

**ENGINEERING CALCULATIONS AND ANALYSIS REPORT**

ECAR No.: 619 ECAR Rev. No.: 0 Project File No.: 0409-C.R-10-000935 Date: 5/4/2009

Title: RSWF REMOTE HANDLED TRANSURANIC WASTE TRANSFER DOSE RATE ANALYSIS

1. Index Codes	Building/Type: RSWF	SSC ID: N/A	Site Area: Materials and Fuels Complex
2. Quality Level:	3		
3. Objective/Purpose	This ECAR calculates the expected individual dose and dose rate for the open air transfer of remote handled transuranic RH-TRU waste from storage liners in the Radioactive Scrap and Waste Facility (RSWF) into a transport container. The maximally exposed individual is expected to be the crane operator.		
4. Conclusions/Recommendations	The exposure rate to the crane operator would be expected to be less than 5 R/hr, if the waste container is maintained at a distance of 30 feet or more from the cab of the crane. This is well within the capability of the crane that is planned to be employed for these transfers. If the waste can is transferred with 30 feet spacing between the load and the crane, the operator would be expected to receive 105 mrem.		

5. Review (R) and Approval (A) and Acceptance (Ac) <sup>1</sup> :			
		Typed Name/Organization	Signature/Date <sup>2</sup>
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Nuclear Safety <sup>3</sup>	Ac	Greg A. Hula / W301	<i>Greg A. Hula</i> 5/4/09

1 Review and Approval are required. See LWP-10200 for definitions and responsibilities.  
 2 An Electronic Change Request (ECR) indicating final review and concurrence by the listed individuals can be used in lieu of signatures.  
 3 If Required, per LWP-10200.

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**Scope and Brief Description**

Remote handled transuranic (RH-TRU) waste stored in storage liners of the Radioactive Scrap and Waste Facility (RSWF) are to be removed and transferred from RSWF to Idaho Nuclear Technology and Engineering Complex (INTEC) for repackaging and eventual shipment to the Waste Isolation Pilot Project (WIPP) in Carlsbad New Mexico. The laboratory will open the storage liners, connect onto the waste container and transfer it with a free air transfer to a shielded shipping cask. The shipment of the cask and further disposition of the waste will be performed by an independent DOE contractor.

This ECAR calculates the expected individual dose and dose rate for the transfer of remote handled transuranic waste from storage liners in the RSWF to a transport container. The maximally exposed individual is expected to be the crane operator.

**Design Inputs and Sources**

The quality level for this analysis was based on Quality Level Determination: All-000477, Calculation and Analysis of Radionuclide Inventory and Dose Rate.

**Results of Literature Searches and Other Background Data**

None

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### Assumptions

1. Radionuclide inventory was obtained from Sealion Database, Liner C-51, Primary Container SN129. Radionuclide inventory was decayed for 10 years using Microshield, Version 7.02 by Grove Software. A listing of the initial radionuclide inventory and the decayed inventory is provided in Appendix A.
2. The mass of the waste was obtained from the Sealion Database as 164597 grams. Waste was assumed to be evenly distributed through a right cylindrical volume with a diameter of 11.6 inches (29.5 cm) and a height of 61 inches (155 cm). The total volume is 6446.7 cubic inches (105642 cm<sup>3</sup>) and the average density is 1.56 g/cm<sup>3</sup>.
3. Shielding provided by the inner and outer waste cans was ignored in this evaluation.
4. Discussed the RH-TRU remote handled transuranic waste transfer operations with the supervisor of the Material Handler personnel at MFC to determine the expected distances from the waste can when it is suspended from the crane and the crane operator. The crane that is planned for use at MFC for these transfers suspends the load between 20 feet and 75 feet from the crane operator. Dose rates were calculated at 20, 30, 40, 50 and 60 feet.
5. The supervisor also estimated that a normal transfer time from leaving the RSWF liner to placement of the waste can in the shipping cask is approximately 1.5 minutes. Dose was calculated for 1.5 minutes and 5 minutes to provide an expected dose and a bounding dose.

### Computer Code Validation

Computer calculations were performed using the following computer:

System Property No.	383296
OS Name	Microsoft Windows XP Professional
Version	5.1.2600 Service Pack 2 Build 2600
System Manufacturer	Dell Inc.
System Model	OptiPlex GX620
Processor	x86 Family15Model 4 Stepping 1 Genuine Intel 2800 Mhz
BIOS Version/Date	Dell Inc. A05, 10/13/2005
Total Physical Memory	1,024.00 MB

Spreadsheet calculations were performed using the following software:

Application Name	Microsoft Office Excel 2003
Version	11.0
Build	8237
Product ID	73931-640-8047002-57560
Language	English (United States)

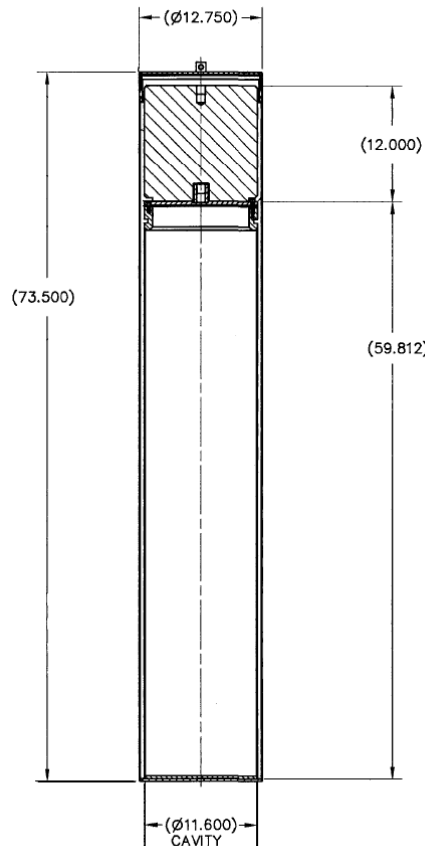
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Shielding calculations were performed using MicroShield, Version 7.02 by Grove Software, Inc. licensed to the Idaho National Laboratory. It is a radiological safety analysis and engineering program that has been used extensively at the INL. It has been independently verified and validated for these types of calculations.

**Body**

The expected and bounding individual dose and dose rate for the transfer of the RH-TRU remote handled transuranic waste container SN129 from storage liners in the RSWF to a shipping cask are calculated. Waste container SN129 is the container that had the highest external radiation levels when transferred to RSWF, based on review of the population of RH-TRU containers identified for retrieval under the RH-TRU project. It was therefore chosen to provide a bounding radiation dose and dose rates for this analysis.

The original radionuclide inventory was obtained from the Sealion Database and it was modeled using the dimensions from a typical HFEF waste container (see Appendix B for Microshield output). See Figure 1 for a dimensional drawing of a waste container with a steel shield plug. The result of this analysis compared well with the recorded dose rates in the Sealion Database. The calculated dose rate was 1.368E+07 mR/hr and the recorded dose rate was 1.4E+07 mR/hr.



**Figure 1 - Typical HFEF Waste Can**

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The dose rates were then calculated for the same configuration with the radionuclides decayed for 10 year (this would correspond to a date of 6/25/2009). See Appendix C for the Microshield output. The dose to the crane operator is calculated for each distance both as a best approximation (1.5 minute transfer) and a bounding level (5 minute transfer). The results are tabulated in the following table.

Distance from Container SN129	Dose Rate (R/hr) with Original Radionuclides	Dose Rate (R/hr) with Decayed Radionuclides	Expected Dose (mrem) 1.5 min Transfer	Bounding Dose (mrem) 5 min Transfer
Contact Reading	13680.0	3672.0	N/A	N/A
20 Feet	34.9	9.3	235	782
30 Feet	15.7	4.2	105	351
40 Feet	8.8	2.3	59	198
50 Feet	5.6	1.5	38	126
60 Feet	3.9	1.0	26	87

**Conclusions**

The exposure rate to the crane operator would be expected to be less than 5 R/hr, if the waste container is maintained at a distance of 30 feet or more from the cab of the crane. This is well within the capability of the crane that is planned to be employed for these transfers. If the waste can is transferred with 30 feet spacing between the load and the crane, the operator would be expected to receive 105 mrem.

**PE Stamp**

None

**References**

Drawing 732856, W0147-0264-ED-04, South Inner Waste Can Assembly  
Sealion Database, Liner C-51, Primary Container SN129, (see PLN-3066, Radioactive Scrap and Waste Facility—Sealion Database and Liner Characterization Stage 1)

**Appendices**

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**Appendix A**

**Radionuclide Source Term for the Waste Can SN129**

<b>Radionuclide</b>	<b>Initial Activity (Ci)</b>	<b>Decayed Activity (Ci)</b>
Ac-225	-	5.55E-13
Ac-227	-	6.28E-09
Am-241	3.84E-07	3.78E-07
At-217	-	5.55E-13
Ba-137m	1.17E-03	9.32E-04
Bi-210	-	2.95E-18
Bi-211	-	6.14E-09
Bi-213	-	5.55E-13
Bi-214	-	4.10E-17
Ce-144	2.83E-04	3.84E-08
Co-57	1.83E-04	1.60E-08
Co-60	1.50E+03	4.03E+02
Cs-134	7.51E-05	2.60E-06
Cs-137	1.24E-03	9.85E-04
Eu-155	2.65E-05	6.55E-06
Fr-221	-	5.55E-13
Fr-223	-	8.66E-11
Mn-54	2.12E+00	6.46E-04
Np-237	2.81E-05	2.81E-05
Pa-231	-	4.38E-08
Pa-233	-	2.81E-05
Pa-234	-	3.68E-08
Pa-234m	-	2.30E-05
Pb-209	-	5.55E-13
Pb-210	-	2.98E-18
Pb-211	-	6.14E-09
Pb-214	-	4.10E-17
Po-210	-	2.40E-18
Po-211	-	1.68E-11

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<b>Radionuclide</b>	<b>Initial Activity (Ci)</b>	<b>Decayed Activity (Ci)</b>
Po-213	-	5.43E-13
Po-214	-	4.10E-17
Po-215	-	6.14E-09
Po-218	-	4.10E-17
Pr-144	2.79E-04	3.84E-08
Pr-144m	-	5.49E-10
Pu-239	4.18E-01	4.18E-01
Ra-223	-	6.14E-09
Ra-225	-	5.60E-13
Ra-226	-	4.12E-17
Rn-219	-	6.14E-09
Rn-222	-	4.10E-17
Sb-125	4.64E-05	3.80E-06
Sr-85	3.09E-05	3.41E-22
Sr-90	3.31E-03	2.60E-03
Te-125m	-	9.31E-07
Th-227	-	6.10E-09
Th-229	-	5.66E-13
Th-230	-	2.88E-14
Th-231	-	2.07E-04
Th-234	-	2.30E-05
Tl-207	-	6.12E-09
Tl-209	-	1.20E-14
U-233	-	1.21E-09
U-234	-	6.46E-10
U-235	2.07E-04	2.07E-04
U-238	2.30E-05	2.30E-05
Y-90	3.31E-03	2.60E-03

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**Appendix B**

**Dose Rates from Bare Waste Can SN129 – No Decay**

<b>MicroShield 7.02 INL (7.02-0000)</b>				
<b>Date</b>		<b>By</b>		<b>Checked</b>
<b>Filename</b>		<b>Run Date</b>	<b>Run Time</b>	<b>Duration</b>
RSWF Waste Initial - Bare.ms7		April 30, 2009	10:05:10 AM	00:00:14
<b>Project Info</b>				
Case Title		RSWF - RHTRU		
Description		Waste Container SN129 - Initial Dose Rates		
Geometry		7 - Cylinder Volume - Side Shields		
<b>Source Dimensions</b>				
Height		154.94 cm (5 ft 1.0 in)		
Radius		14.732 cm (5.8 in)		
<b>Dose Points</b>				
A	X	Y	Z	
#1	17.272 cm (6.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#2	624.332 cm (20 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#3	929.132 cm (30 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#4	1.2e+3 cm (40 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#5	1.5e+3 cm (50 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#6	1.8e+3 cm (60 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
<b>Shields</b>				
Shield N	Dimension	Material	Density	
Source	6446.674 in <sup>3</sup>	Iron	1.56	
Transition		Air	0.00122	
Air Gap		Air	0.00122	
<b>Source Input: Grouping Method - Standard Indices</b>				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Included				
Library: Grove				
Nuclide	Ci	Bq	µCi/cm <sup>3</sup>	Bq/cm <sup>3</sup>
Am-241	3.8400e-007	1.4208e+004	3.6349e-006	1.3449e-001
Ba-137m	1.1730e-003	4.3402e+007	1.1104e-002	4.1084e+002
Ce-144	2.8300e-004	1.0471e+007	2.6789e-003	9.9118e+001





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Co-57	1.8300e-004	6.7710e+006	1.7323e-003	6.4094e+001	
Co-60	1.5028e+003	5.5604e+013	1.4225e+004	5.2634e+008	
Cs-134	7.5100e-005	2.7787e+006	7.1089e-004	2.6303e+001	
Cs-137	1.2400e-003	4.5880e+007	1.1738e-002	4.3430e+002	
Eu-155	2.6500e-005	9.8050e+005	2.5085e-004	9.2813e+000	
Mn-54	2.1200e+000	7.8440e+010	2.0068e+001	7.4251e+005	
Np-237	2.8143e-005	1.0413e+006	2.6640e-004	9.8568e+000	
Pr-144	2.7895e-004	1.0321e+007	2.6405e-003	9.7700e+001	
Pu-239	4.1790e-001	1.5462e+010	3.9558e+000	1.4637e+005	
Sb-125	4.6400e-005	1.7168e+006	4.3922e-004	1.6251e+001	
Sr-85	3.0900e-005	1.1433e+006	2.9250e-004	1.0822e+001	
Sr-90	3.3100e-003	1.2247e+008	3.1332e-002	1.1593e+003	
U-235	2.0688e-004	7.6546e+006	1.9583e-003	7.2458e+001	
U-238	2.3006e-005	8.5122e+005	2.1777e-004	8.0576e+000	
Y-90	3.3100e-003	1.2247e+008	3.1332e-002	1.1593e+003	
<b>Buildup: The material reference is Transition Integration Parameters</b>					
Radial				20	
Circumferential				20	
Y Direction (axial)				40	
<b>Results - Dose Point # 1 - (6.8,30.5,0) in</b>					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm <sup>2</sup> /sec No Buildup	Fluence Rate MeV/cm <sup>2</sup> /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.066e+10	3.398e-01	4.769e-01	2.915e-02	4.091e-02
0.03	3.523e+06	2.201e-02	5.596e-02	2.182e-04	5.546e-04
0.04	1.793e+06	3.868e-02	1.382e-01	1.711e-04	6.114e-04
0.05	5.926e+04	3.086e-03	1.509e-02	8.220e-06	4.019e-05
0.06	3.687e+04	3.821e-03	2.260e-02	7.590e-06	4.489e-05
0.08	8.220e+05	2.347e-01	1.547e+00	3.713e-04	2.448e-03
0.1	1.405e+07	8.051e+00	5.086e+01	1.232e-02	7.781e-02
0.15	3.051e+06	4.860e+00	2.485e+01	8.003e-03	4.092e-02
0.2	4.858e+06	1.349e+01	5.612e+01	2.381e-02	9.905e-02
0.3	8.144e+03	4.333e-02	1.405e-01	8.219e-05	2.666e-04
0.4	5.375e+05	4.348e+00	1.210e+01	8.472e-03	2.357e-02
0.5	1.355e+06	1.503e+01	3.763e+01	2.950e-02	7.387e-02
0.6	9.113e+09	1.304e+05	3.014e+05	2.545e+02	5.884e+02

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0.8	7.842e+10	1.675e+06	3.446e+06	3.186e+03	6.554e+03
1.0	5.560e+13	1.619e+09	3.083e+09	2.985e+06	5.684e+06
1.5	5.560e+13	2.830e+09	4.750e+09	4.761e+06	7.991e+06
2.0	7.989e+04	5.954e+00	9.289e+00	9.208e-03	1.436e-02
<b>Totals</b>	<b>1.113e+14</b>	<b>4.451e+09</b>	<b>7.837e+09</b>	<b>7.749e+06</b>	<b>1.368e+07</b>
<b>Results - Dose Point # 2 - (245.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	2.066e+10	7.026e-04	1.003e-03	6.027e-05	8.606e-05
0.03	3.523e+06	5.695e-05	1.480e-04	5.644e-07	1.466e-06
0.04	1.793e+06	9.728e-05	3.761e-04	4.302e-07	1.664e-06
0.05	5.926e+04	7.767e-06	4.189e-05	2.069e-08	1.116e-07
0.06	3.687e+04	9.677e-06	6.351e-05	1.922e-08	1.261e-07
0.08	8.220e+05	6.014e-04	4.400e-03	9.517e-07	6.963e-06
0.1	1.405e+07	2.082e-02	1.443e-01	3.185e-05	2.208e-04
0.15	3.051e+06	1.270e-02	6.944e-02	2.092e-05	1.144e-04
0.2	4.858e+06	3.546e-02	1.540e-01	6.258e-05	2.718e-04
0.3	8.144e+03	1.146e-04	3.773e-04	2.174e-07	7.157e-07
0.4	5.375e+05	1.154e-02	3.211e-02	2.249e-05	6.256e-05
0.5	1.355e+06	3.996e-02	9.909e-02	7.843e-05	1.945e-04
0.6	9.113e+09	3.469e+02	7.893e+02	6.772e-01	1.541e+00
0.8	7.842e+10	4.454e+03	8.937e+03	8.472e+00	1.700e+01
1.0	5.560e+13	4.298e+06	7.943e+06	7.923e+03	1.464e+04
1.5	5.560e+13	7.459e+06	1.207e+07	1.255e+04	2.031e+04
2.0	7.989e+04	1.560e-02	2.341e-02	2.412e-05	3.620e-05
<b>Totals</b>	<b>1.113e+14</b>	<b>1.176e+07</b>	<b>2.003e+07</b>	<b>2.048e+04</b>	<b>3.497e+04</b>
<b>Results - Dose Point # 3 - (365.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	2.066e+10	1.806e-04	2.614e-04	1.549e-05	2.242e-05
0.03	3.523e+06	2.273e-05	6.176e-05	2.253e-07	6.121e-07
0.04	1.793e+06	4.019e-05	1.641e-04	1.777e-07	7.259e-07
0.05	5.926e+04	3.256e-06	1.859e-05	8.673e-09	4.952e-08
0.06	3.687e+04	4.086e-06	2.827e-05	8.116e-09	5.614e-08
0.08	8.220e+05	2.557e-04	1.966e-03	4.046e-07	3.111e-06
0.1	1.405e+07	8.884e-03	6.456e-02	1.359e-05	9.878e-05

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0.15	3.051e+06	5.456e-03	3.113e-02	8.985e-06	5.127e-05
0.2	4.858e+06	1.530e-02	6.909e-02	2.701e-05	1.219e-04
0.3	8.144e+03	4.978e-05	1.693e-04	9.442e-08	3.211e-07
0.4	5.375e+05	5.034e-03	1.440e-02	9.808e-06	2.806e-05
0.5	1.355e+06	1.749e-02	4.445e-02	3.432e-05	8.724e-05
0.6	9.113e+09	1.522e+02	3.540e+02	2.971e-01	6.910e-01
0.8	7.842e+10	1.962e+03	4.009e+03	3.731e+00	7.626e+00
1.0	5.560e+13	1.898e+06	3.564e+06	3.499e+03	6.570e+03
1.5	5.560e+13	3.309e+06	5.421e+06	5.568e+03	9.121e+03
2.0	7.989e+04	6.939e-03	1.052e-02	1.073e-05	1.627e-05
<b>Totals</b>	<b>1.113e+14</b>	<b>5.210e+06</b>	<b>8.990e+06</b>	<b>9.071e+03</b>	<b>1.570e+04</b>
<b>Results - Dose Point # 4 - (485.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	2.066e+10	5.810e-05	8.496e-05	4.983e-06	7.288e-06
0.03	3.523e+06	1.140e-05	3.228e-05	1.130e-07	3.199e-07
0.04	1.793e+06	2.087e-05	8.953e-05	9.229e-08	3.960e-07
0.05	5.926e+04	1.714e-06	1.034e-05	4.566e-09	2.755e-08
0.06	3.687e+04	2.166e-06	1.578e-05	4.302e-09	3.135e-08
0.08	8.220e+05	1.364e-04	1.101e-03	2.159e-07	1.743e-06
0.1	1.405e+07	4.759e-03	3.621e-02	7.280e-06	5.540e-05
0.15	3.051e+06	2.941e-03	1.749e-02	4.844e-06	2.881e-05
0.2	4.858e+06	8.286e-03	3.885e-02	1.462e-05	6.857e-05
0.3	8.144e+03	2.712e-05	9.520e-05	5.145e-08	1.806e-07
0.4	5.375e+05	2.754e-03	8.099e-03	5.366e-06	1.578e-05
0.5	1.355e+06	9.598e-03	2.499e-02	1.884e-05	4.906e-05
0.6	9.113e+09	8.376e+01	1.991e+02	1.635e-01	3.886e-01
0.8	7.842e+10	1.083e+03	2.255e+03	2.061e+00	4.289e+00
1.0	5.560e+13	1.051e+06	2.005e+06	1.938e+03	3.696e+03
1.5	5.560e+13	1.841e+06	3.052e+06	3.098e+03	5.134e+03
2.0	7.989e+04	3.871e-03	5.925e-03	5.987e-06	9.162e-06
<b>Totals</b>	<b>1.113e+14</b>	<b>2.894e+06</b>	<b>5.059e+06</b>	<b>5.038e+03</b>	<b>8.835e+03</b>
<b>Results - Dose Point # 5 - (605.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	2.066e+10	2.118e-05	3.124e-05	1.817e-06	2.679e-06

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0.03	3.523e+06	6.488e-06	1.908e-05	6.430e-08	1.891e-07
0.04	1.793e+06	1.230e-05	5.537e-05	5.438e-08	2.449e-07
0.05	5.926e+04	1.024e-06	6.503e-06	2.727e-09	1.732e-08
0.06	3.687e+04	1.302e-06	9.985e-06	2.586e-09	1.983e-08
0.08	8.220e+05	8.255e-05	6.993e-04	1.306e-07	1.107e-06
0.1	1.405e+07	2.891e-03	2.303e-02	4.423e-06	3.524e-05
0.15	3.051e+06	1.798e-03	1.114e-02	2.961e-06	1.835e-05
0.2	4.858e+06	5.089e-03	2.476e-02	8.981e-06	4.370e-05
0.3	8.144e+03	1.676e-05	6.068e-05	3.179e-08	1.151e-07
0.4	5.375e+05	1.709e-03	5.162e-03	3.330e-06	1.006e-05
0.5	1.355e+06	5.975e-03	1.593e-02	1.173e-05	3.127e-05
0.6	9.113e+09	5.226e+01	1.269e+02	1.020e-01	2.477e-01
0.8	7.842e+10	6.786e+02	1.437e+03	1.291e+00	2.734e+00
1.0	5.560e+13	6.603e+05	1.279e+06	1.217e+03	2.357e+03
1.5	5.560e+13	1.161e+06	1.947e+06	1.954e+03	3.276e+03
2.0	7.989e+04	2.449e-03	3.783e-03	3.787e-06	5.850e-06
<b>Totals</b>	<b>1.113e+14</b>	<b>1.822e+06</b>	<b>3.227e+06</b>	<b>3.173e+03</b>	<b>5.636e+03</b>
<b>Results - Dose Point # 6 - (725.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	2.066e+10	8.367e-06	1.244e-05	7.177e-07	1.067e-06
0.03	3.523e+06	4.002e-06	1.218e-05	3.966e-08	1.208e-07
0.04	1.793e+06	7.853e-06	3.706e-05	3.473e-08	1.639e-07
0.05	5.926e+04	6.625e-07	4.415e-06	1.765e-09	1.176e-08
0.06	3.687e+04	8.482e-07	6.837e-06	1.685e-09	1.358e-08
0.08	8.220e+05	5.413e-05	4.807e-04	8.566e-08	7.607e-07
0.1	1.405e+07	1.903e-03	1.586e-02	2.912e-06	2.427e-05
0.15	3.051e+06	1.191e-03	7.684e-03	1.962e-06	1.265e-05
0.2	4.858e+06	3.386e-03	1.709e-02	5.976e-06	3.016e-05
0.3	8.144e+03	1.122e-05	4.189e-05	2.128e-08	7.946e-08
0.4	5.375e+05	1.149e-03	3.563e-03	2.239e-06	6.943e-06
0.5	1.355e+06	4.029e-03	1.100e-02	7.908e-06	2.159e-05
0.6	9.113e+09	3.533e+01	8.760e+01	6.896e-02	1.710e-01
0.8	7.842e+10	4.604e+02	9.925e+02	8.757e-01	1.888e+00
1.0	5.560e+13	4.492e+05	8.831e+05	8.280e+02	1.628e+03
1.5	5.560e+13	7.937e+05	1.346e+06	1.335e+03	2.265e+03

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2.0	7.989e+04	1.678e-03	2.617e-03	2.595e-06	4.046e-06
<b>Totals</b>	<b>1.113e+14</b>	<b>1.243e+06</b>	<b>2.230e+06</b>	<b>2.164e+03</b>	<b>3.894e+03</b>

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**Appendix C**

**Dose Rates from Bare Waste Can SN129 – 10 Year Decay**

<b>MicroShield 7.02 INL (7.02-0000)</b>				
<b>Date</b>		<b>By</b>		<b>Checked</b>
<b>Filename</b>		<b>Run Date</b>	<b>Run Time</b>	<b>Duration</b>
RSWF Waste Decayed - Bare.ms7		April 30, 2009	10:01:50 AM	00:00:15
<b>Project Info</b>				
Case Title		RSWF - RHTRU		
Description		Waste Container SN129 - Decayed Dose Rates		
Geometry		7 - Cylinder Volume - Side Shields		
<b>Source Dimensions</b>				
Height		154.94 cm (5 ft 1.0 in)		
Radius		14.732 cm (5.8 in)		
<b>Dose Points</b>				
A	X	Y	Z	
#1	17.272 cm (6.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#2	624.332 cm (20 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#3	929.132 cm (30 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#4	1.2e+3 cm (40 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#5	1.5e+3 cm (50 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
#6	1.8e+3 cm (60 ft 5.8 in)	77.47 cm (2 ft 6.5 in)	0.0 cm (0.0 in)	
<b>Shields</b>				
Shield N	Dimension	Material	Density	
Source	6446.674 in <sup>3</sup>	Iron	1.56	
Transition		Air	0.00122	
Air Gap		Air	0.00122	
<b>Source Input: Grouping Method - Standard Indices</b>				
Number of Groups: 25				
Lower Energy Cutoff: 0.015				
Photons < 0.015: Included				
Library: Grove				
Nuclide	Ci	Bq	µCi/cm <sup>3</sup>	Bq/cm <sup>3</sup>
Ac-225	5.5505e-013	2.0537e-002	5.2540e-012	1.9440e-007
Ac-227	6.2780e-009	2.3229e+002	5.9427e-008	2.1988e-003
Am-241	3.7789e-007	1.3982e+004	3.5771e-006	1.3235e-001



**ENGINEERING CALCULATIONS AND ANALYSIS REPORT**

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At-217	5.5505e-013	2.0537e-002	5.2540e-012	1.9440e-007
Ba-137m	9.3226e-004	3.4493e+007	8.8247e-003	3.2651e+002
Bi-210	2.9532e-018	1.0927e-007	2.7955e-017	1.0343e-012
Bi-211	6.1381e-009	2.2711e+002	5.8103e-008	2.1498e-003
Bi-213	5.5503e-013	2.0536e-002	5.2539e-012	1.9439e-007
Bi-214	4.0968e-017	1.5158e-006	3.8780e-016	1.4348e-011
Ce-144	3.8402e-008	1.4209e+003	3.6351e-007	1.3450e-002
Co-57	1.5985e-008	5.9145e+002	1.5131e-007	5.5986e-003
Co-60	4.0346e+002	1.4928e+013	3.8191e+003	1.4131e+008
Cs-134	2.6046e-006	9.6371e+004	2.4655e-005	9.1225e-001
Cs-137	9.8547e-004	3.6462e+007	9.3284e-003	3.4515e+002
Eu-155	6.5513e-006	2.4240e+005	6.2015e-005	2.2945e+000
Fr-221	5.5505e-013	2.0537e-002	5.2540e-012	1.9440e-007
Fr-223	8.6635e-011	3.2055e+000	8.2008e-010	3.0343e-005
Mn-54	6.4587e-004	2.3897e+007	6.1138e-003	2.2621e+002
Np-237	2.8143e-005	1.0413e+006	2.6640e-004	9.8568e+000
Pa-231	4.3750e-008	1.6187e+003	4.1413e-007	1.5323e-002
Pa-233	2.8143e-005	1.0413e+006	2.6640e-004	9.8568e+000
Pa-234	3.6810e-008	1.3620e+003	3.4844e-007	1.2892e-002
Pa-234m	2.3006e-005	8.5122e+005	2.1777e-004	8.0576e+000
Pb-209	5.5497e-013	2.0534e-002	5.2533e-012	1.9437e-007
Pb-210	2.9798e-018	1.1025e-007	2.8206e-017	1.0436e-012
Pb-211	6.1381e-009	2.2711e+002	5.8103e-008	2.1498e-003
Pb-214	4.0972e-017	1.5160e-006	3.8784e-016	1.4350e-011
Po-210	2.4038e-018	8.8940e-008	2.2754e-017	8.4190e-013
Po-211	1.6757e-011	6.2001e-001	1.5862e-010	5.8690e-006
Po-213	5.4304e-013	2.0093e-002	5.1404e-012	1.9019e-007
Po-214	4.0960e-017	1.5155e-006	3.8773e-016	1.4346e-011
Po-215	6.1382e-009	2.2711e+002	5.8104e-008	2.1498e-003
Po-218	4.0981e-017	1.5163e-006	3.8793e-016	1.4353e-011
Pr-144	3.8403e-008	1.4209e+003	3.6352e-007	1.3450e-002
Pr-144m	5.4915e-010	2.0319e+001	5.1983e-009	1.9234e-004
Pu-239	4.1778e-001	1.5458e+010	3.9547e+000	1.4632e+005
Ra-223	6.1382e-009	2.2711e+002	5.8104e-008	2.1498e-003
Ra-225	5.5952e-013	2.0702e-002	5.2964e-012	1.9597e-007
Ra-226	4.1161e-017	1.5229e-006	3.8962e-016	1.4416e-011

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Rn-219	6.1382e-009	2.2711e+002	5.8104e-008	2.1498e-003	
Rn-222	4.0982e-017	1.5163e-006	3.8793e-016	1.4353e-011	
Sb-125	3.7999e-006	1.4059e+005	3.5969e-005	1.3309e+000	
Sr-85	3.4092e-022	1.2614e-011	3.2271e-021	1.1940e-016	
Sr-90	2.5976e-003	9.6111e+007	2.4589e-002	9.0978e+002	
Te-125m	9.3115e-007	3.4452e+004	8.8142e-006	3.2612e-001	
Th-227	6.1049e-009	2.2588e+002	5.7789e-008	2.1382e-003	
Th-229	5.6617e-013	2.0948e-002	5.3593e-012	1.9830e-007	
Th-230	2.8801e-014	1.0656e-003	2.7263e-013	1.0087e-008	
Th-231	2.0688e-004	7.6547e+006	1.9583e-003	7.2459e+001	
Th-234	2.3006e-005	8.5122e+005	2.1777e-004	8.0576e+000	
Tl-207	6.1213e-009	2.2649e+002	5.7944e-008	2.1439e-003	
Tl-209	1.1989e-014	4.4358e-004	1.1348e-013	4.1989e-009	
U-233	1.2122e-009	4.4853e+001	1.1475e-008	4.2457e-004	
U-234	6.4599e-010	2.3902e+001	6.1149e-009	2.2625e-004	
U-235	2.0688e-004	7.6547e+006	1.9583e-003	7.2459e+001	
U-238	2.3006e-005	8.5122e+005	2.1777e-004	8.0576e+000	
Y-90	2.5983e-003	9.6136e+007	2.4595e-002	9.1002e+002	
<b>Buildup: The material reference is Transition Integration Parameters</b>					
Radial				20	
Circumferential				20	
Y Direction (axial)				40	
<b>Results - Dose Point # 1 - (6.8,30.5,0) in</b>					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm <sup>2</sup> /sec No Buildup	Fluence Rate MeV/cm <sup>2</sup> /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.979e+08	1.148e-02	1.611e-02	9.847e-04	1.382e-03
0.02	6.142e+00	2.997e-09	5.202e-09	1.038e-10	1.802e-10
0.03	3.403e+06	2.126e-02	5.404e-02	2.107e-04	5.356e-04
0.04	5.318e+05	1.147e-02	4.100e-02	5.073e-05	1.813e-04
0.05	1.577e+04	8.212e-04	4.015e-03	2.188e-06	1.070e-05
0.06	8.221e+04	8.520e-03	5.039e-02	1.692e-05	1.001e-04
0.08	1.140e+06	3.255e-01	2.146e+00	5.151e-04	3.396e-03
0.1	8.716e+06	4.996e+00	3.156e+01	7.643e-03	4.828e-02
0.15	1.211e+06	1.929e+00	9.863e+00	3.176e-03	1.624e-02
0.2	4.739e+06	1.316e+01	5.474e+01	2.323e-02	9.662e-02



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0.3	5.222e+05	2.779e+00	9.012e+00	5.271e-03	1.710e-02
0.4	8.074e+04	6.531e-01	1.817e+00	1.273e-03	3.541e-03
0.5	1.609e+04	1.784e-01	4.467e-01	3.502e-04	8.769e-04
0.6	2.466e+09	3.529e+04	8.158e+04	6.887e+01	1.592e+02
0.8	2.399e+07	5.122e+02	1.054e+03	9.743e-01	2.004e+00
1.0	1.493e+13	4.348e+08	8.278e+08	8.014e+05	1.526e+06
1.5	1.493e+13	7.597e+08	1.275e+09	1.278e+06	2.145e+06
2.0	3.559e+01	2.652e-03	4.138e-03	4.102e-06	6.398e-06
<b>Totals</b>	<b>2.986e+13</b>	<b>1.194e+09</b>	<b>2.103e+09</b>	<b>2.080e+06</b>	<b>3.672e+06</b>

**Results - Dose Point # 2 - (245.8,30.5,0) in**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm <sup>2</sup> /sec No Buildup	Fluence Rate MeV/cm <sup>2</sup> /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.979e+08	2.374e-05	3.390e-05	2.036e-06	2.907e-06
0.02	6.142e+00	8.109e-12	1.433e-11	2.809e-13	4.964e-13
0.03	3.403e+06	5.500e-05	1.429e-04	5.451e-07	1.416e-06
0.04	5.318e+05	2.885e-05	1.115e-04	1.276e-07	4.933e-07
0.05	1.577e+04	2.067e-06	1.115e-05	5.506e-09	2.970e-08
0.06	8.221e+04	2.158e-05	1.416e-04	4.286e-08	2.812e-07
0.08	1.140e+06	8.342e-04	6.104e-03	1.320e-06	9.659e-06
0.1	8.716e+06	1.292e-02	8.957e-02	1.976e-05	1.370e-04
0.15	1.211e+06	5.041e-03	2.756e-02	8.302e-06	4.539e-05
0.2	4.739e+06	3.459e-02	1.502e-01	6.105e-05	2.651e-04
0.3	5.222e+05	7.350e-03	2.419e-02	1.394e-05	4.590e-05
0.4	8.074e+04	1.733e-03	4.823e-03	3.377e-06	9.397e-06
0.5	1.609e+04	4.744e-04	1.176e-03	9.311e-07	2.309e-06
0.6	2.466e+09	9.389e+01	2.136e+02	1.833e-01	4.169e-01
0.8	2.399e+07	1.362e+00	2.733e+00	2.591e-03	5.199e-03
1.0	1.493e+13	1.154e+06	2.132e+06	2.127e+03	3.931e+03
1.5	1.493e+13	2.002e+06	3.241e+06	3.369e+03	5.453e+03
2.0	3.559e+01	6.947e-06	1.043e-05	1.074e-08	1.613e-08
<b>Totals</b>	<b>2.986e+13</b>	<b>3.157e+06</b>	<b>5.374e+06</b>	<b>5.497e+03</b>	<b>9.384e+03</b>

**Results - Dose Point # 3 - (365.8,30.5,0) in**

Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm <sup>2</sup> /sec No Buildup	Fluence Rate MeV/cm <sup>2</sup> /sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	6.979e+08	6.101e-06	8.830e-06	5.233e-07	7.574e-07
0.02	6.142e+00	2.800e-12	5.065e-12	9.699e-14	1.755e-13

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0.03	3.403e+06	2.196e-05	5.965e-05	2.176e-07	5.912e-07
0.04	5.318e+05	1.192e-05	4.867e-05	5.271e-08	2.153e-07
0.05	1.577e+04	8.664e-07	4.947e-06	2.308e-09	1.318e-08
0.06	8.221e+04	9.110e-06	6.302e-05	1.810e-08	1.252e-07
0.08	1.140e+06	3.546e-04	2.727e-03	5.612e-07	4.315e-06
0.1	8.716e+06	5.513e-03	4.006e-02	8.434e-06	6.129e-05
0.15	1.211e+06	2.165e-03	1.236e-02	3.566e-06	2.035e-05
0.2	4.739e+06	1.493e-02	6.739e-02	2.634e-05	1.189e-04
0.3	5.222e+05	3.192e-03	1.086e-02	6.055e-06	2.059e-05
0.4	8.074e+04	7.561e-04	2.164e-03	1.473e-06	4.216e-06
0.5	1.609e+04	2.076e-04	5.276e-04	4.075e-07	1.036e-06
0.6	2.466e+09	4.119e+01	9.581e+01	8.040e-02	1.870e-01
0.8	2.399e+07	5.999e-01	1.226e+00	1.141e-03	2.332e-03
1.0	1.493e+13	5.096e+05	9.568e+05	9.394e+02	1.764e+03
1.5	1.493e+13	8.884e+05	1.455e+06	1.495e+03	2.449e+03
2.0	3.559e+01	3.091e-06	4.686e-06	4.780e-09	7.246e-09
<b>Totals</b>	<b>2.986e+13</b>	<b>1.398e+06</b>	<b>2.412e+06</b>	<b>2.434e+03</b>	<b>4.213e+03</b>
<b>Results - Dose Point # 4 - (485.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	6.979e+08	1.963e-06	2.870e-06	1.683e-07	2.462e-07
0.02	6.142e+00	1.213e-12	2.243e-12	4.202e-14	7.769e-14
0.03	3.403e+06	1.101e-05	3.117e-05	1.091e-07	3.089e-07
0.04	5.318e+05	6.188e-06	2.655e-05	2.737e-08	1.174e-07
0.05	1.577e+04	4.561e-07	2.752e-06	1.215e-09	7.332e-09
0.06	8.221e+04	4.829e-06	3.519e-05	9.591e-09	6.990e-08
0.08	1.140e+06	1.892e-04	1.528e-03	2.994e-07	2.418e-06
0.1	8.716e+06	2.953e-03	2.247e-02	4.518e-06	3.438e-05
0.15	1.211e+06	1.167e-03	6.942e-03	1.922e-06	1.143e-05
0.2	4.739e+06	8.082e-03	3.790e-02	1.426e-05	6.689e-05
0.3	5.222e+05	1.739e-03	6.105e-03	3.299e-06	1.158e-05
0.4	8.074e+04	4.137e-04	1.217e-03	8.061e-07	2.370e-06
0.5	1.609e+04	1.139e-04	2.967e-04	2.237e-07	5.824e-07
0.6	2.466e+09	2.267e+01	5.387e+01	4.424e-02	1.052e-01
0.8	2.399e+07	3.314e-01	6.896e-01	6.303e-04	1.312e-03
1.0	1.493e+13	2.823e+05	5.382e+05	5.203e+02	9.921e+02

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1.5	1.493e+13	4.943e+05	8.193e+05	8.316e+02	1.378e+03
2.0	3.559e+01	1.725e-06	2.639e-06	2.667e-09	4.081e-09
<b>Totals</b>	<b>2.986e+13</b>	<b>7.766e+05</b>	<b>1.358e+06</b>	<b>1.352e+03</b>	<b>2.371e+03</b>
<b>Results - Dose Point # 5 - (605.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	6.979e+08	7.156e-07	1.055e-06	6.138e-08	9.052e-08
0.02	6.142e+00	5.961e-13	1.124e-12	2.065e-14	3.895e-14
0.03	3.403e+06	6.267e-06	1.843e-05	6.211e-08	1.826e-07
0.04	5.318e+05	3.647e-06	1.642e-05	1.613e-08	7.262e-08
0.05	1.577e+04	2.724e-07	1.731e-06	7.257e-10	4.610e-09
0.06	8.221e+04	2.903e-06	2.226e-05	5.766e-09	4.422e-08
0.08	1.140e+06	1.145e-04	9.700e-04	1.812e-07	1.535e-06
0.1	8.716e+06	1.794e-03	1.429e-02	2.745e-06	2.187e-05
0.15	1.211e+06	7.137e-04	4.422e-03	1.175e-06	7.282e-06
0.2	4.739e+06	4.964e-03	2.415e-02	8.761e-06	4.263e-05
0.3	5.222e+05	1.075e-03	3.891e-03	2.039e-06	7.382e-06
0.4	8.074e+04	2.567e-04	7.754e-04	5.002e-07	1.511e-06
0.5	1.609e+04	7.093e-05	1.891e-04	1.392e-07	3.712e-07
0.6	2.466e+09	1.414e+01	3.434e+01	2.761e-02	6.703e-02
0.8	2.399e+07	2.075e-01	4.396e-01	3.948e-04	8.362e-04
1.0	1.493e+13	1.773e+05	3.432e+05	3.268e+02	6.327e+02
1.5	1.493e+13	3.118e+05	5.228e+05	5.246e+02	8.796e+02
2.0	3.559e+01	1.091e-06	1.685e-06	1.687e-09	2.606e-09
<b>Totals</b>	<b>2.986e+13</b>	<b>4.891e+05</b>	<b>8.661e+05</b>	<b>8.514e+02</b>	<b>1.512e+03</b>
<b>Results - Dose Point # 6 - (725.8,30.5,0) in</b>					
<b>Energy (MeV)</b>	<b>Activity (Photons/sec)</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec No Buildup</b>	<b>Fluence Rate MeV/cm<sup>2</sup>/sec With Buildup</b>	<b>Exposure Rate mR/hr No Buildup</b>	<b>Exposure Rate mR/hr With Buildup</b>
0.015	6.979e+08	2.827e-07	4.202e-07	2.425e-08	3.604e-08
0.02	6.142e+00	3.174e-13	6.099e-13	1.099e-14	2.113e-14
0.03	3.403e+06	3.865e-06	1.177e-05	3.831e-08	1.166e-07
0.04	5.318e+05	2.329e-06	1.099e-05	1.030e-08	4.861e-08
0.05	1.577e+04	1.763e-07	1.175e-06	4.697e-10	3.130e-09
0.06	8.221e+04	1.891e-06	1.524e-05	3.756e-09	3.028e-08
0.08	1.140e+06	7.509e-05	6.668e-04	1.188e-07	1.055e-06
0.1	8.716e+06	1.181e-03	9.843e-03	1.807e-06	1.506e-05

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0.15	1.211e+06	4.728e-04	3.050e-03	7.786e-07	5.022e-06
0.2	4.739e+06	3.303e-03	1.667e-02	5.829e-06	2.942e-05
0.3	5.222e+05	7.194e-04	2.686e-03	1.365e-06	5.096e-06
0.4	8.074e+04	1.726e-04	5.353e-04	3.362e-07	1.043e-06
0.5	1.609e+04	4.783e-05	1.305e-04	9.388e-08	2.562e-07
0.6	2.466e+09	9.561e+00	2.371e+01	1.866e-02	4.627e-02
0.8	2.399e+07	1.408e-01	3.036e-01	2.678e-04	5.774e-04
1.0	1.493e+13	1.206e+05	2.371e+05	2.223e+02	4.370e+02
1.5	1.493e+13	2.131e+05	3.614e+05	3.585e+02	6.080e+02
2.0	3.559e+01	7.475e-07	1.166e-06	1.156e-09	1.802e-09
<b>Totals</b>	<b>2.986e+13</b>	<b>3.337e+05</b>	<b>5.985e+05</b>	<b>5.808e+02</b>	<b>1.045e+03</b>