WSRC-TR-2002-00062, Rev. 0
SRT-RPP-2002-00022, Rev. 0

RPP-WTP Slurry Wear Evaluation: Slurry Abrasivity

January 31, 2002

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Date: 1/30/02

Westinghouse Savannah River Company
Savannah River Site

Prepared for the U.S. Department of Energy Under Contract Number DEAC09-96SR18500

SRS
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TM

WSRC-TR-2002-00062, Rev. 0
SRT-RPP-2002-00022, Rev. 0

KEYWORDS:
Hanford River Protection Project
Pretreatment
Filtration
Evaporator
Erosion
Corrosion
Stainless Steel
Hanford Waste

RPP-WTP Slurry Wear Evaluation: Slurry Abrasivity

SAVANNAH RIVER TECHNOLOGY CENTER

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January 31, 2002

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This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

DOCUMENT: **WSRC-TR-2002-00062, Rev. 0 (SRT-RPP-2002-00022)**

TITLE: **RPP-WTP Slurry Wear Evaluation: Slurry Abrasivity**

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Contents

Acknowledgments

Despite the fact that this task involved the abrasivity evaluation at a subcontractor, White Rock Engineering Services in Frisco, Texas, (WRES), there was a considerable amount of support work done at the Savannah River Site (SRS). To do each WRES test, simulated DOE Hanford Site wastes had to be supplied along with specimens of the metals that will be used to construct the in-cell piping of the River Protection Project - Waste Treatment and Immobilization Plant. Each slurry sent to WRES had to be designed, made, and chemically evaluated. The accompanying metal samples had to be procured and formed. Finally the items had to be prepared for shipping. Each step was important to the success of this task and dependent upon the expertise of many individuals. Unless stated otherwise, all of the following individuals are connected to the Savannah River Technology Center Division of the Westinghouse Savannah River Company (WSRC) at SRS.

For the metal samples: I want to thank Janet Brewer of the 749-A Machine Shop for obtaining the materials and pedigrees in a short time period. My thanks goes to Ken Imrich, of the Material Technology Section, for having made the samples to WRES's requirements and for suggesting a company to do the abrasivity testing. I would also like to thank Ken for his discussions on materials and on the methods for testing materials.

For the slurry simulants: first and foremost, I want to thank Chuck Coleman, of the Analytical Development Section, and Erich Hansen, of the Waste Processing Technology Section. Their assistance in making the slurries and analyzing the resulting products was extremely important to the success of this task. Each of the seven slurries used in this test required a significant effort to refine their design, to make them, to benchmark their chemical make-up, and then to ship them to WRES. The design phase continued until the last simulant was made and thanks are extended to Russ Eibling, Bond Calloway, and Charles Nash of the Waste Processing Technology Section, and to Mark Crowder of the Actinide Technology Section. The fabrication phase was the most labor intensive and it could not have been done without the help of Frances Williams of the Immobilization Technology Section, and all the fine technicians down at TNX. A significant amount of analytical testing was needed to properly characterize the simulants before being shipped, for this work I would like to thank John Young, Chuck Coleman, Beverly Burch, Leigh Brown, and all the other members of Analytical Development Section who had a hand. Finally, the simulant could not have left SRS to reach WRES in a safe manner, while meeting all the Department of Transportation Regulations, without the help of Susan Hatcher, Andy Foreman, Michael Armstrong, and Vernon Bush of the Engineering Development Section and all the folks in the Transportation Section of the Administration & Infrastucture Division of WSRC.

I thank my technical reviewer, Hector Guerrero, of the Engineering Development Section, for a sharp eye. Finally, I would like to thank Gita Golcar of Pacific Northwest National Laboratory for helping me understand her HLW erosion simulant. A special thanks goes to Mike Johnson of CH_2M Hill Hanford Group, Inc. for initially supporting this effort and to Reid Peterson of Washington Group International for his continued support.

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1.0 Executive Summary

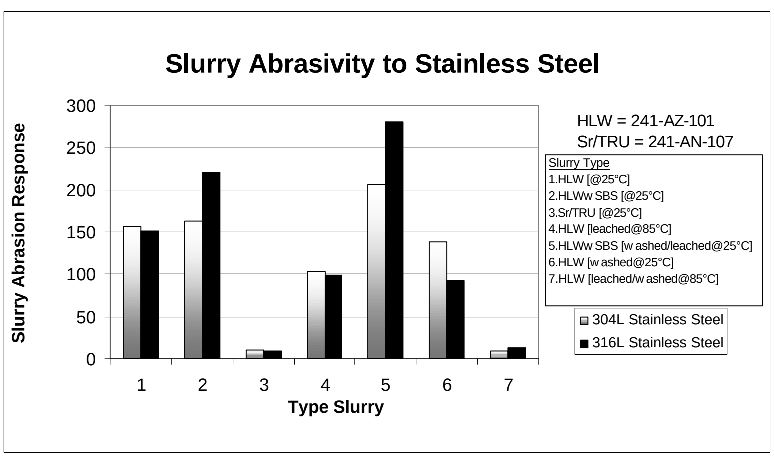
Tests are planned to measure the wear rates in scaled flow loops that represent full-scale systems in the Pretreatment section of the Waste Treatment Plant to be built as part of the Department of Energy (DOE) River Protection Project. Those tests are to be done in the Experimental Thermal Fluids Laboratory of the Savannah River Technology Center at the DOE Savannah River Site.

This report deals with the task of evaluating wear in the cross-flow ultrafiltration system and specifically the need to define a representative slurry in order to obtain prototypic wear rates. The filtration system will treat many different wastes, but it is not practical to run a test for each one. This is especially true when considering that the planned period for testing is 2000 hours long and procurement of appropriate simulants is costly. Considering time and cost, one waste stream needs to be chosen to perform the wear test.

To make such a selection, seven different slurries were evaluated for their ability to abrade materials that will be used to construct the flow system, i.e., 304L and 316L stainless steels. These seven slurries are actually two waste streams that will eventually be a low (radio) activity (level) waste (LAW) and a high (radioactivity) level waste (HLW). The other five waste streams are the result of processing HLW before filtration, e.g., washing, leaching, or premixing with Submerged Bed Scrubber (SBS) condensate, which is recycled from the pretreatment evaporators, etc.

Seven waste stream simulants were made and then they were used in a standard abrasivity test (ASTM G75-2001) to produce a Slurry Abrasion Response (SAR) number with the two stainless steels. The slurry that would produce the highest SAR would be selected for the long-term wear test. The figure below (Fig. 37 in this report and reproduced here for convenience) shows that simulant number 5 (washed and leached HLW simulant with SBS recycle) produced the most wear for both stainless steel types.

This report details the development of each slurry, their chemical and physical properties, and the SAR number results for each one.



2.0 Introduction

Part of the River Protection Project (RPP) is to build a Waste Treatment & Immobilization Plant (WTP) at the Hanford Site to stabilize the radioactive waste currently stored in large tanks at that site. The pretreatment system that prepares the waste for vitrification includes separation technologies like filtration and evaporation. These two systems will contain continuous flows of solids-liquid mixtures that will cause wear to the pipes and associated equipment. To have a system in good working order over the designed plant lifetime of 40 years, where maintenance must be minimized because of a radioactive environment, the rates of wear need to be quantified. Once the wear rates are known, design requirements and maintenance schedules can be developed to insure continuous safe plant operation.

To determine wear rates, experiments are planned to satisfy an RPP Test Specification (Johnson, et al., 2000) by developing scaled experiments to test both the cross-flow filtration system and the evaporation system. As a precursor to experiments, a literature review was done (Duignan and Lee, 2001) to examine prior work in this field, especially in the DOE complex. That review found the complexities of corrosion and erosion mechanisms make the estimation of pipe wear based on published studies difficult, if not impossible; generally a test is needed to accurately measure wear. Ideally such a test will be most accurate if it is done on the actual flow system, using the prototypic working fluid. However, most times, fully prototypic testing is not practical for many reasons that include: a system is only in the planning stage and not available, size, the cost of either the equipment or the working fluid, the actual working conditions, like a radioactive fluid, etc. For this present task the experiment will be scaled, because the separations systems are large, and the working fluid will be a simulant, because the actual slurries are radioactive. To properly scale the flow loop, a computational fluids dynamic analysis was done (Duignan, 2001a). To have a representative working slurry, a wear evaluation of several slurries was done and is the subject of this report.

As already stated, the more a test is non-prototypic, the more difficult it is to obtain representative results, therefore care must be taken. Because the design of the cross-flow filtration system was more advanced than that of the evaporator, and because of the larger number of slurries to be filtered, the wear in that system was chosen to be evaluated first. The filtration system will treat many different LAW (low activity wastes) and HLW (high level wastes) slurries. Further, HLW slurries will be subjected to different treatments like washing, leaching, or receiving additions like Submerge Bed Scrubber (SBS) recycle streams from the evaporators. A HLW from the Hanford tank 241- AZ-101 is thought to be the most abrasive of the first cycle of tanks to be processed by RPP-WTP because it had been previously selected by Battelle's Pacific Northwest National Laboratory (PNNL) due to its content of hard solids. A simulant of that waste was originally made by Golcar et al. (2000) and then it was specifically modified for erosion testing (Elmore, 2000). What is not well known is how the abrasivity of the slurry is affected by the different processes.

To select a slurry that will be representative of one that will be the most abrasive to the filtration system, seven different slurry formulations were compared in a slurry abrasivity test called the SAR (Slurry Abrasivity Response) test. This test is a nationally accepted standard (ASTM G75-2001) to compare slurries as they are used to abrade a material surface of choice. For this work, both 304L and 316L stainless steels were used in the test since they are the materials of construction for the separation systems. This report shows the abrasivity results of the seven different slurries. The most abrasive slurry will be used to carry out a long-term wear test (2000 hours) in a scaled filtration system. Together with the results, details of the abrasivity tests are given below.

3.0 Discussion

3.1 Slurry and Metal Evaluation

One of the problems with conducting a long-term wear test for the cross-flow ultrafiltration system of RPP-WTP is the many slurries that will be processed. While the LAW streams will predominately filter Sr/TRU precipitated slurries at moderate temperatures of 25°C ± 5°C (Stiver, 2000), the HLW streams will treat different slurries under different conditions at both 25°C ± 5°C and 85°C ± 5°C (McTaggart, 2000; Bechtel, 2000 – Section C, Specification 12.2.2.2 (b) and 12.2.3.2 (b-g)). However, the current WTP flow sheet restricts all filtration to 25°C ± 5°C. A planned long-term wear test will be approximately 2000 hours in length, so to test all the slurries would take years to amass data, which is not practical. Moreover, many of the slurry simulants are very expensive to produce, and since each test may involve hundreds of liters of slurry, the expense to do many tests is also prohibitive. A better method would be to select one slurry, which will cause the most wear so that only a single test needs to be done for the cross-filtration system. The question is which slurry? The decision was to do a standard slurry wear test with all of the slurry combinations and system materials so that a comparison could be made and a slurry selected.

There are many types of slurry wear tests, e.g., pot tester, test with slurry jets, Coriolis tester, Miller tester. In general, results from any bench-top tester cannot be extrapolated to determine the wear rates in any flow loop system because of the many variables involved in slurry wear (Duignan and Lee, 2001). However, using the same standard wear test with different slurries, under the same conditions, will indicate which slurry is most abrasive to the particular material of which a flow loop will be constructed. The literature is filled with many versions of different types of wear testers, but only one has been made into an industrial accepted standard by the American Society of Testing & Materials, i.e., Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number), ASTM G 75–2001, Ed. 07/2001. This standard was chosen to compare the slurries in order to select one for the long-term flow loop test and it will be described in the next section.

There are many different types of radioactive wastes stored at the Hanford Site. Most of them will be processed by the RPP-WTP. Each tank of waste is a different mixture of complex chemicals. However, all the waste can generally be classified into two groups: Low (Radio-) Activity (Level) Wastes (LAW) and High (radioactivity) Level Wastes (HLW). In evaluating the slurries with respect to their abrasive response, it is important to choose those that would be the most aggressive. Candidate waste simulants considered are described below.

Many of the wastes are classified as LAW, but the primary interest is in those that will have the highest abrasion capabilities. The LAW slurries that contain "organic complexing agents and their decompositions products…will require…" a precipitation step to reduce the concentrations of Sr and Transuranic compounds (Eibling and Nash, 2000). These slurries are referred to as Sr/TRU and because of the extra processing steps they will contain both entrained solids and precipitated solids. With the extra solids, the Sr/TRU LAW slurries are assumed to be more abrasive than straight LAW slurries. For the wear test, the Sr/TRU waste from Tank 241-AN-107 was simulated since a recipe exists (Eibling and Nash, 2000). When the LAW slurry undergoes precipitation, its insoluble solids concentration will be close to 2 wt%. It will then be concentrated to 20 wt% by a cross-flow filter. The simulant for abrasivity testing will therefore be concentrated to 20 wt%.

- This abrasion test simulant is referred to as: Sr/TRU (or slurry No. 3)

The HLW slurries have a larger variation of processing in pretreatement, such as: washing, leaching, submerged bed scrubber (SBS) recycling, glass former blending, etc. All of these different HLW processed wastes will have insoluble solids in different forms. The combination of different slurries and processing steps that result in the most abrasive mixture is not obvious. A HLW considered abrasive by both the Savannah River Technology Center (SRTC) and Pacific Northwest National Laboratory (PNNL) is the waste from the Hanford site tank 241-AZ-101 (AZ-101) because of a high percentage of hard insoluble sludge solids. That waste has been previously characterized (Hodgson, 1995; Rapko and Wagner, 1997) and a sample of actual AZ-101 waste and one of simulated AZ-101 waste were evaluated (McGrail, 1991) for abrasivity using an in-house Miller Number Machine. Unfortunately, the abrasivity data were not qualified and the test procedure, which was used, makes their use questionable. However, the results did show that the simulated waste gave the same wear results as the actual waste. The fact that AZ-101 waste was an early choice for abrasion testing and that a simulant gave similar wear results makes it a good candidate for this test. Recently, the simulant for AZ-101 was refined (Golcar, et al., 2000) for cross-flow filtration testing and it was further altered (Elmore, 2000) to make it more representative as an abrasive waste. That is, a simulant is necessary for testing because the actual waste is radioactive and expensive to test. However, one of the radioactive insoluble solids is uranium oxide, which is considered hard and therefore abrasive. That compound was replaced with Tungsten oxide (because of its similar density) to maintain the high level of abrasivity. A Slurry Abrasion Response Number test was done (Elmore, 2000) with the new AZ-101 simulant and the slurry was found abrasive to 316L stainless steel, but it was not tested with 304L. For the current slurry evaluation, AZ-101 was chosen once again for abrasivity testing to represent HLW. Since several HLW streams will be subjected to different pretreatment processes, that may affect abrasivity, a different AZ-101 simulant slurry was produced for each process. Those different processes are:

- HLW that is just concentrated to 20 wt% insoluble solids. This simulant is referred to as HLW (or slurry No. 1).

- HLW that is washed to dilute the high caustic supernatant and then concentrated to 20 wt% insoluble solids. This simulant is referred to as HLWwashed (or slurry No. 6).

- HLW that is washed to dilute the high caustic supernatant and then concentrated to 20 wt% insoluble solids. It is then leached in 3 M NaOH at 85°C for a minimum of 8 hours and then reconcentrated to 20 wt%. This simulant is referred to as HLWleached (or slurry No. 4).

- HLW that is washed to dilute the high caustic supernatant and then concentrated to 20 wt% insoluble solids. It is then leached in 3 M NaOH at 85°C for a minimum of 8 hours and then reconcentrated to 20 wt%. It is finally washed 2 times to dilute the high caustic supernatant; each wash is done at 85°C for a minimum of 8 hours and then reconcentrated to 20 wt% insoluble solids. This simulant is referred to as HLWleached/washed (or slurry No. 7).

- Two more effects on the HLW slurries will not be pretreatments but artifacts of the how the pretreatment process operates. That is, there will be a waste stream returning from the action of scrubbing the HLW evaporator offgas. This waste stream is referred to as the Submerged Bed Scrubber recycle, which will also include some of the glass formers and glass fines (called SBS). SBS was included in the HLW simulant before any processing occurs. These simulants are referred to as: HLWwSBS (or slurry No. 2) and HLWwSBS washed&leached (or slurry No. 5), respectively.

The other important factor in abrasion testing of slurries is the material that will be abraded. That is, of what material will the pretreatment ultrafiltration system be made? At the time this wear-test task was developed two metals were indicated for use, i.e., 304L for in-cell pipe (RPP-WRT documentation No. SP W375-M00001, Rev. A, 1/6/2000) and 316L for the cross-flow filter unit. Both of these metals are used in this test to determine the combination of slurry and material that will present the most abrasivity.

The entire test matrix of slurry and material combinations is listed in Table 1. The order of the slurries in the table was initially chosen to do the main three different slurries first i.e., HLW, HLW with SBS, then Sr/TRU, to be followed by different treatments of the HLW, i.e., leached and washed. The slurry and metal sample numbering reflects this order, which was used by the wear test subcontractor. However, for several reasons (e.g., unavailability of certain chemicals) the actual chronological order turned out different than planned. It was: No. 3 (Jan. 01), No. 1 (Mar. 01), No. 6 (Apr. 01), No. 4 (May 01), No. 7 (May 01), No. 2 (Sept. 01), and No. 5 (Nov. 01).

Table 1. Slurry simulants selected to be tested for abrasivity

No.	Slurry	Metal Specimen*	Temperature
1.	HLW	304L-1A/B & 316L-1A/B	25°C ± 5°C
2.	HLWwSBS	304L-2A/B & 316L-2A/B	25°C ± 5°C
3.	Sr/TRU	304L-3A/B & 316L-3A/B	25°C ± 5°C
4.	HLWleached	304L-4A/B & 316L-4A/B	85°C ± 5°C
5.	HLWwSBSwashed&leached	304L-5A/B & 316L-5A/B	25°C ± 5°C**
6.	HLWwashed	304L-6A/B & 316L-6A/B	25°C ± 5°C
7.	HLWleached&washed	304L-7A/B & 316L-7A/B	85°C ± 5°C

* The two metals used for testing were: 304L and 316L. For each metal, the nomenclature, i.e., 3xxL-nA/B, indicates that two specimens of 3xxL, i.e., A and B, were used with each n slurry. That is, two tests were done using the same n slurry and two 304L specimens, to obtain a better estimate of the wear rate. For example, 304L-1A, indicates that the A sample of 304L stainless steel metal was tested with slurry number 1 (n=1=HLW).

** Slurry number 5 was to be filtered initially by RPP-WTP (as well as the other leached slurries numbers 4 and 7) at the leaching temperature 85°C, but by the time this slurry was ready to test (Nov. 2001) the cross-flow filtration system process changed such that all elevated temperature mixing would be isolated to the ultrafiltration feed preparation tanks. That is, RPP-WTP will cool the slurries to 25°C ± 5°C before filtering begins, therefore the filter loop is not expected to experience the higher temperatures.

Testing each slurry and metal combination with the Miller Number System results in a Slurry Abrasion Response Number, which is explained in the next section; the larger the number the more abrasive a slurry is to a material. The combination with the largest SAR number will then be used in a pilot-scale flow-loop wear test.

3.2 Miller Number System

The Miller Number test has been around since 1967†, and it was originally developed to determine the abrasivity of a slurry in a closed-loop pump test (Miller and Miller, 1993). Since then it has evolved into a test to measure the relative abrasivity of many slurries and has been adopted by the American Society of Testing Materials as ASTM G75-2001: "Standard Test Method of Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response of Materials (SAR Number)." Specific definitions of those two numbers are given in the Standard and are quoted here:

"*Miller Number*– a measure of slurry abrasivity as related to the instantaneous rate of mass loss of a standard metal wear block at a specific time on the cumulative abrasion-corrosion time curve."

"*SAR Number* – a measure of the relative abrasion response of any material in any slurry, as related to the instantaneous rate of mass loss of a specimen at a specific time on the cumulative abrasion-corrosion time curve…"

For the Miller Number, the test is designed to use a standard metal specimen, a 27% chromium-iron wear block, which is composed of: C-2.5%, Mn-1.0%, Si-0.6%, Ni-0.25%, Cr-28%, Mo-0.3%, V-0.8%, with iron making up the balance (66.6%). This metal was chosen when the Miller Number System was first developed because it was commonly used in pipeline applications. The Miller Number (MN) has been defined such that MN = 1 for a non-abrasive mixture of 50 wt% of sulfur (Mohs = 1) and water and MN = 1000 for a very abrasive mixture of 50 wt% of 220-mesh Corundum (Mohs = 9) and water. Through years of testing it has been found that a Miller Number of more than 50 indicates a slurry that is abrasive and care must be taken to monitor a piping system components, e.g., pumps, because wear is expected.

The SAR Number test is more general than the Miller Number test in that it applies to all slurries and all materials. The infinite number of slurry-metal combinations leads to more uncertainty in the SAR Number, but from years of testing different combinations, a rule of thumb has been developed that a SAR Numbers greater than 80 indicates a slurry that is abrasive to the wear specimen used and care must be taken to monitor a piping system because wear is expected. While the value of a SAR number may be difficult to apply in an absolute sense, it can be very useful in comparing the relative abrasivity of different slurry mixtures to a certain material or materials.

† In 1967, erosion to pump components was being evaluated in a closed-loop pump test. This test was for the Savage River Pipeline that tranports iron ore 90 kilometers from a mine to a processing plant on the coast of Tasmania, Australia. The slurry contained Magnetite particles with an approximate mean size of 44 microns. The Miller Number System was used to measure the reduction in abrasivity of the slurry with time to know when to replenish the slurry with fresh particles in the closed-loop test in order to maintain a constant level of abrasivity.

3.2.1 *The Miller Number System Equipment*

Figure 1 shows a picture of the Miller Number System test apparatus with three of its four reciprocating arms in place. Figure 2 shows a profile of one reciprocating arm, along with the nomenclature of the different parts. The test apparatus operation is simply the movement of a sample material back and forth on a lap material while being submerged in the test slurry. A specimen is pressed on the lap surface with a 22.24 N (5 lb_f) weight and it is moved along the surface at a constant speed of 48 stokes per minute. Each stroke is 200-mm long and at the end of each forward stroke a cam picks up the specimen from the lap surface a distance of 0.8 mm to allow the slurry to fill the gap. Operational parameters like reciprocation speed, lap material, time duration of a test, etc., have been refined when the test procedure was established for the ASTM standard. Details of that work is beyond the scope of this report and can be found in the standard and in Miller and Miller, 1993. Only certain aspect of the operational parameters are discussed here to better understand the results obtained from this test.

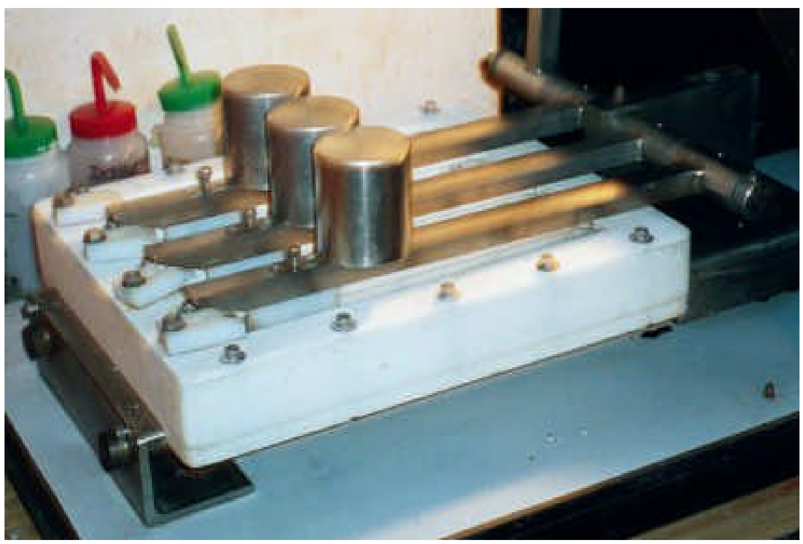


Figure 1. Miller Number System

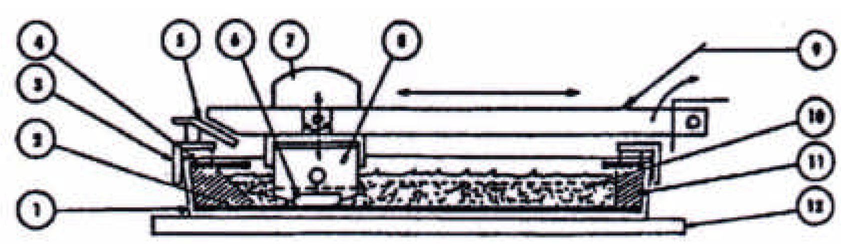


Figure 2. Miller machine nomenclature (Figure 2 from ASTM G 75–2001, Edition: 7/01):

1. Molded Plastic Tray
2. Neoprene Lap
3. Tray Clamp
4. Splash Guard
5. Block Lifting Cam
6. Wear Block
7. Dead Weight (22.24 N)
8. Plastic Wear-Block Holder
9. Pivoted Reciprocating Arm
10. Slurry
11. Plastic Filler "V" Channel
12. Tray Plate

As shown in Fig. 3, the test apparatus can hold up to four specimens to be tested at the same time. However, two of the specimens and slurries are the same to obtain repeat results, leading to a better estimate of the wear rate. Each test is six-hour long, during which wear is measured every two hours by weighing the specimens. Figure 4 shows a test stopped to remove the specimens during one of the two-hour intervals to measure how much mass has been removed. Before the mass measurement is made, each specimen it returned to its original clean state by washing it with a detergent and water, then drying it in an oven at 175°C for 15 minutes. After the measurement, the specimen is returned to the test apparatus and the test continues until three two-hour intervals are complete.

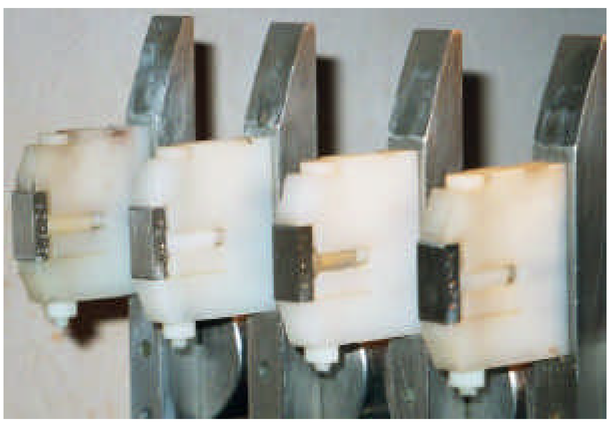


Figure 3. Metal specimens in place

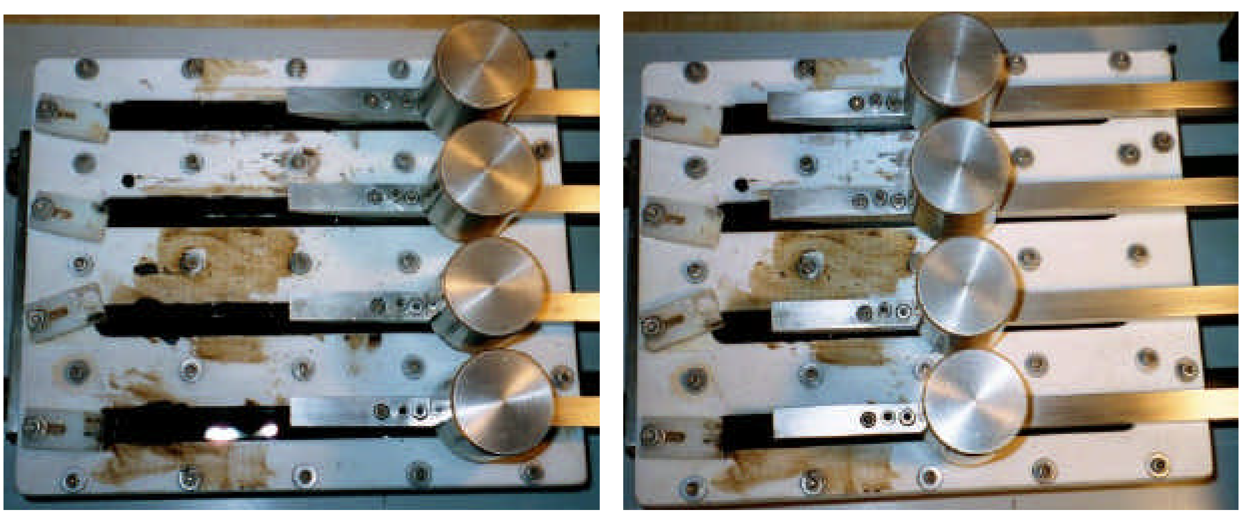
Figure 4. Test stopped to measure wear rates

Other aspects of the test apparatus are the slurry troughs, Fig. 5, and the Neoprene lap material, Fig. 6. Each trough is 50 mm (2 inches) wide and deep, 381 mm (15 inches) long, and filled with about 230 ml of slurry during operation. To help direct the solids towards the specimen and lap surface the sides of the troughs are beveled, which cause a trough to become narrower with depth. Figure 5 shows the empty troughs with the lap surfaces in place. Figure 6 shows the Neoprene lap surfaces removed from the test apparatus. Past experience (Miller and Miller, 1993) has shown that results are dependent upon the hardness of the lap material; therefore a special molded neoprene rubber is used, specified as MIL-R-6855C, Class 2, Grade 80. The lap strips are 3.18 mm (1/8 inch) thick, 57.2 mm (2 ¼ inches) wide, and long enough to fit the test apparatus.

Figure 5. Slurry troughs

Figure 6. Neoprene lap surfaces

Figure 7 show the Miller Number Machine in operation (a) at the end of a backstroke and (b) as the arms approaching the cam at the end of the forward stroke, which will lift it 0.8 mm off the bottom of the trough to allow slurry to fill the gap between the specimen and the lap surface.



(a) (b)

Figure 7. (a) Back stroke; (b) Forward stroke: 203 mm stroke length at 48 strokes per minutes

Through years of testing, the Miller Number has been shown to be linearly dependent on a particle's hardness, Fig. 8[†]. However, for particle size, Fig. 9[†] indicates that for only up to slightly more than 100 microns in diameter the MN is directly proportional; above that diameter the MN is independent of particle size. Note that, the scale in Fig. 9 is in mass loss per time, instead of the MN, but the two are equivalent since the MN is based on the rate of mass loss. The 16-hour period on the ordinate was the original time used to do a Miller test, however, as shown in ASTM G75-2001, a sixteen-hour test, done in four-hour increments, gave the same results as a six-hour tests, done in two-hour increments. When the Standard was originally revised in 1989 the test time interval was reduced to six hours.

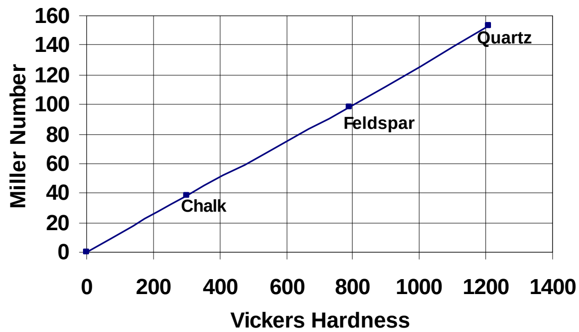


Figure 8. Effect of particle hardness on abrasivity

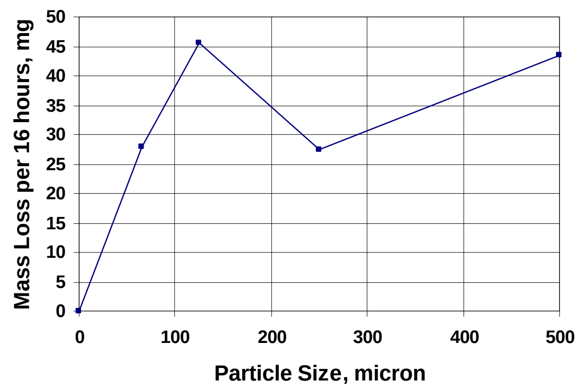


Figure 9. Effect of particle size on abrasivity

Another important dependence exists between the MN and the insoluble solids concentration of a slurry. Figure 10[†] shows that as the solids concentration of sand in water increases to 5 wt%, the MN increases rapidly, almost linearly.

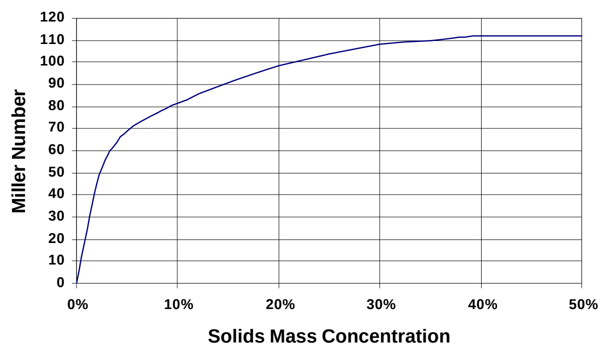


Figure 10. Effect of particle concentration on abrasivity

[†] Figures 8, 9, and 10 were taken from Miller and Miller, 1993 [Figs 5, 6, and 8, respectively].

After 5 wt% the MN still increases, but at a slower pace until is reaches an asymptote at approximately 40 wt%. In fact, the abrading surface is considered saturated with particles at 20 wt%, which means that additional solids do not significantly contribute to abrasion. That is, the small increase in MN above 20 wt% is considered insignificant.

3.2.2 *The Miller/SAR Numbers*

The Miller or SAR Numbers are obtained from the slope of a graph of the cumulative mass loss of a test specimen versus time. Specifically, it is taken as the slope of the curve at the two-hour point. Figure 11 show an example on how to obtain the numbers.

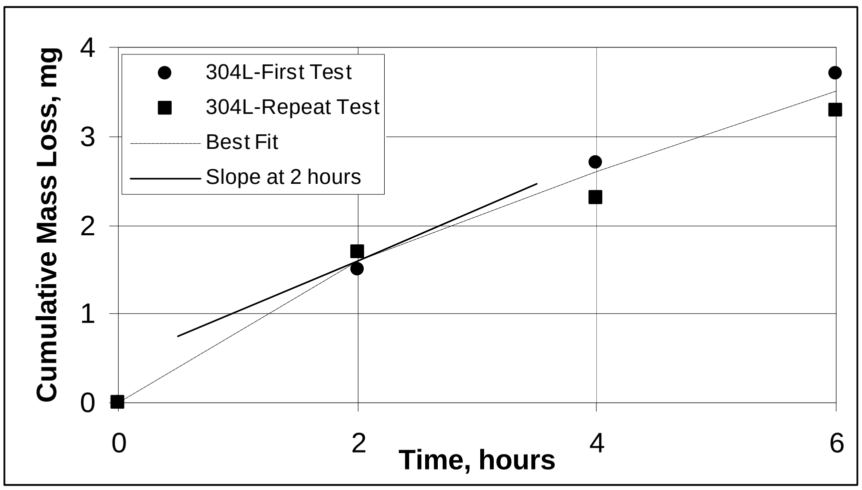


Figure 11. Determining the SAR Number

As previously explained, after each two-hour interval during a test, the specimen is removed from the test apparatus and measured for mass loss. This is done three times until six hours are completed. At the same time, another test specimen is installed in the apparatus to produce a second set of results. Both sets of results are used to develop an average set, which is then used to obtain a best fit curve to the data. However, the best fit curve is preselected to have the form of:

Cumulative Mass Loss = At^B (1)

(For the example in Fig 11: $At^B = 0.9595\, t^{0.72225}$ is the least squares best fit line)

The SAR Number is then obtained by finding the slope of Eq. 1, at the 2-hour point i.e.,

$$d(At^B)/dt|_{t=2} = AB2^{(B-1)} \qquad (2)$$

and multiplying Eq. 2 with 18.18 x ($\rho_{27\%\ chrome\text{-}iron}/\rho_{test\ speciment}$). The constant, 18.18, makes the number relative to a slurry of sulfur and water (MN = 1) and the ratio of the density of the standard Miller Number metal specimen of 27% chrome-iron to the test speciment changes the Miller Number to a SAR Number. That is:

$$\text{SAR Number} = 18.18 \times (\rho_{27\%\ chrome\text{-}iron}/\rho_{test\ speciment}) \times AB2^{(B-1)} \qquad (3)$$

(For the example in Fig 11 Eq. 3 gives:

$$\text{SAR Number} = 18.18 \times (7.58/8.02) \times 0.9595 \times 0.72225\ 2^{(0.72225-1)} = 10$$

where the SpG = 7.58 for the 27% chrome-iron and 8.02 for 304L metal stainless steel.)

One other number that is included in a Miller/SAR Number report is something called Attrition, or in the current version of the ASTM standard, Departure. This number quantifies the deviation of the "best fit" mass-loss curve shown in Fig. 11 from the slope of the curve at the 2-hour point. It was originally called Attrition to indicate the change in abrasivity of a particle with time. Attrition was modified to be called Departure to simply signify the departure of the two curves after two hours, which could be caused by not only particle attrition but also by the work hardening of the test specimen, which would also indicate a change of abrasivity with time. The number Departure is determined by the ratio of the curvature of the "best fit" slope of the cumulative mass loss data to the slope itself, at the 2-hour point, i.e.:

$$D^2(At^B)/dt^2\ /\ d(At^B)/dt\ |_{t=2} = AB(B-1)2^{(B-2)}/\ AB2^{(B-1)} \qquad (4)$$

(For the example in Fig 11 Eq. 4 gives:

$[0.9595 \times 0.72225 \times (0.72225-1)\ 2^{(0.72225-2)} / 0.9595 \times 0.72225 \times 2^{(0.72225-1)}] \times 100 = -14\%$

A Departure Number of - 14% indicates that the abrasivity goes down with time. That is, as seen in Fig. 11, the "best fit" curve of the cumulative mass loss data moves down, away, from the slope at the 2-hour point with time. However, this is not always the case. At times a slurry-metal combination can have positive Departure Number indicating an increase in abrasivity with time. This can happen when the abrasion breaks up relatively soft particles to release smaller, harder particles.

3.3 Slurry Compositions and Preparation

As already explained in the Discussion section of this report, two categories of radioactive wastes were evaluated for abrasivity, i.e., LAW and HLW. The actual slurries tested were simulants of the wastes, made to represent the physical and chemical characteristics from the best knowledge available of the makeup of the real wastes. It was important to have the simulants made to the characteristics of the waste just before they would be filtered, that is, processed to forms suitable for filtration. These forms could be either a diluted concentration of sodium, precipitated complexants, or in various stages of washing or leaching. The following is an explanation of all the recipes used to make all seven simulants, one LAW and six variations of HLW, which will be followed by analytic measurements to characterize the simulant just before being used for the wear test. Refer to Table 1 for a concise listing of the simulants. Note that the order of slurries give below is different than in Table 1 because it was convenient to group all the HLW simulants, which have the same base chemicals, after the LAW simulant, which is very different.

3.3.1 *LAW Simulant of Tank 241-AN-107 with Entrained Solids and Sr/TRU Precipitants*

This LAW simulant, which is referred to as Sr/TRU, was made to represents those wastes which will have both entrained and precipitated solids. For this study, a simulant of Handford tank 241-AN-107 was chosen because its simulant recipe was the most developed (Eibling and Nash, 2001), which is listed in Tables 2a, 2b, and 2c. It was tested at an insoluble solids concentration of 20 wt% to represent the slurry at its highest solids loading. (This slurry is No. 3 in Table 1).

Table 2a. Recipe of 5.5 M Na^+ Supernatant for AN-107 waste simulant

Volume of Feed		80000	mL

To be mixed in a 37 Gallon Pastic Tank

Add	grams	Actual Wt, grams
Water	16000	16000

Transition Metals and Complexing agents

Compounds	Formula	Mass Needed	Actual Wt, grams
Calcium Nitrate	Ca(NO3)2.4H2O	174.70	174.70
Cerium Nitrate	Ce(NO3)3.6H2O	8.21	8.20
Cesium Nitrate	CsNO3	1.37	1.37
Copper Nitrate	Cu(NO3)2.3H2O	5.74	5.74
Ferric Nitrate	Fe(NO3)3.9H2O	613.37	613.50
Lanthanum Nitrate	La(NO3)3.6H2O	7.12	7.13
Lead nitrate	Pb(NO3)2	31.12	31.13
Magnesium Nitrate	Mg(NO3)2.6H2O	13.23	13.24
Manganous Chloride	MnCl2.4H2O	101.75	101.80
Neodymium Nitrate	Nd(NO3)3.6H2O	14.62	14.63
Nickel Nitrate	Ni(NO3)2.6H2O	131.76	131.80
Potassium Nitrate	KNO3	231.03	231.20
Strontium Nitrate	Sr(NO3)2	0.80	0.81
Zinc Nitrate	Zn(NO3)2.6H2O	10.34	10.35
Zirconyl Nitrate		9.60	9.61
EDTA	Na2EDTA	364.17	364.30
HEDTA	HEDTA	108.55	108.60
Sodium Gluconate		197.00	197.00
Glycolic Acid		1351.02	1351.00
Citric Acid		473.63	473.60
Nitrilotriacetic Acid		28.60	28.60
Iminodiacetic Acid		302.96	303.00
Boric acid	H3BO3	10.04	10.04
Sodium Chloride	NaCl	91.25	91.40
Sodium Fluoride	NaF	14.75	14.75
Sodium Chromate	Na2CrO4	27.51	27.52
Sodium Sulfate	Na2SO4	612.05	612.20
Potassium Molybdate	K2MoO4	4.46	4.47

In separate container mix the following

Add	Formula	Mass Needed	Actual Wt, grams
Sodium Hydroxide	NaOH	1267.48	1267.40
Aluminum Nitrate	Al(NO3)3.9H2O	269.25	269.20
Sodium Phosphate	Na3PO4.12H2O	222.90	223.00
Sodium formate	NaHCOO	788.27	788.20
Sodium Acetate	NaCH3COO.3H2O	118.87	118.80
Sodium Oxalate	Na2C2O4	63.09	63.00

Add	grams	Actual Wt, grams
Water	16000	16000.00

Mix thoroughly. Then add this solution to the tared 50 Liter carboy.

Add	Formula	Mass Needed	Actual Wt, grams
Sodium Carbonate	Na2CO3	7437.86	7437.90

Mix thoroughly.

Mix	Formula	Mass Needed	Actual Wt, grams
Sodium Nitrate	NaNO3	14915.16	14915.20
Sodium Nitrite	NaNO2	4590.10	4590.20
Water	H2O	8000	8000.00

Add and Mix thoroughly.

Add	Formula	Mass Needed	Actual Wt, grams
Water	H2O	24884	24884.00

Balanced Used:	Ohaus	M&TE# DWB-513
	Mettler AE 163	M&TE # AD-0045
	Ohaus	M&TE DWB-514
Performed By:	Vickie William	
	Mary Mose	

Table 2b. Recipe of entrained solids for AN-107 waste simulant

C Entrained Solids Simulant

Assumption:	0.5	wt % entrained solids
Density	1.243	g/mL
Volume of Feed	80	Liters
Total entrained solids	497.2	grams

Recipe	**Formula**	**Needed grams**	**Used grams**
Aluminum Oxide	Al_2O_3	25.52	25.52
Calcium Phosphate, tribasic	$Ca_3(PO_4)_2$	0.36	0.36
Chromic Oxide	Cr_2O_3	1.90	1.90
Ferric Oxide	Fe_2O_3	23.72	23.72
Manganese Dioxide	MnO_2	15.36	15.36
Sodium Aluminosilicate	$Na_2O.Al_2O_3.(SiO2)_2.5H_2O$	8.08	not on hand
Sodium Oxalate	$Na_2C_2O_4$	170.02	170.02
Sodium Carbonate Monohydrate	$Na_2CO_3.H_2O$	160.79	160.79
Sodium Fluoride	NaF	24.87	24.87
Sodium Sulfate Decahydrate	Na2SO4.10H2O	20.55	20.55
Sodium Phosphate Dodecahydrate	Na3PO4.12H2O	46.03	46.03
	Total	497.2	

Aluminum Oxide	Al2O3	8.08	8.08
Silica Oxide	SiO2	16.16	16.16

Substituted
Al_2O_3 and SiO_2
for Sodium Aluminosilicate

Balanced Used	Mettle AE240	M&TE BWB-511
Performed By	Sammie King	
Date Performed	10/20/00	

Table 2c. Recipe of precipitation additives† for AN-107 waste simulant

Volume=Vi + Vsr + Vmn

Vsr = Volume*0.075/2

Vmn = Volume*0.05

Volume = Vi + 0.0375*Volume + 0.05* Volume

Volume = 30+ 0.0875*Volume

Feed Volume	80	Liters
Volume	87.671	Liters
Vsr	3.288	
Vmn	4.384	

Density of 2 molar strontium nitrate solution	1285.35	grams/Liter
Density of 1 molar sodium permanganate solution	1096.15	grams/Liter

Strontium Nitrate Solution				
Volume	3.288	Liters		
Bottle	4	Liters		
Formula Weight	211.63	grams		Actual Mass Grams
Add	1391.54	grams	Strontium Nitrate	1391.50
Add	2834.27	grams	DI Water	2834.30
Mix thoroughly to dissolve				

Sodium Permanganate Solution				
Volume	4.384	Liters		
Bottle	8	Liters		
Formula Weight	159.94	grams		Actual Mass Grams
Add	701.11	grams	Sodium Permanganate	701.00
Add	4103.93	grams	DI water	4104.00
Mix thoroughly to dissolve				

Balance Used	OHAUS	M&TE DWB-512
Performed By:	Sammie King	
Date Performed:	10/20/00	

† Missing from Table 2c is the sodium hydroxide that should have been added to boost the hydroxide level to 1 Molar; it was accidentally left out during the simulant preparation. However, this fact was discovered only after carrying out the SAR test when the measured pH of the simulant was 10.4, instead of the expected 14. The missing hydroxide was thought not to affect the insoluble solids in the simulant, and therefore erosion, but there was a concern that the lower pH simulant would less corrosive. To address this error a Nonconformance report was initiated (Duignan, 2001c) and an extensive pit corrosion test was carried out by SRTC with the simulant at pH = 14. The corrosion rate was found to be significantly less than 1 mil per year and therefore insignificant (Mickalonis, 2001).

Simulant Characterization

Because of the complex nature of the Sr/TRU simulant, which contains organic complexants, the order in which it is made is very important and the three tables, i.e., 2a, 2b, and 2c, are in chronological order. The supernate is made first, then the entrained solids are added, then the precipitating agents. Simulant development is beyond the scope of this task, but a complete analysis of the completed simulant was done to quantify its characteristics.

Figure 12 indicates that in general the simulant is chemically similar to what is expected from the precipitated AN-107 waste. That is, the sodium level is approximately 6 M, and the strontium and lanthanum which were added in liquid form have been primarily precipitated.

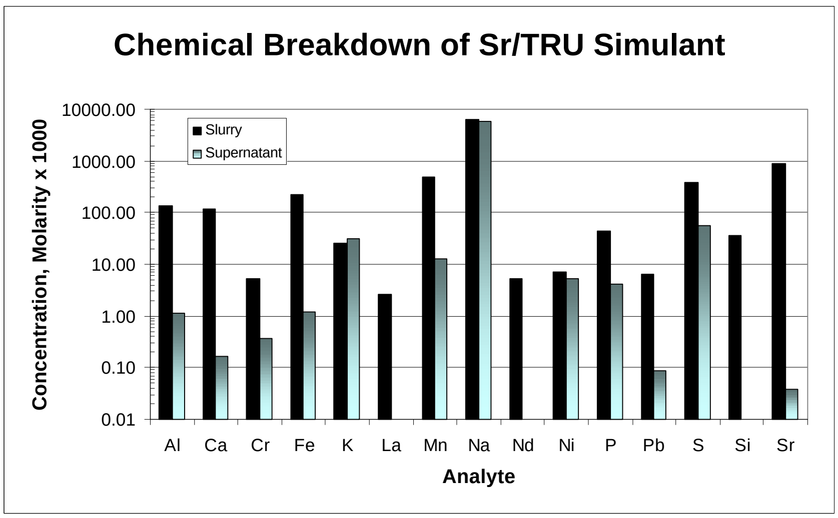


Figure 12. Concentrations of several of the important elements in the AN-107 simulant

With respect to some of the physical characteristics of the AN-107 simulant, Fig. 13, depicts its rheology (which is Fig. 1 of Hansen, 2001a). The two non-linear curves (at 25°C and 50°C) were obtained as the shear rate was increased and they depict a thixotropic character of the precipitate at 20 wt% insoluble solids. The linear curves were obtained as shear rate was decreased in the viscometer, which allowed fitting a Bingham model to the data. The legend of the figure shows the Bingham models with the yield stress as the intercept. The difference in the increasing and decreasing shear rate curves is hysteresis, which is not uncharacteristic of this time dependent pseudoplastic slurry. What is uncharacteristic is the increase in yield stress with increasing temperature, i.e., 22 Pa at 25°C and 42 Pa at 50°C, because yield stress usually decreases with increasing temperature. This phenomenon is not explained but it was confirmed by using a different viscometer. The data shown in Fig. 13 were obtained using a concentric cylinder viscometer, but equivalent data were obtained using a spinning cone viscometer. Detail of the measurements can be found in Hansen, 2001a, but note that the measurement uncertainty of the viscometer is ± 3.2 Pa.

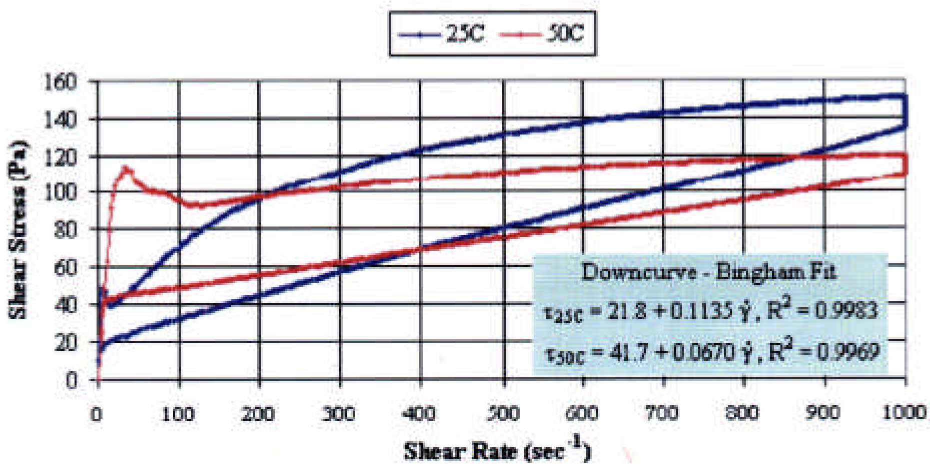


Figure 13. Rheology: Sr/TRU AN-107 simulant at 20 wt% insoluble solids at 25°C and 50°C

Figures 14a and 14b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 14a show the volume distribution and Fig. 14b shows the number distribution (population). The actual waste has particles sizes from 1 to 40 microns, with the majority closer to 1 micron (Lumetta and Hoopes, 1999). The figures confirm that the simulant had a particle distribution similar to the real waste and, as such, is expected to elicit similar erosion characteristics.

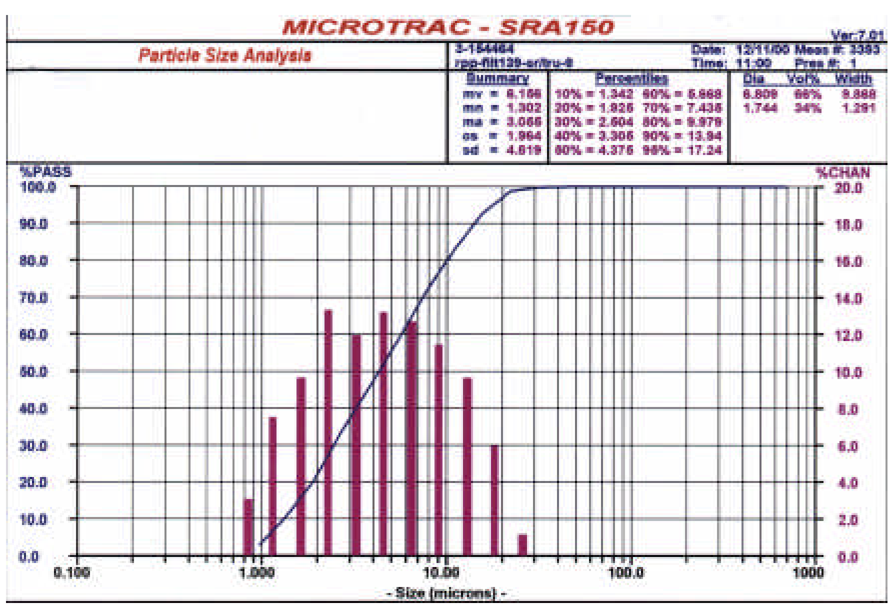


Figure 14a. Solids in the LAW simulant: AN-107, entrained solids, and Sr/TRU precipitants: Particle size distribution by Volume

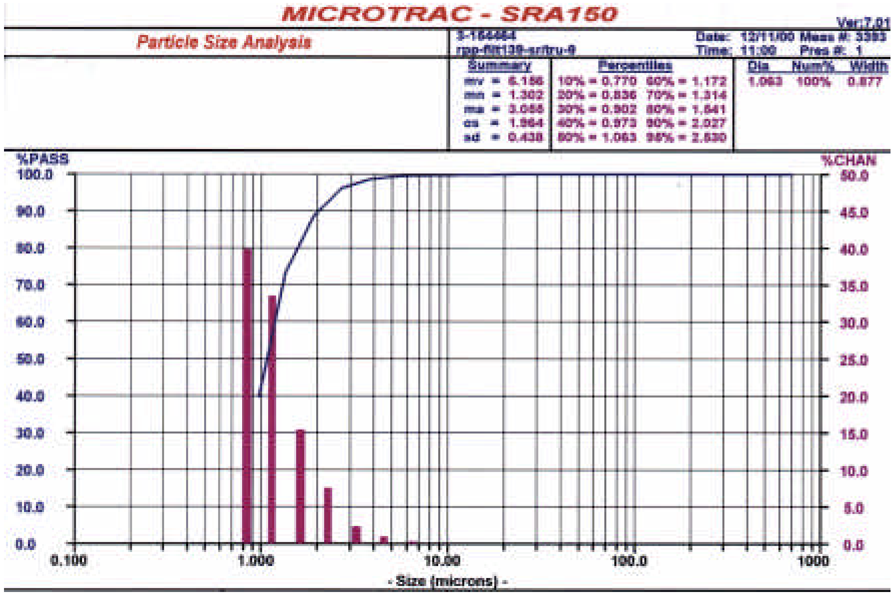


Figure 14b. Solids in the LAW simulant: AN-107, entrained solids, and Sr/TRU precipitants: Particle size distribution by Number

The highlighted data in Figs. 12 and 13, along with all other measurements made on the slurry, are given in Table A3, Appendix A.

3.3.2 HLW Simulant of Tank 241-AZ-101

The HLW slurry will be treated to different processes in the filtration facility, which may affect its erosive and corrosive capability. In order to capture the slurry that will cause the most wear, a simulant was made that represents the slurry as a result of each process. For all of the AZ-101 HLW simulants, the make up of the insoluble solids was the same and was based on the solids used in a simulant made for a previous (Elmore, 2000) erosion test. Table 3 lists those solids.

Table 3. Recipe of Solids used for all HLW (AZ-101) waste simulants

Component	**Mean Particle Size* (μm)**	**% of Total Solids**
Iron oxide A (Hematite – Fe2O3)	37	3
Iron oxide B (Hematite – Fe2O3)	19	31
Red iron oxide (Hematite – Fe2O3)	4	20

Alumina A (Boehmite – Al2O3)	66**	6.7
Alumina B (Gibbsite – Al(OH)3)	29	9.4
Alumina C (Gibbsite – Al(OH)3)	10	6.3
Zirconium hydroxide (ZrO2)	22	11.7
Silicon (Nepheline) (Na3K(AlSiO4)4)	10	4.9
Tungsten oxide (WO3)	***	7
		Total 100%

* The particle sizes were determined from a volume size distribution and the mean value may differ from those listed in a previous erosion test (Elmore, 2000). However, the differences are thought to be insignificant due to the variation is particle size expected from the actual waste.

** Elmore, 2000 and Golcar, 2000 report the mean particle size of the boehmite used was 3-4 nanometers, however, the manufacturer of this substance (HiQ Alumina from Alcoa) reports that this small dimension is actually the crystallite size. It further indicates that the d_{50} = 50 microns, which matches the measured 66 microns as indicated in the Table 3.

*** The size of the Tungsten oxide used in a previous erosion test (Elmore, 2000) was given as a distribution. This effort verified that the procured compound had approximately the same size distribution (by volume), i.e.,

d < 45 mm (29%), 45-63 mm (21%), 63-106 mm (37%), > 106 mm (13%); Elmore, 2000

d < 44 mm (39%), 44-62 mm (20%), 62-106 mm (28%), > 106 mm (13%); this work

Each of the next six HLW simulant will contain the solids shown in Table 3. Depending on the process of the HLW, the actual solids concentration may vary, e.g., a significant amount of alumina is expected to be dissolved after the slurry is leached.

3.3.2.1 HLW Simulant AZ-101

This slurry was made to represents neutralized current acid waste (NCAW) which contains entrained solids and may have a similar or greater corrosive effect than neutralized cladding removal wastes (NCRW); a fact shown in a previous corrosion study by Smith and Elmore, 1992. Further, the NCAW chosen to estimate its erosive/corrosive ability is that of Hanford tank 241-AZ-101. This HLW was assumed to be the most aggressive because of its hard solids and a simulant was previously developed by PNNL (Golcar, et al., 2000) to do erosion studies (Elmore, 2000). For this study, the AZ-101 HLW simulant was tested at an insoluble solids concentration of 20 wt%, to represent the slurry at its highest solids loading. (This slurry is No. 1 as listed in Table 1). The development of this slurry is beyond the scope of this work, but a complete description of the simulant can be found in Golcar, et at., 2000. Table 4 below lists the recipe used to make the slurry.

Table 4a. Recipe of HLW supernatant for AZ-101 waste simulant

Component (volume= 5100 ml)	Concentration used
Sodium hydroxide	1 molar
Sodium nitrate	1 molar

Table 4b. Recipe of Solids for AZ-101 waste simulant (20 wt% insoluble solids)

Component*	Amount Used (g)**
Iron oxide A	42.0
Iron oxide B	434.0
Red iron oxide	280.0
Alumina A	93.8
Alumina B	131.6
Alumina C	88.2
Zirconium hydroxide	163.8
Nepheline	68.6
Tungsten oxide	98.0

* See Table 3 for the definitions of the compounds listed a A, B, or C.

** The absolute amounts of the solids used were such that the concentration of the combined solids resulted in 20 wt%. The amounts of the individual components were based on the percentages used in Elmore, 2000, as shown in Table 3.

Simulant Characterization

Figure 15 indicates that the simulant has key chemical components of the AZ-101 waste. Note that, the iron and zirconium primarily stay in solid form and a high porportion of potassium and silicon stay in solid form.

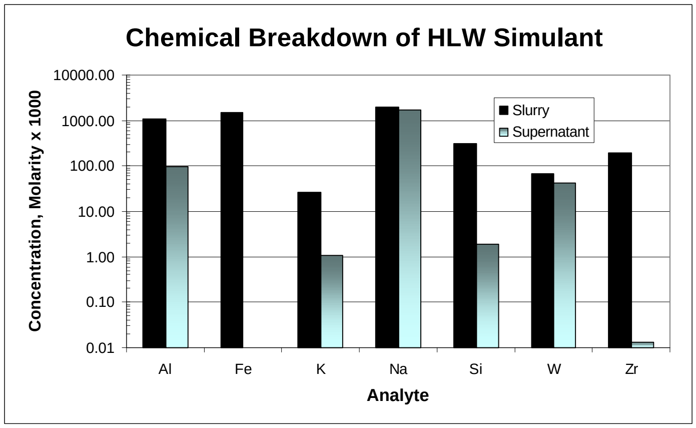


Figure 15. Concentrations of important elements in the HLW simulant

With respect to some of the physical characteristics of the AZ-101 simulant, Fig. 16, depicts its rheology (which is Fig. 1 of Hansen, 2001b). The basically linear curves in Fig. 16 indicate the Newtonian characteristics of the simulant at 20 wt% insoluble solids. The legend of the figure shows the viscosities obtained from the slope of the curves at 25°C and at 50°C. As expected for a Newtonion fluid there was no measurable yield stress. Details of the measurements can be found in Hansen, 2001b, but note that the measurement uncertainty of the viscometer is ± 0.89 Pa.

To compare the rheological properties of the AZ-101 real-waste to the simulant is difficult because of the different types measuring techniques, the limited amount of available real waste samples, and the fundamental differences between real waste and simulants, as explained below. In 1989 two core samples were obtained and rheological properties were measured by Hodgson, 1995. From the second core sample, which was obtained from the tank in two segments, the shear stress versus shear rate was measured, as well as its yield stress. Rheological measurements were made on waste samples with 10 wt% solids and 30 wt% solids. Both samples were found to have pseudoplastic properties (a shear thinning slurry), however, the 10 wt% sample showed no yield stress, while the 30 wt% sample had a finite yield stress (~1.3 Pa). The rheological data were used to develop constants in a power law model to correlate the shear stress, shear rate relationships. Figure 17 includes the results of those correlations, along with a line which is a linear representation of the HLW simulant rheological properties shown in Fig. 16, up to the shear rate that was measured by Hodgson, 1995. Reasons for the differences between the rheological properties of simulant data and the real-waste data can be many, but the primary one may be due to way solids occur in the slurries.

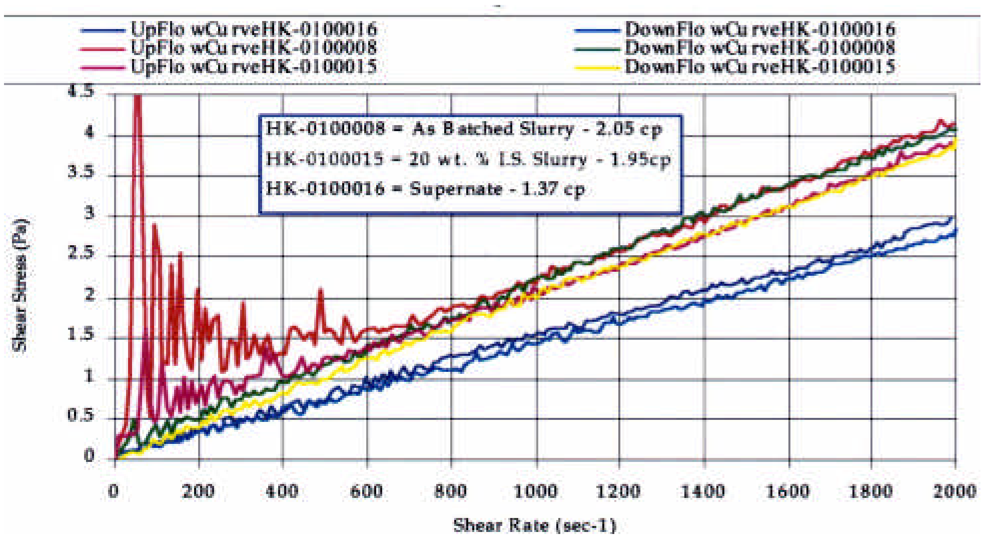


Figure 16. Rheology: AZ-101 simulant at 20 wt% insoluble solids at 25°C

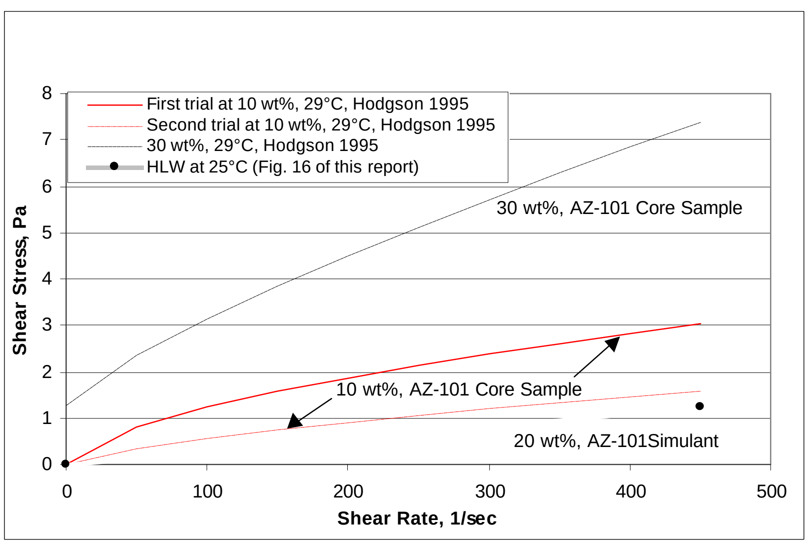


Figure 17. Rheology: AZ-101 Simulant versus 1989 real-waste samples

As seen in Fig. 17, both the AZ-101 real-waste 10 wt% solids and 30 wt% solids curves are above the AZ-101 20 wt% line. This difference is thought to exist because the real waste solids are in an amorphous state, while the simulant solids are not. For the real waste the solids were formed from precipitation and for many years they were closely packed in the storage tank. On the other hand, the simulant was made by adding dry solids to a caustic solvent. The simulant recipe was carefully developed to match the waste chemically, as well as the morphology of the solids (Golcar, 2000). However, the solids in a slurry simulant, made by adding them dry to a liquid, may not match the amorphous phase of the real waste. Table 3-2, in Hodgson, 1995, describes the AZ-101 solids to be "soft, creamy, and sticky dark brown solids." This amorphous sticky state implies that there is considerable adhesion among the particles. The simulant solids did not appear to be sticky. As the adhesive forces among particles increase the shear stress will increase for a given shear rate The different adhesion properties can be seen from the data in Fig. 18. The settling rate for the simulant solids is approximately 12 times faster than the real waste solids, during the first 45 minutes of settling. After about 3 hours the simulant solids settled to an asymptotic height of approximately 30% of the starting solids height. Conversely, the real waste took about 2 days to approach its asymptote, and about 6 days to stop settling at a final height of 47% of its starting height. (Note, the data shown in Fig. 18 were estimated from graphs available in the two indicated sources.)

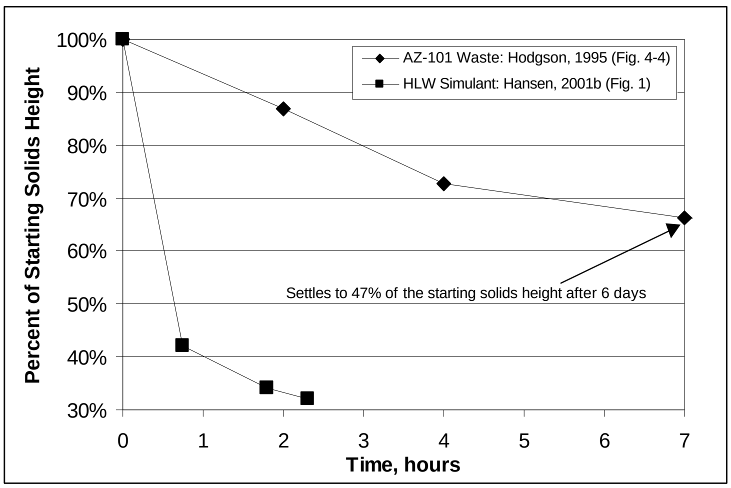


Figure 18. Solids settling rates:AZ-101 real waste composite sample vs. the HLW simulant

Fortunately, while the amorphous differences in the real waste solids to the simulant solids make matching the rheological properties difficult, they help with respect to the abrasion characteristics of the two. That is, the simulant should be conservative, i.e., more abrasive, than the real waste because the particles are distinct and individually available to participate in erosion. The sticky soft real waste particles may actually help to minimize abrasion.

Figures 19a and 19b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 19a shows the volume distribution and Fig. 19b shows the number distribution (population). The actual waste has particle sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997).

The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

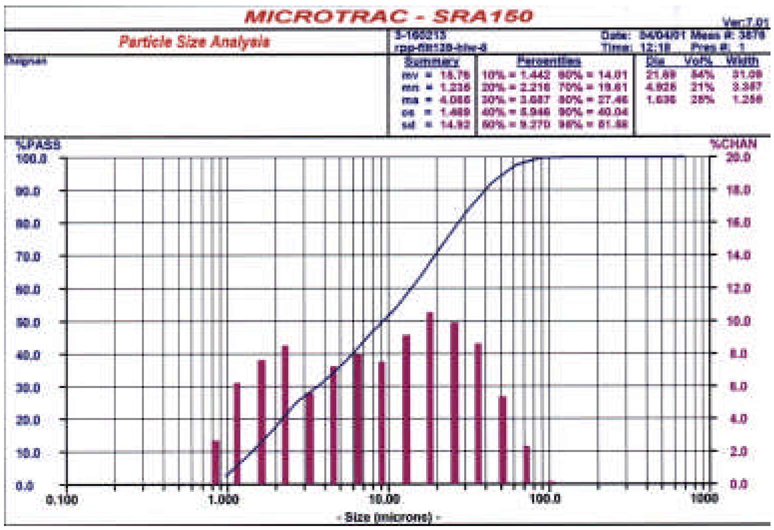


Figure 19a. Solids in the HLW simulant: AZ-101, entrained solids: Particle size distribution by Volume

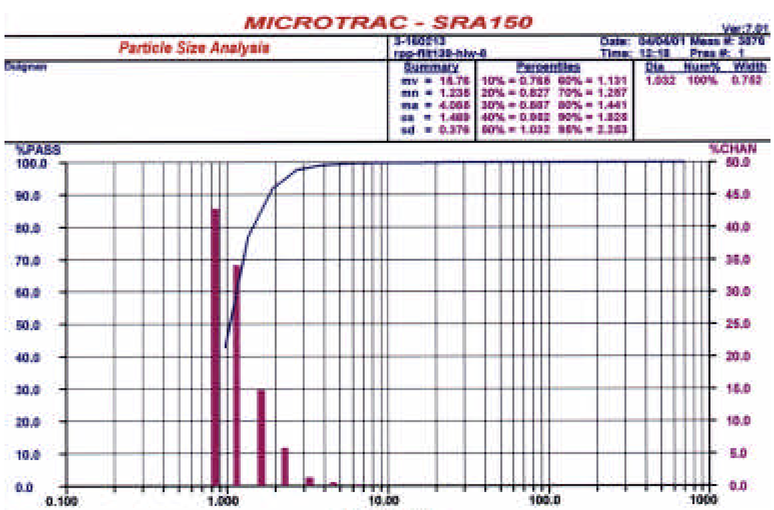


Figure 19b. Solids in the HLW simulant: AZ-101, entrained solids: Particle size distribution by Number

The highlighted data in Figs. 15 and 16, along with all other measurements made on the slurry, are given in Table A1, Appendix A.

3.3.2.2 HLW Simulant with SBS recycle

This slurry is the same as the HLW described in Subsection 3.3.2.1 with an added slurry stream of the Submerged Bed Scrubber recycle with glass fines and glass formers, which is to come from the RPP-WTP melter offgas system. It was tested at an insoluble solids concentration of 20 wt% to represent the slurry at its highest solids loading. (This slurry is No. 2 as listed in Table 1). The development of this slurry is beyond the scope of this work, but a complete description of the HLW simulant can be found in Golcar, et at., 2000. However, the SBS recycle was added in a manner that followed the RPP flowsheet and that was available at the time this simulant was developed.

Simulant Preparation

SBS recycle Simulant

The SBS recycle itself was a simulant because it was obtained from the offgas system of a pilot scale HLW melter that was operated by the VSL[†]. Depending on the makeup of the melt, the offgas, and therefore the SBS recycle stream, may be different. The SBS recycle simulant used in this study may only be considered one candidate for the possible range of recycle streams that the pretreatment system may experience during actual plant operation. In mid-June 2001 SRTC received its shipment of SBS recycle from VSL. Some of the important features of the simulant were:

Total Solids: 0.26 to 0.28 wt%; Insoluble Solid: 0.03 wt%; pH: 2.9; density: 1.0 g/cc

These measurements indicate that the SBS recycle simulant is similar to the recycle expected from the actual HLW melter as per the current WTP flow sheet (Swanson, 2000: Table 13A, Stream 170). That is, it is made mostly of water, it is acidic, and the amount of insoluble solids is very small; the flowsheet states that it may have to be neutralized with 5 M caustic.

In preparation to add the SBS recycle simulant to the HLW simulant it had to be neutralized, as planned for actual plant operation. The simulant was titrated with a 5 M NaOH solution until the pH changed from 3 to 12. It was found that 25 ml of caustic per liter of SBS were needed.

[†] VSL is the Vitreous States Laboratory of The Catholic University of America located in Washington, DC and under a contract with Duratek, Inc.

HLW Simulant

This HLW simulant is similar to the one made in the preceding Subsection except for the larger quantities. The SBS had to be added to the simulant when the concentration of entrained solids was 2.7 wt%, as required by the RPP flowsheet (Swanson, 2000: Table a 13A, Streams 170 (SBS recycle) and 18 (HLW)). A 10-liter batch of the HLW simulant was made at a 3.3 wt% concentration of insoluble solids that dissolved to close to 2.7 wt% after mixing for two hours. The recipe used is shown in Table 5.

Table 5a. Recipe of HLW supernatant for AZ-101 waste simulant

Component (volume= 10 liters)	Concentration used
Sodium hydroxide	1 molar
Sodium nitrate	1 molar

Table 5b. Recipe of Solids for HLW waste simulant (3.3% insoluble solids)

Component*	Amount Used (g)**
Iron oxide A	22.0
Iron oxide B	229.4
Red iron oxide	148.0
Alumina A	49.6
Alumina B	69.6
Alumina C	46.6
Zirconium hydroxide	86.6
Nepheline	32.3
Tungsten oxide	51.8
Total Insoluble Solids	740.0

* See Table 3 for the definitions of the compounds listed as A, B, or C.

**See Table 3 for the actual percentages of each compound. The absolute amounts of the solids used were such that the concentration of the combined solids resulted in a 2.7 wt%. From past experience in making the HLW simulant some of the solids dissolved (especially the alumina) in the caustic solvent. Making the simulant to a certain wt% was an iterative process by assuming a necessary quantity of solids and then measuring the concentration after 2 hours of mixing, which is then followed by an adjustment (adding solids or decantation) until the desired concentration was attained.

HLW with SBS recycle

With both simulants prepared, the SBS was added to the HLW at the ratio of 1 kg of SBS to 8.58 kg of HLW at an insoluble solids concentration of 2.7 wt%. The resulting insoluble solids concentration was approximately 2.4 wt%, which was then decanted until the final concentration of 20 wt% was attained.

Simulant Characterization

Figure 20 indicates key chemical components of the HLW simulant. Note that, the iron and zirconium primarily stay in solid form and a high porportion of potassium and silicon stay in solid form.

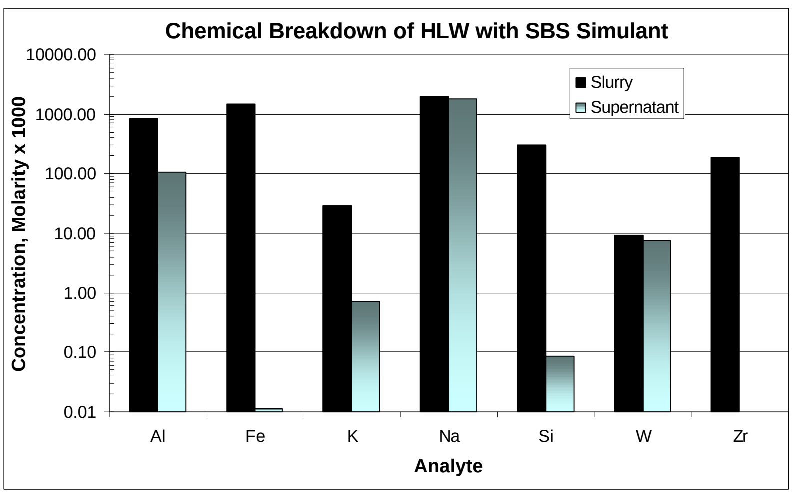
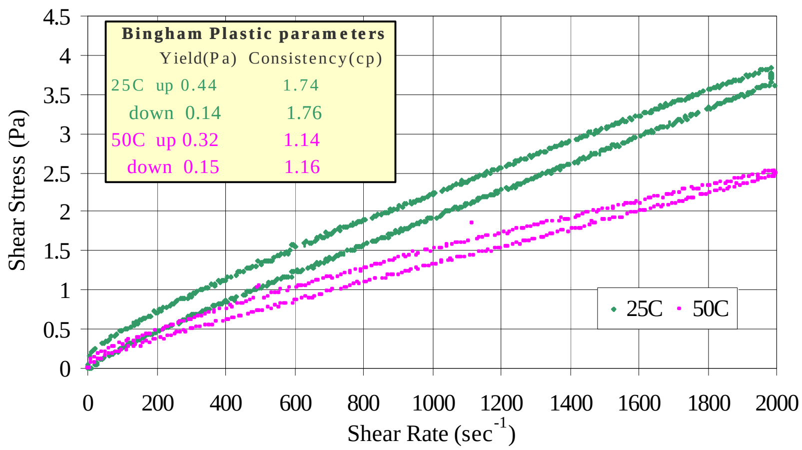


Figure 20. Concentrations of important elements in the HLWwSBS simulant

With respect to some of the physical characteristics of the simulant, Fig. 21, depicts its rheology (which was taken from Hansen, 2002). For the simulant at 20 wt% insoluble solids, the curves were obtained by increasing, then decreasing, the shear rate. While the curves are strictly not linear, they are considered as such for engineering purposes and when taking into account that the measurement uncertainty was ± 0.89 Pa. This assumption allows the data to be fit to a Bingham model. The legend of the figure shows the Bingham models with the yield stress as the intercept. The difference in the increasing and decreasing shear rate curves is hystersis, which is not uncharacteristic of this time dependent pseudoplastic slurry. Detail of the measurements can be found in Hansen, 2002.



Figures 22a and 22b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 22a show the volume distribution and Fig. 22b shows the number distribution (population). The actual waste has particle sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997). The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

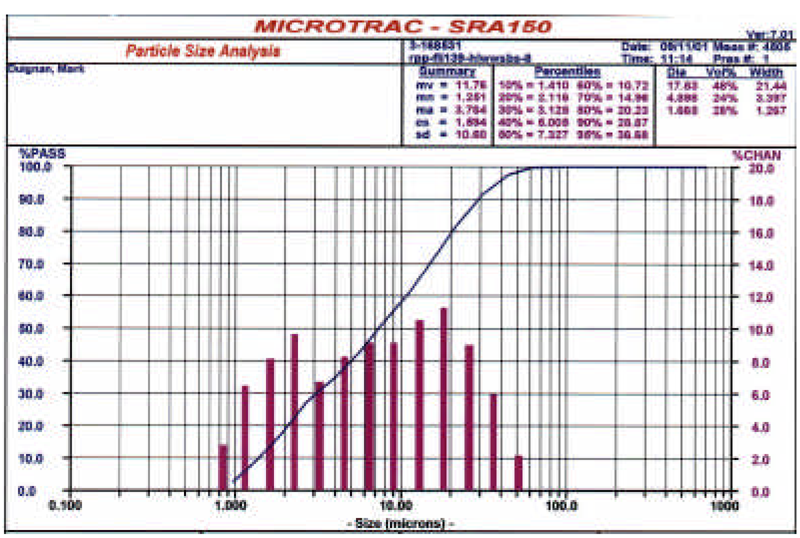


Figure 22a. Solids in the HLW with SBS simulant at 20 wt% insoluble solids: Particle size distribution by Volume

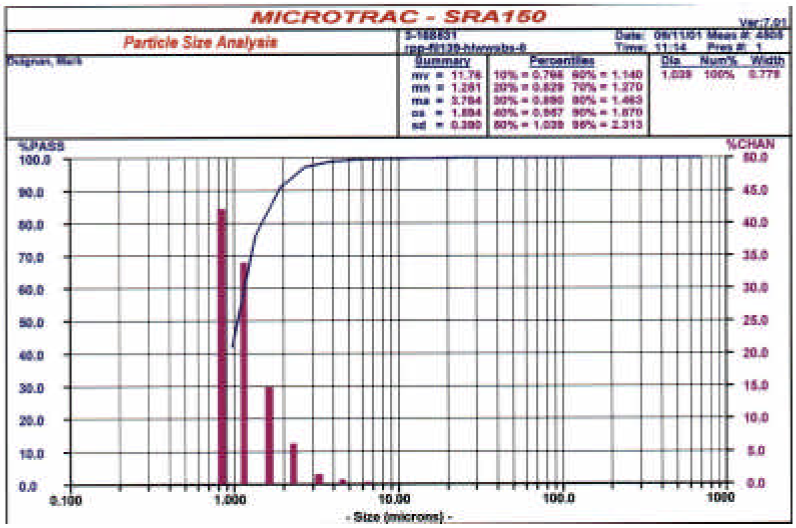


Figure 22b. Solids in the HLW with SBS simulant at 20 wt% insoluble solids: Particle size distribution by Number

The highlighted data in Figs. 20, and 21, along with all other measurements made on the slurry, are given in Table A2, Appendix A

3.3.2.3 Leached HLW Simulant

This slurry is the same as the HLW listed in 3.3.2.1, but then slurry it was leached at 85°C for 8 hours. It was tested at an insoluble solids concentration of 20 wt% to represent the slurry at its highest solids loading. (This slurry is No. 4 as listed in Table 1).

<u>Simulant Preparation</u>

In the actual WTP process the HLW is to be washed with inhibited water (0.01 M NaOH) several times to remove the HLW supernatant before it is ready for leaching. The washing step was therefore not necessary to make this simulant and the dry solids were mixed directly with the leaching solvent, i.e., 3 M NaOH. Knowing that some of the solids will dissolve during leaching, which was done at 85°C, it was not necessary to start with the target insoluble solids concentration of 20 wt%. A mass of 700 grams of solids, Table 3, was added to 2.85 liters of 3 M NaOH and heated at 85°C for 8 hours. The leached slurry resulted in 10.8 wt% insoluble solids. Approximately 1700 grams were then removed from the leached slurry to achieve a mixture with a 20 wt% solids concentration. Table 6 show the quantities of compounds used.

Table 6a. Recipe of HLW leaching supernatant for AZ-101 waste simulant

Component (volume= 2.85 liters)	**Concentration used**
Sodium hydroxide	3 molar

Table 6b. Recipe of Solids for AZ-101 waste simulant (18% insoluble solids)

Component*	**Amount Used (g)****
Iron oxide A	21.0
Iron oxide B	217.0
Red iron oxide	140.0
Alumina A	46.9
Alumina B	65.8
Alumina C	44.1
Zirconium hydroxide	81.9
Nepheline	34.3
Tungsten oxide	49.0
Total Insoluble Solids	700.0

* See Table 3 for the definitions of the compounds listed as A, B, or C and for the actual percentages of each compound.

** The absolute amounts of the solids created a slurry with starting solids concentration of 18 wt%, which was reduced to 10.8 wt% due to leaching. After leaching the concentration was increased to 20 wt%

Simulant Characterization

Figure 23 indicates the key chemical components of the leached HLW simulant. Note that, the iron and zirconium primarily stay in solid form and a high porportion of silicon stays in solid form.

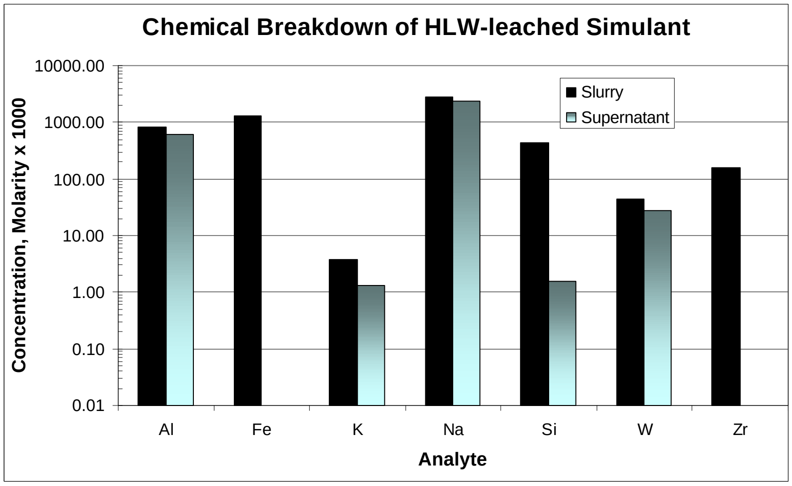


Figure 23. Concentrations of important elements in the leached HLW simulant

With respect to some of the physical characteristics of the simulant, Fig. 24, is a measure of the slurry's rheology (which is Fig. 3 in Wilkinson, 2001b). The basically linear curves obtained indicate the Newtonian characteristics of the simulant at 20 wt% insoluble solids. The viscosities were obtained from the slope of the curves and found be: 3.1 cp at 25°C and 1.9 cp at 50°C.

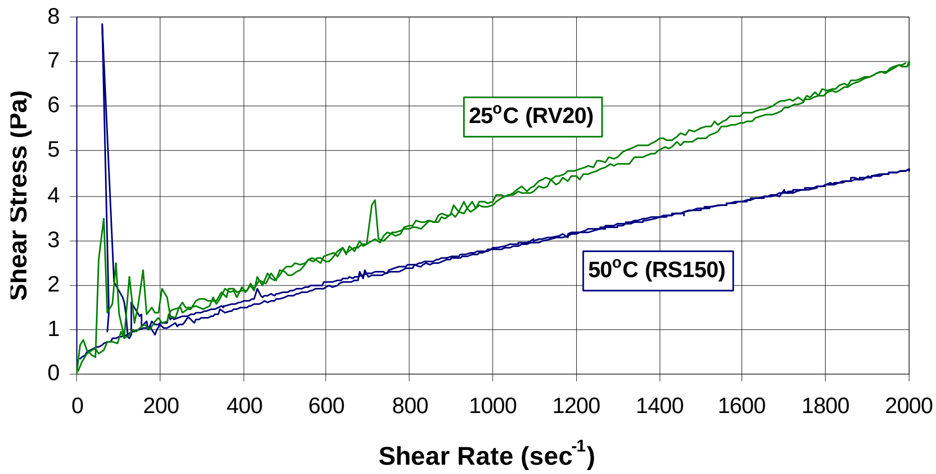


Figure 24. Rheology: leached HLW at 20 wt% insoluble solids at 25°C and 50°C

Stating a viscosity implies the slurry acts as a Newtonian fluid, but Figure 24 indicates that the curves do not go exactly through the origin which implies that the slurry is strictly non-Newtonian. There was a very small yield stress between 0.6 Pa and 1 Pa, however because of the measurement uncertainty for the data was ± 0.89 Pa, this stress is not significant. Furthermore, a close look of the overall shear stress vs. shear rate indicate that the slurry is a pseudoplastic non-Newtonian fluid. For engineering purposes it may be acceptable to treat the slurry as a simple Newtonian fluid since the non-linear curvature is very slight and within the measurement uncertainty of the viscometers. Details of the measurements can be found in Wilkenson, 2001b.

Figures 25a and 25b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 25a show the volume distribution and Fig. 25b shows the number distribution (population). The actual waste has particles sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997). The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

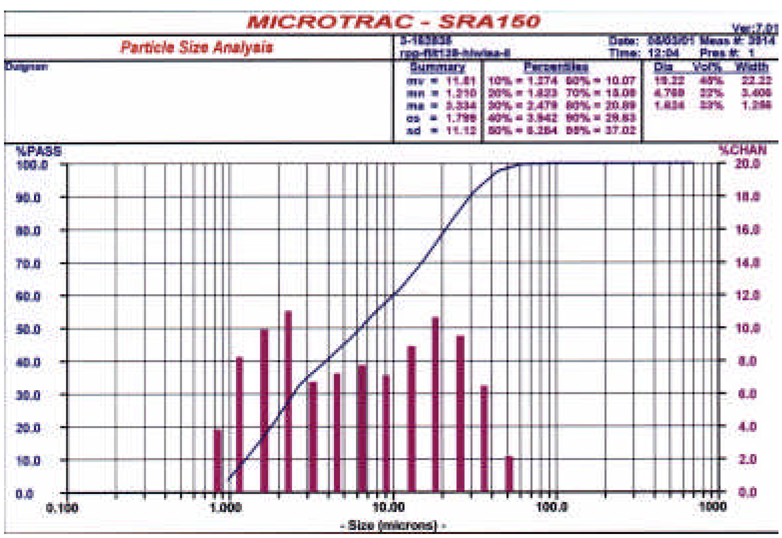


Figure 25a. Solids in the HLW leached simulant: AZ-101, entrained solids: Particle size distribution by Volume

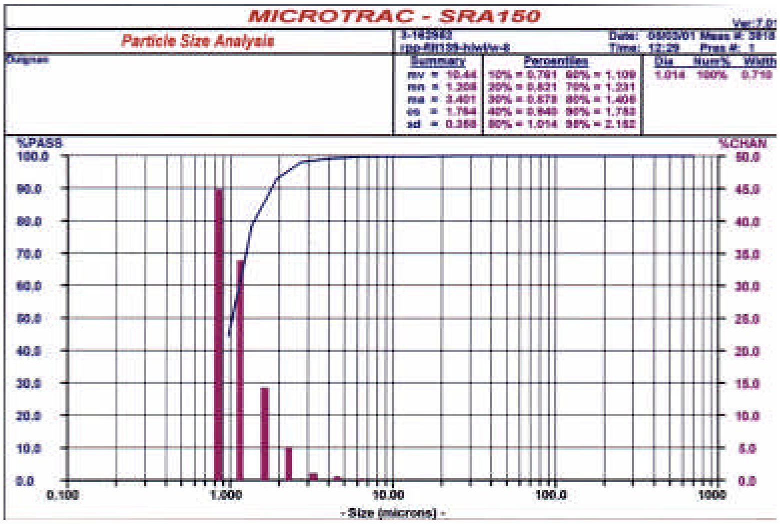


Figure 25b. Solids in the HLW leached simulant: AZ-101, entrained solids: Particle size distribution by Number

The highlighted data in Figs. 23 and 24, along with all other measurements made on the slurry, are given in Table A5, Appendix A.

3.3.2.4 Washed HLW Simulant

This slurry is the same as the HLW listed in 3.3.2.1, but then the slurry was washed with inhibited water (0.01 M NaOH) at 25°C. It was tested at an insoluble solids concentration of 20 wt% to represent the slurry at its highest solids loading. (This slurry is No. 6 as listed in Table 1).

<u>Simulant Preparation</u>

In the actual WTP process the HLW is to be washed with inhibited water (0.01 M NaOH) several times to remove the HLW supernatant before it is ready for leaching. Since the washed slurry will be concentrated before leaching begins, in order to make room in the preparation tank for the leaching solution, the filtration system will experience flows of washed slurry. This simulant is to determine the abrasivity of only the washed slurry. The RPP flow sheet indicates multiple washings to remove interstitial HLW supernatant, which may also dissolve some of the solids. To be more conservative this simulant was simple made by adding the dry solids, Table 7b, so that the resulting mixture contained 20 wt% insoluble solids. To make the mixture 500 grams of dry solids were added to 2 liters of inhibited water, mixed for 16 hours, then its solids concentration was verified to be 20 wt%.

Table 7a. Recipe of washed HLW supernatant for AZ-101 waste simulant

Component (2000 ml)	**Concentration used**
Sodium hydroxide	0.01 molar

Table 7b. Recipe of Solids for AZ-101 waste simulant (20 wt% insoluble solids)

Component*	**Amount Used (g)***
Iron oxide A	15.0
Iron oxide B	155.0
Red iron oxide	100.0
Alumina A	33.5
Alumina B	47.0
Alumina C	31.5
Zirconium hydroxide	58.5
Nepheline	24.5
Tungsten oxide	35.0
Total Insoluble Solids	500.0

* See Table 3 for the definitions of the compounds listed as A, B, or C and for the actual percentages of each compound.

Simulant Characterization

Figure 26 indicates the key chemical components of the washed HLW simulant. Note that, most of the added solids did not dissolve in the inhibited water.

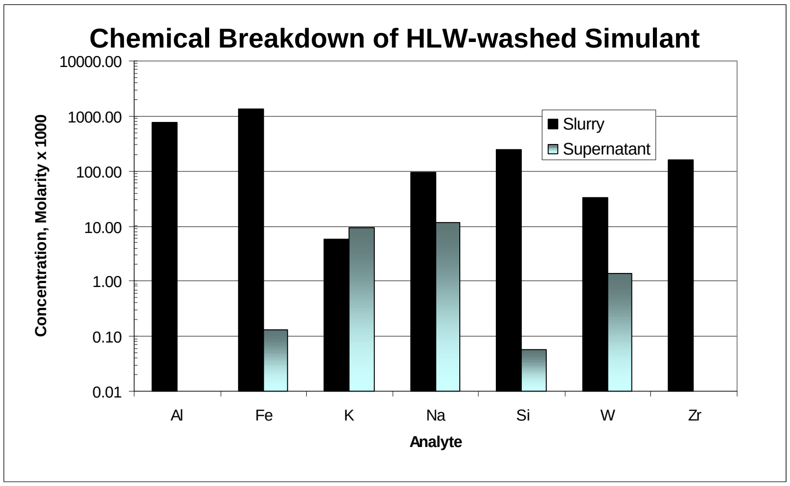


Figure 26. Concentrations of important elements in the washed HLW simulant

With respect to some of the physical characteristics of the simulant, Fig. 27 shows a measure of its rheology (which is Fig. 2 in Wilkinson, 2001b). The basically linear curves indicate the Newtonian characteristics of the simulant at 20 wt% insoluble solids. The viscosities were obtained from the slope of the curves were found to be: 1.8 cp at 25°C and 0.8 cp at 50°C. Stating a viscosity implies the slurry acts as a Newtonian fluid, and within the uncertainty of the measurement (± 0.89 Pa) this is true. Details of the measurements can be found in Wilkenson, 2001b.

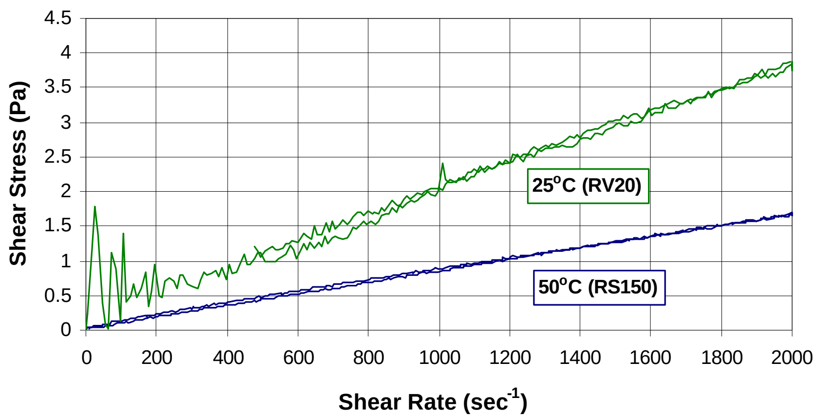


Figure 27. Rheology: washed HLW at 20 wt% insoluble solids at 25°C and 50°C

Figures 28a and 28b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 28a show the volume distribution and Fig. 28b shows the number distribution (population). The actual waste has particles sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997). The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

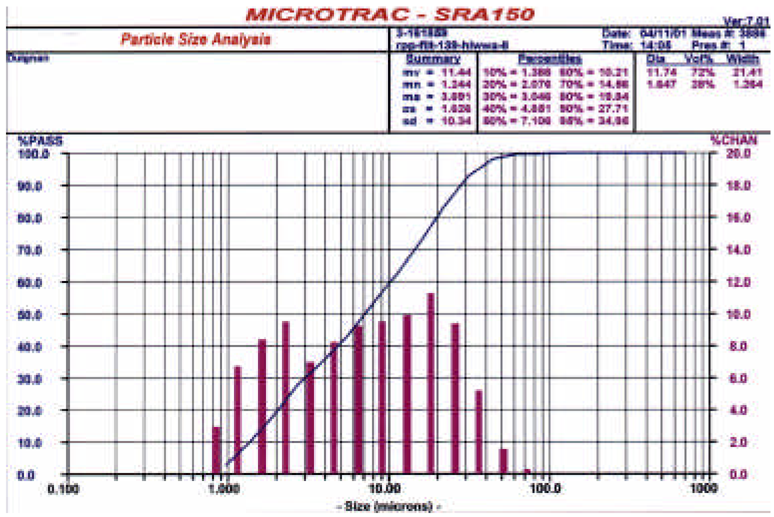


Figure 28a. Solids in the HLW washed simulant: AZ-101, entrained solids: Particle size distribution by Volume

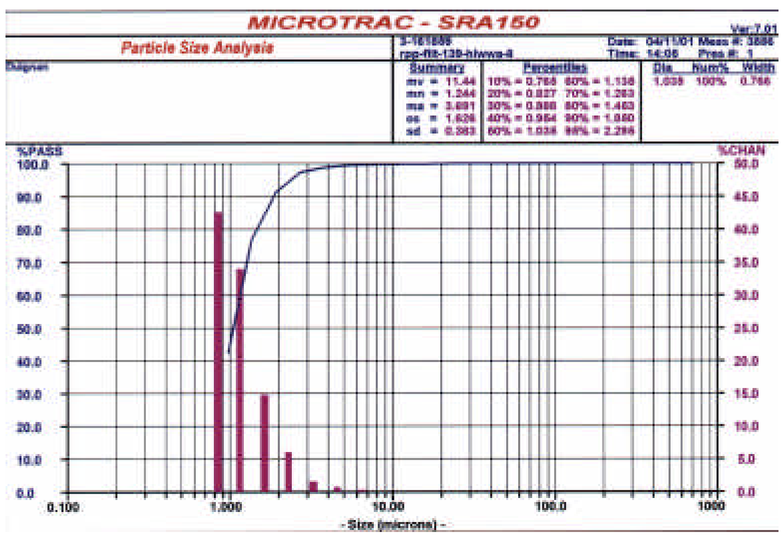


Figure 28b. Solids in the HLW washed simulant: AZ-101, entrained solids: Particle size distribution by Number

The highlighted data in Figs. 26 and 27, along with all other measurements made on the slurry, are given in Table A6, Appendix A.

3.3.2.5 Washed & Leached HLW Simulant with SBS recycle

This slurry is the same as the HLW with SBS recycle described in Subsection 3.3.2.2, which was then washed and leached. It was tested at an insoluble solids concentration of 20 wt% to represent the slurry at its highest solids loading. (This slurry is No. 5 as listed in Table 1)

Simulant Preparation

SBS recycle Simulant

See subsection 3.3.2.2 for an explanation of SBS recycle. For this simulant a quantity of 103.3 grams of 5 M NaOH was added to 3998 grams of SBS recycle to raise its pH from 3 to 12, as per the RPP flow sheet. That is, this titration resulted in adding approximately 22 mL of 5 M NaOH per liter of SBS, which is close to the 25 mL/liter used for the SBS pH adjustment in subsection 3.3.2.2 (slurry number 2). The difference between the two adjustment amounts can be attributed to the uncertainties in pH probes.

HLW Simulant

This HLW simulant is similar to the one made in the subsection 3.3.2.1 except that the quantities are different because the SBS recycle had to be added while HLW concentration of entrained solids was 2.7 wt%. The resulting mixture was then washed with 0.01 M NaOH and the leached with 3 M NaOH. A 30-liter batch of the HLW simulant and the recipe used is shown in Table 8.

Table 8a. Recipe of HLW supernatant for AZ-101 waste simulant

Component	**Concentration used**
For HLW simulant	
[volume = 30 liters (32640 grams)]	
Sodium hydroxide	1 molar
Sodium nitrate	1 molar
For Washing simulant	
[3 x volume = 11.8 liters (11760 grams)]	
Sodium hydroxide	0.01 molar
For Leaching simulant	

[volume = 3.9 liters (4357 grams)]

Sodium hydroxide 3 molar

Table 8b. Recipe of Solids for HLW waste simulant (3.3% insoluble solids)

Component*	Amount Used (g)**
Iron oxide A	33.3
Iron oxide B	344.1
Red iron oxide	222.0
Alumina A	77.4
Alumina B	104.4
Alumina C	69.9
Zirconium hydroxide	129.9
Nepheline	54.4
Tungsten oxide	77.7
Total Insoluble Solids	1110.1

* See Table 3 for the definitions of the compounds listed as A, B, or C.

**See Table 3 for the actual percentages of each compound. The absolute amounts of the solids used were such that the concentration of the combined solids resulted in a 2.7 wt%. From past experience in making the HLW simulant some of the solids dissolved (especially the alumina) in the caustic solvent. Making the simulant to a certain wt% was an iterative process by assuming a necessary quantity of solids and then measuring the concentration after 2 hours of mixing, which is then followed by an adjustment (adding solids or decantation) until the desired concentration was attained.

HLW with SBS recycle

With both simulants prepared, the SBS was added to the HLW at the ratio of 1 kg of SBS to 8.58 kg of HLW at an insoluble solids concentration of 2.7 wt% (The actual amounts used were 3911 grams of SBS to 33557 grams of HLW simulant). The resulting insoluble solids concentration was approximately 2.4 wt%, which was then centrifuged and decanted to increase the solids' concentration to 20 wt% before being washed. The remaining slurry had a total mass of 4702 grams.

Washing: HLW with SBS recycle

As per the RPP-WTP flow sheet the slurry was washed 3 times with 0.01 M NaOH, inhibited water. The slurry was washed at 25°C ±5°C with a volume of inhibited water that is, at least, three times the volume of the HLW with SBS recycle at 20 wt% in solids. The amount of inhibited water used was 11760 grams. After washing for 2 hours, the slurry was concentrated back to its original volume. The washing process was repeated two more times. That is, after each washing, 11760 grams of liquid were removed and replaced with 11760 grams of inhibited water.

Leaching:Washed HLW with SBS recycle

After washing, the slurry mixture was concentrated to at least 20 wt% and then a volume of 3 M NaOH was added that equal, at least, three times the settled volume of the solids. In this case, the washed slurry was centrifuged and all standing supernatant decanted. What remained were 1282 grams of wet solids that had an approximate volume of 650 mL. Six times this volume of 3 M caustic was added (i.e., 3.9 liters) and then the mixture was agitated at 80°C for 8 hours. The reason that six volumes were used was to ensure there would be enough slurry after leaching and concentration to 20 wt% to perform the SAR tests. The resulting solids concentration turned out to be: 33 wt% total solids and 19.5 wt% insoluble solids. The final volume was 2.8 liters, which is based on a measured density of 1.343 g/mL.

<u>Simulant Characterization</u>

Figure 29 indicates the key chemical components of the washed and leached HLW simulant. Note that, the iron and zirconium primarily stay in solid form and a high porportion of silicon stays in solid form.

With respect to some of the physical characteristics of the simulant, Fig. 30, depicts its rheology (which was taken from Hansen, 2002). For the simulant at 20 wt% insoluble solids, the curves were obtained as shear rate was increased and then decreased in the viscometer. To facilitate the use of the data, they were correlated to a Bingham model, which assumes a linear shear stress versus shear rate relation with a finite yield stress. While the data do not exactly follow a linear relationship, they are close enough for engineering purposes and the variance is within the uncertainty of the measurements, i.e., 0.89 Pa. The legend of the figure shows the Bingham models with the yield stress as the intercept. The difference in the increasing and decreasing shear rate curves is hystersis, which is not uncharacteristic of this time dependent pseudoplastic slurry. Detail of the measurements can be found in Hansen, 2002.

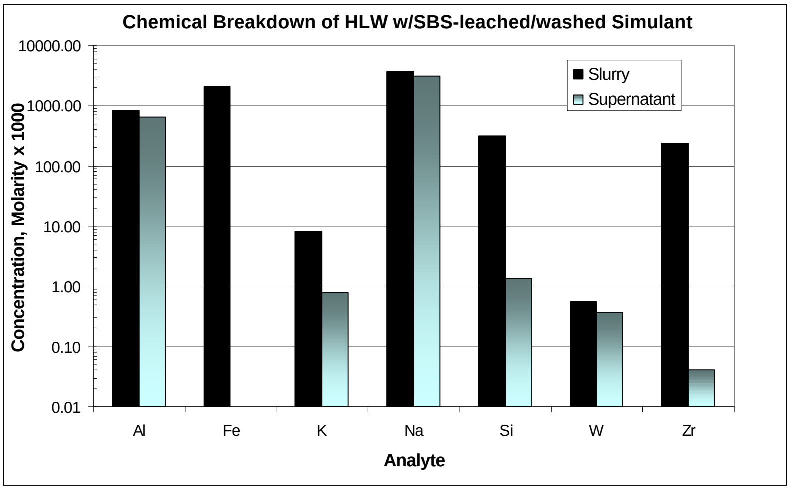


Figure 29. Concentrations of important elements in the washed > leached HLWwSBS simulant

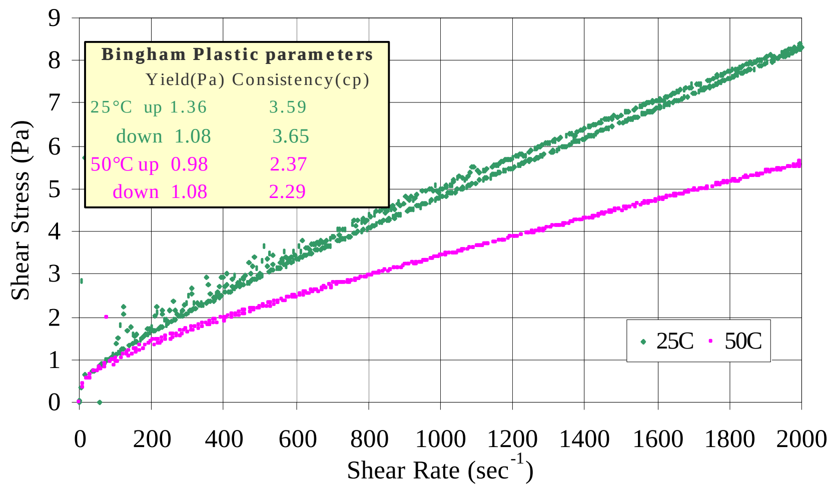


Figure 30. Rheology: washed and leached HLW with SBS recycle at 20 wt% insoluble solids at 25°C and 50°C

Figures 31a and 31b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 31a show the volume distribution and Fig. 31b shows the number distribution (population). The actual waste has particle sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997). The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

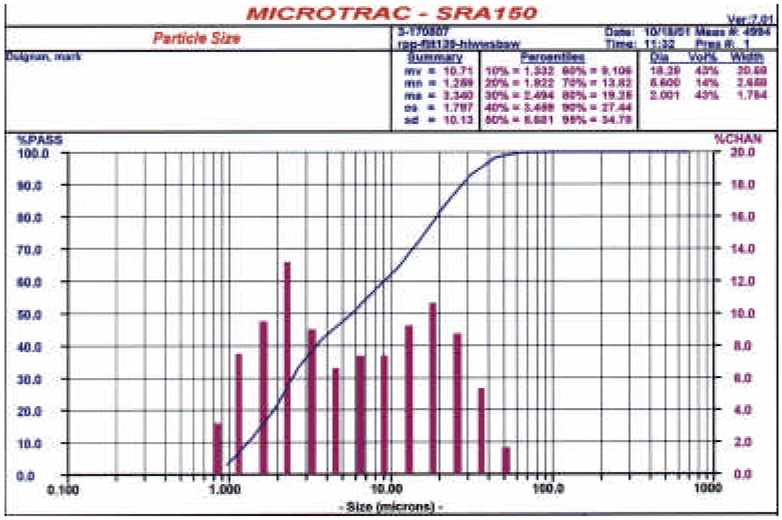


Figure 31a. Solids in the leached and washed HLW with SBS simulant at 20 wt% insoluble solids: Particle size distribution by Volume

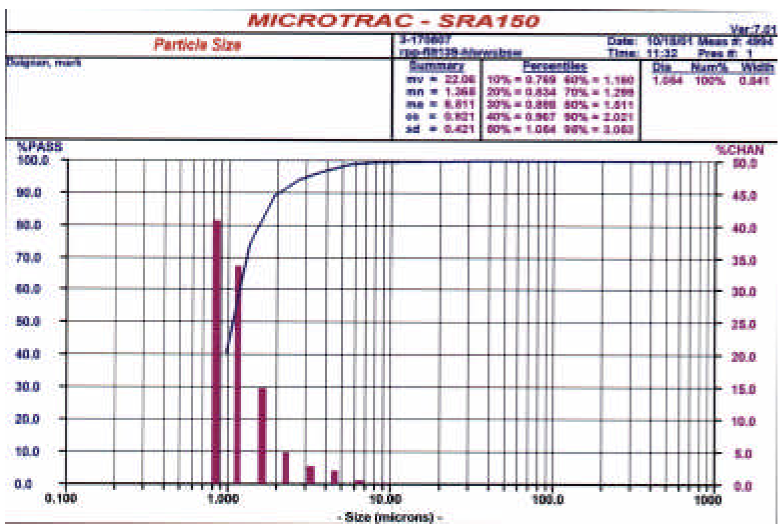


Figure 31b. Solids in the leached and washed HLW with SBS simulant at 20 wt% insoluble solids: Particle size distribution by Number

The highlighted data in Figs. 29, and 30, along with all other measurements made on the slurry, are given in Table A5, Appendix A

3.3.2.6 Leached & Washed HLW Simulant

This slurry is the same as the leached HLW listed in 3.3.2.3, but after leaching the slurry was washed twice with 0.01 M NaOH. (This slurry is No. 7 as listed in Table 1).

Simulant Preparation

As in the actual WTP process, the HLW was washed with inhibited water (0.01 M NaOH) several times at 25°C to remove the HLW supernatant before it was ready for leaching. After leaching the HLW at 85°C and concentrating the solids, the mixture was washed again, but at 85°C for 8 hours (and this final wash was to be done twice). Knowing that some of the solids would dissolve during the 85°C leaching, the solids concentration was started at approximately 27 wt% before leaching, Table 9b. That is, 1000 grams of solids were mixed with 2400 ml of 3 M NaOH for 8 hours, then they were separated from the supernatant by centrifuging. To the remaining 678 ml of wet solids, 2715 ml (a 4:1 volume ratio) of 0.01 M NaOH were added to wash the mixture for 8 hours at 85°C. The centrifugation and washing process was repeated once and then the final mixture was concentrated to 20 wt% insoluble solids. The actual concentration was measured to be 21.5 wt%. Being over 20 wt%, the concentration was considered acceptable because it would be conservative.

Table 9a. Recipe of HLW leaching supernatant for AZ-101 waste simulant

Component	**Concentration used**
Sodium hydroxide (volume = 2400 ml)	3 molar
Sodium hydroxide (volume = 2715 ml x 2)	0.01 molar

Table 9b. Recipe of Solids for AZ-101 waste simulant

Component*	**Amount Used (g)***
Iron oxide A	30.0
Iron oxide B	310.0
Red iron oxide	200.0
Alumina A	67.0
Alumina B	94.0
Alumina C	63.0
Zirconium hydroxide	117.0
Nepheline	49.0

Tungsten oxide	70.0
Total Insoluble Solids	1000.0

* See Table 3 for the definitions of the compounds listed as A, B, or C and for the actual percentages of each compound.

Simulant Characterization

Figure 32 indicates the key chemical components of the leached HLW simulant. Note that, the iron, silicon, and zirconium primarily stay in solid form.

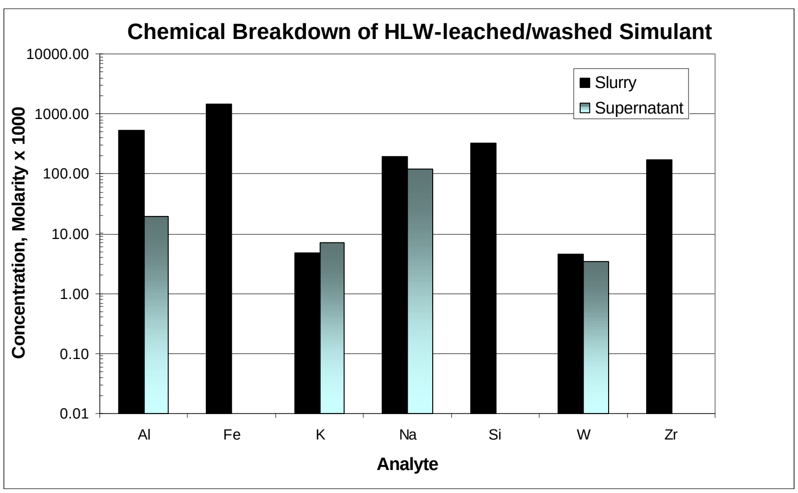


Figure 32. Concentrations of important elements in the leached HLW simulant

With respect to some of the physical characteristics of the simulant, Fig. 33, depicts its rheology (which is Fig. 4 in Wilkinson, 2001b). The basically linear curves indicate the Newtonian characteristics of the simulant at 20 wt% insoluble solids. The viscosities were obtained from the slope of the curves and were found be: 1.6 cp at 25°C and 0.8 cp at 50°C for the slurry. Stating a viscosity implies the slurry acts as a Newtonian fluid, and within the uncertainty of the measurement (± 0.89 Pa). Details of the measurements can be found in Wilkenson, 2001b.

Figures 34a and 34b show the distributions of the solids in the slurry before it was sent for the SAR test. Figure 34a show the volume distribution and Fig. 34b shows the number distribution (population). The actual waste has particles sizes from 0.2 to 50 microns, with the majority closer to 1 micron (e.g., see Fig. 4.11a in Hodgson, 1995 and Fig. 3.3a in Rapko and Wagner, 1997). The figures confirm that the simulant had a particle distribution similar to the real waste and as such is expected to elicit similar erosion characteristics.

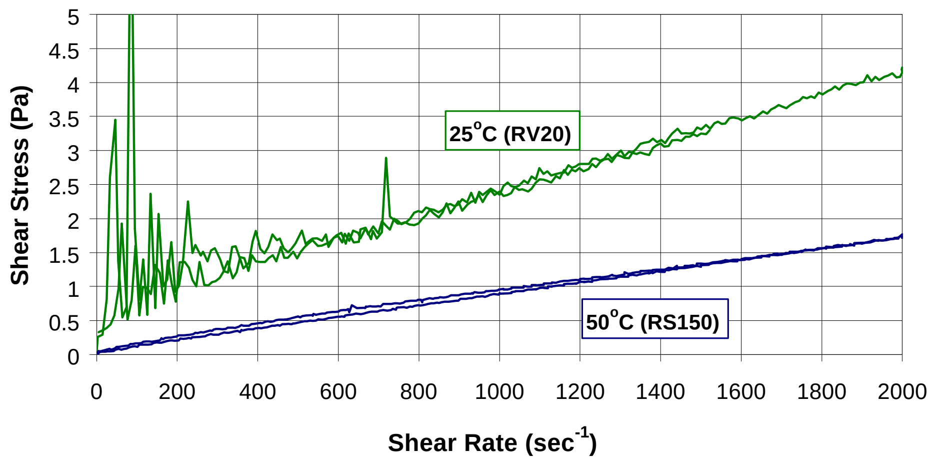


Figure 33. Rheology: leached and washed HLW at 20 wt% insoluble solids at 25°C and 50°C

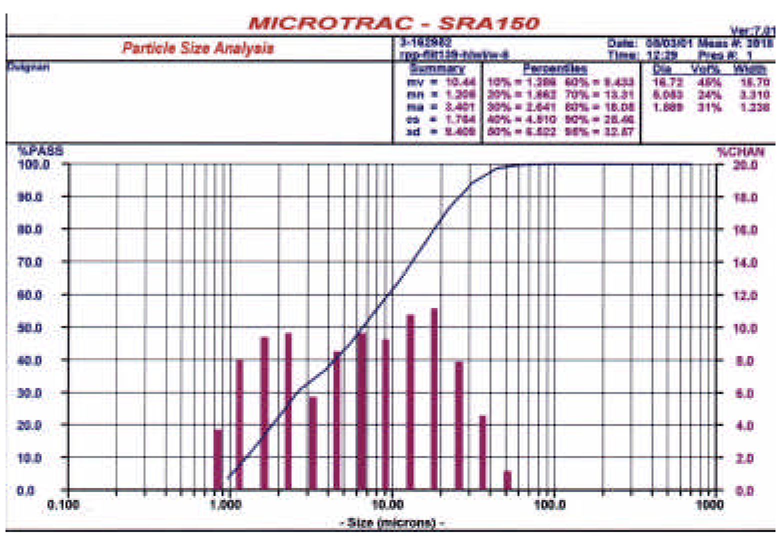


Figure 34a. Solids in the HLW leached simulant: AZ-101, entrained solids: Particle size Distribution by Volume

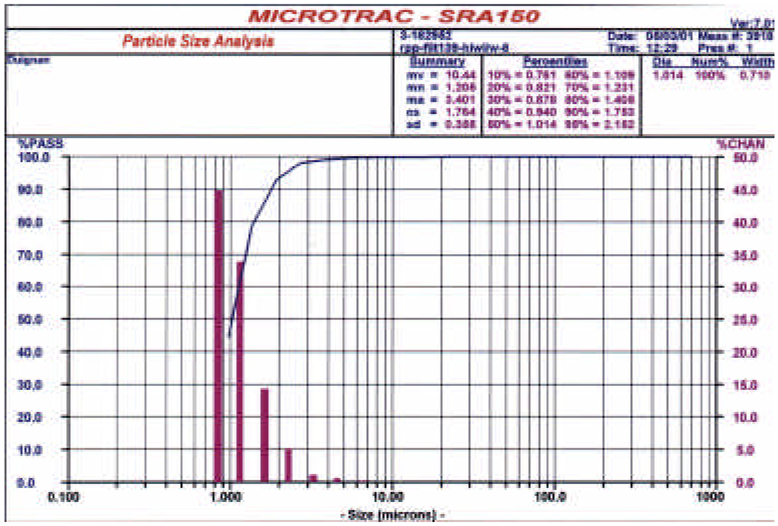


Figure 34b. Solids in the HLW leached simulant: AZ-101, entrained solids: Particle size Distribution by Number

The highlighted data in Figs. 32 and 33, along with all other measurements made on the slurry, are given in Table A7, Appendix A.

3.4 Metal Compositions and Preparation

The main goal of this study is to determine which slurry is the most abrasive so that a long term flow loop test can be done with that abrasive slurry to quantify the wear rate that will occur in the RPP-WTP pretreatment cross-flow filtration system. However, a slurry's abrasiveness can only be discussed with respect to the surface that is being abraded. To date, the selected in-cell pipe material will be made of 304L stainless steel (see RPP-WTP document SP-W375-M0001, Rev. A, 1/6/2000) and the cross-flow filter units will be made of 316L stainless steel. Both of these materials are similar in physical and chemical makeup. However, the slurry evaluation was done with both metals because there are some small differences. For instance, the 316L has more Molybdenum, which may make it a bit more resistant to certain types of corrosion, or that 304L is slightly harder when having similar heat treatments, which may make it more resistant to certain types of erosion. As listed in Table 1, for each slurry, a metal sample of each metal was provided to the subcontractor to test. Table 10 shows the Certified Material Test Report information for both metals.

************************** Austenitic Stainless Steels Used **************************		
AISI Metal Type	**304L**	**316L**
per ASTM	A276	A276
Heat Number	6285	P6463
Manufacturer Location	Germany	England
Heat Treatment	1050°C water quench	1050°C water quench
Grain Size	9.5	7
0.2% Yield Strength, psi	87710	48922
Tensile Strength, psi	112260	94203
Hardness, HB (Rockwell, Vickers)	185 (B92, 37)	159 (B84, 32)
********************************** Chemical Analysis **********************************		
C, %	0.020	0.018
Si, %	0.35	0.18
Mn, %	1.88	1.98
P, %	0.028	0.024
S, %	0.009	0.005
Cr, %	18.72	17.20
Mo, %	0.03	2.15
Ni, %	8.46	11.80
Cu, %	0.09	0.20
N, %	0.065	0.050
Ti, %	NA	<0.010

Table 10. Composition of the metal samples used for slurry abrasivity evaluations

As per the ASTM standard, the metal specimens were made to the dimensions required by the testing equipment before they were sent to the WRES . Figure 35, show those dimensions and Fig. 3 show how the specimens were held in the test rig.

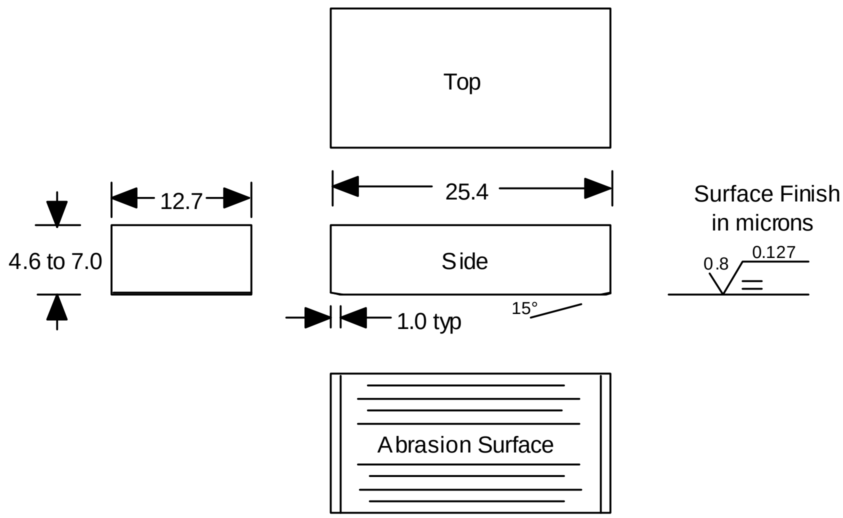


Figure 35. Typical metal specimen (the dimensions are in millimeters except where noted)

[Note: The surface texture symbol at the right indicates that the maximum surface roughness is to be 0.8 μm, the maximum surface waviness is to be 0.127 μm, and that the predominant pattern of surface finish on the bottom of the metal specimen is to be parallel to the long axis, as illustrated.]

3.5 Quality Assurance

While the chosen method to measure the abrasivity of a slurry to a metal was done by a U.S national standard, adopted by the American Society For Testing & Materials, the Quality Assurance program of the subcontractor that performed the test, was evaluated by WSRC. To insure quality, a source inspection visit was made by a qualified WSRC quality assurance inspector. The major conclusion made from that visit (Connelly, 2001) was that the vendor met the requirements of the ASTM standard and thus met the WSRC QA requirements to produce baseline data.

4.0 Results

4.1 Overall Physical and Chemical Slurry Properties

Figure 36 contains some important information to compare the seven slurries used in this slurry evaluation. These data are only highlights of the overall measurements taken for each slurry, which can be found in Tables A1 to A7 in Appendix A. The information here will be used to describe the wear test results in the next section, 4.2.

Slurry Number ---> Slurry Type ---> V V - Type of Measurement - V V	1 HLW	2 HLW with SBS recycle	3 Sr/TRU	4 Leached HLW	5 Leached HLW with SBS recycle	6 Washed HLW	7 Leached & Washed HLW
Normal Slurry Operating Temperature, °C	25	25	25	85	25 (1)	25	85
Slurry Density, g/cc	1.30	1.27	1.44	1.34	1.34	1.17	1.18
Supernatant Density, g/cc	1.12	1.09	1.27	1.13	1.16	1.00	1.01
Slurry Consistency, cp @ 25°C	1.95	1.75	112.00	3.10	3.62	1.80	1.60
Slurry Yield Stress, Pa @ 25°C	0.0	0.30	20.0	0.6 to 1.0	1.22	0.0	0.00
Supernatant Viscosity, cp @ 25°C	1.40	1.23	NA	1.40	2.21	1.10	1.00
Slurry Sodium Concentration, molarity	1.94	2.00	6.47	2.78	3.60	0.09	0.20
Supernatant Sodium Concentration, molarity	1.70	1.81	5.79	2.37	3.09	0.01	0.12
Slurry pH (2)	13.2	12.8	9.6 (3)	11.7	13.4	7.5	11.0
Total Solids, wt%	30.9	26.8	45.7	32.3	33.2	19.2	18 (4)
Insoluble Solids, wt%	20.1	19.9	18.6	20.4	19.5	19.2	18 (4)
Solids Particle Size by Volume, micron (5)	21.7(54%)	16.7 (45%)	6.8 (66%)	19.2 (45%)	17.8 (48%)	11.7 (72%)	16.7 (45%)
Solids Particle Size by Number, micron	1.0	1.0	1.1	1.0	1.0	1.0	1.0

Comments
(1) This slurry was to be tested at 85°C, but the RPP flow sheet changed such that all filtering will be done at 25°C ±5°C, thus the test temperature was lowered.
(2) pH is the lowest measured value from the WRES, Appendix B, which may differ slightly from measurements made at SRS due to uncertainty and time.
(3) Sr/TRU @ pH = 14 was tested for the effect of just corrosion with 304L and 316L stainless steel and found to be < 10 microns/year (SRT-MTS-2001-20007).
(4) This value of an average of a sample concentration of 16 wt% and total batch measure of 20 wt%. The sampling method may have been flawed.
(5) Only the average of largest particle size measured is included in this table, along with its (percentage) contribution to the total.

Figure 36. Physical properties of seven test simulants

Some additional slurry information to that given in Fig. 36 is:

- When this slurry evaluation task began at the end of 2000, the RPP flow sheet indicated that the filtration flow loop would filter leached slurries at the leaching temperature of 85°C. Since then, the flow sheet has been changed such that the leached slurries will be cooled in the preparation tanks to 25°C before any filtering. As such, the last slurry to be tested was the washed and leached HLW with SBS recycle, number 5, and it was originally to be wear tested at 85°C. With a change in the flow sheet the wear test vendor, WRES, was instructed to perform the test at the new filtering temperature, 25°C.

- The main difference between all the HLW slurries and the LAW slurry is that the latter goes through a precipitation step and contains organic components and the former does not contain any organics.

- Rheologically, all of the HLW act as Newtonian mixtures, i.e, their shear stress versus shear rate relations are linear (or almost linear) and do not exhibit significant yield stresses. The LAW is a time dependent pseudoplastic mixture, also known as a thixotropic fluid.

- The insoluble solids in the HLW simulants settle fairly fast, in minutes, whereas the solids in the LAW slurry remain suspended for 30 minutes or more.

- As expected, the simulants which had a final step of washing, i.e., Nos. 6 and 7, displayed the lowest sodium content (0.1 M and 0.2 M, respectively) and the lowest density, < 1.2 g/mL.

- The number of particles with an average size of 1 micron did not change with different process steps.

- Each simulant's pH changed slightly with time. The pH data shown in Fig. 36 were measured by WRES, and are also given in Appendix B. This pH is thought to be the most representative because it was measured just before each test. The exception was simulant No. 3, which was very thick and presented problems to measure, thus it was only measured at SRTC. Coincidentally, simulant No. 3 had a very low pH (~10) because the caustic addition to the simulant was accidentally left out. Because there was a concern that the lower pH would make the slurry less abrasive, a separate corrosion test was done by SRTC (Mikalonis, 2001), as well as at the higher pH, i.e., 14. No significant corrosion was found.

4.2 Slurry Abrasion Response Number

As stated in the beginning of this report, the primary reason to obtain a Slurry Abrasion Response (SAR) Number is to distinguish among all the slurry-metal combinations included in this study as to which will result in the most abrasion. Figure 37 shows the overall results for all the tests. This figure clearly shows the 5th slurry, i.e., HLW with SBS recycle simulant that was washed and leached, was the most abrasive combination, with both 304L and 306L stainless steels. The complete vendor report is included as Appendix B.

On the first page of the report by White Rock Engineering Services, the quantitative SAR numbers are shown to be 206 with 304L stainless steel and 280 with 316L stainless steel. SAR numbers over approximately 80 are considered abrasive and will cause wear to pipe and pump surfaces. The WRES goes further to state that SAR numbers above 200 can cause severe abrasion. However, this measure is only qualitative and can only be used in the context of slurries being more or less abrasive. In this context, slurry number 5 caused the most abrasion among the 7 tested and, therefore, should be used in the planned wear test to give a conservative estimate of wear rates.

Slurry number 2 came in as the second most abrasive, with SAR numbers of 163 for 304L and 221 for 316L. This is important because both slurry 5 and 2 were the only ones that contained the addition of SBS recycle. This was unexpected because the Submerged Bed Scrubber recycle was basically water; it added very little in the way of solids. That is, it had 0.28 wt% in total solids and 0.03 wt% insoluble solids. The recycle stream is condensate, which comes from the glass melter exhaust system after it goes through the SBS system. The solids are some glass fines and glassformers that are carried out of a melter through the off-gas system by the venting vapors.

The as-received SBS recycle was slightly acidic, i.e., pH = 3. Before mixing it with the HLW simulant, its pH was adjusted to a pH = 12 by adding a very small amount of 5 M NaOH. As mentioned in the Discussion sections, 3.3.2.2 and 3.3.2.5, the SBS recycle was added to the HLW simulant with a mass ratio of 1 part SBS recycle to 8.58 parts HLW, which had a insoluble solids content of 2.7 wt%. The resulting mixture was decanted to obtain a final insoluble solids concentration of 20 wt%.

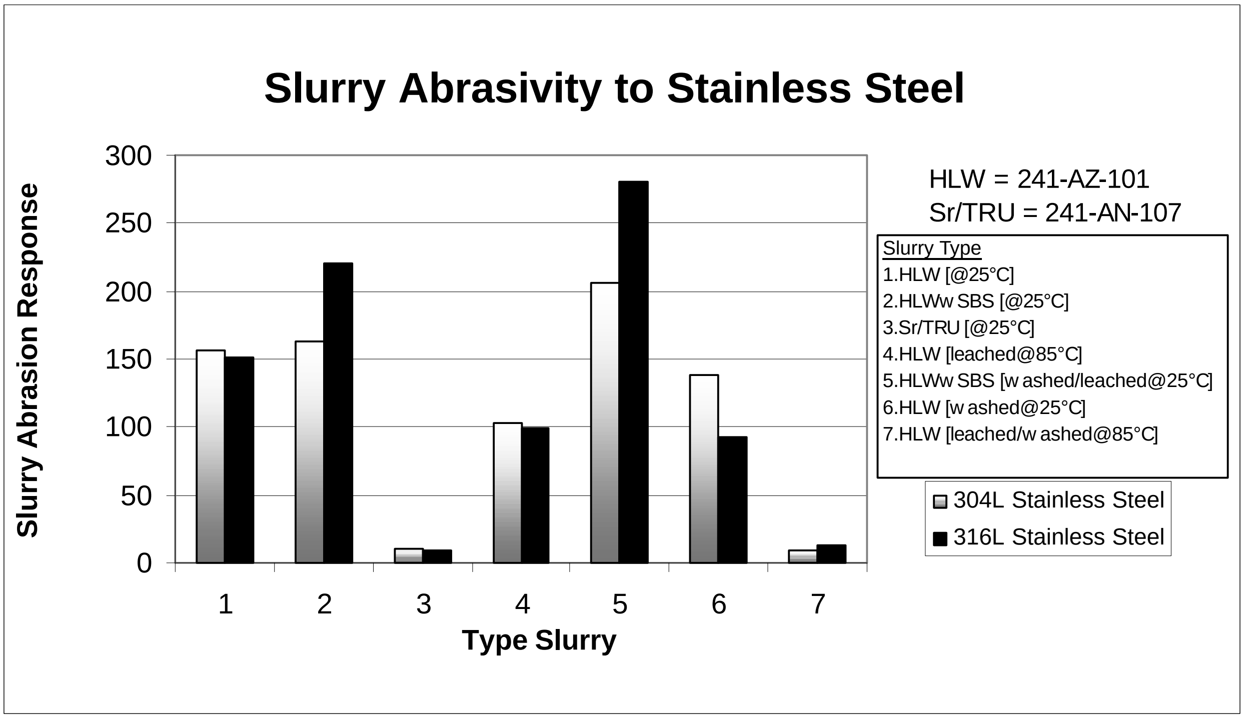


Figure 37. SAR Number for all 7 slurries with both 304L and 316L stainless steels

When comparing the HLW simulant with no SBS recycle, slurry number 1 in Fig. 37, to the HLW with SBS recycle, slurry number 2, there is a significant effect, especially with the high abrasion to 316L stainless steel. The 304L stainless steel was thought to be slightly more susceptible to corrosion than the 316L, and generally that was true, except for slurries with SBS recycle. The non-intuitive effect became more pronounced for slurry number 5, which differs from number 2 in that it had been washed with 0.01 M NaOH and then leached with 3 M NaOH. That is, the base liquid of slurry number 5 was 3 M NaOH whereas for slurry number 2 it was 1 M NaOH and 1 M NaNO3. Another contribution could have been from the small difference in surface hardness. Table 10 shows that the 316L stainless steel was slightly softer (HB159) than the 304L stainless steel (HB185), making the 316 a little more susceptible to ductile erosion, which is the predominant form of erosion in a SAR test (Duignan and Lee, 2001). That is, a SAR test produces wear by rubbing a piece of metal on a lap surface that is saturated with a slurry, as opposed to perpendicularly bombarding a surface with a slurry stream. Whatever is the cause for the higher abrasivity, the addition of SBS recycle cannot be ignored.

The WRES report in Appendix B also includes slurry solids microphotographs for each slurry and the metal specimens that were abraded during the tests. Unfortunately, those photographs do not help to distinguish among the slurries, which were the most abrasive, i.e., numbers 1, 2, 4, 5, and 6. However, there is a distinct difference in abrasivity between those five slurries and numbers 3 and 7. This may indicate that the corrosive element of wear cannot be neglected, and in fact, it is probably the synergistic effect of erosion and corrosion that is producing the most wear.

One final note, the most abrasive slurry-metal combination, number 5 with 316L, had to be repeated because in the first test WRES found the slurry in one of the bottles to be clumping. The original test (see test no. S-1033 in Appendix B) gave two very divergent SAR numbers, (approximately 280 and 380). It is not known why the second trial in that test gave a much higher number, but the test was repeated with spare slurry (S-1033R), which was supplied for just such an event. The new test results agreed well with the first trial of the initial test, giving an average SAR number of 280, therefore this results was taken as accurate.

5.0 Conclusion

Seven RPP-WTP cross-flow ultrafiltration slurry simulants were tested for abrasivity to two different types of stainless steel, 304L and 316L. The slurry, which showed the highest abrasivity, would be selected for use in a scaled flow loop to estimate wear rates in the full-scale filtration system. The abrasivity test is called a Slurry Abrasion Response Number test, which is a nationally accepted standard, ASTM G75-2001. This test cannot give an absolute value of the wear rates in any specific flow system but can indicate if an abrasive environment exists. Further, by comparing SAR numbers of different slurries under similar conditions, it is possible to select a slurry which will present the most abrasion.

- In general, both metals exhibited similar abrasion responses to each slurry simulant, however, there were some difference when SBS recycle was added to the HLW simulants, the 316L seemed to abrade slightly faster.

- Among the seven slurries, number 5, the HLW simulant with SBS recycle that was washed 3 times at 25°C ±5°C and then leached at 85°C ±5°C, showed the highest SAR numbers: 206 for 304L and 280 for 316L. According to the wear test vendor, SAR numbers above 200 exhibit severe abrasion environments. However, the measure is qualitative and such slurries must be tested in more prototypic situations to better quantify actual wear rates.

6.0 Recommendations

- Use slurry number 5 in a scaled test to determine the cross-flow ultrafiltration system wear rates.

- Use both 304L and 316L in the scaled test. The current plan for the actual RPP-WTP in-cell pipe will be made of both 304L and 316L (e.g., the cross-flow filter and its housing are to be of 316L). Since the level of abrasivity was found to be severe for both 304L and 316L the test should include both stainless steels. The 316L stainless steel seems to be more susceptible to wear in the presence of SBS recycle, but the complicated flow mechanisms in the filtering system may also cause considerable wear in 304L.

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APPENDIX A

Data Sheets for Each Simulant

The following seven tables list all physical and chemical properties measured on each of the seven simulants tested. Before the simulated slurries were sent to White Rock Engineering Services, to obtain the Slurry Abrasivity Numbers, samples were taken from each to completely determine the slurry characteristics. The results of the measurements are shown in the tables.

The tables are self explanatory, however, for convenience some major features are explained here:

To save space in the table the RPP sample number was reduced to Prefix + number. For example a sample number may be RPP-FILT139-HLWleached+1, which is the first (+1) sample taken of leached HLW simulant, therefore the first sample in the 2nd row shows the sample number to be Prefix+1. The second sample number is Prefix+2, and so on.

The code numbers in the 6th row indicates what measurements were made or what process was done, i.e., type of dissolution. The number codes are given at the bottom of each table and are repeated here for convenience:

1 = Dissolution – sodium peroxide / uptake with water
2 = Dissolution – sodium peroxide / uptake with hydrochloric acid
3 = Dissolution with aquaregent – 25% nitric and 75% hydrocloric acid
4 = Chloride by ion selective emission
5 = Floride by ion selective emission
6 = ICP – ES
7 = Potasium by Atomic Absorbtion
8 = Total inorganic / organic carbon
9 = IC – anions
10 = Total solids
11 = Suspended solids
12 = Microtrac – particle size distribution
13 = Specific gravity
14 = pH

Columns 5, 6, and 7 contain analytical data for the simulant from three different dissolution methods. There can be data for the same element in all three columns, e.g., Sr. The entry that has a bold border and shaded box is the preferred measurement value. The last column only shows the corrosivity level of the simulant as required by the U.S. Department of Transportation to send it to the wear test vendor. The second to last column only shows the average values of the particle sizes. See the appropriate section in the body of the report of the entire distribution.

Table A1. RPP-WTP Hanford Waste Simulant: HLW (AZ-101)

Most Recent Entry Date: 3-July-2001		Slurry --------------->>	HLW	HLW	HLW	HLW	HLW	HLW	HLW	HLW	HLW
RPP Sample ID (Prefix = RPP-FILT139-HLW_) --------------->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300160207	300160208	300160209	300160210	300160211	300160212	300160213	200138845
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	supernatant	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	250	15	15	15	15	15	10	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.302	n/a	n/a	1.33	1.112	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	<120 ppm	<120 ppm	n/a	<3	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	22500 ppm	20200 ppm	n/a	2670	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	319 ppm	214 ppm	n/a	<2.1	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	<5.0 ppm	<5.0 ppm	n/a	<0.12	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	895 ppm	287 ppm	n/a	<0.4	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	22.4	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<10 ppm	<10 ppm	n/a	<0.14	n/a	n/a	n/a
Cl (Chloride) [less accurate]	ug/mL	(ADS)JC	n/a	<0.2	n/a	n/a	n/a	<20	n/a	n/a	n/a
Cl Sample	ug/mL	(ADS)BC	n/a	33.38	n/a	n/a	72.51	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	<0.44	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	86 ppm	<20 ppm	n/a	6	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	8.73	n/a	n/a	n/a
F (Fluoride) [less accurate]	ug/mL	(ADS)JC	n/a	<0.2	n/a	n/a	n/a	24	n/a	n/a	n/a
F Sample (more accurate resul	ug/mL	(ADS)BC	n/a	<5	n/a	n/a	8.23	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	82500 ppm	65600 ppm	n/a	<0.44	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<100	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	1029 ppm	291 ppm	n/a	46	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	0.08 wt%	0.0228 wt%	n/a	41.713	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<40 ppm	<40 ppm	n/a	<1	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	417 ppm	349 ppm	n/a	<0.84	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	221 ppm	197 ppm	n/a	0.39	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<40 ppm	<40 ppm	n/a	<1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	34300 ppm	n/a	39100	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	<2.6	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	55	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<100	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	93	n/a	n/a	n/a	51729	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<100	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<6.8	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<100	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	1098	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	17.9	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	6670 ppm	1070 ppm	n/a	52.7	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	<2.6	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	<0	n/a	n/a	n/a	32	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	<0.5	<2.0 ppm	<2.0 ppm	n/a	<0.02	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	163 ppm	81 ppm	n/a	3.84	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	<52 ppm	<52 ppm	n/a	<1.3	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	9390 ppm	8820.00	n/a	7850*	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	4.43	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	13550 ppm	n/a	1.18	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	377.40	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	1309.20	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	20.09	n/a	n/a	n/a	n/a	n/a	20.76	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	30.88	n/a	n/a	n/a	n/a	n/a	31.37	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	21.7 (54%)*	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.03	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	1.95	n/a	n/a	n/a	1.4*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	0.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	plastic	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	0.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	13.15	n/a	n/a	n/a	11.53	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Corrosive*
COLUMN-RELATED COMMENTS	*Units of entries unless otherwise noted	Analyst Names DB = Don Blankenship SB = Sarah Brown BB = Beverly Burch SB = Syderis Burkett JC = Joyce Cartledge BC = B.S. Carter EH = Erick Hansen FP = Frank Pennebaker RR = Robert Ray TNX = A laboratory at SRS ADS = Analytical Development Section at SRS		Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Usable values are shaded like the one shown here>			*supernate viscosity came from the TNX sample	*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns in solution which is the majority of the particle sizes.		*The volume distribution actually had three peaks: micons (% total) 1.64 (25%) 4.9 (21%) 21.7 (54%)	*Sample Category 2 Package Group II

OTHER COMMENTS

Analysis Nomenclature

1 = Dissolution - Sodium Peroxide / uptake with Water
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL
4 = CL - Ion Selective Emission
5 = F - Ion Selective Emission
6 = ICP-ES
7 = K by AA
8 = TICTOC
9 = IC-Anions
10 = Total Solids
11 = Suspended Solids
12 = Microtrac - particle size
13 = Specific Gravity
14 = pH

Table A2. RPP-WTP Hanford Waste Simulant: HLW (AZ-101) with SRS Recycle

Most Recent Entry Date: 11-Feb-2002		Slurry --------------->>	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS	HLWwSBS
RPP Sample ID (Prefix = RPP-FILT139-HLWwSBS)->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300168525	300168526	300168527	300168528	300168529	300168530	300168531	200177332
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	supernatant	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	200	15	15	15	15	15	15	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.267	n/a	n/a	n/a	1.093	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	18000 ppm	16100 ppm	n/a	2860	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	<110 ppm	<110 ppm	n/a	22.3	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	39 ppm	<10 ppm	n/a	<0.12	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	1304 ppm	307 ppm	n/a	<0.4	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<15 ppm	<15 ppm	n/a	<0.14	n/a	n/a	n/a
Cl [Chloride by IC - filtered]	ug/mL	(ADS)JC	n/a	9340 ppm	n/a	n/a	n/a	<20	n/a	n/a	n/a
Cl [Chloride by ISE]	ug/mL	(ADS)BC	n/a	25.74 ppm	n/a	n/a	10	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.44	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	174 ppm	<30 ppm	n/a	<2.0	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.5	n/a	n/a	n/a
F (Fluoride by IC - filtered]	ug/mL	(ADS)JC	n/a	<93 ppm	n/a	n/a	n/a	<20	n/a	n/a	n/a
F [Fluoride by ISE]	ug/mL	(ADS)BC	n/a	<1 ppm	n/a	n/a	13	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	67000 ppm	66400 ppm	n/a	0.62	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<467 ppm	n/a	n/a	n/a	<100	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	1440 ppm	500 ppm	n/a	26.2	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	878 ppm	210 ppm	n/a	28.094	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<75 ppm	<75 ppm	n/a	<5	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	415 ppm	354 ppm	n/a	<0.84	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	260 ppm	222 ppm	n/a	<0.09	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	<1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	36200 ppm	n/a	41700	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	158 ppm	<40 ppm	n/a	<0.62	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<467 ppm	n/a	n/a	n/a	<100	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	33624 ppm	n/a	n/a	n/a	36419	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<467 ppm	n/a	n/a	n/a	<100	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<6.8	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<467 ppm	n/a	n/a	n/a	<100	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<6.9	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	6754 ppm	898 ppm	n/a	2.4	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<2.6	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	467 ppm	n/a	n/a	n/a	21	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	103 ppm	34 ppm	n/a	<0.02	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	143 ppm	<70 ppm	n/a	<1.4	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	<70 ppm	<70 ppm	n/a	<1.3	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	1320 ppm	1330 ppm	n/a	1390*	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	<3.7	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	13300 ppm	n/a	<0.48	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	225±25%	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	728	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	19.9	n/a	n/a	n/a	n/a	n/a	17.3	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	29.0	n/a	n/a	n/a	n/a	n/a	26.8	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	see below	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.04	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	1.8	n/a	n/a	n/a	1.2*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	0.3	n/a	n/a	n/a	0*	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	1.2	n/a	n/a	n/a	0.8*	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	0.3	n/a	n/a	n/a	0*	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	13.14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	corrosive*

COLUMN-RELATED COMMENTS

*Units of entries unless otherwise noted

Analyst Names
DB = Don Blankenship
SB = Sarah Brown
BB = Beverly Burch
SB = Syderis Burkett
JC = Joyce Cartledge
BC = B.S. Carter
EH = Erick Hansen
FP = Frank Pennebaker

Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Preferred values are shaded like the one shown here. >>

*supernate viscosity came from the TNX sample

*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns

*The volume distribution had three peaks micons (% total) 1.66 (28%) 4.99 (24%) 17.83 (48%)

Corrositex test indicated a sample Category 1 and a Package Group II for shipping

COLUMN-RELATED COMMENTS

*Units of entries unless otherwise noted

Analyst Names
DB = Don Blankenship
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BB = Beverly Burch
SB = Syderis Burkett
JC = Joyce Cartledge
BC = B.S. Carter
EH = Erick Hansen
FP = Frank Pennebaker
RR = Robert Ray
TNX = A laboratory at SRS
ADS = Analytical Development Section at SRS

*density of supernate as measured by TNX = pendi

Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Preferred values are shaded like the one shown here. >>

*supernate viscosity came from the TNX sample

*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns in solution which is the majority of the particle sizes.

*The volume distribution had three peaks micons (% total) 1.66 (28%) 4.99 (24%) 17.83 (48%)

Corrositex test indicated a sample Category 1 and a Package Group II for shipping

OTHER COMMENTS

Analysis Nomenclature
1 = Dissolution - Sodium Peroxide / uptake with Water
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL
4 = CL - Ion Selective Emission
5 = F - Ion Selective Emission
6 = ICP-ES
7 = K by AA
8 = TICTOC
9 = IC-Anions
10 = Total Solids
11 = Suspended Solids
12 = Microtrac - particle size
13 = Specific Gravity
14 = pH

Table A3. RPP-WTP Hanford Waste Simulant: LAW (AN-107) with Sr/TRU Precipitant

Most Recent Entry Date: 03-May-2001		Slurry --------------->>	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU	Sr/TRU
RPP Sample ID (Prefix = RPP-FILT139-Sr/TRU_) --------------->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	None	Prefix+7	Prefix+8
		ADS Sample ID -->>	None-TNX	300154457	300154458	300154459	300154460	300154461	300158235	300154462	200120183
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	slurry-20 wt%	supernatant	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	250	15	15	15	7*	15	Various*	10	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	4-10,13,14	10, 11	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.44	n/a	n/a	1.33	n/a	n/a	1.273	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<4.6	<3	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	2600 ppm	1250 ppm	n/a	1100 ppm	31.3	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	21 ppm	21.8	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	41 ppm	31 ppm	n/a	34 ppm	<0.12	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	3230 ppm	2560 ppm	n/a	2610 ppm	6.75	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	<500 ppm	<700 ppm	n/a	225 ppm	<7.7	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<10 ppm	<10 ppm	n/a	<2.5 ppm	<0.14	n/a	n/a
Cl (Chloride) [less accurate]	ug/mL	(ADS)JC	n/a	<2	n/a	n/a	n/a	n/a	823	n/a	n/a
Cl Sample	ug/mL	(ADS)BC	n/a	5.70	n/a	n/a	n/a	n/a	1856	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.7	0.66	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	192 ppm	93 ppm	n/a	91 ppm	19.2	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	23 ppm	18.5	n/a	n/a
F (Fluoride) [less accurate]	ug/mL	(ADS)JC	n/a	<2	n/a	n/a	n/a	n/a	1185	n/a	n/a
F Sample (more accurate resul	ug/mL	(ADS)BC	n/a	<1	n/a	n/a	n/a	n/a	22.27	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	8250 ppm	8640 ppm	n/a	6010 ppm	22.4	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<10	n/a	n/a	n/a	n/a	7596	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	3703 ppm	5544 ppm	n/a	870 ppm	1160	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	706 ppm	516 ppm	n/a	n/a	1193.9	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	238 ppm	255 ppm	n/a	193 ppm	<7	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1.5	<1	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	101 ppm	<100 ppm	n/a	84 ppm	<0.84	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	19214 ppm	20568 ppm	n/a	18900 ppm	699	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	5 ppm	22.9	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	103335 ppm	n/a	97100 ppm	133000	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	529 ppm	721 ppm	n/a	428 ppm	<2.6	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	290 ppm	240 ppm	n/a	217 ppm	316	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	n/a	35957	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	215	n/a	n/a	n/a	n/a	141788	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	n/a	763	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	650 ppm	925 ppm	n/a	664 ppm	126	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	n/a	1023	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	820 ppm	905 ppm	n/a	872 ppm	18.4	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	2259 ppm	8586 ppm	n/a	641 ppm	1790	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	690 ppm	164 ppm	n/a	<20 ppm	<1.3	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	<4.0	<2.6	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	<0.5	n/a	n/a	n/a	n/a	4055	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	50200 ppm	53358 ppm	n/a	52300 ppm	3.31	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	<140 ppm	<100 ppm	n/a	<2.2 ppm	<1.4	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	<70 ppm	<70 ppm	n/a	<2.0 ppm	<1.3	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	49 ppm	7.21	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	<50 ppm	n/a	93 ppm	25.2	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	n/a	n/a	9906	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	n/a	n/a	11798	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	20.10	n/a	n/a	n/a	n/a	n/a	0	18.55	n/a
Total Solids	wt%	(ADS)BB & TNX	47.18	n/a	n/a	n/a	n/a	n/a	33.1	45.65	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	112.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	20.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	67.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	38.00	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	9.63	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	NC*

COLUMN-RELATED COMMENTS

*Units of entries unless otherwise noted

Analyst Names
DB = Don Blankenship
SB = Sarah Brown
BB = Beverly Burch
SB = Syderis Burkett
JC = Joyce Cartledge
BC = B.S. Carter
EH = Erick Hansen
FP = Frank Pennebaker
RR = Robert Ray
TNX = A laboratory at SRS
ADS = Analytical Development Section at SRS

Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Usable values are shaded like the one shown here> [shaded cell]

*C.Coleman pH & density but he could not separate the liquid from slurry

*5 mls dilute HNO3 was added and then filtered because of thick slurry.

*these are centrifuged samples of supernate from TNX because ADS could not filter the slurry. They were:
5 mL:pH,SpG, TS
2 mL:ICP-ES,AA
1 mL:IC Anions
7 mL:F,CL,TIC/TOC

*Not Corrosive Category 1 Package Group NC

OTHER COMMENTS

Analysis Nomenclature

1 = Dissolution - Sodium Peroxide / uptake with Water	4 = CL - Ion Selective Emission	7 = K by AA	10 = Total Solids	13 = Specific
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric	5 = F - Ion Selective Emission	8 = TICTOC	11 = Suspended Solids	14 = pH
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL	6 = ICP-ES	9 = IC-Anions	12 = Microtrac - particle size	

Table A4. RPP-WTP Hanford Waste Simulant: Leached HLW (AZ-101)

Most Recent Entry Date: 16-July-2001		Slurry ---------------->>	HLWleached	HLWleached	HLWleached	HLWleached	HLWleached	HLWleached	HLWleached	HLWleached	HLWleached
RPP Sample ID (Prefix = RPP-FILT139-HLWleached_) --------->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300162832	300162834	300162835	300162833	300162836	300162837	300162838	200150961
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	supernatant	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	250	15	15	15	15	15	10	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.336	n/a	n/a	n/a	1.129	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<3	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	16800 ppm	15700 ppm	n/a	16300	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	340 ppm	126 ppm	n/a	<5.0	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	<0.12	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	1100 ppm	240 ppm	n/a	<0.4	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	<600 ppm	<600 ppm	n/a	n/a	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<10 ppm	<10 ppm	n/a	<0.14	n/a	n/a	n/a
Cl (Chloride) [less accurate]	ug/mL	(ADS)JC	n/a	28	n/a	n/a	n/a	<2	n/a	n/a	n/a
Cl Sample	ug/mL	(ADS)BC	n/a	835	n/a	n/a	70.0	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.44	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<5.0	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.5	n/a	n/a	n/a
F (Fluoride) [less accurate]	ug/mL	(ADS)JC	n/a	<0.2	n/a	n/a	n/a	<2	n/a	n/a	n/a
F Sample (more accurate resul	ug/mL	(ADS)BC	n/a	<0.02	n/a	n/a	325.6	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	110200 ppm	54600 ppm	n/a	<0.44	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<10	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	<250 ppm	<250 ppm	n/a	55.3	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	0.0112 wt%	0.019 wt%	n/a	51.36	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<350 ppm	<350 ppm	n/a	<7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	451 ppm	225 ppm	n/a	<0.84	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	305 ppm	174 ppm	n/a	<0.5	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	47900 ppm	n/a	54500	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.62	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<10	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	18	n/a	n/a	n/a	23	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<10	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	<1	<400 ppm	448 ppm	n/a	18.1	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	15	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<6.9	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	<250 ppm	<250 ppm	n/a	n/a	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	9140 ppm	1320 ppm	n/a	44	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<2.6	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	<0.5	n/a	n/a	n/a	<5	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	236 ppm	223 ppm	n/a	<0.02	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	<70 ppm	<70 ppm	n/a	<1.4	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	455 ppm	462 ppm	n/a	<2.0	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	6060 ppm	6550 ppm	n/a	5070*	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	<3.7	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	10800 ppm	n/a	<2.0	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	**	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	**	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	20.10	n/a	n/a	n/a	n/a	n/a	19.20	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	31.90	n/a	n/a	n/a	n/a	n/a	31.73	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	see below	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.02	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	3.1	n/a	n/a	n/a	1.4*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	0.6 to 1.0	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	1.9	n/a	n/a	n/a	1.1*	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	0.6 to 1.0	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	12.58	n/a	n/a	n/a	12.66	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Corrosive
COLUMN-RELATED COMMENTS	*Units of entries unless otherwise noted	Analyst Names DB = Don Blankenship SB = Sarah Brown BB = Beverly Burch SB = Syderis Burkett JC = Joyce Cartledge BC = B.S. Carter EH = Erick Hansen FP = Frank Pennebaker RR = Robert Ray TNX = A laboratory at SRS ADS = Analytical Development Section at SRS	*density of supernate as measured by TNX = 1.133	Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Usable values are shaded like the one shown here>			*supernate viscosity came from the TNX sample **total carbon was 51.7 µg/mL but sample generated a gas that prevented inorg./org. analysis	*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns in solution which is the majority of the particle sizes		*The volume distribution had three peaks micons (% total) 1.62 (33%) 4.77 (22%) 19.2 (45%)	Sample Category 1 Package Group II

OTHER COMMENTS

Analysis Nomenclature

1 = Dissolution - Sodium Peroxide / uptake with Water
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL
4 = CL - Ion Selective Emission
5 = F - Ion Selective Emission
6 = ICP-ES
7 = K by AA
8 = TICTOC
9 = IC-Anions
10 = Total Solids
11 = Suspended Solids
12 = Microtrac - particle size
13 = Specific Gravity
14 = pH

Table A5. RPP-WTP Hanford Waste Simulant: Leached HLW (AZ-101) with SRS Recycle

Most Recent Entry Date: 11-Feb-2002		Slurry --------------->>	***** HLW with SBS recycle that was first washed 3 times then leached with 3 M NaOH for 8 hours at 85°C ±5°C *****								
RPP Sample ID (Prefix = RPP-FILT139-HLWwSBSw&l)->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300170801	300170802	300170803	300170804	300170805	300170806	300170807	200184417
		Type Sample ----->>	slurry20wt%	slurry20wt%	slurry20wt%	slurry20wt%	supernatant	supernatant	slurry20 wt%	slurry20 wt%	slurry20 wt%
		Sample Size (mL) >>	200	15	15	15	15	15	15	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.343	n/a	n/a	n/a	1.162	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	16500 ppm	15600 ppm	n/a	17818	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	132 ppm	112 ppm	n/a	<2.1	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	6.58	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	967 ppm	370 ppm	n/a	0.76	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	<0.14	n/a	n/a	n/a
Cl [Chloride by IC - filtered]	ug/mL	(ADS)JC	n/a	3204 ppm	n/a	n/a	<18**	<47	n/a	n/a	n/a
Cl [Chloride by ISE]	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	not done**	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.44	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	45 ppm	<30 ppm	n/a	1.12	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.5	n/a	n/a	n/a
F [Fluoride by IC - filtered]	ug/mL	(ADS)JC	n/a	<95 ppm	n/a	n/a	<18**	<47	n/a	n/a	n/a
F [Fluoride by ISE]	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	not done**	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	76000 ppm	86900 ppm	n/a	<0.44	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<473 ppm	n/a	n/a	<89**	<94	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	992 ppm	494 ppm	n/a	31	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	836.69 ppm	235.41 ppm	n/a	31.12	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<350 ppm	<350 ppm	n/a	<7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	355 ppm	442 ppm	n/a	<0.84	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	241 ppm	275 ppm	n/a	<0.09	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	61700 ppm	n/a	70958	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	78 ppm	<30 ppm	n/a	0.89	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<473 ppm	n/a	n/a	<89**	<94	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	1468 ppm	n/a	n/a	29**	49	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<473 ppm	n/a	n/a	<89**	<94	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	<350 ppm	<350 ppm	n/a	16	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	813 ppm	n/a	n/a	21**	41	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<350 ppm	<350 ppm	n/a	<8.0	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 p[pm	n/a	<5	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	6630 ppm	1029 ppm	n/a	37.5	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<2.6	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	898 ppm	n/a	n/a	13**	28	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	<80 ppm	<80 ppm	n/a	<0.02	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	137 ppm	93 ppm	n/a	<1.4	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	<75 ppm	<75 ppm	n/a	<1.3	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	76.7 ppm	286 ppm	n/a	67.7	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<180 ppm	<180 ppm	n/a	12.4	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	16300 ppm	n/a	3.66	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	2190.00	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	<10	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	19.5	n/a	n/a	n/a	n/a	n/a	19.8	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	33.2	n/a	n/a	n/a	n/a	n/a	32.1	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	see below	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.05	n/a
Kinematic Viscosity@25°C	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	1.90	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	3.6	n/a	n/a	n/a	2.21*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	1.2	n/a	n/a	n/a	0*	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	2.3	n/a	n/a	n/a	1.27*	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	1.0	n/a	n/a	n/a	0*	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	13.77	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	corrosive*
COLUMN-RELATED COMMENTS	*Units of entries unless otherwise noted	Analyst Names DB = Don Blankenship SB = Sarah Brown BB = Beverly Burch SB = Syderis Burkett JC = Joyce Cartledge BC = B.S. Carter EH = Erick Hansen FP = Frank Pennebaker		Note: Not all the results for these three three dissolution methods can be used because of the way they are done. For instance, 1&2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Preferred values are shaded like the one shown here. >>			*supernate viscosity came from the TNX sample **IC Anions were measured in sample	*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns.		*The volume distribution had three peaks micons(%total) 2.00 (43%) 5.60 (14%) 18.28 (43%)	Corrositex test indicated a sample Category 1 and a Package Group II for shipping
COLUMN-RELATED COMMENTS	*Units of entries unless otherwise noted	Analyst Names DB = Don Blankenship SB = Sarah Brown BB = Beverly Burch SB = Syderis Burkett JC = Joyce Cartledge BC = B.S. Carter EH = Erick Hansen FP = Frank Pennebaker RR = Robert Ray TNX = A laboratory at SRS ADS = Analytical Development Section at SRS	*density of supernate as measured by NTX = pending	Note: Not all the results for these three three dissolution methods can be used because of the way they are done. For instance, 1&2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Preferred values are shaded like the one shown here. >>			*supernate viscosity came from the TNX sample **IC Anions were measured in sample 300170804 by instead of ISE because that test was discontinued.	*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns.		*The volume distribution had three peaks micons(%total) 2.00 (43%) 5.60 (14%) 18.28 (43%)	Corrositex test indicated a sample Category 1 and a Package Group II for shipping

OTHER COMMENTS

Analysis Nomenclature

1 = Dissolution - Sodium Peroxide / uptake with Water	4 = CL - Ion Selective Emission	7 = K by AA	10 = Total Solids	13 = Specific Gravity
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric	5 = F - Ion Selective Emission	8 = TICTOC	11 = Suspended Solids	14 = pH
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL	6 = ICP-ES	9 = IC-Anions	12 = Microtrac - particle size	

Table A6. RPP-WTP Hanford Waste Simulant: Washed HLW (AZ-101)

Most Recent Entry Date: 16-July-2001		Slurry --------------->>	HLWwashed	HLWwashed	HLWwashed	HLWwashed	HLWwashed	HLWwashed	HLWwashed	HLWwashed	HLWwashed
RPP Sample ID (Prefix = RPP-FILT139-HLWwashed_) --------->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300161853	300161854	300161855	300161856	300161857	300161858	300161859	200148456
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	supernatant	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	250	15	15	15	15	15	10	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology*	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.174*&**	n/a	n/a	1.16	<<< n/a	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	<120 ppm	<120 ppm	n/a	<0.3	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	16300 ppm	16200 ppm	n/a	<0.24	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	185 ppm	170 ppm	n/a	<0.21	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	<5.0 ppm	<5.0 ppm	n/a	<0.012	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	940 ppm	255 ppm	n/a	0.92	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<0.5	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<10 ppm	<10 ppm	n/a	<0.014	n/a	n/a	n/a
Cl (Chloride) [less accurate]	ug/mL	(ADS)JC	n/a	<2	n/a	n/a	n/a	3	n/a	n/a	n/a
Cl Sample	ug/mL	(ADS)BC	n/a	<5	n/a	n/a	40.2	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	<0.044	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	65 ppm	<20 ppm	n/a	0.12	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<20 ppm	<20 ppm	n/a	<0.05	n/a	n/a	n/a
F (Fluoride) [less accurate]	ug/mL	(ADS)JC	n/a	<2	n/a	n/a	n/a	0.5	n/a	n/a	n/a
F Sample (more accurate resul	ug/mL	(ADS)BC	n/a	<5	n/a	n/a	2.29	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	56400 ppm	60500 ppm	n/a	7.28	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<10	n/a	n/a	n/a	0.7	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	1057 ppm	351 ppm	n/a	8.45	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	220.58	181.21	n/a	359.09	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<0.7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<40 ppm	<40 ppm	n/a	<0.1	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	371 ppm	301 ppm	n/a	<0.7	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	177 ppm	182 ppm	n/a	0.05	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<40 ppm	<40 ppm	n/a	<0.1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	1720 ppm	n/a	270	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	<2.6	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	1.07	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<10	n/a	n/a	n/a	9	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	6	n/a	n/a	n/a	464	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<10	n/a	n/a	n/a	<1	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	1.74	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<10	n/a	n/a	n/a	<1	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<0.69	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	9.53	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	5500 ppm	1120 ppm	n/a	1.58	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<100 ppm	<100 ppm	n/a	<0.26	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	<5	n/a	n/a	n/a	28	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	<2.0 ppm	<2.0 ppm	n/a	0.01	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	123 ppm	71 ppm	n/a	<0.14	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	<52 ppm	<52 ppm	n/a	<0.13	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	4760 ppm	4330 ppm	n/a	252*	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<0.37	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	11600 ppm	n/a	0.11	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	35.90	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	12.40	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	18.5***	n/a	n/a	n/a	n/a	n/a	19.2	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	18.5***	n/a	n/a	n/a	n/a	n/a	19.2	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	see below	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.04	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	1.8*	n/a	n/a	n/a	1.1*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	0.0*	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	0.8*	n/a	n/a	n/a	0.6*	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	0.0*	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	7.52*	n/a	n/a	n/a	7.53	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	NC*
COLUMN-RELATED COMMENTS	*Units of entries unless otherwise noted	Analyst Names DB = D. Blankenship SB = Sarah Brown BB = Beverly Burch SB = Syderis Burkett JC = Joyce Cartledge BC = B.S. Carter EH = Erick Hansen FP = F. Pennebaker RR = Robert Ray TNX = A lab at SRS ADS = Analytical Development Sect. at SRS	*This sample was remade because of being lost, but used the same recipe. **TNX liquid density=1.003 ***1st sample results, the new sample results are TS=21.0 wt% SS=21.0 wt%	Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc cru-cible so only method 3 gives a usable value for Zr. Usable values are shaded like the one shown here>			*supernate viscosity came from the TNX sample	* this reading may be 5-10% high because of contami-nation from a previous reading. Also filtered sample may have had solids <5 microns that contributed to reading.		*The volume distribution had two peaks micons (% total) 1.65 (28%) 11.74 (72%)	*NC = Non Corrosive Sample Category 1 Package Group NC
OTHER COMMENTS											

Analysis Nomenclature

1 = Dissolution - Sodium Peroxide / uptake with Water
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL
4 = CL - Ion Selective Emission
5 = F - Ion Selective Emission
6 = ICP-ES
7 = K by AA
8 = TICTOC
9 = IC-Anions
10 = Total Solids
11 = Suspended Solids
12 = Microtrac - particle size
13 = Specific Gravity
14 = pH

Table A7. RPP-WTP Hanford Waste Simulant: Leached then washed HLW (AZ-101)

(washed@25°C, leached@85°C, then washed twice@85°C)

Most Recent Entry Date: 16-July-2001		Slurry --------------->>	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w	HLWleach/w
RPP Sample ID (Prefix = RPP-FILT139-HLWleached/washed)->>			Prefix+1	Prefix+2	Prefix+3	Prefix+4	Prefix+5	Prefix+6	Prefix+7	Prefix+8	Prefix+9
		ADS Sample ID -->>	None-TNX	300162946	300162947	300162948	300162949	300162950	300162951	300162952	200155268
		Type Sample ----->>	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%	supernatant	supernatant	slurry-20 wt%	slurry-20 wt%	slurry-20 wt%
		Sample Size (mL) >>	167	15	15	15	15	15	10	15	15
Measurement Made (NUMBERS ARE EXPLAINED BELOW) >>			Rheology	1,4,5,9	2,6,7	3,6,7	4,5,8,13,14	6,7,9	10, 11	MICROTRAC	Corrosivity
Item Measured	Units*	(Lab)Analyst									
Density	g/mL	(ADS)BB&TNX(EH)	1.178	n/a	n/a	n/a	1.004	n/a	n/a	n/a	n/a
Ag	ug/mL	(ADS)FP	n/a	n/a	<150 ppm	<150 ppm	n/a	<3	n/a	n/a	n/a
Al	ug/mL	(ADS)FP	n/a	n/a	11900 ppm	10000 ppm	n/a	518	n/a	n/a	n/a
B	ug/mL	(ADS)FP	n/a	n/a	249 ppm	236 ppm	n/a	<2.1	n/a	n/a	n/a
Ba	ug/mL	(ADS)FP	n/a	n/a	42 ppm	<20 ppm	n/a	<0.12	n/a	n/a	n/a
Ca	ug/mL	(ADS)FP	n/a	n/a	1070 ppm	333 ppm	n/a	<0.4	n/a	n/a	n/a
Ce	ug/mL	(ADS)FP	n/a	n/a	<600 ppm	<600 ppm	n/a	<7.7	n/a	n/a	n/a
Cd	ug/mL	(ADS)FP	n/a	n/a	<10 ppm	<10 ppm	n/a	<0.14	n/a	n/a	n/a
Cl (Chloride) [less accurate]	ug/mL	(ADS)JC	n/a	18	n/a	n/a	n/a	<0.2	n/a	n/a	n/a
Cl Sample	ug/mL	(ADS)BC	n/a	<0.02	n/a	n/a	24.2	n/a	n/a	n/a	n/a
Co	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.44	n/a	n/a	n/a
Cr	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.6	n/a	n/a	n/a
Cu	ug/mL	(ADS)FP	n/a	n/a	<25 ppm	<25 ppm	n/a	<0.5	n/a	n/a	n/a
F (Fluoride) [less accurate]	ug/mL	(ADS)JC	n/a	<0.02	n/a	n/a	n/a	<0.2	n/a	n/a	n/a
F Sample (more accurate resul	ug/mL	(ADS)BC	n/a	<0.02	n/a	n/a	10.82	n/a	n/a	n/a	n/a
Fe	ug/mL	(ADS)FP	n/a	n/a	67300 ppm	68100 ppm	n/a	<0.44	n/a	n/a	n/a
HCOO (Formate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<1	n/a	n/a	n/a
K	ug/mL	(ADS)FP	n/a	n/a	<250 ppm	<250ppm	n/a	13	n/a	n/a	n/a
K (AA)	ug/mL	(ADS)SB	n/a	n/a	0.017 wt%	0.0155 wt%	n/a	278.0025	n/a	n/a	n/a
La	ug/mL	(ADS)FP	n/a	n/a	<350 ppm	<350 ppm	n/a	<7	n/a	n/a	n/a
Li	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Mg	ug/mL	(ADS)FP	n/a	n/a	477 ppm	420 ppm	n/a	<0.84	n/a	n/a	n/a
Mn	ug/mL	(ADS)FP	n/a	n/a	239 ppm	246 ppm	n/a	<0.09	n/a	n/a	n/a
Mo	ug/mL	(ADS)FP	n/a	n/a	<50 ppm	<50 ppm	n/a	<1	n/a	n/a	n/a
Na	ug/mL	(ADS)FP	n/a	n/a	n/a	3840 ppm	n/a	2750	n/a	n/a	n/a
Nd	ug/mL	(ADS)FP	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ni	ug/mL	(ADS)FP	n/a	n/a	<30 ppm	<30 ppm	n/a	<0.62	n/a	n/a	n/a
NO2 (Nitrite)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<1	n/a	n/a	n/a
NO3 (Nitrate)	ug/mL	(ADS)RR&JC	n/a	2	n/a	n/a	n/a	25	n/a	n/a	n/a
C2O4 (Oxalate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	<1	n/a	n/a	n/a
P	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<6.8	n/a	n/a	n/a
PO4 (Phosphate)	ug/mL	(ADS)RR&JC	n/a	<1	n/a	n/a	n/a	1	n/a	n/a	n/a
Pb	ug/mL	(ADS)FP	n/a	n/a	<400 ppm	<400 ppm	n/a	<6.9	n/a	n/a	n/a
S	ug/mL	(ADS)FP	n/a	n/a	<250 ppm	<250 ppm	n/a	<5	n/a	n/a	n/a
Si	ug/mL	(ADS)FP	n/a	n/a	7820 ppm	1450 ppm	n/a	<1.3	n/a	n/a	n/a
Sn	ug/mL	(ADS)FP	n/a	n/a	<300 ppm	<300 ppm	n/a	<2.6	n/a	n/a	n/a
SO4 (Sulfate)	ug/mL	(ADS)RR&JC	n/a	<0.5	n/a	n/a	n/a	3	n/a	n/a	n/a
Sr	ug/mL	(ADS)FP	n/a	n/a	272 ppm	258 ppm	n/a	<0.5	n/a	n/a	n/a
Ti	ug/mL	(ADS)FP	n/a	n/a	<70 ppm	<70 ppm	n/a	<1.4	n/a	n/a	n/a
V	ug/mL	(ADS)FP	n/a	n/a	470 ppm	473 ppm	n/a	<1.3	n/a	n/a	n/a
W	ug/mL	(ADS)FP	n/a	n/a	716 ppm*	1048 ppm*	n/a	651*	n/a	n/a	n/a
Zn	ug/mL	(ADS)FP	n/a	n/a	<200 ppm	<200 ppm	n/a	<3.7	n/a	n/a	n/a
Zr	ug/mL	(ADS)FP	n/a	n/a	n/a	13200 ppm	n/a	<0.48	n/a	n/a	n/a
Total Organic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	538.00	n/a	n/a	n/a	n/a
Total Inorganic Carbon	ug/mL	(ADS)BC	n/a	n/a	n/a	n/a	<100	n/a	n/a	n/a	n/a
Suspended Solids	wt%	(ADS)BB&TNX	20.4	n/a	n/a	n/a	n/a	n/a	16.0 [see (1)]	n/a	n/a
Total Solids	wt%	(ADS)BB & TNX	20.9	n/a	n/a	n/a	n/a	n/a	16.0 [see (1)]	n/a	n/a
Mean Particle Size by Volume	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	see below	n/a
Mean Particle Size by Number	micron	(ADS)DB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1.01	n/a
Kinematic Viscosity	centistoke	(TNX)EH	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@25°C	cP	(TNX)EH	1.6	n/a	n/a	n/a	1.0*	n/a	n/a	n/a	n/a
Yield Stress@25°C	Pa	(TNX)EH	0.0	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
Dyn Visc / Consistency@50°C	cP	(TNX)EH	0.8	n/a	n/a	n/a	0.6*	n/a	n/a	n/a	n/a
Yield Stress@50°C	Pa	(TNX)EH	0.0	n/a	n/a	n/a	0.0*	n/a	n/a	n/a	n/a
pH	none	(ADS)BB&(TNX)EH	12.36	n/a	n/a	n/a	12.39	n/a	n/a	n/a	n/a
Corrosivity	none	(F-Area)SB	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	NC*

COLUMN-RELATED COMMENTS

*Units of entries unless otherwise noted

Analyst Names
DB = Don Blankenship
SB = Sarah Brown
BB = Beverly Burch
SB = Syderis Burkett
JC = Joyce Cartledge
BC = B.S. Carter
EH = Erick Hansen
FP = Frank Pennebaker
RR = Robert Ray
TNX = A laboratory at SRS
ADS = Analytical Development Section at SRS

*density of supernate as measured by TNX = 1.007

Note: Not all the results for these three dissolutions methods can be used because of the way they are done. For instance, 1 & 2 are done in a zinc crucible so only method 3 gives a usable value for Zr. Usable values are shaded like the one shown here>

* these two samples may* be 10-15% high because of being contaminated from previous W readings

*supernate viscosity came from the TNX sample

*The test for Tungsten can measure solids that were in the supernatant. Filtering may leave solids <5 microns in solution which is the majority of the particle sizes.

*The volume distribution had three peaks micons (% total)
1.59 (31%)
5.05 (24%)
16.72 (45%)

*NC = Non Corrosive Sample Category 2 Package Group NC

OTHER COMMENTS

Analysis Nomenclature
1 = Dissolution - Sodium Peroxide / uptake with Water
2 = Dissolution - Sodium Peroxide / uptake with Hydrochloric
3 = Dissolution with Aquaregent - 25% Nitric Acid and 75% HCL
4 = CL - Ion Selective Emission
5 = F - Ion Selective Emission
6 = ICP-ES
7 = K by AA
8 = TICTOC
9 = IC-Anions
10 = Total Solids
11 = Suspended Solids
12 = Microtrac - particle size
13 = Specific Gravity
14 = pH

(1) This solids measurement was done twice. It is assumed that the method of drawing the sample caused the lower solids value than the TNX values of 20 wt%. The sample method was to shake the container vigorously than pour into a 15 ml bottle. The measurement was done a third and fourth time by the shake method and by drawing a sample with a Caliwasa from a well mixed slurry. However, this time both measurements 27.2 wt% and 27.8 wt%, respectively. Since both methods gave the same results it can only be assumed that when the samples were originally taken, which gave the 16 wt% result, care was not taken to make sure it was well mixed while pouring into the sample containers. However, the dilemma is that all of the slurry samples, which were sent to White Rock Engineering forthe erosion tests to obtain SAR numbers, were done at the same time the 16 wt% samples were taken. This means the slurry samples could of have a solids loading from between 16 wt% and 20 wt%. For reporting purposes an insoluble solids concentration of 18 wt% will be used.

APPENDIX B

White Rock Engineering Services Slurry Abrasivity Number Report

The following appendix of thirty-one pages is the WRES SAR Number report in its entirety as it was received by WSRC on 1/11/2002. It does not include information on how the data were obtained; that is done at the beginning of this report. Besides the data for the seven slurries tested, it includes a before and after standard sand test to indicate that the test apparatus was working within ASTM standards. In fact, the initial standard test was observed by a WSRC QA inspector to verify that the procedure used followed the appropriate ASTM standard. WRES did meet at least the minimum qualifications to produced qualified data.

The report format is as follows:

- Vendor pages 1 to 4 give an overall summary of the data within.
- Vendor pages 5 to 9 give the results of standard sand tests to show that the test device could reproduce published sand abrasivity numbers and meet the standard ASTM G75-2001.
- Vendor pages 10 to 31 give the results of all the SAR tests. First, micro-photographs are given of the slurry solids and four metal specimens: two 304L and two 316L stainless steel. These are followed by one page which averages the two 304L test results and by one page which averages the two 316L test results. The exception is vendor page 23 (test S-1033) which shows the original two 316L tests. Those tests were discarded and repeated (test S-1033R) because the result of the second test of S-1033 was inconsistent with the first test due to solids clumping – according to the vendor. However, the two 316L tests shown in test S-1033R gave the same results as the first of the two tests in test S-1033, which confirms that the second test was a bad datum point.

Miller Number and SAR Number Determination by ASTM G75-2001

For

Westinghouse Savannah River – AB80166N

Westinghouse Savanna River submitted seven (7) Slurry Samples and two (2) Wear Specimen Materials (304L and 316L) to conduct the ASTM G75-2001 Slurry Abrasion Response Test (SAR Number). Slurry Batches and Wear Specimens were identified by a Westinghouse Test Number. The 304L and 316L Wear Specimens were received with a slight amount of surface corrosion. The corrosion was removed by sanding with 120 grit sand paper and finished with 320 grit sand paper. Slurry as received at a 20% by mass solids concentration was used. Tests were conducted at either 25 or 85 degrees Celsius within a ± 5 degrees Celsius temperature range. As part of the test program a Standard AFS 50-70 Test Sand Miller Number was conducted at the beginning and end of the SAR Test Sequence as a control of the test procedure. To comply with a Westinghouse Savannah River Company Quality Assurance requirement, the initial Standard Test was done under the observation of a Quality Assurance Inspector, John J. Connelly, during an onsite (Dallas, Texas) visit on January 4-6, 2001. The QA inspector found (WSRC Document No. 2001-SUR-11-0009, Nov. 2001) the actual test procedure used faithfully followed the American Society for Testing & Materials Procedure G75-2001. A **Calcium Hydroxide** corrosion inhibited slurry test was also performed as part of the standard Miller Number Test Procedure.

	Test	Specimen	Slurry	Temp	pH		SAR/Miller Number	
				°C	Low	High	Abrasivity	Attrition %
	M-1023	27% Chrome	AFS 50-70 Test Sand	25	6.7	7.5	129	-8
	M-1023I	27% Chrome	$Ca(OH)_2$ Inhibited	25	7.5	12.6	93	-11
1	S-1024	304L 1A & 1B	HLW	25	13.2	13.3	156	-9
1	S-1025	316L 1A & 1B	HLW	25	13.2	13.2	151	-15
2	S-1026	304L 2A & 2B	HLWwSBS	25	12.8	12.9	163	2
2	S-1027	316L 2A & 2B	HLWwSBS	25	12.8	12.9	221	6
3	S-1028	304L 3A & 3B	Sr/Tru	25	NA	NA	10	-14

	Test	Specimen	Slurry	Temp	pH		SAR/Miller Number	
				°C	Low	High	Abrasivity	Attrition %
3	S-1029	316L 3A & 3B	Sr/Tru	25	NA	NA	9	4
4	S-1030	304L 4A & 4B	HLW leached	85	11.7	11.8	103	-3
4	S-1031	316L 4A & 4B	HLW leached	85	11.7	11.8	99	-4
5	S-1032	304L 5A & 5B	HLWwSBS leached	25	12.4	12.6	206	-4
5	S-1033	316L 5A & 5B	HLWwSBS leached	25	12.4	12.6	384	-4
5	S-1033R	316L 5A & 5B	HLWwSBS leached	25	13.4	13.7	280	4
6	S-1041	304L 6A & 6B	HLW Washed	25	7.7	8.2	138	-11
6	S-1042	316L 6A & 6B	HLW Washed	25	7.5	8.2	92	-25
7	S-1043	304L 7A & 7B	HLW Wash/Leach	85	11.0	11.3	9	-5
7	S-1044	316L 7A & 7B	HLW Wash/Leach	85	11.0	11.3	13	-15
	M-1034	27% Chrome	AFS 50-70 Test Sand	25	8.5	8.9	117	-6
	M-1034I	27% Chrome	$Ca(OH)_2$ Inhibited	25	12.4	12.8	76	-3

Table 3 – Test Results Summary

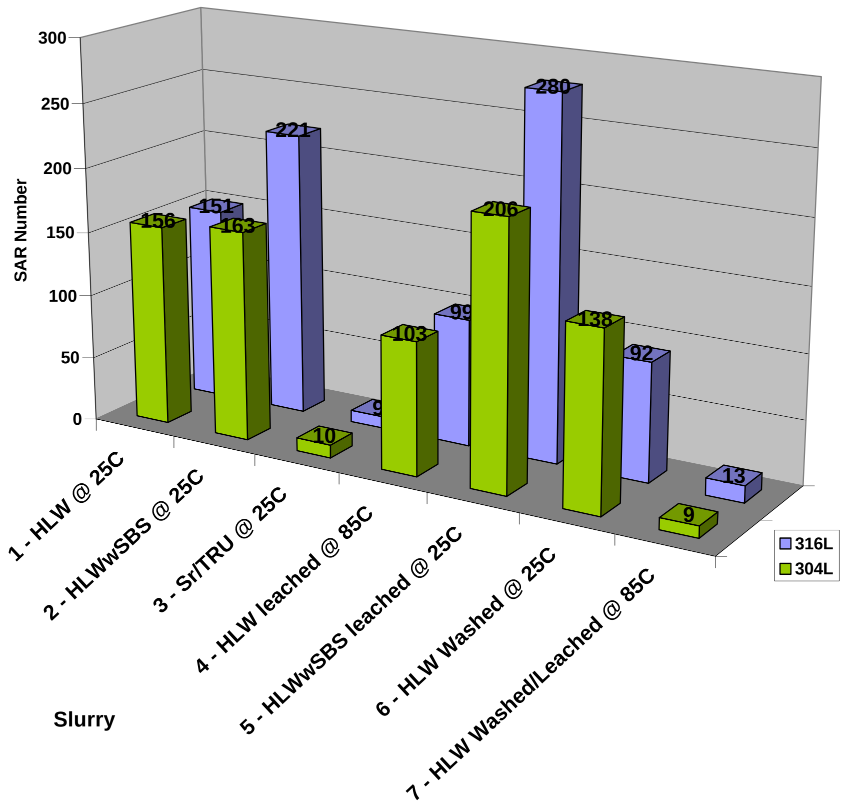


Figure 1 - Test Results Summary

The 304L Stainless Steel was nearly equal to or better from abrasivity (corrosion and erosion) resistance than 316L Stainless Steel in all cases except the HLW Washed material. Test results variability is generally in the range of ± 5% when Miller and SAR Numbers are above a value of 50. Variability of test results increases significantly as Miller and SAR Numbers fall below 15 because of low mass loss of the wear specimen and the magnitude of measurement error.

A significant range of SAR Numbers were obtained from the different slurries. The SAR Numbers ranged from 9 to 280. Most of the slurries tested had a **high** to **severe** abrasivity. Abrasivity ranking of the Miller Number and SAR Number result is considered **low** when the value is below 50, **moderate** between 50 and 100, **high** between 100 and 200, and **severe** when above 200. The ranking of test results between two wear specimens is questionable when test results fall below a Miller Number or SAR Number of 15 because of the small amount of mass loss from the wear specimens and potential for measurement error.

Many factors affect the degree of abrasivity. The factors are corrosion, solids concentration, solids particle size, shape, hardness, and agglomeration. The degree of corrosion and the synergistic effect of corrosion and erosion can not be separated from the erosion process in the G75 Test.

Initially single bottles of 20% by mass slurry were provided where White Rock Engineering Services mixed and transferred slurry to each of four troughs for the 304L and 316L tests. Some degree of mass loss variance was experienced between wear specimens of the same material during HLW Slurry Test S-1024. After experiencing the mixing and transfer problem, subsequent slurry samples were prepared by Westinghouse Savanna River with the required material for each trough in separate bottles. This worked well except we had one bottle of HLWwSBS Leached (Test S-1033) that appeared to have more solids on transfer to the testing trough that resulted in a high SAR Number and a variance of 60% between the two wear specimens. The test (S-1033R) was rerun with two fresh bottles of slurry with acceptable results.

Solid particle sizes in the slurries are smaller than 45um. These particles are very small relative to most mineral slurries and lower SAR Numbers than observed would be expected. Some of the slurries tended to agglomerate that could have caused the solids to act as larger solid particles. Photomicrographs 60X and 200X of solids contained in slurry were taken by applying a drop of water to a small dried sample and mechanically separating as best we could. The colloidal forces that resulted in agglomeration were stronger in some of the slurries than others. The purpose of photomicrographs of the solid particles was to indicate the particle size, shape, and type of material of the large particles that may be different from the majority of the particles in the slurry. Many times quartz is observed in mineral slurries. This very hard and sharp material can be the major cause of the erosion wear. Particle sizes are considerably smaller than normally experienced in mineral slurries being pumped. No conclusions can be made in regard to actual particles other than the potential to agglomerate.

The metal wear specimen photomicrographs 10X and 60X are also presented. Wear specimens are positioned with the direction of motion in the horizontal plane. The 10X photomicrograph shows the full ½" width of the wear specimen and approximately ¾" of the 1" length. The 60X photomicrographs were taken of areas where there was in some cases unusual wear. The actual wear specimens were returned with the printed reports.

J. Davis Miller, P. E.

Standard Miller Number Sand Slurry Test Results M-1023 & M-1034

The initial Miller Number test result was expected to have a Miller Number Range of from 139 to 154 based on Round Robin Test Data conducted in 1985 and documented in the ASTM G75 - Standard Test Method for Determination of Slurry Abrasivity (Miller Number) and Slurry Abrasion Response (SAR Number). The current Miller Number Results of 129 and 117 are based on different batches of AFS 50-70 Test, 27% Chrome Iron Wear Specimens, and Wear Laps. Miller Number System test results from data published[1] in 1993 show that this standard test had a mass loss range of from 21 to 38 mg during the first 4 hours of the test. The current 4 hour mass loss for the two 27% Chrome Iron Wear Blocks were 31.4 & 30.0 mg for M-1023 and 27.7 & 26.8 mg for M-1034 conducted at the end of the tests. Both Miller Number tests mass loss fell in the middle of the range experienced for 25 tests conducted between 1982 and 1989.

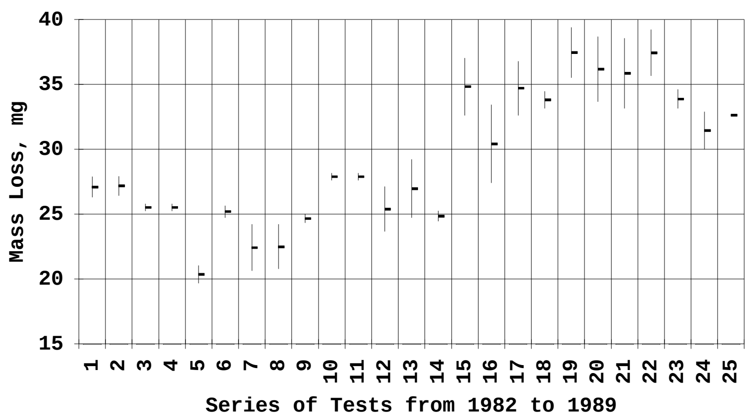
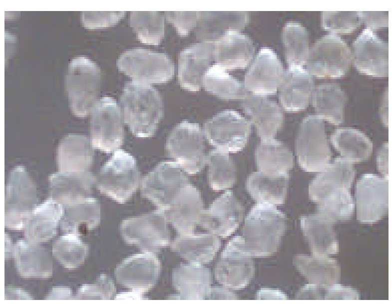


Table 4 - Standard AFS 50-70 Sand Test Results



60X

200X

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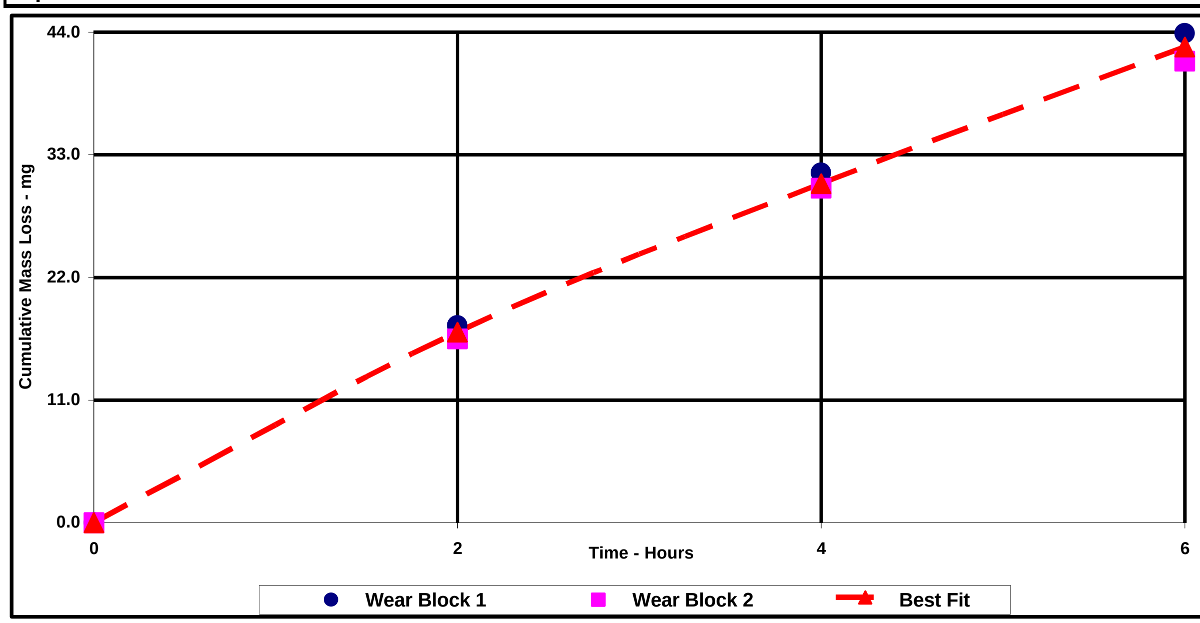
[1] Miller, J. E., and Miller, J. D., "**The Miller Number - A Review”**, <u>12th International Conference on Slurry Handling and Pipeline Transport, HYDROTRANSPORT 12</u>, Brugge, Belgium: 28-30 September 1993

ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test	
Number	: **M-1023**
Type	: **Miller Number**
Date	: **4-Jan-2001**
Project	
Description	: **Westinghouse Savannah River AB80166N**
Slurry	
Description	: **AFS 50-70 Test Sand 150g + 150ml Distilled Water**
Concentration	: **50% by Mass**
Temperature	: **25C +/-5C**
Wear Specimen	
Description	: **27% Chrome Iron**
Specific Gravity	: **7.58**
Hardness	: **60 Rc**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.02**

Wear Specimen	Wear Block 1			Wear Block 2			Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	7.5	20.5723	0.0	7.5	20.7098	0.0	0.0	0.0
After 2 Hours :	6.7	20.5546	17.7	6.7	20.6933	16.5	17.1	17.1
After 4 Hours :	7.0	20.5409	13.7	7.0	20.6798	13.5	30.7	30.4
After 6 Hours :	7.0	20.5284	12.5	7.0	20.6684	11.4	42.7	42.7
Total :			43.9			41.4		

Results			
***Best Fit Mass Loss**	:	**=**	**9.6051 * Hours^ 0.83212**
Miller Number	:	**129.34**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-8%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.02**	**mm**

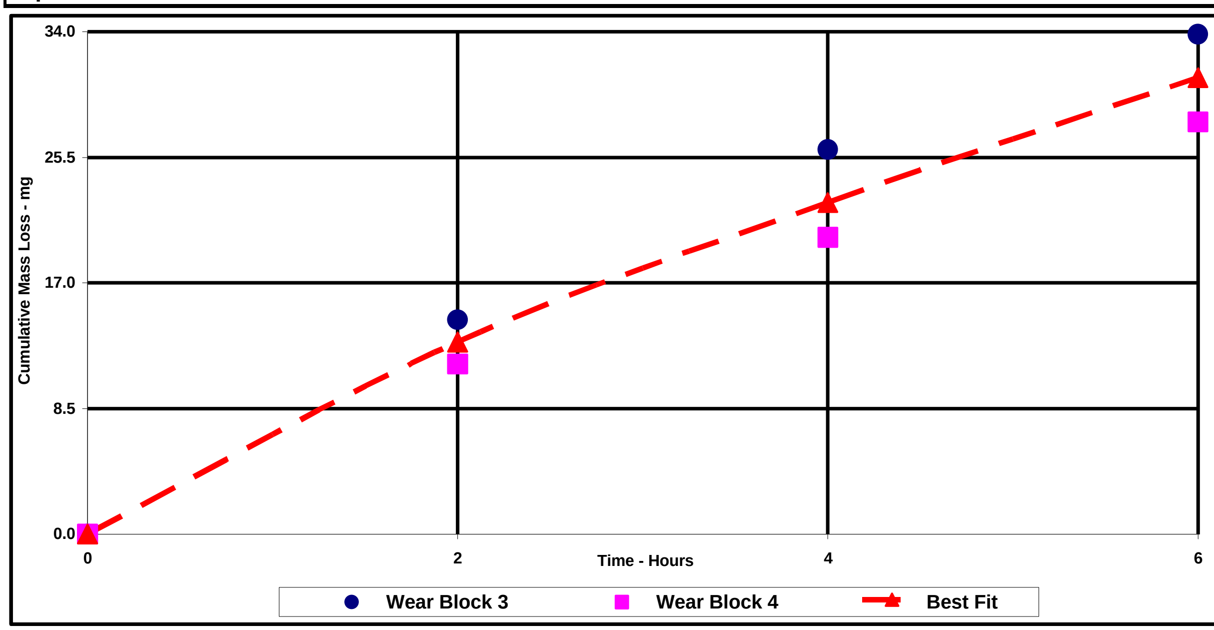


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test		
Number	:	**M-1023I**
Type	:	**Miller Number**
Date	:	**4-Jan-2001**
Project		
Description	:	**Westinghouse Savannah River AB80166N**
Slurry		
Description	:	**AFS 50-70 Test Sand 150g + 150 ml Distilled Water + Ca(OH)2 Inhibited**
Concentration	:	**50% by Mass**
Temperature	:	**25C +/-5C**
Wear Specimen		
Description	:	**27% Chrome Iron**
Specific Gravity	:	**7.58**
Hardness	:	**60 Rc**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.02**

Wear Specimen		Wear Block 3			Wear Block 4			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.5**	**20.0418**	0.0	**12.6**	**20.4448**	0.0	0.0	0.0
After 2 Hours	:	**7.5/12.5**	**20.0273**	14.5	**7.6/12.5**	**20.4333**	11.5	13.0	13.0
After 4 Hours	:	**10.2/12.5**	**20.0158**	11.5	**11.4/12.5**	**20.4247**	8.6	23.0	22.4
After 6 Hours	:	**11.3**	**20.0080**	7.8	**9.8**	**20.4169**	7.8	30.9	30.9
Total	:			33.8			27.9		

Results			
***Best Fit Mass Loss**	:	**=**	**7.5322 * Hours^ 0.78736**
Miller Number	:	**93.04**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-11%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.02**	**mm**

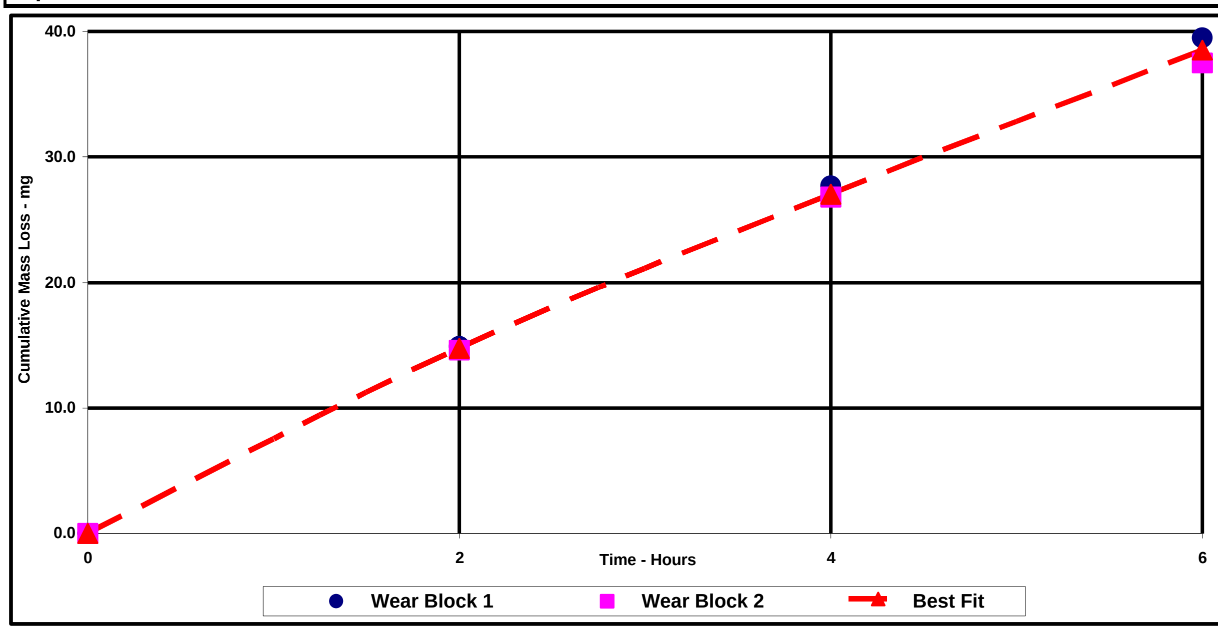


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test		
Number	:	**M-1034**
Type	:	**Miller Number**
Date	:	**2-Nov-2001**
Project		
Description	:	**Westinghouse Savannah River AB80166N**
Slurry		
Description	:	**AFS 50-70 Test Sand 150g + 150ml Distilled Water**
Concentration	:	**50% by Mass**
Temperature	:	**25C +/-5C**
Wear Specimen		
Description	:	**27% Chrome Iron**
Specific Gravity	:	**7.58**
Hardness	:	**60 Rc**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.02**

Wear Specimen		**Wear Block 1**			**Wear Block 2**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**8.9**	**17.7900**	0.0	**8.9**	**17.8700**	0.0	0.0	0.0
After 2 Hours	:	**8.5**	**17.7751**	14.9	**8.4**	**17.8554**	14.6	14.8	14.8
After 4 Hours	:	**8.7**	**17.7623**	12.8	**8.4**	**17.8432**	12.2	27.3	27.0
After 6 Hours	:	**8.7**	**17.7505**	11.8	**8.5**	**17.8325**	10.7	38.5	38.5
Total	:			39.5			37.5		

Results			
***Best Fit Mass Loss**	:	**=**	**8.0515 * Hours^ 0.87339**
Miller Number	:	**117.10**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-6%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.02**	**mm**

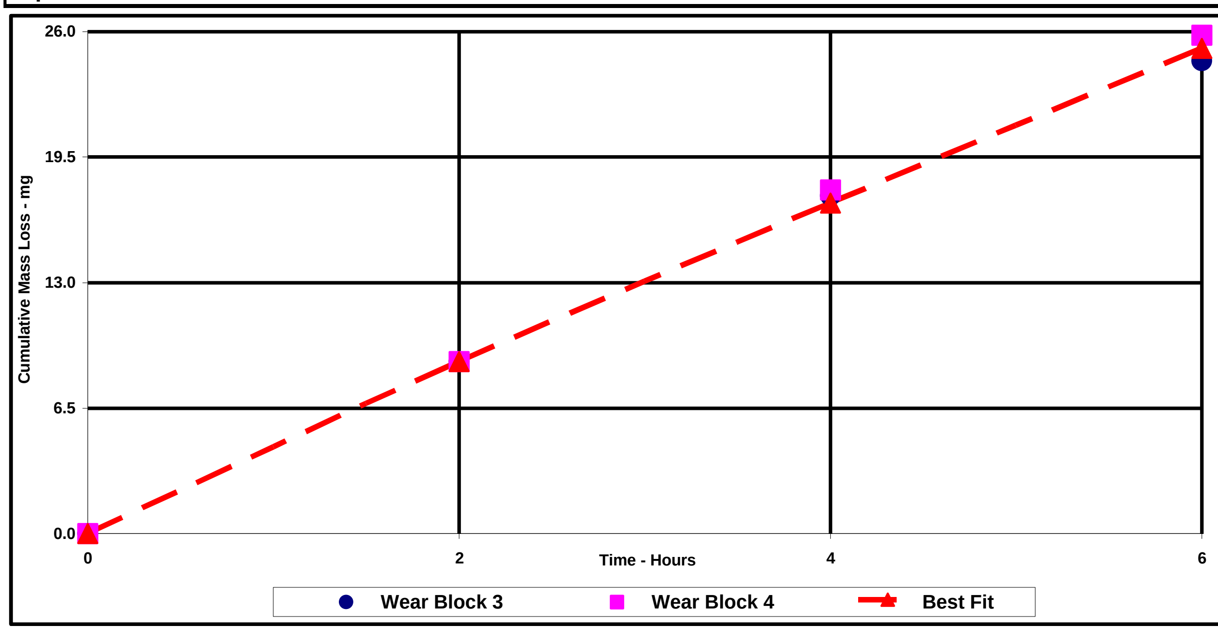


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

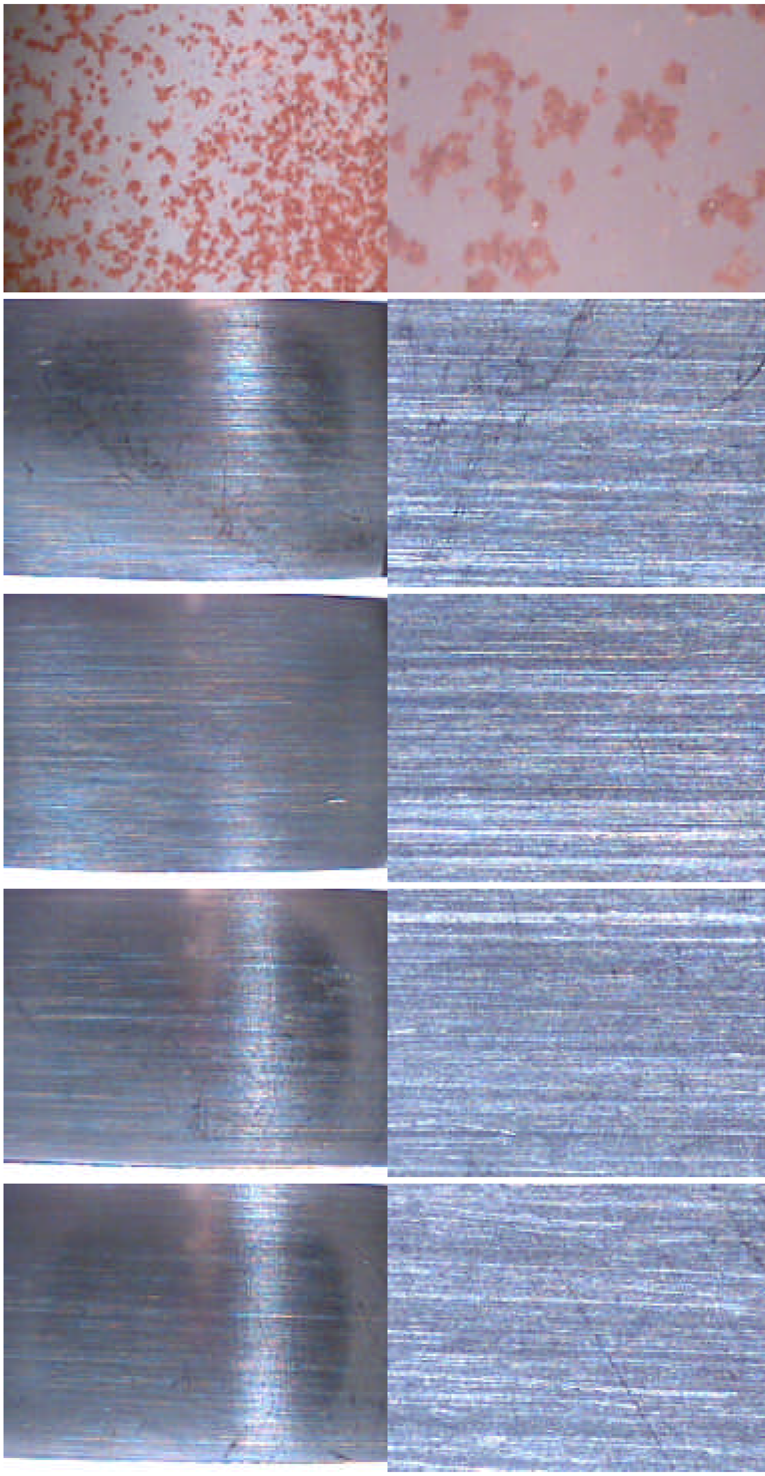
Test	
Number	: **M-1034I**
Type	: **Miller Number**
Date	: **2-Nov-2001**
Project	
Description	: **Westinghouse Savannah River AB80166N**
Slurry	
Description	: **AFS 50-70 Test Sand 150g + 150ml Distilled Water + Ca(OH)2 Inhibited**
Concentration	: **50% by Mass**
Temperature	: **25C +/-5C**
Wear Specimen	
Description	: **27% Chrome Iron**
Specific Gravity	: **7.58**
Hardness	: **60 Rc**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.02**

Wear Specimen		**Wear Block 3**			**Wear Block 4**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.8**	**18.2587**	0.0	**12.8**	**18.8054**	0.0	0.0	0.0
After 2 Hours	:	**12.8**	**18.2498**	8.9	**12.8**	**18.7965**	8.9	8.9	8.9
After 4 Hours	:	**12.8**	**18.2412**	8.6	**12.8**	**18.7876**	8.9	17.6	17.1
After 6 Hours	:	**12.7**	**18.2342**	7.0	**12.4**	**18.7796**	8.0	25.2	25.1
Total	:			24.5			25.8		

Results			
***Best Fit Mass Loss**	:	**=**	**4.6241 * Hours^ 0.94464**
Miller Number	:	**76.42**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-3%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.02**	**mm**



*1 – **HLW Slurry Tst Results S-1024(304L SS) and S-1025(316L SS)***



Solids 60X & 200X

304-A

304-B

316-A

316-B

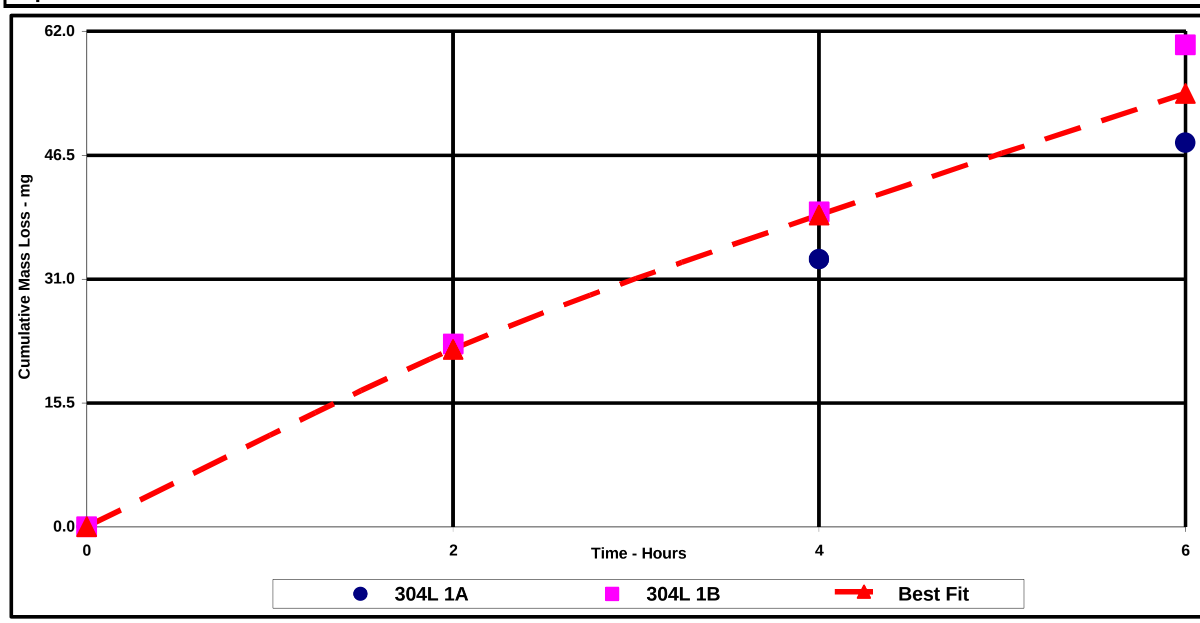
10X ***60X***

ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test	
Number	: **S-1024**
Type	: **SAR Number**
Date	: **21-Mar-2001**
Project	
Description	: **Westinghouse Savannah River - AB80166N**
Slurry	
Description	: **Test 1 - HLW - 230ml ~ 265 grams**
Concentration	: **20% by Mass (as received)**
Temperature	: **25C +/- 5**
Wear Specimen	
Description	: **304L Stainless Steel**
Specific Gravity	: **7.96**
Hardness	: **NA**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.01**

Wear Specimen		**304L 1A**			**304L 1B**		Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	**13.3**	**15.9065**	0.0	**13.3**	**15.9322**	0.0	0.0	0.0
After 2 Hours :	**13.2**	**15.8837**	22.8	**13.2**	**15.9093**	22.9	22.9	22.2
After 4 Hours :	**13.2**	**15.8730**	10.7	**13.2**	**15.8928**	16.5	36.5	39.0
After 6 Hours :	**13.2**	**15.8584**	14.6	**13.2**	**15.8719**	20.9	54.2	54.2
Total :			48.1			60.3		

Results			
***Best Fit Mass Loss**	:	**=**	**12.6330 * Hours^ 0.81282**
SAR Number	:	**156.13**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-9%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

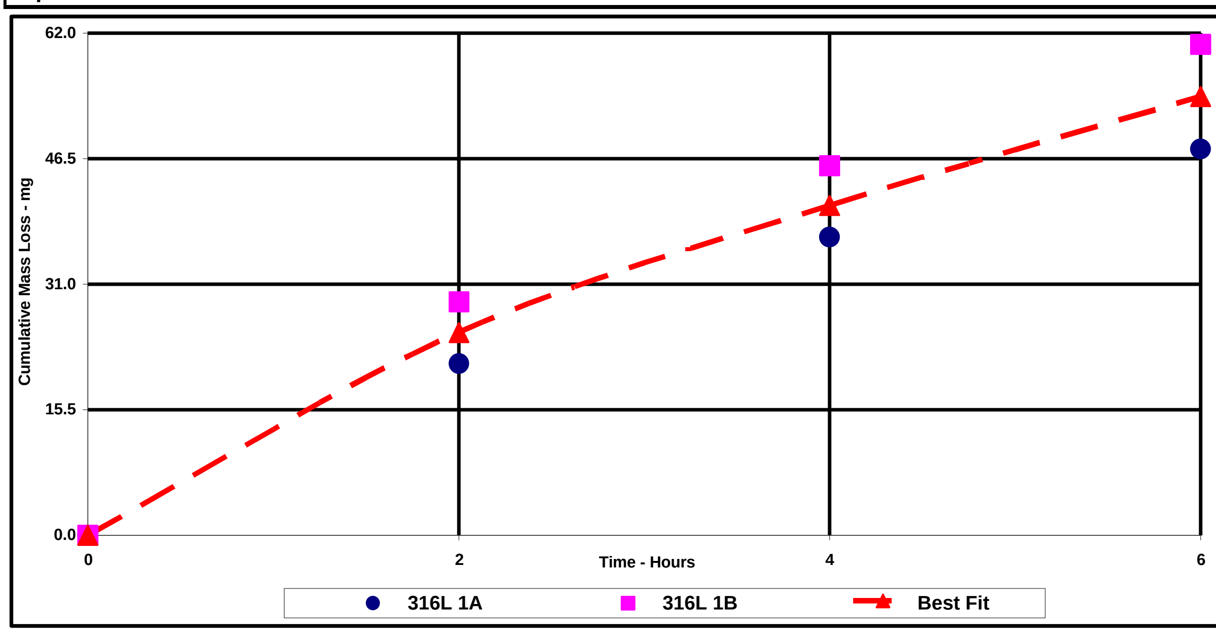


ASTM G75 Slurry Abrasivity Determination By Miller Number System

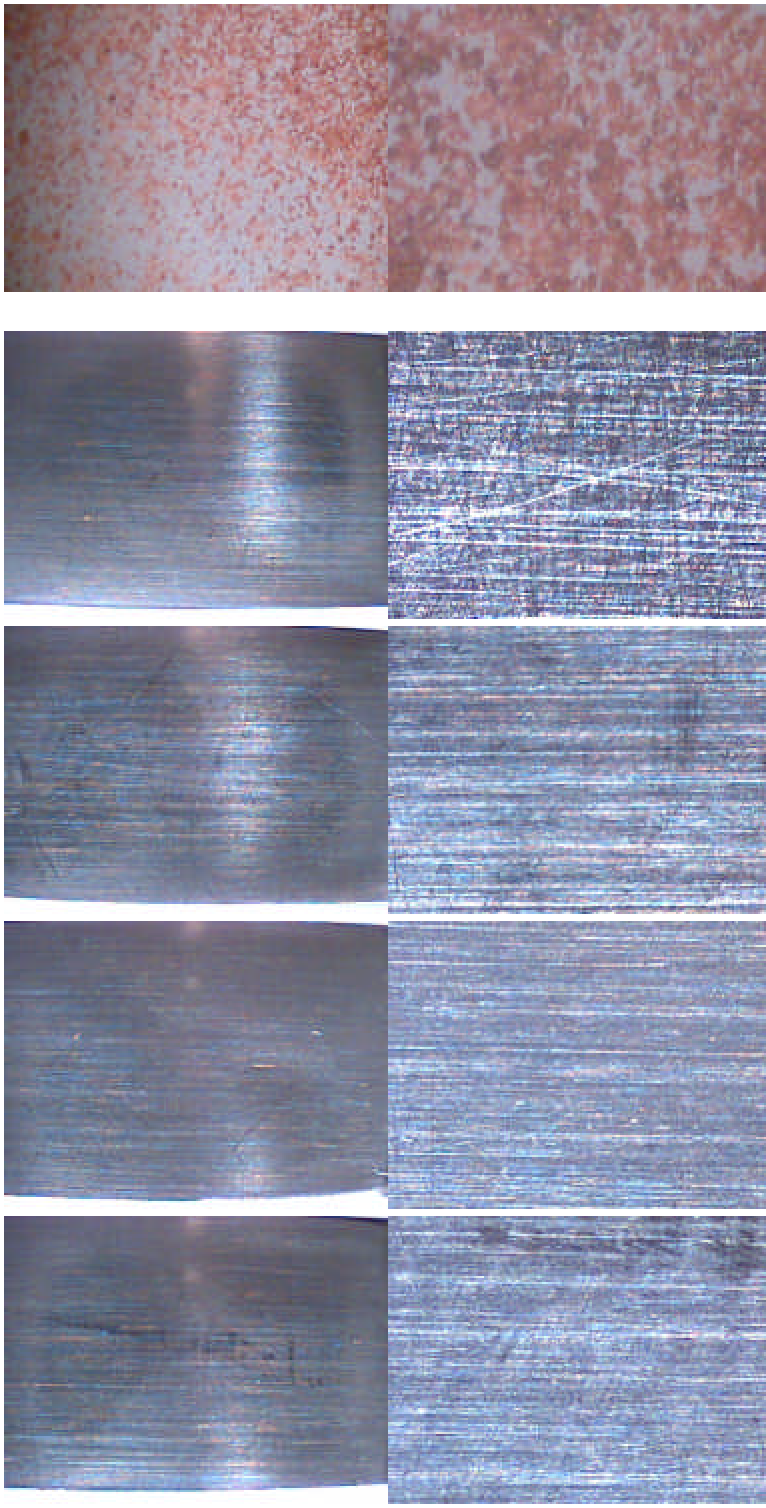
Test	
Number	: **S-1025**
Type	: **SAR Number**
Date	: **21-Mar-2001**
Project	
Description	: **Westinghouse Savannah River - AB80166N**
Slurry	
Description	: **Test 1 - HLW - 230ml ~ 265 grams**
Concentration	: **20% by Mass (as received)**
Temperature	: **25C +/- 5**
Wear Specimen	
Description	: **316L Stainless Steel**
Specific Gravity	: **8.00**
Hardness	: **NA**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.01**

Wear Specimen		**316L 1A**			**316L 1B**		Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	**13.2**	**15.8663**	0.0	**13.2**	**15.9125**	0.0	0.0	0.0
After 2 Hours :	**13.2**	**15.8451**	21.2	**13.2**	**15.8837**	28.8	25.0	25.0
After 4 Hours :	**13.2**	**15.8295**	15.6	**13.2**	**15.8669**	16.8	41.2	40.7
After 6 Hours :	**13.2**	**15.8186**	10.9	**13.2**	**15.8519**	15.0	54.1	54.1
Total :			47.7			60.6		

Results			
***Best Fit Mass Loss**	:	**=**	**15.3525 * Hours^ 0.70346**
SAR Number	:	**151.47**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-15%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



2 – HLWwSBS Slurry Test Results S-1026(304L SS) and S-1027(316L SS



Solids 60X & 200X

304-A

304-B

316-A

316-B

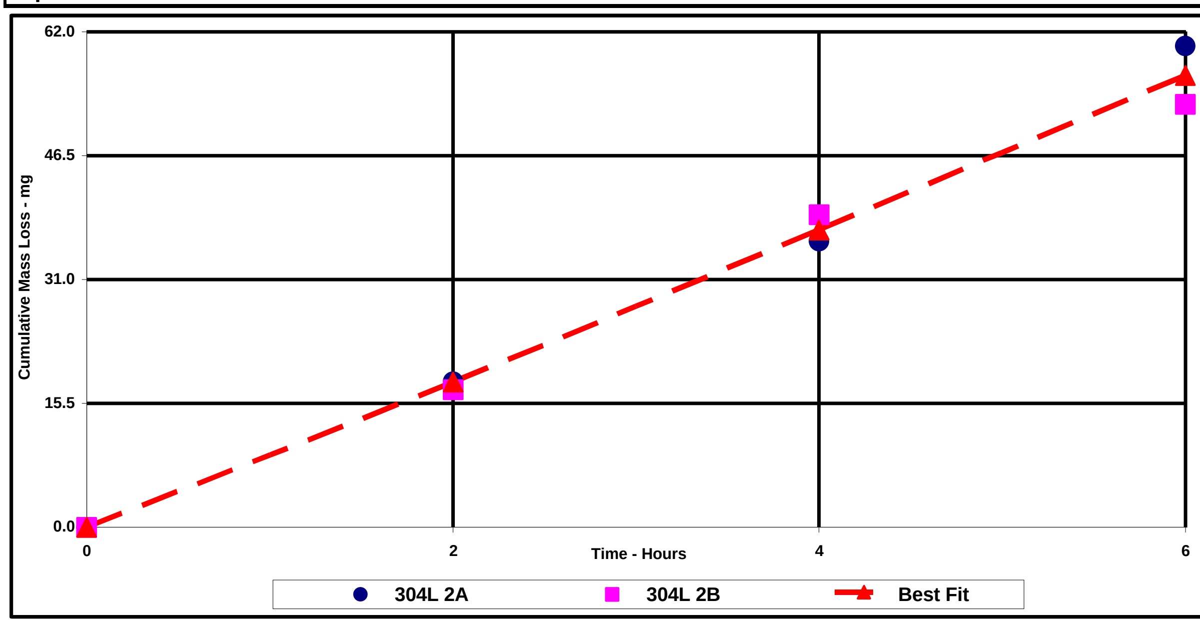
10X ***60X***

ASTM G75 Slurry Abrasivity Determination By Miller Number System

Test		
Number	:	**S-1026**
Type	:	**SAR Number**
Date	:	**6-Oct-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 2 - HLWwSBS - 281 & 288 grams as received**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**304L Stainless Steel**
Specific Gravity	:	**7.96**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen			**304L 2A**			**304L 2B**		Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.9**	**15.6446**	0.0	**12.9**	**15.7398**	0.0	0.0	0.0
After 2 Hours	:	**12.8**	**15.6264**	18.2	**12.8**	**15.7226**	17.2	17.7	18.2
After 4 Hours	:	**12.9**	**15.6088**	17.6	**12.9**	**15.7007**	21.9	37.5	37.2
After 6 Hours	:	**12.8**	**15.5844**	24.4	**12.8**	**15.6869**	13.8	56.6	56.5
Total	:			60.2			52.9		

Results			
***Best Fit Mass Loss**	:	**=**	**8.8624 * Hours^ 1.03435**
SAR Number	:	**162.52**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**2%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

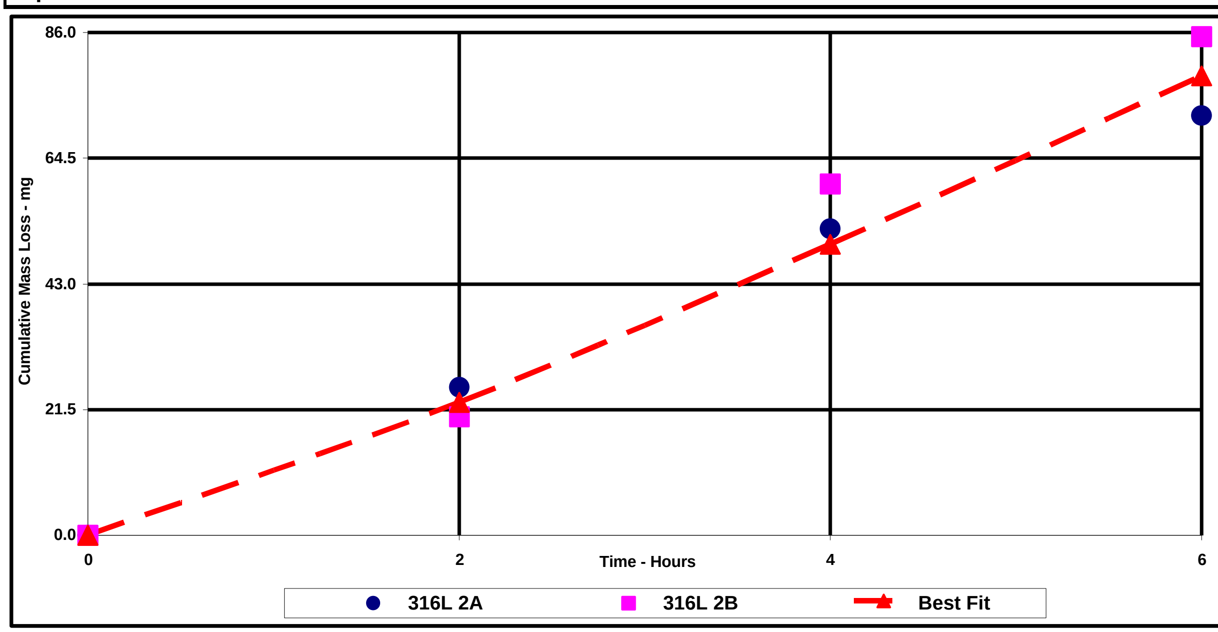


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

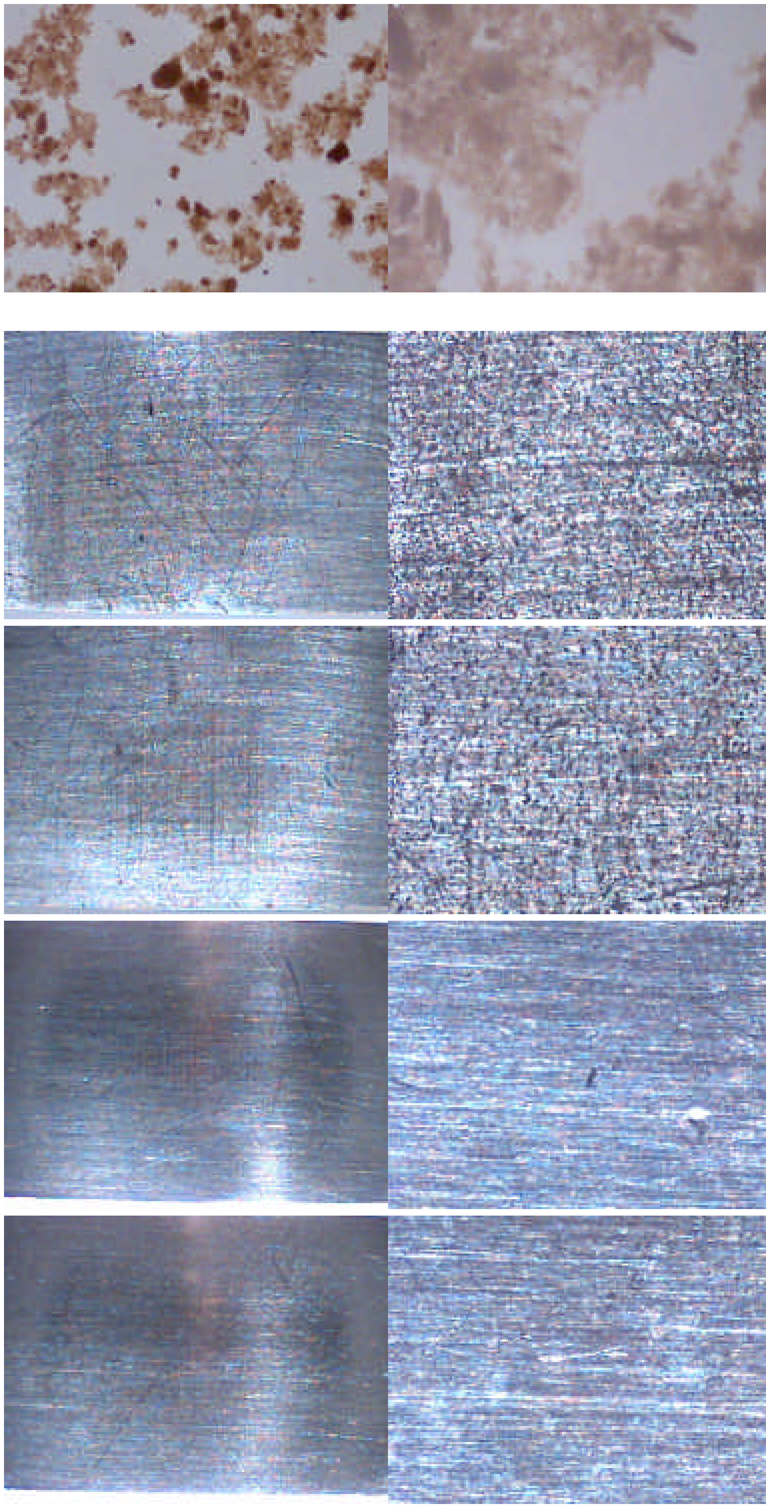
Test		
Number	:	**S-1027**
Type	:	**SAR Number**
Date	:	**6-Oct-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 2 - HLWwSBS - 280 & 301 grams as received**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**316L 2A**			**316L 2B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.9**	**15.7074**	0.0	**12.9**	**15.5065**	0.0	0.0	0.0
After 2 Hours	:	**12.8**	**15.6821**	25.3	**12.8**	**15.4863**	20.2	22.8	22.8
After 4 Hours	:	**12.9**	**15.6550**	27.1	**12.9**	**15.4464**	39.9	56.3	49.7
After 6 Hours	:	**12.8**	**15.6356**	19.4	**12.8**	**15.4212**	25.2	78.5	78.6
Total	:			71.8			85.3		

Results			
***Best Fit Mass Loss**	:	**=**	**10.4098 * Hours^ 1.12794**
SAR Number	:	**221.01**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**6%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



3 – Sr/Tru Slurry Test Results S-1028(304L SS) and S-1029(316L SS)



Solids 60X & 200X

304-A

304-B

316-A

316-B

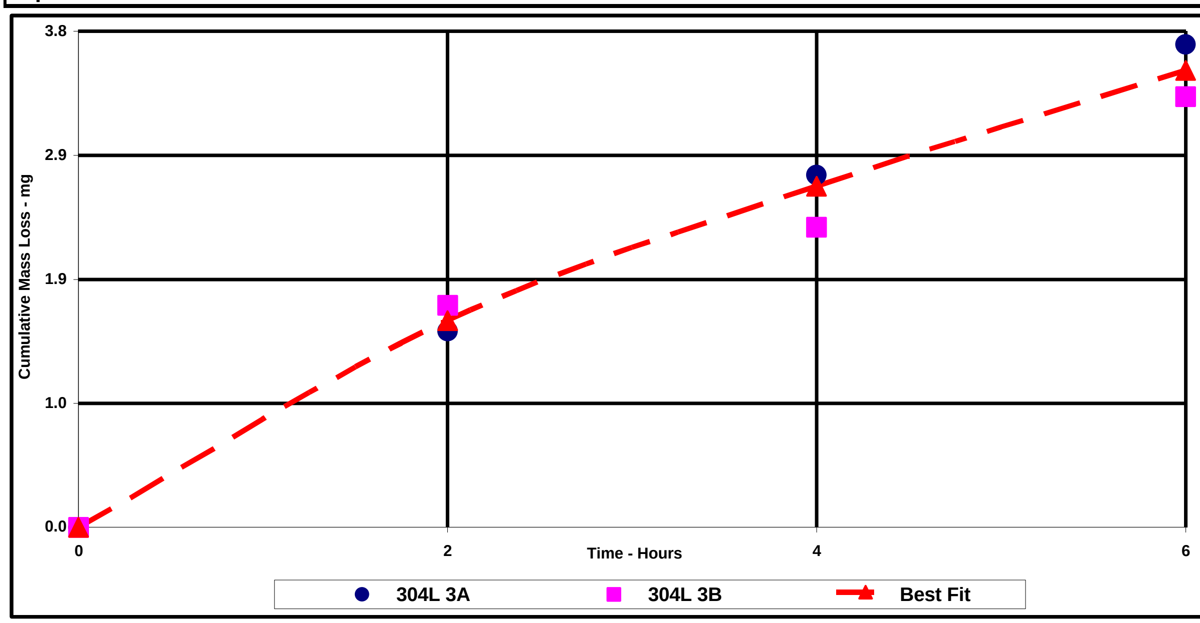
10X ***60X***

ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test		
Number	:	**S-1028**
Type	:	**SAR Number**
Date	:	**5-Jan-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 3 - Sr/TRU - 230ml ~ 265 grams**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**304L Stainless Steel**
Specific Gravity	:	**7.96**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**304L 3A**			**304L 3B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**NA**	**15.9650**	0.0	**NA**	**15.8995**	0.0	0.0	0.0
After 2 Hours	:	**NA**	**15.9635**	1.5	**NA**	**15.8978**	1.7	1.6	1.6
After 4 Hours	:	**NA**	**15.9623**	1.2	**NA**	**15.8972**	0.6	2.5	2.6
After 6 Hours	:	**NA**	**15.9613**	1.0	**NA**	**15.8962**	1.0	3.5	3.5
Total	:			3.7			3.3		

Results			
***Best Fit Mass Loss**	:	=	**0.9595 * Hours^ 0.72225**
SAR Number	:	**9.90**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-14%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

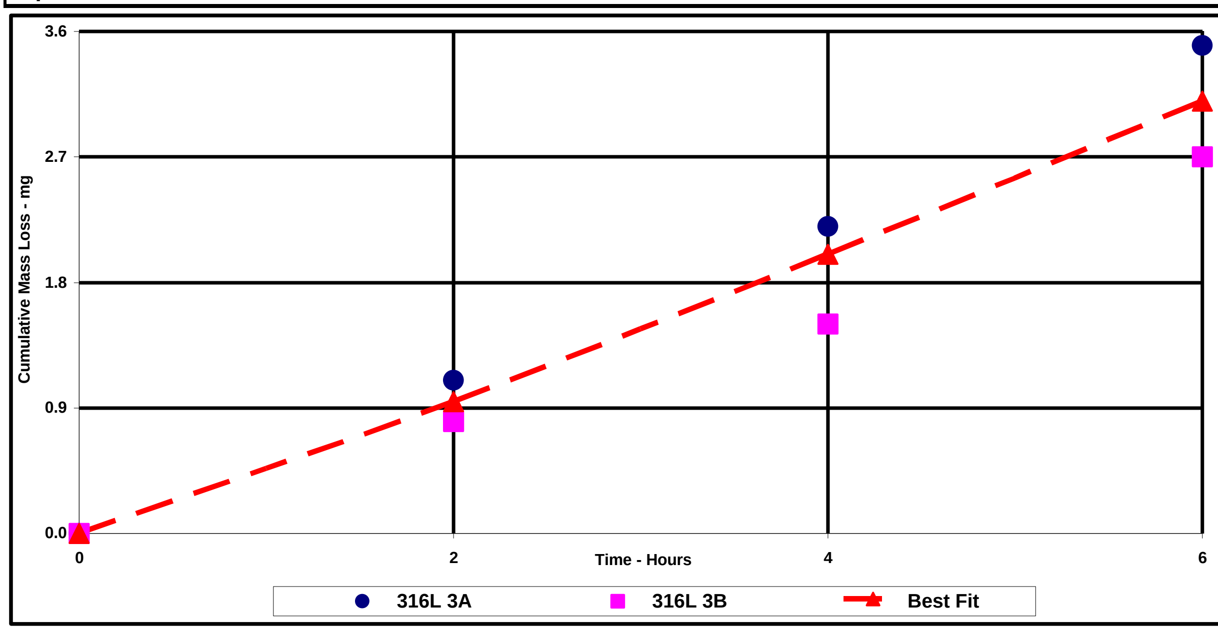


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

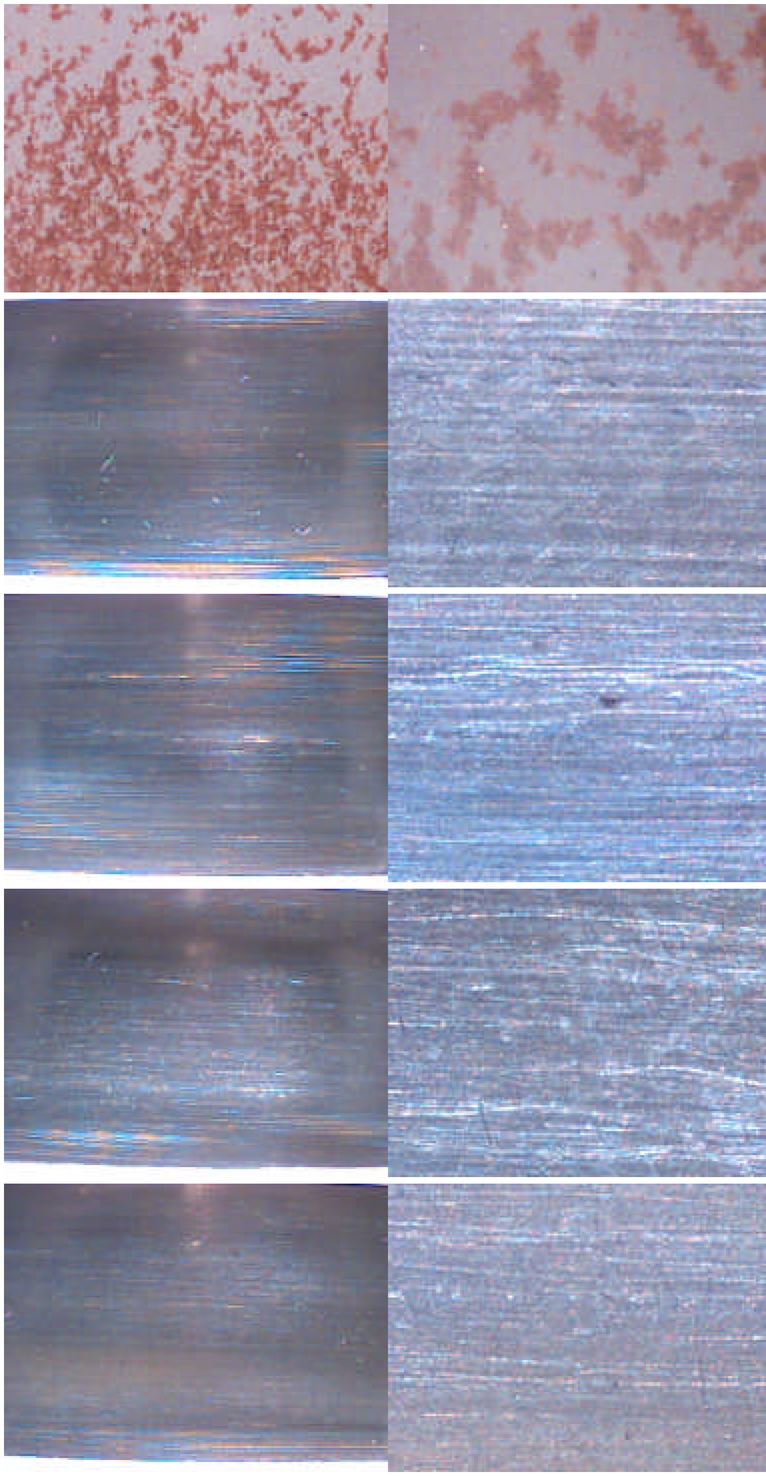
Test		
Number	:	**S-1029**
Type	:	**SAR Number**
Date	:	**5-Jan-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 3 - Sr/TRU - 230 ml ~ 265 grams as received**
Concentration	:	**20% by Mass 9as received)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**316L 3A**			**316L 3B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**NA**	**15.8613**	0.0	**NA**	**15.8795**	0.0	0.0	0.0
After 2 Hours	:	**NA**	**15.8602**	1.1	**NA**	**15.8787**	0.8	0.9	0.9
After 4 Hours	:	**NA**	**15.8591**	1.1	**NA**	**15.8780**	0.7	1.9	2.0
After 6 Hours	:	**NA**	**15.8578**	1.3	**NA**	**15.8768**	1.2	3.1	3.1
Total	:			3.5			2.7		

Results			
***Best Fit Mass Loss**	:	=	**0.4477 * Hours^ 1.08000**
SAR Number	:	**8.80**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**4%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



4 – HLW Leached Slurry Test Results S-1030(304L SS) and S-1031(316L SS)



Solids 60X & 200X

304-A

304-B

316-A

316-B

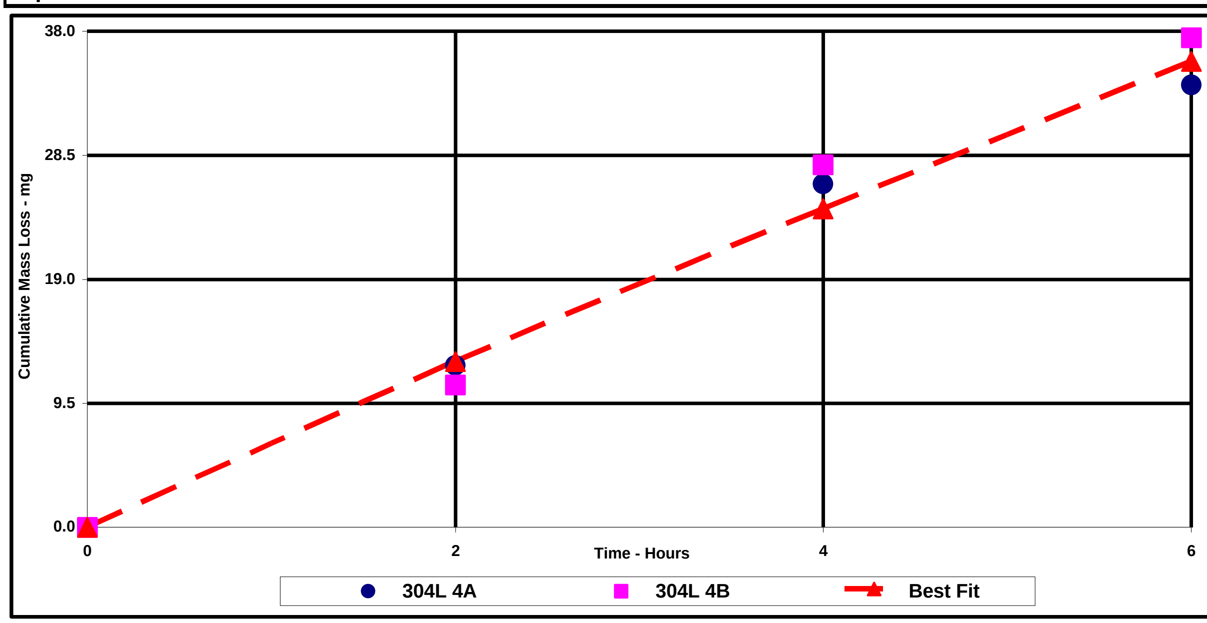
10X ***60X***

ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test	
Number	: **S-1030**
Type	: **SAR Number**
Date	: **24-May-2001**
Project	
Description	: **Westinghouse Savannah River - AB80166N**
Slurry	
Description	: **Test 4 - HLW Leached - 302 & 295 grams as received**
Concentration	: **20% by Mass (as received)**
Temperature	: **85C +/- 5**
Wear Specimen	
Description	: **304L Stainless Steel**
Specific Gravity	: **7.96**
Hardness	: **NA**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.01**

Wear Specimen		304L 4A			304L 4B		Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	**11.8**	**15.8385**	0.0	**11.8**	**15.8731**	0.0	0.0	0.0
After 2 Hours :	**11.8**	**15.8261**	12.4	**11.8**	**15.8622**	10.9	11.7	12.7
After 4 Hours :	**11.7**	**15.8122**	13.9	**11.7**	**15.8453**	16.9	27.1	24.4
After 6 Hours :	**11.7**	**15.8046**	7.6	**11.7**	**15.8356**	9.7	35.7	35.7
Total :			33.9			37.5		

Results			
***Best Fit Mass Loss**	:	=	**6.6301 * Hours^ 0.93960**
SAR Number	:	**103.43**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-3%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

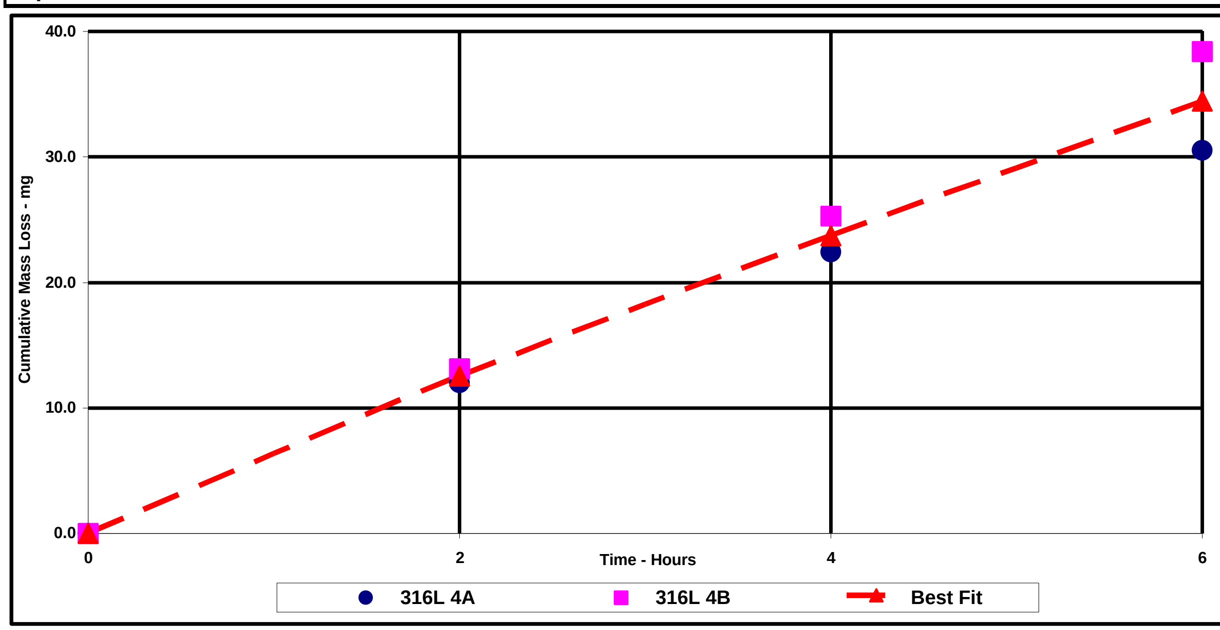


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

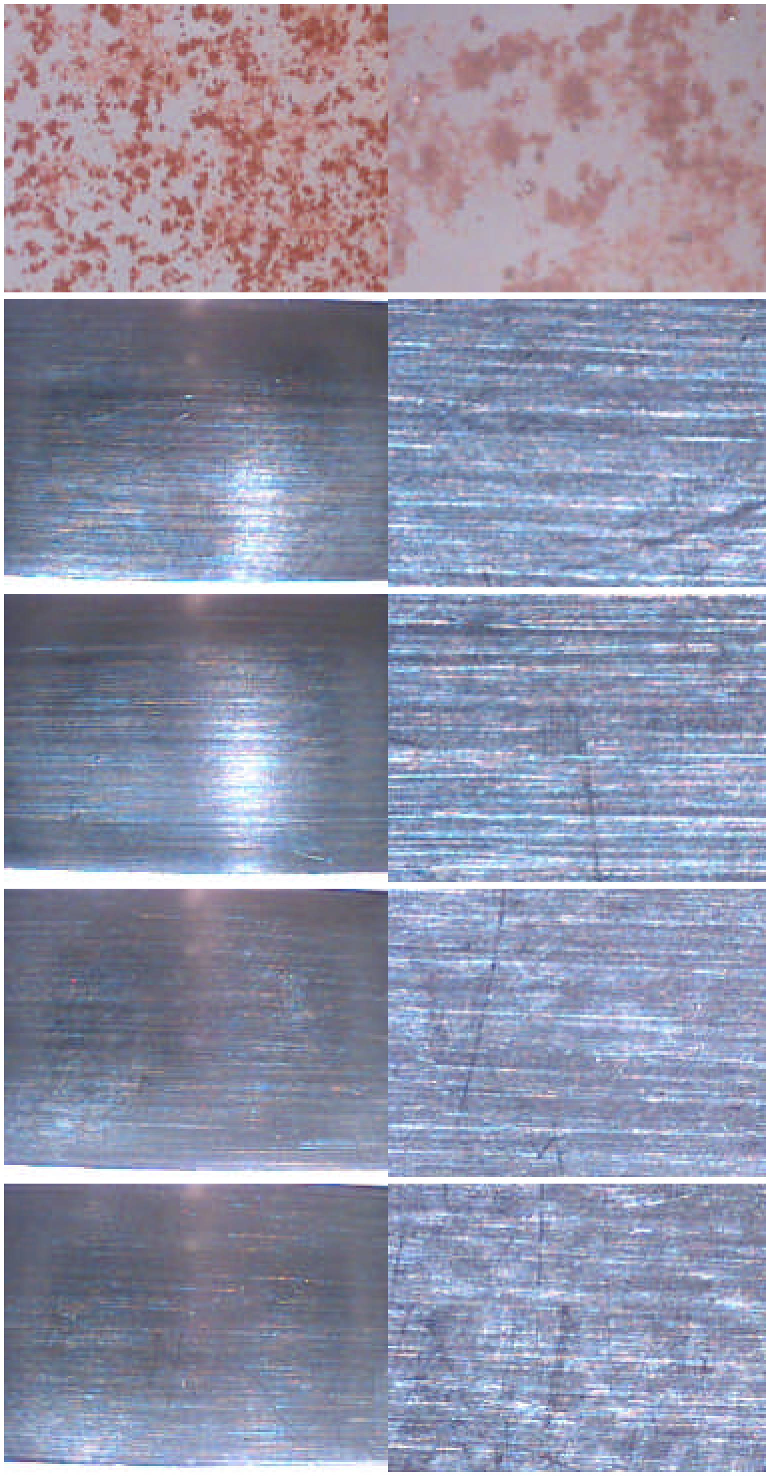
Test		
Number	:	**S-1031**
Type	:	**SAR Number**
Date	:	**24-May-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 4 - HLW Leached - 306 & 305 grams as received**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**85C +/- 5**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**316L 4A**			**316L 4B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**11.8**	**15.8348**	0.0	**11.8**	**15.7740**	0.0	0.0	0.0
After 2 Hours	:	**11.8**	**15.8228**	12.0	**11.8**	**15.7609**	13.1	12.5	12.5
After 4 Hours	:	**11.7**	**15.8124**	10.4	**11.7**	**15.7487**	12.2	23.8	23.7
After 6 Hours	:	**11.7**	**15.8043**	8.1	**11.7**	**15.7356**	13.1	34.4	34.4
Total	:			30.5			38.4		

Results			
***Best Fit Mass Loss**	:	**=**	**6.6368 * Hours^ 0.91912**
SAR Number	:	**99.35**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-4%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



5 – HLWwSBS Leached Slurry Test Results S-1032(304L SS) and S-1033(316L SS)



Solids 60X & 200X

304-A

304-B

316-A

316-B

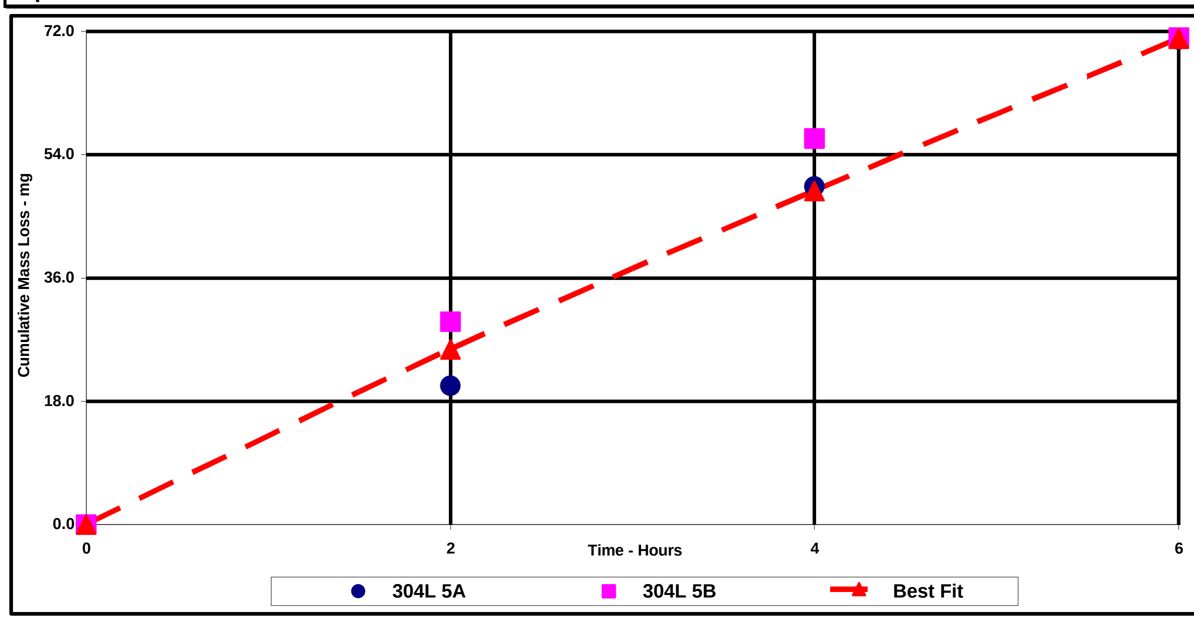
10X ***60X***

ASTM G75 Slurry Abrasivity Determination By Miller Number System

Test		
Number	:	**S-1032**
Type	:	**SAR Number**
Date	:	**1-Nov-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 5 - HLWwSBS Leached - 302 & 298 grams as received**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/- 5C**
Wear Specimen		
Description	:	**304L Stainless Steel**
Specific Gravity	:	**7.96**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		304L 5A			304L 5B			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.6**	**15.8231**	0.0	**12.6**	**15.9059**	0.0	0.0	0.0
After 2 Hours	:	**12.5**	**15.8028**	20.3	**12.5**	**15.8763**	29.6	25.0	25.6
After 4 Hours	:	**12.5**	**15.7737**	29.1	**12.5**	**15.8495**	26.8	52.9	48.7
After 6 Hours	:	**12.4**	**15.7523**	21.4	**12.4**	**15.8348**	14.7	71.0	71.0
Total	:			70.8			71.1		

Results			
***Best Fit Mass Loss**	:	**=**	**13.4570 * Hours^ 0.92785**
SAR Number	:	**205.61**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-4%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

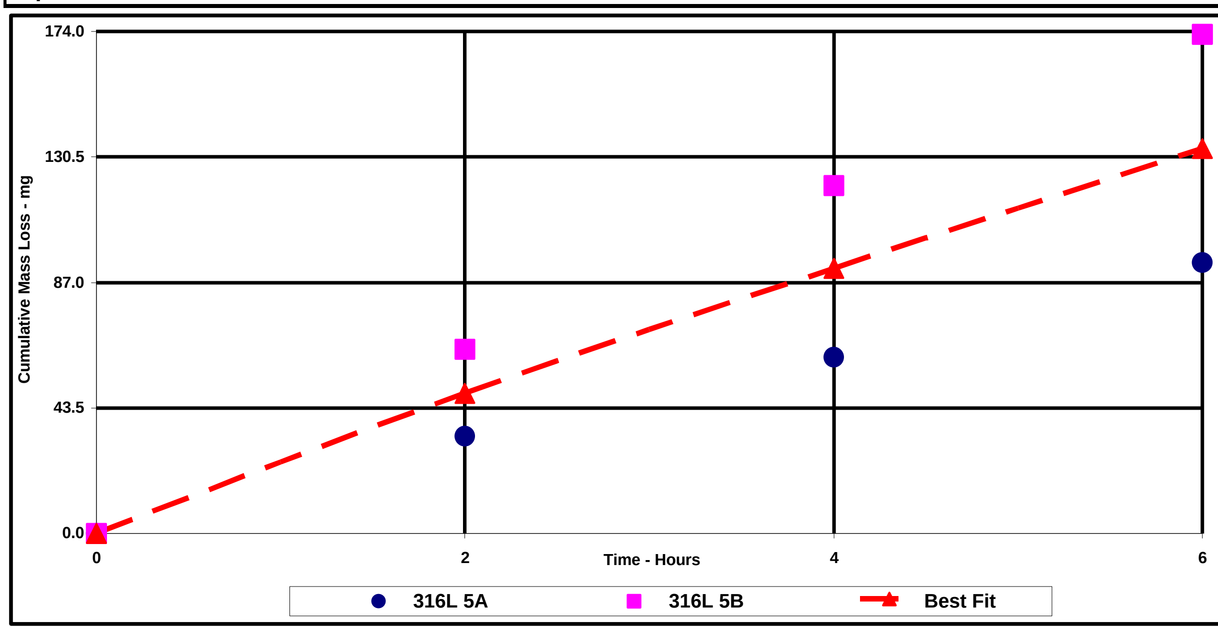


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test		
Number	:	**S-1033**
Type	:	**SAR Number**
Date	:	**1-Nov-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 5 - HLWwSBS Leached - 293 & 307 grams as Received**
Concentration	:	**20% by Mass (as received the 307 g batch had significant more solids)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**316L 5A**			**316L 5B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**12.6**	**15.9283**	0.0	**12.6**	**15.8948**	0.0	0.0	0.0
After 2 Hours	:	**12.5**	**15.8947**	33.6	**12.5**	**15.8310**	63.8	48.7	48.6
After 4 Hours	:	**12.5**	**15.8673**	27.4	**12.5**	**15.7742**	56.8	90.8	91.9
After 6 Hours	:	**12.4**	**15.8345**	32.8	**12.4**	**15.7218**	52.4	133.4	133.4
Total	:			93.8			173.0		

Results			
***Best Fit Mass Loss**	:	**=**	**25.6765 * Hours^ 0.91964**
SAR Number	:	**384.71**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-4%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**

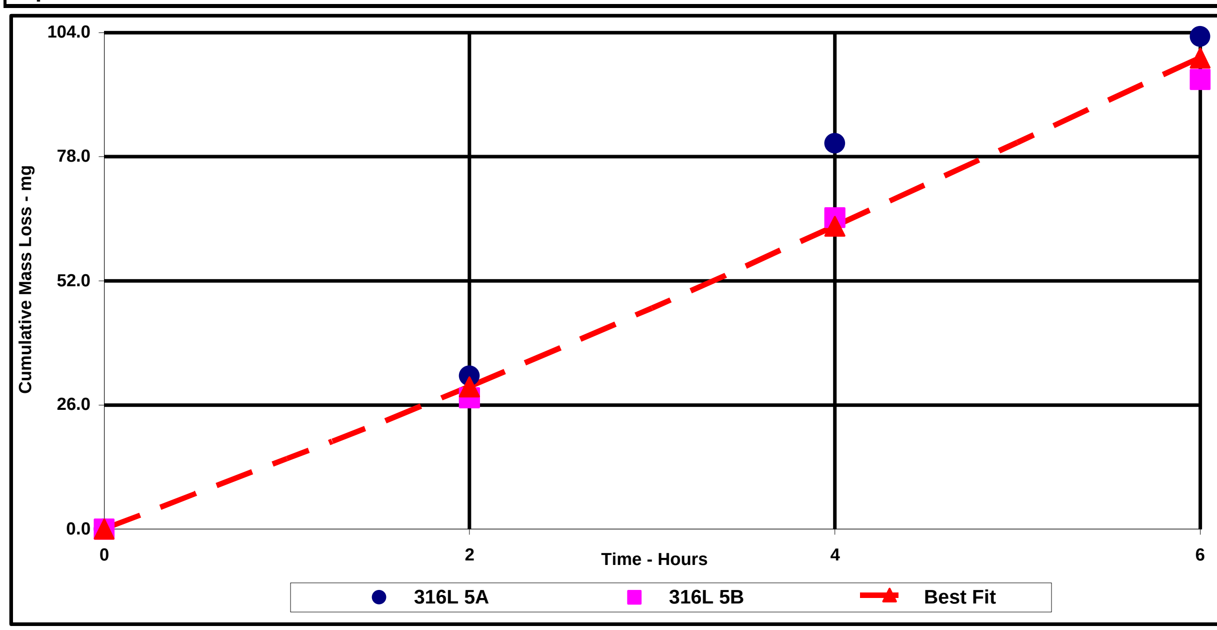


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

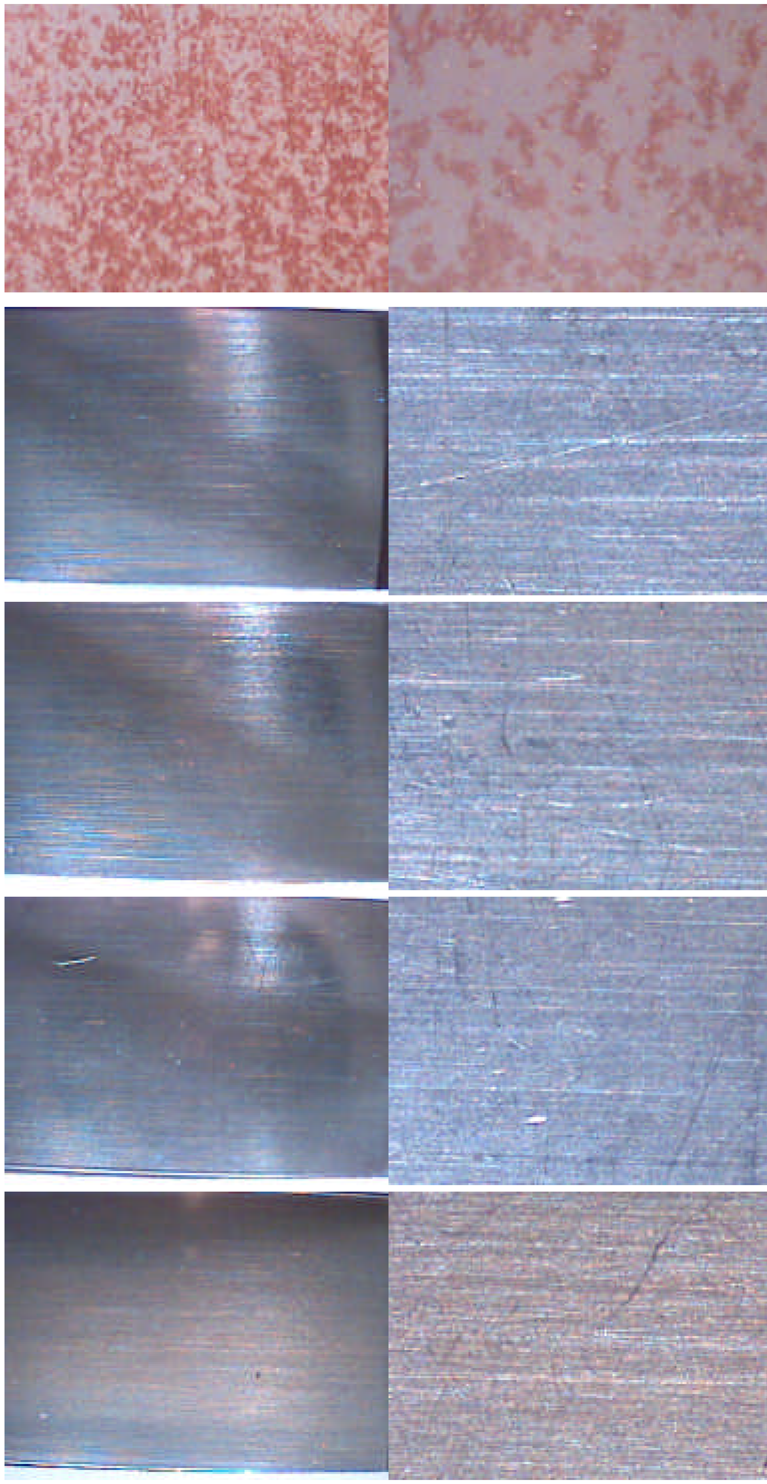
Test		
Number	:	**S-1033R**
Type	:	**SAR Number**
Date	:	**23-Nov-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 5R - HLWwSBS Leached - 302 & 294 grams as Received**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/- 5**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		**316L 5A**			**316L 5B**			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**13.4**	**15.6666**	0.0	**13.4**	**15.5562**	0.0	0.0	0.0
After 2 Hours	:	**13.5**	**15.6345**	32.1	**13.5**	**15.5287**	27.5	29.8	29.8
After 4 Hours	:	**13.4**	**15.5858**	48.7	**13.4**	**15.4910**	37.7	73.0	63.4
After 6 Hours	:	**13.6**	**15.5635**	22.3	**13.7**	**15.4620**	29.0	98.7	98.6
Total	:			103.1			94.2		

Results			
***Best Fit Mass Loss**	:	=	**14.0029 * Hours^ 1.08959**
SAR Number	:	**279.65**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**4%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



*6 – **HLW Washed Slurry Test Results S-1041(304L SS) and S-1042(316L SS***



Solids 60X & 200X

304-A

304-B

316-A

316-B

10X ***60X***

ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test
- Number : **S-1041**
- Type : **SAR Number**
- Date : **2-May-2001**

Project
- Description : **Westinghouse Savannah River - AB80166N**

Slurry
- Description : **Test 6 - HLW Washed - 230 ml ~ 265 grams**
- Concentration : **20% by Mass (as received)**
- Temperature : **25C +/-5C**

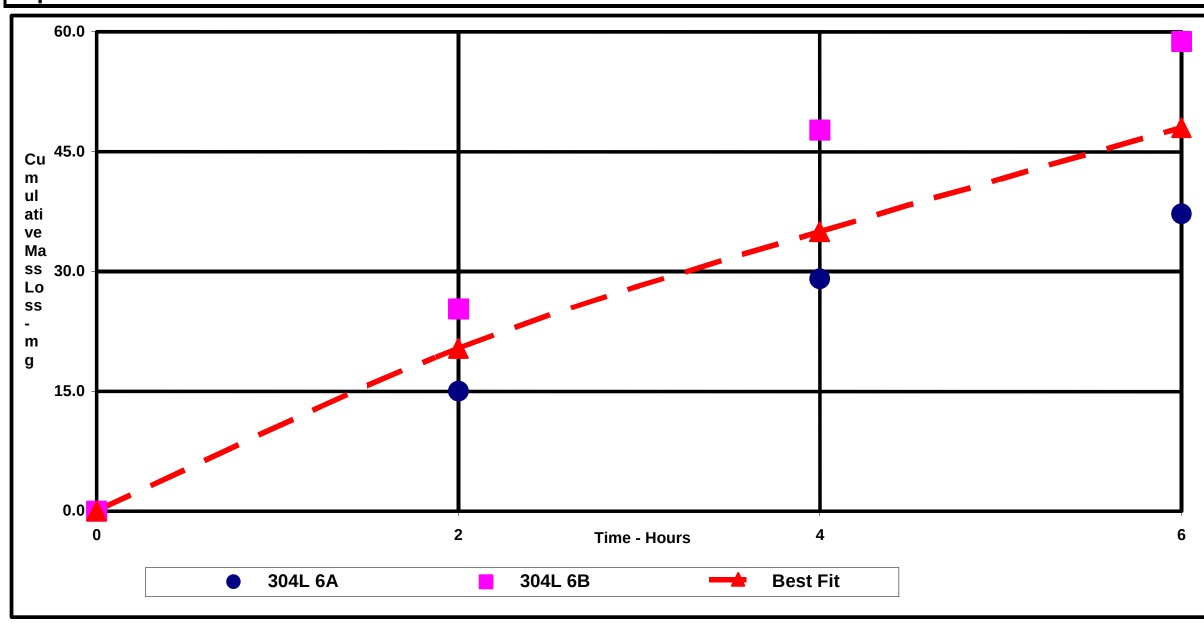
Wear Specimen
- Description : **304L Stainless Steel**
- Specific Gravity : **7.96**
- Hardness : **NA**

Lap Material
- Description : **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
- Hardness - Durometer : **78-82**
- Wear - mm : **0.02**

Wear Specimen	304L 6A			304L 6B			Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	8.2	15.5452	0.0	8.0	15.8453	0.0	0.0	0.0
After 2 Hours :	7.9	15.5302	15.0	7.8	15.8200	25.3	20.1	20.4
After 4 Hours :	7.8	15.5161	14.1	7.7	15.7976	22.4	38.4	35.0
After 6 Hours :	8.0	15.5080	8.1	8.0	15.7865	11.1	48.0	48.0
Total :			37.2			58.8		

Results

*Best Fit Mass Loss	:	=	11.8655 * Hours^ 0.78000
SAR Number	:	137.56	Relative Rate of Mass/Volume loss at 2 hours
Departure	:	-11%	Relative Rate of Change in Mass/Volume loss at 2 hours
Lap Wear	:	0.02	mm

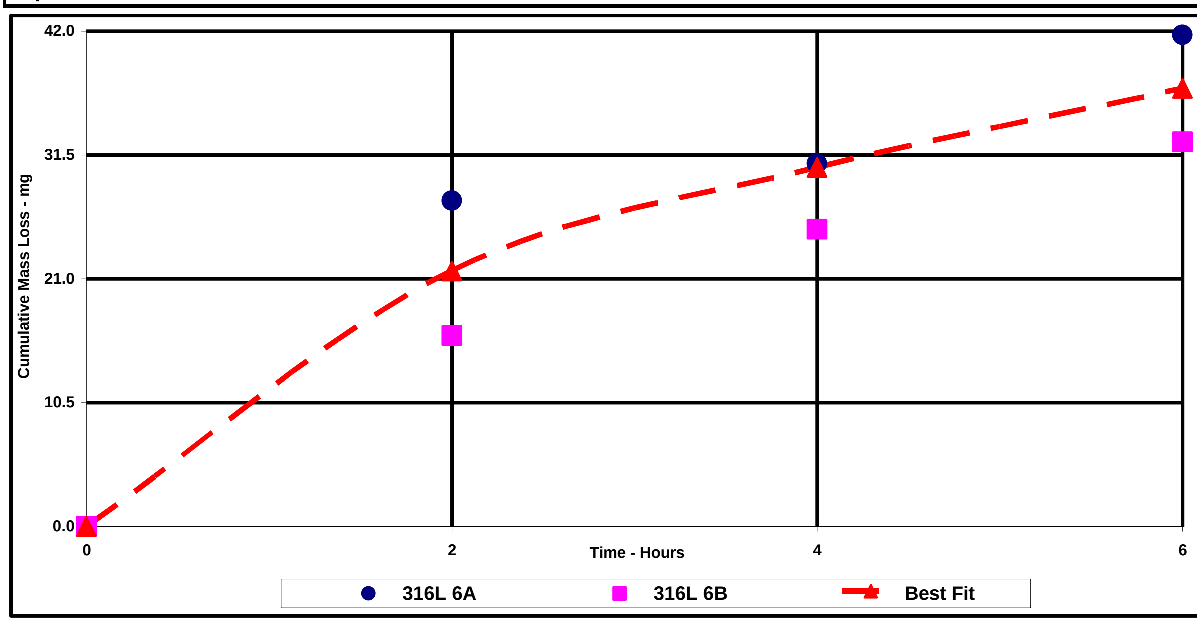


ASTM G75 Slurry Abrasivity Determination
By Miller Number System

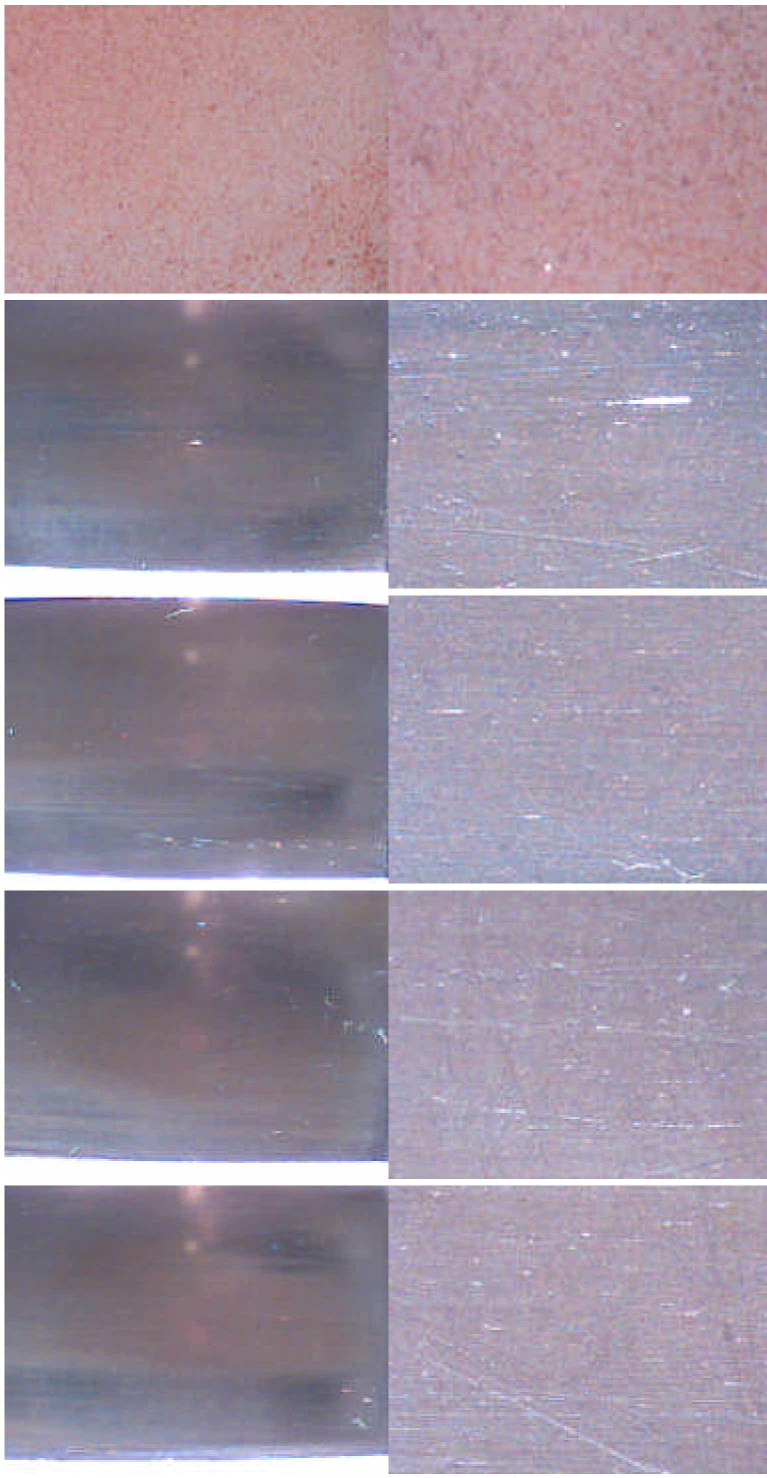
Test		
Number	:	**S-1042**
Type	:	**SAR Number**
Date	:	**2-May-2001**
Project		
Description	:	**Westinghouse Savannah River - AB80166N**
Slurry		
Description	:	**Test 6 - HLW Washed - 230ml ~ 265 grams**
Concentration	:	**20% by Mass (as received)**
Temperature	:	**25C +/-5C**
Wear Specimen		
Description	:	**316L Stainless Steel**
Specific Gravity	:	**8.00**
Hardness	:	**NA**
Lap Material		
Description	:	**MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	:	**78-82**
Wear - mm	:	**0.01**

Wear Specimen		316L 6A			316L 6B			Cumm Loss	
		pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial	:	**8.2**	**15.7325**	0.0	**7.8**	**15.6982**	0.0	0.0	0.0
After 2 Hours	:	**8.1**	**15.7049**	27.6	**7.7**	**15.6820**	16.2	21.9	21.7
After 4 Hours	:	**7.9**	**15.7017**	3.2	**7.6**	**15.6730**	9.0	28.0	30.4
After 6 Hours	:	**7.8**	**15.6908**	10.9	**7.5**	**15.6656**	7.4	37.2	37.1
Total	:			41.7			32.6		

Results			
***Best Fit Mass Loss**	:	**=**	**15.4260 * Hours^ 0.49053**
SAR Number	:	**91.56**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-25%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



7 – HLW Washed/Leached Slurry Test Results S-1043(304L SS) and S-1044(316L SS)



Solids 60X & 200X

304-A

304-B

316-A

316-B

10X 60X

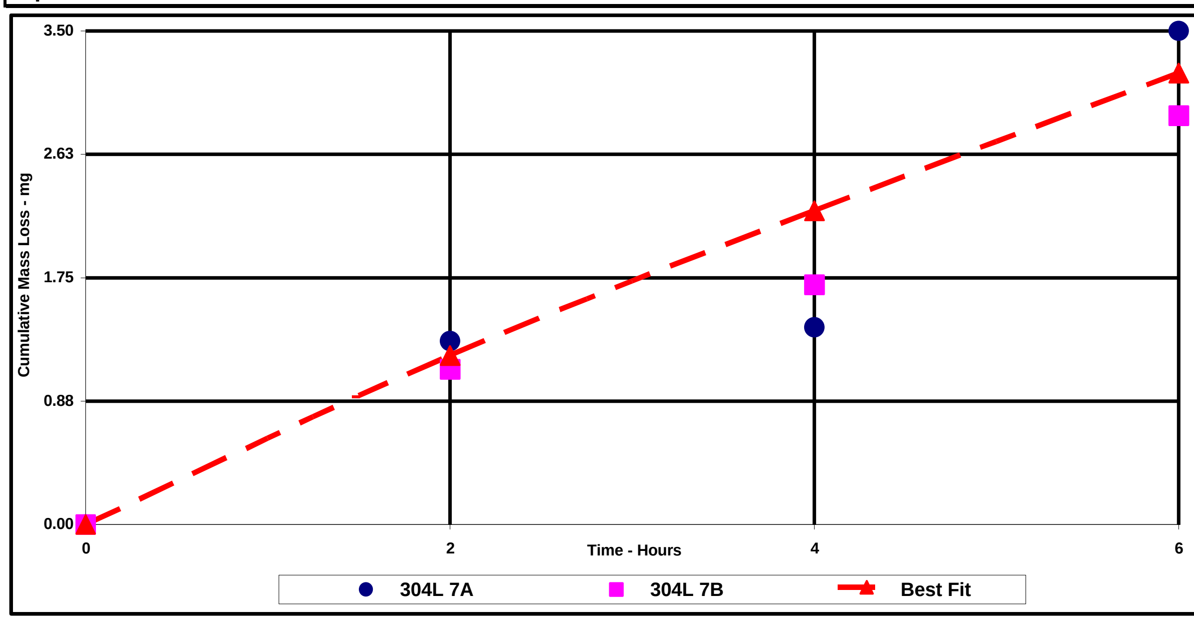
ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test	
Number	: **S-1043**
Type	: **SAR Number**
Date	: **24-May-2001**
Project	
Description	: **Westinghouse Savannah River - AB80166N**
Slurry	
Description	: **Test 7 - HLW Washed/Leached - 266 & 275 grams as received**
Concentration	: **20% by Mass (as received)**
Temperature	: **85C +/- 5C**
Wear Specimen	
Description	: **304L Stainless Steel**
Specific Gravity	: **7.96**
Hardness	: **NA**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.01**

Wear Specimen		**304L 7A**			**304L 7B**		Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	**11.3**	**15.8132**	0.0	**11.3**	**15.8542**	0.0	0.0	0.0
After 2 Hours :	**11.3**	**15.8119**	1.3	**11.3**	**15.8531**	1.1	1.2	1.2
After 4 Hours :	**11.2**	**15.8118**	0.1	**11.2**	**15.8525**	0.6	1.6	2.2
After 6 Hours :	**11.0**	**15.8097**	2.1	**11.0**	**15.8513**	1.2	3.2	3.2
Total :			3.5			2.9		

Results

***Best Fit Mass Loss**	:	=	**0.6446 * Hours^ 0.89424**
SAR Number	:	**9.27**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-5%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



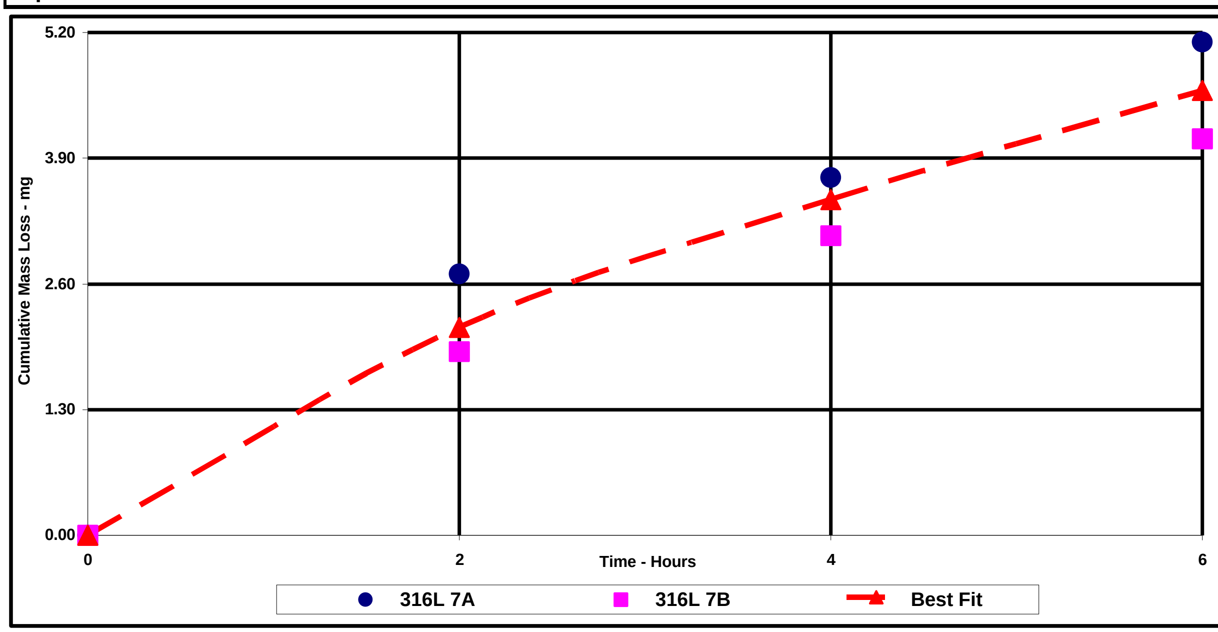
ASTM G75 Slurry Abrasivity Determination
By Miller Number System

Test	
Number	: **S-1044**
Type	: **SAR Number**
Date	: **25-May-2001**
Project	
Description	: **Westinghouse Savannah River - AB80166N**
Slurry	
Description	: **Test 7 - HLW Washed/Leached - 267 & 272 grams as received**
Concentration	: **20% by Mass (as received)**
Temperature	: **85C +/- 5C**
Wear Specimen	
Description	: **316L Stainless Steel**
Specific Gravity	: **8.00**
Hardness	: **NA**
Lap Material	
Description	: **MIL-R-6855 CLASS 2 GRADE 80 NEOPRENE**
Hardness - Durometer	: **78-82**
Wear - mm	: **0.01**

Wear Specimen	**316L 7A**			**316L 7B**			Cumm Loss	
	pH	Mass g	Loss mg	pH	Mass g	Loss mg	Ave mg	*Best Fit mg
Initial :	**11.3**	**15.8964**	0.0	**11.3**	**15.8663**	0.0	0.0	0.0
After 2 Hours :	**11.3**	**15.8937**	2.7	**11.3**	**15.8644**	1.9	2.3	2.1
After 4 Hours :	**11.2**	**15.8927**	1.0	**11.2**	**15.8632**	1.2	3.4	3.5
After 6 Hours :	**11.0**	**15.8913**	1.4	**11.0**	**15.8622**	1.0	4.6	4.6
Total :			5.1			4.1		

Results

***Best Fit Mass Loss**	:	=	**1.3280 * Hours^ 0.69337**
SAR Number	:	**12.82**	**Relative Rate of Mass/Volume loss at 2 hours**
Departure	:	**-15%**	**Relative Rate of Change in Mass/Volume loss at 2 hours**
Lap Wear	:	**0.01**	**mm**



Distribution:

W. L. Tamosaitis, 773-A

H. F. Sturm, 773-A

S. T. Wach, 773-42A

D. B. Burns, 786-5A

T. B. Calloway, 999-W

E. K. Hansen, 773-41A

C. J. Coleman, 773-A

C. A. Nash, 773-42A

S. Y. Lee, 773-42A

H. N. Guerrero, 786-5A

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RPP File, c/o S. G. McKinney, 773-A, Room A-206