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Development of Inactive High Level Waste Envelope D Simulants for Scaled Crossflow Filtration Testing

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Summary

As part of the development of the full-scale filtration system for the River Protection Project-Waste Treatment Plant (RPP-WTP), a multi-tube crossflow filter is to be tested on non-radioactive simulants at British Nuclear Fuel, Ltd.'s (BNFL's) Sellafield plant. The data collected from this pilot-scale unit will be used in conjunction with the results from the actual waste testing with a single-tube crossflow filter to assist in the scale-up effort. The objective of this work was to develop the non-radioactive, physical simulants for use in the multi-tube filter. Two simulant compositions have been targeted: a neutralized current acid waste (NCAW) developed from a composite of AZ-101 and AZ-102 tank compositions, and a high-heat tank waste, based on the composition of the waste in Tank C-106. The second objective of this work was to verify the simulant properties and performance relative to the actual waste.

These simulants were developed to mimic only the sludge properties important to crossflow filtration testing. The simulants were to contain the primary tank waste constituents and be non-hazardous, low cost, and easy to prepare and reproduce. As a first step, the aspects of the high-level waste (HLW) sludge properties that were expected to determine the crossflow filtration performance were identified. The key waste properties for crossflow filtration were determined to be

- the size distribution of particles or agglomerates
- agglomerate compactness and deformation behavior under shearing flow conditions
- major mineral phases contributing to the waste morphology
- major ions
- ionic strength of the supernatant
- the pH of the supernatant
- slurry solids loading
- rheological properties of the slurry at a given solids loading.

Then, the actual waste elemental compositions for the NCAW and the C-106 tank wastes were used to derive a simple chemical composition of the solids and supernatant for simulant formulation. The simulants were tested in the cells unit filter (CUF), and their formulations were adjusted to obtain a specification that performs similarly to actual waste in a crossflow filtration unit.

Table S.1 lists the solid and supernatant components of the AZ-101/102 filtration simulant, and Table S.2 summarizes the composition of the C-106 filtration simulant.

The C-106 Filtration was evaluated with the 0.5-μm Mott filter element to compare its filtration performance with previous experimental data obtained with an actual C-106 sample by Geeting et al. (1997). The testing in both actual and simulant cases was performed at 8 wt% insoluble solids. The filtrate flux for all conditions using the simulant was reasonably close in magnitude and curve shape to the actual waste. The simulant filtrate flux decreased at a continuous rate over the course of an individual run condition due to deformation of a wide spectrum of agglomerates (from soft to hard agglomerates) under imposed shearing of a run condition. Generally, the C-106 simulant filtration fluxes were less than 30% higher than those obtained with the actual waste on the basis of averaged fluxes for individual run

conditions. The difference in averaged fluxes between the simulant and actual waste was partly due to the difference in the shape of flux-verses-time profiles. The C-106 simulant exhibited a uniform decline in the filtration flux whereas the actual waste filtration flux profile showed a rapid decline in the beginning followed by an approximately flat profile in the course of each individual condition. Further, in many cases, there is more significant variability between the first and the second 30 minutes in the actual waste testing than between the actual waste testing and the simulant testing. All of these results suggest that the simulant accurately model the actual waste in its filtration characteristics.

Table S.1. Inactive AZ-101/102 Filtration Simulant Composition

Solids Components					
Compounds Bearing:	**Wt %**	**Mineral Phase**	**Powder Grade**	**Mean Volume PSD (Distribution)**	**Wt %**
Iron	58	Hematite	Iron Oxide No: 07-5001	22 μm	17.400
			Red Iron Oxide No: 07-3752	2–3 μm	29.000
			Synthetic Red Iron Oxide No: 07-2568	0.6 μm	11.600
Aluminum	24	Beohmite	HiQ-10 Alumina	0.0028–0.004 μm	7.200
		Gibbsite	C-231 Ground White Hydrate	14 μm (broad)	8.400
			SpaceRite S-23 Alumina	7.5 μm (broad)	5.040
			SpaceRite S-11 Alumina	0.25 μm (narrow)	3.360
		Gibbsite/Beohmite Ratio: 2.33			
Zirconium	13	Zirconium Hydroxide	Zirconium Hydroxide; Product Code: FZO922/01	15 μm	13.000
Silicon	5	Nepheline	Spectrum A 400 Nepheline Syenite	.10 μm	5.000

Supernatant Components		
Component	**Concentration (M)**	**Concentration (g/L)**
NaOH	0.8	32
$NaNO_3$	1.0	85

The available rheological results for actual C-106 sludge (Urie et al. 1997) were not applicable for designing the C-106 filtration simulant because the rheology of actual C-106 waste was conducted at too low of solids loading. As a result, the actual C-106 waste rheological data was not used for designing the C-106 filtration simulant.

No actual waste AZ-101/102 CUF data were available during this work, however, efforts were made to create a simulant that would have a decreasing flux over time, similar to that seen in most actual waste samples. The testing matrix was performed with the simulant prepared at 5 and 15 wt% insoluble solids. The filtrate flux profiles obtained with the simulant at 5 wt% insoluble solids loading were about 70% higher than the filtrate flux obtained with the simulant at 15 wt% solids loading. The results indicated an overall decrease in filtrate flux over time, similar to what was seen during actual waste testing.

Table S.2. Inactive C-106 Filtration Simulant Composition

Solids Components					
Compounds Bearing:	**Wt %**	**Mineral Phase**	**Powder Grade**	**Mean Volume PSD (Distribution)**	**Wt %**
Iron	31.25	Hematite	Red Iron Oxide No: 07-3752	2-3 μm	18.750
			Synthetic Red Iron Oxide No: 07-2568	0.6 μm	12.50
Aluminum	36.46	Beohmite	HiQ-10 Alumina	0.0028–0.004 μm	18.230
		Gibbsite	SpaceRite S-23 Alumina	7.5 μm (broad)	10.938
			SpaceRite S-11 Alumina	0.25 μm (narrow)	3.646
			SpaceRite S-3 Alumina	1 μm (narrow)	3.646
		Gibbsite /Beohmite Ratio: 2.33			
Zirconium	28.12	Zirconium Hydroxide	Zirconium Hydroxide; Product Code: FZO922/01	15 μm	28.125
Silicon	4.17	Nepheline	Spectrum A 400 Nepheline Syenite	10 μm	4.166

Supernatant Components		
Component	**Concentration (M)**	**Concentration (g/L)**
NaOH	1.07	42.8
$NaNO_3$	1.00	85.0

The rheological results of the radioactive NCAW were available (Gary et al. 1990 and 1993) and used to develop the AZ-101/102 crossflow filtration simulant. The instantaneous viscosity profiles indicated that the AZ-101/102 simulant emulated the viscosity behavior of the actual NCAW waste (core samples from Tanks 101-AZ and AZ-102 wastes) very well at 10, 30, and 40 wt% undissolved solids concentrations as a function of shear rate. At shear rates of less than 30 s^{-1}, the instantaneous viscosity of the AZ-101/102 simulant slurries at all solids loading represented higher values, which rendered the AZ-101/102 simulant slurries conservatively viscous. The yield stress values for the core samples and the simulant slurries at similar solids contents were comparable. The yield stress values for the AZ-101/102 simulant slurries were higher than the radioactive slurries by a factor of 2, but the differences were considered insignificant in discriminating the flow and rheological behavior of the simulant and radioactive slurries.

Rapko et al. (1997) measured the particle-size distribution (PSD) of AZ-101/102 actual waste. These results were compared with the AZ-101/102 simulant PSD under similar conditions using the same particle size analyzer. On a volume-weighted distribution, the actual waste and the simulant exhibited a poly-dispersed behavior, and the simulant encompassed the spectrum of the particle sizes encountered in the actual waste. Despite the slight differences in the distribution shape and the location of the peaks for the actual AZ-101/102 waste and simulant, the overall mean volume and number distribution of the actual waste compare very well with those measured with the simulant. For example, the mean volume and number distribution of the actual waste are 9.93 μm and 0.63 μm, respectively whereas those of the simulant are 9.32 μm and 0.77 μm, respectively. Overall, the particle size distribution and rheology of the actual NCAW slurry were replicated very well by the AZ-101/102 filtration simulant.

Finally, the declining behavior in the filtration flux due to filter fouling and/or particle de-agglomeration over the course of testing were not seen in previous simulant studies. The declining behavior of the current HLW AZ-101/102 and C-106 filtration simulants is consistent with actual waste.

Terms and Abbreviations

BNFL	BNFL, Inc; subsidiary of British Nuclear Fuels, Ltd.
CUF	cells unit filter
DI	deionized (water)
DST	double shell tank
HLW	high-level waste
NCAW	neutralized current acid waste
NIST	National Institute of Standards and Technology
PSD	particle-size distribution
PUREX	plutonium-uranium extraction
RPP-WTP	River Protection Project-Waste Treatment Plant
SEM	scanning electron microscopy
SST	Single-shell tank
TEM	transmission electron microscopy
TMP	trans-membrane pressure

Units

cm	centimeter
°C	degrees Celsius
ft/s	feet per second
g	gram
kg	kilogram
kg/m^3	kilogram per $meter^3$
g/L	gram per liter
gpm/ft^2	gallon per minute per $feet^2$
m^2/g	$meter^2$ per gram
m/s	meter per second
µm	micrometer
mL/s	milliliter per second
mPa.s	millipascal per second
min	minute
M	molarity or moles per liter
nm	nanometer
Num%	number percent
mPa.s	millipascal per second
Pa	pascal
s^{-1}	reciprocal second
Vol%	volume percent
wt%	weight percent

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1.0 Introduction

BNFL, Inc (BNFL) developed flowsheets for the River Protection Project-Waste Treatment Plant (RPP-WTP) in which they made plans to use crossflow filtration for the solid-liquid separation of the Envelope D Hanford sludge (DOE-RL 1996). Unlike traditional dead-end filtration in which a filter cake grows on the surface of the filter medium and slows the rate of filtration, in crossflow filtration, the fluid flows across the medium and sweeps the filter cake away. This filtration method is especially beneficial when there are very fine particles and when system simplicity is required.

As part of the development of the full-scale filtration system for the RPP-WTP, a multi-tube crossflow filter is to be tested on non-radioactive simulants at BNFL's Sellafield plant. The data collected from this pilot-scale unit will be used in conjunction with the results from the actual waste testing with a single-tube crossflow filter to assist in the scale-up effort.

The objective of this work was to develop the non-radioactive, physical simulants for use in the multi-tube filter. Two simulant compositions have been targeted: a Neutralized Current Acid Waste (NCAW) developed from a composite of AZ-101 and AZ-102 tank compositions, and a high-heat tank waste, based on the composition of the waste in Tank C-106. These simulants were developed to mimic the sludge properties important to crossflow filtration testing. The simulants were to contain the primary tank waste constituents and were to be non-hazardous, low cost, and easy to prepare and reproduce.

The second objective of this work was to verify the simulant properties and performance relative to the actual waste. Particle size and rheological data available from past experimental efforts were compared to these high-level waste (HLW) simulants. The simulants were also tested in the cell unit filter (CUF) single-tube crossflow filter, providing a comparison between the simulant results and the available data with actual waste. By comparing the filtration and rheological behavior of actual and simulated waste, the validity of the simulants can be verified. Furthermore, a comparison between the simulant behavior in the CUF unit and in the multi-tube pilot-scale unit provides insight into the impacts of process scale-up.

This report describes the approach taken in developing the AZ-101/AZ-102 and C-106 tank waste simulants. It also provides the simulant formulation, including vendor purchasing information. The utility and limitations of the simulant are also delineated to define acceptable applications. The rheological, filtration, and particle size properties for each simulant are delineated. These properties are compared to the actual waste data, where available. This report also provides a means of transmitting to BNFL the raw filtration, rheological, and particle-size data for the simulants.

2.0 Simulant Development Approach

Simulants are usually designed with a specific process or processes in mind. A simulant that is appropriate for testing one process might be inappropriate for another. In this work, simulants are designed for multi-tube crossflow filtration testing. Thus, the simulants are emulating those aspects of the HLW sludge properties relevant to the performance of crossflow filtration. The approach used to develop non-radioactive HLW physical simulants for multi-tube crossflow filtration is illustrated in Figure 2.1. Additional discussions on the methodology used to develop physical simulants are presented in Golcar et al. (1997 and 2000).

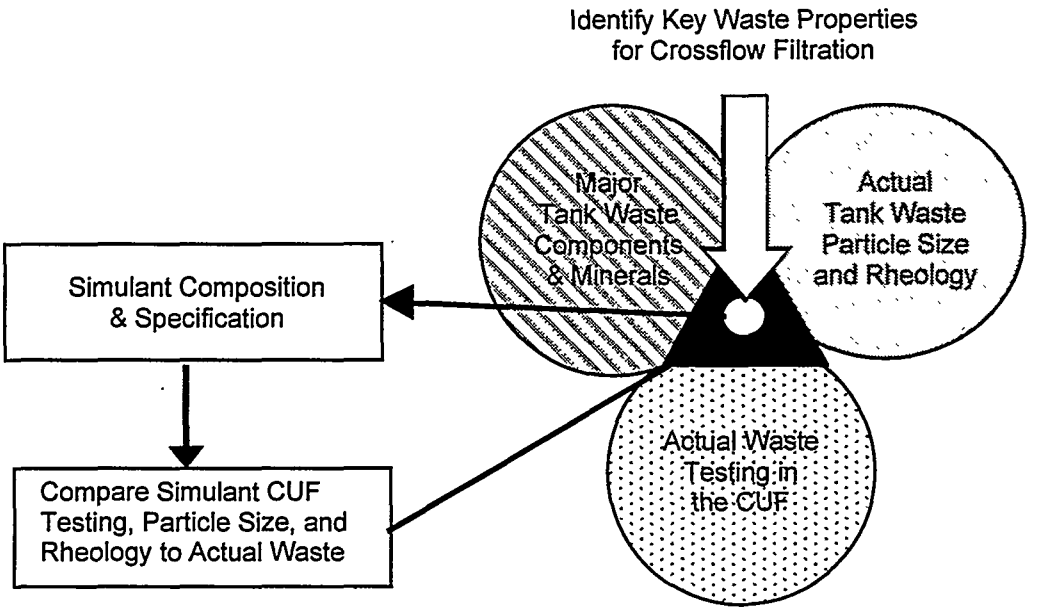


Figure 2.1. Simulant Development Approach

The first step was to identify the waste properties that were expected to determine the crossflow filtration performance. Literature reviews, CUF testing results, and consultation with experts were conducted to determine the mechanisms by which the crossflow filtration process operated. This knowledge was used to develop a list of expected key physical and chemical properties for the crossflow-filtration process. The relevant waste properties for crossflow filtration were determined to be

- Particle-size distribution (PSD): Particle or agglomerate size is likely the most important property for the filtration since it impacts filterability according to their arrangement in the filter cake to form a compressible verses an incompressible film.
- Rheological properties of the slurry at given solids loading: The rheology of the slurry will control the slurry-transporting characteristic in the CUF circulation loop. This information is needed to determine design parameters of velocity and pressure drop across the pipeline.

- Slurry solids loading: The slurry solids loading impact the rheology of the slurry. Obviously, the lower the solids content of slurry, the lower the viscosity over the measurable range of shear rates.
- Agglomerate strength and shearing properties: Agglomerate strength and shearing properties are important due to vigorous mixing and continual pumping that gradually breaks up particles and changes the filtration characteristics by altering the film or cake structure deposited on the membrane surface. As small fine particles are generated, they plug the filter cake, and the filtrate flux could decrease very rapidly to necessitate back flushing to regenerate the membrane.
- Major mineral phases and their contribution to the waste morphology: The mineral types provide inherent characteristics of shape and strength for individual particles that impact rheology and the nature of agglomerates.
- Major ions, the ionic strength, and the pH of the supernatant: The ionic strength and pH of the supernatant will affect the degree of agglomeration or dispersion and the solubility of particles.

The second step was to review the existing actual waste-characterization data for the NCAW and the C-106 tank wastes. These results were used to determine the chemical composition of the solids and supernatant for each waste type. The PSD and the rheological results of the radioactive waste samples were compiled, and their relevance to crossflow filtration simulants was evaluated. Further, the expected range of magnitude for PSD and rheological properties was established and used to develop simulants that fall within these estimates.

The mineral phases of waste were reviewed and replicated in simulants to the extent practical. Mineral phases of solids were selected from the existing electron beam techniques (scanning and transmission electron microscopy [SEM, TEM] with x-ray analysis) of the C-106 waste. Since such data were not available for the NCAW solids, candidate mineral phases were selected from the TEM data conducted on sludge samples from 20 other single-shell tanks (SSTs) and 4 double-shell tanks (DSTs). The waste mineralogy and chemical composition were simplified according to their practicality and significance in terms of size, shape, and solubility (to a certain extent) for the crossflow filtration performance. From the standpoint of simulant quality control and the high cost of some minerals identified by TEM, compromises were made in selecting minerals for simulant formulation. These minerals were substituted with other solid forms of the same component with a similar PSD and shape that were commercially available at reasonably low costs. The mineral phases and their selection criterion are discussed in detail in section 4.3.

In the case of the C-106 simulant, the available small-scale radioactive CUF results were available. Thus, the final step in the simulant-development process was to compare the CUF data using simulant slurry with the radioactive CUF results. Adjustments to the C-106 simulant composition were made to improve the confidence in the validity of the simulant for crossflow filtration.

Simulant compositions were formulated using commercial minerals. The rheology (viscosity and yield stress) and PSD of the simulants were measured. Each formulation was tested in the cold CUF, and its performance was evaluated. The simulant formulation was adjusted numerous times to obtain the final formulation, which was similar to actual waste in filtration, rheological, and PSD properties.

3.0 High-Level Waste Simulant Specification

The specifications and preparation procedures for the inactive HLW – Envelope D filtration simulants are presented in this section. These simulants were developed for the purpose of testing crossflow filtration systems. The applicability of these simulants for filtration studies using washed and leached solids is uncertain and requires additional evaluation. These simulants have not been developed to mimic the chemical properties of the sludge, and their use for washing and caustic-leaching experiments is not recommended. Applicable sludge properties for crossflow filtration were discussed in Section 2.0. Specifications outlined below are for

- AZ-101/102 waste simulant slurry for the NCAW from Hanford Tanks AZ-101 and AZ-102
- C-106 waste simulant slurry for the high-heat tank waste from Hanford Tank C-106. It should be noted that the actual C-106 waste has recently been transferred to Hanford Tank AY-102. The C-106 waste simulant replicates the Hanford tank C-106 waste and it does not replicated the AY-102/C-106 mixed waste.

3.1 AZ-101/102 Slurry Simulant

Table 3.1 lists the solid and supernatant components of the inactive AZ-101/102 waste filtration simulant. Note that the concentration of the solid components is reported on a 100% dry solids basis. For aluminum- and iron-bearing compounds in the simulant several metal oxide/hydroxide powder grades of various PSD ranges were used to produce the required rheological and filtration characteristics. The product descriptions for each mineral, including density and particle size, are provided in Appendix A. The material safety data sheets for listed source chemicals are provided in Appendix B.

3.2 C-106 Slurry Simulant

Table 3.2 lists the solid and supernatant components of the inactive C-106 waste filtration simulant. Similar to the inactive AZ-101/102 simulant, the concentration of the solid components is reported on a 100% dry solids basis. For aluminum- and iron-bearing compounds in the simulant several metal oxide/hydroxide powder grades of various PSD ranges were used to produce the required rheological and filtration characteristics. Appendix A provides the product descriptions for each mineral, including density and particle size. Appendix B provides the material safety data sheets for listed source chemicals.

Following is the procedure for preparing both the AZ-101/102 and C-106 simulants:

- Determine the wt% insoluble solids and the total mass of simulant desired. This simulant should mimic actual waste over the range of 3 to 40 wt% solids loading. At lower than 3 wt% solids loading, the supernatant composition becomes more significant than the particle characteristics. Further development of the supernatant may be required to mimic the actual waste. Additionally, higher than 40 wt% solids loading has not been evaluated in this study. Further validation at these higher concentrations would be required before using these simulants above 40 wt%.
- Weigh out and combine the solid components described in Table 3.1 or 3.2 for the 1) total simulant mass, and 2) wt% solids desired. The order of addition to the mixture is not important.
- Prepare sufficient simulated supernatant for the total mass of slurry at desired solids loading with the molarity specified in Table 3.1 or 3.2.

- Add this simulated supernatant to the dry solids mixture until the total mass of slurry simulant desired is reached. Mix with a stirrer for 20 min immediately after addition and before use.

Table 3.1. Inactive AZ-101/102 Filtration Simulant Composition

Solids Components					
Compounds Bearing:	**Wt %**	**Mineral Phase**	**Powder Grade**	**Mean Volume PSD (Distribution)**	**Wt %**
Iron	58	Hematite	Iron Oxide No: 07-5001	22 µm	17.400
			Red Iron Oxide No: 07-3752	2–3 µm	29.000
			Synthetic Red Iron Oxide No: 07-2568	0.6 µm	11.600
Aluminum	24	Boehmite	HiQ-10 Alumina	0.0028–0.004 µm	7.200
		Gibbsite	C-231 Ground White Hydrate	14 µm (broad)	8.400
			SpaceRite S-23 Alumina	7.5 µm (broad)	5.040
			SpaceRite S-11 Alumina	0.25 µm (narrow)	3.360
		Gibbsite/Boehmite Ratio: 2.33			
Zirconium	13	Zirconium Hydroxide	Zirconium Hydroxide; Product Code: FZO922/01	15 µm	13.000
Silicon	5	Nepheline	Spectrum A 400 Nepheline Syenite	10 µm	5.000

Supernatant Components		
Component	**Concentration (M)**	**Concentration (g/L)**
NaOH	0.8	32
$NaNO_3$	1.0	85

Table 3.2. Inactive C-106 Filtration Simulant Composition

Solids Components					
Compounds Bearing:	**Wt %**	**Mineral Phase**	**Powder Grade**	**Mean Volume PSD (Distribution)**	**Wt %**
Iron	31.25	Hematite	Red Iron Oxide No: 07-3752	2-3 µm	18.750
			Synthetic Red Iron Oxide No: 07-2568	0.6 µm	12.50
Aluminum	36.46	Beohmite	HiQ-10 Alumina	0.0028–0.004 µm	18.230
		Gibbsite	SpaceRite S-23 Alumina	7.5 µm (broad)	10.938
			SpaceRite S-11 Alumina	0.25 µm (narrow)	3.646
			SpaceRite S-3 Alumina	1 µm (narrow)	3.646
		Gibbsite /Boehmite Ratio: 2.33			
Zirconium	28.12	Zirconium Hydroxide	Zirconium Hydroxide; Product Code: FZO922/01	15 µm	28.125
Silicon	4.17	Nepheline	Spectrum A 400 Nepheline Syenite	10 µm	4.166

Supernatant Components		
Component	**Concentration (M)**	**Concentration (g/L)**
NaOH	1.07	42.8
$NaNO_3$	1.00	85.0

3.3 Simulant Material Suppliers

Simulant properties, such as particle size distribution and mineral composition, will vary from those listed in this report if alternative sources for simulant components are used. The brand names of each simulant component are given in Table 3.3.

Table 3.3. Inactive AZ-101/102 and C-106 Filtration Simulant Material Suppliers

Manufacturer	Simulant Material	Powder Grade
The Prince Manufacturing Company http://www.princemfg.com/	Iron Oxide, Hematite	Iron Oxide No: 07-5001
	Iron Oxide, Hematite	Red Iron Oxide No: 07-3752
	Iron Oxide, Hematite	Synthetic Red Iron Oxide No: 07-2568
Alcoa - Port Allen , LA http://www.alcoa.com/ 1-800-860-3290	Beohmite, AlOOH	HiQ-10 Alumina
Alcoa- Bauxite, AR http://www.alcoa.com/ 1-225-382-3338	Gibbsite, $Al(OH)_3$	C-231Ground White Hydrate
		SpaceRite S-23 Alumina
		SpaceRite S-11 Alumina
		SpaceRite S-3 Alumina
Magnesium Electron INC. (MEI) http://www.zrchem.com/ 1-800-366-9596	Zirconium Hydroxide	Product Code: FZO922/01 from FZO 922 series.
Hammill & Gillespie http://www.hamgil.com/ 973-994-3847	Nepheline, $(Na, K)AlSiO_4$	Spectrum A 400 Nepheline Syenite

Detailed simulant characterization and crossflow filtration performance testing are required if alternative commercial products are used. Such results should be similar to the simulant properties documented in this report. Further, the chemical and physical properties listed in Appendix A need to be matched as closely as possible if another commercial source is used.

4.0 Chemical Composition and Mineral Phases

The basis for the elemental and mineral phase content of the simulants is presented in this section. The elemental composition of the NCAW and the C-106 slurries were estimated using analytical results and historical information on the generation of the waste. The elemental compositions were then simplified to meet the simulant development criteria for crossflow filtration testing. Compositions are listed in this section. Further, the rationale for selecting the mineral phases used in the simulant formulation and the significance of these minerals to crossflow filtration is explained.

4.1 Elemental Composition for NCAW

The actual NCAW solids composition was taken from Hodgson (1995) and Lambert (1998). The tank inventories and their percentages on a "sodium-free" and "water-free" basis are provided in Table 4.1. The sodium is removed because it is assumed to be present as either an intrinsic constituent of compounds generated from the analytes in Table 4.1 or as soluble sodium nitrite/nitrate which dissolves or is diluted during the retrieval process. Thus, it is not included in the solids composition. The data in Table 4.1 indicate that approximately 88 to 92 wt% of the NCAW solids are dominated by minerals formed from the following analytes: iron (~42 to 43 wt%), aluminum (~11 to 22 wt%), silicon (~2 to 3 wt%), zirconium (~6 to 15 w%), uranium (~2 to 9 wt%), manganese (~1 to 9 wt%), cadmium (~2 to 5 wt%) and nickel (~2 to 3 wt%).

As shown, approximately 42 to 43 wt% of NCAW sludge consists of iron compounds because a large quantity of iron sulfamate was used in the plutonium-uranium extraction (PUREX) process, which is noted by historical accounts (Ryan 1995). The PUREX process produced the NCAW tank sludges. Aluminum compounds are the second main constituents of sludge, followed by uranium and zirconium compounds. The rest of the analytes (silicon, manganese, cadmium, and nickel) constitute the remainder of the solids.

Uraninite (UO_2) minerals were not added to the list of simulant chemical sources (despite representing 2 to 9 wt% of NCAW solids), because they are radioactive. While uranium-bearing materials are typically dense hard minerals, it was not expected to have a significant impact on the filtration properties because the filterability of slurry is not directly influenced by these properties (see Section 2.0). Therefore, we did not add any dense hard minerals (such as tungsten oxide) as surrogates for uranium.

Manganese oxides and/or hydroxides were also excluded from the simulant materials list to simplify the iterative process of formulation. Manganese oxide or hydroxides tend to be grouped into tight bundles and columnar massive forms of "hard" agglomerates. The behavior of these particles is dominated by the body-force interactions (inertial and frictional forces) rather than colloidal interactions. In this context it is assumed that they behave similar to iron oxide or aluminum trihydroxide described in detail in Section 4.3.

Table 4.1. Reference NCAW Elemental Composition.

Solids Analyte	AZ-101 (kg) [a]	Sodium-Free (Wt %)	AZ-102 (kg) [b]	Sodium-Free (Wt %)
Ag	78.2	0.17	242	0.22
Al*	5320	11.85	24200	22.35
As	111	0.25	-	-
B	57.8	0.13	-	-
Bi	-	-	-	-
Ca	467	1.04	1080	1.00
Cd	1070	2.38	5360	4.95
Ce	234	0.52	-	-
Cr	343	0.76	3930	3.63
Cu	83	0.18	-	-
Fe	19100	42.5	46800	43.22
K	1260	2.81	918	0.85
La	724	1.61	1610	1.49
Li	14	0.03	-	-
Mg	118	0.26	-	-
Mn	4260	9.49	1030	0.95
Mo	24	0.05	-	-
Na	17300	0.00	19880	0.00
Nd	518	1.15	-	-
Ni	855	1.90	3160	2.92
P	558	1.24	164	0.15
Pb	101	0.22	394	0.36
Re	11	0.02	-	-
Rh	83	0.18	-	-
Si	1130	2.52	3390	3.13
Sr	95	0.21	117	0.11
Te	374	0.83	-	-
Ti	127	0.28	-	-
U	1070	2.38	9670	8.93
V	-	-	-	-
Zn	79	0.18		0.00
Zr	6720	14.96	6470	5.97

(a) Projected inventory using core 1 sample composition (Hodgson 1995).
(b) Calculated sludge based on Section 4.0 of the 1995 Tank Characterization Report (Lambert 1998).
* Shaded analytes are the major compound-bearing elements in NCAW solids.

Neither nickel nor cadmium compounds are used in deriving simulant formulation. Cadmium compounds are extremely toxic. Nickel is known to form stable mixed oxides with Al, Fe, Cr, etc. In the alkaline conditions typically encountered in NCAW nickel most likely occur in related mixed oxy hydroxides. It is speculated that the co-precipitation of mixed nickel oxides and hydroxides would not alter the nature of agglomerate compactness common to for example iron-bearing oxides and hydroxides.

Thus, it is assumed that these oxides behave similar to iron oxides, and their inter-particle interactions are governed by body-force type interactions.

Based on the indicated discussions, the elemental composition of the solids fraction of the AZ-101/102 simulants was normalized with the relative proportions of only the four elements of aluminum, iron, silicon, and zirconium. This composition is shown in Table 4.2.

Table 4.2. Target Composition of AZ-101/102 Filtration Simulant

Solids components			
Analyte	**Normalized Estimates (Wt %)**	**Target Analyte Bearing Minerals**	**Target Mineral composition (Wt %)**
Aluminum	17–30	Boehmite; AlOOH Gibbsite; $Al(OH)_3$ (combined)	24
Iron	57–60	Hematite; Fe_2O_3	58
Silicon	3–5	Nepheline; (Na, K)$AlSiO_4$	4
Zirconium	8–21	Zirconium Hydroxide; $Zr(OH)_4$	13
Supernatant components			
Compound	**Target Concentration (M)**	**Significance**	
NaOH	0.80	Liquid viscosity, pH	
$NaNO_3$	1.00	Liquid viscosity, ionic strength	

The composition of the supernatant simulant replicates the pH and ionic strength expected in the feed after the sludge waste is fluidized from the holding tanks with dilute caustic (0.01M NaOH) to yield slurry of metal hydroxide precipitates. Sodium hydroxide, nitrite, and nitrate are the primary soluble compounds in the waste. Since sodium nitrate and nitrite make similar contributions to the ionic strength, only sodium nitrate was included in the supernatant formulation.

4.2 Elemental Composition for C-106

The elemental composition of the C-106 solids is estimated from analytical results and projected inventory from the 1996 grab sample (Schreiber et al. 1996) and projected inventory of waste (Kirkbride et al. 1999) in Tank C-106. The tank inventories and their percentages on a "sodium-free" and "water-free" basis are provided in Table 4.3. The data indicate that approximately 98 wt%[a] of the non-sodium C-106 solids are dominated by minerals formed from following analytes: aluminum (~31 to 33 wt%), iron (~26 to 40 wt%), silicon (~4 to 16 wt%), zirconium (~1 to 26 w%), manganese (~1 to 3 wt%), calcium (~1 to 2 wt%), and phosphorus (~2 wt%).

(a) The sodium is assumed to be present as either an intrinsic constituent of compounds generated from the analytes in Table 4.3 or as soluble sodium nitrite/nitrate which dissolves during the retrieval process. Thus, it is not included in the solids composition.

Aluminum is the main constituent of C-106 sludge (~31 to 33 wt%) closely followed by iron and zirconium compounds. The rest of the analytes (silicon, manganese, and calcium) constitute the remainder of the solids.

Table 4.3. Reference C-106 Elemental Composition

	C-106 (kg) [a]	Sodium-Free (Wt %)	C-106 (kg) [b]	Sodium-Free (Wt%)
Ag	1390	1.20	<1	-
Al*	36000	31.14	56873	32.97
B	53	0.05	0	0
Ba	221	0.19	7.77	0
Bi	0	0	4.536	0
Ca	981	0.85	2866	1.66
Cd	24	0.02	0	0
Ce	158	0.14	<1	-
Cr	475	0.41	1067	0.62
Cs	0	0	10	0
Cu	79	0.07	0	0
Fe	46800	40.48	45506	26.38
Hg	0	0	78	0.05
K	774	0.67	803	0.47
La	57	0.05	228	0.13
Mg	197	0.17	<1	-
Mn	1610	1.39	4977	2.89
Na	145000	0.00	60015	0
Nd	129	0.11	0	0
Ni	455	0.39	1912	1.11
P	1800	1.56	3337	1.93
Pb	1740	1.50	1278	0.74
S	2120	1.83	530	0.31
Si	18400	15.91	7573	4.39
Sr	30.7	0.03	55	0.03
Ti	96.7	0.08	0	0
U	1400	1.21	14	0.01
Zn	48	0.04	0	0
Zr	587	0.51	45372	26.30

(a) Projected inventory using grab sample taken in 1996 (Schrieber et al. 1996)
(b) Projected inventory using tank transfer plans where the C-106 will be transferred to Tank AZ101 or Tank AZ102 (Kirkbride et al. 1999).
* Shaded analytes are the major compound-bearing elements in C-106 solids.

Based on similar logic presented in Section 4.1, the elemental composition of the solids fraction of the C-106 simulants was normalized to 100% with the relative proportions of four major elements (aluminum, iron, silicon, and zirconium). This composition is shown in Table 4.4.

Table 4.4. Target Composition of C-106 Filtration Simulant

Solids Components			
Analyte	**Normalized Estimates (Wt %)**	**Target Analyte Bearing Minerals**	**Target Mineral composition (Wt %)**
Aluminum	35–37	Boehmite; AlOOH Gibbsite; $Al(OH)_3$ (combined)	37
Iron	29–46	Hematite; Fe_2O_3	31
Silicon	5–18	Nepheline; (Na, K)$AlSiO_4$	4
Zirconium	29[(a)]	Zirconium Hydroxide; $Zr(OH)_4$	28
Supernatant components			
Compound	**Target Concentration (M)**	**Significance**	
NaOH	1.07	Liquid viscosity, pH	
$NaNO_3$	1.00	Liquid viscosity, ionic strength	

(a) It is speculated that the zirconium quantity reported in Kirkbride et al. 1999 was under estimated. Thus, this value was not included.

4.3 Major Mineral Phases

In order to replicate various factors of PSD, shape, surface charge, rheological properties, agglomeration, and deformation (under shearing flow conditions) of the actual waste, the mineral phases need to be accounted for. Incorporating all of the aluminum, iron, silicon, and zirconium-bearing mineral phases into the simulant design can easily become complicated. Thus, the AZ-101/102 and C-106 slurry simulants were designed to encompass major mineral phases that govern the expected physical and rheological properties as well as filter-cake agglomeration and deformation (under shearing flow conditions). The major phases identified in the actual waste and the criterion for using individual minerals in the simulant design are described below.

The characterization of mineral compounds by electron beam techniques (scanning and transmission electron microscopy with x-ray analysis) were conducted on sludges from 21 SSTs and 4 DSTs (Lafemina et al. 1995a, 1995b, 1995c). Considering the compositional variety of tank wastes, relatively few major solids phases were present. The major aluminum-containing precipitates were determined to be gibbsite [$Al(OH)_3$] and boehmite [α-AlOOH]. Iron-containing compounds were well-crystallized oxyhydroxide minerals, goethite (α-FeOOH) and hematite (Fe_2O_3). Much of the silicon in the tank wastes appeared to be in various forms, including zeolites such as cancrinite, amorphous aluminosilicate, clay minerals, feldspar, and sand (Lafemina et al. 1995a, 1995b, 1995c).

The AZ-101/102 tank waste mineral compounds were postulated using described major minerals for the 25 Hanford tank sludges because microscopy measurements were not performed on actual AZ-101/102 sludge samples. On the other hand, microscopy measurements were conducted on the untreated radioactive C-106 sludge solids (Lumetta et al. 1996). The TEM coupled with the EDS and electron diffraction of the untreated C-106 solids is shown in Figure 4.1.

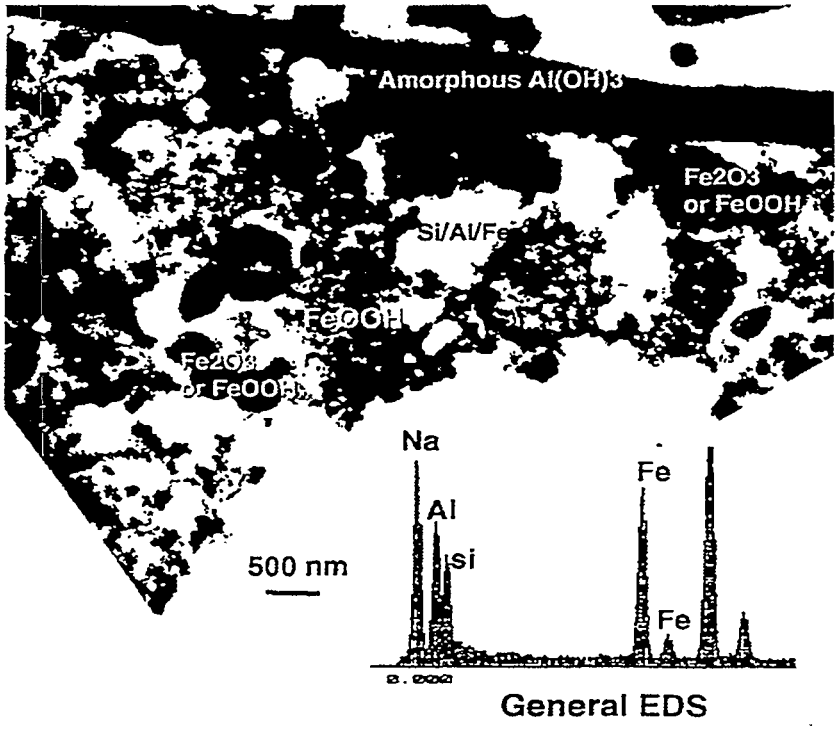


Figure 4.1. TEM and EDS of Large Sample Area of the Untreated C-106 Solids (Lumetta et al. 1996)

Similar to minerals reported in the other 24 tank sludges, the C-106 sludge solids are dominated by gibbsite [$Al(OH)_3$], boehmite [α-AlOOH], goethite (α-FeOOH), hematite (Fe_2O_3) and aluminum/iron bearing silicates. Lumetta at al. (1996) indicated that FeOOH was present in both highly crystalline and poorly crystalline forms.

In terms of solids size, the primary particles and agglomerates in actual tank sludges were observed to span five orders of magnitude (Lafemina et al. 1995a, 1995b, 1995c). As shown schematically in Figure 4.2, the solids are ranging from 1 nm to 100 μm in diameter and vary widely in shape. The small colloidal size particles (~<10 μm) were found to be zirconium oxide/ hydroxides (1 to 10 nm), geothite (<100 nm), various silicates (<100 nm), and boehmite ranging from 100 nm to 1 μm. These sub-micron particles tend to form homogeneous or mixed heterogeneous agglomerates that can be as large as 100 μm (see Figure 4.2). Single crystals of gibbsite and hematite can exceed 20 μm in diameter.

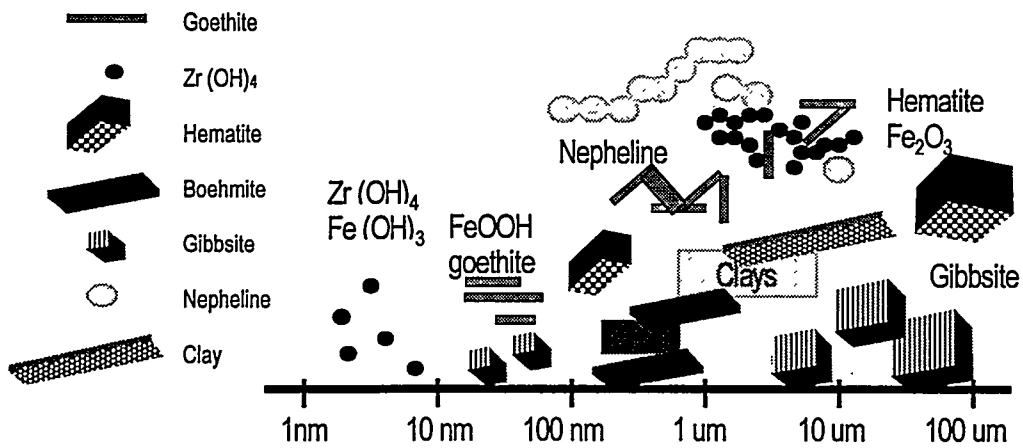


Figure 4.2. Solids Types in the Tank Sludges[a]

The illustration of Figure 4.2 demonstrates that mineral phases found in the actual waste represent a wide variety of particle shapes. For example, the boehmite particles are acicular and/or plate-shape particles that have a specific surface area of approximately 280 m^2/g, and gibbsite particles are tabular on the order of 5 to 50 m^2/g. The hematite crystals are approximately spherical (rounded hexagonal) with a surface area on the order of 50 m^2/g. Thus, particles of various forms of spherical, plate like, and needle shapes were accounted for in choosing the simulant minerals.

To design filtration simulants, commercially available powder grades of aluminum, iron, silicon, and zirconium bearing minerals were selected that represent a diverse spectrum of observed actual tank primary particle sizes (less than 10 nm to 100 μm). Particle or agglomerate size is likely the most important property for the filtration since it impacts filterability. Also, minerals were selected to mimic the formation of both soft and hard agglomerates that behave in different manners under crossflow-filtration shearing flow conditions. Powder grades of boehmite and gibbsite minerals were used since they comprise a large fraction of aluminum-containing minerals. Gibbsite was added in several powder-grade size ranges and ratios to replicate primary gibbsite particles, which either accumulate in soft agglomerate clusters or represent compact crystalline bundles.

Hematite in several size ranges was used for iron-bearing minerals. Powder-grade hematite minerals of narrow 0.6-μm size range, broad 2-μm size range, and 22-μm broad size distribution at various ratios were included in the filtration simulant[b] Although the goethite phase was observed in many actual tank waste sludges, from the standpoint of simulant quality control, it was not considered as a simulant component. The geothite phase is typically synthesized using the Fe (II) or Fe(III) salt solutions. This synthesize path can be time consuming and requires substantial morphological analysis to achieve

(a) Adapted from a view graph presentation by Bruce Bunker et al.

(b) In this text the terms "narrow particle size range" and "broad particle size range" are used to describe the width of a particle peak distribution qualitatively. Details of peak width distribution are provided in Appendix E.

uniformly consistent sizes. Commercially available powder-grade goethite is expensive to acquire ($250 U.S. currency/5 grams) in large quantities. Thus, geothite was not used in the filtration simulant.

Nepheline [(Na, K)$AlSiO_4$] and/or (Na, $AlSiO_4$), an aluminosilicate mineral of the feldspathoid group, was used as the silicon-bearing phase. This mineral is commercially available and used as a substitute for cancrinite [$Na_4Al_3(SiO_4)_3CO_3$] zeolite seen in tank waste sludges. Nephaline was selected because it contains large openings in the crystal structure similar to cancrinite zeolite and has similar particle characteristics. Once again, a powder-grade nepheline with a broad size distribution of 10 μm was used in simulant formulation. A powder-grade zirconium hydroxide was used as the zirconium-containing solid phase.

The minerals described above and illustrated in Figure 4.2 were used as solid-particle building blocks to replicate the PSD results (see Section 6.2) of the actual AZ-101/102 and C-106 wastes and mimic the resulting colloidal and body force inter-particle interactions. Furthermore, close attention was made to encompass a wide spectrum of particle physics that were determined from the mineral phases found in the actual waste. The shape of particles and their surface roughness also affect the rheological properties of the slurry as well as the solids size distribution and the state of agglomerates. By incorporating these factors, unexpected and/or undesirable rheological properties can be evaluated at solids loading of interest. For instance, non-spherical shapes can all provoke particle-particle collisions inducing shear-thickening behavior.

5.0 Simulant Verification by Crossflow Filtration Testing

The CUF parametric tests were conducted at various phases of the AZ-101/102 and C-106 simulant-development efforts. The filtrate flux values and the flux-versus-time results from these tests were compared to results available from filtration tests with actual waste samples. All actual waste samples tested show a continuous reduction in filtrate flux over the course of the experiment as a result of floc de-agglomeration, particle grinding, and irreversible filter fouling (Geeting et al. 1997; Brooks et al. 2000a, 2000b). In addition, in the course of an individual run condition, the filtrate flux declined. An attempt was made to match the flux decline over the course of an individual run condition for both the AZ-101/102 and C-106 filtration simulants.

Results of CUF testing conducted with an actual C-106 sample were used to validate the C-106 simulant (Geeting et al. 1997). In both cases, 0.5-μm Mott filter elements were used. The same transmembrane pressure and axial velocity conditions of the actual waste trials were replicated with the simulant to simplify the comparison. The test matrix and the CUF results are presented and compared in detail in Section 5.2. Further, the final C-106 formulation was tested using a BNFL-specified testing matrix and the BNFL baseline 0.1-μm Mott filter.

During the development of the AZ-101/102 simulant formulation, filtration results for the actual AZ-102 sample were not available. Consequently, the objectives of the AZ-101/102 simulant development effort were to replicate the PSD and rheological characteristics of the actual NCAW slurry. Additionally, the simulant was developed to exhibit a reduction in filtrate flux over the course of an individual condition as well as throughout the entire experiment. The reduction in filtrate flux over an individual condition is believed to be caused by a build-up in material on the filter surface. The reduction in filtrate flux throughout the entire experiment (in spite of backpulsing) is believed to be caused by deagglomeration of the particles by induced shearing in the CUF circulation loop as well as filter fouling. This phenomena has been seen many times with actual waste, but is more difficult to obtain with simulants (see Geeting et al. 1996, 1997). Thus, during the CUF trials, the AZ-101/102 simulant formulation was checked and adjusted several times to obtain a simulant that exhibits a decreasing filtrate flux as a function of time. The final simulant formulation was evaluated using a BNFL-specified testing matrix that was similar to the test matrix used for testing the actual AZ-102 sample. The results of the CUF testing with the AZ-101/102 simulant are discussed in Section 5.3.

5.1 Testing Overview and Apparatus

Crossflow filtration testing of both HLW Envelope D filtration simulants was conducted on a Battelle-modified CUF, with the following specifications:

- single tube filter module, 61-cm-long tube; 0.952-cm ID
- a Mott liquid-service stainless steel filter
- re-circulation flow such that 5 m/s (15ft/s) maximum linear crossflow velocity can be achieved through the filter tube with water
- maximum transmembrane pressure 80 psid with water.

A photograph of the CUF used for this testing is shown in Figure 5.1. The slurry feed is introduced into the CUF through the slurry reservoir. An Oberdorfer progressive cavity pump (powered by an air motor) pumps the slurry from the slurry reservoir through the magnetic flow meter and the filter element. The axial velocity and trans-membrane pressure are controlled by the pump speed (which is controlled by the pressure of the air supplied to the air motor) and the throttle valve position. Additional details of the CUF equipment are provided in Brooks et al. (2000a, 2000b).

The C-106 simulant was tested in the CUF at conditions similar to those used for the actual C-106 sample. For both tests, the filtrate was recycled back into the feed tank to maintain the steady-state solids concentration. Each condition was run for 60 min with backpulsing once after 30 minutes of operation during the condition similar to the actual C-106 trials. The data were taken every 5 minutes. Between each condition, the system was backpulsed twice. The slurry temperature was maintained at 25 ± 5°C for all filtrate rate testing. The temperature was corrected (for both simulant and actual waste) to 25°C using the formula (Equation 5.1) provided by BNFL to correct for viscosity and surface tension changes:

$$Flux_{25C} = Flux_T e^{1200\left(\frac{1}{273+T} - \frac{1}{298}\right)} \tag{5.1}$$

where.$Flux_{25C}$ is the corrected filtrate flux, and T is the temperature (°C) at the flux measurement ($Flux_T$).

The C-106 and AZ-101/102 simulants were also tested with a 0.1-μm Mott liquid-service stainless steel filter. For these tests, the BNFL HLW filtration test conditions are based on an empirically derived matrix to determine the optimum de-watering conditions for the feed slurry. A 5-point matrix around the center-point at 50 psid and 12.2 ft/s tests the conditions of TMP (30 psid, 50 psid, 70 psid) and velocity (9.1 ft/s, 12.2 ft/s, 15.2 ft/s). The filtrate was recycled back into the feed tank to maintain the steady-state solids concentration for testing. Each condition was run for 60 minutes with data taken every 5 minutes similar to the current BNFL HLW testing plans (see Brooks et al. 2000a,b). The system was backpulsed twice between each condition, but was not backpulsed during the testing at each condition. The slurry temperature was maintained at 25 ± 5°C for all filtration testing.

Following the filtration tests with each simulant formulation, the slurry was drained from the CUF and the CUF was rinsed thoroughly with water. One liter of 1 M HNO_3 was then circulated in the CUF for approximately 30 minutes, or until high filtration fluxes were attained. The acid was drained, and the system was flushed with water. After the CUF had been thoroughly cleaned, testing to establish a background filtrate flux was conducted with de-mineralized water, prefiltered using a 0.1 micron absolute rated Millipore filter. Clean water flux testing was performed in the CUF at 20, 10, and 30 psid. Once the filtration flux exceeded 2.5, 1.0, and 2.8 gpm/ft^2, respectively, the filter was considered clean, and the next set of tests could be performed. These flux values were found during the initial filter testing with water.

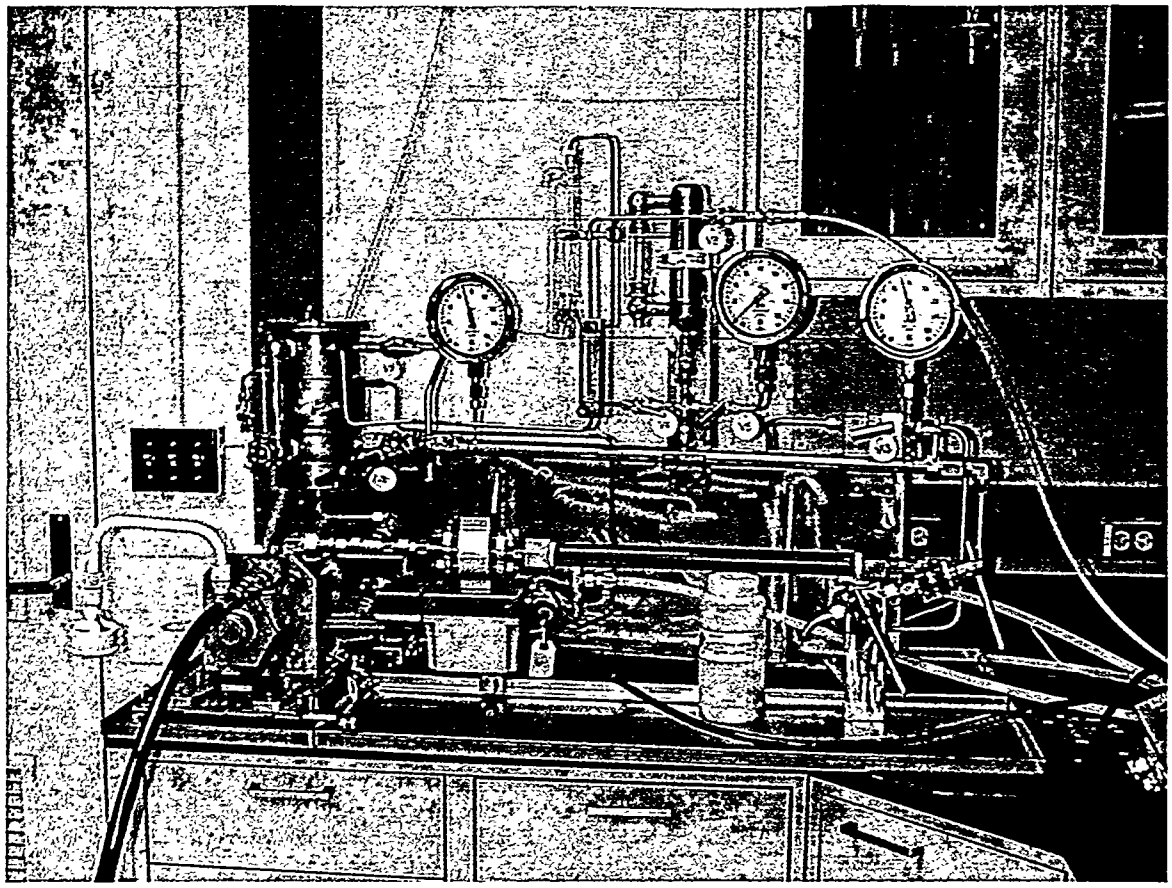


Figure 5.1. Photograph of the Cold Crossflow Filtration System

5.2 C-106 Simulant Slurry Crossflow Filtration

The C-106 simulant developed during this effort was evaluated with the 0.1- and 0.5-μm Mott filters. The 0.5-μm rated filter testing provided a comparison with previous experimental data obtained with an actual C-106 sample (see Geeting et al. 1997). The results obtained with the 0.1-μm rated filter provide a means of comparing the results of the small-scale CUF tests to the results of the Sellafield pilot-scale tests.

The results of test matrices comparing simulated and actual C-106 filtration are shown in Table 5.1. Actual velocities and pressures for both tests were within 5% of the target values, and both test matrices were performed at 8 wt% insoluble solids. Representative flux vs. time curves are presented in Figures 5.2 and 5.3. These curves are the results of testing Conditions 8 and 9, respectively. The filtrate flux curves for all other Conditions are provided in Appendix C. The figures show the filtrate flux decline is reasonably close in curve shape to the actual waste. In most cases, the average filtrate flux of the simulant is within 30% of the actual waste filtrate flux. The filtrate flux for the simulant, however, is generally slightly greater than the filtrate flux for the actual waste. The difference in filtrate flux is greatest for condition 8 (Figure 5.2), which is also the condition of lowest pressure. For simulant

Condition 9 shown in Figure 5.3, the filtrate fluxes are reasonably similar. This is the condition of lowest axial velocity. Overall, the simulant filtrate fluxes are closest to the actual waste filtrate fluxes at conditions that produce low filtrate fluxes. The filtrate flux profiles for simulant and the actual waste at each condition are presented and compared in detail in Appendix C.

Table 5.1. Test Conditions and Average Filtrate Flux for the C-106 Simulated and Actual Waste using a 0.5-Micron Mott Filter

Condition #	Target Velocity (ft/s)	Target Pressure (psid)	Average Filtrate Flux (gpm/ft^2)				
			Simulant (1st 30 min)	Simulant (2nd 30 min)	Actual Waste (1st 30 min)	Actual Waste (2nd 30 min)	% Difference [(a)] (1st/2nd)
1	6	20	0.046	0.039	0.032	0.031	36% / 23%
2	4.5	12.5	0.027	0.029	0.024	0.024	12% / 19%
3	9	20	0.052	0.047	0.044	0.050	17% / -6%
4	6	35	0.032	0.027	0.024	0.028	29% / -4%
5	4.5	27.5	0.026	0.026	0.023	0.022	12% / 17 %
6	6	20	0.034	0.033	0.029	0.029	16% / 13%
7	7.5	12	0.045	0.048	0.035	0.036	25% / 29 %
8	6	5	0.043	0.054	0.018	0.028	82% / 26 %
9	3	20	0.018	0.019	0.016	0.017	12% / 11%
10	7.5	27	0.042	0.039	0.033	0.032	24% / 20%
11	6	20	0.033	0.029	0.026	0.028	24% / 4%

(a) Relative Percentage Difference $=(2(V_s-V_a)/(V_s+V_a)) \times 100$

where: V_s = Average simulant filtrate flux $\geq$10 min

V_a = Average Actual waste filtrate flux $\geq$10 min

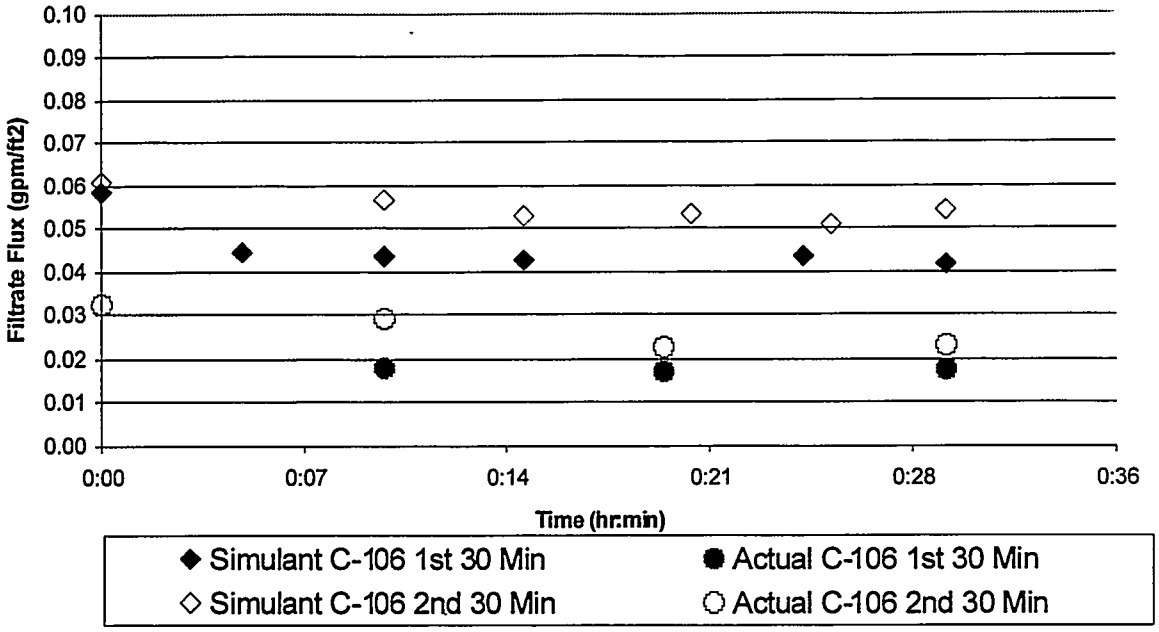


Figure 5.2. Filtrate Flux as a Function of Time for Actual and Simulated C-106 using a 0.5-Micron Mott Filter at 5 psig, 6 ft/s and 8 wt% Solids (Condition 8)

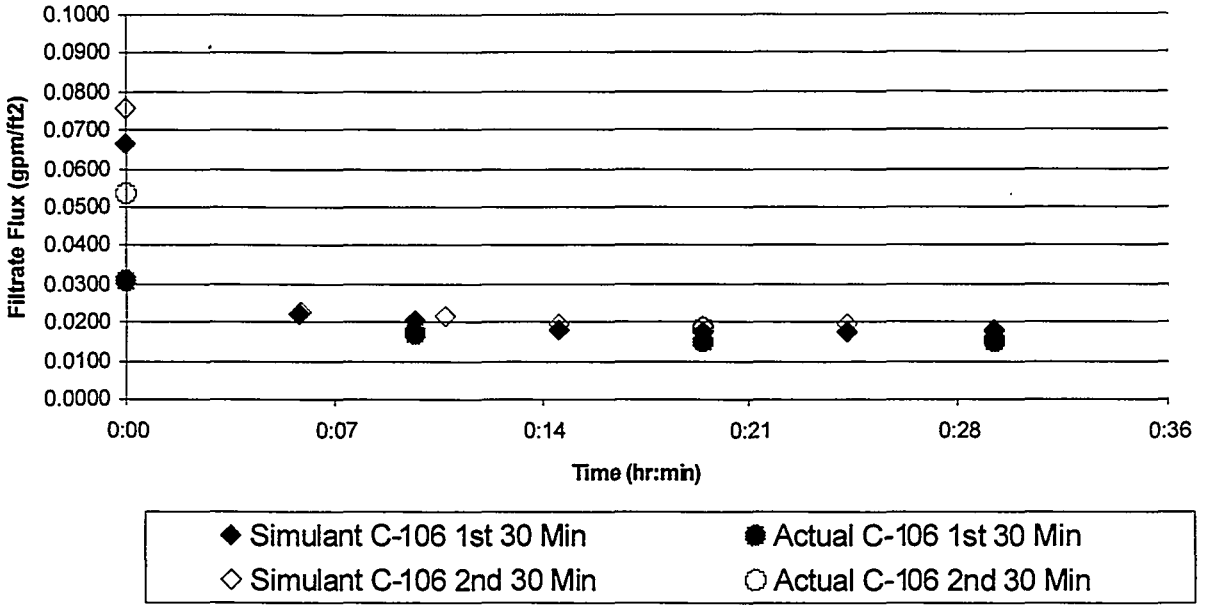


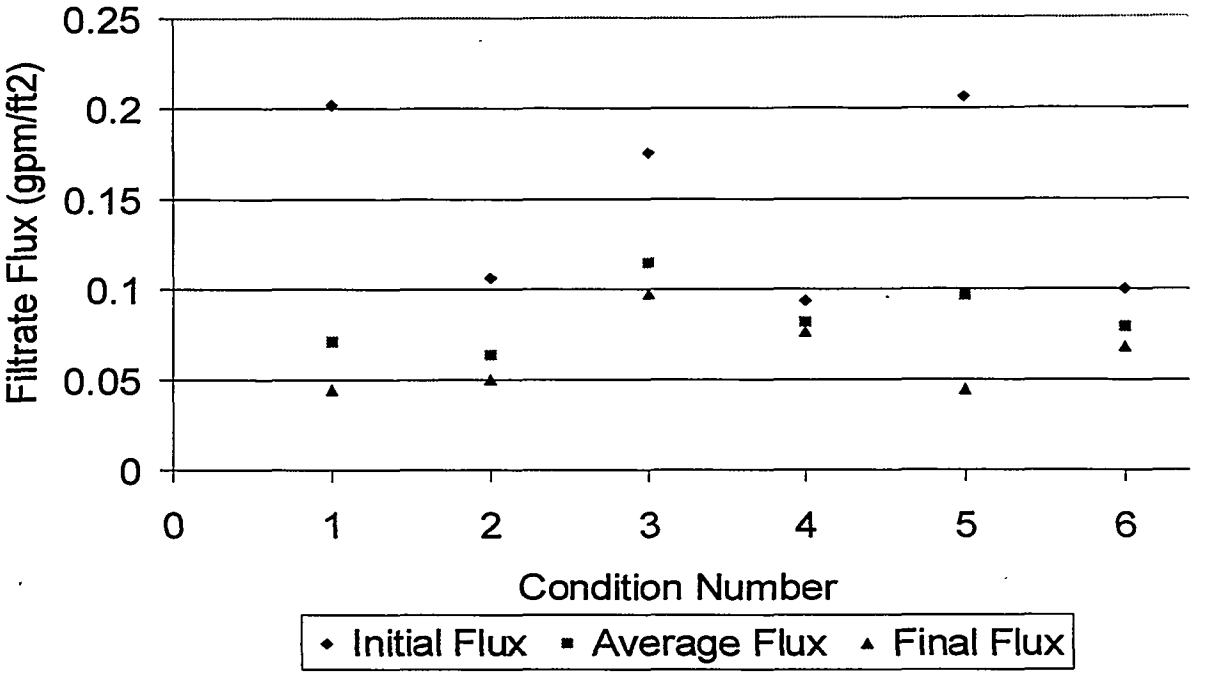
Figure 5.3. Filtrate Flux as a Function of Time for Actual and Simulated C-106 using a 0.5-Micron Mott Filter at 20 psig, 3 ft/s and 8 wt% Solids (Condition 9)

The C-106 simulant was also tested using the 0.1-μm Mott liquid-service filter. In this case, a different matrix, developed by BNFL for actual waste testing, was performed (see Brooks et al. 2000a, 2000b). The test conditions and average filtrate flux for this matrix are shown in Table 5.2. This testing matrix contains much higher axial velocities and pressures than that performed by Geeting et al. (1997) and results in higher filtrate fluxes. The average, initial, and final filtrate flux values of these tests are shown in Figure 5.4. The curves showing filtrate flux as a function of time are presented in Appendix C.

Table 5.2. Test Conditions for the C-106 Simulant Slurry using a 0.1 Micron Mott Filter

Condition #	Target Velocity (ft/s)	Target Pressure (psid)	Average Filtrate Flux (gpm/ft^2)
1	12.2	50	0.071
2	9.2	30	0.064
3	11.3	70	0.115
4	11.4	30	0.082
5	9.1	70	0.096
6	12.2	50	0.079

The highest filtrate flux for the simulant occurred at the highest pressure and a high axial velocity. This result is to be expected in a regime where Darcy's Law applies—increased pressure results in increased filtrate flux. It is surprising, though, that Condition 4 with a trasmembrane pressure of 30 psid has a similar filtrate flux to Condition 6 with similar axial velocities at 50 psid pressure. This simulant



also shows an increase in filtrate flux in Condition 6 when compared to Condition 1. This result suggests little filter fouling or particle deagglomeration for this particular simulant over the course of the entire experiment.

5.3 AZ-101/102 Simulant Slurry Crossflow Filtration

The AZ-101/102 simulant developed during this effort was evaluated with the 0.1 -µm Mott filter. Although no actual waste AZ-101/102 CUF data were available during this work, efforts were made to create a simulant that would have a decreasing flux over time, similar to that seen in CUF testing of most actual waste samples. These results also provide a means of comparing the small-scale CUF tests to the Sellafield pilot-scale tests.

The testing matrix was performed with the simulant prepared at 5 and 15 wt% insoluble solids. Similar to the solids loading conditions performed with the actual AZ-102 waste sample (Brooks et al. 2000b). The target transmembrane pressure and axial velocity conditions along with the average filtrate flux are shown in Table 5.3. These conditions were the same as performed with the actual AZ-102 sample tested by Battelle with the hot CUF ultrafilter during January 2000. Once the results of this upcoming study are published, they can be compared to the simulant results provided here.

Figure 5.4. Initial, Average, and Final Filtrate Flux for Each Test Condition with the C-106 Simulant using a 0.1-Micron Mott Filter and 8 wt% Solids

The average filtrate flux results for both of these conditions are shown in Figure 5.5. The filtrate flux as a function of time for each condition are provided in Appendix C. Figure 5.5 shows that the filtrate flux

obtained with the simulant with a 5 wt% solids loading is about 70% higher than the filtrate flux obtained with the simulant with a 15 wt% solids loading. This figure also shows that although for both solids concentrations, Conditions 1 and 6 (~ 9 ft/s and 50 psid) were nearly identical in velocity and pressure, Condition 1 has a higher filtrate flux. This indicates an overall decrease in filtrate flux over time, similar to what is seen in during actual waste testing due to 1) filter fouling and 2) agglomerate break-up due to the pump shear.

Table 5.3. Test Conditions and Average Filtrate Flux for the AZ-101/102 Simulant using a 0.1-Micron Mott Filter at 5 and 15 wt% Solids

Condition #	Velocity 5 wt% (ft/s)	Velocity 15 wt% (ft/s)	Pressure (psid)	Filtrate Flux (gpm/ft2)	
				5 wt%	15 wt%
1	9.4	7.8	50	0.198	0.092
2	7.6	6.6	30	0.115	0.062
3	7.2	5.9	70	0.124	0.062
4	7.8	8.5	30	0.104	0.069
6*	8.6	8.9	50	0.115	0.077
7	13.1	11.5	30	0.104	0.072

*Condition 5 in the actual waste testing was not performed. It was also not performed here for consistency.

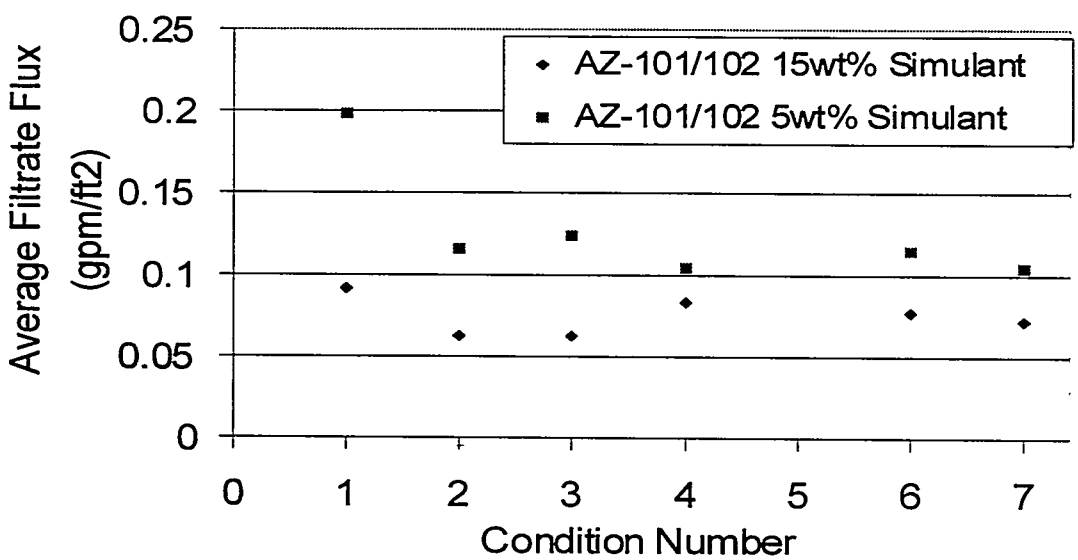


Figure 5.5 Average Filtrate Flux for Each Test Condition with the Simulated AZ-101/102 using a 0.1-Micron Mott Filter with 5 and 15 wt% Solids

5.4 Comparison to Other Simulant and Actual Waste Tests

The decrease in filtrate flux of the AZ-101/102 simulant over the course of testing due to filter fouling and/or particle deagglomeration has not been seen in previous simulant studies, but is consistent with actual waste testing. Filtration simulants S-3 and S-103 were developed as part of Geeting et al. (1996). These simulants were meant to be used as general "HLW" filtration simulants. The S-3 simulant contained boehmite and gibbsite in a 0.1 M NaOH solution. The S-103 simulant was a mixture of precipitated ferric hydroxide, boehmite, gibbsite, silica, and calcium phosphate precipitated to a pH of 10. These were tested with a 0.5-μm Mott filter using the same conditions as described in Table 5.1. As with the work presented here, the first condition was at the same transmembrane pressure and axial velocity as the final condition, thus quantifying any decreases during the course of the test.

The initial and final filtrate fluxes are presented in Figure 5.6 below. Actual tank wastes S-107 and C-107 were also tested under similar conditions with a 0.5-μm Mott filter. These are also shown in the Figure. Note that the filtrate fluxes obtained with simulants S-3 and S-103 do not decrease from the initial to the final condition using the same filter. In contrast, all of the actual wastes decrease. The actual C-106 test using a 0.5-μm Mott filter shows the least decrease in filtrate flux. This is consistent with the C-106 simulant which had very little decrease in filtrate flux as well. In contrast, the AZ-101/102 simulant has a significant decrease in filtrate flux from the initial to the final condition, indicating it may better represent actual waste than previously developed simulants. The absolute value of the AZ-101/102 filtrate flux is considerably higher than for any of the other tests. This may be because it was performed with the much higher pressure and axial velocity test matrix using a 0.1-μm Mott filter.

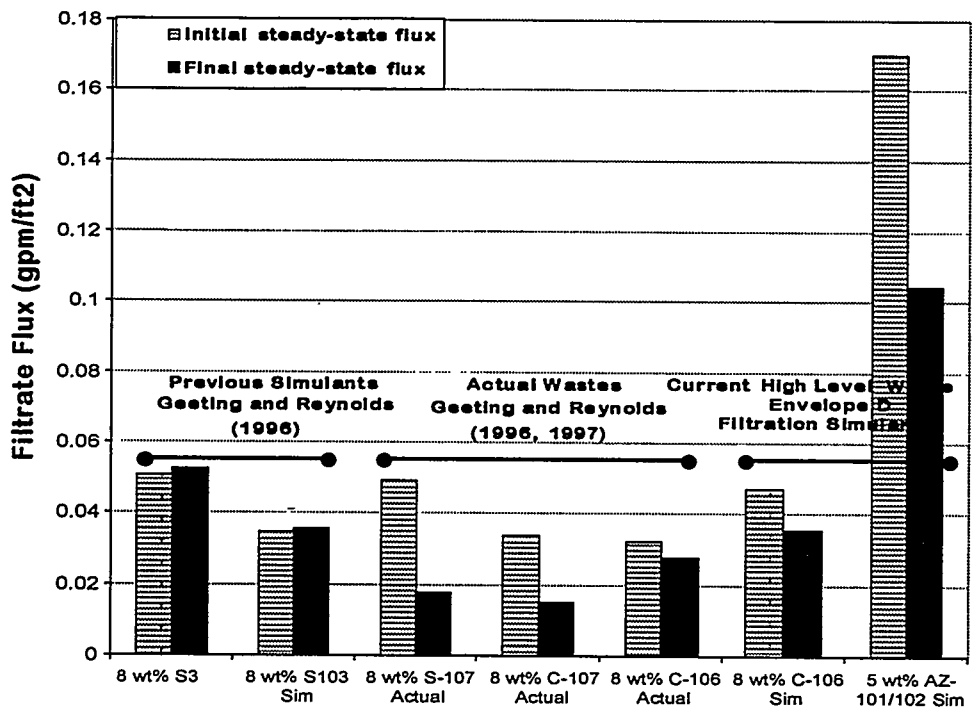


Figure 5.6. Comparison of Average Filtrate Flux for the Initial and Final Conditions of the CUF Filtration Matrix

6.0 Physical and Rheological Properties

The PSD and rheological properties of the filtration simulant are presented in this section. These results were compared with the available actual waste results at the same solids loading and similar supernatant ionic strength. It should be noted that for the AZ-101/102 waste, the rheology of unwashed and unleached actual waste was compared with the filtration simulant.

6.1 Rheology

The rheological results of the radioactive NCAW were used in developing the AZ-101/102 crossflow filtration simulant. The viscosity profiles and the calculated power law models for

- the second core sample from Tank AZ-101 at 10 and 30 wt% undissolved solids concentration were described in Gary et al. (1990)
- the first core sample from Tank AZ-102 at 10 and 40 wt% undissolved solids concentration, reported in Gary et al. (1993),

were applied to mimic the NCAW slurry rheological characteristics. In Section 6.1.1, the experimental process for conducting simulant rheology is described in detail, and the rheological results of actual slurry and simulant slurry for AZ-101/102 waste types are compared in Section 6.1.2.

Unlike the NCAW waste, the available rheological results for actual C-106 sludge (Urie et al. 1997) were not applicable to the C-106 simulant developed under this task because the rheology of actual C-106 waste was conducted at too low of solids loading. As a result, the actual C-106 waste rheological data was not used for designing the C-106 filtration simulant. In Section 6.1.3, the rheological characteristics of the C-106 simulant slurry at various solids loading are presented only to document the rheological properties of this simulant.

6.1.1 Experimental

The rheological measurements of the AZ-101/102 and C-106 slurry simulants were conducted using a Haake rotational viscometer with a CV20 and an M-5 system. For both systems concentric cylinder geometries were used. The concentric cylinder geometry was used to replicate a steady-state shear flow in slurries. In these studies, shear stress as a function of shear rate (controlled rate experiments) were performed. A ME45 concentric cylinder geometry for the CV20 system and a MV1 for the M-5 system, both of which are suitable for medium viscous slurries, were used to measure the slurries. Ascending and descending curves were collected over a run period of 4 minutes for both systems (2 minutes in each direction). The ascending curve was obtained by increasing shear rate from 0 to 300 or 1000 s^{-1} and the descending curve was collected by decreasing the shear rate from 300 or 1000 s^{-1} to 0 s^{-1} . The temperature of the system was kept at 25°C by a water bath.

The CV20 system with an ME45 geometry was used to capture the de-agglomeration of various agglomerates (both weak and compact) as the slurry samples were sheared. For the CV20 system, the shear stress was measured over the shear rate range of 0 to 300 s^{-1}. The M-5 system with an MV1 geometry was used to measure the shear stress over the shear rate range of 0 to 1000 s^{-1} since the

ranges of shear rates for flow in a pipe (similar to the crossflow filtration loop) is about 1 to 1000 s^{-1} (Barnes 1993).[a]

6.1.2 Rheology of AZ-101/102 Slurries

In this section, the results of the rheological measurements for the AZ-101/102 simulant slurries at known solids contents are discussed. Furthermore, the rheological characteristics of the AZ-101/102 simulant slurries are compared with the characteristics of radioactive slurries at similar solids loadings.

The instantaneous viscosity (or apparent viscosity)[b] profile and experimental yield-stress values for the AZ-101/102 simulant slurry at various solids loadings were determined from the controlled shear-rate experiments. Figure 6.1 shows the viscosity as a function of shear rate for the AZ-101/102 simulants at 10, 30, and 40 wt% undissolved solids concentrations in linear and logarithmic scale.

The plots of viscosity as a function of shear rate indicate that the viscosity for the AZ-101/102 simulants at all solids loadings drops to less than 30 mPa.s as the shear rate increases from about 0 to 300 s^{-1}, representing a common shear-thinning behavior. The shear-thinning behavior indicates that the shearing action breaks the agglomerate structures. This behavior is desirable because it suggests that 1) the agglomerates are formed in the AZ-101/102 slurry simulant, and 2) the agglomerates break apart as a function of the shear rate over time. Similar behavior has been seen in the actual waste. It is expected that the AZ-101/102 simulant slurry exhibit a decreasing filtration flux over time as the agglomerates break during the crossflow filtration testing (see Section 5.3).

(a) Close attention to the range of shear rate is made because in a slurry system shear stresses are not linearly related to the shear rate and the slurry behaves as a "non-Newtonian" suspension. In a Newtonian fluid, the shear stress is linearly proportional to the shear rate by a constant viscosity factor. But, the addition of solid particles to a Newtonian fluid produces non-Newtonian behavior where the shear stress is a non-linear function of shear rate; and the viscosity of slurry depends on the shear rate. In dealing with non-Newtonian fluids the viscosities are expressed in terms of shear stress and shear rate at some instant in time.

(b) In this report, the term instantaneous viscosity or apparent viscosity is simply defined as the viscosity measured at one specific shear rate.

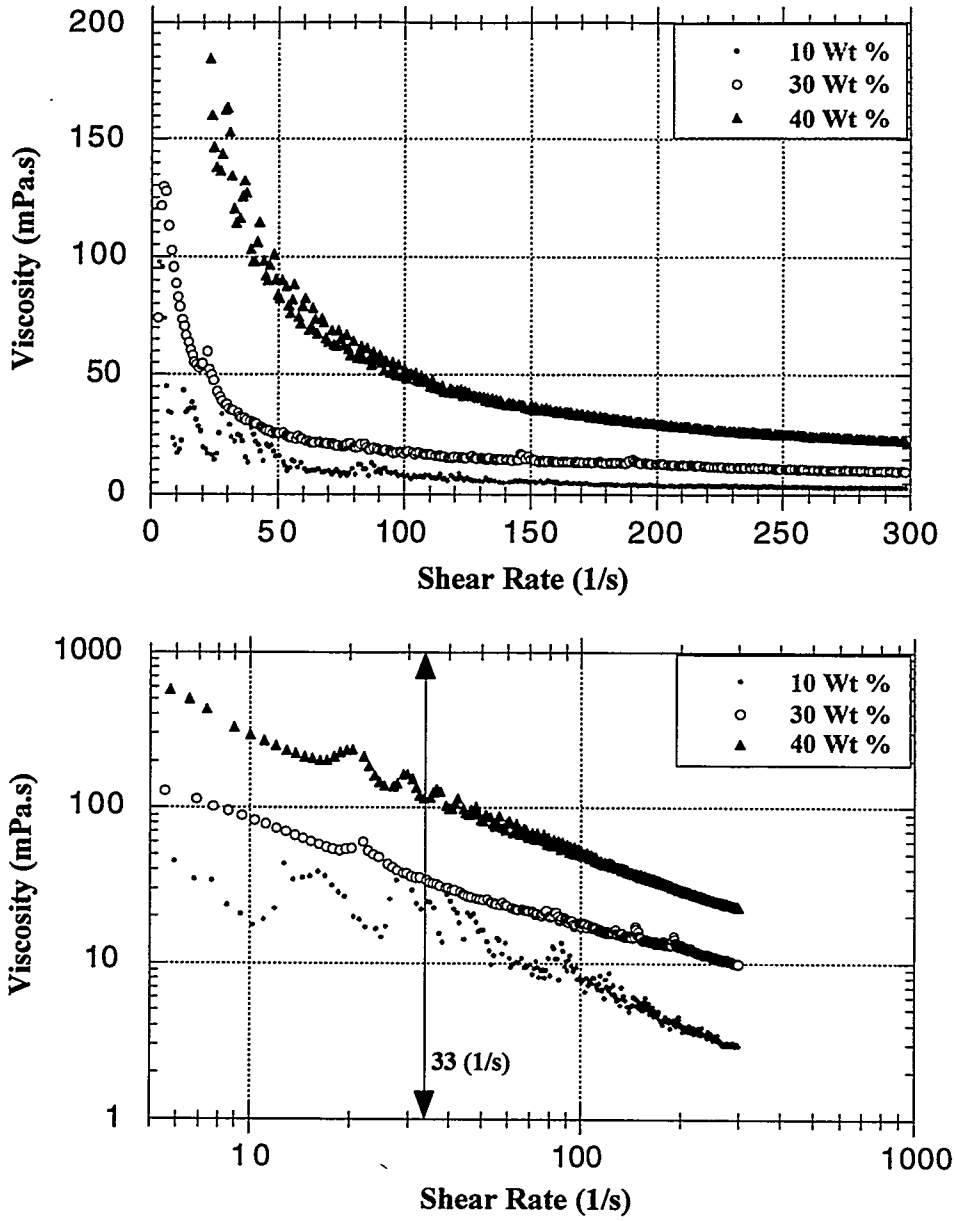


Figure 6.1. Viscosity as a Function of Shear Rate at 25°C for the AZ-101/102 Filtration Simulant

Figure 6.2 shows the plots of shear stress as a function of shear rate for the AZ-101/102 simulant slurry at 10, 30, and 40 wt% undissolved solids concentrations. The rheology of the AZ-101/102 simulant (0 to 300 s-1) at 30 and 40 wt% undissolved solids concentrations displays a yield stress of approximately 2.0 to 5.0 Pa. The maximum yield stress at lower solids loading of 10 wt% undissolved solids concentration is below 1.0 Pa. The yield stress was determined by extrapolating the linear portion of the measured shear stress in the direction of increasing shear rate ("up-curve") as a function of shear rate to shear rate = 0.

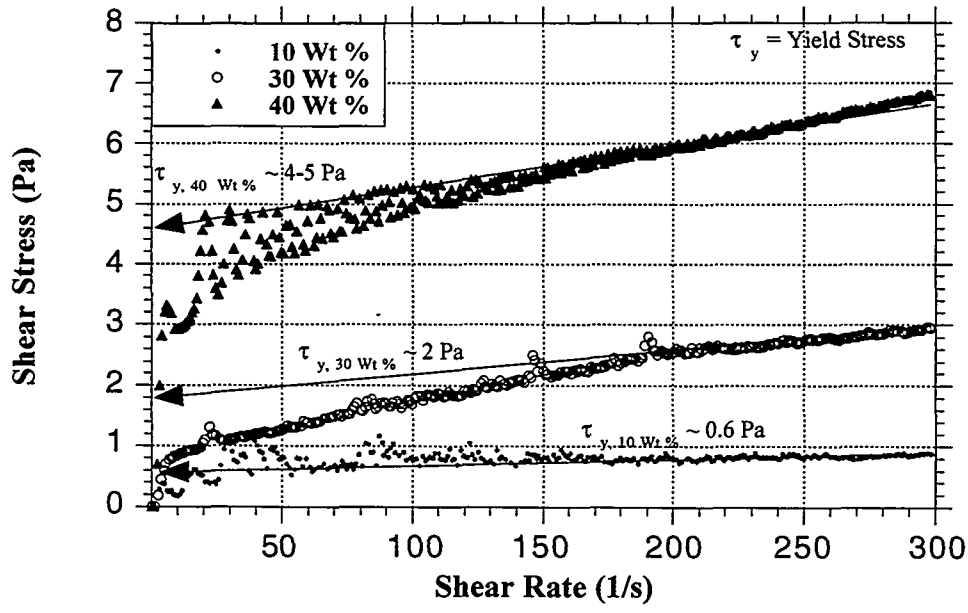


Figure 6.2. Shear Stress verses Shear Rate at 25°C for the AZ-101/102 Filtration Simulant

In all cases, the rheology of the AZ-101/102 simulant slurries (at various solids loading) is mathematically modeled as the Bingham rheology, which is commonly used to describe suspensions that exhibit yield-Newtonian behavior. A yield-pseudoplastic characteristics was observed between 0 to 300 s^{-1}, however, are observed because the rheogram was not measured at sufficiently high shear rates to detect the constant, high shear, Bingham viscosity. Mathematically, Bingham rheology differs from the yield pseudoplastic, but in practice, they are quite similar.

Furthermore as the solids content (wt% undissolved solids concentration) increases, the simulant shows a higher time-dependent rheology evident from the observed thixotropy in the shear-stress plots. The thixotropy (the difference between the up-curve and down-curve) is caused by agglomerates being broken down as the slurry is sheared during the course of the test. As the solids loading increases from 10 to 40 wt%, the slurry becomes highly agglomerated and this effect is more pronounced. In this case, as the shear rate increases at higher solids content, more of the structural

configurations (agglomerates) break down, and the shear stress and measured viscosity decrease, which result in a higher thixotropic hystresis loop (see Figure 6.3). The increased thixotropy and shear thinning as a function of solids loading indicates that for the flow velocity in the crossflow filtration re-circulation line, the AZ-101/102 simulant slurries will flow as a pseudo-homogeneous suspension.

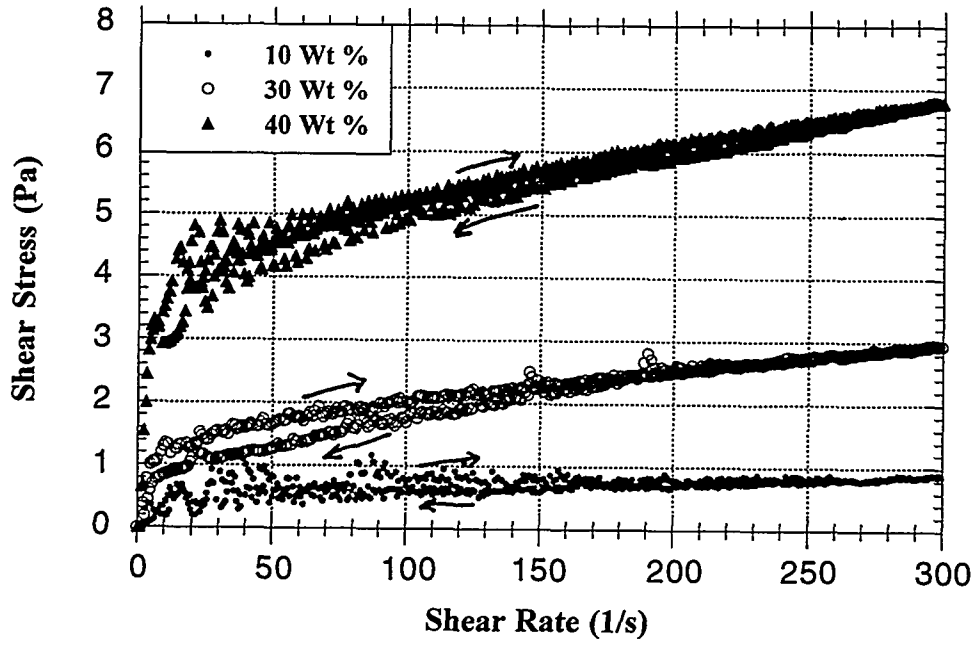


Figure 6.3. Shear Stress verses Shear Rate at 25°C for the AZ-101/102 Filtration Simulant Ascending and Descending Profiles

The rheological properties of the AZ-101/102 simulant slurries were compared to actual AZ-101 and AZ-102 core samples at 10, 30, and 40 wt% undissolved solids concentrations. The rheological measurements presented herein are for the radioactive and simulant slurries before any washing or caustic leaching pretreatment steps. Further, it should be noted that the rheograms of the actual waste data were not available. Instead, only the fitted parameters from the shear stress vs. shear rate curves were provided in the original source report. In these reports, the values listed in Table 6.1 were used to calculate shear stress as a function of shear rate using Equation (6.1) described below:

$$\sigma = \alpha + \beta \gamma^n \tag{6.1}$$

This equation is a nonlinear power law model fit where

σ = Shear stress (Pa)

γ = Shear Rate (s^{-1})

α = Yield stress (Pa)

β , n = Empirical constants often referred to as the coefficients of rigidity in the flow index.

Table 6.1. Results from the Fit to the Rheological Models for the NCAW Radioactive Slurries (Gary et al. 1990 and 1993)

Wt%	40	40	10	10	30	30	10	10	10
Data Set	1	2	1	2	1	2	1	2	3
α	2.02	2.12	0	0	1.26	1.29	0	0	0
β	0.0284	0.0081	0.0015	0.0019	0.05	0.03	0.08	0.024	0.059
n	0.7392	0.9554	0.9419	0.9306	0.7872	0.8664	0.5953	0.6856	0.6472
Temperature (C)	65	65	65	65	NK*	NK	NK	NK	NK

* NK= The temperatures at which these data were taken were not provided in the report but appear to be somewhere close to ambient.

The shear stress as a function of shear rate were calculated for the core samples from equation 6.1 and the fitted parameters listed in Table 6.1 at 10, 30, and 40 wt% solids. The actual waste shear stress profiles are shown in Figure 6.4.

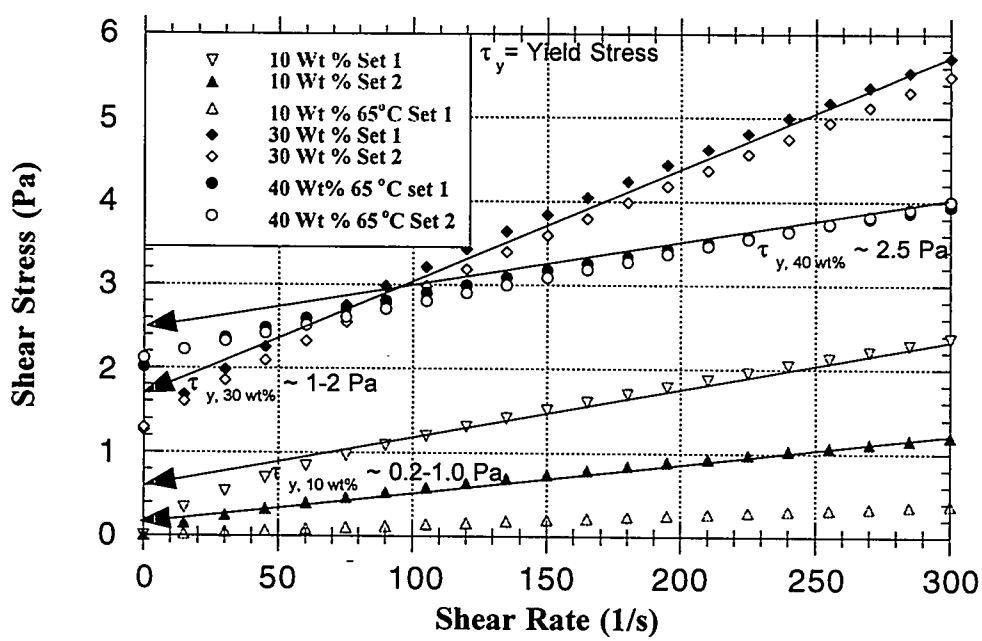


Figure 6.4. Shear Stress verses Shear Rate for the AZ-101/102 Actual Waste

Once again, the yield stress for the core samples was determined by extrapolating the linear portion of the measured shear stress in the direction of increasing shear rate ("up-curve") as a function of shear rate to shear rate = 0. The yield stress values for the core samples and the AZ-101/102 simulant slurries at similar solids contents are compared in Table 6.2. The yield stresses for the simulant slurries (see Figure 6.2) and the actual NCAW slurries are comparable. Although the yield stress values for the AZ-101/102 simulant slurries are higher than the radioactive slurries by a factor of 2, the differences are considered insignificant in discriminating the flow and rheological behavior of the simulant and radioactive slurries.

Table 6.2. Yield Stress for the Actual NCAW and AZ-101/102 Filtration Simulant

Wt %	Actual Waste Yield Stress (Pa)	AZ101/102 Filtration Simulant Yield Stress (Pa)
10	0.2–1	0.6
30	1–2	2
40	2.3–2.6	4–5

Using equation 6.1 the instantaneous viscosities as a function of shear rate were calculated for the actual waste by dividing the shear rate by the shear stress. The instantaneous viscosity profiles (see Figure 6.5) indicate that the AZ-101/102 simulant slurries replicate the viscosity behavior of the radioactive NCAW waste (core samples from tanks AZ-101 and AZ-102 wastes) fairly well at 10, 30 and 40 wt% un-dissolved solids concentrations as a function of shear rate. At shear rates of less than 30 s^{-1}, the instantaneous viscosity of the AZ-101/102 simulant slurries at all solids loading represent higher values, which desirably render the AZ-101/102 simulant slurries conservatively viscous.

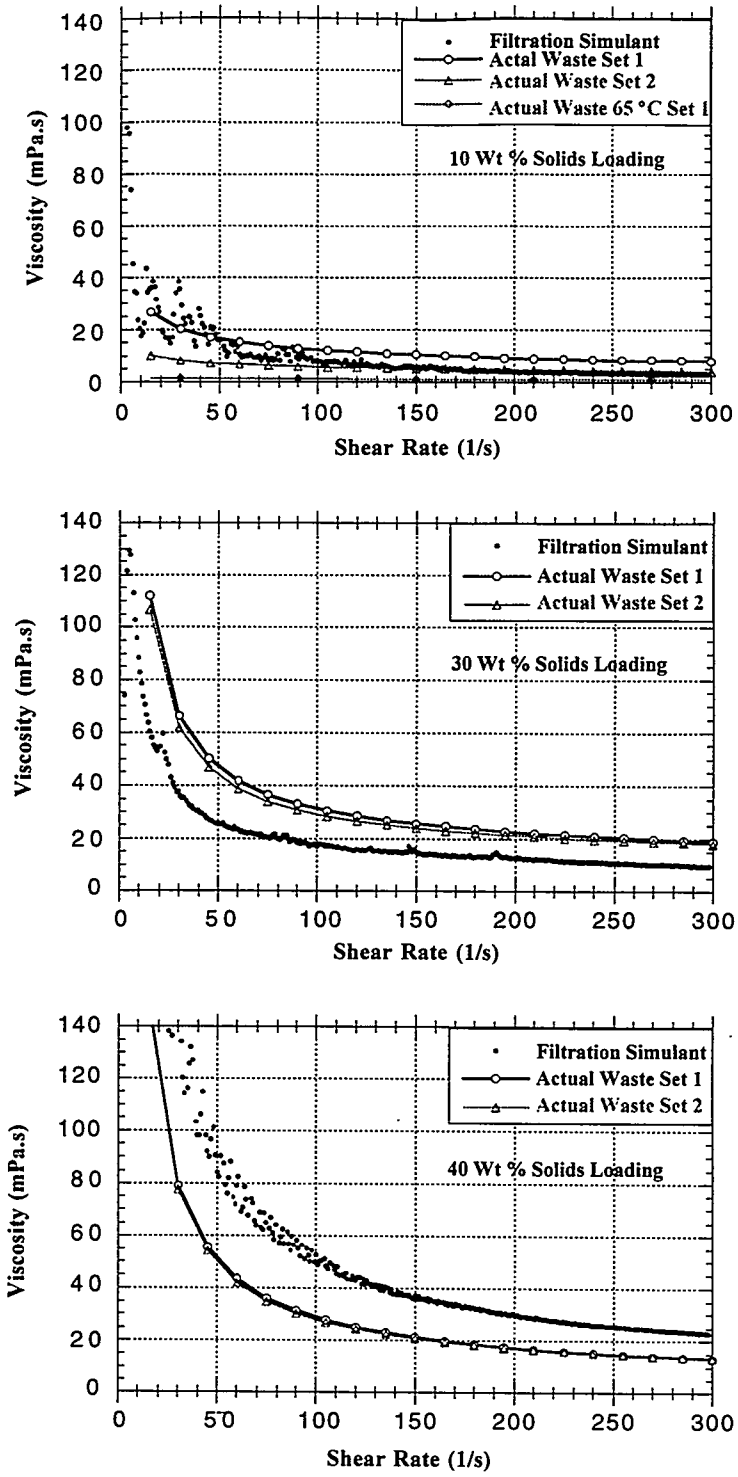


Figure 6.5 Viscosity as a Function of Shear Rate for the Actual AZ-101/102 waste and the AZ101/102 Filtration Simulant

6.1.3 Rheology of C-106 Slurries

The plots of instantaneous viscosity and experimental yield stress values for the C-106 simulant slurry at various solids loadings were determined from the controlled shear-rate experiments. Figure 6.6 shows the viscosity as a function of shear rate for the C-106 simulants at 20, 30, and 40 wt% undissolved solids concentrations in a linear scale.

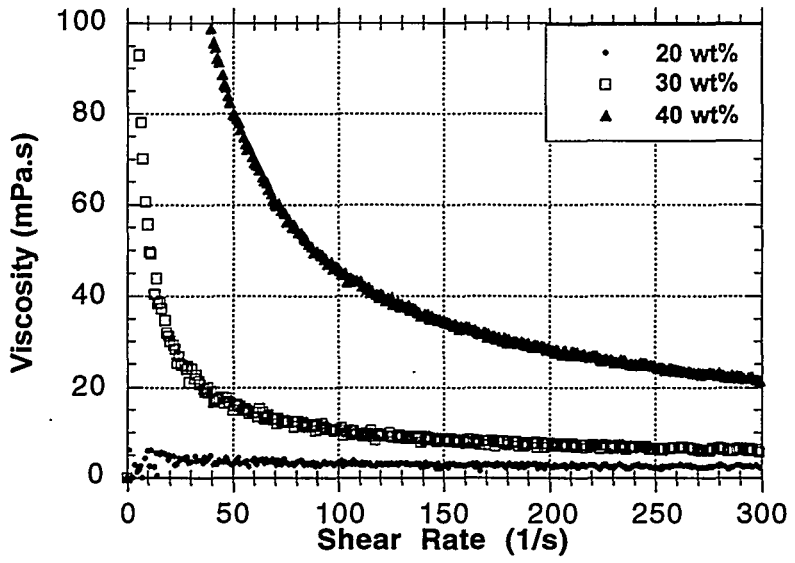


Figure 6.6 Viscosity as a Function of Shear Rate at 25°C for the C-106 Filtration Simulant

The plots of viscosity as a function of shear rate indicate that the viscosity for the C-106 simulants at all solids loadings drops to less than 25 mPa.s as the shear rate increases from about 0 to 300 s^{-1}, representing a common shear-thinning behavior. Figure 6.7 shows the plots of shear stress as a function of shear rate for C-106 simulant slurry at 10, 20, 30, and 40 wt% undissolved solids concentrations. The rheology of the C-106 simulant (0 to 300 s-1) at 30 and 40 wt% undissolved solids concentration displays a yield stress of approximately 1.0 to 4.0 Pa. The maximum yield stress at lower solids loadings of 10 and 20 wt% undissolved solids concentrations are below 1.0 Pa.

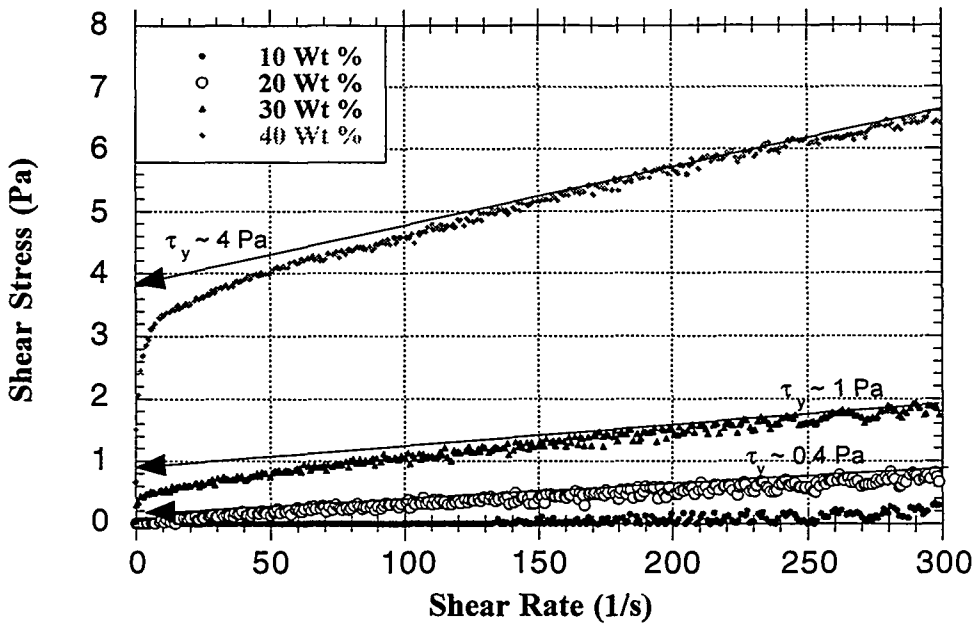


Figure 6.7 Shear Stress Verses Shear Rate at 25°C for the C-106 Filtration Simulant

6.2 Particle Size Distribution

The particle size distributions of the AZ-101/102 and C-106 filtration simulants are described below. The filtration simulant PSD was conducted for comparison with the particle size distribution of the actual waste. These measurements were conducted using the same instrument to produce actual waste data. The results for the actual waste particle size distributions are compared with the simulants. The criteria for developing a particle size distribution for the simulant were aimed at

- encompassing the particle size range observed in the actual waste
- achieving a poly-dispersed slurry system containing a broad range of sizes for selected solid phases
- representing a similar de-agglomeration trend as the actual waste when subjected to treatments of circulation and sonication in the particle-size analyzer flow loop
- modifying the PSD of simulants to attain a slurry that exhibit reduced filtrate flux over time comparable to the reduction seen with actual waste.

6.2.1 Experimental

A Microtrac X-100 Particle Analyzer was used to measure the PSD of these samples. The operation of the Mircotrac X-100 was checked against National Institute of Standards and Technology (NIST) traceable standards from Duke Scientific Corporation. The PSD results of NIST-traceable standards are documented in Appendix E.

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 particle size distribution of the simulants was measured on the Microtrac X-100 after applying a variety of circulation times, circulation flow rates, and sonication treatments identical to the actual waste. The treatments in successive order included 1) circulation at 40 mL/s, 2) circulation at 60 mL/s, and 3) circulation at 60 mL/s with 40 W sonication for 90 s. A detailed comparison of the flow condition in the PSD analyzer and crossflow filtration is presented in Section 6.2.3. For each sample, the particle size distribution 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 the surrogate supernatants specified in Section 3.0 so that the simulant PSD results can be related to the distribution of solids in the crossflow filtration loop. A 0.8 M NaOH/1.0 M $NaNO_3$ solution was used for measuring the PSD of the AZ-101/102 simulant, and a supernatant solution of 1.0 M NaOH/1.0 M $NaNO_3$ was used for the C-106 simulant slurry.

In Appendix E, the PSD plots for the samples 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 of 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 this case, larger particles are treated as more important in the distribution than the smaller particles.

6.2.2 Particle Size Distribution of AZ-101/102 Slurry

The PSD of actual AZ-101/102 waste was measured by Rapko et al. (1997) in three supernatant solutions (1) deionized (DI) water, (2) 0.1 M $NaNO_3$, and (3) 1.0 M $NaNO_3$. In this report, in order to compare the simulant characteristics under similar ionic strength conditions, the PSD of the actual AZ-101/102 waste obtained in a 1.0 M $NaNO_3$ solution was used to compare with the AZ-101/102 simulant PSD. Figure 6.8 shows a comparison of the cumulative undersize percentage as a function of the particle diameter for the actual waste and the simulant samples. Figure 6.9 illustrates the results as a volume-weighted distribution. It can be seen from Figures 6.8 and 6.9 that both the actual waste and the simulant exhibit a poly-dispersed behavior, and the simulant PSD range (0.7 to 74 μm) encompasses the spectrum of the particle sizes encountered in the actual waste (0.4 to 53 μm).

A close examination of the volume-weighted distribution plot (Figure 6.9) of the actual AZ-101/102 waste show a uniform distribution that can be approximated by three Gaussian distributions populated around 12.1, 3.0, and 1.0 μm. The simulant, on the other hand, exhibits more well-defined peaks at 18, 6.5, and 1.4 μm. Despite these slight differences in the distribution shape and the location of the peaks, the overall mean volume and number distribution of the actual waste compare very well with those measured with the simulant. For example, the mean volume and number distribution of the actual waste are 9.93 μm and 0.63 μm, respectively, whereas those of the simulant are 9.32 and 0.77 μm, respectively. The major particle-size peak modes along with the relative volume or number percentage that each peak represents are summarized in Table 6.3.

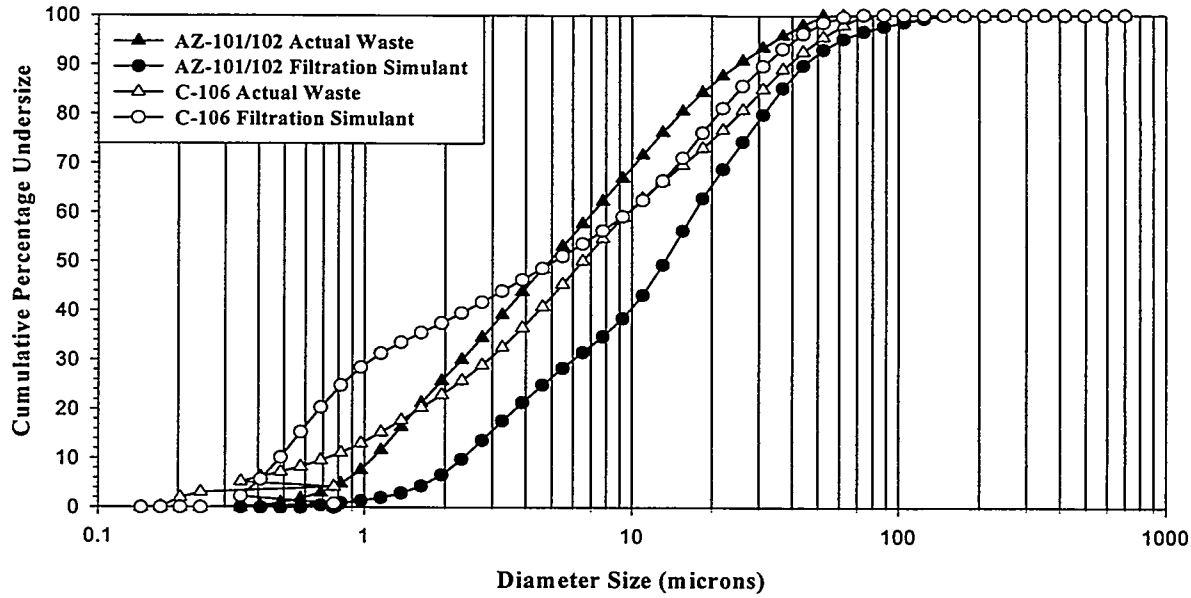


Figure 6.8. Cumulative Under-Size Percentage Distribution for Actual AZ-101/102 and C-106 Wastes Verses the AZ-101/102 and C-106 Filtration Simulant Slurries

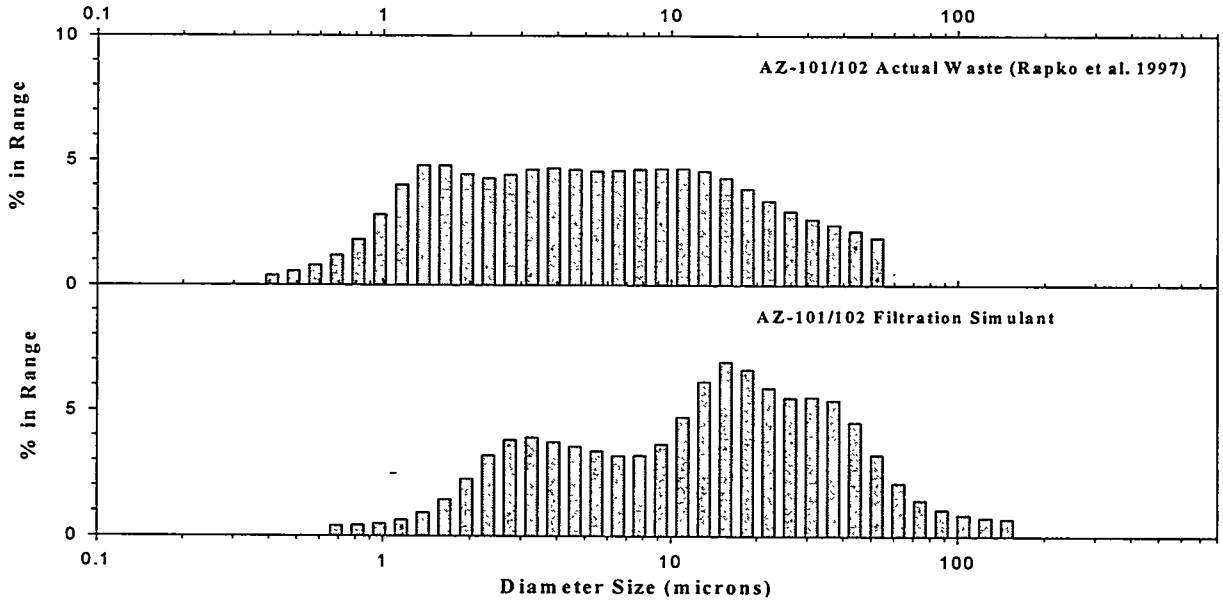


Figure 6.9. Volume-Weighted Distribution for AZ-101/102 Actual Waste and AZ-101/102 Filtration Simulant

Table 6.3. Particle Size Distribution of AZ-101/102 Samples

Sample	Volume-Weighted Distribution			Number-Weighted Distribution		
	Mode Diameter (μm)	Vol %	Width	Mode Diameter (μm)	Num %	Width
AZ-101/102 Actual waste	12.1	52 %	21.5	0.6	100 %	0.7
	3.0	23 %	1.8			
	1.2	25 %	0.9			
AZ-101/102 Filtration Simulant	17.9	31 %	17.8	0.4	100 %	0.6
	6.4	40 %	5.2			
	1.4	25 %	1.4			
AZ-101/102 Actual Waste, Sonicated	4.4	64 %	7.4	0.2	100 %	0.2
	1.1	30 %	0.7			
	0.3	6 %	0.1			
AZ-101/102 Filtration Simulant Sonicated	14.5	55 %	18.4	0.16	100 %	0.1
	0.9	20 %	0.8			
	0.3	18 %	0.2			
	0.1	7 %	0.03			

In crossflow filtration, a slight decrease in the filtrate flux is caused by the formation of a porous filter cake as the particles are deposited on the membrane surface. However, as small fine particles begin to plug the filter cake, the filtrate flux could decrease very rapidly and necessitate back flushing to regenerate the membrane. The shearing of the solids across the surface of the membrane/filter cake could produce fine particles which plug the membrane surface. Rapko et al. (1997) also measured the PSD of the actual waste after sonication. Although sonication does not represent the shear fields that are encountered in crossflow filtration, the data still provide some information regarding the breakup of the agglomerates.

Figure 6.10 shows a comparison of the volume-weighted distribution of the actual and simulated samples after sonication. It can be seen from Figure 6.10 that, although the simulant represented the PSD of the actual waste before sonication, the differences are much more pronounced after sonication. For example, 45% of the particles in the sonicated simulant sample are smaller than 1 μm whereas the sonicated actual waste sample has only 25% of the particles of <1 μm in size. In other words, the de-agglomerating nature of the actual waste is conservatively replicated by the simulant. Filtration (CUF) data obtained with actual AZ-102 waste were not available during the development of the simulant. Thus, the performance of the AZ101/102 filtration simulant for the crossflow filtration testing was not verified.

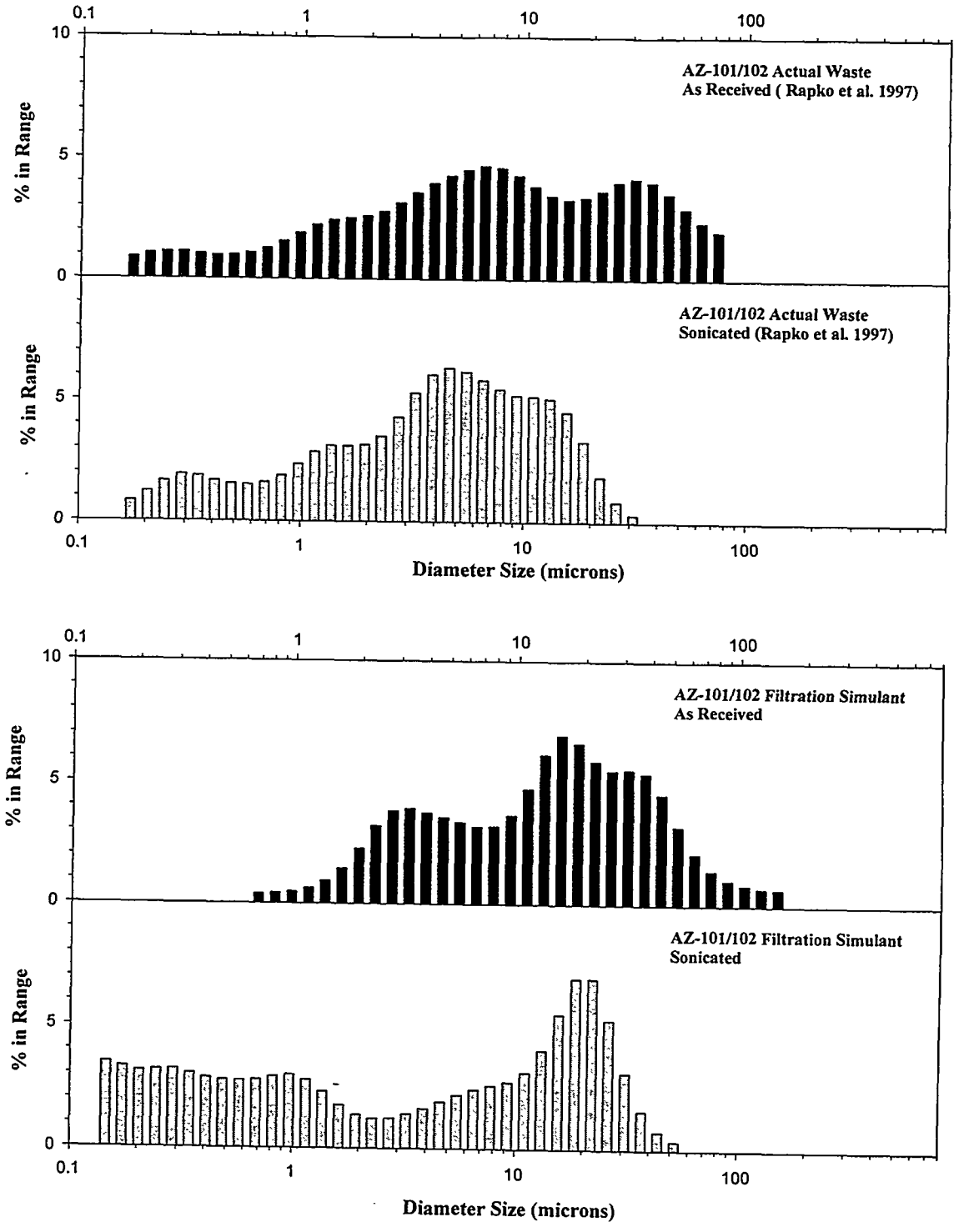


Figure 6.10. Volume-Weighted Distribution for AZ-101/102 Actual Waste and AZ-101/102 Filtration Simulant Before and After Sonication

6.2.3 Particle Size Distribution in Crossflow Filtration and X-100 Particle Analyzer

Solid particles are expected to de-agglomerate in the crossflow filtration loop as a result of the shearing that occurs. Similarly, the solid particles are subjected to a shear field by circulation in the particle size analyzer at setup velocities ranging from 1.3 – 3.4 m/s (40 mL/sec and 60 mL/sec). In order to compare the PSD anticipated during crossflow filtration to the PSD data obtained using the particle analyzer, the Reynolds numbers for the flow condition in the CUF and PSD analyzer were calculated. It is postulated that by comparing the Reynolds numbers, one can conceptualize the order of magnitude of the shear field that solid particles experienced in the crossflow filtration and particle-size analyzer and therefore relate the information from the particle analyzer to the crossflow filtration unit.

The Reynolds numbers for the simulant slurry in the crossflow filtration re-circulation line were calculated using measured slurry viscosities (see Section 6.1.2) and densities. Solids loading of 10, 20, and 30 wt% were used in the Reynolds number calculation. The diameter of the filter unit itself and the average velocity were also used in this calculation.

The Reynolds numbers for the particle size analyzer were calculated assuming that material being pumped had the viscosity and density of water. Since the solids concentration is diluted to less than 2 volume percent in order to conduct the PSD analyses, the solids concentration did not impact the solution properties. The results of these calculations are summarized in Table 6.4.

It can be seen from Table 6.4 that the Reynolds numbers for the crossflow filtration and the Microtrac X-100 particle size analyzer are comparable. With the exception of 30 wt% solids loading, the flow is maintained in a turbulent regime for both the Microtrac particle size analyzer and the crossflow filtration re-circulation lines. Thus, it is speculated that in qualitative terms, the particles experience similar vigorous mixing and shearing in the particle analyzer and the crossflow filtration unit. It should be noted that this simple methodology does not account for the kinetics of de-agglomeration as a function of circulation time.

Table 6.4. Calculated Reynolds Number for the Crossflow Filtration and Particle Analyzer

Crossflow Filtration System, 0.1-μm Mott Filter with 3/8 inch Inner Diameter					
Solids Loading (wt %)	Velocity		Slurry Viscosity (mPa.s)	Slurry Density (kg/m^3)	Reynolds Number
	(ft/s)	(m/s)			
10	12.2	3.7	2.17	1150	18760
20			4.03	1240	10880
30			9.90	1340	4800
Crossflow Filtration System, 0.5-μm Mott Filter with 0.5 inch Inner Diameter					
Solids Loading (wt %)	Velocity		Slurry Viscosity (mPa.s)	Slurry Density (kg/m^3)	Reynolds Number
	(ft/s)	(m/s)			
10	12.2	3.7	2.17	1150	16700

Table 6.4 Continued

20			4.03	1240	9670
30			9.9	1340	4270
Microtrac X-100 Particle size analyzer					
Tubing Diameter (mm)	Flow Rate (ml/s)	Flow Rate (m/s)	Slurry Viscosity (mPa.s)	Slurry Density (kg/m^3)	Reynolds Number
4.8	40	2.25	1.00	1	10690
6.3	40	1.26	1.00	1	8020
4.8	60	3.37	1.00	1	16040
6.3	60	1.90	1.00	1	12030

6.2.4 Particle Size Distribution of C-106 Slurry

The PSD of actual C-106 waste was measured by Lumetta et al. (1996) in three supernatant solutions: 1) DI water, 2) 0.1 M $NaNO_3$, and 3) 1.0 M $NaNO_3$. Once again in this report, in order to compare the simulant characteristics under similar ionic strength conditions, the PSD of the actual C-106 waste was conducted in a 1.0 M $NaNO_3$ solution. The cumulative undersize percentage data as a function of the particle diameter for the actual C-106 waste and the simulant samples are shown in Figure 6.8. Figure 6.11 illustrates the results as a volume-weighted distribution. It can be seen from Figure 6.11 that the simulant exhibits poly-dispersed behavior similar to actual waste. Further, the simulant PSD range (0.3 to 88 μm) encompasses the spectrum of the particle sizes encountered in the actual waste (0.2 to 62 μm).

A close examination of the volume-weighted distribution plot (Figure 6.11) of the actual C-106 waste shows a uniform distribution that can be approximated by three Gaussian distributions populated around 28.8, 3.8, and 0.2 μm. The simulant, on the other hand, exhibits two well-defined peaks at 22 and 0.6 μm. There are differences between the distribution shape and the location of the peaks. In the case of the C-106 simulant, a modal distribution that was centered around 0.6 μm was deliberately introduced. This distribution was inserted into the simulant formulation as a compromise to achieve similar crossflow filtration fluxes as the actual C-106 waste (see Section 6.2). These small particles were also added to the simulant slurry to generate a C-106 filtration simulant that exhibits de-agglomeration and formation of small fine particles that begin to plug the filter cake. By deviating from the actual C-106 waste PSD, we were able to formulate a simulant that generated smaller agglomerates at comparable time scales as the actual C-106 waste under similar vigorous mixing and shearing of particles in the CUF. Earlier, C-106 simulant formulations, which replicated the PSD of actual waste very well, did not show a similar decline in the filtration flux as a function of re-circulation time.

The mean volume and number distribution of the actual waste are 13.7 μm and 0.2 μm, respectively, whereas those of the simulant are 11.3 and 0.3 μm, respectively. The mean volume and number distribution of the actual waste compare fairly well with those measured with the simulant. The major particle-size peak modes along with the relative volume or number percentage that each peak represents are summarized in Table 6.5.

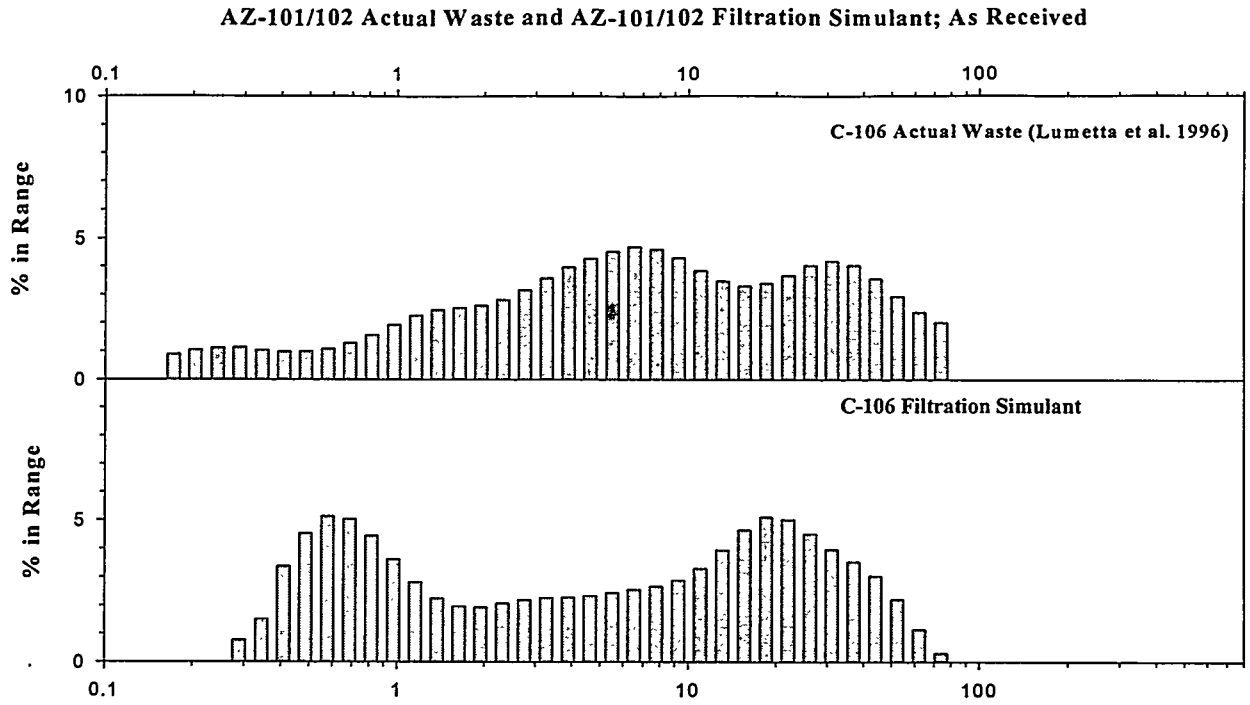


Figure 6.11. Volume-Weighted Distribution for C-106 Actual Waste and C-106 Filtration Simulant

Table 6.5. Particle Size Distribution of C-106 Samples

Sample	Volume –Weighted Distribution			Number –Weighted Distribution		
	Mode Diameter (μm)	Vol %	Width	Mode Diameter (μm)	Num %	Width
C-106 Actual Waste	28.8	34 %	31.9	0.2	100 %	0.1
	3.8	61 %	7.2			
	0.2	5 %	0.1			
C-106 Filtration Simulant	22.0	59 %	16.0	0.3	100 %	0.1
	6.5	12%	0.7			
	0.6	29 %	1.7			
C-106 Actual Waste, Sonicated	5.5	76 %	10.0	0.2	100 %	0.1
	0.9	13 %	0.6			
	0.3	11 %	0.2			
C-106 Filtration Simulant, Sonicated	16.14	57 %	18.4	0.2	100	0.1
	0.8	24 %	0.8			
	0.2	19 %	0.2			

Similar to AZ-102, the shearing of the solids across the membrane/filter cake surface could produce the fine particles to plug the membrane surface that may be simulated in the PSD analyzer with sonication. Although sonication does not represent the shear fields that are encountered in crossflow filtration, the data still provide some information regarding the breakup of the agglomerates. Lumetta et al. (1996) also measured the PSD of the actual waste after sonication.

Figure 6.12 shows a comparison of the volume-weighted distribution of the actual and simulated samples after sonication. It can be seen from Figures 6.12 and 6.13 that the differences are much more notable after sonication. For example, 43% of the particles in the sonicated simulant sample are smaller than 1 μm whereas the sonicated actual waste sample has only 24% of the particles of <1 μm size.

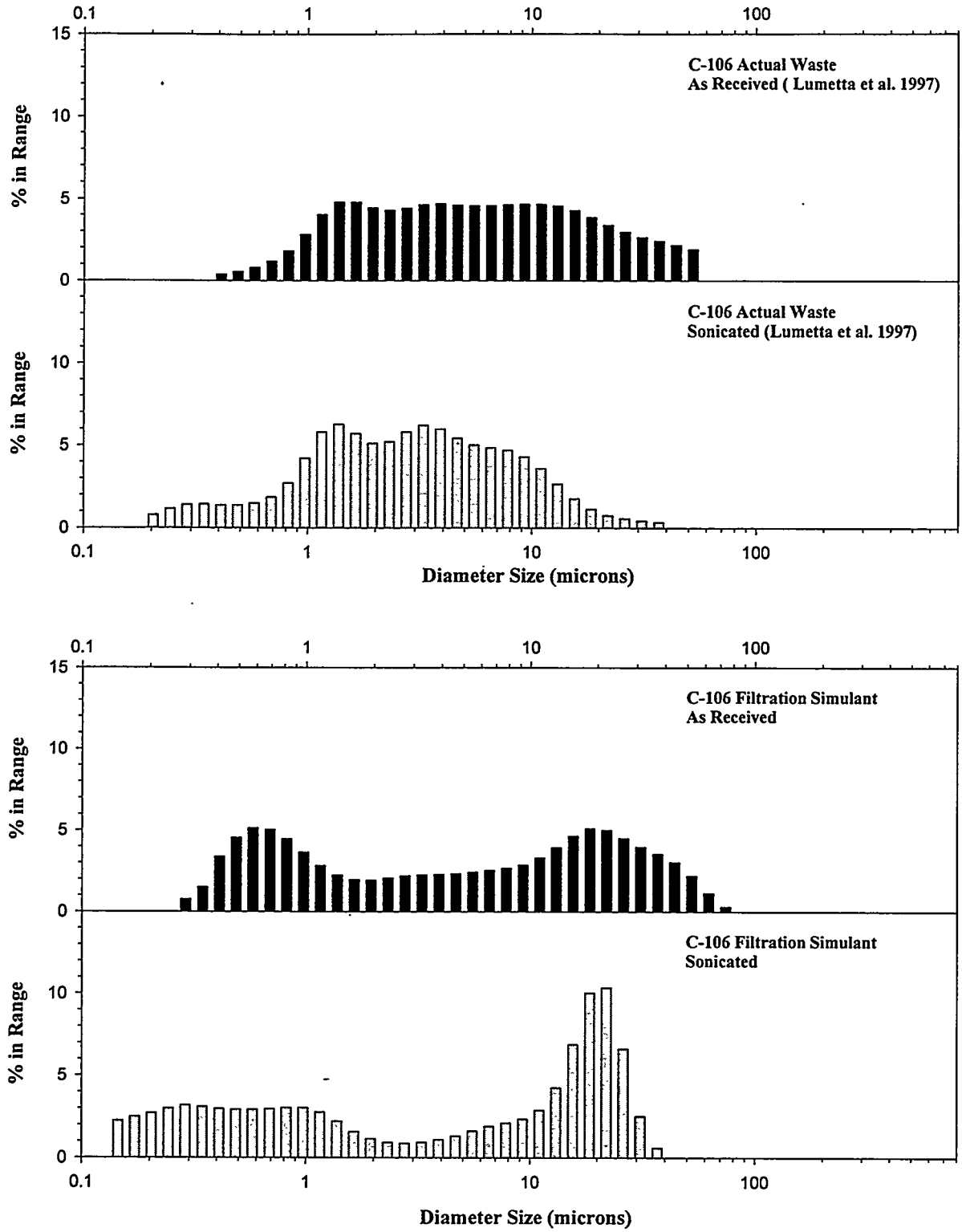


Figure 6.12. Volume-Weighted Distribution for C-106 Actual Waste and C-106 Filtration Simulant before and after Sonication

7.0 Conclusions and Recommendations

Based on the testing and analysis performed on HLW AZ-101/102 and C-106 crossflow filtration simulants, the following conclusions and recommendations were obtained. They have been divided in two categories for clarity.

Conclusions

C-106

- The C-106 crossflow filtration simulant performance in the CUF suggested that the simulant accurately models the actual C-106 waste in its filtration characteristics. The rheological properties of the C-106 simulant require verification with actual waste data because the available C-106 radioactive rheological data were not applicable for such evaluations. The rheology of actual C-106 waste was conducted at too low of solids loading.

NCAW

- The PSD and rheology of the actual NCAW slurry were emulated well by the AZ-101/102 filtration simulant. This simulant exhibited an overall decrease in filtrate flux over time, similar to what was seen in most CUF testing of other actual waste samples due to 1) filter fouling and 2) agglomerate break-up due to vigorous mixing and the pump shear in the CUF circulation line.
- The AZ-101/102 simulant crossflow filtration needs to be verified by comparing with actual NCAW results as a means to establish confidence in quantifying how closely the actual waste filtration performance is emulated by the simulant.
- Overall simulant properties, such as PSD and mineral composition, rheology, and filterability will vary from those listed in this report if alternative sources for simulant minerals and product brand name are used. Detailed simulant characterization and crossflow filtration performance testing are required if alternative commercial products are used. Such results should emulate the simulant properties documented in this report.

Recommendations

- Care should be taken in use of alternative commercial sources for simulants. The chemical and physical properties for each product description listed in Appendix A need to be matched in the case of choosing another commercial source.
- The applicability of these simulants for filtration studies of washed solids is uncertain and requires additional evaluation. These simulants have not been developed to mimic the chemical properties of the sludge, and their use for washing and caustic leaching experiments is not recommended.
- The application of these simulants for vitrification studies to make melter feeds for the purpose of preparing glass for waste form evaluation, final glass composition, or chemical durability, melt viscosity, etc. are not recommended. The elemental composition of all oxides, carbonates, and other salts with appropriate substitutions for radioisotopes significant to vitrification studies are not duplicated.
- Addition of the iron-bearing goethite (α-FeOOH) phase to the simulant formulation may improve the simulant performance in replicating the actual waste filtration behavior. Further testing is suggested to examine this hypothesis. If improvements resulted, an inexpensive acicular mineral source similar in properties to goethite needs to be identified and included in the formulation of the simulants.

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Appendix A: Material Safety Data Sheets

Boehmite

MATERIAL SAFETY DATA SHEET

10, 15, 20, 30 & 40

ALCOA

NO. 272

3502 South Riverview Drive, Port Allen, LA 70767

Original: July 1, 1996

Product Name: PSEUDOBOEHMITE ALUMINA

Alcoa Alumina & Chemicals, L.L.C., 425 Sixth Avenue, Pittsburgh, PA 15219-1850 USA

Emergency Phone: 1-412-553-4001

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Chemical Formula: $Al_2O_3 \cdot H_2O$

HIQ 10

Product Use: Catalyst supports, binders, abrasives/polishing compounds, and viscosifiers.

Other Designations: Hydrated alumina, Aluminum oxide hydroxide, HiQ®-x alumina, where x is a number or number and letter(s) designating various products.

Manufacturer: Alcoa Port Allen Works

USA Phones: Chemtrec: 1-800-424-9300; Health & Safety: 1-412-553-4649; Product Information: 1-504-382-3336
1-504-389-9945

2. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous ingredients are listed if they comprise ≥ 1.0% by weight. "Special Hazardous Substances" (Pennsylvania Right-to-Know Regulations) are listed if they comprise ≥ 0.01% by weight.

Component	CAS No.	EINECS No.	Typical % by Weight	Form	EXPOSURE LIMITS (TWA in mg/m³) ACGIH TLV	OSHA PEL
Aluminum oxide (non-fibrous)	1344-28-1	2152843	75	Total dust	10	15
				Respirable	—	5
Water	—	—	25	—	—	—

3. HAZARDS INFORMATION

EMERGENCY OVERVIEW

White crystalline powder; odorless; non-flammable, non-corrosive; not an explosion hazard. Can cause irritation to the eyes, skin, and respiratory tract.

Potential Health Effects

EYES: Can cause mild irritation.
SKIN: Can cause mild irritation.
INHALATION: Can cause mild upper respiratory tract irritation.
INGESTION: May cause mild irritation.

Alumina is a low health risk by inhalation. Treat as a nuisance dust as specified by the ACGIH.

Medical conditions aggravated by exposure to the product:
Asthma, chronic lung disease, and skin rashes.

4. FIRST AID MEASURES

EYES: Flush eyes with plenty of water or saline for at least 15 minutes. Consult a physician if irritation persists.
SKIN: Wash with soap and water for at least 15 minutes. Consult a physician if irritation persists.
INHALATION: Remove to fresh air. Check for clear airway, breathing, and presence of pulse. Provide CPR for persons without pulse or respirations. Consult a physician.
INGESTION: If swallowed, dilute by drinking large amounts of water. *Never give anything by mouth to a convulsing or unconscious person.* Do **not** induce vomiting. Consult a physician.

5. FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES: Non-flammable.
Flash Point: None.
Flammable Limits: Not applicable.

AUTO-IGNITION TEMPERATURE: Not applicable.

PRODUCTS OF DECOMPOSITION: None.

EXTINGUISHING MEDIA: Use extinguishing agent applicable to surrounding fire.

FIRE FIGHTING INSTRUCTIONS: Fire fighters should wear NIOSH approved. positive pressure. self-contained breathing apparatus and full protective clothing when appropriate.

6. ACCIDENTAL RELEASE MEASURES

SMALL/LARGE SPILL: Clean up using dry procedures; avoid dusting.

7. HANDLING AND STORAGE

HANDLING: Avoid dusting and contact with eyes and skin. Avoid inhaling dust.

STORAGE: Keep material dry.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS: Use with adequate ventilation to meet exposure limits listed in Section 2.

RESPIRATORY PROTECTION: Use NIOSH-approved dust respirator if potential for overexposure exists.

EYE PROTECTION: Wear safety glasses to avoid eye contact.

SKIN PROTECTION: Wear appropriate gloves to avoid direct skin contact.

9. PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE: White crystalline powder
BOILING POINT: Not applicable
FREEZE-MELT POINT: Not determined
VAPOR PRESSURE (mm): Not applicable
VAPOR DENSITY (air = 1): Not applicable
SOLUBILITY IN WATER: Nil
SPECIFIC GRAVITY: See Density
DENSITY: Loose bulk: 37-50 lb/ft^3 (0.6-0.8 g/cm^3)
pH: Not determined
ODOR: None
ODOR THRESHOLD (ppm): Not applicable
COEFFICIENT OF WATER/OIL DISTRIBUTION: Not applicable

10. STABILITY AND REACTIVITY

Chemical Stability: Stable under normal conditions of use, storage, handling and transportation.
With heat: When exposed to fire or heat, hydrated alumina loses its water of crystallization beginning at 392°F (200°C).

Non-corrosive

11. TOXICOLOGICAL INFORMATION

LD_{50} or LC_{50} found for oral, dermal or inhalation routes of administration:

This product has not been specifically tested. Data for similar products are provided below:

Eyes: Rabbit eye irritation index: 6 (Max. score possible is 110); minimally irritating

Skin: Primary skin irritation index (rabbits): 0.0 (Max. score is 8.0); not a primary skin irritant.
Acute dermal LD_{50} (rabbits): >2 g/kg; practically non-toxic.

Inhalation: Inhalation of fine particles (6-8 microns diameter) for 4 hours by rats resulted in no signs of toxicity.
Rats survived exposure to a concentration of 83 mg/l for one hour

Ingestion: Acute oral LD_{50} (rat) - >5 g/kg; practically non-toxic.

12. ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL/CHEMICAL FATE INFORMATION: No information found.

13. DISPOSAL CONSIDERATION

Collect in containers, bags, or covered dumpster boxes. If reuse or recycling is not possible, material may be disposed of at an industrial landfill.

RCRA Hazardous Waste No.: Not federally regulated in the U.S.

14. TRANSPORT INFORMATION

U.S.A. DOT: Not Regulated.– Enter the proper freight classification, "MSDS Number," and "Product Name" on the shipping paperwork.

Canadian TDG Hazard Class & PIN: Not regulated.

15. REGULATORY INFORMATION

U.S. Federal Regulations

TSCA STATUS: All components of this product are listed on the TSCA inventory.

CERCLA HAZARDOUS SUBSTANCES: None.

SARA TITLE III:

Section 311/312 Physical and Health Hazard Categories: Immediate (acute).

Section 313 Toxic Chemicals: None.

In reference to Title VI of the Clean Air Act of 1990, this material does not contain nor was it manufactured using ozone-depleting chemicals.

International Regulations

CANADIAN DOMESTIC SUBSTANCES LIST: All components of this product are listed on the Canadian DSL.

EUROPEAN COMMUNITY: All components of this product are listed on ECOIN, the European Core Inventory.

AUSTRALIA: All components of this product are listed on the AICS inventory.

JAPAN: All components of this product are listed on MITI, the Ministry of International Trade Industry.

16. OTHER INFORMATION

MSDS STATUS: Original issue
PREPARED BY: Hazardous Materials Control Committee.

HAZMIN Number: 042402

- Guide to Occupational Exposure Values-1995, Compiled by the American Conference of Governmental Industrial Hygienists (ACGIH).
- Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, 1991, Compiled by the American Conference of Governmental Industrial Hygienists, Inc. (ACGIH).
- NIOSH Pocket Guide to Chemical Hazards, U.S. Department of Health and Human Services. June 1994.
- Dangerous Properties of Industrial Materials, Sax, N. Irving, Van Nostrand Reinhold Co., Inc., 1984.
- Patty's Industrial Hygiene and Toxicology: Volume II: Toxicology, 4th ed., 1994, Patty, F. A.; edited by Clayton, G. D. and Clayton, F. E.: New York: John Wiley & Sons, Inc.

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LEGEND:

ACGIH	American Conference of Governmental Industrial Hygienists
AICS	Australian Inventory of Chemical Substances
CAS	Chemical Abstract Services
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOT	Department of Transportation
DSL	Domestic Substances List (Canada)
ECOIN	European Core Inventory
EPA	Environmental Protection Agency
IARC	International Agency for Research on Cancer
LC_{50}	Lethal concentration (50 percent kill)
LC_{Lo}	Lowest published lethal concentration
LD_{50}	Lethal dose (50 percent kill)
LD_{Lo}	Lowest published lethal dose
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PIN	Product Identification Number
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
STEL	Short Term Exposure Limit
TCLP	Toxic Chemicals Leachate Program
TDG	Transportation of Dangerous Goods
TLV	Threshold Limit Value
TSCA	Toxic Substances Control Act
TWA	Time Weighted Average

atm	atmosphere
cm	centimeter
g, gm	gram
in	inch
kg	kilogram
lb	pound
m	meter
mg	milligram
ml, ML	milliliter
mm	millimeter
n.o.s.	not otherwise specified
ppb	parts per billion
ppm	parts per million
psia	pounds per square inch absolute
µ, u	micron
µg	microgram

Gibbsite

Aluminum Company of America

ALCOA

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

* 1 CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

· Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

· Other Designations:
Aluminum Trihydroxide ATH Series, Bayer Hydrated Alumina, Bayerite, BayGraNite(TM), Bayer Scale Fines, C-230, C-231, C-30, C-33/31, C-31C, C-37G, C-330, C-333/331, C-40, C-430, C-431, C-530, C-531, C-DPS-1, C-NEV-1, Coated ATH, CHSO-1, CV-3002, CV-3003, CV-3004, Flame Gard(R) Series, Hydral(R) Series, Hydral(R) 705, Hydral(R) 707, Hydral(R) 710, Hydral(R) 716, Hydral(R) 719, Hydral(R) Brite 100, Hydral(R) Coat 2, Hydral(R) Coat 5, Hydral(R) Coat 7, Hydral(R) PGA, Hydral(R) PGA SD, Hydrate 17LVB, Hydrogard CP, Hydrogard GP, Hydrogard HI, HyGraNite(TM) Series, KB-30, KB-308, KC-30, KH-30, LD-100, Lubral CSP, Onyx Classica Series, P-3, P-5, P-7, SpaceRite(TM) Series, SRP-A-11, SRP-A-12, SRP-A-13, SRP-A-14, SRP-A-17, SRP-A-18, and SRP-A-89E.
(R) Registered Trademark of Aluminum Company of America
(TM) Trademark of Aluminum Company of America

· Manufacturer/Supplier:
Alcoa Alumina & Chemicals, L.L.C.
PO Box 300, Bauxite, AR 72011
Tel: +1-501-776-4654
+1-800-860-3290

Alcoa Point Comfort Operations
State Highway 35, Point Comfort
Calhoun County, TX 77978-0101
Tel: +1-512-987-2631

Dalton Alumina & Chemicals Co., Inc.
PO Box 1601
Dalton, GA 30722
+1-706-278-4434

Alcoa of Australia Ltd. - Kwinana Works
PO Box 161, Kwinana
Western Australia 6167 Australia
Tel. +61-9-410-3111

Alcoa Moerdijk B.V.
Vlasweg 19
4782 PW Moerdijk
The Netherlands
+31-168-324865

Alcoa Aluminio SA
Rodovia Pocos/Andradas, Km 10
37701-970 Pocos de Caldas MG
Brazil
+55-35-729-5000

· Emergency Information:
USA: Chemtrec: +1-703-527-3887 +1-800-424-9300 ALCOA: +1-412-553-4001

* 2 Composition/Data on components:

Components:
21645-51-2 Aluminum trihydroxide (non fibrous) 99.5 %
EINECS: 244-492-7

· Additional information:
Loss on ignition 34-35 %

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

* 3 Hazards identification

· EMERGENCY OVERVIEW:
Can cause mild irritation to eyes, skin, and upper respiratory tract.

· Hazard description:
· Medical conditions aggravated by exposure to the product:
Asthma, chronic lung disease, and skin rashes.
· Information pertaining to particular dangers for man and environment
· See item 11.
· Classification system
The classification was made according to the latest editions of the EU-lists, and expanded upon from company and literature data.

* 4 First aid measures

· After inhalation
Remove to fresh air.
Check for clear airway, breathing, and presence of pulse.
Provide cardiopulmonary resuscitation for persons without pulse or respirations.
Consult a physician.
· After skin contact
Wash with soap and water for at least 15 minutes.
Consult a physician if irritation persists.
· After eye contact
Flush eyes with plenty of water for at least 15 minutes.
Consult a physician.
· After swallowing
Do not induce vomiting.
Never give anything by mouth to a convulsing or unconscious person.
If swallowed, dilute by drinking large amounts of water.
Consult a physician.

5 Fire fighting measures

· Suitable extinguishing agents
Use fire fighting measures that suit the environment.
· Protective equipment:
Wear self-contained respiratory protective device.
Wear fully protective suit.

* 6 Accidental release measures

· Person-related safety precautions: Wear protective clothing.
· Measures for environmental protection: No special measures required.
· Measures for cleaning/collecting:
Clean up using dry procedures; avoid dusting.

* 7 Handling and storage

· Handling
· Information for safe handling:

(Contd. on page 3)

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

(Contd. from page 2)

Ensure good ventilation/exhaust at the workplace.
Prevent formation of dust.
Provide suction extractors if dust is formed.
· Information about protection against explosions and fires:
No special measures required.

· Storage
· Requirements to be met by storerooms and receptacles:
Keep material dry.
· Information about storage in one common storage facility: Not required.
· Further information about storage conditions: None.

* 8 Exposure controls and personal protection

· Additional information about design of technical systems:
No further data; see item 7.

Components with limit values that require monitoring at the workplace:
The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.

· Personal protective equipment
· General protective and hygienic measures
Avoid contact with the eyes.
Do not inhale dust.
· Breathing equipment:
Use suitable respiratory protective device in case of insufficient ventilation.
Short term filter device:
Filter P2.
· Protection of hands: Impervious gloves.
· Eye protection: Safety glasses.

* 9 Physical and chemical properties:

· Form: Crystalline powder
· Color:
White
Whitish
· Odor: Odorless

	Value/Range	Unit	Method
· Change in condition			
· Melting point/Melting range:	2040	° C	
· Boiling point/Boiling range:	2980 ° C ± 60	° C	
· Flash point:	Not applicable		
· Auto igniting:	Product is not self igniting.		

· Danger of explosion:
Product does not present an explosion hazard.

(Contd. on page 4)

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

(Contd. from page 3)

· Density:	at	20 ° C	2.4 g/cm3	
· Bulk density:	at	20 ° C	0.15-1.3 g/cm3	
· Solubility in / Miscibility with · Water:			Insoluble	
· pH-value:	at	20 ° C	8.5-10.2	20% in H2O
· Solvent content:				
· Organic solvents:			0.0 %	
· Water:			0.0-1.0 %	
· Solids content:			99.0 %	

* 10 Stability and reactivity

· Thermal decomposition / conditions to be avoided:
No decomposition if used according to specifications.
· Dangerous reactions:
When exposed to fire or heat, hydrated alumina loses its water cf crystallization beginning at 200°C (390°F).
· Dangerous products of decomposition:
No dangerous decomposition products known.
Coated ATH: Formaldehyde, Carbon monoxide and carbon dioxide.
· Additional information: Non-corrosive.

* 11 Toxicological information

· Primary irritant effect:
· On the skin: Can cause mild irritation.
· On the eye: Can cause mild irritation, especially when wet.
· Inhalation: Can cause mild upper respiratory tract irritation.
· Ingestion: Can cause mild irritation.
· Additional toxicological information:
The product is not subject to classification according to the calculation method of the General EU Classification Guidelines for Preparations as issued in the latest version:

* 12 Ecological information:

· General notes:
Water hazard class 0 (German Regulation) (Self-assessment): generally not hazardous for water.

* 13 Disposal considerations

· Product:
· Recommendation
Collect in containers, bags, or covered dumpster boxes. If reuse or recycling is not possible, material may be disposed of at an industrial landfill.

(Contd. on page 5)

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

(Contd. from page 4)

· European Community Waste disposal key: 16 03 01 513 08

· Uncleaned packagings:
· Recommendation:
Disposal must be made according to official regulations.

* 14 Transport information

· DOT regulations:
· Remarks:
U.S.A. DOT: Not regulated - Enter the proper freight classification. "MSDS Number," and "Product Name" on the shipping paperwork.
Canadian TDG Hazard Class & PIN: Not regulated.

· Maritime transport IMDG:
· Marine pollutant: No

* 15 Regulations

· U.S. Federal Regulations:
· TSCA STATUS:
All components of this product are listed on the TSCA inventory.
· CERCLA REPORTABLE QUANTITY: None.
· SARA TITLE III:
Section 302 Extremely Hazardous Substances:
None.
· Section 311/312 Hazardous Categories: None.
· Section 313 Toxic Categories: None.
· OTHER INFORMATION:
In reference to Title VI of the Clean Air Act of 1990, this material does not contain nor was it manufactured using ozone-depleting chemicals.

· Markings according to EU guidelines:
Observe the general safety regulations when handling chemicals.
The product is not subject to identification regulations under EU Directives and the Ordinance on Hazardous Materials (GefStoffV).

· National regulations

· Classification according to VbF: Void
· International Regulations:
· CANADIAN DOMESTIC SUBSTANCES LIST:
All components of this product are listed on the Canadian DSL.
· AUSTRALIAN INVENTORY OF CHEMICAL SUBSTANCES:
All components of this product are listed on the AICS.
· JAPAN Ministry of International Trade Industry (MITI):
All components of this product are listed on MITI.

Material Safety Data Sheet
acc. to 91/155/EEC

Printing date 08/18/98 Reviewed on 06/26/98

Product Name: Hydrated Aluminas/Aluminum Trihydroxide 839

* 16 Other information:
This information is based on our present knowledge. However, this shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.

- Department issuing MSDS:
Hazardous Materials Control Committee, Alcoa, Pittsburgh, PA 15219 USA
26.06.98 Supersedes 20.02.98
- Alcoa MS #: 134231
- Appendix:
  - Guide to Occupational Exposure Values 1997, Compiled by the American Conference of Governmental Industrial Hygienists (ACGIH).
  - Documentation of the Threshold Limit Values and Biological Exposure Indices, Sixth Edition, 1991, Compiled by the American Conference of Governmental Industrial Hygienists, Inc. (ACGIH).
  - NIOSH Pocket Guide to Chemical Hazards, U.S. Department of Health and Human Services, June 1994.
  - Dangerous Properties of Industrial Materials, Sax, N. Irving, Van Nostrand Reinhold Co., Inc., 1984.
  - Patty's Industrial Hygiene and Toxicology: Volume II: Toxicology, 4th ed., 1994, Patty, F. A.; edited by Clayton, G. D. and Clayton, F. E.: New York: John Wiley & Sons, Inc.
- LEGEND:

ACGIH	American Conference of Governmental Industrial Hygienists
CAS	Chemical Abstract Services
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
DOT	Department of Transportation
DSL	Domestic Substances List (Canada)
ECOIN	European Core Inventory
EINECS	European Inventory of Existing Commercial Chemical Substances
EWC	European Waste Catalogue
EPA	Environmental Protective Agency
IARC	International Agency for Research on Cancer
LC	Lethal Concentration
LD	Lethal Dose
MAK	Maximum Workplace Concentration (Germany) "maximale Arbeitsplatz-Konzentration"
NDSL	Non-Domestic Substances List (Canada)
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OEL	Occupational Exposure Limit
OSHA	Occupational Safety and Health Administration
PIN	Product Identification Number
RCRA	Resource Conservation and Recovery Act
SARA	Superfund Amendments and Reauthorization Act
STEL	Short Term Exposure Limit
TCLP	Toxic Chemicals Leachate Program
TDG	Transportation of Dangerous Goods
TLV	Threshold Limit Value
TSCA	Toxic Substances Control Act
TWA	Time Weighted Average

m meter, cm centimeter, mm millimeter, in inch,
g gram, kg kilogram, lb pound, µg microgram,
ppm parts per million

Hematite

Material Safety Data Sheet

page 1a

Substance Identification

Identity: SYNTHETIC RED IRON OXIDE **Cas #:** 1309-37-1
Trade Names:

Manufacturer: The Prince Manufacturing Co.
One Prince Plaza
Quincy, IL 62301
217-222-8854

Emergency: Chemtrec
1-800-424-9300

Components and Contaminants

Chemical Name:	CAS #	OSHA PEL	ACGIH TLV	Percent
Iron Oxide	1309-37-1	—	—	80-95% Fe_2O_3
Particles not otherwise Regulated				
Total		15 mg/m^3	15 mg/m^3 (TWA)	
Respirable Fraction		5 mg/m^3	5 mg/m^3 (TWA)	

Physical Data

Boiling Point:	NA	**Specific Gravity (H_2O=1):**	4.8-5.3
Vapor Pressure (mm/Hg):	NA	**Melting Point:**	> 1700° C
Vapor Density (Air=1):	NA	**Evaporation Rate (Butyl Acetate=1):**	NA
Solubility in Water:	insoluble		
Appearance and Odor:	red to reddish-brown powder, no odor.		

Fire and Explosion Hazard Data

Flash Point: Not combustible
Flammable Limits: LEL NA UEL NA
Extinguishing Media: Foam, CO_2, dry chemical or water.
Special Fire Fighting Procedures: In the event of fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.
Unusual Fire and explosion hazards: Not combustible.

Reactivity Data

Stability: Stable under ordinary conditions of use and storage.
Conditions to avoid: None Known.
Incompatibility (materials to avoid): Aluminum, Ethylene Oxide, Hydrazine, Calcium Hypochlorite, Performic Acid, Bromine Pentaflouride.
Hazardous Decomposition or Byproducts: None Known.
Hazardous Polymerization: Will not occur.

Health Hazard Data

Route of Entry:
INHALATION: May cause irritation of mucous membrane if dust is inhaled over a prolonged period of time.
SKIN: No.
INGESTION: Ingestion of mineral compounds may cause abdominal pain and nausea.

Health Hazard Data (cont.)

Health Hazards (Acute and Chronic):	Respiratory disease may result from prolonged overexposure. Can cause eye irritation.
Carcinogenicity:	NTP: No IARC Monographs: Yes (Silica)
Signs and Symptoms of Exposure:	Excessive inhalation of dust may result in shortness of breath and reduced pulmonary function. Symptoms of silicosis include impaired pulmonary function and wheezing.
Aggravation of Pre-existing Conditions:	Persons with impaired respiratory function may be more susceptible to the effect of this substance.
Emergency and First Aid Procedures:	**IF INHALED,** remove to fresh air and seek medical attention for any breathing difficulty. **IN CASE OF SKIN CONTACT,** wash with soap & water. Seek medical attention if red & irritated. **IN CASE OF EYE CONTACT,** flush eyes immediately with water for at least 15 minutes. Seek medical attention if irritation persists. **IF INGESTED,** induce vomiting immediately by giving two glasses of water and sticking finger down throat. Never give anything by mouth to an unconscious person. Call a physician immediately.

Precautions for Safe Handling and Use

Material Release or Spill Precautions:	Should a spill occur, ventilate area. Clean-up personnel require respiratory protection. Recover uncontaminated material for use. Vacuum or sweep remaining material, keeping dust to a minimum.
Waste Disposal Method:	Dispose of unreclaimable material in a RCRA-approved waste facility.
Handling and Storing Precautions:	Protect containers from damage and keep closed when not in use.
Other Precautions:	Observe good personal hygiene. Wash after handling.

Control Measures

Respiratory Protection:	Use NIOSH approved particulate respirator if dust generation occurs or is anticipated. OSHA standard 1910.134 or ANSI Z88.2-1980 specifications are recommended.
Ventilation:	A system of local and / or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, "Industrial Ventilation, A Manual of Recommended Practices", most recent edition, for details.
Protective Gloves:	Yes
Eye Protection:	Safety goggles are recommended.
Other Protective Clothing or Equipment:	Use other protective equipment when necessary in order to avoid prolonged exposure to skin.
Work and Hygienic Practices:	Observe good personal hygiene. Wash after handling.

SARA Title III Section 313 Supplier Notification

This product contains the following toxic chemicals subject to the reporting requirements of section 313 of the Emergency Planning and Community Right-to Know Act of 1986 and of 40 CFR 372.45:

Component	CAS #	% by Weight
Chromium (III) Compounds	7440-47-3	10 - 16% Cr

This information must be included in all MSDS's that are copied and distributed for this material.

Material Safety Data Sheet

page 2d

Substance Identification

Identity:	IRON OXIDE	CAS #:	1309-37-1
Item Numbers:	04-5113, 04-5114		

Manufacturer:	The Prince Manufacturing Company One Prince Plaza Quincy, IL 62301 217-222-8854	Emergency:	Chemtrec 1-800-424-9300

Components and Contaminants

Chemical Name	CAS #	OSHA PEL	ACGIH TLV	Percent
Iron Oxide	1309-37-1	---	---	45-70% Fe_2O_3
Chromium Cr^{+3}	7440-47-3	0.5mg/m^3	0.5 mg/m^3	10-16% Cr
Aluminum Oxide (non-fibrous) (respirable fraction)	1344-28-1	5 mg/m^3	5 mg/m^3 (TWA)	5-8% Al_2O_3
Magnesium Oxide	1309-48-4	—	---	3-5% MgO
Silica, Crystalline Quartz (respirable)	14808-60-7	0.1 mg/m^3	0.1 mg/m^3 (TWA)	0.5-1% SiO_2

Physical Data

Boiling Point:	NA	Specific Gravity (H_2O=1):	4.5 - 5.0
Vapor Pressure (mm/Hg):	NA	Melting Point:	1300-1700° C
Vapor Density (Air=1):	NA	Evaporation Rate (Butyl Acetate=1):	NA
Solubility in Water:	insoluble		
Appearance and Odor:	red to reddish-brown powder, no odor.		

Fire and Explosion Hazard Data

Flash Point:	Not combustible
Flammable Limits:	LEL NA UEL NA
Extinguishing Media:	Foam, CO_2, or dry chemical or water.
Special Fire Fighting Procedures:	In the event of fire, wear full protective clothing and NIOSH-approved self-contained breathing apparatus with full face piece operated in the pressure demand or other positive pressure mode.
Unusual Fire and explosion hazards:	Not combustible.

Reactivity Data

Stability:	Stable under ordinary conditions of use and storage.
Conditions to avoid:	None Known
Incompatibility (materials to avoid):	Aluminum, Ethylene Oxide, $Ca(OCl)_2$, N_2H_4.
Hazardous Decomposition or Byproducts:	None Known.
Hazardous Polymerization:	Will not occur.

Health Hazard Data

Route of Entry:

INHALATION: May cause irritation of mucous membrane or delayed respiratory disease if dust is inhaled over a prolonged period of time.
SKIN: No.
INGESTION: Ingestion of mineral compounds may cause abdominal pain and nausea.

Health Hazard Data (cont.)

Health Hazards (Acute and Chronic):	Can cause eye irritation. Injury to skin may occur by direct mechanical action.
Carcinogenicity:	NTP: No IARC Monographs: No
Signs and Symptoms of Exposure:	Excessive inhalation of dust may result in shortness of breath and reduced pulmonary function. Iron oxide fume has been linked to siderosis which is considered to be a benign pneumoconiosis that exhibits no adverse health effects. To the best of our knowledge, this condition has not been observed after prolonged exposure to iron oxide pigments.
Aggravation of Pre-existing Conditions:	None Known.
Emergency and First Aid Procedures:	IF INHALED, remove to fresh air and seek medical attention for any breathing difficulty. IN CASE OF SKIN CONTACT, wash with soap & water. Seek medical attention if red & irritated. IN CASE OF EYE CONTACT, flush eyes immediately with water for at least 15 minutes. Seek medical attention if irritation persists. IF INGESTED, induce vomiting immediately by giving two glasses of water and sticking finger down throat. Never give anything by mouth to an unconscious person. Call a physician immediately.

Precautions for Safe Handling and Use

Material Release or Spill Precautions:	Should a spill occur, ventilate area. Clean-up personnel require respiratory protection. Recover uncontaminated material for use. Vacuum or sweep remaining material, keeping dust to a minimum.
Waste Disposal Method:	Dispose of unreclaimable material in a RCRA-approved waste facility.
Handling and Storing Precautions:	Protect containers from damage and keep closed when not in use.
Other Precautions:	Observe good personal hygiene. Wash after handling.

Control Measures

Respiratory Protection:	Use NIOSH approved particulate respirator if dust generation occurs or is anticipated. OSHA standard 1910.134 or ANSI Z88.2-1980 specifications are recommended.
Ventilation:	A system of local and/or general exhaust is recommended to keep employee exposures below the Airborne Exposure Limits. Local exhaust is generally preferred because it can control the emissions of the contaminant at its source, preventing dispersion of it into the general work area. Please refer to the ACGIH document, "Industrial Ventilation, A Manual of Recommended Practices", most recent edition, for details.
Protective Gloves:	Yes
Eye Protection:	Safety goggles are recommended.
Other Protective Clothing or Equipment:	Use other protective equipment when necessary in order to avoid prolonged exposure to skin.
Work and Hygienic Practices:	Observe good personal hygiene. Wash after handling.

SARA Title III Section 313 Supplier Notification

This product does not contain chemicals subject to the reporting requirements of section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 and of 40 CFR 372.45:

This information must be included in all MSDS's that are copied and distributed for this material.

Nepheline

UNIMIN CORPORATION
258 Elm Street
New Canaan, CT 06840

Emergency Telephone Number
(203) 966-8880

Telephone Number for Information
(203) 966-8880

Date Prepared: October 1998

SECTION 1: IDENTIFICATION

PRODUCT NAME: Nepheline Syenite - various grades

SYNONYMS: Anhydrous sodium potassium alumino silicate, Inorganic feldspathic mineral

SECTION 2: COMPONENTS

CAS#	Component	Percentage	Exposure Limits
37244-96-5	Nepheline Syenite	100%	PEL- 5 mg/m³ TWA (respirable fraction) TLV- 10 mg/m³ TWA (inhalable fraction) MSHA- 5 mg/m³ TWA (respirable fraction)

PEL means OSHA Permissible Exposure Limit.
TLV means American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value.
MSHA means Mine Safety and Health Administration Exposure Limit.
TWA means 8 hour time weighted average.

Note: The Permissible Exposure Limits (PEL) reported above are the pre-1989 limits that were reinstated by OSHA June 30, 1993 following a decision by the 11th Circuit Court of Appeals. These PELs are now being enforced by Federal OSHA. Be aware that more restrictive exposure limits may be enforced by some states, agencies or other authorities.

SECTION 3: HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

This product is a chemically inert, non-combustible mineral. Excessive inhalation of dust may cause lung injury with symptoms of shortness of breath and reduced pulmonary function.

HEALTH HAZARDS:

Inhalation: Inhalation of dust may cause irritation of the nose, throat and respiratory passages.

Skin Contact: No adverse effects expected.

Eye Contact: Contact may cause mechanical irritation and possible injury.

Ingestion: No adverse effects expected for normal, incidental ingestion.

Chronic Health Effects: Prolonged overexposure to any nuisance dust may cause lung injury. Symptoms include cough, shortness of breath, and reduced pulmonary function.

Cancer Status:: None of the components of this product are listed as carcinogens or suspected carcinogens by IARC, NTP or OSHA.

Medical Conditions Aggravated by Exposure: Individuals with respiratory disease, including but not limited to, asthma and bronchitis, or subject to eye irritation should be excluded from exposure.

Signs and Symptoms of Exposure: Overexposure to nuisance dusts may cause mucous membrane and respiratory irritation, cough, sore throat, nasal congestion, sneezing and shortness of breath.

==========

SECTION 4: FIRST AID

Gross Inhalation: Remove victim to fresh air. If breathing has stopped, perform artificial respiration. If breathing is difficult have qualified personnel administer oxygen. Get prompt medical attention.

Skin Contact: No first aid should be needed since this product does not affect the skin. Wash exposed skin with soap and water before breaks and at the end of the shift.

Eye Contact: Flush the eyes immediately with large amounts of running water, lifting the upper and lower lids occasionally. If irritation persists or for imbedded foreign body, get immediate medical attention.

Ingestion: If large amounts are swallowed, get immediate medical attention.

==========

SECTION 5: FIRE AND EXPLOSION DATA

Flash Point (Method Used): Fully oxidized, will not burn.
Autoignition Temp: Will not burn.

Flammable Limits: LEL: Not applicable UEL: Not applicable

DISTRIBUTED BY
HAMMILL & GILLESPIE, INC.
P.O. Box 164, 124 S. Hillyard Ave.
Spokane, Wash. 99239

Extinguishing Media: This product will not burn but is compatible with all extinguishing media. Use any media that is appropriate for the surrounding fire.

Special Fire Fighting Procedures: None required with respect to this product. Firefighters should always wear self-contained breathing apparatus for fires indoors or in confined areas.

Unusual Fire and Explosion Hazards: None.

Hazardous Combustion Products: None.

SECTION 6: ACCIDENTAL RELEASE MEASURES

If uncontaminated, collect using dustless method (HEPA vacuum or wet method) and place in appropriate container for use. If contaminated, use appropriate method for the nature of contamination. Consider possible toxic or fire hazards. Wear appropriate protective equipment. Collect for disposal.

SECTION 7: HANDLING AND STORAGE

Avoid breathing dust. Use normal precautions against bag breakage or spills of bulk material. Avoid creation of respirable dust. Use good housekeeping in storage and use areas to prevent accumulation of dust in work area.

Use adequate ventilation and dust collection. Maintain and use proper, clean respiratory equipment (See Section 8). Launder clothing that has become dusty. WARN and TRAIN employees in accordance with state and federal regulations.

WARN YOUR EMPLOYEES (AND YOUR CUSTOMERS - USERS IN CASE OF RESALE) BY POSTING AND OTHER MEANS OF THE HAZARDS AND OSHA PRECAUTIONS TO BE USED. PROVIDE TRAINING FOR YOUR EMPLOYEES ABOUT OSHA PRECAUTIONS.

SECTION 8: EXPOSURE CONTROLS/PERSONAL PROTECTION

Ventilation: Use local exhaust as required to maintain exposures below applicable occupational exposure limits. See also ACGIH "Industrial Ventilation - A Manual for Recommended Practice", (current edition).

Respiratory Protection: Use appropriate respiratory protection for respirable particulates based on consideration of airborne workplace concentrations and duration of exposure. Refer to the most recent standards of ANSI (Z88.2) OSHA (29 CFR 1910.134), MSHA (30 CFR Parts 56 and 57) and NIOSH Respirator Decision Logic.

Gloves: Protective gloves recommended.

Eye Protection: Safety glasses or goggles recommended.

Other Protective Equipment/Clothing: As appropriate for the work environment. Dusty clothing should be laundered before reuse.

9: PHYSICAL AND CHEMICAL PROPERTIES

Appearance and Odor: White powder, odorless.

pH: Not applicable
Boiling Point: Not applicable
Melting Point: 1223°C / 2233°F
Solubility in Water: Negligible
Percent Volatile: 0%

Specific Gravity (water=1): 2.61
Vapor Pressure: Not applicable
Vapor Density: Not applicable
Evaporation Rate: Not applicable

SECTION 10: STABILITY AND REACTIVITY

Stability: Stable
Conditions to Avoid: None
Incompatibility: None known.

Hazardous Decomposition Products: None

Hazardous Polymerization: Will not occur.
Conditions to Avoid: None

SECTION 11: TOXICOLOGICAL INFORMATION

No acute toxicity data is available for product or components. Refer to Section 3 for health hazard information.

SECTION 12: ECOLOGICAL INFORMATION

No ecotoxicity data is available. This product is not expected to present an environmental hazard.

SECTION 13: DISPOSAL

Waste Disposal Method: If uncontaminated, dispose as an inert, non-metallic mineral. If contaminated, dispose in accordance with all applicable local, state/provincial and federal regulations.

SECTION 14: TRANSPORTATION DATA

U.S. DOT HAZARD CLASSIFICATION
Proper Shipping Name: Not Regulated
Technical Name: N/A
UN Number: N/A
Hazard Class/Packing Group: N/A
Labels Required: None
DOT Packaging Requirements: N/A

DISTRIBUTED BY
HAMMILL & GILLESPIE INC.

Exceptions: N/A

SECTION 15: OTHER REGULATORY INFORMATION

SARA 311/312: Hazard Categories for SARA Section 311/312 Reporting:
Not Applicable

SARA 313 This Product Contains the Following Chemicals Subject to Annual Release Reporting Requirements Under the SARA Section 313 (40 CFR 372):
None

CERCLA Section 103 Reportable Quantity: None

California Proposition 65: This product does not contain substances regulated under California Proposition 65.

Canadian WHMIS Classification: Not a controlled product.

16: OTHER INFORMATION

European Community Labeling Classification: N/A

European Community Risk and Safety Phrases: None

NFPA Hazard Rating:	Health: 0	Fire: 0	Reactivity: 0
HMIS Hazard Rating:	Health: 0	Fire: 0	Reactivity: 0

References:

Registry for Toxic Effects of Chemical Substances (RTECS), 1998
Patty's Industrial Hygiene and Toxicology
NTP Seventh Annual Report on Carcinogens, 1994
Hawley's Condensed Chemical Dictionary, twelfth edition
Toxline Database, NLM, 1998

Revision Summary: Revise exposure limits (Section 2)

The data in this Material Safety Data Sheet relates only to the specific material designated herein and does not relate to use in combination with any other material or in any process. The information set forth herein is based on technical data the Unimin Corporation believes reliable. It is intended for use by persons having technical skill and at their own discretion and risk. Since conditions of use are outside the control of Unimin Corporation, no warranties, expressed or implied, are made and no liability is assumed in connection with any use of this information. Any use of these data and information must be determined by the user to be in accordance with federal, state and local laws and regulations.

Zirconium Hydroxide

MATERIAL SAFETY DATA SHEET

1. PRODUCT IDENTIFICATION

MANUFACTURES NAME	Magnesium Elektron, Inc.
ADDRESS	500 Point Breeze Road, Flemington, NJ
TRADE NAME	Zirconium Hydroxide
SYNONYMS	Hydrous Zirconia
CAS NUMBER	14475-83-9
REGULAR PHONE NO. (908)782-5800	Emergency Telephone No. (908)782-5800

2. HAZARDOUS INGREDIENTS

MATERIAL OR COMPONENT	
Zirconium Oxide 60 - 85 %	
Balance Water	

3. PHYSICAL DATA

BOILING POINT (°F)	Decomposes @ 100 °C	DENSITY	3.25
VAPOR PRESSURE (mm Hg.)	NO	MELTING POINT(° C)	NA
SOLUBILITY IN WATER	< 1 mg/l	VAPOR DENSITY	ND
APPEARANCE AND ODOR	White, bulky, amorphous solid with no oder		

4. FIRE AND EXPLOSION DATA

FLASH POINT (TEST METHOD)	Not Flammable	AUTO IGNITION TEMPERATURE (°C)	> 400

FLAMMABLE LIMITS IN AIR. % BY VOL. Flammable	Not	LOWER	N/A	UPPER	N/A

EXTINGUISHING MEDIA	Use Media suitable for surrounding fires, this material is not flammable
SPECIAL FIRE FIGHTING PROCEDURES	None Known
UNUSUAL FIRE AND EXPLOSION HAZARD	None Known

5. HEALTH HAZARD INFORMATION

FIRST AID:	
EYES	Flush eyes with running water for at least 15 minutes. If irritation persists, seek medical aid.
SKIN:	Flush affected area with water. If irritation persists seek medical aid.
INHALATION:	Remove to fresh air. If breathing has stopped administer artificial respiration, seek medical aid immediately.
INGESTION:	Wash mouth out with water. Do not induce vomiting, seek medical attention.
NATURE OF HAZARD	
EYES:	No known effects, treat as a foreign object.
SKIN:	Unlikely to be an irritant based studies of similar material.
INHALATION:	No known effects from widespread user and manufacture experience.
INGESTION:	No known effects

EFFECTS OF OVEREXPOSURE	No Known effects of overexposure.
ACUTE OVEREXPOSURE	No Known effects of overexposure
CHRONIC OVEREXPOSURE	Zirconium Compounds - OSHA PEL :
THRESHOLD LIMIT VALUE (TLV)	5.0 mg/m3 (TWA) 10.0 mg/m3 (STEL)
SKIN CONTACT:	No known effects
EYE CONTACT:	No known effects
INHALATION:	No known effects
INGESTION:	No known effects, NOT RECOMMENDED

6. REACTIVITY DATA

CONDITIONS CONTRIBUTING TO INSTABILITY	Stable
INCOMPATIBILITY	None Known
HAZARDOUS DECOMPOSITION PRODUCTS	None Known
CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION	Not Applicable

7. SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	Take precautions to avoid creating and breathing dust. Dampen any spilled material, collect by vacuum or shovel and place into labeled container for disposal.
NEUTRALIZING CHEMICALS	None Required
WASTE DISPOSAL METHOD	Not defined as a hazardous waste under 40 CFR Part 261 of the Resource Conservation and Recovery Act (RCRA).

8. SPECIAL PROTECTION INFORMATION

VENTILATION REQUIREMENTS	Use local exhaust ventilation to avoid inhaling dust.
SPECIFIC PERSONAL PROTECTIVE EQUIPMENT	Skin contact should be prevented by protective clothing. In all areas of dust concentration, dust masks should be provided, and in case of fumes, masks with proper canisters or supplied air respirators should be used.
RESPIRATORY:	NIOSH/MSHA Approved dust/particulate respirator is recommended.
EYES:	Safety glasses as a minimum.
GLOVES:	As with all chemicals, gloves should be worn to prevent excessive or repeated skin contact.
OTHER CLOTHING AND EQUIPMENT:	Long sleeve shirts or coveralls to minimize skin contact.

9. SPECIAL PRECAUTIONS

HAZARD CLASSIFICATION INFORMATION • Not Regulated under the Department of Transportation
DOT Hazard Class: UN Number:

HANDLING AND STORAGE MATERIALS AND COATINGS
Suitable:Store in a cool, dry place. Avoid contact with water
SARA TITLE III: Not Applicable
TSCA : Zirconium Hydroxide is Listed on the TSCA Chemical Substance Inventory under CAS NO. 14475-63-9
Date: 01/26/99 JFB Supercedes MSDS Dated: 9/2/94

Appendix B: Mineral Product Specifications

Boehmite

CHEMICALS PRODUCT DATA

Alcoa Industrial Chemicals

HiQ® Alumina Product Line: Boehmite Phase

HiQ®-10, HiQ®-20, HiQ®-30, HiQ®-40

Powders for Catalysts and Abrasives **MAY 1998**

Product Information

Alcoa markets high purity boehmite worldwide under the* HiQ® - Alumina *trade name. The manufacturing process for this product begins with primary aluminum to produce an alumina of extraordinary purity. This is unlike other processes that start with trihydrate and yield aluminas which are subject to common purities such as sodium, iron, or silica. High purity denotes very low levels (less than 0.01 wt%) of such impurities.

Description

HiQ® aluminas are available as white, free-flowing, spray-dried powders. These aluminas consist of small boehmite crystals, often referred to as pseudoboehmite. The crystalline character of each alumina is controlled in order to tailor their chemical and physical properties. HiQ®-10 alumina exhibits the smallest crystallite size and is mainly used for making extruded catalysts. HiQ®-20 alumina is the general-purpose grade of alumina that is easy to mull and extrude. HiQ®-30 is typically used as the binder for extruded oxide blends. Additionally, supports made from HiQ®-30 have very narrow micro/meso pore distributions. HiQ®-40 alumina offers the largest crystallite size and is well suited for applications requiring exceptionally high acid dispersibility or binding ability.

Applications

HiQ® Alumina is a specialty product but its applications are quite diverse: specialty chemical catalysts; automotive washcoat catalysts; catalyst binders and supports; sol-gel abrasives; polishing compounds; viscosifiers; and anti-skid agents.

Typical Physical Properties

	HiQ®-10	HiQ®-20	HiQ®-30	HiQ®-40
Surface Area (m^2/g)	290	280	280	250
Pore Volume (cc/g)	0.45	0.48	0.48	0.5
Acid Dispersibility (wt%)	80	88	89	94
Loose Bulk Density (g/l)	730	730	730	730
NAG (minutes)	60	10	4	<1
Crystallite Size (A)				
020 peak	26	30	33	47
021	41	43	50	72

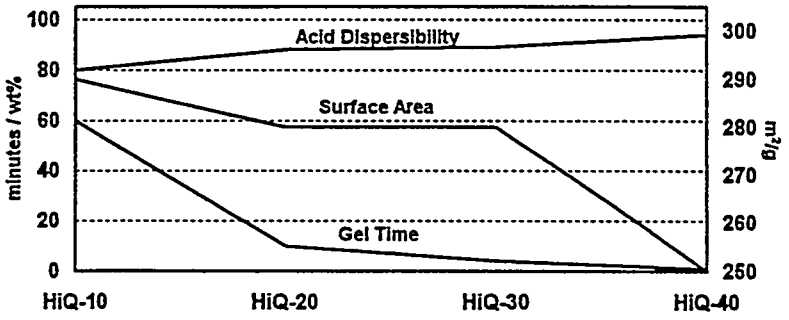
Particle Size, wt% (HiQ Product Line)

d_{50} (µm)	<125 µm	<88 µm	<44 µm
50	95	95	80

Typical Chemical Properties (HiQ Product Line)

Al_2O_3 (wt%)	Carbon (wt%)	SiO_2 (ppm)	Fe_2O_3 (ppm)	Na_2O (ppm)
72	<0.3	<100	<50	<10

HiQ® Aluminas-Typical Properties



For recommendations on your specific application, call Alcoa's Applications Manager, (504) 382-3353. For price and shipment information contact your Alcoa Sales Representative or Sales Service Unit at (800) 533-4511.

Information presented herein is believed to be accurate and reliable but does not imply any guarantee or warranty by Alcoa. Nothing herein shall be construed as an invitation to use processes covered by patents without proper arrangements with individuals or companies owning these patents.

Alcoa Industrial Chemicals
Adsorbents and Catalysts Division
16010 Barker's Point Lane, Suite 250
Houston TX 77079

PRODUCT:	**HiQ(R) 10 Alumina**
LOT NUMBER:	**8K30-1**

Analysis Property	Value
*Al_2O_3 Content, wt%:	73.7
**Surface Area, sq M/g.:	281
**Pore Volume (pores<1000A dia),cc/g:	0.61
Loose Bulk Density, g/l:	747
Carbon Content, wt%:	0.49
Particle Size Distribution, wt%:	
<44 microns	52.7
>88 microns	12.7
Impurities, wt. %:	
SiO_2	0.007
Fe_2O_3	0.006
Na_2O	0.01

Gibbsite

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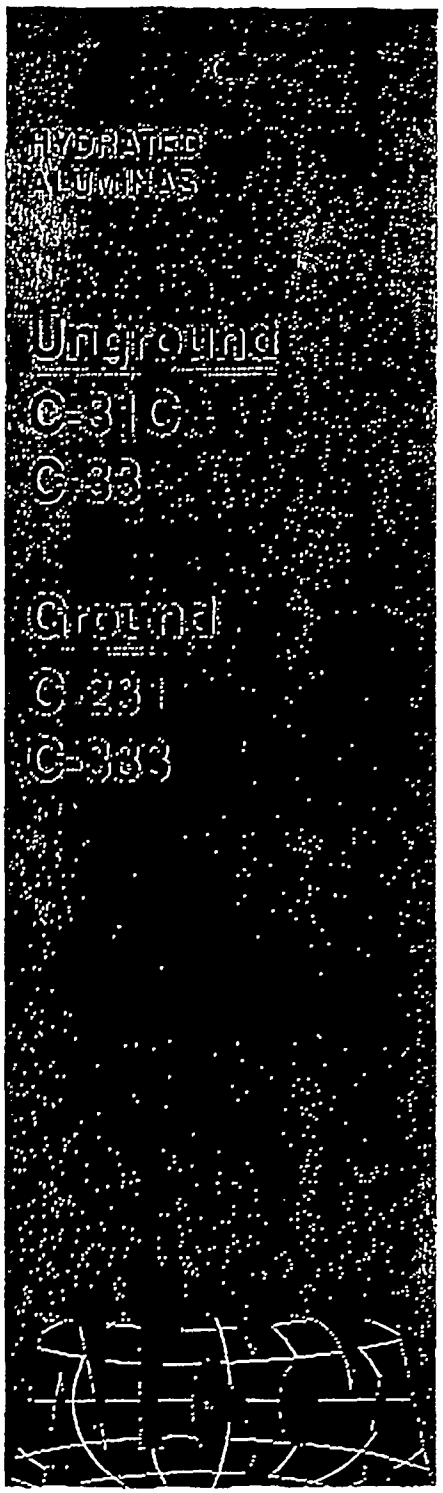

Exceptionally pure white hydrates

Product Information

Alcoa® white hydrated alumina, is aluminum trihydroxide, $Al(OH)_3$, that is produced through special processing of alumina-bearing feedstocks and stringent process control systems. The result is an alumina trihydroxide of exceptional purity and whiteness. Although hydrated alumina is a dry powder, it contains a high proportion, approximately 35 percent by weight, of chemically combined water. The hydrate is a nonabrasive, low-density material with a Mohs' hardness index of 2.5 - 3.5 and a specific gravity of 2.42 g/cc. White hydrates are used primarily in applications where color and the absence of impurities are critical. They are halogen-free making them excellent nontoxic flame retardant/smoke suppressant fillers for plastic compounds.

Product Description

Alcoa precipitates a highly pure gibbsite phase of alpha alumina trihydrate. The Alcoa proprietary white stream process is designed, through chemical and recrystallization processes, to achieve near 100 percent photovolt brightness and relatively uniform particles.

C-33 and C-31C (coarse)
The precipitation process is controlled to produce two median particle sizes, Grades C-33 (50 microns) and C-31C (85 microns). Both grades have free-flowing properties.

C-231 and C-333 Ground White Hydrates
Intermediate and fine size grades are produced by grinding the precipitated grades to form C-231 (14 microns) and C-333 (7 microns).

Applications

Grades C-33 and C-31C hydrates are used in the manufacture of glass, chemicals, catalysts, vitreous enamels and ceramic whitewares, and as additives in high quality pigments. These products are also used as additives and fillers in polymer systems such as electrical wire insulation and high quality cultured marble and solid countertop surfacing material. Hydrated aluminas are preferred because of their good arc and track resistance, aesthetic properties, reinforcing characteristics and performance as nontoxic smoke suppressants and flame retardants.

Grades C-231 and C-333 are ground versions of Grade C-33. They are used in polymer formulations, toothpastes, adhesives, coatings, paper, cosmetics, waxes and polishes.

Typical Properties of Alcoa White Series Alumina Trihydrates

Chemical Analysis	C-33	C-31C	C-231	C-333
$Al(OH)_3$ (%)	99.6	99.6	99.6	99.6
LOI (%)	34.6	34.6	34.6	34.6
Al_2O_3 (%)	65.0	65.0	65.0	65.0
SiO_2 (%)	0.003	0.003	0.003	0.003
Fe_2O_3 (%)	0.009	0.009	0.009	0.009
Na_2O (% Total)	0.17	0.26	0.17	0.17
Na_2O (% Soluble)	0.010	0.010	0.023	0.022
Moisture (%)	0.05	0.06	0.15	0.15
Physical Analysis				
Loose Bulk Density (g/cm³)	1.17	1.15	0.8	0.6
Packed Bulk Density (g/cm³)	1.38	1.33	–	–
Surface Area (m²/g)	–	–	2.5	3.0
Particle Size Analysis				
% on 100 Tyler Mesh	0	3	–	0
% on 200 Tyler Mesh	10	60	3	0
% on 325 Tyler Mesh	55	90	20	2
% through 325 Tyler Mesh	45	10	80	98
Median Micron (D50)	50	85	14	7

Physical Constants		Test Methods	
Refractive Index	1.57	$Al(OH)_3$ and Al_2O_3 - by difference	Loose Bulk Density - Modified ASTM B212-89
Density (g/cm³)	2.42	LOI(Loss On Ignition) - from 110° to 1100° Centigrade	Packed Bulk Density - Modified ASTM B527-85
Mohs' Hardness	2.5-3.5	SiO_2 - by DC Arc Optical Emission Spectrometry	Surface area measured by Brunauer-Emmett Color Teller method of nitrogen adsorption
Color	White	Fe_2O_3 - by DC Arc Optical Emission Spectrometry	% through Tyler 325 Mesh- by wet screen
		Total Soda - by DC Arc Optical Emission Spectrometry	Median Micron (D50) - Microtrac (C-33/31C)
		Soluble Soda - by Flame Emission Photometry	Median Micron (D50) - Sedigraph 5100 (C-231/333)
		Moisture by Microwave	

Information presented herein is believed to be accurate and reliable but is not intended to meet any specification and does not imply any guarantee or warranty by Alcoa.

MSDS Number-839

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Alcoa Industrial Chemicals

HYDRATED ALUMINAS

SpaceRite S-23 Alumina

Pure white, fine crystalline powder with broad particle size distribution

Product Information

Alcoa SpaceRite® S-23 is a special purpose white hydrated alumina. White hydrated alumina is aluminum trihydroxide, $Al(OH)_3$, that is produced through special processing of aluminous feedstocks and stringent process control systems. The result is hydrated alumina unequaled in purity and whiteness. Although hydrated alumina is a dry powder, it contains a high proportion, approximately 35 percent by weight, of chemically combined water.

Hydrates are nonabrasive, low-density materials that have been used extensively in the coatings industry and other applications where color and the absence of impurities are critical.

SpaceRite aluminas meet FDA specification 175.300. MSDS Section IX, Regulatory Information, states: "For purposes of SARA III reporting, this substance contains no ingredients listed on the Extremely Hazardous, CERCLA, or Section III lists."

Product Description

SpaceRite S-23 is a fine crystalline, aluminum trihydroxide with uniform particles averaging about 7.5 microns in diameter. It is an organic-free, pure white powder produced by a proprietary precipitation process. SpaceRite S-23 can also replace other extenders providing enhanced performance and benefits in coatings and adhesives.

Product Features

- Broad particle size distribution (7.5 microns median)
- Low oil absorption
- High brightness
- Clean white color
- Low specific gravity
- Nonabrasive
- Excellent dispersion characteristics
- Chemically inert
- UV transparent

Applications	Properties
Architectural coatings	•Extender (flat and semigloss). •Will not impact color. •Easily dispersed (5+ Hegman). •Weather resistant. •Inert.
High solids/low VOC coatings	•Highly inert. •Low oil absorption and high loading capability. •Reduces yellowing in alkyds. •Easily dispersed (5+ Hegman). •Can be used in wide range of colors (no impact on colors).
UV coatings	•RMC reduction (formulation extender). •Improves photoinitiator efficiency. •Will not adversely affect speed or depth of cure (UV transparent). •Easily dispersed.
Organic colored pigments	•Ideal pigment extender (invisible at levels up to 5%). •Inert. •Excellent weatherability. •Low oil absorption. •Will not impact hue. •Easily dispersed (5+ Hegman).

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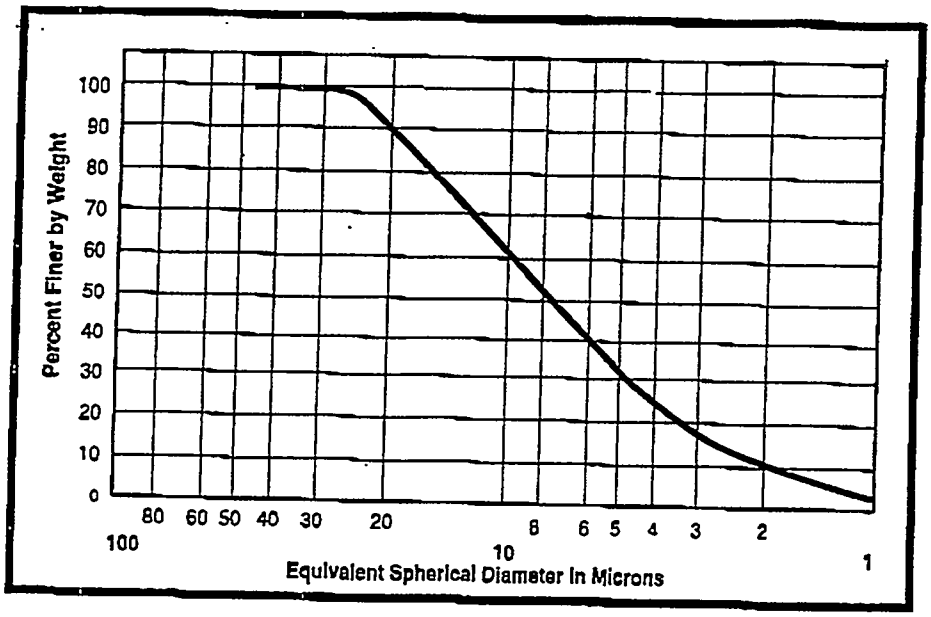
PRODUCT DATA



SpaceRite S-23 Alumina Typical Particle-Size Analysis by Sedigraph

Information presented herein is believed to be accurate and reliable but is not intended to meet any specification and does not imply any guarantee or warranty by Alcoa.

MSDS Number-839

Typical Properties of SpaceRite S-23 Alumina

Chemical Composition	
$Al(OH)_3$ (% minimum)	98.0
Moisture content (%)	0.01-0.5
Na_2O (% soluble)	0.0-0.04

Physical Properties	
Specific gravity	2.42
Moh's hardness	2.5 - 3.5
Pounds per gallon	20.20
Gallons per pound	0.0495
Median particle size, µm	7.5
Oil absorption, g/100g	18-20
pH* (ASTM 1208)	9.8
Refractive index	1.57
Brightness – Z percent**	98.0
Color	white
Bulk density, loose, g/cm³	1.52
Bulk density, packed, g/cm³	2.65

* Not a buffer
** Z percent brightness is the Z value of the XYZ tristimulus divided by 1.18103

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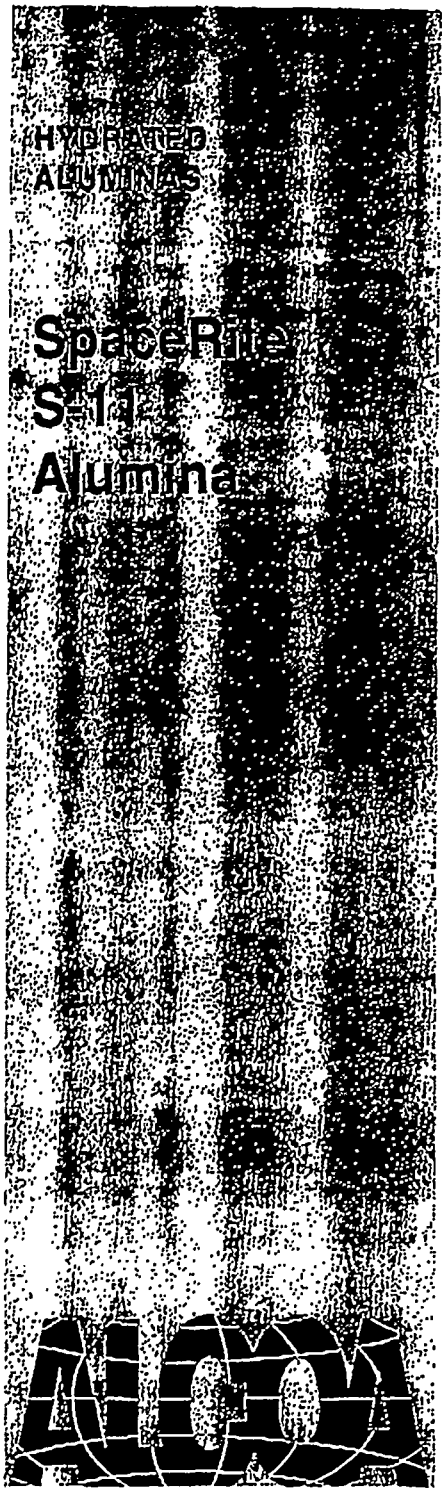


PRODUCT DATA

Unequaled purity and whiteness

Product Information

Alcoa SpaceRite® S-11 is a special purpose white hydrated alumina. White hydrated alumina is aluminum trihydroxide, $Al(OH)_3$, that is produced through special processing of aluminous feedstocks and stringent process control systems. The result is hydrated alumina unequaled in purity and whiteness. Although hydrated alumina is a dry powder, it contains a high proportion, approximately 35 percent by weight, of chemically combined water.

Hydrates are nonabrasive, low-density materials that have been used extensively in the coatings industry and other applications where color and purity are critical.

SpaceRite aluminas meet FDA specification 175.300. MSDS Section IX, Regulatory Information, states: "For purposes of SARA III reporting, this substance contains no ingredients listed on the Extremely Hazardous, CERCLA, or Section III lists."

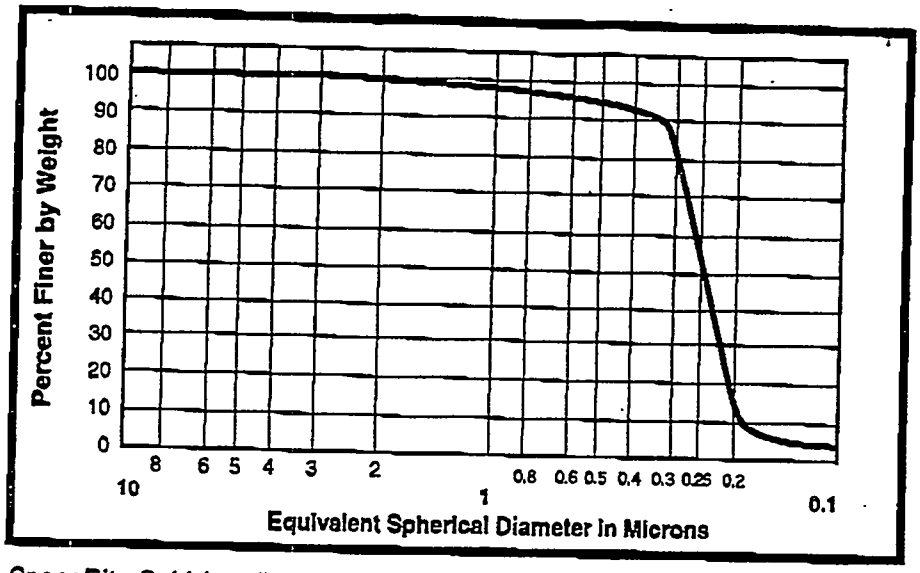
Product Description

SpaceRite S-11 is a fine crystalline aluminum trihydroxide with uniform particles averaging 1/4 micron in diameter. It is an organic-free, pure white powder that has been further processed to function in coatings and adhesives.

Features

- Narrow particle size distribution (0.25 micron median)
- Low oil absorption
- High brightness
- Clean white color
- Low specific gravity
- Nonabrasive
- Excellent dispersion characteristics
- Chemically inert
- UV transparent

Applications	Properties
Architectural coatings	•TiO_2 replacement. •Will not reduce gloss. •Excellent gloss retention. •Will not impact color. •Easily dispersed (7+ Hegman). •Weather resistant. •Inert.
High solids/low VOC coatings	•Highly inert. •Low oil absorption and high loading capability. •Will not reduce gloss. •Excellent gloss retention. •Reduces yellowing in alkyds. •Easily dispersed (7+ Hegman). •Can be used in wide range of colors (no impact on colors).
UV coatings	•RMC reduction (formulation extender). •Improves photoinitiator efficiency. •Will not adversely affect speed or depth of cure (UV transparent). •Easily dispersed.
Organic colored pigments	•Ideal pigment extender (invisible at levels up to 5%). •Inert. •Excellent weatherability. •Low oil absorption. •Will not impact hue. •Easily dispersed (7+ Hegman).



SpaceRite S-11 is a fine crystalline aluminum trihydroxide with uniform particles averaging 1/4 micron in diameter. (This typical particle size analysis is by Sedigraph.)

Information presented herein is believed to be accurate and reliable but is not intended to meet any specification and does not imply any guarantee or warranty by Alcoa.

MSDS Number-839

Typical Properties of SpaceRite S-11 Alumina

Chemical Composition	
$Al(OH)_3$ (% minimum)	99.0
Moisture content (%)	0.6
Na_2O (% soluble)	0.10 - 0.25

Physical Properties	
Specific gravity	2.42
Moh's hardness	2.5 - 3.5
Pounds per gallon	20.20
Gallons per pound	0.0495
Median particle size, µm	0.25 - 0.30
Oil absorption, g/100g	24 - 28
pH* (ASTM 1208)	9.8
Refractive index	1.57
Brightness - Z percent**	98.0
Color	white
Bulk density, loose, g/cm³	0.13 - 0.24
Bulk density, packed, g/cm³	0.26 - 0.45

* Not a buffer
** Z percent brightness is the Z value of the XYZ tristimulus divided by 1.18103

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South America São Paulo, Brazil • Europe Frankfurt, Germany • Asia Booragoon, Western Australia

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CHEMICALS PRODUCT DATA

Alcoa Industrial Chemicals

CHE 909A

SpaceRite S-3 Alumina

Hydrated Aluminas

Product Information

Alcoa SpaceRite® S-3 is a special purpose white hydrated alumina. White hydrated alumina is aluminum trihydroxide, $Al(OH)_3$, that is produced through special processing of aluminous feedstocks and stringent process control systems. The result is hydrated alumina unequaled in purity and whiteness. Although hydrated alumina is a dry powder, it contains a high proportion, approximately 35 percent by weight, of chemically combined water.

Hydrates are nonabrasive, low-density materials that have been used extensively in the coatings industry and other applications where color and the absence of impurities are critical.

SpaceRite aluminas meet FDA specification 175.300. MSDS Section IX, Regulatory Information, states: "For purposes of SARA III reporting, this substance contains no ingredients listed on the Extremely Hazardous, CERCLA, or Section III lists."

Product Description

SpaceRite S-3 is a fine crystalline, aluminum trihydroxide with uniform particles averaging about one micron in diameter. It is an organic-free, pure white powder produced by a proprietary precipitation process that closely controls particle-size distributions. SpaceRite S-3 can also replace other extenders providing enhanced performance and benefits in coatings and adhesives.

Product Features

- Narrow particle size distribution (1.0 micron median)
- Low oil absorption
- High brightness
- Clean white color
- Low specific gravity
- Nonabrasive
- Excellent dispersion characteristics
- Chemically inert
- UV transparent

Typical Properties of SpaceRite S-3 Alumina

Chemical Composition	
$Al(OH)_3$ (% minimum)	99.0
Moisture content (% maximum)	0.7
Na_2O (% soluble)	0.08
Physical Properties	
Specific gravity	2.42
Moh's hardness	2.5 - 3.5
Pounds per gallon	20.20
Gallons per pound	0.0495
Median particle size, µm	1.0
Oil absorption, g/100g	30-33
pH* (ASTM 1208)	9.8
Refractive index	1.57
Brightness – Z percent**	98.0
Color	white
Bulk density, loose, g/cm³	0.22
Bulk density, packed, g/cm³	0.37

* Not a buffer
** Z percent brightness is the Z value of the XYZ tristimulus divided by 1.18103

Applications	Properties
Architectural coatings	•TiO_2 replacement. •Will not reduce gloss. •Excellent gloss retention. •Will not impact color. •Easily dispersed (7+ Hegman). •Weather resistant. •Inert.
High solids/low VOC coatings	•Highly inert. •Low oil absorption and high loading capability. •Will not reduce gloss. •Excellent gloss retention. •Reduces yellowing in alkyds. •Easily dispersed (7+ Hegman). •Can be used in wide range of colors (no impact on colors).
UV coatings	•RMC reduction (formulation extender). •Improves photoinitiator efficiency. •Will not adversely affect speed or depth of cure (UV transparent). •Easily dispersed.
Organic colored pigments	•Ideal pigment extender (invisible at levels up to 5%). •Inert. •Excellent weatherability. •Low oil absorption. •Will not impact hue. •Easily dispersed (7+ Hegman).

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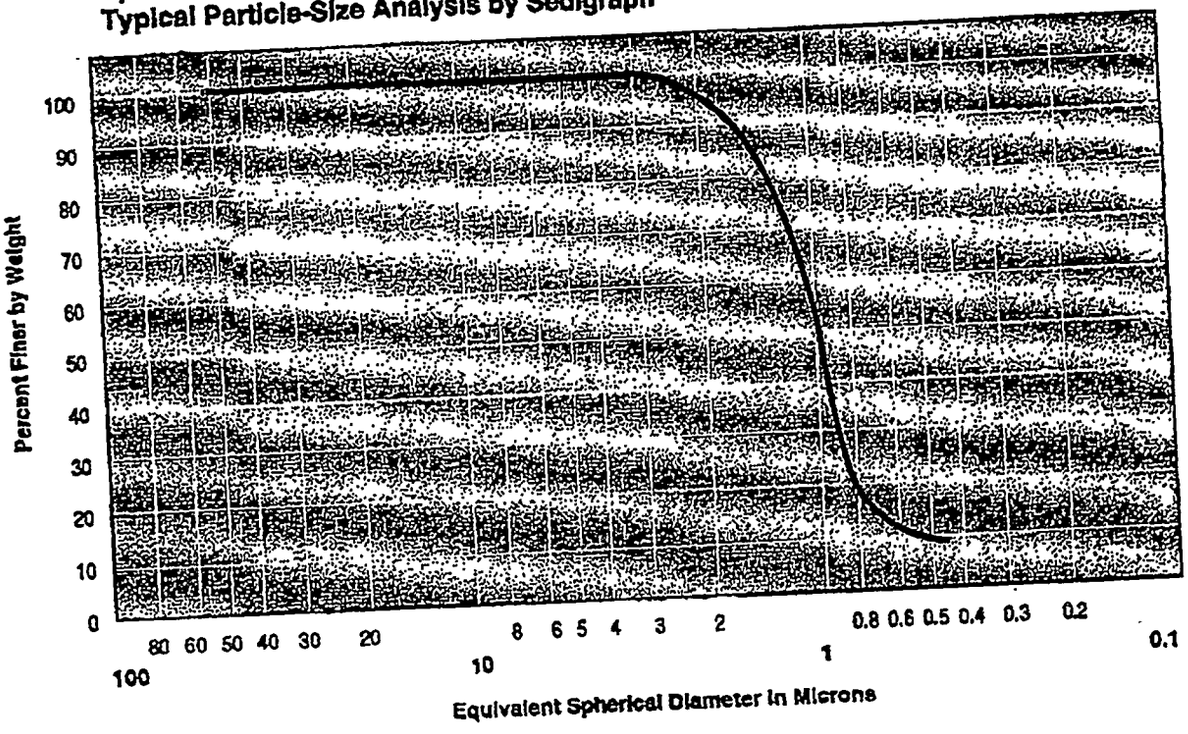
SpaceRite S-3 Alumina
Typical Particle-Size Analysis by Sedigraph



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ALCOA

Printed in U.S.A. 9509

F35-15383

Hematite

THE PRINCE MANUFACTURING COMPANY

Established 1858

DATA SHEET

Iron Oxide 5001

Fe_2O_3

Item Number: 07-5001

Typical Chemical Analysis

Fe	67.8%
Fe_2O_3	97.0%
Al_2O_3	1.50%
SiO_2	1.35%
P	0.115%
MgO	0.10%
Mn	0.09%
CaO	0.04%
S	0.032%

Physical Description

Color	rouge
Fineness	99% thru 325 Mesh
Apparent Bulk Density	
Loose	70 lb/ft^3
Compacted	170 lb/ft^3
Package	50 lb 3 ply paper bag 2000 lb SuperSack

$320/2000lbs

The information and data contained herein are believed to be correct. However, we do not warrant either expressly or by implication, the accuracy thereof. We recommend that the prospective user determine the suitability of our materials and suggestions before adopting them on a commercial scale. No statement in this bulletin is to be construed as violating any copyright or patent.

6/95

COLLECT DISPLAY - MICROTRAC FULL RANGE PARTICLE ANALYZER - Ver 3.02

Fe2O3 Sample#: 07-5001
in DI water

GRG

Meas/Pres #: - param #2: 0.000 Lot Code:
param #1: 0.000 param #3: 0.000 Account#:

Id #1:
Distrib. Format: Volume
Filter: On
Run Time: 60 seconds
Run #:AVG of 3 runs
Loading Index: 0.86
Laser Intensity: 1.055
Residuals: Disabled
Above Residuals: 0.00
Below Residuals: 0.00

Summary Data

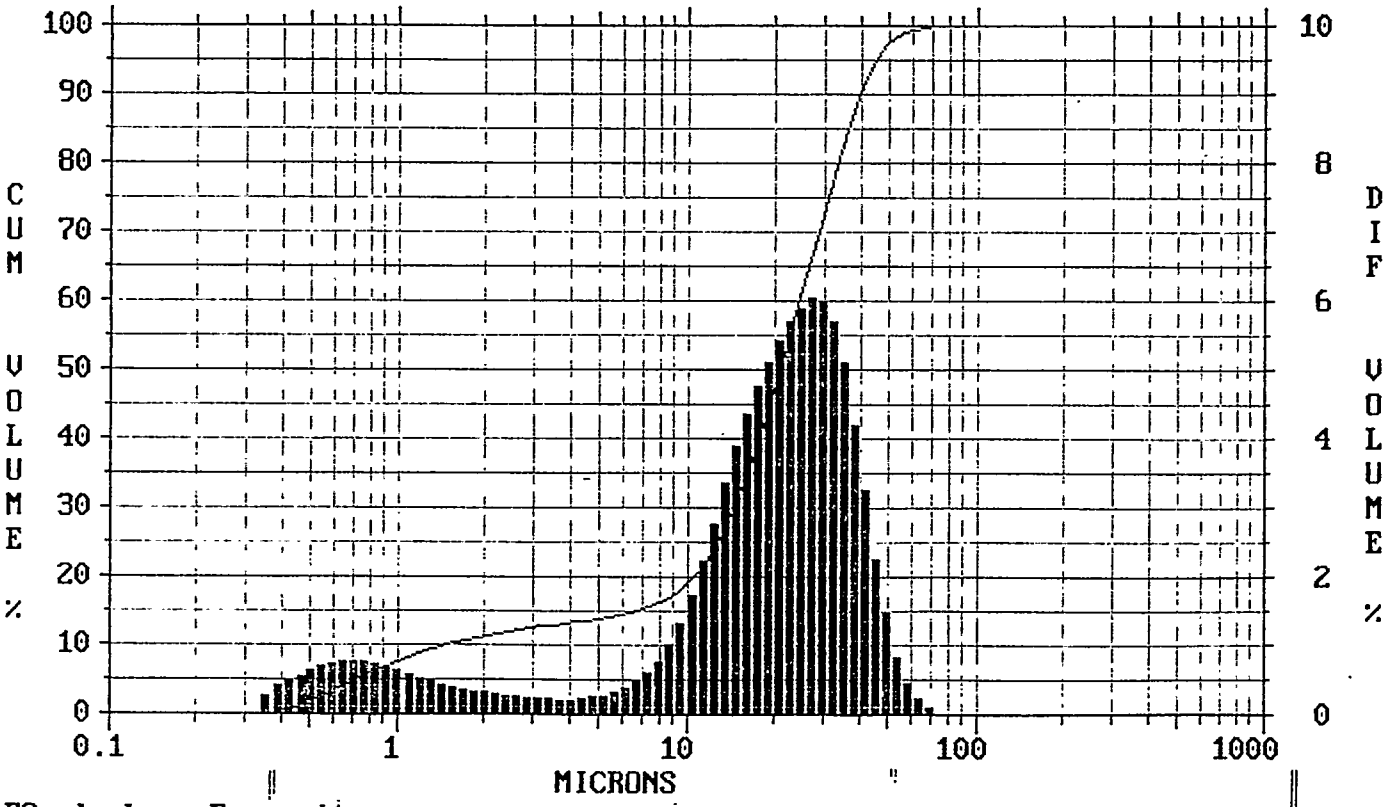
dv	=	0.1205
5%	=	0.72
50%	=	21.07
95%	=	44.58
mv	=	21.71
ma	=	4.81
cs	=	1.247
sd	=	13.63

Id #2:
Date: 03/30/99 Time: 12:49
Chan. Progression: Geom/Srt2
Upper Channel Edge: 704.00
Lower Channel Edge: 0.12
Number of Channels: 100
Fluid Refractive Index: n/a
Transparent Particles: No
Spherical Particles: n/a
Part. Refractive index: n/a

ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn
704.00	100.00	0.00	80.70	100.00	0.00	9.25	17.79	1.00	1.06	5.11	0.63
645.57	100.00	0.00	74.00	100.00	0.10	8.48	16.79	0.77	0.97	7.48	0.68
591.99	100.00	0.00	67.86	99.90	0.24	7.78	16.02	0.60	0.89	6.80	0.72
542.86	100.00	0.00	62.23	99.66	0.46	7.13	15.42	0.48	0.82	6.08	0.75
497.80	100.00	0.00	57.06	99.20	0.84	6.54	14.94	0.39	0.75	5.33	0.76
456.49	100.00	0.00	52.33	98.36	1.47	6.00	14.55	0.32	0.69	4.57	0.76
418.60	100.00	0.00	47.98	96.89	2.26	5.50	14.23	0.28	0.63	3.81	0.74
383.86	100.00	0.00	44.00	94.63	3.26	5.04	13.95	0.25	0.58	3.07	0.69
352.00	100.00	0.00	40.35	91.37	4.20	4.62	13.70	0.23	0.53	2.38	0.64
322.79	100.00	0.00	37.00	87.17	5.11	4.24	13.47	0.21	0.49	1.74	0.56
296.00	100.00	0.00	33.93	82.06	5.70	3.89	13.26	0.21	0.45	1.18	0.48
271.43	100.00	0.00	31.11	76.36	5.97	3.57	13.05	0.22	0.41	0.70	0.43
248.90	100.00	0.00	28.53	70.39	6.04	3.27	12.83	0.23	0.37	0.27	0.27
228.24	100.00	0.00	26.16	64.35	5.90	3.00	12.60	0.24	0.34	0.00	0.00
209.30	100.00	0.00	23.99	58.45	5.69	2.75	12.36	0.26	0.32	0.00	0.00
191.93	100.00	0.00	22.00	52.76	5.43	2.52	12.10	0.28	0.29	0.00	0.00
176.00	100.00	0.00	20.17	47.33	5.12	2.31	11.82	0.30	0.27	0.00	0.00
161.39	100.00	0.00	18.50	42.21	4.78	2.12	11.52	0.32	0.24	0.00	0.00
148.00	100.00	0.00	16.96	37.43	4.36	1.94	11.20	0.34	0.22	0.00	0.00
135.71	100.00	0.00	15.56	33.07	3.89	1.78	10.86	0.37	0.20	0.00	0.00
124.45	100.00	0.00	14.27	29.18	3.36	1.64	10.49	0.39	0.19	0.00	0.00
114.12	100.00	0.00	13.08	25.82	2.76	1.50	10.10	0.43	0.17	0.00	0.00
104.65	100.00	0.00	12.00	23.06	2.22	1.38	9.67	0.47	0.16	0.00	0.00
95.96	100.00	0.00	11.00	20.84	1.73	1.26	9.20	0.52	0.14	0.00	0.00
88.00	100.00	0.00	10.09	19.11	1.32	1.16	8.68	0.57	0.13	0.00	0.00

F2-Commands Esc-exit

Record Number: 0



F2-clr key Esc-exit

PRINCE

THE PRINCE MANUFACTURING COMPANY

Established 1858

DATA SHEET

Red Iron Oxide 3752 *

Fe_2O_3

Item Number: 07-3752

Typical Chemical Analysis

Fe	57%
Fe_2O_3	82%
SiO_2	9.0%
Al_2O_3	2.9%
MgO	1.1%
CaO	0.5%
Mn	0.36%
P	0.1%
Pb	30 ppm
As	20 ppm

Physical Description

325 mesh = sieve opening 45μm

Color	red
Fineness	99.9% thru 325 Mesh
Average Particle Size	2 microns
Apparent Bulk Density	
Loose	24 lb/ft^3
Compacted	81 lb/ft^3
Package	50 lb 3 ply paper bag
	2000 lb SuperSack

21¢/lb

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7/94

COLLECT DISPLAY - MICROTRAC FULL RANGE PARTICLE ANALYZER - Ver 3.02

Fe2O3 Sample#: 07-3752
In DI water

GRG

Meas/Pres #: - param #2: 0.000 Lot Code:
param #1: 0.000 param #3: 0.000 Account#:

Id #1:
Distrib. Format: Volume
Filter: On
Run Time: 60 seconds
Run #:AVG of 3 runs
Loading Index: 0.88
Laser Intensity: 1.057
Residuals: Disabled
Above Residuals: 0.00
Below Residuals: 0.00

Summary Data

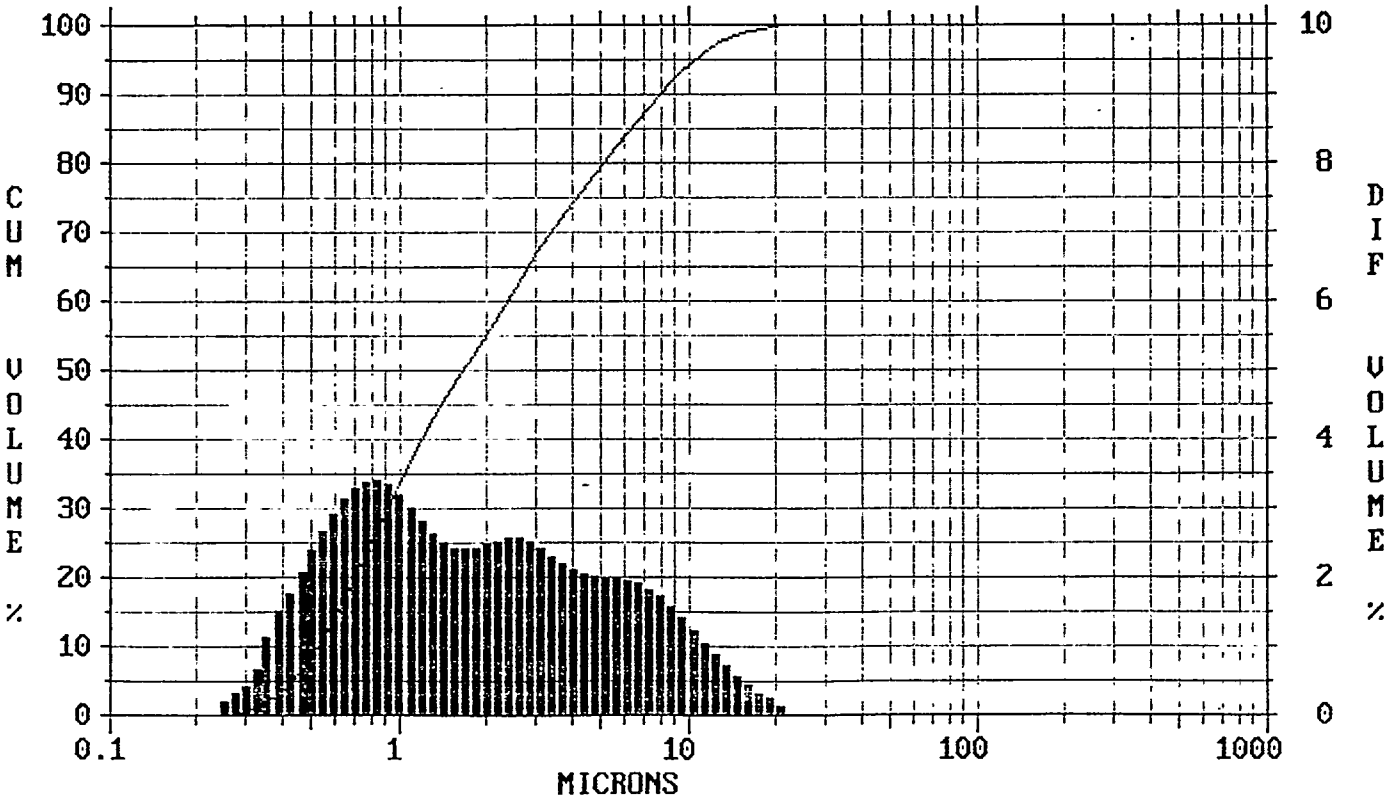
dv	=	0.0341
5%	=	0.43
50%	=	1.68
95%	=	10.57
mv	=	3.11
ma	=	1.19
cs	=	5,049
sd	=	2.70

Id #2:
Date: 03/30/99 Time: 15:55
Chan. Progression: Geom/Srt2
Upper Channel Edge: 704.00
Lower Channel Edge: 0.12
Number of Channels: 100
Fluid Refractive Index: n/a
Transparent Particles: No
Spherical Particles: n/a
Part. Refractive index: n/a

ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn
704.00	100.00	0.00	80.70	100.00	0.00	9.25	92.89	1.59	1.06	35.93	3.21
645.57	100.00	0.00	74.00	100.00	0.00	8.48	91.30	1.72	0.97	32.72	3.36
591.99	100.00	0.00	67.86	100.00	0.00	7.78	89.58	1.83	0.89	29.36	3.42
542.86	100.00	0.00	62.23	100.00	0.00	7.13	87.75	1.91	0.82	25.94	3.40
497.80	100.00	0.00	57.06	100.00	0.00	6.54	85.84	1.95	0.75	22.54	3.31
456.49	100.00	0.00	52.33	100.00	0.00	6.00	83.89	1.97	0.69	19.23	3.14
418.60	100.00	0.00	47.98	100.00	0.00	5.50	81.92	1.98	0.63	16.09	2.93
383.86	100.00	0.00	44.00	100.00	0.00	5.04	79.94	2.00	0.58	13.16	2.66
352.00	100.00	0.00	40.35	100.00	0.00	4.62	77.94	2.04	0.53	10.50	2.38
322.79	100.00	0.00	37.00	100.00	0.00	4.24	75.90	2.10	0.49	8.12	2.07
296.00	100.00	0.00	33.93	100.00	0.00	3.89	73.80	2.20	0.45	6.05	1.78
271.43	100.00	0.00	31.11	100.00	0.00	3.57	71.60	2.30	0.41	4.27	1.52
248.90	100.00	0.00	28.53	100.00	0.00	3.27	69.30	2.42	0.37	2.75	1.14
228.24	100.00	0.00	26.16	100.00	0.00	3.00	66.88	2.51	0.34	1.61	0.67
209.30	100.00	0.00	23.99	100.00	0.00	2.75	64.37	2.57	0.32	0.94	0.41
191.93	100.00	0.00	22.00	100.00	0.15	2.52	61.80	2.57	0.29	0.53	0.33
176.00	100.00	0.00	20.17	99.85	0.26	2.31	59.23	2.53	0.27	0.20	0.20
161.39	100.00	0.00	18.50	99.59	0.34	2.12	56.70	2.48	0.24	0.00	0.00
148.00	100.00	0.00	16.96	99.25	0.45	1.94	54.22	2.42	0.22	0.00	0.00
135.71	100.00	0.00	15.56	98.80	0.58	1.78	51.80	2.41	0.20	0.00	0.00
124.45	100.00	0.00	14.27	98.22	0.72	1.64	49.39	2.43	0.19	0.00	0.00
114.12	100.00	0.00	13.08	97.50	0.89	1.50	46.96	2.52	0.17	0.00	0.00
104.65	100.00	0.00	12.00	96.61	1.06	1.38	44.44	2.65	0.16	0.00	0.00
95.96	100.00	0.00	11.00	95.55	1.24	1.26	41.79	2.83	0.14	0.00	0.00
88.00	100.00	0.00	10.09	94.31	1.42	1.16	38.96	3.03	0.13	0.00	0.00

F2-Commands Esc-exit

Record Number: 0



F2-clr key Esc-exit

THE PRINCE MANUFACTURING COMPANY

Established 1858

DATA SHEET

Synthetic Red 2568

Fe_2O_3

Item Number: 07-2568

Typical Chemical Analysis

Fe	67.5%
Fe_2O_3	96.5%
Al_2O_3 & SiO_2	3.0%
Oil Absorption	26
Total Water Solubles	0.3%
Soluble Sulfates	0.3%
Loss on Ignition	0.5%
pH	6

Physical Description

Color	red
Fineness	99.9% thru 325 Mesh
Tap Density	68.7 lb/ft^3
Specific Gravity	5.0
Package	50 lb 3 ply paper bag 114 lbs

114/lbs

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COLLECT DISPLAY - MICROTRAC FULL RANGE PARTICLE ANALYZER - Ver 3.02

Fe2O3 Sample#: 07-2568
in DI water

GRG

Meas/Pres #: - param #2: 0.000 Lot Code:
param #1: 0.000 param #3: 0.000 Account#:

Id #1:
Distrib. Format: Volume
Filter: On
Run Time: 60 seconds
Run #:AVG of 3 runs
Loading Index: 0.79
Laser Intensity: 1.057
Residuals: Disabled
Above Residuals: 0.00
Below Residuals: 0.00

Summary Data

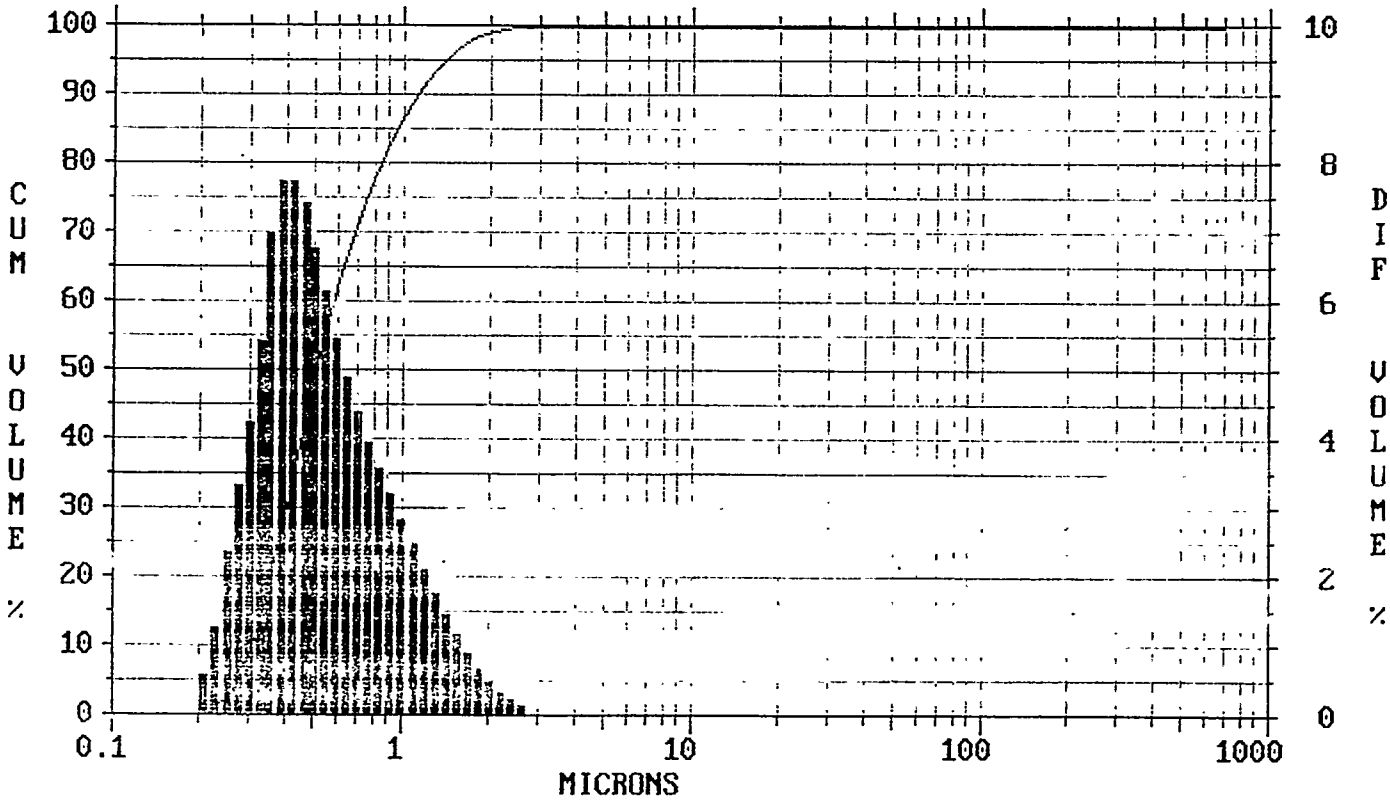
dv	=	0.0341
5%	=	0.28
50%	=	0.51
95%	=	1.41
mv	=	0.63
ma	=	0.49
cs	=	12.238
sd	=	0.30

Id #2:
Date: 03/30/99 Time: 12:14
Chan. Progression: Geom/8rt2
Upper Channel Edge: 704.00
Lower Channel Edge: 0.12
Number of Channels: 100
Fluid Refractive Index: n/a
Transparent Particles: No
Spherical Particles: n/a
Part. Refractive index: n/a

ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn
704.00	100.00	0.00	80.70	100.00	0.00	9.25	100.00	0.00	1.06	88.24	2.83
645.57	100.00	0.00	74.00	100.00	0.00	8.48	100.00	0.00	0.97	85.41	3.19
591.99	100.00	0.00	67.86	100.00	0.00	7.78	100.00	0.00	0.89	82.22	3.57
542.86	100.00	0.00	62.23	100.00	0.00	7.13	100.00	0.00	0.82	78.65	3.96
497.80	100.00	0.00	57.06	100.00	0.00	6.54	100.00	0.00	0.75	74.69	4.40
456.49	100.00	0.00	52.33	100.00	0.00	6.00	100.00	0.00	0.69	70.29	4.88
418.60	100.00	0.00	47.98	100.00	0.00	5.50	100.00	0.00	0.63	65.41	5.46
383.86	100.00	0.00	44.00	100.00	0.00	5.04	100.00	0.00	0.58	59.95	6.13
352.00	100.00	0.00	40.35	100.00	0.00	4.62	100.00	0.00	0.53	53.82	6.78
322.79	100.00	0.00	37.00	100.00	0.00	4.24	100.00	0.00	0.49	47.04	7.42
296.00	100.00	0.00	33.93	100.00	0.00	3.89	100.00	0.00	0.45	39.62	7.72
271.43	100.00	0.00	31.11	100.00	0.00	3.57	100.00	0.00	0.41	31.90	7.73
248.90	100.00	0.00	28.53	100.00	0.00	3.27	100.00	0.00	0.37	24.17	6.95
228.24	100.00	0.00	26.16	100.00	0.00	3.00	100.00	0.00	0.34	17.20	5.43
209.30	100.00	0.00	23.99	100.00	0.00	2.75	100.00	0.15	0.32	11.77	4.23
191.93	100.00	0.00	22.00	100.00	0.00	2.52	99.85	0.24	0.29	7.54	3.34
176.00	100.00	0.00	20.17	100.00	0.00	2.31	99.63	0.34	0.27	4.20	2.35
161.39	100.00	0.00	18.50	100.00	0.00	2.12	99.29	0.48	0.24	1.85	1.28
148.00	100.00	0.00	16.96	100.00	0.00	1.94	98.81	0.68	0.22	0.57	0.52
135.71	100.00	0.00	15.56	100.00	0.00	1.78	98.13	0.90	0.20	0.00	0.00
124.45	100.00	0.00	14.27	100.00	0.00	1.64	97.23	1.18	0.19	0.00	0.00
114.12	100.00	0.00	13.08	100.00	0.00	1.50	96.05	1.46	0.17	0.00	0.00
104.65	100.00	0.00	12.00	100.00	0.00	1.38	94.59	1.77	0.16	0.00	0.00
95.96	100.00	0.00	11.00	100.00	0.00	1.26	92.82	2.11	0.14	0.00	0.00
88.00	100.00	0.00	10.09	100.00	0.00	1.16	90.71	2.47	0.13	0.00	0.00

F2-Commands Esc-exit

Record Number: 0



F2-clr key Esc-exit

Nepheline

THE MINERAL NEPHELINE

- **Chemistry: (Na, K)AlSiO4 , Sodium Potassium Aluminum Silicate.**
- **Class: Silicates**
- **Subclass: Tectosilicates**
- **Group: Feldspathoid.**
- **Uses: As mineral specimens and as raw material for special kinds of glass and ceramics.**
- **Specimens**

Nepheline is a major rock forming mineral that is not often sold in rock shops due to a lack of good crystals or attractive specimens. It is a major component of several igneous rocks called *nepheline syenite, nepheline monzonite* and *nephelinite* . The basic difference between these is in the amount and types of feldspars present. In *nepheline syenite* potassium feldspars or K-spars are the predominant feldspar. In the *nepheline monzonite* rocks both k-spars and plagioclase feldspars are present in near equal proportions. And finally in the *nephelinites* there is little of any of the feldspars present and the rock is mostly nepheline.

The formula of nepheline in some sources will list it as NaAlSiO4. There are very few natural nephelines that have this "pure" chemistry although it produces a stable structure and it is manufactured for use in ceramics and glass production. Potassium is always present in some amounts and often the chemical analysis of nepheline will approach Na3K(AlSiO4)4. This result reflects the fact that the alkali sites for the sodiums and potassiums have an interesting difference in the amount of space within the nepheline structure. There is actually one site out of four that is larger than the other three sites. This larger site is a more comfortable fit for the larger potassium ion.

Nepheline is a member of the feldspathoid group of minerals. Minerals whose chemistries are close to that of the alkali **feldspars** but are poor in silica (SiO2) content, are called feldspathoids. As a result or more correctly as a function of the fact, they are found in silica poor rocks containing other silica poor minerals and no **quartz**. If quartz were present when the melt was crystallizing, it would react with any feldspathoids and form a feldspar. Localities that have feldspathoids are few.

Nepheline is reactive to acids although it does not bubble like many of the **carbonates**. If powdered it will dissolve in hydrochloric acid and if clear specimens are dipped in acid they will become cloudy or frosted. This could be helpful in distinguishing nepheline from some similar looking **feldspars, scapolite** and **cryolite**.

The greasy luster of nepheline also is diagnostic. Massive nepheline with a greasy luster is given the variety name "eleolite" which is derived from the greek word for *oil* . Nepheline is derived from the greek word for *cloud* in allusion to its cloudy or translucent crystals and masses.

PHYSICAL CHARACTERISTICS:

- **Color** is usually off white to gray or brown and occasionally other tints.
- **Luster** is mostly greasy to dull in weathered specimens.
- **Transparency:** Crystals are translucent to more rarely transparent.
- **Crystal System:** Hexagonal; 6
- **Crystal Habits:** Usually massive or granular. Some prismatic to columnar crystals are found with a simple hexagonal cross section.
- **Cleavage** is poor, in three directions, prismatic, but rarely seen.
- **Fracture** is conchoidal to uneven.
- **Hardness** is 5.5 - 6
- **Specific Gravity** is 2.6+ (average)
- **Streak** is white.
- **Other Characteristics:** Application of acids onto the surface of nepheline will cause a cloudy frosting and powdered nepheline will dissolve in hydrochloric acid.
- **Associated Minerals** include **calcite**, feldspars such as **albite, apatite, biotite, hornblende, cancrinite, sodalite** and other **feldspathoids**.
- **Notable Occurrences** include Kola Pennisula, Russia; Mt. Vesuvius, Italy; Bancroft area, Ontario, Canada and Kennebec Co., Maine, USA.
- **Best Field Indicators** luster, associations, reaction to acids, locality and hardness.

COLLECT DISPLAY - MICROTRAC FULL RANGE PARTICLE ANALYZER - Ver 3.02

Spectrum NEP. Syenite/A-400

GRG

Meas/Pres #: - param #2: 0.000 Lot Code:
param #1: 0.000 param #3: 0.000 Account#:

Id #1:
Distrib. Format: Volume
Filter: On
Run Time: 60 seconds
Run #:AVG of 3 runs
Loading Index: 0.86
Laser Intensity: 1.055
Residuals: Disabled
Above Residuals: 0.00
Below Residuals: 0.00

Summary Data

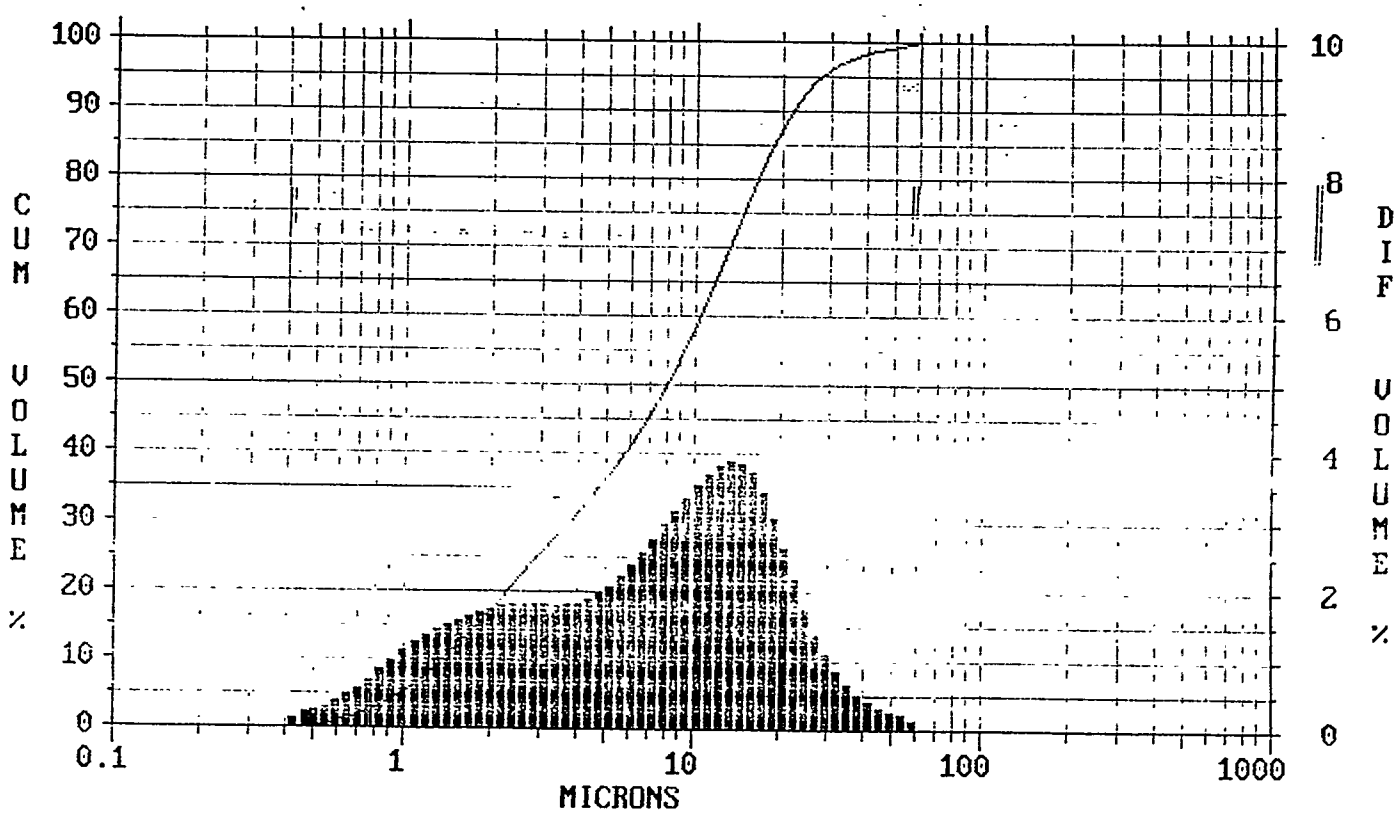
dv	=	0.1484
5%	=	0.98
50%	=	8.04
95%	=	27.62
mv	=	10.27
ma	=	3.62
cs	=	1.656
sd	=	8.22

Id #2:
Date: 03/25/99 Time: 16:25
Chan. Progression: Geom/8rt2
Upper Channel Edge: 704.00
Lower Channel Edge: 0.12
Number of Channels: 100
Fluid Refractive Index: n/a
Transparent Particles: No
Spherical Particles: n/a
Part. Refractive index: n/a

ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn	ch top	%pass	%-chn
704.00	100.00	0.00	80.70	100.00	0.00	9.25	55.02	3.17	1.06	6.02	1.13
645.57	100.00	0.00	74.00	100.00	0.00	8.48	51.85	2.98	0.97	4.89	0.99
591.99	100.00	0.00	67.86	100.00	0.00	7.78	48.87	2.78	0.89	3.90	0.85
542.86	100.00	0.00	62.23	100.00	0.14	7.13	46.09	2.59	0.82	3.05	0.71
497.80	100.00	0.00	57.06	99.86	0.23	6.54	43.50	2.40	0.75	2.34	0.58
456.49	100.00	0.00	52.33	99.63	0.26	6.00	41.10	2.23	0.69	1.76	0.47
418.60	100.00	0.00	47.98	99.37	0.32	5.50	38.87	2.09	0.63	1.29	0.38
383.86	100.00	0.00	44.00	99.05	0.41	5.04	36.78	1.97	0.58	0.91	0.30
352.00	100.00	0.00	40.35	98.64	0.52	4.62	34.81	1.89	0.53	0.61	0.25
322.79	100.00	0.00	37.00	98.12	0.67	4.24	32.92	1.84	0.49	0.36	0.22
296.00	100.00	0.00	33.93	97.45	0.86	3.89	31.08	1.82	0.45	0.14	0.14
271.43	100.00	0.00	31.11	96.59	1.10	3.57	29.26	1.81	0.41	0.00	0.00
248.90	100.00	0.00	28.53	95.49	1.40	3.27	27.45	1.83	0.37	0.00	0.00
228.24	100.00	0.00	26.16	94.09	1.78	3.00	25.62	1.83	0.34	0.00	0.00
209.30	100.00	0.00	23.99	92.31	2.20	2.75	23.79	1.84	0.32	0.00	0.00
191.93	100.00	0.00	22.00	90.11	2.65	2.52	21.95	1.82	0.29	0.00	0.00
176.00	100.00	0.00	20.17	87.46	3.07	2.31	20.13	1.79	0.27	0.00	0.00
161.39	100.00	0.00	18.50	84.39	3.45	2.12	18.34	1.76	0.24	0.00	0.00
148.00	100.00	0.00	16.96	80.94	3.72	1.94	16.58	1.71	0.22	0.00	0.00
135.71	100.00	0.00	15.56	77.22	3.86	1.78	14.87	1.65	0.20	0.00	0.00
124.45	100.00	0.00	14.27	73.36	3.89	1.64	13.22	1.59	0.19	0.00	0.00
114.12	100.00	0.00	13.08	69.47	3.83	1.50	11.63	1.53	0.17	0.00	0.00
104.65	100.00	0.00	12.00	65.64	3.71	1.38	10.10	1.46	0.16	0.00	0.00
95.96	100.00	0.00	11.00	61.93	3.55	1.26	8.64	1.36	0.14	0.00	0.00
88.00	100.00	0.00	10.09	58.38	3.36	1.16	7.28	1.26	0.13	0.00	0.00

F2-Commands Esc-exit

Record Number: 0



F2-clr key Esc-exit

Zirconium Hydroxide

ZIRCONIUM HYDROXIDE DRY POWDER GRADES PRODUCT DETAILS

MEI supplies pure zirconium hydroxide grades produced by chemical precipitation processes. These grades have controlled purity and morphology.

PRODUCT DATA FOR ZIRCONIUM HYDROXIDE DRY POWDER GRADES

Product	General Description
FZO922/01	Dry, coarse hydroxide
FZO935/01	Dry, fine hydroxide

Customised variations can be made available on request.

FZO 922 SERIES

PRODUCT CODE - FZO922/01
ZIRCONIUM HYDROXIDE

Typical ZrO_2 content range: 65-75%

TYPICAL IMPURITIES	
Na	0.02%
Cl	0.02%
SiO_2	0.1%
SO_3	0.1%
L.O.I. (1000°C)	30%
PARTICLE SIZE	
d_{50}	15–20 μm
Surface area as received (m^2g^{-1})[a]	300–400
POROSITY	
Pore Volume	0.2 cm^3g^{-1}[a] 0.3 cm^3g^{-1}[b]

[a] After degassing at 260°C
[b] After degassing at 80°C

FZO 935 SERIES

PRODUCT CODE - FZO935/01
ZIRCONIUM HYDROXIDE

Typical ZrO_2 content range: 55-65%

TYPICAL IMPURITIES	
Na	0.02%
Cl	0.02%
SiO_2	0.1%
SO_3	0.1%
L.O.I. (1000°C)	40%
PARTICLE SIZE	
d_{50}	1–2 μm
Surface area as received (m^2g^{-1})[a]	300–400
POROSITY	
Pore Volume	0.2 cm^3g^{-1}[a]

ZIRCONIUM HYDROXIDE PASTE GRADE PRODUCT DETAILS

MEI supplies pure zirconium hydroxide grades produced by chemical precipitation processes. These grades have controlled purity and morphology and are available as white paste.

Customised variations can be made available on request.

HCP

ZIRCONIUM HYDROXIDE PASTE

Typical ZrO_2 content range: 45-55%

TYPICAL IMPURITIES	
Na	0.01%
Cl	0.01%
SiO_2	0.05%
SO_3	<0.1%
TiO_2	0.2%
Fe	0.001%
PARTICLE SIZE	
d_{50}	20-30 μm

Surface area against calcination temperature

Temp. (°C)	Surface Area (m^2g^{-1})
400	100
700	35

Appendix C: Crossflow Filtration Raw Data

C-106 Slurry CUF Testing Using 0.1µm Graver Filter

Same sequence of run condition as actual waste

BNFL AZ102 testing--AZ-102
Using 0.1 Micron Mott filter-3/8 inch ID

Run #	V (ft/s)	V (m/s)	GPM	Psid
1.0.1	12.2	3.72	4.20	10
1.0.2	12.2	3.72	4.20	20
1.0.3	12.2	3.72	4.20	30
1.1	12.2	3.72	4.20	50
1.2	9.1	2.77	3.13	30
1.3	15.2	4.63	5.23	70
1.4	15.2	4.63	5.23	30
1.5	9.1	2.77	3.13	70
1.6	12.2	3.72	4.20	50

J.G.H. Geeting et al, PNNL-11652 Sept. 1997
Using 0.5 Micron Mott filter-0.5 inch ID

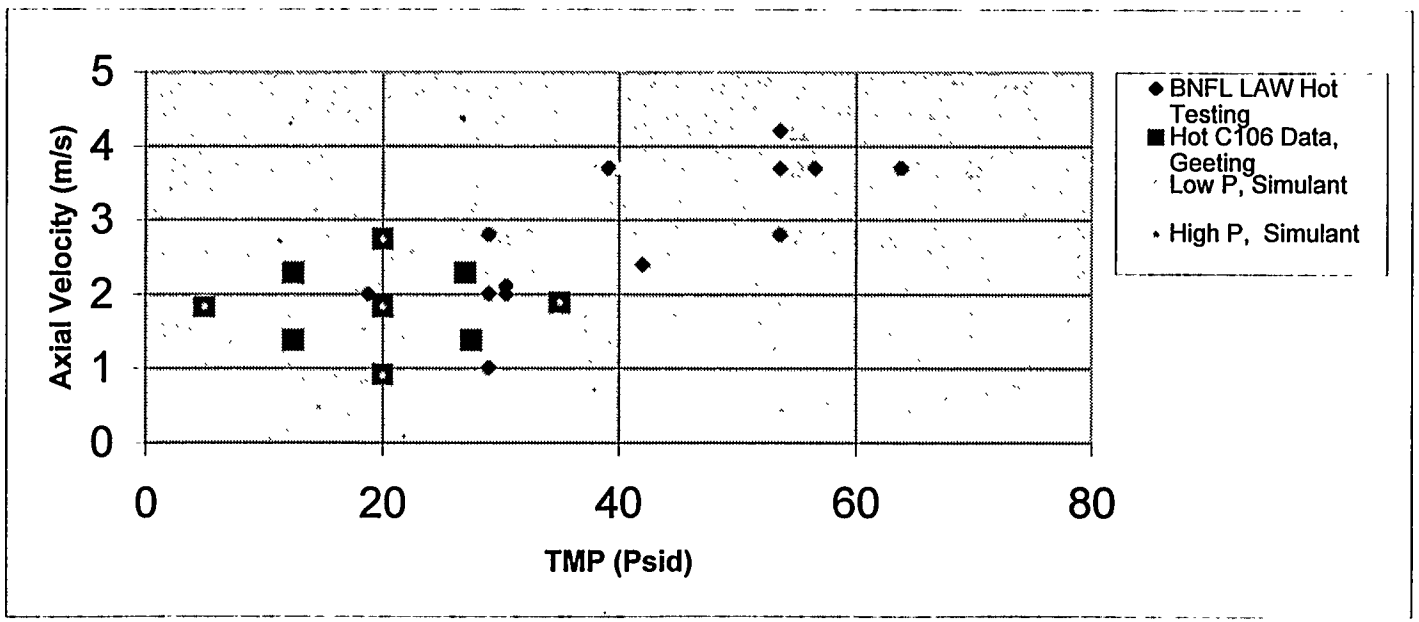
Run #	V (ft/s)	V (m/s)	GPM	Psid
1	6.1	1.86	3.73	20
2	4.5	1.37	2.75	12.5
3	9	2.74	5.51	20
4	6.2	1.89	3.79	35
5	4.5	1.37	2.75	27.5
6	6	1.83	3.67	20
7	7.5	2.29	4.59	12.5
8	6	1.83	3.67	5
9	3	0.91	1.84	20
10	7.5	2.29	4.59	27
11	6	1.83	3.67	20

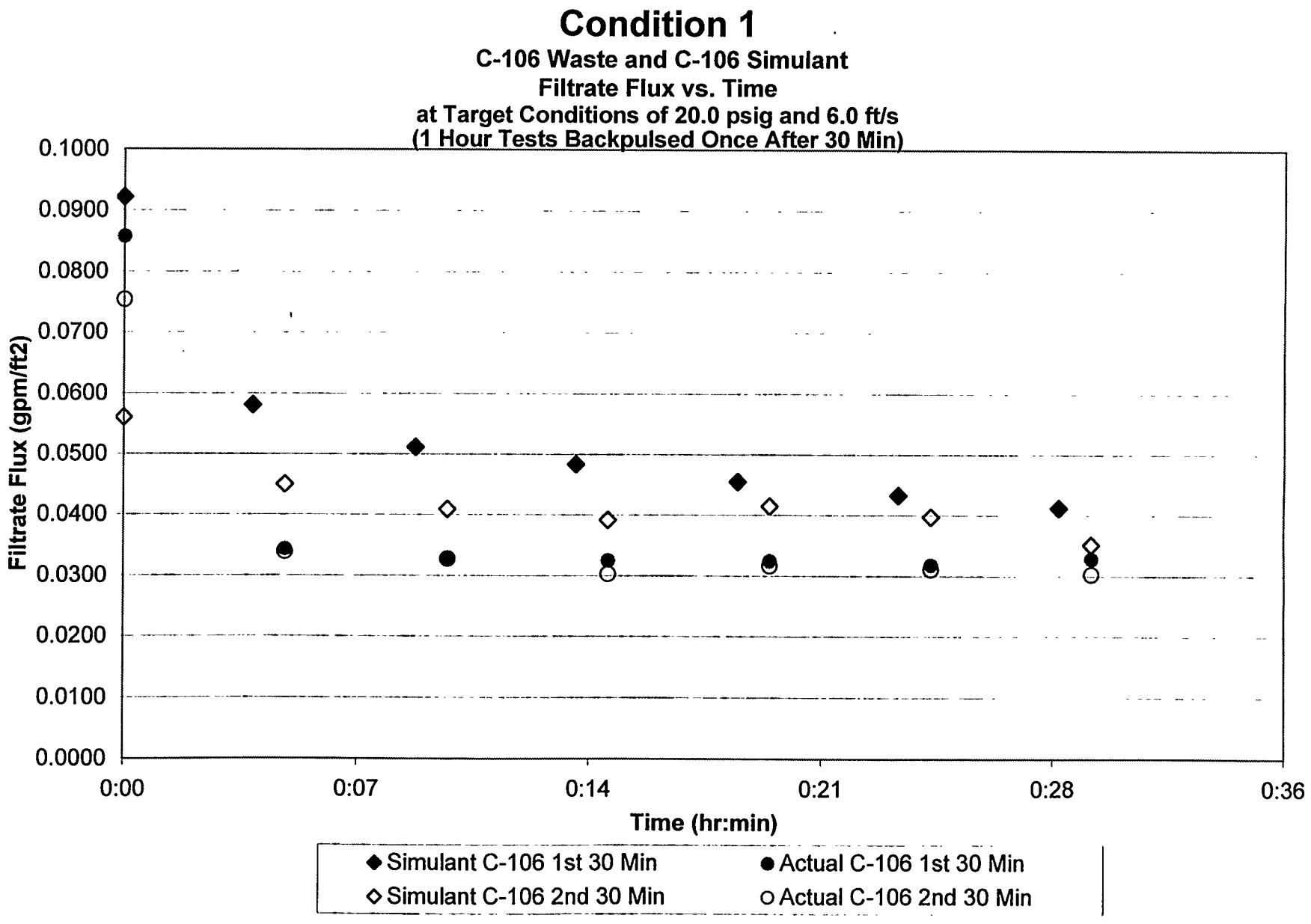
BNFL LAW testing

Run #	V (m/s)	GPM	Psid
2&8&14	3.7	1.86	55
9	3.7	1.86	40
10	3.7	1.86	70
11	2.8	1.5	55
[illegible]	[illegible]	[illegible]	[illegible]
12	4.2	2.1	55

Geeting et al.

Run #	V (m/s)	GPM	Psid
1&6&11	1.83	0.93	20
4	1.89	0.95	35
8	1.83	0.92	5
9	0.91	0.46	20
3	2.74	1.38	20




Condition 1
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 20.0 psig and 6.0 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

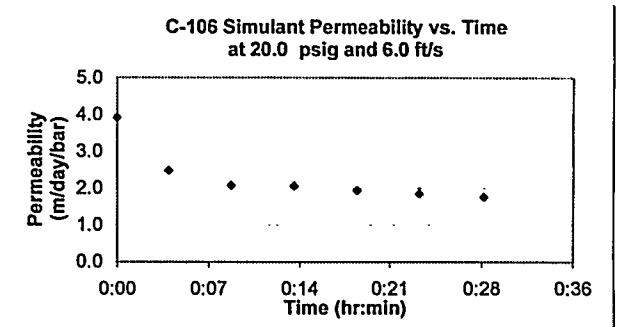
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
1a	14:11	0.00	3 67	NM	20	9	22.25	0 404	27.2	5.405	3.920	0.0921
1a	14:15	0.04	3.74	NM	20	9	37.1	0.243	25.4	3.408	2.472	0.0581
1a	14:20	0:09	3.7	NM	21	9	43.78	0.206	24.1	2.996	2.069	0.0511
1a	14:25	0:14	3.63	NM	20	9	47.34	0.190	23.3	2.835	2.056	0.0483
1a	14:30	0:19	3.66	NM	20	9	50.56	0.178	23.1	2.669	1.936	0.0455
1a	14:35	0:24	3.69	NM	20	9	52.53	0.171	23.5	2.540	1.842	0.0433
1a	14:40	0:29	3.69	NM	20	9	54.87	0.164	23.7	2.418	1.753	0.0412

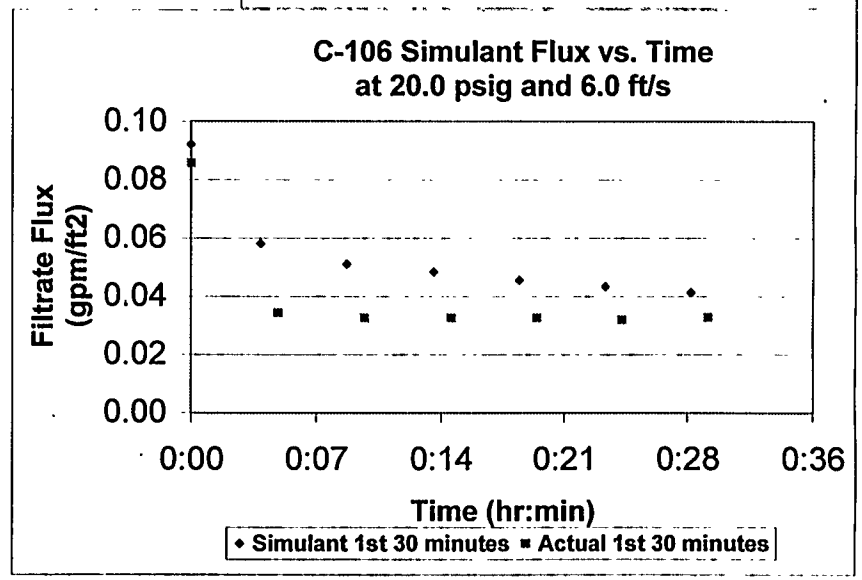
Average Pressure = 20.1 psig Average Flow = 0.222 Average Flux = 3.182 0.046

RAW Average Slurry Flow = 3.68 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1a	14:11	18	27.2	3.67	NM	0	20	9	19.5	0.462
1a	14:15	14	25.4	3.74	NM	0	20	9	26.1	0.345
1a	14:20	15	24.1	3.7	NM	0	21	9	28.37	0.317
1a	14:25	16	23.3	3.63	NM	0	20	9	31.03	0.290
1a	14:30	17	23.1	3.66	NM	0	20	9	34.07	0.264
1a	14:35	18	23.5	3.69	NM	0	20	9	35.63	0.253
1a	14:40	19	23.7	3.69	NM	0	20	9	35.63	0.253

NM = Not Measured

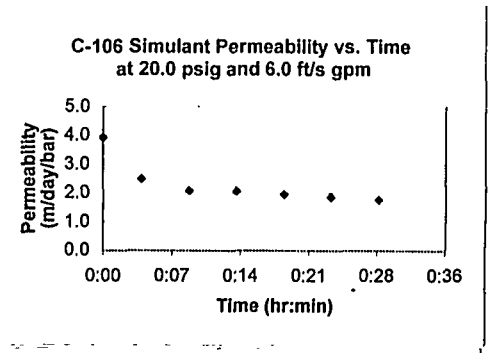




John Geeting Data

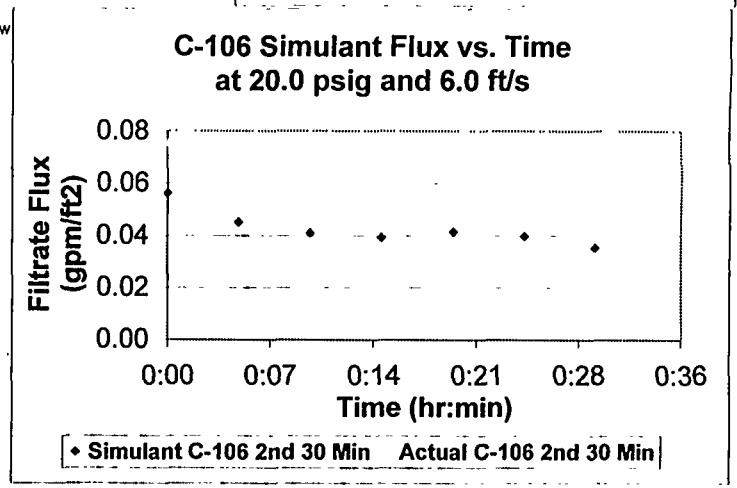
	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.3	0.102	0.0857
	0:05	31.8	0.0414	0.0343
	0:10	31.8	0.0393	0.0326
	0:15	32.2	0.0396	0.0325
	0:20	32.7	0.0401	0.0325
	0:25	32.7	0.0393	0.0318
	0:30	32.3	0.0401	0.0328
2nd 30 minutes	0;00	32.4	0.0924	0.0754
	0:05	32	0.0411	0.0339
	0:10	31.9	0.0396	0.0328
	0:15	31.9	0.0366	0.0303
	0:20	31.8	0.0382	0.0317
	0:25	31.8	0.0375	0.0311
	0:30	31.7	0.0364	0.0303

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
1b	14:55	0:00	3 77	NM	20	9	39.79	0 226	24.2	3.287	2.384	0.0560
1b	15:00	0 05	3.66	NM	20.5	9	49 68	0.181	24.1	2.640	1.868	0.0450
1b	15.05	0.10	3 7	NM	20	9	54 56	0 165	24.2	2.397	1.739	0.0409
1b	15:10	0:15	3 69	NM	20	9	56.65	0.159	24.4	2.296	1.665	0.0391
1b	15:15	0:20	3.67	NM	20	9	52.88	0.170	24.8	2.432	1.764	0.0415
1b	15.20	0:25	3.66	NM	20.5	9	54 88	0.164	25	2.330	1 649	0.0397
1b	15:25	0:30	3.82	NM	20	9	62.13	0.145	25	2.058	1.493	0.0351
		Average Pressure =		20.1		Average Flow =		0.173	Average Flux =	2.492		0.039
RAW	Average Slurry Flow =		3.71 gpm			Filtrate						

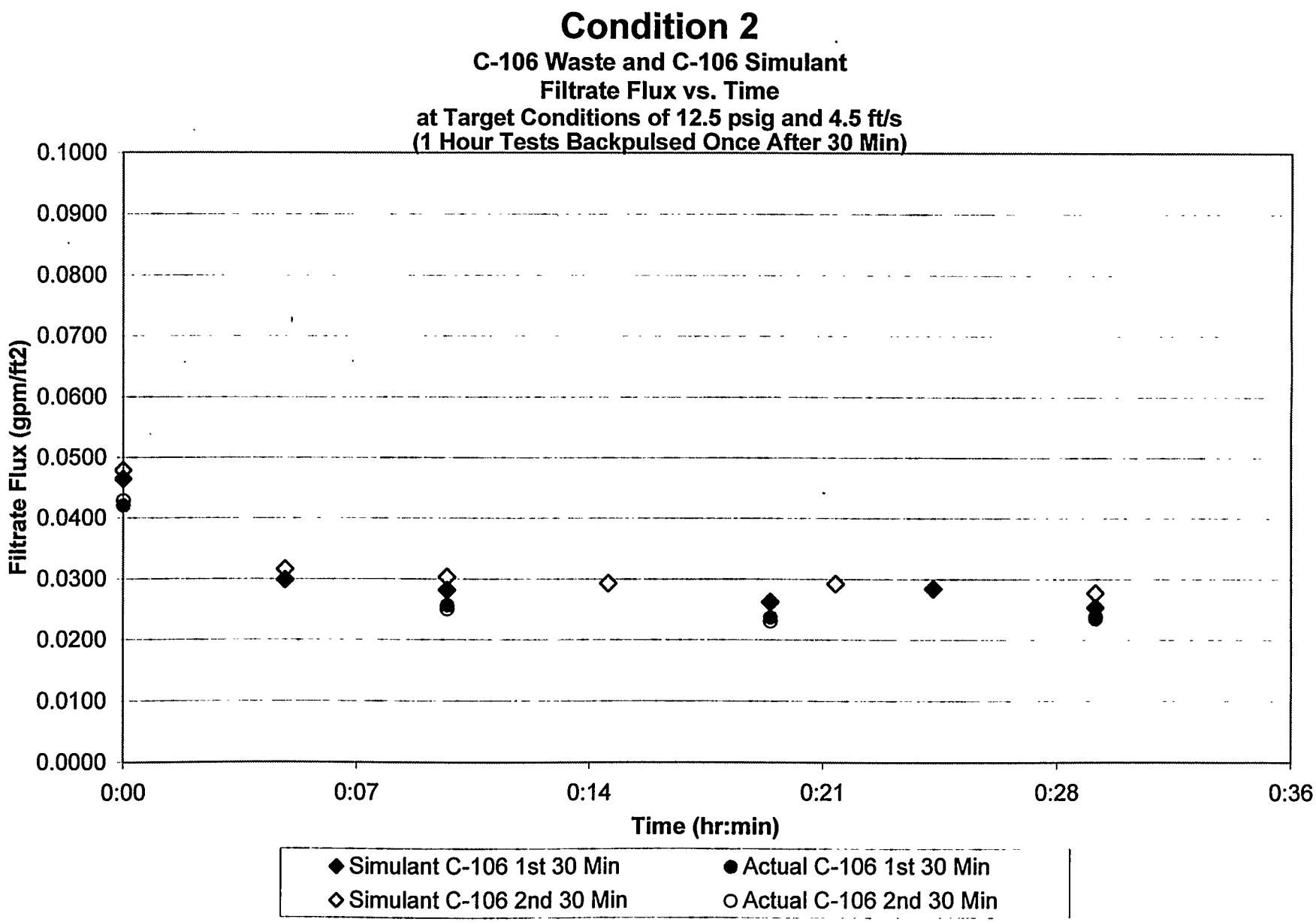


Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1b	14:55	18	23.8	0.89	NM	1	20	10	25.81	0.387
1b	15:00	18	24.2	0.93	NM	1	20.5	10	28.43	0.352
1b	15:05	18	24.6	0.96	NM	1	20.5	10	30.62	0.327
1b	15:10	20	24.9	0.98	NM	1	20.5	10	31.16	0.321
1b	15:15	20	25	0.9	NM	1	20	10	33.81	0.296
1b	15:20	19	25.1	0.89	NM	1	20.5	10	34.07	0.294
1b	15:25	19	25.5	0.86	NM	1	20	10	36 97	0.270

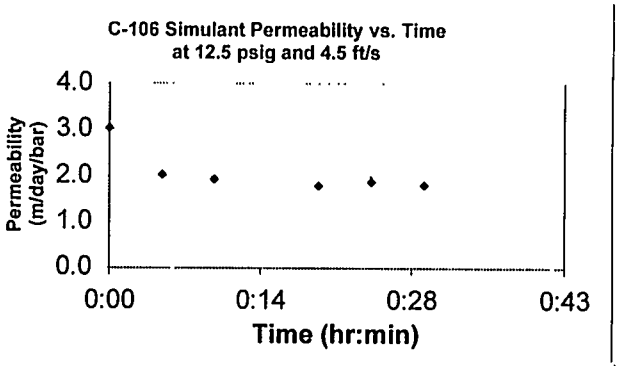
NM = Not Measured



John Geeting Data	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.3	0.102	0.0857
	0:05	31.8	0.0414	0.0343
	0:10	31.8	0.0393	0.0326
	0:15	32.2	0.0396	0.0325
	0:20	32.7	0.0401	0.0325
	0:25	32.7	0.0393	0.0318
	0:30	32.3	0.0401	0.0328
2nd 30 minutes	0:00	32.4	0.0924	0.0754
	0:05	32	0.0411	0.0339
	0:10	31.9	0.0396	0.0328
	0:15	31.9	0.0366	0.0303
	0:20	31.8	0.0382	0.0317
	0:25	31.8	0.0375	0.0311
	0:30	31.7	0.0364	0.0303

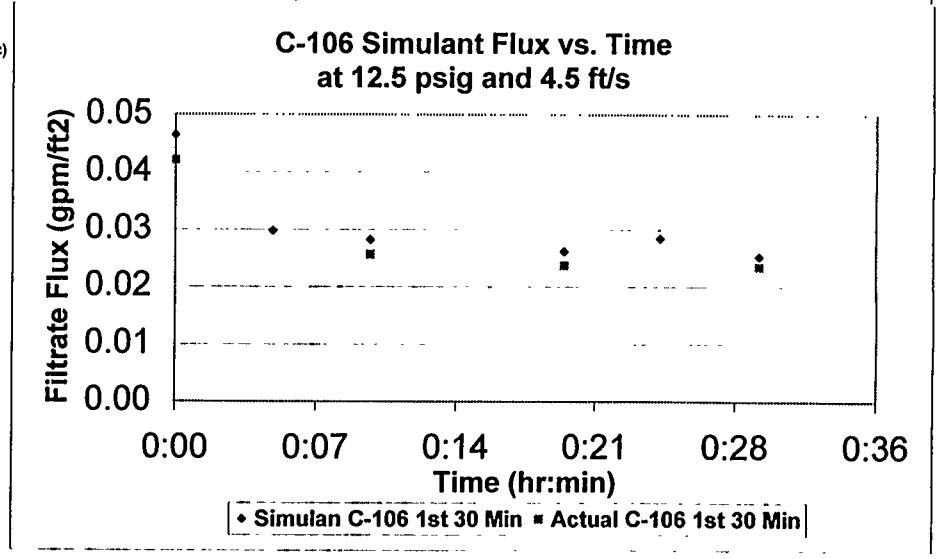

Condition 2
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 12.5 psig and 4.5 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
2a	16:10	0:00	2 76	NM	13	15	73 84	0.203	27 1	2.722	3 037	0.0484
2a	16:15	0:05	2.76	NM	12.5	9	69.97	0 129	26.6	1.748	2.028	0.0298
2a	16:20	0 10	2 7	NM	12 5	9	74 84	0.120	26 2	1.652	1 917	0.0282
2a	16:30	0.20	2.5	NM	12.5	9	81.22	0.111	25.9	1 535	1.781	0.0262
2a	16 35	0:25	2.75	NM	13	9	74.56	0.121	26	1.668	1 861	0.0284
2a	16:40	0 30	2.77	NM	12	9	81.5	0.110	27	1.484	1.793	0.0253
		Average Pressure =		12.6		Average Flow =		0.132	Average Flux =	1.801		0.027
RAW	Average Slurry Flow =		2.71 gpm			Filtrate						



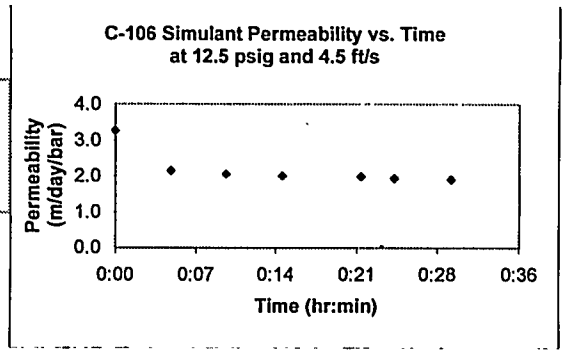
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2a	16:10	13	27.1	2.76	NM	0	13	15	73.84	0.203
2a	16:15	12.5	26 6	2.76	NM	0	12.5	9	69.97	0.129
2a	16:20	12.5	26.2	2.7	NM	0	12.5	9	74 84	0.120
2a	16:30	12.5	25.9	2.5	NM	0	12.5	9	81.22	0.111
2a	16:35	13	26	2.75	NM	0	13	9	74.56	0.121
2a	16:40	12	27	2.77	NM	0	12	9	81.5	0.110

NM = Not Measured



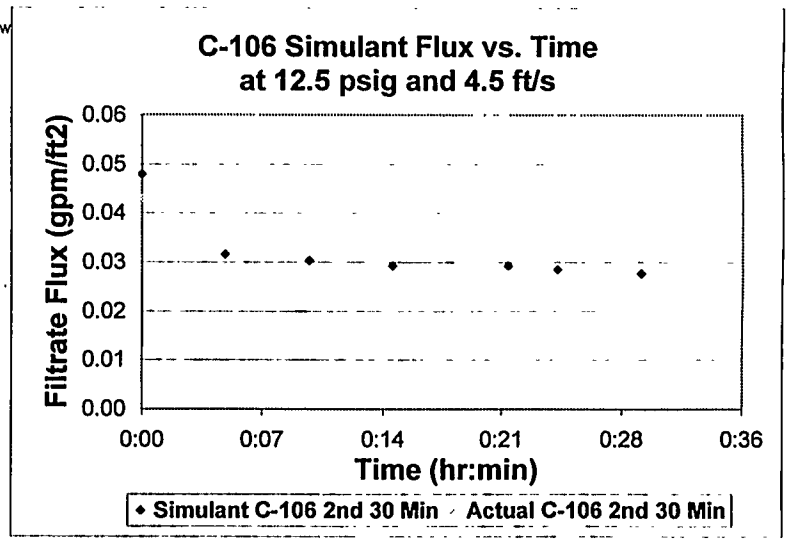
John Geeting Data	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 39 minutes	0:00	30.8	0.0494	0.0421
	0:10	29.5	0.0290	0.0256
	0:20	29.2	0.0266	0.0237
	0:30	29.2	0.0264	0.0235
2nd 30 minutes	0:00	29.5	0.0486	0.0429
	0:10	29.3	0.0283	0.0251
	0:20	29.3	0.026	0.0231
	0:30	29.2	0.0268	0.0239

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
2b	10:53	0:00	2.87	NM	12.5	9	45.28	0.199	25.2	2.808	3.259	0.0479
2b	10:58	0:05	2.64	NM	12.5	9	68.66	0.131	25.2	1.852	2.149	0.0316
2b	11:03	0:10	2.69	NM	12.5	9	72	0.125	25	1.776	2.061	0.0303
2b	11:08	0:15	2.79	NM	12.5	9	74.72	0.120	24.9	1.716	1.991	0.0293
2b	11:15	0:22	2.82	NM	12.5	9	75.25	0.120	24.7	1.714	1.989	0.0292
2b	11:18	0.25	2.77	NM	12.5	9	77.47	0.116	24.7	1.665	1.932	0.0284
2b	11:23	0:30	2.73	NM	12.5	9	79.47	0.113	24.7	1.623	1.883	0.0277
		Average Pressure =			12.5	Average Flow =		0.132	Average Flux =	1.879		0.029
RAW	Average Slurry Flow =		2.76			Filtrate						

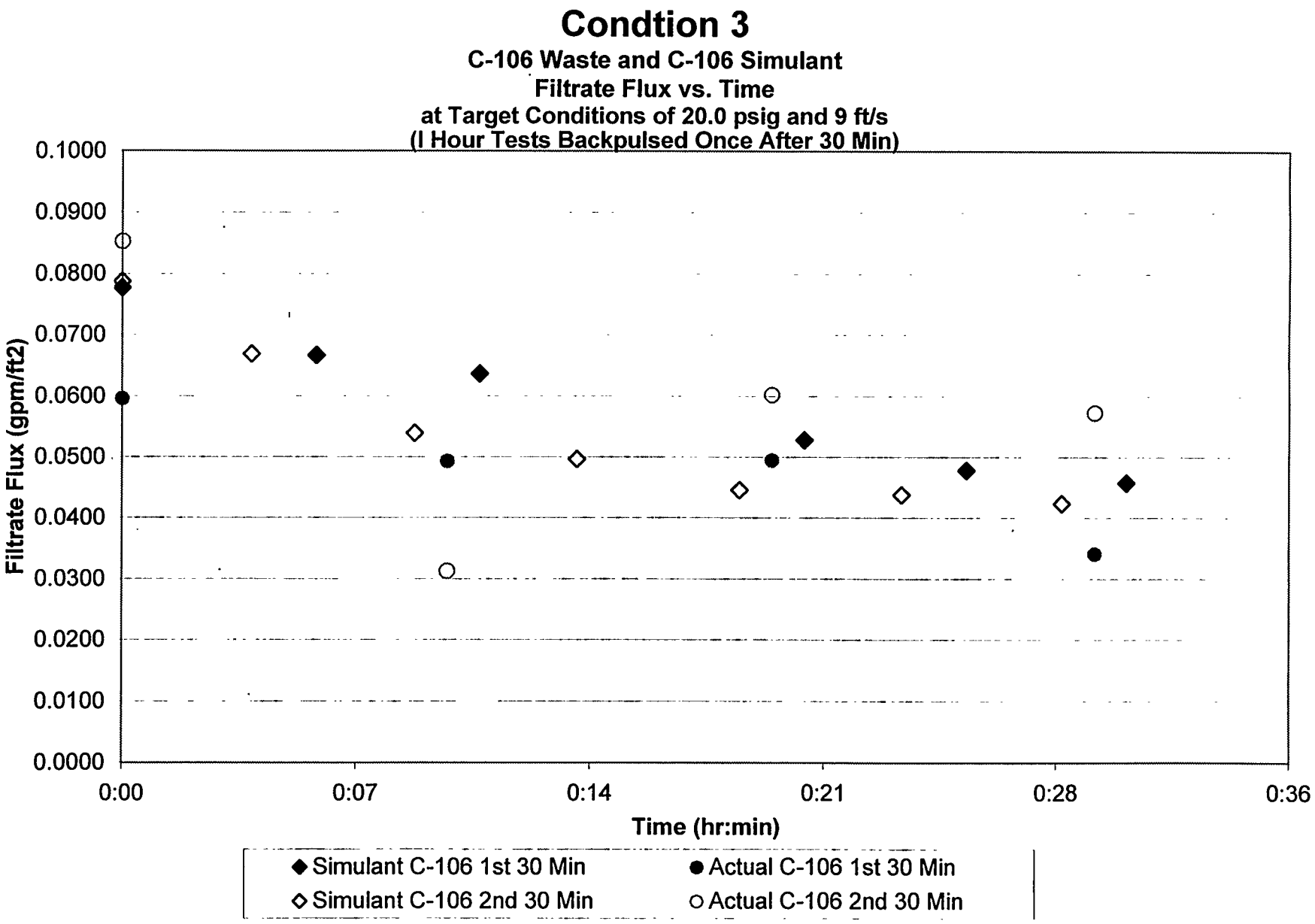


Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2b	10:53	19	25.2	2.87	NM	0	12.5	9	45.28	0.199
2b	10:58	17	25.2	2.64	NM	0	12.5	9	68.66	0.131
2b	11:03	18	25	2.69	NM	0	12.5	9	72	0.125
2b	11:08	17	24.9	2.79	NM	0	12.5	9	74.72	0.120
2b	11:15	18	24.7	2.82	NM	0	12.5	9	75.25	0.120
2b	11:18	18	24.7	2.77	NM	0	12.5	9	77.47	0.116
2b	11:23	18	24.7	2.73	NM	0	12.5	9	79.47	0.113

NM = Not Measured



John Geeting Data	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	30.8	0.0494	0.0421
	0:10	29.5	0.0290	0.0256
	0:20	29.2	0.0266	0.0237
	0:30	29.2	0.0264	0.0235
2nd 30 minutes	0:00	29.5	0.0486	0.0429
	0:10	29.3	0.0283	0.0251
	0:20	29.3	0.026	0.0231
	0:30	29.2	0.0268	0.0239


Condtion 3
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 20.0 psig and 9 ft/s
(I Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

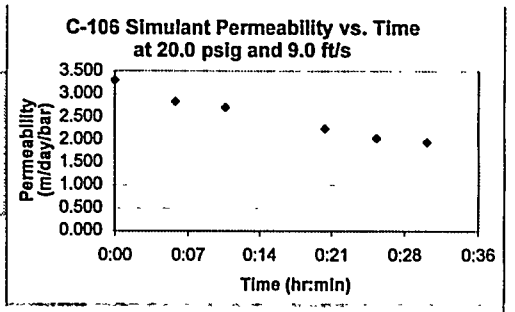
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
3a	11:59	0.00	5 59	NM	20	9	27.75	0.324	25.4	4.557	3.305	0.0777
3a	12:05	0·06	5.52	NM	20	9	32.62	0.276	25.1	3.909	2.835	0.0666
3a	12:10	0.11	5.51	NM	20	9	34.85	0.258	24.4	3.732	2.707	0.0636
3a	12:20	0.21	5.52	NM	20	9	42.63	0.211	23.9	3.095	2.244	0.0528
3a	12:25	0·26	5.54	NM	20	9	46 81	0.192	24.1	2 802	2.032	0.0478
3a	12:30	0 31	5.54	NM	20	9	48.75	0.185	24.2	2.683	1.946	0.0457

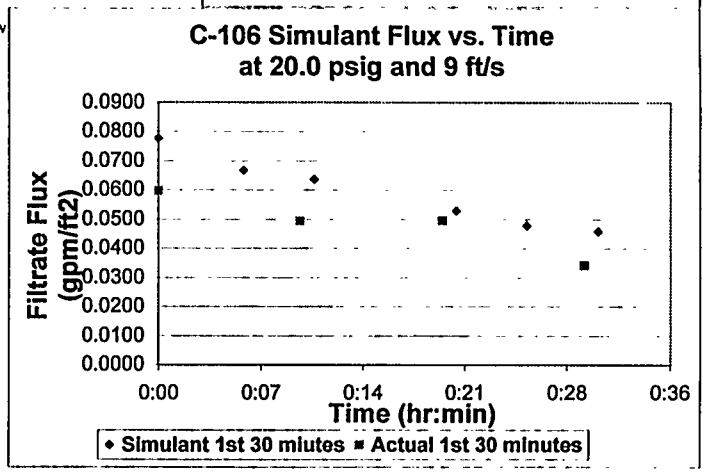
RAW Average Pressure = 20 Average Flow = 0 241 Average Flux = 3.463 0.052

Average Slurry Flow = 5.54

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
3a	11:59	18	25.4	5.59	NM	0	20	9	27.75	0.324
3a	12:05	15	25.1	5.52	NM	0	20	9	32.62	0.276
3a	12:10	15	24.4	5.51	NM	0	20	9	34.85	0.258
3a	12:20	15	23.9	5.52	NM	0	20	9	42.63	0.211
3a	12:25	16	24.1	5 54	NM	0	20	9	46.81	0.192
3a	12:30	15	24.2	5.54	NM	0	20	9	48.75	0.185

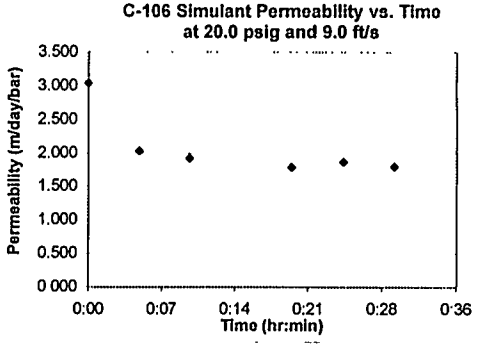
NM = Not Measured





John Geeting Data	Total Time Elapsed (Min)	JG Slurry Temp C	Filtrate Flux (gpm/ft2)	
1st 30 minutes	0;00	33.4	0.0750	0.0596
	0;10	34.4	0.0637	0.0493
	0:20	34.3	0.0637	0.0494
	0;30	35.1	0.0449	0.0341
2nd 30 minutes	0:00	29.5	0.0966	0.0853
	0;10	29.3	0.0352	0.0312
	0:20	29.3	0.0678	0.0602
	0;30	29.2	0.0644	0.0573

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressure (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
3b	12.41	0:00	5.51	NM	20	9	28	0.321	24 6	4.619	3.350	0.0787
3b	12:45	0 04	5.51	NM	20	9	32 72	0.275	24.9	3.919	2.842	0.0668
3b	12 50	0.09	5 54	NM	20	9	40.47	0 222	25	3.160	2.292	0.0539
3b	12:55	0.14	5.52	NM	20	9	43.72	0.206	25.2	2.909	2.109	0.0496
3b	13:00	0:19	5.52	NM	20	9	48.5	0.186	25.3	2.615	1.896	0.0446
3b	13:05	0:24	5 55	NM	20	9	49 44	0 182	25.3	2.565	1 860	0.0437
3b	13.10	0:29	5.52	NM	20	9	51.65	0 174	24.9	2.483	1 801	0.0423

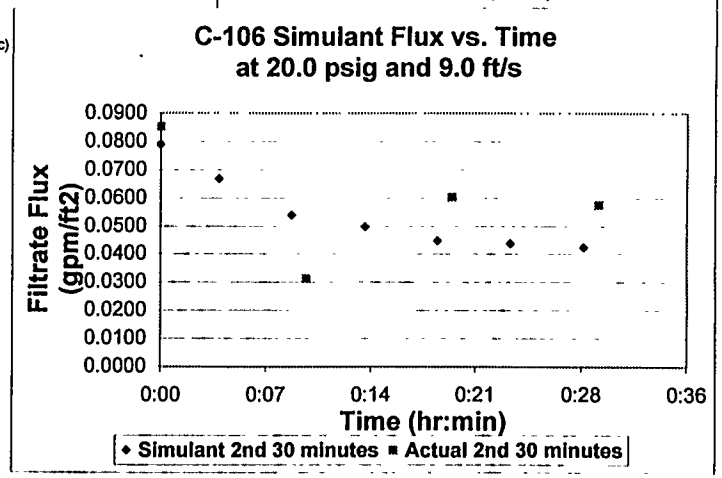


Average Pressure = 20 Average Flow = 0.224 Average Flux = 3.181 0.047

RAW Average Slurry Flow = 5.52

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressure (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
3b	12:41	16	24.6	5.51	NM	0	20	9	28	0.321
3b	12:45	16	24.9	5.51	NM	0	20	9	32.72	0.275
3b	12:50	17	25	5 54	NM	0	20	9	40.47	0.222
3b	12:55	16	25 2	5.52	NM	0	20	9	43.72	0.206
3b	13:00	17	25.3	5.52	NM	0	20	9	48.5	0.186
3b	13:05	16	25.3	5.55	NM	0	20	9	49.44	0.182
3b	13:10	15	24.9	5.52	NM	0	20	9	51.65	0.174

NM = Not Measured

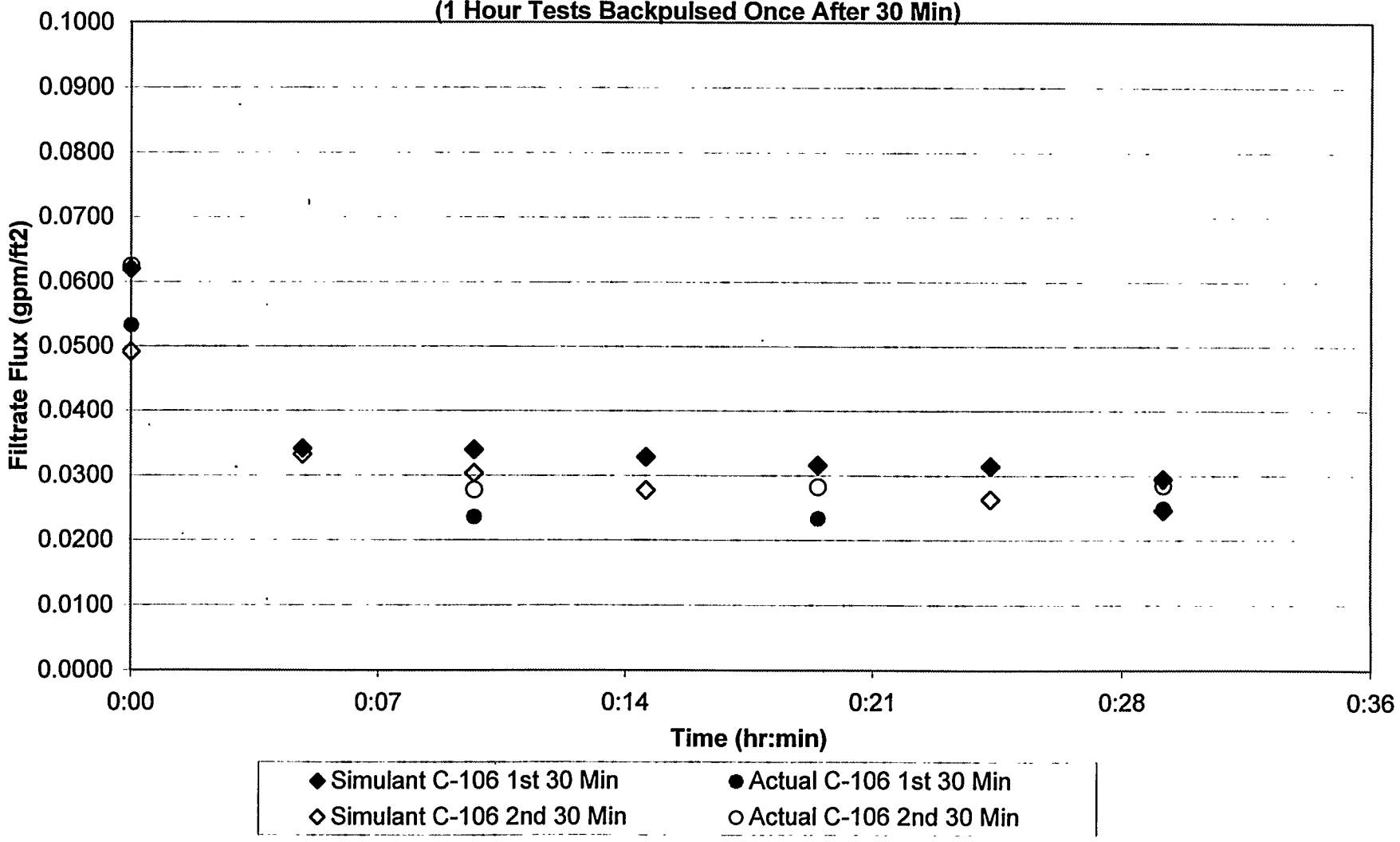


John Geeting Data

	Total Time Elapsed (Min)	JG Slurry Temp C		Filtrate Flux (gpm/ft2)
1st 30 minutes	0:00	33.4	0.0750	0.0596
	0:10	34.4	0.0637	0.0493
	0:20	34.3	0.0637	0.0494
	0:30	35.1	0 0449	0.0341
2nd 30 minutes	0:00	29.5	0.0966	0.0853
	0:10	29 3	0 0352	0.0312
	0:20	29.3	0.0678	0.0602
	0:30	29.2	0.0644	0.0573

Condition 4

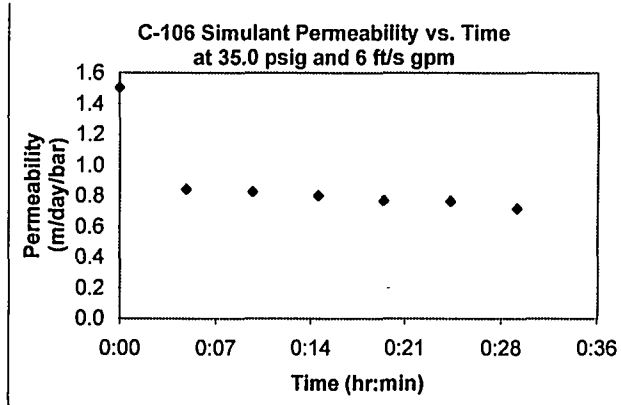
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 35.0 psig and 6 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)



Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
4a	13:30	0:00	3.63	NM	35	9	32.66	0.276	27.7	3.632	1.505	0.0619
4a	13:35	0:05	3.68	NM	34.5	9	58.28	0.154	28.3	2.002	0.842	0.0341
4a	13:40	0:10	3.68	NM	35	9	58.28	0.154	28.5	1.991	0.825	0.0339
4a	13:45	0:15	3.63	NM	35	9	62.25	0.145	27.3	1.927	0.798	0.0328
4a	13:50	0:20	3.62	NM	35	9	61.84	0.146	29	1.851	0.767	0.0315
4a	13:55	0:25	3.69	NM	35	9	62.44	0.144	28.8	1.843	0.764	0.0314
4a	14:00	0:30	3.67	NM	35	9	66.57	0.135	28.8	1.728	0.716	0.0295
		Average Pressure =		34.928571	Average Flow =			0.165	Average Fl	2.139		0.032

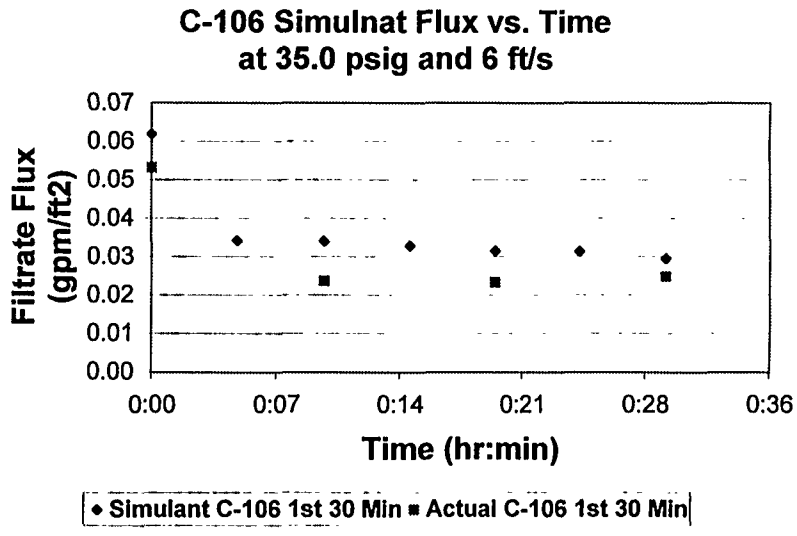
RAW Average Slurry Flow = 3.66 gpm

Filtrate



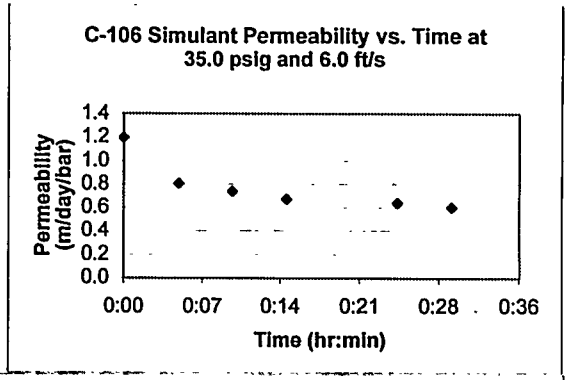
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
4a	13:30	15	27.7	3.63	NM	0	35	9	32.66	0.276
4a	13:35	15	28.3	3.68	NM	0	34.5	9	58.28	0.154
4a	13:40	16	28.5	3.68	NM	0	35	9	58.28	0.154
4a	13:45	17	27.3	3.63	NM	0	35	9	62.25	0.145
4a	13:50	16	29	3.62	NM	0	35	9	61.84	0.146
4a	13:55	16	28.8	3.69	NM	0	35	9	62.44	0.144
4a	14:00	16	28.8	3.67	NM	0	35	9	66.57	0.135

NM = Not Measured



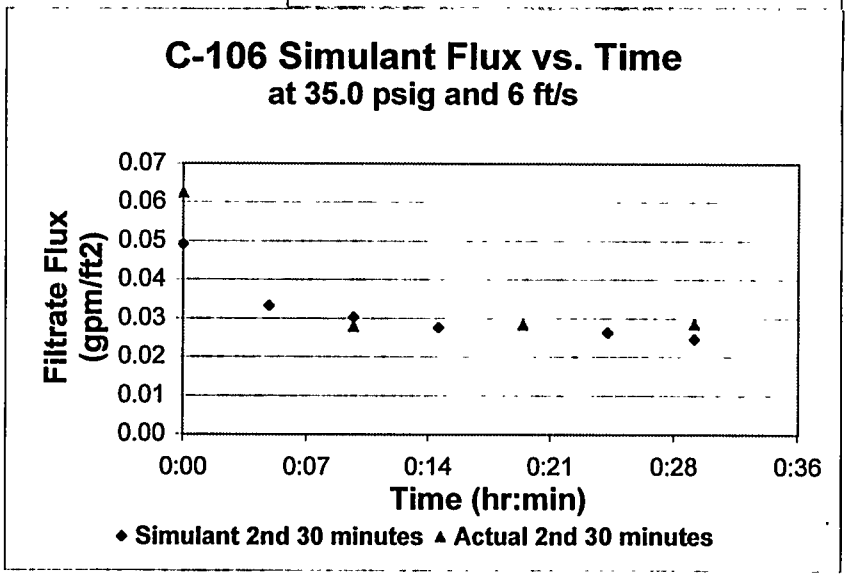
John Geeting Data	Total Time Elapsed (Min)	JG Slurry Temp C		Filtrate Flux (gpm/ft2)
1st 30 minutes	0:00	35.5	0.0708	0.0532
	0:10	36.1	0.0319	0.0236
	0:20	35.9	0.0314	0.0234
	0:30	35.8	0.0334	0.0249
2nd 30 minutes	0:00	36.4	0.085	0.0624
	0:10	36.6	0.038	0.0278
	0:20	37.2	0.0393	0.0283
	0:30	36.7	0.0391	0.0285

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
4b	14:15	0:00	3.69	NM	35	9	45	0.200	24.5	2.882	1.194	0.0491
4b	14:20	0:05	3.67	NM	35	9	66.59	0.135	24.5	1.948	0.807	0.0332
4b	14:25	0:10	3.63	NM	35	9	72.69	0.124	24.6	1.779	0.737	0.0303
4b	14:30	0:15	3.64	NM	35	9	79.85	0.113	24.5	1.624	0.673	0.0277
4b	14:40	0:25	3.69	NM	35	9	83.9	0.107	24.6	1.542	0.639	0.0263
4b	14:45	0:30	3.67	NM	35	9	89.31	0.101	24.7	1.444	0.598	0.0246
		Average Pressure =			35	Average Flow =		0.130	Average Flu	1.870		0.027
RAW	Average Slurry Flow =		3.67 gpm				Filtrate					

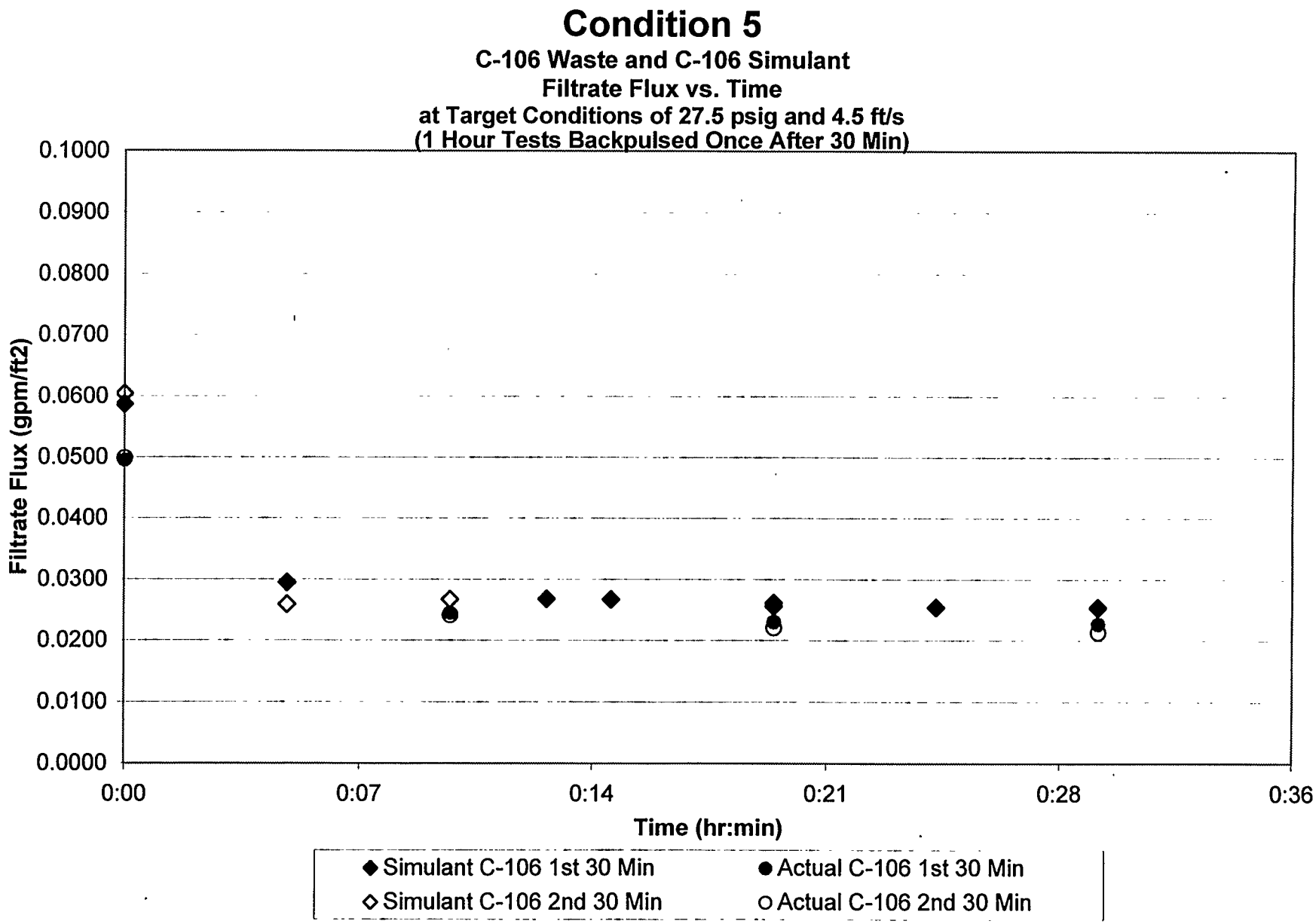


Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
4b	14:15	16	24.5	3.69	NM	35	9	45	0.200
4b	14:20	16	24.5	3.67	NM	35	9	66.59	0.135
4b	14:25	16	24.6	3.63	NM	35	9	72.69	0.124
4b	14:30	16	24.5	3.64	NM	35	9	79.85	0.113
4b	14:40	16	24.6	3.69	NM	35	9	83.9	0.107
4b	14:45	17	24.7	3.67	NM	35	9	89.31	0.101

NM = Not Measured



John Geeting Dat	Total Time Elapsed (Min)	JG Slurry Temp C		Filtrate Flux (gpm/ft2)
1st 30 minutes	0:00	35.5	0.0708	0.0532
	0:10	36.1	0.0319	0.0236
	0:20	35.9	0.0314	0.0234
	0:30	35.8	0.0334	0.0249
2nd 30 minutes	0:00	36.4	0.085	0.0624
	0:10	36.6	0.038	0.0278
	0:20	37.2	0.0393	0.0283
	0:30	36.7	0.0391	0.0285


Condition 5
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 27.5 psig and 4.5 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

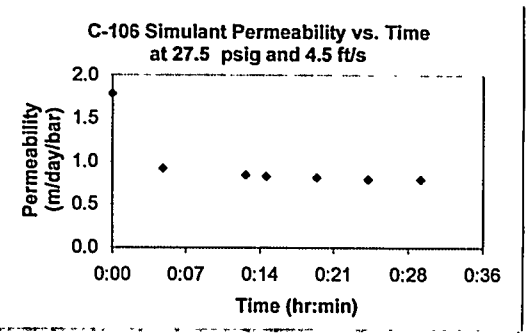
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
5a	15:15	0:00	2.73	NM	28	9	36.47	0.247	25.7	3.438	1.781	0.0585
5a	15:20	0:05	2.75	NM	27.5	9	72.44	0.124	25.8	1.726	0.910	0.0294
5a	15:28	0:13	2.7	NM	27	9	80	0.113	25.7	1.567	0.842	0.0267
5a	15:30	0:15	2.63	NM	27.5	9	80.37	0.112	25 6	1.565	0.825	0.0267
5a	15:35	0:20	2.66	NM	27.5	9	82.68	0.109	25.4	1.529	0.807	0.0261
5a	15:40	0:25	2.68	NM	27.5	9	85.81	0.105	25	1.490	0.786	0.0254
5a	15:45	0:30	2.8	NM	27.5	9	86.22	0.104	24.8	1.492	0.787	0.0254

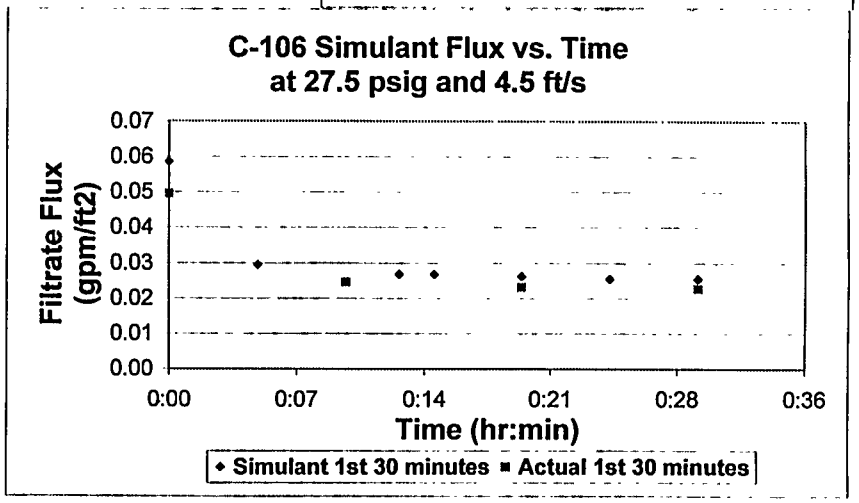
Average Pressure = 27.5 psig Average Flow = 0.131 Average Flux = 1.830 0.026

RAW Average Slurry Flow = 2.71 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
5a	15:15	18	25.7	2.73	NM	20	9	36.47	0.247
5a	15:20	18	25.8	2.75	NM	20	9	72.44	0.124
5a	15:28	16	25.7	2.7	NM	21	9	80	0.113
5a	15:30	16	25.6	2.63	NM	20	9	80.37	0.112
5a	15:35	16	25.4	2.66	NM	20	9	82.68	0.109
5a	15:40	15	25	2.68	NM	20	9	85.81	0.105
5a	15:45	15	24.8	2.8	NM	20	9	86.22	0.104

NM = Not Measured

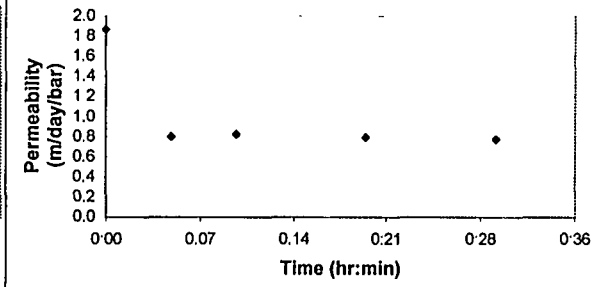




John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0;00	31.7	0.0596	0.0496
	0;10	31.9	0.0296	0.0245
	0;20	31.5	0.0275	0.0230
	0;30	31.1	0.0269	0.0227
2nd 30 minutes	0;00	31.5	0.0596	0.0498
	0;10	31.3	0.0287	0.0241
	0;20	31.3	0.0263	0.0221
	0;30	31.3	0.0254	0.0214

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
5b	16:10	0 00	2 74	NM	27 5	9	36.22	0.248	24 9	3 541	1 867	0.0304
5b	16:15	0.05	2.7	NM	27.5	9	84 59	0.106	24 9	1 516	0.800	0.0258
5b	16.20	0:10	2.78	NM	27 5	9	82 32	0.109	24 8	1.562	0.824	0.0266
5b	16:30	0:20	2.74	NM	27.5	9	86	0.105	24.7	1.500	0 791	0.0256
5b	16:40	0.30	2.73	NM	28	9	86.85	0.104	24.7	1 485	0.769	0.0253
												0.026

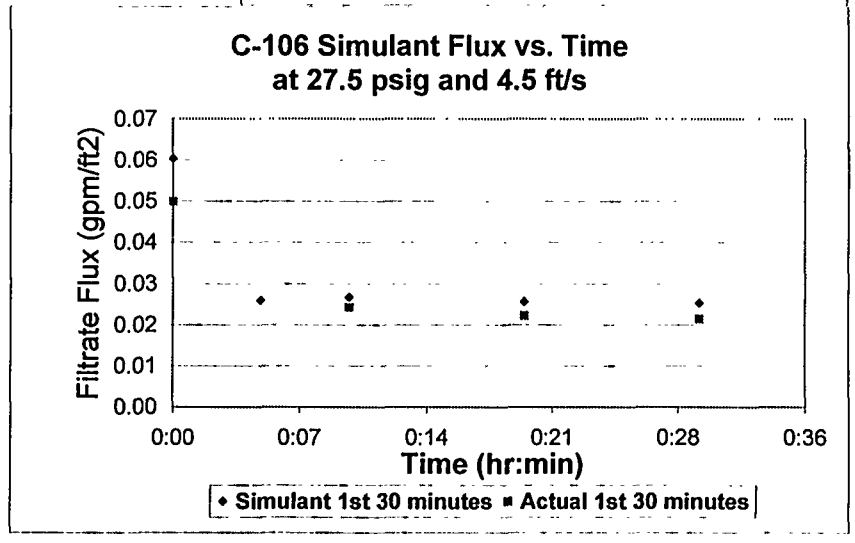


Average Pressure = 27.6 psig Average Flow = 0.134 Average Flux = 1.921

RAW Average Slurry Flow = 2.74 gpm

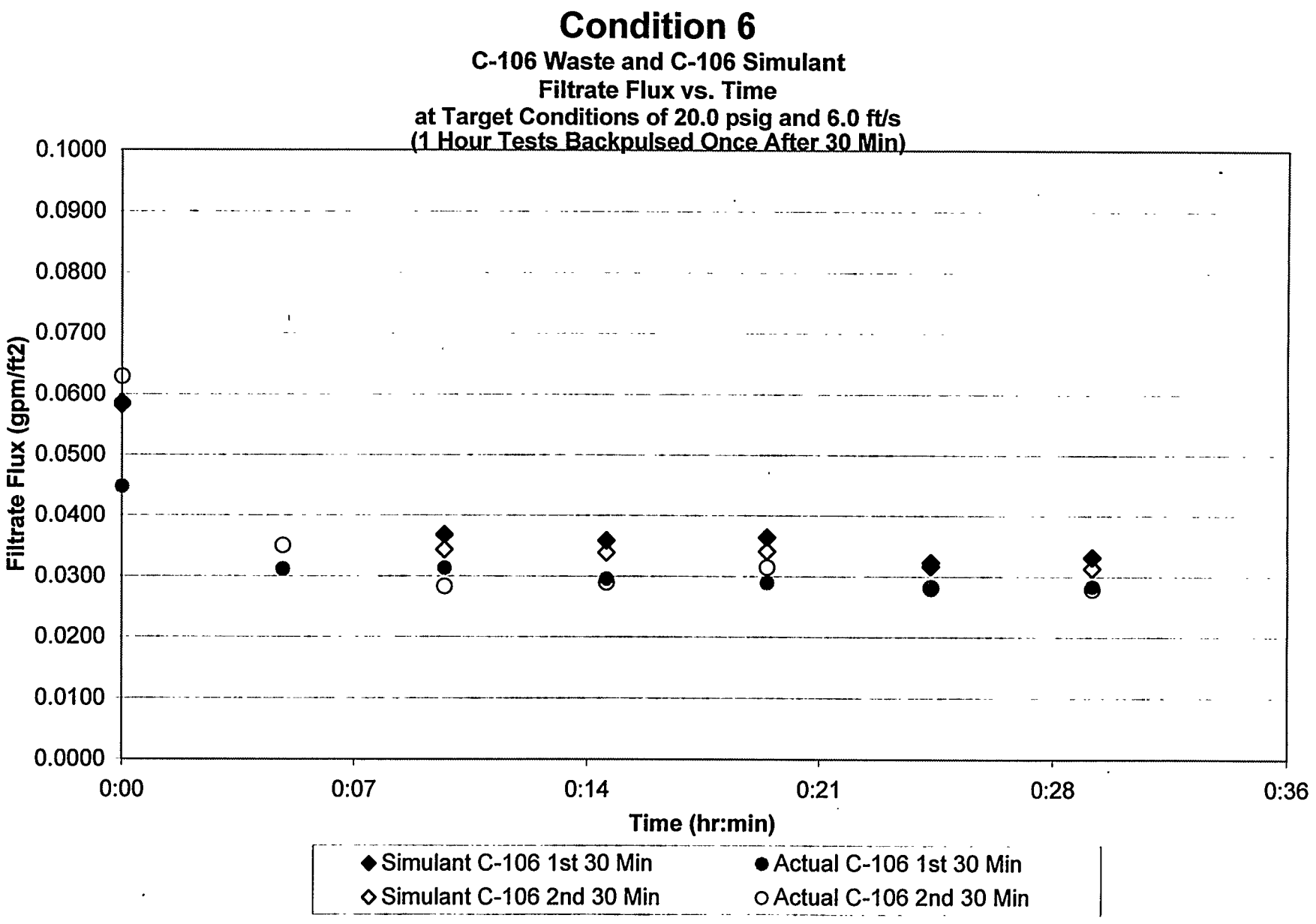
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
5b	16:10	16	24.9	2.74	NM	27.5	9	36.22	0.248
5b	16:15	16	24.9	2.7	NM	27.5	9	84.59	0.106
5b	16:20	15	24.8	2.78	NM	27.5	9	82.32	0.109
5b	16:30	16	24.7	2.74	NM	27.5	9	86	0.105
5b	16:40	15	24.7	2.73	NM	28	9	86.85	0.104

NM = Not Measured



John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.7	0.0596	0.0496
	0:10	31.9	0.0296	0.0245
	0:20	31.5	0.0275	0.0230
	0:30	31.1	0.0269	0.0227
2nd 30 minutes	0:00	31.5	0.0596	0.0498
	0:10	31 3	0.0287	0.0241
	0:20	31.3	0.0263	0.0221
	0:30	31.3	0.0254	0.0214


Condition 6
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 20.0 psig and 6.0 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

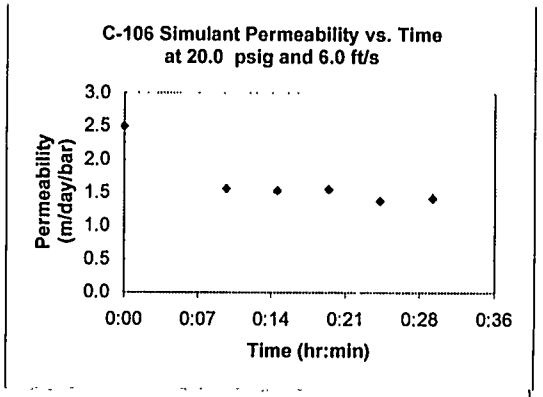
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
6a	18:40	0 00	3 5	NM	20	9	35.62	0.253	26.6	3.433	2.490	0.0585
6a	18:50	0 10	3 64	NM	20	9	61.72	0 146	23.6	2 156	1 563	0.0367
6a	18:55	0.15	3.67	NM	20	9	64	0.141	23 2	2 103	1.525	0.0358
6a	19.00	0:20	3 67	NM	20	9	63 25	0.142	23.1	2.134	1.547	0.0364
6a	19:05	0:25	3 63	NM	20	9	70.94	0 127	23.3	1.892	1.372	0.0322
6a	19:10	0 30	3.64	NM	20	9	69 06	0.130	23.3	1.943	1.409	0.0331

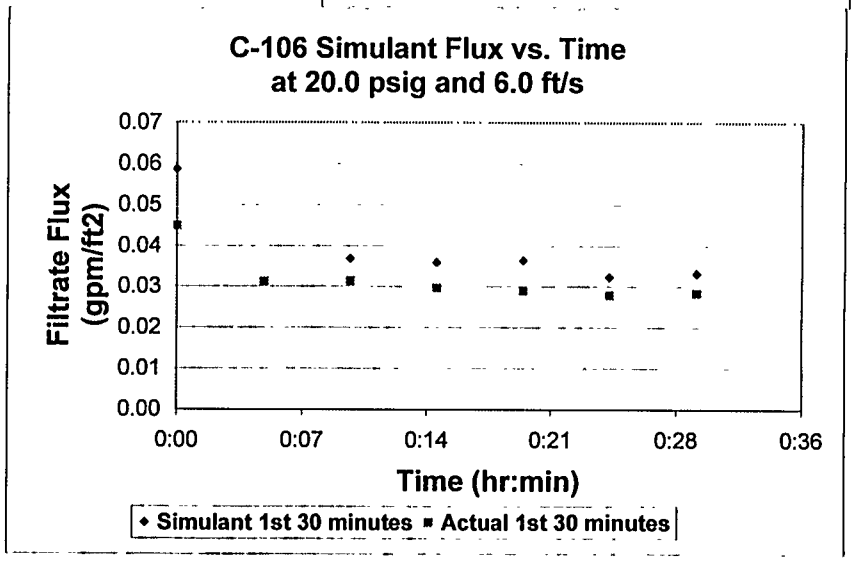
Average Pressure = 20.0 psig Average Flow = 0.156 Average Flux = 2.277 0.034

RAW Average Slurry Flow = 3.63 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
6a	18:40	16	26.6	3.5	NM	0	20	9	35.62	0.253
6a	18:50	14	23.6	3.64	NM	0	20	9	61.72	0.146
6a	18:55	14	23.2	3.67	NM	0	20	9	64	0.141
6a	19.00	15	23.1	3.67	NM	0	20	9	63.25	0 142
6a	19:05	15	23.3	3 63	NM	0	20	9	70.94	0.127
6a	19:10	16	23 3	3.64	NM	0	20	9	69.06	0.130

NM = Not Measured





John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.5	0.0536	0.0448
	0.05	31.3	0.0371	0.0312
	0:10	31.3	0.0373	0.0314
	0:15	31.3	0.0352	0.0296
	0:20	31.2	0.0344	0.0290
	0:25	31.3	0.0332	0.0279
	0:30	31.3	0.0337	0.0283
2nd 30 minutes	0.00	31.4	0.075	0.0629
	0.05	31.3	0.0417	0.0351
	0:10	31.1	0.0335	0.0283
	0:15	31.1	0.0343	0.0290
	0:20	31.1	0.0373	0.0315
	0:25	31.3	0.0335	0.0282
	0:30	31.3	0.0332	0.0279

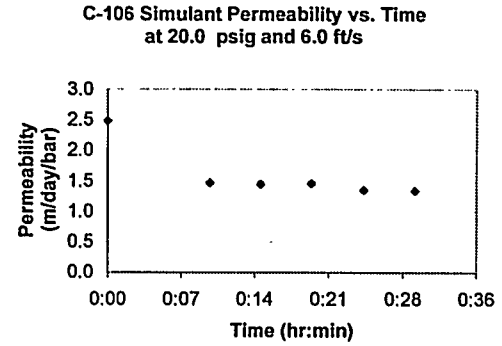
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
6b	19:25	0:00	3.68	NM	20	9	39.31	0.229	23.3	3.414	2.476	0.0582
6b	19:35	0:10	3.63	NM	20	9	66.22	0.136	23.5	2.015	1.461	0.0343
6b	19:40	0:15	3.67	NM	20	9	67.25	0.134	23.5	1.984	1.439	0.0338
6b	19:45	0:20	3.64	NM	20	9	66.53	0.135	23.6	2.000	1.450	0.0341
6b	19:50	0.25	3.7	NM	20	9	70.9	0.127	24	1.855	1.346	0.0316
6b	19:55	0:30	3.65	NM	20	9	71.04	0.127	24.3	1.836	1.332	0.0313

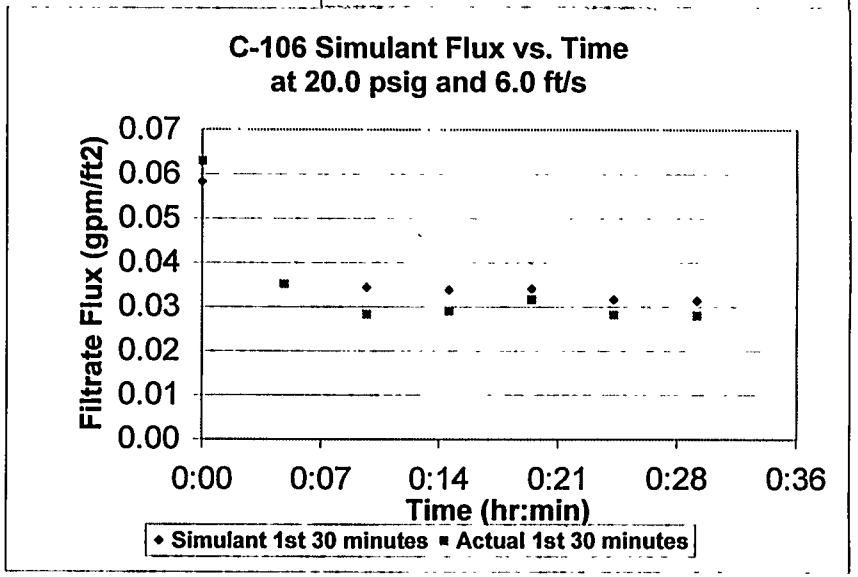
Average Pressure = 20.0 psig Average Flow = 0.148 Average Flux = 2.184 0.033

RAW Average Slurry Flow = 3.66 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
6b	19:25	15	23.3	3.68	NM	0	20	9	49.31	0.183
6b	19:35	15	23.5	3.63	NM	0	20	9	66.22	0.136
6b	19.40	16	23.5	3.67	NM	0	20	9	67.25	0.134
6b	19:45	15	23.6	3.64	NM	0	20	9	66.53	0.135
6b	19.50	16	24	3.7	NM	0	20	9	70.9	0.127
6b	19:55	16	24.3	3.65	NM	0	20	9	71.04	0.127

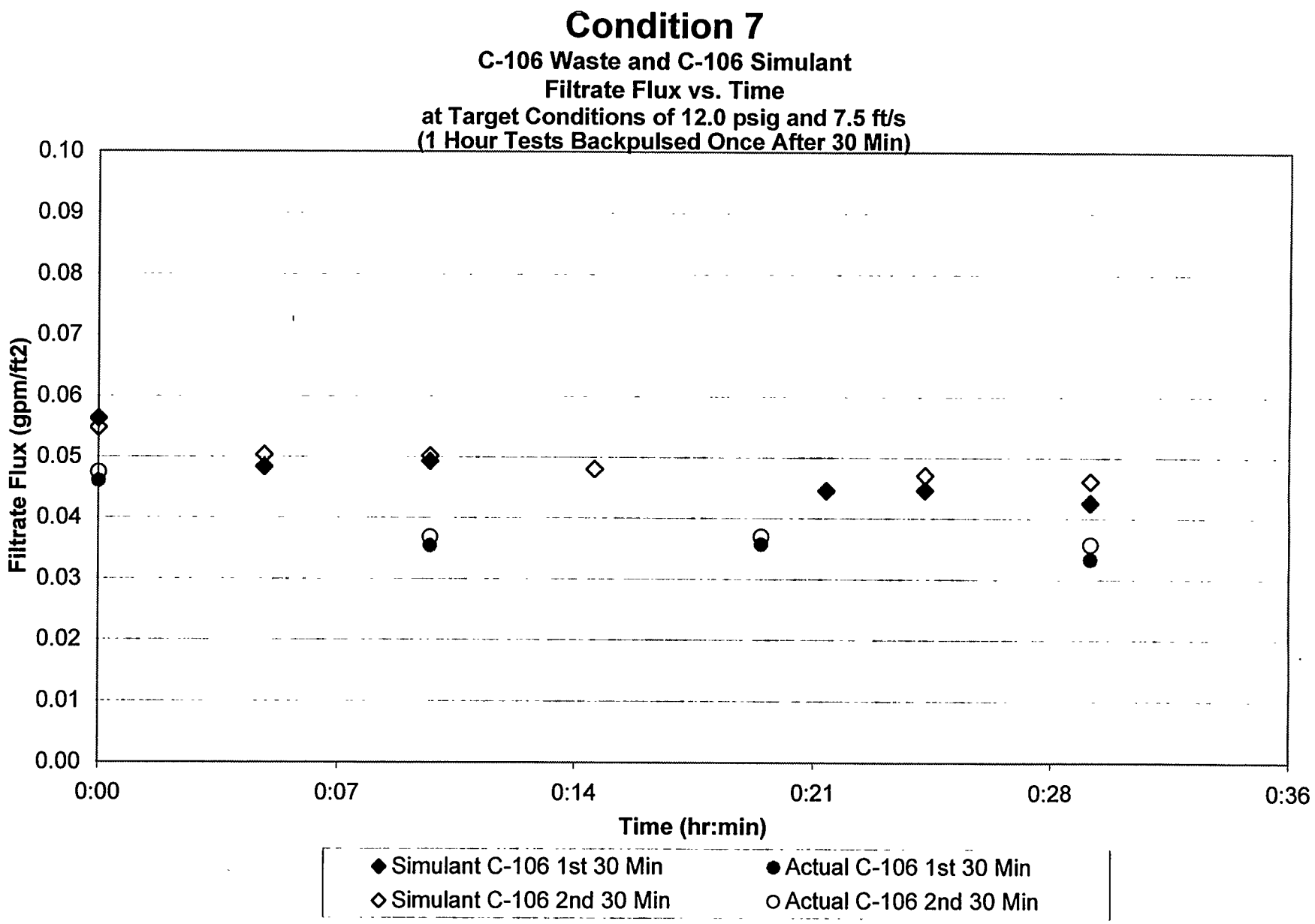
NM = Not Measured



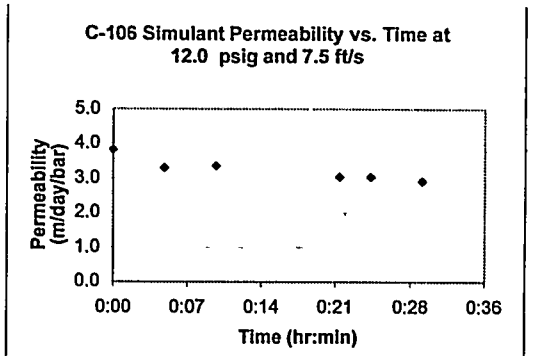


John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.5	0.0536	0.0448
	0:05	31.3	0.0371	0.0312
	0:10	31.3	0.0373	0.0314
	0:15	31.3	0.0352	0.0296
	0:20	31.2	0.0344	0.0290
	0:25	31.3	0.0332	0.0279
	0:30	31.3	0.0337	0.0283
2nd 30 minutes	0.00	31.4	0.075	0.0629
	0.05	31.3	0.0417	0.0351
	0:10	31.1	0.0335	0.0283
	0:15	31.1	0.0343	0.0290
	0:20	31.1	0.0373	0.0315
	0:25	31.3	0.0335	0.0282
	0:30	31.3	0 0332	0.0279


Condition 7
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 12.0 psig and 7.5 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
7a	14:45	0.00	4.63	NM	12.5	9	41.87	0.215	22.3	3.298	3.826	0.0562
7a	14:50	0:05	4.52	NM	12.5	9	48.12	0.187	22.7	2.837	3.292	0.0484
7a	14:55	0:10	4.55	NM	12.5	9	46.44	0.194	23.3	2.890	3.353	0.0493
7a	15:07	0:22	4.52	NM	12.5	9	50.53	0.178	23.9	2.611	3.029	0.0445
7a	15:10	0:25	4.54	NM	12.5	9	50.22	0.179	24	2.619	3.039	0.0447
7a	15:15	0:30	4.56	NM	12.5	9	52.66	0.171	24	2.498	2.899	0.0426

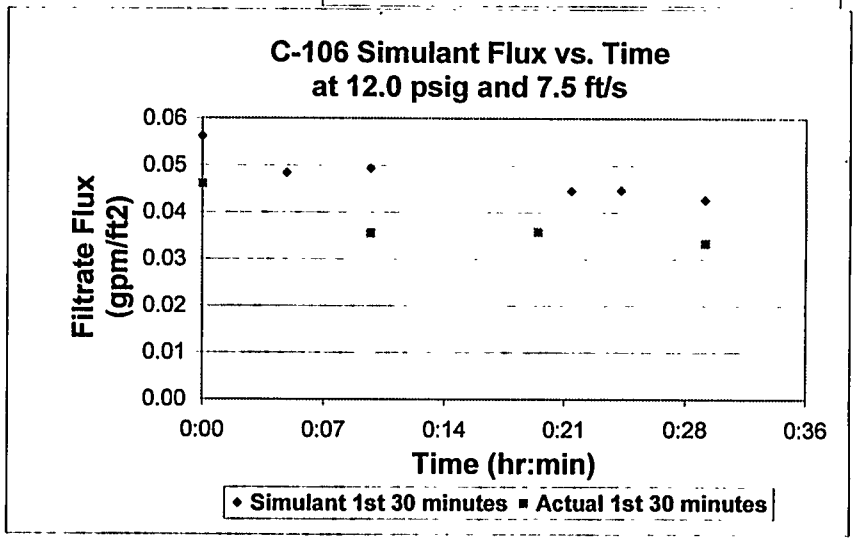


Average Pressure = 12.5 psig Average Flow = 0.187 Average Flux = 2.792 0.045

RAW Average Slurry Flow = 4.55 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
7a	14:45	17	22.3	4.63	NM	0	12.5	9	41.87	0.215
7a	14:50	19	22.7	4.52	NM	0	12.5	9	48.12	0.187
7a	14:55	19	23.3	4.55	NM	0	12.5	9	46.44	0.194
7a	15:07	20	23.9	4.52	NM	0	12.5	9	50.53	0.178
7a	15:10	19	24	4.54	NM	0	12.5	9	48.22	0.187
7a	15:15	19	24	4.56	NM	0	12.5	9	52.66	0.171

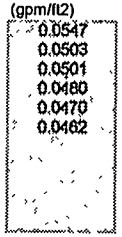
NM = Not Measured

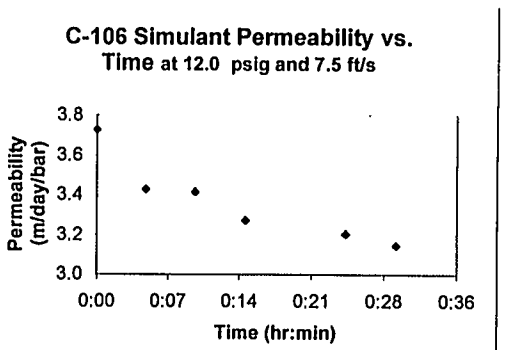


John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	30.8	0.054	0.0460
	0:10	30.6	0.0414	0.0355
	0:20	31	0.0422	0.0358
	0:30	31	0.0393	0.0333
2nd 30 minutes	0.00	31.6	0.0569	0.0474
	0:10	31.7	0.0443	0.0368
	0:20	31.8	0.0446	0.0370
	0:30	32	0.0434	0.0358

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
7b	15 30	0.00	4 57	NM	12 5	9	40 16	0 224	24 7	3 211	3 726	0.0547
7b	15:35	0:05	4.59	NM	12.5	9	43.44	0.207	24 9	2.952	3 425	0.0503
7b	15:40	0:10	4.6	NM	12.5	9	43 6	0 206	24.9	2 941	3.413	0.0501
7b	15:45	0 15	4 6	NM	12.5	9	45.4	0.198	25	2.817	3.268	0.0480
7b	15 55	0:25	4.59	NM	12.5	9	46 35	0.194	25	2.759	3 201	0.0470
7b	16:00	0:30	4.58	NM	12.5	9	47.63	0 189	24.7	2 708	3.142	0.0462



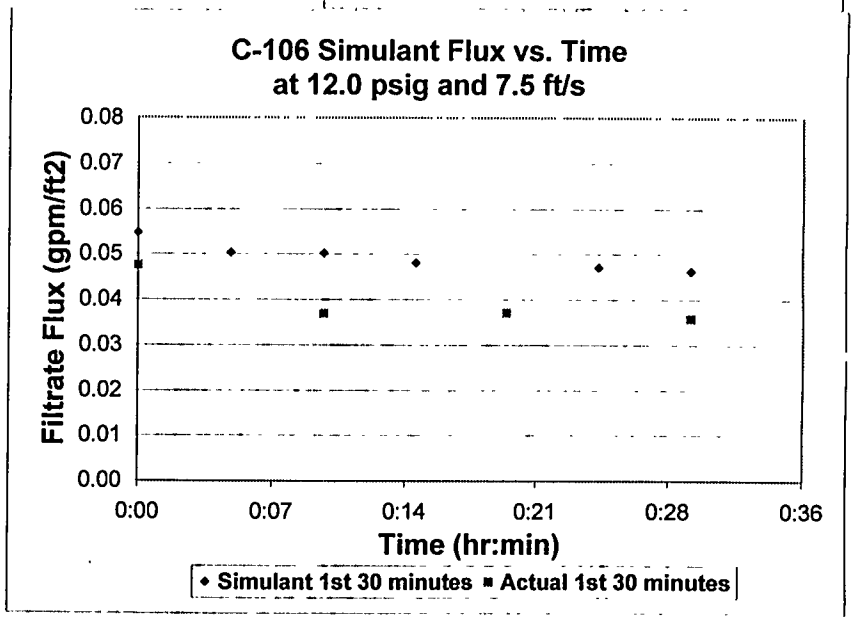


Average Pressure = 12.5 psig Average Flow = 0.203 Average Flux = 2.898 0.048

RAW Average Slurry Flow = 4.59 gpm

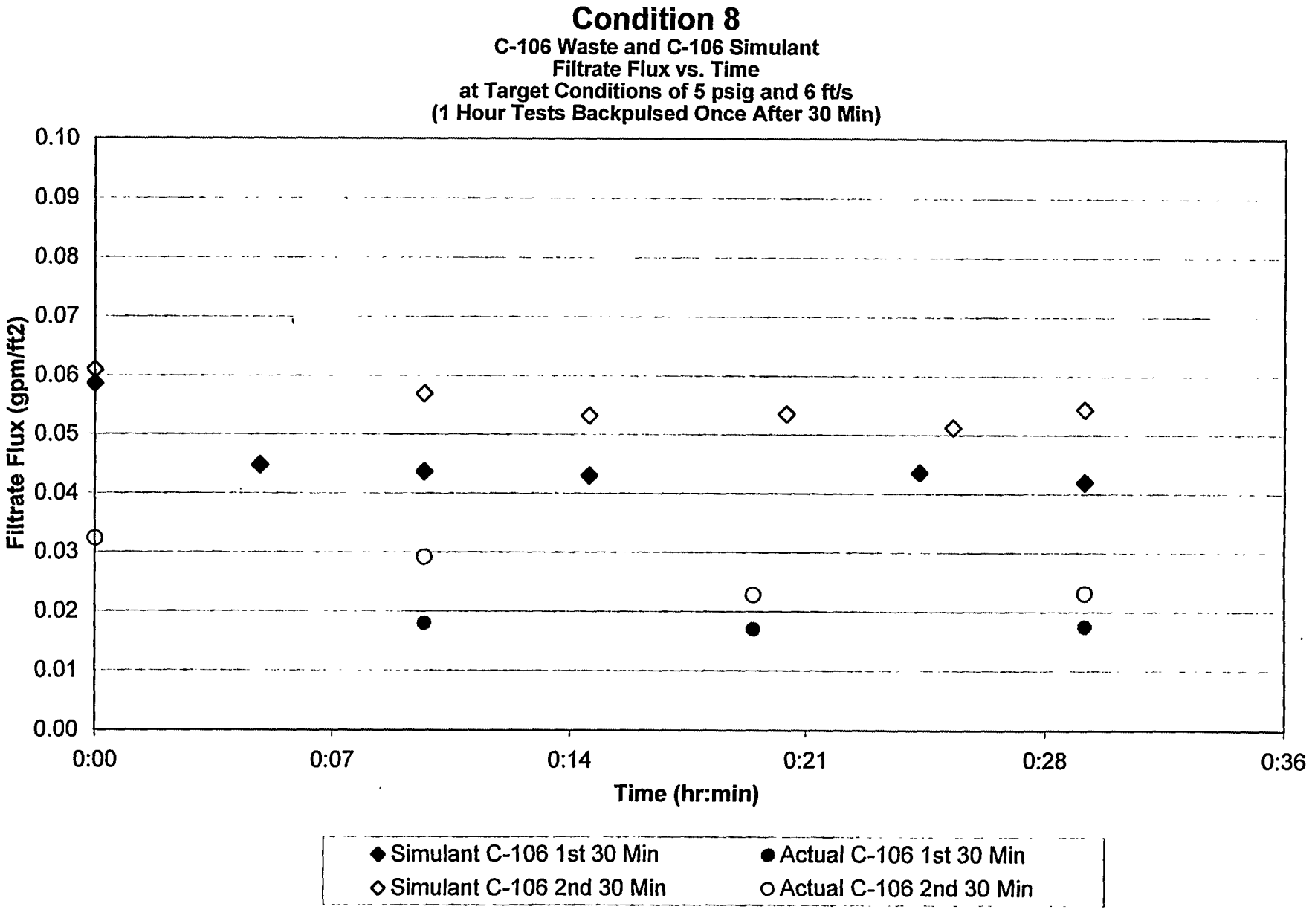
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
7b	15:30	21	24.7	4.57	NM	0	12.5	9	40.16	0.224
7b	15:35	21	24.9	4.59	NM	0	12.5	9	43.44	0.207
7b	15:40	20	24.9	4.6	NM	0	12.5	9	43.6	0.206
7b	15:45	21	25	4.6	NM	0	12.5	9	45.4	0.198
7b	15:55	19	25	4.59	NM	0	12.5	9	46.35	0.194
7b	16:00	19	24.7	4.58	NM	0	12.5	9	47.63	0.189

NM = Not Measured



John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	30.8	0.054	0.0460
	0:10	30.6	0.0414	0.0355
	0:20	31	0.0422	0.0358
	0:30	31	0.0393	0.0333
2nd 30 minutes	0:00	31.6	0.0569	0.0474
	0:10	31.7	0.0443	0.0368
	0:20	31.8	0.0446	0.0370
	0:30	32	0.0434	0.0358


Condition 8
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 5 psig and 6 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

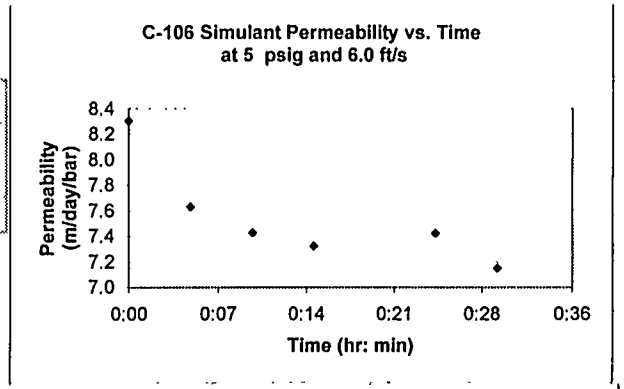
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
8a	16:30	0 00	3 67	NM	6	9	37.75	0 238	24.5	3.436	8.305	0.0595
8a	16:35	0.05	3 69	NM	5	9	49.32	0 182	24 5	2.630	7.628	0.0448
8a	16:40	0:10	3 64	NM	5	9	49.94	0.180	25	2 561	7.428	0.0437
8a	16:45	0:15	3.69	NM	5	9	50.41	0.179	25.2	2 523	7.318	0.0430
8a	16:55	0.25	3.71	NM	5	9	49.85	0.181	25.1	2.558	7.421	0.0436
8a	17:00	0:30	3 7	NM	5	9	51.75	0.174	25 1	2.464	7.148	0.0420

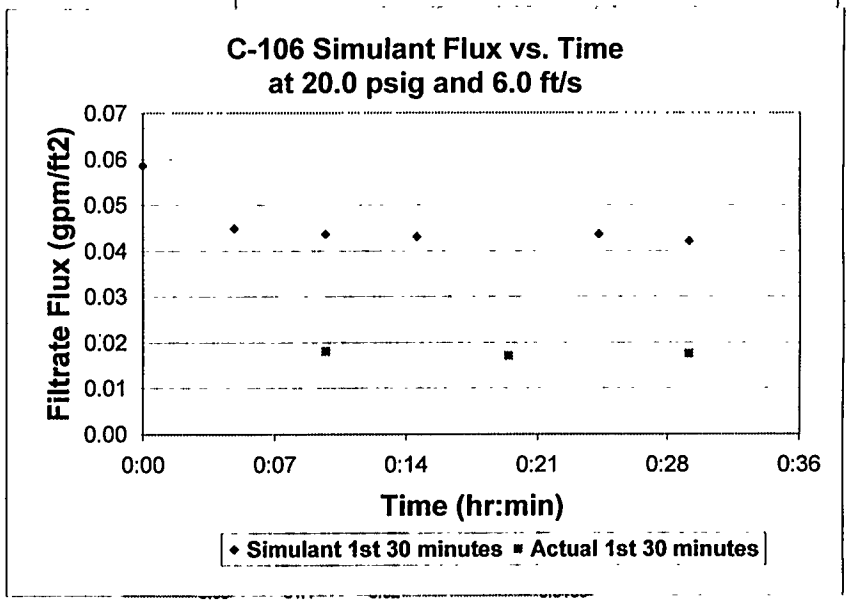
Average Pressure = 5.2 psig Average Flow = 0.189 Average Flux = 2.695 0.043

RAW Average Slurry Flow = 3 68 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
8a	16:30	20	24.5	3.67	NM	0	6	9	37.75	0.238
8a	16:35	20	24.5	3.69	NM	0	5	9	49.32	0.182
8a	16:40	22	25	3.64	NM	0	5	9	49.94	0.180
8a	16:45	22	25.2	3.69	NM	0	5	9	50.41	0.179
8a	16:55	20	25.1	3.71	NM	0	5	9	49.85	0.181
8a	17.00	21	25.1	3.7	NM	0	5	9	51.75	0.174

NM = Not Measured

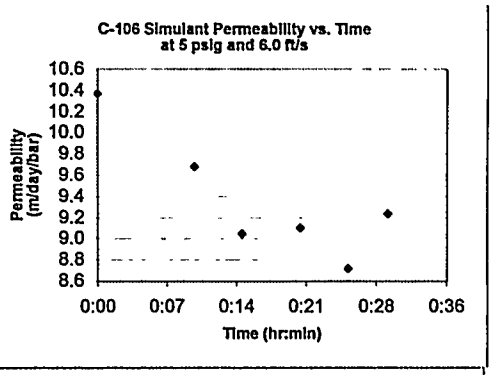




John Geeting

1st 30 minutes	0:10	29.9	0.0206	0.0180	
	0:20	29.4	0.0192	0.0170	
	0:30	29.1	0.0196	0.0175	0.0175
2nd 30 minutes	0:00	29.4	0.0366	0.0324	
	0:10	29.2	0.0328	0.0292	
	0:20	29.1	0.0256	0.0228	
	0:30	29.1	0.026	0.0232	0.0251

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
8b	12.30	0:00	3.75	NM	5	9	36.5	0.247	24.3	3.574	10.366	0.0609
8b	12.40	0:10	3.64	NM	5	9	38.53	0.234	24.8	3.338	9.682	0.0569
8b	12:45	0:15	3.65	NM	5	9	41	0.220	25	3.119	9.048	0.0532
8b	12:51	0:21	3.65	NM	5	9	40.54	0.222	25.2	3.137	9.099	0.0535
8b	12:56	0:26	3.64	NM	5	9	42.43	0.212	25.1	3.006	8.718	0.0512
8b	13.00	0:30	3.65	NM	5	9	39.94	0.225	25.2	3.184	9.236	0.0543

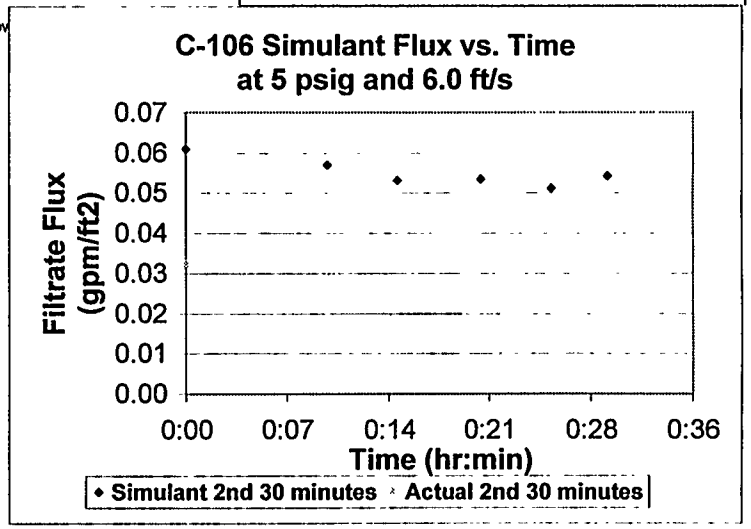


RAW Average Pressure = 5.0 psig Average Flow = 0.227 Average Flux = 3.226 0.054

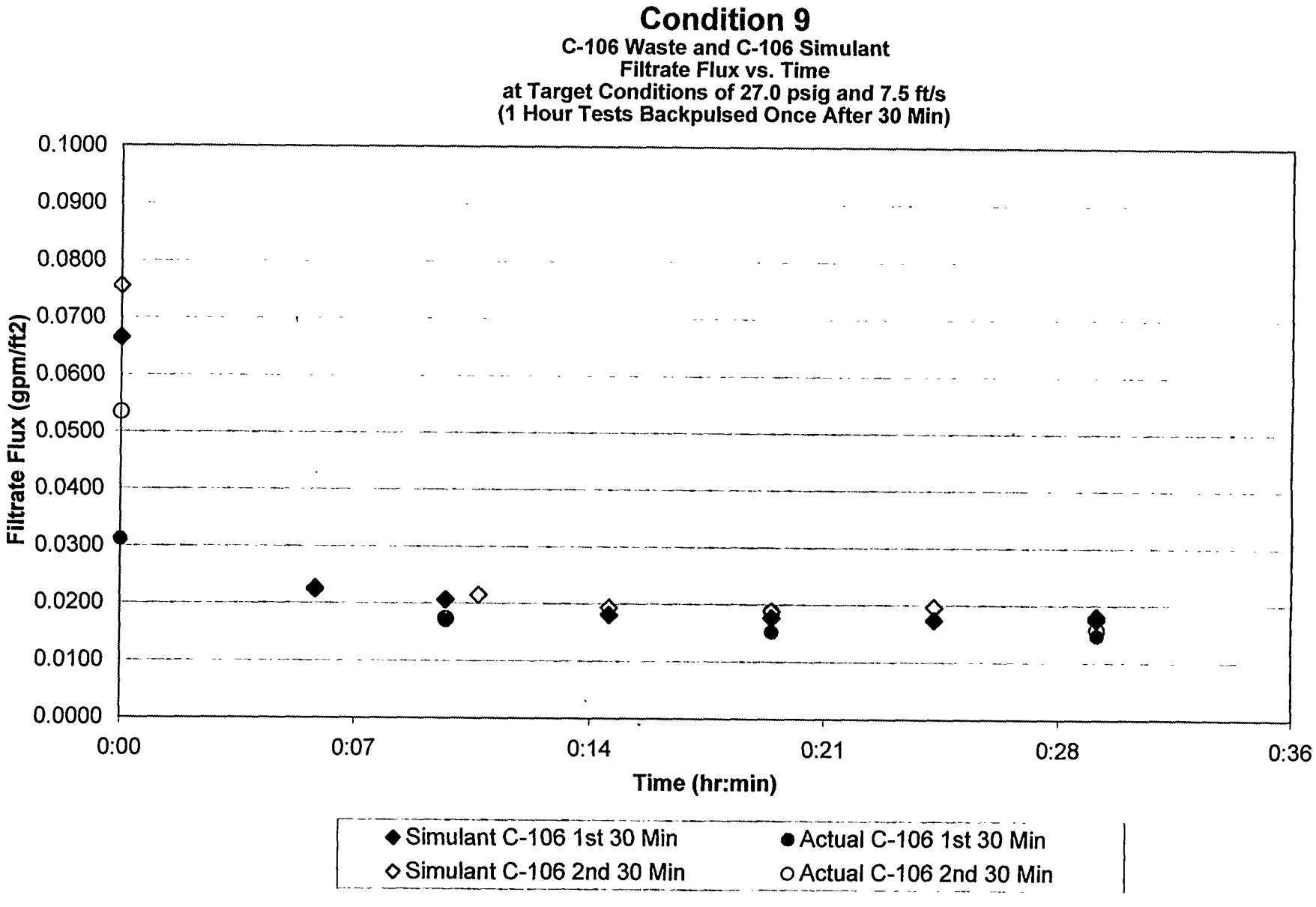
Average Slurry Flow = 3.66 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
8b	12:30	22	24.3	3.75	NM	0	5	9	36.5	0.247
8b	12:40	22	24.8	3.64	NM	0	5	9	38.53	0.234
8b	12:45	21	25	3.65	NM	0	5	9	41	0.220
8b	12:51	22	25.2	3.65	NM	0	5	9	40.54	0.222
8b	12:56	22	25.1	3.64	NM	0	5	9	42.43	0.212
8b	13:00	21	25.2	3.65	NM	0	5	9	39.94	0.225

NM = Not Measured



John Geeting Data	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.1	0.02	0.0169
	0:10	29.9	0.0206	0.0180
	0:20	29.4	0.0192	0.0170
	0:30	29.1	0.0196	0.0175
2nd 30 minutes	0:00	29.4	0.0366	0.0324
	0:10	29.2	0.0328	0.0292
	0:20	29.1	0.0256	0.0228
	0:30	29.1	0.026	0.0232


Condition 9
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 27.0 psig and 7.5 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Time (hr:min)
Simulant C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 1st 30 Min
Actual C-106 2nd 30 Min

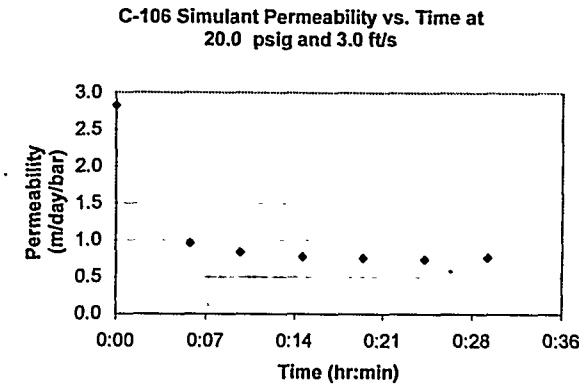
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
9a	13:30	0.00	1.8	NM	20	9	32.53	0.277	25.3	3.898	2.827	0.0665
9a	13:36	0:06	1.82	NM	20	9	96.53	0.093	25.3	1.314	0.953	0.0224
9a	13:40	0:10	1.8	NM	21	9	104.84	0 086	25.3	1.210	0.835	0.0206
9a	13:45	0:15	1.82	NM	20	9	119.47	0.075	25.3	1.061	0.770	0.0181
9a	13:50	0:20	1.82	NM	20	9	123	0.073	25.1	1.037	0.752	0.0177
9a	13:55	0:25	1.81	NM	20	9	125.63	0.072	25	1.018	0.738	0.0174
9a	14:00	0:30	1.81	NM	20	5	67.44	0.074	25	1.053	0.764	0.0180

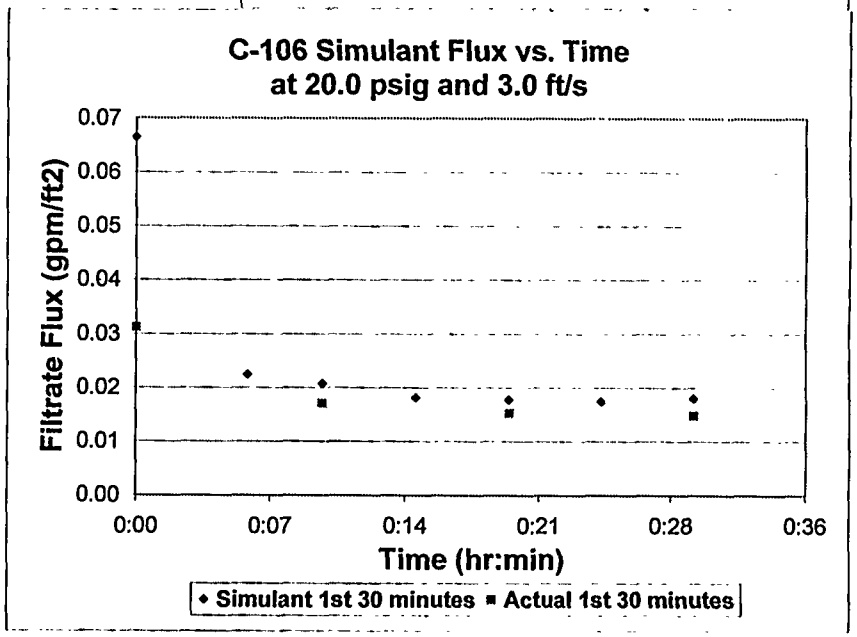
Average Pressure = 20.1 psig Average Flow = 0.107 Average Flux = 1.513 0.018

RAW Average Slurry Flow = 1.81 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
9a	13:30	21	25.3	1.8	NM	0	20	9	32.53	0.277
9a	13:36	20	25.3	1.82	NM	0	20	9	96.53	0.093
9a	13:40	21	25.3	1.8	NM	0	21	9	104.84	0.086
9a	13:45	21	25.3	1.82	NM	0	20	9	119.47	0.075
9a	13:50	20	25.1	1.82	NM	0	20	9	123	0.073
9a	13:55	20	25	1.81	NM	0	20	9	125.63	0.072
9a	14:00	20	25	1.81	NM	0	20	5	67.44	0.074

NM = Not Measured

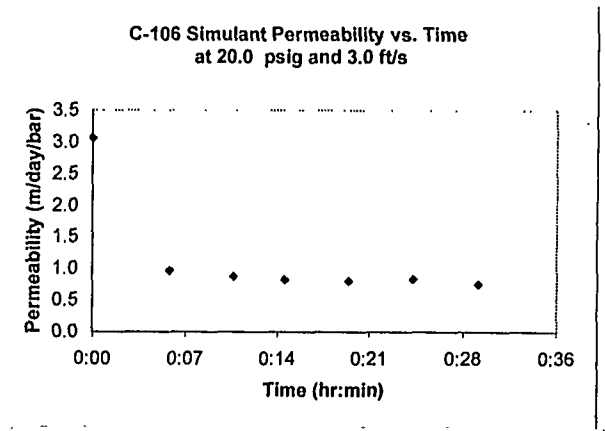




John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)	
1st 30 minutes	0.00	29.6	0.0354	0.0312	
	0:10	29.3	0.0192	0.0170	
	0:20	29.3	0.0171	0.0152	
	0:30	29.3	0.0166	0.0147	0.0156
2nd 30 minutes	0:00	29.6	0.0607	0.0534	
	0:10	29.6	0.0197	0.0175	
	0:20	29.3	0.0211	0.0187	
	0:30	29.3	0.0177	0.0382	0.0248

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressure (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
9b	22:05	0:00	1.81	NM	21	9	28.22	0.319	25.8	4.431	3.060	0.0755
9b	22:11	0:06	1.8	NM	20	9	95.22	0.095	25.6	1.321	0.958	0.0225
9b	22:16	0:11	1.86	NM	21	5	56.09	0.089	25.3	1.256	0.867	0.0214
9b	22:20	0.15	1.83	NM	20	5	62.07	0.081	25.3	1.135	0.823	0.0193
9b	22:25	0:20	1.81	NM	20	5	64.82	0.077	24.7	1.105	0.802	0.0188
9b	22:30	0:25	1.82	NM	20	5	63.03	0.079	24.3	1.150	0.834	0.0196
9b	22:35	0:30	1.81	NM	20	5	70.78	0.071	24.2	1.027	0.745	0.0175
												0.019

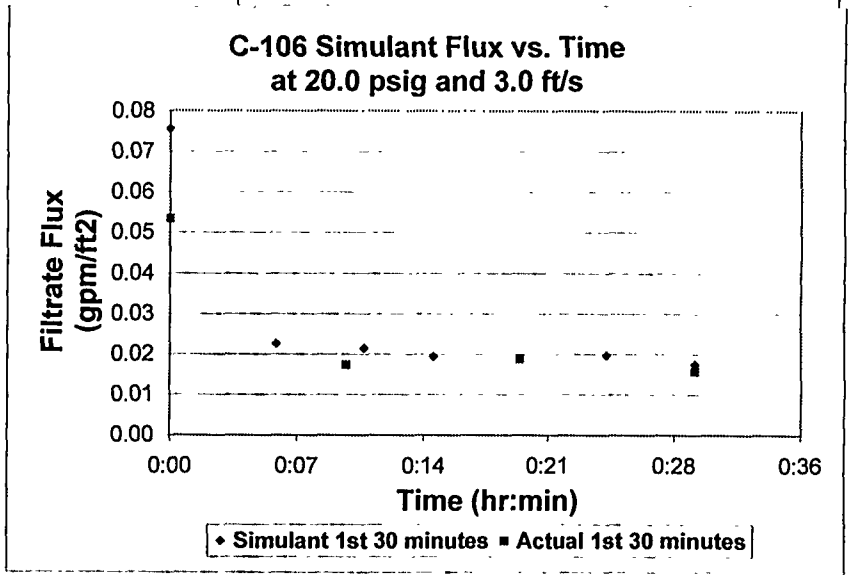


RAW Average Pressure = 20.3 psig Average Flow = 0.116 Average Flux = 1.632

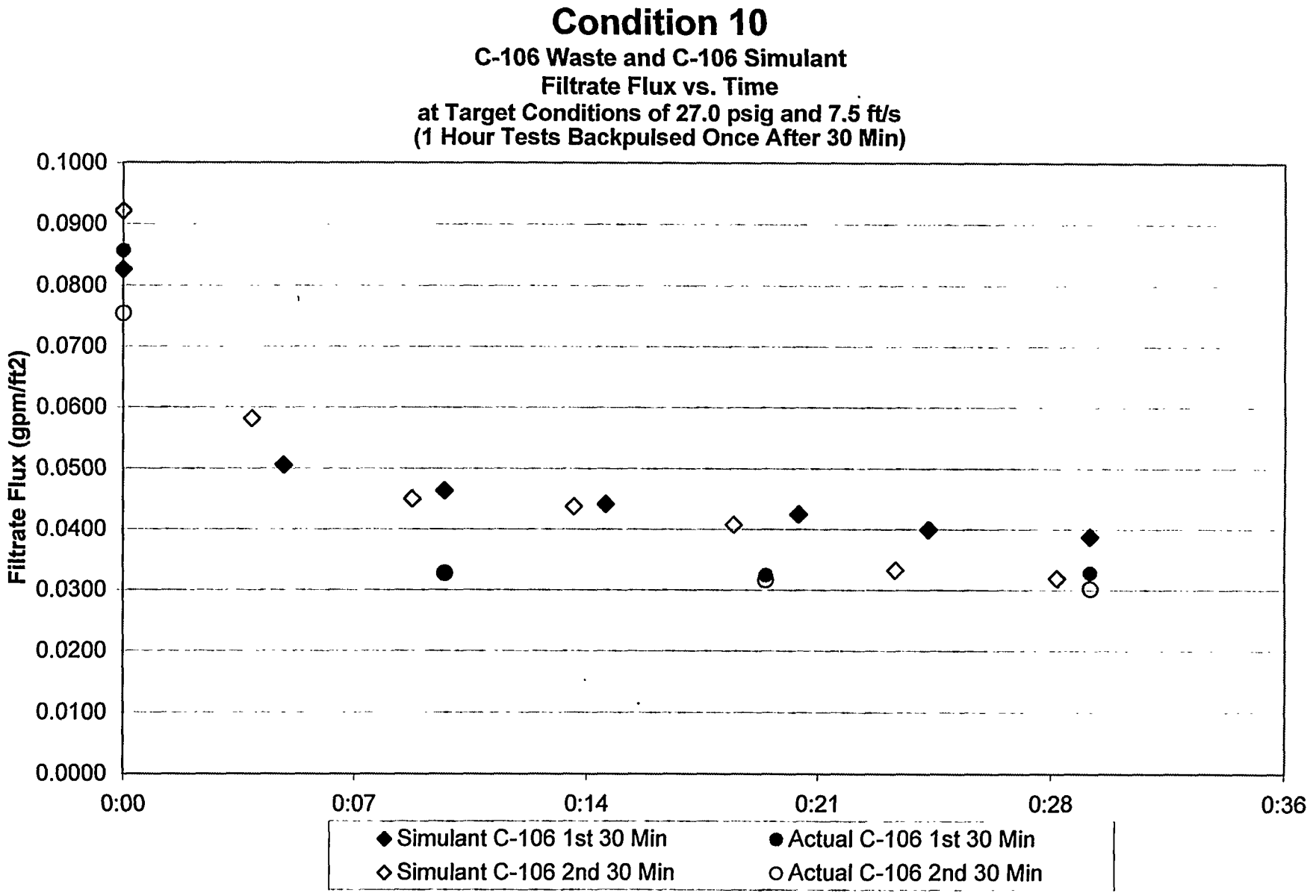
Average Slurry Flow = 1.82 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressure (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
9b	22:05	22	25.8	1.81	NM	0	21	9	28.22	0.319
9b	22:11	20	25.6	1.8	NM	0	20	9	95.22	0.095
9b	22:16	20	25.3	1.86	NM	0	21	5	56.09	0.089
9b	22:20	20	25.3	1.83	NM	0	20	5	62.07	0.081
9b	22:25	18	24.7	1.81	NM	0	20	5	64.82	0.077
9b	22:30	18	24.3	1.82	NM	0	20	5	63.03	0.079
9b	22:35	18	24.2	1.81	NM	0	20	5	70.78	0.071

NM = Not Measured

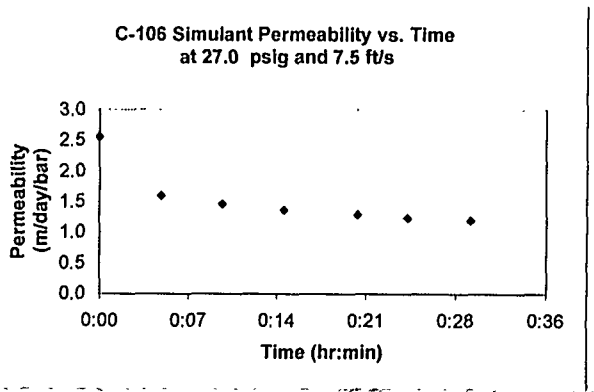


John Geeting Data	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)	
1st 30 minutes	0:00	29.6	0.0354	0.0312	
	0:10	29.3	0.0192	0.0170	
	0:20	29.3	0.0171	0.0152	
	0:30	29.3	0.0166	0.0147	0.0156
2nd 30 minutes	0:00	29.6	0.0607	0.0534	
	0:10	29.6	0.0197	0.0173	
	0:20	29.3	0.0211	0.0187	
	0:30	29.3	0.0177	0.0157	0.0173


Condition 10
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 27.0 psig and 7.5 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
0:36
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
10a	23:25	0 00	4 54	NM	27 5	9	28.6	0.315	22 2	4.842	2.554	0.0825
10a	23 30	0:05	4.53	NM	27	9	46.5	0.194	22.4	2 961	1 591	0.0505
10a	23:35	0 10	4.54	NM	27	9	49.84	0.181	23	2.716	1.459	0.0463
10a	23:40	0:15	4.55	NM	27.5	9	51.66	0.174	23.5	2 583	1.362	0.0440
10a	23:46	0:21	4.57	NM	28	9	53.12	0.169	23 8	2.491	1.290	0.0425
10a	23:50	0.25	4.55	NM	27.5	9	56 41	0.160	23.9	2.339	1 233	0.0399
10a	23:55	0:30	4 56	NM	27 5	9	57.94	0.155	24	2 270	1.197	0.0367

0 042

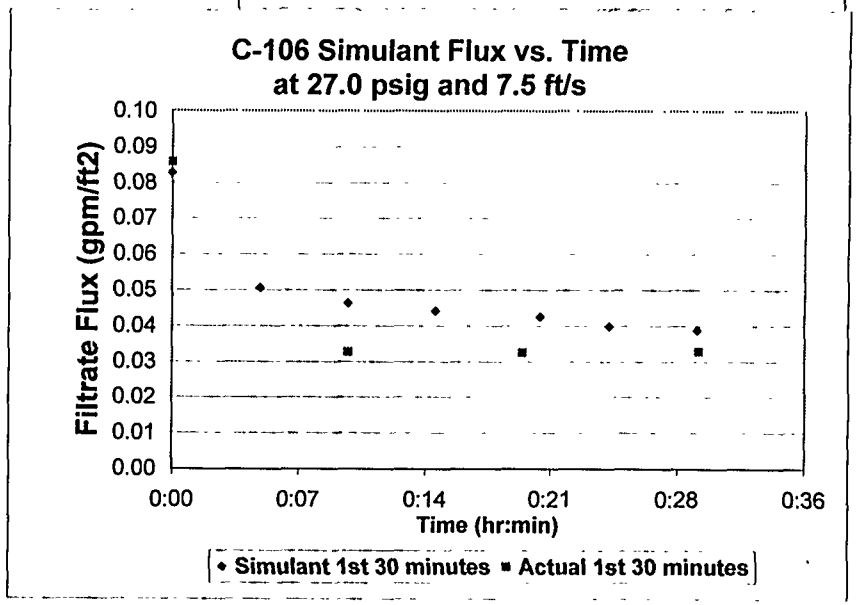


RAW Average Pressure = 27.4 psig Average Flow = 0.192 Average Flux = 2.886

Average Slurry Flow = 4.55 gpm

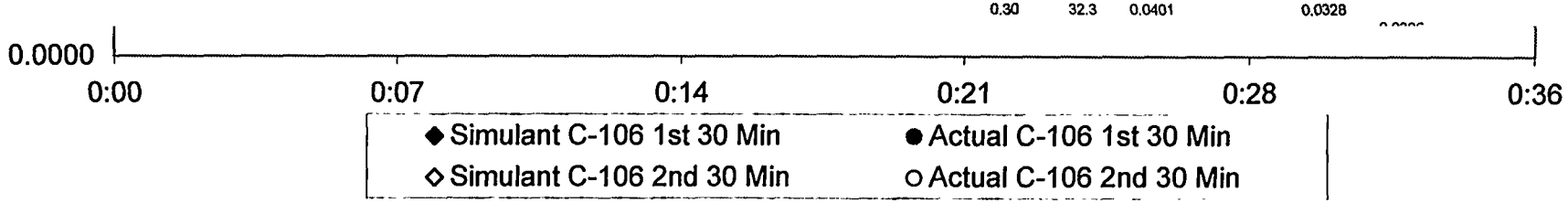
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
10a	23:25	15	22.2	4.54	NM	0	20	9	28.6	0.315
10a	23:30	17	22.4	4.53	NM	0	20	9	46.5	0.194
10a	23:35	17	23	4.54	NM	0	21	9	49.84	0.181
10a	23:40	17	23 5	4.55	NM	0	20	9	51 66	0.174
10a	23:46	17	23.8	4.57	NM	0	20	9	53.12	0.169
10a	23:50	18	23.9	4.55	NM	0	20	9	56.41	0.160
10a	23:55	18	24	4.56	NM	0	20	9	57.94	0.155

NM = Not Measured

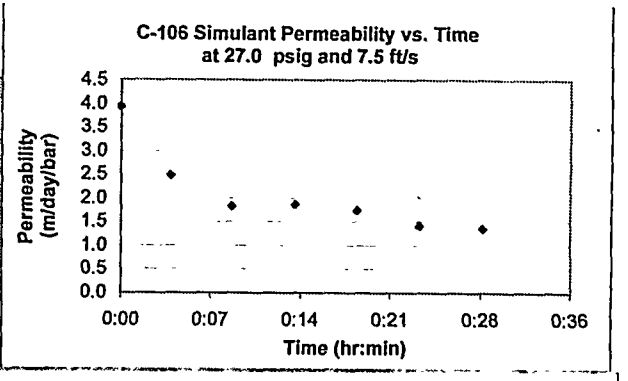


John Geeting Data
1st 30 minutes

Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
0:00	31.3	0.102	0.0857
0:10	31.8	0.0393	0.0326
0:20	32.7	0.0401	0.0325
0.30	32.3	0.0401	0.0328



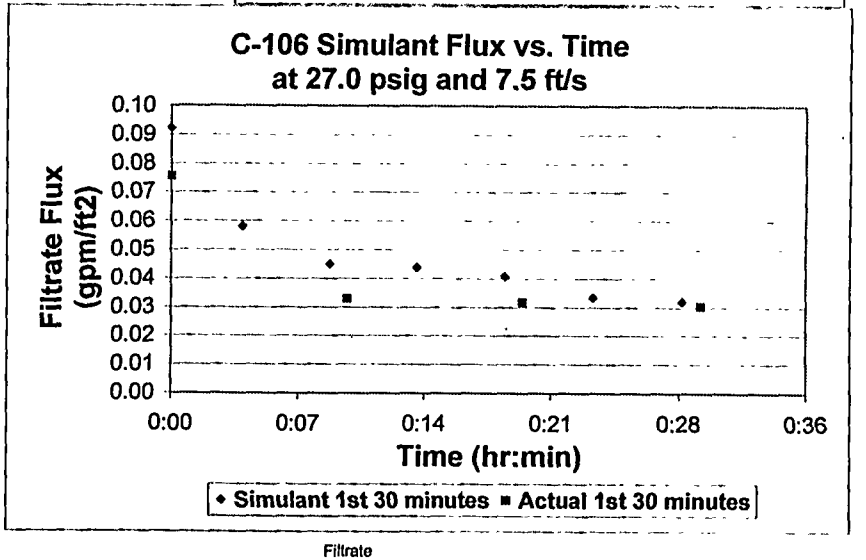
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
10b	14:11	0:00	3.67	NM	20	9	22.25	0.404	27.2	5.405	3.920	0.0921
10b	14:15	0.04	3.74	NM	20	9	37.1	0.243	25.4	3.408	2.472	0.0581
10b	14:20	0:09	3.7	NM	21	9	49.78	0.181	24.1	2.635	1.820	0.0449
10b	14:25	0:14	3.63	NM	20	9	52.34	0.172	23.3	2.564	1.859	0.0437
10b	14:30	0:19	3.66	NM	20	9	56.56	0.159	23.1	2.386	1.730	0.0407
10b	14:35	0:24	3.69	NM	20	9	68.53	0.131	23.5	1.947	1.412	0.0332
10b	14:40	0:29	3.69	NM	20	9	70.87	0.127	23 7	1.872	1.358	0.0319



RAW Average Pressure = 20.1 psig Average Slurry Flow = 3.68 gpm Average Flow = 0.202 Average Flux = 2.888 0.039

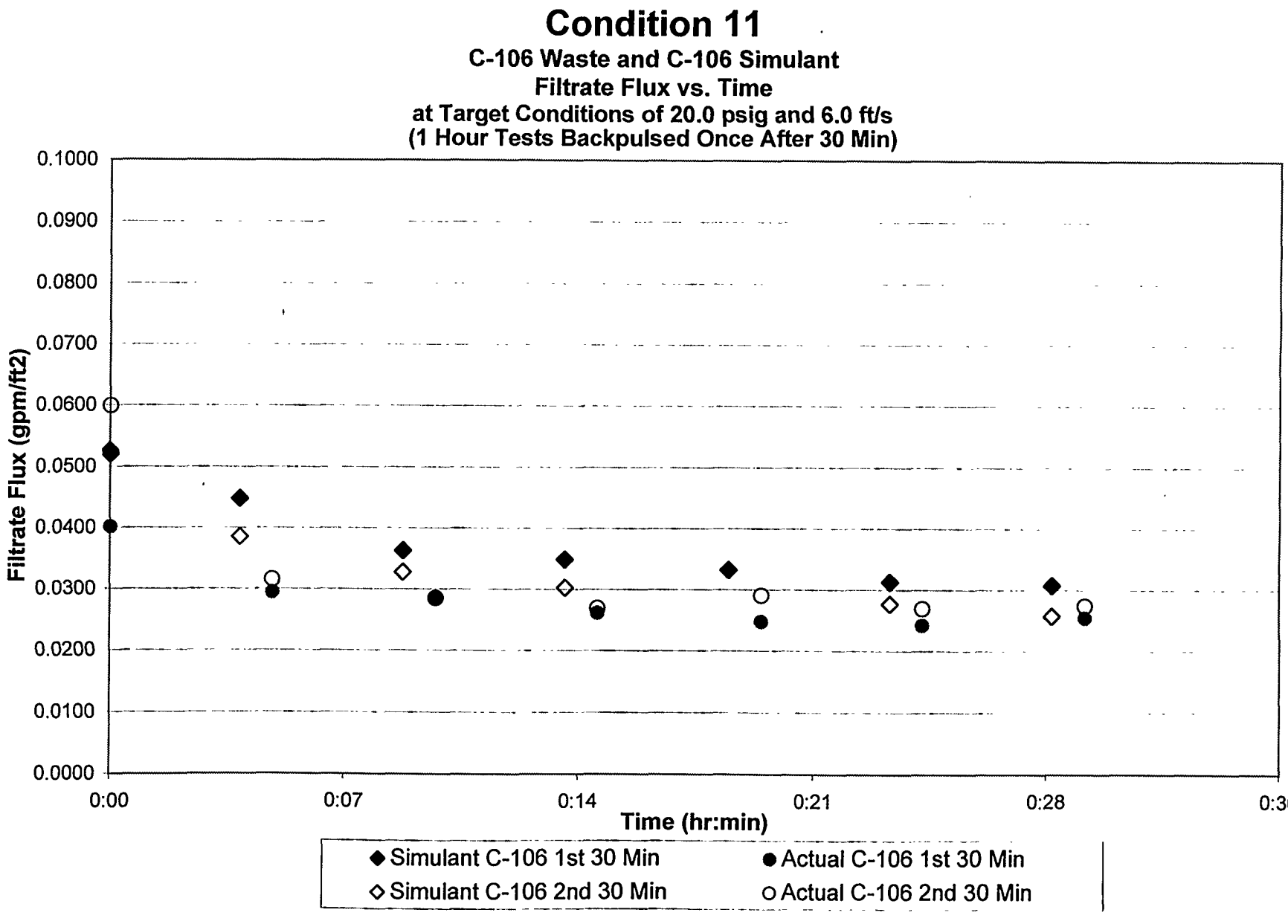
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
10b	14:11	18	27.2	3.67	NM	0	20	9	22.25	0.404
10b	14:15	14	25.4	3.74	NM	0	20	9	37.1	0.243
10b	14:20	15	24.1	3.7	NM	0	21	9	49.78	0.181
10b	14:25	16	23.3	3.63	NM	0	20	9	52.34	0.172
10b	14:30	17	23.1	3.66	NM	0	20	9	56.56	0.159
10b	14:35	18	23.5	3.69	NM	0	20	9	68.53	0.131
10b	14:40	19	23.7	3.69	NM	0	20	9	70.87	0.127

NM = Not Measured



John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	31.3	0.102	0.0657
	0:10	31.8	0.0393	0.0326
	0:20	32.7	0.0401	0.0325
	0:30	32.3	0.0401	0.0328
2nd 30 minutes	0:00	32.4	0.0924	0.0754
	0:10	31.9	0.0396	0.0328
	0:20	31.8	0.0382	0.0317
	0:30	31.7	0.0364	0.0303

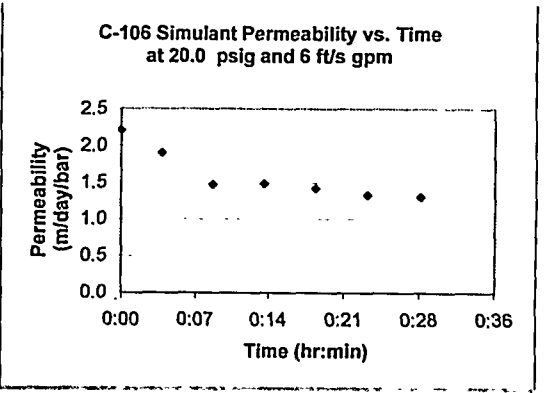

Condition 11
C-106 Waste and C-106 Simulant
Filtrate Flux vs. Time
at Target Conditions of 20.0 psig and 6.0 ft/s
(1 Hour Tests Backpulsed Once After 30 Min)
Filtrate Flux (gpm/ft2)
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
0:00
0:07
0:14
0:21
0:28
Time (hr:min)
Simulant C-106 1st 30 Min
Actual C-106 1st 30 Min
Simulant C-106 2nd 30 Min
Actual C-106 2nd 30 Min

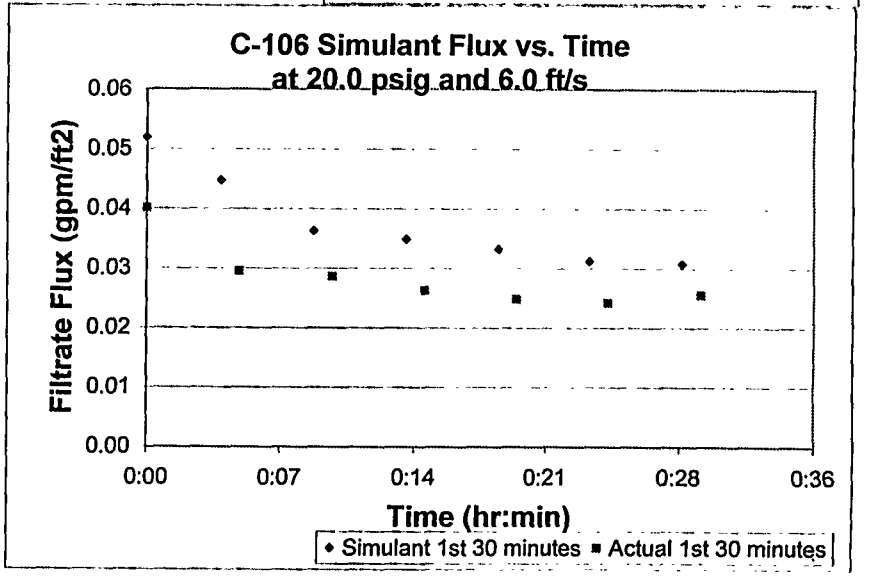
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
11a	14:11	0.00	3.72	NM	20	9	43.16	0.209	24	3.048	2.210	0.0520
11a	14:15	0.04	3 68	NM	20	9	50.12	0.180	24	2.625	1.903	0.0447
11a	14:20	0.09	3.66	NM	21	9	61.16	0.147	24.4	2.127	1.469	0.0363
11a	14:25	0:14	3.68	NM	20	9	63.6	0.142	24.4	2.045	1.483	0.0349
11a	14:30	0:19	3.69	NM	20	9	66.34	0.136	24.6	1.950	1.414	0.0332
11a	14:35	0:24	3.67	NM	20	9	69.6	0.129	25.1	1.832	1.329	0.0312
11a	14:40	0:29	3.7	NM	20	9	70.81	0.127	25.1	1.801	1.306	0.0307

RAW Average Pressure = 20.1 psig Average Slurry Flow = 3.69 gpm Average Flow = 0.153 Average Flux = 2.204 0.033

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
11a	14:11	20	24	3.72	NM	0	20	9	43.16	0.209
11a	14:15	19	24	3.68	NM	0	20	9	56.22	0.160
11a	14:20	21	24.4	3.66	NM	0	21	9	56.56	0.159
11a	14:25	20	24.4	3.68	NM	0	20	9	62.12	0.145
11a	14:30	20	24.6	3.69	NM	0	20	9	61.16	0.147
11a	14:35	22	25.1	3.67	NM	0	20	9	61.6	0.146
11a	14:40	21	25.1	3.7	NM	0	20	9	63.81	0.141

NM = Not Measured





John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Filtrate Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)	
1st 30 minutes	0:00	35	0.0527	0.0401	
	0.05	33.8	0.0375	0.0295	
	0:10	33.2	0.0358	0.0286	
	0:15	33.1	0.0327	0.0262	
	0:20	33	0.0309	0.0248	
	0:25	32.9	0.0301	0.0242	
	0:30	32.9	0.0317	0.0255	
					0.0259
2nd 30 minutes	0:00	33.2	0.075	0.0599	
	0.05	33	0.0393	0.0316	
	0;10	33.1	0.0356	0.0285	
	0:15	32.9	0.0335	0.0270	
	0:20	32.8	0.036	0.0291	
	0:25	33.4	0.0339	0.0269	
	0:30	33.3	0.0344	0.0274	

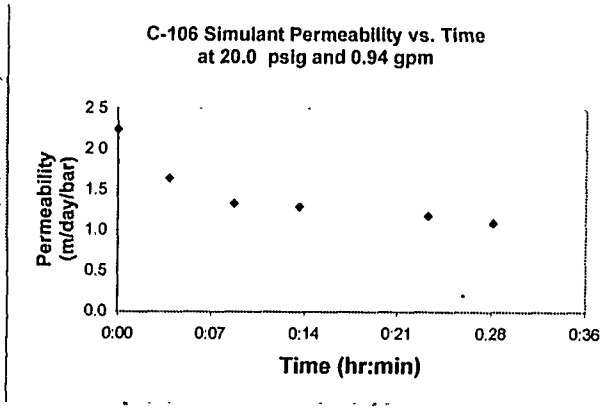
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)
11b	14:11	0 00	3 68	NM	20	9	39	0 231	27 2	3.084	2 236	0.0526
11b	14:15	0.04	3 69	NM	20	9	55.97	0.161	25 4	2 259	1.638	0.0385
11b	14:20	0.09	3 74	NM	21	9	68 29	0 132	24 1	1 921	1 327	0.0327
11b	14:25	0:14	3 7	NM	20	9	75.63	0 119	23.3	1.774	1.287	0.0302
11b	14:35	0:24	3 69	NM	20	9	82.25	0.109	23.5	1.622	1.176	0.0277
11b	14:40	0:29	3 69	NM	20	9	87 97	0.102	23.7	1.508	1 094	0.0257

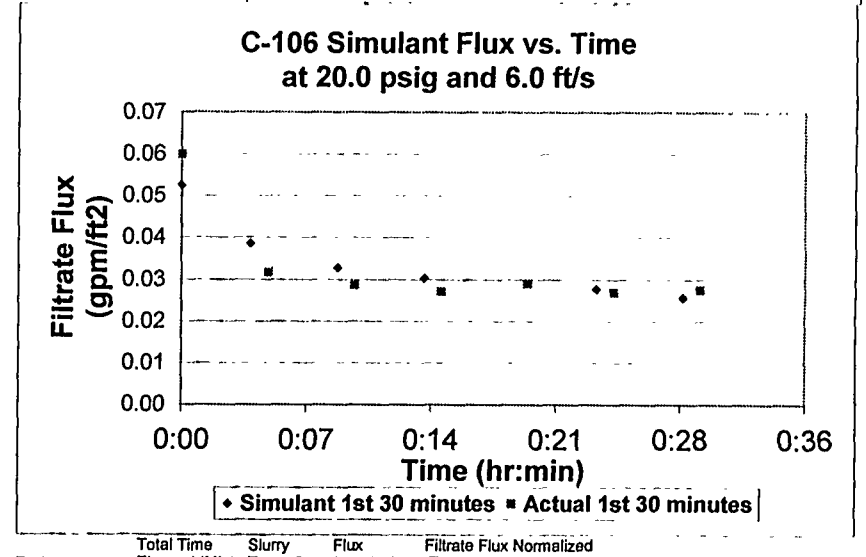
Average Pressure = 20 2 psig Average Flow = 0.142 Average Flux = 2.028 0.029

RAW Average Slurry Flow = 3.70 gpm

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filtrate Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
11b	14:11	18	27.2	3.67	NM	0	20	9	19.5	0.462
11b	14:15	14	25.4	3.74	NM	0	20	9	26.1	0.345
11b	14:20	15	24.1	3.7	NM	0	21	9	28.37	0.317
11b	14:25	16	23.3	3.63	NM	0	20	9	31.03	0.290
11b	14:30	17	23.1	3.66	NM	0	20	9	34.07	0.264
11b	14:35	18	23.5	3.69	NM	0	20	9	35.63	0.253
11b	14:40	19	23.7	3.69	NM	0	20	9	35.63	0.253

NM = Not Measured





John Geeting Data

	Total Time Elapsed (Min)	Slurry Temp C	Flux (gpm/ft2)	Filtrate Flux Normalized Temperature (gpm/ft2)
1st 30 minutes	0:00	35	0.0527	0.0401
	0;05	33.8	0.0375	0.0295
	0:10	33.2	0.0358	0.0286
	0:15	33.1	0.0327	0 0262
	0:20	33	0.0309	0.0248
	0:25	32.9	0.0301	0.0242
	0:30	32.9	0.0317	0.0255
2nd 30 minutes	0:00	33.2	0.075	0.0599
	0:05	33	0.0393	0.0316
	0:10	33.1	0.0356	0.0285
	0:15	32.9	0.0335	0.0270
	0:20	32.8	0.036	0.0291
	0:25	33.4	0.0339	0.0269
	0:30	33 3	0.0344	0.0274

C-106 Filtration Simulant at 8 wt% Solids Loading

0.1μm Mott filter element

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
1	6:55	0:00	4.22	48	54	6	30	12.72	2.358	22.9	11.856	3.372
1	7:00	0:05	4.18	47	52	5	30	23.44	1.280	26.4	5.829	1.708
1	7:05	0:10	4.26	48	53	5	30	27	1.111	27.4	4.922	1.413
1	7:10	0:15	4.15	47	52.5	5.5	30	32.97	0.910	27	4.075	1.188
1	7:15	0:20	4.2	47	52	5	30	37.87	0.792	26	3.648	1.069
1	7:20	0:25	4.2	47	52.5	5.5	30	41.5	0.723	25.1	3.414	0.995
1	7:25	0:30	4.18	47	52	5	30	44.94	0.668	24.7	3.189	0.934
1	7:30	0:35	4.12	47.5	53	5.5	30	46.66	0.643	24.5	3.089	0.891
1	7:35	0:40	4.26	47	52	5	30	50.16	0.598	24.4	2.881	0.844
1	7:40	0:45	4.16	47	52.5	5.5	30	50.96	0.589	24.3	2.844	0.829
1	7:45	0:50	4.21	47	53	6	30	52.21	0.575	24.2	2.784	0.807
1	7:50	0:55	4.19	47.5	53	5.5	30	54.03	0.555	24.3	2.682	0.774
1	7:55	1:00	4.24	47	52.5	5.5	30	55.5	0.541	24.5	2.597	0.757

Average Pressure = 49.92308

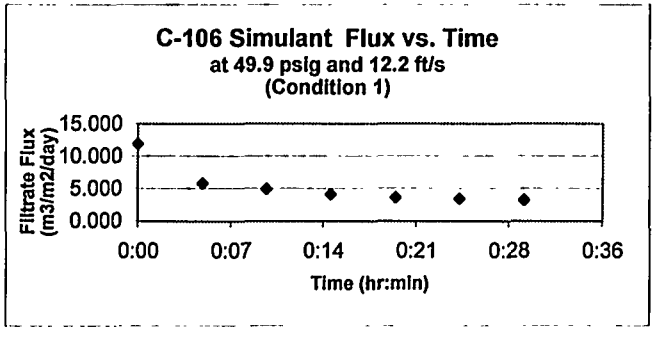
Average Flow = 0.872

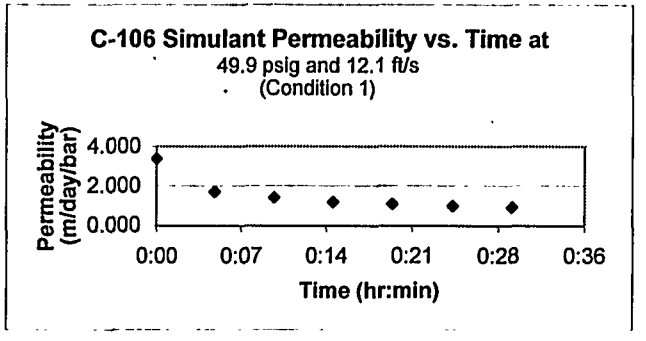
Average Flux = 3.496

RAW Average Slurry Flow = 4.20

Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1	6:55	19	22.9	4.22	48		54	30	12.72	2.358
1	7:00	19	26.4	4.18	47		52	30	23.44	1.280
1	7:05	15	27.4	4.26	48		53	30	27	1.111
1	7:10	12	27	4.15	47		52.5	30	32.97	0.910
1	7:15	9	26	4.2	47		52	30	37.87	0.792
1	7:20	8	25.1	4.2	47		52.5	30	41.5	0.723
1	7:25	9	24.7	4.18	47		52	30	44.94	0.668
1	7:30	8	24.5	4.12	47.5		53	30	46.66	0.643
1	7:35	8	24.4	4.26	47		52	30	50.16	0.598
1	7:40	9	24.3	4.16	47		52.5	30	50.96	0.589
1	7:45	10	24.2	4.21	47		53	30	52.21	0.575
1	7:50	9	24.3	4.19	47.5		53	30	54.03	0.555
1	7:55	9	24.5	4.24	47		52.5	30	55.5	0.541

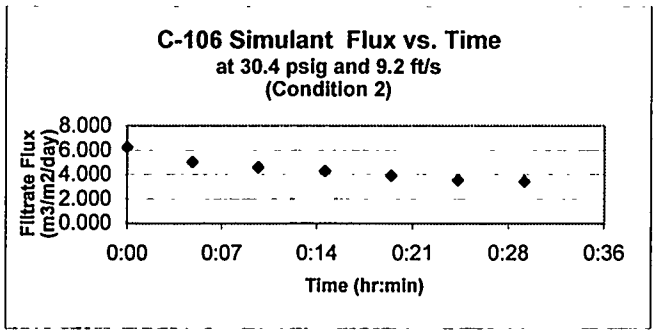


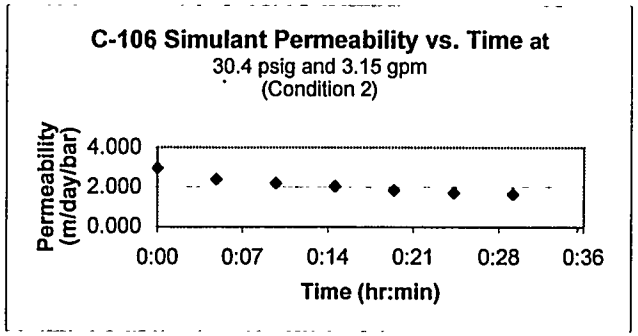


Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
2	8:05	0:00	3.16	28	33.5	5.5	30	23.97	1.252	23.2	6.238	2.942
2	8:10	0:05	3.12	28	33	5	30	30.56	0.982	22.3	5.020	2.387
2	8:15	0:10	3.17	28	32	4	30	34.03	0.882	21.8	4.574	2.211
2	8:20	0:15	3.13	28	33	5	30	36.25	0.828	22.1	4.257	2.024
2	8:25	0:20	3.13	28	33	5	30	38.6	0.777	23.1	3.885	1.847
2	8:30	0:25	3.16	28	32	4	30	41.28	0.727	24.1	3.531	1.707
2	8:35	0:30	3.12	28	33	5	30	42.03	0.714	24.6	3.419	1.626
2	8:40	0:35	3.2	28	33	5	30	46.47	0.646	24.6	3.092	1.471
2	8:45	0:40	3.08	28	33	5	30	47.38	0.633	24	3.085	1.467
2	8:50	0:45	3.18	28	33	5	30	49.47	0.606	22.9	3.049	1.450
2	8:55	0:50	3.18	28	33	5	30	50.56	0.593	23.2	2.957	1.406
2	9:00	0:55	3.16	28	32.5	4.5	30	53.59	0.560	22.8	2.822	1.353
2	9:05	1:00	3.18	28	33	5	30	53.5	0.561	21.6	2.926	1.391

RAW Average Slurry Flow = 3.15 Average Pressure = 30.42308 Average Flow = Filtrate 0.751 Average Flux = With First Point Removed 3.551

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2	8:05	10	23.2	3.16	28		33.5	30	23.97	1.252
2	8:10	12	22.3	3.12	28		33	30	30.56	0.982
2	8:15	13	21.8	3.17	28		32	30	34.03	0.882
2	8:20	16	22.1	3.13	28		33	30	36.25	0.828
2	8:25	18	23.1	3.13	28		33	30	38.6	0.777
2	8:30	19	24.1	3.16	28		32	30	41.28	0.727
2	8:35	18	24.6	3.12	28		33	30	42.03	0.714
2	8:40	18	24.6	3.2	28		33	30	46.47	0.646
2	8:45	18	24	3.08	28		33	30	47.38	0.633
2	8:50	18	22.9	3.18	28		33	30	49.47	0.606
2	8:55	18	23.2	3.18	28		33	30	50.56	0.593
2	9:00	19	22.8	3.16	28		32.5	30	53.59	0.560
2	9:05	19	21.6	3.18	28		33	30	53.5	0.561





Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
3	9:20	0:00	4.05	67.5	72	4.5	30	15.44	1.943	21	10.316	2.145
3	9:25	0:05	3.96	67.5	72.5	5	30	19.28	1.556	21	8.261	1.712
3	9:30	0:10	3.9	67	72.5	5.5	30	21.06	1.425	20.7	7.629	1.586
3	9:35	0:15	3.87	67.5	73	5.5	30	22.59	1.328	20.7	7.112	1.468
3	9:40	0:20	3.87	68	73	5	30	23.97	1.252	20.6	6.722	1.383
3	9:45	0:25	3.89	68	73	5	30	26	1.154	20.5	6.215	1.279
3	9:50	0:30	3.89	67	72.5	5.5	30	26.72	1.123	20.4	6.065	1.261
3	9:55	0:35	3.91	67	72.5	5.5	30	27.4	1.095	20.4	5.915	1.230
3	10:00	0:40	3.89	67.5	72.5	5	30	27	1.111	20.5	5.985	1.240
3	10:05	0:45	3.89	67	72	5	30	27.32	1.098	20.5	5.915	1.234
3	10:10	0:50	3.82	67	72	5	30	27.75	1.081	20.8	5.773	1.205
3	10:15	0:55	3.91	67.5	72	4.5	30	27.44	1.093	20.9	5.821	1.210
3	10:20	1:00	3.9	67.5	72.5	5	30	27.82	1.078	21	5.725	1.186

Average Pressure = 69.92308

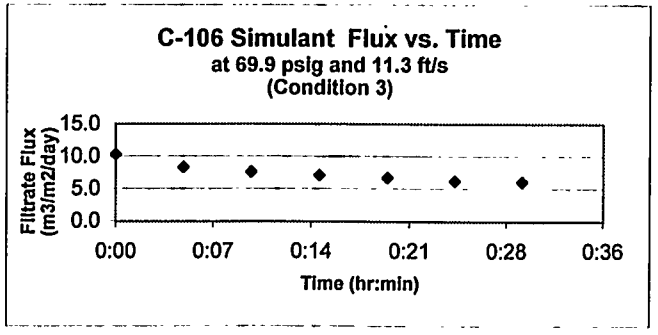
Average Flow = 1.257

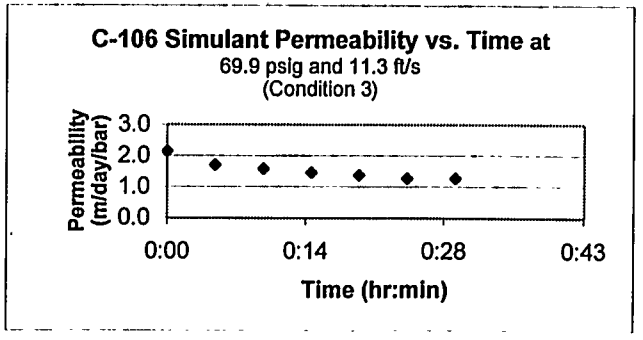
Average Flux = 6.428

RAW Average Slurry Flow = 3.90

With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
3	9:20	9	21	4.05	67.5		72	30	15.44	1.943
3	9:25	9	21	3.96	67.5		72.5	30	19.28	1.556
3	9:30	10	20.7	3.9	67		72.5	30	21.06	1.425
3	9:35	11	20.7	3.87	67.5		73	30	22.59	1.328
3	9:40	12	20.6	3.87	68		73	30	23.97	1.252
3	9:45	16	20.5	3.89	68		73	30	26	1.154
3	9:50	21	20.4	3.89	67		72.5	30	26.72	1.123
3	9:55	24	20.4	3.91	67		72.5	30	27.4	1.095
3	10:00	26	20.5	3.89	67.5		72.5	30	27	1.111
3	10:05	29	20.5	3.89	67		72	30	27.32	1.098
3	10:10	28	20.8	3.82	67		72	30	27.75	1.081
3	10:15	29	20.9	3.91	67.5		72	30	27.44	1.093
3	10:20	29	21	3.9	67.5		72.5	30	27.82	1.078

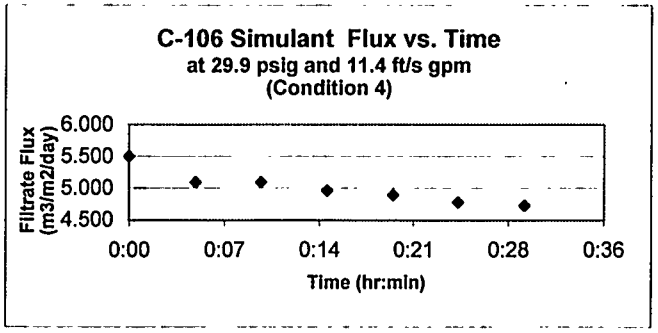


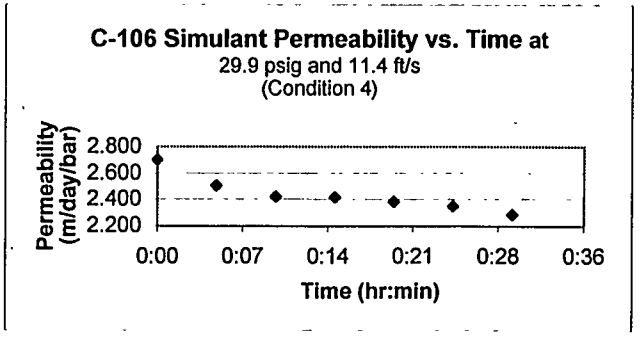


Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
4	11:35	0:00	3.96	27	32	5	30	30.53	0.983	19.2	5.498	2.703
4	11:40	0:05	3.92	27	32	5	30	32.75	0.916	19.4	5.095	2.505
4	11:45	0:10	3.93	28	33	5	30	32.66	0.919	19.5	5.094	2.422
4	11:50	0:15	3.91	27	32.5	5.5	30	33.47	0.896	19.6	4.956	2.416
4	11:55	0:20	3.91	27	32.5	5.5	30	33.87	0.886	19.7	4.884	2.381
4	12:00	0:25	3.89	27	32	5	30	34.65	0.866	19.7	4.774	2.347
4	12:05	0:30	3.9	27.5	32.5	5	30	35	0.857	19.7	4.726	2.285
4	12:10	0:35	3.88	27.5	32.5	5	30	35.16	0.853	19.9	4.677	2.261
4	12:16	0:41	3.95	27.5	33.5	6	30	34.47	0.870	20	4.757	2.262
4	12:21	0:46	3.83	27	32	5	30	36.94	0.812	20	4.439	2.182
4	12:26	0:51	3.92	27.5	33	5.5	30	35.94	0.835	20	4.562	2.187
4	12:30	0:55	3.89	27.5	33	5.5	30	36.59	0.820	20.2	4.455	2.136
4	12:35	1:00	3.9	27.5	32.5	5	30	36.69	0.818	20.1	4.456	2.154

RAW Average Slurry Flow = 3.91 Average Pressure = 29.92308 Average Flow = Filtrate 0.872 Average Flux = With First Point Removed 4.798

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
4	11:35	22	19.2	3.96	27		32	30	30.53	0.983
4	11:40	23	19.4	3.92	27		32	30	32.75	0.916
4	11:45	24	19.5	3.93	28		33	30	32.66	0.919
4	11:50	25	19.6	3.91	27		32.5	30	33.47	0.896
4	11:55	26	19.7	3.91	27		32.5	30	33.87	0.886
4	12:00	26	19.7	3.89	27		32	30	34.65	0.866
4	12:05	27	19.7	3.9	27.5		32.5	30	35	0.857
4	12:10	28	19.9	3.88	27.5		32.5	30	35.16	0.853
4	12:16	28	20	3.95	27.5		33.5	30	34.47	0.870
4	12:21	29	20	3.83	27		32	30	36.94	0.812
4	12:26	29	20	3.92	27.5		33	30	35.94	0.835
4	12:30	30	20.2	3.89	27.5		33	30	36.59	0.820
4	12:35	30	20.1	3.9	27.5		32.5	30	36.69	0.818



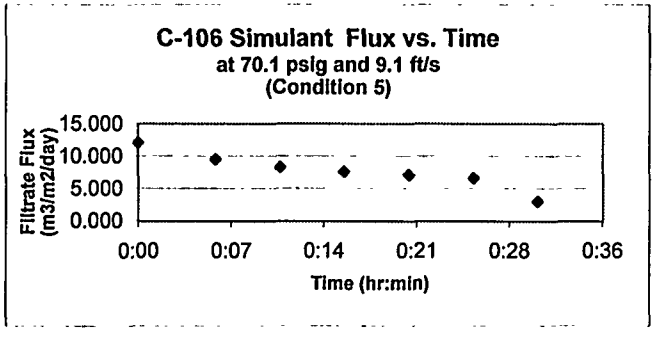


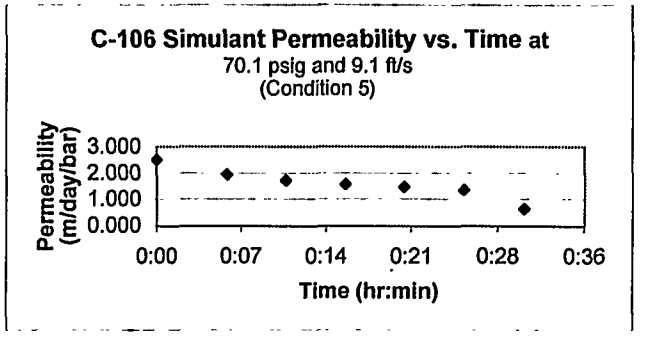
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
5	13:09	0:00	3.14	68	72	4	30	13.32	2.252	20.6	12.097	2.506
5	13:15	0:06	3.17	68	73	5	30	16.97	1.768	20.7	9.468	1.948
5	13:20	0:11	3.14	68	72	4	30	19.46	1.542	20.7	8.256	1.711
5	13:25	0:16	3.11	68	72	4	30	21.13	1.420	20.8	7.582	1.571
5	13:30	0:21	3.13	68	72.5	4.5	30	22.53	1.332	20.8	7.110	1.468
5	13:35	0:26	3.13	68	72	4	30	24.34	1.233	20.9	6.563	1.360
5	13:40	0:31	3.1	68	72	4	30	26.78	1.120	46.3	3.032	0.628
5	13:45	0:36	3.16	68	72	4	30	29.78	1.007	43.5	2.922	0.605
5	13:50	0:41	3.13	68	72.5	4.5	30	32.19	0.932	40.7	2.901	0.599
5	13:55	0:46	3.13	68	72.5	4.5	30	0	#DIV/0!	38	#DIV/0!	#DIV/0!
5	14:00	0:51	3.19	68	72.5	4.5	30	39.56	0.758	35.7	2.686	0.554
5	14:05	0:56	3.15	68.5	73	4.5	30	42.47	0.706	33.5	2.651	0.544
5	14:10	1:01	3.13	68	72.5	4.5	30	44.72	0.671	32.3	2.600	0.537

Average Pressure = 70.19231 Average Flow = #DIV/0! Average Flux = #DIV/0!

RAW Average Slurry Flow = 3.14 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
5	13:09	33	20.6	3.14	68		72	30	13.32	2.252
5	13:15	35	20.7	3.17	68		73	30	16.97	1.768
5	13:20	35	20.7	3.14	68		72	30	19.46	1.542
5	13:25	36	20.8	3.11	68		72	30	21.13	1.420
5	13:30	37	20.8	3.13	68		72.5	30	22.53	1.332
5	13:35	37	20.9	3.13	68		72	30	24.34	1.233
5	13:40	33	46.3	3.1	68		72	30	26.78	1.120
5	13:45	25	43.5	3.16	68		72	30	29.78	1.007
5	13:50	21	40.7	3.13	68		72.5	30	32.19	0.932
5	13:55	18	38	3.13	68		72.5	30		#DIV/0!
5	14:00	15	35.7	3.19	68		72.5	30	39.56	0.758
5	14:05	13	33.5	3.15	68.5		73	30	42.47	0.706
5	14:10	12	32.3	3.13	68		72.5	30	44.72	0.671



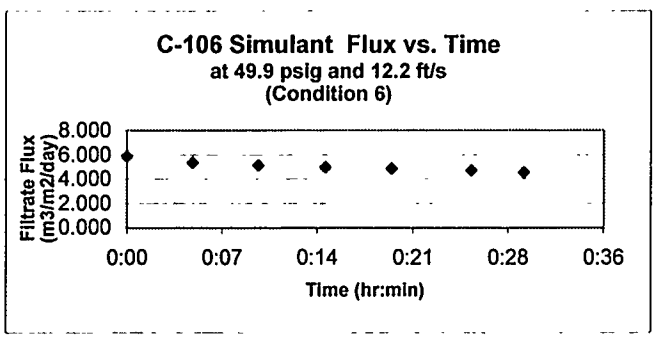


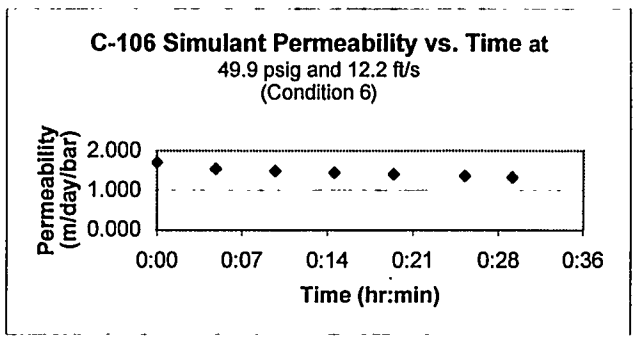
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
6	2:20	0:00	4.24	47	53	6	30	21.56	1.391	29.3	5.849	1.697
6	2:25	0:05	4.22	47	53	6	30	24.53	1.223	28.1	5.313	1.541
6	2:30	0:10	4.17	46.5	53	6.5	30	26.1	1.149	27.1	5.134	1.497
6	2:35	0:15	4.2	47	53	6	30	27.81	1.079	26.1	4.954	1.437
6	2:40	0:20	4.22	47	53	6	30	28.87	1.039	25.6	4.840	1.404
6	2:46	0:26	4.22	47	53	6	30	30.28	0.991	25	4.693	1.361
6	2:50	0:30	4.15	46.5	52	5.5	30	31.78	0.944	24.7	4.509	1.328
6	2:56	0:36	4.19	46.5	53	6.5	30	31.81	0.943	25	4.467	1.302
6	3:00	0:40	4.17	47	53	6	30	32.72	0.917	25.1	4.331	1.256
6	3:05	0:45	4.18	46.5	52.5	6	30	34.25	0.876	24.8	4.172	1.222
6	3:10	0:50	4.2	47	53	6	30	34.56	0.868	24.8	4.135	1.199
6	3:15	0:55	4.19	47	53	6	30	35.66	0.841	24.9	3.996	1.159
6	3:20	1:00	4.19	47	53	6	30	35.81	0.838	24.8	3.990	1.158

Average Pressure = 49.86538 Average Flow = 1.008 Average Flux = 4.544

RAW Average Slurry Flow = 4.20 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
6	2:20	10	29.3	4.24	47		53	30	21.56	1.391
6	2:25	9	28.1	4.22	47		53	30	24.53	1.223
6	2:30	9	27.1	4.17	46.5		53	30	26.1	1.149
6	2:35	8	26.1	4.2	47		53	30	27.81	1.079
6	2:40	8	25.6	4.22	47		53	30	28.87	1.039
6	2:46	8	25	4.22	47		53	30	30.28	0.991
6	2:50	9	24.7	4.15	46.5		52	30	31.78	0.944
6	2:56	10	25	4.19	46.5		53	30	31.81	0.943
6	3:00	11	25.1	4.17	47		53	30	32.72	0.917
6	3:05	10	24.8	4.18	46.5		52.5	30	34.25	0.876
6	3:10	10	24.8	4.2	47		53	30	34.56	0.868
6	3:15	11	24.9	4.19	47		53	30	35.66	0.841
6	3:20	10	24.8	4.19	47		53	30	35.81	0.838





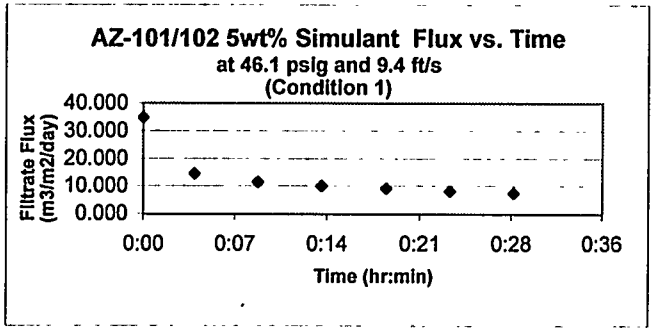
AZ-101/102 Filtration Simulant at 5 wt% Solids Loading CUF Testing

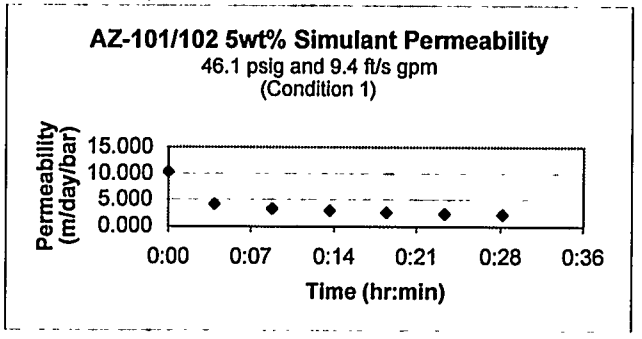
0.1μm Mott filter element

Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
1	3:36	0:00	3.23	47	51	4	30	4.19	7.160	24.1	34.785	10.296
1	3:40	0:04	3.22	48	52	4	30	10	3.000	24.1	14.575	4.228
1	3:45	0:09	3.2	48	52	4	30	12.54	2.392	24.6	11.460	3.324
1	3:50	0:14	3.27	48	52	4	30	14.34	2.092	24.7	9.993	2.899
1	3:55	0:19	3.23	48	52	4	30	15.78	1.901	24.9	9.030	2.619
1	4:00	0:24	3.23	48	52	4	30	17.56	1.708	24.9	8.115	2.354
1	4:05	0:29	3.25	48	52	4	30	19.31	1.554	24.2	7.527	2.183
1	4:10	0:34	3.28	48	52	4	30	20.97	1.431	23.9	6.990	2.028
1	4:15	0:39	0	0	0	0	0	0				
1	4:20	0:44	3.22	48	52	4	30	13.88	2.161	21.9	11.181	3.243
1	4:25	0:49	3.17	48	53	5	30	16.87	1.778	22.1	9.147	2.627
1	4:30	0:54	3.23	47.5	52.5	5	30	18.4	1.630	22.2	8.362	2.426
1	4:35	0:59	3.26	48	52.5	4.5	30	19.06	1.574	22.7	7.958	2.297

RAW Average Slurry Flow = 2.98 Average Pressure = 46.13462 Average Flow = Filtrate 2.365 Average Flux = With First Point Removed 9.485

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1	3:36	15	24.1	3.23	47		51	30	4.19	7.160
1	3:40	15	24.1	3.22	48		52	30	10	3.000
1	3:45	15	24.6	3.2	48		52	30	12.54	2.392
1	3:50	14	24.7	3.27	48		52	30	14.34	2.092
1	3:55	15	24.9	3.23	48		52	30	15.78	1.901
1	4:00	13	24.9	3.23	48		52	30	17.56	1.708
1	4:05	12	24.2	3.25	48		52	30	19.31	1.554
1	4:10	12	23.9	3.28	48		52	30	20.97	1.431
1	4:15									
1	4:20	11	21.9	3.22	48		52	30	13.88	2.161
1	4:25	12	22.1	3.17	48		53	30	16.87	1.778
1	4:30	12	22.2	3.23	47.5		52.5	30	18.4	1.630
1	4:35	13	22.7	3.26	48		52.5	30	19.06	1.574



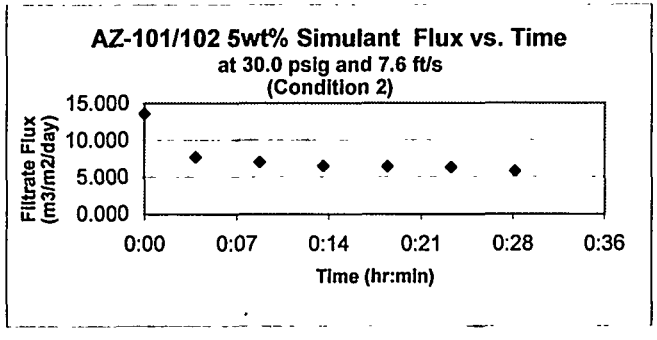


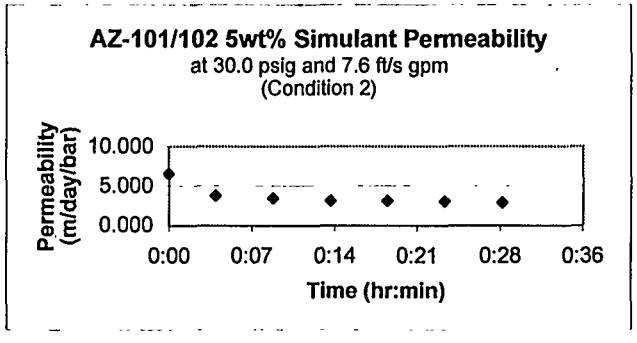
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
2	9:21	0:00	2.72	28	32	4	30	11.25	2.667	22.3	13.638	6.593
2	9:25	0:04	2.55	28	32	4	30	20	1.500	21.9	7.760	3.752
2	9:30	0:09	2.58	28	32	4	30	22.25	1.348	21.5	7.056	3.411
2	9:35	0:14	2.51	28	32	4	30	24.03	1.248	21.9	6.458	3.122
2	9:40	0:19	2.62	28	32	4	30	23.72	1.265	22.5	6.431	3.109
2	9:45	0:24	2.64	28	32	4	30	23.91	1.255	22.7	6.344	3.067
2	9:50	0:29	2.6	27.5	31	3.5	30	26.06	1.151	23.1	5.754	2.853
2	9:55	0:34	2.64	28	32.5	4.5	30	25.84	1.161	23.2	5.787	2.774
2	10:00	0:39	2.62	28	32	4	30	27.03	1.110	23.3	5.516	2.667
2	10:10	0:49	2.47	28	32	4	30	27.47	1.092	23.4	5.412	2.617
2	10:15	0:54	2.59	28	32	4	30	27.28	1.100	23.5	5.435	2.627
2	10:20	0:59	2.6	29	33	4	30	27.22	1.102	23.5	5.447	2.548

Average Pressure = 30.04167 Average Flow = Filtrate 1.333 Average Flux = With First Point Removed 6.127

RAW Average Slurry Flow = 2.60

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2	9:21	13	22.3	2.72	28		32	30	11.25	2.667
2	9:25	13	21.9	2.55	28		32	30	20	1.500
2	9:30	14	21.5	2.58	28		32	30	22.25	1.348
2	9:35	17	21.9	2.51	28		32	30	24.03	1.248
2	9:40	18	22.5	2.62	28		32	30	23.72	1.265
2	9:45	18	22.7	2.64	28		32	30	23.91	1.255
2	9:50	18	23.1	2.6	27.5		31	30	26.06	1.151
2	9:55	17	23.2	2.64	28		32.5	30	25.84	1.161
2	10:00	17	23.3	2.62	28		32	30	27.03	1.110
2	10:10	17	23.4	2.47	28		32	30	27.47	1.092
2	10:15	17	23.5	2.59	28		32	30	27.28	1.100
2	10:20	18	23.5	2.6	29		33	30	27.22	1.102



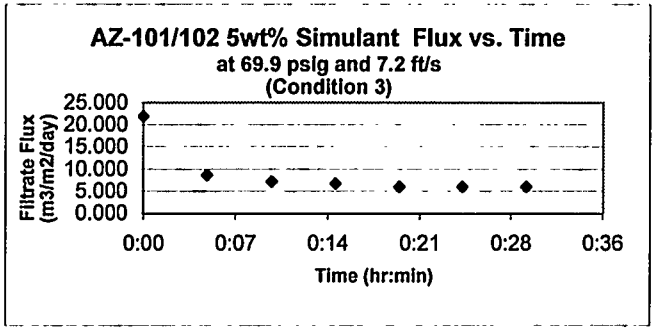


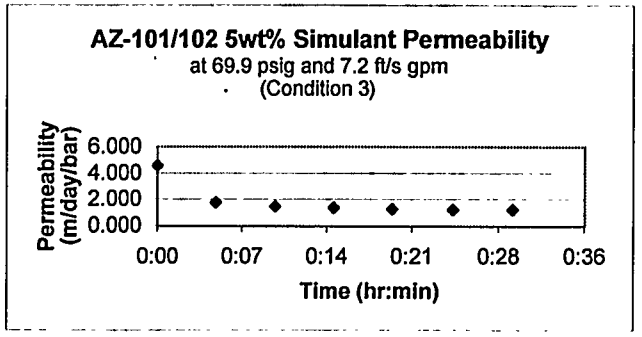
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
3	10:25	0:00	2.6	68	72	4	30	6.56	4.573	24.5	21.968	4.552
3	10:30	0:05	2.5	68	72	4	30	16.91	1.774	24.3	8.571	1.776
3	10:35	0:10	2.4	68	71.5	3.5	30	20.4	1.471	24.2	7.124	1.481
3	10:40	0:15	2.45	68	71.5	3.5	30	21.84	1.374	24.2	6.655	1.384
3	10:45	0:20	2.48	68	71.5	3.5	30	24	1.250	24.3	6.039	1.256
3	10:50	0:25	2.47	68	72	4	30	24.31	1.234	24.3	5.962	1.235
3	10:55	0:30	2.52	68	72	4	30	24.16	1.242	24.5	5.965	1.236
3	11:00	0:35	2.52	68	71.5	3.5	30	25.37	1.182	24.7	5.648	1.175
3	11:05	0:40	2.47	68.5	72	3.5	30	25.69	1.168	24.9	5.547	1.145
3	11:10	0:45	2.42	68	72	4	30	26.44	1.135	25.1	5.359	1.110
3	11:15	0:50	2.4	68	71	3	30	27.03	1.110	25	5.257	1.097
3	11:20	0:55	2.42	68	72	4	30	27.47	1.092	24.9	5.187	1.075
3	11:25	1:00	2.43	68	72	4	30	28.63	1.048	24.9	4.977	1.031

Average Pressure = 69.90385 Average Flow = 1.512 Average Flux = 6.024

RAW Average Slurry Flow = 2.47 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
3	10:25	13	24.5	2.6	68		72	30	6.56	4.573
3	10:30	11	24.3	2.5	68		72	30	16.91	1.774
3	10:35	12	24.2	2.4	68		71.5	30	20.4	1.471
3	10:40	12	24.2	2.45	68		71.5	30	21.84	1.374
3	10:45	12	24.3	2.48	68		71.5	30	24	1.250
3	10:50	12	24.3	2.47	68		72	30	24.31	1.234
3	10:55	12	24.5	2.52	68		72	30	24.16	1.242
3	11:00	12	24.7	2.52	68		71.5	30	25.37	1.182
3	11:05	13	24.9	2.47	68.5		72	30	25.69	1.168
3	11:10	13	25.1	2.42	68		72	30	26.44	1.135
3	11:15	13	25	2.4	68		71	30	27.03	1.110
3	11:20	12	24.9	2.42	68		72	30	27.47	1.092
3	11:25	12	24.9	2.43	68		72	30	28.63	1.048



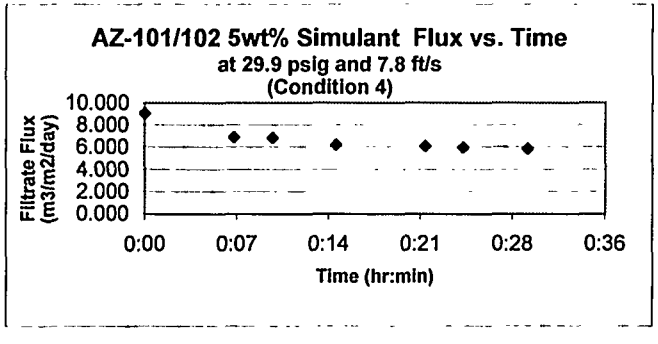


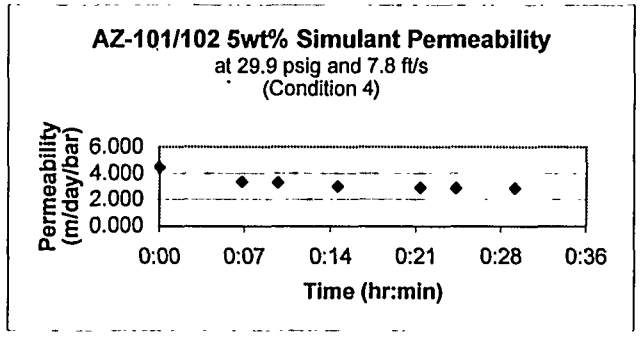
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
4	11:35	0:00	2.65	28	31	3	30	16.82	1.784	22.5	9.069	4.459
4	11:42	0:07	2.7	28	32	4	30	22.5	1.333	22	6.878	3.325
4	11:45	0:10	2.83	28	32	4	30	22.44	1.337	22.3	6.837	3.305
4	11:50	0:15	2.57	28	32	4	30	24.6	1.220	22.6	6.183	2.989
4	11:57	0:22	2.8	28	33	5	30	24.72	1.214	23	6.083	2.893
4	12:00	0:25	2.75	28.5	32	3.5	30	25.31	1.185	23	5.942	2.849
4	12:05	0:30	2.68	28	32	4	30	25.53	1.175	23.1	5.874	2.840
4	12:10	0:35	2.9	28	31	3	30	26.65	1.126	23.1	5.627	2.766
4	12:17	0:42	2.76	27	31	4	30	27.5	1.091	23.2	5.437	2.719
4	12:25	0:50	2.44	28	31	3	30	28	1.071	23.3	5.325	2.618
4	12:30	0:55	2.75	28	32	4	30	29.09	1.031	23.2	5.140	2.485
4	12:35	1:00	2.5	28	32	4	30	28.94	1.037	23.1	5.182	2.505

Average Pressure = 29.85417 Average Flow = Filtrate 1.217 Average Flux = With First Point Removed 5.864

RAW Average Slurry Flow = 2.69

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
4	11:35	12	22.5	2.65	28		31	30	16.82	1.784
4	11:42	16	22	2.7	28		32	30	22.5	1.333
4	11:45	17	22.3	2.83	28		32	30	22.44	1.337
4	11:50	16	22.6	2.57	28		32	30	24.6	1.220
4	11:57	16	23	2.8	28		33	30	24.72	1.214
4	12:00	17	23	2.75	28.5		32	30	25.31	1.185
4	12:05	17	23.1	2.68	28		32	30	25.53	1.175
4	12:10	17	23.1	2.9	28		31	30	26.65	1.126
4	12:17	18	23.2	2.76	27		31	30	27.5	1.091
4	12:25	17	23.3	2.44	28		31	30	28	1.071
4	12:30	17	23.2	2.75	28		32	30	29.09	1.031
4	12:35	18	23.1	2.5	28		32	30	28.94	1.037



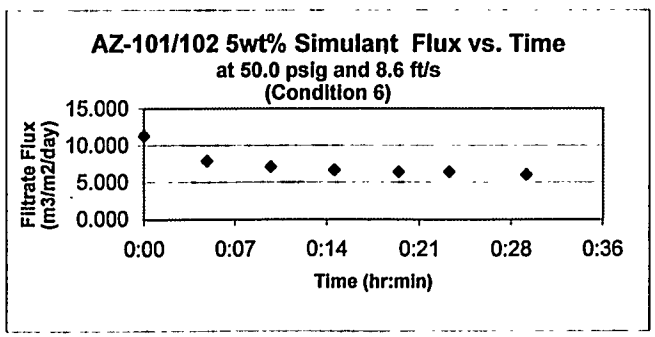


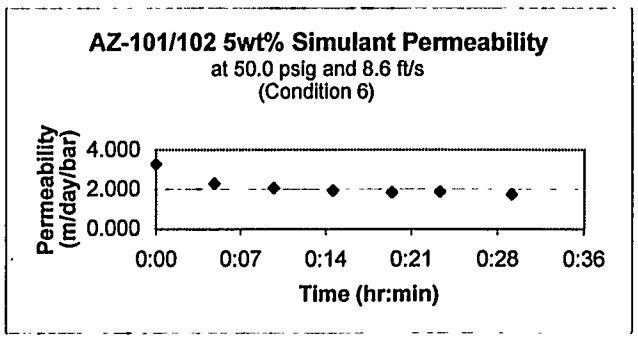
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
6	12:45	0:00	3.08	48	52	4	30	12.66	2.370	24.8	11.287	3.274
6	12:50	0:05	2.91	48	52	4	30	18.06	1.661	24.8	7.912	2.295
6	12:55	0:10	2.88	48	52	4	30	20.44	1.468	24.2	7.111	2.063
6	13:00	0:15	3.07	48	52	4	30	21.69	1.383	24.5	6.644	1.927
6	13:05	0:20	2.89	48	52	4	30	22.19	1.352	25.1	6.386	1.852
6	13:09	0:24	2.94	48	52	4	30	22.31	1.345	24.9	6.387	1.853
6	13:15	0:30	2.92	48	52	4	30	23.75	1.263	24.7	6.034	1.750
6	13:20	0:35	2.87	48	52	4	30	24.09	1.245	24.7	5.949	1.726
6	13:25	0:40	2.94	48	52	4	30	25.34	1.184	25.1	5.592	1.622
6	13:30	0:45	2.9	47.5	52	4.5	30	25.38	1.182	25.2	5.567	1.623
6	13:35	0:50	2.93	48	52	4	30	25.25	1.188	25	5.627	1.632
6	13:46	1:01	3.03	48	52	4	30	26.87	1.116	25.1	5.273	1.530

Average Pressure = 49.97917 Average Flow = 1.396 Average Flux = 6.226

RAW Average Slurry Flow = 2.95 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
6	12:45	18	24.8	3.08	48		52	30	12.66	2.370
6	12:50	13	24.8	2.91	48		52	30	18.06	1.661
6	12:55	13	24.2	2.88	48		52	30	20.44	1.468
6	13:00	16	24.5	3.07	48		52	30	21.69	1.383
6	13:05	16	25.1	2.89	48		52	30	22.19	1.352
6	13:09	14	24.9	2.94	48		52	30	22.31	1.345
6	13:15	15	24.7	2.92	48		52	30	23.75	1.263
6	13:20	15	24.7	2.87	48		52	30	24.09	1.245
6	13:25	16	25.1	2.94	48		52	30	25.34	1.184
6	13:30	16	25.2	2.9	47.5		52	30	25.38	1.182
6	13:35	15	25	2.93	48		52	30	25.25	1.188
6	13:46	15	25.1	3.03	48		52	30	26.87	1.116



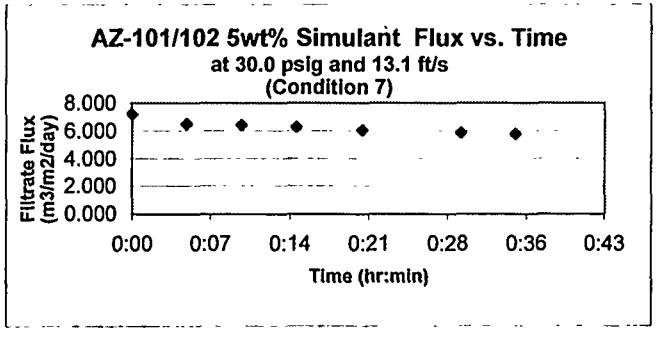


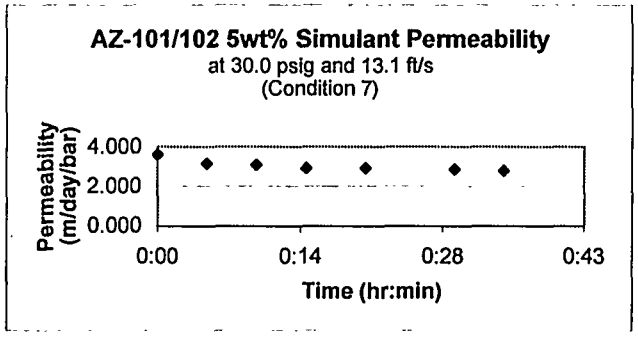
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
7	1:55	0:00	4.54	26	32	6	30	19.75	1.519	25	7.195	3.598
7	2:00	0:05	4.44	27	33	6	40	29.22	1.369	25	6.484	3.135
7	2:05	0:10	4.47	27	33	6	30	22.31	1.345	24.9	6.387	3.088
7	2:10	0:15	4.55	28	34	6	30	22.47	1.335	25.3	6.271	2.934
7	2:16	0:21	4.48	27	33	6	30	23.22	1.292	25.5	6.034	2.917
7	2:25	0:30	0	27	33	6	30	24.15	1.242	25.1	5.867	2.837
7	2:30	0:35	4.46	27	33	6	30	24.62	1.219	25	5.771	2.790
7	2:35	0:40	4.48	27	33	6	30	24	1.250	25	5.921	2.862
7	2:40	0:45	4.52	27	33	6	30	24.28	1.236	25	5.852	2.829
7	2:45	0:50	4.52	27	33	6	30	24.53	1.223	25	5.793	2.801
7	2:50	0:55	4.52	27	33.5	6.5	30	24.09	1.245	25.1	5.882	2.820
7	2:55	1:00	4.48	27	33	6	30	24.9	1.205	24.8	5.739	2.774

Average Pressure = 30.02083 Average Flow = 1.290 Average Flux = 6.000

RAW Average Slurry Flow = 4.12 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
7	1:55	14	25	4.54	26		32	30	19.75	1.519
7	2:00	14	25	4.44	27		33	40	29.22	1.369
7	2:05	14	24.9	4.47	27		33	30	22.31	1.345
7	2:10	16	25.3	4.55	28		34	30	22.47	1.335
7	2:16	15	25.5	4.48	27		33	30	23.22	1.292
7	2:25	14	25.1		27		33	30	24.15	1.242
7	2:30	14	25	4.46	27		33	30	24.62	1.219
7	2:35	15	25	4.48	27		33	30	24	1.250
7	2:40	14	25	4.52	27		33	30	24.28	1.236
7	2:45	14	25	4.52	27		33	30	24.53	1.223
7	2:50	14	25.1	4.52	27		33.5	30	24.09	1.245
7	2:55	12	24.8	4.48	27		33	30	24.9	1.205





AZ-101/102 Filtration Simulant at 15 wt% Solids Loading CUF Testing

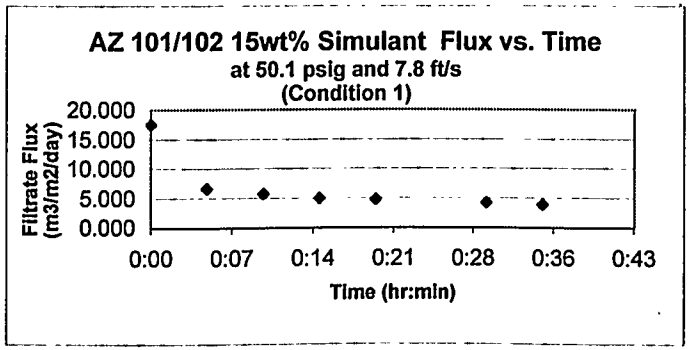
0.1µm Motl filter element

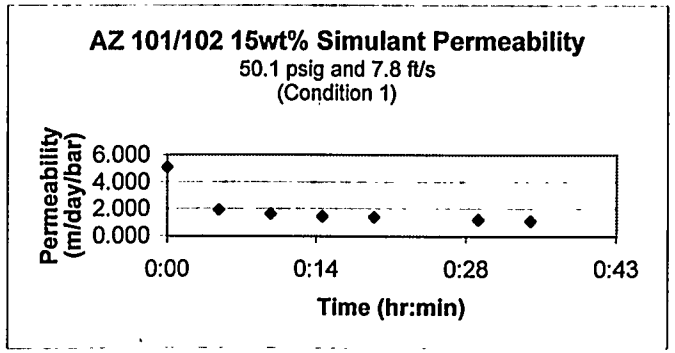
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
1	9:50	0:00	2.71	48	52	4	30	8.22	3.650	24.6	17.482	5.071
1	9:55	0:05	2.71	48	52.5	4.5	30	21.68	1.384	24.7	6.610	1.908
1	10:00	0:10	2.64	48	52	4	30	25.09	1.196	24.9	5.679	1.647
1	10:05	0:15	2.71	48	52	4	30	28.57	1.050	24.9	4.988	1.447
1	10:10	0:20	2.7	48	52	4	30	30.09	0.997	24.6	4.776	1.385
1	10:20	0:30	2.73	48	52	4	30	34.31	0.874	24.4	4.212	1.222
1	10:25	0:35	2.73	49	53	4	30	37.09	0.809	24.5	3.885	1.105
1	10:30	0:40	2.76	48	52.5	4.5	30	38.75	0.774	24.5	3.719	1.073
1	10:35	0:45	2.67	48	52	4	30	41.07	0.730	24.5	3.509	1.018
1	10:40	0:50	2.72	48.5	52	3.5	30	41.06	0.731	24.5	3.510	1.013
1	10:45	0:55	2.67	48	52	4	30	43.75	0.686	24.6	3.285	0.953
1	10:50	1:00	2.67	48	52	4	30	46.16	0.650	24.6	3.113	0.903

Average Pressure = 50.14583 Average Flow = 1.128 Average Flux = 4.299

RAW Average Slurry Flow = 2.70 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1	9:50	19	24.6	2.71	48		52	30	8.22	3.650
1	9:55	17	24.7	2.71	48		52.5	30	21.68	1.384
1	10:00	11	24.9	2.64	48		52	30	25.09	1.196
1	10:05	16	24.9	2.71	48		52	30	28.57	1.050
1	10:10	15	24.6	2.7	48		52	30	30.09	0.997
1	10:20	15	24.4	2.73	48		52	30	34.31	0.874
1	10:25	15	24.5	2.73	49		53	30	37.09	0.809
1	10:30	15	24.5	2.76	48		52.5	30	38.75	0.774
1	10:35	15	24.5	2.67	48		52	30	41.07	0.730
1	10:40	15	24.5	2.72	48.5		52	30	41.06	0.731
1	10:45	15	24.6	2.67	48		52	30	43.75	0.686
1	10:50	15	24.6	2.67	48		52	30	46.16	0.650



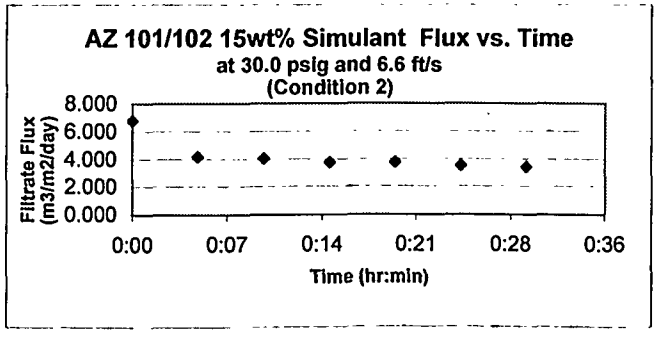


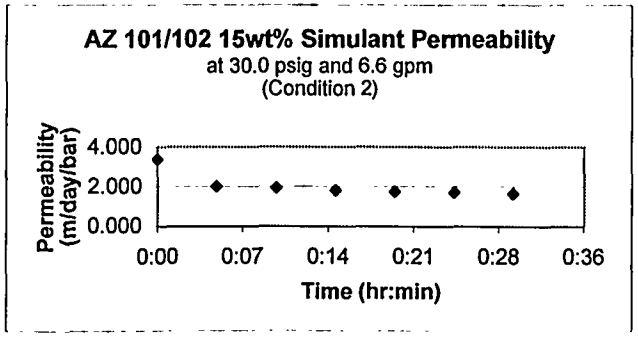
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
2	11:00	0:00	2.15	27	31.5	4.5	30	21.81	1.376	23.6	6.778	3.361
2	11:05	0:05	2.29	28	32	4	30	36.32	0.826	22.9	4.152	2.007
2	11:10	0:10	2.38	28	32	4	30	37.75	0.795	22.8	4.006	1.937
2	11:15	0:15	2.35	28	32	4	30	40.31	0.744	22.7	3.763	1.819
2	11:20	0:20	2.47	29	33	4	30	40.38	0.743	22.8	3.745	1.752
2	11:25	0:25	2.15	28	32	4	30	43.09	0.696	22.9	3.500	1.692
2	11:30	0:30	2.09	28	32	4	30	44.25	0.678	22.9	3.408	1.648
2	11:35	0:35	2.27	28	32	4	30	45.22	0.663	23.1	3.316	1.603
2	11:40	0:40	2.3	28	32	4	30	47.63	0.630	23.2	3.139	1.518
2	11:46	0:46	2.3	28	32	4	30	49.13	0.611	23.2	3.043	1.471
2	11:50	0:50	2.24	28	32	4	30	50.31	0.596	23.2	2.972	1.437
2	11:55	0:55	2.32	28	32	4	30	52.09	0.576	23.2	2.871	1.388
2	12:00	1:00	2.18	28	32	4	30	52.78	0.568	23.1	2.841	1.374

Average Pressure = 30.01923 Average Flow = 0.731 Average Flux = 3.396

RAW Average Slurry Flow = 2.27 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2	11:00	15	23.6	2.15	27		31.5	30	21.81	1.376
2	11:05	16	22.9	2.29	28		32	30	36.32	0.826
2	11:10	16	22.8	2.38	28		32	30	37.75	0.795
2	11:15	16	22.7	2.35	28		32	30	40.31	0.744
2	11:20	18	22.8	2.47	29		33	30	40.38	0.743
2	11:25	18	22.9	2.15	28		32	30	43.09	0.696
2	11:30	17	22.9	2.09	28		32	30	44.25	0.678
2	11:35	18	23.1	2.27	28		32	30	45.22	0.663
2	11:40	18	23.2	2.3	28		32	30	47.63	0.630
2	11:46	18	23.2	2.3	28		32	30	49.13	0.611
2	11:50	18	23.2	2.24	28		32	30	50.31	0.596
2	11:55	18	23.2	2.32	28		32	30	52.09	0.576
2	12:00	17	23.1	2.18	28		32	30	52.78	0.568



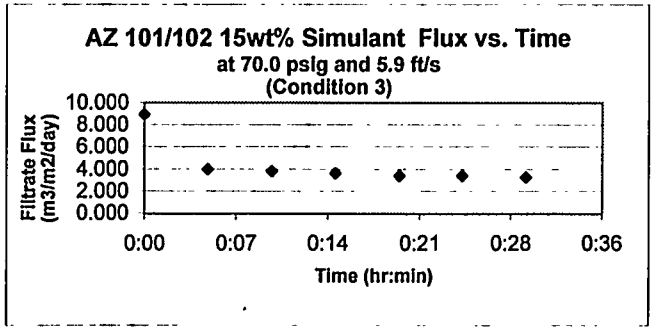


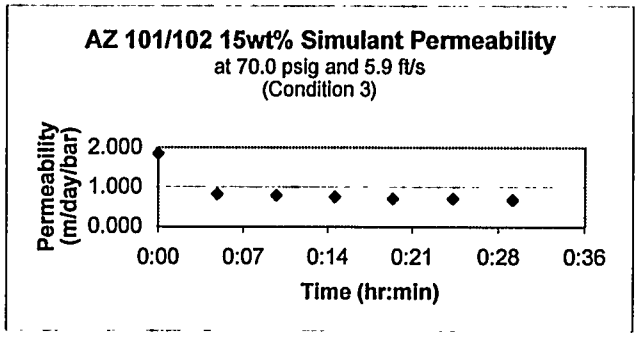
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
3	12:35	0:00	2.05	68	72	4	30	15.32	1.958	26.2	8.968	1.858
3	12:40	0:05	2.07	68	72.5	4.5	30	35.06	0.856	25.8	3.963	0.818
3	12:45	0:10	2.03	68	71.5	3.5	30	37.22	0.806	25.2	3.796	0.789
3	12:50	0:15	2.02	68.5	71.5	3	30	39.47	0.760	24.9	3.610	0.748
3	12:55	0:20	2.05	68.5	71.5	3	30	42.12	0.712	24.7	3.402	0.705
3	13:00	0:25	1.95	68	71.5	3.5	30	42.72	0.702	24.6	3.364	0.699
3	13:05	0:30	2.06	68	72	4	30	43.81	0.685	24.9	3.253	0.674
3	13:10	0:35	2.03	68	72	4	30	46.5	0.645	25.1	3.047	0.631
3	13:15	0:40	2.08	68.5	72	3.5	30	47.22	0.635	25.1	3.001	0.620
3	13:20	0:45	2.07	68	72	4	30	48.84	0.614	25.2	2.893	0.599
3	13:25	0:50	2.06	68	71	3	30	50.87	0.590	25	2.793	0.583
3	13:30	0:55	2.05	68	72	4	30	52.37	0.573	24.9	2.721	0.564
3	13:35	1:00	2	68	72	4	30	53.53	0.560	24.8	2.669	0.553

Average Pressure = 69.96154 Average Flow = 0.777 Average Flux = 3.209

RAW Average Slurry Flow = 2.04 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
3	12:35	17	26.2	2.05	68		72	30	15.32	1.958
3	12:40	13	25.8	2.07	68		72.5	30	35.06	0.856
3	12:45	13	25.2	2.03	68		71.5	30	37.22	0.806
3	12:50	13	24.9	2.02	68.5		71.5	30	39.47	0.760
3	12:55	13	24.7	2.05	68.5		71.5	30	42.12	0.712
3	13:00	13	24.6	1.95	68		71.5	30	42.72	0.702
3	13:05	14	24.9	2.06	68		72	30	43.81	0.685
3	13:10	14	25.1	2.03	68		72	30	46.5	0.645
3	13:15	14	25.1	2.08	68.5		72	30	47.22	0.635
3	13:20	14	25.2	2.07	68		72	30	48.84	0.614
3	13:25	13	25	2.06	68		71	30	50.87	0.590
3	13:30	13	24.9	2.05	68		72	30	52.37	0.573
3	13:35	12	24.8	2	68		72	30	53.53	0.560



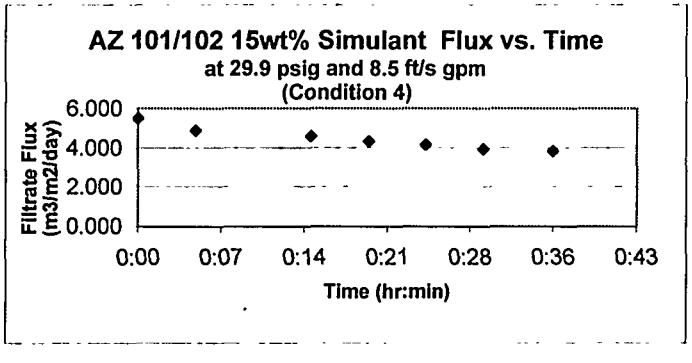


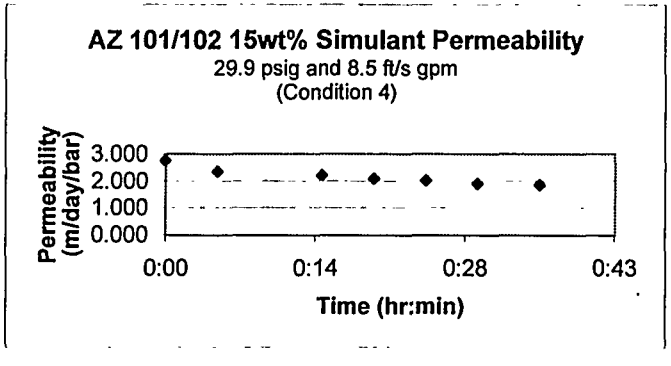
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
4	1:45	0:00	2.87	27	31	4	30	26.44	1.135	24.2	5.497	2.749
4	1:50	0:05	3.04	28	32	4	30	29.75	1.008	24.2	4.885	2.362
4	2:00	0:15	3	28	32	4	30	31.97	0.938	24	4.572	2.210
4	2:05	0:20	3	28	32	4	30	34	0.882	23.9	4.311	2.084
4	2:10	0:25	2.89	28	32	4	30	34.93	0.859	24.3	4.149	2.006
4	2:15	0:30	2.94	28	32	4	30	36.84	0.814	24.3	3.934	1.902
4	2:21	0:36	2.88	28	32	4	30	37.56	0.799	24.5	3.837	1.855
4	2:25	0:40	2.92	28	32.5	4.5	30	38.94	0.770	24.4	3.711	1.779
4	2:30	0:45	2.98	28	32	4	30	40.29	0.745	24.5	3.577	1.729
4	2:35	0:50	2.98	28	32	4	30	41.94	0.715	24.5	3.436	1.661
4	2:40	0:55	2.86	28	32	4	30	42.5	0.706	24	3.439	1.663
4	2:45	1:00	2.87	28	32	4	30	43.88	0.684	24	3.331	1.610

Average Pressure = 29.9375 Average Flow = 0.838 Average Flux = 3.926

RAW Average Slurry Flow = 2.94 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
4	1:45	15	24.2	2.87	27		31	30	26.44	1.135
4	1:50	17	24.2	3.04	28		32	30	29.75	1.008
4	2:00	17	24	3	28		32	30	31.97	0.938
4	2:05	17	23.9	3	28		32	30	34	0.882
4	2:10	18	24.3	2.89	28		32	30	34.93	0.859
4	2:15	18	24.3	2.94	28		32	30	36.84	0.814
4	2:21	19	24.5	2.88	28		32	30	37.56	0.799
4	2:25	18	24.4	2.92	28		32.5	30	38.94	0.770
4	2:30	18	24.5	2.98	28		32	30	40.29	0.745
4	2:35	18	24.5	2.98	28		32	30	41.94	0.715
4	2:40	18	24	2.86	28		32	30	42.5	0.706
4	2:45	16	24	2.87	28		32	30	43.88	0.684



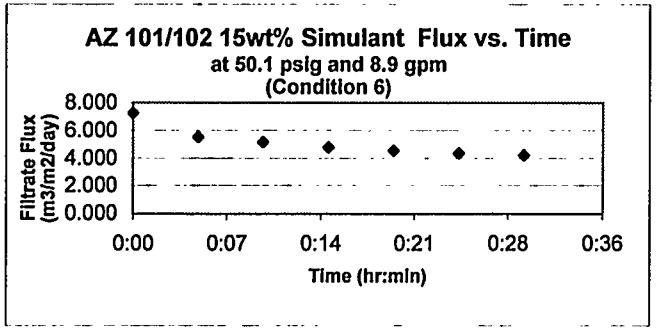


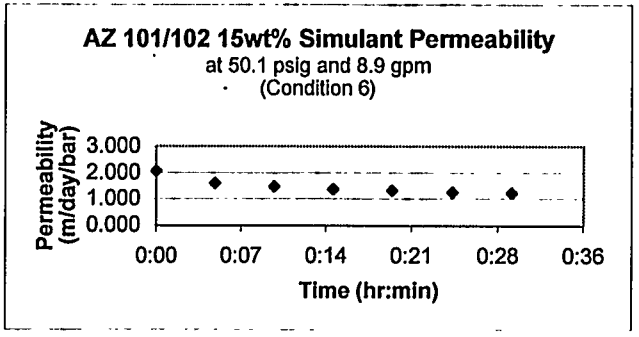
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
6	2:55	0:00	2.95	49	53	4	30	20.65	1.453	23.2	7.241	2.059
6	3:00	0:05	3.09	48	52	4	30	26.68	1.124	23.8	5.510	1.598
6	3:05	0:10	3.11	48	52.5	4.5	30	27.81	1.079	24.9	5.124	1.479
6	3:10	0:15	3.12	48	52	4	30	29.47	1.018	25.3	4.781	1.387
6	3:15	0:20	3.1	48	52	4	30	31	0.968	25.3	4.545	1.318
6	3:20	0:25	3.14	48	52	4	30	32.41	0.926	25.2	4.360	1.265
6	3:25	0:30	3.07	48	52	4	30	33.56	0.894	25.2	4.210	1.221
6	3:30	0:35	3.12	48	52	4	30	35.41	0.847	24.8	4.035	1.171
6	3:35	0:40	3.08	48	52	4	30	36.62	0.819	24.7	3.913	1.135
6	3:40	0:45	3.02	48	52	4	30	37.94	0.791	24.8	3.766	1.093
6	3:45	0:50	3.08	48	52	4	30	38.88	0.772	25.1	3.644	1.057
6	3:50	0:55	3.05	48	52	4	30	39	0.769	25.2	3.623	1.051
6	3:55	1:00	3.04	48	52	4	30	40.59	0.739	25.2	3.481	1.010

Average Pressure = 50.09615 Average Flow = 0.938 Average Flux = 4.249

RAW Average Slurry Flow = 3.07 Filtrate With First Point Removed

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
6	2:55	12	23.2	2.95	49		53	30	20.65	1.453
6	3:00	14	23.8	3.09	48		52	30	26.68	1.124
6	3:05	17	24.9	3.11	48		52.5	30	27.81	1.079
6	3:10	15	25.3	3.12	48		52	30	29.47	1.018
6	3:15	14	25.3	3.1	48		52	30	31	0.968
6	3:20	14	25.2	3.14	48		52	30	32.41	0.926
6	3:25	14	25.2	3.07	48		52	30	33.56	0.894
6	3:30	13	24.8	3.12	48		52	30	35.41	0.847
6	3:35	13	24.7	3.08	48		52	30	36.62	0.819
6	3:40	15	24.8	3.02	48		52	30	37.94	0.791
6	3:45	15	25.1	3.08	48		52	30	38.88	0.772
6	3:50	15	25.2	3.05	48		52	30	39	0.769
6	3:55	14	25.2	3.04	48		52	30	40.59	0.739

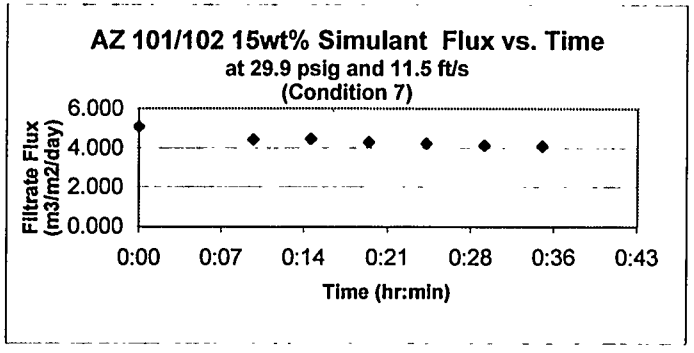


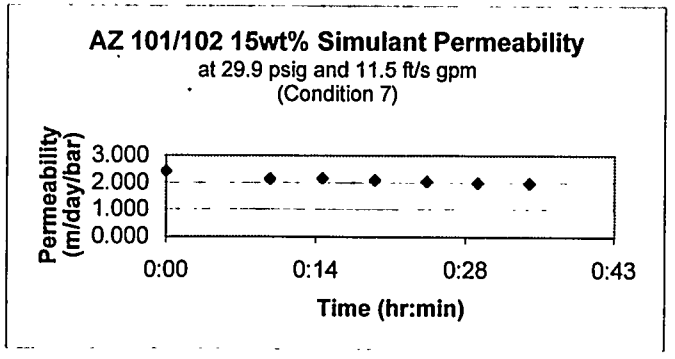


Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)
7	4:05	0:00	4	27.5	33	5.5	30	26.75	1.121	26.6	5.079	2.435
7	4:15	0:10	3.93	27	33	6	30	31.36	0.957	25.8	4.430	2.142
7	4:20	0:15	3.93	27	33	6	30	31.53	0.951	25.4	4.456	2.154
7	4:25	0:20	3.99	27	32.5	5.5	30	33.16	0.905	25.1	4.273	2.083
7	4:30	0:25	3.99	27	33	6	30	33.63	0.892	25	4.225	2.043
7	4:35	0:30	3.99	27	33	6	30	33.97	0.883	25.5	4.125	1.994
7	4:40	0:35	3.99	27	33	6	30	34.63	0.866	25.2	4.080	1.973
7	4:45	0:40	4.01	27	33	6	30	34.97	0.858	25	4.063	1.964
7	4:50	0:45	3.97	27	33	6	30	35.41	0.847	24.9	4.024	1.946
7	4:55	0:50	3.98	27	33	6	30	36.06	0.832	24.9	3.952	1.910
7	5:00	0:55	3.95	27	32	5	30	36.37	0.825	24.9	3.918	1.926
7	5:05	1:00	3.93	27	32.5	5.5	30	35.88	0.836	24.8	3.983	1.942

RAW Average Slurry Flow = 3.97 Average Pressure = 29.9375 Average Flow = Filtrate 0.898 Average Flux = With First Point Removed 4.139

Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
7	4:05	19	26.6	4	27.5		33	30	26.75	1.121
7	4:15	15	25.8	3.93	27		33	30	31.36	0.957
7	4:20	15	25.4	3.93	27		33	30	31.53	0.951
7	4:25	15	25.1	3.99	27		32.5	30	33.16	0.905
7	4:30	15	25	3.99	27		33	30	33.63	0.892
7	4:35	16	25.5	3.99	27		33	30	33.97	0.883
7	4:40	16	25.2	3.99	27		33	30	34.63	0.866
7	4:45	16	25	4.01	27		33	30	34.97	0.858
7	4:50	15	24.9	3.97	27		33	30	35.41	0.847
7	4:55	15	24.9	3.98	27		33	30	36.06	0.832
7	5:00	15	24.9	3.95	27		32	30	36.37	0.825
7	5:05	15	24.8	3.93	27		32.5	30	35.88	0.836

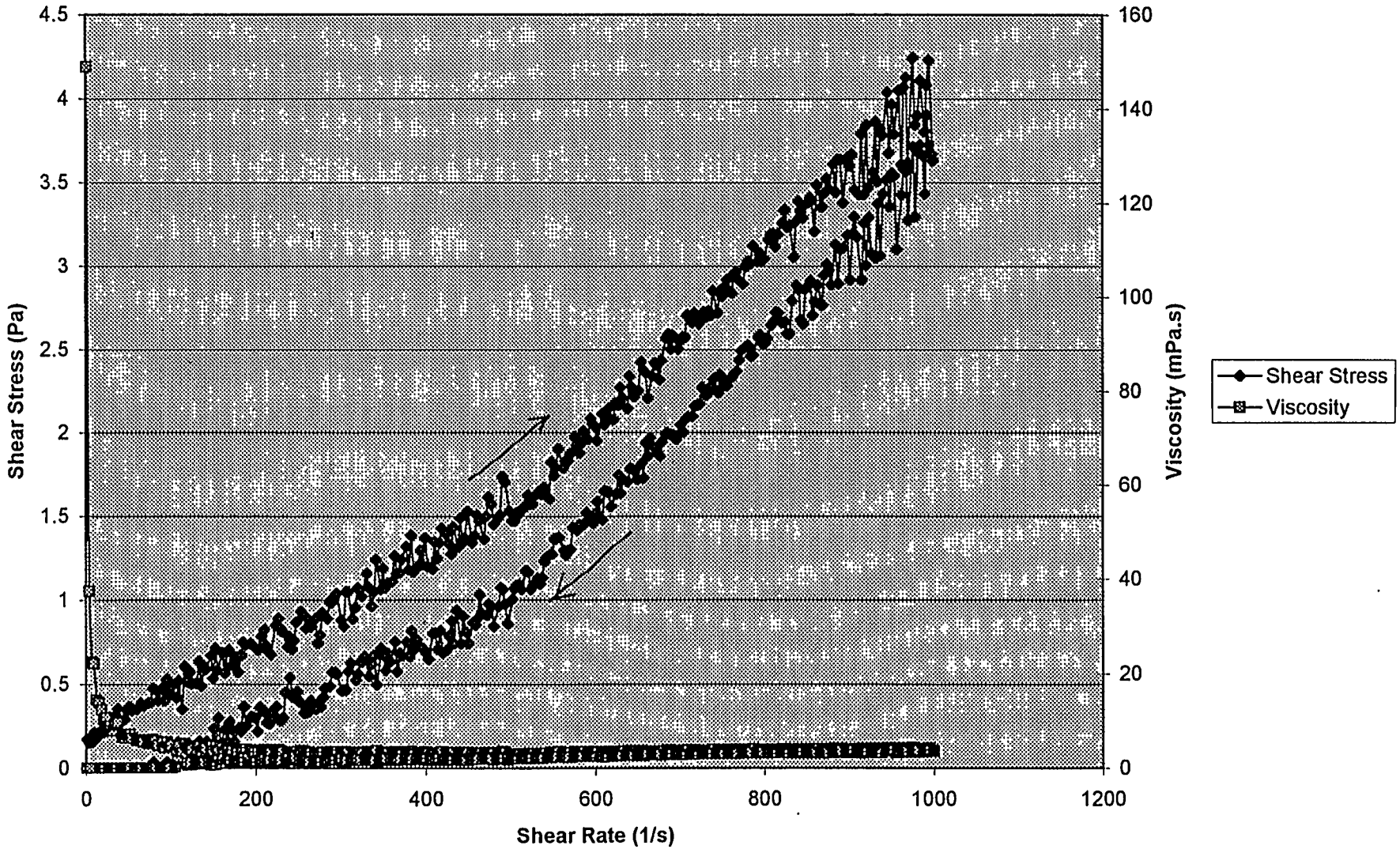




Appendix D: Rheological Properties Raw Data

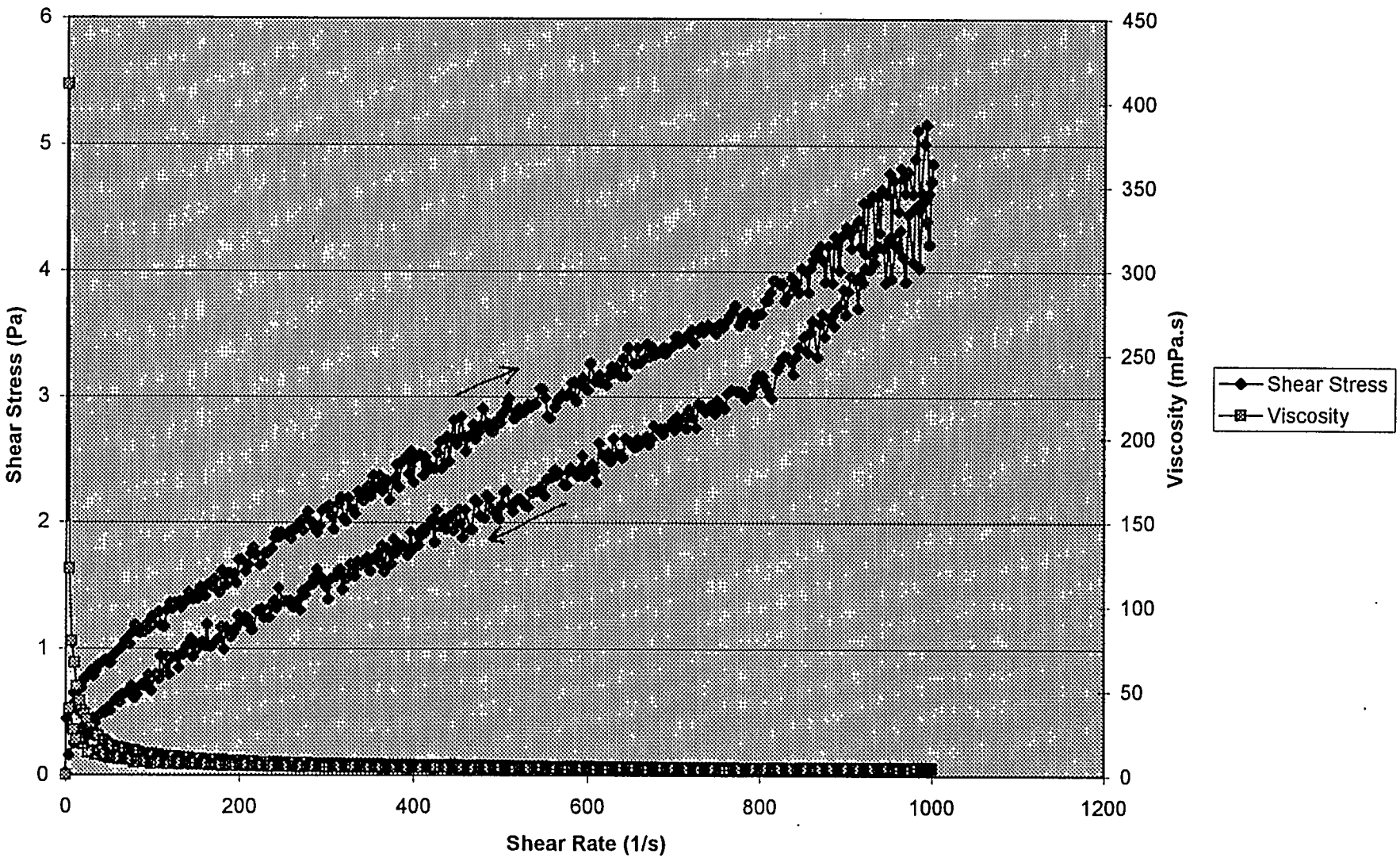
C106 Simulant at 20 wt%

R1201000



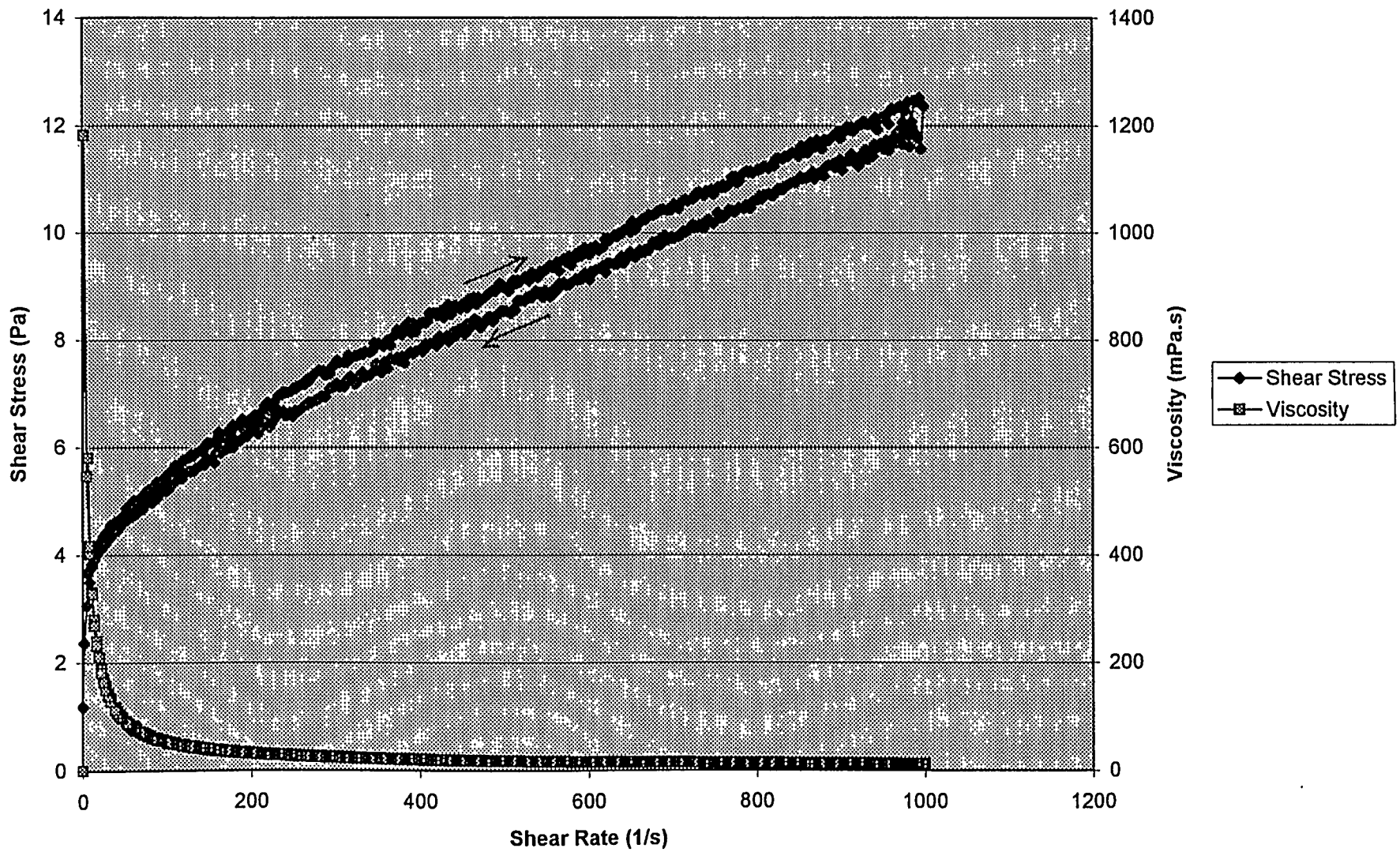
C106 Simulant at 30 wt%

R1301000

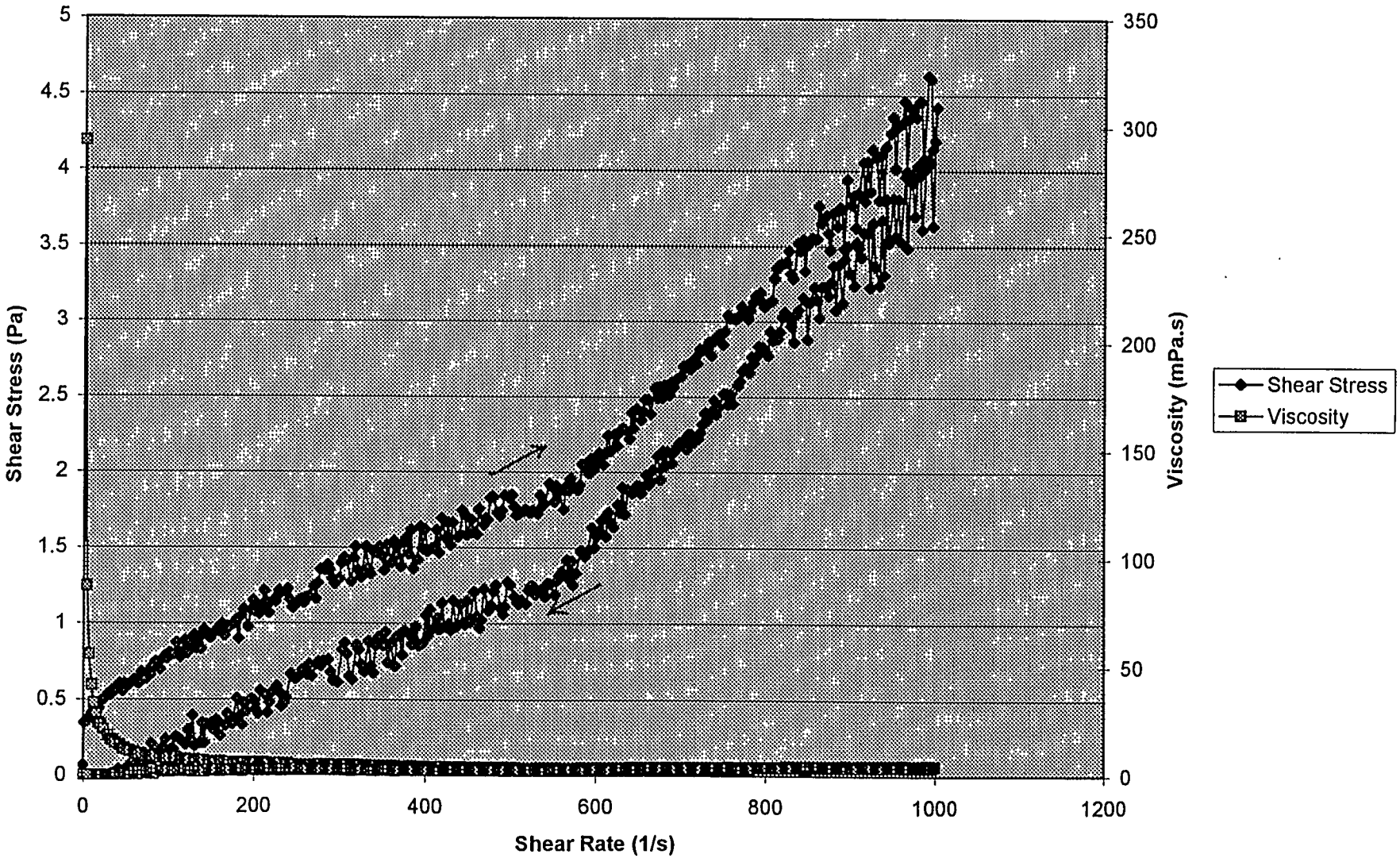


C106 Simulant at 40 wt%

R1401000

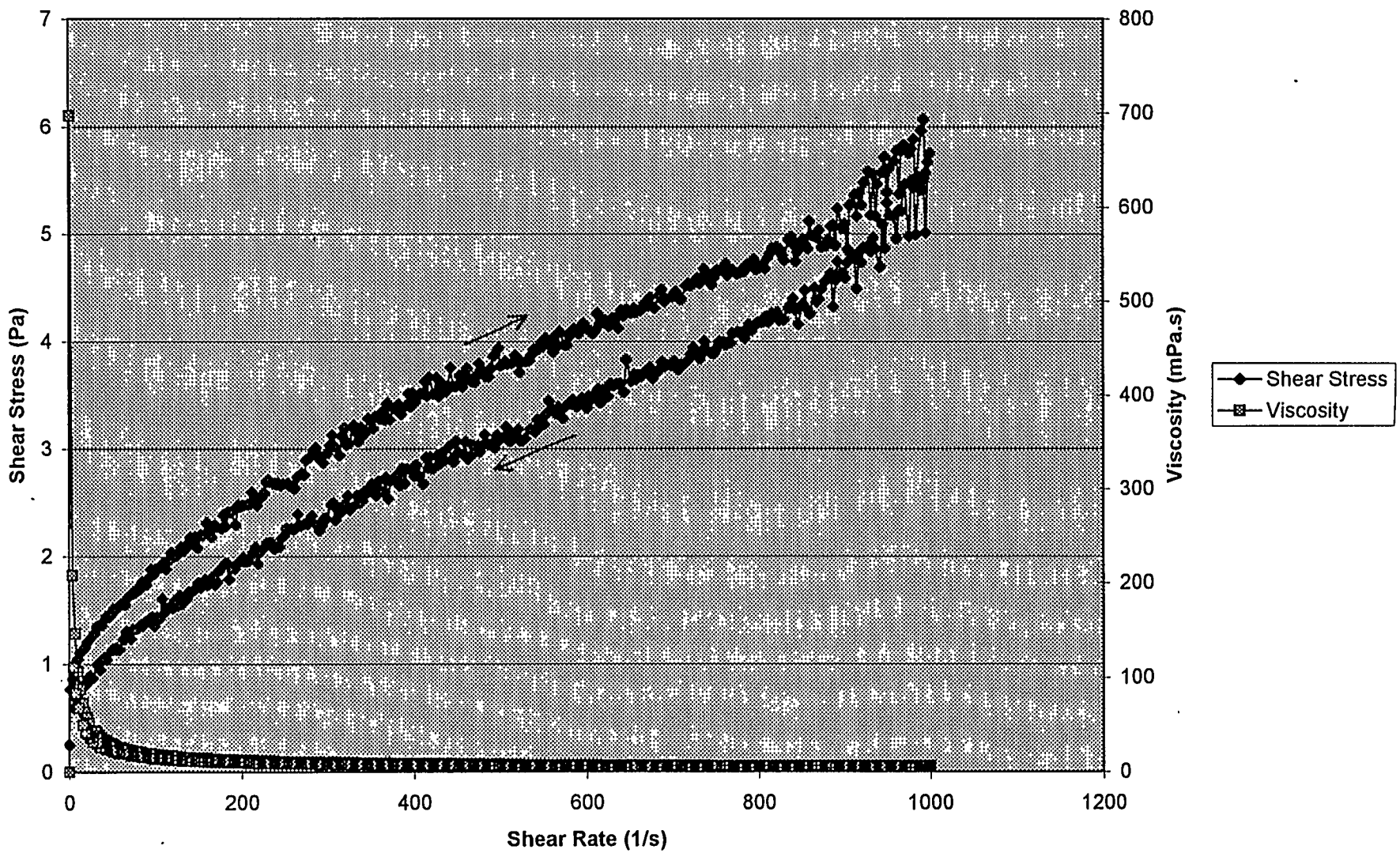


AZ101/102 Simulant at 20 wt% A1201000



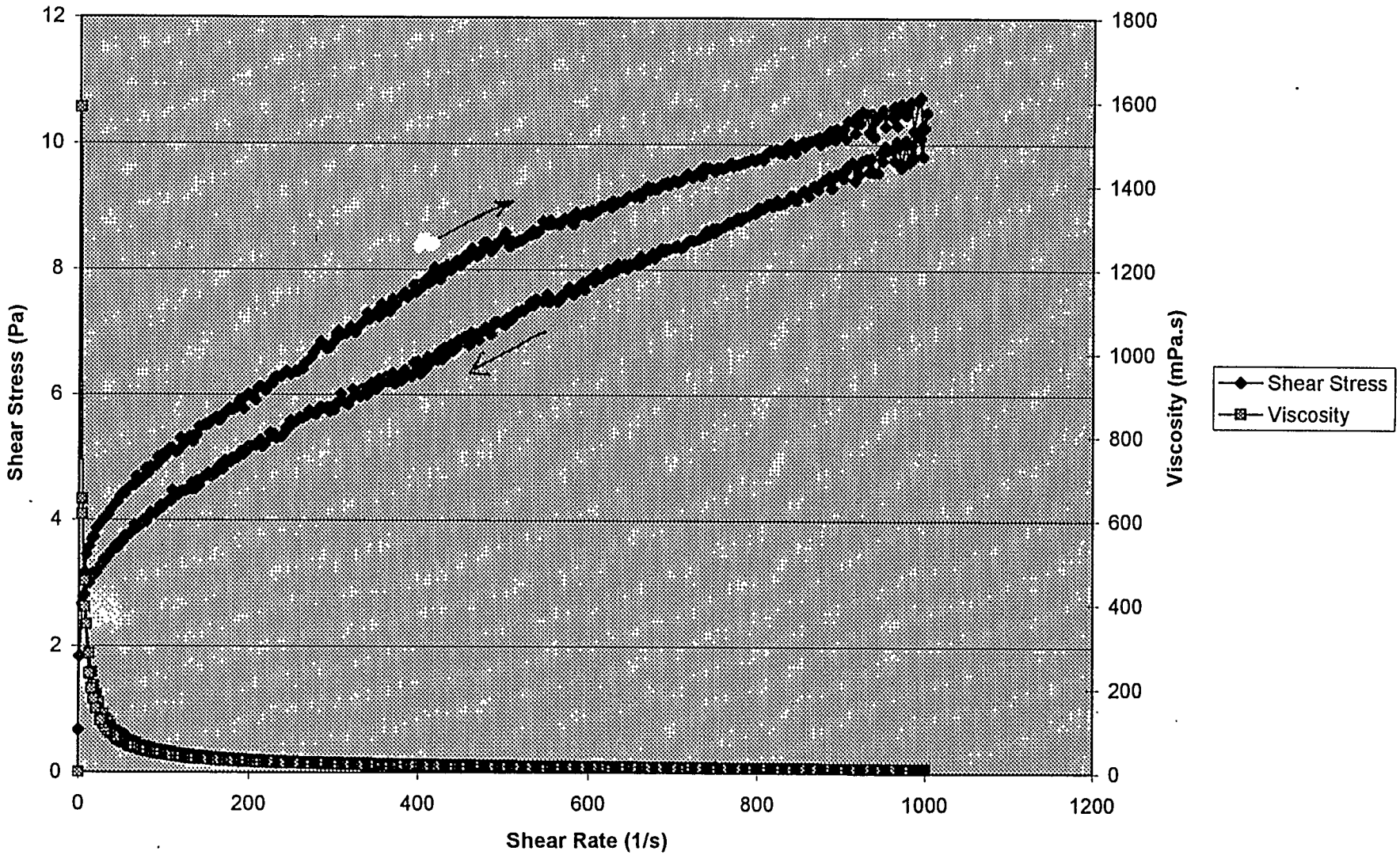
AZ101/102 Simulant at 30 wt%

A1301000



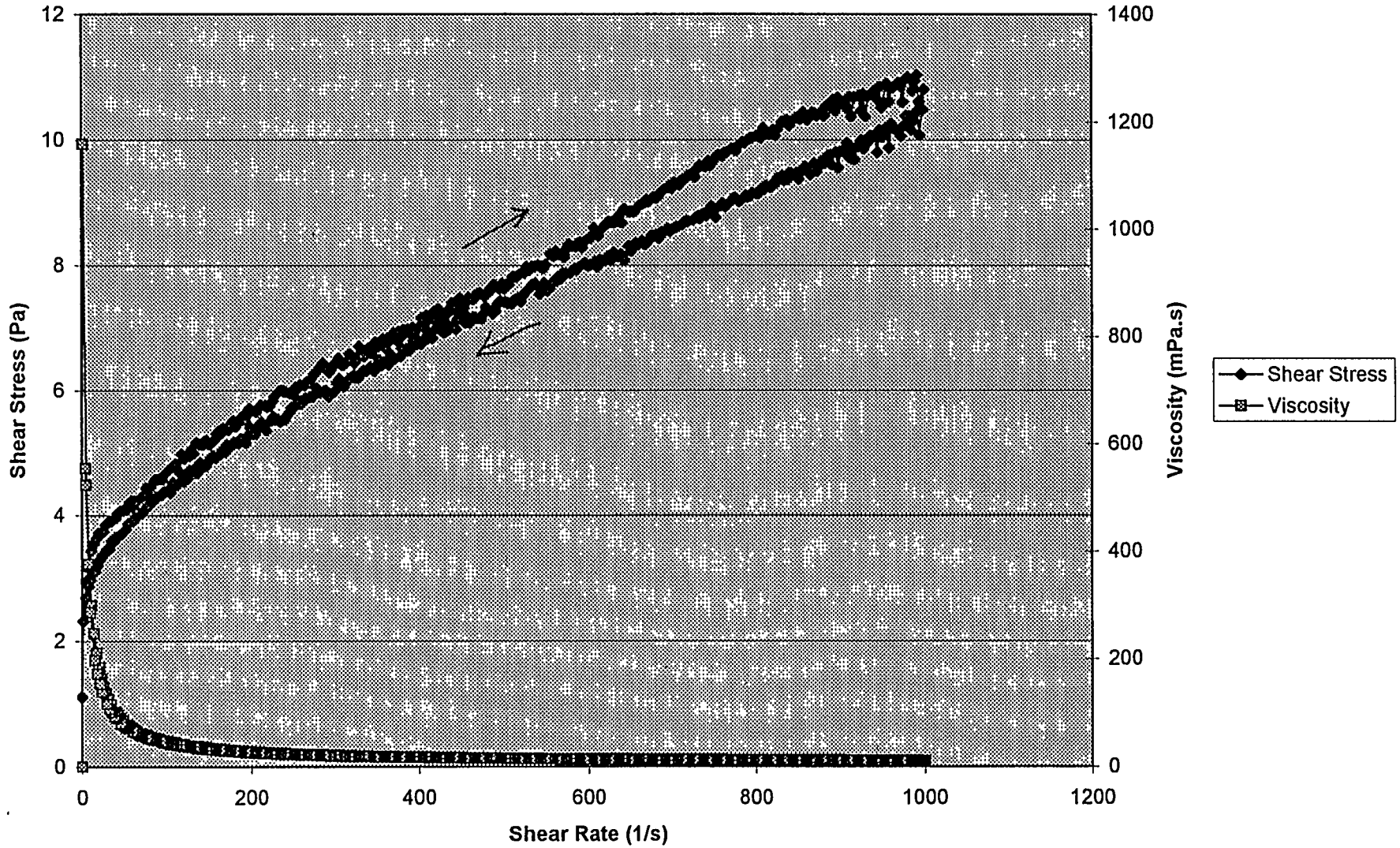
AZ101/102 Simulant at 40 wt%

A1401000



AZ101/102 Simulant @ 40 wt%

A2401000



Appendix E: Particle Size Distribution Raw Data

Particle Size Distribution Plots
For NIST Traceable Standards from Duke Scientific Corporation

Particle Size Analysis

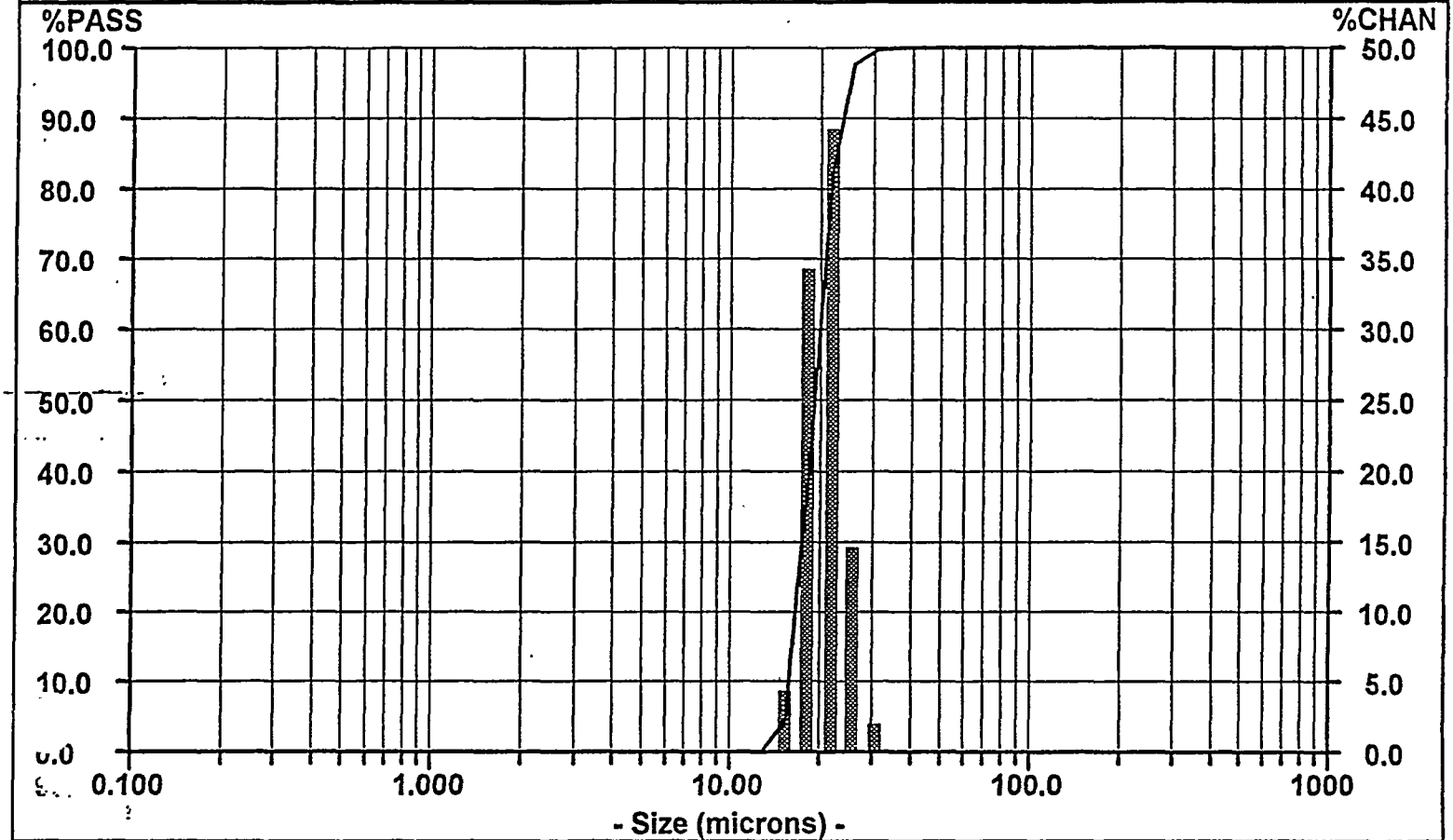
Duke Standard 20um
1 mM KCl

Date: ~~02/04/0~~ Meas #: N/A
Time: 13:56 Pres #: N/A

Duke Standard- 20.00 um, lot# 19411
in 1 mM KCl solution

Number Distribution
.1-100

Summary	Percentiles		Dia	Vol%	Width
mv = 20.98	10% = 16.20	60% = 19.99	19.29	100%	5.403
mn = 19.65	20% = 17.09	70% = 20.77			
ma = 20.50	30% = 17.87	80% = 21.70			
cs = 0.293	40% = 18.59	90% = 23.20			
sd = 2.702	50% = 19.29	95% = 24.70			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	0.00	0.00						
592.0	100.00	0.00	7.778	0.00	0.00						
497.8	100.00	0.00	6.541	0.00	0.00						
418.6	100.00	0.00	5.500	0.00	0.00						
352.0	100.00	0.00	4.625	0.00	0.00						
296.0	100.00	0.00	3.889	0.00	0.00						
248.9	100.00	0.00	3.270	0.00	0.00						
209.3	100.00	0.00	2.750	0.00	0.00						
176.0	100.00	0.00	2.312	0.00	0.00						
148.0	100.00	0.00	1.945	0.00	0.00						
124.5	100.00	0.00	1.635	0.00	0.00						
104.7	100.00	0.00	1.375	0.00	0.00						
88.00	100.00	0.00	1.156	0.00	0.00						
74.00	100.00	0.00	0.972	0.00	0.00						
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	0.19	0.486	0.00	0.00						
31.11	99.81	2.08	0.409	0.00	0.00						
26.16	97.73	14.68	0.344	0.00	0.00						
22.00	83.05	44.36	0.289	0.00	0.00						
18.50	38.69	34.24	0.243	0.00	0.00						
[illegible]	4.45	4.45	0.204	0.00	0.00						
[illegible]	0.00	0.00	0.172	0.00	0.00						
[illegible]	0.00	0.00	0.145	0.00	0.00						

Particle Size Analysis

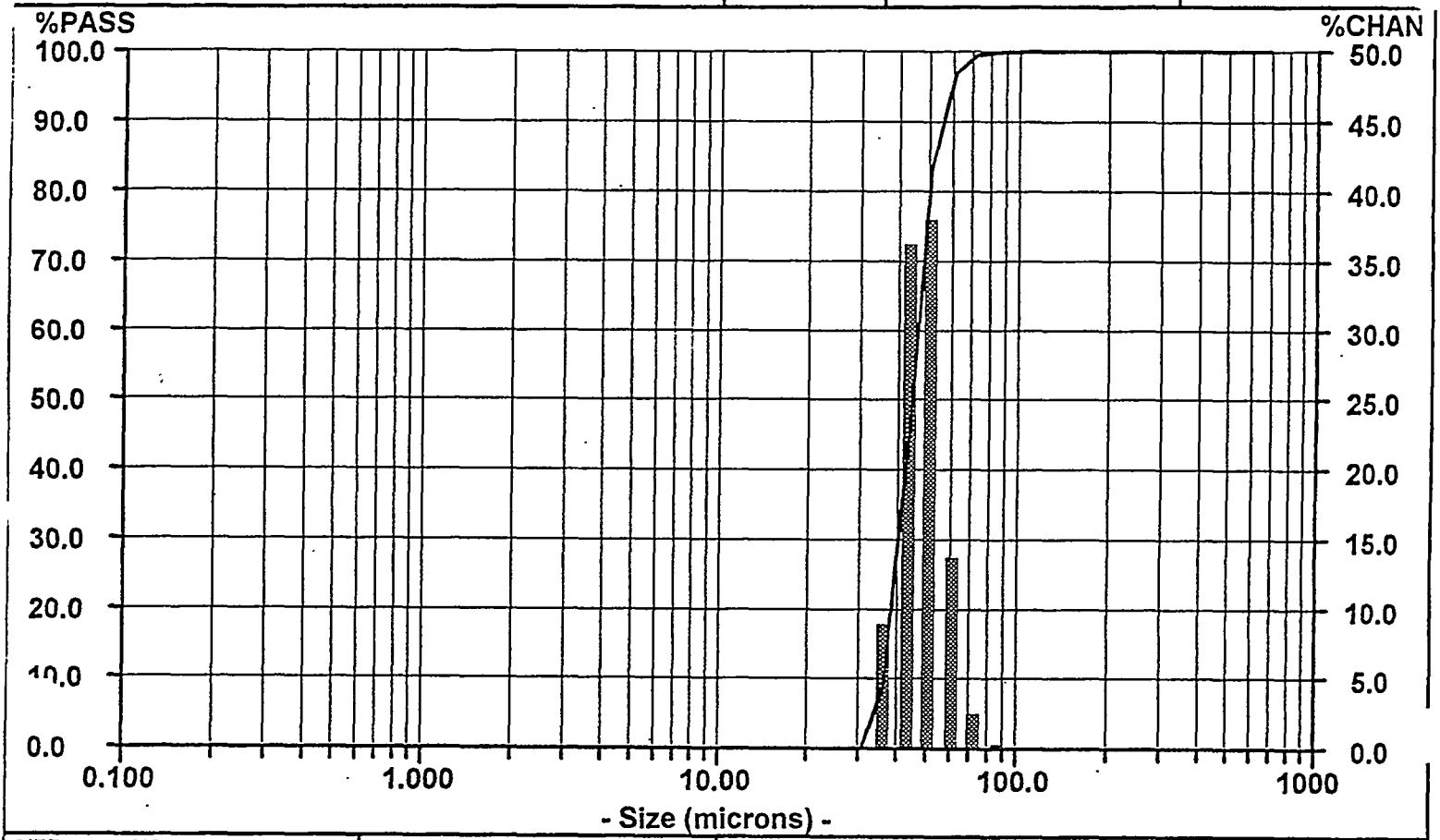
Duke Standard
1 mM KCl

Date: ~~02/04/0~~ Meas #: N/A
Time: 13:34 Pres #: N/A

Duke Standard- 50.4 um, lot# 19213
in 1 mM KCl solution

Number Distribution
X-100

Summary	Percentiles		Dia	Vol%	Width
mv = 50.24	10% = 37.25	60% = 46.78	44.88	100%	13.99
mn = 46.05	20% = 39.43	70% = 48.87			
ma = 48.69	30% = 41.29	80% = 51.40			
cs = 0.123	40% = 43.07	90% = 55.49			
sd = 6.993	50% = 44.88	95% = 59.46			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	0.00	0.00						
592.0	100.00	0.00	7.778	0.00	0.00						
497.8	100.00	0.00	6.541	0.00	0.00						
418.6	100.00	0.00	5.500	0.00	0.00						
352.0	100.00	0.00	4.625	0.00	0.00						
296.0	100.00	0.00	3.889	0.00	0.00						
248.9	100.00	0.00	3.270	0.00	0.00						
209.3	100.00	0.00	2.750	0.00	0.00						
176.0	100.00	0.00	2.312	0.00	0.00						
148.0	100.00	0.00	1.945	0.00	0.00						
124.5	100.00	0.00	1.635	0.00	0.00						
104.7	100.00	0.05	1.375	0.00	0.00						
88.00	99.95	0.36	1.156	0.00	0.00						
74.00	99.59	2.57	0.972	0.00	0.00						
62.23	97.02	13.73	0.818	0.00	0.00						
52.33	83.29	38.06	0.688	0.00	0.00						
44.00	45.23	36.31	0.578	0.00	0.00						
37.00	8.92	8.92	0.486	0.00	0.00						
31.11	0.00	0.00	0.409	0.00	0.00						
26.16	0.00	0.00	0.344	0.00	0.00						
22.00	0.00	0.00	0.289	0.00	0.00						
18.50	0.00	0.00	0.243	0.00	0.00						
[illegible]	0.00	0.00	0.204	0.00	0.00						
[illegible]	0.00	0.00	0.172	0.00	0.00						
11.00	0.00	0.00	0.145	0.00	0.00						

Particle Size Analysis

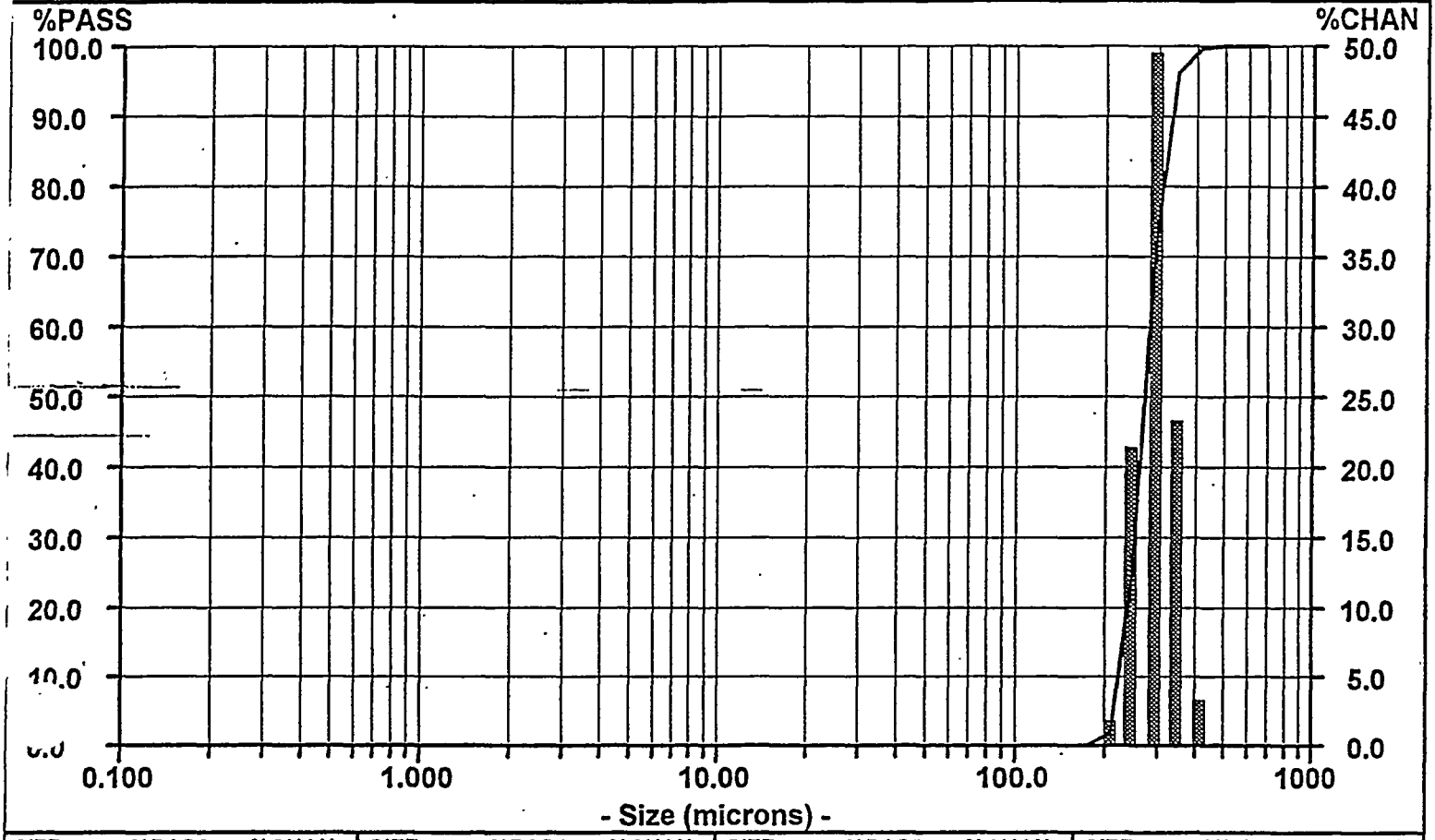
Duke Standard 301um
1 mM KCl

Date: ~~02/04/0~~ Meas #: N/A
Time: 14:40 Pres #: N/A

Duke Standard- 301 um, lot# 19136
in 1 mM KCl solution

Number Distribution
-100

Summary	Percentiles		Dia	Vol%	Width
mv = 294.9	10% = 229.7	60% = 282.3	273.2	100%	74.89
mn = 278.1	20% = 244.6	70% = 292.8			
ma = 289.0	30% = 255.3	80% = 306.8			
cs = 0.021	40% = 264.4	90% = 328.5			
sd = 37.45	50% = 273.2	95% = 346.0			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	0.00	0.00						
592.0	100.00	0.00	7.778	0.00	0.00						
497.8	100.00	0.23	6.541	0.00	0.00						
418.6	99.77	3.37	5.500	0.00	0.00						
352.0	96.40	23.42	4.625	0.00	0.00						
296.0	72.98	49.68	3.889	0.00	0.00						
248.9	23.30	21.48	3.270	0.00	0.00						
209.3	1.82	1.82	2.750	0.00	0.00						
176.0	0.00	0.00	2.312	0.00	0.00						
148.0	0.00	0.00	1.945	0.00	0.00						
124.5	0.00	0.00	1.635	0.00	0.00						
104.7	0.00	0.00	1.375	0.00	0.00						
88.00	0.00	0.00	1.156	0.00	0.00						
74.00	0.00	0.00	0.972	0.00	0.00						
62.23	0.00	0.00	0.818	0.00	0.00						
52.33	0.00	0.00	0.688	0.00	0.00						
44.00	0.00	0.00	0.578	0.00	0.00						
37.00	0.00	0.00	0.486	0.00	0.00						
31.11	0.00	0.00	0.409	0.00	0.00						
26.16	0.00	0.00	0.344	0.00	0.00						
22.00	0.00	0.00	0.289	0.00	0.00						
18.50	0.00	0.00	0.243	0.00	0.00						
[illegible]	0.00	0.00	0.204	0.00	0.00						
	0.00	0.00	0.172	0.00	0.00						
1.000	0.00	0.00	0.145	0.00	0.00						

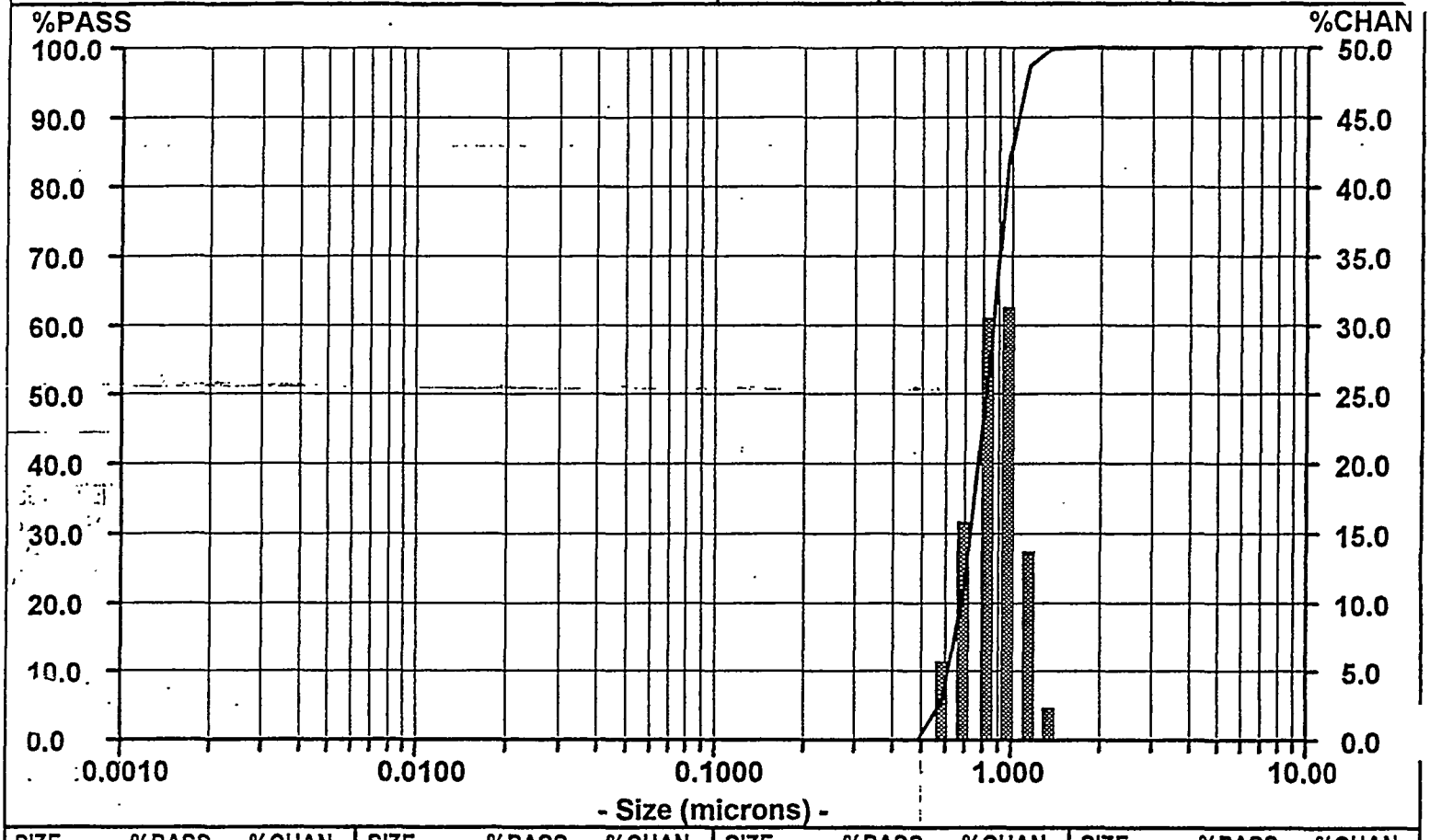
Particle Size Analysis

895 nm Duke Standard
log # 15924

Date: ~~02/09/89~~ Meas #: 00029
Time: 14:17 Pres #: 01

895 nm Duke Standard
log #15924
UPA
30 seconds
nber Distribution

Summary	Percentiles		Dia	Vol%	Width
mv = .9179	10% = .6152	60% = .8497	.8080	100%	.3183
mn = .8229	20% = .6785	70% = .8949			
ma = .8860	30% = .7252	80% = .9491			
cs = 6.772	40% = .7670	90% = 1.030			
sd = .1592	50% = .8080	95% = 1.100			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.00	0.0859	0.00	0.00						
5.500	100.00	0.00	0.0723	0.00	0.00						
4.625	100.00	0.00	0.0608	0.00	0.00						
3.889	100.00	0.00	0.0511	0.00	0.00						
3.270	100.00	0.00	0.0430	0.00	0.00						
2.750	100.00	0.00	0.0361	0.00	0.00						
2.313	100.00	0.00	0.0304	0.00	0.00						
1.945	100.00	0.00	0.0255	0.00	0.00						
1.635	100.00	0.17	0.0215	0.00	0.00						
1.375	99.83	2.38	0.0181	0.00	0.00						
1.156	97.45	13.73	0.0152	0.00	0.00						
0.9723	83.72	31.36	0.0128	0.00	0.00						
0.8176	52.36	30.70	0.0107	0.00	0.00						
0.6875	21.66	15.94	0.0090	0.00	0.00						
0.5781	5.72	5.72	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									
5	0.00	0.00									
0.1022	0.00	0.00									

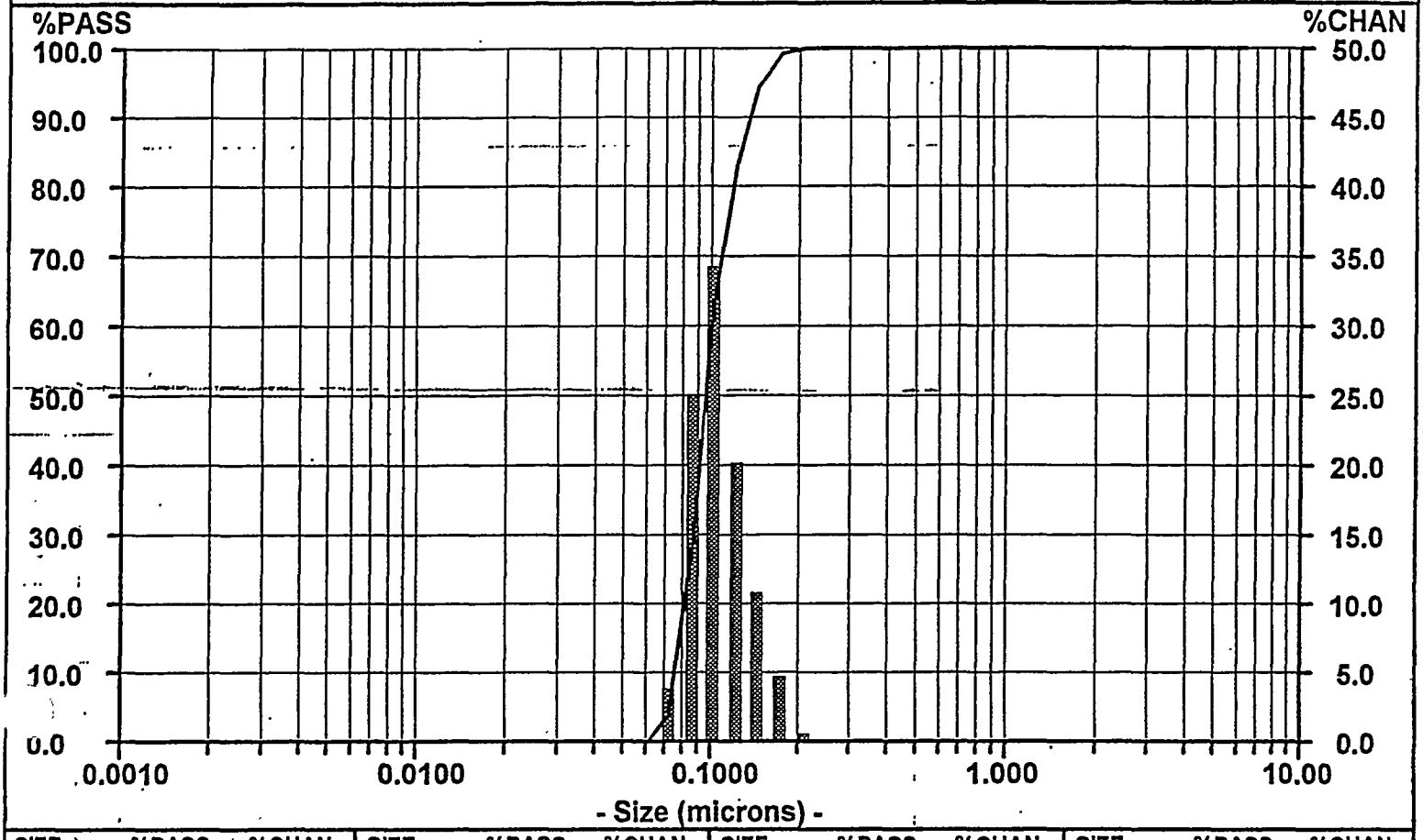
Particle Size Analysis

96 nm Duke Standard
log # 16339

Date: ~~02/09/89~~ Meas #: 00028
Time: 14:06 Pres #: 01

96 nm Duke Standard
log #16339
UPA
30 seconds
ume Distribution

Summary	Percentiles		Dia	Vol%	Width
mv = .1003	10% = .0765	60% = .1004	.0953	100%	.0423
mn = .0894	20% = .0818	70% = .1069			
ma = .0960	30% = .0863	80% = .1168			
cs = 62.47	40% = .0907	90% = .1326			
sd = .0212	50% = .0953	95% = .1466			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
6.541	100.00	0.00	0.0859	29.00	25.14						
5.500	100.00	0.00	0.0723	3.86	3.86						
4.625	100.00	0.00	0.0608	0.00	0.00						
3.889	100.00	0.00	0.0511	0.00	0.00						
3.270	100.00	0.00	0.0430	0.00	0.00						
2.750	100.00	0.00	0.0361	0.00	0.00						
2.313	100.00	0.00	0.0304	0.00	0.00						
1.945	100.00	0.00	0.0255	0.00	0.00						
1.635	100.00	0.00	0.0215	0.00	0.00						
1.375	100.00	0.00	0.0181	0.00	0.00						
1.156	100.00	0.00	0.0152	0.00	0.00						
0.9723	100.00	0.00	0.0128	0.00	0.00						
0.8176	100.00	0.00	0.0107	0.00	0.00						
0.6875	100.00	0.00	0.0090	0.00	0.00						
0.5781	100.00	0.00	0.0076	0.00	0.00						
0.4861	100.00	0.00	0.0064	0.00	0.00						
0.4088	100.00	0.00	0.0054	0.00	0.00						
0.3437	100.00	0.00	0.0045	0.00	0.00						
0.2891	100.00	0.00	0.0038	0.00	0.00						
0.2431	100.00	0.00									
0.2044	100.00	0.67									
0.1719	99.33	4.89									
[illegible]445	94.44	10.82									
[illegible]15	83.62	20.29									
0.1022	63.33	34.33									

AZ101/102 Filtration Simulant

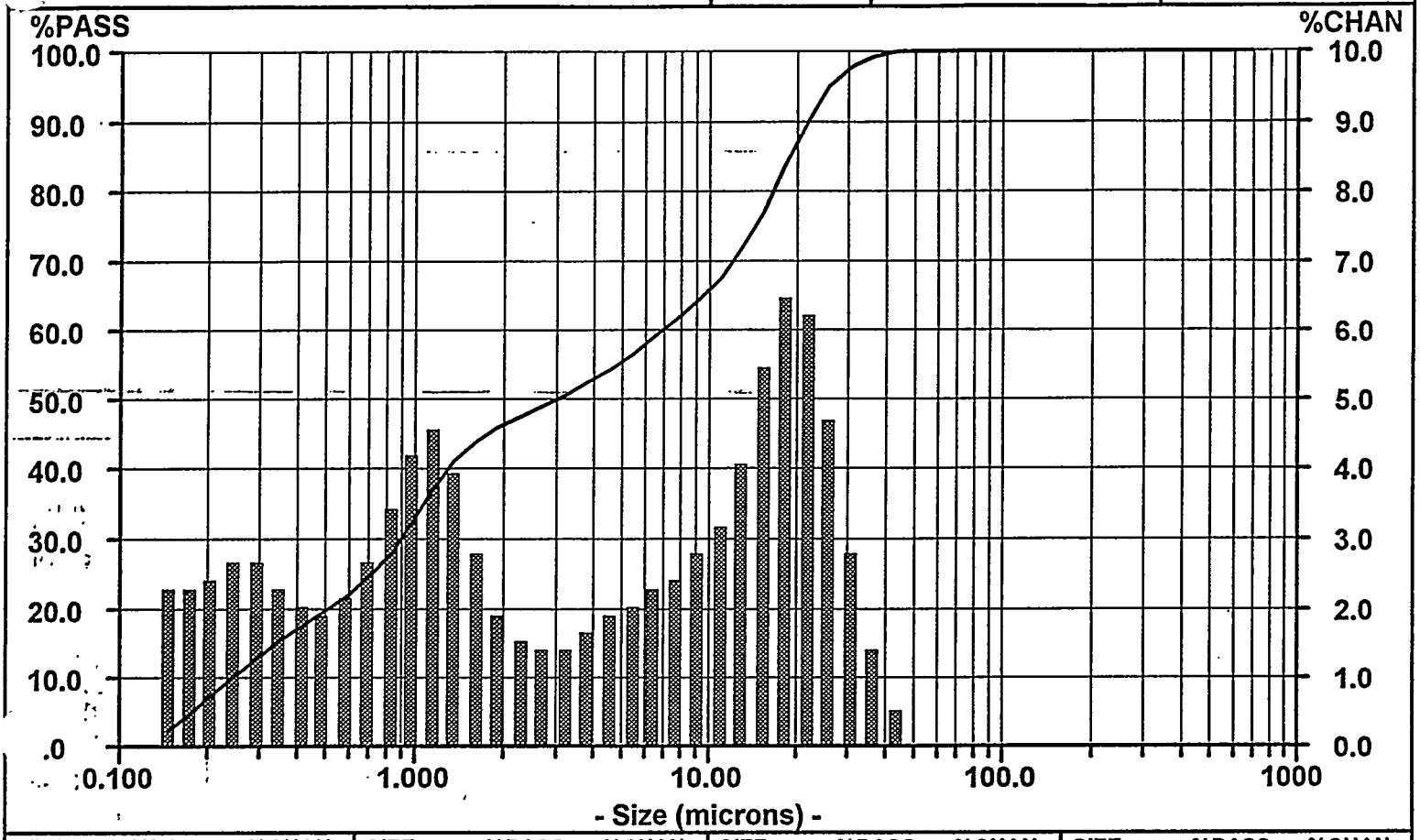
Particle Size Analysis

AZ101/102 Simulant
Sample S2-1/20

Date: 02/07/89 Meas #: 00037
Time: 15:13 Pres #: 01

AZ101/102 Simulant; Sample S2-1/20
in 1.0 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.962	10% = 0.240	60% = 6.986	13.96	52%	17.64
mn = 0.185	20% = 0.502	70% = 12.16	0.978	30%	0.914
ma = 0.808	30% = 0.886	80% = 16.68	0.240	16%	0.165
cs = 7.423	40% = 1.304	90% = 21.77	0.136	2%	0.012
sd = 9.068	50% = 3.011	95% = 26.02			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	64.45	2.82						
592.0	100.00	0.00	7.778	61.63	2.59						
497.8	100.00	0.00	6.541	59.04	2.40						
418.6	100.00	0.00	5.500	56.64	2.18						
352.0	100.00	0.00	4.625	54.46	1.95						
296.0	100.00	0.00	3.889	52.51	1.74						
248.9	100.00	0.00	3.270	50.77	1.58						
209.3	100.00	0.00	2.750	49.19	1.51						
176.0	100.00	0.00	2.312	47.68	1.62						
148.0	100.00	0.00	1.945	46.06	2.04						
124.5	100.00	0.00	1.635	44.02	2.89						
104.7	100.00	0.00	1.375	41.13	4.00						
88.00	100.00	0.00	1.156	37.13	4.68						
74.00	100.00	0.00	0.972	32.45	4.38						
62.23	100.00	0.00	0.818	28.07	3.51						
52.33	100.00	0.00	0.688	24.56	2.71						
44.00	100.00	0.64	0.578	21.85	2.24						
37.00	99.36	1.42	0.486	19.61	2.06						
31.11	97.94	2.81	0.409	17.55	2.14						
26.16	95.13	4.76	0.344	15.41	2.45						
22.00	90.37	6.36	0.289	12.96	2.77						
18.50	84.01	6.58	0.243	10.19	2.76						
15.56	77.43	5.51	0.204	7.43	2.54						
[illegible]08	71.92	4.19	0.172	4.89	2.43						
[illegible]00	67.73	3.28	0.145	2.46	2.46						

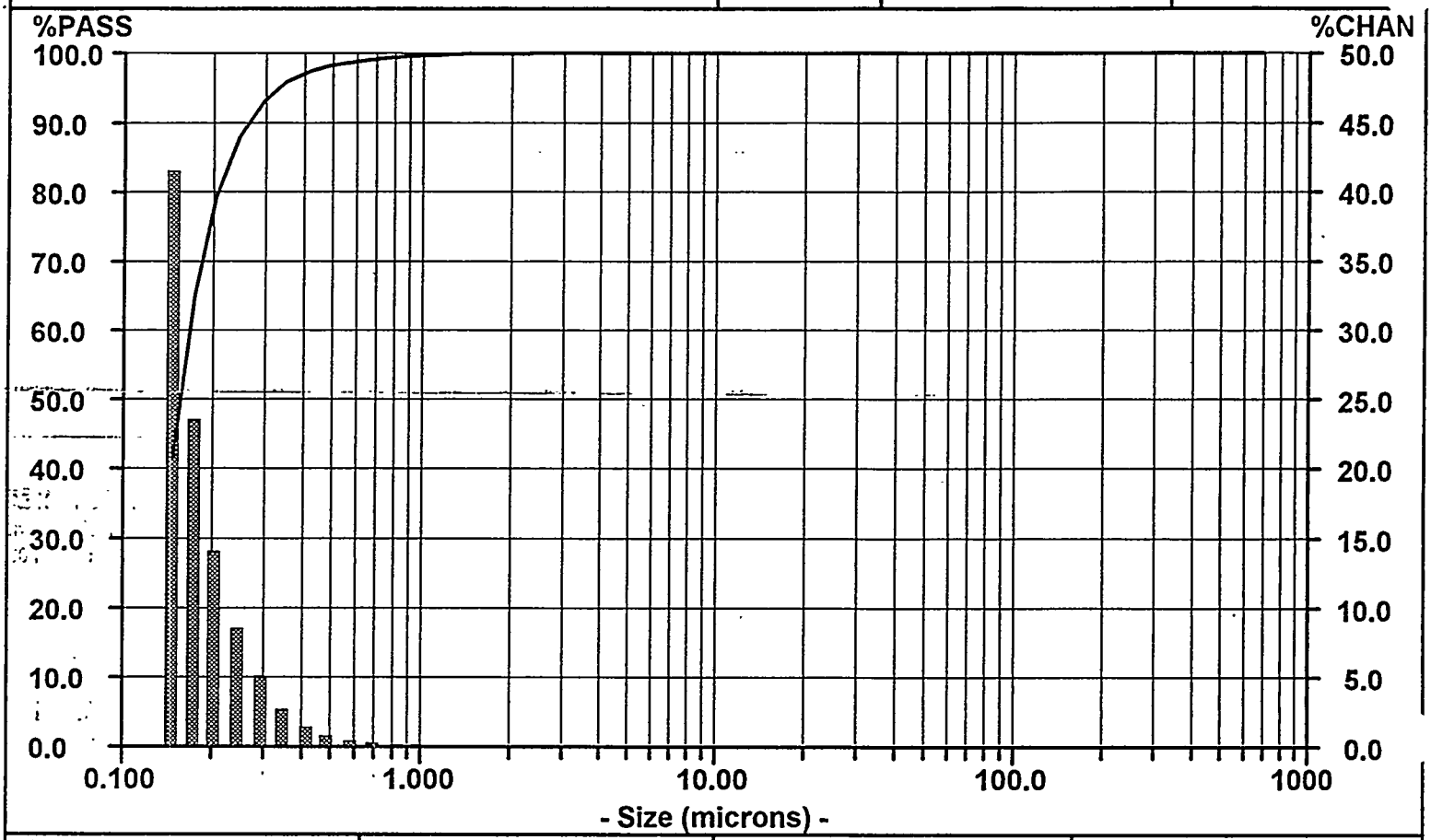
Particle Size Analysis

AZ101/102SimulantDUP
Sample S1-1/24

Date: 02/08/89 Meas #: 00008
Time: 09:31 Pres #: 01

AZ101/102 Simulant; Sample S1-1/24
in 0.8 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 9.777	10% = 0.128	60% = 0.164	0.152	100%	0.091
mn = 0.182	20% = 0.133	70% = 0.180			
ma = 0.877	30% = 0.137	80% = 0.206			
cs = 6.838	40% = 0.144	90% = 0.257			
sd = 0.046	50% = 0.152	95% = 0.320			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.01						
124.5	100.00	0.00	1.635	99.98	0.03						
104.7	100.00	0.00	1.375	99.95	0.06						
88.00	100.00	0.00	1.156	99.89	0.12						
74.00	100.00	0.00	0.972	99.77	0.20						
62.23	100.00	0.00	0.818	99.57	0.29						
52.33	100.00	0.00	0.688	99.28	0.39						
44.00	100.00	0.00	0.578	98.89	0.56						
37.00	100.00	0.00	0.486	98.33	0.88						
31.11	100.00	0.00	0.409	97.45	1.49						
26.16	100.00	0.00	0.344	95.96	2.78						
22.00	100.00	0.00	0.289	93.18	5.15						
18.50	100.00	0.00	0.243	88.03	8.68						
15.56	100.00	0.00	0.204	79.35	14.12						
13.08	100.00	0.00	0.172	65.23	23.61						
11.00	100.00	0.00	0.145	41.62	41.62						

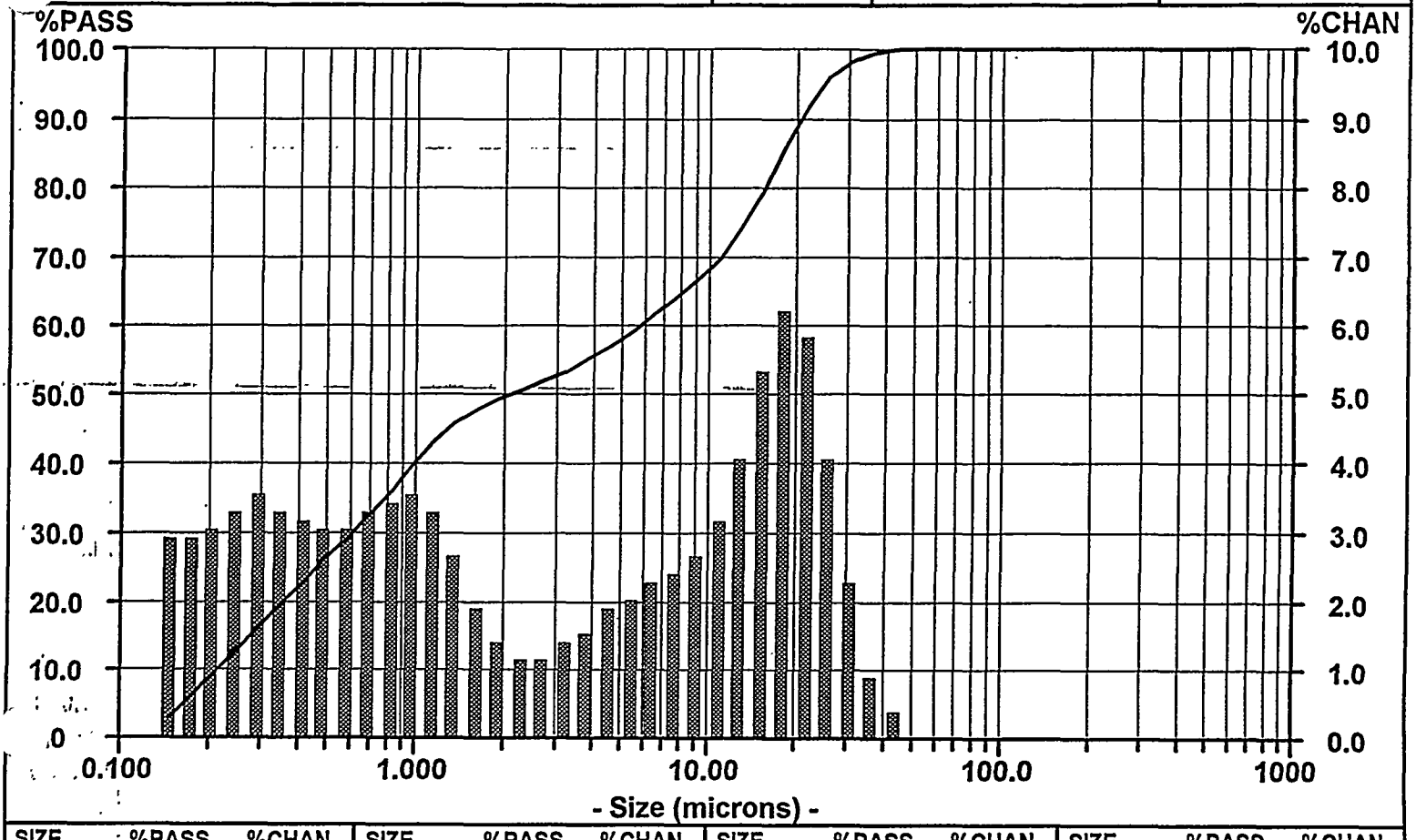
Particle Size Analysis

AZ101/102 Simulant
Sample S2-1/20

Date: 02/07/89 Meas #: 00041
Time: 15:28 Pres #: 01

AZ101/102 Simulant; Sample S2-1/20
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicated at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.284	10% = 0.212	60% = 5.822	13.31	51%	17.16
mn = 0.185	20% = 0.349	70% = 10.95	0.820	26%	0.791
ma = 0.673	30% = 0.600	80% = 15.72	0.232	23%	0.184
cs = 8.910	40% = 0.982	90% = 20.70			
sd = 8.619	50% = 2.094	95% = 24.74			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	66.89	2.74						
592.0	100.00	0.00	7.778	64.15	2.53						
497.8	100.00	0.00	6.541	61.62	2.38						
418.6	100.00	0.00	5.500	59.24	2.18						
352.0	100.00	0.00	4.625	57.06	1.93						
296.0	100.00	0.00	3.889	55.13	1.67						
248.9	100.00	0.00	3.270	53.46	1.44						
209.3	100.00	0.00	2.750	52.02	1.29						
176.0	100.00	0.00	2.312	50.73	1.29						
148.0	100.00	0.00	1.945	49.44	1.50						
124.5	100.00	0.00	1.635	47.94	2.00						
104.7	100.00	0.00	1.375	45.94	2.74						
88.00	100.00	0.00	1.156	43.20	3.40						
74.00	100.00	0.00	0.972	39.80	3.65						
62.23	100.00	0.00	0.818	36.15	3.52						
52.33	100.00	0.00	0.688	32.63	3.32						
44.00	100.00	0.46	0.578	29.31	3.19						
37.00	99.54	1.08	0.486	26.12	3.16						
31.11	98.46	2.31	0.409	22.96	3.24						
26.16	96.15	4.19	0.344	19.72	3.43						
22.00	91.96	5.93	0.289	16.29	3.60						
18.50	86.03	6.38	0.243	12.69	3.42						
15.56	79.65	5.43	0.204	9.27	3.16						
[illegible]08	74.22	4.13	0.172	6.11	3.06						
[illegible]0	70.09	3.20	0.145	3.05	3.05						

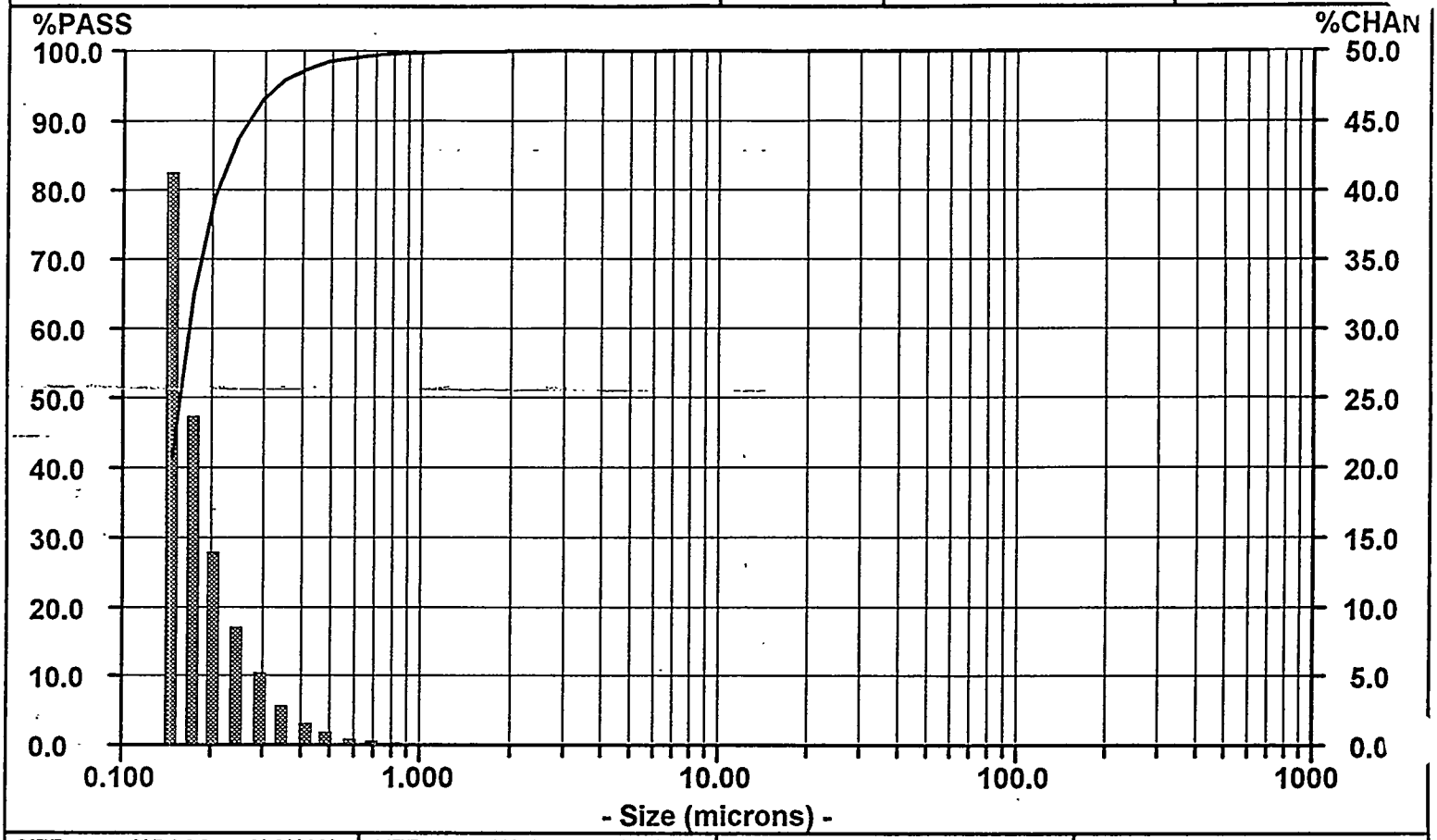
Particle Size Analysis

AZ101/102SimulantDUP
Sample S1-1/24

Date: 02/08/89 Meas #: 00012
Time: 09:41 Pres #: 01

AZ101/102 Simulant; Sample S1-1/24
in 0.8 M NaOH/1.0 M NaNO3 solution
Sonicated at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 8.881	10% = 0.128	60% = 0.164	0.152	100%	0.092
mn = 0.181	20% = 0.133	70% = 0.180			
ma = 0.752	30% = 0.137	80% = 0.207			
cs = 7.983	40% = 0.144	90% = 0.259			
sd = 0.046	50% = 0.152	95% = 0.321			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.02						
104.7	100.00	0.00	1.375	99.97	0.04						
88.00	100.00	0.00	1.156	99.93	0.08						
74.00	100.00	0.00	0.972	99.85	0.14						
62.23	100.00	0.00	0.818	99.71	0.23						
52.33	100.00	0.00	0.688	99.48	0.36						
44.00	100.00	0.00	0.578	99.12	0.58						
37.00	100.00	0.00	0.486	98.54	0.95						
31.11	100.00	0.00	0.409	97.59	1.63						
26.16	100.00	0.00	0.344	95.96	2.93						
22.00	100.00	0.00	0.289	93.03	5.23						
18.50	100.00	0.00	0.243	87.80	8.60						
15.56	100.00	0.00	0.204	79.20	14.09						
13.08	100.00	0.00	0.172	65.11	23.76						
11.00	100.00	0.00	0.145	41.35	41.35						

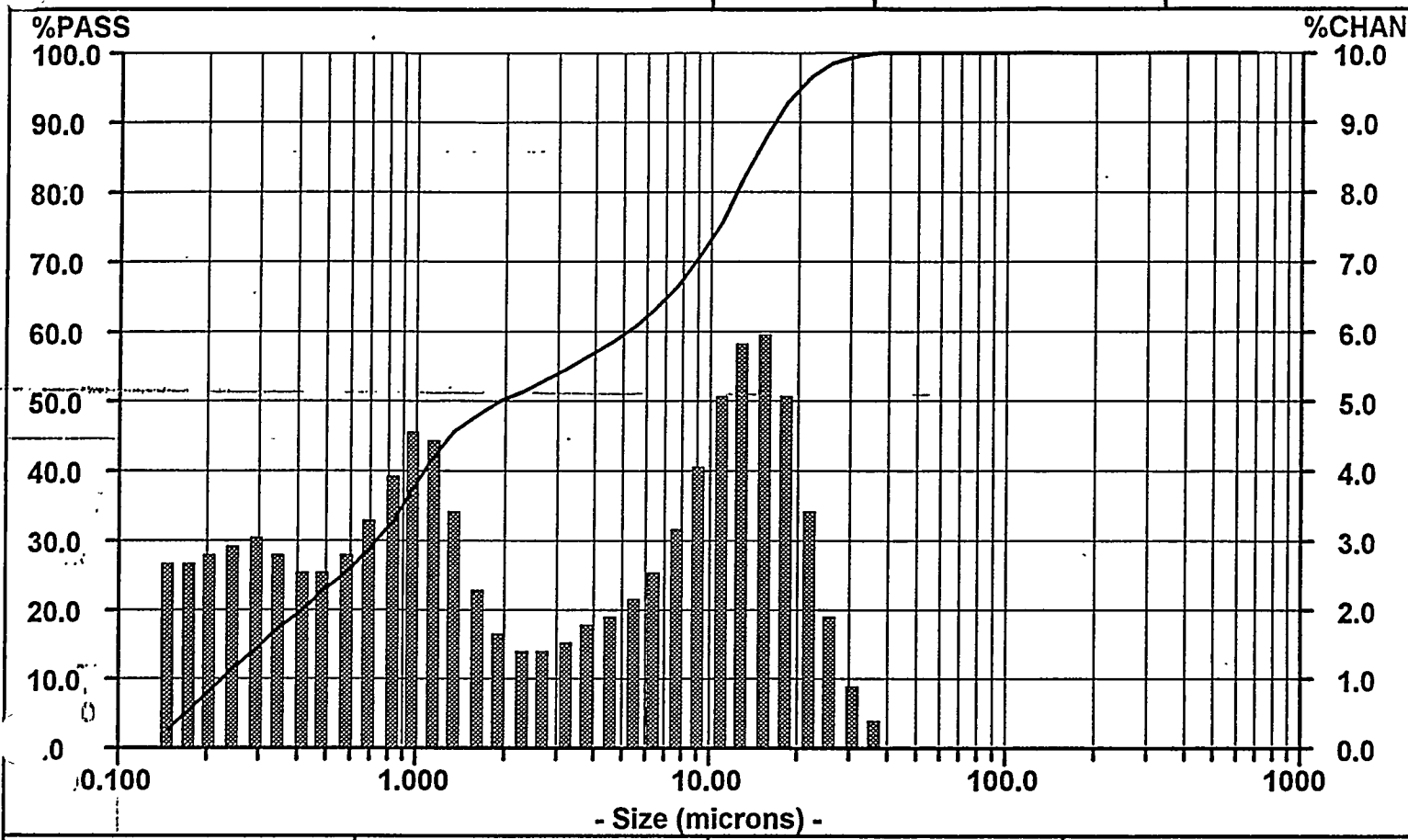
Particle Size Analysis

AZ101/102Simulant
Sample S5-1/24

Date: 02/08/89 Meas #: 00020
Time: 10:10 Pres #: 01

AZ101/102 Simulant; Sample S5-1/24
in 0.8 M NaOH/1.0 M NaNO3 solution
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 6.016	10% = 0.224	60% = 5.181	10.68	50%	13.33
mn = 0.186	20% = 0.406	70% = 8.957	0.884	30%	0.780
ma = 0.719	30% = 0.721	80% = 12.39	0.228	20%	0.180
cs = 8.350	40% = 1.058	90% = 16.59			
sd = 6.782	50% = 1.929	95% = 20.10			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	70.84	4.13						
592.0	100.00	0.00	7.778	66.71	3.26						
497.8	100.00	0.00	6.541	63.45	2.64						
418.6	100.00	0.00	5.500	60.81	2.24						
352.0	100.00	0.00	4.625	58.57	2.00						
296.0	100.00	0.00	3.889	56.57	1.83						
248.9	100.00	0.00	3.270	54.74	1.65						
209.3	100.00	0.00	2.750	53.09	1.51						
176.0	100.00	0.00	2.312	51.58	1.50						
148.0	100.00	0.00	1.945	50.08	1.78						
124.5	100.00	0.00	1.635	48.30	2.49						
104.7	100.00	0.00	1.375	45.81	3.58						
88.00	100.00	0.00	1.156	42.23	4.53						
74.00	100.00	0.00	0.972	37.70	4.67						
62.23	100.00	0.00	0.818	33.03	4.08						
52.33	100.00	0.00	0.688	28.95	3.36						
44.00	100.00	0.00	0.578	25.59	2.85						
37.00	100.00	0.40	0.486	22.74	2.62						
31.11	99.60	0.96	0.409	20.12	2.64						
26.16	98.64	2.00	0.344	17.48	2.88						
22.00	96.64	3.54	0.289	14.60	3.14						
18.50	93.10	5.15	0.243	11.46	3.07						
15.56	87.95	6.03	0.204	8.39	2.87						
[illegible]08	81.92	5.95	0.172	5.52	2.77						
[illegible]0	75.97	5.13	0.145	2.75	2.75						

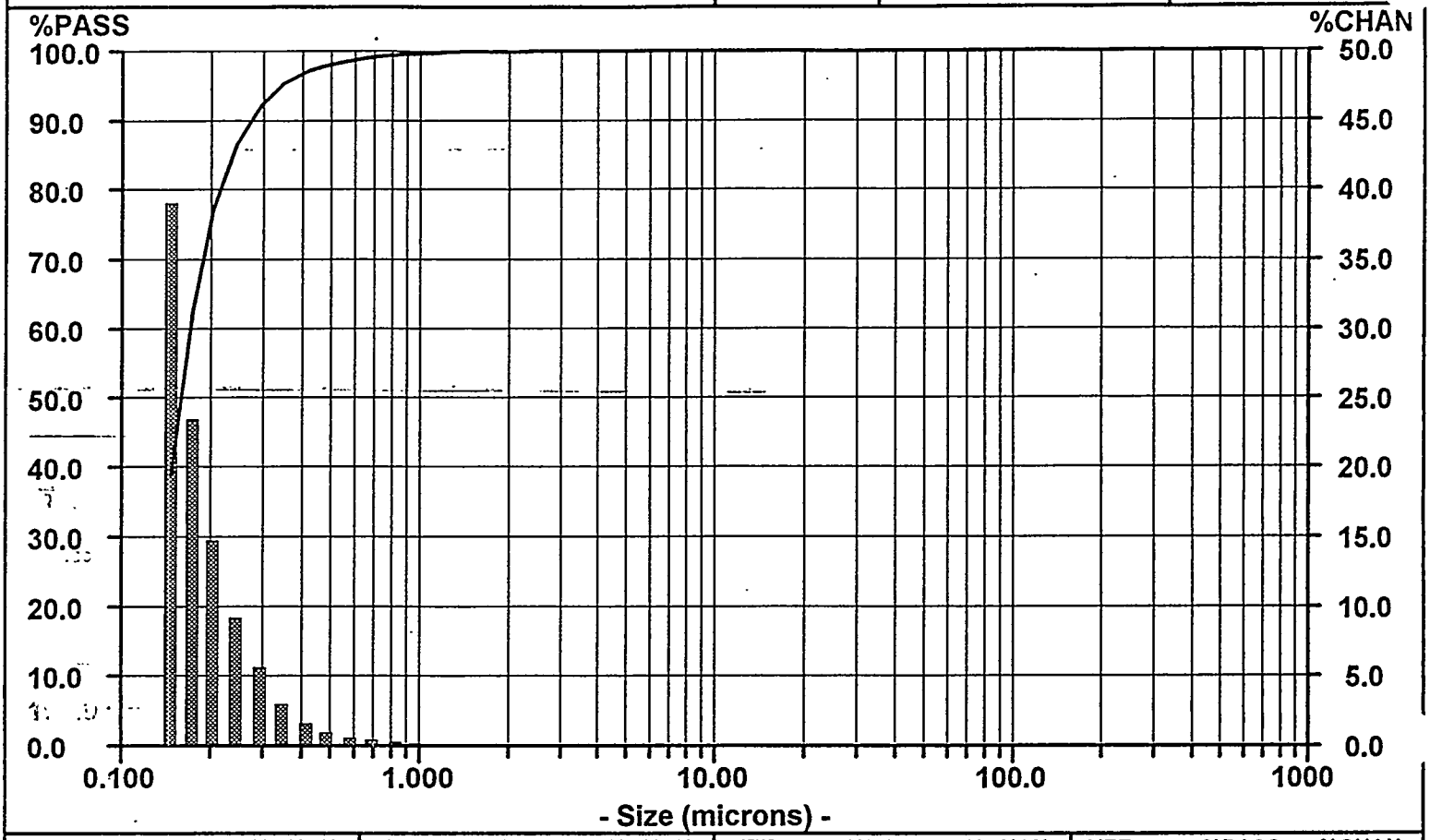
Particle Size Analysis

AZ101/102Simulant
Sample S5-1/24

Date: 02/08/89 Meas #: 00020
Time: 10:10 Pres #: 01

AZ101/102 Simulant; Sample S5-1/24
in 0.8 M NaOH/1.0 M NaNO3 solution
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 6.016	10% = 0.128	60% = 0.168	0.155	100%	0.098
mn = 0.186	20% = 0.134	70% = 0.185			
ma = 0.719	30% = 0.138	80% = 0.212			
cs = 8.350	40% = 0.146	90% = 0.266			
sd = 0.049	50% = 0.155	95% = 0.333			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.01						
124.5	100.00	0.00	1.635	99.98	0.02						
104.7	100.00	0.00	1.375	99.96	0.06						
88.00	100.00	0.00	1.156	99.90	0.13						
74.00	100.00	0.00	0.972	99.77	0.22						
62.23	100.00	0.00	0.818	99.55	0.32						
52.33	100.00	0.00	0.688	99.23	0.45						
44.00	100.00	0.00	0.578	98.78	0.64						
37.00	100.00	0.00	0.486	98.14	0.99						
31.11	100.00	0.00	0.409	97.15	1.68						
26.16	100.00	0.00	0.344	95.47	3.09						
22.00	100.00	0.00	0.289	92.38	5.66						
18.50	100.00	0.00	0.243	86.72	9.28						
15.56	100.00	0.00	0.204	77.44	14.71						
13.08	100.00	0.00	0.172	62.73	23.54						
11.00	100.00	0.00	0.145	39.19	39.19						

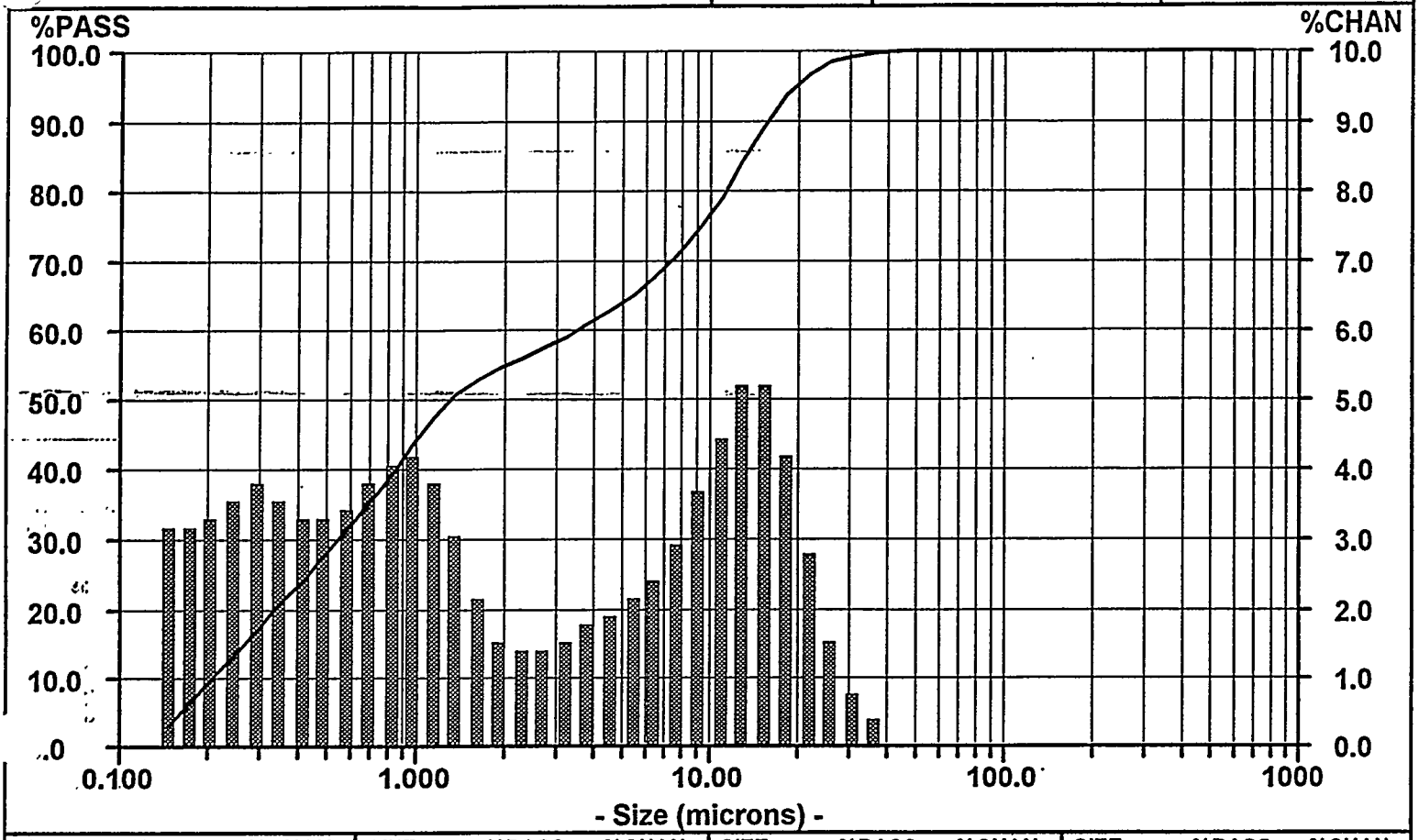
Particle Size Analysis

AZ101/102SimulantDUP
Sample S5-1/20

Date: 02/07/89 Meas #: 00065
Time: 16:47 Pres #: 01

AZ101/102 Simulant; Sample S5-1/20
Duplicate
in 0.8 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.408	10% = 0.206	60% = 3.555	10.29	45%	13.33
mn = 0.186	20% = 0.329	70% = 7.411	0.821	30%	0.773
ma = 0.624	30% = 0.541	80% = 11.31	0.247	21%	0.172
cs = 9.619	40% = 0.837	90% = 15.78	0.136	4%	0.012
sd = 6.319	50% = 1.307	95% = 19.54			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	74.64	3.73						
592.0	100.00	0.00	7.778	70.91	3.05						
497.8	100.00	0.00	6.541	67.86	2.58						
418.6	100.00	0.00	5.500	65.28	2.26						
352.0	100.00	0.00	4.625	63.02	2.04						
296.0	100.00	0.00	3.889	60.98	1.84						
248.9	100.00	0.00	3.270	59.14	1.62						
209.3	100.00	0.00	2.750	57.52	1.45						
176.0	100.00	0.00	2.312	56.07	1.41						
148.0	100.00	0.00	1.945	54.66	1.63						
124.5	100.00	0.00	1.635	53.03	2.21						
104.7	100.00	0.00	1.375	50.82	3.11						
88.00	100.00	0.00	1.156	47.71	3.97						
74.00	100.00	0.00	0.972	43.74	4.32						
62.23	100.00	0.00	0.818	39.42	4.16						
52.33	100.00	0.00	0.688	35.26	3.84						
44.00	100.00	0.14	0.578	31.42	3.58						
37.00	99.86	0.47	0.486	27.84	3.45						
31.11	99.39	0.88	0.409	24.39	3.47						
26.16	98.51	1.67	0.344	20.92	3.65						
22.00	96.84	2.90	0.289	17.27	3.81						
18.50	93.94	4.32	0.243	13.46	3.62						
15.56	89.62	5.21	0.204	9.84	3.33						
[illegible]08	84.41	5.22	0.172	6.51	3.23						
[illegible]00	79.19	4.55	0.145	3.28	3.28						

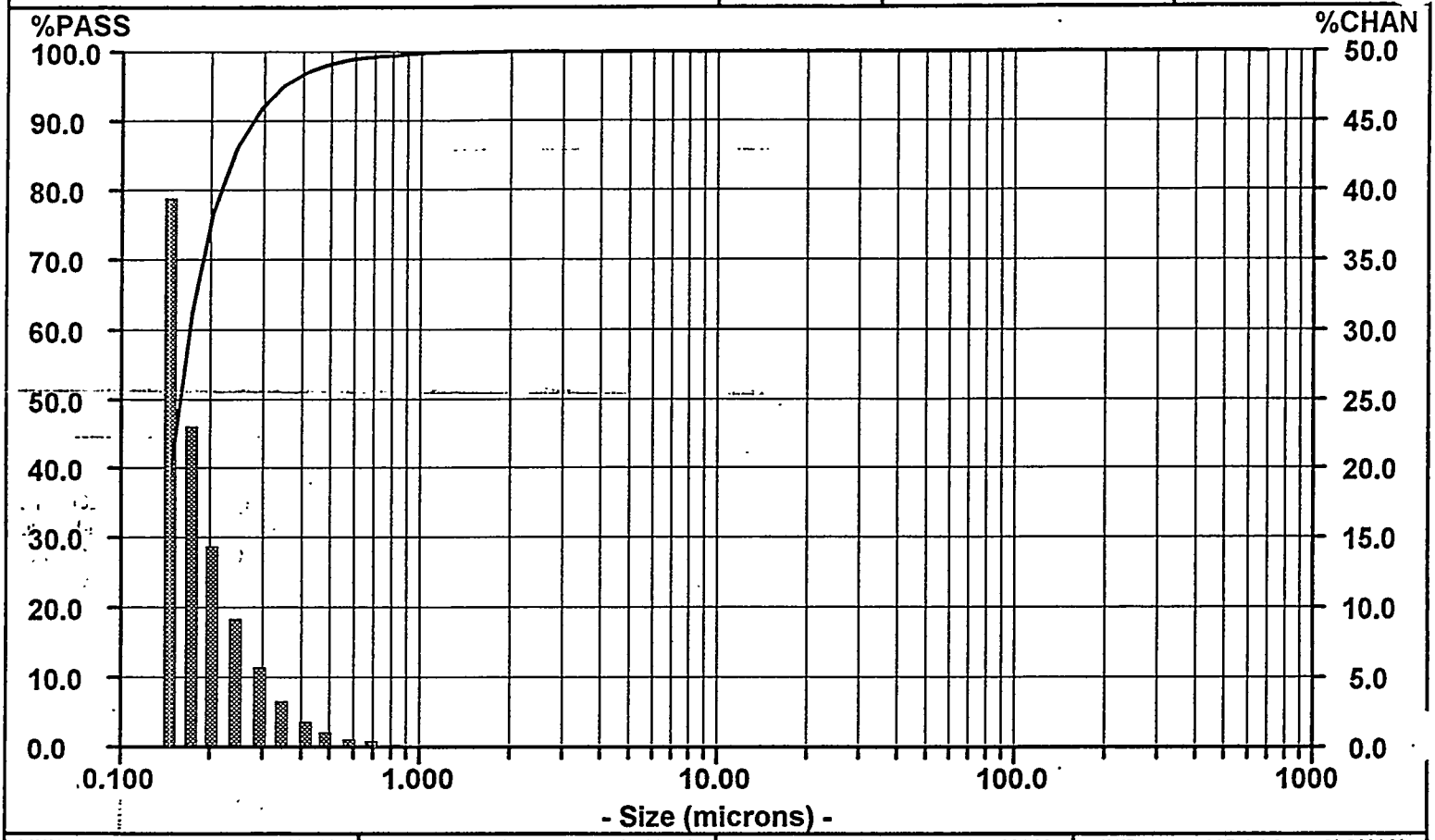
Particle Size Analysis

AZ101/102SimulantDUP
Sample S5-1/20

Date: 02/07/89 Meas #: 00066
Time: 16:47 Pres #: 01

AZ101/102 Simulant; Sample S5-1/20
Duplicate
in 0.8 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.408	10% = 0.128	60% = 0.168	0.155	100%	0.100
mn = 0.186	20% = 0.133	70% = 0.186			
ma = 0.624	30% = 0.138	80% = 0.214			
cs = 9.619	40% = 0.145	90% = 0.270			
sd = 0.050	50% = 0.155	95% = 0.337			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.02						
104.7	100.00	0.00	1.375	99.97	0.04						
88.00	100.00	0.00	1.156	99.93	0.09						
74.00	100.00	0.00	0.972	99.84	0.17						
62.23	100.00	0.00	0.818	99.67	0.28						
52.33	100.00	0.00	0.688	99.39	0.43						
44.00	100.00	0.00	0.578	98.96	0.68						
37.00	100.00	0.00	0.486	98.28	1.10						
31.11	100.00	0.00	0.409	97.18	1.86						
26.16	100.00	0.00	0.344	95.32	3.30						
22.00	100.00	0.00	0.289	92.02	5.79						
18.50	100.00	0.00	0.243	86.23	9.23						
15.56	100.00	0.00	0.204	77.00	14.40						
13.08	100.00	0.00	0.172	62.60	23.16						
11.00	100.00	0.00	0.145	39.44	39.44						

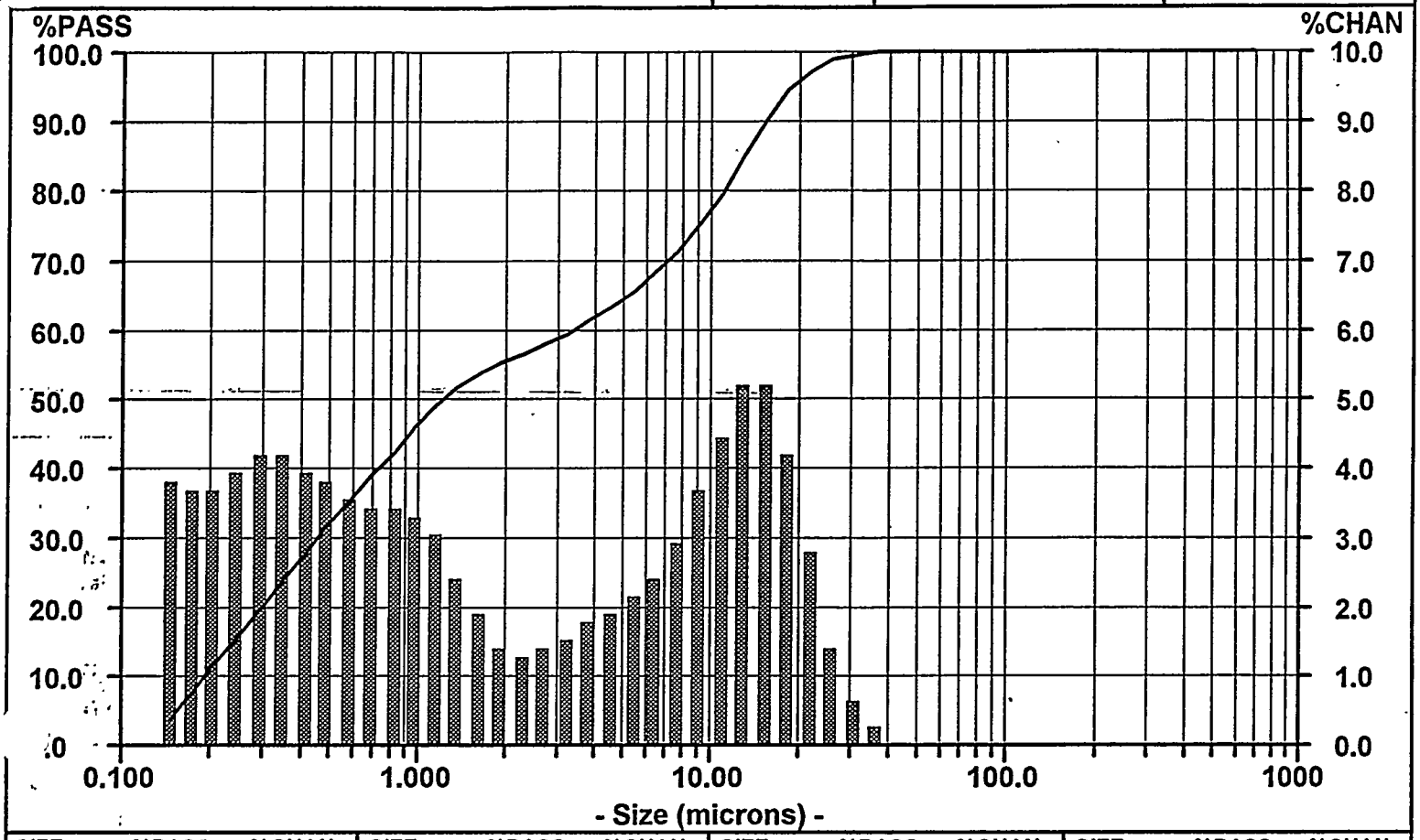
Particle Size Analysis

AZ101/102SimulantDUP
Sample S5-1/20

Date: 02/07/89 Meas #: 00069
Time: 16:58 Pres #: 01

AZ101/102 Simulant; Sample S5-1/20
Duplicate
in 0.8 M NaOH/1.0 M NaNO3 solution
sonicate at 40W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.205	10% = 0.191	60% = 3.380	10.19	45%	12.98
mn = 0.183	20% = 0.292	70% = 7.169	0.479	48%	0.813
ma = 0.571	30% = 0.448	80% = 11.11	0.147	7%	0.030
cs = 10.50	40% = 0.721	90% = 15.45			
sd = 6.223	50% = 1.212	95% = 18.93			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	75.20	3.70						
592.0	100.00	0.00	7.778	71.50	3.04						
497.8	100.00	0.00	6.541	68.46	2.58						
418.6	100.00	0.00	5.500	65.88	2.28						
352.0	100.00	0.00	4.625	63.60	2.07						
296.0	100.00	0.00	3.889	61.53	1.87						
248.9	100.00	0.00	3.270	59.66	1.64						
209.3	100.00	0.00	2.750	58.02	1.44						
176.0	100.00	0.00	2.312	56.58	1.36						
148.0	100.00	0.00	1.945	55.22	1.50						
124.5	100.00	0.00	1.635	53.72	1.92						
104.7	100.00	0.00	1.375	51.80	2.56						
88.00	100.00	0.00	1.156	49.24	3.18						
74.00	100.00	0.00	0.972	46.06	3.49						
62.23	100.00	0.00	0.818	42.57	3.54						
52.33	100.00	0.00	0.688	39.03	3.56						
44.00	100.00	0.00	0.578	35.47	3.67						
37.00	100.00	0.34	0.486	31.80	3.84						
31.11	99.66	0.73	0.409	27.96	4.02						
26.16	98.93	1.54	0.344	23.94	4.20						
22.00	97.39	2.84	0.289	19.74	4.27						
18.50	94.55	4.34	0.243	15.47	4.01						
15.56	90.21	5.27	0.204	11.46	3.77						
[illegible]08	84.94	5.22	0.172	7.69	3.79						
[illegible]00	79.72	4.52	0.145	3.90	3.90						

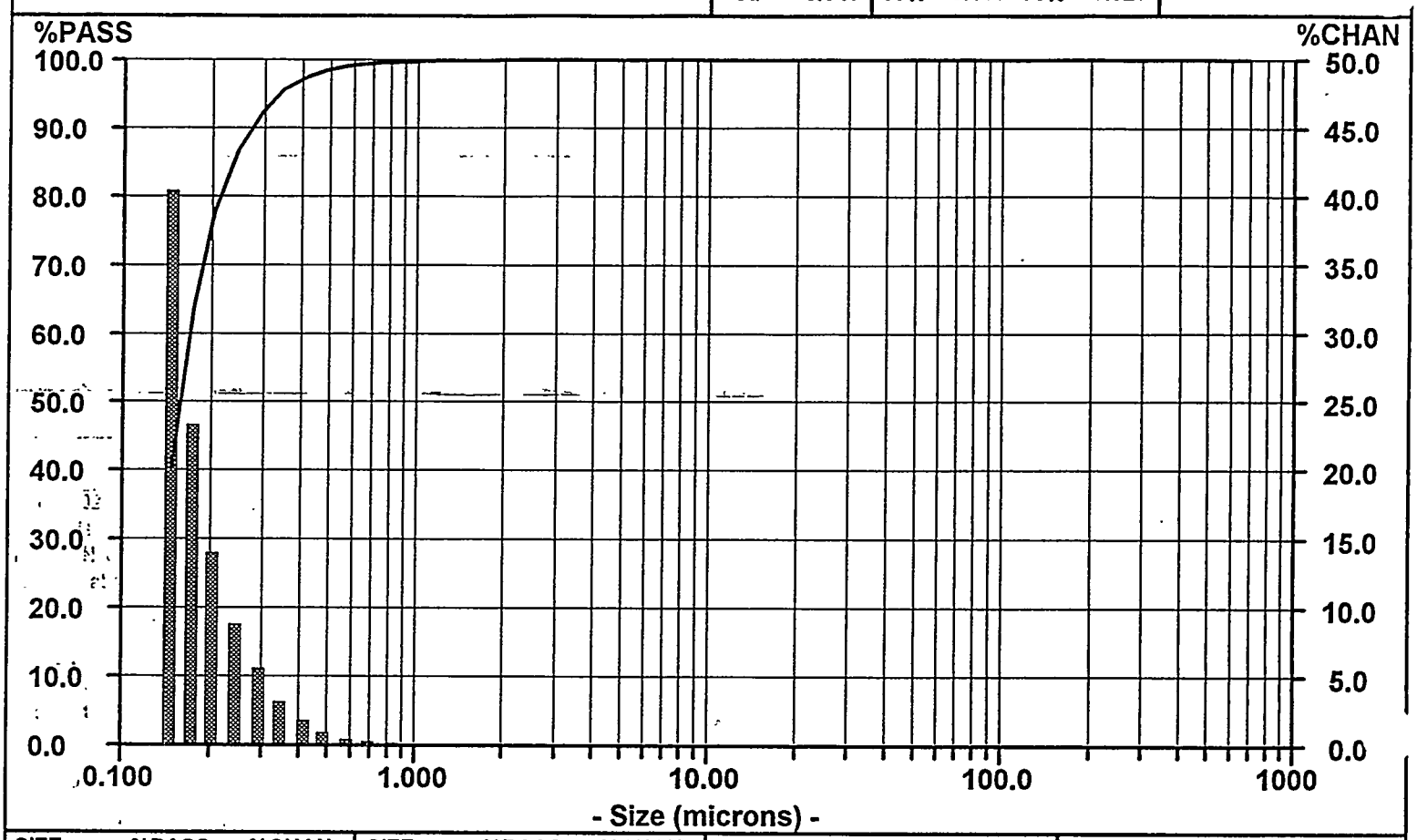
Particle Size Analysis

AZ101/102SimulantDUP
Sample S5-1/20

Date: 02/07/89 Meas #: 00069
Time: 16:58 Pres #: 01

AZ101/102 Simulant; Sample S5-1/20
Duplicate
in 0.8 M NaOH/1.0 M NaNO3 solution
sonicate at 40W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 5.205	10% = 0.128	60% = 0.166	0.153	100%	0.097
mn = 0.183	20% = 0.133	70% = 0.183			
ma = 0.571	30% = 0.138	80% = 0.211			
cs = 10.50	40% = 0.145	90% = 0.266			
sd = 0.049	50% = 0.153	95% = 0.329			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.01						
104.7	100.00	0.00	1.375	99.98	0.03						
88.00	100.00	0.00	1.156	99.95	0.07						
74.00	100.00	0.00	0.972	99.88	0.12						
62.23	100.00	0.00	0.818	99.76	0.20						
52.33	100.00	0.00	0.688	99.56	0.35						
44.00	100.00	0.00	0.578	99.21	0.60						
37.00	100.00	0.00	0.486	98.61	1.06						
31.11	100.00	0.00	0.409	97.55	1.86						
26.16	100.00	0.00	0.344	95.69	3.28						
22.00	100.00	0.00	0.289	92.41	5.60						
18.50	100.00	0.00	0.243	86.81	8.83						
15.56	100.00	0.00	0.204	77.98	14.07						
13.08	100.00	0.00	0.172	63.91	23.45						
11.00	100.00	0.00	0.145	40.46	40.46						

C-106 Filtration Simulant

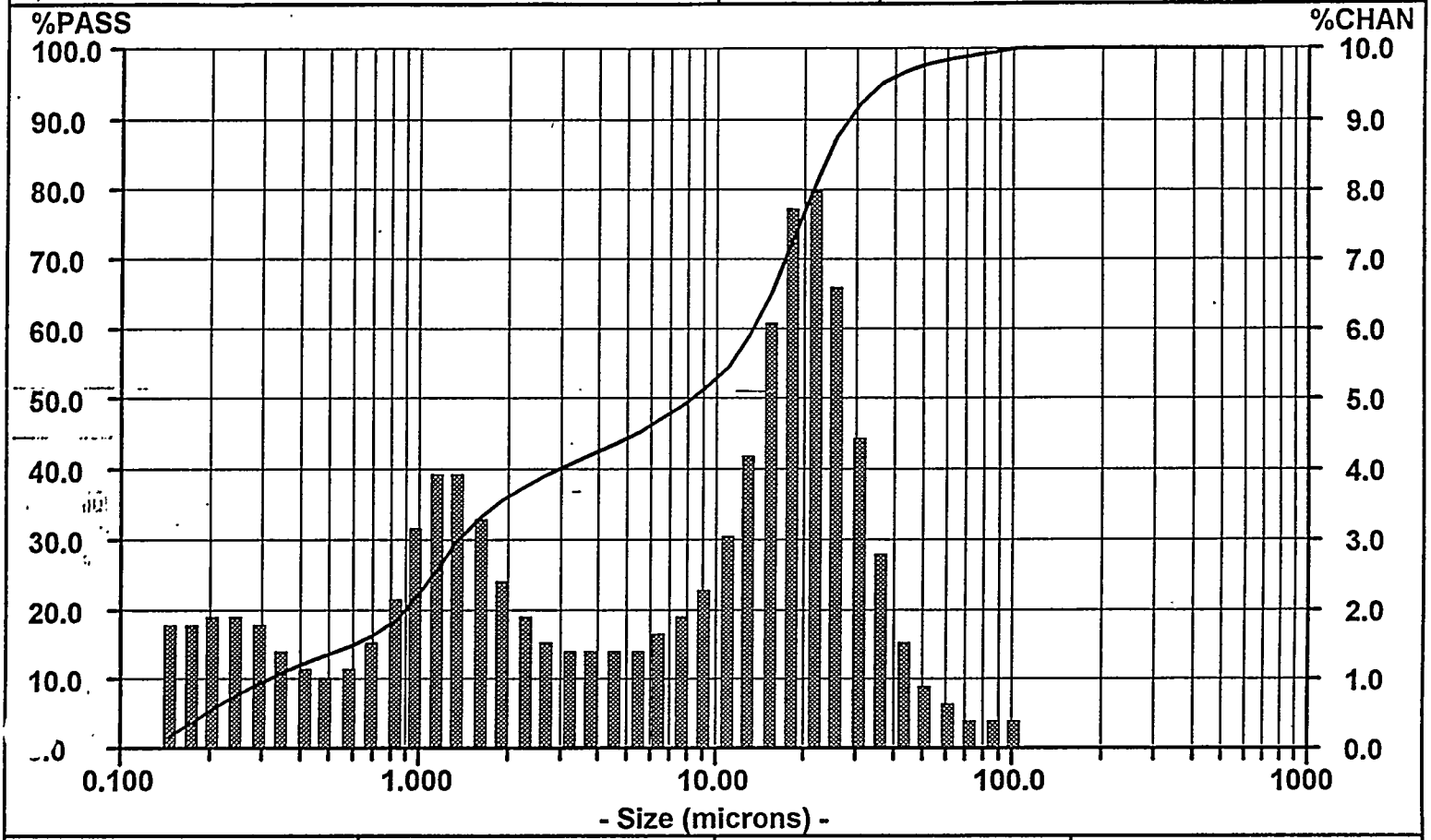
Particle Size Analysis

C106 Simulant
AR-S1-1/17

Date: 02/04/ 0 Meas #: N/A
Time: 15:03 Pres #: N/A

C106 Simulant- Sample:AR-S1-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 12.31	10% = 0.305	60% = 13.53	17.52	59%	20.27
mn = 0.183	20% = 0.885	70% = 17.37	1.187	28%	1.295
ma = 1.090	30% = 1.376	80% = 21.46	0.233	11%	0.159
cs = 5.506	40% = 2.966	90% = 28.22	0.136	2%	0.012
sd = 11.45	50% = 8.366	95% = 36.67			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	51.47	2.43						
592.0	100.00	0.00	7.778	49.04	2.03						
497.8	100.00	0.00	6.541	47.01	1.77						
418.6	100.00	0.00	5.500	45.24	1.57						
352.0	100.00	0.00	4.625	43.67	1.45						
296.0	100.00	0.00	3.889	42.22	1.41						
248.9	100.00	0.00	3.270	40.81	1.45						
209.3	100.00	0.00	2.750	39.36	1.60						
176.0	100.00	0.00	2.312	37.76	1.92						
148.0	100.00	0.00	1.945	35.84	2.50						
124.5	100.00	0.00	1.635	33.34	3.35						
104.7	100.00	0.42	1.375	29.99	4.07						
88.00	99.58	0.44	1.156	25.92	4.04						
74.00	99.14	0.53	0.972	21.88	3.22						
62.23	98.61	0.72	0.818	18.66	2.27						
52.33	97.89	1.07	0.688	16.39	1.61						
44.00	96.82	1.70	0.578	14.78	1.28						
37.00	95.12	2.81	0.486	13.50	1.19						
31.11	92.31	4.52	0.409	12.31	1.28						
26.16	87.79	6.65	0.344	11.03	1.55						
22.00	81.14	8.15	0.289	9.48	1.88						
18.50	72.99	7.88	0.243	7.60	1.98						
15.56	65.11	6.17	0.204	5.62	1.90						
[illegible]	58.94	4.35	0.172	3.72	1.85						
[illegible]	54.59	3.12	0.145	1.87	1.87						

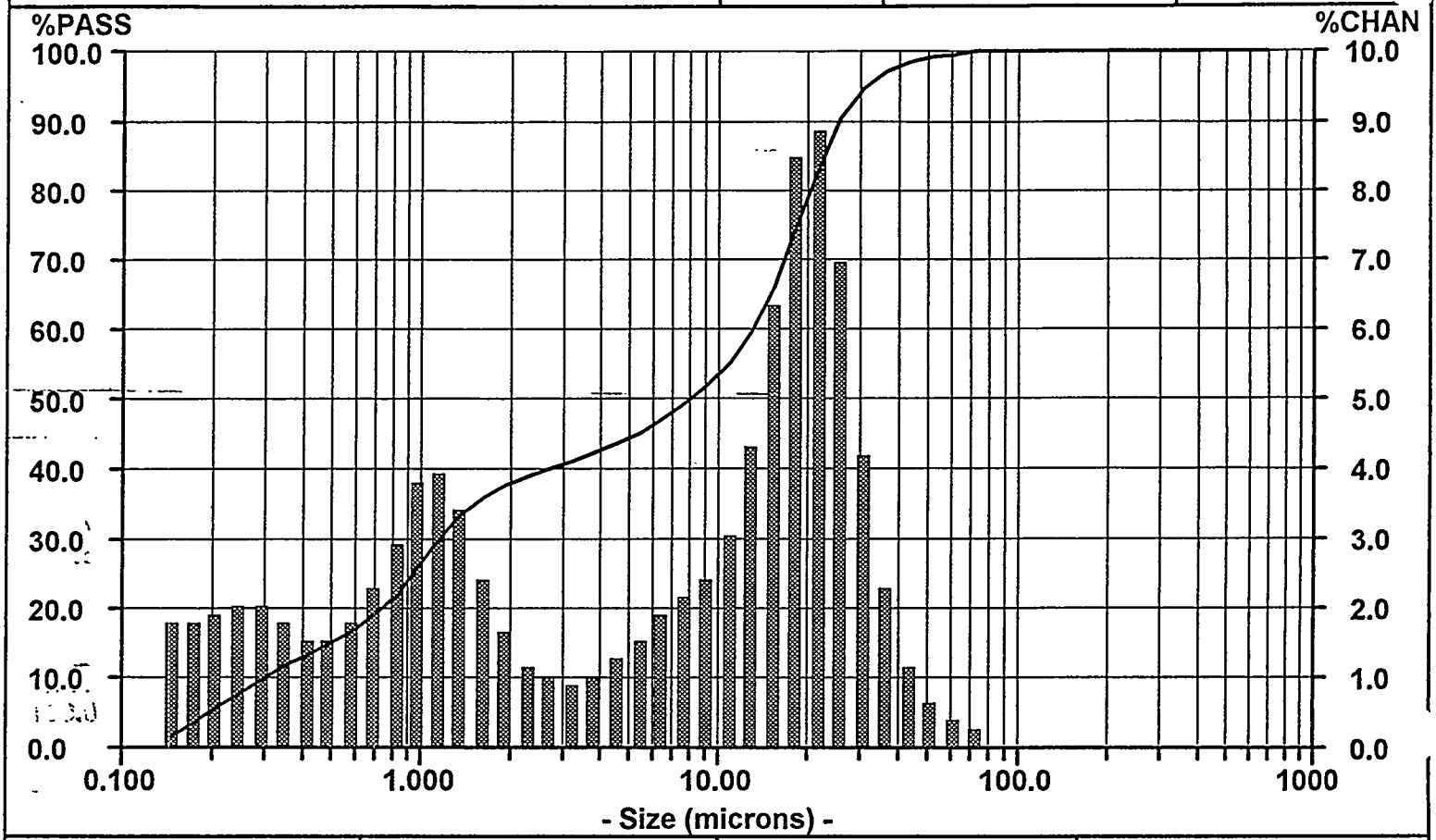
Particle Size Analysis

C106 Simulant
AR-S1-1/17

Date: 02/04/ 0 Meas #: N/A
Time: 15:23 Pres #: N/A

C106 Simulant- Sample:AR-S1-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
70 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 11.08	10% = 0.292	60% = 13.24	16.92	60%	18.09
mn = 0.188	20% = 0.729	70% = 16.90	1.005	27%	0.988
ma = 1.022	30% = 1.154	80% = 20.47	0.226	13%	0.174
cs = 5.870	40% = 2.689	90% = 25.70			
sd = 10.82	50% = 8.081	95% = 31.26			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	52.04	2.57						
592.0	100.00	0.00	7.778	49.47	2.22						
497.8	100.00	0.00	6.541	47.25	1.91						
418.6	100.00	0.00	5.500	45.34	1.61						
352.0	100.00	0.00	4.625	43.73	1.34						
296.0	100.00	0.00	3.889	42.39	1.17						
248.9	100.00	0.00	3.270	41.22	1.08						
209.3	100.00	0.00	2.750	40.14	1.10						
176.0	100.00	0.00	2.312	39.04	1.27						
148.0	100.00	0.00	1.945	37.77	1.71						
124.5	100.00	0.00	1.635	36.06	2.51						
104.7	100.00	0.00	1.375	33.55	3.51						
88.00	100.00	0.00	1.156	30.04	4.10						
74.00	100.00	0.33	0.972	25.94	3.83						
62.23	99.67	0.45	0.818	22.11	3.05						
52.33	99.22	0.71	0.688	19.06	2.31						
44.00	98.51	1.25	0.578	16.75	1.82						
37.00	97.26	2.34	0.486	14.93	1.60						
31.11	94.92	4.29	0.409	13.33	1.61						
26.16	90.63	7.00	0.344	11.72	1.83						
22.00	83.63	8.96	0.289	9.89	2.12						
18.50	74.67	8.61	0.243	7.77	2.15						
15.56	66.06	6.45	0.204	5.62	1.98						
13.08	59.61	4.40	0.172	3.64	1.84						
11.00	55.21	3.17	0.145	1.80	1.80						

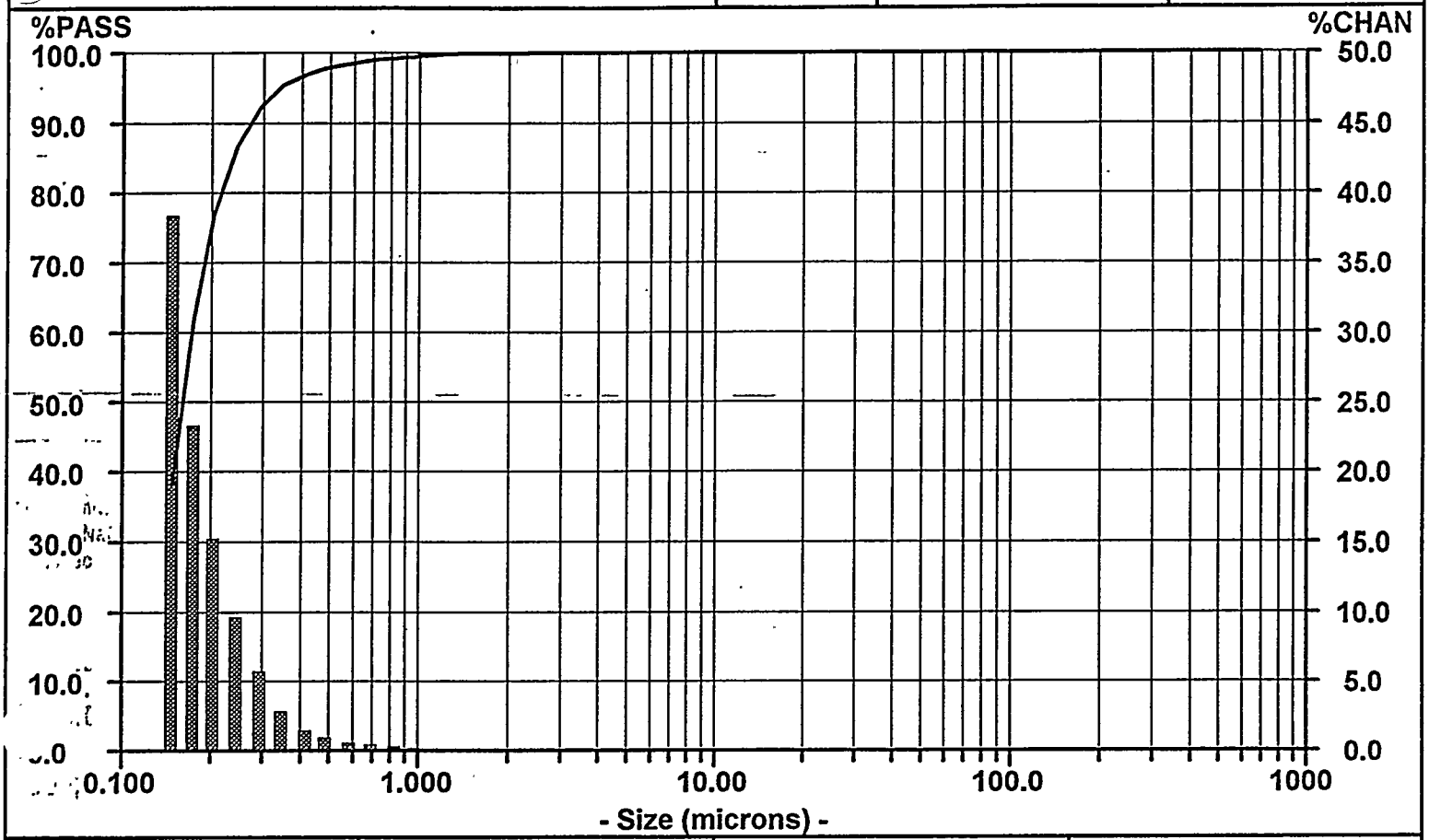
Particle Size Analysis

C106 Simulant
AR-S1-1/17

Date: 02/04/ 0 Meas #: N/A
Time: 15:23 Pres #: N/A

C106 Simulant- Sample:AR-S1-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
70 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 11.08	10% = 0.128	60% = 0.169	0.156	100%	0.098
mn = 0.188	20% = 0.134	70% = 0.186			
ma = 1.022	30% = 0.139	80% = 0.213			
cs = 5.870	40% = 0.146	90% = 0.264			
sd = 0.049	50% = 0.156	95% = 0.330			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.02						
124.5	100.00	0.00	1.635	99.97	0.04						
104.7	100.00	0.00	1.375	99.93	0.09						
88.00	100.00	0.00	1.156	99.84	0.17						
74.00	100.00	0.00	0.972	99.67	0.27						
62.23	100.00	0.00	0.818	99.40	0.36						
52.33	100.00	0.00	0.688	99.04	0.46						
44.00	100.00	0.00	0.578	98.58	0.61						
37.00	100.00	0.00	0.486	97.97	0.91						
31.11	100.00	0.00	0.409	97.06	1.53						
26.16	100.00	0.00	0.344	95.53	2.94						
22.00	100.00	0.00	0.289	92.59	5.72						
18.50	100.00	0.00	0.243	86.87	9.74						
15.56	100.00	0.00	0.204	77.13	15.22						
[illegible]8	100.00	0.00	0.172	61.91	23.44						
[illegible]0	100.00	0.00	0.145	38.47	38.47						

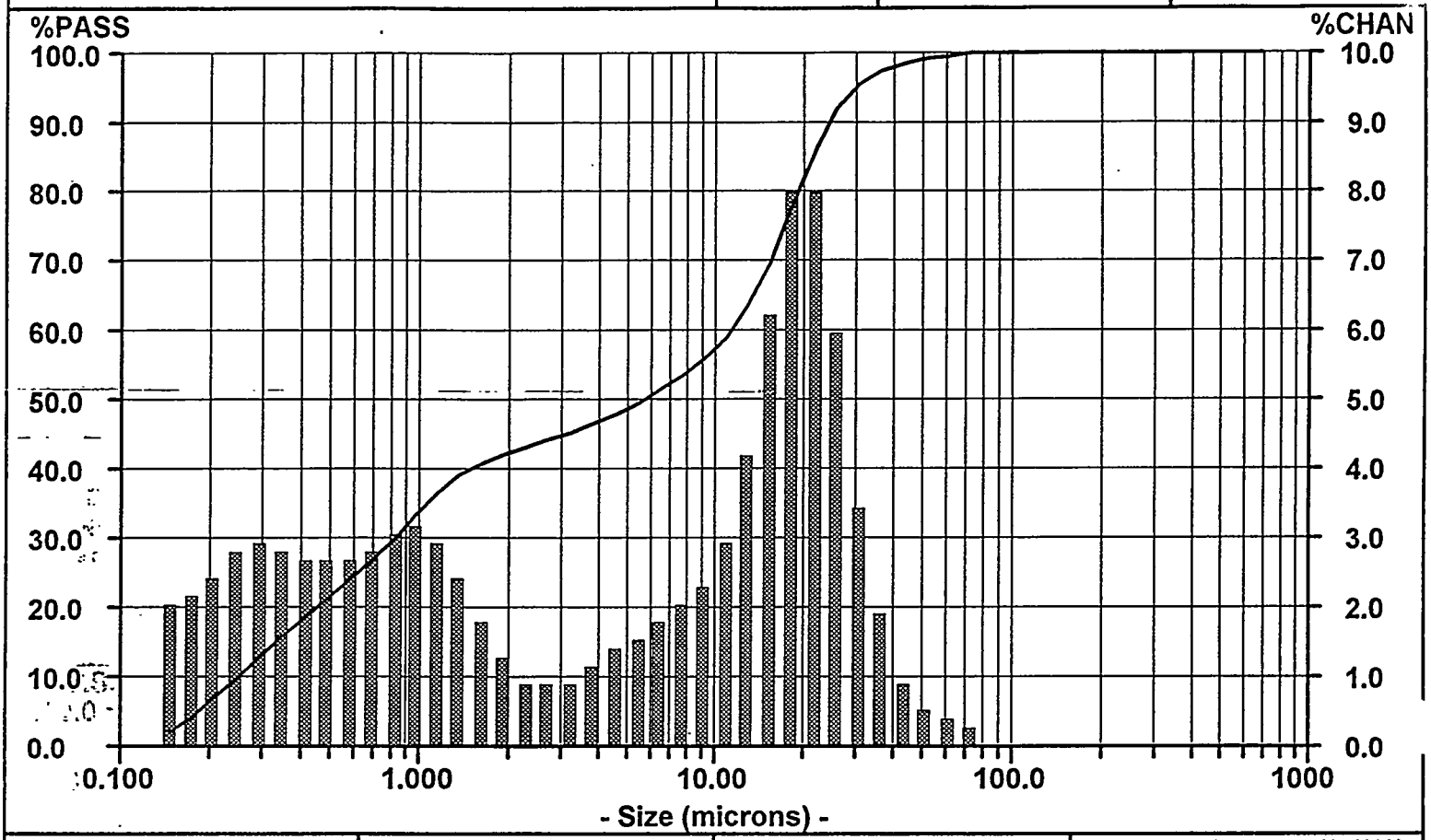
Particle Size Analysis

C106 Simulant
AR-S1-1/17

Date: 02/04/ 0 Meas #: N/A
Time: 15:35 Pres #: N/A

C106 Simulant- Sample:AR-S1-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicate at 40W, 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 10.05	10% = 0.247	60% = 11.50	16.22	57%	18.12
mn = 0.191	20% = 0.450	70% = 15.65	0.850	25%	0.880
ma = 0.825	30% = 0.812	80% = 19.29	0.239	18%	0.182
cs = 7.272	40% = 1.498	90% = 24.45			
sd = 10.32	50% = 5.717	95% = 29.91			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	55.99	2.41						
592.0	100.00	0.00	7.778	53.58	2.10						
497.8	100.00	0.00	6.541	51.48	1.88						
418.6	100.00	0.00	5.500	49.60	1.65						
352.0	100.00	0.00	4.625	47.95	1.41						
296.0	100.00	0.00	3.889	46.54	1.22						
248.9	100.00	0.00	3.270	45.32	1.08						
209.3	100.00	0.00	2.750	44.24	1.01						
176.0	100.00	0.00	2.312	43.23	1.07						
148.0	100.00	0.00	1.945	42.16	1.32						
124.5	100.00	0.00	1.635	40.84	1.82						
104.7	100.00	0.00	1.375	39.02	2.51						
88.00	100.00	0.00	1.156	36.51	3.09						
74.00	100.00	0.32	0.972	33.42	3.29						
62.23	99.68	0.42	0.818	30.13	3.16						
52.33	99.26	0.63	0.688	26.97	2.95						
44.00	98.63	1.06	0.578	24.02	2.79						
37.00	97.57	1.93	0.486	21.23	2.72						
31.11	95.64	3.56	0.409	18.51	2.76						
26.16	92.08	6.01	0.344	15.75	2.93						
22.00	86.07	8.12	0.289	12.82	3.07						
18.50	77.95	8.19	0.243	9.75	2.87						
15.56	69.76	6.37	0.204	6.88	2.51						
13.08	63.39	4.34	0.172	4.37	2.25						
11.00	59.05	3.06	0.145	2.12	2.12						

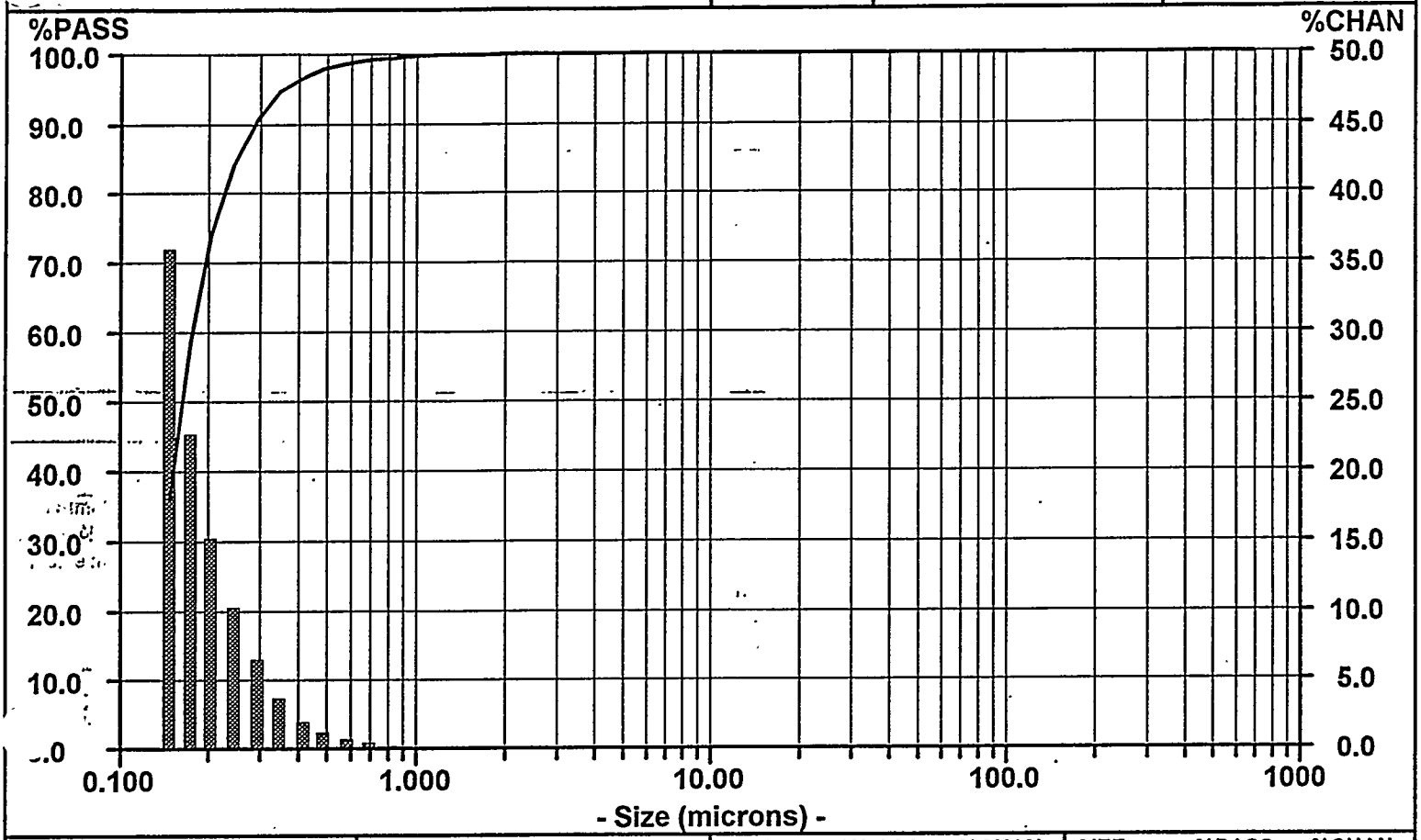
Particle Size Analysis

C106 Simulant
AR-S1-1/17

Date: 02/04/ 0 Meas #: N/A
Time: 15:35 Pres #: N/A

C106 Simulant- Sample:AR-S1-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicate at 40W, 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 10.05	10% = 0.129	60% = 0.174	0.159	100%	0.109
mn = 0.191	20% = 0.134	70% = 0.194			
ma = 0.825	30% = 0.140	80% = 0.224			
cs = 7.272	40% = 0.148	90% = 0.280			
sd = 0.054	50% = 0.159	95% = 0.349			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.02						
104.7	100.00	0.00	1.375	99.97	0.05						
88.00	100.00	0.00	1.156	99.92	0.10						
74.00	100.00	0.00	0.972	99.82	0.19						
62.23	100.00	0.00	0.818	99.63	0.30						
52.33	100.00	0.00	0.688	99.33	0.47						
44.00	100.00	0.00	0.578	98.86	0.75						
37.00	100.00	0.00	0.486	98.11	1.22						
31.11	100.00	0.00	0.409	96.89	2.09						
26.16	100.00	0.00	0.344	94.80	3.74						
22.00	100.00	0.00	0.289	91.06	6.59						
18.50	100.00	0.00	0.243	84.47	10.34						
15.56	100.00	0.00	0.204	74.13	15.33						
[illegible]8	100.00	0.00	0.172	58.80	22.79						
[illegible]0	100.00	0.00	0.145	36.01	36.01						

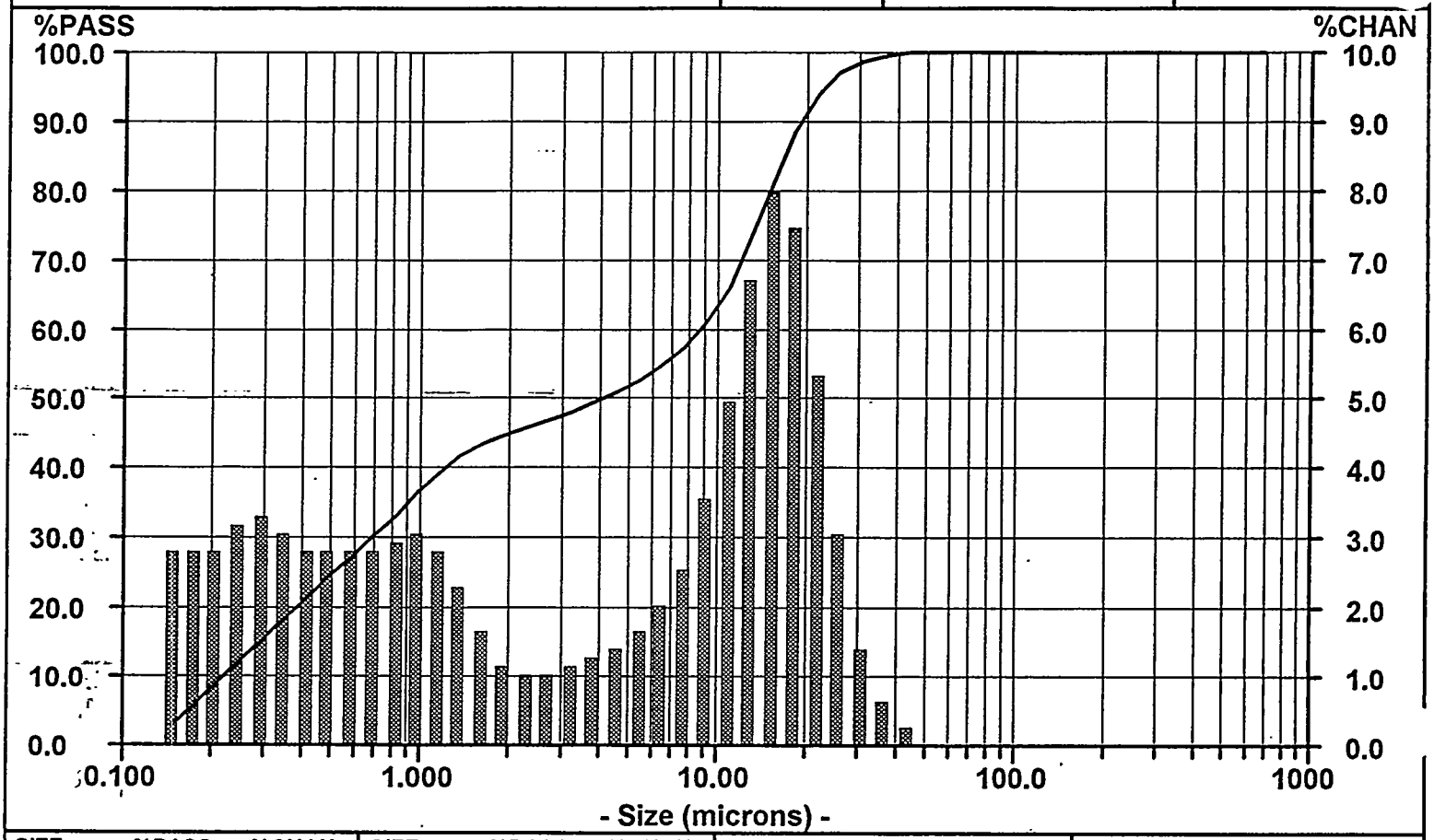
Particle Size Analysis

C106 Simulant
Sample S2-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 12:28 Pres #: N/A

C106 Simulant; Sample S2-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicate at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.638	10% = 0.219	60% = 8.798	12.85	55%	13.93
mn = 0.185	20% = 0.377	70% = 12.16	0.805	23%	0.787
ma = 0.727	30% = 0.680	80% = 15.17	0.231	22%	0.183
cs = 8.253	40% = 1.213	90% = 19.13			
sd = 8.115	50% = 4.168	95% = 22.81			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	61.17	3.62						
592.0	100.00	0.00	7.778	57.55	2.68						
497.8	100.00	0.00	6.541	54.87	2.12						
418.6	100.00	0.00	5.500	52.75	1.79						
352.0	100.00	0.00	4.625	50.96	1.56						
296.0	100.00	0.00	3.889	49.40	1.38						
248.9	100.00	0.00	3.270	48.02	1.21						
209.3	100.00	0.00	2.750	46.81	1.10						
176.0	100.00	0.00	2.312	45.71	1.10						
148.0	100.00	0.00	1.945	44.61	1.28						
124.5	100.00	0.00	1.635	43.33	1.71						
104.7	100.00	0.00	1.375	41.62	2.33						
88.00	100.00	0.00	1.156	39.29	2.88						
74.00	100.00	0.00	0.972	36.41	3.12						
62.23	100.00	0.00	0.818	33.29	3.09						
52.33	100.00	0.00	0.688	30.20	2.98						
44.00	100.00	0.38	0.578	27.22	2.92						
37.00	99.62	0.76	0.486	24.30	2.92						
31.11	98.86	1.56	0.409	21.38	2.99						
26.16	97.30	3.11	0.344	18.39	3.16						
22.00	94.19	5.41	0.289	15.23	3.32						
18.50	88.78	7.57	0.243	11.91	3.20						
15.56	81.21	8.11	0.204	8.71	2.99						
13.08	73.10	6.86	0.172	5.72	2.89						
11.00	66.24	5.07	0.145	2.83	2.83						

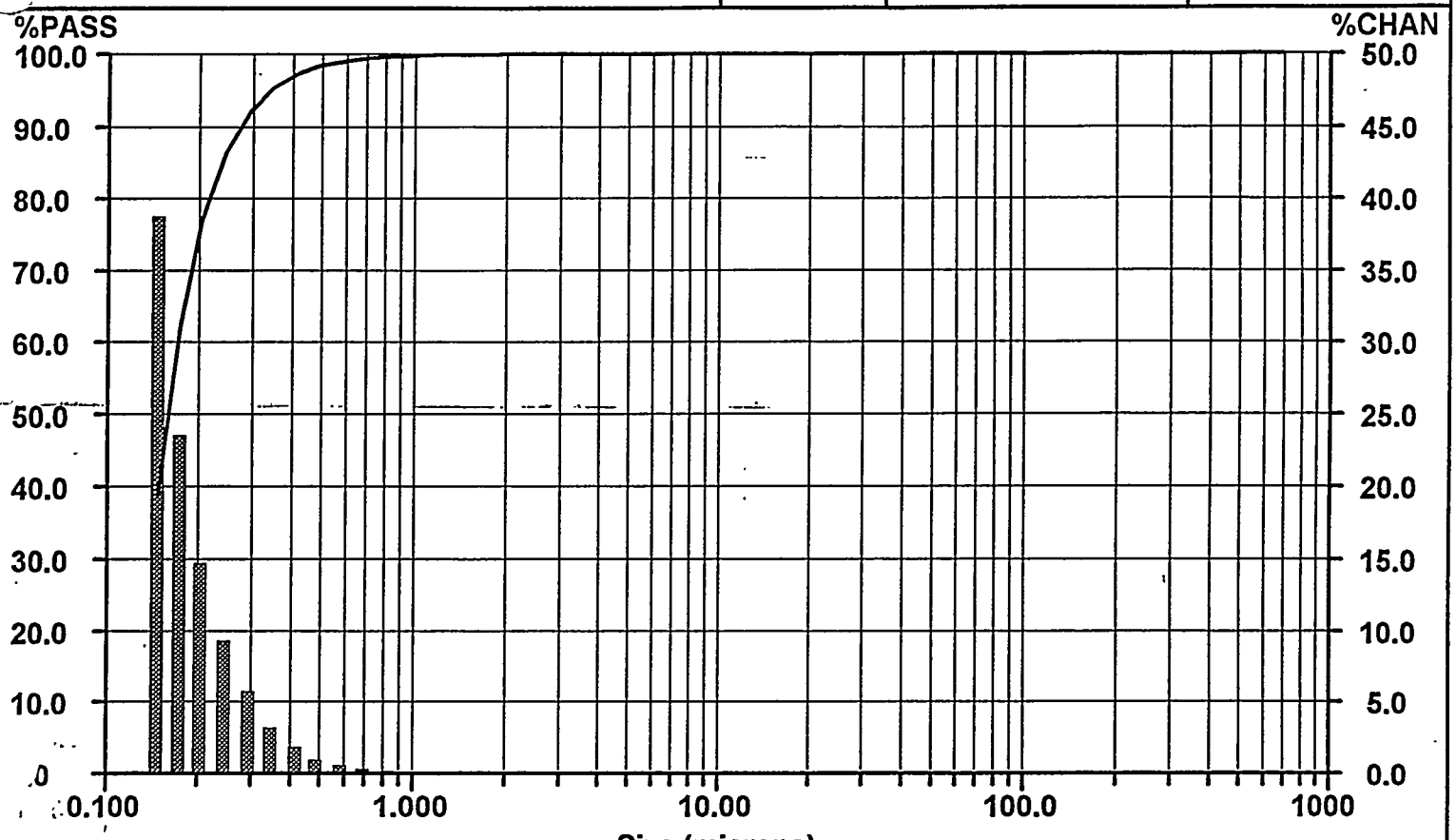
Particle Size Analysis

C106 Simulant
Sample S2-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 12:28 Pres #: N/A

C106 Simulant; Sample S2-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicate at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.638	10% = 0.128	60% = 0.168	0.155	100%	0.099
mn = 0.185	20% = 0.134	70% = 0.186			
ma = 0.727	30% = 0.139	80% = 0.213			
cs = 8.253	40% = 0.146	90% = 0.267			
sd = 0.049	50% = 0.155	95% = 0.331			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.02						
104.7	100.00	0.00	1.375	99.97	0.04						
88.00	100.00	0.00	1.156	99.93	0.08						
74.00	100.00	0.00	0.972	99.85	0.14						
62.23	100.00	0.00	0.818	99.71	0.24						
52.33	100.00	0.00	0.688	99.47	0.38						
44.00	100.00	0.00	0.578	99.09	0.63						
37.00	100.00	0.00	0.486	98.46	1.06						
31.11	100.00	0.00	0.409	97.40	1.83						
26.16	100.00	0.00	0.344	95.57	3.26						
22.00	100.00	0.00	0.289	92.31	5.76						
18.50	100.00	0.00	0.243	86.55	9.31						
15.56	100.00	0.00	0.204	77.24	14.76						
[illegible]08	100.00	0.00	0.172	62.48	23.65						
[illegible]0	100.00	0.00	0.145	38.83	38.83						

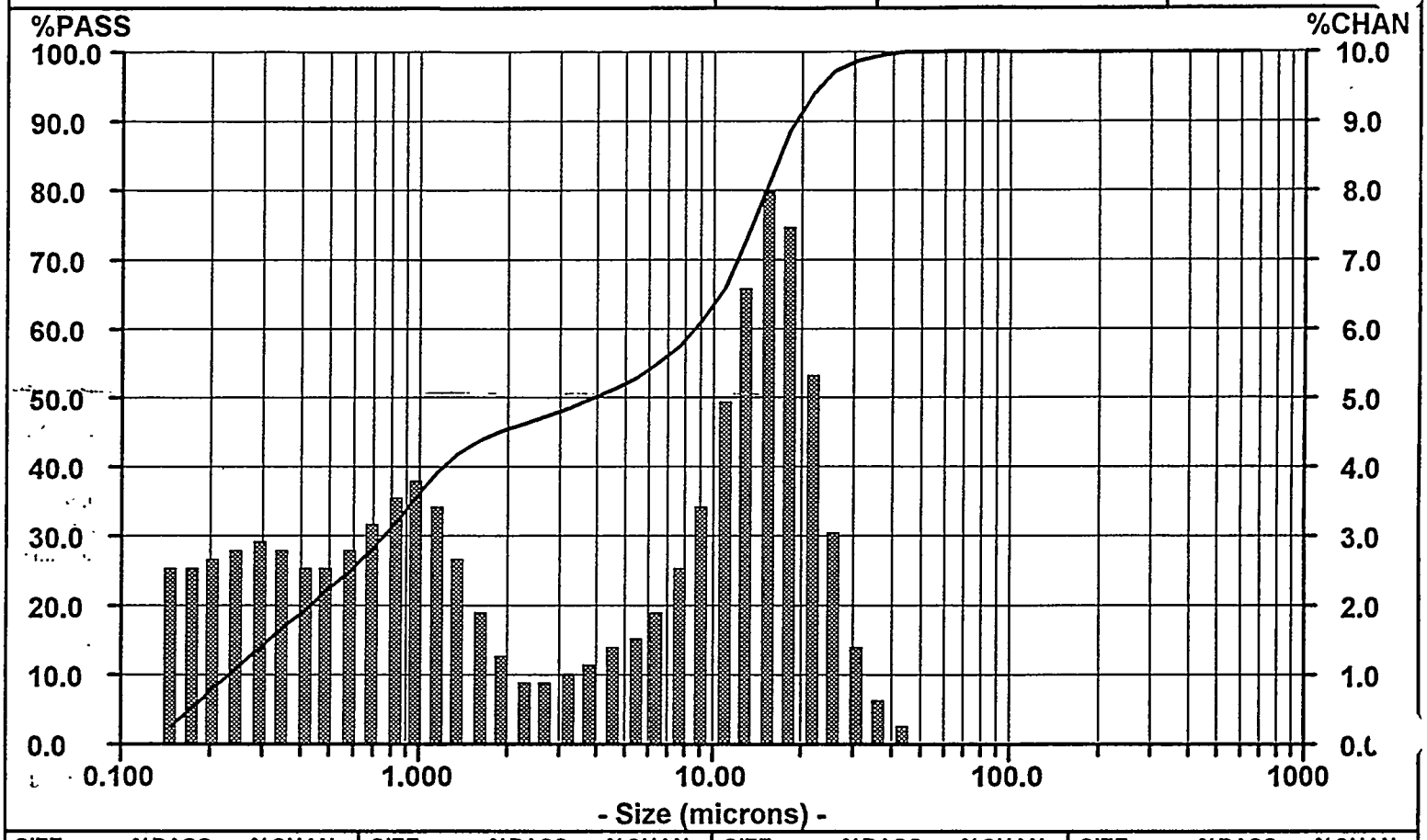
Particle Size Analysis

C106 Simulant
Sample S2-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 12:05 Pres #: N/A

C106 Simulant; Sample S2-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.624	10% = 0.230	60% = 8.752	13.12	54%	13.48
mn = 0.186	20% = 0.424	70% = 12.16	0.805	30%	0.868
ma = 0.761	30% = 0.746	80% = 15.20	0.212	16%	0.143
cs = 7.883	40% = 1.200	90% = 19.16			
sd = 8.119	50% = 3.963	95% = 22.81			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	61.27	3.57						
592.0	100.00	0.00	7.778	57.70	2.63						
497.8	100.00	0.00	6.541	55.07	2.06						
418.6	100.00	0.00	5.500	53.01	1.70						
352.0	100.00	0.00	4.625	51.31	1.46						
296.0	100.00	0.00	3.889	49.85	1.28						
248.9	100.00	0.00	3.270	48.57	1.12						
209.3	100.00	0.00	2.750	47.45	1.03						
176.0	100.00	0.00	2.312	46.42	1.08						
148.0	100.00	0.00	1.945	45.34	1.34						
124.5	100.00	0.00	1.635	44.00	1.91						
104.7	100.00	0.00	1.375	42.09	2.76						
88.00	100.00	0.00	1.156	39.33	3.54						
74.00	100.00	0.00	0.972	35.79	3.83						
62.23	100.00	0.00	0.818	31.96	3.64						
52.33	100.00	0.00	0.688	28.32	3.26						
44.00	100.00	0.37	0.578	25.06	2.91						
37.00	99.63	0.75	0.486	22.15	2.69						
31.11	98.88	1.56	0.409	19.46	2.65						
26.16	97.32	3.14	0.344	16.81	2.81						
22.00	94.18	5.47	0.289	14.00	3.01						
18.50	88.71	7.59	0.243	10.99	2.95						
15.56	81.12	8.05	0.204	8.04	2.76						
13.08	73.07	6.79	0.172	5.28	2.65						
11.00	66.28	5.01	0.145	2.63	2.63						

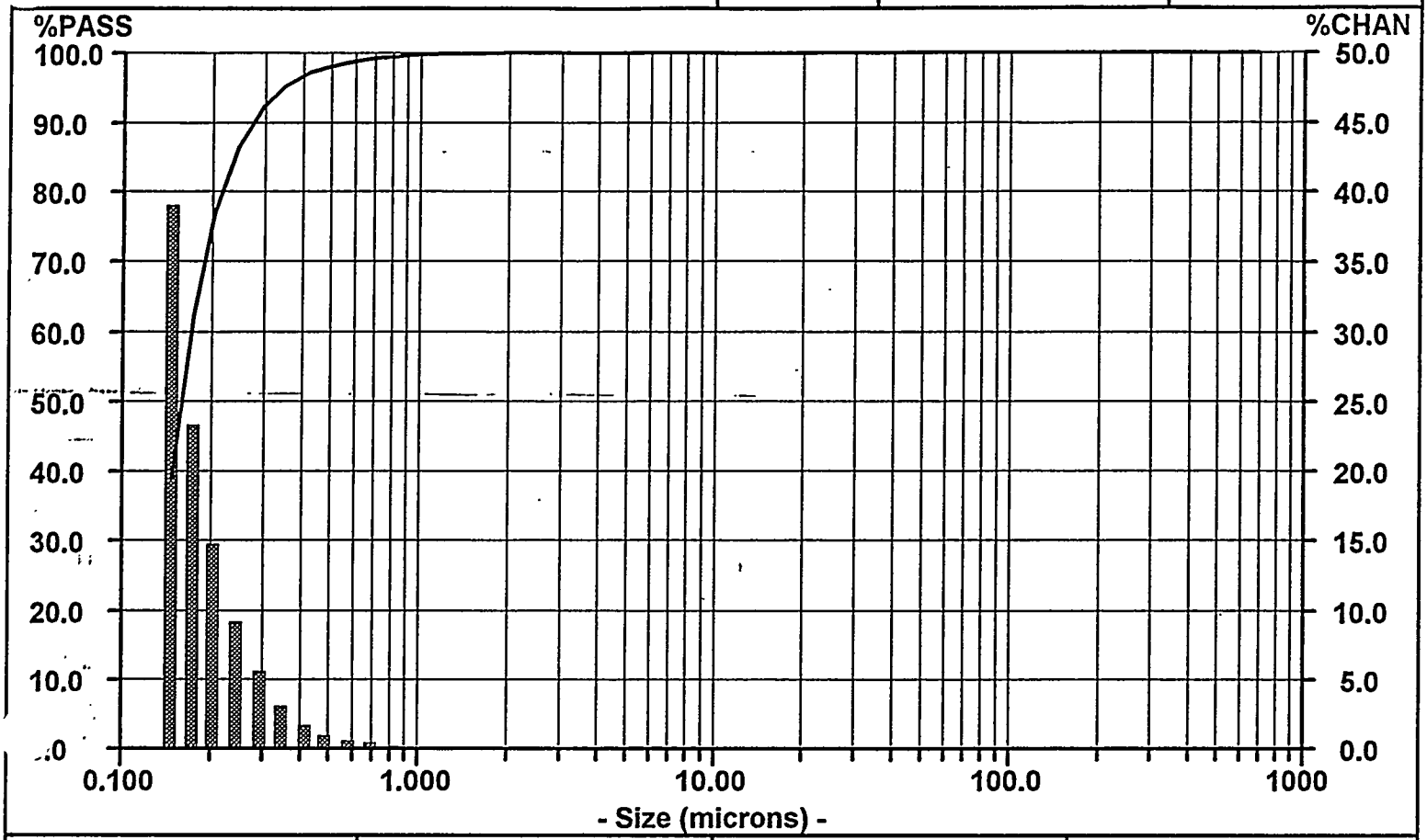
Particle Size Analysis

C106 Simulant
Sample S2-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 12:05 Pres #: N/A

C106 Simulant; Sample S2-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 7.624	10% = 0.128	60% = 0.168	0.155	100%	0.099
mn = 0.186	20% = 0.134	70% = 0.185			
ma = 0.761	30% = 0.138	80% = 0.213			
cs = 7.883	40% = 0.146	90% = 0.267			
sd = 0.049	50% = 0.155	95% = 0.335			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.00						
148.0	100.00	0.00	1.945	100.00	0.01						
124.5	100.00	0.00	1.635	99.99	0.02						
104.7	100.00	0.00	1.375	99.97	0.05						
88.00	100.00	0.00	1.156	99.92	0.10						
74.00	100.00	0.00	0.972	99.82	0.19						
62.23	100.00	0.00	0.818	99.63	0.30						
52.33	100.00	0.00	0.688	99.33	0.46						
44.00	100.00	0.00	0.578	98.87	0.68						
37.00	100.00	0.00	0.486	98.19	1.06						
31.11	100.00	0.00	0.409	97.13	1.76						
26.16	100.00	0.00	0.344	95.37	3.14						
22.00	100.00	0.00	0.289	92.23	5.65						
18.50	100.00	0.00	0.243	86.58	9.29						
15.56	100.00	0.00	0.204	77.29	14.75						
[illegible]08	100.00	0.00	0.172	62.54	23.47						
[illegible]0	100.00	0.00	0.145	39.07	39.07						

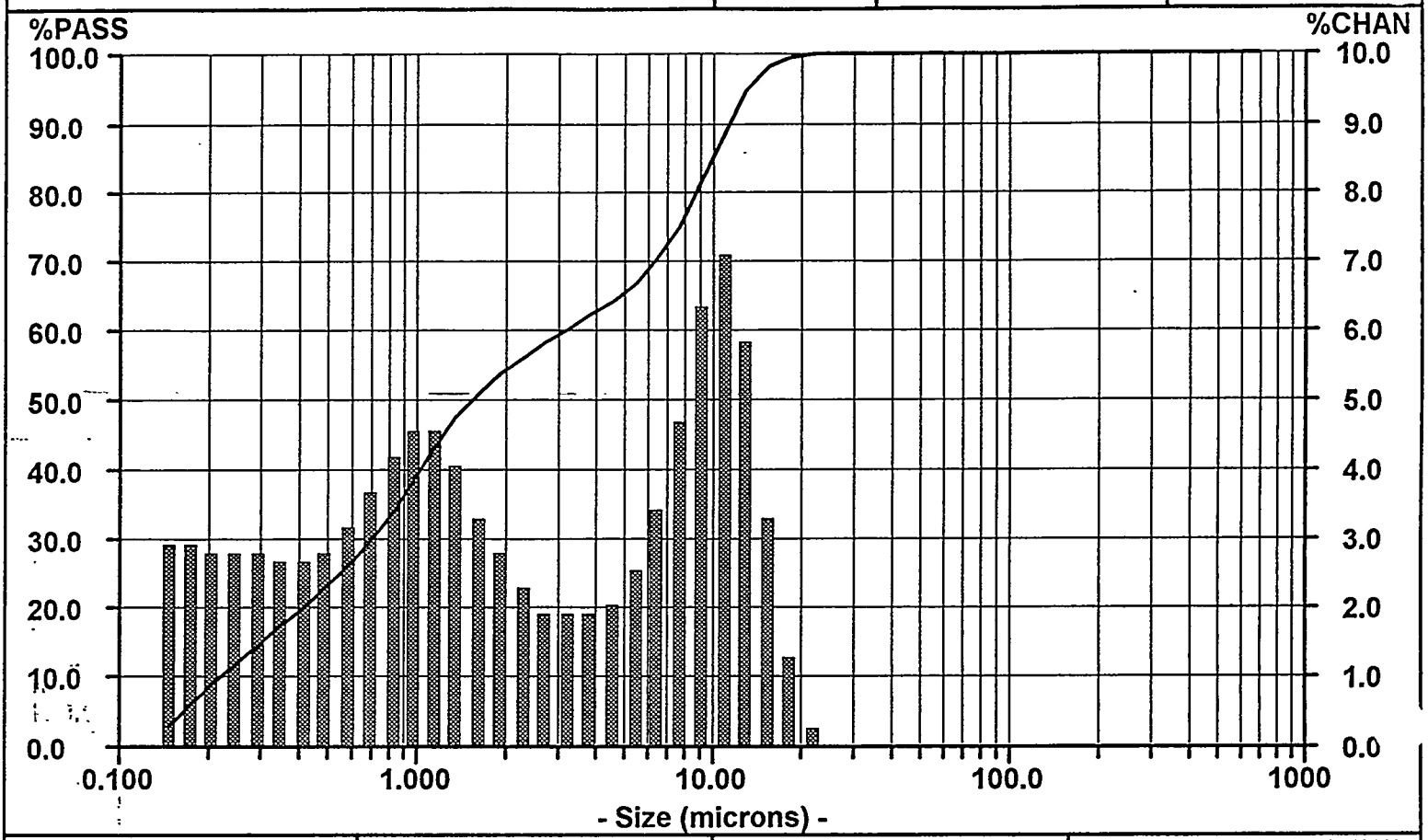
Particle Size Analysis

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
40 ml/sec

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:11 Pres #: N/A

Summary	Percentiles		Dia	Vol%	Width
mv = 4.149	10% = 0.218	60% = 3.196	8.645	42%	7.590
mn = 0.184	20% = 0.408	70% = 6.403	0.939	41%	1.184
ma = 0.688	30% = 0.693	80% = 8.838	0.205	17%	0.143
cs = 8.717	40% = 1.017	90% = 11.31			
sd = 4.720	50% = 1.542	95% = 13.13			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	81.81	6.43						
592.0	100.00	0.00	7.778	75.38	4.89						
497.8	100.00	0.00	6.541	70.49	3.51						
418.6	100.00	0.00	5.500	66.98	2.61						
352.0	100.00	0.00	4.625	64.37	2.15						
296.0	100.00	0.00	3.889	62.22	1.96						
248.9	100.00	0.00	3.270	60.26	1.95						
209.3	100.00	0.00	2.750	58.31	2.07						
176.0	100.00	0.00	2.312	56.24	2.34						
148.0	100.00	0.00	1.945	53.90	2.80						
124.5	100.00	0.00	1.635	51.10	3.47						
104.7	100.00	0.00	1.375	47.63	4.19						
88.00	100.00	0.00	1.156	43.44	4.67						
74.00	100.00	0.00	0.972	38.77	4.67						
62.23	100.00	0.00	0.818	34.10	4.26						
52.33	100.00	0.00	0.688	29.84	3.71						
44.00	100.00	0.00	0.578	26.13	3.21						
37.00	100.00	0.00	0.486	22.92	2.87						
31.11	100.00	0.00	0.409	20.05	2.71						
26.16	100.00	0.00	0.344	17.34	2.73						
22.00	100.00	0.35	0.289	14.61	2.84						
18.50	99.65	1.31	0.243	11.77	2.86						
15.56	98.34	3.44	0.204	8.91	2.89						
13.08	94.90	5.96	0.172	6.02	3.01						
11.00	88.94	7.13	0.145	3.01	3.01						

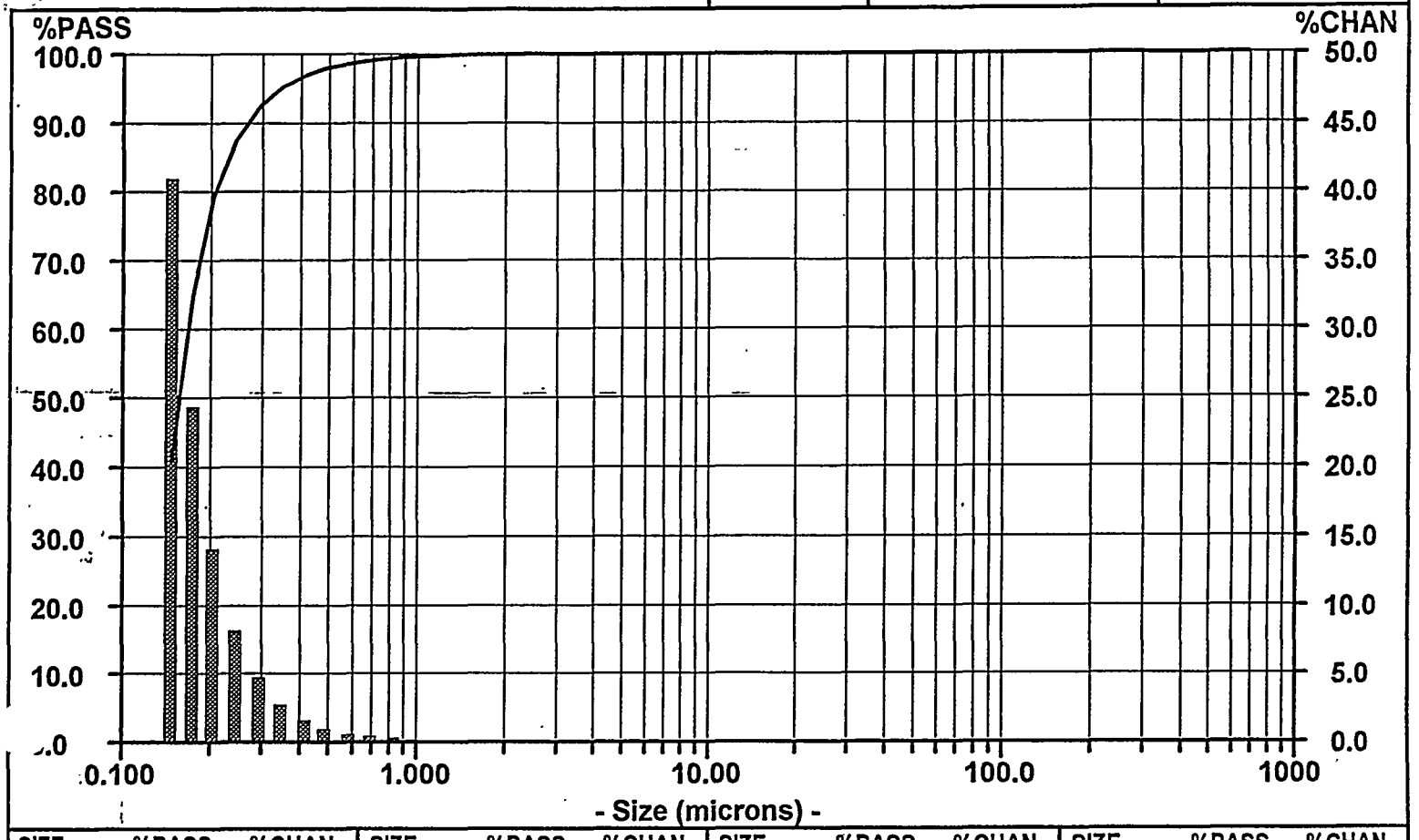
Particle Size Analysis

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:11 Pres #: N/A

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
40 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.149	10% = 0.128	60% = 0.164	0.152	100%	0.091
mn = 0.184	20% = 0.133	70% = 0.180			
ma = 0.688	30% = 0.138	80% = 0.206			
cs = 8.717	40% = 0.144	90% = 0.261			
sd = 0.046	50% = 0.152	95% = 0.334			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.02						
124.5	100.00	0.00	1.635	99.97	0.03						
104.7	100.00	0.00	1.375	99.94	0.07						
88.00	100.00	0.00	1.156	99.87	0.13						
74.00	100.00	0.00	0.972	99.74	0.21						
62.23	100.00	0.00	0.818	99.53	0.32						
52.33	100.00	0.00	0.688	99.21	0.47						
44.00	100.00	0.00	0.578	98.74	0.69						
37.00	100.00	0.00	0.486	98.05	1.03						
31.11	100.00	0.00	0.409	97.02	1.64						
26.16	100.00	0.00	0.344	95.38	2.79						
22.00	100.00	0.00	0.289	92.59	4.88						
18.50	100.00	0.00	0.243	87.71	8.25						
15.56	100.00	0.00	0.204	79.46	14.13						
[illegible]08	100.00	0.00	0.172	65.33	24.40						
[illegible]00	100.00	0.00	0.145	40.93	40.93						

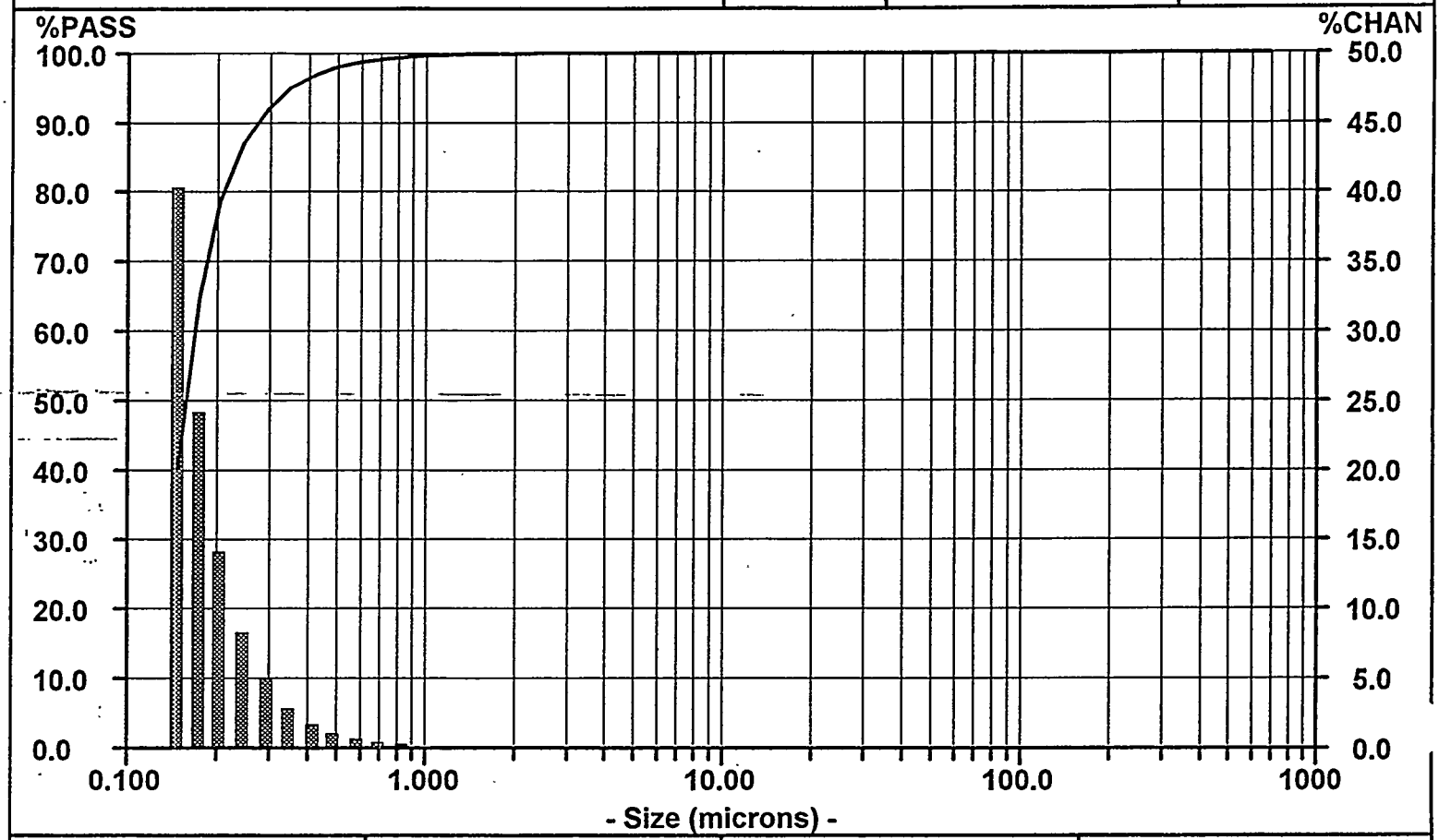
Particle Size Analysis

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:20 Pres #: N/A

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.203	10% = 0.128	60% = 0.165	0.153	100%	0.094
mn = 0.185	20% = 0.133	70% = 0.181			
ma = 0.662	30% = 0.138	80% = 0.208			
cs = 9.069	40% = 0.145	90% = 0.265			
sd = 0.047	50% = 0.153	95% = 0.341			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.01						
124.5	100.00	0.00	1.635	99.98	0.03						
104.7	100.00	0.00	1.375	99.95	0.05						
88.00	100.00	0.00	1.156	99.90	0.10						
74.00	100.00	0.00	0.972	99.80	0.19						
62.23	100.00	0.00	0.818	99.61	0.31						
52.33	100.00	0.00	0.688	99.30	0.49						
44.00	100.00	0.00	0.578	98.81	0.75						
37.00	100.00	0.00	0.486	98.06	1.15						
31.11	100.00	0.00	0.409	96.91	1.79						
26.16	100.00	0.00	0.344	95.12	2.95						
22.00	100.00	0.00	0.289	92.17	5.00						
18.50	100.00	0.00	0.243	87.17	8.31						
15.56	100.00	0.00	0.204	78.86	14.19						
13.08	100.00	0.00	0.172	64.67	24.30						
11.00	100.00	0.00	0.145	40.37	40.37						

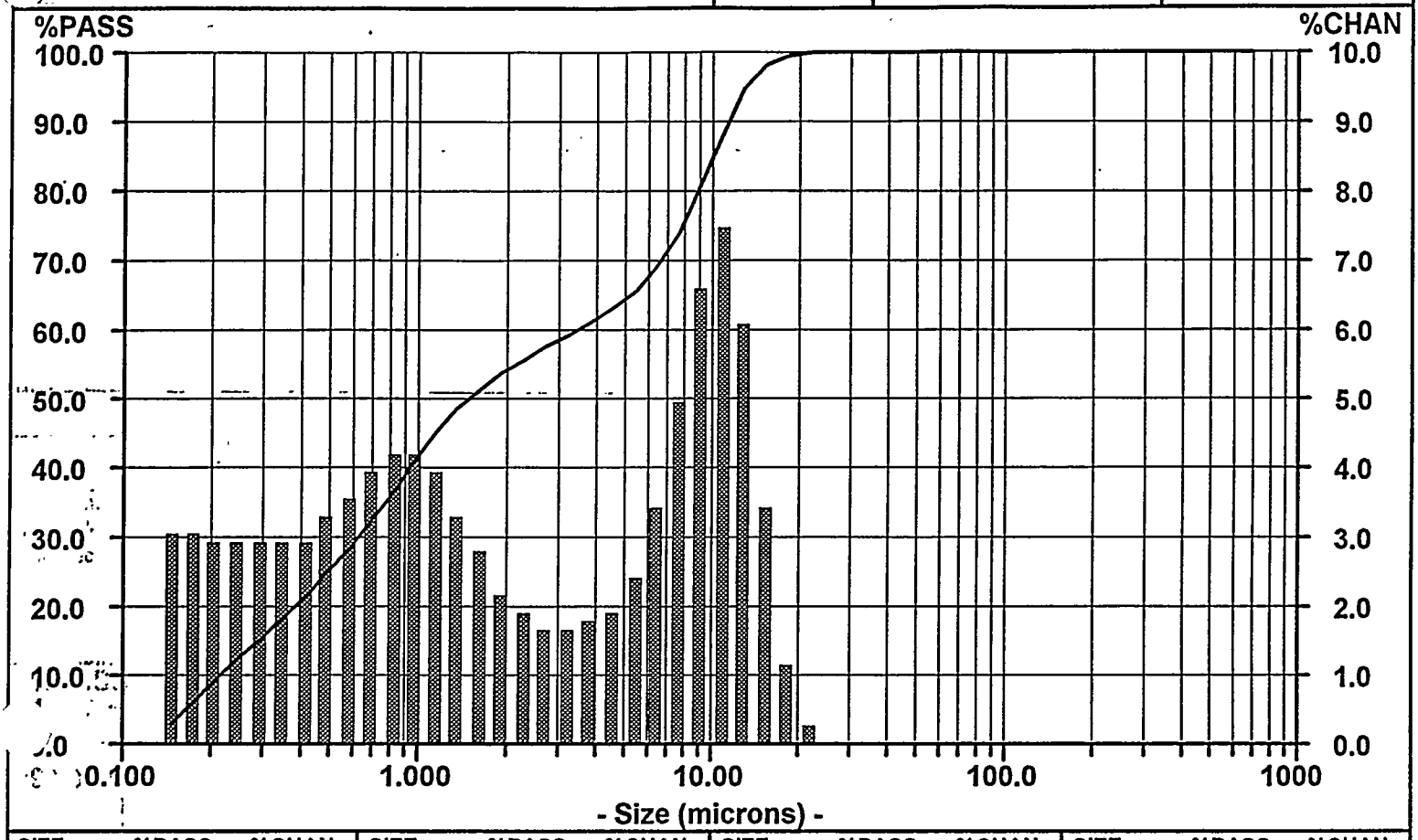
Particle Size Analysis

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:20 Pres #: N/A

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.203	10% = 0.212	60% = 3.485	8.744	42%	7.384
mn = 0.185	20% = 0.377	70% = 6.711	0.806	42%	1.134
ma = 0.662	30% = 0.618	80% = 9.003	0.243	6%	0.058
cs = 9.069	40% = 0.926	90% = 11.38	0.160	10%	0.052
sd = 4.791	50% = 1.477	95% = 13.14			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	81.14	6.74						
592.0	100.00	0.00	7.778	74.40	5.05						
497.8	100.00	0.00	6.541	69.35	3.54						
418.6	100.00	0.00	5.500	65.81	2.58						
352.0	100.00	0.00	4.625	63.23	2.06						
296.0	100.00	0.00	3.889	61.17	1.82						
248.9	100.00	0.00	3.270	59.35	1.74						
209.3	100.00	0.00	2.750	57.61	1.78						
176.0	100.00	0.00	2.312	55.83	1.95						
148.0	100.00	0.00	1.945	53.88	2.29						
124.5	100.00	0.00	1.635	51.59	2.83						
104.7	100.00	0.00	1.375	48.76	3.48						
88.00	100.00	0.00	1.156	45.28	4.07						
74.00	100.00	0.00	0.972	41.21	4.36						
62.23	100.00	0.00	0.818	36.85	4.32						
52.33	100.00	0.00	0.688	32.53	4.05						
44.00	100.00	0.00	0.578	28.48	3.68						
37.00	100.00	0.00	0.486	24.80	3.33						
31.11	100.00	0.00	0.409	21.47	3.09						
26.16	100.00	0.00	0.344	18.38	3.02						
22.00	100.00	0.33	0.289	15.36	3.05						
18.50	99.67	1.29	0.243	12.31	3.02						
15.56	98.38	3.50	0.204	9.29	3.04						
08	94.88	6.23	0.172	6.25	3.14						
00	88.65	7.51	0.145	3.11	3.11						

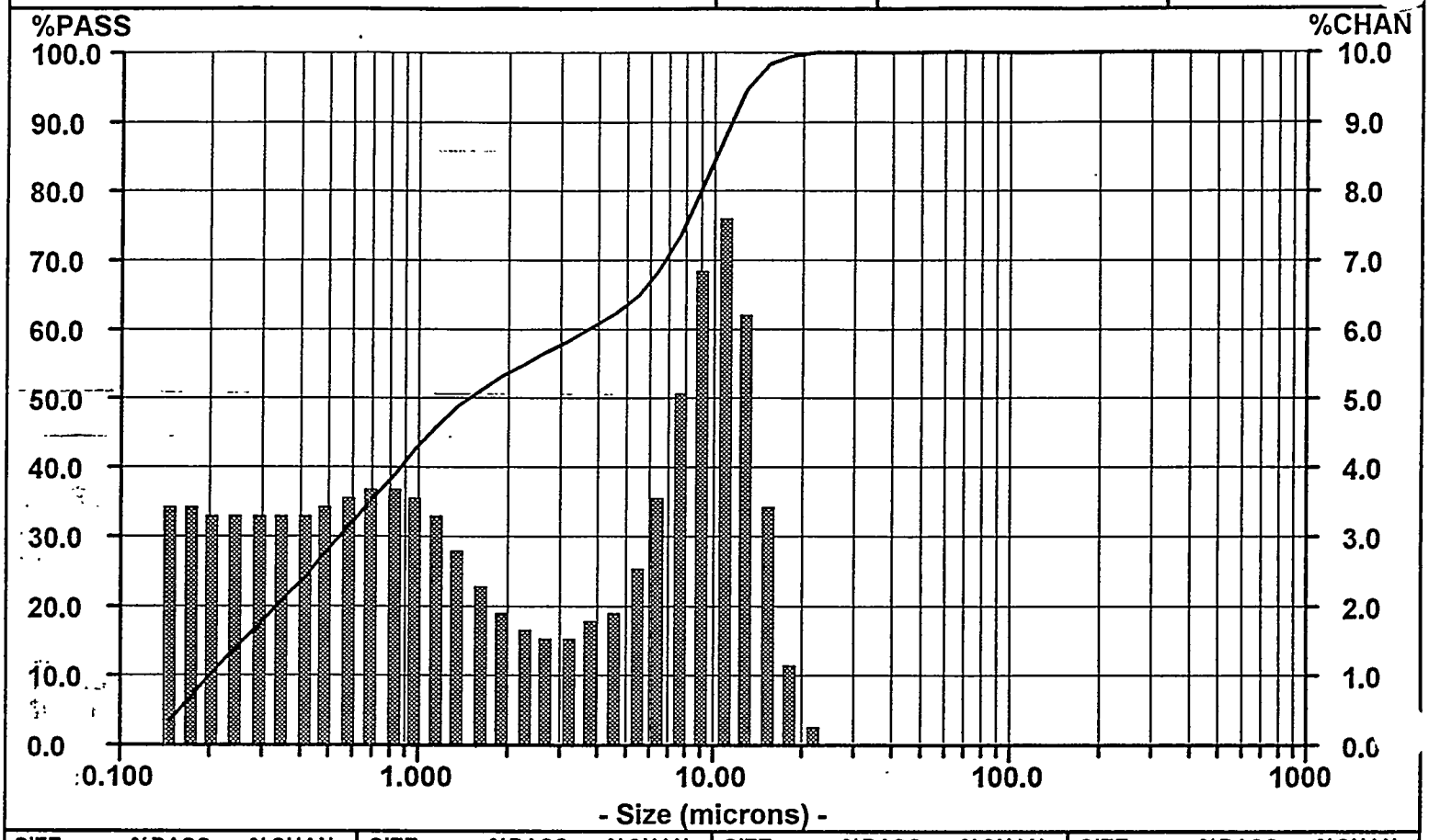
Particle Size Analysis

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:32 Pres #: N/A

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicated at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.237	10% = 0.198	60% = 3.763	8.584	45%	7.707
mn = 0.182	20% = 0.328	70% = 6.884	0.720	38%	1.001
ma = 0.618	30% = 0.538	80% = 9.094	0.243	7%	0.058
cs = 9.717	40% = 0.853	90% = 11.41	0.160	10%	0.052
sd = 4.841	50% = 1.479	95% = 13.15			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	80.74	6.93						
592.0	100.00	0.00	7.778	73.81	5.16						
497.8	100.00	0.00	6.541	68.65	3.61						
418.6	100.00	0.00	5.500	65.04	2.61						
352.0	100.00	0.00	4.625	62.43	2.07						
296.0	100.00	0.00	3.889	60.36	1.81						
248.9	100.00	0.00	3.270	58.55	1.70						
209.3	100.00	0.00	2.750	56.85	1.70						
176.0	100.00	0.00	2.312	55.15	1.79						
148.0	100.00	0.00	1.945	53.36	2.02						
124.5	100.00	0.00	1.635	51.34	2.40						
104.7	100.00	0.00	1.375	48.94	2.88						
88.00	100.00	0.00	1.156	46.06	3.33						
74.00	100.00	0.00	0.972	42.73	3.64						
62.23	100.00	0.00	0.818	39.09	3.77						
52.33	100.00	0.00	0.688	35.32	3.76						
44.00	100.00	0.00	0.578	31.56	3.67						
37.00	100.00	0.00	0.486	27.89	3.55						
31.11	100.00	0.00	0.409	24.34	3.44						
26.16	100.00	0.00	0.344	20.90	3.42						
22.00	100.00	0.32	0.289	17.48	3.47						
18.50	99.68	1.27	0.243	14.01	3.42						
15.56	98.41	3.54	0.204	10.59	3.45						
13.08	94.87	6.39	0.172	7.14	3.59						
11.00	88.48	7.74	0.145	3.55	3.55						

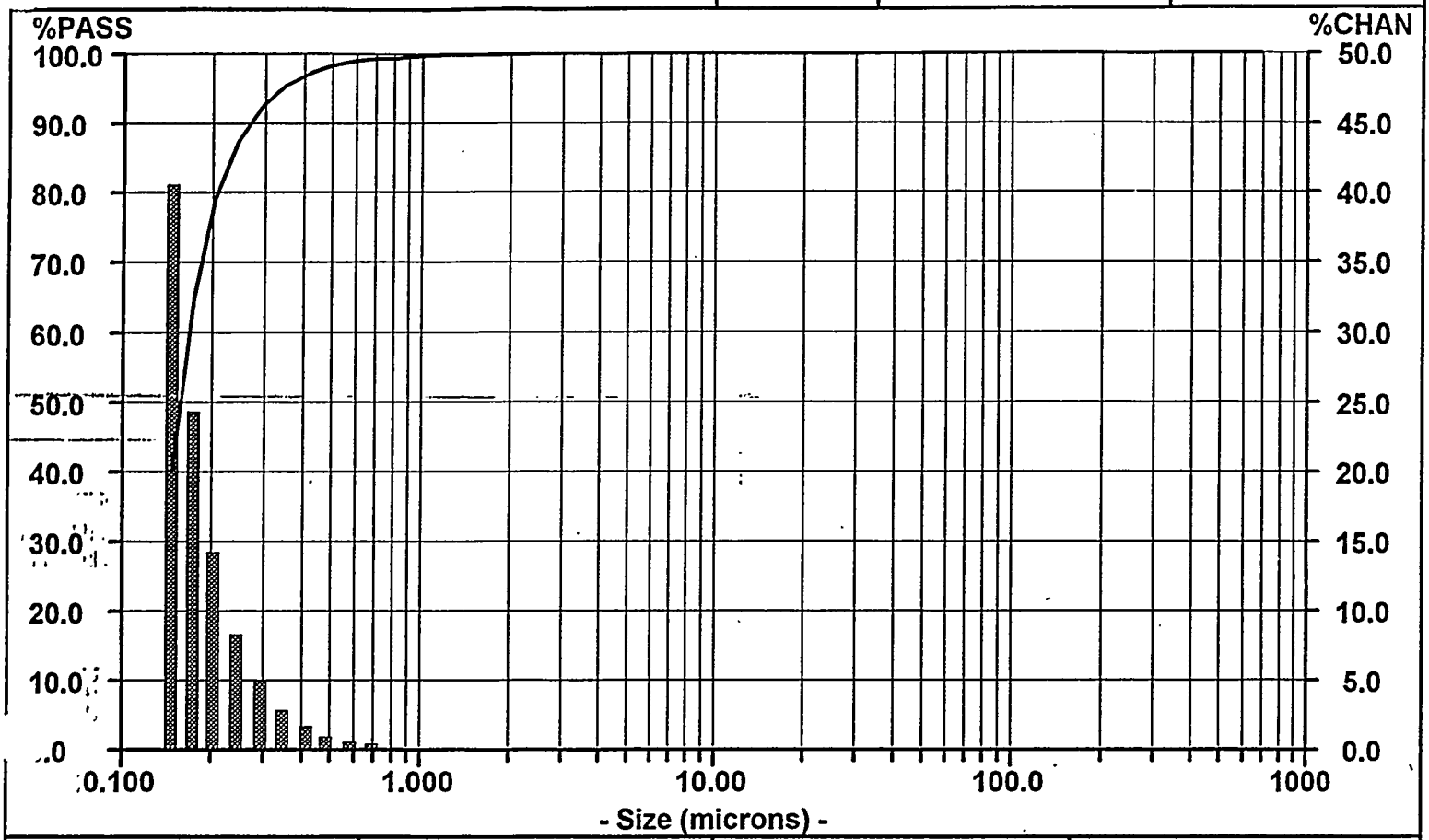
Particle Size Analysis

C106 Simulant
Sample S4-1/17

Date: 02/07/ 0 Meas #: N/A
Time: 14:32 Pres #: N/A

C106 Simulant; Sample S4-1/17
in 1.0 M NaOH/1.0 M NaNO3 solution
Sonicated at 40 W for 90 sec; 60 ml/sec

Summary	Percentiles		Dia	Vol%	Width
mv = 4.237	10% = 0.128	60% = 0.165	0.153	100%	0.092
mn = 0.182	20% = 0.133	70% = 0.180			
ma = 0.618	30% = 0.138	80% = 0.207			
cs = 9.717	40% = 0.145	90% = 0.261			
sd = 0.046	50% = 0.153	95% = 0.330			



SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN	SIZE	%PASS	%CHAN
704.0	100.00	0.00	9.250	100.00	0.00						
592.0	100.00	0.00	7.778	100.00	0.00						
497.8	100.00	0.00	6.541	100.00	0.00						
418.6	100.00	0.00	5.500	100.00	0.00						
352.0	100.00	0.00	4.625	100.00	0.00						
296.0	100.00	0.00	3.889	100.00	0.00						
248.9	100.00	0.00	3.270	100.00	0.00						
209.3	100.00	0.00	2.750	100.00	0.00						
176.0	100.00	0.00	2.312	100.00	0.01						
148.0	100.00	0.00	1.945	99.99	0.01						
124.5	100.00	0.00	1.635	99.98	0.02						
104.7	100.00	0.00	1.375	99.96	0.04						
88.00	100.00	0.00	1.156	99.92	0.08						
74.00	100.00	0.00	0.972	99.84	0.14						
62.23	100.00	0.00	0.818	99.70	0.24						
52.33	100.00	0.00	0.688	99.46	0.40						
44.00	100.00	0.00	0.578	99.06	0.66						
37.00	100.00	0.00	0.486	98.40	1.08						
31.11	100.00	0.00	0.409	97.32	1.76						
26.16	100.00	0.00	0.344	95.56	2.94						
22.00	100.00	0.00	0.289	92.62	5.02						
18.50	100.00	0.00	0.243	87.60	8.30						
15.56	100.00	0.00	0.204	79.30	14.20						
08	100.00	0.00	0.172	65.10	24.49						
00	100.00	0.00	0.145	40.61	40.61						

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