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RESULTS FROM TESTS OF TFL HYDRAGARD LOOP (U)

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J. L. Steimke

Author

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SAVANNAH RIVER TECHNOLOGY CENTER, AIKEN, SC 29808
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Z. H. Qureshi, Technical Reviewer Date:

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D. R. Muhlbaier, Responsible Manager Date:

3/23/95

M. R. Buckner, Level 3 Manager Date:

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ABSTRACT

When the Defense Waste Processing Facility (DWPF) is operational, processed radioactive sludge will be transferred in batches to the Slurry Mix Evaporator (SME). In the SME, glass frit will be added and the contents concentrated by boiling. Glass frit will be added in a particular proportion to the solids content of sludge so that the final vitrified product will be a glassy form having low leachability and acceptable processing characteristics. Batches of sludge and frit slurry mixture are transferred from the SME to the Melter Feed Tank (MFT). Hydragard ® sampling systems are used on the SME and the MFT for collecting slurry samples in vials for chemical analysis. However, the ability of the Hydragard sampling system to collect a representative sample has not been well characterized. In response to a request from DWPT and DWPF, an accurate replica of the Hydragard sampling system was built and tested in the Thermal Fluids Laboratory (TFL). The primary method for characterizing the accuracy of slurry sampling was through accurate measurements of slurry density. This was supplemented by chemical analyses of 158 vials of slurry. It was determined that the original Hydragard valve frequently drew a non-representative sample stream through the sample vial that ranged from frit enriched to frit depleted. The degree of sampling error depended on the flowrate through the sample vial. Review of the technical literature indicated that the probable reason for the frit enrichment was the fact that the plunger of the Hydragard valve protruded into the flow when it was in the open position.

The Hydragard valve was modified by moving the plunger and its seat backwards so that the outer surface of the plunger was flush with the inside diameter of the transfer line when the valve was open. This change effectively removed the dependence on flow of the composition of the slurry flowing through the vial. The slurry flowing through the vial accurately represented the composition of the slurry in the reservoir for two types of slurries, different dilution factors, a range of transfer flows and a range of vial flows. It is recommended that DWPF modify the Hydragard valves for the SME and MFT in this way.

While the slurry flowing through the vial accurately reflected the composition of the slurry reservoir, the 15 mL of slurry left in the vial when the Hydragard valve was closed, which is what will be analyzed at DWPF, had a lower ratio of frit to sludge as characterized by the lithium to iron ratio than the slurry flowing through it. As a best estimate the lithium to iron ratio for the slurry in the vials collected by the Hydragard was 4.5% less than for the slurry that

flowed through the vials. This resulted from a vial lithium content that was, on average, 1.5% too low and a vial iron content that was, on average, 3.1% too high. In addition, the variability for chemical analyses for Hydragard sample vials collected during a run was approximately three times as large as the variability of sample vials collected from the slurry reservoir or the Hydragard overflow. Tests with relatively high vial flows in which the valve open time was changed or in which the speed of valve closure was increased did not make an appreciable difference in the chemical analyses of the sample vials. The reason for these differences is not understood at this time but it is recommended that additional experimentation be performed with the TFL Hydragard loop to determine the cause.

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1. INTRODUCTION

1.1 Background

When the Defense Waste Processing Facility (DWPF) is operational it will convert high level radioactive waste in the form of a wet sludge into a glassy form that is well suited for long term storage. After several processing steps the radioactive sludge is transferred in batches to the Slurry Mix Evaporator (SME) [Bahr, 1993]. In the SME, glass frit is added and the contents are concentrated by boiling. Glass frit is added in a particular proportion to the solids content of the sludge so that the final vitrified product will be a glassy form having low leachability and acceptable processing properties. Batches of sludge and frit slurry mixture are transferred from the SME to the Melter Feed Tank (MFT), which transfers feed to the melter. Hydragard sampling systems are used on the SME and the MFT for collecting slurry samples in vials for chemical analysis. Two Hydragard sampling systems are employed to collect representative samples from the two tanks. Tests, such as the WP-19 Tests or FA-10.02 Tests, have been conducted at the SME and MFT using a non-radioactive sludge simulant mixed with glass frit. Chemical analyses were made of slurry samples from the SME or MFT and slurry samples collected with the Hydragard [e.g. Edwards, 1994]. However, there were ambiguities in the test results that made it difficult to determine how representative the Hydragard samples were. The Program Plan for addressing the problem of uncertain accuracy of sampling was described by Randall and Smith [1994].

The Experimental Thermal-Fluids (ETF) Group built a test station at the Thermal Fluids Laboratory (TFL) that accurately reproduced the Hydragard sampling loop. Test results with the loop indicated that the Hydragard collected biased slurry samples under some conditions. The loop was also used to test a modification of the Hydragard valve that improved the accuracy of sampling. This task was performed on a very aggressive schedule. Modification of the Melter Feed Loop to Hydragard Loop configuration began on October 14, 1994. Testing of the Hydragard Loop began on October 18. On December 13, DWPF decided to modify the Hydragard valve based on test results at the TFL.

This work is a baseline activity and the plan was prepared in accordance with the 1Q Manual and the E-7 Manual Procedure 2.02 and was in response to DWPT Task Technical Request 94-DWPT-PMC-T0004 [Smith, 1994] which was in response to DWPF Task Technical Request HLW/DWPF/TTR-940011 [Edwards, 1994]. This report on the Hydragard Loop Tests at the TFL provides data that support the modification of the Hydragard valve.

1.2 Literature Survey

The report on "Testing of the TFL Melter Feed Loop" by Steimke [1994 b] contains a literature survey on the sampling of flows of slurries. A report by Nasr-El-Din, et al. [1985] is particularly relevant to the testing of the Hydragard valve. They describe testing of side wall samplers consisting of holes of different sizes in the wall of a vertical pipe having upward flow of sand and water slurries. A sand and water slurry settles much faster than DWPF frit and sludge slurry, and is therefore, more difficult to sample accurately. However, trends in the sand and water sampling data should be relevant for the sampling of frit and sludge slurries. Figure 1, which was taken from Nasr-El-Din report, shows the normalized concentration of sand drawn off by the simple side wall sampler. Note that the accuracy of sampling improved when the draw-off velocity was increased and when the size of the sand particles decreased. For comparison, the average diameter of the glass frit was 150 μm , about the same as the fine sand. Also, note that the side stream was always depleted in sand, although sometimes only slightly. The original strainer on the Melter Feed Loop [Steimke, 1994 b] was a simple side wall sampler, but with 26 small holes rather than one larger hole. For comparison, average values of Li/Fe ratio, a measure of the concentration of glass frit, for the original strainer on the Melter Feed Loop are plotted in Figure 1. The two slurries are different and the holes sizes are different (0.082" for strainer vs. 0.203" for side wall sampler) however, the trend of draw off velocity on sampling is the same and the sampled stream was always depleted in frit.

Figure 2 from the Nasr-El-Din report shows the results of test with a projection into the main flow stream near the location of the side wall sampler. Note that for velocity ratios below 0.4 the side stream becomes significantly enriched in sand. Sampling becomes more accurate as the draw off velocity increases.

The SRS literature relevant to the Hydragard loop was reviewed by Steimke [1994 b].

2. TEST DESCRIPTION

2.1 Test Loop Hardware

This test was performed as part of Task 94-008-1 [Steimke, 1994 a] and run according to Procedure FP-593 [Rohleder, 1994]. Figure 3 is a schematic of the TFL Hydragard Loop test setup which consisted of three flow loops: the recirculation loop, the transfer loop and the vial loop. The flow loop was designed by T. J. Steeper using dimensions taken from DWPF Drawing Numbers W755706, W755681, W759027, P-DCP-S-94012 and Lawrence Pumps, Inc. drawing A41761. The design of the TFL Hydragard Loop is documented in drawings SRT-ETF-DD-945-018, SRT-ETF-DD94022, SRT-ETF-DD94023, SRT-ETF-DD94024. The TFL Hydragard Loop was a very accurate duplication of the DWPF loop having prototypical pipe and tubing diameters, line lengths, elevations and elbow locations. However, two exceptions must be noted. First, the TFL Loop had two pumps connected in series rather than the one more powerful pump in the DWPF loop. Second, to design the TFL Hydragard loop, all dimensions from the DWPF Hydragard Loop were referenced to typical slurry levels in the TFL slurry reservoir and the DWPF MFT, rather than referenced to the bottoms of the reservoir and the tank. Typical slurry levels in the TFL slurry reservoir and the DWPF SME and Melter Feed Tank (MFT) were 28" and 84", respectively. The distance from the surface of the slurry to the Hydragard valve is 220" in both cases. If elevations had been referenced to tank bottom the pressure at the Hydragard valve in the TFL loop would have been lower than the pressure at the DWPF Hydragard valve by the equivalent of 56" (84"-28") of slurry.

The TFL Hydragard Loop used the tank, pumps and agitator from the previous Melter Feed Test [Steimke, 1994 b]. DWPT and DWPF separately provided drums of slurry, called TNX slurry and DWPF slurry, respectively, consisting of the simulated waste sludge, frit, and water. Both types of slurry were used at different times during testing. The slurry was placed in the reservoir where it was mechanically agitated. The agitator had blades at two elevations on the shaft but only the lower blades contacted the slurry. If enough slurry was added so that the slurry contacted the upper blades, the result was to stir air into the slurry which caused operational problems. The slurry was drawn through an inlet that has a prototypical strainer (a box perforated with many holes), through two centrifugal pumps located above the reservoir, through a magnetic flowmeter and around a recirculation loop. There is no flowmeter in the recirculation loop at DWPF. The only location available for the recirculation flowmeter in the TFL loop was only 10" downstream from the discharge of the second pump. As a result the flowmeter output was noisy. It is known that the recirculation flow did not actually vary significantly because the pressure gages had steady outputs. The first half of the recirculation pipe was 1 1/2" pipe (ID = 1.61") and the second half was 1" pipe (ID = 1.05"). Just before the slurry flowed back into the bottom of the tank there was a 0.50" flow restrictor to increase the pressure in the recirculation loop. On 11/07/94 an additional 9/16" orifice plate was installed in the recirculation loop 60" before the flow restrictor. The reason was that it was difficult for the TFL pumps to supply enough pressure to the circulating slurry. From 12/01/94 until 12/03 heavy DWPF slurry (250 dyne/cm²) was tested in the loop. Because of the higher pump pressures necessary, multiple pump seal failures were encountered. The transfer line piping was temporarily changed to allow testing to continue. The 3/4" tubing leading from the "Y" branch to three feet below the Hydragard valve followed the prototypical tortuous route. It was replaced with 1" tubing which followed a more direct path and had fewer elbows. This reduced the pressure at the pump, which reduced the frequency of seal failures and allowed testing to continue.

The original prototypical tubing was later reconnected. Notes on loop hardware changes are listed in Table 1.

The flow restrictor and the extra orifice plate in the recirculation loop generated the pressure which drove from 4 gpm to 10 gpm of slurry from the recirculation line into the transfer line. The transfer line (ID = 0.62") was attached at a 45° angle to a vertical section of recirculation line where it was constructed from 1 1/2" pipe. The first 3" of the transfer line had an ID of 1.61" which reduced to 0.62". The transfer line was routed to the Hydragard valve which was installed in the transfer line using a standard 3/4" Swagelok ® tee. In the DWPF transfer line above the Hydragard valve there is a flowmeter and a nearby pressure tap. The TFL transfer loop had this pressure tap (TR-3411) and flowmeter (TR-20347) as well as other pressure taps and flowmeters. It should be noted that the transfer flowmeter was positioned after the Hydragard valve. The slurry flow in the transfer line upstream of the Hydragard valve was the sum of the measured transfer flow and measured vial flow. The transfer line returned the slurry to the reservoir just above the surface to reduce foaming and splashing. The last two feet of the line was made from flexible Tygon ® tubing which could be moved to allow a slurry sample to be collected. The Hydragard valve is shown in Figure 4 and was manufactured by Hinds International, Inc. The valve had a plunger which resembled the intake valve on a gasoline engine. Normally the outer surface of the plunger was nearly flush with the inside of the 3/4" tubing and no flow passed through the valve as shown in Figure 5. When a sample was desired the plunger was pushed forward 1/4" so that it projected into the flow stream in the 3/4" tubing. Slurry flowed past the plunger, in and out of the sample vial and out the overflow and back to the slurry reservoir. Valve open times of 7 and 30 seconds were tested.

The fixed speed centrifugal pump on the recirculation loop was used when higher transfer flows were required. The speed of the variable speed pump was adjusted to set the transfer flow. For example, during tests on 12/13 increasing the sum of the two pump speeds by 56% doubled the transfer flow. The TFL transfer loop has the same length and resistance as the SME transfer loop at DWPF, but some of the elbows at the TFL loop were turned in different orientations to reduce the building space that was consumed. The flow of the slurry in all three flow loops was measured using magnetic flow meters. Vial flow and transfer flow measurements were occasionally checked by collecting all of the flow in a bucket for a measured time and then weighing the contents. Normally however, the feed flow was piped back to the slurry reservoir. Slurry samples were collected from the reservoir, Hydragard vials, the overflow from the Hydragard samples and occasionally the transfer line. Elemental chemical analyses were performed on some samples by the Analytical Laboratory at TNX. Accurate densities of other samples were measured at the TFL. Both types of analysis were done to quantify frit depletion.

A vacuum pump was used to pull the slurry up to prime the pumps in the TFL Hydragard loop. Once slurry was pulled into the pumps, the vacuum line was valved off and one or both pumps started. Priming in the DWPF Melter Feed Tank is accomplished differently, by injecting water into the end of the pump suction line inside the strainer box. However, that method could not be used in the TFL loop because it requires about 100 gallons of water and the slurry reservoir only has about 100 gallons of slurry in it. Priming the pump just once would have diluted the slurry by a factor of two.

The slurry was agitated enough to insure suspension of solids but not so much that air was entrained into the slurry reservoir. For a few experiments a controlled and measured amount of air was mixed with the slurry at the pump discharge to investigate the effects of air in the recirculation loop on performance of the Hydragard sampling system because there was evidence of air entrainment in the slurry in the DWPF MFT for low tank levels.

2.2 Operating Procedure

The testing followed a written procedure [Rohleder, 1994]. At the start of each day of testing the pressure lines were purged with water to remove air or solids. Then the zero pressure reading on

the differential pressure gages was recorded. One or both slurry pumps were turned on depending on the required flowrate for the test. The temperature of the slurry was controlled to $\pm 2^{\circ}\text{C}$ using tubing coils that could be supplied with either chilled cooling water or steam. The speed on the variable speed pump was adjusted to give the desired transfer flow. A clean sample vial was attached to the Hydragard valve. A rubber septum on the top of the vial sealed around the tubes of the Hydragard valve as shown in Figure 4. After steady state operation had been achieved, logging was begun on the data acquisition system (DAS). If it was desired to fill sample vials to be sent off for analysis, then the Hydragard valve was held open for 7 seconds, or, in some cases 30 seconds, then closed. The vial was replaced and the process repeated until five or six vials had been collected. Vial collection was not always performed, but the slurry overflowing from the vial was nearly always collected. The overflow passed through a flowmeter and out the end of a tube where it flowed into a funnel. A 500 mL flask was held above the funnel to collect about 350 mL of slurry. Then a Coliwasa (Section 2.4) was used to collect a 350 mL sample from the slurry reservoir. At this time the DAS that had been started earlier was stopped. After the loop was shut down the densities of the flask samples were measured using the procedure outlined in Section 2.4. In a few early tests slurry was collected from the end of the transfer line. This practice was discontinued because slurry sprayed on the technician doing the collection and because the more important comparison was between the slurry reservoir and the Hydragard. Those slurry densities are listed in Table 3 and did not differ significantly from the reservoir slurry density.

2.3. Instrumentation

Figure 3 shows the location of four gage pressure measurements, three differential pressure measurements, two air flow measurements and five temperature measurements. An electronic scale, instrument number L-25492, was used to measure masses of less than 400 grams, with an accuracy of 0.02 g. Another electronic scale, TR-30074, was used to measure masses of up to 100 lb, with an accuracy of 0.1 lb. For a few tests an uncalibrated linear displacement gage was attached to the handle of the Hydragard so that closing time could be measured.

The identifying numbers of the instruments connected to the DAS, their calibration equations, the data acquisition system (DAS) calibration equations and uncertainties are listed in Table 2. DAS calibrations were necessary for instruments that had a milliamp output. The milliamp output was passed through calibrated 500 ohm resistors that produced the voltages that were read by the DAS. Data were recorded using a Macintosh® based data acquisition system (DAS) with Strawberry Tree® boards and using Workbench® software. Some data were recorded manually in a laboratory notebook. Data were reduced using Trapeze® data analysis spreadsheet software. All of the software and hardware mentioned in this paragraph have been validated before. In particular there was a formal review of all of them for the Type Q Septifoil tests performed at the TFL [Steimke, et al., 1992]. No software was developed for this task.

The pressure gages were located near the floor of the laboratory and were connected to the pressure taps on the loop with tubing filled with water. Therefore, the reported readings reflect the head of water in the tubing. The bottom of the slurry reservoir was located 13" above the floor. The reservoir typically contained 28" of slurry. Pressure gages TR-3412, TR-3413, TR-20305 and TR-2919 were located 56" above the floor. Pressure gages TR-3282, TR-3411, TR-3279 and TR-2146 were located 43" above the floor. Elevations of pressure taps with respect to the floor are listed in Table 2.

Two important measurements were the transfer flowrate and the vial flowrate. The flows measured by the two magnetic flowmeters were checked by comparison with the fundamental method of collecting the flow in a bucket for a measured period of time. The flowrate was computed using the measured time, the measured weight and the measured density. The flowmeter data was processed by the DAS hardware and software, the data reduction software and the data summary software. Therefore, a comparison of the flows using the bucket and using the flowmeter checks all of those steps for the acquisition and processing of the two flowrates. The results are listed below.

Checks of Transfer Flowmeter, TR-20347

date	time	flow at meter, gpm	flow in bucket, gpm	% difference
10/28/94	1338	4.09	3.98	2.7
10/31	1122	8.37	8.21	1.9
10/31	1238	7.00	6.87	1.8
12/04	1125	3.92	3.87	1.3
12/14	1351	6.03	5.96	1.2

Checks of Vial Flowmeter, TR-20352

date	time	flow at meter, gpm	flow in bucket, gpm	% difference
10/21/94	1413	1.204	1.189	1.3
10/21	1505	0.612	0.604	1.3
12/04	1145	1.480	1.456	1.6
12 14	1311	1.196	1.171	2.1

The two flow meters read about 2% higher than the fundamental bucket method, which is good accuracy.

2.4 Slurry sampling and density measurement

Slurry was removed from the slurry reservoir using a Coliwasa (composite liquid waste sampler) shown in Figure 6. The Coliwasa is an accepted method for collecting representative samples of liquids and slurries [deVera, 1980] and is a refinement of thief sampling as described by Kirk-Othmer [1994]. The Coliwasa held about 100 mL. It was filled three times and emptied into a 500 mL round bottom glass flask where it was stored temporarily until a density measurement could be performed. Slurry from the end of the feed line was collected by placing a 500 mL flask under the end of the slurry stream and collecting approximately 350 mL.

A step preliminary to measuring slurry densities was to prepare a 100 mL volumetric flask by etching marks along its length at 1 mm increments, in addition to the factory installed mark at 100.0 mL. The flask was weighed empty and then with water at a known temperature to various levels on its neck to calibrate the additional marks. The accuracy of the volume measurement was 0.14 mL.

Densities of slurry samples were measured in the following way. The small electronic scale was zeroed with the empty, dry 100 mL flask on it. A magnetic stirring bar was placed inside a 500 mL flask. The contents were stirred vigorously. While the stirring continued, the 500 mL flask was tilted and slurry was poured into the 100 mL flask so that the level was halfway up the neck of the 100 mL flask. A cotton swab was used to remove the film of slurry coating the inside of the neck. The volume, V_1 , and mass, M , were measured and recorded. Then a rubber stopper was pushed into the flask opening. The stopper was connected to a vacuum pump and a pressure gage using flexible tubing. A valve was adjusted to allow an air leak into the tubing so that the flask pressure was 50% of atmospheric pressure. The slurry level in the flask increased, typically about 1 mL. The new volume, V_2 , was noted and recorded. The difference in volumes was caused by entrained air bubbles doubling in volume. If no air had been present, only slurry, the volume would have been $(2 V_1 - V_2)$. The density, corrected for the presence of air bubbles, was computed using the following equation.

$$\rho = M / (2 V_1 - V_2) \quad (1)$$

This equation takes advantage of the fact that no air bubbles are observed to rise to the surface of the viscous slurry during the 15 seconds required to make the measurement of V_2 . It should be noted

that the primary interest was in the determination of relative densities. Any consistent error, if present, should have a negligible effect on relative density.

The root sum square method [Abemethy, et al., 1985] was used with Equation 1 to determine the uncertainty of the density measurements. The uncertainties in M , V_1 and V_2 were 0.02 g, 0.114 mL and 0.114 mL, respectively. The resulting uncertainty in slurry density was 0.0034 g/mL. As will be shown, this uncertainty is about the same as the minimum observed scatter in the measured densities.

2.5. Data Reduction

A Trapeze® spreadsheet was written that plotted the instantaneous values of flows, gage pressures, differential pressures, temperatures and the output of the gamma densitometer. Average values were computed and placed in a table in the spreadsheet. The averages from that table were copied and pasted into the large table in a data summary, Table 3. The code for hardware type used the following table.

Code	Hardware Description
1	Original Hydragard hardware
2	Plunger was removed and replaced with rod of same diameter (0.25") but which did not protrude into bore of Swagelok tee.
3	New plunger was made with a smaller diameter at end (0.563"). Plunger and its seat were pulled back 0.25"
4	Same as #3 but with 3 mL Teflon thimble inside vial. Done at request of C. J. Coleman.
5	Original plunger but side arm of Swagelok tee extended 0.25"

"Pump speed" in Table 3 is the percentage of full speed for the variable speed pump. "Pump on?" is equal to 100% when the fixed speed pump was on, otherwise it is equal to 0%. Many of the DAS logs were started before the Hydragard valve was open and stopped after it was closed. In order to compute meaningful averages for the data a period of time was chosen during which the valve was fully open. "First line averaged" and "Last line averaged" specify the inclusive lines of data that were averaged. If these two entries are zero, the entire log was averaged. One line of data was collected each second.

Plots of pressures as functions of recirculation flow or feed flow were made. "F trnsfr m" and "F vial m" were flowrates for the transfer line and vial as measured using a bucket and stopwatch. These were entered into the table manually. "Rho"s are densities measured for the reservoir, the vial overflow and occasionally the transfer line. Normally two density measurements were made for both the reservoir and the vial overflow. They were also entered manually. "Std recirc" is the standard deviation of the fluctuations in the measured recirculation flowrate. "Discrep 1 for rho" is the percentage by which the first density measurement of the overflow slurry from the Hydragard exceeds the first density measurement for the slurry reservoir. "Discrep 2 for rho" is for the two second density measurements. "High vial flow" was equal to one when the vial flow was forced to be higher than it would have been, otherwise it was equal to zero. "Low vial flow" was equal to one when the vial flow was forced to be lower. When both "high vial flow" and "low vial flow" were equal to zero, "normal vial flow" was equal to one. The code for slurry type used the following table.

Code	Slurry Description
1	TNX slurry, density = 1.35 g/mL
2	TNX slurry, density = 1.31 g/mL
3	TNX slurry, density = 1.27 g/mL
4	DWPF slurry, density = 1.46 g/mL
5	DWPF slurry, density = 1.38 g/mL

2.6. Slurry Description

Two slurries were tested in the TFL Hydragard loop, TNX slurry and DWPF slurry. The TNX slurry differs from DWPF slurry in three respects as described by Steimke [1994]. The primary difference is that the TNX slurry has about three times the yield stress of DWPF slurry for the same weight percent insoluble solids. Slurry rheologies measured by the TNX Analytical Laboratory during the course of testing using Sample Profile JS-MFTR are listed below.

User Sample ID: JS-10-14-94

Sample taken on 10/12 at 11:35 for TNX slurry with density of 1.35 g/mL.

consistency	15.60	cp
yield stress	89.70	dyne/cm ²
temperature	25	°C

consistency	8.841	cp
yield stress	110.4	dyne/cm ²
temperature	50	°C

User Sample ID: JS-246

Sample taken on 11/16 at 10:13 for diluted TNX slurry with density of 1.31 g/mL

consistency	15.3	cp
yield stress	63.4	dyne/cm ²
temperature	25	°C

consistency	11.9	cp
yield stress	80.6	dyne/cm ²
temperature	50	°C

User Sample ID: JS-254

Sample taken on 11/17 at 12:34 for further diluted TNX slurry with density of 1.26 g/mL.

consistency	11.1	cp
yield stress	30.9	dyne/cm ²
temperature	25	°C

consistency	9.44	cp
yield stress	33.2	dyne/cm ²
temperature	50	°C

User Sample ID: JS-275

Sample taken on 12/01 at 15:53 for DWPF slurry with density of 1.45 g/mL.

consistency	29.5	cp
yield stress	250	dyne/cm ²
temperature	25	°C

consistency	38.7	cp
yield stress	231	dyne/cm ²

temperature	25	°C
consistency	26.4	cp
yield stress	263	dyne/cm ²
temperature	50	°C

User Sample ID: JS-281

Sample taken on 12/03 at 14:08 for diluted DWPF slurry with density of 1.38 g/mL

consistency	19.4	cp
yield stress	77.3	dyne/cm ²
temperature	25	°C
consistency	16.4	cp
yield stress	88.7	dyne/cm ²
temperature	25	°C
consistency	15.3	cp
yield stress	89.1	dyne/cm ²
temperature	50	°C

User Sample ID: JS-297

Sample taken on 12/04 at 11:17 for TNX slurry reconcentrated using immersion heaters to density of 1.35 g/mL.

consistency	16.2	cp
yield stress	109.3	dyne/cm ²
temperature	25	°C
consistency	15.2	cp
yield stress	115.9	dyne/cm ²
temperature	25	°C
consistency	14.1	cp
yield stress	130	dyne/cm ²
temperature	50°C	°C

2.7 Hydraulic Verification of Flow Loop

R. M. Novak provided flow, pressure and rheology data from DWPF to compare with the TFL Hydragard Loop. On 7/7/94 at 22:17 the transfer flow, pressure, consistency and yield stress at the SME were 7 gpm and 27 psig, 37 cp and 165 dyne/cm², respectively. On 8/14/94 at 09:12 the transfer flow, pressure, consistency and yield stress at the MFT were 8 gpm and 19 psig, 21 cp and 79 dyne/cm², respectively. Figure 7 plots gage pressure versus transfer flow squared. Flows and pressures are also plotted for the TFL runs with DWPF slurry for yield stresses of 240 dyne/cm² and 83 dyne/cm². The TFL pressure gage was located below the point of measurement. Therefore, the pressure resulting from the head of water in the pressure sensing line at the TFL, 8.8 psi, was subtracted from the pressure transducer reading. The DWPF point for 164 dynes/cm² falls midway between the TFL data for 240 and 83 dynes/cm² as it should. The DWPF point for 79 dynes/cm² falls somewhat below the TFL data for 83 dynes/cm² as it should. Therefore, this graph serves as hydraulic verification of the TFL Hydragard Loop.

2.8 Quality Assurance Controls

The Task Plan for the TFL Hydragard Loop was prepared in accordance with the 1Q Manual in response to a Task Technical Request per the E-7 Manual Procedure 2.02 [Smith, 1994]. An approved operating procedure and calibrated instruments were used. The Hydragard Loop underwent a safety inspection.

3. DISCUSSION OF RESULTS

3.1 Relationship Between Density, Li/Fe Ratio and Elemental Composition of Slurry

Steimke [1994 b] described the relationship between changes in slurry density and changes in Li/Fe ratio over spans of time that are short enough that there is no dilution of slurry with water or significant evaporation of water from the slurry. Two additional points are now available and all direct comparisons of changes in density and changes in Li/Fe are plotted in Figure 8. The two additional points result from measurements of density and Li/Fe for slurry overflowing the Hydragard vial on 12/09/94. Each point of the graph represents eight or ten chemical analyses. During a run four or five vials were filled from a stirred beaker collected from the end of the Melter Feed Line or the Hydragard overflow and the same number of vials were filled from a stirred beaker whose contents were collected from the slurry reservoir using the Coliwasa. The average Li/Fe for the Melter Feed Line vials or the Hydragard overflow vials was divided by the average Li/Fe for the reservoir vials. The linear least squares fit is

$$\frac{\text{Li/Fe}_{\text{feed}}}{\text{Li/Fe}_{\text{res}}} = -7.4135 + 8.4099 \frac{\rho_{\text{feed}}}{\rho_{\text{res}}} \quad (2)$$

Theoretically the best fit line on the graph should pass through the point 1.000, 1.000. Actually it passes through 1.000, 0.9964 which is as close as could be expected for the confidence intervals of the data. The confidence intervals marked on the graph, $\pm\omega$, are based solely on the variability in the individual chemical analyses.

$$\omega = \frac{2\sigma}{\sqrt{N-1}} \quad (3)$$

The symbols σ and N are the standard deviation of the Li/Fe values for a group of vials and N is the number of vials. Steimke [1994 b] also established the relationship between the Li/Fe ratio and Li and Fe for slurry. For example, if the Li/Fe ratios for two samples differ by 10%, the best estimate of the differences in Li and Fe are 3.30% $\pm$ 0.11% and -6.95% $\pm$ 0.12, respectively.

3.2 Comparison of Sampling with Coliwasa and Grab Sampler

All of the slurry samples collected from the slurry reservoir during the earlier Melter Feed Loop Tests and most of reservoir samples collected during the Hydragard Test were collected using a Coliwasa (Section 2.4) which is the best available method for sampling slurry from tanks in the 20 gallon to 150 gallon range. All of the slurry samples collected directly from the MFT or SME during tests at DWPF were collected using a grab sampler. Because of the long handle on the grab sampler it can be used to collect a sample from a 10,000 gallon tank. The heart of the grab sampler is a hollow stainless steel cylinder that can hold one 15 mL sample vial. The grab sampler has three 0.50" holes arranged around the circumference which can be covered or exposed. To use the grab sampler an empty vial is placed inside the cylinder and the holes are covered. The cylinder is lowered into the tank to the desired elevation at the end of a boom. The holes are exposed for 10 seconds and then covered. The grab sampler is removed from the tank, the vial is removed from the cylinder, the outside of the vial is cleaned and it is capped. Twice during testing of the Hydragard Loop, on 11/02/94 and 11/17/94, a direct comparison was made of the Coliwasa and the grab sampler. A total of eight vials were filled directly from the reservoir using the grab sampler and eight vials were filled by filling the Coliwasa three times from the reservoir, emptying them into

a stirred flask and pouring slurry into vials. The results are listed in tabular form in Table 4. The average Li/Fe ratios for the grab sampler on the two dates were 0.220 ± 0.002 and 0.222 ± 0.001 . The average Li/Fe ratios for the Coliwasa samples on the two dates were 0.230 ± 0.003 and 0.229 ± 0.003 . Therefore, on average, the grab sampler read a 3.7% lower Li/Fe ratio than the Coliwasa sampler.

3.3. Tests With Original Hydragard Valve

The flow loop was run with the original Hydragard valve with both TNX slurry and DWPF slurry, for three rheologies for the TNX slurry and two rheologies for the DWPF slurry, and for transfer flows of 4 gpm, 6 gpm, 8 gpm and 10 gpm. Most of the runs were done at 30°C. A few of the runs were done at 30°C with air being added to the slurry or at 40°C and no air added. The overflow from the Hydragard and a sample of the slurry reservoir were nearly always collected and their densities measured. For a smaller number of runs the contents of the slurry reservoir, the sample vial or the overflow were analyzed for elemental composition. The density of the slurry in a 15 mL vial could not be measured because the highly accurate method used required that 350 mL of slurry be collected in a 500 mL flask. Hydraulic data, slurry densities, hardware type code, date and time from the runs are listed in Table 3. The code for the original hardware is 1. The results of chemical analyses are listed in Table 4.

The primary method for tracking performance was the use of slurry density. Slurry densities for the reservoir, the overflow for the Hydragard vial are plotted in Figure 9 versus run number. The reservoir slurry density increased and decreased as water evaporated from the slurry or when the slurry was intentionally diluted or when the slurry was removed and replaced with a different type. The density of the slurry at the overflow agreed fairly well with the reservoir slurry for the TNX slurry at 110 dynes/cm², but not well for TNX slurry at 60 dynes/cm². It is not known how well the original hardware would sample TNX slurry at 30 dynes/cm². The points listed for runs 81 and 82 had vial flows forced to be higher than normal and the effect of vial flow on sampling will be discussed. The original hardware sampled DWPF slurry at 240 and 83 dyne/cm² fairly well. The percentage difference between the density of the slurry at the overflow and the slurry reservoir is shown as a function of run number in Figure 10. The percentage difference between the density of the slurry at the overflow and the slurry reservoir is plotted in Figure 11 as a function of transfer flow and vial flow. Data for flows of 8 and 10 gpm were consolidated because there were only two runs at 10 gpm. There is a clear trend for all three graphs. For the higher vial flows the sampling was fairly good, although the density of the overflow slurry was as much as 0.5% lower than the slurry in the reservoir. As the vial flow decreased the stream that was drawn off was biased high in frit. This is consistent with the results reported by Nasr-El-Din [1985] using side wall sampling. Some of the Nasr-El-Din tests employed a projection into the main flow stream near the point of draw off. The side stream tended to be enriched in sand and the enrichment increased as the side flow decreased. Significant sand enrichment was observed for velocity ratios less than 0.4. A typical transfer flow in the Hydragard loop was 8 gpm or a velocity of 8.5 ft/sec. A typical vial flow was 1.5 gpm. The diameter of the end of the plunger was 0.625" and the plunger protruded 0.25" so that the flow area past the plunger was 0.5 inch². The slurry velocity through that flow area was 1 ft/sec. The velocity ratio for those typical flows was 0.12, which is smaller than the velocity ratio below which Nasr-El-Din observed sand enrichment. Some of the points in Figure 11 had vial flows that were forced to be higher or lower. Lower vial flows were achieved by installing a partially closed ball valve between the plunger and the vial. Higher vial flows were achieved by installing a partially closed ball valve at the end of the transfer line to increase the pressure in the transfer line. Figure 12 shows the data from Figure 11 but with those runs having vial flows forced higher or lower deleted. All of the variation in vial flows shown in Figure 12 occurred naturally in the testing. Some, but not all, of the variation can be explained by differences in slurry rheology. The rest of the variation may be the result of partial pluggage of the internal flow passages of the Hydragard valve. Considering all of the points plotted on Figure 11 for the original hardware the average and maximum slurry density increases at the overflow were 0.53%

and 2.25%, respectively. Using Figure 7 this corresponds to an increase in Li/Fe ratio of 4% and 17%, respectively.

Comparison of data from the TFL Hydragard Loop with data from the Hydragard samplers is hampered by the fact that no vial flows were measured at DWPF and sampling is affected by vial flow. Figure 10 in a report by Edwards [1994] compared measured Fe/Li ratios for the low grab sampler and the Hydragard for Phase 2 of FA-10.02 Extended testing at DWPF. The average Li/Fe ratios for the low grab and the Hydragard were 0.334 ± 0.004 and 0.299 ± 0.008 , respectively. Using the result from Section 3.2 of this report, the grab sampler read about 3.7% lower Li/Fe than the Coliwasa, so it is inferred that the Coliwasa would have collected a sample having Li/Fe equal to 0.346. Referring to Figure 11, for high vial flows the original Hydragard can draw a sample having an decrease in density with respect to the Coliwasa of as much as about 0.5% or about 4.5% in terms of Li/Fe. Reducing the inferred Li/Fe for the Coliwasa by 4.5% gives the inferred Li/Fe for the vial overflow of 0.331. On average, the Li/Fe ratio for the vial is 3.7% less than the Li/Fe for the vial overflow. Reducing the inferred Li/Fe for the vial overflow by 3.7% gives the inferred Li/Fe for the vial of 0.319, which is in approximate agreement with the DWPF value of 0.299.

3.4 Design and Testing of Modified Hydragard Valve

Tests of the original Hydragard indicated that the composition of the slurry that was drawn off tended to be frit rich and the composition was a function of the draw off flowrate. This agreed with the Nasr-El-Din results for side wall sampling with a projection. Therefore it was decided to test a modified Hydragard without a projection into the transfer line. A few tests were run in which the plunger was replaced with a rod having a diameter of 0.25". The end of the rod was positioned flush with the inside of the transfer line. A ball valve between the rod and the vial was used to start and stop flow to the vial. This was not a usable design for DWPF but was done to quickly test the concept of removing the projection. Accuracy of slurry sampling immediately improved. Then the rod was replaced with a plunger having a somewhat smaller diameter than the original plunger and having a straight back side rather than the hemispherical back side of the original, Figure 13. The smaller plunger was adjusted to that its outer face was flush with the inside of the transfer line when it was in the open position. It also gave good sampling results. Finally the Swagelok tee that holds the Hydragard valve was modified so that the original plunger could be used. Two Swagelok tees were cut and welded back together so that the side arm was 0.25" longer. The original plunger was reinstalled and adjusted so its outer surface was flush with the inside of the transfer line when the valve was open, Figure 5. The outer surface of the plunger was retracted 0.25" when the valve was closed. The modified Hydragard valve is different than the original valve in two ways. First, the plunger does not protrude into the flow stream so that frit enrichment is not expected. Second, the flow area is less by a factor of roughly four so that the velocity of sampling increases by the same factor. Nasr-El-Din showed that increasing the velocity of sampling increased the accuracy of sampling. The modified design would appear to be more restrictive and allow less slurry to flow through the valve. This was not the case. A pressure tap on the side of the Hydragard valve read nearly the same pressure as in the transfer line. This showed that the vial, not the plunger, was the dominant flow resistance.

As was the case for the testing of the original Hydragard, the primary method for tracking performance was the use of slurry density. Slurry densities for the reservoir and the overflow for the Hydragard vial are plotted in Figure 9 versus run number. Sampling was always good. The percentage difference between the density of the slurry at the overflow and the slurry reservoir is shown as a function of run number in Figure 10. Considering all of the points plotted on Figure 10 for the modified hardware the average and maximum density increases at the overflow was -0.007% and 0.5%, respectively, which are negligible errors and a great improvement over the performance of the original Hydragard valve.

The percentage difference between the density of the slurry at the overflow and the slurry reservoir is plotted in Figure 11 as a function of transfer flow and vial flow. Some of the points had

intentionally increased or decreased vial flows. Runs for intentionally decreased vial flow are identified in Table 3, the tabular hydraulic data, by having "Low vial flow" equal to 1. Runs for intentionally increased vial flow are identified in Table 3, the tabular hydraulic data, by having "High vial flow" equal to 1. The percentage difference between the density of the slurry at the overflow and the slurry reservoir is plotted in Figure 12 for only those runs in which the vial flow was not forced. The modified Hydragard drew an accurate sample for all vial flows, transfer flows, both types of slurry and different slurry dilutions.

3.5 Chemical Analyses of Slurry

For some of the runs, chemical analyses were performed for the contents of sample vials, samples drawn from the slurry reservoir using the Coliwas and for vial overflow samples. Chemical analyses and density measurements of slurry overflowing sample vials further validated the relationship between changes in Li/Fe ratio and changes in slurry density. Chemical analyses are important because the chemical analysis of Hydragard sample vials is used to monitor the composition of the SME and MFT. The contents of 158 vials were analyzed and the results are listed in Table 4. A listing of vial numbers and the conditions at which they were collected is listed below. There are gaps in the numbers because some of the vials were never analyzed.

Vials	Date	Time	Conditions
213-215	10/27	11:00	TNX slurry, original hardware, Hydragard valve open 5 s
216-218	10/27	11:05	original hardware, Hydragard valve open 60 sec.
219-221	10/27	11:11	original hardware, Hydragard valve open 10 min.
226-235	11/02	13:54	smaller diameter plunger recessed 0.25"
236-245	11/16	10:16	extended Swagelok tee, 0.25"
246-253	11/17	12:34	extended Swagelok tee
255-264	11/23	09:31	original hardware
265-274	12/01	21:41	DWPF slurry, extended Swagelok tee
276-286	12/03	16:30	DWPF slurry, extended Swagelok tee
287-296	12/04	12:12	TNX slurry, extended Swagelok tee
298-307	12/05	10:21	TNX slurry, original hardware
308-317	12/06	10:01	TNX slurry, original hardware
337-346	12/09	16:53	TNX slurry, extended Swagelok tee
347-356	12/09	17:15	TNX slurry, extended Swagelok tee
357-366	12/09	16:53	TNX slurry, extended Swagelok tee
377-396	12/13	13:53	TNX slurry, extended Swagelok tee
377-396	12/13	14:17	TNX slurry, extended Swagelok tee, valve snapped shut
397-406	02/15	0927	TNX slurry, original hardware

The modified Hydragard valve was tested with two slurries having different dilutions, for a range of transfer flowrates and a range of vial flowrates. In Section 3.4 it was shown that the modified Hydragard drew a slurry stream having the same density, on average, as the slurry in the reservoir. Section 3.1 and Figure 8 showed a linear, well defined relationship between changes in slurry density and changes in Li/Fe ratio. For two runs chemical analyses were performed on slurry flowing out of the vial. The chemical analyses for the overflow and the reservoir agreed and the slurry densities for the overflow and the reservoir agreed. However, for those two runs the Li/Fe ratios for the sample vial filled by the Hydragard were lower than for the slurry flowing through the vial. In addition, the measured Li/Fe ratios for the Hydragard vials were lower than expected from the density of the overflow slurry. This relationship is shown in Figure 14 which plots the Li/Fe ratio for the Hydragard vial divided by the Li/Fe ratio for the slurry in the reservoir versus the slurry density at the vial overflow divided by the slurry density in the reservoir. For reference, the least squares fit from Figure 8 is plotted. For Figure 8 elemental compositions and densities were measured at the same locations. For Figure 14 elemental composition was measured at the vial and density was measured at the vial overflow. The uncertainty bars

for most of the points plotted in Figure 14 cross the least squares fit from Figure 8 but tend to have lower values of normalized Li/Fe ratio. The least squares fit through the data of Figure 14 follows.

$$\frac{\text{Li/Fe}_{\text{vial}}}{\text{Li/Fe}_{\text{res}}} = -7.4045 + 8.3595 \frac{\rho_{\text{overflow}}}{\rho_{\text{res}}} \quad (4)$$

For a perfect match of slurry density the x axis is 1.000. The corresponding y coordinate for the fit is 0.955, or 4.5% lower than expected. Figure 15 shows the same data but shows the 95% confidence interval for the linear fit. At an x axis value of 1.000 the confidence limits on the linear fit are ± 0.013 . Therefore, increasing the average Li/Fe ratio measured for Hydragard vials by 4.5%, which has an uncertainty of $\pm 1.3\%$, will give the best estimate Li/Fe ratio for the tank being sampled. Section 3.1 mentioned that differences in Li and Fe were 33.0% and -69.5% as large as differences in Li/Fe. Therefore, the difference in Li/Fe of 4.5% corresponds to differences of 1.5% and -3.1% for Li and Fe, respectively.

Lithium and iron are generally considered to be the best tracers for frit and sludge respectively. However, silicon and aluminum are nearly as good. As a consistency check a plot was made of Si/Al vs. Li/Fe. For a given slurry a plot was expected to give a linear relationship. The plot is shown in Figure 16 and there is a linear relationship with significant scatter for both the TNX and DWPF slurries.

For most of the times that vials were filled the valve was in the open position for about 7 seconds and the valve was closed manually which required about 150 milliseconds. A few times the valve was held open for 30 seconds and manually closed and a few times the valve was held open for 7 seconds and snapped shut which required 50 milliseconds. The graph on the left side of Figure 17 plots the measured value of Li/Fe for the contents of the vial divided by the predicted value of Li/Fe based on the density of the slurry flowing through the vial (Equation 2) versus the flow rate through the vial. There are no discernible trends in the data with respect to vial flow, valve open time and valve closure time. The graph on the right side of Figure 17 is a similar plot but where the symbols indicate different slurry types and densities. Again, there are no discernible trends in the data.

3.6 Relationship of Vial Flow to Transfer Flow, Pressure and Rheology

The flow past the Hydragard plunger and through the vial is characterized by increases and decreases in flow area and also changes in flow direction. Therefore, it is expected that the pressure drop through the Hydragard valve will be proportional to slurry density times flowrate squared. The pressure measurement available at DWPF is located 19" above the Hydragard valve. The corresponding pressure measurement is labeled TR-3411 on Figure 3. The overflow from the valve is referenced to atmospheric pressure 30" below the Hydragard. Neglecting the frictional loss in the transfer line from the Hydragard to the pressure tap the pressure drop necessary to drive slurry through the Hydragard is the pressure indicated on the DWPF pressure gage plus 49" head of slurry. Because the correction for 49" head of slurry is relatively small, a typical slurry density of 1.35 g/mL was used for the elevation correction rather than using the actual density for each elevation correction. The DWPF pressure transducer is located at the point of measurement. The TFL pressure transducer is located lower and is connected to the point of measurement with a water filled tube. When the TFL loop is empty, the pressure gage (TR-3411) reads 8.8 psi. Therefore, for the TFL loop the pressure drop necessary to drive slurry through the Hydragard is the pressure indicated on TR-3411 minus 8.8 psi plus 2.4 psi (49" of slurry). Figure 18 is a plot of vial flowrate squared times actual slurry density versus the pressure loss through the Hydragard (the reading of TR-3411 minus 6.4 psi). Runs for which the vial flow was intentionally decreased were not plotted. For all five slurry densities there is a linear relationship between the maximum value of vial flow squared times density and driving pressure drop. However, there are many points for

tests with TNX slurry with vial flows less than indicated by the linear relationship. The reason for this is not known but may be caused by partial plugging of the internal passages of the Hydragard valve. Figure 18 shows no reduced vial flows for DWPF slurry. The accuracy of slurry sampling by the modified Hydragard valve is much less dependent on the flow through the valve and vial than was the case for the original Hydragard. Installing the modified Hydragard valve at the SME and MFT would make the issue of variable flows less important. The line of maximum flow marked on Figure 18 does not go through the origin because the slurries are Bingham plastics and a certain pressure drop is necessary to initiate flow.

4.0 UNRESOLVED ISSUE

There is an unresolved issue that should be resolved with further experiments at the TFL Melter Feed Loop. While the modified Hydragard sampler draws a slurry stream that is representative of the slurry in the slurry reservoir, the 15 mL of slurry that remains in the sample vial filled by the Hydragard valve has a lower lithium to iron ratio by 4.5%, on average. There is a significant variability in Li/Fe from vial to vial, typically $\pm 6\%$. Some tests have been run to determine the cause for the lower Li/Fe ratio and the variability. Two different valve open times were used, 7 seconds and 30 seconds. Also two different valve closing times were employed. Manual valve closure requires 150 msec and allowing the return spring to snap the valve shut requires 50 msec. None of the changes eliminated the difference between the composition of the slurry flowing through the vial and the slurry that remained in the vial. It is recommended that further tests be run at the TFL to determine the cause of this difference and, if possible, eliminate it. The difference may be related to the high velocity at which slurry flows into the vial, as much as 30 ft/sec. Chemical analyses of the Hydragard vials could be adjusted to give a best estimate of the contents of the tanks that they sample. For example, the average lithium to iron ratio measured for a group of sample vials would be increased by 4.5% to give the best estimate of the contents of the tank. Iron content would be decreased by 3.1%.

5. CONCLUSIONS AND RECOMMENDATIONS

The original Hydragard valve was tested in a prototypic flow loop with two types of slurry which contained glass frit. In many experimental runs the original Hydragard valve drew a non-representative slurry sample. The sampling error ranged from frit rich to frit poor and the magnitude of error in sampling depended on the flowrate through the valve and sample vial.

A relatively simple modification of the Hydragard valve was made which allowed the valve to draw off a slurry stream that closely matched the composition of slurry reservoir. During testing with two different slurries each with different dilutions and a range of transfer flows and vial flows, the modified Hydragard removed a slurry stream having a composition very close to that in the slurry reservoir. By contrast the original Hydragard valve drew a sample having a composition that depended on vial flowrate. ETF recommends that the Hydragard valves on the MFT and SME be modified.

While the modified Hydragard valve clearly draws a more representative sample stream, ETF recommends that unresolved issues concerning the variability of Hydragard samples and the difference in composition between the Hydragard sample vial and the slurry stream that flowed though it be investigated.

6. ACKNOWLEDGEMENTS

Tim Steeper designed and supervised the construction of the flow loop which has many useful features. Steeper also designed the modification of the Hydragard valve. Keith Rohleder wrote the test procedure, chose the instruments, analyzed the instrument calibration data, made the drawings of the flow loop that appear in this report and reduced data from the experiment. Mike Armstrong constructed part of the flow loop, did most of the actual testing, refined the technique of accurate density measurements of the slurry and made valuable suggestions about the details of operating the

loop. Jerry Corbett, Andy Foreman and Tony Kinsey worked very fast to construct the loop. The TNX Analytical Laboratory, Curtis Johnson and Jim Marek performed many careful chemical and rheological analyses.

7. REFERENCES

Abernethy, R. B., Benedict, R. P., and Dowdell, R. B., "ASME Measurement Uncertainty", *J. Fluids Engineering*, vol. 107, p. 161, 1985.

Bahr, H. M., Baladi, J. Y., England, A. D., Gill, G. L., Hollman, D. D., Johnson, L. E., Little D. B., Purhoit, J. J., "Report in the DWPF Vertical Cantilevered Centrifugal Pump Operability and Reliability", M-ESR-S-0005, November 1993.

Edwards, R. E., HLW/DWPF/TTR-940011, October 31, 1994.

Edwards, T. B., "Statistical Analysis of Data from the Modified FA-10.02 Extended Testing at DWPF", SRT-ASG-940012, February 25, 1994.

Hinds International, Inc., "Instruction Manual for Model 1813 In-Line Closed Loop Liquid Sampler System", 1986.

Kirk-Othmer, *Encyclopedia of Chemical Technology*, vol. 20, page 535, 1994.

Marek, J. C., "Rheological Properties of DWPF FA 10.02 Concentrates", SRTC-PTD-94-0021, March 9, 1994.

Nasr-El-Din, H., Shook, C. A., and Esmail, M. N., "Wall Sampling in Slurry Systems", *Can. J. Chem. Eng.*, Vol. 63, pp. 746-753, 1985.

Randall, C. T. and Smith, F. G., "Program Plan for Mitigation of Frit Segregation in DWPF Hydragard Sample and Melter Feed Systems, WSRC-RP-94-1113, September 26, 1994.

Rohleder, K. H., "Hydragard Loop Operating Procedure", FP-593, Rev. 0., October 19, 1994.

Smith, F. G., Technical Task Request 94-DWPT-PMC-T0004, Rev. 1, September 12, 1994.

Steimke, J. L., Fowley, M. D. and Guerrero, H. N., "Hydraulic Testing of Type Q Septifoils Including Modifications, WSRC-TR-92-370, September 1992.

Steimke, J. L., Task Plan "TFL Hydragard Loop", SRT-ETF-TT-94-008-1, 1994 a.

Steimke, J. L., "Results of Tests of TFL Melter Feed Loop, WSRC-TR-94-0570, November 1994 b.

TABLE 1
Notes on Hydragard Loop and Slurry Changes

<u>Date</u>	<u>Time</u>	<u>Action</u>
1018		Test started using TNX slurry with density = 1.35 g/mL
1020	11:00	Learned that sample vial had not been pushed on all the way
1021	13:35	Replaced vial because flow had decreased
1027	06:30	Diluted TNX slurry to density = 1.31 g/mL
1027	12:30	While making long runs lost vial flow, then purged with water
1101	16:00	Installed 0.80" orifice plate in recirculation line
1107	13:30	Replaced 0.80" orifice plate in recirculation line with 9/16" orifice plate
1111		Installed extended Swagelok for Hydragard
1117	10:48	Diluted TNX slurry to density = 1.27 g/mL
1118	09:45	Installed 3/4" ball valve at end of transfer line to increase vial flow and installed original Hydragard
1121	09:15	Replaced original Hydragard with modified Hydragard
1122	13:30	Opened 3/4" ball valve so had normal vial flow, then installed 1/4" ball valve at Hydragard valve
1123	08:15	Removed 1/4" ball valve
1201	09:00	Original slurry was removed and replaced with DWPF slurry with density = 1.46 g/mL. Replaced 3/4" tubing leading to Hydragard valve with 1" tubing to reduce pressure at pump and allow more transfer flow.
1202	17:30	Replaced modified Hydragard with original Hydragard
1203	13:40	Diluted DWPF slurry to density = 1.38 g/mL
1203	16:00	Installed modified Hydragard
1204	08:00	Removed DWPF slurry and replaced with condensed TNX slurry having density = 1.35 g/mL
1205	09:00	Reinstalled original Hydragard
1205	15:00	Diluted TNX slurry to density = 1.32 g/mL
1206	08:40	Restored transfer line to original piping
1207	09:00	Reinstalled 1/4" ball valve restricting vial flow, log 1207 1012 had restricted flow
1208	13:30	Installed modified Hydragard with ball valve still in place
1208 &	12:09	Some vial flows were reduced using 1/4" ball valve
1213	11:30	Linear displacement gage installed on Hydragard valve handle

TABLE 2

HYDRAGARD LOOP INSTRUMENTS

The following is a listing of the instrumentation being used on the Hydragard Loop experiment compiled by K. H. Rohleder on October 17, 1994.

Pressure:

TR-2146, range output: 4 to 20 mAmps; range input 0 to 75 psig, tol. ± 0.2 psi
TR-2919, range output: 4 to 20 mAmps; range input: 0 to 75 psig, tol. ± 0.2 psi
TR-3279, range output: 4 to 20 mAmps; range input: 0 to 75 psig, tol. ± 0.2 psi
TR-3282, range output: 4 to 20 mAmps; range input: 0 to 75 psig, tol. ± 0.2 psi
TR-3411, range output: 4 to 20 mAmps; range input: 0 to 50 psig, tol. ± 0.2 psi
TR-3412, range output: 4 to 20 mAmps; range input: 0 to 50 psig, tol. ± 0.2 psi
TR-20305, range output: 4 to 20 mAmps; range input: 0 to 50 psid, tol. ± 0.2 psid
TR-3413, range output: 4 to 20 mAmps; range input: 0 to 5 psid, tol. ± 0.02 psid

Air:

TR-21628, range output: 0 to 5 volts; range input: 0 to 45 slpm, tolerance ± 2 slpm
TR-21629, range output: 0 to 5 volts; range input: 0 to 45 slpm, tolerance ± 2 slpm

Temperature:

TR-1515, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C
TR-1520, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C
TR-1523, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C
TR-1525, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C
TR-1526, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C
TR-1544, E-type, 1/8 diameter sheath; tolerance ± 1.7 °C

Liquid Flow:

TR-20347, range output: 4 to 20 mAmps; range input: 0 to 20 gpm, ± 0.15 gpm
TR-20350, range output: 4 to 20 mAmps; range input: 0 to 50 gpm ± 0.284 gpm
(Accuracy state above was for calibration, because of required meter location near pump actual accuracy was ± 5 gpm)
TR-20352, range output: 4 to 20 mAmps; range input: 0 to 2.5 gpm ± 0.03 gpm

TABLE 2, continued
INSTRUMENTS

Instrument Calibrations

Instrument calibrations are listed below. The general equation is

$$\text{output} = A * \text{input}^2 + B * \text{input} + C$$

The input can be volts or ma. The output can be psi or gpm or °C.

measurement	instrument number	A	B	C	tap elevation/s	
flow vial	TR-20352	0.000	0.156	-0.628		
flow transfer	TR-20347	0.000	1.250	-5.003		
flow recirculation	TR-20350	0.000	3.115	-12.427		
differential pressure	TR-20305	0.000	3.125	-12.528	101"	41"
pressure	TR-3411	0.000	3.185	-12.761	281"	
pressure	TR-3412	0.000	3.185	-12.834	81"	
pressure	TR-2146	0.000	4.695	-18.850	99"	
pressure	TR-2919	0.000	4.695	-18.779	128"	
pressure	TR-3279	0.000	4.695	-18.854	260"	
pressure	TR-3282	0.000	4.695	-18.840	262"	
differential pressure	TR-3413	0.000	0.313	-1.259	99"	81"
air flow 1	TR-21628	0.000	8.835	0.655		
air flow 2	TR-21629	0.000	9.267	-0.211		

TABLE 3
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	1	2	3	4	5	6	7	8	9
day	1	1018	1018	1018	1018	1018	1020	1020	1020
time	2	1253	1410	1415	1419	1424	933	1035	1041
hardware	3	1	1	1	1	1	1	1	1
flow vial TR-20352 0-2.5 gpm	4	0	0	0	0	0	0.417	0.397	1.918
flow trans TR-20347 0-20 gpm	5	0	2.017	0	0	7.94	0	1.955	2.077
flow recirc TR-20350 0-50 gpm	6	0	32.511	26.267	18.347	44.067	0	34.059	37.14
DP pump TR-20305 0-50 psid	7	1.663	29.164	18.902	9.833	61.75	1.694	29.75	29.944
P dnstr HG TR-3411 0-50 psig	8	9.038	13.732	8.28	5.305	30.139	8.843	13.853	13.925
P flow res TR-3412 0-50 psig	9	1.13	24.489	24.456	24.427	24.383	0.949	25.651	25.826
P pump dis TR-2146 0-75 psig	10	2.458	28.82	18.646	9.598	60.98	2.256	29.463	29.641
P branch TR-2919 0-75 psig	11	2.776	27.24	17.324	8.506	58.589	2.351	27.754	27.981
P HG supply TR-3279 0-75 psig	12	8.151	14.126	8.593	5.489	31.93	7.897	14.404	14.491
P vial TR-3282 0-75 psig	13	-0.173	-0.191	-0.188	-0.19	-0.195	7.533	13.93	14.014
DP orifice TR-3413 0-5 psid	14	0.679	0.396	0.2	-0.009	1.005	0.673	0.589	0.597
air 1 TR-21628 0-50 slpm	15	0.681	0.682	0.681	0.681	0.682	0.672	0.683	0.681
air 2 TR-21629 0-50 slpm	16	-0.191	-0.19	-0.19	-0.19	-0.189	-0.191	-0.191	-0.192
T reserv TR-1523 °C	17	19.376	21.812	22.062	22.047	22.661	21.277	29.288	29.835
T amb lo TR-1520 °C	18	22.956	21.918	21.975	21.782	21.999	19.436	20.117	19.97
T vial TR-1525 °C	19	-44.82	-179.268	-179.129	-179.14	-179.367	19.551	28.585	29.321
T transfer TR-1526 °C	20	24.631	22.37	22.559	22.662	23.266	20.431	29.555	30.405
T amb hi TR-1544 °C	21	26.072	24.999	25.005	25.011	24.893	19.526	20.404	20.529
T recirc TR-1515 °C	22	24.96	21.935	22.146	22.215	22.792	20.14	29.643	30.466
pump speed %	23	0.15	99.894	79.943	58.981	99.872	0	99.959	0.15
flrst line averaged	24	0	0	0	0	0	0	0	0
last line averaged	25	0	0	0	0	0	0	0	0
F trans m gpm	26	0	#NA	#NA	#NA	#NA	0	#NA	#NA
F vial m gpm	27	0	#NA	#NA	#NA	#NA	0	#NA	#NA
rho reser 1 g/cc	28	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho reser 2 g/cc	29	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 1 g/cc	30	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2 g/cc	31	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1 g/cc	32	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 2 g/cc	33	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
std recirc gpm	34	#NA	4	0.72	0.09	#NA	#NA	2.99	4.46
pump on?	35	0	0	0	0	100	0	0	100
air cor slpm		-0.01	-0.01	-0.01	-0.01	-0.00	-0.02	-0.01	-0.01
discrep 1 for density		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
discrep 2 for density		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
high vial flow		0	0	0	0	0	0	0	0
low vial flow		0	0	0	0	0	0	0	0
normal vial flow		1	1	1	1	1	1	1	1
slurry type		1	1	1	1	1	1	1	1

TABLE 3, continued

column of data		10	11	12	13	14	15	16	17	18	19	20
day		1020	1020	1020	1020	1020	1020	1021	1021	1021	1021	1021
time		1239	1243	1248	1258	1301	1314	851	1021	1026	1339	1413
hardware		1	1	1	1	1	1	1	1	1	1	1
flow vial	TR-20352	1.531	1.211	0.986	0.884	0.998	1.846	0	0.961	0.837	1.825	1.204
flow trnsfr	TR-20347	4.652	2.88	1.602	1.021	1.679	7.119	0	1.23	#NA	7.149	4.519
flow recirc	TR-20350	38.799	33.04	36.657	33.336	36.667	46.74	0	34.336	32.206	54.252	43.22
DP pump	TR-20305	43.747	34.792	29.478	27.178	29.741	61.905	1.707	29.595	26.918	61.558	43.299
P dnstr HG	TR-3411	19.145	15.421	13.211	12.276	13.384	25.539	8.916	13.515	12.346	25.654	19.339
P flow res	TR-3412	38.126	30.182	25.377	23.344	25.574	54.478	0.78	25.45	23.01	54.106	37.678
P pump dis	TR-2146	43.168	34.348	29.09	26.829	29.306	61.105	2.201	29.282	26.54	60.704	42.666
P branch	TR-2919	41.019	32.553	27.462	25.265	27.69	58.297	2.154	27.591	24.942	58.064	40.691
P HG supply	TR-3279	19.962	15.863	13.513	12.648	13.772	27.354	7.954	13.929	12.705	27.405	20.43
P vial	TR-3282	19.42	15.435	13.121	12.191	13.304	26.185	7.707	13.374	12.17	26.387	19.698
DP orifice	TR-3413	0.768	0.698	0.604	0.415	0.602	1.094	0.686	0.633	0.579	1.025	0.826
alr 1	TR-21628	0.681	0.682	0.681	0.681	0.682	0.683	0.681	0.682	0.682	0.683	0.682
alr 2	TR-21629	-0.191	-0.19	-0.191	-0.19	-0.189	-0.19	-0.191	-0.19	-0.19	-0.187	-0.188
T reserv	TR-1523	30.181	29.88	29.571	29.697	29.625	30.068	23.346	30.424	28.151	35.963	33.857
T amb lo	TR-1520	20.903	20.721	20.668	21.127	21.125	21.256	18.039	20.808	20.73	22.378	22.297
T vial	TR-1525	30.822	30.65	30.451	30.339	30.425	31.115	19.452	33.703	33.435	35.446	33.294
T transfer	TR-1526	31.517	31.376	31.226	31.003	31.146	31.769	19.326	34.285	34.278	36.011	33.868
T amb hi	TR-1544	22.17	22.066	21.811	22.025	22.016	22.054	19.288	20.933	20.814	23.919	24.23
T recirc	TR-1515	31.318	31.241	31.211	31.126	31.084	31.522	19.504	34.504	34.473	35.829	33.731
pump speed		62.016	35.078	0.15	95.536	99.965	99.947	0.15	99.887	94.587	99.93	61.515
first line	averaged	0	0	0	0	1	1	0	1	1	1	1
last line	averaged	0	0	0	0	62	61	0	62	108	100	60
F trnsfr m		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
F vial m		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	1.189
rho reser 1		#NA	#NA	#NA	#NA	#NA	1.3483	#NA	#NA	#NA	#NA	#NA
rho reser 2		#NA	#NA	#NA	#NA	#NA	1.3485	#NA	#NA	#NA	#NA	#NA
rho trns 1		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over	flow 1	#NA	#NA	#NA	#NA	#NA	1.3514	#NA	#NA	#NA	#NA	#NA
rho over	flow 2	#NA	#NA	#NA	#NA	#NA	1.3511	#NA	#NA	#NA	#NA	#NA
std recirc		5.83	4.01	5.42	2.74	3.25	9.04	0.00001	2	1.43	#NA	4.54
pump on?		100	100	100	0	0	100	0	0	0	100	100
alr cor		-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.01	-0.01	-0.01	-0.00	-0.00
discrep 1	for density	#NA	#NA	#NA	#NA	#NA	0.2299	#NA	#NA	#NA	#NA	#NA
discrep 2	for density	#NA	#NA	#NA	#NA	#NA	0.1928	#NA	#NA	#NA	#NA	#NA
high vial	flow	0	0	0	0	0	0	0	0	0	0	0
low vial	flow	0	0	0	0	0	0	0	0	0	0	0
normal	vial flow	1	1	1	1	1	1	1	1	1	1	1
slurry	type	1	1	1	1	1	1	1	1	1	1	1

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	21	22	23	24	25	26	27	28	29	30	31
day	1021	1021	1021	1025	1025	1025	1025	1025	1025	1025	1027
time	1426	1505	1520	1201	1309	1330	1340	1347	1423	1615	850
hardware	1	1	1	1	1	1	1	1	1	1	1
flow vial	1.168	0.612	0.605	0	0	1.887	1.908	1.874	1.637	0	0
flow transr	4.526	1.857	1.848	0	6.986	5.974	5.986	5.957	6.1	0	0
flow recirc	42.366	35.287	35.136	19.856	48.066	43.914	54.635	43.706	56.191	0	0
TR-20350	43.349	30.978	31.025	1.692	54.96	54.892	54.863	54.774	54.899	0.901	1.617
TR-20305	19.396	14.272	14.218	8.531	26.362	23.454	23.568	23.553	23.906	8.363	8.983
TR-3411	37.617	26.49	26.454	1.194	48.058	48.036	47.989	47.9	47.999	-0.41	1.004
TR-3412	42.629	30.386	30.35	2.573	54.189	54.087	54.075	53.968	54.1	0.704	2.525
TR-2146	40.692	28.944	28.885	2.654	51.931	51.387	51.662	51.495	51.727	1.108	2.305
TR-2919	20.479	14.742	14.685	7.569	27.695	24.749	24.827	24.869	25.217	7.459	8.09
TR-3279	19.761	14.275	14.219	7.541	7.433	23.689	23.773	23.844	24.295	7.576	7.763
TR-3282	0.849	0.688	0.698	0.669	0.947	0.947	0.956	0.938	0.945	0.615	0.637
TR-3413	0.682	0.682	0.681	0.681	0.681	0.681	0.681	0.682	0.682	0.681	0.681
TR-21628	-0.187	-0.19	-0.192	-0.191	-0.19	-0.19	-0.189	-0.19	-0.19	-0.191	-0.191
TR-21629	33.132	31.469	31.028	20.19	30.013	30.24	30.269	30.274	30.293	29.973	20.209
TR-1523	22.592	22.243	22.176	19.885	21.92	22.403	22.488	22.487	22.976	22.217	17.391
TR-1520	32.623	30.844	30.432	21.009	22.549	29.633	29.861	29.916	29.93	26.439	20.072
TR-1525	33.182	31.468	30.992	20.272	30.168	30.537	30.465	30.452	30.477	27.263	19.836
TR-1526	24.335	24.508	24.656	21.089	23.019	23.55	23.58	23.683	24.267	23.448	20.309
TR-1544	33.031	31.445	30.974	20.465	29.949	30.237	30.191	30.181	30.203	24.045	19.814
TR-1515	61.511	9.631	9.635	0.15	86.967	86.97	86.971	86.971	86.967	0.15	0.15
pump speed	1	1	1	0	1	83	23	22	28	0	0
first line averaged	60	70	60	0	60	85	79	65	68	0	0
last line averaged	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
F transr m	#NA	0.604	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
F vial m	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho reser 1	#NA	#NA	#NA	#NA	1.3523	#NA	1.3523	1.3523	1.3529	#NA	#NA
rho reser 2	#NA	#NA	#NA	#NA	1.35	#NA	1.35	1.35	1.3519	#NA	#NA
rho trns 1	#NA	#NA	#NA	#NA	1.3519	#NA	#NA	#NA	1.35	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	1.3494	#NA	#NA	#NA	1.3507	#NA	#NA
rho over flow 1	#NA	#NA	#NA	#NA	#NA	#NA	1.3483	1.359	1.3593	#NA	#NA
rho over flow 2	#NA	#NA	#NA	#NA	#NA	#NA	1.3504	1.3541	1.3599	#NA	#NA
std recirc	4.79	2.02	2.1	0	6.75	6.54	5.88	6.92	5.78	0	0
pump on?	100	100	100	0	100	100	100	100	100	0	0
air cor	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
discrep 1 for density	#NA	#NA	#NA	#NA	#NA	#NA	-0.2958	0.4955	0.4731	#NA	#NA
discrep 2 for density	#NA	#NA	#NA	#NA	#NA	#NA	0.0296	0.3037	0.5918	#NA	#NA
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	0	0	0	0	0	0	0	0	0	0	0
normal vial flow	1	1	1	1	1	1	1	1	1	1	1
slurry type	1	1	1	1	1	1	1	1	1	1	2

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	32	33	34	35	36	37	38	39	40	41	42
day	1027	1027	1027	1027	1027	1027	1027	1028	1028	1028	1031
time	1008	1049	1100	1105	1111	1144	1213	1222	1328	1338	1037
hardware	1	1	1	1	1	1	1	1	1	1	1
flow vial TR-20352	0	0	0.924	1.037	0.98	0.685	0.252	0	0	0	0
flow trnsfr TR-20347	7.543	7.003	6.606	6.57	6.597	6.722	6.864	0	4.09	4.089	0
flow reclrc TR-20350	47.256	44.974	45.162	48.508	45.186	48.259	45.605	0	36.877	36.527	0
DP pump TR-20305	51	45.316	45.321	45.323	45.338	45.375	45.315	1.636	28.194	28.219	1.635
P dnstr HG TR-3411	26.001	22.693	20.145	19.854	19.97	20.678	21.583	8.925	13.572	13.582	7.308
P flow res TR-3412	45.004	39.774	39.742	39.833	39.798	39.876	39.781	0.903	24.323	24.37	1.048
P pump dls TR-2146	50.736	44.914	44.873	44.938	44.899	44.927	44.819	2.199	27.791	27.791	2.258
P branch TR-2919	48.27	42.641	42.604	42.525	42.614	42.788	42.713	2.183	26.116	26.21	2.655
P HG supply TR-3279	27.389	23.911	21.575	21.284	21.402	22.187	23.272	7.927	14.17	14.169	6.327
P vial TR-3282	7.619	7.551	20.844	20.56	20.721	21.6	22.741	7.824	7.512	7.504	7.048
DP orifice TR-3413	0.823	0.795	0.765	0.766	0.768	0.772	0.763	0.583	0.462	0.462	0.653
air 1 TR-21628	0.682	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681	0.681
air 2 TR-21629	-0.189	-0.19	-0.193	-0.19	-0.19	-0.19	-0.19	-0.192	-0.191	-0.191	-0.191
T reserv TR-1523	29.26	30.094	30.112	30.104	30.076	30.177	29.884	21.55	30.107	30.133	23.093
T amb lo TR-1520	19.366	20.824	21.098	21.212	21.248	21.767	22.192	20.078	22.298	22.461	21.537
T vial TR-1525	28.224	23.818	29.044	29.74	29.761	29.8	29.556	22.38	23.38	23.589	23.214
T transfer TR-1526	29.437	30.284	30.312	30.291	30.292	30.374	30.083	22.252	30.312	30.353	23.093
T amb hi TR-1544	20.746	21.451	21.51	21.577	21.607	22.325	22.861	22.676	23.033	23.196	21.724
T reclrc TR-1515	29.279	30.134	30.116	30.125	30.119	30.203	29.901	21.708	30.21	30.233	22.903
pump speed	86.976	70.981	70.984	70.985	70.988	70.986	70.986	0.15	0.15	0.15	0.15
first line averaged	0	1	86	22	32	30	1	0	1	1	1
last line averaged	0	58	90	78	85	90	120	0	60	60	60
F trnsfr m	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	3.98	0
F vial m	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	0
rho reser 1	#NA	1.3069	#NA	1.3069	1.3069	1.3041	#NA	#NA	1.3072	#NA	#NA
rho reser 2	#NA	1.3055	#NA	1.3055	1.3055	1.305	#NA	#NA	1.3056	#NA	#NA
rho trns 1	#NA	1.3058	#NA	#NA	#NA	1.3028	#NA	#NA	1.307	#NA	#NA
rho trns 2	#NA	1.3035	#NA	#NA	#NA	1.3	#NA	#NA	1.304	#NA	#NA
rho over flow 1	#NA	#NA	#NA	1.3155	1.3259	1.3335	#NA	#NA	#NA	#NA	#NA
rho over flow 2	#NA	#NA	#NA	1.3129	1.3237	1.3324	#NA	#NA	#NA	#NA	#NA
std reclrc	7.04	5.2	6.13	6.29	5.86	4.47	6.61	0	2.7	2.54	0
pump on?	100	100	100	100	100	100	100	0	100	100	0
air cor	-0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
discrep 1 for denslty	#NA	#NA	#NA	0.6580	1.4538	2.2544	#NA	#NA	#NA	#NA	#NA
discrep 2 for denslty	#NA	#NA	#NA	0.5668	1.3941	2.0996	#NA	#NA	#NA	#NA	#NA
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	0	0	0	0	0	0	0	0	0	0	0
normal vial flow	1	1	1	Reservoir densities for 1027 1049			1	1	1	1	1
slurry type	2	2	2	copied for 1105 and 1111 2			2	2	2	2	2

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	43	44	45	46	47	48	49	50	51	52	53
day	1031	1031	1031	1031	1101	1101	1101	1101	1101	1103	1103
time	1122	1128	1238	1243	1016	1056	1113	1127	1226	1041	1249
hardware	1	1	1	1	1	1	1	1	1	2	2
flow vial TR-20352	0	0	0	0	0	0.418	0.549	1.03	0	0	0.626
flow transr TR-20347	8.369	8.396	6.996	7.032	0	3.745	5.623	7.451	0	0	3.697
flow recirc TR-20350	50.824	53.495	48.303	50.107	0	36.73	42.063	53.052	0	0	35.268
DP pump TR-20305	59.979	60.585	45.598	45.603	-0.314	28.27	36.465	55.842	1.711	1.663	28.147
P dnstr HG TR-3411	29.918	30.087	22.498	22.362	1.34	13.094	16.565	24.831	8.612	8.79	13.151
P flow res TR-3412	52.79	53.195	39.779	39.816	-1.107	24.154	31.461	48.759	0.622	1.27	22.979
P pump dis TR-2146	59.298	59.722	44.826	44.877	-0.618	27.72	35.815	54.979	1.915	2.608	27.669
P branch TR-2919	57.119	57.578	42.965	42.985	-1.351	26.198	33.971	52.771	2.245	2.662	26.156
P HG supply TR-3279	31.584	31.75	23.693	23.55	1.227	13.822	17.703	26.754	7.692	7.84	13.591
P vial TR-3282	7.381	7.384	7.234	7.234	7.415	13.343	17.129	25.893	7.482	7.647	13.221
DP orifice TR-3413	0.161	0.22	0.641	0.773	-0.037	0.522	0.661	0.346	0.63	0.697	1.982
air 1 TR-21628	0.684	0.685	0.682	0.681	0.681	0.683	0.682	0.683	0.681	0.681	0.682
air 2 TR-21629	-0.19	-0.188	-0.19	-0.19	-0.191	-0.189	-0.19	-0.19	-0.191	-0.191	-0.19
T reserv TR-1523	30.297	30.197	29.758	29.694	27.085	30.061	29.978	30.036	29.016	24.422	29.918
T amb lo TR-1520	22.183	22.135	22.197	22.284	20.029	20.896	20.608	20.553	20.405	21.081	23.187
T vial TR-1525	23.172	23.115	23.599	23.689	22.335	28.71	29.149	29.64	23.564	23.991	29.149
T transfer TR-1526	30.527	30.454	30.046	30.007	21.31	29.943	29.95	30.159	24.361	22.911	30.052
T amb hl TR-1544	22.32	22.361	23.306	23.387	21.002	21.293	21.286	21.371	21.648	24.149	24.401
T recirc TR-1515	30.263	30.175	29.755	29.693	21.212	29.84	29.821	29.96	26.181	23.304	29.905
pump speed	99.955	99.95	70.991	70.993	0.15	99.99	45.071	92.053	0.15	0.15	99.476
flrst line averaged	1	1	1	1	1	20	20	20	1	1	30
last line averaged	60	75	60	60	60	205	90	130	60	60	105
F transr m	8.21	#NA	6.87	0	0	#NA	#NA	#NA	#NA	0	#NA
F vial m	0	0	0	0	0	#NA	#NA	#NA	#NA	0	#NA
rho reser 1	1.3105	#NA	1.3101	1.3101	#NA	1.3128	1.3096	1.3082	#NA	#NA	1.3116
rho reser 2	1.3106	#NA	1.3102	1.3102	#NA	1.3092	1.3093	1.3122	#NA	#NA	1.3108
rho trns 1	1.3102	#NA	1.3116	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	1.3112	#NA	1.3127	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1	#NA	#NA	1.328	1.3302	#NA	1.3262	1.3251	1.3257	#NA	#NA	1.3041
rho over flow 2	#NA	#NA	1.3275	1.3303	#NA	1.3274	1.3294	1.3213	#NA	#NA	1.3062
std recirc	7.52	5.74	3.91	3.82	0	1.5	4.12	6.61	0	0	1.41
pump on?	100	100	100	100	0	0	100	100	0	0	0
air cor	-0.00	0.00	-0.01	-0.01	-0.01	-0.00	-0.01	-0.00	-0.01	-0.01	-0.01
discrep 1 for density	#NA	#NA	1.3663	1.5342	#NA	1.0207	1.1836	1.3377	#NA	#NA	-0.5718
discrep 2 for density	#NA	#NA	1.3204	1.5341	#NA	1.3902	1.5352	0.6935	#NA	#NA	-0.3509
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	0	0	0	0	0	0	0	0	0	0	0
normal vial flow	1	1	1	Densities for 1031 1238			1	1	1	1	1
slurry type	2	2	2	sampled for 1243			2	2	2	2	2

TABLE 3, continued

column of data		54	55	56	57	58	59	60	61	62	63	64
day		1103	1103	1103	1104	1104	1104	1104	1107	1107	1107	1107
time		1310	1325	1601	903	1237	1304	1401	1345	1501	1523	1554
hardware		2	2	2	2	2	2	2	3	3	3	3
flow vial	TR-20352	0.916	1.273	0	0	0.422	0.561	1.031	0	0.92	1.18	1.685
flow trnsfr	TR-20347	5.513	7.443	0	0	3.788	5.694	7.538	0	3.56	5.37	7.241
flow reclrc	TR-20350	42.406	54.257	0	0	35.158	43.055	50.679	0	29.704	34.424	42.57
DP pump	TR-20305	36.48	55.93	1.7	#NA	28.155	36.563	55.993	1.653	28.662	36.883	56.021
P dnstr HG	TR-3411	16.447	24.728	8.772	#NA	13.248	16.878	25.446	8.863	13.199	16.462	23.86
P flow res	TR-3412	30.003	46.362	0.773	#NA	23.887	30.964	48.247	0.951	14.084	18.287	28.09
P pump dis	TR-2146	35.856	55.117	1.965	#NA	27.778	35.903	55.217	2.157	28.288	36.334	55.482
P branch	TR-2919	34.057	52.834	2.286	#NA	26.21	34	52.965	2.322	26.624	34.462	53.061
P HG spply	TR-3279	17.056	25.784	7.808	#NA	13.775	17.634	26.561	7.884	13.646	17.072	24.893
P vial	TR-3282	16.65	25.359	7.627	#NA	13.403	17.245	26.17	7.676	12.83	15.96	22.986
DP orifice	TR-3413	2.363	3.847	0.691	#NA	0.309	0.327	0.397	0.722	5.249	5.249	5.249
air 1	TR-21628	0.683	0.684	0.681	#NA	0.685	0.684	0.685	0.681	0.685	0.685	0.684
air 2	TR-21629	-0.189	-0.19	-0.191	#NA	-0.189	-0.19	-0.189	-0.191	-0.19	-0.191	-0.19
T reserv	TR-1523	30.164	30.327	27.028	#NA	30.176	30.164	30.132	21.874	29.871	30.111	29.894
T amb lo	TR-1520	23.533	22.478	22.043	#NA	21.845	22.441	22.613	21.189	22.36	21.765	22.66
T vial	TR-1525	29.708	29.947	24.494	#NA	29.403	29.592	29.645	22.625	29.265	29.683	29.49
T transfer	TR-1526	30.326	30.55	24.794	#NA	30.263	30.297	30.341	22.259	29.99	30.316	30.12
T amb hl	TR-1544	24.799	24.281	23.785	#NA	22.356	23.248	23.925	22.053	22.824	23.03	23.52
T reclrc	TR-1515	30.152	30.347	23.487	#NA	30.104	30.102	30.076	22.094	29.827	30.132	29.839
pump speed		44.556	91.555	0.15	#NA	99.499	45.073	92.555	0.15	97.515	41.577	89.032
first line	averaged	30	30	1	#NA	25	60	65	1	65	80	80
last line	averaged	105	98	60	#NA	105	145	105	145	115	115	128
F trnsfr m		#NA	#NA	0	0	#NA	#NA	#NA	0	#NA	#NA	#NA
F vial m		#NA	#NA	0	0	#NA	#NA	#NA	0	#NA	#NA	#NA
rho reser 1		1.3093	1.3088	#NA	#NA	1.3088	1.3096	1.3077	#NA	1.3123	1.3088	1.3114
rho reser 2		1.3061	1.3092	#NA	#NA	1.3071	1.311	1.3096	#NA	1.3083	1.3108	1.311
rho trns 1		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over	flow 1	1.3099	1.3068	#NA	#NA	1.3086	1.3095	1.3074	#NA	1.3086	1.3105	1.3114
rho over	flow 2	1.307	1.3064	#NA	#NA	1.3097	1.307	1.3083	#NA	1.3073	1.3099	1.31
std reclrc		4.1	5.57	0	0	1.41	4.37	5.1	0	0.7	2.01	4.21
pump on?		100	100	0	0	0	100	100	0	0	100	100
air cor		-0.00	-0.00	-0.01	#NA	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00	-0.00
discrep 1	for density	0.0458	-0.1528	#NA	#NA	-0.0153	-0.0076	-0.0229	#NA	-0.2819	0.1299	-0.0000
discrep 2	for density	0.0689	-0.2139	#NA	#NA	0.1989	-0.3051	-0.0993	#NA	-0.0764	-0.0687	-0.0763
high vial	flow	0	0	0	0	0	0	0	0	0	0	0
low vial	flow	0	0	0	0	0	0	0	0	0	0	0
normal	vial flow	1	1	1	1	1	1	1	1	1	1	1
slurry	type	2	2	2	2	2	2	2	2	2	2	2

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	65	66	67	68	69	70	71	72	73	74	75
day	1108	1108	1108	1108	1114	1114	1114	1114	1116	1116	1116
time	1239	1333	1345	1359	918	1019	1047	1106	836	1016	1043
hardware	3	4	3	3	5	5	5	5	5	5	5
flow vial	TR-20352	0	1,283	0	1,815	0	0,964	1,252	1,728	0	1,739
flow transr	TR-20347	0	7,435	7,555	7,195	0	3,784	5,331	7,262	0	7,268
flow recirc	TR-20350	0	42,214	40,105	44,844	0	30,552	35,078	44,638	0	43,151
DP pump	TR-20305	1,629	56,089	52,663	55,415	1,565	30,633	38,266	56,632	1,635	34,129
P dnstr HG	TR-3411	8,882	24,863	27,002	24,052	8,844	13,959	17,228	23,804	8,792	36,402
P flow res	TR-3412	0,867	28,072	27,315	28,61	0,891	14,979	18,909	28,233	0,767	15,888
P pump dis	TR-2146	2,118	55,544	52,239	54,941	2,072	30,185	37,827	56,043	2,043	17,73
P branch	TR-2919	2,225	53,436	50,081	52,512	2,346	28,528	35,931	53,643	2,249	35,91
P HG spply	TR-3279	7,929	25,986	28,357	24,969	7,841	14,407	17,755	24,688	7,82	34,125
P vial	TR-3282	7,685	24,638	6,874	23,181	7,662	13,908	17,169	23,915	7,596	16,437
DP orifice	TR-3413	0,724	5,248	5,248	5,248	0,723	5,248	5,248	5,248	5,248	15,782
air 1	TR-21628	0,681	0,683	0,677	0,676	0,69	0,681	0,682	0,681	0,682	5,248
air 2	TR-21629	-0,191	-0,191	10,457	8,145	-0,19	-0,192	-0,189	-0,187	-0,191	0,683
T reserv	TR-1523	21,735	30,029	30,018	30,09	22,2	30,184	29,996	29,939	22,777	-0,188
T amb lo	TR-1520	20,796	21,985	21,85	21,818	21,828	22,731	23,325	23,627	19,747	39,848
T vial	TR-1525	22,15	29,691	27,349	29,721	24,496	29,009	29,259	29,417	21,122	22,131
T transfer	TR-1526	22,245	30,298	30,299	30,389	23,935	30,403	30,215	30,161	21,098	39,08
T amb hi	TR-1544	21,962	22,613	22,651	22,796	24,335	23,584	24,333	24,718	40,247	39,942
T recirc	TR-1515	21,782	30,063	30,076	30,15	23,881	30,27	29,993	29,923	22,149	22,27
pump speed	0,15	89,023	89,744	91,556	0,15	23,881	30,27	29,993	29,923	21,088	39,897
first line	averaged	1	128	1	90	1	80	47,059	90,029	84,496	39,575
last line	averaged	60	162	223	138	60	120	85	1	175	85
F transr m	0	#NA	#NA	#NA	#NA	0	#NA	#NA	0	210	128
F vial m	0	#NA	#NA	#NA	#NA	0	#NA	#NA	0	#NA	#NA
rho reser 1	#NA	1,31	1,3098	#NA	#NA	#NA	1,317	1,3146	#NA	1,3152	1,3158
rho reser 2	#NA	1,3137	1,3117	#NA	#NA	#NA	1,3149	1,3163	#NA	1,3129	1,3155
rho trns 1	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over	#NA	1,3106	1,3125	#NA	#NA	#NA	1,315	1,3145	#NA	1,3152	1,3164
rho over	#NA	1,3114	1,3107	#NA	#NA	#NA	1,3175	1,3148	#NA	1,3143	1,3164
std recirc	0	4,34	4,88	0	0	0	0,95	1,84	0	4,25	2,01
pump on?	0	100	100	100	0	100	100	100	0	100	100
air cor	-0,01	-0,01	10,64	8,32	0,00	-0,01	-0,00	-0,00	-0,00	-0,00	-0,00
discrep 1	#NA	0,0458	0,2061	#NA	#NA	-0,1519	-0,0076	0,0760	#NA	0,0000	0,0456
discrep 2	#NA	-0,1751	-0,0762	#NA	#NA	0,1977	-0,1140	-0,1368	#NA	0,1066	0,0684
high vial	flow	0	0	0	0	0	0	0	0	0	0
low vial	flow	0	0	0	0	0	0	0	0	0	0
normal	vial flow	1	1	1	1	1	1	1	1	1	1
slurry	type	2	2	2	2	2	2	2	2	2	2

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	76	77	78	79	80	81	82	83	84	85	86
day	1117	1117	1117	1117	1118	1118	1118	1121	1121	1121	1122
time	940	1234	1305	1342	953	1117	1256	941	1305	1320	912
hardware	5	5	5	5	1	1	1	5	5	5	5
flow vlal	TR-20352	0	0.502	1.084	0	1.709	2.265	0	1.661	1.967	0
flow trnsfr	TR-20347	0	3.998	3.745	0	3.619	5.74	0	3.718	5.499	0
flow recirc	TR-20350	0	25.353	25.643	0	33.055	40.435	0	33.898	40.065	0
DP pump	TR-20305	1.632	20.322	20.36	31.975	35.103	55.551	1.626	35.172	48.682	1.635
P dnstr HG	TR-3411	8.733	9.881	9.504	13.975	21.513	31.144	8.977	21.471	27.027	8.78
P flow res	TR-3412	0.696	9.625	9.589	15.695	17.208	27.895	0.918	17.275	24.467	0.675
P pump dis	TR-2146	1.968	20.046	19.978	31.62	34.54	55.29	2.186	34.752	48.356	2.069
P branch	TR-2919	2.213	18.647	18.538	29.926	33.147	53.185	2.427	33.261	46.578	2.038
P HG apply	TR-3279	7.777	10.326	9.846	14.531	21.953	32.062	7.986	21.696	27.493	7.821
P vlal	TR-3282	7.544	6.824	9.478	13.998	21.205	30.975	7.594	20.883	26.555	7.728
DP orifice	TR-3413	0.709	5.248	5.248	0.715	5.248	5.248	0.721	5.248	5.248	0.707
air 1	TR-21628	0.681	0.683	0.682	0.683	0.683	0.682	0.681	0.681	0.681	0.681
air 2	TR-21629	-0.19	-0.189	-0.19	-0.189	-0.189	-0.189	-0.19	-0.188	-0.188	-0.19
T reserv	TR-1523	28.862	29.832	30.183	30.052	30.278	30.408	22.022	29.797	29.731	23.729
T amb lo	TR-1520	20.185	20.509	20.774	20.677	21.068	22.732	19.325	22.241	22.71	18.429
T vlal	TR-1525	21.752	22.589	28.952	29.472	29.669	29.848	20.693	29.159	29.435	20.021
T transfer	TR-1526	21.516	29.794	30.174	30.158	30.354	30.591	22.318	30.361	30.467	20.398
T amb hl	TR-1544	21.53	21.696	21.695	21.738	21.912	23.626	20.714	22.973	23.285	19.828
T recirc	TR-1515	21.231	29.724	30.1	30.056	30.256	30.337	21.399	30.206	30.268	20.628
pump speed		0.15	83.009	83.009	32.103	42.576	99.977	0.15	42.576	99.98	0.15
first line	averaged	1	100	90	1	80	110	1	108	43	1
last line	averaged	60	135	125	60	112	120	60	125	65	60
F trnsfr m		0	#NA	#NA	0	#NA	#NA	0	#NA	#NA	0
F vlal m		0	#NA	#NA	0	#NA	#NA	0	#NA	#NA	0
rho reser 1		#NA	1.2651	1.2663	#NA	1.2655	1.2642	#NA	1.2656	1.2664	#NA
rho reser 2		#NA	1.2616	1.2653	#NA	1.2631	1.2643	#NA	1.2633	1.2648	#NA
rho trns 1		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2		#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over	flow 1	#NA	1.2669	1.2625	#NA	1.2609	1.2604	#NA	1.2665	1.2634	#NA
rho over	flow 2	#NA	1.2639	1.2632	#NA	1.2585	1.2592	#NA	1.2668	1.2632	#NA
std recirc		0	0	0	0	1.34	2.92	#NA	1.69	3.22	#NA
pump on?		0	0	100	0	100	100	0	100	100	0
air cor		-0.01	-0.01	-0.00	-0.01	-0.00	-0.00	-0.01	-0.00	-0.00	-0.01
discrep 1	for density	#NA	0.1423	-0.3001	#NA	-0.3635	-0.3006	#NA	0.0711	-0.2369	#NA
discrep 2	for density	#NA	0.1823	-0.1660	#NA	-0.3642	-0.4034	#NA	0.2771	-0.1265	#NA
high vlal	flow	0	0	0	1	1	1	1	1	1	1
low vlal	flow	0	0	0	0	0	0	0	0	0	0
normal	vial flow	1	1	1	0	0	0	0	0	0	0
slurry	type	3	3	3	3	3	3	3	3	3	3

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	87	88	89	90	91	92	93	94	95	96	97
day	1122	1122	1122	1122	1122	1123	1123	1201	1201	1201	1201
time	1002	1010	1125	1428	1451	835	931	839	1412	1558	2200
hardware	5	5	5	5	5	5	5	5	5	5	5
flow vial TR-20352	0	1.9	2.657	0.227	0.576	0	1.405	0	0	1.948	2.392
flow transr TR-20347	5.892	5.365	5.394	3.887	5.783	0	5.45	0	4.345	3.04	5.671
flow recirc TR-20350	36.055	37.267	43.459	26.626	33.152	0	34.137	0	40.334	25.36	30.324
DP pump TR-20305	44.847	41.12	60.209	22.531	33.898	1.642	34.99	1.651	-25.75	-0.033	-0.03
P dnstr HG TR-3411	29.118	21.956	36.434	11.384	16.518	8.696	15.949	9.227	34.444	30.772	39.632
P flow res TR-3412	23.238	21.618	30.026	10.837	16.674	0.654	17.482	1.123	36.015	34.788	26.669
P pump dis TR-2146	44.757	41.048	59.952	22.128	33.402	2.098	34.785	2.818	70.606	67.653	51.987
P branch TR-2919	42.815	38.998	57.763	20.817	31.761	1.928	32.652	2.356	67.47	64.76	4.793
P HG supply TR-3279	29.942	22.354	36.753	11.743	17.136	7.768	16.471	8.324	36.074	31.591	40.627
P vial TR-3282	7.688	21.485	35.033	11.41	16.769	7.774	15.811	7.841	7.752	29.939	38.925
DP orifice TR-3413	5.248	5.248	5.248	5.248	5.248	0.72	5.248	0.677	5.249	5.249	5.249
air 1 TR-21628	0.674	0.675	0.685	0.683	0.683	0.681	0.684	0.681	0.684	0.682	0.682
air 2 TR-21629	6.182	8.042	-0.188	-0.189	-0.189	-0.191	-0.188	-0.191	-0.187	-0.189	-0.19
T reserv TR-1523	29.975	29.913	40.119	30.027	30.018	24.745	30.394	17.938	23.327	31.704	30.957
T amb lo TR-1520	20.321	20.541	21.718	23.068	22.984	17.897	19.529	15.657	17.22	20.653	19.235
T vial TR-1525	20.953	29.33	39.37	28.827	29.492	20.599	29.858	18.778	23.23	31.593	31.113
T transfer TR-1526	30.387	30.287	40.35	30.099	30.284	20.666	30.551	18.556	22.938	32.202	19.921
T amb hi TR-1544	20.521	20.64	22.152	24.36	24.388	20.769	21.706	18.868	22.216	23.558	20.899
T recirc TR-1515	30.324	30.22	40.372	30.036	30.137	20.57	30.544	18.841	22.834	32.157	31.703
pump speed	99.991	99.989	99.982	88.012	41.574	0.15	59.042	0.15	99.954	98.966	71.48
first line averaged	1	100	80	40	32	1	192	1	1	90	125
last line averaged	135	132	119	90	55	65	225	59	59	120	159
F transr m	#NA	#NA	#NA	#NA	#NA	0	#NA	0	#NA	#NA	#NA
F vial:m	#NA	#NA	#NA	#NA	#NA	0	#NA	0	#NA	#NA	#NA
rho reser 1	#NA	1.2638	1.2656	1.2675	1.2661	#NA	1.2707	#NA	#NA	1.4521	1.46
rho reser 2	#NA	1.2641	1.2643	1.2675	1.2679	#NA	1.2689	#NA	#NA	1.4561	1.4643
rho trns 1	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1	#NA	1.264	1.2659	1.2659	1.2662	#NA	1.2693	#NA	#NA	1.4569	1.4588
rho over flow 2	#NA	1.2657	1.2652	1.2642	1.266	#NA	1.2711	#NA	#NA	1.4578	1.4615
std recirc	#NA	#NA	#NA	#NA	#NA	0	#NA	0	#NA	#NA	#NA
pump on?	100	100	100	0	100	0	0	0	100	100	100
air cor	6.36	8.22	0.00	-0.00	-0.00	-0.01	-0.00	-0.01	-0.00	-0.00	-0.01
discrep 1 for density	#NA	0.0158	0.0237	-0.1262	0.0079	#NA	-0.1102	#NA	#NA	0.3306	-0.0822
discrep 2 for density	#NA	0.1266	0.0712	-0.2604	-0.1499	#NA	0.1734	#NA	#NA	0.1168	-0.1912
high vial flow	1	1	1	0	0	0	0	0	0	0	0
low vial flow	0	0	0	1	1	0	0	0	0	0	0
normal vial flow	0	0	0	0	0	1	1	1	1	1	1
slurry type	3	3	3	3	3	3	3	4	4	4	4

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	98	99	100	101	102	103	104	105	106	107	108
day	1202	1202	1202	1203	1203	1203	1203	1203	1203	1204	1204
time	1320	1513	1553	930	952	1408	1615	1630	1657	1050	1120
hardware	5	5	5	1	1	1	5	5	5	5	5
flow vial	TR-20352	0	2.473	0	2.399	1.673	1.34	1.71	2.343	0	1.53
flow trnsfr	TR-20347	7.897	5.946	0	5.548	5.577	3.872	5.662	8.015	0	3.743
flow recirc	TR-20350	34.733	38.597	0	35.106	31.326	26.554	30.587	42.089	0	29.38
DP pump	TR-20305	-0.044	-0.051	1.428	50.863	28.389	22.708	28.7	42.475	1.636	26.378
P dnstr HG	TR-3411	49.895	41.41	8.526	37.814	20.642	16.259	21.18	32.86	8.673	19.383
P flow res	TR-3412	33.063	27.595	0.458	26.006	14.155	11.054	14.324	21.588	0.573	12.991
P pump dls	TR-2146	63.674	53.126	1.855	50.197	27.585	21.801	27.892	41.427	1.791	25.781
P branch	TR-2919	7.739	9.241	7.272	7.803	12.462	14.387	14.503	13.897	5.47	6.268
P HG sply	TR-3279	52.427	43.245	7.541	39.123	21.735	16.518	21.576	34.296	7.689	19.867
P vial	TR-3282	7.58	7.545	6.881	37.755	20.475	15.326	20.972	25.956	7.673	19.149
DP office	TR-3413	5.248	5.248	0.698	5.249	5.248	5.248	5.248	5.248	0.704	5.248
air 1	TR-21628	0.681	0.675	0.681	0.68	0.681	0.681	0.681	0.68	0.681	0.675
air 2	TR-21629	-0.185	14.543	-0.185	-0.184	-0.184	-0.185	-0.183	-0.183	-0.186	-0.183
T reserv	TR-1523	30.22	30.253	31.998	31.448	30.651	29.824	29.636	28.243	27.608	29.97
T amb lo	TR-1520	21.616	22.995	22.057	22.558	26.672	27.494	27.633	27.353	21.771	22.674
T vial	TR-1525	23.879	26.266	23.665	31.304	30.379	29.544	29.454	28.319	22.444	29.258
T transfer	TR-1526	22.973	25.311	22.862	23.34	28.101	29.468	29.332	29.184	23.409	23.6
T amb hi	TR-1544	24.25	26.239	23.773	24.352	29.373	30.308	30.187	29.98	21.767	22.762
T recirc	TR-1515	30.603	30.649	27.108	31.99	30.983	30.054	29.985	28.75	23.079	30.233
pump speed	93.496	75.484	79.486	0.15	70.493	97.895	86.44	98.445	61.503	0.15	93.532
first line averaged	1	1	25	1	53	35	68	67	54	1	85
last line averaged	8	240	59	61	64	52	76	76	60	60	119
F trnsfr m	#NA	#NA	#NA	0	#NA	#NA	#NA	#NA	#NA	0	#NA
F vial m	#NA	#NA	#NA	0	#NA	#NA	#NA	#NA	#NA	0	#NA
rho reser 1	#NA	#NA	1.4595	#NA	1.4509	1.3794	1.3788	1.3773	1.3781	#NA	1.3449
rho reser 2	#NA	#NA	1.4625	#NA	1.4579	1.3797	1.378	1.3781	1.3808	#NA	1.347
rho trns 1	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1	#NA	#NA	1.4587	#NA	1.4529	1.3781	1.3853	1.3782	1.379	#NA	1.3483
rho over flow 2	#NA	#NA	1.4627	#NA	1.4542	1.3784	1.3843	1.3796	1.378	#NA	1.3494
sid recirc	#NA	#NA	#NA	0	4.28	3.32	1.11	2.06	5.87	0	0
pump on?	100	100	100	0	100	0	0	0	0	0	0
air cor	-0.00	14.72	9.18	-0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.01
discrep 1 for density	#NA	#NA	-0.0548	#NA	0.1378	-0.0942	0.4714	0.0653	0.0653	#NA	0.2528
discrep 2 for density	#NA	#NA	0.0137	#NA	-0.2538	-0.0942	0.4572	0.1088	-0.2028	#NA	0.1782
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	0	0	0	0	0	0	0	0	0	0	0
normal vial flow	1	1	1	1	1	1	1	1	1	1	1
slurry type	4	4	4	4	4	5	5	5	5	1	1

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	109	110	111	112	113	114	115	116	117	118	119
day	1204	1204	1204	1204	1205	1205	1205	1206	1206	1206	1207
time	1125	1145	1212	1232	946	1021	1035	912	1001	1016	913
hardware	5	5	5	5	1	1	1	1	1	1	1
flow vial TR-20352	0	1.48	1.863	2.236	0	1.945	2.293	0	1.541	2.034	0
flow trnsfr TR-20347	3.921	3.749	5.743	7.761	0	5.57	7.574	0	5.143	7.09	0
flow reclrc TR-20350	28.283	29.667	34.451	39.006	0	33.92	40.029	0	36.801	44.862	0
DP pump TR-20305	26.793	26.776	32.858	40.546	1.447	33.97	42.656	1.509	39.809	59.017	1.656
P dnstr HG TR-3411	19.866	19.626	24.49	30.791	8.819	25.199	32.016	8.949	17.811	24.566	8.946
P flow res TR-3412	13.098	13.154	16.422	20.62	0.701	17.077	21.622	0.759	20.311	30.323	0.722
P pump dis TR-2146	25.994	26.114	32.099	40.126	1.989	33.619	42.077	2.288	39.734	58.666	2.424
P branch TR-2919	6.284	6.566	6.63	6.977	5.773	4.984	4.908	2.007	37.275	55.836	2.053
P HG sply TR-3279	20.585	20.123	25.249	31.822	7.844	26.401	33.833	8.334	18.889	26.281	8.04
P vial TR-3282	7.673	19.313	24.329	30.788	7.674	25.509	32.619	7.778	17.998	24.99	7.698
DP orifice TR-3413	5.248	5.248	5.248	5.248	0.7	5.248	5.248	0.697	5.248	5.249	0.709
alr 1 TR-21628	0.675	0.675	0.673	0.674	0.681	0.673	0.673	0.681	0.673	0.673	0.681
alr 2 TR-21629	-0.184	-0.184	-0.185	-0.185	-0.186	-0.184	-0.184	-0.186	-0.183	-0.183	-0.185
T reserv TR-1523	30.086	30.067	30.24	29.899	26.441	29.86	29.964	24.828	29.711	30.077	23.929
T amb lo TR-1520	22.545	22.64	22.314	22.906	20.398	19.518	19.509	17.731	18.833	19.382	15.785
T vial TR-1525	26.807	29.301	29.641	29.501	21.834	29.447	29.503	18.484	29.142	29.653	17.259
T transfer TR-1526	23.643	23.802	23.956	24.102	21.668	21.28	21.363	20.052	30.143	30.619	17.662
T amb hl TR-1544	22.905	23.115	23.303	23.592	21.781	21.28	21.135	18.709	19.358	19.732	17.376
T reclrc TR-1515	30.338	30.286	30.54	30.346	21.856	30.209	30.284	21.822	30.034	30.45	17.606
pump speed	93.534	94.528	22.11	53.536	0.15	28.593	59.026	0.15	53.039	95.511	0.15
flrst line averaged	1	61	158	71	1	155	81	1	142	80	1
last line averaged	240	285	200	110	60	200	125	60	182	120	60
F trnsfr m	3.87	#NA	#NA	#NA	0	#NA	#NA	0	#NA	#NA	0
F vial m	#NA	1.456	#NA	#NA	0	#NA	#NA	0	#NA	#NA	0
rho reser 1	#NA	#NA	1.3467	1.3501	#NA	1.348	1.3483	#NA	1.3196	1.3153	#NA
rho reser 2	#NA	#NA	1.3458	1.3499	#NA	1.3494	1.3481	#NA	1.3155	1.3158	#NA
rho trns 1	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1	#NA	#NA	1.3466	1.3469	#NA	1.3394	1.3467	#NA	1.3165	1.3143	#NA
rho over flow 2	#NA	#NA	1.347	1.3453	#NA	1.3439	1.3457	#NA	1.3153	1.3146	#NA
std reclrc	0	0	0	0	0	0	0	0	0	0	0
pump on?	0	0	100	100	0	0	0	0	0	0	0
alr cor	-0.01	-0.01	-0.01	-0.01	-0.00	-0.01	-0.01	-0.00	-0.01	-0.01	-0.00
discrep 1 for density	#NA	#NA	-0.0074	-0.2370	#NA	-0.6380	-0.1187	#NA	-0.2349	-0.0760	#NA
discrep 2 for density	#NA	#NA	0.0892	-0.3408	#NA	-0.4076	-0.1780	#NA	-0.0152	-0.0912	#NA
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	0	0	0	0	0	0	0	0	0	0	0
normal vial flow	1	1	1	1	1	1	1	1	1	1	1
slurry type	1	1	1	1	1	1	1	2	2	2	2

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

column of data	120	121	122	123	124	125	126	127	128	129	130
day	1207	1209	1209	1209	1209	1209	1209	1213	1213	1213	1213
time	1012	850	955	1616	1633	1653	1715	841	1357	1405	1411
hardware	1	5	5	5	5	5	5	5	5	5	5
flow vial TR-20352	0.554	0	0.52	0.489	0.487	1.009	0.869	0	0.926	0.927	0.923
flow trnsfr TR-20347	5.734	0	5.799	5.78	7.789	7.635	3.605	0	3.563	3.549	3.535
flow recirc TR-20350	36.518	0	36.486	36.044	45.508	32.432	30.81	0	32.14	31.813	32.231
DP pump TR-20305	41.584	1.651	41.602	41.908	60.727	59.753	32.341	1.66	33.514	33.337	33.292
P dnstr HG TR-3411	20.403	9.02	20.723	20.763	30.947	28.141	14.996	8.969	15.662	15.634	15.614
P flow res TR-3412	21.176	0.811	21.293	21.387	31.286	30.762	16.358	0.796	16.732	16.745	16.836
P pump dis TR-2146	41.299	2.395	41.669	41.7	60.471	59.484	32.201	2.438	32.965	33.08	33.222
P branch TR-2919	39.006	2.101	39.066	39.4	57.71	56.607	30.162	2.093	31.14	31.13	31.169
P HG sply TR-3279	21.637	8.09	21.582	21.527	32.246	29.328	15.531	8.062	16.117	16.079	16.049
P vial TR-3282	20.988	7.743	21.089	21.178	31.91	28.866	15.04	7.679	15.624	15.649	15.62
DP orifice TR-3413	5.248	0.709	5.248	5.248	5.248	5.248	5.248	0.69	5.248	5.248	5.248
alr 1 TR-21628	0.673	0.681	0.673	0.679	0.676	0.677	0.679	0.681	0.681	0.681	0.681
alr 2 TR-21629	-0.184	-0.185	-0.184	-0.185	-0.184	-0.185	-0.185	-0.185	-0.185	-0.185	-0.185
T reserv TR-1523	30.001	21.412	29.993	29.978	30.141	30.202	30.182	16.613	29.777	29.779	29.796
T amb lo TR-1520	18.15	16.962	18.465	19.765	20.21	20.28	20.178	17.083	19.862	19.875	19.94
T vial TR-1525	27.746	18.568	29.612	29.033	30.456	30.548	30.078	21.266	28.918	29.257	29.359
T transfer TR-1526	30.429	18.223	30.297	30.256	30.633	30.641	30.327	20.526	30.102	30.092	30.125
T amb hi TR-1544	18.666	18.113	18.826	20.986	20.891	20.877	20.924	21.157	22.146	22.202	22.219
T recirc TR-1515	30.36	18.748	30.416	30.345	30.649	30.645	30.475	20.555	30.168	30.17	30.187
pump speed	57.535	0.15	57.517	58.526	98.46	96.987	20.608	0.15	27.107	27.106	27.108
first line averaged	39	1	88	20	340	126	110	1	32	32	25
last line averaged	68	60	120	44	370	148	130	59	62	62	57
F trnsfr m	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
F vial m	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho reser 1	1.3157	#NA	1.3183	#NA	1.3183	1.3183	1.3183	#NA	1.3231	1.3231	1.3231
rho reser 2	1.3163	#NA	1.3205	#NA	1.3205	1.3205	1.3205	#NA	1.3231	1.3231	1.3231
rho trns 1	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho trns 2	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
rho over flow 1	1.3317	#NA	1.314	#NA	1.3166	1.3189	1.3207	0	1.3252	1.3212	1.3213
rho over flow 2	1.3299	#NA	1.3153	#NA	1.3181	1.3173	1.3206	0	1.3249	1.3244	1.3231
std recirc	0	0	2.58	2.58	4.95	5.79	1.68	0	0	0	0
pump on?	100	0	100	100	100	100	100	0	100	100	100
alr cor	-0.01	-0.00	-0.01	-0.00	-0.01	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00
discrep 1 for density	1.2161	#NA	-0.3262	#NA	-0.1290	0.0455	0.1821	#NA	0.1587	-0.1436	-0.1360
discrep 2 for density	1.0332	#NA	-0.3938	#NA	-0.1817	-0.2423	0.0076	#NA	0.1360	0.0983	-0.0000
high vial flow	0	0	0	0	0	0	0	0	0	0	0
low vial flow	1	0	1	1	1	1	0	0	0	0	0
normal vial flow	0	1	0	0	0	0	1	1	1	1	1
slurry type	2	2	2	2	2	2	2	2	2	2	2

Note: Temporary densities have been inserted for 1209, 120955, 1633 and 1715

TABLE 3, continued
SUMMARY OF HYDRAULIC AND DENSITY MEASUREMENTS

		131	132	133	134	135
1	day	1213	1213	1213	1214	1214
2	time	1417	1427	1440	1311	1351
3	hardware	5	5	5	5	5
4	flow vial TR-20352	0.921	1.515	0.878	1.196	0
5	flow trnsfr TR-20347	3.538	7.396	3.618	5.479	6.029
6	flow recirc TR-20350	31.393	44.512	31.725	37.329	36.839
7	DP pump TR-20305	33.4	61.224	33.536	43.433	42.966
8	P dnstr HG TR-3411	15.609	27.759	15.348	20.62	21.247
9	P flow res TR-3412	16.703	31.45	16.863	22.077	21.792
10	P pump dis TR-2146	33.023	60.647	33.327	43.094	42.794
11	P branch TR-2919	31.109	57.958	31.267	40.721	40.331
12	P HG sply TR-3279	16.044	28.833	15.88	21.28	22.289
13	P vial TR-3282	15.622	28.17	15.369	20.61	6.846
14	DP orifice TR-3413	5.248	5.249	5.248	5.249	5.248
15	air 1 TR-21628	0.681	0.681	0.681	0.681	0.681
16	air 2 TR-21629	-0.184	-0.184	-0.185	-0.185	-0.185
17	T reserv TR-1523	29.835	29.94	30.291	30.019	30.107
18	T amb lo TR-1520	19.965	20.13	20.267	19.981	17.878
19	T vial TR-1525	29.178	30.139	29.513	30.272	25.59
20	T transfer TR-1526	30.127	30.441	30.598	30.399	30.433
21	T amb hi TR-1544	22.257	22.331	22.437	21.935	21.624
22	T recirc TR-1515	30.196	30.407	30.654	30.425	30.467
23	pump speed	27.61	99.518	27.607	63.026	61.542
24	first line averaged	20	28	40	100	1
25	last line averaged	40	50	75	500	180
26	F trnsfr m	#NA	#NA	#NA	#NA	5.955
27	F vial m	#NA	#NA	#NA	1.171	#NA
28	rho reser 1	#NA	1.3231	1.3231	#NA	#NA
29	rho reser 2	#NA	1.3231	1.3231	#NA	#NA
30	rho trns 1	#NA	#NA	#NA	#NA	#NA
31	rho trns 2	#NA	#NA	#NA	#NA	#NA
32	rho over flow 1	#NA	1.3221	1.3225	#NA	#NA
33	rho over flow 2	#NA	1.324	1.3244	#NA	#NA
34	std recirc	0	0	0	0	0
35	pump on?	100	100	100	100	100
	air cor	-0.00	-0.00	-0.00	-0.00	-0.00
	discrep 1 for density	#NA	-0.0756	-0.0453	#NA	#NA
	discrep 2 for density	#NA	0.0680	0.0983	#NA	#NA
	high vial flow	0	0	0	0	0
	low vial flow	0	0	0	0	0
	normal vial flow	1	1	1	1	1
	slurry type	2	2	2	2	2

TABLE 4 SUMMARY OF CHEMICAL ANALYSES

vial	#NA	213	214	215	216	217	218	219	220	221	226	227	228
location	1	2	2	2	2	2	2	2	2	2	4	4	4
boron	#NA	2.48	2.49	2.5	2.49	2.5	2.5	2.47	2.48	2.49	2.48	2.49	2.51
iron	#NA	9.12	9.48	9.23	9.74	9.13	9.29	8.88	8.92	9.15	9.93	9.88	10
silicon	#NA	25.4	25	25.4	24.9	25.4	25.4	25.8	25.8	25.3	24.4	24.4	24.5
aluminum	#NA	1.63	1.69	1.66	1.71	1.64	1.66	1.59	1.6	1.65	1.77	1.76	1.77
lithium	#NA	2.23	2.21	2.24	2.2	2.25	2.24	2.24	2.26	2.24	2.17	2.2	2.2
potassium	#NA	2.13	2.26	2.18	2.27	2.2	2.2	2.08	2.04	2.15	2.48	2.45	2.48
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	1.3054	#NA	#NA	#NA	1.3142	1.3142	1.3142	1.3248	1.3248	1.3248	#NA	#NA	#NA
date	1027	1027	1027	1027	1027	1027	1027	1027	1027	1027	1102	1102	1102
time	1105	1100	1100	1100	1105	1105	1105	1111	1111	1111	1354	1354	1354
Li/Fe	#NA	0.245	0.233	0.243	0.226	0.246	0.241	0.252	0.253	0.245	0.219	0.223	0.220
Si/Al	#NA	15.58	14.79	15.30	14.56	15.49	15.30	16.23	16.13	15.33	13.79	13.86	13.84
	1	2	3	4	5	6	7	8	9	10	11	12	13
		0.240	0.009			0.238	0.015		0.250	0.006			0.220
		0.245	0.233	0.243	0.226	0.246	0.241	0.252	0.253	0.245	0.219	0.223	0.22

1 = reservoir
 2 = vial
 3 = transfer line
 4 = grab sample
 5 = 30 sec vial
 6 = overflow
 7 = snap shut

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	229	230	231	232	233	234	235	236	237	238	239	240	241
location	4	4	1	1	1	1	1	1	1	1	1	1	2
boron	2.44	2.48	2.5	2.51	2.51	2.49	2.51	#NA	2.47	2.48	2.48	2.48	#NA
Iron	9.79	9.92	9.58	9.59	9.76	9.59	9.62	#NA	9.42	9.49	9.45	9.45	#NA
silicon	24	24.4	24.6	24.8	24.7	24.5	24.7	#NA	24.3	24.2	24.4	24.5	#NA
aluminum	1.74	1.75	1.69	1.72	1.74	1.71	1.71	#NA	1.65	1.67	1.67	1.65	#NA
lithium	2.14	2.18	2.23	2.21	2.21	2.22	2.21	#NA	2.18	2.17	2.17	2.2	#NA
potassium	2.46	2.44	2.38	2.42	2.47	2.4	2.43	#NA	2.23	2.33	2.34	2.24	#NA
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	#NA	#NA	#NA	40.16	#NA	#NA	#NA	#NA	39.18
TFL density	#NA	#NA	1.3106	1.3106	1.3106	1.3106	1.3106	1.314	1.314	1.314	1.314	1.314	1.3148
date	1102	1102	1102	1102	1102	1102	1102	1116	1116	1116	1116	1116	1116
time	1354	1354	1354	1354	1354	1354	1354	1016	1016	1016	1016	1016	1016
Li/Fe	0.219	0.220	0.233	0.230	0.226	0.231	0.230	#NA	0.231	0.229	0.230	0.233	#NA
Si/Al	13.79	13.94	14.56	14.42	14.20	14.33	14.44	#NA	14.73	14.49	14.61	14.85	#NA
	14	15	16	17	18	19	20	21	22	23	24	25	26
	0.002			0.230	0.003					0.231	0.002		
	0.219	0.22	0.233	0.23	0.226	0.231	0.23		0.231	0.229	0.23	0.233	

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	242	243	244	245	246	247	248	249	250	251	252	253	255
location	2	2	2	2	4	4	4	4	1	1	1	1	2
boron	2.46	2.47	2.48	2.47	#NA	2.46	2.49	2.47	#NA	2.48	2.46	2.45	#NA
iron	9.78	9.8	9.83	9.48	#NA	9.66	9.76	9.74	#NA	9.54	9.44	9.52	#NA
silicon	24	24	23.8	24.3	#NA	23.9	24	24	#NA	24.3	24.4	24.3	#NA
aluminum	1.71	1.71	1.72	1.66	#NA	1.69	1.7	1.69	#NA	1.67	1.66	1.65	#NA
lithium	2.15	2.14	2.15	2.18	#NA	2.14	2.16	2.16	#NA	2.19	2.18	2.16	#NA
potassium	2.37	2.36	2.37	2.3	#NA	2.34	2.36	2.35	#NA	2.27	2.31	2.25	#NA
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	34.62	#NA	#NA	#NA	34.78	#NA	#NA	#NA	34.6
TFL density	1.3148	1.3148	1.3148	1.3148	#NA	#NA	#NA	#NA	1.2633	1.2633	1.2633	1.2633	1.2702
date	1116	1116	1116	1116	1117	1117	1117	1117	1117	1117	1117	1117	1123
time	1016	1016	1016	1016	1234	1234	1234	1234	1234	1234	1234	1234	931
Li/Fe	0.220	0.218	0.219	0.230	#NA	0.222	0.221	0.222	#NA	0.230	0.231	0.227	#NA
Si/Al	14.04	14.04	13.84	14.64	#NA	14.14	14.12	14.20	#NA	14.55	14.70	14.73	#NA
	27	28	29	30	31	32	33	34	35	36	37	38	39
		0.222	0.006				0.222	0.001			0.229	0.003	
	0.22	0.218	0.219	0.23		0.222	0.221	0.222		0.23	0.231	0.227	

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	256	257	258	259	260	261	262	263	264	265	266	267	268
location	2	2	2	2	1	1	1	1	1	2	2	2	2
boron	2.49	2.5	2.49	2.48	#NA	2.51	2.5	2.5	2.52	#NA	2.07	2.07	2.08
iron	10.1	9.87	9.86	10.1	#NA	9.54	9.5	9.51	9.55	#NA	9.74	9.67	9.3
silicon	23.8	24	24.2	23.7	#NA	24.4	24.6	24.3	24.7	#NA	23.4	23.4	23.2
aluminum	1.79	1.74	1.75	1.78	#NA	1.69	1.67	1.68	1.69	#NA	2.89	2.88	2.83
lithium	2.12	2.13	2.15	2.11	#NA	2.18	2.18	2.18	2.2	#NA	1.98	1.97	1.97
potassium	2.49	2.49	2.44	2.46	#NA	2.39	2.33	2.38	2.41	#NA	2.07	2.09	2.04
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	35.3	#NA	#NA	#NA	#NA	52.6	#NA	#NA	#NA
TFL density	1.2702	1.2702	1.2702	1.2702	1.2698	1.2698	1.2698	1.2698	1.2698	1.4602	1.4602	1.4602	1.4602
date	1123	1123	1123	1123	1123	1123	1123	1123	1123	1201	1201	1201	1201
time	931	931	931	931	931	931	931	931	931	2141	2141	2141	2141
Li/Fe	0.210	0.216	0.218	0.209	#NA	0.229	0.229	0.229	0.230	#NA	0.203	0.204	0.212
Si/Al	13.30	13.79	13.83	13.31	#NA	14.44	14.73	14.46	14.62	#NA	8.10	8.13	8.20
	40	41	42	43	44	45	46	47	48	49	50	51	52
		0.213	0.005				0.229	0.001			0.206	0.005	
	0.21	0.216	0.218	0.209		0.229	0.229	0.229	0.23		0.203	0.204	0.212

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	269	270	271	272	273	274	276	277	278	279	280	282	283
location	2	1	1	1	1	1	2	2	2	2	2	1	1
boron	2.08	#NA	2.07	2.11	2.08	2.1	#NA	2.04	2.06	2.08	2.1	#NA	2.06
iron	9.62	#NA	9.21	8.96	9.12	9.01	#NA	9.62	9.46	9.48	8.94	#NA	9.14
silicon	23.3	#NA	24.1	24.1	24	24.2	#NA	23.2	23.9	23.8	24.4	#NA	24
aluminum	2.86	#NA	2.75	2.72	2.73	2.7	#NA	2.85	2.76	2.8	2.62	#NA	2.7
lithium	1.96	#NA	2.01	2.04	2.04	2.01	#NA	1.93	1.97	1.97	2.03	#NA	2
potassium	2.04	#NA	2.03	1.98	1.98	2.03	#NA	2.02	1.9	1.97	1.89	#NA	1.91
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	52.14	#NA	#NA	#NA	#NA	45.35	#NA	#NA	#NA	#NA	45.9	#NA
TFL density	1.4602	1.4622	1.4622	1.4622	1.4622	1.4622	1.3789	1.3789	1.3789	1.3789	1.3789	1.3777	1.3777
date	1201	1201	1201	1201	1201	1201	1203	1203	1203	1203	1203	1203	1203
time	2141	2141	2141	2141	2141	2141	1630	1630	1630	1630	1630	1630	1630
Li/Fe	0.204	#NA	0.218	0.228	0.224	0.223	#NA	0.201	0.208	0.208	0.227	#NA	0.219
Si/Al	8.15	#NA	8.76	8.86	8.79	8.96	#NA	8.14	8.66	8.50	9.31	#NA	8.89
	53	54	55	56	57	58	59	60	61	62	63	64	65
				0.223	0.005				0.211	0.013			
	0.204		0.218	0.228	0.224	0.223	0.201	0.208	0.208	0.227		0.219	

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	284	285	286	287	288	289	290	291	292	293	294	295	296
location	1	1	1	2	2	2	2	2	1	1	1	1	1
boron	2.06	2.07	2.08	#NA	2.44	2.4	2.37	2.43	#NA	2.45	2.41	2.43	2.42
iron	9.23	9.21	9.14	#NA	9.67	9.76	9.64	9.65	#NA	9.58	9.47	9.34	9.4
silicon	24.1	24.1	24	#NA	24	23.9	24	24.3	#NA	24.6	24.7	24.6	24.6
aluminum	2.67	2.73	2.69	#NA	1.75	1.77	1.72	1.75	#NA	1.73	1.72	1.7	1.7
lithium	2.01	2.02	1.98	#NA	2.07	2.11	2.1	2.11	#NA	2.11	2.12	2.14	2.12
potassium	1.92	1.91	1.89	#NA	2.11	2.11	2.1	2.14	#NA	2.07	2.06	2.08	2.11
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	42.28	#NA	#NA	#NA	#NA	43.49	#NA	#NA	#NA	#NA
TFL density	1.3777	1.3777	1.3777	1.3468	1.3468	1.3468	1.3468	1.3468	1.3463	1.3463	1.3463	1.3463	1.3463
date	1203	1203	1203	1204	1204	1204	1204	1204	1204	1204	1204	1204	1204
time	1630	1630	1630	1212	1212	1212	1212	1212	1212	1212	1212	1212	1212
Li/Fe	0.218	0.219	0.217	#NA	0.214	0.216	0.218	0.219	#NA	0.220	0.224	0.229	0.226
Si/Al	9.03	8.83	8.92	#NA	13.71	13.50	13.95	13.89	#NA	14.22	14.36	14.47	14.47
	66	67	68	69	70	71	72	73	74	75	76	77	78
	0.218	0.001			0.217	0.003				0.225	0.004		
	0.218	0.219	0.217	0.214	0.216	0.218	0.219		0.22	0.224	0.229	0.226	

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	298	299	300	301	302	303	304	305	306	307	308	309	310
location	2	2	2	2	2	1	1	1	1	1	1	1	1
boron	#NA	2.43	2.44	2.42	2.46	#NA	2.49	2.47	2.48	2.44	#NA	2.45	2.46
iron	#NA	9.54	10	9.55	10.1	#NA	9.7	9.56	9.56	9.59	#NA	9.63	9.6
silicon	#NA	24.6	24.2	23.8	24.3	#NA	25.1	24.8	24.5	24.4	#NA	24.8	25
aluminum	#NA	1.69	1.8	1.71	1.82	#NA	1.74	1.72	1.72	1.72	#NA	1.77	1.79
lithium	#NA	2.16	2.14	2.13	2.14	#NA	2.22	2.2	2.15	2.18	#NA	2.16	2.14
potassium	#NA	2.06	2.19	2.09	2.23	#NA	2.12	2.08	2.06	2.08	#NA	2.2	2.26
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	42.24	#NA	#NA	#NA	#NA	42.74	#NA	#NA	#NA	#NA	39.42	#NA	#NA
TFL density	1.3417	1.3417	1.3417	1.3417	1.3417	1.3487	1.3487	1.3487	1.3487	1.3487	1.3176	1.3176	1.3176
date	1205	1205	1205	1205	1205	1205	1205	1205	1205	1205	1206	1206	1206
time	1021	1021	1021	1021	1021	1021	1021	1021	1021	1021	1001	1001	1001
Li/Fe	#NA	0.226	0.214	0.223	0.212	#NA	0.229	0.230	0.225	0.227	#NA	0.224	0.223
Si/Al	#NA	14.56	13.44	13.92	13.35	#NA	14.43	14.42	14.24	14.19	#NA	14.01	13.97
	79	80	81	82	83	84	85	86	87	88	89	90	91
		0.219	0.008				0.228	0.003				0.224	
	0.226	0.214	0.223	0.212		0.229	0.23	0.225	0.227		0.224	0.223	

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	311	312	313	314	315	316	317	337	338	339	340	341	342
location	1	1	2	2	2	2	2	2	2	2	2	2	5
boron	2.45	2.43	#NA	2.43	2.44	2.47	2.43	2.45	2.39	2.4	2.43	2.44	2.39
iron	9.55	9.52	#NA	9.75	10.1	9.45	10.2	10	9.93	9.67	9.92	10	9.95
silicon	24.8	24.5	#NA	24.3	24.4	25.1	24.3	23.8	24	24.2	24	23.9	23.8
aluminum	1.78	1.76	#NA	1.81	1.88	1.74	1.86	1.86	1.84	1.8	1.84	1.86	1.84
lithium	2.14	2.15	#NA	2.14	2.12	2.2	2.1	2.11	2.06	2.14	2.11	2.1	2.08
potassium	2.18	2.22	#NA	2.24	2.28	2.14	2.3	2.3	2.28	2.22	2.26	2.29	2.26
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	39.7	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	1.3176	1.3176	1.3159	1.3159	1.3159	1.3159	1.3159	1.3181	1.3181	1.3181	1.3181	1.3181	1.3181
date	1206	1206	1206	1206	1206	1206	1206	1209	1209	1209	1209	1209	1209
time	1001	1001	1001	1001	1001	1001	1001	1653	1653	1653	1653	1653	1653
LI/Fe	0.224	0.226	#NA	0.219	0.210	0.233	0.206	0.211	0.207	0.221	0.213	0.210	0.209
SI/Al	13.93	13.92	#NA	13.43	12.98	14.43	13.06	12.80	13.04	13.44	13.04	12.85	12.93
	92	93	94	95	96	97	98	99	100	101	102	103	104
	0.001			0.217	0.014				0.212	0.005			
	0.224	0.226		0.219	0.21	0.233	0.206	0.211	0.207	0.221	0.213	0.21	0.209

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	343	344	345	346	347	348	349	350	351	352	353	354	355
location	5	5	5	5	2	2	2	2	2	5	5	5	5
boron	2.42	2.43	2.41	2.42	2.42	2.38	2.43	2.42	2.4	2.4	2.38	2.41	2.37
iron	9.72	9.77	9.97	9.96	9.87	10.2	9.81	9.71	9.93	9.4	9.28	9.44	9.92
silicon	24.2	24.1	23.8	24	24	23.5	24.1	24.2	23.6	24.2	24.1	24.5	23.6
aluminum	1.8	1.81	1.84	1.84	1.82	1.85	1.8	1.79	1.84	1.74	1.73	1.74	1.83
lithium	2.11	2.11	2.13	2.11	2.12	2.07	2.12	2.14	2.09	2.15	2.11	2.15	2.08
potassium	2.28	2.27	2.23	2.2	2.25	2.28	2.22	2.24	2.24	2.16	2.11	2.15	2.27
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	1.3181	1.3181	1.3181	1.3181	1.3206	1.3206	1.3206	1.3206	1.3206	1.3206	1.3206	1.3206	1.3206
date	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209
time	1653	1653	1653	1653	1715	1715	1715	1715	1715	1715	1715	1715	1715
Li/Fe	0.217	0.216	0.214	0.212	0.215	0.203	0.216	0.220	0.210	0.229	0.227	0.228	0.210
Si/Al	13.44	13.31	12.93	13.04	13.19	12.70	13.39	13.52	12.83	13.91	13.93	14.08	12.90
	105	106	107	108	109	110	111	112	113	114	115	116	117
	0.214	0.003				0.213	0.007				0.222	0.008	
	0.217	0.216	0.214	0.212	0.215	0.203	0.216	0.22	0.21	0.229	0.227	0.228	0.21

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	356	357	358	359	360	361	362	363	364	365	366	377	378
location	5	1	1	1	1	1	6	6	6	6	6	6	6
boron	2.4	2.38	2.4	2.41	2.39	2.39	2.38	2.39	2.4	2.4	2.37	2.4	2.45
iron	9.65	9.21	9.33	9.29	9.35	9.25	9.38	9.28	9.28	9.38	9.35	9.43	9.3
silicon	23.8	23.9	24	24	24.3	24.2	24.1	24.2	24.2	24.2	23.9	24.7	24.9
aluminum	1.78	1.73	1.75	1.73	1.74	1.74	1.74	1.74	1.73	1.76	1.72	1.76	1.76
lithium	2.1	2.12	2.14	2.16	2.14	2.13	2.16	2.13	2.14	2.13	2.13	2.16	2.16
potassium	2.22	2.18	2.18	2.18	2.2	2.16	2.13	2.16	2.14	2.14	2.13	2.17	2.17
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
total solids	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	1.3206	1.3199	1.3199	1.3199	1.3199	1.3199	1.3181	1.3181	1.3181	1.3181	1.3181	1.3206	1.3206
date	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209	1209
time	1715	1651	1651	1651	1651	1651	1653	1653	1653	1653	1653	1715	1715
Li/Fe	0.218	0.230	0.229	0.233	0.229	0.230	0.230	0.230	0.231	0.227	0.228	0.229	0.232
Si/Al	13.37	13.82	13.71	13.87	13.97	13.91	13.85	13.91	13.99	13.75	13.90	14.03	14.15
	118	119	120	121	122	123	124	125	126	127	128	129	130
			0.230	0.002				0.229	0.002				0.232
	0.218	0.23	0.229	0.233	0.229	0.23	0.23	0.23	0.231	0.227	0.228	0.229	0.232

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	379	380	381	382	383	384	385	386	387	388	389	390	391
location	6	6	6	1	1	1	1	1	7	7	7	7	7
boron	2.41	2.42	2.41	2.45	2.44	2.41	2.41	2.42	2.4	2.41	2.39	2.39	2.39
iron	9.33	9.29	9.26	9.51	9.4	9.38	9.47	9.29	9.3	9.7	9.77	9.7	9.52
silicon	24.7	24.5	24.6	24.6	24.6	24.7	24.8	24.5	25	24.1	24.2	23.7	24.3
aluminum	1.77	1.73	1.74	1.76	1.76	1.75	1.75	1.73	1.74	1.81	1.81	1.82	1.79
lithium	2.13	2.19	2.18	2.19	2.17	2.13	2.13	2.13	2.15	2.11	2.11	2.08	2.12
potassium	2.12	2.09	2.09	2.17	2.14	2.11	2.13	2.08	2.1	2.23	2.17	2.23	2.18
density	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	1.3206	1.3206	1.3206	1.3231	1.3231	1.3231	1.3231	1.3231	1.3222	1.3222	1.3222	1.3222	1.3222
date	1209	1209	1209	1213	1213	1213	1213	1213	1213	1213	1213	1213	1213
time	1715	1715	1715	1353	1353	1353	1353	1353	1417	1417	1417	1417	1417
Li/Fe	0.228	0.236	0.235	0.230	0.231	0.227	0.225	0.229	0.231	0.218	0.216	0.214	0.223
Si/Al	13.95	14.16	14.14	13.98	13.98	14.11	14.17	14.16	14.37	13.31	13.37	13.02	13.58
	131	132	133	134	135	136	137	138	139	140	141	142	143
	32	0.004			0.228	0.002				0.220	0.007		
	0.228	0.236	0.235	0.23	0.231	0.227	0.225	0.229	0.231	0.218	0.216	0.214	0.223

TABLE 4 SUMMARY OF CHEMICAL ANALYSES, continued

vial	1	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406
location	2	7	7	7	7	7	1	1	1	1	1	6	6	6	6	6
boron	3	2.4	2.44	2.38	2.42	2.37	2.37	2.38	2.41	2.4	2.39	2.39	2.39	2.38	2.4	2.39
iron	4	9.86	9.41	9.93	9.71	9.91	9.17	9.23	9.19	9.31	9.19	8.8	8.9	8.87	8.91	8.86
silicon	5	23.9	24.4	24.2	24.4	23.8	22.6	23	23.1	23	23.1	23.5	23.1	23.5	23.3	23.3
aluminum	6	1.83	1.75	1.82	1.82	1.85	1.72	1.73	1.74	1.75	1.73	1.67	1.67	1.66	1.67	1.69
lithium	7	2.14	2.15	2.1	2.13	2.09	2.04	2.11	2.13	2.13	2.11	2.17	2.14	2.17	2.16	2.13
potassium	8	2.23	2.15	2.23	2.2	2.25	2.08	2.09	2.13	2.12	2.1	2.04	2.04	2.03	2.07	1.97
density	9	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
tot solids	10	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA	#NA
TFL density	11	1.3235	1.3235	1.3235	1.3235	1.3235	1.3119	1.3119	1.3119	1.3119	1.3119	1.321	1.321	1.321	1.321	1.321
date	12	1213	1213	1213	1213	1213	215	215	215	215	215	215	215	215	215	215
time	13	1427	1427	1427	1427	1427	924	924	924	924	924	927	927	927	927	927
Li/Fe		0.2170	0.2285	0.2115	0.2194	0.2109	0.2225	0.2286	0.2318	0.2288	0.2296	0.2466	0.2404	0.2446	0.2424	0.2404
Si/Al		13.06	13.94	13.30	13.41	12.86	13.14	13.29	13.28	13.14	13.35	14.07	13.83	14.16	13.95	13.79
		144	145	146	147	148	149	150	151	152	153	154	155	156	157	158
			0.2175	0.0071				0.2283	0.0035				0.2429	0.0027		
		0.217	0.2285	0.2115	0.2194	0.2109	0.2225	0.2286	0.2318	0.2288	0.2296	0.2466	0.2404	0.2446	0.2424	0.2404

Figure 1 Effect of Particle Size and Sampling Velocity on Concentration Ratio for Side Wall Sampling

Figure 2 Effect of Sampling Velocity on Concentration Ratio for Side Wall Sampling with Projection

Figure 3
Piping Schematic for Hydragard Sampling System

Figure 4 Hydragard Valve and Vial

Figure 5 Details of Valve Action for Original and Modified Hydragard

Figure 6
COLIWASA (Composite Liquid Waste Sampler)

Figure 7
Gage Pressure Drop Just Downstream of Hydragard Valve

Figure 8 Relationship Between Changes in Slurry Density and Li/Fe

Figure 9 Slurry Densities Measured in TFL Hydragard Loop

Figure 10 TFL Hydragard Test

Percentage Discrepancy Between Slurry Density Slurry Reservoir and Vial Overflow

Figure 11 Increase in Slurry Density at Hydragard Overflow as Compared with Slurry Reservoir

Figure 12 Increase in Slurry Density at Hydragard Overflow as Compared with Slurry Reservoir, Runs with Forced Vial Flow Deleted

Figure 13 Short Term Modification of Hydragard Valve.

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Tests of TFL Hydragard Sampling Loop
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**Figure 14 Comparison of Li/Fe in Vial
with Slurry Density at Overflow**

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Li Fe norm By rho norm

Linear Fit

Summary of Fit

Rsquare	0.739443
Root Mean Square Error	0.023475
Mean of Response	0.963933
Observations (or Sum Wgts)	15

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	0.02033094	0.020331	36.8931
Error	13	0.00716399	0.000551	Prob>F
C Total	14	0.02749493		0.0000

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob> t
Intercept	-7.404516	1.37777	-5.37	0.0001
rho norm	8.3595325	1.37629	6.07	0.0000

Figure 15 Statistics and Confidence Limits for Relation Between Density and Li/Fe Ratio

Figure 16
Relationship of Silicon, Aluminum, Silicon
and Lithium for TNX and DWPF Slurries

Figure 17 Measured Li/Fe for Hydragard Vials Divided by Predicted Li/Fe Based on Slurry Density

Figure 18
Hydragard Vial Flow as Function of Driving Pressure