FILTRATION OF A HANFORD AN-104 SAMPLE (U)

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ABSTRACT

The Savannah River Technology Center (SRTC) conducted ultrafiltration tests with samples from the Hanford Site's 241-AN-104 tank. The test objectives were to measure filter flux during dewatering and the removal of soluble species during washing.

The filtration tests were conducted with the Cells Unit Filter (CUF) currently installed in Cell 16 of the SRTC High Activity Caves. Following filtration, personnel performed inhibited water washing to remove soluble species. Because of the limited volume of concentrated slurry, the washing was performed with a volumetric flask rather than a crossflow filter. Following the washing, personnel chemically cleaned the filter with 1 M nitric acid and periodically measured the clean water flux.

The results of the testing follow.

- The average measured flux of 0.085 gpm/ft^2 during dewatering, which exceeded the target of 0.03 gpm/ft^2. The low insoluble solids content (0.9 wt%) contributed to the high flux.
- A statistically significant correlation was observed between filter flux and transmembrane pressure.
- The measured mean particle size was 0.8 – 1.7 micron.
- The filtrate viscosity measured 3.5 cp, and the slurry viscosity measured 3.9 cp at 0.9 wt % insoluble solids. The washed filtrate viscosity measured 1.3 cp. The washed slurry was concentrated to 2.2 wt% insoluble solids. Its viscosity measured 1.9 cp with a yield stress of 1.47 Pa.

INTRODUCTION

The Hanford Waste Treatment Plant (WTP) Research &Technology Program identified Tank 241-AN-104 as one of the waste solutions to be used to perform the filtration and sludge washing tests. Filtration tests were conducted to validate the flux chosen for equipment design. Washing tests were performed to assess the reduction in quantity of High Level Waste (HLW) by removing soluble components.

SRTC personnel characterized the waste sample. Following characterization, SRTC personnel processed the waste sample through the filter to measure the flux, and washed the concentrated solids to determine the amount of soluble species that could be removed prior to vitrification. After the filtration testing, they chemically cleaned the filter with 1 M nitric acid.

EXPERIMENTS

Test Equipment

Filtration tests were conducted with the CUF currently installed in Cell 16 of SRTC High Activity Caves (see Figure 1). The unit has a 2 ft long stainless steel Mott

crossflow filter of 3/8" ID and 0.1 micron nominal pore size. The system can provide up to 16.5 ft/s crossflow velocity and 80 psi TMP. Feed from the reservoir passes through a progressive cavity pump. The pump is operated at variable speed by controlling the air pressure supplied to the pump motor. The slurry is pumped through a magnetic flow meter and heat exchanger that removes heat. Ice water, contained in a 3-gallon Igloo cooler, removes heat from the system. The slurry then passes through the crossflow filter. A throttle valve downstream of the filter is used to adjust the filter feed pressure. The filtrate flow rate is measured with a sight glass and calibrated stopwatch. The system is equipped with a manual backpulse system. The feed, concentrate, and filtrate pressures are measured with standard Bourdon-type pressure gauges. A thermocouple mounted near the bottom of the feed reservoir measures the slurry temperature.

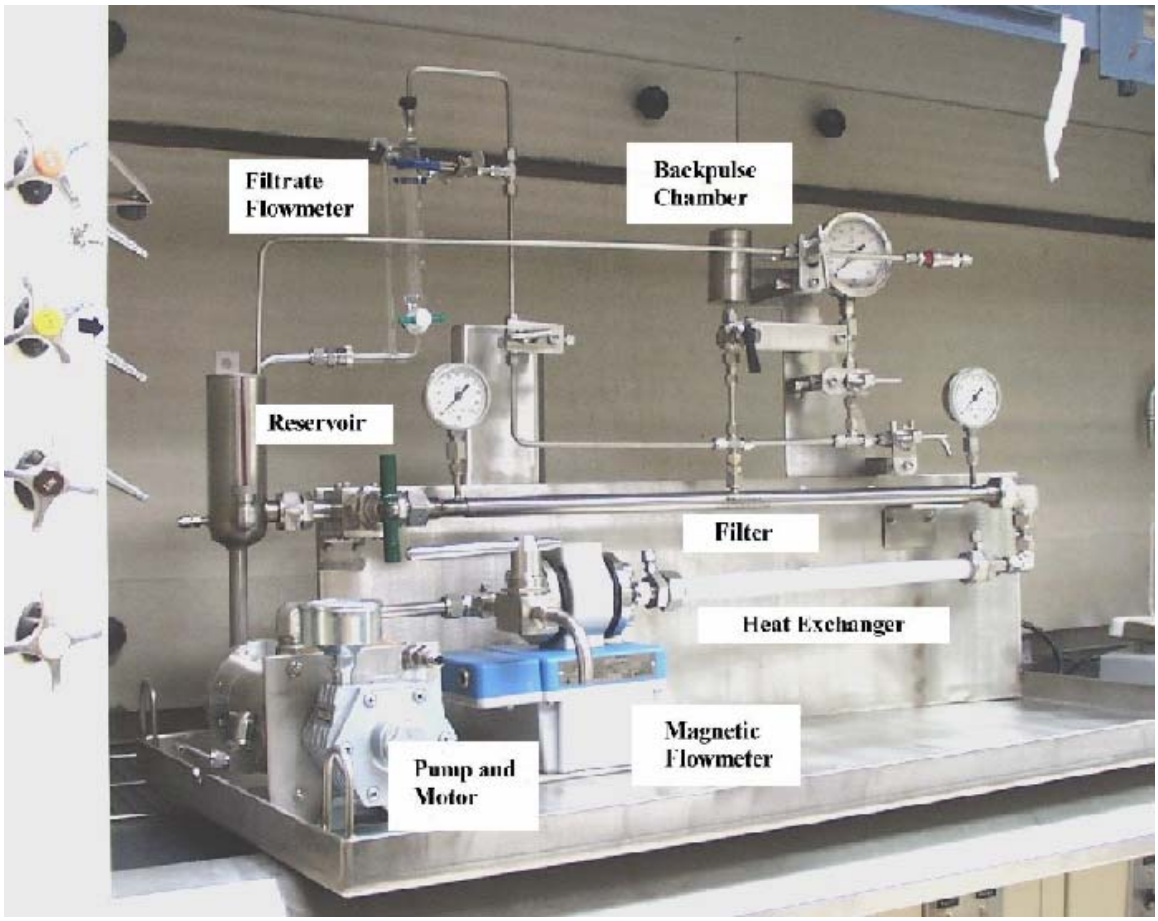

Figure 1 Cells Unit Filter (CUF)

Test Preparation

Researchers received a sample of Hanford AN-104 waste. The sample contained 5 M sodium prior to the start of the filtration tests.

Filtration Tests

Personnel performed clean water flux tests with 0.01 M NaOH solution that was filtered through a 0.1 micron filter. The tests were performed at 11 ft/s axial velocity and 10 and 20 psi transmembrane pressure (TMP). Following the clean water flux tests, personnel performed tests with 5 wt. % strontium carbonate at 11 ft/s axial velocity and 10, 20, and 30 psi TMP. Following the strontium carbonate test, they performed an additional clean water flux test at 11 ft/s axial velocity and 20 psi TMP.

Personnel added 4.7 liters of AN-104 slurry to the filter feed tank. They concentrated the feed slurry from ~ 0.07 wt. % to ~ 0.9 wt. % by reducing its volume over 12 hours. During the dewatering process, the axial velocity was 11 ft/s, and the transmembrane pressure was 40 psi. Following dewatering process, personnel conducted filtration matrix tests with the conditions shown in Table 1. Due to equipment limitations, three of the test conditions could not be met. Since the TMP has a greater effect on filter flux, the TMP was met at the expense of somewhat lower axial velocities for those three test conditions.

Table 1 Filtration Test Matrix Conditions

TMP (psi)	Axial Velocity (ft/s)
40	11
40	11
40	11
30	9
30	13
50	13*
50	9
40	11
40	7
40	15*
20	11
60	11*
40	11

* Could not achieve target velocity

About midway through the dewatering step, a stable foam was formed in the CUF and overflowed both the slurry tank and the slurry tank level sight glass. Foaming continued until the end of the dewatering step. No addition foaming occurred during the matrix flow tests. Figure 2 is a photograph of the foam at the end of the dewatering test. The equipment configuration with the small slurry tank may contribute to the occurrence of foam. This foam was still present five days later when it was rinsed off the unit with water.

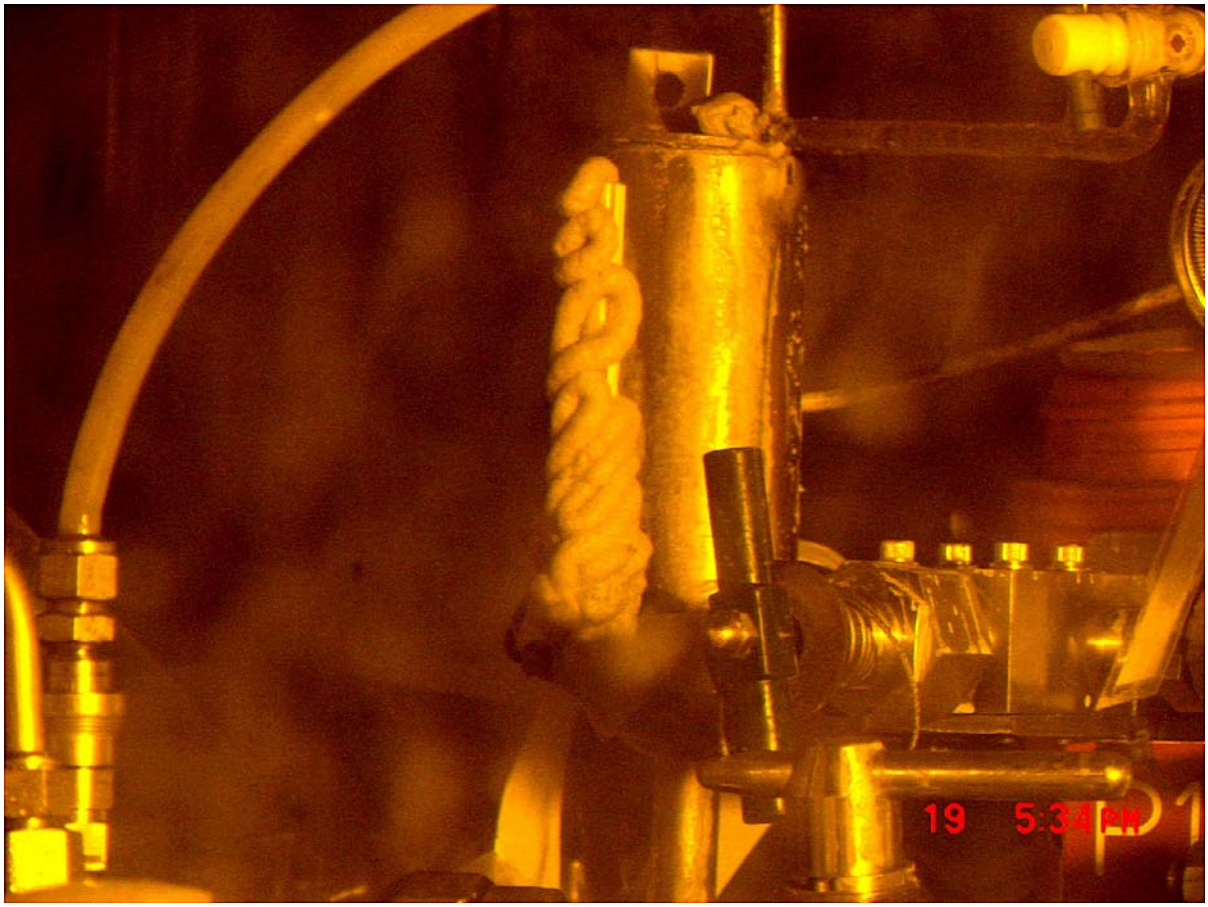

Figure 2 Foam Observed during Dewatering

Washing Test

Because of the low volume of solids in the feed slurry, 94 mL of the 500 mL of feed slurry were decanted into a 100 mL volumetric flask. The washing process was performed in the volumetric flask rather than with the CUF.

To perform the wash, personnel added 9.5 mL of inhibited water to the slurry in the volumetric flask. They capped the flask and inverted and shook it to contact the slurry and wash water. The flask was then set in a pan to allow the solids to separate from the liquid by settling. Following the settling, 9.5 mL liquid was removed with a disposable pipette that had a “stop” attached to it that would only allow it to go so far down into the volumetric flask.

Personnel repeated this process for a total of twelve washes.

Rheology

Personnel performed rheological measurements with a RV30/m5 rotoviscometer. They performed the measurements at 25 ºC with an NV double concentric rotor and cylinder. The rotor ramped from 0 – 2700 sec^{-1} shear rate in five minutes, held the 2700 sec^{-1} shear rate for one minute, and ramped from 2700 – 0 sec^{-1} in five minutes. Each sample was measured at least two times.

The filtrate and unwashed slurry data was fit with the following rheological model

$$\tau = \mu \gamma/1000$$

where τ is the shear stress (in Pascals), μ is the Newtonian viscosity (in centipoises), and γ is the shear rate (in sec^{-1}). The slope of shear stress versus shear rate yields the viscosity (in Pascal second). The factor of 1000 converts Pascal seconds to centipoise.

The data from the concentrated and washed slurry was fit with a Bingham plastic model described by the following equation

$$\tau = \tau_\psi + \eta \gamma/1000$$

where τ_ψ is the yield stress (in Pascal) and η is the consistency or infinite viscosity (in centipoises).

The total solids (both insoluble solids and soluble salts) were measured by heating at 115 +/- 5 ^oC until a constant dry weight was achieved.

The weight % insoluble solids and weight % soluble solids were calculated after measuring the weight % total solids in the slurry and the weight % soluble solids in a filtered portion of the supernatant. This technique is used for determining the weight % insoluble solids rather than collecting and measuring the insoluble solids directly for two reasons: (1) it is less prone to experimental errors; and (2) it includes the water-soluble salts that would be dissolved during the water rinse of the solids to remove interstitial supernatant. The expression used for calculating the insoluble solids is:

$$IS = TS - (100-TS) \times \frac{(FS/100)}{(1-FS/100)}$$

where

IS = weight % insoluble solids in the slurry
TS = weight % total solids in the slurry
FS = weight % soluble solids in the filtered supernatant

The weight % soluble solids in the as-received slurry (SS) was then calculated from the difference in measured total weight % solids in the slurry (TS) and the calculated weight % insoluble solids (IS):

SS= TS-IS

Density measurements were performed by weighing a known volume of sample.

Slurry samples were collected, dried and then submitted for particle size analysis by scanning electron microscope (SEM). The analysis was performed at 41X, 333X, 2300X, and 4600X. Personnel measured the size of particles on each of the pictures.

Filtrate samples were dissolved prior to analysis to ensure that all components were soluble. The dissolution was performed by mixing 5 mL of sample, 5 mL of nitric acid, and 2 mL of hydrogen peroxide. The samples were capped, mixed, and heated to 115 ºC for two hours. After heating, the samples were cooled and diluted to 100 mL with deionized water.

Acid digestion of the final solids slurry was performed as follows. Personnel mixed between 0.5 and 1 grams of the slurry, 3 mL of nitric acid, 9 mL of HCl, and 5 mL of HF in a Teflon pressure vessel. The vessel was capped, mixed, and placed into a 115 ºC oven for three hours. After three hours, the vessel was removed from the oven, allowed to cool, and the contents diluted to 1000 mL with 0.6 M boric acid.

Water leaching of the solids was performed so TIC/TOC and anion analyses could be performed. About 115 mL of slurry from the CUF was split up among 3 centrifuge tubes and centrifuged at high speed for over an hour. All liquid was poured off; then the wet solids were weighed. Twenty five mL of deionized water was added to the solids in each centrifuge tube. After vigorously shaking the tubes, they were placed in an oven at 115 ^{o}C for three hours. After cooling, the water/solids solutions were diluted to about 40 mL including rinses of the centrifuge tubes.

RESULTS

Filtration Test Results

Table 2 shows the clean water flux and strontium carbonate flux data. Since one measured clean water flux at 20 psi was 0.63 gpm/ft2, the filter was considered clean and the testing begun.

Table 2 Clean Water and Strontium Carbonate Flux

Feed	Temperature (ºC)	Axial velocity (ft/s)	TMP (psi)	Flux (gpm/ft2)@25º C
Water	20.7	11.0	10	0.34
Water	20.7	11.0	20	0.63

SrCO3	21.0	11.1	10	0.25
SrCO3	22.4	11.0	20	0.44
SrCO3	23.0	11.2	30	0.62
Water	25.0	11.1	20	0.31

Figure 3 shows the filter flux during dewatering. The average measured flux of 0.085 gpm/ft^2 exceeds the target of 0.03 gpm/ft^2.

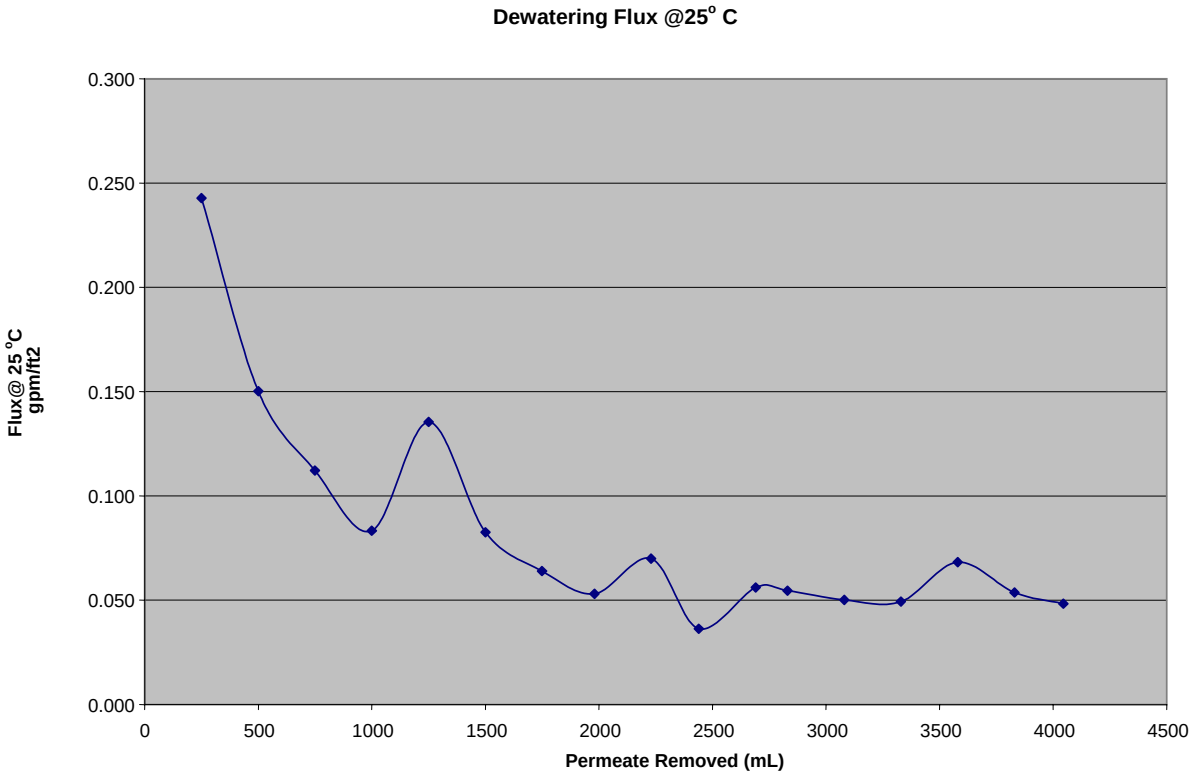

Figure 3. Filter Flux During Dewatering

Figure 4 and Figure 5 show the filter flux during the matrix tests performed at 0.9 wt. % insoluble solids. In all cases, the filter flux is less than 0.03 gpm/ft^2. There is a correlation between transmembrane pressure and filter flux. There is no observed correlation between axial velocity and filter flux.

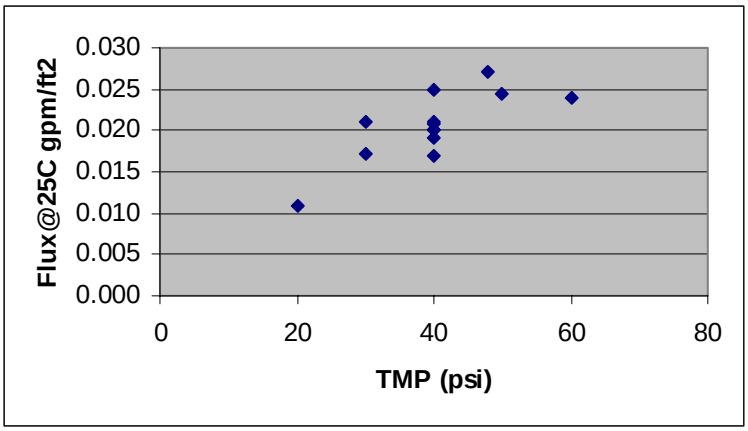

Figure 4 Filter Flux of 0.9 wt.% AN-104 Slurry

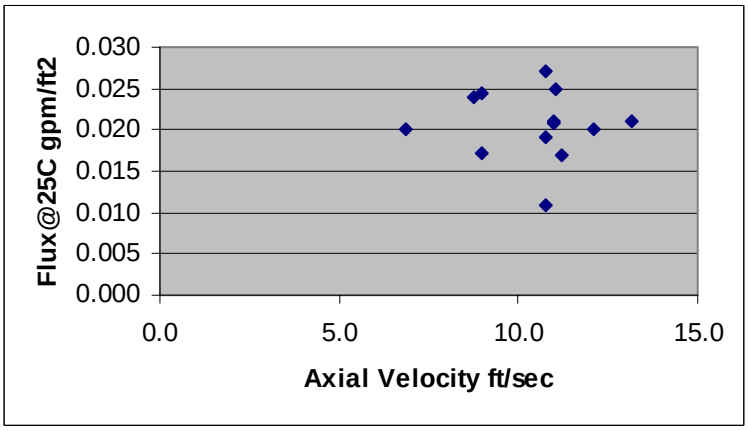

Figure 5 Filter Flux of 0.9 wt.% AN 104 Slurry

Washing Results

Table 3 shows the sodium and Cs-137 concentration in supernate samples collected during the washing. The sodium concentration in the supernate decreases fairly linearly throughout the washes as expected. The Na results vary widely in Table 4 between the AA and the ICPES methods for determining it. The Cs-137 decreases steadily as expected.

Table 3 Washing Sample Results

Sample	Na (g/mL)	Cs-137 Ci/g
Wash 1	106,000.	2.85E+02
Wash 2	100,000.	

Wash 3	90,100.	
Wash 4	82,100.	1.78E+02
Wash 5	75,900.	
Wash 6	68,200.	
Wash 7	60,000.	
Wash 8	55,300.	1.13E+02
Wash 9	50,000.	
Wash 10	47,000.	
Wash 11		
Wash 12	41200.	9.32E+01

Table 4 shows the composition of the wash solution 12. Wash solution 12 is the only wash that had the full suite of analyses performed on it. The units are per mL of wash solution.

Table 4 Washing Sample Results of Wash 12

K	**µg/mL**	875	**% Uncertainty**
Na-ICPES	**conc, µg/mL**	41200	
Cs-137	**µCi/mL**	1.17E+02	2.4
Co-60	**µCi/mL**	1.20E-04	2.49
Eu-154	**µCi/mL**	6.30E-05	6.77
Eu-155	**µCi/mL**	3.45E-05	mda
Am-241	**µCi/mL**	1.62E-04	5.92
Gross Alpha	**µCi/mL**	1.10E-03	15
Hg	**µg/mL**	<0.110	
BROMIDE	**µg/mL**	<100	
CHLORIDE	**µg/mL**	1060	
FLUORIDE	**µg/mL**	<20	
FORMATE	**µg/mL**	183	
NITRATE	**µg/mL**	23200	
NITRITE	**µg/mL**	14300	
OXALATE	**µg/mL**	1040	
PHOSPHATE	**µg/mL**	<100	
SULFATE	**µg/mL**	960	
PU-238	**µCi/mL**	2.25E-04	38.9
PU-239/240	**µCi/mL**	7.34E-05	35.38
Beta	**µCi/mL**	1.39E+02	20

SR-90	**µCi/mL**	2.13E-01	12.4
TC-99	**µCi/mL**	3.17E-02	5.5
TIC	**µg/mL**	1740	
TOC	**µg/mL**	800	
TC	**µg/mL**	2540	

Analytical Results

Particle Size Data

Table 5 shows the results of the particle size data. The results shown are from the same sample, using different magnification and examining different fractions of the sample. The mean particle size varies widely, depending on the magnification of the SEM. In reviewing the pictures, the authors observed that at low magnification, the particles were extremely small. They had difficulty determining the location of the edges of the particles and therefore, determining their size. At magnification 2300X and larger, the mean particle size is approximately the same. The authors recommend using a mean particle size of 0.8 – 1.7 micron for the AN-104 sample.

Table 5 Particle Size of AN-104 Solids

Sample ID	# of particles	Avg. D, µ	Std Dev, µ	Max. D, µ	Min. D, µ
3-191232-10X-SE	61	4.8	1.5	9.4	2.4
3-193822-41X-SE	23	38	11	60	20
3-193282-41X-BS	26	39	11	67	19
3-193822-333X-BS	52	13	6	31	4
3-193822-2300X-SE	37	1.5	0.4	2.4	1.0
3-193822-2300X-BS	60	1.7	0.7	5.7	0.7
3-193822-4600X-SE	44	0.77	0.21	1.5	0.36
3-193822-4600-BS	59	1.29	0.30	2.18	0.73

1.1.1.1 Filtrate Data

The filtrate was visually inspected for solids and none were observed.
Table 6 shows the composition of filtrate samples collected at the start of the dewatering process. The units are per mL of filtrate. Table 7 shows the anion data for both the filtrate after concentration and the filtrate at the end of washing.

Table 6 Chemical Composition of Filtrate Samples

Sample ID		Filtrate 1	Filtrate 2	Filtrate 3
ICPES				
Ag	µg/mL	<1.95	<1.94	<1.65
Al	µg/mL	16128	13734	13734
B	µg/mL	35.2	20.7	24.1
Ba	µg/mL	<4.63	<4.61	<3.91
Ca	µg/mL	<5.60	<5.58	<4.75
Cd	µg/mL	<1.02	<1.01	<0.866
Ce	µg/mL	13.5	<6.5	<5.56
Cr	µg/mL	180	150	150
Cu	µg/mL	2.22	1.63	1.15
Fe	µg/mL	<0.488	<0.486	0.818
Gd	µg/mL	<5.71	<5.68	<4.83
La	µg/mL	2.12	<1.75	1.68
Li	µg/mL	<10.5	<10.4	<8.88
Mg	µg/mL	<1.30	<1.29	<1.09
Mn	µg/mL	<0.195	<0.194	<0.165
Mo	µg/mL	61.7	38.2	40.4
Na	µg/mL	139000	117000	116000
Ni	µg/mL	<3.29	<3.28	<2.78
P	µg/mL	562	498	462
Pb	µg/mL	14.2	13.2	11.0
S	µg/mL	1575	1298	1323
Sb	µg/mL	<92.1	<91.7	<78.0
Si	µg/mL	105	92.5	90.6
Sn	µg/mL	62.2	35.0	39.9
Sr	µg/mL	<1.85	<1.84	<1.57
Ti	µg/mL	<1.88	<1.86	<1.59
U	µg/mL	61.9	<55.0	<46.9
Zn	µg/mL	3.23	2.62	2.82
Zr	µg/mL	<5.56	<5.53	<4.71
AA				
K	µg/mL	2646	2054	2079
Na	µg/mL	197820	92988	101052
PUTTA				
Pu238	µCi/mL	3.60E-04	3.81E-04	5.57E-04
%Uncertainty		40.92	40.09	17.82
Pu239/240	µCi/mL	<1.02E-04	<8.63E-05	3.01E-04
		MDA	MDA	36.06

Sample ID		Filtrate 1	Filtrate 2	Filtrate 3
RAD screen				
alpha count	µCi/mL	1.33E-01	1.30E-01	1.31E-01

Sample ID		Filtrate 1	Filtrate 2	Filtrate 3
% Uncertainty		7	7	7
beta count	μCi/mL	3.24E+02	2.72E+02	2.70E+02
% Uncertainty		15	15	15
Sr90 beta liq sint	μCi/mL	9.25E-02	1.06E-01	8.80E-02
% Uncertainty		9.9	9.6	9.7
Tc99 beta liq scnt	μCi/mL	1.02E-01	9.14E-02	8.23E-02
% Uncertainty		6.2	6.3	5.8
Cs-137	μCi/mL	2.67E+02	2.28E+02	2.24E+02
% Uncertainty		150.00%	1.6	1.5
Co	μg/mL	1.26E-01	1.26E-01	1.26E-01
Mo	μg/mL	3.40E+01	2.99E+01	3.02E+01
Am-241	μCi/mL	<1.80E-03	< 1.44E-03	<1.62E-03
Co-60	μCi/mL	3.02E-04	2.95E-04	2.82E-04
% Uncertainty		9	3.6	7.9
Eu-154	μCi/mL	5.11E-03	4.40E-03	4.43E-03
% Uncertainty		1.4	1.6	1.3
Eu-155	μCi/mL	4.81E-04	4.45E-04	3.60E-04
% Uncertainty		21.6	11.1	26.4
U-235	μg/mL	5.04E-02	5.04E-02	3.78E-02
U-238	μg/mL	8.19E+00	6.93E+00	7.06E+00

Table 7 Filtrate vs. Washed Filtrate Anion-Organic Data

Anion	Units	Unwashed Filtrate	Washed Filtrate	Wash Factors
F	μg/ml	66	46	0.70
Cl	μg/ml	3170	1100	0.35
NO2	μg/ml	43300	14000	0.32
NO3	μg/ml	75300	21800	0.29
PO4	μg/ml	1490	195	0.13
SO4	μg/ml	3810	1050	0.28
TC	μg/ml	6040	2760	0.46
TIC	μg/ml	3330	1620	0.49
TOC	μg/ml	2710	1140	0.42

Unwashed Solids Data

Table 8 shows the composition of final 0.9 wt.% insoluble solids slurry samples collected and prepared by water leaching. The units are per gram of wet solids after centrifugation and decantation.

Table 8 Chemical Composition of Unwashed Solids Sample by Water Leach

Sample ID		Leachate 1	Leachate 2	Leachate 3
ICA				
FLUORIDE	µg/g	6.68E+01	9.04E+01	6.24E+01
FORMATE	µg/g	4.34E+02	4.52E+02	4.68E+02
NITRITE	µg/g	2.48E+04	2.46E+04	2.80E+04
CHLORIDE	µg/g	2.07E+03	1.81E+03	2.03E+03
OXALATE	µg/g	2.91E+04	4.61E+04	2.79E+04
SULFATE	µg/g	1.90E+03	1.72E+03	1.87E+03
PHOSPHATE	µg/g	<334	<452	<311
NITRATE	µg/g	4.24E+04	4.57E+04	4.61E+04
TIC/TOC				
Total Inorganic Carbon	µg/g	2.64E+03	2.83E+03	2.38E+03
Total Organic Carbon	µg/g	1.03E+04	1.46E+04	1.00E+04
Total Carbon	µg/g	1.29E+04	1.74E+04	1.24E+04

Concentrated, Washed Slurry Data

Table 9 shows the composition of final solids slurry samples collected and prepared by acid digestion. The units are per gram of dried total solids. The high variability observed between samples is probably due to the large dilution of a small amount of solids.

Table 9 Chemical Composition of Final Solids Sample by Acid Digestion

Sample		WSLURY-1	WSLURY-2	WSLURY-3
ICPES				
Ag	**µg/g**	<465	<397	<360
Al	**µg/g**	24107	22441	49983
Ba	**µg/g**	<1105	<942	<853
Ca	**µg/g**	<1340	1234	4658

Cd	**µg/g**	<244	<208	<189
Ce	**µg/g**	<1571	<1340	<1214
Cr	**µg/g**	19177	15879	34682
Cu	**µg/g**	322.7	203.0	346.8
Fe	**µg/g**	1741	955	3104
La	**µg/g**	<418	<357	<324
Li	**µg/g**	<2503	<2132	<1935
Mg	**µg/g**	<309	<263	<238
Mn	**µg/g**	<46.6	<39.8	<36.0
Mo	**µg/g**	<3087	<2628	<2384
Na	**µg/g**	138728	127508	267936
Ni	**µg/g**	<785	<670	<609
P	**µg/g**	<4012	<3434	4318
Pb	**µg/g**	<1857	<1581	1731
Si	**µg/g**	16321	14111	22543
Sn	**µg/g**	82625	59164	57123
Sr	**µg/g**	1081	840	2265
Ti	**µg/g**	<449	<381	<347
U	**µg/g**	<13230	<11250	<10200
V	**µg/g**	751	513	401
Zn	**µg/g**	186.7	615.4	751.4
AA				
As	**µg/g**	<291	<248	<225
K	**µg/g**	3434	3434	5712
Na	**µg/g**	115607	109487	247535
Se	**µg/g**	<291	<248	<225
Hg	**µg/g**	<639	<544	<496
CS-137	**µCi/g**			
Am-241	**µCi/g**	5.33E-01	3.11E-01	5.67E-01
Uncertainty, %		7.75	18.68	6.38
PU-238	**µCi/g**	9.96E-02	5.58E-02	1.17E-01
Uncertainty, %		24.82	47.76	20
PU-239/240	**µCi/g**	7.89E-02	4.89E-02	9.39E-02
Uncertainty, %		18.1	43.93	17.81
Sample Name		**WSLURY-1**	**WSLURY-2**	**WSLURY-3**
ALPHA COUNT	**µCi/g**	5.74E+00	5.58E+00	7.83E+00
Uncertainty, %		20	20	20
BETA COUNT	**µCi/g**	1.00E+03	9.68E+02	1.84E+03
Uncertainty, %		10	10	10
SR90 BETA LIQ SCINT	**µCi/g**	2.40E+02	1.99E+02	3.78E+02
Uncertainty, %		10.1	10.8	10
TC99 BETA LIQ SCINT	**µCi/g**	2.05E-01	2.13E-01	3.05E-01
Uncertainty, %		15.1	12	8.9
Co	**µg/l**	3.85E+00	2.93E+00	5.75E+00

Co-60	**µCi/g**	9.02E-02	5.91E-02	1.23E-01
Uncertainty, %		24.6	24.3	9.4
Eu-154	**µCi/g**	<9.76E-02	<8.60E-02	4.73E-01
Eu-155	**µCi/g**	<1.33E-01	<1.12E-02	2.04E-01

Rheology

Table 10 shows the rheology data. The samples were both unwashed and washed filtrate and slurry. The filtrate viscosity is 3.5 cp. The slurry yield stress measured 1.5 Pa, which is not very high and should not cause processing problems. However, because of the low volume of insoluble solids, personnel were unable to create a sample in sufficient quantity to even approach 15 wt% insoluble solids slurry. If the insoluble solids concentration had been higher, the yield stress would have been much higher.

Table 10 Rheology Data

Sample ID (AN-104)	Viscosity or Consistency (cP)	Yield Stress (Pa)
CUF Filtrate	3.5	0
CUF 0.4 wt% Slurry	3.85	0
CUF Washed Filtrate	1.3	0
CUF Washed 2 wt% Slurry	1.9	1.47

Density and Solids Concentration

Table 11 shows the density and solids data.

Table 11 Density and Solids Data

Sample	Density g/mL	Total Solids	Insoluble Solids	Soluble Solids
Filtrate	1.26	29.3 wt %	0	29.3 wt %
CUF Concentrated Slurry	N/A	30.0 wt %	0.9 wt %	29.1 wt %
1:5 Decanted, Washed CUF Slurry	N/A	11.6 wt %	2.2 wt %	11.62 wt %
Washed Slurry Supernate	N/A	13.6 wt %	0	13.6 wt %

Filter Cleaning

Table 12 shows the flux following filter cleaning. The axial velocity for all filter cleaning and flux testing is 11 feet per second. The filter was flushed four times with

inhibited water initially. On the second, third, and fourth batch significant foaming was observed. The filter was then cleaned with five successive batches of 1M nitric acid, then two batches of 0.01M nitric acid. Values for inhibited after and strontium carbonate fluxes prior to the AN-104 run are placed in the PRE-Run Flux column for comparison with the Post AN-104 run fluxes after cleaning. The % change column shows the sign and the percentage change going from the PRE-run fluxes to the POST-run fluxes. In all cases, the POST-run fluxes were significantly less than the PRE-run fluxes. It will require further study for us to understand why the filter fluxes do not return to PRE-run conditions and what filter cleaning methods are required for this to be achieved.

Table 12 Filter Cleaning Data

Cleaning Agent	TMP (psi)	POST-Run Flux gpm/ft^2	PRE-Run Flux gpm/ft^2	% Change
Inhibited Water 1	40	0.132	N/A	N/A
Inhibited Water 2 **foamed**	40	0.079	N/A	N/A
Inhibited Water 3 **foamed**	40	0.042	N/A	N/A
Inhibited Water 4 **foamed**	40	0.026	N/A	N/A
1M Nitric Acid 1	40	0.282	N/A	N/A
1M Nitric Acid 2	40	0.163	N/A	N/A
1M Nitric Acid 3	40	0.45	N/A	N/A
1M Nitric Acid 4	40	0.439	N/A	N/A
1M Nitric Acid 5	40	1.19	N/A	N/A
0.01 M Nitric Acid 1	40	0.383	N/A	N/A
0.01 M Nitric Acid 2	40	0.445	N/A	N/A
Inhibited Water 5	40	0.531	N/A	N/A
Inhibited Water 6	10	0.108	.34	-67%
Inhibited Water 6	20	0.195	.63	-69%
Inhibited Water 6	30	0.34	omitted	N/A
SrCO3	10	0.112	.25	-55%
SrCO3	20	0.29	.44	-34%
SrCO3	30	0.15	.62	-76%
Inhibited Water 7	20	0.091	.31	-71%