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Resusp ension and Settling of Monosodium Titanate and Sludge in Supernate Simulant for the Savannah River Site

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Chemical Technology Division

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P. A. Taylor and C. H. Mattus

ABSTRACT

The Savannah River Site (SRS) is testing several methods for their effectiveness in removing the major radionuclides from the supernate solutions that are stored in the high-level waste tanks at the site. One option is to mix the tank contents (sludge and supernate), in situ, with monosodium titanate (MST) powder to remove ^{90}Sr and transuranics. The sludge and MST would be allowed to settle, and the treated supernate would then be decanted. The sludge and MST would need to be resuspended later so that the solids could be pumped to the Defense Waste Processing Facility for vitrification. Small-scale tests evaluated the effect of various storage conditions on the rheological properties of the sludge/MST slurry. Laboratory-scale and pilot-scale tests were conducted to determine the mixing requirements for resuspending slurries of sludge simulant and MST, following settling periods of various lengths.

The results of the small-scale rheology tests show that storage at room temperature has only a small effect on the viscosity and the yield stress of the sludge/MST/supernate slurry. The yield stress increased by a factor of 5, but the viscosities only increased by about 50% for storage periods up to 61 days. The viscosities measured during the later portions of the tests, after the slurry had been mixed for about 15-25 min, did not change significantly as the storage time increased. Gamma irradiation doses of up to 160 MR also caused only small changes in the rheological properties of the this simulant slurry. Storage at 80°C had a dramatic effect on both the viscosity and the yield stress of the slurry. The viscosity increased by up to a factor of 30 and the yield stress increased by a factor of >300 for storage periods up to 61 days.

Mixing tests in the laboratory-scale vessel showed that the settled solids from the slurry could be resuspended following settling times of up to 60 days. Results of the resuspension tests indicated that the small increases in viscosity and yield stress for slurries that had been stored for 60 days at room temperature caused a definite change in the mixing requirements to resuspend the slurry. Comparing mixing requirements to resuspend the slurry after settling for 4 days vs 60 days showed that the required mixer speed increased from 800 to 1100 rpm and the power increased from 4.8 to 7.3 W. The pilot-scale vessel was not mixed at a sufficient speed to resuspend all of the solids after a 60-day settling period. Comparing mixing requirements to resuspend the slurry in the pilot-scale vessel after settling for 4 days vs 60 days showed that the required mixer speed increased from 150 to >207 rpm and the motor power increased from 130 to >300 W. Calculations suggest that the required mixer speed would be about 280 rpm to completely mix the slurry in the pilot-scale vessel after the 60-day settling period. Based on the results from the small-scale rheology tests, it is unlikely that the single impellers in either the laboratory-scale or the pilot-scale mixing vessels would have been capable of resuspending the slurry if it had been stored at 80°C for more than a few days.

1. INTRODUCTION

The Savannah River Site (SRS) is evaluating methods for removing the major radionuclides from the supernate solutions that are stored in the high-level waste tanks at the site. The decontaminated supernate would then be solidified for disposal as low-level waste. Monosodium titanate (MST) powder is planned for use to remove ^{90}Sr and various transuranium elements from the supernate. One of the options being evaluated involves contacting the supernate with MST powder within the large high-level waste tanks. The tank contents (sludge, supernate and added MST) would be mixed to contact the supernate with the MST, and then the sludge and MST would be allowed to settle and the supernate would be decanted. The sludge and MST would need to be resuspended later so that the solids could be pumped to the Defense Waste Processing Facility for vitrification. A series of laboratory-scale and pilot-scale tests was conducted to determine the mixing requirements for resuspending slurries of sludge simulant and MST, following settling periods of various lengths. The goal is to resuspend essentially all of the sludge, and to produce a homogeneous slurry within the tank. The effects of various storage conditions on the rheological properties of the sludge/MST slurry were evaluated in small-scale tests. The results of these tests will help determine the feasibility of conducting the MST contact in the high-level waste tanks, and will also provide design data if the decision is made to construct a new facility to perform the MST contacting.

2. MATERIALS AND METHODS

2.1 SLURRY PREPARATION

The sludge simulants and MST for preparing the slurry were supplied by SRS. Three 55-gal drums each of HM and PUREX sludge simulant, and five drums of MST slurry were shipped to ORNL. The sludge simulants were prepared by AFF, Inc. (currently Optima Chemicals, Inc., Douglas, GA), and the MST was also manufactured by Optima. The HM sludge was formulated to represent the sludge in the H-area tanks at SRS, and the PUREX sludge represents the sludge in the F-area tanks. Each of the sludge simulants was mainly composed of iron hydroxide and aluminum hydroxide, with smaller amounts of numerous other compounds.[1] The average total suspended solids (TSS) concentrations of the HM, Purex and MST slurries were 6.65, 13.46 and 14.43 wt %, respectively. The solids in both sludge simulants were fairly easy to resuspend, but the MST had set-up into a very hard mass in the bottom of the drums. It was impossible to push a stainless steel stirring rod through the MST by hand. A drum pump was used to grind down through the MST in order to resuspend the particles. The settling rate of the individual sludge and MST slurries was not measured quantitatively, but the MST settled very rapidly, the Purex sludge was fairly slow, and the HM sludge was very slow. The six drums of sludge simulant contained enough solids to make 746 L (197 gal) of a slurry containing 10 wt % sludge solids. The slurry was prepared in the pilot-scale mixing vessel (described below), and then small amounts were transferred into the laboratory-scale mixing vessel and the rheology test bottles. The final slurry was calculated to contain 10 wt % sludge solids and 5 wt % MST solids, for a total of 15 wt % TSS. The supernate was prepared using the recipe for the SRS average supernate simulant[2] (see Table 1). The density of the supernate simulant was measured to be 1.27 g/cm^3, which correlates to a sodium concentration of 5.9 *M*, based on the formula (density = 1.009 + 0.04454[Na^+]) determined by Savannah River Technical Center.[2] Because of a mistake in calculating the solids concentrations of the sludge and MST slurries, the prepared sludge/MST/supernate slurry originally contained only 9.9 wt % TSS; therefore, supernate was removed from the laboratory-scale and pilot-scale vessels to increase the TSS concentrations. Measurement of the total suspended solids concentration for two samples of the slurry from the pilot-scale vessel gave values of 14.7 and 14.9 wt %, and the density of the slurry was determined to be 1.39 g/cm^3. Slurry from the pilot-scale vessel was used to refill the rheology test bottles.

Table 1. Composition of SRS supernate simulant.

Component	Concentration (M)
Na^+	5.9
K^+	0.016
OH^-	2.01
NO_3^-	2.26
NO_2^-	0.55
AlO_2^-	0.33
CO_3^{2-}	0.17
SO_4^{2-}	0.16
Cl^-	0.026
F^-	0.034
PO_4^{3-}	0.010
$C_2O_4^{2-}$	0.008
SiO_3^{2-}	0.004
MoO_4^{2-}	0.0002

2.2 RHEOLOGY TESTS

Samples of the sludge/MST/supernate slurry were stored in 500-mL glass bottles at room temperature and at 80°C for various time periods prior to measurement of the yield stress and viscosity of the slurry. Some of the samples that were stored at room temperature were irradiated in a gamma field in the spent-fuel storage pool of the High Flux Isotope Reactor (HFIR) for periods calculated to give total radiation doses of about 30, 70, and 140 MR. These doses correspond to storage for 14, 30 and 60 days in the SRS high-level waste tanks.

2.3 RESUSPENSION TESTS

A clear glass tank, 29 cm (11.5 in.) ID and 29 cm tall, was used for the laboratory-scale resuspension tests. Three 2.5-cm-wide vertical baffles were equally spaced inside the vessel, 1 cm from the wall. A laboratory-scale, variable speed mixer (Lightnin LabMaster model L1UO8), with an 8.6-cm-OD, A-310 impeller was used to mix the slurry. This mixer has a built-in dynamometer for measuring power levels. The impeller was positioned 3 cm up from the bottom of the vessel. Figure 1 shows a photograph of the laboratory-scale system.

The pilot-scale tests were performed in a flat-bottom stainless steel tank, 1.5 m (5 ft) ID by 1.2 m (4 ft) tall. This tank has a 2.6 kW (3.5 hp) mixer (Lightnin model XDQ350), with a 46-cm (18-in.) OD, A-310 impeller located 16 cm up from the bottom of the tank. An Allen-Bradley frequency drive controller, with actual motor speed and power-level feedback readings, was used to control the speed of the pilot-scale mixer. The tank is equipped with three baffles, equally spaced on the sides of the vessel, that are 13 cm wide and mounted 3 cm from the wall. A large, hinged opening on the top of the tank permits visual observation of the interior (see Fig. 2).

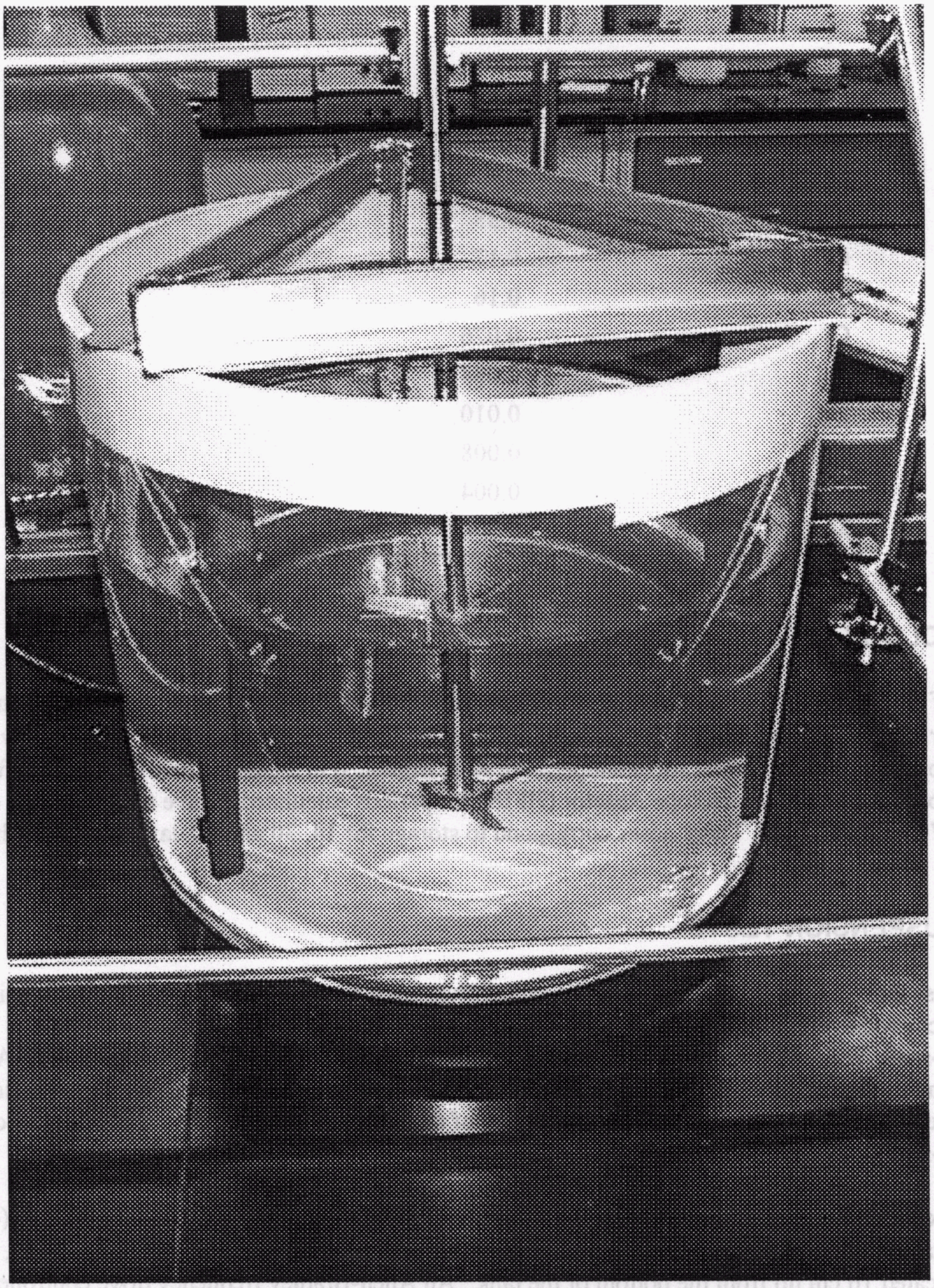

Fig. 1. Photograph of the laboratory-scale mixing vessel.

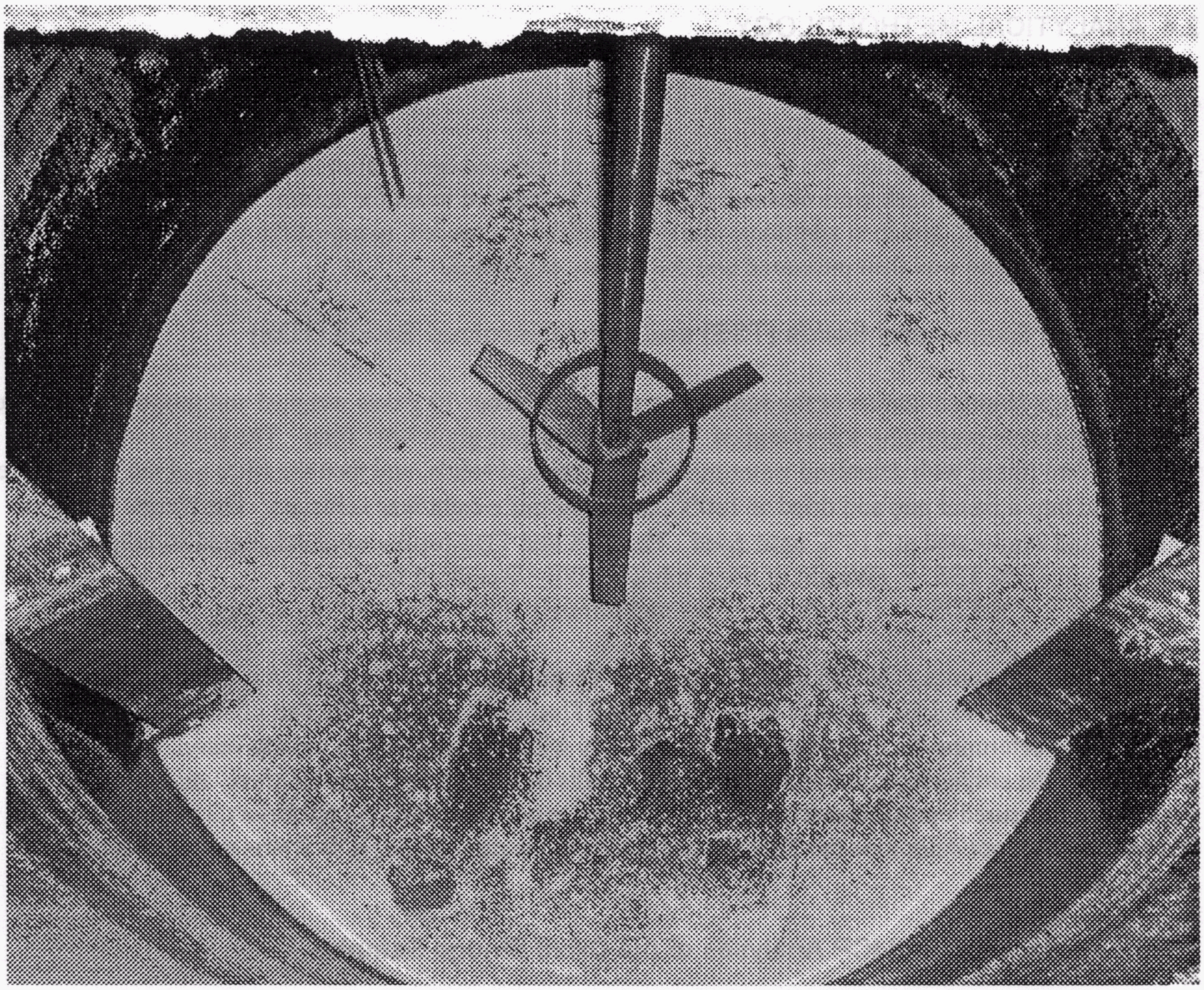

Fig. 2. Photograph of interior of the pilot-scale mixing vessel.

The two systems are dimensionally similar, with the ratio of impeller diameter to tank diameter and impeller height to impeller diameter being the same, so the results between the laboratory-scale and pilot-scale tests should be comparable.

For both vessels, the slurries were initially mixed, then allowed to settle for periods of four, fourteen and sixty days between remixing. The laboratory-scale vessel was kept in an air-conditioned building, so the temperature stayed at 23°C. The temperature of the pilot-scale vessel varied from 23 to 35°C. Samples of the slurries were collected from various locations within the vessels during the resuspension tests, and analyzed for total suspended solids and ICP metals to determine if the solids were completely resuspended. The samples were collected using a peristaltic pump with a piece of stainless steel tubing on the suction end of the flexible tubing. The stainless steel tubing was located at the position to be sampled, slurry was pumped through the tubing into a waste container until the line was purged, and then the sample was collected from the discharge of the tubing.

2.4 ANALYTICAL METHODOLOGY

2.4.1 Density Measurement

After thorough homogenization, the slurry sample was introduced into a tared 50-mL class A volumetric flask. The walls of the flask were cleaned, the slurry was allowed to set for several hours to liberate the entrapped air bubbles, and then additional slurry was added, as needed, to adjust the volume. The weight of the known volume was then measured and the density calculated.

2.4.2 Total Suspended Solids (TSS) and Total Dissolved Solids (TDS)

After thorough homogenization of the sample, an aliquot of about 10 g was weighed and introduced into the filtering apparatus containing a preweighed 1.6 μm borosilicate glass fiber filter. The solids remaining on the filter were rinsed with deionized water to remove dissolved solids, and then the filter and the solids were transferred into a metal pan and dried at 110°C until constant weight was achieved. The filtrate was collected and evaporated at 110°C until dried. The TSS and TDS results were calculated as follows:

$$\%\,TSS = (\text{Weight of dried solids} \times 100) / \text{Weight of the aliquot},$$
$$\%\,TDS = (\text{Weight of evaporated filtrate} \times 100) / \text{Weight of the aliquot}.$$

A single-beam photometer, Model 612 (Wedgewood Technologies, San Carlos, CA), with a submersible probe was tested in various dilutions of the sludge/MST/supernate slurry. We had planned to use this instrument to determine the optical density of the slurry within the pilot-scale mixing vessel, as a real-time indication of the suspended solids concentration. Results of the tests showed that there was almost no response in measured optical density with TSS until the solids concentration fell below 3 wt %. This instrument could not determine the TSS concentrations in the desired range, so it was not used during the mixing tests.

2.4.3 Preparation and ICP Analyses of the Dried Sludge Samples

Ordinary preparation methods from the Environment Protection Agency (EPA) such as SW846-3051 could not be used with the dried sludges since they contained siliceous and other hard-to-dissolve materials. Therefore, an aggressive sample preparation method (EPA SW846-3052) was followed to dissolve all the solids using a microwave oven (Model CDS 7000 from Spex Industries). About 0.25 g of sample was mixed with 5 mL of concentrated HNO_3 and 5 mL of HF. The vessel containing this sample was heated in the microwave oven to 180°C in 5.5 min, and then held at 180°C for 14.5 min. After the vessel had been cooled, 5 mL of concentrated HCl was added, followed by 2 g of boric acid, and the heating cycle was repeated. The boric acid was used to complex the fluoride in order to protect the ICP equipment (e.g. mixing chamber and nebulizer) during analysis. This procedure resulted in clear yellow solutions, indicating that the sample digestion was complete.

Preliminary tests had shown that this procedure provided more effective dissolution of the sludge samples than the standard EPA 3051 preparation. Standard reference samples from the National Institute of Standards and Technology (NIST) were prepared along with the samples to verify the accuracy of the preparation methods. Following the sample preparation, analyses were performed using an Inductively Coupled Argon Plasma–Atomic Emission Spectrometer (ICP-AES), model 61E Trace from Thermo Jarrell Ash. The analysis was performed following standard EPA method SW846-6010B. The results obtained for the reference standards were within 5% of the certified concentrations for the main components of the sludge (Al, Fe, Si, and Ti).

2.4.4 Viscosity Measurements

We had planned to use a Brookfield (Stoughton, MA) DV-III Rheometer, equipped with a cylindrical spindle, for the yield stress measurements. The 500-mL bottles that were used to store the slurries would fit under the instrument, and the spindle could be positioned so that it was covered by the sludge. However, the torque of this instrument did not allow measurement of the very thick sludges obtained for the samples kept at 80°C. Therefore, all of the yield stress and the viscosity measurements were made using a Haake Rheostress RS150 (Paramus, NJ). The specifications of this instrument are as follows: a maximum torque of 0.15 Nm, a minimum torque of 0.5×10^{-7} Nm, a maximum speed of 1000 min^{-1}, and a minimum speed of 0.01 min^{-1}. The cylinder sensor system used was model Z38 (38.2 mm OD and 55 mm tall), and the beaker was model TEF/Z48 (54 mm ID). The temperature was controlled at 23°C during the measurements. Because of its very high torque, this instrument was able to measure the thick samples obtained after storage at 80°C; however, because of the configuration of the instrument, the glass bottles containing the slurry samples would not fit under the spindle. Consequently, in order to measure the yield stress of the slurries, the supernate was removed using a syringe, and then the sludge was gently transferred into the measuring beaker of the instrument using a spoon. The beaker was then placed in the instrument, the spindle was lowered into the sludge, and the software controlling the measurement was initiated. The shear rate used for this analysis was 0.09 s^{-1}. The shear stress values were recorded for ten minutes. Typically, the shear stress increased until the spindle started to turn, and then decreased. The maximum shear stress recorded during the early part of the test was used as the yield stress.

After the sludge sample and the supernate had been returned to the original container, the bottle was manually shaken to homogenize the slurry, and then an aliquot was taken for measurement of the flow curve. The conditions selected for these tests were as follows: ramping up of the shear rate from 0.01 to 500 s^{-1} in 10 min, remaining at 500 s^{-1} for 5 min, then ramping down from 500 to 0.01 s^{-1} in 10 min. Both the shear stress and the viscosity were recorded for each value of shear rate.

3. RESULTS

3.1 RHEOLOGY TESTS

The settling rate of the sludge/MST solids was determined by measuring the height of the solids interface over a period of several days for slurry samples that were placed in graduated cylinders. During the initial 4 h of settling, the velocity of the interface was fairly constant at 0.22 cm/h; then it decreased as the solids were compacted. A graph of the results is shown in Fig. 2. The initial height of the slurry in the graduated cylinders was 18.6 and 21.5 cm for the 250 and 500 mL cylinders, respectively. After settling for a period of 7 days, the height of clear supernate was about 30% and the height of the settled solids was 70% in each cylinder.

The viscosity and the yield stress were measured for bottles of the sludge/MST/supernate slurry following storage at 23 and 80°C. Table 2 shows the average viscosity results at three different shear rates for replicate samples at each storage condition; a listing of all the results is given in Appendix A. There was good agreement between the replicates for the viscosity measurements, but the yield stress measurements showed significant scatter. For the slurries stored at room temperature, there was only a small difference in the viscosities measured during the increasing (up rate) and decreasing (down rate) shear rate ramps The suspended solids caused a large increase in the viscosity of the slurries, as compared with the clear supernate, which is shown in Table 2 for comparison.

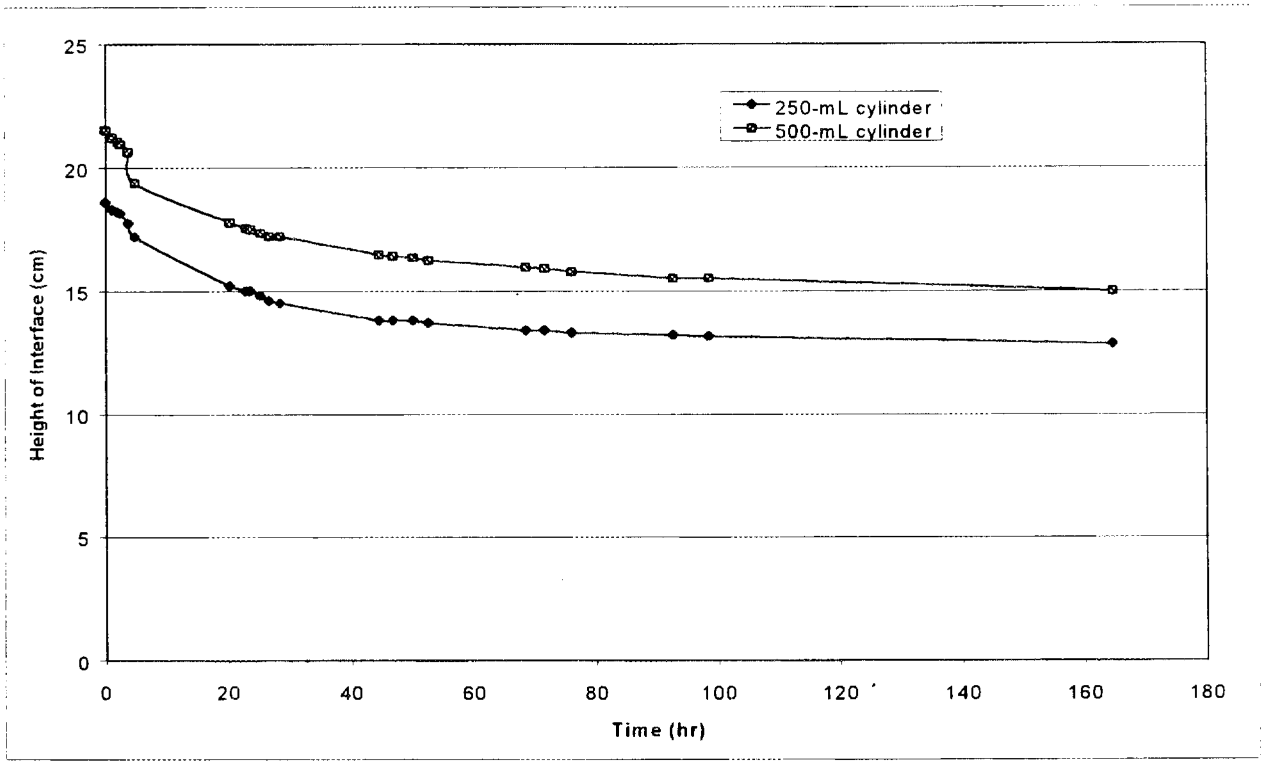

Fig. 3. Results of settling tests using sludge/MST/supernate slurry.

For the slurries stored at 80°C, the up-rate viscosities were much higher than the down-rate viscosities, and the difference increased with longer storage times. After storage for 30 and 61 days at 80°C, the slurry was so thick that a good curve for viscosity vs. shear rate could not be obtained. The slurry next to the spindle fluidized, but the remainder of the slurry did not move; thus, the numbers given in Table 2 should be considered only qualitative for these samples.

Figures 4–7 illustrate the viscosity-vs-shear rate curves for the samples stored at 23 and 80°C for 7 and 14 days. Figure 4 shows that there was essentially no difference in the viscosities measured during the up-rate and down-rate portions of the test for the replicate samples stored at 23°C for 7 days, except for one sample that had a higher viscosity during the up-rate portion. After storage for 14 days at 23°C (see Fig. 5), there was a slight difference in the up-rate and down-rate viscosities, and this same pattern was increasingly evident in the samples that were stored for 30 and 61 days. The yield stress and the up-rate viscosity of the slurry samples slowly increased for storage times of 14 to 61 days.

Table 2. Yield stress and Viscosity Measurements of Slurry Samples [a]

Sample description	Yield stress (Pa)	Viscosity (mPa·s = cP): Shear rate = 100 (1/s)		Shear rate = 150 (1/s)		Shear rate = 200 (1/s)	
		Up rate[b]	Down rate[c]	Up rate	Down rate	Up rate	Down rate
Supernate		6	5	7	7	8	8
Initial slurry	1.6	63	56	48	43	42	37
1 day – 23°C	1.5	60	56	46	43	39	37
3 days – 23°C	1.2	60	54	46	42	39	36
7 days – 23°C	1.8	60	54	46	42	39	36
14 days – 23°C	2.4	75	62	58	48	48	41
30 days – 23°C	3.2	80	57	60	44	49	38
61 days – 23°C	7.2	100	55	72	43	57	37
1 day – 80°C	2.3	155	64	106	50	81	43
3 days – 80°C	20.0	416	87	251	70	177	61
7 days – 80°C	58.5	846	89	558	72	408	63
14 days – 80°C	118	1058	139	670	111	524	96
30 days – 80°C	172	1542	185	958	144	359	123
61 days – 80°C	>500	2098	361	1176	274	845	230
27 days – 43 MR	2.3	166	112	120	85	96	70
27 days – 31 MR	1.8	158	99	114	76	90	63
27 days -Control	2.6	94	77	71	59	59	49
46 days – 81 MR	3.2	144	85	103	65	81	54
46 days – 58 MR	2.2	144	82	104	60	81	51
46 days – Control	2.9	105	72	78	55	63	47
82 days – 160 MR	5.3	206	80	136	61	101	52
82 days – 120 MR	5.5	183	76	124	59	92	50
82 days – Control	9.9	77	48	57	38	47	33

[a] Results for 30 and 61 days at 80°C are only qualitative.
[b] Viscosity measured during increasing shear rate (up rate) portion of test.
[c] Viscosity measured during decreasing shear rate (down rate) portion of test.

The down-rate portion of the viscosity curves did not show any significant change as the storage time increased. Apparently, the stirring that occurred during the higher shear-rate portion of the viscosity measurements was sufficient to break up any bonds that formed between the particles during storage at room temperature. Figure 6 shows the results for replicate samples stored at 80°C for 7 days. The viscosity of the slurry increased rapidly as the samples were stored at 80°C. The viscosities measured during the up-rate portion of the test were much higher than those measured during the later, down-rate, portion of the test. The stirring that occurred during the viscosity measurements reduced the viscosity of the slurry, but even the down-rate viscosity values continued to increase as the storage time increased at 80°C. After storage for 14 days at 80°C, the viscosities measured during the up-rate portion of the test showed some unusual behavior (see Fig 7). Longer storage times at 80°C led to even more radical behavior.

We had originally planned to store the irradiated samples for periods of 14, 30, and 60 days and have the irradiation performed sometime during these periods; however, because of delays in getting the samples irradiated, longer storage times were necessary. The control samples were stored along with the samples that were irradiated, so the storage conditions were the same, except for during the time of the irradiation. The temperature in the spent-fuel storage pool at HFIR is about 35°C and the radiation generated additional heat, so the irradiated samples were at a higher temperature for a few hours. The samples were contained in a stainless steel vessel, with one sample bottle stacked on top of the other, during the irradiation period. The operator at HFIR stated that the samples were hot to the touch, possibly 55-60°C, when removed from the containment vessel; however, the temperature was not measured. The irradiation times were about 6, 11 and 23 h for the 27-, 46- and 82-day samples, respectively. The dose rate for the samples was about 7.2 MR/hr for the lower bottle and 5.0 MR/hr for the upper bottle. The irradiation dose for each sample is shown in Table 2. Appendix B gives a detailed description of the irradiation tests, including the gamma dose rates for each bottle.

The slurry in the bottles that were irradiated was apparently stirred to some extent, possibly by the heat generated during the irradiation, because there was only one phase visible after the bottles had been removed from the containment vessel. Each of the other bottles had a clear supernate layer on top of the sludge. The gamma radiation had less effect on the yield stress than it did on the viscosity of the samples, possibly due to the stirring that occurred during the irradiation. Any mixing of the settled solids would decrease the yield stress. The viscosities of the irradiated samples were slightly higher than those for the associated control samples, and the sample with the higher radiation dose generally showed a higher viscosity than the paired sample at the lower dose. This increase in viscosities could have been caused by the higher temperature experienced by the irradiated samples, since the temperature would increase as the dose irradiation increased. The relatively high gamma irradiation doses used in these tests (up to 160 MR) caused only small, in any, changes in the rheological properties of the this simulant slurry.

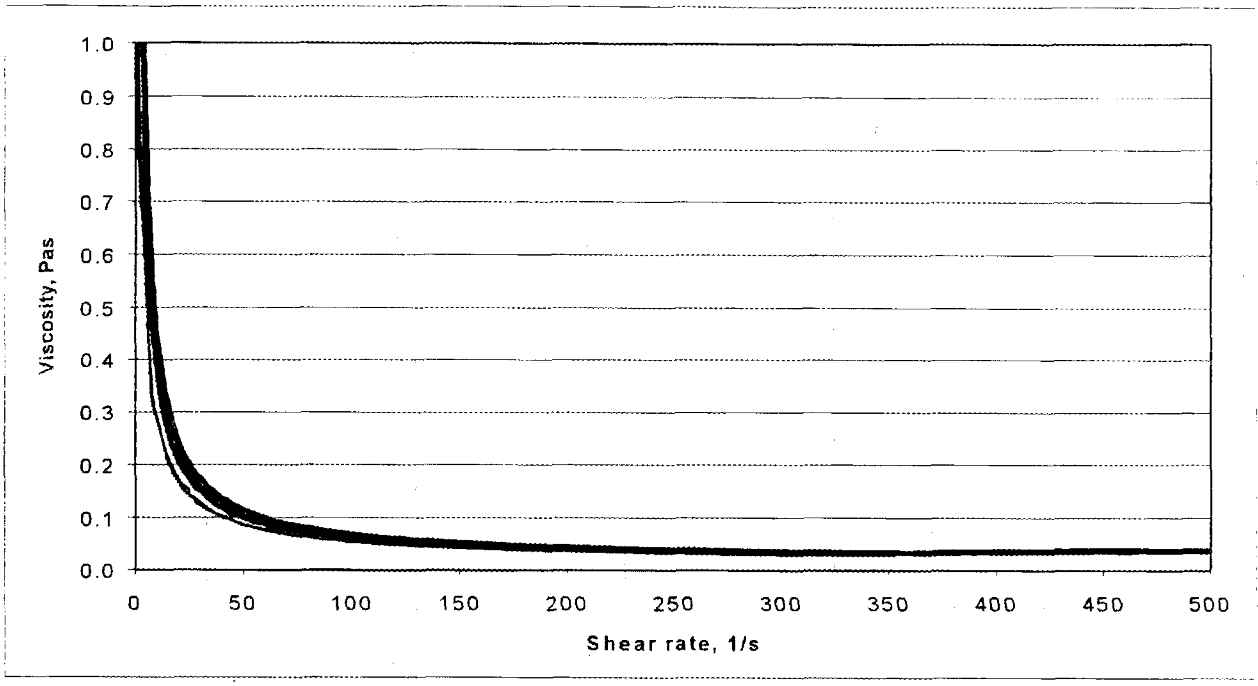

Fig. 4. Viscosity vs shear rate for sludge/MST/supernate slurry stored at 23°C for 7 days.

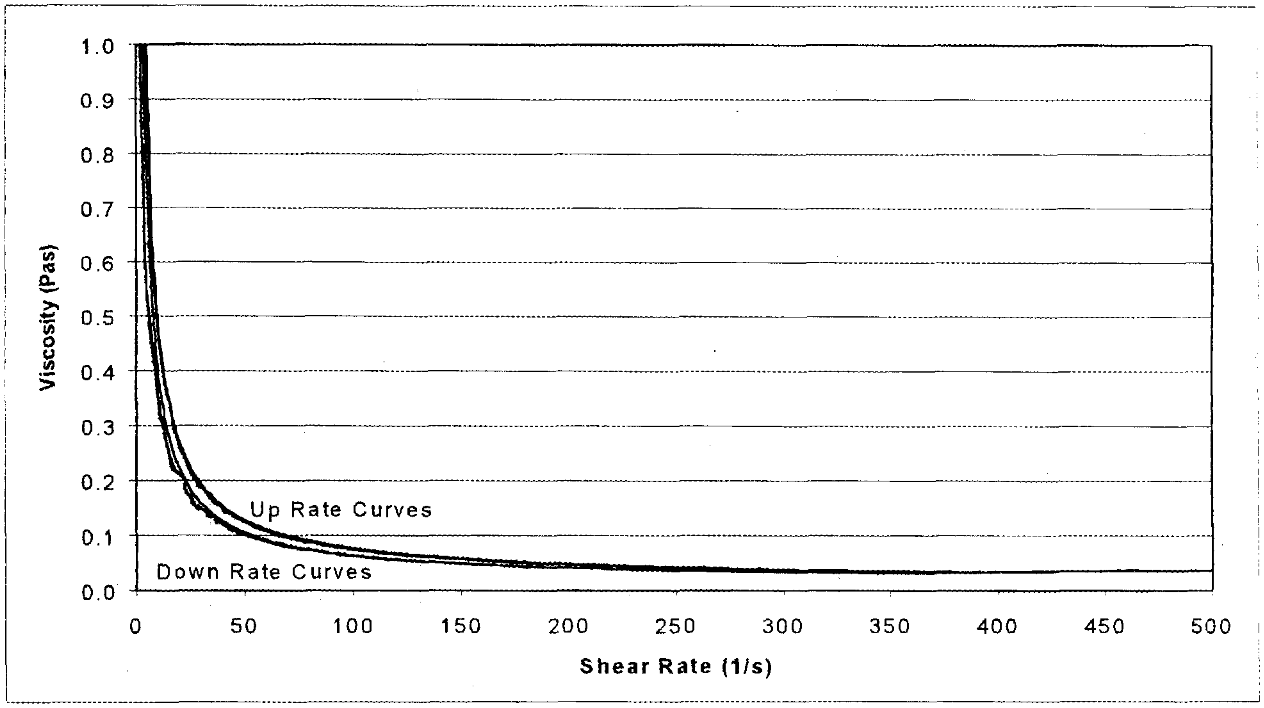

Fig. 5. Viscosity vs shear rate for sludge/MST/supernate slurry stored at 23°C for 14 days.

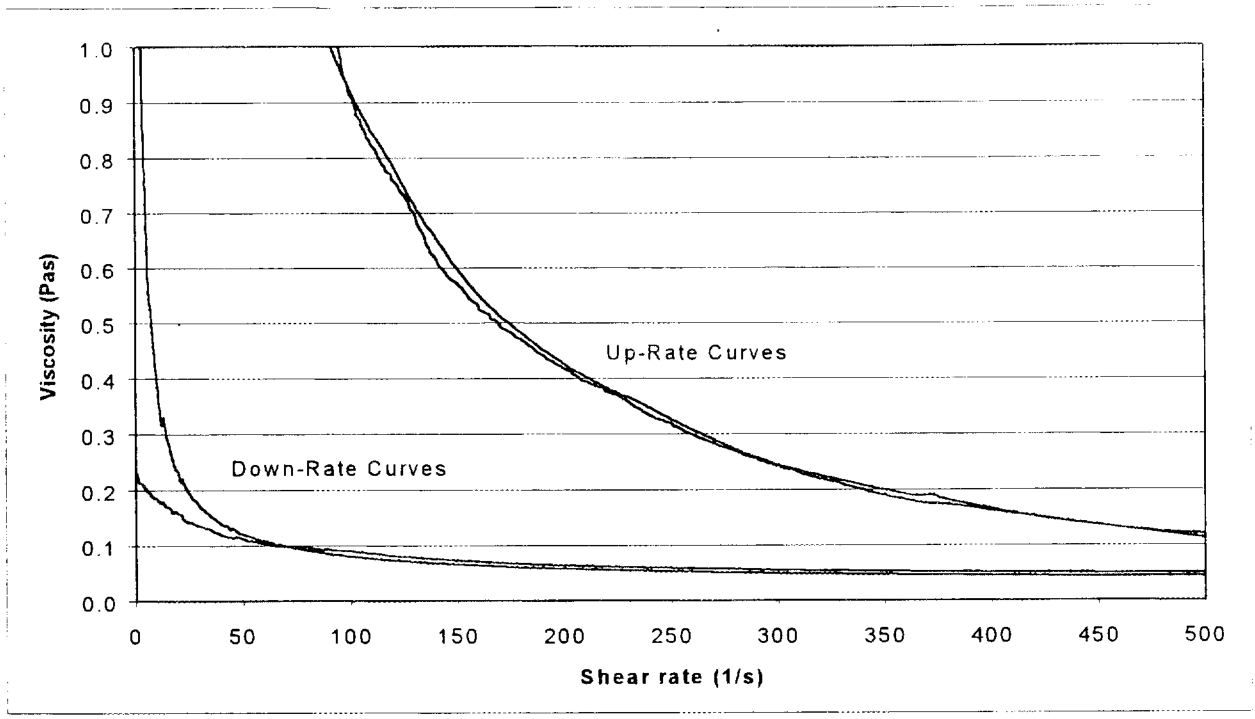

Fig. 6. Viscosity vs shear rate for sludge/MST/supernate slurry stored at 80°C for 7 days.

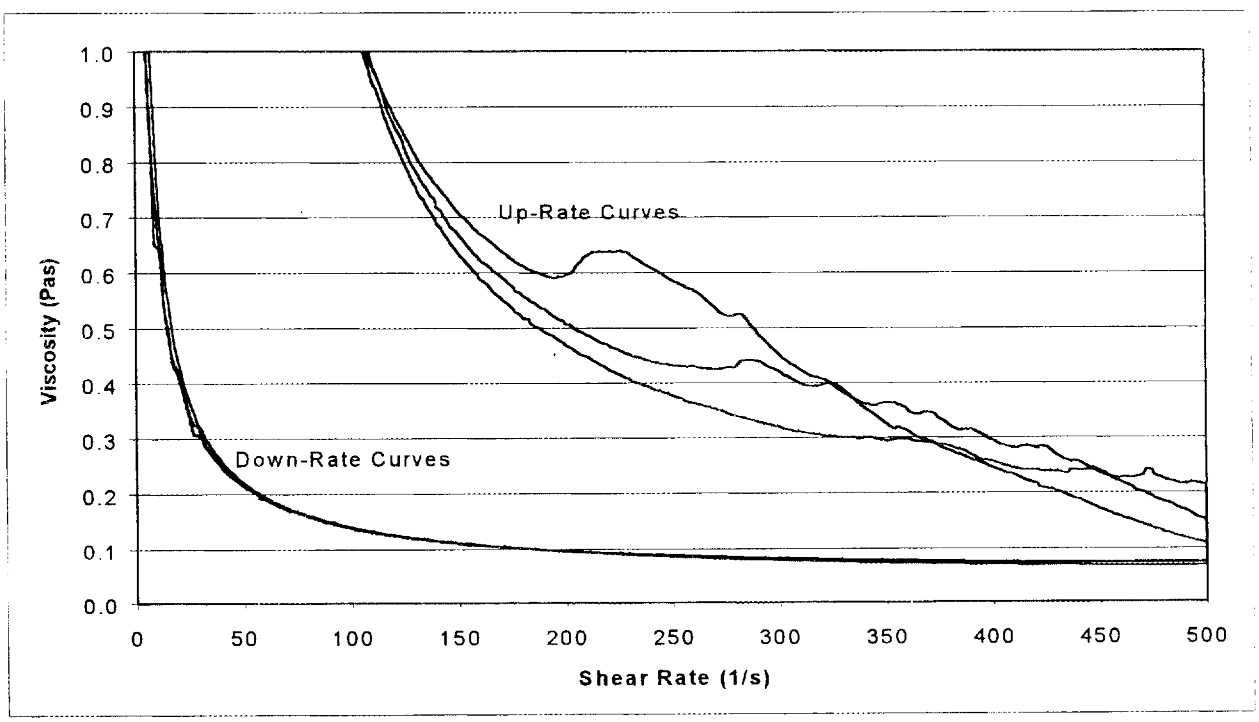

Fig. 7. Viscosity vs shear rate for sludge/MST/supernate slurry stored at 80°C for 14 days.

Both the irradiated and the control samples showed higher viscosities than the samples that were kept in the laboratory at 23°C for similar storage times. The reason for this is not known. The control samples taken to HFIR were kept in an air-conditioned building, so they were not exposed to higher temperatures during storage. The samples were transported to HFIR in a truck, so they were exposed to summer-time temperatures for about 15 min and were also subjected to vibrations from the vehicle; however, neither of these conditions seems likely to have affected the viscosity of the samples.

3.2 RESUSPENSION TESTS

3.2.1 Resuspension Tests Following a 4-day Settling Period

The laboratory-scale vessel initially contained 8.6 L of slurry, which gives a depth of 13 cm. After being allowed to settle for 4 days, the slurry was mixed to resuspend the solids. The laboratory-scale vessel was stirred at speeds from 500 to 1800 rpm; the corresponding impeller tip speeds and mixer power are shown in Table 3. During calibration of the laboratory-scale mixer, the mixer automatically measures the power levels for the full range of speeds while the impeller is turning in air and then subtracts the corresponding value from the measurement while mixing the slurry, before displaying the power reading. The values listed in Table 3 are the net increases in power due to the resistance of the slurry. The power levels that were measured for mixing 13 L of water and SRS average supernate simulant in the laboratory-scale vessel are shown for comparison. The power required to stir a fluid is directly proportional to the fluid density, and the difference in densities for the three liquids (water = 1.0, supernate = 1.27 and slurry = 1.39 g/cm^3) correlates well with the measured power levels. An interface in the slurry was visible through the glass wall of the vessel, at a depth of about 6 cm, at all of the mixer speeds tested, even though the bulk fluid appeared to be completely mixed. Apparently, the fluid velocity adjacent to the wall was low enough to allow particles to segregate by density.

While being mixed at 800 rpm, the slurry was sampled from near the top and the bottom of the vessel and analyzed for total suspended solids (TSS). The dried solids from each of the TSS samples were digested, and ICP-AES was used to measure the concentrations of metals. Selected results are presented in Table 4, and a complete listing of the ICP results is given in Appendix C. These results show that the solids were evenly distributed within the vessel. The ratio of iron, which is the major component of the sludge, to titanium, which is the major component of the MST, indicates that there was no segregation between the sludge and the MST particles within the slurry. The TSS concentration measured for the slurry in the laboratory-scale vessel is higher than the initial concentration measured in the pilot-scale vessel, which indicates that proportionally more of the supernate was removed from the laboratory-scale vessel while adjusting the solids concentrations (see Section 2.1).

Table 3. Mixer data during resuspension test of sludge/MST/supernate slurry in laboratory-scale vessel, following 4 days of settling

Speed (rpm)	500	600	700	800	900	1000	1200	1400	1600	1800
Tip speed (m/min)	136	163	190	217	244	271	326	380	434	489
Power (W)	1.4	2.4	3.4	4.8	5.7	6.4	8.7	12.3	17.1	23.5
Water[a] – power (W)	0.8	1.6	2.5	3.6	4.7	-	-	-	-	-
Supernate[a] - power (W)	1.0	1.9	2.9	4.4	5.3	-	-	-	-	-

[a]Power levels for mixing water and supernate simulant are included for comparison.

Table 4. Summary of data from laboratory-scale vessel, following 4 days of settling

Description	Sample I.D. Top	Bottom
Distance from bottom (cm)	11	1
Distance in from side (cm)	2	2
Mixer speed (rpm)	800	800
Total suspended solids (wt %)	16.4	16.0
<u>ICP results for samples of dried sludge (mg/kg)</u>		
Aluminum	54,606	55,447
Calcium	15,093	16,285
Chromium	1,650	1,735
Iron	157,167	165,850
Manganese	36,250	38,182
Nickel	13,079	13,791
Titanium	140,187	148,230
Zirconium	10,993	11,718
Fe/Ti ratio	1.12	1.12

The depth of slurry in the pilot-scale vessel was 44 cm, which corresponds to a volume of 780 L, and 3 cm of clear supernate was present above the settled sludge layer. Samples of the slurry were taken from near the top and the bottom of the settled sludge layer, and the TSS concentrations were 15.4 and 17.7 wt %, respectively. The slurry was mixed at speeds of 150 and 170 rpm, which correspond to impeller tip speeds of 215 and 245 m/min. The motor power values at these settings were 220 and 280 W, compared with values of 90 and 110 W when the impeller was turning in air; thus, the power increase due to the slurry was 130 and 170 W at 150 and 170 rpm, respectively. Samples were taken from three different depths at each speed and analyzed for both TSS and metals. The TSS and selected ICP results are presented in Table 5. A listing of the ICP results is included in Appendix D.

The averages for the TSS results are 14.7 wt % at 150 rpm and 15.1 wt % at 170 rpm, with standard deviations of 0.24 and 0.33, respectively. It is possible that some solids were not suspended while mixing at 150 rpm, although the difference in the average TSS concentrations is small and samples from near the bottom of the vessels did not have higher TSS concentrations than the samples from other locations. The statistical probability that the average TSS concentration at 170 rpm represents an actual difference from the value at 150 rpm is only about 60%, so it is likely that the sludge in the pilot-scale vessel was fully suspended at a mixer speed of 150 rpm. The slurry was homogeneously mixed at both speeds. The average TSS concentration measured for two samples of the starting slurry from the pilot-scale vessel was 14.8 wt %, which compares well with the results of the samples taken during the mixing test.

Table 5. Summary of data from pilot-scale mixing test, following 4 days of settling.

Description	Sample I.D.	SRS-3	SRS-4	SRS-5	SRS-6	SRS-7	SRS-8
Distance from bottom (cm)		5	25	45	5	25	45
Distance in from side (cm)		5	5	5	5	5	5
Mixer speed (rpm)		150	150	150	170	170	170
Total suspended solids (wt %)		14.5	14.5	15.0	14.7	15.5	15.0
ICP results for samples of dried sludge (mg/kg)							
Aluminum		59,479	57,750	55,508	58,829	56,031	56,716
Calcium		16,710	16,105	15,812	17,152	15,601	15,546
Chromium		1,823	1,757	1,660	1,775	1,642	1,670
Iron		175,107	169,360	159,807	171,472	158,488	160,921
Manganese		40,242	38,840	36,804	39,371	36,428	37,061
Nickel		14,506	14,014	13,216	14,191	13,102	13,280
Titanium		157,114	151,732	144,237	154,651	142,909	146,316
Zirconium		12,026	116,89	11,069	11,913	11,016	11,192
Fe/Ti ratio		1.11	1.12	1.11	1.11	1.11	1.10

3.2.2 Resuspension Tests Following a 14-day Settling Period

The slurries in the laboratory-scale and pilot-scale mixing vessels were allowed to settle for 2 weeks and then were mixed again to resuspend the solids.

In these tests, the laboratory-scale vessel was mixed at speeds of 500-900 rpm (tip speeds of 136-244 m/min). Visual observation of individual particles in the slurry was much more difficult, as compared with the earlier resuspension tests. Apparently, the larger particles had been broken up during the earlier mixing. Particle-size analysis of slurry samples from the pilot-scale vessel (see below) confirmed that there was some reduction in particle size during mixing. Three slurry samples were taken at a mixer speed of 500 rpm, and one sample was taken at 900 rpm. The power measurements are presented in Table 6, and the results of TSS and ICP analyses (averages of triplicate analyses) are summarized in Table 7. Listings of the individual TSS and ICP results are included in Appendixes E and F, respectively. The TSS results suggest that the slurry was not completely suspended at a mixer speed of 500 rpm, and possibly not even at 900 rpm, although visually we did not observe any stagnant material in the bottom of the vessel at either mixer speed. The sample taken at 900 rpm had a lower TSS concentration than earlier samples from the laboratory-scale vessel, and also from later samples. The slurry was homogeneous at a mixer speed of 500 rpm. The mixer power levels measured for this test were lower than those measured during the earlier resuspension test; however, the reason for the difference is not known. The lower TSS concentration in the slurry that was suspended would cause a slight decrease the density of the slurry, as compared to the earlier mixing test when all of the solids were suspended. The lower density would cause a proportionally lower power level for the mixer, but this small decrease in density can not explain all of the power level reduction that was observed.

Table 6. Mixer speed and power data for laboratory-scale mixing test, following 14 days of settling

Speed (rpm)	500	600	700	800	900
Tip speed (m/min)	136	163	190	217	244
Power (W)	1.2	1.9	2.8	3.0	3.9

Table 7. Summary of data from laboratory-scale mixing test, following 14 days of settling [a]

Description Sample I.D.	SRS-L1	SRS-L2	SRS-L3	SRS-L4
Distance from bottom (cm)	2	10	10	10
Distance from side (cm)	2	2	13	13
Mixer speed (rpm)	500	500	500	900
Total suspended solids (wt %)	13.4	13.3	13.2	14.4
ICP results for samples of dried sludge (mg/kg)				
Aluminum	59,638	57,631	57,439	56,065
Calcium	15,982	15,862	14,099	13,404
Chromium	1,709	1,660	1,577	1,512
Iron	165,792	161,394	153,841	148,411
Manganese	38,112	37,081	35,771	34,453
Nickel	13,663	13,281	12,555	12,091
Titanium	153,010	147,974	145,585	139,671
Zirconium	11,462	11,021	10,730	10,378
Fe/Ti ratio	1.08	1.09	1.06	1.06

[a] TSS and ICP results are averages of triplicate analyses.

The velocity of the slurry in the pilot-scale vessel, at a mixer speed of 150 rpm (tip speed = 215 m/min) was measured using a rented Marsh-McBirney Model 511 electromagnetic velocity probe, which measures the velocity of the fluid in two directions. The probe was oriented such that the axial (vertical) and the radial components of the slurry velocity were measured. Table 8 shows the velocities measured near the bottom outside edge of the vessel as the mixer was started. A period of almost 2 min was required for the slurry to start moving at this location and 5 min to reach a steady axial velocity of 29 m/min (1.6 ft/s). Table 8 shows the velocities measured at several locations within the pilot-scale vessel after the mixer had been running for about 10 min. Samples were taken from the same locations and analyzed for TSS and metals. Each analysis was performed in triplicate; the averages of the results are shown in Table 9. All of the TSS results and statistical calculations are listed in Appendix E, and the ICP results are summarized in Appendix G.

Table 8. Velocity measurements from near the bottom outside edge of the pilot-scale vessel [a]

Time (min)	1	1.5	2	3	4	5
Axial velocity (m/min)	0	0	24	27	27	29
Radial velocity (m/min)	0	0	9	9	7	7

[a] The mixer was started at time = 0.

Table 9. Summary of data from pilot-scale mixing test, following 14 days of settling [a]

Description	Sample I.D.	SRS-P1	SRS-P2	SRS-P3	SRS-P4	SRS-P5	SRS-P6	SRS-P7
Distance From Bottom (cm)		5	25	40	5	25	40	40
Distance From Side (cm)		5	5	5	25	25	25	70
Axial Velocity (m/min)		29	26	15	9	15	7	11
Radial Velocity (m/min)		7	9	11	0	2	11	33
Total Suspended Solids (wt %)		14.9	15.0	15.0	14.8	14.8	14.7	14.8
<u>ICP Results for Samples of Dried Sludge (mg/kg)</u>								
Aluminum		58670	57196	57345	59583	57702	60045	59396
Calcium		14191	13862	13652	14648	13943	14338	14583
Chromium		1573	1521	1522	1590	1545	1600	1603
Iron		154094	149868	150141	157347	152340	157748	157244
Manganese		35629	34764	34715	36302	35269	36408	36267
Nickel		12545	12186	12192	12774	12345	12762	12781
Titanium		144759	141396	141264	147589	142804	148039	146737
Zirconium		10930	10658	10663	11092	10697	11002	11025
Ratio Fe/Ti		1.06	1.06	1.06	1.06	1.06	1.06	1.07

[a] Vessel was mixed at 150 rpm. TSS and ICP results are averages of triplicate analyses.

The TSS results show that the solids were completely resuspended, and that the slurry was homogeneously mixed within the vessel. The ICP results indicate that there was no segregation between the MST and the sludge during mixing, since the ratio of iron to titanium concentrations did not change significantly between the samples. The motor power during the mixing was 220 W, which is the same as that measured during the earlier mixing tests at a mixer speed of 150 rpm, giving a net power increase of 130 W due to the slurry.

The particle size distributions of two samples of the slurry were measured: a sample of the original slurry and a sample from the pilot-scale vessel during mixing (SRS-P4). The initial sample had a mean particle size of 4.51 μm and a median size of 3.90 μm, while the respective values for SRS-P-4 were 3.90 μm and 3.44 μm. For the initial sample, 10% of the particles were larger than 8.74 μm, as compared with 10% being larger than 7.75 μm for SRS-P-4. The mixing caused a slight decrease in the particle size distribution of the slurry.

3.2.3 Resuspension Tests Following a 60-day Settling Period

The slurries in the laboratory-scale and pilot-scale vessels were mixed again following 60 days of settling. The slurry in the laboratory-scale vessel was much more difficult to resuspend than in the previous tests. At mixer speeds of 500 and 700 rpm, we could detect a stagnant layer of thick sludge near the bottom outside edge of the tank by using a rod, and the slurry near the top of the tank did not show any vertical circulation. At a mixer speed of 900 rpm, some vertical circulation occurred, but only in portions of the vessel. The slurry appeared to be completely mixed at 1100 rpm. Samples were taken from near the bottom and the top of the vessel at each mixer speed and analyzed for TSS in triplicate. These samples were not submitted for ICP analysis, since the earlier results had shown that there was no separation between the sludge and the MST solids. The average TSS results for each sample are shown in Table 10; a complete listing of the results are presented in Appendix H.

Table 10. Summary of data from laboratory-scale mixing test, following 60 days of settling[a]

Description	Sample I.D.	SRS-L-5	SRS-L-6	SRS-L-7	SRS-L-8	SRS-L-9	SRS-L-10	SRS-L-11	SRS-L-12
Distance From Bottom (cm)		2	10	2	10	2	10	2	10
Distance From Side (cm)		2	2	2	2	2	2	2	2
Mixer speed (rpm)		500	500	700	700	900	900	1100	1100
Impeller Tip Speed (m/min)		136	136	190	190	244	244	300	300
Mixer power (W)		1.0	1.0	1.3	1.3	2.6	2.6	7.3	7.3
Total Suspended Solids (wt %)		9.53	10.29	12.80	11.98	15.05	14.57	16.15	16.18

[a] TSS results are the average of triplicate analyses.

The TSS results correlate with the visual observations during the mixing tests. The TSS concentration in the slurry increased as the mixer speed is increased up to 1100 rpm. It appears that the samples taken from near the bottom of the vessel at the slower mixer speeds did not collect the thicker stagnant slurry that was present, since these samples had lower TSS concentrations than the samples taken at 1100 rpm. The TSS concentrations in both the top and the bottom samples at 1100 rpm matched those measured during the earlier resuspension test following 4 days of settling, so the solids in the vessel had been completely suspended and the slurry was homogeneous. The TSS results for the earlier resuspension test, following 14 days of settling, were all lower than 16 wt %, so it appears that the slurry did not get fully resuspended during those tests, which were conducted using mixer speeds of 500 to 900 rpm.

The pilot-scale vessel was mixed at speeds of 150, 172, and 207 rpm. A full circulation pattern was established in the vessel at a mixer speed of 150 rpm. Samples of the slurry were taken from near the top and the bottom of the vessel at each of the mixer speeds and analyzed for TSS in triplicate. The motor power levels shown on the controller were 190, 280 and, 420 W for speeds of 150, 172 and 207, respectively. The values for net power increase caused by mixing the slurry are shown in Table 11, along with the average TSS results. All of the individual TSS results are listed in Appendix H. Based on the TSS results, it appears that none of the mixing speeds tested was not sufficient to resuspend all of the solids. The TSS results for all of the samples showed higher concentrations for the samples taken near the bottom, as compared with those taken from near the top of the slurry. Increasing the mixer speed from 172 rpm to 207 rpm reduced, but did not eliminate, the difference in TSS concentrations between the top and bottom samples. The average concentration for each of the two samples at each mixer speed is about the same; thus, it does not appear that any additional solids were resuspended at the higher mixer speed. The TSS concentrations in all of these samples are lower than the results obtained during both of the earlier mixing tests. It appears that some of the solids were not resuspended; however, we could not detect any solids on the bottom of the tank like we could for the laboratory-scale vessel at the slower mixing speeds. This mixing test did not achieve either complete resuspension of the solids or a homogeneous slurry within the vessel.

Table 11. Summary of data from pilot-scale mixing test, following 60 days of settling [a]

Description	Sample I.D.	SRS-P-8	SRS-P-9	SRS-P-10	SRS-P-11	SRS-P-12	SRS-P-13
Distance From Bottom (cm)		5	45	5	45	5	45
Distance From Side (cm)		5	5	5	5	5	5
Mixer speed (rpm)		150	150	172	172	207	207
Impeller Tip Speed (m/min)		215	215	248	248	297	297
Mixer power (W)		100	100	170	170	300	300
Total Suspended Solids (wt %)		11.70	10.65	14.05	12.04	13.88	12.67

[a] TSS results are the average of triplicate analyses.

4. DISCUSSION

The results of the small-scale rheology tests show that storage at room temperature has only a small effect on the viscosity and the yield stress of the sludge/MST/supernate slurry. For storage up to 61 days, the yield stress increased by a factor of 5, while the viscosities increased by only about 50%. The viscosities measured during the down-rate portion of the tests, after the slurry had been mixed for about 15-25 min, did not change significantly as the storage time increased. Storage at 80°C had a dramatic effect on both the viscosity and the yield stress of the slurry. For storage times up to 61 days, the viscosity increased by up to a factor of 30 and the yield stress increased by over a factor of 300. Gamma radiation up to 160 MR had only a small, if any, effect on the viscosity or the yield stress of the slurry.

The slurry samples that were stored at 23°C exhibited Bingham plastic type behavior, with an yield stress (yield stress), followed by a linear shear stress-vs-shear rate response. There was a small thixotropic response, where the shear stress decreased with time, indicating a breakdown of the slurry structure as it was stirred. After the samples had been stirred for several minutes, all of them showed lower shear stress and viscosity values for the ramp-down portion of the viscosity measurement. The difference between the ramp-up and ramp-down portions of the test increased as the storage time increased. The samples that were stored at 80°C showed strong thixotropic behavior, which increased rapidly with increasing storage times.

For the pilot-scale mixing vessel, an impeller tip speed of 215 m/min (700 ft/min) was sufficient to resuspend the settled solids following settling times of 4 and 14 days. A tip speed of 215 m/min is the common design speed for large industrial mixers.[3] The same impeller tip speed successfully resuspended the solids in the laboratory-scale vessel after a settling time of 4 days, but did not give favorable results after 14 days of settling. The difficulty in resuspending the slurry that had settled for 60 days demonstrates that the small increases in viscosity and yield stress measured for the rheology samples that were stored for 60 days at room temperature caused a definite change in the mixing requirements to resuspend the slurry. The mixer speed required for the laboratory-scale vessel increased from 800 to 1100 rpm and the required power increased from 4.8 to 7.3 W. For the pilot-scale vessel, the required mixer speed increased from 150 to 170 rpm, and the motor power increased from 130 to 170 W. Based on the results from the small-scale rheology tests, it is unlikely that the single impellers in either the laboratory-scale or the pilot-scale mixing vessels would have been capable of resuspending the slurry if it had been stored at 80°C for more than a few days.

For dimensionally similar mixing vessels, the mixing power required to suspend a slurry in a large vessel can be predicted based on measurements in a small vessel. The power number is used to correlate the mixer power. The dimensionless power number is defined as:

$$\text{Power number} = \text{Measured power} / (\text{slurry density})(\text{mixer speed})^3 (\text{impeller diameter})^5$$

The power number was calculated for both the laboratory-scale and the pilot-scale mixing tests, and the results were compared to determine how well the correlation from the laboratory-scale test predicted the results for the pilot-scale test. Correlations for power number vs Reynolds number are given for a series of different marine propellers in *Mixing-Theory and Practice*.[4] In determining the Reynolds number in mixing tanks, the characteristic diameter is the impeller diameter and the characteristic velocity is the tip speed. For a given impeller tip speed, the Reynolds number is proportionally larger for larger impellers.

Table 12 shows the measured power and both the calculated power number and the Reynolds number for the laboratory-scale and pilot-scale resuspension tests following 4 days of settling. The density of the slurry was 1.39 g/cm^3 and the viscosity used for calculating the Reynolds number was 41mPa·s, which is the average of the values measured for the 3-day rheology samples at shear rates of 150–200 s^{-1}. At impeller tip speeds of about 215 and 245 m/min, where both the laboratory-scale and the pilot-scale mixers were both tested, the calculated power numbers were very similar for the two vessels. The laboratory-scale results predict the pilot-scale mixer power within an average of 3% for a scaleup in tank and impeller diameter of more than a factor of 5. For the resuspension tests following 60 days of settling, the power numbers for the laboratory-scale mixer at 1100 rpm and the pilot-scale mixer at 207 rpm, where the tip speeds for each are about 300 m/min, were 0.18 and 0.24, respectively. The laboratory-scale mixer underpredicts the power requirements for the pilot-scale mixer by 25%.

Table 12. Results of power number and Reynolds number calculations.

Parameter	Laboratory-scale						Pilot-Scale	
Speed (rpm)	500	600	700	800	900	1000	150	170
Tip Speed (m/min)	136	163	190	217	244	271	215	245
Power (W)	1.4	2.4	3.4	4.8	5.7	6.4	130	170
Power number	0.371	0.368	0.328	0.310	0.259	0.212	0.291	0.261
Reynolds number	2090	2500	2920	3340	3760	4170	17800	20500

A graph in ref. 4 gives power numbers in the range of 0.23 to 0.48 at Reynolds numbers of 1000 to 15,000 for the most efficient propellers in fully-baffled tanks. The results for the ORNL mixing tests using the sludge/MST/supernate slurry are within the range of the published data.

The settling velocity of the solids in the sludge/MST/supernate slurry was very low (0.22 cm/h), which would generally suggest that the slurry could be treated as a single phase when designing mixing equipment.[5] However, the volumetric concentration of solids, which was about 70% after settling for several days, and the high viscosity of the slurry as compared with the free liquid (supernate), indicate that the slurry should be considered a high-concentration particle suspension.[5-7] Most of the experimental testing and correlations found in the literature involve slurries of free-settling particles, and these results may not correctly predict the behavior of high-concentration slurries. The mixer speed required to keep solids suspended increases rapidly as the volume of settled solids increases above 60%.[7] Resuspending slurries that have a high yield stress (>30 Pa) may not be feasible for tanks stirred by a single-impeller.[5] The sludge/MST/supernate slurry samples stored at 80°C for 7 days or longer had yield stress values over 30 Pa. Such results indicate that it may be necessary to control the temperature in the high-level waste tanks at SRS if the MST contact is performed in situ. The effect of storage temperatures intermediate between 23 and 80°C was not determined in this study.

Michael Poirier of the Savannah River Technology Center used the Cavern Model[8,9] to predict the mixing speeds required for the slurry used in these tests. The basis of this model is that close to the impeller the shear stresses generated by the impeller are greater than the yield stress of the slurry, and the slurry is well mixed. At large distances from the impeller, the slurry yield stress is larger than the shear stress generated by the impeller, and the slurry is not well mixed. Equations [1] – [3] describe the cavern model.[8-10]

$$N_c = \frac{\pi}{D_I}\sqrt{\frac{\left(\frac{H_c}{D_c}+\frac{1}{3}\right)\left(\frac{T}{D_I}\right)^3 \tau_y}{\rho N_p}} \quad [1]$$

$$N_c = \sqrt{\frac{4V_c\pi\left(\frac{H_c}{D_c}+\frac{1}{3}\right)\tau_y}{\left(\frac{H_c}{D_c}\right)\rho N_p D_I^5}} \quad [2]$$

$$N_c = \sqrt{\frac{\left(\frac{T}{D_I}\right)^3 \pi^2 \tau_y}{1.32 N_p D_I^2}} \quad [3]$$

In equations [1] – [3], N_c is the impeller speed required to completely mix the entire tank, V_c is the cavern volume, H_c is the cavern height, D_c is the cavern diameter, T is the tank diameter, D_I is the impeller diameter, τ_y is the slurry yield stress, ρ is the slurry density, and Np is the impeller power number. For a completely-mixed tank, the cavern volume is equal to the slurry volume, the cavern height is equal to the slurry height in the tank and the cavern diameter is equal to the tank diameter.

Table 13 shows the operating parameters for the laboratory-scale and the pilot-scale tanks, along with the predictions for required agitator speed to mix the tanks. The predictions are based on the slurry conditions following a 60-day settling period. The model predictions agree reasonably well with each other for the laboratory-scale and the pilot-scale tanks. The models over-predict the required impeller speed that was measured using the laboratory-scale tank by approximately 50%. The models suggest that the impeller speed in the pilot-scale tank would have needed to be increased by 35% to achieve complete mixing of the slurry.

Since the small-scale tests showed that slurry that had sat for 61 days at 80°C had a yield stress greater than 500 Pa, the Cavern Model was employed to determine the required impeller speed to mix the pilot-scale tank if it contained slurry with a yield stress of 500 Pa. For these conditions, the predicted impeller speed to completely mix the tank is 2336 rpm (last column of Table 13), which would require motor power of 350 kW (>800 times higher than the maximum that was tested). These calculations emphasize the importance of controlling the temperature of sludge/MST/supernate slurries during storage.

Sludge from several inactive underground storage tanks at ORNL has been resuspended and transferred into the Melton Valley Storage Tanks. Rheology data was measured for core samples of sludge from three of these tanks, W-21, W-22 and W-23, prior to mixing. These samples had yield stress values of 8.5 to 19.7 Pa and viscosities of 16 to 19 mPa·s. The sludge in these tanks was successfully resuspended using a fluidic pulse jet mixing system that was designed and fabricated by AEA Technology (Cheshire, United Kingdom)[11]. Sludges in several other tanks have been resuspended using high-pressure sluicing nozzles, but the rheology of these sludges was not measured. There has not been any experience at ORNL with resuspending sludges with yield stresses >100Pa.

Table 13. Comparison between measured values and Cavern Model predictions

Parameter	Lab-Scale Tank	Pilot-Scale Tank	Pilot-Scale Tank
H_c	12.5 cm	46 cm	46 cm
D_c	29 cm	152.4 cm	152.4 cm
T	29 cm	152.4 cm	152.4 cm
D_I	8.6 cm	46 cm	46 cm
τ_y	7.2 Pa = 72 $g\cdot(cm\cdot s)^{-1}$	7.2 Pa = 72 $g\cdot(cm\cdot s)^{-1}$	500 Pa = 5000 $g\cdot(cm\cdot s)^{-1}$
ρ	1.39 g/cc	1.39 g/cc	1.39 g/cc
N_p	0.3	0.3	0.3
Settling Time	60 days	60 days	60 days
Temperature	Ambient	Ambient	80° C
N_c (Equation [1])	1558 rpm	259 rpm	2155 rpm
N_c (Equation [2])	1591 rpm	249 rpm	2079 rpm
N_c (Equation [3])	1829 rpm	333 rpm	2775 rpm
Average	1659 rpm	280 rpm	2336 rpm
N_c (Measured)	1100 rpm	> 207 rpm	N/A

5. REFERENCES

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6. APPENDIXES

Appendix A.

VISCOSITY AND YIELD STRESS DATA FOR SMALL-SCALE RHEOLOGY TESTS: VISCOSITY DATA AT A SHEAR RATE OF 100 s^{-1}.

Description	Viscosity (Pa·s) at 100 (1/s) shear rate[a]							Average	S_x
Standard,	0.0562			(ramp up)				0.0562	0.00000
0.055 Pa·s	*0.0537*			*(ramp down)*				*0.0537*	*0.00000*
Standard,	0.115							0.1150	0.00000
0.10 Pa·s	*0.112*							*0.1120*	*0.00000*
Initial slurry	0.0616	0.0641						0.0629	0.00125
	0.0547	*0.0569*						*0.0558*	*0.00110*
1 day - 23°C	0.0569	0.0641	0.062	0.0643	0.0569	0.0575	0.0565	0.0597	0.00331
	0.0555	*0.057*	*0.0537*	*0.0578*	*0.0553*	*0.0558*	*0.0548*	*0.0557*	*0.00126*
3 days - 23°C	0.0601	0.0608						0.0605	0.00035
	0.0545	*0.0538*						*0.0542*	*0.00035*
7 days - 23°C	0.0559	0.0545	0.0555	0.0598	0.0623	0.0627	0.0675	0.0597	0.00440
	0.0457	*0.0528*	*0.0537*	*0.056*	*0.0515*	*0.055*	*0.0603*	*0.0536*	*0.00414*
14 days - 23°C	0.0763	0.073	0.0754					0.0749	0.00139
	0.0619	*0.0626*	*0.0622*					*0.0622*	*0.00029*
30 days - 23°C	0.0831	0.0758	0.0837	0.0792				0.0805	0.00319
	0.0593	*0.0557*	*0.0563*	*0.0572*				*0.0571*	*0.00136*
61 days - 23°C	0.121	0.121	0.0568	0.103				0.1005	0.02625
	0.063	*0.0641*	*0.0381*	*0.0542*				*0.0549*	*0.01040*
l day - 80°C	0.158	0.157	0.158	0.157	0.143			0.1546	0.00582
	0.0671	*0.063*	*0.0671*	*0.063*	*0.0582*			*0.0637*	*0.00330*
3 days - 80°C	0.411	0.447	0.389					0.4157	0.02391
	0.0838	*0.0901*	*0.0862*					*0.0867*	*0.00260*
7 days - 80°C	0.728	0.887	0.924					0.8463	0.08503
	0.0975	*0.0901*	*0.0802*					*0.0893*	*0.00709*
14 days - 80°C	1.08	1.08	1.013					1.0577	0.03158
	0.14	*0.138*	*0.14*					*0.1393*	*0.00094*
30 days - 80°C	1.43	1.62	1.99	1.13				1.5425	0.31188
	0.126	*0.246*	*0.181*	*0.187*				*0.1850*	*0.04249*
61 days - 80°C	2.89	2.39	1.51	1.6				2.0975	0.57146
	0.392	*0.387*	*0.325*	*0.339*				*0.3608*	*0.02923*
27 days - irradiated	0.158							0.1580	0.00000
31 MR	*0.099*							*0.0990*	*0.00000*
27 days - irradiated	0.166							0.1660	0.00000
43 MR	*0.112*							*0.1120*	*0.00000*
27 days - control	0.0935							0.0935	0.00000
0.0 R	*0.0774*							*0.0774*	*0.00000*
46 days - irradiated	0.144							0.1440	0.00000
58 MR	*0.0817*							*0.0817*	*0.00000*
46 days - irradiated	0.144							0.1440	0.00000
81 MR	*0.0848*							*0.0848*	*0.00000*
46 days - control	0.105							0.1050	0.00000
0.0 R	*0.0717*							*0.0717*	*0.00000*
82 days - irradiated	0.183							0.1830	0.00000
120 MR	*0.0755*							*0.0755*	*0.00000*
82 days - irradiated	0.206							0.2060	0.00000
160 MR	*0.0795*							*0.0795*	*0.00000*
82 days - control	0.0769							0.0769	0.00000
0.0 R	*0.0483*							*0.0483*	*0.00000*

[a]Values obtained with increasing shear rate (ramp up);
Values obtained with decreasing shear rate (ramp down).

Appendix A (continued): VISCOSITY DATA AT A SHEAR RATE OF 150 s^{-1}.

Description	Viscosity (Pa·s) at 150 (1/s) shear rate[a]							Average	S_x
Standard,	0.0547				(ramp up)			0.0547	0.00000
0.055 Pa·s	*0.0537*				*(ramp down)*			*0.0537*	*0.00000*
Standard,	0.113							0.1130	0.00000
0.10 Pa·s	*0.112*							*0.1120*	*0.00000*
Initial slurry	0.0473	0.0488						0.0481	0.00075
	0.0424	*0.0444*						*0.0434*	*0.00100*
1 day - 23°C	0.0438	0.0493	0.0475	0.0499	0.0438	0.0444	0.0437	0.0461	0.00256
	0.0428	*0.0447*	*0.0423*	*0.0448*	*0.0428*	*0.0432*	*0.0426*	*0.0433*	*0.00094*
3 days - 23°C	0.0465	0.0465						0.0465	0.00000
	0.0422	*0.0421*						*0.0422*	*0.00005*
7 days - 23°C	0.0431	0.0421	0.0429	0.0458	0.048	0.048	0.0517	0.0459	0.00325
	0.0364	*0.041*	*0.0411*	*0.0437*	*0.0407*	*0.0424*	*0.047*	*0.0418*	*0.00299*
14 days - 23°C	0.0587	0.0559	0.058					0.0575	0.00119
	0.0488	*0.0479*	*0.0481*					*0.0483*	*0.00039*
30 days - 23°C	0.0611	0.057	0.0619	0.0594				0.0599	0.00188
	0.0456	*0.0435*	*0.0439*	*0.0447*				*0.0444*	*0.00080*
61 days - 23°C	0.084	0.0863	0.0428	0.074				0.0718	0.01736
	0.0491	*0.0487*	*0.0305*	*0.0422*				*0.0426*	*0.00752*
1 day - 80°C	0.109	0.107	0.109	0.107	0.0984			0.1061	0.00394
	0.0525	*0.0497*	*0.0525*	*0.0494*	*0.0458*			*0.0500*	*0.00247*
3 days - 80°C	0.25	0.271	0.233					0.2513	0.01554
	0.0679	*0.0715*	*0.0692*					*0.0695*	*0.00149*
7 days - 80°C	0.503	0.577	0.593					0.5577	0.03920
	0.0783	*0.0734*	*0.0653*					*0.0723*	*0.00536*
14 days - 80°C	0.708	0.633	0.668					0.6697	0.03064
	0.111	*0.11*	*0.112*					*0.1110*	*0.00082*
30 days - 80°C	0.842	0.967	1.24	0.781				0.9575	0.17634
	0.0991	*0.19*	*0.142*	*0.145*				*0.1440*	*0.03216*
61 days - 80°C	1.44	1.32	1.03	0.913				1.1758	0.21267
	0.295	*0.29*	*0.257*	*0.253*				*0.2738*	*0.01889*
27 days - irradiated	0.114							0.1140	0.00000
31 MR	*0.0758*							*0.0758*	*0.00000*
27 days - irradiated	0.12							0.1200	0.00000
43 MR	*0.085*							*0.0850*	*0.00000*
27 days - control	0.0713							0.0713	0.00000
0.0 R	*0.0589*							*0.0589*	*0.00000*
46 days - irradiated	0.104							0.1040	0.00000
58 MR	*0.0602*							*0.0602*	*0.00000*
46 days - irradiated	0.103							0.1030	0.00000
81 MR	*0.0646*							*0.0646*	*0.00000*
46 days - control	0.776							0.7760	0.00000
0.0 R	*0.0552*							*0.0552*	*0.00000*
82 days - irradiated	0.124							0.1240	0.00000
120 MR	*0.0587*							*0.0587*	*0.00000*
82 days - irradiated	0.136							0.1360	0.00000
160 MR	*0.0614*							*0.0614*	*0.00000*
82 days - control	0.0573							0.0573	0.00000
0.0 R	*0.0381*							*0.0381*	*0.00000*

[a]Values obtained with increasing shear rate (ramp up);
Values obtained with decreasing shear rate (ramp down).

Appendix A (continued): VISCOSITY DATA AT A SHEAR RATE OF 200 s^{-1}.

Description	Viscosity (Pa·s) at 200 (1/s) shear rate[a]							Average	S_x
Standard,	0.0549				(ramp up)			0.0549	0.00000
0.055 Pa·s	*0.0542*				*(ramp down)*			*0.0542*	*0.00000*
Standard,	0.113							0.1130	0.00000
0.10 Pa·s	*0.111*							*0.1110*	*0.00000*
Initial slurry	0.0399	0.0431						0.0415	0.00160
	0.036	*0.038*						*0.0370*	*0.00100*
1 day - 23°C	0.037	0.0417	0.0401	0.042	0.037	0.0376	0.0368	0.0389	0.00215
	0.0367	*0.0382*	*0.0359*	*0.0384*	*0.0367*	*0.0369*	*0.0364*	*0.0370*	*0.00086*
3 days - 23°C	0.0394	0.0392						0.0393	0.00010
	0.036	*0.0355*						*0.0358*	*0.00025*
7 days - 23°C	0.0362	0.0359	0.0362	0.038	0.0397	0.0408	0.0438	0.0387	0.00273
	0.0311	*0.0352*	*0.0358*	*0.0375*	*0.0355*	*0.0363*	*0.04*	*0.0359*	*0.00249*
14 days - 23°C	0.0484	0.0464	0.0482					0.0477	0.00090
	0.0412	*0.041*	*0.0408*					*0.0410*	*0.00016*
30 days - 23°C	0.0502	0.0473	0.0506	0.0485				0.0492	0.00133
	0.0388	*0.0371*	*0.0375*	*0.0378*				*0.0378*	*0.00063*
61 days - 23°C	0.0651	0.0681	0.0358	0.0578				0.0567	0.01263
	0.0416	*0.0418*	*0.0271*	*0.0366*				*0.0368*	*0.00596*
l day - 80°C	0.0831	0.0818	0.0831	0.0818	0.076			0.0812	0.00264
	0.0448	*0.0424*	*0.0448*	*0.0424*	*0.0393*			*0.0427*	*0.00203*
3 days - 80°C	0.176	0.188	0.167					0.1770	0.00860
	0.0591	*0.0631*	*0.0602*					*0.0608*	*0.00169*
7 days - 80°C	0.376	0.424	0.424					0.4080	0.02263
	0.0676	*0.0643*	*0.0578*					*0.0632*	*0.00407*
14 days - 80°C	0.596	0.469	0.507					0.5240	0.05322
	0.095	*0.0953*	*0.0972*					*0.0958*	*0.00097*
30 days - 80°C	0.525	0.761	0.0763	0.073				0.3588	0.29617
	0.0842	*0.161*	*0.123*	*0.125*				*0.1233*	*0.02717*
61 days - 80°C	1.02	0.977	0.699	0.685				0.8453	0.15408
	0.244	*0.241*	*0.227*	*0.21*				*0.2305*	*0.01346*
27 days - irradiated	0.0904							0.0904	0.00000
31 MR	*0.063*							*0.0630*	*0.00000*
27 days - irradiated	0.0959							0.0959	0.00000
43 MR	*0.0702*							*0.0702*	*0.00000*
27 days - control	0.0594							0.0594	0.00000
0.0 R	*0.0492*							*0.0492*	*0.00000*
46 days - irradiated	0.0807							0.0807	0.00000
58M R	*0.0515*							*0.0515*	*0.00000*
46 days - irradiated	0.0807							0.0807	0.00000
81 MR	*0.0542*							*0.0542*	*0.00000*
46 days - control	0.0633							0.0633	0.00000
0.0 R	*0.0468*							*0.0468*	*0.00000*
82 days - irradiated	0.0916							0.0916	0.00000
120 MR	*0.05*							*0.0500*	*0.00000*
82 days - irradiated	0.101							0.1010	0.00000
160 MR	*0.0524*							*0.0524*	*0.00000*
82 days - control	0.047							0.0470	0.00000
0.0 R	*0.033*							*0.0330*	*0.00000*

[a]Values obtained with increasing shear rate (ramp up);
Values obtained with decreasing shear rate (ramp down).

Appendix A (continued): YIELD STRESS DATA.

Description	Yield stress (Pa), at rotation speed of 0.09 rpm				Average	S_x
Initial slurry	1.7	1.6	1.45		1.6	0.10
1 day - 23°C	1.75	1.6	1.25		1.5	0.21
3 days - 23°C	1.25	1.1	1.1		1.2	0.07
7 days - 23°C	1.8	1.75	1.9		1.8	0.06
14 days - 23°C	1.3	2.7	3.3		2.4	0.84
30 days - 23°C	3.2	3.2	3.1		3.2	0.05
61 days - 23°C	9.5	7.5	6.2	5.4	7.2	1.55
1 day - 80°C	2.6	2.2	2.2		2.3	0.19
3 days - 80°C	23	22.5	14.5		20.0	3.89
7 days - 80°C	67	50			58.5	8.50
14 days - 80°C	162	107	86		118	32.0
30 days - 80°C	250	205	60		172	81.1
61 days - 80°C	>500				>500	0
27 days - irradiated 31 MR	1.8				1.8	0.00
27 days - irradiated 43 MR	2.3				2.3	0.00
27 days - control 0.0 R	2.6				2.6	0.00
46 days - irradiated 58 MR	2.2				2.2	0.00
46 days - irradiated 81 MR	3.2				3.2	0.00
46 days - control 0.0 R	2.9				2.9	0.00
82 days - irradiated 120 MR	5.5				5.5	0.00
82 days - irradiated 160 MR	5.3				5.3	0.00
82 days - control 0.0 R	9.9				9.9	0.00

Appendix B.

NOTES FROM HFIR PERSONNEL ON IRRADIATION OF SLURRY SAMPLES.

Irradiation #1: Target Dose = 35 MR
Sample irradiation started 7/28/99 at 13:25
Sample irradiation ended 7/28/99 at 19:20
Time = 5.92 hrs
Dose Rate lower bottle = 7.28 MR/hr (axial avg.) Dose upper bottle = 43.1 MR
Dose Rate upper bottle = 5.17 MR/hr (axial avg.) Dose lower bottle = 30.6 MR
Avg. = 36.9 MR

Irradiation #2: Target Dose = 70 MR
Sample irradiation started 7/29/99 at 08:22
Sample irradiation ended 7/29/99 at 19:42
Time = 11.333 hrs
Dose Rate lower bottle = 7.15 MR/hr (axial avg.) Dose upper bottle = 81.0 MR
Dose Rate upper bottle = 5.08 MR/hr (axial avg.) Dose lower bottle = 57.5 MR
Avg. = 69.3 MR

Irradiation #3: Target Dose = 140 MR
Sample irradiation started 7/30/99 at 09:04
Sample irradiation ended 7/31/99 at 08:28
Time = 23.4 hrs
Dose Rate lower bottle = 7.00 MR/hr (axial avg.) Dose upper bottle = 164 MR
Dose Rate upper bottle = 4.97 MR/hr (axial avg.) Dose lower bottle = 116 MR
Avg. = 140 MR

General notes:

All samples were hot to touch (guess at 120 to 140°F) upon removal from stainless steel containment vessel.

Approximately 1 oz of solution loss (thermal expansion out jar ?) was observed for each of the three irradiations.

Two phase mixture upon insertion (brown , approx. 3/4 clear liquid at top)
Only one phase upon removal
No odor at insertion : fairly strong odor at removal

Sample 1 was green tagged , samples 2 and 3 slightly above green tagable level (1500 and 1200 dpm respectively) and returned with yellow tag.

Appendix C.

COMPOSITION (mg/kg) OF THE DRIED SLUDGE FROM SLURRY SAMPLES TAKEN DURING RESUSPENSION TESTS FOLLOWING SETTLING FOR 4 DAYS IN THE LABORATORY-SCALE VESSEL

Analyte	Small-scale top	Small-scale bottom	Average of population	Sx	% RSD
Silver	< 10	< 13	< 12	1	11
Aluminum	54,606	55,447	55,027	421	1
Arsenic	< 51	< 65	< 58	7	11
Barium	1,634	1,725	1,680	46	3
Beryllium	< 1	< 2	< 2	0	11
Calcium	15,093	16,285	15,689	596	4
Cadmium	< 3	< 4	< 4	0	11
Chromium	1,650	1,735	1,692	43	3
Cesium	< 34,282	< 43,159	< 38,721	4,439	11
Copper	1,494	1,643	1,569	74	5
Iron	157,167	165,850	161,509	4,341	3
Potassium	1,597	1,467	1,532	65	4
Magnesium	3,245	3,478	3,361	116	3
Manganese	36,250	38,182	37,216	966	3
Molybdenum	< 10	< 13	< 12	1	11
Sodium	48,505	38,311	43,408	5,097	12
Nickel	13,079	13,791	13,435	356	3
Lead	2,214	2,332	2,273	59	3
Selenium	< 51	< 65	< 58	7	11
Antimony	< 86	< 108	< 97	11	11
Silicon	44,947	59,099	52,023	7,076	14
Strontium	1,270	1341	1,305	36	3
Thorium	< 1,714	< 2,158	< 1,936	222	11
Titanium	140,187	148,230	144,209	4,021	3
Thallium	< 51	< 65	< 58	7	11
Uranium	< 514	< 647	< 581	67	11
Vanadium	< 69	< 86	< 77	9	11
Zinc	1,279	1,360	1,319	41	3
Zirconium	10,993	11,718	11,355	362	3

Appendix D. COMPOSITION (mg/kg) OF THE DRIED SLUDGE FROM SLURRY SAMPLES TAKEN DURING RESUSPENSION TESTS, FOLLOWING A 4-DAY SETTLING PERIOD IN THE PILOT-SCALE VESSEL

Analyte	SRS-1	SRS-2	SRS-2 dup	SRS-3	SRS-4	SRS-5	SRS-6	SRS-7	SRS-8	Average of Population	Sx	% RSD
Silver	< 12	< 13	< 12	< 13	< 12	< 12	< 13	< 12	< 13	< 12	0.45	3.6
Aluminum	57514	60305	58978	59479	57750	55508	58829	56031	56716	57901	1531	2.6
Arsenic	< 62	< 65	< 59	< 64	< 59	< 61	< 64	< 61	< 63	< 62	2.24	3.6
Barium	1682	1811	1772	1852	1835	1714	1871	1710	1793	1782	63.60	3.6
Beryllium	< 2	2	2	2	2	2	2	2	3	2	0.34	15.9
Calcium	16022	16249	16006	16710	16105	15812	17152	15601	15546	16134	488	3.0
Cadmium	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	0.15	3.6
Chromium	1697	1774	1732	1823	1757	1660	1775	1642	1670	1725	58.23	3.4
Cesium	< 41597	< 43497	< 39308	< 42882	< 39002	< 40404	< 42608	< 40601	< 41982	< 41320	1496	3.6
Copper	1629	1725	1649	1819	1753	1675	1806	1717	1742	1724	61.36	3.6
Iron	161792	169894	166056	175107	169360	159807	171472	158488	160921	165877	5553	3.3
Potassium	1541	1545	1469	1423	1491	1490	1433	1767	1591	1528	98.88	6.5
Magnesium	3488	3429	3351	3553	3420	3238	3530	3192	3182	3376	134.95	4.0
Manganese	37431	39576	38524	40242	38840	36804	39371	36428	37061	38253	1287	3.4
Molybdenum	< 12	< 13	< 12	< 13	< 12	< 12	< 13	< 12	< 13	< 12	0.45	3.6
Sodium	48042	39117	38368	36221	37999	42525	37277	54901	44861	42146	5816	13.8
Nickel	13475	14124	13783	14506	14014	13216	14191	13102	13280	13743	468.64	3.4
Lead	2270	2378	2325	2427	2340	2206	2370	2178	2206	2300	83.42	3.6
Selenium	< 62	< 65	< 59	< 64	< 59	< 61	< 64	< 61	< 63	< 62	2.24	3.6
Antimony	< 104	< 109	< 98	< 107	< 98	< 101	< 107	< 102	< 105	< 103	3.74	3.6
Silicon	57810	60056	55418	57286	56651	61905	63320	60964	67659	60119	3628	6.0
Strontium	1328	1416	1391	1440	1404	1334	1437	1333	1373	1384	41.80	3.0
Thorium	< 2080	< 2175	< 1965	< 2144	< 1950	< 2020	< 2130	< 2030	< 2099	< 2066	74.78	3.6
Titanium	141473	151399	148092	157114	151732	144237	154651	142909	146316	148658	5104	3.4
Thallium	< 62	< 65	< 59	< 64	< 59	< 61	< 64	< 61	< 63	< 62	2.24	3.6
Uranium	< 624	< 652	< 590	< 643	< 585	< 606	< 639	< 609	< 630	< 620	22.43	3.6
Vanadium	< 83	< 87	< 79	< 86	< 78	< 81	< 85	< 81	< 84	< 83	2.99	3.6
Zinc	1317	1393	1369	1466	1408	1311	1424	1290	1337	1368	55.59	4.1
Zirconium	13219	13490	13292	12026	11689	11069	11913	11016	11192	12101	935.64	7.7

Appendix E.

TOTAL SUSPENDED SOLIDS (TSS) AND TOTAL DISSOLVED SOLIDS (TDS) FOR SLUDGE/MST SLURRY DURING RESUSPENSION TESTS, FOLLOWING A 14-DAY SETTLING PERIOD IN THE LABORATORY-SCALE AND PILOT-SCALE VESSELS

Sample ID	Weight (g)	**TSS** (wt %)	**Average** (wt %)	Sx (wt %)	RSD-TSS (%)	**TDS** (wt %)	**Average** (wt %)	Sx (wt %)	RSD-TDS (%)
SRS-L-1A	9.5719	13.491				26.9612			
SRS-L-1B	8.7754	13.305	**13.403**	0.0759	0.567	29.5177	**27.905**	1.146	4.107
SRS-L-1C	9.1311	13.413				27.2355			
SRS-L-2A	9.1796	13.299				27.350			
SRS-L-2B	9.1032	13.296	**13.259**	0.0553	0.417	32.4315	**29.807**	2.078	6.972
SRS-L-2C	8.7372	13.180				29.6388			
SRS-L-3A	8.8281	13.398				30.301			
SRS-L-3B	9.2471	13.181	**13.234**	0.1186	0.896	29.030	**28.921**	1.1742	4.060
SRS-L-3C	9.109	13.122				27.4311			
SRS-L-4A	9.3056	14.722				26.6925			
SRS-L-4B	9.2071	14.217	**14.455**	0.2073	1.434	26.9249	**27.753**	1.3395	4.826
SRS-L-4C	9.4201	14.424				29.643			
SRS-P-1A	9.4328	14.805				31.5018			
SRS-P-1B	8.8204	14.815	**14.860**	0.0718	0.483	26.550	**28.101**	2.4076	8.568
SRS-P-1C	9.0598	14.962				26.2522			
Blank-1	70	-9E-04				0.00043			
SRS-P-2A	9.457	15.038				26.2948			
SRS-P-2B	10.236	14.808	**14.947**	0.0998	0.668	26.4048	**27.027**	0.9592	3.549
SRS-P-2C	9.2741	14.994				28.3823			
SRS-P-3A	9.4185	15.265				26.0169			
SRS-P-3B	9.6923	14.968	**15.033**	0.1688	1.123	27.7973	**27.810**	1.469	5.282
SRS-P-3C	9.0798	14.867				29.6152			
SRS-P-4A	9.3061	14.813				29.8256			
SRS-P-4B	9.5693	14.761	**14.754**	0.051	0.346	27.880	**28.794**	0.7987	2.774
SRS-P-4C	9.3019	14.688				28.6769			
SRS-P-5A	9.0467	14.689				27.8322			
SRS-P-5B	9.6812	14.707	**14.747**	0.0697	0.472	26.6165	**28.387**	1.718	6.052
SRS-P-5C	9.7332	14.845				30.7134			
ARA-P-6A	9.3835	14.839				27.1967			
SRS-P-6B	9.3062	14.690	**14.743**	0.0678	0.460	29.7952	**29.336**	1.5923	5.428
SRS-P-6C	8.8503	14.700				31.0148			
SRS-P-7A	9.4462	14.729				30.2746			
SRS-P-7B	9.2509	14.781	**14.781**	0.0423	0.286	30.6576	**30.073**	0.578	1.922
SRS-P-7C	10.0288	14.832				29.2857			
BLANK-2	80	-5E-04				-0.0034			

Appendix F.

COMPOSITION (mg/kg) OF THE DRIED SLUDGE FROM SLURRY SAMPLES TAKEN DURING RESUSPENSION TESTS FOLLOWING A 14-DAY SETTLING PERIOD IN THE LABORATORY-SCALE VESSEL: AVERAGES OF TRIPLICATE ANALYSES

Analyte	SRS-L-1	SRS-L-2	SRS-L-3	SRS-L-4	Average of Population	Sx	%RSD
Silver	12	13	12	12	12	0	2.1
Aluminum	59,638	57,631	57,439	56,065	57,693	1,275	2.2
Arsenic	61	63	60	62	61	1	2.1
Barium	1,850	1,811	1,856	1,784	1,825	30	1.6
Beryllium	3	4	5	5	4	1	17.8
Calcium	15,982	15,862	14,099	13,404	14,837	1,113	7.5
Cadmium	4	4	4	4	4	0	2.1
Chromium	1,709	1,660	1,577	1,512	1,615	76	4.7
Cesium	40,375	42,327	40,056	41,086	40,961	872	2.1
Copper	1,853	1,831	1,814	1,737	1,809	44	2.4
Iron	165,792	161,394	153,841	148,411	157,359	6,705	4.3
Potassium	1,593	1,390	1,388	1,413	1,446	85	5.9
Magnesium	3,266	3,180	2,917	2,820	3,046	183	6.0
Manganese	38,112	37,081	35,771	34,453	36,354	1,376	3.8
Molybdenum	12	13	12	12	12	0	2.1
Sodium	45,756	39,497	37,523	40,817	40,898	3,040	7.4
Nickel	13,663	13,281	12,555	12,091	12,898	613	4.7
Lead	2,257	2,192	2,047	1,980	2,119	110	5.2
Selenium	61	63	60	62	61	1	2.1
Antimony	101	106	100	103	102	2	2.1
Silicon	75,699	75,020	69,640	71,381	72,935	2,513	3.4
Strontium	1,437	1,403	1,431	1,386	1,414	21	1.5
Thorium	2,019	2,116	2,019	2,095	2,062	44	2.1
Titanium	153,010	147,974	145,585	139,671	146,560	4,796	3.3
Thallium	61	63	60	62	61	1	2.1
Uranium	606	635	601	616	614	13	2.1
Vanadium	81	85	80	82	82	2	2.1
Zinc	1,379	1,351	1,303	1,251	1,321	49	3.7
Zirconium	11,462	11,021	10,730	10,378	10,898	398	3.6

Appendix F (continued) ICP RESULTS FOR INDIVIDUAL ANALYSES

Analyte	SRS-L-1A	SRS-L-1B	SRS-L-1C	SRS-L1	Sx	% RSD	SRS-L-2A	SRS-L-2B	SRS-L-2C	SRS-L2	Sx	% RSD
Silver	< 11	< 12	< 13	**12**	1	7.0	< 13	< 12	< 13	**13**	0	2.4
Aluminum	60885	58647	59382	**59638**	931	1.6	59035	58074	55783	**57631**	1364	2.4
Arsenic	< 55	< 62	< 65	**61**	4	7.0	< 64	< 61	< 65	**63**	2	2.4
Barium	1861	1811	1880	**1850**	29	1.6	1835	1845	1753	**1811**	41	2.3
Beryllium	3	3	4	**3**	0	9.4	4	3	4	**4**	0	3.3
Calcium	16213	15733	15999	**15982**	196	1.2	16000	15441	16146	**15862**	304	1.9
Cadmium	< 4	< 4	< 4	**4**	0	7.0	< 4	< 4	< 4	**4**	0	2.4
Chromium	1734	1689	1706	**1709**	19	1.1	1699	1675	1604	**1660**	40	2.4
Cesium	< 36563	< 41254	< 43309	**40375**	2823	7.0	< 42772	< 40900	< 43309	**42327**	1033	2.4
Copper	1855	1835	1867	**1853**	13	0.7	1855	1870	1769	**1831**	44	2.4
Iron	168341	163519	165516	**165792**	1978	1.2	164995	162675	156511	**161394**	3580	2.2
Potassium	1714	1494	1569	**1593**	91	5.7	1501	1397	1273	**1390**	93	6.7
Magnesium	3295	3243	3260	**3266**	22	0.7	3279	3174	3087	**3180**	78	2.5
Manganese	38619	37677	38039	**38112**	388	1.0	37997	37318	35928	**37081**	861	2.3
Molybdenum	< 11	< 12	< 13	**12**	1	7.0	< 13	< 12	< 13	**13**	0	2.4
Sodium	49496	43674	44098	**45756**	2651	5.8	43685	40591	34215	**39497**	3943	10.0
Nickel	13863	13484	13642	**13663**	156	1.1	13596	13391	12856	**13281**	312	2.3
Lead	2288	2221	2261	**2257**	27	1.2	2247	2203	2127	**2192**	50	2.3
Selenium	< 55	< 62	< 65	**61**	4	7.0	< 64	< 61	< 65	**63**	2	2.4
Antimony	< 91	< 103	< 108	**101**	7	7.0	< 107	< 102	< 108	**106**	3	2.4
Silicon	73242	76630	77226	**75699**	1754	2.3	73472	77474	74115	**75020**	1755	2.3
Strontium	1461	1416	1433	**1437**	19	1.3	1430	1411	1367	**1403**	27	1.9
Thorium	< 1828	< 2063	< 2165	**2019**	141	7.0	< 2139	< 2045	< 2165	**2116**	52	2.4
Titanium	156512	150098	152421	**153010**	2651	1.7	151449	149353	143119	**147974**	3538	2.4
Thallium	< 55	< 62	< 65	**61**	4	7.0	< 64	< 61	< 65	**63**	2	2.4
Uranium	< 548	< 619	< 650	**606**	42	7.0	< 642	< 613	< 650	**635**	15	2.4
Vanadium	< 73	< 83	< 87	**81**	6	7.0	< 86	< 82	< 87	**85**	2	2.4
Zinc	1388	1340	1408	**1379**	28	2.1	1360	1366	1327	**1351**	17	1.3
Zirconium	11692	11295	11400	**11462**	168	1.5	11309	11075	10678	**11021**	261	2.4

Appendix F (continued) ICP RESULTS FOR INDIVIDUAL ANALYSES

Analyte	SRS-L-3A	SRS-L-3B	SRS-L-3C	**SRS-L3**	Sx	% RSD	SRS-L-4A	SRS-L-4B	SRS-L-4C	**SRS-L4**	Sx	% RSD
Silver	< 11	< 13	< 12	**12**	1	6.6	< 12	< 13	< 12	**12**	0	2.1
Aluminum	57159	58972	56186	**57439**	1155	2.0	54767	56320	57109	**56065**	973	1.7
Arsenic	< 55	< 65	< 60	**60**	4	6.6	< 61	< 63	< 61	**62**	1	2.1
Barium	1830	1904	1835	**1856**	33	1.8	1723	1798	1831	**1784**	45	2.5
Beryllium	4	5	5	**5**	0	6.2	5	5	5	**5**	0	3.3
Calcium	14022	14726	13548	**14099**	484	3.4	12896	13714	13603	**13404**	362	2.7
Cadmium	< 4	< 4	< 4	**4**	0	6.6	< 4	< 4	< 4	**4**	0	2.1
Chromium	1563	1617	1551	**1577**	29	1.8	1471	1522	1544	**1512**	30	2.0
Cesium	< 36887	< 43346	< 39936	**40056**	2638	6.6	< 40469	< 42319	< 40469	**41086**	872	2.1
Copper	1786	1844	1811	**1814**	24	1.3	1662	1776	1773	**1737**	53	3.1
Iron	152591	157594	151339	**153841**	2702	1.8	144163	149178	151891	**148411**	3201	2.2
Potassium	1458	1371	1335	**1388**	52	3.7	1501	1399	1338	**1413**	67	4.8
Magnesium	2903	2993	2855	**2917**	57	2.0	2722	2853	2886	**2820**	71	2.5
Manganese	35485	36653	35175	**35771**	636	1.8	33484	34609	35265	**34453**	735	2.1
Molybdenum	< 11	< 13	< 12	**12**	1	6.6	< 12	< 13	< 12	**12**	0	2.1
Sodium	42365	34546	35656	**37523**	3454	9.2	45234	41034	36184	**40817**	3698	9.1
Nickel	12471	12855	12339	**12555**	219	1.7	11756	12156	12362	**12091**	252	2.1
Lead	2034	2096	2012	**2047**	35	1.7	1928	1983	2028	**1980**	41	2.1
Selenium	< 55	< 65	< 60	**60**	4	6.6	< 61	< 63	< 61	**62**	1	2.1
Antimony	< 92	< 108	< 100	**100**	7	6.6	< 101	< 106	< 101	**103**	2	2.1
Silicon	61906	78710	68304	**69640**	6925	9.9	69405	72277	72461	**71381**	1399	2.0
Strontium	1417	1467	1408	**1431**	26	1.8	1345	1392	1421	**1386**	32	2.3
Thorium	1892	< 2167	< 1997	**2019**	114	5.6	< 2023	< 2116	2145	**2095**	52	2.5
Titanium	144525	149490	142739	**145585**	2856	2.0	135691	140316	143007	**139671**	3021	2.2
Thallium	< 55	< 65	< 60	**60**	4	6.6	< 61	< 63	< 61	**62**	1	2.1
Uranium	< 553	< 650	< 599	**601**	40	6.6	< 607	< 635	< 607	**616**	13	2.1
Vanadium	< 74	< 87	< 80	**80**	5	6.6	< 81	< 85	< 81	**82**	2	2.1
Zinc	1284	1342	1284	**1303**	27	2.1	1206	1261	1285	**1251**	33	2.6
Zirconium	10633	11083	10473	**10730**	258	2.4	10136	10452	10547	**10378**	176	1.7

Appendix G. COMPOSITION (mg/kg) OF THE DRIED SLUDGE FROM SLURRY SAMPLES TAKEN DURING RESUSPENSION TESTS, FOLLOWING A 14-DAYSETTLING PERIOD IN THE PILOT-SCALE VESSEL: AVERAGES OF TRIPLICATE ANALYSES.

Analyte	SRS-P1	SRS-P2	SRS-P3	SRS-P4	SRS-P5	SRS-P6	SRS-P7	Average of Population	Sx	% RSD
Silver	12	12	12	12	12	12	11	12	0.6	5.3
Aluminum	58670	57196	57345	59583	57702	60045	59396	58562	1767.5	3.0
Arsenic	59	61	61	59	62	62	56	60	3.2	5.3
Barium	1879	1816	1818	1926	1873	1935	1906	1879	64.2	3.4
Beryllium	5	5	5	5	5	5	5	5	0.4	7.4
Calcium	14191	13862	13652	14648	13943	14338	14583	14174	660.4	4.7
Cadmium	4	4	4	4	4	4	4	4	0.2	5.3
Chromium	1573	1521	1522	1590	1545	1600	1603	1565	49.8	3.2
Cesium	39011	40881	40760	39618	41302	41339	37446	40051	2120.2	5.3
Copper	1844	1768	1790	1908	1814	1868	1850	1835	71.4	3.9
Iron	154094	149868	150141	157347	152340	157748	157244	154112	4949.1	3.2
Potassium	1510	1405	1413	1389	1326	1370	1408	1403	93.0	6.6
Magnesium	2924	2876	2847	3000	2886	2994	2994	2932	98.7	3.4
Manganese	35629	34764	34715	36302	35269	36408	36267	35622	1076.6	3.0
Molybdenum	12	12	12	12	12	12	11	12	0.6	5.3
Sodium	42721	41573	42359	38102	36345	39328	39021	39921	3654.4	9.2
Nickel	12545	12186	12192	12774	12345	12762	12781	12512	401.7	3.2
Lead	2047	1997	1995	2081	2015	2086	2095	2045	63.6	3.1
Selenium	59	61	61	59	62	62	56	60	3.2	5.3
Antimony	98	102	102	99	103	103	94	100	5.3	5.3
Silicon	71619	68398	75731	69949	79799	88566	90217	77754	8999.8	11.6
Strontium	1451	1409	1414	1486	1426	1475	1454	1445	48.3	3.3
Thorium	2002	2044	2251	2064	2167	2189	2030	2107	139.9	6.6
Titanium	144759	141396	141264	147589	142804	148039	146737	144656	4427.7	3.1
Thallium	59	61	61	59	62	62	56	60	3.2	5.3
Uranium	585	613	611	594	620	620	562	601	31.8	5.3
Vanadium	78	82	82	79	83	83	75	80	4.2	5.3
Zinc	1315	1265	1267	1347	1298	1341	1694	1361	242.4	17.8
Zirconium	10930	10658	10663	11092	10697	11002	11025	10867	339.7	3.1

Appendix G (continued) RESULTS OF INDIVIDUAL ANALYSES

Analyte	SRS-P-1A	SRS-P-1B	SRS-P-1C	**SRS-P1**	*Sx*	% RSD	SRS-P-2A	SRS-P-2B	SRS-P-2C	**SRS-P2**	*Sx*	% RSD
Silver	< 12	< 12	< 11	**12**	1	5.1	< 12	< 13	< 12	**12**	0	3.0
Aluminum	56331	57175	62503	**58670**	2733	4.7	56980	56775	57832	**57196**	458	0.8
Arsenic	< 62	< 60	< 54	**59**	3	5.1	< 59	< 64	< 61	**61**	2	3.0
Boron	1177231	1150918	1065103	**1131084**	47876	4.2	1112643	1211178	1167620	**1163814**	40317	3.5
Barium	1816	1840	1981	**1879**	73	3.9	1806	1816	1825	**1816**	8	0.4
Beryllium	5	5	5	**5**	0	3.7	5	6	5	**5**	0	3.6
Calcium	13251	13505	15817	**14191**	1155	8.1	13796	13925	13865	**13862**	53	0.4
Cadmium	< 4	< 4	< 4	**4**	0	5.1	< 4	< 4	< 4	**4**	0	3.0
Chromium	1516	1537	1666	**1573**	66	4.2	1516	1517	1531	**1521**	7	0.4
Cesium	< 41000	< 39761	< 36271	**39011**	2002	5.1	< 39526	< 42499	< 40617	**40881**	1228	3.0
Copper	1764	1807	1963	**1844**	86	4.6	1720	1782	1800	**1768**	34	1.9
Iron	148371	150154	163756	**154094**	6871	4.5	149193	149474	150936	**149868**	764	0.5
Potassium	1440	1473	1618	**1510**	78	5.1	1397	1263	1555	**1405**	119	8.5
Magnesium	2811	2853	3109	**2924**	132	4.5	2856	2913	2859	**2876**	26	0.9
Manganese	34345	34768	37775	**35629**	1527	4.3	34610	34794	34889	**34764**	116	0.3
Molybdenum	< 12	< 12	< 11	**12**	1	5.1	< 12	< 13	< 12	**12**	0	3.0
Sodium	41272	40631	46258	**42721**	2515	5.9	43987	35647	45085	**41573**	4214	10.1
Nickel	12091	12220	13325	**12545**	554	4.4	12147	12149	12262	**12186**	54	0.4
Lead	1970	2000	2171	**2047**	88	4.3	1998	1987	2006	**1997**	8	0.4
Selenium	< 62	< 60	< 54	**59**	3	5.1	< 59	< 64	< 61	**61**	2	3.0
Antimony	< 103	< 99	< 91	**98**	5	5.1	< 99	< 106	< 102	**102**	3	3.0
Silicon	71945	70865	72047	**71619**	535	0.7	63329	69265	72600	**68398**	3834	5.6
Strontium	1387	1410	1556	**1451**	75	5.2	1403	1404	1421	**1409**	8	0.6
Thorium	< 2050	2044	1911	**2002**	64	3.2	< 1976	< 2125	< 2031	**2044**	61	3.0
Titanium	139248	140974	154056	**144759**	6612	4.6	140671	140841	142675	**141396**	907	0.6
Thallium	< 62	< 60	< 54	**59**	3	5.1	< 59	< 64	< 61	**61**	2	3.0
Uranium	< 615	< 596	< 544	**585**	30	5.1	< 593	< 637	< 609	**613**	18	3.0
Vanadium	< 82	< 80	< 73	**78**	4	5.1	< 79	< 85	< 81	**82**	2	3.0
Zinc	1266	1281	1398	**1315**	59	4.5	1254	1263	1278	**1265**	10	0.8
Zirconium	10465	10616	11709	**10930**	554	5.1	10559	10617	10798	**10658**	102	1.0

Appendix G (continued) RESULTS OF INDIVIDUAL ANALYSES

Analyte	SRS-P-3A	SRS-P-3B	SRS-P-3C	**SRS-P3**	Sx	% RSD	SRS-P-4A	SRS-P-4B	SRS-P-4C	**SRS-P4**	Sx	% RSD
Silver	< 12	< 12	< 12	**12**	0	1.9	< 12	< 13	< 11	**12**	1	4.3
Aluminum	56131	58115	57790	**57345**	869	1.5	58539	61162	59048	**59583**	1136	1.9
Arsenic	< 60	< 62	< 62	**61**	1	1.9	< 58	< 63	< 57	**59**	3	4.3
Boron	1137056	1178829	1166070	**1160652**	17479	1.5	1126309	1212862	1122440	**1153870**	41743	3.6
Barium	1760	1851	1844	**1818**	41	2.3	1902	1954	1922	**1926**	21	1.1
Beryllium	5	5	5	**5**	0	2.5	5	6	5	**5**	0	4.4
Calcium	13253	13898	13806	**13652**	284	2.1	13962	14666	15316	**14648**	553	3.8
Cadmium	< 4	< 4	< 4	**4**	0	1.9	< 4	< 4	< 4	**4**	0	4.3
Chromium	1483	1545	1537	**1522**	28	1.8	1567	1638	1565	**1590**	34	2.1
Cesium	< 39667	< 41477	< 41135	**40760**	785	1.9	< 38986	< 41946	< 37922	**39618**	1703	4.3
Copper	1702	1836	1831	**1790**	62	3.5	1846	1966	1912	**1908**	49	2.6
Iron	146000	152544	151878	**150141**	2941	2.0	154290	162042	155710	**157347**	3370	2.1
Potassium	1540	1386	1315	**1413**	94	6.6	1366	1394	1408	**1389**	17	1.2
Magnesium	2785	2875	2882	**2847**	44	1.6	2928	3074	2998	**3000**	59	2.0
Manganese	33752	35257	35136	**34715**	683	2.0	35550	37449	35908	**36302**	823	2.3
Molybdenum	< 12	< 12	< 12	**12**	0	1.9	< 12	< 13	< 11	**12**	1	4.3
Sodium	49371	41459	36247	**42359**	5395	12.7	37103	41002	36201	**38102**	2083	5.5
Nickel	11865	12390	12321	**12192**	233	1.9	12532	13149	12641	**12774**	269	2.1
Lead	1951	2016	2020	**1995**	32	1.6	2047	2141	2054	**2081**	43	2.1
Selenium	< 60	< 62	< 62	**61**	1	1.9	< 58	< 63	< 57	**59**	3	4.3
Antimony	< 99	< 104	< 103	**102**	2	1.9	< 97	< 105	< 95	**99**	4	4.3
Silicon	70366	78491	78337	**75731**	3794	5.0	77482	71396	60967	**69949**	6819	9.7
Strontium	1367	1440	1434	**1414**	33	2.4	1450	1522	1484	**1486**	29	2.0
Thorium	2477	2219	< 2057	**2251**	173	7.7	< 1949	2250	1992	**2064**	133	6.4
Titanium	136945	143852	142995	**141264**	3074	2.2	144852	151464	146450	**147589**	2817	1.9
Thallium	< 60	< 62	< 62	**61**	1	1.9	< 58	< 63	< 57	**59**	3	4.3
Uranium	< 595	< 622	< 617	**611**	12	1.9	< 585	< 629	< 569	**594**	26	4.3
Vanadium	< 79	< 83	< 82	**82**	2	1.9	< 78	< 84	< 76	**79**	3	4.3
Zinc	1232	1292	1278	**1267**	26	2.0	1326	1361	1356	**1347**	16	1.2
Zirconium	10327	10952	10710	**10663**	257	2.4	10867	11372	11036	**11092**	210	1.9

Appendix G (continued) RESULTS OF INDIVIDUAL ANALYSES

Analyte	SRS-P-5A	SRS-P-5B	SRS-P-5C	**SRS-P5**	Sx	% RSD	SRS-P-6A	SRS-P-6B	SRS-P-6C	**SRS-P6**	Sx	% RSD
Silver	< 11	< 13	< 13	**12**	1	6.2	< 13	< 12	< 12	**12**	0	2.6
Aluminum	57533	57196	58378	**57702**	497	0.9	58060	62424	59651	**60045**	1804	3.0
Arsenic	< 57	< 66	< 63	**62**	4	6.2	< 64	< 61	< 60	**62**	2	2.6
Boron	1070447	1270613	1195896	**1178985**	82588	7.0	1209312	1136843	1139481	**1161879**	33558	2.9
Barium	1894	1861	1865	**1873**	15	0.8	1842	2022	1940	**1935**	74	3.8
Beryllium	5	6	5	**5**	0	4.4	5	5	5	**5**	0	2.5
Calcium	13824	13956	14047	**13943**	92	0.7	13984	14885	14143	**14338**	393	2.7
Cadmium	< 4	< 4	< 4	**4**	0	6.2	< 4	< 4	< 4	**4**	0	2.6
Chromium	1543	1537	1554	**1545**	7	0.5	1546	1667	1588	**1600**	50	3.1
Cesium	< 37936	< 44111	< 41859	**41302**	2551	6.2	< 42827	< 40900	< 40290	**41339**	1081	2.6
Copper	1795	1795	1853	**1814**	27	1.5	1815	1951	1837	**1868**	60	3.2
Iron	152046	150980	153994	**152340**	1248	0.8	152225	164441	156580	**157748**	5055	3.2
Potassium	1310	1309	1358	**1326**	23	1.7	1333	1446	1333	**1370**	53	3.9
Magnesium	2892	2855	2910	**2886**	23	0.8	2920	3114	2948	**2994**	86	2.9
Manganese	35096	35039	35672	**35269**	286	0.8	35279	37826	36121	**36408**	1060	2.9
Molybdenum	< 11	< 13	< 13	**12**	1	6.2	< 13	< 12	< 12	**12**	0	2.6
Sodium	35905	35412	37717	**36345**	991	2.7	38052	40401	39532	**39328**	969	2.5
Nickel	12324	12226	12486	**12345**	107	0.9	12325	13306	12655	**12762**	407	3.2
Lead	2007	2009	2030	**2015**	10	0.5	2010	2173	2076	**2086**	67	3.2
Selenium	< 57	< 66	< 63	**62**	4	6.2	< 64	< 61	< 60	**62**	2	2.6
Antimony	< 95	< 110	< 105	**103**	6	6.2	< 107	< 102	< 101	**103**	3	2.6
Silicon	78640	77317	83441	**79799**	2631	3.3	88428	90525	86744	**88566**	1546	1.7
Strontium	1424	1412	1441	**1426**	12	0.8	1423	1540	1463	**1475**	49	3.3
Thorium	2055	2352	< 2093	**2167**	132	6.1	< 2141	2302	2124	**2189**	80	3.7
Titanium	142419	141956	144038	**142804**	893	0.6	142764	154009	147344	**148039**	4617	3.1
Thallium	< 57	< 66	< 63	**62**	4	6.2	< 64	< 61	< 60	**62**	2	2.6
Uranium	< 569	< 662	< 628	**620**	38	6.2	< 642	< 613	< 604	**620**	16	2.6
Vanadium	< 76	< 88	< 84	**83**	5	6.2	< 86	< 82	< 81	**83**	2	2.6
Zinc	1303	1299	1291	**1298**	5	0.4	1284	1397	1341	**1341**	46	3.4
Zirconium	10659	10612	10820	**10697**	89	0.8	10646	11515	10847	**11002**	372	3.4

Appendix G (continued) RESULTS OF INDIVIDUAL ANALYSES

Analyte	SRS-P-7A	SRS-P-7B	SRS-P-7C	**SRS-P7**	Sx	% RSD
Silver	< 11	< 11	< 12	**11**	0	4.0
Aluminum	60486	59028	58674	**59396**	784	1.3
Arsenic	< 53	< 57	< 58	**56**	2	4.0
Boron	1007788	1090187	1145644	**1081206**	56637	5.2
Barium	1961	1904	1853	**1906**	44	2.3
Beryllium	5	5	4	**5**	0	9.5
Calcium	14312	14059	15376	**14583**	571	3.9
Cadmium	< 4	< 4	< 4	**4**	0	4.0
Chromium	1608	1567	1635	**1603**	28	1.7
Cesium	< 35361	< 38081	< 38895	**37446**	1511	4.0
Copper	1926	1821	1804	**1850**	54	2.9
Iron	158651	153766	159315	**157244**	2474	1.6
Potassium	1369	1317	1539	**1408**	95	6.7
Magnesium	2999	2858	3125	**2994**	109	3.6
Manganese	36563	35578	36659	**36267**	489	1.3
Molybdenum	< 11	< 11	< 12	**11**	0	4.0
Sodium	39721	38757	38585	**39021**	500	1.3
Nickel	12819	12428	13095	**12781**	273	2.1
Lead	2084	2048	2153	**2095**	44	2.1
Selenium	< 53	< 57	< 58	**56**	2	4.0
Antimony	< 88	< 95	< 97	**94**	4	4.0
Silicon	85458	90190	95003	**90217**	3897	4.3
Strontium	1494	1446	1420	**1454**	31	2.1
Thorium	2076	2069	< 1945	**2030**	60	3.0
Titanium	149176	144886	146150	**146737**	1800	1.2
Thallium	< 53	< 57	< 58	**56**	2	4.0
Uranium	< 530	< 571	< 583	**562**	23	4.0
Vanadium	< 71	< 76	< 78	**75**	3	4.0
Zinc	1341	1313	2428	**1694**	519	30.6
Zirconium	11127	10813	11134	**11025**	150	1.4

Appendix H. TOTAL SUSPENDED SOLIDS (TSS) AND TOTAL DISSOLVED SOLIDS (TDS) FOR SLUDGE/MST SLURRY DURING RESUSPENSION TESTS, FOLLOWING A 60-DAY SETTLING PERIOD IN THE LABORATORY-SCALE AND PILOT-SCALE VESSELS

Sample ID	Wt sample (g)	**TSS** (wt %)	**Average** (wt %)	Sx (wt %)	RSD-TSS (%)	**TDS** (wt %)	**Average** (wt %)	Sx (wt %)	RSD-TDS (%)
SRS-L-5A	8.4496	9.578				29.3138			
SRS-L-5B	8.2695	9.6451	**9.532**	0.1162	1.220	30.7262	**30.414**	0.8022	2.637
SRS-L-5C	9.0174	9.3719				31.203			
SRS-L-6A	8.5628	10.33				29.1599			
SRS-L-6B	9.1839	10.28	**10.289**	0.0305	0.297	29.1281	**29.283**	0.1964	0.671
SRS-L-6C	9.95	10.256				29.5598			
SRS-L-7A	9.3195	12.809				28.2816			
SRS-L-7B	8.6161	12.718	**12.802**	0.0664	0.519	28.4943	**28.836**	0.6395	2.218
SRS-L-7C	9.4128	12.88				29.7319			
SRS-L-8A	8.3335	12.104				28.3506			
SRS-L-8B	8.3358	11.787	**11.980**	0.1384	1.156	28.9426	**28.622**	0.2443	0.853
SRS-L-8C	9.3068	12.048				28.5716			
SRS-L-9A	9.2839	14.855				28.6324			
SRS-L-9B	8.4169	15.203	**15.054**	0.1463	0.972	27.9984	**28.188**	0.3155	1.119
SRS-L-9C	7.4587	15.103				27.9325			
SRS-L-10A	7.9333	14.564				28.6854			
SRS-L-10B	6.8802	14.702	**14.568**	0.1077	0.739	28.8945	**28.834**	0.1058	0.367
SRS-L-10C	5.9981	14.438				28.9225			
SRS-L-11A	9.4202	16.186				28.7244			
SRS-L-11B	9.2543	16.164	**16.146**	0.0428	0.265	28.4235	**28.111**	0.6662	2.370
SRS-L-11C	9.2051	16.087				27.1849			
SRS-L-12A	9.536	16.148				28.4218			
SRS-L-12B	9.4738	16.226	**16.175**	0.0357	0.221	27.0873	**27.617**	0.5784	2.094
SRS-L-12C	9.5964	16.152				27.3425			
Blank-1	100	-4E-04				-1E-04			
Blank-2	100	-0.001	**-0.001**	0.0003	-46.667	-0.0002	**0.000**	5E-05	-33.333
SRS-P-8A	8.6808	11.778				28.1184			
SRS-P-8B	9.0617	11.679	**11.703**	0.0543	0.464	28.4726	**28.452**	0.2639	0.927
SRS-P-8C	8.1297	11.651				28.7637			
SRS-P-9A	8.6482	10.753				28.5632			
SRS-P-9B	8.0354	10.66	**10.650**	0.0882	0.828	28.861	**29.049**	0.4919	1.693
SRS-P-9C	9.0061	10.537				29.7232			
SRS-P-10A	8.8906	14.132				27.6483			
SRS-P-10B	9.1835	13.828	**14.049**	0.1579	1.124	27.4362	**27.511**	0.0974	0.354
SRS-P-10C	9.1723	14.187				27.4479			
SRS-P-11A	9.0411	12.067				27.9103			
SRS-P-11B	9.0259	11.974	**12.044**	0.0501	0.416	27.3801	**28.043**	0.6033	2.151
SRS-P-11C	8.9467	12.09				28.8397			
SRS-P-12A	9.0109	13.729				27.328			
SRS-P-12B	8.9114	13.723	**13.875**	0.2108	1.520	28.7968	**27.667**	0.8199	2.963
SRS-P-12C	9.6055	14.173				26.8763			
SRS-P-13A	8.8967	12.541				27.4113			
SRS-P-13B	8.3915	12.933	**12.666**	0.1888	1.491	27.2538	**27.869**	0.7611	2.731
SRS-P-13C	8.577	12.525				28.9414			

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