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**LOS ALAMOS NATIONAL LABORATORY  
CARLSBAD OPERATIONS**

**Simple Analysis Report  
INV-SAR-08  
Revision 0**

**Analysis of RH TRU Wastes for Containment in Lead Shielded Containers**

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## 1.0 PURPOSE

Los Alamos National Laboratory Carlsbad Operations (LANL-CO) Inventory Team is supporting the development of the Performance Assessment (PA) Lead Shielded Container Planned Change Request (PCR) by supplying Sandia National Laboratories (SNL) with transuranic (TRU) waste inventory data (Dunagan 2007, see attachment 1). This inventory information has been requested by SNL, so that they can perform a PA to assess whether any changes that result from a request made by the Department of Energy – Carlsbad Field Office (CBFO) to the Environmental Protection Agency (EPA) for use of shielded containers has any effect on the performance of the Waste Isolation Pilot Plant (WIPP) repository. Information from the TRU-Waste inventory Performance Assessment Baseline Calculation (PABC) is used to determine the amount of new emplacement and packaging materials that account for the changes in packaging and emplacement materials that are expected with the emplacement of shielded containers on the floor of the Waste Isolation Pilot Plant (WIPP) repository rather than in the walls.

This analysis report addresses data needs for packaging and emplacement materials to support this PA. In addition to these material parameters, candidate waste streams that have a high probability of containing waste that can be adequately shielded with one inch of lead have been identified using gamma factor screening and Microshield modeling.

The purpose of this analysis is to calculate the number of 30-gallon drum equivalents expected to be generated using the Waste Isolation Pilot Plant (WIPP) capacity volume for RH waste (7080 m<sup>3</sup>). Each 30-gallon drum will be inserted in a 55-gallon shielded container (see figure 1 for a drawing of the shielded container). The number of 30-gallon drums is identical to the number of shielded containers in the WIPP repository RH-TRU waste capacity of 7080 m<sup>3</sup>. Once the number of shielded containers is determined, the inventories of cellulose, plastic, and rubber (CPR), steel, and lead used in packaging and emplacement were determined. The emplacement scenarios for the shielded container assume that 3-packs will be stacked 3 high in the WIPP repository. As part of this analysis, the RH-TRU waste inventory was also screened using gamma factors and Microshield evaluations to estimate the limiting gamma emitter activity per shielded container that would produce a contact dose of less than 200 mrem/h. Candidate waste streams were then selected from populations of drums that have a high probability to be adequately shielded (ie. are less than 200 mrem/h) for handling based on these calculations.

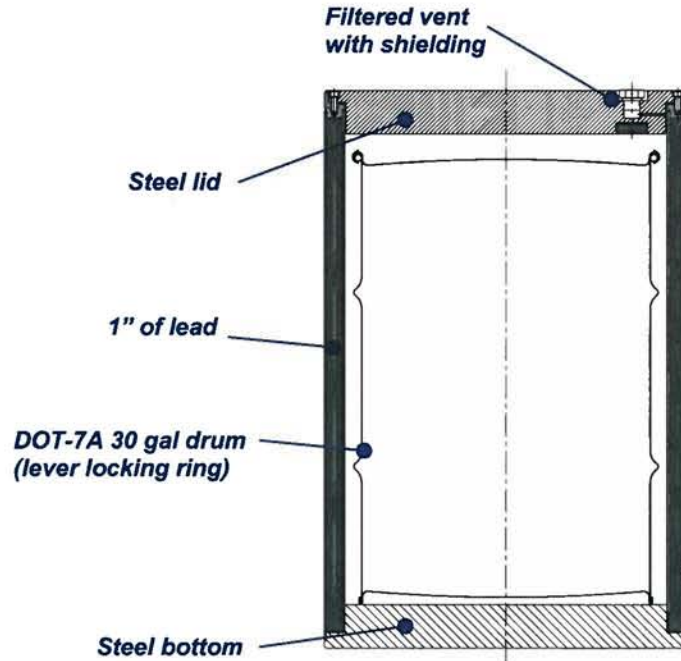


Figure 1

## 2.0 SCOPE AND LIMITATIONS

This simple analysis was performed as delineated in INV-AP-01, Revision 2, *Analysis Plan for Transuranic Inventory* and INV-SP-03, Revision 3, *Responding to Request for Quality Level 1 Inventory Information* under the LANL-CO Quality Assurance Program defined in LCO-QPD-01, *LANL-CO WIPP Quality Assurance Plan*. This simple analysis was documented in accordance with LCO-QP9-1, Revision 2, *Analyses*. Microshield software is qualified in accordance with LCO-QP19-1, *Software Quality Assurance* (LANL 2005).

The limits for this analysis include the WIPP RH capacity volume of 7080 m<sup>3</sup> and the interior volume of a 30-gallon drum of 0.113 m<sup>3</sup>. The limiting activity for a shielded container, not taking credit for the waste's radiation absorption and assuming uniform radioactivity, is 2 Ci Cs-137 or 0.12 Ci Co-60 per 30-gallon waste drum<sup>1</sup>. A sum of fractions rule is used when more than one of the limiting radionuclides is present in a waste stream.

## 3.0 DEFINITIONS AND ACRONYMS

Acronyms and definitions for terms used in this procedure are located in *LANL-CO Acronyms and Definitions* in the LANL-CO Document Center (<http://lcodocs.lanl.gov/>) and are available as a stand alone document upon request.

<sup>1</sup>These two isotopes dominate the external radiation of 67 of the 87 RH waste streams.

**4.0 CONTAINER AND EMPLACEMENT MATERIAL METHODOLOGY**

The packaging and emplacement materials for RH TRU waste reported in the PABC inventory were calculated using RH canisters emplaced in walls in the rooms in the WIPP. Therefore in order to account for shielded containers emplaced on the floor of the repository, the CPR, lead and steel used in emplacing shielded containers with different packaging materials were required for the PA supporting the shielded container PCR.

**4.1 Cellulose, Plastic, Rubber, Steel and Lead in the PABC CH Inventory**

The Performance Assessment Baseline Calculation (PABC) Contact-Handled (CH) TRU waste inventory of CPR for packaging and emplacement materials was reported directly from the Transuranic Waste Baseline Inventory Report – 2004 (TWBIR-2004) (DOE 2006) (see Table 4 Section 6.1. *Packaging and Emplacement Material Densities for CH-TRU Waste Reproduced from the PABC Inventory*).

The steel packaging material density (kg/m<sup>3</sup>) from the PABC CH-TRU inventory is used in this analysis and is reproduced in Table 4. There is no lead in packaging or emplacement materials in the PABC inventory for CH-TRU waste (see Table 3 Section 6.1. *Packaging and Emplacement Material Densities for CH-TRU Waste Reproduced from the PABC Inventory*).

**4.2 Cellulose, Plastic, Rubber, Steel and Lead Associated with Shielded Container Emplacement**

The CPR for RH-TRU waste packaging and emplacement materials are calculated based on the capacity volume of the waste in section 4.3 *Number of 30-gallon Containers, 3-Packs and Stacks for Shielded Containers*. The calculations in sections 4.3 *Number of 30-gallon Containers, 3-Packs, and Stacks for the Shielded Containers*, 4.4 *Mass of Plastic, Steel, and Lead Packaging Materials* and 4.5 *Mass of Emplacement Materials (CPR)* are based on the arrangements and assumptions provided in Table 1. There is no cellulose or rubber in packaging materials. The only plastic packaging material used is for the drum handling bag for 30-gallon drums. These bags are included in the shielded containers packaging material (see Table 1 Assumptions). CPR used in emplacement is based on the number of shielded container 3-packs stacked 3 high and the placement of one supersack of MgO on each of these stacks.

Table 1 – Assumptions used for Determination of Cellulose, Plastic, Rubber, Steel and Lead for TRU Waste Inventory based on PABC Inventory

Constituent	Assumption
General	1) Emplacement materials for RH waste will be calculated based on 3-packs of shielded containers stacked 3 high. 2) A supersack of MgO is placed on every stack of 3-packs and is assumed to be the same type of supersack as is currently being emplaced.

Constituent	Assumption
CPR	<p><b><u>Packaging Material - CPR:</u></b></p> <ol style="list-style-type: none"> <li>1) There is no cellulose in packaging materials for shielded containers.</li> <li>2) The plastic drum handling bag mass in the shielded container is 4 lbs or 1.81 kg (Donner 2007).</li> <li>3) There is no rubber in packaging material for the shielded container.</li> </ol> <p><b><u>Emplacement Material - Plastic in a 3-pack:</u></b></p> <ol style="list-style-type: none"> <li>4) A top reinforcement plate and a bottom slip-sheet of polyethylene are used for each 3-pack of shielded containers.</li> <li>5) The mass of the reinforcing plate and bottom slip-sheet are 15.785 kg for each 3-pack of shielded containers (Burns 2005).</li> <li>6) Plastic stretch wrap is used for each 3-pack in the same mass as that used for seven-packs of 55-gallon drums.</li> <li>7) The mass of the plastic wrap is assumed to be 0.998 kg per 3-pack (Burns 2005).</li> </ol> <p><b><u>Emplacement Material - Plastic in a 3 high stack of 3-packs:</u></b></p> <ol style="list-style-type: none"> <li>8) The supersacks containing MgO are composed of woven polypropylene.</li> <li>9) The mass of the polypropylene in the supersack is 3.447 kg per sack.</li> <li>10) Each supersack has a polyethylene slip-sheet on the bottom of the sack.</li> <li>11) The mass of the supersack plastic slip-sheet is 7.892 kg per supersack.</li> </ol> <p><b><u>Emplacement Material - Cellulose in a 3 high stack of 3-packs:</u></b></p> <ol style="list-style-type: none"> <li>12) Cardboard stabilizers (composed of cellulosic material) are used for the supersacks.</li> <li>13) The cellulosic material in the stabilizer is assumed to be 3.447 kg (Burns 2005)</li> </ol>
Steel	<ol style="list-style-type: none"> <li>1) The total steel per shielded container including 30-gallon drum is 901 lb or 409 kg (assuming 3.00 inch thickness in base and lid).</li> <li>2) There is no steel used in the repository for emplacement of shielded containers.</li> </ol>
Lead	<ol style="list-style-type: none"> <li>1) The total lead per shielded container is 950 lbs or 431 kg.</li> <li>2) There is no lead used in the repository for emplacement of shielded containers.</li> </ol>

#### 4.3 Number of 30-gallon Containers, 3-Packs and Stacks for Shielded Containers

The maximum number of 30-gallon drums that can be contained in a shielded container is 1. Therefore, the number of 30-gallon drum equivalents of waste in the WIPP RH-TRU capacity volume of 7080 m<sup>3</sup> was calculated using equation 1. The result represents the number of shielded containers that can be emplaced in the WIPP repository.

$$\text{Eqn. 1. } \frac{\text{Capacity Volume}}{\text{Volume}_{30\text{-gallon Drum}}} = N_{30}$$

Where

Capacity Volume is 7080 m<sup>3</sup>,

Volume<sub>30-gallon</sub> is 0.113 m<sup>3</sup>, and

N<sub>30</sub> is the number of 30-gallon drums generated from a capacity volume of waste.

The number of 3-packs that can be constructed from the total number of shielded containers in a capacity volume is:

$$\text{Eqn. 2. } N_{30} / 3 = N_{3\text{-pk}}$$

Where

N<sub>30</sub> is the number of 30-gallon drums generated from a capacity volume of waste, and

N<sub>3-pk</sub> is the number of 3-packs generated from the 30-gallon drums in the repository.

The number of stacks of 3-packs that can be constructed from the total number of shielded containers is:

$$\text{Eqn. 3. } N_{3\text{-pk}} / 3 = N_{\text{stacks}}$$

Where

N<sub>3-pk</sub> is the number of 3-packs generated from the 30-gallon drums in the repository, and

N<sub>stacks</sub> is the number of stacks that will be generated from the 3-packs of shielded containers stacked 3 high.

The number of 30-gallon containers equivalents or shielded containers, the number of 3-packs, the number of stacks that result from stacking 3-packs 3 high are provided in Table 5 of 6.2 *Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers*.



#### 4.4 Mass of Plastic, Steel, and Lead Packaging Materials

The masses of lead, steel and plastic ( $M_{\text{Pb/steel/plastic}}$ ) packaging material provided in Table 1 were used to determine the total mass of each packaging material constituent as shown in equation 4.

$$\text{Eqn. 4.} \quad N_{30} \times M_{\text{Pb/steel/plastic}} = \text{PT}_{\text{Pb/steel/plastic}}$$

Where:

$N_{30}$  is the number of shielded containers based on the capacity volume of 7080 m<sup>3</sup> (eqn. 1),

$M_{\text{Pb/steel/plastic}}$  is the mass of lead, steel or plastic packaging material (see Table 1), and  $\text{PT}_{\text{Pb/steel/plastic}}$  is the total mass of lead, steel or plastic packaging material in WIPP from shielded containers.

The mass of each of these packaging materials and the total mass of each constituent expected to be present in the capacity volume of RH-TRU waste in the repository is presented in Table 6 of section 6.2 *Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers*.

#### 4.5 Mass of Emplacement Materials (CPR)

The total mass of plastic emplacement material in the repository that is contributed by the shielded containers and the stacks described above, is the sum of the plastic associated with the 3-packs and the plastic associated with the stacks. The total mass of plastic emplacement material is calculated using equation 5, below.

$$\text{Eqn. 5.} \quad (N_{3\text{pk}} \times \text{PM}_{3\text{pk}}) + (N_{\text{stack}} \times \text{PM}_{\text{ss}}) = \text{ET}_{\text{plastic}}$$

Where:

$N_{3\text{pk}}$  is the number of 3-packs generated from the 30-gallon drums in the repository,  $\text{PM}_{3\text{pk}}$  is the mass of the plastic slip-sheet, reinforcement plate and stretch wrap for each 3-pack of shielded containers,

$N_{\text{stack}}$  is the number of stacks that will be generated from shielded containers stacked 3 high,

$\text{PM}_{\text{ss}}$  is the mass of the plastic in the supersack and slip-sheet in a stack, and

$\text{ET}_{\text{plastic}}$  is the total mass of plastic emplacement material associated with the shielded containers in the repository.

The total mass of emplaced plastic material in the repository is presented in Table 7 of section 6.2 *Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers*.

The total mass of cellulose emplacement material in the repository is contributed solely by the cardboard stabilizer in the supersacks. There is no rubber used for emplacement of

shielded containers. The total mass of cellulose emplacement material is determined using equation 6, below.

$$\text{Eqn. 6.} \quad CM_{CS} \times N_{\text{stacks}} = ET_{\text{Cellulose}}$$

Where:

$CM_{CS}$  is the mass of cellulose from the cardboard stabilizer,

$N_{\text{stacks}}$  is the number of stacks of shielded containers, and

$ET_{\text{Cellulose}}$  is the total mass of cellulose emplacement material for shielded containers in the repository

The total mass of cellulose emplacement material in the repository is presented in Table 7 of section 6.2 *Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers*.

#### 4.6 Densities of Cellulose, Plastic, Steel and Lead Packaging and Emplacement Materials in the Repository

Cellulose and plastic are used in emplacement of waste in the repository and plastic, steel and lead are used in the packaging materials for shielded containers. The densities of these constituents were determined using equation 7, below.

$$\text{Eqn. 7.} \quad M_{\text{cellulose/plastic/steel/Pb}} / \text{Capacity Volume} = D_{\text{cellulose/plastic/steel/Pb}}$$

Where:

$M_{\text{cellulose/plastic/steel/Pb}}$  is the mass of the cellulose, plastic, steel or lead packaging or emplacement materials,

Capacity Volume is 7080 m<sup>3</sup>, and

$D_{\text{cellulose/plastic/steel/Pb}}$  is the density of the cellulose, plastic, steel or lead packaging or emplacement materials.

The densities for these materials are reported separately in Table 8 of section 6.2 *Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers*.

#### 5.0 Candidate Waste Stream Methodology

The RH TRU waste inventory was evaluated to determine the candidate waste streams that could be shielded below 200 mrem/h using 1 inch of lead in a shielded container (55-gallon drum). The evaluation was performed in two parts: 1) identification of dominant gamma emitting radionuclides (those contributing to at least 95% of the external radiation hazard) in the PABC RH-TRU waste inventory; and 2) determination of an activity limit for 30-gallon drums of waste shielded in 55-gallon shielded containers based on the dominant gamma emitting radionuclides identified in the first evaluation.

**5.1 Determination of Dominant Gamma Emitters in the PABC RH Inventory**

The activity concentration for each radionuclide in each RH waste stream was multiplied by a gamma factor (Shleien, 1992) specific to that radionuclide to identify the dominant gamma emitters (contributing to at least 95% of the external radiation dose). The gamma factors of the dominant gamma emitting radionuclides were adjusted using Microshield (in some cases using user defined sources) to reflect gamma absorption in the 30-gallon drum’s steel wall (waste absorption was not considered). These results are presented in Table 9 section 6.4. *Candidate Waste Streams* (see Table 2 for absorption assumptions used in screening).

Table 2 – Assumptions and Knowns Used for Determination of Dominant Gamma Emitter and Maximum Activity for Shielded Containers

Considerations	Assumptions
Important Drum Characteristics	The drum is composed of 18 gauge (0.047 inch) iron wall.
Absorption	1) The gamma emitted is not absorbed by the waste. 2) The gamma emitted is not absorbed by the container wall for determination of the shielded container curie limits but is absorbed for the dominant gamma emitting radionuclide determination..

Microshield 6.02 was used subsequent to the gamma factor screening to determine the maximum activity of the dominant gamma emitters that would result in a contact dose rate less than 200 mrem/h when overpacked in a shielded container. Microshield calculations were performed on a Dell 3.2 GHz platform equipped with 2.0 Gb RAM and 233 Gb Hard Drive using a Windows XP Professional Service Pack 2 operating system. The maximum activity loadings are presented in section 5.2 *Determination of the Maximum Activity Concentration Loading for the Shielded Containers*.

The shielded container was modeled as having a 3" thick iron top and bottom, with radial walls consisting of a 0.188" thick iron inner liner, 1" thick lead and 0.125" thick Fe outer liner. A cylindrical volume representing a 30 gallon drum was uniformly filled with 1 curie of each dominant radionuclide. The exposure rate at the very top of the shielded container and at the radial wall surface at the shielded container half-height was calculated. The largest of these values was used to set the activity limit per shielded container. The energies and intensities of the gamma radiations modeled are printed with the results in attachment 2

The final results of gamma factor screening using radionuclides from waste streams decay corrected to 2002 are presented in Table 10 section 6.4 *Candidate Waste Streams*. The candidate waste streams are also presented in this table.

## 5.2 Determination of the Maximum Activity Concentration Loading for the Shielded Containers

The maximum activity loadings for the dominant gamma emitters in the RH-TRU waste inventory were determined by dividing 200 mrem/h by the Microshield 6.02 modeled contact dose rate per unit activity. Again, no credit was taken for radiation absorption by the waste and the inner 30-gallon drum was assumed to be uniformly contaminated. The results are listed in Table 3.

In practice, the maximum activity loading of Am-241, Cm-244, Pu-238, Pu-239, Pu-240, Pu-243 and Th-229 will be limited to much lower values by the WIPP Waste Acceptance Criteria and transportation requirements.

Table 3 – Maximum Activity Loading for Dominant Gamma Emitting Radionuclides

Dominant Gamma Emitting Radionuclide	Maximum Activity Loading (Ci)
Am-241	208,855
Cs-137	2.0
Cm-243	213
Cm-244	697,800
Cm-247	10
Co-60	0.12
Cs-134	0.64
Eu-152	0.39
Eu-154	0.29
Pu-238	2,855,368
Pu-239	151,240
Pu-240	9,365,050
Pu-243	1,396
Th-229	4,435

## 6.0 RESULTS

### 6.1 Packaging and Emplacement Material Densities for CH-TRU Waste Reproduced from the PABC Inventory

Densities for packaging materials were obtained from TWBIR -2004 (DOE 2006) and reported without change in Table 4. The density (in kg/m<sup>3</sup>) of cellulose and plastic for emplacement materials were determined from the masses of each material divided by the disposal capacity of CH-TRU waste for WIPP (168,485 m<sup>3</sup>). There is no rubber in CH-TRU waste packaging or emplacement materials.

Table 4 – CH-TRU Cellulose, Plastic, Steel and Lead Inventory  
Data Reproduced from TWBIR-2004

	Packaging Density <sup>1</sup> (kg/m <sup>3</sup> )	Emplacement Mass <sup>2</sup> (kg)	Emplacement Density (kg/m <sup>3</sup> )
<b>Cellulose</b>	0	2.07 x 10 <sup>5</sup>	1.22 x 10 <sup>0</sup>
<b>Plastic</b>	1.7 x 10 <sup>1</sup>	1.48 x 10 <sup>6</sup>	8.78 x 10 <sup>0</sup>
<b>Steel</b>	1.7 x 10 <sup>2</sup>	0	0
<b>Lead</b>	0 <sup>3</sup>	0	0

<sup>1</sup>Taken from Table 25 (DOE 2006).

<sup>2</sup>Taken from Table 34 (DOE 2006).

<sup>3</sup>A small amount of lead (1.3 x 10<sup>-2</sup>) has been reported in repository waste material parameter roll ups. This quantity is essentially zero.

## 6.2 Packaging and Emplacement Material Densities for RH-TRU Waste in Shielded Containers

The total number of shielded containers based on the RH capacity volume of 7080 m<sup>3</sup> is presented in Table 5. In addition to the number of shielded containers, the number of 3-packs of shielded containers and the number of stacks is reported in Table 5.

Table 5- Number of Containers in Capacity Volume

Capacity Volume (m <sup>3</sup> )	Volume of 30- gallon container (m <sup>3</sup> )	Container Count	No. 3-packs	No. Stack
7080	0.113	62,655	20,885	6,962

The packaging material for a shielded container includes plastic, steel and lead. The masses for plastic in a shielded container were obtained from (Donner 2007). The masses of steel and lead in the shielded containers were obtained from the assumptions provided in Table 1 of this report and arose from the Shielded Container Project guidance. The total

mass of each of these components was determined by multiplying the mass of each component by the number of shielded containers reported in Table 6.

Table 6– RH-TRU Plastic, Steel and Lead Packaging Materials

Mass Plastic (kg) /30-gallon container <sup>1</sup>	Total Mass Plastic (kg)	Mass Steel (kg) /30-gallon container <sup>2</sup>	Total Mass Steel (kg)	Mass Lead (kg) /30-gallon container <sup>3</sup>	Total Mass Lead (kg)
1.81	$1.13 \times 10^5$	409	$2.56 \times 10^7$	431	$2.70 \times 10^7$

<sup>1</sup>Total plastic per shielded container is 4 lbs or 1.81 kg.

<sup>2</sup>Total steel per shielded container is 901 lbs or 409 kg.

<sup>3</sup>Total lead per shielded container is 950 lbs or 431 kg.

The emplacement materials used to emplace 3-packs of shielded containers are provided in Table 7. There is no rubber, lead or steel used in emplacement of shielded containers. Plastic is calculated from wrapping applied to 3-packs of shielded containers, slip-sheets and supersacks. Cellulose is only calculated for stacks.

Table 7 – RH-TRU CPR Emplacement Materials

Plastic (kg)	Cellulose (kg)	Rubber (kg)
$4.29 \times 10^5$	$2.40 \times 10^4$	0

The summary of materials used in packaging and emplacement of RH-TRU waste in shielded containers is provided in Table 7. There is no rubber in RH-TRU waste packaging or emplacement materials. The densities reported in this table were calculated by taking the mass of the individual components and dividing by the RH-TRU waste capacity for the WIPP repository.

Table 8– RH-TRU Cellulose, Plastic, Steel and Lead Inventory

	Mass from Packaging <sup>1</sup> (kg)	Packaging Density (kg/m <sup>3</sup> )	Mass from Emplacement <sup>2</sup> (kg)	Emplacement Material Density (kg/m <sup>3</sup> )
Cellulose	0	0	$2.40 \times 10^4$	$3.39 \times 10^0$
Plastic	$1.13 \times 10^5$	$1.60 \times 10^1$	$4.29 \times 10^5$	$6.06 \times 10^1$

	Mass from Packaging <sup>1</sup> (kg)	Packaging Density (kg/m <sup>3</sup> )	Mass from Emplacement <sup>2</sup> (kg)	Emplacement Material Density (kg/m <sup>3</sup> )
<b>Steel</b>	2.56 x 10 <sup>7</sup>	3.62 x 10 <sup>3</sup>	0	0
<b>Lead</b>	2.70 x 10 <sup>7</sup>	3.81 x 10 <sup>3</sup>	0	0

<sup>1</sup>Mass of packaging materials taken from Table 6.

<sup>2</sup>Mass of emplacement materials taken from Table 7.

### 6.3 Dominant Gamma Emitters

The ranking of the dominant external dose contributors in the PABC RH-TRU waste inventory is shown in Table 9. The results clearly indicate that the contribution of Cs-137 is highest for most of the RH-TRU waste streams. The second highest gamma contribution comes from Am-241 and the third is Co-60.

Table 9– Radionuclides Contributing to Highest Dose in PABC RH-TRU Waste Streams

Radionuclide	Rank					Total Times in Top 5
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>	
Am-241	10	14	3	0	0	27
Cs-137	56	6	0	0	0	62
Cm-243	0	0	1	1	0	2
Cm-244	2	1	0	0	0	3
Cm-247	0	1	0	0	0	1
Co-60	11	6	0	0	0	17
Cs-134	0	3	4	0	0	7
Eu-152	1	2	0	1	0	4
Eu-154	0	2	3	2	0	7
Pu-238	3	4	1	0	0	8
Pu-239	4	3	1	0	0	8
Pu-240	0	0	5	1	0	6
Pu-243	0	0	1	0	0	1
Th-229	0	0	0	0	1	1

<sup>1</sup>Ranking is equivalent to the number of waste streams where the radionuclide was identified as contributing to >95% of the gamma dose accounting for absorption due to the container wall.

#### 6.4 Candidate Waste Streams

The maximum activity for a 30-gallon container shielded in a 55-gallon drum is 2.0 Ci Cs-137 or 0.12 Ci Co-60 per 30-gallon waste drum (see table 3 for the maximum activity of other radionuclides). Using this limiting activity, the candidate waste streams, prominent gamma emitting radionuclide, waste volume and shielded container equivalents are in Table 10. Waste streams identified in Table 10 do not exceed the limiting activities for the dominant radionuclide identified. However, since the waste stream activity is reported and the distribution among the containers is not provided, some containers may assay above the limiting activity during characterization. Similarly, the containers from some waste streams that have exceeded the activity limits may assay within the limits identified in this analysis.

Table 10 – Candidate Waste Streams for Shielded Containers

Waste Stream ID	Waste Stream Volume (m3)	30 Gallon drum Eq.
AE-T009	45.2	400
AW-W026	4.72	42
AW-W028	7.70	69
BCLRH-T001	0.42	4
BCLRH-T007	0.21	2
BCLRH-T008	0.42	4
BCLRH-T011	2.91	26
ET-R1-DLR	1.50	14
ET-R2-D107	0.42	4
IN-AE-AGHC-01	70.80	627
IN-AW-161	0.90	8
IN-INTEC-SFS-01	0.23	3
IN-NRF-153	3.19	29
IN-TRA-150	2.29	21
IN-TRA-157	3.12	28
IN-W358.949	1.48	14
IN-W372.918	2.97	27
KA-T001	7.10	63
KA-W016	0.70	7
LA-TA-03-27	72.81	645
OR-W211	76.54	678
OR-W212	193.13	1710
OR-W213	196.69	1741
OR-W214	1.78	16
RL-T121	53.40	473
RL-W161	5.34	47
RL-W162	18.69	166
RL-W419	3.56	32



RL-W420	26.70	237
RL-W421	315.59	2793
RL-W428	21.36	190
RL-W433	43.61	386
RL-W436	488.61	4324
RL-W445	130.83	1158
RL-W446	22.25	197
RL-W621	12.46	111
RL-W658	43.61	386
RL-W663	16.02	142
RL-W664	2.67	24
RL-W686	0.89	8
RL-W687	0.89	8
RL-W701	0.89	8
T003-773A-HET	17.04	151
Totals	1,921.64	17,023

## 7.0 SUMMARY

The CPR, steel and lead have been reported for CH-TRU waste using the PABC TRU waste inventory and have been calculated for new packaging and emplacement materials assuming 7080 m<sup>3</sup> of waste will be emplaced in the WIPP repository using lead shielded containers. The PABC TRU waste inventory has also been evaluated for candidate waste streams. The candidate waste streams that are expected to contain less than 2.0 Ci Cs-137 or 0.12 Ci Co-60 per 30-gallon drum constitute 1,922 m<sup>3</sup> of the total PABC RH-TRU waste inventory. Some waste streams that exceed the limiting activity for 30-gallons of waste may also be considered for shipment to WIPP in shielded containers based on assay results on a per container basis.

## 8.0 ATTACHMENTS

Attachment 1: Letter from Dunagan

Attachment 2: Example Microshield 6.02 Output

## 9.0 REFERENCES

Burns 2005. Estimation of Cellulose, Plastic and Rubber Based on TWBID, Revision 2.1, Data Version D.4.16, Los Alamos National Laboratory, Carlsbad NM. INV-0607-01-46-26.

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Dunagan 2007. Letter to Patterson June 18, 2007 *Re: Sandia's Inventory Data Needs for Shielded Container Performance Assessment*. Sandia National Laboratory, Carlsbad New Mexico.

Los Alamos (LANL) 2005, *MicroShield 6 Primitive Baseline Memorandum (for MicroShield 6.02)*. Dated February 22, 2005, LANL Record Number SQA-0502-01-01-01.

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Los Alamos (LANL) 2006b, *Analyses*. LCO-QP9-1 Revision 3. Los Alamos National Laboratory – Carlsbad Operations, Carlsbad, New Mexico.

Los Alamos (LANL) 2007a, *LANL-CO WIPP Quality Assurance Plan*, LCO-QPD-01 Revision 4, Los Alamos National Laboratory – Carlsbad Operations, Carlsbad, New Mexico.

Los Alamos (LANL) 2007b, *Analysis Plan for TRU Inventory*, INV-AP-01 Revision 2, Los Alamos National Laboratory – Carlsbad Operations, Carlsbad, New Mexico.

Shleien, Bernard, *The Health Physics and Radiological Health Handbook*, Scinta, Inc. 1992.

## Attachment 1 - Dunagan Letter



**Sandia National Laboratories**

Energy by

Operated for the U.S. Department of

**Sandia Corporation**

**Sean Dunagan**

4100 National Parks Hwy  
Senior Member of Technical

Carlsbad, NM 88220

Phone: (505) 234-0127

Fax: (505) 234-0061

Internet: [sdunaga@sandia.gov](mailto:sdunaga@sandia.gov)

Staff

June 18, 2007

Russ Patterson  
Department of Energy  
Carlsbad Field Office  
4021 National Parks Hwy  
Carlsbad, NM 88220

**Subject: Sandia's Inventory Data Needs for Shielded Container Performance Assessment**

The Department of Energy has requested that Sandia National Laboratories conduct a performance assessment (PA) that assesses the impact of placing remote-handled (RH) waste in shielded containers on the long term performance of the Waste Isolation Pilot Plant (WIPP). This letter details Sandia's inventory data needs for that analysis.

We will use the CRA-2004 baseline inventory for this impact assessment. Also, we will take a bounding approach and, consequently, we will assume the following:

1. 7,080 m<sup>3</sup> of RH waste will be placed in the WIPP.
2. All of the RH waste will be placed in shielded containers on the disposal room floors, not in the walls of the rooms.

To conduct this PA, we will need the following quantities based on the above assumptions:

1. Inventory of Cellulosics, Plastics, and Rubbers in waste materials, container materials, and emplacement materials. Provide in same units as previously provided in, density (kg/m<sup>3</sup>).
2. Inventory of steel in waste materials, container materials, and emplacement materials. Provide in same units as previously provided in, density (kg/m<sup>3</sup>).
3. Inventory of lead in waste materials, container materials, and emplacement materials. Provide in same units as previously provided in, density (kg/m<sup>3</sup>).

To be consistent with PA calculations and models, a volume of 7,080 m<sup>3</sup> should be used when determining the density of RH emplacement materials. A volume of 169,000 m<sup>3</sup> should be used to calculate the density of CH emplacement materials.

The procedure used to determine these quantities should be consistent with the above assumptions, and the data must be collected and analyzed in accordance with a quality assurance program approved by the Carlsbad Field Office. In order to complete our analysis according to DOE's schedule, we will need this information on or before August 31, 2007. If you have any questions about the requested data, please contact me.

Sincerely,

*Signature on file*

Sean Dunagan

Cc:

Steve Kouba, WTS

Sean White, WTS

Beverly Crawford, LANL

Bill McInroy, LANL

Moo Lee, SNL

David Kessel, SNL

Eric Vugrin, SNL

Department 6711 Day File

Subject: Shielded Container Inventory Needs  
Date: Tue, 7 Aug 2007 14:42:22 -0600  
Thread-Topic: Shielded Container Inventory Needs  
From: "Dunagan, Sean" <sdunaga@sandia.gov>  
To: "Beverly Crawford" <crawford@lanl.gov>, "Bill McInroy" <wmcinroy@lanl.gov>  
cc: "Vugrin, Eric D" <edvugri@sandia.gov>, "Lee, Moo" <mylee@sandia.gov>  
X-OriginalArrivalTime: 07 Aug 2007 20:42:22.0823 (UTC)  
FILETIME=[74B99F70:01C7D933]

Beverly and Bill

Per our discussion earlier today, I am sending an email to modify our June 18th, 2007 inventory request for the shielded container PA. The items that we require for that PA are

- 1) the CPR quantities associated with the RH container and emplacement materials
- 2) Iron quantities associated with RH container and emplacement materials
- 3) Lead quantities associated with RH containers and emplacement materials

These quantities should still be calculated under the assumption that all (7,080 m<sup>3</sup>) of the RH waste is placed in shielded containers on the repository floor.

Note that this data represents a subset of the previous request, and all other inventory data will be taken from the current baseline inventory.

Thanks,

**Sean Dunagan**

Sandia National Laboratories  
4100 National Parks Highway  
Building NPHA/405  
Carlsbad, NM 88220

Work: (505) 234-0127  
Work (ABQ direct): (505) 845-0406  
Fax: (505) 234-0061  
Cell: (505) 302-1318

X-Sieve: CMU Sieve 2.2  
X-Server-Uid: 6CEB1540-FE13-491B-9872-FD67060ED864  
Subject: RE: Shielded Container Inventory Needs  
Date: Wed, 8 Aug 2007 06:58:35 -0600  
X-MS-Has-Attach:  
X-MS-TNEF-Correlator:  
Thread-Topic: Shielded Container Inventory Needs  
Thread-Index: AcfZQToMdLUJFi2ITG+tOPvvMtl0gQAenYlQ  
From: "Dunagan, Sean" <sdunaga@sandia.gov>  
To: "Beverly Crawford" <crawford@lanl.gov>  
X-OriginalArrivalTime: 08 Aug 2007 12:58:36.0142 (UTC)  
FILETIME=[D524D0E0:01C7D9BB]  
X-TMWD-Spam-Summary: TS=20070808125835; SEV=2.2.2; DFV=B2007080809;  
IFV=2.0.4,4.0-9; AIF=B2007080809; RPD=5.02.0125; ENG=IBF;  
RPDID=7374723D303030312E30413031303230362E34364239424446422E303042332C7373  
3D312C6667733D30;  
CAT=NONE; CON=NONE  
X-MMS-Spam-Filter-ID: B2007080809\_5.02.0125\_4.0-9  
X-WSS-ID: 6AA762761V83166346-01-01  
X-Proofpoint-Virus-Version: vendor=fsecure engine=4.65.5502:2.3.11,1.2.37,4.0.164  
definitions=2007-08-08\_04:2007-08-07,2007-08-08,2007-08-08 signatures=0  
X-Proofpoint-Spam: 0  
X-PMX-Version: 4.7.1.128075

From what I understand the iron won't be changing but the steel from the containers will cause a changes. So, yes we are interested in the steel. Do you expect a change in iron from the containers as well?

Sean Dunagan

-----Original Message-----

From: Beverly Crawford [<mailto:crawford@lanl.gov>]  
Sent: Tuesday, August 07, 2007 4:18 PM  
To: Dunagan, Sean  
Cc: Vugrin, Eric D; Lee, Moo; Bill McInroy  
Subject: Re: Shielded Container Inventory Needs

Sean:

I think in item 2 of your request you are asking for the density of steel (as per the original request) not iron. Please let me know.  
Bev

At 02:42 PM 8/7/2007, Dunagan, Sean wrote:

>Beverly and Bill

>  
>Per our discussion earlier today, I am sending an email to modify our  
>June 18th, 2007 inventory request for the shielded container PA. The  
>items that we require for that PA are  
>  
>1) the CPR quantities associated with the RH container and emplacement  
>materials  
>2) Iron quantities associated with RH container and emplacement  
>materials  
>3) Lead quantities associated with RH containers and emplacement  
>materials  
>  
>These quantities should still be calculated under the assumption that  
>all (7,080 m<sup>3</sup>) of the RH waste is placed in shielded containers on the  
  
>repository floor.  
>  
>Note that this data represents a subset of the previous request, and  
>all other inventory data will be taken from the current baseline  
inventory.  
>  
>Thanks,  
>  
>Sean Dunagan  
>Sandia National Laboratories  
>4100 National Parks Highway  
>Building NPHA/405  
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>Work: (505) 234-0127  
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Beverly Crawford, PhD.  
TRU Waste Inventory Program Team Leader  
LANL-Carlsbad Office  
115 N. Main  
Carlsbad, NM 88220  
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## Attachment 2: MicroShield 6.02 Outputs

<b>Example 1 – Side shields with a 1 Ci Cs-137 source. ....</b>	<b>27</b>
<b>Example 2 - Top shield with 1 Ci Cs-137 source. ....</b>	<b>28</b>
<b>Example 3 - Dose with 30 gallon drum wall.....</b>	<b>29</b>
<b>Example 4 - Dose without 30 gallon drum wall.....</b>	<b>30</b>
<b>Example 5 - User defined Am-241 source. ....</b>	<b>31</b>
<b>Example 6 - User defined Cm-244 source. ....</b>	<b>32</b>
<b>Example 7 - User defined Pu-238 source.....</b>	<b>33</b>
<b>Example 8 - User defined Pu-239 source.....</b>	<b>34</b>
<b>Example 9 - User defined Pu-240 source.....</b>	<b>35</b>

This attachment presents:

- example output from Microshield runs performed to determine the curie limits for Cs-137 per shielded container (Examples 1 and 2),

The shielded container was modeled as having a 3" thick Fe top and bottom, with radial walls consisting of a 0.188" thick Fe inner liner, 1" thick Pb and 0.125" thick Fe outer liner. A cylindrical volume representing a 30 gallon drum was uniformly filled with 1 curie of each dominant radionuclide. The exposure rate at the very top of the shielded container and at the radial wall surface at the shielded container half-height was calculated. The largest of these values was used to set the activity limit per shielded container. The energies and intensities of the gamma radiations modeled are printed with the results.

- example output from Microshield runs performed to determine the impact of the 30 gallon drum wall on the external dose rate (for radionuclide ranking purposes, Examples 3 and 4), and

To adjust the dose from each of the dominant gamma emitters for radiation absorption in the 30 gallon drum wall, the gamma exposure rate at a fixed point with and without a 0.047" Fe shield was modeled using Microshield 6.02. The ratio of the exposure rate with the shield to the exposure rate without the shield was then built into the ranking of the dominant gamma emitting radionuclides.

- listings of the user defined sources used for Am-241, Cm-244, Pu-238,-239,-240 (Examples 5 through 9).

10.0 Example 1 – Side shields with a 1 Ci Cs-137 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

Page :1  
 DOS File :ModifiedShieldedDrumSideShield.ms6  
 Run Date : August 30, 2007  
 Run Time : 10:43:19 AM  
 Duration : 00:00:00

File Ref :  
 Date :  
 By :  
 Checked :

Case Title:  
 Description:

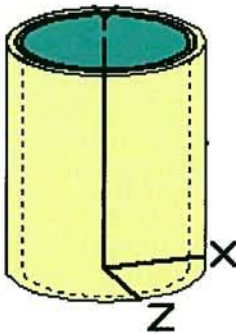
Geometry: 7 - Cylinder Volume - Side Shields

**Source Dimensions:**

Height 70.333 cm (2 ft 3.7 in)  
 Radius 24.498 cm (9.6 in)

**Dose Points**

A	X	Y	Z
# 1	29.2354 cm 11.5 in	35.1663 cm 1 ft 1.8 in	0 cm 0.0 in



**Shields**

Shield N	Dimension	Material	Density
Source	8092.399 in <sup>3</sup>	Air	0.00122
Shield 1	.542 in	Air	0.00122
Shield 2	.188 in	Iron	7.86
Shield 3	1.0 in	Lead	11.34
Shield 4	.125 in	Iron	7.86
Transition		Air	0.00122
Air Gap		Air	0.00122

**Source Input : Grouping Method - Actual Photon Energies**

Nuclide	curies	becquerels	μCi/cm <sup>3</sup>	Bq/cm <sup>3</sup>
Ba-137m	9.4600e-001	3.5002e+010	7.1337e+000	2.6395e+005
Cs-137	1.0000e+000	3.7000e+010	7.5409e+000	2.7901e+005

**Buildup : The material reference is - Shield 3**  
**Integration Parameters**

Radial	10
Circumferential	10
Y Direction (axial)	20

**Results**

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
0.0045	3.634e+08	0.000e+00	1.205e-24	0.000e+00	8.259e-25
0.0318	7.246e+08	0.000e+00	1.768e-23	0.000e+00	1.473e-25
0.0322	1.337e+09	1.963e-318	3.304e-23	1.580e-320	2.659e-25
0.0364	4.865e+08	1.229e-229	1.375e-23	6.982e-232	7.815e-26
0.6616	3.149e+10	2.036e+04	3.759e+04	3.948e+01	7.288e+01
<b>Totals</b>	<b>3.441e+10</b>	<b>2.036e+04</b>	<b>3.759e+04</b>	<b>3.948e+01</b>	<b>7.288e+01</b>

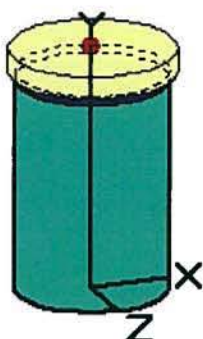
11.0 Example 2 - Top shield with 1 Ci Cs-137 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
**DOS File** :ModifiedShieldedDrumTopShield.ms6  
**Run Date** : August 30, 2007  
**Run Time** : 10:47:07 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** Shielded Drum v.2  
**Description:** Top Shield  
**Geometry:** 8 - Cylinder Volume - End Shields



**Source Dimensions:**

**Height** 70.333 cm (2 ft 3.7 in)  
**Radius** 24.498 cm (9.6 in)

**Dose Points**

A	X	Y	Z
# 1	0 cm 0.0 in	80.64754 cm 2 ft 7.8 in	0 cm 0.0 in

**Shields**

Shield N	Dimension	Material	Density
Source	8092.399 in <sup>3</sup>	Air	0.00122
Shield 1	3.0 in	Iron	7.86
Air Gap		Air	0.00122
Top Clad	1.06 in	Air	0.00122

**Source Input : Grouping Method - Actual Photon Energies**

Nuclide	curies	becquerels	μCi/cm <sup>3</sup>	Bq/cm <sup>3</sup>
Ba-137m	9.4600e-001	3.5002e+010	7.1337e+000	2.6395e+005
Cs-137	1.0000e+000	3.7000e+010	7.5409e+000	2.7901e+005

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

Radial	20
Circumferential	10
Y Direction (axial)	10

**Results**

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
0.0045	3.634e+08	0.000e+00	8.277e-25	0.000e+00	5.674e-25
0.0318	7.246e+08	9.112e-174	1.285e-23	7.590e-176	1.070e-25
0.0322	1.337e+09	1.092e-167	2.408e-23	8.787e-170	1.938e-25
0.0364	4.865e+08	6.096e-118	1.055e-23	3.464e-120	5.997e-26
0.6616	3.149e+10	7.622e+03	5.502e+04	1.478e+01	1.067e+02
<b>Totals</b>	<b>3.441e+10</b>	<b>7.622e+03</b>	<b>5.502e+04</b>	<b>1.478e+01</b>	<b>1.067e+02</b>

12.0 Example 3 - Dose with 30 gallon drum wall.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
**DOS File** :18GaugeSteel.ms6  
**Run Date** : August 30, 2007  
**Run Time** : 10:50:28 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** Case 1  
**Description:** Case 1  
**Geometry:** 1 - Point

**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in



**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - Actual Photon Energies**

Nuclide	curies	becquerels
Ba-137m	9.4600e-001	3.5002e+010
Cs-137	1.0000e+000	3.7000e+010

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

**Results**

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm <sup>2</sup> /sec		Exposure Rate mR/hr	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0318	7.246e+08	3.407e+01	3.646e+01	2.838e-01	3.037e-01
0.0322	1.337e+09	7.840e+01	8.396e+01	6.309e-01	6.757e-01
0.0364	4.865e+08	1.959e+02	2.117e+02	1.113e+00	1.203e+00
0.6616	3.149e+10	1.547e+07	1.629e+07	3.000e+04	3.158e+04
<b>Totals</b>	<b>3.404e+10</b>	<b>1.548e+07</b>	<b>1.629e+07</b>	<b>3.000e+04</b>	<b>3.158e+04</b>

13.0 Example 4 - Dose without 30 gallon drum wall.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
**DOS File** :18GaugeSteel.ms6  
**Run Date** : August 30, 2007  
**Run Time** : 10:51:17 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** Case 1  
**Description:** Case 1  
**Geometry:** 1 - Point

**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in



**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Air	0.00122
Air Gap		Air	0.00122

**Source Input : Grouping Method - Actual Photon Energies**

Nuclide	curies	becquerels
Ba-137m	9.4600e-001	3.5002e+010
Cs-137	1.0000e+000	3.7000e+010

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

**Results**

Energy MeV	Activity Photons/sec	Fluence Rate MeV/cm <sup>2</sup> /sec		Exposure Rate mR/hr	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0318	7.246e+08	1.828e+04	1.836e+04	1.523e+02	1.530e+02
0.0322	1.337e+09	3.413e+04	3.428e+04	2.747e+02	2.759e+02
0.0364	4.865e+08	1.405e+04	1.411e+04	7.982e+01	8.018e+01
0.6616	3.149e+10	1.657e+07	1.658e+07	3.212e+04	3.214e+04
<b>Totals</b>	<b>3.404e+10</b>	<b>1.663e+07</b>	<b>1.665e+07</b>	<b>3.262e+04</b>	<b>3.265e+04</b>

14.0 Example 5 - User defined Am-241 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
**DOS File** :18GaugeSteel.ms6  
**Run Date** : August 30, 2007  
**Run Time** : 10:57:03 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** 1 Ci Am-241  
**Description:** Case 1  
**Geometry:** 1 - Point



**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in

**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - User Defined Energies**

Group #	Energy (Mev)	Activity Photons/sec	Point Source Photons/sec	% Energy Activity
1	0.0263	8.8800e+008	8.8800e+008	2.853
2	0.0322	6.4380e+006	6.4380e+006	.025
3	0.0332	4.6620e+007	4.6620e+007	.189
4	0.0427	2.0350e+006	2.0350e+006	.011
5	0.0434	2.7010e+007	2.7010e+007	.143
6	0.0556	6.6970e+006	6.6970e+006	.045
7	0.0579	1.9240e+006	1.9240e+006	.014
8	0.0595	1.3283e+010	1.3283e+010	96.451
9	0.0698	1.0730e+006	1.0730e+006	.009
10	0.0758	2.2200e+005	2.2200e+005	.002
11	0.099	7.5110e+006	7.5110e+006	.091
12	0.103	7.2150e+006	7.2150e+006	.091
13	0.123	3.7000e+005	3.7000e+005	.006
14	0.1253	1.5096e+006	1.5096e+006	.023
15	0.1466	1.7057e+005	1.7057e+005	.003
16	0.1696	6.4010e+004	6.4010e+004	.001
17	0.208	2.9267e+005	2.9267e+005	.007
18	0.3225	5.6240e+004	5.6240e+004	.002
19	0.3324	5.5130e+004	5.5130e+004	.002
20	0.3354	1.8352e+005	1.8352e+005	.008
21	0.3686	8.0290e+004	8.0290e+004	.004
22	0.3767	5.1060e+004	5.1060e+004	.002
23	0.619	2.1978e+004	2.1978e+004	.002
24	0.6624	1.3468e+005	1.3468e+005	.011
25	0.722	7.2520e+004	7.2520e+004	.006

15.0 Example 6 - User defined Cm-244 source.

**MicroShield v6.02 (6.02-00069)**  
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**Run Time** : 10:58:26 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** 1 Ci Cm-244  
**Description:** Case 1  
**Geometry:** 1 - Point



**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in

**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - User Defined Energies**

Group #	Energy (Mev)	Activity Photons/sec	Point Source Photons/sec	% Energy Activity
1	0.0428	8.8800e+006	8.8800e+006	68.010
2	0.0989	5.9940e+005	5.9940e+005	10.598
3	0.1526	3.6260e+005	3.6260e+005	9.898
4	0.2515	3.6260e+003	3.6260e+003	.163
5	0.2634	1.9980e+004	1.9980e+004	.941
6	0.2892	1.7390e+002	1.7390e+002	.009
7	0.303	6.1790e+003	6.1790e+003	.335
8	0.3407	6.2900e+002	6.2900e+002	.038
9	0.5072	2.8860e+003	2.8860e+003	.262
10	0.5546	2.9230e+004	2.9230e+004	2.899
11	0.5974	1.8130e+004	1.8130e+004	1.937
12	0.6061	2.7010e+003	2.7010e+003	.293
13	0.7586	4.6990e+003	4.6990e+003	.638
14	0.8179	2.3680e+004	2.3680e+004	3.464
15	0.8575	1.9980e+003	1.9980e+003	.306
16	0.8953	6.2900e+002	6.2900e+002	.101
17	0.9004	4.4400e+002	4.4400e+002	.071
18	0.938	2.2200e+002	2.2200e+002	.037



16.0 Example 7 - User defined Pu-238 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
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**Run Date** : August 30, 2007  
**Run Time** : 10:59:24 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** 1 Ci Pu-238  
**Description:** Case 1  
**Geometry:** 1 - Point



**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in

**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - User Defined Energies**

Group #	Energy (Mev)	Activity Photons/sec	Point Source Photons/sec	% Energy Activity
1	0.0435	1.5000e+007	1.5000e+007	66.149
2	0.0999	2.7000e+006	2.7000e+006	27.331
3	0.1527	3.5000e+005	3.5000e+005	5.418
4	0.201	1.4000e+003	1.4000e+003	.029
5	0.2582	3.1000e+001	3.1000e+001	.001
6	0.2991	1.8000e+001	1.8000e+001	.001
7	0.7059	2.0000e+001	2.0000e+001	.001
8	0.7083	1.5000e+002	1.5000e+002	.011
9	0.7428	1.9000e+003	1.9000e+003	.143
10	0.7664	8.1000e+003	8.1000e+003	.629
11	0.7834	8.9000e+000	8.9000e+000	.001
12	0.7863	1.2000e+003	1.2000e+003	.096
13	0.8044	4.4000e+001	4.4000e+001	.004
14	0.8058	2.2000e+001	2.2000e+001	.002
15	0.8082	3.0000e+002	3.0000e+002	.025
16	0.8517	4.6000e+002	4.6000e+002	.040
17	0.8805	5.9000e+001	5.9000e+001	.005
18	0.8832	2.8000e+002	2.8000e+002	.025
19	0.9044	2.4000e+001	2.4000e+001	.002
20	0.9267	2.1000e+002	2.1000e+002	.020
21	0.9419	1.7000e+002	1.7000e+002	.016
22	0.946	3.2000e+001	3.2000e+001	.003
23	1.001	3.7000e+002	3.7000e+002	.038
24	1.042	8.1000e+001	8.1000e+001	.009
25	1.085	3.4000e+001	3.4000e+001	.004

17.0 Example 8 - User defined Pu-239 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

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**Run Time** : 11:00:09 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** 1 Ci Pu-239  
**Description:** Case 1  
**Geometry:** 1 - Point



**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in

**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - User Defined Energies**

Group #	Energy (Mev)	Activity Photons/sec	Point Source Photons/sec	% Energy Activity
1	0.0387	3.8850e+006	3.8850e+006	7.527
2	0.0462	2.7380e+005	2.7380e+005	.634
3	0.0516	1.0027e+007	1.0027e+007	25.942
4	0.0568	4.1810e+005	4.1810e+005	1.191
5	0.0776	1.5170e+005	1.5170e+005	.590
6	0.0988	4.5140e+005	4.5140e+005	2.235
7	0.103	8.5100e+004	8.5100e+004	.439
8	0.1154	1.7020e+005	1.7020e+005	.984
9	0.1163	2.2089e+005	2.2089e+005	1.287
10	0.1293	2.3347e+006	2.3347e+006	15.129
11	0.1442	1.0471e+005	1.0471e+005	.757
12	0.2035	2.1053e+005	2.1053e+005	2.148
13	0.3328	1.8278e+005	1.8278e+005	3.049
14	0.3361	4.1440e+004	4.1440e+004	.698
15	0.345	2.0572e+005	2.0572e+005	3.557
16	0.3671	3.2930e+004	3.2930e+004	.606
17	0.3686	3.2560e+004	3.2560e+004	.601
18	0.375	5.7498e+005	5.7498e+005	10.807
19	0.3802	1.1285e+005	1.1285e+005	2.150
20	0.3828	9.5830e+004	9.5830e+004	1.838
21	0.3926	7.5850e+004	7.5850e+004	1.492
22	0.3931	1.2950e+005	1.2950e+005	2.551
23	0.4137	5.4242e+005	5.4242e+005	11.246
24	0.4226	4.5140e+004	4.5140e+004	.956
25	0.4515	7.0078e+004	7.0078e+004	1.586

18.0 Example 9 - User defined Pu-240 source.

**MicroShield v6.02 (6.02-00069)**  
**Los Alamos National Laboratories**

**Page** :1  
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**Run Date** : August 30, 2007  
**Run Time** : 11:23:04 AM  
**Duration** : 00:00:00

**File Ref** :  
**Date** :  
**By** :  
**Checked** :

**Case Title:** 1 Ci Pu-240  
**Description:** Case 1  
**Geometry:** 1 - Point

**Dose Points**

A	X	Y	Z
# 1	10 cm 3.9 in	0 cm 0.0 in	0 cm 0.0 in



**Shields**

Shield N	Dimension	Material	Density
Shield 1	.047 in	Iron	7.86
Air Gap		Air	0.00122

**Source Input : Grouping Method - User Defined Energies**

Group #	Energy (Mev)	Activity Photons/sec	Point Source Photons/sec	% Energy Activity
1	0.045	1.6650e+007	1.6650e+007	71.219
2	0.104	2.6196e+006	2.6196e+006	25.896
3	0.16	1.4874e+005	1.4874e+005	2.262
4	0.212	1.0730e+004	1.0730e+004	.216
5	0.538	5.4000e+001	5.4000e+001	.003
6	0.642	4.8100e+003	4.8100e+003	.294
7	0.688	1.2950e+003	1.2950e+003	.085
8	0.698	9.0000e+000	9.0000e+000	.001
9	0.874	2.1500e+002	2.1500e+002	.018
10	0.958	3.7000e+001	3.7000e+001	.003
11	0.96	1.9000e+001	1.9000e+001	.002
12	0.967	1.9000e+001	1.9000e+001	.002
<b>Totals</b>	<b>1.944e+07</b>	<b>2.390e+02 2.729e+02</b>	<b>4.734e-01</b>	<b>5.375e-01</b>