Calculation of DWPF Canister Decay Heat for Sludge Macro-Batches 1B to 9

by

A. S. Choi

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

DOE Contract No. **DE-AC09-96SR18500**

This paper was prepared in connection with work done under the above contract number with the U. S. Department of Energy. By acceptance of this paper, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper, along with the right to reproduce and to authorize others to reproduce all or part of the copyrighted paper.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

WSRC-TR-98-00466

**Keywords: DWPF, Canister, Decay
Heat, HLW System Plan
Revision 9, Macro-Batches**

Retention Period: Permanent

**CALCULATION OF
DWPF CANISTER DECAY HEAT FOR
SLUDGE MACRO-BATCHES 1B TO 9 (U)**

February 18, 1999

Alexander S. Choi

**Immobilization Technology Section
Savannah River Technology Center
Westinghouse Savannah River Company**

This page left intentionally blank.

SUMMARY

The rates of heat generation of DWPF glass canisters due to radioactive decay have been estimated for the remaining nine macro-batches of sludge feed. The estimated decay heat ranged from 177.5 Watts for each Macro-batch 1B canister to 498.4 Watts for each Macro-batch 8 canister. These projections are based on the HLW radionuclide inventory data available as of 4/1/98, and do not reflect further decay since then. It was assumed that each DWPF glass canister would also contain a nominal quantity of salt waste based on the reference coupled feed flowsheet. Issue of this report successfully closes a recent technical assistance request (HLW/DWPF-TAR-990003).

INTRODUCTION

DWPF successfully completed the first macro-batch campaign (1A) in October 1998, and produced a total of 492 canisters, each containing about 3,810 lb of glass on the average;¹ on a 4,000 lb of glass-per-canister basis, this is equivalent to 469 canisters. This adjusted actual canister yield for Macro-batch 1A was very close to the theoretical prediction of 466 made by the CPES model.² Currently, DWPF is processing the second macro-batch (1B) at a rate of about 250 canisters per year. Once sealed and decontaminated, these canisters must be stored on-site temporarily, until they are shipped to a federal repository for permanent disposal. In anticipation of potentially a long delay in the opening of such a repository, DWPF is now designing a second Glass Waste Storage Building (GWSB-II). It was the objective of this study to provide the radioactive decay heat projections for all future canisters in support of GWSB-II design.

The baseline glass compositions used in this study to estimate the decay heat were those calculated earlier using the CPES model in support of the HLW System Plan Revision 9.³ The baseline glass compositions were calculated based on the sludge processing schedule outlined in the HLW System Plan, which calls for processing the entire sludge inventory in ten macro-batches.² Table 1 shows the makeup of each macro-batch and the projected canister yields.

The chemical composition of each macro-batch thus defined was developed from the tank-by-tank waste characterization system (WCSys) database available as of October 1997,⁴ and was used in the CPES model to calculate a complete HLW flowsheet material balance for each macro-batch, including the baseline glass compositions.³ The resulting material balance predicted the total canister yield of 5,084 for the entire duration of sludge campaign, each canister containing 4,000 lb of glass.² Glass blending was optimized in each CPES run using the Product Composition Control System (PCCS),⁵ so the total canister yield predicted by the model represents the theoretical minimum required to convert the entire sludge inventory into glass at the highest waste loading.

During this study, two major modifications were made to the calculated baseline glass compositions. First, the CPES model was run based on the assumption that all macro-batches of sludge would be fed to DWPF along with the tetraphenyl borate (TPB) precipitate produced from the average salt feed for the first 10 years of planned in-tank precipitation (ITP) operation. This hypothetical salt feed is called the 10-year average

salt; its composition was developed in the 1980's, and has been used in several design basis material balances for DWPF.⁶ Recently, however, the composition of a new blend salt was developed using the WCSys database available as of April 1998 in support of the salt disposition alternatives down-selection process,⁷ and its impact on the total canister yield was also assessed.⁸

The composition of the new blend salt thus developed is compared in Table A-1 against to that of the 10-year average (called the old blend salt in this memo). For the purpose of this study, the important species to follow are soluble Cs and Sr and insoluble solids containing Pu and Sr. The soluble and insoluble species shown in Table A-1 are further combined into the elemental and ionic distributions in Table A-2; it can be clearly seen that the concentrations of all actinides and most fission products except Cs are significantly higher in the new blend salt than in the old. As a result, it became necessary in this study to revise the salt (or PHA) fraction of the baseline glass compositions using the mass ratios given in Table 3 for an accurate projection of radioactive decay heat.

Second, the concentration of Cs given in the WCSys database available as of October 1997 were found to be erroneously high for the supernate phase of each tank, thus impacting the soluble Cs level in each macro-batch and eventually the baseline glass compositions. As a result, a volume-averaged reduction factor of Cs was calculated in this study for each macro-batch using the WCSys database available as of April 1998 and applied to the sludge fraction of Cs in each glass matrix.

TABLE 1. Sludge Processing Schedule Used in HLW System Plan Revision 9.

Macro-Batch	Tanks	Canister Yield @ 4,000 lb glass/can
1A	51	467 [#]
1B	42	572 [*]
2	8, 40	479
3	7 (70%), 11, 18, 19	591
4	4, 7 (30%), 12, 14	527
5	5, 6, 13 (30%), 15, 21, 22	497
6	13 (70%), 23, 47	740
7	26, 32, 33	473
8	34, 35, 39, 43, 40 heel	467
9	1, 2, 3, 9, 10, 36, 41, 42 heel, 51 heel	416

[#] Actual DWPF data after adjustment to 4,000 lb glass/canister.

^{*} Data taken from Ref. 1 and adjusted to 4,000 lb glass/canister.

BASES

The WCSys database contains the inventory information for 41 radionuclide isotopes, and the CPES model tracks only the major radionuclides involving Cs, Sr, Pu, Tc and U. For most sludge tanks, the Sr-90/Y-90 pair alone accounts for close to 90% or more of the total radioactivity in a tank. Excluding Tank 51, however, there are eight or so tanks in which the Sr-90/Y-90 pair accounts for less than 80% of the total radioactivity. In order to identify additional nuclides that contribute significantly to the total radioactivity in those tanks, Table A-3 was constructed from the April 1998 WCSys database by adding different radionuclides to the Sr-90/Y-90 pair. As shown by the last column in Table A-3, nearly all radioactivity in every tank except Tank 19 is accounted for when Cs-137/Ba-137m, Pm-147, Pu-238, Am-241 and Cm-244 are included in addition to Sr-90/Y-90. For Tank 19, it is shown that only 90% of the total radioactivity is accounted for by these radionuclides, since Pu-241 which accounts for nearly 9% of the total radioactivity in the tank was not included. However, Pu-241 has more than two orders of magnitude lower radioisotopic power than Pu-238, so its omission from the decay heat calculations is justified.

As a result, the following radionuclides were selected for all decay heat calculations made in this study:

Sr-90/Y-90
Cs-137/Ba-137m
Pm-147
Pu-238
Am-241
Cm-244

Calculations showed that as of April 1998 these radionuclides contributed to more than 96% of the total decay heat generated in all tanks. Additional key bases used in the calculations include:

- All radioactive decay modes are frozen as of April 1998.
- Each canister produced contains 4,000 lb of glass consisting of both sludge and salt oxides according to the reference coupled feed flowsheet.⁶ The fraction of salt oxides in glass is nominally 6.1 wt%.³
- The chemical composition of the salt feed to the ITP is that of the old blend salt.
- The concentrations of Cs, Pu and Sr in the salt fraction of each baseline glass matrix were multiplied by the following ratios found in Table A-2:

Cs	0.91
Pu	16.01
Sr	31.50

- The following wt% distributions of Sr-90 and Cs-137 were assumed in both sludge and salt feeds:**

Sr-90	36.86 wt% of total Sr
Cs-137	22.56 wt% of total Cs

- The following distribution of Pu isotopes in each macro-batch glass matrix was obtained by mass-averaging contributions from all constituent tanks (see Sample Calculations in Appendix):

TABLE 2. Calculated Mass-Averaged Pu Isotope Distributions (wt% total Pu).

Macro-Batch	Pu-238	Pu-239
1B	5.96	85.64
2	0.22	95.29
3	9.38	81.23
4	8.62	81.33
5	7.27	82.49
6	2.98	89.79
7	14.34	74.0
8	21.79	63.86
9	11.37	78.05

- The concentration of Cs in the sludge fraction of each macro-batch glass matrix was multiplied by the following volume-averaged reduction factors to account for the error found in the October 1997 WCSysstem supernate database:

TABLE 3. Volume-Averaged Reduction Factors for Soluble Cs in Sludge Feed.

Macro-Batch	Reduction Factor
1B	N/A
2	0.00267
3	0.00444
4	0.01938
5	0.00188
6	0.00579
7	0.00164
8	0.00311
9	0.00814

** As a comparison, DWPF isotopic data issued in 1985 showed the following wt% distributions:⁹

	sludge	salt
Sr-90	59.5	53.5
Cs-137	44.6	39.0

- The concentrations of Pm-147, Am-241 and Cm-244 in glass were estimated by multiplying the composite mass ratio of each nuclide to Pu-239 in each macro-batch with the mass of Pu-239 in the sludge fraction of glass (see Sample Calculations in Appendix).
- The modified concentrations of those selected radionuclides in the baseline glass matrices were multiplied by the following radioisotopic power data to calculate the decay heat:¹⁰

TABLE 4. Radioisotopic Power Data Used in Decay Heat Calculations.

Nuclide	Watt/gm
Sr-90 ⁺	0.916
Cs-137 ⁺	0.427
Pm-147	0.340
Pu-238	0.558
Am-241	0.113
Cm-244	2.78

⁺ Includes daughter radiations.

RESULTS

The radioactive decay heat projections calculated using the bases discussed above are shown in Table 5. These projections include both primary and gamma radiations emitted as of April 1998 by those nuclides selected above plus all of their daughters. It is shown that the projected decay heat ranges from 177.5 Watts for each Macro-batch 1B canister that DWPF is currently producing to 498.4 Watts for each Macro-batch 8 canister. As a comparison, the decay heat calculated earlier for the blend sludge-precipitate glass was about 500 Watts per canister for a 10-year old sludge;⁹ although not mentioned in the reference, it is believed that each canister was assumed to contain 3,700 lb of glass.

Table 5 also shows that the last three macro-batches together generate nearly 50% of all decay heat, and the contributions by sludge and salt components to the total decay heat are quite comparable except for these three macro-batches along with Macro-batches 1B. The decay heat projections are further broken down into contributions by individual sludge and salt components in Tables 6 and 7. As expected, Sr-90 and its daughter radiations are shown to account for 90% or more of the decay heat generated by all sludge components except for the last three macro-batches.

Table 7 shows that for Macro-batches 8 and 9 the combined contributions by Pm-147, Am-241 and Cm-244 are 13.4 and 18.0%, respectively, of the total decay heat generated by all sludge components. It is also shown in Table 7 that 30 to 40% of the total decay heat generated by all salt components are due to Sr-90 and its daughter radiations, while the remaining 60 to 70% is due to Cs-137 and its daughter radiations. Pu-238 is shown to contribute significantly to the total decay heat only in Macro-batch 8.

TABLE 5. Calculated Radioactive Decay Heat Projections.

Macro-batch	Decay Heat (Watts/Canister)	Salt Contribution (% total Watts)	Sludge Contribution (% total Watts)
1B	177.5	79.6	20.4
2	294.4	50.2	49.8
3	307.5	51.5	48.5
4	331.9	48.7	51.3
5	319.5	47.7	52.3
6	249.2	56.5	43.5
7	417.0	41.3	58.7
8	498.4	36.2	63.8
9	434.5	40.3	59.7

TABLE 6. Contributions to Total Decay Heat by Individual Radionuclides (% total Watts).

Macro-batch	salt components				sludge components				
	Cs ⁺	Pu	Sr ⁺	total	Cs ⁺	Pm/Am/Cm	Pu	Sr ⁺	total
1B	55.0	0.5	24.0	79.6	0.1	0.9	1.3	18.2	20.4
2	29.7	0.0	20.4	50.2	0.1	0.4	0.0	49.4	49.8
3	31.8	0.7	19.0	51.5	0.1	1.4	2.3	44.8	48.5
4	29.4	0.6	18.6	48.7	0.2	1.3	2.2	47.6	51.3
5	30.6	0.4	16.8	47.7	0.0	2.9	1.3	48.0	52.3
6	39.2	0.2	17.1	56.5	0.0	0.6	0.6	42.2	43.5
7	23.4	1.2	16.7	41.3	0.0	3.8	5.6	49.3	58.7
8	19.6	2.7	13.9	36.2	0.0	8.5	13.7	41.6	63.8
9	22.5	0.9	16.9	40.3	0.7	10.8	3.9	44.3	59.7

+ Includes daughter radiations.

TABLE 7. Contributions by Individual Radionuclides to Total Sludge or Salt Decay Heat (% total Watts by Sludge or Salt).

Macro-batch	salt components				sludge components				
	Cs ⁺	Pu	Sr ⁺	total	Cs ⁺	Pm/Am/Cm	Pu	Sr ⁺	total
1B	69.1	0.7	30.2	100.0	0.5	4.2	6.2	89.1	100.0
2	59.2	0.0	40.7	100.0	0.2	0.7	0.1	99.0	100.0
3	61.7	1.3	37.0	100.0	0.1	2.9	4.7	92.3	100.0
4	60.5	1.2	38.3	100.0	0.3	2.6	4.3	92.8	100.0
5	64.0	0.7	35.2	100.0	0.1	5.6	2.5	91.9	100.0
6	69.4	0.3	30.3	100.0	0.1	1.4	1.4	97.1	100.0
7	56.7	3.0	40.3	100.0	0.0	6.4	9.6	84.0	100.0
8	54.2	7.5	38.3	100.0	0.1	13.4	21.4	65.1	100.0
9	55.8	2.3	42.0	100.0	1.1	18.0	6.6	74.3	100.0

+ Includes daughter radiations.

CONCLUSION

The decay heat projections given in Table 5 are valid as of April 1998, and further decay since then was not accounted for. Furthermore, calculations showed that those eight radionuclides chosen for this study accounted for over 96% of the total decay heat generated in all waste tanks; the remaining 4% is mainly due to the decay of Co-60 and Eu-154. Therefore, it can be concluded that the design of GWSB-II based on the decay heat projections given for the last three macro-batches would be conservative.

REFERENCES

1. Occhipinti, J. E., Shah, H. B., Lee, E. D., and Choi, A. S., "Preliminary Evaluation of DWPF Canisters Predicted vs DWPF Canisters Poured," **HLW-DEN-99-0074**, March 4, 1999.
2. Davis, N. E., and Wells, M. N., "High Level Waste System Plan Revision 9 (U)," **HLW-OVP-98-0037**, April 1998.
3. Choi, A. S., Unpublished Results of CPES Runs, March 1998.
4. Hester, J. R., "High Level Waste Characterization System (WCS)," **WSRC-TR-96-0264 (Revision 0)**, December 1996.
5. Brown, K. G. and Postles, R. L., "SME Acceptability Determination for DWPF Process Control," **WSRC-TR-95-0364 (Revision 3)**, February 21, 1996.
6. Choi, A. S., "Material Balance Tables for the DWPF Coupled Feed Flowsheet with Batch One Sludge (U)," **WSRC-TR-93-203 (Rev. 0)**, August 19, 1993.
7. Rutland, P. L., Fowler, J. R., Beck, S., Choi, A. S., Jacobs, R. A., Elder, H. H., Taylor, G. A., and Duarte, O. E., "Bases, Assumptions, and Results of the Flowsheet Calculations for the Initial Eighteen Salt Disposition Alternatives," **WSRC-RP-98-00166 (Revision 0)**, June 1998.
8. Choi, A. S., "Impact of New Blend Salt Feed Composition on Canister Yield," **SRT-PCC-98-0013**, August 19, 1998.
9. Fowler, J. R., "DWPF Isotopic Data," **DPST-84-971**, February 21, 1985.
10. **Nuclides and Isotopes**, Fourteenth Edition, GE Nuclear Energy, San Jose, California (1989).
11. Accountability Manual Accountability Standard Decay and Activity Values (U), **DPSOP 23-11 Revision 5**, September 1985.

APPENDIX

TABLE A-1. Compositions of New and Old Blend Salt Feeds Calculated by CPES Model.

insolubles	New (wt% dry)	Old (wt% dry)	Ratio (New/Old)	solubles	New (wt% dry)	Old (wt% dry)	Ratio (New/Old)
Ag ₂ O	2.2449E-04	3.9622E-05	5.67	NaNO ₂	9.2300E+00	1.2675E+01	0.73
Al ₂ O ₃	2.7638E-02	5.3673E-03	5.15	NaNO ₃	4.6978E+01	5.0922E+01	0.92
BaSO ₄	5.1104E-04	1.0089E-04	5.07	NaOH	2.2612E+01	1.2543E+01	1.80
Ca ₃ (PO ₄) ₂	2.5552E-04	3.2406E-05	7.89	Na ₂ CO ₃	4.2202E+00	5.3637E+00	0.79
CaC ₂ O ₄	1.3440E-03	1.5053E-04	8.93	Na ₂ SO ₄	5.2664E+00	6.1158E+00	0.86
CaCO ₃	4.9058E-03	1.6142E-03	3.04	NaAl(OH) ₄	9.2300E+00	1.0390E+01	0.89
CaCO ₃ (14)	3.8174E-10	5.6242E-11	6.79	NaCl	3.9084E-01	3.8228E-01	1.02
CaF ₂	2.1982E-04	3.9659E-05	5.54	NaF	3.4113E-01	1.9085E-01	1.79
CaO				Na ₂ C ₂ O ₄	6.5984E-01	3.3169E-01	1.99
CaSO ₄	1.1689E-03	7.7484E-05	15.09	Ba(OH) ₂	4.0870E-06	5.2866E-03	0.00
CoO	1.2966E-05	2.4177E-06	5.36	Ca(OH) ₂	1.1764E-04	4.3401E-04	0.27
Cr ₂ O ₃	4.5126E-04	9.4800E-05	4.76	CsOH	5.8154E-03	6.4239E-03	0.91
Cs ₂ O	9.5776E-06			Group A	1.3743E-03	4.5015E-03	0.31
CuO	1.8291E-04	3.3716E-05	5.43	KNO ₃	7.6803E-02	1.5801E-04	486.06
Fe ₂ O ₃	4.2657E-02	1.4070E-02	3.03	KOH	1.7966E-01	2.4030E-01	0.75
Group B	2.1800E-03	1.1556E-05	188.64	NH ₄ OH			
HgO	2.3717E-03	6.6954E-04	3.54	NH ₄ NO ₃	7.7777E-03		
K ₂ O				Na(HgO(OH))	9.0545E-03	1.0291E-02	0.88
La ₂ O ₃	8.9701E-04	4.2521E-04	2.11	Na ₂ B ₄ O ₇	4.0091E-03		
MgO	3.8564E-04	1.3695E-04	2.82	Na ₂ CO ₃ (14)		5.4517E-09	
MnO ₂	9.2332E-03	1.8388E-03	5.02	Na ₂ CrO ₄	1.2209E-01	1.6484E-01	0.74
Na ₂ O	2.6205E-06			Na ₂ MoO ₄	9.3144E-03	2.7171E-02	0.34
NiO	5.1267E-03	2.1025E-04	24.38	Na ₂ RhO ₄	2.1543E-04	6.8569E-04	0.31
PbCO ₃	1.3018E-04	1.9107E-05	6.81	Na ₂ RuO ₄	5.3996E-03	2.9467E-03	1.83
PbSO ₄	3.7297E-04	1.6418E-04	2.27	Na ₂ SiO ₃	1.1082E-01	1.4385E-01	0.77
PdO	2.2323E-04	3.5708E-05	6.25	Na ₃ PO ₄	3.2618E-01	4.3364E-01	0.75
alpha (PuO ₂)	8.3365E-05	5.5068E-06	15.14	NaAg(OH) ₂	1.6611E-04	2.3682E-04	0.70
RhO ₂				NaI	3.8564E-04	1.0100E-04	3.82
RuO ₂	5.3736E-04	8.5848E-05	6.26	NaTeO ₄	8.6322E-04	2.8132E-03	0.31
SiO ₂	4.4184E-03	9.4396E-04	4.68	Na ₂ PuO ₂ (OH) ₄	9.2137E-05	5.3343E-06	17.27
SrCO ₃	3.1640E-04	2.9797E-05	10.62	Pb(NO ₃) ₂	8.1026E-04		
TcO ₂	1.4708E-04	1.3273E-05	11.08	Sr(OH) ₂	5.3346E-04	6.4386E-07	828.53
ThO ₂	1.8658E-03	1.1729E-04	15.91	Tritium*	2.9162E-14	7.3411E-10	0.00
TiO ₂	2.1520E-06	8.3904E-06	0.26	UO ₂ (OH) ₂	2.1757E-02	3.7568E-05	579.15
U ₃ O ₈	1.4295E-02	7.9465E-04	17.99	Y(OH) ₃ *	1.8778E-07	6.4900E-07	0.29
Y ₂ (CO ₃) ₃	3.9116E-08	1.8355E-09	21.31	C ₆ H ₅ OH salt	3.2128E-02		
ZnO	3.2488E-04	9.8028E-05	3.31	C ₆ H ₅ NH ₂	2.1364E-04		
ZrO ₂	7.8719E-04	2.0134E-04	3.91	NH ₃		4.4795E-03	
hyd H ₂ O	3.2199E-02	7.9428E-03	4.05				
zeolite	3.9376E-04	1.5354E-03	0.26				
total insolubles	1.5588E-01	3.6910E-02	4.22	total solubles	9.9844E+01	9.9963E+01	1.00
				total solids	1.0000E+02	1.0000E+02	

TABLE A-2. Elemental and Anion Compositions of New and Old Blend Salt Feeds.

elements	old (wt% dry)	new (wt% dry)	ratio (new/old)	anions	old (molar)	new (molar)	ratio (new/old)
Ag	1.918E-04	3.198E-04	1.67	NO3	2.540E+00	2.352E+00	0.93
Al	2.382E+00	2.128E+00	0.89	NO2	7.786E-01	5.681E-01	0.73
Ba	4.294E-03	3.038E-04	0.07	OH	1.719E+00	2.745E+00	1.60
Ca	1.018E-03	3.011E-03	2.96	CO3	2.144E-01	1.692E-01	0.79
Co	1.900E-06	1.019E-05	5.36	SO4	1.824E-01	1.574E-01	0.86
Cr	5.297E-02	3.950E-02	0.75	C2O4	1.049E-02	2.096E-02	2.00
Cs	5.697E-03	5.167E-03	0.91	PO4	1.120E-02	8.451E-03	0.75
Cu	2.694E-05	1.462E-04	5.43	NH4	1.115E-03	4.121E-04	0.37
Fe	9.855E-03	2.982E-02	3.03				
Hg	8.667E-03	9.277E-03	1.07				
I	8.554E-05	3.266E-04	3.82				
K	1.675E-01	1.549E-01	0.92				
La	3.636E-04	9.483E-04	2.61				
Mg	9.424E-05	2.355E-04	2.50				
Mn	1.162E-03	5.835E-03	5.02				
Mo	1.641E-02	5.487E-03	0.33				
Na	3.217E+01	3.488E+01	1.08				
Ni	1.652E-04	4.030E-03	24.39				
P	8.196E-02	6.170E-02	0.75				
Pb	1.269E-04	8.629E-04	6.80				
Pd	3.110E-05	1.940E-04	6.24				
Pu	8.190E-06	1.311E-04	16.01				
Rh	3.312E-04	1.041E-04	0.31				
Ru	1.477E-03	2.995E-03	2.03				
S	1.382E+00	1.191E+00	0.86				
Si	3.385E-02	2.763E-02	0.82				
Sr	1.816E-05	5.720E-04	31.50				
Tc	1.507E-03	5.704E-04	0.38				
Th	1.031E-04	1.640E-03	15.91				
Ti	5.034E-06	1.291E-06	0.26				
U	7.032E-04	2.916E-02	41.47				
Y	4.130E-07	1.387E-07	0.34				
Zn	7.871E-05	2.609E-04	3.31				
Zr	1.525E-04	1.247E-03	8.18				

TABLE A-3. Tank-By-Tank Major Radionuclides Distributions (% Total Ci)

Tank	Sr-90/Y-90	Sr-90/Y-90 Pu-238	Sr-90/Y-90 Pm-147	Sr-90/Y-90 Am-241	Sr-90/Y-90 Cs-137/Ba-137m	Sr-90/Y-90 Pu-238 Am-241	Sr-90/Y-90 Cs-137/Ba-137m Pm-147 Pu-238 Am-241 Cm-244
1	93.19083	93.19083	93.28030	93.35120	99.54802	93.35120	99.79790
2	93.24847	93.24847	93.26543	93.42549	99.65477	93.42549	99.84879
3	93.23167	93.23167	93.26137	93.40941	99.62005	93.40941	99.82752
4	91.29367	91.29367	93.23533	91.42257	97.43911	91.42257	99.50970
5	93.08541	93.08541	93.28432	93.23504	99.40759	93.23504	99.75618
6	92.87982	92.87982	93.28105	93.01921	99.15643	93.01921	99.69709
7	93.08884	93.08884	93.15384	93.32400	99.45276	93.32400	99.75295
8	92.35409	92.35409	93.17583	92.52690	98.58321	92.52690	99.57780
9	93.26774	93.26774	93.28460	93.43513	99.67557	93.43513	99.85985
10	93.26440	93.26440	93.28466	93.44310	99.63224	93.44310	99.83124
11	91.92516	92.94364	92.48549	92.41548	96.80379	93.43396	98.87335
12	93.11837	93.71321	93.31973	93.36961	98.18884	93.96445	99.23669
13	93.53910	93.77343	93.65238	93.70182	98.98488	93.93615	99.49549
14	93.44634	93.48869	93.47929	93.60762	99.51557	93.64997	99.75226
15	93.76315	94.02995	93.91198	93.91184	98.77745	94.17865	99.34220
16							
17	88.68078	88.68078	89.70037	90.86509	94.64921	90.86509	97.85316
18	88.98413	88.98413	89.92874	91.01609	94.98237	91.01609	97.95897
19	67.36934	67.36934	68.44054	84.67471	71.88356	84.67471	90.26015
20							
21	91.39443	92.04976	93.23713	91.44579	96.19182	92.10112	98.74168
22	91.90923	92.43779	93.41748	91.94329	96.73451	92.47185	98.80587
23					99.88377		99.88377
24							
25							
26	66.03848	66.03848	88.82634	67.19269	70.39276	67.19269	94.33485
27							
28							
29							
30	76.52826	79.46351	87.36668	77.85199	80.50968	80.78725	95.60755
31							
32	88.03259	89.47497	91.29795	88.71121	92.67007	90.15360	98.05690
33	71.86873	71.86873	92.18667	71.95267	76.60998	71.95267	97.01191
34	74.40737	74.40737	92.66879	74.49259	79.32339	74.49259	97.67007
35	86.36694	87.95937	90.74518	87.12623	90.89603	88.71867	97.62647
36	88.11661	90.40613	90.02258	89.12357	92.74952	91.41309	97.95245
37							
38							
39	80.53932	82.62128	88.96119	81.61266	84.73911	83.69461	96.31674
40	91.05650	91.42442	92.38447	91.67955	96.24184	92.04747	98.56113
41	88.82159	89.39772	93.08065	88.85097	93.45375	89.42710	98.31881
42	88.98328	90.49288	91.22221	89.86876	94.08944	91.37835	98.81233
43	78.57810	80.43729	90.37614	78.78849	82.65493	80.64769	96.52303
44							
45							
46							
47	74.99712	74.99712	88.92373	76.80484	79.95552	76.80484	95.68989
48							
49							
50							
51	59.52562	69.04729	63.61532	62.37863	74.78581	71.90029	97.65535

This page left intentionally blank.

SAMPLE CALCULATIONS

All sample calculations are for Marco-batch 4, which consists of Tanks 4, 12, 14, and 30% of Tank 7.

Calculation of Isotopic Distribution of Pu-238 and 239

The following data are obtained from the WCSysstem database:

Tank	Pu-238 (Ci)	Pu-239 (Ci)	Pu-240 (Ci)	Pu-241 (Ci)	Pu-242 (Ci)
4		5.977E+02	1.336E+02	5.365E+02	2.749E-02
7		3.666E+03	8.756E+02	2.116E+03	2.824E-01
12	1.203E+05	2.316E+03	1.280E+03	1.532E+04	1.849E+00
14	2.001E+02	6.045E+01	1.952E+01	2.776E+01	3.574E-03

In addition, the following specific curie data in Ci/gm are used:¹¹

Pu-238	Pu-239	Pu-240	Pu-241	Pu-242
17.12	0.06132	0.2256	103.3	0.003925

For Tank 4,

$$\begin{aligned}
 Pu(\text{Tank 4}) &= 5.997E2/0.06132 + 1.336E2/0.2256 + 5.365E2/103.3 \\
 &\quad + 2.749E-2/0.003925 \\
 &= 10,384 \text{ g}
 \end{aligned}$$

The total Pu in Tanks 7 (30%), 12 and 14 are calculated similarly, and the total Pu in Macro-batch 4 is then:

$$\begin{aligned}
 Pu(\text{MB4}) &= 10,384 + 19,128 + 51,089 + 1,084 \\
 &= 81,685 \text{ g}
 \end{aligned}$$

So, the mass-averaged weight percent of Pu-238 then becomes:

$$\begin{aligned}
 \text{wt\% Pu-238} &= \frac{1.203E5 + 2.001E2}{(17.12)(81,685)} (100) \\
 &= 8.62
 \end{aligned}$$

Similarly,

$$\begin{aligned}
 \text{wt\% Pu-239} &= \frac{5.977E2 + (3.666E3)(0.3) + 2.316E3 + 6.045E1}{(0.06132)(81,685)} (100) \\
 &= 81.33
 \end{aligned}$$

Calculation of Decay Heat by Pm-147, Am-241 and Cm-244

The following curie inventory data are obtained from the WCSysstem database:

Tank	Pm-147 (Ci)	Pu-238 (Ci)	Pu-239 (Ci)	Ingrown Am-241	Am-241 (Ci)	Cm-244 (Ci)	Tank Total (Ci)
4	1.893E+05		5.977E+02	1.291E+03	1.128E+04	3.864E+00	9.751E+06
7	5.727E+03		3.666E+03	7.924E+03	1.280E+04	3.018E+00	8.811E+06
12	4.073E+04	1.203E+05	2.316E+03	3.735E+04	1.347E+04	8.055E+01	2.023E+07
14	1.557E+02	2.001E+02	6.045E+01	1.294E+02	6.328E+02	5.582E-01	4.725E+05

In addition, the following specific curie data in Ci/gm are used:¹¹

Pm-147	Am-241	Cm-244
927.6	3.416	80.88

The total amount of Pu-239 in Macro-batch 4 is:

$$\begin{aligned}
 Pu\ 239 &= (81,685)(81.33) / 100 \\
 &= 66,434\ g
 \end{aligned}$$

The mass ratio of Pm-147 to Pu-239 is then:

$$\begin{aligned}
 MR(Pm / Pu) &= [1.893E5 + (5.727E3)(0.3) + 4.073E4 + 1.557E2] / 927.6 / 66,434 \\
 &= 0.003763
 \end{aligned}$$

Similarly, the mass ratios of Am-241 and Cm-244 to Pu-239 are:

$$\begin{aligned}
 MR(Am / Pu) &= \left[\frac{1.291E3 + 1.128E4 + (7.924E3 + 1.280E4)(0.3)}{+ 3.735E4 + 1.347E4 + 1.294E2 + 6.328E2} \right] / 3.416 / 66,434 \\
 &= 0.31
 \end{aligned}$$

$$\begin{aligned}
 MR(Cm / Pu) &= [3.864 + (3.018)(0.3) + (80.05) + 0.5582] / 80.88 / 66,434 \\
 &= 1.6E-5
 \end{aligned}$$

The material balance showed that the sludge fraction of total Pu in glass is 8.593 g/hr per 228 lb/hr glass production.³ So, the total Pu-239 in one Macro-batch 4 canister is:

$$\begin{aligned}
 M(Pu - 239) &= (8.593)(0.8133)(4,000 / 228) \\
 &= 122.609\ g
 \end{aligned}$$

So, the mass of Pm-147 in one Macro-batch 4 canister is:

$$\begin{aligned} M(Pm-147) &= (122.609)(0.003763) \\ &= 0.4614 \text{ g} \end{aligned}$$

The decay heat generated by Pm-147 is then:

$$\begin{aligned} DH(Pm-147) &= (0.4614)(0.34) \\ &= 0.157 \text{ Watt} \end{aligned}$$

Similarly,

$$\begin{aligned} DH(Am-241) &= (122.609)(0.31)(0.113) \\ &= 4.295 \text{ Watt} \end{aligned}$$

$$\begin{aligned} DH(Am-241) &= (122.609)(1.6E-5)(2.78) \\ &= 0.0055 \text{ Watt} \end{aligned}$$

WSRC-TR-98-00466

**CALCULATION OF DWPF CANISTER DECAY HEAT FOR
SLUDGE MACRO-BATCHES 1B TO 9 (U)**

Distribution:

W. D. Kerley, 704-S

J. F. Ortaldo, 704-S

R. E. Edwards, 704-25S

J. A. Gentilucci, 704-18S

L. M. Papouchdo, 773-A

E. W. Holtzscheiter, 773-A

L. F. Landon, 704-1T

S. M. Marra, 704-1T

M. J. Mahoney, 703-H

N. R. Davis, 703-H