PNWD-3216
WTP-RPT-019, Rev 0

Performance of Tubular Porous Metal Crossflow Filters

G. R. Golcar

November 2002

Prepared for Bechtel National Inc.
under Contract No. 24590-101-TSA-W0000-0004

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Battelle, Pacific Northwest Division
Richland, Washington, 99352

Completeness of Testing

This report describes the results of work and testing not specified by a test plan or test specification. The work and any associated testing followed the quality assurance requirements of the WTP Support Project. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

_____________________________________ _________________

Gordon H. Beeman, Manager Date
WTP R&T Support Project

_____________________________________ _________________

G. Todd Wright, Manager Date
Research and Technology

Summary

In the course of developing Envelope D simulants for scaled crossflow filtration testing in support of the River Protection Project-Waste Treatment Plant (RPP-WTP) project documented in Golcar et al. (2000), simulants were tested in the cell unit filter (CUF) and a large number of crossflow filtration flux results were obtained using a 0.1-micron Graver, a 0.1-micron liquid-service, industrial-grade Mott, and 0.5-micron liquid-service, industrial-grade Mott filter elements. The goal of conducting parametric CUF tests with various filter elements was to replicate the operating and experimental conditions of the actual waste trials and to validate simulant filtration performance. A large amount of filtration data were obtained but only those results that provided direct simulant filtration performance data compared with actual waste results were reported (Golcar et al. 2000).

The objective of this report is to document the unpublished crossflow filtration data generated from testing the Envelope D HLW filtration simulants during the development phase of these simulants. This report is merely a compilation of previous test data and mostly not the work performed directly in support of the WTP. The goal of testing in FY 2000 was not to examine the performance of various filters in a comprehensive parametric fashion, but because these data provide valuable insight into optimum filter elements for the design of the WTP they are presented in this report. A detailed filtration flux data package for each filter element at various test matrix conditions is also provided in this document.

Filter flux data were measured using the C-106 and AZ-101/102 filtration simulants at various slurry solids loadings. The experiments were conducted in a Battelle-constructed CUF testing apparatus with a single-tube filter module similar to the system used for the radioactive waste testing. The C-106 simulant was tested in the CUF at two series of "low" and "high" axial velocities (6–9 ft/sec and 9–12 ft/sec) and transmembrane pressures (12.5–35 psid versus 30–70 psid) at 8 wt% insoluble solids loading. The AZ-101/102 simulant was tested only at "high" testing conditions at 5 and 15 wt% insoluble solids. In all tests the filtrate was recycled back into the feed tank to maintain a constant solids concentration. The baseline 0.1-micron industrial grade, Mott stainless steel filter was compared with a 0.5-micron industrial grade, Mott stainless steel filter and a 0.1-micron "Scepter" Graver filter. A list of filtration flux data for each filter type is summarized in Table S.1.

Table S.1. List of Filtration Flux Data Discussed in This Report

Filter Element	C-106 Simulant at 8 wt%, "Low" Conditions	C-106 Simulant at 8 wt%, "High" Conditions	AZ-101/102 Simulant at 5 wt%, "High" Conditions	AZ101/102 Simulant at 15 wt%, "High" Conditions
0.1-micron Mott Industrial Grade	Not Available	9–12 ft/sec; 30–70 psid	7.2–13.1 ft/sec; 30–70 psid	6–11.5 ft/sec; 30–70 psid
0.5-micron Mott Industrial Grade	4.5–9 ft/sec; 12.5–35 psid	9–12 ft/sec; 30–70 psid	7.2–13.1 ft/sec; 30–70 psid	6–11.5 ft/sec; 30–70 psid
0.1-micron Graver	4.5–9 ft/sec; 12.5–35 psid	Not Available	Not Available	Not Available

The filtrate fluxes for the C-106 simulant at “low” testing conditions of 4.5–9 ft/sec axial velocity and 12.5–35 psid transmembrane pressure indicate that, overall, the filtrate fluxes were similar when the simulant was crossflow-filtered either with the 0.5-micron industrial grade Mott filter or the 0.1-micron Graver filter. A closer examination of the center point (20 psid and 6 ft/sec) flux data show that in the course of ~8 hours of CUF operation, the performance of the 0.1-micron Graver filter was less sensitive (or almost insensitive) to particle deagglomeration and subsurface pore plugging than the 0.5-micron industrial grade Mott filter.

The results for the C-106 simulant at “high” testing conditions of 9–12 ft/sec axial velocity and 30–70 psid transmembrane pressure indicate that the fluxes of the 0.1-micron industrial grade Mott filter for all run conditions are greater than those achieved with 0.5-micron, liquid-service, industrial-grade Mott filter. Depending on the test matrix conditions, the filtrate flux with the 0.1-micron liquid-service Mott filter were 14% to 450% greater than the results with 0.5-micron, liquid-service Mott filter.

Similarly, for all run conditions with the AZ-101/102 simulant, the average filtrate fluxes with 0.1-micron industrial grade Mott filter were greater than the fluxes observed with 0.5-micron, liquid-service, industrial-grade Mott filter at 5 wt% insoluble solids. The results support our conclusion that the larger pore size of the 0.5-micron Mott filter caused the filter to be more susceptible to internal/subsurface fouling.

Reference

Golcar GR, KP Brooks, JG Darab, JM Davis, and LK Jagoda. 2000. *Development of Inactive High-Level Waste Envelope D Simulants for Scaled Crossflow Filtration Testing.* BNFL-RPT-033 Rev. 0, PNWD-3042, Battelle Pacific Northwest Division, Richland, Washington.

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Acronyms

CUF	cell unit filter
HLW	high-level waste
LAW	low-activity waste
PSD	particle-size distribution
RPP-WTP	River Protection Project-Waste Treatment Plant
SST	single-shell tank
TMP	transmembrane pressure
BNI	Bechtel National Inc.

1.0 Introduction

The baseline flow sheets for the River Protection Project-Waste Treatment Plant (RPP-WTP) indicate the use of a crossflow filtration system for solid-liquid separation of low-activity waste (LAW) and high-level waste (HLW) streams (DOE-RL 1996). The RPP-WTP flow sheets also use crossflow filtration to separate the leach and wash solutions from the solids between each step. The work reported compares the performance of various tubular porous metal filters examined in the cell unit filter (CUF) filtration rig fabricated at Battelle.

In the course of developing Envelope D- simulants for scaled cross flow filtration testing in support of the RPP-WTP project, simulants were tested in the CUF, and a large number of crossflow filtration flux results were obtained. The tests were conducted to examine and verify the filtration performance of formulated simulants relative to the available actual waste data at filter media and operating conditions similar to those used in the actual waste testing. The CUF testing conducted in FY 2000 was not aimed at examining the performance of various filters in a comprehensive parametric fashion. This report is merely a compilation of previous test data and mostly not the work performed directly in support of the WTP.

CUF trials were conducted at various axial velocity and transmembrane pressure conditions using a 0.1-micron Graver filter, a 0.1-micron liquid-service, industrial-grade Mott filter, and 0.5-micron industrial-grade, Mott filter elements. The entire set of simulant CUF testing results with various filters was not included in the Envelope-D HLW simulant development report prepared in FY 2000 (Golcar et al. 2000). Only the simulant CUF results that provide direct comparison with the available actual waste data were reported. The results of unpublished crossflow filtration tests for 0.1-micron Graver filter and 0.5-micron liquid-service, industrial-grade Mott filter provide valuable insight in determining the performance of alternative filter media against the baseline Mott 0.1-micron liquid-service, industrial-grade filter. Thus, the Bechtel filtration design team has requested that Battelle prepare and publish a document describing these comparative CUF results.

1.1 Objectives

The specific objectives of this report are to:

- Document the unpublished crossflow filtration data produced from testing the Envelope-D HLW filtration simulants in support of the RPP-WTP project.
- Compare the filtrate flux rates of the baseline 0.1-micron Mott filter media with the filtrate flux rates of the 0.5-micron Mott filter and 0.1-micron Graver filter at the same axial velocity and transmembrane pressure conditions.
- Describe the HLW filtration simulant slurries used in these CUF trials and their solids loadings.
- Provide details of the CUF testing matrix and the experimental apparatus.
- Present the filtrate flux profiles as a function of time for tested filter elements.
- Provide a detailed crossflow filtration raw data package sustaining tested filters performance evaluation.

2.0 Experimental

The filtration simulant slurries were tested at various slurry solids loadings. A Battelle-constructed CUF testing apparatus and single tube filter modules similar to the system for the radioactive testing were used. The specifics of the slurry materials, equipment description, filter element ratings and dimensions, and testing conditions are described in the following sections.

2.1 Tested Slurry Materials

The AZ-101/102 and C-106 Envelope-D HLW simulants developed by Battelle for the crossflow filtration equipment testing were used (Golcar et al. 2000) in evaluating the performance of various filter elements. In this document the filtrate flux data at 8 wt% insoluble solids are presented for the tests with the C-106 filtration simulant. In the case of testing with the AZ-101/102 filtration simulant, the CUF results at 5 and 15 wt% insoluble solids are discussed.

Because the morphology of the AZ-101/102 and C-106 filtration slurry simulants are unique, the performance of the filter elements is examined for two different types of slurries (see section 3.2 for detail). The solids morphology and agglomeration/deagglomeration of the AZ-101/102 simulant is driven by the high concentration of iron-bearing solids, whereas the C-106 simulant morphology is influenced by the high concentration of aluminum-bearing solids. The difference in the morphology of these two simulants induces variation in the declining behavior of the filtrate flux over the course of testing as a result of particle deagglomeration, cake enrichment with fine particles over time, and filter plugging.

The simulant formulations are described in Appendix A. Detailed characteristics of these simulants, the formulation rationale, and the supporting CUF validation performance against radioactive CUF trials are described in Golcar et al. (2000).

2.2 Equipment Description

The Battelle-constructed CUF testing apparatus and single-tube filter modules were used for this work. The filtration test target conditions (presented in Tables 2.3 and 2.4) were based on the conditions used for the actual C-104 and AZ-102 CUF testing. In the actual waste CUF testing, these conditions were used to determine the optimum waste feed dewatering conditions.

2.2.1 Filter Media Specification

The baseline 0.1-micron rated Mott liquid-service stainless steel filter was compared with a 0.5-micron liquid-service stainless steel Mott filter and a 0.1-micron “Scepter” Graver filter. The engineering properties and dimensions of tested filters are summarized in Table 2.1.

Table 2.1. Properties and Dimensions of Tested Porous Metal Filters

Filter Media	Micron Grade	Outer Diameter (in)	Inner Diameter (in)	Porous Element Length (in)
Liquid-service, industrial-grade Mott	0.1	0.500	0.375	24
Liquid-service, industrial-grade Mott	0.5	0.625	0.500	6
"Scepter" Graver	0.1	--	0.250	24

The liquid-service Mott filters are seamless tubes fabricated by sintering 316 stainless steel pregraded particles. The pore size is controlled by the size of primary particles and the sintering condition. The pore size distribution is controlled uniformly within the thickness of the filter. Both Mott filters are 0.0625 inches wall thickness.

The "Scepter" Graver filter is a coated ceramic stainless steel filter that is fabricated by applying a thin layer of sintered titanium dioxide coating, 0.1-micron pore size, that is bonded to the porous stainless steel substrate tube of 1.0-micron pore size. The resulting Graver filter has 0.1-micron pores at the surface and a more open internal structure to reduce overall filter resistance.

2.2.2 Test Apparatus and Operation

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, as described in Section 2.2.1
- recirculation flow such that 5 m/s (15ft/sec) 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 2.1. 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 transmembrane 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 slurry temperature was maintained at 25 ± 5°C for all filtrate rate testing. The flux was corrected (for both simulant and actual waste) to 25°C using the formula (Equation 2.1) provided by Bechtel National Inc. (BNI) to correct for viscosity and surface tension changes:

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

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

Because the RPP-WTP project has plans to operate the crossflow filtration system at higher axial velocity and transmembrane pressure, the C-106 and AZ-101/102 simulants were also tested at these higher experimental conditions. The HLW filtration test conditions were based on a 5-point matrix around the center-point at 50 psid and 12.2 ft/sec, transmembrane pressures of 30, 50, and 70 psid, and a velocity range of 9.1–13.1ft/sec.

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. The system was back pulsed twice between each condition except during the testing at conditions similar to those conducted on actual waste samples (see Brooks et al. 2000a,b). The 0.1- and 0.5-micron Mott filters were used for these test series. The slurry temperature was maintained at 25 ± 5°C for all filtration testing.

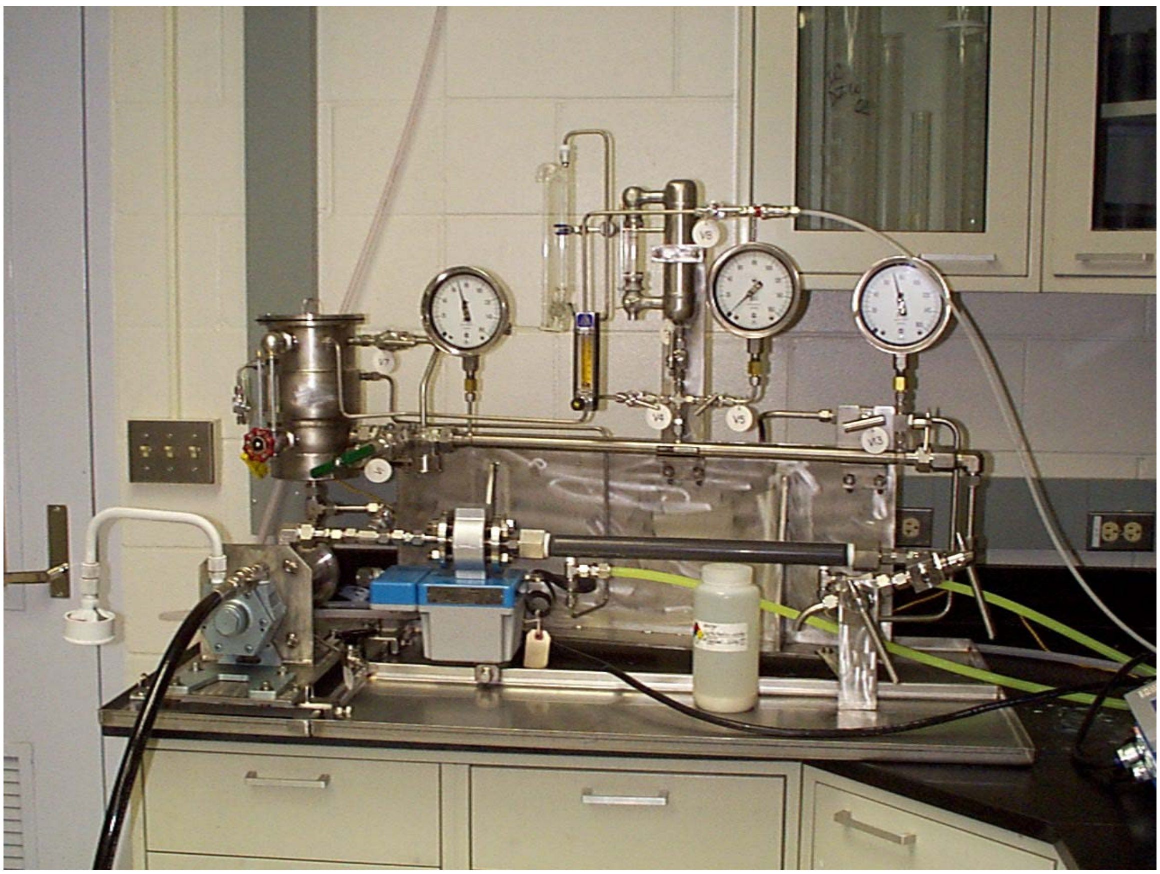

Figure 2.1. Photograph of the Cold Crossflow Filtration System

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 demineralized 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 and are presented in Table 2.2 for the 0.1 micron Graver filter, and the 0.1 and 0.5 micron Liquid-service Industrial-grade Mott Filters. Once the filtration flux exceeded the listed fluxes in Table 2.2 and were maintained constant for 30 minutes, the filter was considered clean and the next set of test were performed.

Table 2.2. Clean Water Flux for 0.1 Micron Graver, 0.1 and 0.5 Micron Liquid-Service, Industrial-Grade Mott Filters

Trans-Membrane Pressure (psid)	Flux (gpm/ft^2)		
	Graver Filter 0.1-micron	Mott Filter 0.1-micron	Mott Filter 0.5-micron
10	0.072	1.0	2.8
20	0.132	2.5	5.0
30	0.215	2.8	7.4

2.3 Experimental Matrix

The target axial velocity and transmembrane pressures for the low and high testing condition series using C-106 filtration simulant at 8 wt% insoluble solids are presented in Table 2.3.

The C-106 simulant was tested in the CUF at two distinct series of low and high axial velocities and transmembrane experimental conditions. The solids loading in the C-106 slurry simulant was 8 wt% insoluble solids for both the low and high series. The AZ-101/102 simulant was tested only at high testing conditions.(1) The AZ-101/102 simulant was tested at 5 and 15 wt% insoluble solids. In all tests the filtrate was recycled back into the feed tank to maintain the steady-state solids concentration.

Table 2.3. The C-106 Filtration Simulant "Low" Testing Condition Series Target conditions

"Low" Testing Condition Series 0.1 Micron Graver and 0.5 Micron Mott Filters			"High" Testing Condition Series 0.1 and 0.5 Micron Mott Filters		
Condition #	Target Velocity (ft/s)	Target Pressure (psid)	Condition #	Target Velocity (ft/s)	Target Pressure (psid)
1	6	20	1	12.2	50
2	4.5	12.5	2	9.2	30
3	9	20	3	11.3	70
4	6	35	4	11.4	30
5	6	20	5	9.1	70
6	6	5	6	12.2	50
7	7.5	27			
8	6	20			

(1) As discussed in Golcar et al. (2000), at the time of developing the AZ-101/102 filtration simulant, no actual waste CUF data were available to examine the performance of the developed simulant. Efforts were made to create a simulant that exhibited a declining flux behavior over time (in terms of the one-hour run time and over the entire testing matrix), similar to that seen in the CUF testing of most actual waste samples.

For the low testing condition series the axial velocities of 3–7.5 ft/sec and transmembrane pressures of 5–35 psid were targeted. The C-106 simulant CUF testing in the low testing condition series was driven by emulating the same CUF testing condition conducted on the actual C-106 waste (see Geeting and Reynolds 1997). Each condition was tested for 60 minutes with back pulsing 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 back-pulsed twice. The 0.1-micron Graver and 0.5-micron Mott filters were used for the low testing condition series.

Filter back pulsing was conducted by opening a toggle valve and allowing the back-pulse chamber to fill with filtrate. The toggle valve was then closed and the back-pulse chamber was pressurized with air at approximate 60 psi through a three-way valve. Once charged, the toggle valve was then opened, allowing the pressurized filtrate to back-pulse the filter element.

The matrix performed with the AZ-101/102 filtration simulant prepared at 5 and 15 wt% insoluble solids at various target transmembrane pressure and axial velocity conditions are listed in Table 2.4. These conditions were the same as the planned conditions for the actual AZ-102 sample that was later tested by Battelle with the hot CUF ultra filter during January 2000.

Table 2.4. Test Conditions for the AZ-101/102 Simulant at 5 and 15 wt% Solids Using 0.1- and 0.5-micron Mott Filters

Condition #	Velocity at 5 wt% (ft/sec)	Velocity at 15 wt% (ft/sec)	Pressure (psid)
1	9.4	7.8	50
2	7.6	6.6	30
3	7.2	5.9	70
4	7.8	8.5	30
5	8.6	8.9	50
6	13.1	11.5	30

3.0 Results and Discussion

The results discussion is divided into three sections. Section 3.1 describes C-106 simulant filter performance results at 8 wt% insoluble solids loading; Section 3.2 discusses AZ-101/102 simulant filter performance results at 5 and 15 wt% insoluble solids loading; and section 3.3 compares the particle size distribution of the C-106 and AZ-101/102 filtration simulants. The filtrate flux profiles and raw data at each condition are presented and compared in detail in Appendix B.

3.1 C-106 Simulant Filter Performance Results

The unpublished data for the C-106 simulant at 8 wt% insoluble solids consisted of two sets of testing matrixes:

- 0.1-micron Graver and 0.5-micron liquid-service, industrial-grade Mott filters at low axial velocities of 6–9 ft/sec and 12.5–35 psid transmembrane pressures conditions
- 0.5-micron liquid-service, industrial-grade Mott filter and the project baseline 0.1-micron liquid-service, industrial-grade Mott Filter at high axial velocities of 9–12 ft/sec and 30–70 psid transmembrane pressure conditions.

A fresh batch of simulant was used for each testing matrix to account for solids de-agglomeration as the flux results for each filter type are compared. The solid particles are expected to de-agglomerate in the crossflow filtration loop as a result of the shearing that occurs during the course of the CUF testing. The low axial velocity and transmembrane pressure set consisted of eight conditions. In this matrix incremental increases in the condition number also represent an increase in the total time of CUF operation. For instance, the condition #1 represent the first hour of the slurry re-circulation in the CUF flow loop and the condition #6 represents six hours of slurry re-circulation in the CUF.

As described in section 2.2.2 each condition was run for 60 min with back pulsing once after 30 minutes of operation. The average filtrate fluxes for the 0.1-micron Graver and 0.5-micron liquid-service, industrial-grade Mott filters for these conditions are shown in Table 3.1. The actual velocities and pressures for both sets are within 5% of the target values for both testing matrices. For comparison of test conditions, the flux rate is averaged over the 30 minutes of continuous operation, except the first 5 minutes of operation after the system was back pulsed. All the flux data have been corrected to 25°C using the formula (Equation 2.1, see section 2.2.2) to correct for viscosity and surface tension changes.

Table 3.1. The C-106 Filtration Simulant Average Filtrate Flux at Low Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron Graver & 0.5 micron Liquid-Service Mott Filters

Condition #	Average Velocity (ft/s)	Average Pressure (psid)	Average Filtrate Flux (gpm/ft^2)				% Difference [a] ($1^{st}/2^{nd}$)
			0.1 Micron Graver Filter		0.5 Micron Mott Filter		
			(1^{st} 30 min)	(2^{nd} 30 min)	(1^{st} 30 min)	(2^{nd} 30 min)	
1	6.0	20.1	0.038	0.038	0.048	0.040	-23%/-5%
2	4.5	12.6	0.024	0.025	0.028	0.029	-15%/-15%
3	9.1	20.0	0.102	0.022	0.063	0.062	47%/51%
4	6.0	35.0	0.034	0.033	0.032	0.036	6%/-9%
5	6.0	20.0	0.039	0.037	0.035	0.033	11%/11%
6	6.0	5.2	0.025	0.021	0.043	0.054	-53%/-88%
7	7.4	27.4	0.032	0.035	0.044	0.042	-32%/-18%
8	6.0	20.1	0.038	0.036	0.035	0.029	14%/22%

(a) Relative Percentage Difference =($2(V_{0.1g}-V_{0.5m})/(V_{0.1g}+V_{0.5m})$) x 100
where: $V_{0.1g}$ = Average 0.1 micron Graver filtrate flux ≥5 min
$V_{0.5m}$ = Average 0.5 micron Mott filtrate flux ≥5 min

The first 5 minutes of CUF operation was excluded from averaging the fluxes because fluxes collected at this stage are a direct result of the variation in the system back pulsing operation. The flux profiles in all cases (see Appendix B) show that the high initial flux rates drop within a few minutes to a lower, more consistent flux rate that slowly decreases over time. An example of this rapid decline in the filtration flux in the initial minutes of testing is illustrated in Figure 3.1.

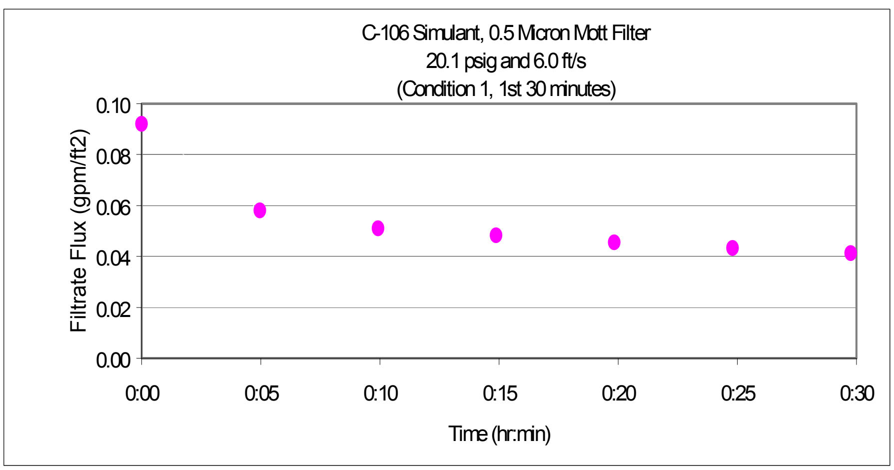

Figure 3.1. An Illustration of the Rapid Decline in the Filtration Flux in the Initial Minutes of Testing

The average filtrate flux as a function of run condition is graphed in Figure 3.2. The results shown in Figure 3.2 and Table 3.1 indicate that, overall, the filtrate fluxes were similar when the simulant was crossflow filtered with the 0.5 micron liquid-service industrial grade Mott filter or the 0.1 micron Graver filter except for condition #3 and condition #6. At higher axial velocity of 9 ft/s for condition #3, the average flux was 50% higher for the 0.1 micron Graver filter, whereas the average flux of the 0.1 micron Graver filter was approximately 50-80% lower as the transmembrane pressure was decreased to 5 psi for condition #6.

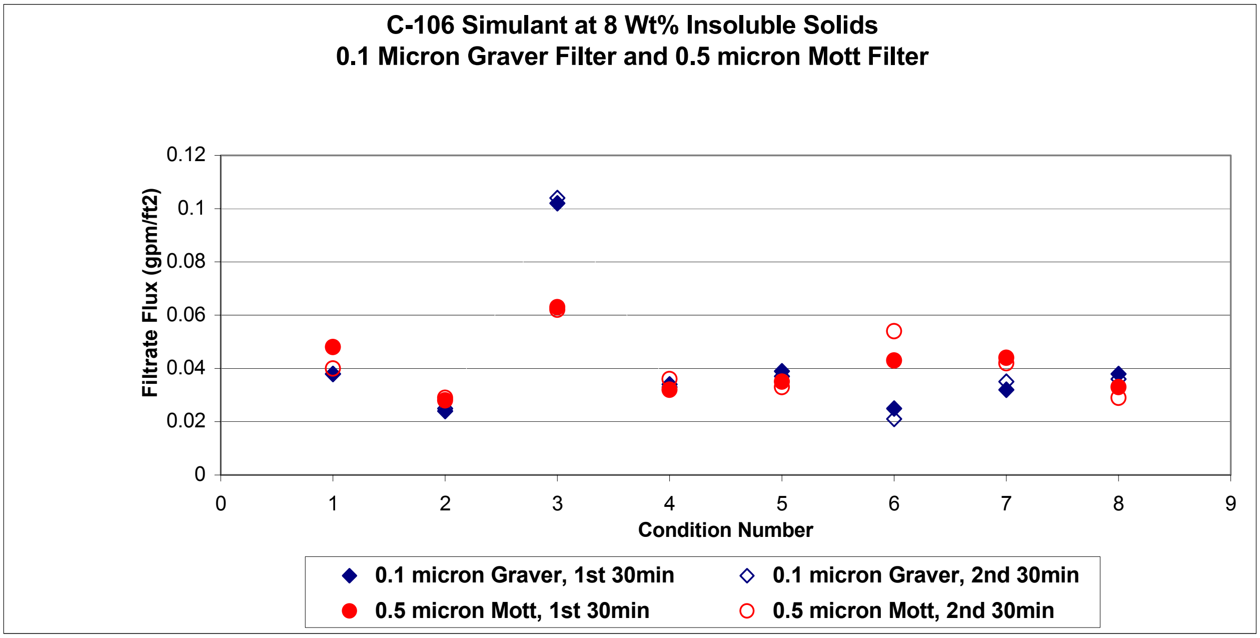

Figure 3.2. C-106 Filtration Simulant Average Filtrate Flux at Low Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron Graver & 0.5 micron Liquid-Service Mott Filters

A closer examination of the test matrix center point (conditions 1, 5 and 8) filtrate flux profiles at 20 psid transmembrane pressure and 6 ft/s axial velocity shown in Figure 3.3 and Figure 3.4 for the 1st and 2nd 30 minutes of testing reveal additional insight to the performance of these two filters. As seen in condition #1, the 0.5 micron Mott filter fluxes are initially higher when compared to the results with the 0.1 micron Graver filter. However, the 0.5 micron Mott filter fluxes gradually decline below the 0.1 micron Graver filter filtration fluxes during the 8 hours of CUF operation at similar axial velocity and transmembrane pressure of the conditions #5 and #8. These center point (20 psid and 6 ft/s) fluxes show that in the course of ~ 8 hours of CUF operation, the 0.1 micron Graver filter is less sensitive (or almost insensitive) to the flux decline and filter fouling as compared to the 0.5 micron liquid-service Mott filter.

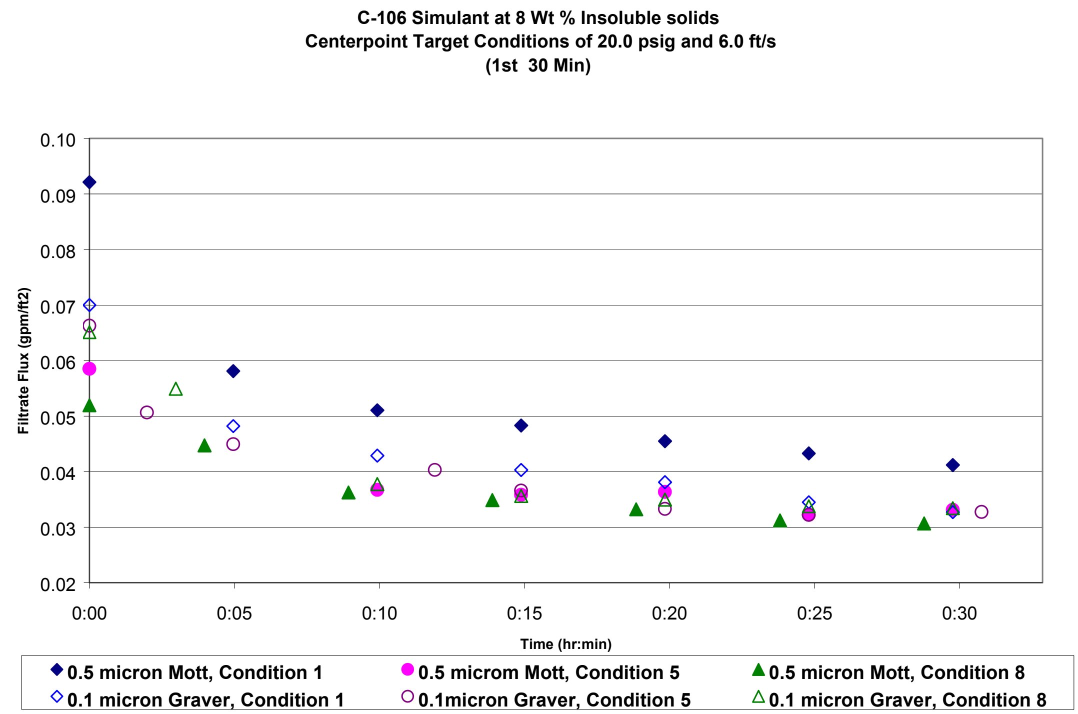

Figure 3.3. C-106 Simulant Center Point 1st 30 Minutes Filtrate Flux Profile at Low Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron Graver & 0.5 micron Liquid-Service Mott Filters

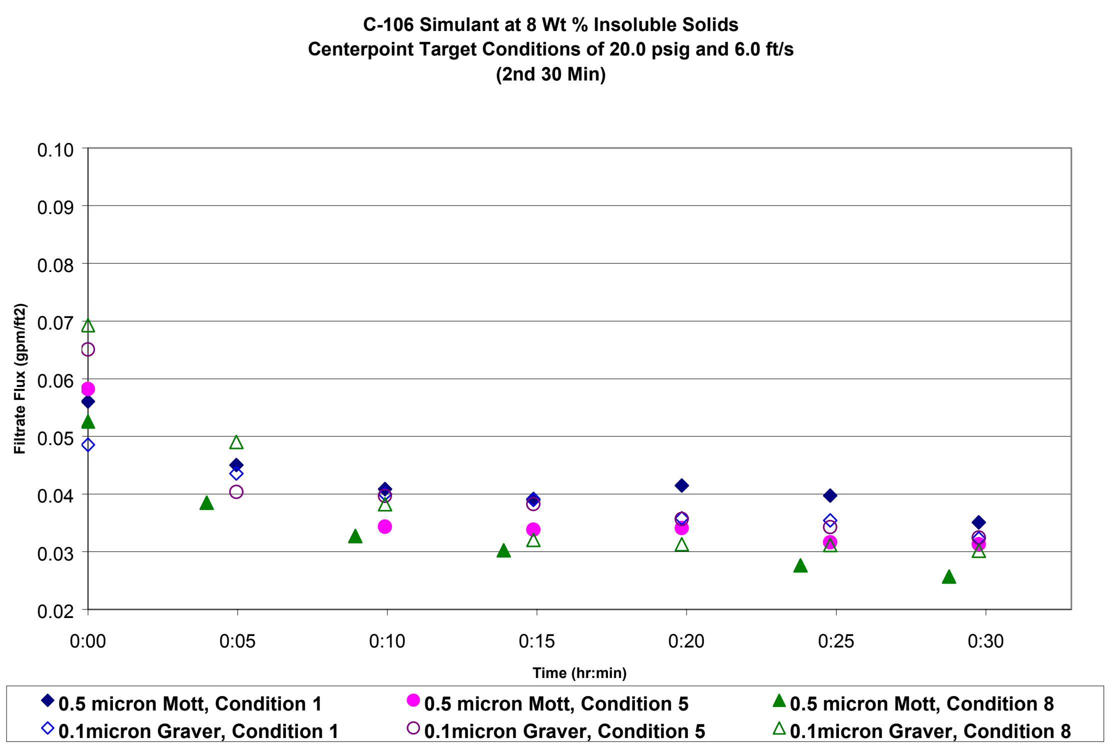

Figure 3.4. C-106 Simulant Center Point 2nd 30 Minutes Filtrate Flux Profile at Low Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron Graver & 0.5 micron Liquid-Service Mott Filters

One explanation could be that since the 0.1 micron Graver is fabricated by sintering a thin coating of 0.1 micron porous TiO_2 layer on the perforated filter substrate (see section 2.2.1), the decline in the filtrate flux may be primarily influenced by the formation of cake layer and cake enrichment with fine particles on the filter surface which induce surface fouling rather than internal pore blockage. Considerations for surface fouling can be further substantiated by the lack of significant change in the flux behavior of the center point condition and the higher average flux of condition #3 that was observed for the 0.1 micron Graver as a result of cake layer removal and the sweeping action of the increased axial velocity (9 ft/s) as opposed to the 0.5 micron Mott results. On the other hand, the larger pores of the 0.5 micron porous liquid-service Mott filter that are distributed within the filter thickness seem to facilitate the penetration of the fine particles inside the pores, which promote the internal pore fouling observed in the center point behavior. This hypothesis may be further supported by the improved performance of the 0.5 micron Mott filter at low transmembrane pressure of condition #6 and the examination of center point data presented in Figures 3.3 and 3.4.

The high axial velocity and transmembrane pressure matrix consisted of six conditions. The average filtrate fluxes for the 0.1-micron and 0.5-micron liquid-service Mott filters for these conditions are listed in Table 3.2. As described in section 2.2.2 in this test series each condition was run for 60 minutes and was backpulsed twice in between each condition. Again, the flux rates were averaged over the duration of each condition run, in this case 1-hour of run operation, and the first 5 minutes of operation was excluded from the average The fluxes have been corrected to 25°C using the formula (Equation 2.1, see section 2.2.2) to correct for viscosity and surface tension changes.

Table 3.2. The C-106 Filtration Simulant Average Filtrate Flux at High Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron and 0.5 micron Liquid-Service Industrial Grade Mott Filters

High Axial Velocity and Transmembrane Conditions				
Condition #	**Target Velocity (ft/s)**	**Target Pressure (psid)**	**Average Filtrate Flux (gpm/ft^2) 0.1 Micron Mott Filter (60 min)**	**Average Filtrate Flux (gpm/ft^2) 0.5 Micron Mott Filter (60 min)**
1	12.2	50	0.090	0.073
2	9.2	30	0.064	0.032
3	11.3	70	0.115	0.021
4	11.4	30	0.082	0.053
5	9.1	70	0.098	0.086
6	12.2	50	0.079	0.050

The average filtrate fluxes listed in Table 3.2 imply that the filtrate fluxes of the 0.1-micron liquid-service Mott filter for all run conditions are greater than the fluxes achieved with 0.5-micron liquid-service Mott filter using the C-106 slurry simulant at 8 wt% insoluble solids. The results indicate that the filtrate fluxes in tests with the 0.1-micron liquid-service Mott filter for conditions #1, 4, 5, 6 are, respectively, 23%, 55%, 14%, and 58% higher than those with 0.5-micron liquid-service Mott filter. Furthermore, the performance of the 0.1-micron Mott filter is 2 times higher for condition #2 and 450% times higher for condition #3. A plausible explanation for the significantly better performance of the 0.1 micron Mott filter for condition # 3 can be described in term of filter pore sizes. It is speculated that as the transmembrane pressure was increased in the condition #3 additional solid particles were penetrated inside the larger pores of the 0.5 micron filter as opposed to the smaller pores of the 0.1 micron Mott filter, which increased the subsurface pore plugging of the 0.5 micron Mott filter.

The illustration of the filtrate fluxes in Figure 3.5 over approximately 6-hours of CUF operation further imply that the extent of fouling becomes more significant for the 0.5 micron Mott. The additional fouling of the 0.5-micron filter is evidenced by the widening difference in the average filtrate flux of center point (conditions 1 and 6) filtrate fluxes at 50 psid transmembrane pressure and 12.2 ft/s axial velocity. The observed fluxes (shown in Table 3. 2 and Figure 3.5) seem to indicate that in crossflow filtration more open media (i.e. 0.5 micron pores) usually yield-after a certain initial time- a lower filtrate flux owing to a high degree of internal clogging.

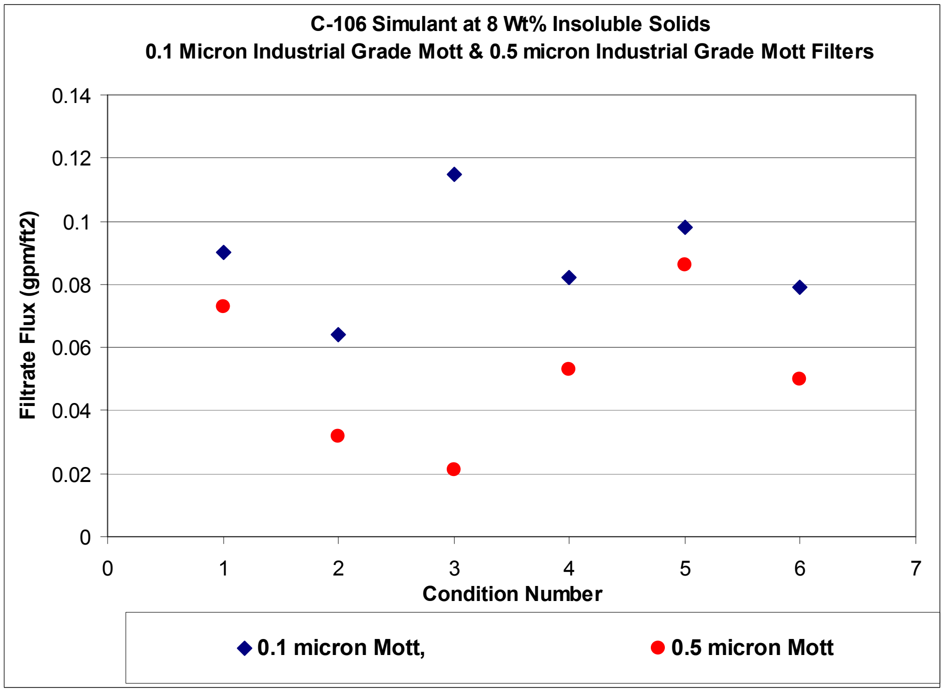

Figure 3.5. The C-106 Filtration Simulant Average Filtrate Flux at High Axial Velocity and Transmembrane Pressure Conditions Using 0.1 micron and 0.5 micron Industrial Grade Mott Filters

3.2 AZ-101/102 Simulant Filter Performance Results

The AZ-101/102 filtration simulant was tested with both 0.1- and 0.5-micron liquid-service Mott filters. The same crossflow filtration matrices (see Section 2.3) were conducted at 5 and 15 wt% insoluble solids.

The morphology of the AZ-101/102 filtration simulant is different than that of the C-106 filtration simulant. It is speculated that the solids morphology and agglomeration/deagglomeration of the AZ-101/102 simulant is driven by the high concentration of iron-bearing solids, whereas the C-106 simulant morphology is influenced by the high concentration of aluminum-bearing solids. The examination conducted during the development phase of these two Envelope-D filtration simulants indicated that the agglomerates formed in the AZ-101/102 simulant demonstrated a broader range of agglomerate compaction than the C-106 simulant. The broader range of agglomerate compaction in the AZ-101/102 filtration simulant induce a dynamic solids attrition behavior during the ~6-hours of CUF operation.

The difference in the solids attrition/de-agglomeration characteristics of the AZ-101/102 and the C-106 filtration simulants can be further explained by examining the viscosities of the AZ-101/102 and C-106 simulants as a function of shear rate shown in Figures 3.6 and 3.7. In these figures, both measurements were conducted at 25^{o}C. The viscosity profiles of the AZ-101/102 simulant at 10, 30 and 40 Wt% solids loading show several fluctuation points. As the shear rate is increased and the solids/agglomerates structure break down, the AZ-101/102 slurry viscosity changes from shear thinning to dilatant and back to shear-thinning again several times. This behavior in the AZ-101/102 simulant indicates that the solid particles or the agglomerates of various compactions are present that are not de-agglomerating or breaking down uniformly as the slurry is sheared. On the other hand, these fluctuation points are absent from the C-106 viscosity profiles. Lack of the fluctuation points suggest that the C-106 solids/agglomerates break down uniformly as the shear rate is increased as opposed to the AZ-101/102 solids.

As explained in the previous paragraphs since the solids attrition/de-agglomeration characteristics behavior of the AZ-101/102 simulant slurries differs from the C-106 simulant slurry the performance of the 0.1 micron and 0.5 micron filters were tested using the AZ-101/102 simulant.

3.2.1 5 Wt% Insoluble Solids Loading

In this set of experiments, six conditions were tested. The average filtrate fluxes for the 0.1-micron and 0.5-micron liquid-service Mott filters at 5-wt% insoluble solids in the AZ-101/102 simulant are listed in Table 3.3. For comparison of test conditions, the flux rate was averaged over the 1-hour run time, excluding for the initial 5 minutes of operation and the flux data have been corrected to 25°C.

Table 3.3. The AZ-101/102 Filtration Simulant Average Filtrate Flux at 5 wt% Insoluble Solids Using 0.1-micron and 0.5-micron Liquid-Service Mott Filters

Condition	**Target Velocity (ft/sec)**	**Target Pressure (psid)**	**Average Filtrate Flux (gpm/ft^2) 0.1-micron Mott Filter** (60 min)	**Average Filtrate Flux (gpm/ft^2) 0.5-micron Mott Filter** (60 min)
1	9.4	50	0.198	0.172
2	7.6	30	0.115	0.058
3	7.2	70	0.124	0.021
4	7.8	30	0.104	0.073
5	8.6	50	0.115	0.032
6	13.1	30	0.104	0.068

Once again, the average filtrate fluxes listed in Table 3.3 indicate that, at 5 wt% insoluble solids, the 0.1-micron liquid-service Mott filter filtrate fluxes for all run conditions are greater than the fluxes achieved with 0.5-micron liquid-service Mott filter. These results support the observation discussed in a previous section indicating that the larger pore size of the 0.5-micron Mott filter causes the filter to be more susceptible to internal/subsurface fouling.

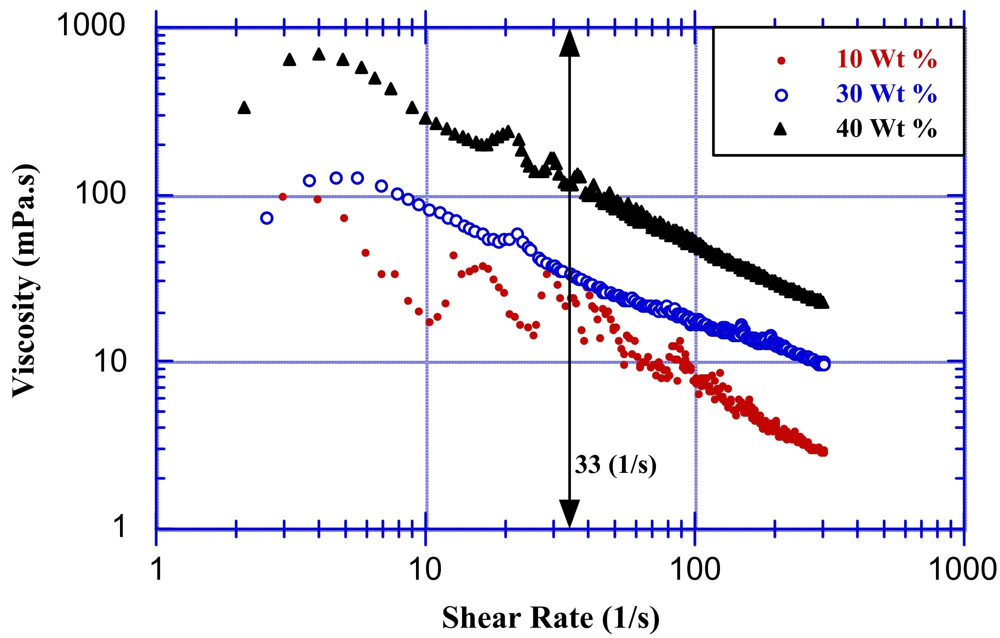

Figure 3.6. Viscosity as a Function of Shear Rate at 25°C for the AZ-101/102 Filtration Simulant

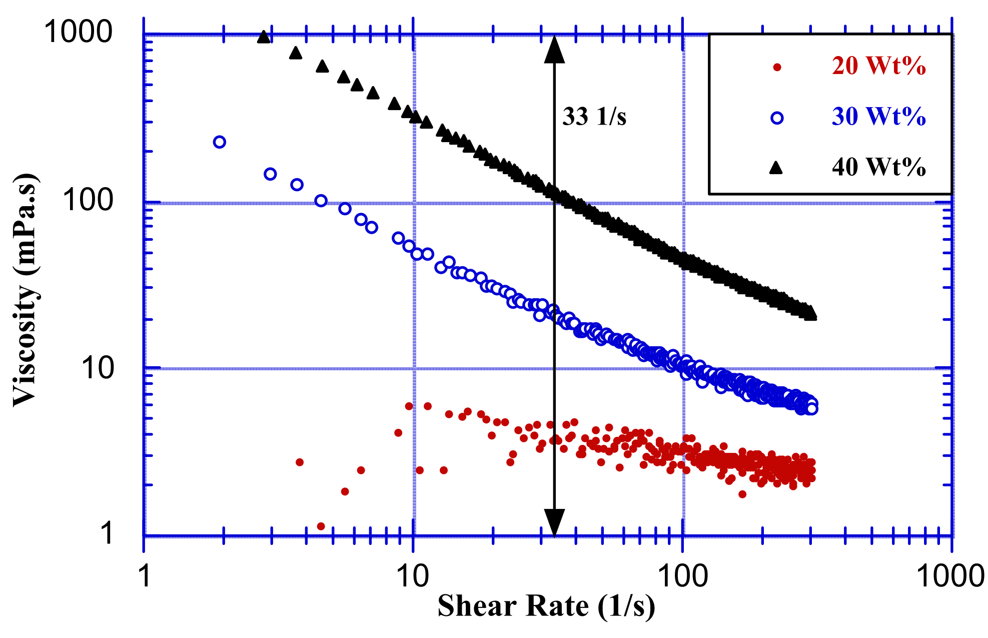

Figure 3.7. Viscosity as a Function of Shear Rate at 25°C for the C-106 Filtration Simulant

Table 3.3 and Figure 3.8 show that the flux rates from the 0.1 µm Mott filter are greater than that of the 0.5 µm filter, despite the fact that the hydraulic resistance of the former is less (when new). The difference in flux is most likely due to the 0.5 µm filter being more susceptible to in-depth fouling, causing the hydraulic resistance during the run to be greater than the smaller pore size filter, resulting in the lower filtration rates. While no clean water flux measurements were made to confirm this hypothesis, these results are consistent with those of Geeting (1997) who reported less in-depth fouling and better filtration results with a 0.1 µm Graver filter compared with a 0.5 µm Mott on Hanford tank wastes.

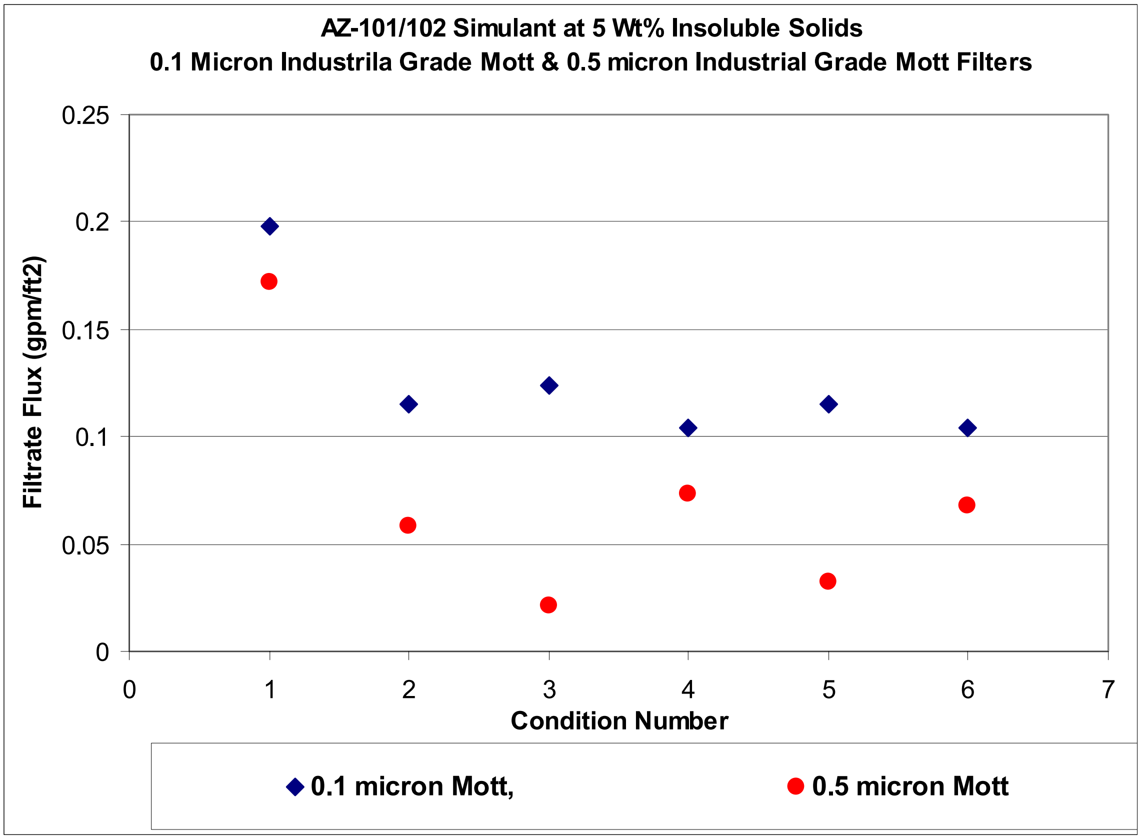

Figure 3.8. The AZ-101/102 Filtration Simulant Average Filtrate Flux at 5wt% Insoluble Solids Using 0.1 micron and 0.5 micron Liquid-Service Mott Filters

3.2.2 15 Wt% Insoluble Solids Loading

The average filtrate fluxes for 0.1- and 0.5-micron liquid-service Mott filters at 15 wt% insoluble solids in the AZ-101/102 simulant are listed in Table 3.4. For comparing test conditions, the flux rate was averaged over the 1-hour run time except for the initial 5 minutes of operation, and flux data have been corrected to 25°C.

Table 3.4. AZ-101/102 Filtration Simulant Average Filtrate Flux at 15 wt% Insoluble Solids Using 0.1- and 0.5-micron Liquid-Service Mott Filters

Condition	Target Velocity (ft/sec)	Target Pressure (psid)	Average Filtrate Flux (gpm/ft^2) 0.1-micron Mott Filter (60 min)	Average Filtrate Flux (gpm/ft^2) 0.5-micron Mott Filter (60 min)
1	7.8	50	0.092	0.086
2	6.6	30	0.062	0.053
3	5.9	70	0.062	0.021
4	8.5	30	0.069	0.058
5	8.9	50	0.077	0.050
6	11.5	30	0.072	0.036

At 15 wt% solids the filtrate flux differences for conditions #1 and #2 are less significant than those in the 5 wt% solids loading. However, during the testing with the 0.5-micron Mott filter, repeated back pulsing was required to re-establish the filtrate flux. The need for back pulsing increased significantly between conditions #3 and #4 in tests with the 0.5-micron filter. It is speculated that in the case of the 0.5-micron filter, in addition to the compaction of the cake layer deposited on the surface, the increased transmembrane pressure contributed substantially to the subsurface fouling of the filter. The average filtrate fluxes are also shown in Figure 3.9.

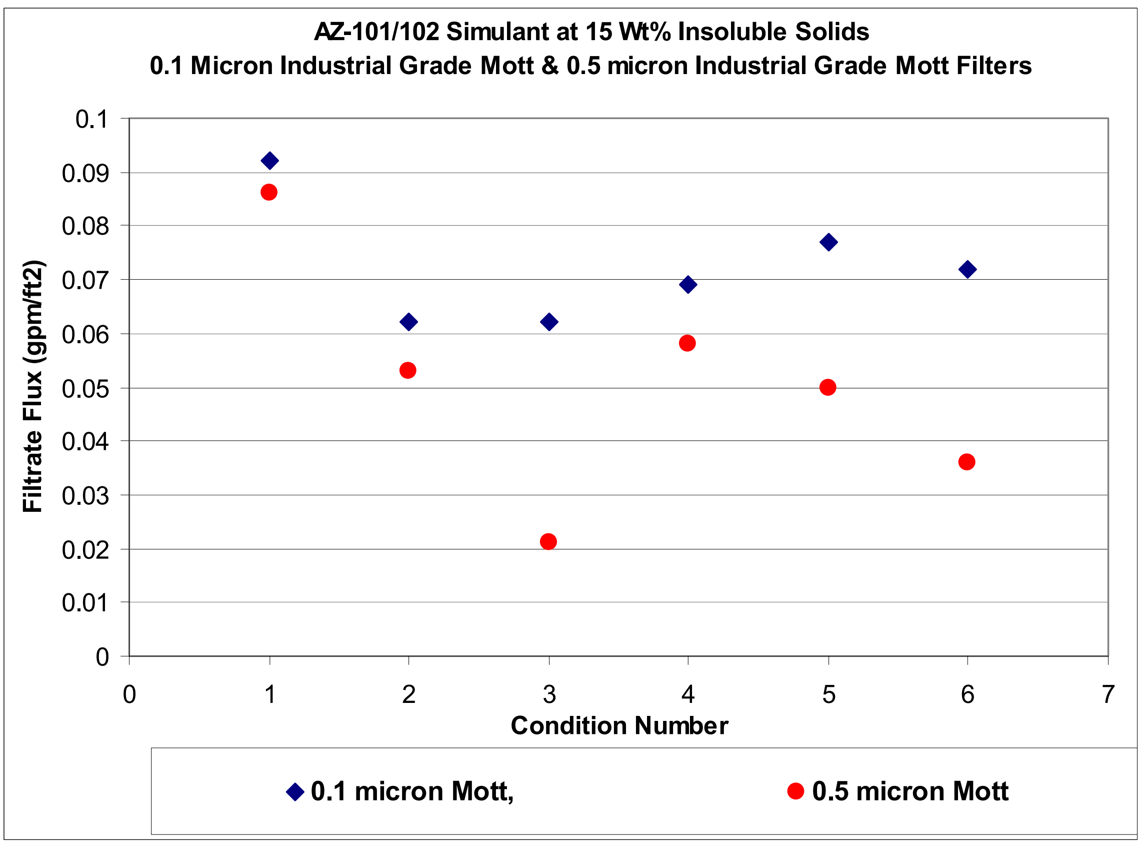

Figure 3.9. The AZ-101/102 Filtration Simulant Average Filtrate Flux at 5wt% Insoluble Solids Using 0.1 micron and 0.5 micron Liquid-Service Mott Filters

3.3 Particle Size Distribution Comparison of Tested Simulants

The Particle size distribution of the C-106 simulant feed that was used in CUF testing is shown in Figure 3.10 on a volume-weighted distribution before and after sonication. As described before, a fresh batch of simulant was prepared and used for each CUF testing series for each test matrix to account for changes in the particles/agglomerates size distribution induced by vigorous mixing and attrition of particles in the CUF re-circulation as a function of CUF operation time. The major particle size peak modes along with the relative volume and number-weighted percentage that each peak represents are summarized in Table 3.5 before and after sonication. To emulate deagglomeration of solids in the CUF recirculation the solids were sonicated in conducting the particle size distribution measurements.

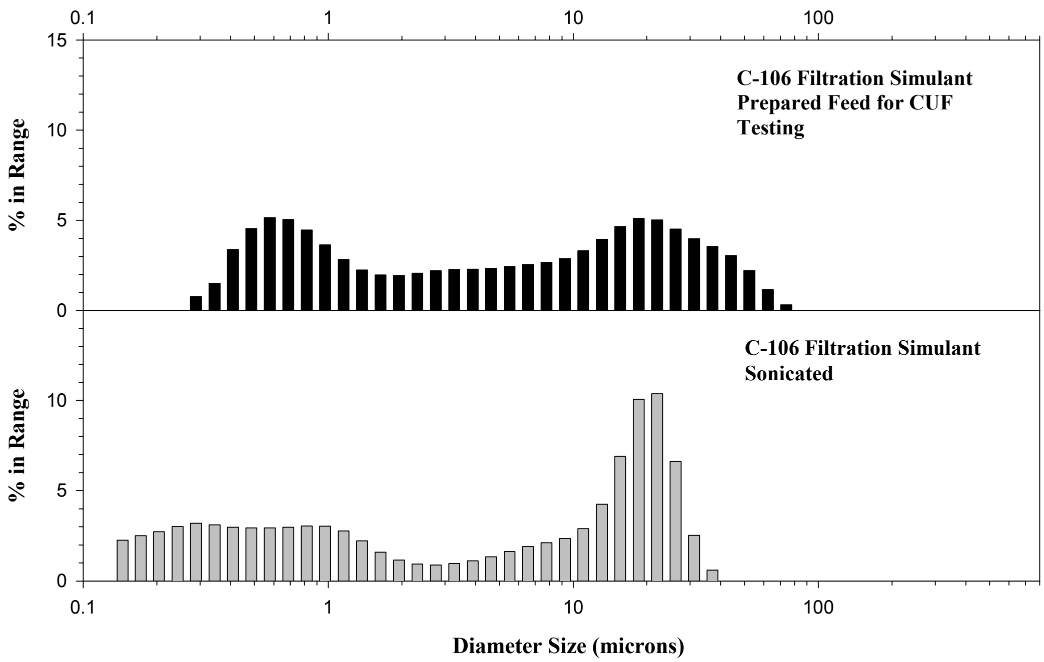

Figure 3.10. Volume-Weighted Distribution for C-106 Filtration Simulant Before and After Sonication

The particle size distribution of the C-106 simulant feed for the CUF testing on a volume-weighted distribution is approximated by three Gaussian peak distributions populated around 22.0, 6.5 and 0.6 µm with respectively 59%, 12% and 29% for each peak. When particles were sonicated in the particle size analyzer circulation loop the solids de-agglomerated and smaller size particles were produced. On a volume-weighted distribution the sonicated particle size peak distributions were populated around 16.0, 0.8 and 0.2 µm with respectively 57%, 24% and 19% for each peak. These results indicate that 35% of the particles in the sonicated simulant sample were smaller than 0.8 µm for the C-106 simulant.

Table 3.5. Particle Size Distribution of C-106 Filtration Simulant

Sample	Volume–Weighted Distribution			Number–Weighted Distribution		
	Mode Diameter (μm)	Vol%	Width	Mode Diameter (μm)	Num%	Width
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 Filtration Simulant, Sonicated	16.14	57 %	18.4	0.2	100	0.1
	0.8	24 %	0.8			
	0.2	19 %	0.2			

The Particle size distribution of the AZ-101/102 simulant feed is shown in Figure 3.11 on a volume-weighted distribution before and after sonication. The major particle size peak modes along with the relative volume and number-weighted percentage that each peak represents are summarized in Table 3.6 before and after sonication.

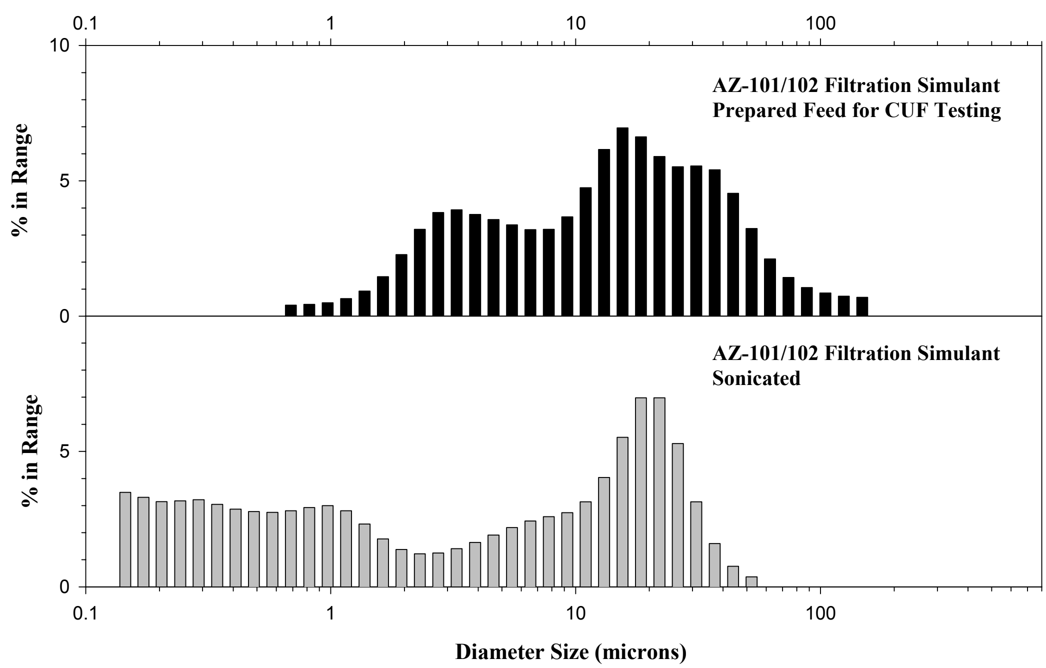

Figure 3.11. Volume-Weighted Distribution for AZ-101/102 Filtration Simulant Before and After Sonication

Table 3.6. Particle Size Distribution of AZ-101/102 Samples

	Volume–Weighted Distribution			Number–Weighted Distribution		
Sample	**Mode Diameter (μm)**	**Vol%**	**Width**	**Mode Diameter (μm)**	**Num%**	**Width**
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 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			

The particle size distribution of the AZ-101/102 simulant feed for the CUF testing on a volume-weighted distribution is approximated by three Gaussian peak distributions populated around 18, 6.4 and 1.4 μm with respectively 31%, 40% and 25% for each peak. When particles were sonicated in the particle size analyzer circulation loop smaller size particles were produced. On a volume-weighted distribution the sonicated particle size peak distributions were populated around 14.0, 0.9, 0.3 and 0.1 μm with respectively 55%, 20%, 18% and 7% for each peak. These results indicate that 25% of the particles in the sonicated simulant sample were smaller than 0.3 μm for the AZ-101/102 simulant.

Although sonication does not represent the shear fields that are encountered in crossflow filtration CUF flow loop, the data still provide some information regarding the breakup of the agglomerates. The results support that sonication of the C-106 and AZ-101/102 simulant slurries could produce a large number of sub-micron particles that can penetrate the pores and promote filter fouling. In addition, these fine particles can also decrease the permeability of the formed filter cake on the membrane surface. This outcome results in a net increase in the membrane and filter cake resistance and declining filter flux at a given transmembrane pressure and axial velocity. However, for the case of a 0.5-micron Mott filter element more fine particles can deposit within the pores as compared to a 0.1-micron filter element; resulting in larger membrane resistance and lower filter fluxes than the 0.1-micron filter elements.

Furthermore, the clean water described in section 2.2.2 and presented once again in Table 3.7 below show that the clean water flux for the 0.5 micron Mott filter is respectively higher than clean water fluxes for 01.micron Mott and 0.1 micron Graver filters. The higher clean water flux of the 0.5 micron Mott with a pore size of 0.5 micron is expected since the resistance due to the pore size is the least compared to the 0.1 micron Mott and Graver filters. However, as described above the presences of sub-micron particles below 0.5 micron in the AZ-101/102 and C-106 simulant slurry will adversely affect the performance of the 0.5 micron Mott filter by promoting particles inside the pores and the internal filter clogging.

Table 3.7. Clean Water Flux for 0.1 Micron Graver, 0.1 and 0.5 Micron Liquid-Service, Industrial-Grade Mott Filters

Trans-Membrane Pressure (psid)	Flux (gpm/ft^2)		
	Graver Filter 0.1-micron	Mott Filter 0.1-micron	Mott Filter 0.5-micron
10	0.072	1.0	2.8
20	0.132	2.5	5.0
30	0.215	2.8	7.4

4.0 Conclusions

Based on the testing and analysis performed on the HLW C-106 and AZ-101/102 crossflow filtration simulants, the following conclusions and recommendations were obtained.

- The filtrate fluxes for the C-106 simulant at “low” testing conditions indicate that overall the filtrate fluxes are similar when the simulant was crossflow filtered either with the 0.5-micron liquid-service Mott filter or the 0.1-micron Graver Filter.

- An examination of the test matrix center point (conditions 1, 5 and 8) filtrate flux profiles at 20 psid transmembrane pressure and 6 ft/s axial velocity for the tests conducted with C-106 simulant at “low” testing conditions reveal additional insight into the performance of these two filters. For condition #1, the 0.5 micron Mott filter fluxes are initially higher when compared to the results with the 0.1 micron Graver filter. However, the 0.5 micron Mott filter fluxes gradually decline below the 0.1 micron Graver filter filtration fluxes during the 8 hours of CUF operation at similar axial velocity and transmembrane pressure of the conditions #5 and #8. These center point (20 psid and 6 ft/s) fluxes show that in the course of ~ 8 hours of CUF operation, the 0.1 micron Graver filter is less sensitive (or almost insensitive) to the flux decline and filter fouling as compared to the 0.5 micron liquid-service Mott filter.

- Because the 0.1-micron Graver is fabricated by sintering a thin coating of 0.1-micron porous TiO_2 on the perforated filter substrate (see Section 2.2.1), it is plausible that the decline in the filtrate flux may be primarily influenced by the formation of cake layer and cake enrichment with fine particles on the filter surface.

- In general the Graver filter has a lower permeability compared to the micron Mott filters that results in lower overall filtration flux throughput.

- Over the course of CUF operation the extent of fouling became more significant for the 0.5-micron Mott as compared to the 0.1-micron Mott for the C-106 simulant at “high” testing conditions. The additional fouling of the 0.5-micron filter is evidence by the widening difference in the average filtrate flux of center point (conditions 1 and 6) filtrate fluxes at 50 psid transmembrane pressure and 12.2 ft/sec axial velocity. The observed fluxes seem to indicate that in crossflow filtration more open media (i.e. 0.5 micron pores) usually yield-after a certain initial time- a lower filtrate flux owing to a high degree of internal pore fouling.

- The average filtrate fluxes in testing with AZ-101/102 simulant once again indicate that the filtrate fluxes of the 0.1-micron liquid-service Mott filter for all run conditions were greater than those achieved with the 0.5-micron liquid-service Mott filter at 5 wt% insoluble solids. These results support previous observations that the larger pore size of the 0.5-micron Mott filter causes the filter to be more susceptible to internal/subsurface fouling.

- The filter flux rates obtained for the 0.1 micron Mott Liquid-service, Industrial –grade Mott filter ranged from 15% to 3.5 times higher than fluxes with 0.5-micron Liquid-service, Industrial –grade Mott filter using the AZ-101/102 simulant at 5 wt% insoluble solids

5.0 References

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Geeting JGH and BA Reynolds. 1997. *Bench-Scale Crossflow Filtration of Hanford Tank C-106, C-107, B-110, and U-110 Sludge Slurries*. PNNL-11652, Pacific Northwest National Laboratory, Richland, Washington.

Golcar GR, KP Brooks, JG Darab, JM Davis, and LK Jagoda. 2000. *Development of Inactive High-Level Waste Envelope D Simulants for Scaled Crossflow Filtration Testing.* BNFL-RPT-033 Rev. 0, PNWD-3042, Battelle, Pacific Northwest Division, Richland, Washington.

Appendix A

Envelope D High-Level Waste Filtration Simulant Specification

Appendix A

Envelope-D High-Level Waste Filtration 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 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. 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

The actual C-106 waste has recently been transferred to Hanford Tank AY-102. The C-106 waste simulant replicates the Tank C-106 waste and does not replicate the AY-102/C-106 mixed waste.

A-1. AZ-101/102 Slurry Simulant

Table A-1 lists the solid and supernatant components of the inactive AZ-101/102 waste filtration 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.

A-2. C-106 Slurry Simulant

Table A-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 particle size distribution (PSD) ranges were used to produce the required rheological and filtration characteristics. The product descriptions for each mineral, including density and particle size; the material safety data sheets for listed source chemicals are provided in Golcar et al. (2000).

A-3. Preparation Procedure

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 either Table A.1 or A.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 A.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 A.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	Boehmite	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

A-4. 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 A-3.

Table A.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 described in Appendix A of Golcar et al. (2000) report need to be matched as closely as possible if another commercial source is used.

Reference

Golcar GR, KP Brooks, JG Darab, JM Davis, and LK Jagoda. 2000. *Development of Inactive High-Level Waste Envelope D Simulants for Scaled Crossflow Filtration Testing.* BNFL-RPT-033 Rev. 0, PNWD-3042, Battelle Pacific Northwest Division, Richland, Washington.

Appendix B

Filtrate Flux Raw Data Package at Each Operating Condition

0.1 micron Graver Filter

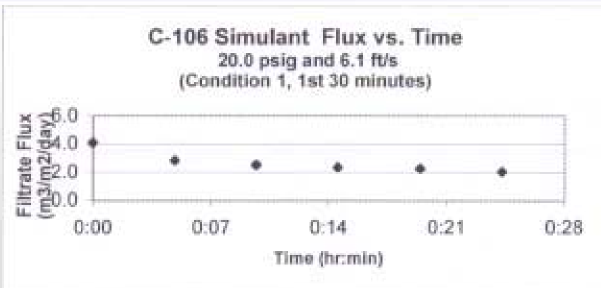
C-106 Filtration Simulant at 8 wt% Solids Loading Cuf Testing

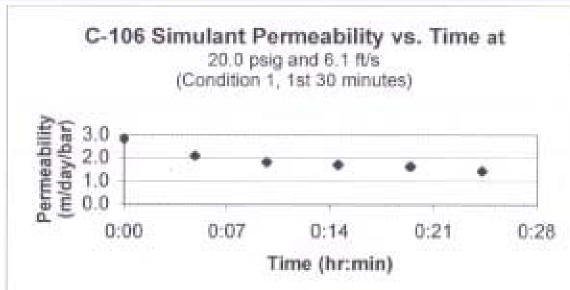
Low Axial Velocity and Transmembrane Pressure Conditions

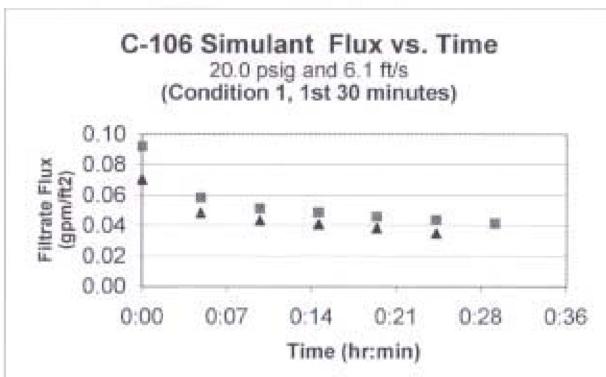
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1a	9:40	0:00	0.97	21	21	0	40	70.44	0.568	24.4	4.103	2.834	0.07	0.003329
1a	9:45	0:05	0.97	20	19	-1	40	98.81	0.405	25.6	2.828	2.103	0.0482	0.002470
1a	9:50	0:10	0.95	20	20	0	40	109.93	0.364	26	2.514	1.823	0.0429	0.002141
1a	9:55	0:15	0.9	20	20	0	40	115.93	0.345	26.3	2.364	1.714	0.0403	0.002013
1a	10:00	0:20	0.9	20	20	0	40	122.32	0.327	26.4	2.234	1.62	0.0381	0.001903
1a	10:05	0:25	0.96	21	20	-1	40	135.32	0.296	26.3	2.025	1.433	0.0345	0.001683
1a	10:10	0:30	0.94	20	20	0	40	143.81	0.278	26.1	1.916	1.39	0.0327	0.001633

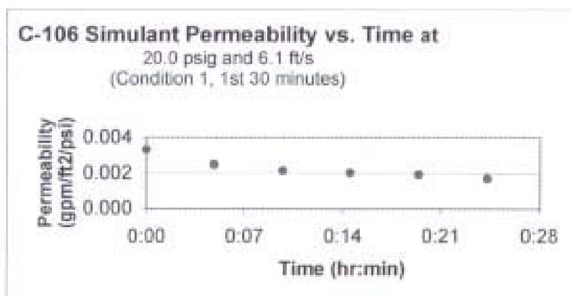
1a	Average Slurry Flow gpm =	0.94	ft/s =	6.12	
1a	Average Pressure psid =	20.17			
1a	Average Filtrate Flow mL/sec =	0.384			
1a	Average Filtrate Flux gpm/ft2 =	0.039	With First Point Removed		
1a	Average Permeability gpm/ft2/psi =	0.002			

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)		
1a	9:58	11	21.3	0.89	20	1	20	10	19.5	0.513	0:00	0.092139
1a	10:03	9	20.8	0.94	20	1	20	10	26.1	0.383	0:05	0.058106
1a	10:08	11	21	0.92	20	1	20	10	28.37	0.352	0:10	0.051078
1a	10:13	15	21.6	0.9	20	1	20	10	31.03	0.322	0:15	0.048323
1a	10:23	15	23.1	0.98	20	1	20	10	34.07	0.294	0:20	0.045504
1a	10:28	15	23.8	0.98	20	1	20	10	35.63	0.281	0:25	0.043301
											0:30	0.04122





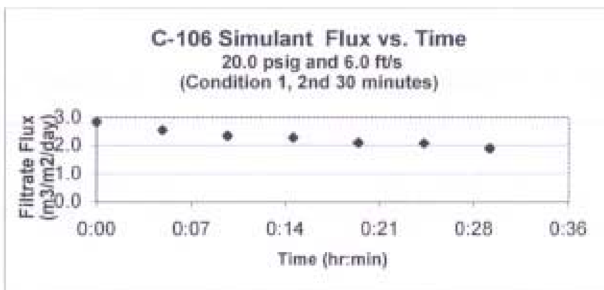


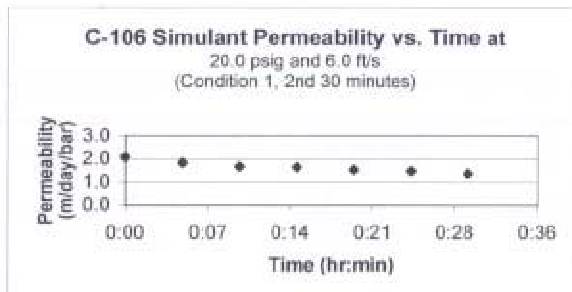


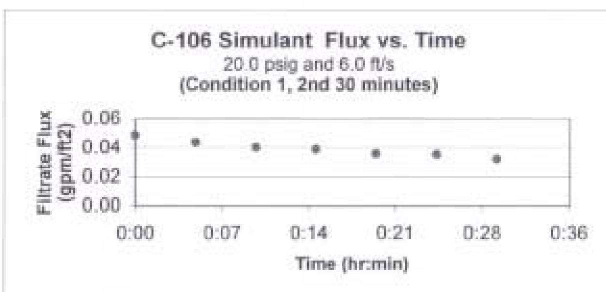
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1b	10:40	0:00	0.89	19.5	20	0.5	10	25.81	0.387	23.8	2.848	2.091	0.0485	0.002456234
1b	10:45	0:05	0.93	20	20.5	0.5	10	28.43	0.352	24.2	2.556	1.831	0.0438	0.002150302
1b	10:50	0:10	0.96	20	20.5	0.5	10	30.62	0.327	24.6	2.347	1.681	0.0400	0.001974063
1b	10:55	0:15	0.98	20	20.5	0.5	10	31.16	0.321	24.9	2.286	1.638	0.0390	0.001923511
1b	11:00	0:20	0.9	19.5	20	0.5	10	33.81	0.296	25	2.101	1.543	0.0358	0.001812516
1b	11:05	0:25	0.89	20	20.5	0.5	10	34.07	0.294	25.1	2.079	1.489	0.0354	0.001749342
1b	11:10	0:30	0.86	20	20	0	10	36.97	0.270	25.5	1.895	1.374	0.0323	0.001614031

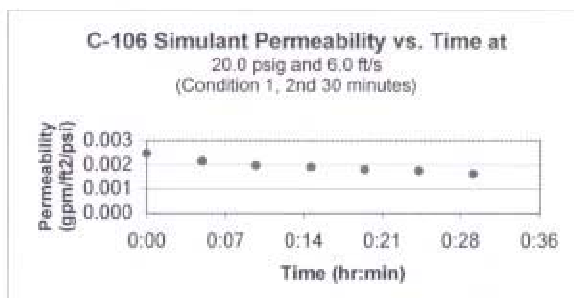
1b Average Slurry Flow gpm = 0.92 ft/s = 6
1b Average Pressure psid = 20.07
1b Average Filtrate Flow mL/sec = 0.321
1b Average Filtrate Flux gpm/ft2 = 0.038 With First Point Removed
1b Average Permeability gpm/ft2/psi = 0.002

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	10:40	13	23.8	0.89	19.5	1	20	10	25.81	0.387
1b	10:45	15	24.2	0.93	20	1	20.5	10	28.43	0.352
1b	10:50	15	24.6	0.96	20	1	20.5	10	30.62	0.327
1b	10:55	15	24.9	0.98	20	1	20.5	10	31.16	0.321
1b	11:00	15	25	0.9	19.5	1	20	10	33.81	0.296
1b	11:05	15	25.1	0.89	20	1	20.5	10	34.07	0.294
1b	11:10	15	25.5	0.86	20	1	20	10	36.97	0.270





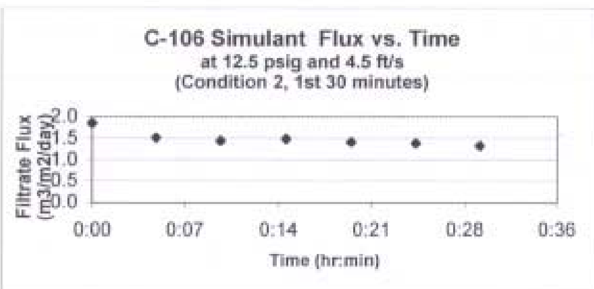


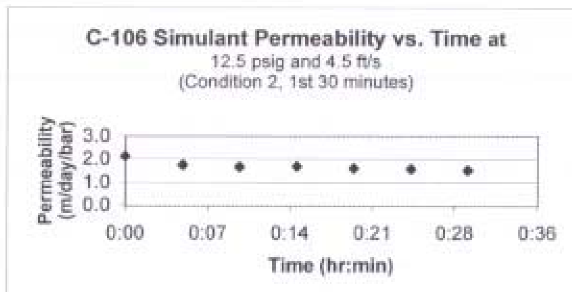


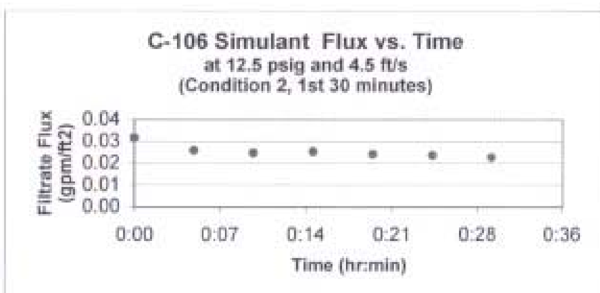
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2a	11:33	0:00	0.6	12.5	12.5	0	10	40.5	0.247	23	1.857	2.154	0.0316	0.002530
2a	11:38	0:05	0.64	12.5	12.5	0	10	50.28	0.199	22.6	1.513	1.755	0.0258	0.002061
2a	11:43	0:10	0.61	12.5	12.5	0	10	52.79	0.189	22.6	1.441	1.672	0.0246	0.001963
2a	11:48	0:15	0.76	12.5	12.5	0	10	53.19	0.188	21.5	1.476	1.712	0.0252	0.002011
2a	11:53	0:20	0.75	12.5	12.5	0	10	54.84	0.182	22	1.411	1.637	0.0241	0.001923
2a	11:58	0:25	0.72	12.5	12.5	0	10	55.12	0.181	22.5	1.384	1.606	0.0236	0.001886
2a	12:03	0:30	0.72	12.5	12.5	0	10	56.57	0.177	23.2	1.322	1.533	0.0225	0.001801

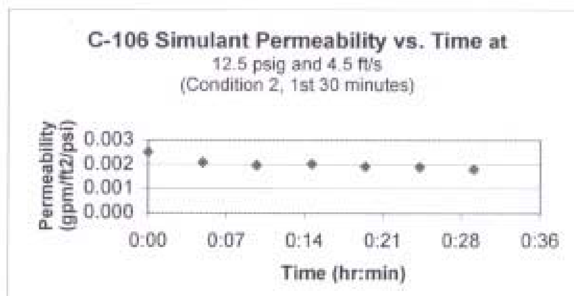
2a	Average Slurry Flow gpm =	0.69	ft/s =	4.5
2a	Average Pressure psid =	12.50		
2a	Average Filtrate Flow mL/sec =	0.195		
2a	Average Filtrate Flux gpm/ft2 =	0.024	With First Point Removed	
2a	Average Permeability gpm/ft2/psi =	0.002		

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	11:33	15	23	0.6	12.5	0	12.5	10	40.5	0.247
2a	11:38	15	22.6	0.64	12.5	0	12.5	10	50.28	0.199
2a	11:43	14	22.6	0.61	12.5	0	12.5	10	52.79	0.189
2a	11:48	14	21.5	0.76	12.5	0	12.5	10	53.19	0.188
2a	11:53	14	22	0.75	12.5	0	12.5	10	54.84	0.182
2a	11:58	14	22.5	0.72	12.5	0	12.5	10	55.12	0.181
2a	12:03	14	23.2	0.72	12.5	0	12.5	10	56.57	0.177





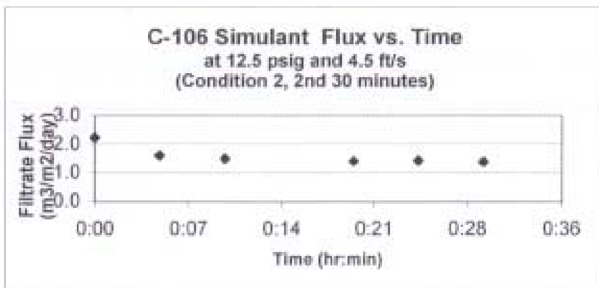


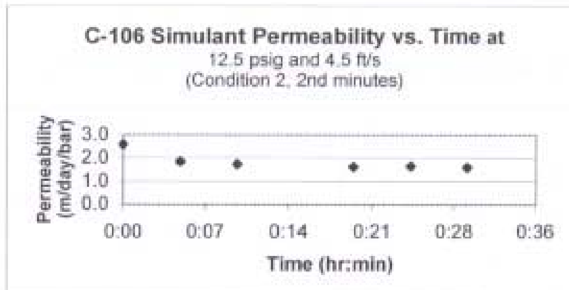


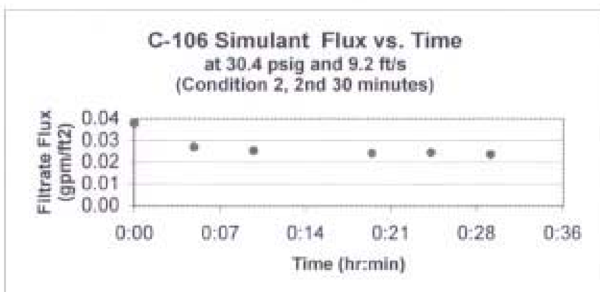
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2b	12:17	0:00	0.71	12.5	12.5	0	10	33.12	0.302	23.8	2.219	2.575	0.0378	0.003024
2b	12:22	0:05	0.71	12.5	12.5	0	10	45.81	0.218	24	1.595	1.851	0.0272	0.002174
2b	12:27	0:10	0.69	12.5	12.5	0	10	49.28	0.203	23.9	1.487	1.726	0.0254	0.002027
2b	12:37	0:20	0.66	12.5	12.5	0	10	52.07	0.192	23.9	1.408	1.633	0.0240	0.001918
2b	12:42	0:25	0.68	12.5	12.5	0	10	51.38	0.195	23.9	1.426	1.655	0.0243	0.001944
2b	12:47	0:30	0.69	12.5	12.5	0	10	52.7	0.190	24	1.387	1.609	0.0236	0.001890

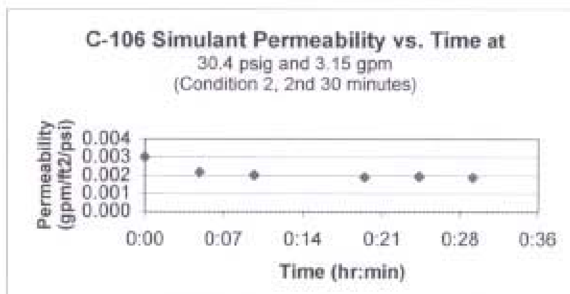
2b	Average Slurry Flow gpm =	0.69	ft/s =	4.5
2b	Average Pressure psid =	12.50		
2b	Average Filtrate Flow mL/sec =	0.217		
2b	Average Filtrate Flux gpm/ft2 =	0.025	With First Point Removed	
2b	Average Permeability gpm/ft2/psi =	0.002		

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	12:17	15	23.8	0.71	12.5	0	12.5	10	33.12	0.302
2b	12:22	15	24	0.71	12.5	0	12.5	10	45.81	0.218
2b	12:27	14	23.9	0.69	12.5	0	12.5	10	49.28	0.203
2b	12:37	14	23.9	0.66	12.5	0	12.5	10	52.07	0.192
2b	12:42	14	23.9	0.68	12.5	0	12.5	10	51.38	0.195
2b	12:47	14	24	0.69	12.5	0	12.5	10	52.7	0.190





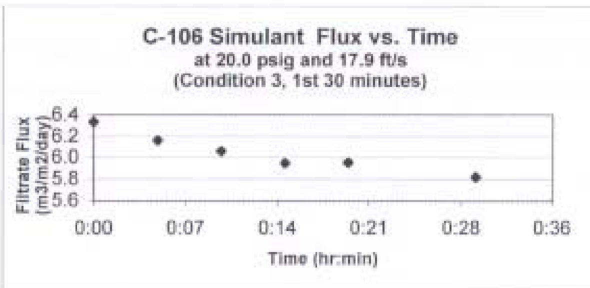


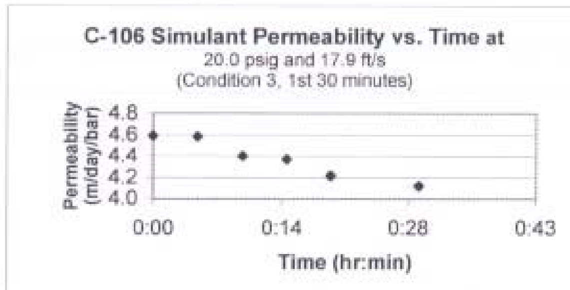


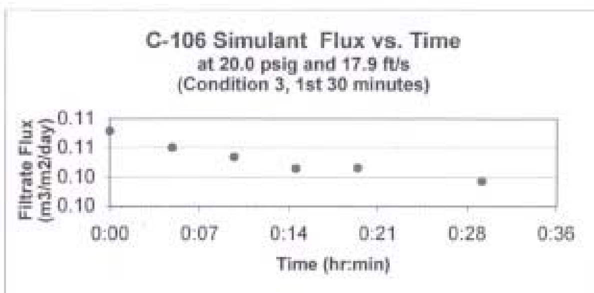
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3a	13:13	0:00	2.73	17	23	6	20	21.94	0.912	25.8	6.333	4.592	0.1080	0.005394
3a	13:18	0:05	2.74	16	23	7	20	22.35	0.895	26.1	6.165	4.585	0.1051	0.005385
3a	13:23	0:10	2.73	16.5	23.5	7	20	22.59	0.885	26.3	6.065	4.398	0.1034	0.005166
3a	13:28	0:15	2.77	16.5	23	6.5	20	23.03	0.868	26.3	5.949	4.369	0.1014	0.005131
3a	13:33	0:20	2.7	17	24	7	20	23	0.870	26.3	5.957	4.215	0.1016	0.004950
3a	13:43	0:30	2.75	17	24	7	20	23.35	0.857	26.6	5.819	4.117	0.0992	0.004835

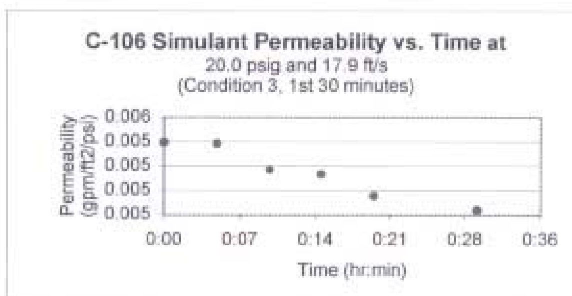
3a	Average Slurry Flow gpm =	2.74	ft/s =	17.9
3a	Average Pressure psid =	20.04		
3a	Average Filtrate Flow mL/sec =	0.881		
3a	Average Filtrate Flux gpm/ft2 =	0.102	With First Point Removed	
3a	Average Permeability gpm/ft2/psi =	0.005		

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	13:13	15	2.77	2.73	17	0	23	20	21.94	0.912
3a	13:18	15	2.77	2.74	16	0	23	20	22.35	0.895
3a	13:23	14	2.71	2.73	16.5	0	23.5	20	22.59	0.885
3a	13:28	14	2.72	2.77	16.5	0	23	20	23.03	0.868
3a	13:33	14	2.74	2.7	17	0	24	20	23	0.870
3a	13:43	14	2.72	2.75	17	0	24	20	23.35	0.857





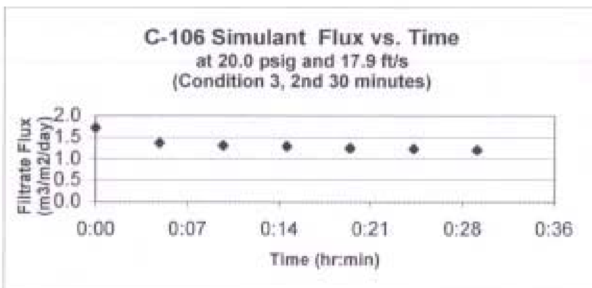


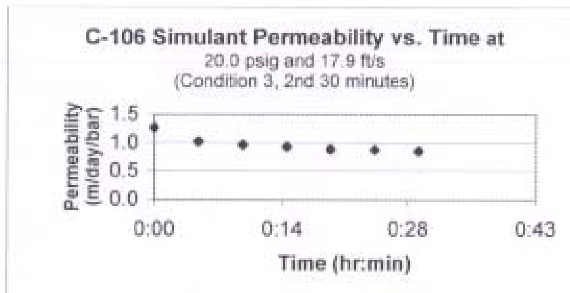


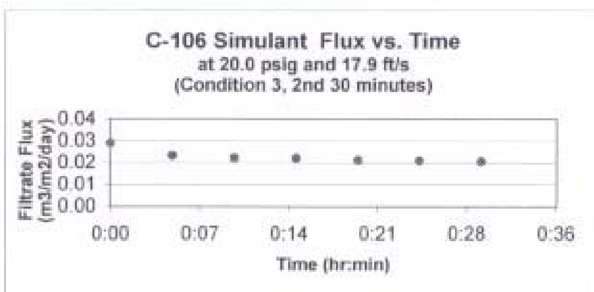
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3b	13:50	0:00	2.77	16	23.5	7.5	10	40.5	0.247	25.8	1.715	1.260	0.0292	0.001480
3b	13:55	0:05	2.77	16	23	7	10	50.28	0.199	26.1	1.370	1.019	0.0234	0.001197
3b	14:00	0:10	2.71	16	23	7	10	52.79	0.189	26.3	1.298	0.965	0.0221	0.001134
3b	14:05	0:15	2.72	17	23	6	10	53.19	0.188	26.3	1.288	0.934	0.0220	0.001097
3b	14:10	0:20	2.74	17	24	7	10	54.84	0.182	26.3	1.249	0.884	0.0213	0.001038
3b	14:15	0:25	2.72	17	24	7	10	55.12	0.181	26.6	1.232	0.872	0.0210	0.001024
3b	14:20	0:30	2.73	17	24	7	10	56.57	0.177	26.6	1.201	0.850	0.0205	0.000998

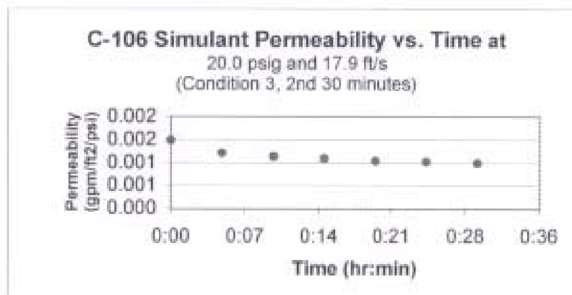
3b	Average Slurry Flow gpm =	2.74	ft/s =	17.9
3b	Average Pressure psid =	20.04		
3b	Average Filtrate Flow mL/sec =	0.195		
3b	Average Filtrate Flux gpm/ft2 =	0.022	With First Point Removed	
3b	Average Permeability gpm/ft2/psi =	0.001		

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)
3b	13:50	15	25.8	2.77	12.5	0	12.5	10	40.5	0.247
3b	13:55	15	26.1	2.77	12.5	0	12.5	10	50.28	0.199
3b	14:00	14	26.3	2.71	12.5	0	12.5	10	52.79	0.189
3b	14:05	14	26.3	2.72	12.5	0	12.5	10	53.19	0.188
3b	14:10	14	26.3	2.74	12.5	0	12.5	10	54.84	0.182
3b	14:15	14	26.6	2.72	12.5	0	12.5	10	55.12	0.181
3b	14:20	14	26.6	2.73	12.5	0	12.5	10	56.57	0.177







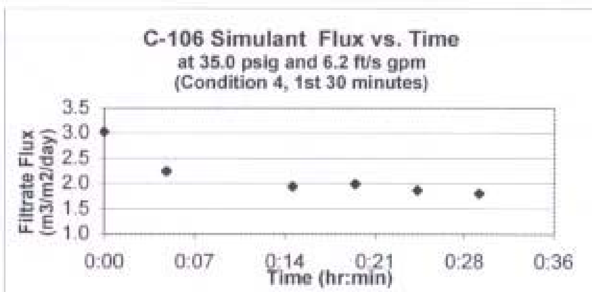


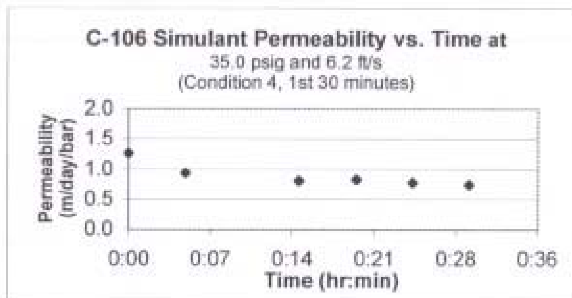
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4a	14:35	0:00	0.98	35	35	0	10	21.72	0.460	27.7	3.034	1.257	0.0517	0.001477
4a	14:40	0:05	0.91	35	35	0	10	28.84	0.347	28.3	2.247	0.931	0.0383	0.001094
4a	14:50	0:15	0.9	35	35	0	10	33.25	0.301	28.5	1.938	0.803	0.0330	0.000943
4a	14:55	0:20	0.97	35	35	0	10	33.53	0.298	27.3	1.987	0.823	0.0339	0.000967
4a	15:00	0:25	0.92	35	35	0	10	34.2	0.292	29	1.859	0.770	0.0317	0.000905
4a	15:05	0:30	0.95	35	35.5	0.5	10	35.53	0.281	28.8	1.799	0.740	0.0307	0.000869

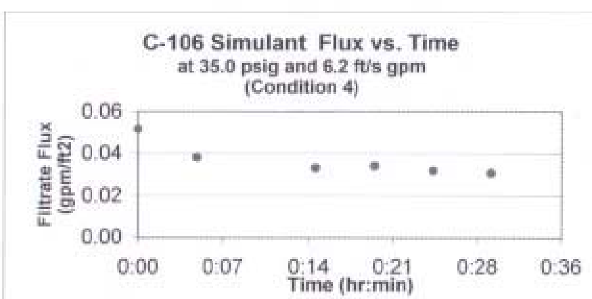
4a	Average Slurry Flow gpm =	0.94	ft/s =	6.16	
4a	Average Pressure psid =	35.04			
4a	Average Filtrate Flow mL/sec =	0.330			
4a	Average Filtrate Flux gpm/ft2 =	0.034	With First Point Removed		
4a	Average Permeability gpm/ft2/psi =	0.001			

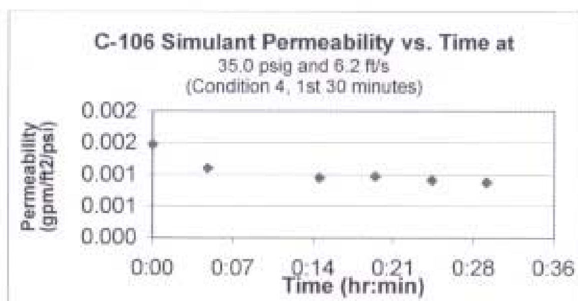
RAW Average Slurry Flow = 0.94 Average Pressure = 35.04167 Average Flow = Filtrate 0.330 Average Flux = 1.966 With First Point Removed

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)
4a	14:35	22	27.7	0.98	35		35	10	21.72	0.460
4a	14:40	23	28.3	0.91	35		35	10	28.84	0.347
4a	14:50	24	28.5	0.9	35		35	10	33.25	0.301
4a	14:55	25	27.3	0.97	35		35	10	33.53	0.298
4a	15:00	26	29	0.92	35		35	10	34.2	0.292
4a	15:05	26	28.8	0.95	35		35.5	10	35.53	0.281





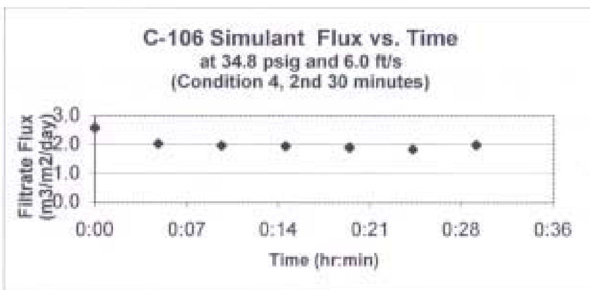


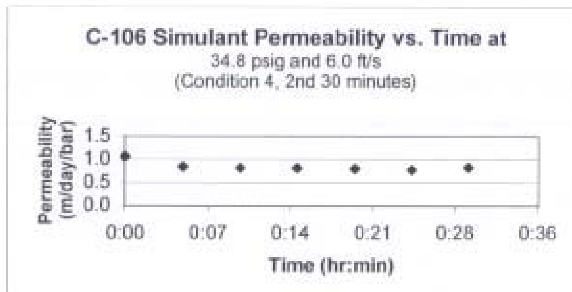


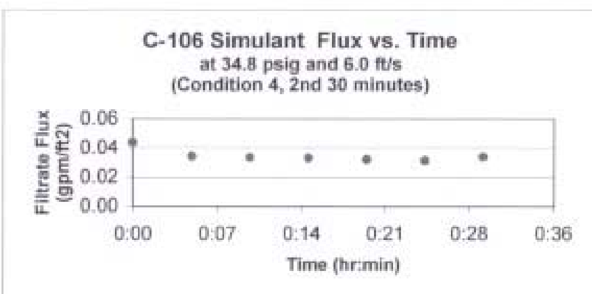
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4b	15:15	0:00	0.92	35	35	0	10	24.57	0.407	29.2	2.573	1.066	0.0439	0.001253
4b	15:20	0:05	0.93	35	35	0	10	31	0.323	29.4	2.028	0.841	0.0346	0.000987
4b	15:25	0:10	0.92	35	35	0	10	32.4	0.309	28.9	1.968	0.815	0.0335	0.000958
4b	15:30	0:15	0.92	34.5	35	0.5	10	33.56	0.298	28.3	1.931	0.806	0.0329	0.000947
4b	15:35	0:20	0.93	34.5	34.5	0	10	34.47	0.290	28	1.896	0.797	0.0323	0.000936
4b	15:40	0:25	0.9	34.5	34.5	0	10	36.47	0.274	27.3	1.827	0.768	0.0311	0.000902
4b	15:45	0:30	0.93	34.5	35	0.5	10	35.88	0.279	25	1.980	0.826	0.0338	0.000971

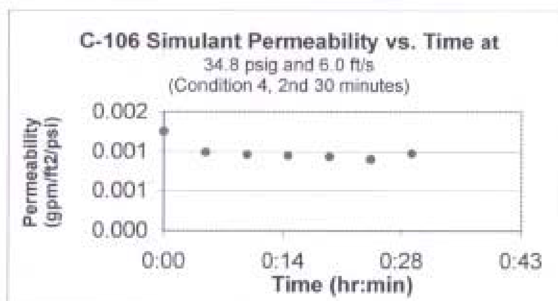
4b	Average Slurry Flow gpm =	0.92	ft/s =	6.00	
4b	Average Pressure psid =	34.79			
4b	Average Filtrate Flow mL/sec =	0.311			
4b	Average Filtrate Flux gpm/ft2 =	0.033	With First Point Removed		
4b	Average Permeability gpm/ft2/psi =	0.001			

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)
4b	15:15	33	29.2	0.92	35		35	10	24.57	0.407
4b	15:20	35	29.4	0.93	35		35	10	31	0.323
4b	15:25	35	28.9	0.92	35		35	10	32.4	0.309
4b	15:30	36	28.3	0.92	34.5		35	10	33.56	0.298
4b	15:35	37	28	0.93	34.5		34.5	10	34.47	0.290
4b	15:40	37	27.3	0.9	34.5		34.5	10	36.47	0.274
4b	15:45	33	25	0.93	34.5		35	10	35.88	0.279







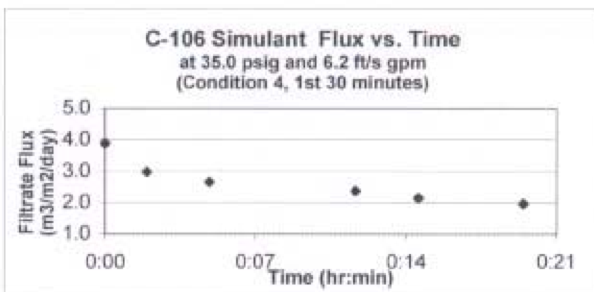


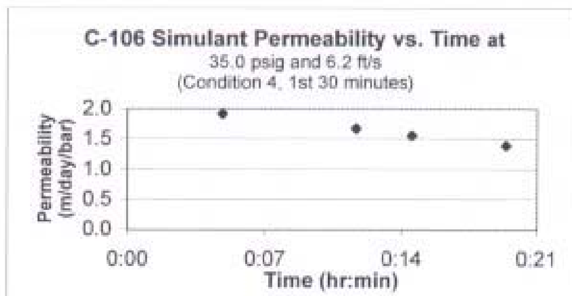
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5a	16:05	0:00	0.96	20	21	1	5	8.96	0.558	25.7	3.887	2.750	0.0663	0.003230
5a	16:07	0:02	0.95	20	21	1	5	11.72	0.427	25.7	2.972	2.103	0.0507	0.002470
5a	16:10	0:05	1	20	20	0	5	13.1	0.382	26	2.637	1.912	0.0449	0.002246
5a	16:17	0:12	1.02	20	21	1	5	13.97	0.358	27.6	2.365	1.673	0.0403	0.001965
5a	16:20	0:15	0.85	20	20	0	5	15.35	0.326	27.7	2.146	1.556	0.0366	0.001828
5a	16:25	0:20	0.82	20	21	1	5	16.59	0.301	28.3	1.953	1.382	0.0333	0.001623
5a	16:30	0:25	0.92	19.5	20.5	1	5	17.19	0.291	28.2	1.890	1.371	0.0322	0.001610
5a	16:36	0:31	0.92	20	21	1	5	17.15	0.292	27.7	1.921	1.359	0.0327	0.001596

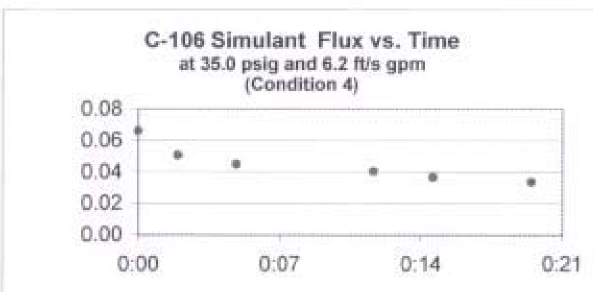
5a	Average Slurry Flow gpm =	0.93	ft/s =	6.16	
5a	Average Pressure psid =	20.33			
5a	Average Filtrate Flow mL/sec =	0.392			
5a	Average Filtrate Flux gpm/ft2 =	0.039	With First Point Removed		
5a	Average Permeability gpm/ft2/psi =	0.002			

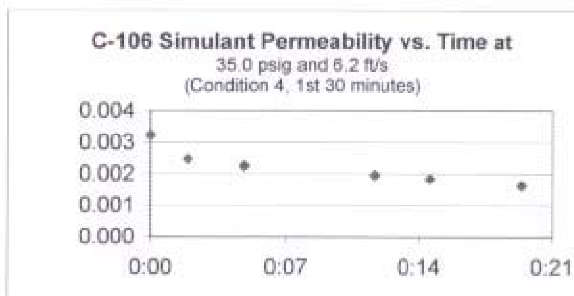
RAW Average Slurry Flow = 0.93 Average Pressure = 20.33333 Average Flow = Filtrate 0.392 Average Flux = 2.415 With First Point Removed

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)
5a	16:05	22	27.7	0.96	20		21	5	8.96	0.558
5a	16:07	23	28.3	0.95	20		21	5	13.72	0.364
5a	16:10	24	28.5	1	20		20	5	14.82	0.337
5a	16:17	25	27.3	1.02	20		21	5	13.97	0.358
5a	16:20	26	29	0.85	20		20	5	15.35	0.326
5a	16:25	26	28.8	0.82	20		21	5	16.59	0.301
5a	16:30	26	29	0.92	19.5		20.5	5	18.19	0.275
5a	16:36	26	28	0.92	20		21	5	17.15	0.292









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)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5b	16:40	0:00	0.93	20	22	2	5	9	0.556	26.2	3.816	2.636	0.0651	0.003096
5b	16:45	0:05	0.95	20	21	1	5	14.02	0.357	27.4	2.370	1.676	0.0404	0.001969
5b	16:50	0:10	0.96	20	22	2	5	14	0.357	28.1	2.327	1.607	0.0397	0.001888
5b	16:55	0:15	1.03	18	20	2	5	14.32	0.349	28.6	2.244	1.713	0.0383	0.002012
5b	17:00	0:20	0.95	19	20	1	5	15.27	0.327	28.8	2.093	1.557	0.0357	0.001829
5b	17:05	0:25	0.92	20	21	1	5	16.29	0.307	27.9	2.011	1.423	0.0343	0.001671
5b	17:10	0:30	1.02	19	19	0	5	17.55	0.285	27.2	1.903	1.453	0.0324	0.001707

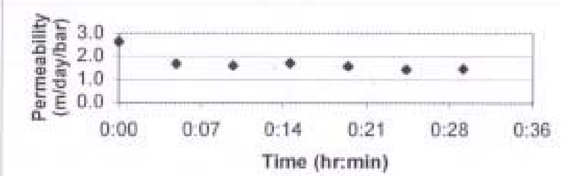
5b	Average Slurry Flow gpm =	0.96	ft/s =	6.16	
5b	Average Pressure psid =	20.25			
5b	Average Filtrate Flow mL/sec =	0.375			
5b	Average Filtrate Flux gpm/ft2 =	0.037	With First Point Removed		
5b	Average Permeability gpm/ft2/psi =	0.002			

RAW Average Slurry Flow = 0.96 Average Pressure = 20.25 Average Flow = Filtrate 0.375 Average Flux = 2.209 With First Point Removed

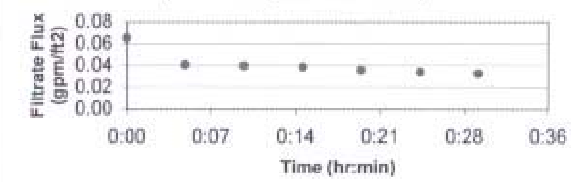
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
5b	16:40		26.2	0.93	20		22	5	9	0.556
5b	16:45		27.4	0.95	20		21	5	14.02	0.357
5b	16:50		28.1	0.96	20		22	5	14	0.357
5b	16:55		28.6	1.03	20		20	5	14.32	0.349
5b	17:00		28.8	0.95	20		20	5	15.27	0.327
5b	17:05		27.9	0.92	20		21	5	16.29	0.307
5b	17:10		27.2	1.02	20		19	5	17.55	0.285

C-106 Simulant Flux vs. Time
at 34.8 psig and 6.0 ft/s
(Condition 4, 2nd 30 minutes)

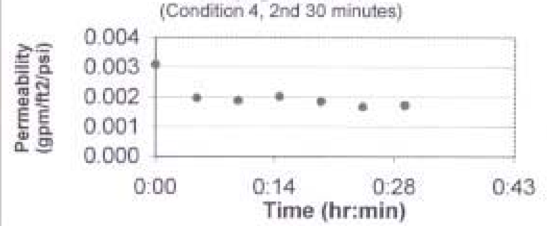
C-106 Simulant Permeability vs. Time at
34.8 psig and 6.0 ft/s
(Condition 4, 2nd 30 minutes)



C-106 Simulant Flux vs. Time
at 34.8 psig and 6.0 ft/s
(Condition 4, 2nd 30 minutes)



C-106 Simulant Permeability vs. Time at
34.8 psig and 6.0 ft/s
(Condition 4, 2nd 30 minutes)



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)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)	Permeability (gpm/ft2/psi)
8a	16:05	0:00	0.93	20	20	0	20	35.66	0.561	26.5	3.821	2.771	0.0651	0.003254	0.000077
8a	16:08	0:03	0.94	19	21	2	20	41.22	0.485	27.4	3.224	2.338	0.0550	0.002746	0.000065
8a	16:15	0:10	0.94	19	21	2	20	59.5	0.336	27.7	2.215	1.606	0.0378	0.001887	0.000044
8a	16:20	0:15	0.98	20	21	1	20	63.41	0.315	27.5	2.090	1.479	0.0356	0.001737	0.000042
8a	16:25	0:20	1.03	19	21	2	20	64.75	0.309	27.4	2.052	1.488	0.0350	0.001748	0.000041
8a	16:30	0:25	0.97	19	21	2	20	67.25	0.297	27.3	1.981	1.437	0.0338	0.001688	0.000040
8a	16:35	0:30	0.94	19	21	2	20	67.75	0.295	27.4	1.961	1.422	0.0334	0.001671	0.000039

RAW

Average Pressure = 20.9 psig   Average Flow = 57.077   Average Flux = 27.314   1.486

Average Slurry Flow = 0.96 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)
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

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)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
8b	16:40	0:00	0.86	20	21	1	10	17.78	0.562	24.4	4.064	2.875	0.0693	0.003377
8b	16:45	0:05	1.02	20	20	0	10	24.5	0.408	25.3	2.876	2.085	0.0490	0.002449
8b	16:50	0:10	1.2	20	21	1	5	15.79	0.317	25.1	2.243	1.587	0.0382	0.001864
8b	16:55	0:15	0.99	20	21	1	5	19.06	0.262	24.7	1.880	1.330	0.0320	0.001562
8b	17:00	0:20	0.96	20	21	1	5	19.4	0.258	24.9	1.836	1.299	0.0313	0.001526
8b	17:05	0:25	0.94	20	20	0	5	19.16	0.261	25.5	1.828	1.326	0.0312	0.001557
8b	17:10	0:30	0.94	20	20	0	5	19.8	0.253	25.5	1.769	1.283	0.0302	

Average Pressure = 20.6 psig Average Flow = 19.356 Average Flux = 25.057 1.485

RAW Average Slurry Flow = 0.99 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)
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

0.1 micron Liquid- Service Mott Filter

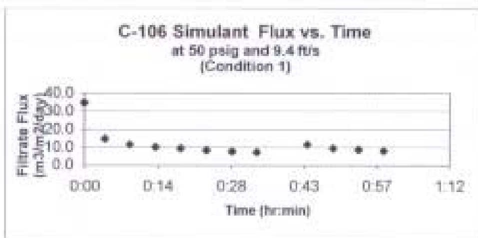
C-106 Filtration Simulant at 8 wt% Solids Loading
Cuf Testing

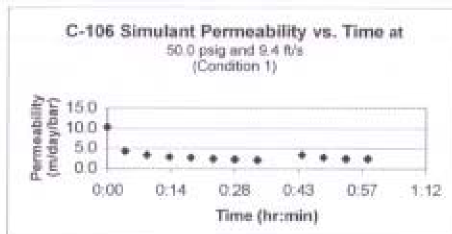
High Axial Velocity and Transmembrane Pressure Conditions

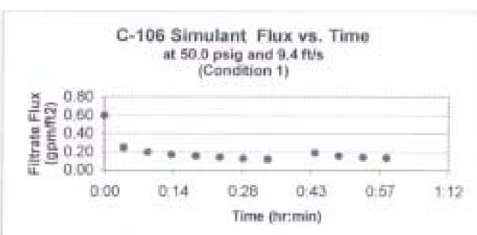
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1	3:36	0:00	3.23	47	51	4	30	4.19	7.160	24.1	34.785	10.296	0.593002	0.012093
1	3:40	0:04	3.22	48	52	4	30	10	3.000	24.1	14.575	4.228	0.248468	0.004966
1	3:45	0:09	3.2	48	52	4	30	12.54	2.392	24.6	11.460	3.324	0.195359	0.003904
1	3:50	0:14	3.27	48	52	4	30	14.34	2.092	24.7	9.993	2.899	0.170355	0.003405
1	3:55	0:19	3.23	48	52	4	30	15.78	1.901	24.9	9.030	2.619	0.153939	0.003077
1	4:00	0:24	3.23	48	52	4	30	17.56	1.708	24.9	8.115	2.354	0.138335	0.002765
1	4:05	0:29	3.25	48	52	4	30	19.31	1.554	24.2	7.527	2.183	0.128309	0.002564
1	4:10	0:34	3.28	48	52	4	30	20.97	1.431	23.9	6.990	2.028	0.119161	0.002382
1	4:20	0:44	3.22	48	52	4	30	13.88	2.161	21.9	11.181	3.243	0.190609	0.003809
1	4:25	0:49	3.17	48	53	5	30	16.87	1.778	22.1	9.147	2.627	0.155927	0.003085
1	4:30	0:54	3.23	47.5	52.5	5	30	18.4	1.630	22.2	8.362	2.426	0.142552	0.002849
1	4:35	0:59	3.26	48	52.5	4.5	30	19.06	1.574	22.7	7.958	2.297	0.135659	0.002698

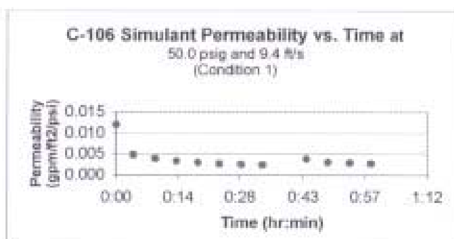
1	Average Slurry Flow gpm =	3.23	ft/s =	9.4
1	Average Pressure psid =	49.98		
1	Average Filtrate Flow mL/sec =	2.437		
1	Average Filtrate Flux gpm/ft2 =	0.198		
1	Average Permeability gpm/ft2/psi =	0.004		

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





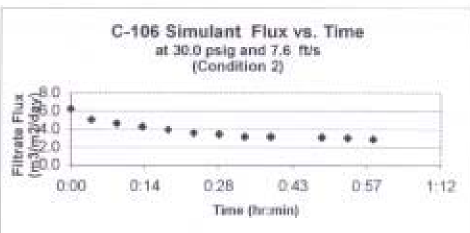


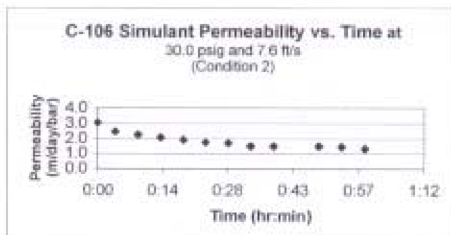


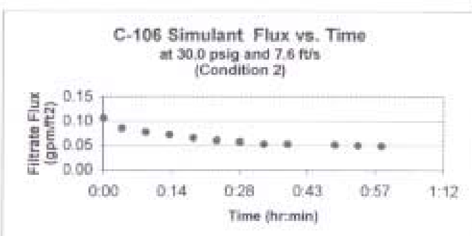
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2	9:21	0:00	2.72	28	32	4	30	23.97	1.252	23.2	6.238	3.016	0.106342	0.003542
2	9:25	0:04	2.55	28	32	4	30	30.56	0.982	22.3	5.020	2.427	0.085584	0.002851
2	9:30	0:09	2.58	28	32	4	30	34.03	0.882	21.8	4.574	2.211	0.077969	0.002597
2	9:35	0:14	2.51	28	32	4	30	36.25	0.828	22.1	4.257	2.058	0.072565	0.002417
2	9:40	0:19	2.62	28	32	4	30	38.6	0.777	23.1	3.885	1.878	0.066225	0.002206
2	9:45	0:24	2.64	28	32	4	30	41.28	0.727	24.1	3.531	1.707	0.060191	0.002005
2	9:50	0:29	2.6	27.5	31	3.5	30	42.03	0.714	24.6	3.419	1.695	0.058287	0.001991
2	9:55	0:34	2.64	28	32.5	4.5	30	46.47	0.646	24.6	3.092	1.483	0.052718	0.001741
2	10:00	0:39	2.62	28	32	4	30	47.38	0.633	24	3.085	1.491	0.052590	0.001752
2	10:10	0:49	2.47	28	32	4	30	49.47	0.606	22.9	3.049	1.474	0.051969	0.001731
2	10:15	0:54	2.59	28	32	4	30	50.56	0.593	23.2	2.957	1.430	0.050416	0.001679
2	10:20	0:59	2.6	29	33	4	30	53.59	0.560	22.8	2.822	1.320	0.048111	0.001551

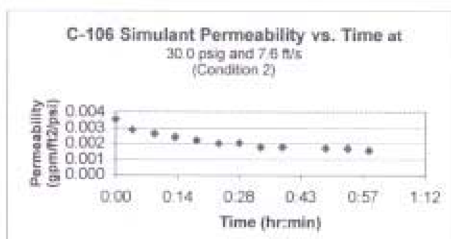
2 Average Slurry Flow gpm = 2.60 ft/s = 7.6
2 Average Pressure psid = 30.04
2 Average Filtrate Flow mL/sec = 0.767
2 Average Filtrate Flux gpm/ft2 = 0.065
2 Average Permeability gpm/ft2/psi = 0.002

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





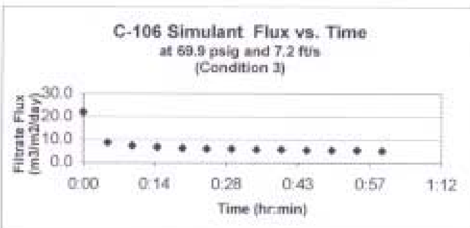


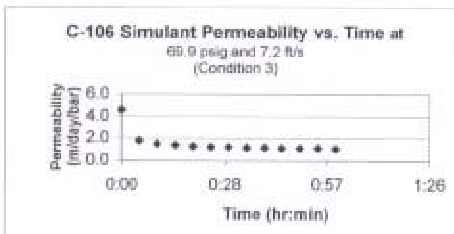


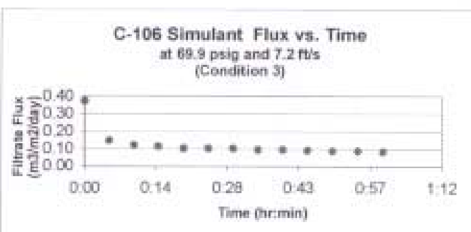
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3	10:25	0:00	2.6	68	72	4	30	6.56	4.573	24.5	21.968	4.552	0.374501	0.005346
3	10:30	0:05	2.5	68	72	4	30	16.91	1.774	24.3	8.571	1.776	0.146106	0.002086
3	10:35	0:10	2.4	68	71.5	3.5	30	20.4	1.471	24.2	7.124	1.481	0.121454	0.001740
3	10:40	0:15	2.45	68	71.5	3.5	30	21.84	1.374	24.2	6.655	1.384	0.113446	0.001625
3	10:45	0:20	2.48	68	71.5	3.5	30	24	1.250	24.3	6.039	1.256	0.102944	0.001475
3	10:50	0:25	2.47	68	72	4	30	24.31	1.234	24.3	5.962	1.235	0.101631	0.001451
3	10:55	0:30	2.52	68	72	4	30	24.16	1.242	24.5	5.965	1.236	0.101686	0.001452
3	11:00	0:35	2.52	68	71.5	3.5	30	25.37	1.182	24.7	5.648	1.175	0.096291	0.001380
3	11:05	0:40	2.47	68.5	72	3.5	30	25.69	1.168	24.9	5.547	1.145	0.094557	0.001345
3	11:10	0:45	2.42	68	72	4	30	26.44	1.135	25.1	5.359	1.110	0.091359	0.001304
3	11:15	0:50	2.4	68	71	3	30	27.03	1.110	25	5.257	1.097	0.089616	0.001289
3	11:20	0:55	2.42	68	72	4	30	27.47	1.092	24.9	5.187	1.075	0.088430	0.001262
3	11:25	1:00	2.43	68	72	4	30	28.63	1.048	24.9	4.977	1.031	0.084847	0.001211

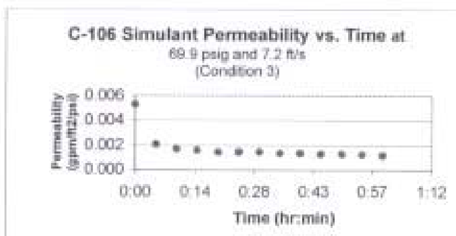
3 Average Slurry Flow gpm = 2.47 ft/s = 7.2
3 Average Pressure psid = 69.90
3 Average Filtrate Flow mL/sec = 1.512
3 Average Filtrate Flux gpm/ft2 = 0.124
3 Average Permeability gpm/ft2/psi = 0.002

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





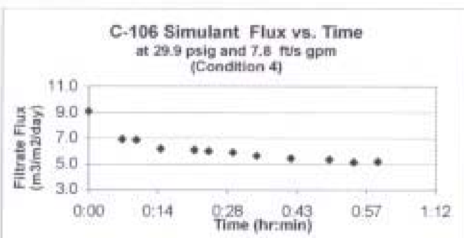


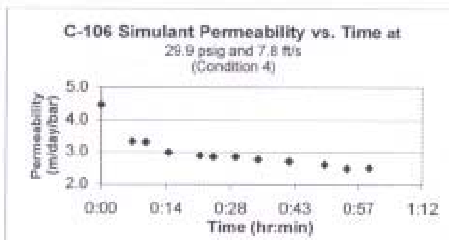


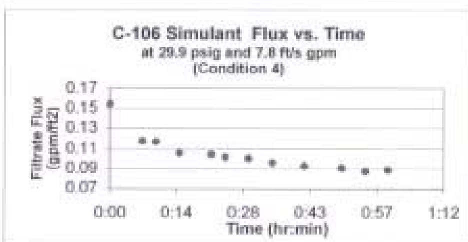
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4	11:35	0:00	2.65	28	31	3	30	16.82	1.784	22.5	9.069	4.459	0.154608	0.005237
4	11:42	0:07	2.7	28	32	4	30	22.5	1.333	22	6.878	3.325	0.117247	0.003905
4	11:45	0:10	2.83	28	32	4	30	22.44	1.337	22.3	6.837	3.305	0.116553	0.003882
4	11:50	0:15	2.57	28	32	4	30	24.6	1.220	22.6	6.183	2.989	0.105409	0.003511
4	11:57	0:22	2.8	28	33	5	30	24.72	1.214	23	6.083	2.893	0.103706	0.003398
4	12:00	0:25	2.75	28.5	32	3.5	30	25.31	1.185	23	5.942	2.849	0.101288	0.003346
4	12:05	0:30	2.68	28	32	4	30	25.53	1.175	23.1	5.874	2.840	0.100129	0.003335
4	12:10	0:35	2.9	28	31	3	30	26.65	1.126	23.1	5.627	2.766	0.095921	0.003249
4	12:17	0:42	2.76	27	31	4	30	27.5	1.091	23.2	5.437	2.719	0.092692	0.003194
4	12:25	0:50	2.44	28	31	3	30	28	1.071	23.3	5.325	2.618	0.090778	0.003075
4	12:30	0:55	2.75	28	32	4	30	29.09	1.031	23.2	5.140	2.485	0.087625	0.002919
4	12:35	1:00	2.5	28	32	4	30	28.94	1.037	23.1	5.182	2.505	0.088331	0.002942

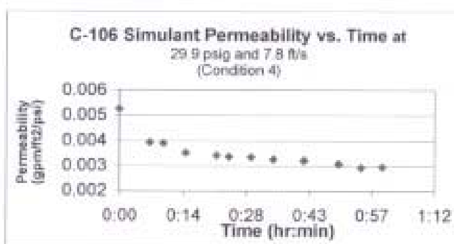
4	Average Slurry Flow gpm =	2.69	ft/s =	7.8
4	Average Pressure psid =	29.85		
4	Average Filtrate Flow mL/sec =	1.217		
4	Average Filtrate Flux gpm/ft2 =	0.105		
4	Average Permeability gpm/ft2/psi =	0.003		

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





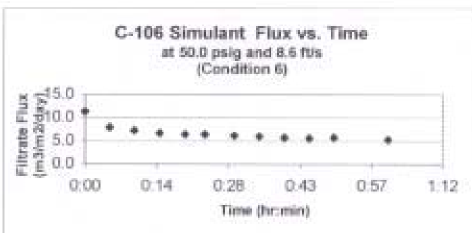


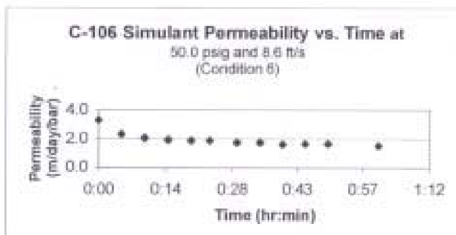


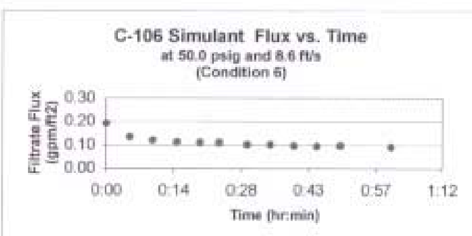
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5	12:45	0:00	3.08	48	52	4	30	12.66	2.370	24.8	11.287	3.274	0.192418	0.003846
5	12:50	0:05	2.91	48	52	4	30	18.06	1.661	24.8	7.912	2.295	0.134885	0.002696
5	12:55	0:10	2.88	48	52	4	30	20.44	1.468	24.2	7.111	2.063	0.121216	0.002423
5	13:00	0:15	3.07	48	52	4	30	21.69	1.383	24.5	6.644	1.927	0.113265	0.002264
5	13:05	0:20	2.89	48	52	4	30	22.19	1.352	25.1	6.386	1.852	0.108856	0.002176
5	13:09	0:24	2.94	48	52	4	30	22.31	1.345	24.9	6.387	1.853	0.108882	0.002176
5	13:15	0:30	2.92	48	52	4	30	23.75	1.263	24.7	6.034	1.750	0.102859	0.002056
5	13:20	0:35	2.87	48	52	4	30	24.09	1.245	24.7	5.949	1.726	0.101407	0.002027
5	13:25	0:40	2.94	48	52	4	30	25.34	1.184	25.1	5.592	1.622	0.095324	0.001905
5	13:30	0:45	2.9	47.5	52	4.5	30	25.38	1.182	25.2	5.567	1.623	0.094907	0.001906
5	13:35	0:50	2.93	48	52	4	30	25.25	1.188	25	5.627	1.632	0.095934	0.001917
5	13:46	1:01	3.03	48	52	4	30	26.87	1.116	25.1	5.273	1.530	0.089897	0.001797

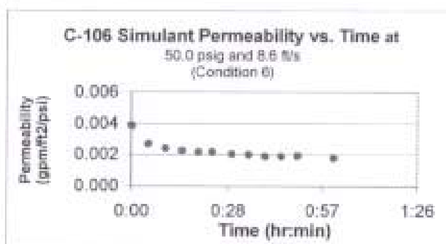
5	Average Slurry Flow gpm =	2.95	ft/s =	8.6
5	Average Pressure psid =	49.98		
5	Average Filtrate Flow mL/sec =	1.396		
5	Average Filtrate Flux gpm/ft2 =	0.113		
5	Average Permeability gpm/ft2/psi =	0.002		

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	12:45	18	24.8	3.08	48		52	30	12.66	2.370
5	12:50	13	24.8	2.91	48		52	30	18.06	1.661
5	12:55	13	24.2	2.88	48		52	30	20.44	1.468
5	13:00	16	24.5	3.07	48		52	30	21.69	1.383
5	13:05	16	25.1	2.89	48		52	30	22.19	1.352
5	13:09	14	24.9	2.94	48		52	30	22.31	1.345
5	13:15	15	24.7	2.92	48		52	30	23.75	1.263
5	13:20	15	24.7	2.87	48		52	30	24.09	1.245
5	13:25	16	25.1	2.94	48		52	30	25.34	1.184
5	13:30	16	25.2	2.9	47.5		52	30	25.38	1.182
5	13:35	15	25	2.93	48		52	30	25.25	1.188
5	13:46	15	25.1	3.03	48		52	30	26.87	1.116





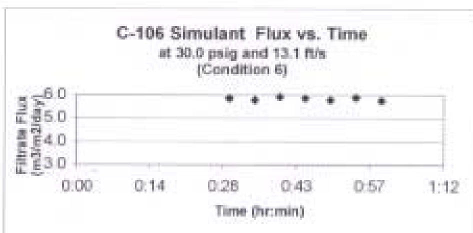


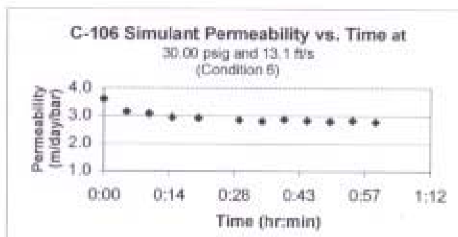


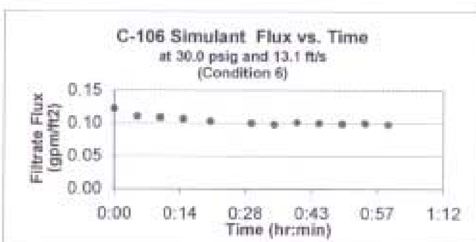
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
6	1:55	0:00	4.54	26	32	6	30	19.75	1.519	25	7.195	3.598	0.122650	0.004226
6	2:00	0:05	4.44	27	33	6	40	29.22	1.369	25	6.484	3.135	0.110533	0.003682
6	2:05	0:10	4.47	27	33	6	30	22.31	1.345	24.9	6.387	3.088	0.108882	0.003627
6	2:10	0:15	4.55	28	34	6	30	22.47	1.335	25.3	6.271	2.934	0.106897	0.003446
6	2:16	0:21	4.48	27	33	6	30	23.22	1.292	25.5	6.034	2.917	0.102865	0.003426
6	2:25	0:30	4.47	27	33	6	30	24.15	1.242	25.1	5.867	2.837	0.100022	0.003332
6	2:30	0:35	4.46	27	33	6	30	24.62	1.219	25	5.771	2.790	0.098389	0.003277
6	2:35	0:40	4.48	27	33	6	30	24	1.250	25	5.921	2.862	0.100930	0.003362
6	2:40	0:45	4.52	27	33	6	30	24.28	1.236	25	5.852	2.829	0.099766	0.003323
6	2:45	0:50	4.52	27	33	6	30	24.53	1.223	25	5.793	2.801	0.098750	0.003289
6	2:50	0:55	4.52	27	33.5	6.5	30	24.09	1.245	25.1	5.882	2.820	0.100271	0.003312
6	2:55	1:00	4.48	27	33	6	30	24.9	1.205	24.8	5.739	2.774	0.097832	0.003259

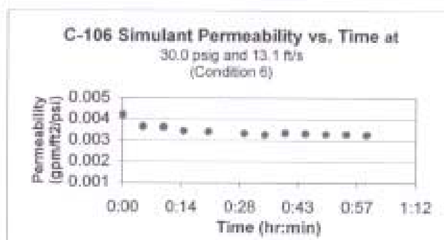
6 Average Slurry Flow gpm = 4.49 ft/s = 13.1
6 Average Pressure psid = 30.02
6 Average Filtrate Flow mL/sec = 1.290
6 Average Filtrate Flux gpm/ft2 = 0.104
6 Average Permeability gpm/ft2/psi = 0.003

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	1:55	14	25	4.54	26		32	30	19.75	1.519
6	2:00	14	25	4.44	27		33	40	29.22	1.369
6	2:05	14	24.9	4.47	27		33	30	22.31	1.345
6	2:10	16	25.3	4.55	28		34	30	22.47	1.335
6	2:16	15	25.5	4.48	27		33	30	23.22	1.292
6	2:25	14	25.1	4.47	27		33	30	24.15	1.242
6	2:30	14	25	4.46	27		33	30	24.62	1.219
6	2:35	15	25	4.48	27		33	30	24	1.250
6	2:40	14	25	4.52	27		33	30	24.28	1.236
6	2:45	14	25	4.52	27		33	30	24.53	1.223
6	2:50	14	25.1	4.52	27		33.5	30	24.09	1.245
6	2:55	12	24.8	4.48	27		33	30	24.9	1.205









0.5 micron Liquid- Service Mott Filter

C-106 Filtration Simulant at 8 wt% Solids Loading Cuf Testing

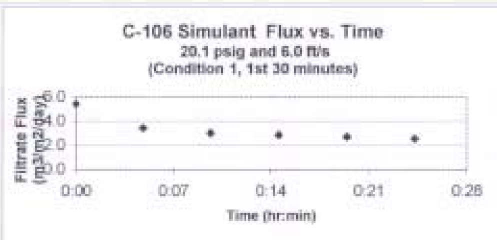
Low Axial Velocity and Transmembrane Pressure Conditions

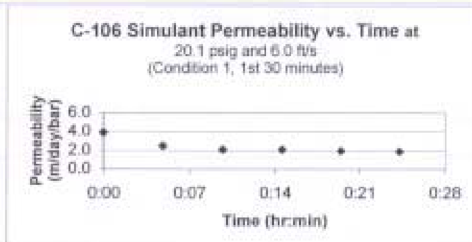
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1a	14:10	0:00	3.67	NM	20	9	22.25	0.404	27.2	5.405	3.920	0.0921	0.004604
1a	14:15	0:05	3.74	NM	20	9	37.1	0.243	25.4	3.408	2.472	0.0581	0.002903
1a	14:20	0:10	3.7	NM	21	9	43.78	0.206	24.1	2.996	2.069	0.0511	0.002431
1a	14:25	0:15	3.63	NM	20	9	47.34	0.190	23.3	2.835	2.056	0.0483	0.002414
1a	14:30	0:20	3.66	NM	20	9	50.56	0.178	23.1	2.669	1.936	0.0455	0.002274
1a	14:35	0:25	3.69	NM	20	9	52.53	0.171	23.5	2.540	1.842	0.0433	0.002164
1a	14:40	0:30	3.69	NM	20	9	54.87	0.164	23.7	2.418	1.753	0.0412	0.002060

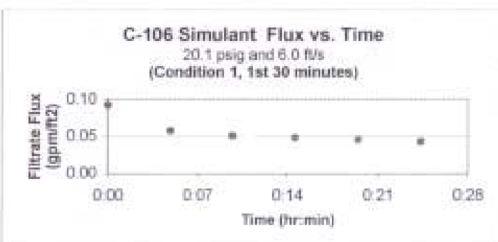
1a	Average Slurry Flow gpm =	3.68	ft/s =	6.02
1a	Average Pressure psid =	20.14		
1a	Average Filtrate Flow mL/sec =	0.222		
1a	Average Filtrate Flux gpm/ft2 =	0.048	With First Point Removed	
1a	Average Permeability gpm/ft2/psi =	0.003		

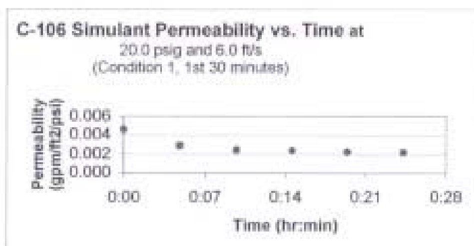
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)		
1a	14:11	18	27.2	3.67	NM	0	20	9	19.5	0.462	0:00	0.069
1a	14:15	14	25.4	3.74	NM	0	20	9	26.1	0.345	0:05	0.069019882
1a	14:20	15	24.1	3.7	NM	0	21	9	28.37	0.317	0:10	0.052317474
1a	14:25	16	23.3	3.63	NM	0	20	9	31.03	0.290	0:15	0.047853532
1a	14:30	17	23.1	3.66	NM	0	20	9	34.07	0.264	0:25	0.043000174
1a	14:35	18	23.5	3.69	NM	0	20	9	35.63	0.253	0:30	0.037515423
1a	14:40	19	23.7	3.69	NM	0	20	9	35.63	0.253	0:00	0.035165603

NM = Not Measured







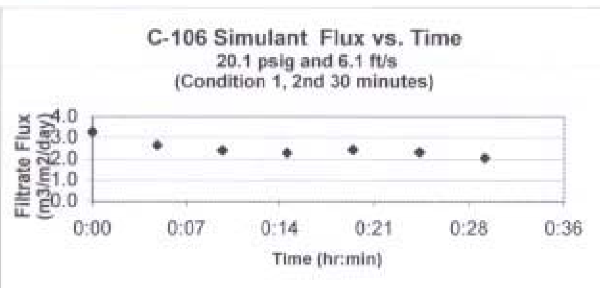


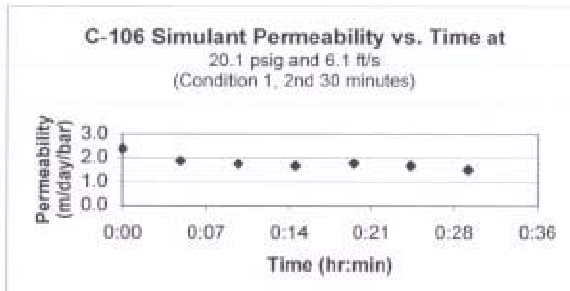
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1b	14:55	0:00	3.77	NM	20	9	39.79	0.226	24.2	3.287	2.384	0.0560	0.0028
1b	15:00	0:05	3.66	NM	20.5	9	49.68	0.181	24.1	2.640	1.868	0.0450	0.002194
1b	15:05	0:10	3.7	NM	20	9	54.56	0.165	24.2	2.397	1.739	0.0409	0.002042
1b	15:10	0:15	3.69	NM	20	9	56.65	0.159	24.4	2.296	1.665	0.0391	0.001956
1b	15:15	0:20	3.67	NM	20	9	52.88	0.170	24.8	2.432	1.764	0.0415	0.002072
1b	15:20	0:25	3.66	NM	20.5	9	54.88	0.164	25	2.330	1.649	0.0397	0.001936
1b	15:25	0:30	3.82	NM	20	9	62.13	0.145	25	2.058	1.493	0.0351	0.001753

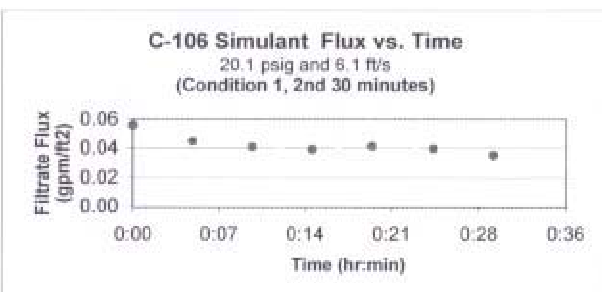
1b	Average Slurry Flow gpm =	3.71	ft/s =	6.1
1b	Average Pressure psid =	20.14		
1b	Average Filtrate Flow mL/sec =	0.173		
1b	Average Filtrate Flux gpm/ft2 =	0.040	With First Point Removed	
1b	Average Permeability gpm/ft2/psi =	0.002		

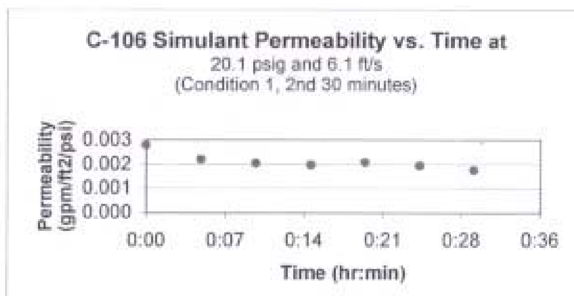
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
1b	14:55	18	23.8	0.89	NM	1	20	10	25.81	0.387
1b	15:00	18	24.2	0.93	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







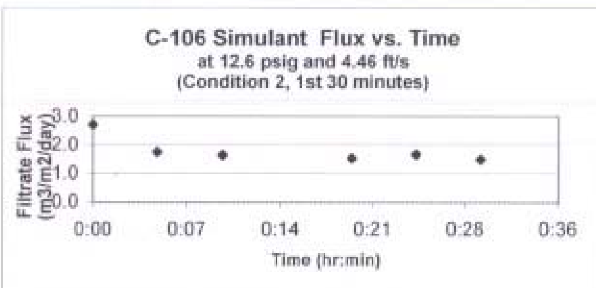


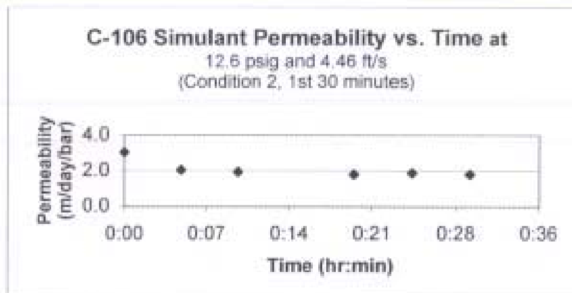
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2a	16:10	0:00	2.76	NM	13	15	73.84	0.203	27.1	2.722	3.037	0.0464	0.003567
2a	16:15	0:05	2.76	NM	12.5	9	69.97	0.129	26.6	1.748	2.028	0.0298	0.002382
2a	16:20	0:10	2.7	NM	12.5	9	74.84	0.120	26.2	1.652	1.917	0.0282	0.002252
2a	16:30	0:20	2.5	NM	12.5	9	81.22	0.111	25.9	1.535	1.781	0.0262	0.002092
2a	16:35	0:25	2.75	NM	13	9	74.56	0.121	26	1.668	1.861	0.0284	0.002185
2a	16:40	0:30	2.77	NM	12	9	81.5	0.110	27	1.484	1.793	0.0253	0.002106

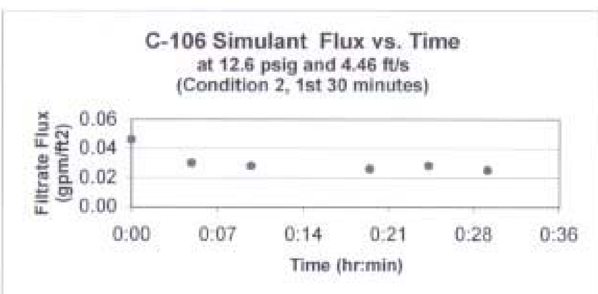
2a	Average Slurry Flow gpm =	2.71	ft/s =	4.46
2a	Average Pressure psid =	12.58		
2a	Average Filtrate Flow mL/sec =	0.132		
2a	Average Filtrate Flux gpm/ft2 =	0.028	With First Point Removed	
2a	Average Permeability gpm/ft2/psi =	0.002		

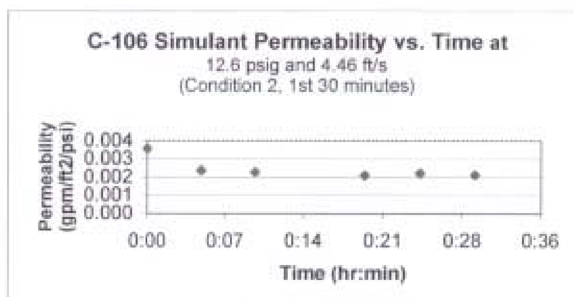
Test Number	Time	Chiller Temp C	Slurry Temp C	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Permeate Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)
2a	16:10	13	27.1	2.76	NM	0	13	15	73.84	0.203
2a	16:15	12.5	26.6	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





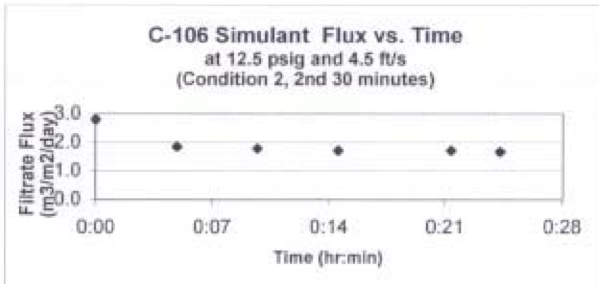


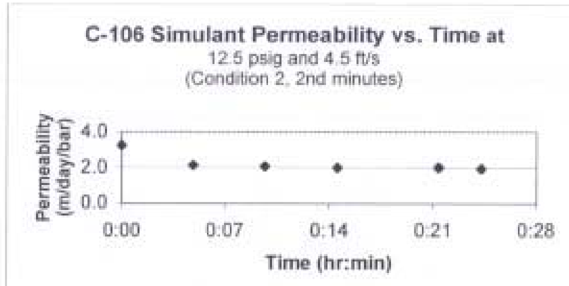


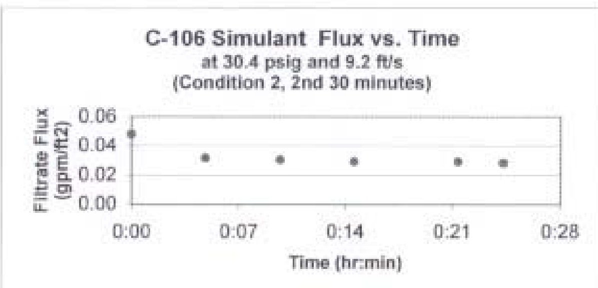
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2b	10:53	0:00	2.87	NM	12.5	9	45.28	0.199	25.2	2.808	3.259	0.0479	0.003827
2b	10:58	0:05	2.64	NM	12.5	9	68.66	0.131	25.2	1.852	2.149	0.0316	0.002524
2b	11:03	0:10	2.69	NM	12.5	9	72	0.125	25	1.776	2.061	0.0303	0.002421
2b	11:08	0:15	2.79	NM	12.5	9	74.72	0.120	24.9	1.716	1.991	0.0293	0.002339
2b	11:15	0:22	2.82	NM	12.5	9	75.25	0.120	24.7	1.714	1.989	0.0292	0.002336
2b	11:18	0:25	2.77	NM	12.5	9	77.47	0.116	24.7	1.665	1.932	0.0284	0.002269
2b	11:23	0:30	2.73	NM	12.5	9	79.47	0.113	24.7	1.623	1.883	0.0277	0.002212

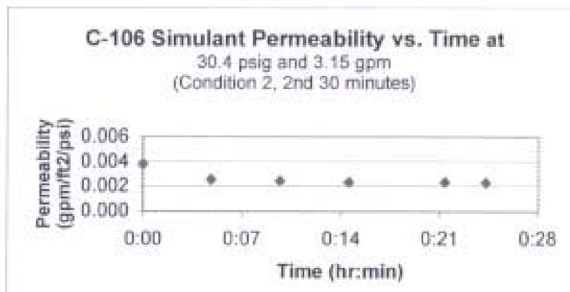
2b	Average Slurry Flow gpm =	2.76	ft/s =	4.51	
2b	Average Pressure psid =	12.50			
2b	Average Filtrate Flow mL/sec =	0.132			
2b	Average Filtrate Flux gpm/ft2 =	0.029	With First Point Removed		
2b	Average Permeability gpm/ft2/psi =	0.003			

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





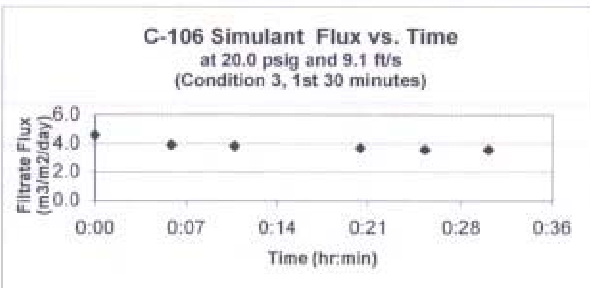


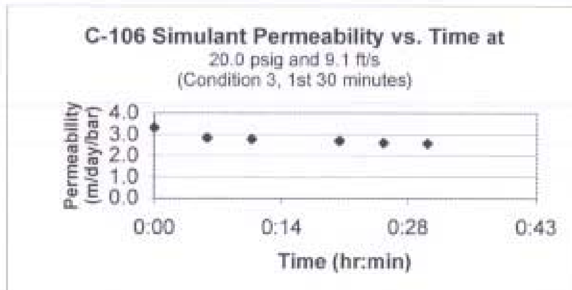


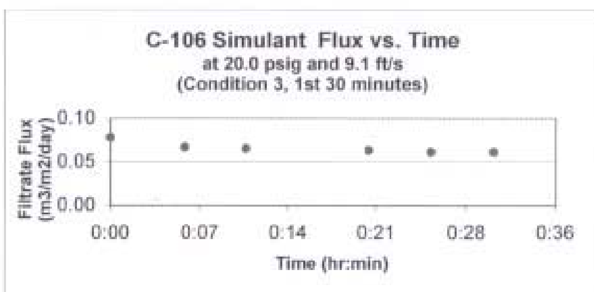
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3a	11:59	0:00	5.59	NM	20	9	27.75	0.324	25.4	4.557	3.305	0.0777	0.003881
3a	12:05	0:06	5.52	NM	20	9	32.62	0.276	25.1	3.909	2.835	0.0666	0.003330
3a	12:10	0:11	5.51	NM	20	9	33.85	0.266	24.4	3.842	2.787	0.0655	0.003273
3a	12:20	0:21	5.52	NM	20	9	35.63	0.253	23.9	3.703	2.685	0.0631	0.003154
3a	12:25	0:26	5.54	NM	20	9	36.81	0.244	24.1	3.564	2.584	0.0608	0.003035
3a	12:30	0:31	5.54	NM	20	9	36.75	0.245	24.2	3.559	2.581	0.0607	0.003032

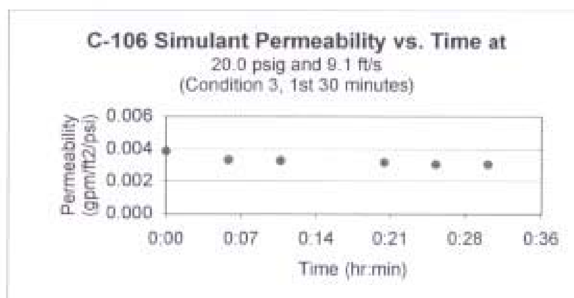
3a	Average Slurry Flow gpm =	5.54	ft/s =	9.06
3a	Average Pressure psid =	20.00		
3a	Average Filtrate Flow mL/sec =	0.268		
3a	Average Filtrate Flux gpm/ft2 =	0.063	With First Point Removed	
3a	Average Permeability gpm/ft2/psi =	0.003		

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	33.85	0.266
3a	12:20	15	23.9	5.52	NM	0	20	9	35.63	0.253
3a	12:25	16	24.1	5.54	NM	0	20	9	36.81	0.244
3a	12:30	15	24.2	5.54	NM	0	20	9	36.75	0.245





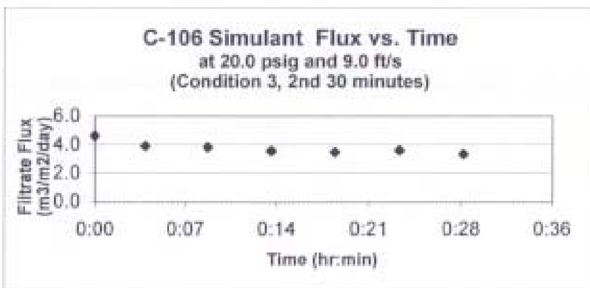


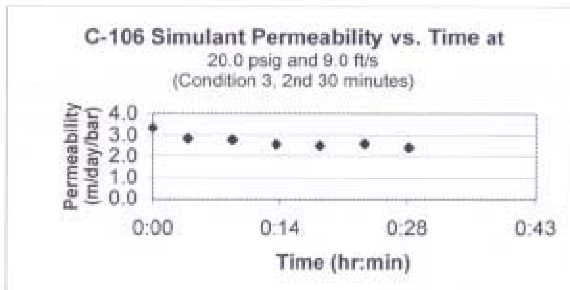


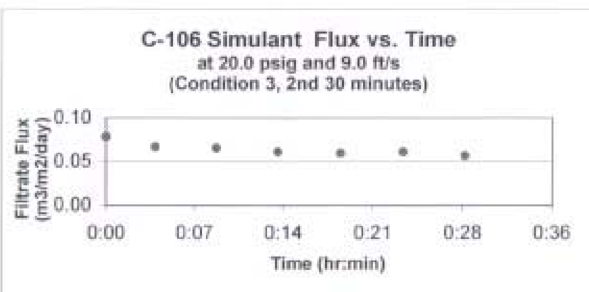
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3b	12:41	0:00	5.51	NM	20	9	28	0.321	24.6	4.619	3.350	0.0787	0.003934
3b	12:45	0:04	5.51	NM	20	9	32.72	0.275	24.9	3.919	2.842	0.0668	0.003338
3b	12:50	0:09	5.54	NM	20	9	33.47	0.269	25	3.821	2.771	0.0651	0.003254
3b	12:55	0:14	5.52	NM	20	9	35.72	0.252	25.2	3.560	2.582	0.0607	0.003032
3b	13:00	0:19	5.52	NM	20	9	36.5	0.247	25.3	3.474	2.519	0.0592	0.002959
3b	13:05	0:24	5.55	NM	20	9	35.44	0.254	25.3	3.578	2.595	0.0610	0.003048
3b	13:10	0:29	5.52	NM	20	9	38.65	0.233	24.9	3.318	2.406	0.0566	0.002826

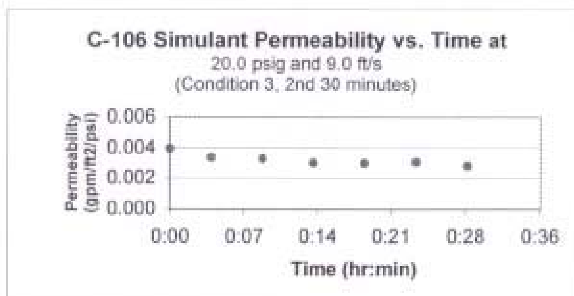
3b	Average Slurry Flow gpm =	5.52	ft/s =	9.02	
3b	Average Pressure psid =	20.00			
3b	Average Filtrate Flow mL/sec =	0.264			
3b	Average Filtrate Flux gpm/ft2 =	0.062	With First Point Removed		
3b	Average Permeability gpm/ft2/psi =	0.003			

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)
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	33.47	0.269
3b	12:55	16	25.2	5.52	NM	0	20	9	35.72	0.252
3b	13:00	17	25.3	5.52	NM	0	20	9	36.5	0.247
3b	13:05	16	25.3	5.55	NM	0	20	9	35.44	0.254
3b	13:10	15	24.9	5.52	NM	0	20	9	38.65	0.233





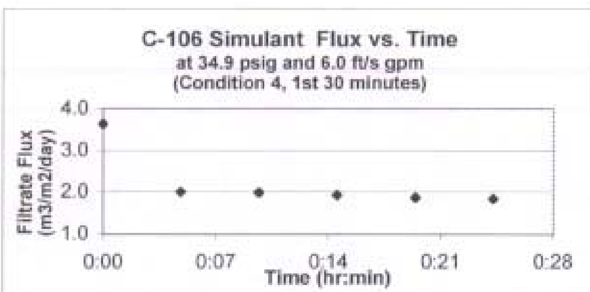


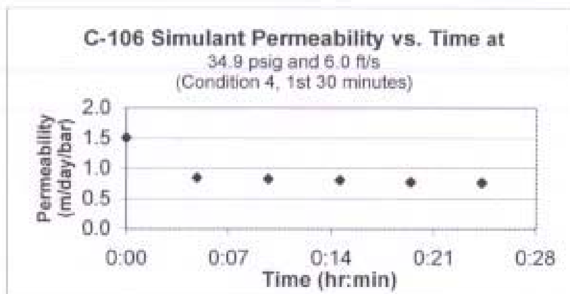


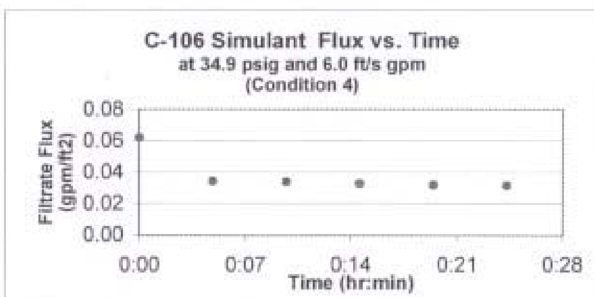
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4a	13:30	0:00	3.63	NM	35	9	32.66	0.276	27.7	3.632	1.505	0.0619	0.001768
4a	13:35	0:05	3.68	NM	34.5	9	58.28	0.154	28.3	2.002	0.842	0.0341	0.000988
4a	13:40	0:10	3.68	NM	35	9	58.28	0.154	28.5	1.991	0.825	0.0339	0.000969
4a	13:45	0:15	3.63	NM	35	9	62.25	0.145	27.3	1.927	0.798	0.0328	0.000938
4a	13:50	0:20	3.62	NM	35	9	61.44	0.146	29	1.863	0.772	0.0318	0.000907
4a	13:55	0:25	3.69	NM	35	9	62.57	0.144	28.8	1.839	0.762	0.0313	0.000895
4a	14:00	0:30	3.67	NM	35	9	66	0.136	28.8	1.743	0.722	0.0297	0.000849

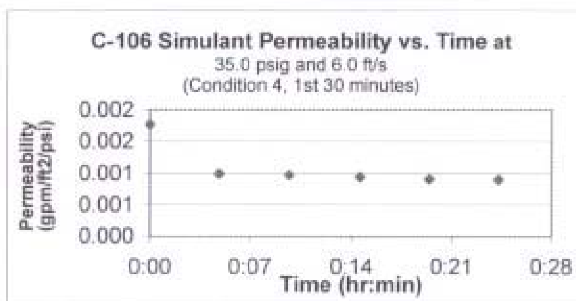
4a	Average Slurry Flow gpm =	3.66	ft/s =	5.98
4a	Average Pressure psid =	34.93		
4a	Average Filtrate Flow mL/sec =	0.165		
4a	Average Filtrate Flux gpm/ft2 =	0.032	With First Point Removed	
4a	Average Permeability gpm/ft2/psi =	0.001		

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	61.44	0.146
4a	13:55	16	28.8	3.69	NM	0	35	9	62.57	0.144
4a	14:00	16	28.8	3.67	NM	0	35	9	66	0.136





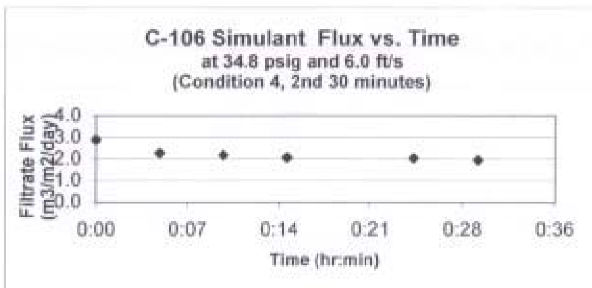


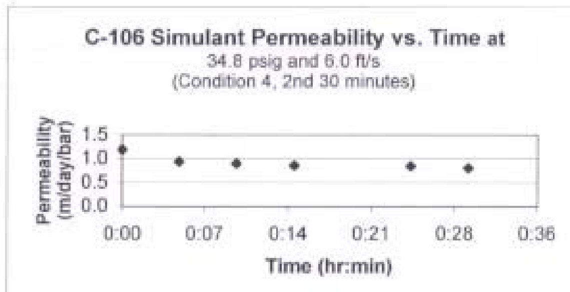


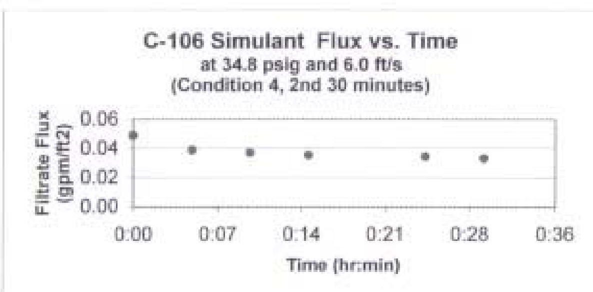
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4b	14:15	0:00	3.69	NM	35	9	45	0.200	24.5	2.882	1.194	0.0491	0.001403
4b	14:20	0:05	3.67	NM	35	9	57.06	0.158	24.5	2.273	0.942	0.0387	0.001106
4b	14:25	0:10	3.63	NM	35	9	59.34	0.152	24.6	2.180	0.903	0.0372	0.001061
4b	14:30	0:15	3.64	NM	35	9	62.59	0.144	24.5	2.072	0.859	0.0353	0.001009
4b	14:40	0:25	3.69	NM	35	9	63.69	0.141	24.6	2.031	0.842	0.0346	0.000988
4b	14:45	0:30	3.67	NM	35	9	66.85	0.135	24.7	1.929	0.799	0.0329	0.000939

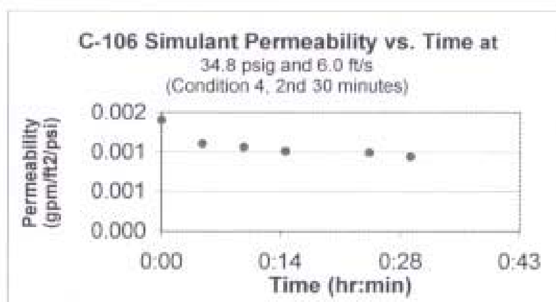
4b	Average Slurry Flow gpm =	3.67	ft/s =	6.00
4b	Average Pressure psid =	35.00		
4b	Average Filtrate Flow mL/sec =	0.155		
4b	Average Filtrate Flux gpm/ft2 =	0.036	With First Point Removed	
4b	Average Permeability gpm/ft2/psi =	0.001		

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	57.06	0.158
4b	14:25	16	24.6	3.63	NM	35	9	59.34	0.152
4b	14:30	16	24.5	3.64	NM	35	9	62.59	0.144
4b	14:40	16	24.6	3.69	NM	35	9	63.69	0.141
4b	14:45	17	24.7	3.67	NM	35	9	66.85	0.135





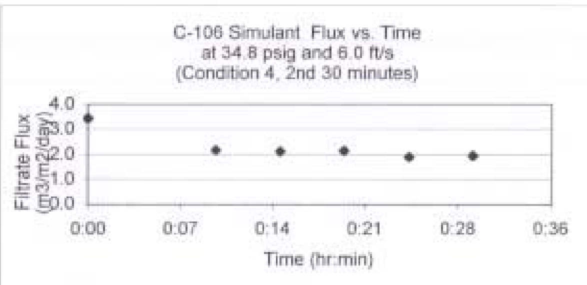


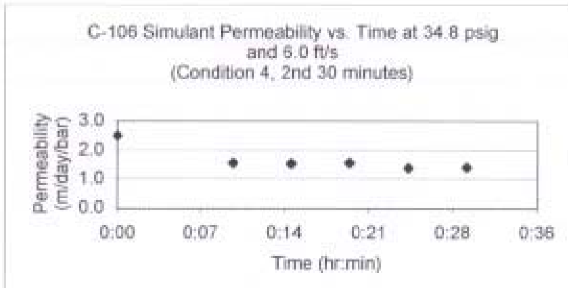


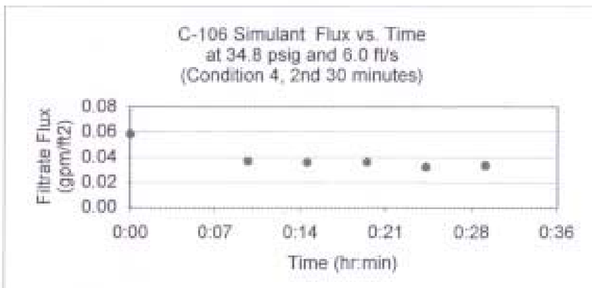
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5a	18:40	0:00	3.5	NM	20	9	35.62	0.253	26.6	3.433	2.490	0.0585	0.002924
5a	18:50	0:10	3.64	NM	20	9	61.72	0.146	23.6	2.156	1.563	0.0367	0.001836
5a	18:55	0:15	3.67	NM	20	9	64	0.141	23.2	2.103	1.525	0.0358	0.001791
5a	19:00	0:20	3.67	NM	20	9	63.25	0.142	23.1	2.134	1.547	0.0364	0.001817
5a	19:05	0:25	3.63	NM	20	9	70.94	0.127	23.3	1.892	1.372	0.0322	0.001611
5a	19:10	0:30	3.64	NM	20	9	69.06	0.130	23.3	1.943	1.409	0.0331	0.001655

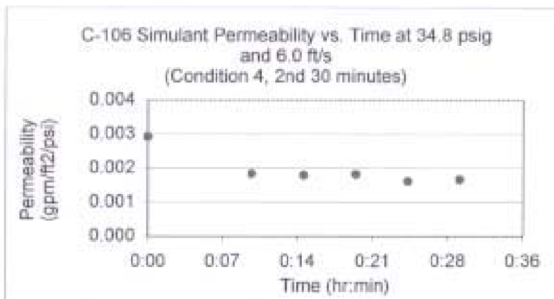
5a	Average Slurry Flow gpm =	3.63	ft/s =	5.94	
5a	Average Pressure psid =	20.00			
5a	Average Filtrate Flow mL/sec =	0.156			
5a	Average Filtrate Flux gpm/ft2 =	0.035	With First Point Removed		
5a	Average Permeability gpm/ft2/psi =	0.002			

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	18:40	16	26.6	3.5	NM	0	20	9	35.62	0.253
5a	18:50	14	23.6	3.64	NM	0	20	9	61.72	0.146
5a	18:55	14	23.2	3.67	NM	0	20	9	64	0.141
5a	19:00	15	23.1	3.67	NM	0	20	9	63.25	0.142
5a	19:05	15	23.3	3.63	NM	0	20	9	70.94	0.127
5a	19:10	16	23.3	3.64	NM	0	20	9	69.06	0.130





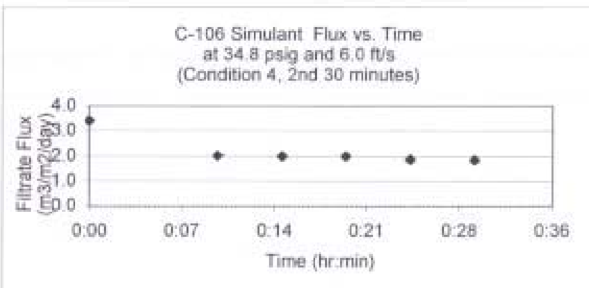


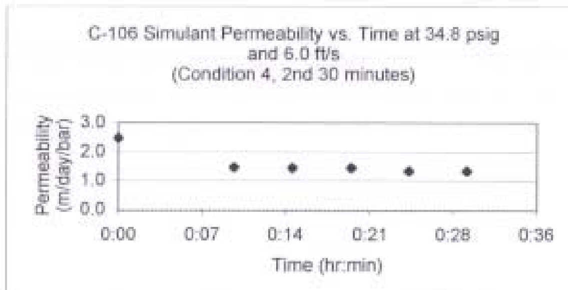


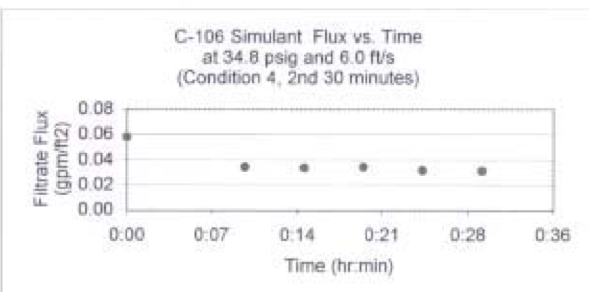
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5b	19:25	0:00	3.68	NM	20	9	39.31	0.229	23.3	3.414	2.476	0.0582	0.002908
5b	19:35	0:10	3.63	NM	20	9	66.22	0.136	23.5	2.015	1.461	0.0343	0.001716
5b	19:40	0:15	3.67	NM	20	9	67.25	0.134	23.5	1.984	1.439	0.0338	0.001690
5b	19:45	0:20	3.64	NM	20	9	66.53	0.135	23.6	2.000	1.450	0.0341	0.001703
5b	19:50	0:25	3.7	NM	20	9	70.9	0.127	24	1.855	1.346	0.0316	0.001580
5b	19:55	0:30	3.65	NM	20	9	71.04	0.127	24.3	1.836	1.332	0.0313	0.001564

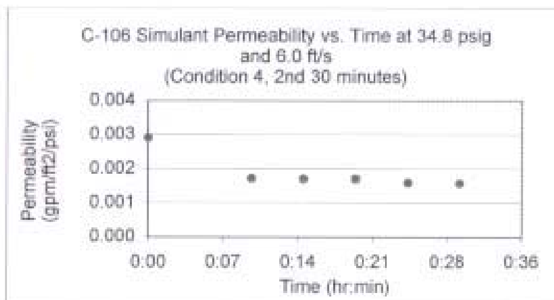
5b	Average Slurry Flow gpm =	3.66	ft/s =	5.98
5b	Average Pressure psid =	20.00		
5b	Average Filtrate Flow mL/sec =	0.148		
5b	Average Filtrate Flux gpm/ft2 =	0.033	With First Point Removed	
5b	Average Permeability gpm/ft2/psi =	0.002		

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)	
5b	19:25	15	23.3	3.68	NM	0	20	9	49.31	0.183
5b	19:35	15	23.5	3.63	NM	0	20	9	66.22	0.136
5b	19:40	16	23.5	3.67	NM	0	20	9	67.25	0.134
5b	19:45	15	23.6	3.64	NM	0	20	9	66.53	0.135
5b	19:50	16	24	3.7	NM	0	20	9	70.9	0.127
5b	19:55	16	24.3	3.65	NM	0	20	9	71.04	0.127





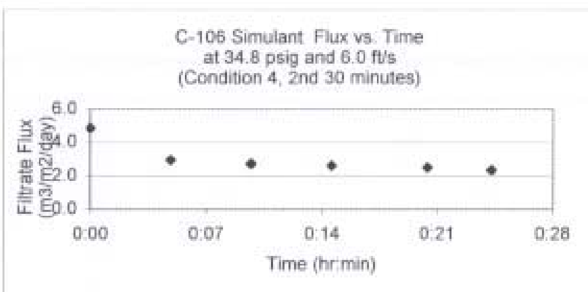


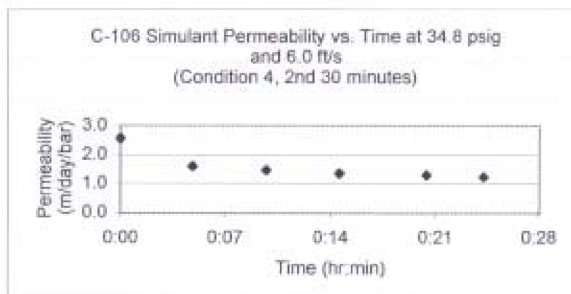


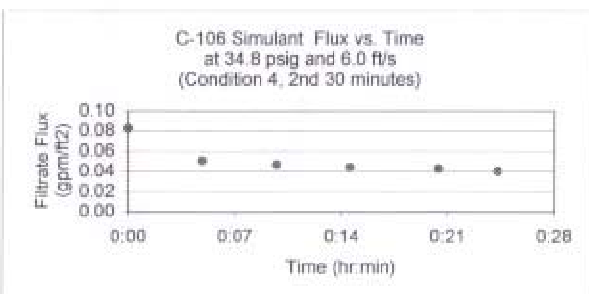
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
7a	23:25	0:00	4.54	NM	27.5	9	28.6	0.315	22.2	4.842	2.554	0.0825	0.002999
7a	23:30	0:05	4.53	NM	27	9	46.5	0.194	22.4	2.961	1.591	0.0505	0.001868
7a	23:35	0:10	4.54	NM	27	9	49.84	0.181	23	2.716	1.459	0.0463	0.001713
7a	23:40	0:15	4.55	NM	27.5	9	51.66	0.174	23.5	2.583	1.362	0.0440	0.001600
7a	23:46	0:21	4.57	NM	28	9	53.12	0.169	23.8	2.491	1.290	0.0425	0.001515
7a	23:50	0:25	4.55	NM	27.5	9	56.41	0.160	23.9	2.339	1.233	0.0399	0.001449
7a	23:55	0:30	4.56	NM	27.5	9	57.94	0.155	24	2.270	1.197	0.0387	0.001406

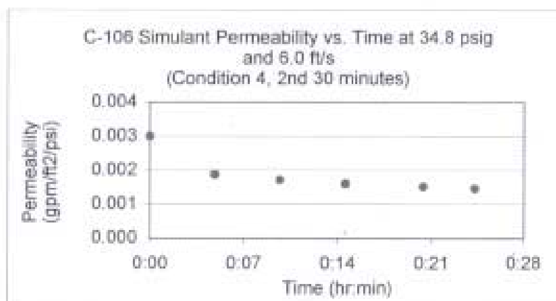
7a	Average Slurry Flow gpm =	4.55		ft/s =	7.44
7a	Average Pressure psid =	27.43			
7a	Average Filtrate Flow mL/sec =	0.192			
7a	Average Filtrate Flux gpm/ft2 =	0.044	With First Point Removed		
7a	Average Permeability gpm/ft2/psi =	0.002			

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	23:25	15	22.2	4.54	NM	0	20	9	28.6	0.315
7a	23:30	17	22.4	4.53	NM	0	20	9	46.5	0.194
7a	23:35	17	23	4.54	NM	0	21	9	49.84	0.181
7a	23:40	17	23.5	4.55	NM	0	20	9	51.66	0.174
7a	23:46	17	23.8	4.57	NM	0	20	9	53.12	0.169
7a	23:50	18	23.9	4.55	NM	0	20	9	56.41	0.160
7a	23:55	18	24	4.56	NM	0	20	9	57.94	0.155





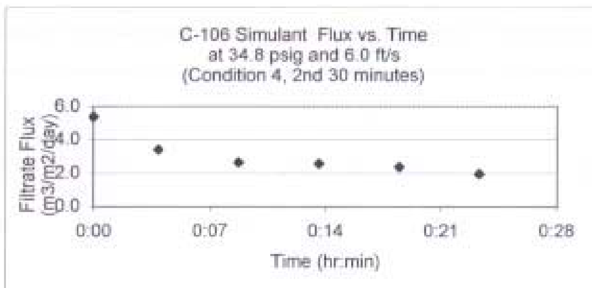


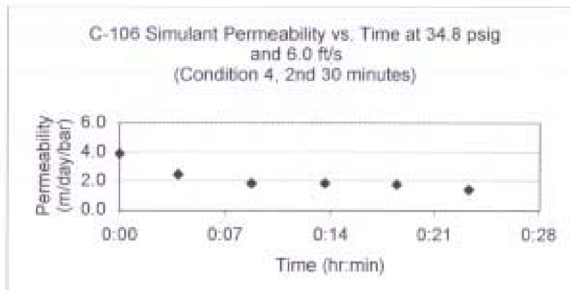


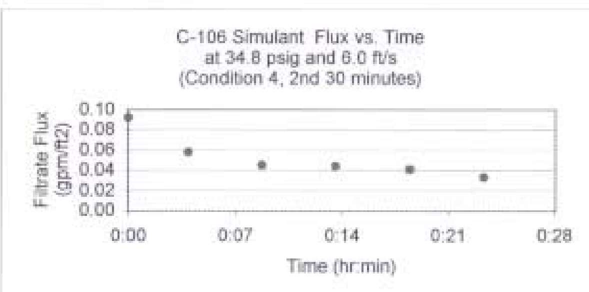
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
7b	14:11	0:00	3.67	NM	20	9	22.25	0.404	27.2	5.405	3.920	0.0921	0.004604
7b	14:15	0:04	3.74	NM	20	9	37.1	0.243	25.4	3.408	2.472	0.0581	0.002903
7b	14:20	0:09	3.7	NM	21	9	49.78	0.181	24.1	2.635	1.820	0.0449	0.002138
7b	14:25	0:14	3.63	NM	20	9	52.34	0.172	23.3	2.564	1.859	0.0437	0.002184
7b	14:30	0:19	3.66	NM	20	9	56.56	0.159	23.1	2.386	1.730	0.0407	0.002032
7b	14:35	0:24	3.69	NM	20	9	68.53	0.131	23.5	1.947	1.412	0.0332	0.001658
7b	14:40	0:29	3.69	NM	20	9	70.87	0.127	23.7	1.872	1.358	0.0319	0.001595

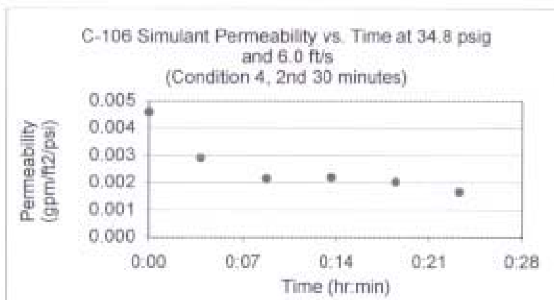
7b	Average Slurry Flow gpm =	3.68	ft/s =	6.00	
7b	Average Pressure psid =	20.14			
7b	Average Filtrate Flow mL/sec =	0.202			
7b	Average Filtrate Flux gpm/ft2 =	0.042	With First Point Removed		
7b	Average Permeability gpm/ft2/psi =	0.002			

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)	
7b	14:11	18	27.2	3.67	NM	0	20	9	22.25	0.404
7b	14:15	14	25.4	3.74	NM	0	20	9	37.1	0.243
7b	14:20	15	24.1	3.7	NM	0	21	9	49.78	0.181
7b	14:25	16	23.3	3.63	NM	0	20	9	52.34	0.172
7b	14:30	17	23.1	3.66	NM	0	20	9	56.56	0.159
7b	14:35	18	23.5	3.69	NM	0	20	9	68.53	0.131
7b	14:40	19	23.7	3.69	NM	0	20	9	70.87	0.127





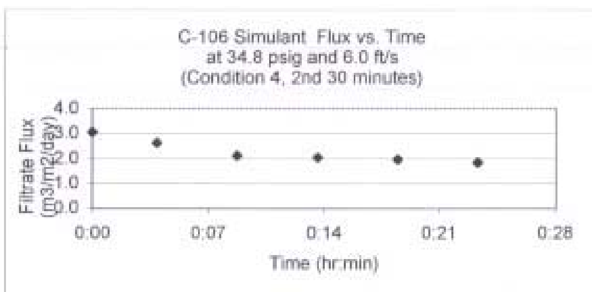


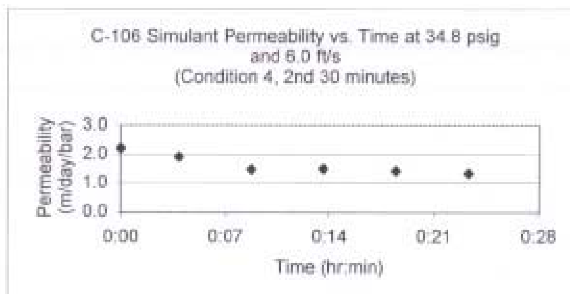


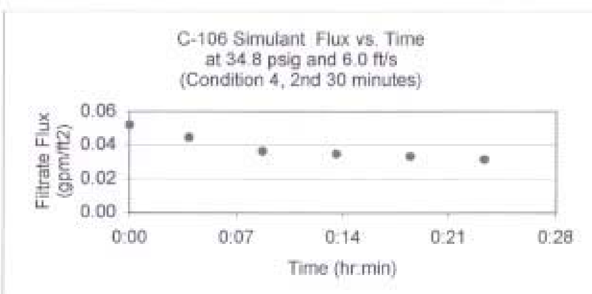
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
8a	14:11	0:00	3.72	NM	20	9	43.16	0.209	24	3.048	2.210	0.0520	0.002596
8a	14:15	0:04	3.68	NM	20	9	50.12	0.180	24	2.625	1.903	0.0447	0.002236
8a	14:20	0:09	3.66	NM	21	9	61.16	0.147	24.4	2.127	1.469	0.0363	0.001725
8a	14:25	0:14	3.68	NM	20	9	63.6	0.142	24.4	2.045	1.483	0.0349	0.001742
8a	14:30	0:19	3.69	NM	20	9	66.34	0.136	24.6	1.950	1.414	0.0332	0.001661
8a	14:35	0:24	3.67	NM	20	9	69.6	0.129	25.1	1.832	1.329	0.0312	0.001561
8a	14:40	0:29	3.7	NM	20	9	70.81	0.127	25.1	1.801	1.306	0.0307	0.001534

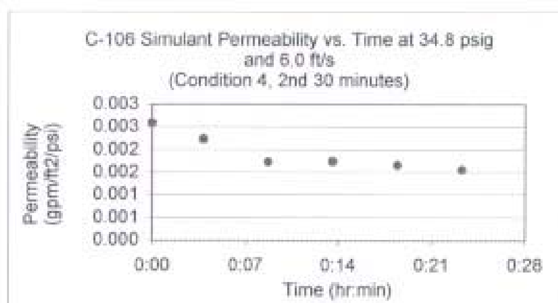
8a	Average Slurry Flow gpm =	3.69	ft/s =	6.00	
8a	Average Pressure psid =	20.14			
8a	Average Filtrate Flow mL/sec =	0.153			
8a	Average Filtrate Flux gpm/ft2 =	0.035	With First Point Removed		
8a	Average Permeability gpm/ft2/psi =	0.002			

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)
8a	14:11	20	24	3.72	NM	0	20	9	43.16	0.209
8a	14:15	19	24	3.68	NM	0	20	9	56.22	0.160
8a	14:20	21	24.4	3.66	NM	0	21	9	56.56	0.159
8a	14:25	20	24.4	3.68	NM	0	20	9	62.12	0.145
8a	14:30	20	24.6	3.69	NM	0	20	9	61.16	0.147
8a	14:35	22	25.1	3.67	NM	0	20	9	61.6	0.146
8a	14:40	21	25.1	3.7	NM	0	20	9	63.81	0.141





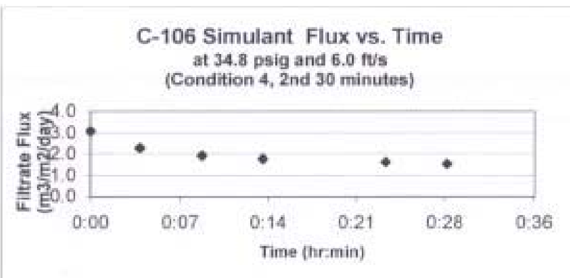


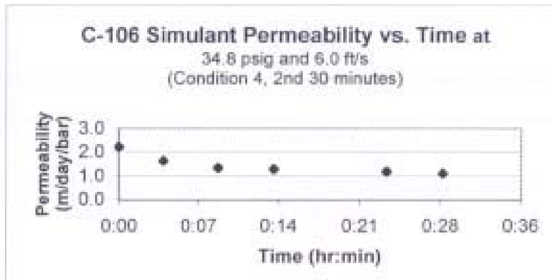


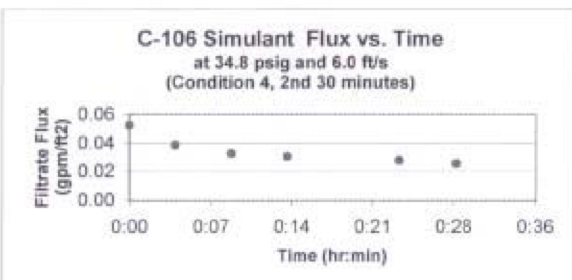
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
8b	14:11	0:00	3.68	NM	20	9	39	0.231	27.2	3.084	2.236	0.0526	0.002626
8b	14:15	0:04	3.69	NM	20	9	55.97	0.161	25.4	2.259	1.638	0.0385	0.001924
8b	14:20	0:09	3.74	NM	21	9	68.29	0.132	24.1	1.921	1.327	0.0327	0.001558
8b	14:25	0:14	3.7	NM	20	9	75.63	0.119	23.3	1.774	1.287	0.0302	0.001511
8b	14:35	0:24	3.69	NM	20	9	82.25	0.109	23.5	1.622	1.176	0.0277	0.001382
8b	14:40	0:29	3.69	NM	20	9	87.97	0.102	23.7	1.508	1.094	0.0257	0.001285

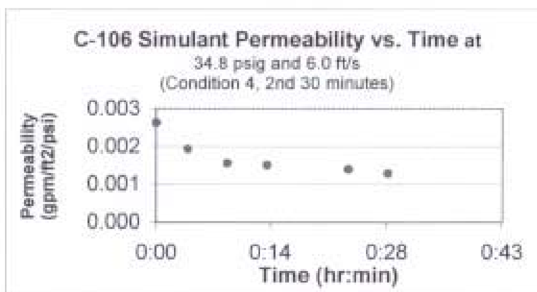
8b	Average Slurry Flow gpm =	3.70	ft/s =	6.10	
8b	Average Pressure psid =	20.17			
8b	Average Filtrate Flow mL/sec =	0.142			
8b	Average Filtrate Flux gpm/ft2 =	0.031	With First Point Removed		
8b	Average Permeability gpm/ft2/psi =	0.002			

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	14:11	18	27.2	3.67	NM	0	20	9	19.5	0.462
8b	14:15	14	25.4	3.74	NM	0	20	9	26.1	0.345
8b	14:20	15	24.1	3.7	NM	0	21	9	28.37	0.317
8b	14:25	16	23.3	3.63	NM	0	20	9	31.03	0.290
8b	14:30	17	23.1	3.66	NM	0	20	9	34.07	0.264
8b	14:35	18	23.5	3.69	NM	0	20	9	35.63	0.253
8b	14:40	19	23.7	3.69	NM	0	20	9	35.63	0.253









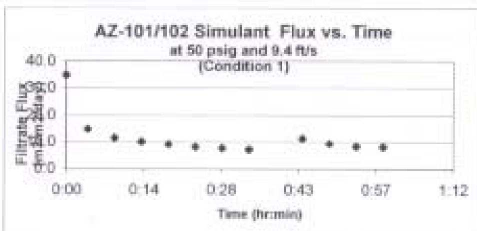
0.1 micron Liquid- Service Mott Filter

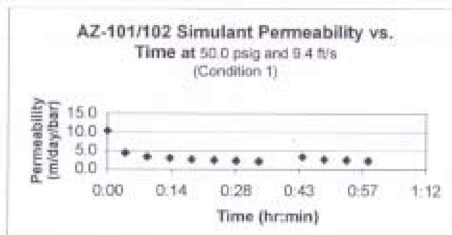
AZ-101/102 Filtration Simulant at 5 wt% Solids Loading Cuf Testing

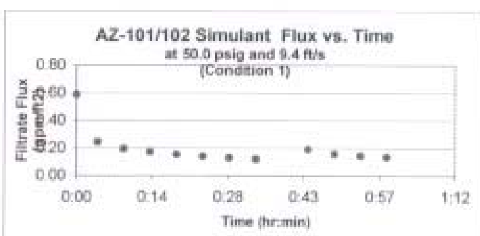
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1	3:36	0:00	3.23	47	51	4	30	4.19	7.160	24.1	34.785	10.296	0.593002	0.012093
1	3:40	0:04	3.22	48	52	4	30	10	3.000	24.1	14.575	4.228	0.248468	0.004966
1	3:45	0:09	3.2	48	52	4	30	12.54	2.392	24.6	11.460	3.324	0.195359	0.003904
1	3:50	0:14	3.27	48	52	4	30	14.34	2.092	24.7	9.993	2.899	0.170355	0.003405
1	3:55	0:19	3.23	48	52	4	30	15.78	1.901	24.9	9.030	2.619	0.153939	0.003077
1	4:00	0:24	3.23	48	52	4	30	17.56	1.708	24.9	8.115	2.354	0.138335	0.002765
1	4:05	0:29	3.25	48	52	4	30	19.31	1.554	24.2	7.527	2.183	0.128309	0.002564
1	4:10	0:34	3.28	48	52	4	30	20.97	1.431	23.9	6.990	2.028	0.119161	0.002382
1	4:20	0:44	3.22	48	52	4	30	13.88	2.161	21.9	11.181	3.243	0.190609	0.003809
1	4:25	0:49	3.17	48	53	5	30	16.87	1.778	22.1	9.147	2.627	0.155927	0.003085
1	4:30	0:54	3.23	47.5	52.5	5	30	18.4	1.630	22.2	8.362	2.426	0.142552	0.002849
1	4:35	0:59	3.26	48	52.5	4.5	30	19.06	1.574	22.7	7.958	2.297	0.135659	0.002698

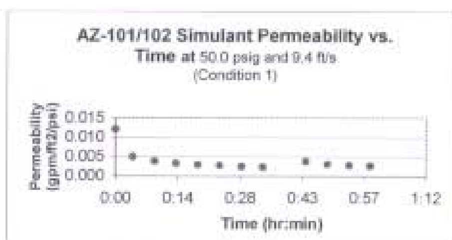
1	Average Slurry Flow gpm =	3.23	ft/s =	9.4
1	Average Pressure psid =	49.98		
1	Average Filtrate Flow mL/sec =	2.437		
1	Average Filtrate Flux gpm/ft2 =	0.198		
1	Average Permeability gpm/ft2/psi =	0.004		

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





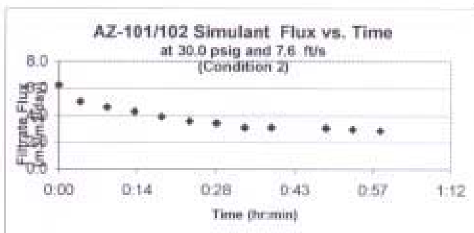


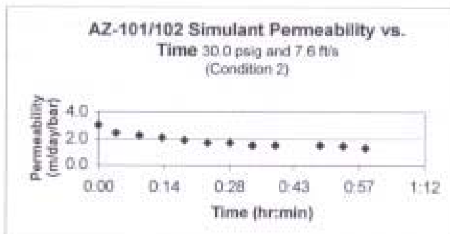


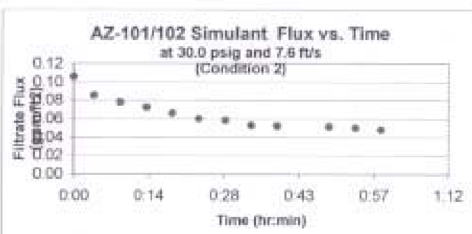
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2	9:21	0:00	2.72	28	32	4	30	23.97	1.252	23.2	6.238	3.016	0.106342	0.003542
2	9:25	0:04	2.55	28	32	4	30	30.56	0.982	22.3	5.020	2.427	0.085584	0.002851
2	9:30	0:09	2.58	28	32	4	30	34.03	0.882	21.8	4.574	2.211	0.077969	0.002597
2	9:35	0:14	2.51	28	32	4	30	36.25	0.828	22.1	4.257	2.058	0.072565	0.002417
2	9:40	0:19	2.62	28	32	4	30	38.6	0.777	23.1	3.885	1.878	0.066225	0.002206
2	9:45	0:24	2.64	28	32	4	30	41.28	0.727	24.1	3.531	1.707	0.060191	0.002005
2	9:50	0:29	2.6	27.5	31	3.5	30	42.03	0.714	24.6	3.419	1.695	0.058287	0.001991
2	9:55	0:34	2.64	28	32.5	4.5	30	46.47	0.646	24.6	3.092	1.483	0.052718	0.001741
2	10:00	0:39	2.62	28	32	4	30	47.38	0.633	24	3.085	1.491	0.052590	0.001752
2	10:10	0:49	2.47	28	32	4	30	49.47	0.606	22.9	3.049	1.474	0.051969	0.001731
2	10:15	0:54	2.59	28	32	4	30	50.56	0.593	23.2	2.957	1.430	0.050416	0.001679
2	10:20	0:59	2.6	29	33	4	30	53.59	0.560	22.8	2.822	1.320	0.048111	0.001551

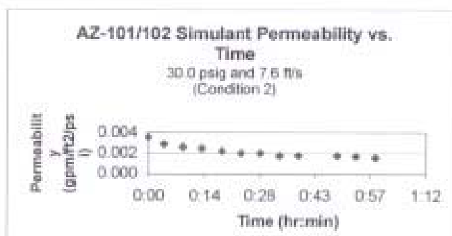
2	Average Slurry Flow gpm =	2.60	ft/s =	7.6
2	Average Pressure psid =	30.04		
2	Average Filtrate Flow mL/sec =	0.767		
2	Average Filtrate Flux gpm/ft2 =	0.065		
2	Average Permeability gpm/ft2/psi =	0.002		

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





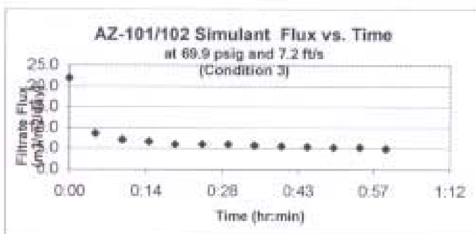


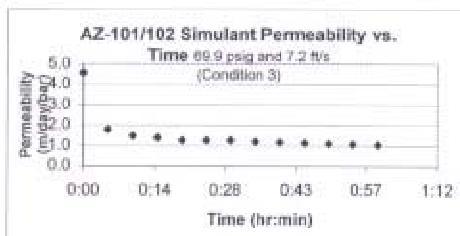


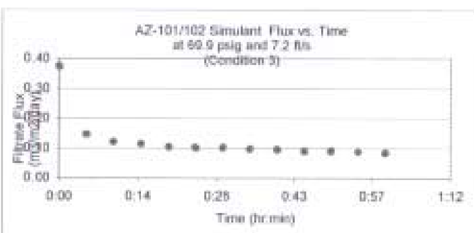
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3	10:25	0:00	2.6	68	72	4	30	6.56	4.573	24.5	21.968	4.552	0.374501	0.005346
3	10:30	0:05	2.5	68	72	4	30	16.91	1.774	24.3	8.571	1.776	0.146106	0.002086
3	10:35	0:10	2.4	68	71.5	3.5	30	20.4	1.471	24.2	7.124	1.481	0.121454	0.001740
3	10:40	0:15	2.45	68	71.5	3.5	30	21.84	1.374	24.2	6.655	1.384	0.113446	0.001625
3	10:45	0:20	2.48	68	71.5	3.5	30	24	1.250	24.3	6.039	1.256	0.102944	0.001475
3	10:50	0:25	2.47	68	72	4	30	24.31	1.234	24.3	5.962	1.235	0.101631	0.001451
3	10:55	0:30	2.52	68	72	4	30	24.16	1.242	24.5	5.965	1.236	0.101686	0.001452
3	11:00	0:35	2.52	68	71.5	3.5	30	25.37	1.182	24.7	5.648	1.175	0.096291	0.001380
3	11:05	0:40	2.47	68.5	72	3.5	30	25.69	1.168	24.9	5.547	1.145	0.094557	0.001345
3	11:10	0:45	2.42	68	72	4	30	26.44	1.135	25.1	5.359	1.110	0.091359	0.001304
3	11:15	0:50	2.4	68	71	3	30	27.03	1.110	25	5.257	1.097	0.089616	0.001289
3	11:20	0:55	2.42	68	72	4	30	27.47	1.092	24.9	5.187	1.075	0.088430	0.001262
3	11:25	1:00	2.43	68	72	4	30	28.63	1.048	24.9	4.977	1.031	0.084847	0.001211

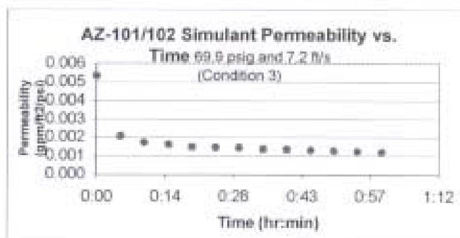
3 Average Slurry Flow gpm = 2.47 ft/s = 7.2
3 Average Pressure psid = 69.90
3 Average Filtrate Flow mL/sec = 1.512
3 Average Filtrate Flux gpm/ft2 = 0.124
3 Average Permeability gpm/ft2/psi = 0.002

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





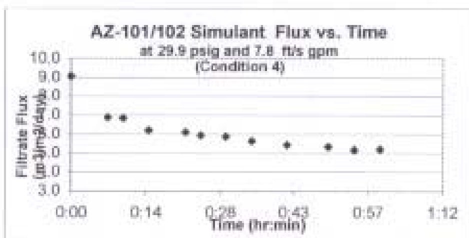


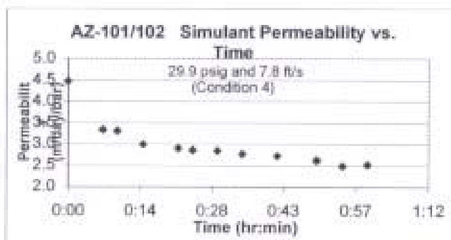


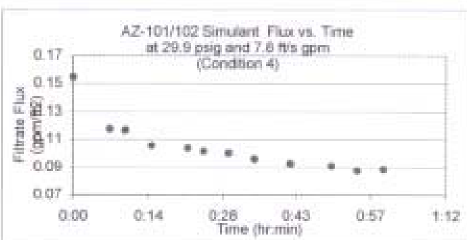
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4	11:35	0:00	2.65	28	31	3	30	16.82	1.784	22.5	9.069	4.459	0.154608	0.005237
4	11:42	0:07	2.7	28	32	4	30	22.5	1.333	22	6.878	3.325	0.117247	0.003905
4	11:45	0:10	2.83	28	32	4	30	22.44	1.337	22.3	6.837	3.305	0.116553	0.003882
4	11:50	0:15	2.57	28	32	4	30	24.6	1.220	22.6	6.183	2.989	0.105409	0.003511
4	11:57	0:22	2.8	28	33	5	30	24.72	1.214	23	6.083	2.893	0.103706	0.003396
4	12:00	0:25	2.75	28.5	32	3.5	30	25.31	1.185	23	5.942	2.849	0.101288	0.003346
4	12:05	0:30	2.68	28	32	4	30	25.53	1.175	23.1	5.874	2.840	0.100129	0.003335
4	12:10	0:35	2.9	28	31	3	30	26.65	1.126	23.1	5.627	2.766	0.095921	0.003249
4	12:17	0:42	2.76	27	31	4	30	27.5	1.091	23.2	5.437	2.719	0.092692	0.003194
4	12:25	0:50	2.44	28	31	3	30	28	1.071	23.3	5.325	2.618	0.090778	0.003075
4	12:30	0:55	2.75	28	32	4	30	29.09	1.031	23.2	5.140	2.485	0.087625	0.002919
4	12:35	1:00	2.5	28	32	4	30	28.94	1.037	23.1	5.182	2.505	0.088331	0.002942

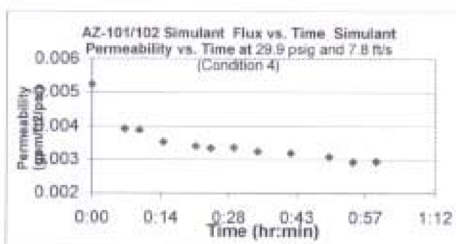
4 Average Slurry Flow gpm = 2.69 ft/s = 7.8
4 Average Pressure psid = 29.85
4 Average Filtrate Flow mL/sec = 1.217
4 Average Filtrate Flux gpm/ft2 = 0.105
4 Average Permeability gpm/ft2/psi = 0.003

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





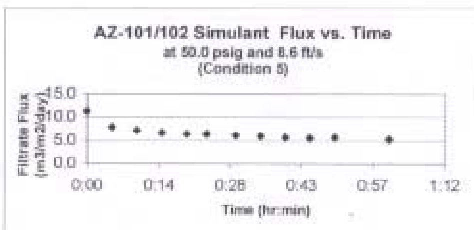


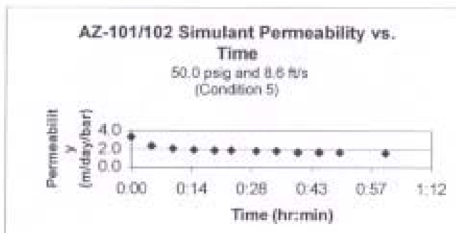


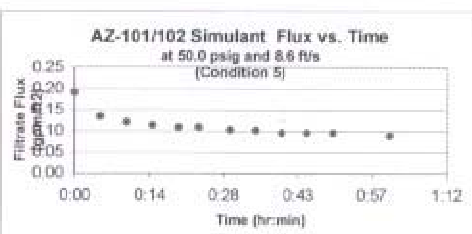
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5	12:45	0:00	3.08	48	52	4	30	12.66	2.370	24.8	11.287	3.274	0.192418	0.003846
5	12:50	0:05	2.91	48	52	4	30	18.06	1.661	24.8	7.912	2.295	0.134885	0.002696
5	12:55	0:10	2.88	48	52	4	30	20.44	1.468	24.2	7.111	2.063	0.121216	0.002423
5	13:00	0:15	3.07	48	52	4	30	21.69	1.383	24.5	6.644	1.927	0.113265	0.002264
5	13:05	0:20	2.89	48	52	4	30	22.19	1.352	25.1	6.386	1.852	0.108856	0.002176
5	13:09	0:24	2.94	48	52	4	30	22.31	1.345	24.9	6.387	1.853	0.108882	0.002176
5	13:15	0:30	2.92	48	52	4	30	23.75	1.263	24.7	6.034	1.750	0.102859	0.002056
5	13:20	0:35	2.87	48	52	4	30	24.09	1.245	24.7	5.949	1.726	0.101407	0.002027
5	13:25	0:40	2.94	48	52	4	30	25.34	1.184	25.1	5.592	1.622	0.095324	0.001905
5	13:30	0:45	2.9	47.5	52	4.5	30	25.38	1.182	25.2	5.567	1.623	0.094907	0.001906
5	13:35	0:50	2.93	48	52	4	30	25.25	1.188	25	5.627	1.632	0.095934	0.001917
5	13:46	1:01	3.03	48	52	4	30	26.87	1.116	25.1	5.273	1.530	0.089897	0.001797

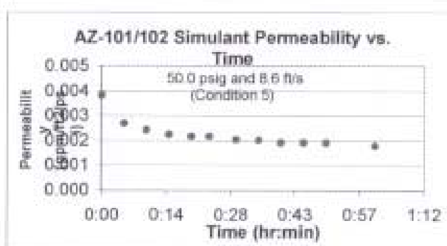
5	Average Slurry Flow gpm =	2.95	ft/s =	8.6
5	Average Pressure psid =	49.98		
5	Average Filtrate Flow mL/sec =	1.396		
5	Average Filtrate Flux gpm/ft2 =	0.113		
5	Average Permeability gpm/ft2/psi =	0.002		

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	12:45	18	24.8	3.08	48		52	30	12.66	2.370
5	12:50	13	24.8	2.91	48		52	30	18.06	1.661
5	12:55	13	24.2	2.88	48		52	30	20.44	1.468
5	13:00	16	24.5	3.07	48		52	30	21.69	1.383
5	13:05	16	25.1	2.89	48		52	30	22.19	1.352
5	13:09	14	24.9	2.94	48		52	30	22.31	1.345
5	13:15	15	24.7	2.92	48		52	30	23.75	1.263
5	13:20	15	24.7	2.87	48		52	30	24.09	1.245
5	13:25	16	25.1	2.94	48		52	30	25.34	1.184
5	13:30	16	25.2	2.9	47.5		52	30	25.38	1.182
5	13:35	15	25	2.93	48		52	30	25.25	1.188
5	13:46	15	25.1	3.03	48		52	30	26.87	1.116





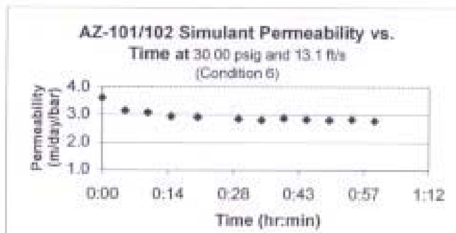


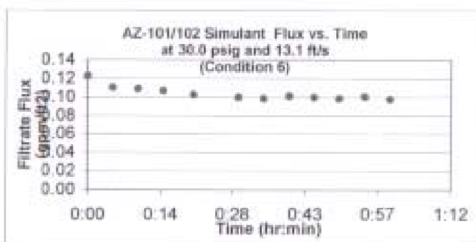


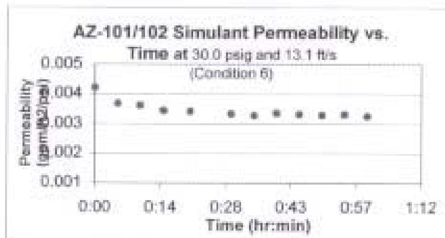
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
6	1:55	0:00	4.54	26	32	6	30	19.75	1.519	25	7.195	3.598	0.122650	0.004226
6	2:00	0:05	4.44	27	33	6	40	29.22	1.369	25	6.484	3.135	0.110533	0.003682
6	2:05	0:10	4.47	27	33	6	30	22.31	1.345	24.9	6.387	3.088	0.108882	0.003627
6	2:10	0:15	4.55	28	34	6	30	22.47	1.335	25.3	6.271	2.934	0.106897	0.003446
6	2:16	0:21	4.48	27	33	6	30	23.22	1.292	25.5	6.034	2.917	0.102865	0.003426
6	2:25	0:30	4.47	27	33	6	30	24.15	1.242	25.1	5.867	2.837	0.100022	0.003332
6	2:30	0:35	4.46	27	33	6	30	24.62	1.219	25	5.771	2.790	0.098389	0.003277
6	2:35	0:40	4.48	27	33	6	30	24	1.250	25	5.921	2.862	0.100930	0.003362
6	2:40	0:45	4.52	27	33	6	30	24.28	1.236	25	5.852	2.829	0.099766	0.003323
6	2:45	0:50	4.52	27	33	6	30	24.53	1.223	25	5.793	2.801	0.098750	0.003289
6	2:50	0:55	4.52	27	33.5	6.5	30	24.09	1.245	25.1	5.882	2.820	0.100271	0.003312
6	2:55	1:00	4.48	27	33	6	30	24.9	1.205	24.8	5.739	2.774	0.097832	0.003259

6 Average Slurry Flow gpm = 4.49 ft/s = 13.1
6 Average Pressure psid = 30.02
6 Average Filtrate Flow mL/sec = 1.290
6 Average Filtrate Flux gpm/ft2 = 0.104
6 Average Permeability gpm/ft2/psi = 0.003

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	1:55	14	25	4.54	26		32	30	19.75	1.519
6	2:00	14	25	4.44	27		33	40	29.22	1.369
6	2:05	14	24.9	4.47	27		33	30	22.31	1.345
6	2:10	16	25.3	4.55	28		34	30	22.47	1.335
6	2:16	15	25.5	4.48	27		33	30	23.22	1.292
6	2:25	14	25.1	4.47	27		33	30	24.15	1.242
6	2:30	14	25	4.46	27		33	30	24.62	1.219
6	2:35	15	25	4.48	27		33	30	24	1.250
6	2:40	14	25	4.52	27		33	30	24.28	1.236
6	2:45	14	25	4.52	27		33	30	24.53	1.223
6	2:50	14	25.1	4.52	27		33.5	30	24.09	1.245
6	2:55	12	24.8	4.48	27		33	30	24.9	1.205







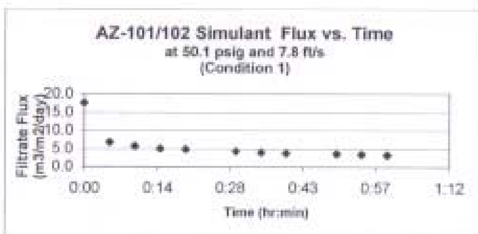
0.1 micron Liquid- Service Mott Filter

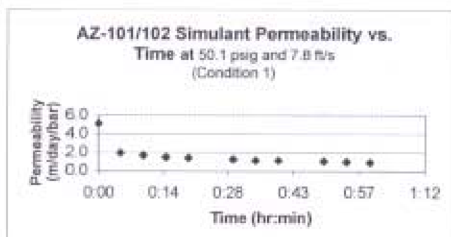
AZ-101/102 Filtration Simulant at 15 wt% Solids Loading Cuf Testing

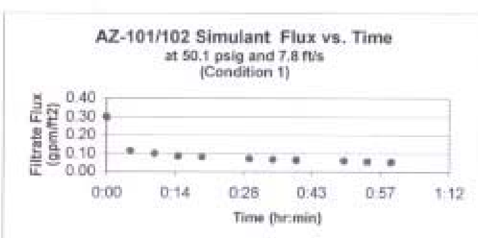
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
1	9:50	0:00	2.71	48	52	4	30	8.22	3.650	24.6	17.482	5.071	0.298029	0.005956
1	9:55	0:05	2.71	48	52.5	4.5	30	21.68	1.384	24.7	6.610	1.908	0.112680	0.002241
1	10:00	0:10	2.64	48	52	4	30	25.09	1.196	24.9	5.679	1.647	0.096818	0.001935
1	10:05	0:15	2.71	48	52	4	30	28.57	1.050	24.9	4.988	1.447	0.085025	0.001699
1	10:10	0:20	2.7	48	52	4	30	30.09	0.997	24.6	4.776	1.385	0.081416	0.001627
1	10:20	0:30	2.73	48	52	4	30	34.31	0.874	24.4	4.212	1.222	0.071806	0.001435
1	10:25	0:35	2.73	49	53	4	30	37.09	0.809	24.5	3.885	1.105	0.066237	0.001298
1	10:30	0:40	2.76	48	52.5	4.5	30	38.75	0.774	24.5	3.719	1.073	0.063399	0.001261
1	10:40	0:50	2.72	48.5	52	3.5	30	41.06	0.731	24.5	3.510	1.013	0.059833	0.001190
1	10:45	0:55	2.67	48	52	4	30	43.75	0.686	24.6	3.285	0.953	0.055995	0.001119
1	10:50	1:00	2.67	48	52	4	30	46.16	0.650	24.6	3.113	0.903	0.053072	0.001061

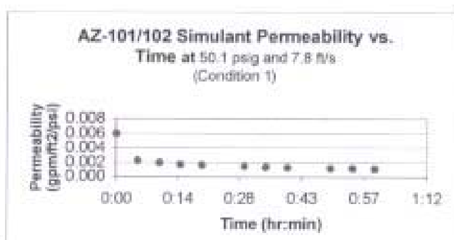
1	Average Slurry Flow gpm =	2.70	ft/s =	7.8
1	Average Pressure psid =	50.16		
1	Average Filtrate Flow mL/sec =	1.164		
1	Average Filtrate Flux gpm/ft2 =	0.075	With First Point Removed	
1	Average Permeability gpm/ft2/psi =	0.002		

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





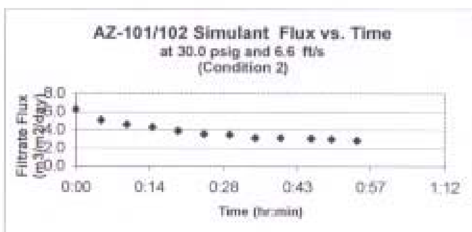


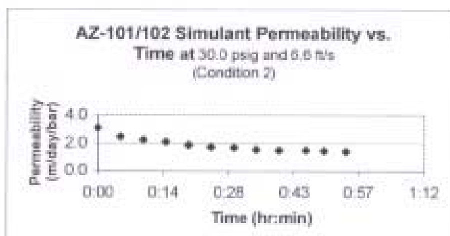


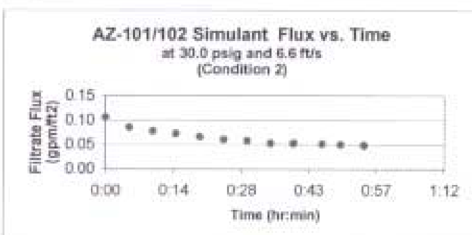
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
2	11:00	0:00	2.15	27	31.5	4.5	30	23.97	1.252	23.2	6.238	3.093	0.106342	0.003633
2	11:05	0:05	2.29	28	32	4	30	30.56	0.982	22.3	5.020	2.427	0.085584	0.002851
2	11:10	0:10	2.38	28	32	4	30	34.03	0.882	21.8	4.574	2.211	0.077969	0.002597
2	11:15	0:15	2.35	28	32	4	30	36.25	0.828	22.1	4.257	2.058	0.072565	0.002417
2	11:20	0:20	2.47	29	33	4	30	38.6	0.777	23.1	3.885	1.818	0.066225	0.002135
2	11:25	0:25	2.15	28	32	4	30	41.28	0.727	24.1	3.531	1.707	0.060191	0.002005
2	11:30	0:30	2.09	28	32	4	30	42.03	0.714	24.6	3.419	1.653	0.058287	0.001942
2	11:35	0:35	2.27	28	32	4	30	46.47	0.646	24.6	3.092	1.495	0.052718	0.001756
2	11:40	0:40	2.3	28	32	4	30	47.38	0.633	24	3.085	1.491	0.052590	0.001752
2	11:46	0:46	2.3	28	32	4	30	49.47	0.606	22.9	3.049	1.474	0.051969	0.001731
2	11:50	0:50	2.24	28	32	4	30	50.56	0.593	23.2	2.957	1.430	0.050416	0.001679
2	11:55	0:55	2.32	28	32	4	30	53.59	0.560	22.8	2.822	1.364	0.048111	0.001603

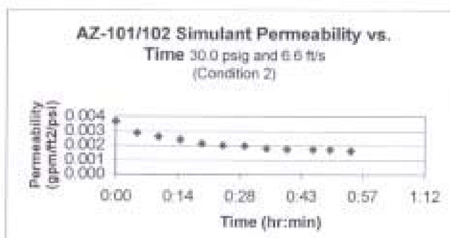
2 Average Slurry Flow gpm = 2.28 ft/s = 6.6
2 Average Pressure psid = 30.02
2 Average Filtrate Flow mL/sec = 0.767
2 Average Filtrate Flux gpm/ft2 = 0.062 With First Point Removed
2 Average Permeability gpm/ft2/psi = 0.002

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





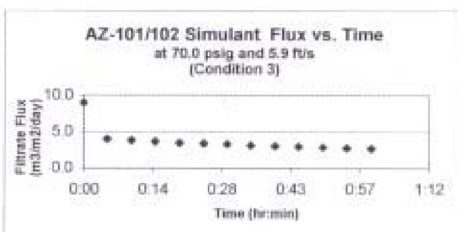


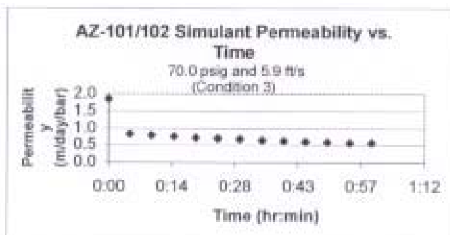


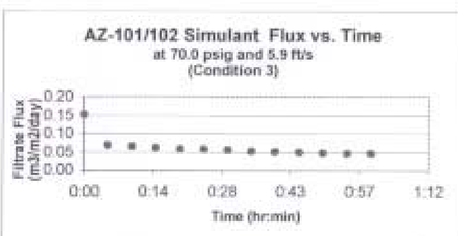
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
3	12:35	0:00	2.05	68	72	4	30	15.32	1.958	26.2	8.968	1.858	0.152884	0.002183
3	12:40	0:05	2.07	68	72.5	4.5	30	35.06	0.856	25.8	3.963	0.818	0.067556	0.000961
3	12:45	0:10	2.03	68	71.5	3.5	30	37.22	0.806	25.2	3.796	0.789	0.064716	0.000927
3	12:50	0:15	2.02	68.5	71.5	3	30	39.47	0.760	24.9	3.610	0.748	0.061544	0.000879
3	12:55	0:20	2.05	68.5	71.5	3	30	42.12	0.712	24.7	3.402	0.705	0.057998	0.000828
3	13:00	0:25	1.95	68	71.5	3.5	30	42.72	0.702	24.6	3.364	0.699	0.057345	0.000822
3	13:05	0:30	2.06	68	72	4	30	43.81	0.685	24.9	3.253	0.674	0.055448	0.000792
3	13:10	0:35	2.03	68	72	4	30	46.5	0.645	25.1	3.047	0.631	0.051947	0.000742
3	13:15	0:40	2.08	68.5	72	3.5	30	47.22	0.635	25.1	3.001	0.620	0.051155	0.000728
3	13:20	0:45	2.07	68	72	4	30	48.84	0.614	25.2	2.893	0.599	0.049319	0.000704
3	13:25	0:50	2.06	68	71	3	30	50.87	0.590	25	2.793	0.583	0.047618	0.000685
3	13:30	0:55	2.05	68	72	4	30	52.37	0.573	24.9	2.721	0.564	0.046385	0.000662
3	13:35	1:00	2	68	72	4	30	53.53	0.560	24.8	2.669	0.553	0.045507	0.000650

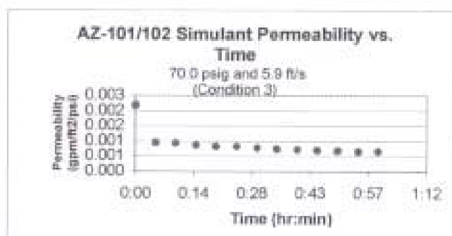
3	Average Slurry Flow gpm =	2.04	ft/s =	5.9
3	Average Pressure psid =	69.96		
3	Average Filtrate Flow mL/sec =	0.777		
3	Average Filtrate Flux gpm/ft2 =	0.055 With First Point Removed		
3	Average Permeability gpm/ft2/psi =	0.001		

Test Number	Time	Chiller Temp C	Slurry Temp C	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





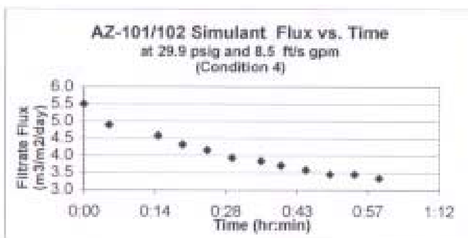


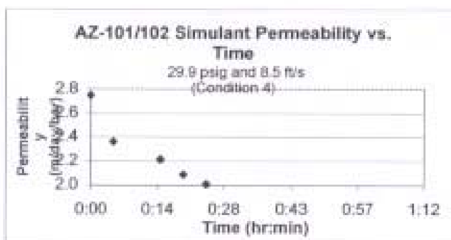


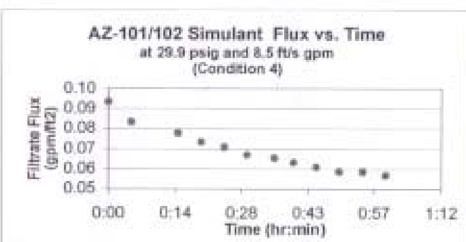
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
4	1:45	0:00	2.87	27	31	4	30	26.44	1.135	24.2	5.497	2.749	0.093708	0.003229
4	1:50	0:05	3.04	28	32	4	30	29.75	1.008	24.2	4.885	2.362	0.083282	0.002774
4	2:00	0:15	3	28	32	4	30	31.97	0.938	24	4.572	2.210	0.077940	0.002596
4	2:05	0:20	3	28	32	4	30	34	0.882	23.9	4.311	2.084	0.073494	0.002448
4	2:10	0:25	2.89	28	32	4	30	34.93	0.859	24.3	4.149	2.006	0.070732	0.002356
4	2:15	0:30	2.94	28	32	4	30	36.84	0.814	24.3	3.934	1.902	0.067064	0.002234
4	2:21	0:36	2.88	28	32	4	30	37.56	0.799	24.5	3.837	1.855	0.065408	0.002179
4	2:25	0:40	2.92	28	32.5	4.5	30	38.94	0.770	24.4	3.711	1.779	0.063269	0.002090
4	2:30	0:45	2.98	28	32	4	30	40.29	0.745	24.5	3.577	1.729	0.060976	0.002031
4	2:35	0:50	2.98	28	32	4	30	41.94	0.715	24.5	3.436	1.661	0.058577	0.001951
4	2:40	0:55	2.86	28	32	4	30	42.5	0.706	24	3.439	1.663	0.058629	0.001953
4	2:45	1:00	2.87	28	32	4	30	43.88	0.684	24	3.331	1.610	0.056785	0.001891

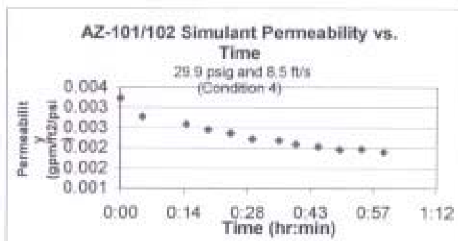
4	Average Slurry Flow gpm =	2.94	ft/s =	8.5	
4	Average Pressure psid =	29.94			
4	Average Filtrate Flow mL/sec =	0.838			
4	Average Filtrate Flux gpm/ft2 =	0.067	With First Point Removed		
4	Average Permeability gpm/ft2/psi =	0.002			

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





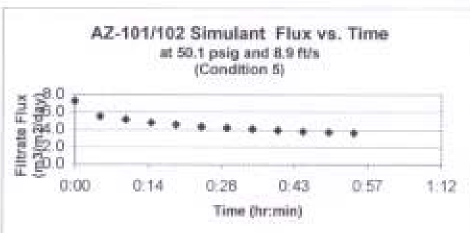


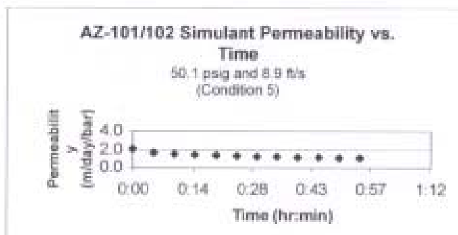


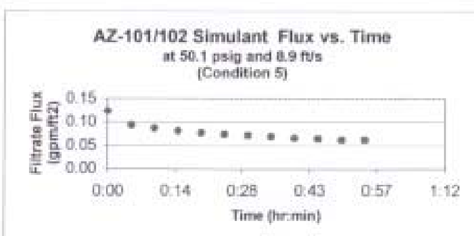
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
5	2:55	0:00	2.95	49	53	4	30	20.65	1.453	23.2	7.241	2.059	0.123439	0.002419
5	3:00	0:05	3.09	48	52	4	30	26.68	1.124	23.8	5.510	1.598	0.093924	0.001877
5	3:05	0:10	3.11	48	52.5	4.5	30	27.81	1.079	24.9	5.124	1.479	0.087348	0.001737
5	3:10	0:15	3.12	48	52	4	30	29.47	1.018	25.3	4.781	1.387	0.081506	0.001629
5	3:15	0:20	3.1	48	52	4	30	31	0.968	25.3	4.545	1.318	0.077483	0.001549
5	3:20	0:25	3.14	48	52	4	30	32.41	0.926	25.2	4.360	1.265	0.074321	0.001485
5	3:25	0:30	3.07	48	52	4	30	33.56	0.894	25.2	4.210	1.221	0.071774	0.001434
5	3:30	0:35	3.12	48	52	4	30	35.41	0.847	24.8	4.035	1.171	0.068795	0.001375
5	3:35	0:40	3.08	48	52	4	30	36.62	0.819	24.7	3.913	1.135	0.066709	0.001333
5	3:40	0:45	3.02	48	52	4	30	37.94	0.791	24.8	3.766	1.093	0.064207	0.001283
5	3:45	0:50	3.08	48	52	4	30	38.88	0.772	25.1	3.644	1.057	0.062128	0.001242
5	3:50	0:55	3.05	48	52	4	30	39	0.769	25.2	3.623	1.051	0.061763	0.001234

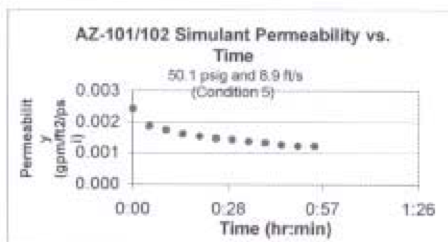
5 Average Slurry Flow gpm = 3.08 ft/s = 8.9
5 Average Pressure psid = 50.10
5 Average Filtrate Flow mL/sec = 0.955
5 Average Filtrate Flux gpm/ft2 = 0.074 With First Point Removed
5 Average Permeability gpm/ft2/psi = 0.002

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	2:55	12	23.2	2.95	49		53	30	20.65	1.453
5	3:00	14	23.8	3.09	48		52	30	26.68	1.124
5	3:05	17	24.9	3.11	48		52.5	30	27.81	1.079
5	3:10	15	25.3	3.12	48		52	30	29.47	1.018
5	3:15	14	25.3	3.1	48		52	30	31	0.968
5	3:20	14	25.2	3.14	48		52	30	32.41	0.926
5	3:25	14	25.2	3.07	48		52	30	33.56	0.894
5	3:30	13	24.8	3.12	48		52	30	35.41	0.847
5	3:35	13	24.7	3.08	48		52	30	36.62	0.819
5	3:40	15	24.8	3.02	48		52	30	37.94	0.791
5	3:45	15	25.1	3.08	48		52	30	38.88	0.772
5	3:50	15	25.2	3.05	48		52	30	39	0.769
5	3:55	14	25.2	3.04	48		52	30	40.59	0.739





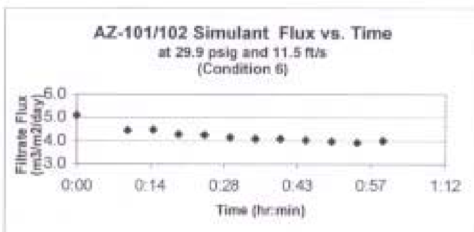


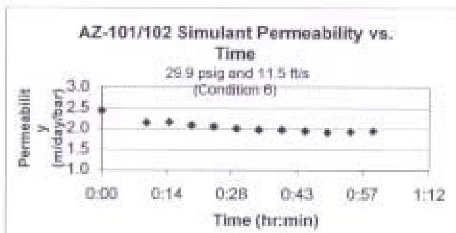


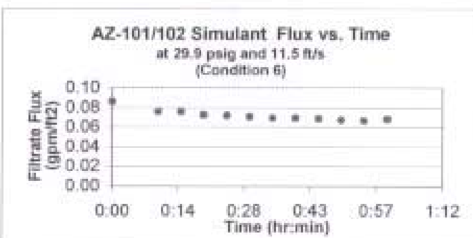
Condition Number	Time	Total Time Elapsed (Min)	Slurry Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Filtrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2)	Permeability (gpm/ft2/psi)
6	4:05	0:00	4	27.5	33	5.5	30	26.75	1.121	26.6	5.079	2.435	0.086587	0.002860
6	4:15	0:10	3.93	27	33	6	30	31.36	0.957	25.8	4.430	2.142	0.075527	0.002516
6	4:20	0:15	3.93	27	33	6	30	31.53	0.951	25.4	4.456	2.154	0.075967	0.002530
6	4:25	0:20	3.99	27	32.5	5.5	30	33.16	0.905	25.1	4.273	2.083	0.072844	0.002447
6	4:30	0:25	3.99	27	33	6	30	33.63	0.892	25	4.225	2.043	0.072029	0.002399
6	4:35	0:30	3.99	27	33	6	30	33.97	0.883	25.5	4.125	1.994	0.070313	0.002342
6	4:40	0:35	3.99	27	33	6	30	34.63	0.866	25.2	4.080	1.973	0.069556	0.002317
6	4:45	0:40	4.01	27	33	6	30	34.97	0.858	25	4.063	1.964	0.069269	0.002307
6	4:50	0:45	3.97	27	33	6	30	35.41	0.847	24.9	4.024	1.946	0.068601	0.002285
6	4:55	0:50	3.98	27	33	6	30	36.06	0.832	24.9	3.952	1.910	0.067364	0.002244
6	5:00	0:55	3.95	27	32	5	30	36.37	0.825	24.9	3.918	1.926	0.066790	0.002262
6	5:05	1:00	3.93	27	32.5	5.5	30	35.88	0.836	24.8	3.983	1.942	0.067893	0.002281

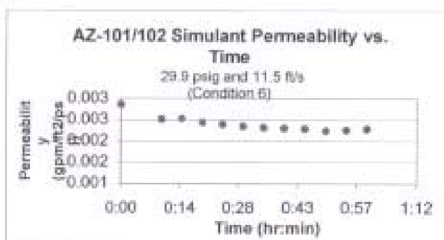
6 Average Slurry Flow gpm = 3.97 ft/s = 11.5
6 Average Pressure psid = 29.94
6 Average Filtrate Flow mL/sec = 0.898
6 Average Filtrate Flux gpm/ft2 = 0.071 With First Point Removed
6 Average Permeability gpm/ft2/psi = 0.002

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	4:05	19	26.6	4	27.5		33	30	26.75	1.121
6	4:15	15	25.8	3.93	27		33	30	31.36	0.957
6	4:20	15	25.4	3.93	27		33	30	31.53	0.951
6	4:25	15	25.1	3.99	27		32.5	30	33.16	0.905
6	4:30	15	25	3.99	27		33	30	33.63	0.892
6	4:35	16	25.5	3.99	27		33	30	33.97	0.883
6	4:40	16	25.2	3.99	27		33	30	34.63	0.866
6	4:45	16	25	4.01	27		33	30	34.97	0.858
6	4:50	15	24.9	3.97	27		33	30	35.41	0.847
6	4:55	15	24.9	3.98	27		33	30	36.06	0.832
6	5:00	15	24.9	3.95	27		32	30	36.37	0.825
6	5:05	15	24.8	3.93	27		32.5	30	35.88	0.836









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