Decay Heat of Selected DOE-Managed Waste Materials

Fuel Cycle Research & Development

Prepared for
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June 2016
FCRD-UFD-2016-000635
SRNL-RP-2016-00474

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Acronyms

DOE	Department of Energy
DOE-NE	Department of Energy Office of Nuclear Energy
FCR&D	Fuel Cycle Research and Development
GA	General Atomics
HIP	Hot Isostatic Pressing
HLW	High Level Waste
HM	Heavy Metal
INL	Idaho National Laboratory
MT	Metric Ton
MTHM	Metric Tons of Heavy Metal
OCRWM	Office of Civilian Radioactive Waste Management
SNF	Spent Nuclear Fuel
SRS	Savannah River Site
TRIGA	Training, Research, and Isotope Reactors (built by GA)
TRU	Transuranic
UFD	Used Fuel Disposition
UNF	Used Nuclear Fuel

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FUEL CYCLE TECHNOLOGY

USED NUCLEAR FUEL DISPOSITION

1. Introduction

This study provides 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.

2. DOE-Managed Waste Inventory

Since the inception of nuclear reactors, the DOE and its predecessor agencies operated or sponsored a variety of research, test, training, and other experimental reactors both domestically and overseas.

Aqueous reprocessing of DOE SNF has occurred at the Hanford Site, the Idaho National Laboratory (INL), and the Savannah River Site (SRS). The INL is pursuing the use of electrometallurgical treatment processing for ~60 MTHM of sodium bonded SNF.

The waste requiring disposition from these DOE activities are fairly well understood and documented. This section summarizes these wastes.

2.1 DOE-Managed Spent Nuclear Fuel

DOE-managed SNF (DSNF) is primarily generated by DOE production reactors, demonstration commercial power reactors, and domestic and foreign research and training reactors. DSNF includes some commercial SNF not in the possession of NRC-licensed commercial utilities.

Over the past several decades, since the inception of nuclear reactors, the DOE and its predecessor agencies operated or sponsored a variety of research, test, training, and other experimental reactors with different characteristics from the commercial power reactors of today. DOE SNF generated in production reactors supported weapons and other isotope production programs. An example of SNF existing today from production reactors is the N Reactor SNF stored at Hanford. Some SNF from commercial power reactors, such as Shippingport, Peach Bottom, and Fort St. Vrain, is stored within the DOE complex. This SNF was generated for commercial power demonstration purposes or as part of research projects. Also, the Three Mile Island Unit 2 SNF debris is stored at the INL.

DOE has sponsored nuclear research activities in the U. S. and overseas. There are numerous university and government research reactor sites within the United States. SNF from research reactors is stored primarily at the INL and SRS. Examples of research reactor SNF being stored within the DOE complex include the High-Flux Beam Reactor SNF stored at the SRS; the Fast Flux Test Facility SNF stored at Hanford and the INL; training, research, and isotope reactors (built by GA) (TRIGA) SNF stored at Hanford and the INL; and the Advanced Test Reactor SNF stored at the Idaho National Laboratory. Additional research reactor SNF is being returned to the U. S. from foreign research reactors as part of the DOE Foreign Research Reactor Spent Nuclear Fuel Return Program.

2.1.1 DOE-Managed SNF Inventory

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.

The majority of DOE SNF (about 2500 metric tons of heavy metal (MTHM) that has been generated is in storage. DOE continues to operate several research reactors and will be receiving SNF from universities and the foreign research reactor return program. Projected material amounts are relatively small (about 50 MTHM) and there is some uncertainty as to the total amount that will be generated or received. The inventory discussed below covers all DOE SNF, SNF which is currently in DOE storage and projected SNF generation or receipts.

DOE SNF comes from a wide range of reactor types, such as light- and heavy-water-moderated reactors, graphite-moderated reactors, and breeder reactors, with various cladding materials and enrichments, varying from depleted uranium to over 93% enriched U235. Many of these reactors, now decommissioned, had unique design features, such as core configuration, fuel element and assembly geometry, moderator and coolant materials, operational characteristics, and neutron spatial and spectral properties.

As described below, there is a large diversity of reactor and fuel designs. In addition, there is a relatively large number (over 200,000) of fuel pieces or assemblies, which range from a large number of pieces for some reactors (N Reactor) to a few individual pieces for other unique reactors (Chicago Pile-5 converter cylinders).

2.1.2 DOE SNF Storage/Canisters

Although DOE SNF is stored throughout the U. S. at numerous facilities, a decision was made in 1995 to consolidate DOE SNF at three existing DOE sites; Hanford Site in Washington, the INL in Idaho, and the SRS in South Carolina. The vast majority of DOE SNFs are currently stored at these three sites. The storage configurations vary for each of the sites and include both dry and wet storage. On a MTHM basis, a large portion of the SNF (about 2100 MTHM) is contained in about 400 sealed canisters. The majority of the remaining SNF will most likely be placed in canisters.

Decay heat of DOE Spent Nuclear Fuel (SNF) is based on the estimated radionuclide inventory. In support of the Yucca Mountain License Application, an analytical approach, using process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE SNF was used to develop a radionuclide inventory estimate. 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.

The radionuclide inventory and resulting decay heat was calculated in the year 2010 for SNF in the possession of DOE, but excluded Naval SNF.

Table 2-1 provides the distribution of DOE SNF canisters of non-commercial fuel based on the 2010 decay heat using the 2035 total canister count. The 2010 data indicates approximately 45% of the DOE SNF canisters will be less than 50 watts. Approximately 90% of the DOE SNF canisters will be less than 300 watts. Nearly all the DOE SNF canisters (>99%) will be less than 1 kW. Table 2-2 provides the distribution of DOE SNF canisters of commercial fuel.

The decay heat over time for the DOE SNF bins is presented in Appendix A.

Table 2-1 DOE Spent Nuclear Fuel from Defense and Research and Development Activities Canister Decay Heat

Decay heat per canister (watts)	2010	
	Number of canisters	Cumulative %
<50	1163	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	**2485**	
Total Decay Heat (watts)	**540,064**	

Does not include the Savannah River Site SRE fuel or commercial fuel in DOE possession

Table 2-2 DOE Commercial Spent Nuclear Fuel Canister Decay Heat

Decay heat per canister (watts)	2010	
	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	**1386**	
Total Decay Heat (watts)	**242,950**	

2.1.3 DOE-Managed SNF Radionuclide Inventory

Process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE SNF was used to develop a source-term estimate. In support of the Yucca Mountain License Application, an analytical approach, using process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE SNF was used to develop a radionuclide inventory 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 is presented in Appendix A.

2.2 DOE-Managed High Level Waste

2.2.1 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. Therefore, the SRS inventory can be described as those canisters in the current inventory and those projected from future operations. 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. The total Savannah River canister count is based in information supporting Savannah River Liquid Waste Disposition Plan revision 18.(3; 4)

Table 2-3 provides the canister distribution of SRS canisters based on the nominal decay heat at the time of production, with the average year of production of each bin. The data indicates: 37% of the Savannah River canisters will be less than 50 watts; 96% of the Savannah River canisters will be less than 300 watts; all the SRS canisters will be less than 500 watts.

Table 2-3 Savannah River Canister Decay Heat Distribution

Decay heat per canister (watts)	Number of canisters	Cumulative %	Average Year of Production
<50	2,948	37.7%	2003
50-100	497	44.0%	2013
100-200	3,592	89.9%	2018
200-300	501	96.3%	2020
300-500	286	100.0%	2019
>500	-	100.0%	-
Total	**7,824**		
Total Decay Heat (watts)		**787,562**	

2.2.1 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 (5). 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. The data in Table 3-2 indicates: 83% of the Hanford canisters will be less than 50 watts, and 100% of the Hanford canisters will be less than 300 watts, except for those canister produced from vitrification of the contents of the Cs/Sr capsules, as shown in Table 2-4. Decay heat is reported at the time of production based on the reference assessment, with the average year of production for each bin listed below. For the glass resulting from the incorporation of the Cs/Sr capsules which are referenced to 2010 and 2043.

The number of canisters and the decay heat estimates include the potential contribution from inclusion of the Hanford cesium/strontium capsules. 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), which are calculated to contain an average of ~390 watts/canister (2043 value) , as shown in Table 2-6. This thermal load is the calculated value if these capsules are processed at the end of the WTP mission, as stated in the EIS. The year 2043 is the currently projected end of the WTP mission (8). If the Cs/Sr capsules are sent for direct disposal there are a total of 1,936 capsules for disposal combined. These capsules are all under 500 watts/capsule, as shown in Table 2-7.

Table 2-4 Hanford Borosilicate Glass Canister Inventory

Decay heat per canister (watts)	Number of canisters	Cumulative %	Average Year of Production
<50	10,012	84.8%	2030
50-100	1,237	95.3%	2020
100-200	523	99.5%	2019
200-300	28	100.0%	2019
>300	-	100.0%	-
Total	**11,800**		
Total Decay Heat (watts)		**304,904**	

2.2.1 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" (9). 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.

Table 2-5 provides the distribution of DOE calcine canisters based on the nominal decay heat in the year 2016. The data indicates that 100% of calcine canisters will be less than or equal to 50 watts, even after adjustment for the HIP process density increase.

Table 2-5 Idaho Calcine Waste Canister Inventory

	Idaho Calcine (2016)	
Decay heat per canister (watts)	Number of canisters	Cumulative %
<50	4,391	100.0%
>50	-	
Total	**4,391**	
Total Decay Heat (watts)		**95,581**

Table 2-6 Hanford Cs/Sr Capsule Glass

	2010		2043	
Decay heat per canister (watts)	Number of canisters	Cumulative %	Number of canisters	Cumulative %
<50	-	0.0%	-	0.0%
50-100	-	0.0%	-	0.0%
100-200	-	0.0%	-	0.0%
200-300	-	0.0%	-	0.0%
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**	

Table 2-7 Hanford Cs/Sr Capsules for 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**	

The combined inventory from all three sites is presented in Table 2-8. 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.

Table 2-8 Decay Heat for All DOE HLW

	All DOE HLW Canisters	
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	0	100.0%
Total	**24,355**	
Total Decay Heat (watts)	**1,320,669**	

2.2.2 DOE HLW Radionuclide Inventory

Appendix B lists the total HLW radionuclide inventory for each of the generating sites based on the time of production based on the reference assessment, except for the Cs/Sr capsule glass and direct disposal which is reported for the year 2010.

3. References

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Appendix A: DOE Spent Nuclear Fuel Decay Heat and Radionuclide Inventory

A-1. DOE SNF Not in Commercial Que Radionuclide and Decay Heat Bins

Table A- 1 DOE SNF Average Radionuclide inventory per canister for <50 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation
^{227}Ac	4.70E-04	5.64E-05
^{241}Am	1.73E+03	2.79E+01
^{242m}Am	1.58E-01	5.02E-02
^{243}Am	1.18E-01	1.19E-01
^{137m}Ba	1.71E+03	8.13E+02
^{14}C	3.04E-03	1.93E-02
^{113m}Cd	1.40E-01	1.17E-01
^{144}Ce	7.11E+00	1.07E+02
^{36}Cl	4.75E-05	4.24E-04
^{242}Cm	4.63E-03	3.84E-02
^{243}Cm	7.52E-03	6.28E-02
^{244}Cm	8.82E-01	5.42E+00
^{245}Cm	1.58E-04	1.11E-03
^{246}Cm	2.72E-05	2.09E-04
^{247}Cm	5.16E-11	4.38E-10
^{60}Co	1.61E+00	1.53E+02
^{134}Cs	3.30E+01	5.19E+01
^{135}Cs	8.22E-01	1.05E-02
^{137}Cs	1.91E+03	9.11E+02
^{154}Eu	1.88E+01	7.39E+01
^{155}Eu	5.52E+00	2.63E+01
^{55}Fe	1.28E-01	9.22E+01
^{3}H	2.12E+00	2.42E+00
^{129}I	5.45E-02	3.54E-04
^{85}Kr	1.34E+02	6.48E+01
^{93m}Nb	3.59E+00	1.69E-02
^{94}Nb	2.72E-04	1.72E-03
^{59}Ni	6.95E-03	8.17E-02
^{63}Ni	1.38E+00	1.40E+01
^{237}Np	3.20E-01	3.02E-03
^{231}Pa	9.77E-04	1.07E-04

Radionuclide	Curies	Std. Deviation
^{210}Pb	4.36E-08	4.29E-08
^{107}Pd	9.45E-02	8.73E-04
^{147}Pm	4.59E+02	3.74E+02
^{238}Pu	1.96E+02	5.40E+01
^{239}Pu	2.33E+03	7.63E+00
^{240}Pu	7.12E+02	8.42E+00
^{241}Pu	6.64E+03	4.72E+02
^{242}Pu	8.43E-02	2.05E-02
^{226}Ra	1.34E-07	1.23E-07
^{228}Ra	1.57E-06	4.99E-05
^{106}Ru	3.68E+00	2.06E+01
^{125}Sb	5.19E+00	1.26E+01
^{79}Se	8.98E-01	7.15E-03
^{147}Sm	1.08E-06	1.56E-05
^{151}Sm	1.83E+03	2.56E+01
^{126}Sn	1.34E+00	8.35E-03
^{90}Sr	1.84E+03	8.54E+02
^{99}Tc	2.90E+01	1.70E-01
^{229}Th	2.37E-06	1.55E-04
^{230}Th	1.57E-05	2.81E-05
^{232}Th	7.32E-07	5.64E-05
^{232}U	4.11E-04	6.90E-03
^{233}U	1.02E-03	5.98E-02
^{234}U	5.24E-02	4.32E-01
^{235}U	9.79E-01	8.86E-03
^{236}U	8.35E-01	3.62E-02
^{238}U	6.69E+00	8.30E-03
^{90}Y	1.75E+03	8.15E+02
^{93}Zr	4.19E+00	2.22E-02
Total	2.14E+04	3.82E+03

Table A- 2 Decay heat for average canister of DOE SNF in the <50 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	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	13.116	11.927	10.567	4.125	1.274	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.001	0.004	0.000	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.397	0.192	0.111	0.005	0.001	0.000	0.000
Actinides Ac, Th, Pa, U	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	1.043	1.014	0.987	0.820	0.683	0.245	0.000
Others	0.150	0.097	0.067	0.005	0.000	0.000	0.003
Total	**14.709**	**13.236**	**11.734**	**4.957**	**1.961**	**0.247**	**0.005**

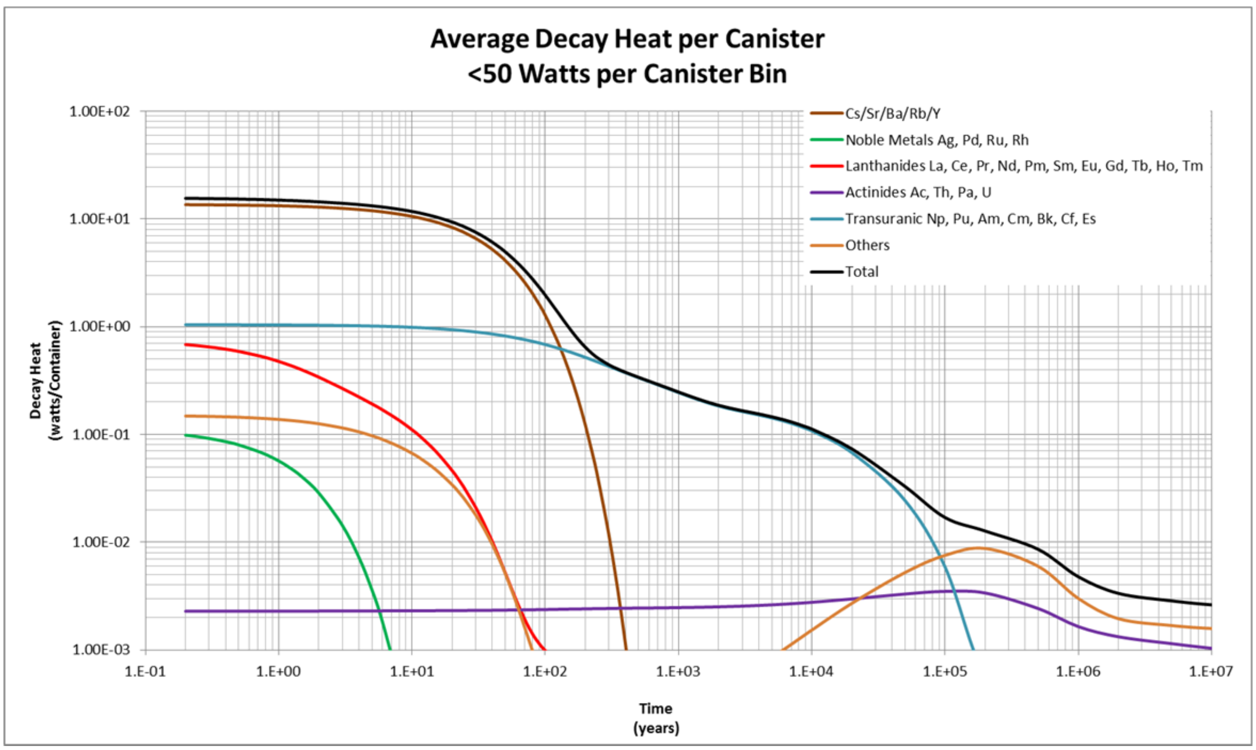

Figure A-1 Decay heat for average canister of DOE SNF in the <50 Watts per canister bin

Table A- 3 DOE SNF Average Radionuclide inventory per canister for 50-100 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation
^{227}Ac	1.21E-05	4.03E-05
^{241}Am	8.95E+01	1.18E+02
^{242m}Am	1.15E-01	2.19E-01
^{243}Am	8.58E-02	3.19E-01
^{137m}Ba	4.60E+03	1.22E+03
^{14}C	6.12E-02	4.28E-02
^{113m}Cd	5.01E-01	2.63E-01
^{144}Ce	1.95E+02	2.74E+02
^{36}Cl	6.05E-04	8.74E-04
^{242}Cm	2.71E-02	1.11E-01
^{243}Cm	4.15E-02	1.81E-01
^{244}Cm	3.21E+00	1.05E+01
^{245}Cm	6.90E-04	2.39E-03
^{246}Cm	1.33E-04	4.83E-04
^{247}Cm	2.82E-10	1.26E-09
^{60}Co	2.46E+02	4.01E+02
^{134}Cs	1.48E+02	1.18E+02
^{135}Cs	3.47E-02	3.36E-02
^{137}Cs	5.90E+03	1.22E+03
^{154}Eu	4.76E+01	2.54E+01
^{155}Eu	2.25E+01	1.18E+01
^{55}Fe	1.48E+02	2.41E+02
^{3}H	1.40E+01	4.84E+00
^{129}I	1.90E-03	7.54E-04
^{85}Kr	3.79E+02	1.06E+02
^{93m}Nb	8.03E-02	4.24E-02
^{94}Nb	3.08E-03	5.54E-03
^{59}Ni	1.16E-01	1.71E-01
^{63}Ni	1.38E+01	2.00E+01
^{237}Np	1.18E-02	6.96E-03
^{231}Pa	2.91E-05	9.27E-05

Radionuclide	Curies	Std. Deviation
^{210}Pb	9.77E-10	1.29E-07
^{107}Pd	2.30E-03	2.29E-03
^{147}Pm	1.67E+03	7.71E+02
^{238}Pu	3.42E+01	8.45E+01
^{239}Pu	5.03E+01	7.40E+01
^{240}Pu	4.07E+01	6.71E+01
^{241}Pu	1.30E+03	1.92E+03
^{242}Pu	1.33E-02	7.24E-02
^{226}Ra	9.42E-08	3.74E-07
^{228}Ra	2.28E-08	4.59E-08
^{106}Ru	4.83E+01	5.29E+01
^{125}Sb	2.88E+01	3.15E+01
^{79}Se	4.11E-02	1.37E-02
^{147}Sm	5.13E-07	2.20E-07
^{151}Sm	7.52E+01	6.77E+01
^{126}Sn	3.07E-02	2.54E-02
^{90}Sr	5.13E+03	1.09E+03
^{99}Tc	1.00E+00	3.10E-01
^{229}Th	2.05E-08	7.36E-08
^{230}Th	1.93E-06	3.79E-05
^{232}Th	2.37E-08	5.75E-08
^{232}U	1.73E-04	6.37E-04
^{233}U	2.12E-05	3.40E-05
^{234}U	7.26E-02	1.49E-01
^{235}U	1.27E-02	8.49E-03
^{236}U	3.04E-02	1.38E-02
^{238}U	3.54E-02	1.72E-02
^{90}Y	4.59E+03	1.28E+03
^{93}Zr	1.20E-01	4.36E-02
Total	**2.48E+04**	**3.71E+03**

Table A- 4 Decay heat for average canister of DOE SNF in the 50-100 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	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	57.486	56.148	49.729	19.418	6.003	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.003	0.015	0.000	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	1.179	0.479	0.245	0.014	0.004	0.000	0.000
Actinides Ac, Th, Pa, U	0.004	0.004	0.004	0.005	0.005	0.005	0.008
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	7.040	6.955	6.873	6.339	5.855	3.247	0.001
Others	0.659	0.440	0.307	0.024	0.002	0.001	0.013
Total	**66.372**	**64.043**	**57.159**	**25.799**	**11.869**	**3.253**	**0.022**

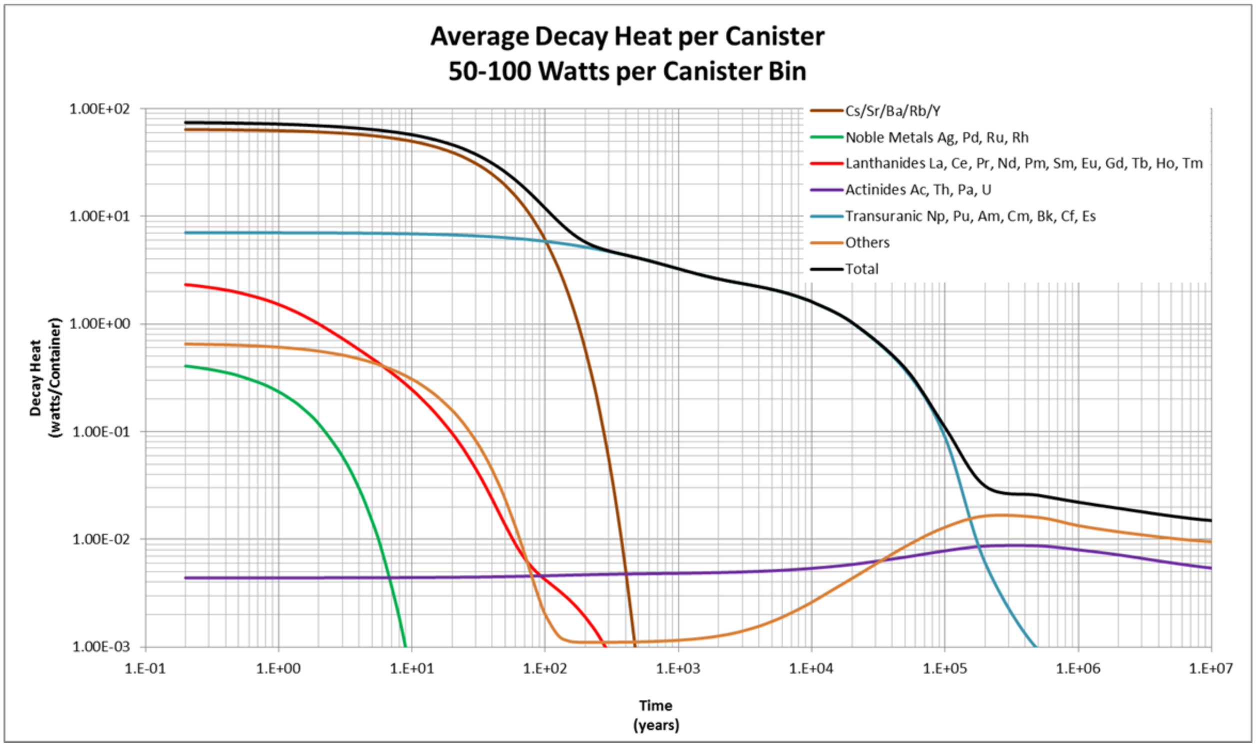

Figure A-2 Decay heat for average canister of DOE SNF in the 50-100 Watts per canister bin

Table A- 5 DOE SNF Average Radionuclide inventory per canister for 100-200 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation
^{227}Ac	6.28E-06	6.35E-05
^{241}Am	2.91E+02	2.84E+02
^{242m}Am	4.39E-01	4.63E-01
^{243}Am	6.59E-01	8.52E-01
^{137m}Ba	8.15E+03	2.61E+03
^{14}C	1.14E-01	1.79E-01
^{113m}Cd	9.87E-01	4.85E-01
^{144}Ce	2.57E+02	6.14E+02
^{36}Cl	1.24E-03	1.54E-03
^{242}Cm	1.73E-01	2.64E-01
^{243}Cm	2.96E-01	4.84E-01
^{244}Cm	2.95E+01	2.80E+01
^{245}Cm	6.17E-03	6.38E-03
^{246}Cm	1.17E-03	1.29E-03
^{247}Cm	2.04E-09	3.38E-09
^{60}Co	3.76E+02	6.65E+02
^{134}Cs	2.57E+02	2.55E+02
^{135}Cs	4.74E-02	4.67E-02
^{137}Cs	1.14E+04	2.54E+03
^{154}Eu	1.10E+02	4.86E+01
^{155}Eu	3.44E+01	2.07E+01
^{55}Fe	2.24E+02	4.01E+02
^{3}H	2.10E+01	1.06E+01
^{129}I	3.67E-03	1.72E-03
^{85}Kr	6.53E+02	1.93E+02
^{93m}Nb	1.66E-01	2.08E-01
^{94}Nb	3.08E-03	9.00E-03
^{59}Ni	1.57E-01	2.84E-01
^{63}Ni	4.86E+01	3.32E+01
^{237}Np	3.35E-02	2.30E-02
^{231}Pa	1.00E-05	1.46E-04

Radionuclide	Curies	Std. Deviation
^{210}Pb	4.59E-09	8.85E-09
^{107}Pd	6.15E-03	5.08E-03
^{147}Pm	2.45E+03	1.44E+03
^{238}Pu	1.42E+02	9.90E+01
^{239}Pu	1.13E+02	1.51E+02
^{240}Pu	1.04E+02	1.28E+02
^{241}Pu	3.83E+03	3.14E+03
^{242}Pu	7.58E-02	8.45E-02
^{226}Ra	1.64E-07	5.26E-07
^{228}Ra	1.99E-05	7.39E-08
^{106}Ru	6.82E+01	1.10E+02
^{125}Sb	5.21E+01	5.35E+01
^{79}Se	7.24E-02	2.78E-02
^{147}Sm	8.12E-07	3.72E-07
^{151}Sm	1.42E+02	1.31E+02
^{126}Sn	5.83E-02	5.15E-02
^{90}Sr	9.46E+03	2.17E+03
^{99}Tc	1.85E+00	7.28E-01
^{229}Th	5.40E-06	8.82E-08
^{230}Th	8.02E-06	1.68E-05
^{232}Th	1.92E-06	9.43E-08
^{232}U	7.01E-04	7.07E-04
^{233}U	2.10E-03	5.45E-05
^{234}U	1.18E-01	2.55E-01
^{235}U	1.88E-02	1.14E-02
^{236}U	5.82E-02	3.15E-02
^{238}U	6.15E-02	1.74E-01
^{90}Y	7.92E+03	2.69E+03
^{93}Zr	2.41E-01	1.20E-01
Total	**4.62E+04**	**7.17E+03**

Table A- 6 Decay heat for average canister of DOE SNF in the 100-200 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	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	102.107	105.711	93.659	36.587	11.316	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.004	0.021	0.001	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	2.076	0.945	0.524	0.029	0.008	0.000	0.000
Actinides Ac, Th, Pa, U	0.008	0.008	0.008	0.008	0.008	0.009	0.017
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	22.137	21.709	21.306	18.968	17.095	8.265	0.002
Others	1.143	0.760	0.529	0.041	0.004	0.002	0.027
Total	**127.475**	**129.154**	**116.027**	**55.632**	**28.431**	**8.277**	**0.047**

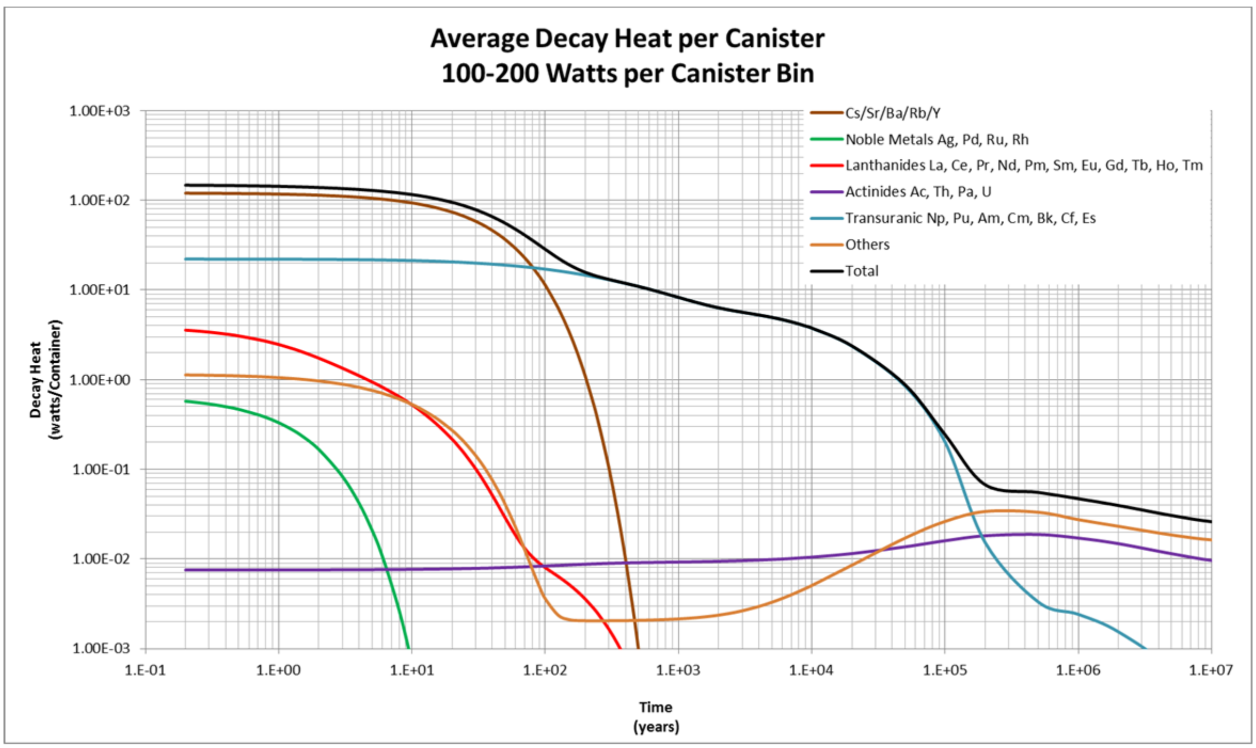

Figure A-3 Decay heat for average canister of DOE SNF in the 100-200 Watts per canister bin

Table A- 7 DOE SNF Average Radionuclide inventory per canister for 200-300 Watts per Canister Bin (2010)

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
^{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

Radionuclide	Curies	Std. Deviation
^{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
^{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

Table A- 8 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**

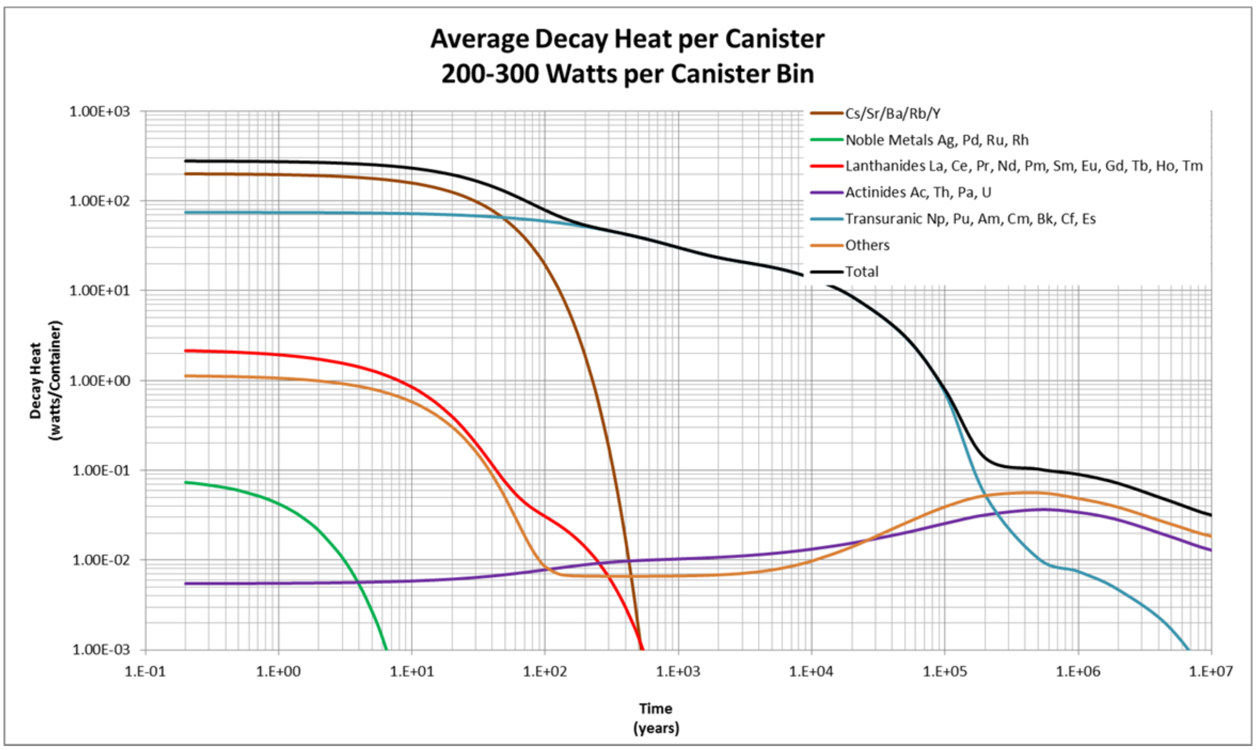

Figure A-4 Decay heat for average canister of DOE SNF in the 200-300 Watts per canister bin

Table A- 9 DOE SNF Average Radionuclide inventory per canister for 300-500 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{227}Ac	2.58E-06	2.37E-04	^{210}Pb	7.52E-09	1.65E-08
^{241}Am	1.86E+03	1.16E+03	^{107}Pd	3.12E-02	2.51E-02
^{242m} Am	3.26E+00	2.10E+00	^{147}Pm	2.32E+03	2.56E+03
^{243}Am	4.02E+00	3.47E+00	^{238}Pu	6.36E+02	3.96E+02
^{137m}Ba	1.98E+04	9.31E+03	^{239}Pu	8.04E+02	9.02E+02
^{14}C	2.99E-01	2.28E-01	^{240}Pu	7.60E+02	7.64E+02
^{113m}Cd	4.12E+00	2.87E+00	^{241}Pu	2.17E+04	1.66E+04
^{144}Ce	1.81E+02	4.73E+02	^{242}Pu	3.84E-01	3.76E-01
^{36}Cl	4.32E-03	3.71E-03	^{226}Ra	4.40E-08	5.37E-08
^{242}Cm	1.22E+00	1.07E+00	^{228}Ra	4.82E-08	8.67E-08
^{243}Cm	2.20E+00	1.99E+00	^{106}Ru	5.46E+01	1.47E+02
^{244}Cm	1.40E+02	1.11E+02	^{125}Sb	6.68E+01	1.14E+02
^{245}Cm	3.14E-02	2.56E-02	^{79}Se	1.66E-01	8.47E-02
^{246}Cm	6.26E-03	5.19E-03	^{147}Sm	1.90E-06	1.32E-06
^{247}Cm	1.53E-08	1.39E-08	^{151}Sm	7.63E+02	7.58E+02
^{60}Co	5.37E+02	1.53E+03	^{126}Sn	2.31E-01	1.96E-01
^{134}Cs	3.45E+02	5.29E+02	^{90}Sr	2.14E+04	4.00E+03
^{135}Cs	1.34E-01	1.58E-01	^{99}Tc	4.75E+00	2.64E+00
^{137}Cs	3.42E+04	1.11E+04	^{229}Th	4.00E-07	3.76E-07
^{154}Eu	3.45E+02	1.99E+02	^{230}Th	8.74E-06	6.00E-06
^{155}Eu	5.71E+01	4.43E+01	^{232}Th	5.11E-08	5.74E-08
^{55}Fe	3.10E+02	9.54E+02	^{232}U	3.54E-03	3.18E-03
^{3}H	6.15E+01	3.35E+01	^{233}U	1.67E-04	1.46E-04
^{129}I	1.07E-02	6.71E-03	^{234}U	6.08E-02	4.01E-02
^{85}Kr	1.09E+03	3.40E+02	^{235}U	2.43E-02	1.96E-02
^{93m}Nb	4.55E-01	3.32E-01	^{236}U	1.09E-01	5.05E-02
^{94}Nb	1.02E-02	3.05E-02	^{238}U	7.58E-02	7.40E-02
^{59}Ni	2.11E-01	6.54E-01	^{90}Y	1.65E+04	7.12E+03
^{63}Ni	4.83E+01	7.75E+01	^{93}Zr	6.57E-01	4.01E-01
^{237}Np	1.14E-01	6.56E-02			
^{231}Pa	9.06E-06	5.47E-04	**Total**	1.24E+05	2.60E+04

Table A- 10 Decay heat for average canister of DOE SNF in the 300-500 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	0.002	0.001	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	235.107	274.773	243.938	95.523	29.616	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.003	0.017	0.001	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	4.166	2.407	1.530	0.116	0.042	0.000	0.000
Actinides Ac, Th, Pa, U	0.008	0.008	0.009	0.010	0.012	0.016	0.057
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	136.288	134.204	132.205	120.389	110.579	57.938	0.013
Others	1.857	1.261	0.887	0.072	0.009	0.007	0.079
Total	**377.432**	**412.671**	**378.571**	**216.110**	**140.259**	**57.961**	**0.149**

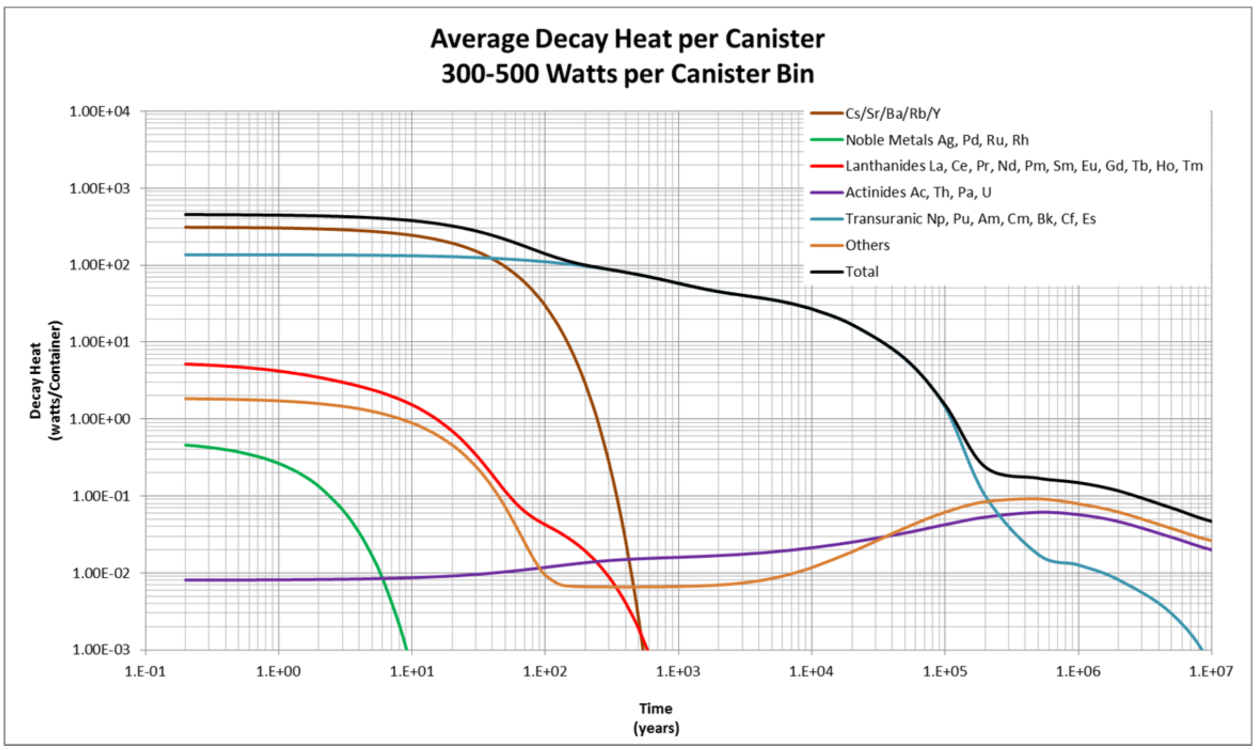

Figure A-5 Decay heat for average canister of DOE SNF in the 300-500 Watts per canister bin

Table A- 11 DOE SNF Average Radionuclide inventory per canister for 500-1,000 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation
^{227}Ac	4.00E-06	2.85E-06
^{241}Am	3.27E+03	2.08E+03
^{242m}Am	5.74E+00	3.71E+00
^{243}Am	7.96E+00	7.23E+00
^{137m}Ba	3.33E+04	1.81E+04
^{14}C	6.51E-01	5.34E-01
^{113m}Cd	8.11E+00	5.69E+00
^{144}Ce	2.03E+03	4.34E+03
^{36}Cl	9.79E-03	9.38E-03
^{242}Cm	2.55E+00	2.20E+00
^{243}Cm	4.40E+00	4.15E+00
^{244}Cm	2.74E+02	2.30E+02
^{245}Cm	6.15E-02	5.31E-02
^{246}Cm	1.23E-02	1.08E-02
^{247}Cm	3.04E-08	2.91E-08
^{60}Co	1.60E+03	4.16E+03
^{134}Cs	1.22E+03	2.18E+03
^{135}Cs	2.22E-01	1.38E-01
^{137}Cs	5.58E+04	1.49E+04
^{154}Eu	7.14E+02	4.06E+02
^{155}Eu	1.59E+02	1.71E+02
^{55}Fe	9.61E+02	2.58E+03
^{3}H	1.36E+02	5.85E+01
^{129}I	1.92E-02	1.25E-02
^{85}Kr	1.71E+03	1.02E+03
^{93m}Nb	8.55E-01	6.39E-01
^{94}Nb	2.38E-02	2.57E-02
^{59}Ni	6.48E-01	1.70E+00
^{63}Ni	1.14E+02	2.07E+02
^{237}Np	2.14E-01	1.32E-01
^{231}Pa	1.09E-05	8.33E-06

Radionuclide	Curies	Std. Deviation
^{210}Pb	1.55E-08	1.24E-08
^{107}Pd	6.17E-02	5.26E-02
^{147}Pm	5.90E+03	1.11E+04
^{238}Pu	1.19E+03	9.29E+02
^{239}Pu	1.23E+03	1.57E+03
^{240}Pu	1.15E+03	1.34E+03
^{241}Pu	3.33E+04	2.87E+04
^{242}Pu	5.09E-01	5.64E-01
^{226}Ra	9.75E-08	5.69E-08
^{228}Ra	1.11E-07	1.00E-07
^{106}Ru	4.74E+02	8.77E+02
^{125}Sb	2.20E+02	3.85E+02
^{79}Se	2.56E-01	1.53E-01
^{147}Sm	2.99E-06	1.76E-06
^{151}Sm	1.16E+03	1.28E+03
^{126}Sn	4.50E-01	3.47E-01
^{90}Sr	3.38E+04	5.09E+03
^{99}Tc	8.20E+00	4.90E+00
^{229}Th	5.46E-07	5.65E-07
^{230}Th	1.59E-04	3.98E-04
^{232}Th	8.10E-08	1.01E-07
^{232}U	6.31E-03	6.30E-03
^{233}U	2.64E-04	2.29E-04
^{234}U	3.16E+00	8.34E+00
^{235}U	6.86E-02	1.61E-01
^{236}U	3.57E-01	6.73E-01
^{238}U	1.02E-01	1.12E-01
^{90}Y	2.61E+04	1.42E+04
^{93}Zr	1.23E+00	7.49E-01
Total	2.06E+05	2.85E+04

Table A- 12 Decay heat for average canister of DOE SNF in the 500-1,000 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	0.005	0.004	0.003	0.000	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	388.828	442.443	391.918	153.411	47.577	0.000	0.000
Noble Metals Ag, Pd, Ru, Rh	0.028	0.147	0.005	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	10.100	5.211	3.161	0.206	0.065	0.000	0.000
Actinides Ac, Th, Pa, U	0.106	0.107	0.107	0.111	0.113	0.121	0.117
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	231.864	227.937	224.197	202.329	184.474	91.324	0.022
Others	3.268	2.087	1.423	0.115	0.017	0.014	0.190
Total	**634.199**	**677.936**	**620.813**	**356.173**	**232.247**	**91.460**	**0.329**

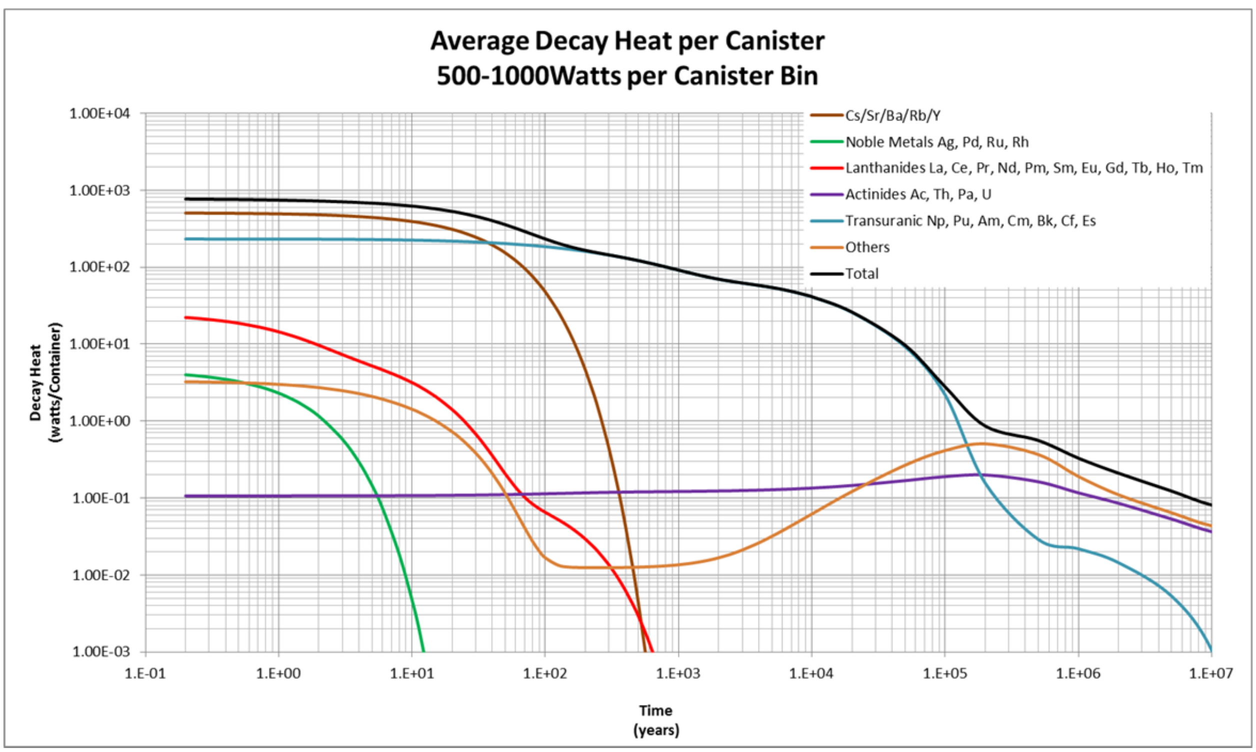

Figure A-6 Decay heat for average canister of DOE SNF in the 500-1,000 Watts per canister bin

Table A- 13 DOE SNF Average Radionuclide inventory per canister for 1,000-1,500 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{227}Ac	3.16E-03	9.55E-09	^{210}Pb	2.24E-07	8.12E-10
^{241}Am	4.99E+03	1.78E+03	^{107}Pd	6.69E-02	1.44E-03
^{242m} Am	9.22E+00	3.29E+00	^{147}Pm	2.24E+01	0.00E+00
^{243}Am	7.09E-01	2.53E-01	^{238}Pu	8.99E+02	3.21E+02
^{137m}Ba	5.94E+04	0.00E+00	^{239}Pu	3.74E+03	1.34E+03
^{14}C	1.08E+00	2.37E-03	^{240}Pu	3.24E+03	1.16E+03
^{113m}Cd	1.65E+01	0.00E+00	^{241}Pu	7.35E+04	2.63E+04
^{144}Ce	3.81E-09	0.00E+00	^{242}Pu	7.81E-02	2.79E-02
^{36}Cl	2.86E-03	4.41E-05	^{226}Ra	7.71E-07	1.83E-08
^{242}Cm	9.39E-30	0.00E+00	^{228}Ra	1.16E-06	8.60E-10
^{243}Cm	7.04E-10	0.00E+00	^{106}Ru	2.39E-01	8.53E-02
^{244}Cm	6.40E+01	2.29E+01	^{125}Sb	2.70E+00	0.00E+00
^{245}Cm	1.22E-02	4.37E-03	^{79}Se	8.31E-01	5.26E-03
^{246}Cm	2.08E-03	7.42E-04	^{147}Sm	1.71E-05	0.00E+00
^{247}Cm	1.68E-27	0.00E+00	^{151}Sm	6.29E+03	1.15E+03
^{60}Co	2.51E+02	6.63E+01	^{126}Sn	1.88E+00	6.83E-03
^{134}Cs	6.10E+01	2.18E+01	^{90}Sr	8.02E+04	9.07E+03
^{135}Cs	2.24E+00	4.84E-03	^{99}Tc	2.27E+01	1.83E-01
^{137}Cs	1.31E+05	2.45E+04	^{229}Th	1.34E-08	2.66E-09
^{154}Eu	6.89E+00	0.00E+00	^{230}Th	1.14E-05	3.98E-06
^{155}Eu	4.27E+01	0.00E+00	^{232}Th	4.57E-09	2.19E-10
^{55}Fe	2.72E-01	0.00E+00	^{232}U	2.54E-06	0.00E+00
^{3}H	2.29E+02	3.06E+01	^{233}U	6.91E-06	1.88E-06
^{129}I	5.80E-02	5.12E-04	^{234}U	7.76E-02	2.74E-02
^{85}Kr	2.37E+03	3.05E+02	^{235}U	3.04E-02	4.35E-04
^{93m}Nb	2.79E+00	4.22E-02	^{236}U	3.22E-02	1.07E-02
^{94}Nb	4.11E-01	8.00E-05	^{238}U	2.43E-02	3.90E-03
^{59}Ni	3.39E+00	8.60E-03	^{90}Y	5.49E+04	0.00E+00
^{63}Ni	1.81E+02	4.18E+01	^{93}Zr	3.33E+00	2.47E-02
^{237}Np	2.13E-01	1.77E-02			
^{231}Pa	7.29E-03	1.93E-07	**Total**	4.22E+05	6.61E+04

Table A- 14 Decay heat for average canister of DOE SNF in the 1,000-1,500 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	0.008	0.006	0.005	0.001	0.000	0.000	0.000
Cs/Sr/Ba/Rb/Y	776.332	1,040	925.5	362.7	112.5	0.001	0.001
Noble Metals Ag, Pd, Ru, Rh	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.8	0.8	0.719	0.503	0.341	0.000	0.000
Actinides Ac, Th, Pa, U	0.005	0.006	0.006	0.009	0.011	0.020	0.134
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	414.1	411.3	408.6	389.2	369.9	236.3	0.027
Others	3.6	2.6	1.9	0.19	0.06	0.05	0.17
Total	**1,194.8**	**1,455.4**	**1,336.8**	**752.6**	**482.8**	**236.3**	**0.330**

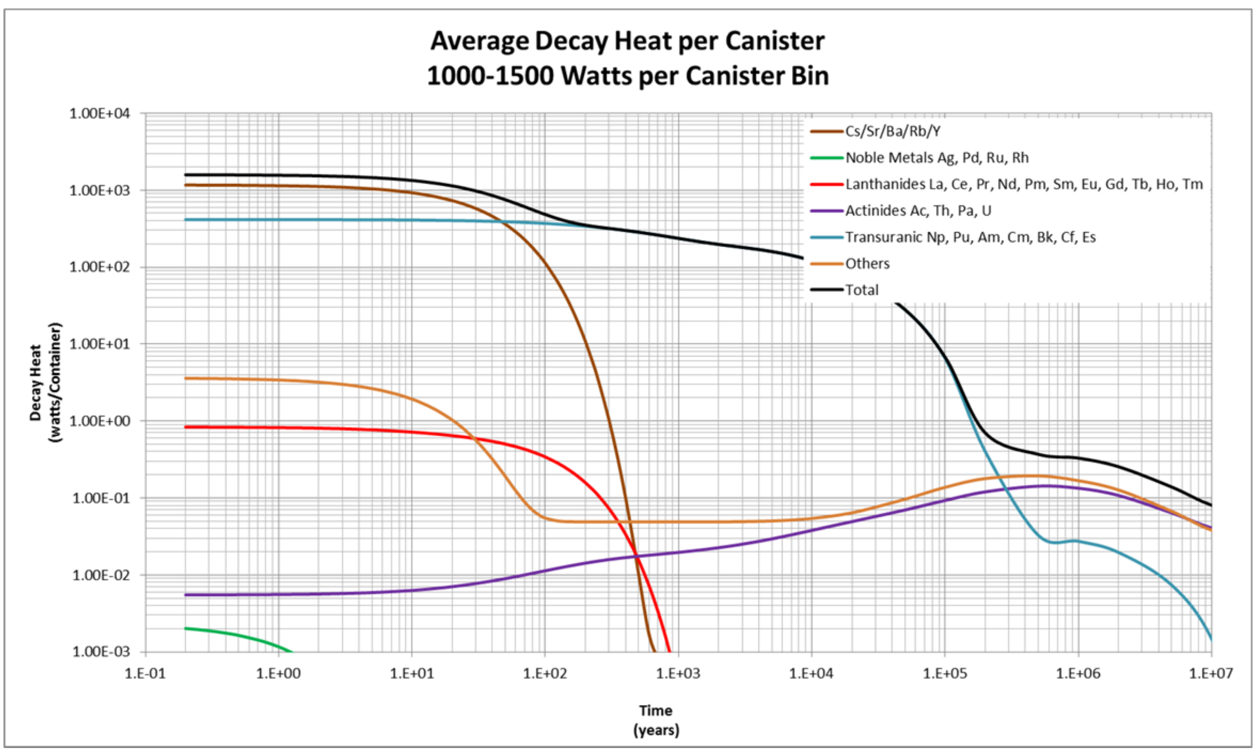

Figure A-7 Decay heat for average canister of DOE SNF in the 1,000-1,500 Watts per canister bin

Table A- 15 DOE SNF Average Radionuclide inventory per canister for >2,000 Watts per Canister Bin (2010)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{227}Ac	6.16E-02	8.71E-02	^{210}Pb	4.79E-06	5.43E-06
^{241}Am	1.05E+06	1.48E+06	^{107}Pd	2.07E+00	5.38E-01
^{242m} Am	1.93E+03	2.74E+03	^{147}Pm	4.38E+02	6.19E+02
^{243}Am	1.49E+02	2.10E+02	^{238}Pu	1.77E+05	2.51E+05
^{137m}Ba	1.16E+06	1.64E+06	^{239}Pu	7.38E+05	1.04E+06
^{14}C	2.24E+01	2.77E+01	^{240}Pu	6.39E+05	9.04E+05
^{113m}Cd	3.21E+02	4.54E+02	^{241}Pu	1.45E+07	2.05E+07
^{144}Ce	7.44E-08	1.05E-07	^{242}Pu	1.54E+01	2.18E+01
^{36}Cl	7.92E-02	3.88E-02	^{226}Ra	2.48E-05	4.66E-06
^{242}Cm	1.83E-28	2.59E-28	^{228}Ra	2.30E-05	3.11E-05
^{243}Cm	1.37E-08	1.94E-08	^{106}Ru	5.01E+01	7.09E+01
^{244}Cm	1.34E+04	1.90E+04	^{125}Sb	5.27E+01	7.46E+01
^{245}Cm	2.57E+00	3.63E+00	^{79}Se	1.90E+01	1.81E+01
^{246}Cm	4.36E-01	6.16E-01	^{147}Sm	3.33E-04	4.71E-04
^{247}Cm	3.27E-26	4.62E-26	^{151}Sm	7.36E+05	8.71E+05
^{60}Co	4.02E+04	5.33E+04	^{126}Sn	4.03E+01	4.56E+01
^{134}Cs	1.28E+04	1.81E+04	^{90}Sr	6.40E+06	6.02E+06
^{135}Cs	4.63E+01	5.74E+01	^{99}Tc	5.40E+02	4.60E+02
^{137}Cs	1.56E+07	1.86E+07	^{229}Th	1.59E-06	1.91E-06
^{154}Eu	1.34E+02	1.90E+02	^{230}Th	2.21E-03	3.10E-03
^{155}Eu	8.32E+02	1.18E+03	^{232}Th	1.98E-07	6.17E-08
^{55}Fe	5.31E+00	7.51E+00	^{232}U	4.97E-05	7.03E-05
^{3}H	2.08E+04	2.15E+04	^{233}U	1.07E-03	1.42E-03
^{129}I	1.40E+00	1.14E+00	^{234}U	1.52E+01	2.14E+01
^{85}Kr	2.09E+05	2.11E+05	^{235}U	8.11E-01	4.67E-01
^{93m}Nb	7.70E+01	3.87E+01	^{236}U	5.97E+00	8.32E+00
^{94}Nb	8.05E+00	1.13E+01	^{238}U	2.42E+00	2.68E+00
^{59}Ni	7.06E+01	8.56E+01	^{90}Y	1.07E+06	1.51E+06
^{63}Ni	2.58E+04	3.30E+04	^{93}Zr	7.81E+01	6.93E+01
^{237}Np	1.36E+01	1.02E+01			
^{231}Pa	1.42E-01	2.01E-01	**Total**	4.24E+07	4.69E+07

Table A- 16 Decay heat for average canister of DOE SNF in the >2,000 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	0.706	0.535	0.406	0.049	0.010	0.006	0.001
Cs/Sr/Ba/Rb/Y	35,292	104,997	93,406	36,696	11,418	0.01	0.01
Noble Metals Ag, Pd, Ru, Rh	0.003	0.016	0.001	0.0	0.0	0.000	0.000
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	88.2	84.1	80.6	58.7	39.9	0.039	0.000
Actinides Ac, Th, Pa, U	0.7	0.8	0.9	1.397	1.9	3.5	24.5
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	83,762	83,221	82,646	78690.6	74,727	47,003	5.1
Others	313	228	165	13	1.6	1.1	29.9
Total	**119,458**	**188,531**	**176,299**	**115,460**	**86,188**	**47,008**	**59.5**

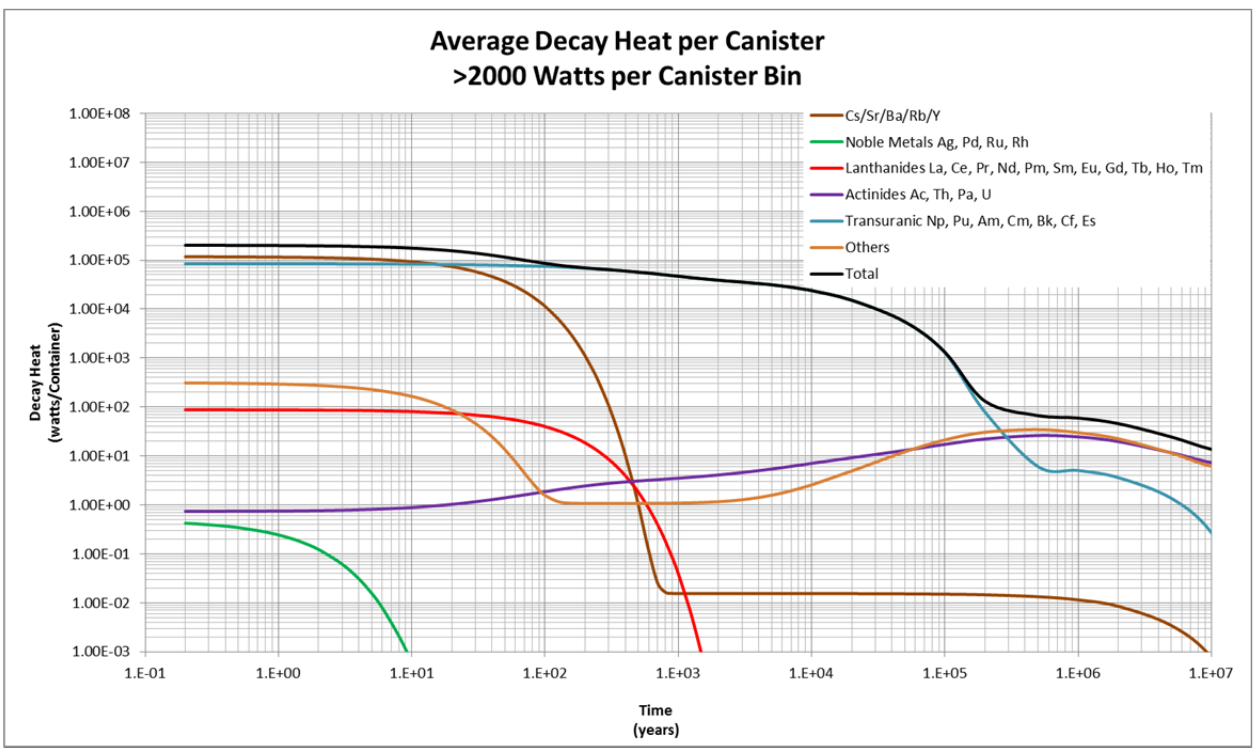

Figure A-8 Decay heat for average canister of DOE SNF in the >2,000 Watts per canister bin

Appendix B: HLW Inventory - SRS Borosilicate Glass, Hanford Borosilicate Glass, Hanford Sr and Cs Capsules and Idaho Calcine

B-1. SRS Borosilicate Glass Canisters

Table B- 1 SRS Borosilicate Glass Average Radionuclide inventory per canister for <50 Watts per Canister Bin (2003)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{241}Am	1.08E+01	7.99E+00	^{238}Pu	4.33E+01	2.65E+01
^{242m} Am	2.16E-02	3.41E-02	^{239}Pu	6.19E+00	3.29E+00
^{243}Am	5.08E-01	6.21E-01	^{240}Pu	2.10E+00	1.31E+00
^{247}Bk	1.77E-03	4.33E-03	^{241}Pu	3.49E+01	2.63E+01
^{249}Cf	4.00E-03	9.80E-03	^{242}Pu	2.80E-03	1.62E-03
^{251}Cf	7.00E-03	8.38E-03	^{79}Se	1.92E-02	1.45E-02
^{36}Cl	0.00E+00	0.00E+00	^{151}Sm	7.10E+01	6.24E+01
^{244}Cm	2.98E+01	2.91E+01	^{121m}Sn	9.12E-01	1.14E+00
^{245}Cm	6.63E-03	1.07E-02	^{126}Sn	5.23E-02	9.84E-02
^{246}Cm	1.34E-02	9.26E-03	^{90}Sr	2.68E+03	2.10E+03
^{247}Cm	4.40E-03	8.80E-03	^{99}Tc	1.28E-01	2.51E-02
^{248}Cm	4.60E-03	9.20E-03	^{229}Th	3.45E-05	4.00E-05
^{60}Co	0.00E+00	0.00E+00	^{233}U	1.62E-02	7.46E-03
^{137}Cs	1.51E+02	1.05E+02	^{234}U	2.14E-02	4.74E-03
^{93m}Nb	4.32E-02	6.11E-02	^{235}U	2.62E-04	2.91E-04
^{59}Ni	2.13E-01	2.39E-01	^{236}U	5.07E-04	2.60E-04
^{63}Ni	2.03E+01	2.24E+01	^{238}U	1.17E-02	5.98E-03
^{237}Np	1.40E-02	8.24E-03	^{93}Zr	7.68E-02	6.77E-02
			Total	3.05E+03	2.39E+03

Table B- 2 Decay heat for average canister of SRS Borosilicate Glass in the <50 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	18.65	16.60	14.74	5.70	1.73	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.01	0.01	0.01	0.01	0.00	0.00	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	3.11	2.88	2.68	1.76	1.29	0.35	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	21.77	19.49	17.43	7.47	3.03	0.35	0.01

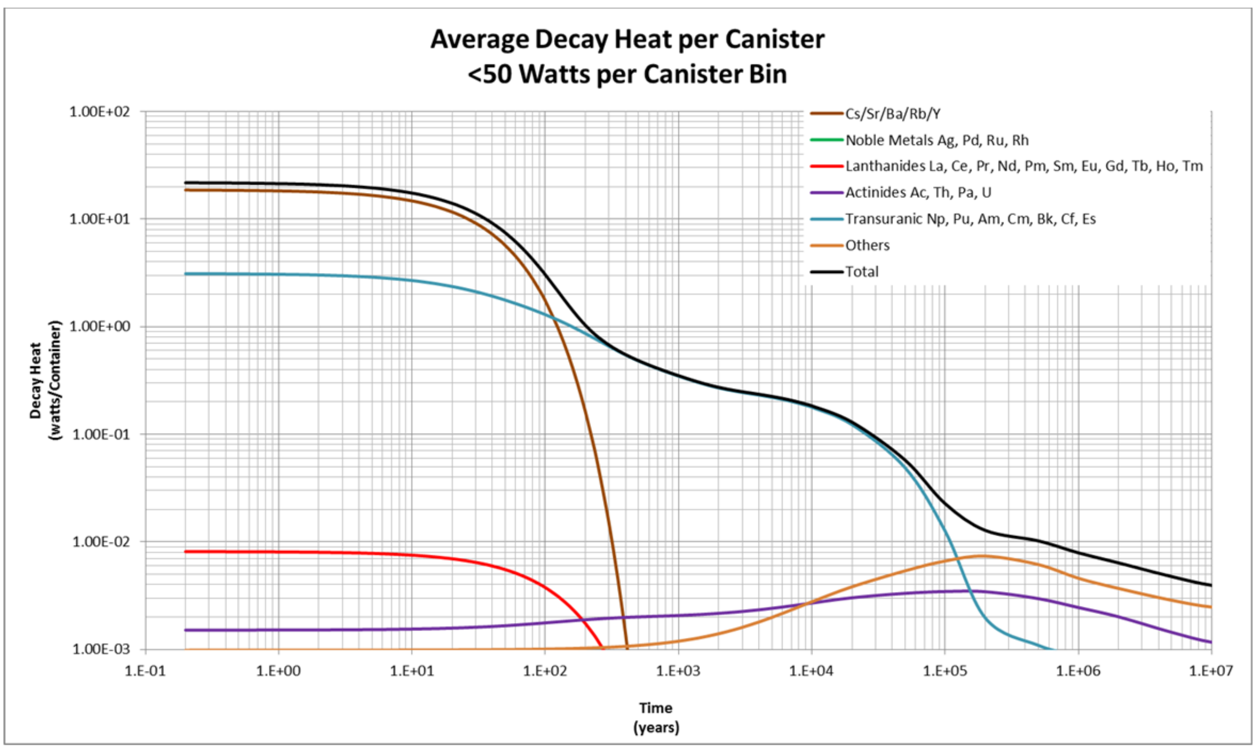

Figure B- 1 Decay heat for average canister of SRS Borosilicate Glass in the <50 Watts per canister bin

Table B- 3 SRS Borosilicate Glass Average Radionuclide inventory per canister for 50-100 Watts per Canister Bin (2013)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{241}Am	2.92E+01	1.40E+00	^{238}Pu	1.42E+02	6.83E+00
^{242m} Am	2.68E-02	1.29E-03	^{239}Pu	1.03E+01	4.93E-01
^{243}Am	4.50E-01	2.16E-02	^{240}Pu	3.23E+00	1.56E-01
^{247}Bk	7.89E-04	3.80E-05	^{241}Pu	4.42E+01	2.13E+00
^{249}Cf	3.16E-03	1.52E-04	^{242}Pu	1.81E-02	8.73E-04
^{251}Cf	7.26E-03	3.49E-04	^{79}Se	6.00E-03	2.88E-04
^{36}Cl	1.97E-04	9.49E-06	^{151}Sm	1.81E+02	8.73E+00
^{244}Cm	1.50E+01	7.21E-01	^{121m}Sn	4.50E-02	2.16E-03
^{245}Cm	2.21E-03	1.06E-04	^{126}Sn	5.05E-01	2.43E-02
^{246}Cm	5.76E-03	2.77E-04	^{90}Sr	1.10E+04	5.31E+02
^{247}Cm	7.26E-08	3.49E-09	^{99}Tc	7.89E-02	3.80E-03
^{248}Cm	2.45E-04	1.18E-05	^{229}Th	4.97E-04	2.39E-05
^{60}Co	2.13E+00	1.02E-01	^{233}U	1.03E-01	4.93E-03
^{137}Cs	1.58E+03	7.58E+01	^{234}U	3.79E-02	1.82E-03
^{93m}Nb	3.63E-01	1.75E-02	^{235}U	5.05E-04	2.43E-05
^{59}Ni	1.18E+00	5.69E-02	^{236}U	8.68E-04	4.18E-05
^{63}Ni	1.97E+01	9.49E-01	^{238}U	1.18E-02	5.69E-04
^{237}Np	1.74E-02	8.35E-04	^{93}Zr	4.18E-01	2.01E-02
			Total	1.31E+04	6.29E+02

Table B- 4 Decay heat for average canister of SRS Borosilicate Glass in the 50-100 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	81.40	72.45	64.34	24.90	7.60	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.02	0.02	0.02	0.01	0.01	0.00	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	6.63	6.36	6.11	4.62	3.45	0.62	0.00
Others	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Total	88.06	78.85	70.49	29.55	11.07	0.64	0.01

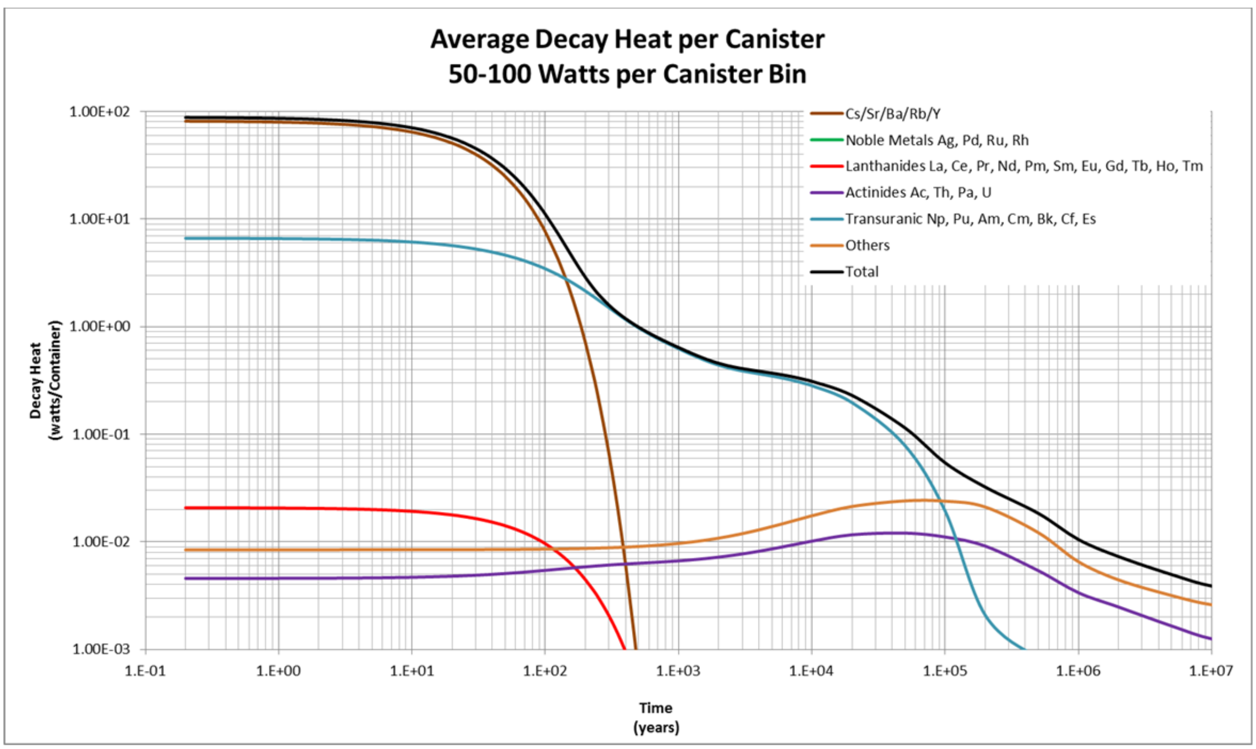

Figure B- 2 Decay heat for average canister of SRS Borosilicate Glass in the 50-100 Watts per canister bin

Table B- 5 SRS Borosilicate Glass Average Radionuclide inventory per canister for 100-200 Watts per Canister Bin (2018)

Radionuclide	Curies	Std. Deviation
^{241}Am	5.12E+01	1.28E+01
^{242m} Am	5.45E-02	3.78E-02
^{243}Am	8.66E-01	4.43E-01
^{247}Bk	1.46E-03	5.35E-04
^{249}Cf	5.88E-03	2.41E-03
^{251}Cf	1.38E-02	5.58E-03
^{36}Cl	8.82E-03	7.68E-02
^{244}Cm	2.91E+01	1.53E+01
^{245}Cm	4.59E-03	3.70E-03
^{246}Cm	1.13E-02	6.71E-03
^{247}Cm	1.34E-07	4.81E-08
^{248}Cm	5.56E-04	8.03E-04
^{60}Co	3.73E+00	9.42E-01
^{137}Cs	2.75E+03	7.19E+02
^{93m}Nb	6.36E-01	1.60E-01
^{59}Ni	2.07E+00	5.31E-01
^{63}Ni	3.70E+01	1.21E+01
^{237}Np	3.12E-02	7.29E-03

Radionuclide	Curies	Std. Deviation
^{238}Pu	2.54E+02	5.80E+01
^{239}Pu	1.82E+01	4.19E+00
^{240}Pu	5.76E+00	1.31E+00
^{241}Pu	7.89E+01	1.79E+01
^{242}Pu	3.16E-02	8.48E-03
^{79}Se	1.05E-02	2.73E-03
^{151}Sm	3.19E+02	7.80E+01
^{121m}Sn	1.68E-01	5.66E-01
^{126}Sn	8.76E-01	2.46E-01
^{90}Sr	1.96E+04	4.52E+03
^{99}Tc	1.40E-01	3.28E-02
^{229}Th	8.57E-04	2.60E-04
^{233}U	1.79E-01	4.82E-02
^{234}U	6.74E-02	1.54E-02
^{235}U	8.88E-04	2.18E-04
^{236}U	1.53E-03	3.63E-04
^{238}U	2.08E-02	5.17E-03
^{93}Zr	7.34E-01	1.83E-01
Total	2.31E+04	5.45E+03

Table B- 6 Decay heat for average canister of SRS Borosilicate Glass in the 100-200 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	144.17	128.32	113.96	44.10	13.46	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.04	0.04	0.03	0.02	0.02	0.00	-
Actinides Ac, Th, Pa, U	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	11.92	11.43	10.97	8.25	6.15	1.10	0.00
Others	0.00	0.01	0.01	0.01	0.01	0.02	0.01
Total	156.14	139.81	124.99	52.40	19.65	1.13	0.02

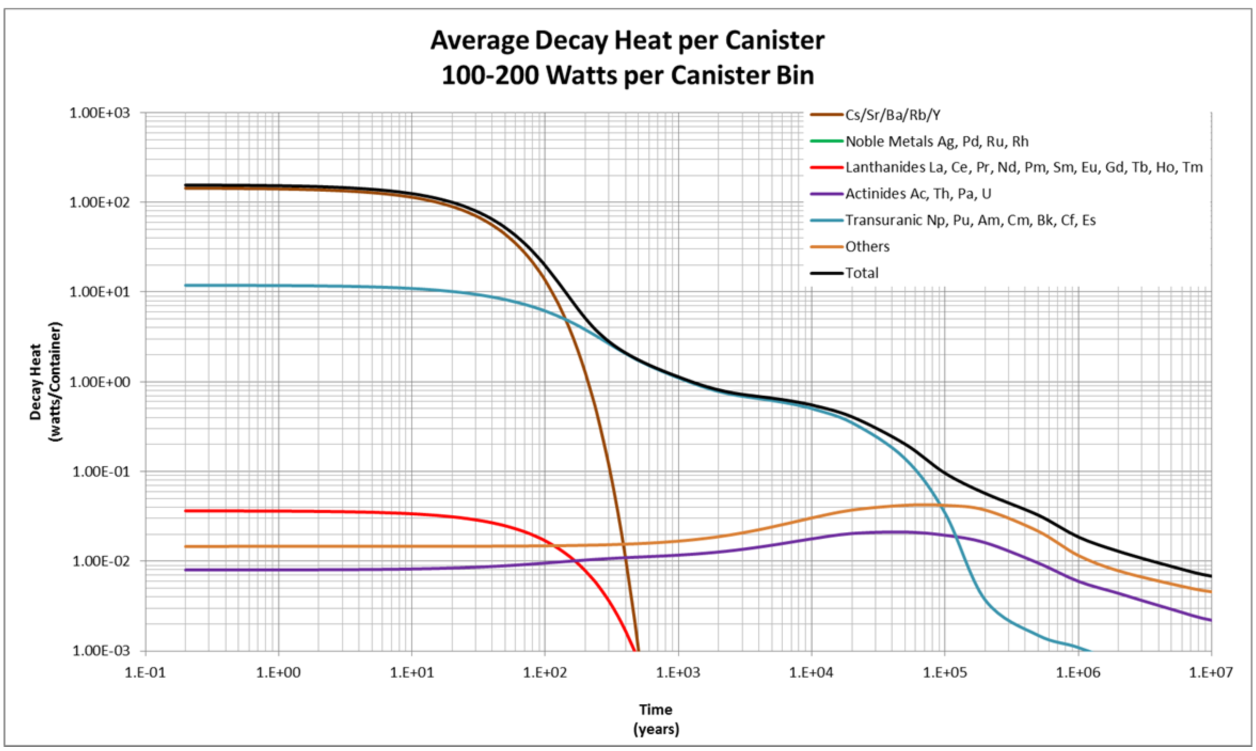

Figure B- 3 Decay heat for average canister of SRS Borosilicate Glass in the 100-200 Watts per canister bin

Table B- 7 SRS Borosilicate Glass Average Radionuclide inventory per canister for 200-300 Watts per Canister Bin (2020)

Radionuclide	Curies	Std. Deviation
^{241}Am	6.66E+01	5.85E-01
^{242m}Am	6.12E-02	5.38E-04
^{243}Am	1.03E+00	9.02E-03
^{247}Bk	1.80E-03	1.58E-05
^{249}Cf	7.20E-03	6.33E-05
^{251}Cf	1.66E-02	1.46E-04
^{36}Cl	4.50E-04	3.96E-06
^{244}Cm	3.42E+01	3.01E-01
^{245}Cm	5.04E-03	4.43E-05
^{246}Cm	1.31E-02	1.16E-04
^{247}Cm	1.66E-07	1.46E-09
^{248}Cm	5.58E-04	4.90E-06
^{60}Co	4.86E+00	4.27E-02
^{137}Cs	3.60E+03	3.16E+01
^{93m}Nb	8.28E-01	7.28E-03
^{59}Ni	2.70E+00	2.37E-02
^{63}Ni	4.50E+01	3.96E-01
^{237}Np	3.96E-02	3.48E-04
^{238}Pu	3.24E+02	2.85E+00
^{239}Pu	2.34E+01	2.06E-01
^{240}Pu	7.38E+00	6.49E-02
^{241}Pu	1.01E+02	8.86E-01
^{242}Pu	4.14E-02	3.64E-04
^{79}Se	1.37E-02	1.20E-04
^{151}Sm	4.14E+02	3.64E+00
^{121m}Sn	1.03E-01	9.02E-04
^{126}Sn	1.15E+00	1.01E-02
^{90}Sr	2.52E+04	2.22E+02
^{99}Tc	1.80E-01	1.58E-03
^{229}Th	1.13E-03	9.97E-06
^{233}U	2.34E-01	2.06E-03
^{234}U	8.64E-02	7.59E-04
^{235}U	1.15E-03	1.01E-05
^{236}U	1.98E-03	1.74E-05
^{238}U	2.70E-02	2.37E-04
^{93}Zr	9.54E-01	8.39E-03
Total	2.98E+04	2.62E+02

Table B- 8 Decay heat for average canister of SRS Borosilicate Glass 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	185.79	165.37	146.86	56.83	17.35	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.05	0.05	0.04	0.03	0.02	0.00	-
Actinides Ac, Th, Pa, U	0.01	0.01	0.01	0.01	0.01	0.02	0.01
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	15.14	14.52	13.95	10.54	7.87	1.42	0.00
Others	0.00	0.02	0.02	0.02	0.02	0.02	0.01
Total	200.99	179.97	160.89	67.44	25.27	1.46	0.02

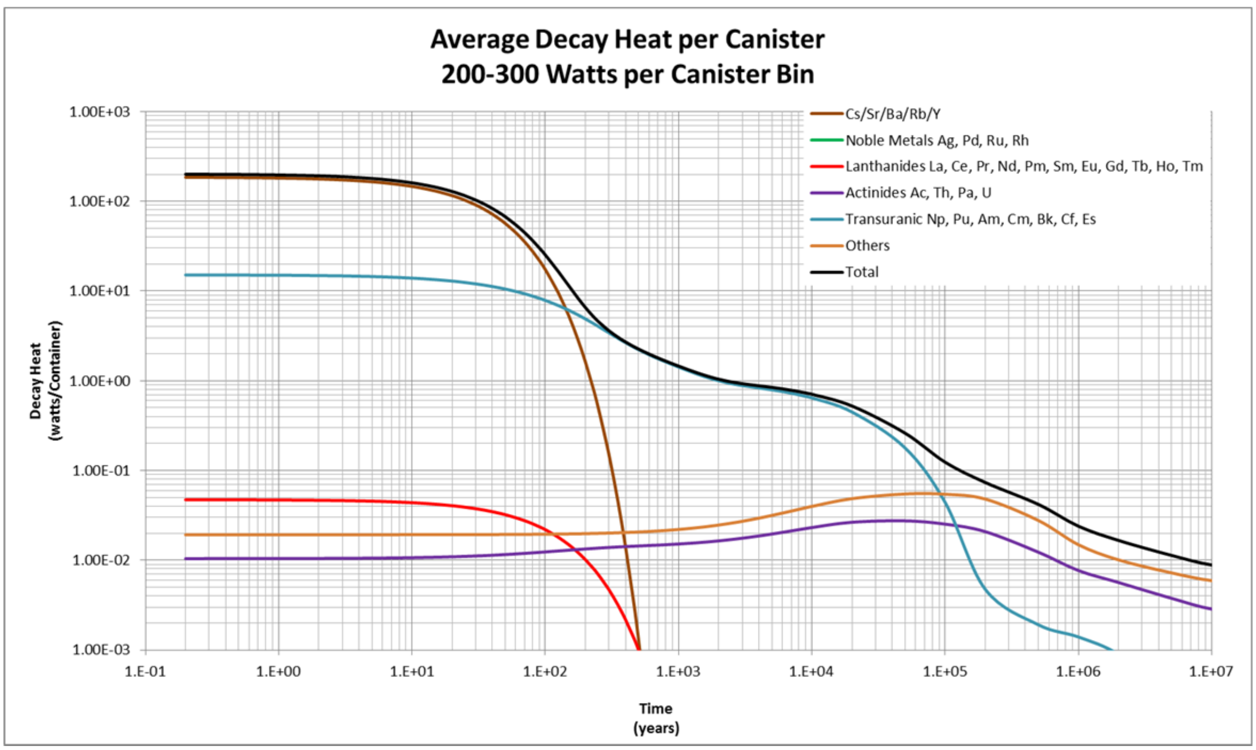

Figure B- 4 Decay heat for average canister of SRS Borosilicate Glass in the 200-300 Watts per canister bin

Table B- 9 SRS Borosilicate Glass Average Radionuclide inventory per canister for 300-500 Watts per Canister Bin (2019)

Radionuclide	Curies	Std. Deviation	Radionuclide	Curies	Std. Deviation
^{241}Am	1.55E+02	1.33E+00	^{238}Pu	7.54E+02	6.46E+00
^{242m}Am	1.42E-01	1.22E-03	^{239}Pu	5.45E+01	4.67E-01
^{243}Am	2.39E+00	2.05E-02	^{240}Pu	1.72E+01	1.47E-01
^{247}Bk	4.19E-03	3.59E-05	^{241}Pu	2.35E+02	2.01E+00
^{249}Cf	1.68E-02	1.44E-04	^{242}Pu	9.63E-02	8.26E-04
^{251}Cf	3.85E-02	3.30E-04	^{79}Se	3.18E-02	2.73E-04
^{36}Cl	1.05E-03	8.98E-06	^{151}Sm	9.63E+02	8.26E+00
^{244}Cm	7.96E+01	6.82E-01	^{121m}Sn	2.39E-01	2.05E-03
^{245}Cm	1.17E-02	1.01E-04	^{126}Sn	2.68E+00	2.30E-02
^{246}Cm	3.06E-02	2.62E-04	^{90}Sr	5.86E+04	5.03E+02
^{247}Cm	3.85E-07	3.30E-09	^{99}Tc	4.19E-01	3.59E-03
^{248}Cm	1.30E-03	1.11E-05	^{229}Th	2.64E-03	2.26E-05
^{60}Co	1.13E+01	9.69E-02	^{233}U	5.45E-01	4.67E-03
^{137}Cs	8.37E+03	7.17E+01	^{234}U	2.01E-01	1.72E-03
^{93m}Nb	1.93E+00	1.65E-02	^{235}U	2.68E-03	2.30E-05
^{59}Ni	6.28E+00	5.39E-02	^{236}U	4.61E-03	3.95E-05
^{63}Ni	1.05E+02	8.98E-01	^{238}U	6.28E-02	5.39E-04
^{237}Np	9.22E-02	7.90E-04	^{93}Zr	2.22E+00	1.90E-02
			Total	6.94E+04	5.95E+02

Table B- 10 Decay heat for average canister of SRS Borosilicate Glass in the 300-500 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	432.22	384.71	341.65	132.21	40.36	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.11	0.11	0.10	0.07	0.05	0.00	-
Actinides Ac, Th, Pa, U	0.02	0.02	0.02	0.03	0.03	0.04	0.02
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	35.22	33.78	32.46	24.52	18.32	3.31	0.00
Others	0.00	0.04	0.04	0.05	0.05	0.05	0.03
Total	467.58	418.67	374.28	156.88	58.80	3.39	0.06

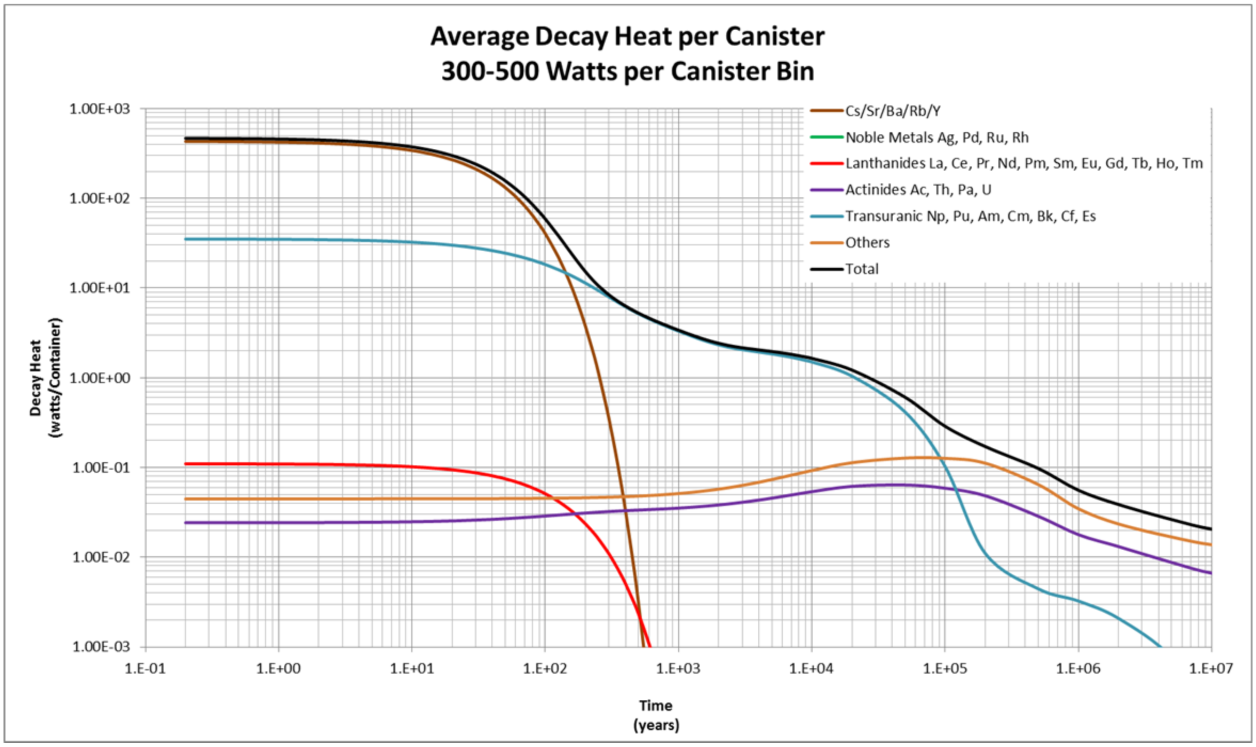

Figure B- 5 Decay heat for average canister of SRS Borosilicate Glass in the 300-500 Watts per canister bin

B-2. Hanford Borosilicate Glass Canisters

Table B- 11 Hanford Borosilicate Glass Average Radionuclide inventory per canister for all Decay Heat Bins (See Table 2-4 for reference year)

Decay Heat per Canister (watts)	^{137}Cs (Ci)	Std Dev	^{90}Sr (Ci)	Std Dev	^{99}Tc (Ci)	Std Dev	TRU (Ci)	Std Dev
<50	1,214.5	1,428.4	1,216.4	691.8	0.119	0.068	10.14	8.05
50-100	6,406.9	2,878.4	6,781.1	2,904.4	0.221	0.148	44.00	12.41
100-200	8,680.6	3,826.2	11,979.6	3,448.1	0.141	0.083	75.42	36.41
200-300	15,235.1	2,728.0	20,640.8	1,824.7	0.201	0.022	160.57	20.43

Table B- 12 Decay heat for average canister of Hanford Borosilicate Glass in the <50 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	13.98	12.44	11.06	4.32	1.33	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.41	0.40	0.40	0.36	0.33	0.25	0.00
Others	-	0.00	0.00	0.00	0.00	0.00	0.00
Total	14.39	12.84	11.46	4.68	1.66	0.25	0.00

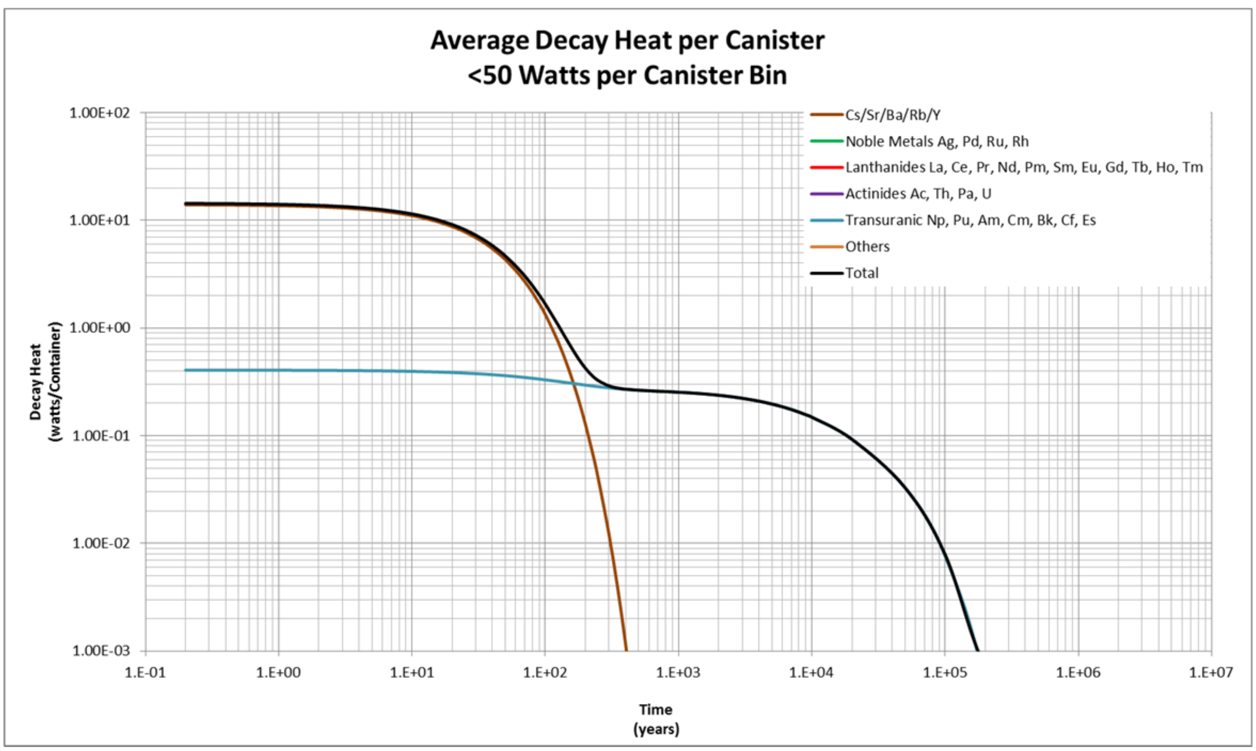

Figure B- 6 Decay heat for average canister of Hanford Borosilicate Glass in the <50 Watts per canister bin

Table B- 13 Decay heat for average canister of Hanford Borosilicate Glass in the 50-100 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	76.17	67.78	60.26	23.53	7.26	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	1.84	1.82	1.80	1.64	1.50	1.15	0.00
Others	-	0.00	0.00	0.00	0.00	0.00	0.00
Total	78.02	69.60	62.06	25.17	8.76	1.15	0.00

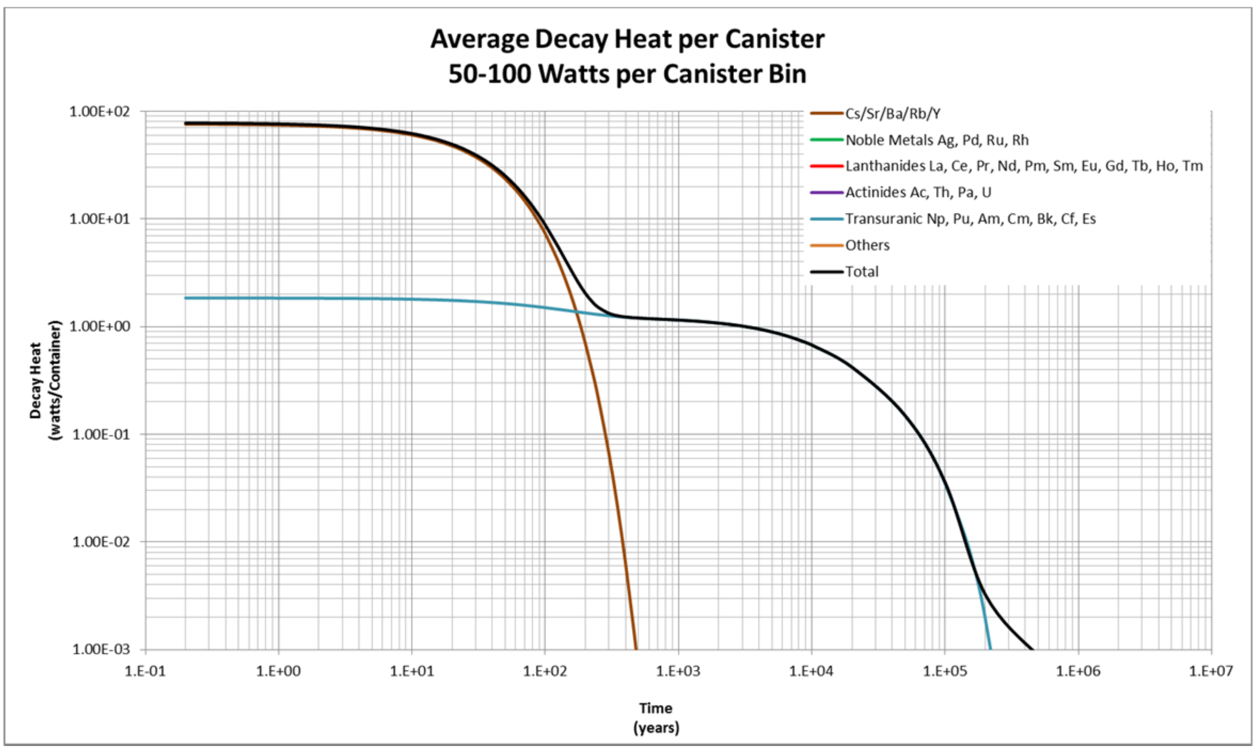

Figure B- 7 Decay heat for average canister of Hanford Borosilicate Glass in the 50-100 Watts per canister bin

Table B- 14 Decay heat for average canister of Hanford Borosilicate Glass in the 100-200 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	121.79	108.38	96.34	37.54	11.56	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	3.24	3.19	3.15	2.88	2.63	2.02	0.00
Others	-	0.00	0.00	0.00	0.00	0.00	0.00
Total	125.03	111.58	99.49	40.42	14.20	2.02	0.00

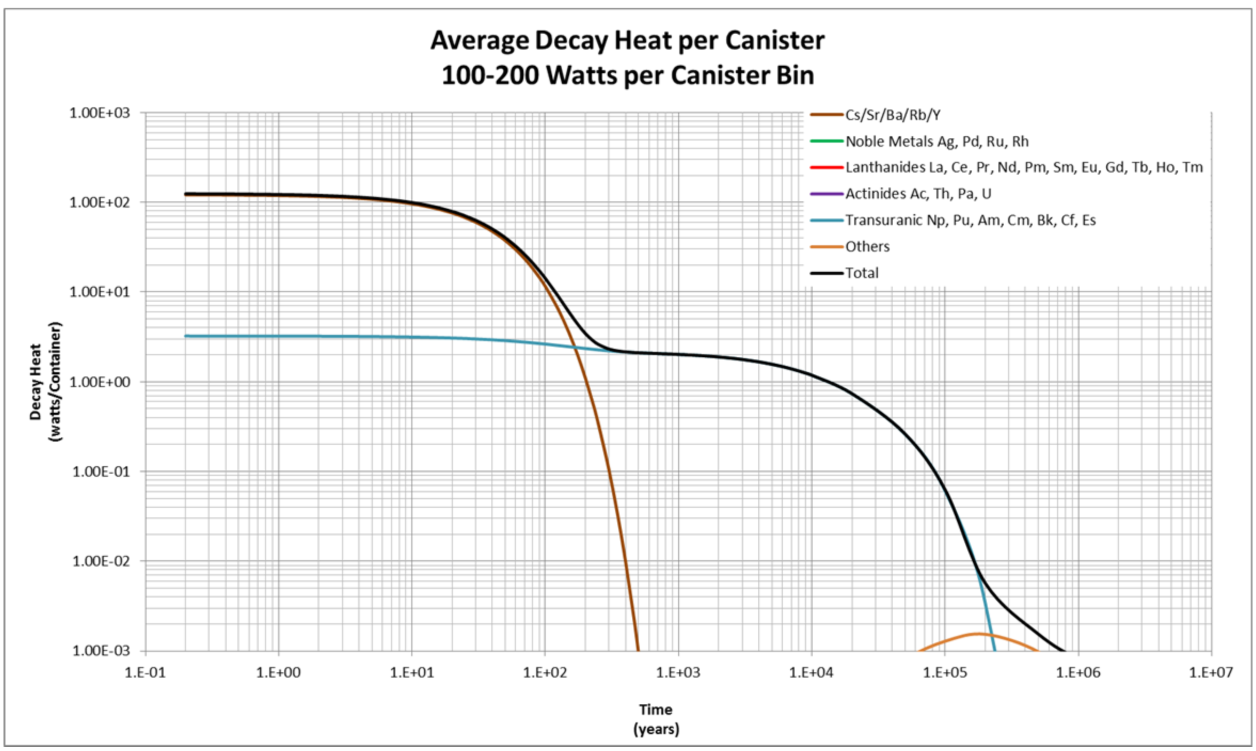

Figure B- 8 Decay heat for average canister of Hanford Borosilicate Glass in the 100-200 Watts per canister bin

Table B- 15 Decay heat for average canister of Hanford Borosilicate Glass 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	211.20	187.94	167.06	65.11	20.06	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	6.71	6.62	6.54	5.97	5.46	4.19	0.00
Others	-	0.00	0.00	0.00	0.00	0.00	0.00
Total	217.91	194.57	173.60	71.08	25.52	4.19	0.00

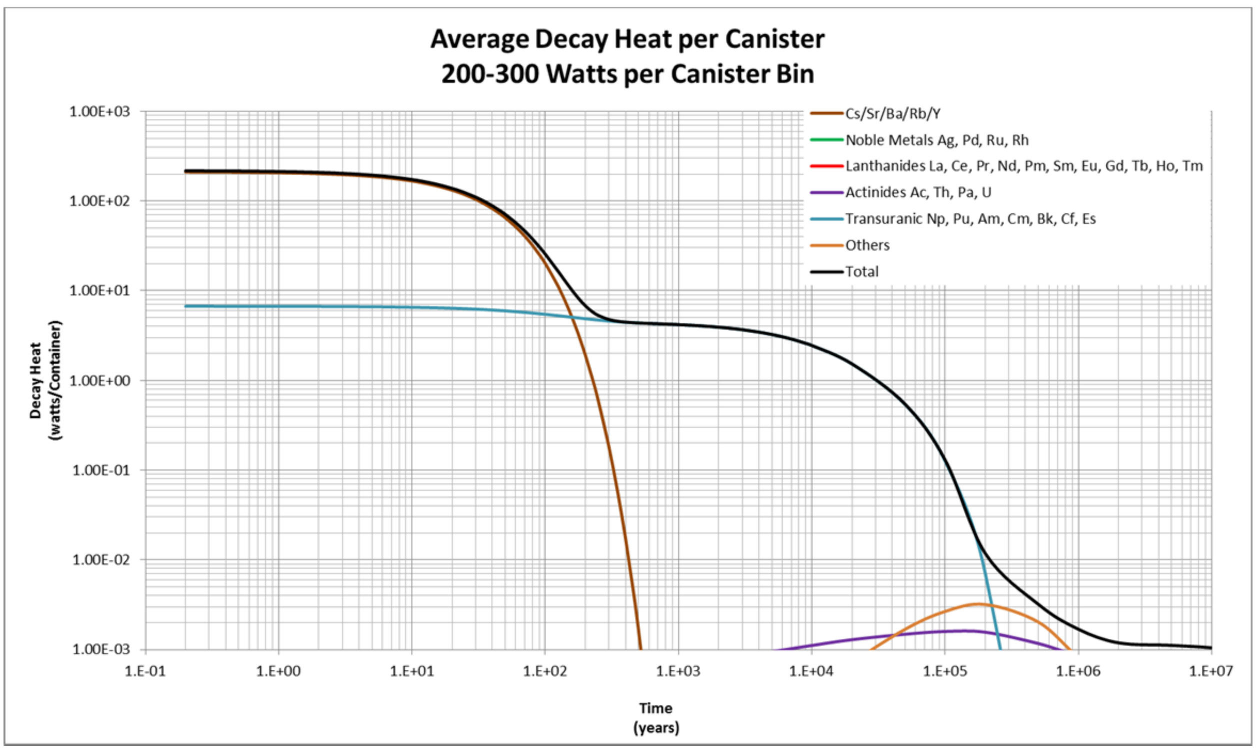

Figure B- 9 Decay heat for average canister of Hanford Borosilicate Glass in the 200-300 Watts per canister bin

B-3. Hanford Borosilicate Glass from Cs/Sr Capsules

Table B- 16 Hanford Borosilicate Glass from Cs/Sr Capsules Average Radionuclide inventory per canister for 500-1,000 watts per canister bin (2010)

Decay Heat per Canister (watts)	^{137}Cs (Ci)	^{90}Sr (Ci)
500-1,000	1.08E+05	4.69E+04

Table B- 17 Decay heat for average canister of Hanford Borosilicate Glass from the Cs/Sr Capsules in the 500-1,000 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	849.04	755.41	672.12	264.02	82.12	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	849.04	755.41	672.12	264.02	82.12	0.00	0.00

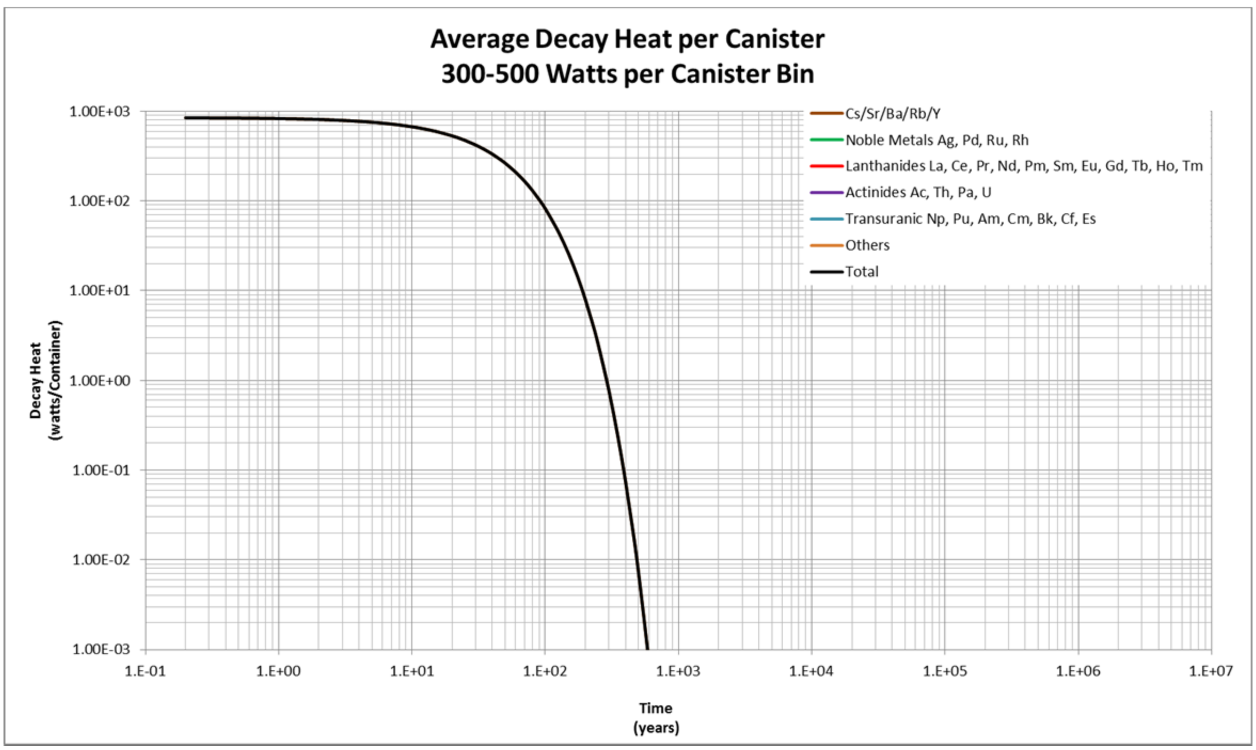

Figure B- 10 Decay heat for average canister of Hanford Borosilicate Glass from the Cs/Sr Capsules in the 500-1,000 Watts per canister bin

B-4. Hanford Cs/Sr Capsules for Direct Disposal

Table B- 18 Hanford Cs Capsules Average Radionuclide inventory per canister for all Decay Heat Bins (2010)

Decay Heat per Canister (watts)	^{137}Cs (Ci)	Std. Deviation
<50	6.70E+03	3.13E+03
50-100	1.84E+04	9.17E+00
100-200	2.76E+04	2.39E+03
200-300		

Table B- 19 Hanford Sr Capsules Average Radionuclide inventory per canister for all Decay Heat Bins (2010)

Decay Heat per Canister (watts)	^{90}Sr (Ci)	Std. Deviation
<50	5.92E+03	6.47E+00
50-100	1.09E+04	2.04E+03
100-200	2.33E+04	4.22E+03
200-300	3.39E+04	3.94E+03
300-500	5.11E+04	4.34E+03

Table B- 20 Decay heat for average Cs Capsule in the <50 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	33.16	29.50	26.28	10.43	3.28	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	33.16	29.50	26.28	10.43	3.28	0.00	0.00

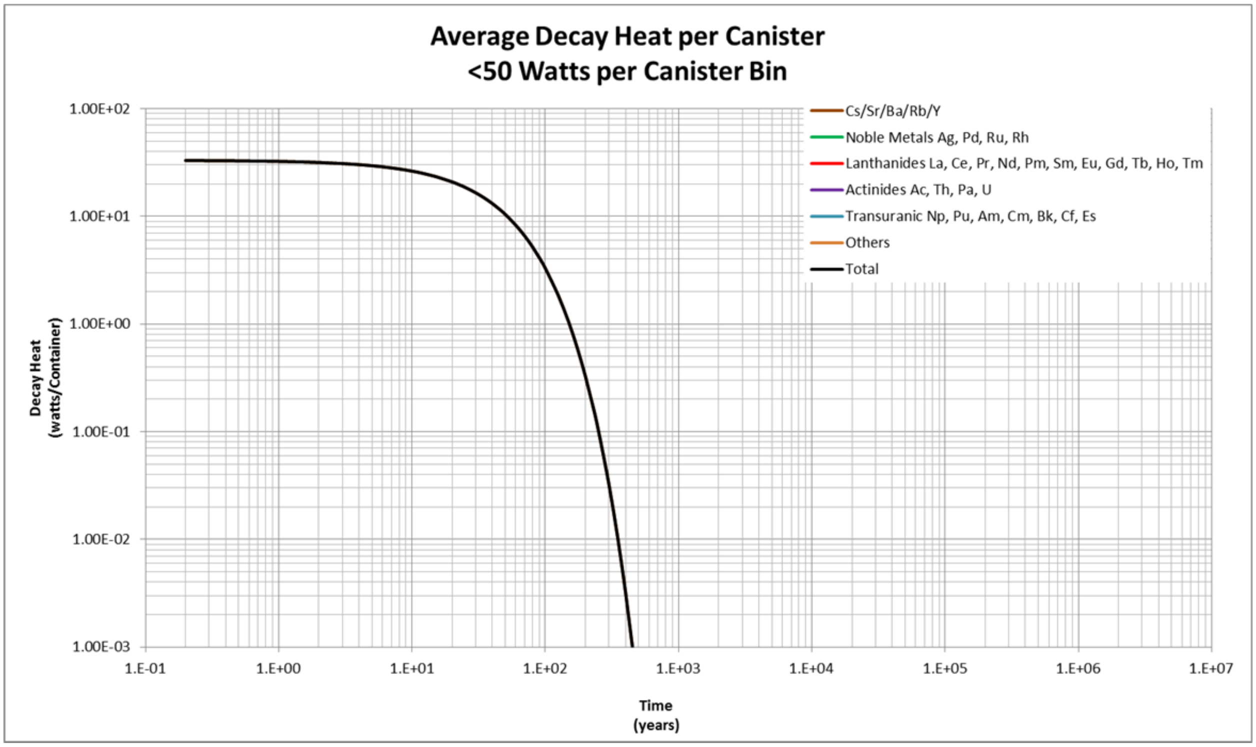

Figure B- 11 Decay heat for average Cs Capsule in the <50 Watts per canister bin

Table B- 21 Decay heat for average Cs Capsule in the 50-100 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	91.25	81.16	72.31	28.69	9.04	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	91.25	81.16	72.31	28.69	9.04	0.00	0.00

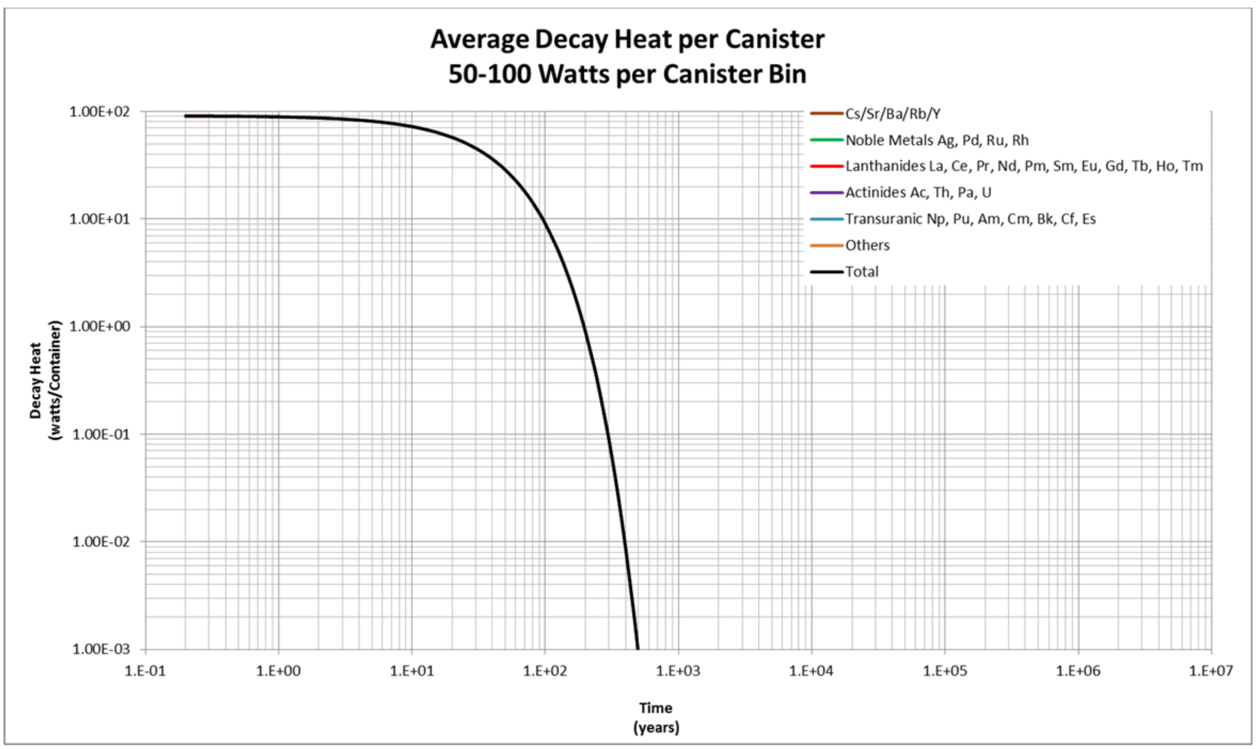

Figure B- 12 Decay heat for average Cs Capsule in the 50-100 Watts per canister bin

Table B- 22 Decay heat for average Cs Capsule in the 100-200 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	136.77	121.65	108.38	43.01	13.55	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	136.77	121.65	108.38	43.01	13.55	0.00	0.00

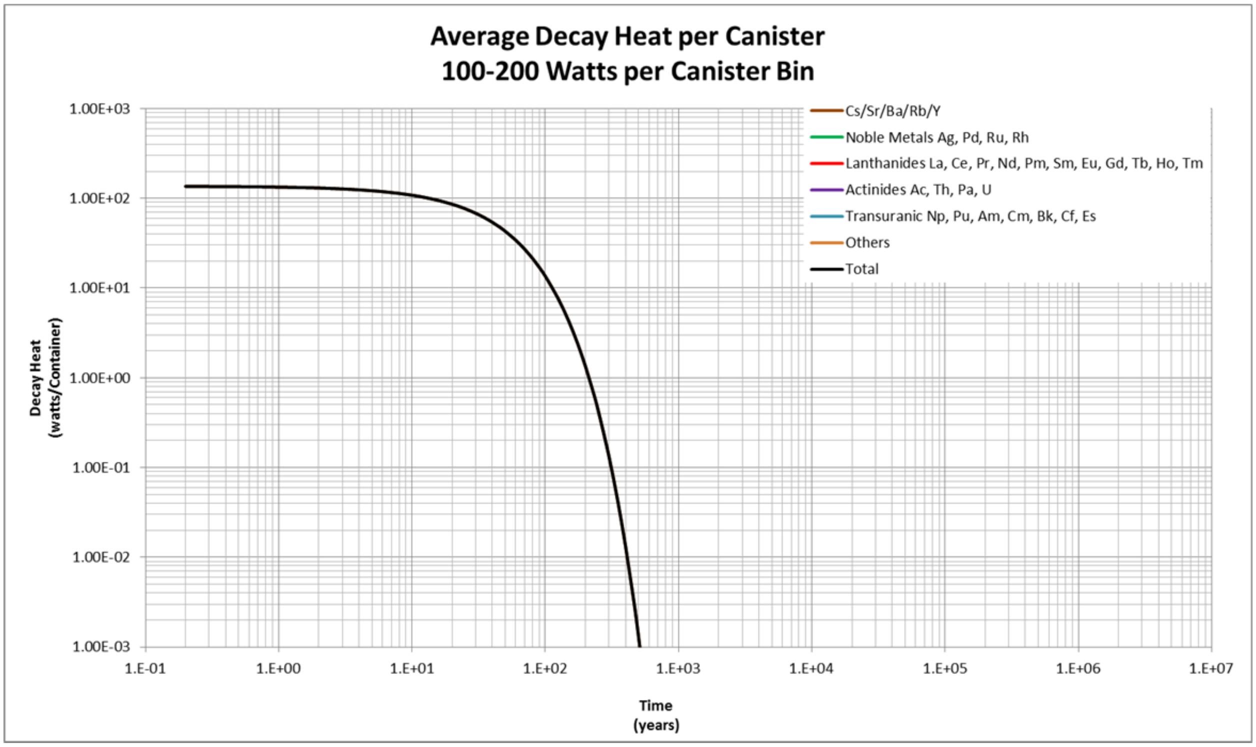

Figure B- 13 Decay heat for average Cs Capsule in the 100-200 Watts per canister bin

Table B- 23 Decay heat for average Sr Capsule in the <50 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	39.69	35.33	31.37	12.11	3.68	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	39.69	35.33	31.37	12.11	3.68	0.00	0.00

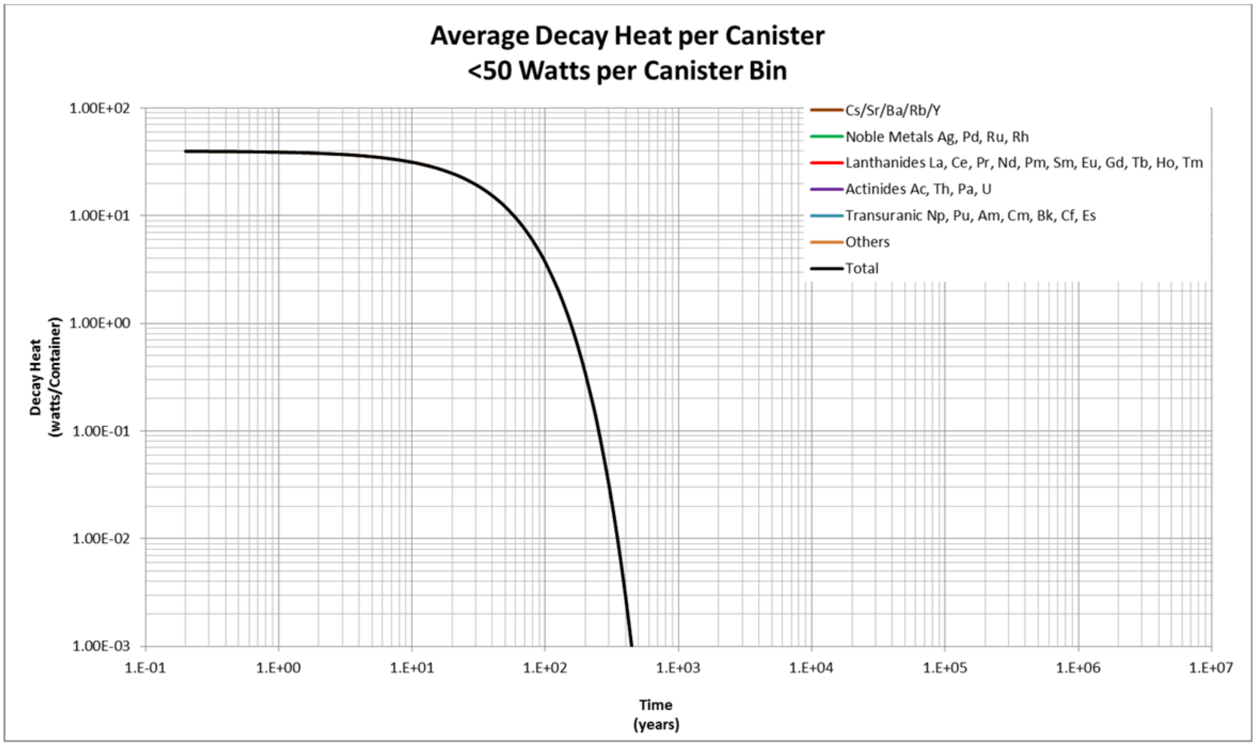

Figure B- 14 Decay heat for average Sr Capsule in the <50 Watts per canister bin

Table B- 24 Decay heat for average Sr Capsule in the 50-100 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	73.77	65.67	58.30	22.50	6.85	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	73.77	65.67	58.30	22.50	6.85	0.00	0.00

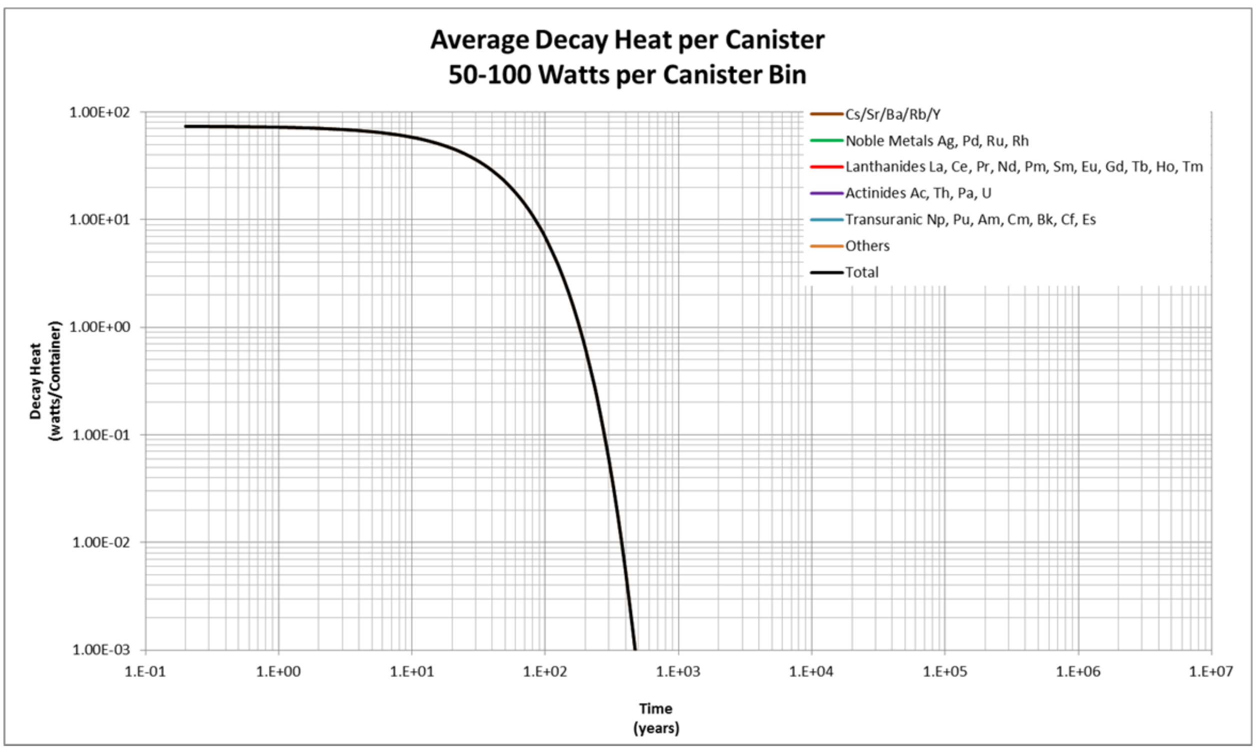

Figure B- 15 Decay heat for average Sr Capsule in the 50-100 Watts per canister bin

Table B- 25 Decay heat for average Sr Capsule in the 100-200 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	157.56	140.25	124.52	48.06	14.62	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	157.56	140.25	124.52	48.06	14.62	0.00	0.00

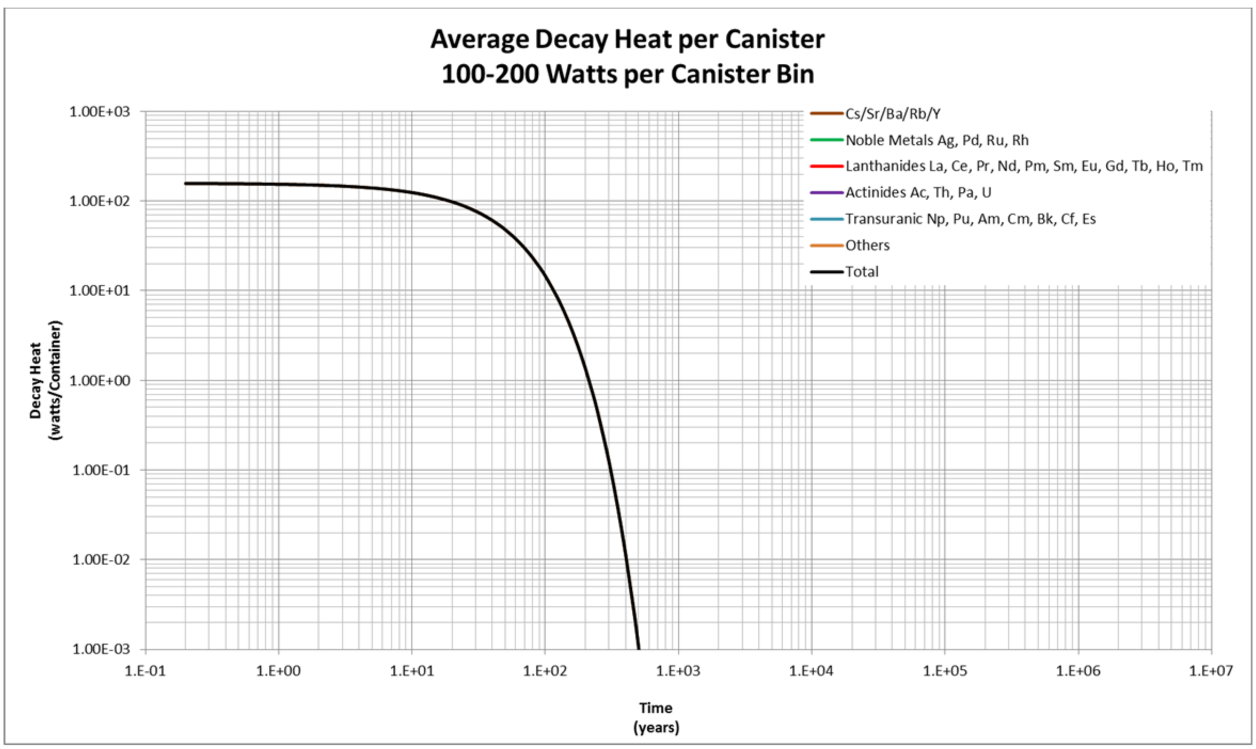

Figure B- 16 Decay heat for average Sr Capsule in the 100-200 Watts per canister bin

Table B- 26 Decay heat for average Sr Capsule 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	228.36	203.28	180.47	69.65	21.19	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	228.36	203.28	180.47	69.65	21.19	0.00	0.00

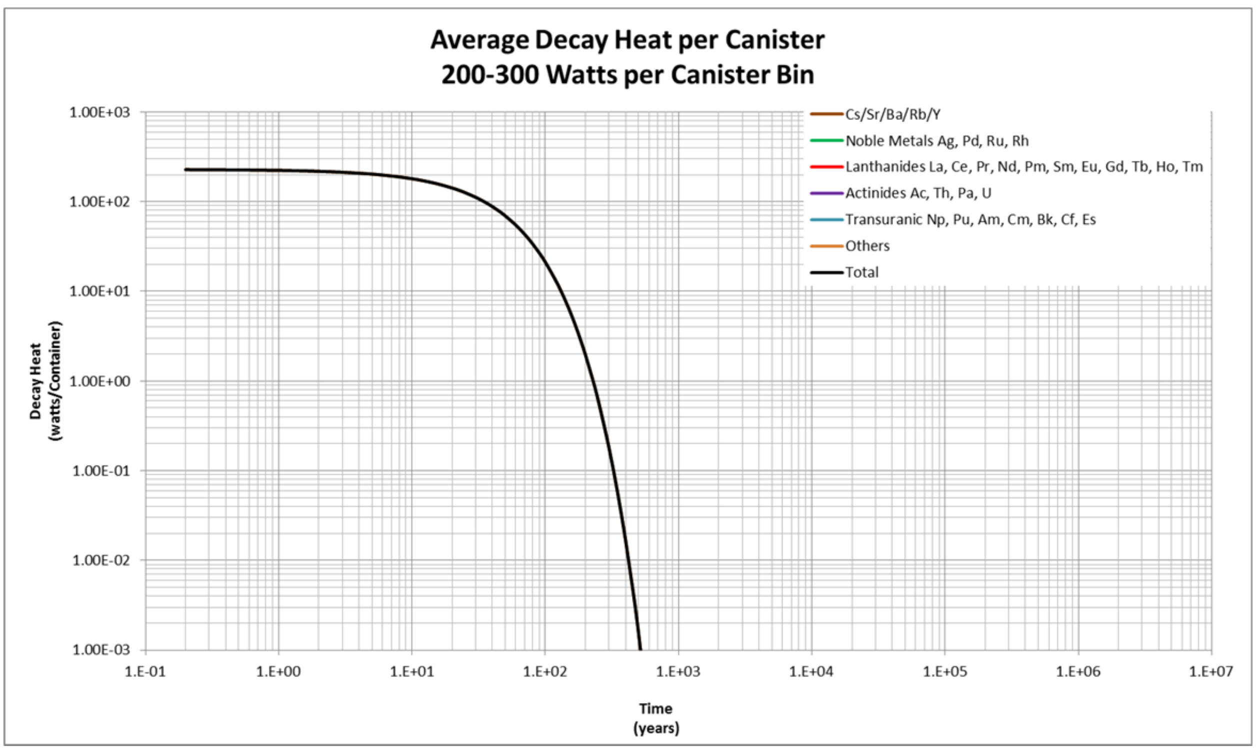

Figure B- 17 Decay heat for average Sr Capsule in the 200-300 Watts per canister bin

Table B- 27 Decay heat for average Sr Capsule in the 300-500 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	-	-	-	-	-	-	-
Cs/Sr/Ba/Rb/Y	342.08	304.50	270.34	104.34	31.74	0.00	-
Noble Metals Ag, Pd, Ru, Rh	-	-	-	-	-	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	-	-	-	-	-	-	-
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Others	-	-	-	-	-	-	0.00
Total	342.08	304.50	270.34	104.34	31.74	0.00	0.00

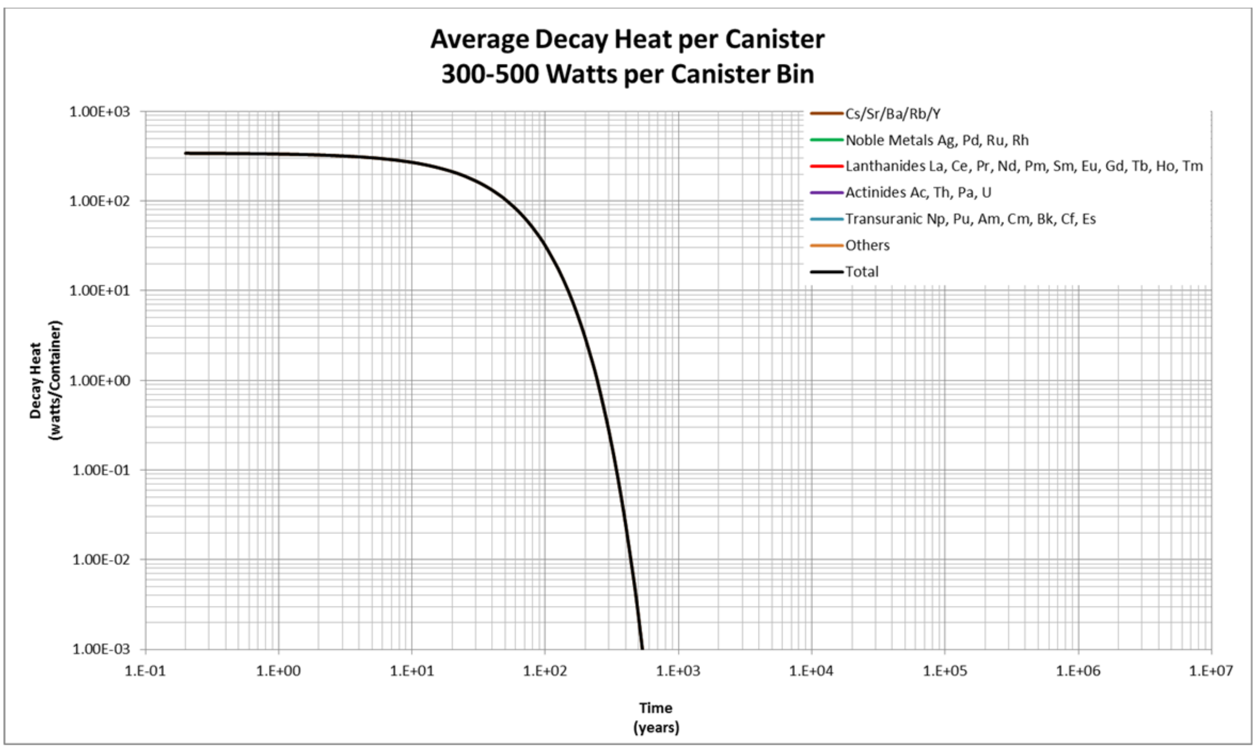

Figure B- 18 Decay heat for average Sr Capsule in the 300-500 Watts per canister bin

B-5. Idaho Calcine Waste Canisters

Table B- 28 Idaho Calcine Waste after HIP Average Radionuclide inventory per canister for <50 watts per canister bin (2016)

Radionuclide	Curies	Std. Deviation
^{241}Am	1.82E+00	1.230509326
^{243}Am	1.16E-03	0.000693339
^{137m}Ba	2.03E+03	867.8719085
^{144}Ce	2.56E-09	4.11971E-09
^{242}Cm	2.91E-03	0.001702846
^{244}Cm	1.08E-03	0.000551938
^{60}Co	1.75E-01	0.288803594
^{134}Cs	9.82E-03	0.015229739
^{135}Cs	3.59E-02	0.012284494
^{137}Cs	2.14E+03	918.522426
^{152}Eu	5.71E-02	0.024096837
^{154}Eu	3.90E+00	2.492506714
^{155}Eu	2.66E-01	0.181740548
^{129}I	2.03E-04	0.000110449
^{63}Ni	8.50E+01	57.1091469
^{237}Np	1.64E-02	0.017122661
^{233}Pa	1.64E-02	0.017122661
^{147}Pm	6.12E-02	0.028329345
^{144}Pr	2.56E-09	4.11971E-09
^{238}Pu	1.98E+01	15.4389073

Radionuclide	Curies	Std. Deviation
^{239}Pu	5.04E-01	0.325311934
^{240}Pu	2.82E-01	0.164369003
^{241}Pu	7.67E+00	5.002469513
^{106}Ru	9.29E-08	1.43341E-07
^{125}Sb	2.71E-02	0.03281276
^{126}Sb	3.55E-03	0.001875817
^{126m}Sb	2.53E-02	0.013400497
^{151}Sm	2.63E+01	24.75754739
^{90}Sr	1.88E+03	762.6670141
^{99}Tc	9.52E-01	0.528149313
^{230}Th	1.36E-04	0.000197357
^{231}Th	8.50E-05	2.0779E-05
^{232}U	5.43E-05	5.20196E-05
^{233}U	3.59E-06	2.23596E-06
^{234}U	1.69E-02	0.010175082
^{235}U	8.49E-05	3.49689E-05
^{236}U	2.45E-04	0.000133605
^{237}U	1.92E-04	0.000119107
^{238}U	2.85E-05	4.3411E-05
^{90}Y	1.88E+03	762.6670141
Total	8.08E+03	3.42E+03

Table B- 29 Decay heat for average canister of Idaho Calcine after HIP in the <50 Watts per canister bin

<50	years						
	0	5	10	50	100	1,000	1,000,000
Gases H, C, Xe, Kr, I	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cs/Sr/Ba/Rb/Y	22.98	20.39	18.13	7.09	2.19	0.00	0.00
Noble Metals Ag, Pd, Ru, Rh	0.00	0.00	0.00	0.00	0.00	-	-
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	0.04	0.03	0.02	0.00	0.00	0.00	0.00
Actinides Ac, Th, Pa, U	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	0.74	0.72	0.69	0.53	0.38	0.04	0.00
Others	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	23.77	21.13	18.84	7.62	2.57	0.04	0.00

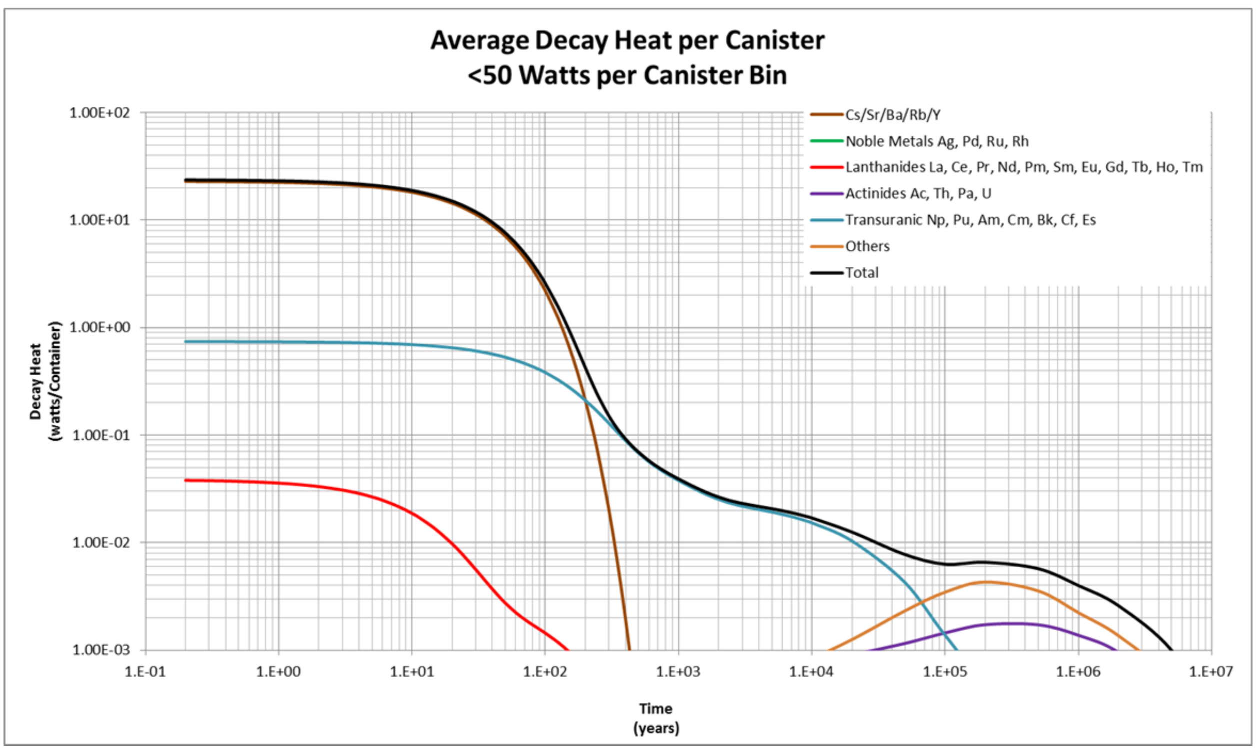

Figure B- 19 Decay heat for average canister of Idaho Calcine after HIP in the <50 Watts per canister bin