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Decay Heat of Selected DOE-Managed Waste Materials

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Introduction

- This study provided a common data source for current DOE defense waste inventory and projections that are traceable, transparent, and reproducible. The intent of this study is to provide enough information to support both a general description (canister count) and specific details (radionuclide inventory and decay heat) of the material.

DOE-Managed Spent Nuclear Fuel

- The source of current inventory data for this study is information collected in support of the Office of Civilian Radioactive Waste's Management (OCRWM) efforts for licensing the Yucca Mountain Repository. [1, 2]
  - Complex wide DOE SNF data has been collected and is maintained in the Spent Fuel Database. The Spent Fuel Database contains the following information: inventory data by site, area, and facility; physical characteristics; chemical composition of the fuel compound, cladding, and other significant constituent components; burn-up data; source term data.
  - Based upon this information, spreadsheets were generated to calculate the decay heat and radionuclide inventory of the canisters for disposition.
- Decay heat of DOE SNF is based on the estimated radionuclide inventory.
  - This methodology was applied to each fuel in the DOE SNF inventory to develop a radionuclide estimate.
  - Also in support of the Yucca Mountain License Application, a packaging plan was developed using the DOE standardized canisters.
  - These two data sources are detailed in the DOE SNF database maintained by INL and used to estimate the decay heat per canister for DOE SNF.

DOE Spent Nuclear Fuel from Defense and R&D Activities Canister Decay Heat

	2010	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	1,163	46.8%
50-100	234	56.2%
100-200	940	94.1%
200-300	12	94.5%
300-500	41	96.2%
500-1000	88	99.7%
1000-1500	4	99.9%
1500 - 2000	0	99.9%
>2000	3	100.0%
Total	**2,485**	
Total Decay Heat (watts)		**540,064**

DOE Commercial Spent Nuclear Fuel Canister Decay Heat

	2010	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	339	24.4%
50-100	380	51.9%
100-200	182	65.0%
200-300	390	93.1%
300-500	58	97.3%
500-1000	33	99.7%
1000-1500	1	99.8%
1500 - 2000	0	99.8%
>2000	3	100.0%
Total	**1,386**	
Total Decay Heat (watts)		**242,950**

DOE-Managed High Level Waste: SRS Borosilicate Glass Canisters

- SRS began conversion of the liquid defense waste into borosilicate glass in 1996 and is the only DOE site with defense HLW in a packaged configuration.
- A total of 3,781 canisters have been produced through March 2014.
- Decay heat of the current inventory is based on radiological inventories contained in the production records for those canisters.
- The decay heat of future canisters is estimated based on radionuclide inventory of HLW remaining in the liquid waste storage tanks.
- The radionuclide and resulting decay heat was calculated based on the year the canister is/will be produced.

SRS Borosilicate Glass Canisters

Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	2,948	37.7%
50-100	497	44.0%
100-200	3,592	89.9%
200-300	501	96.3%
300-500	286	100.0%
>500	-	100.0%
Total	**7,824**	
Total Decay Heat (watts)		**787,562**

DOE-Managed High Level Waste: Hanford Borosilicate Glass Canisters

- The Hanford Waste Treatment Project (WTP) is currently under construction and therefore the Hanford borosilicate glass canisters are based on a projected inventory for their future production taken from the March 2012 Waste Treatment Plant document.
- This projection is the baseline scenario for vitrification of all tank waste as HLW in WTP, and does not account for potential diversion of any tank waste as TRU.
- Decay heat is reported at the time of production based on the reference assessment

Hanford Borosilicate Glass Canisters

Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	10,012	84.8%
50-100	1,237	95.3%
100-200	523	99.5%
200-300	28	100.0%
>300	-	100.0%
Total	**11,800**	
Total Decay Heat (watts)		**304,904**

Hanford Cs/Sr Capsule Direct Disposal

	Cs Capsules (2010)		Sr Capsules (2010)		Total Capsules	
Decay heat per canister (watts)	Number of canisters	Cumulative %	Number of canisters	Cumulative %	Number of canisters	Cumulative%
<50	3	0.2%	37	6.2%	40	2.1%
50-100	10	1.0%	108	24.1%	118	8.2%
100-200	1,322	100.0%	243	64.6%	1,565	89.0%
200-300	-	100.0%	119	84.4%	119	95.1%
300-500	-	100.0%	94	100.0%	94	100.0%
>500	-	100.0%	-	100.0%	-	100.0%
Total	**1,335**		**601**			
Total Decay Heat (watts)		**181,816**		**106,858**		**288,675**

DOE-Managed High Level Waste: Hanford Cs/Sr Capsule

- The Record of Decision states that incorporation into HLW glass is the selected disposition pathway for the capsule contents.
  - The 1,335 cesium capsules and 601 strontium capsules are estimated to contain 24 million curies of Cs-137/Ba-137m and Sr-90/Y-90 (133 kW) as of January, 2043 (6).
- The capsule contents have potential to generate an additional 340 HLW glass canisters (7)

Hanford Cs/Sr Capsule Borosilicate Glass Disposal

	2010		2043	
Decay heat per canister (watts)	Number of canisters	Cumulative %	Number of canisters	Cumulative %
300-500	-	0.0%	340	100.0%
500-1000	340	100.0%		100.0%
>1000	-	100.0%	-	100.0%
Total	**340**		**340**	
Total Decay Heat (watts)		**228,675**		**132,622**

DOE-Managed High Level Waste: Idaho Calcine Waste Canisters

- Decay heat load of DOE HLW that has been calcined and is currently stored at the Idaho site is taken from the October 2005 Idaho Cleanup Project document titled "Decay Heat and Radiation from Direct Disposed Calcine".
  - This report provides data for direct disposal of the calcine waste. The current Record of Decision for disposal of the calcine is for it to be treated using a hot isostatic pressing (HIP), which will result in an approximate 50% increase in the mass of calcine material in each disposal canister and a corresponding 50% increase in the decay heat per canister versus the current density of granular calcine.
  - This study assumes the HIP product material is packaged for disposal in a standard 2 ft x 10 ft cylindrical canister, resulting in approximately 4400 canisters.

Idaho Calcine Waste Canisters

	2010	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	4,391	100.0%
>50	-	100.0%
Total	**4,391**	
Total Decay Heat (watts)		**95,581**

Decay Heat for All DOE Managed High Level Waste

- The data indicate: ~71% of the HLW canisters will be less than 50 watts; ~78% of the canisters will be less than 100 watts; 97% will be less than 300 watts and all the canisters will be less than 700 watts. The total decay heat to be emplaced in these cases is above 1.3 million watts.

Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	17,351	71.2%
50-100	1,734	78.4%
100-200	4,115	95.3%
200-300	529	97.4%
300-500	626	100.0%
>500	-	100.0%
Total	**24,355**	
Total Decay Heat (watts)		**1,320,669**

Decay Heat and Source Term for All DOE Managed High Level Waste

- Process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE SNF was used to develop a source-term estimate.
- This methodology was applied to each fuel in the DOE SNF inventory to develop a radionuclide estimate.
- This source term estimate was then compiled into the decay heat bins and the average and standard deviation of the radionuclide information was compiled.
- The total HLW radionuclide inventory for each of the generating sites based on the time of production was used as reference for this assessment
  - Except for the Cs/Sr capsule glass and direct disposal which is reported for the year 2010.

DOE SNF Average Radionuclide inventory per canister for 200-300 Watts Bin

Radionuclide	Curies	Std. Deviation
^{227}Ac	1.83E-04	5.08E-05
^{241}Am	1.01E+03	6.04E+02
^{242m}Am	1.76E+00	9.68E-01
^{243}Am	2.42E+00	1.64E+00
^{137m}Ba	1.46E+04	4.86E+03
^{14}C	2.16E-01	5.03E-01
^{113m}Cd	3.39E+00	9.06E-01
^{144}Ce	1.35E+01	4.10E+02
^{36}Cl	2.16E-03	2.53E-03
^{242}Cm	7.51E-01	3.55E-01
^{243}Cm	1.37E+00	6.53E-01
^{244}Cm	7.93E+01	1.28E+02
^{245}Cm	1.81E-02	2.38E-02
^{246}Cm	3.65E-03	4.12E-03
^{247}Cm	9.53E-09	4.55E-09
^{60}Co	2.88E+01	1.17E+03
^{134}Cs	1.06E+02	2.48E+02
^{135}Cs	2.00E-01	5.06E-02
^{137}Cs	2.16E+04	7.09E+03
^{154}Eu	1.90E+02	7.33E+01

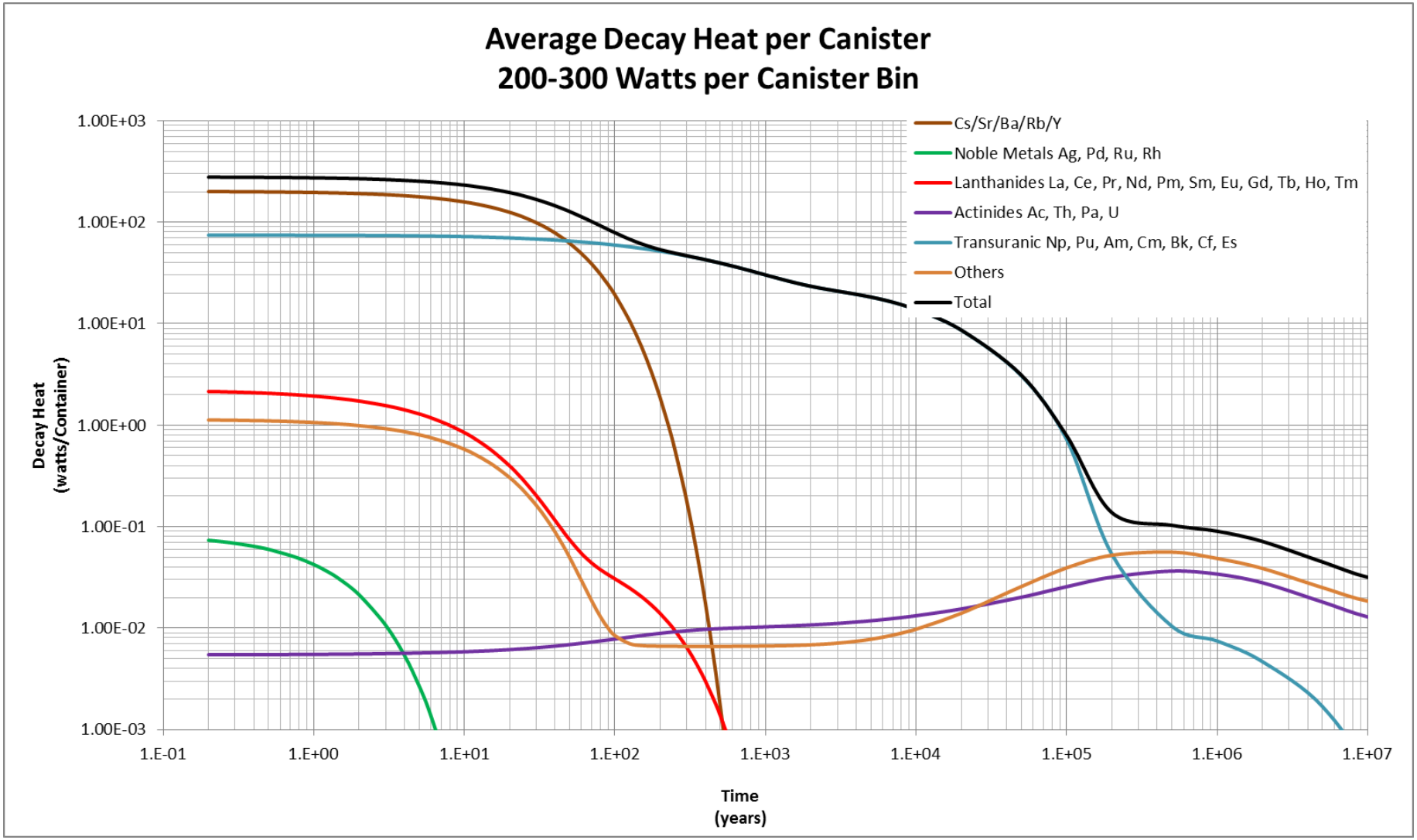
Radionuclide	Curies	Std. Deviation
^{155}Eu	2.68E+01	3.19E+01
^{55}Fe	3.06E-02	7.16E+02
^{3}H	5.41E+01	1.93E+01
^{129}I	9.43E-03	4.25E-03
^{85}Kr	7.18E+02	2.68E+02
^{93m}Nb	4.14E-01	6.27E-01
^{94}Nb	2.80E-02	7.20E-03
^{59}Ni	1.97E-01	4.84E-01
^{63}Ni	1.48E+01	3.24E+02
^{237}Np	7.46E-02	5.15E-02
^{231}Pa	4.24E-04	4.72E-05
^{210}Pb	1.71E-08	2.00E-08
^{107}Pd	2.23E-02	1.27E-02
^{147}Pm	8.98E+02	2.22E+03
^{238}Pu	3.97E+02	3.15E+02
^{239}Pu	4.09E+02	3.75E+02
^{240}Pu	3.99E+02	3.09E+02
^{241}Pu	1.19E+04	8.57E+03
^{242}Pu	2.65E-01	1.77E-01
^{226}Ra	6.68E-08	1.62E-06

Radionuclide	Curies	Std. Deviation
^{228}Ra	9.03E-08	2.39E-04
^{106}Ru	8.72E+00	9.68E+01
^{125}Sb	1.69E+01	8.61E+01
^{79}Se	1.41E-01	5.32E-02
^{147}Sm	2.07E-06	5.02E-07
^{151}Sm	5.54E+02	2.99E+02
^{126}Sn	2.44E-01	1.05E-01
^{90}Sr	1.44E+04	4.83E+03
^{99}Tc	3.97E+00	1.78E+00
^{229}Th	2.73E-07	6.42E-05
^{230}Th	5.71E-06	3.82E-05
^{232}Th	2.62E-08	2.27E-05
^{232}U	2.44E-03	1.00E-03
^{233}U	9.54E-05	2.48E-02
^{234}U	3.91E-02	7.13E-01
^{235}U	2.07E-02	2.51E-02
^{236}U	6.54E-02	8.59E-02
^{238}U	5.66E-02	5.38E-01
^{90}Y	1.22E+04	4.84E+03
^{93}Zr	5.59E-01	2.53E-01
Total	7.96E+04	1.02E+04

Decay heat for average canister of DOE SNF in the 200-300 Watts per canister bin

Elements	Decay Heat (watts)						
	Time (years)						
	0	5	10	50	100	1,000	1,000,000
Gases H, C, Xe, Kr, I	0.002	0.001	0.001	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	166.617	178.401	158.530	62.066	19.232	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.001	0.003	0.000	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	2.111	1.292	0.845	0.074	0.031	0.000	0.000
Actinides Ac, Th, Pa, U	0.005	0.006	0.006	0.007	0.008	0.010	0.034
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	74.602	73.381	72.214	65.301	59.580	30.251	0.007
Others	1.137	0.806	0.578	0.050	0.008	0.007	0.049
Total	**244.474**	**253.890**	**232.175**	**127.498**	**78.859**	**30.268**	**0.090**

Decay heat for average canister of DOE SNF in the 200-300 Watts per canister bin



References

- DOE. Yucca Mountain Repository License Application. In., 2008.
- Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain. In.: Nye County, Nevada, 2002.
- CHEW, D. P. AND B. A. HAMM. Savannah River Liquid Waste System Plan. 2012.
- MCILMOYLE, D. W. AND B. A. HAMM. Canister Wattage Projections for Future Sludge and Salt Processing at DWPF Using Liquid Waste System Plan Rev. 16. 2011.
- JENKINS, K. D., S. L. ORCUTT AND I. Z. STONE. 2010 WTP Tank Utilization Assessment. 2010.
- COVEY, L. I. WESF Capsule and EDS Configuration Document. 2002.
- Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS). In. Benton County, Washington, 2012.
- CERTA, P. J. AND M. N. WELLS. River Protection Project System Plan. 2011.
- HERBST, A. K. Decay Heat and Radiation from Direct Disposed Calcine. Idaho National Engineering and Environmental Laboratory: 2005.