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

LEGAL NOTICE

This report was prepared by Battelle Memorial Institute (Battelle) as an account of sponsored research activities. Neither Client nor Battelle nor any person acting on behalf of either: **makes any warranty or representation, express or implied**, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, process, or composition disclosed in this report may not infringe privately owned rights; or assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, process, or composition disclosed in this report.

References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by Battelle. The views and opinions of authors expressed herein do not necessarily state or reflect those of Battelle.

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

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 WTP R&T Support Project Date

G. Todd Wright, Manager Research and Technology Date

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.

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	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
Industrial Grade				
0.5-micron Mott	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
Industrial Grade				
0.1-micron Graver	4.5–9 ft/sec; 12.5–35 psid	Not Available	Not Available	Not Available

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

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.

Contents

1.0	Intro	oduction	1.1
	1.1	Objectives	1.1
2.0	Exp	erimental	2.1
	2.1	Tested Slurry Materials2.2.1Filter Media Specification2.2.2Test Apparatus and Operation	2.1 2.1 2.2
3.0	Resu	ults and Discussion 3.2.1 5 Wt% Insoluble Solids Loading 3.2.2 15 Wt% Insoluble Solids Loading	3.1 3.7 3.9
4.0	Con	clusions	4.1
5.0	Refe	erences	5.1
App	endix	A Envelope D High-Level Waste Filtration Simulant Specification	A.1
	A-1.	AZ-101/102 Slurry Simulant	A.2
	A-2.	C-106 Slurry Simulant	A.2
	A-3.	Preparation Procedure	A.2
	A-4.	Simulant Material Suppliers	A.4
App	endix	B Filtrate Flux Raw Data Package at Each Operating Condition	B.1

Figures

Figure 2.1.	Photograph of the Cold Crossflow Filtration System	2.3
Figure 3.1.	An Illustration of the Rapid Decline in the Filtration Flux in the Initial	
C	Minutes of Testing	3.2
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	3.3
Figure 3.3.	C-106 Simulant Center Point 1 st 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	3.4
Figure 3.4.	C-106 Simulant Center Point 2 nd 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	3.4
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	
	Liquid-Service Industrial Grade Mott Filters	3.6
Figure 3 6	Viscosity as a Function of Shear Rate at 25 ^o C for the AZ-101/102 Filtration	
8	Simulant	
Figure 2.7	Viscosity as a Eurotian of Shaar Pate at 25° C for the C 106 Eiltration	
Figure 5.7.	Simulant	28
Eiguro 2 8	The A7 101/102 Eiltration Simulant Average Eiltrate Elux at 5wt% Insoluble	3.8
Figure 5.8.	Solida Using 0.1 migron and 0.5 migron Liquid Sorvice Mott Filters	2.0
Figure 3.0	The A.7 101/102 Filtration Simulant Average Filtrate Flux at 5wt% Insoluble	5.9
Figure 5.9.	Solids Using 0.1 micron and 0.5 micron Liquid Service Mott Filters	3 10
Figure 3 10	Volume Weighted Distribution for C 106 Filtration Simulant Before and	5.10
Figure 5.10	After Sonication	3 1 1
Figure 3 11	Volume Weighted Distribution for A7 101/102 Filtration Simulant Defore	
riguit 5.11	and After Sonication	3 1 2

Tables

Table S.1.	List of Filtration Flux Data Discussed in this Report	iii
Table 2.1.	Properties and Dimensions of Tested Porous Metal Filters	2.2
Table 2.2.	Clean Water Flux for 0.1 Micron Graver, 0.1 and 0.5 Micron Liquid-Service,	
	Industrial-Grade Mott Filters	2.4
Table 2.3.	The C-106 Filtration Simulant "Low" Testing Condition Series Target	
	conditions	2.4
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	2.5
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	3.2
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	3.5
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	3.7
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	3.10
Table 3.5.	Particle Size Distribution of C-106 Filtration Simulant	3.12
Table 3.6.	Particle Size Distribution of AZ-101/102 Samples	3.13
Table 3.7.	Clean Water Flux for 0.1 Micron Graver, 0.1 and 0.5 Micron Liquid-Service,	
	Industrial-Grade Mott Filters	3.14
Table A.1.	Inactive AZ-101/102 Filtration Simulant Composition	A.3
Table A.2.	Inactive C-106 Filtration Simulant Composition	A.4
Table A.3.	Inactive AZ-101/102 and C-106 Filtration Simulant Material Suppliers	A.5

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 Battelleconstructed 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.

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

Table 2.1. Properties and Dimensions of Tested Porous Metal Filters

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 $25 \pm 5^{\circ}$ 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:

$$Flux_{25C} = Flux_{T}e^{2500\left(\frac{1}{273+T} - \frac{1}{298}\right)}$$
(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 9.1–13.1 ft/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 $25 \pm 5^{\circ}$ 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 HNO₃ 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.

	Flux (gpm/ft ²)					
Trans-Membrane Pressure (psid)	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			

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

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.

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

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

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 liquidservice, 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	Average	A	Average Filtrate Flux (gpm/ft ²)				
#	Velocity (ft/s)	Pressure (psid)	0.1 Micron (1 st 30 min)	Graver Filter (2 nd 30 min)	0.5 Micron (1 st 30 min)	Mott Filter (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 \geq 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.



C-106 Simulant at 8 Wt % Insoluble solids Centerpoint Target Conditions of 20.0 psig and 6.0 ft/s (1st 30 Min)

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



C-106 Simulant at 8 Wt % Insoluble Solids Centerpoint Target Conditions of 20.0 psig and 6.0 ft/s (2nd 30 Min)

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 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° 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.

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

 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

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^oC for the AZ-101/102 Filtration Simulant



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

Table 3.3 and Figure 3.8 show that the flux rates from the 0.1 μ m Mott filter are greater than that of the 0.5 μ m 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 μ m 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 μ m Graver filter compared with a 0.5 μ m 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.

	Target Velocity	Target Pressure	Average Filtrate Flux (gpm/ft ²) 0.1-micron Mott Filter	Average Filtrate Flux (gpm/ft ²) 0.5-micron Mott Filter
Condition	(ft/sec)	(psid)	(60 min)	(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

Table 3.4. AZ-101/102 Filtration Simulant Average Filtrate Flux at 15 wt% Insoluble Solids Using0.1- and 0.5-micron Liquid-Service Mott Filters

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 μ m 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 μ m 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 μ m for the C-106 simulant.

	Volume–Weighted Distribution			Number–Weighted Distribution			
Sample	Mode Diameter (μm)	Vol%	Width	Mode Diameter (μm)	Num%	Width	
	22.0	59 %	16.0	0.3	100 %	0.1	
C-106 Filtration Simulant	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				

Table 3.5. 1	Particle Size	Distribution	of C-106	Filtration	Simulant
--------------	---------------	--------------	----------	------------	----------

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

	Volume–Weighted Distribution			Number–Weighted Distribution			
Sample	Mode Diameter (μm)	Vol%	Width	Mode Diameter (μm)	Num%	Width	
A 7 101/102	17.9	31 %	17.8	0.4	100 %	0.6	
Filtration Simulant	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				
Sometica	0.1	7 %	0.03				

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

The particle size distribution of the AZ-101/102 simulant feed for the CUF testing on a volumeweighted distribution is approximated by three Gaussian peak distributions populated around 18, 6.4 and 1.4 μ m 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 μ m 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 μ m 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; 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-Servi	ce, Industrial-Grade
	Mott Filters	

	Flux (gpm/ft ²)						
Trans-Membrane Pressure (psid)	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 TiO₂ 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 0.5micron 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

Brooks KP, PR Bredt, GR Golcar, SA Hartley, LK Jagoda, KG Rappe, and MW Urie. 2000a. *Characterization, Washing, Leaching, and Filtration of C-104 Sludge*. BNFL-RPT-030 Rev. 0, PNWD-3024, Battelle, Pacific Northwest Division, Richland, Washington.

Brooks KP, PR Bredt, SK Cooley, GR Golcar, LK Jagoda, KG Rappe, and MW Urie. 2000b. *Characterization, Washing, Leaching, and Filtration of AZ-102 Sludge*. BNFL-RPT-038 Rev. 0, PNWD-3045, Battelle, Pacific Northwest Division, Richland, Washington.

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.

	Solids Components						
Compounds		Mineral			Mean Volume PSD		
Bearing	wt%	Phase		Powder Grade	(distribution)	wt%	
			Iron Oxide	e No: 07-5001	22 µm	17.400	
Iron	58	Hematite	Red Iron (Oxide No: 07-3752	2–3 µm	29.000	
11011	50	Tiemane	Synthetic No: 07-25	Red Iron Oxide 68	0.6 µm	11.600	
		Boehmite	HiQ-10 A	lumina	0.0028–0.004 µm	7.200	
	l	Gibbsite	C-231 Ground White Hydrate		14 µm (broad)	8.400	
Aluminum	24		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	Zirconium	Hydroxide; Product Code:	15 µm	13.000	
Ziicomum	15	Hydroxide	FZO922/0	1			
Silicon	5	Nepheline	Spectrum	A 400 Nepheline Syenite	10 µm	5.000	
			Supern	atant Components			
Component	t (Concentration	1 (M)	Concer	ntration (g/L)		
NaOH		0.8			32		
NaNO ₃		1.0		85			

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

	Solids Components								
Compounds Bearing	wt%	Mineral Phase	J	Powder Grade	Mean Volume PSD (distribution)	wt%			
	21.25		Red Iron O	vxide No: 07-3752	2-3 μm	18.750			
Iron	31.25	Hematite	Synthetic R 2568	Red Iron Oxide No: 07-	0.6 µm	12.50			
		Boehmite	HiQ-10 Al	umina	0.0028–0.004 μm	18.230			
	ĺ		SpaceRite S-23 Alumina		7.5 µm (broad)	10.938			
Aluminum	36.46	.46 Gibbsite	SpaceRite S-11 Alumina		0.25 μm (narrow)	3.646			
			SpaceRite ?	S-3 Alumina	1 μm (narrow)	3.646			
		Gibbsite /Boeł	mite Ratio:	2.33					
Zirconium	28.12	Zirconium Hydroxide	Zirconium FZO922/01	Hydroxide; Product Code:	15 μm	28.125			
Silicon	4.17	Nepheline	Spectrum A	A 400 Nepheline Syenite	10 µm	4.166			
		-	Superna	atant Components					
Component Concentration (M)			n (M)	Conce	entration (g/L)				
NaOH		1.07	7 42.8						
NaNO ₃		1.00			85.0				

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

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.
Manufacturer	Simulant Material	Powder Grade
	Iron Oxide, Hematite	Iron Oxide No: 07-5001
The Prince Manufacturing Company	Iron Oxide, Hematite	Red Iron Oxide No: 07-3752
http://www.princemig.com/	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
		C-231Ground White Hydrate
Alcoa- Bauxite, AR	Cibbaita A1(OU)	SpaceRite S-23 Alumina
1-225-382-3338	Globsite, $Al(OH)_3$	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

Table A.3. Inactive AZ-101/102 and C-106 Filtration Simulant Material Suppliers

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

Permeability (gpm/ft2/psi)	0.003329	0.002470	0.002141	0.002013	0.001903	0.001683	0.001633							e.															
Filtrate Flux (gpm/ft2)	10.0	0.0482	0.0429	0.0403	0.0361	0.0345	0.0327									0.092139	0.058106	0.051078	0.048323	0.045504	0.043301	0.04122							
Permeability (m/day/bar)	2 834	2 103	1.823	1.714	1.62	1.433	1.39									00:0	0:05	0:10	0.15	0:20	0:25	0:30							
Filtrate Flux (m3/m2/day)	4.103	2.828	2.514	2364	2.234	2.025	1.916																						
Slurry Temp C	24.4	25.6	26	26.3	26.4	26.3	26.1							Fitrate Flow Rate (mL/sec)		0.513	0.383	0.352	0.322	0.294	0.281		vs. Time at		(se		•		
Filtrate Flow Rate (mL/sec)	0.568	0.405	0.384	0.345	0.327	0.296	0.278							Time of Collection	(Sec)	19.5	26.1	28.37	31.03	34.07	35.63		neability	and 6.1 ft/s	st 30 minute		•		
Time of Collection (Sec)	70.44	98.81	109.93	115.93	122.32	135.32	143,81						Filtrate	Sample Volume	(mL)	10	10	10	10	10	10		ulant Pen	20.0 psig a	ondition 1, 1			-	
Filtrate Sample Volume) (mL)	40	40	40	40	40	40	40				hed			Filter Inlet Pressue	(pisig)	20	20	20	20	20	20		C-106 Sim		0	30.	2.0	0.0	
Pressure Drop (psig	Ū	1			Ĭ	1	Ŭ	6.12			oint Remov			Permeate Pressure	(Bisd)											וג) וְנָא	idsən idsən	שפנש) שופנ	1
Filter Inlet Pressue (psig)	21	19	20	20	20	20	20	= S/U			With First P		Filter	Outlet Pressure	(pisig)	20	20	20	20	20	20					[T	00.00
Filter Outlet Pressure (psig)	21	20	20	20	20	21	20	0.94	20.17	0.384	0.039	0.002	Slurry	Loop Flow Rate	(mdb)	0.89	0.94	0.92	0.9	0.98	0.98		Time		s)				+0.0+
Shurry Loop Flow Rate (gpm)	16.0	0.97	0.95	0.9	0.9	0.96	0.94			= 005	M12 =	n/ft2/psi =		Slumy	Temp C	21.3	20.8	21	21.6	23.1	23.8		Flux vs.	nd 6.1 ft/s	st 30 minute				1.44
otal Time (lapsed Min)	0:00	0:02	0:10	0:15	0:20	0:25	0:30	IN Flow apm	isure psid =	ate Flow mL	ate Flux gpm	neability gpr		chilter Temp		11	Ch.	11	15	15	15		Simulant	20.0 psig a	ndition 1, 1s		•		
Time	9:40	9:45	9:50	9:55	10:00	10:05	10:10	Average Slun	Average Pres	Average Filtra	Average Filtre	Average Pen		2	Time C	9:58	10:03	10:08	10:13	10.23	10.28		C-106		(C0)		•		-0
Condition	la	1a	1a	13	1a	1a	a	0	m	1a	10	a a		Test	Number	1a	13	10	13	13	13					0.9 (Xe Xn	e bist bist bist bist bist bist bist bist	H 10.00+	0.0



0:28

0:21

0:14

0:07

0:00

0:28

0:21

0:14

0:07

0:00

Time (hr:min)

Time (hr:min)

Permeability (gpm/ft2/psi)	0.002456234	0.002150302	0.001974063	0.001923511	0.001812516	0.001749342	0.001614031																											
Filtrate Flux (gpm/ft2)	0.0485	0.0438	0.0400	0.0390	0.0358	0.0354	0.0323																											
Permeability (m/day/bar)	2.091	1.831	1.681	1.638	1,543	1.489	1.374																											
Filtrate Flux (m3/m2/day)	2.848	2.656	2.347	2.286	2.101	2.079	1.895															1						9	5					
Sturry Temp C	23.8	24.2	24.6	24.9	25	26.1	25.5						Filtrate Flow	Rate (mL/sec)	0.387	0.352	0.327	0.321	0.296	0.294	0.270		vs. Time at	es)				0:28 0:3		vs. Time at	ss)		•	
Filtrate Flow Rate (mL/sec)	0.387	0.352	0.327	0.321	0.296	0.294	0.270						Time of	Collection (Sec)	25.81	28.43	30.62	31.16	33.81	34.07	36.97		meability and 6.0 ft/s	2nd 30 minut		•		14 0:21	ne (hr:min)	neability	and 6.0 ft/s nd 30 minute		•	
Time of Collection (Sec)	25.81	28.43	30.62	31.16	33.81	34.07	36.97					Filtrate	Sample	Volume.	10	10	10	10	10	10	10		20.0 psid	ondition 1, 2		•		0:07 0:0	Ē	ulant Perr	20.0 psig a		:	
Filtrate Sample Volume (mL)	10	10	10	10	10	10	10				p		Fitter Inlet	Pressue (nsia)	20	20.5	20.5	20.5	20	20.5	20		2-106 Sim	0)		•	0.0	0:00		-106 Sim	(C		002	000
Pressure Drop (psig)	0.5	0.5	0.5	0.5	0.5	0.5	0	9			oint Remove		Permeate	Pressure (osia)	1 reads		-	-	**	-			U		en) lity	ides ides	sb/m)))		0		2 (14 (14)	ilids9 eabili 2 O O	o c (abur Perm
Filter Inlet Pressue (psig)	20	20.5	20.5	20.5	20	20.5	20	ft/s =			With First P	Filter	Outlet	Pressure (nsin)	19.5	20	20	20	19.5	20	20				-			0:36					11	95-0
Filter Outlet Pressure (psig)	19.6	20	20	20	19.5	20	20	0.92	20.07	0.321	0.038	Shurry	Loop Flow	Rate (nom)	0.89	0.93	0.96	0.98	0.0	0.89	0.86		Time	(sa		•		0:28		Time	(se		•	D-28
Slurry Loop Flow Rate (gpm)	0.89	0.93	0.96	0.98	0.0	0.89	0.86	11		/sec =	n/ff/2 = m/ff/2/psi =		-	Slurry Temp C	23.8	24.2	24.6	24.9	25	25.1	25.5		Flux vs.	nd 30 minut		•		0:21	(hr:min)	Flux vs.	nd 6.0 ft/s d 30 minute		•	4 0.21
Total Time Elapsed Min)	00:0	0:02	0:10	0.15	0.20	0:25	0:30	rry Flow apri	ssure psid =	ate Flow mL	rate Flux gpr meability gpr		a contraction	Chiller Temp	13	15	15	15	15	15	15		Simulant 20.0 psig a	ndition 1, 21	•		-	0:14	Time	Simulant	20.0 psig al rdition 1, 2n			07 0-1
Time	10:40	10:45	10:50	10.55	11:00	11:05	11:10	Average Slui	Average Pre	Average Filts	Average Filt Average Per			Time	10:40	10:45	10:50	10:55	11:00	11:05	11:10		C-106	(Co	•			0 0:07		C-106	(Cor	9	2 8	0-00-0
Condition	1b	10	1b	4 1 1		12 13	Test	1b	1b	1b	10	1b	1b	1b				e (Xe xnj	uzvá te F	entii 0.60	н. (° 0:0				xn) (z	Hater Humble Co	0.0 5) 1113							

0:36

0.28

0:14 0:21 Time (hr:min)

0:07

0:00

0:36

0:28

0:14 0:21 Time (hr:min) 0:21

0:07

0:00

τ.

Permeability (gpm/ft2/psi)	0.002530	0.002061	0.001963	0.002000	010010000	0.001801																							
Filtrate Flux (com/tt2)	0.0316	0.0258	0,0246	7070.0	0.0238	0.0225																							
Permeability (m/day/bar)	2.154	1.755	1/9/2	71/1	10001	1.533																							
Filtrate Flux (m3/m2/dav)	1.857	1.513	144.1	0/4/1	1 28.4	1.322						2																	5
Sturry Temp C	23	22.8	9.77	0.17	305	23.2						Filtrate Flow Rate (mL/sec)	faces much some	0.247	0.199	0.189	0.188	0.104	0.101	vs. Time at ^{es)}		•	0:28 0:34		vs. Time at es)		•	1 0-28 0-3	(1
Filtrate Flow Rate (mL/sec)	0.247	0.199	0,103	0.100	0 181	0.177						Time of Collection	(Sec)	40.5	50.28	52.79	12.15	10.10	21.00	meability and 4.5 ft/s 1st 30 minut		•	14 0.21	ne (hr:min)	meability and 4.5 ft/s 1st 30 minut		•	0.7	ime (hr:mi
Time of Collection (Sec)	40.5	50.28	A 70	23.12	55.12	58.57					Filtrate	Sample	(mL)	10	10	10	2 9		2 9	ulant Per 12.5 psig condition 2,		•	0.07 0.	Ę	12.5 psig condition 2,		•	0.07	L L
Filtrate Sample Volume (mL)	10	0		2 0	10	10				pa		Filter Inlet Pressue	(pisig)	12.5	12.5	12.5	0.71	10.21	12.21	C-106 Sim	0.0		0:00		C-106 Sim	1003	002	000.0	2
Pressure Drop (psig)	0	0.0				0	4.5			oint Remov		Permeate	(pisig)		0	0 0		0.0			ar) ar)	deem i/day/b	99 n)			(is	ilidsem q\\$J]\rr	udb)	
Filter Inlet Pressue (psig)	12.5	12.0		10.41	10.51	12.5	ft/s =			With First F	Filter	Outlet Pressure	(bisd)	12.5	12.5	12.5	12.0	14.04	12.21				0:36					0:36	
Filter Outlet Pressure (psia)	12.5	12.5		N. N.	10.61	12.5	0.69	12.50	0.195	0.024	Slurry	Loop Flow Rate	(mdg)	0.6	0.64	0.61	0.76	010	21.0	Time es)			0:28		Time es)		•	0:28	
Slurry Loop Flow Rate (dpm)	9.0	0.6	0.0	22.0	070	0.72	= E		L/sec =	m/ft2 = 5m/ft2/psi =		Slurry	Temp C	23	22.6	22.6	0.12	44 00	0.22	t Flux vs. and 4.5 ft/s st 30 minut	•		0:21	e (hr:min)	Elux vs. and 4.5 ft/s st 30 minut			14 0.21	me (hr:min)
Total Time Elapsed (Min)	00:0	0.02	2.4	00.0	0.25	0:30	urry Flow an	essure psid	trate Flow m	trate Flux gp irmeability gi		Chiller	Temp C	15	15	14		: ;	t 1	5 Simulan at 12.5 psig ondition 2, 1			7 0:14	Tim	Simulant at 12.5 psig indition 2, 1		•	0:07 0:	F
Time	11:33	11.38	04.40	11.40	11-58	12.03	Average Sh	Average Pri	Average Fil	Average Fil Average Pe			Time	11:33	11:38	11:43	11.40		12-03	C-10	•		0.0		C-106			00:0	
Condition	2a	82	50	000	23	2a	2a	2a	2a	2a 2a		Test	Number	2a	2a	23	87	00	5a		XUI: O. S.	H aterti 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	EI (EV.C			xn[:	i eterti 1 eterti 1 eterti	1	

τ.

Permeablity (gpm/ft2/psi)	0.003024	0.002174	0.002027	0.001918	0.001944	0.001890													
Filtrate Flux (gpm/ft2)	0.0378	0.0272	0.0254	0.0240	0.0243	0.0236													
Permeability (m/day/bar)	2.575	1.851	1.726	1.633	1.655	1.609						3							
Filtrate Flux (m3/m2/day)	2.219	1.595	1.487	1.408	1.426	1.387													
Slurry Temp C	23.8	24	23.9	23.9	23.9	24						Filtrata Flow	Rate (mL/sec)	0.302	0.218	0.203	0.192	0.195	0.190
Filtrate Flow Rate (mL/sec)	0.302	0.218	0.203	0.192	0.195	0.190						Time of	Collection (Sec)	33.12	45.81	49.28	52.07	51.38	52.7
Time of Collection (Sec)	33.12	45.81	49.28	52.07	51.38	52.7						Filtrate	Volume (mL)	10	10	10	10	10	10
Filtrate Sample Volume (mL)	10	10	10	10	10	10				T		Filter Inlet	Pressue (12.5	12.5	12.5	12.5	12.5	12.5
Pressure Drop (psig)	0	0	0	0	0	0	4.5			oint Remove		Permeate	Pressure (psia)	0	0	0	0	0	0
Filter Inlet Pressue (psig)	12.5	12.5	12.5	12.5	12.5	12.5	ft/s =			With First Po		Filter	Pressure (psia)	12.5	12.5	12.5	12.5	12.5	12.5
Filter Outiet Pressure (psig)	12.5	12.5	12.5	12.5	12.5	12.5	0.69	12.50	0.217	0.025	0.002	Slumy Loop Flow	Rate (apm)	0.71	0.71	0.69	0.66	0.68	0.69
Slurry Loop Now Rate gpm)	0.71	0.71	0,69	0,66	0.68	0.69	11		/sec =	n/ft2 =	m/ft2/psi =		Slurry emp C	23.8	24	23.9	23,9	23.9	24
Fotal Time S Elapsed F Min) ((0:00	0:05	0.10	0.20	0.25	0:30	ry Flow gpm	ssure psid =	ate Flow mL	ate Flux gpn	meability gpr		Chiller S	15	15	41	14	14	4
Time	12:17	12.22	12:27	12:37	12:42	12:47	Average Slur	Average Pre-	Average Filtr.	Average Filtr.	Average Per		Time	12.17	12.22	12:27	12.37	12:42	12:47
Condition	2b	20	20	2b	2b		Test Number	20	25	2b	2b	2b	20						



Permeability (gpm/ft2/psi)	0.005394	0.005385	0.005166	0.005131	0.004950	0,004835												
Filtrate Flux (gpm/ft2)	0.1080	0.1051	0.1034	0.1014	0,1016	0.0992												
Permeability (m/day/bar)	4.592	4.585	4.398	4 369	4.215	4.117												
Fittrate Flux (m3/m2/day)	6.333	6.165	6.085	5.949	5.957	5.819												
Slurry Temp C	25.8	26.1	26.3	26.3	26.3	26.6						These Plane	Rate (mL/sec)	0.912	0.895	0.885	0.868	0.870
Filtrate Flow Rate (mL/sec)	0.912	0.895	0.885	0.868	0.870	0.857						Tomot	Collection F (Sec)	21.94	22.35	22.59	23.03	23
Time of Collection (Sec)	21.94	22.35	22.59	23.03	23	23.35						Filtrate	Volume (mL)	20	20	20	20	20
Filtrate Sample Volume (mL)	20	20	20	20	20	20				13		Cittar Intat	psig)	23	23	23.5	23	24
Pressure Drop (psig)	9	2	1	6.5	7	7	17.9			oint Remove		Darmasta	Pressure (psig)	0	0	0	0	0
Filter Inlet Pressue (psig)	23	23	23.5	23	24	24	ft/s =			With First Po		Filter	Pressure (psig)	17	16	16.5	16.5	17
Filter Outliet Pressure (psig)	17	16	16.5	16.5	17	17	2.74	20.04	0.881	0.102	0.005	Slurry Loon Elow	Rate (gpm)	2.73	2.74	2.73	2.77	27
Slurry Loop Flow Rate (gpm)	2.73	2.74	2.73	2.77	2.7	2.75	= u		L/sec =	m/ft2 =	im/ft2/psi =		Slumy Temp C	2.77	2.77	271	2.72	2.74
Total Time Elapsed (Min)	00:00	0:05	0:10	0:15	0:20	0:30	my Flow gpr	ssure psid =	rate Flow ml	rate Flux gpi	meability gp		Chiller Temp C	15	15	14	14	14
Time	13:13	13.18	13.23	13-28	13:33	13.43	Average Slu	Average Pre	Average Filth	Average Filth	Average Per		Time	13,13	13:18	13:23	13.28	13:33
Condition	3a	3a	3a	3a	3a	33	3a	3a	38	3a	3a		Test Number	3a	3a	3a	3a	3a

C.

0.857

23.35

50

24

0

17

2.75

2.72

4

13:43

3a



Permeability (gpm/ft2/psi)	0.001480	0.001197	0.001134	0.001097	0.001038	0.001024	0.000998														
Filtrate Flux (gpm/ft2)	0.0292	0.0234	0.0221	0.0220	0.0213	0.0210	0.0205						e.								
Permeability (m/day/bar)	1.260	1.019	0.965	0.934	0.884	0.872	0.850														
Filtrate Flux (m3/m2/day)	1.715	1.370	1.298	1.288	1.249	1.232	1.201														
Slurry Temp C	25.8	26.1	26.3	26.3	26.3	26.6	26.6						Eiltrata Elow	Rate (mL/sec)	0.247	0.199	0.189	0.188	0.182	0.181	0.177
Filtrate Flow Rate (mU/sec)	0.247	0.199	0.189	0.188	0.182	0.181	0.177						Time of	Collection (Sec)	40.5	50.28	52.79	53.19	54.84	55.12	56.57
Time of Collection (Sec)	40.5	50.28	52.79	53.19	54.84	55.12	58.57						Filtrate	Volume (mL)	10	10	10	10	10	10	10
Fittrate Sample Volume (mL)	10	10	10	10	10	10	10				pa		Filter Inlet	Pressue (psig)	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Pressure Drop (psig)	7.5	1	7	9	2	7	1	17.9			oint Remove		Permeate	Pressure (psig)	0	0	0	0	0	0	0
Filter Inlet Pressue (psig)	23.5	23	23	23	24	24	24	fl/s =			With First P		Filter	Pressure (psig)	12.5	12.5	12.5	12.5	12.5	12.6	12.5
Fitter Outlet Pressure (psig)	16	16	16	17	17	17	11	2.74	20.04	0.195	0.022	0.001	Slurry Loop Flow	Rate (gpm)	2.77	2.77	2.71	2.72	2.74	2.72	2.73
Slurry Loop Flow Rate (gpm)	2.77	2.77	2.71	2.72	2.74	2.72	2.73	= u		L/sec =	m/ft2 =	om/tt2/psi =		Sturry Temp C	25.8	26.1	26.3	26.3	26.3	26.6	26.6
Total Time Elapsed (Min)	00:00	0:02	0:10	0:15	0:20	0,25	0:30	irry Flow gp	essure psid	trate Flow m	trate Flux gp	meability gi		Chiller Temp C	15	15	14	14	14	14	14
Time	13:50	13:55	14:00	14:05	14:10	14:15	14:20	Average Slu	Average Pri	Average Filt	Average Filt	Average Pe		Time	13:50	13:55	14:00	14:05	14:10	14:15	14:20
Condition	35	30	35	3b	30	35	3b	3b	3b	35	ab	30	(R)	Test Number	35	35	35	35	35	35	30



Filtrate Flux (gpm/ft2)	0.0517	0.0383	0.0330	0.0339	0.0317	0.0307																	
Permeability (m/day/bar)	1.257	0.931	0.803	0.823	0.770	0.740																	
Filtrate Flux (m3/m2/day)	3.034	2.247	1.938	1.987	1.859	1.799							1,966	moved									
Slurry Temp C	27.7	28.3	28.5	27.3	29	28.8							Average Flux =	With First Point Re		Rate (mL/sec)	STATE OF THE STATE OF THE STATE	0.460	0.347	0.301	0.298	0.292	0.281
Filtrate Flow Rate (mL/sec)	0.460	0.347	0.301	0.298	0.292	0.281							0.330	2	Time of	Collection	(Sec)	21.72	28,84	33.25	33,53	34.2	35.53
Time of Collection (Sec)	21.72	28.84	33.25	33.63	34.2	35.53							= M		Filtrate	Volume	(mL)	10	10	10	10	10	10
Filtrate Sample Volume (mL)	10	10	10	10	10	10					g		Average Flo	Filtrate	Cline Infert	Pressue	(pisig)	35	35	35	35	35	35.5
Pressure Drop (psig)	0	0	0	0	0	0,5	6 16			1212-2410-250 P	oint Remove				Deservation	Pressure	(psig)						
Filter Inlet Pressue (psig)	35	35	35	35	35	35,5	= 5/4			Carlo Contra Carlo	With First PI		35.04167		Filter	Pressure	(bisid)	35	35	35	35	35	35
Fitter Outlet Pressure (psig)	35	35	35	35	35	35	0.94	35.04	0.330	0000	0.034	0.001	= entre		Slumy	Rate Rate	(mdg)	0.98	0.91	0,9	76.0	0.92	0.95
Sturry Loop Flow Rate (gpm)	0.98	0.91	0.9	0.97	0.92	0.95	H		lear =	-neen-	m/ft2 =	im/ft2/psi =	Average Pre	0.94		Slurry	Temp C	27.7	28.3	28.5	27.3	29	28.8
Total Time Elapsed (Min)	00.0	0.05	0:15	0.20	0:25	0:30	rrv Flow apr	serire risid =	rate Elow m	IN LINK III	rate Flux gp	meability gp		rry Flow =		Chiller	Temp C	22	23	24	25	26	26
Time	14:35	14:40	14:50	14:55	15:00	15:05	Average Slu	Average Pre	Average Filt	WALING AND LIN	Average Filt	Average Per		Average Slb			Time	14:35	14:40	14:50	14:55	15:00	15:05
Condition	64	4a	4a	43	4a	4a	4a	4.0	44	B.	43	43		RAW		Test	Number	4a	4a	64	4a	4a	4a

Permeabili ty (gpm/ft2/p si)

0.001477 0.001094 0.000943 0.000967 0.000967 0.000965



eabili ft2/p	1253	1980	0947	9680	0902	1160																						
Perm ty (gpm/ si)	0.00	0000	0.00	0.00	0.00	0.00																						
Filtrate Flux (dom/ft2)	0.0439	0.0335	0.0329	0.0323	0.0311	0.0338																						
Permeability (m/day/bar)	1.066	0.815	0.806	0.797	0.768	0.826					2																	
Filtrate Flux (m3/m2/dav)	2.573	1 968	1.931	1.896	1.827	1.980																						
Slurry Temp C	29.2	28.9	28.3	28	27.3	25					Filtrate Flow Rate (mL/sec)	0.407	505 U	0.309	892.0	0.290	0.274	0.279	rs. Time at	s)		•	0.28 0.36		s. Time at	6		
Filtrate Flow Rate (mL/sec)	0.407	0.309	0.298	D.290	0.274	0.279					Time of F Collection F	24.57	31	37.4	33.56	34.47	36.47	35.88	meability v	and 6.0 ft/s 2nd 30 minute		•	14 0.21	ne (hr:min)	neability v: nd 6.0 ft/s	samuim os pr	•	
Time of Collection (Sec)	24.57	32.4	33,56	34.47	36.47	35.88					Filtrate Sample Volume (mL)	10	C.	P P		10	10	10	nulant Per	34.8 psig Condition 4, 2		•	0.07 0	1	ulant Pern 34.8 psig a	Condition 4, 21	:	
Filtrate Sample Volume 1 (mL)	99		10	10	10	7				pa	Filter Inlet Pressue (nsin)	35	36	35	35	34.5	345	35	C-106 Sin	5)		1.5	0.0	į	2-106 Sim	0 000	0.001	0.001
Pressure Drop (psig			0.5			0.5	6.00			oint Remov	Permeate Pressure (nsin)	1 Bundy									,	day/bar)	neq Peri				(isq\Sf)	mqg) Perm
Filter Inlet Pressue (osia)	35	2 63	35	34.5	34.5	35	11/s =		Surresson Fe	With First F	Filter Outlet Pressure (nsin)	35	26	35	34.5	34.5	34.5	34.5					0:36					00.0
Filter Outlet Pressure (psia)	35	35	34.5	34.5	34.5	34.5	0.92	34.76	0.311	0.033	Slurry Loop Flow Rate (mm)	0.92	0.03	0.92	0.92	0.93	0.9	0.93	. Time	s ites)		•	0:28		Time	(sa)	•	0000
Slurry Loop Flow Rate (apm)	0.92	0.92	0.92	0.93	0.0	0.93	= WI	н.	nL/sec =	pm/ft2 = pm/ft2/psi =	Slurry Temp C	28.2	704	28.9	28.3	28	27.3	25	t Flux vs	and 6.0 ft/ 2nd 30 minu		•	0:21	ie (hr:min)	t Flux vs and 6.0 ft/		•	
Total Time Elapsed (Min)	00:00	01:0	0.15	0.20	0:25	0:30	urry Flow gp	essure psid	Itrate Flow n	trate Flux gr ermeability g	Chiller Termo C	33	36	8	36	37	37	33	i Simulan	at 34.8 psig indition 4, 2		•	7 0:14	Tim	Simulani at 34.8 psig	nuiuon 4, 4	•	
Time	15:15	15.25	15:30	15:35	15:40	15:45	Average SI	Average Pr	Average Fil	Average Fi Average Pe	tm	15:15	16-20	15-25	15.30	15.35	15:40	15:45	C-106	(Cc		•	0:0		C-106	200	5 4	00
Condition	44	49	40	4b	45	4P	4b	4b	4b	4b 4b	Test Number	4b	4h	4b	44	40	4b	4b			× -3.0	rate Flu Mg2/day	111 (m) (m) (m)			2	culif eter (Stil\mq 9 9 9 9	6) (1)

٠ 0:14 0:21 Time (hr:min) ٠ ٠ . 0:07 -0:00 . (gpm/ft2) (gpm/ft2) (gpm/ft2)

0:43

0:14 0:28 Time (hr:min)

0:00

0.000 0.001

0:36

0:28

Condition	Time	Total Time Elapsed (Min)	Slumy Loop Flow Rate (gpm)	Filter Outlet Pressure (psig)	Filter Inlet Pressue (psig)	Pressure Drop (psig)	Fritrate Sample Volume (mL)	Time of Collection (Sec)	Filtrate Flow Rate (mL/sec)	Slurry Temp C	Filtrate Flux (m3/m2/day)	Permeability (m/day/bar)	Filtrate Flux (gpm/ft2
5a	16:05	0:00	0.96	20	21	-		5 8.9	6 0.558	25.7	3.887	2.750	0.0661
58	16.07	0.02	2 0.95	20	21			5 11.7	2 0.427	25.7	2.972	2.103	0.050
5a	16:10	0:02	1	20	20	0		13	1 0.382	26	2.637	1.912	0.0449
5a	16:17	0:12	1.02	20	21	-		13.9	7 0.358	27.6	2.365	1.673	0.0403
5a	16.20	0.15	5 0.85	20	20			5 15.3	5 0.326	27.7	2.146	1.556	0.0366
5a	16.25	0:20	0.82	20	21	-		5 16.5	9 0.301	28.3	1.953	1.382	0.0333
5a	16:30	0:25	5 0.92	19.5	20.5			17.1	9 0.291	28.2	1.890	1.371	0.0322
5a	16:36	0:31	0.92	20	21	-		5 17.1	5 0.292	27.7	1.921	1.359	0.0327
ę,	Average SI	inter Elevan	=	0.03	Hie =	а+ а а+	1942						
100	Average Pr	essure psid		20.33			23.						
5a	Average Fil	Itrate Flow n	nL/sec =	0.392									
5a	Average Fil	itrate Flux g	pm/ft2 =	0.039	With First P	oint Remov	ed						
5a	Average Pe	ermeability g	gpm/ft2/psi =	0.002									
RAW II	Average SI	urry Flow =	Average Pi	ressure =	20,33333		Average F	= mol	0.392	Average Flux =	2.415 amoved		
4400	UVDIONC OF	- MOUT LINE	0.0		Ethor		11000	Elitrato		WHILE FROM FURNER	navoula		
10.000			3	Slurry	Outlet	Permeate	Filter Inlet	Sample	Time of	Filtrate Flow			
Test Number	Time	Chiller Temp C	Slumy Temp C	Rate (apm)	Pressure (psig)	Pressure (psia)	Pressue (psig)	Volume (mL)	Collection (Sec)	Rate (mL/sec)			
5a	16:05	22	27.7	0.96	20	1	N		5 8.96	0.558			
5a	16:07	23	28.3	0.95	20		0		5 13.72	0.364			
5a	16:10	24	28.5	1	20		2	0	5 14.82	0.337			
5a	16:17	26	27.3	1.02	20		CN .		5 13.97	0.358			
58	16:20	26	29	0.85	20		12		5 15.35	0.326			
Sa	16:25	26	1 28.8	0.82	20		¢4		5 16.59	0.301			
53	16:30	26	29	0.92	19.5		20.	10	5 18,19	0.275			
Sa	16;36	26	5 28	0.92	20		2		5 17,15	0.292			
	C-10	6 Simular	It Flux vs	. Time		- 1759	C-106 Sir	nulant Pe	rmeability	vs. Time at			
1	ξŪ	ondition 4,	1st 30 minu	tes)				Condition 4	1 1 1 2 0 minur 1 1 2 0 minur	es)			
0.0						() (4	2.0	•	•				
C T (I X						用目			*				



.

Permeabili ty (gpm/ff2/p 0.0023470 0.002246 0.001828 0.001828 0.001623 0.001623 0.001623

Permeability (m/day/bar) 2.636 1.676 1.676 1.713 1.713 1.453 1.453 (m3/m2/day) Filtrate Flux 3.816 2.370 2.327 2.244 2.244 2.093 2.011 2.209 With First Point Removed 0:36 Slurry Temp C () 26.2 28.5 28.6 28.6 28.6 28.6 27.9 27.2 0:43 Average Flux = Filtrate Flow Rate (mL/sec) Time at C-106 Simulant Permeability vs. Time at 0.556 0.357 0.357 0.357 0.357 0.357 0.357 0.357 0.307 0.307 0:28 ٠ C-106 Simulant Permeability vs. 0:14 0:28 Time (hr:min) ٠ 34.8 psig and 6.0 ft/s (Condition 4, 2nd 30 minutes) 34.8 psig and 6.0 ft/s (Condition 4, 2nd 30 minutes) Time of Collection (Sec) 9 14.02 14.32 14.32 16.29 16.29 17.55 Time (hr:min) 0:21 Filtrate Flow Rate 0.375 0.556 0.357 0.357 0.357 0.349 0.349 0.307 0.307 (mL/sec) ٠ 0:14 ٠ 9 14.02 14.32 14.32 16.29 16.29 Time of Collection (Sec) Sample Volume (mL) Filtrate ٠ 0:07 Average Flow = ٠ Filter Inlet 0:00 Fittrate Sample Volume (mL) Pressue Filtrate 0.002 0.003 0.000 0.004 0.001 (bisd) 0:00 0.96 ft/s = 6.16 20.25 0.375 With First Point Removed 0.002 3.0 Drop (psig) N-NN--0 Permeate (m/day/bar) Permeability Pressure Pressure Permeability (gpm/ft2/psi) (pisig) 20.25 88888888 Outlet Pressure Filler Inlet Pressue (psig) 0:36 0:36 (pisig) Filter Loop Flow (Rate ((gpm) (0.93 0.96 0.96 0.95 0.92 1.02 20 20 20 20 20 20 19 19 Filter Outlet Pressure . 0:28 ٠ 0:28 Average Pressure = (pisig) Slumy C-106 Simulant Flux vs. Time C-106 Simulant Flux vs. Time at 34.8 psig and 6.0 ft/s (Condition 4, 2nd 30 minutes) at 34.8 psig and 6.0 ft/s (Condition 4, 2nd 30 minutes) ٠ ٠ Slurry Loop Flow Rate (gpm) Temp C 26.2 27.4 28.1 28.6 28.6 28.8 28.8 28.8 27.9 27.2 0.93 0.95 0.96 0.96 0.96 0.96 0.96 0.96 0.96 0.92 0.92 0:21 0.96 Average Permeability gpm/ft2/psi = Time (hr:min) 0:21 Time (hr:min) . Average Filtrate Flow mL/sec = Average Filtrate Flux gpm/ft2 = Slumy ٠ Average Slurry Flow gpm = Average Pressure psid = 0:14 ٠ 0:00 0:10 0:15 0:25 0:25 0:25 0:14 **Total Time** ٠ Elapsed (Min) Chiller Temp C Average Slurry Flow ٠ 0:07 ٠ 0:07 16:40 16:45 16:50 16:55 16:55 17:00 17:05 16.40 16.50 16.55 16.55 17.00 17.00 ٠ ٠ Time Time 0:00 Filtrate Flux (gpm/ft2) 0.02 4 0.08 0.00 xulf ate Flux (m3/m2/day), 0 0 0 0 Condition Number RAW 88888888 88888

0.001829 0.001671 0.001707

0.0404 0.0397 0.0357 0.0357 0.0357 0.0357

(gpm/ff2/p si) 0.003096 0.001969 0.001888 0.001888

Filtrate Flux (gpm/ft2) 0.0651

Permeabili

² ermeability (gpm/ft2/psi)	0.000077	0.000065	0 000044	0 000042	0 000041	0.000040	0.000039										
Permeabili ty (gpm/ft2/p si)	0.003254	0.002746	0.001887	0.001737	0.001748	0.001688	0.001671										
Fittrate Flux (gpm/ft2)	0.0651	0.0550	0.0378	0.0356	0.0350	0.0338	0.0334										
Permeability (m/day/bar)	2.771	2.338	1.606	1.479	1.488	1.437	1,422	204.1	0.04.1								
Filtrate Flux (m3/m2/day)	3.821	3.224	2.215	2.090	2.052	1.981	1.961										
Slurry Temp C	26.5	27.4	27.7	27.5	27.4	27.3	27.4	77 344	L 1 1 1 1 1	Eiltrata Elow	Rate (mL/sec)	000 0	0.182	0.180	0.179	0.181	0.174
Fitrate Flow Rate (mL/sec)	0.561	0.485	0.336	0.315	0.309	0.297	0.295	Averana Flinv =	uni i stanina i		Time of Collection	(28C) 97.7E	CE 67	49.94	50.41	49.85	51.75
Time of Collection (Sec)	35.66	0 41.22	59.5	63.41	0 64.75	0 67.25	0 67.75	57 077	1 1 1 1 1 1 1	Filtrate Samole	Volume	(mu) a		0	6	6	8
Filtrate Sample Volume g) (mL)	0 20	2	2 20	1 20	2 20	2 20	2 20	= low =	Cileman	Filler Inlet	Pressue	(Bied)	00	0	0	0	40
f Pressure Drop (psi	20	21	21	21	21	21	21	Average	all	Permeate	Pressure	(Bred)					
Filter Inle Pressue (psig)	20	61	6	20	19	0	6	9 nsin	n i i	Filter w Outlet	Pressure	(Bied)	WW 65	54 NM	MN 60	WN L	WW L
Filter w Outlet Pressure (psig)	93	34	94	98	03	16	34	20	mine BE	Slurry Loop Flo	Rate	(mdB)		25 3.0	2 3.6	1 3.	1
Slurry e Loop Flor Rate (gpm)	0 0.5	3 0.5	0.0	5 0.5	0.1.0	5 0.5	0.0	Tressure =	00		Slumy	Produinat 0	24	0	2 25	25 0	1 25
Total Time Elapsed (Min)	0:0	0:0	5 0.1	0.1	5 0.2	0.2	5 0:3	Average F	humu Elosu -	- work Liow -	Chiller Tamo C	o duisi		2	2	2	2
Time	16:01	16:01	16:11	16:21	16:21	16:30	16.35		Augrana C	n aferanu	Time	18-30	16.35	16.40	16:45	16:55	17:00
Condition	8a	8a	8a	83	88	8a	8a		DAW		Test	Ra	8a	8a	8a	8a	8a

NM = Not Measured

Permeabili ty (gpm/ft2/p si)	0.003377	0.002449	0.001864	0.001562	0.001526	0.001557														
Filtrate Flux (gpm/ft2)	0.0693	0.0490	0.0382	0.0320	0.0313	0.0312	0.0302													
Permeability (m/day/bar)	2.875	2 085	1.587	1.330	1.299	1.326	1.283	204.4	0.04-1											
Filtrate Flux (m3/m2/day)	4.064	2.876	2.243	1,880	1.836	1.828	1.769													
Slurry Temp C	24.4	25.3	25.1	24.7	24.9	25.5	25.5	75.057	100'07		1.00	-ittrate Flow	(ate (mL/sec)	0.247	0.234	0.220	0.222	0.212	0.225	
ittrate Flow Rate	0.562	0.408	0.317	0.262	0.258	0.261	0.253	internet Eliter -	- vniu afierak		20		me of Collection F lec)	36.5	38.53	41	40.54	42.43	39,94	
Time of Fi Collection (r (Sec)	17.78	24.5	15.79	19.06	19.4	19.16	19.8	10.956	000.01		Filtrate	Sample	Volume Ti (mL) (S	6	6	G	0	a	0	
Filtrate Sample Volume (mL)	10	10	5	ŝ	2	ŝ	5			Filtrate		Filter Inlet	Pressue (psig)	S	LD	9	2 2	S	5	
Pressure Drop (psig)	-	0	-		**	0	0	Autoria El	LI SABBIAN			Permeate	Pressure (psig)	0	0	0	0	0	0	
Filter Inlet Pressue (psig)	0 2	0 2	0 2	0 2	2 0	0 2	0 2	mine B	Bind o	141000	Filter	/ Outlet	Pressure (psig)	MM 9	4 NM	NMN 9	WN 9	WW P	WW 9	
Filter Outlet Pressure (psig)	2	0	8	9 2	5	1 2	1	TUC	A.4	mdg (Slurry	Loop Hidw	(gpm)	3.71	3.6	3.6	3.6	3.6	3.6	
Slurry Loop Flow Rate (gpm)	0.86	1.02	1.1	6.0	0.96	0.94	0.94	- 011200	- 010000	0.96			Slumy Temp C	24.3	24.8	25	25.2	26.1	25.2	
Total Time Elapsed (Min)	00:0	0:02	0:10	0.15	0:20	0:25	0:30	Averane D	L offininau	urry Flow =			Chiller Temp C	22	22	21	22	22	21	
Time	16:40	16:45	16:50	16.55	17:00	17:05	17:10			Average SI			Time	12:30	12:40	12:45	12:51	12:56	13:00	Aeasured
Condition Number	80	85	8b	8b	8b	8b	8b			RAW			Test Number	80	GB	QB	Gb	GB	80	NM = Not A

τ.

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

ammeability gpm/ft2/psi)	0.012083	0.004986	0.003904	0.003405	0.003077	0.000765	Providence of	0.000389	0.003809	0.003085	0.002849	0.002698																							
Filtrate Flux (gpm/ft2)	0.583002	0.248468	0.195359	0.170355	D 153930	0.138335	D 128300	D 110161	0.190609	0.155927	0.142552	0.135059																							
Permaability (m/day/bar)	30.296	4.228	3.324	2 899	2.619	2.354	2 180	2.038	3 243	2.627	2.426	2.297																							
Filtrate Flux (m3/m2/day)	34,785	14.575	11.460	9.993	9.030	B 115	7527	6:990	11 181	9.147	8.362	7,958																						1	_
Slurry Temp C	24.1	24.1	24.6	24.7	24.9	24.12	0.40	23.9	21.9	22.1	22.2	22.7						Cheve Down	Rate (mL/sec)	7 160	3 000	0.960	2 082	1 901	1 706	1 554	1431	102220	2.161	1.778	1 630	4 27.4	1	AN SALEBOOK	vs. Time at
Filtrate Flow Rate (mU/sec)	7/160	3.000	2.392	2.092	1.901	1,708	1.554	1.431	2.161	1.778	1.830	1.574						Time of	Collection	4.19	10	12 54	14 34	15.78	17.58	19.31	20.97	1025202	13.88	16.87	18.4	10.00	0	1000	neability nd 9.4 ft/s
Time of Collection (Sec)	4,19	10	12.54	14.34	15.78	17.56	15.21	20.97	13.88	16.87	18.4	19.06						Fitrato	Volume	R	05	9	30	9	30	30	06	8	30	30	30	Line .	ł		50.0 psig a
r itrate Sample Volume (mL)	30	8	8	R	8	30	8	98	30	30	8	30						Fiber inlet	Pressue (psid)	53	63	12	29	13	12	52	0	R.	23	3	52.5	10.02	7		-106 Simu
Pressure Drop (psig)	4	4	¥	4	4	4	4	4	4	5	10	4.5	9.4					Permente	Pressure (psid)															9	0
Fitter Intert Pressue (psig)	19	23	8	23	3	3	3	22	3	13	52.5	52.6	#18 +					Filter Outliet	Pressure (psid)	47	AL	44	48	19	84	48	107	1000	48	48	47.5	-	ł		
Pressure (psig)	47	48	早	40	84	48	48	44	4.0	48	47.5	48	3.23	40.00		2.437	0.196	Slurry Looo Flow	Rate (com)	3.23	3 32	0.0	3 27	3.23	3 23	325	3.28	Sec.	3.22	3 17	3.23	10.00		1000	Time
Slurry Loop Flow Rate (gpm)	3.23	3.22	3.2	327	3 23	3.23	325	3.28	3.22	3.17	3.23	3.26				= 285	AL2 =		Sturry Temp C	24.1	24.4	24.8	24.7	24.9	24.9	24.2	23.9		21.9	22.1	22.2	1.55	ī	C. North Com	Flux vs. nd 9.4 ft/s
otal Time lapaed An)	0.00	0.04	60.0	0.14	D-19	D:24	0.29	0.34	0:44	0:49	154	0:59	v Flow apm	sure rout -	- number of the second	the Flow mill	the Fluck gpm		hiller amp C	15	51	ţ	14	15	1	12	1		11	12	1	\$	1	0.00000	t 50 psig an
Time	3:36	3:40	3,45	3.50	3.55	4:00	4.05	4.10	4.20	4.25	430	4:35	Average Sturr	Average Dreet	and a second second	Average Filtra	Average Filtra Average Perm	e	Time 10	3.36	3-40	3.45	3.50	3.65	4:00	4:05	4.10	4:15	4:20	4.25	4.30	A-95		1000	C-106
Condition	+	F	-	+	+	-	÷	-	-		Ŧ	+	1						Number	-	-			1	-	4			-	-					

ie.



1:12

0:57

0:43

0.14

00:0

1.12

0.57

0.43 0.28 0.43 Time (hr:min)

0.14

000

•••••

••••••

Time (hr:min) 0.28

Permeability (mudatybar) (mudatybar) (00 00 • •

'ermeability gpm/ft2/psi)	0.003542	0.002851	0.002597	0.002417	0.002206	0.002005	0.001991	0.001741	0.001752	0.001731	0.001679	0.001551																				
Filtrate Flux (0.106342	0.085684	0.077969	0.072565	0.066225	0.080191	0.058287	0.052718	0.052560	0.061969	0.050416	0.048111																				
Permeability (m/day/bar)	3.016	2.427	2.211	2.058	1.878	1 707	1.096	1 483	1491	1.474	1.430	1.320																				
Filtrate Flux m3/m2/day)	6.238	5.020	4.574	4,257	3.885	3.531	3.419	3.092	3 085	3.049	2.957	2.822						in the second se														
Slury Temp C	2.82	22.3	21.6	22.1	23.1	24.1	24.6	24.6	24	22.9	23.2	22.8							Fillenta Flow	Rate (mL/sec)	2,667	1 500	1.348	1.248	1,265	1.255	1.151	1.161	1.110	1.092	1.100	1.102
Fitrate Flow Rate (mL/sec)	1.252	0.982	0.882	0.828	0.777	0.727	0.714	0.648	0.633	0.606	0.593	0.560							Time of	Collection	11.26	2	22.25	24.03	23.72	23.91	26.06	25.84	27.03	27.47	27.28	27.22
Time of Collection (Sec)	23.87	30.55	34.03	36.25	38.5	41.28	42.03	45.47	47.38	49.47	50.66	53.59						Clinical of	Sample	Valume	8	R	30	30	30	8	8	8	8	92	30	8
Filtrate Ssmple Volume (mL)	30	8	30	30	30	30	30	30	30	30	30	30							Filter Inlet	pression	CE IBand	R	51	32	33	2	He I	32.5	33	22	32	33
Pressure Drop (psig)	4	4	4	4	4	4	3.5	म म	4	4	4	4	7.6						Permerade	Pressure	(Field											
Fitter Inlet Pressue (psig)	32	32	27	32	Pf	5	10	32.5	32	12	No.	33	10's =					Citor	Outlet	Pressure	19mm	13	28	8	28	28	27.5	28	28	28	28	29
Fifter Outliet Pressure (psig)	8	13	R	28	R	58	27,5	28	18	28	82	59	2.60	30.04	0.767	0.065	0.002	Channel	Loop Flow	Rate	2.72	2.55	2.58	2.51	2.62	2.64	26	2.64	2,62	2.47	2.59	2.6
lurry Loop low Rate Ipm)	2.72	2,65	2.68	2.51	2.62	2.64	20	2.64	2.82	2.47	2,69	2.6	н		H Date	m2 =	n/ff2/psi =			luny	22.3	21.9	21.5	21.9	22.5	22.7	137	23.2	23.3	23.4	23.5	23.5
atal Time S lapsed F Min) ((0.00	0.04	0.09	0.14	0.19	0.24	0:29	0,34	0:39	0.49	155	0:20	y Flow gpm	sure psid =	the Flow mL	de Flux gpm	neability gpr			hiller S	11	13	74	11	18	18	18	12	21	24	17	18
Time	921	9.25	9.30	9-35	9.40	945	9.50	9.55	10:00	10.10	10:15	10.20	Average Shur	Average Pres	Average Filtra	Average Filtra	Average Perm			O.F	921	9.25	9:30	9-35	9.40	9.45	9.50	916	10.00	10.10	10:15	10.20
Condition	IN	P.	24	P4	PN .	N	04	CN.	N	14	en	D4	2	t's	EV.	74	Pe			Test	17	N	N	14	^N	N.	N	0	C4	2	CH.	es.



Permeability (gpm/ti2/psi)	0.006346	0.002098	0.001740	0.001625	0.001475	0.001451	0.001452	0.001380	0 001345	0.001304	0.001289	0.001262	0.001211																		
Filtrate Flux (gpm/#2)	0.374501	0 146106	0.121454	0 113448	0.102944	0 10 10 1831	0.101696	0.098291	0.094557	0.091359	0.069616	0.068430	0.084847																		
Permeability (m/day/bar)	4.552	1.778	1481	1.384	1,256	1 235	1 2345	1.175	1.145	1,110	1 097	1.075	1.031																		
Fitrate Flux (m3/m2/day)	21.968	B.571	7.124	6.655	6.009	5.962	5.965	5.648	5.547	5.359	5257	5.187	4.977																		
Stury Temp C	24.5	24.3	24.2	242	24.3	24.3	24.5	24.7	24.9	25.1	25	24.9	24.9			Fitrate Flow Rate	(ml.) sec)	4.573	1.774	1/4/1	1.374	1,250	1,234	1.242	1.182	1.158	1,135	1.110	1.082	1.048	
Fitnate Flow Rate (mL/sec)	4.573	1.774	1.471	1.374	1,250	1234	1.242	1.182	1.168	1,135	1.110	1.092	1.048			Time of	(Sec)	0.56	16.91	20.4	21.84	24	24.31	24,16	25.37	25.69	26.44	27.03	27.47	28.63	
Time of Collection (Sec)	0.56	16.91	20.4	21.84	24	24.31	24.18	25.37	25.69	26.44	27.03	27.47	28.63		2	Sample	m()	30	30	30	30	30	30	30	30	30	30	30	30	30	
Fitrate Sample Volume (mL)	30	30	30	30	30	30	30	30	30	30	30	8	8			Fitter Inlet	(pisig)	22	72	71.5	71.5	715	12	12	715	22	22	F	22	72	
Pressure Drap (psig)	4	*	3.6	3.5	3.5	ч	4	3.5	前の	**	10	4		7.2		Permeate	(pisig)														
Filter Intet Pressua (psig)	72	72	212	71.5	71.5	12	72	2115	12	2	2	12	12	- 52		Filter	(psig)	昭	8	8	8	8	89	8	8	68.5	69	68	68	89	
Filter Outlet Pressure (psig)	68	88	60	89	89	88	68	69	683	8	8	8	8	2.47 69.90 1.512 0.124	0,000	Surry	Rate (gpm)	26	2.6	24	2.45	2.48	2.47	2.52	2.52	2.47	2.42	2.4	2.42	2.43	
Slurry Loop Flaw Rate (gpm)	2.6	25	2.4	2.45	2.48	2.47	2.52	2.52	2.47	2.42	24	2.42	2.43	1 = /566 = n/ft2 =	- Hedrohum		Temp C	24.5	24.3	242	24.2	243	24.3	24.5	24.7	24.9	12	53	24.9	24.9	
Total Time Elapsed Mini	00:0	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0:40	0:45	0:50	0,55	1.00	rry Flow gpr ssure psid = ate Flow ml ate Flox gpr	di Ammeri	1	Temp C	13	11	19	12	ę	12	ţ2	12	13	13	EF	12	12	
Time	10.25	10:30	10.35	10/40	10:45	10:50	10:55	11:00	11:05	11.10	11.15	11:20	11:25	Average Slu Average Pro Average Filt Average Filt	www.age.r.m	,	Time	10.25	10:30	10.35	10.40	10.45	10:50	10.55	11:00	11:05	11:10	11:15	11:20	11:25	
Candilian	10	0	63	10	20	19	17	ei.	175	0	n	m	<i>m</i>	0000	9	Taxet	Number	10	n	r).	n	0	n	ri.	m	97	n	n	m	67	

ε,



0.034											-																
Fittrate Flux (com/h2)	0.154608	0 117247	0.118553	0.106409	0.103706	0.101288	0 100129	0.095921	0.092692	0.090778	0.087825	0.088331		12													
Permeability (m/day/bar)	4.459	3.325	3.305	2.969	2.893	2.849	2.840	2,766	2.719	2.018	2.485	2.505															
Filtrate Flux (m3/m2/day)	090.6	6.878	6.837	6.183	6.003	5.942	5.874	5.627	5.437	5.325	5.140	5.182															
Stury Temp C	22.5	22	22.3	22.6	8	53	23.1	23.1	23.2	23.3	23.2	23.1			Fitrate Flow Rate (mU/sec)	1.784	1.333	1.337	1.220	1.214	1,185	1,175	1.128	1.091	1.071	1.031	1.037
Filtrate Flow Rate (mL/sac)	1 784	1.333	1.337	1.220	1.214	1 185	1.175	1.120	1.091	1.071	1.031	1.037			Time of Collection (Sec)	18.82	22.5	22 44	24,6	24.72	25.31	25.53	26.65	27.5	82	29,09	28.94
Time of Collection (Sec)	16.82	22.5	22.44	246	24.72	25.31	25.53	20.65	27.5	28	29.09	28.84		and the second	Sample Volume (mL)	8	99	02	30	98	30	30	30	30	30	8	30
Filtrate Sample Volume (mL)	8	8	8	5	8	8	2	92	30	8	30	30			Filter triet Pressue (psid)	31	22	22	32	33	32	27	31	31	31	32	R
Pressure Drop (psig)	e	ч	4	4	+0	3.5	4	0	4	m	4	7	7.8		Permeate Pressure (psid)												
Fitter Injet Pressue (palg)	31	21	14 171	27	EE	32	13	10	31	31	32	32	10.5 =	C. C	Pressure (psic)	28	28	28	28	28	28.5	28	28	27	28	28	12
Filter Outlet Pressure (psig)	28	28	13日	28	2	28.5	2	28	27	28	28	28	2 69 29 85 1.217 0.105 0.003	1000	Loop Flow Rate (apmi)	2.65	27	2.83	2.57	2.8	2.75	2.68	29	2.76	2,44	2.75	25
Sturry Loop Flow Rate (gpm)	2,65	2.7	2.83	2.57	28	2.75	2,68	2.9	2.76	2.44	2.75	2.5	m = = i(Lisac = om/t2 = pm/t2/psi =		Sturry Temp C	22.5	22	22.3	22.6	23	EN I	23.1	23.1	23.2	23.3	23.2	23.1
Total Time Elapsed (Min)	0:00	0.07	0:10	0.15	0.22	0.25	0:30	0.35	0.42	0.50	0.55	1.00	urry Flow gp essure psid trate Flow m trate Flux gs rmeability o		Chiller Temp C	12	10	15	16	49	11	11	17	18	44	11	18
Time	11,35	11:42	11:45	11:50	11:57	12:00	12.05	12:30	12.17	12.25	12-30	12.35	Average St Average Fil Average Fil Average Fil		Time	11.35	11:42	11:45	11.50	11:57	12:00	12.06	12:10	12:17	12:25	12:30	12:35
Condition	4	4	4	य	च	4	4	*	4	4	4	4	*****		Test Number	4	4	4	4	4	4	4	4	4	4	*	*



Permarbili ty (gpm/ft2/p st) C

P > 20	-																																			
Fibrate Flux (opm/#2)	0.192418	0.134885	0.121236	0.113265	0.106856	0.106982	0.102859	0.101407	0.095324	0.094907	D.089897																									
Permeability (m/day/bar)	3.274	2 295	2.063	1.927	1.852	1.853	1,750	1.728	1.022	1,023	1530																									
Filtrate Flux (m3/m2/dav)	11.287	7.912	7,111	6.644	0.386	6.387	6.034	5.949	286.6	0.001	5273																-					~		ĨŦ		
Shrry Temp C	24.8	24.8	24.2	24.5	25.1	0.92	24.7	24.7	0.7	24	18			e	Filtrate Flow Rate	(man man)	2.370	1001	1 383	1 352	1.345	1,263	1,245	1,184	1,182	1,116	vs. Time at					0.57 1.12			rs. Time at	
Filtrate Flow Rate (mL/bec)	2370	1.661	1 468	1 383	1.352	1345	1,263	1.245	101.1	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	1.116				Time of Collection	(Bec)	12,66	201.01	37.83	22.19	22.31	223.75	24.08	20.20	時間	28.87	meability	and 8.6 fb/s ition 6)		:	3	28 0.43	ne (hr:min)		neability v nd 8.6 Ms	-
Time of Collection (Sec)	12.08	18.06	20.44	21.69	22.19	22.31	21.52	24.09	10.45	25,25	26.87				Filtrate Sample Volume	(Jul)	90	00	R	30	30	30	R	00	8 9	88	ulant Por	50.0 psig : (Cond				14 0.2	μ,		50.0 psig a	
Filtrate Sample Volume (mL)	30	30	30	30	8	8	8	8.3	8.9	8 9	28				Filter Inlet Pressue	(Brad)	12	2 2	1 2	123	23	3	2	21 1	2 5	2 2	-106 Sim		. 0	•••••	0	0:00 0			106 Simu	900
Pressure Drop (psig)	4	4	4	10	4	τ.·	4.	* *	1.4	n H	4	8.6			Permeate	(pisig)											0		(JE (JE	ideet diya ci	0) (U) (U) (U)	d			Ċ	2
Filter Intet Pressue (psig)	25	52	23	3	8	21	8	3 5	8 2	2 5	1 28	= 5/1			Filter Outlet Pressure	(psig)	Ş :	9 S	1	\$	4	49	8	8	4	₽ ₩			Î		1	1.12		11		ſ
Filter Outlet Prossure (psig)	48	48	48	8	Ş :	17 S	Ş :	φ 4	47.5	100	\$	2.95	49.98	0 113	Shurry Loop Flaw	Rate (gpm)	3.00	AR C	307	2.89	2.94	2.92	2.87	2.94	18	3.03	Time			:		0.57			Time	
Sluny Loop Flow Rate (gpm)	3.08	2.91	2.68	10.5	2.69	194	200		100	23.62	102	I.	- 1990 m	mft2 = m/ft2/psi =	Surv	Temp C	24.8	24.2	24.5	25.1	24.9	24.7	24.7	25.1	N N	25.1	Flux vs.	and 8.6 ft/s tion 6)		:		0.43	e (hr:min)		Flux vs. and 8.6 ft/s ion 6)	
Total Time Elapsed (Min)	0.00	0.05	0110	0.15	0.20	0.24	0.30	020	140	0.50	1.01	my Flow gpn	- bise and a set	rate Flux gp meability gp	Chiller	Temp C	¥ :	2 [2	9	16	14	15	10	₽ 1	2 4	2 ¥1	Simulant	it 50.0 psig. (Condit		:		4 0.28	Tim		Simulant 50.0 psig /	
Tate	12.45	12-50	t2:55	13:00	13.05	13,09	0	12.20	UP-ST	13.35	13:46	Average Stu	Average Pro Average Filb	Average Filt Average Per		Time	12.45	12-46	13:00	13:05	13.09	13:15	13:20	13.25	10.00	13:46	C-106			•		00 0.14			C-106	
Condition	'n	in.	M2)	90.1	0.3	DN	0.4	n u		1 10	10	ŝ	un in	in in	Test	Number	40.4	0.40	-0	-	10	0	0.1	D 4	n v	5 v2			and and and and and and and and and and	H eda Marka	100 mil	0.6				x 0.30

1:26

0:28 0:57 Time (hr:min)

0.00

12

0:57

0.28 0.43 Time (hr:min)

0.14

000

0.002 * * * * * * * * * *

Yillidsemne9 (isq\Sfimqg)

.

٠

xulf atstiff (gm/g) 0.20 0.10 0.00 0.00 0.00 0.00

r

Permentbill y y (http://lpts 0.0025696 0.0002696 0.0002778 0.0002778 0.0002778 0.0002778 0.0002778 0.0002778 0.0002778 0.0002766 0.0002778 0.0007907 0.0007906

-	1	5		1		÷.,	1	1		10		-																														
Ethrate Flux (com/#2)	C strange	100221-0	0.11003	0.10990	n 40000	0.102800	C CORRER	0.100830	0.0997690	0.098750	0.100271	0.097832																														
Permesbility (m/day/har)	0 608 ·	10000	000 0	0000	1.400	118.2	2 790	2.862	2.829	2.801	2820	2774																														
Fittrate Flux m3/m2/dav)	7 105	1000	10404	10000	a nut	1000	5 771	5.921	5.852	5.780	5.882	5.739																								-1	-					
Stury Temp C	36	1 2	D MC	1.25		26.4	32	55	12	5	25.1	24.8					Filtrate Flow Rate	(mL/sec)	1.519	1.369	1345	1 205	1 242	1.219	1,250	1.236	1,223	1,205	vs. Time at			••••		0-57 1-12			s. Time at	Ī				0:57 1:12
Fibrate Ficw Rate (mL/sec)	1 510	1000	1 145	1 335	1 202	1 242	1219	1.250	1.238	1.223	1245	1.205					Time of	(Sec)	19.75	28.22	22.31	21.22	24.15	24.62	24	24.28	24.53	24.9	neability -	nd 13.1 ft/s tion 6)		•		8 0.43	thrmin		d 13,1 f/s on 60					28 0:43
Time of Collection (Sec)	10.76	20.00	12 00	TA CC	24.22	24.15	24.62	24	24.28	24.53	24.09	24.9					Filtrate Sampie	Volume (mlL)	8	1	8.8	8.8	8	8	90	8	8	8.8	ulant Perm	30.00 psig a (Condi				14 0.2	L.		lant Perm 30.0 psig an (Conditi			E E		0:14 02
Fittrate Sample Volume (mL)	OF	4D	28	19	COE.	2.6	8	00	8	8	8	8					Filter Inlet	(psig)	32	R	8	8 2	R	33	33	33	33	33.0	-106 Sim			•		0:00			106 Simu	005	004 .	003	001	00:00
Pressure Drop (psig)	-	10				2.0	Ð	9	9	φ	6.6	9	13.1		1		Permeate	(psig)											0		(JB (4))	ni (qife) qee)	me9 (mid /				Ú	0 (1 %	sd/2	iem Mma	0 16) 9d	
Filter Intet Pressue (psig)	32	EE.	19	1	R	8 8	12	8	8	33	33.5	2	= 5jU				Filter	(Drad)	8	12	1	9 14	22	27	R	12	12	11	11		1	1		1:12				Γ	T	Т	T	1:12
Filtor Outlet Pressure (psig)	92	22	10	28	27	1	12	27	27	27	12	27	4,49	20.02	0 454	0.003	Slurry	Rate (gpm)	4.55	4.44	19.61	4.48	4.47	4.46	4.48	4	4	4.48	Time		:			0.57			Time		••••		-	0:57
Slurry Loop Flow Rate (gpm)	4.54	4.44	4.47	4.55	4.48	4.87	4.48	4.48	4.52	4.52	4.52	4.45	1	fame of	= caput	m/f2/pai =		Temp C	2	22	2.52	255	25.1	10	193	81	1	24.8	Flux vs.	tion 6)	:			0.43	(hr:min)		Flux vs. nd 13.1 ft/s ion 6)		-			8 0:43
Total Time Elapsed (Min)	000	0.05	0-10	0.15	0.21	0:30	0:35	0:40	0,45	0:50	0.55	1:00	irry Flow gpt	assume paid -	rate Flix m	meability op		Temp C	2	2.3	t t	2.15	14	4	12	2	4	19	Simulant	(Condit	İ			0:28	Time		Simulant 30.0 psig a (Condit		•		-	14 0.2
Ē	1.55	2.00	2.05	2.10	2.16	2-25	2:30	2:35	2:40	2:45	2.50	3.52	verage Sil	verage PN	versens Fai	verage Pe		em	1:65	8.7	01.4	2.16	2:25	2:30	2.35	240	142	2.55	C-106					0:14			C-106	1	•			000
Condison Number Ti	9	9	9	-ip	¢	0	¢	φ	φ	ω	φ	Ð	6 A1	1 4 B		N D		Number Ti	9	D G	0 4	0	9	9	0	0	0 1	φ.			1 290 H	1314		0.00				x 0.15	E 10.10	10.05 m	LE 0.00	0

0.004226 0.003662 0.003627

Permeability (gpm/ft2/psi) 003446 003426 003332

0.003362

0.003323

0.003312

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

	17							
Permeabili 1970 1970 1000000 10000001 10000001 100000011 1000000								
- 225-8889 -	0.000	17474 17474 53532 53532 00174 15423 55603						
0.000 000 000 000 000 000 000 000 000 0		0.0590 0.0523 0.0478 0.0478 0.0478 0.0476 0.0476						
R.S.	000	0.10 0.15 0.25 0.20 0.20						
mesblit day/bit 3.920 2.472 2.056 1.936 1.153								
Per (mu)				111	0.28		0:28	
Flux May) Aday) Ada 835 835 835 835 835 835 835 835	Flow (L/sec)	345 345 284 283 283 283	ne at	•				
2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Filtrate Rate (n	000000	vs. Tit		0.21	10 at	0.21	
y 272 281 233 231 231 231 231 237	of dion	26.1 26.1 31.03 34.07 35.63 35.63 35.63	bility o fus minute		14 rcmin)	s. Tim	+ 14 hrmin	
Term	Time Colle (Sec		ermea g and 6		0.1 Lime (h	0 fVs minutes	Time (
mirale ow Rat 0.404 0.243 0.130 0.171 0.173 0.173	ttrate simple olume		ant P. 20.1 ps		20:0	rmeat 1ard 6. 1st 30	0:01	
f Film Film (17) 37.1 37.1 37.1 37.1 2.55 2.55 2.55 4.67 4.67	의 비원 이 사진 이 기 이 사진 이 기	3 8 8 8 3 3 8	Simul (Cor	•		int Per 0.0 psig		
Collect (Sec) 2 2 5 5 5 5	ed Filter (Pressu (psig)		3-106	000	0:00	limula 22 (Conc	006	
하여 여 여 여 여 여 여 여 여 여 여 여 여 여 여 여 여 여 여	6.02 Removir R	000000	U	(day/bar) (day/bar)	nag m)	-106 S	Permeability (gpm/ft2/psi (gpm/ft2/psi	
Filtr Sam Volt 20 20 20 20 20 20 20 20 20 20 20 20 20	Parr Parr (psi)		_			0		
ther Infe ressue faig)	It's Alth Fire Iter ressure NM			(TTT	0.28	1	0.28	
E SESSES	3.68 00.14 0.222 0.222 0.048 V 0.003 0.003 0.003 0.003 0.003 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000 0.000000	3.74 3.73 3.63 3.65 3.66 3.66 3.69 3.69		•	41.00		•	
Press N N N N N N N N N N N N N N N N N N N	Sturry Earte (gpm)		Time es)		0.21	Time es)	0.2	
7 p Flow 3.74 3.78 3.63 3.69 3.69 3.69 3.69 3.69 3.69	npsi =	23,3 23,3 23,3 23,3 23,3 23,3 23,3 23,3	UX VS. L0 ft/s		(uim	IX VS. 0 f/vs minute	e rrmin)	
Sur 1000 1111 1111 1111 1111 1111 1111 111	pm = 1= mL/sec pm/m2 gpm/m2 gpm/m2 fer Ten	112 112 112 112 112 112 112 112 112 112	nt Flu g and 6	•	0:14 me (hr:	nt Flu 1 and 6. 1 st 30	D-1	
antime cocococo cococococo cococococo cocococo cocococo cocococo cocococo cocococo coco cococo co	Flow g ure psk a Flow ability flar Ter		imula 0.1 psi itton 1		F	imula 0.1 psig	- 20	
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	e Filtrab Filtrab Perma Perma	288889	106 S (Cond		0.02	106 S 2 (Cond	•	
and 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	Average Average Average Average	222222	U U			ů .	8	
E a	- Contraction of the second se			000	- 8 - 8	0.10	(71)/wd6)	
ta a contract a contra	1a 1a 1a 1a 1a 1a 1a 1a	tastas j	Ē	xul3 eter	#II:H	x	Flitrate Flu	

Filtrate Flux (gpm/tt2)	0.0560	0.0450	0.0409	0.0391	0.0415	0.0397	0.0351														
Permeability (m/day/bar)	2.384	1.868	1.739	1.665	1.764	1.649	1.493														
Filtrate Flux (m3/m2/day)	3.287	2.640	2.397	2.296	2.432	2.330	2.058						Filtrate Flow	Rate (mL/sec)	0.387	0.352	0.327	0.321	0.296	0.294	0.270
Slumy Temp C	24.2	24.1	24.2	24.4	24.8	25	25						Time of	(Sec)	25.81	28.43	30.62	31.16	33.81	34.07	36.97
Filtrate Flow Rate (mL/sec)	0.226	0.181	0.165	0.159	0.170	0.164	0.145						Filtrate Sample	(mL)	10	10	10	10	10	10	10
Time of Collection (Sec)	39.79	49.68	54,56	56.65	52.88	54.88	62.13				ed		Filter Inlet	Pressue (psig)	20	20.5	20.5	20.5	20	20.5	20
Filtrate Sample Volume (mL)	6	6	0	6	0	a	6	6.1			Point Remov		Permeate	Pressure (psig)	-	1	7	7	-	-	1
Filter Inlet Pressue (psig)	20	20.5	20	20	20	20.5	20	1 ft/s =			0 With First I	2	Filter Outlet	Pressure (psig)	MN 1	MM	MN	MN	MN	MN	MN
Filter Outlet Pressure (psig)	MM	NM	NM	NN	NN	NN	MM	3.7	20.14	0.173	0.04(0.00	Skurry Loop Flow	(gpm)	0,85	0.93	0.96	0.98	0.6	0.85	0.86
Slurry Loop Flaw Rate (gpm)	3,77	3.66	3.7	3.69	3.67	3.66	3.82	11		/sec =	n/ft2 =	m/ft2/psi =	i	Temp C	23.8	24.2	24.6	24.9	25	25.1	25.5
Fotat Time Elapsed Min)	00:00	0:05	0:10	0:15	0:20	0:25	0:30	rry Flow gpm	ssure psid =	ate Flow mL	ate Flux gpr	meability gpr		Chiller Temp	18	18	18	20	20	19	19
Time	14:55	15:00	15.05	15:10	15:15	15.20	15.25	Average Slur	Average Pret	Average Filtr	Average Filtr	Average Pen		Time	14:55	15:00	15:05	15:10	15:15	15:20	15:25
Condition Number	1b	1b	1b	1b	1b	4	đ	1b	10	1b	1b	1	2	Number	1b	1b	11	1b	11	11	1b

0.002194 0.002042 0.001956 0.001956 0.001936 0.001936

ty (gpm/ft2/p si) 0.0028

Permeabili

NM = Not Measured





Permeability (gpm/ft2/psi)	0.003567	0.002382	0.002252	0.002092	0.002185	0.002106																											
Fitrate Flux (gpm/ft2)	0.0464	0.0298	0.0282	0.0262	0.0284	0.0253																											
Permeability (m/day/bar)	3,037	2.028	1.917	1.781	1.861	1.793																				T	0.36				-		0:36
Filtrate Flux (m3/m2/day)	2.722	1.748	1,652	1.535	1,668	1.484							Filtrate Flow	Indertili autou	0.203	0.129	0.120	0 111	0.121	0.110		vs. Time at			•		0:28		vs. Time at			•	1 0:28 (
Sturry Temp C	27.1	26.6	26.2	25.9	26	27							Time of Collection	(Sec)	73.84	69.97	74.84	81 22	74.56	81.5		rmeability and 4.46 ft/s 1st 30 minute			•		14 0.21	me (hr:min)	rmeability and 4.46 ft/s 1st 30 minute			•	0:14 0:2
Filtrate Flow Rate (mL/sec)	0.203	0.129	0.120	0.111	0.121	0.110						Filtrate	Sample	(mL)	11	6	G	1.07	0	6		12.6 psig Condition 2,			•		0.07	H	nulant Pe 12.6 psig Condition 2.			•	0:07
Time of Collection (Sec)	73.84	69 97	2 74.84	9 81.22	9 74.56	9 81.5	12			par			Filter Inlet Pressue	(Disig)	13	12.5	12.5	12.5	13	12		C-106 Sin	0.0	•	2.0	0.0	0.00		C-106 Sin		0.004	0000	0:00
Filtrate Sample Volume (mL)	11						4.40			oint Remov			Permeate	(pisig)						0			() (4)	eq	кер) ееш	ner Per					(isq)	tsemn Stit/mo	d6) Iðd
Filter Inlet Pressue (psig)	13	12.5	12.5	12.5	133	12	= S/4			With First P		Filter	Outlet	(pisig)	NM	NM	NMN	NM	NN	MM			Γ	T		0.36	000				Π		0:36
Filter Outlet Pressure (psig)	NM	MM	MM	MN	MM	MN	2.74	12.58	0.132	0.028	0.002	Slumy	Loop Flow Rate	(mdb)	2.76	2.76	27	2.5	2.75	2.77		Time s			•	80-0	07.0		Time				0:28
Slurry Loop Flow Rate (gpm)	2.76	2.76	2.7	2.5	2.75	2.77	= 00	1	iL/sec =	m/ft2 =	pm/ft2/psi =		Slurv	Temp C	27.1	26.6	26.2	25.9	26	27		t Flux vs. and 4.46 ft/ 1st 30 minut			•	+0.0	17.0	o (hr;min)	t Flux vs. and 4.46 ft/s st 30 minuth			•	14 0.21
Total Time Elapsed (Min)	00:0	0:05	0:10	0.20	0.25	0:30	irry Flow ap	essure psid	trate Flow m	trate Flux gp	rmeability g		Chiller	Temp C	13	12.5	12.5	12.5	13	12		5 Simulan at 12.6 psig andition 2, '				0.14	1.0	III.	Simulant tt 12.6 psig ndition 2, 1			•	0:07 0:
Time	16:10	16.15	16:20	16.30	16.35	16:40	Average Sh	Average Pn	Average Fil	Average Fil	Average Pe		1	Time	16:10	16:15	16:20	16:30	16:35	16:40	leasured	C-10(•		cu-u u	0.0		C-106		9 4	2	0:00
Condition	2a	2a	2a	2a	2a		Test	Number	2a	2a	2a	2a	2a	2a	NM = Not N		• 0.0 (AE XN	FT 122.0	sterte 3/mz	+ 0.01	2.2			ALC: NO	xul7 s (271/1	(gpm (gpm	4						

Time (hr:min)

Permeability (gpm/ft2/psi)	0.003827	0.002524	0.002421	0.002339	0.002336	0.002269	0.002212																															
Filtrate Flux (dom/ft2)	0.0479	0.0316	0.0303	0.0283	0.0292	0.0284	0.0277						10										3															
Permeability (m/day/bar)	3.259	2.149	2.061	1.991	1.989	1.932	1,883																						-	128		Ĩ			1).28
Filtrate Flux (m3/m2/dav)	2.808	1,852	1.776	1.716	1.714	1.665	1.623						Cilentes Close	Rate (mL/sec)		0,199	0,131	0.125	0.120	0.120	0.116	0.113	vs. Time at	10 01001 104	5)			•		0.21 0			vs. Time at	es)			•	0:21 (
Sturry Temp C	25.2	25.2	25	24.9	24.7	24.7	24.7						Time of	Collection	(Sec)	45.28	68,66	72	74.72	75.25	77.47	79.47	meability	and 4.5 ft/s	, 2nd minutes			•		0:14	me (hr:min)		rmeability	and 3.15 gpm 2nd 30 minute			•	0:14 Time (hr:min
Filtrate Flow Rate (mL/sec)	0.199	0.131	0.125	0.120	0.120	0.116	0,113						Filtrate	Volume	(mL)	đ	8	σ	a	σ	6	6	ulant Per	12.5 psig	Condition 2					0:07	T		ulant Per	30.4 psig a ondition 2,			•	0:07
Time of Collection (Sec)	45.28	68.66	72	74.72	75.25	77.47	19.47				p		Filter Inlet	Pressue	(bisd)	12.5	12.5	12.5	12.5	12.5	12.5	12.5	2-106 Sim		·		•	0	0	0:00			2-106 Sim	0	006	004 +	002	0:00
Filtrate Sample Volume (mL)	6	6	6	6	8	6	71	4,51			oint Remove		Permeste	Pressure	(bisd)	0	0	0	0	0	0	0		,		4	ed/	∾i Kep/ eeu	(m/	0			0		ei) lity	d/Z1	burlt	5 16) 84
Filter Inlet Pressue (psia)	12.5	12.5	12.5	12.5	12.5	12.5	12.0	= \$/¥			With First P		Filter 0	Pressure	(pisig)	MM	NM	MM	MM	MM	WW	MM				[T	0:28								0:28
Filter Outlet Pressure (psia)	MN	MM	WN	MN	MN	MN	MN	2.76	12.50	0.132	0.029	222.2	Slurry Loon Flow	Rate	(mdg)	2.87	2.64	2.69	2.79	2.82	277	273	Time		es)		•		1	0:21			Time	is)				0:21
Slurry Loop Flow Rate (apm)	2.87	2.64	2.69	2.79	2.82	2.77	2.13	= u		L/sec =	m/ft2 =	- 100/27113114		Slurry	Temp C	25.2	25,2	25	24.9	24.7	24.7	24.7	Fliry vs	and 4.5 ft/s	nd 30 minut		•		-	0:14	e (hr:min)		Flux vs.	and 9.2 ft/s nd 30 minute		•		0:14 me (hr:min)
Total Time Elapsed (Min)	0:00	0:05	0:10	0:15	0.22	0.25	05.0	irry Flow gpr	essure psid =	rate Flow m	rrate Flux gp	ff Amosim		Chiller	Temp C	19	17	18	17	18	18	18	Simulan	at 12.5 psig	ndition 2, 2		•			:01	Tim		Simulant	nt 30.4 psig ndition 2, 21		•		0:07 Ti
Time	10:53	10:58	11:03	11:08	11:15	11:18	11.23	Average Slu	Average Pri	Average Fill	Average Fill	or agoint			Time	10:53	10:58	11:03	11:08	11.15	11:18	11:23	C.106		(Co		•			0			C-106	(Col			0	0:00
Condition	2b	25	20	20	30	25	9	2b	2b	20	84	7		Test	Number	2b	29	2b	2b	2b	2b	29			- SUS	• (//a xn	日 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	ateri 2 0	+ 0.00) + 111	0:0					xul7 (Sf	ete hmi	10) 10)	

Permeabilit y (gpm/ft2/psi 0.003333 0.003333 0.003335 0.003335 0.003335 0.003035	*.		
Filtrate Flux (gpm/ft2) 0.0777 0.0665 0.0665 0.0665 0.0608 0.0607			
Permeability (m(day/bar) 3.305 2.335 2.685 2.685 2.584 2.581			136
Filtrate Flux (m3/m2/day) 4.557 3.909 3.842 3.644 3.559 3.559	Filtrate Flow Rate (mL/sec) 0.324 0.276 0.245 0.245 0.245	vs. Time at	vs. Time at es) • • • 21 0:28 0
^a Sturry Temp C 25.4 24.1 24.1 24.1 24.2 24.2 24.2	Time of Collection (Sec) 32.65 9 33.85 9 33.65 9 35.63 9 36.81	ermeability g and 9.1 ft/s 1st 30 minute • • 14 (Time (hr.mi	armeability g and 9.1 ft/s g, 1st 30 minut e 0.14 0.2 Time (hr.mi
Filtrate Flow Rath (mL/sec) 5 0.324 5 0.265 3 0.265 3 0.245 5 0.245	Filtrate Sample Volume (mL)	Condition 2 (Condition 2 0	Condition 3 (Condition 3 (0.07
Time of Collection (Sec) 27.77 33.8 33.8 35.6 35.6 36.8 36.77	ed Filter Inlet Pressue (psig) 20 20 20 22 22 22 22 22 22 22 22 22 22	C-106 Sir (m/day/bar) C-106 Sir 0.00 0 0.00 0 0.00 0	C-106 Sir (9pm/r2/9s) 0.006 (9pm/r2/9s) 0.002 (9pm/r2/9s) 0.002
Sample Volume (mL)	9.06 Permeate Pressure (psig)	Permeability	Permeability
Filter Inlet Pressue (psig) 20 20 20 20 20 20 20 20 20 20 20 20 20	ft/s = ther filter Outliet Pressure (psig) NM NM NM NM NM NM NM	0:36	0:36
Priter Outlet Pressure (psig) NM NM NM NM NM NM NM	5.54 20.00 0.268 0.063 0.003 0.003 0.0063 0.0003 0.00630000000000	• • •	es) es) 0:28
Slurry Loop Flow Rate 5.55 5.54 5.54 5.54 5.54 5.54 5.54 5.5	n = L'sec = m/ft2 = m/ft2/psi = sm/ft2/psi = 25.4 25.4 25.4 24.1 24.2 24.2	Flux vs. and 9.1 ft/s st 30 minut et 30 minut et 30 minut	Flux vs. and 9.1 ft/s st 30 minuti e 0.21
Total Time Elapsed (Min) 0:00 0:11 0:21 0:21 0:231	rry Flow gpi rate Flow m rate Flow gpi rate Flux gp meability gg Temp C 18 15 15 15 15 15 15	Simulant t 20.0 psig ndition 3, 1 0:14 Tim	Simulant t 20.0 psig idition 3, 1 e 7 0:14
Time 11:59 12:10 12:10 12:25 12:25	Average Slu Average Prit Average Fitt Average Peit Average Pei 11:59 12:05 12:20 12:20 12:25 12:25 12:25	C-106 (Co	C-106 (Col 0 0:0:
Condition Number 3a 3a 3a 3a 3a 3a 3a 3a	3a 3a 3a 3a 3a 3a 3a 3a 3a 3a 3a 3a 3a 3	xura atsuria (yean 2000) (100)	Filtrate Flux (m3/m2/day) 0.00

Permeabilit y (gpm/ft2/psi	0.003934	0.003338	0.003254	0.002959	0.003048	0.002826																							
Filtrate Flux (gpm/ff2)	0 0787	0.0668	7090.0	0.0592	0.0610	0.0566																							
Permeability (m/day/bar)	3.350	2.842	2.1/1	2.519	2.595	2.406				5								[:43					.36
Filtrate Flux (m3/m2/dav)	4.619	3.919	3.460	3 474	3.578	3.318				Filtrate Flow Rate (mUsec)		125.0	0/7/0	C3C U	0.247	0.254	0.233		vs. Time at	(50		•		0.28 0	(u	vs. Time at			1 0:28 0
Slurry Temp C	24.6	24.9	C 76	25.3	25.3	24.9				Time of Collection	(Sec)	87 50 50	71.70 0	14.00 B	385	9 35.44	9 38.65		ermeability v	g and 9.0 tris , 2nd 30 minute		•		14 0	Time (hr:mir	armeability v g and 9.0 ft/s . 2nd 30 minute			0:14 0:2
Filtrate Flow Rate (mL/sec)	0.321	0.275	0.265	0.247	0.254	0.233				Filtrate Sample Volume	(mL)								nulant Pe	condition 3		•		0		20.0 psi 20.0 psi 20.0 dition 3			0:07
Time of Collection (Sec)	9 28	32.12	25.75	36.5	35.44	38.65		. 8	Day	Filter Inlet Pressue	(big)	000		200	20	20	20		C-106 Sin	0)	(18) 0.4 c	0.0.0 10.0 10.0 10.0	0.0 p/ш	00:0		C-106 Sin	2 0.006	(gpm/r	0:00
Filtrate Sample Volume (mL)						- Di	9.02		NOLISAVI TURI	Permeate	(Bisd)		2 0	5.0	, .		0				(1)IFY	dea	ແມອ	đ			Yillida	Perme	
Fitter Inlet Pressue (psia)	20	07	200	02	20	20	11/5 =	Athen Plant P		Filter Outlet Pressure	(psig)	MIN	NIN N	MM	MM	WW	MM				[0:36					0:36
Filter Outlet Pressure (psig)	MN	MN	MIN	MN	NMN	MN	5.52	0.264	0.003	Slurry Loop Flow Rate	(mdg)	10,0	0.0	40'0 40'0	5.52	5.55	5.52		Time	es)		•		0:28		Time es)			0:28
Slurry Loop Flow Rate (gpm)	5.51	0.0	40.0	222	5.55	5.52	=	L/sec =	m/ft2/psi =	Slurry	Temp C	0.67	2.4.2	25.2	26.3	26.3	24.9		Flux vs.	and 30 minut		•		0:21	(hr:min)	Flux vs. and 9.0 ft/s			0:21
otal Time (lapsed Min)	0:00	0.04	0.14	0.19	0.24	0-29	ry Flow gpr sure psid :	ate Flow m	neability gp	chiller	emp C	D1	2 1	191	17	16	15		Simulant	dition 3, 2r		•		0:14	Time	Simulant 20.0 psig			0:14
Time E	12:41	12.45	12.50	13:00	13:05	13:10	Average Sturi Average Pres	Average Filtra	Average Per	0	Time T	14/21	12.40	12-55	13.00	13:05	13:10		C-106	(Con				0:07		C-106 S at (Conc			0:00 0:07
Condition	3b	30	100	3 8	3b	3b	99	181	2.6	Test	Number	00	0 10	90	8	30	30				X 26.0 T	0. 5 5 1 4 0 1 4	m/sri m/sr 0 0	0:00			Flux (day) 0.10	Filtrate m3/m2 0.00	0:0

0:36

0:28

0:14 0:21 Time (hr:min)

0:01

0:00

0:14 0:21 Time (hr:min)

 T_i^i

Permeabili ty montrol	0.0619 0.001768	0.0341 0.000988	0.0339 0.000969	0.0328 0.000938	0.0318 0.000907	0.0313 0.000895	0.0297 0.000849																							
Permeability (m/day/bar) Filt	1 505	0.842	0.825	0.798	0.772	0.762	0.722																			Inter	28			
Filtrate Flux	3.632	2.002	1.991	1.927	1,863	1.839	1.743						Rate (mL/sec)	0.276	0.154	0.154	0.145	0.146	0.144	0.136	vs. Time at	(88)			•		0.21 0.	vs. Time at es)		
Slurry Termo C	27.7	28.3	28.5	27.3	29	28.8	28.8						Collection	37 BR	58.28	58.28	62.25	61.44	62.57	66	meability	and 6.0 ft/s 1st 30 minute			•		0:14 me (hr:min)	rmeability and 6.0 ft/s , 1st 30 minut		
Filtrate Flow Rate (mL/sec)	0.276	0.154	0.154	0.145	0.146	0.144	0.136					Filtrate	Volume	(1111)	6	0	8	6	8	6	ulant Per	34.9 psig			•	10100	0:07 Tii	nulant Pe 35.0 psig		
Time of Collection	32.66	58.28	58.28	62.25	61.44	62.57	99			3	De	Fritado Latera	Pressue	SE /Ried)	34.5	35	35	35	35	35	C-106 Sim	9)	0.0	5	0. 4	00	0:00	C-106 Sir	002	
Fittrate Sample Volume	0	0	Ø	đ	0	đ	6	5.98		and Damage	NOLIEN ILIED.		Pressure	0 (Ried)	0	0	0	0	0	0			1	(hed)	kep/ sou	u) bei			o o lity	1
Filter Inlet Pressue	98	34.5	35	35	35	35	35	fl/s =		Web Class D	VNICH FILIST F	Filter	Pressure	WN	MN	MN	MM	MM	MN	MM			-				0:28			
Filter Outlet Pressure (resia)	MN	MM	MN	MM	MM	MM	MM	3.66	34,93	0.165	0.001	Slumy	Rate (mm)	3.63	3.68	3,68	3,63	3.62	3,69	3.67	Time	om es)					0:21	Time		
Sturry Loop Flow Rate (nom)	3.63	3.68	3.68	3.63	3.62	3.69	3.67	= L		L/sec =	mmz/psi =		Slumy	2.22	28.3	28.5	27.3	29	28,8	28.8	Flux vs.	d 6.0 ft/s gt st 30 minut	Control States of the states o			10	0.14 b (hr:min)	Flux vs. d 6.0 ft/s gp ion 4)		
Total Time Elapsed Mint	0:00	0:02	0:10	0:15	0.20	0.25	0:30	rrv Flow apr	ssure psid =	rate Flow mi	meability gp		Chiller	15	15	16	11	16	16	16	Simulant	4.9 psig an idition 4. 1			•	6	07 Time	Simulant 4.9 psig and (Conditi		
Time	13.30	13.35	13.40	13:45	13.50	13:55	14:00	Average Slur	Average Pre-	Average Filtr	Average Fen			13-30	13:35	13:40	13:45	13.50	13:55	14:00	C-106	at 3.	ALC: N		•		0	C-106 2 at 34		
Condition	4a	0	43	4a	4a	43	4a	4a	43	49	43		Test	48	4a	4a	4a	4a	4a	4a			4.0	(10 (10 (10 (10 (10 (10))	ate F	Filtra (m3/i 5	000			11

0:28

0:07 Time (hr:min) 0:21

0:00

0:28

0:14 0:21 Time (hr:min)

0:07

00:0

Permeabili ty (gpm/ft2/p	C ON A ADO	0.0014000	0.001100.0	0.00100	D ANAGRE	0.000939																													
Fitrate Flux	1201010	10000	0.000	0.0363	N D346	0.0329																													
Permeability (m/day/bar)	101	12 C P C C	0.002	0 850	0.847	0.799																		ſ			.36		1						0
Filtrate Flux (m3/m2/dav)	Loo L	200.2	01212	2072	2 031	1.929						e										/s. lime at	(2)		•		0:28 0			s. Time at	(5)				28 0.4
Slurry Termn C	a we		24.6	24.5	24.6	24.7						- ALAN A	Flow Rate	(mL/sec)	0.200	0.158	0.152	0.144	0.141	0.135	1.114	and 6.0 ft/s	Zhđ 30 minute				14 0.21	me (hr:min)		meability v	and 6.0 ft/s ind 30 minutes				14 0.
Filtrate Flow Rate (mL/sec)	vuc u	0.450	0.150	0 144	0 141	0.135							Time of	(Sec)	45	57.06	59.34	62.59	63.69	66.85		34.8 psig	ondition 4,		•		0.07 0	F		ulant Per	34.8 psig a				0.
Time of Collection	AF	80 13	20.00	62.63	63.60	66.85				ed		Filtrate	Sample	(mL)	6	đ	G	0	a	6		TIC 001-0	2	.5	•	5.0	00:00			-106 Sim	(0	0.002	0.001	0.001	00:0
Volume (mL)	o /min	h d	b. 0		1.0	6		00.9		oint Remov			Filter Inlet	(Dsid)	35	35	35	35	35	36				9L) (JE	q/fi	ep/u	, n) 94			0		(is ()	ilide q\27	thm/f	5) d
Filter Inlet Pressue (risio)	18 Roods	200	2 4	35	35	35		= 8/11		With First P		Filter	Outlet	(DSig)	MN	MN	NM	MM	MM	WN					1		0:36						Т		0:36
Pressure (osia)	WWW IReads	NIN	NIM	NIM	NIN	MM		35.00	0.155	0.036	0.001	Slurry	Loop Flow	(mon)	3.69	3.67	3.63	3.64	3.69	3.67	ł	lime	(sa)		•		0:28			Time	es)		•		0:28
Loop Flow Rate (com)	1 COL	19.0	2.9.5	3.64	3.69	3.67		= E =	1 lear =	m/ft2 =	pm/ft2/psi =		Churrent	Temp C	24.5	24.5	24.6	24.5	24.6	24.7	ī	and 6.0 ft/s	nd 30 minu				0:21	e (hr:min)		Flux vs.	and 6.0 ft/s nd 30 minut				14 0:21 me (hr:min)
Total Time Elapsed (Min)	00-00	1000	010	0.15	0.25	0:30	ĩ	urry How gp	trate Flow m	trate Flux op	ermeability g		Challen	Temp.C	16	16	16	16	16	17		at 34.8 psig	indition 4, 2		•		7 0:14	Tim		Simulant	at 34.8 psig ndition 4, 21				0.07 D.
Time	14.45	10.11	14-25	14-30	14.40	14.45		Average SI	Average Fil	Average Fill	Average Pe			Time	14:15	14:20	14:25	14:30	14:40	14:45	007.0	C-10	(C0		•		0 0:03			C-106	(Col	1 9	4	0	0:00
Condition	Ab.		14	40	44	4b	3	40	44	4	4b		Taul	Number	4b	4b	4b	4b	4b	4b			0.7	(AE)	te F	6, 0 1/2/0	н (F					xn) (2	17 ett 17/m 0.0	(3b) (3b)	

Permeabili ty (gpm/ft2/p si)	0.002924	0.001836	0.001791	0.001817	0.001611	0.001655								
Filtrate Flux (gpm/ft2)	0.0585	0.0367	0.0358	0.0364	0.0322	0.0331								
Permeability (m/day/bar)	2.490	1.563	1.525	1.547	1.372	1.409								
Filtrate Flux m3/m2/day)	3.433	2.156	2.103	2.134	1.892	1.943			0.253	0.146	0.141	0.142	0.127	0.130
Slurry Temp C	26.6	23.6	23.2	23.1	23.3	23.3		Filtrate Flow Rate (mL/sec)	35.62	61.72	64	63.25	70.94	69.06
Filtrate Flow Rate (mL/sec)	0.253	0.146	0.141	0.142	0.127	0.130		Time of Collection (Sec)	6	0	8	đ	8	6
Time of Collection (Sec)	35.62	61.72	64	63.25	70.94	69.06	R	Filtrate Sample Volume (mL)	20	20	20	20	20	20
Filtrate Sample Volume (mL)	G	6	σι	0	o	a	5.94 aint Remove	Filter Inlet Pressue (psig)	0	0	0	0	0	0
Filter Inlet Pressue (psig)	20	20	20	20	20	20	ft/s = With First P	Filter Outlet Pressure (psig)	MM	MM	MM	MM	MM	MN
Filter Outlet Pressure (psig)	MM	MM	MM	MM	MM	MN	3.63 20.00 0.156 0.035 0.035	Slurry Loop Flow Rate (gpm)	3.5	3.64	3.67	3.67	3.63	3.64
Slurry Loop Flow Rate (gpm)	3.5	3.84	3.67	3.67	3.63	3.64	m = L/sec = m/ft2 = m/ft2/psi =	Slurry Temp C	26.6	23.6	23.2	23.1	23.3	23.3
Total Time Elapsed (Min)	00:00	0:10	0:15	0:20	0.25	0:30	urry Flow gpi essure psid : trate Flow mi trate Flux gp meability gp	Chiller Temp C	16	14	4	15	15	16
Time	18:40	18.50	18:55	19.00	19:05	19.10	Average Sil Average Pri Average Filt Average Pel	Time	18:40	18:50	18:55	19:00	19:05	19:10
Condition Number	5a	5a	5a	5a	5a	5a	ភ្លេស ភ្លេស ភ្លេស ភ្លេស ភ្លេស ភ្លេស	Test Number	5a	5a	5a	5a	5a	5a



Permeabili ty (gpm/ft2/p si)	0.002908	0.001716	0.001690	0.001703	0.001580	0.001564			R :										
Filtrate Flux (gpm/ft2)	0.0582	0.0343	0.0338	0.0341	0.0316	0.0313													
Permeability (m/day/bar)	2.476	1.461	1.439	1.450	1.346	1.332												P-1	
Filtrate Flux (m3/m2/day)	3.414	2.015	1.984	2.000	1.855	1.836				0.183	0.136	0.134	0.135	0.127	0.127		i at 34.8 psig is)	e	•
Slurry Temp C	23.3	23.5	23.5	23.6	24	24.3			Filtrate Flow Rate (mL/sec)	49.31	66.22	67.25	66.53	70.9	71.04		5.0 ft/s ond 30 minute		•
Filbate Flow Rate (mL/sec)	0.229	0,136	0.134	0.135	0.127	0.127			Time of Collection (Sec)	6	đ	0	6	6	σı.		ant Permea and (condition 4, 2		•
Time of Collection (Sec)	39.31	66.22	67.25	66.53	70.9	71,04		pa	Filtrate Sample Volume (mL)	20	20	20	20	20	20	0.000.00	(C	0	0.0
Fittrate Sample Volume (mL)	6	8	6	6	đ	6	5.98	oint Remov	Filter Inlet Pressue (psig)	0	0	0	0	0	D			y/bar) (Noar)	eb\m)
Filter Inlet Pressue (psig)	20	20	20	20	20	20	this =	With First P	Filter Outlet Pressure (psig)	MM	MM	MN	MM	MN	WN				
Filter Outlet Pressure (psig)	NM	MM	MMN	MM	MM	MM	3.66 20.00 0.148	0.033	Slurry Loop Flow Rate (gpm)	3,68	3.63	3.67	3,64	3.7	3,65		me es)		
Slurry Loop Flow Rate (gpm)	3.68	3,63	3.67	3.64	3.7	3.65	m = = L/sec =	m/ft2 = pm/ft2/psi =	Slurry Temp C	23.3	23.5	23.5	23.6	24	24.3	1	and 6.0 ft/s and 30 minute	•	
Total Time Elapsed (Min)	0:00	0:10	0.15	0.20	0.25	0:30	urry Flow gpi essure psid : trate Flow m	trate Flux gp rmeability gi	Chiller Temp C	15	15	16	15	16	16		at 34.8 psig andition 4, 2		
Time	19:25	19:35	19:40	19:45	19:50	19:55	Average Slu Average Pri Average Fitt	Average Fil Average Pe	Time	19:25	19:35	19:40	19:45	19:50	19:55		2 0	6	
Condition	55	5b	5b	5b	55	5b	6 6 9	5b 5b	Test Number	50	50	50	50	50	29			X) 48 2) 48 2) 48 2) 49 2) 49	tertiif شکریت را جار



Permeabili ty (gpm/ft2/p si) 0.002999 0.001868 0.001713 0.001713 0.001715 0.001715 0.0011606			
Filtrate Flux (gpm/th2) 0.0825 0.0505 0.0505 0.0443 0.0443 0.0445 0.0389 0.0387			
Permeability (m/day/bar) 2.554 1.591 1.352 1.290 1.290 1.233	<i>k</i> .	538	8
Filtrate Flux (m3/m2/day) 4.842 2.961 2.261 2.261 2.263 2.563 2.253 2.339 2.233	Filtrate Flow Rate (mL/sec) 0.194 0.174 0.174 0.160 0.160 0.155	s at 34.8 psig ss) • •	s) (21 0.21 0.2
Slurry Temp C 22 4 22 4 23 5 23 5 23 9 23 9 23 9 23 9 23 9	Time of Time of Collection 1 (Sec) 28.6 48.5 48.4 5.12 66.41 65.12 66.41 65.12 66.41 1 65.12 65.41 1 65.12 65.11 1 65.12 65.11 1 65.	6.0 ft/s 6.0 ft/s 2nd 30 minute 0.14 0.14 Ime (hr.min)	5.0 ft/s 5.0 ft/s 2nd 30 minutes 0.14
Filtrate Flow Rate (mL/sec) 0.194 0.194 0.174 0.169 0.169 0.169 0.155	Fittrate Sample (mL)	ant Perme and ondition 4, 0:07	Int Permeal and 6 and 4, 2 0.07
Time of Collection (Sec) 28.6 48.5 49.84 51.65 53.12 55.41 57.94	ed Fitter Inlet Pressue (psig) 20 20 20 20 20 20 20 20 20 20 20	C-106 Simul	-106 Simula 0.004 (Cc 0.003 0.002 0.002 0.001 0.000
Filtrate Sample Volume 9 9 9 9 9 9 9 9	7.44 oint Removi Permeate (psig) 0 0 0 0 0 0 0 0 0	Permesbility (m/day/bar) © N ← O	Permeability Permeability
Filter Inlet Pressue (psig) 27,5 27,5 27,5 28,5 28,5 27,5 27,5 27,5 27,5 27,5 27,5 27,5 27	tt/s = With First P Filter Custet Pressure NM NM NM NM NM	0.28	0:28
Pressure Outlet Pressure (psig) NM NM NM NM NM NM NM NM NM	4.55 27.43 27.43 0.192 0.044 0.002 Slury Loop Flow 4.54 4.55 4.55 4.55 4.55	me 35) • 0:21	ne s) 0.21
Slurry Loop Flow Rate (gpm) 4.55 4.55 4.55 4.55 4.55	m = Lisec = m/ft2 = m/ft2 si = 22.4 23.5 23.5 23.5 23.5 23.5 23.5 23.5 23.5	t Flux vs. Tr and 6.0 fbs of 30 minut e 0.14 0.14	Flux vs. Til and 6.0 ft/s of 30 minute 0:14 0:14 me (hr:min)
Total Time Elapsed (Min) 0:00 0:15 0:15 0:21 0:22 0:22	rry Flow gp ssure psid rate Flow m rate Flux gp meablity gr 17 17 17 18 18	o6 Simulant at 34.8 psig ndition 4, 2 • 07 Time	06 Simulant tt 34.8 psig ndition 4, 2r e 0.07
Time 23.25 23.30 23.40 23.46 23.46 23.50 23.55	Average Slu Average Fit Average Fit Average Fit Average Pel 23:35 23:40	• (Co	0:00 CC CC CC
Condition 7a 7a 7a 7a 7a 7a 7a 7a	7a 7a 7a 7a 7a 7a 7a 7a 7a 7a 7a 7a 7a 7	Filthate Flux	xul7 atetil7 (Sff/mqg) 5.00.000 5.00.000 5.00000

0.14 Time (hr.min)

Permeabil ty lux (gpm/ft2/p si)	21 0.004604	81 0.002903	49 0.002138	37 0.002184	07 0.002032	32 0.001658	19 0.001595										
Filtrate F (gpm/ft2)	0.092	0.058	0.047	0.043	0.040	0.033	0.03										
Permeability (m/day/bar)	3.920	2.472	1.820	1.859	1.730	1.412	1.358										
-litrate Flux m3/m2/day)	5.405	3.408	2.635	2.564	2.386	1.947	1.872				0.404	0.243	0.181	0.172	0.159	0.131	0.127
Slurry Temp C	27.2	25.4	24.1	23.3	23.1	23.5	23.7			Filtrate Flow Rate (mL/sec)	22.25	37.1	49.78	52.34	56.55	68.53	70.87
Filtrate Flow Rate (mL/sec)	0.404	0.243	0.181	0.172	0.159	0.131	0.127		8	Time of Collection (Sec)	6	0	0	6	8	6	G
Time of Collection (Sec)	22.25	37.1	49.78	52.34	56.56	68.53	70,87	g		Filtrate Sample Volume (mL)	20	20	21	20	20	20	20
Filtrate Sample Volume (mL)	0	6	CT	8	6	6	6	6.00 oint Remove		Filter Inlet Pressue (psig)	0	0	0	0	0	0	0
Filter Inlet Pressue (psig)	20	20	21	20	20	20	20	ft/s = With First P		Filter Outlet Pressure (psig)	MM	MM	MM	MM	MM	NM	MN
Filter Outlet Pressure (psig)	IMN	MM	MN	MM	MMN	MM	MN	3.68 20.14 0.202 0.042	100.0	Slurry Loop Flow Rate (gpm)	3.67	3.74	3.7	3.63	3.66	3,69	3.69
Slurry Loop Flow Rate (gpm)	3.67	3.74	3.7	3.63	3.66	3.69	3.69	m = = hL/sec = sm/ft2 = sm/ft2/nei =	- iod or i sud	Slumy Temp C	27.2	25.4	24.1	23.3	23.1	23.5	23.7
Total Time Elapsed (Min)	0:00	0:04	0:08	0:14	0.19	0.24	0:29	urry Flow gp essure psid trate Flow m trate Flow gp	R function R	Chiller Temp C	18	14	15	16	17	18	19
Time	14:11	14:15	14:20	14:25	14:30	14:35	14:40	Average SI Average Fit Average Fit Average Fit	- african	Time	14.11	14:15	14.20	14:25	14:30	14:35	14:40
Condition	10	7b	42	7b	2p	7b	75	66666	2	Test Number	7b						



Permeabili ty (gpm/ft2/p si) 0.002596	0.001/25 0.001742 0.001661 0.001561 0.001534																												
Filtrate Flux (gpm/tt2) 0.0520	0.0349 0.0332 0.0332	2																											
Permeability (m/day/bar) 2.210 1.903	1,409 1,414 1,329 1,326			0.28	8																								
(m3/m2/day) 3.048 2.625	2.12/ 2.045 1.950 1.832 1.801	Filtrate Flow Rate (mL/sec)	0.209 0.160 0.169 0.145 0.146 0.146 0.141 0.141 0.141	es)	at 34.8 psig																								
Slurry Temp C 24	24.4 24.6 25.1 25.1	Time of Collection	43 16 56 22 56 56 61 15 61 16 63 81 63 81	20105 2nd 30 minute 0.14 ime (hr.min)	bility vs. Time 5.0 fbs ind 30 minute e 0:14 Time (hr.min)																								
Filtrate Flow Rate (mL/sec) 0.209 0.180	0.147 0.142 0.136 0.129 0.127	Filtrate Sample Volume	ant Permea	0.07	nt Permeal and 6 and 6																								
Time of Collection (Sec) 50.12 50.12	01.10 63.6 66.34 69.6 70.81	d Filter Inlet Pressue	20 20 20 20 20 20 20 20 20 20 20 20 20 2		106 Simula (Cc 0003 0002 0002 0001 0001 0000 0:00																								
Filtrate Sample Volume (mL) 9		6.00 bint Remove Permeate Pressure	000000	Permeability (m/day/bar) Permeability	Permeabulity (isplation)																								
Filter Inlet Pressue (psig) 20	52 52 52	Nth First Po Mith First Po Dutlet Pressure	WN WN WN WN	0.28	0.28																								
Filter Outlet Pressure NM NM	WN WN	3.69 20.14 0.153 0.035 0.002 Slurry Loop Flow	3.72 3.68 3.68 3.66 3.69 3.67 3.77 3.77 3.77 3.77	s) • 0.21	ne 6.0																								
Slumy Loop Flow Rate (gpm) 3.72 3.68	3.68 3.69 3.67 3.77	n = L'sec = m/ft2/psi = Slurry	24.4 24.4 24.6 24.6 24.6 24.6 25.1 25.1 25.1 25.1	of 30 minute 0.14 (hr.min)	Flux vs. Tir and 6.0 ft/s an 0.0 ft/s an 0.0 ft/s an 0.14 be (hr.min)																								
Total Time Elapsed (Min) 0:04 0:04	0.14 0.19 0.24 0.28	rrry Flow gpi sssure psid : rate Flow m rate Flow gp meablifty gr Tomiler	20 21 20 20 20 21 21 21 21 21 21	at 04:0 psg ndtton 4, 2 07 Time	06 Simulant at 34.8 psig ndition 4, 2n e																								
Time 14:11 14:15	14:35 14:35 14:35	Average Slu Average Filt Average Filt Average Per	14.11 14.25 14.25 14.25 14.35 14.35 14.35 14.40	•	C-11																								
Condition Number 8a 8a	68 88 88 88	8a 8a 8a 8a 8a 8a 8a	80 80 80 80 80 80 80 80 80 80 80 80 80 8	xula eistina (∰3/m2(day) ≜ 0	xulf etertiif (Sthimgg) 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0																								
Permeabilit y 0,0pm/ft2/ps	0.002626	5 0.001924	7 0.001558	2 0.001511	7 0.001382																								
---	----------	------------	------------	------------	------------	--------	---	--------------	--------------	---------------------------	----------	---------------------	------------	-------	-------	-------	-------	----------	-------	---	-------------------	-----------------	---------------	---------------	--------------	---	------------	---------------------------------	----------------------
Filtrate Flu (apm/#21)	0.0521	0.038	0.032	0.0301	0,027	A NA A																							
Permeability (m/day/bar)	2 236	1.638	1.327	1.287	1.176							100								_	-			36		1			
Filtrate Flux m3/m2/dav)	3.084	2.259	1.921	1.774	1.622	2						Filtrate Flow Rate	(Include)	0.462	0,345	0.317	0.290	0.204	0.253	/s. Time at ^{ss)}			•	0:28 0:		s. Time at			
Slurry Temp C	27.2	25.4	24.1	23.3	23.5							Time of Collection	(Sec)	19.5	26.1	28.37	31.03	35.63	35,63	rmeability v and 6.0 ft/s 2nd 30 minute				14 0.21	ime (hr:min)	meability v and 6.0 ft/s ind 30 minutes		•	
Filtrate Flow Rate (mL/sec)	0.231	0.161	0.132	0.119	0.109	-					Citeria	Sample	(mL)	6	a	6	09 C	21 10	n di	ulant Per 34.8 psig				0.07 0.	F	Jant Peri 34.8 psig a		÷	
Time of Collection (Sec)	39	55.97	68.29	75.63	82.25					p		Filter Inlet	(pisig)	20	20	23	20	02	39	-106 Sim	0	• • •	0.0	00:00		-106 Simu	0.003	0.002	0000
Filtrate Sample Volume (mL)	6	ch.	a	đ	a a	E.		6.10		aint Remove		Permeate	(pisig)	0	0	0	0 0	0 0		0	ص بنه الإلم	∧ A\p spj	eb/m	5 1) 8d		Ŭ	(is Ity	ideem 1/271/mo	iß ə _c
Filter Inlet Pressue (psia)	20	20	21	20	202	i.		11/8 =		With First Pi	Citize .	Outlet	(pisig)	MM	MN	WN	MN	MN	WN		Π	T		0:36			Γ		
Filter Outlet Pressure (rosia)	WN	MM	MM	WN	MM			3.70	0.142	0.031		Shurry Loon Flow	Rate (gpm)	3.67	3.74	3.7	3.63	3.60	3.69	Time es)				0:28		Time es)		•	
Slurry Loop Flow Rate (com)	3.68	3.69	3.74	3.7	3.69			" E "	L/sec =	m/ft2 = pm/ft2/psi =	2	Shurry	Temp C	27.2	25.4	24.1	23.3	7.62	23.7	t Flux vs. and 6.0 ft/s nd 30 minut				0:21	e (hr:min)	Flux vs. and 6.0 ft/s of 30 minut			
Total Time Etapsed (Min)	0:00	0:04	0:00	0.14	0.24		1	arry Flow gp	trate Flow m	trate Flux gp		Childer	Temp C	18	14	15	91	18	6	Simulant at 34.8 psig ndition 4, 2		•		7 0:14	Tim	Simulant at 34.8 psig ndition 4, 21		•	
Time	14.11	14:15	14:20	14:25	14:35			Average Sil	Average Filt	Average Fil Average Pe	0		Time	14:11	14:15	14:20	14:25	14.30	14:40	C-106 (Co		•		0:0 00		C-106	• •		
Condition	86	8b	8b	8b	00	3		89 89	8b	88 88		Test	Number	8b	dB	8b	OD IS	OB 48	8 8		N N N	191 191	11111 1121	н (F			(z xn)	l etertii fi\mqg) 9 9 9 9	IL U.

0:14 0:28 Time (hr:min)

.

0.1 micron Liquid- Service Mott Filter

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

Permeability (gpm/ft2/psi)	0.012093	0.004560	In Infranties	0.002077	T POPOLICE I	0.0002000	CBECOULD	0.000and	0.00000F	0 000840	0.002698																											
Filtrate Flux (gpm/ft2)	0.583002	0.245400	0 170965	0 163030	120225	0.130/300	0.140401	0.100600	0.165027	0.142652	0.135659																											
Permeability (m/day/bar)	10.296	077.6	0.000	2.619	2 16.4	0 183	900 0	EPC E	2 837	2 4296	2.297																											
ritrate Fiux m3/m2/day)	34,785	14,0/0	000	0.030	10 + 4 K	7637	6.900	11 181	147	B. 362	7.958																										17	
Stury Temp C	24.1	1.47	7.90	24.9	0.40	0.70	1000	210	1 02	222	22.7					Fata Flow Rate (mL/sec)	7,160	3,000	2.392	2.092	1001	1001	1.431		2,161	1.778	1,630	4/01	ability on	fils				•••	0-57 1-12		100 mm	ability vs.
Fibrate Filow Rate (mL/sec)	7.160	000.0	2 002	1.901	1 708	1 554	1431	2 161	1778	1830	1,574				1	Collection (Sec)	4.19	01	12.54	14.34	10.12	10 11	20.97		13.88	16.87	10.4	18,00	of Domo	usig and 9.4	tion 1)			•	DE 0.43	ne (hr:min	1	It Permea
Time of Collection (Sec)	4 19	12.64	14.34	15.78	17 140	19.31	20.87	13 88	16.87	18.4	10.06				Filtrate	Volume (mil.)	8	30	8	99	89	8.9	88		90	90	8	R	clumb 00	me at 50.0 p	(Condi			••••	0.14 0.2	ET.		2 Simular
Filtrate Sample Volume (mL)	89	8.9	3 9	8	08	98	30	F	30	98	30				China Indea	Pressue ptsig)	51	52	2	21	25	12	1 21		52	13	8 8	2	101101	TIT		0	+ 0	•	000			DL/LOL-Z
Pressure Drop (psig)	4 1	1	4	1		2		1	10	- 40	4	9.4			Tanna and a	Pressure psig)	Ē															(Jan 19)		ep/u) 비 년			4
Ther Inlet	50	¥ 2	1 21	3	65	12	12	3	173	52.5	52.5	= 5,Q			the second	Pressure F	47	48	48	48	8	48	48		48	14 A	4	ŧ.							1.12			
Outlet Pressure (psig)	14	100	4	40	48	48	48	48	48	47.5	48	3.23		0.198 0.004	Slurry F	Rate F	3.23	3.22	32	3.27	222	50.6	3.28		3.22	3.17	27.5	07-0	e Timo					•	0:57			. 11110
Sluny Loop Flow (gpm)	3.23	2.0	327	3.23	3 23	3.25	3.28	322	3.17	3.23	3.26			sec = M2 = vM2/psi =		Sturry Temp C	24.1	24.1	24.8	24.7	8.67	140	23.9		21.9	22.1	N N N	ž	of Elay o	d 9.4 ft/s	on 1)		•		0:43	hrmin)		N. FJUX VI
otal Time lapsed An)	000	500	0.14	0.19	0.24	0.29	0.34	0.44	0.49	0.54	0.59	y Flow gpm	- nod anno	te Flux gpm reability gpm		viller amp C	15	12	4	1	2:	i p	12		=		2	2	2 Simula	t 50 psig ar	Conditi			:	0.28	Time	· chandra	ternine 2
ami ami	3.36		3.50	3:55	4.00	4.05	4-10	4.20	4.25	4:30	4:35	verage Stur	waite a figura	werage Filtra werage Filtra werage Pern		0 F	3:36	3:40	3.45	3.50	100-1	4.05	4.10	4.15	4.20	4 20	4.90	00%	A7-404/140						0.14		OFFICE CA	10 11 11 - 7W
Condition Number			+	÷	+	+		-		-		1.1			12	Test Number T	*	-	-		• •		-	-			.,	65		0.04	e out	end of	e contracter a		0.00			



Permeability (gpm/ft2/psi)	0.0035	0.0028	0.00256	0.0024	0.0022(0.00200	0.00196	0.00174	0.00175	0.00173	0.00167	0.00155																				
Filtrate Flux (gpm/ft2)	0.106342	0.065584	0.077969	0.072565	0.086225	0.060191	0.058287	0.052718	0.052590	0.051969	0.050416	0.048111																				
Permeability (m/day/bar)	3.016	2.427	2.211	2.058	1.878	1.707	1 695	1.483	1.491	1.474	1.430	1.320																				
Fittrate Flux (m3/m2/day)	6.236	5.020	4.574	4.257	3.885	3.531	3.419	3.092	3.085	3.049	2.957	2.822						1														
Sturry Temp C	23.2	22.3	21.8	22.1	23.1	24.1	24.6	24,6	24	22.9	23.2	22.8							100 m 000	Filtrate Flow Rate (mU/sec)	2.687	1.500	1.348	1 248	1,205	1.255	1.155	1.161	1.110	1.092	1.100	1.102
Filtrate Flow Ratin (mU/sec)	1.252	0.982	0.882	0.828	0.777	0.727	0.714	0.648	0.633	0.606	0.593	0.560							Taxat	Collection	11.25	20	22.25	24.03	23.72	23.91	26.06	25.84	27.03	27.47	27.28	27.72
Time of Collection (Sec)	23.97	30.56	34.03	記留	38.6	41.28	42.03	46.47	47,38	49.47	50.56	53.59							Fatrato	Volume	R	8	8	8	8	8	8	R	90	30	8	R
Volume (mL)	30	30	30	B	99	8	8	8	8	8	8	8							Citiza Indas	Pressue Pressue	CH.	32	32	8	M	32	31	32.6	R	32	32	100
Pressure Drop (psig)	4	*	4	4	4	4	51 10	4.5	4	4	4	4	7.6						Damana	Pressure Pressure (nein)	(Rised)											
Filter Intet Pressue (psig)	3	22	32	22	R	32	17 17	32.5	32	22	32	3	M/8 ==						Filter	Pressure	26	28	38	28	28	38	27.5	26	28	E	28	53
Pressure (psig)	28	82	28	28	BN	28	27.5	28	28	82	23	8	2.60	30.04	0.787	0.065	0.002		Shrry	Rate Rate	272	2.55	2.58	2.51	2.62	264	2.6	2.64	2.62	2.47	2.59	2.6
Slumy Loop Flow Rate (gpm)	2.72	2.55	2.58	2.51	2.82	2.64	2.6	264	2.82	2.47	2.59	2.6	= 5		Lisec =	m/12 =	sm/fh2/psi =			Slurry Temp C	22.3	21.9	11.12	21.9	22.5	22.7	23.1	23.2	23.3	23.4	23.5	522
Total Time Elapsed (Min)	0000	0.04	60.0	0.14	0,19	0.24	0:29	100	0:30	0,49	\$30	0.50	rry Flow gpr	ssure psid -	ate Flow m	ate Flux gp	meability gp	0		Chiller Temp C	\$	13	4	14	18	18	10	24	17	17	17	18
Time	9.25	9.25	9:30	9:35	9:40	B.45	9.50	9-55	10.00	10:10	10-15	10.20	Average Stu	Average Pre	Average Fith	Average Fith	Average Per			Time	921	8:25	8:30	8:35	9:40	8:45	9:50	9-55	10:00	10.10	10:15	10.20
Condision	ev.	CV.	τ¥.	¢4	64	r.i	RÌ.	e¥.	14	N	N	Ci l	P4	N	104	IN	04			Test Number	CV.	114	r.	D4	ev.	EN.	C)		Pe.	e¥.	ri.	64

Ċ

0.003542 0.002851 0.002851 0.002597 0.002205 0.002205 0.001752 0.001752 0.001751 0.001751 0.001751 0.001751



Pormeability (gpm/ft2/ps()	0.005346	0.002066	0.001740	0.001625	0.001475	0.001451	0.001452	0.001380	0.001345	0.001304	0.001288	0.001262	0.001211																			
Fitrate Flux (ppm/ft2)	0.374501	0.146106	0.121454	0.113446	0.102944	0.101631	0.101686	0.096291	0.094557	0.091359	0.069616	0.088430	0.084847																			
Permeshility (m/day/bar)	4.552	1.776	1.481	1.384	1.256	1.235	1.230	1.175	1.145	1.110	1,097	1.075	1,031																			
Filtrate Flux (m3/m2/day)	21.968	8.571	7.124	0.655	6009	5.962	5.965	5.648	5.547	6.359	5.257	5.187	4.977																			
Stury Temp C	24.5	24.3	242	242	24.3	24.3	24.5	24.7	24.9	25.1	25	24.9	24.9						Fitrate Flow Rale (mL/sec)	4 573	1.774	1.471	1.374	1.250	1.234	1.242	1,182	1.168	1,135	1.110	1.082	1.048
Filtrate Flow Rate (mL/soc)	4.573	1774	1,471	1.374	1.250	1234	1242	1.182	1.168	1,135	1.110	1.092	1.048						Time of Collection	0.56	16.91	20.4	21.84	24	24 31	24.18	25.37	25.69	20.44	27.03	27.47	28.63
Time of Collection (Sec)	6.56	16.91	20.4	21.84	24	24.31	24 16	25.37	25.69	13.44	27.03	27.47	28,63					Thrate	Sample Volume	8	8	8	8	90	30	30	8	30	30	30	30	30
Filtrate Sample Volume (mL)	8	8	30	8	8	30	30	30	30	30	30	30	3D						Fitter Inlet	22	12	71.5	71.5.	71.5	12	22	71.0	72	2	11	2	22
Pressure Drop (psig)	7	4	50.00	3.6	3.5	4	4	3.5	3.5	4	m	4	4	7.2					Permeate Pressure (main)	(Really)												
Filter Inlet Pressue (psig)	12	2	71.5	71.5	71.5	22	72	71.5	72	72	12	72	12	N/8 =				Filter	Oudet Pressure (nein)	68	68	68	68	68	88	68	88	68.5	68	80	68	88
Filter Oudlet Pressure (psig)	89	68	68	89	89	B	68	69	583	88	3	8	8	2.47	09.50	1.512	200.0		Sturry Loop Flow Rate (onm)	2.6	2.5	24	2.45	2.48	2.47	2.52	2.62	2.47	2.42	2.4	2.42	2.43
Slurry Loop Flow Rate (gpm)	2.6	2.5	2.4	2.45	2.48	2.47	2.52	2.52	2.47	2.42	24	2.42	2.43	=	in the second se	- 198C =	m/f/2/psi =		Slumy Tamo C	24.5	24.3	24.2	24.2	24.3	54.3	24.5	24.7	24.9	25.1	8	24.9	24.9
Total Time Elapsed (Mirt)	00:0	0.05	0.10	0.15	0.20	0.25	0:30	0.35	0.40	0:45	0:50	0:55	1:00	rry Flow gpn	anne bed	Tate Flow Int	meability op		Chiller Temp C	13	1	12	5	12	12	12	12	1	13	13	4	12
Tame	10.25	10:30	10.35	10:40	10:45	10,50	10:55	11:00	11:02	01111	11.15	11.20	11.25	Average Slu	and affermant	Average Fils	Average Per		Time	10:25	10:30	10:35	10:40	10:45	10:50	10.55	11:00	11:06	11:10	11.15	11.20	11.25
Condition	15	69	61	(7)	0	in.	0	71	es.	e.	m.	m	0	0 1	3 1	0.17	0 e9		Test	-	11	r1	m	n	n	m	m	n	n	m	m	n

r.



F 5 2 8																														
Fitrate Flux (gpm/ft2)	0.154608	0.117247	0.116563	0.105409	0.103706	0.101288	0 100129	0.095921	0.092692	0.090778	0.087825	0.088331																		
Permeability (m/day/bar)	4.459	3,325	3.305	2 989	2,893	2.849	2 840	2766	2.719	2.618	2.485	2.505				È,														
Filtrate Flux (m3/m2/day)	9.069	6.878	6.837	6.163	0.083	5.942	5.874	5.627	5.437	5.326	5 140	5.182																		
Stury Temp C	22.5	22	22.3	22.6	23	52	23.1	23.1	23.2	23.3	23.2	23.1					Fittrate Flow Rate (mUsec)		1.784	1 333	1,337	1.220	1.214	1,185	1,175	1 126	1.091	1.071	1.031	1.037
Filtrate Flow Rate (mU/sec)	1.784	1.333	1 337	1 220	1.214	1 186	1 175	1.126	1 091	1.071	1.031	1 037					Time of Collection	(Sec)	18.82	22.5	22.44	24.6	24.72	25.31	25.53	26.65	27.5	28	29.09	28.94
Time of Collection (Sec)	16.82	22.5	22.44	246	24.72	25.31	25.53	26.65	27.5	28	29.09	28.94				and have	Fatrate Sample Volume	(mL)	8	8	30	92	30	00	02	8	30	30	8	8
Filtrate Sample Volume (mL)	Œ	30	30	DE	30	8	8	8	8	8	8	8					Filler Inlet Pressue	(Desd)	5	33	Ħ	10	8	8	9	ē	5	5	8	M
Pressure Drop (psig)	5	4	4	4	40	3.5	4	17	4	11)	4	4	7.0	1			Parmaata Pressure	(Dead)												
Filter Injet Pressue (psig)	33	22	8	32	12	32	22	31	31	31	32	32	B/e =	1 1 1 1		and the second sec	Pressure	(Brad)	2	89	26	28	28	28.5	28	28	27	28	28	20
Filter Outlet Pressure (psig)	28	28	28	28	28	28.5	28	28	27	28	2H	28	2.60	10. T	29.85 1.217 0.105 0.003		Loop Flow Rate	(uudb)	2.60	2.2	2.83	2.57	2.8	2.75	2.68	2.9	2.76	2.44	2.75	25
Sturry Loop Flow Rate (gpm)	2.65	2.7	2 83	2.57	2.8	275	2.68	2.9	2.76	2.44	2.76	2.6			= L/sec = m/f2 = pm/f2/psi =		Sturry	Temp C	22	a	223	22.6	R	2	23.1	23.1	23.2	23.3	23.2	23.1
Total Time Elapsed (Min)	00/0	0:01	0:10	0.15	0.22	0:25	0:30	0:35	0.42	0:50	0.55	1:00	erv Flow on	Will many 1 King	etsure psid trate Flow m trate Flux gp rmeability ox		Chilter	Temp C		9	11	16	16	11	21	17	18	15	41	16
Time	11:35	11:42	11.45	11.50	11.57	12:00	12.05	12-10	12-17	12.25	12:30	12,35	Avarage Sh	and affering of	Average Pr Average Fil Average Fil Average Po		10.000	emit	11.35	11.42	11.45	11.50	11.57	12:00	12:05	12.10	12.17	12.25	12:30	12.35
Condition	4	*	4	4	4	4	4	4	4	4	4	4	9	F.S	* * * *		Test	Murriber	e -	•	4	4	*	4	4	4	4	4	4	4

Permeabili Permeabili N (gpmAt2)P so 0.005537 0.0003082 0.0003046 0.0003346 0.0003346 0.0003346 0.0003346 0.0003346 0.0003249 0.0002919 0.0002919 0.0002919 0.0002919 0.0002919 0.0002919 0.0002919



Filtrate Flux (com/ft2)	0.192418	0.134885	0.121216	0.113265	0.108856	0.108882	0.102859	0.101407	0.095324	0.094907	0.069897																																
Permeability (m/day/bar)	3.274	2.295	2,063	1.927	1,852	1.853	1.750	1.72/6	1.622	1.023	1,530																																
Rhrate Flux m3/m2/day)	11.287	7.912	7.111	6.644	6.300	0.387	6.034	0.949	5.592	1000	5.273																		1														
Shirry Temp C	24.8	24.8	24.2	24.5	25.1	24.9	1 42	24.7	191	2.07	3 12						Filtrate Flow Rate (mL/sec)	2.370	1.681	1.468	1 383	1.302	12021	1.245	1.184	1.182	1.168	1.116	ability vs.					C1-1 12-0 E	1	2	bility vs.				•		0:57 1:12
Filuste Flow Rate (mL/sec)	2.370	1.661	1.468	1.2403	1,352	1,245	1.203	1.245	1.164	1.162	1116						Time of Collection (Sec)	12.66	18.06	20.44	21.09	10.02	23.75	24.09	25.34	25.38	25.25	20.87	int Perme	and 8.6 fus	(gun 5)		•	0.28 0.4	Time (hr:mi		it Permea	00	100 D)	10.000 M			8 0:43
Time of Collection (Sec)	12.66	18.06	20.44	21.09	22 19	15.22	27.52	24.00	20.22		26.87					- Contraction	Volume Volume (mil.)	30	30	30	8 9	8.8	8.8	8	8	8	30	8	02 Simula	50.0 psig	Cond		:	0.14			2 Simular	TIT	(Condit				14 0.2
Fittrate Sample Volume (mL)	30	8	8	8	RI	8 8	DR DR	22	DR I	202	38						Filter Inlet Pressue (psia)	23	23	22	88	3 2	8 23	25	52	21	24	23	AZ-101/1			540 ×	0 co	(m)			AZ-101/10	5		•	N F	. 0	0:00
Pressure Drop (psig)	4	4	4	*	4	¢.,	10	¢.,	4 14	0.1	्यः	90					Permeale Pressure (rosid)														3	HEQ	vem.	19d				0.00	000 111	dear	men Brag	00.0	
Filter Infet Pressue (psig)	12	23	23	8	81	88	35	3 (88	2 5	121	= 54				Change of the second seco	Pressure Pressure (psici)	40	导	早	容 3	9 9	₽ \$	48	48	47.5	48	48			ſ	1	1	1.12				ľ	T		1	1.12	
Cutlet Prossure (psig)	\$	84	₽	4	8	4	₽ ₹	2 4	124	0.76	4 4	2.95	49.98	1.386	0.113		Slurry Loop Flow Rate (com)	3.08	2.91	2.88	3.07	204	2.65	2.67	2.94	2.9	2.93	3.03	/s. Time					0.57			s. Time					0.57	
Sturry Loop Flow Rate (gpm)	3.08	2.91	2.88	10E	2.08	44.7	287	107	65.7	2.0	3.03	=		L/sec =	mutt2 = mutt2/psi =	1010100	Slurry Tamo C	24.8	24.8	242	24.0	24.0	24.7	24.7	25.1	18.2	2	81	ant Flux v	tion 5)				0:43	e (hrmin)		int Flux v	and 8.6 fils ion 51			2000 - 2000 I	0.43	(hrmin)
Total Time Elapsed (Min)	0:00	90:02	0.10	0.15	070	47.0	1000	000	040	040	101	my Flow apr	= pisd aurest	rate Flow m	meability gp		Chiller Tamp C	18	13	13	<u>0</u>	0.2	1	む	10	18	5	ψ.	02 Simula	(Condit		• • •		4 0:28	Tim		02 Simula	t 50.0 psig i		•		0.28	Time
Time	12:45	12.50	12:55	13,00	13.03	AD DI	2 9 9	13.20	12.69	10.00	13:46	Average Stu	Avorage Pre	Average Fill	Average Filt Average Per		Time	12:45	12.50	12:55	13:00	13,00	13:15	13:20	13.25	13.30	13:35	13:46	AZ-101/1			•••••		0.14			AZ-101/10	4		:		0:14	
Constian	10	40	0	0	0.4	0.4	() U	6, N	n e	9.4	143	50	10	47	an an		Tast Number	41	4D	0	en se	ni w	9, 40	10	40	10	0	a:			x 215.0		m/En	E (C)				0.25	ND 30	eter Binneg	E 405	0.00	

0.003948 0.002696 0.0027594 0.0027594 0.002175 0.002175 0.002175 0.002179 0.001917 0.0011917 0.0011797

Permaabilit gpm/ft2/pri

Permeability apm/ff2/bail)		0.004226	0.003627	0.003446	0.003426	0.003332	CIRCEDO D	0.003323	0.003289	a ap3312	0.003259																														
Fitrate Flux	(gpm/ft2)	0.122650	0.108882	0.106897	0.102985	0.100022	0.100930	0.099766	0.098750	0.100271	0.097832																														
Permeability (midewiber)		HHOT Y	3.089	2.934	2,917	1007 0	2.862	2.829	2 801	2.820	2.174			15																											
Filtrate Flux	m3/m2/day)	0.484	6.387	6.271	100 0	5 774	5.921	5.852	5.793	5,882	80.0																_							í.							
F.	Slury Temp C	X 9	24.9	25.3	25.5	10	18	122	25	26.1	24.8					Filtrate Flow Rate	(paecruu)	1.519	1.309	1,335	1 292	1 242	1 250	1 236	1.223	1,205		ability vs. 1 ms				0-47 1-12	()		ability vs.	102		•			0:57 1:12
Filtrate Flow Rate	(Date of the other	1 385	1,345	1.335	1.282	1 249	1250	1.230	1.223	1.245	0071					Time of Collection	Sec)	19.75	12 22 22	22.47	23.22	24.15	22	24.28	24.55	24.9		at Perme sig and 13	10U (2)			0.40	e (hr.mir	Porter of	T Perme	() and 13.1		•		-	0:43
Time of Collection	(Sec)	28.22	22.31	22.47	23.22	24.00	24	24.28	24.53	24.09	5.67				trate	Sample	mL)	90	88	8	8	8.8	3 8	8	88	8		2 Simular e at 30 00 p	(Condi	-		C-0 14	1	cimina (C SIMUIAN	(Conditi		•			4 0.28 Time
Filtrate Sample Volume	(mil)	2.07	30	8	85	8.8	8	8	30	30	De					Filter Inlet	(Disd	SF 8	8 8	2	22	88	3.25	EE .	33.5	22		MIT		•		0 00:0		7 404140	ULTIUT-2						00:00
Pressure	Drop (psg)	0.0	Ð	(C) 1	0,6	2.40) a	Ð	0	0		1.21				Permeate	(bisd)												20.4	indan Isdiyi G	eb/m eb/m	- -			1	900.0	111	689) (689)	Perm (\$002	0.001	
Filter Inlet Pressue	(firsd	33	12	5	RR	3 8	8	8	8	33.5	8	= 571			Ther	Dutiet	(Bisd	81	NIN	28	27	27	12	12	12	27	Γ		1		T	1.12		1	5	ŕ	T		1		1:12
Filter Outlet Pressure	(Disd)	8 5	27	28	10	10	27	22	27	12		10.00	1,290	0.104		Shurry coop Flow	Rate (gpm)	4.54	4.47	4.55	4.48	4.45	4.48	4.52	4.52	4.48		s. Time	10.00			0.57		Time			•				0:57
Sturry Dop Flaw	(alle (gpm)	4.44	4.47	4 5 4	4.40	4 48	4.48	4.52	4.52	4.52	7		= 2987	uff2 = n/ff2/psi =		Surv 1	emp C	5	54.9	25.3	25.5	R R	18	131	G 19	24.8		nt Flux v nd 13.1 fus	in in			0.43	(nrmin)	t Flux vs.	od 13.1 ft/s	(g uc	•••••				0:43 (hr:min)
otal Time	(Jum	500	0.10	0.15	120	0.35	0.40	0:45	0:50	550	and and	TION SUIT	the Flow mil.	ate Flux gon		hiller S	emp C 1	23	2.2	16	\$P ;	4 12	1	4	2.2	ţ		2 Simula 30.0 psig ar	-			0.28	Time	02 Simular	30.0 psig an	(Condition	•				0.28 Time
	1100 + KK	200	2.05	2.40	20.02	2.30	2:35	2:40	2.45	2.50		warage Crus	Warage Filtra	Average Fibr		0	Time 1	155	2.05	2:30	2,16	2.30	2.35	2.40	2.50	2.55		AZ-101/10				0:14		AZ-101/1	H		•			-	0.14
Cardtion	Number	0.00	Φ	¢ 4	0.10	9	4D	φ	Ø	ic i	5 6		N 8	00		est	Number 1	00	o xo	0	0.	φ	0	10	0 10	8		0	- BO	Sidey Sidey		0:00			0.44	× 0.12 +	F133.10	ate 08	100 100 100 100 100 100 100 100 100 100	0.00	0:00

0.1 micron Liquid- Service Mott Filter

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

day/bar) Fitrate day/bar) Fiux (gpm/t2)	5.071 0.29802	1 908 0 11288	1.647 0.09581	1.447 0.08500	1 285 0.06144	MBP5/2 0 000-1	4 406 0 00600	1100 000 0000	1.0/3	1.011 0.059833	0.953 0.05598	0.903 0.903072																							
A (m	1																																		
Fitrate Flu (m3/m2/da	17.48	6.610	5.679	4.066	A 776	010 4	1000	000010	0.138	3.510	3.285	111 11																	F	_					
Stury Temp C	24.6	24.7	24.0	24.9	24.6	D. A.C.	3.46	1 1 1 1		24.5	24.6	24.6					Fittrate Flow Rate (mL/sec)	3.650	1.384	1,196	1.050	0.874	0.800	0.774	0.730	0.731	0.686	0.650		ability vs.			• • •	0.57 1.12	
Flow Rate (mL/sec)	3,650	1.384	1.196	1.050	0 997	0.874	0.800	A77.0	11.14	0.731	0.0865	0.650				1	Time of Collection (Sec)	8.22	21.68	52 08	10.02	AU.UC	37.09	22 28	41.07	41.00	43.75	46.16		nt Perme big and 7.8	1000		•••	8 0.43	te (hr:min)
Time of Collection (Sec)	822	21.68	25.09	28.57	30.09	112.012	27 00	20,100	20.00	41.00	43.75	46.16					Fibrate Sample Volume (mL)	98	8	8	De of	8.8	30	30	30	30	DE	30		2 Simula te at 50.1 p			•	14 0.2	Tim
Volume Volume (mL)	30	30	30	30	30	90		00	00	DR I	R	8			P	1	Filter Inlet Pressue (psig)	23	52.6	21 1	2.2	¥ 24	13	52.5	23	52	52	8		AZ-101/10 Tim			•	0 00 0	
Pressure Drop (psig)	4	4.5	Ŧ	्य	4	4	4	1	n 4 F c	2	¢)	e.	7,8		and Remove		Permeate Pressure psig)														(A	nediy nediy	emis	i u) ≇d	
Fitter Inlet Pressue (psig)	13	52.5	55	25	25	12	12	10		81	81	2	= 5/1		With First Po		Fitter Outliet Pressure psig)	4	\$	æ :	P 9	₽ ₽	4	48	4	48.5	48	48			Î	11		1:12	
Pressure Pressure pisig)	48	24	8	89	48	48	00		f q	0.04	Ş !	4	270	50.16	0.075	0.002	Jurry oop Flow tate tate	2.71	271	2.64	1.4	12	2.73	2.76	2.67	2.72	2.67	2.87		. Time			•	10.57	
Tate Tate gpm)	2.71	2.71	2.04	2.71	2.7	273	273	276		212	107	2.07			mc =	mid/psi =	shurry F	24.6	24.7	24.9	2.9.2	24.4	24.5	24.5	24.5	24.5	24.6	24.6		nt Flux vs ad 7.8 ft/s in 1)				0:43	Department)
there (n	000	0.05	0.10	0.15	0.20	0.30	0.35	0.40	the state	200	00.0	1:00	Flow gpm	ure paid =	9 Flux com/	eability gpm	fler 5 TPD C T	19	4	= \$	E ¥	2 12	5	\$2	15	10	1	ŧ		2 Simular 90.1 psig ar (Conditio			•	0.28	Time
2012 8	9.50	9.55	10:00	10:05	10.10	10:20	10-25	10.30	04.04	10.40	10,40	09:01	erage Stury	erage Press	arage Filbah	erage Permi	e Ter	9.50	9:55	00.01	0000	10.20	10.25	10.30	10.35	10:40	10:45	05.01		Z-101/102			•	0:14	
5 2	-	÷	÷	+-	-	+	÷	÷	.,	÷	.,		1 AV	NY L	1 AV	1 Av	E	-	+ 1		4	4		-	÷	-	-			4			0.0	00:00	
mber																1	Test Number														N 200	ep/gu	entil mitra	4) 11	

1:12

0.57

1.12

0.57

0:28 0:43 Time (hr:min)

0.14

00:0

AZ-101/102 Simulant Flux vs. Time at 50.1 psig and 7.8 ft/s (Condition 1)

Time (hr:min)

Permeability 0:00 0:14 0:28 0:43

AZ-101/102 Simulant Permeability vs. Time at 50.1 psg and 7.8 Ms (Condition 1)

 2°

0.005956 0.002241 0.002241 0.001935 0.001935 0.001939 0.001298 0.001298 0.001298 0.001298 0.001199 0.001199

ability (20)ss()	0.003633	0.002851	0.002597	0.002417	0.002135	0.002005	0.001942	0.001756	0.001752	0.001731	0.001679	0.001603									
Perme																					
Fittrate Flux (gpm/ft2)	0.106342	0.085584	0.077969	0.072565	0.066225	0.060191	0.058287	0.052718	0.052580	0.051909	0.050416	0.048111									
Permeability (m/day/bar)	3.093	2.427	2.215	2.058	1.618	1,707	1,653	1.495	1491	1.474	1.430	1 364									
Fitrate Flux (m3/m2/day)	6.238	5.020	4.574	4.257	3,865	3.531	3.419	3.082	3.085	3.049	2.957	2.822				D.					
Sturry Temp C	23.2	22.3	21.8	22.1	23.1	24.1	24.6	24.6	24	22.9	23.2	22.8					Fâtrate Flow Rata (mL/sec)		1.376	0.826	0.706
Fibrate Flow Rate (mL/Sec)	1.252	0.982	0.682	0.828	0.777	0.727	0.714	0.646	0.633	0.606	0.593	0.560					Time of Collection	[nac]	21.81	36.32	97.7K
Time of Collection (Sec)	23.97	30.56	34,03	87.98	38.6	41,28	42.03	46.47	47.38	49.47	50.55	53.59					fitrate Sample Volume		8	8	92
Fittrate Sample Volume mL)	30	30	30	30	8	R	8	8	8	8	8	8					ittor Iniat	IRent	31.5	32	08
Pressure (pisq) (or	4.5	4	4	4	4	4	4	4	4	e	4	4	8.8			int Removed	Pressure F	(Past			
Filter Inlet Pressue Psig)	31.5	32	32	N	33	32	32	32	8	32	22	R	fh's =			With First Po	Dutlet F	(Passed	27	87	36
Filter Outlet Pressure (psig)	27	2	8	39	62	58	28	28	28	28	28	28	2.28	30.02	0.767	0.002	Sluny Loop Flow	(interest	2.15	2.29	2.38
Slurry Loop Row Rate gpm)	2.15	2.28	2.38	235	2.47	2.15	2.09	2.27	23	2.3	2.24	2.32	÷		1 Uatr	nft2 = mft2/psi =	, Lund	-	23.6	22.8	22.8
dal Time S lapsed R	800	0.05	0110	0:15	0:20	0:25	0:30	0:35	0:40	0:46	0:50	0.55	ry Flow gpm	ssure paid =	ate Flow mil.	ate Fluicigen nestriky gpr	Tiller	-	10	16	16
aul	11.00	11:05	11.10	11.15	11:20	11.25	11:30	11.35	11:40	11.46	11.50	11-55	werage Stur	Average Prei	Average Fittr	Werage Filtr Werage Peri			11:00	11.05	11-10
Condition	P4	¢4	¢4	re	<14	P4	N	64	Ñ	er e	PN.	N	N	ei i	N	NN	Test	in the second se	ni.	r.v	-

c



termeability	0.002183	0.000961	0 000037	0.000879	0.000828	0.0008022	0.000792	0.000742	0.000728	0.000704	0.000685	0.000982	0.000050																				
Filtrate Flux ((apm/tt2)	0.152884	0.067556	0.064736	0.061544	0.057998	0.057345	0.055448	0.051947	0.051155	0.049319	0.047518	0.046385	0.045507																				
Permeability (m/day/bar)	1.858	0.818	0.789	0.748	0.705	0.699	0.674	0.631	0.620	0.550	0.583	0.564	0 553																				
Filtrate Flux (m3/m2/day)	8.968	3.903	3,796	3.610	3.402	3,364	3.253	3.047	3.001	2.893	2.793	2.721	2.669																				
Sturry Temp C	26.2	25.8	197	24.0	1.12	24.6	24.9	25.1	25.1	25.2	52	24.9	24.8							Filtrate Flow Rate (mL/sec)	1.958	0.856	0.806	0.760	0.712	0.702	0.685	0.645	0.635	0.614	0.590	0.573	0.560
Filtrate Flow Rate (mL/sec)	1.958	0.856	0.806	0.780	0.712	0.702	0.685	0,645	0,635	0.614	0.590	0.573	0.560							Colection Sact	15.32	35.06	37.22	30.47	42.12	42.72	43.81	46.5	47.22	48.84	50,87	52.37	53.53
Time of Collection (Sec)	15.32	35.06	37.22	143	42.12	42.72	43.81	48.5	47.22	48.84	50.87	52.37	53.53						110015	Anthe Volume	30	30	30	30	30	30	30	30	30	30	20	8	90
Fibrate Sample Volume (mL)	30	30	8	20	30	8	8	8	8	00	30	92	8				U			Pressue	22	72.5	71.5	71.5	71.5	71.5	12	22	22	72	F	12	22
Pressure Drop (psig)	4	4	10.07	-	10	3.5	4	4	3.5	4	0	4	4	9 5			aint Ramove			Permoatio													
Filter Inlet Pressue (psig)	72	725	715	715	21.15	71.6	22	P.	12	12	E.	72	12	10,2 =			With First Po			Pressure	3	8	8	88.5	68.5	68	88	88	68.5	99	88	89	88
Filter Outlet Pressure (phig)	89	80	88	68.5	68.5	99	00	89	88.5	60	89	18	3	2.04	00.00	1110	0.055	100.0	1222	Flow Rate (gpm)	2.05	2.07	2.03	2.02	2.05	1.95	2.08	2.03	2.08	2.07	5.8	2.05	CN.
Sturry Loop Flow Rate (gpm)	2.05	2.07	2.03	2 02	2.05	1.95	2.08	2.03	2.08	2.07	82	2.05	11			I hear	mm2 =	pm/ft2/psi =		Sturry Temp C	26.2	25.8	25.2	24.9	24.7	24.6	24.9	25.1	25.1	25.2	25	24.9	24.8
Total Time Elapsed (Min)	00:0	0:02	0:10	0:15	0.20	0.25	0.30	0.35	040	0.45	0.50	0.55	1.00	my Flow go	there are a start	rote Elevier	rate Flux gp	rmeebility or		Chiller Temp C	24	13	13	13	13	11	4	14	14	14	13	5	12
Tme	12:35	12:40	12:45	12:50	12.55	13:00	13:05	13.10	13.15	13.20	13.25	13.30	13.35	Average Stu	Automan Dra	Average FIA	Average Fill	Average Per		Tma	12:35	12:40	12:45	12:50	12:55	13:00	13-05	13:10	13.15	13.20	13.25	13.30	13.35
Condition	n	n	-	n	0	n	m	n	(7)	n	0	m	10	17	9	2.4	1 (7)	0		est lumber	17)	0	17	m	n	20	ei,	e	0	n	m	61	62

10



Permeability (m/day/bar)	2.748	2 382	2 2 10	2 084	2 006	1 902	1.855	1.779	1729	1861	1.663	1.610																			
Fittrate Flux (m3/m2/day)	5,497	4,885	4.572	4.311	4 149	3,934	3.837	3.711	3.577	3.436	3.439	3.331																			
Shirry Terrip C	242	24.2	24	23.9	24.3	24.3	24.5	24.4	24.5	24.5	24	24						0	Filtrate Flow Rate (mL/sec)	1.135	1.008	0.938	0.882	0.859	0.814	0.799	0.770	0.745	0.715	0.706	0.884
Filtrate Flow Rate (mL/sec)	1,135	1.008	0.938	0.882	0.859	0.814	0.799	0.770	0.745	0.715	0.709	0.684							Time of Collection	26.44	29.75	31.97	34	34.93	30.84	37,56	38.94	40.29	41.94	42.5	43,88
Time of Collection (Sec)	28.44	29,75	31.97	Ä	34.83	36.84	37.56	38.94	40.29	41.94	42.5	43.88						Elivata	Sample Voluma	30	30	œ	30	30	30	90	8	90	8	06	8
Fibrate Sample Volume (mL)	R	90	8	8	8	8	8	8	8	8	8	8				p			Filler Injet. Pressue (psia)	15	32	CF.	8	8	8	F	32.5	32	22	2	55
Pressure Drop (psig)	4	4	4	7	۲	4	4	4.5	4	4	4	а	8.5	47		oint Ramova			Permeste Pressure												
Fitter Intet Pressue (psig)	15	ş	22	2	6	32	£1	32.5	3	(re	32	Ħ	= 5/11	= 5/1		With First Po		Ether	Pressure	12	8	28	28	28	28	28	- 28	28	28	28	28
Filter Outfet Pressure (psig)	22	28	82	28	8	23	12	8	28	28	28	28	2.9	N I	29.94	0.067	0.002	Surv	Rate (apm)	2.87	3.04	0		2,813	2.94	2,89	2.92	2,58	2,98	2,86	2.87
Sturry Loop Flow Rate (gpm)	2.67	101	0	0	2,89	2.94	2.86	2.92	2.98	2.98	2.86	2.87		=	face in	mitt2 =	m/ft2/psi =		Shiny Temp C	24.2	24.2	24	23,9	24.3	24.3	24.5	24.4	24.5	24.0	24	24
Total Time Elapsed Min)	000	0.05	0.15	0.20	0.25	050	190.0	0.40	0.45	0:50	0:55	1:00	my Flow gor	my Flow go	in pist annual	rate Flux gp.	meability gp		Chiller Temp C	15	17	11	21	18	18	19	18	18	18	0 <u>0</u>	18
Time	1:45	1,50	2:00	2:05	2:10	2:15	2.21	2.25	2.30	2.35	2.40	2.45	Average Slu	Average Ski	Average Pre	Average Filt	Average Per		lime	1:45	1:50	2:00	2.05	2:10	2:15	2.21	2.25	2.30	2.35	2.40	2.45
Number	4	47	4	Ħ	ę	4	4	4	4	4	4	4	4 1	e i	4 4	4	4		Test fumber	4	4	4	4	4	4	4	4	4	4	4	4



Permeabili ty (gpm/ff2/p s0

10 CT 10 CT																																									
Fitrate Flux (gpm/ft2)	0.123439	0.093924	0.06/348	0.077483	0.074321	0.071774	0.068795	0.006709	0.064207	0.061763																															
Permeability (miday/thar)	2.059	1 598	1.478	1318	1.265	1.221	1.171	1.135	1090	1.051																															
Filtrate Flux (m3/m2/day)	7.241	5.510	4 785	4.545	4.360	4.210	4 035	3.913	3,100	3.823																							65	1	_						
Stury Temp C	23.2	23.8	2.45	253	25.2	25.2	24.8	24.7	1.97	22.2				Fibrate Flow Rate	(mL/sec)	1.453	1.124	1.0/18	0.968	0.926	0 894	0.847	1010	0.772	0.769	0.739	ability vs.	2)				3 0.57 1:12	u)		bility vs.						57 1:26 n)
Filtrate Flow Rafe (miL/sec)	1.453	1.124	1.079	0.968	0.926	0.894	0.847	0.819	1022.0	0100				Time of	(Sec)	20.65	29.68	29.47	31	32.41	23.55	35.41	37.94	36.88	8	40.59	nt Perme	me and 8.9 m/s	tion 5)		• • • •	0.28 0.4	Time (hr:m		nt Permea	10 8.9 ft/s	(sup	100	* * * *		8 0. De (hr:mli
Time of Collection (Sec)	20.65	26.68	10.72	15	32.41	33.56	35.41	828	100 000 000 000	en oc				Filtrate Sample	(mL)	8	89	8.8	8	30	30	89	30	30	8	30	02 Simula	50.1 psq1	(Cond		• • •	0.14	1		2 Simular	50.1 psig a	(Condit				0.2
Sample Volume (mL)	8	89	8.08	18	30	OE I	8.9	DR OR	8.5	88			σ	Filter Intet	(prig)	23 1	53 E E	200	1 23	3	27 1	3 12	¥ 24	55	8	23	AZ-101/1		1	240	- 02 m	(m) (m)			VZ-101/10		E003	0.002 *	0.001	000	0.00
Pressure Drop (psig)	4	4.4	n e	4	4	4	4.5	4.4		1 4	8.8		ant Remove	Permeate	(Disid)														1	HIH	keen Y	bec					** 11	urs/	lo long long long	a a	
Filter Intel Pressue (psig)	23	21	1.02	121	25	23 5	CH 6	2 13	3 5	8 28	= 8/1		With First Pr	Filter	(bisd)	8	8	6 4	4	48	8	5 5	7 5	48	8	48			r		T	1.12						-	П	1:12	
Outlet Pressure (psig)	40	₽ 4	1	4	\$	₽ :	₽ \$	\$ 4	74	₽ ₽	3.08	50.10	0.074	Sumy	Rate (gpm)	2.95	60 H	3 12	3.1	3,14	20.6	3.12	2015	3.08	3.6	3.04	's. Time					0.57			s. Time					0-57	
Shrty Loop Flow Rate (gpm)	2.95		1 1	1.0	1.14	3.07	11.0	000	2000	3.05			mitt2 = mitt2 =		TenpC	23.2	8.62	25.3	25.3	25.2	2223	2.4.2	24.8	15	83	29.5	ant Flux	and 8.9 ft/s ion 5)		:		0:43	(hr:min)		nt Flux v	ion 5)		•		B 0:43	ne (hr.min)
Total Time Elapsed (Min)	80	8.6	2 4	0:20	0:25	0.30	9.9	0.40	09-0	0.55	my Flow oon	- pisd amssi	rate Flux gp meability gp		Temp C	23	4.0	= #P	14	14	4	2 \$	2 12	ħ	\$2.5	12	02 Simula	It 50.1 psig (Condit		:		0:28	Time		02 Simula	(Condit				14 0.2	The
	320	300	3.10	3.15	3-20	3.25	000	de la	246	38	oe Stu	ge Pre	E B B			2.55	300	3.10	3.15	320	325	335	3.40	3,45	19.0	102	101/1			•		0.14			01/1	-		•		0	
Time											Avera	Avera	Averal		Time												AZ-1		1	•		3			AZ-1		4	-		0:00	
Condition	10.0	25 U	0.143	10	10	17 1	n u	n e	n w	n wit	10	10	0 10 10		Number .	10.1	0.2	1.10	5	5		n 41	1 40	-	an v	ñ			* 0.00 × n	0.0 6 14	anul Dife	E (5.00					x1) 0.15	1 ett	90.00		

0.002419 0.001577 0.001577 0.001549 0.001485 0.001485 0.001485 0.001485 0.001485 0.001283 0.001283

Permeabilit y (gpm/ft2)ps

Parmasbility (gpm/ft2/psi)	0.002860	0.002516	0.000447	0.002389	0.002342	0.002317	0.002307	0.002285	0,000000	0.002281																												
Filtrate Flux (gpm/ft2)	0.086587	0.075527	0.072844	0.072029	0.070313	0.089556	0.069269	0.068601	0.0007000	0.067853																												
Permeability (m/day/bar)	2.435	2.142	2,083	2 045	1.994	1.973	1,964	1.940	1000	1942																												
Filtrate Flux (m3/m2/day)	5.079	4,430	4 273	4 225	4.125	4.080	4,063	4.024	3 048	3.983																							-					
Sturry Temp C	26.6	25.0	251	25	5 52	25.2	8	5 4 7 0 Y C	0.40	24.8			Fibrate Flow Rate (mL/teet)	+ 4.2+	0.957	0.951	0.905	0.892	0.866	0.858	0.847	0.832	0.825 0.836	-	ability vs.			and the second	•	+	0.57 1.12		bility vs.			•		Caller Caller
Filtrate Flow Rate (mL/sec)	1.121	10000	0.905	0.892	0.883	0.866	2000	0.830	568.0	0.836			Time of Collection	(Sec) 26.76	31.36	21.53	33.16	33.63	34.63	34.97	35.41	36.06	35.88		nt Permes	ne	tion 6)		•	100	8 0.43	hr:min)	it Permea	10 11.5 R/s	00 (t)	* * * *		
Time of Collection (Sec)	51.92	12 H	20,16	33,63	33.97	B N	18,80	14.00	16.96	35.88			Fittrate Sample Volume	(Jul) 30	3.8	8	98	88	30	8	30	30	8 8		02 Simula	29.9 psig a (Condi	••••	•••••		D:14 0:5		12 Simular	Tin 29.9 psig at	(Condit				
Fibrate Sample Volume (mL)	02	2.5	3.05	30	30	88	88	8.8	19	8		Ţ	Filler Inlet Pressue	(Bisd)	33	8	32.5	R 8	8	8	12	8	32.5		AZ-101/10		0	•	2 40	0	0:00		4Z-101/10		• 200	003	002	
Pressure Drop (psig)	10 4 10	0.4	9.9	10	9	0 1	Ð 9	o s	9 40	iri iri	11,5	oint Remove	Pressure	(Bisd)													e Li Hi	lideenme9 y sdvysbim)					Permeabilit Permeabilit Permeabilit					
Filter Inlet Pressue (psig)	88	3 6	32.5	2	123	2:	2 8	85	P	32.5	fb/s =	With First P	Filter Outlet Pressure	(Desd)	22	27	12	In In	22	27	27	27	22				Ĩ	-	T	1	2112							Γ
Filter Outlet Pressure (psig)	27.5	12	27	27	27	51.5	1	12	12	22	3.97	0.002	Surry Loop Flow	Kete (00m)	3.93	3.93	3.99	199.5	3.99	4.01	3.87	3.98	3.95		's. Time				:	-	10:0		s, Time			•		2
Sluny Loop Flow Rate (gpm)	4 000	2 10 1	3.99	3.99	3.99	3 39	10.4	HE S	395	3.93		Jisec = mft2 = mft2ipsi =	Slurry	2018	25.8	25.4	1.52	298	25.2	35	24.9	24.9	24.9		int Flux v	ind 11.5 ft/s ion 61	NAVE OF		:		0.43	(usural)	nt Flux v	00 6)				
Total Time Elapsed (Min)	000	0.15	0.20	0.25	0:30	0.35	0.45	050	0.55	1:00	try Flow gpt	rate Flow m rate Flux gp meability gp	Chiller	D due	12	2	ιņ.	6 9	12	16	15	15	約 約		02 Simula	Candit			:		87.0		02 Simula	(Condit				
2	4.05	4.20	4.25	4:30	4:35		199	4.65	200	505	erage Stu	erage Fill erage Fill erage Fill erage Pee		4:05	4.15	4:20	4.25	4.35	4:40	4:45	4:50	4:55	505		2-101/1	8		10.00	•		0.14		-101/10	ä	ľ			
Condition Number Tim	10 1	1 42	0	0	0	0 0	0 4	5. IC	¢	ø	6 AW	0 AV 6 AV 6 AV	Test	number III	9	ø	0	0 C	8	0	Ø	g	00		N.		× < 6.0 T	- 0.550	elen 0.5m%	正 (3.0 +	00.0		A2	0 10	xu) 0.08	1 otto 1 0.06	16) 16)	and a

1:12

0:57

0:28 0:43 (Time (hr:min)

0:14

0:00

1.12

0:28 0:43 0:57 Time (hr:min)

0:14

0.00

c

Distribution

No. of Copies

OFFSITE

No. of Copies

ONSITE

4 <u>Savannah River Technology Center</u> Jim Marra PO Box 616, Road 1 Building 773-43A Aiken, South Carolina 29808

> Charles Nash PO Box 616, Road 1 Building 773-42A Aiken, South Carolina 29808

> Michael Poirior PO Box 616, Road 1 Building 773-42A Aiken, South Carolina 29808

> Harold Sturm PO Box 616, Road 1 Building 773-A Aiken, South Carolina 29808

18	Battelle - Pacific Northwest Division											
	K. P. Brooks	K6-24										
	J. L. Buelt	K9-09										
	J. G. H. Geeting	P7-28										
	G. R. Golcar (10)	K6-24										
	D. E. Kurath	P7-28										
	S. N. Schlahta	K9-14										
	Project File	P7-28										
	Information Release (2)	K1-06										
7	Bechtel National, Inc.											
	S. Barnes	H4-02										
	W. Graves	H4-02										
	S. Jenkins	H4-02										
	I. Papp	H4-02										
	R. Peterson	H4-02										
	P. Townson	H4-02										
	WTP PDC Coordinator	H4-02										