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**ANALYSIS OF TANK 48H SAMPLES
HTF-E-04-049 AND HTF-E-04-050
(AUGUST 23, 2004)**

D. P. Lambert
T. B. Peters
M. J. Barnes
S. D. Fink

| May 2005

Waste Processing Technology Section
Savannah River National Laboratory
Aiken, SC 29808

Prepared for the U.S. Department of Energy Under Contract Number
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SRNL
SAVANNAH RIVER NATIONAL LABORATORY

REVIEWS AND APPROVALS

AUTHORS

D. P. Lambert, author

5-12-05

Date



T. B. Peters, coauthor

5-12-2005

Date

DESIGN CHECK (per Manual E7, Procedure 2.40)

M. S. Hay

5-13-05

Date



M. E. Stallings

5-12-2005

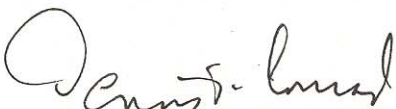
Date

APPROVALS

B. C. Rogers, Technology Manager for Tank 48H

5/20/05

Date



D. T. Conrad, Manager, Low Curie Salt Engineering

5/23/05

Date



S. D. Fink, Manager, Liquid Waste Processing Group

5-19-2005

Date



J. C. Griffin, Manager, Waste Processing Technology Section

5/20/05

Date

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LIST OF ACRONYMS

1PB	phenylboronic acid
2PB	diphenylborinic acid
3PB	triphenylborane
4PB	tetraphenylborate anion – $[\text{B}(\text{C}_6\text{H}_5)_4]^-$
AA	Atomic Absorption
ADS	Analytical Development Section
CsTPB	Cesium tetraphenylborate ($\text{Cs}[\text{B}(\text{C}_6\text{H}_5)_4]$)
FW	Formula Weight
HPLC	High Performance Liquid Chromatography
IC	Ion Chromatography
ICP-ES	Inductively Coupled Plasma – Emission Spectrometry
ICP-MS	Inductively Coupled Plasma – Mass Spectroscopy
ITP	In-Tank Precipitation
KTPB	potassium tetraphenylborate – $\text{K}[\text{B}(\text{C}_6\text{H}_5)_4]$
MST	monosodium titanate
MW	Molecular Weight
NA	Not Applicable
NM	Not Measured
NaTPB	Sodium tetraphenylborate – $\text{Na}[\text{B}(\text{C}_6\text{H}_5)_4]$
SRNL	Savannah River National Laboratory
TPB	Tetraphenylborate - $[\text{B}(\text{C}_6\text{H}_5)_4]^-$
WPTS	Waste Processing Technology Section

1.0 EXECUTIVE SUMMARY

Personnel analyzed samples taken from Tank 48H, on August 23, 2004, for chemical and radiological constituents. This report documents the analytical results and analysis of this data.

- The measured potassium tetrphenylborate (KTPB) concentration is 1.95 ± 0.22 wt %.
- The calculated monosodium titanate (MST) concentration is 0.15 ± 0.015 wt % MST.
- The measured insoluble solids content was 1.69 ± 0.22 wt %. The sum of KTPB and MST is 24% higher than the insoluble solids concentration. The insoluble solids result is lower than the tank based on previous Tank 48H analyses.
- The free hydroxide concentration in the Tank 48H filtrate sample (1.16 ± 0.007 M) is greater than the Tank 48H limit (1.0 M). This is an increase of 0.37 M since the September 2003 sample due to the addition of 6,424 gallons of 50 wt % sodium hydroxide to Tank 48H on October 30, 2003.
- The soluble potassium content in the filtrate continues to follow the linear trend that began in 1995 showing slow, radiolytic decomposition of the tetraphenylborate solids.
- The measured ^{137}Cs concentration is $9.05\text{E}+08 \pm 1.07+07$ dpm/mL (1.54 Ci/gallon) in the slurry and $2.57\text{E}+07 \pm 6.01\text{E}+04$ dpm/mL in the filtrate. This is equivalent to 367,000 total ^{137}Cs curies in Tank 48H. The ^{137}Cs does not follow the earlier linear trend.
- The measured Total Alpha concentration is $1.01\text{E}+04 \pm 6.51\text{E}+02$ dpm/mL in the slurry and $2.00\text{E}+03 \pm 3.891\text{E}+02$ dpm/mL in the filtrate. This is equivalent to 4.13 total curies from alpha emitters in Tank 48H.
- Three tetraphenylborate decomposition products, triphenylborane (3PB), diphenylborinic acid (2PB), phenylboronic acid (1PB), were all detected in the slurry but not in the filtered sample.

The more significant analytical data is summarized in Table 1.

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Table 1 – Summary of Significant Tank 48H Sample Results

Analyte	Slurry	Supernate	Source
Volume, gal	239,031	N/A	Tank 48H
Density, g/mL	1.162	1.164	Density
Total Solids, wt %	19.08%	17.68%	Solids
Total Insolubles, wt %	1.69%	NM	Calculation
KTPB, wt %	1.95%	<0.001%	HPLC
MST solids, wt %	0.15%	NM	ICP-ES
Metals			
Sodium, M	3.26	2.99	ICP-ES
Potassium, M	0.068	0.0065	AA
Anions			
Free Hydroxide, M	NM	1.155	Titration
Carbonate, M	NM	0.492	Titration
Nitrite, M	NM	0.649	Anion
Nitrate, M	NM	0.304	Anion
RadChem			
^{137}Cs , dpm/mL	9.05E+08	2.57E+07	RadChem
Total Alpha, dpm/mL	1.01E+04	2.00E+03	RadChem

NM=Not Measured

2.0 INTRODUCTION

Due to the need for additional HLW storage, successful disposition of the material in Tank 48H and return of the tank to routine service are two critically needed activities.¹ As an initial step in the process, SRNL compositionally characterized the components of the Tank 48H slurry. A nominal Tank 48H Tank 48H slurry sample was collected on August 23, 2004 (HTF-E-04-049 and HTF-E-04-050). The August 23, 2004 sample contained approximately 2 Liters of Tank 48H slurry.

This document provides the chemical and radiological properties of a Tank 48H slurry sample. A Technical Task Request defines the required analyses². A Task Plan summarized the analyses required and the methods for completing these analyses³. The Tank 48H volume was 239,000 gallons (68.2 inches) at the time of the sampling.

5-L Sample Vessels

The Tank 48H team requested collection of two five-liter samples of Tank 48H slurry material after a minimum of 24 hours of slurry pump operations and immediately after pump shutdown. Sample collection utilized a sampler fabricated by Salt Works.

The total volume of the sampler is 6.54 liters with a liquid fill volume of 4.95 liters. The sample enters the 5-Liter vessel through the inlet port located on the top of the sampler. A crane lowered the sampler approximately 18 inches below the liquid surface. Once filled, the crane raised the sampler to the surface and capped the sampler. The sampler was washed, pulled to the top of the tank, and radiation rates monitored by Radiological Control inspector to confirm the presence of material in the sampler prior to placement in the 8-ton cask.⁴

Collection of the Tank 48H sample occurred on August 23, 2004 by lowering the uncapped 5-L sampler into Tank 48H. Personnel pulled sample HTF-E-04-0049 within 2 minutes of shutting down all four slurry pumps and following 11 hours of continuous operation at full speed (1180 rpm). The four slurry pumps were restarted and operated for an additional 2 continuous hours at full speed (1180 rpm). Personnel pulled sample HTF-E-04-0050 within 8 minutes of shutting down all four slurry pumps. Data concerning the pump operational times, Tank 48H volume, and seal leakage estimates are summarized in Appendix A.

3.0 EXPERIMENTAL DETAILS

Operations shipped two samples to SRNL. Personnel placed the two samplers (HTF-E-03-127) into the shielded cells on August 24, 2004. Technicians emptied the sample vessels, on August 25, 2004, by pumping the contents of the sampler into the calibrated 15-L polypropylene carboy using a peristaltic pump with ¼ inch Tygon[®] tubing. The sample was later transferred to a 4-L carboy. Researchers recovered 1.9 L of slurry from the two samplers. The samplers were sealed after emptying.

3.1 PREPARATION OF SLURRY SAMPLES

Personnel diluted the slurry samples as required for analyses. Analysis of all slurry samples occurred in duplicate. Dilution used deionized water while digestion used an acid/hydrogen

peroxide solution to destroy the organic, dissolve the metals and dilute the samples. Table 2 summarizes the slurry samples submitted for analysis.

Table 2 – Listing of Requested Slurry Analyses and Dilutions

OPERATION	Samples	Sample Volume, mL	Dilution Volume, mL	Diluent	Tk 48 Volume, mL
HLC-DENSITY	2	2	0	None	4
DISSOLVED SOLIDS (B101)	2	3	0	None	6
TOTAL SOLIDS (B101)	2	3	0	None	6
HPLC (B123)	2	2	8	DI Water	4
Gross Alpha (B145)	2	0.5	Nitric acid Prep in Cells		1
GAMMA SPEC (B145)	2	0.1			0.2
CVAA HG (B143)	2	1			2
RAD K by AA	2	1			2
RAD ICP-ES LCS (B151)	2	1			2
RADICPMS (B067)	2	1			2

3.2 PREPARATION OF FILTERED SAMPLES

Personnel filtered approximately 60 mL of slurry to produce approximately 50 mL of filtrate for analysis. Technicians removed a portion of the slurry from the 4-L carboy and filtered it using a 0.45 μm supported acrylic copolymer disc filter. They prepared sub-samples from this filtrate without dilution and submitted for analysis as summarized in Table 3.

Table 3 – Listing of Requested Filtrate Analyses

OPERATION	Samples	Sample Volume, mL	Dilution Volume, mL	Diluent	Tk 48 Volume, mL
DISSOLVED SOLIDS (B101)	2	1	0	None	2
HPLC (B123)	2	2	0	None	4
IC ANIONS LCS (B134)	2	1	0	None	2
Gross Alpha (B145)	2	0.1	9.9	.1 M Nitric	0.2
GAMMA SPEC (B145)	2	0.1	9.9	.1 M Nitric	
RAD ICP-ES LCS (B151)	2	2	8	.1 M Nitric	4
RAD K by AA	2	2	8	.1 M Nitric	4
CARBONATE (B154)	2	1	0	None	2
T BASE/OH/OTHER BASE EXC CO ₃ (B154)	2	1	0	None	2

3.3 IN-CELL ANALYSES

Personnel performed two analyses, each in duplicate, in Shielded Cell Block B to minimize the dose to analytical personnel. Personnel gravimetrically determined the density of the slurry, and gravimetrically determined the total and insoluble solids concentration of the slurry. Note that insoluble solids are defined as those solids that can be removed by filtration, soluble solids are those solids that can not be filtered, and total solids are a sum of the two. These results are reported in wt % solids on a slurry basis.

Personnel gravimetrically determined the density of the slurry at ambient Shielded Cells temperature using 2 mL Class A micro-volumetric flasks.

Technicians gravimetrically determined the total solids by drying portions of the sample to constant mass at 100 ± 5 °C. They used duplicate analysis of a nominal 15 wt % NaCl standard, slurry sample and the filtered filtrate to measure total solids and dissolved solids in the Tank 48H material. Technicians pre-weighed clean, dry Pyrex™ beakers for each analysis. Personnel mixed the samples thoroughly, removed ~3 mL aliquots, and delivered to each beaker (i.e., 3 mL of the 15 wt % NaCl standard to beakers 1-2, 3 mL of Tank 48H slurry sample to beakers 3-4 and, and 3 mL of Tank 48H filtrate to beakers 5-6). Personnel weighed each beaker with sample immediately after addition then proceeded to dry the samples in a 100-115 °C oven for 8 hours. Samples cooled in a dessicator for 15 min before additional-weighing. Technicians repeated the drying cycle 3 additional times to ensure complete drying.

4.0 EXPERIMENTAL RESULTS

ADS personnel completed the analyses between September 1, 2004 and October 21, 2004. The slurry results are generally reported as mg/L of slurry. The filtrate results are reported as mg/L filtrate. To convert the filtrate results to a slurry basis, multiply filtrate result, in mg/L, by 0.981*. This correction is necessary to compare the filtrate and slurry results to determine the insoluble solids concentration. The results are reported in this section and discussed in Section 5.0, Analysis of Data.

4.1 ADS SLURRY SAMPLE RESULTS

ADS personnel analyzed the diluted or digested slurry in duplicate. We report the analytical data, together with the one standard deviation (1σ) uncertainty.

4.1.1 High Performance Liquid Chromatography

HPLC analysis is used to detect TPB, phenylborates (3PB, 2PB, and 1PB), phenol, and other TPB decomposition products. HPLC analysis of a Tank 48H slurry sample provided detectable quantities of TPB, triphenylborane (3PB), diphenylborinic acid (2PB), phenylboronic acid (1PB) nitrobenzene, phenol and biphenyl (Table 4). Less than detectable quantities (<50 mg/L) of nitrosobenzene, 4-phenylphenol, 2-phenylphenol, diphenylamine, o-terphenyl, m-terphenyl, and p-terphenyl existed. The KTPB concentration is 22,600 mg/L or 1.95 ± 0.22 wt % assuming all the TPB is present as KTPB.

The prior Tank 48H sample (September 2003) did not have a detectable concentration of 3PB, 2PB or 1PB (each has a detection limit of <50 mg/L after accounting for the dilution necessary to move samples from the shielded cells to ADS for analysis). A reanalysis of the slurry confirmed the presence of the phenylborate intermediates.

* This factor is the ratio of filtrate mass (mg/L) to Slurry mass (mg/L). It is calculated by the following formula: filtrate correction factor = density slurry/density filtrate*(1-insoluble solids) = $1.162/1.164*(1-0.0169) = 0.981$

Table 4 – HPLC Slurry Results for the Tank 48H sample

Analyte	Sample HTF-E-04-049 and HTF-E-0050 (mg/L)	1 σ Uncertainty (mg/L)
TPB	20,100	235
Calculated KTPB	22,600	263
Phenol	735	24.0
Biphenyl	384	61.4
3PB	162	35.0
2PB	123	6.1
1PB	120	5.6

Analytical uncertainty is 10% for all analytes except biphenyl (20%)

4.1.2 Radionuclide Composition

Many of the radioisotopes are measured using ICP-MS methods. However, personnel determined ^{90}Sr , ^{137}Cs and gross alpha by radio-counting analyses for the Tank 48H slurry – see Table 5. The major radiation hazard in Tank 48H comes from the ^{137}Cs , with a concentration of 1.54 Ci/gallon. This is equivalent to 367,000 total ^{137}Cs curies in Tank 48H. The gross alpha analysis is used to calculate 4.13 total curies from alpha emitters in Tank 48H.

Table 5 – Tank 48H Slurry Radiation Chemistry Analytical Results

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
^{137}Cs (dpm/mL)	9.05E+08	1.07E+07
Gross Alpha (dpm/mL)	1.01E+04	6.51E+02

4.1.3 Inductively Coupled Spectroscopy – Emission Spectroscopy

Personnel determined the elemental composition of the digested slurry by ICP-ES. The major constituents found in the slurry include Na, K, Al, and B. The element sodium is present in the highest concentration at $74,900 \pm 660$ mg/L (3.26 ± 0.029 M). Aluminum and boron are present in appreciable levels. Elements measured below instrument detection limits include Ag, Be, Cd, Gd, La, Ni, Pb, V, and Zr. The elemental results of the Tank 48H slurry sample are presented in Table 6.

Table 6 – Major Elemental Constituents by ICP-ES in the Tank 48H Slurry Sample

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
Al	2,240	0.00
B	1,030	1.64
Ba	2.52	0.03
Ca	21.4	1.23
Ce	6.89	0.11
Cr	51.1	0.16
Cu	2.97	0.16
Fe	43.4	0.16
K	2,380	16
Mg	18.5	0.25
Mn	6.38	0.06
Mo	13.30	0.08
Na	74,900	657
P	207	4.93
S	245	1.64
Sb	11.5	0.16
Si	106	0.99
Sn	22.1	2.05
Sr	5.29	0.17
Ti	840	0.82
U	17.6	0.74
Zn	12	0.08

4.1.4 Inductively Coupled Spectroscopy – Mass Spectroscopy

SRNL performed three analyses of the Tank 48H slurry for actinides (with one of the samples analyzed at two different dilutions). The replicate samples showed excellent precision (Table 7). ²⁴⁰Pu, ²⁴¹Am, ²⁴³Am, and ²⁴⁴Cm are all less than the detection limits. ²³⁸Pu can not be detected by this analytical method.

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Table 7 – Actinide Results for the Slurry Sample

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
Np-237, mg/L	2.22E-01	8.09E-03
Pu-239, mg/L	3.33E-02	5.55E-03
U-233, mg/L	6.13E-02	7.39E-03
U-234, mg/L	3.25E-01	1.94E-02
U-235, mg/L	6.53E-01	4.43E-02
U-236, mg/L	1.44E-01	4.85E-03
U-238, mg/L	4.12E+00	2.24E-01
U Total, mg/L	5.31E+00	2.89E-01

We analyzed a slurry sample for metals (Ag, Pd, Rh, and Ru). The elemental results of the Tank 48H slurry sample are presented in Table 8.

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Table 8 – ICP-MS Catalytic Components Present in the Tank 48H Slurry Sample

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
Total Ag, mg/L	1.88E-02	2.12E-03
Total Pd, mg/L	9.28E-02	6.78E-03
Total Rh, mg/L	1.53E-01	1.61E-02
Total Ru, mg/L	3.80E-01	8.43E-03

4.1.5 Atomic Absorption Spectroscopy

Personnel determined the elemental composition of the digested slurry by AA for K only. The element potassium is present in $2,650 \pm 184$ mg/L (0.068 ± 0.0047 M).

4.2 FILTRATE SAMPLE RESULTS

ADS personnel analyzed the filtrate in duplicate for the Tank 48H sample. Personnel removed samples of the Tank 48H filtrate from the cells without dilution. ADS personnel diluted the filtrate as appropriate for the analyses. We report the analytical data, together with the one standard deviation (1σ) uncertainty. To compare the slurry results with the filtrate results, multiply filtrate results by 0.982 to convert them to a slurry basis. Note that a filtrate sample has been filtered to remove insoluble solids and a supernate sample has been pulled from an unslurried tank but has not been filtered. It is expected that supernate results from previous samples would have slightly higher insoluble solids concentrations.

4.2.1 Anion Analysis by Ion Chromatography

Table 9 and Table 10 contain the measured values of the Tank 48H filtered sample. Table 9 includes the measured anion concentrations for the tank sample. Nitrate and nitrite concentrations are 0.216 M and 0.465 M respectively.

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Table 9 – Anion Results for the Filtered Tank 48H sample, mg/L

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
F ⁻	<20	NA
CO ₂ H ⁻	680.0	428
Cl ⁻	370	183
NO ₂ ⁻	30,400	1,800
Br ⁻	<100	NA
NO ₃ ⁻	18,750	926
PO ₄ ³⁻	916	222
SO ₄ ²⁻	528	210
C ₂ O ₄ ²⁻	1613	116

For comparison, Table 10 contains the measured values from this Tank 48H sample, but also other recent measurements.

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Table 10 – Comparison of Filtrate Anion Values, Molarity

Anion	HTF-E-04-049 and HTF-E-0050 Aug 04	HTF-E-03-127 Sept 03	HTF-E-03-73 June 03
NO ₃ ⁻	0.304	0.216	0.22
NO ₂ ⁻	0.649	0.465	0.45
SO ₄ ²⁻	0.00643	0.00285	0.005
Cl ⁻	0.0127	0.00351	0.005
HCO ₂ ⁻	0.0192	0.0096	0.009
PO ₄ ³⁻	0.0102	0.00542	0.016
C ₂ O ₄ ²⁻	0.0183	0.0123	0.023

4.2.2 High Pressure Liquid Chromatography

ADS completed analysis of the Tank 48H filtrate for tetraphenylborate and 14 of its common decomposition products. Only phenol at 526 ± 2.47 mg/L occurs above the detection limit. Nitrobenzene, Nitrosobenzene, 4-phenylphenol, 2-phenylphenol, diphenylamine, biphenyl, o-terphenyl, m-terphenyl, p-terphenyl, TPB, 3PB, 2PB, and 1PB all fell below detection limits (10 mg/L).

4.2.3 Wet Chemistry

ADS personnel analyzed the filtrate samples using titration methods, carbon analyses and density measurements. The total base is 2.04 ± 0.071 M, the free hydroxide is 1.16 ± 0.007 M, other base is 0.185 ± 0.004 M, and carbonate is 0.492 ± 0.001 M.

The free hydroxide concentration (1.16 M) has increased since the September 2003 sample (0.790 M) due to the addition of sodium hydroxide in October 2003.

The shielded cells technicians measured the Tank 48H filtrate density as 1.164 ± 0.001 g/mL.

The total solids concentration of the Tank 48H filtrate was $17.68\% \pm 0.14$ wt %. The total solids concentration of the Sept 2003 filtrate was 16.28 ± 0.269 wt %.

4.2.4 Radionuclide Composition

ADS personnel analyzed the filtered sample using radio-analytical methods. Cesium (^{137}Cs) is the major radioactive analyte in the filtrate at a concentration of $5.22 \text{ E} +05$ nCi/g. Table 11 summarizes the radionuclide concentrations. Other isotopes were not analyzed. Table 12 provides a comparison with previous sample results.

Table 11 – Tank 48H Filtrate Radiation Chemistry Data

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
^{137}Cs (dpm/mL)	2.57E+07	6.01E+04
Gross Alpha (dpm/mL)	2.00E+03	3.89E+02

Table 12 – Radionuclide Comparison with Previous Samples

Sample ID Radiochemical Analysis	Sample HTF-E-04-049 and HTF-E-0050	HTF-E-03-127 3-L sample Sept. 2003	HTF-E-03-73 June 2003	Previous Sample Measurements
^{137}Cs (nCi/g)	9.95 E+03	1.08 E+04	1.12 E+04	1.50 E+04 [Ref. 6]
^{90}Sr (mg/L)	Not Measured	7.12 E-06	8.59E-06	<2.44 E-06 [Ref. 8]
^{99}Tc (mg/L)	Not Measured	2.26 E+00	1.15 E+00	1.85 E+00 [Ref. 8]

4.2.5 Atomic Absorption Spectroscopy

ADS analyzed the filtered samples for potassium using atomic absorption spectroscopy. The K concentration of the Tank 48H filtrate was 255 ± 24.7 mg/L.

4.2.6 Inductively Coupled Spectroscopy – Emission Spectroscopy

ADS determined the elemental composition of the filtrate by the ICP-ES method. The major constituents found in the filtrate included Na, Al, and B. The element sodium is present in the highest concentration at 2.81 M. Aluminum and boron are present in appreciable levels. Elements measured below instrument detection limits include Ag, Ba, Cd, Ce, Fe, Gd, La, Li, Mg, Mn, Ni, Pb, Sn, Ti, U, and Zr. Table 13 provides the elemental results of the Tank 48H filtrate samples. Table 14 provides a comparison with historical data.

Table 13 – Tank 48H Filtrate ICP-ES Data

Analyte	Sample HTF-E-04-049 and HTF-E-0050	1 σ Uncertainty
B, mg/L	412	12.7
Cu, mg/L	1.014	0.221
K, mg/L	372.5	53.0
Na, mg/L	68,800	2,263
Si, mg/L	4.675	0.361

Table 14 – Major Elemental Constituents Present in the Tank 48H Filtrate Sample

Sample ID Analysis	Units	Sample HTF-E-04-049 and HTF-E-0050	HTF-E-03-127 3-L sample	HTF-E-03-73 Tk 48-2L-1	1998 Analyses ⁵
ICP-ES					
Al	M	Not Measured	0.0808	0.074	0.082
B	M	0.038	0.0410	0.041	0.034
Na	M	2.99	3.012	2.81	2.56
S	M	Not Measured	0.00872	0.01	NM
K	M	0.010	0.00633	0.01	NM
AA					
K	M	0.0065	0.00550	0.005	0.0004
Cs	M	Not Measured	2.88E-06	3.61E-06	NM

4.3 IN-CELL SLURRY SAMPLE RESULTS

Personnel performed analyses in the cells, because of the high radiation dose of the sample. Solids analyses, slurry titration and density analyses were completed in duplicate. These analytical data are summarized together with the one standard deviation (1σ) uncertainty.

4.3.1 In-cell Solids Analyses

Based on the average of three analyses, the slurry contained total solids of $19.08 \pm 0.08\%$ and the filtrate contained dissolved solids of $17.68 \pm 0.14\%$. We calculate the value for the insoluble solids (1.69 ± 0.22 wt %) using the following formula.⁶

$$\text{Insoluble Solids} = \frac{\text{total solids} - (100 - \text{total solids}) * \text{dissolved solids}/100}{\text{dissolved solids}/100}$$

$$\text{Insoluble Solids} = 19.08 - (100 - 19.08) * 17.68/100 / (1 - 17.68/100) = 1.69$$

Based on this calculation, the insoluble solids measurement was significantly lower than expected results based on previous analyses (2.3%).⁷ The insoluble solids measurement has a range of 1.47 wt% to 1.91 wt% based on the calculated uncertainties. This overlaps with the sum of the measured KTPB plus MST concentration which has a range of 1.86 wt % to 2.34 wt %.

4.3.2 In-cell Density

Technicians determined density from the average of duplicate measurements of the Tank 48H slurry. Based on these measurements, the density of the Tank 48H slurry equals 1.16 ± 0.009 g/mL.

5.0 ANALYSIS OF DATA

Completion of an anion and cation balance provides a consistency check on the data. By comparing filtrate potassium and cesium concentrations, one can obtain an understanding of the decomposition rate for the tetraphenylborate in Tank 48H.

5.1 TANK 48H ION BALANCE

The sum of the major cations exceeds the sum of the major anions by ~8%, well within the accuracy typically experienced for such analyses. Table 15 sums the anions and cations using the filtrate analyses for the major components.

Table 15 – Tank 48H Filtrate Anion/Cation Balance

Analyte	Moles ions	1 σ Uncertainty, moles	Method
AlO ₂ ⁻	0.083	0.0000	ICP-ES
BO ₃ ³⁻	0.286	0.0005	ICP-ES
C ₂ O ₄ ²⁻	0.037	0.0013	IC
Cl ⁻	0.010	0.0026	IC
COOH ⁻	0.015	0.0048	IC
CO ₃ ²⁻	0.932	0.0007	Titration
NO ₂ ⁻	0.661	0.0320	IC
NO ₃ ⁻	0.302	0.0124	IC
OH ⁻	1.155	0.0071	Titration
PO ₄ ³⁻	0.029	0.0012	IC
SO ₄ ²⁻	0.011	0.0011	IC
Total Anions	3.52	0.064	Calculation
K ⁺	0.007	0.0047	AA
Na ⁺	3.259	0.0286	ICP-ES
Total Cations	3.27	0.033	Calculation

5.2 TANK 48H SOLUBLE POTASSIUM AND CESIUM

The tetraphenylborate in Tank 48H continues to slowly decompose. As the tetraphenylborate decomposes, cesium and potassium are released from the insoluble solids and return to solution. As a result, the concentrations of cesium and potassium continue to increase over time. Data exist for the soluble cesium and potassium concentrations in the filtrate for the last eight years. Figure 1 and Figure 2 provide the measured values, with 10% error bars. Note that we corrected the data for changes in Tank 48H volume (normalizing to the volume as of 240,000, the volume on 11-3-96) and ¹³⁷Cs radioactive decay.

Based on the potassium data, the tetraphenylborate apparently continues to degrade at the same rate as experienced since 1996. The potassium data, shown on Figure 1, fits a linear curve ($r^2=0.993$) almost as well as a 2nd order polynomial ($r^2 = 0.995$). The ¹³⁷Cs data, shown on Figure 2, is no longer following the straight line. A better fit of the ¹³⁷Cs data fit is a 2nd order polynomial curve ($r^2 = 0.993$) better than a linear curve ($r^2 = 0.90$). The drop in ¹³⁷Cs concentration could be caused by establishment of a new equilibrium due to decomposition or to the increase in ionic strength causing precipitation of cesium (due to the depletion of hydroxide followed by addition of sodium hydroxide to control corrosion).

Figure 1 – K Soluble Concentration Increase Due to KTPB Decomposition
(K Data volume corrected to 240,000 gallons in Tank 48H)

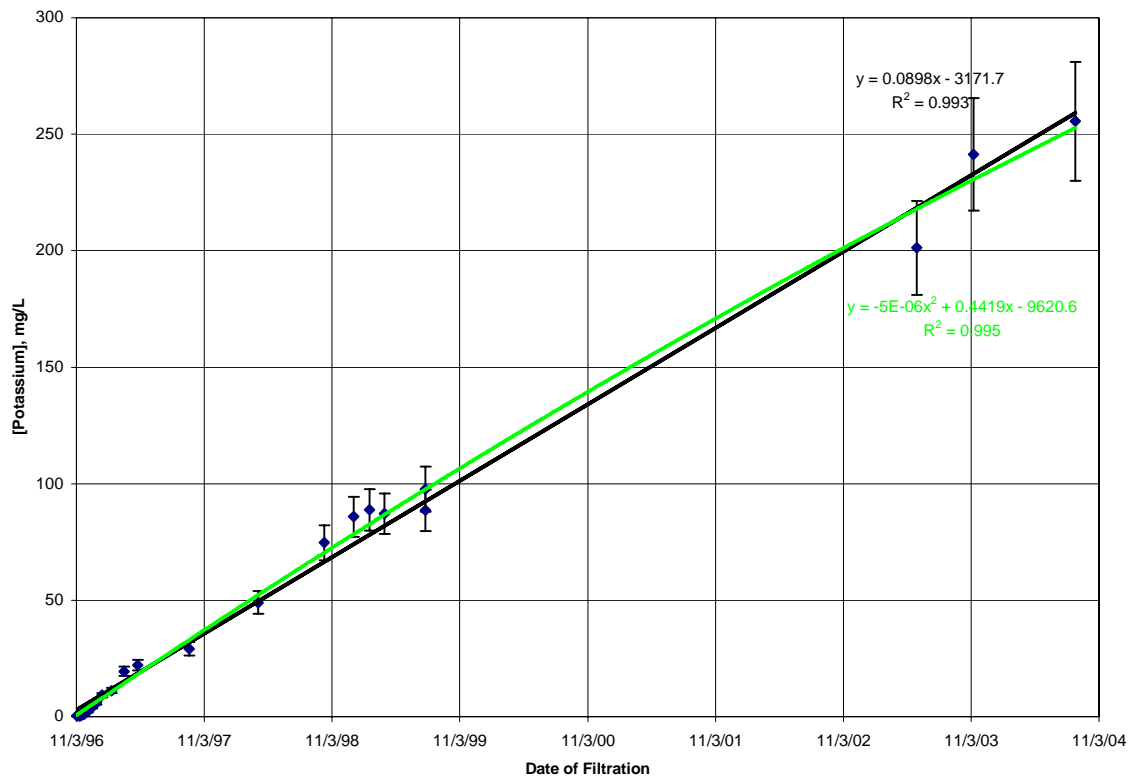
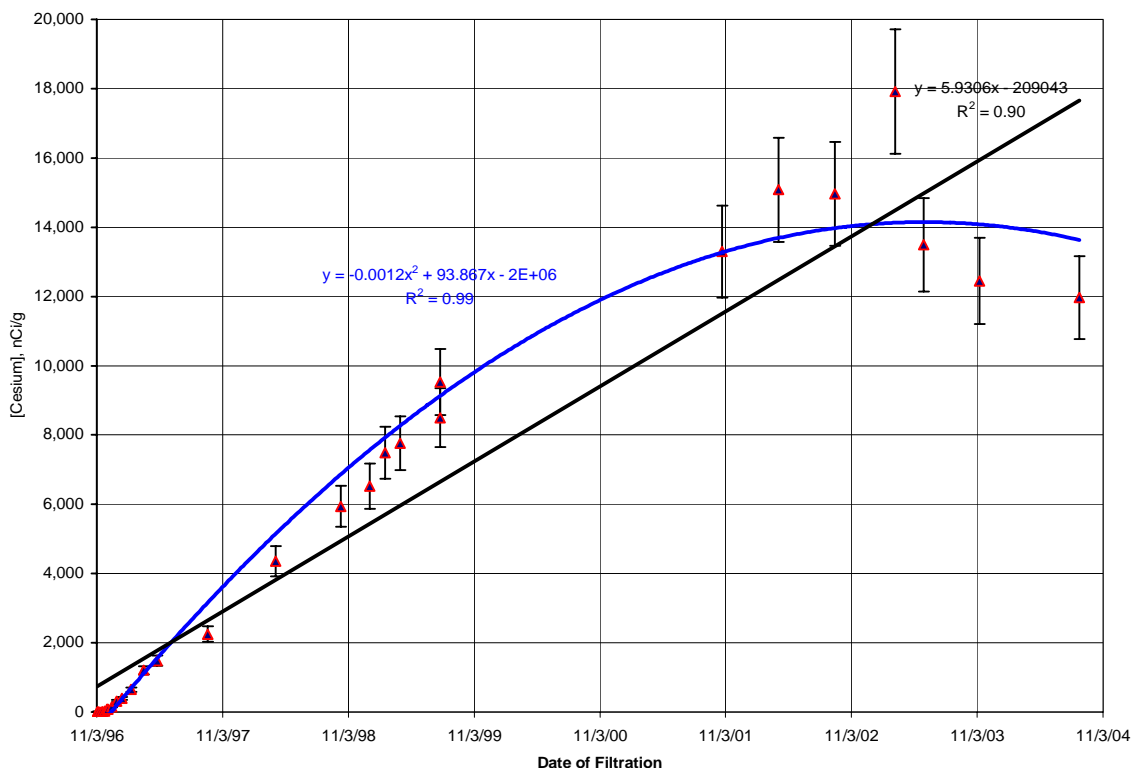


Figure 2 – ^{137}Cs Concentration Increase Due to CsTPB Decomposition**(Cs Data was corrected to 240,000 gal and adjusted for radioactive decay since 1996)**

6.0 SUMMARY

Personnel analyzed samples taken from Tank 48H on August 23, 2004 for chemical and radiological constituents. This report documents the analytical results and analysis of this data.

The results demonstrate that samples pulled in September 2003 and August 2004 are very similar in chemical composition. The free hydroxide concentration, sodium concentration, soluble solids and density have all increased as expected due to the addition of 6,424 gallons of 50 wt % sodium hydroxide on October 30, 2003.

The tetraphenylborate in Tank 48H continues to slowly decompose at a rate of approximately 0.0898 mg K/L/day or 1.3 % TPB decomposition per year. This is consistent with the measured decomposition over the last eight years.

The analyses requested were primarily designed to support an in-tank catalyzed hydrolysis process and the actual waste testing of the hydrolysis and aggregation process alternatives. The Tank 48H sample contains $9.28\text{E-}02 \pm 6.78\text{E-}03$ mg/L Pd, 2.97 ± 0.156 mg/L Cu and 20.4 ± 0.86 mg/L Hg. Additional analyses may be required for alternative processes such as Aggregation.

Data collected during sampling is summarized in Appendix A. The Tank 48H analytical results are summarized in Appendix B.

7.0 ACKNOWLEDGEMENTS

This task required the support of a large team of people. We thank the following individuals but note that many others assisted in completing this task.

We thank the dedicated Shielded Cells Technicians Debbie Burckhalter, Nan Stanley and Dee Wheeler for receiving the Tank 48H sample, completing the analyses in the cells as requested, and preparing the hundreds of samples for transfer to ADS.

We thank the following personnel in the Analytical Development Section for analyzing samples in a busy time period. We list the researchers involved but omit the many technicians supporting them to complete this task on schedule. Thanks to Leigh Brown, Jon Kuhns, Kim Mitchell, John Young, Tom White, Robert Ray, Curtis Johnson, David DiPrete, Ceci DiPrete, June Hart, Bill Boyce, Chuck Coleman, and Damon Click.

We appreciate the continued support of our WPT technicians, Kim Wyszynski and Liz Coleman, who prepared the sample bottles for the shielded cells technicians and verified that the written instructions accomplished the intended tasks.

We appreciate the support of the Tank 48H team, especially Rick Fowler, Steve Strohmeier, Ben Dean, Delane Maxwell, Dennis Conrad, and Bernice Rogers for their technical support in helping us accomplish this task.

8.0 REFERENCES

- ¹ T. B. Peters, D. P. Lambert, M. E. Smith, and S. D. Fink, "Task Technical and Quality Assurance Plan for Destruction of Tetraphenylborate in Tank 48H", WSRC-RP-2003-00396, Rev. 1, June 10, 2003.
- ² Tank 48H 10 Liter Sample Analyses, SP-TTR-2004-00020, August 4, 2004.
- ³ D. P. Lambert, T. B. Peters, M. S. Hay, S. D. Fink, "Task Technical and Quality Assurance Plan for Analysis and Acceptance of Tank 48H Sample", WSRC-RP-2004-00598, Revision 0, August 2004.
- ⁴ W. B. Dean, "Tank 48H Dissolution Sampling Plan", CBU-SPT-2003-00104, Rev. 0, May 15, 2003.
- ⁵ D. T. Hobbs, et al., "Radioactive Testing Results in Support of the In-Tank Precipitation Facility", WSRC-TR-98-00070, Rev. 0, April 2, 1998.
- ⁶ C. J. Coleman, D. D. Walker, "Statistical Study of Weight % Insoluble Methods for In-Tank Precipitation (ITP) Cold Run Support", WSRC-TR-92-256, December 9, 1992.
- ⁷ D. D. Walker, W. T. Boyce, C. J. Coleman, D. P. DiPrete, T. B. Edwards, A. A. Ekechuckwu, C. W. Hsu, S. F. Peterson, L. L. Tovo, and M. J. Whitaker, "Tank 48H Waste Composition and Results of Investigations of Analytical Methods", WSRC-TR-97-0063, April 2, 1997.

Appendix A Data Collected during Sampling

Figure A-1 – Temperature and Pump Data during Sampling

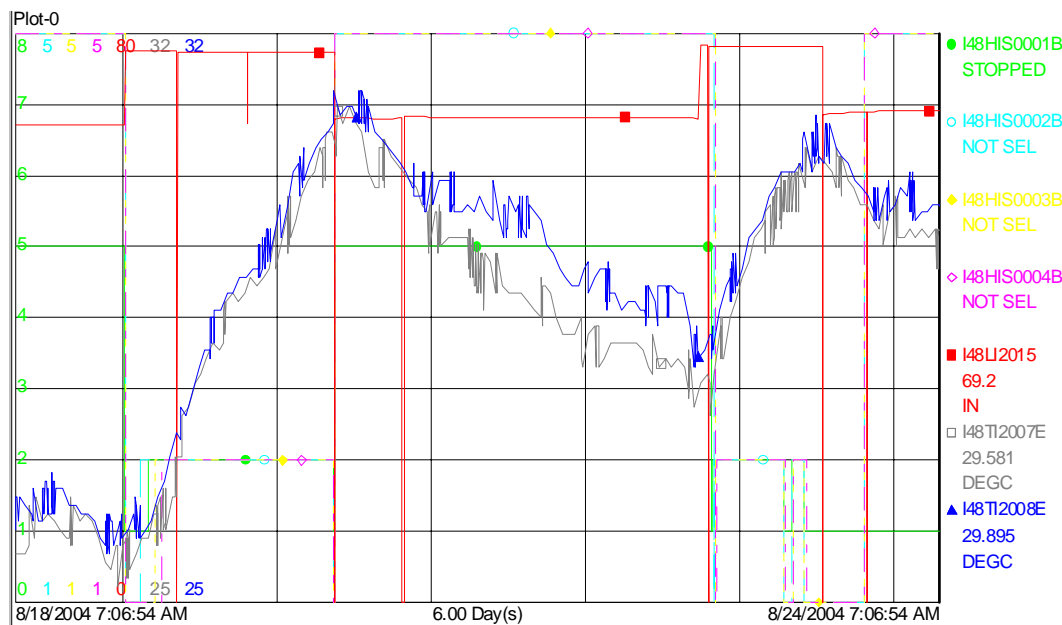


Table A-1 – Pump Start and Stop Time for Samples HTF-E-04-049 and 04-050

Pump	Start time	Stop Time	Duration #1, hrs	Downtime, hrs
B1	8/19/04 2:51	8/20/04 8:42	30	60
	8/22/04 19:58	8/22/04 7:01	11	13
	8-23-04 20:08	8-23-04 21:58	2	
B4	8/19/04 3:53	8/20/04 7:48	28	60
	8/22/04 20:13	8/22/04 7:30	11	13
	8-23-04 20:13	8-23-04 22:03	2	
V1	8/19/04 5:08	8/20/04 8:15	27	60
	8/22/04 20:27	8/22/04 7:30	11	13
	8-23-04 20:21	8-23-04 22:03	2	
V2	8/19/04 6:00	8/20/04 8:20	26	60
	8/22/04 20:27	8/22/04 7:30	11	13
	8-23-04 20:28	8-23-04 22:28	2	

The tank level increased from 67.2 to 69.1 inches as a result of the sampling. This is a volume increase of 6,670 gallons. The pumps operated for a total time of 163 hours for a calculated inleakage of 41 gallons per hour.

Table A-3 -- Data collected During June sampling

Pump	Bearing Water flow	
	mL/min	gallons/hr
V2	Not recorded	
V1	150	2.4
B4	150	2.4
B1	200	3.2
Total	>500	>8.0

Appendix B – Tank 48H Sample Results Summary (Results > 1 mg/L)

Analyte	Slurry	Filtrate	Source
Volume, gal	239,031	NM	Tank 48H
Density, mg/L	1.162	1.164	Density
Total Solids, wt %	19.08%	17.68%	Solids
Total Insolubles	1.69%	NM	Calculation
KTPB, wt %	1.95%	<0.001%	HPLC
MST solids, wt %	0.15%	NM	ICP-ES
Anions			
Free Hydroxide, M	NM	1.16	Titration
Carbonate, M	NM	0.492	Titration
Nitrite, M	NM	0.649	Anion
Nitrate, M	NM	0.304	Anion
Oxalate, mg/L	NM	1,613	Anion
Formate, mg/L	NM	680	Anion
Chloride, mg/L	NM	370.25	Anion
Phosphate, mg/L	NM	915.75	Anion
Sulfate, mg/L	NM	527.5	Anion
Organic Species			
TPB Anion, mg/L	20,100	<10	HPLC
3PB, mg/L	162	<10	HPLC
2PB, mg/L	123	<10	HPLC
PBA, mg/L	120	<10	HPLC
PHENOL, mg/L	735	529	HPLC
Nitrobenzene, mg/L	<50	<10	HPLC
Nitrososbezene, mg/L	<50	<10	HPLC
4phenylphenol, mg/L	<50	<10	HPLC
2phenylphenol, mg/L	<50	<10	HPLC
Diphenylamine, mg/L	<50	<10	HPLC
Biphenyl, mg/L	384	<10	HPLC
o-terphenyl, mg/L	<50	<10	HPLC
m-terphenyl, mg/L	<50	<10	HPLC
p-terphenyl, mg/L	<50	<10	HPLC

Metals	Slurry	Filtrate	Source
Potassium, M	0.068	0.0061	AA
Hg, mg/L	22.0	NM	AA
Sodium, M	3.26	2.99	ICP-ES
Potassium, M	0.061	0.0095	ICP-ES
Aluminum, mg/L	2,242	NM	ICP-ES
Boron, mg/L	1,030	412	ICP-ES
Sulfur, mg/L	245.08	NM	ICP-ES
Phosphorus, mg/L	206.75	NM	ICP-ES
Silicon, mg/L	106.28	4.675	ICP-ES
Iron, mg/L	43.44	<0.709	ICP-ES
Chromium, mg/L	51.11	NM	ICP-ES
Magnesium, mg/L	18.53	NM	ICP-ES
Calcium, mg/L	21.43	NM	ICP-ES
Molybdenum, mg/L	13.30	NM	ICP-ES
Antimony, mg/L	11.50	NM	ICP-ES
Zinc, mg/L	11.91	NM	ICP-ES
Manganese, mg/L	6.38	NM	ICP-ES
Strontium, mg/L	5.29	NM	ICP-ES
Barium, mg/L	2.52	NM	ICP-ES
Copper, mg/L	2.97	1.014	ICP-ES
Total Ag, mg/L	1.88E-02	2.12E-03	ICP-MS
Total Pd, mg/L	9.28E-02	6.78E-03	ICP-MS
Total Rh, mg/L	1.53E-01	1.61E-02	ICP-MS
Total Ru, mg/L	3.80E-01	8.43E-03	ICP-MS
Total Cd, mg/L	2.16E-02	1.57E-02	ICP-MS
Total Hg, mg/L	4.45E+00	6.73E-02	ICP-MS
Np-237, mg/L	2.22E-01	8.09E-03	ICP-MS
Pu-239, mg/L	3.33E-02	5.55E-03	ICP-MS
U-233, mg/L	6.13E-02	7.39E-03	ICP-MS
U-234, mg/L	3.25E-01	1.94E-02	ICP-MS
U-235, mg/L	6.53E-01	4.43E-02	ICP-MS
U-236, mg/L	1.44E-01	4.85E-03	ICP-MS
U-238, mg/L	4.12E+00	2.24E-01	ICP-MS
U Total, mg/L	5.31E+00	2.89E-01	ICP-MS

Distribution

WSRC-TR-2004-00514, Rev 1

R. A.	Adams	241-162H, Rm. 4	(E)	D. B.	Little	703-H, Rm. 3	(E)
J. W.	Barber	704-2H, Rm. 197	(E)	S. R.	Loflin	773-41A, Rm. 223	(E)
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L. R.	Bragg	766-H, Rm. 2434	(E)	C. J.	Martino	735-11A, Rm. 121	(E)
T. E.	Britt	742-4G, Rm. 3	(E)				
H. L.	Bui	742-4G, Rm. 3	(E)	G. J.	Matis	766-H, Rm. 1066F	(E)
S. G.	Campbell	703-H, Rm. 107	(E)	D.	Maxwell	766-H, Rm. 2231	(E)
L.	Carey	766-H, Rm. 2005A	(E)	D. J.	McCabe	73-42-A, Rm. 153	(E)
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W. D.	Clark	766-H, Rm. 2412	(E)	L. T.	McGuire	766-H, Rm. 2441	(E)
S. L.	Clifford	766-H, Rm. 2443	(E)	M. S.	Miller	772-7B, Rm. 6	(E)
J. J.	Connelly	773-41A, Rm. 231	(E)	C. A.	Nash	773-42A, Rm. 182	(E)
D. T.	Conrad	766-H, Rm. 2007	(E)	L. M.	Nelson	773-43A, Rm. 222	(E)
D. R.	Cox	730-2B, Rm. 118	(E)	M. A.	Norato	704-27S, Rm. 6	(E)
A. D.	Cozzi	773-43A, Rm. 218	(E)	M. R.	Norton	66-H, Rm. 2002	(E)
C. L.	Crawford	773-41A, Rm. 180	(E)	J. E.	Occhipinti	704-S, Rm. 18	(E)
D. A.	Crowley	773-A, Rm. A-262	(E)	L. D.	Olson	703-H, Rm. 5	(E)
N. R.	Davis	766-H, Rm. 1006	(E)	L. M.	Papouchado	773-A, Rm. A-263	(P)
W. B.	Dean	766-H, Rm. 2243	(E)	T. B.	Peters	773-42A, Rm. 128	(E)
V. G.	Dickert	703-H, Rm. 4	(E)	J. A.	Pike	703-H, Rm. 99	(E)
C. L.	Donahue	241-162H, Rm. 6	(E)	M. R.	Poirier	773-42A, Rm. 123	(E)
M. D.	Drumm	766-H, Rm. 2050	(E)	S. H.	Reboul	703-H, Rm. 84	(E)
M. C.	Duff	773-43A, Rm. 217	(E)	T. R.	Reynolds	704-S, Rm. 65	(E)
C. R.	Dyer	766-H, Rm. 2426	(E)	M.A.	Rios-Armstrong	766-H, Rm. 2054	(E)
R. E.	Eibling	999-W, Rm. 335	(E)	S. J.	Robertson	766-H, Rm. 2500	(P)
G. N.	Eide	241-121H, Rm. 6	(E)	B. C.	Rogers	766-H, Rm. 2008	(E)
H. H.	Elder	703-H, Rm. 95	(E)	R. A.	Runnels	766-H, Rm. 2011	(E)
S. D.	Fink	773-A, Rm. B-112	(E, P)	P. J.	Ryan	704-61S, Rm. 6	(E)
F. F.	Fondeur	773-A, Rm. B-124	(E)	E.	Saldivar	766-H, Rm. 2004	(E)
R. C.	Fowler	703-H, Rm. 98	(E)	S. C.	Shah	766-H, Rm. 2037	(E)
L. M.	Fox	703-H, Rm. 3	(E)	D. C.	Sherburne	704-S, Rm. 18	(E)
M.W.	Geeting	766-H, Rm. 2035	(E)	T. J.	Spears	766-H, Rm. 2015	(E)
B. A.	Gifford	766-H, Rm. 1066D	(E)	R. H.	Spires	766-H, Rm. 2003	(E)
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B. A.	Hamm	766-H, Rm. 2237	(E)	S. J.	Strohmeier	766-H, Rm. 2022	(E)
H. D.	Harmon	766-H, Rm. 2014	(P)	S. G.	Subosits	766-H, Rm. 2052	(E)
K. D.	Harp	755-H, Rm. 1066B	(E)	P. C.	Suggs	766-H, Rm. 2436	(E)
E. W.	Harrison	766-H, Rm. 2034	(E)	G. A.	Taylor	703-H, Rm. 96	(E)
K. A.	Hauer	703-H, Rm. 11	(E)	S. A.	Thomas	766-H, Rm. 2016	(E)
D. T.	Herman	735-11A, Rm. 104	(E)	P. J.	Valenti	730-4B, Rm. 2062	(E)
P. J.	Hill	766-H, Rm. 1066C	(E)	W. B.	Van-Pelt	704-S, Rm. 16	(E)
R. N.	Hinds	766-H, Rm. 2430	(E)	D. D.	Walker	773-A, Rm. B-124	(E)
D. T.	Hobbs	773-A, Rm. B-117	(E)	A. O.	Waring	766-H, Rm. 2423	(E)
E. W.	Holtzscheiter	773-A, Rm. A-230	(E)	F. A.	Washburn	766-H, Rm. 2054	(E)
C. M.	Jantzen	773-A, Rm. B-104	(E)	V. B.	Wheeler	766-H, Rm. 2438	(E)
R. T.	Jones	766-H, Rm. 2463	(E)	G. G.	Wicks	773-A, Rm. B-129	(E)
E. T.	Ketusky	703-H, Rm. 83	(E)	W. R.	Wilmarth	773-42A, Rm. 171	(E)
D. P.	Lambert	773-A, Rm. B-132	(E)	G. C.	Whinship	766-H, Rm. 2024	(E)
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C. A.	Langton	773-43A, Rm. 219	(E)	STI		703-43A (E) (P 3 copies)	
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