PNWD-3000
BNFL-RPT-002, Rev. 0

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

Ultrafiltration and Characterization of AW-101 Supernatant and Entrained Solids

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Summary

A 0.1-µm sintered metal Mott filter was used for cross-flow filtration testing of Hanford Double Shell Tank AW-101 entrained solids. While the filtrate was being recirculated, a matrix of 14 transmembrane pressures (1.4 to 4.8 bar) and axial velocities (1 to 4.2 m/s) were investigated, each over 1 hour's time. The slurry was dewatered from 2.2 L to 1.0 L, and a second matrix of 4 transmembrane pressures (2.1 to 4.8 bar) and axial velocities (3.8 to 4.6 m/s) were investigated.

The slurry was then dead-end filtered and the solids washed three times with water. The original feed, permeate, wash solutions, and final solids were analyzed for chemical and radiochemical constituents. Slurry samples were taken before testing and after dewatering. These samples were analyzed for density, viscosity, particle size distribution, and solids concentration.

For the cross-flow filtration tests, filtrate permeabilities ranged from 0.34 to 0.67 m^3/m^2/day/bar. Filtrate fluxes were 1.6 m^3/m^2/day as compared to the design basis of 5.9 m^3/m^2/day. This lower than expected value may be caused by high filter-cake resistance (due to very small particles) or filter resistance (due to a low porosity filter)[1]. Higher pressures are recommended for AW-101 entrained solids filtration with the filter and conditions evaluated in this work. The best performance occurred at 4.5 bar and 3.75 m/s. After dewatering the slurry from 2.2 L to 1.0 L, the filtrate permeabilities decreased to a range of 0.17 to 0.26 m^3/m^2/day/bar.

After the entrained solids had been washed three times with 28 mL water/g dry solids, the sodium in the wash solutions had still not decreased to below the required 60 g/kg dry entrained solids. The difficulty in removing sodium from the entrained solids is believed to be caused by slightly soluble sodium oxalate.

Results for the radiochemical analyses indicate that the entrained solids are transuranic (TRU) while the filtrate has been decontaminated from any measurable TRU and ^{90}Sr isotopes.

The CUF feed was Newtonian in behavior while the CUF dewatered slurry was slightly shear-thinning or pseudoplastic. Both materials had viscosities ranging from 5 to 10 cP (at shear rates > 100 s^{-1}) and slurry densities of 1.3 g/mL.

[1] After operation, it was determined that this filter was designed for gaseous rather than liquid applications. Gas filters have a lower porosity than liquid filters and offer a greater resistance to liquid flow.

Glossary

µm	Micron
AES	Atomic emission spectroscopy
BNFL	British Nuclear Fuels, Ltd., Inc.
cP	centipoise
CUF	Cells Unit Filter
DI	Deionized
DOE	U.S. Department of Energy
g	gram
GEA	Gamma energy analysis
HLW	High level waste
IC	Ion chromatography
ICP	Inductively coupled plasma
L	Liter
LAW	Low activity waste
MS	Mass spectrometry
MSE	Mean squared error
psi	Pounds per square inch
psid	Pounds per square inch differential
RPP-WTP	River Protection Project Waste Treatment Plant
SRTC	Savannah River Technology Center
TIC	Total inorganic carbon
TMP	Transmembrane Pressure
TOC	Total organic carbon
TRU	Transuranic
Vol%	Volume percent
Wt%	Weight percent

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1.0 Introduction

The River Protection Project Waste Treatment Plant (RPP-WTP) (1996) flow sheet uses cross-flow filtration as the solid/liquid separation technique. Unlike traditional dead-end filtration, which has a declining rate caused by the growth of a filter cake on the surface of the filter medium, in cross-flow filtration, the filter cake is swept away by the fluid flowing across it. This filtration method is especially beneficial when there are very fine particles and when system simplicity is required.

One of the applications of cross-flow filtration is to remove the entrained solids from Envelope A supernatants[1] retrieved from the tanks. The filtration should remove sufficient solids to prevent plugging of the ion exchange column downstream and to ensure that insoluble ^{90}Sr and transuranic isotopes are removed. These solids are then to be concentrated and returned to the U.S. Department of Energy (DOE). The RPP-WTP Privatization Contract (1996) specifies certain isotopic, chemical, and physical limits for the entrained solids returning to the DOE double-shell tanks.

During Phase 1A, the Savannah River Technology Center (SRTC) tested an entrained solids simulated Envelope A material at 0.15 wt% solids. The SRTC cross-flow filtration system used a 0.5-µm Mott sintered metal filter. Filter permeabilities ranging from 2.7 to 56 m^3/m^2/day/bar (0.0032 to 0.066 gpm/ft^2/psi) were obtained over a transmembrane pressure drop range of 0.68 to 2.2 bar (10 to 31 psi) (Nash and Siler 1997).

The objective of this work was to test cross-flow filtration using actual Envelope A Hanford tank waste. Similar to the Phase 1A study, we evaluated the permeability of an Envelope A feed through a single element filter as a function of transmembrane pressure, axial velocity, solids concentration, and time. In addition, the efficiency of back pulse and chemical cleaning on the filter performance was evaluated. The chemical and radiochemical composition of the filtrate and solids was measured to determine efficiency of the filtration process.

This report describes the test apparatus, the experimental approach, the results of the tests, and the chemical and radiochemical analysis for supernatants taken from Hanford Tank AW-101[2]. This report also provides a means of transmitting to British Nuclear Fuels, Limited (BNFL) the completed test instruction and raw filtration and analytical data.

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[1] Envelope A refers to a volume of tank waste that will be provided to the Privatization contractor to process that falls within a certain composition range. Envelope A encompasses a large fraction of the double shell tank waste.

[2] The results presented in this report are based on work conducted under Test Plan TP-29953-004, test instructions TP-29953-012, -021, -022, and -024, and Procedure TP-29953-020. Some data are recorded in Laboratory Record Book (LRB)# 13745.

2.0 Experimental Approach

2.1 Test Apparatus

The cross-flow filtration apparatus had the following specifications:

- Mott sintered SS metal filter rated at 0.1 μm; 24-in. length and 3/8-in. diameter (total area 0.0182 m^2)
- Re-circulation flow with a maximum linear crossflow velocity of 5 m/s along the axis of the filter
- Maximum transmembrane pressures of 5.5 bar (80 psid)
- Temperature control of 25 $\pm$ 5°C during operation.

The system was fabricated based on modifications of the Cells Unit Filter (CUF) system designed by SRTC. A process flow diagram is shown in Figure 2.1, and a photograph is shown in Figure 2.2. The entire system has a maximum operating volume of 2500 mL and a minimum volume of 800 to 1000 mL. The system is connected with stainless steel tubing and Swagelok fittings. The feed solution is introduced into the slurry reservoir. An air driven Oberdorfer progressive cavity pump provides flow through a magnetic flow meter and into the Mott filter rated at 0.1 μm.[1] The axial velocity and transmembrane pressure of the filter are controlled by adjusting the pump speed (via the air-pressure supply to the air motor) and the throttle valve (V1). Filtrate passes through the Mott filter and is reconstituted with the slurry in the slurry reservoir. The filtrate is measured by means of a fill and drain graduated cylinder or a rotameter (if the flows are too high to be measured by the graduated cylinder).

The filtrate can be recycled to or redirected from the slurry reservoir using V7. The former approach, i.e., recirculation of the filtrate, ensures that the solids concentration and fluid volume remain relatively constant during the course of an experiment. The latter approach, i.e., redirecting the fluid from the slurry reservoir, enables periodic sampling of the filtrate or increasing the solids concentration in the reservoir for higher solids-loading tests. The slurry can be sampled at run conditions using a two-valve system (V2 & V10). One valve is opened at a time to prevent loss of material during sampling. The high velocities during system operation will provide high enough mixing to ensure that a homogeneous and representative sample of slurry is collected.

The slurry temperature is measured both in the slurry reservoir and in-line. A 1-kW chiller pumps coolant through heat-exchanger jackets around the tank and around the tubing between the flow meter and filter.

The filter is back pulsed by opening the toggle valve (V3) and allowing the back-pulse chamber to be filled half full with filtrate. The toggle valve is then closed, and the back-pulse chamber is pressurized with air. Once charged, the toggle valve is then opened, allowing the pressurized filtrate to back pulse the filter element. The system is drained at valves V2 and V9. Air from the back-pulse chamber is used to force the liquid from the filter out of the system. However, some liquid/slurry, typically 100 to 200 g, still remains in the system after draining and cannot be removed without disassembling the system.

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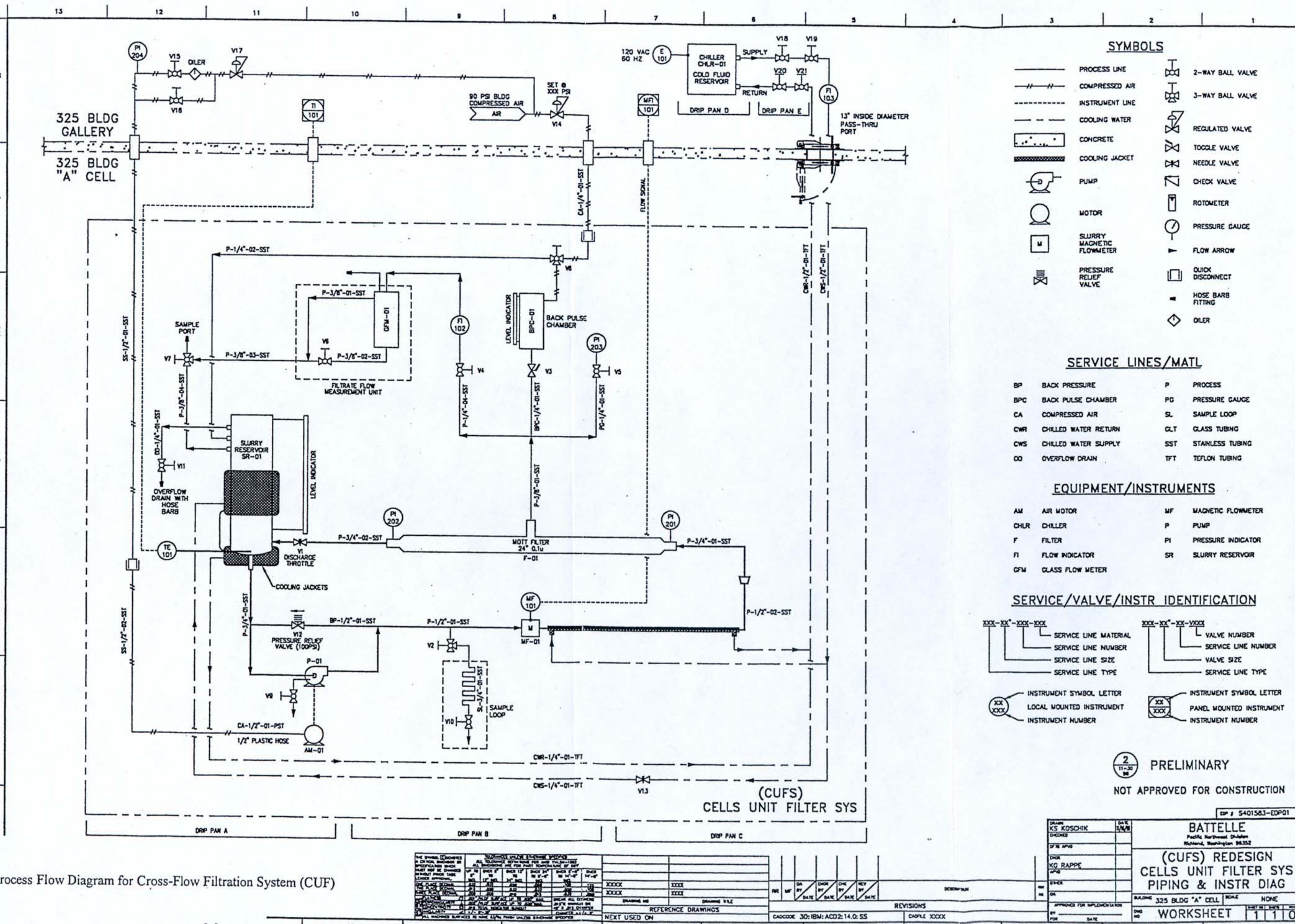
[1] After operation, it was determined that this filter was designed for gaseous rather than liquid applications. Gas filters have a lower porosity than liquid filters and offer a greater resistance to liquid flow.



1. Process Flow Diagram for Cross-Flow Filtration System (CUF)

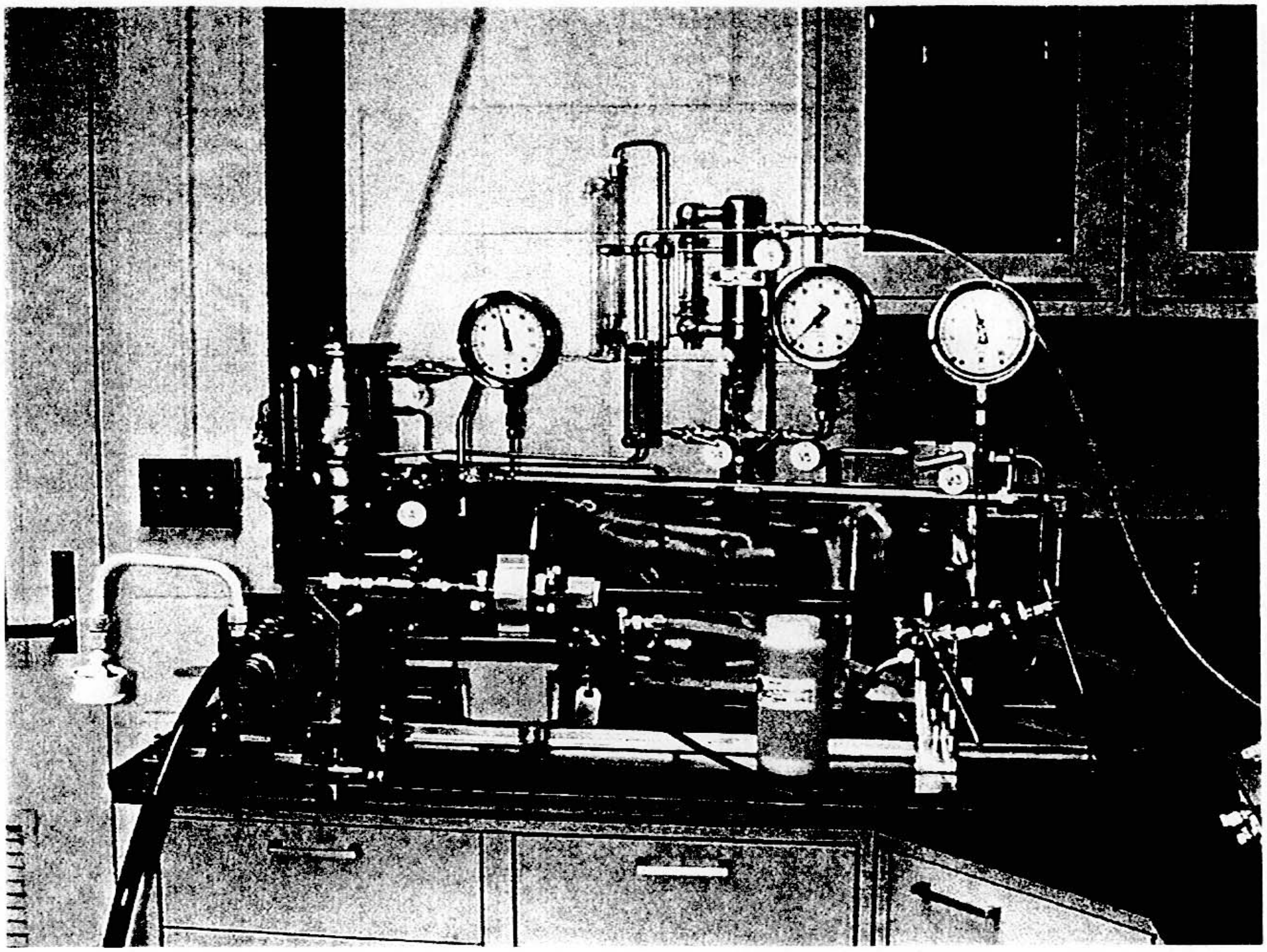


Figure 2.2. Photograph of the Cross Flow Filtration System (CUF) Before Installation in the Hot Cell

2.2 Test Material Preparation

We received approximately 3400 g of AW-101 material from the 222-S laboratory for testing in 29 containers. These containers were composited, and samples were removed for chemical, radiochemical, and organics analysis (See Urie et al. 1999). The original feed was determined to be approximately 11 M Na. Mixing of this as-received AW-101 waste resulted in rapid settling of the solids from the supernatant. The supernatant was clear yellow-green in color. The solids were dark brown in color (See Figure 2.3). These solids contained some large crystals.

Following directions from Test Plan 29953-6, we diluted the material to 6.5 M sodium and then distributed approximately 450 mL for analysis and laboratory testing. To ensure that the solids content of the sample was representative of the diluted slurry feed, the diluted slurry feed was stirred using an overhead mixer while the samples were collected. This material was analyzed for physical properties as well as chemical and radiochemical properties. Testing with the diluted AW-101 material included ion exchange batch contacts, solubility versus temperature measurements, and caustic leach testing. The remaining 2880 g of diluted AW-101 was used for the testing in the cross-flow filtration work. Figure 2.4 shows the sample pathway before AW-101 material was placed inside the CUF.

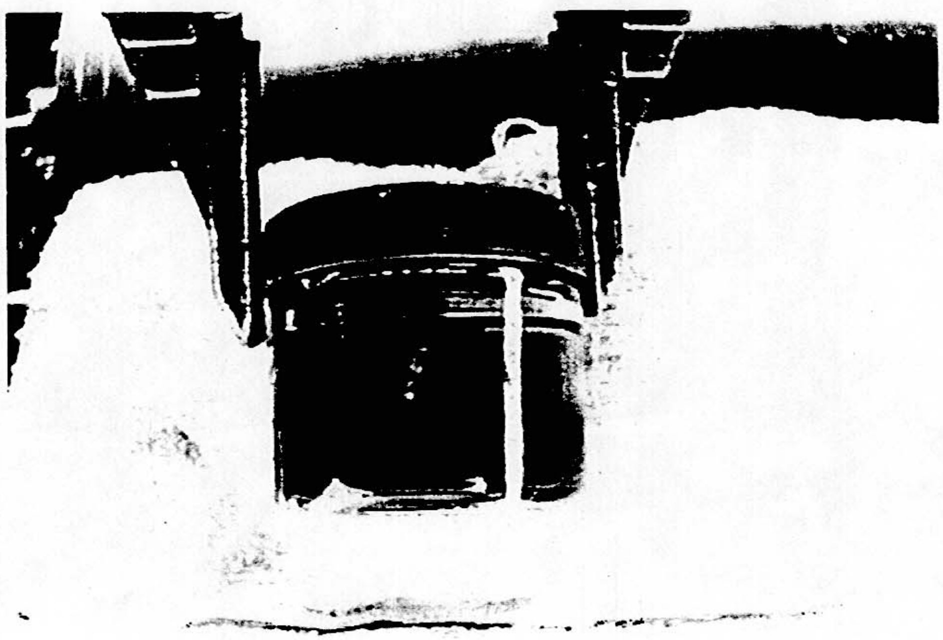


Figure 2.3. Photograph of As-Received AW-101 Tank Supernatant

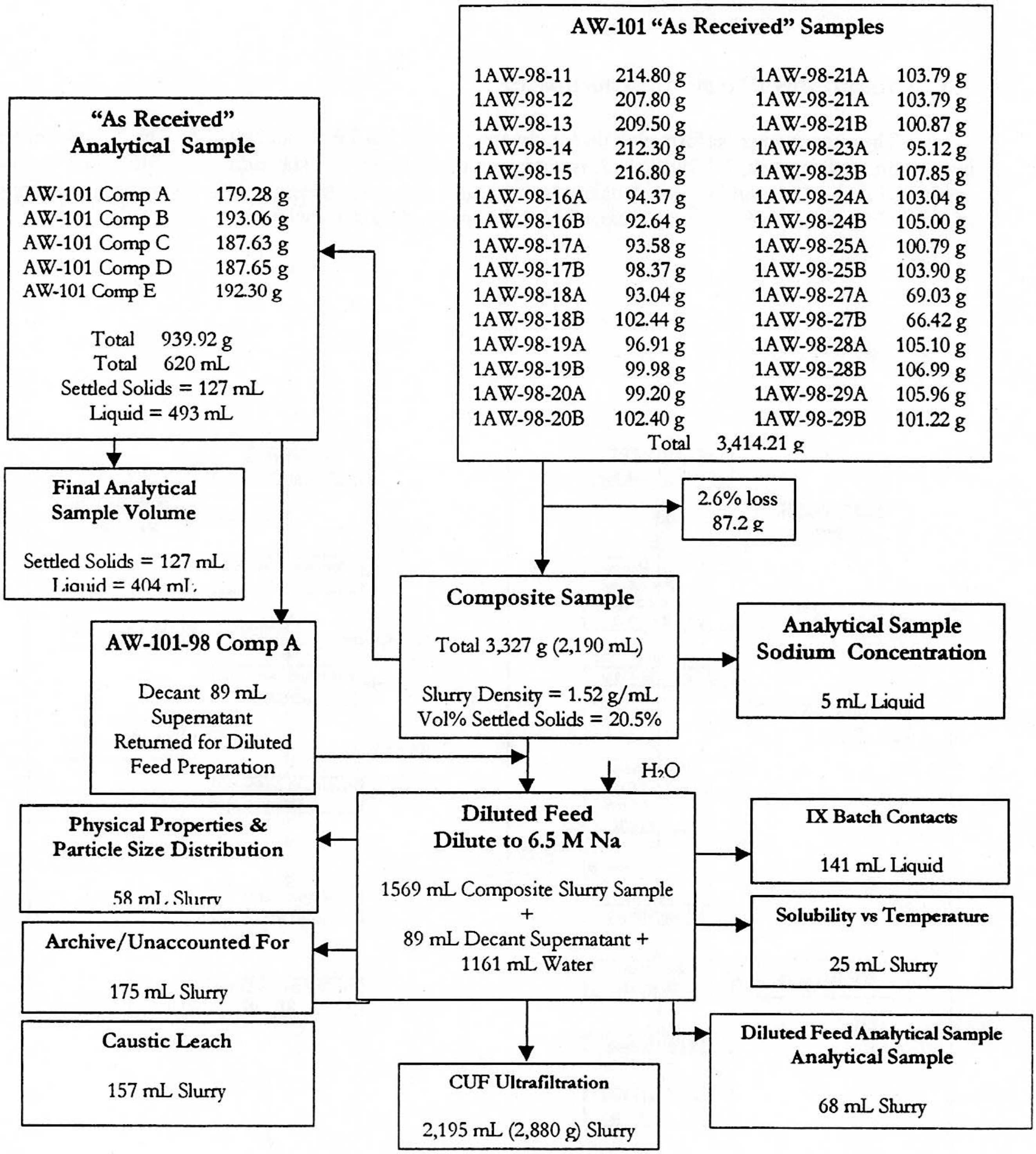
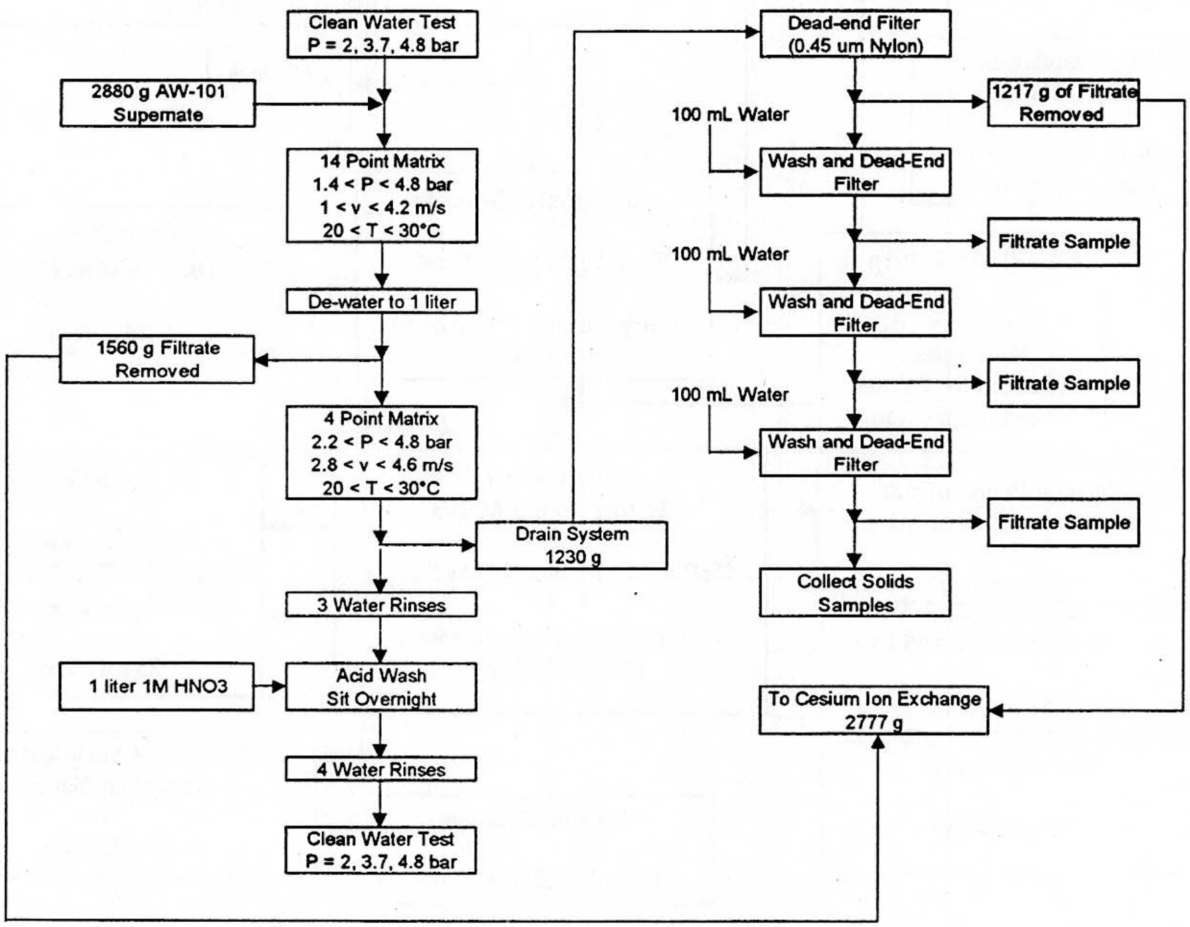


Figure 2.4. Sample Flow Diagram for the AW-101 Before Cross-Flow Filtration Testing

2.3 Cross-Flow Filtration Experiments

The experiments performed in this study are described in Test Plan 29953-4. The completed test instruction for this work, TP-29953-022, is contained in Appendix A. The radioactive filtration tests were conducted in the 325 Building A-cell using the as-diluted AW-101 material. A flow sheet of the testing is shown in Figure 2.5, and the various experimental steps are discussed below.



P = transmembrane pressure (bar)
v = axial velocity in filter element (m/s)
T = temperature of slurry (°C)

Figure 2.5. Filtration Test Experimental Steps

In all tests, the slurry temperature was maintained at 25 ± 3°C. The filtrate flux values were corrected for these temperature variations using the equation provided by BNFL:

$$Flux_{25C} = Flux_T e^{\left(2500 \bullet \left[\frac{1}{273+T} - \frac{1}{298}\right]\right)} \tag{2.1}$$

where $Flux_T$ is the calculated flux at the measured temperature, T is the experimentally measured temperature, and $Flux_{25C}$ is the normalized temperature at 25°C.

During each test, filtrate flux, re-circulation flows, module inlet and outlet pressure, and slurry temperature were monitored every 10 minutes. Each test condition was run for 60 minutes. Upon completion of each test condition, the filter was back pulsed twice and a new condition set.

In the first set of experiments, we determined the flux of clean water through the membrane at three different transmembrane pressure drops of 2, 3.7, and 4.8 bar (30, 55, and 70 psid). The axial velocities for these tests were 1, 4.6, and 3.7 m/s, respectively. Each experiment lasted 20 minutes. The clean water flux from these tests provided a baseline to evaluate the cleaning efficiency of nitric acid wash. After testing, the water was drained, but approximately 150 g of water remained in the CUF. This water cannot be removed without disassembling the equipment.

After testing the system with water, approximately 2200 mL of diluted AW-101 was then placed into the CUF slurry reservoir. Using the diluted AW-101 material, the permeate fluxes were determined at 14 conditions of axial velocities and transmembrane pressures. The test conditions for the 14 different experiments are shown in Table 2.1 and Figure 2.6. The purpose of theses tests was to determine the optimum permeate flux conditions for the dilute AW-101 slurry. During this test matrix, the filtrate was recycled back into the slurry reservoir to hold the solids concentration and volume relatively constant. The matrix consists of two testing regimes, one at low velocities and pressures and the other at higher velocities and pressures. A 5-point matrix around a center-point at 2 bar and 2 m/s tested the lower conditions of transmembrane pressure (TMP) (1.38 to 2.75 bar) and velocity (1 m/s to 2.8 m/s). A 5-point matrix around a center-point at 3.8 bar and 3.7 m/s tests the higher TMP and velocities of (2.75 to 4.82 bar) and (2.8 m/s to 4.6 m/s). The first, seventh, and thirteenth conditions were all to be performed at the lower center-point. The second, eighth, and fourteenth conditions were all to be performed at the upper center-point. This duplication of conditions allowed us to determine how the filtrate flux is changing versus time (due to filter fouling and changes in the particle characteristics).

After testing this 14-point matrix, we selected the condition with the highest filtrate flux for the de-watering operation. The condition selected was 4.8 bar and 3.5 m/s axial velocity. The slurry concentrated until approximately 1200 mL of filtrate had been removed. Approximately 1 L of slurry remained in the system. Following the dewatering step, samples of the collected filtrate, the dewatered slurry, and final permeate were taken. The filtrate samples were analyzed for chemical and radiochemical constituents, while the slurry samples were analyzed for viscosity, solids loading, and particle-size distribution.

Table 2.1. Test Conditions for Low Solids Matrix

Test #	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Axial Velocity (m/s)	2.1	3.7	2.4	1.0	2.0	2.8	2.0	3.7	3.7	3.7	2.8	4.2	2.0	3.7
TMP (bar)	2.1	3.9	2.9	2.0	1.3	2.0	2.0	3.7	2.7	4.4	3.7	3.7	2.1	3.9

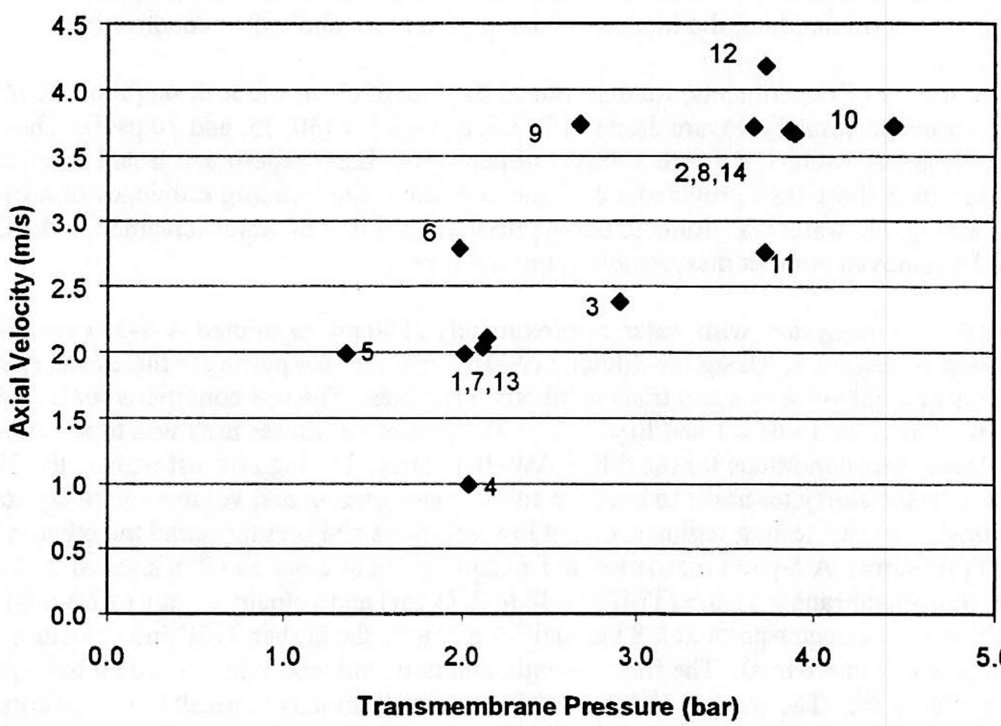


Figure 2.6. Experimental Conditions and Order Used in Testing the Diluted AW-101 Slurry with the CUF

A second test matrix was then performed at the higher solids loading. Table 2.2 and Figure 2.7 show the conditions and run order for this matrix. Although the pump was able to reach 4.8 bar at 3.5 m/s during dewatering, during the second test matrix, the pump was not able to reach all the intended target conditions. The reason for this difference is not clear. The maximum pressure obtained at 3.7 m/s axial velocity was 3.4 bar (50 psid). To reach 4.8 bar (70 psid) for Condition 4, the axial velocity was reduced to 2.8 m/s. Similarly, the maximum pressure obtained for Condition 5 at a set axial velocity of 4.6 m/s was 2.2 bar (32 psid).

Table 2.2. Test Conditions for High Solids Matrix

Test #	1	2	3	4
Axial Velocity (m/s)	3.7	3.7	2.8	4.6
TMP (bar)	2.6	3.4	4.8	2.2

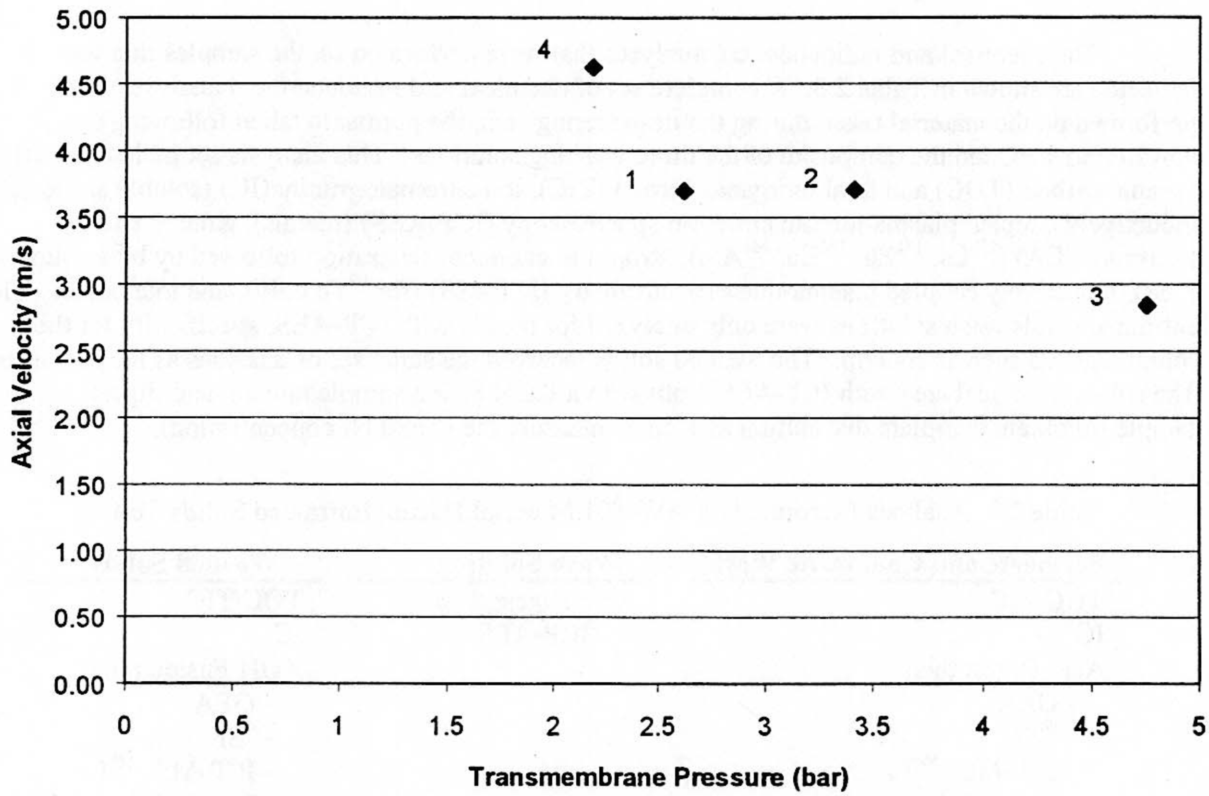


Figure 2.7. Experimental Conditions and Order Used in Testing the Dewatered AW-101 Slurry with the CUF

Following this matrix, the slurry was drained from the CUF. Because of the limitations in sample size, no further dewatering was performed as was originally specified in Test Plan 29953-4. After draining, the CUF was rinsed three times with distilled water to bring the pH back to neutral. One liter of 1 M HNO_3 was then run through the CUF for approximately 30 minutes; then the pump was stopped, and the acid was allowed to sit in the CUF overnight. The acid was then drained, and the CUF was rinsed with distilled water four times to bring the pH back to neutral. During the acid wash and subsequent water flushes, the filtrate flux was measured after 10 minutes of operation. After the membrane had been thoroughly cleaned, water fluxes through the membrane were measured once again at 2, 3.7, and 4.8 bar (30, 55, and 70 psid) and 1, 4.6, and 3.7 m/s, respectively. These pressure drops and velocities were the same as those performed with clean water at the beginning of the study. We should be able to compare the water fluxes at the beginning and the end of the study and determine the cleaning efficiency.

2.4 Dead-End Filtration Experiments

The AW-101 slurry that was drained from the CUF was dead-end filtered with a 0.45-µm nylon filter. The filtering was accomplished within approximately 20 minutes. This filtered material, along with the permeate collected during de-watering, was transferred to the ion exchange work. The filtered solids were washed and filtered three times each with 100 mL of distilled water. Samples of the water from each of the three individual washes as well as a composite of all three washes were taken for chemical and radiochemical analysis.

2.5 Sample Analysis

The chemical and radiochemical analyses that were performed on the samples that were collected are shown in Table 2.3. A complete set of chemical and radiochemical analyses was performed on the material taken during the de-watering step, the permeate taken following the dewatering step, and the composite of the three washing solutions. This analysis set included total organic carbon (TOC) and total inorganic carbon (TIC), ion chromatography (IC) (soluble anions), inductively coupled plasma-atomic emission spectroscopy (ICP-AES) (metals), gamma energy analysis (GEA) (^{137}Cs, ^{155}Eu, ^{156}Eu, ^{241}Am), strontium chemical separation followed by beta counting (^{90}Sr), inductively coupled plasma-mass spectrometry (ICP-MS) (for ^{99}Tc only), and total alpha. The entrained solids wash solutions were only analyzed for metals with ICP-AES, specifically for the soluble metals such as sodium. The washed solids received the same set of analyses as the permeates. The solids were analyzed with ICP-AES, both with a KOH fusion sample and an acid-digested sample (to obtain complete dissolution as well as measure the K and Ni concentration).

Table 2.3 Analysis Performed on AW-101 Material During Entrained Solids Testing

Permeate and Composite Wash	Wash Solution	Washed Solids
TOC/TIC	Acid Digest then	TOC/TIC
IC	- ICP-AES	IC
Acid Digest then		KOH Fusion then
- GEA		- GEA
- ^{90}Sr		- ^{90}Sr
- ICP-MS: ^{99}Tc		- ICP-MS: ^{99}Tc
- Total Alpha		- Total Alpha
- ICP-AES		- ICP-AES
		Acid Digest then
		- ICP-AES

3.0 Experimental Results

3.1 Cross Flow Filtration Results

3.1.1 Testing with AW-101

The as-diluted AW-101 material filtered relatively slowly with an average filtrate flux of 1.25 m^3/m^2/day (0.0213 gpm/ft^2) as compared to the BNFL design goal of 5.9 m^3/m^2/day (0.1 gpm/ft^2). The well mixed slurry was light brown in color while the filtrate appeared a clear yellowish green in color under the hot cell lights. The material did not froth or foam during testing. The slurry reservoir remained fairly well mixed and homogeneous as indicated by the significant movement of the liquid surface in the slurry reservoir.

A sample filtrate fllowrate curve is shown in Figure 3.1. Although the filtrate flowrate was taken every 10 minutes during the hour of each test condition, only the data taken after the first 20 minutes of the run were averaged to obtain an average flux for the test condition. We did this to reduce the effect of the initial high values while still providing sufficient data to create a reasonable average of the equilibrium flux number.

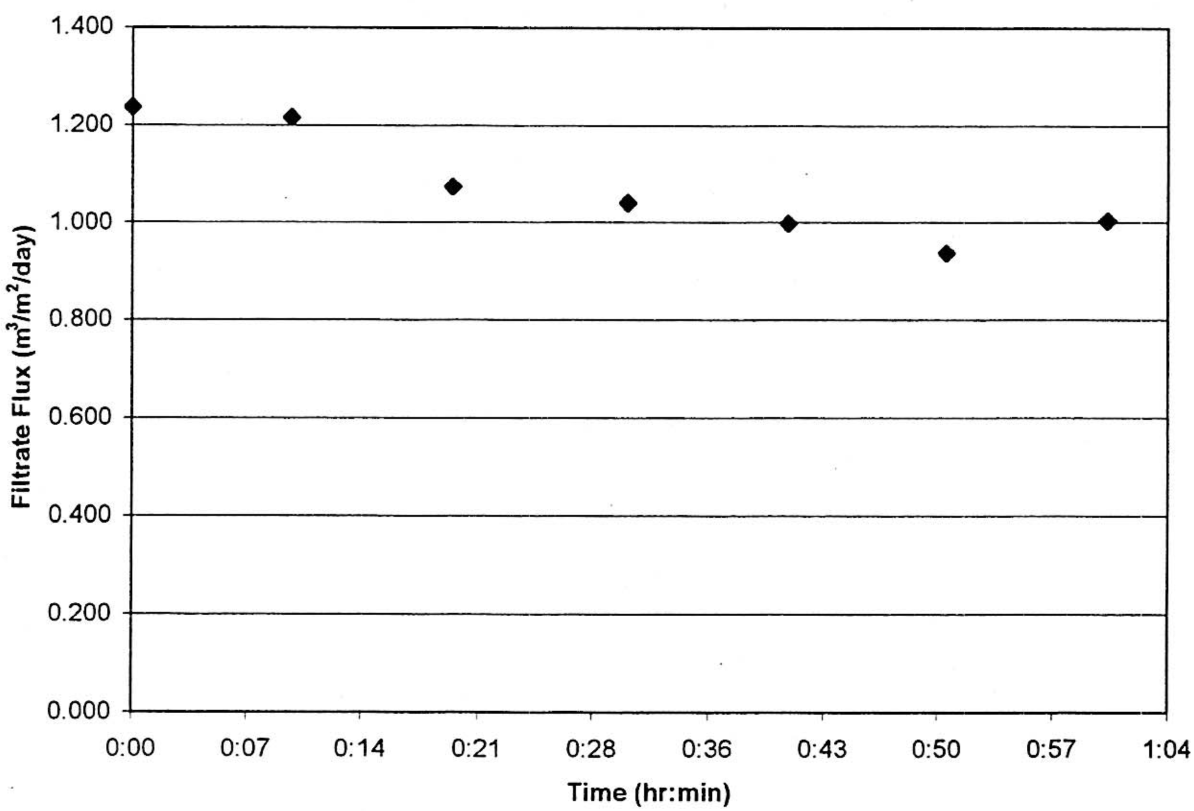


Figure 3.1. Filtrate Flowrate as a Function of Time for Condition 1 with Diluted AW-101 Slurry in the CUF

As mentioned in the previous section, the system was backpulsed twice between each condition. For the first test matrix, these back pulses were performed by pressurizing approximately 50 mL of permeate to 3.43 bar (50 psi) and forcing this liquid back through the filter. A comparison between the initial, average, and final filtrate flux is shown graphically in Figure 3.2. For this first matrix, there is only a 23% average increase in flux due to the back pulsing. For the second test matrix, 50 mL of permeate was pressurized to 5.5 bar (80 psi). In this case, there was a 30% average increase in flux due to back pulsing, although the differences between the two matrices are not statistically significant.

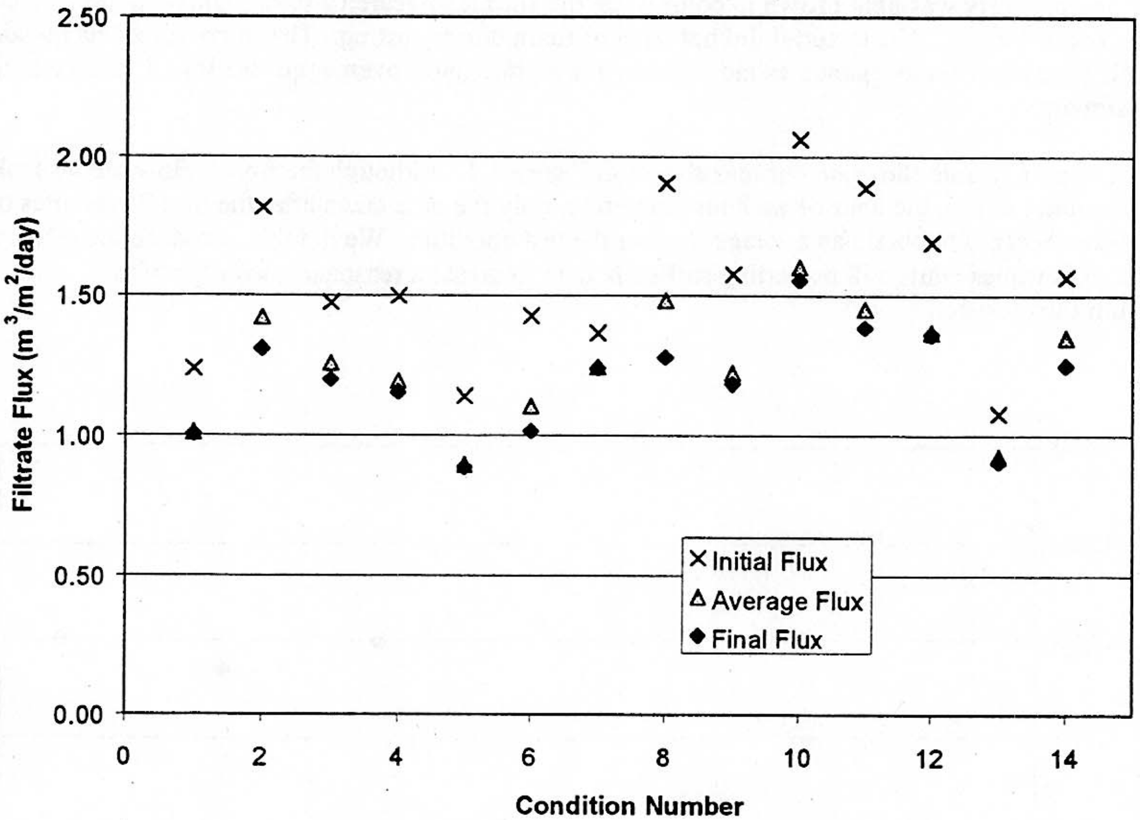


Figure 3.2. Initial, Average, and Final Filtrate Flux for Each of Conditions in the 14 Point Matrix with the Diluted AW-101 Slurry

The filtrate flux results are shown in Figure 3.3 as a function of presssure and velocity. The filtrate values range from a minimum of 0.9 $m^3/m^2/day$ (0.0153 gpm/ft^2) at 1.4 bar (20 psid) to a maximum of 1.6 $m^3/m^2/day$ (0.0273 gpm/ft^2) at 4.5 bar (65 psid). For this filter and range of test conditions, the higher pressures increase the filtrate flux while the velocity does not appear to have a strong effect on the filtrate flux. When the data points at constant velocity are plotted as a function of pressure, a nearly linear relationship appears as shown in Figure 3.4.

The permeability is the filtrate flux divided by the transmembrane pressure. For the low solids-loading matrix, permeabilities range from 0.34 to 0.67 $m^3/m^2/day/bar$ (0.0004 to 0.0008 $gpm/ft^2/psi$). The lower permeabilities are associated with higher pressures, while the higher permeabilities are associated with the lower pressures.

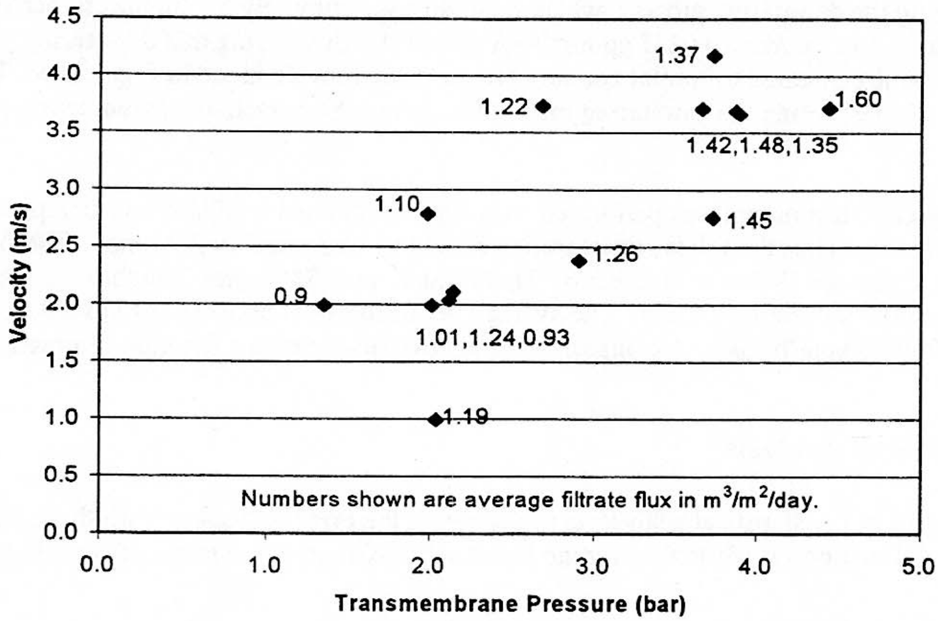


Figure 3.3. Results of the 14 Point Matrix as a Function of Transmembrane Pressure and Velocity. Values next to the points indicate the filtrate flux in $m^3/m^2/day$.

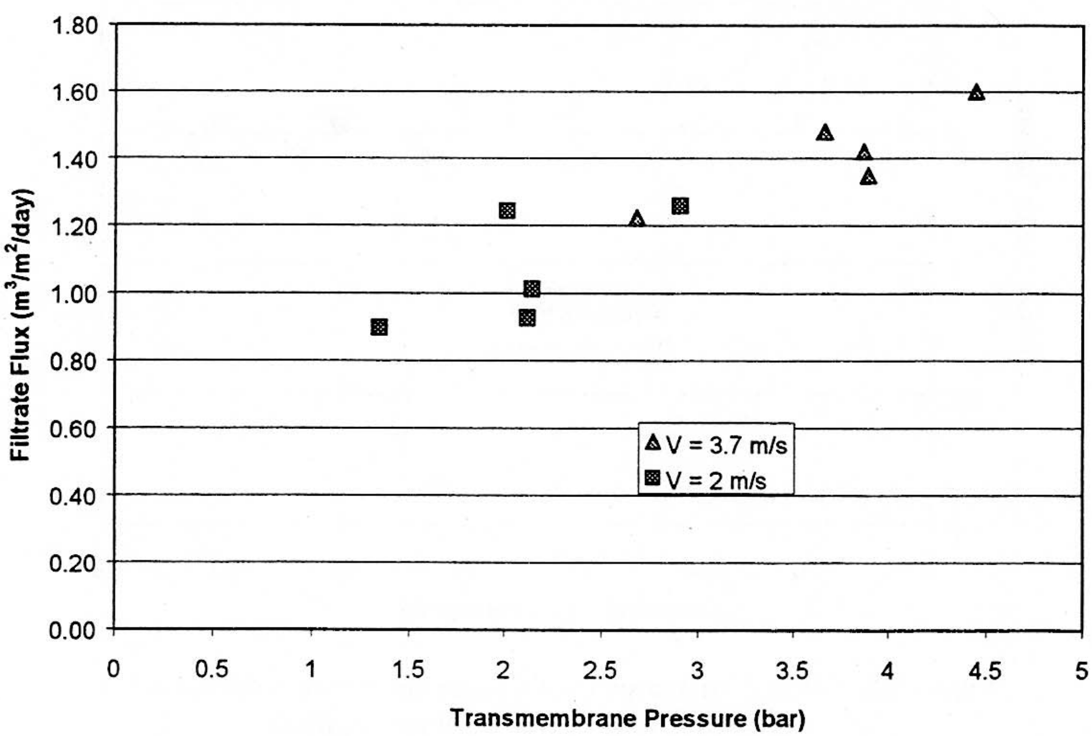


Figure 3.4. Filtrate Flux as a Function of Pressure at Constant Velocity for the Diluted AW-101 Slurry

The solution was dewatered from 2.2 L to 1 L using the optimum conditions of the 14-point matrix. A transmembrane pressure of 4.8 bar (70 psid) and 3.5 m/s axial velocity was selected for this process. During the dewatering process, which required approximately 53 minutes to perform, the filtrate flux averaged 1.51 m^3/m^2/day (0.0257 gpm/ft^2). A plot of the flux during this dewatering process as a function of time is compared to similar conditions during the recycle mode in Figure 3.5. The filtrate flux is consistently lower during the dewatering mode than during the recycle mode indicating possible filter fouling.

The second test matrix was performed with approximately 1 L of slurry as compared to 2.2 L for the first test matrix. Thus the solids concentration should be increased by 2.2 times. The filtrate-flux results of these tests are shown in Figure 3.6. These results are 52% lower than those at similar conditions with the low solids loading. The average permeability is between 0.17 and 0.26 m^3/m^2/day/bar (0.0002 and 0.0003 gpm/ft^2/psi). A comparison of the two matrices as a function of pressure is shown in Figure 3.7.

3.1.2 Statistical Analysis

The goal of the statistical analysis is to determine the error associated with these tests and to develop a model that best predicts the average flux for AW-101 over the range of conditions studied.

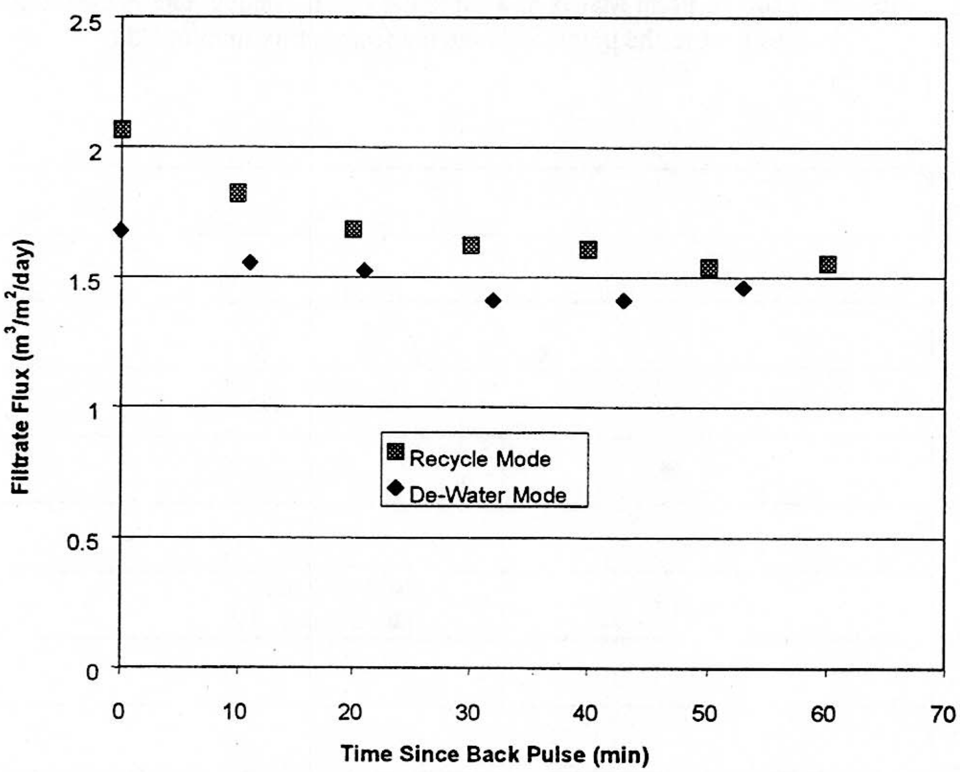


Figure 3.5. Filtrate Flux Versus Time Comparison Between the Recycle Mode (Condition 10) and the De-Watering Mode

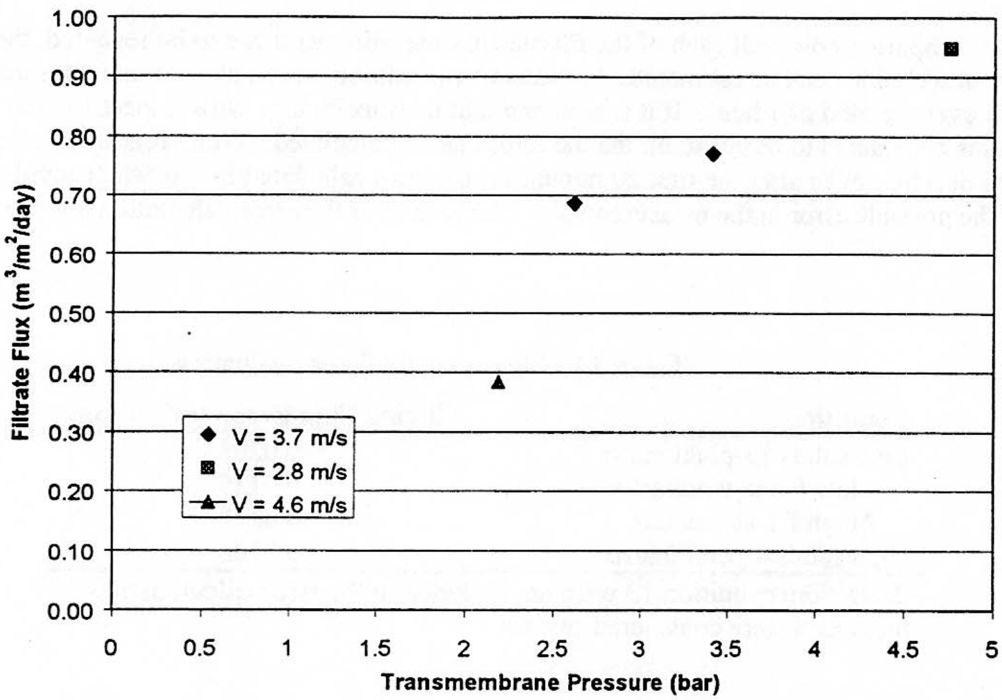


Figure 3.6. Filtrate Flux as a Function of Pressure for the De-Watered AW-101 Slurry

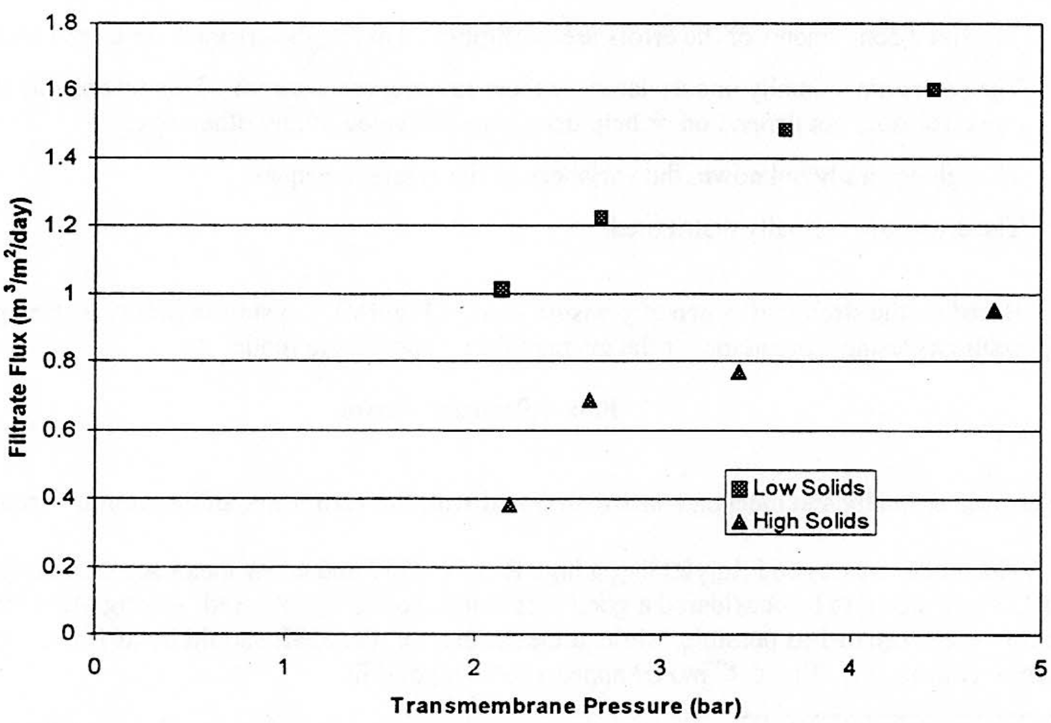


Figure 3.7. Comparison of Filtrate Flux Between the Diluted and De-Watered AW-101 Slurry as a Function of Pressure

By comparing how well each of the filtrate-flux measurements are to be repeated, the error of the measurement technique can be estimated. For each test condition, seven measurements were taken at the same point over a period of 1 hour. If it is assumed that the flux change with respect to time after the first 20 minutes is considered to be constant, the the error can be calculated. While it is true that the flux does continue to decrease even after the first 20 minutes, the values calculated in this way provide an upper bound on the possible error in the measurements. The results of the error calculation are provided in Table 3.1.[1]

Table 3.1. Measurement Error Evaluation

Conditions	Filtrate Flux Error ($m^3/m^2/day$)
Low solids 13-point matrix[a]	0.0208
6 low P and v points[a]	0.0135
7 high P and v points	0.0272
High solids 4 point matrix	0.0102

[a]Data from condition 13 were not included in the error calculation as these data were considered suspect.

A statistical model can be used to understand the important factors, predict filtrate flux performance, and eliminate effects particular to the CUF test and equipment that would not be seen in actual operation (i.e., run number). Three possible factors were evaluated: velocity, pressure, time (run order), or any combination of those variables. The following assumptions are used for fitting these models:

- The fixed components of the errors are negligible. That is, the errors have a zero mean.
- The errors are mutually uncorrelated, or their covariances are zero. This means that the value of one error does not depend on or help determine the value of any other error.
- Though generally unknown, the variances of the errors are equal.
- The errors are normally distributed.

Based on the strong influence of pressure seen in Figure 3.8, a simple model was employed first using pressure as a single predictor for the average flux. The simple model is

$$\text{Flux} = \text{Pressure} + \text{error} \tag{3.1}$$

where error is normally and independently distributed with the zero mean and common variance σ^2.

The model was a good fit, yielding a high R^2 of 0.8557 and a low mean squared error (MSE) of 0.00613. For a model to be considered a good prediction model, it is desired, among other things, that the R^2 should be as close to 1 as possible, while at the same time, the MSE should be as low as possible. From these criteria, this "first cut" model appears to be a good fit.

[1] The calculation is done by subtracting the mean of the data points taken at the same location (replicates) from each raw measurement, squaring those differences, adding them up, and dividing that total by the number of degrees of freedom.

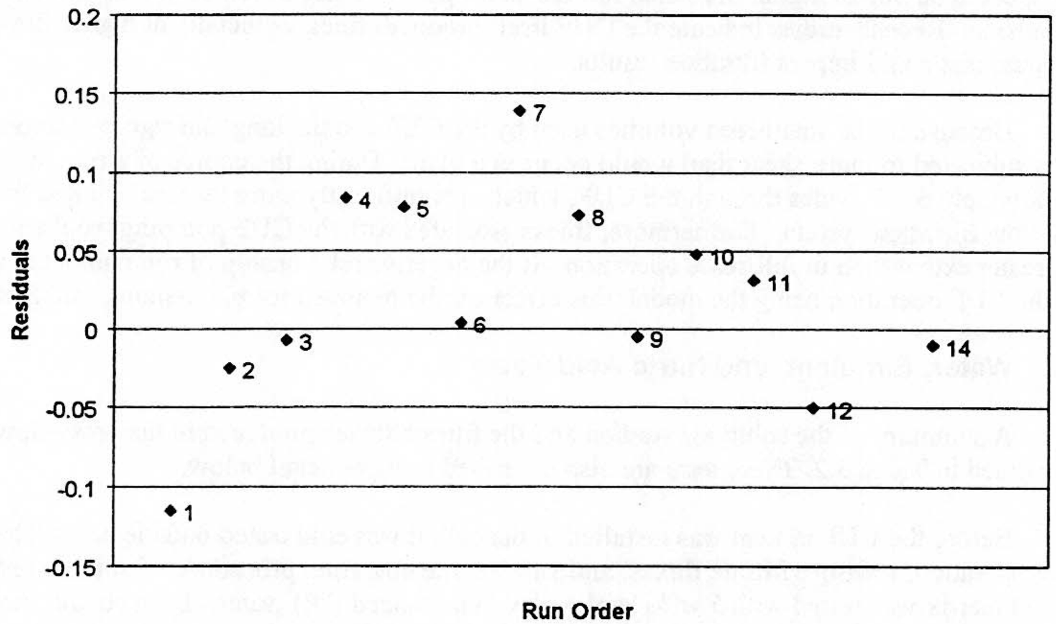


Figure 3.8. Residuals as a Function of Run Order from the Statistical Model Using Pressure as the Only Experimental Factor

As can be seen from Figure 3.8, the model yields residuals that, when plotted against the run order, look quadratic. The plot of the residuals gradually increases as the run order increases in the first half of the plot, while the residuals gradually decrease as the run order increases during the second half of the plot, yielding an overall quadratic effect. From this plot, it can be expected that the run order will have a significant impact to the fit of the model, and that impact will be quadratic in nature. It was thus included in a more extensive model.

A selection process was employed to determine the best model across the data for the low solids loading matrix (13 points), and the following model was chosen:

$$\text{Flux} = 0.544 + 0.247\ (\text{Pressure}) - 0.056\ (\text{Velocity}) + 0.063\ (\text{Run}) - 0.004\ (\text{Run}^2) \tag{3.2}$$

This model yielded an $R^2 = 0.9678$, and has an MSE= 0.0018. In this case, velocity has a negative relationship and the pressure a positive relationship with the average flux. The inverse velocity relationship seen here is surprising, but has occurred with previous CUF studies using C-106 sludge at 0.05 wt% solids loading (see Geeting and Reynolds 1997). This trend is believed to result from higher velocities pulling larger particles away from the filter surface, thus allowing the smaller particles to form a more impermeable cake on the filter surface.

The run number has a positive relationship for the first 7 points and then a negative relationship for the remaining points. Interestingly, the first 7 points correspond primarily to the low pressure and velocity matrix, and the following 7 points correspond to the high pressure and velocity matrix. The consistent reduction in filter permeability at the high pressure and velocity suggests possible particle deagglomeration or filter fouling not found at the lower conditions. The particle de-agglomeration would result in smaller particles that would form a more impermeable cake on the filter surface. The filter fouling could be due to higher pressures forcing small particles into the filter that cannot be removed by backpulsing. Recent studies indicate the CUF itself produces fines, especially at higher flows and pressures, that could impact filtration results.

Because of the small feed volumes used by the CUF and the long and rigorous testing matrix, the feed is subjected to more shear than would occur in a plant. During the course of a run, the feed makes approximately 6800 cycles through the CUF, which is significantly more than envisioned for a full-scale cross-flow filtration system. Furthermore, fines associated with the CUF pumping would also concentrate to a greater extent than in full-scale operation. If the negative relationship of run number is associated with the CUF operation using the model, this effect can be removed for plant-sizing calculations.

3.1.3 Water, Simulant, and Nitric Acid Tests

A summary of the solutions studied and the filtrate fluxes produced in the cross-flow filter are summarized in Table 3.2. These tests are also described in more detail below.

Before the CUF system was installed in the cell, it was cold tested outside the cell to ensure proper operation, measure filtrate fluxes, and validate the operating procedure. For these tests, the entire 14-point matrix was tested with 5 wt% kaolin clay in deionized (DI) water. Each condition was evaluated for 1 hour. As with the actual AW-101 material, the highest fluxes occurred at the highest pressures. Fluxes ranged from 2.3 to 10.3 $m^3/m^2/day$ (0.039 to 0.175 gpm/ft^2). However, unlike the actual AW-101 testing, increasing the axial velocity did positively impact the filtrate flux, especially at lower velocities (between 1 to 2 m/s).

Table 3.2. Summary of Filtrate Flux Results for both Radioactive and Non-Radioactive Tests

	Filtrate Flux ($m^3/m^2/day$)		
	Transmembrane Pressure (bar)		
Solution Tested	**2.0**	**3.7**	**4.9**
Kaolin Clay/Water	5.1	9.4	10.3
AW-101 Simulant	nm	1.8	nm
Nitric Acid	nm	nm	nm
Clean Water	3.9	7.9	10.4
AW-101 Actual	1.1	1.4	1.6
Nitric Acid	15.0	nm	44.0
Clean Water	3.8	4.8	4.0

nm = not measured

After running the CUF with kaolin clay, a simulated 5 M chemical simulant of AW-101 was tested in the CUF. The recipe for this simulant is found in Appendix D. Only a transmembrane pressure of 3.8 bar (55 psid) was tested with an axial velocity of 3.7 m/s. The average from 20 to 60 minutes of operation was 1.80 $m^3/m^2/day$ (0.031 gpm/ft^2). This result compares very favorably to the average taken at 3.8 bar (55 psid) with the actual AW-101 of 1.43 $m^3/m^2/day$ (0.0244 gpm/ft^2).

After running the AW-101 simulant, the system was rinsed several times with filtered DI water and then soaked overnight with 1 M HNO_3. The filtrate flux was quite high during this nitric acid cleaning, but was not measured. The system was rinsed with DI water, installed into the hot cell, and tested with water. The actual AW-101 test was then performed.

After the test with actual AW-101, the system was cleaned with 1 L of 1 M HNO_3. Once again, the filtrate flux was very high. The filtrate flux was measured this time at 2.1 and 5.0 bar (31 and 73 psi) transmembrane pressure. The fluxes achieved were 15 and 44 $m^3/m^2/day$ (0.256 and 0.75 gpm/ft^2), respectively. These values are considerably higher than those seen either before or after actual waste processing when measured with clean water.

Before and after the actual AW-101 test, once the CUF was reassembled in the cell, clean-water flux measurements were performed. Three pressures were tested, each for 20 minutes: 2.0, 3.7, and 4.9 bar (30, 55, and 70 psi) and 1.0, 4.6, and 3.8 m/s, respectively. The results of these two tests are shown in Figure 3.9. The filtrate fluxes for initial and final conditions at 2 bar were nearly identical. However, the filtrate fluxes for the final conditions at TMP 3.7 and 4.9 bar are much lower than the filtrate fluxes for the initial conditions. The fact that the flux was identical at low pressures and velocities, but not at higher pressures and velocities, seemed to indicate that filter fouling is occurring during the course of the test rather than being residual from incomplete cleaning. More recent experiments with the CUF have shown that the progressive cavity pump did indeed produce particulate matter that caused a reduction in filtrate flux, especially at high axial velocity and transmembrane pressure.

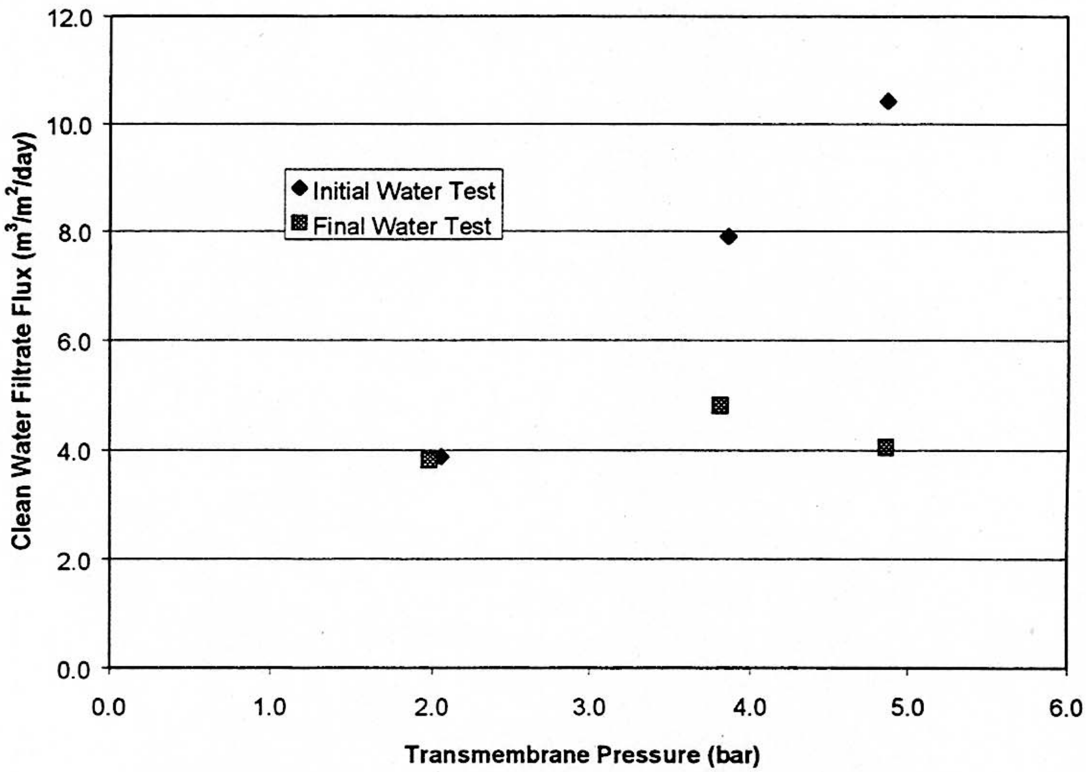


Figure 3.9. Clean Water Flux Test Results Before and After Testing with AW-101 (filter was cleaned with 1M HNO_3 before each clean-water flux test.)

4.0 Chemical and Radiochemical Properties

Nine distinct samples were analyzed for their chemical and radiochemical properties. These samples are described below. After the as-received AW-101 material was diluted to 6.5 M Na, 68 mL was submitted for analysis (See Figure 2.4). This material was centrifuged and the solids and liquids analyzed separately. These analyses were not performed as part of this study, but are averaged values taken from Urie et al. (1999). After performing the 14-point matrix in the cross-flow filter, the solution was dewatered. A sample of the composited permeate and a sample of the final permeate at the end of dewatering were taken and submitted for analysis (see Figure 2.5). At the completion of the crossflow filtration experiments, the CUF was drained, and the solids were washed three times with water in a dead-end filter. Each of these washes, the solids remaining, and a composite of the wash water were also submitted for analysis.

The results of these analyses are shown in Tables 4.1 through 4.4. As seen in Table 4.1, there are very few differences between the initial centrifuged supernatant, average permeate, and final permeate analyte concentrations. The uncertainty in the analytical results makes differences between the filtered and centrifuged solutions difficult to see. There does appear to be a decrease in the concentration from the initial centrifuged supernatant to the crossflow filtration permeate. Approximately 7% of the decrease is due to dilution with the 150 mL of DI water left in the CUF after clean water testing.

As seen in Table 4.1, most radionuclides are below the detection level. The high concentration of cesium in the supernatant prevents a lower detection level for these minor radiochemical constituents. Thus, changes in concentration of total alpha, ^{90}Sr, and ^{241}Am, which would normally be removed by solid/liquid separation in alkaline solutions, cannot be detected.

Table 4.2 presents the concentrations of the non-radioactive components of the initial centrifuged and the final damp solids collected on a filter. This filter contained 5.5 g of wet solids drained from AW-101. A small fraction of these solids was dried and found to be 49% water. The final damp solids contain four major components, which are Si, Al, Na, and U. By comparing the concentrations of the initial centrifuged solids and the final washed solids, we can see the components that may have been concentrated in the supernatant or in the solids. Based on the results in Table 4.2, components that are neither concentrated nor diluted more than would be expected due to the removal of the water and soluble components during washing and filtration appear to have a ratio of 10 to 11. Iron and silicon have values higher than 11, indicating that they may not be separated from the supernatant by centrifugation, but may have been removed with filtration. K, Na, P, and several of the anions have values considerably lower than 11. These soluble materials were probably removed from the solids during the wash steps.

Similar to Table 4.2, Table 4.3 presents the concentrations of the radioactive components of the initial centrifuged and the final damp solids. It also provides data on the composite wash solution composition. Similar to the K, Na, and P, cesium was removed from the solids during washing; the ratio of cesium in the initial centrifuged solids to the final washed solids is considerably less than 10 to 11. The alpha emitters and ^{90}Sr, in contrast, were not removed.

The washed solids contain 5.8-μ Ci/g total alpha and 2.8-μ Ci/g ^{241}Am. At these concentrations, the solids would be considered transuranic, based on the NRC Class C limit of > 100-n Ci/g and would require disposal with the HLW stream rather than the LAW stream (10 CFR 61). Similar to the alpha isotopes, the strontium concentrated in the solids while cesium and technetium did not.

Table 4.1. Concentration of Components in the Initial Centrifuged Supernatant and Filtered Permeate from the CUF

Analyte	Initial Centrifuged Supernatant Conc., µg/mL	Average Permeate Conc., µg/mL	Final Permeate Conc., µg/mL
Al	16350	15200	15600
Ba	< 1	< 1	< 1
Ca	< 32	9	9
Cd	< 2	2	2
Co	< 6	< 6	< 6
Cr	56	54	55
Cu	< 3	5.4	5.7
Fe	5	10	10
K	23000	21100	21750
La	< 6	< 6	< 6
Mg	< 13	< 13	< 13
Mn	< 6	< 6	< 6
Mo	< 6	< 6	< 6
Na	148500	139000	135500
Nd	< 13	< 13	< 13
Ni	4.8	5.2	5.3
P	323	302	306
Pb	41	36	35
Si	130	84	130
Ti	< 3	< 3	< 3
Zr	8	6.1	6.0
Zn	14	7.3	7.5
TIC	2155	1780	1882
TOC	1560	1750	1955
Cl	3450	3300	3400
F	845	1200	1300
NO_3^-	128000	112000	112500
NO_2^-	65100	56500	56550
$SO4^{-2}$	1900	1300	1350
$PO4^{-3}$	2050	910	1155
$C_2O_4^{2-}$	< 790	520	515
Component	**µCi/g**	**µCi/g**	**µCi/g**
Total Alpha	< 8.E-03	< 7.E-04	< 8.E-04
^{90}Sr	< 4.E-01	< 3.E-01	< 3.E-01
^{99}Tc	5 (µg/g)	5.1 (µg/g)	5.3 (µg/g)
^{137}Cs	1.8E+02	1.8E+02	1.7E+02
^{134}Cs	4.E-02	4.E-02	3.E-02
^{60}Co	< 8.E-03	< 2.E-03	< 2.E-03
^{154}Eu	< 3.E-02	< 1.E-02	< 1.E-02
^{155}Eu	< 3.E-01	< 1.E-01	< 1.E-01
^{241}Am	< 3.E-01	< 1.E-01	< 1.E-01

Table 4.2. Concentration of Non-Radioactive Components in the Initial and Final Entrained Solids

Analyte	Initial Centrifuged Solids Conc., µg/g	Damp Solids Conc., µg/g	Ratio: Damp Solids Initial Solids
Al	14500	58833	4.1
Ba	25	275	11.0
Ca	1700	13167	7.7
Cd	34.5	376	10.9
Co	< 44	62	N/A⁺
Cr	1620	15633	9.7
Cu	< 23	217	N/A
Fe	1390	23900	17.2
K	17200	1160	0.1
La	28	304	10.9
Mg	314	3403	10.8
Mn	1415	14400	10.2
Mo	< 8	27	N/A
Na	127500	56567	0.4
Nd	29	340	11.7
Ni	215	2093	9.7
P	501	277	0.6
Pb	120	1150	9.6
Si	2200	62600	28.5
Ti	8	86	11.3
U	5400	54200	10.0
Zr	351	3650	10.4
Zn	16	160	10.0
TIC	27500	6306	0.2
TOC	20100	16400	0.8
Cl	2700	< 120	N/A
F	1600	< 120	N/A
NO_3^-	80900	4800	0.1
NO_2^-	41500	407	0.0
$SO4^{-2}$	< 2300	447	N/A
$PO4^{-3}$	< 2300	2517	N/A
$C_2O_4^{2-}$	42000	6300	0.2

⁺ N/A = not applicable, one or more of solids concentrations are below detection limits.

Table 4.3. Concentration of Radioactive Components in the Composite Wash Solution and the Initial and Final Entrained Solids

Component	Initial Centrifuged Solids Conc., μCi/g	Composite Wash Conc., μCi/g	Damp Solids Conc., μCi/g	Ratio: Damp Solids Initial Solids
Total Alpha	5.1E-01	< 4.E-05	5.8E+00	11.4
^{90}Sr	1.5E+02	1.2E-02	1.7E+03	11.1
^{99}Tc	2.09E+01 (μg/g)	2.4E-01 (μg/g)	1.62E+02 (μg/g)	7.8
^{137}Cs	1.9E+02	4.3E+00	4.0E+02	2.1
^{134}Cs	< 8.E-02	8.5E-04	9.4E-02	NA
^{60}Co	< 7.E-02	2.5E-04	4.3E-01	NA
^{154}Eu	< 2.E-01	< 1.E-04	3.1E+00	NA
^{155}Eu	< 5.E-01	< 1.5E-03	3.5E+00	NA
^{241}Am	2.5E-01	< 1.5E-03	2.8E+00	11.1

$^{+}$ N/A = not applicable, one or more of solids concentrations are below detection limits.

Table 4.4 presents the concentrations of each 100-mL wash using a 0.45-μ dead-end filter along with a composite of all three washes. As would be expected, with each subsequent wash, the concentration of soluble species, such as Al, Cr, K, P, and Na, decreased.

The privatization contract requires that the slurry containing entrained solids be returned to DOE with less than 60 g of Na/kg of dry entrained solids. At these low-solids concentrations, this requires significant washing for sodium removal. During the washing process, there were approximately 2.8 g of dry solids. The third wash removed 0.23 g of Na from these solids. Assuming the third wash was returned with the entrained solids to DOE, this solution would contain 82 g sodium per kg of entrained solids. This is above the current DOE limit.

Based the ratio of sodium in the supernatant to sodium in the first wash and assuming the concentration is by dilution alone, a 100-mL wash solution should decrease the sodium concentration in each subsequent wash by ten fold. However, the second wash decreased the sodium concentration by only three fold and the third wash by only 2 fold. This reduction in sodium removal with each subsequent wash seems to indicate the presence of some slightly soluble sodium salt that is limiting the rate of sodium removal. Based on the data, this salt is believed to be sodium oxalate. The oxalate concentration in the permeate is approximately 500 μg/mL. The composite wash solution, in contrast, is nearly 14 times higher, at 6800 μg/mL oxalate. These results are also verified by the high TOC measurements of the composite wash solution. Thus, as the sodium concentration decreased, more of the sparingly soluble sodium oxalate was dissolved from the solids. This in turn resulted in higher sodium concentrations in the later washes than would be predicted by dilution alone.

Table 4.4. Composition of the Entrained Solids Wash Solutions, Individually and as a Composite

Analyte	First Wash Conc., µg/mL	Second Wash Conc., µg/mL	Third Wash Conc., µg/mL	Composite Wash Conc., µg/mL
Al	1010	31	18.8	253
Ba	< 1	< 1	< 1	< 1
Ca	< 32	< 6	< 6	1.3
Cd	< 3	< 1	< 1	< 1
Co	< 6	< 1	< 1	< 1
Cr	5	4	2.58	3.3
Cu	< 3	< 1	< 1	< 1
Fe	< 3	< 1	< 1	0.2
K	1510	24	< 52	363
La	< 6	< 1	< 1	< 1
Mg	< 13	< 3	< 3	< 3
Mn	< 6	< 1	< 1	< 1
Mo	< 6	< 1	< 1	< 1
Na	13900	4130	2340	5560
Nd	< 13	< 3	< 3	< 3
Ni	< 3	< 1	< 1	< 1
P	23	1	< 3	6.3
Pb	< 13	< 3	< 3	1.9
Si	27	18	25	18
Ti	< 3	< 1	< 1	< 1
U	< 260	< 52	< 52	< 52
Zr	< 6	< 1	< 1	< 1
Zn	< 6	< 1	< 1	< 1
TIC	NM*	NM	NM	87
TOC	NM	NM	NM	2310
Cl	NM	NM	NM	52
F	NM	NM	NM	30
NO_3^-	NM	NM	NM	1800
NO_2^-	NM	NM	NM	890
SO_4^{-2}	NM	NM	NM	47
PO_4^{-3}	NM	NM	NM	50
$C_2O_4^{2-}$	NM	NM	NM	6800

* NM = not measured

5.0 Physical Properties Testing and Results

Two AW-101 slurry samples were analyzed for density of the bulk slurries, settled solids, settled supernatant, centrifuged solids, and centrifuged supernatant. The first "diluted slurry" was taken following dilution of the as-received material (See Figure 2.4). The second "dewatered slurry" was taken from the crossflow filter system after dewatering from 2200 mL to 1000 mL (See Figure 2.5).

A known mass of each slurry was placed in duplicate in volume-graduated centrifuge cones. The duplicates were then allowed to settle for 3 days. The total mass (M_B) and volume (V_B) of the settled solids were recorded, and the density of the bulk slurry was calculated ($D_B=M_B/V_B$). In addition, the volume of the settled solids (V_{ss}) and the volume of the settled supernatant (V_{sl}) were recorded. The vol% settled solids were then calculated ($Vol\%_{ss}=V_{ss}/V_B \times 100\%$). A portion of the settled supernatant was then transferred to a graduated cylinder, and its mass (M_{slb}) and volume (V_{slb}) were recorded. Using these data, the density of the settled supernatant was calculated ($D_{sl}=M_{slb}/V_{slb}$).

Since all of the settled supernatant could not be removed from the centrifuge cone without disturbing the settled solids, the mass of the settled solids (M_{ss}) could not be measured directly. Therefore, the mass of the settled solids was calculated. This was done by first calculating the mass of the settled supernatant in the centrifuge cone using the measured supernatant density and volume ($M_{sl} = D_{sl} \times V_{sl}$) and then subtracting this mass for the mass of the bulk slurry to get the mass of the settled solids ($M_{ss}=M_B-M_{sl}$). The density of the settled solids was then calculated ($D_{ss}=M_{ss}/V_{ss}$) as well as the wt% settled solids ($Wt\%_{ss}=M_{ss}/M_B \times 100\%$).

The settled supernatant was then added back to the centrifuge cones and centrifuged at approximately 1000 times the force of gravity for 1 hour. All of the centrifuged supernatant was then transferred to a graduated cylinder, and its mass (M_{cl}) and volume (V_{cl}) were recorded. The density was calculated ($D_{cl}=M_{cl}/V_{cl}$). The mass (M_{cs}) and volume (V_{cs}) of the centrifuged solids were then recorded, and the density was calculated ($D_{cs}=M_{cs}/V_{cs}$). In addition, the wt% centrifuged solids ($Wt\%_{cs}=M_{cs}/M_B \times 100\%$), and vol% centrifuged solids ($Vol\%_{cl}=V_{cl}/V_B \times 100\%$) were also calculated.

The centrifuged solids and supernatants were then each dried at 105°C for 24 hours. The mass of the dried centrifuged supernatant (M_{dcl}) and dried centrifuged solids (M_{dcs}) was then measured. Assuming all mass lost during the drying process is water and not another volatile component, the wt% total solids in the bulk slurry was calculated (wt% total solids = $(M_{dcs}+M_{dcl})/(M_{cs}+M_{cl}) \times 100\%$).

An additional calculation was performed to determine the wt% solids in the samples, excluding all interstitial liquid (wt% undissolved solids). This wt% undissolved solids can also be thought of as the solids left if all the supernatant could be removed from the bulk slurry. The following equation was used:

$$Wt\%\ undissolved\ solids = \left(1 - \frac{1-\dfrac{M_{dsc}}{M_{cs}}}{1-\dfrac{M_{dcl}}{M_{cl}}}\right) \times \frac{M_{cs}}{M_B} \times 100\% \qquad (5.1)$$

This calculation assumes 1) that the supernatant above the centrifuged solids and the interstitial liquid surrounding the centrifuged solids have the same composition and 2) that all mass loss during the drying of the centrifuged solids is water loss from interstitial liquid.

The density results are listed in Table 5.1. The weight percent (wt%) and volume percent (vol%) settled solids, wt% and vol% centrifuged solids, and wt% total solids were measured for these samples as well. The wt% and vol% solids results are listed in Table 5.2.

The results in Table 5.1 suggest the density of the liquid did not vary by more than 3% before and after the dewatering step. This small decrease in liquid density is probably caused by the 150 g of water left in the CUF after clean water flux testing. An average of the diluted feed and dewatered slurry was calculated at the bottom of Table 5.1. Since there were only sufficient solids to perform density calculations on the dewatered samples, the average solids-density data are just for the dewatered slurry.

Table 5.1. Density Measurement for Samples of AW-101 Diluted Slurry Feed and Dewatered Slurry

	Density, g/mL				
	Slurry	**Settled Solids**	**Settled Supernatant**	**Centrifuged Solids**	**Centrifuged Supernatant**
Diluted Slurry Feed	1.30	NA	1.28	NA	1.311
Diluted Slurry Feed Duplicate	1.33	NA	1.28	NA	1.308
Diluted Slurry Feed Average	1.31	NA	1.28	NA	1.310
Relative Percent Difference	2.0%	NA	0%	NA	0.2%
Dewatered Slurry	1.30	1.41	1.30	1.55	1.290
Dewatered Slurry Duplicate	1.30	1.63	1.30	1.60	1.270
Dewatered Average	1.30	1.52	1.30	1.58	1.280
Relative Percent Difference	0%	14.4%	0%	3.4%	1.6%
AW-101 Average	1.31	1.52*	1.29	1.58*	1.295

NA, insufficient solids

* Only includes the Dewatered Slurry

The results of the calculation in Equation 5.1 are listed in Table 5.3 along with the wt% dried residue from the centrifuged solids (Solids Residue=$M_{cs}/M_{dcs} \times 100\%$) and dried centrifuged supernatant (Supernatant Residue= $M_{dsl}/M_{sl} \times 100\%$). Table 5.3 shows that the wt% undissolved solids is negative or nearly 0 and that the wt% residual solids in the centrifuged liquid is higher than in the wt% residual solids in the centrifuged solids (i.e., the centrifuged solids contain more water than the supernatant). Therefore, one or both of the two of the original assumptions above is wrong. Since the solids and liquids were homogenized both before and after the dewatering step, it is almost certain that the interstitial liquid and supernatant have the same composition. Therefore, it is likely that some of the mass loss from the centrifuged solids was not water loss from interstitial liquid. This could have been loss of a volatile constituent other than water or the loss of waters of hydration associated with the solids.

Table 5.2. Wt% and Vol% Solids Data for AW-101 Diluted Feed and Dewatered Slurry Samples

	Wt% Settled	Wt% Centrifuged	Vol% Settled	Vol% Centrifuged	Wt% Total
Diluted Slurry Feed	5.3	1.8	6.1	2.0	38.3
Diluted Slurry Feed Duplicate	7.3	2.5	6.0	1.4	39.7
Diluted Slurry Feed Average	6.3	2.1	6.1	1.7	39.0
Relative Percent Difference	31.8	31.4	1.5	37.8	3.6
Dewatered Slurry	9.9	3.1	9.1	2.6	36.5
Dewatered Slurry Duplicate	11.5	3.0	9.2	2.5	37.3
Dewatered Slurry Average	10.7	3.0	9.2	2.5	36.9
Relative Percent Difference	15.5	0.6	1.3	3.8	2.2

Table 5.3. Results of Wt% Residual Solids and Undissolved Solids Calculation Following Drying at 105°C for 24 Hours

Sample	Wt% Residual Centrifuged Solids	Wt% Residual Centrifuged Supernatant	Wt% Undissolved Solids
Diluted Slurry Feed	29.1	40.2	-0.3
Diluted Slurry Feed Duplicate	46.1*	39.9	0.3*
Dewatered Slurry	32.9	38.1	-0.3
Dewatered Slurry Duplicate	31.8	37.9	-0.3
Average	31.3	39.0	-0.3

* Not included in average

This is supported by the observation that the wt% total solids in Table 5.2 is higher for the diluted feed (39.0 wt%) compared to the dewatered slurry (36.9 wt%). Given that the dewatered slurry contained a higher wt% centrifuged solids (3.0 wt%) compared to the diluted feed (2.1 wt%), the only explanation for these data is that the solids contain a volatile material not associated with the interstitial liquid and that this is most likely waters of hydration associated with the solids. It is also possible that the high salts of the centrifuged supernatant retained or reabsorbed water during the heating, cooling, and weighing process. In any case, it appears that this technique was not adequate to measure the low solids concentration in a high-salt solution.

5.1 Rheological and Flow Properties

The AW-101 diluted feed and dewatered slurry were analyzed for shear stress as a function of shear rate from approximately 0.1 to 300 s^{-1} according to procedure 29953-010. The AW-101 diluted feed was analyzed using the Bohlin CS viscometer modified for glovebox operations. Concentric cylinders with a 25-mm-diameter inner cylinder and a "small sample cell" outer cylinder were used as the measuring geometries. The dewatered slurry was analyzed using a Haake M5 measuring head modified for hot cell operations. An MVI measuring geometry was used on the Haake. Both the diluted feed and dewatered slurry were analyzed in duplicate at 25°C. A 49.9 cP standard, Brookfield lot 102298, was used to check the calibration of both instruments before samples were analyzed.

The samples were stirred to combine the separated liquid and solid layers before testing. Shear stress as a function of shear-rate data was obtained by measuring the shear stress produced at a specific shear rate. The shear rate was gradually increased from approximately 0.1 to 300 s^{-1}, generating the increasing shear-rate curve, and then back down to 0.1 s^{-1}, generating the decreasing curve. For the dewatered slurry, the shear rate was analyzed again with the same sample still in the instrument. A difference between the first and second run would indicate potentially unusual behavior in the samples, including (but not limited to) settling of the solids within the instrument, the sample being affected by shearing in the instrument, or water loss through evaporation. In all cases, the first and second runs were virtually identical. The sample cup was then cleaned, and a duplicate sample was analyzed using the same parameters.

Rheograms for AW-101 diluted slurry feed and dewatered slurry are presented in Figures 5.1 and 5.2. Figure 5.1 provides a plot of shear stress versus shear rate for both the diluted feed and dewatered slurry. Figure 5.2 gives the viscosity as a function of shear rate for the same runs. The standards and duplicates are presented in figures in Appendix F. As seen in the diluted feed sample (shear rate of 0 to 1000 s^{-1}), there is a nearly linear relationship between shear stress and shear rate over the shear-rate range examined and no detectable yield stress. This is referred to as Newtonian behavior. The Newtonian behavior seen here is because the concentration of solids is so small and insignificant that a non-Newtonian feature of particulate/fluid suspensions is not produced. The viscosity was nearly constant between 5 to 7 cP (50 to 650 s^{-1}) over the shear-rate range examined.

The viscosity of the dewatered slurry was between 5 to 10 cP (50 to 300 s^{-1}). The dewatered slurry exhibited some deviation from Newtonian character: a slight shear-thinning or pseudoplastic behavior, especially at shear rates less than 100 s^{-1}. This behavior results from particle and fluid interactions. A shear-thinning or pseudoplastic behavior is a common feature of low solids content suspensions.

Given the small vol% settled solids in both the diluted feed (6.1%) and the dewatered feed (9.2%), it is not surprising that the two samples have similar viscosities. For both slurries, at shear rates greater than 50 s^{-1}, the viscosity is due to the high salt concentration rather than to the influence of solids. For example, a similar solution of 7 M NaOH has a viscosity of 6.1 cP without any solids present (Weast 1984).

5.2 AW-101 Slurry Particle-Size Distribution Measurements

The particle-size distribution (PSD) of the AW-101 diluted feed (sample 101-AW-PSD) and the dewatered slurry (sample CUF-101-AW-005) is described below. The first sample was diluted AW-101 waste that was fed into the CUF (diluted feed). The second sample was the slurry that was pumped in the recirculating loop of the CUF during 14 hours of test matrix and then dewatered to 45% of its original volume (dewatered slurry).

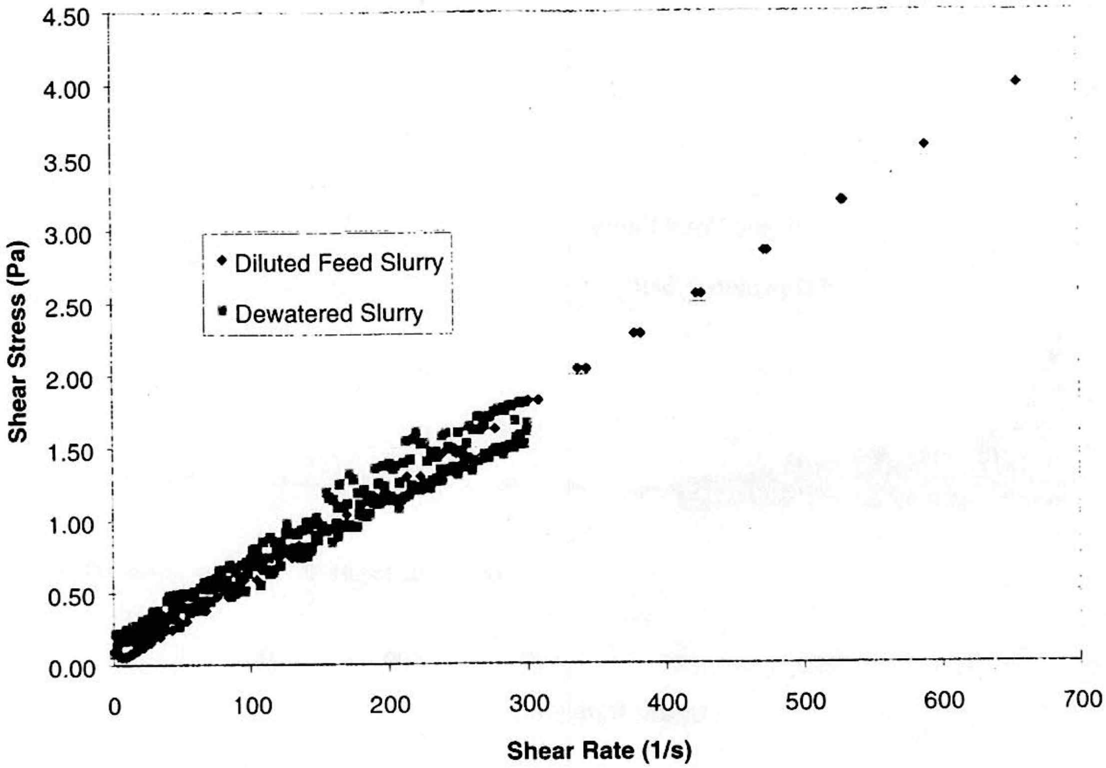


Figure 5.1. Rheogram of Shear Stress as a Function of Shear Rate for the Diluted and De-Watered Slurries

A Microtrac X-100 Particle Analyzer and a Microtrac Ultrafine Particle Analyzer (UPA) were both used to measure the PSD of these tank samples. The Microtrac X-100 Particle Analyzer measures particle diameter by scattered light from a laser beam projected through a stream of the sample particles diluted in a suspending medium. The amount and direction of light scattered by the particles is measured by an optical detector array and then analyzed to determine the size distribution of the particles. This measurement is limited to particles with diameters between 0.12 and 700 µm. The Microtrac UPA measures particle diameter by Doppler-shifted scattered light. This method is limited to particles with diameters between 3 nm and 6.5 µm.

The particle-size distribution of both samples and their duplicates was measured on the Microtrac X-100 at a flow rate of 40 mL/s and on the Microtrac UPA under conditions of Brownian motion. For each sample replicate, the PSD was measured three times and averaged. The PSD of the averaged data on a volume-weighted basis and on a number-weighted basis is reported. The suspending medium for these analyses was a surrogate supernatant based on the ICP and IC data obtained for the 101-AW supernatant. The composition of this supernatant is reported in Table 5.4.

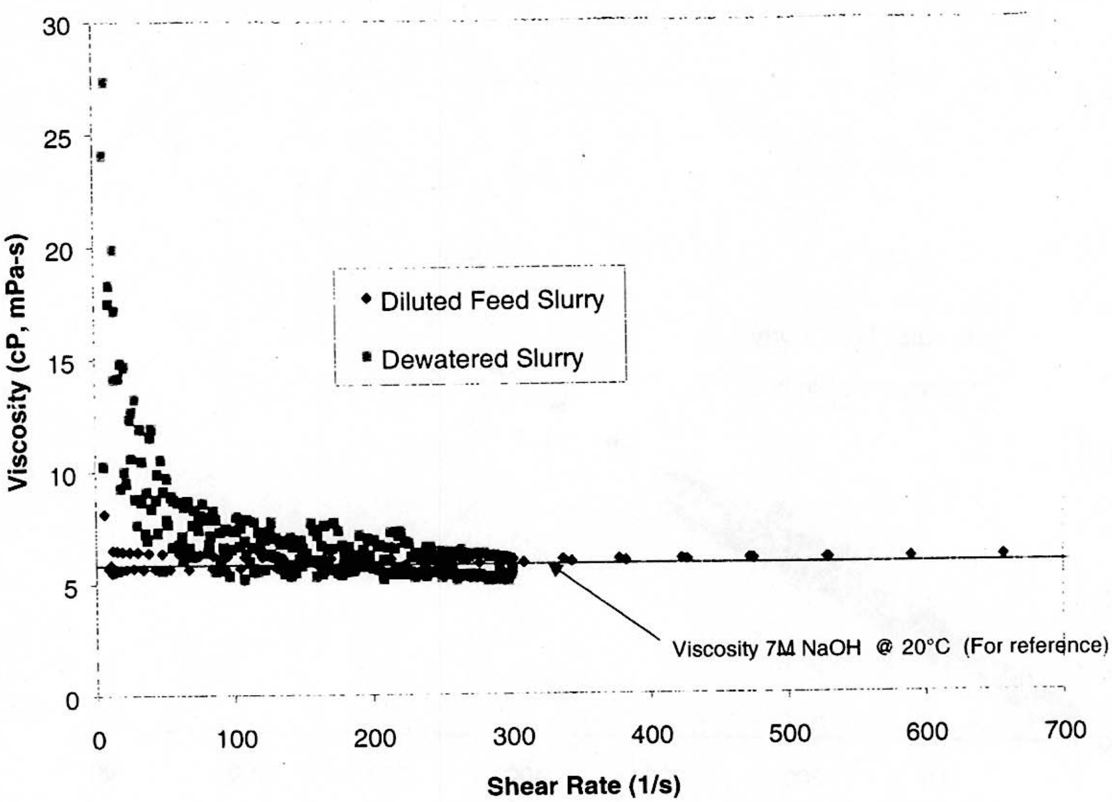


Figure 5.2. Rheogram of Viscosity as a Function of Shear Rate for the Diluted and De-Watered AW-101 Slurries

Table 5.4. Surrogate Supernatant Composition

Component	Concentration (M)
$Cr(NO_3)_3 \cdot 9\,H_2O$	0.0010
$NaNO_3$	1.98
KOH	0.59
$NaOH$	3.07
$Al(OH)_3$	0.61
Na_2SO_4	0.019
$Na_2HPO_4 \cdot 7\,H_2O$	0.020
$NaCl$	0.094
NaF	0.044
$NaNO_2$	1.37

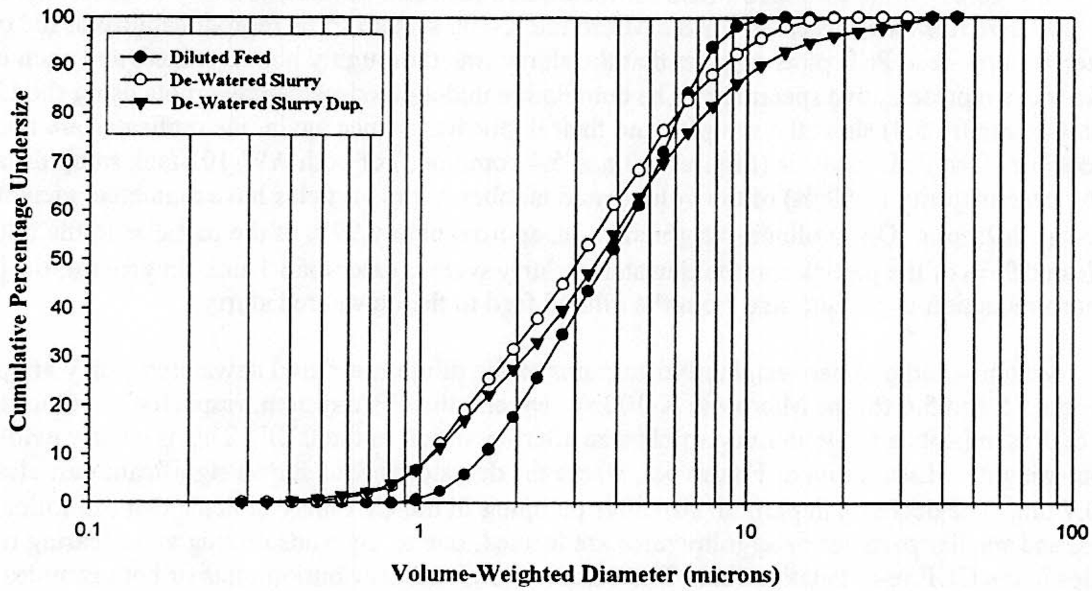
In Appendix H, the PSD plots for the standards and the samples and their duplicates under all conditions measured are presented in volume-weighted distribution and number-weighted distribution form. The number-weighted PSD is computed by counting each particle and by weighting all the particle diameters equally. The volume-weighted PSD, however, is weighted by the volume of each particle measured, which is proportional to the cube of the particle diameter. In general, the PSD plots show that both samples and their duplicates were polydispersed, and as a result, the mean size of the volume-weighted distribution is much larger than the mean size of the number-weighted distribtuion.

In Figure 5.3, the averaged PSDs for the diluted feed and dewatered slurry in cumulative under-size-percentage form are presented for the Microtrac X-100 system. The reproducability of the two dewatered slurry-feed PSD plots suggest that the slurry was thoroughly homogenized, and each extracted sample was a representative specimen. The cumulative under-sized-percentage plots using the UPA system (see Figure 5.4) show the samples and their duplicates. Once again, the replicates are reasonably reproducible. The PSD analysis (Figures 5.3 and 5.4 combined) of both AW-101 tank samples indicate that the large majority (> 99 %) of the volume and number of the particles have diameters greater than 0.2 and less than 25 μm. On a volume-weighted basis, approximately 99% of the particles in the diluted feed sample and 95% of the particles in the dewatered slurry were greater than 1 μm. In general, the plots indicate a reduction in particle size from the diluted feed to the dewatered slurry.

Volume- and number-weighted histograms of the diluted feed and dewatered slurry are presented in Figures 5.5 and 5.6 for the Microtrac X-100 system and the UPA system, respectively. Once again, these figures indicate a reduction in particle size after operation in the CUF. This is clearly evident in the number-weighted distribution of Figure 5.5, where the dewatered feed shows significant particles less than 0.7 μm. The decrease in particle size after pumping in the CUF may indicate that the solids are eroded, and smaller particles or aggolmerates are formed, due to vigorous mixing and shearing of particles in the CUF re-circulation line. The volume-weighted distribution plots of both samples show a bimodal distribution formed from overlapping two Gaussian distribution peaks. The major particle-size peaks along with the relative volume or number percentage that each peak represents are summarized in Tables 5.5 and 5.6. Two particle distributions with peaks between 1 and 2 μm and 4 and 6 μm were observed in both tank samples. In a sample of diluted feed, approximately 42% of the volume of the particles is found in the first distribution, which centers around 2 μm with a distribution width of 1.4 μm. The second distribution for this sample (occupying approximately 58% of the volume or mass of particles) centers around 5.5 μm in diameter with a distribution width of 3.5 μm.

In a sample of dewatered slurry, approximately 25% of the volume (mass) of the particles is found in the first distribution, which centers around 1 μm with a distribution width of 0.7 μm. The second distribution for this sample (occupying approximately 75% of the volume or mass of particles) centers around 4 μm in diameter with a distribution width of 6 μm. A third distribution was observed in the duplicate sample of the dewatered slurry at 31 μm. This distribution accounts for only a small percent of the volume of particles (3%).

Since the majority of the particles are below 10 μm in diameter, the behavior of the particles will be colloidal in nature. Thus, particles will be governed by surface chemistry and van der Waals attractions. Furthermore, because of their small size, the particles could form a low permeability filter cake on the filter surface, which would result in (1) low filtrate fluxes, (2) reduced permeability at high pressures, and (3) little effect of axial velocity on filtrate flux. As more of these particles are generated during testing, the filtrate flux would be reduced further. In general, these observations were seen during cross-flow filtration testing.



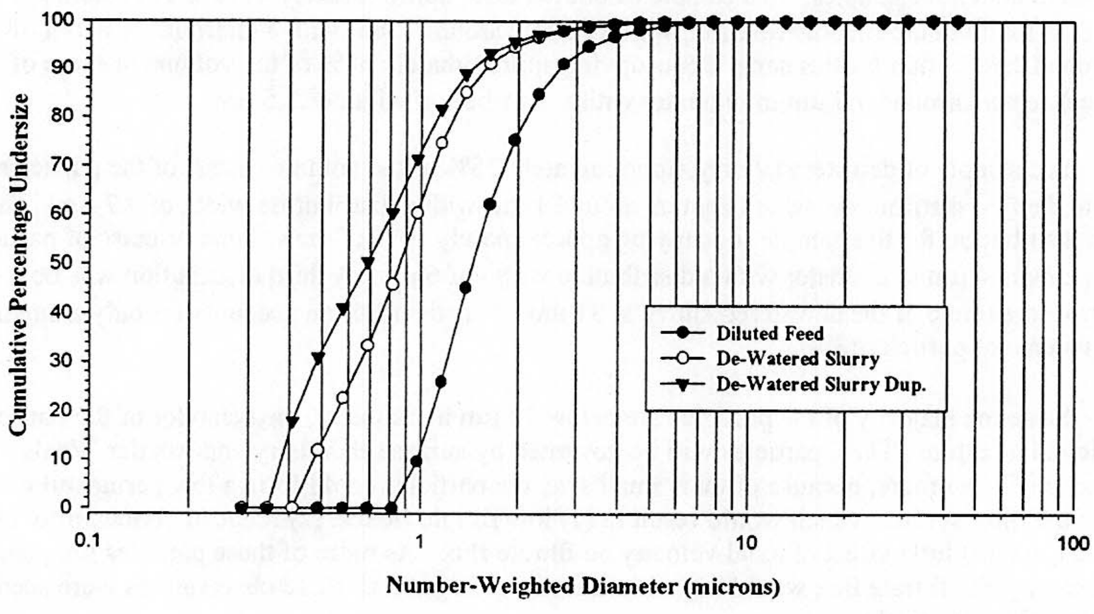
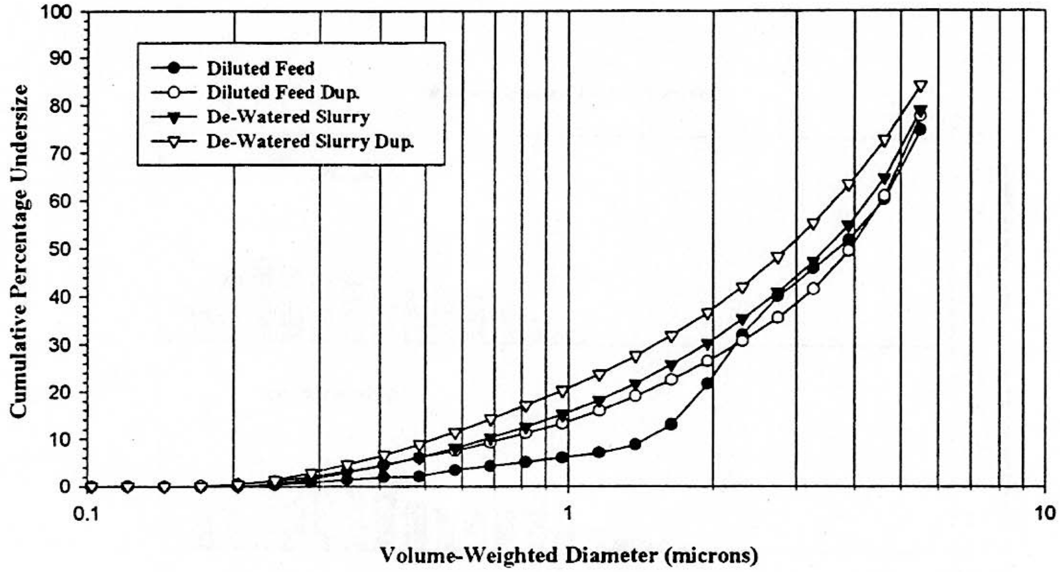


Figure 5.3. Cumulative Under-Size Percentage Distribution for AW-101 Using the Microtrac X-100



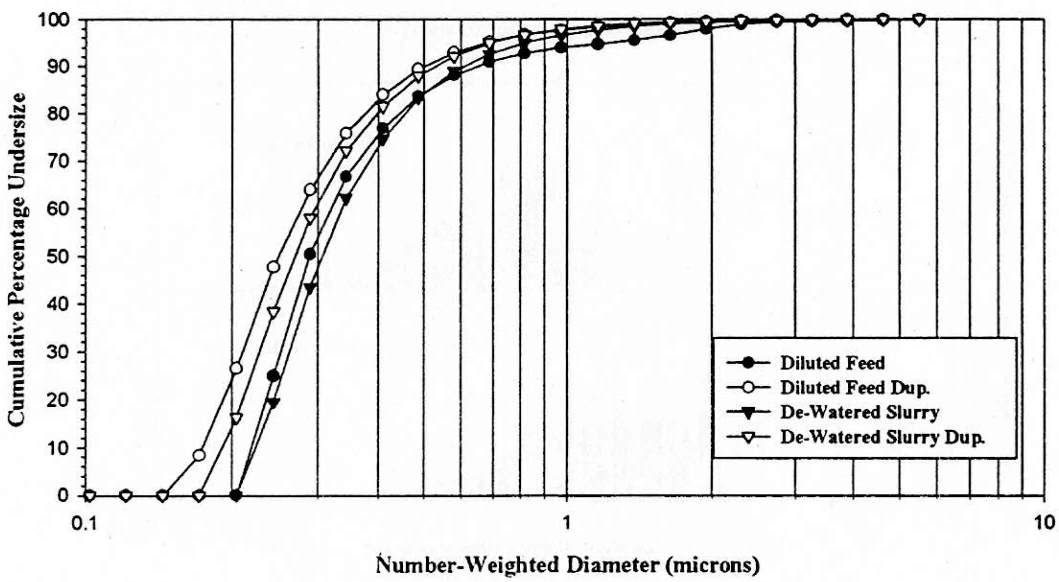


Figure 5.4. Cumulative Under-Size Percentage Distribution of AW-101 Using the Microtrac UPA

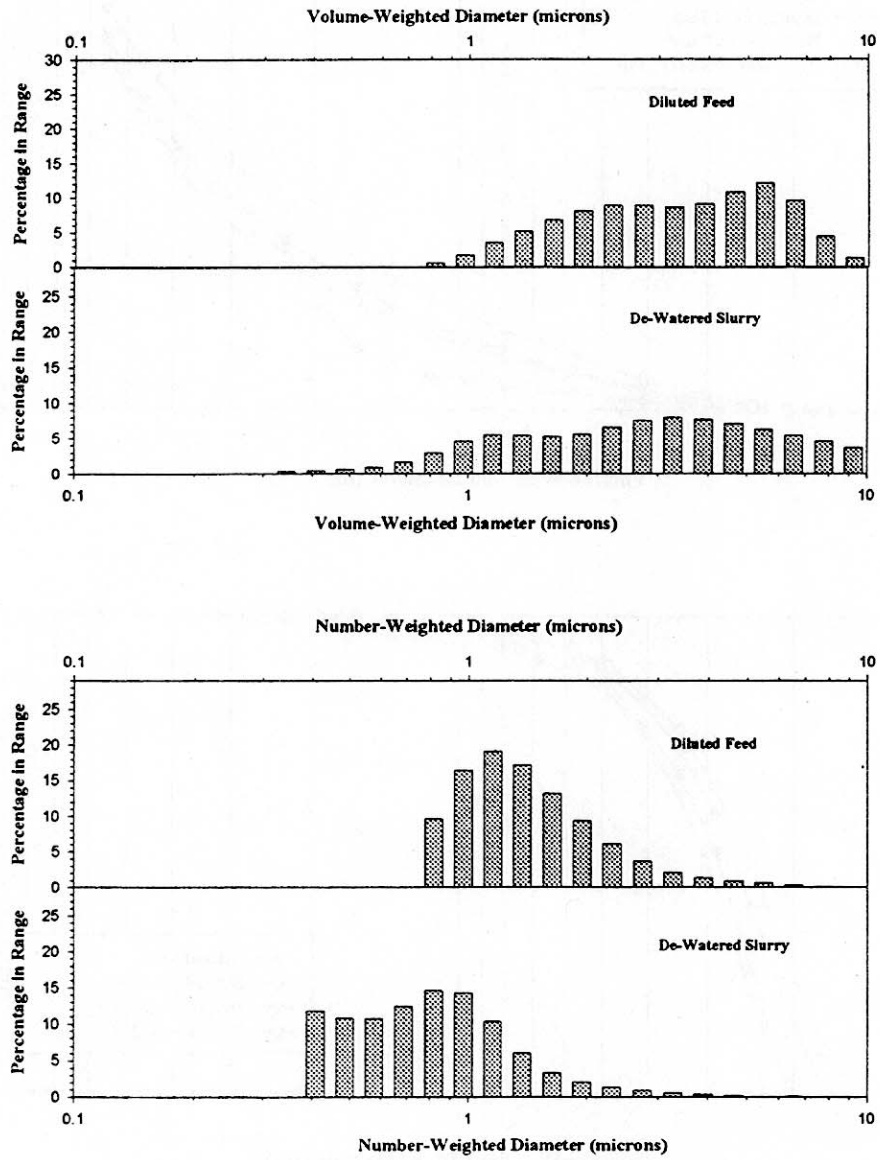
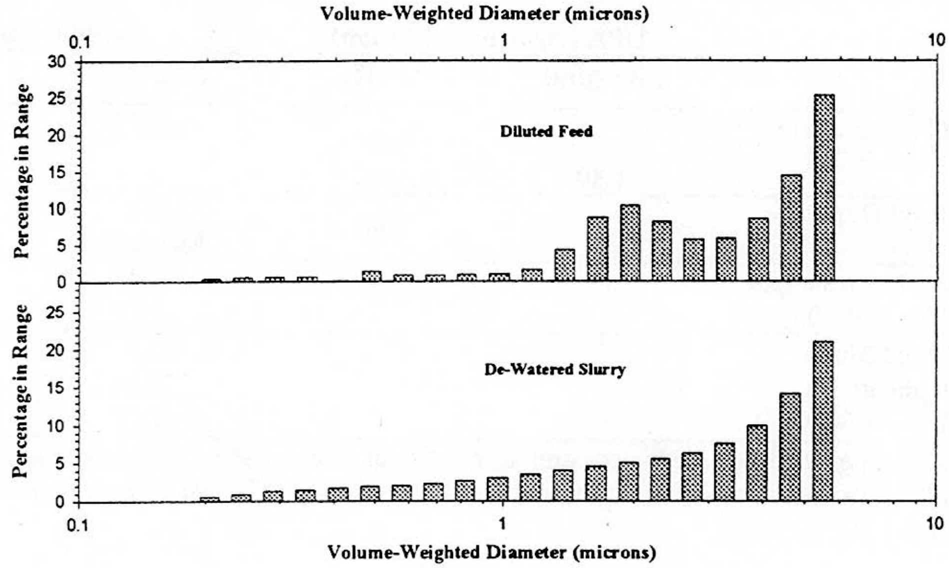


Figure 5.5. Histogram of AW-101 Using the Microtrac X-100



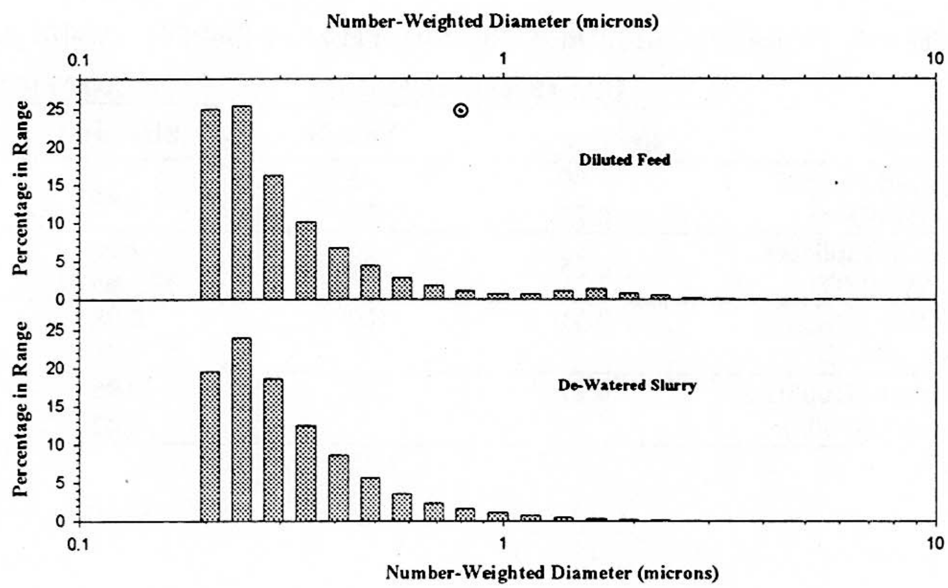


Figure 5.6. Histogram of AW-101 Using the Microtrac UPA

Table 5.5. Particle Size Distribution (Volume) of Hanford Tank 241-AW-101 Samples

Sample	UPA (Brownian Motion) Size (μm)	UPA (Brownian Motion) Vol%	X-100 (40 mL/sec) Size (μm)	X-100 (40 mL/sec) Vol%
Diluted Feed Sample (101-AW-PSD)	*	60	5.47	58
	1.89	40	2.13	42
Diluted Feed Duplicate (101-AW-PSD)	*	100	Not Measured	Not Measured
Dewatered Slurry Sample (CUF 101-AW-005)	*	100	4.00	74
			1.17	26
Dewatered Slurry Duplicate (CUF 101-AW-005)	*	100	30.8	3
			4.29	75
			1.15	22

* The mean diameter of these particles cannot be determined because a significant fraction of the volume of the particles in this distribution exceed the maximum effective particle diameter range of the Microtrac UPA (6.5 μm).

Table 5.6. Particle Size Distribution (Number) of Hanford Tank 241-AW-101 Samples

Sample	UPA (Brownian Motion) Size (μm)	UPA (Brownian Motion) Num %	X-100 (40 mL/sec) Size (μm)	X-100 (40 mL/sec) Num %
Diluted Feed Sample (101-AW-PSD)	1.80	5	1.44	100
	0.28	95		
Diluted Feed Duplicate (101-AW-PSD)	0.25	100	Not Measured	Not Measured
Dewatered Slurry Sample (CUF 101-AW-005)	0.31	100	0.98	77
			0.48	23
Dewatered Slurry Duplicate (CUF 101-AW-005)	0.27	100	0.96	59
			0.42	41

6.0 Conclusions

Based on the cross-flow filtration testing of Hanford Tank AW-101 with a 0.1-µm Mott filter,[1] the following conclusions have been obtained. They have been divided up into categories for clarity.

AW-101 Crossflow Filtration

- Cross flow filtration with a 0.1-µm Mott filter produced a clear supernatant with no observable solids.
- Using a 0.1-µm Mott filter and AW-101 feed (diluted to 6.5M Na), filtrate fluxes ranged from 0.9 to 1.6 m^3/m^2/day. The lowest fluxes occurred at 1.4 bar and 2.0 m/s and the highest fluxes at 4.5 bar and 3.6 m/s. Both these results are significantly less than the 5.9 m^3/m^2/day design basis.
- After testing, it was determined that the 0.1-µm Mott filter was designed for gas applications. The gas filters have a lower porosity than liquid filters. By obtaining the proper filter, higher filtrate fluxes may be possible.
- Filtrate flux was found to be directly proportional to transmembrane pressure and inversely proportional to velocity over the range of study.
- At the higher pressures and velocities, there was a reduction in flux associated with operating time. This indicates possible fouling of the filter due to particulates from the slurry or from CUF equipment itself.
- Filtrate flux was 52% less after concentrating the slurry from 2.2 L to 1.0 L.

Cold Filtration and Acid Washing Tests

- The filtrate flux results generated from the AW-101 simulant at 3.8 bar were 1.8 m^3/m^2/day as compared to those of the actual AW-101, which were 1.4 m^3/m^2/day. The AW-101 simulant does a reasonably good job of simulating filtration results of the actual waste.
- Nitric acid rinses produced higher fluxes than the clean-water fluxes.
- Clean-water fluxes were measured before and after the AW-101 test matrix. At low pressure (2 bar), the same clean-water flux was obtained both before and after testing. At high pressure (4.8 bar), the final flux was 40% of the initial flux. The reduction in flux appears to be caused by filter fouling during the water testing.

AW-101 Chemical and Radiochemical Properties

- The entrained solids contain U, Al, Si, and Na as well as high concentrations of TRU, ^{90}Sr, and ^{99}Tc. The radionuclide concentrations indicate that the entrained solids would be considered TRU (> 100 nCi/g).
- Sodium removal during entrained solids washing is limited by sparingly soluble oxalate. This may result in the entrained solids requiring more than three washes to obtain the required 60 g sodium per kg dried entrained solids.
- Because of the high ^{137}Cs concentration in the supernatant, it was not possible to determine the decontamination factor of TRU and ^{90}Sr through the filter. Additional chemical separation would be required to decrease the detection limit below the levels found in the permeate.

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[1] After operation, it was determined that this filter was designed for gaseous rather than liquid applications. Gas filters have a lower porosity than liquid filters and offer a greater resistance to liquid flow.

Physical Properties

- The weight percent insoluble solids was difficult to measure in the high salt solution because of its low concentration. The low insoluble-solids concentration also resulted in no change in density in the dewatered slurry as compared to the original feed.

- The slurry feed behaved as a Newtonian fluid due to the low concentration of solids. The dewatered slurry, in contrast, deviated from Newtonian character as slightly shear-thinning or pseudoplastic. Both the original feed and dewatered slurry had viscosities ranging from 5 to 10 cP.

- The particle-size distribution of AW-101 diluted feed and dewatered slurry was similar, but the particle size of the dewatered slurry was reduced. Thus, it appears that there was particle deagglomeration after the 15 hours of CUF operation. The reduction in the filtrate flux in the CUF with the de-watered slurry (See Section 3.1) may be the result of the reduction of the particle size observed in the de-watered slurry sample.

- In the case of both AW-101 diluted feed and dewatered slurry, the particle size ranged from 0.2 to 30 μm (> 95% of particles). There were no particles detected at less than 0.17 μm. This would indicate that the solids should be removed with the 0.1-μm filter, but may create an impermeable film on the filter surface and reduce the filtration rate.

7.0 References

10 CFR 61. 1993. U.S. Department of Energy, "Licensing Requirements for Land Disposal of Radioactive Waste," Subpart D, Section 55, U.S. Code of Federal Regulations.

Geeting, J. G. H., and B. A. Reynolds. 1997. "Bench-Scale Crossflow Filtration of Hanford Tank C-106, C-107, B-110, and U-110 Sludge Slurries," PNNL-11652. Pacific Northwest National Laboratory, Richland, Washington.

Nash, C. A., and J. Siler. 1997. "Filtration of Nonradioactive Hanford Waste Simulants." SRTC-BNFL-016. Savannah River Technology Center, Westinghouse Savannah River Company, Aiken, South Carolina.

River Protection Project Waste Treatment Plant (RPP-WTP) (formerly TWRS) Privatization Contract. 1996. DE-RP06-96RL13308. U.S. Department of Energy, Richland, Washington.

Urie, M. W., J. J. Wagner, L. R. Greenwood, O. T. Farmer, S. K. Fiskum, R. T. Ratner, and C. Z. Soderquist. 1999. " Inorganic and Radiochemical Analysis of AW-101 and AN-107 'Diluted Feed' Materials," PNWD-2463, Rev. 1. Pacific Northwest National Laboratory, Richland, Washington.

Weast, R. C. (Ed). 1984. CRC Handbook of Chemistry and Physics, 64th Edition, CRC Press, Inc., Boca Raton, Florida.

Appendix A: AW-101 Cross Flow Filtration Test Instruction

PNNL Test Instruction

Document No.: BNFL-TP-29953-022
Rev. No.: 0

Title: Entrained Solids Removal of AW-101

Work Location: RPL SFO HLRF	**Page** 1 of 10
Author: Kriston P. Brooks	**Effective Date:** Upon Final Approval **Supercedes Date: New**
Use Category Identification: Information	
Identified Hazards: ___Radiological ___ Hazardous Materials ___ Physical Hazards ___ Hazardous Environment ___ Other:	**Required Reviewers:** _X_Technical Reviewer __SFO Manager

Are One-Time Modifications Allowed to this Test Instruction? _X_ Yes ___ No

NOTE: If Yes, then modifications are not anticipated to impact safety. For documentation requirements of a modification see SBMS or the controlling Project QA Plan as appropriate.

On-The Job Training Required? _____ Yes or __X__ No

FOR REVISIONS:
Is retraining to this procedure required? _____Yes __X__ No

Does the OJT package associated with this procedure require revision to reflect procedure changes?
_____Yes _____No __X__ N/A

Approval	**Signature**	**Date**
Author	K P Brooks	2/16/99
Technical Reviewer	Kenneth ...	2/16/99

1.0 Applicability

This test instruction is to be used to perform the testing of the Cell Unit Filter (CUF) in the HLRF A-cell with approximately 2200 mL of AW-101 supernatant.

2.0 Supporting Documents

This test instruction is not a stand-alone document. It will be used in conjunction with PNNL Operating Procedure BNFL-TP-29953-020 which contains the necessary procedural information for the safe operation of the CUF. It is also linked to PNNL Test Plan No. BNFL-TP-29953-4 which contains an overall description of the project, ES&H compliance, emergency response, and the hazards assessment and mitigation.

3.0 Responsible Staff

The staff responsible for executing this test plan are as follows.

- Task Manager – Kriston Brooks
- SFO Manager – Randy Thornhill
- Test Engineers – Kriston Brooks, Ken Rappe, Lynette Jagoda
- Hot Cell Technician – Steve Forbes and Mac Zumhoff
- Radiological Control Technician

4.0 Materials, Equipment, Supplies and Reagents Needed

4.1 Materials Required

1. Twenty-five 20 mL plastic scintillation vials for filtrate and slurry samples, pre-labeled as follows:
   CUF-AW101-001 through CUF-AW101-025.
2. One 2 liter polyethylene bottle and two 1 liter polyethylene bottles. They should be labeled as follows: "AW-101 Filtrate," "AW-101 Drained Slurry," and "CUF AW-101 First Rinse." The bottle labeled "AW-101 Filtrate" should be marked with a black line for 1.2 liter volume. The bottle labeled "CUF AW-101 First Rinse" should be marked with a black line for 1 liter volume.
3. Tubing for de-watering mode.
4. 1 - 1000 mL capacity, 0.45 micron nylon filter unit. The bottle and filter unit should be labeled, "AW-101 filtrate."
5. A 500 mL bottle labeled "AW-101 Composite Wash."
6. Two 10 liter containers, one labeled for the alkaline rinses and the other labeled for the acidic rinses.
7. Containers for draining from the bottom of the pump and from the sample valve.
8. Transfer AW-101 UFA, AW-101 UFB, AW-101 UFC, AW-101 UFD, AW-101 UFE, and AW-101 UFF from C-cell to A-cell.

4.2 Equipment

1. 4000 gram balance
2. pH probe
3. Hand held periscope. To be used to read filtrate flowmeter.
4. Stopwatch
5. Calculator

6. CUF Ultrafiltration system
7. 1000 W Chiller

4.3 Reagents Needed

1. 1 liter of 1M HNO_3

4.4 Other Supplies

1. Workplace Copy of Operating Procedure BNFL-TP-29953-020
2. Extra Copies of Data Sheets 1, 2, and 3
3. Laboratory Record Book

5.0 Test Instructions

The test engineer will initial or check in the left hand margin of each step below when completed.

The laboratory record book (LRB) shall be used to record other testing information as required by this procedure and all test conditions not stated by this procedure.

Cross-contamination between samples and contamination of samples from outside sources must be minimized at each step. Use new tools and bottles for each sample as much as possible. Those tools that are reused should be washed and rinsed prior to reuse.

Keep all test materials in sealed containers as much as possible to prevent them from drying.

5.1 Prestart

5.1.1 Inventory materials, equipment, supplies, and reagents to ensure all required items are available. Assure that all materials have been modified for remote handling.

5.1.2 Do the following and initial and date when each item is completed.

KPB ______ Review PNNL Operating Procedure BNFL-TP-29953-020.

KPB ______ Review the work instructions in BNFL-TP-29953-022.

5.1.3 Conduct the "0.0 Pre-Start" operations in BNFL-TP-29953-020.

5.1.4 Obtain the following information:

M&TE List:

K6R ___ Balance 1:

Calib ID 362-06-01-054 Calib Exp Date 8/99

Location Acell North

KGR Balance 2:

Calib ID 362-06-01-061 Calib Exp Date 8/99

Location A cell South

5.1.5 Weigh each jar with lid and AW-101 supernatant. Record the weights below.

AW-101 UFA	AW-101 UFB	AW-101 UFC
Total 862.80 g	Total 869.09 g	Total 839.78 g
AW-101 UFD *	**AW-101 UFE**	**AW-101 UFF**
Total 841.44 g	Total 899.67 g	Total 722.97 g

5.1.6 Conduct the "1.0 Start-Up" operations in BNFL-TP-29953-020 using AW-101. Shake the jars thoroughly before adding them to the slurry reservior. There may be some solids left the jars that cannot be transferred by shaking. If so, consult with the cognizant engineer on recovering these solids. Record the method of recovery in the LRB.

5.1.7 Record the weights of the jar and lid in the spaces provided below. Calculate the amount of material remaining in the jar. The cognizant engineer will determine if further solids recovery is warranted.

AW-101 UFA	AW-101 UFB	AW-101 UFC
Jar+Lid 356.32 g	Jar+Lid 358.71 g	Jar+Lid 358.36 g
Tare 354.9244 g	Tare 356.9183 g	Tare 356.3316 g
Total 1.40 g	Total 1.79 g	Total 2.03 g

AW-101 UFD	AW-101 UFE	AW-101 UFF
Jar+Lid 361.96 g	Jar+Lid 360.64 g	Jar+Lid 359.75 g
Tare 360.5024 g	Tare 359.207 g	Tare 358.5115 g
Total 1.46 g	Total 1.44 g	Total 1.24 g

5.1.8 Record the level in the slurry reservoir.

Height 4 7/8 inches

5.2 Operation

5.2.1 Conduct the "3.0 Operation during Ultrafilter Recycle Mode" operations in BNFL-TP-29953-020 using the conditions below. Filtrate flow rate should be monitored and data collected as specified in the operating procedure. After each condition, the test engineer should initial and date the table below.

Condition	Flowrate (gpm)	Transmembrane Pressure (psig)	Initial and date when complete
1	2.27	30	KGR 2/16
2	4.20	55	KGR 2/16
3	2.27	40	[illegible] 2/16
4	1.13	30	[illegible] 2/16
5	2.27	20	[illegible] 2/16
6	3.13	30	[illegible] 2/16
7	2.27	30	[illegible] 2/17
8	4.20	55	[illegible] 2/17
9	4.20	40	TIB 2/17
10	4.20	70	TIB 2/17
11	3.13	55	TIB 2/17
12	5.23	55	TIB 2/17
13	2.27	30	TIB 2/17
14	4.20	55	KGR 2/17

5.2.2 Tare weigh a 2 liter bottle labeled "AW-101 Filtrate."

Weight of empty "AW-101 Filtrate" with lid 333.96 g

5.2.3 Conduct the "4.0 Operation during Ultrafilter Dewatering Mode" operations in BNFL-TP-29953-020 using the optimum conditions from step 5.2.1. Fill "AW-101 Filtrate" to the 1.2 liter line. When the dewatering is approximately half-way done, place the stainless steel plug into the slurry reservoir.

5.2.4 Replace the lids on the bottles and weigh.

Weight of "AW-101 Filtrate" with lid 1895.75 g

Total weight of material removed 1561.79 g

Volume of material removed (wt/1.3) 1201.38 mL

5.2.5 Record the level in the slurry reservoir.

Height 2 1/2 inches Video #53

5.2.6 Tare weigh two sample vials. Obtain 2 samples of at least 20 grams each from the container labeled "AW-101 Filtrate." Record the weight and sample number in Data Sheet 3. These will be used for chemical and radiochemical analyses.

5.2.7 Obtain 2 filtrate samples of at least 20 grams each following "8.0 Filtrate Sampling" in BNFL-TP-29953-020 and using the pre-labeled sample vials. If required, more than two sample vials may be used. Record the weight and sample number in Data Sheet 3. These will be used for chemical and radiochemical analyses.

5.2.8 Obtain 1 slurry sample of at least 20 grams following "7.0 Slurry Sampling" in BNFL-TP-29953-020 and using the pre-labeled sample vials. This will be used for physical property analyses. Obtain 2 slurry samples of at least 10 grams following "7.0 Slurry Sampling" in BNFL-TP-29953-020 and using the pre-labeled sample vials. This will be used for particle size distribution measurements.

5.2.9 Using the rheometer sample cup, obtain 40 mL of slurry material for rheological measurements following "7.0 Slurry Sampling" in BNFL-TP-29953-020. This may require as many as eight samplings to obtain this material.

5.2.10 Adjust the flow to < 2 gpm and the pressure to < 10 psig or turn off the pump while the rheology of the material is measured. Pour the 40 mL used for rheological measurements back into the CUF.

5.2.11 Increase the flow and pressure to its optimal value and repeat step 5.2.9 and 5.2.10 for a second 40 mL slurry sample.

5.2.12 Conduct the "3.0 Operation during Ultrafilter Recycle Mode" operations in BNFL-TP-29953-020 using the conditions below. Filtrate flow rate should be monitored and data collected as specified in the operating procedure. After each condition, the test engineer should initial and date the table below.

Condition	Flowrate (gpm)	Transmembrane Pressure (psig)	Initial and date when complete
1	4.20	40	~~KTB~~ 2/17
2	4.20	55	~~KTB~~ 2/17
3	4.20	70	KTB skipped
4	3.13	~~Optimum from 1-3~~ 70 psig	~~KTB~~ 2/17
5	5.23	~~Optimum from 1~~-3	

Maximum possible - 35 psig

5.2.13 Conduct the "11.0 Shutting down" operation in BNFL-TP-29953-020.

5.3 Rinsing and Draining the System

5.3.1 Tare weigh the 1 liter bottle labeled, "AW-101 Drained Slurry."

Weight of bottle and lid ___294.957___ g

5.3.2 Conduct the "10.0 Draining the system" operation in BNFL-TP-29953-020. Collect liquid in 1 liter bottle. Weigh bottle after all liquid has been removed.

Weight of slurry, bottle and lid ___1528.45___ g

Weight of material collected ___1233.49___ g

5.3.3 Conduct the "9.0 Rinsing the system" operation in BNFL-TP-29953-020. The first rinse should be done with 1 liter of distilled water. This liquid should be collected and saved in the container labeled "CUF AW-101 First Rinse." The second rinse should be done with 2.2 liters of distilled water, and the final rinse with 1 liter distilled water. The second and third rinses should be collected separately from the first in the alkaline rinse storage container. The acidic solutions should be placed in a separate container.

5.3.4 Conduct the "12.0 Lay Up" operation in BNFL-TP-29953-020.

5.4 Washing the Entrained Solids

NOTE: Washing of the entrained solids can be completed anytime after Step 5.3.2.

NOTE: As much work as possible should be performed inside of the CUF drip pan.

5.4.1 Weigh the filtration system without the bottle. Attach vacuum system to 1000 mL filtration system.

Weight of filtration system without the bottle ___149.75g___ g

Weight of filtration bottle and cap ___203.63___ g

5.4.2 Pour off clear supernate from the 1 liter bottle "AW-101 Drained Slurry" into 1000 mL filter. Allow solution to filter. Agitate bottle and pour remaining material into the filter. Remove as much material as possible. Reweigh empty bottle.

Weight of empty bottle with lid ___295.53___ g

5.4.3 Cover filtration system and complete filtration.

5.4.4 Once all standing liquid is has been filtered and only wet solids remain, remove the filtrate bottle and cap. Place a clean bottle on the filtration unit.

Weight of filtered AW-101 ___1420.77___ g

(1217.14g of liquid)

5.4.5 Obtain the tare weight of a graduated cylinder. Prepare 100 mL of distilled water in the cylinder. Weigh the full graduated cylinder.

Tare Weight of Graduated Cylinder 104.78 g 104.98 g (empty)
Full Weight of Graduated Cylinder 210.01 g
Volume in Graduated Cylinder 105.23 mL (g)

5.4.6 Pour the distilled water from the graduated cylinder into the bottle labeled "AW-101 Drained Slurry." Cap and shake. Pour contents onto the filter. Allow it to filter.

Weight of Empty "AW-101 Drained Slurry" with lid 294.84 g

✓ 5.4.7 Once all standing liquid is has been filtered and only wet solids remain, remove the filtrate bottle and cap. Take three (3) samples of the filtrate of 20 mL each by performing the following.

a) Obtain the tare weight of a pre-labeled sample vial. Record weight on Data Sheet 3.
b) Pipet out approximately 20 mL of material.
c) Weigh sample vial and record in Data Sheet 3.

✓ 5.4.8 Pour the remaining liquid in a 500 mL bottle labeled "AW-101 Composite Wash."

✓ 5.4.9 Obtain the tare weight of a graduated cylinder. Prepare 100 mL of distilled water in the cylinder. Weigh the full graduated cylinder.

Tare Weight of Graduated Cylinder 104.99 g
Full Weight of Graduated Cylinder 207.79 g
Volume in Graduated Cylinder 102.8 mL

Place the bottle back on the filtration unit and pour the distilled water onto the filter. Allow it to filter.

✓ 5.4.10 Once all standing liquid is has been filtered and only wet solids remain, remove the filtrate bottle and cap. Take three (3) samples of the filtrate of 20 mL each by performing the following.

a) Obtain the tare weight of a pre-labeled sample vial. Record weight on Data Sheet 3.
b) Pipet out approximately 20 mL of material.
c) Weigh sample vial and record in Data Sheet 3.

✓ 5.4.11 Pour the remaining liquid in a 500 mL bottle labeled "AW-101 Composite Wash."

✓ 5.4.12 Obtain the tare weight of the graduated cylinder. Prepare 100 mL of distilled water in the cylinder. Weigh the full graduated cylinder.

Tare Weight of Graduated Cylinder 104.89 g
Full Weight of Graduated Cylinder 204.51 g
Volume in Graduated Cylinder 99.62 mL

✓ Place the bottle back on the filtration unit and pour the distilled water onto the filter. Allow it to filter.

5.4.13 Repeat steps 5.4.10 through 5.4.11.

5.4.14 Agitate the contents of the 500 mL bottle labeled "AW-101 Composite Wash." Take two (2) samples of the filtrate of 20 mL each by performing the following twice.

a) Obtain the tare weight of a pre-labeled sample vial. Record weight on Data Sheet 3.
b) Pipet out approximately 20 mL of material into the sample vial. 68.19g → AW-101 Composite Empty
c) Weigh sample vial and record in Data Sheet 3. 229.54g → AW-101 Composite w/ solution

196.81 g → Filter bottom empty

5.4.15 Obtain three (3) samples of the filtered material by performing the following.

a) Obtain the tare weight of a pre-labeled sample vial. Record weight on Data Sheet 3.
b) Scrape out approximately 20 mL of material and place inside of the sample vial.
c) Weigh sample vial and record in Data Sheet 3.

5.4.16 Clean up experiment. Save solutions and allow the filtered material to dry for 24-48 hours. Reweigh the filtration system without the bottle.

Weight of filtration system without the bottle 150.71 g

6.0 Sample Analysis

The point of contact for physical property sample analysis of the slurry samples is Paul Bredt. The point of contact for the sample analysis of the filtrate, wash, and filtered solids samples is Mike Urie and Rick Steele.

6.1 Slurry Sample Physical Analysis

The slurry samples taken following the dewatering step will remain in A-cell for physical testing. These samples will be used for obtaining the following information: bulk density, supernatant density, particle size distribution, volume percent settled and centrifuged solids, and suspended solids loading. Each of these analyses will be done in duplicate. The viscosity of these samples was performed previously during testing in Section 5.0.

6.2 Chemical and Radiochemical Analysis

The following samples should be transferred to the SAL hot cells for prep work and analysis. There are three types of analyses performed on these samples. The analytical requirements for each group are shown in the table below.

- One sample from the dewatering step -- Analysis Group 1
- Two samples taken from the bottle labeled "AW-101 Filtrate" – Analysis Group 1
- Two of the three samples taken from each of the washing steps – Analysis Group 2
- Two samples taken from the bottle labeled "AW-101 Composite Wash"–Analysis Group 1

- Two of the three wet filtered solids samples taken following solids washing – Analysis Group 3

Analysis Group 1	Analysis Group 2	Analysis Group 3
Acid Digest GEA Sr-90 ICP-MS: Tc-99 Total Alpha ICP-AES TOC/TIC IC	Acid Digest ICP-AES	Acid Digest KOH Fusion GEA Sr-90 ICP-MS: Tc-99 Total Alpha ICP-AES TOC/TIC IC

Data Sheet 3: Sample Log

RJB 2/18/99

Tank Number AW-101 Entrained Solids

Test Number ________________

Sample Number	Date	Time	Sample Type	Tare Weight (g)	Total Mass (g)	Mass of Sample (g)	Operators Initials
CUF-AW101-001	2/17/99	11:41	filtrate	8.104	35.681	27.577	KR
-002	2/17/99	11:49	filtrate	8.107	33.755	25.648	KR
-003	2/17/99	12:05	slurry	8.083	32.297	24.214	KR
-004	2/17/99	12:11	slurry	8.029	20.072	12.043	KR
-005	2/17/99	12:17	slurry	8.116	20.605	12.489	KR
-006	2/17/99	15:52	filtrate	8.154	26.581	18.427	RJB from bottle
-007	2/17/99	15:52	filtrate	8.082	27.915	19.833	RJB from bottle
-008	2/18/99	14:00	wash 1	8.12 g	20.68	12.56	RJB
-009	2/18/99	14:21	Wash 1	8.09 g	21.60	13.51	RJB
-010	2/18/99	14:19	Wash 1	8.14 g	21.45	13.31	RJB
-011	2/18/99	14:41	Wash 2	8.15 g	19.20	11.05	RJB
-012	2/18/99	14:43	Wash 2	8.13 g	20.11	11.98	RJB
-013	2/18/99	14:45	Wash 2	8.2 g	20.71	12.51	RJB
-014	2/18/99	15:00	Wash 3	8.15 g	20.15	12.00	RJB
-015	2/18/99	15:04	Wash 3	8.12 g	19.62	11.5	RJB
-016	2/18/99	15:06	Wash 3	8.21	20.45	12.24	RJB
-017	2/18/99	15:12	Wash Composite	8.07 g	27.59	19.52	RJB
-018	2/18/99	15:14	Wash Composite	8.14	28.34	20.20	RJB
-019	2/18/99	15:21	Solids	8.07 g	9.07 g	1.0	RJB
-020	2/18/99	15:25	Solids	8.20	9.34 g	1.14	RJB
-021	2/18/99	15:32	Solids	8.30 g	9.81 g	1.51	RJB

Appendix B: Chemical and Radiochemical Results

Battelle
Putting Technology To Work

Project No. ~~29802~~ 29953 mul

Internal Distribution

Date March 31, 1999 File/LB

To K. Brooks

From M. Urie MUrie

Subject Carbon Analysis CUF AW-101 Series

The analysis of the CUF AW-101 samples submitted under ASR 5274 was done by the hot persulfate wet oxidation method, PNL-ALO-381, rev. 1. The hot persulfate method uses acid decomposition for TIC and acidic potassium persulfate oxidation at 92-95 °C for TOC, all on the same weighed sample, with TC being the sum of the TIC and TOC.

The samples were analyzed on March 26, 1999 and Table 1 below shows the results, rounded to three significant figures. The raw data bench sheets and calculation work sheets showing all calculations are attached. All sample results are corrected for average percent recovery of system calibration standards and are also corrected for contribution from the blank. All results are reported in µgC/g or µgC/ml, based on the weight or volume of sample, as applicable.

QC Narrative

The TIC standard is calcium carbonate and TOC standard is α-Glucose (the certificates of purity are attached). The standard materials were used in solid form for system calibration standards as well as matrix spikes. TIC and TOC percent recovery are determined using the appropriate standard (i.e., calcium carbonate for TIC or glucose for TOC).

The QC for the methods involves calibration blanks, system calibration standards, sample duplicates, and one matrix spike per matrix type (i.e., solids and liquids). The QC system calibration standards were all within acceptance criteria, with the average recovery being 96.7% for TIC and 91.7% for TOC. The calibration blanks were acceptable, averaging 1.4 µgC for TIC and 8.8 µgC for TOC.

The accuracy of the carbon measurements can be estimated by the recovery results from the matrix spike. Matrix spike recoveries ranged from 95% to 114%, well within the acceptance criteria of 75% to 125%. The precision, estimated by the RPD (Relative Percent Difference) between duplicates, met acceptance criteria (i.e., RPD <20%) for all carbon analyses.

Table 1: TIC, TOC, and TC Results

ALO Number	Sample ID	Wt. (g)	TIC* (ug/g)	TIC RPD (%)	TOC* (ug/g)	TOC RPD (%)	TC* (ug/g)	TC RPD (%)	Hot Cell DF
99-1149	CUF-AW101-20	0.0486	5780		16900		22700		1
99-1149 Dup	CUF-AW101-20	0.0506	5820	1	16100	5	21900	4	1
99-1150	CUF-AW101-21	0.0757	7320		16200		23500		1
99-1150 Mat. Spike	CUF-AW101-21MS	0.0545	109%		114%		112%		
		(ml)	(ug/ml)		(ug/ml)		(ug/ml)		
99-1143 DB	DILUENT BLANK	2.00	220		55		275		5
99-1143 DB	DILUENT BLANK	2.00	210	5	45	n/a	255	8	5
99-1143	CUF-AW101-002	0.50	1960		2130		4090		5
99-1143	CUF-AW101-002	1.00	1890	4	1920	10	3810	7	5
99-1143 Dup	CUF-AW101-002	1.00	1840		1890		3730		5
99-1143 Dup	CUF-AW101-002	1.00	1840	0	1880	1	3720	0	5
99-1144	CUF-AW101-006	1.00	1760		1710		3470		5
99-1144	CUF-AW101-006	1.00	1800	2	1790	5	3590	3	5
99-1148	CUF-AW101-018	1.00	55		2350		2410		5
99-1148	CUF-AW101-018	1.00	120	n/a	2270	4	2390	1	5
99-1148 Mat. Spike	CUF-AW101-018MS	1.00	95%		103%		99%		

* Corrected for Hot Cell Dilution

RPD = Relative Percent Difference (n/a = not calculated since results <5xMDL)
RPD calculated from raw data; reported results have been rounded and may not provide the same RPD value

Approve: [signature] 3/31/99

Archive Information:

Files: C123-P-701.doc, C123-701.xls	ASR: 5274

PNNL Radiochemical Processing Group: TOC/TIC/TC Calculations **Review** Report - Hot Persulfate Method PNL-ALO-381

Samples: K. Brooks Analyzed 03/25/99

Analyzer M&TE: WA92040 – 701
Balance M&TE: 360-06-01-023
Project No. 29953 k48480 IL II ASR 5274

TIC STD: CaCO3 CMS-13285>>> 11.99% Carbon <<[C]
TOC STD: Glucose CSM-53219>>> 40.00% Carbon <<[G]

Procedure: PNL-ALO-381
Archive File: C120-P-701.XLS

Standard and Blank Calculations **

Blanks:		TIC (ug):			TOC (ug):		
	Calibration blank (start of batch)	16.5	Average:	14.4 ugC	53.1	Average:	52.8 ugC
	Calibration blank (start of batch)	13.3	SD:	1.6 ugC	64.6	SD:	8.8 ugC
	Calibration blank (middle of batch)	12.9	Pooled SD:	2.16 ugC	43.6	Pooled SD:	5.8 ugC
	Calibration blank (end of batch)	14.9	MDL (ug):	6.5 ugC.	49.9	MDL (ug):	17.3 ugC

		[A] Raw TIC (ug)	[B] Blk (ug)	[D] Std wt (g)	TIC % Rec		[E] Raw TOC (ug)	[F] Blk (ug)	[H] Std wt (g)	TOC % Rec	
Standards:	Calibration Standard (start of batch)	1245	14.4	0.0104	98.6		1265	52.8	0.00335	90.5	
	Calibration Standard (start of batch)	1074	14.4	0.0093	94.8		1242	52.8	0.00320	92.9	
	Calibration Standard (middle of batch)	1365	14.4	0.0116	96.8		906	52.8	0.00232	91.9	
	Calibration Standard (end of batch)	1333	14.4	0.01138	96.6		1475	52.8	0.00388	91.6	
			Average TIC % Rec >>>>		96.7	<<[L]		Average TOC % Rec >>>		91.7	<<[P]

Sample Calculations **

ACL Number	Client Sample ID	[I] Raw TIC (ug)	[J] Blk (ug)	[K] Sam Wt (g)	TIC (ugC/g)	TIC RPD (%)	– ug/ml – mdl	5xmdl	[M] Raw TOC (ug)	[N] Blk (ug)	[O] Sam Wt (g)	TOC (ugC/g)	TOC RPD (%)	– ug/g – mdl	5xmdl	TC (ugC/g)	TC RPD (%)
99-1149	CUF-AW101-20	286	14.4	0.0486	5779		188	939	806	52.8	0.0486	16894		364	1820	22673	
99-1149 dupe	CUF-AW101-20	299	14.4	0.0506	5816	1	180	902	798	52.8	0.0506	16054	5	350	1748	21870	4
99-1150 ~~dupe~~ 2	CUF-AW101-21	550	14.4	0.0757	7316		121	603	1175	52.8	0.0757	16160		234	1168	23476	
99-1150 MS	CUF-AW101-21	1489	14.4	0.0545	see below		167	837	2355	52.8	0.0545	46047		325	1623	46047	
				Vol (ml)	(ugC/ml)							(ugC/ml)				(ugC/ml)	
99-1143 DB	DILUENT BLANK	100	14.4	2.0000	44		5	23	73.4	52.8	2.0000	11		9	44	55	
99-1143 DB	DILUENT BLANK	96	14.4	2.0000	42	5	5	23	69.8	52.8	2.0000	9	n/a	9	44	51	8
99-1143	CUF-AW101-002	204	14.4	0.5000	392		18	91	248	52.8	0.5000	426		35	177	818	
99-1143	CUF-AW101-002	380	14.4	1.0000	378	4	9	46	406	52.8	1.0000	385	10	18	88	763	7
99-1143 dupe	CUF-AW101-002	370	14.4	1.0000	368		9	46	400	52.8	1.0000	378		18	88	746	
99-1143 dupe	CUF-AW101-002	370	14.4	1.0000	368	0	9	46	398	52.8	1.0000	376	1	18	88	744	0
99-1144	CUF-AW101-006	355	14.4	1.0000	352		9	46	367	52.8	1.0000	343		18	88	695	
99-1144	CUF-AW101-006	363	14.4	1.0000	360	2	9	46	382	52.8	1.0000	359	5	18	88	719	3
99-1148	CUF-AW101-018	25	14.4	1.0000	11		9	46	485	52.8	1.0000	471		18	88	482	
99-1148	CUF-AW101-018	38	14.4	1.0000	24	n/a	9	46	469	52.8	1.0000	454	4	18	88	478	1
99-1148 MS	CUF-AW101-018	1203	14.4	1.0000	see below		9	46	1711	52.8	1.0000	1808		18	88	1808	

Matrix Spike Results **

ACL Number	Client Sample ID	[Q] Raw MS (ugC)	[R] MS Blk (ugC)	[S] Sam (ugC/g)	[T] MS Sam Wt (g)	[V] Sample (ugC)	Spike Wt (g)	[U] Spike (ugC)	MS % Recovery	
99-1150 MS	TIC	1489	14.9	7316	0.0545	399	0.0086	1036	108.7	TIC
	TOC	2355	55.8	16160	0.0545	881	0.0036	1432	113.5	TOC
	Total Carbon Recovery (TIC + TOC)	–	–	–	–		–	2468	111.5	TC
				(ugC/ml)	Vol (ml)					
99-1148 MS	TIC	1203	14.4	24	1.0000	24	0.0106	1272	94.7	TIC
	TOC	1711	52.8	454	1.0000	454	0.0033	1320	102.6	TOC
	Total Carbon Recovery (TIC + TOC)							2592	98.7	TC

Formulaes **

Standard TIC % Recovery = $((A-B)/((C/100)*D))*10^{-6}*100$
Standard TOC % Recovery = $((E-F)/((G/100)*H))*10^{-6}*100$
Sample TIC (ugC/g) = $(I-J)/(K*L/100)$
Sample TOC (ugC/g) = $(M-N)/(O*P/100)$

Matrix Spike Recoveries:
TIC % Recovery = $(((Q-R)/(L/100))-S*T)*100/U$
TOC % Recovery = $(((Q-R)/(P/100))-S*T)*100/U$
TC % Recovery = $((((Q^{TIC}-R^{TIC})/(L/100))-V^{TIC})+(((Q^{TOC}-R^{TOC})/(P/100))-V^{TOC}))*100/U^{TIC+TOC}$

Comments:

Due to the precision carried in the spreadsheet, some results may appear to be slightly off due to rounding.
The Pooled SD is the averaged SD for a recent list of 12 sample batches. MDL is based upon the Pooled SD. MDL = 3 x pooled SD.
If either the Sample or Duplicate are < 5x mdl, then the RPD is not calculated and displayed as "n/a".
TIC and TOC are measured; TC is the sum of the TIC and TOC results.

Preparer/date: MWUrie 3/30/99

Reviewer/date: DBSelleni 3/31/99

Battelle
Pacific Northwest Laboratories

Project Number

Internal Distribution

329/4 File
Mike Urie

Date March 31, 1999

To KP Brooks

From James Bramson

Subject ICP/MS Analysis of Submitted Samples

Pursuant to your request, the samples that you submitted for analysis were analyzed by ICPMS for ^{99}Tc. The results of this analysis are reported on the attached page.

An Amersham ^{99}Tc was used to generate the calibration curve. An independent Amersham ^{99}Tc standard was used as the continuing calibration verification (CCV) standard. Unless otherwise specified, the overall uncertainty of the values is conservatively estimated at ±10%, and is based on the precision between consecutive analytical runs as well as the accuracy of the CCV standard results.

The ^{99}Tc values reported assume that the Ru present is exclusively fission-product Ru, and therefore does not have an isotope at m/z 99; i.e., everything observed at m/z 99 is due to ^{99}Tc. The fingerprint we're seeing for Ru is obviously not natural, and is consistent with that observed in previous tank waste analyses. Approximate ^{101}Ru concentrations are provided for your information.

If you have any questions regarding this analysis, feel free to call me at 372-0624 or Tom Farmer at 372-0700

JPBrown
3/31/99

BNFL Tc-99 (Acid Digestion)

March 29, 1999

The results are reported in µg analyte/g of original sample.
The uncertainty of the results is estimated at ±10%.

Sample Number	Client Number	ICP/MS Number	Tc-99 µg/g	Ru ratio 101/102 (*0.541)	†Ru-101 µg/g
1%HNO3		9324a_B1	<0.01		
1%HNO3		9324a_B26	<0.01		
99-1143-PB	Process Blank	9324a11	<0.01	1.5309	0.04
99-1143	CUF-AW101-002	9324a12	4.1±0.5	1.1329	1.5
99-1143-DUP	CUF-AW101-002	9324a13	3.90	1.1371	1.2
99-1144	CUF-AW101-006	9324a14	3.93	1.0520	1.1
99-1148	CUF-AW101-018	9324a15	0.116	1.1060	0.04
99-1148 + spike	CUF-AW101-018	9324a16	0.251		
Spike Recovery			**105%**		
CCV results are reported in ng/ml					
5ppb Tc-99		9324a_C9	5.02		
5ppb Tc-99		9324a_C28	5.05		

* Natural $^{101}Ru/^{102}Ru$ ratio.
†Based on response from indium

DATA REVIEW

Reviewed by: Cecil Thomas Lemmrich

Date: 31mar99 Pages: 1 of 1

Battelle
Pacific Northwest Laboratories

Project Number

Internal Distribution

329/4 File
Mike Urie

Date March 31, 1999

To KP Brooks

From James Bramson *James*

Subject ICP/MS Analysis of Submitted Samples

Pursuant to your request, the samples that you submitted for analysis were analyzed by ICPMS for ^{99}Tc. The results of this analysis are reported on the attached page.

An Amersham ^{99}Tc was used to generate the calibration curve. An independent Amersham ^{99}Tc standard was used as the continuing calibration verification (CCV) standard. Unless otherwise specified, the overall uncertainty of the values is conservatively estimated at ±10%, and is based on the precision between consecutive analytical runs as well as the accuracy of the CCV standard results.

The ^{99}Tc values reported assume that the Ru present is exclusively fission-product Ru, and therefore does not have an isotope at m/z 99; i.e., everything observed at m/z 99 is due to ^{99}Tc. The fingerprint we're seeing for Ru is obviously not natural, and is consistent with that observed in previous tank waste analyses. Approximate ^{101}Ru concentrations are provided for your information.

If you have any questions regarding this analysis, feel free to call me at 372-0624 or Tom Farmer at 372-0700

JPBramson
3/24/99

BNFL Tc-99 (Ni/KOH Fusion)

March 19, 1999

The results are reported in µg analyte/g of original sample.
The uncertainty of the results is estimated at ±10%.

Sample Number	Client Number	ICP/MS Number	Tc-99 µg/g	Ru ratio 101/102 (*0.541)	†Ru-101 µg/g
1%HNO3		9311a1	<0.1		
1%HNO3		9311a14	<0.1		
1%HNO3		9311a30	<0.1		
99-1149-PB	Process Blank	9311a9	<0.1	2.171	180
99-1149	CUF-AW101-020	9311a26	144	1.243	6100
99-1149 + spike	CUF-AW101-020	9311a29	214		
Spike Recovery			**106%**		
99-1150	CUF-AW101-021	9311a27	145	1.266	5800
99-1150-DUP	CUF-AW101-021	9311a28	146	1.151	5700
CCV results are reported in ng/ml					
1ppb Tc-99		9311a11	1.01		
5ppb Tc-99		9311a31	5.18		

* Natural ^{101}Ru/^{102}Ru ratio.
†Based on response from indium

DATA REVIEW
Reviewed by: O.J. Farmer III
Date: 24Mar99 Pages: 1 of 1

Battelle PNNL/325 Bldg/RPG/Inorganic Analysis: ICPAES Analytical Report

Project: 29953
Client: K. P. Brooks

ACL Number(s): 99-01143 and 99-01150

Client ID: "CUF-AW101-002" and "CUF-AW101-021"

ASR Number: 5274

Total Samples: 10

Procedure: PNL-ALO-211, "Determination of Elements by Inductively Coupled Argon Plasma Atomic Emission Spectrometry" (ICP-AES).

Analyst: D. R. Sanders

Analysis Date (Filename): 03/22/99 (A0520); 03/24/99 (A0521)

Instrument File: "ICP-325-405-1" for traceability to Calibration; Quality Control, Verification, and Raw Data.

M&TE Number: ICPAES instrument -- WB73520
Mettler AT400 Balance -- Ser. No. 360-06-01-029

Jerry Wagner 4-12-99
Reviewed by

MW Urie 4/13/99
Concur

4/12/99

Battelle PNNL/RPG/Inorganic Analysis ... ICPAES Data Report

Det. Limit (ug/mL)	Multiplier=	5.0	25.2	25.2	25.1	24.6
	ALO#=	99-1143-PB	99-1143 @5	99-1143-DUP @5	99-1144 @5	99-1145 @5
	Client ID=	ProcessBlk ALO-128)	CUF-AW101-002	CUF-AW101-002	CUF-AW101-006	CUF-AW101-009
	Run Date=	3/22/99	3/22/99	3/22/99	3/22/99	3/22/99
	(Analyte)	(ug/mL)	(ug/mL)	(ug/mL)	(ug/mL)	(ug/mL)
0.025	Ag	--	--	--	--	--
0.060	Al	[1.2]	15,300	15,900	15,200	1,010
0.250	As	--	--	--	[7.5]	--
0.050	B	12.4	47.0	45.3	45.0	13.4
0.010	Ba	--	--	--	--	--
0.010	Be	--	[1.3]	[1.3]	[1.3]	--
0.100	Bi	--	--	--	--	--
0.250	Ca	--	[8.5]	[8.7]	[8.6]	--
0.015	Cd	--	[2.3]	[2.3]	[2.2]	--
0.200	Ce	--	--	--	--	--
0.050	Co	--	--	--	--	--
0.020	Cr	--	54.3	56.2	54.1	[4.7]
0.025	Cu	--	[5.7]	[6.0]	[5.4]	--
0.050	Dy	--	--	--	--	--
0.100	Eu	--	--	--	--	--
0.025	Fe	[0.26]	9.88	10.2	9.69	--
2.000	K	--	21,400	22,100	21,100	1,510
0.050	La	--	--	--	--	--
0.030	Li	--	--	--	--	--
0.100	Mg	--	--	--	--	--
0.050	Mn	--	--	--	--	--
0.050	Mo	--	--	--	--	--
0.150	Na	16.3	134,000	137,000	139,000	13,900
0.100	Nd	--	--	--	--	--
0.030	Ni	--	[5.3]	[5.5]	[5.3]	--
0.100	P	--	299	313	302	[23]
0.100	Pb	--	34.6	36.0	35.6	--
0.750	Pd	--	--	--	--	--
0.300	Rh	--	--	--	--	--
1.100	Ru	--	--	--	--	--
0.500	Sb	--	--	--	--	--
0.250	Se	--	--	--	--	--
0.500	Si	[23]	[85]	176	[84]	[27]
1.500	Sn	--	[71]	[74]	[73]	--
0.015	Sr	--	--	--	--	--
1.500	Te	--	--	--	--	--
1.000	Th	--	--	--	--	--
0.025	Ti	--	--	--	--	--
0.500	Tl	--	--	--	--	--
2.000	U	--	--	--	--	--
0.050	V	--	--	--	--	--
2.000	W	--	[64]	[63]	[65]	--
0.050	Y	--	--	--	--	--
0.050	Zn	--	[7.3]	[7.6]	[7.3]	--
0.050	Zr	--	[6.1]	[6.1]	[6.2]	--

Note: 1) Overall error greater than 10-times detection limit is estimated to be within +/- 15%.
2) Values in brackets [] are within 10-times detection limit with errors likely to exceed 15%.
3) "--" indicate measurement is below detection. Sample detection limit may be found by multiplying "det. limit" (far left column) by "multiplier" (top of each column).

Battelle PNNL/RPG/Inorganic Analysis ... ICPAES Data Report

Det. Limit	Multiplier=	4.9	4.9	5.1	110.4	126.3
	ALO#=	99-1146	99-1147	99-1148	99-1149 @2	99-1150 @2
	Client ID=	CUF-AW101-012	CUF-AW101-015	CUF-AW101-018	CUF-AW101-020	CUF-AW101-021
	Run Date=	3/22/99	3/22/99	3/22/99	3/22/99	3/22/99
(ug/mL)	(Analyte)	(ug/mL)	(ug/mL)	(ug/mL)	ug/g	ug/g
0.025	Ag	--	--	--	161	196
0.060	Al	31.1	18.8	253	70,900	93,600
0.250	As	--	--	--	--	--
0.050	B	10.2	14.3	10.5	272	288
0.010	Ba	--	--	--	384	515
0.010	Be	--	--	--	[4.5]	[6.1]
0.100	Bi	--	--	--	460	617
0.250	Ca	--	--	[1.3]	16,100	21,400
0.015	Cd	--	--	--	478	641
0.200	Ce	--	--	--	[210]	284
0.050	Co	--	--	--	69.9	93.8
0.020	Cr	3.82	2.58	3.29	20,000	26,400
0.025	Cu	--	--	[0.22]	290	393
0.050	Dy	--	--	--	[16]	[21]
0.100	Eu	--	--	--	[12]	[16]
0.025	Fe	--	--	[0.18]	31,100	40,400
2.000	K	[24]	--	363	[1,700]	[2,400]
0.050	La	--	--	--	402	537
0.030	Li	--	--	--	[19]	[26]
0.100	Mg	--	--	--	4,380	5,800
0.050	Mn	--	--	--	19,800	25,600
0.050	Mo	--	--	--	--	--
0.150	Na	4,130	2,340	5,560	85,100	114,000
0.100	Nd	--	--	--	460	622
0.030	Ni	--	--	--	3,170	4,190
0.100	P	[0.61]	--	6.32	176	227
0.100	Pb	--	--	[1.9]	1,550	2,030
0.750	Pd	--	--	--	--	--
0.300	Rh	--	--	--	[53]	[73]
1.100	Ru	--	--	--	--	[140]
0.500	Sb	--	--	--	--	[95]
0.250	Se	--	--	--	[66]	[87]
0.500	Si	[18]	[25]	[18]	33,400	53,900
1.500	Sn	--	--	--	[250]	[320]
0.015	Sr	--	--	--	280	376
1.500	Te	--	--	--	--	--
1.000	Th	--	--	--	1,230	1,740
0.025	Ti	--	--	--	130	174
0.500	Tl	--	--	--	--	--
2.000	U	--	--	--	73,500	98,600
0.050	V	--	--	--	[9.7]	[13]
2.000	W	--	--	--	--	--
0.050	Y	--	--	--	[35]	[47]
0.050	Zn	--	--	--	240	322
0.050	Zr	--	--	--	2,770	4,170

Note: 1) Overall error greater than 10-times detection limit is estimated to be within +/- 15%.
2) Values in brackets [] are within 10-times detection limit with errors likely to exceed 15%.
3) "--" indicate measurement is below detection. Sample detection limit may be found by multiplying "det. limit" (far left column) by "multiplier" (top of each column).

Battelle PNNL/325 Bldg/RPG/Inorganic Analysis: ICPAES Analytical Report

Eight samples and duplicate were prepared by SAL using ALO-128/ALO-129 Acid Digestion of liquids and solids procedures. Approximately 5 mL for each liquid sample was digested and diluted to a final volume of 25 mL. Approximately 0.4 grams for each solid sample was digested and diluted to a final volume of 25 mL. Density of sample CUF-AW101-002 and CUF-AW101-006 (liquid) is 1.31 g/mL. Density of the other liquid samples was presumed to be approximately the same as distilled water.

Two samples (solids) were also prepared by SAL using ALO-115 KOH/Ni Fusion procedure. Approximately 0.2 grams of solids sample were fused and diluted to a final volume of 50 mL. Measurement results are reported in μg/g.

All samples were analyzed by ICPAES after appropriate dilutions were made. Analytes of interest include AL, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, La, Mg, Mn, Mo, Na, Ni, Pb, Si, Ti, U, and Zn. Samples CUF-AW101-002, CUF-AW101-021 (acid digestion) and CUF-AW101-020 (KOH/Ni fusion) were post spiked. Samples CUF-AW101-020 and CUF-AW101-021 prepared by acid digestion appear to have a much higher concentration for all analytes than the concentration found in the KOH/Ni fusion prepared samples, particularly for Na. The reason for the apparent higher concentration may be due to the sample drying out in the hot cell. Approximately two weeks or more elapsed between preparation of the KOH/Ni fusion prepared samples (prepared 1st) and the acid digestion prepared samples. An attempt was made to normalize the Analyte concentration of the acid digested samples with respect to the KOH/Ni fusion prepared samples using Sodium concentration. However the normalization results were inconclusive, probably because Al and other analytes did not dissolve completely during the acid digestion procedure. The results from the KOH/Ni fusion prepared samples are more likely to represent the best data because, a) the fusion digestion procedure is more rigorous and, b) the solid sample had not had time to dry out.

Quality control samples include 5-fold serial dilution, relative percent difference between duplicate samples, post-spiked samples, QC check standards, high-end linear range check standards, and process blank. All QC samples analyzed were within tolerance limits specified in MCS-033 for all Analytes of interest except as follows.

--Serial dilution (5-fold) of samples CUF-AW101-020 and CUF-AW101-021 (acid digested solid samples) exceeded tolerance limit of 10%. Recovery of nearly all analytes of interest was greater than 10% and ranged between 10 to 17% for both samples (this may have been related to poor pipette performance).

4/13/99

Battelle PNNL/325 Bldg/RPG/Inorganic Analysis: ICPAES Analytical Report

--Relative Percent Difference in Si concentration between sample and duplicate for CUF-AW101-002 exceeded tolerance limit of 20% (actual RPD was 70%). All other analytes of interest was less than 5% RPD.

--Post Spike recovery of Mo in sample CUF-AW101-002 (acid digestion of liquid) exceeded tolerance limit of 75 to 125%. Only about 14% of Mo were recovered. Post Spike recovery of Mo in sample CUF-AW101-021 was 101%. A reason for the discrepancy is not known.

See attached "ICPAES Data Report" for measurement results, detection limits, and etc. Concentration measurements other than analytes of interest are for information only.

Please note bracketed values listed in the data report are within ten times instrument detection limit. Those measurement values have a potential uncertainty much greater than 15%.

Comments:

1) **"Final Results" have been corrected for all laboratory dilution performed on the sample during processing and analysis unless specifically noted otherwise.**

2) **Detection limits (DL) shown are for acidified water. Detection limits for other matrices may be determined if requested.**

3) **Routine precision and bias is typically ± 15% or better for samples in dilute, acidified water (eg. 2% v/v HNO_3 or less) at analyte concentrations greater than ten times detection limit up to the upper calibration level. This also presumes that the total dissolved solids concentration in the sample is less than 5000 µg/mL (0.5 per cent by weight).**

4) **Absolute precision, bias and detection limits may be determined on each sample if required by the client.**

5) **The maximum number of significant figures for all ICP measurements is 2.**

4/12/99

Battelle PNNL/RPG/Inorganic Analysis ... ICPAES Data Report

Det. Limit (ug/mL)	(Analyte)					
	Multiplier=	506.1	526.6	501.0	501.0	
	ALO#=	99-1149-PB KOH @2	99-1149 KOH @2	99-1150 KOH @2	99-1150 KOH DUP @2	
	Client ID=	*Proc.Blank*	*CUF-AW101-020*	*CUF-AW101-021*	*CUF-AW101-021*	
	Run Date=	3/24/99	3/24/99	3/24/99	3/24/99	
		ug/g	ug/g	ug/g	ug/g	
0.025	Ag	--	293	416	373	--
0.060	Al	[80]	58,400	58,200	59,900	--
0.250	As	--	--	--	--	--
0.050	B	--	[71]	[70]	[73]	--
0.010	Ba	--	276	268	281	--
0.010	Be	--	--	--	--	--
0.100	Bi	--	[360]	[350]	[370]	--
0.250	Ca	--	12,600	13,200	13,700	--
0.015	Cd	--	379	369	381	--
0.200	Ce	--	[190]	[190]	[190]	--
0.050	Co	--	[61]	[59]	[65]	--
0.020	Cr	--	15,000	15,700	16,200	--
0.025	Cu	--	223	214	214	--
0.050	Dy	--	--	--	--	--
0.100	Eu	--	--	--	--	--
0.025	Fe	[66]	24,000	23,400	24,300	--
0.050	La	--	304	298	309	--
0.030	Li	--	--	--	--	--
0.100	Mg	--	3,420	3,320	3,470	--
0.050	Mn	[34]	13,900	14,400	14,900	--
0.050	Mo	--	--	[28]	[27]	--
0.150	Na	[570]	55,600	56,600	57,500	--
0.100	Nd	--	[340]	[330]	[350]	--
0.100	P	--	[260]	[290]	[280]	--
0.100	Pb	--	1,150	1,090	1,210	--
0.750	Pd	--	--	--	--	--
0.300	Rh	--	--	--	--	--
1.100	Ru	--	--	--	--	--
0.500	Sb	--	--	--	--	--
0.250	Se	--	--	--	--	--
0.500	Si	--	61,400	62,200	64,300	--
1.500	Sn	--	--	--	--	--
0.015	Sr	--	199	194	203	--
1.500	Te	--	--	--	--	--
1.000	Th	--	[870]	[860]	[890]	--
0.025	Ti	--	290	270	289	--
0.500	Tl	--	--	--	--	--
2.000	U	--	54,500	52,800	55,300	--
0.050	V	--	--	--	--	--
2.000	W	--	--	--	--	--
0.050	Y	--	[30]	[30]	[31]	--
0.050	Zn	--	[180]	[200]	[200]	--
0.050	Zr	--	3,560	3,600	3,790	--

Note: 1) Overall error greater than 10-times detection limit is estimated to be within +/- 15%.

2) Values in brackets [] are within 10-times detection limit with errors likely to exceed 15%.

3) "--" indicate measurement is below detection. Sample detection limit may be found by multiplying "det. limit" (far left column) by "multiplier" (top of each column).

Samples CUF-AW101 Tank Sludge and Supernates
Radiochemistry Analytical Results

Sample Preparation

Tank sludge and supernate liquid samples were analyzed from tank AW101. The solids were prepared for analysis in a hot cell according to procedure PNL-ALO-115 by fusing approximately 0.2 g with KOH + KNO_3 in a nickel crucible. The cooled fusion was dissolved in dilute HCl + HNO_3, then diluted to 50.0 mL for analysis. The supernate liquids were prepared for analysis in a hot cell according to procedure PNL-ALO-128/129 by digesting about 0.5 g with nitric acid and diluting the product to 25.0 mL. The radiochemical analyses that followed required further dilution in most cases.

Radiochemistry results are shown on the attached table along with 1-sigma total uncertainties. All results are reported on a uCi per gram weight basis. Samples labeled "duplicate" are independent analyses from separate aliquots of starting material in the hot cell; those labeled "replicate" are separate aliquots analyzed in the laboratory.

Gamma Emitters

The hot cell preparations were directly gamma counted following procedure PNL-ALO-450. Most of the gamma emission from these samples is from Cs-137. Other detectable gamma emitters were Co-60, Ru/Rh-106, Cs-134, Eu-154, Eu-155, and Am-241. The hot cell blanks had detectable activities that were much lower than the samples. All of the duplicate results agree within the expected uncertainties. Since gamma analyses do not involve chemical separations, no sample spiking is performed. Due to the high level of Cs-137 in these samples, it was not possible to detect all of the other analytes at the requested Minimum Reportable Quantity values.

Gross Alpha

For gross alpha measurements, aliquots of the hot cell preparations were evaporated on planchets for counting following procedures PNL-ALO-420 and 421. The sludge samples all had about 5.8 uCi/g of total alpha activity. By comparison with the GEA results, about half of this activity is due to Am-241. No alpha activity could be detected in the supernates. Duplicate results show good agreement and the blank and sample spike recoveries were acceptable.

Strontium-90

The Sr-90 analyses were conducted according to procedures PNL-ALO-476, 484, and 450 using a Sr-85 tracer to monitor the chemical yields. Due to the high beta activity seen in the samples, which turned out to be due to Cs-137, the samples were highly diluted prior to chemical separation. For the supernate samples, this dilution led to relatively high detection limits, slightly above the requested Minimum Reportable Quantity values. For the sludge samples, duplicate and replicate results were in good agreement at about 1600 uCi/g. Negligible Sr-90 activities were seen in the hot cell blanks. The blank and sample spike recoveries were acceptable.

LR Greenwood
3-25-99

Battelle Pacific Northwest Laboratory
Radiochemical Processing Group-325 Building
Radioanalytical Applications Team

99-1143
3/25/99

Client : KP Brooks

Cognizant Scientist: L R Greenwood Date : 3/25/99

Concur : T Trang-le Date : 3/25/99

Measured Activities (uCi/g)

ALO ID Client ID	Alpha Error %	Sr-90 Error %	Co-60 Error %	Sb-125 Error %	Ru/Rh-106 Error %	Cs-134 Error %	Cs-137 Error %	Eu-154 Error %	Eu-155 Error %	Am-241 Error %
			Gamma Energy Analyses							
99-1143PB Process Blank	6.63E-5 7%	3.03E-2 3%	1.25E-5 14%	<3.E-5	<6.E-5	4.03E-5 6%	1.26E-3 2%	1.87E-5 22%	<3.E-5	<3.E-5
99-1143 CUF-AW101-002	<8.E-4	<3.E-1	<4.E-3	<3.E-1	<5.E-1	7.18E-2 13%	3.43E+2 2%	<2.E-2	<2.E-1	<2.E-1
99-1143DUP CUF-AW101-002	<8.E-4	<3.E-1	<4.E-3	<3.E-1	<5.E-1	6.35E-2 13%	3.49E+2 2%	<2.E-2	<2.E-1	<2.E-1
RPD						12%	2%			
99-1143 Rep CUF-AW101-002		<3.E-1								
99-1144 CUF-AW101-006	<7.E-4	<3.E-1	<4.E-3	<3.E-1	<5.E-1	7.51E-2 11%	3.55E+2 2%	<2.E-2	<2.E-1	<2.E-1
99-1148 CUF-AW101-018	<8.E-5	2.44E-2 17%	5.03E-4 8%	<6.E-3	<1.E-2	1.69E-3 5%	8.52E+0 2%	<2.E-4	<3.E-3	<3.E-3
99-1149PB Process Blank	1.74E-3 11%	1.45E-1 5%	6.69E-5 22%	<3.E-4	5.73E-4 40%	1.54E-3 10%	3.66E-2 5%	4.05E-4 15%	2.46E-4 30%	3.49E-4 39%
99-1149 CUF-AW101-020	5.72E+0 2%	1.76E+3 3%	4.41E-1 4%	<9.E-1	<2.E0	<6.E-2	3.88E+2 2%	3.10E+0 3%	3.16E+0 7%	2.44E+0 19%
99-1150 CUF-AW101-021	5.78E+0 2%	1.56E+3 3%	4.18E-1 4%	1.14E+0 16%	<2.E0	1.22E-1 18%	4.13E+2 2%	3.11E+0 2%	3.85E+0 6%	2.85E+0 12%
99-1150 DUP CUF-AW101-021	5.95E+0 2%	1.66E+3 3%	4.35E-1 4%	8.67E-1 29%	<2.E0	1.01E-1 26%	4.10E+2 2%	3.05E+0 2%	3.62E+0 5%	2.98E+0 11%
RPD	3%	6%	4%	27%		19%	1%	2%	6%	4%
99-1150 Rep CUF-AW101-021	5.84E+0 2%									
Matrix Spike	109%	96%								
Blank Spike	107%	91%								
Blank	<4.E-4	<3.E-5								

Battelle PNNL/RPG/Inorganic Analysis --- IC Report

WO/Project: W48480/29953
Client: K. Brooks

REVISION 1
(Change to Fluoride CUF-AW-101-006 & -018)

ACL Nmbr(s): 99-1143, -1144, -1148, -1149, -1150

Client ID: CUF-AW-101-002, -006, -018, -020, -021

ASR Nmbr 5274

Total Samples: 5 (3 liquid, 2 leached solids)

Procedure: PNL-ALO-212, "Determination of Inorganic Anions by Ion Chromatography" (IC).

Analyst: MJ Steele

Analysis Date: March 11, 1999

See Chemical Measurement Center 98620: IC File for Calibration and Maintenance Records.

M&TE Number: IC instrument -- WD25214
Mettler AT400 Balance – Cal. No. 360-06-01-031

Analyst: MJ Steele 4/7/99

Approval: MWUrie 4/7/99

Final Results:

Three liquid and two leach solids samples were analyzed by ion chromatography (IC) for inorganic anions as specified in ASR 5274. The liquid samples were diluted 5 fold during the preparation of the samples in the Shielded Analytical Laboratory (SAL) hot cells, and were diluted an additional 10-fold to 1000-fold to ensure that all anions were within the calibration range. Solid samples were leached using procedure ALO-103 resulting in an SAL dilution factor of approximately 50 for each sample. The leaches were diluted an additional 10-fold prior to analysis.

The results for the samples are presented in Table 1.

TABLE 1. CUF AW-101 --- Anion Results

SAMPLE ID	Client ID	F µg/ml	Cl µg/ml	NO_2 µg/ml	Br µg/ml	NO_3 µg/ml	PO_4 µg/ml	SO_4 µg/ml	C_2O_4 µg/ml
99-1143-DB	DILUTION BLANK	< 0.25	< 0.25	< 0.5	< 0.25	1	1	1	< 0.5
99-1143	CUF-AW101-002	1,300	3,400	57,800	< 250	115,000	910	1,400	510
99-1143 Dup	CUF-AW101-002	1,300	3,400	55,300	< 250	110,000	1,400	1,300	520
	RPD	0	0	4	n/a	5	42	3	2
99-1144	CUF-AW101-006	1,200	3,300	56,500	< 250	112,000	910	1,300	520
99-1148	CUF-AW101-018	30	52	890	< 13	1,800	50	47	6,800
99-1148-MS (%Rec)	CUF-AW101-018MS	96%	92%	97%	96%	93%	92%	90%	99%
SAMPLE ID	**Client ID**	**F µg/g**	**Cl µg/g**	**NO_2 µg/g**	**Br µg/g**	**NO_3 µg/g**	**PO_4 µg/g**	**SO_4 µg/g**	**C_2O_4 µg/g**
99-1149 PB	PROCESS BLANK	< 0.5	< 0.5	< 1	< 0.5	2	< 1	2	< 1
99-1149	CUF-AW101-020	< 130	< 130	390	< 130	4,600	< 250	500	6,000
99-1150	CUF-AW101-021	< 120	< 120	430	< 120	4,900	3,200	460	6,200
99-1150 Dup	CUF-AW101-021	< 120	< 120	400	< 120	4,900	4,100	380	6,700
	RPD	n/a	n/a	7	n/a	1	23	19	9

RPD = Relative Percent Difference (between sample and duplicate)

Q.C. Comments:

Following are results of quality control checks performed during IC analyses. In general, quality control checks met the requirements of the governing QA Plan, MCS-033.

<u>Working Blank Spike:</u> No working blank spikes were analyzed. The sample were diluted and leached in the SAL without spiking. Spiking was performed at the analytical stations and the diluted verification standards are used to assess blank standard performance.

Matrix Spiked Sample: The matrix spike recovery for sample 99-148 provided acceptable recovery for all anions reported, with recoveries ranging from 90% to 99%. These recoveries are well within the 75% to 125% acceptance criteria.

Duplicate: Liquid sample 99-1143 and leached solid sample 99-1150 were analyzed in duplicate. Except for phosphate, the RPD's are within the acceptance criteria of 20%. The poor precision demonstrated on the liquid sample is considered to be due to the level of the phosphate measured in the analysis sample (i.e., only 2 times the reportable limit. For the solids, the poor phosphate precision is most likely due to sample heterogeneity (e.g., although within RDP acceptance criteria, the sulfate also demonstrates poor precision) or to phosphate precipitation.

System Blank/Processing Blanks: The eluent system blank, as well as the dilution blank and leach processing blank from the SAL, measured a small contribution from nitrate, phosphate, and sulfate; however, the levels are insignificant when compared to the reported results.

Quality Control Calibration Verification Check Standards: Mid-range verification standards were analyzed with the samples. For all reported results, the concentrations of all analytes of interest were recovered within the governing QA Plan acceptance criteria of ± 10% for the verification standard, except for chloride. All chloride verifications standards recoveries were within 87% to 90%. Based on the verification standard recoveries, reported chloride results could be bias low by approximately 10%.

Notes:

1) "Final Results" have been corrected for all laboratory dilution performed on the sample during processing and analysis.

2) The low calibration standards are defined as the estimated quantitation limit (EQL) for the reported results and assume non-complex aqueous matrices. Actual detection limits or quantitation limits for specific sample matrices may be determined, if requested.

3) Routine precision and bias is typically ± 15% or better for non-complex aqueous samples that are free of interference and have similar concentrations as the measured anions. Sample-specific precision and bias may be determined on each sample if required.

Tank Material	AW 101 Diluted Feed [1]									
Matrix	Supernatant				Centrifuged Solids (Wet)					
Dissolution	Acid Digest				KOH Fusion				Acid Digest [2]	
Lab ID	99-0648-pb	99-0644	99-0644-d	[3]	99-0646-pb	99-0646	99-0646-d	[3]	99-0646-pb	99-0646
Sample ID	Proc Blnk	Sample	Duplicate	RPD	Proc Blnk	Sample	Duplicate	RPD	Proc Blnk	Sample
Units	µg/mL	µg/mL	µg/mL	(%)	µg/g	µg/g	µg/g	(%)	µg/g	µg/g
BNFL List										
Ag	< 3	< 3	< 3		< 24	[90]	[89]		< 4	81
Al	< 7	17,800	14,900	18	[91]	14,700	14,300	3	< 10	14,500
Ba	< 1	< 1	< 1		< 9	[25]	[25]		< 2	24
Ca	< 31	< 32	< 32		< 235	[1,700]	[1,700]		< 41	1,160
Cd	< 2	< 2	< 2		< 14	[34]	[35]		< 2	32
Co	< 6	< 6	< 6		< 47	< 48	< 44		< 8	< 10
Cr	< 2	61.1	51.1	18	< 19	1,640	1,600	2	< 3	1,610
Cu	< 3	< 3	< 3		< 24	< 24	< 22		< 4	[10]
Fe	< 3	[5.1]	[4.3]		[91]	1,350	1,430	6	< 4	1,430
K	< 247	25,200	20,800	19	n/a	n/a	n/a		< 326	17,200
La	< 6	< 6	< 6		< 47	< 48	< 44		< 8	[28]
Mg	< 12	< 13	< 13		< 94	[260]	[250]		< 16	314
Mn	< 6	< 6	< 6		[56]	1,390	1,440	4	< 8	1,300
Mo	< 6	< 6	< 6		< 47	< 48	< 44		< 8	< 10
Na	[41]	163,000	134,000	20	[1,300]	128,000	127,000	1	[140]	128,000
Ni	< 4	[5.4]	[4.2]		n/a	n/a	n/a		< 5	215
Pb	< 12	[45]	[37]		< 94	[120]	[120]		< 16	[119]
Si	[72]	[145]	[115]		< 470	[2,200]	[2,200]		[230]	2,300
Ti	< 3	< 3	< 3		< 24	< 24	< 22		< 4	[7.6]
U	< 247	< 257	< 259		< 1,882	[5,800]	[5,700]		< 326	5,400
Zn	[7.6]	[14]	[13]		< 47	< 48	< 44		< 8	[16]
Zr	< 6	[8.2]	[6.9]		< 47	[200]	[240]		< 8	351
Other Analytes Detected										
As	< 31	[104]	[84]		< 235	< 239	< 219		< 41	[79]
Ce	< 25	< 26	< 26		< 188	< 191	< 175		< 33	< 40
Nd	< 12	< 13	< 13		< 94	< 96	< 87		< 16	[29]
P	< 12	353	293	19	< 94	[360]	[410]		< 16	501
Sr	< 2	< 2	< 2		< 14	[24]	[24]		< 2	[17]
Y	< 6	< 6	< 6		< 47	< 48	< 44		< 8	< 10

(1) Overall error for reported results is estimated to be within ±15%; however, results in brackets "[ ]" are within 10-times detection limit and error is anticipated to be greater than ±15%.

(2) Solids acid digestions results normalized to KOH fusion Na results. See narrative.

(3) Relative Percent Difference (RPD) only calculated when both sample and duplicate exceed estimated quantitation limit (EQL).

Tank Material	AN 107 Diluted Feed (1)											
Matrix	Supernatant				Centrifuged Solids (Wet)							
Dissolution	Acid Digest				KOH Fusion				Acid Digest (2)			
Lab ID	99-0644-pb	99-0645	99-0645-d	(3)	99-0646-pb	99-0647	99-0647-d	(3)	99-0646-pb	99-0647	99-0647-d	(3)
Sample ID	ProcBlank	Sample	Duplicate	RPD	ProcBlank	Sample	Duplicate	RPD	ProcBlank	Sample	Duplicate	RPD
Units	µg/mL	µg/mL	µg/mL	(%)	µg/g	µg/g	µg/g	(%)	µg/g	µg/g	µg/g	(%)
BNFL List												
Ag	< 3	< 3	< 3		< 24	< 23	< 25		< 4	< 3	< 3	
Al	< 7	4,040	3,820	6	[91]	7,550	7,450	1	< 10	7,140	7,650	7
Ba	< 1	[4.1]	[4.0]		< 9	[44]	[44]		< 2	45	46	2
Ca	[52]	461	416	10	< 235	[780]	[520]		< 41	359	377	5
Cd	< 2	48	46	5	< 14	[37]	[36]		< 2	33	34	3
Co	< 6	< 4	< 4		< 47	< 46	< 51		< 8	< 6	< 7	
Cr	< 2	149	142	5	< 19	725	718	1	< 3	697	723	4
Cu	< 3	[22]	[20]		< 24	< 23	< 25		< 4	[19]	[20]	
Fe	[5.6]	1,170	1,110	5	[91]	9,960	8,670	14	< 4	8,260	8,690	5
K	< 234	[1,300]	[1,240]		n/a	n/a	n/a		< 326	[670]	[647]	
La	< 6	[23]	[22]		< 47	[65]	[60]		< 8	108	112	4
Mg	< 12	< 12	< 12		< 94	< 93	< 102		< 16	[30]	[30]	
Mn	< 6	108	106	2	[56]	4,910	5,130	4	< 8	4,920	4,989	1
Mo	< 6	< 6	< 6		< 47	< 46	< 51		< 8	< 6	< 7	
Na	[34]	176,000	171,000	3	[1,300]	134,000	139,000	4	[140]	134,000	139,000	4
Ni	< 4	402	382	5	n/a	n/a	n/a		< 5	269	285	6
Pb	< 12	263	249	5	< 94	[580]	[640]		< 16	755	784	4
Si	< 59	< 45	< 44		< 470	< 463	< 509		[230]	[264]	[419]	
Ti	< 3	< 3	< 3		< 24	< 23	< 25		< 4	[4.5]	[4.8]	
U	< 234	< 244	< 241		< 1,882	< 1,851	< 2,036		< 326	< 231	< 279	
Zn	[11]	[22]	[16]		< 47	< 46	< 51		< 8	64	[67]	
Zr	< 6	[42]	[44]		< 47	[110]	[92]		< 8	197	206	4
Other Analytes Detected												
As	< 29	[98]	[93]		< 235	< 231	< 254		< 41	[77]	[83]	
Ce	< 23	[27]	[26]		< 188	[190]	< 204		< 33	[212]	[219]	
Nd	< 12	[73]	[68]		< 94	[210]	[190]		< 16	311	326	5
P	< 12	505	488	3	< 94	[500]	[520]		< 16	418	436	4
Sr	< 2	[2.7]	[2.5]		< 14	< 14	< 15		< 2	[6.2]	[6.3]	
Y	< 6	[11]	[11]		< 47	< 46	< 51		< 8	[31]	[32]	

(1) Overall error for reported results is estimated to be within ±15%; however results in brackets "[ ]" are within 10-times detection limit and error is anticipated to be greater than ±15%..

(2) Solids acid digestion results normalized to KOH fusion Na results. See narrative.

(3) Relative Percent Difference (RPD) only calculated when both sample and duplicate exceed estimated quantitation limit (EQL).

Tank Material	AW-101 Diluted Feed											
Matrix	Supernatant						Centrifuged Solids (Wet)					
Dissolution	Acid Digest						KOH Fusion					
Lab ID	99-0648-pb		99-0644		99-0644-d		99-0646-pb		99-0646		99-0646-d	
Sample ID	ProcBlnk		Sample		Duplicate		ProcBlnk		Sample		Duplicate	
Units (%Error)	µCi/mL (±1s)		µCi/mL (±1s)		µCi/mL (±1s)		µCi/g (±1s)		µCi/g (±1s)		µCi/g (±1s)	
Co-60 (GEA)	< 3.E-4		< 1.E-2		< 1.E-2		< 5.E-2		< 7.E-2		< 7.E-2	
Sr-90	1.69E-2	21%	< 5.E-1		< 5.E-1		1.60E-2	12%	1.41E+2	4%	1.60E+2	4%
Cs-134 (GEA)	< 3.E-4		5.60E-2	15%	5.64E-2	12%	< 5.E-2		< 8.E-2		< 6.E-2	
Cs-137 (GEA)	8.67E-4	13%	2.50E+2	2%	2.10E+2	2%	2.25E-1	12%	1.96E+2	2%	1.87E+2	2%
Eu-154 (GEA)	< 7.E-4		< 4.E-2		< 4.E-2		< 2.E-1		< 2.E-1		< 2.E-1	
Eu-155 (GEA)	< 7.E-4		< 4.E-1		< 4.E-1		< 2.E-1		< 5.E-1		< 5.E-1	
Pu-238	7.08E-6	15%	< 3.E-5		< 5.E-5		6.36E-5	30%	3.43E-2	9%	4.61E-2	7%
Pu-239+Pu-240	2.49E-6	29%	1.65E-4	15%	1.37E-4	13%	7.42E-5	19%	2.48E-1	4%	2.56E-1	4%
Am-241 (GEA)	< 7.E-4		< 4.E-1		< 4.E-1		< 2.E-1		< 5.E-1		< 5.E-1	
Am-241 (AEA)	9.12E-6	19%	1.16E-4	13%	8.94E-5	14%	< 6.E-7		2.53E-1	5%	2.43E-1	5%
Cm-242	< 1.E-6		< 5.E-6		< 4.E-6		< 5.E-8		< 6.E-4		4.84E-4	45%
Cm-243+Cm-244	9.96E-6	18%	2.41E-5	31%	< 9.E-6		4.93E-7	23%	8.45E-3	14%	9.49E-3	12%
Total Alpha	< 3.E-4		< 1.E-2		< 1.E-2		<2.E-3		4.56E-1	9%	5.66E-1	7%
Total Beta	4.48E-2	3%	2.75E+2	3%	2.25E+2	3%	5.03E-2	7%	4.80E+2	4%	4.78E+2	4%
	µg/mL (±1s)		µg/mL (±1s)		µg/mL (±1s)		µg/g (±1s)		µg/g (±1s)		µg/g (±1s)	
Total Cs	--	--	1.17E+1	2%	9.80E+0	2%	--	--	9.17E+0	2%	--	--
Total U	2.20E-2	2%	3.32E+0	2%	3.12E+0	2%	2.86E-1	2%	5.42E+3	4%	5.46E+3	4%

Tank Material	AN-107 Diluted Feed											
Matrix	Supernatant						Centrifuged Solids (Wet)					
Dissolution	Acid Digest						KOH Fusion					
Lab ID	99-0644-pb		99-0645		99-0645-d		99-0646-pb		99-0647		99-0647-d	
Sample ID	ProcBlnk		Sample		Duplicate		ProcBlnk		Sample		Duplicate	
Units (%Error)	µCi/mL (±1s)		µCi/mL (±1s)		µCi/mL (±1s)		µCi/g (±1s)		µCi/g (±1s)		µCi/g (±1s)	
Co-60 (GEA)	< 3.E-4		1.11E-1	7%	1.15E-1	7%	< 5.E-2		< 9.E-2		< 9.E-2	
Sr-90	< 4.E-3		7.72E+1	5%	7.46E+1	5%	1.60E-2	12%	1.90E+2	4%	1.93E+2	4%
Cs-134 (GEA)	< 3.E-4		< 3.E-2		< 3.E-2		< 5.E-2		< 8.E-2		< 9.E-2	
Cs-137 (GEA)	4.71E-4	27%	2.61E+2	2%	2.50E+2	2%	2.25E-1	12%	1.65E+2	2%	1.65E+2	2%
Eu-154 (GEA)	< 5.E-4		6.20E-1	4%	6.03E-1	4%	< 2.E-1		1.44E+0	5%	1.17E+0	7%
Eu-155 (GEA)	< 7.E-4		4.50E-1	16%	2.61E-1	25%	< 2.E-1		9.87E-1	14%	6.49E-1	21%
Pu-238	7.57E-6	21%	7.02E-3	15%	8.36E-3	9%	6.36E-5	30%	5.01E-2	7%	3.75E-2	9%
Pu-239+Pu-240	4.06E-6	31%	3.08E-2	7%	3.20E-2	5%	7.42E-5	19%	1.68E-1	5%	1.33E-1	5%
Am-241 (GEA)	< 5.E-4		5.66E-1	23%	2.30E-1	50%	< 2.E-1		2.49E+0	12%	1.68E+0	18%
Am-241 (AEA)	6.61E-6	18%	3.93E-1	5%	3.64E-1	5%	< 6.E-7		1.67E+0	5%	1.27E+0	5%
Cm-242	< 4.E-7		1.60E-3	21%	1.28E-3	28%	< 5.E-8		4.18E-3	16%	4.24E-3	11%
Cm-243+Cm-244	3.43E-6	25%	1.19E-2	9%	1.26E-2	10%	4.93E-7	23%	3.67E-2	7%	2.52E-2	23%
TotalAlpha	< 1.E-4		4.43E-1	3%	4.50E-1	3%	<2.E-3		2.14E+0	4%	1.52E+0	5%
Total Beta	1.40E-2	3%	4.66E+2	3%	4.34E+2	3%	5.03E-2	7%	5.20E+2	4%	5.09E+2	4%
	µg/mL (±1s)		µg/mL (±1s)		µg/mL (±1s)		µg/g (±1s)		µg/g (±1s)		µg/g (±1s)	
Total Cs	--	--	1.23E+1	2%	1.17E+1	2%	--	--	7.72E+0	2%	7.63E+0	2%
Total U	9.84E-3	2%	7.44E+1	2%	7.18E+1	2%	2.86E-1	2%	1.03E+2	2%	1.03E+2	2%

Tank Material	AW-101 Diluted Feed									
Matrix	Supernatant					Centrifuged Solids (Wet)				
Lab ID		99-0648-pb	99-0644	99-0644-d	(1)		99-0646-pb	99-0646	99-0646-d	(1)
Sample ID		ProcBlnk	Sample	Duplicate	RPD		ProcBlnk	Sample	Duplicate	RPD
Units	Type of Prep	µg/mL	µg/mL	µg/mL	(%)	Type of Prep	µg/g	µg/g	µg/g	(%)
Tc-99 (ICP/MS)	Acid Digest	<0.02	5.88	5.12	14	KOH Fusion	0.1	20.9	20.9	0
Tc-99 (ICP/MS)	Direct/Dilution	n/a	5.20	5.24	1	n/a	n/a	n/a	n/a	
TIC	Hot Persulfate	73	2,190	2,120	3	Hot Persulfate	n/a	27,500	n/m	
TOC	Hot Persulfate	<85	1,460	1,660	13	Hot Persulfate	n/a	20,100	n/m	
TC (sum)		73	3,650	3,780	4		n/a	47,600		
Fluoride	Direct/Dilution	<21	1000	660	40	Water Leach	<120	1,600	n/m	
Chloride	Direct/Dilution	<21	3,300	3,300	1	Water Leach	<120	2,700	n/m	
Nitrite	Direct/Dilution	<42	63,500	62,000	2	Water Leach	<240	41,500	n/m	
Bromide	Direct/Dilution	<21	<400	<380		Water Leach	<120	<1200	n/m	
Nitrate	Direct/Dilution	<42	125,000	121,000	3	Water Leach	<240	80,900	n/m	
Phosphate	Direct/Dilution	<42	2,000	1,900	3	Water Leach	<240	<2300	n/m	
Sulfate	Direct/Dilution	<42	1,900	1,800	4	Water Leach	<240	<2300	n/m	
Oxalate	Direct/Dilution	<41	<800	<760		Water Leach	<240	42,000	n/m	
		mmole/mL	mmole/mL	mmole/mL						
OH	Direct/Dilution	n/d	3.02	3.09	2	n/m	n/m	n/m	n/m	
		pH	pH	pH						
pH	Direct					n/m	n/m	n/m	n/m	

Tank Material	AN-107 Diluted Feed									
Matrix	Supernatant					Centrifuged Solids (Wet)				
Lab ID		99-0644-pb	99-0645	99-0645-d			99-0646-pb	99-0647	99-0647-d	
Sample ID		ProcBlnk	Sample	Duplicate	RPD		ProcBlnk	Sample	Duplicate	RPD
Units	Type of Prep	µg/mL	µg/mL	µg/mL	(%)	Type of Prep	µg/g	µg/g	µg/g	(%)
Tc-99 (ICP/MS)	Acid Digest	<0.02	4.40	4.23	4	KOH Fusion	0.1	3.62	3.92	8
Tc-99 (ICP/MS)	Direct/Dilution	<0.05	4.09	3.98	3	n/a	n/a	n/a	n/a	
TIC	Direct/Dilution	76	16,400	16,200	1	Direct	n/a	18,200	17,500	4
TOC	Direct/Dilution	<85	30,000	29,800	0	Direct	n/a	31,100	32,900	1
TC (sum)	Direct/Dilution	76	46,400	46,000	1	Direct	n/a	51,200	50,400	2
Fluoride	Direct/Dilution	<17	6,300	6,400	2	Water Leach	<120	4,500	4,300	3
Chloride	Direct/Dilution	<17	1,400	1,400	2	Water Leach	<120	<1200	<1200	
Nitrite	Direct/Dilution	<35	51,100	51,600	1	Water Leach	<240	30,900	31,200	1
Bromide	Direct/Dilution	<17	<490	<480		Water Leach	<120	<1200	<1200	
Nitrate	Direct/Dilution	<35	161,000	161,000	0	Water Leach	<240	111,000	111,000	0
Phosphate	Direct/Dilution	<35	3,000	3,000	2	Water Leach	<240	<2400	<2400	
Sulfate	Direct/Dilution	<35	7,900	7,400	6	Water Leach	<240	7,000	7,000	1
Oxalate	Direct/Dilution	<34	1,300	1,300	1	Water Leach	<240	32,200	32,000	1
		mmole/mL	mmole/mL	mmole/mL						
OH	Direct/Dilution	(2)	0.722	0.712	1	n/m	n/m	n/m	n/m	
		pH	pH	pH						
pH	Direct	n/a				n/m	n/m	n/m	n/m	

(1) RPD only calculated when sample and duplicate results above reporting threshold for method's RPD calculation. (Calculated prior to rouding)

(2) Not titration inflection point detected; no OH calculated.

n/a = not applicable to method; n/m = not measured due to applicable of method OR availability of sample material

Appendix C: Cross Flow Filtration Raw Data

Initial Clean Water Flux Measurements

DI Water--Pre-filtered to 0.2 micron

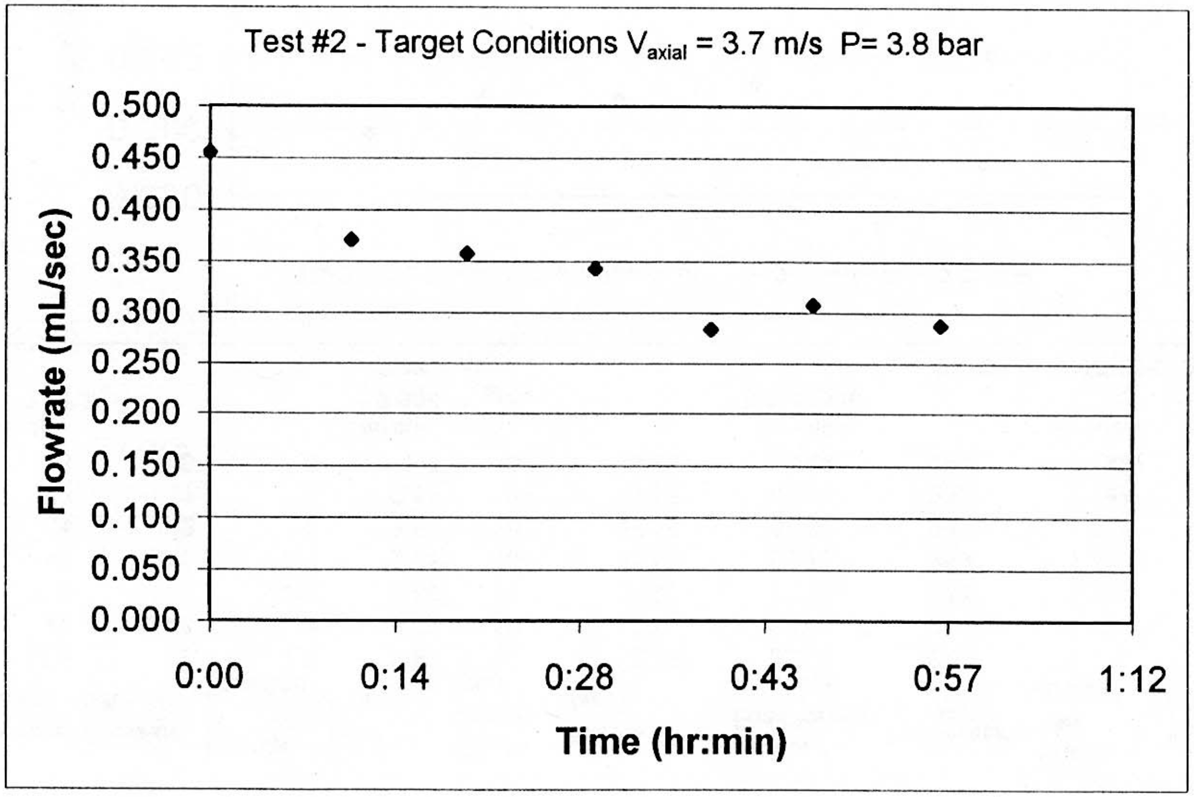
Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Filtrate Flux (m3/m2/day)	Average
0	30	30	0	1.06	30	33.65	0.89	4.22	
17	30	28	2	1.06	30	38.03	0.79	3.74	
23	31	30	1	1.02	30	36.6	0.82	3.88	3.947135
0	59	56	3	4.8	30	17.94	1.67	7.92	
8	56	54	2	4.9	30	19.63	1.53	7.24	
19	57	54	3	4.95	30	17.97	1.67	7.91	7.688796
0	72	70	2	4.1	30	13.72	2.19	10.36	
11	71	69	2	4.09	30	15.25	1.97	9.32	
21	71.5	70	1.5	4.05	30	13.97	2.15	10.17	
64	72	70	2	3.95	30	13.63	2.20	10.43	10.06769

Condition 1

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
0:00	0:00	31	30	1	2.23	10	40.84	0.245	22.7	1.238	0.589
0:10	0:10	34	33	1	2.29	10	37.03	0.270	26.8	1.216	0.527
0:10	0:20	33	32	1	2.3	10	41.81	0.239	26.9	1.074	0.479
0:11	0:31	31.5	30	1.5	2.4	10	44.72	0.224	25.6	1.041	0.491
0:10	0:41	32	30	2	2.38	10	44.94	0.223	26.9	0.999	0.468
0:10	0:51	31	30	1	2.46	10	47.72	0.210	27	0.939	0.446
0:10	1:01	31.5	30	1.5	2.38	10	54.22	0.184	20.1	1.005	0.474
		Average			Average			Average		Average	
		2.14	bar		2.384	gpm		0.228		1.011739579	m3/m2/day
					2.11	m/s			Std Dev.	0.050833041	m3/m2/day

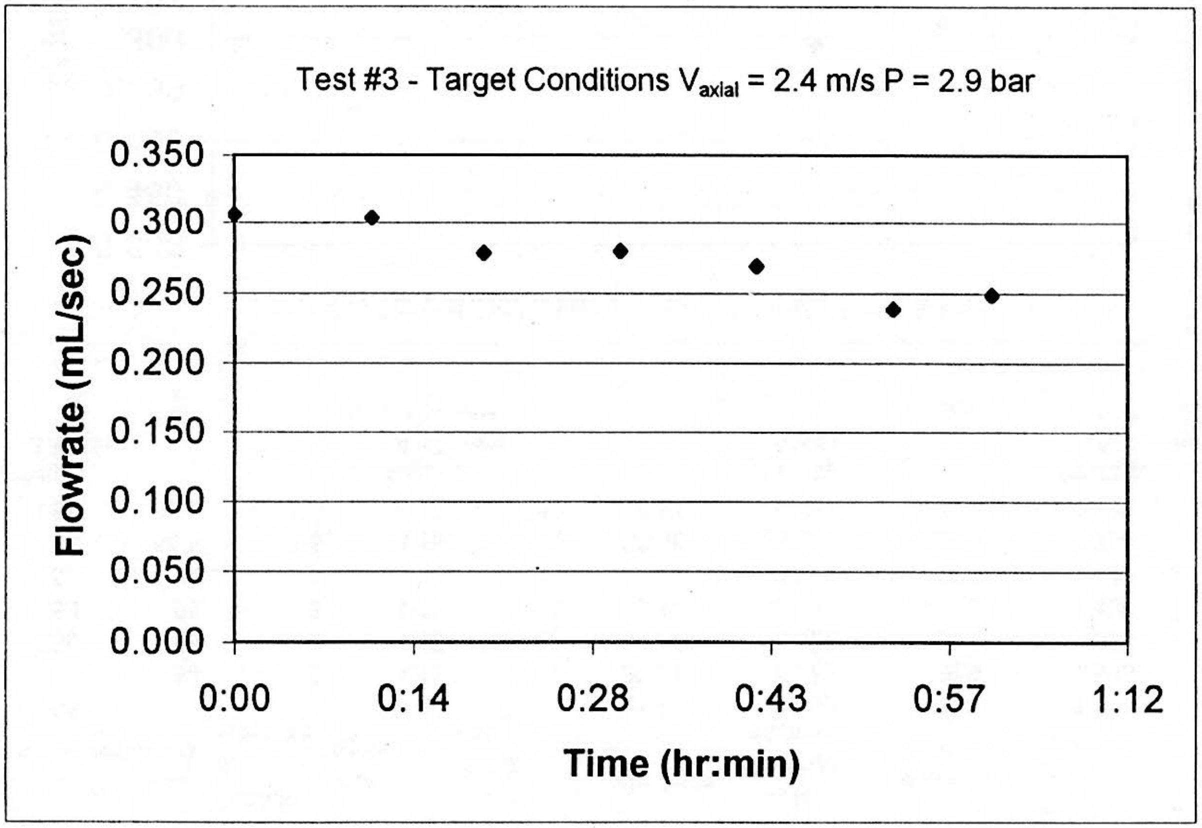
Condition 2

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	58	55	3	4.02	10	21.97	0.455	31.2	1.817	0.466
0:11	0:11	57	54	3	4.13	10	26.94	0.371	29.9	1.535	0.401
0:09	0:20	58	55	3	4.15	10	27.94	0.358	28.1	1.555	0.399
0:10	0:30	58	55	3	4.15	10	29.12	0.343	29.9	1.420	0.365
0:09	0:39	57	54	3	4.2	10	35.28	0.283	23.1	1.417	0.370
0:08	0:47	58	54.5	3.5	4.15	10	32.56	0.307	26.3	1.403	0.362
0:10	0:57	58	53.5	4.5	4.2	10	34.84	0.287	26.3	1.311	0.341
		Average			Average			Average		Average	
		3.87	bar		4.17	gpm		0.344		1.421	m3/m2/day
					3.691	m/s			Std Dev.	0.087	m3/m2/day



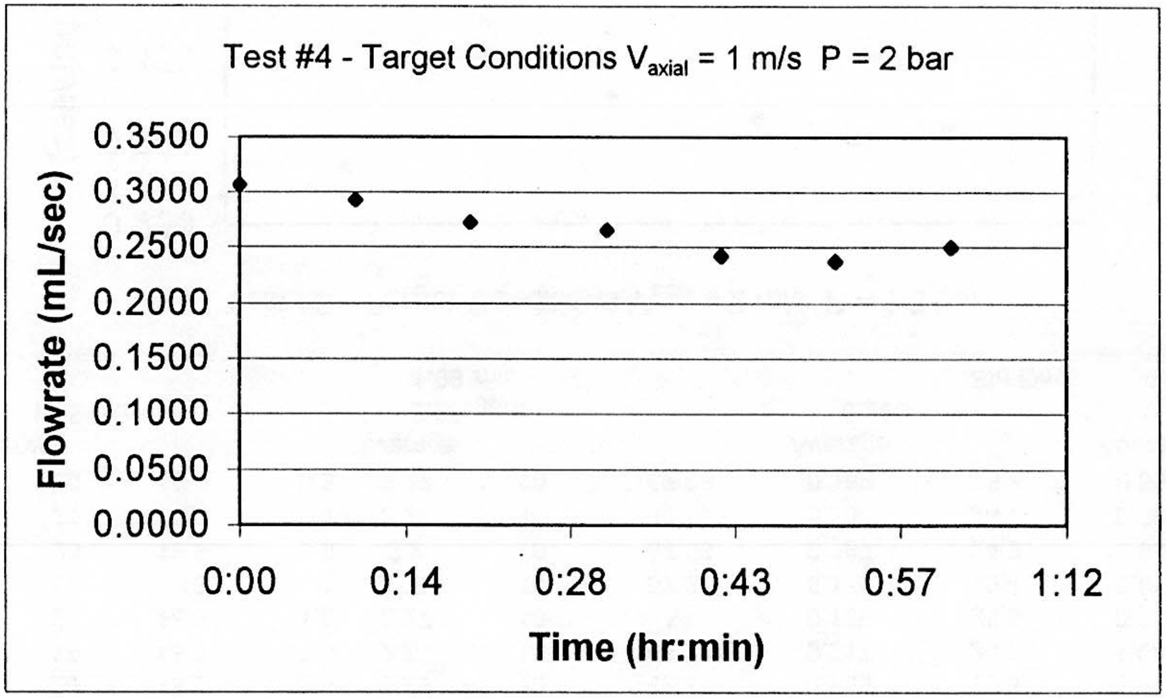
Condition 3

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	42.5	40	2.5	2.69	10	32.75	0.305	24.3	1.475	0.519
0:11	0:11	42	40	2	2.69	10	33	0.303	25.9	1.399	0.495
0:09	0:20	43.5	41	2.5	2.66	10	35.97	0.278	23.6	1.370	0.470
0:11	0:31	43	40.5	2.5	2.75	10	35.81	0.279	25.4	1.308	0.454
0:11	0:42	44	42	2	2.68	10	37.19	0.269	26.2	1.231	0.415
0:11	0:53	42	41	1	2.68	10	41.87	0.239	23.3	1.187	0.415
0:08	1:01	43	41.5	1.5	2.7	10	40.18	0.249	24.4	1.199	0.412
		Average			Average			Average		Average	
		2.91	bar		2.694	gpm		0.2746056		1.259	m3/m2/day
					2.384	m/s			Std Dev.	0.077866	m3/m2/day



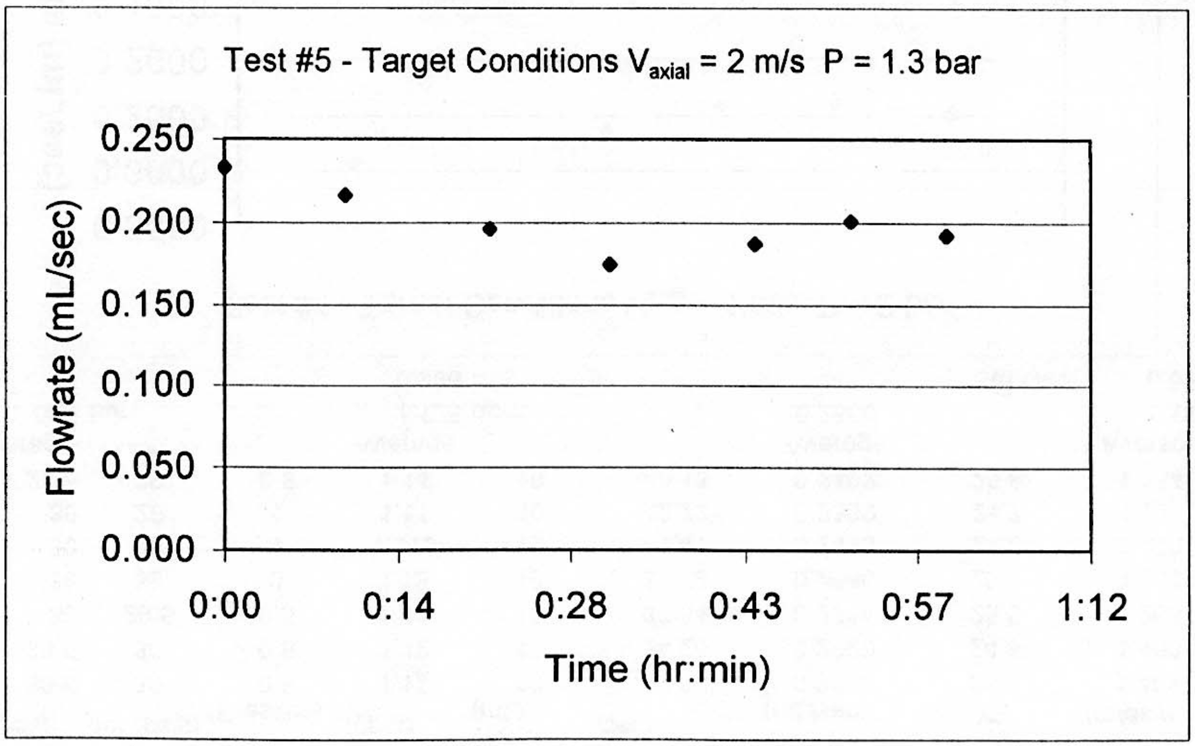
Condition 4

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	30.5	30	0.5	1.12	10	32.62	0.3066	23.9	1.498	0.718
0:10	0:10	30.5	30	0.5	1.12	10	34.25	0.2920	24.5	1.403	0.672
0:10	0:20	30	29.5	0.5	1.13	10	36.84	0.2714	25.5	1.268	0.618
0:12	0:32	30	30	0	1.13	10	37.79	0.2646	25.4	1.239	0.599
0:10	0:42	30	29	1	1.115	10	41.41	0.2415	24.2	1.170	0.575
0:10	0:52	30	29	1	1.11	10	42.22	0.2369	24.7	1.131	0.556
0:10	1:02	29.5	29	0.5	1.14	10	40.13	0.2492	25.8	1.154	0.572
		Average			Average			Average		Average	
		2.041 bar			1.125 gpm			0.2660		1.192 m3/m2/day	
					0.996 m/s				Std Dev.	0.058 m3/m2/day	



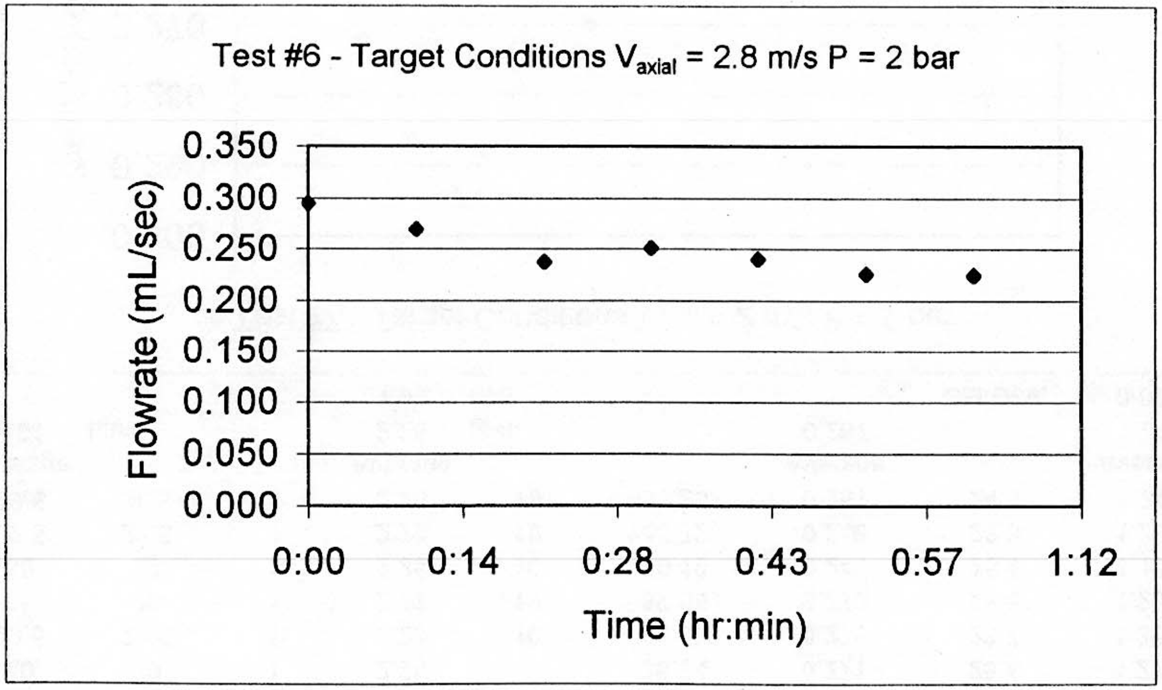
Condition 5

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	20	18.5	1.5	2.23	10	42.84	0.233	23.9	1.141	0.859
0:10	0:10	19	18.5	0.5	2.25	10	46.18	0.217	24.5	1.040	0.805
0:12	0:22	20	18.5	1.5	2.27	10	51	0.196	25.5	0.916	0.690
0:10	0:32	19	18	1	2.26	10	57.37	0.174	25.4	0.816	0.640
0:12	0:44	20	19.5	0.5	2.2	10	53.53	0.187	24.2	0.905	0.665
0:08	0:52	21	20	1	2.25	10	49.78	0.201	24.7	0.960	0.679
0:08	1:00	20	19.5	0.5	2.27	10	52.06	0.192	25.8	0.890	0.653
		Average			Average			Average		Average	
		1.35 bar			2.25 gpm			0.200		0.897	m3/m2/day
					1.99 m/s				Std Dev.	0.052	m3/m2/day



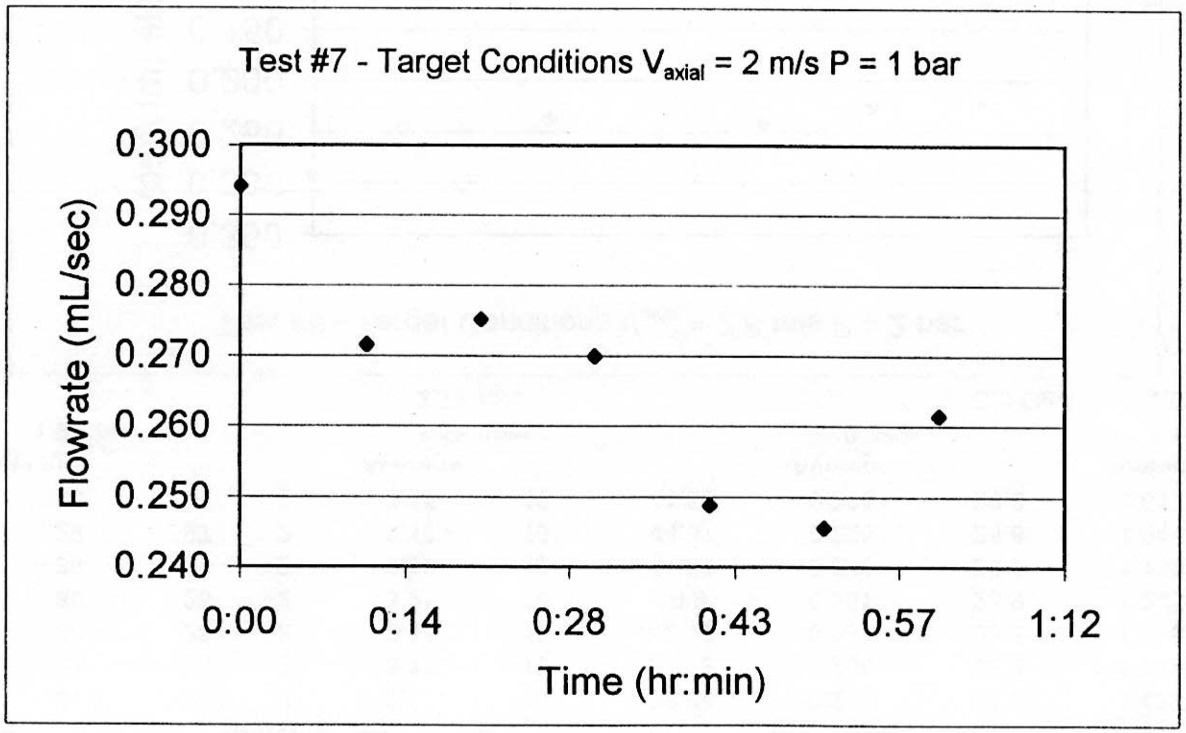
Condition 6

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	31	28	3	3.13	10	33.94	0.295	24.2	1.427	0.702
0:10	0:10	31	29	2	3.11	10	37.12	0.269	25.3	1.265	0.612
0:12	0:22	30	28	2	3.11	10	42.13	0.237	25.8	1.099	0.550
0:10	0:32	30	28	2	3.21	10	39.9	0.251	23.9	1.225	0.612
0:10	0:42	30	28	2	3.18	10	41.69	0.240	24.9	1.139	0.570
0:10	0:52	29	27	2	3.13	10	44.37	0.225	25.8	1.044	0.541
0:10	1:02	30	28	2	3.15	10	44.53	0.225	26.6	1.017	0.509
		Average			Average			Average		Average	
		1.99 bar			3.16 gpm			0.249		1.105	m3/m2/day
					2.79 m/s				Std Dev.	0.082	m3/m2/day



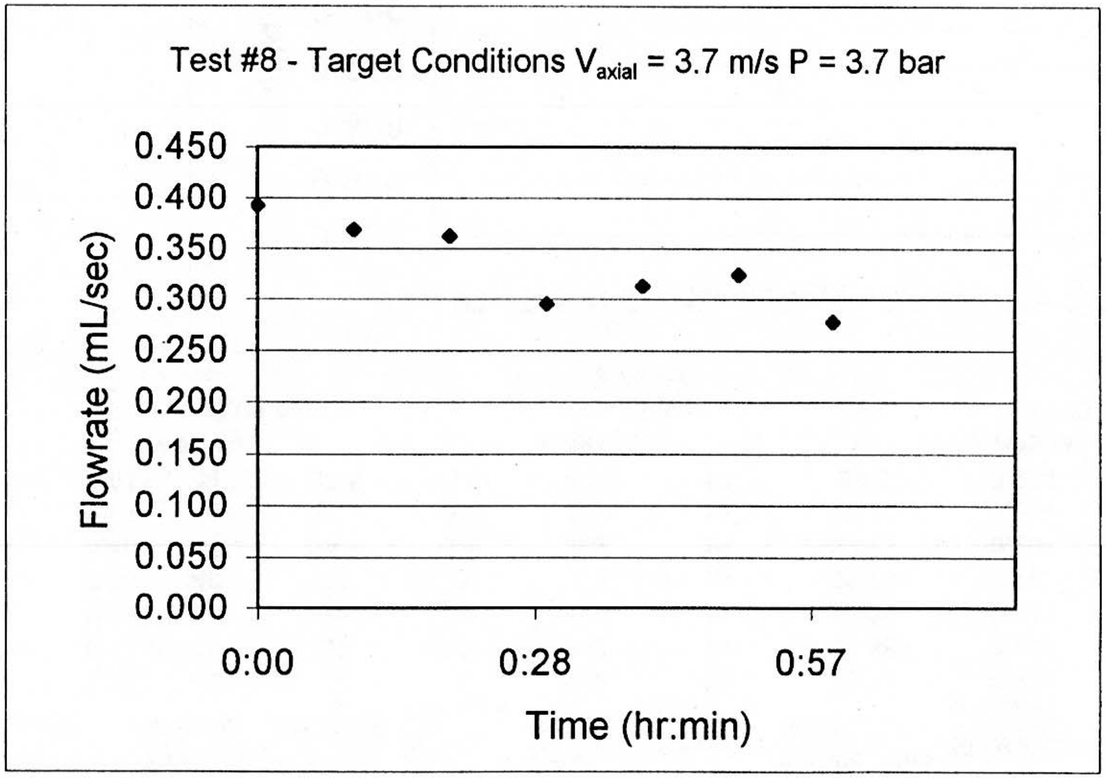
Condition 7

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)		Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	29.5	28	1.5	2.27		10	34	0.294	25.7	1.366	0.689
0:11	0:11	30	29	1	2.26		10	36.84	0.271	25.4	1.271	0.625
0:10	0:21	29.5	28.5	1	2.23		10	36.37	0.275	23.7	1.351	0.676
0:10	0:31	30	29	1	2.23		10	37.06	0.270	25.6	1.257	0.618
0:10	0:41	30	29	1	2.25		10	40.19	0.249	25.4	1.165	0.573
0:10	0:51	29.5	28.5	1	2.27		10	40.72	0.246	23.8	1.203	0.602
0:10	1:01	29.5	28.5	1	2.26		10	38.25	0.261	24.9	1.242	0.621
		Average			Average				Average		Average	
		2.01	bar		2.25	gpm			0.267		1.244	m3/m2/day
					1.99	m/s				Std Dev.	0.070	m3/m2/day



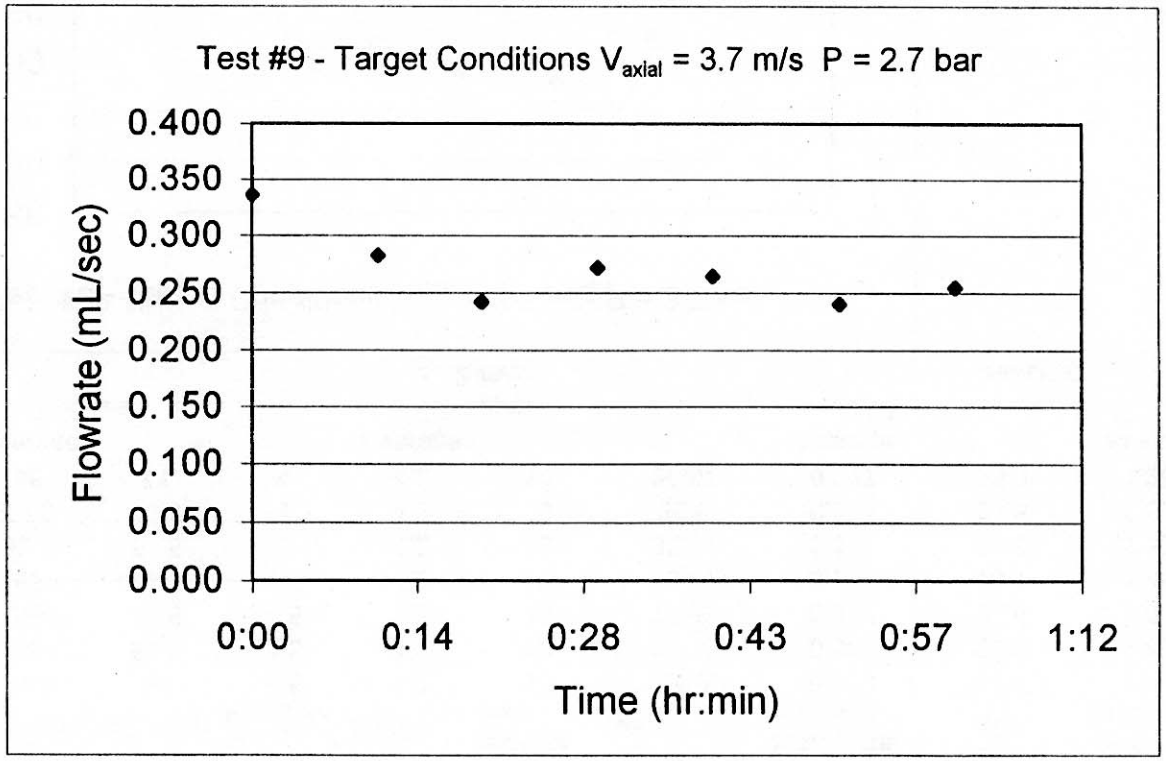
Condition 8

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	54.5	50	4.5	4.2	10	25.5	0.392	24.1	1.905	0.529
0:10	0:10	55	50.5	4.5	4.2	10	27.16	0.368	23.8	1.804	0.496
0:10	0:20	55	50.5	4.5	4.2	10	27.63	0.362	25.4	1.695	0.466
0:10	0:30	56	51.5	4.5	4.2	10	33.91	0.295	26.1	1.354	0.365
0:10	0:40	55.5	51.5	4	4.2	10	32.01	0.312	23.9	1.526	0.414
0:10	0:50	54.5	50.5	4	4.2	10	30.9	0.324	24.5	1.555	0.429
0:10	1:00	55	51	4	4.2	10	36.07	0.277	25.9	1.280	0.350
		Average			Average			Average		Average	
		3.66 bar			4.20 gpm			0.333		1.482	m3/m2/day
					3.72 m/s				Std Dev.	0.166	m3/m2/day



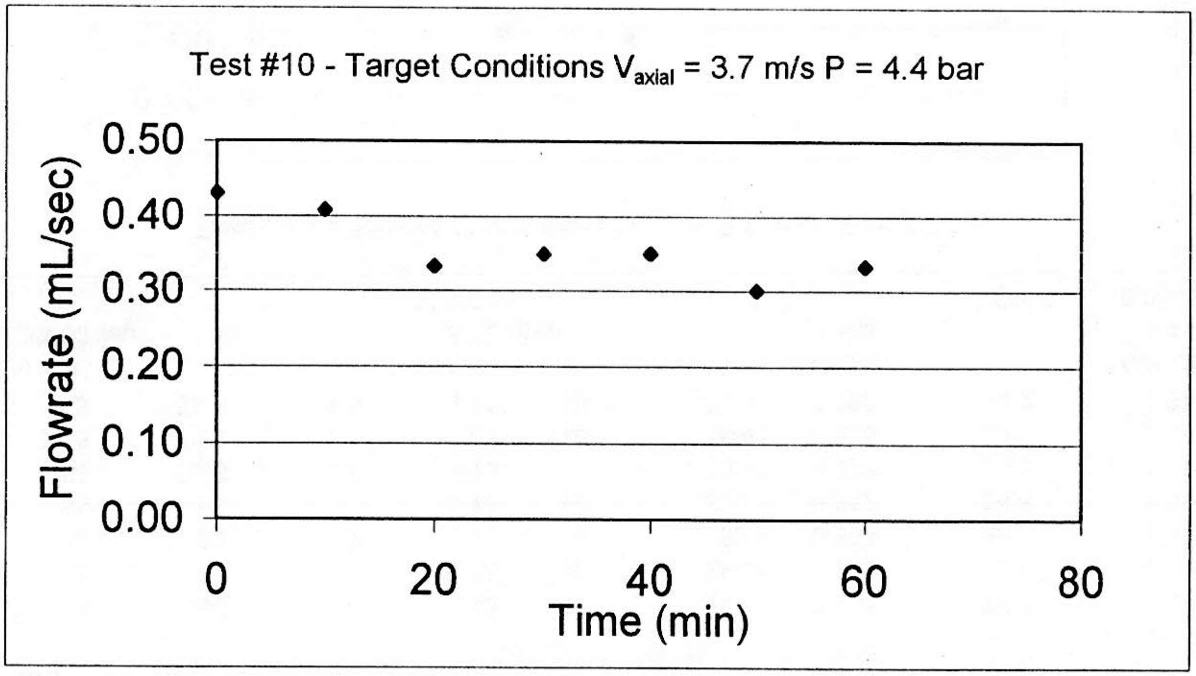
Condition 9

Change in Time (hr:min)	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0:00	0:00	40	37	3	4.2	10	29.78	0.336	25.3	1.577	0.594
0:11	0:11	40	37	3	4.2	10	35.38	0.283	25.6	1.316	0.496
0:09	0:20	39	36	3	4.22	10	41.38	0.242	22.8	1.218	0.471
0:10	0:30	40	37	3	4.2	10	36.78	0.272	25.1	1.284	0.484
0:10	0:40	41	38.5	2.5	4.2	10	37.85	0.264	26.1	1.213	0.443
0:11	0:51	41	37.5	3.5	4.31	10	41.6	0.240	22.7	1.215	0.449
0:10	1:01	41	37.5	3.5	4.19	10	39.3	0.254	25.6	1.185	0.438
		Average 2.68 bar			Average 4.22 gpm 3.74 m/s			Average 0.270	Std Dev.	Average 1.223 m3/m2/day; 0.037 m3/m2/day	



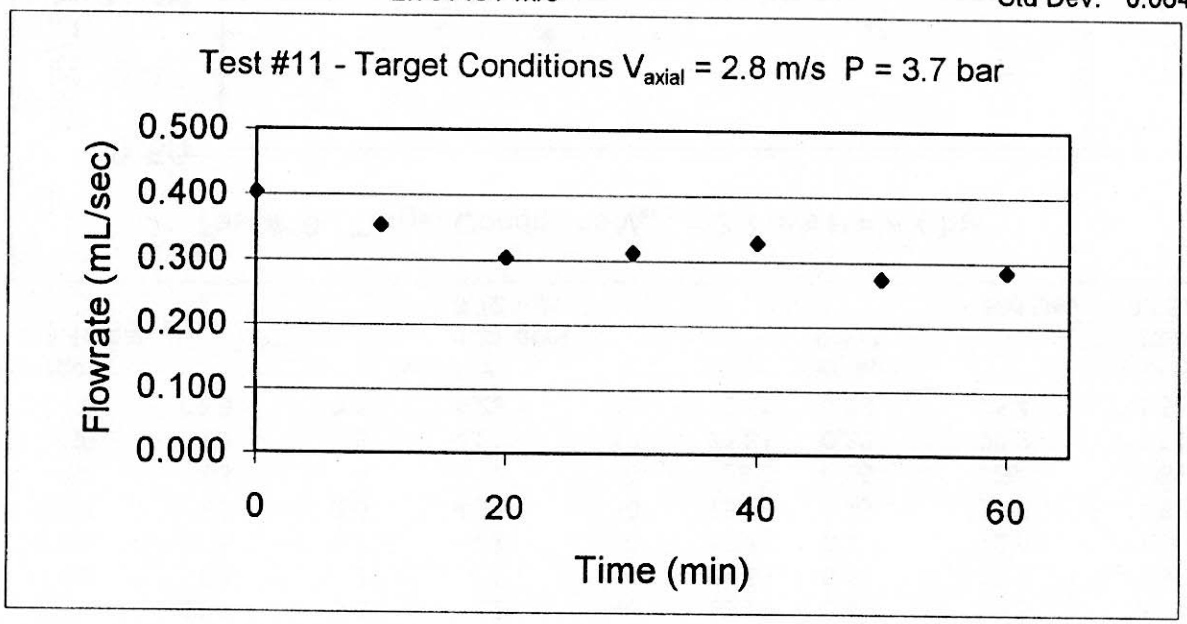
Condition 10

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	67	63.5	3.5	4.2	10	23.28	0.43	24.5	2.06	0.46
10	65	62	3	4.2	10	24.53	0.41	27.1	1.82	0.42
20	66	61.5	4.5	4.2	10	30.12	0.33	22.6	1.68	0.38
30	66.5	63	3.5	4.21	10	28.68	0.35	25.6	1.62	0.36
40	67	63	4	4.17	10	28.6	0.35	26	1.61	0.36
50	66	63	3	4.23	10	33.31	0.30	22.2	1.54	0.35
60	66	62.5	3.5	4.23	10	30.1	0.33	25.4	1.56	0.35
	Average			Average			Average		Average	
	4.44 bar			4.21 gpm			0.357		1.60	m3/m2/day
				3.72 m/s				Std Dev.	0.05737	m3/m2/day



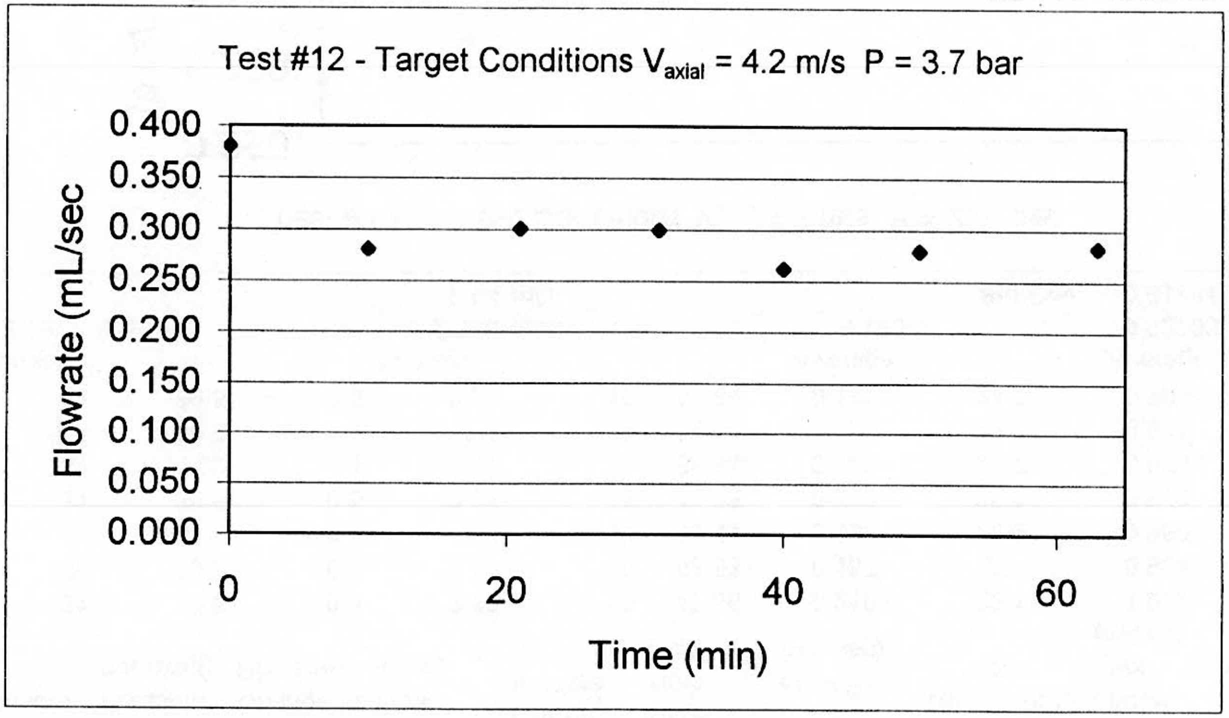
Condition 11

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	55	53	2	3.13	10	24.78	0.404	25.4	1.89	0.508
10	55	53	2	3.13	10	28.34	0.353	26.5	1.60	0.430
20	55	53	2	3.13	10	32.9	0.304	23.2	1.51	0.407
30	55	53	2	3.13	10	32.06	0.312	24.4	1.50	0.404
40	55	53.5	1.5	3.13	10	30.47	0.328	26.8	1.48	0.395
50	54.5	53	1.5	3.1	10	36.41	0.275	22.9	1.38	0.373
60	55	53.5	1.5	3.11	10	34.94	0.286	24.2	1.39	0.371
	Average			Average			Average		Average	
	3.726603 bar			3.12 gpm			0.323		1.45	m3/m2/day
				2.761434 m/s				Std Dev.	0.064368	m3/m2/day



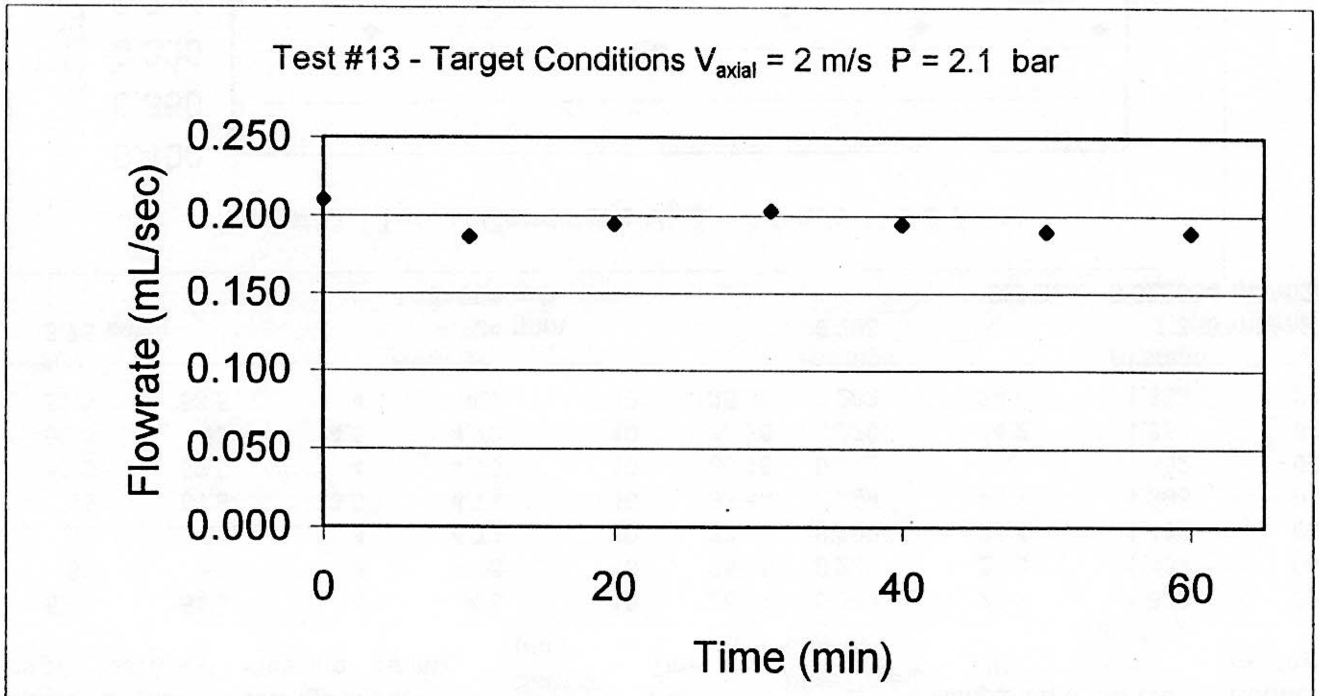
Condition 12

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	55.5	51.5	4	4.8	10	26.31	0.380	27.2	1.693	0.459
10	55	51	4	4.76	10	35.65	0.281	21.6	1.464	0.401
21	55	51	4	4.73	10	33.28	0.300	25.4	1.407	0.385
31	55	51.5	3.5	4.71	10	33.44	0.299	26.3	1.366	0.372
40	56.5	52.5	4	4.75	10	38.16	0.262	22	1.352	0.360
50	56.5	52	4.5	4.73	10	35.78	0.279	24.2	1.354	0.362
63	57.5	53.5	4	4.7	10	35.35	0.283	24.4	1.363	0.356
	Average			Average			Average		Average	
	3.73 bar			4.724 gpm			0.298		1.368	m3/m2/day
				4.181094 m/s				Std Dev.	0.022564	m3/m2/day



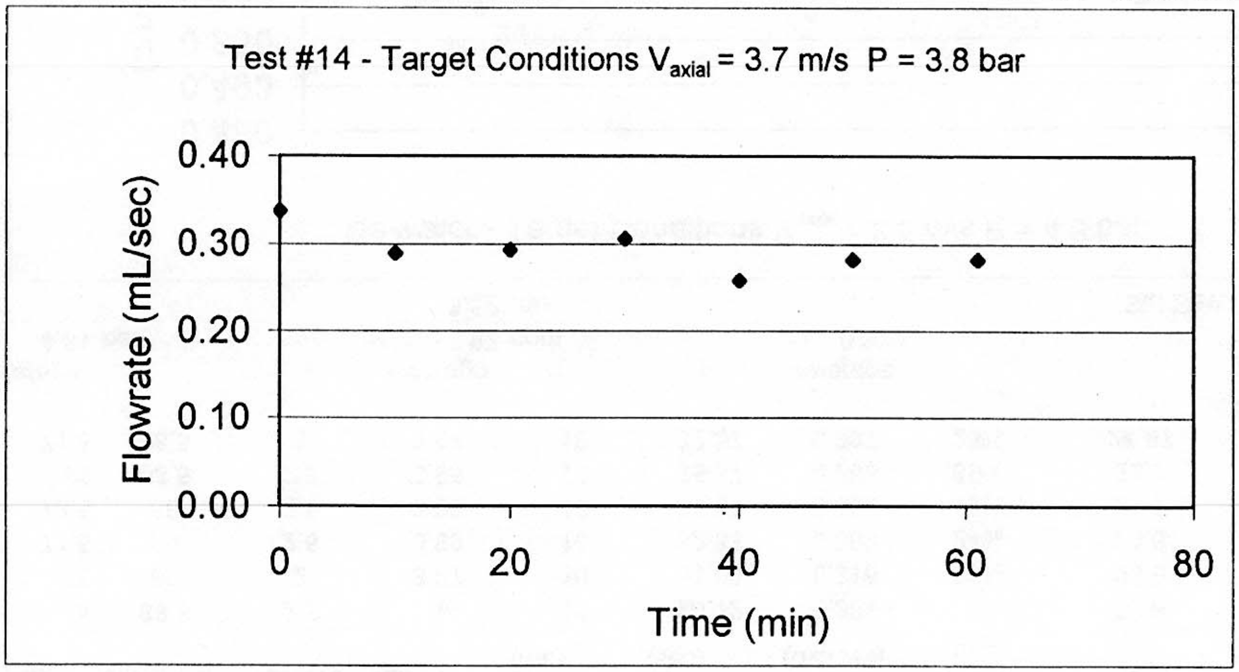
Condition 13

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	31	30.5	0.5	2.19	10	47.66	0.210	22.1	1.079	0.509
10	30	29.5	0.5	2.27	10	53.53	0.187	22	0.964	0.470
20	31	30.5	0.5	2.4	10	51.41	0.195	23.9	0.950	0.448
31	31	30.5	0.5	2.23	10	49.25	0.203	25.8	0.940	0.444
40	31	30	1	2.31	10	51.34	0.195	25.7	0.905	0.430
50	31.5	30.5	1	2.3	10	52.63	0.190	23.8	0.931	0.436
60	31	30.5	0.5	2.29	10	52.85	0.189	24.5	0.909	0.429
	Average			Average			Average		Average	
	2.12	bar		2.306 gpm			0.195		0.92706	
				2.04 m/s				Std Dev.	0.01981	



Condition 14

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	59	55	4	4.14	10	29.72	0.34	25.6	1.567	0.399
10	57.5	54.5	3	4.19	10	34.57	0.29	20.8	1.545	0.400
20	59.5	54	5.5	4.19	10	34.16	0.29	24.1	1.422	0.363
30	58	54.5	3.5	4.16	10	32.69	0.31	27	1.370	0.353
40	57.5	54.5	3	4.11	10	38.72	0.26	21.5	1.352	0.350
50	58.5	55	3.5	4.13	10	35.5	0.28	24.3	1.361	0.348
61	58	55	3	4.13	10	35.5	0.28	27.3	1.251	0.321
	Average			Average			Average		Average	
	3.89	bar		4.144	gpm		0.292		1.351171	m3/m2/day
				3.668	m/s			Std Dev.	0.062249	m3/m2/day



De-Watering Condition

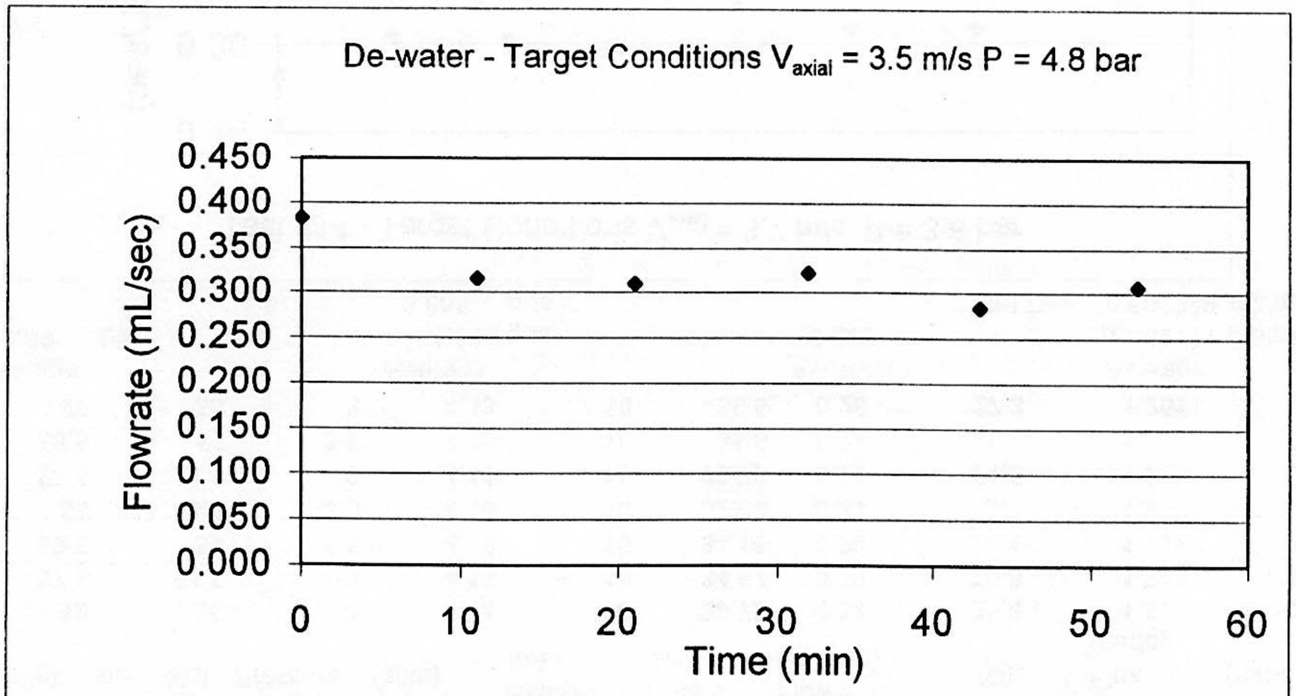
Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	% of Initial Flux	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	71	68.5	2.5	4	10	26.12	0.383		27.8	1.677	
11	71	69	2	3.97	10	31.69	0.316	21%	23.6	1.555	0.635
21	71.5	69	2.5	3.99	10	32.33	0.309	24%	23.6	1.524	0.618
32	70.5	68	2.5	3.98	10	31.09	0.322	19%	27.7	1.413	0.581
43	71	68.5	2.5	3.95	10	35.37	0.283	35%	23.2	1.409	0.576
53	71.5	68.5	3	3.97	10	32.57	0.307	25%	24.87	1.460	0.592

Average
4.81 bar

Average
3.97 gpm
3.52 m/s

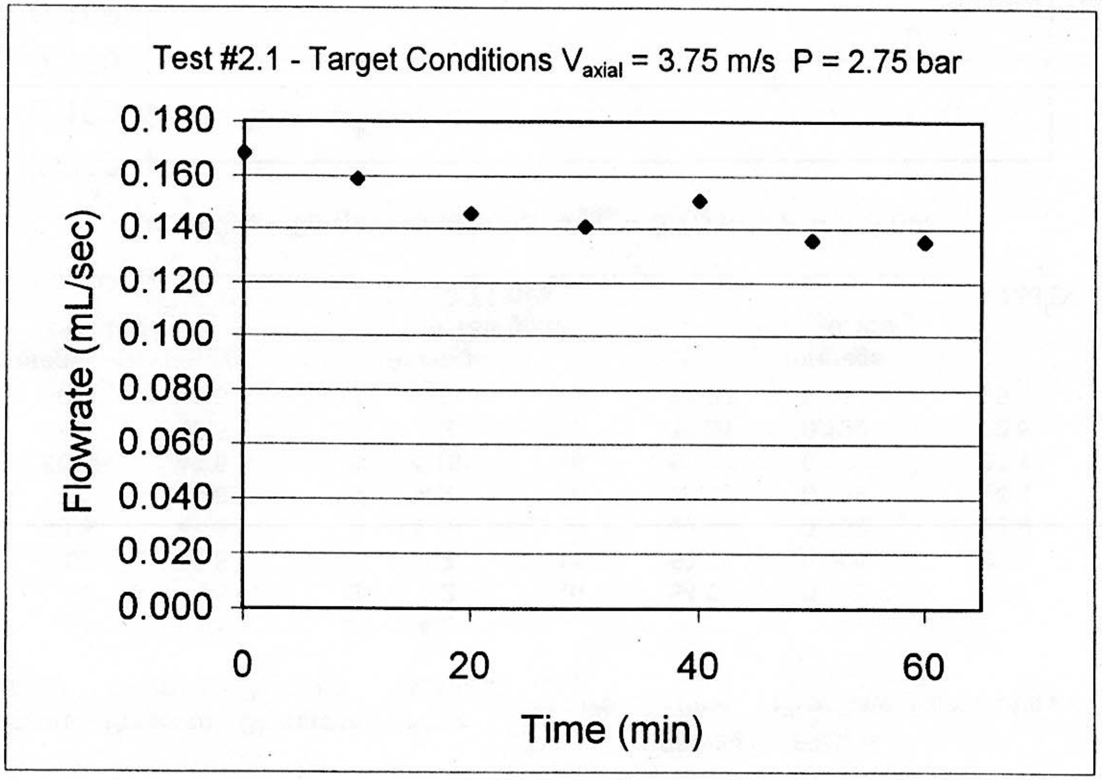
Average
0.320

Average
1.506 m3/m2/day
Std Dev. 0.054 m3/m2/day



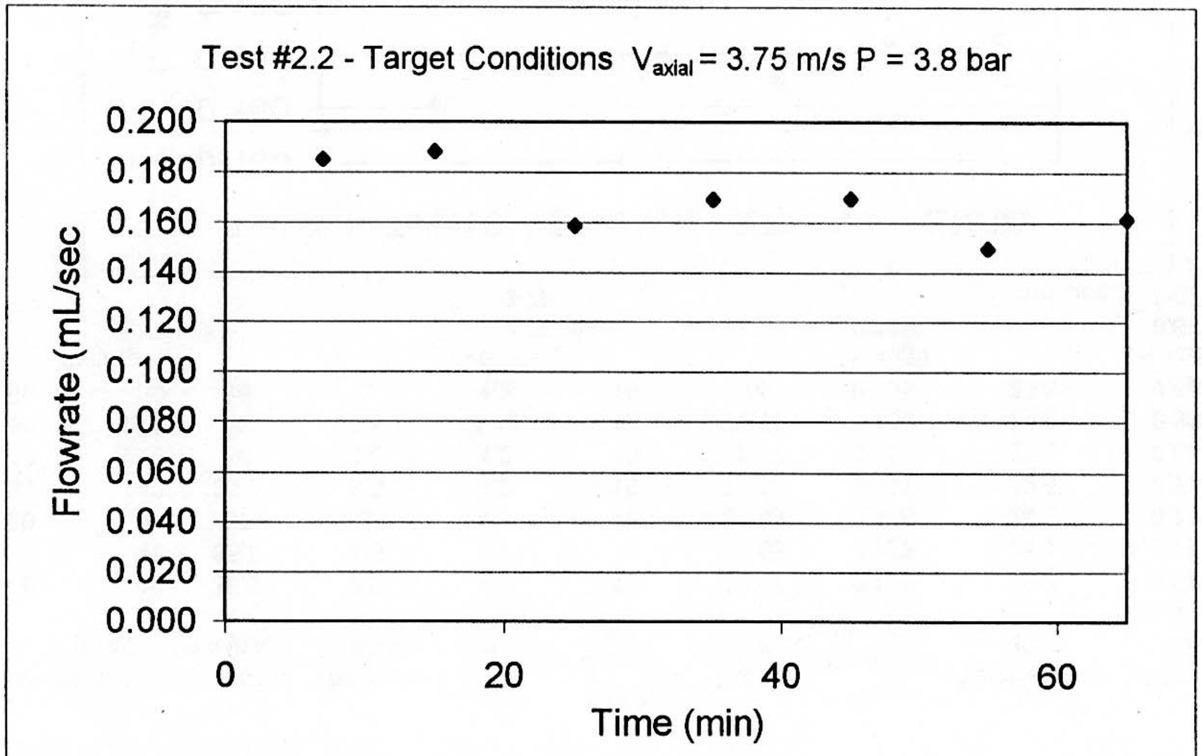
Condition 2.1

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	40	36.5	3.5	4.2	10	59.47	0.168	19.7	0.927	0.352
10	40	35.5	4.5	4.2	10	63.03	0.159	24.1	0.771	0.296
20	40	37	3	4.1	10	68.69	0.146	24.3	0.703	0.265
30	40	36.5	3.5	4.2	10	71.06	0.141	22.6	0.714	0.271
40	39.5	36	3.5	4.2	10	66.47	0.150	25.8	0.697	0.268
50	39.5	36	3.5	4.18	10	73.65	0.136	24.2	0.658	0.253
60	39	36	3	4.2	10	74	0.135	23.8	0.662	0.256
	Average			Average			Average		Average	
	2.62 bar			4.18 gpm			0.148		0.687	m3/m2/day
				3.70 m/s				Std Dev.	0.025	m3/m2/day



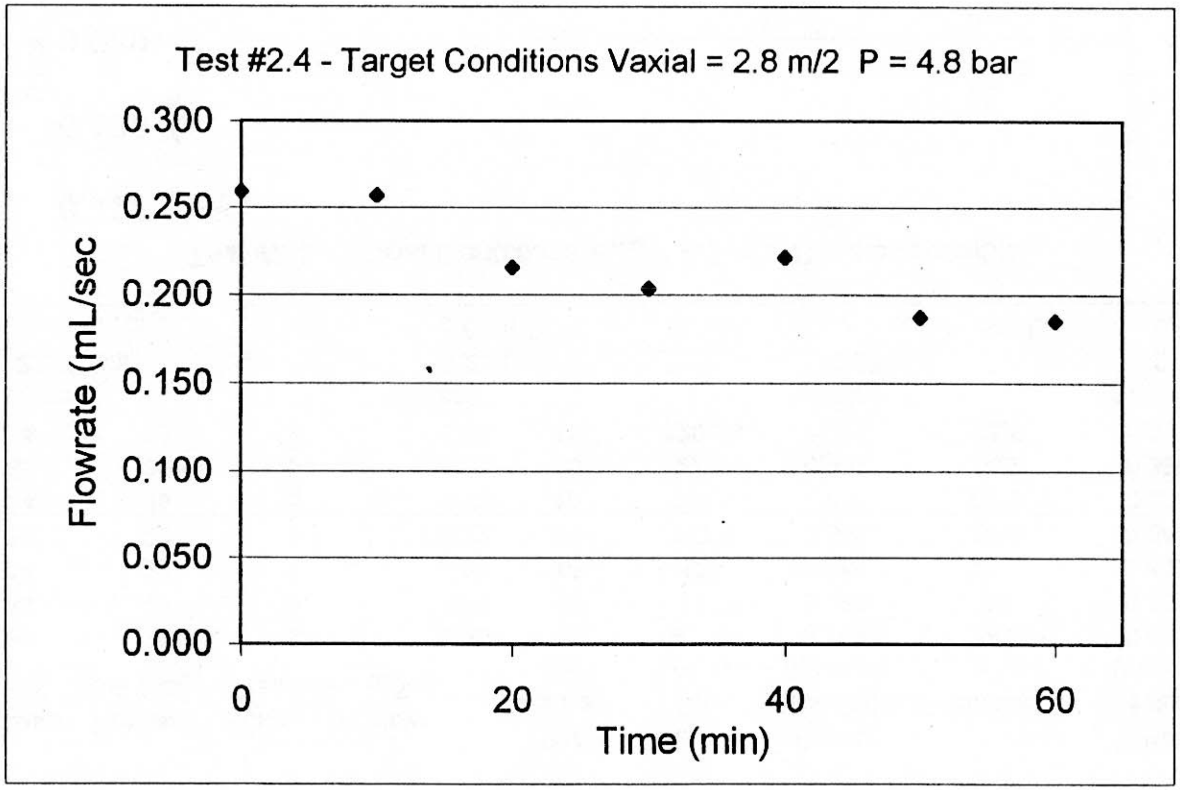
Condition 2.2

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	51	48	3	4.2						
7	51	48	3	4.2	10	54.06	0.185	23.6	0.912	0.267
15	50	46.5	3.5	4.2	10	53.13	0.188	27.6	0.829	0.249
25	50.5	47.5	3	4.18	10	62.94	0.159	23.9	0.776	0.230
35	51	48	3	4.2	10	59.13	0.169	24.4	0.815	0.239
45	50.5	47.5	3	4.15	10	59.09	0.169	27.1	0.756	0.224
55	51.5	49.5	2	4.2	10	66.81	0.150	22.6	0.759	0.218
65	50.5	48.5	2	4.21	10	61.97	0.161	25.9	0.745	0.218
	Average			Average			Average		Average	
	3.41 bar			4.188 gpm			0.169		0.770	m3/m2/day
				3.71 m/s				Std Dev.	0.027	m3/m2/day



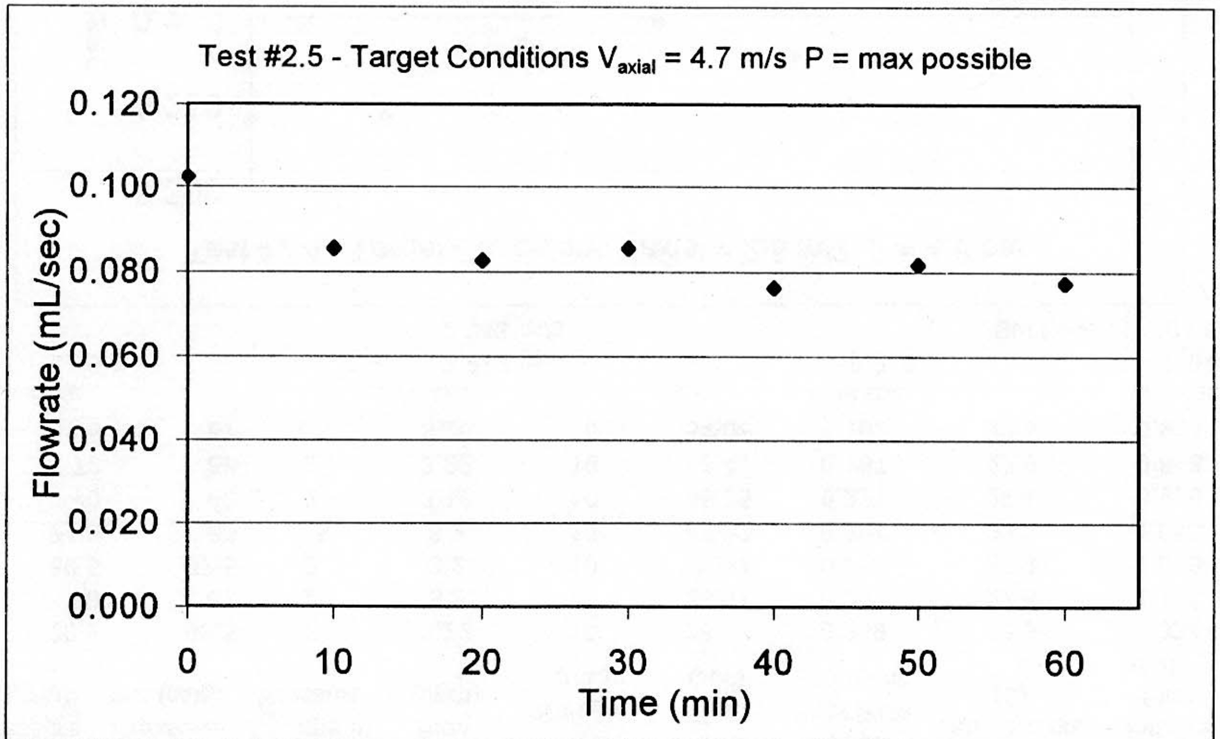
Condition 2.4

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	70.5	68.5	2	3.22	10	38.62	0.259	22.3	1.324	0.276
10	69	67	2	3.2	10	38.91	0.257	27.5	1.135	0.242
20	69.5	67.5	2	3.2	10	46.37	0.216	25.2	1.016	0.215
30	71.5	69	2.5	3.2	10	49.12	0.204	23.2	1.015	0.209
40	70	68	2	3.18	10	45.25	0.221	27.4	0.979	0.206
50	70	68	2	3.22	10	53.41	0.187	27.9	0.818	0.172
60	69.5	67	2.5	3.26	10	54.06	0.185	23.5	0.914	0.194
	Average			Average			Average		Average	
	4.76 bar			3.212 gpm			0.218		0.948	m3/m2/day
				2.843 m/s				Std Dev.	0.084	m3/m2/day



Condition 2.5

Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Temperature (C)	Filtrate Flux (m/day)	Permeability (m/day/bar)
0	35	30	5	5.23	10	97.78	0.102	24.4	0.493	0.2199
10	34	29	5	5.25	10	117.09	0.085	27	0.383	0.1761
20	34	29	5	5.23	10	121	0.083	23.2	0.412	0.1897
30	34	29	5	5.22	10	117.1	0.085	26.8	0.385	0.1771
40	34	29	5	5.23	10	131.1	0.076	23.6	0.376	0.1731
50	35	30	5	5.24	10	122.31	0.082	24.2	0.396	0.1768
60	34	29	5	5.21	10	129.38	0.077	26.5	0.351	0.1616
	Average			Average			Average		Average	
	2.186 bar			5.23 gpm			0.084		0.384	m3/m2/day
				4.63 m/s				Std Dev.	0.023	m3/m2/day



Final Nitric Acid Rinse and Clean Water Flux

Target Test Conditions	Total Time Elapsed	Pressure in (psig)	Pressure out (psig)	Change in Pressure	Flow (gpm)	Filtrate Sample (mL)	Filtrate Time (sec)	Filtrate Flow Rate (mL/sec)	Filtrate Flux (m/day)	Average
Nitric Acid Wash	10	32	30	2	NM	30	9.4	3.19	15.12	
(prefiltered to 0.2 micron)	20	74	72	2	NM	30	3.21	9.35	44.27	
Fourth Water Wash (distilled, but not filtered)										
Flow =4.6 gpm	0	29	27	2	4.7	30	6	5.00	23.68	
	11	32	29.5	2.5	4.5	10	7.91	1.26	5.99	
	25	30	27.5	2.5	4.7	10	12.44	0.80	3.81	11.15923
Flow =2.6 gpm	0	56	55	1	2.5	10	6.18	1.62	7.66	
	10	55.5	55	0.5	2.6	10	9.28	1.08	5.10	
	15	56	55	1	2.6	10	8.72	1.15	5.43	
	20	55.5	55	0.5	2.6	10	9.87	1.01	4.80	5.749672
Flow =1.7 gpm	0	70	70	0	1.3	10	9.25	1.08	5.12	
	10	71	70	1	1.7	10	11.1	0.90	4.27	
	20	71	70	1	1.9	10	11.72	0.85	4.04	4.476309

Appendix D: AW-101 Simulant Composition

Table D1. AW-101 5M Na Solution

Component	FW,	Molarity	g/L	g for 10L
EDTA	292.24	3.70E-03	1.081	10.813
Citric Acid	210.14	3.70E-03	0.778	7.775
$Na_3HEDTA \cdot 2H_2O$	344.00	3.70E-03	1.273	12.728
Na_3NTA	257.10	3.70E-03	0.951	9.513
Na Gluconate	218.00	3.70E-03	0.807	8.066
Na_2Iminodiacetic	177.07	3.70E-03	0.655	6.552
$Cd(NO_3)_4 \cdot H_2O$	308.00	0.00E+00	0.00E+00	0.000
$Fe(NO_3)_3 \cdot 9H_2O$	404.02	5.00E-05	2.02E-02	0.202
$Mg(NO_3)_2 \cdot 6H_2O$	256.40	1.50E-03	0.385	3.846
$Mn(NO_3)_2$, 50%	8.46	6.63E-05	0.561 mL	5.609 mL
MoO_3	143.95	2.86E-04	4.12E-02	0.412
$Ni(NO_3)_2 \cdot 6H_2O$	290.80	1.33E-04	3.87E-02	0.387
SiO_2	60.08	2.93E-03	0.176	1.760
$BaNO_3$	261.38	1.33E-04	3.48E-02	0.348
$Ca(NO_3)_2$	236.16	4.13E-04	0.098	0.975
$Sr(NO_3)_2$	211.65	1.30E-05	2.75E-03	0.028
$RbNO_3$	147.47	1.00E-05	1.47E-03	0.015
$CsNO_3$	194.92	6.40E-05	1.25E-02	0.125
$NaNO_3$	85.00	0.00E+00	0.00	0.000
KNO_3	101.11	0.00E+00	0.00	0.000
$LiNO_3$	69.00	5.51E-04	0.04	0.380
KOH	56.11	4.30E-01	24.13	241.273
NaOH	40.00	3.89E+00	155.60	1556.000
$Al(NO_3)_3 \cdot 9H_2O$	375.15	5.06E-01	189.83	1898.259
Na_2CO_3	105.99	1.00E-01	10.60	105.990
Na_2SO_4	142.05	2.36E-03	0.34	3.352
$Na_2HPO_4 \cdot 7H_2O$	268.07	1.73E-03	0.46	4.638
NaCl	58.45	6.93E-02	4.05	40.506
NaF	41.99	1.10E-02	0.46	4.619
$NaNO_2$	69.00	7.90E-01	54.51	545.100

Appendix E: Density and Solids Concentration Raw Data

diluted feed physical.xls
1/26/99
PR Bredt

Sample	Slurry Mass, g	Volume, ml	Density	Average	RPD	Vol% Settled Solid volume, ml	Vol %	Average	RPD
AN-107 A	10.894	8.25	1.32	1.32	0.3%	0.52	6.3%	6.5%	5.6%
AN-107 B	11.845	9.00	1.32			0.6	6.7%		
AW-101 A	11.431	8.80	1.30	1.31	2.0%	0.54	6.1%	6.1%	1.5%
AW-101 B	11.399	8.60	1.33			0.52	6.0%		

Sample	Settled Superantant Mass, g	Volume, ml	Density	Average	RPD	Centrifuged Supernatant Mass, g	Volume, ml	Density	Average	RPD
AN-107 A	6.741	4.90	1.38	1.32	8.8%	10.026	7.65	1.311	1.314	0.5%
AN-107 B	5.165	4.10	1.26			11.063	8.40	1.317		
AW-101 A	6.745	5.25	1.28	1.28	0.6%	10.881	8.30	1.311	1.310	0.2%
AW-101 B	6.642	5.20	1.28			11.121	8.50	1.308		

Sample	Settled Solids Liquid, ml	liqiud, g	Solids, g	wt% settled	Average	RPD	Density	Average	RPD
AN-107 A	7.73	10.1308471	0.7631529	7.0%	6.8%	5.9%	1.47	1.39	11.9%
AN-107 B	8.4	11.063	0.782	6.6%			1.30		
AW-101 A	8.26	10.8285614	0.6024386	5.3%	6.3%	31.8%	1.12	1.35	35.1%
AW-101 B	8.08	10.5714918	0.8275082	7.3%			1.59		

Sample	Centrifuged Solids Mass, g	Volume, ml	Vol%	Average	RPD	wt%	Average	RPD	Density	Average	RPD
AN-107 A	0.489	0.26	3.2%	3.1%	1.3%	4.5%	4.5%	1.9%	1.88	1.91	2.9%
AN-107 B	0.542	0.28	3.1%			4.6%			1.94		
AW-101 A	0.206	0.18	2.0%	1.7%	37.8%	1.8%	2.1%	31.4%	1.14	1.75	69.0%
AW-101 B	0.282	0.12	1.4%			2.5%			2.35		

Too little solids

Sample	Tare	Wet Total	Sample	Dry Total	Sample	Wt Fraction Dry Solids	Water	Superantan	Wt% Solids Undissolved	Total
AN-107 A	19.745	20.234	0.489	19.992	0.247	0.505	0.495	0.876	0.56%	41.7%
AN-107 AL	16.669	26.534	9.865	20.960	4.291	0.435	0.565			
AN-107 B	19.928	20.470	0.542	20.208	0.280	0.517	0.483	0.854	0.67%	42.4%
AN-107 BL	16.709	27.630	10.921	21.449	4.740	0.434	0.566			
AW-101 A	19.943	20.149	0.206	20.003	0.060	0.291	0.709	1.186	-0.33%	38.3%
AW-101 AL	16.639	27.376	10.737	20.954	4.315	0.402	0.598			
AW-101 B	19.978	20.260	0.282	20.108	0.130	0.461	0.539	0.897	0.25%	39.7%
AW-101 BL	16.656	27.657	11.001	21.049	4.393	0.399	0.601			

AW-101 A has problem, but AW-101 AL looks good

	Density, g/ml Slurry	Supernatant	Centrifuged Solids	Vol% Solids Settled	Centrifuged	Wt% Solids Settled	Centrifuged	Total	Undissolved	Viscosity, cP
AN-107	1.32	1.311	1.88	6.3%	3.2%	7.0%	4.5%	41.7%	0.6%	10-11
AN-107 Dup	1.32	1.317	1.94	6.7%	3.1%	6.6%	4.6%	42.4%	0.7%	12
AW-101	1.30	1.311	[redacted]	6.1%	2.0%	5.3%	1.8%	38.3%	-0.3%	6
AW-101 Dup	1.33	1.308	[redacted]	6.0%	1.4%	7.3%	2.5%	39.7%	0.3%	6.8

Too Little

Appendix F: Rheograms for AW-101 and Standards

Figure 1. 50 cP Standard , Brookfield Lot 102298, Analyzed on Bohlin CS Before AW-101 Diluted Feed Samples

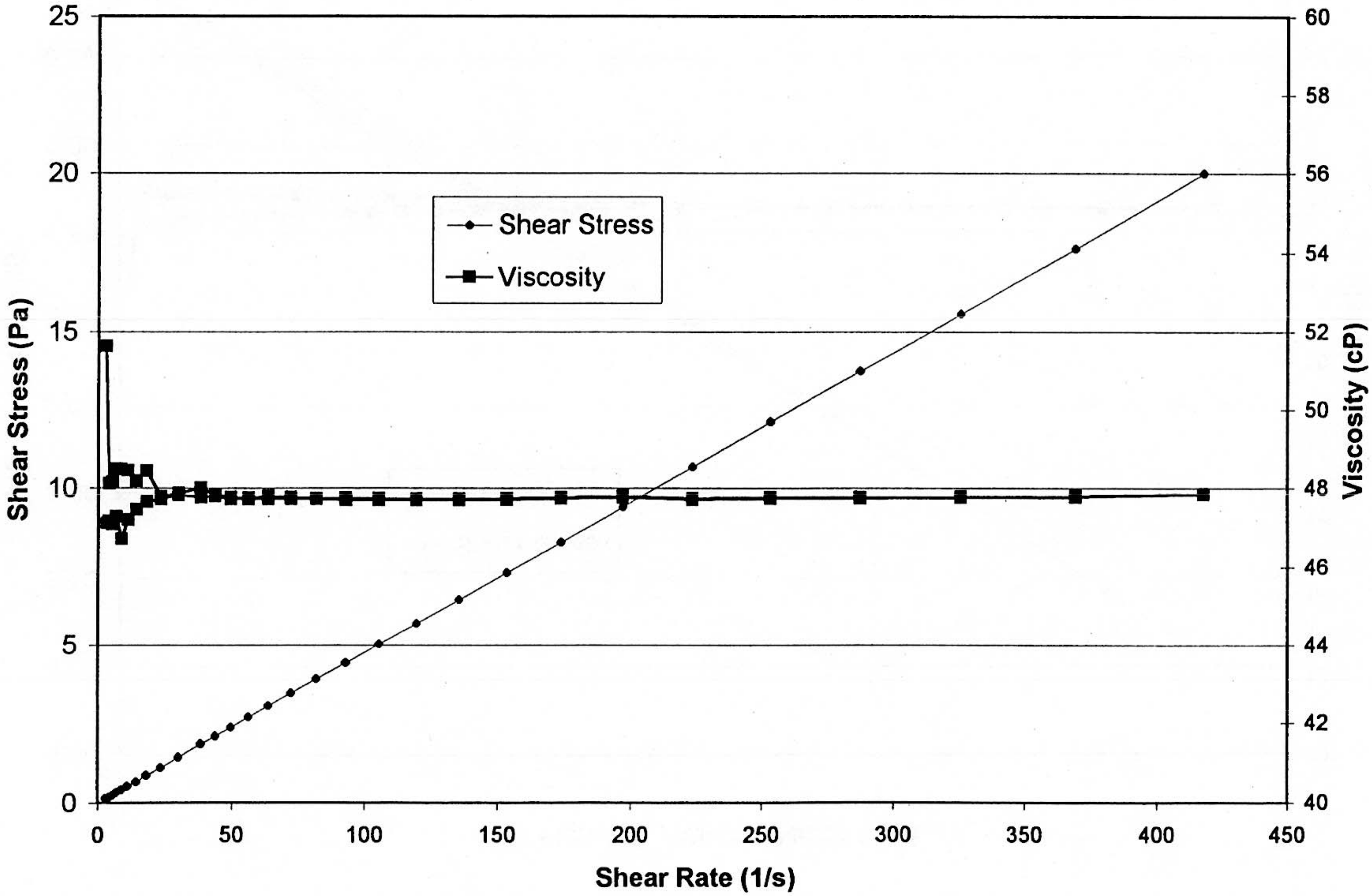


Figure 2. AW-101 Diluted Feed

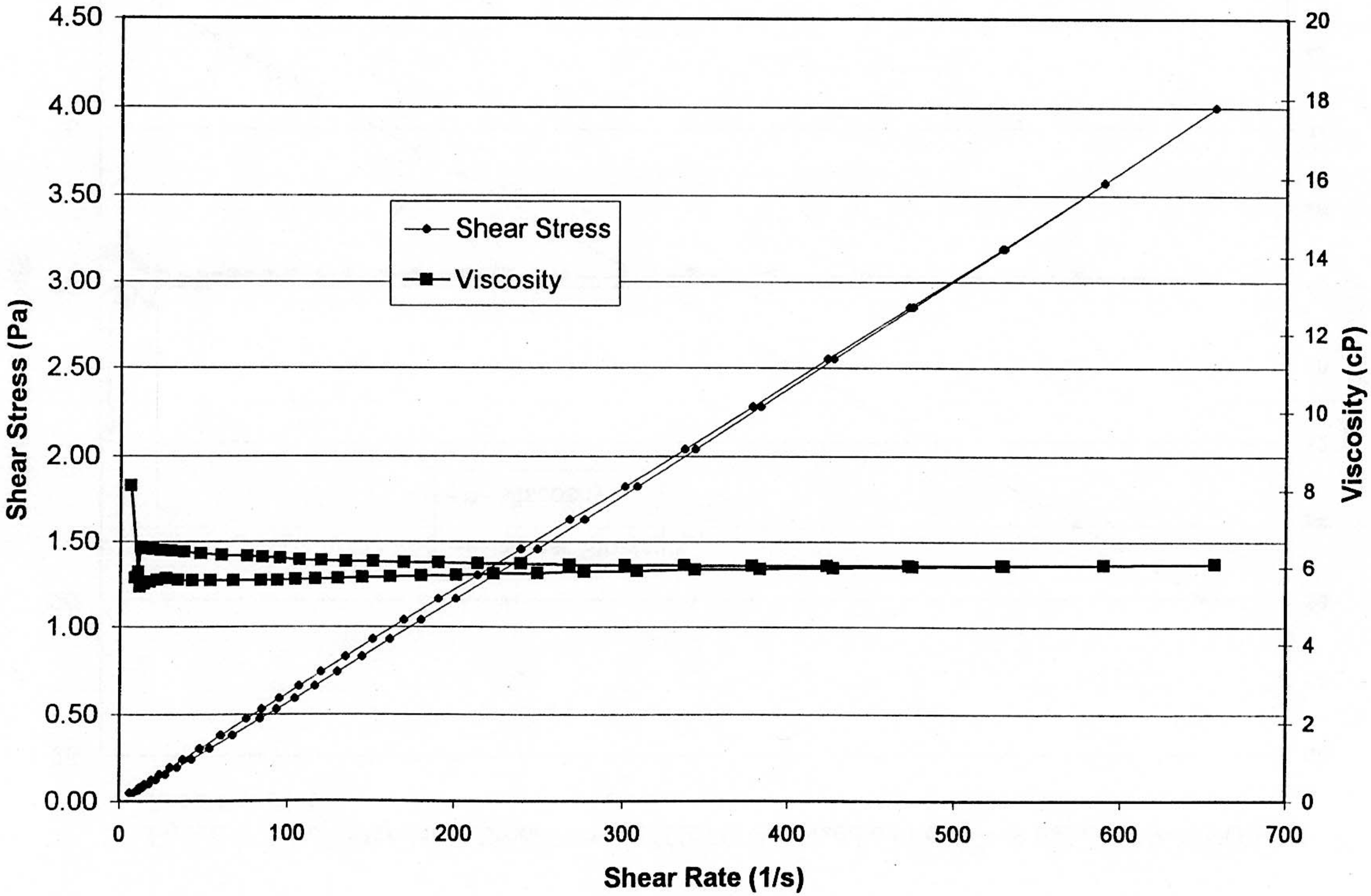


Figure 3. AW-101 Diluted Feed Duplicate

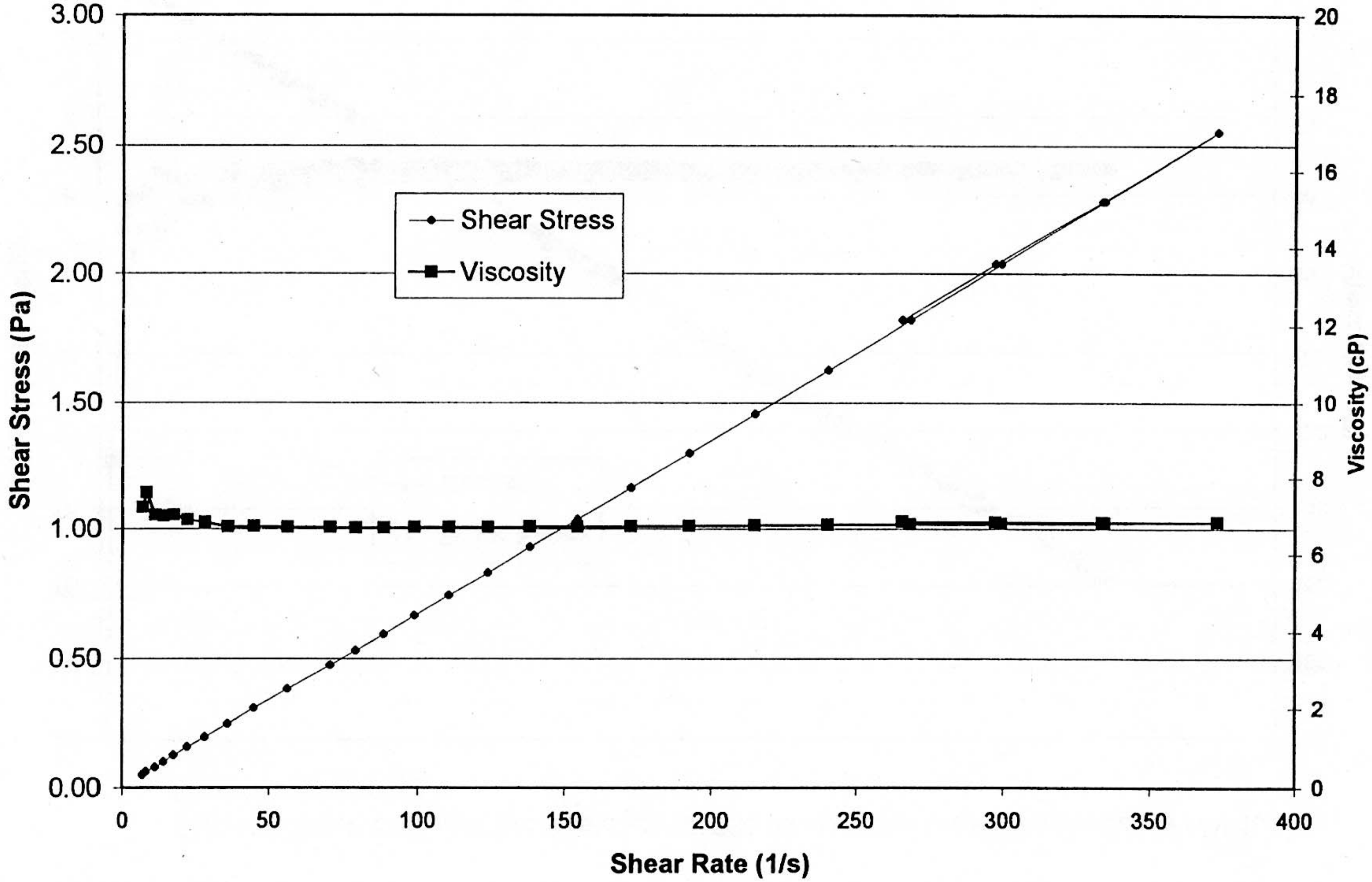


Figure 4. 50 cP Standard, Brookfield Lot 102298, Analyzed on the Haake M5 Before AW-101 Dewatered Samples

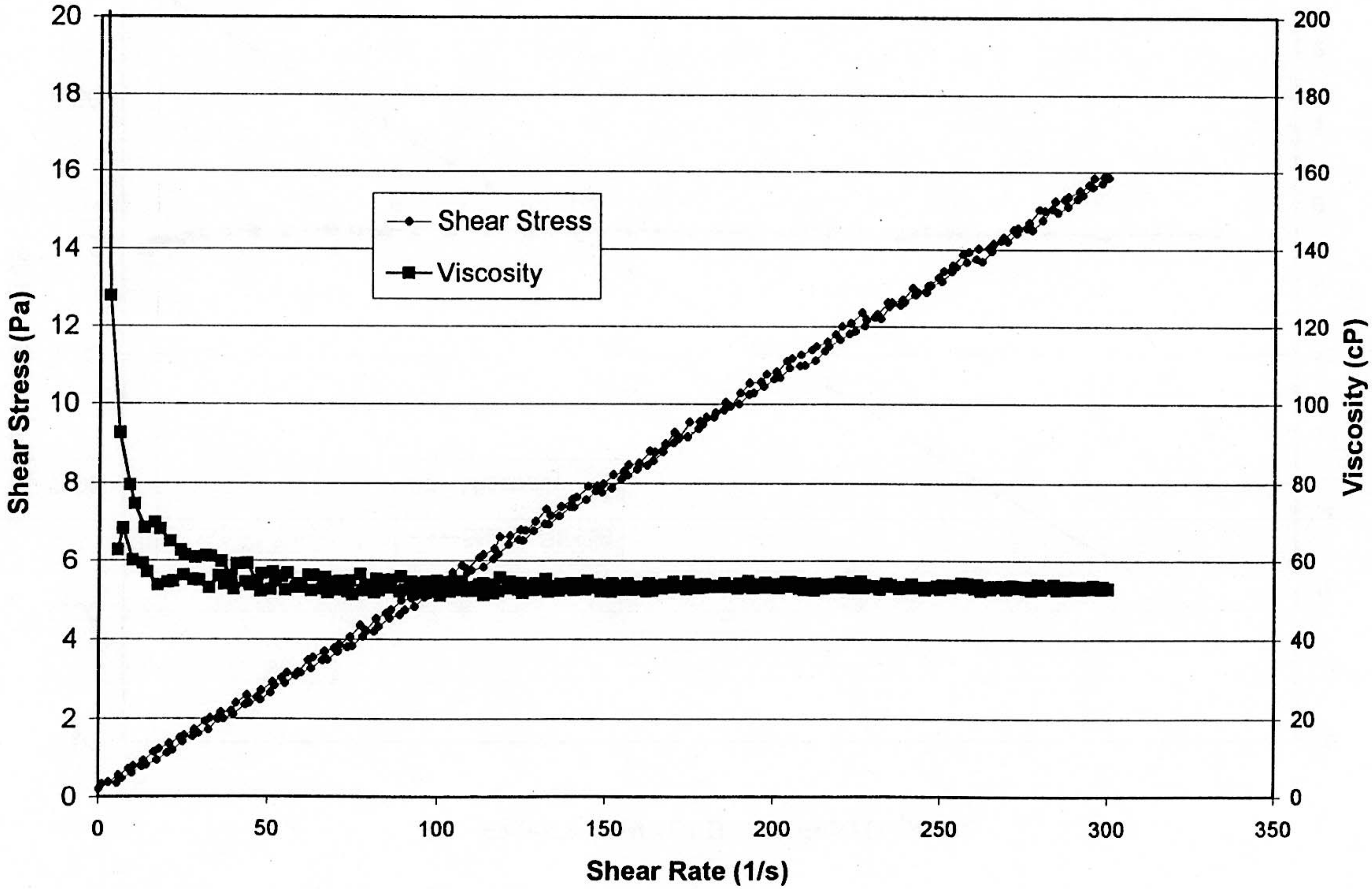


Figure 5. AW-101 Dewatered Slurry, First Analysis

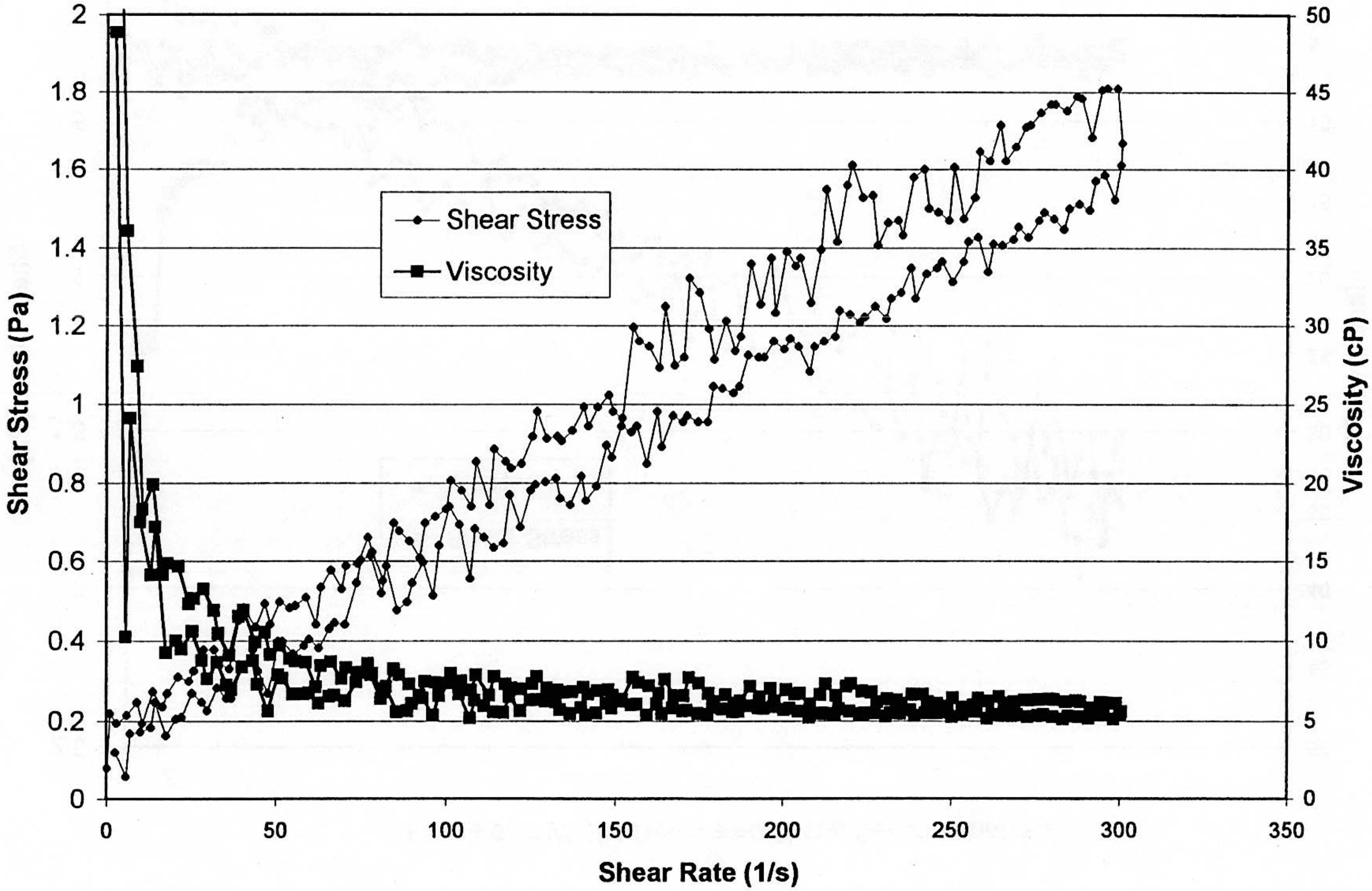


Figure 6. AW-101 Dewatered Slurry, Second Analysis

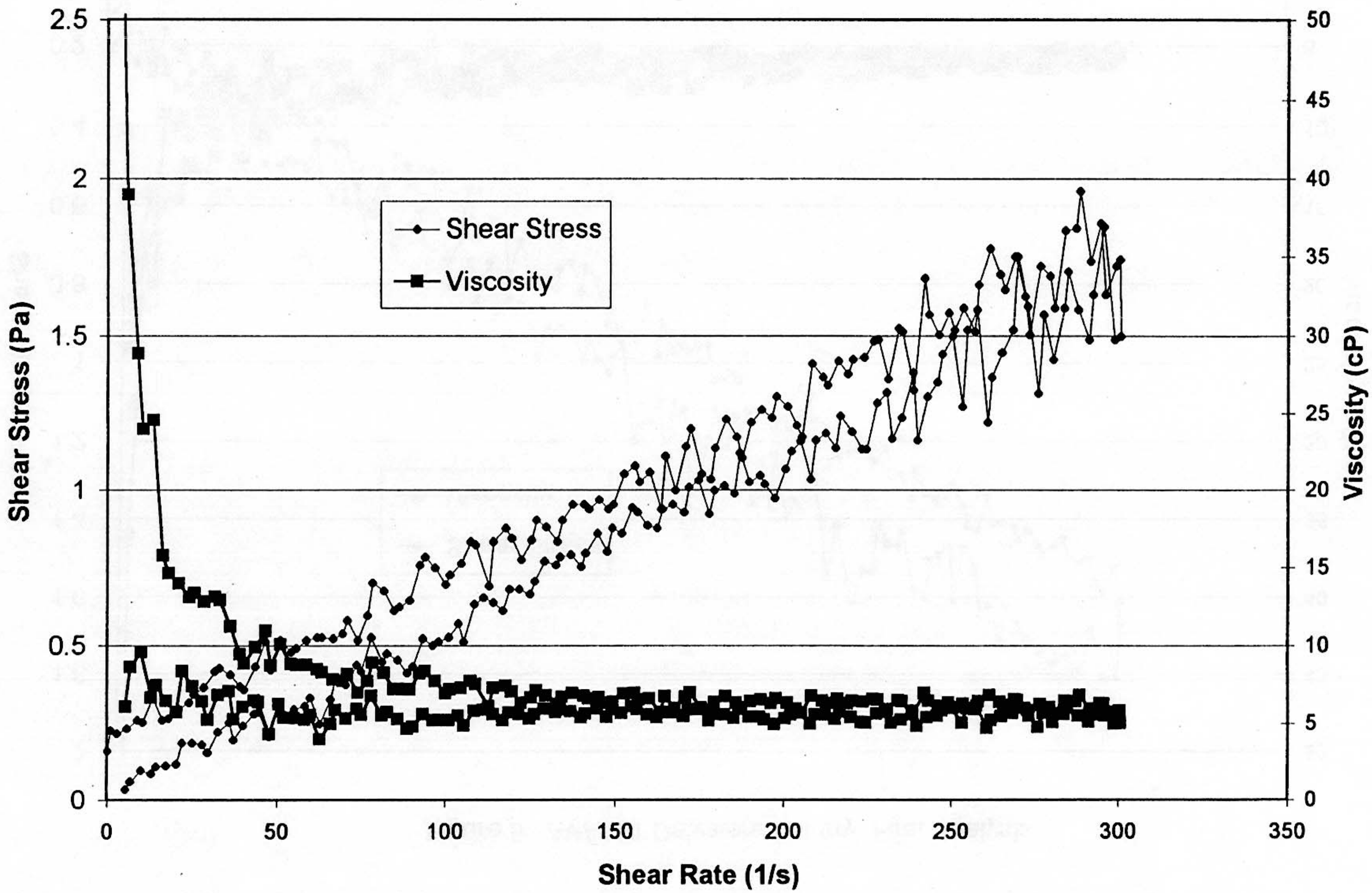


Figure 7. AW-101 Dewatered Slurry, Sample 2, First Analysis

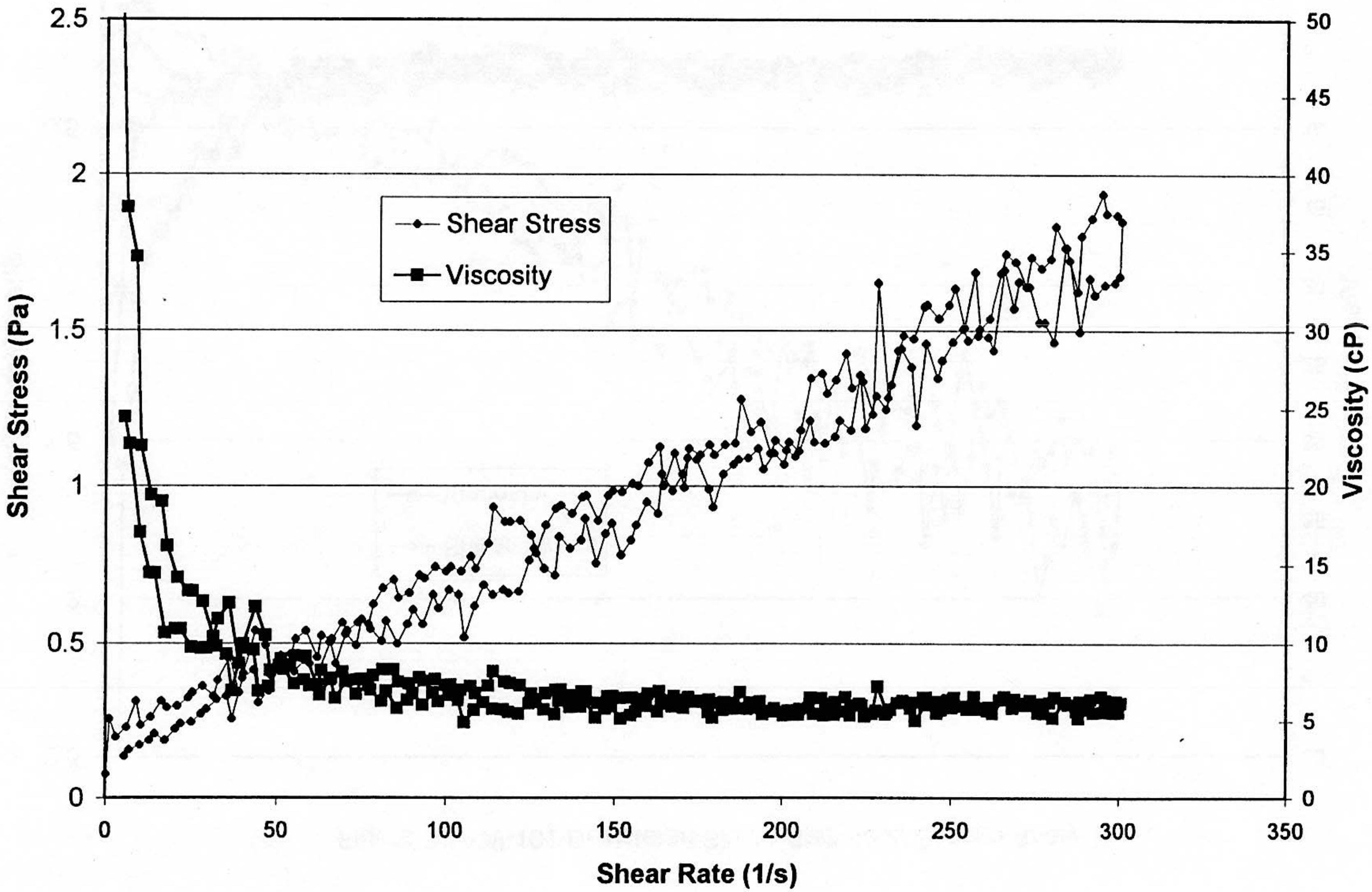
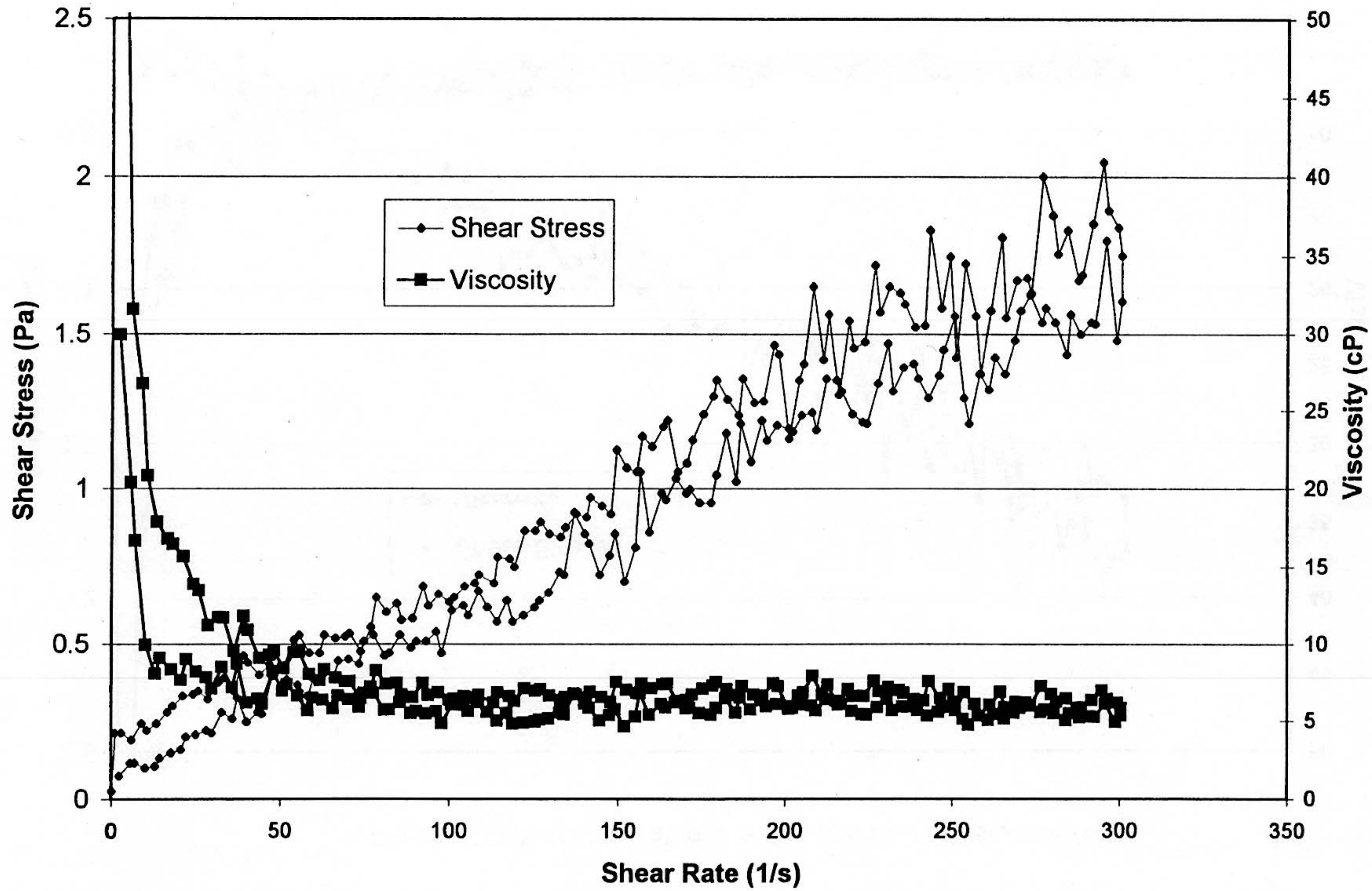


Figure 8. AW-101 Dewatered Slurry, Sample 2, Second Analysis



Appendix G: Key Personnel Affiliated with LAW Entrained Solids Removal Task

Key Personnel in the Entrained Solids Ultrafiltration Task

Name	Responsibility	Telephone/email
Eugene Morrey	Battelle Project Manager	(509) 376-1982 eugene.morrey@pnl.gov
Dean Kurath	Battelle Project Engineer	(509) 376-6752 dean.kurath@pnl.gov
Kriston Brooks	Ultrafiltration Task Manager, Filtration and CUF Testing	(509) 376-2233 kriston.brooks@pnl.gov
Paul Bredt	Rheology and Physical Properties Measurement	(509) 376-3777 paul.bredt@pnl.gov
Joel Tingey	Particle Size Distribution Measurement	(509) 376-2580 joel.tingey@pnl.gov
Stacey Hartley	Statistical Analysis	(509) 372-4945 stacey.hartley@pnl.gov
Mike Urie	Chemical and Radiochemical Analysis	(509) 376-9454 mike.urie@pnl.gov
Ken Rappe	CUF Design and Testing	(509) 372-3918 ken.rappe@pnl.gov
Gita Golcar	CUF Design and Test Plan Preparation	(509) 372-1967 gita.golcar@pnl.gov
Lynette Jagoda	CUF Testing	(509) 376-9951 lynette.jagoda@pnl.gov
Rick Steele	Hot Cell Operations	(509) 372-0038 rick.steele@pnl.gov

Appendix H: Particle Size Distribution Raw Data

Particle Size Distribution Standards Results

The instrument performance was checked against a range of NIST traceable standards from Duke Scientific Corporation. These standards are polymer microspheres dispersed in 1 mM KCl. Results are shown in Table G1. These standards were run prior to analysis of the sample and duplicate. The percentile shows the given percent of the volume (or weight if the specific gravity for all particles is the same) that is smaller than the indicated size. The mean diameter of the volume distribution (mv) represents the center of gravity of the distribution and is weighted by the presence of coarser particles.

Table G1. Calibration Standards

UPA			
	96 nm Lot 16339	304 nm Lot 15928	2013 nm Lot 15992
Percentile	**Size (nm)**	**Size (nm)**	**Size (nm)**
10	81	251	1563
50	95	304	2083
90	125	368	3130
mv	99	307	2250
X-100			
	2.013 µm Lot 15992	50.4 µm Lot 19213	301 µm Lot 19136
Percentile	**Size (µm)**	**Size (µm)**	**Size (µm)**
10	1.41	39	267
50	1.73	48	309
90	2.19	59	347
mv	1.77	48	308

Particle Size Distribution Raw Data for AW-101 Using the Microtrac X-100

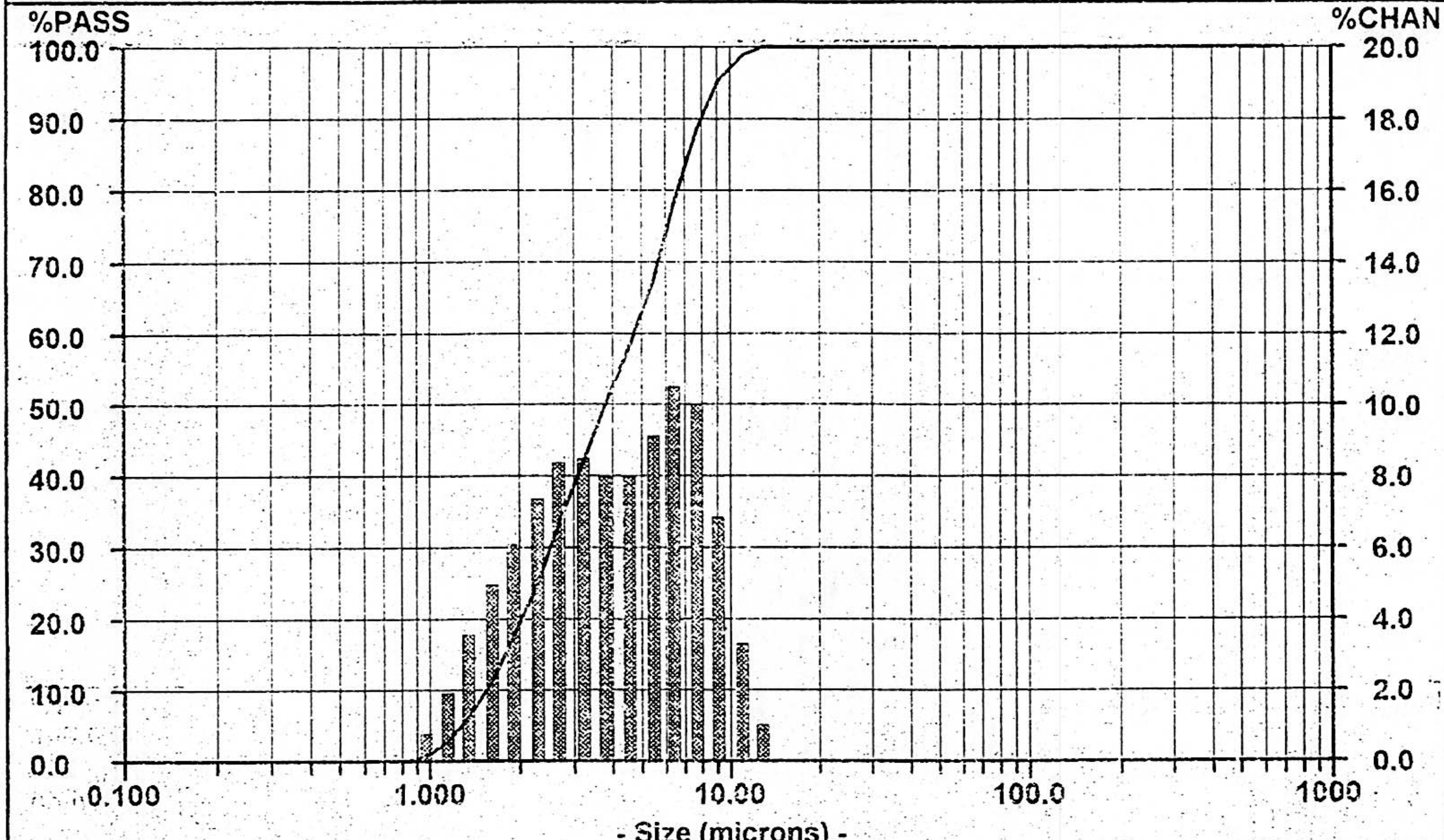
Particle Size Analysis

101-AW-PSD

Date: 04/12/99 Meas #: 00047
Time: 10:54 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.420	10% = 1.532	60% = 4.770	5.815	58%	4.167
mn = 1.653	20% = 2.061	70% = 5.715	2.113	42%	1.463
ma = 3.060	30% = 2.561	80% = 6.713			
cs = 1.961	40% = 3.132	90% = 8.024			
sd = 2.653	50% = 3.867	95% = 9.121			

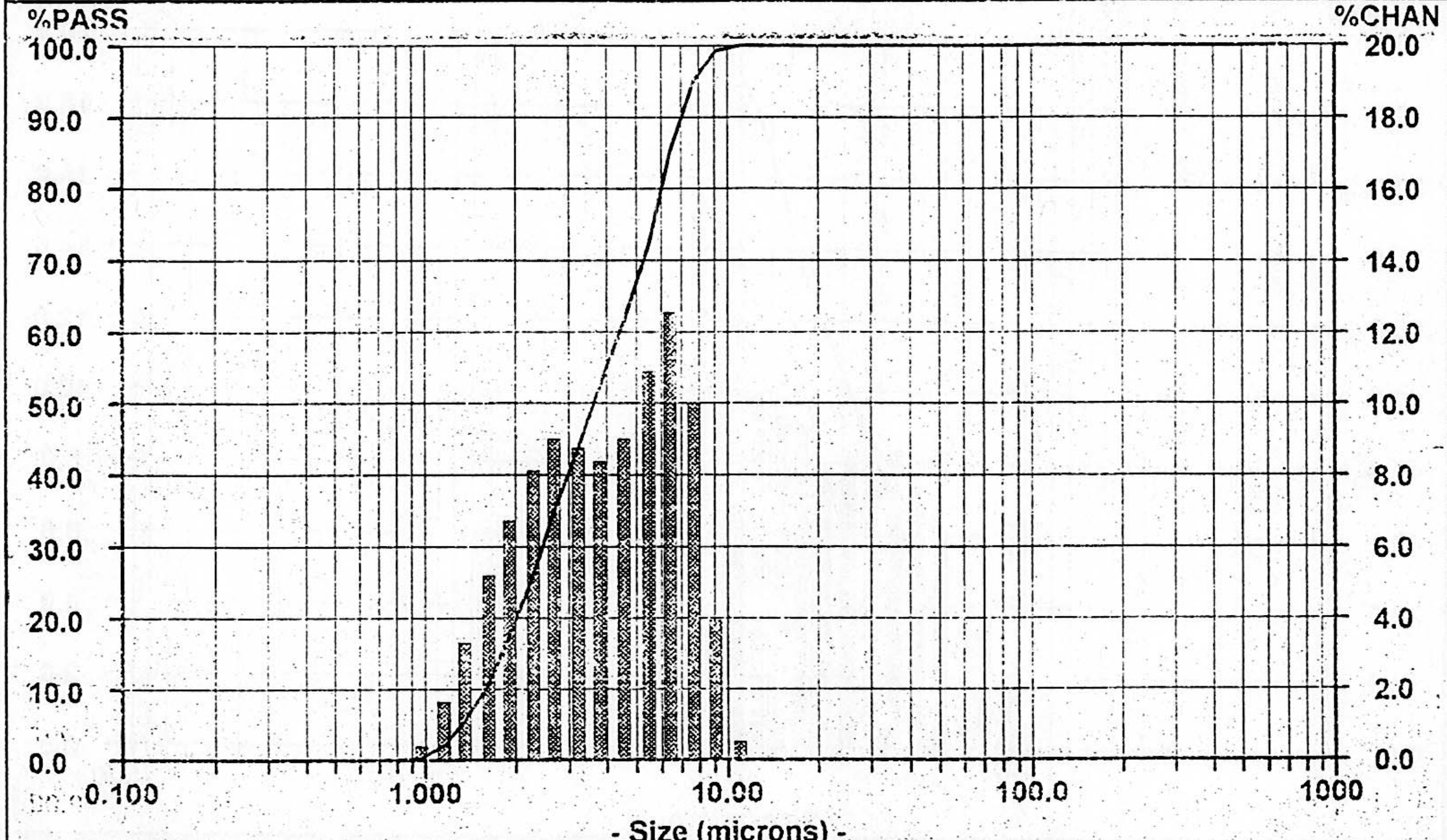


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	95.46	6.94						
592.0	100.00	0.00	7.778	88.52	10.12						
497.8	100.00	0.00	6.541	78.40	10.68						
418.6	100.00	0.00	5.500	67.72	9.27						
352.0	100.00	0.00	4.625	58.45	8.18						
296.0	100.00	0.00	3.889	50.27	8.15						
248.9	100.00	0.00	3.270	42.12	8.58						
209.3	100.00	0.00	2.750	33.54	8.44						
176.0	100.00	0.00	2.312	25.10	7.45						
148.0	100.00	0.00	1.945	17.65	6.20						
124.5	100.00	0.00	1.635	11.45	5.01						
104.7	100.00	0.00	1.375	6.44	3.62						
88.00	100.00	0.00	1.156	2.82	2.02						
74.00	100.00	0.00	0.972	0.80	0.80						
62.23	100.00	0.00	0.818	0.00	0.00						
52.33	100.00	0.00	0.688	0.00	0.00						
44.00	100.00	0.00	0.578	0.00	0.00						
37.00	100.00	0.00	0.486	0.00	0.00						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	1.14	0.172	0.00	0.00						
11.00	98.86	3.40	0.145	0.00	0.00						

Particle Size Analysis	101-AW-PSD	Date: 04/12/99 Time: 10:55	Meas #: 00048 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.059	10% = 1.589	60% = 4.494	5.459	56%	3.226
mn = 1.718	20% = 2.040	70% = 5.298	2.130	44%	1.405
ma = 2.983	30% = 2.492	80% = 6.086			
cs = 2.012	40% = 3.018	90% = 7.031			
sd = 2.283	50% = 3.691	95% = 7.722			

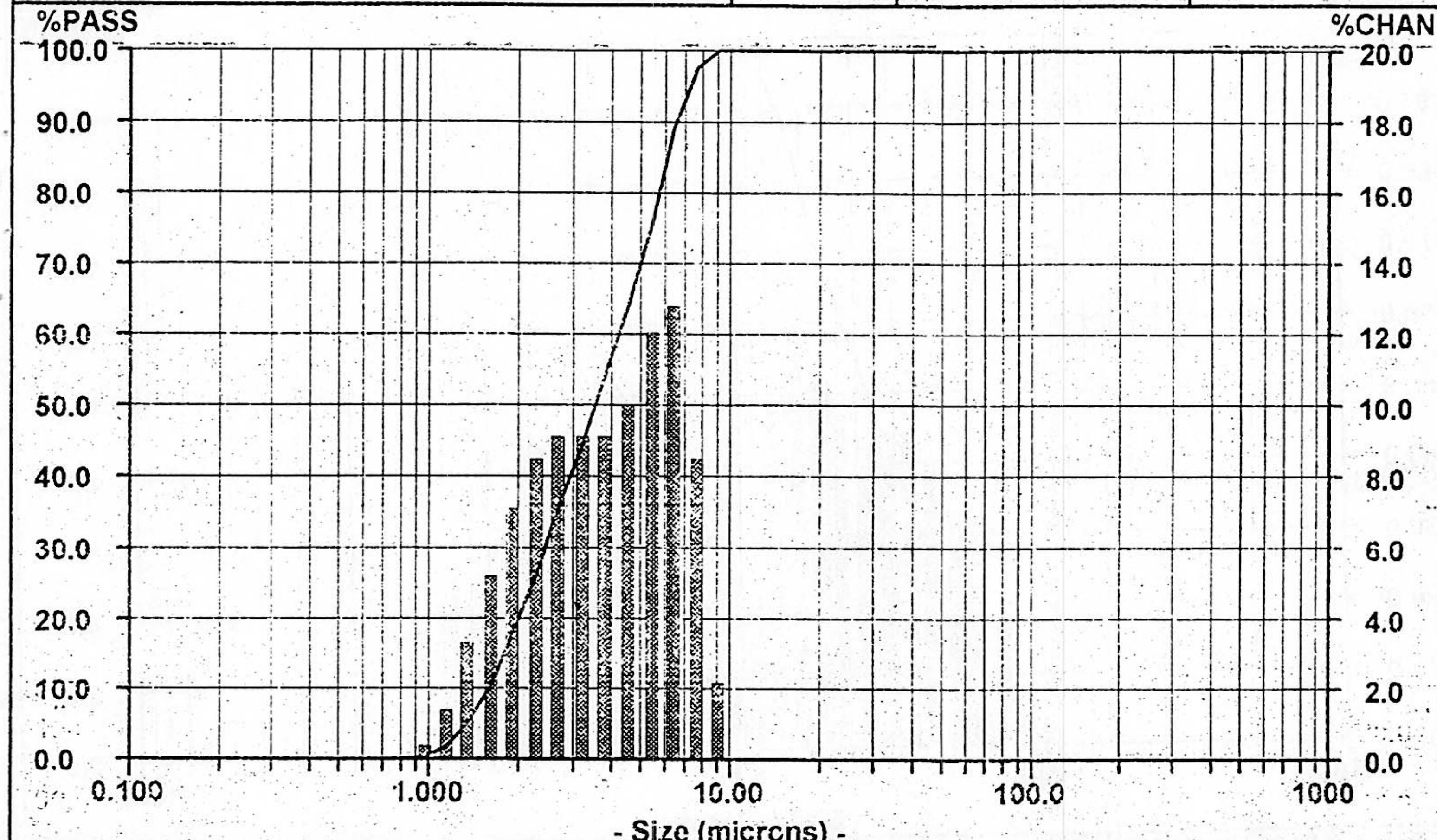


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	99.36	4.02						
592.0	100.00	0.00	7.778	95.34	10.09						
497.8	100.00	0.00	6.541	85.25	12.69						
418.6	100.00	0.00	5.500	72.56	10.96						
352.0	100.00	0.00	4.625	61.60	9.03						
296.0	100.00	0.00	3.869	52.57	8.49						
248.9	100.00	0.00	3.270	44.08	8.89						
209.3	100.00	0.00	2.750	35.19	9.06						
176.0	100.00	0.00	2.312	26.13	8.28						
148.0	100.00	0.00	1.945	17.85	6.86						
124.5	100.00	0.00	1.635	10.99	5.24						
104.7	100.00	0.00	1.375	5.75	3.45						
88.00	100.00	0.00	1.156	2.30	1.72						
74.00	100.00	0.00	0.972	0.58	0.58						
62.23	100.00	0.00	0.818	0.00	0.00						
52.33	100.00	0.00	0.688	0.00	0.00						
44.00	100.00	0.00	0.578	0.00	0.00						
37.00	100.00	0.00	0.486	0.00	0.00						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.00	0.172	0.00	0.00						
11.00	100.00	0.64	0.145	0.00	0.00						

Particle Size Analysis	101-AW-PSD	Date: 04/12/99 Time: 10:56	Meas #: 00049 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 3.902	10% = 1.605	60% = 4.321	5.221	55%	2.891
mn = 1.757	20% = 2.038	70% = 5.046	2.142	45%	1.388
ma = 2.949	30% = 2.479	80% = 5.773			
cs = 2.034	40% = 2.985	90% = 6.626			
sd = 2.107	50% = 3.605	95% = 7.258			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	2.28						
592.0	100.00	0.00	7.778	97.72	8.61						
497.8	100.00	0.00	6.541	89.21	12.94						
418.6	100.00	0.00	5.500	76.27	12.11						
352.0	100.00	0.00	4.625	64.16	10.09						
296.0	100.00	0.00	3.889	54.07	9.20						
248.9	100.00	0.00	3.270	44.87	9.26						
209.3	100.00	0.00	2.750	35.61	9.27						
176.0	100.00	0.00	2.312	26.34	8.54						
148.0	100.00	0.00	1.945	17.80	7.14						
124.5	100.00	0.00	1.635	10.66	5.34						
104.7	100.00	0.00	1.375	5.32	3.31						
88.00	100.00	0.00	1.156	2.01	1.53						
74.00	100.00	0.00	0.972	0.48	0.48						
62.23	100.00	0.00	0.818	0.00	0.00						
52.33	100.00	0.00	0.688	0.00	0.00						
44.00	100.00	0.00	0.578	0.00	0.00						
37.00	100.00	0.00	0.486	0.00	0.00						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.00	0.172	0.00	0.00						
11.00	100.00	0.00	0.145	0.00	0.00						

Particle Size Analysis

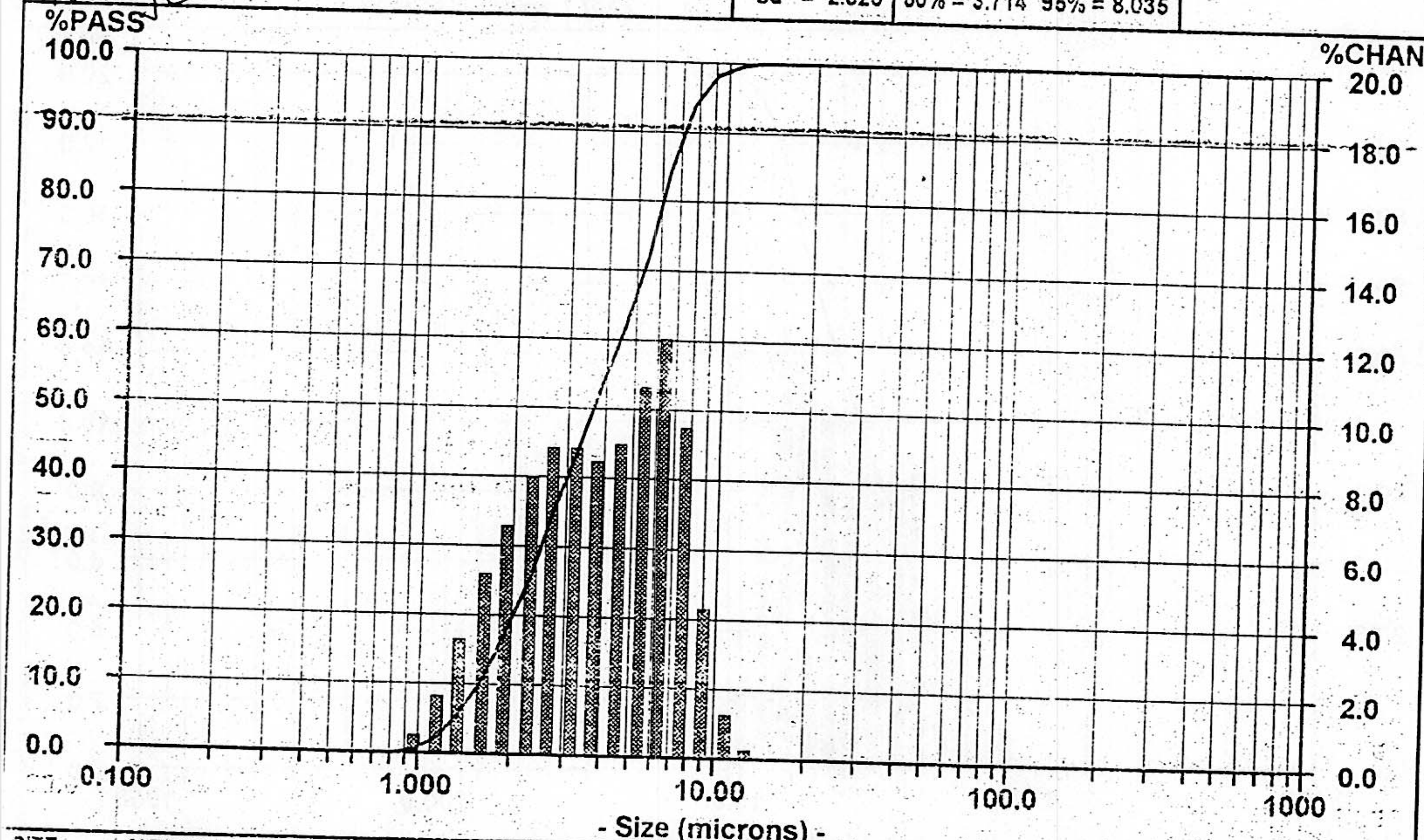
101-AW-PSD

Date: 04/12/99 Meas #: 00050
Time: 10:56 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.127	10% = 1.586	60% = 4.611	5.473	56%	3.402
mn = 1.708	20% = 2.045	70% = 5.323	2.129	44%	1.418
ma = 2.996	30% = 2.509	80% = 6.146			
cs = 2.002	40% = 3.043	90% = 7.185			
sd = 2.325	50% = 3.714	95% = 8.035			

Average



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	98.27	4.41						
592.0	100.00	0.00	7.778	93.86	9.57						
497.8	100.00	0.00	6.541	84.29	12.11						
418.6	100.00	0.00	5.500	72.18	10.78						
352.0	100.00	0.00	4.625	61.40	9.10						
296.0	100.00	0.00	3.889	52.30	8.61						
248.9	100.00	0.00	3.270	43.69	8.91						
209.3	100.00	0.00	2.750	34.78	8.92						
176.0	100.00	0.00	2.312	25.86	8.09						
148.0	100.00	0.00	1.945	17.77	6.73						
124.5	100.00	0.00	1.635	11.04	5.20						
104.7	100.00	0.00	1.375	5.84	3.46						
88.00	100.00	0.00	1.156	2.38	1.76						
74.00	100.00	0.00	0.972	0.62	0.62						
62.23	100.00	0.00	0.818	0.00	0.00						
52.33	100.00	0.00	0.688	0.00	0.00						
44.00	100.00	0.00	0.578	0.00	0.00						
37.00	100.00	0.00	0.486	0.00	0.00						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.38	0.172	0.00	0.00						
11.00	99.62	1.35	0.145	0.00	0.00						

Particle Size Analysis

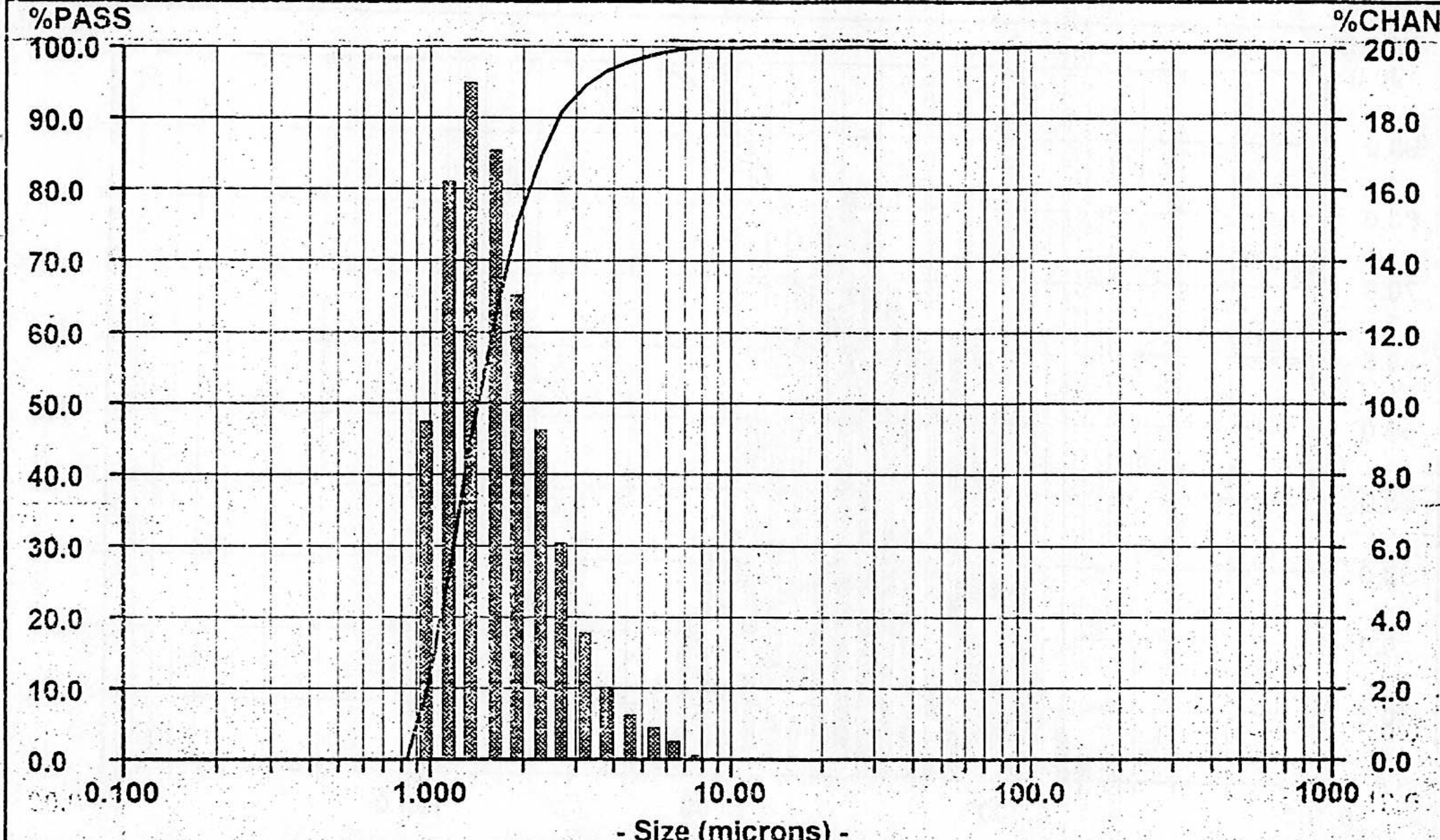
101-AW-PSD

Date: 04/12/99 Meas #: 00050
Time: 10:56 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Average Number Distribution

Summary	Percentiles		Dia	Vol%	Width
mv = 4.127	10% = 0.976	60% = 1.595	1.440	100%	1.227
mn = 1.708	20% = 1.090	70% = 1.799			
ma = 2.996	30% = 1.199	80% = 2.101			
cs = 2.002	40% = 1.312	90% = 2.661			
sd = 0.613	50% = 1.440	95% = 3.353			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	99.99	0.08						
592.0	100.00	0.00	7.778	99.91	0.29						
497.8	100.00	0.00	6.541	99.62	0.62						
418.6	100.00	0.00	5.500	99.00	0.93						
352.0	100.00	0.00	4.625	98.07	1.32						
296.0	100.00	0.00	3.889	96.75	2.10						
248.9	100.00	0.00	3.270	94.65	3.66						
209.3	100.00	0.00	2.750	90.99	6.16						
176.0	100.00	0.00	2.312	84.83	9.39						
148.0	100.00	0.00	1.945	75.44	13.15						
124.5	100.00	0.00	1.635	62.29	17.10						
104.7	100.00	0.00	1.375	45.19	19.14						
88.00	100.00	0.00	1.156	26.05	16.37						
74.00	100.00	0.00	0.972	9.68	9.68						
62.23	100.00	0.00	0.818	0.00	0.00						
52.33	100.00	0.00	0.688	0.00	0.00						
44.00	100.00	0.00	0.578	0.00	0.00						
37.00	100.00	0.00	0.486	0.00	0.00						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.00	0.172	0.00	0.00						
11.00	100.00	0.01	0.145	0.00	0.00						

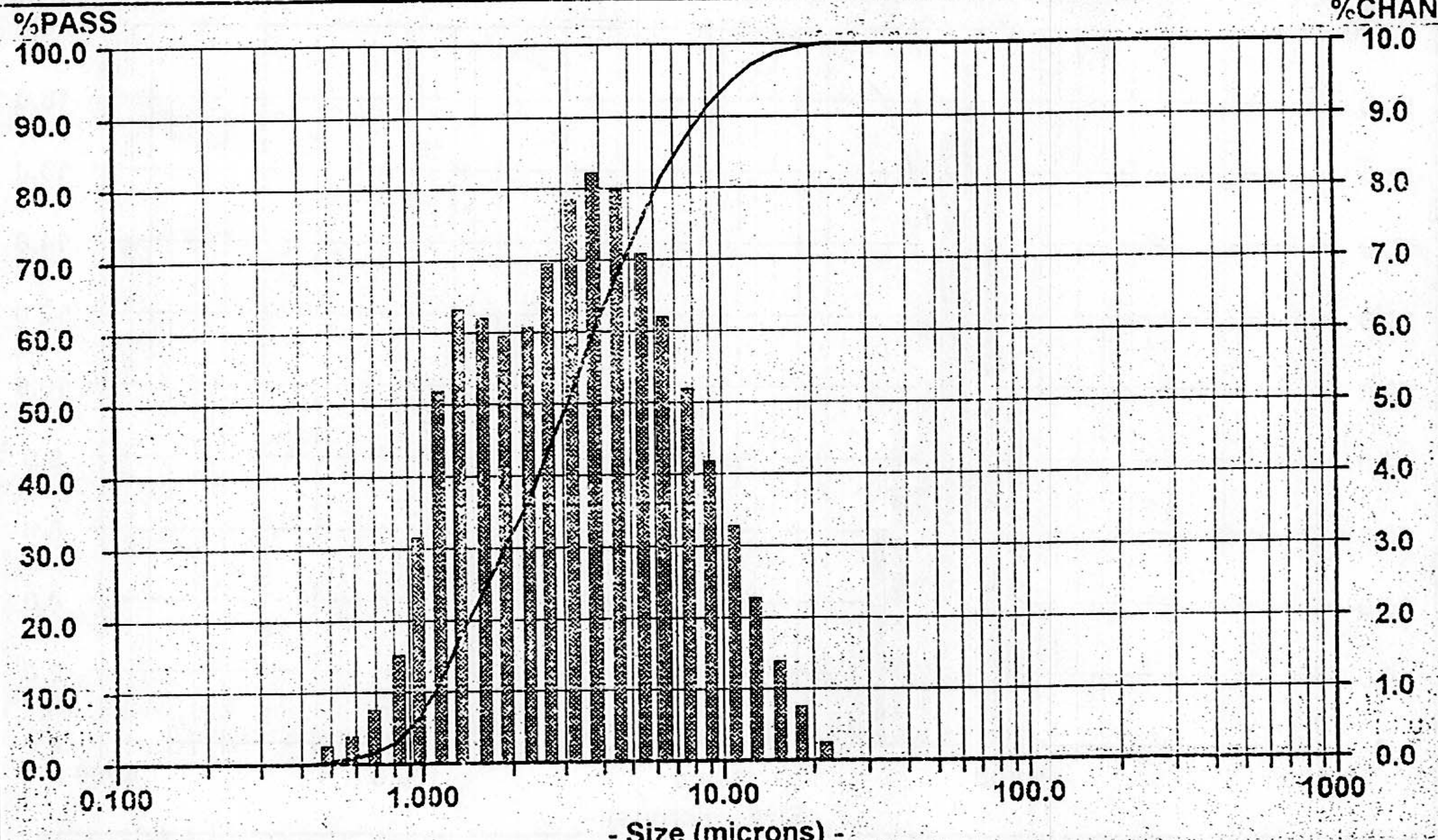
Particle Size Analysis	CUF 101-AW-005	Date: 04/12/99 Time: 09:02	Meas #: 00023 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary
mv = 4.129
mn = 0.998
ma = 2.297
cs = 2.612
sd = 2.848

Percentiles	
10% = 1.097	60% = 3.875
20% = 1.444	70% = 4.821
30% = 1.915	80% = 6.206
40% = 2.509	90% = 8.677
50% = 3.146	95% = 11.13

Dia	Vol%	Width
4.065	75%	5.699
1.173	25%	0.615

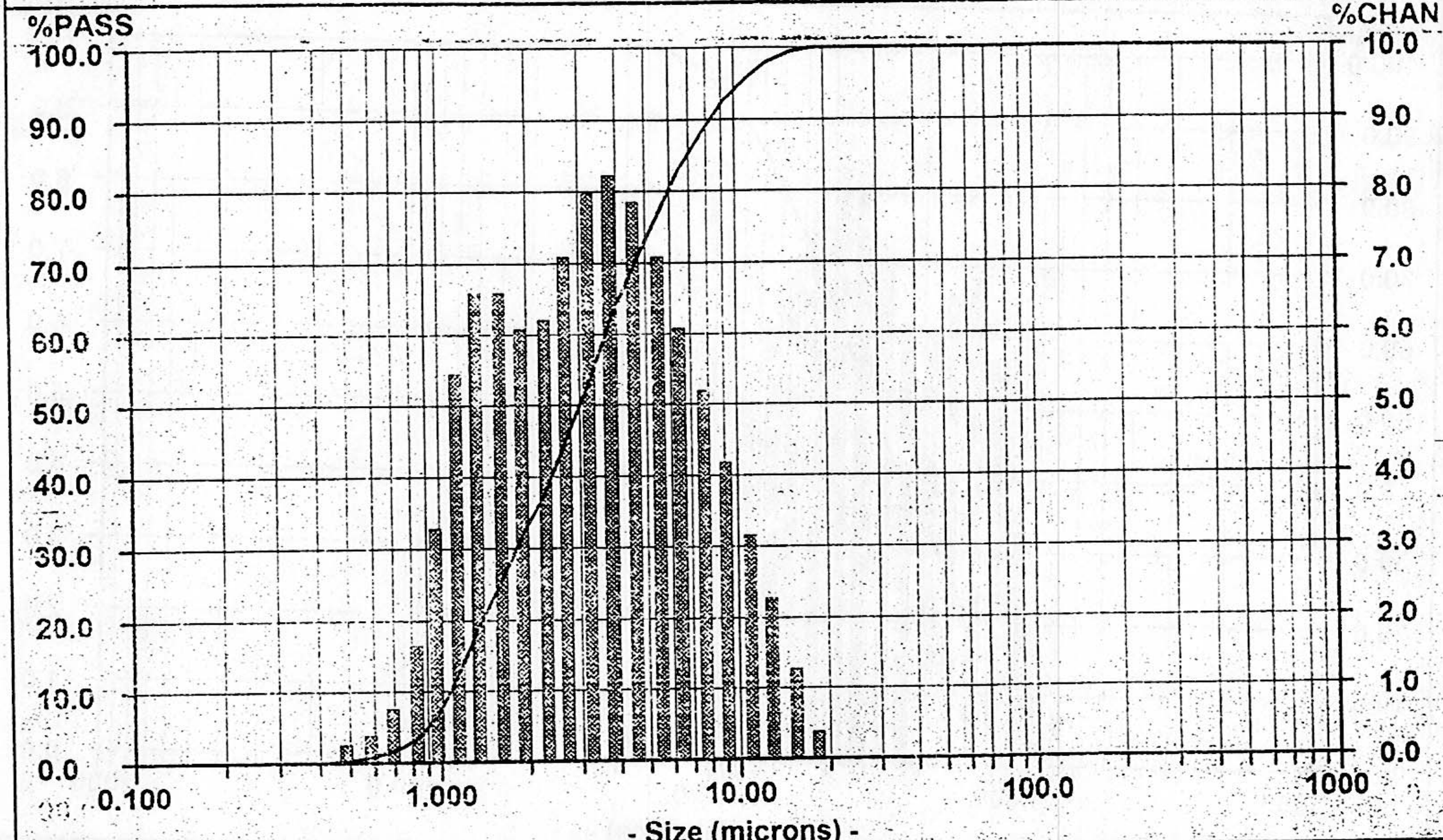


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	91.49	4.32						
592.0	100.00	0.00	7.778	87.17	5.34						
497.8	100.00	0.00	6.541	81.83	6.36						
418.6	100.00	0.00	5.500	75.47	7.29						
352.0	100.00	0.00	4.625	68.18	8.01						
296.0	100.00	0.00	3.889	60.17	8.33						
248.9	100.00	0.00	3.270	51.84	7.97						
209.3	100.00	0.00	2.750	43.87	7.08						
176.0	100.00	0.00	2.312	36.79	6.24						
148.0	100.00	0.00	1.945	30.55	6.01						
124.5	100.00	0.00	1.635	24.54	6.35						
104.7	100.00	0.00	1.375	18.19	6.43						
88.00	100.00	0.00	1.156	11.76	5.24						
74.00	100.00	0.00	0.972	6.52	3.20						
62.23	100.00	0.00	0.818	3.32	1.63						
52.33	100.00	0.00	0.688	1.69	0.84						
44.00	100.00	0.00	0.578	0.85	0.51						
37.00	100.00	0.00	0.486	0.34	0.34						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.31	0.289	0.00	0.00						
18.50	99.69	0.86	0.243	0.00	0.00						
15.56	98.83	1.59	0.204	0.00	0.00						
13.08	97.24	2.42	0.172	0.00	0.00						
11.00	94.82	3.33	0.145	0.00	0.00						

Particle Size Analysis	CUF 101-AW-005	Date: 04/12/99 Time: 09:04	Meas #: 00024 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 3.950	10% = 1.079	60% = 3.745	3.980	74%	5.470
mn = 0.993	20% = 1.405	70% = 4.655	1.171	26%	0.613
ma = 2.237	30% = 1.841	80% = 6.990			
cs = 2.683	40% = 2.418	90% = 8.321			
sd = 2.737	50% = 3.042	95% = 10.50			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	92.50	4.26						
592.0	100.00	0.00	7.778	88.24	5.22						
497.8	100.00	0.00	6.541	83.02	6.18						
418.6	100.00	0.00	5.500	76.84	7.11						
352.0	100.00	0.00	4.625	69.73	7.92						
296.0	100.00	0.00	3.889	61.81	8.36						
248.9	100.00	0.00	3.270	53.45	8.05						
209.3	100.00	0.00	2.750	45.40	7.15						
176.0	100.00	0.00	2.312	38.25	6.32						
148.0	100.00	0.00	1.945	31.93	6.15						
124.5	100.00	0.00	1.635	25.78	6.60						
104.7	100.00	0.00	1.375	19.18	6.77						
88.00	100.00	0.00	1.156	12.41	5.54						
74.00	100.00	0.00	0.972	6.87	3.38						
62.23	100.00	0.00	0.818	3.49	1.72						
52.33	100.00	0.00	0.688	1.77	0.89						
44.00	100.00	0.00	0.578	0.88	0.53						
37.00	100.00	0.00	0.486	0.35	0.35						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.57	0.243	0.00	0.00						
15.56	99.43	1.34	0.204	0.00	0.00						
13.08	98.09	2.30	0.172	0.00	0.00						
11.00	95.79	3.29	0.145	0.00	0.00						

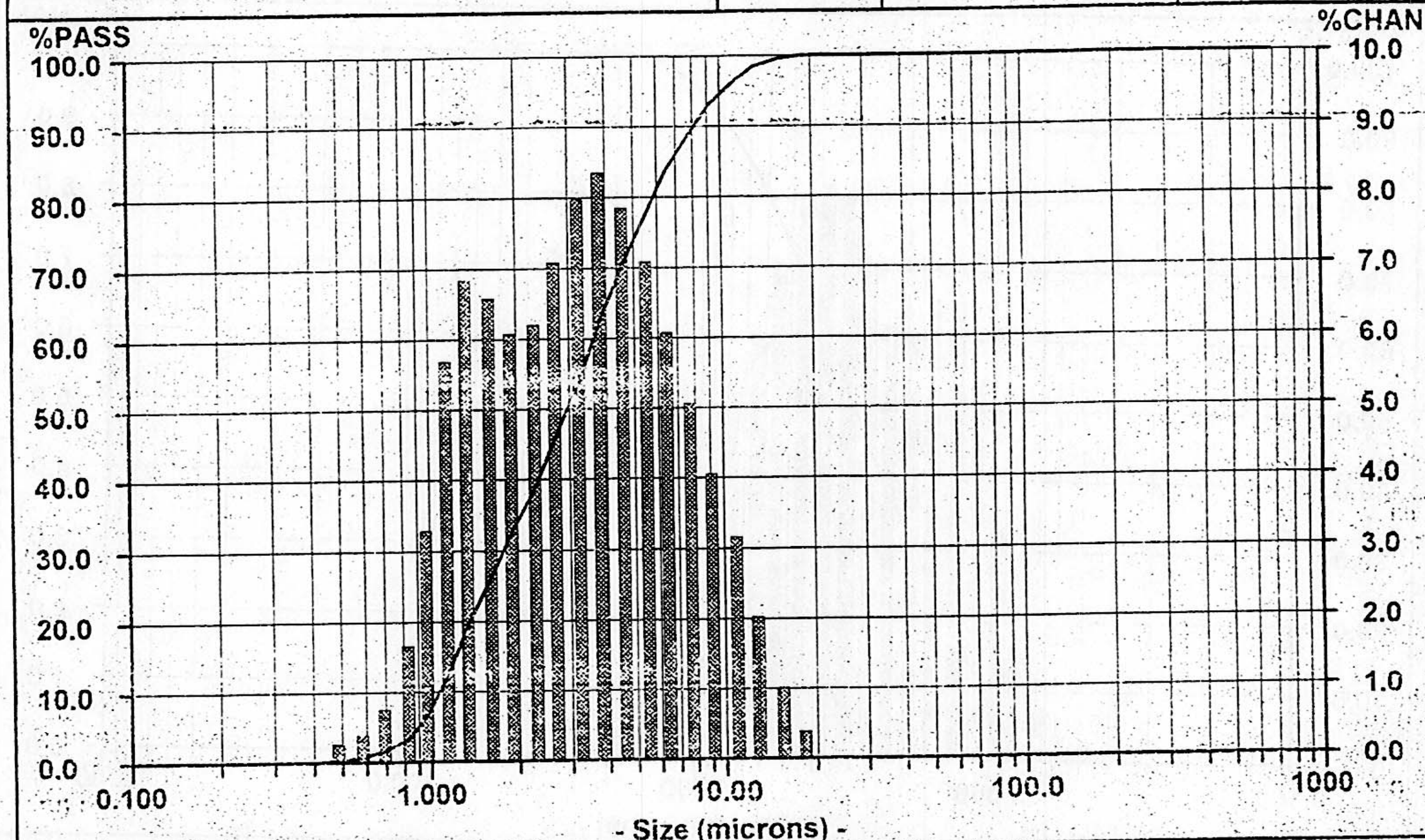
Particle Size Analysis

CUF 101-AW-005

Date: 04/12/99 Meas #: 00025
Time: 09:05 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 3.870	10% = 1.073	60% = 3.691	3.946	74%	5.336
mn = 0.997	20% = 1.387	70% = 4.576	1.172	26%	0.609
ma = 2.211	30% = 1.804	80% = 5.872			
cs = 2.714	40% = 2.374	90% = 8.121			
sd = 2.671	50% = 2.998	95% = 10.22			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	93.05	4.18						
592.0	100.00	0.00	7.778	88.87	5.15						
497.8	100.00	0.00	6.541	83.72	6.13						
418.6	100.00	0.00	5.500	77.59	7.10						
352.0	100.00	0.00	4.625	70.49	7.96						
296.0	100.00	0.00	3.889	62.53	8.40						
248.9	100.00	0.00	3.270	54.13	8.04						
209.3	100.00	0.00	2.750	46.09	7.11						
176.0	100.00	0.00	2.312	38.98	6.32						
148.0	100.00	0.00	1.945	32.66	6.23						
124.5	100.00	0.00	1.635	26.43	6.77						
104.7	100.00	0.00	1.375	19.66	6.99						
88.00	100.00	0.00	1.156	12.67	5.70						
74.00	100.00	0.00	0.972	6.97	3.46						
62.23	100.00	0.00	0.818	3.51	1.75						
52.33	100.00	0.00	0.688	1.76	0.89						
44.00	100.00	0.00	0.578	0.87	0.53						
37.00	100.00	0.00	0.486	0.34	0.34						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.42	0.243	0.00	0.00						
15.56	99.58	1.16	0.204	0.00	0.00						
13.08	98.42	2.17	0.172	0.00	0.00						
11.00	96.25	3.20	0.145	0.00	0.00						

Particle Size Analysis

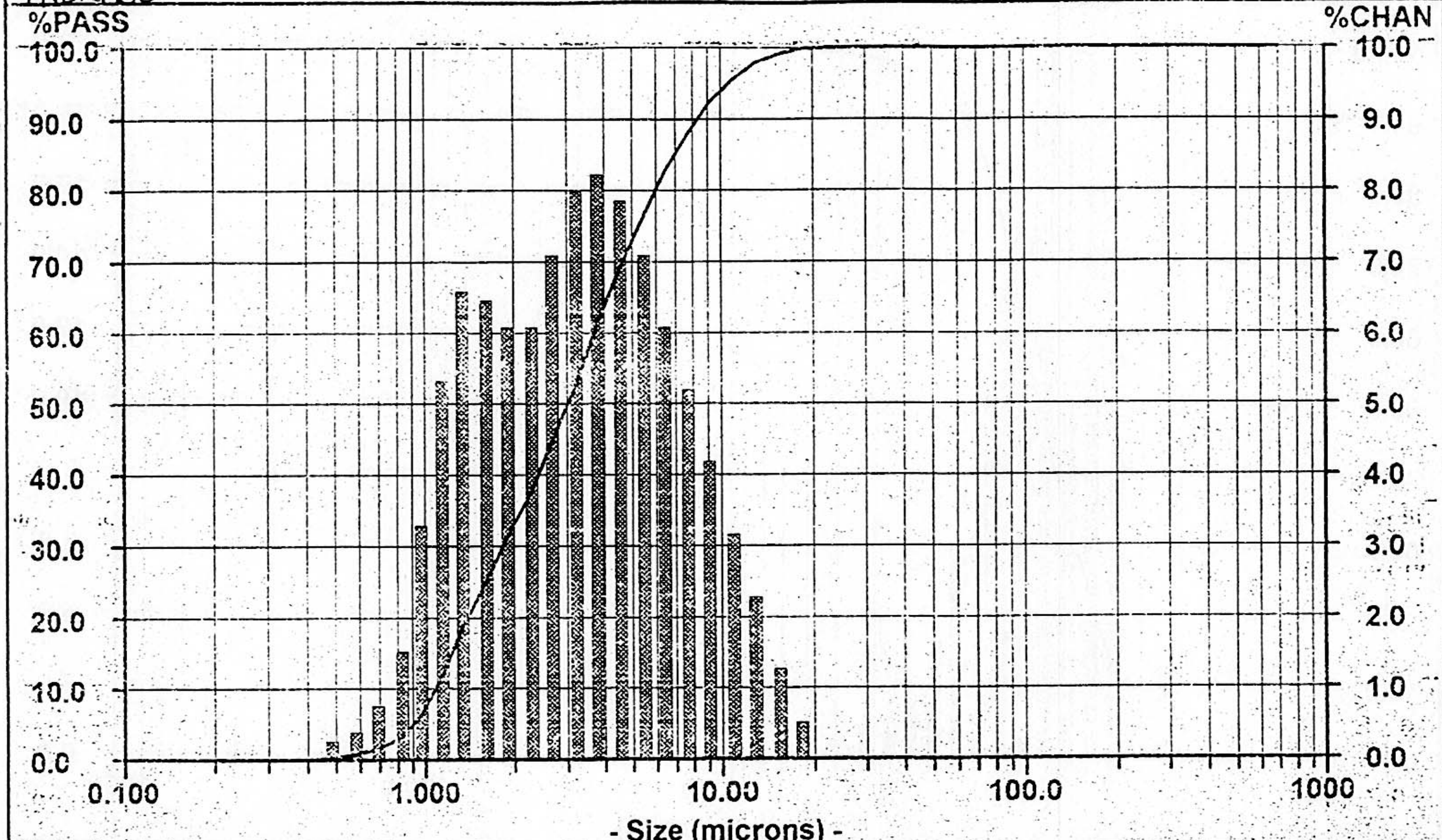
CUF 101-AW-005

Date: 04/12/99 Meas #: 00026
Time: 09:05 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

AVERAGE

Summary	Percentiles		Dia	Vol%	Width
mv = 3.983	10% = 1.083	60% = 3.770	3.996	74%	5.494
mn = 0.997	20% = 1.411	70% = 4.683	1.172	26%	0.612
ma = 2.249	30% = 1.853	80% = 6.020			
cs = 2.668	40% = 2.435	90% = 8.368			
sd = 2.750	50% = 3.063	95% = 10.60			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	92.35	4.25						
592.0	100.00	0.00	7.778	88.10	5.24						
497.8	100.00	0.00	6.541	82.86	6.22						
418.6	100.00	0.00	5.500	76.64	7.17						
352.0	100.00	0.00	4.625	69.47	7.96						
296.0	100.00	0.00	3.889	61.51	8.39						
248.9	100.00	0.00	3.270	53.12	8.02						
209.3	100.00	0.00	2.750	45.10	7.11						
176.0	100.00	0.00	2.312	37.99	6.29						
148.0	100.00	0.00	1.945	31.70	6.13						
124.5	100.00	0.00	1.635	25.57	6.57						
104.7	100.00	0.00	1.375	19.00	6.73						
88.00	100.00	0.00	1.156	12.27	5.49						
74.00	100.00	0.00	0.972	6.78	3.35						
62.23	100.00	0.00	0.818	3.43	1.70						
52.33	100.00	0.00	0.688	1.73	0.87						
44.00	100.00	0.00	0.578	0.86	0.52						
37.00	100.00	0.00	0.486	0.34	0.34						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.10	0.289	0.00	0.00						
18.50	99.90	0.62	0.243	0.00	0.00						
15.56	99.28	1.36	0.204	0.00	0.00						
13.08	97.92	2.30	0.172	0.00	0.00						
11.00	95.62	3.27	0.145	0.00	0.00						

Particle Size Analysis

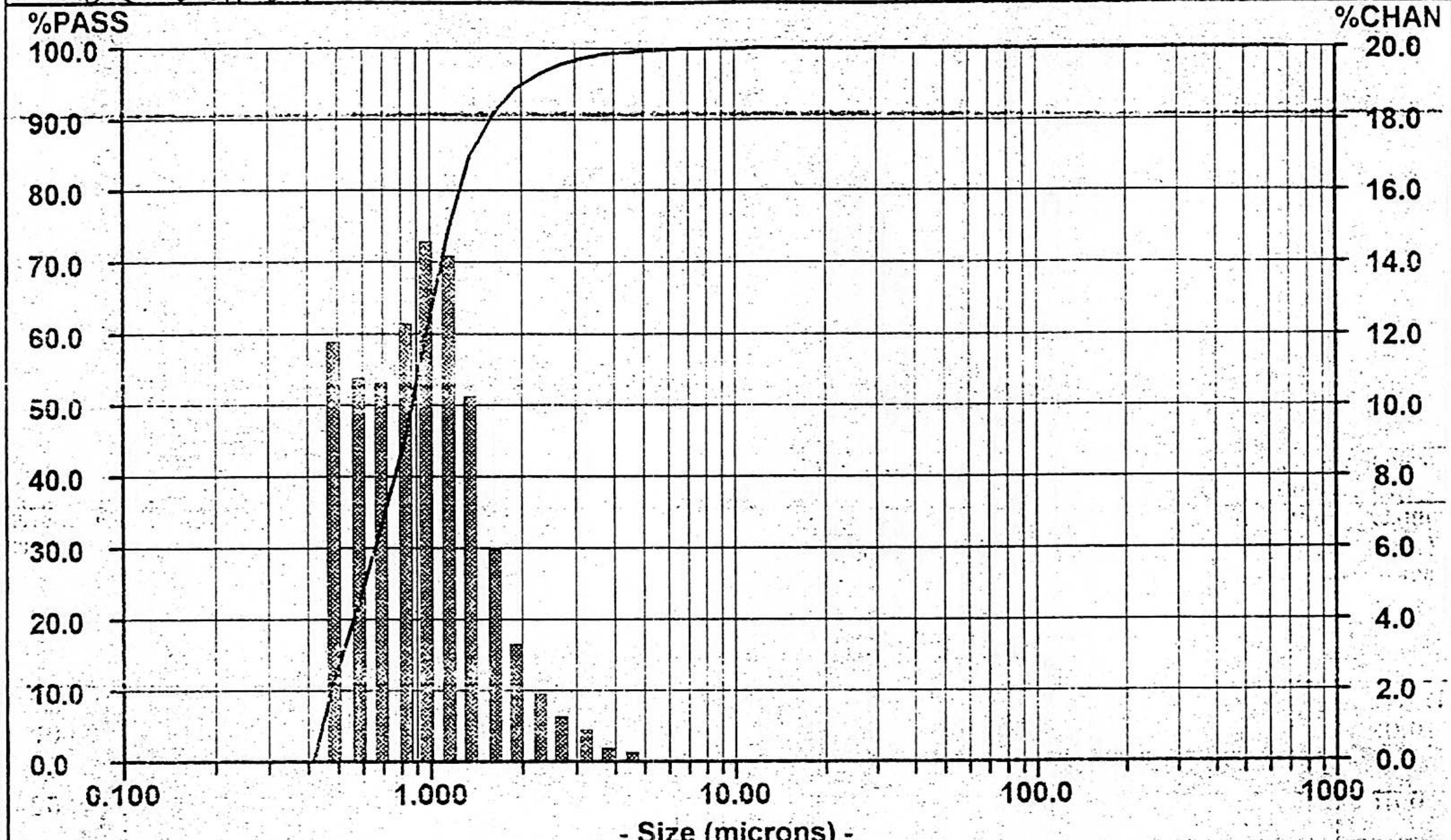
CUF 101-AW-005

Date: 04/12/99 Meas #: 00026
Time: 09:05 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

AVERAGE
NUMBER DISTRIBUTION

Summary	Percentiles		Dia	Vol%	Width
mv = 3.983	10% = 0.475	60% = 0.967	0.982	77%	0.759
mn = 0.997	20% = 0.554	70% = 1.089	0.483	23%	0.108
ma = 2.249	30% = 0.652	80% = 1.252			
cs = 2.668	40% = 0.757	90% = 1.572			
sd = 0.414	50% = 0.861	95% = 2.026			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	99.99	0.02						
592.0	100.00	0.00	7.778	99.97	0.04						
497.8	100.00	0.00	6.541	99.93	0.09						
418.6	100.00	0.00	5.500	99.84	0.17						
352.0	100.00	0.00	4.625	99.67	0.32						
296.0	100.00	0.00	3.889	99.35	0.57						
248.9	100.00	0.00	3.270	98.78	0.92						
209.3	100.00	0.00	2.750	97.86	1.37						
176.0	100.00	0.00	2.312	96.49	2.04						
148.0	100.00	0.00	1.945	94.45	3.34						
124.5	100.00	0.00	1.635	91.11	6.03						
104.7	100.00	0.00	1.375	85.08	10.37						
88.00	100.00	0.00	1.156	74.71	14.25						
74.00	100.00	0.00	0.972	60.46	14.60						
62.23	100.00	0.00	0.818	45.86	12.46						
52.33	100.00	0.00	0.688	33.40	10.75						
44.00	100.00	0.00	0.578	22.65	10.80						
37.00	100.00	0.00	0.486	11.85	11.85						
31.11	100.00	0.00	0.409	0.00	0.00						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.00	0.172	0.00	0.00						
11.00	100.00	0.01	0.145	0.00	0.00						

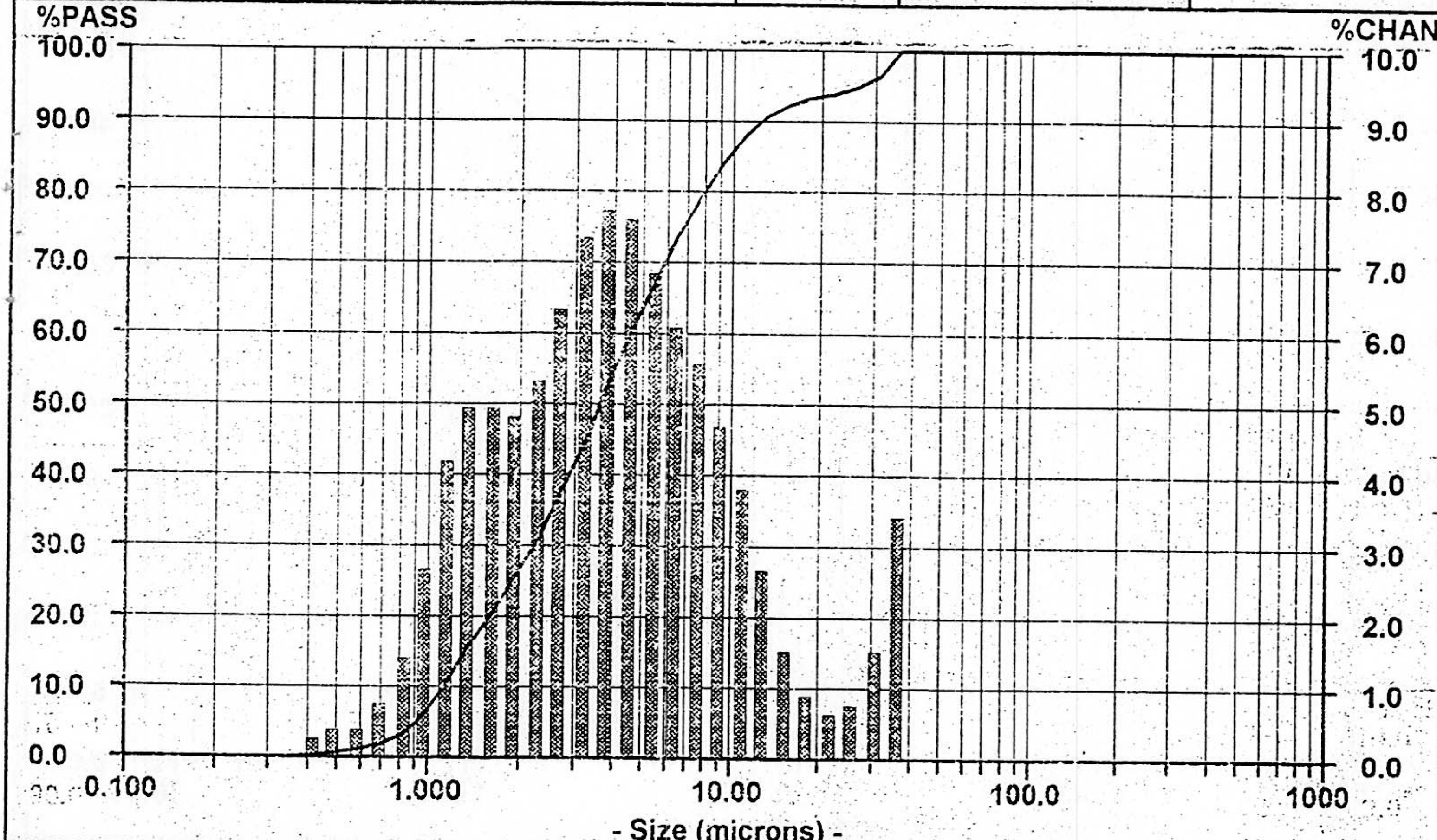
Particle Size Analysis

101-AW Simulant Supernatant
40 ml/sec

CUF 101-AW-005
Duplicate

Date: 04/12/99 Meas #: 00035
Time: 09:57 Pres #: 01

Summary	Percentiles		Dia	Vol%	Width
mv = 6.104	10% = 1.135	60% = 4.599	31.39	7%	10.95
mn = 0.856	20% = 1.607	70% = 5.924	4.278	73%	6.074
ma = 2.530	30% = 2.252	80% = 8.013	1.146	20%	0.662
cs = 2.372	40% = 2.933	90% = 12.48			
sd = 3.929	50% = 3.969	95% = 26.84			

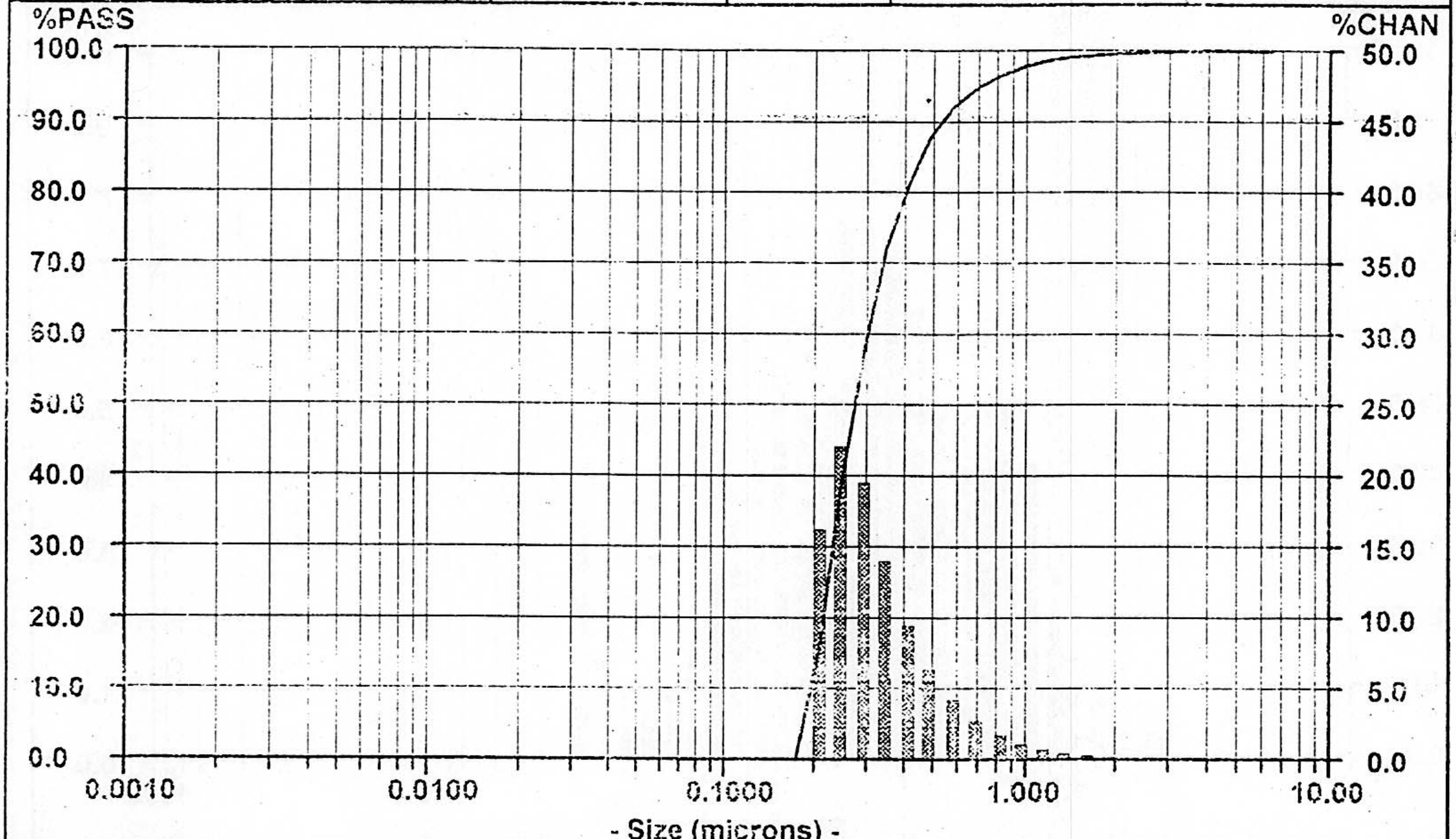


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	83.98	4.86						
592.0	100.00	0.00	7.778	79.12	5.60						
497.8	100.00	0.00	6.541	73.52	6.29						
418.6	100.00	0.00	5.500	67.23	6.98						
352.0	100.00	0.00	4.625	60.25	7.60						
296.0	100.00	0.00	3.889	52.65	7.86						
248.9	100.00	0.00	3.270	44.79	7.46						
209.3	100.00	0.00	2.750	37.33	6.45						
176.0	100.00	0.00	2.312	30.88	5.43						
148.0	100.00	0.00	1.945	25.45	4.94						
124.5	100.00	0.00	1.635	20.51	5.00						
104.7	100.00	0.00	1.375	15.51	5.02						
88.00	100.00	0.00	1.156	10.49	4.21						
74.00	100.00	0.00	0.972	6.28	2.72						
62.23	100.00	0.00	0.818	3.56	1.49						
52.33	100.00	0.00	0.688	2.07	0.82						
44.00	100.00	0.00	0.578	1.25	0.52						
37.00	100.00	3.55	0.486	0.73	0.40						
31.11	96.45	1.61	0.409	0.33	0.33						
26.16	94.84	0.86	0.344	0.00	0.00						
22.00	93.98	0.72	0.289	0.00	0.00						
18.50	93.26	0.97	0.243	0.00	0.00						
15.56	92.29	1.65	0.204	0.00	0.00						
13.08	90.64	2.74	0.172	0.00	0.00						
11.00	87.90	3.92	0.145	0.00	0.00						

Particle Size Analysis	CUF AW-101-005 Duplicate Sample	Date: 04/09/99 Time: 15:43	Meas #: 00145 Pres #: 01

AVERAGE NUMBER DISTRIBUTION

Summary	Percentiles		Dia	Vol%	Width
mv = 3.041	10% = .1937	60% = .2952	.2679	100%	.2297
mn = .3391	20% = .2105	70% = .3335			
ma = 1.364	30% = .2277	80% = .3954			
cs = 4.399	40% = .2462	90% = .5237			
sd = .1149	50% = .2679	95% = .6884			



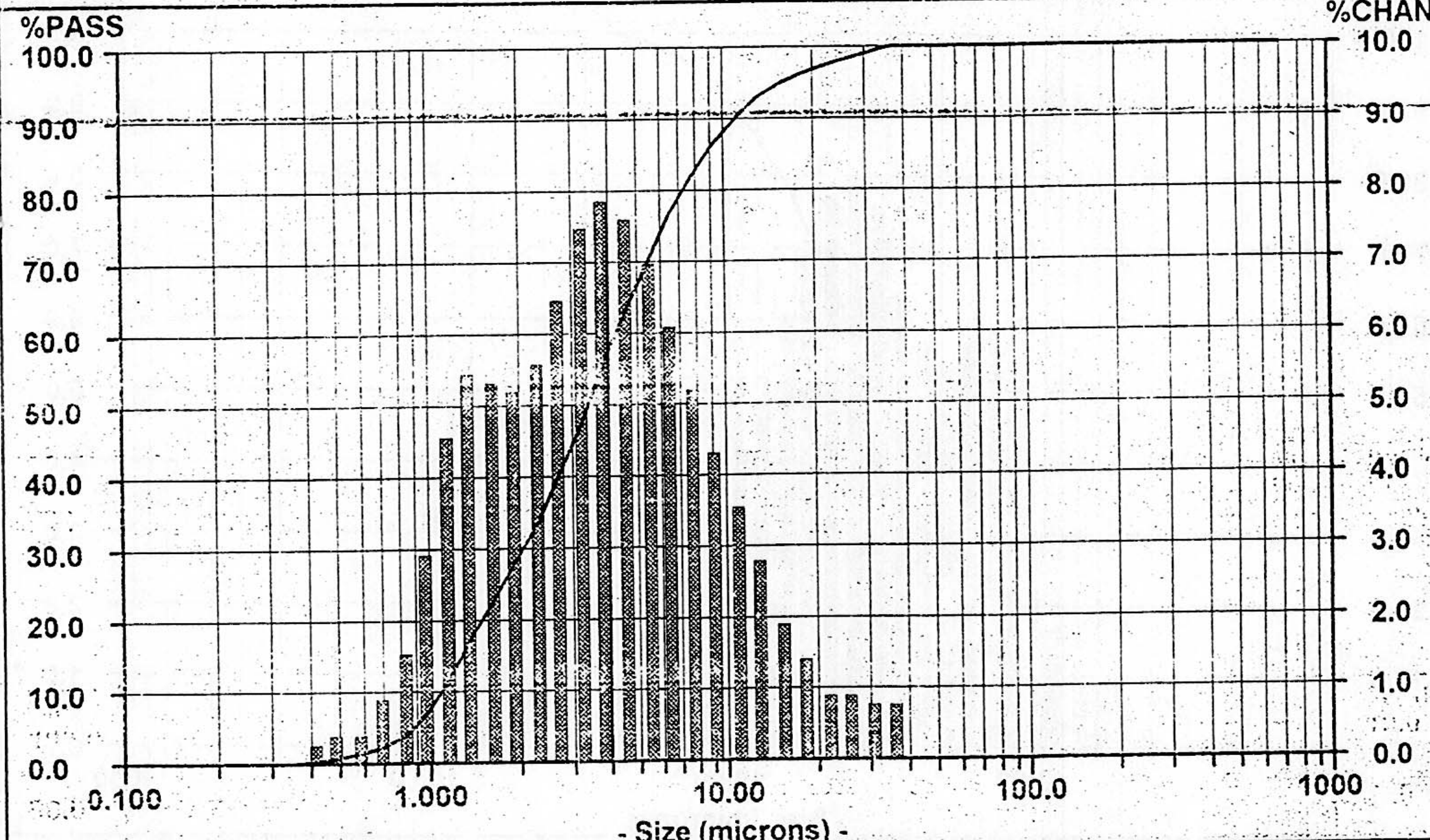
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.02	0.0859	0.00	0.00						
5.500	99.98	0.02	0.0723	0.00	0.00						
4.625	99.96	0.03	0.0608	0.00	0.00						
3.889	99.93	0.04	0.0511	0.00	0.00						
3.270	99.89	0.07	0.0430	0.00	0.00						
2.750	99.82	0.10	0.0361	0.00	0.00						
2.313	99.72	0.14	0.0304	0.00	0.00						
1.945	99.58	0.21	0.0255	0.00	0.00						
1.635	99.37	0.32	0.0215	0.00	0.00						
1.376	99.05	0.48	0.0181	0.00	0.00						
1.156	98.57	0.73	0.0152	0.00	0.00						
0.9723	97.84	1.12	0.0128	0.00	0.00						
0.8176	96.72	1.74	0.0107	0.00	0.00						
0.6875	94.98	2.77	0.0090	0.00	0.00						
0.5781	92.21	4.25	0.0076	0.00	0.00						
0.4861	87.96	6.41	0.0064	0.00	0.00						
0.4088	81.55	9.44	0.0054	0.00	0.00						
0.3437	72.11	14.05	0.0045	0.00	0.00						
0.2891	58.06	19.60	0.0038	0.00	0.00						
0.2431	38.46	22.12									
0.2044	16.34	16.34									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

CUF 101-AW-005	Date: 04/12/99	Meas #: 00036
Duplicate	Time: 09:59	Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.145	10% = 1.090	60% = 4.282	4.421	77%	7.378
mn = 0.839	20% = 1.494	70% = 5.443	1.144	23%	0.663
ma = 2.373	30% = 2.067	80% = 7.280			
cs = 2.528	40% = 2.733	90% = 10.99			
sd = 3.538	50% = 3.436	95% = 15.73			

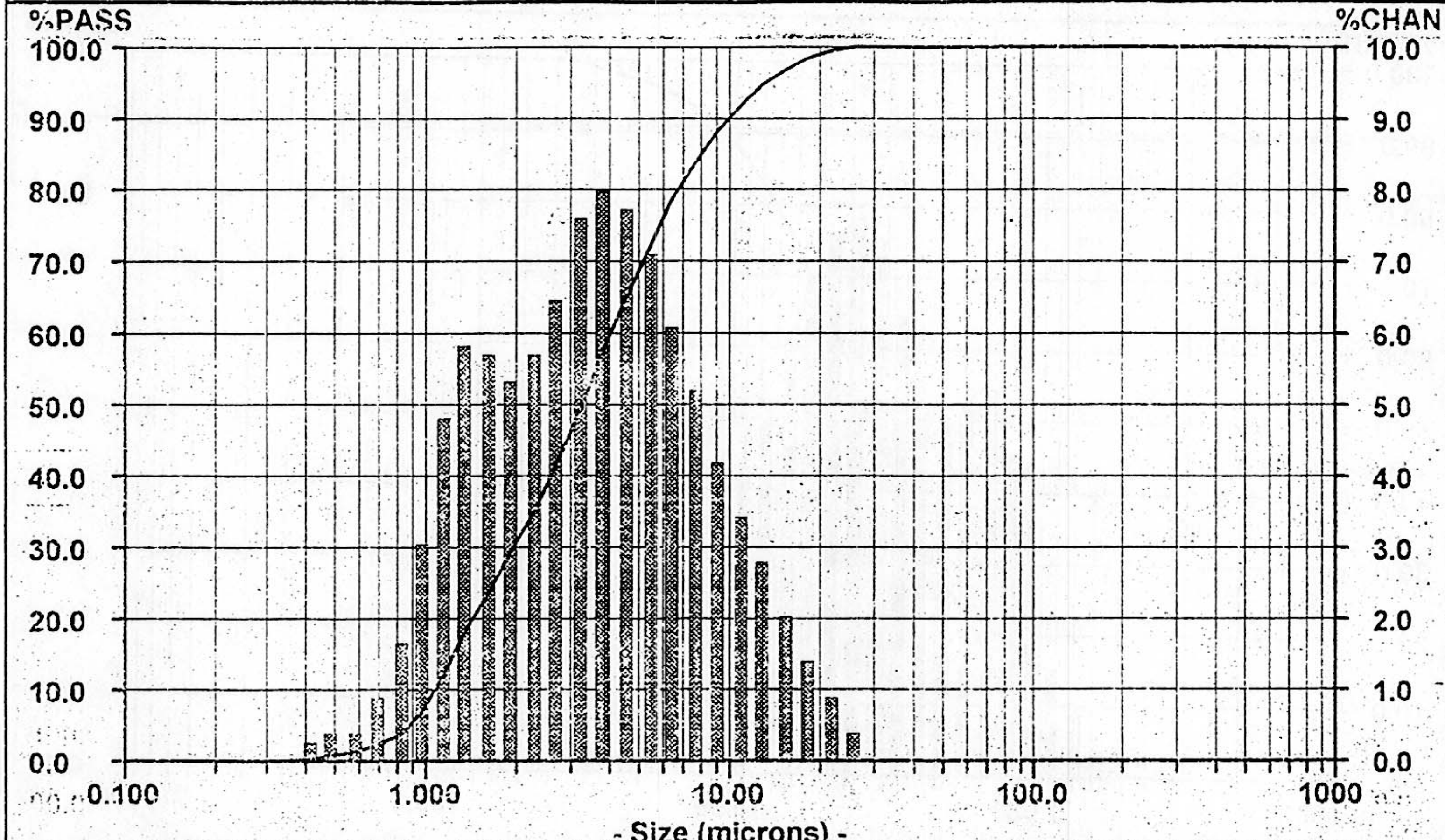


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	86.39	4.45						
592.0	100.00	0.00	7.778	81.94	5.32						
497.8	100.00	0.00	6.541	76.62	6.21						
418.6	100.00	0.00	5.500	70.41	7.04						
352.0	100.00	0.00	4.625	63.37	7.69						
296.0	100.00	0.00	3.889	55.68	7.92						
248.9	100.00	0.00	3.270	47.76	7.51						
209.3	100.00	0.00	2.750	40.25	6.53						
176.0	100.00	0.00	2.312	33.72	5.62						
148.0	100.00	0.00	1.945	28.10	5.28						
124.5	100.00	0.00	1.635	22.82	5.49						
104.7	100.00	0.00	1.375	17.33	5.59						
88.00	100.00	0.00	1.156	11.74	4.69						
74.00	100.00	0.00	0.972	7.05	3.03						
62.23	100.00	0.00	0.818	4.02	1.66						
52.33	100.00	0.00	0.688	2.36	0.92						
44.00	100.00	0.00	0.578	1.44	0.60						
37.00	100.00	0.80	0.486	0.84	0.46						
31.11	99.20	0.87	0.409	0.38	0.38						
26.16	98.33	0.91	0.344	0.00	0.00						
22.00	97.42	1.07	0.289	0.00	0.00						
18.50	96.35	1.45	0.243	0.00	0.00						
15.56	94.90	2.06	0.204	0.00	0.00						
13.08	92.84	2.82	0.172	0.00	0.00						
11.00	90.02	3.63	0.145	0.00	0.00						

Particle Size Analysis	CUF 101-AW-005 Duplicate	Date: 04/12/99 Time: 10:00	Meas #: 00037 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.570	10% = 1.077	60% = 4.107	4.289	76%	6.649
mn = 0.851	20% = 1.451	70% = 5.162	1.148	24%	0.654
ma = 2.307	30% = 1.980	80% = 6.785			
cs = 2.601	40% = 2.633	90% = 9.961			
sd = 3.232	50% = 3.317	95% = 13.27			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	88.41	4.33						
592.0	100.00	0.00	7.778	84.08	5.27						
497.8	100.00	0.00	6.541	78.81	6.26						
418.6	100.00	0.00	5.500	72.55	7.19						
352.0	100.00	0.00	4.625	65.36	7.89						
296.0	100.00	0.00	3.889	57.47	8.12						
248.9	100.00	0.00	3.270	49.35	7.60						
209.3	100.00	0.00	2.750	41.75	6.59						
176.0	100.00	0.00	2.312	35.16	5.72						
148.0	100.00	0.00	1.945	29.44	5.48						
124.5	100.00	0.00	1.635	23.96	5.80						
104.7	100.00	0.00	1.375	18.16	5.95						
88.00	100.00	0.00	1.156	12.21	4.97						
74.00	100.00	0.00	0.972	7.24	3.17						
62.23	100.00	0.00	0.818	4.07	1.72						
52.33	100.00	0.00	0.688	2.35	0.94						
44.00	100.00	0.00	0.578	1.41	0.60						
37.00	100.00	0.00	0.486	0.81	0.45						
31.11	100.00	0.00	0.409	0.36	0.36						
26.16	100.00	0.50	0.344	0.00	0.00						
22.00	99.50	0.96	0.289	0.00	0.00						
18.50	98.54	1.55	0.243	0.00	0.00						
15.56	96.99	2.19	0.204	0.00	0.00						
13.08	94.80	2.85	0.172	0.00	0.00						
11.00	91.95	3.54	0.145	0.00	0.00						

Particle Size Analysis

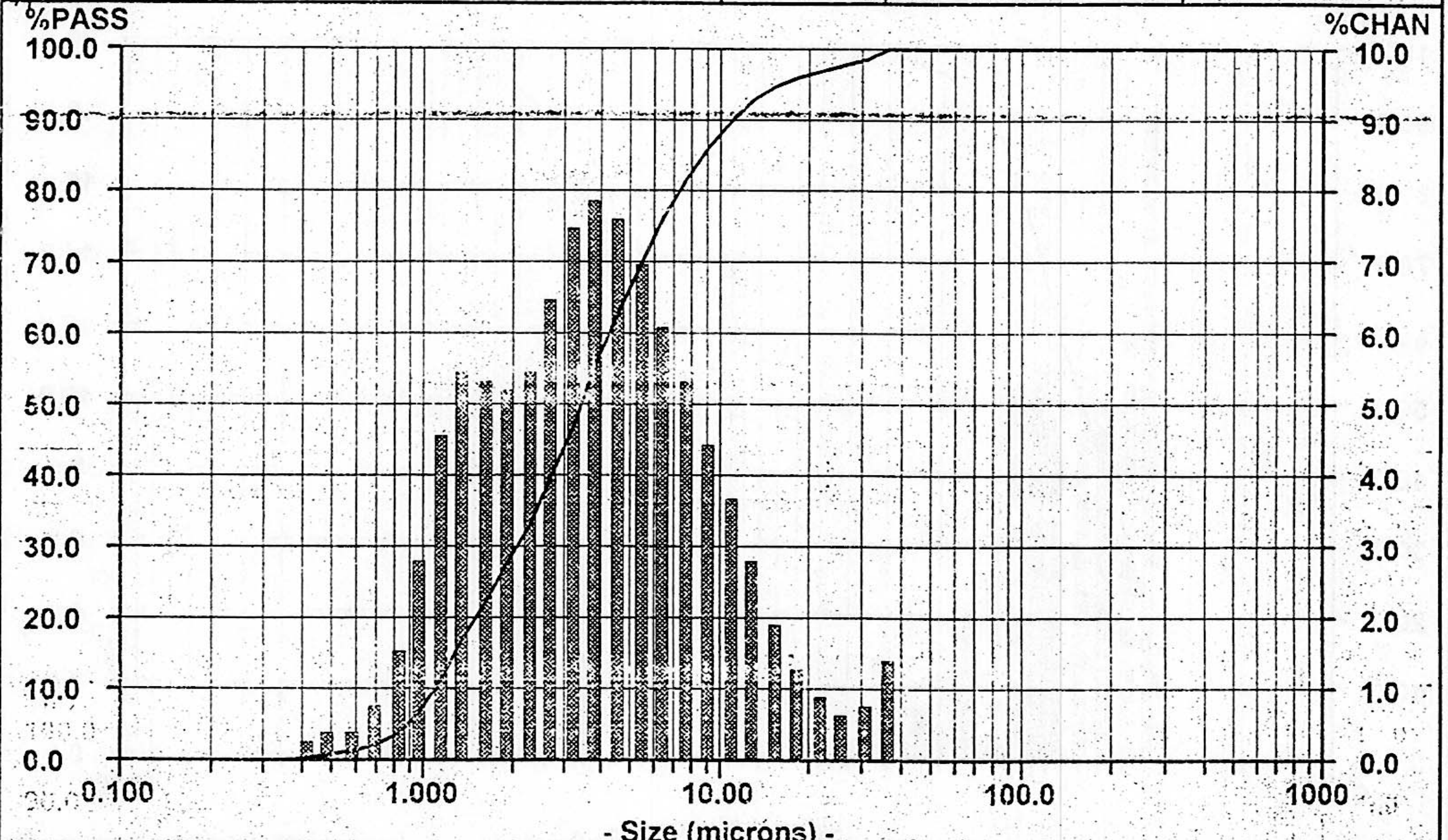
CUF 101-AW-005
Duplicate

Date: 04/12/99 Meas #: 00038
Time: 10:00 Pres #: 01

101-AW Simulant Supernatant
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.275	10% = 1.099	60% = 4.322	30.76	3%	10.06
mn = 0.848	20% = 1.512	70% = 5.493	4.291	75%	6.418
ma = 2.400	30% = 2.097	80% = 7.346	1.146	22%	0.659
cs = 2.500	40% = 2.766	90% = 11.03			
sd = 3.561	50% = 3.471	95% = 16.07			

AVERAGE



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	86.25	4.55						
592.0	100.00	0.00	7.778	81.70	5.40						
497.8	100.00	0.00	6.541	76.30	6.25						
418.6	100.00	0.00	5.500	70.05	7.07						
352.0	100.00	0.00	4.625	62.98	7.73						
296.0	100.00	0.00	3.889	55.25	7.97						
248.9	100.00	0.00	3.270	47.28	7.52						
209.3	100.00	0.00	2.750	39.76	6.52						
176.0	100.00	0.00	2.312	33.24	5.59						
148.0	100.00	0.00	1.945	27.65	5.23						
124.5	100.00	0.00	1.635	22.42	5.43						
104.7	100.00	0.00	1.375	16.99	5.52						
88.00	100.00	0.00	1.156	11.47	4.62						
74.00	100.00	0.00	0.972	6.85	2.97						
62.23	100.00	0.00	0.818	3.88	1.62						
52.33	100.00	0.00	0.688	2.26	0.89						
44.00	100.00	0.00	0.578	1.37	0.57						
37.00	100.00	1.45	0.486	0.80	0.44						
31.11	98.55	0.83	0.409	0.36	0.36						
26.16	97.72	0.76	0.344	0.00	0.00						
22.00	96.96	0.92	0.289	0.00	0.00						
18.50	96.04	1.32	0.243	0.00	0.00						
15.56	94.72	1.97	0.204	0.00	0.00						
13.08	92.75	2.80	0.172	0.00	0.00						
11.00	89.95	3.70	0.145	0.00	0.00						

Particle Size Analysis	CUF 101-AW-005 Duplicate	Date: 04/12/99 Time: 10:00	Meas #: 00038 Pres #: 01

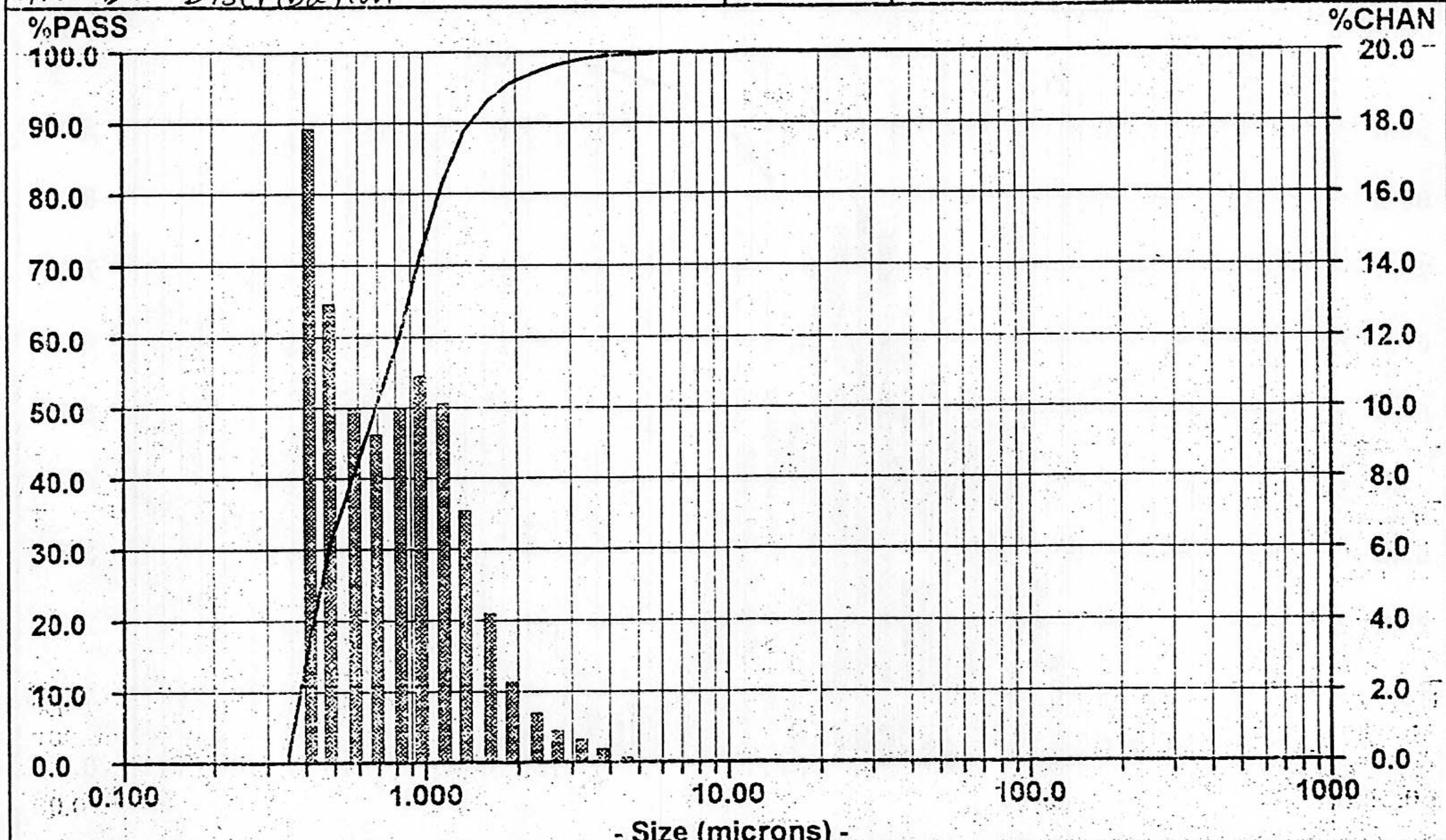
101-AW Simulant Supernatant
40 ml/sec

Average
Number Distribution

Summary	
mv	= 5.275
mn	= 0.848
ma	= 2.400
cs	= 2.500
sd	= 0.405

Percentiles	
10% = 0.382	60% = 0.811
20% = 0.419	70% = 0.949
30% = 0.479	80% = 1.120
40% = 0.567	90% = 1.423
50% = 0.683	95% = 1.843

Dia	Vol%	Width
0.957	59%	0.764
0.421	41%	0.144



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	99.99	0.02						
592.0	100.00	0.00	7.778	99.97	0.04						
497.8	100.00	0.00	6.541	99.93	0.08						
418.6	100.00	0.00	5.500	99.85	0.14						
352.0	100.00	0.00	4.625	99.71	0.27						
296.0	100.00	0.00	3.889	99.44	0.46						
248.9	100.00	0.00	3.270	98.98	0.73						
209.3	100.00	0.00	2.750	98.25	1.07						
176.0	100.00	0.00	2.312	97.18	1.54						
148.0	100.00	0.00	1.945	95.64	2.43						
124.5	100.00	0.00	1.635	93.21	4.24						
104.7	100.00	0.00	1.375	88.97	7.24						
88.00	100.00	0.00	1.156	81.73	10.20						
74.00	100.00	0.00	0.972	71.53	11.00						
62.23	100.00	0.00	0.818	60.53	10.10						
52.33	100.00	0.00	0.688	50.43	9.36						
44.00	100.00	0.00	0.578	41.07	10.07						
37.00	100.00	0.00	0.486	31.00	13.04						
31.11	100.00	0.00	0.409	17.96	17.96						
26.16	100.00	0.00	0.344	0.00	0.00						
22.00	100.00	0.00	0.289	0.00	0.00						
18.50	100.00	0.00	0.243	0.00	0.00						
15.56	100.00	0.00	0.204	0.00	0.00						
13.08	100.00	0.00	0.172	0.00	0.00						
11.00	100.00	0.01	0.145	0.00	0.00						

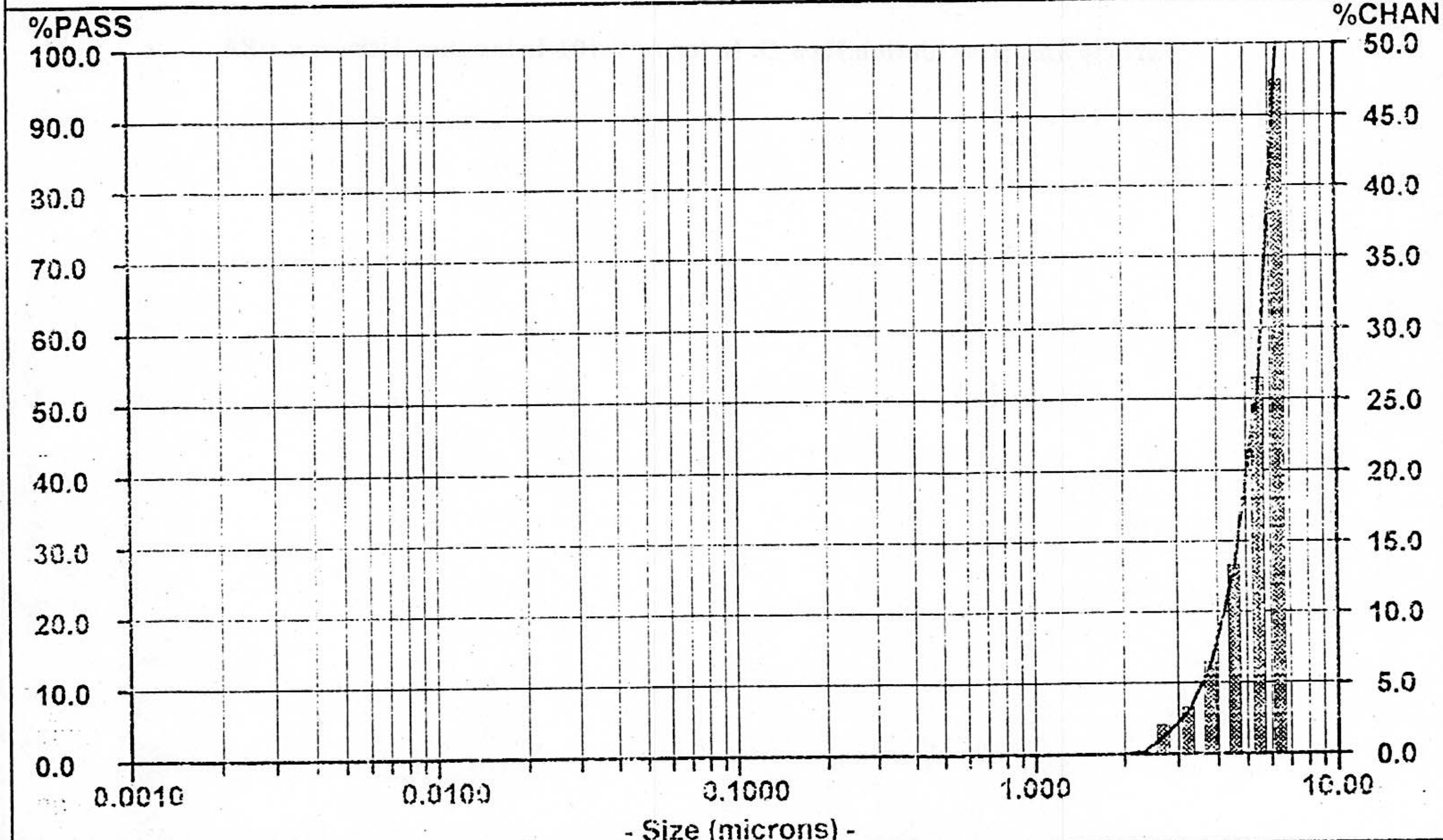
Particle Size Distribution Raw Data for AW-101 Using the Microtrac UPA

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD
~~Duplicate Sample~~

Date: 04/09/99 Time: 15:50
Meas #: N/A Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 5.171	10% = 3.681	60% = 5.647	6.436	100%	1.993
mn = 4.244	20% = 4.342	70% = 5.838			
ma = 4.925	30% = 4.798	80% = 6.028			
cs = 1.218	40% = 5.157	90% = 6.235			
sd = .9965	50% = 5.436	95% = 6.380			

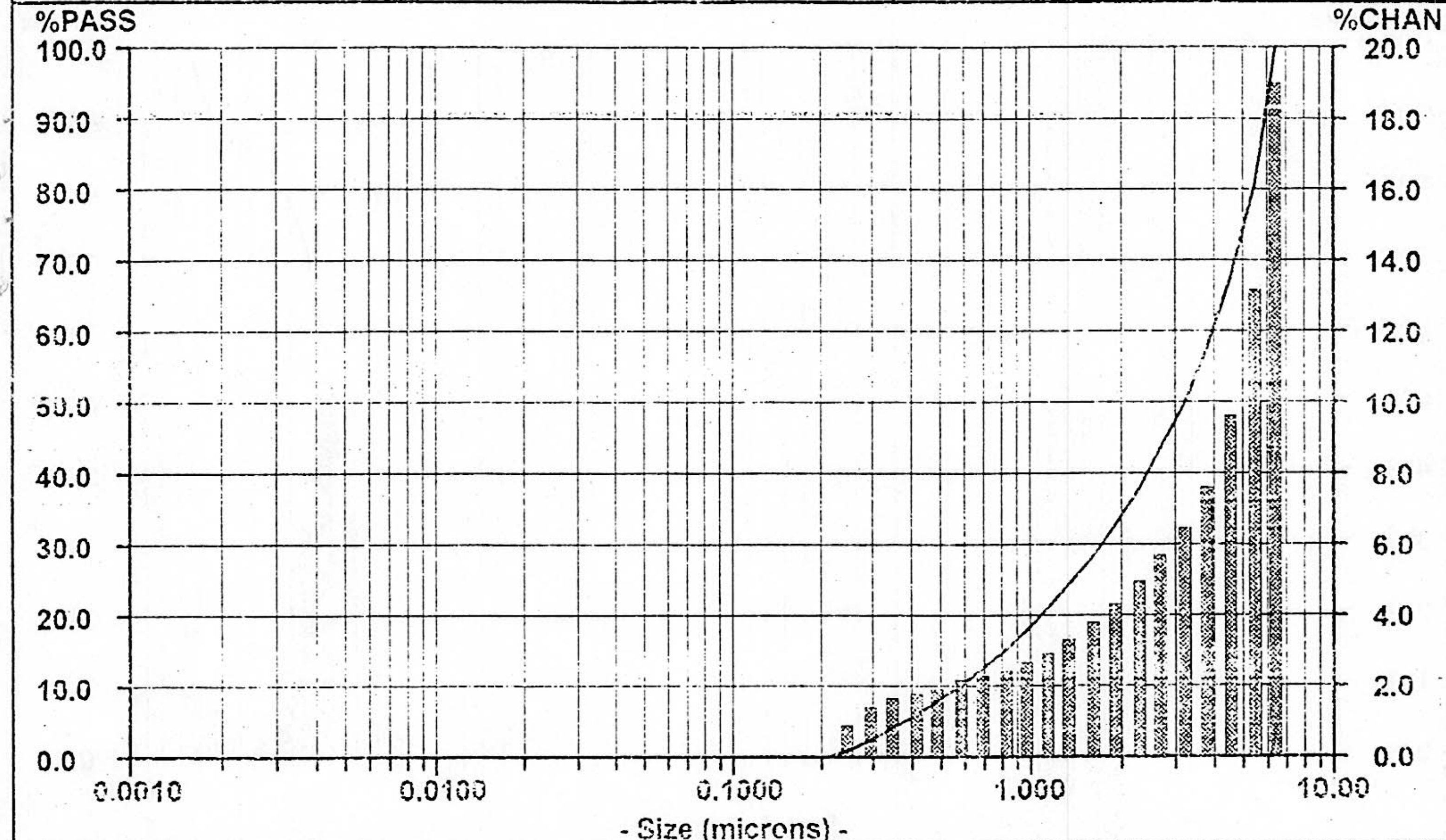


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	47.51	0.0859	0.00	0.00						
5.500	52.49	26.58	0.0723	0.00	0.00						
4.626	25.91	13.34	0.0608	0.00	0.00						
3.889	12.57	6.56	0.0511	0.00	0.00						
3.270	6.01	3.46	0.0430	0.00	0.00						
2.750	2.55	2.19	0.0361	0.00	0.00						
2.313	0.36	0.36	0.0304	0.00	0.00						
1.945	0.00	0.00	0.0255	0.00	0.00						
1.635	0.00	0.00	0.0215	0.00	0.00						
1.376	0.00	0.00	0.0181	0.00	0.00						
1.156	0.00	0.00	0.0152	0.00	0.00						
0.9723	0.00	0.00	0.0128	0.00	0.00						
0.8176	0.00	0.00	0.0107	0.00	0.00						
0.6875	0.00	0.00	0.0090	0.00	0.00						
0.5781	0.00	0.00	0.0076	0.00	0.00						
0.4861	0.00	0.00	0.0064	0.00	0.00						
0.4088	0.00	0.00	0.0054	0.00	0.00						
0.3437	0.00	0.00	0.0045	0.00	0.00						
0.2891	0.00	0.00	0.0038	0.00	0.00						
0.2431	0.00	0.00									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD Date: 04/09/99 Meas #: N/A
~~Duplicate Sample~~ Time: 15:51 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 3.266	10% = .5678	60% = 4.053	3.258	100%	4.786
mn = .3612	20% = 1.092	70% = 4.795			
ma = 1.489	30% = 1.744	80% = 5.448			
cs = 4.030	40% = 2.469	90% = 5.926			
sd = 2.393	50% = 3.258	95% = 6.178			



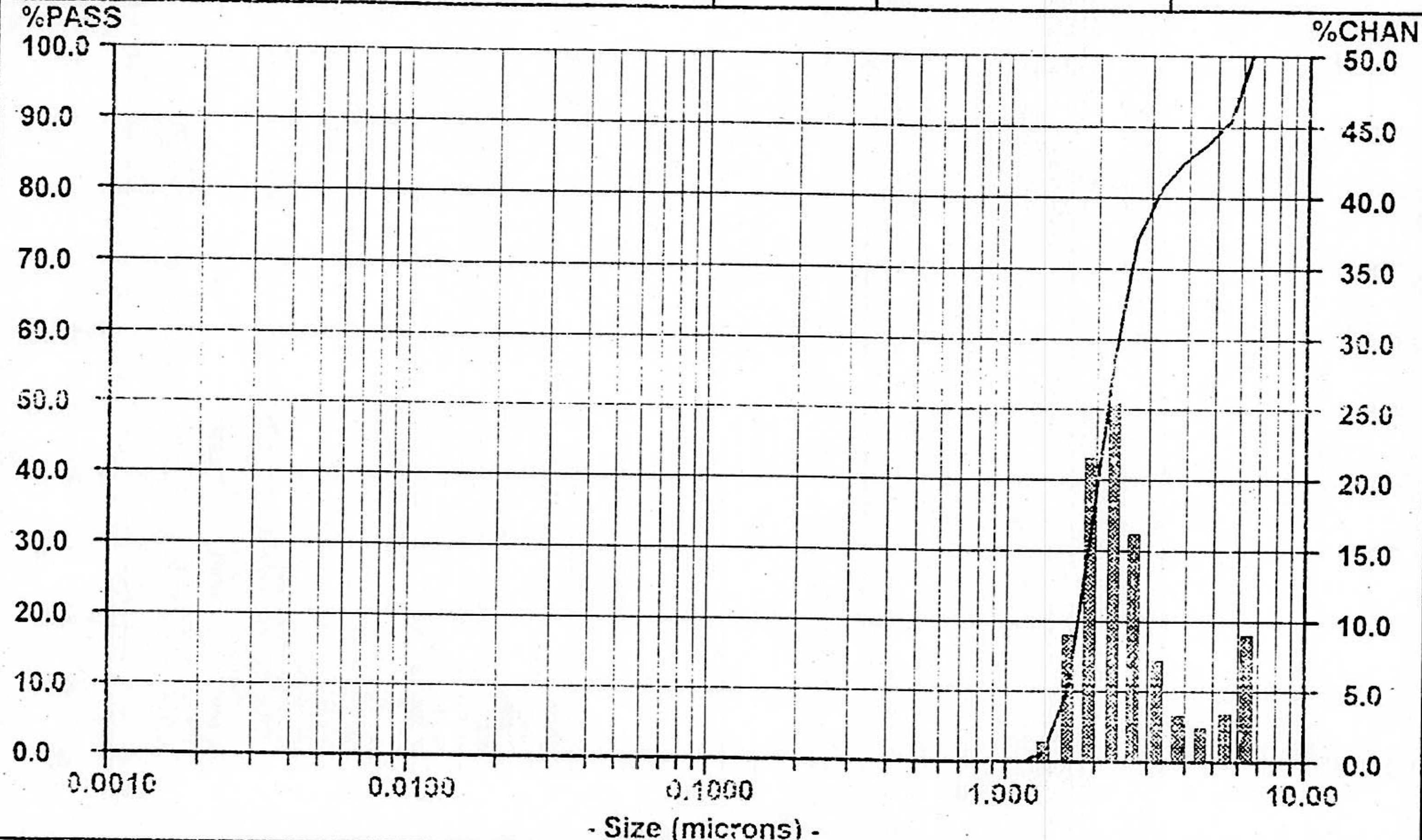
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	19.09	0.0859	0.00	0.00						
5.500	80.91	13.22	0.0723	0.00	0.00						
4.625	67.69	9.79	0.0608	0.00	0.00						
3.889	57.90	7.75	0.0511	0.00	0.00						
3.270	50.15	6.52	0.0430	0.00	0.00						
2.750	43.63	5.70	0.0361	0.00	0.00						
2.313	37.93	5.05	0.0304	0.00	0.00						
1.945	32.88	4.47	0.0255	0.00	0.00						
1.635	28.41	3.92	0.0215	0.00	0.00						
1.375	24.49	3.44	0.0181	0.00	0.00						
1.156	21.05	3.05	0.0152	0.00	0.00						
0.9723	18.00	2.78	0.0128	0.00	0.00						
0.8176	15.22	2.53	0.0107	0.00	0.00						
0.6875	12.64	2.40	0.0090	0.00	0.00						
0.5781	10.24	2.21	0.0076	0.00	0.00						
0.4861	8.03	2.00	0.0064	0.00	0.00						
0.4088	6.03	1.80	0.0054	0.00	0.00						
0.3437	4.23	1.72	0.0045	0.00	0.00						
0.2891	2.51	1.58	0.0038	0.00	0.00						
0.2431	0.93	0.93									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD
~~Duplicate Sample~~

Date: 04/09/99 Time: 15:52 Meas #: N/A Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 2.665	10% = 1.624	60% = 2.358	5.664	15%	1.603
mn = 1.908	20% = 1.781	70% = 2.604	2.081	85%	.9619
ma = 2.269	30% = 1.916	80% = 3.115			
cs = 2.645	40% = 2.048	90% = 5.333			
sd = .9739	50% = 2.188	95% = 5.920			



SIZE	%PASS	%CHAN
6.541	100.00	9.02
5.500	90.98	3.50
4.625	87.48	2.53
3.889	84.95	3.46
3.270	81.49	7.38
2.750	74.11	16.39
2.313	57.72	25.54
1.946	32.18	21.64
1.635	10.54	9.02
1.375	1.52	1.52
1.156	0.00	0.00
0.9723	0.00	0.00
0.8176	0.00	0.00
0.6875	0.00	0.00
0.5781	0.00	0.00
0.4861	0.00	0.00
0.4088	0.00	0.00
0.3437	0.00	0.00
0.2891	0.00	0.00
0.2431	0.00	0.00
0.2044	0.00	0.00
0.1719	0.00	0.00
0.1445	0.00	0.00
0.1215	0.00	0.00
0.1022	0.00	0.00

SIZE	%PASS	%CHAN
0.0859	0.00	0.00
0.0723	0.00	0.00
0.0608	0.00	0.00
0.0511	0.00	0.00
0.0430	0.00	0.00
0.0361	0.00	0.00
0.0304	0.00	0.00
0.0255	0.00	0.00
0.0215	0.00	0.00
0.0181	0.00	0.00
0.0152	0.00	0.00
0.0128	0.00	0.00
0.0107	0.00	0.00
0.0090	0.00	0.00
0.0076	0.00	0.00
0.0064	0.00	0.00
0.0054	0.00	0.00
0.0045	0.00	0.00
0.0038	0.00	0.00

SIZE	%PASS	%CHAN

SIZE	%PASS	%CHAN

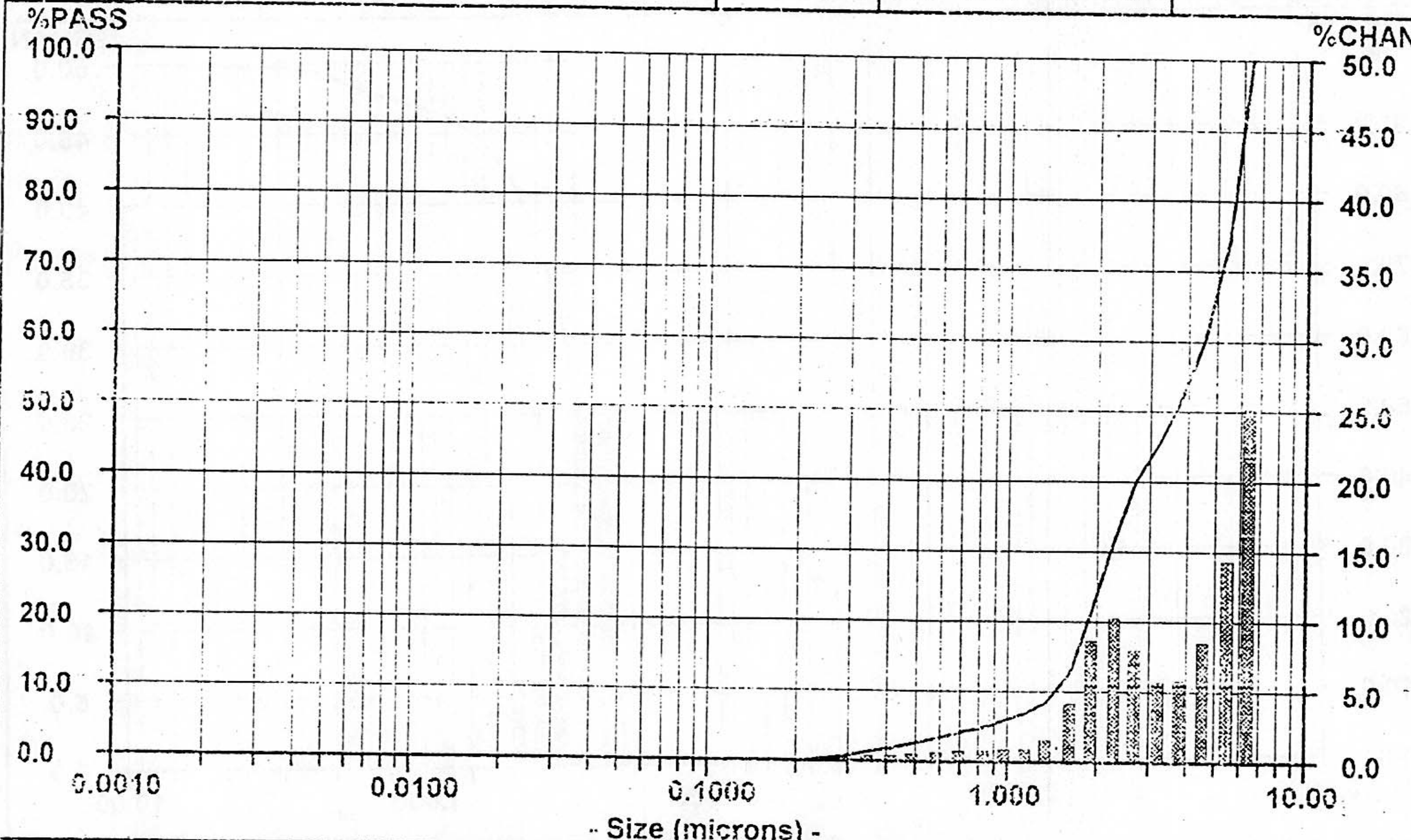
Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD
~~Duplicate Sample~~

Date: 04/09/99 Time: 15:52
Meas #: 00146 Pres #: 01

Summary	Percentiles		Dia	Vol%	Width
mv = 3.701	10% = 1.475	60% = 4.597	5.272	60%	2.397
mn = .4255	20% = 1.888	70% = 5.270	1.890	40%	1.341
ma = 2.280	30% = 2.233	80% = 5.692			
cs = 2.632	40% = 2.743	90% = 6.051			
sd = 2.042	50% = 3.704	95% = 6.247			

AVERAGE



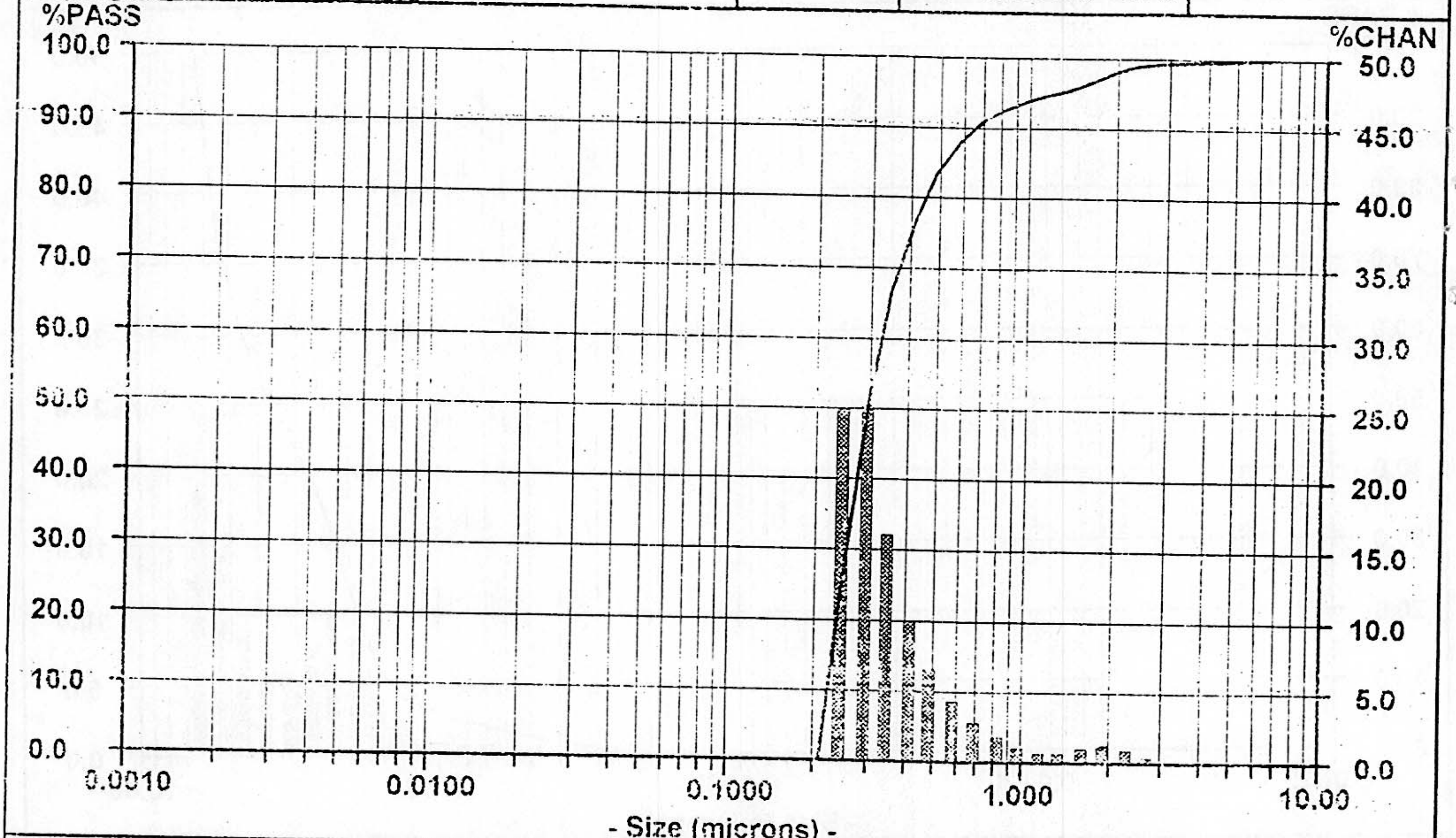
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	25.21	0.0859	0.00	0.00						
5.500	74.79	14.43	0.0723	0.00	0.00						
4.625	60.36	8.55	0.0608	0.00	0.00						
3.889	51.81	5.92	0.0511	0.00	0.00						
3.270	45.89	5.79	0.0430	0.00	0.00						
2.750	40.10	8.09	0.0361	0.00	0.00						
2.313	32.01	10.32	0.0304	0.00	0.00						
1.946	21.69	8.70	0.0255	0.00	0.00						
1.635	12.99	4.31	0.0215	0.00	0.00						
1.375	8.68	1.65	0.0181	0.00	0.00						
1.156	7.03	1.02	0.0152	0.00	0.00						
0.9723	6.01	0.93	0.0128	0.00	0.00						
0.8176	5.08	0.86	0.0107	0.00	0.00						
0.6875	4.22	0.80	0.0090	0.00	0.00						
0.5781	3.42	0.74	0.0076	0.00	0.00						
0.4861	2.68	0.67	0.0064	0.00	0.00						
0.4088	2.01	0.60	0.0054	0.00	0.00						
0.3437	1.41	0.57	0.0045	0.00	0.00						
0.2891	0.84	0.53	0.0038	0.00	0.00						
0.2431	0.31	0.31									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD Date: 04/09/99 Meas #: 00146
~~Duplicate Sample~~ Time: 15:52 Pres #: 01

Summary	Percentiles		Dia	Vol%	Width
mv = 3.701	10% = .2222	60% = .3165	1.798	5%	1.071
mn = .4255	20% = .2361	70% = .3607	.2824	95%	.2051
ma = 2.280	30% = .2507	80% = .4392			
cs = 2.632	40% = .2678	90% = .6434			
sd = .1306	50% = .2881	95% = 1.243			

AVERAGE
NUMBER DISTRIBUTION



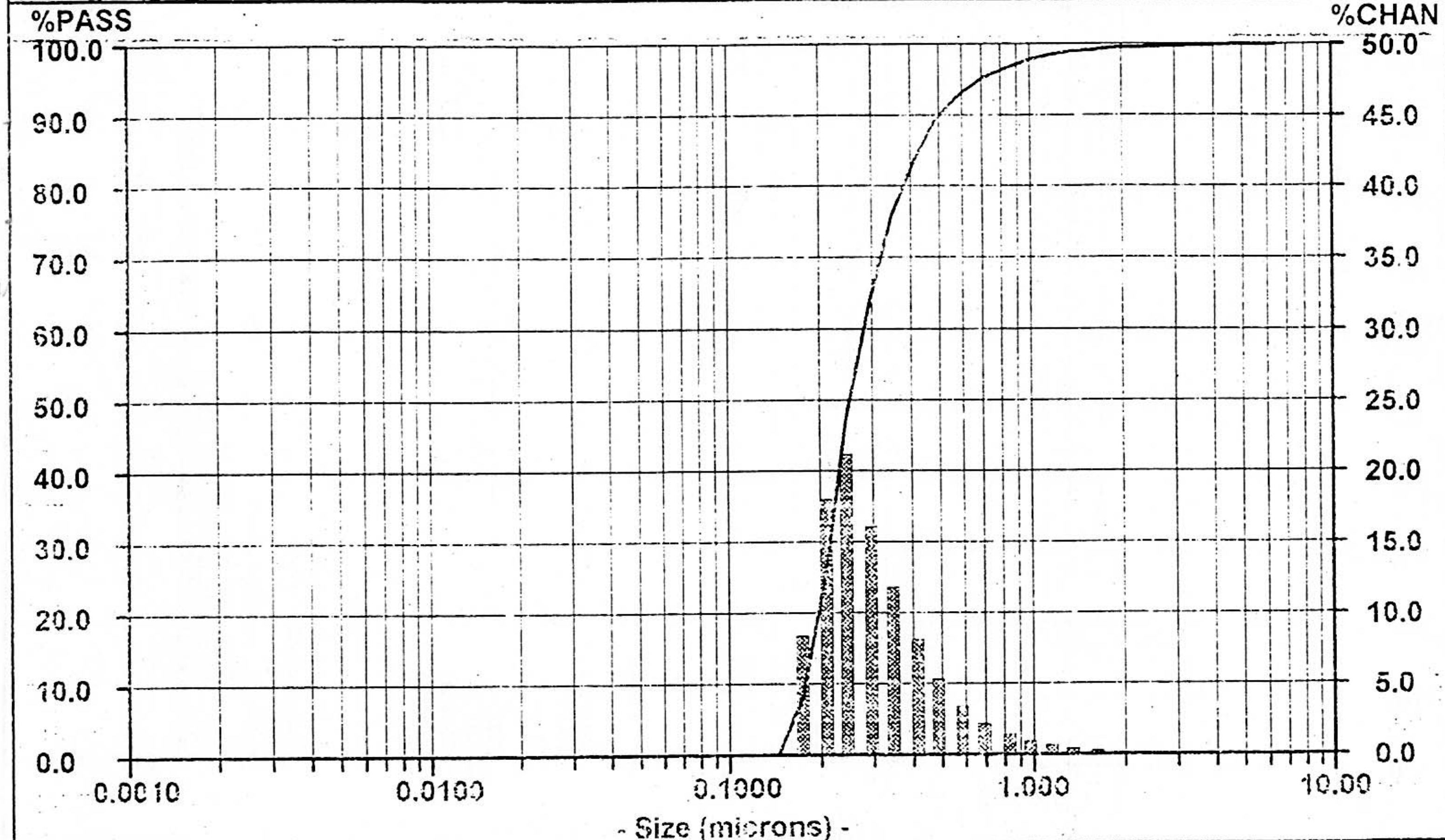
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.10	0.0859	0.00	0.00						
5.500	99.90	0.10	0.0723	0.00	0.00						
4.625	99.80	0.10	0.0608	0.00	0.00						
3.889	99.70	0.12	0.0511	0.00	0.00						
3.270	99.58	0.19	0.0430	0.00	0.00						
2.750	99.39	0.45	0.0361	0.00	0.00						
2.313	98.94	0.97	0.0304	0.00	0.00						
1.945	97.97	1.37	0.0255	0.00	0.00						
1.635	96.60	1.14	0.0215	0.00	0.00						
1.375	95.46	0.74	0.0181	0.00	0.00						
1.156	94.72	0.76	0.0152	0.00	0.00						
0.9723	93.96	1.17	0.0128	0.00	0.00						
0.8176	92.79	1.82	0.0107	0.00	0.00						
0.6875	90.97	2.85	0.0090	0.00	0.00						
0.5781	88.12	4.44	0.0076	0.00	0.00						
0.4861	83.68	6.76	0.0064	0.00	0.00						
0.4088	76.92	10.18	0.0054	0.00	0.00						
0.3437	66.74	16.27	0.0045	0.00	0.00						
0.2891	50.47	25.45	0.0038	0.00	0.00						
0.2431	25.02	25.02									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-BD Date: 04/09/99 Meas #: 00147
Duplicate Sample Time: 16:02 Pres #: 01

Summary	Percentiles		Dia	Vol%	Width
mv = 3.608	10% = .1750	60% = .2757	.2483	100%	.2226
mn = .3239	20% = .1933	70% = .3137			
ma = 1.742	30% = .2102	80% = .3729			
cs = 3.444	40% = .2278	90% = .4978			
sd = .1113	50% = .2483	95% = .6760			

AVERAGE
NUMBER DISTRIBUTION



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.03	0.0859	0.00	0.00						
5.500	99.97	0.04	0.0723	0.00	0.00						
4.625	99.93	0.05	0.0608	0.00	0.00						
3.889	99.88	0.06	0.0511	0.00	0.00						
3.270	99.82	0.07	0.0430	0.00	0.00						
2.750	99.75	0.10	0.0361	0.00	0.00						
2.313	99.65	0.15	0.0304	0.00	0.00						
1.945	99.50	0.23	0.0255	0.00	0.00						
1.635	99.27	0.34	0.0215	0.00	0.00						
1.375	98.93	0.52	0.0181	0.00	0.00						
1.156	98.41	0.73	0.0152	0.00	0.00						
0.9723	97.68	1.00	0.0128	0.00	0.00						
0.8176	96.68	1.48	0.0107	0.00	0.00						
0.6876	95.20	2.23	0.0090	0.00	0.00						
0.5781	92.97	3.51	0.0076	0.00	0.00						
0.4861	89.46	5.45	0.0064	0.00	0.00						
0.4088	84.01	8.23	0.0054	0.00	0.00						
0.3437	75.78	11.83	0.0045	0.00	0.00						
0.2891	63.95	16.16	0.0038	0.00	0.00						
0.2431	47.79	21.24									
0.2044	26.55	18.10									
0.1719	8.45	8.45									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

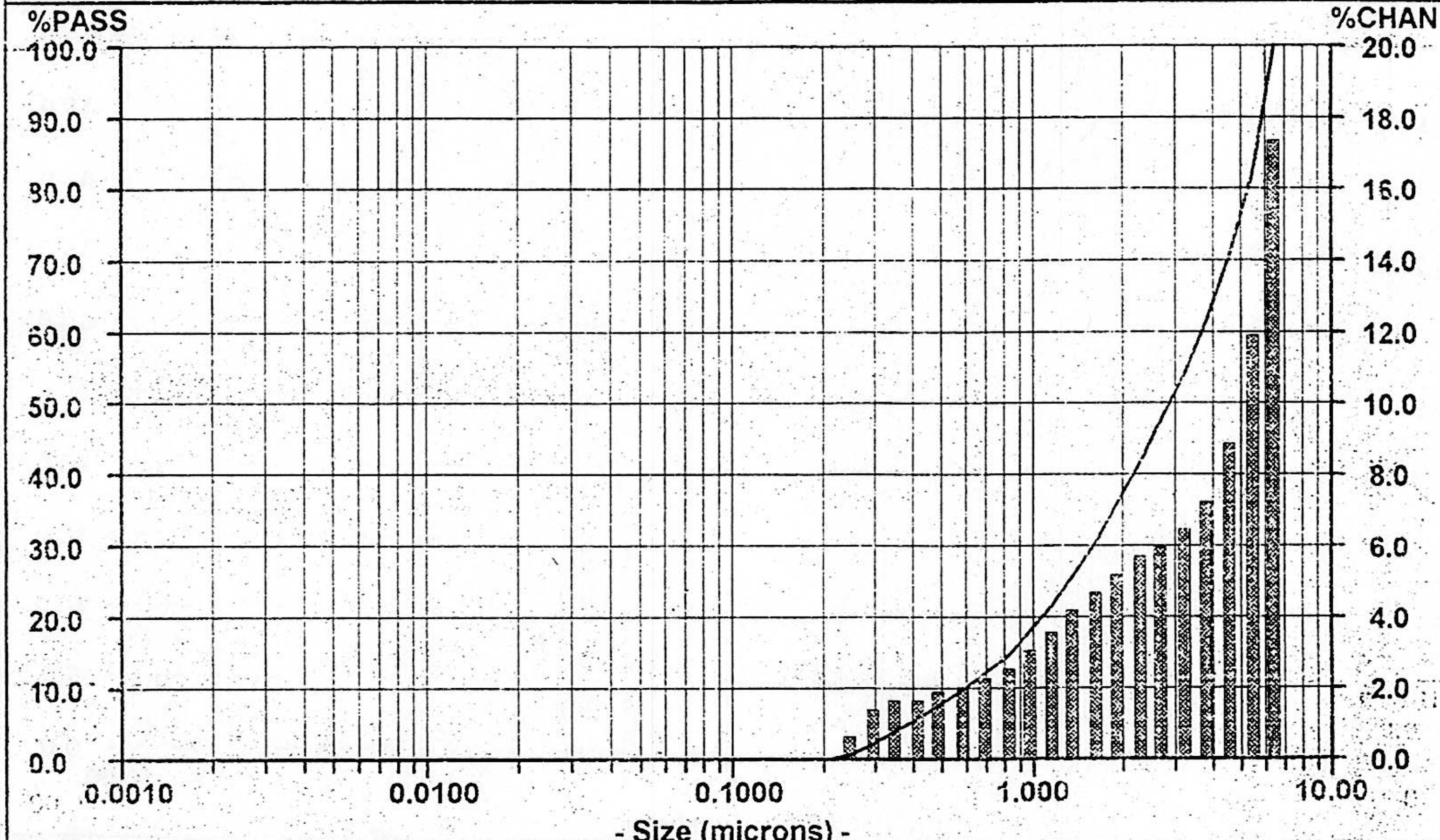
Particle Size Analysis

CUF AW-101-005

Date: 04/09/99 Meas #: N/A
Time: 15:01 Pres #: N/A

Simulant Supernatant

Summary	Percentiles		Dia	Vol%	Width
mv = 3.125	10% = .5854	60% = 3.750	3.086	96%	4.568
mn = .3729	20% = 1.073	70% = 4.575	.2820	4%	.0854
ma = 1.467	30% = 1.601	80% = 5.340			
cs = 4.090	40% = 2.203	90% = 5.884			
sd = 2.352	50% = 2.925	95% = 6.155			

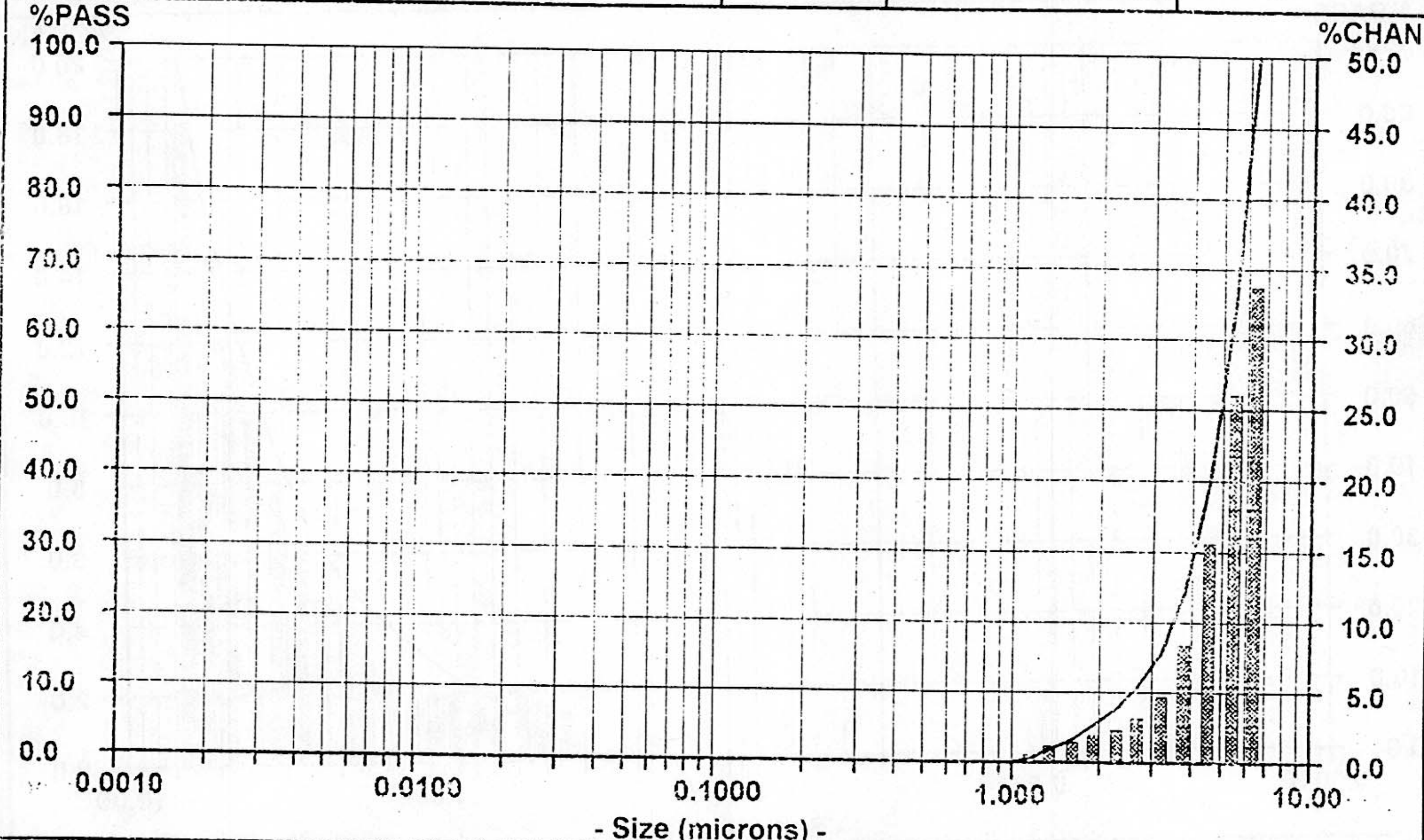


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	17.48	0.0859	0.00	0.00						
5.500	82.52	11.90	0.0723	0.00	0.00						
4.625	70.62	8.97	0.0608	0.00	0.00						
3.889	61.65	7.37	0.0511	0.00	0.00						
3.270	54.28	6.54	0.0430	0.00	0.00						
2.750	47.74	6.09	0.0361	0.00	0.00						
2.313	41.65	5.73	0.0304	0.00	0.00						
1.945	35.92	5.30	0.0256	0.00	0.00						
1.635	30.62	4.78	0.0215	0.00	0.00						
1.375	25.84	4.20	0.0181	0.00	0.00						
1.156	21.64	3.63	0.0152	0.00	0.00						
0.9723	18.01	3.12	0.0128	0.00	0.00						
0.8176	14.89	2.69	0.0107	0.00	0.00						
0.6875	12.20	2.36	0.0090	0.00	0.00						
0.5781	9.84	2.12	0.0076	0.00	0.00						
0.4861	7.72	1.92	0.0064	0.00	0.00						
0.4088	5.80	1.76	0.0054	0.00	0.00						
0.3437	4.04	1.78	0.0045	0.00	0.00						
0.2891	2.26	1.47	0.0038	0.00	0.00						
0.2431	0.79	0.79									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1446	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-BD Date: 04/09/99 Meas #: N/A
Duplicate Sample Time: 16:00 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 4.679	10% = 2.615	60% = 5.314	4.986	100%	2.686
mn = 2.308	20% = 3.900	70% = 5.537			
ma = 4.060	30% = 4.186	80% = 5.857			
cs = 1.478	40% = 4.621	90% = 6.133			
sd = 1.343	50% = 4.986	95% = 6.303			

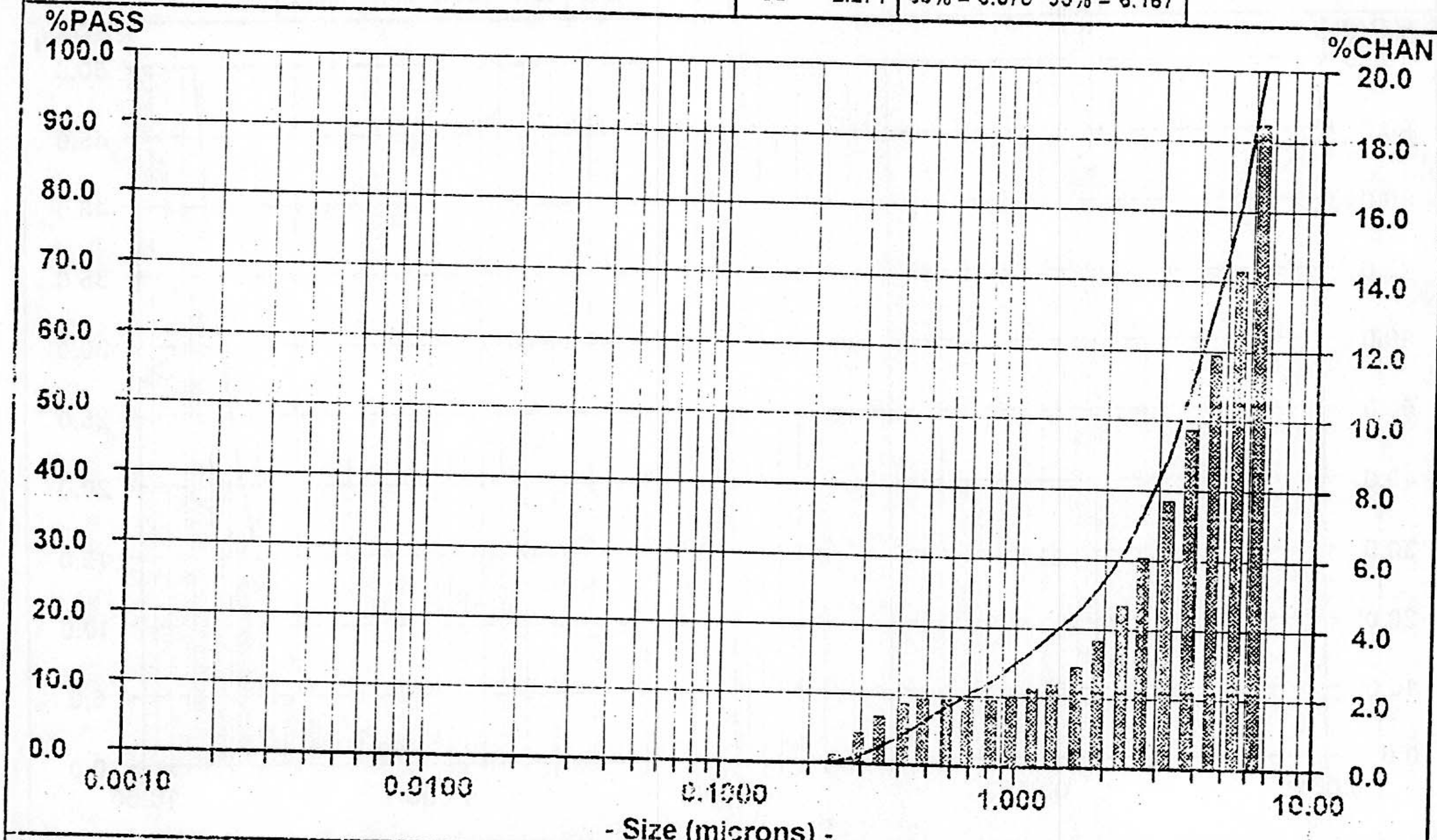


SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	33.73	0.0859	0.00	0.00						
5.600	66.27	26.17	0.0723	0.00	0.00						
4.625	40.10	15.69	0.0608	0.00	0.00						
3.889	24.41	8.49	0.0511	0.00	0.00						
3.270	15.92	4.87	0.0430	0.00	0.00						
2.750	11.05	3.22	0.0361	0.00	0.00						
2.313	7.83	2.42	0.0304	0.00	0.00						
1.945	5.41	1.93	0.0255	0.00	0.00						
1.635	3.48	1.54	0.0215	0.00	0.00						
1.375	1.94	1.28	0.0181	0.00	0.00						
1.156	0.66	0.66	0.0152	0.00	0.00						
0.9723	0.00	0.00	0.0128	0.00	0.00						
0.8175	0.00	0.00	0.0107	0.00	0.00						
0.6875	0.00	0.00	0.0090	0.00	0.00						
0.5781	0.00	0.00	0.0076	0.00	0.00						
0.4861	0.00	0.00	0.0064	0.00	0.00						
0.4088	0.00	0.00	0.0054	0.00	0.00						
0.3437	0.00	0.00	0.0045	0.00	0.00						
0.2891	0.00	0.00	0.0038	0.00	0.00						
0.2431	0.00	0.00									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD Date: 04/09/99 Meas #: N/A
Duplicate Sample Time: 16:01 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 3.449	10% = .6588	60% = 4.197	3.843	91%	3.999
mn = .4039	20% = 1.416	70% = 4.815	.4016	9%	.2206
ma = 1.726	30% = 2.232	80% = 5.420			
cs = 3.476	40% = 2.934	90% = 5.907			
sd = 2.271	50% = 3.578	95% = 6.167			



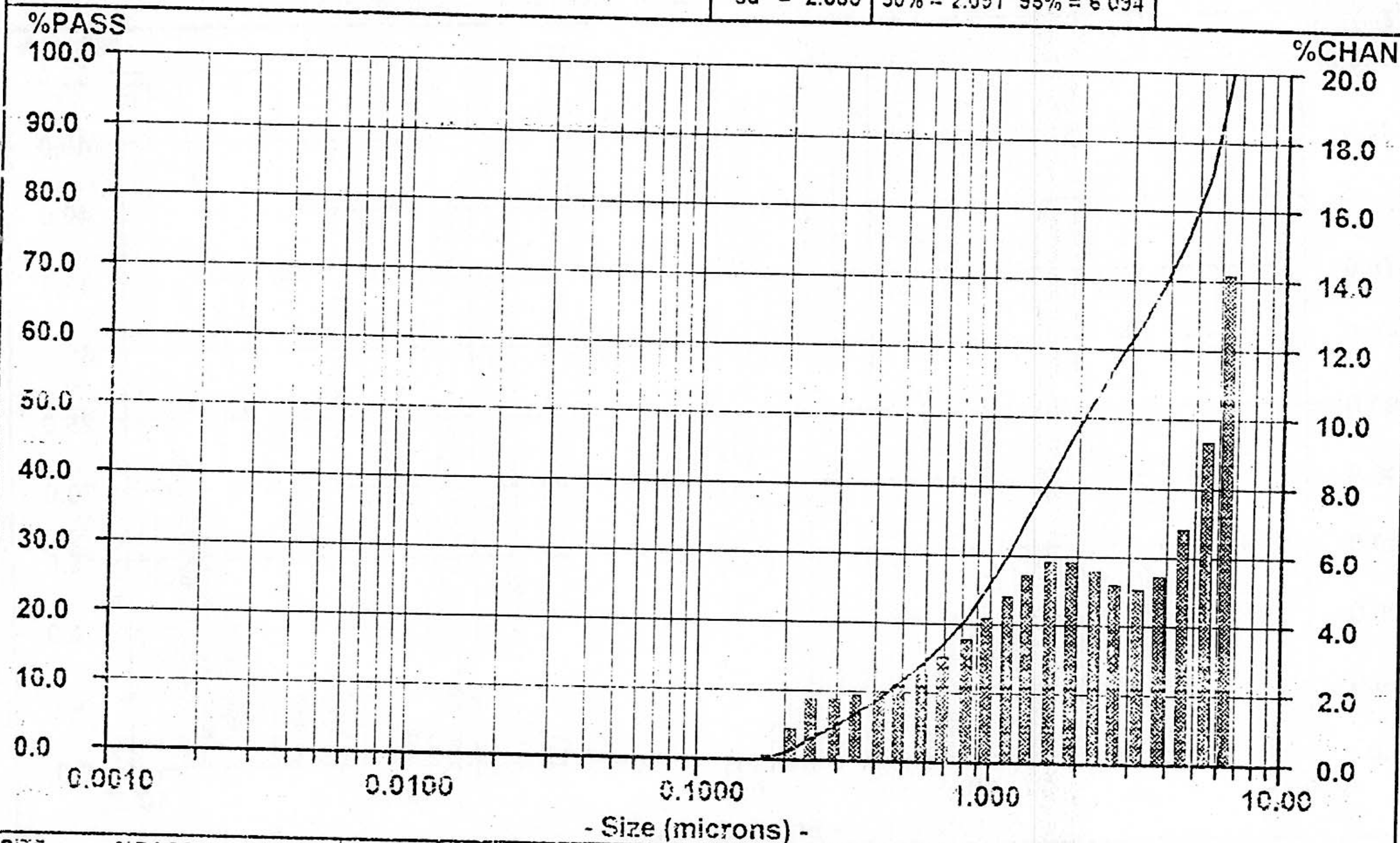
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	18.55	0.0859	0.00	0.00						
5.500	81.45	14.45	0.0723	0.00	0.00						
4.625	67.00	12.00	0.0608	0.00	0.00						
3.889	55.00	9.85	0.0511	0.00	0.00						
3.270	45.15	7.89	0.0430	0.00	0.00						
2.750	37.26	6.18	0.0361	0.00	0.00						
2.313	31.08	4.78	0.0304	0.00	0.00						
1.946	26.29	3.74	0.0255	0.00	0.00						
1.635	22.55	3.02	0.0215	0.00	0.00						
1.375	19.53	2.57	0.0181	0.00	0.00						
1.156	16.96	2.31	0.0152	0.00	0.00						
0.9723	14.65	2.15	0.0128	0.00	0.00						
0.8176	12.50	2.02	0.0107	0.00	0.00						
0.6875	10.48	1.96	0.0090	0.00	0.00						
0.5781	8.52	2.05	0.0076	0.00	0.00						
0.4861	6.47	2.01	0.0064	0.00	0.00						
0.4088	4.46	1.81	0.0054	0.00	0.00						
0.3437	2.66	1.42	0.0045	0.00	0.00						
0.2891	1.23	0.92	0.0038	0.00	0.00						
0.2431	0.31	0.31									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD
Duplicate Sample

Date: 04/09/99 Time: 16:02 Meas #: N/A Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 2.695	10% = .4375	60% = 2.893	4.944	41%	2.547
mn = .2885	20% = .7844	70% = 3.974	1.183	55%	1.563
ma = 1.113	30% = 1.150	80% = 5.018	.2092	4%	.0518
cs = 5.389	40% = 1.559	90% = 5.775			
sd = 2.365	50% = 2.091	95% = 6.094			



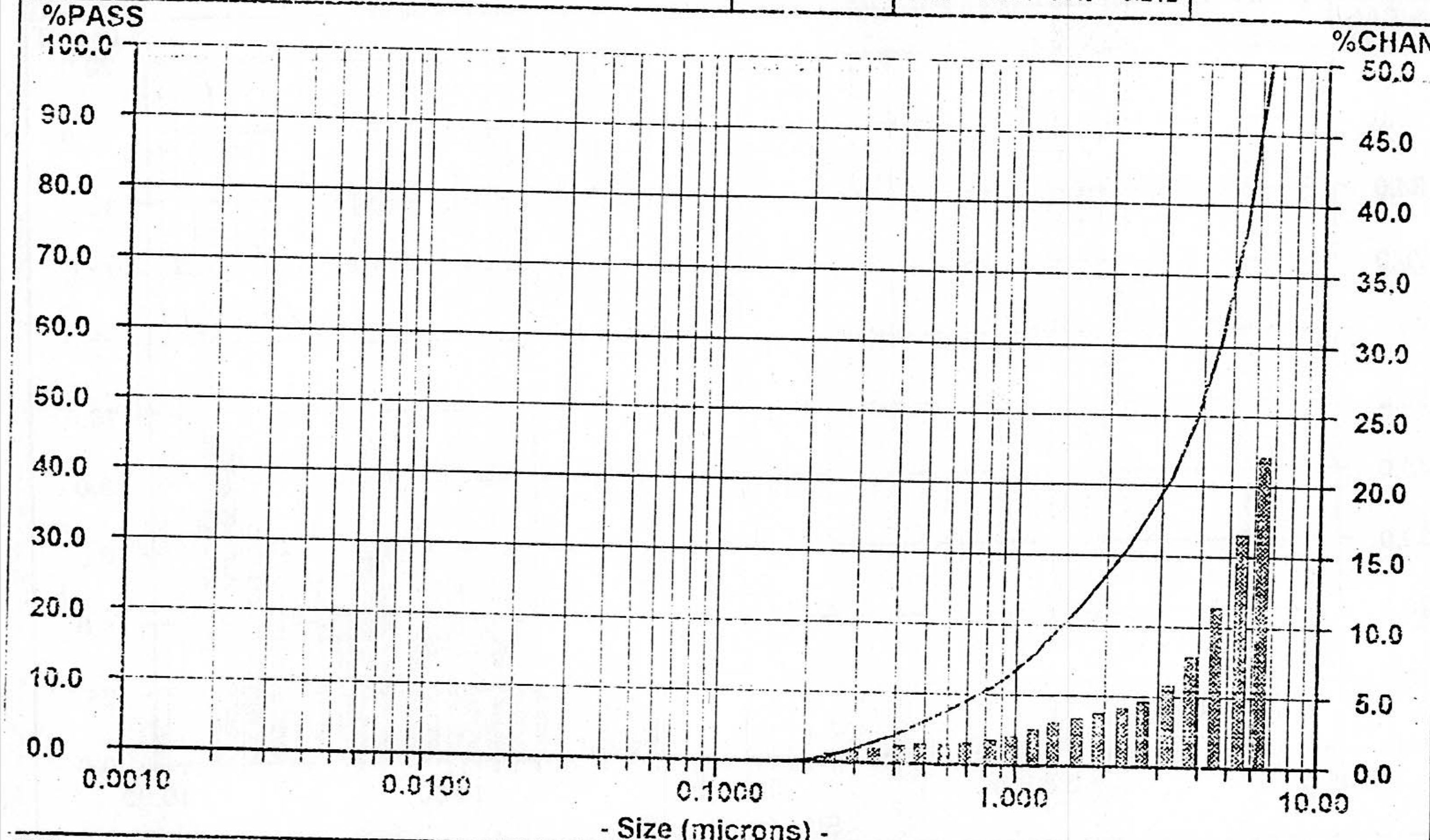
SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	14.37	0.0859	0.00	0.00						
5.500	85.63	9.48	0.0723	0.00	0.00						
4.625	76.15	6.92	0.0608	0.00	0.00						
3.889	69.23	5.59	0.0511	0.00	0.00						
3.270	63.64	5.13	0.0430	0.00	0.00						
2.750	58.51	5.26	0.0361	0.00	0.00						
2.313	53.25	6.25	0.0304	0.00	0.00						
1.945	47.00	5.35	0.0255	0.00	0.00						
1.635	41.65	5.93	0.0215	0.00	0.00						
1.375	35.72	5.55	0.0181	0.00	0.00						
1.156	30.17	4.95	0.0152	0.00	0.00						
0.9723	25.22	4.29	0.0128	0.00	0.00						
0.8176	20.93	3.66	0.0107	0.00	0.00						
0.6876	17.27	3.12	0.0090	0.00	0.00						
0.5781	14.15	2.68	0.0076	0.00	0.00						
0.4861	11.47	2.36	0.0064	0.00	0.00						
0.4088	9.11	2.13	0.0054	0.00	0.00						
0.3437	6.98	1.94	0.0045	0.00	0.00						
0.2891	5.04	1.82	0.0038	0.00	0.00						
0.2431	3.22	1.83									
0.2044	1.39	1.09									
0.1719	0.30	0.30									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

~~CUF AW-101-005~~ AW-101-PSD Date: 04/09/99 Meas #: 00147
Duplicate Sample Time: 16:02 Pres #: 01

AVERAGE

Summary	Percentiles		Dia	Vol%	Width
mv = 3.608	10% = .7389	60% = 4.561	3.921	100%	4.585
mn = .3239	20% = 1.444	70% = 5.122			
ma = 1.742	30% = 2.250	80% = 5.588			
cs = 3.444	40% = 3.138	90% = 5.987			
sd = 2.293	50% = 3.921	95% = 6.212			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	22.22	0.0859	0.00	0.00						
5.500	77.78	16.70	0.0723	0.00	0.00						
4.625	61.08	11.54	0.0608	0.00	0.00						
3.889	49.54	7.98	0.0511	0.00	0.00						
3.270	41.56	5.96	0.0430	0.00	0.00						
2.750	35.60	4.89	0.0361	0.00	0.00						
2.313	30.71	4.29	0.0304	0.00	0.00						
1.945	26.42	3.87	0.0255	0.00	0.00						
1.635	22.55	3.50	0.0215	0.00	0.00						
1.375	19.05	3.13	0.0181	0.00	0.00						
1.156	15.92	2.64	0.0152	0.00	0.00						
0.9723	13.28	2.15	0.0128	0.00	0.00						
0.8176	11.13	1.89	0.0107	0.00	0.00						
0.6875	9.24	1.69	0.0090	0.00	0.00						
0.5781	7.55	1.58	0.0076	0.00	0.00						
0.4861	5.97	1.46	0.0064	0.00	0.00						
0.4088	4.51	1.31	0.0054	0.00	0.00						
0.3437	3.20	1.12	0.0045	0.00	0.00						
0.2891	2.08	0.91	0.0038	0.00	0.00						
0.2431	1.17	0.71									
0.2044	0.46	0.36									
0.1719	0.10	0.10									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

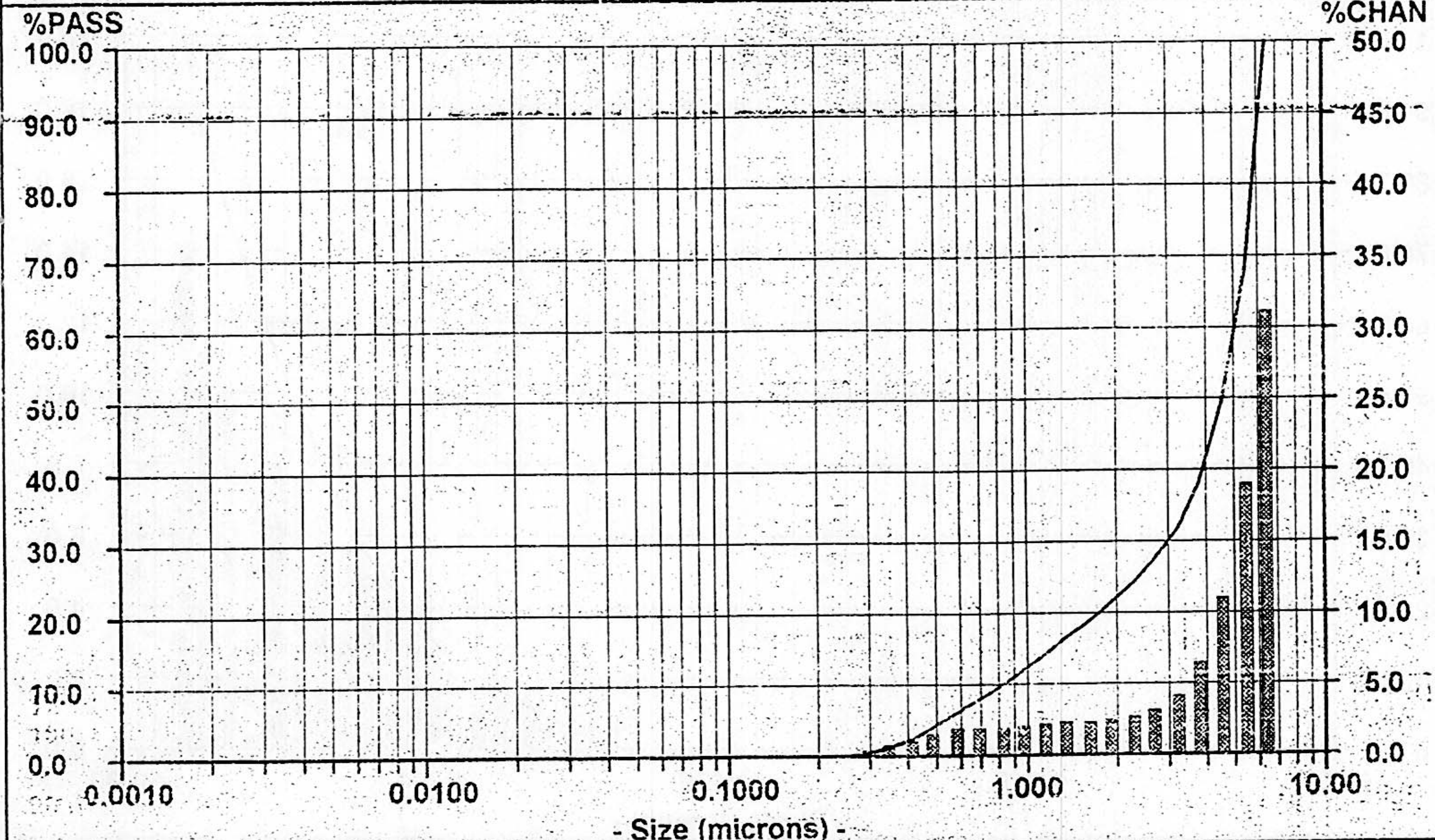
Particle Size Analysis

CUF AW-101-005

Date: 04/09/99 Meas #: N/A
Time: 15:02 Pres #: N/A

Simulant Supernatant

Summary	Percentiles		Dia	Vol%	Width
mv = 4.032	10% = .8162	60% = 5.157	4.820	94%	4.079
mn = .4627	20% = 1.748	70% = 5.538	.4322	6%	.2121
ma = 2.102	30% = 3.058	80% = 5.828			
cs = 2.855	40% = 4.012	90% = 6.125			
sd = 2.317	50% = 4.650	95% = 6.294			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	31.29	0.0859	0.00	0.00						
5.500	68.71	19.17	0.0723	0.00	0.00						
4.625	49.54	11.14	0.0608	0.00	0.00						
3.889	38.40	6.56	0.0511	0.00	0.00						
3.270	31.84	4.30	0.0430	0.00	0.00						
2.750	27.54	3.24	0.0361	0.00	0.00						
2.313	24.30	2.74	0.0304	0.00	0.00						
1.945	21.56	2.50	0.0255	0.00	0.00						
1.635	19.06	2.38	0.0215	0.00	0.00						
1.375	16.68	2.30	0.0181	0.00	0.00						
1.156	14.38	2.23	0.0152	0.00	0.00						
0.9723	12.15	2.13	0.0128	0.00	0.00						
0.8176	10.02	1.99	0.0107	0.00	0.00						
0.6875	8.03	1.91	0.0090	0.00	0.00						
0.5781	6.12	1.93	0.0076	0.00	0.00						
0.4861	4.19	1.60	0.0064	0.00	0.00						
0.4088	2.59	1.19	0.0054	0.00	0.00						
0.3437	1.40	0.86	0.0045	0.00	0.00						
0.2891	0.54	0.54	0.0038	0.00	0.00						
0.2431	0.00	0.00									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

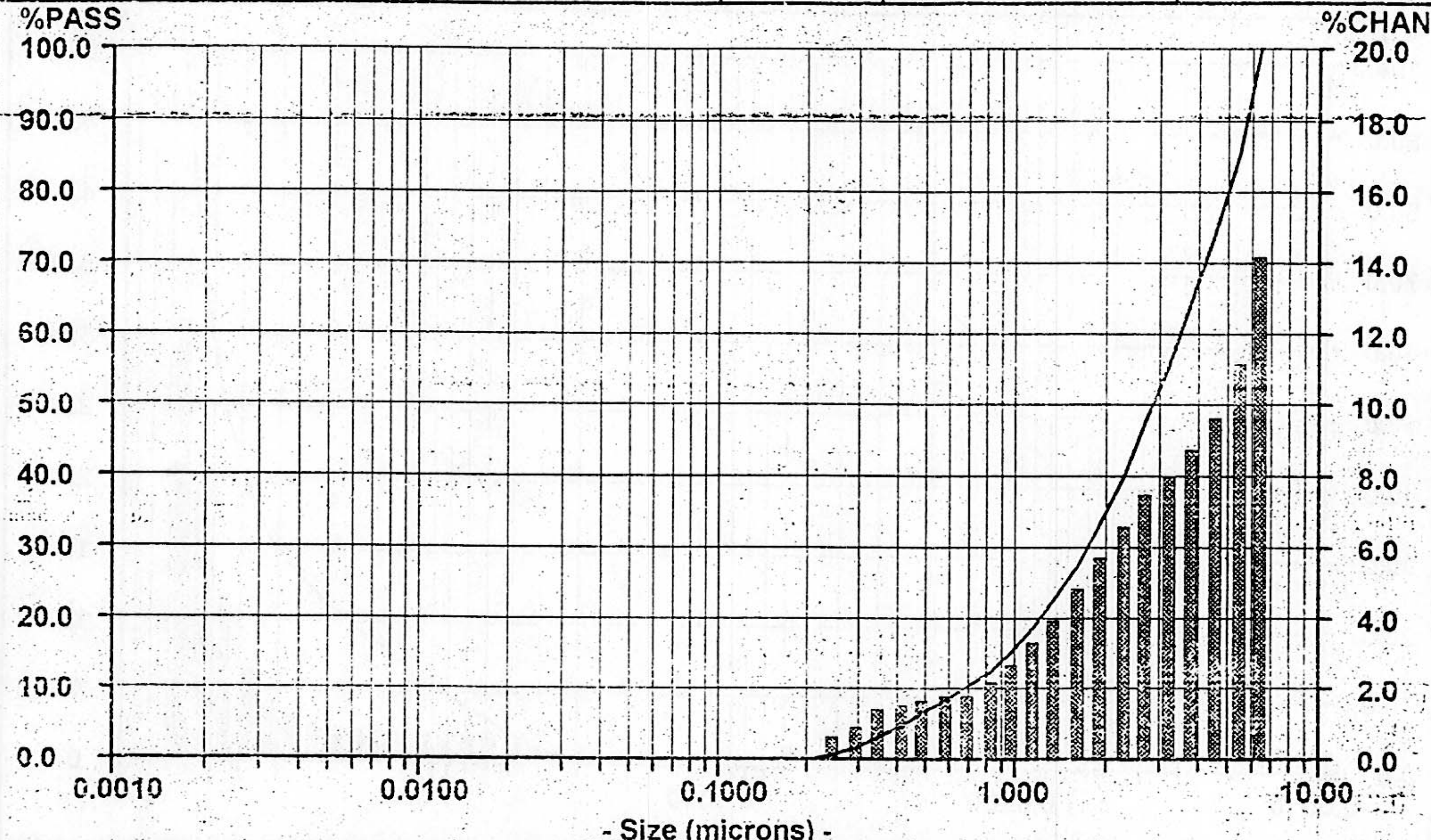
Particle Size Analysis

CUF AW-101-005

Date: 04/09/99 Meas #: N/A
Time: 15:03 Pres #: N/A

Simulant Supernatant

Summary	Percentiles		Dia	Vol%	Width
mv = 3.085	10% = .6690	60% = 3.558	2.894	100%	4.363
mn = .3833	20% = 1.233	70% = 4.288			
ma = 1.571	30% = 1.762	80% = 5.073			
cs = 3.820	40% = 2.304	90% = 5.764			
sd = 2.181	50% = 2.894	95% = 6.085			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	14.29	0.0859	0.00	0.00
5.500	85.71	11.29	0.0723	0.00	0.00
4.625	74.42	9.79	0.0608	0.00	0.00
3.889	64.63	8.82	0.0511	0.00	0.00
3.270	55.81	8.15	0.0430	0.00	0.00
2.750	47.66	7.51	0.0361	0.00	0.00
2.313	40.15	6.73	0.0304	0.00	0.00
1.945	33.42	5.83	0.0255	0.00	0.00
1.635	27.59	4.92	0.0215	0.00	0.00
1.375	22.67	4.09	0.0181	0.00	0.00
1.156	18.58	3.34	0.0152	0.00	0.00
0.9723	15.24	2.71	0.0128	0.00	0.00
0.8176	12.53	2.22	0.0107	0.00	0.00
0.6875	10.31	1.87	0.0090	0.00	0.00
0.5781	8.44	1.82	0.0076	0.00	0.00
0.4861	6.62	1.79	0.0064	0.00	0.00
0.4088	4.83	1.62	0.0054	0.00	0.00
0.3437	3.21	1.41	0.0045	0.00	0.00
0.2891	1.80	1.08	0.0038	0.00	0.00
0.2431	0.72	0.72			
0.2044	0.00	0.00			
0.1719	0.00	0.00			
0.1445	0.00	0.00			
0.1215	0.00	0.00			
0.1022	0.00	0.00			

Particle Size Analysis

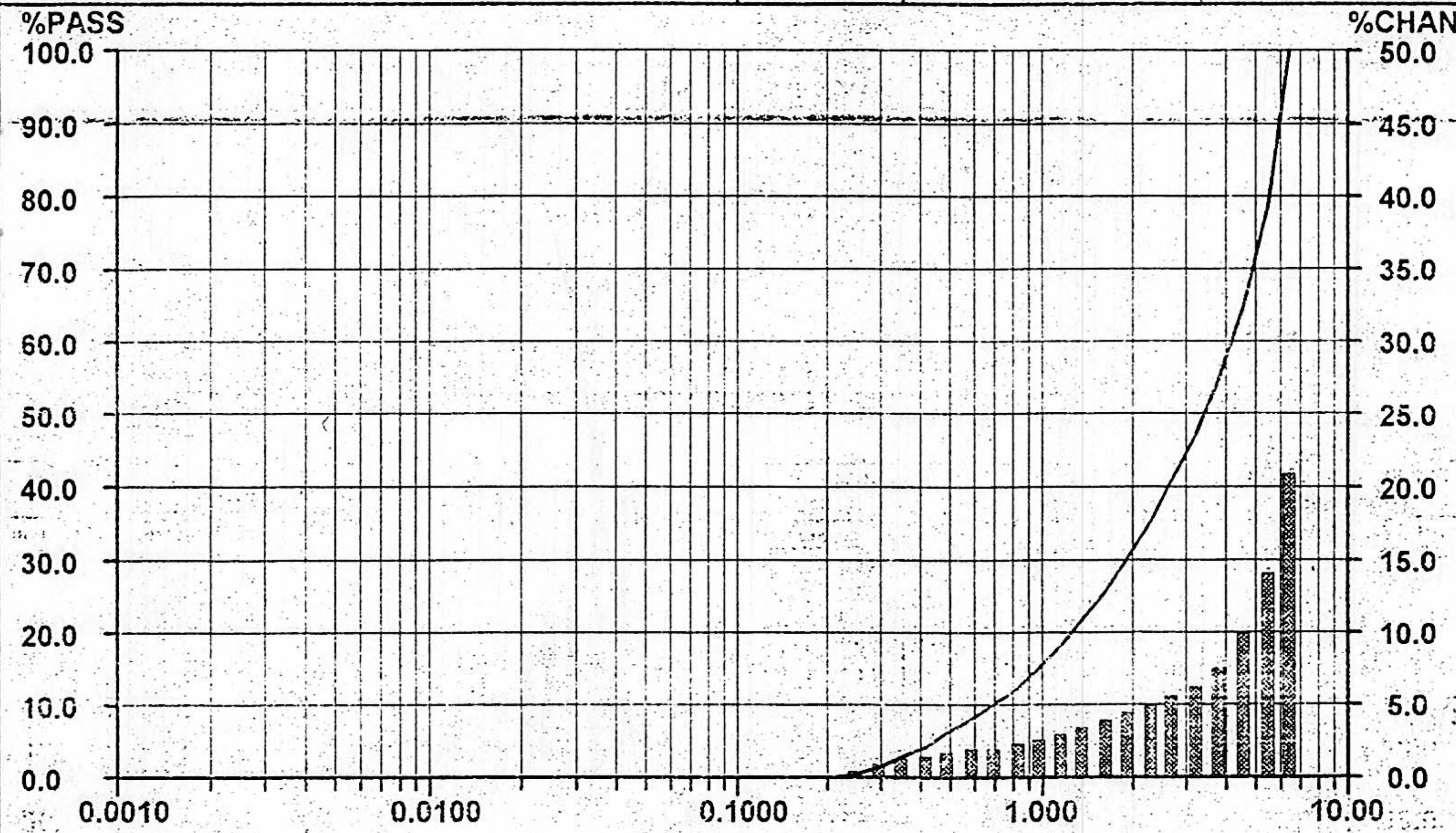
CUF AW-101-005

Date: 04/09/99 Meas #: 00143
Time: 15:03 Pres #: 01

Simulant Supernatant

AVERAGE

Summary	Percentiles		Dia	Vol%	Width
mv = 3.414	10% = .6776	60% = 4.278	3.493	100%	4.692
mn = .3943	20% = 1.267	70% = 4.978			
ma = 1.673	30% = 1.924	80% = 5.544			
cs = 3.587	40% = 2.672	90% = 5.970			
sd = 2.349	50% = 3.493	95% = 6.203			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	21.02	0.0859	0.00	0.00						
5.500	78.98	14.12	0.0723	0.00	0.00						
4.625	64.86	9.97	0.0608	0.00	0.00						
3.889	54.89	7.58	0.0511	0.00	0.00						
3.270	47.31	6.33	0.0430	0.00	0.00						
2.750	40.98	5.61	0.0361	0.00	0.00						
2.313	35.37	5.07	0.0304	0.00	0.00						
1.945	30.30	4.54	0.0255	0.00	0.00						
1.635	25.76	4.03	0.0215	0.00	0.00						
1.375	21.73	3.53	0.0181	0.00	0.00						
1.156	18.20	3.07	0.0152	0.00	0.00						
0.9723	15.13	2.65	0.0128	0.00	0.00						
0.8176	12.48	2.30	0.0107	0.00	0.00						
0.6875	10.18	2.05	0.0090	0.00	0.00						
0.5781	8.13	1.96	0.0076	0.00	0.00						
0.4861	6.17	1.77	0.0064	0.00	0.00						
0.4088	4.40	1.52	0.0054	0.00	0.00						
0.3437	2.88	1.35	0.0045	0.00	0.00						
0.2891	1.53	1.03	0.0038	0.00	0.00						
0.2431	0.50	0.50									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

Particle Size Analysis

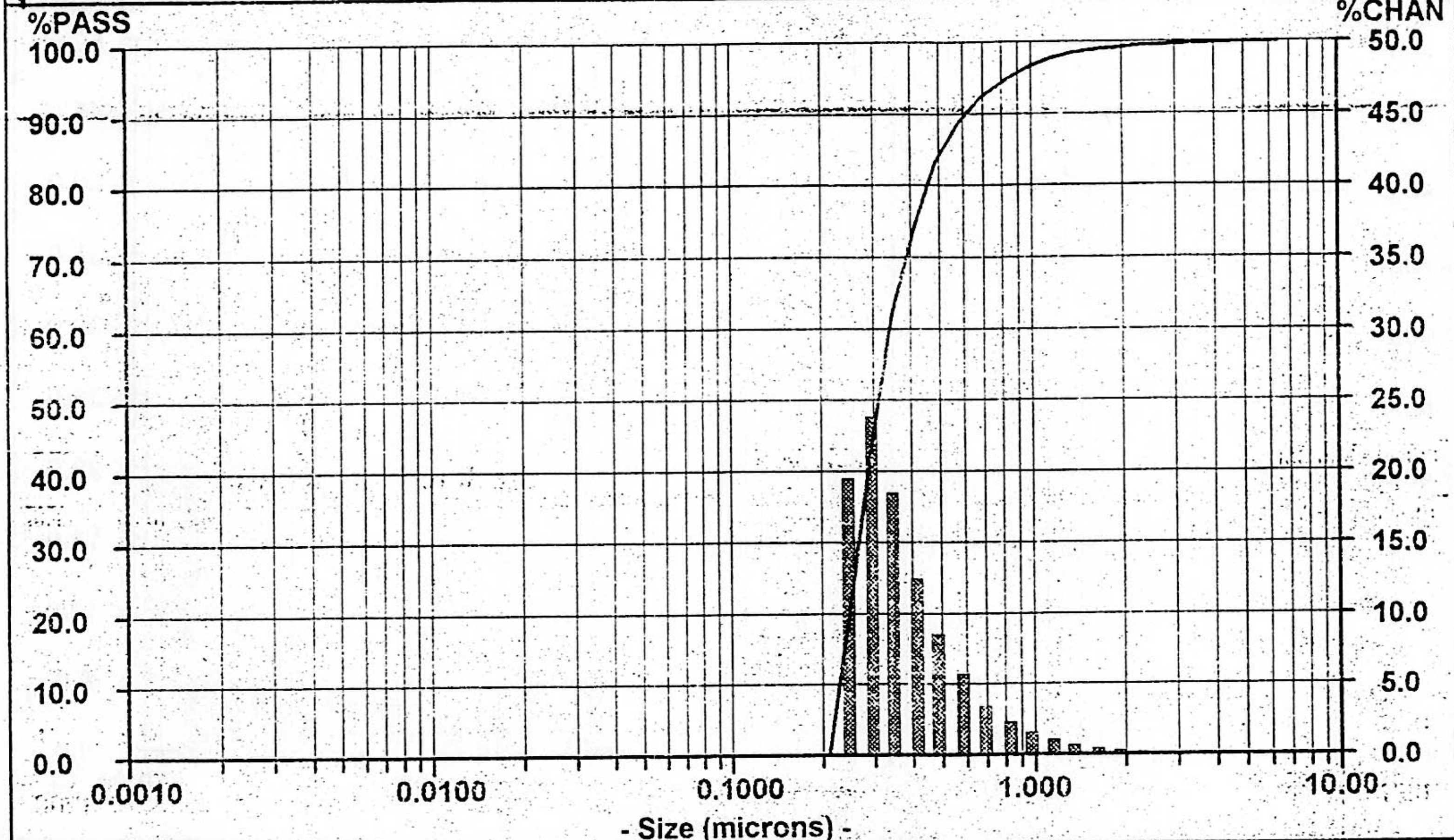
CUF AW-101-005

Date: 04/09/99 Meas #: 00143
Time: 15:03 Pres #: 01

Simulant Supernatant

Average
Number Distribution

Summary	Percentiles		Dia	Vol%	Width
mv = 3.414	10% = .2266	60% = .3359	.3052	100%	.2577
mn = .3943	20% = .2439	70% = .3802			
ma = 1.673	30% = .2619	80% = .4515			
cs = 3.587	40% = .2816	90% = .6019			
sd = .1289	50% = .3052	95% = .8227			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.04	0.0859	0.00	0.00						
5.500	99.96	0.05	0.0723	0.00	0.00						
4.625	99.91	0.06	0.0608	0.00	0.00						
3.889	99.85	0.07	0.0511	0.00	0.00						
3.270	99.78	0.10	0.0430	0.00	0.00						
2.750	99.68	0.15	0.0361	0.00	0.00						
2.313	99.53	0.23	0.0304	0.00	0.00						
1.945	99.30	0.35	0.0255	0.00	0.00						
1.635	98.95	0.52	0.0215	0.00	0.00						
1.375	98.43	0.76	0.0181	0.00	0.00						
1.156	97.67	1.12	0.0152	0.00	0.00						
0.9723	96.55	1.62	0.0128	0.00	0.00						
0.8176	94.93	2.36	0.0107	0.00	0.00						
0.6875	92.57	3.54	0.0090	0.00	0.00						
0.5781	89.03	5.70	0.0076	0.00	0.00						
0.4861	83.33	8.65	0.0064	0.00	0.00						
0.4088	74.68	12.50	0.0054	0.00	0.00						
0.3437	62.18	18.67	0.0045	0.00	0.00						
0.2891	43.51	23.95	0.0038	0.00	0.00						
0.2431	19.56	19.56									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

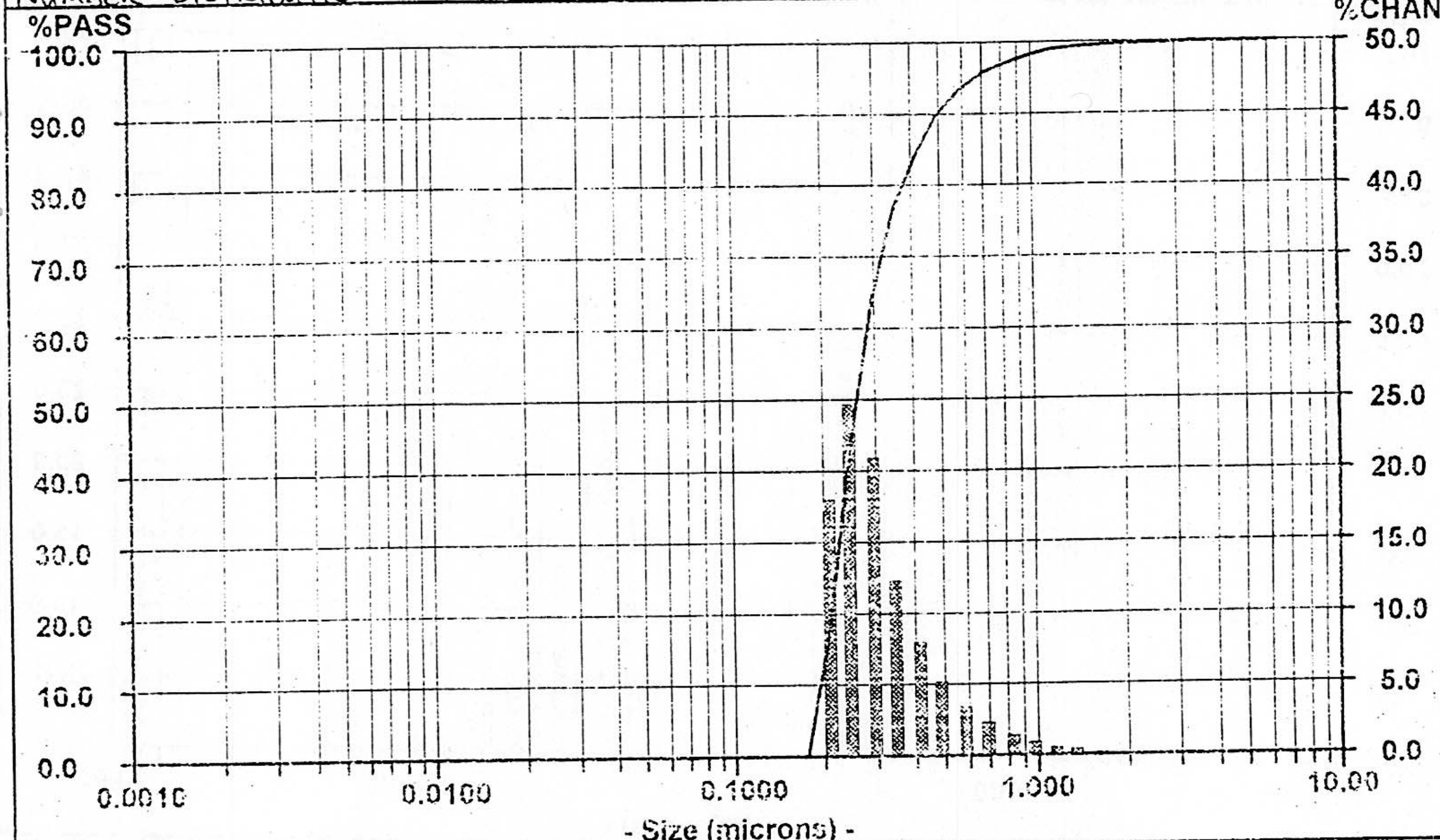
Particle Size Analysis

CUF AW-101-005
Duplicate Sample

Date: 04/09/99 Meas #: N/A
Time: 15:41 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 2.883	10% = .1919	60% = .2779	.2553	100%	.2026
mn = .3194	20% = .2071	70% = .3107			
ma = 1.178	30% = .2221	80% = .3684			
cs = 5.094	40% = .2380	90% = .4839			
sd = .1013	50% = .2559	95% = .6446			

NUMBER DISTRIBUTION



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.01	0.0859	0.00	0.00						
5.500	99.99	0.02	0.0723	0.00	0.00						
4.625	99.97	0.02	0.0608	0.00	0.00						
3.889	99.95	0.03	0.0511	0.00	0.00						
3.270	99.92	0.04	0.0430	0.00	0.00						
2.750	99.88	0.06	0.0361	0.00	0.00						
2.313	99.82	0.09	0.0304	0.00	0.00						
1.945	99.73	0.15	0.0255	0.00	0.00						
1.635	99.58	0.24	0.0215	0.00	0.00						
1.375	99.34	0.40	0.0181	0.00	0.00						
1.150	98.94	0.64	0.0152	0.00	0.00						
0.9723	98.30	1.00	0.0128	0.00	0.00						
0.8176	97.30	1.54	0.0107	0.00	0.00						
0.6875	95.76	2.35	0.0090	0.00	0.00						
0.5781	93.41	3.55	0.0076	0.00	0.00						
0.4861	89.86	5.36	0.0064	0.00	0.00						
0.4088	84.50	8.09	0.0054	0.00	0.00						
0.3437	76.41	12.33	0.0045	0.00	0.00						
0.2891	64.08	21.02	0.0038	0.00	0.00						
0.2431	43.06	24.86									
0.2044	18.16	18.18									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

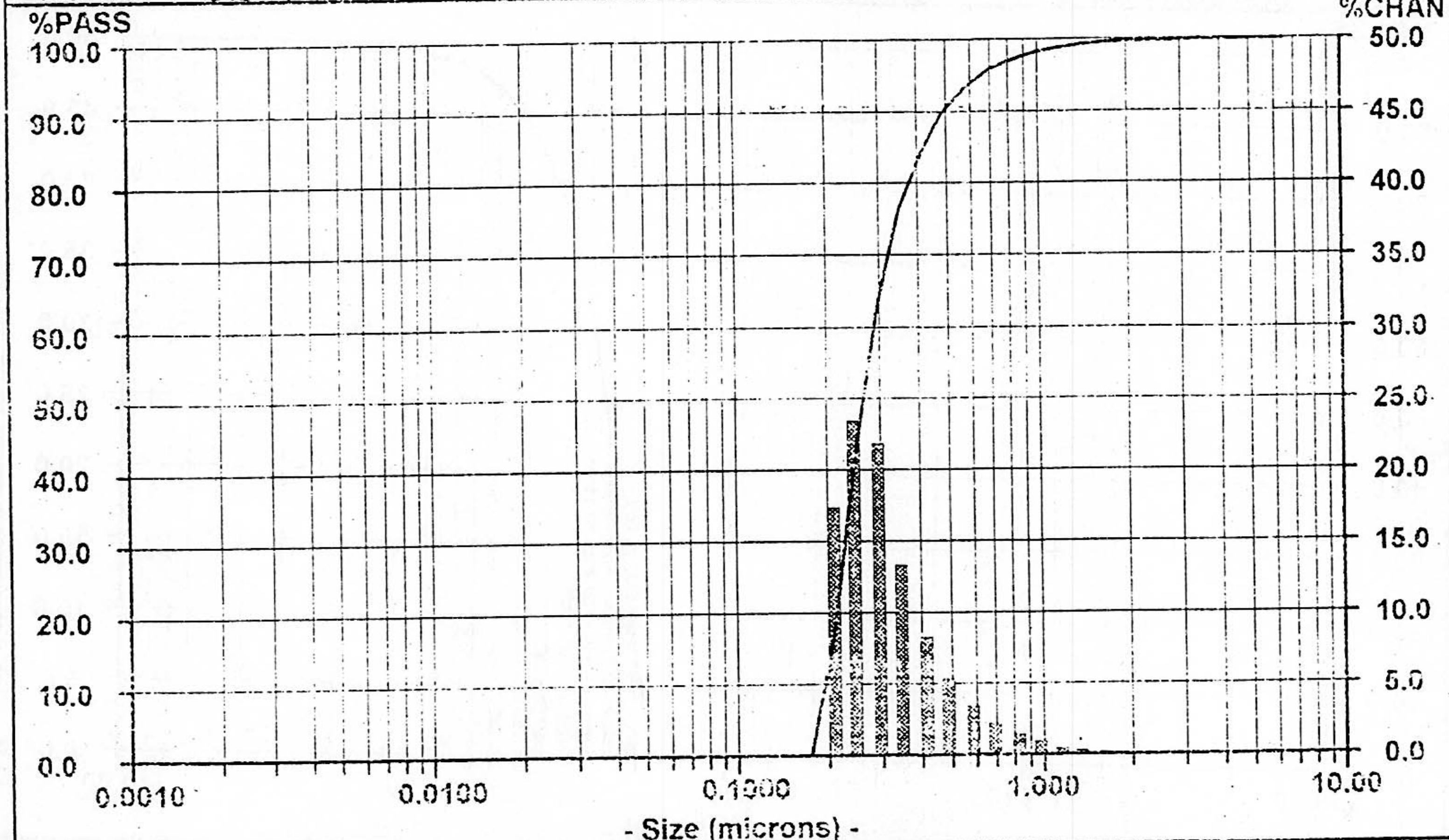
Particle Size Analysis

CUF AW-101-005
Duplicate Sample

Date: 04/09/99 Meas #: N/A
Time: 15:42 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 2.826	10% = .1925	60% = .2817	.2597	100%	.1998
mn = .3208	20% = .2084	70% = .3132			
ma = 1.176	30% = .2245	80% = .3677			
cs = 5.103	40% = .2413	90% = .4833			
sd = .0999	50% = .2597	95% = .6338			

NUMBER DISTRIBUTION



SIZE	%PASS	%CHAN
6.541	100.00	0.01
5.500	99.99	0.01
4.625	99.98	0.02
3.889	99.96	0.03
3.270	99.93	0.04
2.750	99.89	0.07
2.313	99.82	0.11
1.946	99.71	0.17
1.635	99.54	0.26
1.375	99.28	0.39
1.156	98.89	0.60
0.9723	98.29	0.92
0.8176	97.37	1.44
0.6875	95.93	2.25
0.5781	93.68	3.53
0.4861	90.15	5.46
0.4088	84.69	8.35
0.3437	76.34	13.46
0.2891	62.88	21.85
0.2431	41.03	23.56
0.2044	17.47	17.47
0.1719	0.00	0.00
0.1445	0.00	0.00
0.1215	0.00	0.00
0.1022	0.00	0.00

SIZE	%PASS	%CHAN
0.0859	0.00	0.00
0.0723	0.00	0.00
0.0608	0.00	0.00
0.0511	0.00	0.00
0.0430	0.00	0.00
0.0361	0.00	0.00
0.0304	0.00	0.00
0.0256	0.00	0.00
0.0215	0.00	0.00
0.0181	0.00	0.00
0.0152	0.00	0.00
0.0128	0.00	0.00
0.0107	0.00	0.00
0.0090	0.00	0.00
0.0076	0.00	0.00
0.0064	0.00	0.00
0.0054	0.00	0.00
0.0045	0.00	0.00
0.0038	0.00	0.00

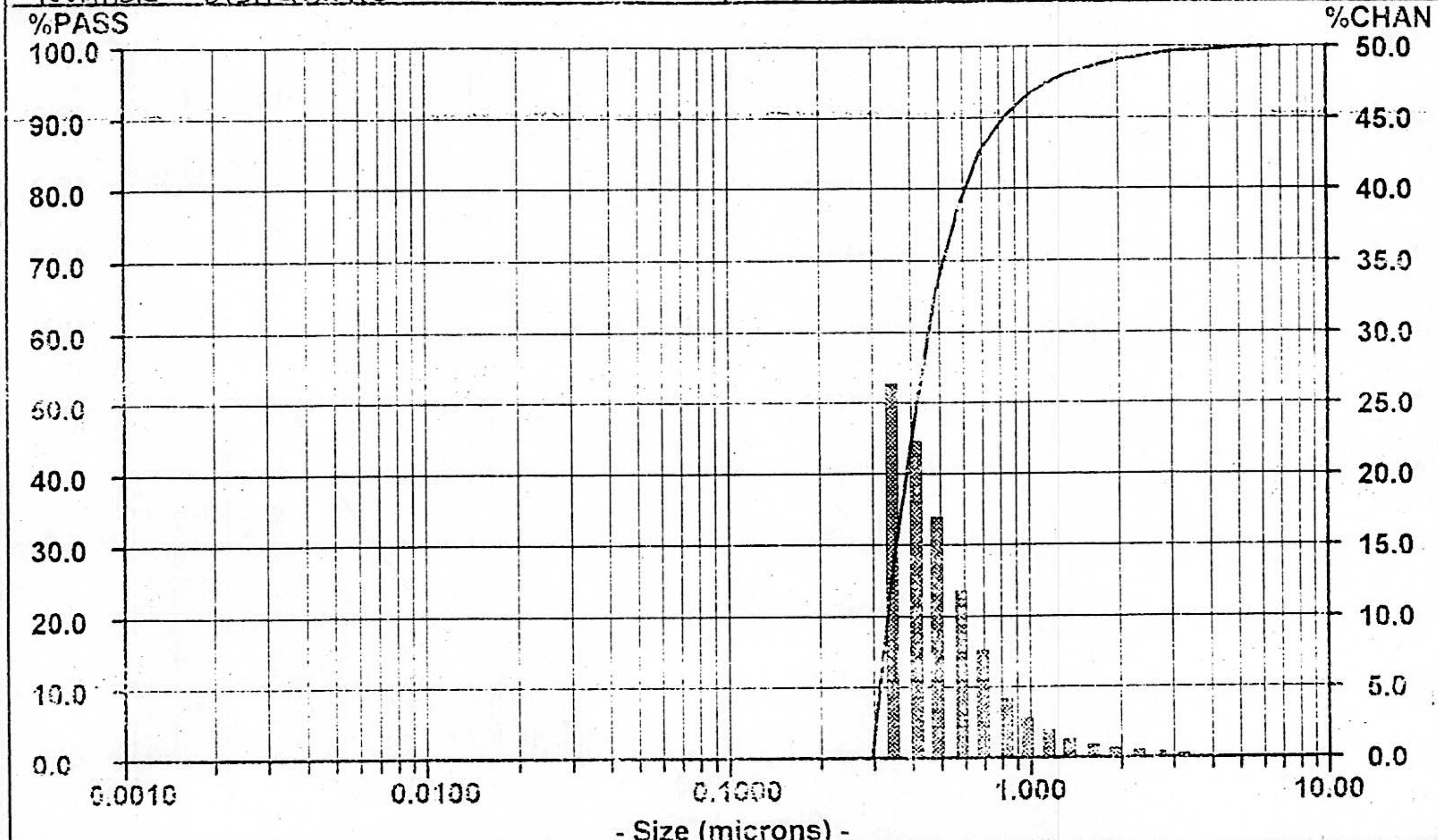
SIZE	%PASS	%CHAN

SIZE	%PASS	%CHAN

Particle Size Analysis	CUF AW-101-005 Duplicate Sample	Date: 04/09/99 Time: 15:43	Meas #: N/A Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 3.416	10% = .3125	60% = .4545	.4127	100%	.3340
mn = .5419	20% = .3312	70% = .5117			
ma = 1.998	30% = .3521	80% = .6017			
cs = 3.002	40% = .3792	90% = .8176			
sd = .1670	50% = .4127	95% = 1.179			

NUMBER DISTRIBUTION



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.07	0.0859	0.00	0.00						
5.500	99.93	0.10	0.0723	0.00	0.00						
4.625	99.83	0.16	0.0608	0.00	0.00						
3.889	99.67	0.24	0.0511	0.00	0.00						
3.270	99.43	0.34	0.0430	0.00	0.00						
2.750	99.09	0.47	0.0361	0.00	0.00						
2.313	98.62	0.61	0.0304	0.00	0.00						
1.945	98.01	0.73	0.0255	0.00	0.00						
1.635	97.23	1.02	0.0215	0.00	0.00						
1.375	96.21	1.38	0.0181	0.00	0.00						
1.156	94.83	1.95	0.0152	0.00	0.00						
0.9723	92.88	2.87	0.0128	0.00	0.00						
0.8176	90.01	4.38	0.0107	0.00	0.00						
0.6875	85.63	7.73	0.0090	0.00	0.00						
0.5781	77.90	11.87	0.0076	0.00	0.00						
0.4861	66.03	17.05	0.0064	0.00	0.00						
0.4088	48.98	22.49	0.0054	0.00	0.00						
0.3437	26.49	26.49	0.0045	0.00	0.00						
0.2891	0.00	0.00	0.0038	0.00	0.00						
0.2431	0.00	0.00									
0.2044	0.00	0.00									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

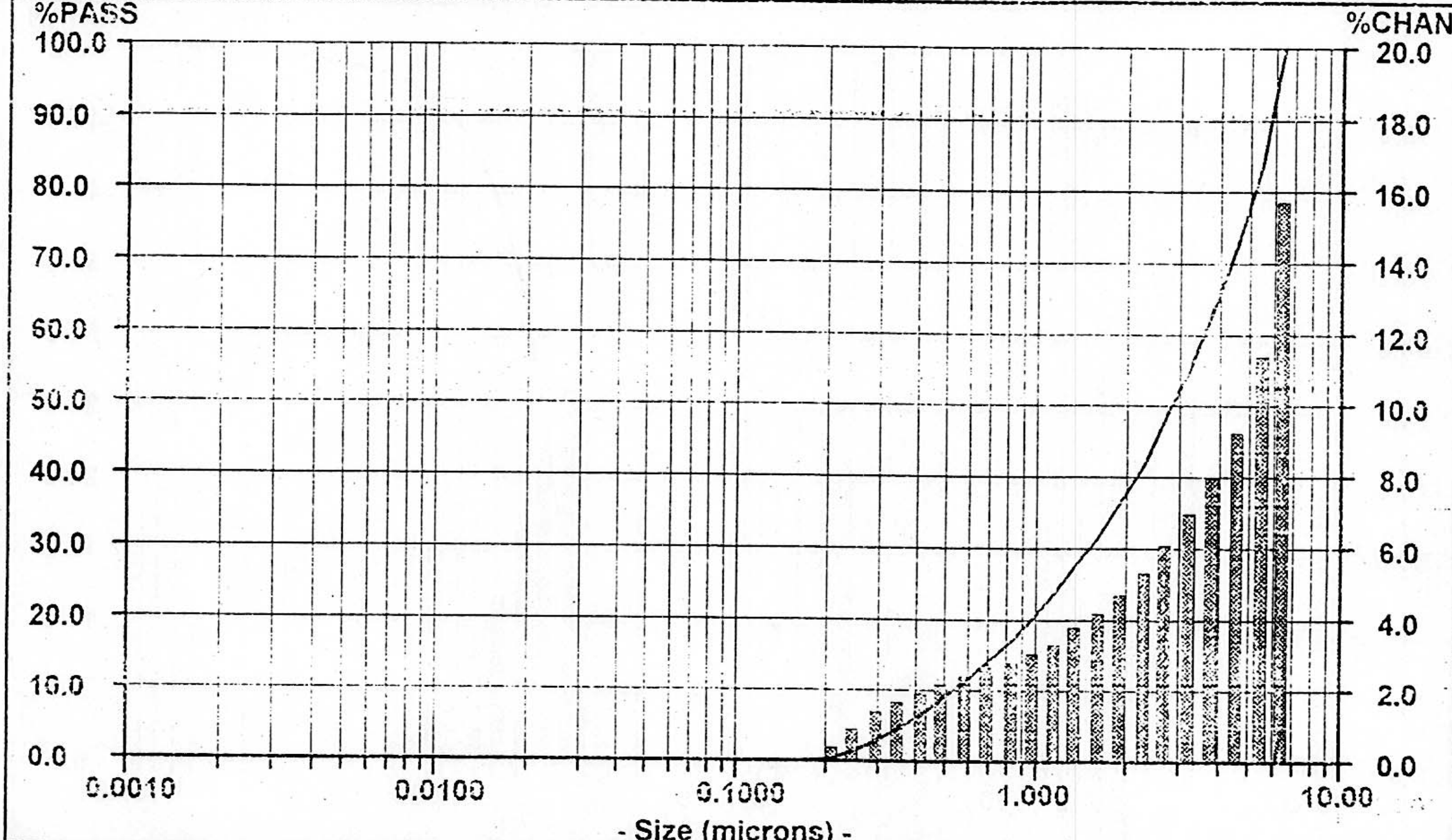
Particle Size Analysis

CUF AW-101-005
Duplicate Sample

Date: 04/09/99 Meas #: 00145
Time: 15:43 Pres #: 01

Summary	Percentiles		Dia	Vol%	Width
mv = 3.041	10% = .5257	60% = 3.624	2.873	100%	4.721
mn = .3391	20% = .9572	70% = 4.407			
ma = 1.364	30% = 1.519	80% = 5.209			
cs = 4.399	40% = 2.170	90% = 5.828			
sd = 2.361	50% = 2.873	95% = 6.123			

AVERAGE VOLUME DISTRIBUTION



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	15.82	0.0859	0.00	0.00						
5.500	84.18	11.44	0.0723	0.00	0.00						
4.625	72.74	9.34	0.0608	0.00	0.00						
3.889	63.40	8.03	0.0511	0.00	0.00						
3.270	55.37	7.07	0.0430	0.00	0.00						
2.750	48.30	6.22	0.0361	0.00	0.00						
2.313	42.08	5.41	0.0304	0.00	0.00						
1.946	36.64	4.73	0.0255	0.00	0.00						
1.635	31.36	4.25	0.0215	0.00	0.00						
1.375	27.61	3.83	0.0181	0.00	0.00						
1.156	23.78	3.48	0.0152	0.00	0.00						
0.9723	20.30	3.18	0.0128	0.00	0.00						
0.8176	17.12	2.93	0.0107	0.00	0.00						
0.6875	14.19	2.77	0.0090	0.00	0.00						
0.5781	11.42	2.53	0.0076	0.00	0.00						
0.4861	8.89	2.27	0.0064	0.00	0.00						
0.4088	6.62	1.99	0.0054	0.00	0.00						
0.3437	4.63	1.76	0.0045	0.00	0.00						
0.2891	2.87	1.46	0.0038	0.00	0.00						
0.2431	1.41	0.98									
0.2044	0.43	0.43									
0.1719	0.00	0.00									
0.1445	0.00	0.00									
0.1215	0.00	0.00									
0.1022	0.00	0.00									

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