Idaho National Engineering and Environmental Laboratory

INEEL/EXT-2000-01378
Revision 0

October 2000

Feed Composition for Sodium-Bearing Waste Treatment Process

C. M. Barnes

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Published October 2000

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Prepared for the
U.S. Department of Energy
Assistant Secretary for
Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-99ID13727

ABSTRACT

Treatment of sodium-bearing waste (SBW) at the Idaho Nuclear Technology and Engineering Center (INTEC) within the Idaho National Engineering and Environmental Laboratory is mandated by a Settlement Agreement between the Department of Energy and the State of Idaho. One of the requirements of the Settlement Agreement is to complete treatment of SBW by December 31, 2012. To support both design and development studies for the SBW treatment process, detailed feed compositions are needed. This report contains the expected compositions of these feed streams and the sources and methods used in obtaining these compositions.

SUMMARY

A sodium-bearing waste (SBW) treatment facility will treat liquid wastes contained in existing and new tanks at the Idaho Nuclear Technology and Engineering Center (INTEC). Unless removed before treatment, a small amount of solids will be entrained in these liquid feed streams. The treatment facility may also treat tank heel sludges that remain in the tanks after the liquids are withdrawn.

This document provides the most recent compilation of the volumes and compositions of these feed streams. As new characterization data are received and as changes are made in the INTEC Tank Farm management plans, this document will be updated. The assumptions and source documents used in calculating the treatment process feed compositions are identified in this report.

Two treatment processes are being considered for treatment of SBW. One process, referred to as the "CsIX process," removes cesium from the liquid waste and grouts the cesium-free liquid. For the CsIX process, suspended and heel solids would likely be separated from the feed streams and treated in a separate process. The second process, referred to as "direct vitrification," treats both liquids and solids from the INTEC tanks.

Current Tank Farm management plans show that either facility would be required to treat six separate feed streams. Three of these feed streams are "SBW" – acidic, radioactive, and hazardous liquid waste containing small amounts of undissolved solids. SBW has been generated mostly from past decontamination activities at the INEEL. Another feed is a high-solids sludge from heels in existing tanks. The final two feeds are mostly liquid wastes from future operations at the INEEL, often referred to as "newly generated liquid waste" (NGLW). These NGLW streams may be similar in composition to SBW, but insufficient information is available from which to project NGLW compositions. Thus, this report contains composition data for the three SBW feeds and the heel solids but not for the future NGLW feeds.

Less data, and hence more uncertainty, is present in estimates of solid compositions and quantities than liquid compositions and quantities. Solid compositions are based primarily on samples from three of the 10 Tank Farm tanks. Because of the uncertainty in solid heel composition, the "average" heel solids composition was calculated by three different methods.

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TABLES

ACRONYMS

ANN	aluminum nitrate nonahydrate
HLLWE	High-Level Liquid Waste Evaporator
INTEC	Idaho Nuclear Technology and Engineering Center
LDUA	light-duty utility arm
NGLW	newly generated liquid waste
NWCF	New Waste Calcining Facility
PEW	process equipment waste
PEWE	Process Equipment Waste Evaporator
SBW	sodium-bearing waste
UDS	undissolved solids

Feed Composition for Sodium-Bearing Waste Treatment Process

1. INTRODUCTION

Sodium-bearing waste (SBW) and newly generated liquid waste (NGLW) at the Idaho National Engineering and Environmental Laboratory (INEEL) will be processed into final waste forms ready for disposal starting sometime around 2010. The start and completion dates depend on the specific treatment process used and other factors; however, based on a Settlement Agreement between the Department of Energy and the State of Idaho, the requirement is to process all waste currently in the Tank Farm at the Idaho Nuclear Technology and Engineering Center (INTEC) by the end of 2012.

To support both design and development studies for this treatment process, detailed feed compositions are needed. This report contains the expected compositions of these feed streams and the sources and methods used in estimating these compositions.

1.1 Primary Sources and Methods

Feed streams to the SBW treatment process are expected to come from existing tanks at the INTEC Tank Farm and from new tanks that will be constructed and in use before the startup of the treatment facility. The schedule for filling, emptying, and closing tanks was taken from two Excel spreadsheets, which are in part contained in *INTEC Waste Management Through 2070*[1]:

"FY2000 CsIX of SBW," August 28, 2000[2]
"FY2000 Direct Vit of SBW," August 31, 2000.[3]

Compositions of waste currently in the Tank Farm were taken from another spreadsheet prepared by C. B. Millet, "Tank Farm Composition Database Working Copy."[4] Composition data in this spreadsheet are either averages of analyses or estimates from calculations performed by D. R. Wenzel. Logs used in obtaining average concentrations are documented on the spreadsheet. For a few species[a] estimates are not shown on the spreadsheet, and these were obtained from a separate publication of D. R. Wenzel, *Calculation of 1999 Radionuclide Inventory for Sodium Bearing Waste*.[5]

NGLW compositions were mostly obtained from Appendix B of J. L. Tripp, *Supporting Information for the INEEL Liquid Waste Management Plan*.[6]

The general procedure in calculating feed compositions was to obtain from References 2 or 3 the sources and volumes of wastes that will be contained in the tanks that will feed the SBW treatment process. Compositions were obtained from References 4 through 6. ASPEN Plus was used to simulate process equipment waste (PEW) evaporation of NGLW streams and high-level liquid waste evaporation of Tank Farm wastes. The model used in the ASPEN simulations was similar to that used by Schindler.[7] Compositions of the final tank wastes were then calculated by blending the appropriate streams.

a. Ac, Am, Bi, Cs, Cm, Eu, Fr, In, Np, Nb, Po, Pr, Pm, Ra, Sr, Tl, and Th.

1.2 Feeds to the CsIX Treatment Process

The CsIX process would remove undissolved solids (UDS) and then cesium from the waste feed stream. UDS from the solid/liquid separation step would be returned to the Tank Farm or to a new tank for separate processing into a final waste form. Cesium-free liquid would be grouted to produce a contact-handled transuranic waste. Current plans do not call for the CsIX process to be designed to process the tank heel sludges.

According to Reference 2, the tank waste feeds to the CsIX treatment process are:

1. 271,000 gallons (not including steam dilution from transfer to the treatment facility) from WM-180, processed January to October 2010.

2. 270,000 gallons (not including steam dilution from transfer to the treatment facility) from WM-188, processed October 2010 to June 2011.

3. 280,000 gallons (not including steam dilution from transfer to the treatment facility) from WM-189, processed June 2011 to May 2012.

4. 52,265 gallons (not including steam dilution from transfer to the treatment facility) of heel solids from WM-187, processed May to July 2012. **Note:** This waste would not be processed by CsIX but would require separate treatment.

5. 32,289 gallons (not including steam dilution from transfer to the treatment facility) of NGLW from WM-100, -101, and -102, processed July 2012 and August 2013.

6. 103,143 gallons (not including steam dilution from transfer to the treatment facility) from new tanks, processed November 2015 through March 2016. This waste includes NGLW and evaporated heel flushes from WM-188, -189 and -187.

1.3 Feeds to Direct Vitrification

The direct vitrification treatment process for SBW would process all existing and new Tank Farm waste, including liquids, liquids with small concentrations of solids, and heel sludges. Evaluations are currently being performed to determine the costs and benefits of mixing tank heel solids with the liquid waste feed compared to processing tank heel solids in a separate melter campaign.

According to Reference 3, the feeds to the tank waste vitrification treatment process are:

1. 271,000 gallons (not including steam dilution from transfer to the treatment facility) from WM-180, processed January to July 2012.

2. 270,000 gallons (not including steam dilution from transfer to the treatment facility) liquid from WM-188, processed July 2012 to February 2013.

3. 280,000 gallons (not including steam dilution from transfer to the treatment facility) from WM-189, processed February 2013 to September 2013.

4. 32,289 gallons (not including steam dilution from transfer to the treatment facility) of NGLW from WM-100, -101, and -102, processed September to October 2013.

5. 62,265 gallons (not including steam dilution from transfer to the treatment facility) of heel solids from WM-187 processed from October to November 2013.

6. 101,993 gallons (not including steam dilution from transfer to the treatment facility) from new tanks, processed October 2015 to January 2016. This waste includes NGLW and evaporated heel flushes from WM-188, -189 and -187.

As can be seen from the above lists, apart from the processing schedule, the feeds to the two treatment facilities are identical except that the direct vitrification facility processes an additional 10,000 gallons of tank solids from WM-187 and 1,150 gallons less in the final treatment campaign.

1.4 Scope

Because of the uncertainties in the composition of future NGLW streams, the composition for the NGLW feeds (feeds 4 and 6 for direct vitrification or 5 and 6 for CsIX) will not be calculated at this time. Also, stream 5 for the direct vitrification facility, the heel solids, will be calculated assuming collection of solids in a single tank. More details of the assumed processing scenario for heel solids are discussed later in this report and are also contained in "Tank Farm Facility Storage Solids Storage Tank Process Development."[8]

2. LIQUID WASTE COMPOSITION

This section discusses the sources and amounts of wastes that will be in tanks fed to the treatment process. Projected compositions of the liquid in these tanks, and the basis for calculating these compositions, are also given.

2.1 Source Streams

No additions to or transfers from Tank WM-180 are expected between now and the time of processing (2010 for CsIX and 2012 for direct vitrification). Thus, the composition in WM-180 is expected to remain the same between now and the time of processing, apart from radionuclide decay. This composition for WM-180 was taken from Reference 4 and is shown in Section 2.5.

The sources of wastes that will be present in Tanks WM-188 and -189 at the time of processing are shown in Tables 1 and 2. The "Stream ID" shown in Tables 1 and 2 refers to a unique composition; different streams may thus have the same Stream ID if their composition is the same.

Table 1. Sources of waste in WM-188 at the time of processing.

Stream Description	Gallons	Volume Fraction	Stream ID
Heel in WM-188 as of July 1999	13,600	0.048	WM-188 P
Concentrate from WM-181/6 HLLWE in FY01	207,375	0.728	WM-181/6 C
Concentrate from WM-181/4 HLLWE in FY01	23,925	0.084	WM-181/4 C
Type 1 NGLW generated in FY01	250	0.0009	NGLW #1
Concentrate from WM-187 HLLWE in 2005	39,850	0.140	WM-187 C#2
Total	285,000	1.000	
Remaining heel	15,000		
Transferred out of WM-188 to treatment	270,000		

Table 2. Sources of waste in WM-189 at the time of processing.

Stream Description	Gallons[a]	Volume Fraction[a]	Gallons[b]	Volume Fraction[b]	Stream ID
Transfer from WM-180 sample	2,600	0.009	2,600	0.009	WM-180 S
Steam dilution of WM-180 sample	200	0.0007	200	0.0007	Steam
WM-189 current heel	20,100	0.072	20,100	0.070	WM-189 P
Concentrate from WM-181/4 HLLWE in FY2001	170,652	0.599	170,652	0.594	WM-181/4 C
Concentrate from WM-187 HLLWE in 2001	85,375	0.300	91,660	0.319	WM-187 C#1
Concentrate from WM-187 HLLWE in 2005	4,031	0.014	0	0	WM-187 C#2
Type 1 NGLW generated 2001 through 2005	2,042	0.007	2,042	0.007	NGLW #2
Total	285,000	1.000	287,254	1.000	
Remaining heel	5,000		5,000		
Transferred out of Tank WM-189 to treatment	280,000		282,254		

a. Based on Tank Farm management plan (References 2 and 3)

b. Based on ASPEN results of WM-187 evaporation showing different concentrate factors than assumed in Tank Farm management plan.

In order to calculate the composition of streams WM-187 C#1 and WM-187 C#2, the composition of the dilute waste in WM-187 is needed at the times of evaporation. The sources of these wastes are shown in Tables 3 and 4.

Table 3. WM-187 at the time of first evaporation (2001).

Stream Description	Gallons	Volume Fraction	Stream ID
June 1999 volume	48,300	0.181	WM-187 P
B-10 construction wastes	12,900	0.048	NGLW #3
1999-2000 Type 1 NGLW	21,800	0.082	NGLW #4
Other NGLW generated July 2000 through July 2001	45,110	0.169	NGLW #5
WM-185 transfer	38,100	0.143	WM-185 T
Heel flush of WM-183	10,000	0.038	WM-183 HF
Rinse of WM-182	40,000	0.150	WM-182 R
Rinse of WM-183	40,000	0.150	WM-183 R
Transfer from WM-182	2,300	0.009	WM-182 T
Transfer from WM-183	8,000	0.030	WM-183 T
Total	266,510	1.000	

Table 4. WM-187 at the time of second evaporation (2005).

Stream Description	Gallons	Volume Fraction	Stream ID
Heel after WM-187 HLLW evaporation #1	25,300	0.099	WM-187 H#1
Heel flush of WM-184	40,000	0.157	WM-184 R
Heel flush of WM-185	40,000	0.157	WM-185 R
Heel flush of WM-186	40,000	0.157	WM-186 R
Heel flush of WM-181	40,000	0.157	WM-181 R
Final heel of WM-182	5,000	0.020	WM-182 F
Final heel of WM-183	5,000	0.020	WM-183 F
Type 1 NGLW generated 2001-2005	13,102	0.051	NGLW #6
Type 2 NGLW generated 2001-2005	46,639	0.183	NGLW #7
Total	255,041	1.000	

2.2 Newly Generated Liquid Wastes

The above tables for WM-188, -189, and -187 show seven NGLW streams. Calculation of the composition of these NGLW streams is described in Sections 2.2.1 through 2.2.7.

2.2.1 NGLW #1

NGLW #1 includes projected volumes of Type 1 NGLW for the months of October 2000 through March 2001. For major species such as acid, aluminum, and nitrate, I assumed the composition of this waste was equivalent to H-4 New Waste Calcining Facility (NWCF) scrub solution.[b] For other species, I assumed concentrations equivalent to those in the NWCF H-4 total feed, calculated assuming an aluminum to sodium plus potassium molar ratio of 4. The total feed was thus WM-189 waste plus aluminum nitrate nonahydrate (ANN) plus calcium nitrate. The composition of WM-189 liquid was taken from Millet's Tank Farm composition database spreadsheet.[4]

NGLW #1 has a volume of only 250 gallons, contributing less than 0.1% to the total volume of WM-188. Thus, if this waste has a slightly different composition than estimated by the above method, the effect on WM-188 composition would be negligible.

2.2.2 NGLW #2

NGLW #2 is Type 1 NGLW generated from 2001 to 2005. The volume is based on generation of 42 gallons per month, or 500 gallons per year, of Tank Farm line flushes. The waste is assumed not to be concentrated in the Process Equipment Waste Evaporator (PEWE).

The composition of this stream was assumed to be the average of log numbers 96-10028, 96-10229, 96-10171, and 96-11131. Copies of these logs are included in Appendix B of the *Transmittal of Process Basis Information for the Feasibility Study of the Preferred Alternative for Treatment of ICCP Sodium-Bearing Wastes, Calcine and Low-Level Wastes*.[9] The analyses were performed in 1996 on samples from a tank that contained Tank Farm line flushes and other Type 1 NGLW. The analyses include only H^+, Hg, Cl, F, $SO4^{-2}$, U, ^{60}Co, ^{134}Cs, ^{137}Cs, and ^{154}Eu. Nitrate was calculated based on charge balance. Radionuclide concentrations were decayed from the analyses dates to July 1999.

2.2.3 NGLW #3

Based on a discussion with C. B. Millet, this waste includes 1,300 gallons of a transfer from WM-185, 900 gallons of line flushes, and 10,700 gallons from the decontamination of NCC-101/102/103. The composition of WM-185 was taken from Millet's Tank Farm composition database.[4] The composition of the line flushes was assumed the same as NGLW #2. The NCC-101/102/103 decontamination waste composition was based on compositions given in Reference 6 for NGLW stream 4d, decontamination waste from the NWCF. Analytical data for stream 4d includes only acid, aluminum, mercury, chloride, fluoride, sulfate, nitrate, uranium, total organic carbon, UDS, ^{3}H, ^{94}Nb, ^{129}I, ^{135}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu, and ^{60}Co. Radionuclide concentrations were decayed from the analysis date to July 1999. The combined composition was then concentrated by a factor of 10 to simulate PEW evaporation. Based on an ASPEN simulation of this evaporation, 4% of the acid in the feed is retained in

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b. The average scrub solution concentrations of H^+, Al^{+3}, NO_3^{-1} and UDS from logs 000509-1 through 000528-1 (May 9 through May 28, 2000) were used. The stream density was also taken from these logs.

the concentrate. For later reference, the streams' composition IDs for the three components of NGLW #3 are WM-185 P, NGLW #2, and NGLW 4d.

2.2.4 NGLW #4

The volume of NGLW #4 is based on the actual increase in WM-187 tank volume in May and June 2000. The composition was assumed equal to NWCF H-4 feed composition, calculated as WM-189 calciner feed plus ANN and $Ca(NO_3)_2$. The resultant composition, 1.6 molar acid and 6.7 molar nitrate, was not further concentrated.

2.2.5 NGLW #5

NGLW #5 includes 27,710 gallons of NWCF bed dissolution waste generated in July 2000, 4,774 gallons of other Type 1 NGLW, and 12,626 gallons of Type 2 NGLW generated from 2000 through 2001. The bed dissolution waste composition was based on (a) estimated H-4 calcine composition from *Updated Aluminum Nitrate/WM-189 Blend Calculations For 500°C and 600°C Operations During NWCF RUN H4*,[10] using a Al to Na plus K ratio of 4; (b) dissolution of this calcine with six liters of 10 molar nitric acid per kilogram of calcine; (c) a calcine to NWCF fresh feed ratio of 0.1847, based on RAW-01-00; (d) radionuclide concentrations based on WM-189 tank waste and the ratio of dissolved calcine volume to NWCF fresh feed; and (e) an assumed UDS concentration of three grams per liter.

The "other Type 1 NGLW" was assumed equal in composition to NGLW #2. The Type 2 NGLW composition was based on the major contributors (only considering those with defined steam compositions) to total Type 2 waste generated in 2000 and 2001. These major Type 2 waste streams include NGLW 4d, NWCF decontamination facility waste; NGLW 4e, CPP-601/627/640 deactivation wastes; and NGLW 4f, CPP-603 deactivation waste. Dilute compositions for these three NGLW waste streams were taken from Reference 6. Each was concentrated by a factor of 10 to account for PEW evaporation. Analyses of stream 4f show it to be neutral; thus, the concentrate from its evaporation was assumed to contain all chlorides and fluorides in the dilute waste. Based on an ASPEN simulation, the concentrate from NGLW 4f will contain 90% of the acid and 100% of the chlorides contained in the dilute waste.

Table 5 summarizes the components of NGLW #5.

Table 5. Summary of NGLW #5 components.

Stream Description	Gallons	Volume Fraction	Stream ID
July 2000 NWCF bed dissolution	27,710	0.614	NWCF BD
Other Type 1 NGLW, August 2000 to July 2001	4,774	0.106	NGLW #2
Type 2 NGLW generated July 2000 to July 2001, assumed to be:			
NGLW 4d, concentrated	7,740	0.172	NGLW 4d
NGLW 4e, concentrated	3,093	0.069	NGLW 4e
NGLW 4f, concentrated	1,793	0.040	NGLW 4f
Total	45,110	1.000	

2.2.6 NGLW #6

NGLW #6 is Type 1 NGLW generated from November 2001 through March 2005. I assumed the composition of this stream to be the same as NGLW #2.

2.2.7 NGLW #7

NGLW #7 is Type 2 NGLW generated from November 2001 through March 2005. The major Type 2 NGLW streams over this period include concentrated CPP-603 basin water, CPP-601 laboratory drains, waste from the NWCF decontamination facility, the TRA-689 decontamination waste, PEWE descale waste, CPP-601/627/640 deactivation wastes, and CPP-603 deactivation waste. TRA-689 waste was assumed to have the same composition as that reported in Reference 6 for TRA-605 waste. For the remaining five wastes, dilute compositions were taken from Reference 6, and ASPEN simulations were made to calculate the PEWE bottoms compositions. Two of the six wastes listed above were also components of NGLW #5 and have the compositions “NGLW 4e” and “NGLW 4f.”

The CPP-603 basin water was assumed concentrated by a factor of 1,000. Since analyses of the dilute waste show it to be neutral, no acids are expected in the PEWE condensate, and all chlorides and fluorides are thus retained in the concentrate. Analyses for this waste show 32 chemical species, but only six radionuclides – total transuranic radionuclides (which I assumed to be 67% ^{238}Pu and 33% ^{241}Pu), ^{90}Sr, ^{125}Sb, ^{137}Cs, ^{152}Eu, and ^{60}Co.

The dilute CPP-601 laboratory drain composition was concentrated by a factor of 35. At this concentration factor, ASPEN showed 30% retention of acid in the concentrate, 2% retention of chloride, and 88% retention of mercury. All fluoride was assumed retained by, if needed, addition of ANN. Analyses were available for 19 chemical species but no radionuclides.

Dilute NWCF decontamination waste was assumed concentrated by a factor of 10. At this concentration factor, ASPEN showed 73% retention of acid in the concentrate, 13% retention of chloride, and 95% retention of mercury. All fluoride was assumed retained by, if needed, addition of ANN. Analyses were available for only nine chemical species and eight radionuclides – ^{3}H, ^{94}Nb, ^{129}I, ^{134}Cs, ^{137}Cs, ^{154}Eu, ^{155}Eu, and ^{60}Co.

No concentration was applied to the PEWE descale waste composition from Reference 6. Analyses were available for only seven chemical species and no radionuclides.

Table 6 summarizes the components of NGLW #7.

Table 6. Summary of NGLW #7 components.

Stream Description	Gallons	Volume Fraction	Stream ID
Concentrated CPP-603 basin water	3,280	0.070	NGLW 1k
CPP-601 laboratory drains	5,196	0.111	NGLW 4b
NWCF decontamination facility	21,323	0.457	NGLW 4d
TRA-689 decontamination solution	2,187	0.047	NGLW 5a
PEWE descale	2,624	0.056	NGLW 5f
CPP-603 deactivation	3,280	0.070	NGLW 4f
CPP-601/627/640 deactivation	8,748	0.188	NGLW 4e
Total	46,639	1.000	

2.3 High-Level Liquid Waste Evaporation

ASPEN PLUS simulations were made for high-level liquid waste evaporation of blended WM-181/184 waste, blended WM-181/186 waste, WM-187 waste evaporated in 2001, and WM-187 waste evaporated in 2005. Volumes of concentrate were kept the same as assumed in the Tank Farm planning spreadsheets (References 1 through 3) for the first two of these evaporations, but not for the WM-187 wastes, for reasons discussed below.

For WM-181/184 and WM-181/186 evaporation, the feed to the evaporator consisted of two volumes of WM-184 or -186 waste to one volume of WM-181 waste, plus an additional 5% for steam jet dilution. The waste was then concentrated to 50% of the original (without jet dilution) volume. The density of the bottoms calculated by ASPEN was 1.356 g/cm^3 for WM-181/184 evaporation, very close to the typical High-Level Liquid Waste Evaporator (HLLWE) bottoms density of 1.35 g/cm^3. However, for WM-181/186 evaporation the calculated density of the bottoms was 1.29 g/cm^3, indicating that a higher concentration factor may be achievable. Table 7 shows the retention fractions of volatile species for these two simulations.

Table 7. Retention fractions of volatile species from WM-181/4 and WM-181/6 evaporation simulations.

	Fraction in Bottoms	
	WM-181/4	WM-181/6
Cl	0.899	0.934
F	0.689	0.734
NO3	0.926	0.946
Hg	0.976	0.987

For the 2001 evaporation of WM-187, the dilute waste has an acid concentration of 0.9 molar and a nitrate concentration of 4.3 molar. The Tank Farm management plan (References 1 through 3) assumes a concentration of 241,210 gallons of WM-187 waste to a volume of 85,375 gallons. However, simulation of this evaporation showed a bottoms density of 1.4 g/cm^3 when the bottoms volume was 91,660 gallons. Although this density may be higher than allowed by HLLWE procedures, I used the results of this run for the feed composition calculations. NGLW feed compositions contain sufficient uncertainty that it is not expected that a small change in this volume (to reduce the density to 1.35 g/cm^3) would have a significant impact on the final WM-189 composition.

The waste composition of WM-187 at the time of the 2005 evaporation is quite different. The acid molarity is 1.04 molar, but the nitrate molarity is only 1.34 molar. The Tank Farm management plan (References 1 through 3) assumes a concentration of 216,300 gallons of WM-187 waste to a volume of 43,881 gallons, 39,850 gallons of which are sent to WM-188 and 4,031 gallons to WM-189. To avoid exceeding the capacity of WM-189, no additional concentrate from the 2005 WM-187 evaporation was assumed to be added to this tank. Concentration to a bottoms volume of 39,850 gallons, the volume planned for addition to WM-188, would be acceptable, because the ASPEN results for this case showed a bottoms density of 1.28 g/cm^3. Table 8 shows retention fractions for WM-187 high-level liquid waste evaporation.

Table 8. Retention fractions of volatile species from WM-187 HLLW evaporation simulation.

	Fraction in Bottoms	
	2001	2005
Nitric Acid	0.67	0.65
Chloride	0.9	0.6
Fluoride	0.9984	0.991
Mercury	0.947	0.963

2.4 Liquid Concentrations of Heel Flushes and Final Heels

According to the Tank Farm management plan (Reference 1 through 3), most of the Tank Farm tanks will be drawn down to an assumed heel of 5,000 gallons, then flushed with 40,000 gallons of water.[c] These flushes, 40,000 gallons per tank, are sent to WM-187. When the tank is closed and filled with grout, the final 5,000 gallons of displaced liquid is pumped out to another tank.

2.4.1 WM-182 and -183

According to the Tank Farm management plan (References 1 through 3), waste will be transferred from WM-182 down to a heel volume of 5,000 gallons. This heel will then be flushed with 40,000 gallons of water, leaving 5,000 gallons of final heel. The fraction of WM-182 waste transferred to WM-187 before the 2001 evaporation was estimated to be approximately:

$$1 - (5000/7300) * (1/3)^3(1/2) = 0.987$$

and, in calculating WM-187 evaporator feed composition, rounded up to 1.0.

The above calculation is based on (a) transfer of 2,300 gallons from an original volume of 7,300 gallons to WM-187 and (b) three flushes of 10,000 gallons each, which each reduce the heel concentrations to one-third of their original value, and one additional flush which reduces the heel concentrations to one-half their original value. Because the flush effluent will contain approximately 35,000 gallons of water and 5,000 gallons of original waste, the dilution factor is approximately equivalent to three 10,000-gallon flushes and one 5,000-gallon flush.

For WM-183, the Tank Farm management plan shows a 10,000-gallon flush when the heel level is 13,000 gallons, removal of liquid to a level of 5,000 gallons, and then flushes with 40,000 gallons of water. The fraction of the original liquid in the final heel is thus approximately:

$$1 - (5/23) * (1/3)^3*(1/2) = 0.996.$$

For the calculation of WM-187 evaporator feed composition, the fraction was rounded up to 1.0. However, for the calculation of the 2005 WM-187 evaporator feed composition, the above fractions (without rounding up) were used to calculate the amount of WM-182 or -183 liquid waste (at full

c. The planned flush volume has recently been increased to 100,000 gallons per tank, and Tank Farm planning documents are currently being revised. This larger flush volume, being water, should not affect the average SBW concentration, although it could affect concentrations in individual tanks.

concentration levels before any flushes) transferred in the final heel. These volumes are 93 and 52 gallons, respectively.

2.4.2 WM-184, -185, -186 and -181

Heel flushes from WM-184, -185, -186, and -181 all are part of the 2005 WM-187 evaporator feed volume. For each tank, an original heel, assumed to be 5,000 gallons, is flushed with 40,000 gallons of water. In terms of liquid only, an original heel of 5,000 gallons plus 40,000 gallons of flush water results in approximately 5,000 gallons of tank waste plus 35,000 gallons of water being transferred to WM-187, with 5,000 gallons of water remaining in the flushed tank. The amount of tank waste transferred to WM-187 from each tank was estimated to be:

$5{,}000 * (1 – (1/3)^3*(1/2)) = 4{,}907$ gallons.

2.5 WM-180, -188, and -189 Compositions

After obtaining the compositions for WM-180, -188, and -189 as described above, several mathematical tests were performed and the compositions adjusted if needed. The first test was that of ionic charge balance. To obtain charge balance, the nitrate concentration for WM-180 was increased from 4.51 to 5.05 moles per liter, for WM-188 from 6.03 to 6.34 moles per liter, and for WM-189 from 7.05 to 7.44 moles per liter.

The second test was for consistency between radionuclide activities and chemical concentrations. Activities of radionuclides were converted to molar concentrations and compared to concentrations as calculated for the chemical species. If the sum of the concentrations of all isotopes of an element, converted from activities, was greater than the chemical concentration for that element, the chemical concentration was replaced by that sum.[d] For example, if the concentration of Americium, as calculated by conversion of ^{241}Am, ^{242m}Am, ^{242}Am, and ^{243}Am concentrations in curies per liter to moles per liter and summed, was greater than the molar concentration of Am calculated as a chemical species, then the sum of the isotopes was used as the concentration.

The third test was a comparison of concentrations to those calculated by Wenzel for SBW. In this test, Wenzel's SBW concentrations were first adjusted to account for more or less dilution in a given tank than what Wenzel assumed in his SBW waste composition. Then these adjusted concentrations were compared to those calculated from constituent tank components. If the adjusted Wenzel concentration was greater than that calculated from constituent wastes, Wenzel's adjusted value was used. The only species that were changed from this test were Bi, Cs, Sr, and Eu.

The final calculated compositions of WM-180, -188, and -189, along with the composite for these three tanks, are shown in Table 9. The tank volumes shown below are volumes transferred out of the tanks to the treatment facility; thus, they have been adjusted, as have the concentrations, for jet dilution and the residual tank heel volume. Table 10 shows the tank liquid compositions converted to an oxide basis.

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d. In most cases, the chemical concentration is greater than that of the same species calculated from isotopic concentrations because of non-radioactive isotopes.

Table 9. Final calculated compositions of WM-180, -188, and -189.

Radionuclides decayed to 7/1/99		WM-180	WM-188	WM-189	Total or Average
Earliest date composition valid		Jun-00	Jun-05	Apr-05	
	Volume, gallons	284,550	288,000	296,000	868,550
	Density, g/cm3	1.26	1.28	1.35	1.30
	UDS, g/liter	0.62	2.56	1.94	1.72
	TOC, g/liter		0.60	10.40	3.74
	pH	-0.05	-0.41	-0.37	-0.28
		Moles/liter	Moles/liter	Moles/liter	Moles/liter
H+	Acid	1.13E+00	2.56E+00	2.35E+00	2.02E+00
Ac+3	Actinium	9.53E-16	1.93E-15	2.40E-15	1.77E-15
Al+3	Aluminum	5.82E-01	5.40E-01	9.99E-01	7.10E-01
Am+4	Americium	7.52E-08	1.34E-07	1.33E-07	1.14E-07
Sb+5	Antimony	3.19E-08	1.20E-06	2.50E-06	1.26E-06
As+5	Arsenic	4.67E-05	1.31E-04	2.30E-05	6.67E-05
At	Astatine	2.36E-28	4.76E-28	5.93E-28	4.37E-28
Ba+2	Barium	5.04E-05	7.68E-05	6.53E-05	6.43E-05
Be+2	Beryllium	4.76E-09	3.34E-07	1.26E-06	5.41E-07
Bi+5	Bismuth	4.53E-18	1.04E-17	1.10E-17	8.67E-18
B+3	Boron	1.01E-02	2.64E-02	1.91E-02	1.86E-02
Br-1	Bromine	1.52E-07	9.57E-05	4.26E-07	3.19E-05
Cd+2	Cadmium	7.64E-04	8.59E-03	7.23E-03	5.56E-03
Ca+2	Calcium	3.35E-02	8.98E-02	7.13E-02	6.50E-02
Cf+3	Californium	9.08E-21	1.83E-20	2.28E-20	1.68E-20
Ce+4	Cerium	8.92E-06	2.06E-05	2.09E-05	1.69E-05
Cs+1	Cesium	9.49E-06	2.18E-05	2.30E-05	1.82E-05
Cl-1	Chloride	3.07E-02	2.70E-02	3.13E-02	2.97E-02
Cr+3	Chromium	3.25E-03	1.55E-02	6.41E-03	8.40E-03
Co+2	Cobalt		4.92E-06	7.74E-06	4.27E-06
Cu+2	Copper		6.65E-06	9.37E-05	3.41E-05
Cm+3	Curium	4.77E-12	9.65E-12	1.20E-11	8.85E-12
Dy+3	Dysprosium	3.14E-10	7.26E-10	7.64E-10	6.04E-10
Er+3	Erbium	5.16E-12	1.19E-11	1.26E-11	9.93E-12
Eu+3	Europium	2.57E-07	5.91E-07	6.22E-07	4.92E-07
F-1	Fluoride	4.13E-02	9.41E-02	1.11E-01	8.26E-02
Fr+1	Francium	2.76E-23	5.57E-23	6.93E-23	5.11E-23
Gd+3	Gadolinium	3.29E-07	3.20E-06	3.11E-05	1.18E-05
Ga+3	Gallium	9.56E-15	2.21E-14	2.33E-14	1.84E-14
Ge+4	Germanium	4.43E-09	2.24E-07	1.09E-08	7.95E-08
Ho+3	Holmium	1.33E-11	3.08E-11	3.24E-11	2.56E-11
In+3	Indium	6.70E-07	1.35E-06	1.69E-06	1.24E-06
I-1	Iodine	1.18E-03	4.26E-04	4.36E-04	6.76E-04
Fe+3	Iron	1.73E-02	2.72E-02	2.60E-02	2.36E-02
La+3	Lanthanum	4.52E-06	1.04E-05	1.10E-05	8.69E-06
Pb+2	Lead	1.22E-03	1.13E-03	9.66E-04	1.10E-03
Li+1	Lithium	1.91E-07	1.23E-06	1.29E-05	4.86E-06

Table 9. (continued)

Mg+2	Magnesium			3.43E-04	1.17E-04
Mn+4	Manganese		2.24E-02	1.97E-02	1.41E-02
Hg+2	Mercury	9.60E-04	2.00E-03	2.48E-03	1.82E-03
Mo+6	Molybdenum	1.80E-05	3.52E-04	3.16E-04	2.30E-04
Nd+3	Neodymium	1.49E-05	3.46E-05	3.64E-05	2.88E-05
Np+4	Neptunium	1.64E-05	9.87E-06	1.72E-05	1.45E-05
Ni+2	Nickel	1.46E-03	5.55E-03	4.35E-03	3.80E-03
Nb+5	Niobium	3.18E-08	1.86E-06	2.19E-06	1.37E-06
NO3-1	Nitrate	5.05E+00	6.34E+00	7.44E+00	6.29E+00
Pd+4	Palladium	1.77E-06	4.09E-06	4.26E-06	3.39E-06
PO4-3	Phosphate		5.82E-03	1.37E-02	6.58E-03
Pu+4	Plutonium	5.47E-06	6.36E-06	6.82E-06	6.22E-06
Po+4	Polonium	1.08E-18	2.18E-18	2.71E-18	2.00E-18
K+1	Potassium	1.81E-01	2.29E-01	1.59E-01	1.90E-01
Pr+4	Praseodymium	4.17E-06	9.66E-06	1.02E-05	8.03E-06
Pm+3	Promethium	1.53E-09	3.08E-09	3.84E-09	2.83E-09
Pa+4	Protactinium	4.25E-12	8.59E-12	1.07E-11	7.89E-12
Ra+2	Radium	1.52E-14	3.07E-14	3.82E-14	2.81E-14
Rn	Radon	1.14E-19	2.30E-19	2.87E-19	2.11E-19
Rh+4	Rhodium	1.83E-06	4.23E-06	4.45E-06	3.52E-06
Rb+1	Rubidium	2.80E-06	6.47E-06	6.81E-06	5.39E-06
Ru+3	Ruthenium	8.54E-06	2.63E-05	2.32E-05	1.94E-05
Sm+3	Samarium	2.87E-06	6.64E-06	6.98E-06	5.52E-06
Se+2	Selenium	1.02E-05	1.27E-04	8.84E-06	4.85E-05
Si+4	Silicon		1.58E-03	1.53E-04	5.77E-04
Ag+1	Silver	4.37E-06	1.17E-04	2.51E-05	4.88E-05
Na+1	Sodium	1.97E+00	1.59E+00	1.70E+00	1.75E+00
Sr+2	Strontium	4.95E-06	1.14E-05	1.20E-05	9.48E-06
SO4-2	Sulfate	4.22E-02	5.88E-02	4.58E-02	4.90E-02
Tc+7	Technetium	2.80E-06	6.80E-06	7.30E-06	5.66E-06
Te+6	Tellurium	1.44E-06	3.34E-06	3.52E-06	2.78E-06
Tb+4	Terbium	1.06E-09	2.45E-09	2.58E-09	2.04E-09
Tl+3	Thallium	2.89E-20	4.15E-07	1.43E-06	6.24E-07
Th+4	Thorium	9.34E-11	1.89E-10	2.35E-10	1.73E-10
Tm+3	Thulium	2.55E-15	5.91E-15	6.22E-15	4.91E-15
Sn+4	Tin	1.78E-07	4.39E-07	9.94E-07	5.43E-07
Ti+4	Titanium			2.34E-06	7.97E-07
U+4	Uranium	1.48E-04	3.31E-04	4.04E-04	2.96E-04
V+5	Vanadium		2.12E-06	8.38E-06	3.56E-06
Yb+3	Ytterbium	4.30E-16	9.96E-16	1.05E-15	8.29E-16
Y+3	Yttrium	3.44E-06	7.96E-06	8.38E-06	6.62E-06
Zn+2	Zinc		4.96E-05	1.19E-04	5.71E-05
Zr+2	Zirconium	1.10E-03	1.87E-02	2.03E-02	1.35E-02
	Actinides and Daughters	Ci/liter	Ci/liter	Ci/liter	Ci/liter
	Tl-207	1.57E-11	3.17E-11	3.94E-11	2.91E-11
	Tl-208	1.10E-09	2.22E-09	2.76E-09	2.04E-09

Table 9. (continued)

Pb-209	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Pb-210	1.06E-12	2.14E-12	2.66E-12	1.96E-12
Pb-211	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Pb-212	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Pb-214	3.37E-12	6.81E-12	8.48E-12	6.25E-12
Bi-210m	1.06E-25	2.14E-25	2.66E-25	1.96E-25
Bi-210	1.06E-12	2.14E-12	2.66E-12	1.96E-12
Bi-211	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Bi-212	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Bi-213	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Bi-214	3.37E-12	6.81E-12	8.48E-12	6.25E-12
Po-210	1.02E-12	2.06E-12	2.56E-12	1.89E-12
Po-213	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Po-214	3.37E-12	6.81E-12	8.48E-12	6.25E-12
Po-215	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Po-216	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Po-218	3.37E-12	6.81E-12	8.48E-12	6.25E-12
At-217	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Rn-219	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Rn-220	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Rn-222	3.37E-12	6.81E-12	8.48E-12	6.25E-12
Fr-221	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Fr-223	2.20E-13	4.44E-13	5.52E-13	4.07E-13
Ra-223	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Ra-224	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Ra-225	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Ra-226	3.37E-12	6.81E-12	8.48E-12	6.25E-12
Ra-228	2.23E-16	4.52E-16	5.62E-16	4.14E-16
Ac-225	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Ac-227	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Ac-228	2.23E-16	4.52E-16	5.62E-16	4.14E-16
Th-227	1.57E-11	3.17E-11	3.94E-11	2.91E-11
Th-228	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Th-229	8.23E-14	1.66E-13	2.07E-13	1.53E-13
Th-230	3.88E-10	7.84E-10	9.76E-10	7.20E-10
Th-231	1.02E-08	2.06E-08	2.56E-08	1.89E-08
Th-232	3.41E-16	6.89E-16	8.58E-16	6.33E-16
Th-234	1.02E-08	2.06E-08	2.56E-08	1.89E-08
Pa-231	4.31E-11	8.71E-11	1.08E-10	8.00E-11
Pa-233	1.41E-06	2.85E-06	3.55E-06	2.62E-06
Pa-234m	1.02E-08	2.06E-08	2.56E-08	1.89E-08
Pa-234	1.29E-11	2.61E-11	3.25E-11	2.40E-11
U-232	9.41E-10	1.90E-09	2.37E-09	1.75E-09
U-233	1.57E-11	3.17E-11	3.94E-11	2.91E-11
U-234	3.89E-07	1.50E-06	1.50E-06	1.14E-06
U-235	1.01E-08	3.94E-08	3.98E-08	3.00E-08

Table 9. (continued)

U-236	1.59E-08	7.29E-08	7.02E-08	5.33E-08
U-237	3.68E-09	7.45E-09	9.27E-09	6.84E-09
U-238	1.01E-08	1.98E-08	2.56E-08	1.86E-08
U-240	3.29E-16	6.65E-16	8.28E-16	6.11E-16
Np-237	2.75E-06	1.65E-06	2.87E-06	2.42E-06
Np-238	3.76E-11	7.60E-11	9.47E-11	6.98E-11
Np-239	1.06E-08	2.14E-08	2.66E-08	1.96E-08
Np-240m	3.29E-16	6.65E-16	8.28E-16	6.11E-16
Pu-236	3.10E-09	6.26E-09	7.79E-09	5.74E-09
Pu-238	5.43E-04	7.95E-04	8.11E-04	7.18E-04
Pu-239	7.77E-05	8.82E-05	9.45E-05	8.69E-05
Pu-240	5.10E-06	9.45E-06	1.21E-05	8.92E-06
Pu-241	1.49E-04	4.80E-04	5.75E-04	4.04E-04
Pu-242	3.84E-09	3.58E-08	1.23E-08	1.73E-08
Pu-244	3.29E-16	6.65E-16	8.28E-16	6.11E-16
Am-241	6.20E-05	1.10E-04	1.09E-04	9.42E-05
Am-242m	7.45E-09	1.51E-08	1.87E-08	1.38E-08
Am-242	7.45E-09	1.51E-08	1.87E-08	1.38E-08
Am-243	1.06E-08	2.14E-08	2.66E-08	1.96E-08
Cm-242	1.06E-08	2.14E-08	2.66E-08	1.96E-08
Cm-243	1.49E-08	3.01E-08	3.75E-08	2.76E-08
Cm-244		1.98E-06	2.46E-06	1.49E-06
Cm-245	1.45E-10	2.93E-10	3.65E-10	2.69E-10
Cm-246	9.41E-12	1.90E-11	2.37E-11	1.75E-11
Cm-247	1.06E-17	2.14E-17	2.66E-17	1.96E-17
Cm-248	1.14E-17	2.30E-17	2.86E-17	2.11E-17
Cf-249	8.62E-18	1.74E-17	2.17E-17	1.60E-17
Cf-250	8.23E-18	1.66E-17	2.07E-17	1.53E-17
Cf-251	1.33E-19	2.69E-19	3.35E-19	2.47E-19
Fission Products	Ci/liter	Ci/liter	Ci/liter	Ci/liter
H-3	2.15E-05	2.55E-05	2.53E-05	2.41E-05
Be-10	1.45E-12	2.93E-12	3.65E-12	2.69E-12
C-14	5.88E-11	3.72E-06	1.48E-10	1.23E-06
Se-79	2.12E-07	4.28E-07	5.32E-07	3.93E-07
Rb-87	1.41E-11	2.85E-11	3.55E-11	2.62E-11
Sr-90	2.15E-02	4.50E-02	6.11E-02	4.28E-02
Y-90	2.70E-02	5.47E-02	6.80E-02	5.02E-02
Zr-93	1.06E-06	2.14E-06	2.66E-06	1.96E-06
Nb-93m	7.84E-07	1.58E-06	1.97E-06	1.45E-06
Nb-94	5.49E-07	1.15E-06	1.42E-06	1.05E-06
Zr-95			3.60E-05	1.23E-05
Tc-98	1.25E-12	2.53E-12	3.16E-12	2.33E-12
Tc-99	4.70E-06	1.14E-05	1.23E-05	9.50E-06
Ru-106	5.10E-06	7.97E-06	9.11E-06	7.42E-06
Rh-102	9.80E-10	1.98E-09	2.47E-09	1.82E-09
Rh-106	5.10E-06	1.03E-05	1.28E-05	9.45E-06

Table 9. (continued)

Pd-107	7.84E-09	1.58E-08	1.97E-08	1.45E-08
Cd-113m	1.92E-06	3.88E-06	4.83E-06	3.56E-06
In-115	4.70E-17	9.51E-17	1.18E-16	8.73E-17
Sn-121m	3.41E-08	6.89E-08	8.58E-08	6.33E-08
Sn-126	2.00E-07	4.04E-07	5.03E-07	3.71E-07
Sb-125	1.48E-05	5.87E-05	5.61E-05	4.34E-05
Sb-126m	2.00E-07	4.04E-07	5.03E-07	3.71E-07
Sb-126	2.78E-08	5.62E-08	7.00E-08	5.16E-08
Te-123	1.84E-19	3.72E-19	4.63E-19	3.42E-19
Te-125m	3.65E-06	7.37E-06	9.17E-06	6.76E-06
I-129	2.68E-05	1.37E-06	2.11E-07	9.31E-06
Cs-134	7.19E-04	1.37E-04	1.26E-04	3.24E-04
Cs-135	4.31E-07	9.34E-07	1.78E-06	1.06E-06
Cs-137	2.67E-02	5.44E-02	6.75E-02	4.97E-02
Ba-137m	2.51E-02	5.07E-02	6.31E-02	4.65E-02
La-138	9.41E-17	1.90E-16	2.37E-16	1.75E-16
Ce-142	1.45E-11	2.93E-11	3.65E-11	2.69E-11
Ce-144	7.06E-06	9.88E-06	1.18E-05	9.60E-06
Pr-144	8.23E-08	1.66E-07	2.07E-07	1.53E-07
Nd-144	7.84E-16	1.58E-15	1.97E-15	1.45E-15
Pm-146	3.84E-08	7.76E-08	9.66E-08	7.13E-08
Pm-147	2.08E-04	4.20E-04	5.23E-04	3.85E-04
Sm-146	1.33E-13	2.69E-13	3.35E-13	2.47E-13
Sm-147	3.57E-12	7.21E-12	8.97E-12	6.62E-12
Sm-148	1.84E-17	3.72E-17	4.63E-17	3.42E-17
Sm-149	1.65E-18	3.33E-18	4.14E-18	3.05E-18
Sm-151	1.69E-04	3.41E-04	4.24E-04	3.13E-04
Eu-150	7.45E-12	1.51E-11	1.87E-11	1.38E-11
Eu-152	1.45E-06	2.95E-06	3.66E-06	2.70E-06
Eu-154	5.10E-05	2.75E-04	2.72E-04	2.01E-04
Eu-155	1.28E-04	1.72E-04	2.19E-04	1.74E-04
Gd-152	6.66E-19	1.35E-18	1.68E-18	1.24E-18
Ho-166m	2.23E-11	4.52E-11	5.62E-11	4.14E-11
Tm-171	8.62E-16	1.74E-15	2.17E-15	1.60E-15
Activation Products	Ci/liter	Ci/liter	Ci/liter	Ci/liter
Co-60	2.76E-05	9.76E-05	8.04E-05	6.88E-05
Ni-63	2.50E-05	5.55E-05	5.65E-05	4.59E-05

Table 10. Tank liquid compositions converted to an oxide basis.

	WM-180	WM-188	WM-189		WM-180	WM-188	WM-189
g oxides/ liter waste	103.9	104.0	137.5	g oxides/ liter waste	103.9	104.0	137.5
	Wt fraction	Wt fraction	Wt fraction		Wt fraction	Wt fraction	Wt fraction
Ac2O3	2.30E-15	4.65E-15	4.38E-15	P2O5		3.97E-03	7.05E-03
Al2O3	2.86E-01	2.65E-01	3.68E-01	PuO2	1.44E-05	1.68E-05	1.36E-05
AmO2	1.99E-07	3.54E-07	2.66E-07	PoO2	2.51E-18	5.08E-18	4.78E-18
Sb2O5	4.97E-08	1.89E-06	2.95E-06	K2O	8.20E-02	1.06E-01	7.59E-02
As2O5	5.17E-05	4.66E-05	1.92E-05	Pr2O3	6.62E-06	1.53E-05	1.22E-05
At2O3	5.31E-28	1.07E-27	1.01E-27	Pm2O3	2.48E-09	5.01E-09	4.72E-09
BaO	7.43E-05	1.01E-04	7.29E-05	PaO2	1.08E-11	2.18E-11	2.05E-11
BeO	1.15E-09	8.14E-08	2.29E-07	RaO	3.53E-14	7.15E-14	6.72E-14
Bi2O5	1.08E-17	2.50E-17	1.99E-17	Rh2O3	2.37E-06	5.49E-06	4.37E-06
B2O3	3.38E-03	8.85E-03	4.85E-03	Rb2O3	2.52E-06	5.83E-06	4.63E-06
CdO	9.43E-04	1.06E-02	6.75E-03	Ru2O3	1.03E-05	3.16E-05	2.11E-05
CaO	1.81E-02	4.84E-02	2.91E-02	Sm2O3	4.81E-06	1.11E-05	8.86E-06
Cf2O3	2.38E-20	4.82E-20	4.54E-20	SeO2	1.09E-05	1.27E-05	7.14E-06
CeO2	1.48E-05	3.42E-05	2.61E-05	SiO2			6.69E-05
Cs2O	1.29E-05	2.96E-05	2.36E-05	Ag2O	4.88E-06	2.62E-05	2.11E-05
Cr2O3	2.37E-03	5.04E-03	4.01E-03	Na2O	5.88E-01	4.81E-01	4.49E-01
CoO		3.56E-06	4.22E-06	SrO	4.93E-06	1.14E-05	9.03E-06
CuO		5.23E-06	5.42E-05	Tc2O7	4.12E-06	1.00E-05	8.13E-06
Cm2O3	1.24E-11	2.50E-11	2.35E-11	TeO3	2.44E-06	5.65E-06	4.49E-06
Dy2O3	5.63E-10	1.30E-09	1.04E-09	Tb2O3	9.74E-10	2.26E-09	1.79E-09
Er2O3	9.49E-12	2.20E-11	1.75E-11	Tl2O3	6.36E-20	9.40E-07	2.37E-06
Eu2O3	4.35E-07	1.00E-06	7.96E-07	ThO2	2.37E-10	4.80E-10	4.51E-10
Fr2O	6.12E-23	1.24E-22	1.16E-22	Tm2O3	4.74E-15	1.10E-14	8.72E-15
Gd2O3	5.73E-07	5.58E-06	4.10E-05	SnO2	2.59E-07	6.37E-07	1.09E-06
Ga2O3	8.62E-15	2.00E-14	1.59E-14	TiO2			1.36E-06
GeO2	4.46E-09	2.26E-07	8.30E-09	UO2	3.84E-04	8.60E-04	7.93E-04
Ho2O3	2.42E-11	5.60E-11	4.46E-11	V2O5		1.86E-06	5.54E-06
In2O3	8.95E-07	1.81E-06	1.70E-06	Yb2O3	8.16E-16	1.89E-15	1.50E-15
Fe2O3	1.33E-02	2.09E-02	1.51E-02	Y2O3	3.74E-06	8.65E-06	6.88E-06
La2O3	7.08E-06	1.64E-05	1.30E-05	ZnO		3.91E-05	7.06E-05
PbO	2.61E-03	2.34E-03	1.57E-03	ZrO2	1.30E-03	2.21E-02	1.82E-02
Li2O	2.75E-08	1.76E-07	1.40E-06	Total	1.00000	1.00000	1.00000
MgO			1.01E-04				
MnO2		1.91E-02	1.57E-02	Br	5.85E-08	3.68E-05	1.24E-07
MoO3	4.99E-05	9.75E-04	6.61E-04	Cl	5.24E-03	4.56E-03	3.95E-03
Nd2O3	2.42E-05	5.60E-05	4.46E-05	F	7.55E-03	1.72E-02	1.49E-02
NpO2	4.26E-05	2.56E-05	3.36E-05	I	7.19E-04	2.60E-04	2.01E-04
NiO	1.05E-03	3.99E-03	2.36E-03	Hg	9.27E-04	3.83E-03	3.60E-03
Nb2O5	4.07E-08	2.38E-06	2.11E-06	SO4-2	3.90E-02	5.43E-02	3.16E-02
Pd2O3	2.22E-06	5.13E-06	4.04E-06				

3. SOLID WASTE COMPOSITION

3.1 Tank Heel Solids

Based on analyses of light-duty utility arm (LDUA) samples, the composition of heel solids in tanks WM-182, -183, and -188 is shown in Table 11.

Table 11. Composition of heel solids in tanks WM-182, -183, and -188.

	WM-182	WM-183	WM-188		WM-182	WM-183	WM-188
	mg/kg	mg/kg	mg/kg		mg/kg	mg/kg	mg/kg
Al	21,880	24,911	35,406	Sr	9	11	
Sb	14	32	33	SO4	33,240	13,647	
As	281	56	351	S	8,743	2,849	
Ba	127	24	12,542	Tc		0	
Be	1	1	0.2	Tl	17	14	783
B	150	182	482	Sn	4,072	1,466	
Cd	325	142	1,189	Ti	650	711	
Ca	1,765	1,868	5,630	U	4.62E+01	1.93E-01	
Ce	21	20		V	13	11	6
Cs	42	9		Zn	179	148	126
Cl	2,015	1,308		Zr	101,470	34,867	64,844
Cr	552	949	1,341	Total	467,177	500,167	157,952
Co	9	9	9	TOC			12
Cu	298	166					
F	14,800	4,373			mCi/g	mCi/g	mCi/g
Gd	53	170		Am-241	8.46E-04	2.45E-04	2.11E-04
Fe	4,476	17,967	5,769	Sb-125	5.77E-02	2.90E-03	1.12E-02
Pb	369	274	647	Cs-134	6.64E-03	5.89E-04	7.97E-03
Li	6	4		Cs-137	4.50E+00	8.68E-01	2.44E+00
Mg	410	434		Co-60	2.14E-04		6.30E-04
Mn	565	740	758	Cm-244	2.84E-06		
Hg	310	324	1,566	Eu-154	1.48E-03	7.56E-04	5.43E-04
Mo	2,495	694	2,518	I-129	2.22E-07	9.03E-08	9.51E-04
Ni	309	417	427	Np-237	1.68E-06	1.76E-06	2.85E-06
Nb	1,279	623	5,101	Nb-95			3.68E-03
NO3	70,720	174,955		Pu-238	1.93E-02	4.00E-03	7.56E-03
Pd	5,766	1,444		Pu-239	1.47E-03	1.25E-03	4.30E-04
PO4	97,806	139,740		Sr-90	2.29E-01	1.82E-01	5.46E+00
P	9,586	4,607	16,422	Tc-99	2.63E-03	3.29E-05	4.49E-03
K	7,050	10,900		H-3	1.15E-05		
Ru	829	2,126	273	U-234	2.40E-06	3.30E-06	2.00E-05
Se	91	13	1,720	U-235	2.61E-07	9.29E-08	1.97E-07
Si	43,920	35,344		U-236	3.05E-07	3.40E-08	2.07E-07
Ag	65	220	9	U-238	3.83E-08	6.91E-08	1.18E-07
Na	30,400	21,400					

Weight fractions on an oxide basis were obtained from the concentrations in Table 11, with one assumption regarding for Si, Na, and K concentrations in WM-188 solids. Since these three species, which were not analyzed for in WM-188 samples, were major components of WM-182 and -183 wastes, the weighted average WM-182 and -183 analyses was assumed for WM-188. With this assumption, the oxide composition is shown in Table 12.

Table 12. Oxide composition for WM-182, -183, and -188.

	WM-182	WM-183	WM-188		WM-182	WM-183	WM-188
Al2O3	9.63%	13.09%	18.33%	Nb2O5	0.43%	0.25%	2.00%
Sb2O5	0.00%	0.01%	0.01%	Pd2O3	1.65%	0.49%	0.00%
As2O3	0.09%	0.02%	0.13%	P2O5	17.03%	29.04%	10.31%
BaO	0.03%	0.01%	3.84%	K2O	1.98%	3.65%	3.09%
BeO	0.0007%	0.0007%	0.0002%	Ru2O3	0.24%	0.73%	0.09%
B2O3	0.11%	0.16%	0.43%	SeO2	0.03%	0.01%	0.66%
CdO	0.09%	0.05%	0.37%	SiO2	21.90%	21.03%	21.32%
CaO	0.58%	0.73%	2.16%	Ag2O	0.02%	0.07%	0.00%
CeO2	0.006%	0.007%	0.000%	Na2O	9.55%	8.02%	8.53%
Cs2O	0.010%	0.003%	0.000%	SrO	0.003%	0.004%	0.000%
Cr2O3	0.19%	0.39%	0.54%	Tl2O3	0.004%	0.004%	0.24%
CoO	0.003%	0.003%	0.003%	SnO2	1.20%	0.52%	0.00%
CuO	0.09%	0.06%	0.00%	TiO2	0.25%	0.33%	0.00%
Gd2O3	0.01%	0.05%	0.00%	V2O5	0.01%	0.01%	0.00%
Fe2O3	1.49%	7.14%	2.26%	ZnO	0.05%	0.05%	0.04%
PbO	0.09%	0.08%	0.19%	ZrO2	31.94%	13.10%	24.00%
Li2O	0.003%	0.002%	0.000%	Total	100.00%	100.00%	100.00%
MgO	0.16%	0.20%	0.00%	Cl	0.47%	0.36%	0.00%
MnO	0.17%	0.27%	0.27%	F	3.45%	1.22%	0.00%
MoO3	0.87%	0.29%	1.03%	Hg	0.07%	0.09%	0.64%
NiO	0.09%	0.15%	0.15%	SO4	7.75%	3.80%	0.00%

Estimates of the amount of solids are shown in Table 13.

Table 13. Estimated solids quantities (equivalent inches of sludge).[11]

Tank	Sludge Height	Sludge on Walls	Total Sludge
WM-180 (like WM-182)	4.00	0.50	4.5
WM-181 (like WM-182)	4.00	0.50	4.5
WM-182	4.00	0.50	4.5
WM-183	8.00	0.50	8.5
WM-184 (like WM-182)	4.00	0.50	4.5
WM-185 (like WM-182)	4.00	0.50	4.5
WM-186 (like WM-182)	4.00	0.50	4.5
WM-187 (like WM-188)	0.25	0.25	0.5
WM-188	0.25	0.25	0.5
WM-189 (like WM-188)	0.25	0.25	0.5
WM-190 (empty)	0.00	0.00	0.0
Total	32.75	4.25	37.0

The values shown in Table 13 for WM-182, -183 and -188 are based on video footage obtained during LDUA sampling. Values for the other tanks are estimates with an uncertainty that is likely high but cannot be quantified.

Other assumptions regarding the quantity of heel solids in the tanks are:[11]

1. The sludge is 25 volume percent solids and 75 volume percent liquid.

2. The solids particle density is 2 g/cm^3.

With the above assumptions, the total quantity of heel solids is:

$37\text{-in} * (\pi * 50^2/4)\ ft^2 /12\ in/ft * 0.25 * 7.48\ gal/ft^3 * 3.785\ l/gal * 2\ kg/l = 85{,}700\ kg.$

It should be noted that based on WM-182 and -183 analyses, about 50% of the total solids mass is unaccounted for. This unaccounted for mass is thought to be residual water and water of hydration.

The estimated solids in WM-187 in mid-2005 are shown in Table 14.

Table 14. Estimated solids in WM-187 in March 2005 (inches of sludge).

Tank	Total in Original Tank	Remaining in Original Tank after Wash Ball	Sludge Depth in WM-187
From WM-181	4.5	1.0	3.5
From WM-182	4.5	1.0	3.5
From WM-183	8.5	1.0	7.5
From WM-184	4.5	1.0	3.5
From WM-185	4.5	1.0	3.5
From WM-186	4.5	1.0	3.5
Initial in WM-187	0.5	—	0.5
Total	31.0	6.0	25.5

The total mass of the 25.5 inches of sludge expected to be in WM-187 is:

85,700 kg * 25.5/37 = 59,000 kg.

Solid heels from only three of the tanks have been characterized. Because of the unknown composition of solids in the other tanks, the average heel solids composition was calculated using three different methods. These compositions are shown in Table 15. The first column is based on the arithmetic average of the compositions of the three tanks. The second method is based on the weighting of 8.5 inches of WM-183 solids, 1.5 inches of WM-188-type solids, and 27 inches of WM-182-type solids. This method has the implicit assumption that solids composition is related to the estimated solids depth for the different tanks, i.e., solids of the same depth in different tanks have the same composition. The third column is based on the above table for WM-187 solids, i.e., 7.5 inches of WM-183 solids, 0.5 inches of WM-188 solids, and 17.5 inches of WM-182 solids. Additional sampling, analysis, and modeling are needed to provide a better overall average solids composition. However, a rough estimate of the possible composition range can be seen by comparing the three columns in Table 15.

Table 15. Average heel solids compositions derived using three different methods.

	Arithmetic Average	Wt'd Based on 37-in	Wt'd Based on 25.5-in		Arithmetic Average	Wt'd Based on 37-in	Wt'd Based on 25.5-in
g oxide/g solids	0.382	0.405	0.402	g oxide/g solids	0.382	0.405	0.402
Al2O3	13.68%	10.78%	10.82%	Nb2O5	0.89%	0.45%	0.40%
Sb2O5	0.01%	0.01%	0.01%	Pd2O3	0.71%	1.31%	1.27%
As2O3	0.08%	0.07%	0.07%	P2O5	18.79%	19.52%	20.43%
BaO	1.29%	0.18%	0.10%	K2O	2.91%	2.41%	2.49%
BeO	0.001%	0.001%	0.001%	Ru2O3	0.35%	0.35%	0.38%
B2O3	0.23%	0.14%	0.13%	SeO2	0.23%	0.05%	0.03%
CdO	0.17%	0.09%	0.08%	SiO2	21.41%	21.67%	21.63%
CaO	1.15%	0.67%	0.65%	Ag2O	0.03%	0.03%	0.03%
CeO2	0.004%	0.01%	0.01%	Na2O	8.70%	9.16%	9.08%
Cs2O	0.004%	0.01%	0.01%	SrO	0.002%	0.003%	0.003%
Cr2O3	0.37%	0.25%	0.25%	Tl2O3	0.08%	0.01%	0.01%
CoO	0.003%	0.003%	0.003%	SnO2	0.57%	1.00%	0.98%
CuO	0.05%	0.08%	0.08%	TiO2	0.19%	0.26%	0.27%
Gd2O3	0.02%	0.02%	0.03%	V2O5	0.005%	0.01%	0.01%
Fe2O3	3.63%	2.82%	3.17%	ZnO	0.05%	0.05%	0.05%
PbO	0.12%	0.09%	0.09%	ZrO2	23.01%	27.29%	26.24%
Li2O	0.002%	0.003%	0.003%	Total	100.00%	100.00%	100.00%
MgO	0.12%	0.16%	0.17%	Cl	0.28%	0.43%	0.43%
MnO	0.23%	0.20%	0.20%	F	1.56%	2.80%	2.72%
MoO3	0.73%	0.75%	0.70%	Hg	0.27%	0.10%	0.09%
NiO	0.13%	0.11%	0.11%	SO4	3.85%	6.52%	6.43%

3.2 Suspended or Entrained Solids

Some tank liquid samples contain small amounts of solids, often referred to as "undissolved solids" or UDS. These may be suspended solids, or they may include heel solids entrained during jetting liquid from tanks. Table 16 shows the estimated quantity of these solids.

Table 16. Estimated amounts of UDS in tanks.

Tank[a]	UDS Concentration (g/liter)	Volume (gallons)[b]	Suspended Solids (kg)
WM-180	0.63[c]	278,600	664
WM-181	0.17[c]	275,900	178
WM-184	1.61[d]	262,600	1,600
WM-185	4.8[c]	20,600	374
WM-186	5.05[d]	281,500	5,381
WM-187	1.99[d]	48,300	364
Total[a]		1,167,500	8,561

a. Contribution of tanks not listed are negligible, because their liquid volumes are at or near heel level.
b. Volumes as of July 1999 as taken from Excel file "Tank Farm Composition Database" (Reference 4).
c. From *Compositions of Wastes in Tank Farm*.[12]
d. From *Tank Farm Inventory – June, 1994*.[13]

The average composition of the UDS was estimated by Arlin Olson primarily based on data contained in *Historical Tank Farm Sample Results*.[14] Table 17 shows this estimated composition, and Table 18 shows the average UDS composition converted to oxides.

Table 17. Estimated average composition of UDS.

	Wt%	Likely Forms
Al	2.01%	$AlPO_4$
B	3.34%	B_2O_3
Ca	1.02%	CaF_2
Cr	0.26%	Cr_2O_3
Fe	2.79%	$FePO_4$-$2H_2O$
Hg	0.66%	$HgCl_2$
K	1.79%	$KNbO_3$
Mn	0.44%	KCl
Na	4.88%	MnO_2
Nb	0.17%	NaCl
Ni	1.64%	NaF
Si	4.58%	Na_3PO_4
Zr	15.62%	NiO
Cl	3.05%	SiO_2
F	2.98%	ZrO_2
PO_4	14.07%	$Zr(SO_4)_2$-$4H_2O$
SO_4	16.45%	
H_2O	7.97%	
O	16.29%	
	100.00%	

Table 18. Average UDS composition converted to oxides.

	Wt%
Al_2O_3	5.17
B_2O_3	14.64
CaO	1.94
Cr_2O_3	0.51
Fe_2O_3	5.43
K_2O	2.94
MnO_2	0.94
Na_2O	8.94
Nb_2O_5	0.34
NiO	2.83
SiO_2	13.32
ZrO_2	28.70
P_2O_5	14.30
Total	100.00
Cl	4.14
F	4.05
SO_4	22.37
Hg	0.90

4. EXPECTED REVISIONS AND UNCERTAINTIES

The SBW treatment facility feed composition will be updated as new data are received. In the near term, expected new data include:

1. Analyses of both liquid and UDS samples from tank WM-180

2. Updated compositional data for NGLW streams

3. Evaluations based on glass formulations that could indicate the need for additional tank transfers

4. The revised and issued *INTEC Waste Management Through 2070* report, which may contain changes from the draft document.

Uncertainties are present in some of the compositions shown in this document due to inadequate analyses or unverified assumptions. These include:

- The amount and composition of tank heel solids contain major uncertainties.

- The basis for some of the NGLW stream compositions is inadequate for chemical composition, radiological composition, or both.

- Volumes of flush water that will be used in tank closure activities are uncertain and could affect the proportions of different wastes in the different tanks.

- Concentrations of UDS in some tanks are uncertain, and whether the UDS are entrained heel solids or suspended solids with different properties and compositions is unknown.

- The assumed degree of concentration of NGLW in the PEWE and Tank Farm wastes in the HLLWE needs to be updated based on ASPEN simulations and new NGLW compositional data.

5. REFERENCES

1. W. B. Palmer, W. B. McNaught, C. B. Millet, M. D. Staiger, F. S. Ward, *INTEC Waste Management Through 2070*, INEEL/EXT-2000-01005, Draft, September 9, 2000.

2. C. B. Millet, Excel Spreadsheet, “FY2000 CsIX of SBW,” August 28, 2000.

3. C. B. Millet, Excel Spreadsheet, “FY2000 Direct Vit of SBW,” August 31, 2000.

4. C. B. Millet, Excel Spreadsheet, “Tank Farm Composition Database Working Copy,” May 10, 2000.

5. D. R. Wenzel, *Calculation of 1999 Radionuclide Inventory for Sodium Bearing Waste*, Wen-20-99, May 18, 1999.

6. J. L. Tripp, *Supporting Information for the INEEL Liquid Waste Management Plan*, *Appendix B*, INEEL/EXT-98-00730, July, 1998.

7. R. E. Schindler, *Management of HLLWE Condensates*, Schi-21-98, September 23, 1998.

8. C. M. Barnes, “Tank Farm Facility Solids Storage Tank Process Development,” Engineering Design File EDF-TST-005, October 18, 2000.

9. C. M. Barnes, *Transmittal of Process Basis Information for the Feasibility Study of the Preferred Alternative for Treatment of ICCP Sodium-Bearing Wastes, Calcine and Low-Level Wastes*, Appendix B, CMB-01-97, April 16, 1997.

10. R. A. Wood, *Updated Aluminum Nitrate/WM-189 Blend Calculations for 500°C and 600°C Operations During NWCF RUN H4*, RAW-01-00, February 14, 2000.

11. A. Poloski, “Solids Characterization,” Engineering Design File EDF-TST-001, September 20, 2000.

12. R. E. Schindler, *Compositions of Wastes in Tank Farm*, Schi-4-99, February 11, 1999.

13. K. J. Rebish and J. A. Nenni, *Tank Farm Inventory – June, 1994*, KJR-02-94/JAN-03-94, June 23, 1994.

14. M. C. Swenson, *Historical Tank Farm Sample Results*, MCS-27-92, December 17, 1992.