to the total vessel source term, determined in EDF-6958, is 55.60%. The activity of the Be reflector is then determined as follows:

$$Be_reflector_activity = 59,273Ci * 55.60\% = 32,956Ci$$

The sum of all of the individual activity values for the radionuclides in the Be reflector equals the total Be reflector source term as shown in the equation below:

$$H-3_{activity} + Be-10_{activity} + \dots + Cm-248_{activity} = 32,956 Ci$$

The activity value of each radionuclide is determined from the Co-60 activity and the scaling factor (SF) of that radionuclide to Co-60 presented in EDF-6958 and Attachment 2. For example, the H-3 activity is determined as follows:

$$2.97E4 * Co-60_{activity} = H-3_{activity}$$

Thus, the equation for the Be reflector activity becomes:

$$(2.97E4 * Co-60_{activity}) + (3.36E-1 * Co-60_{activity}) + \dots + (9.05E-10 * Co-60_{activity}) = 32,956 Ci$$

The above equation can be simplified as shown below:

$$Co60_{activity} * \sum_{i=1}^n SF_i = 32,956Ci$$

Where:

n = The radionuclides in the Be reflector;

SF_i = The scaling factor of radionuclide i to Co-60;

From the Attachment 3 data for the Be reflector, $\sum_{i=1}^n SF_i = 2.97 * 10^4 Ci / Ci$

The Co-60 activity can then be determined as shown below:

$$Co60_{activity} = \frac{32,956Ci}{2.97 * 10^4 Ci / Ci} = 1.11Ci$$

Once the Co-60 activity is determined, the H-3 activity can be determined as follows:

$$H3_{activity} = 2.97 * 10^4 * 1.11Ci = 3.3 * 10^4 Ci$$

4. The source term due to surface contamination in the vessel was then determined. The surface contamination source term in the ETR reactor is based on the average contamination results of the primary system identified in EDF-6291 and the reactor internal surface area provided by the Engineering Department. The calculation used to determine the surface contamination source term was as follows:

$$Rx_{sc} = SC * A$$

Where:

Rx_{sc} = Reactor Surface Contamination (Ci);

SC = Surface contamination value from EDF-6291 for each radionuclide (Ci/cm²);

A = Reactor internal surface area provided by ETR Engineering (cm²).

5. VERIFICATION AND VALIDATION OF MICROSHIELD V6.10

MicroShield v6.10 (reference 8) was used to develop a model of the geometry and material composition of the waste. MicroShield is maintained under INEEL Software Configuration and Control Number 161146 and is fully validated, verified, and controlled in accordance with applicable INEEL requirements. MicroShield is installed on CPU number 382434, which is located at TRA 1601.

6. RESULTS

Table 4 presents the calculated source term for the reactors internal contaminated surfaces.

Table 4. Reactor Surface Contamination.

Area Description	Surface Area (cm) ²	Am241 (Ci)	C14 (Ci)	Co60 (Ci)	Cs137 (Ci)	Fe55 (Ci)	Ni59 (Ci)	Ni63 (Ci)	Pu238 (Ci)	Pu239 (Ci)	Sr90 (Ci)	U233 (Ci)	U235 (Ci)
Reactor Vessel	1520713	1.68E-06	2.69E-06	4.88E-03	3.49E-05	6.63E-03	1.25E-04	1.19E-02	1.93E-06	2.99E-06	3.27E-05	2.94E-07	7.85E-09

Table 5 presents the total calculated source term for the reactor.

Table 5. Reactor Source Term.

Nuclide	Station Point #1 (Ci)	Station Point #2 (Ci)	Station Point #3 (Ci)	Station Point #4 (Ci)	Station Point #5 (Ci)	Station Point #6 (Ci)	Station Point #7 (Ci)	Contaminated Surfaces (Ci)	Total (Ci)
Ac-227	4.55E-07	4.71E-07	5.40E-08	2.07E-08	7.13E-09	2.52E-09	2.41E-09		1.01E-06
Ag-108m	1.09E-01	1.13E-01	1.29E-02	4.90E-03	1.71E-03	6.03E-04	5.76E-04		2.42E-01
Ag-110m	3.32E-11	3.44E-11	3.94E-12	1.51E-12	5.21E-13	1.84E-13	1.76E-13		7.40E-11
Am-241	8.15E-02	8.45E-02	9.67E-03	3.72E-03	1.28E-03	4.52E-04	4.31E-04	1.68E-06	1.82E-01
Am-243	1.24E-03	1.29E-03	1.47E-04	5.66E-05	1.95E-05	6.88E-06	6.57E-06		2.76E-03
Be-10	1.67E-01	1.74E-01	1.99E-02	7.64E-03	2.63E-03	9.28E-04	8.87E-04		3.73E-01
C-14	5.96E+00	6.18E+00	7.08E-01	2.72E-01	9.35E-02	3.30E-02	3.16E-02	2.69E-06	1.33E+01
Ce-144	1.02E-09	1.05E-09	1.21E-10	4.64E-11	1.60E-11	5.64E-12	5.38E-12		2.26E-09
Cl-36	5.66E-02	5.87E-02	6.72E-03	2.58E-03	8.88E-04	3.14E-04	3.00E-04		1.26E-01
CM-243	2.26E-04	2.35E-04	2.69E-05	1.03E-05	3.55E-06	1.25E-06	1.20E-06		5.04E-04
CM-244	1.44E-01	1.49E-01	1.71E-02	6.55E-03	2.25E-03	7.97E-04	7.61E-04		3.20E-01
CM-245	2.72E-05	2.82E-05	3.22E-06	1.24E-06	4.26E-07	1.51E-07	1.44E-07		6.05E-05
CM-246	3.00E-05	3.11E-05	3.56E-06	1.37E-06	4.71E-07	1.66E-07	1.59E-07		6.68E-05
CM-247	2.11E-10	2.19E-10	2.51E-11	9.63E-12	3.31E-12	1.17E-12	1.12E-12		4.71E-10
CM-248	3.79E-09	3.93E-09	4.50E-10	1.73E-10	5.95E-11	2.10E-11	2.01E-11		8.45E-09
Co-60	8.85E+02	9.17E+02	1.05E+02	4.03E+01	1.39E+01	4.90E+00	4.68E+00	4.88E-03	1.97E+03
Cs-134	1.32E-03	1.37E-03	1.57E-04	6.03E-05	2.07E-05	7.33E-06	7.00E-06		2.95E-03
Cs-137	1.21E+00	1.26E+00	1.44E-01	5.54E-02	1.91E-02	6.73E-03	6.43E-03	3.49E-05	2.71E+00
Eu-152	8.17E-02	8.47E-02	9.70E-03	3.72E-03	1.28E-03	4.53E-04	4.32E-04		1.82E-01
Eu-154	4.70E-01	4.87E-01	5.58E-02	2.14E-02	7.37E-03	2.60E-03	2.49E-03		1.05E+00
Fe-55								6.63E-03	6.63E-03
H-3	1.48E+04	1.53E+04	1.76E+03	6.74E+02	2.32E+02	8.20E+01	7.83E+01		3.29E+04

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Table 5 (continued)

Nuclide	Station Point #1 (Ci)	Station Point #2 (Ci)	Station Point #3 (Ci)	Station Point #4 (Ci)	Station Point #5 (Ci)	Station Point #6 (Ci)	Station Point #7 (Ci)	Contaminated Surfaces (Ci)	Total (Ci)
I-129	1.91E-06	1.98E-06	2.26E-07	8.69E-08	2.99E-08	1.06E-08	1.01E-08		4.24E-06
Mn-54	1.44E-06	1.49E-06	1.71E-07	6.57E-08	2.26E-08	7.99E-09	7.63E-09		3.21E-06
Nb-94	2.17E+00	2.25E+00	2.58E-01	9.89E-02	3.40E-02	1.20E-02	1.15E-02		4.83E+00
Ni-59	5.94E+01	6.16E+01	7.05E+00	2.71E+00	9.32E-01	3.29E-01	3.15E-01	1.25E-04	1.32E+02
Ni-63	1.09E+04	1.13E+04	1.29E+03	4.95E+02	1.70E+02	6.02E+01	5.75E+01	1.19E-02	2.42E+04
Np-237	9.64E-07	9.99E-07	1.14E-07	4.39E-08	1.51E-08	5.34E-09	5.10E-09		2.15E-06
Pa-231	6.66E-07	6.90E-07	7.90E-08	3.04E-08	1.04E-08	3.69E-09	3.53E-09		1.48E-06
Pb-210	3.09E-11	3.21E-11	3.67E-12	1.41E-12	4.85E-13	1.71E-13	1.64E-13		6.89E-11
Pu-238	3.75E-02	3.89E-02	4.46E-03	1.71E-03	5.89E-04	2.08E-04	1.99E-04	1.93E-06	8.36E-02
Pu-239	8.15E-03	8.45E-03	9.67E-04	3.72E-04	1.28E-04	4.52E-05	4.31E-05	2.99E-06	1.82E-02
Pu-240	1.00E-02	1.04E-02	1.19E-03	4.56E-04	1.57E-04	5.54E-05	5.29E-05		2.23E-02
Pu-241	8.15E-01	8.45E-01	9.67E-02	3.72E-02	1.28E-02	4.52E-03	4.31E-03		1.82E+00
Pu-242	1.28E-04	1.32E-04	1.52E-05	5.82E-06	2.00E-06	7.08E-07	6.76E-07		2.84E-04
Pu-244	1.20E-10	1.24E-10	1.42E-11	5.47E-12	1.88E-12	6.65E-13	6.35E-13		2.67E-10
Ra-226	5.00E-11	5.18E-11	5.93E-12	2.28E-12	7.84E-13	2.77E-13	2.65E-13		1.11E-10
Ru-106	1.41E-07	1.46E-07	1.67E-08	6.42E-09	2.21E-09	7.80E-10	7.45E-10		3.13E-07
Sb-125	2.96E-03	3.07E-03	3.52E-04	1.35E-04	4.65E-05	1.64E-05	1.57E-05		6.60E-03
Sr-90	3.79E-01	3.93E-01	4.50E-02	1.73E-02	5.95E-03	2.10E-03	2.01E-03	3.27E-05	8.45E-01
Tc-99	2.85E-03	2.95E-03	3.38E-04	1.30E-04	4.47E-05	1.58E-05	1.51E-05		6.34E-03
Th-228	8.05E-05	8.35E-05	9.56E-06	3.67E-06	1.26E-06	4.46E-07	4.26E-07		1.79E-04
Th-229	5.39E-07	5.59E-07	6.40E-08	2.46E-08	8.46E-09	2.99E-09	2.86E-09		1.20E-06
Th-230	5.26E-09	5.46E-09	6.25E-10	2.40E-10	8.26E-11	2.92E-11	2.79E-11		1.17E-08
Th-232	9.20E-07	9.54E-07	1.09E-07	4.20E-08	1.44E-08	5.10E-09	4.87E-09		2.05E-06
U-232	7.75E-05	8.04E-05	9.20E-06	3.53E-06	1.22E-06	4.30E-07	4.11E-07		1.73E-04
U-233	1.53E-04	1.59E-04	1.82E-05	6.97E-06	2.40E-06	8.48E-07	8.10E-07	2.94E-07	3.41E-04
U-234	1.38E-05	1.43E-05	1.64E-06	6.29E-07	2.16E-07	7.64E-08	7.30E-08		3.07E-05
U-235	1.14E-07	1.18E-07	1.35E-08	5.20E-09	1.79E-09	6.33E-10	6.04E-10	7.85E-09	2.62E-07
U-236	3.24E-07	3.36E-07	3.85E-08	1.48E-08	5.09E-09	1.80E-09	1.72E-09		7.23E-07
U-238	3.83E-06	3.97E-06	4.55E-07	1.75E-07	6.01E-08	2.12E-08	2.03E-08		8.53E-06
Zn-65	7.68E-11	7.96E-11	9.11E-12	3.50E-12	1.20E-12	4.26E-13	4.07E-13		1.71E-10
Total									59273

Table 6 presents the vessel component activity values.

Table 6. Component Radionuclide Activity Values.

Isotope	Be Reflector (Ci)	Grid Plate (Ci)	I-Beams (Ci)	C-7 In-Pile Tube (Ci)	F-10 In-Pile Tube (Ci)	M-13 In-Pile Tube (Ci)	N-14 In-Pile Tube (Ci)	Upper Support Frame (Ci)	Inner Tank (Ci)	Internal Thermal Shields (Ci)	External Thermal Shield (Ci)	External Tank (Ci)	Black Rod Poison (Ci)	Gray Rod Poison (Ci)
H-3	3.294E+04	4.748E+00	1.567E-06	1.475E-01	1.118E-01	1.122E-01	9.034E-02	3.832E-07	3.202E+00	9.497E-02	8.236E-04	1.908E-03	1.189E-01	1.395E-04
Be-10	3.731E-01	8.572E-07	2.727E-13	3.021E-08	8.404E-08	3.790E-08	1.941E-08	6.681E-14	5.841E-07	1.647E-08	1.824E-10	4.202E-10	1.954E-07	1.252E-06
C-14	2.967E+00	4.706E+00	1.307E-06	1.769E-01	5.421E-01	2.395E-01	1.172E-01	3.198E-07	3.181E+00	7.942E-02	7.186E-05	2.093E-04	1.252E+00	3.992E-04
Cl-36	3.626E-02	4.832E-02	1.038E-08	1.387E-03	3.912E-03	1.824E-03	9.118E-04	2.542E-09	2.509E-02	6.303E-04	1.618E-07	7.396E-07	7.942E-03	1.340E-05
Mn-54	9.160E-09	1.626E-06	3.105E-13	4.832E-08	1.639E-07	1.454E-07	6.303E-08	7.606E-14	7.564E-07	1.883E-08	1.030E-10	2.429E-10	3.736E-07	6.051E-09
Ni-59	2.689E-02	5.547E+00	7.312E-06	9.034E-01	1.744E+00	1.038E+00	5.757E-01	1.790E-06	1.702E+01	4.454E-01	1.139E-04	5.211E-04	2.172E+00	1.030E+02
Co-60	1.109E+00	5.505E+02	2.072E-04	2.983E+01	8.110E+01	5.799E+01	2.824E+01	5.084E-05	4.958E+02	1.256E+01	5.715E-03	2.038E-02	1.391E+02	5.757E+02
Ni-63	3.879E+00	6.345E+02	7.732E-04	1.030E+02	2.765E+02	1.370E+02	6.933E+01	1.895E-04	1.862E+03	4.706E+01	1.265E-02	5.547E-02	5.084E+02	2.055E+04
Zn-65	4.286E-11	3.845E-11	7.690E-18	1.311E-12	6.681E-12	4.622E-12	1.773E-12	1.874E-18	1.954E-11	4.664E-13	2.773E-15	1.382E-15	2.357E-11	3.219E-11
Sr-90	7.522E-01	4.874E-02	3.429E-09	1.361E-03	6.219E-03	2.715E-03	1.093E-03	8.404E-10	1.782E-02	2.105E-04	8.362E-07	2.009E-06	1.298E-02	3.265E-06
Nb-94	8.194E-03	4.748E+00	1.777E-08	2.353E-03	6.345E-03	3.046E-03	1.542E-03	4.328E-09	4.286E-02	1.076E-03	1.584E-06	4.202E-06	1.206E-02	3.244E-06
Tc-99	5.505E-04	3.215E-03	7.059E-10	9.034E-05	2.252E-04	1.126E-04	5.883E-05	1.723E-10	1.651E-03	4.244E-05	1.126E-08	5.084E-08	3.803E-04	1.067E-07
Ru-106	3.068E-07	3.853E-09	1.740E-17	1.210E-10	4.622E-10	4.622E-10	1.798E-10	4.244E-18	1.277E-09	1.441E-12	4.135E-15	9.959E-15	7.438E-10	1.672E-13
Ag-108m	3.500E-02	6.513E-02	1.416E-08	1.887E-03	5.169E-03	2.509E-03	1.265E-03	3.463E-09	3.408E-02	8.572E-04	4.202E-03	8.026E-06	9.245E-02	2.643E-06
Ag-110m	2.609E-11	1.227E-11	3.509E-18	4.181E-13	3.261E-13	7.648E-13	4.874E-13	8.572E-19	7.522E-12	2.126E-13	1.046E-12	1.992E-15	2.467E-11	3.908E-17
Sb-125	6.891E-04	2.853E-03	6.051E-10	9.329E-05	3.278E-04	2.483E-04	1.084E-04	1.483E-10	1.467E-03	3.673E-05	1.357E-07	4.328E-08	7.858E-04	1.513E-07
I-129	4.093E-06	9.497E-08	2.172E-15	2.567E-09	1.193E-08	5.042E-09	1.992E-09	5.337E-16	3.034E-08	1.378E-10	5.169E-13	1.244E-12	2.214E-08	6.093E-12
Cs-134	2.332E-03	3.269E-04	7.564E-11	1.080E-05	2.492E-05	2.551E-05	1.273E-05	1.845E-11	1.761E-04	4.580E-06	1.172E-09	5.379E-09	3.227E-05	8.320E-09
Cs-137	2.517E+00	1.008E-01	3.727E-09	2.790E-03	1.361E-02	5.925E-03	2.299E-03	9.118E-10	3.353E-02	2.324E-04	9.034E-07	2.168E-06	2.786E-02	7.059E-06
Ce-144	2.198E-09	3.710E-11	1.420E-18	1.177E-12	4.370E-12	4.328E-12	1.710E-12	3.471E-19	1.357E-11	8.908E-14	3.467E-16	8.320E-16	7.354E-12	1.626E-15
Eu-152	1.530E-02	3.744E-02	2.752E-07	1.567E-03	6.765E-06	9.455E-05	5.631E-04	6.723E-08	1.084E-01	1.639E-02	6.135E-04	1.387E-03	5.295E-06	1.756E-09
Eu-154	8.992E-01	9.034E-02	1.572E-08	2.748E-03	2.088E-03	3.177E-03	2.130E-03	3.845E-09	4.412E-02	9.539E-04	3.492E-05	7.942E-05	9.875E-04	3.694E-07
Pb-210	1.605E-11	1.664E-11	4.370E-14	4.131E-13	4.538E-12	9.287E-13	2.618E-13	8.824E-14	5.841E-12	3.366E-12	1.114E-12	2.219E-12	1.740E-11	3.782E-15
Ra-226	2.244E-11	4.080E-11	1.261E-13	1.038E-12	3.921E-12	1.412E-12	6.009E-13	2.559E-13	1.559E-11	9.707E-12	3.219E-12	6.429E-12	6.051E-12	2.013E-15
Ac-227	1.265E-07	5.084E-07	7.900E-13	1.483E-08	1.588E-08	1.273E-08	8.530E-09	1.353E-12	3.042E-07	8.530E-09	1.433E-10	3.236E-10	1.240E-08	4.622E-12
Th-228	6.303E-05	6.345E-05	4.958E-09	1.664E-06	1.151E-05	4.538E-06	1.467E-06	1.004E-08	1.597E-05	3.807E-07	4.790E-07	9.118E-07	1.614E-05	5.084E-09
Th-229	1.055E-07	6.093E-07	2.286E-13	1.790E-08	1.265E-08	1.139E-08	9.118E-09	5.589E-14	4.122E-07	1.277E-08	2.055E-10	4.706E-10	1.072E-08	3.900E-12

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Table 6. (continued).

Isotope	Be Reflector (Ci)	Grid Plate (Ci)	I-Beams (Ci)	C-7 In-Pile Tube (Ci)	F-10 In-Pile Tube (Ci)	M-13 In-Pile Tube (Ci)	N-14 In-Pile Tube (Ci)	Upper Support Frame (Ci)	Inner Tank (Ci)	Internal Thermal Shields (Ci)	External Thermal Shield (Ci)	External Tank (Ci)	Black Rod Poison (Ci)	Gray Rod Poison (Ci)
Th-230	3.273E-09	3.786E-09	1.273E-11	9.875E-11	3.828E-10	1.626E-10	6.555E-11	2.584E-11	1.395E-09	9.749E-10	3.252E-10	6.471E-10	5.505E-10	1.765E-13
Th-232	1.298E-08	1.017E-07	5.000E-09	3.311E-09	1.328E-09	1.467E-09	1.525E-09	1.013E-08	1.261E-07	3.803E-07	4.832E-07	9.203E-07	1.000E-09	3.656E-13
Pa-231	2.017E-07	7.354E-07	1.567E-12	2.168E-08	2.395E-08	1.979E-08	1.311E-08	2.820E-12	4.370E-07	1.227E-08	2.168E-10	4.874E-10	1.937E-08	7.017E-12
U-232	6.135E-05	6.135E-05	2.500E-16	1.618E-06	1.122E-05	4.412E-06	1.424E-06	4.496E-17	1.542E-05	3.576E-09	6.597E-13	1.815E-12	1.572E-05	4.958E-09
U-233	3.492E-05	1.689E-04	6.387E-11	5.127E-06	3.534E-06	3.631E-06	2.895E-06	1.563E-11	1.151E-04	3.584E-06	5.757E-08	1.315E-07	2.786E-06	9.959E-10
U-234	1.374E-05	7.186E-06	3.076E-08	1.937E-07	7.774E-07	4.244E-07	1.588E-07	6.261E-08	2.475E-06	2.341E-06	7.858E-07	1.567E-06	9.497E-07	2.883E-10
U-235	3.815E-09	1.008E-08	1.399E-09	3.673E-10	6.093E-11	5.042E-11	1.177E-10	2.841E-09	2.257E-08	1.063E-07	3.572E-08	7.101E-08	8.488E-11	2.483E-14
U-236	5.505E-07	9.413E-08	3.324E-14	2.849E-09	2.252E-09	1.912E-09	1.576E-09	8.110E-15	6.471E-08	2.009E-09	7.858E-12	1.887E-11	3.782E-09	9.749E-13
U-238	2.404E-06	6.009E-07	3.038E-08	1.954E-08	6.639E-09	8.194E-09	8.908E-09	6.177E-08	7.564E-07	2.315E-06	7.774E-07	1.546E-06	3.786E-09	1.563E-12
Np-237	1.887E-06	1.790E-07	6.051E-15	4.748E-09	7.101E-09	5.757E-09	3.311E-09	1.479E-15	5.169E-08	3.618E-10	1.429E-12	3.433E-12	8.614E-09	2.488E-12
Pu-238	7.774E-02	4.328E-03	1.202E-16	9.287E-05	3.488E-04	2.051E-04	6.639E-05	3.547E-18	4.143E-04	5.547E-09	2.618E-13	7.606E-13	2.307E-04	8.698E-08
Pu-239	1.265E-02	2.790E-03	1.614E-09	8.782E-05	3.513E-05	4.286E-05	4.370E-05	3.946E-10	2.416E-03	9.539E-05	3.807E-07	9.160E-07	2.009E-05	8.278E-09
Pu-240	1.811E-02	2.605E-03	9.707E-15	7.606E-05	6.597E-05	5.673E-05	4.622E-05	2.857E-16	1.202E-03	4.580E-07	2.118E-11	6.135E-11	8.320E-05	2.635E-08
Pu-241	1.639E+00	1.286E-01	2.794E-18	3.517E-03	4.454E-03	4.832E-03	2.912E-03	9.917E-21	2.954E-02	1.055E-07	5.631E-14	1.975E-13	3.576E-03	1.240E-06
Pu-242	2.761E-04	4.958E-06	3.626E-28	1.156E-07	1.303E-06	5.925E-07	1.412E-07	1.551E-31	4.131E-07	1.088E-14	6.765E-23	2.862E-22	1.210E-06	4.496E-10
Pu-244	2.542E-10	9.455E-14	0.000E+00	1.828E-15	1.630E-12	1.866E-13	7.606E-15	0.000E+00	1.248E-15	2.088E-27	1.765E-39	1.084E-38	1.105E-11	1.744E-15
Am-241	1.593E-01	1.647E-02	3.584E-19	4.370E-04	4.706E-04	5.127E-04	3.236E-04	1.273E-21	3.799E-03	1.349E-08	7.228E-15	2.534E-14	3.273E-04	1.223E-07
Am-243	2.706E-03	1.517E-05	4.790E-33	3.101E-07	1.702E-05	4.496E-06	5.379E-07	2.454E-37	5.253E-07	1.139E-16	8.236E-27	4.202E-26	1.908E-05	6.891E-09
CM-243	4.832E-04	1.416E-05	6.009E-33	2.983E-07	3.454E-06	1.677E-06	3.437E-07	3.097E-37	5.883E-07	1.433E-16	1.038E-26	5.295E-26	1.563E-06	7.732E-10
CM-244	3.055E-01	3.265E-04	3.908E-37	5.883E-06	3.429E-03	3.290E-04	1.618E-05	0.000E+00	4.412E-06	7.438E-18	6.261E-30	3.857E-29	1.059E-02	2.727E-06
CM-245	5.715E-05	3.471E-08	0.000E+00	5.715E-10	8.026E-07	5.757E-08	1.925E-09	0.000E+00	2.320E-10	3.710E-24	3.639E-38	2.698E-37	2.576E-06	6.807E-10
CM-246	4.790E-05	5.589E-09	0.000E+00	7.984E-11	1.357E-06	3.110E-08	4.160E-10	0.000E+00	1.441E-11	1.794E-27	4.496E-44	1.559E-42	1.769E-05	2.866E-09
CM-247	2.147E-10	6.513E-15	0.000E+00	8.194E-17	9.917E-12	9.959E-14	6.177E-16	0.000E+00	6.849E-18	6.891E-36	0.000E+00	0.000E+00	2.441E-10	3.353E-14
CM-248	1.004E-09	7.101E-15	0.000E+00	7.816E-17	8.992E-11	3.189E-13	8.656E-16	0.000E+00	2.975E-18	2.395E-38	0.000E+00	0.000E+00	7.354E-09	6.765E-13
Total Activity	3.296E+04	1.205E+03	9.909E-04	1.340E+02	3.600E+02	1.964E+02	9.837E+01	2.431E-04	2.381E+03	6.027E+01	2.423E-02	7.997E-02	6.513E+02	2.123E+04

7. UNCERTAINTY ANALYSIS

Sources of uncertainty in the characterization of the ETR vessel documented in EDF-6133 consist of the following:

- Uncertainty associated with the material composition of the reactor and uncertainty associated with the ORIGEN2 code in determining the radionuclides in the materials;
 - Uncertainty associated with the TLD and instrument measurements;
 - Uncertainty with the MicroShield model
1. Uncertainty associated with the Reactor Materials and the resulting uncertainty associated with the ORIGEN2 code in determining the radionuclides in the materials.

The impurities associated with the materials used in the ORIGEN2 code for determining the radionuclides in the vessel are shown in EDF-6958. The data used in the ORIGEN2 code for the Engineering Test Reactor was that material data determined for the Advanced Test Reactor (ATR). It was assumed in the ORIGEN2 model for the ETR that the materials were the same however this may or may not be the case.

The Be reflector contributes the most activity to the total reactor source term (~60%) The uncertainty associated with the Co-60 in the Beryllium is listed Attachment 3 of EDF-6958 as +/-38%. Many other radionuclides in that attachment did not have an uncertainty value associated with them so an uncertainty value associated with the reactor materials cannot be determined.

The uncertainty associated with the ORIGEN2 estimated neutron activation product inventory for ETR is due to a combination of at least two individual uncertainty values: (1) the uncertainty in the alloy composition for the precursor element that neutron activates to the isotope of concern, as discussed above, and (2) the uncertainty in the computer code to accurately predict the isotope inventory (due to uncertainties in decay or cross-section data and mathematical models in the code). The fundamental uncertainty in the ORIGEN2 code (per G. Longhurst) is at least 10%.

2. Uncertainty associated with the TLD measurements:

The radionuclides in the activated materials forming the ETR vessel emit a wide spectrum of photon energies. Of all the different photon energies, those associated with the decay of Co-60 (1.1 and 1.3 MeV) are the most abundant at the TLD monitoring locations. Table 7 below lists the dominant photon energies for the various radionuclides identified in the ETR. Table 8 presents the MicroShield results demonstrating that 99.6% of the photons at the TLD location are in the Co-60 energy range.

From Ron Perry of INL Dosimetry, "The LiF loose chip system is calibrated to Cs-137 by irradiation of TLD chips to 300 mrem. Generally, the source used for the calibration irradiations is located at HPIL but can also be DOE. In this case, the source was the Cs-137 irradiator at HPIL. The TLD calibration chips were placed on a phantom for irradiation. The TLDs were read to verify reader response and to develop a mrem to nano-coulomb conversion factor which was applied to the field TLD results to yield mrem or mR results (in this situation the term mR was used to better represent the irradiation condition). The processing technique used for this test condition was a semi-duplication of the routine used for personnel monitoring and included applicable sections of

the operating procedures for that system. The dosimeter provided was based on the requirement that it had to go down a 1/2" hole. This precluded anything but loose chips in a sachet. The error introduced into the results by the TLD being calibrated to Cs-137 when the irradiation energy was Co-60 introduced the energy error as 1 to 5% between Cs-137 and Co-60."

Table 7

Nuclide	Predominant Gamma Energy (MeV)	Nuclide	Predominant Gamma Energy (MeV)
Ac-227	1.30E-02	Pa-231	2.70E-02
Ag-108m	7.33E-01	Pb-210	1.10E-02
Ag-110m	0.66 & 0.88	Pr-144	6.96E-01
Am-241	0.014 & 0.060	Pu-238	1.36E-02
Am-243	0.014 & 0.075	Pu-239	1.36E-02
Ba-137m	6.60E-01	Pu-240	1.36E-02
Be-10	-	Pu-241	-
C-14	-	Pu-242	1.36E-02
Ce-144	1.33E-01	Pu-244	1.36E-02
Cl-36	-	Ra-226	1.86E-01
Cm-243	1.43E-02	Rh-106	5.12E-01
Cm-244	1.43E-02	Ru-106	-
Cm-245	1.43E-02	Sb-125	4.28E-01
Cm-246	1.43E-02	Sr-90	-
Cm-247	4.93E-01	Tc-99	8.90E-02
Cm-248	1.43E-02	Th-228	1.23E-02
Co-60	1.173 & 1.332	Th-229	1.23E-02
Cs-134	0.605 & 0.796	Th-230	1.23E-02
Cs-137	-	Th-232	1.23E-02
Eu-152	4.00E-02	U-232	1.30E-02
Eu-154	1.23E-01	U-233	1.30E-02
H-3	-	U-234	1.30E-02
I-129	3.00E-02	U-235	1.86E-01
Mn-54	8.35E-01	U-236	1.30E-02
Nb-94	2.58E-01	U-238	1.30E-02
Ni-59	7.00E-03	Y-90	-
Ni-63	-	Zn-65	1.12E+00
Np-237	1.33E-02		

Table 8

Energy (MeV)	Activity (Photons/s)
0.0385	1.67E+09
0.1229	9.38E+08
0.2453	1.69E+08
0.3433	9.72E+07
0.4327	4.49E+08
0.4537	2.95E+07
0.5892	1.36E+08
0.6618	5.67E+09
0.7051	1.05E+10
0.871	9.81E+09
0.9018	2.89E+07
0.9988	6.39E+08
1.1019	9.86E+07
1.1732	3.89E+12
1.2739	7.60E+08
1.3325	3.89E+12
1.4091	7.62E+07
1.4966	1.43E+07
1.5952	5.93E+07
2.1857	3.41E-02
Totals	7.80E+12
% Co-60 Energy range	99.60%

In addition to the error introduced due to the differences in calibration photon energy and the actual photon energy at the measurement location, further sources of uncertainty exists in the TLD measurements and are discussed in EDF-7227 (Reference 6). The total estimated uncertainty associated with the TLD measurements in EDF-7227 is estimated to be 34% at the 95% confidence limit.

3. Uncertainty associated with the MicroShield model

The uncertainty value associated with the MicroShield model can not be determined. As noted below, conservative assumptions were used in developing the MicroShield models.

Propagated Error for the Reactor Source Term

The total propagated uncertainty associated with the ORIGEN2 radionuclides (10%) and the TLD measurements (34%) is calculated to be +/-35%. The assumptions used in the MicroShield model however, contribute to a source term that is thought to be conservative. For example, the use of an effective density of 5.38 g/cm³ versus a calculated effective density of 4.14 g/cm³ result in a source term value which is ~29% higher. The modeling of the core internals as iron (the most abundant material) versus aluminum (the second most abundant material) result in a source term which is ~5% higher.

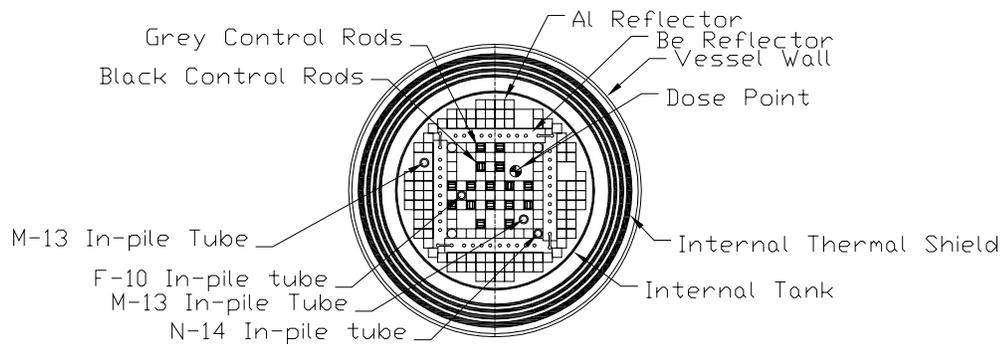
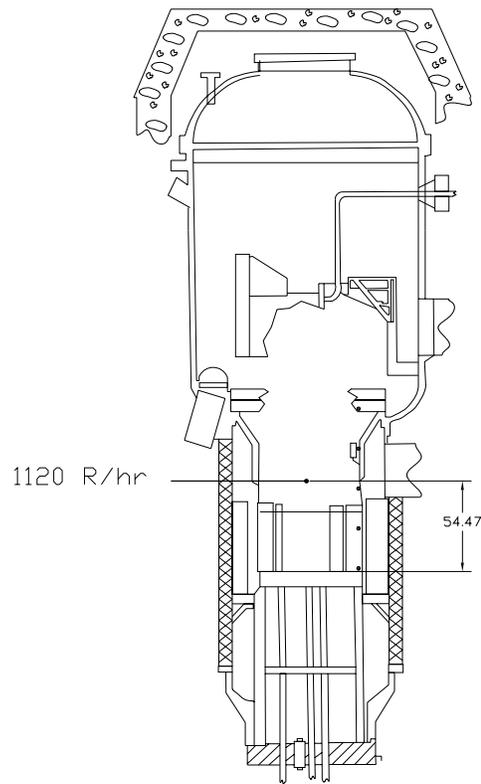
The conservatism in the source term determined in the MicroShield models based on TLD measurements was verified by modeling each component in the vessel independently and comparing the dose produced by each component (based on the component radionuclide activity values shown in Table 6) to that performed by instrument measurements performed within the vessel. This analysis is detailed in the "Source Term Verification" section below.

Source Term Verification

The TLD measurements could not be confirmed with direct measurements due to the small size of the rabbit tube (the tube is too small to allow for the insertion of an instrument probe. Additionally, the dose rates measured by the TLDs could not be verified with MCNP model due to assumptions required in the MCNP model in calculating the dose rate at the TLD measurement location (see Attachment 4 for discussion of the MCNP modeling). Thus the source term was verified with additional MicroShield modeling.

As a method to demonstrate the source term shown in Tables 5 and 6 above is conservative, MicroShield models were developed for each component in the vessel. The activity values and geometry of each component were used to determine a dose rate at a specific point in the vessel. If the dose rate, based on the component source terms, is greater than that actually measured, then it can be reasonably assumed that the calculated source term is conservative.

Dose rate measurements were performed inside of the vessel using an AMP-100 and a RO-7 probe during the beryllium sampling evolution in the ETR vessel. Using the locations of the various components inside of the vessel relative to the probe measurement location and the Table 6 component activity values, MicroShield models were generated for the vessel components to determine the dose rate that the components contribute to the location where the actual measurement was performed. Each highly activated component was modeled independently thus eliminating the need for the various simplifying assumptions used when modeling the reactor as a whole and allowed for the actual component size, effective density, and material to be used. The positions of the component, relative to the dose point, was determined from AutoCAD drawings developed based on the component locations described in IDO-16871-3, *Fundamentals in the Operation of Nuclear Test Reactors, Vol. 3 Engineering Test Reactor Design and Operation* (Reference 4). The maximum documented dose rate was 1,120 R/hr and was located ~54.5" above the grid plate. These drawings are presented below:



The results of these models are shown in Table 9 below and the MicroShield output files are presented in Attachment 3.

Table 9. Component Dose Rates.

Component	Dose Rate @Measurement
Grid Plate	86.98
Be Reflector	4
Internal Tank (Upper)	361
Internal Tank (Lower)	41.8
Control Rod K-11	14.8
Control Rod J-5	56.88
Control Rod E-9	51.85
Control Rod E-11	49.2
Control Rod K-9	40.96
Control Rod M-9	51.47
Control Rod G-9	55.69
Control Rod I-11	56.76
Control Rod M-11	57.71
Control Rod J-7	45.12
F-10 In-pile Tube	94.43
N-14 In-pile Tube	72.05
M-13 In-pile Tube	83.01
C-7 In-pile Tube	36.19
Total	1259.9

The other activated components such as the Internal Thermal Shield, Upper Support Frame, etc. were not modeled. The dose rate from the components that were modeled already exceeds the measured dose rate, demonstrating that the source term determined from the TLD measurements is conservative.

8. CONCLUSION

The source term calculation provided in this EDF was determined based on the radionuclides and scaling factors presented in EDF-6958 and MicroShield models. The total surface contamination in the reactor was based on the results of actual sample data and the internal surface area of the reactor.

9. REFERENCES

1. C. A. Nesshoefer, 2005, Characterization of the ETR Complex Internal Surfaces, EDF-6291, Idaho National Laboratory, Idaho Falls, Idaho.
2. C. A. Nesshoefer, 2006, Engineering Test Reactor Radionuclides and the Radionuclide Relative Ratios, EDF-6958, Idaho National Laboratory, Idaho Falls, Idaho.
3. www.MatWeb.com, Automation Creations Inc.

4. R. J. Nertney et al., 1964, Fundamentals in the Operation of Nuclear Test Reactors, Vol. 3, Engineering Test Reactor Design and Operation, Phillips Petroleum Company.
5. MicroShield v6.10 Shielding Code, Grove Engineering
6. O. R. Perry, 2006, Estimated Uncertainty Associated with the July 2005 ETR TLD Results, EDF-7227, Idaho National Laboratory, Idaho Falls, Idaho.

10. APPENDIXES

Appendix A, Vessel MicroShield results

Appendix B, Component radionuclide scaling factors and percent activity values

Appendix C, Component MicroShield models

Appendix D, MCNP discussion

Appendix A
MicroShield Results

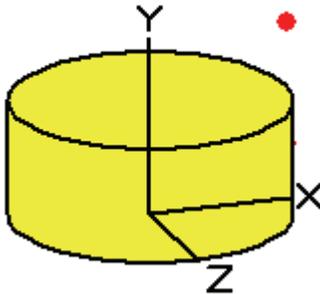
Appendix A

MicroShield Results

MicroShield v6.10 (0063)
INL

Page	1	File Ref	
DOS File	ETR reactor dose point 1.ms6	Date	
Run Date	August 15, 2005	By	
Run Time	11:33:23 AM	Checked	
Duration	00:00:27		

Case Title: ETR Reactor
Description: Dose Point 1
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height	57.15 cm	(1 ft 10.5 in)
Radius	67.31 cm	(2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	26.67 cm 10.5 in	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	87.63 cm 2 ft 10.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.13e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-227	4.5457e-007	1.6819e+004	5.5882e-007	2.0676e-002
Ag-108m	1.0883e-001	4.0268e+009	1.3379e-001	4.9503e+003
Ag-110m	3.3197e-011	1.2283e+000	4.0810e-011	1.5100e-006
Am-241	8.1483e-002	3.0149e+009	1.0017e-001	3.7063e+003
Am-243	1.2411e-003	4.5921e+007	1.5258e-003	5.6453e+001
Ba-137m	1.1491e+000	4.2517e+010	1.4127e+000	5.2268e+004
Be-10	1.6749e-001	6.1972e+009	2.0591e-001	7.6186e+003
C-14	5.9603e+000	2.2053e+011	7.3273e+000	2.7111e+005
Ce-144	1.0167e-009	3.7616e+001	1.2498e-009	4.6243e-005
Cl-36	5.6585e-002	2.0937e+009	6.9563e-002	2.5738e+003
Cm-243	2.2634e-004	8.3746e+006	2.7825e-004	1.0295e+001
Cm-244	1.4373e-001	5.3179e+009	1.7669e-001	6.5375e+003
Cm-245	2.7161e-005	1.0050e+006	3.3390e-005	1.2354e+000
Cm-246	2.9990e-005	1.1096e+006	3.6868e-005	1.3641e+000
Cm-247	2.1125e-010	7.8163e+000	2.5970e-010	9.6090e-006
Cm-248	3.7912e-009	1.4028e+002	4.6607e-009	1.7245e-004
Co-60	8.8462e+002	3.2731e+013	1.0875e+003	4.0238e+007
Cs-134	1.3222e-003	4.8922e+007	1.6255e-003	6.0142e+001

Cs-137	1.2147e+000	4.4944e+010	1.4933e+000	5.5252e+004
Eu-152	8.1672e-002	3.0218e+009	1.0040e-001	3.7149e+003
Eu-154	4.6966e-001	1.7377e+010	5.7737e-001	2.1363e+004
H-3	1.4788e+004	5.4714e+014	1.8179e+004	6.7263e+008
I-129	1.9050e-006	7.0487e+004	2.3420e-006	8.6652e-002
Mn-54	1.4410e-006	5.3319e+004	1.7715e-006	6.5547e-002
Nb-94	2.1691e+000	8.0257e+010	2.6666e+000	9.8664e+004
Ni-59	5.9415e+001	2.1983e+012	7.3041e+001	2.7025e+006
Ni-63	1.0864e+004	4.0198e+014	1.3356e+004	4.9418e+008
Np-237	9.6384e-007	3.5662e+004	1.1849e-006	4.3841e-002
Pa-231	6.6582e-007	2.4635e+004	8.1853e-007	3.0285e-002
Pb-210	3.0933e-011	1.1445e+000	3.8028e-011	1.4070e-006
Pr-144	1.0021e-009	3.7078e+001	1.2319e-009	4.5582e-005
Pu-238	3.7535e-002	1.3888e+009	4.6144e-002	1.7073e+003
Pu-239	8.1483e-003	3.0149e+008	1.0017e-002	3.7063e+002
Pu-240	9.9968e-003	3.6988e+008	1.2289e-002	4.5471e+002
Pu-241	8.1483e-001	3.0149e+010	1.0017e+000	3.7063e+004
Pu-242	1.2769e-004	4.7247e+006	1.5698e-004	5.8083e+000
Pu-244	1.1996e-010	4.4386e+000	1.4747e-010	5.4565e-006
Ra-226	4.9984e-011	1.8494e+000	6.1447e-011	2.2736e-006
Rh-106	1.4071e-007	5.2062e+003	1.7298e-007	6.4003e-003
Ru-106	1.4071e-007	5.2062e+003	1.7298e-007	6.4003e-003
Sb-125	2.9613e-003	1.0957e+008	3.6405e-003	1.3470e+002
Sr-90	3.7912e-001	1.4028e+010	4.6607e-001	1.7245e+004
Tc-99	2.8481e-003	1.0538e+008	3.5013e-003	1.2955e+002
Th-228	8.0540e-005	2.9800e+006	9.9012e-005	3.6634e+000
Th-229	5.3945e-007	1.9960e+004	6.6317e-007	2.4537e-002
Th-230	5.2624e-009	1.9471e+002	6.4694e-009	2.3937e-004
Th-232	9.2046e-007	3.4057e+004	1.1316e-006	4.1868e-002
U-232	7.7522e-005	2.8683e+006	9.5302e-005	3.5262e+000
U-233	1.5297e-004	5.6599e+006	1.8805e-004	6.9579e+000
U-234	1.3788e-005	5.1016e+005	1.6950e-005	6.2716e-001
U-235	1.1411e-007	4.2222e+003	1.4029e-007	5.1906e-003
U-236	3.2442e-007	1.2004e+004	3.9883e-007	1.4757e-002
U-238	3.8289e-006	1.4167e+005	4.7071e-006	1.7416e-001
Y-90	3.7912e-001	1.4028e+010	4.6607e-001	1.7245e+004
Zn-65	7.6768e-011	2.8404e+000	9.4374e-011	3.4918e-006

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,26.67,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.404e+10	3.756e+00	4.056e+00	1.833e-02	1.980e-02
0.1229	7.896e+09	4.001e+02	5.944e+02	6.282e-01	9.333e-01
0.2453	1.423e+09	2.906e+02	5.634e+02	5.344e-01	1.036e+00
0.3433	8.188e+08	2.823e+02	5.781e+02	5.437e-01	1.113e+00
0.4327	3.786e+09	1.841e+03	3.811e+03	3.601e+00	7.456e+00
0.4537	2.487e+08	1.297e+02	2.683e+02	2.541e-01	5.259e-01
0.5892	1.146e+09	8.759e+02	1.787e+03	1.711e+00	3.492e+00
0.6618	4.772e+10	4.324e+04	8.727e+04	8.383e+01	1.692e+02
0.7051	8.878e+10	8.830e+04	1.770e+05	1.702e+02	3.412e+02
0.871	8.266e+10	1.124e+05	2.195e+05	2.114e+02	4.131e+02
0.9018	2.431e+08	3.480e+02	6.767e+02	6.518e-01	1.268e+00
0.9988	5.382e+09	8.972e+03	1.720e+04	1.654e+01	3.170e+01
1.1019	8.304e+08	1.604e+03	3.028e+03	2.904e+00	5.482e+00
1.1732	3.273e+13	6.945e+07	1.298e+08	1.241e+05	2.320e+05
1.2739	6.404e+09	1.538e+04	2.837e+04	2.697e+01	4.976e+01
1.3325	3.273e+13	8.407e+07	1.540e+08	1.459e+05	2.672e+05
1.4091	6.417e+08	1.792e+03	3.255e+03	3.065e+00	5.568e+00
1.4966	1.206e+08	3.685e+02	6.634e+02	6.204e-01	1.117e+00
1.5952	4.996e+08	1.677e+03	2.993e+03	2.775e+00	4.951e+00
2.1857	2.870e-01	1.522e-06	2.604e-06	2.288e-09	3.915e-09
Totals	6.572e+13	1.538e+08	2.844e+08	2.705e+05	5.003e+05

Results - Dose Point # 2 - (68.58,87.63,0) cm

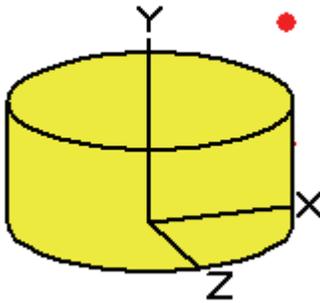
Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.404e+10	2.829e-23	9.366e-23	1.381e-25	4.572e-25
0.1229	7.896e+09	9.654e-02	2.327e-01	1.516e-04	3.654e-04
0.2453	1.423e+09	3.060e-01	9.859e-01	5.628e-04	1.813e-03
0.3433	8.188e+08	3.753e-01	1.223e+00	7.226e-04	2.355e-03
0.4327	3.786e+09	2.751e+00	8.768e+00	5.382e-03	1.715e-02
0.4537	2.487e+08	1.980e-01	6.265e-01	3.880e-04	1.228e-03
0.5892	1.146e+09	1.492e+00	4.488e+00	2.914e-03	8.769e-03
0.6618	4.772e+10	7.703e+01	2.262e+02	1.493e-01	4.386e-01
0.7051	8.878e+10	1.611e+02	4.671e+02	3.106e-01	9.005e-01
0.871	8.266e+10	2.218e+02	6.171e+02	4.174e-01	1.161e+00
0.9018	2.431e+08	6.958e-01	1.924e+00	1.303e-03	3.603e-03
0.9988	5.382e+09	1.864e+01	5.064e+01	3.436e-02	9.337e-02
1.1019	8.304e+08	3.459e+00	9.258e+00	6.262e-03	1.676e-02
1.1732	3.273e+13	1.534e+05	4.073e+05	2.742e+02	7.279e+02
1.2739	6.404e+09	3.509e+01	9.230e+01	6.155e-02	1.619e-01
1.3325	3.273e+13	1.953e+05	5.118e+05	3.389e+02	8.879e+02
1.4091	6.417e+08	4.259e+00	1.111e+01	7.285e-03	1.901e-02
1.4966	1.206e+08	8.977e-01	2.335e+00	1.511e-03	3.932e-03
1.5952	4.996e+08	4.197e+00	1.090e+01	6.942e-03	1.803e-02
2.1857	2.870e-01	4.372e-09	1.134e-08	6.572e-12	1.705e-11
Totals	6.572e+13	3.493e+05	9.206e+05	6.141e+02	1.619e+03

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 2.ms6
Run Date October 11, 2005
Run Time 2:24:24 PM
Duration 00:00:11

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 2
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	5.29e+04 in ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-227	4.7133e-007	1.7439e+004	5.4322e-007	2.0099e-002
Ag-108m	1.1285e-001	4.1753e+009	1.3006e-001	4.8121e+003
Ag-110m	3.4421e-011	1.2736e+000	3.9671e-011	1.4678e-006
Am-241	8.4488e-002	3.1261e+009	9.7373e-002	3.6028e+003
Am-243	1.2869e-003	4.7614e+007	1.4831e-003	5.4876e+001
Ba-137m	1.1915e+000	4.4085e+010	1.3732e+000	5.0808e+004
Be-10	1.7367e-001	6.4258e+009	2.0016e-001	7.4058e+003
C-14	6.1801e+000	2.2866e+011	7.1227e+000	2.6354e+005
Ce-144	1.0541e-009	3.9003e+001	1.2149e-009	4.4952e-005
Cl-36	5.8672e-002	2.1709e+009	6.7620e-002	2.5020e+003
Cm-243	2.3469e-004	8.6835e+006	2.7048e-004	1.0008e+001
Cm-244	1.4903e-001	5.5140e+009	1.7176e-001	6.3550e+003
Cm-245	2.8163e-005	1.0420e+006	3.2458e-005	1.2009e+000
Cm-246	3.1096e-005	1.1506e+006	3.5839e-005	1.3260e+000
Cm-247	2.1904e-010	8.1046e+000	2.5245e-010	9.3406e-006
Cm-248	3.9310e-009	1.4545e+002	4.5306e-009	1.6763e-004
Co-60	9.1724e+002	3.3938e+013	1.0571e+003	3.9114e+007
Cs-134	1.3710e-003	5.0726e+007	1.5801e-003	5.8462e+001
Cs-137	1.2595e+000	4.6601e+010	1.4516e+000	5.3709e+004
Eu-152	8.4683e-002	3.1333e+009	9.7599e-002	3.6112e+003
Eu-154	4.8698e-001	1.8018e+010	5.6125e-001	2.0766e+004

H-3	1.5333e+004	5.6732e+014	1.7671e+004	6.5384e+008
I-129	1.9753e-006	7.3086e+004	2.2766e-006	8.4233e-002
Mn-54	1.4942e-006	5.5285e+004	1.7221e-006	6.3716e-002
Nb-94	2.2491e+000	8.3217e+010	2.5921e+000	9.5908e+004
Ni-59	6.1606e+001	2.2794e+012	7.1001e+001	2.6271e+006
Ni-63	1.1265e+004	4.1681e+014	1.2983e+004	4.8038e+008
Np-237	9.9938e-007	3.6977e+004	1.1518e-006	4.2617e-002
Pa-231	6.9038e-007	2.5544e+004	7.9567e-007	2.9440e-002
Pb-210	3.2074e-011	1.1867e+000	3.6966e-011	1.3677e-006
Pr-144	1.0391e-009	3.8446e+001	1.1975e-009	4.4309e-005
Pu-238	3.8919e-002	1.4400e+009	4.4855e-002	1.6596e+003
Pu-239	8.4488e-003	3.1261e+008	9.7373e-003	3.6028e+002
Pu-240	1.0365e-002	3.8352e+008	1.1946e-002	4.4201e+002
Pu-241	8.4488e-001	3.1261e+010	9.7373e-001	3.6028e+004
Pu-242	1.3240e-004	4.8989e+006	1.5260e-004	5.6461e+000
Pu-244	1.2438e-010	4.6022e+000	1.4336e-010	5.3041e-006
Ra-226	5.1827e-011	1.9176e+000	5.9731e-011	2.2101e-006
Rh-106	1.4590e-007	5.3982e+003	1.6815e-007	6.2215e-003
Ru-106	1.4590e-007	5.3982e+003	1.6815e-007	6.2215e-003
Sb-125	3.0705e-003	1.1361e+008	3.5388e-003	1.3094e+002
Sr-90	3.9310e-001	1.4545e+010	4.5306e-001	1.6763e+004
Tc-99	2.9532e-003	1.0927e+008	3.4036e-003	1.2593e+002
Th-228	8.3510e-005	3.0899e+006	9.6246e-005	3.5611e+000
Th-229	5.5934e-007	2.0696e+004	6.4465e-007	2.3852e-002
Th-230	5.4565e-009	2.0189e+002	6.2887e-009	2.3268e-004
Th-232	9.5440e-007	3.5313e+004	1.1000e-006	4.0698e-002
U-232	8.0381e-005	2.9741e+006	9.2640e-005	3.4277e+000
U-233	1.5861e-004	5.8686e+006	1.8280e-004	6.7636e+000
U-234	1.4296e-005	5.2897e+005	1.6477e-005	6.0964e-001
U-235	1.1832e-007	4.3779e+003	1.3637e-007	5.0456e-003
U-236	3.3639e-007	1.2446e+004	3.8769e-007	1.4345e-002
U-238	3.9701e-006	1.4690e+005	4.5756e-006	1.6930e-001
Y-90	3.9310e-001	1.4545e+010	4.5306e-001	1.6763e+004
Zn-65	7.9599e-011	2.9451e+000	9.1738e-011	3.3943e-006

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (27,12,0) in

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.456e+10	3.649e+00	3.941e+00	1.781e-02	1.924e-02
0.1229	8.188e+09	3.890e+02	5.780e+02	6.108e-01	9.075e-01
0.2453	1.475e+09	2.827e+02	5.481e+02	5.198e-01	1.008e+00
0.3433	8.490e+08	2.746e+02	5.625e+02	5.288e-01	1.083e+00
0.4327	3.925e+09	1.791e+03	3.708e+03	3.503e+00	7.255e+00
0.4537	2.579e+08	1.261e+02	2.611e+02	2.472e-01	5.118e-01
0.5892	1.188e+09	8.521e+02	1.739e+03	1.665e+00	3.398e+00
0.6618	4.948e+10	4.207e+04	8.493e+04	8.155e+01	1.646e+02
0.7051	9.205e+10	8.591e+04	1.723e+05	1.656e+02	3.321e+02
0.871	8.571e+10	1.093e+05	2.137e+05	2.057e+02	4.021e+02
0.9018	2.521e+08	3.386e+02	6.587e+02	6.341e-01	1.234e+00

0.9988	5.581e+09	8.730e+03	1.674e+04	1.609e+01	3.086e+01
1.1019	8.610e+08	1.561e+03	2.948e+03	2.825e+00	5.337e+00
1.1732	3.394e+13	6.758e+07	1.264e+08	1.208e+05	2.259e+05
1.2739	6.640e+09	1.496e+04	2.762e+04	2.624e+01	4.845e+01
1.3325	3.394e+13	8.181e+07	1.500e+08	1.419e+05	2.602e+05
1.4091	6.653e+08	1.744e+03	3.169e+03	2.983e+00	5.422e+00
1.4966	1.251e+08	3.586e+02	6.461e+02	6.037e-01	1.088e+00
1.5952	5.180e+08	1.632e+03	2.915e+03	2.700e+00	4.822e+00
2.1857	2.976e-01	1.481e-06	2.537e-06	2.227e-09	3.815e-09
Totals	6.815e+13	1.497e+08	2.769e+08	2.632e+05	4.871e+05

Results - Dose Point # 2 - (27,36,0) in

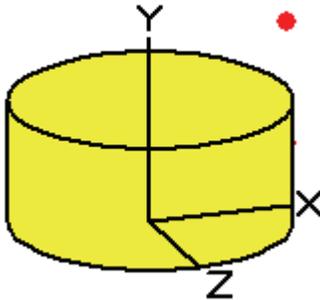
Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0385	1.456e+10	2.750e-23	9.326e-23	1.343e-25	4.553e-25
0.1229	8.188e+09	9.385e-02	2.263e-01	1.474e-04	3.552e-04
0.2453	1.475e+09	2.980e-01	9.614e-01	5.481e-04	1.768e-03
0.3433	8.490e+08	3.658e-01	1.195e+00	7.044e-04	2.300e-03
0.4327	3.925e+09	2.683e+00	8.572e+00	5.249e-03	1.677e-02
0.4537	2.579e+08	1.931e-01	6.126e-01	3.785e-04	1.201e-03
0.5892	1.188e+09	1.456e+00	4.392e+00	2.845e-03	8.581e-03
0.6618	4.948e+10	7.522e+01	2.214e+02	1.458e-01	4.293e-01
0.7051	9.205e+10	1.574e+02	4.572e+02	3.034e-01	8.815e-01
0.871	8.571e+10	2.167e+02	6.042e+02	4.079e-01	1.137e+00
0.9018	2.521e+08	6.800e-01	1.884e+00	1.274e-03	3.528e-03
0.9988	5.581e+09	1.822e+01	4.959e+01	3.359e-02	9.142e-02
1.1019	8.610e+08	3.381e+00	9.064e+00	6.122e-03	1.641e-02
1.1732	3.394e+13	1.500e+05	3.988e+05	2.681e+02	7.127e+02
1.2739	6.640e+09	3.432e+01	9.036e+01	6.019e-02	1.585e-01
1.3325	3.394e+13	1.911e+05	5.010e+05	3.315e+02	8.692e+02
1.4091	6.653e+08	4.166e+00	1.088e+01	7.126e-03	1.861e-02
1.4966	1.251e+08	8.782e-01	2.286e+00	1.478e-03	3.848e-03
1.5952	5.180e+08	4.105e+00	1.066e+01	6.791e-03	1.764e-02
2.1857	2.976e-01	4.277e-09	1.109e-08	6.430e-12	1.668e-11
Totals	6.815e+13	3.416e+05	9.013e+05	6.006e+02	1.585e+03

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 3.ms6
Run Date August 15, 2005
Run Time 11:52:36 AM
Duration 00:00:28

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 3
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.68e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	5.3967e-008	1.9968e+003	6.2198e-008	2.3013e-003
Ag-108m	1.2921e-002	4.7807e+008	1.4891e-002	5.5098e+002
Ag-110m	3.9411e-012	1.4582e-001	4.5422e-012	1.6806e-007
Am-241	9.6737e-003	3.5793e+008	1.1149e-002	4.1252e+002
Am-243	1.4735e-004	5.4518e+006	1.6982e-004	6.2832e+000
Ba-137m	1.3642e-001	5.0476e+009	1.5723e-001	5.8175e+003
Be-10	1.9885e-002	7.3574e+008	2.2918e-002	8.4795e+002
C-14	7.0762e-001	2.6182e+010	8.1554e-001	3.0175e+004
Ce-144	1.2070e-010	4.4658e+000	1.3911e-010	5.1469e-006
Cl-36	6.7179e-003	2.4856e+008	7.7424e-003	2.8647e+002
Cm-243	2.6871e-005	9.9424e+005	3.0970e-005	1.1459e+000
Cm-244	1.7063e-002	6.3135e+008	1.9666e-002	7.2763e+002
Cm-245	3.2246e-006	1.1931e+005	3.7164e-006	1.3751e-001
Cm-246	3.5605e-006	1.3174e+005	4.1035e-006	1.5183e-001
Cm-247	2.5080e-011	9.2796e-001	2.8905e-011	1.0695e-006
Cm-248	4.5010e-010	1.6654e+001	5.1874e-010	1.9193e-005
Co-60	1.0502e+002	3.8858e+012	1.2104e+002	4.4785e+006
Cs-134	1.5697e-004	5.8080e+006	1.8091e-004	6.6938e+000
Cs-137	1.4421e-001	5.3358e+009	1.6620e-001	6.1496e+003
Eu-152	9.6961e-003	3.5876e+008	1.1175e-002	4.1347e+002

Eu-154	5.5758e-002	2.0631e+009	6.4262e-002	2.3777e+003
H-3	1.7556e+003	6.4957e+013	2.0234e+003	7.4864e+007
I-129	2.2617e-007	8.3682e+003	2.6066e-007	9.6445e-003
Mn-54	1.7108e-007	6.3300e+003	1.9717e-007	7.2954e-003
Nb-94	2.5752e-001	9.5282e+009	2.9679e-001	1.0981e+004
Ni-59	7.0538e+000	2.6099e+011	8.1296e+000	3.0079e+005
Ni-63	1.2898e+003	4.7724e+013	1.4865e+003	5.5002e+007
Np-237	1.1443e-007	4.2338e+003	1.3188e-007	4.8795e-003
Pa-231	7.9047e-008	2.9247e+003	9.1103e-008	3.3708e-003
Pb-210	3.6724e-012	1.3588e-001	4.2325e-012	1.5660e-007
Pr-144	1.1897e-010	4.4020e+000	1.3712e-010	5.0733e-006
Pu-238	4.4562e-003	1.6488e+008	5.1358e-003	1.9003e+002
Pu-239	9.6737e-004	3.5793e+007	1.1149e-003	4.1252e+001
Pu-240	1.1868e-003	4.3912e+007	1.3678e-003	5.0610e+001
Pu-241	9.6737e-002	3.5793e+009	1.1149e-001	4.1252e+003
Pu-242	1.5160e-005	5.6092e+005	1.7472e-005	6.4647e-001
Pu-244	1.4242e-011	5.2695e-001	1.6414e-011	6.0732e-007
Ra-226	5.9341e-012	2.1956e-001	6.8391e-012	2.5305e-007
Rh-106	1.6705e-008	6.1809e+002	1.9253e-008	7.1236e-004
Ru-106	1.6705e-008	6.1809e+002	1.9253e-008	7.1236e-004
Sb-125	3.5157e-004	1.3008e+007	4.0519e-004	1.4992e+001
Sr-90	4.5010e-002	1.6654e+009	5.1874e-002	1.9193e+003
Tc-99	3.3813e-004	1.2511e+007	3.8970e-004	1.4419e+001
Th-228	9.5618e-006	3.5379e+005	1.1020e-005	4.0774e-001
Th-229	6.4044e-008	2.3696e+003	7.3811e-008	2.7310e-003
Th-230	6.2476e-010	2.3116e+001	7.2005e-010	2.6642e-005
Th-232	1.0928e-007	4.0433e+003	1.2594e-007	4.6599e-003
U-232	9.2035e-006	3.4053e+005	1.0607e-005	3.9246e-001
U-233	1.8161e-005	6.7194e+005	2.0930e-005	7.7442e-001
U-234	1.6369e-006	6.0566e+004	1.8866e-006	6.9803e-002
U-235	1.3548e-008	5.0126e+002	1.5614e-008	5.7771e-004
U-236	3.8516e-008	1.4251e+003	4.4390e-008	1.6424e-003
U-238	4.5458e-007	1.6819e+004	5.2390e-007	1.9384e-002
Y-90	4.5010e-002	1.6654e+009	5.1874e-002	1.9193e+003
Zn-65	9.1139e-012	3.3721e-001	1.0504e-011	3.8864e-007

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,30.48,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.667e+09	4.178e-01	4.512e-01	2.040e-03	2.203e-03
0.1229	9.375e+08	4.454e+01	6.618e+01	6.994e-02	1.039e-01
0.2453	1.689e+08	3.236e+01	6.276e+01	5.951e-02	1.154e-01
0.3433	9.721e+07	3.145e+01	6.441e+01	6.055e-02	1.240e-01
0.4327	4.494e+08	2.050e+02	4.246e+02	4.011e-01	8.307e-01
0.4537	2.953e+07	1.444e+01	2.990e+01	2.831e-02	5.860e-02
0.5892	1.361e+08	9.757e+01	1.991e+02	1.906e-01	3.890e-01
0.6618	5.665e+09	4.817e+03	9.724e+03	9.338e+00	1.885e+01
0.7051	1.054e+10	9.836e+03	1.972e+04	1.896e+01	3.802e+01
0.871	9.813e+09	1.252e+04	2.446e+04	2.355e+01	4.604e+01

0.9018	2.886e+07	3.876e+01	7.542e+01	7.261e-02	1.413e-01
0.9988	6.390e+08	9.995e+02	1.917e+03	1.843e+00	3.534e+00
1.1019	9.859e+07	1.787e+02	3.375e+02	3.235e-01	6.111e-01
1.1732	3.886e+12	7.738e+06	1.447e+07	1.383e+04	2.586e+04
1.2739	7.603e+08	1.713e+03	3.163e+03	3.005e+00	5.547e+00
1.3325	3.886e+12	9.367e+06	1.717e+07	1.625e+04	2.979e+04
1.4091	7.618e+07	1.997e+02	3.629e+02	3.415e-01	6.208e-01
1.4966	1.432e+07	4.106e+01	7.397e+01	6.913e-02	1.245e-01
1.5952	5.931e+07	1.869e+02	3.338e+02	3.092e-01	5.521e-01
2.1857	3.407e-02	1.696e-07	2.905e-07	2.550e-10	4.368e-10
Totals	7.803e+12	1.714e+07	3.171e+07	3.014e+04	5.577e+04

Results - Dose Point # 2 - (68.58,91.44,0) cm

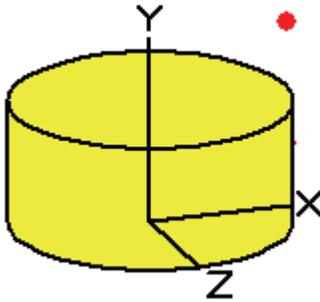
Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.667e+09	3.149e-24	1.068e-23	1.537e-26	5.213e-26
0.1229	9.375e+08	1.075e-02	2.591e-02	1.687e-05	4.068e-05
0.2453	1.689e+08	3.413e-02	1.101e-01	6.275e-05	2.024e-04
0.3433	9.721e+07	4.188e-02	1.368e-01	8.065e-05	2.634e-04
0.4327	4.494e+08	3.072e-01	9.815e-01	6.010e-04	1.920e-03
0.4537	2.953e+07	2.211e-02	7.014e-02	4.334e-05	1.375e-04
0.5892	1.361e+08	1.667e-01	5.029e-01	3.258e-04	9.825e-04
0.6618	5.665e+09	8.612e+00	2.535e+01	1.670e-02	4.915e-02
0.7051	1.054e+10	1.802e+01	5.235e+01	3.473e-02	1.009e-01
0.871	9.813e+09	2.481e+01	6.918e+01	4.670e-02	1.302e-01
0.9018	2.886e+07	7.786e-02	2.157e-01	1.458e-04	4.040e-04
0.9988	6.390e+08	2.086e+00	5.678e+00	3.846e-03	1.047e-02
1.1019	9.859e+07	3.872e-01	1.038e+00	7.010e-04	1.879e-03
1.1732	3.886e+12	1.718e+04	4.566e+04	3.070e+01	8.160e+01
1.2739	7.603e+08	3.929e+00	1.035e+01	6.892e-03	1.815e-02
1.3325	3.886e+12	2.188e+04	5.736e+04	3.795e+01	9.952e+01
1.4091	7.618e+07	4.770e-01	1.245e+00	8.159e-04	2.130e-03
1.4966	1.432e+07	1.005e-01	2.617e-01	1.693e-04	4.406e-04
1.5952	5.931e+07	4.701e-01	1.221e+00	7.776e-04	2.020e-03
2.1857	3.407e-02	4.897e-10	1.270e-09	7.362e-13	1.909e-12
Totals	7.803e+12	3.912e+04	1.032e+05	6.877e+01	1.814e+02

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 4.ms6
Run Date August 15, 2005
Run Time 11:55:10 AM
Duration 00:00:28

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 4
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.68e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	5.3967e-008	1.9968e+003	6.2198e-008	2.3013e-003
Ag-108m	1.2921e-002	4.7807e+008	1.4891e-002	5.5098e+002
Ag-110m	3.9411e-012	1.4582e-001	4.5422e-012	1.6806e-007
Am-241	9.6737e-003	3.5793e+008	1.1149e-002	4.1252e+002
Am-243	1.4735e-004	5.4518e+006	1.6982e-004	6.2832e+000
Ba-137m	1.3642e-001	5.0476e+009	1.5723e-001	5.8175e+003
Be-10	1.9885e-002	7.3574e+008	2.2918e-002	8.4795e+002
C-14	7.0762e-001	2.6182e+010	8.1554e-001	3.0175e+004
Ce-144	1.2070e-010	4.4658e+000	1.3911e-010	5.1469e-006
Cl-36	6.7179e-003	2.4856e+008	7.7424e-003	2.8647e+002
Cm-243	2.6871e-005	9.9424e+005	3.0970e-005	1.1459e+000
Cm-244	1.7063e-002	6.3135e+008	1.9666e-002	7.2763e+002
Cm-245	3.2246e-006	1.1931e+005	3.7164e-006	1.3751e-001
Cm-246	3.5605e-006	1.3174e+005	4.1035e-006	1.5183e-001
Cm-247	2.5080e-011	9.2796e-001	2.8905e-011	1.0695e-006
Cm-248	4.5010e-010	1.6654e+001	5.1874e-010	1.9193e-005
Co-60	1.0502e+002	3.8858e+012	1.2104e+002	4.4785e+006
Cs-134	1.5697e-004	5.8080e+006	1.8091e-004	6.6938e+000
Cs-137	1.4421e-001	5.3358e+009	1.6620e-001	6.1496e+003
Eu-152	9.6961e-003	3.5876e+008	1.1175e-002	4.1347e+002

Nuclide	curies	becquerels	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Eu-154	5.5758e-002	2.0631e+009	6.4262e-002	2.3777e+003
H-3	1.7556e+003	6.4957e+013	2.0234e+003	7.4864e+007
I-129	2.2617e-007	8.3682e+003	2.6066e-007	9.6445e-003
Mn-54	1.7108e-007	6.3300e+003	1.9717e-007	7.2954e-003
Nb-94	2.5752e-001	9.5282e+009	2.9679e-001	1.0981e+004
Ni-59	7.0538e+000	2.6099e+011	8.1296e+000	3.0079e+005
Ni-63	1.2898e+003	4.7724e+013	1.4865e+003	5.5002e+007
Np-237	1.1443e-007	4.2338e+003	1.3188e-007	4.8795e-003
Pa-231	7.9047e-008	2.9247e+003	9.1103e-008	3.3708e-003
Pb-210	3.6724e-012	1.3588e-001	4.2325e-012	1.5660e-007
Pr-144	1.1897e-010	4.4020e+000	1.3712e-010	5.0733e-006
Pu-238	4.4562e-003	1.6488e+008	5.1358e-003	1.9003e+002
Pu-239	9.6737e-004	3.5793e+007	1.1149e-003	4.1252e+001
Pu-240	1.1868e-003	4.3912e+007	1.3678e-003	5.0610e+001
Pu-241	9.6737e-002	3.5793e+009	1.1149e-001	4.1252e+003
Pu-242	1.5160e-005	5.6092e+005	1.7472e-005	6.4647e-001
Pu-244	1.4242e-011	5.2695e-001	1.6414e-011	6.0732e-007
Ra-226	5.9341e-012	2.1956e-001	6.8391e-012	2.5305e-007
Rh-106	1.6705e-008	6.1809e+002	1.9253e-008	7.1236e-004
Ru-106	1.6705e-008	6.1809e+002	1.9253e-008	7.1236e-004
Sb-125	3.5157e-004	1.3008e+007	4.0519e-004	1.4992e+001
Sr-90	4.5010e-002	1.6654e+009	5.1874e-002	1.9193e+003
Tc-99	3.3813e-004	1.2511e+007	3.8970e-004	1.4419e+001
Th-228	9.5618e-006	3.5379e+005	1.1020e-005	4.0774e-001
Th-229	6.4044e-008	2.3696e+003	7.3811e-008	2.7310e-003
Th-230	6.2476e-010	2.3116e+001	7.2005e-010	2.6642e-005
Th-232	1.0928e-007	4.0433e+003	1.2594e-007	4.6599e-003
U-232	9.2035e-006	3.4053e+005	1.0607e-005	3.9246e-001
U-233	1.8161e-005	6.7194e+005	2.0930e-005	7.7442e-001
U-234	1.6369e-006	6.0566e+004	1.8866e-006	6.9803e-002
U-235	1.3548e-008	5.0126e+002	1.5614e-008	5.7771e-004
U-236	3.8516e-008	1.4251e+003	4.4390e-008	1.6424e-003
U-238	4.5458e-007	1.6819e+004	5.2390e-007	1.9384e-002
Y-90	4.5010e-002	1.6654e+009	5.1874e-002	1.9193e+003
Zn-65	9.1139e-012	3.3721e-001	1.0504e-011	3.8864e-007

Buildup : The material reference is - Source Integration Parameters

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,30.48,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	1.667e+09	4.178e-01	4.512e-01	2.040e-03	2.203e-03
0.1229	9.375e+08	4.454e+01	6.618e+01	6.994e-02	1.039e-01
0.2453	1.689e+08	3.236e+01	6.276e+01	5.951e-02	1.154e-01
0.3433	9.721e+07	3.145e+01	6.441e+01	6.055e-02	1.240e-01
0.4327	4.494e+08	2.050e+02	4.246e+02	4.011e-01	8.307e-01
0.4537	2.953e+07	1.444e+01	2.990e+01	2.831e-02	5.860e-02
0.5892	1.361e+08	9.757e+01	1.991e+02	1.906e-01	3.890e-01
0.6618	5.665e+09	4.817e+03	9.724e+03	9.338e+00	1.885e+01
0.7051	1.054e+10	9.836e+03	1.972e+04	1.896e+01	3.802e+01

ENGINEERING DESIGN FILE

0.871	9.813e+09	1.252e+04	2.446e+04	2.355e+01	4.604e+01
0.9018	2.886e+07	3.876e+01	7.542e+01	7.261e-02	1.413e-01
0.9988	6.390e+08	9.995e+02	1.917e+03	1.843e+00	3.534e+00
Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
1.1019	9.859e+07	1.787e+02	3.375e+02	3.235e-01	6.111e-01
1.1732	3.886e+12	7.738e+06	1.447e+07	1.383e+04	2.586e+04
1.2739	7.603e+08	1.713e+03	3.163e+03	3.005e+00	5.547e+00
1.3325	3.886e+12	9.367e+06	1.717e+07	1.625e+04	2.979e+04
1.4091	7.618e+07	1.997e+02	3.629e+02	3.415e-01	6.208e-01
1.4966	1.432e+07	4.106e+01	7.397e+01	6.913e-02	1.245e-01
1.5952	5.931e+07	1.869e+02	3.338e+02	3.092e-01	5.521e-01
2.1857	3.407e-02	1.696e-07	2.905e-07	2.550e-10	4.368e-10
Totals	7.803e+12	1.714e+07	3.171e+07	3.014e+04	5.577e+04

Results - Dose Point # 2 - (68.58,91.44,0) cm

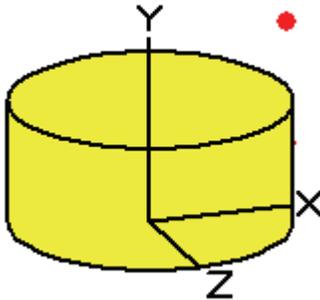
Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.0385	1.667e+09	3.149e-24	1.068e-23	1.537e-26	5.213e-26
0.1229	9.375e+08	1.075e-02	2.591e-02	1.687e-05	4.068e-05
0.2453	1.689e+08	3.413e-02	1.101e-01	6.275e-05	2.024e-04
0.3433	9.721e+07	4.188e-02	1.368e-01	8.065e-05	2.634e-04
0.4327	4.494e+08	3.072e-01	9.815e-01	6.010e-04	1.920e-03
0.4537	2.953e+07	2.211e-02	7.014e-02	4.334e-05	1.375e-04
0.5892	1.361e+08	1.667e-01	5.029e-01	3.258e-04	9.825e-04
0.6618	5.665e+09	8.612e+00	2.535e+01	1.670e-02	4.915e-02
0.7051	1.054e+10	1.802e+01	5.235e+01	3.473e-02	1.009e-01
0.871	9.813e+09	2.481e+01	6.918e+01	4.670e-02	1.302e-01
0.9018	2.886e+07	7.786e-02	2.157e-01	1.458e-04	4.040e-04
0.9988	6.390e+08	2.086e+00	5.678e+00	3.846e-03	1.047e-02
1.1019	9.859e+07	3.872e-01	1.038e+00	7.010e-04	1.879e-03
1.1732	3.886e+12	1.718e+04	4.566e+04	3.070e+01	8.160e+01
1.2739	7.603e+08	3.929e+00	1.035e+01	6.892e-03	1.815e-02
1.3325	3.886e+12	2.188e+04	5.736e+04	3.795e+01	9.952e+01
1.4091	7.618e+07	4.770e-01	1.245e+00	8.159e-04	2.130e-03
1.4966	1.432e+07	1.005e-01	2.617e-01	1.693e-04	4.406e-04
1.5952	5.931e+07	4.701e-01	1.221e+00	7.776e-04	2.020e-03
2.1857	3.407e-02	4.897e-10	1.270e-09	7.362e-13	1.909e-12
Totals	7.803e+12	3.912e+04	1.032e+05	6.877e+01	1.814e+02

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 5.ms6
Run Date August 15, 2005
Run Time 12:02:51 PM
Duration 00:00:28

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 5
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.68e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	μCi/cm ³	Bq/cm ³
Ac-227	7.1316e-009	2.6387e+002	8.2192e-009	3.0411e-004
Ag-108m	1.7074e-003	6.3175e+007	1.9678e-003	7.2810e+001
Ag-110m	5.2081e-013	1.9270e-002	6.0024e-013	2.2209e-008
Am-241	1.2784e-003	4.7299e+007	1.4733e-003	5.4513e+001
Am-243	1.9471e-005	7.2044e+005	2.2441e-005	8.3031e-001
Ba-137m	1.8028e-002	6.6703e+008	2.0777e-002	7.6876e+002
Be-10	2.6277e-003	9.7226e+007	3.0285e-003	1.1205e+002
C-14	9.3509e-002	3.4598e+009	1.0777e-001	3.9875e+003
Ce-144	1.5950e-011	5.9014e-001	1.8382e-011	6.8015e-007
Cl-36	8.8775e-004	3.2847e+007	1.0231e-003	3.7856e+001
Cm-243	3.5510e-006	1.3139e+005	4.0926e-006	1.5142e-001
Cm-244	2.2549e-003	8.3430e+007	2.5988e-003	9.6155e+001
Cm-245	4.2612e-007	1.5766e+004	4.9111e-007	1.8171e-002
Cm-246	4.7051e-007	1.7409e+004	5.4226e-007	2.0064e-002
Cm-247	3.3143e-012	1.2263e-001	3.8197e-012	1.4133e-007
Cm-248	5.9479e-011	2.2007e+000	6.8550e-011	2.5364e-006
Co-60	1.3878e+001	5.1350e+011	1.5995e+001	5.9182e+005
Cs-134	2.0744e-005	7.6752e+005	2.3907e-005	8.8457e-001
Cs-137	1.9057e-002	7.0511e+008	2.1963e-002	8.1265e+002
Eu-152	1.2813e-003	4.7409e+007	1.4767e-003	5.4639e+001

Eu-154	7.3683e-003	2.7263e+008	8.4921e-003	3.1421e+002
H-3	2.3200e+002	8.5839e+012	2.6738e+002	9.8931e+006
I-129	2.9887e-008	1.1058e+003	3.4446e-008	1.2745e-003
Mn-54	2.2608e-008	8.3649e+002	2.6056e-008	9.6407e-004
Nb-94	3.4030e-002	1.2591e+009	3.9220e-002	1.4512e+003
Ni-59	9.3213e-001	3.4489e+010	1.0743e+000	3.9749e+004
Ni-63	1.7045e+002	6.3065e+012	1.9644e+002	7.2684e+006
Np-237	1.5121e-008	5.5949e+002	1.7427e-008	6.4482e-004
Pa-231	1.0446e-008	3.8649e+002	1.2039e-008	4.4544e-004
Pb-210	4.8530e-013	1.7956e-002	5.5932e-013	2.0695e-008
Pr-144	1.5722e-011	5.8170e-001	1.8120e-011	6.7042e-007
Pu-238	5.8887e-004	2.1788e+007	6.7868e-004	2.5111e+001
Pu-239	1.2784e-004	4.7299e+006	1.4733e-004	5.4513e+000
Pu-240	1.5684e-004	5.8029e+006	1.8075e-004	6.6879e+000
Pu-241	1.2784e-002	4.7299e+008	1.4733e-002	5.4513e+002
Pu-242	2.0033e-006	7.4124e+004	2.3089e-006	8.5429e-002
Pu-244	1.8820e-012	6.9635e-002	2.1691e-012	8.0255e-008
Ra-226	7.8418e-013	2.9014e-002	9.0377e-013	3.3440e-008
Rh-106	2.2075e-009	8.1679e+001	2.5442e-009	9.4136e-005
Ru-106	2.2075e-009	8.1679e+001	2.5442e-009	9.4136e-005
Sb-125	4.6459e-005	1.7190e+006	5.3544e-005	1.9811e+000
Sr-90	5.9479e-003	2.2007e+008	6.8550e-003	2.5364e+002
Tc-99	4.4683e-005	1.6533e+006	5.1498e-005	1.9054e+000
Th-228	1.2636e-006	4.6752e+004	1.4563e-006	5.3882e-002
Th-229	8.4632e-009	3.1314e+002	9.7539e-009	3.6090e-004
Th-230	8.2560e-011	3.0547e+000	9.5152e-011	3.5206e-006
Th-232	1.4441e-008	5.3430e+002	1.6643e-008	6.1579e-004
U-232	1.2162e-006	4.5000e+004	1.4017e-006	5.1863e-002
U-233	2.3999e-006	8.8795e+004	2.7659e-006	1.0234e-001
U-234	2.1631e-007	8.0036e+003	2.4930e-007	9.2243e-003
U-235	1.7903e-009	6.6241e+001	2.0633e-009	7.6343e-005
U-236	5.0897e-009	1.8832e+002	5.8660e-009	2.1704e-004
U-238	6.0071e-008	2.2226e+003	6.9232e-008	2.5616e-003
Y-90	5.9479e-003	2.2007e+008	6.8550e-003	2.5364e+002
Zn-65	1.2044e-012	4.4562e-002	1.3881e-012	5.1358e-008

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,30.48,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	2.203e+08	5.521e-02	5.963e-02	2.695e-04	2.911e-04
0.1229	1.239e+08	5.886e+00	8.745e+00	9.242e-03	1.373e-02
0.2453	2.232e+07	4.277e+00	8.293e+00	7.865e-03	1.525e-02
0.3433	1.285e+07	4.155e+00	8.511e+00	8.001e-03	1.639e-02
0.4327	5.939e+07	2.709e+01	5.610e+01	5.301e-02	1.098e-01
0.4537	3.902e+06	1.909e+00	3.951e+00	3.741e-03	7.743e-03
0.5892	1.798e+07	1.289e+01	2.631e+01	2.519e-02	5.141e-02
0.6618	7.486e+08	6.365e+02	1.285e+03	1.234e+00	2.491e+00
0.7051	1.393e+09	1.300e+03	2.607e+03	2.506e+00	5.025e+00
0.871	1.297e+09	1.654e+03	3.233e+03	3.113e+00	6.084e+00

0.9018	3.814e+06	5.122e+00	9.966e+00	9.595e-03	1.867e-02
0.9988	8.444e+07	1.321e+02	2.533e+02	2.435e-01	4.670e-01
1.1019	1.303e+07	2.361e+01	4.460e+01	4.275e-02	8.075e-02
1.1732	5.135e+11	1.023e+06	1.913e+06	1.827e+03	3.418e+03
1.2739	1.005e+08	2.264e+02	4.179e+02	3.971e-01	7.331e-01
1.3325	5.135e+11	1.238e+06	2.269e+06	2.148e+03	3.937e+03
1.4091	1.007e+07	2.638e+01	4.796e+01	4.513e-02	8.203e-02
1.4966	1.893e+06	5.426e+00	9.775e+00	9.135e-03	1.646e-02
1.5952	7.838e+06	2.470e+01	4.411e+01	4.086e-02	7.296e-02
2.1857	4.503e-03	2.241e-08	3.839e-08	3.369e-11	5.772e-11
Totals	1.031e+12	2.264e+06	4.190e+06	3.983e+03	7.370e+03

Results - Dose Point # 2 - (68.58,91.44,0) cm

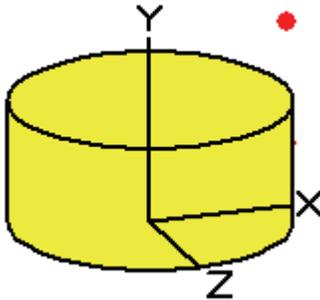
Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	2.203e+08	4.161e-25	1.411e-24	2.031e-27	6.888e-27
0.1229	1.239e+08	1.420e-03	3.423e-03	2.230e-06	5.375e-06
0.2453	2.232e+07	4.510e-03	1.455e-02	8.292e-06	2.675e-05
0.3433	1.285e+07	5.535e-03	1.808e-02	1.066e-05	3.481e-05
0.4327	5.939e+07	4.059e-02	1.297e-01	7.942e-05	2.538e-04
0.4537	3.902e+06	2.922e-03	9.269e-03	5.727e-06	1.817e-05
0.5892	1.798e+07	2.203e-02	6.645e-02	4.305e-05	1.298e-04
0.6618	7.486e+08	1.138e+00	3.350e+00	2.206e-03	6.495e-03
0.7051	1.393e+09	2.381e+00	6.918e+00	4.590e-03	1.334e-02
0.871	1.297e+09	3.279e+00	9.141e+00	6.171e-03	1.720e-02
0.9018	3.814e+06	1.029e-02	2.850e-02	1.927e-05	5.338e-05
0.9988	8.444e+07	2.757e-01	7.503e-01	5.082e-04	1.383e-03
1.1019	1.303e+07	5.116e-02	1.371e-01	9.263e-05	2.483e-04
1.1732	5.135e+11	2.270e+03	6.034e+03	4.057e+00	1.078e+01
1.2739	1.005e+08	5.193e-01	1.367e+00	9.107e-04	2.398e-03
1.3325	5.135e+11	2.891e+03	7.580e+03	5.015e+00	1.315e+01
1.4091	1.007e+07	6.303e-02	1.646e-01	1.078e-04	2.815e-04
1.4966	1.893e+06	1.329e-02	3.458e-02	2.237e-05	5.822e-05
1.5952	7.838e+06	6.212e-02	1.614e-01	1.028e-04	2.669e-04
2.1857	4.503e-03	6.471e-11	1.678e-10	9.729e-14	2.523e-13
Totals	1.031e+12	5.169e+03	1.364e+04	9.087e+00	2.398e+01

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 6.ms6
Run Date August 15, 2005
Run Time 12:07:59 PM
Duration 00:00:28

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 6
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.68e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	2.5198e-009	9.3232e+001	2.9041e-009	1.0745e-004
Ag-108m	6.0328e-004	2.2321e+007	6.9529e-004	2.5726e+001
Ag-110m	1.8402e-013	6.8086e-003	2.1208e-013	7.8470e-009
Am-241	4.5168e-004	1.6712e+007	5.2056e-004	1.9261e+001
Am-243	6.8797e-006	2.5455e+005	7.9290e-006	2.9337e-001
Ba-137m	6.3697e-003	2.3568e+008	7.3412e-003	2.7162e+002
Be-10	9.2845e-004	3.4353e+007	1.0700e-003	3.9592e+001
C-14	3.3039e-002	1.2225e+009	3.8078e-002	1.4089e+003
Ce-144	5.6355e-012	2.0851e-001	6.4950e-012	2.4031e-007
Cl-36	3.1366e-004	1.1606e+007	3.6150e-004	1.3376e+001
Cm-243	1.2547e-006	4.6422e+004	1.4460e-006	5.3502e-002
Cm-244	7.9671e-004	2.9478e+007	9.1822e-004	3.3974e+001
Cm-245	1.5056e-007	5.5707e+003	1.7352e-007	6.4203e-003
Cm-246	1.6624e-007	6.1510e+003	1.9160e-007	7.0891e-003
Cm-247	1.1710e-012	4.3328e-002	1.3496e-012	4.9936e-008
Cm-248	2.1016e-011	7.7757e-001	2.4221e-011	8.9616e-007
Co-60	4.9036e+000	1.8143e+011	5.6515e+000	2.0911e+005
Cs-134	7.3293e-006	2.7118e+005	8.4471e-006	3.1254e-001
Cs-137	6.7333e-003	2.4913e+008	7.7603e-003	2.8713e+002
Eu-152	4.5272e-004	1.6751e+007	5.2177e-004	1.9305e+001

Eu-154	2.6034e-003	9.6326e+007	3.0005e-003	1.1102e+002
H-3	8.1971e+001	3.0329e+012	9.4473e+001	3.4955e+006
I-129	1.0560e-008	3.9072e+002	1.2171e-008	4.5031e-004
Mn-54	7.9880e-009	2.9556e+002	9.2063e-009	3.4063e-004
Nb-94	1.2024e-002	4.4488e+008	1.3858e-002	5.1273e+002
Ni-59	3.2935e-001	1.2186e+010	3.7958e-001	1.4044e+004
Ni-63	6.0224e+001	2.2283e+012	6.9409e+001	2.5681e+006
Np-237	5.3428e-009	1.9768e+002	6.1576e-009	2.2783e-004
Pa-231	3.6908e-009	1.3656e+002	4.2537e-009	1.5739e-004
Pb-210	1.7147e-013	6.3444e-003	1.9762e-013	7.3120e-009
Pr-144	5.5549e-012	2.0553e-001	6.4021e-012	2.3688e-007
Pu-238	2.0806e-004	7.6984e+006	2.3980e-004	8.8725e+000
Pu-239	4.5168e-005	1.6712e+006	5.2056e-005	1.9261e+000
Pu-240	5.5414e-005	2.0503e+006	6.3865e-005	2.3630e+000
Pu-241	4.5168e-003	1.6712e+008	5.2056e-003	1.9261e+002
Pu-242	7.0784e-007	2.6190e+004	8.1579e-007	3.0184e-002
Pu-244	6.6497e-013	2.4604e-002	7.6639e-013	2.8356e-008
Ra-226	2.7707e-013	1.0252e-002	3.1933e-013	1.1815e-008
Rh-106	7.7998e-010	2.8859e+001	8.9894e-010	3.3261e-005
Ru-106	7.7998e-010	2.8859e+001	8.9894e-010	3.3261e-005
Sb-125	1.6415e-005	6.0736e+005	1.8919e-005	6.9999e-001
Sr-90	2.1016e-003	7.7757e+007	2.4221e-003	8.9616e+001
Tc-99	1.5788e-005	5.8415e+005	1.8196e-005	6.7324e-001
Th-228	4.4645e-007	1.6519e+004	5.1454e-007	1.9038e-002
Th-229	2.9903e-009	1.1064e+002	3.4463e-009	1.2751e-004
Th-230	2.9171e-011	1.0793e+000	3.3620e-011	1.2439e-006
Th-232	5.1023e-009	1.8878e+002	5.8804e-009	2.1758e-004
U-232	4.2972e-007	1.5900e+004	4.9526e-007	1.8325e-002
U-233	8.4794e-007	3.1374e+004	9.7726e-007	3.6159e-002
U-234	7.6430e-008	2.8279e+003	8.8086e-008	3.2592e-003
U-235	6.3256e-010	2.3405e+001	7.2903e-010	2.6974e-005
U-236	1.7983e-009	6.6539e+001	2.0726e-009	7.6687e-005
U-238	2.1225e-008	7.8531e+002	2.4462e-008	9.0508e-004
Y-90	2.1016e-003	7.7757e+007	2.4221e-003	8.9616e+001
Zn-65	4.2554e-013	1.5745e-002	4.9044e-013	1.8146e-008

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,30.48,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	7.785e+07	1.951e-02	2.107e-02	9.524e-05	1.029e-04
0.1229	4.377e+07	2.080e+00	3.090e+00	3.265e-03	4.852e-03
0.2453	7.886e+06	1.511e+00	2.930e+00	2.779e-03	5.388e-03
0.3433	4.539e+06	1.468e+00	3.007e+00	2.827e-03	5.791e-03
0.4327	2.098e+07	9.572e+00	1.982e+01	1.873e-02	3.878e-02
0.4537	1.379e+06	6.743e-01	1.396e+00	1.322e-03	2.736e-03
0.5892	6.352e+06	4.556e+00	9.297e+00	8.901e-03	1.816e-02
0.6618	2.645e+08	2.249e+02	4.540e+02	4.360e-01	8.802e-01
0.7051	4.921e+08	4.593e+02	9.210e+02	8.854e-01	1.775e+00
0.871	4.582e+08	5.844e+02	1.142e+03	1.100e+00	2.150e+00

0.9018	1.348e+06	1.810e+00	3.521e+00	3.390e-03	6.596e-03
0.9988	2.984e+07	4.667e+01	8.949e+01	8.604e-02	1.650e-01
1.1019	4.603e+06	8.343e+00	1.576e+01	1.510e-02	2.853e-02
1.1732	1.814e+11	3.613e+05	6.757e+05	6.456e+02	1.208e+03
1.2739	3.550e+07	7.999e+01	1.477e+02	1.403e-01	2.590e-01
1.3325	1.814e+11	4.374e+05	8.018e+05	7.588e+02	1.391e+03
1.4091	3.557e+06	9.322e+00	1.694e+01	1.595e-02	2.898e-02
1.4966	6.688e+05	1.917e+00	3.454e+00	3.228e-03	5.815e-03
1.5952	2.769e+06	8.727e+00	1.558e+01	1.444e-02	2.578e-02
2.1857	1.591e-03	7.918e-09	1.357e-08	1.190e-11	2.039e-11
Totals	3.643e+11	8.001e+05	1.480e+06	1.407e+03	2.604e+03

Results - Dose Point # 2 - (68.58,91.44,0) cm

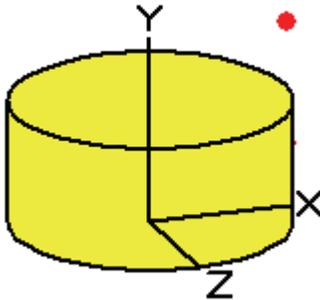
Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	7.785e+07	1.470e-25	4.985e-25	7.177e-28	2.434e-27
0.1229	4.377e+07	5.018e-04	1.210e-03	7.878e-07	1.899e-06
0.2453	7.886e+06	1.593e-03	5.140e-03	2.930e-06	9.451e-06
0.3433	4.539e+06	1.956e-03	6.387e-03	3.766e-06	1.230e-05
0.4327	2.098e+07	1.434e-02	4.583e-02	2.806e-05	8.966e-05
0.4537	1.379e+06	1.032e-03	3.275e-03	2.024e-06	6.419e-06
0.5892	6.352e+06	7.785e-03	2.348e-02	1.521e-05	4.587e-05
0.6618	2.645e+08	4.021e-01	1.184e+00	7.795e-04	2.295e-03
0.7051	4.921e+08	8.412e-01	2.444e+00	1.622e-03	4.712e-03
0.871	4.582e+08	1.159e+00	3.230e+00	2.180e-03	6.079e-03
0.9018	1.348e+06	3.635e-03	1.007e-02	6.809e-06	1.886e-05
0.9988	2.984e+07	9.740e-02	2.651e-01	1.796e-04	4.888e-04
1.1019	4.603e+06	1.808e-02	4.846e-02	3.273e-05	8.773e-05
1.1732	1.814e+11	8.022e+02	2.132e+03	1.433e+00	3.810e+00
1.2739	3.550e+07	1.835e-01	4.831e-01	3.218e-04	8.473e-04
1.3325	1.814e+11	1.021e+03	2.678e+03	1.772e+00	4.647e+00
1.4091	3.557e+06	2.227e-02	5.815e-02	3.809e-05	9.947e-05
1.4966	6.688e+05	4.695e-03	1.222e-02	7.904e-06	2.057e-05
1.5952	2.769e+06	2.195e-02	5.701e-02	3.630e-05	9.431e-05
2.1857	1.591e-03	2.286e-11	5.930e-11	3.437e-14	8.915e-14
Totals	3.643e+11	1.826e+03	4.818e+03	3.211e+00	8.472e+00

MicroShield v6.10 (0063)
INL

Page 1
DOS File ETR reactor dose point 7.ms6
Run Date August 15, 2005
Run Time 12:12:34 PM
Duration 00:00:28

File Ref
Date
By
Checked

Case Title: ETR Reactor
Description: Station Point 7
Geometry: 7 - Cylinder Volume - Side Shields



Source Dimensions:

Height 60.96 cm (2 ft)
Radius 67.31 cm (2 ft 2.5 in)

Dose Points

A	X	Y	Z
# 1	68.58 cm 2 ft 3.0 in	30.48 cm 1 ft	0 cm 0.0 in
# 2	68.58 cm 2 ft 3.0 in	91.44 cm 3 ft	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	8.68e+05 cm ³	Iron	5.38
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Iron	5.38

Source Input : Grouping Method - Linear Energy

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	2.4071e-009	8.9061e+001	2.7742e-009	1.0264e-004
Ag-108m	5.7630e-004	2.1323e+007	6.6419e-004	2.4575e+001
Ag-110m	1.7579e-013	6.5041e-003	2.0260e-013	7.4960e-009
Am-241	4.3147e-004	1.5965e+007	4.9728e-004	1.8399e+001
Am-243	6.5720e-006	2.4316e+005	7.5743e-006	2.8025e-001
Ba-137m	6.0848e-003	2.2514e+008	7.0128e-003	2.5948e+002
Be-10	8.8692e-004	3.2816e+007	1.0222e-003	3.7821e+001
C-14	3.1562e-002	1.1678e+009	3.6375e-002	1.3459e+003
Ce-144	5.3834e-012	1.9919e-001	6.2045e-012	2.2957e-007
Cl-36	2.9963e-004	1.1086e+007	3.4533e-004	1.2777e+001
Cm-243	1.1985e-006	4.4346e+004	1.3813e-006	5.1109e-002
Cm-244	7.6107e-004	2.8160e+007	8.7715e-004	3.2454e+001
Cm-245	1.4382e-007	5.3215e+003	1.6576e-007	6.1331e-003
Cm-246	1.5881e-007	5.8758e+003	1.8303e-007	6.7720e-003
Cm-247	1.1186e-012	4.1390e-002	1.2892e-012	4.7702e-008
Cm-248	2.0076e-011	7.4280e-001	2.3137e-011	8.5608e-007
Co-60	4.6843e+000	1.7332e+011	5.3987e+000	1.9975e+005
Cs-134	7.0015e-006	2.5905e+005	8.0693e-006	2.9856e-001
Cs-137	6.4322e-003	2.3799e+008	7.4132e-003	2.7429e+002
Eu-152	4.3247e-004	1.6002e+007	4.9843e-004	1.8442e+001

Nuclide	curies	becquerels	$\mu\text{Ci}/\text{cm}^3$	Bq/cm^3
Eu-154	2.4870e-003	9.2018e+007	2.8663e-003	1.0605e+002
H-3	7.8305e+001	2.8973e+012	9.0247e+001	3.3391e+006
I-129	1.0088e-008	3.7325e+002	1.1626e-008	4.3017e-004
Mn-54	7.6307e-009	2.8234e+002	8.7945e-009	3.2540e-004
Nb-94	1.1486e-002	4.2498e+008	1.3238e-002	4.8980e+002
Ni-59	3.1462e-001	1.1641e+010	3.6260e-001	1.3416e+004
Ni-63	5.7530e+001	2.1286e+012	6.6304e+001	2.4532e+006
Np-237	5.1038e-009	1.8884e+002	5.8822e-009	2.1764e-004
Pa-231	3.5257e-009	1.3045e+002	4.0634e-009	1.5035e-004
Pb-210	1.6380e-013	6.0606e-003	1.8878e-013	6.9849e-009
Pr-144	5.3065e-012	1.9634e-001	6.1158e-012	2.2628e-007
Pu-238	1.9876e-004	7.3540e+006	2.2907e-004	8.4756e+000
Pu-239	4.3147e-005	1.5965e+006	4.9728e-005	1.8399e+000
Pu-240	5.2936e-005	1.9586e+006	6.1009e-005	2.2573e+000
Pu-241	4.3147e-003	1.5965e+008	4.9728e-003	1.8399e+002
Pu-242	6.7618e-007	2.5019e+004	7.7930e-007	2.8834e-002
Pu-244	6.3523e-013	2.3503e-002	7.3211e-013	2.7088e-008
Ra-226	2.6468e-013	9.7931e-003	3.0504e-013	1.1287e-008
Rh-106	7.4509e-010	2.7568e+001	8.5873e-010	3.1773e-005
Ru-106	7.4509e-010	2.7568e+001	8.5873e-010	3.1773e-005
Sb-125	1.5681e-005	5.8019e+005	1.8072e-005	6.6868e-001
Sr-90	2.0076e-003	7.4280e+007	2.3137e-003	8.5608e+001
Tc-99	1.5082e-005	5.5802e+005	1.7382e-005	6.4313e-001
Th-228	4.2648e-007	1.5780e+004	4.9152e-007	1.8186e-002
Th-229	2.8565e-009	1.0569e+002	3.2922e-009	1.2181e-004
Th-230	2.7866e-011	1.0310e+000	3.2116e-011	1.1883e-006
Th-232	4.8741e-009	1.8034e+002	5.6174e-009	2.0784e-004
U-232	4.1050e-007	1.5188e+004	4.7311e-007	1.7505e-002
U-233	8.1001e-007	2.9970e+004	9.3355e-007	3.4541e-002
U-234	7.3011e-008	2.7014e+003	8.4146e-008	3.1134e-003
U-235	6.0426e-010	2.2358e+001	6.9642e-010	2.5768e-005
U-236	1.7179e-009	6.3563e+001	1.9799e-009	7.3257e-005
U-238	2.0275e-008	7.5019e+002	2.3368e-008	8.6460e-004
Y-90	2.0076e-003	7.4280e+007	2.3137e-003	8.5608e+001
Zn-65	4.0650e-013	1.5041e-002	4.6850e-013	1.7335e-008

**Buildup : The material reference is - Source
Integration Parameters**

Radial	30
Circumferential	30
Y Direction (axial)	30

Results - Dose Point # 1 - (68.58,30.48,0) cm

Energy MeV	Activity Photons/sec	Fluence Rate	Fluence Rate	Exposure Rate	Exposure Rate
		MeV/cm ² /sec No Buildup	MeV/cm ² /sec With Buildup	mR/hr No Buildup	mR/hr With Buildup
0.0385	7.436e+07	1.864e-02	2.013e-02	9.098e-05	9.825e-05
0.1229	4.181e+07	1.987e+00	2.952e+00	3.119e-03	4.635e-03
0.2453	7.534e+06	1.444e+00	2.799e+00	2.654e-03	5.147e-03
0.3433	4.336e+06	1.403e+00	2.873e+00	2.701e-03	5.532e-03
0.4327	2.005e+07	9.144e+00	1.894e+01	1.789e-02	3.705e-02
0.4537	1.317e+06	6.442e-01	1.333e+00	1.263e-03	2.614e-03
0.5892	6.068e+06	4.352e+00	8.881e+00	8.503e-03	1.735e-02
0.6618	2.527e+08	2.148e+02	4.337e+02	4.165e-01	8.408e-01
0.7051	4.701e+08	4.387e+02	8.798e+02	8.458e-01	1.696e+00

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0.871	4.377e+08	5.582e+02	1.091e+03	1.051e+00	2.054e+00
0.9018	1.287e+06	1.729e+00	3.364e+00	3.238e-03	6.301e-03
0.9988	2.850e+07	4.458e+01	8.549e+01	8.219e-02	1.576e-01
Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
1.1019	4.397e+06	7.970e+00	1.505e+01	1.443e-02	2.726e-02
1.1732	1.733e+11	3.451e+05	6.455e+05	6.168e+02	1.154e+03
1.2739	3.391e+07	7.641e+01	1.411e+02	1.340e-01	2.474e-01
1.3325	1.733e+11	4.178e+05	7.659e+05	7.249e+02	1.329e+03
1.4091	3.398e+06	8.905e+00	1.619e+01	1.523e-02	2.769e-02
1.4966	6.388e+05	1.831e+00	3.299e+00	3.083e-03	5.555e-03
1.5952	2.646e+06	8.337e+00	1.489e+01	1.379e-02	2.463e-02
2.1857	1.520e-03	7.564e-09	1.296e-08	1.137e-11	1.948e-11
Totals	3.480e+11	7.643e+05	1.414e+06	1.344e+03	2.488e+03

Results - Dose Point # 2 - (68.58,91.44,0) cm

0.0385	7.436e+07	1.404e-25	4.762e-25	6.856e-28	2.325e-27
0.1229	4.181e+07	4.793e-04	1.155e-03	7.526e-07	1.814e-06
0.2453	7.534e+06	1.522e-03	4.910e-03	2.799e-06	9.028e-06
0.3433	4.336e+06	1.868e-03	6.101e-03	3.597e-06	1.175e-05
0.4327	2.005e+07	1.370e-02	4.378e-02	2.681e-05	8.565e-05
0.4537	1.317e+06	9.863e-04	3.129e-03	1.933e-06	6.132e-06
0.5892	6.068e+06	7.436e-03	2.243e-02	1.453e-05	4.382e-05
0.6618	2.527e+08	3.841e-01	1.131e+00	7.447e-04	2.192e-03
0.7051	4.701e+08	8.036e-01	2.335e+00	1.549e-03	4.502e-03
0.871	4.377e+08	1.107e+00	3.085e+00	2.083e-03	5.807e-03
0.9018	1.287e+06	3.473e-03	9.620e-03	6.504e-06	1.802e-05
0.9988	2.850e+07	9.305e-02	2.532e-01	1.715e-04	4.669e-04
1.1019	4.397e+06	1.727e-02	4.629e-02	3.127e-05	8.381e-05
1.1732	1.733e+11	7.663e+02	2.037e+03	1.369e+00	3.640e+00
1.2739	3.391e+07	1.753e-01	4.615e-01	3.074e-04	8.094e-04
1.3325	1.733e+11	9.757e+02	2.558e+03	1.693e+00	4.439e+00
1.4091	3.398e+06	2.127e-02	5.555e-02	3.639e-05	9.502e-05
1.4966	6.388e+05	4.485e-03	1.167e-02	7.550e-06	1.965e-05
1.5952	2.646e+06	2.097e-02	5.446e-02	3.468e-05	9.009e-05
2.1857	1.520e-03	2.184e-11	5.665e-11	3.284e-14	8.516e-14
Totals	3.480e+11	1.745e+03	4.603e+03	3.067e+00	8.093e+00

Appendix B
EDF-6958 Data

Appendix B, EDF-6958 Data

Isotope	Be Reflector (Be) (Ci/Ci)	Grid Plate (304-SS) (Ci/Ci)	I-Beams (all 6, 304-SS) (Ci/Ci)	C-7 In-Pile Tube (304-SS) (Ci/Ci)	F-10 In-Pile Tube (304-SS) (Ci/Ci)	M-13 In-Pile Tube (304-SS) (Ci/Ci)	N-14 In-Pile Tube (304-SS) (Ci/Ci)	Upper Support Frame (304-SS) (Ci/Ci)	Inner Tank (304-SS, Steel) (Ci/Ci)	Internal Thermal Shields (304-SS) (Ci/Ci)	External Thermal Shield (304-SS, Pb) (Ci/Ci)	External Tank (304-SS, Steel) (Ci/Ci)	Black Rod Poison (Cd) (Ci/Ci)	Gray Rod Poison (Ni) (Ci/Ci)
H-3	2.97E+04	8.63E-03	7.57E-03	4.94E-03	1.38E-03	1.93E-03	3.20E-03	7.54E-03	6.46E-03	7.56E-03	1.44E-01	9.36E-02	8.55E-04	2.42E-07
Be-10	3.36E-01	1.56E-09	1.32E-09	1.01E-09	1.04E-09	6.54E-10	6.88E-10	1.31E-09	1.18E-09	1.31E-09	3.19E-08	2.06E-08	1.40E-09	2.18E-09
C-14	2.67E+00	8.55E-03	6.31E-03	5.93E-03	6.68E-03	4.13E-03	4.15E-03	6.29E-03	6.42E-03	6.32E-03	1.26E-02	1.03E-02	9.00E-03	6.93E-07
Cl-36	3.27E-02	8.78E-05	5.01E-05	4.65E-05	4.82E-05	3.14E-05	3.23E-05	5.00E-05	5.06E-05	5.02E-05	2.83E-05	3.63E-05	5.71E-05	2.33E-08
Mn-54	8.26E-09	2.95E-09	1.50E-09	1.62E-09	2.02E-09	2.51E-09	2.23E-09	1.50E-09	1.53E-09	1.50E-09	1.80E-08	1.19E-08	2.69E-09	1.05E-11
Ni-59	2.42E-02	1.01E-02	3.53E-02	3.03E-02	2.15E-02	1.79E-02	2.04E-02	3.52E-02	3.43E-02	3.55E-02	1.99E-02	2.56E-02	1.56E-02	1.79E-01
Co-60	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
Ni-63	3.50E+00	1.15E+00	3.73E+00	3.45E+00	3.41E+00	2.36E+00	2.46E+00	3.73E+00	3.75E+00	3.75E+00	2.21E+00	2.72E+00	3.66E+00	3.57E+01
Zn-65	3.86E-11	6.98E-14	3.71E-14	4.39E-14	8.24E-14	7.97E-14	6.28E-14	3.69E-14	3.94E-14	3.71E-14	4.85E-13	6.78E-14	1.69E-13	5.59E-14
Si-90	6.78E-01	8.85E-05	1.66E-05	4.56E-05	7.67E-05	4.68E-05	3.87E-05	1.65E-05	3.59E-05	1.68E-05	1.46E-04	9.86E-05	9.34E-05	5.67E-09
Nb-94	7.39E-03	8.63E-03	8.58E-05	7.89E-05	7.82E-05	5.25E-05	5.46E-05	8.51E-05	8.64E-05	8.56E-05	2.77E-04	2.06E-04	8.67E-05	5.64E-09
Tc-99	4.96E-04	5.84E-06	3.41E-06	3.03E-06	2.78E-06	1.94E-06	2.08E-06	3.39E-06	3.33E-06	3.38E-06	1.97E-06	2.49E-06	2.73E-06	1.85E-10
Ru-106	2.77E-07	7.00E-12	8.40E-14	4.06E-12	5.70E-12	7.97E-12	6.37E-12	8.35E-14	2.58E-12	1.15E-13	7.24E-13	4.89E-13	5.35E-12	2.91E-16
Ag-108m	3.16E-02	1.18E-04	6.84E-05	6.32E-05	6.37E-05	4.33E-05	4.48E-05	6.81E-05	6.87E-05	6.82E-05	7.35E-01	3.94E-04	6.65E-04	4.59E-09
Ag-110m	2.35E-11	2.23E-14	1.69E-14	1.40E-14	4.02E-15	1.32E-14	1.73E-14	1.69E-14	1.52E-14	1.69E-14	1.83E-10	9.77E-14	1.77E-13	6.79E-20
Sb-125	6.21E-04	5.18E-06	2.92E-06	3.13E-06	4.04E-06	4.28E-06	3.84E-06	2.92E-06	2.96E-06	2.92E-06	2.38E-05	2.12E-06	5.65E-06	2.63E-10
I-129	3.69E-06	1.73E-10	1.05E-11	8.61E-11	1.47E-10	8.70E-11	7.05E-11	1.05E-11	6.12E-11	1.10E-11	9.04E-11	6.10E-11	1.59E-10	1.06E-14
Cs-134	2.10E-03	5.94E-07	3.65E-07	3.62E-07	3.07E-07	4.40E-07	4.51E-07	3.63E-07	3.55E-07	3.65E-07	2.05E-07	2.64E-07	2.32E-07	1.45E-11
Cs-137	2.27E+00	1.83E-04	1.80E-05	9.35E-05	1.68E-04	1.02E-04	8.14E-05	1.79E-05	6.76E-05	1.85E-05	1.58E-04	1.06E-04	2.00E-04	1.23E-08
Ce-144	1.98E-09	6.74E-14	6.86E-15	3.94E-14	5.39E-14	7.46E-14	6.06E-14	6.83E-15	2.74E-14	7.09E-15	6.07E-14	4.08E-14	5.29E-14	2.82E-18
Eu-152	1.38E-02	6.80E-05	1.33E-03	5.25E-05	8.34E-08	1.63E-06	1.99E-05	1.32E-03	2.19E-04	1.30E-03	1.07E-01	6.80E-02	3.81E-08	3.05E-12
Eu-154	8.11E-01	1.64E-04	7.59E-05	9.21E-05	2.58E-05	5.48E-05	7.54E-05	7.56E-05	8.90E-05	7.59E-05	6.11E-03	3.90E-03	7.10E-06	6.42E-10
Pb-210	1.45E-11	3.02E-14	2.11E-10	1.38E-14	5.60E-14	1.60E-14	9.27E-15	1.74E-09	1.18E-14	2.68E-13	1.95E-10	1.09E-10	1.25E-13	6.57E-18
Ra-226	2.02E-11	7.41E-14	6.09E-10	3.48E-14	4.83E-14	2.43E-14	2.13E-14	5.03E-09	3.14E-14	7.75E-13	5.63E-10	3.15E-10	4.35E-14	3.50E-18

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Isotope	Be Reflector (Ci/Ci)	Grid Plate (304-SS) (Ci/Ci)	I-Beams (all 6, 304-SS) (Ci/Ci)	C-7 In-Pile Tube (304-SS) (Ci/Ci)	F-10 In-Pile Tube (304-SS) (Ci/Ci)	M-13 In-Pile Tube (304-SS) (Ci/Ci)	N-14 In-Pile Tube (304-SS) (Ci/Ci)	Upper Support Frame (304-SS) (Ci/Ci)	Inner Tank (304-SS, Steel) (Ci/Ci)	Internal Thermal Shields (304-SS) (Ci/Ci)	External Thermal Shield (304-SS, Pb) (Ci/Ci)	External Tank (304-SS, Steel) (Ci/Ci)	Black Rod Poison (Cd) (Ci/Ci)	Gray Rod Poison (Ni) (Ci/Ci)
Ac-227	1.14E-07	9.24E-10	3.81E-09	4.97E-10	1.96E-10	2.20E-10	3.02E-10	2.66E-08	6.14E-10	6.79E-10	2.51E-08	1.59E-08	8.91E-11	8.03E-15
Th-228	5.68E-05	1.15E-07	2.39E-05	5.58E-08	1.42E-07	7.83E-08	5.19E-08	1.98E-04	3.22E-08	3.03E-08	8.38E-05	4.47E-05	1.16E-07	8.83E-12
Th-229	9.51E-08	1.11E-09	1.10E-09	6.00E-10	1.56E-10	1.96E-10	3.23E-10	1.10E-09	8.31E-10	1.02E-09	3.60E-08	2.31E-08	7.70E-11	6.77E-15
Th-230	2.95E-09	6.88E-12	6.15E-08	3.31E-12	4.72E-12	2.80E-12	2.32E-12	5.08E-07	2.81E-12	7.76E-11	5.69E-08	3.18E-08	3.96E-12	3.07E-16
Th-232	1.17E-08	1.85E-10	2.41E-05	1.11E-10	1.64E-11	2.53E-11	5.40E-11	1.99E-04	2.54E-10	3.03E-08	8.46E-05	4.52E-05	7.19E-12	6.55E-16
Pa-231	1.82E-07	1.34E-09	7.57E-09	7.27E-10	2.95E-10	3.41E-10	4.64E-10	5.55E-08	8.81E-10	9.77E-10	3.79E-08	2.39E-08	1.39E-10	1.22E-14
U-232	5.53E-05	1.11E-07	1.21E-12	5.42E-08	1.38E-07	7.61E-08	5.04E-08	8.84E-13	3.11E-08	2.85E-10	1.15E-10	8.91E-11	1.13E-07	8.61E-12
U-233	3.15E-05	3.07E-07	3.08E-07	1.72E-07	4.36E-08	6.26E-08	1.03E-07	3.07E-07	2.32E-07	2.83E-07	1.01E-05	6.45E-06	2.00E-08	1.73E-12
U-234	1.24E-05	1.31E-08	1.48E-04	6.49E-09	9.59E-09	7.32E-09	5.63E-09	1.23E-03	4.99E-09	1.86E-07	1.38E-04	7.69E-05	6.83E-09	5.01E-13
U-235	3.44E-09	1.83E-11	6.75E-06	1.23E-11	7.51E-13	8.70E-13	4.17E-12	5.59E-05	4.55E-11	8.46E-09	6.25E-06	3.48E-06	6.10E-13	4.31E-17
U-236	4.96E-07	1.71E-10	1.60E-10	9.55E-11	2.78E-11	3.30E-11	5.58E-11	1.60E-10	1.31E-10	1.60E-10	1.38E-09	9.26E-10	2.72E-11	1.69E-15
U-238	2.17E-06	1.09E-09	1.47E-04	6.55E-10	8.19E-11	1.41E-10	3.15E-10	1.21E-03	1.53E-09	1.84E-07	1.36E-04	7.59E-05	2.72E-11	2.72E-15
Np-237	1.70E-06	3.25E-10	2.92E-11	1.59E-10	8.76E-11	9.93E-11	1.17E-10	2.91E-11	1.04E-10	2.88E-11	2.50E-10	1.68E-10	6.19E-11	4.32E-15
Pu-238	7.01E-02	7.86E-06	5.80E-13	3.11E-06	4.30E-06	3.54E-06	2.35E-06	6.98E-14	8.36E-07	4.41E-10	4.58E-11	3.73E-11	1.66E-06	1.51E-10
Pu-239	1.14E-02	5.07E-06	7.79E-06	2.94E-06	4.33E-07	7.39E-07	1.55E-06	7.76E-06	4.87E-06	7.59E-06	6.66E-05	4.49E-05	1.44E-07	1.44E-11
Pu-240	1.63E-02	4.73E-06	4.69E-11	2.55E-06	8.13E-07	9.78E-07	1.64E-06	5.62E-12	2.42E-06	3.65E-08	3.71E-09	3.01E-09	5.98E-07	4.58E-11
Pu-241	1.48E+00	2.34E-04	1.35E-14	1.18E-04	5.49E-05	8.33E-05	1.03E-04	1.95E-16	5.96E-05	8.39E-09	9.85E-12	9.69E-12	2.57E-05	2.15E-09
Pu-242	2.49E-04	9.01E-09	1.75E-24	3.87E-09	1.61E-08	1.02E-08	5.00E-09	3.05E-27	8.33E-10	8.66E-16	1.18E-20	1.40E-20	8.70E-09	7.81E-13
Pu-244	2.29E-10	1.72E-16	0.00E+00	6.13E-17	2.01E-14	3.22E-15	2.69E-16	0.00E+00	2.52E-18	1.66E-28	3.09E-37	5.32E-37	7.95E-14	3.03E-18
Am-241	1.44E-01	2.99E-05	1.73E-15	1.46E-05	5.80E-06	8.84E-06	1.15E-05	2.50E-17	7.66E-06	1.07E-09	1.26E-12	1.24E-12	2.35E-06	2.12E-10
Am-243	2.44E-03	2.76E-08	2.31E-29	1.04E-08	2.10E-07	7.75E-08	1.90E-08	4.83E-33	1.06E-09	9.06E-18	1.44E-24	2.06E-24	1.37E-07	1.20E-11
Cm-243	4.36E-04	2.57E-08	2.90E-29	1.00E-08	4.26E-08	2.89E-08	1.22E-08	6.09E-33	1.19E-09	1.14E-17	1.82E-24	2.60E-24	1.12E-08	1.34E-12
Cm-244	2.75E-01	5.93E-07	1.89E-33	1.97E-07	4.23E-05	5.67E-06	5.73E-07	0.00E+00	8.90E-09	5.92E-19	1.10E-27	1.89E-27	7.61E-05	4.74E-09
Cm-245	5.15E-05	6.31E-11	0.00E+00	1.92E-11	9.90E-09	9.93E-10	6.82E-11	0.00E+00	4.68E-13	2.95E-25	6.37E-36	1.32E-35	1.85E-08	1.18E-12
Cm-246	4.32E-05	1.02E-11	0.00E+00	2.68E-12	1.67E-08	5.36E-10	1.47E-11	0.00E+00	2.91E-14	1.43E-28	7.87E-42	7.65E-41	1.27E-07	4.98E-12
Cm-247	1.94E-10	1.18E-17	0.00E+00	2.75E-18	1.22E-13	1.72E-15	2.19E-17	0.00E+00	1.38E-20	5.48E-37	0.00E+00	0.00E+00	1.76E-12	5.82E-17
Cm-248	9.05E-10	1.29E-17	0.00E+00	2.62E-18	1.11E-12	5.50E-15	3.07E-17	0.00E+00	6.00E-21	1.91E-39	0.00E+00	0.00E+00	5.29E-11	1.18E-15
% of Total Reactor Activity	55.60%	2.03%	1.7E-06%	0.226%	0.607%	0.331%	0.166%	4.1E-07%	4.02%	0.10167%	4.1E-05%	0.00013%	1.09865%*	35.80920%

Appendix C

Component MicroShield Models

Appendix C

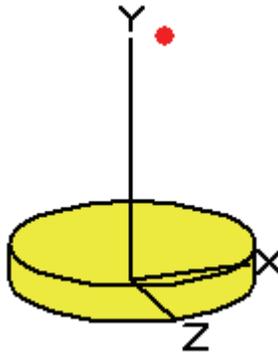
Component MicroShield Models

MicroShield v6.10 (0063)
INL

Page 1
DOS File Grid Plate.ms6
Run Date July 20, 2006
Run Time 12:45:34 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Grid Plate
Description: Dose Point at survey location
Geometry: 8 - Cylinder Volume - End Shields



		Source Dimensions:	
Height		24.13 cm	(9.5 in)
Radius		79.007 cm	(2 ft 7.1 in)
Dose Points			
A	X	Y	Z
# 1	22.7584 cm 9.0 in	162.56 cm 5 ft 4.0 in	0 cm 0.0 in
Shields			
Shield N	Dimension	Material	Density
Source	4.73e+05 cm ³	Iron	4.53
Air Gap		Air	0.00122

Source Input : Grouping Method - Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	5.0800e-007	1.8796e+004	1.0736e-006	3.9722e-002
Ag-108m	6.5100e-002	2.4087e+009	1.3758e-001	5.0904e+003
Ag-110m	1.2300e-011	4.5510e-001	2.5994e-011	9.6177e-007
Am-241	1.6500e-002	6.1050e+008	3.4870e-002	1.2902e+003
Am-243	1.5200e-005	5.6240e+005	3.2122e-005	1.1885e+000
Ba-137m	9.5546e-002	3.5352e+009	2.0192e-001	7.4710e+003
Be-10	8.5700e-007	3.1709e+004	1.8111e-006	6.7011e-002
C-14	4.7100e+000	1.7427e+011	9.9537e+000	3.6829e+005
Ce-144	3.7100e-011	1.3727e+000	7.8404e-011	2.9010e-006
Cl-36	4.8300e-002	1.7871e+009	1.0207e-001	3.7767e+003
Cm-243	1.4200e-005	5.2540e+005	3.0009e-005	1.1103e+000
Cm-244	3.2700e-004	1.2099e+007	6.9106e-004	2.5569e+001
Cm-245	3.4700e-008	1.2839e+003	7.3332e-008	2.7133e-003
Cm-246	5.5900e-009	2.0683e+002	1.1813e-008	4.3710e-004
Cm-247	6.5100e-015	2.4087e-004	1.3758e-014	5.0904e-010
Cm-248	7.1000e-015	2.6270e-004	1.5005e-014	5.5517e-010
Co-60	5.5000e+002	2.0350e+013	1.1623e+003	4.3006e+007
Cs-134	3.2700e-004	1.2099e+007	6.9106e-004	2.5569e+001
Cs-137	1.0100e-001	3.7370e+009	2.1345e-001	7.8975e+003
Eu-152	3.7400e-002	1.3838e+009	7.9038e-002	2.9244e+003
Eu-154	9.0300e-002	3.3411e+009	1.9083e-001	7.0608e+003

H-3	4.7500e+000	1.7575e+011	1.0038e+001	3.7142e+005
I-129	9.5000e-008	3.5150e+003	2.0077e-007	7.4283e-003
Mn-54	1.6300e-006	6.0310e+004	3.4447e-006	1.2745e-001
Nb-94	4.7500e+000	1.7575e+011	1.0038e+001	3.7142e+005
Ni-59	5.5500e+000	2.0535e+011	1.1729e+001	4.3397e+005
Ni-63	6.3500e+002	2.3495e+013	1.3420e+003	4.9652e+007
Np-237	1.7900e-007	6.6230e+003	3.7828e-007	1.3997e-002
Pa-231	7.3500e-007	2.7195e+004	1.5533e-006	5.7472e-002
Pb-210	1.6600e-011	6.1420e-001	3.5081e-011	1.2980e-006
Pr-144	3.6569e-011	1.3531e+000	7.7283e-011	2.8595e-006
Pu-238	4.3300e-003	1.6021e+008	9.1507e-003	3.3857e+002
Pu-239	2.7900e-003	1.0323e+008	5.8962e-003	2.1816e+002
Pu-240	2.6100e-003	9.6570e+007	5.5158e-003	2.0408e+002
Pu-241	1.2900e-001	4.7730e+009	2.7262e-001	1.0087e+004
Pu-242	4.9600e-006	1.8352e+005	1.0482e-005	3.8784e-001
Pu-244	9.4500e-014	3.4965e-003	1.9971e-013	7.3892e-009
Ra-226	4.0800e-011	1.5096e+000	8.6223e-011	3.1903e-006
Rh-106	3.8500e-009	1.4245e+002	8.1363e-009	3.0104e-004
Ru-106	3.8500e-009	1.4245e+002	8.1363e-009	3.0104e-004
Sb-125	2.8500e-003	1.0545e+008	6.0230e-003	2.2285e+002
Sr-90	4.8700e-002	1.8019e+009	1.0292e-001	3.8080e+003
Tc-99	3.2100e-003	1.1877e+008	6.7838e-003	2.5100e+002
Th-228	6.3500e-005	2.3495e+006	1.3420e-004	4.9652e+000
Th-229	6.0900e-007	2.2533e+004	1.2870e-006	4.7619e-002
Th-230	3.7900e-009	1.4023e+002	8.0095e-009	2.9635e-004
Th-232	1.0200e-007	3.7740e+003	2.1556e-007	7.9757e-003
U-232	6.1400e-005	2.2718e+006	1.2976e-004	4.8010e+000
U-233	1.6900e-004	6.2530e+006	3.5715e-004	1.3215e+001
U-234	7.1900e-006	2.6603e+005	1.5195e-005	5.6221e-001
U-235	1.0100e-008	3.7370e+002	2.1345e-008	7.8975e-004
U-236	9.4100e-008	3.4817e+003	1.9886e-007	7.3579e-003
U-238	6.0100e-007	2.2237e+004	1.2701e-006	4.6994e-002
Y-90	4.8700e-002	1.8019e+009	1.0292e-001	3.8080e+003
Zn-65	3.8400e-011	1.4208e+000	8.1151e-011	3.0026e-006

**Buildup : The material reference is - Source
Integration Parameters**

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm ² /sec		Exposure Rate mR/hr	
		No Buildup	With Buildup	No Buildup	With Buildup
0.015	7.151e+10	9.947e-35	2.911e-23	8.532e-36	2.497e-24
0.02	1.615e+09	1.547e-16	1.598e-16	5.358e-18	5.535e-18
0.03	2.710e+08	5.220e-06	5.601e-06	5.173e-08	5.551e-08
0.04	1.552e+09	3.383e-02	3.766e-02	1.496e-04	1.665e-04
0.05	3.775e+08	1.235e-01	1.430e-01	3.289e-04	3.808e-04
0.06	2.203e+08	2.634e-01	3.158e-01	5.232e-04	6.273e-04
0.08	1.711e+08	7.103e-01	9.039e-01	1.124e-03	1.430e-03
0.1	1.746e+09	1.474e+01	2.023e+01	2.255e-02	3.096e-02
0.15	2.764e+05	6.542e-03	1.058e-02	1.077e-05	1.743e-05
0.2	3.400e+08	1.416e+01	2.583e+01	2.500e-02	4.558e-02
0.3	3.747e+08	3.038e+01	6.101e+01	5.763e-02	1.157e-01
0.4	2.309e+09	2.884e+02	5.935e+02	5.619e-01	1.156e+00
0.5	2.613e+07	4.527e+00	9.280e+00	8.887e-03	1.822e-02
0.6	9.059e+09	2.047e+03	4.136e+03	3.995e+00	8.073e+00
0.8	3.552e+11	1.223e+05	2.389e+05	2.326e+02	4.544e+02

1.0	2.035e+13	9.741e+06	1.840e+07	1.796e+04	3.392e+04
1.5	2.035e+13	1.776e+07	3.126e+07	2.989e+04	5.259e+04
2.0	1.047e-02	1.384e-08	2.329e-08	2.140e-11	3.601e-11
Totals	4.115e+13	2.763e+07	4.990e+07	4.808e+04	8.698e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File Be reflector.ms6
Run Date July 20, 2006
Run Time 1:01:27 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Be reflector
Description: Dose Rate from closest wall
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	11.43 cm	(4.5 in)
Width	77.216 cm	(2 ft 6.4 in)
Height	52.07 cm	(1 ft 8.5 in)

Dose Points

A	X	Y	Z
# 1	33.2994 cm 1 ft 1.1 in	89.7636 cm 2 ft 11.3 in	23.0886 cm 9.1 in

Shields

Shield N	Dimension	Material	Density
Source	4.60e+04 cm ³	Aluminum	1.41
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	3.0160e-008	1.1159e+003	6.5628e-007	2.4282e-002
Ag-108m	8.3200e-003	3.0784e+008	1.8104e-001	6.6986e+003
Ag-110m	6.2000e-012	2.2940e-001	1.3491e-010	4.9917e-006
Am-241	3.7920e-002	1.4030e+009	8.2514e-001	3.0530e+004
Am-243	6.4400e-004	2.3828e+007	1.4013e-002	5.1850e+002
Ba-137m	5.6760e-001	2.1001e+010	1.2351e+001	4.5699e+005
Be-10	8.8800e-002	3.2856e+009	1.9323e+000	7.1495e+004
C-14	7.0800e-001	2.6196e+010	1.5406e+001	5.7002e+005
Ce-144	5.2400e-010	1.9388e+001	1.1402e-008	4.2188e-004
Cl-36	8.6400e-003	3.1968e+008	1.8801e-001	6.9562e+003
Cm-243	1.1520e-004	4.2624e+006	2.5068e-003	9.2750e+001
Cm-244	7.2800e-002	2.6936e+009	1.5841e+000	5.8613e+004
Cm-245	1.3600e-005	5.0320e+005	2.9594e-004	1.0950e+001
Cm-246	1.1400e-005	4.2180e+005	2.4806e-004	9.1784e+000
Cm-247	5.1200e-011	1.8944e+000	1.1141e-009	4.1222e-005
Cm-248	2.3920e-010	8.8504e+000	5.2050e-009	1.9258e-004
Co-60	2.6400e-001	9.7680e+009	5.7446e+000	2.1255e+005
Cs-134	5.5600e-004	2.0572e+007	1.2099e-002	4.4765e+002
Cs-137	6.0000e-001	2.2200e+010	1.3056e+001	4.8307e+005
Eu-152	3.6400e-003	1.3468e+008	7.9206e-002	2.9306e+003
Eu-154	2.1400e-001	7.9180e+009	4.6566e+000	1.7230e+005
H-3	7.8400e+003	2.9008e+014	1.7060e+005	6.3121e+009

I-129	9.7600e-007	3.6112e+004	2.1238e-005	7.8580e-001
Mn-54	2.1800e-009	8.0660e+001	4.7437e-008	1.7552e-003
Nb-94	1.9520e-003	7.2224e+007	4.2476e-002	1.5716e+003
Ni-59	6.4000e-003	2.3680e+008	1.3926e-001	5.1528e+003
Ni-63	9.2400e-001	3.4188e+010	2.0106e+001	7.4393e+005
Np-237	4.4800e-007	1.6576e+004	9.7485e-006	3.6069e-001
Pa-231	4.8000e-008	1.7760e+003	1.0445e-006	3.8646e-002
Pb-210	3.8200e-012	1.4134e-001	8.3123e-011	3.0756e-006
Pr-144	5.1651e-010	1.9111e+001	1.1239e-008	4.1585e-004
Pu-238	1.8520e-002	6.8524e+008	4.0300e-001	1.4911e+004
Pu-239	3.0120e-003	1.1144e+008	6.5541e-002	2.4250e+003
Pu-240	4.3200e-003	1.5984e+008	9.4003e-002	3.4781e+003
Pu-241	3.9000e-001	1.4430e+010	8.4864e+000	3.1400e+005
Pu-242	6.5600e-005	2.4272e+006	1.4275e-003	5.2816e+001
Pu-244	6.0400e-011	2.2348e+000	1.3143e-009	4.8629e-005
Ra-226	5.3600e-012	1.9832e-001	1.1663e-010	4.3154e-006
Rh-106	7.3200e-008	2.7084e+003	1.5928e-006	5.8935e-002
Ru-106	7.3200e-008	2.7084e+003	1.5928e-006	5.8935e-002
Sb-125	1.6400e-004	6.0680e+006	3.5686e-003	1.3204e+002
Sr-90	1.7920e-001	6.6304e+009	3.8994e+000	1.4428e+005
Tc-99	1.3120e-004	4.8544e+006	2.8549e-003	1.0563e+002
Th-228	1.5000e-005	5.5500e+005	3.2640e-004	1.2077e+001
Th-229	2.5120e-008	9.2944e+002	5.4661e-007	2.0225e-002
Th-230	7.8000e-010	2.8860e+001	1.6973e-008	6.2799e-004
Th-232	3.0920e-009	1.1440e+002	6.7282e-008	2.4894e-003
U-232	1.4600e-005	5.4020e+005	3.1770e-004	1.1755e+001
U-233	8.3200e-006	3.0784e+005	1.8104e-004	6.6986e+000
U-234	3.2720e-006	1.2106e+005	7.1199e-005	2.6344e+000
U-235	9.0800e-010	3.3596e+001	1.9758e-008	7.3105e-004
U-236	1.3120e-007	4.8544e+003	2.8549e-006	1.0563e-001
U-238	5.7200e-007	2.1164e+004	1.2447e-005	4.6053e-001
Y-90	1.7920e-001	6.6304e+009	3.8994e+000	1.4428e+005
Zn-65	1.0200e-011	3.7740e-001	2.2195e-010	8.2122e-006

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.932e+09	6.544e-01	6.868e-01	5.613e-02	5.891e-02
0.02	2.019e+08	6.123e-01	6.630e-01	2.121e-02	2.296e-02
0.03	1.275e+09	2.285e+01	2.749e+01	2.265e-01	2.724e-01
0.04	1.985e+09	9.439e+01	1.323e+02	4.174e-01	5.851e-01
0.05	4.294e+08	3.867e+01	6.398e+01	1.030e-01	1.704e-01
0.06	5.073e+08	7.079e+01	1.426e+02	1.406e-01	2.833e-01
0.08	3.763e+07	9.166e+00	2.223e+01	1.451e-02	3.519e-02
0.1	3.245e+09	1.128e+03	2.972e+03	1.726e+00	4.546e+00
0.15	1.252e+05	7.653e-02	2.050e-01	1.260e-04	3.376e-04
0.2	5.519e+08	4.917e+02	1.252e+03	8.678e-01	2.210e+00
0.3	3.708e+07	5.582e+01	1.278e+02	1.059e-01	2.424e-01
0.4	3.435e+08	7.507e+02	1.578e+03	1.463e+00	3.075e+00
0.5	1.883e+07	5.500e+01	1.079e+02	1.080e-01	2.118e-01
0.6	1.985e+10	7.351e+04	1.363e+05	1.435e+02	2.660e+02
0.8	3.554e+09	1.915e+04	3.268e+04	3.643e+01	6.215e+01
1.0	1.226e+10	8.835e+04	1.421e+05	1.629e+02	2.620e+02

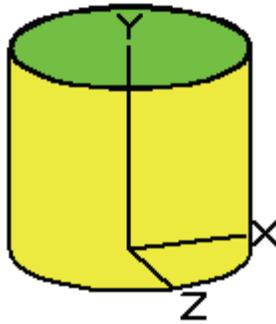
1.5	1.289e+10	1.570e+05	2.287e+05	2.641e+02	3.848e+02
2.0	1.479e-01	2.593e-06	3.572e-06	4.009e-09	5.523e-09
Totals	5.912e+10	3.407e+05	5.462e+05	6.121e+02	9.867e+02

MicroShield v6.10 (0063)
INL

Page 1
DOS File Internal Tank Upper Section.ms6
Run Date July 20, 2006
Run Time 1:47:23 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Internal Tank
Description: Upper section
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions:

Height	142.24 cm	(4 ft 8.0 in)
Inner Cyl Radius	78.994 cm	(2 ft 7.1 in)
Inner Cyl Thickness	0.0 cm	(0.0 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	22.7584 cm 9.0 in	37.592 cm 1 ft 2.8 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	78.994 cm	Air	0.00122
Source	9.04e+04 cm ³	Iron	7.86

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.5200e-007	5.6240e+003	1.6818e-006	6.2226e-002
Ag-108m	1.7000e-002	6.2900e+008	1.8809e-001	6.9594e+003
Ag-110m	3.7600e-012	1.3912e-001	4.1602e-011	1.5393e-006
Am-241	1.9000e-003	7.0300e+007	2.1022e-002	7.7782e+002
Am-243	2.6300e-007	9.7310e+003	2.9099e-006	1.0767e-001
Ba-137m	1.5893e-002	5.8803e+008	1.7584e-001	6.5062e+003
Be-10	2.9200e-007	1.0804e+004	3.2308e-006	1.1954e-001
C-14	1.5900e+000	5.8830e+010	1.7592e+001	6.5091e+005
Ce-144	6.7900e-012	2.5123e-001	7.5127e-011	2.7797e-006
Cl-36	1.2500e-002	4.6250e+008	1.3830e-001	5.1172e+003
Cm-243	2.9400e-007	1.0878e+004	3.2529e-006	1.2036e-001
Cm-244	2.2100e-006	8.1770e+004	2.4452e-005	9.0473e-001
Cm-245	1.1600e-010	4.2920e+000	1.2835e-009	4.7488e-005
Cm-246	7.2100e-012	2.6677e-001	7.9774e-011	2.9516e-006
Cm-247	3.4200e-018	1.2654e-007	3.7840e-017	1.4001e-012
Cm-248	1.4900e-018	5.5130e-008	1.6486e-017	6.0997e-013
Co-60	2.4800e+002	9.1760e+012	2.7439e+003	1.0153e+008
Cs-134	8.8000e-005	3.2560e+006	9.7366e-004	3.6025e+001
Cs-137	1.6800e-002	6.2160e+008	1.8588e-001	6.8776e+003
Eu-152	5.4200e-002	2.0054e+009	5.9968e-001	2.2188e+004
Eu-154	2.2100e-002	8.1770e+008	2.4452e-001	9.0473e+003
H-3	1.6000e+000	5.9200e+010	1.7703e+001	6.5501e+005

I-129	1.5200e-008	5.6240e+002	1.6818e-007	6.2226e-003
Mn-54	3.7800e-007	1.3986e+004	4.1823e-006	1.5475e-001
Nb-94	2.1400e-002	7.9180e+008	2.3678e-001	8.7607e+003
Ni-59	8.5100e+000	3.1487e+011	9.4157e+001	3.4838e+006
Ni-63	9.3100e+002	3.4447e+013	1.0301e+004	3.8113e+008
Np-237	2.5800e-008	9.5460e+002	2.8546e-007	1.0562e-002
Pa-231	2.1900e-007	8.1030e+003	2.4231e-006	8.9654e-002
Pb-210	2.9200e-012	1.0804e-001	3.2308e-011	1.1954e-006
Pr-144	6.6929e-012	2.4764e-001	7.4052e-011	2.7399e-006
Pu-238	2.0700e-004	7.6590e+006	2.2903e-003	8.4741e+001
Pu-239	1.2100e-003	4.4770e+007	1.3388e-002	4.9535e+002
Pu-240	6.0100e-004	2.2237e+007	6.6496e-003	2.4604e+002
Pu-241	1.4800e-002	5.4760e+008	1.6375e-001	6.0588e+003
Pu-242	2.0700e-007	7.6590e+003	2.2903e-006	8.4741e-002
Pu-244	6.2400e-016	2.3088e-005	6.9041e-015	2.5545e-010
Ra-226	7.7900e-012	2.8823e-001	8.6191e-011	3.1891e-006
Rh-106	6.3900e-010	2.3643e+001	7.0701e-009	2.6159e-004
Ru-106	6.3900e-010	2.3643e+001	7.0701e-009	2.6159e-004
Sb-125	7.3300e-004	2.7121e+007	8.1101e-003	3.0007e+002
Sr-90	8.9100e-003	3.2967e+008	9.8583e-002	3.6476e+003
Tc-99	8.2600e-004	3.0562e+007	9.1391e-003	3.3815e+002
Th-228	7.9800e-006	2.9526e+005	8.8293e-005	3.2668e+000
Th-229	2.0600e-007	7.6220e+003	2.2792e-006	8.4332e-002
Th-230	6.9800e-010	2.5826e+001	7.7229e-009	2.8575e-004
Th-232	6.3000e-008	2.3310e+003	6.9705e-007	2.5791e-002
U-232	7.7100e-006	2.8527e+005	8.5306e-005	3.1563e+000
U-233	5.7600e-005	2.1312e+006	6.3730e-004	2.3580e+001
U-234	1.2400e-006	4.5880e+004	1.3720e-005	5.0763e-001
U-235	1.1300e-008	4.1810e+002	1.2503e-007	4.6260e-003
U-236	3.2400e-008	1.1988e+003	3.5848e-007	1.3264e-002
U-238	3.7800e-007	1.3986e+004	4.1823e-006	1.5475e-001
Y-90	8.9100e-003	3.2967e+008	9.8583e-002	3.6476e+003
Zn-65	9.7700e-012	3.6149e-001	1.0810e-010	3.9996e-006

**Buildup : The material reference is - Source
Integration Parameters**

Radial	10
Circumferential	10
Y Direction (axial)	20

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	8.164e+05	1.445e-01	1.459e-01	1.239e-02	1.251e-02
0.02	4.127e+08	6.347e-02	6.478e-02	2.198e-03	2.244e-03
0.03	4.860e+07	1.466e-01	1.516e-01	1.453e-03	1.502e-03
0.04	1.362e+09	1.348e+01	1.417e+01	5.960e-02	6.269e-02
0.05	3.390e+08	7.896e+00	8.551e+00	2.103e-02	2.278e-02
0.06	2.537e+07	1.164e+00	1.310e+00	2.312e-03	2.603e-03
0.08	4.459e+07	5.594e+00	6.886e+00	8.852e-03	1.090e-02
0.1	9.012e+08	2.229e+02	2.967e+02	3.410e-01	4.539e-01
0.15	6.968e+04	4.320e-02	6.386e-02	7.113e-05	1.052e-04
0.2	2.082e+08	2.063e+02	3.134e+02	3.642e-01	5.531e-01
0.3	5.424e+08	9.300e+02	1.385e+03	1.764e+00	2.628e+00
0.4	7.057e+08	1.728e+03	2.481e+03	3.366e+00	4.834e+00
0.5	1.594e+07	5.101e+01	7.073e+01	1.001e-01	1.388e-01
0.6	2.759e+09	1.096e+04	1.474e+04	2.139e+01	2.877e+01
0.8	2.832e+09	1.575e+04	2.025e+04	2.996e+01	3.853e+01
1.0	9.177e+12	6.612e+07	8.240e+07	1.219e+05	1.519e+05

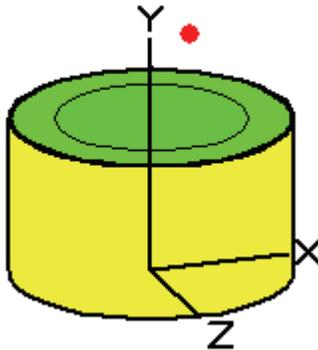
1.5	9.177e+12	1.051e+08	1.244e+08	1.768e+05	2.093e+05
2.0	1.917e-03	3.026e-08	3.487e-08	4.679e-11	5.393e-11
Totals	1.836e+13	1.713e+08	2.069e+08	2.988e+05	3.613e+05

MicroShield v6.10 (0063)
INL

Page 1
DOS File Internal Tank Lower Section.ms6
Run Date July 20, 2006
Run Time 1:45:12 PM
Duration 00:00:00

File Ref
Date
By
Checked

Case Title: Internal Tank
Description: Lower section
Geometry: 11 - Annular Cylinder - Internal Dose Point



Source Dimensions:

Height	91.44 cm	(3 ft)
Inner Cyl Radius	54.61 cm	(1 ft 9.5 in)
Inner Cyl Thickness	24.384 cm	(9.6 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	22.7584 cm 9.0 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	54.61 cm	Air	0.00122
Shield 1	24.384 cm	Aluminum	1.41
Source	5.81e+04 cm ³	Iron	7.86

Source Input : Grouping Method - Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	1.5200e-007	5.6240e+003	2.6161e-006	9.6795e-002
Ag-108m	1.7000e-002	6.2900e+008	2.9259e-001	1.0826e+004
Ag-110m	3.7600e-012	1.3912e-001	6.4714e-011	2.3944e-006
Am-241	1.9000e-003	7.0300e+007	3.2701e-002	1.2099e+003
Am-243	2.6300e-007	9.7310e+003	4.5265e-006	1.6748e-001
Ba-137m	1.5893e-002	5.8803e+008	2.7353e-001	1.0121e+004
Be-10	2.9200e-007	1.0804e+004	5.0256e-006	1.8595e-001
C-14	1.5900e+000	5.8830e+010	2.7366e+001	1.0125e+006
Ce-144	6.7900e-012	2.5123e-001	1.1686e-010	4.3239e-006
Cl-36	1.2500e-002	4.6250e+008	2.1514e-001	7.9601e+003
Cm-243	2.9400e-007	1.0878e+004	5.0601e-006	1.8722e-001
Cm-244	2.2100e-006	8.1770e+004	3.8037e-005	1.4074e+000
Cm-245	1.1600e-010	4.2920e+000	1.9965e-009	7.3870e-005
Cm-246	7.2100e-012	2.6677e-001	1.2409e-010	4.5914e-006
Cm-247	3.4200e-018	1.2654e-007	5.8862e-017	2.1779e-012
Cm-248	1.4900e-018	5.5130e-008	2.5645e-017	9.4885e-013
Co-60	2.4800e+002	9.1760e+012	4.2684e+003	1.5793e+008
Cs-134	8.8000e-005	3.2560e+006	1.5146e-003	5.6039e+001
Cs-137	1.6800e-002	6.2160e+008	2.8915e-001	1.0698e+004
Eu-152	5.4200e-002	2.0054e+009	9.3284e-001	3.4515e+004
Eu-154	2.2100e-002	8.1770e+008	3.8037e-001	1.4074e+004

H-3	1.6000e+000	5.9200e+010	2.7538e+001	1.0189e+006
I-129	1.5200e-008	5.6240e+002	2.6161e-007	9.6795e-003
Mn-54	3.7800e-007	1.3986e+004	6.5058e-006	2.4071e-001
Nb-94	2.1400e-002	7.9180e+008	3.6832e-001	1.3628e+004
Ni-59	8.5100e+000	3.1487e+011	1.4647e+002	5.4193e+006
Ni-63	9.3100e+002	3.4447e+013	1.6024e+004	5.9287e+008
Np-237	2.5800e-008	9.5460e+002	4.4405e-007	1.6430e-002
Pa-231	2.1900e-007	8.1030e+003	3.7692e-006	1.3946e-001
Pb-210	2.9200e-012	1.0804e-001	5.0256e-011	1.8595e-006
Pr-144	6.6929e-012	2.4764e-001	1.1519e-010	4.2621e-006
Pu-238	2.0700e-004	7.6590e+006	3.5627e-003	1.3182e+002
Pu-239	1.2100e-003	4.4770e+007	2.0825e-002	7.7054e+002
Pu-240	6.0100e-004	2.2237e+007	1.0344e-002	3.8272e+002
Pu-241	1.4800e-002	5.4760e+008	2.5472e-001	9.4248e+003
Pu-242	2.0700e-007	7.6590e+003	3.5627e-006	1.3182e-001
Pu-244	6.2400e-016	2.3088e-005	1.0740e-014	3.9737e-010
Ra-226	7.7900e-012	2.8823e-001	1.3407e-010	4.9608e-006
Rh-106	6.3900e-010	2.3643e+001	1.0998e-008	4.0692e-004
Ru-106	6.3900e-010	2.3643e+001	1.0998e-008	4.0692e-004
Sb-125	7.3300e-004	2.7121e+007	1.2616e-002	4.6678e+002
Sr-90	8.9100e-003	3.2967e+008	1.5335e-001	5.6740e+003
Tc-99	8.2600e-004	3.0562e+007	1.4216e-002	5.2601e+002
Th-228	7.9800e-006	2.9526e+005	1.3734e-004	5.0818e+000
Th-229	2.0600e-007	7.6220e+003	3.5455e-006	1.3118e-001
Th-230	6.9800e-010	2.5826e+001	1.2013e-008	4.4449e-004
Th-232	6.3000e-008	2.3310e+003	1.0843e-006	4.0119e-002
U-232	7.7100e-006	2.8527e+005	1.3270e-004	4.9098e+000
U-233	5.7600e-005	2.1312e+006	9.9136e-004	3.6680e+001
U-234	1.2400e-006	4.5880e+004	2.1342e-005	7.8965e-001
U-235	1.1300e-008	4.1810e+002	1.9449e-007	7.1960e-003
U-236	3.2400e-008	1.1988e+003	5.5764e-007	2.0633e-002
U-238	3.7800e-007	1.3986e+004	6.5058e-006	2.4071e-001
Y-90	8.9100e-003	3.2967e+008	1.5335e-001	5.6740e+003
Zn-65	9.7700e-012	3.6149e-001	1.6815e-010	6.2216e-006

**Buildup : The material reference is - Shield 1
Integration Parameters**

Radial	10
Circumferential	10
Y Direction (axial)	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	8.164e+05	1.193e-136	6.724e-28	1.023e-137	5.767e-29
0.02	4.127e+08	1.225e-58	5.389e-25	4.242e-60	1.867e-26
0.03	4.860e+07	7.807e-21	1.628e-20	7.737e-23	1.614e-22
0.04	1.362e+09	8.592e-10	3.073e-09	3.800e-12	1.359e-11
0.05	3.390e+08	9.557e-07	5.829e-06	2.546e-09	1.553e-08
0.06	2.537e+07	4.283e-06	4.062e-05	8.508e-09	8.068e-08
0.08	4.459e+07	3.574e-04	5.781e-03	5.655e-07	9.148e-06
0.1	9.012e+08	4.650e-02	1.019e+00	7.114e-05	1.558e-03
0.15	6.968e+04	3.206e-05	8.141e-04	5.280e-08	1.341e-06
0.2	2.082e+08	2.912e-01	6.758e+00	5.139e-04	1.193e-02
0.3	5.424e+08	2.883e+00	4.995e+01	5.469e-03	9.474e-02
0.4	7.057e+08	8.992e+00	1.195e+02	1.752e-02	2.328e-01
0.5	1.594e+07	3.905e-01	4.134e+00	7.666e-04	8.115e-03
0.6	2.759e+09	1.137e+02	9.994e+02	2.220e-01	1.951e+00
0.8	2.832e+09	2.587e+02	1.707e+03	4.922e-01	3.248e+00

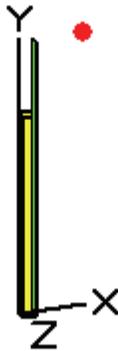
1.0	9.177e+12	1.522e+06	8.115e+06	2.805e+03	1.496e+04
1.5	9.177e+12	4.252e+06	1.595e+07	7.153e+03	2.683e+04
2.0	1.917e-03	1.722e-09	5.264e-09	2.663e-12	8.140e-12
Totals	1.836e+13	5.774e+06	2.407e+07	9.960e+03	4.180e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File K11 control rod.ms6
Run Date July 20, 2006
Run Time 4:02:31 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: M-11 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	33.147 cm 1 ft 1.1 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001

H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002
I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	9.791e-18	9.889e-18	8.398e-19	8.482e-19
0.02	5.341e+03	3.374e-14	3.476e-14	1.169e-15	1.204e-15
0.03	1.431e+03	1.089e-08	1.156e-08	1.080e-10	1.145e-10
0.04	5.418e+02	2.388e-07	2.618e-07	1.056e-09	1.158e-09
0.05	5.979e+01	1.691e-07	1.945e-07	4.505e-10	5.182e-10
0.06	1.387e+02	1.141e-06	1.377e-06	2.267e-09	2.734e-09
0.08	5.911e+02	1.710e-05	2.298e-05	2.706e-08	3.637e-08
0.1	4.661e+02	2.935e-05	4.412e-05	4.490e-08	6.750e-08
0.15	1.520e+00	2.851e-07	5.303e-07	4.695e-10	8.733e-10
0.2	1.140e+02	3.845e-05	8.048e-05	6.786e-08	1.420e-07
0.3	3.769e+00	2.534e-06	5.625e-06	4.807e-09	1.067e-08
0.4	7.471e+03	7.844e-03	1.715e-02	1.528e-05	3.342e-05
0.5	5.114e+01	7.506e-05	1.581e-04	1.473e-07	3.104e-07
0.6	2.897e+08	5.567e+02	1.126e+03	1.087e+00	2.198e+00
0.8	2.783e+04	8.145e-02	1.532e-01	1.549e-04	2.914e-04

1.0	1.776e+12	7.178e+06	1.273e+07	1.323e+04	2.347e+04
1.5	1.776e+12	1.276e+07	2.035e+07	2.147e+04	3.424e+04
2.0	3.839e-08	4.075e-13	6.117e-13	6.302e-16	9.460e-16
Totals	3.661e+12	1.994e+07	3.308e+07	3.471e+04	5.771e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File J5 control rod.ms6
Run Date July 20, 2006
Run Time 3:59:02 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: J-5 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	27.2034 cm 10.7 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	2.327e-21	2.539e-21	1.996e-22	2.178e-22
0.02	5.341e+03	8.187e-16	8.431e-16	2.836e-17	2.920e-17
0.03	1.431e+03	3.230e-09	3.427e-09	3.201e-11	3.397e-11
0.04	5.418e+02	1.492e-07	1.646e-07	6.599e-10	7.278e-10
0.05	5.979e+01	1.339e-07	1.549e-07	3.568e-10	4.126e-10
0.06	1.387e+02	9.633e-07	1.169e-06	1.913e-09	2.322e-09
0.08	5.911e+02	1.488e-05	2.015e-05	2.354e-08	3.189e-08
0.1	4.661e+02	2.580e-05	3.923e-05	3.947e-08	6.002e-08
0.15	1.520e+00	2.533e-07	4.800e-07	4.172e-10	7.904e-10
0.2	1.140e+02	3.441e-05	7.388e-05	6.073e-08	1.304e-07
0.3	3.769e+00	2.293e-06	5.265e-06	4.350e-09	9.988e-09
0.4	7.471e+03	7.160e-03	1.626e-02	1.395e-05	3.167e-05
0.5	5.114e+01	6.898e-05	1.512e-04	1.354e-07	2.968e-07
0.6	2.897e+08	5.146e+02	1.084e+03	1.004e+00	2.115e+00
0.8	2.783e+04	7.602e-02	1.489e-01	1.446e-04	2.832e-04
1.0	1.776e+12	6.752e+06	1.246e+07	1.245e+04	2.297e+04

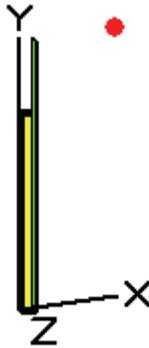
1.5	1.776e+12	1.218e+07	2.016e+07	2.050e+04	3.391e+04
2.0	3.839e-08	3.929e-13	6.104e-13	6.075e-16	9.439e-16
Totals	3.661e+12	1.894e+07	3.262e+07	3.295e+04	5.688e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File E9 control rod.ms6
Run Date July 24, 2006
Run Time 6:41:15 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: E-9 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	5.00e+01 cm 1 ft 7.7 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.33

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	2.023e-13	2.043e-13	1.735e-14	1.752e-14
0.02	5.341e+03	2.817e-12	2.901e-12	9.759e-14	1.005e-13
0.03	1.431e+03	4.646e-08	4.890e-08	4.604e-10	4.846e-10
0.04	5.418e+02	4.265e-07	4.641e-07	1.886e-09	2.053e-09
0.05	5.979e+01	2.133e-07	2.428e-07	5.682e-10	6.468e-10
0.06	1.387e+02	1.295e-06	1.546e-06	2.571e-09	3.071e-09
0.08	5.911e+02	1.860e-05	2.476e-05	2.943e-08	3.918e-08
0.1	4.661e+02	3.160e-05	4.693e-05	4.835e-08	7.180e-08
0.15	1.520e+00	3.042e-07	5.526e-07	5.010e-10	9.100e-10
0.2	1.140e+02	4.061e-05	8.196e-05	7.168e-08	1.447e-07
0.3	3.769e+00	2.629e-06	5.531e-06	4.987e-09	1.049e-08
0.4	7.471e+03	8.026e-03	1.648e-02	1.564e-05	3.211e-05
0.5	5.114e+01	7.594e-05	1.496e-04	1.491e-07	2.936e-07
0.6	2.897e+08	5.578e+02	1.052e+03	1.089e+00	2.054e+00
0.8	2.783e+04	8.031e-02	1.408e-01	1.528e-04	2.679e-04
1.0	1.776e+12	6.986e+06	1.156e+07	1.288e+04	2.132e+04

1.5	1.776e+12	1.212e+07	1.815e+07	2.040e+04	3.053e+04
2.0	3.839e-08	3.809e-13	5.392e-13	5.890e-16	8.338e-16
Totals	3.661e+12	1.911e+07	2.971e+07	3.327e+04	5.185e+04

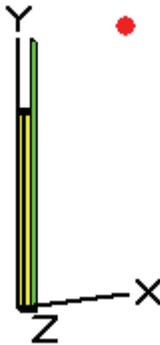
MicroShield v6.10 (0063)

INL

Page 1
DOS File E11 control rod.ms6
Run Date July 24, 2006
Run Time 6:44:48 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: E-11 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	5.52e+01 cm 1 ft 9.7 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.33

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	8.350e-13	8.433e-13	7.162e-14	7.234e-14
0.02	5.341e+03	5.270e-12	5.422e-12	1.825e-13	1.878e-13
0.03	1.431e+03	5.644e-08	5.937e-08	5.594e-10	5.884e-10
0.04	5.418e+02	4.593e-07	4.993e-07	2.031e-09	2.208e-09
0.05	5.979e+01	2.185e-07	2.482e-07	5.820e-10	6.612e-10
0.06	1.387e+02	1.302e-06	1.552e-06	2.586e-09	3.082e-09
0.08	5.911e+02	1.854e-05	2.461e-05	2.933e-08	3.895e-08
0.1	4.661e+02	3.140e-05	4.646e-05	4.805e-08	7.108e-08
0.15	1.520e+00	3.011e-07	5.431e-07	4.958e-10	8.943e-10
0.2	1.140e+02	4.005e-05	7.999e-05	7.069e-08	1.412e-07
0.3	3.769e+00	2.579e-06	5.350e-06	4.893e-09	1.015e-08
0.4	7.471e+03	7.846e-03	1.585e-02	1.529e-05	3.089e-05
0.5	5.114e+01	7.402e-05	1.434e-04	1.453e-07	2.815e-07
0.6	2.897e+08	5.425e+02	1.007e+03	1.059e+00	1.965e+00
0.8	2.783e+04	7.781e-02	1.342e-01	1.480e-04	2.553e-04
1.0	1.776e+12	6.749e+06	1.100e+07	1.244e+04	2.027e+04

1.5	1.776e+12	1.165e+07	1.720e+07	1.960e+04	2.893e+04
2.0	3.839e-08	3.648e-13	5.099e-13	5.641e-16	7.885e-16
Totals	3.661e+12	1.840e+07	2.819e+07	3.204e+04	4.920e+04

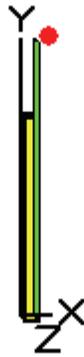
MicroShield v6.10 (0063)

INL

Page 1
DOS File K9 control rod.ms6
Run Date July 20, 2006
Run Time 3:46:23 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: K-9 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	13.97 cm 5.5 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	2.714e-38	2.160e-22	2.328e-39	1.853e-23
0.02	5.341e+03	4.500e-23	4.688e-23	1.559e-24	1.624e-24
0.03	1.431e+03	2.658e-11	2.849e-11	2.635e-13	2.824e-13
0.04	5.418e+02	1.742e-08	1.957e-08	7.705e-11	8.655e-11
0.05	5.979e+01	3.390e-08	3.991e-08	9.030e-11	1.063e-10
0.06	1.387e+02	3.232e-07	4.023e-07	6.420e-10	7.990e-10
0.08	5.911e+02	6.061e-06	8.561e-06	9.592e-09	1.355e-08
0.1	4.661e+02	1.130e-05	1.824e-05	1.728e-08	2.791e-08
0.15	1.520e+00	1.191e-07	2.483e-07	1.961e-10	4.090e-10
0.2	1.140e+02	1.679e-05	4.075e-05	2.964e-08	7.191e-08
0.3	3.769e+00	1.179e-06	3.131e-06	2.236e-09	5.940e-09
0.4	7.471e+03	3.821e-03	1.012e-02	7.446e-06	1.973e-05
0.5	5.114e+01	3.792e-05	9.719e-05	7.444e-08	1.908e-07
0.6	2.897e+08	2.899e+02	7.133e+02	5.659e-01	1.392e+00
0.8	2.783e+04	4.455e-02	1.015e-01	8.473e-05	1.931e-04
1.0	1.776e+12	4.083e+06	8.720e+06	7.525e+03	1.607e+04

1.5	1.776e+12	7.807e+06	1.479e+07	1.314e+04	2.489e+04
2.0	3.839e-08	2.619e-13	4.623e-13	4.050e-16	7.149e-16
Totals	3.661e+12	1.189e+07	2.351e+07	2.066e+04	4.096e+04

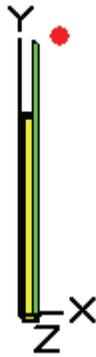
MicroShield v6.10 (0063)

INL

Page 1
DOS File M9 control rod.ms6
Run Date July 20, 2006
Run Time 3:52:00 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: M-9 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	20.066 cm 7.9 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	1.786e-30	2.056e-22	1.532e-31	1.764e-23
0.02	5.341e+03	7.483e-20	7.705e-20	2.592e-21	2.669e-21
0.03	1.431e+03	2.419e-10	2.593e-10	2.397e-12	2.570e-12
0.04	5.418e+02	5.811e-08	6.475e-08	2.570e-10	2.864e-10
0.05	5.979e+01	7.962e-08	9.280e-08	2.121e-10	2.472e-10
0.06	1.387e+02	6.490e-07	7.962e-07	1.289e-09	1.581e-09
0.08	5.911e+02	1.078e-05	1.485e-05	1.706e-08	2.349e-08
0.1	4.661e+02	1.918e-05	2.984e-05	2.934e-08	4.565e-08
0.15	1.520e+00	1.928e-07	3.786e-07	3.175e-10	6.235e-10
0.2	1.140e+02	2.652e-05	5.964e-05	4.681e-08	1.053e-07
0.3	3.769e+00	1.802e-06	4.383e-06	3.418e-09	8.314e-09
0.4	7.471e+03	5.708e-03	1.380e-02	1.112e-05	2.689e-05
0.5	5.114e+01	5.564e-05	1.301e-04	1.092e-07	2.554e-07
0.6	2.897e+08	4.192e+02	9.422e+02	8.182e-01	1.839e+00
0.8	2.783e+04	6.292e-02	1.315e-01	1.197e-04	2.502e-04
1.0	1.776e+12	5.662e+06	1.114e+07	1.044e+04	2.053e+04

1.5	1.776e+12	1.047e+07	1.839e+07	1.762e+04	3.095e+04
2.0	3.839e-08	3.433e-13	5.645e-13	5.309e-16	8.730e-16
Totals	3.661e+12	1.613e+07	2.953e+07	2.805e+04	5.147e+04

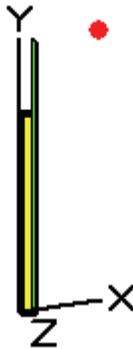
MicroShield v6.10 (0063)

INL

Page 1
DOS File G9 control rod.ms6
Run Date July 24, 2006
Run Time 6:49:41 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: G-9 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	41.46169 cm 1 ft 4.3 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.14

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	5.666e-15	5.723e-15	4.860e-16	4.909e-16
0.02	5.341e+03	5.752e-13	5.931e-13	1.993e-14	2.054e-14
0.03	1.431e+03	2.780e-08	2.934e-08	2.755e-10	2.908e-10
0.04	5.418e+02	3.471e-07	3.787e-07	1.535e-09	1.675e-09
0.05	5.979e+01	1.980e-07	2.265e-07	5.276e-10	6.033e-10
0.06	1.387e+02	1.256e-06	1.507e-06	2.495e-09	2.993e-09
0.08	5.911e+02	1.836e-05	2.454e-05	2.906e-08	3.884e-08
0.1	4.661e+02	3.131e-05	4.675e-05	4.790e-08	7.152e-08
0.15	1.520e+00	3.027e-07	5.558e-07	4.985e-10	9.153e-10
0.2	1.140e+02	4.062e-05	8.337e-05	7.170e-08	1.471e-07
0.3	3.769e+00	2.652e-06	5.719e-06	5.031e-09	1.085e-08
0.4	7.471e+03	8.148e-03	1.721e-02	1.588e-05	3.353e-05
0.5	5.114e+01	7.748e-05	1.572e-04	1.521e-07	3.087e-07
0.6	2.897e+08	5.716e+02	1.112e+03	1.116e+00	2.171e+00
0.8	2.783e+04	8.287e-02	1.499e-01	1.576e-04	2.851e-04
1.0	1.776e+12	7.250e+06	1.237e+07	1.336e+04	2.279e+04

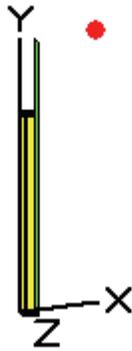
1.5	1.776e+12	1.271e+07	1.955e+07	2.139e+04	3.290e+04
2.0	3.839e-08	4.022e-13	5.837e-13	6.219e-16	9.026e-16
Totals	3.661e+12	1.996e+07	3.192e+07	3.475e+04	5.569e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File I11 control rod.ms6
Run Date July 20, 2006
Run Time 4:23:48 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: I-11 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	38.1 cm 1 ft 3.0 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.2

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	6.993e-16	7.063e-16	5.998e-17	6.058e-17
0.02	5.341e+03	2.264e-13	2.334e-13	7.843e-15	8.086e-15
0.03	1.431e+03	2.044e-08	2.162e-08	2.026e-10	2.143e-10
0.04	5.418e+02	3.043e-07	3.326e-07	1.346e-09	1.471e-09
0.05	5.979e+01	1.853e-07	2.123e-07	4.936e-10	5.657e-10
0.06	1.387e+02	1.198e-06	1.441e-06	2.380e-09	2.862e-09
0.08	5.911e+02	1.771e-05	2.375e-05	2.802e-08	3.759e-08
0.1	4.661e+02	3.033e-05	4.553e-05	4.640e-08	6.966e-08
0.15	1.520e+00	2.948e-07	5.461e-07	4.855e-10	8.993e-10
0.2	1.140e+02	3.971e-05	8.248e-05	7.009e-08	1.456e-07
0.3	3.769e+00	2.607e-06	5.711e-06	4.945e-09	1.083e-08
0.4	7.471e+03	8.042e-03	1.728e-02	1.567e-05	3.367e-05
0.5	5.114e+01	7.670e-05	1.585e-04	1.506e-07	3.110e-07
0.6	2.897e+08	5.673e+02	1.124e+03	1.107e+00	2.193e+00
0.8	2.783e+04	8.259e-02	1.520e-01	1.571e-04	2.891e-04
1.0	1.776e+12	7.249e+06	1.257e+07	1.336e+04	2.317e+04

1.5	1.776e+12	1.279e+07	1.996e+07	2.151e+04	3.358e+04
2.0	3.839e-08	4.060e-13	5.973e-13	6.279e-16	9.237e-16
Totals	3.661e+12	2.003e+07	3.253e+07	3.487e+04	5.676e+04

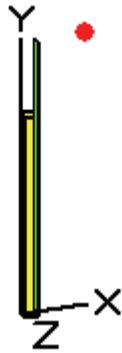
MicroShield v6.10 (0063)

INL

Page 1
DOS File M11 control rod.ms6
Run Date July 20, 2006
Run Time 4:02:31 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: M-11 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	33.147 cm 1 ft 1.1 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	9.791e-18	9.889e-18	8.398e-19	8.482e-19
0.02	5.341e+03	3.374e-14	3.476e-14	1.169e-15	1.204e-15
0.03	1.431e+03	1.089e-08	1.156e-08	1.080e-10	1.145e-10
0.04	5.418e+02	2.388e-07	2.618e-07	1.056e-09	1.158e-09
0.05	5.979e+01	1.691e-07	1.945e-07	4.505e-10	5.182e-10
0.06	1.387e+02	1.141e-06	1.377e-06	2.267e-09	2.734e-09
0.08	5.911e+02	1.710e-05	2.298e-05	2.706e-08	3.637e-08
0.1	4.661e+02	2.935e-05	4.412e-05	4.490e-08	6.750e-08
0.15	1.520e+00	2.851e-07	5.303e-07	4.695e-10	8.733e-10
0.2	1.140e+02	3.845e-05	8.048e-05	6.786e-08	1.420e-07
0.3	3.769e+00	2.534e-06	5.625e-06	4.807e-09	1.067e-08
0.4	7.471e+03	7.844e-03	1.715e-02	1.528e-05	3.342e-05
0.5	5.114e+01	7.506e-05	1.581e-04	1.473e-07	3.104e-07
0.6	2.897e+08	5.567e+02	1.126e+03	1.087e+00	2.198e+00
0.8	2.783e+04	8.145e-02	1.532e-01	1.549e-04	2.914e-04
1.0	1.776e+12	7.178e+06	1.273e+07	1.323e+04	2.347e+04

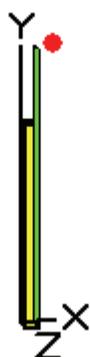
1.5	1.776e+12	1.276e+07	2.035e+07	2.147e+04	3.424e+04
2.0	3.839e-08	4.075e-13	6.117e-13	6.302e-16	9.460e-16
Totals	3.661e+12	1.994e+07	3.308e+07	3.471e+04	5.771e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File J7 control rod.ms6
Run Date July 20, 2006
Run Time 3:55:20 PM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: Control Rods
Description: J-7 position
Geometry: 13 - Rectangular Volume



Source Dimensions:

Length	6.35 cm	(2.5 in)
Width	6.35 cm	(2.5 in)
Height	101.6 cm	(3 ft 4.0 in)

Dose Points

A	X	Y	Z
# 1	15.9512 cm 6.3 in	138.43 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Source	4096.766 cm ³	Iron	2.5
Shield 1	.635 cm	Aluminum	2.7
Air Gap		Air	0.00122
Immersion		Air	0.00122

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	3.8500e-013	1.4245e-002	9.3977e-011	3.4771e-006
Ag-108m	2.2000e-007	8.1400e+003	5.3701e-005	1.9869e+000
Ag-110m	3.2600e-018	1.2062e-007	7.9575e-016	2.9443e-011
Am-241	1.0200e-008	3.7740e+002	2.4898e-006	9.2121e-002
Am-243	5.7400e-010	2.1238e+001	1.4011e-007	5.1841e-003
Ba-137m	5.5625e-007	2.0581e+004	1.3578e-004	5.0238e+000
Be-10	1.0400e-007	3.8480e+003	2.5386e-005	9.3928e-001
C-14	3.3300e-005	1.2321e+006	8.1284e-003	3.0075e+002
Ce-144	1.3600e-016	5.0320e-006	3.3197e-014	1.2283e-009
Cl-36	1.1200e-006	4.1440e+004	2.7339e-004	1.0115e+001
Cm-243	6.4400e-011	2.3828e+000	1.5720e-008	5.8163e-004
Cm-244	2.2700e-007	8.3990e+003	5.5410e-005	2.0502e+000
Cm-245	5.6700e-011	2.0979e+000	1.3840e-008	5.1209e-004
Cm-246	2.3900e-010	8.8430e+000	5.8339e-008	2.1585e-003
Cm-247	2.7900e-015	1.0323e-004	6.8102e-013	2.5198e-008
Cm-248	5.6400e-014	2.0868e-003	1.3767e-011	5.0938e-007
Co-60	4.8000e+001	1.7760e+012	1.1717e+004	4.3351e+008
Cs-134	6.9300e-010	2.5641e+001	1.6916e-007	6.2588e-003
Cs-137	5.8800e-007	2.1756e+004	1.4353e-004	5.3105e+000
Eu-152	1.4600e-010	5.4020e+000	3.5638e-008	1.3186e-003
Eu-154	3.0800e-008	1.1396e+003	7.5181e-006	2.7817e-001
H-3	1.1600e-005	4.2920e+005	2.8315e-003	1.0477e+002

I-129	5.0800e-013	1.8796e-002	1.2400e-010	4.5880e-006
Mn-54	5.0400e-010	1.8648e+001	1.2302e-007	4.5519e-003
Nb-94	2.7000e-007	9.9900e+003	6.5906e-005	2.4385e+000
Ni-59	8.5800e+000	3.1746e+011	2.0943e+003	7.7490e+007
Ni-63	1.7100e+003	6.3270e+013	4.1740e+005	1.5444e+010
Np-237	2.0700e-013	7.6590e-003	5.0528e-011	1.8695e-006
Pa-231	5.8500e-013	2.1645e-002	1.4280e-010	5.2834e-006
Pb-210	3.1500e-016	1.1655e-005	7.6890e-014	2.8449e-009
Pr-144	1.3406e-016	4.9600e-006	3.2722e-014	1.2107e-009
Pu-238	7.2500e-009	2.6825e+002	1.7697e-006	6.5478e-002
Pu-239	6.9000e-010	2.5530e+001	1.6843e-007	6.2317e-003
Pu-240	2.2000e-009	8.1400e+001	5.3701e-007	1.9869e-002
Pu-241	1.0300e-007	3.8110e+003	2.5142e-005	9.3025e-001
Pu-242	3.7500e-011	1.3875e+000	9.1536e-009	3.3868e-004
Pu-244	1.4500e-016	5.3650e-006	3.5394e-014	1.3096e-009
Ra-226	1.6800e-016	6.2160e-006	4.1008e-014	1.5173e-009
Rh-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Ru-106	1.3900e-014	5.1430e-004	3.3929e-012	1.2554e-007
Sb-125	1.2600e-008	4.6620e+002	3.0756e-006	1.1380e-001
Sr-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Tc-99	8.8900e-009	3.2893e+002	2.1700e-006	8.0290e-002
Th-228	4.2400e-010	1.5688e+001	1.0350e-007	3.8294e-003
Th-229	3.2500e-013	1.2025e-002	7.9331e-011	2.9352e-006
Th-230	1.4700e-014	5.4390e-004	3.5882e-012	1.3276e-007
Th-232	3.0500e-014	1.1285e-003	7.4449e-012	2.7546e-007
U-232	4.1300e-010	1.5281e+001	1.0081e-007	3.7300e-003
U-233	8.3000e-011	3.0710e+000	2.0260e-008	7.4962e-004
U-234	2.4000e-011	8.8800e-001	5.8583e-009	2.1676e-004
U-235	2.0700e-015	7.6590e-005	5.0528e-013	1.8695e-008
U-236	8.1200e-014	3.0044e-003	1.9821e-011	7.3336e-007
U-238	1.3000e-013	4.8100e-003	3.1732e-011	1.1741e-006
Y-90	2.7200e-007	1.0064e+004	6.6394e-005	2.4566e+000
Zn-65	2.6800e-012	9.9160e-002	6.5417e-010	2.4204e-005

**Buildup : The material reference is - Source
Integration Parameters**

X Direction	10
Y Direction	20
Z Direction	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.088e+11	8.315e-37	2.130e-22	7.132e-38	1.827e-23
0.02	5.341e+03	2.246e-22	2.332e-22	7.781e-24	8.077e-24
0.03	1.431e+03	5.250e-11	5.630e-11	5.203e-13	5.579e-13
0.04	5.418e+02	2.696e-08	3.021e-08	1.192e-10	1.336e-10
0.05	5.979e+01	4.744e-08	5.566e-08	1.264e-10	1.483e-10
0.06	1.387e+02	4.290e-07	5.310e-07	8.521e-10	1.055e-09
0.08	5.911e+02	7.664e-06	1.072e-05	1.213e-08	1.696e-08
0.1	4.661e+02	1.401e-05	2.231e-05	2.144e-08	3.412e-08
0.15	1.520e+00	1.450e-07	2.952e-07	2.387e-10	4.861e-10
0.2	1.140e+02	2.024e-05	4.764e-05	3.572e-08	8.408e-08
0.3	3.769e+00	1.402e-06	3.595e-06	2.660e-09	6.820e-09
0.4	7.471e+03	4.502e-03	1.150e-02	8.773e-06	2.241e-05
0.5	5.114e+01	4.436e-05	1.097e-04	8.707e-08	2.152e-07
0.6	2.897e+08	3.371e+02	8.006e+02	6.580e-01	1.563e+00
0.8	2.783e+04	5.132e-02	1.131e-01	9.761e-05	2.151e-04
1.0	1.776e+12	4.669e+06	9.662e+06	8.607e+03	1.781e+04

1.5	1.776e+12	8.814e+06	1.623e+07	1.483e+04	2.731e+04
2.0	3.839e-08	2.930e-13	5.038e-13	4.532e-16	7.790e-16
Totals	3.661e+12	1.348e+07	2.589e+07	2.344e+04	4.512e+04

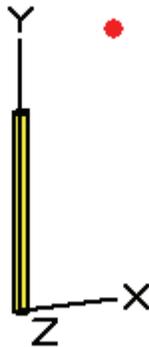
MicroShield v6.10 (0063)

INL

Page 1
DOS File F10 IPT.ms6
Run Date July 24, 2006
Run Time 7:22:57 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: F-10 In-pile Tube
Description: Dose rate at measurement point
Geometry: 12 - Annular Cylinder - External Dose Point



Source Dimensions:

Height	101.6 cm	(3 ft 4.0 in)
Inner Cyl Radius	3.136 cm	(1.2 in)
Inner Cyl Thickness	0.0 cm	(0.0 in)
Outer Cyl Thickness	0.0 cm	(0.0 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	47.7774 cm 1 ft 6.8 in	138.3538 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	3.136 cm	Air	0.00122
Source	1116.975 cm ³	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Air	0.26

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm ³	Bq/cm ³
Ac-227	1.5550e-008	5.7536e+002	1.3922e-005	5.1510e-001
Ag-108m	5.0563e-003	1.8708e+008	4.5267e+000	1.6749e+005
Ag-110m	3.1883e-013	1.1797e-002	2.8544e-010	1.0561e-005
Am-241	4.6064e-004	1.7044e+007	4.1240e-001	1.5259e+004
Am-243	1.6626e-005	6.1516e+005	1.4885e-002	5.5074e+002
Ba-137m	1.2583e-002	4.6555e+008	1.1265e+001	4.1680e+005
Be-10	8.2152e-008	3.0396e+003	7.3549e-005	2.7213e+000
C-14	5.3008e-001	1.9613e+010	4.7456e+002	1.7559e+007
Ce-144	4.2739e-012	1.5813e-001	3.8263e-009	1.4157e-004
Cl-36	3.8240e-003	1.4149e+008	3.4235e+000	1.2667e+005
Cm-243	3.3741e-006	1.2484e+005	3.0207e-003	1.1177e+002
Cm-244	3.3545e-003	1.2412e+008	3.0032e+000	1.1112e+005
Cm-245	7.8533e-007	2.9057e+004	7.0309e-004	2.6014e+001
Cm-246	1.3301e-006	4.9213e+004	1.1908e-003	4.4059e+001
Cm-247	9.7018e-012	3.5897e-001	8.6857e-009	3.2137e-004
Cm-248	8.7922e-011	3.2531e+000	7.8715e-008	2.9124e-003
Co-60	7.9316e+001	2.9347e+012	7.1009e+004	2.6273e+009
Cs-134	2.4352e-005	9.0103e+005	2.1802e-002	8.0667e+002
Cs-137	1.3301e-002	4.9213e+008	1.1908e+001	4.4059e+005

Eu-152	6.6211e-006	2.4498e+005	5.9277e-003	2.1932e+002
Eu-154	2.0440e-003	7.5629e+007	1.8300e+000	6.7709e+004
H-3	1.0954e-001	4.0528e+009	9.8065e+001	3.6284e+006
I-129	1.1638e-008	4.3061e+002	1.0419e-005	3.8552e-001
Mn-54	1.6039e-007	5.9345e+003	1.4359e-004	5.3130e+000
Nb-94	6.2103e-003	2.2978e+008	5.5599e+000	2.0572e+005
Ni-59	1.7017e+000	6.2964e+010	1.5235e+003	5.6370e+007
Ni-63	2.6993e+002	9.9873e+012	2.4166e+005	8.9414e+009
Np-237	6.9438e-009	2.5692e+002	6.2166e-006	2.3001e-001
Pa-231	2.3472e-008	8.6846e+002	2.1014e-005	7.7751e-001
Pb-210	4.4401e-012	1.6428e-001	3.9751e-009	1.4708e-004
Pr-144	4.2127e-012	1.5587e-001	3.7716e-009	1.3955e-004
Pu-238	3.4132e-004	1.2629e+007	3.0558e-001	1.1306e+004
Pu-239	3.4328e-005	1.2701e+006	3.0733e-002	1.1371e+003
Pu-240	6.4548e-005	2.3883e+006	5.7788e-002	2.1382e+003
Pu-241	4.3521e-003	1.6103e+008	3.8963e+000	1.4416e+005
Pu-242	1.2714e-006	4.7042e+004	1.1383e-003	4.2115e+001
Pu-244	1.5941e-012	5.8983e-002	1.4272e-009	5.2806e-005
Ra-226	3.8338e-012	1.4185e-001	3.4323e-009	1.2699e-004
Rh-106	4.5184e-010	1.6718e+001	4.0452e-007	1.4967e-002
Ru-106	4.5184e-010	1.6718e+001	4.0452e-007	1.4967e-002
Sb-125	3.2078e-004	1.1869e+007	2.8719e-001	1.0626e+004
Sr-90	6.0832e-003	2.2508e+008	5.4461e+000	2.0151e+005
Tc-99	2.2005e-004	8.1419e+006	1.9701e-001	7.2892e+003
Th-228	1.1247e-005	4.1614e+005	1.0069e-002	3.7256e+002
Th-229	1.2323e-008	4.5594e+002	1.1032e-005	4.0819e-001
Th-230	3.7457e-010	1.3859e+001	3.3535e-007	1.2408e-002
Th-232	1.3007e-009	4.8127e+001	1.1645e-006	4.3087e-002
U-232	1.0954e-005	4.0528e+005	9.8065e-003	3.6284e+002
U-233	3.4523e-006	1.2774e+005	3.0908e-003	1.1436e+002
U-234	7.5991e-007	2.8117e+004	6.8032e-004	2.5172e+001
U-235	5.9560e-011	2.2037e+000	5.3323e-008	1.9729e-003
U-236	2.2005e-009	8.1419e+001	1.9701e-006	7.2892e-002
U-238	6.4939e-009	2.4028e+002	5.8138e-006	2.1511e-001
Y-90	6.0832e-003	2.2508e+008	5.4461e+000	2.0151e+005
Zn-65	6.5330e-012	2.4172e-001	5.8489e-009	2.1641e-004

**Buildup : The material reference is - Source
Integration Parameters**

Radial	10
Circumferential	20
Y Direction (axial)	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.369e+05	1.224e-06	1.237e-06	1.050e-07	1.061e-07
0.02	1.228e+08	1.604e-02	1.627e-02	5.555e-04	5.636e-04
0.03	3.319e+07	4.935e-02	5.086e-02	4.891e-04	5.041e-04
0.04	2.254e+07	1.103e-01	1.159e-01	4.877e-04	5.126e-04
0.05	3.948e+06	4.562e-02	4.943e-02	1.215e-04	1.317e-04
0.06	6.192e+06	1.410e-01	1.589e-01	2.800e-04	3.156e-04
0.08	1.367e+07	8.575e-01	1.058e+00	1.357e-03	1.673e-03
0.1	3.078e+07	3.911e+00	5.278e+00	5.984e-03	8.074e-03
0.15	3.599e+04	1.252e-02	1.967e-02	2.062e-05	3.239e-05
0.2	6.102e+06	3.587e+00	6.026e+00	6.330e-03	1.064e-02
0.3	1.346e+05	1.448e-01	2.474e-01	2.746e-04	4.693e-04
0.4	1.724e+08	2.732e+02	4.556e+02	5.323e-01	8.878e-01
0.5	1.407e+06	2.981e+00	4.809e+00	5.852e-03	9.439e-03

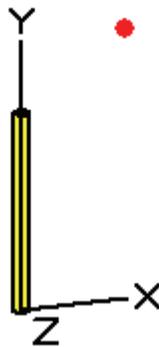
0.6	1.078e+09	2.886e+03	4.506e+03	5.633e+00	8.796e+00
0.8	6.593e+08	2.541e+03	3.762e+03	4.834e+00	7.156e+00
1.0	2.935e+12	1.498e+07	2.129e+07	2.761e+04	3.924e+04
1.5	2.935e+12	2.474e+07	3.279e+07	4.162e+04	5.517e+04
2.0	1.207e-03	1.435e-08	1.832e-08	2.219e-11	2.833e-11
Totals	5.872e+12	3.972e+07	5.409e+07	6.924e+04	9.443e+04

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INL

Page 1
DOS File N14 IPT.ms6
Run Date July 24, 2006
Run Time 7:35:54 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: N-14 In-pile Tube
Description: Dose rate at measurement point
Geometry: 12 - Annular Cylinder - External Dose Point



Source Dimensions:

Height	101.6 cm	(3 ft 4.0 in)
Inner Cyl Radius	3.136 cm	(1.2 in)
Inner Cyl Thickness	0.0 cm	(0.0 in)
Outer Cyl Thickness	0.0 cm	(0.0 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	53.4162 cm 1 ft 9.0 in	138.3538 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	3.136 cm	Air	0.00122
Source	1116.975 cm ³	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Air	0.31

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.2663e-008	4.6852e+002	1.1337e-005	4.1946e-001
Ag-108m	4.1174e-003	1.5234e+008	3.6862e+000	1.3639e+005
Ag-110m	2.5963e-013	9.6062e-003	2.3244e-010	8.6002e-006
Am-241	3.7510e-004	1.3879e+007	3.3582e-001	1.2425e+004
Am-243	1.3539e-005	5.0094e+005	1.2121e-002	4.4847e+002
Ba-137m	1.0246e-002	3.7911e+008	9.1731e+000	3.3941e+005
Be-10	6.6898e-008	2.4752e+003	5.9892e-005	2.2160e+000
C-14	4.3165e-001	1.5971e+010	3.8644e+002	1.4298e+007
Ce-144	3.4803e-012	1.2877e-001	3.1158e-009	1.1528e-004
Cl-36	3.1139e-003	1.1522e+008	2.7878e+000	1.0315e+005
Cm-243	2.7476e-006	1.0166e+005	2.4598e-003	9.1014e+001
Cm-244	2.7317e-003	1.0107e+008	2.4456e+000	9.0486e+004
Cm-245	6.3951e-007	2.3662e+004	5.7254e-004	2.1184e+001
Cm-246	1.0831e-006	4.0075e+004	9.6968e-004	3.5878e+001
Cm-247	7.9003e-012	2.9231e-001	7.0729e-009	2.6170e-004
Cm-248	7.1596e-011	2.6491e+000	6.4098e-008	2.3716e-003

Co-60	6.4588e+001	2.3898e+012	5.7824e+004	2.1395e+009
Cs-134	1.9830e-005	7.3372e+005	1.7754e-002	6.5688e+002
Cs-137	1.0831e-002	4.0075e+008	9.6968e+000	3.5878e+005
Eu-152	5.3916e-006	1.9949e+005	4.8270e-003	1.7860e+002
Eu-154	1.6645e-003	6.1586e+007	1.4902e+000	5.5136e+004
H-3	8.9197e-002	3.3003e+009	7.9856e+001	2.9547e+006
I-129	9.4772e-009	3.5065e+002	8.4847e-006	3.1393e-001
Mn-54	1.3061e-007	4.8326e+003	1.1693e-004	4.3265e+000
Nb-94	5.0571e-003	1.8711e+008	4.5275e+000	1.6752e+005
Ni-59	1.3857e+000	5.1272e+010	1.2406e+003	4.5903e+007
Ni-63	2.1981e+002	8.1328e+012	1.9679e+005	7.2811e+009
Np-237	5.6544e-009	2.0921e+002	5.0623e-006	1.8730e-001
Pa-231	1.9114e-008	7.0720e+002	1.7112e-005	6.3314e-001
Pb-210	3.6157e-012	1.3378e-001	3.2370e-009	1.1977e-004
Pr-144	3.4305e-012	1.2693e-001	3.0712e-009	1.1364e-004
Pu-238	2.7794e-004	1.0284e+007	2.4884e-001	9.2069e+003
Pu-239	2.7954e-005	1.0343e+006	2.5026e-002	9.2597e+002
Pu-240	5.2562e-005	1.9448e+006	4.7058e-002	1.7411e+003
Pu-241	3.5440e-003	1.3113e+008	3.1728e+000	1.1739e+005
Pu-242	1.0353e-006	3.8307e+004	9.2690e-004	3.4295e+001
Pu-244	1.2981e-012	4.8031e-002	1.1622e-009	4.3001e-005
Ra-226	3.1219e-012	1.1551e-001	2.7949e-009	1.0341e-004
Rh-106	3.6794e-010	1.3614e+001	3.2940e-007	1.2188e-002
Ru-106	3.6794e-010	1.3614e+001	3.2940e-007	1.2188e-002
Sb-125	2.6122e-004	9.6651e+006	2.3386e-001	8.6529e+003
Sr-90	4.9536e-003	1.8328e+008	4.4348e+000	1.6409e+005
Tc-99	1.7919e-004	6.6300e+006	1.6042e-001	5.9357e+003
Th-228	9.1586e-006	3.3887e+005	8.1995e-003	3.0338e+002
Th-229	1.0035e-008	3.7128e+002	8.9838e-006	3.3240e-001
Th-230	3.0502e-010	1.1286e+001	2.7308e-007	1.0104e-002
Th-232	1.0592e-009	3.9191e+001	9.4829e-007	3.5087e-002
U-232	8.9197e-006	3.3003e+005	7.9856e-003	2.9547e+002
U-233	2.8113e-006	1.0402e+005	2.5169e-003	9.3124e+001
U-234	6.1880e-007	2.2896e+004	5.5400e-004	2.0498e+001
U-235	4.8501e-011	1.7945e+000	4.3421e-008	1.6066e-003
U-236	1.7919e-009	6.6300e+001	1.6042e-006	5.9357e-002
U-238	5.2881e-009	1.9566e+002	4.7343e-006	1.7517e-001
Y-90	4.9536e-003	1.8328e+008	4.4348e+000	1.6409e+005
Zn-65	5.3199e-012	1.9684e-001	4.7628e-009	1.7622e-004

**Buildup : The material reference is - Source
Integration Parameters**

Radial	10
Circumferential	20
Y Direction (axial)	20

Results

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.929e+05	1.186e-06	1.198e-06	1.017e-07	1.028e-07
0.02	9.996e+07	1.395e-02	1.415e-02	4.832e-04	4.900e-04
0.03	2.702e+07	4.003e-02	4.123e-02	3.967e-04	4.086e-04
0.04	1.835e+07	8.852e-02	9.301e-02	3.915e-04	4.113e-04
0.05	3.215e+06	3.661e-02	3.966e-02	9.751e-05	1.057e-04
0.06	5.042e+06	1.131e-01	1.276e-01	2.247e-04	2.534e-04
0.08	1.113e+07	6.886e-01	8.493e-01	1.090e-03	1.344e-03
0.1	2.507e+07	3.134e+00	4.224e+00	4.794e-03	6.463e-03
0.15	2.931e+04	9.937e-03	1.552e-02	1.636e-05	2.556e-05
0.2	4.969e+06	2.830e+00	4.706e+00	4.994e-03	8.306e-03

0.3	1.096e+05	1.135e-01	1.913e-01	2.154e-04	3.629e-04
0.4	1.404e+08	2.135e+02	3.508e+02	4.160e-01	6.835e-01
0.5	1.146e+06	2.325e+00	3.693e+00	4.563e-03	7.249e-03
0.6	8.780e+08	2.246e+03	3.455e+03	4.383e+00	6.743e+00
0.8	5.368e+08	1.972e+03	2.878e+03	3.751e+00	5.474e+00
1.0	2.390e+12	1.159e+07	1.626e+07	2.137e+04	2.998e+04
1.5	2.390e+12	1.907e+07	2.500e+07	3.209e+04	4.206e+04
2.0	9.825e-04	1.104e-08	1.395e-08	1.707e-11	2.157e-11
Totals	4.781e+12	3.067e+07	4.127e+07	5.347e+04	7.205e+04

MicroShield v6.10 (0063)
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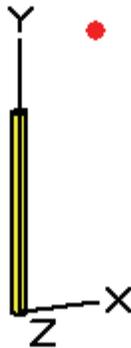
Page 1
DOS File M13 IPT.ms6
Run Date July 24, 2006
Run Time 7:50:13 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: M-13 In-pile Tube

Description: Dose rate at measurement point

Geometry: 12 - Annular Cylinder - External Dose Point



Source Dimensions:

Height	101.6 cm	(3 ft 4.0 in)
Inner Cyl Radius	3.136 cm	(1.2 in)
Inner Cyl Thickness	0.0 cm	(0.0 in)
Outer Cyl Thickness	0.0 cm	(0.0 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	39.2176 cm 1 ft 3.4 in	138.3538 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	3.136 cm	Air	0.00122
Source	1116.975 cm ³	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122
Immersion		Air	0.31

Source Input : Grouping Method - Standard Indices

Number of Groups : 25

Lower Energy Cutoff : 0.015

Photons < 0.015 : Included

Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.2500e-008	4.6249e+002	1.1191e-005	4.1406e-001
Ag-108m	4.0644e-003	1.5038e+008	3.6387e+000	1.3463e+005
Ag-110m	2.5628e-013	9.4825e-003	2.2944e-010	8.4895e-006
Am-241	3.7028e-004	1.3700e+007	3.3150e-001	1.2265e+004
Am-243	1.3365e-005	4.9449e+005	1.1965e-002	4.4270e+002
Ba-137m	1.0114e-002	3.7423e+008	9.0551e+000	3.3504e+005
Be-10	6.6036e-008	2.4433e+003	5.9121e-005	2.1875e+000
C-14	4.2609e-001	1.5765e+010	3.8147e+002	1.4114e+007
Ce-144	3.4355e-012	1.2711e-001	3.0757e-009	1.1380e-004
Cl-36	3.0738e-003	1.1373e+008	2.7519e+000	1.0182e+005
Cm-243	2.7122e-006	1.0035e+005	2.4282e-003	8.9842e+001
Cm-244	2.6965e-003	9.9770e+007	2.4141e+000	8.9322e+004
Cm-245	6.3128e-007	2.3357e+004	5.6517e-004	2.0911e+001

Cm-246	1.0692e-006	3.9559e+004	9.5719e-004	3.5416e+001
Cm-247	7.7986e-012	2.8855e-001	6.9819e-009	2.5833e-004
Cm-248	7.0675e-011	2.6150e+000	6.3273e-008	2.3411e-003
Co-60	6.3757e+001	2.3590e+012	5.7080e+004	2.1119e+009
Cs-134	1.9575e-005	7.2428e+005	1.7525e-002	6.4843e+002
Cs-137	1.0692e-002	3.9559e+008	9.5719e+000	3.5416e+005
Eu-152	5.3222e-006	1.9692e+005	4.7649e-003	1.7630e+002
Eu-154	1.6430e-003	6.0793e+007	1.4710e+000	5.4426e+004
H-3	8.8049e-002	3.2578e+009	7.8828e+001	2.9166e+006
I-129	9.3552e-009	3.4614e+002	8.3754e-006	3.0989e-001
Mn-54	1.2893e-007	4.7703e+003	1.1543e-004	4.2708e+000
Nb-94	4.9920e-003	1.8471e+008	4.4692e+000	1.6536e+005
Ni-59	1.3679e+000	5.0612e+010	1.2246e+003	4.5312e+007
Ni-63	2.1698e+002	8.0281e+012	1.9425e+005	7.1874e+009
Np-237	5.5817e-009	2.0652e+002	4.9971e-006	1.8489e-001
Pa-231	1.8868e-008	6.9810e+002	1.6892e-005	6.2499e-001
Pb-210	3.5691e-012	1.3206e-001	3.1953e-009	1.1823e-004
Pr-144	3.3863e-012	1.2529e-001	3.0317e-009	1.1217e-004
Pu-238	2.7437e-004	1.0152e+007	2.4563e-001	9.0884e+003
Pu-239	2.7594e-005	1.0210e+006	2.4704e-002	9.1405e+002
Pu-240	5.1886e-005	1.9198e+006	4.6452e-002	1.7187e+003
Pu-241	3.4984e-003	1.2944e+008	3.1320e+000	1.1588e+005
Pu-242	1.0220e-006	3.7814e+004	9.1496e-004	3.3854e+001
Pu-244	1.2814e-012	4.7413e-002	1.1472e-009	4.2447e-005
Ra-226	3.0817e-012	1.1402e-001	2.7590e-009	1.0208e-004
Rh-106	3.6320e-010	1.3438e+001	3.2516e-007	1.2031e-002
Ru-106	3.6320e-010	1.3438e+001	3.2516e-007	1.2031e-002
Sb-125	2.5786e-004	9.5407e+006	2.3085e-001	8.5415e+003
Sr-90	4.8898e-003	1.8092e+008	4.3778e+000	1.6198e+005
Tc-99	1.7688e-004	6.5447e+006	1.5836e-001	5.8593e+003
Th-228	9.0407e-006	3.3451e+005	8.0939e-003	2.9947e+002
Th-229	9.9055e-009	3.6650e+002	8.8681e-006	3.2812e-001
Th-230	3.0109e-010	1.1141e+001	2.6956e-007	9.9738e-003
Th-232	1.0456e-009	3.8686e+001	9.3608e-007	3.4635e-002
U-232	8.8049e-006	3.2578e+005	7.8828e-003	2.9166e+002
U-233	2.7751e-006	1.0268e+005	2.4845e-003	9.1926e+001
U-234	6.1084e-007	2.2601e+004	5.4687e-004	2.0234e+001
U-235	4.7876e-011	1.7714e+000	4.2863e-008	1.5859e-003
U-236	1.7688e-009	6.5447e+001	1.5836e-006	5.8593e-002
U-238	5.2200e-009	1.9314e+002	4.6734e-006	1.7291e-001
Y-90	4.8898e-003	1.8092e+008	4.3778e+000	1.6198e+005
Zn-65	5.2515e-012	1.9430e-001	4.7015e-009	1.7396e-004

**Buildup : The material reference is - Source
Integration Parameters**

Radial	10
Circumferential	20
Y Direction (axial)	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	1.904e+05	6.121e-07	6.183e-07	5.250e-08	5.303e-08
0.02	9.867e+07	1.040e-02	1.056e-02	3.601e-04	3.659e-04
0.03	2.668e+07	3.773e-02	3.893e-02	3.739e-04	3.858e-04
0.04	1.812e+07	8.699e-02	9.152e-02	3.847e-04	4.048e-04
0.05	3.174e+06	3.615e-02	3.919e-02	9.631e-05	1.044e-04
0.06	4.977e+06	1.118e-01	1.260e-01	2.220e-04	2.502e-04
0.08	1.099e+07	6.801e-01	8.384e-01	1.076e-03	1.327e-03

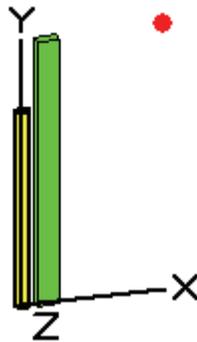
0.1	2.474e+07	3.113e+00	4.209e+00	4.763e-03	6.439e-03
0.15	2.893e+04	1.014e-02	1.612e-02	1.670e-05	2.655e-05
0.2	4.905e+06	2.940e+00	5.040e+00	5.189e-03	8.896e-03
0.3	1.082e+05	1.201e-01	2.111e-01	2.279e-04	4.005e-04
0.4	1.386e+08	2.283e+02	3.926e+02	4.448e-01	7.650e-01
0.5	1.131e+06	2.504e+00	4.167e+00	4.915e-03	8.180e-03
0.6	8.667e+08	2.433e+03	3.919e+03	4.749e+00	7.650e+00
0.8	5.299e+08	2.156e+03	3.288e+03	4.102e+00	6.253e+00
1.0	2.359e+12	1.277e+07	1.866e+07	2.354e+04	3.440e+04
1.5	2.359e+12	2.127e+07	2.888e+07	3.579e+04	4.860e+04
2.0	9.698e-04	1.241e-08	1.618e-08	1.919e-11	2.503e-11
Totals	4.720e+12	3.405e+07	4.755e+07	5.934e+04	8.301e+04

MicroShield v6.10 (0063)
INL

Page 1
DOS File C7 IPT.ms6
Run Date July 24, 2006
Run Time 8:02:07 AM
Duration 00:00:01

File Ref
Date
By
Checked

Case Title: C-7 In-pile Tube
Description: Dose rate at measurement point
Geometry: 12 - Annular Cylinder - External Dose Point



Source Dimensions:

Height	101.6 cm	(3 ft 4.0 in)
Inner Cyl Radius	3.136 cm	(1.2 in)
Inner Cyl Thickness	0.0 cm	(0.0 in)
Outer Cyl Thickness	0.0 cm	(0.0 in)
Source	1.0 cm	(0.4 in)

Dose Points

A	X	Y	Z
# 1	73.914 cm 2 ft 5.1 in	138.3538 cm 4 ft 6.5 in	0 cm 0.0 in

Shields

Shield N	Dimension	Material	Density
Cyl. Radius	3.136 cm	Air	0.00122
Source	1116.975 cm ³	Iron	7.86
Transition	3.366 cm	Air	0.00122
Shield 5	11.333 cm	Aluminum	1.41
Air Gap		Air	0.00122
Immersion		Air	0.31

Source Input : Grouping Method - Standard Indices

Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Included
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Ac-227	1.4300e-008	5.2909e+002	1.2802e-005	4.7368e-001
Ag-108m	4.6497e-003	1.7204e+008	4.1627e+000	1.5402e+005
Ag-110m	2.9319e-013	1.0848e-002	2.6249e-010	9.7119e-006
Am-241	4.2360e-004	1.5673e+007	3.7923e-001	1.4032e+004
Am-243	1.5289e-005	5.6569e+005	1.3688e-002	5.0645e+002
Ba-137m	1.1571e-002	4.2812e+008	1.0359e+001	3.8328e+005
Be-10	7.5546e-008	2.7952e+003	6.7634e-005	2.5025e+000
C-14	4.8745e-001	1.8036e+010	4.3640e+002	1.6147e+007
Ce-144	3.9302e-012	1.4542e-001	3.5186e-009	1.3019e-004

Cl-36	3.5165e-003	1.3011e+008	3.1482e+000	1.1648e+005
Cm-243	3.1028e-006	1.1480e+005	2.7778e-003	1.0278e+002
Cm-244	3.0848e-003	1.1414e+008	2.7617e+000	1.0218e+005
Cm-245	7.2218e-007	2.6721e+004	6.4655e-004	2.3922e+001
Cm-246	1.2231e-006	4.5255e+004	1.0950e-003	4.0516e+001
Cm-247	8.9216e-012	3.3010e-001	7.9873e-009	2.9553e-004
Cm-248	8.0852e-011	2.9915e+000	7.2385e-008	2.6782e-003
Co-60	7.2938e+001	2.6987e+012	6.5299e+004	2.4161e+009
Cs-134	2.2394e-005	8.2857e+005	2.0049e-002	7.4180e+002
Cs-137	1.2231e-002	4.5255e+008	1.0950e+001	4.0516e+005
Eu-152	6.0886e-006	2.2528e+005	5.4510e-003	2.0169e+002
Eu-154	1.8796e-003	6.9547e+007	1.6828e+000	6.2264e+004
H-3	1.0073e-001	3.7269e+009	9.0179e+001	3.3366e+006
I-129	1.0702e-008	3.9599e+002	9.5815e-006	3.5452e-001
Mn-54	1.4749e-007	5.4573e+003	1.3205e-004	4.8858e+000
Nb-94	5.7109e-003	2.1130e+008	5.1128e+000	1.8917e+005
Ni-59	1.5649e+000	5.7900e+010	1.4010e+003	5.1837e+007
Ni-63	2.4822e+002	9.1842e+012	2.2223e+005	8.2224e+009
Np-237	6.3854e-009	2.3626e+002	5.7167e-006	2.1152e-001
Pa-231	2.1584e-008	7.9863e+002	1.9324e-005	7.1499e-001
Pb-210	4.0831e-012	1.5107e-001	3.6555e-009	1.3525e-004
Pr-144	3.8740e-012	1.4334e-001	3.4683e-009	1.2833e-004
Pu-238	3.1387e-004	1.1613e+007	2.8100e-001	1.0397e+004
Pu-239	3.1567e-005	1.1680e+006	2.8261e-002	1.0457e+003
Pu-240	5.9357e-005	2.1962e+006	5.3141e-002	1.9662e+003
Pu-241	4.0021e-003	1.4808e+008	3.5830e+000	1.3257e+005
Pu-242	1.1692e-006	4.3259e+004	1.0467e-003	3.8729e+001
Pu-244	1.4659e-012	5.4240e-002	1.3124e-009	4.8560e-005
Ra-226	3.5255e-012	1.3044e-001	3.1563e-009	1.1678e-004
Rh-106	4.1550e-010	1.5374e+001	3.7199e-007	1.3764e-002
Ru-106	4.1550e-010	1.5374e+001	3.7199e-007	1.3764e-002
Sb-125	2.9499e-004	1.0915e+007	2.6410e-001	9.7715e+003
Sr-90	5.5940e-003	2.0698e+008	5.0081e+000	1.8530e+005
Tc-99	2.0235e-004	7.4871e+006	1.8116e-001	6.7030e+003
Th-228	1.0343e-005	3.8267e+005	9.2594e-003	3.4260e+002
Th-229	1.1332e-008	4.1928e+002	1.0145e-005	3.7537e-001
Th-230	3.4445e-010	1.2745e+001	3.0838e-007	1.1410e-002
Th-232	1.1961e-009	4.4257e+001	1.0709e-006	3.9622e-002
U-232	1.0073e-005	3.7269e+005	9.0179e-003	3.3366e+002
U-233	3.1747e-006	1.1746e+005	2.8422e-003	1.0516e+002
U-234	6.9880e-007	2.5856e+004	6.2562e-004	2.3148e+001
U-235	5.4771e-011	2.0265e+000	4.9035e-008	1.8143e-003
U-236	2.0235e-009	7.4871e+001	1.8116e-006	6.7030e-002
U-238	5.9717e-009	2.2095e+002	5.3463e-006	1.9781e-001
Y-90	5.5940e-003	2.0698e+008	5.0081e+000	1.8530e+005
Zn-65	6.0077e-012	2.2228e-001	5.3785e-009	1.9901e-004

**Buildup : The material reference is - Shield 5
Integration Parameters**

Radial	10
Circumferential	20
Y Direction (axial)	20

Energy MeV	Activity Photons/sec	Results			
		Fluence Rate MeV/cm ² /sec No Buildup	Fluence Rate MeV/cm ² /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.179e+05	5.385e-68	2.083e-28	4.619e-69	1.786e-29
0.02	1.129e+08	2.948e-29	1.711e-25	1.021e-30	5.927e-27
0.03	3.052e+07	4.649e-11	8.702e-11	4.608e-13	8.624e-13

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0.04	2.073e+07	2.168e-06	6.132e-06	9.586e-09	2.712e-08
0.05	3.631e+06	3.244e-05	1.375e-04	8.641e-08	3.664e-07
0.06	5.694e+06	5.056e-04	2.982e-03	1.004e-06	5.924e-06
0.08	1.257e+07	1.185e-02	1.027e-01	1.875e-05	1.626e-04
0.1	2.831e+07	9.307e-02	9.730e-01	1.424e-04	1.489e-03
0.15	3.310e+04	5.121e-04	5.453e-03	8.432e-07	8.979e-06
0.2	5.612e+06	1.915e-01	1.800e+00	3.380e-04	3.177e-03
0.3	1.238e+05	1.079e-02	7.779e-02	2.046e-05	1.476e-04
0.4	1.586e+08	2.542e+01	1.481e+02	4.953e-02	2.885e-01
0.5	1.294e+06	3.274e-01	1.605e+00	6.426e-04	3.151e-03
0.6	9.915e+08	3.610e+02	1.543e+03	7.047e-01	3.011e+00
0.8	6.062e+08	3.868e+02	1.343e+03	7.357e-01	2.555e+00
1.0	2.699e+12	2.629e+06	7.860e+06	4.847e+03	1.449e+04
1.5	2.699e+12	5.504e+06	1.289e+07	9.260e+03	2.169e+04
2.0	1.109e-03	3.682e-09	7.531e-09	5.694e-12	1.165e-11
Totals	5.399e+12	8.134e+06	2.076e+07	1.411e+04	3.619e+04

Appendix D
MCNP Discussion

Appendix D

MCNP Discussion

The following discussion of the MCNP dose rate modeling was provided by Dr. J. Perry:

“Dose determination with MCNP:

Rad dose:

Requires placing a water (or preferred material) phantom at the dose point, tallying the energy deposition in the phantom, and converting to a Rad dose.

Rem dose:

Requires placing a water (or preferred material) phantom at the dose point, tallying the flux in the phantom, and applying a dose energy and a dose function card to the tally to calculate a Rem dose. The dose energy cards and dose function cards are based on an appropriate standard, possibly from NCRP, ICRP, ANSI, or ANS.

Either of these conversions do not appear to be too difficult. I assume the choice of the appropriate standard for the particular situation could be a point of discussion in a Rem dose calculation.

The difficulty lies in defining the source. MCNP does not generate radiation from radioactive decay. The radiation field would need to be defined explicitly. MCNP only transports one type of source particle per run. If a dose from gammas and betas was desired, it would take a gamma source definition for one run and a beta source definition for another run and the combination of the two results.

The source would be based on the original MCNP-ORIGEN calculations. The radionuclide inventory for each component (major components at a minimum) would need to be converted to a gamma spectrum and a beta spectrum (not a simple task). The source spectrum would need to be defined for each component. Assumptions would need to be made as to what auxiliary materials have been placed in the reactor, their physical geometry, their location, and their material. All this other equipment would need to be modeled in MCNP.

Assumptions in this process:

1. Detailed power history replaced with a constant average power used for the radionuclide inventory calculation
2. No fuel burnup
3. Impurity levels in materials
4. Uniform distribution of radionuclides in the materials
5. Physical configuration of the components added to the reactor after shutdown.

If the measured dose is not close to the calculated dose, you have to decide where to refine your model, or do you scale the entire source? Refining assumptions 1, 2, and 4 could require significant amounts of time depending on the accuracy desired.”

Improving assumption 3 would require extensive sampling of the vessel internal materials which, due to the high dose rates in the vessel interior and the high dose rates associated with the samples is not possible.