0036747

Sta #10 (23) MAY 25 1994

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 155434

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) TWRS Process Technology	4. Related EDT No.: 155434
5. Proj./Prog./Dept./Div.: TWRS/LLW Vitrification	6. Cog. Engr.: J. W. Shade	7. Purchase Order No.: NA
8. Originator Remarks: Document required to meet TPA milestone M-60-01A		9. Equip./Component No.: NA
		10. System/Bldg./Facility: TWRS Proc. Tech./309
11. Receiver Remarks:		12. Major Assm. Dwg. No.: NA
		13. Permit/Permit Application No.: NA
		14. Required Response Date: 5-16-94

JUN 1994 RECEIVED EDMC

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Impact Level	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-TI-624		0	Waste Simulant Development for Evaluation of LLW Melter System Technology	4			

16. KEY

Impact Level (F)	Reason for Transmittal (G)	Disposition (H) & (I)
1, 2, 3, or 4 (see MRP 5.43)	1. Approval 4. Review 2. Release 5. Post-Review 3. Information 6. Dist. (Receipt Acknow. Required)	1. Approved 4. Reviewed no/comment 2. Approved w/comment 5. Reviewed w/comment 3. Disapproved w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Impact Level for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1		Cog.Eng. J. W. Shade	J. W. Shade	5/10/94		Env. N/A					
1		Cog. Mgr. D. J. Washenfelder	SEE BLOCK 20 FOR REQUIRED SIGNATURE			K.C. Burgard	KC Burgard	5/9/94		1	
		QA N/A									
		Safety N/A									

18. J. W. Shade J. W. Shade 5/10/94 Signature of EDT Originator Date	19. KC Burgard K.C. Burgard 5/9/94 Authorized Representative for Receiving Organization Date	20. DJ Washenfelder D. J. Washenfelder 5/11/94 Cognizant/Project Engineer's Manager Date	21. DOE APPROVAL (if required) Ltr. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments

BD-7400-172-1 (02/89)

SUPPORTING DOCUMENT

1. Total Pages 31

2. Title	3. Number	4. Rev No.
Waste Simulant Development for Evaluation of LLW Melter System Technology	WHC-SD-WM-TI-624	0

5. Key Words	6. Author
LLW, Simulant, Recipe	Name: J. W. Shade J. W. Shade Signature Organization/Charge Code 7E320/D47N1

7. Abstract

This document describes the LLW simulant compositions, basis for the simulants, and recipes for preparing nonradioactive simulants for LLW melter tests.

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10. RELEASE STAMP

OFFICIAL RELEASE BY WHC (23)
DATE MAY 25 1994
Sta #10

9. Impact Level 4

WHC-SD-WM-TI-624

WASTE SIMULANT DEVELOPMENT

FOR EVALUATION OF LLW MELTER SYSTEM TECHNOLOGY

Prepared for
U.S. DEPARTMENT OF ENERGY,
RICHLAND OPERATIONS OFFICE

by

J.W.Shade
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May 1994

ACKNOWLEDGEMENTS

Thanks are extended to M.J. Kupfer, B.A. Higley, and L.W. Shelton of WHC for supplying the nominal LLW compositions from the TWRS baseline flowsheet. R.O. Lokken and P.F. Martin of PNL are thanked for preparing and characterizing laboratory batches of simulant.

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WASTE SIMULANT DEVELOPMENT FOR EVALUATION OF LLW MELTER SYSTEM TECHNOLOGY

1.0 INTRODUCTION

Defense wastes at the Hanford Site are currently contained in double-shell tanks (DSTs) and older single-shell tanks (SSTs) in the form of liquids, slurries, sludges, and salt cakes. The Tank Waste Remediation System (TWRS) Program was established in 1991 to safely manage and immobilize these radioactive tank wastes for disposal. The *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement), signed January 25, 1994 establishes enforceable milestones for this program (Ecology et al. 1994). A reference chemical flowsheet is being developed in compliance with the Tri-Party Agreement that includes retrieval by sluicing and pumping along with waste pretreatment operations that involve sludge washing and ion-exchange prior to vitrification. Some degree of blending is assumed as part of the pretreatment operations. The pretreatment process will separate the wastes into high-level waste (HLW) and low-level waste (LLW) fractions. The LLW fraction will be Class C waste or lower in activity with an estimated volume of approximately 230,000 m^3 (60.8 Mgal) (Wilson 1994).

The DST waste compositions and volumes are better characterized than SST wastes so the strategy is to retrieve and pretreat DST wastes first followed by SST wastes. Processing of both wastes is assumed to follow the same reference chemical flowsheet. For evaluation of LLW melter systems, two simulants were developed based on the compositions of the LLW fraction of DST wastes and SST wastes, respectively. The simulants based on the DST wastes are designated double-shell slurry feed (DSSF) and will be used in Phase 1 testing of melter system technology while simulants based on the remaining LLW inventory, which include SST wastes, will be used in Phase 2 melter system testing. The basis for simulant selection, simulant compositions, chemical formulation sequences, and chemical and physical characteristics are discussed in this document with emphasis on the DSSF-derived simulants for Phase 1 testing. The status and data for the remaining inventory simulants are included to the extent available. The simulants are based on data that include analytical results from tank samples, waste process history, and the reference chemical flowsheet operations.

2.0 PURPOSE

This document describes the chemical composition for DSSF and remaining inventory simulated wastes and defines the chemical compounds and mixing sequence for formulating the simulants. The simulated waste compositions are based on the LLW fractions of actual DSSF inventory and a remaining inventory, which together represent the total LLW inventory at the Hanford Site. These inventories were defined by a reference, baseline flowsheet that includes waste retrieval, pretreatment, and blending prior to vitrification. The simulants will be used to conduct nonradioactive tests of melter system

technology and will also be used in the development and confirmation testing of LLW glass formulations. Certain physical properties of interest for melter feed systems, such as densities, viscosities, and the volume fraction of precipitates are also described. Initial laboratory tests of simulant formulation alternatives and their properties have been conducted to define compositions, physical properties, and compositional tolerances as specifications to commercial specialty chemical vendors to supply large volumes of simulant for melter system tests. The simulants are designed to include the major constituents of real waste plus enhanced concentrations of certain constituents known to cause process problems in order to evaluate their effect on different melter technologies and to ensure sufficient quantities of these constituents to conduct selected vitrification process tests.

3.0 FORMULATIONS

The chemical components selected for use in formulating DSSF and remaining inventory simulants were determined by a team of engineers and scientists experienced with Hanford Site wastes and simulant development. The components selected were based on measured waste compositions from tank sampling and analysis plus projected compositions of real LLW streams generated by flowsheet operations. The nominal LLW stream discharged from the waste pretreatment and separation process will likely have a 2 to 6*M* Na concentration. The LLW vitrification facility may include provisions to concentrate the waste to higher sodium molarity. The projected average blended nominal compositions of the DSSF and remaining inventory waste streams normalized to 5*M* Na are given in Appendix A, Table A-1. The 5*M* Na value was selected for convenience. The selection includes major and minor waste constituents of interest to LLW glass formulation development. Also, the requirements of the melter system process tests and experience from development of previous simulants of Hanford Site wastes were considered in determining the chemical constituents and formulation sequence to represent the two LLW waste types. The chemical and physical property requirements are based on tank characterization data and planned process operations including pretreatment and melter feed system requirements.

3.1 BASIS FOR DSSF SIMULANTS

Wastes contained in DSTs can be categorized as five main types: (1) the DSSF family, which predominantly consists of sodium salts of nitrates, nitrite, and aluminates plus sodium hydroxide in both slurry and liquid form; (2) complexant concentrate (CC) wastes containing a high concentration of organic complexants (EDTA, HEDTA, citrate); (3) neutralized current acid wastes (NCAW) which are high-level, first-cycle solvent extraction wastes; (4) neutralized cladding removal wastes (NCRW) consisting of dissolved fuel cladding neutralized to meet tank storage requirements; and (5) Plutonium Finishing Plan (PFP) wastes from plutonium purification operations. The PFP wastes also include wastes from T Plant and 222-S laboratory operations. Characterization data consisting of both sampling and analysis as well as process history records from these waste type sources, plus miscellaneous

facilities waste sources were used by Hendrickson and Conner (1994) to develop LLW feed projections for the former grout treatment facility. These feed projections were used to support various grout treatment operations including grout volume projections and LLW inventory from DSTs for use in the grout disposal system performance assessment. The first LLWs to be processed by the grout treatment facility were expected to be DSSF wastes. Consequently these waste types have the best characterization history, are existing wastes, and are also among the first waste types to be processed by the LLW vitrification facility. Accordingly the DSSF family of wastes were selected as the basis for the composition of the first (Phase 1) waste simulant development for initial melter system technology testing.

The DSSF composition was based on the weighted mean compositions of LLW in each of six DSTs plus the weighted mean composition of dilute wastes currently in several DSTs but which will be concentrated in evaporator/ crystallizer campaigns. Weighted mean compositions of waste in each of the six DSTs plus the dilute waste composition are included in Hendrickson and Conner (1994). These detailed compositions, including all minor components and radionuclide averages for each of the six tanks plus the dilute category, are given in Appendix A, Table A-2. Wastes compositions contained in tanks 241-AP-106, 241-AW-101, and 241-AN-103 are based primarily on direct sampling and analysis while compositions in tanks 241-AP-105, 241-AN-104, and 241-AN-105 are based primarily on detailed process and transfer history. Compositions of dilute wastes are based on both approaches.

Elements and chemical species chosen to be included for the simulant are the major DSSF constituents plus those constituents in lower concentrations that are of concern either to the vitrification process or have low solubility in silicate glasses. For example, Cs, I, Cl, and Mo may potentially be volatile during vitrification while PO_4, SO_4, Cl, and F are known to have low solubility limits in silicate glasses. After selection of desired constituents from the projected DSSF feed streams, target concentrations for each constituent were determined by calculating an average value, weighted according to waste volume, from the concentrations in the six tanks plus the dilutes. Sr has also been included to simulate ^{90}Sr because this radionuclide is expected to be the highest activity radionuclide present in LLW. The average concentrations of Cs, Sr, I, and Tc were less than considered necessary to allow mass balance calculations during melter testing so each of these constituents were spiked to 0.01*M* in the simulant. Mo was used as a stand-in for Tc. Chemical compounds consisting of readily soluble salts were selected to represent each chosen constituent. A cation-anion balance was done on concentrations of these compounds representing the target values then the simulant composition was normalized to 6.0*M* Na. The final DSSF simulant target concentrations plus the concentrations of compounds used to make up the simulant are given in Table 1.

Table 1. Low-Level Waste Simulant for DSSF Waste Based on an Average of Six Tanks Plus Dilutes Normalized to 6.0*M* Na.

Component	Target Feed Concentration (moles/L)	Compound	Formula Weight	Moles Required for Simulant
Al^{+3}	0.61	$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.61
Ca^{+2}	6.3 E-04	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	6.3 E-04
Cr^{+3}	5.2 E-03	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	5.2 E-03
Fe^{+3}	4.6 E-04	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	4.6 E-04
K^{+}	0.30	KOH	56.10	0.30
Mg^{+2}	6.2 E-04	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	6.2 E-04
Mn^{+2}	2.5 E-04	$Mn(NO_3)_2$	178.94	2.5 E-04
Mo^{+6} (Tc)	0.01	$Na_2MoO_4 \cdot H_2O$	241.95	0.01
Na^{+}	6.0	--	--	--
Sr^{+2}	0.01	$SrCl_2$	158.52	0.01
Cs^{+}	0.01	$CsNO_3$	194.91	0.01
PO_4^{-3}	0.026	$NaH_2PO_4 \cdot H_2O$	138.00	0.026
IO_3^{-}	0.01	$NaIO_3$	197.89	0.01
CO_3^{-2}	0.16	Na_2CO_3	106.00	0.16
Cl^{-}	0.096	NaCl	58.45	0.076
F^{-}	0.15	NaF	42.00	0.15
SO_4^{-2}	0.026	Na_2SO_4	142.06	0.026
NO_3^{-}	1.9	--	--	--
NO_2^{-}	1.0	$NaNO_2$	69.00	1.0
OH^{-} [a]	2.3	NaOH	40.00	4.0
TOC	0.81 (9.7 g/L)	$Na_4EDTA \cdot 2H_2O$, ClO	416.20	0.081

[a]To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 1.4 moles of NaOH are included.

EDTA = ethylenediamenetetraacetate.

TOC = total organic carbon.

3.2 BASIS FOR REMAINING INVENTORY SIMULANTS

The remaining inventory composition was determined by taking the difference between a total, nominal LLW inventory used in reference, baseline flowsheet calculations and the DSSF inventory described above. The total, nominal LLW inventory is based on a combination of SST inventory estimates and DST inventories followed by various pretreatment operations assumed in the baseline flowsheet.

The wastes contained in the SSTs were generated from a variety of fuel reprocessing and material recovery programs. These include reduction oxidation, plutonium-uranium extraction, bismuth phosphate, uranium recovery, ferrocyanide scavenging, and Cs and Sr removal. The physical characteristics of the SST alkaline wastes range from hard, dry, solids to sludges, thick slurries, and liquids. The salt cake, slurry, and liquid wastes consist primarily of sodium nitrates, nitrites, aluminates, and hydroxide. Hydrous metal oxides of iron, aluminum, chromium, and manganese are the major sludge components. SST chemical data are taken from *Hanford Defense Waste Disposal Alternatives: Engineering Support Data for the Hanford Defense Waste: Environmental Impact Statement* (RHO 1985). These chemical compositions were derived from records of fuel elements processed, chemicals procured, and a limited number of waste sample analyses. The radionuclide inventory in SSTs was based on computer modeling of spent reactor fuel processed at the Hanford Site while Cs and Sr inventories were modified according to the integrated data base for 1991 (DOE 1991). These sources are summarized in Boomer et al. (1993). The DST wastes are described by Hanlon (1993). The compositions of various DST waste streams are given in Hendrickson and Conner (1994) and Lowe (1991) for CC, NCRW, and PFP wastes as well as in Boomer et al. (1993) for NCAW and others.

The baseline flowsheet uses a combined SST and DST inventory. The pretreatment flowsheet is designed to separate the combined SST and DST wastes into HLW and LLW fractions by various pretreatment operations. These included alkaline leaching of solids using 3*M* sodium hydroxide (enhanced sludge washing) to reduce the amount of Al, Cr, and PO_4 loading to the HLW stream. This caustic wash operation will slightly increase the amount of sodium in the LLW stream above that in the original inventory. In addition, it was assumed that the combined inventory passes through a Cs ion exchanger to remove 99% of the Cs which will be sent to HLW. The resulting LLW stream from pretreatment will consist primarily of sodium salts. The nominal DSSF inventory was subtracted from this total LLW stream to determine the nominal remaining inventory composition for LLW. The remaining inventory composition, normalized to 5*M* Na, is given in appendix Table A-1 and forms the basis for the remaining inventory simulant.

The main concentration differences between the remaining inventory composition and the DSSF inventory composition is slightly more NO_3, PO_4, and SO_4 and somewhat less Al, and total organic carbon (TOC) in the remaining inventory composition than in the DSSF composition. The same chemical constituents, and the compounds used to represent these constituents, were selected for the remaining inventory simulant as were selected for the DSSF simulant. Target values for the selected constituents were based on concentrations in the remaining inventory composition with the same chemical species spiked to concentrations above nominal as were enhanced in the DSSF

simulant. A cation-anion balance was done on the concentrations of compounds representing the target values. The remaining inventory simulant composition was also normalized to 6*M* Na. Both the target concentrations and the concentrations of compounds used to make up the remaining inventory simulant are given in Table 2. This simulant will be the reference simulant for the Phase 2 melter testing.

Table 2. Low-Level Waste Simulant for the Remaining Inventories Based on Process Flowsheet Estimates Less DSSF Inventory--Normalized to 6*M* Na.

Component	Target Feed Concentration (moles/L)	Compound	Formula Weight	Moles Required for Simulant
Al^{+3}	0.16	$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.16
Ca^{+2}	4.0 E-04	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	4.0 E-04
Cr^{+3}	4.2 E-03	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	4.2 E-03
Fe^{+3}	2.4 E-04	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	2.4 E-04
K^{+}	5.8 E-03	KOH	56.10	5.8 E-03
Mg^{+2}	1.1 E-06	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	1.1 E-06
Mn^{+2}	1.0 E-03	$Mn(NO_3)_2$	178.94	1.0 E-03
Mo^{+6} (Tc)	0.01	$Na_2MoO_4 \cdot H_2O$	241.95	0.01
Na^{+}	6.0	--	--	--
Sr^{+2}	0.01	$Sr(NO_3)_2$	149.63	0.01
Cs^{+}	0.01	$CsNO_3$	194.91	0.01
PO_4^{-3}	0.11	$NaH_2PO_4 \cdot H_2O$	138.00	0.11
IO_3^{-}	0.01	$NaIO_3$	197.89	0.01
CO_3^{-2}	0.05	Na_2CO_3	106.00	0.05
Cl^{-}	9.2 E-03	NaCl	58.45	9.2 E-03
F^{-}	0.13	NaF	42.00	0.13
SO_4^{-2}	0.038	Na_2SO_4	142.06	0.038
NO_3^{-}	3.6	$NaNO_3$	85.00	3.0
NO_2^{-}	0.26	$NaNO_2$	69.00	0.26
OH^{-} [a]	1.4	NaOH	40.00	2.2
TOC	0.11 (1.3 g/L)	Na_4EDTA, C10	416.20	0.011

[a]To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 0.8 moles of NaOH are included.
EDTA = ethylenediamenetetraacetate.
TOC = total organic carbon.

3.3 COMPOSITIONS OF ALTERNATE OR CONCENTRATED SIMULANTS

The remaining inventory simulant is expected to be one of two or more simulants used in Phase 2 of melter testing and is considered the Phase 2 reference simulant in this document. Additional LLW simulants that may be used in Phase 2 testing, depending on melter test objectives, may include additional minor components or higher concentrations of components, such as phosphate, sulfate, nitrates, halogens, hydroxide, or chrome, than shown in Table 2.

For certain types of melters or feed systems it may be more efficient and desirable to use a concentrated feed with Na concentrations in the 10 to 15*M* range to decrease the quantity of water fed to the melter. Experience with tank farm evaporator operations indicate that this concentration range of feed will result in the precipitation of some salts producing a slurry ranging from about 5 to 30 vol% undissolved solids depending on the degree of concentration and feed temperature. Typically the bulk of the salt precipitation occurs at concentrations above 12*M* Na. To minimize the potential for simulant handling problems during initial melter tests, dilute simulant formulations were developed. Accordingly, both the DSSF simulant and the remaining inventory simulant shown in Tables 1 and 2 normalized to 6*M* Na were recalculated to a normalized 10*M* Na basis. The normalized 10*M* Na compositions for both simulants are given in Tables 3 and 4, respectively. Laboratory testing was done on the 6*M* Na composition for both simulants and also on the 10*M* Na composition for the DSSF simulant because this information is needed for Phase 1 melter testing. Future simulant development and testing will include 10*M* and possibly higher Na concentrations.

Table 3. Low-Level Waste Simulant for DSSF Waste Normalized to 10*M* Na.

Component	Target Feed Concentration (moles/L)	Compound	Formula Weight	Moles Required for Simulant
Al^{+3}	1.02	$Al(NO_3)_3 \cdot 9H_2O$	375.14	1.02
Ca^{+2}	1.0 E-03	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	1.0 E-03
Cr^{+3}	8.7 E-03	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	8.7 E-03
Fe^{+3}	7.7 E-04	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	7.7 E-04
K^{+}	0.50	KOH	56.10	0.50
Mg^{+2}	1.0 E-03	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	1.0 E-03
Mn^{+2}	4.2 E-04	$Mn(NO_3)_2$	178.94	4.2 E-04
Mo^{+6} (Tc)	0.017	$Na_2MoO_4 \cdot H_2O$	241.95	0.017
Na^{+}	10.0	--	--	--
Sr^{+2}	0.017	$SrCl_2$	158.52	0.017
Cs^{+}	0.017	$CsNO_3$	194.91	0.017
PO_4^{-3}	0.043	$NaH_2PO_4 \cdot H_2O$	138.00	0.043
IO_3^{-}	0.017	$NaIO_3$	197.89	0.017
CO_3^{-2}	0.27	Na_2CO_3	106.00	0.27
Cl^{-}	0.16	NaCl	58.45	0.13
F^{-}	0.25	NaF	42.00	0.25
SO_4^{-2}	0.043	Na_2SO_4	142.06	0.043
NO_3^{-}	3.2	--	--	--
NO_2^{-}	1.7	$NaNO_2$	69.00	1.7
OH^{-} [a]	3.8	NaOH	40.00	6.7
TOC	1.4 (16 g/L)	Na_4EDTA, C10	416.20	0.14

[a]To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 2.9 moles of NaOH are included.

EDTA = ethylenediamenetetraacetate.

TOC = total organic carbon.

Table 4. Low-Level Waste Simulant of Remaining Inventory Waste Normalized to 10*M* Na.

Component	Target Feed Concentration (moles/L)	Compound	Formula Weight	Moles Required for Simulant
Al^{+3}	0.27	$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.27
Ca^{+2}	6.7 E-04	$Ca(NO_3)_2 \cdot 4H_2O$	236.16	6.7 E-04
Cr^{+3}	7.0 E-03	$Cr(NO_3)_3 \cdot 9H_2O$	400.17	7.0 E-03
Fe^{+3}	4.0 E-04	$Fe(NO_3)_3 \cdot 9H_2O$	404.01	4.0 E-04
K^{+}	9.7 E-03	KOH	56.10	9.7 E-03
Mg^{+2}	1.8 E-06	$Mg(NO_3)_2 \cdot 6H_2O$	256.41	1.8 E-06
Mn^{+2}	1.7 E-03	$Mn(NO_3)_2$	178.94	1.7 E-03
Mo^{+6} (Tc)	0.017	$Na_2MoO_4 \cdot H_2O$	241.95	0.017
Na^{+}	10.0	--	--	--
Sr^{+2}	0.017	$Sr(NO_3)_2$	149.63	0.017
Cs^{+}	0.017	$CsNO_3$	194.91	0.017
PO_4^{-3}	0.18	$NaH_2PO_4 \cdot H_2O$	138.00	0.18
IO_3^{-}	0.017	$NaIO_3$	197.89	0.017
CO_3^{-2}	0.083	Na_2CO_3	106.00	0.083
Cl^{-}	1.5 E-02	NaCl	58.45	1.5 E-02
F^{-}	0.22	NaF	42.00	0.22
SO_4^{-2}	0.063	Na_2SO_4	142.06	0.063
NO_3^{-}	6.0	$NaNO_3$	85.00	5.0
NO_2^{-}	0.43	$NaNO_2$	69.00	0.43
OH^{-} [a]	2.3	NaOH	40.00	3.7
TOC	0.18 (1.3 g/L)	Na_4EDTA, C10	416.20	0.018

[a]To neutralize acidic hydrolyzable metal salts of Al, Ca, Cr, Fe, Mg, Mn, and Sr, an excess of 1.4 moles of NaOH are included.

EDTA = ethylenediamenetetraacetate.

TOC = total organic carbon.

4.0 RECIPES FOR SIMULANTS

The simulate formulations described below are designed to prepare 1 L of simulant. Concentrations are reported on a molar basis and the formulation can be scaled to larger volumes as required. Ordinary chemical glassware can be used to prepare laboratory batches of simulant, but because of the high caustic nature of the solutions that tend to dissolve and corrode silicate-based glass, they should not be stored in glass containers. Polyethylene, polypropylene, polyvinylchloride, or Teflon[1] containers are recommended for storage.

To minimize the amount of solid precipitates that can occur in chemically complex caustic solutions, the simulants were made by first making two solutions, each containing part of the chemical constituents, then mixing the two solutions together. One solution contained compounds that are typically soluble in neutral to slightly acid solutions. This was termed the "acid" solution and contained Al and Fe nitrates as well as the sodium ethylenediamenetetraacetate (EDTA) as a representative of TOC. The EDTA is a complexant and helps prevent Al and Fe hydroxides, which are difficult to redissolve, from precipitating when the solution is added to a base. The other solution included the hydroxides, phosphates, sulfates, carbonates, and nitrites and is termed the "base" solution. The strategy was to slowly add the "acid" solution to the "base" solution so that excess hydroxide in the base would form soluble $Al(OH)_4^-$ and similar soluble metal species to minimized metal hydroxide precipitation. Related to this approach was a desire to evaluate if the two separate solutions would be more stable and have less precipitates than the total mixed solution. This evaluation was required to determine if the simulant shipped to melter test vendors would be easier to use (have less sludge or caked precipitates) in large quantities as two solutions mixed at the test site or as one solution.

These recipes are for laboratory scale quantities and use reagent-grade chemicals. It is expected that large volumes of these simulants will use technical-grade chemicals which contain more impurities. In general it is not expected that the impurity levels in technical grade chemicals will cause any significant problems with these simulants.

For all simulants described below, the compounds were added to about 300 ml of deionized water in the order listed in the following tables, which describe the "acid" and "base" solutions. The solutions/slurries were constantly agitated during the additions and were not heated. After all the chemicals were added to each "acid" or "base" solution/slurry, each of these portions were transferred to a graduated cylinder and the volume adjusted to 500 ml. The densities were determined from the weight of the 500-ml solution. Final simulants were prepared by adding equal volumes of the "acid" components to the "base" components. The simulants were constantly agitated until no more solids dissolved.

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[1]Teflon is a trademark of E. I. du Pont de Nemours & Company.

4.1 RECIPE FOR DSSF SIMULANT

The following recipe describes the preparation of a 1-L batch of 6*M* DSSF simulant.

1. Obtain a 600 ml or larger beaker and add about 300 ml of deionized water along with a stir bar or other stirring device.

2. Add the chemical listed in Table 5 to prepare the "acid" solution.

3. In another 1-L flask or container, add 300 to 400 ml of deionized water.

4. Add the chemicals listed in Table 6 to prepare the "base" solution.

5. Very slowly add the "acid" solution to the "base" solution to avoid excessive heating. After mixing, fill the mixture to the 1-L mark. This mixture should be similar to the target 6*M* DSSF composition given in Table 1.

6. For the preparation of a 10*M* batch of DSSF simulant, follow the same procedure as above, but use the chemicals listed in Tables 7 and 8.

Table 5. Chemicals Required to Form the "Acid" Solution for 6*M* DSSF Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.61	228.84
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	0.00063	0.15
$Cr(NO_3)_3 \cdot 9H_2O$	400.17	0.0052	2.08
$Fe(NO_3)_3 \cdot 9H_2O$	404.01	0.00046	0.19
$Mg(NO_3)_2 \cdot 6H_2O$	256.41	0.00062	0.16
$Mn(NO_3)_2$ (50% soln)	178.94	0.00025	0.0447
$CsNO_3$	194.91	0.01	1.95
$Na_2MoO_4 \cdot H_2O$	241.95	0.01	2.42
$Na_4EDTA \cdot 2H_2O$	416.2	0.081	33.71

EDTA = ethylenediamenetetraacetate.

Table 6. Chemicals Required to Prepare the "Base" Solution for 6*M* DSSF Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$NaNO_2$	69	1	69.00
KOH	56.1	0.3	16.83
$SrCl_2 \cdot 6H_2O$	266.62	0.01	2.67
$NaH_2PO_4 \cdot H_2O$	138	0.026	3.59
$NaIO_3$	197.89	0.01	1.98
Na_2CO_3	106	0.16	16.96
NaCl	58.45	0.076	4.44
NaF	42	0.15	6.30
Na_2SO_4	142.06	0.026	3.69
NaOH (pellets)	40	4	160.00

Table 7. Chemicals Required to Prepare the "Acid" Solution for 10*M* DSSF Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$Al(NO_3)_3 \cdot 9H_2O$	375.14	1.02	381.39
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	.00105	0.25
$Cr(NO_3)_3 \cdot 9H_2O$	400.17	.00867	3.47
$Fe(NO_3)_3 \cdot 9H_2O$	404.01	0.000767	0.31
$Mg(NO_3)_2 \cdot 6H_2O$	256.41	0.00103	0.26
$Mn(NO_3)_2$ (50% soln)	178.94	0.000417	0.0746
$CsNO_3$	194.91	0.0167	3.25
$Na_2MoO_4 \cdot H_2O$	241.95	0.0167	4.03
$Na_4EDTA \cdot 2H_2O$	416.2	0.135	56.19

EDTA = ethylenediamenetetraacetate.

Table 8. Chemical Required to Prepare the "Base" Solution of 10*M* DSSF Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$NaNO_2$	69	1.67	115.00
KOH	56.1	0.5	28.05
$SrCl_2 \cdot 6H_2O$	266.62	0.0167	4.44
$NaH_2PO_4 \cdot H_2O$	138	0.0433	5.98
$NaIO_3$	197.89	0.0167	3.30
Na_2CO_3	106	0.267	28.27
NaCl	58.45	0.127	7.40
NaF	42	0.25	10.50
Na_2SO_4	142.06	0.0433	6.16
NaOH (pellets)	40	6.67	266.67

4.2 RECIPE FOR REMAINING INVENTORY SIMULANT

The procedure for preparing a 1-L batch of 6*M* Na remaining inventory simulant is the same as described for the DSSF simulant. Use the chemicals listed in Tables 9 and 10 below.

Table 9. Chemicals Required for Preparation of the "Acid" Solution for the 6*M* Remaining Inventory Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$Al(NO_3)_3 \cdot 9H_2O$	375.14	0.16	60.02
$Ca(NO_3)_2 \cdot 4H_2O$	236.16	.0004	0.09
$Cr(NO_3)_3 \cdot 9H_2O$	400.17	.0042	1.68
$Fe(NO_3)_3 \cdot 9H_2O$	404.01	0.00024	0.10
$Mg(NO_3)_2 \cdot 6H_2O$	256.41	1.10 E-06	0.0003
$Mn(NO_3)_2$ (50% soln)	178.94	0.001	0.1789
$CsNO_3$	194.91	0.01	1.95
$NaNO_3$	85	3	255.00
$Sr(NO_3)_2$	211.63	0.01	2.12
$Na_2MoO_4 \cdot H_2O$	241.95	0.01	2.42
$Na_4EDTA \cdot 2H_2O$	416.2	0.011	4.58

EDTA = ethylenediamenetetraacetate.

Table 10. Chemicals Required to Prepare "Base" Solution for the 6*M* Remaining Inventory Simulant.

Compound	Formula Wt.	Moles/Liter	Grams per Batch
$NaNO_2$	69	0.26	17.94
KOH	56.1	0.0058	0.33
$NaH_2PO_4 \cdot H_2O$	138	0.11	15.18
$NaIO_3$	197.89	0.01	1.98
Na_2CO_3	106	0.05	5.30
NaCl	58.45	0.0092	0.54
NaF	42	0.13	5.46
Na_2SO_4	142.06	0.038	5.40
NaOH (pellets)	40	2.2	176.00

5.0 QUALIFICATION OF SIMULANTS

The following sections describes the results of selected physical property measurements and chemical analyses for the simulants.

5.1 PHYSICAL PROPERTIES

5.1.1 Settled Solids

The amount of settled solids were measured by allowing the freshly prepared solutions to remain undisturbed in a closed container for greater than 24 hours and estimating the total volume of precipitated solids. The two "base" DSSF solutions contained fairly large amounts of gelatinous solids, but when mixed with the "acid" solutions, they redissolved so the total amount of solids in the final solution was reduced to less than 5 vol%. The settling rates of the solids were very slow for the 6*M* and 10*M* Na DSSF simulants and required several hours for a clear supernate to develop. The remaining inventory simulant contained some light-colored undissolved solids that settled out rapidly and a finer, darker fraction that resembled the solids in the other two simulants. A summary of the estimated volume of settled solids is given in Table 11.

Table 11. Estimated Volume Percent Settled Solids After 24 Hours at 55°C for "Acid" and "Base" Solutions and at Room Temperature for the Mixtures.

Simulant	"Acid"	"Base"	Mixture
DSSF, 6*M* Na	<5	15	<3
DSSF, 10*M* Na	<5	50	<5
RI, 6*M* Na	10	5	10

5.1.2 Resuspendability

An Important property of slurries is the ability to resuspend the solids once they have settled. A qualitative evaluation of the "resuspendability" of the solids in the three simulants was done by allowing the solids to settle in a Teflon bottle for more than 24 hours and then slowly agitating them by turning the containers end-over-end several times, each time inspecting the bottom for the presence of remaining solids. The solids in the 6*M* and 10*M* Na simulants and the finer, dark solids in the remaining inventory simulant were resuspended during the first couple of rotations of the bottles. The lighter colored solids in the remaining inventory sample appeared gelatinous and "dripped" from the bottom when the bottle was inverted. After about five rotations of the bottle, all of the solids were resuspended. Based on these observations, it appears that the solids in all the simulants could be easily resuspended by moderate agitation.

5.1.3 Density

The densities of the solutions/slurries were measured by weighing a known volume within a graduated cylinder. The results are summarized in Table 12.

Table 12. Densities of Simulated Wastes at Room Temperature, g/cm^3.

Simulant	"Acid"	"Base"	Mixture
DSSF, 6*M* Na	1.21	1.38	1.31
DSSF, 10*M* Na	1.39	1.58	1.42
RI, 6*M* Na	1.35	1.22	1.28

5.1.4 Viscosity

Viscosities of the mixtures were measured using a Haake Rotovisco RV20 with a CS20 measuring system and a DA45 sensor according to procedure WHC-053-01. The viscosities at room temperature (23 °C) are given in Table 13.

Table 13. Viscosity of Simulated Wastes at 23 °C.

Simulant	Viscosity, cP
DSSF, 6*M* Na	3.6 ± 0.2
DSSF, 10*M* Na	11.1 ± 0.2
RI, 6*M* Na	2.6 ± 0.2

5.2 CHEMICAL PROPERTIES

5.2.1 Moisture Content

Samples of the simulants were dried at 120 °C in a vacuum oven for several days to determine weight loss (moisture content). The results are shown in Table 14.

Table 14. Moisture Content of Simulated Wastes (determined by drying at 120 °C).

Simulant	Moisture Content, wt%
DSSF, 6*M* Na	65
DSSF, 10*M* Na	50
RI, 6*M* Na	65

5.2.2 Chemical Composition

The chemical composition of the simulated waste mixtures was determined by Inductively Coupled Argon Plasma Spectroscopy (ICP) using a Jarrell-Ash Model 975 ICP according to procedure PNL-ALO-211.2, Rev 0. The solutions were acidified using 2 vol% nitric acid. Anion concentrations were measured using a Dionex Series 4000i ion chromatograph according to procedure PNL-ALO-212, Rev 1. Carbon analyses were conducted using a Xertex-Dohrmann Model DC-80 carbon analyzer according to procedure PNL-ALO-382.1, Rev 0. The hydroxide demand was determined by titration to evaluate free hydroxide and the amount used to form the metal hydroxides and/or hydroxy complexes. A summary of these analytical results is given in Table 15.

Table 15. Chemical Composition of Simulated Wastes, mg/L.

Element/Species	DSSF, 6*M*, Na	DSSF, 10*M*, Na	RI, 6*M*, Na
Al	16,400	25,600	4,220
Ca	22	24	(6)
Cr	268	430	214
Fe	34	54	<10
K	10,600	17,000	<400
Mg	(14)	<40	<20
Mn	8	12	34
Mo	988	1,436	968
Na	131,400	208,600	129,800
PO_4	2,600	4,400	11,080
Sr	866	1,384	868
F	2,280	6,000	2,300
Cl	3,340	6,200	220
NO_2	45,800	76,000	11,200
NO_3	112,800	180,000	220,000
TOC	9,400	13,800	1,286
TIC	3,420	4,940	1,286
OH	30,600	48,400	25,000

TIC = total inorganic carbon.
TOC = total organic carbon.

6.0 CONCLUSIONS

These results suggest that both 6*M* Na and 10*M* Na simulants for both the DSSF waste and remaining inventory wastes can be prepared so that major element concentrations are within about 10 mol% of the target values. The simulants appear to be stable as mixtures and do not require shipment or storage as separate "acid" and "base" solutions. The small amount of precipitate can be resuspended with moderate agitation.

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APPENDIX A

WASTE STREAM INVENTORIES

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Table A-1. Nominal Low-Level Waste Streams.

Component	Double-shell slurry feed (mol/L)	Remaining inventory (mol/L)	Solids (wt%)
Ag^{+}	7.3 E-05	5.0 E-07	3.4 E-03
Al^{+3}	--	--	2.2
$Al(OH)_4^{-}$	5.6 E-01	1.6 E-01	--
As^{+5}	1.9 E-04	3.4 E-06	5.4 E-03
B^{+3}	--	1.3 E-05	0.02
Ba^{+2}	3.2 E-05	1.3 E-07	0.02
Be^{+2}	2.0 E-03	1.4 E-07	7.6 E-05
Bi^{+3}	2.1 E-04	5.2 E-04	1.6
Ca^{+2}	5.7 E-04	3.3 E-04	1.3
Cd^{+2}	5.7 E-05	2.9 E-05	0.07
Ce^{+3}	--	2.9 E-05	1.9
Co^{+3}	--	1.5 E-06	6.3 E-03
Cr^{+3}	--	--	0.27
$Cr(OH)_4^{-}$	4.7 E-03	3.5 E-03	--
Cu^{+2}	1.1 E-04	2.9 E-07	6.3 E-03
Fe^{+3}	4.2 E-04	2.0 E-04	6.0
Hg^{+2}	7.1 E-06	7.4 E-06	7.3 E-05
K^{+}	2.8 E-01	4.8 E-03	0.14
La^{+3}	--	4.0 E-06	0.32
Li^{+}	--	7.5 E-06	2.8 E-04
Mg^{+2}	5.7 E-04	9.2 E-07	0.04
Mo^{+6}	2.8 E-04	8.8 E-06	0.04
Na^{+}	5.0 E+00	5.0 E+00	5.8
Ni^{+3}	4.0 E-04	4.3 E-07	0.08
Pb^{+4}	5.0 E-04	3.0 E-07	0.24
Rb^{+}	--	1.2 E-06	2.1 E-05
Re^{+7}	--	4.2 E-08	3.2 E-04
Rh^{+3}	--	2.0 E-07	3.5 E-03
Ru^{+3}	7.9 E-08	4.4 E-07	4.3 E-03
Sb^{+5}	1.5 E-03	7.8 E-07	0.01
Se^{+6}	2.3 E-04	1.2 E-05	0.02
Si^{+4}	2.0 E-03	3.2 E-04	0.38
Sm^{+3}	--	3.5 E-09	2.6 E-04
Sr^{+2}	--	7.0 E-06	0.30
Te^{+6}	--	6.8 E-08	2.0 E-03
Th^{+4}	--	2.4 E-06	0.22
Ti^{+4}	5.8 E-05	2.3 E-07	3.6 E-03
Ti^{+3}	--	2.5 E-06	0.04
UO_2^{+2}	2.2 E-06	5.2 E-04	12.0
V^{+5}	3.5 E-04	3.2 E-07	3.2 E-04
W^{+6}	1.3 E-03	--	--
Zn^{+2}	8.8 E-04	1.2 E-06	0.01
Cl^{-}	8.7 E-02	7.7 E-03	0.02
CO_3^{-2}	1.5 E-01	4.2 E-02	1.4
F^{-}	1.4 E-01	1.0 E-01	0.47
$Fe(CN)_6^{-3}$	--	--	--
I^{-}	--	2.0 E-06	2.4 E-05
NO_2^{-}	9.4 E-01	2.1 E-01	0.54
NO_3^{-}	1.3 E+00	2.9 E+00	8.4
OH^{-}	2.1 E+00	1.1 E+00	13.5
PO_4^{-3}	2.4 E-02	9.0 E-02	3.8
SO_4^{-2}	2.4 E-02	3.2 E-02	0.33
Cancrinite	--	--	22.3
MnO_2	2.3 E-04	8.1 E-04	3.2
$Ni_2Fe(CN)_6$	--	--	4.1
$P_2O_5 \cdot 24WO_2 \cdot 44H_2O$	--	--	0.17
Organic carbon (g/L)	8.8 E+00	1.0 E+00	3.2
$ZrO_2 \cdot 2H_2O$	1.7 E-04	2.5 E-04	7.9
Polyelectrolyte	--	1.2 E-03	0.52
Total kilograms	--	--	8.00 E+04
Total volume (L)	7.7 E+07	6.0 E+08	--

*Cancrinite = $2NaAlSiO_4 \cdot 0.52NaNO_3 \cdot 0.68\ H_2O$.

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (4 sheets)

DSSF Family Wastes			Decayed to		10/01/93					
Units: Molarity; uCi/L for radionuclides; others as noted							[NOT Decayed]			
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Future	Required	Total	ConcWaste
Component	106-AN	101-AW	105-AP	104-AN	105-AN	103-AN	DSSF	Dilutes	Family	Std. Dev.
Ag	3.37e-05	3.09e-04	2.00e-04			1.48e-04	7.10e-05	1.64e-05	8.90e-05	1.14e-04
Al	3.44e-01	1.03e+00	1.60e-01	1.39e+00	1.74e+00	2.13e+00	1.50e-01	4.76e-02	4.92e-01	7.77e-01
As	9.61e-07	1.33e-07	8.58e-08			2.14e-03	1.00e-04	8.85e-06	2.00e-04	1.07e-03
B										
Ba	8.08e-05	6.80e-05	4.35e-05			1.17e-04	4.40e-05	6.13e-06	4.66e-05	3.04e-05
Be						1.78e-03			1.78e-03	
Bi	6.94e-04	5.79e-04	3.70e-04			2.30e-04		5.91e-05	3.13e-04	2.08e-04
Ca	2.25e-03	8.26e-04	1.08e-03			2.16e-03		8.48e-05	1.00e-03	7.30e-04
Cd	4.41e-04	1.08e-05	6.92e-06			1.42e-04	4.05e-05	3.93e-06	6.45e-05	2.04e-04
Ce										
Cr	1.08e-02	3.09e-03	3.32e-03	1.30e-02	1.30e-02	1.63e-02	1.33e-03	2.19e-04	4.23e-03	5.49e-03
Cu	5.90e-05	3.81e-04	2.42e-04			1.89e-04		3.89e-05	1.49e-04	1.33e-04
Fe	1.24e-04	7.86e-04	2.00e-04	2.00e-04	2.00e-04	1.26e-03	3.15e-03	3.04e-04	1.78e-03	4.61e-04
Hg	2.49e-07	7.82e-07	4.99e-07			7.98e-05	1.66e-07	4.11e-08	5.49e-06	3.96e-05
K	2.76e-02	1.07e+00	8.57e-01	1.83e-01	1.57e-01	3.89e-01		1.11e-01	3.44e-01	4.21e-01
La										
Li										
Mg	1.14e-04	2.16e-03	4.95e-04			1.18e-03	2.29e-03	2.73e-04	1.61e-03	8.96e-04
Mn	1.01e-03	4.76e-04	3.06e-04			5.24e-04	1.77e-04	3.13e-05	2.62e-04	3.04e-04
Mo	6.94e-04	6.00e-04	3.86e-04			9.17e-04		6.12e-05	4.24e-04	2.20e-04
Na	3.93e+00	1.00e+01	6.35e+00	1.20e+01	1.20e+01	1.46e+01	4.82e+00	7.71e-01	6.00e+00	3.98e+00
Nd										
Ni			2.15e-03			4.09e-04		1.75e-04	6.22e-04	1.23e-03
P	1.97e-01		1.43e-02					2.26e-03	4.98e-02	1.29e-01

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (4 sheets)

DSSF Family Wastes			Decayed to		10/01/93					
Units: Molarity; uCi/L for radionuclides; others as noted							[NOT Decayed]			
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Future	Required	Total	ConcWaste
Component	106-AN	101-AW	105-AP	104-AN	105-AN	103-AN	DSSF	Dilutes	Family	Std. Dev.
Pb	2.22e-03	1.46e-03	9.33e-04			3.47e-04	3.35e-04	7.75e-05	5.37e-04	7.96e-04
Pd										
Sb						1.31e-03			1.31e-03	
Se	1.70e-06	4.20e-07	2.73e-07			2.63e-03	6.74e-07	7.33e-08	1.75e-04	1.32e-03
Si		4.36e-03	3.53e-03			9.68e-03		4.40e-04	3.38e-03	3.34e-03
Sn										
Ta	7.18e-07							1.88e-05	1.36e-05	
Ti	7.33e-05	9.88e-05	6.38e-05			3.34e-04		1.01e-05	9.14e-05	1.29e-04
U g/L	1.68e-05	9.39e-04	6.06e-04			5.18e-04	3.39e-02	1.03e-02	2.11e-02	3.81e-04
V						3.14e-04			3.14e-04	
W						1.13e-03			1.13e-03	
Zn	1.44e-04	4.84e-03	1.16e-03			7.34e-04	2.00e-03	3.39e-04	1.66e-03	2.12e-03
Zr	3.05e-04	5.54e-04	3.59e-04			2.63e-04		5.65e-05	2.50e-04	1.29e-04
CN-	2.31e-04	1.03e-03	6.65e-04			1.29e-03	3.12e-04	6.19e-05	4.01e-04	4.61e-04
S-2										
NH4+	7.22e-03	1.45e-02	2.34e-03				5.29e-03	4.20e-03	5.75e-03	6.12e-03
NH3				6.99e-03	2.00e-02				1.46e-02	9.20e-03
CO3-2	3.27e-01	2.05e-01	2.53e-01	4.72e-01	3.63e-01	1.49e-01		2.06e-02	2.12e-01	1.17e-01
Cl-	6.94e-02	1.46e-01	7.28e-02	2.12e-01	2.40e-01	2.71e-01	6.14e-02	1.03e-02	9.24e-02	8.60e-02
F-	3.24e-03	4.02e-03	1.30e-01			3.87e-02	1.03e+00	9.13e-02	6.11e-01	5.96e-02
SO4-2	2.24e-02	1.07e-02	2.48e-02	6.82e-02	6.82e-02	1.67e-02	1.25e-01	1.14e-02	7.63e-02	2.60e-02
NO3-	1.10e+00	3.46e+00	2.66e+00	3.10e+00	3.12e+00	2.58e+00	1.54e+00	1.86e-01	1.74e+00	8.32e-01
NO2-	6.44e-01	2.19e+00	1.09e+00	1.92e+00	2.61e+00	2.99e+00	4.80e-01	7.83e-02	9.37e-01	8.96e-01
PO4-3	1.94e-01	2.22e-02	1.62e-02	2.94e-02	2.00e-02	9.77e-03	1.85e-02	2.36e-03	2.69e-02	7.14e-02

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (4 sheets)

DSSF Family Wastes			Decayed to		10/01/93					
Units: Molarity; uCi/L for radionuclides; others as noted							[NOT Decayed]			
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Future	Required	Total	ConcWaste
Component	106-AN	101-AW	105-AP	104-AN	105-AN	103-AN	DSSF	Dilutes	Family	Std. Dev.
OH-	4.74e-01	5.07e+00	4.63e+00	4.09e+00	3.64e+00	5.74e+00	1.43e+00	4.09e-01	2.15e+00	1.85e+00
TOC g/L	3.26e+00	2.46e+00	3.92e+00	5.53e+01	4.66e+01	6.13e-01	2.98e+00	4.27e-01	8.15e+00	2.51e+01
TIC g/L		2.46e+00					6.79e+00	9.85e-01	5.19e+00	
SPG	1.23	1.56	1.347377	1.499809	1.503333	1.6	1.25e+00	1.03e+00	1.29e+00	1.40e-01
TotSolids										
pH				13.5	13.5				1.35e+01	
3H	2.68e+00	5.90e+00	7.40e+00			2.44e+00	5.58e+00	4.49e+00	5.12e+00	2.44e+00
14C	3.35e-01	3.70e-01	2.36e-01			2.00e+00	1.51e-01	2.20e-02	2.85e-01	8.44e-01
54Mn										
59Mn										
60Co	5.10e+00	1.94e+01	1.04e+01			1.20e+01	6.17e+01	6.40e+00	3.91e+01	5.92e+00
63Ni										
79Se	2.40e-01	4.80e-01	3.06e-01			4.30e+01	1.33e-01	2.72e-02	3.00e+00	2.13e+01
90Sr	2.01e+03	1.01e+03	1.90e+02	9.84e+03	3.23e+03	1.05e+04	1.82e+02	1.37e+03	1.82e+03	4.55e+03
94Nb	2.30e+01	6.82e+01	4.35e+01			7.10e+00	5.76e+01	7.27e+00	4.33e+01	2.64e+01
95Nb							6.67e+01	8.67e+00	5.34e+01	
99Tc	6.92e+01	1.52e+02	1.79e+01			1.70e+02	3.44e+01	7.86e+00	4.87e+01	7.14e+01
103Ru							1.62e+02	2.10e+01	1.29e+02	
106RuRh	6.78e+01	4.18e+02	9.90e+01			1.73e-01	2.68e+03	3.56e+02	1.62e+03	1.86e+02
113Sn							2.22e+02	2.89e+01	1.78e+02	
129I	7.50e-02	3.03e-01	4.18e-02			5.20e-01	2.63e-01	3.28e-02	2.18e-01	2.23e-01
134Cs	5.33e+00	5.20e+02	5.25e+02	6.23e+01	6.23e+01	5.75e+00	9.80e+02	1.35e+02	5.76e+02	2.54e+02
137Cs	1.85e+05	4.83e+05	2.56e+05	7.56e+05	5.04e+05	6.13e+05	1.21e+05	2.22e+04	2.27e+05	2.15e+05
144CePr							1.22e+03	1.59e+02	9.80e+02	

Table A-2. Double-Shell Slurry Feed Family Waste Summary. (4 sheets)

DSSF Family Wastes			Decayed to		10/01/93					
Units: Molarity; uCi/L for radionuclides; others as noted							[NOT Decayed]			
Waste	Tank	Tank	Tank	Tank	Tank	Tank	Future	Required	Total	ConcWaste
Component	106-AN	101-AW	105-AP	104-AN	105-AN	103-AN	DSSF	Dilutes	Family	Std. Dev.
154Eu							1.84e+02	2.39e+01	1.47e+02	
155Eu							3.56e+02	4.63e+01	2.85e+02	
226Ra							1.66e+03	2.15e+02	1.32e+03	
234U						5.30e-02	5.47e-02	7.11e-03	4.45e-02	
235U						1.10e-03	3.58e-03	4.65e-04	2.71e-03	
238U						1.40e-02	1.28e-02	1.64e-03	1.04e-02	
237Np	2.11e+00	2.16e+00	1.39e+00			2.00e-02		3.10e-04	8.81e-01	9.98e-01
238Pu	1.93e-02		3.67e-02			9.14e-01		1.00e-01	2.23e-01	5.12e-01
239/240Pu	3.78e-02	1.14e+00	4.23e-02	1.04e+01	1.04e+01	1.90e+00	1.27e+00	1.47e-01	2.09e+00	5.03e+00
241Am	6.02e-01	1.20e+00	1.33e+00	1.12e+04	1.12e+04	2.27e+00	8.80e-01	1.16e-01	1.35e+03	5.80e+03
242Cm										
243Cm	4.23e-02	4.94e-02	3.07e-02						4.14e-02	9.42e-03
244Cm						3.00e-01		6.60e-03	8.92e-02	
TB								1.56e+04	1.56e+04	
AT								1.86e+00	1.86e+00	
Volume L	3667985	3826969	3145609	3024479	4269852	3546854	30282640	9045555	60809943	

Notes: Where no values are displayed for an analyte in a tank, the mean for that analyte across the tanks is calculated as the weighted (volume) mean of those reported. Less-than values calculated as real values. NH_4^+ and NH_3 jointly summarized as NH_3 in overall summary. Concentrate waste standard deviation is calculated using the first six tank data columns.

Source: Hendrixsen and Conner (1994).

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Part 1