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Page 1 of 1

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1	1	Cog.Eng. D.A.Himes	<i>[Signature]</i>	7/27/96	A3-34				
1	1	Cog. Mgr. D.S. Leach	<i>[Signature]</i>	7/27/96	A3-34				
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Verification of DST Energy Deposition Rates and Development of Correction for Gamma Losses

D.A. Himes

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Abstract: An independent verification of a series of recently calculated energy deposition rates within dispersed and layered organic waste in double shell tanks was performed. In addition, a simple method was developed to correct for gamma losses from a waste layer when calculating energy deposition rates.

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VERIFICATION OF DST ENERGY DEPOSITION RATES AND DEVELOPMENT OF CORRECTION FOR GAMMA LOSSES

D.A. Himes
7/8/96

Energy deposition rates (dose rates) within dispersed and layered organic waste in a series of double shell tank mixes were recently calculated with the results shown in Attachment 1. An independent verification is required for the tank mixes shown in bold print in the attachment. In addition, it is desired that a simple method be developed for correcting for gamma losses from a waste layer when calculating energy deposition rates.

A cylindrical layer of liquid waste (supernate) is assumed in which an organic component may be uniformly dispersed, or separated as a layer floating on top. No alpha, beta or gamma losses from the supernate were assumed for the dispersed case. For the layered case the gamma dose rate 5 cm into the organic layer was calculated using MICROSHIELD.¹

Dispersed organic cases:

The initial step in the calculations was to assemble the energy per disintegration carried off by alphas, betas and gammas for each of the isotopes listed in the mix inventories in Attachment 1. These are shown in Table 1.

Table 1: Energy production per disintegration

Isotope	Energy per Disintegration (MeV/dis)		
	Alpha	Beta	Gamma
C-14	-	4.95E-2	-
Sr-90	-	1.96E-1	-
Y-90	-	9.35E-1	-
Tc-99	-	8.46E-2	5.36E-7
Cs-137	-	1.71E-1	-
Ba-137m	-	6.37E-2	5.98E-1
Eu-154	-	2.25E-1	1.25E+0
Np-237	4.76E+0	6.24E-2	3.30E-2
Pu-238	5.49E+0	8.26E-3	1.60E-3
Pu-239	5.15E+0	4.88E-3	6.54E-4
Pu-240	5.15E+0	8.33E-3	1.53E-3
Pu-241	-	5.23E-3	-
Am-241	5.48E+0	2.94E-2	2.81E-2

¹MICROSHIELD is a registered trademark of Grove Engineering, Inc.

To obtain the volumetric energy deposition rate it is merely necessary to multiply the energies per disintegration shown in Table 1 by the corresponding isotopic concentrations (Ci/L) and make use of the definition of a Ci as 3.7×10^{10} dis/s. This yields MeV/s·L which can be converted to ergs/cm³·h by using the fact that 1 MeV = 1.602×10^{-6} ergs and finally to rads/h by dividing by the supernate density and using the definition of a rad as 100 ergs/g absorbed. The resulting energy deposition rates for the required DST mixes are shown in Table 2. A sample calculation (105AP) is shown in Attachment 2. The corresponding values which were to be verified are shown in parentheses.

Table 2: Resulting energy deposition (dose) rates
for dispersed organics case

Tank Mix	ergs/cm ³ ·h			Total Supernate/ Organic (rad/h)
	Alpha	Beta	Gamma	
105AP	1.90E+1	2.25E+3	2.13E+3	3.33E+1 (3.33E+1)
103C+105AP	-	3.09E+3	7.02E+3	9.19E+1 (9.17E+1)
107AP	4.00E-2	1.23E-3	2.04E-3	4.28E-4 (4.22E-4)
103C+107AP	-	2.61E+3	6.29E+3	8.40E+1 (8.40E+1)
103U+105U+ 109U+107AP	-	1.87E+4	4.03E+4	4.37E+2 (4.38E+2)
103C+103U+ 105U+109U+ 107AP	-	1.54E+4	3.36E+4	3.80E+2 (3.80E+2)
102AY	2.27E+1	2.74E+3	5.90E+3	7.59E+1 (7.59E+1)
103C+102AY	-	2.81E+3	6.16E+3	7.94E+1 (7.93E+1)
102AZ	2.61E+2	2.04E+4	1.79E+4	3.47E+2 (3.47E+2)

There is some variation in the deposition rates attributed to the individual radiative components due to differences in the way the energy was apportioned, possible differences in the data, and (most significantly) in whether minor components were neglected (e.g., β contributions from a primary α emitter). The total dose rates in the supernate/organic dispersion, however, seemed to agree well in every case.

Layered organic cases:

The layered organic cases were calculated using the MICROSHIELD 3.12 code (Grove 1988) with a simple cylindrical geometry. The supernate layer density, thickness and diameter were taken from the information in Attachment 1. A typical geometry set-up is shown in the sample calculation in Attachment 2. The MICROSHIELD files for all the mixes are listed for reference in Attachment 3. The resulting dose rates at a point 5 cm into the organic layer are shown in Table 3. The corresponding values which were to be verified are shown in parentheses.

Table 3: Dose rates 5 cm into the organic layer

Tank Mix	Dose Rate (rad/h)
105AP	6.13E+0 (6.18E+0)
103C+105AP	2.78E+1 (2.78E+1)
107AP	6.98E-6 (4.46E-6)
103C+107AP	2.59E+1 (2.58E+1)
103U+105U+ 109U+107AP	1.22E+2 (1.34E+2)
103C+103U+ 105U+109U+ 107AP	1.10E+2 (1.31E+2)
102AY	2.25E+1 (2.77E+1)
103C+102AY	2.55E+1 (3.26E+1)
102AZ	6.70E+1 (7.75E+1)

In general the results follow pretty well although there are some differences, possible due to differences in the details of the code set-up.

Correction for gamma losses:

In an infinite medium in which a radioactive material is uniformly distributed (constant concentration) elementary thermodynamic considerations require that the power absorbed at each point must be equal to the power generated at the same point and the power density must be uniform throughout the medium. This

is the assumption made in the above calculations where the losses from the finite medium were assumed to be zero, i.e., an infinite medium was assumed. For very short range radiation (alphas and betas) this is a good assumption unless the medium is very small. For gamma heating, however, the size of the medium can easily be comparable to the range of the radiation leading to significant energy losses due to leakage from the boundaries of the medium. In this case, the infinite medium assumption could produce a significant overprediction of the average gamma heating in the material. Since the material of interest here is in the form of a disk with a radius much greater than its thickness, an infinite slab model will be assumed with losses only out of the two faces.

Let us now divide the infinite medium into two semi-infinite half-spaces with the boundary at $x = 0$. Let the right half-space (positive x) contain a uniform concentration of a gamma emitter while the left half-space (negative x) contains medium, but no gamma emitter. We wish to calculate the amount of reduction in the volumetric energy absorption rate as a function of position (x) in the right half-space due to gamma leakage across the boundary into the left half-space. Consider the opposite case where the left half-space is filled uniformly with the gamma emitter (same concentration) and the right half-space has none. The energy absorbed at a point x in the right half-space is now just the amount which would be missing if the left half-space were empty as compared to the infinite medium case (i.e., both half-spaces filled with gamma emitter).

This calculation was performed for a series of positive values of x using MICROSHIELD (output files are listed for reference in Attachment 4). A density of 1.5 g/cm^3 was assumed for the medium (both halves) and the gamma emitter was assumed to be ^{137}Ba at a concentration of 1 Ci/L . The semi-infinite left half-space was simulated by an infinite slab with a thickness of 100 cm. It was found that increasing the slab thickness beyond 100 cm did not increase the dose rate at a point on the boundary ($x = 0$) and, therefore, the 100 cm slab was infinitely thick for practical purposes. The results of the calculation for x out to 80 cm from the boundary are shown in Table 4. Note that, by superposition, the dose rate for an infinite medium is exactly two times the dose calculated here at the boundary ($x = 0$) between the two half-spaces, or $1.27\text{E}+3 \text{ rads/h}$. F is the fraction of the infinite medium deposition rate produced by the gamma emitter in the left half-space (i.e., column 2 divided by $1.27\text{E}+3 \text{ rads/h}$). The last column ($1 - F$) is the net fraction of the infinite medium deposition rate remaining after the contribution due to the gamma emitter in the left half-space has been subtracted.

Table 4: Reduction in energy deposition rate due to boundary at $x = 0$

x (cm)	Depos. Rate (rads/h)	F	1 - F
0	6.35E+2	5.00E-1	0.500
1	5.25E+2	4.13E-1	0.587
10	1.54E+2	1.21E-1	0.879
20	4.41E+1	3.47E-2	0.965
30	1.29E+1	1.02E-2	0.990
40	3.83E+0	3.02E-3	0.997
50	1.14E+0	8.98E-4	0.999
60	3.43E-1	2.70E-4	1.000
70	1.03E-1	8.11E-5	1.000
80	3.11E-2	2.45E-5	1.000

Note that the assumed value for gamma emitter concentration is arbitrary and does not effect F. Because of the nature of the process the function $F(x)$ can be approximated by an exponential decay function of the form $F = b \exp(-mx)$. Matching the function to the points $F(0 \text{ cm}) = 0.500$ and $F(10 \text{ cm}) = 0.121$ in order to obtain the best fit in the region of maximum effect, it is easily shown that $m = 0.142 \text{ cm}^{-1}$ and $b = 0.500$. This approximation is compared to the numerical results in Table 5.

Table 5: Comparison of $F = 0.500 \exp(-0.142 x)$ to numerical results shown in Table 4

x (cm)	Numerical		Formula	
	F	1 - F	F	1 - F
0	5.00E-1	0.500	5.00E-1	0.500
1	4.13E-1	0.587	4.34E-1	0.566
10	1.21E-1	0.879	1.21E-1	0.879
20	3.47E-2	0.965	2.92E-2	0.971
30	1.02E-2	0.990	7.06E-3	0.993
40	3.02E-3	0.997	1.71E-3	0.998
50	8.98E-4	0.999	4.13E-4	1.000
60	2.70E-4	1.000	9.97E-5	1.000
70	8.11E-5	1.000	2.41E-5	1.000
80	2.45E-5	1.000	5.83E-6	1.000

In like manner the approximate formula for $F(x)$ can be extended to other isotopes as shown in Table 6 for the principal gamma emitters. The parameter $b = 0.500$ in all cases. (corresponding MICROSHIELD run files are listed in Attachment 4.)

Table 6: m parameter values for the principal gamma emitters

Isotope	$F(0 \text{ cm})$	$F(10 \text{ cm})$	$m \text{ (cm}^{-1}\text{)}$
Co-60	0.500	0.147	0.122
Zr-95	0.500	0.126	0.138
Sb-125	0.500	0.110	0.151
Cs-134	0.500	0.124	0.139
Ba-137m	0.500	0.121	0.142
Eu-154	0.500	0.135	0.131

The volumetric average energy deposition rate as a fraction of the infinite medium rate in a slab of thickness T in the interval $x = 0$ to $x = T$ with the boundary at $x = 0$ (i.e., with a boundary on only one side) can be obtained by integrating $1 - F$ over the slab thickness as follows

$$\frac{\Phi_{ave}}{\Phi_{\infty}} = \frac{\int_0^T (1 - F) dx}{T} \quad (1)$$

or

$$\frac{\Phi_{ave}}{\Phi_{\infty}} = \frac{\int_0^T (1 - \frac{1}{2} e^{-mx}) dx}{T} \quad (2)$$

The integration is easily carried out to yield

$$\frac{\Phi_{ave}}{\Phi_{\infty}} = 1 - \frac{1}{2mT} [1 - e^{-mT}] \quad (3)$$

Note that the fractional average energy deposition rate, Φ_{ave}/Φ_{∞} , goes to 1 as T goes to ∞ and to $1/2$ as T goes to 0, as expected.

Now let us consider the case of a slab of thickness T (from $x = 0$ to $x = T$) with boundaries on both sides. At position x (where $0 \leq x \leq T$) the total fractional loss due to absence of active material outside the slab is therefore equal to $F_1 + F_2$ where, by symmetry,

$$F_1 = \frac{1}{2} e^{-mx} \quad (4)$$

and

$$F_2 = \frac{1}{2} e^{-m(T-x)} \quad (5)$$

The average fractional energy deposition rate is, as before,

$$\frac{\Phi_{ave}}{\Phi_{\infty}} = \frac{\int_0^T (1 - F_1 - F_2) dx}{T} \quad (6)$$

where, using eqns. 4 and 5,

$$1 - F_1 - F_2 = 1 - \frac{1}{2} (e^{-mx} - e^{mx} e^{-mT}) \quad (7)$$

Again the integration is easily carried out to yield

$$\frac{\Phi_{ave}}{\Phi_{\infty}} = 1 - \frac{1}{mT} (1 - e^{-mT}) \quad (8)$$

As before, the fractional average energy deposition rate goes to 1 as T goes to ∞ , however in this case the energy deposition goes to 0 as T goes to 0 since the active material disappears. Typical values of the correction to be made for gamma leakage in a slab geometry (double boundary) are shown in Table 7 for the cases of ^{137}mBa (0.66 MeV γ) and ^{154}Eu (1.3 MeV γ). This correction factor can be applied directly to an internal gamma dose rate calculated with the infinite medium assumption (such as the ones reported in column 4 of Table 2).

Table 7: Gamma leakage correction factors for ^{137m}Ba ($m = 0.142 \text{ cm}^{-1}$) and ^{154}Eu ($m = 0.131 \text{ cm}^{-1}$) in a slab geometry (double boundary)

T (cm)	$^{137m}\text{Ba} \Phi_{\text{ave}}/\Phi_{\infty}$	^{154}Eu
0	0	0
1	0.068	0.062
5	0.284	0.266
10	0.466	0.443
20	0.668	0.646
30	0.769	0.751
40	0.825	0.810
50	0.859	0.848
100	0.930	0.924
500	0.986	0.985
1000	0.993	0.992

It should be noted that these factors only correct for gamma leakage from the faces of an infinite slab. They do not account for the leakage which would occur from the edges of a finite slab (such as a disk). For the cases of interest here, however, the source disk diameter is over 2000 cm so the correction for edge leakage would be negligible. In addition, if a substantial layer of other material lies under (or on top of) the supernate layer with about the same gamma activity as the supernate, then only gamma leakage from one surface of the supernate layer should be corrected for. The single boundary correction factor given by Eqn.3 will work nicely for this. Note that the reduction in the average energy deposition rate for such a case will be exactly half the reduction for the double boundary case given by Eqn.8.

If a mix of radionuclides is present, the dose rates could be calculated and corrected separately and added, or, alternatively, the correction factor corresponding to the nuclide with the lowest energy gammas (least leakage) could be applied to the total dose rate. A lower energy gamma corresponds to a higher attenuation factor, i.e., a higher value of m in Table 6. The correction factor for ^{137m}Ba ($m = 0.142 \text{ cm}^{-1}$) could therefore be conservatively applied to a $^{137m}\text{Ba} + ^{154}\text{Eu}$ mix.

Correction factors for gamma leakage which could be applied to the gamma energy deposition rates shown in column 4 of Table 2 are shown in Table 8. These factors are conservatively based on leakage due to ^{137m}Ba gammas ($m = 0.142 \text{ cm}^{-1}$).

Table 8: Gamma leakage correction factors for tank mix cases shown in Table 2 ($m = 0.142 \text{ cm}^{-1}$)

Tank Mix	Supernate Thickness (cm)	Leakage Correction Single Boundary	Leakage Correction Double Boundary
105AP	18.5	0.823	0.647
103C+105AP	141	0.975	0.950
107AP	28.6	0.879	0.758
103C+107AP	151	0.977	0.953
103U+105U+ 109U+107AP	475	0.993	0.985
103C+103U+ 105U+109U+ 107AP	598	0.994	0.988
102AY	729	0.995	0.990
103C+102AY	850	0.996	0.992
102AZ	652	0.995	0.989

Conclusion:

Independent calculations of the total energy deposition rates in the dispersed supernate/organic mixes agreed well as shown in Table 2. Calculations of energy deposition rates in the organic layer cases tracked reasonably well as shown in Table 3, although the agreement was not as good as for the dispersed cases. A scheme for correcting for gamma leakage was developed, but for most cases the correction is small. The only appreciable correction in the cases shown in Table 2 is for 105AP where the total average energy deposition rate would be reduced by 17%. This is the only case considered here where the supernate/organic layer was relatively thin and the gamma activity contributed a major fraction of the overall heating.

References:

Grove 1988, *Microshield 3 Manual*, Grove Engineering, Inc., April 12, 1988.

Attachment 1
DST Energy Deposition Rate Calculations
to be Verified

ENERGY DEPOSITION IN DST

4/22/96	Energy deposition in dispersed and layered organic within DSTs is given below. Dispersed case assumes no alpha, beta or gamma losses from the supernate. The layered case assumes a constant dose rate equal to the gamma dose rate 5 cm into the organic, as calculated by MICROSIELD.					
	SUPERNATE CURIES PER LITER					
FOR THE DISPERSED ORGANIC CASE:						
ISOTOPES	101AN	102AN	103AN	104AN	105AN	106AN
14C	3.23E-08	1.74E-05	1.96E-06	0.00E+00	0.00E+00	4.52E-08
90Sr	1.90E-05	5.48E-02	7.13E-03	4.86E-03	1.59E-03	6.32E-03
90Y	1.90E-05	5.48E-02	7.13E-03	4.86E-03	1.59E-03	6.32E-03
99Tc	9.82E-06	2.95E-04	1.67E-04	1.80E-04	1.75E-04	6.41E-05
137Cs	2.64E-06	1.82E-01	4.24E-01	3.86E-01	2.57E-01	3.53E-02
137Ba	2.51E-06	1.73E-01	4.02E-01	3.67E-01	2.44E-01	3.36E-02
154Eu	1.76E-06	7.58E-04	0.00E+00	0.00E+00	0.00E+00	1.80E-06
235U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
238U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
237Np	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.69E-10
238Pu	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	4.30E-07
239Pu	8.57E-09	6.37E-05	1.87E-06	1.04E-05	1.04E-05	2.99E-06
240Pu	8.58E-12	1.62E-05	2.87E-07	1.60E-06	1.59E-06	7.38E-07
241Pu	0.00E+00	1.56E-05	3.62E-07	1.59E-06	1.58E-06	2.30E-07
241Am	1.65E-07	5.91E-05	2.24E-06	1.52E-06	1.51E-06	1.62E-05
SUPERNATE VOLUME (LITERS)	3.68E+06	3.95E+06	3.62E+06	3.02E+06	4.29E+06	4.47E+06
SUPERNATE DENSITY (GRAMS/CC)	1.3	1.37	1.5	1.46	1.46	1.37
SUPERNATE THICKNESS (CM)	8.98E+02	9.65E+02	8.84E+02	7.38E+02	1.05E+03	1.09E+03
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR	2.03E-01	1.57E+02	4.99E+00	1.50E+01	1.49E+01	2.36E+01
BETA ERGS PER CC-HR	4.76E+00	1.99E+04	1.72E+04	1.53E+04	9.75E+03	2.81E+03
GAMMA ERGS PER CC-HR	6.20E-01	2.45E+04	5.68E+04	5.18E+04	3.44E+04	4.73E+03
SUPERNATE/ORGANIC RAD/HR	4.30E-02	3.25E+02	4.93E+02	4.59E+02	3.03E+02	5.53E+01
GAMMA ONLY RAD/HR	4.77E-03	1.79E+02	3.78E+02	3.55E+02	2.36E+02	3.46E+01
FOR THE LAYERED ORGANIC CASE:						
SUPERNATE Ba-137 CURIES	9.21E+00	6.83E+05	1.46E+06	1.11E+06	1.05E+06	1.50E+05
SUPERNATE Eu-154 CURIES	6.46E+00	3.00E+03	0.00E+00	0.00E+00	0.00E+00	8.03E+00
RAD/HR TO ORGANIC LAYER						

ENERGY DEPOSITION IN DST

4/22/96						
SUPERNATE CURIES PER LITER						
FOR THE DISPERSED ORGANIC CASE:						
ISOTOPES	107AN	101AP	102AP	103AP	104AP	105AP
14C	0.00E+00	1.96E-07	4.19E-07	4.46E-09	2.52E-14	8.73E-09
90Sr	4.83E-02	1.14E-04	8.71E-04	1.53E-06	2.16E-09	5.72E-03
90Y	4.83E-02	1.14E-04	8.71E-04	1.53E-06	2.16E-09	5.72E-03
99Tc	4.74E-04	6.31E-05	8.58E-05	1.08E-06	1.99E-07	4.46E-05
137Cs	1.38E-01	1.28E-01	1.42E-03	3.92E-03	1.29E-05	1.76E-02
137Ba	1.31E-01	1.21E-01	1.34E-03	3.72E-03	1.23E-05	1.67E-02
154Eu	1.45E-03	4.94E-09	0.00E+00	1.69E-05	0.00E+00	0.00E+00
235U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
238U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
237Np	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.36E-10	0.00E+00
238Pu	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
239Pu	3.55E-05	1.44E-07	7.50E-08	6.97E-09	4.46E-10	2.41E-06
240Pu	9.03E-06	2.22E-08	1.15E-08	1.07E-09	1.61E-10	6.02E-07
241Pu	8.52E-06	3.30E-08	1.70E-08	1.47E-09	1.56E-09	2.14E-07
241Am	3.50E-04	3.67E-07	4.17E-07	1.13E-08	1.50E-12	1.34E-05
SUPERNATE VOLUME (LITERS)	3.68E+06	3.39E+06	4.16E+06	1.02E+05	4.23E+06	7.56E+04
SUPERNATE DENSITY (GRAMS/CC)	1.33	1.32	1.21	1.01	1.28	1.32
SUPERNATE THICKNESS (CM)	8.99E+02	8.27E+02	1.02E+03	2.50E+01	1.03E+03	1.85E+01
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR	4.59E+02	6.13E-01	5.83E-01	2.21E-02	1.22E-03	1.90E+01
BETA ERGS PER CC-HR	1.67E+04	4.68E+03	2.62E+02	1.44E+02	4.72E-01	2.02E+03
GAMMA ERGS PER CC-HR	1.87E+04	1.71E+04	1.90E+02	5.28E+02	1.73E+00	2.35E+03
SUPERNATE/ORGANIC RAD/HR	2.70E+02	1.65E+02	3.74E+00	6.65E+00	1.72E-02	3.33E+01
GAMMA ONLY RAD/HR	1.41E+02	1.30E+02	1.57E+00	5.22E+00	1.35E-02	1.78E+01
FOR THE LAYERED ORGANIC CASE:						
SUPERNATE Ba-137 CURIES	4.82E+05	4.11E+05	5.59E+03	3.80E+02	5.20E+01	1.26E+03
SUPERNATE Eu-154 CURIES	5.33E+03	1.67E-02	0.00E+00	1.73E+00	0.00E+00	0.00E+00
RAD/HR TO ORGANIC LAYER						6.18

ENERGY DEPOSITION IN DST

4/22/96					
SUPERNATE CURIES PER LITER					
FOR THE DISPERSED ORGANIC CASE:	¹⁰³ C + ¹⁰⁵ AP	106AP	¹⁰³ C + ¹⁰⁵ AP	¹⁰³ U + ¹⁰⁶ U + ¹⁰⁹ U	
ISOTOPES	¹⁰³ AP		¹⁰⁷ AP	¹⁰⁷ AP	¹⁰⁷ AP
14C		4.09E-14	8.97E-11		
90Sr	9.64E-04	3.19E-10	2.02E-09	2.03E-04	9.14E-03
90Y	9.64E-04	3.19E-10	2.02E-09	2.03E-04	9.14E-03
99Tc		2.93E-11	5.78E-10		
137Cs	5.79E-02	4.75E-08	8.77E-09	5.19E-02	3.33E-01
137Ba	5.50E-02	4.51E-08	8.33E-09	4.93E-02	3.16E-01
154Eu		2.22E-12	3.27E-09		
235U		0.00E+00	0.00E+00		
238U		0.00E+00	0.00E+00		
237Np		4.54E-14	0.00E+00		
238Pu		0.00E+00	1.53E-11		
239Pu		5.36E-12	1.51E-08		
240Pu		2.81E-14	2.31E-09		
241Pu		1.87E-13	3.45E-09		
241Am		1.61E-11	1.78E-08		
SUPERNATE VOLUME (LITERS)	5.79E+05	3.03E+06	1.17E+05	6.20E+05	1.95E+06
SUPERNATE DENSITY (GRAMS/CC)	1.10	1.38	1.01	1.06	1.35
SUPERNATE THICKNESS (CM)	1.41E+02	7.40E+02	2.86E+01	1.51E+02	4.75E+02
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR		2.48E-05	4.00E-02		
BETA ERGS PER CC-HR	2.34E+03	1.81E-03	9.66E-04	1.94E+03	1.43E+04
GAMMA ERGS PER CC-HR	7.76E+03	6.36E-03	1.67E-03	6.96E+03	4.46E+04
SUPERNATE/ORGANIC RAD/HR	9.17E+01	5.94E-05	4.22E-04	8.40E+01	4.38E+02
GAMMA ONLY RAD/HR	7.04E-01	4.61E-05	1.65E-05	6.57E+01	3.31E+02
FOR THE LAYERED ORGANIC CASE:					
SUPERNATE Ba-137 CURIES	3.19E+04	1.37E-01	9.77E-04	3.06E+04	6.14E+05
SUPERNATE Eu-154 CURIES		6.73E-06	3.84E-04		
RAD/HR TO ORGANIC LAYER	27.8		4.46E-06	25.83	133.6

ENERGY DEPOSITION IN DST

	4/22/96				
	SUPERNATE CURIES PER LITER				
FOR THE DISPERSED ORGANIC CASE:	103C+103U+105U+-				
ISOTOPES	109U+107AP	108AP	101AW	102AW	103AW
14C		2.99E-12	3.69E-07		0.00E+00
90Sr	7.31E-03	1.80E-04	5.63E-04		0.00E+00
90Y	7.31E-03	1.80E-04	5.63E-04		0.00E+00
99Tc		1.54E-04	1.51E-04		0.00E+00
137Cs	2.77E-01	1.10E-01	2.68E-01		4.75E-02
137Ba	2.63E-01	1.05E-01	2.55E-01		4.51E-02
154Eu		1.63E-09	0.00E+00		0.00E+00
235U		0.00E+00	0.00E+00		0.00E+00
238U		0.00E+00	0.00E+00		0.00E+00
237Np		1.15E-11	0.00E+00		0.00E+00
238Pu		1.05E-08	0.00E+00		1.16E-04
239Pu		6.93E-12	1.54E-06		0.00E+00
240Pu		1.06E-12	2.36E-07		0.00E+00
241Pu		1.75E-13	3.04E-07		0.00E+00
241Am		1.55E-12	1.61E-06		0.00E+00
SUPERNATE VOLUME (LITERS)	2.45E+06	3.10E+06	3.94E+06		5.41E+05
SUPERNATE DENSITY (GRAMS/CC)	1.29	1.1	1.51	0	1.04
SUPERNATE THICKNESS (CM)	5.98E+02	7.57E+02	9.62E+02	0.00E+00	1.32E+02
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR		1.24E-02	3.84E+00	0.00E+00	1.36E+02
BETA ERGS PER CC-HR	1.19E+04	4.06E+03	9.92E+03	0.00E+00	1.73E+03
GAMMA ERGS PER CC-HR	3.72E+04	1.48E+04	3.60E+04	0.00E+00	6.37E+03
SUPERNATE/ORGANIC RAD/HR	3.80E+02	1.71E+02	3.04E+02	0.00E+00	7.92E+01
GAMMA ONLY RAD/HR	2.88E+02	1.34E+02	2.38E+02		6.12E+01
FOR THE LAYERED ORGANIC CASE:					
SUPERNATE Ba-137 CURIES	6.45E+05	3.25E+05	1.00E+06	0.00E+00	2.44E+04
SUPERNATE Eu-154 CURIES		5.05E-03	0.00E+00	0.00E+00	0.00E+00
RAD/HR TO ORGANIC LAYER	131.3				

ENERGY DEPOSITION IN DST

4/22/96						
SUPERNATE CURIES PER LITER						
FOR THE DISPERSED ORGANIC CASE:						103C +
ISOTOPES	104AW	105AW	106AW	101AY	102AY	102AY
14C	4.48E-08	5.04E-15		1.89E-06	0.00E+00	
90Sr	6.99E-05	3.77E-11		3.18E-02	1.37E-03	1.21E-03
90Y	6.99E-05	3.77E-11		3.18E-02	1.37E-03	1.21E-03
99Tc	1.36E-05	3.61E-12		9.10E-05	2.24E-05	
137Cs	1.40E-02	2.93E-04		1.25E-01	4.87E-02	5.09E-02
137Ba	1.33E-02	2.78E-04		1.19E-01	4.62E-02	4.83E-02
154Eu	2.44E-06	2.74E-13		0.00E+00	0.00E+00	
235U	0.00E+00	0.00E+00		0.00E+00	0.00E+00	
238U	0.00E+00	0.00E+00		0.00E+00	0.00E+00	
237Np	0.00E+00	1.53E-10		1.69E-07	0.00E+00	
238Pu	0.00E+00	1.40E-07		0.00E+00	0.00E+00	
239Pu	6.87E-08	6.61E-13		9.39E-08	2.06E-05	
240Pu	9.87E-09	3.47E-15		2.57E-08	0.00E+00	
241Pu	1.55E-08	2.13E-14		5.89E-08	0.00E+00	
241Am	1.57E-07	1.98E-12		1.52E-04	1.44E-07	
SUPERNATE VOLUME (LITERS)	5.68E+05	4.31E+06		1.52E+06	2.98E+06	3.48E+06
SUPERNATE DENSITY (GRAMS/CC)	1.07	1.06	0	1.05	1.14	1.13
SUPERNATE THICKNESS (CM)	1.39E+02	1.05E+03	0.00E+00	3.70E+02	7.29E+02	8.50E+02
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR	2.70E-01	1.65E-01	0.00E+00	1.79E+02	2.29E+01	
BETA ERGS PER CC-HR	5.27E+02	1.07E+01	0.00E+00	1.23E+04	2.11E+03	2.15E+03
GAMMA ERGS PER CC-HR	1.87E+03	3.93E+01	0.00E+00	1.68E+04	6.52E+03	6.82E+03
SUPERNATE/ORGANIC RAD/HR	2.24E+01	4.73E-01	0.00E+00	2.78E+02	7.59E+01	7.93E+01
GAMMA ONLY RAD/HR	1.75E+01	3.71E-01		1.60E+02	5.72E+01	6.03E+01
FOR THE LAYERED ORGANIC CASE:						
SUPERNATE Ba-137 CURIES	7.54E+03	1.20E+03	0.00E+00	1.81E+05	1.38E+05	1.68E+05
SUPERNATE Eu-154 CURIES	1.38E+00	1.18E-06	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RAD/HR TO ORGANIC LAYER					27.7	32.6

ENERGY DEPOSITION IN DST

	4/27/96				
SUPERNATE CURIES PER LITER					
FOR THE DISPERSED ORGANIC CASE:					
ISOTOPES	101AZ	102AZ	101SY	102SY	103SY
14C	0.00E+00	2.74E-06	0.00E+00	0.00E+00	0.00E+00
90Sr	2.21E-03	5.43E-02	1.89E-03	1.80E-09	5.37E-03
90Y	2.21E-03	5.43E-02	1.89E-03	1.80E-09	5.37E-03
99Tc	3.46E-04	3.29E-05	2.23E-03	1.44E-07	2.04E-04
137Cs	1.89E+00	1.47E-01	2.85E-01	1.07E-05	6.93E-02
137Ba	1.80E+00	1.40E-01	2.71E-01	1.02E-05	6.58E-02
154Eu	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
235U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
238U	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
237Np	0.00E+00	2.45E-07	0.00E+00	3.88E-10	0.00E+00
238Pu	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
239Pu	4.14E-07	3.42E-06	1.38E-07	3.23E-10	3.20E-07
240Pu	1.14E-07	3.35E-09	3.51E-08	1.16E-10	8.13E-08
241Pu	1.64E-06	5.40E-08	2.85E-08	1.48E-09	4.99E-08
241Am	1.82E-05	2.20E-04	5.62E-07	1.50E-12	1.62E-06
SUPERNATE VOLUME (LITERS)	2.95E+06	2.67E+06	6.81E+04	1.40E+05	6.43E+05
SUPERNATE DENSITY (GRAMS/CC)	1.27	1.11	1.41	1.29	1.39
SUPERNATE THICKNESS (CM)	7.21E+02	6.52E+02	1.66E+01	3.43E+01	1.57E+02
SUPERNATE DIAMETER (CM)	2286	2286	2286	2286	2286
ALPHA ERGS PER CC-HR	2.19E+01	2.62E+02	8.49E-01	8.82E-04	2.33E+00
BETA ERGS PER CC-HR	6.95E+04	1.85E+04	1.08E+04	3.90E-01	3.82E+03
GAMMA ERGS PER CC-HR	2.53E+05	1.97E+04	3.82E+04	1.43E+00	9.28E+03
SUPERNATE/ORGANIC RAD/HR	2.54E+03	3.47E+02	3.48E+02	1.41E-02	9.43E+01
GAMMA ONLY RAD/HR	2.00E+03	1.78E+02	2.71E+02	1.11E-02	6.68E+01
FOR THE LAYERED ORGANIC CASE:					
SUPERNATE Ba-137 CURIES	5.30E+06	3.74E+05	1.84E+04	1.43E+00	4.24E+04
SUPERNATE Eu-154 CURIES	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
RAD/HR TO ORGANIC LAYER		77.5			

ENERGY DEPOSITION IN DST

4/22/96	TANK	SUPERNATE	DENSITY	Cs-137	Sr-90
	103C	503,000 L	1.07	.064 Ci/L	2.5E-4 Ci/L
	103U	6.28E+5 L	1.385	.376 Ci/L	.0105 Ci/L
	105U	5.94E+5 L	1.35	.295 Ci/L	.0185 Ci/L
	109U	6.06E+5 L	1.365	.3885 Ci/L	.0003 Ci/L
ASSUME NO OTHER RADIONUCLIDES FOR THE ABOVE					
FOR THE DISPERSED ORGANIC CASE:					
ISOTOPES					
14C	THICKNESS OF SUPERNATE = VOLUME (L) / 4094.5 (L/CM) ²				
90Sr					
90Y					
99Tc					
137Cs					
137Ba					
154Eu					
235U					
238U					
237Np					
238Pu					
239Pu					
240Pu					
241Pu					
241Am					
SUPERNATE VOLUME (LITERS)					
SUPERNATE DENSITY (GRAMS/CC)					
SUPERNATE THICKNESS (CM)					
SUPERNATE DIAMETER (CM)					
ALPHA ERGS PER CC-HR					
BETA ERGS PER CC-HR					
GAMMA ERGS PER CC-HR					
SUPERNATE/ORGANIC RAD/HR					
GAMMA ONLY RAD/HR					
FOR THE LAYERED ORGANIC CASE:					
SUPERNATE Ba-137 CURIES					
SUPERNATE Eu-154 CURIES					
RAD/HR TO ORGANIC LAYER					

WHC-SD-WM-CN-050 Rev 0

Attachment 2
Sample Calculation for 105AP

Tank 105 AP

isotope	Ci/L	MuV/sL	α	MeV/sL	β	MeV/sL	γ	MeV/sL	δ	erg/cm ² h
C-14	8.75-9	-	-	1.60+1	9.22-5	-	-	-	-	-
Sr-90	5.72-3	-	-	4.15+7	2.39+2	-	-	-	-	-
Y-90	5.72-3	-	-	1.98+8	1.14+3	-	-	-	-	-
Tc-99	4.46-5	-	-	1.40+5	8.05-1	8.85-1	5.10-6	-	-	-
Cs-137	1.76-2	-	-	1.11+8	6.42+2	-	-	-	-	-
Ba-137m	1.67-2	-	-	3.94+7	2.27+2	3.70+8	2.13+3	-	-	-
Pu-239	2.41-6	4.5915	2.65+0	4.35+2	2.51-3	5.83+1	3.36-4	-	-	-
Pu-240	6.02-7	1.15+5	6.62-1	1.86+2	1.07-3	3.41+1	1.97-4	-	-	-
Pu-241	2.14-7	-	-	4.14+1	2.39-4	-	-	-	-	-
Am-241	1.34-5	2.72+6	1.57+1	1.46+4	8.41-2	1.39+4	8.03-2	-	-	-
			1.90+1		2.25+3		2.13+3	-	-	-

$\frac{C_i}{L} \left[(3.7 + 10 \frac{f.s.}{C_i}) (\frac{MeV}{dis}) \right]$
 $\frac{MeV}{S.L} \left[\left(\frac{1.602 \times 10^{19} ergs}{MeV} \right) \left(\frac{1.L}{10^6 C_i} \right) \left(\frac{3600 S}{h} \right) \right]$
 $\text{grand total} = 4.40 + 3 \text{ ergs/g.h}$

$\text{Total ergs/g.h} = (4.40 + 3 \text{ ergs/cm}^2\text{h}) \left(\frac{1}{1.32 \text{ g/cm}^2} \right) = 3.83 + 3 \text{ ergs/g.h}$
 $= 3.83 + 1 \frac{rad.s}{h}$

1/2

Tank 105AP

& dose to organic layer

$$\text{Total Ba 137m} \Rightarrow (1.67 - 2 \text{ Ci/L})(7.56 + 4 \text{ L})$$

$$= 1.26 + 3 \text{ Ci}$$

WHC-SD-WM-CN-050 Rev 0

Attachment 3
MICROSHIELD Files for Organic Layer Cases

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 105AP.MSH
 Run date: July 11, 1996
 Run time: 1:51 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: tank 105AP organic dose

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	23.5	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	18.5	"
Thickness of second shield.....	T2	5.	"

Source Volume: 7.59301e+7 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.320	1.0
Zirconium		

Page 2

File: 105AP.MSH

CASE: tank 105AP organic dose

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.2600e+03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	4.195e+13	2.954e+06	6.125e+03
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		4.195e+13	2.954e+06	6.125e+03

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 103C105A.MSH
Run date: July 11, 1996
Run time: 2:04 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 103C + 105AP

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	146.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	141.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 5.78711e+8 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.10	1.0
Zirconium		

CASE: tank 103C + 105AP

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	3.1900e+04	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	1.062e+15	1.342e+07	2.782e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.062e+15	1.342e+07	2.782e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 107AP.MSH
Run date: July 11, 1996
Run time: 2:05 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 107AP

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	33.6	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	28.6	"
Thickness of second shield.....	T2	5.	"

Source Volume: 1.17384e+8 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.010	1.0
Zirconium		

Page 2

CASE: tank 107AP

File: 107AP.MSH

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	9.7700e-04	Co-60	0.0000e+00	Cs-137	0.0000e+00
Eu-154	3.8400e-04	N-16	0.0000e+00		

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.2993	5.690e+06	6.163e-01	1.119e-03
2	1.0051	4.108e+06	3.355e-01	6.469e-04
3	.8417	2.609e+06	1.847e-01	3.682e-04
4	.6676	3.669e+07	2.287e+00	4.738e-03
5	.5189	6.707e+04	3.746e-03	7.680e-06
6	.4453	7.161e+04	3.412e-03	6.978e-06
7	.3984	2.975e+04	1.198e-03	2.458e-06
8	.2422	9.380e+05	1.725e-02	3.349e-05
9	.1953	3.228e+04	4.308e-04	7.896e-07
10	.1172	5.749e+06	3.470e-02	5.477e-05
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		5.598e+07	3.484e+00	6.979e-03

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 103C107A.MSH
 Run date: July 11, 1996
 Run time: 2:06 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: tank 103C + 107AP

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	156.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	151.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 6.19754e+8 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.060	1.0
Zirconium		

Page 2

File: 103C107A.MSH

CASE: tank 103C + 107AP

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	3.0600e+04	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	1.019e+15	1.247e+07	2.585e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.019e+15	1.247e+07	2.585e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 103U105U.MSH
Run date: July 11, 1996
Run time: 2:24 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 103U + 105U + 109U + 107AP

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	480.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	475.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 1.94956e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.350	1.0
Zirconium		

CASE: tank 103U + 105U + 109U + 107AP

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	6.1400e+05	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	2.044e+16	5.879e+07	1.219e+05
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.044e+16	5.879e+07	1.219e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 103C103U.MSH
Run date: July 11, 1996
Run time: 2:08 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 103C + 103U + 105U + 109U + 107AP

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	603.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	598.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 2.45439e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.290	1.0
Zirconium		

Page 2

File: 103C103U.MSH

CASE: tank 103C + 103U + 105U + 109U + 107AP

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	6.4500e+05	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	2.147e+16	5.302e+07	1.099e+05
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		2.147e+16	5.302e+07	1.099e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 102AY.MSH
Run date: July 11, 1996
Run time: 2:10 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 102AY

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	734.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	729.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 2.99206e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.140	1.0
Zirconium		

Page 2

File: 102AY.MSH

CASE: tank 102AY

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi).....	15
Number of radial segments (Nradius).....	15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.3800e+05	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	4.594e+15	1.087e+07	2.253e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		4.594e+15	1.087e+07	2.253e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1

File : 103C102A.MSH

Run date: July 11, 1996

Run time: 2:30 p.m.

File Ref: _____

Date: ____/____/____

By: _____

Checked: _____

CASE: tank 103C + 102AY

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	855.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	850.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 3.48868e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.130	1.0
Zirconium		

CASE: tank 103C + 102AY

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.6800e+05	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	5.593e+15	1.231e+07	2.552e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		5.593e+15	1.231e+07	2.552e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 102AZ.MSH
Run date: July 11, 1996
Run time: 2:12 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: tank 102AZ

GEOMETRY 10: Cylindrical source from end - slab shields

Distance to detector.....	X	657.	cm.
Source cylinder radius.....	R	1143.	"
Source cylinder length.....	T1	652.	"
Thickness of second shield.....	T2	5.	"

Source Volume: 2.67602e+9 cubic centimeters

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.110	1.0
Zirconium		

Page 2

File: 102AZ.MSH

CASE: tank 102AZ

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

Number of angle segments (Npsi)..... 15
Number of radial segments (Nradius)..... 15

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	3.7400e+05	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	1.245e+16	3.232e+07	6.703e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		1.245e+16	3.232e+07	6.703e+04

Attachment 4
MICROSHIELD files for gamma leakage calculations

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : OCM.MSH
Run date: July 11, 1996
Run time: 3:09 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

Page 2

CASE: 0 cm

File: OCM.MSH

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	3.063e+08	6.351e+05
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	3.063e+08	6.351e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : ICM.MSH
 Run date: July 11, 1996
 Run time: 3:10 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 1 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	101.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	1.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

Page 2

CASE: 1 cm

File: ICM.MSH

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	2.532e+08	5.251e+05
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	2.532e+08	5.251e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 10CM.MSH
Run date: July 11, 1996
Run time: 3:12 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	110.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	7.430e+07	1.541e+05
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	7.430e+07	1.541e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 20CM.MSH
 Run date: July 11, 1996
 Run time: 3:13 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 20 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	120.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	20.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

Page 2

File: 20CM.MSH

CASE: 20 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	2.126e+07	4.409e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	2.126e+07	4.409e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 30CM.MSH
Run date: July 11, 1996
Run time: 3:14 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 30 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	130.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	30.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 30 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	6.237e+06	1.293e+04
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	6.237e+06	1.293e+04

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 40CM.MSH
Run date: July 11, 1996
Run time: 3:15 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 40 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	140.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	40.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 40 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	1.849e+06	3.834e+03
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	1.849e+06	3.834e+03

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : 50CM.MSH
Run date: July 11, 1996
Run time: 3:15 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 50 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	150.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	50.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	5.517e+05	1.144e+03
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	5.517e+05	1.144e+03

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 60CM.MSH
 Run date: July 11, 1996
 Run time: 3:16 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 60 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	160.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	60.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.50	1.50
Zirconium		

Page 2

File: 60CM.MSH

CASE: 60 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	1.654e+05	3.429e+02
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	1.654e+05	3.429e+02

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 70CM.MSH
 Run date: July 11, 1996
 Run time: 3:17 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 70 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	170.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	70.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.50	1.50
Zirconium		

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	4.975e+04	1.032e+02
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	4.975e+04	1.032e+02

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : 80CM.MSH
 Run date: July 11, 1996
 Run time: 3:18 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 80 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	180.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	80.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 80 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	1.0000e-03	Co-60	0.0000e+00	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6641	3.329e+07	1.501e+04	3.113e+01
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.329e+07	1.501e+04	3.113e+01

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : COOCCM.MSH
Run date: July 11, 1996
Run time: 3:19 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

Page 2

CASE: 0 cm

File: COOCM.MSH

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	0.0000e+00	Co-60	1.0000e-03	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3359	3.700e+07	6.153e+08	1.110e+06
2	1.1797	3.700e+07	5.346e+08	9.934e+05
3	.6953	6.035e+03	5.708e+04	1.176e+02
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.401e+07	1.150e+09	2.104e+06

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : CO10CM.MSH
Run date: July 11, 1996
Run time: 3:20 p.m.

File Ref: _____
Date: _____
By: _____
Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector..... X	110.	cm.
Source slab thickness..... T1	100.	"
Thickness of second shield..... T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Nuclide	Curies	Nuclide	Curies	Nuclide	Curies
Ba-137m	0.0000e+00	Co-60	1.0000e-03	Cs-137	0.0000e+00
N-16	0.0000e+00				

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3359	3.700e+07	1.847e+08	3.334e+05
2	1.1797	3.700e+07	1.534e+08	2.850e+05
3	.6953	6.035e+03	1.406e+04	2.896e+01
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		7.401e+07	3.381e+08	6.184e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : ZROCM.MSH
 Run date: July 11, 1996
 Run time: 3:21 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 0 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Zr-95: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.7578	2.048e+07	2.034e+08	4.130e+05
2	.7266	1.615e+07	1.567e+08	3.205e+05
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.663e+07	3.601e+08	7.335e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : ZR10CM.MSH
Run date: July 11, 1996
Run time: 3:21 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	110.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Zr-95: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.7578	2.048e+07	5.161e+07	1.048e+05
2	.7266	1.615e+07	3.919e+07	8.015e+04
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.663e+07	9.080e+07	1.850e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : SBOCM.MSH
 Run date: July 11, 1996
 Run time: 3:22 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 0 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Sb-125: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6371	4.859e+06	4.389e+07	9.116e+04
2	.6016	8.434e+06	7.490e+07	1.550e+05
3	.4379	1.479e+07	1.032e+08	2.112e+05
4	.4141	6.728e+04	4.346e+05	8.909e+02
5	.3828	5.534e+05	3.199e+06	6.574e+03
6	.3203	1.543e+05	6.958e+05	1.413e+03
7	.2139	2.580e+05	6.708e+05	1.259e+03
8	.1797	2.617e+06	5.397e+06	9.699e+03
9	.1641	2.580e+04	4.718e+04	8.307e+01
10	.1172	9.658e+04	1.130e+05	1.784e+02
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.186e+07	2.326e+08	4.774e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : SB10CM.MSH
 Run date: July 11, 1996
 Run time: 3:23 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	110.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Sb-125: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	.6371	4.859e+06	1.053e+07	2.187e+04
2	.6016	8.434e+06	1.774e+07	3.670e+04
3	.4379	1.479e+07	2.126e+07	4.349e+04
4	.4141	6.728e+04	8.672e+04	1.778e+02
5	.3828	5.534e+05	6.076e+05	1.248e+03
6	.3203	1.543e+05	1.181e+05	2.398e+02
7	.2139	2.580e+05	8.777e+04	1.647e+02
8	.1797	2.617e+06	6.307e+05	1.133e+03
9	.1641	2.580e+04	5.197e+03	9.150e+00
10	.1172	9.658e+04	9.780e+03	1.544e+01
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		3.186e+07	5.107e+07	1.050e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : CSOCM.MSH
Run date: July 11, 1996
Run time: 3:24 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 0 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Cs-134: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3672	1.125e+06	1.923e+07	3.451e+04
2	1.1641	6.660e+05	9.493e+06	1.770e+04
3	1.0391	3.700e+05	4.672e+06	8.945e+03
4	.8047	3.230e+06	3.307e+07	6.645e+04
5	.7891	3.160e+07	3.206e+08	6.464e+05
6	.6016	3.611e+07	3.207e+08	6.635e+05
7	.5703	8.810e+06	7.637e+07	1.575e+05
8	.4766	5.402e+05	4.239e+06	8.650e+03
9	.2734	1.310e+04	4.739e+04	9.399e+01
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.246e+07	7.884e+08	1.604e+06

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : CS10CM.MSH
 Run date: July 11, 1996
 Run time: 3:25 p.m.

File Ref: _____
 Date: _____
 By: _____
 Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	110.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Cs-134: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.3672	1.125e+06	5.831e+06	1.046e+04
2	1.1641	6.660e+05	2.713e+06	5.059e+03
3	1.0391	3.700e+05	1.294e+06	2.477e+03
4	.8047	3.230e+06	8.562e+06	1.720e+04
5	.7891	3.160e+07	8.251e+07	1.664e+05
6	.6016	3.611e+07	7.596e+07	1.572e+05
7	.5703	8.810e+06	1.773e+07	3.656e+04
8	.4766	5.402e+05	9.182e+05	1.873e+03
9	.2734	1.310e+04	7.237e+03	1.435e+01
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		8.246e+07	1.955e+08	3.972e+05

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
File : EU0CM.MSH
Run date: July 11, 1996
Run time: 3:26 p.m.

File Ref: _____
Date: ____/____/____
By: _____
Checked: _____

CASE: 0 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	100.001	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	0.001	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 0 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Eu-154: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.2993	1.482e+07	2.384e+08	4.329e+05
2	1.0051	1.070e+07	1.302e+08	2.510e+05
3	.8417	6.794e+06	7.151e+07	1.425e+05
4	.6954	1.083e+07	1.024e+08	2.109e+05
5	.5189	1.747e+05	1.444e+06	2.959e+03
6	.4453	1.865e+05	1.332e+06	2.724e+03
7	.3984	7.749e+04	4.749e+05	9.745e+02
8	.2422	2.443e+06	7.481e+06	1.453e+04
9	.1953	8.405e+04	1.941e+05	3.558e+02
10	.1172	1.497e+07	1.752e+07	2.765e+04
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		6.108e+07	5.710e+08	1.087e+06

Microshield 3.12

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(Westinghouse Hanford Company - #197)

Page : 1
 File : EU10CM.MSH
 Run date: July 11, 1996
 Run time: 3:26 p.m.

File Ref: _____
 Date: ____/____/____
 By: _____
 Checked: _____

CASE: 10 cm

GEOMETRY 14: Infinite slab source - slab shields

Distance to detector.....	X	110.	cm.
Source slab thickness.....	T1	100.	"
Thickness of second shield.....	T2	10.	"

MATERIAL DENSITIES (g/cc):

Material	Source	Shield 2
-----	-----	-----
Air		
Aluminum		
Carbon		
Concrete		
Hydrogen		
Iron		
Lead		
Lithium		
Nickel		
Tin		
Titanium		
Tungsten		
Urania		
Uranium		
Water	1.50	1.50
Zirconium		

CASE: 10 cm

BUILDUP FACTOR: based on TAYLOR method.
Using the characteristics of the materials in shield 1.

INTEGRATION PARAMETERS:

None - analytically integrated.

SOURCE NUCLIDES:

Eu-154: 1.0000e-03 curies

RESULTS:

Group #	Energy (MeV)	Activity (photons/sec)	Dose point flux MeV/(sq cm)/sec	Dose rate (mr/hr)
1	1.2993	1.482e+07	7.075e+07	1.285e+05
2	1.0051	1.070e+07	3.573e+07	6.889e+04
3	.8417	6.794e+06	1.870e+07	3.728e+04
4	.6954	1.083e+07	2.524e+07	5.197e+04
5	.5189	1.747e+05	3.239e+05	6.640e+02
6	.4453	1.865e+05	2.770e+05	5.664e+02
7	.3984	7.749e+04	9.274e+04	1.903e+02
8	.2422	2.443e+06	1.053e+06	2.046e+03
9	.1953	8.405e+04	2.407e+04	4.412e+01
10	.1172	1.497e+07	1.516e+06	2.393e+03
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
TOTALS:		6.108e+07	1.537e+08	2.925e+05

CHECKLIST FOR PEER REVIEW

Document Reviewed: VERIFICATION OF DST ENERGY DEPOSITION RATES AND DEVELOPMENT OF CORRECTION FOR GAMMA LOSSES, D.A. Himes, 7/8/96

Scope of Review: entire document

Yes	No	NA	
☐	☐	☒	* Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☐	☐	☒	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☒	☐	☐	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be <i>spot checked</i> treated exactly the same as hand calculations.
☒	☐	☐	Software input correct and consistent with document reviewed.
☐	☐	☐	Software output consistent with input and with results reported in document reviewed.
☐	☐	☒	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☐	☐	☒	Format consistent with appropriate NRC Regulatory Guide or other standards
☐	☐	☒	* Review calculations, comments, and/or notes are attached.
☒	☐	☐	Document approved.

C. H. Huang (C. H. Huang)
Reviewer (Printed Name and Signature)

7/29/96
Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

DISTRIBUTION SHEET

To	From	Page 1 of 1				
Process Technology 73510	Consequence Analysis 8M400	Date 7/9/96				
Project Title/Work Order		EDT No. 156488				
Verification of DST Energy Deposition Rates and Development of Correction for Gamma Losses		ECN No. N/A				
Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only	
G.F. Boothe	H5-27	X				
D.A. Himes (2)	A3-34	X				
C.H. Huang	A3-34	X				
J.C. Van Keuren	A3-34	X				
D.J. Washenfelder	H5-27	X				
Central Files (original + 3)	A3-88	X				
Docket Files (2)	B1-17	X				