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under Contract DE-AC05-76RL01830

Ion Exchange Testing with SRF Resin FY 2012

RL Russell
DE Rinehart
RA Peterson

June 2014

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Test Specification: 24590 PTF-TSP-RT-09-002, Rev. 0
Test Plan: TP-RPP-WTPSP-002, Rev. 3.0
Test Exceptions: 24590-PTF-TEF-RT-11-00003, Rev. 0 and
24590-PTF-TEF-RT-11-00004, Rev. 0
R&T Focus Area: Pretreatment
Test Scoping Statement: 24590-WTP-PL-RT-07-0002, Rev 0; M6-3

Prepared for the U.S. Department of Energy
Under Contract DE-AC05-76RL01830
Pacific Northwest National Laboratory
Richland, Washington 99352

Completeness of Testing

This report describes the results of work and testing specified by Test Specification, 24590-PTF-TSP-RT-09-002, Rev 0, Test Exception 24590-PTF-TEF-RT-11-00003, Rev. 0, and Test Plan TP-WTPSP-002, Rev. 3.0. The work followed the quality assurance requirements outlined in the Test Specification and Test Plan. The descriptions provided in this report are an accurate account of both the conduct of the work and the data collected. Test Plan results are reported. Also reported are any unusual or anomalous occurrences that are different from expected results. The test results and this report have been reviewed and verified.

Approved:

Reid A Peterson, Manager
WTP R&T Support Project

7/2/14
Date

Testing Summary

Ion exchange using spherical resorcinol-formaldehyde (SRF) resin has been selected by the U.S. Department of Energy's Office of River Protection (DOE-ORP) for use in the Pretreatment Facility (PTF) of the Hanford Tank Waste Treatment and Immobilization Plant (WTP) and for potential application in at-tank deployment. Numerous studies have shown SRF resin to be effective for removing ^{137}Cs from a wide variety of actual and simulated tank waste supernatants (Adamson et al. 2006; Blanchard et al. 2008; Burgeson et al. 2004; Duignan and Nash 2009; Fiskum et al. 2006a; Fiskum et al. 2006b; Fiskum et al. 2006c; Fiskum et al. 2007; Hassan and Adu-Wusu 2003; King et al. 2004; Nash et al. 2006). Prior work at the Pacific Northwest National Laboratory (PNNL) has focused primarily on the loading behavior for 4 to 6 M Na solutions at 25 to 45°C. Recent proposed changes to the WTP ion exchange process baseline indicate that loading may include a broader range of sodium molarities (0.1 to 8 M) and higher temperatures (50°C) to alleviate post-filtration precipitation issues. Previous work focused on testing the higher Na concentrations (5 to 8M) as reported by Russell et al. (2012).

This report discusses ion exchange loading kinetics testing activities performed in accordance with Test Plan TP-WTPSP-002, Rev. 3.0[1], which was prepared and approved in response to the Test Specification 24590-PTF-TSP-RT-09-002, Rev. 0 (Lehrman 2010) and Test Exception 24590-PTF-TEF-RT-11-00003, Rev. 0 (Meehan 2011). This testing focused on column tests evaluating the impact of elevated temperature on resin degradation over an extended period of time and batch contacts evaluating the impact on Cs loading over a broad range of sodium concentrations (0.1 to 5 M). These changes may be required to alleviate post-filtration precipitation issues and broaden the data range of SRF resin loading under the conditions expected with the new equipment and process changes.

Objectives

The test objectives included the following:

- Determine the impact of 0.1 to 5 M sodium, 0.005 to 0.05 M potassium, 0.1 to 1 M free hydroxide, and 5E-06 to 5E-03 M cesium on the Cs ion exchange loading of the SRF resin at 25, 35, and 50°C.
- Determine the impact of temperature (25, 35, 40, and 45°C) on Cs ion exchange kinetics and loading of the SRF resin.
- Determine the impact of temperature (45, 50, 55, and 60°C) on Cs ion exchange loading of the SRF resin during extended (>30-day) exposure to flowing waste simulant.

Table S.1 provides test objectives and results for the ion exchange loading kinetics testing task.

[1]Russell RL. 2010. *Cesium Ion Exchange Simulant Testing in Support of M6*. TP-WTPSP-002, Rev. 3.0, Pacific Northwest National Laboratory, Richland, Washington.

Table S.1. Summary of Test Objectives and Results

Test Objective	Objective Met?	Discussion
• Determine the impact of 0.1 to 5 M sodium, 0.005 to 0.05 M potassium, 0.1 to 1 M free hydroxide, and 5E-06 to 5E-03 M cesium on the Cs loading of the SRF resin at various temperatures.	Yes	Batch loading tests were performed using simulants with varying Na, OH, K, and Cs concentrations. It was found that Cs loading was primarily affected by Na concentration. Potassium appeared to have a varying effect on the Cs loading; lower Cs concentrations had greater K effect. This was expected due to the competition for the resin sites between the K and the Cs. The OH concentration did not have a significant effect on the resin Cs loading. The temperature effect on the resin Cs loading appeared to be dependent on Na concentration with the effect being greater at lower Na concentrations. At 5 M Na, only a slight negative effect of increasing temperature was observed; however, at 1 M Na, the effect of increasing temperature was much greater. These results are discussed in Section 4.3.
• Determine the impact of multiple moderate temperature loading cycles on Cs ion exchange kinetics and loading of the SRF resin.	Yes	Columns were loaded with a 5 M Na feed initially and then cycled through several loading and elution cycles. After five cycles, columns were loaded with the same 5 M Na feed as used initially under the same conditions. The level of Cs loading on the resin was then compared. Moderate temperature cycling up to 45°C only affected the resin Cs loading slightly and did not have a significant effect on the loading kinetics of the resin. These results are discussed in Section 4.2.
• Determine the impact of temperature on Cs ion exchange loading of the SRF resin during extended (>30-day) exposure to flowing waste simulants.	No	Ion exchange columns were held at varying temperatures from 45 to 60°C for 14 to 30 days with feed passing through them. Simulant feed samples were taken periodically to assess the Cs loading of the resin. Testing for these extended times at elevated temperatures showed that resin loading capacity decreased at 45°C and continually decreased with increasing temperature. Column plugging was observed in all runs above 45°C prior to the end of the 30-day test period. These results are discussed in Section 4.2.

Test Exceptions

Test Exceptions applicable to Test Plan TP-WTPSP-002, Rev. 3[1] are presented in Table S.2.

Table S.2. Test Exceptions

Test Exception Number	Description of Test Exception
24590-PTF-TEF-RT-11-00003, Rev 0	This Test Exception was received from Bechtel National, Inc. (BNI) on September 13, 2011. Two requests to expand the process limits evaluation for cesium ion exchange resin were received and the outcome of earlier testing temperatures at 55°C and above requires further testing to confirm appropriate operating limits for WTP ion exchange. The WTP mission simulations using the G2 Dynamic model have shown that the cesium ion exchange process (CXP) feed stream will 'frequently' be below 2.0 M Na. Therefore, the process limits were changed to evaluate cesium removal performance at Na concentrations as low as 0.71 M. Also, unexpected challenges were experienced for conditions at 55°C and above during cesium removal. BNI suspected that the mechanism for these issues was related to the simple simulant applied during testing the previous year. Therefore, they wanted to use a more complex simulant to assess performance in extended 30-day duration in solutions at and above 55°C in this testing. These temperature evaluations are needed to identify the specific operating temperature range for SRF resin. Data on the fire safety limits for soot/particulate generation and ignition temperature for the SRF resin was also requested. This is addressed in report WTP-RPT-218 (Kim 2012).
24590-PTF-TEF-RT-11-00004, Rev 0	This Test Exception was received from BNI on December 22, 2011. This is not applicable to the task in this report and is addressed in report WTP-RPT-218 (Kim 2012).

[1]Russell RL. 2010. *Cesium Ion Exchange Simulant Testing in Support of M6*. TP-WTPSP-002, Rev. 3.0, Pacific Northwest National Laboratory, Richland, Washington.

Results and Performance Against Success Criteria

The Research and Technology (R&T) success criteria for achieving the test objectives is discussed in Table S.3.

Table S.3. Success Criteria Ion Exchange Loading Kinetics

List Success Criteria	Explain How the Tests Did or Did Not Meet the Success Criteria
1) Develop empirical information that allows determination of the effect of temperature and initial Na, initial K, initial Cs, and free OH ion concentrations on Cs loading capacity of the ion exchange resin.	This success criterion was met. The batch bottles were loaded with various compositions of simulants and SRF resin at a volumetric phase ratio of 150:1 for 72 hr. The level of Cs in the solution was measured before and after the 72 hr and the results were compared. It was found that Cs loading was primarily affected by Na and Cs concentrations. Potassium appeared to have a varying effect on Cs loading; lower Cs concentrations had greater K effect. This was expected due to the competition for the resin sites between the K and the Cs. The OH concentration did not have a significant effect on the resin Cs loading. The temperature effect on the resin loading appeared to be dependent on Na concentration with the effect being greater at lower Na concentrations. At 5 M Na, only a slight negative effect of increasing temperature was observed; however, at 1 M Na, the effect was greater.
2) Develop empirical information that allows determination of the effect of multiple moderate temperature loading cycles on the Cs kinetics and loading of the SRF resin.	This success criterion was met. The columns were loaded with a 5 M Na feed initially and then cycled through several loading and elution tests. After a total of four 10 hr cycles and one extended cycle at elevated temperature (14 to 30 days), the column was loaded with the same 5 M Na feed as used initially under the same conditions. The level of Cs loading on the resin was then compared to determine the effect of these variables. Moderate temperature cycling up to 45°C only affected the resin Cs loading slightly and did not have a significant effect on the loading kinetics of the resin.
3) Develop empirical information that allows determination of the impact of temperature on Cs loading of the SRF resin during extended (>30-day) exposure to flowing waste simulants.	This success criterion was partially met. The extended run tests at 55°C and 60°C that were intended to run for 720 hr were aborted after ~336 hr due to column plugging. The extended run test at 50°C that was intended to run for 720 hr was aborted after ~600 hr due to column plugging. Columns were held at varying temperatures from 45 to 60°C for 14 to 30 days with feed passing through them. Samples were taken periodically to assess the Cs loading of the resin. Testing for these extended times at elevated temperatures showed that the resin Cs loading decreased at 45°C and continually decreased with increasing temperature.

Quality Requirements

The PNNL Quality Assurance (QA) Program is based on requirements defined in the DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830, *Energy/Nuclear Safety Management*, and Subpart A--*Quality Assurance Requirements* (a.k.a. the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.

- ASME NQA-1-2000, Part II, Subpart 2.7, *Quality Assurance Requirements for Computer Software for Nuclear Facility Applications*.
- ASME NQA-1-2000, Part IV, Subpart 4.2, *Graded Approach Application of Quality Assurance Requirements for Research and Development*.

The procedures necessary to implement the requirements are documented through PNNL's "How Do I…?" (HDI).[1]

The Waste Treatment Plant Support Project (WTPSP) implements an NQA-1-2000 QA Program, graded on the approach presented in NQA-1-2000, Part IV, Subpart 4.2. The WTPSP QA Manual (QA-WTPSP-0002) describes the technology life cycle stages under the WTPSP QA Plan (QA-WTPSP-0001). The technology life cycle includes the progression of technology development, commercialization, and retirement in process phases of basic and applied research and development (R&D), engineering and production and operation until process completion. The life cycle is characterized by flexible and informal quality assurance activities in basic research, which becomes more structured and formalized through the applied R&D stages.

The work described in this report has been completed under the QA technology level of Applied Research. WTPSP addresses internal verification and validation activities by conducting an Independent Technical Review of the final data report in accordance with WTPSP's procedure QA-WTPSP-601, *Document Preparation and Change*. This review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that the reported work satisfies the test plan objectives.

R&T Test Conditions

This report summarizes the ion exchange removal of Cs from a simple waste simulant using Microbeads SRF resin, Lot 5E-370/641. The resin was sub-sampled from existing stock that had been stored under N_2 at PNNL for more than 4 years in the H^+-form. The resin was bulk pretreated with de-ionized (DI) water, 1 M NaOH, and 0.5 M HNO_3 to cycle between Na^+ and H^+-forms.

The batch testing samples required 72 simulants to be prepared with varying amounts of Cs, Na, K, OH, and NO_3. The Na^+ form resin was contacted with each simulant for 72 hr at varying temperatures (25, 35, 50°C) with mixing and then sampled to determine the Cs loading on the resin.

For column testing, resin was placed in columns and further pretreated with another acid/base cycle prior to simulant loading. For batch resin testing, the resin was loaded after the bulk pretreatment. Dry resin density was determined by drying duplicate samples under vacuum at 50°C to constant mass.

Four columns of SRF resin were loaded with a simple simulant containing Cs, Na, K, Al, OH, and NO_3, partially eluted with 3 bed volumes (BV) 0.5 M HNO_3 and then eluted with 25+ BV of 0.25 M HNO_3 solution. These columns were cycled through a series of five loading and elution cycles.

All test conditions delineated by the test plan and test exceptions were met. A summary of test conditions is provided in Table S.4.

[1] System for managing the delivery of PNNL policies, requirements, and procedures.

Table S.4. R&T Test Condition Summary

List R&T Test Conditions	Were Test Conditions Followed?
1) Ion Exchange Loading Kinetics Tests	
(a) Small-column ion exchange loading tests were performed using near prototypic flow conditions with feed recycle until equilibrium loading was achieved in order to evaluate cesium uptake kinetics.	(a) A series of column loading and elution cycles were completed as detailed in Table 3.4. The composition of the simulant used is shown in Table 3.1. The ion exchange columns were loaded with simulant feed solution at temperatures between 25±2°C and 60±2°C. The solution was processed at various flow velocities as shown in Table 3.4 for the 10 h to 30 days of loading. Following loading, the feed solution was displaced with 7.5 BV of 0.1 M NaOH, rinsed with 7.5 BV of DI water, and the resin was neutralized with 3 BV of 0.5 M HNO_3 at 3 BV/h as is outlined in Table 3.3.
(b) The results from these tests will be used to assess the impact of linear load velocity and the impact of high free hydroxide on resin degradation during extended solution flow using elevated temperatures. Preliminary results of testing will be transmitted to the WTP Project lead.	(b) The results from these tests were used to assess the impact of linear load velocity and the impact of high free hydroxide on resin degradation during extended solution flow using elevated temperatures as discussed in Sections 4.1 and 4.2. Preliminary results of the testing were transmitted to the WTP Project lead.
2) Ion Exchange Batch Loading Tests	
(a) Several small (<1 mL) batches of conditioned SRF resin were each contacted with supernate simulants containing various Na, Cs, K, and OH ion concentrations. The balance of the simulant was nitrate ion. Approximately 0.1 g resin was contacted with ~25 mL of simulant (volumetric phase ratio of 150:1) for 72 hr to ensure equilibrium had been reached. Sub-sets of samples were mixed at approximately 25°C, 35°C and 50°C.	(a) Approximately 0.1 g of dry resin was added to ~25 mL of each of the 72 simulants and mixed at the designated temperature of 25, 35, or 50°C for 72 hr and then sampled. Samples were analyzed for Cs concentration to determine Cs loading under these conditions.
(b) Data from this testing was analyzed to determine the impact of Na, OH, and K levels on Cs loading.	(b) The data from this testing was analyzed and the impact of these variables is reported in Section 4.3.

Simulant Use

The small-column kinetics loading testing task was performed using a single nonradioactive aqueous simulant solution for Cs loading of the SRF resin. The nominal Na, Cs, OH, and Al concentrations were selected to be 5 M, 4.5E-05 M, 1.2 M, and 0.115 M, respectively. This simulant was not selected to represent any particular Hanford tank waste type.

The batch loading tests were performed with a variety of 72 different simulants with varying amounts of Na, K, Cs, OH, and NO_3. Na ranged from 0.1 to 5 M and the Cs ranged from 5.0E-06 to 5.0E-03 M. K was either 0.005 or 0.05 M and free OH was either 0.1 or 1 M. The anion used to obtain these concentrations was nitrate. The simulants were not selected to represent any particular Hanford tank waste type but to assess the ion effect over varying concentration ranges.

Discrepancies and Follow-on Tests

The extended run tests at 55 and 60°C that were intended to run for 720 hr were aborted after ~336 hr due to column plugging. The extended run test at 50°C intended to run for 720 hr was aborted after ~600 hr due to column plugging. When tested, the resin was a hard clump that was difficult to break up, and therefore prevented solution from flowing through it. Two columns had to be opened and the resin mass broken up before they could be eluted.

Acknowledgments

The authors would like to thank the Southwest Research Institute (Daniel Ramirez and other staff, San Antonio, Texas) for analytical support. The authors also would like to thank David Sherwood of the Hanford Tank Waste Treatment and Immobilization Plant project for his support. The authors are grateful for the assistance of Pacific Northwest National Laboratory staff members Mike Parker for editorial and document design support and Garrett Brown for technical review.

Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
BNI	Bechtel National, Inc.
BV	bed volumes
CXP	cesium ion exchange process
DIW	de-ionized water
DOE	U.S. Department of Energy
FFPM	perfluorinated elastomer
GGRF	ground gel resorcinol-formaldehyde
HDI	How Do I
HLW	high-level waste
IC	ion chromatography
ICP	inductively coupled plasma
LAW	low activity waste
MS	mass spectroscopy
NA	not applicable
OES	optical emission spectroscopy
ORP	Office of River Protection
PNNL	Pacific Northwest National Laboratory
PTF	Pretreatment Facility
PTFE	polytetrafluoroethylene
PVDF	polyvinylidene fluoride
QA	quality assurance
R&D	research and development
RF	resorcinol-formaldehyde
RPP	River Protection Project
R&T	research and technology
RV	resin volume
SRF	spherical resorcinol-formaldehyde
SwRI	Southwest Research Institute
TIC	total inorganic carbon
TOC	total organic carbon
TRU	transuranic
WSRC	Westinghouse Savannah River Company
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WTPSP	Waste Treatment Plant Support Project

Contents

Figures

Tables

1.0 Introduction

The U.S. Department of Energy (DOE) Hanford Site contains more than 53 million gallons of legacy waste generated as a byproduct of plutonium production and reprocessing operations. The wastes are a complex mixture composed mostly of $NaNO_3$, $NaNO_2$, NaOH, $NaAlO_2$, Na_3PO_4, and Na_2SO_4, with a number of minor and trace metals, organics, and radionuclides stored in underground waste tanks. The DOE's Office of River Protection (ORP) has contracted Bechtel National Incorporated (BNI) to build a pretreatment facility (PTF), the River Protection Project-Waste Treatment Plant (RPP-WTP), that will separate long-lived transuranics (TRU) and highly radioactive components (specifically ^{137}Cs and, in selected cases, ^{90}Sr) from the bulk (nonradioactive) constituents and immobilize the wastes by vitrification. The plant is designed to produce two waste streams: a high-volume low-activity waste (LAW) and a low-volume high-activity waste (HLW).

Ion exchange using the spherical resorcinol-formaldehyde (SRF) resin has been selected by the WTP project and approved by DOE-ORP for use in the PTF of the RPP-WTP. The SRF resin is an engineered spherical form of the older ground gel resorcinol-formaldehyde (GGRF) resin, also termed resorcinol-formaldehyde (RF), which was developed and evaluated at the Westinghouse Savannah River Company (WSRC) in the 1980s (Ebra and Wallace 1983; Bibler et al. 1989). Numerous studies at Hanford and other DOE sites have shown the GGRF and SRF resins to be effective for removing ^{137}Cs from a wide variety of simulated and actual tank waste supernatants and for achieving less than the proposed spent waste classification criteria of <100 nCi TRU and <60 μCi ^{137}Cs per gram of spent resin (Adamson et al. 2006; Blanchard et al. 2008; Burgeson et al. 2004; Duignan and Nash 2009; Fiskum et al. 2006a; Fiskum et al. 2006b; Fiskum et al. 2006c; Fiskum et al. 2007; Hassan and Adu-Wusu 2003; King et al. 2004; Kurath et al. 1994; Nash et al. 2006).

Prior work has focused primarily on loading behavior for 5 M Na solutions at 25°C (Hassan et al. 2004; King et al. 2004; Peterson et al. 2006; Fiskum et al. 2006a). Recent proposed changes to the process baseline in the PTF indicate that both a broader range of sodium molarities (0.1 to 8 M) and higher temperatures may be required to alleviate post-filtration precipitation issues. The objective of this report is to summarize the results of the resin's Cs loading under lower Na concentrations and higher temperatures as well as the resin's Cs loading kinetics and degradation at 5 M Na under higher temperatures. Previous work focused on testing the higher Na concentrations (5 to 8 M) as reported by Russell (2012).

Section 1.0 provides a brief historical background for HLW, Cs ion exchange, and the test design. Section 2.0 details the basis of the Pacific Northwest National Laboratory (PNNL) Quality Assurance (QA) Program as applied to the RPP-WTP quality requirements. Section 3.0 describes the test design, solution and resin preparations, equipment, process steps, and chemical analyses. Section 4.0 provides a summary of the experimental data and includes a discussion of the results of the Cs ion exchange kinetics testing and the Cs loading under various conditions. Section 5.0 provides a list of conclusions obtained from this experimental work. Section 6.0 provides a list of references cited in this report. Appendix A and Appendix B list experimental conditions and analytical data, respectively.

2.0 Quality Assurance

The PNNL QA Program is based on the requirements defined in DOE Order 414.1D, *Quality Assurance,* and Title10 of the Code of Federal Regulations (CFR) Part 830, *Energy/Nuclear Safety Management*, and Subpart A, *Quality Assurance Requirements* (a.k.a. the Quality Rule). PNNL has chosen to implement the following consensus standards in a graded approach:

- ASME NQA-1-2000, *Quality Assurance Requirements for Nuclear Facility Applications*, Part 1, Requirements for Quality Assurance Programs for Nuclear Facilities.
- ASME NQA-1-2000, Part II, Subpart 2.7, *Quality Assurance Requirements for Computer Software for Nuclear Facility Applications*.
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The work described in this report has been completed under the QA technology level of Applied Research. WTPSP addresses internal verification and validation activities by conducting an Independent Technical Review of the final data report in accordance with the WTPSP procedure QA-WTPSP-601, *Document Preparation and Change*. This independent review verifies that the reported results are traceable, that inferences and conclusions are soundly based, and that the reported work satisfies the test plan objectives.

[1] System for managing delivery of PNNL policies, requirements, and procedures.

3.0 Experimental

This section summarizes the loading simulant preparation, acid solution preparation, NaOH solution preparation, SRF resin, resin pretreatment processing, ion exchange column system, column testing experimental procedure, batch loading testing system, and batch testing experimental procedure. Detailed laboratory test instructions were provided by internal documentation.[1,2,3] Data and observations were recorded on photocopied datasheets and the printed test instructions. Experimental conditions and analytical data are provided in Appendix A and Appendix B, respectively.

3.1 Loading Simulant Preparation

3.1.1 Kinetic Column Simulant

The small-column Cs loading kinetics testing task was performed using one nonradioactive aqueous simulant solution for loading Cs onto the SRF resin. This loading simulant composition is shown in Table 3.1. The nominal Na, Cs, OH, and K concentrations were selected to be 5 M, 4.51E-05 M, 1.2 M, and 0.030 M, respectively. This Cs loading simulant was not selected to represent any particular Hanford tank waste type.

Approximately 6 L of this Cs loading simulant solution was prepared. All chemicals were added to the bottle based on weight (±0.1 g) and were within 0.1 percent of the target. The density of the Cs loading simulant was measured to be 1.23 g/mL.

Table 3.1. Column Testing Simulant Solution for Cesium Ion Exchange Loading

Compound	Formula	Concentration (M) (1)
Potassium nitrate	KNO_3	0.030
Aluminum nitrate	$Al(NO_3)_3$-$9H_2O$	0.150
Sodium phosphate	Na_3PO_4-$12H_2O$	0.013
Sodium nitrate	$NaNO_3$	1.56
Sodium sulfate	Na_2SO_4	0.011
Sodium hydroxide	NaOH	1.20
Sodium carbonate	Na_2CO_3	0.663
Sodium oxalate	$Na_2C_2O_4$	0.017
Sodium nitrite	$NaNO_2$	0.831
Cesium nitrate	$CsNO_3$	4.51E-5

(1) This is the concentration of chemical that was added to the simulant and not the final ion concentration.

[1] Russell RL. 2012. *Simulant Preparation for Ion Exchange Batch Testing.* TI-WTPSP-064, Rev. 0, Pacific Northwest National Laboratory, Richland, Washington.
[2] Russell RL. 2012. *Resin Batch Contact Loading Tests.* TI-WTPSP-065, Rev 0, Pacific Northwest National Laboratory, Richland, Washington.
[3] Russell RL. 2012. FY12 *Small Column SRF Ion Exchange Kinetics Testing.* TI-WTPSP-077, Rev 0, Pacific Northwest National Laboratory, Richland, Washington.

3.1.2 Batch Loading Simulants

The batch Cs loading testing task was performed using 72 nonradioactive aqueous simulant solutions for Cs loading onto the SRF resin. These Cs loading simulant compositions are shown in Table 3.5 and were chosen to provide a wide range of each ion. The nominal Na concentration was selected to be between 0.1 and 5 M, the nominal Cs concentration was selected to be between 5.0E-06 and 5.0E-03 M, the free OH concentration was selected to be either 0.1 or 1.0 M, and the K concentration was selected to be either 0.005 or 0.05 M. The anion used to obtain these concentrations was nitrate. These simulants did not contain Al as opposed to the column test simulant. These Cs loading simulants were not selected to represent any particular Hanford tank waste type.

Approximately 500 mL of each Cs loading simulant solution was prepared. All chemicals were added to the bottle based on weight (±0.1 g) and were within 0.1 percent of the target except Cs which was added based on weight but to ±0.0001 g. The density of the Cs loading simulants were measured and ranged from 1.00 to 1.26 g/mL.

3.2 Acid Solution Preparation

Elution (0.25 M HNO_3) and acid conversion solutions (0.50 M HNO_3) were prepared by volumetric dilution of reagent-grade concentrated HNO_3 with de-ionized (DI) water in a volumetric flask.

3.3 NaOH Solution Preparation

NaOH solutions for SRF resin pretreatment (1.0 M), regeneration (0.50 M), and feed displacement (0.10 M) were prepared by weighing (±0.1 g) 50 percent NaOH solution into volumetric flasks and diluting to volume using DI water.

3.4 SRF Resin

The SRF resin used in these tests was from existing stock (Microbeads, Skedsmokorset, Norway, Lot Number 5E-370/641) that had been stored at PNNL for more than four years. The resin had been stored in the H^+-form in water under N_2 in sealed 2-L plastic bottles. A small (3 mm) layer of the resin was dark brown, indicating possible oxidative degradation, in contrast to the orange color of the remaining bulk. Upon opening the container, the top layer of resin was removed by vacuum sluicing and disposed of without use. The remaining resin was thoroughly mixed, and a representative sample was removed for use in the experiments using a coring technique consistent with the American Society for Testing and Materials (ASTM) Method 2687, Standard Practice for Sampling Particulate Ion-Exchange Materials (ASTM 2001). Even after vacuum sluicing of the top, darker brown layer and mixing the remaining material, a small fraction (<1 percent) of the sampled resin still exhibited the darker brown color as shown in Figure 3.1. The small fraction was deemed inconsequential and no further separation was attempted. Figure 3.2 displays an example visible light microscopy image of the SRF resin.

Figure 3.1. Representative SRF Resin Sample for Column Testing Showing Darkened Resin Beads

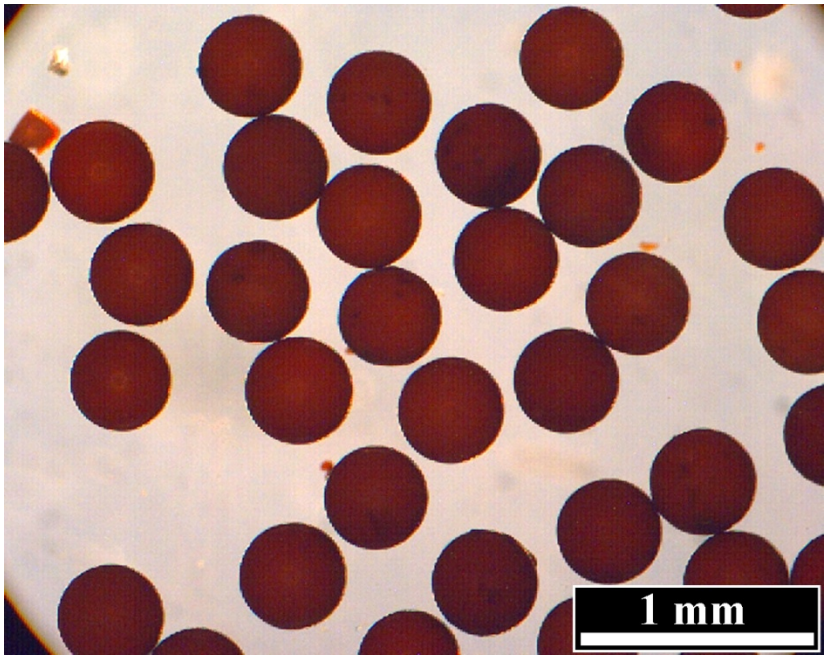

Figure 3.2. A Visible Light Microscopy Image of SRF Resin

3.5 Resin Pretreatment Processing

The overall resin bulk pretreatment and column pretreatment steps are shown in Table 3.2 and Table 3.3, respectively, and are consistent with previous testing[1] (Arm and Blanchard 2004; Fiskum et al. 2006b; Fiskum et al. 2006c). The bulk pretreatment processes used a full resin expansion/contraction cycle in an open beaker format as described in Fiskum et al. 2007, which allows for full expansion of the resin without it being constrained inside the ion exchange column and for the batch testing resin to be pretreated.

Table 3.2. Ion Exchange Bulk Pretreatment

Process/Pretreatment Step	Solution	Volume	Time	Mixing	Flowrate
Batch Bulk Pretreatment					
Water Rinse	DI Water	5 RV(a)	0.5 hr	Swirl(b)	NA(c)
Resin Expansion	1 M NaOH	5 RV	16 hr	Soak	NA
Water Rinse – 1st	DI Water	4.2RV	0.5 hr	Swirl	NA
Water Rinse – 2nd	DI Water	4.2RV	0.5 hr	Swirl	NA
Water Rinse – 3rd	DI Water	4.2RV	0.5 hr	Swirl	NA
Resin Conversion	0.5 M HNO_3	7.5 RV	2.5 hr	Swirl	NA
Water Rinse – 4th	DI Water	7.5 RV	2 min	Swirl	NA
Resin Expansion	1 M NaOH	7.5 RV	1.33 hr	Swirl	NA
Water Rinse – 5th	DI Water	7.5 RV	2 min	Swirl	NA

(a) Resin volume (RV) based on the settled volume of the initial H^+-form resin added to the beaker.
(b) Gently swirling by hand every 10 min.
(c) Not applicable (NA).

Following bulk pretreatment, some of the Na^+-form resin was slurry-transferred into the ion exchange column, rinsed with DI water, and converted into the H^+-form with up-flow 0.5 M HNO_3. The resin was then converted back into the Na^+-form with up-flow 0.5 M NaOH.

Six 10 mL sub-samples of the resin, three in the H^+-form and three that had been converted to the Na^+-form, were dried to a constant mass at 50°C in a vacuum oven. Constant mass was defined as <0.1 percent mass variation over two consecutive measurements taken at an interval of at least 7 hr. The average density of the resin was calculated to be 0.454 g/mL (mass of dried H^+-form resin per mL of settled H^+-form resin under water in a 10 mL graduated cylinder), consistent with values reported previously (Fiskum et al. 2006b; Fiskum et al. 2006c). The average density of the Na^+-form resin was calculated to be 0.348 g/mL (mass of dried Na^+-form resin per mL of settled Na^+-form resin).

[1] Nash CA and CE Duffey. August 17, 2004. *Hanford RPP-WTP Alternate Resin Program -Protocol P1-RF: Spherical Resin Sampling from Containers, Resin Pretreatment, F-Factor, and Resin Loading to Column*, WTP 097893, Savannah River National Laboratory.

Table 3.3. Ion Exchange Pretreatment and Process Steps in Column

Process/Pretreatment Step	Solution	Volume	Time	Mixing	Flowrate
Column Pretreatment					
Water Rinse	DI Water	7.5 BV[(a)]	2.5 hr	Flow	3 BV/h
Acid Rinse	0.5 M HNO_3	8 BV	2.7 hr	Flow	3 BV/h
Water Rinse	DI Water	3 BV	1 hr	Flow	3 BV/h
Feed Prep	0.5 M NaOH	6 BV	2 hr	Flow	3 BV/h
Column Loading/Eluting					
Simulant	Simulant	variable	10 hr	Flow	variable
Feed Displaced	0.1 M NaOH	7.5 BV	2.5 hr	Flow	3 BV/h
Water Rinse	DI Water	7.5 BV	2.5 hr	Flow	3 BV/h
Neutralization	0.5 M HNO_3	3 BV	1 hr	Flow	3 BV/h
Acid Elution	0.25 M HNO_3	25 BV	10 hr	Flow	2.8 BV/h
Water Rinse	DI Water	3 BV	1 hr	Flow	3 BV/h
Regeneration	0.5 M NaOH	6 BV	2 hr	Flow	3 BV/h

(a) Bed volume (BV) as Na^+-form loaded into the column.

3.6 Ion Exchange Column System

The kinetics experimental setup was based on a differential column concept described in detail in Duffey et al. (2003). This concept uses a thin resin bed exposed to a feed solution with nearly uniform uptake throughout the bed. In essence, this setup is designed to determine resin adsorption properties of a differential cross-sectional area of an ion exchange column. Implementation requires a controlled flow of liquid through the resin bed, a controlled temperature throughout the system, and continuous homogenization of the liquid phase. A schematic of the kinetics experimental setup is shown in Figure 3.3 and the actual system is shown in Figure 3.4.

Resin test samples were placed into the jacketed column. The resin was held in place between 200 mesh stainless steel screens. The simulant was fed through the column in an up-flow manner to minimize the amount of air initially in the system. The entire system remained closed with the exception of a small vent/sampling port in the simulant feed bottle. The target resin bed path length and diameter were 10.1 and 15.0 mm respectively, giving a target resin volume of 1.8 mL, which is similar to those reported by Duffey et al. (2003).

Between 170 mL and 180 mL of simulant feed was held within a capped 250 mL polyethylene bottle and was continually stirred with a 1-in. polytetrafluoroethylene (PTFE) stir bar. Approximately 3 mL samples were taken from the simulant feed bottle at 0, 6, 12, 18, 24, 36, 48, 60, 80, 120, 180, 240, and 600 minutes using a 10 mL plastic syringe with a 4-in. #18 stainless steel needle through the sampling port. The simulant feed bottle was wrapped in a heat jacket that was temperature controlled using a calibrated Type K thermocouple and a Digi-Sense temperature controller (Thermo Fisher, Waltham, Massachusetts). These experiments were conducted with a Stepdos reduced pulsation diaphragm-metering pump (KNF Neuberger, Trenton, New Jersey) with a polyvinylidene fluoride head, perfluorinated elastomer valves and gaskets, and PTFE-coated diaphragm. The jacketed column temperature was controlled using a Haake DC-5 (Thermo Electron, Newington, New Hampshire) re-circulating chiller/heater.

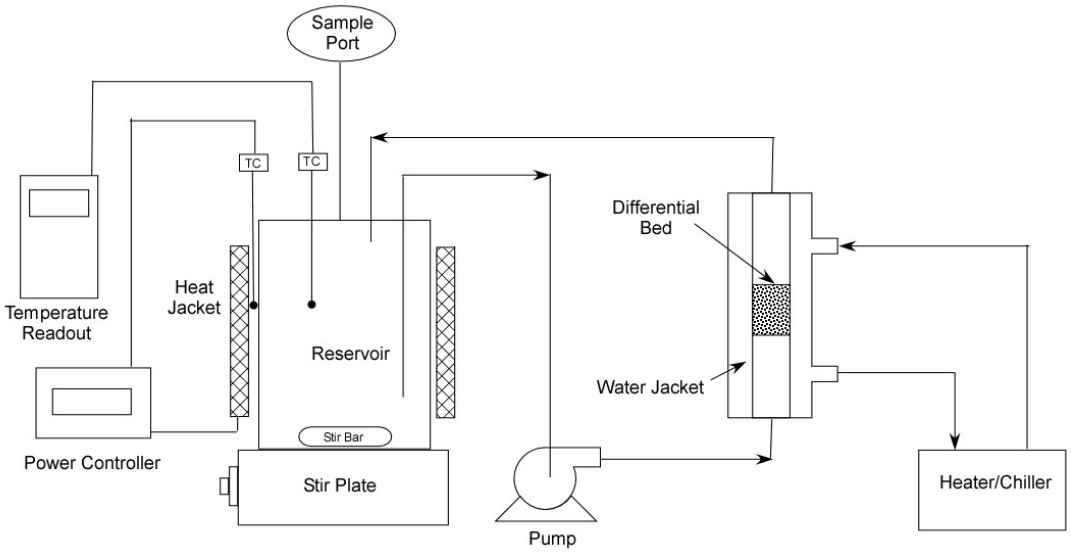

Figure 3.3. Differential Column Ion Exchange Kinetics Schematic

Figure 3.4. Ion Exchange Kinetics Testing Apparatus

3.7 Column Testing Experimental Procedure

A series of column Cs loading and elution cycles was completed as detailed in Table 3.4. The composition of the simulant used is shown in Table 3.1. The general column processing steps (e.g., pretreatment, loading, feed displacement, rinsing, elution, rinsing, and regeneration) are described in Table 3.3.

Table 3.4. Ion Exchange Temperature Impact Experimental Design

	Ion Exchange Kinetic Loading Conditions							Column Elution Conditions			
Run ID[e]	hr [a][b]	T °C	Cs[c] C/C_0	Flow cm/min[h]	Na M	K M	Initial Cs, M	T °C	BV [d]	BV h[g]	HNO_3 M[d]
Test-4-A-1	10	45	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-A-2	10	45	0.52	8	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-A-3	10	45	0.52	4	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-A-4	10	45	0.52	6	5.0	0.03	4.51E-5	25	NA	NA	NA
Test-4-A-4B	720	60	0.52	<0.1[f]	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-A-5	10	45	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-B-1	10	40	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-B-2	10	40	0.52	8	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-B-3	10	40	0.52	4	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-B-4	10	40	0.52	6	5.0	0.03	4.51E-5	25	NA	NA	NA
Test-4-B-4B	720	55	0.52	<0.1[f]	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-B-5	10	40	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-C-1	10	30	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-C-2	10	30	0.52	8	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-C-3	10	30	0.52	4	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-C-4	10	30	0.52	6	5.0	0.03	4.51E-5	25	NA	NA	NA
Test-4-C-4B	720	50	0.52	<0.1[f]	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-C-5	10	30	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-D-1	10	25	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-D-2	10	25	0.52	8	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-D-3	10	25	0.52	4	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-D-4	10	25	0.52	6	5.0	0.03	4.51E-5	25	NA	NA	NA
Test-4-D-4B	720	45	0.52	<0.1[f]	5.0	0.03	4.51E-5	25	25	2.8	0.25
Test-4-D-5	10	25	0.52	6	5.0	0.03	4.51E-5	25	25	2.8	0.25

(a) Resin loading is expected to require approximately 10 hr to achieve kinetic equilibrium. Samples were collected periodically to define the cesium uptake curve (i.e., 0, 6, 12, 18, 24, 36, 48, 60, 80, 120, 180, 240, 600 min).

(b) The 10 hr kinetics tests were completed at temperatures specified for each run. Four extended duration (720 hr target) solution flow tests were completed at 45°, 50°, 55°, and 60°C.

(c) The total simulant solution volume used was targeted to obtain an expected loading of 0.52 C/C_0. However, this ratio was not achieved in this testing. The actual C/C_0 was about 0.15 because the resin capacity was greater than expected for the simulant used.

(d) BV = Bed Volume. Elution with 0.25 M HNO_3 commenced after feed displacement (7.5 BV 0.1 M NaOH), water rinse (7.5 BV DI water) and acid neutralization (3 BV 0.5M HNO_3) solutions were passed through the column. A single elution composite sample was collected and analyzed.

(e) Each test series (e.g., A, B, C and D) represents an independent ion exchange column that was loaded and eluted one or more times using the conditions listed. The BV of the ion exchange resin was ~1.8 mL.

(f) The actual flow velocity was limited by the pump configuration and determined at the time of experimentation; however, it was estimated to be approximately 0.08 mL/min. The flow was as slow as possible to look at resin degradation.

(g) The flow rate for elution was expected to be approximately 2.8 BV/h. The flow rate was approximately 5 mL/h.

(h) 6 cm/min = 10.62 mL/min; 8 cm/min = 14.16 mL/min; 4 cm/min = 7.08 mL/min.

The ion exchange columns were loaded with simulant feed solution at temperatures of 25, 30, 40, 45, 50, 55, and 60± 2°C. The solution was processed at various linear flow velocities (<0.1, 4, 6, and 8 cm/min) as shown in Table 3.4. Following Cs loading, the feed solution was displaced with 7.5 BV of 0.1 M NaOH, rinsed with 7.5 BV of DI water, and the resin was neutralized with 3 BV of 0.5 M HNO_3 at 3 BV/hr as outlined in Table 3.3 except after the fourth cycle. After the fourth cycle, the columns weren't eluted but were then loaded with fresh simulant feed solution at a very slow flow rate (0.08 mL/min) at a higher temperature for a target of 720 hr to determine the effect of temperature on the resin Cs loading.

The ion exchange columns were eluted with approximately 25 BV of 0.25 M HNO_3 processed at 25°C and at 2.8 BV/hr, as shown in Table 3.4. Following elution, the columns were rinsed with 3 BV of DI water and regenerated with 6 BV of 0.5 M NaOH at 3 BV/hr before beginning the next Cs loading cycle. Weights of each sample and the temperature of the simulant were recorded for each sampling.

Simulant samples were submitted to Southwest Research Institute (SwRI) for chemical analysis. Analysis methods included inductively coupled plasma-mass spectroscopy (ICP-MS) for Cs; inductively coupled plasma-optical emission spectroscopy (ICP-OES) for Na, K, and Al; ion chromatography (IC) for anions; total inorganic carbon (TIC); total organic carbon (TOC); and titration for total and free OH analysis. QA and quality control procedures for using blanks, duplicates, and spikes, along with standard results for each analysis set, are maintained in records and not reported here.

3.8 Batch Loading Testing System

A series of batch Cs loading tests was completed as detailed in Table 3.5. The composition of each feed simulant used in the loading tests is also shown in Table 3.5. The batch feed simulants were placed into 30 mL bottles, the required amount of resin was added to the bottles, and then the bottles were placed on an IKA KS 4000 orbital shaker table (IKA Works, Wilmington, North Carolina) with a temperature control to hold them at the specified temperature (25, 35, or 50°C). A picture of this orbital shaker table is shown in Figure 3.5. The temperature was measured using a calibrated Type K thermocouple and Fluke 52II temperature readout (Fluke, Everett, Washington). The samples were rotated at 140 rpm to ensure that samples were mixed thoroughly for the entire contact time.

3.9 Batch Testing Experimental Procedure

Several small batches of conditioned SRF resin were contacted with feed simulant solutions (Table 3.5) containing variable Na, Cs, K, and OH ion concentrations. The balance of the simulant was nitrate ion. Approximately 0.1 g dry resin was contacted with ~25 mL of feed simulant solution (phase ratio of 150:1) for 72 hr as shown in Table 3.5 to ensure equilibrium had been reached. Samples were mixed at one of three temperatures (i.e., 25, 35 and 50 ±2°C).

Simulant samples were submitted to SwRI for the same chemical analysis as described in Section 3.7.

Table 3.5. Sodium Impact Experimental Design

	Ion Exchange Loading Conditions					
Run ID	hr	T °C	Na M	OH M	Initial Cs, M	K M
Test-5-Na-A1	72	50	0.1	0.1	5.0E-06	0.005
Test-5-Na-A2	72	50	0.5	0.1	5.0E-06	0.005
Test-5-Na-A3	72	50	0.75	0.1	5.0E-06	0.005
Test-5-Na-A4	72	50	1.0	0.1	5.0E-06	0.005
Test-5-Na-A5	72	50	3.0	0.1	5.0E-06	0.005
Test-5-Na-A6[(1)]	72	50	5.0	0.1	5.0E-06	0.005
Test-5-Na-B1	72	50	0.1	0.1	5.0E-06	0.05
Test-5-Na-B2	72	50	0.5	0.1	5.0E-06	0.05
Test-5-Na-B3	72	50	0.75	0.1	5.0E-06	0.05
Test-5-Na-B4	72	50	1.0	0.1	5.0E-06	0.05
Test-5-Na-B5	72	50	3.0	0.1	5.0E-06	0.05
Test-5-Na-B6	72	50	5.0	0.1	5.0E-06	0.05
Test-5-Na-C1	72	50	1.0	1	5.0E-06	0.005
Test-5-Na-C2	72	50	3.0	1	5.0E-06	0.005
Test-5-Na-C3	72	50	5.0	1	5.0E-06	0.005
Test-5-Na-D1	72	50	1.0	1	5.0E-06	0.05
Test-5-Na-D2	72	50	3.0	1	5.0E-06	0.05
Test-5-Na-D3	72	50	5.0	1	5.0E-06	0.05
Test-5-Na-E1	72	25	0.1	0.1	5.0E-06	0.005
Test-5-Na-E2	72	25	0.5	0.1	5.0E-06	0.005
Test-5-Na-E3	72	25	0.75	0.1	5.0E-06	0.005
Test-5-Na-E4	72	25	1.0	0.1	5.0E-06	0.005
Test-5-Na-E5	72	25	3.0	0.1	5.0E-06	0.005
Test-5-Na-E6[(1)]	72	25	5.0	0.1	5.0E-06	0.005
Test-5-Na-F1	72	25	0.1	0.1	5.0E-06	0.05
Test-5-Na-F2	72	25	0.5	0.1	5.0E-06	0.05
Test-5-Na-F3	72	25	0.75	0.1	5.0E-06	0.05
Test-5-Na-F4	72	25	1.0	0.1	5.0E-06	0.05
Test-5-Na-F5	72	25	3.0	0.1	5.0E-06	0.05
Test-5-Na-F6	72	25	5.0	0.1	5.0E-06	0.05
Test-5-Na-G1	72	25	1.0	1	5.0E-06	0.005
Test-5-Na-G2	72	25	3.0	1	5.0E-06	0.005
Test-5-Na-G3	72	25	5.0	1	5.0E-06	0.005
Test-5-Na-H1	72	25	1.0	1	5.0E-06	0.05
Test-5-Na-H2	72	25	3.0	1	5.0E-06	0.05
Test-5-Na-H3	72	25	5.0	1	5.0E-06	0.05
Test-5-Na-I1[(1)]	72	50	0.1	0.1	5.0E-05	0.005
Test-5-Na-I2[(1)]	72	50	0.5	0.1	5.0E-05	0.005
Test-5-Na-I3[(1)]	72	50	0.75	0.1	5.0E-05	0.005
Test-5-Na-I4[(1)]	72	50	1.0	0.1	5.0E-05	0.005

Table 3.5. (contd)

	Ion Exchange Loading Conditions					
Run ID	hr	T °C	Na M	OH M	Initial Cs, M	K M
Test-5-Na-I5[(1)]	72	50	3.0	0.1	5.0E-05	0.005
Test-5-Na-I6[(1)]	72	50	5.0	0.1	5.0E-05	0.005
Test-5-Na-J1[(1)]	72	50	0.1	0.1	5.0E-05	0.05
Test-5-Na-J2[(1)]	72	50	0.5	0.1	5.0E-05	0.05
Test-5-Na-J3[(1)]	72	50	0.75	0.1	5.0E-05	0.05
Test-5-Na-J4[(1)]	72	50	1.0	0.1	5.0E-05	0.05
Test-5-Na-J5[(1)]	72	50	3.0	0.1	5.0E-05	0.05
Test-5-Na-J6[(1)]	72	50	5.0	0.1	5.0E-05	0.05
Test-5-Na-K1[(1)]	72	50	1.0	1	5.0E-05	0.005
Test-5-Na-K2[(1)]	72	50	3.0	1	5.0E-05	0.005
Test-5-Na-K3[(1)]	72	50	5.0	1	5.0E-05	0.005
Test-5-Na-L1[(1)]	72	50	1.0	1	5.0E-05	0.05
Test-5-Na-L2[(1)]	72	50	3.0	1	5.0E-05	0.05
Test-5-Na-L3[(1)]	72	50	5.0	1	5.0E-05	0.05
Test-5-Na-M1[(1)]	72	25	0.1	0.1	5.0E-05	0.005
Test-5-Na-M2[(1)]	72	25	0.5	0.1	5.0E-05	0.005
Test-5-Na-M3[(1)]	72	25	0.75	0.1	5.0E-05	0.005
Test-5-Na-M4[(1)]	72	25	1.0	0.1	5.0E-05	0.005
Test-5-Na-M5[(1)]	72	25	3.0	0.1	5.0E-05	0.005
Test-5-Na-M6[(1)]	72	25	5.0	0.1	5.0E-05	0.005
Test-5-Na-N1[(1)]	72	25	0.1	0.1	5.0E-05	0.05
Test-5-Na-N2[(1)]	72	25	0.5	0.1	5.0E-05	0.05
Test-5-Na-N3[(1)]	72	25	0.75	0.1	5.0E-05	0.05
Test-5-Na-N4[(1)]	72	25	1.0	0.1	5.0E-05	0.05
Test-5-Na-N5[(1)]	72	25	3.0	0.1	5.0E-05	0.05
Test-5-Na-N6[(1)]	72	25	5.0	0.1	5.0E-05	0.05
Test-5-Na-O1[(1)]	72	25	1.0	1	5.0E-05	0.005
Test-5-Na-O2[(1)]	72	25	3.0	1	5.0E-05	0.005
Test-5-Na-O3[(1)]	72	25	5.0	1	5.0E-05	0.005
Test-5-Na-P1[(1)]	72	25	1.0	1	5.0E-05	0.05
Test-5-Na-P2[(1)]	72	25	3.0	1	5.0E-05	0.05
Test-5-Na-P3[(1)]	72	25	5.0	1	5.0E-05	0.05
Test-5-Na-Q1	72	50	0.1	0.1	5.0E-04	0.005
Test-5-Na-Q2	72	50	0.5	0.1	5.0E-04	0.005
Test-5-Na-Q3	72	50	0.75	0.1	5.0E-04	0.005
Test-5-Na-Q4	72	50	1.0	0.1	5.0E-04	0.005
Test-5-Na-Q5	72	50	3.0	0.1	5.0E-04	0.005
Test-5-Na-Q6	72	50	5.0	0.1	5.0E-04	0.005
Test-5-Na-R1	72	50	0.1	0.1	5.0E-04	0.05
Test-5-Na-R2	72	50	0.5	0.1	5.0E-04	0.05
Test-5-Na-R3	72	50	0.75	0.1	5.0E-04	0.05
Test-5-Na-R4	72	50	1.0	0.1	5.0E-04	0.05
Test-5-Na-R5	72	50	3.0	0.1	5.0E-04	0.05
Test-5-Na-R6	72	50	5.0	0.1	5.0E-04	0.05
Test-5-Na-S1	72	50	1.0	1	5.0E-04	0.005

Table 3.5. (contd)

	Ion Exchange Loading Conditions					
Run ID	hr	T °C	Na M	OH M	Initial Cs, M	K M
Test-5-Na-S2	72	50	3.0	1	5.0E-04	0.005
Test-5-Na-S3	72	50	5.0	1	5.0E-04	0.005
Test-5-Na-T1	72	50	1.0	1	5.0E-04	0.05
Test-5-Na-T2	72	50	3.0	1	5.0E-04	0.05
Test-5-Na-T3	72	50	5.0	1	5.0E-04	0.05
Test-5-Na-U1	72	25	0.1	0.1	5.0E-04	0.005
Test-5-Na-U2	72	25	0.5	0.1	5.0E-04	0.005
Test-5-Na-U3	72	25	0.75	0.1	5.0E-04	0.005
Test-5-Na-U4	72	25	1.0	0.1	5.0E-04	0.005
Test-5-Na-U5	72	25	3.0	0.1	5.0E-04	0.005
Test-5-Na-U6	72	25	5.0	0.1	5.0E-04	0.005
Test-5-Na-V1	72	25	0.1	0.1	5.0E-04	0.05
Test-5-Na-V2	72	25	0.5	0.1	5.0E-04	0.05
Test-5-Na-V3	72	25	0.75	0.1	5.0E-04	0.05
Test-5-Na-V4	72	25	1.0	0.1	5.0E-04	0.05
Test-5-Na-V5	72	25	3.0	0.1	5.0E-04	0.05
Test-5-Na-V6	72	25	5.0	0.1	5.0E-04	0.05
Test-5-Na-W1	72	25	1.0	1	5.0E-04	0.005
Test-5-Na-W2	72	25	3.0	1	5.0E-04	0.005
Test-5-Na-W3	72	25	5.0	1	5.0E-04	0.005
Test-5-Na-X1	72	25	1.0	1	5.0E-04	0.05
Test-5-Na-X2	72	25	3.0	1	5.0E-04	0.05
Test-5-Na-X3	72	25	5.0	1	5.0E-04	0.05
Test-5-Na-Y1	72	50	0.1	0.1	5.0E-03	0.005
Test-5-Na-Y2	72	50	0.5	0.1	5.0E-03	0.005
Test-5-Na-Y3	72	50	0.75	0.1	5.0E-03	0.005
Test-5-Na-Y4	72	50	1.0	0.1	5.0E-03	0.005
Test-5-Na-Y5	72	50	3.0	0.1	5.0E-03	0.005
Test-5-Na-Y6	72	50	5.0	0.1	5.0E-03	0.005
Test-5-Na-Z1	72	50	0.1	0.1	5.0E-03	0.05
Test-5-Na-Z2	72	50	0.5	0.1	5.0E-03	0.05
Test-5-Na-Z3	72	50	0.75	0.1	5.0E-03	0.05
Test-5-Na-Z4	72	50	1.0	0.1	5.0E-03	0.05
Test-5-Na-Z5	72	50	3.0	0.1	5.0E-03	0.05
Test-5-Na-Z6	72	50	5.0	0.1	5.0E-03	0.05
Test-5-Na-AA1	72	50	1.0	1	5.0E-03	0.005
Test-5-Na-AA2	72	50	3.0	1	5.0E-03	0.005
Test-5-Na-AA3	72	50	5.0	1	5.0E-03	0.005
Test-5-Na-BB1	72	50	1.0	1	5.0E-03	0.05
Test-5-Na-BB2	72	50	3.0	1	5.0E-03	0.05
Test-5-Na-BB3	72	50	5.0	1	5.0E-03	0.05
Test-5-Na-CC1	72	25	0.1	0.1	5.0E-03	0.005
Test-5-Na-CC2	72	25	0.5	0.1	5.0E-03	0.005
Test-5-Na-CC3	72	25	0.75	0.1	5.0E-03	0.005
Test-5-Na-CC4	72	25	1.0	0.1	5.0E-03	0.005

Table 3.5. (contd)

	Ion Exchange Loading Conditions					
Run ID	hr	T °C	Na M	OH M	Initial Cs, M	K M
Test-5-Na-CC5	72	25	3.0	0.1	5.0E-03	0.005
Test-5-Na-CC6	72	25	5.0	0.1	5.0E-03	0.005
Test-5-Na-DD1	72	25	0.1	0.1	5.0E-03	0.05
Test-5-Na-DD2	72	25	0.5	0.1	5.0E-03	0.05
Test-5-Na-DD3	72	25	0.75	0.1	5.0E-03	0.05
Test-5-Na-DD4	72	25	1.0	0.1	5.0E-03	0.05
Test-5-Na-DD5	72	25	3.0	0.1	5.0E-03	0.05
Test-5-Na-DD6	72	25	5.0	0.1	5.0E-03	0.05
Test-5-Na-EE1	72	25	1.0	1	5.0E-03	0.005
Test-5-Na-EE2	72	25	3.0	1	5.0E-03	0.005
Test-5-Na-EE3	72	25	5.0	1	5.0E-03	0.005
Test-5-Na-FF1	72	25	1.0	1	5.0E-03	0.05
Test-5-Na-FF2	72	25	3.0	1	5.0E-03	0.05
Test-5-Na-FF3	72	25	5.0	1	5.0E-03	0.05
Test-5-Na-GG1	72	35	5.0	1	5.0E-03	0.05
Test-5-Na-GG2	72	35	5.0	1	5.0E-04	0.05
Test-5-Na-GG3[(1)]	72	35	5.0	1	5.0E-05	0.05
Test-5-Na-GG4	72	35	5.0	1	5.0E-06	0.05
Test-5-Na-HH1	72	35	5.0	1	5.0E-03	0.005
Test-5-Na-HH2	72	35	5.0	1	5.0E-04	0.005
Test-5-Na-HH3[(1)]	72	35	5.0	1	5.0E-05	0.005
Test-5-Na-HH4	72	35	5.0	1	5.0E-06	0.005
Test-5-Na-II1	72	35	0.5	0.1	5.0E-03	0.05
Test-5-Na-II2	72	35	0.5	0.1	5.0E-04	0.05
Test-5-Na-II3[(1)]	72	35	0.5	0.1	5.0E-05	0.05
Test-5-Na-II4	72	35	0.5	0.1	5.0E-06	0.05
Test-5-Na-JJ1	72	35	0.5	0.1	5.0E-03	0.005
Test-5-Na-JJ2	72	35	0.5	0.1	5.0E-04	0.005
Test-5-Na-JJ3[(1)]	72	35	0.5	0.1	5.0E-05	0.005
Test-5-Na-JJ4	72	35	0.5	0.1	5.0E-06	0.005
Test-5-Na-KK1	72	35	3.0	1	5.0E-04	0.05
Test-5-Na-KK2	72	35	3.0	1	5.0E-03	0.05
Test-5-Na-LL1	72	50	0.1	0.1	5.0E-06	0.005
Test-5-Na-LL2	72	50	0.5	0.1	5.0E-06	0.005
Test-5-Na-LL3	72	50	0.75	0.1	5.0E-06	0.005
Test-5-Na-LL4	72	50	1.0	0.1	5.0E-06	0.005
Test-5-Na-LL5	72	50	3.0	0.1	5.0E-06	0.005
Test-5-Na-LL6	72	50	5.0	0.1	5.0E-06	0.005
Test-5-Na-MM1	72	50	0.1	0.1	5.0E-06	0.05
Test-5-Na-MM2	72	50	0.5	0.1	5.0E-06	0.05
Test-5-Na-MM3	72	50	0.75	0.1	5.0E-06	0.05
Test-5-Na-MM4	72	50	1.0	0.1	5.0E-06	0.05
Test-5-Na-MM5	72	50	3.0	0.1	5.0E-06	0.05
Test-5-Na-MM6	72	50	5.0	0.1	5.0E-06	0.05
Test-5-Na-NN1	72	50	1.0	1	5.0E-06	0.005

Table 3.5. (contd)

	Ion Exchange Loading Conditions					
Run ID	hr	T °C	Na M	OH M	Initial Cs, M	K M
Test-5-Na-NN2[(1)]	72	50	3.0	1	5.0E-06	0.005
Test-5-Na-NN3	72	50	5.0	1	5.0E-06	0.005
Test-5-Na-OO1	72	50	1.0	1	5.0E-06	0.05
Test-5-Na-OO2	72	50	3.0	1	5.0E-06	0.05
Test-5-Na-OO3	72	50	5.0	1	5.0E-06	0.05
Test-5-Na-PP1	72	35	5.0	1	5.0E-06	0.05
Test-5-Na-PP2	72	35	5.0	1	5.0E-06	0.005
Test-5-Na-PP3	72	35	0.5	0.1	5.0E-06	0.05
Test-5-Na-PP4	72	35	0.5	0.1	5.0E-06	0.005
Test-5-Na-QQ1	72	25	0.1	0.1	5.0E-06	0.005
Test-5-Na-QQ2	72	25	0.5	0.1	5.0E-06	0.005
Test-5-Na-QQ3	72	25	0.75	0.1	5.0E-06	0.005
Test-5-Na-QQ4	72	25	1.0	0.1	5.0E-06	0.005
Test-5-Na-QQ5	72	25	3.0	0.1	5.0E-06	0.005
Test-5-Na-QQ6	72	25	5.0	0.1	5.0E-06	0.005
Test-5-Na-RR1	72	25	0.1	0.1	5.0E-06	0.05
Test-5-Na-RR2	72	25	0.5	0.1	5.0E-06	0.05
Test-5-Na-RR3	72	25	0.75	0.1	5.0E-06	0.05
Test-5-Na-RR4	72	25	1.0	0.1	5.0E-06	0.05
Test-5-Na-RR5	72	25	3.0	0.1	5.0E-06	0.05
Test-5-Na-RR6	72	25	5.0	0.1	5.0E-06	0.05
Test-5-Na-SS1	72	25	1.0	1	5.0E-06	0.005
Test-5-Na-SS2[(1)]	72	25	3.0	1	5.0E-06	0.005
Test-5-Na-SS3	72	25	5.0	1	5.0E-06	0.005
Test-5-Na-TT1	72	25	1.0	1	5.0E-06	0.05
Test-5-Na-TT2	72	25	3.0	1	5.0E-06	0.05
Test-5-Na-TT3	72	25	5.0	1	5.0E-06	0.05

(1) The simulants for these tests were prepared incorrectly and/or inaccurate analytical data was received and therefore no data for them is presented.

Figure 3.5. Batch Cs Loading Temperature Controlled Orbital Shaker Table

4.0 Results and Discussion

This research examined the impact of linear load velocity (4, 6, 8 cm/min) and temperature (25, 30, 40, 45°C) on the Cs loading kinetics in columns. The resin degradation during extended solution flow at elevated temperatures (45, 50, 55, 60°C) was also studied using columns. The effect of the initial Na concentration (0.1, 0.5, 0.75, 1, 3, 5 M), initial K concentration (0.005 and 0.05 M), and free OH concentration (0.1 and 1 M) on the resin's Cs loading capacity at temperatures of 25, 35, and 50°C was tested using batch tests. The results of this research are discussed in this section.

4.1 Impacts of Linear Load Velocity and Temperature on Resin Cs Loading Kinetics

A series of column Cs loading and elution cycles were completed using the test matrix as detailed in Table 3.4. The axial velocity and temperature were the primary variables studied. Test results were then compared.

Tests performed at varying linear load velocities provided a measurement of the impact of the film mass transfer coefficient on the Cs loading kinetics. The molar Cs concentration was calculated by converting the reported Cs concentration from mg/kg to mol/L using a solution density of 1.24 g/mL and a MW of 132.905 g/mol for Cs. Then the Cs loading was calculated by subtracting the final molar Cs concentration from the initial molar Cs concentration, multiplying by the amount of simulant used, and then dividing by the weight of resin used, which in this case was 0.82 g. The analytical error in these results is reported to be ±10%. An example calculation is as follows:

[(5.19 mg Cs/kg solution -1.95 mg Cs/kg solution)*(1.23 kg solution/L solution)*(1g Cs/1000 mg Cs)*(1 mol Cs/132.905 g Cs)*(1L solution/1000 mL solution)*(1000 mmol Cs/mol Cs)*(180 mL solution)]/0.82 g resin = 0.0066 mmol Cs/g resin.

The overall effect of the linear load velocity was considered insignificant on the Cs loading kinetics as shown in Figure 4.1 through Figure 4.4. Previous work showed a greater effect of the loading velocity on the Cs loading when performed at 45°C to 60°C (Russell et al. 2012). The decrease in the impact of velocity with decreasing temperature is somewhat expected. As temperature is decreased, the kinetics of the sorption process will decrease. It would appear that below 45°C, the sorption process becomes the dominant factor in the Cs loading in place of the mass transfer process, which results in velocity not having a significant effect.

The Cs loading appears to be slightly lower with the higher linear load velocity of 8 cm/min at all temperatures. Lower linear load velocity allows more time for diffusion into the ion exchange particles and has been noted in previous work (Smith et al. 2009, Smith et al. 2007, and King et al. 2004). However, with such a small difference, it is hard to confirm what is actually occurring when accounting for experimental error or if there really is an effect.

It was found that temperature under these conditions had a negligible effect on the Cs loading kinetics. The 25°C and 30°C tests were essentially the same and the 40°C and 45°C tests were essentially the same. However, there appears to have been a slight increase in the kinetics between the 30°C and 40°C tests. These results are shown in Figure 4.5 through Figure 4.7.

Comparing Run 1 and Run 4 for each column, which were duplicate runs, showed that the Cs loading difference was between 4% and 12% lower for each column after 10 hr, indicating agreement within experimental error and no effect of the load cycling at any of the temperatures tested.

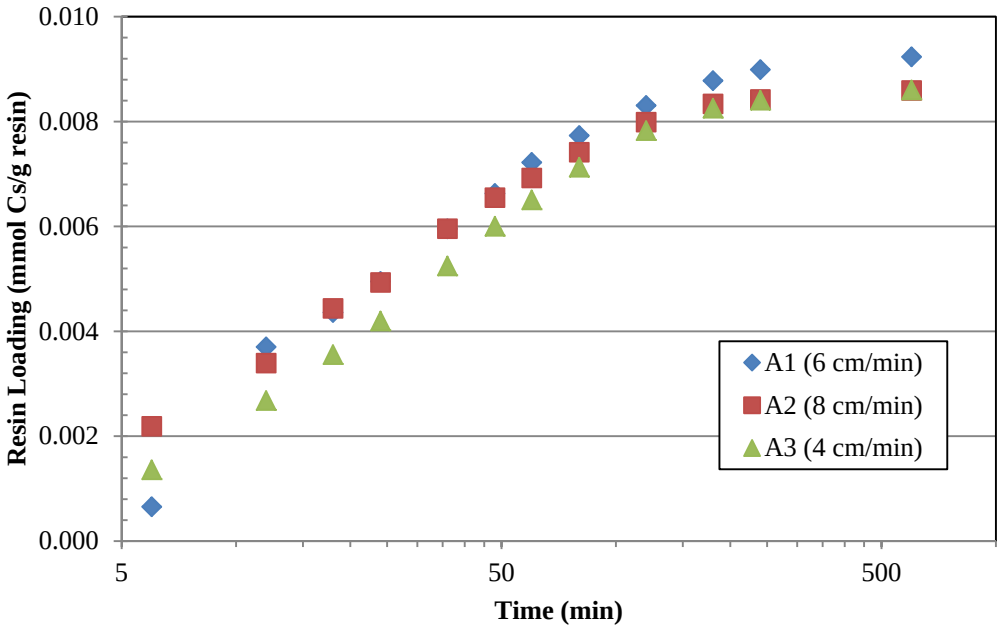

Figure 4.1. Velocity Impact on Kinetics of Column A (45°C) Cs Loading

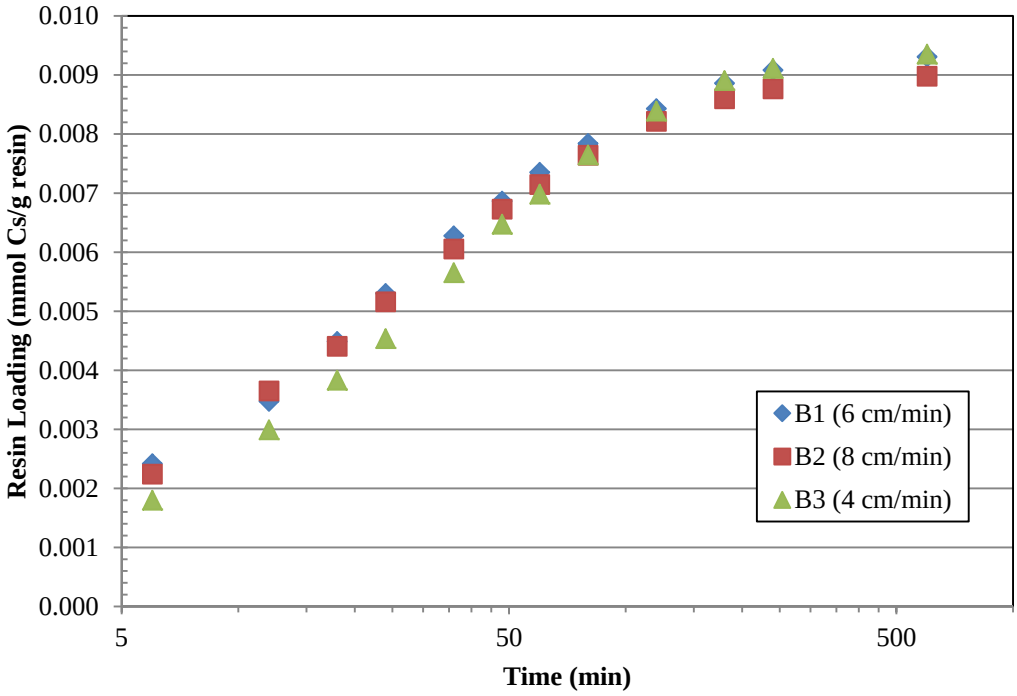

Figure 4.2. Velocity Impact on Kinetics of Column B (40°C) Cs Loading

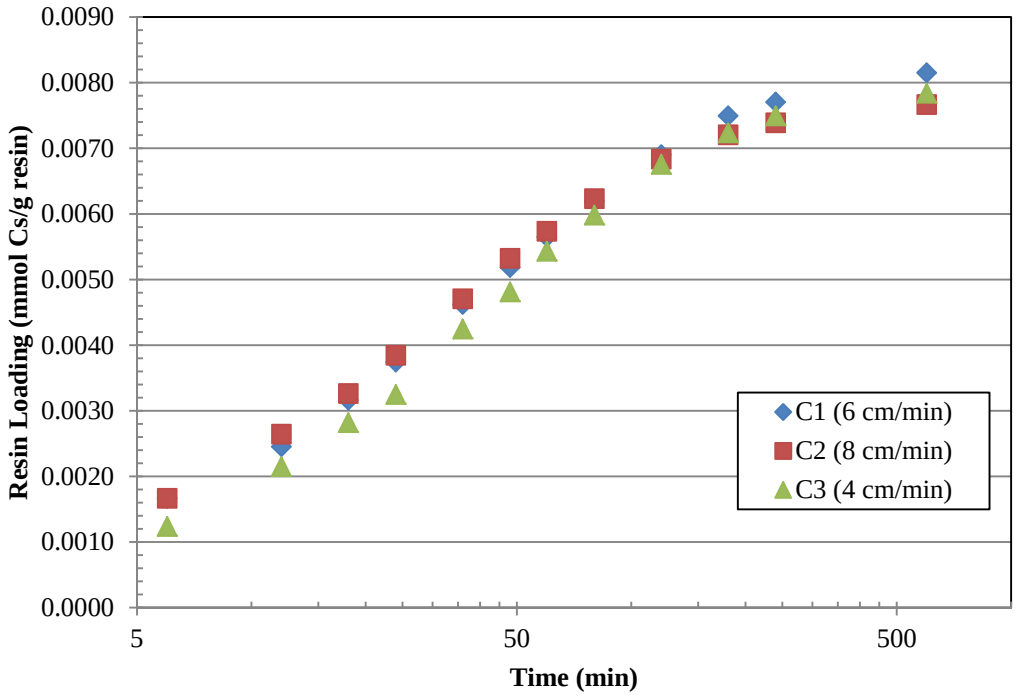

Figure 4.3. Velocity Impact on Kinetics of Column C (30°C) Cs Loading

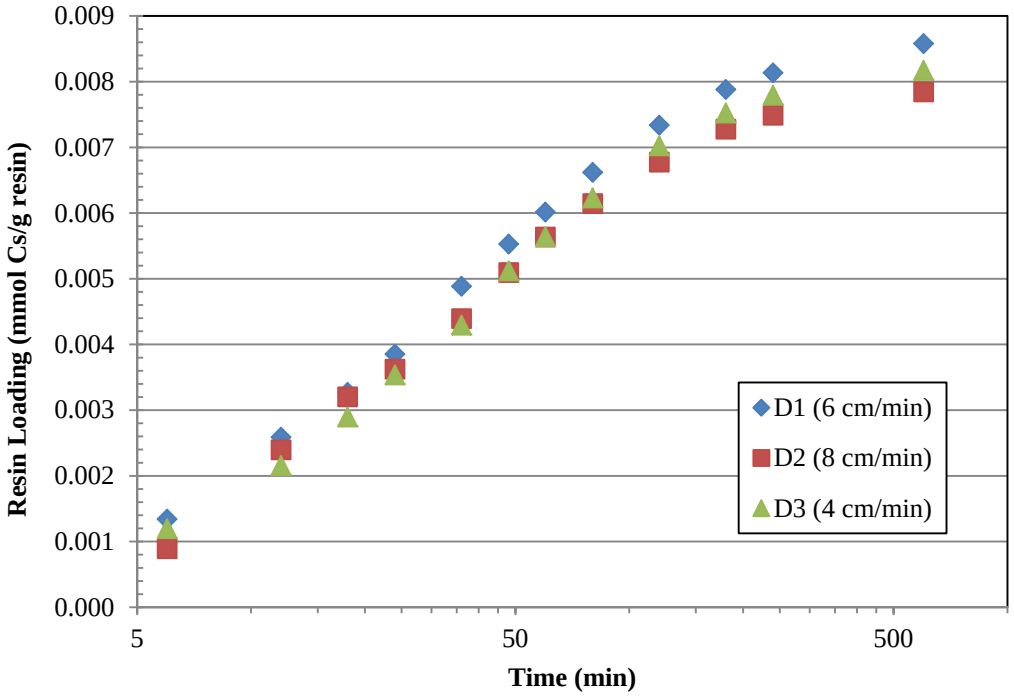

Figure 4.4. Velocity Impact on Kinetics of Column D (25°C) Cs Loading

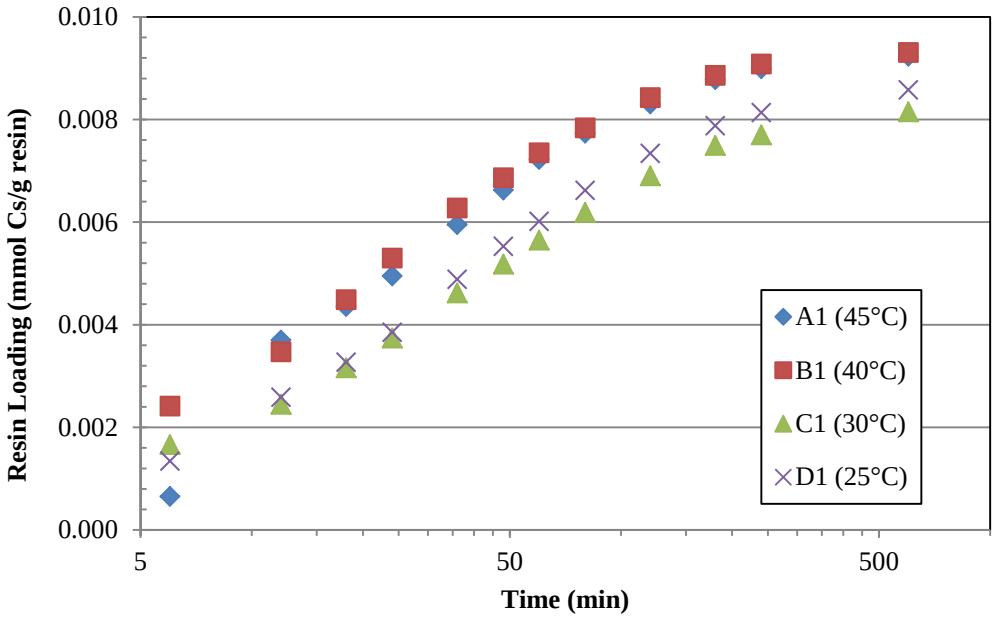

Figure 4.5. Temperature Effect on Cs Loading Kinetics of Test 1 (6 cm/min)

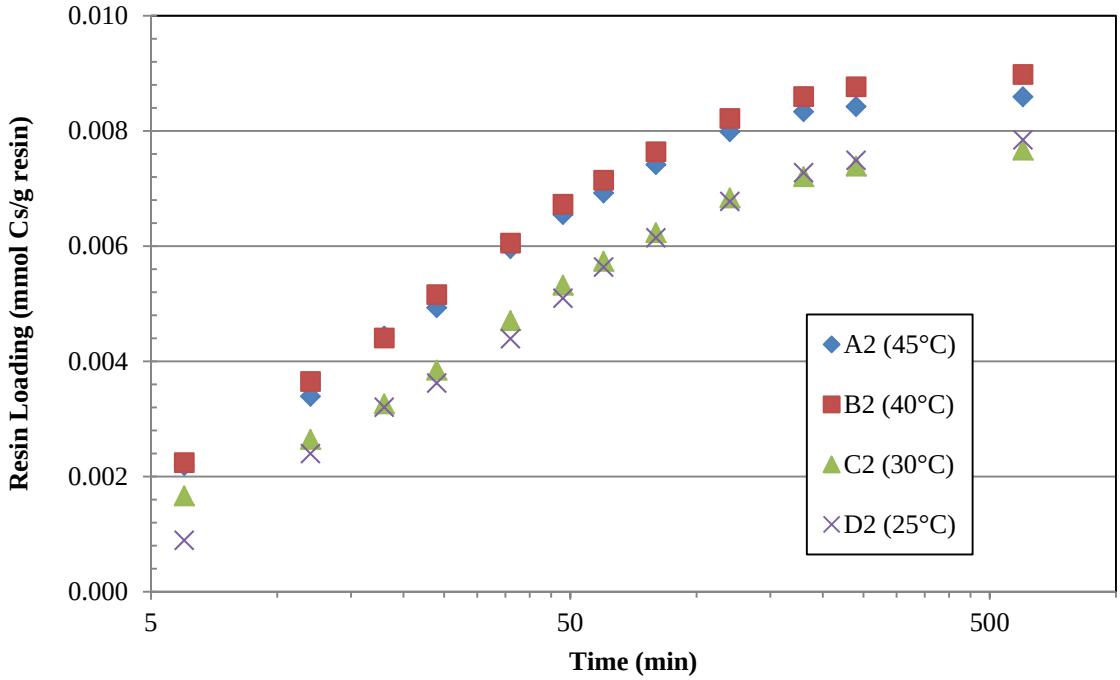

Figure 4.6. Temperature Effect on Cs Loading Kinetics of Test 2 (8 cm/min)

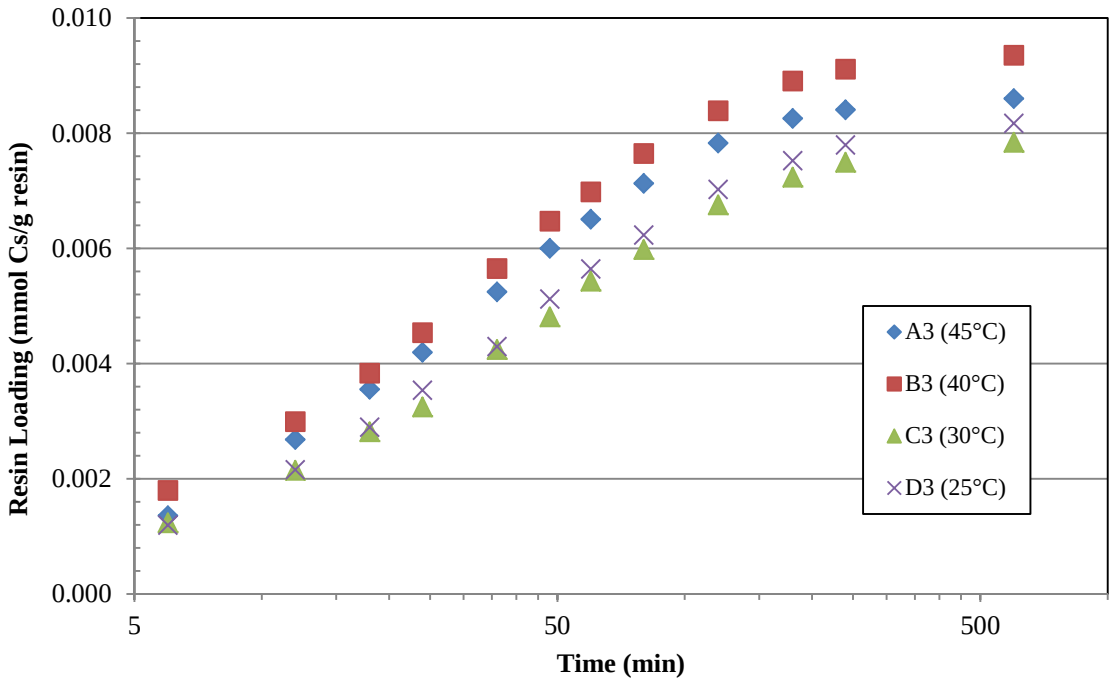

Figure 4.7. Temperature Effect on Kinetics of Test 3 (4 cm/min)

4.2 Impacts of Extended Elevated Temperature on Resin Loading

Resin was loaded for 336 to 720 hr at several elevated temperatures at a very low linear load velocity (~0.08 cm/min) compared to the column tests described in Section 4.1. The linear load velocity was as slow as possible to observe what was happening to the resin when held at higher temperatures for extended times. These tests are designated as -4B in Table 3.4. Samples were taken periodically throughout the test to determine the Cs uptake curve as shown in Figure 4.8. These tests were not scaled to the WTP ion exchange columns but were to just observe the degradation and temperature effect on the ion exchange resin over time.

Testing for these extended times at elevated temperatures showed that the Cs loading decreased with increasing temperature. At 60°C, the Cs loading had decreased by 14 percent from the 45°C test. All columns, with the exception of the 45°C column, plugged prior to 720 hr of testing. The 55°C and 60°C columns plugged after about 14 days (336 hr) and the 50°C column plugged after about 25 days (600 hr). The resin that plugged the columns was found to be hard clumps that were difficult to break apart. These agglomerates effectively inhibited the flow of solution. Two of the columns had to be opened and the resin masses broken up before the columns could be eluted. The overall Cs loading at these temperatures is shown in Figure 4.8. These loading results are in strong agreement with previous work (Russell et al. 2012).

Regardless of temperature, Cs loading peaked after about 72 hr (see Figure 4.9). At the lower temperatures (45°C, 50°, and 55°C), the Cs loading remained stable within experimental error (<10%). However at the highest temperatures (60°C) there was a loading decrease of ~ 16%, even after accounting for evaporation by adjusting the Cs concentration present based on the percent change in the Na and NO_3^-

concentrations, which shouldn't have been changing without evaporation. Previous work of Cs loading over extended times also showed that the Cs loading peaked after ~72 hr and then began to decrease (Russell et al. 2012). This indicates that the resin loses Cs loading ability over time and with increased temperature, making it unable to hold the Cs over a long period of time at elevated temperatures. These results could be significant if the WTP is operating at elevated temperatures and indicate that resin may have to be eluted more often and/or Cs may be lost into the effluent off the column.

In addition, during the 720 hr loading tests, a white precipitate formed on the top and bottom edge of the resin column. It was also noticed that during the tests, and especially during the feed displacement portion of the test, the solution coming out of the column had turned a yellow color after having entered the column completely clear. This is shown in Figure 4.10. This may indicate the presence of chemical resin degradation, which would explain the lower Cs loading.

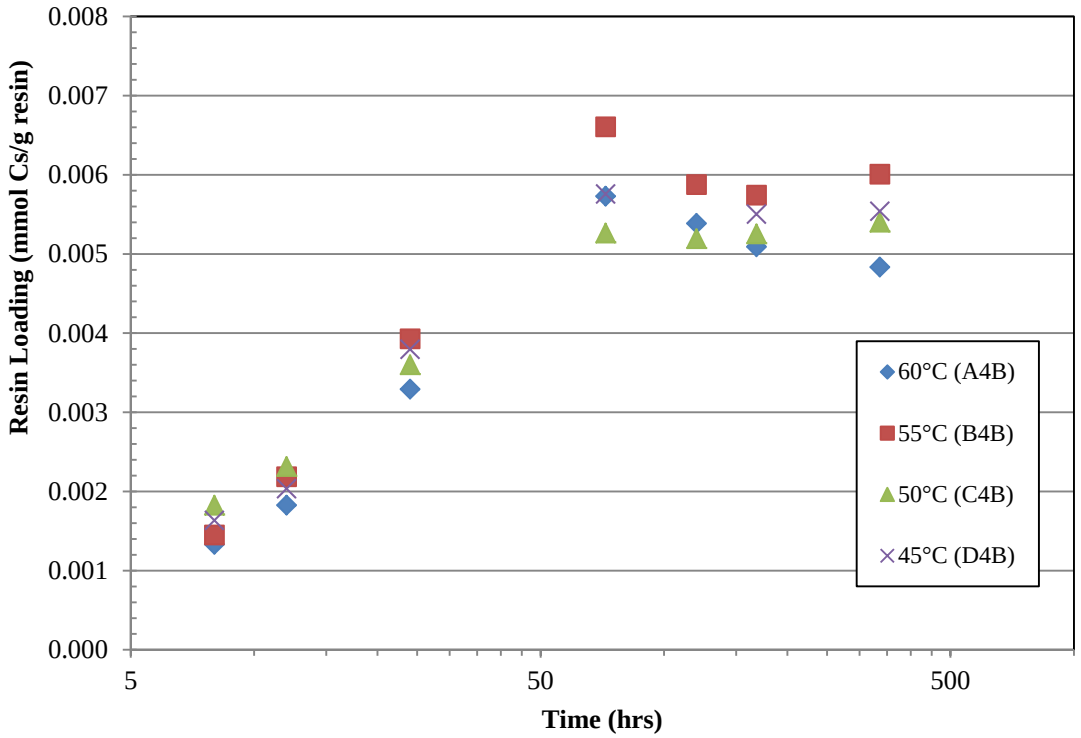

Figure 4.8. Resin Cs Loading During Extended Flow Testing

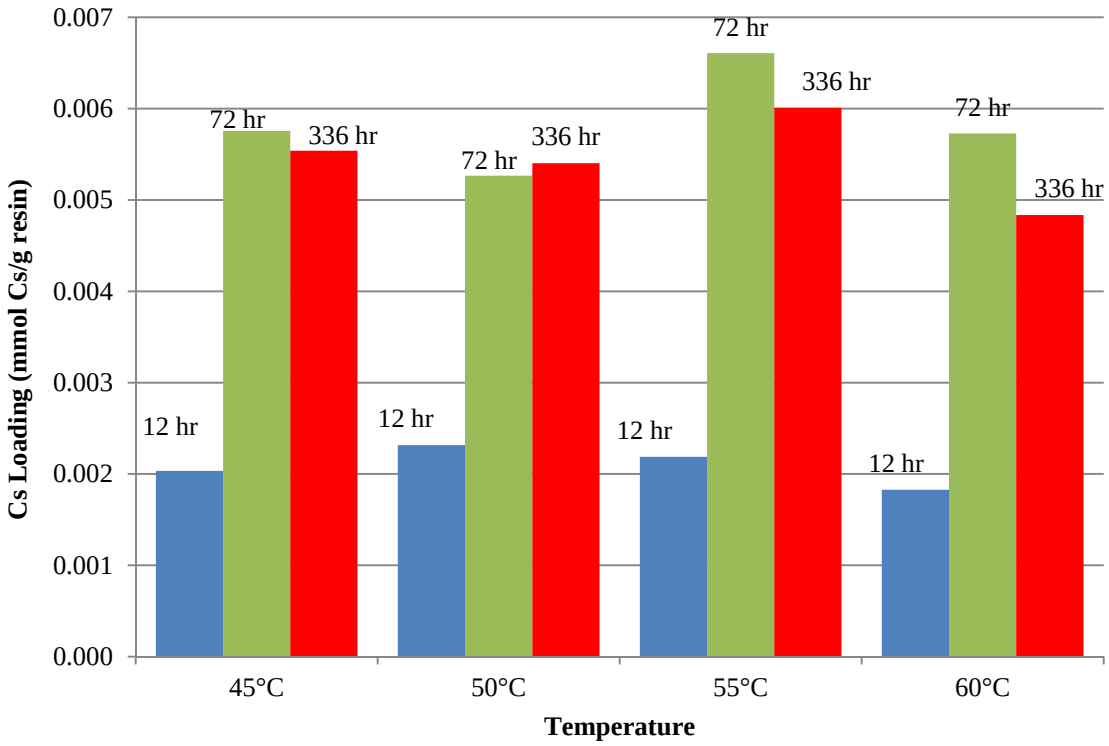

Figure 4.9. Resin Total Cs Loading During Extended Flow Testing

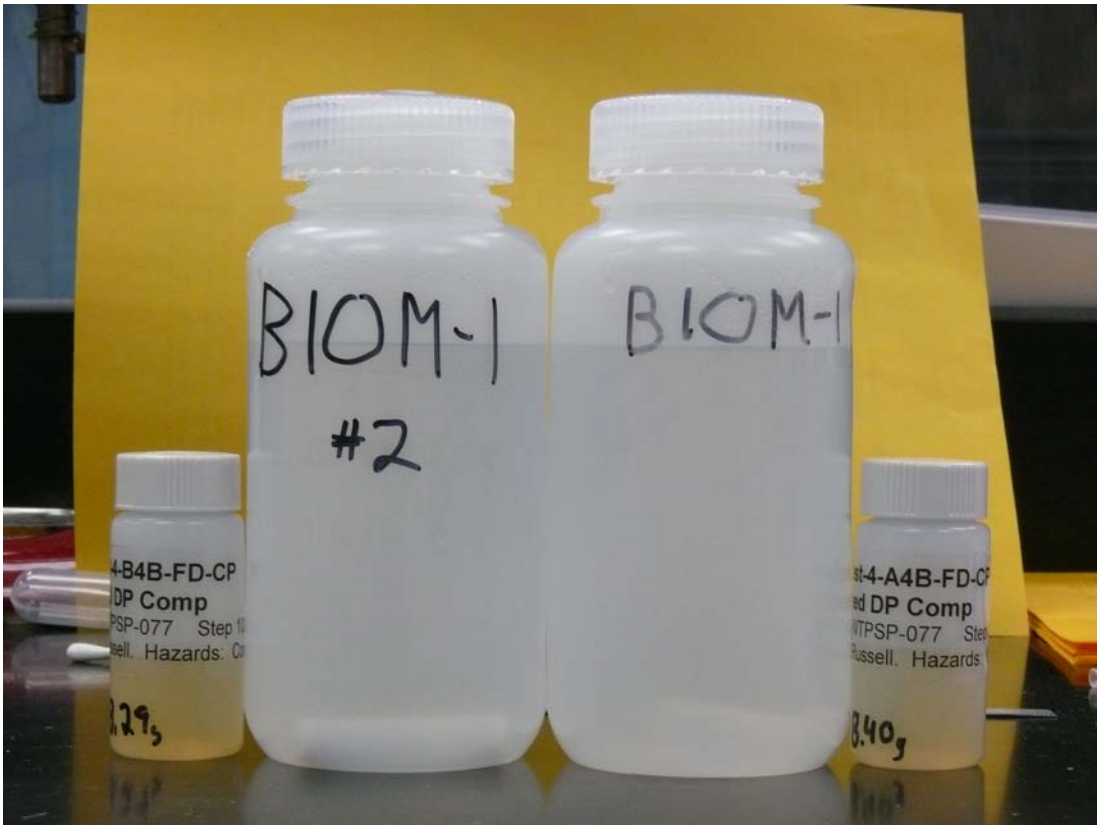

Figure 4.10. Feed Displacement Solution Compared Before and After Running through the Column

After the elevated temperature extended flow testing, the resin was loaded again for 10 hr under the same conditions as the initial cycle. This was the last test of each series (-5), shown in Table 3.4, and was used to determine the change in resin Cs loading kinetics and/or Cs uptake after being cycled several times and held at a higher temperature. At cycles kept at 55°C and 60°C, a slight decrease in resin Cs loading (7.9 percent and 12.7 percent, respectively) was observed as well as a slight decrease in kinetics, as shown in Figure 4.11 and Figure 4.12. For the cycles kept at 50°C and 45°C, a slight increase in Cs loading (13 percent for 50°C and 15 percent for 45°C) was observed but not in Cs loading kinetics as shown in Figure 4.13 and Figure 4.14. However, the resin does appear to degrade and shows decreased Cs loading after being held at elevated temperatures (above 50°C) for extended periods of time. These results could be significant to WTP operations at elevated temperatures as they indicate that resin would need to be exchanged more often.

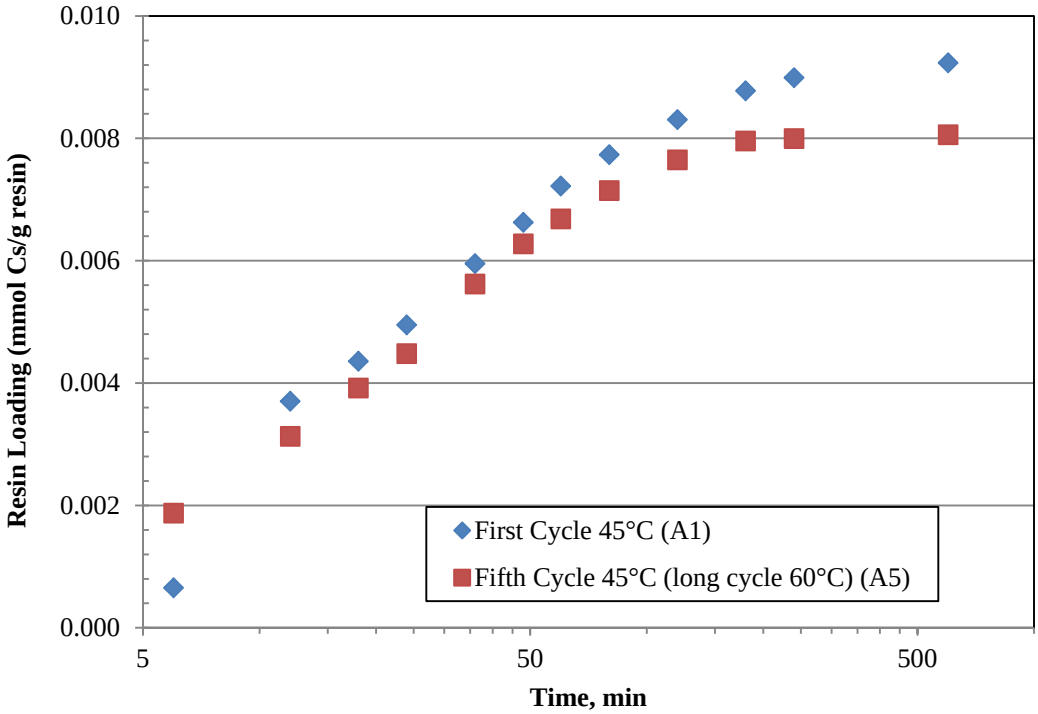

Figure 4.11. First and Fifth Resin Loading Cycles Compared at 45°C with Long Loading Cycle at 60°C

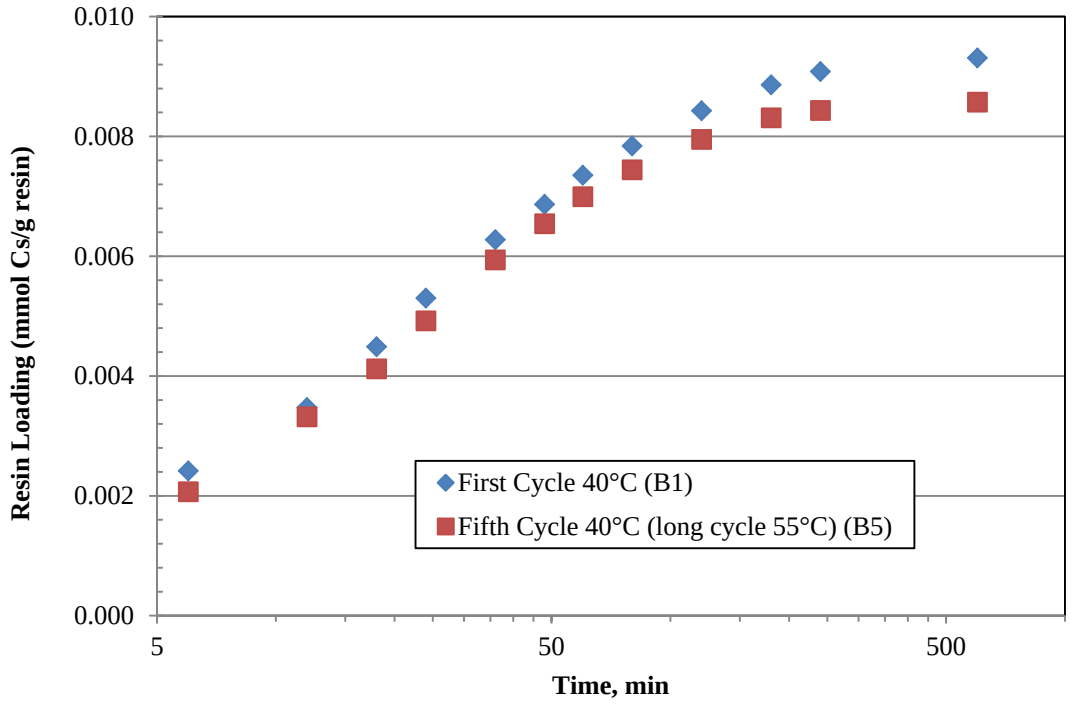

Figure 4.12. First and Fifth Resin Loading Cycles Compared at 40°C with Long Loading Cycle at 55°C

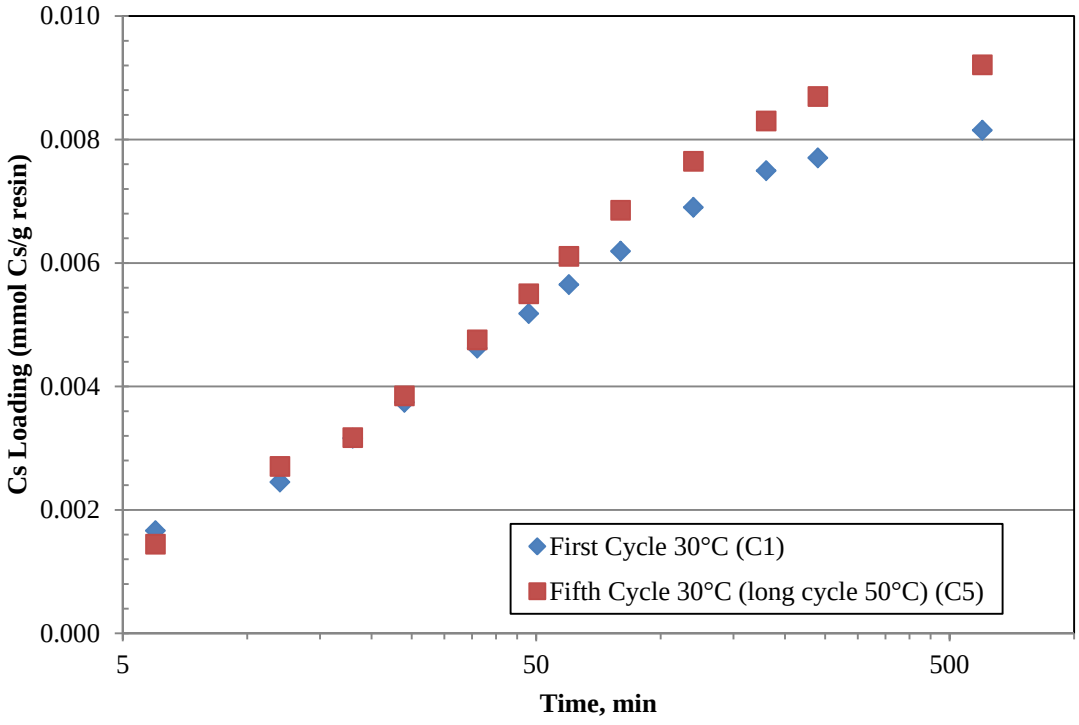

Figure 4.13. First and Fifth Resin Loading Cycles Compared at 30°C with Long Loading Cycle at 50°C

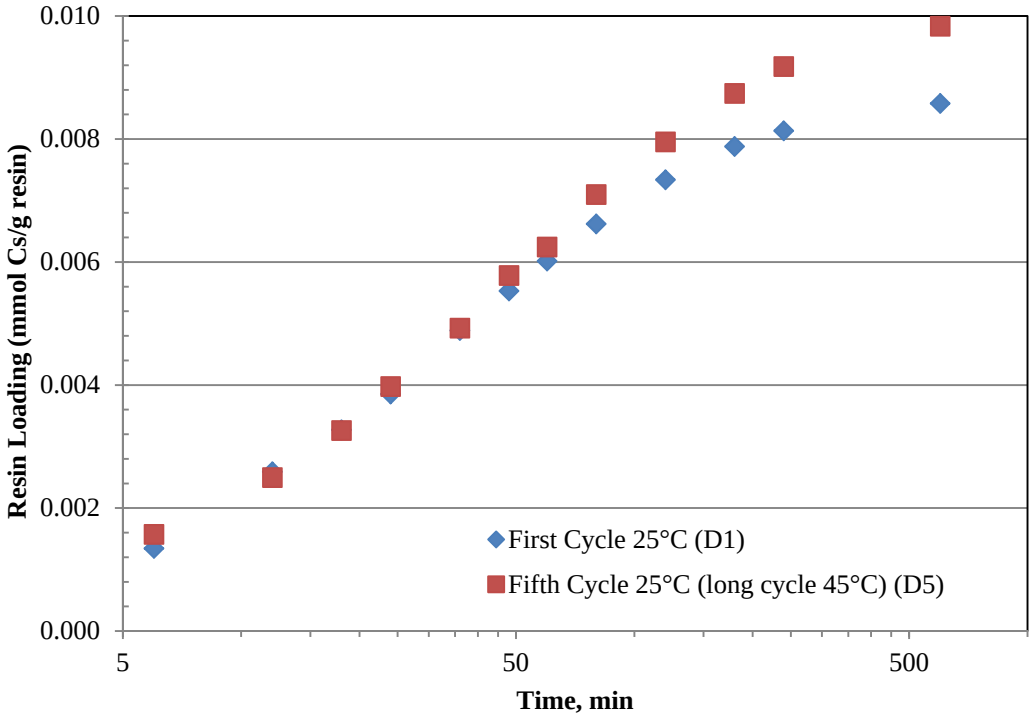

Figure 4.14. First and Fifth Resin Loading Cycles Compared at 25°C with Long Loading Cycle at 45°C

When testing was completed, the columns were dismantled and observed for resin degradation and precipitates. An unidentified flaky translucent precipitate was observed on the resin. However, no substantial physical degradation of the resin was observed. The new and used resin was examined under a microscope for comparison (Figure 4.15) and average particle size was measured (Table 4.1). No significant particle size reduction was observed with all results being within experimental error, which indicates that physical degradation of the resin did not occur or occurred in a very slight manner over this testing period.

Table 4.1. Average Particle Size of Resin Both Before and After Use

	Average (mm)	Std Dev (mm)
New Na^+ SRF Resin	0.400	0.024
New H^+ SRF Resin	0.373	0.004
Column A Used (45°C and 60°C)	0.383	0.027
Column B Used (40°C and 55°C)	0.380	0.042
Column C Used (30°C and 50°C)	0.382	0.031
Column D Used (25°C and 45°C)	0.372	0.012

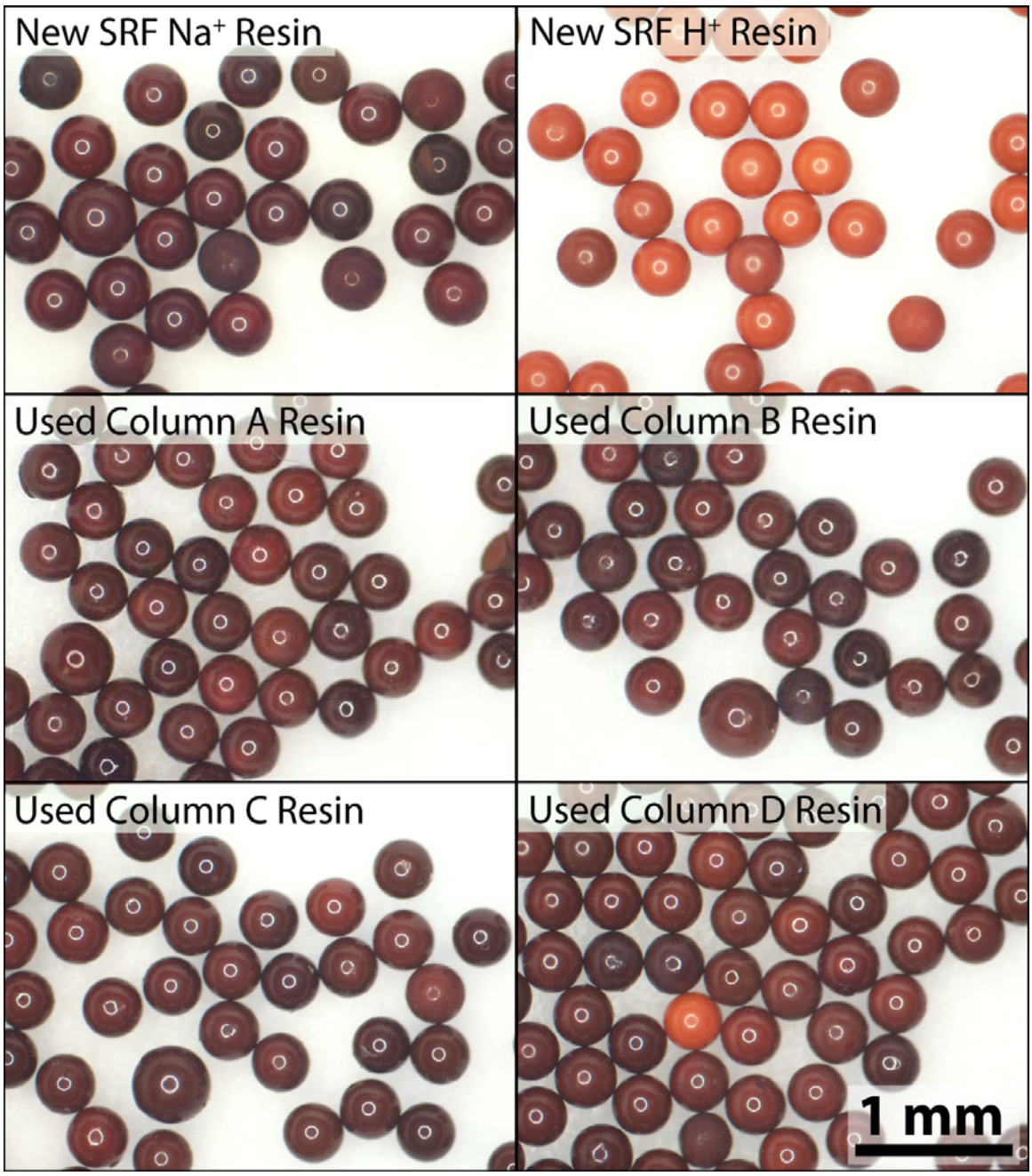

Figure 4.15. Microscopic Comparison of Resin from All Tests (circles are light reflections)

4.3 Batch Loading Test Results

The effect of the initial Na concentration (0.1, 0.5, 0.75, 1, 3, 5 M), initial K concentration (0.005 and 0.05 M), and initial OH concentration (0.1 and 1 M) on the resin's Cs loading at temperatures of 25°C, 35°C, and 50°C was tested using batch tests. The results of this research are discussed in this section.

4.3.1 Na Effect on Resin Cs Loading

Figure 4.16 presents the effect of different Na levels on resin Cs loading at 50°C with K and OH concentrations of 0.005 and 0.1 M, respectively. Clearly, Na has a significant effect on the Cs loading, with the more Na present the less Cs loaded. Previous work also observed this effect (Nash et al. 2006 and Russell et al. 2012). The 0.1 M Na shows the highest Cs loading at all concentrations and 5 M Na shows the lowest Cs loading. This is expected because the Na concentration is orders of magnitude higher than the Cs concentration in the feed and therefore takes the resin loading sites more easily. Lower Na concentration allows Cs to compete for the resin sites more effectively. The same effects were seen at 25°C (Figure 4.17). Therefore, the lower the Na level that the PTF processes, the better Cs loading the WTP should obtain on the SRF resin.

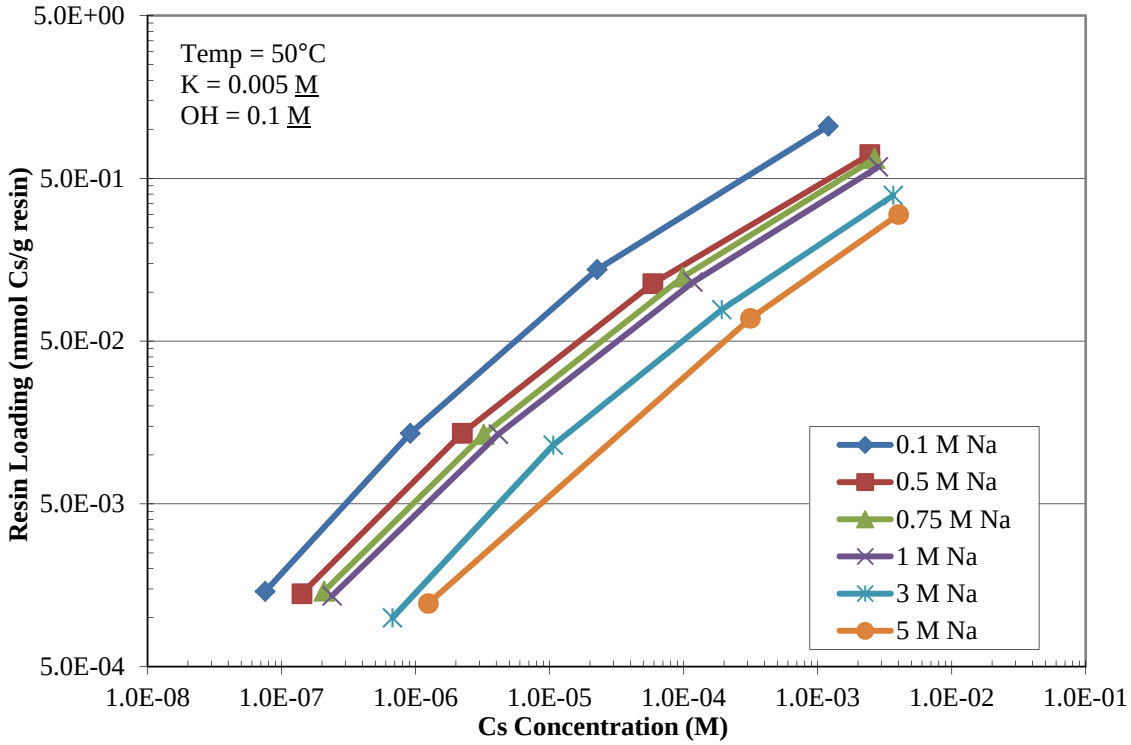

Figure 4.16. Na Effect on Cs Loading at 50°C, 0.005 M K, and 0.1 M OH

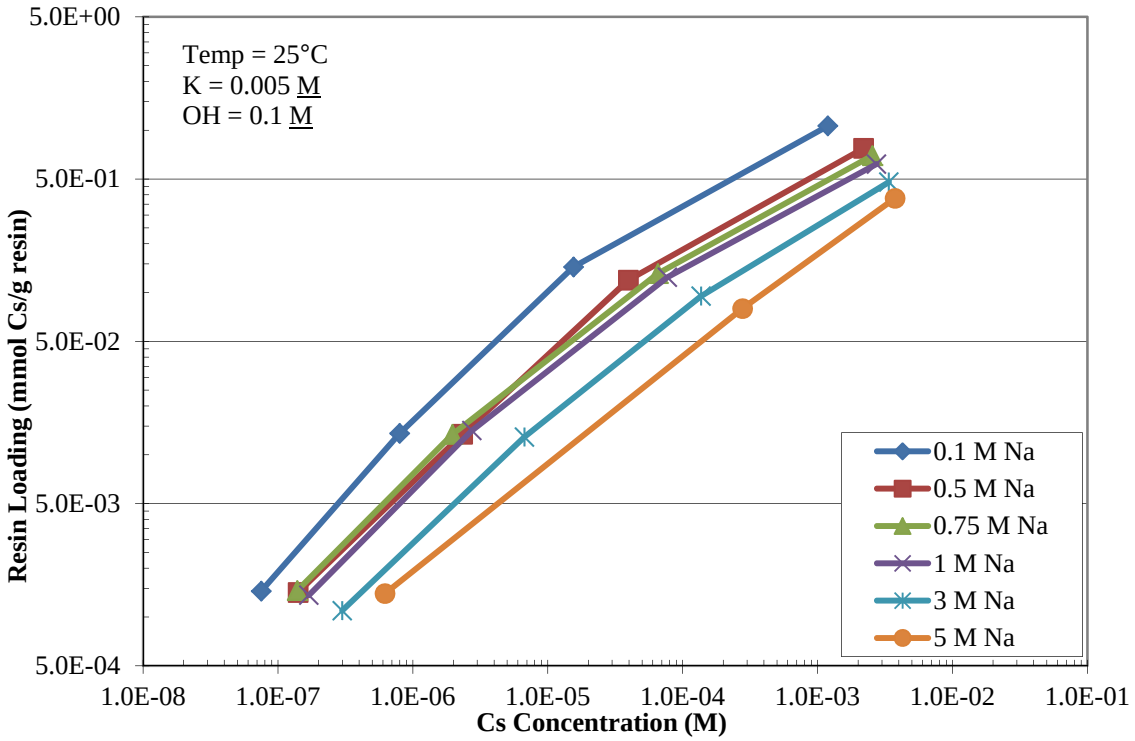

Figure 4.17. Na Effect on Cs Loading at 25°C, 0.005 M K, and 0.1 M OH

4.3.2 K Effect on Resin Cs Loading

Figure 4.18 presents the effect of different K levels on resin Cs loading at 50°C with a 1 M OH concentration and 1 and 5 M Na concentrations. The effect of K on Cs loading appears to vary. Lower Cs concentrations yielded greater K effect, which was expected due to competition for the resin sites between K and Cs. Higher Cs concentrations were less affected by K. At the highest Cs concentration tested (0.005 M), no significant K effect was observed. This could be due to the fact that as more Cs is present, there is a greater competition for the resin sites between the Cs and K. The affinity of the resin is higher for Cs than for K, causing it to load essentially the same amount of Cs with or without the K. Previous studies also noted this trend and observed that above a Cs concentration of 0.001 M, the Cs adsorption was more favorable at higher K concentration (Nash and Isom 2010). Higher concentrations of Cs were not tested here in order to confirm this observation because Hanford waste does not contain those levels of Cs. The effect of the K is also greater at the 1 M Na than at the 5 M Na indicating again that at higher Na concentrations, Na takes the resin sites regardless of K concentration.

The effect of K concentration on Cs resin loading at 25°C with 5 M Na appears negligible regardless of Cs concentration (Figure 4.19). However, at 1 M Na, the effect of K becomes greater with Cs loading decreasing with Cs concentration to about the same level as 5 M Na at the lowest Cs concentration.

At 0.1 M Na, the K effect is greatly increased especially, at lower Cs concentrations, with Cs loading at both 50 and 25°C reduced by about 40 percent as shown in Figure 4.20 and Figure 4.21. This is due to less Na competing for resin sites and K being the dominant ion.

Again, the K effect varies depending on Cs and Na concentrations. The K concentration has a greater effect at both lower Cs and Na levels. At 3 M Na and 0.001 M Cs, the K effect is negligible. Bray et al. (1996) reported similar results using ground gel RF and neutralized current acid waste. At 0.003 M Cs with 3 M Na solution, K competition appeared to vanish. At 0.1 M Na and low Cs concentration, K lowered the Cs loading level to less than that of 1 M Na, without the high K levels.

4.3.3 OH Effect on Resin Cs Loading Capacity

Figure 4.22 through Figure 4.23 show that the effect of different OH levels on Cs loading is not significant at the levels tested. OH concentration appears to have a slightly positive effect at higher Cs and lower Na concentrations. The presence of OH helps de-protonize the resin, opening up exchange sites and allowing the Cs ions to load more easily. Therefore, at higher Cs concentrations, more OH will be needed to form the ionic sites on the resin to accept the Cs. If not enough OH is present to form these sites, Cs loading decreases. This effect was also observed in Nash et al. (2006) and Nash and Isom (2010). These results indicate that the presence of OH in the WTP feed may slightly help resin Cs loading at higher Cs concentrations, but probably will not make a notable difference, especially in the presence of high Na and K concentrations where this effect is decreased.

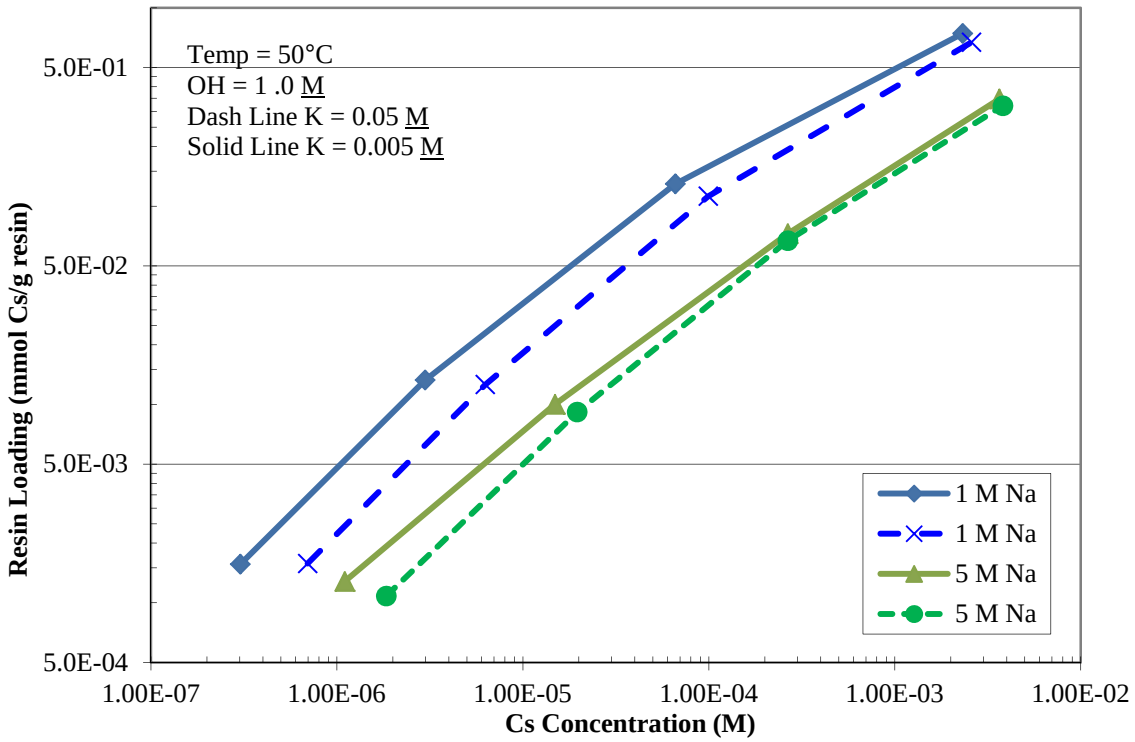

Figure 4.18. K Effect on Cs Loading at 50°C, 1 and 5 M Na, and 1.0 M OH

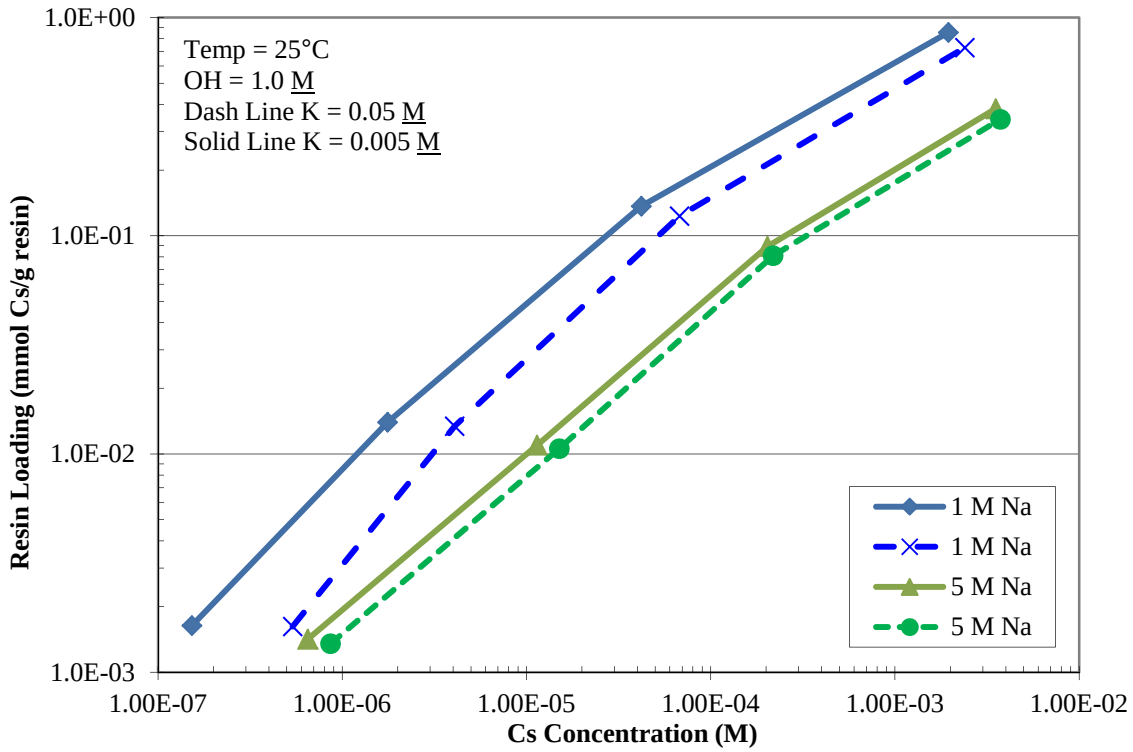

Figure 4.19. K Effect on Cs Loading at 25°C, 1 and 5 M Na, and 1.0 M OH

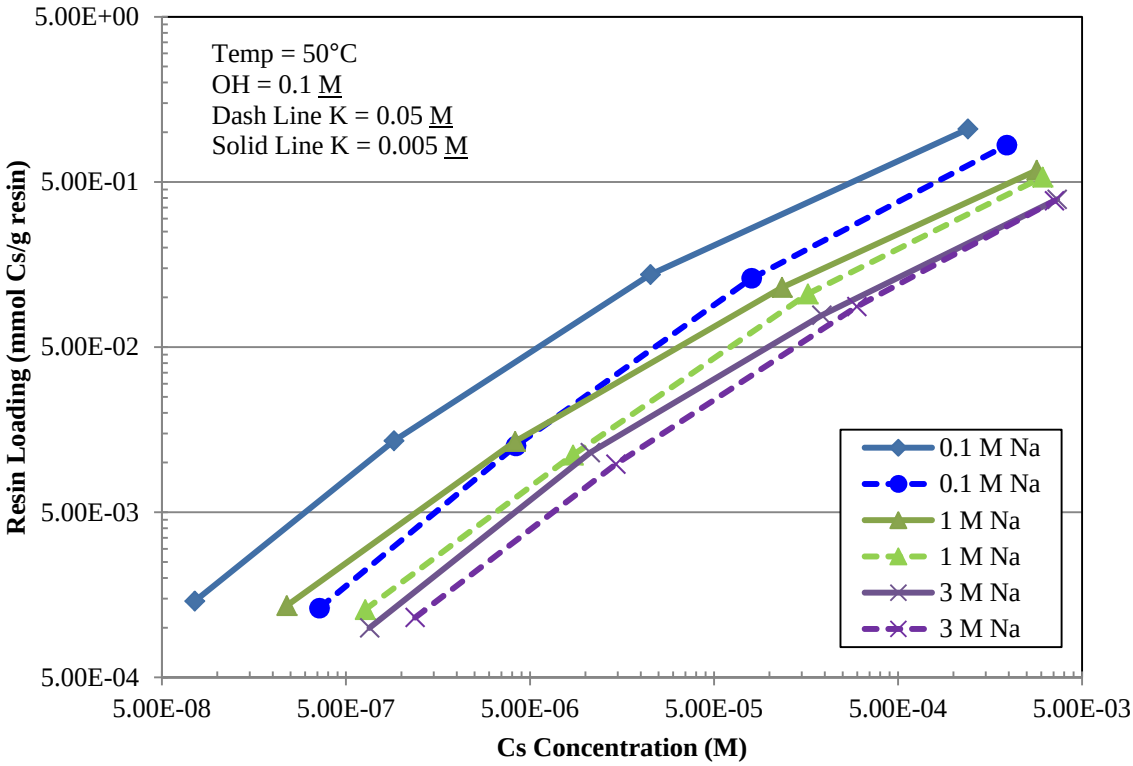

Figure 4.20. K Effect on Cs Loading at 50°C and 0.1 M OH

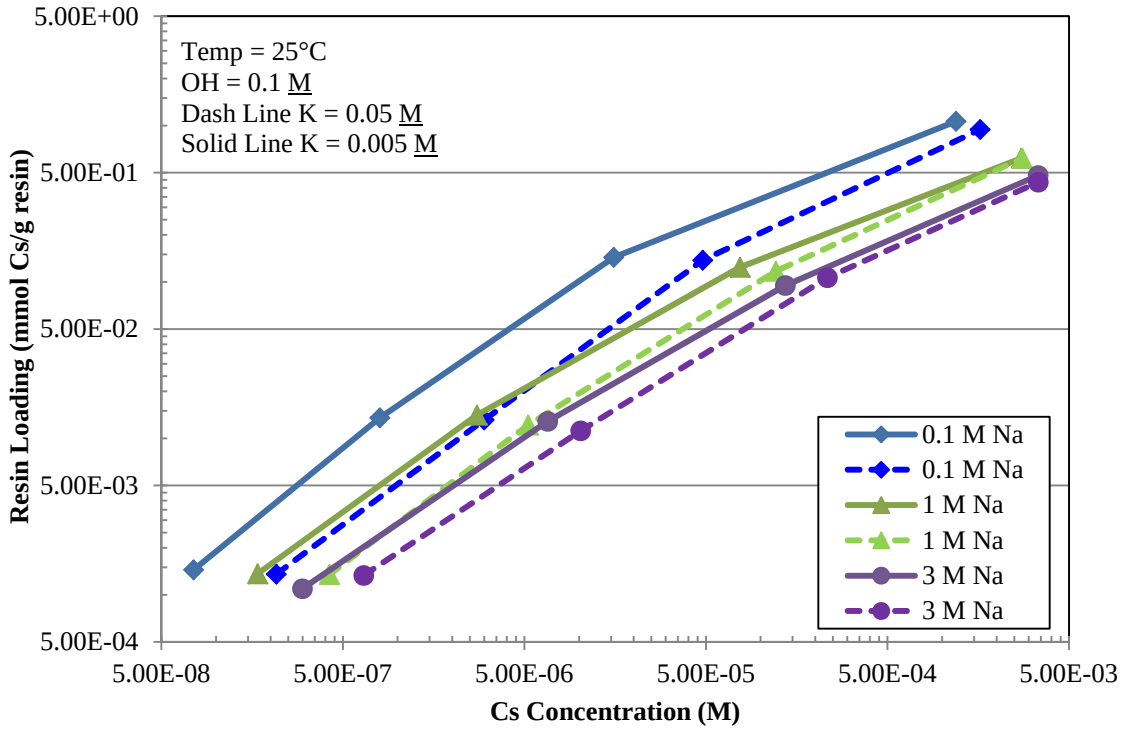

Figure 4.21. K Effect on Cs Loading at 25°C and 0.1 M OH

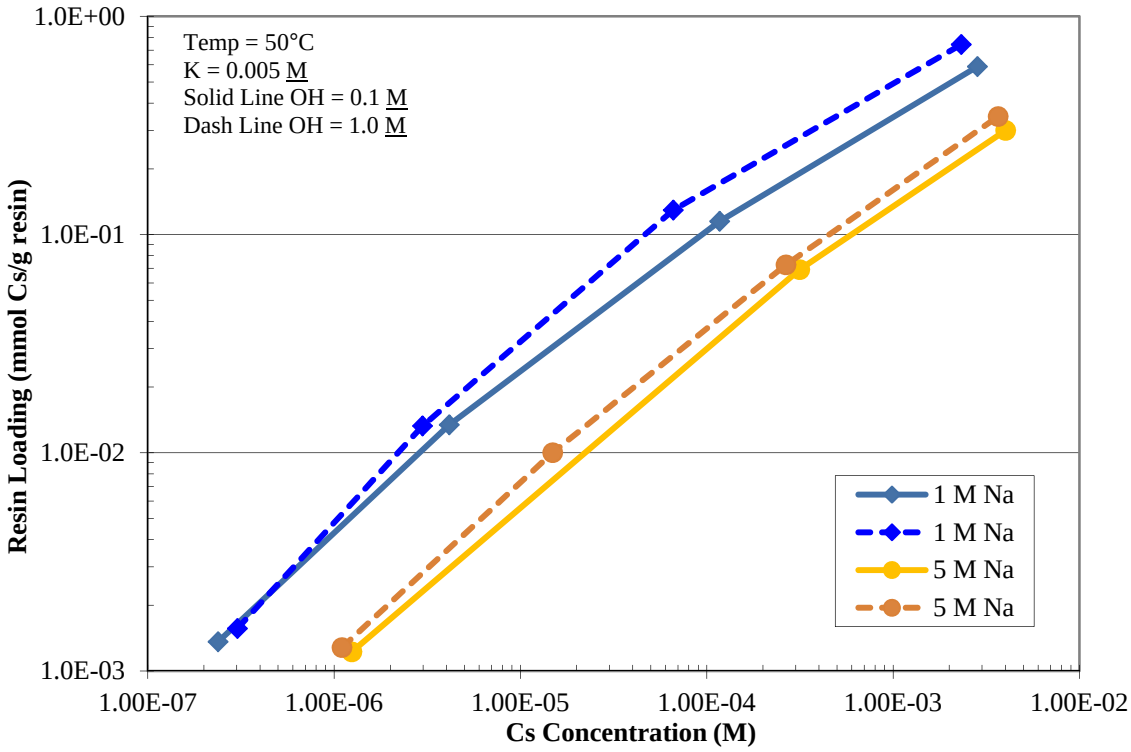

Figure 4.22. OH Effect on Cs Loading at 50°C and 0.005 M K

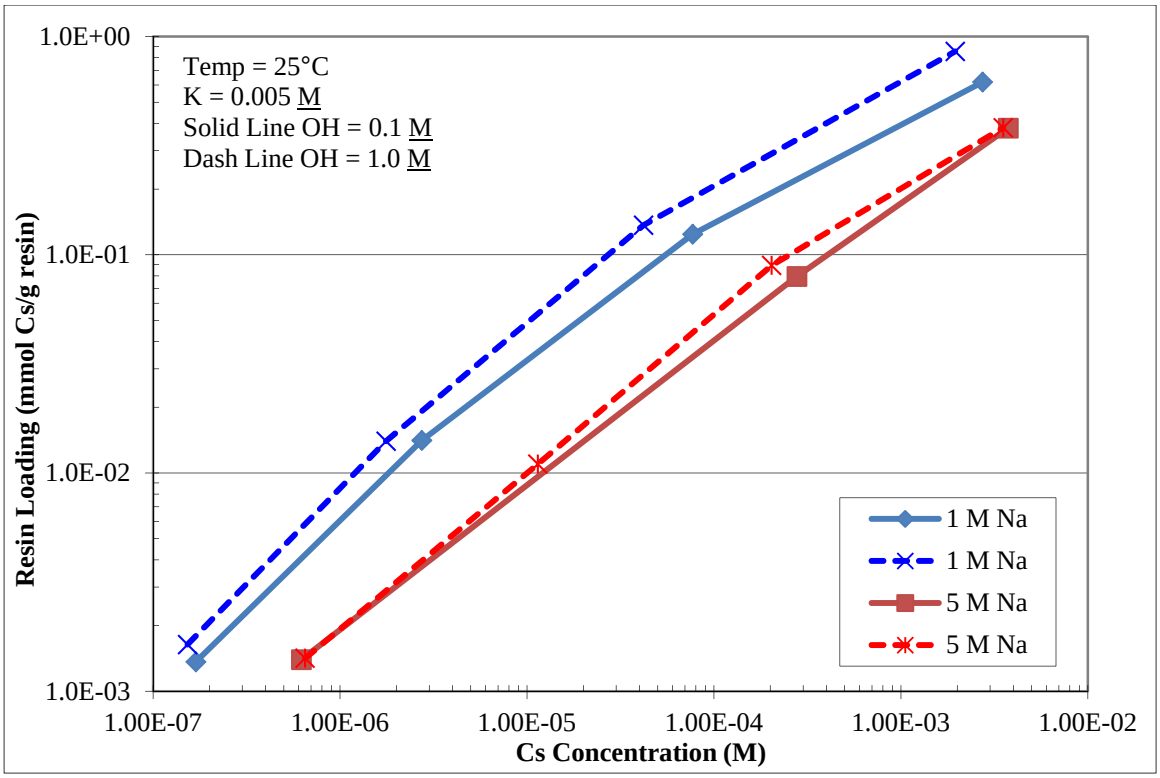

Figure 4.23. OH Effect on Cs Loading at 25°C and 0.005 M K

4.3.4 Temperature Effect on Resin Cs Loading Capacity

The effect of temperature on the resin loading capacity appears to be dependent on Na concentration with the effect being greater at higher Na. Figure 4.24 shows that at 0.1 M Na, temperature has basically no effect on Cs loading, but that the effect of temperature increases with Na concentration. Previous work observed an almost linear effect of temperature on the loading at 4 M and 6 M Na (Nash et al. 2006). This may be due to the density/viscosity difference between 0.1 and 5 M Na solutions, which allows the lower Na solutions to flow more readily through the resin and not be as affected by temperature as the higher Na solutions.

The presence of K does not appear to make a significant difference in the effect of temperature (Figure 4.25), with only a slight difference seen at low Cs concentrations and no effect seen at higher Cs concentrations. At higher K concentrations, the temperature effect is larger. However, the temperature effect of OH appears to be dependent on the presence of the other ions (Figure 4.26 and Figure 4.27). At higher OH concentrations and the lower Cs, Na and K concentrations, temperature has a greater effect on Cs loading. At 5 M Na and 0.05 M K, Cs loading is essentially the same at both OH concentrations; however, Cs loading decreases slightly when the temperature is raised to 50°C. With 1 M Na and 0.005 M K, Cs loading was greater at 1.0 M OH than at 0.1 M OH, but Cs loading decreased when the temperature was increased from 25 to 50°C.

Overall, higher temperatures result in lower equilibrium Cs loadings. Increasing the temperature from 25 to 50°C resulted in less Cs being removed from the simulant solution, with the percent decrease dependent on the presence of the other ions. This observation is in agreement with previous work (Nash

et al. 2006) and implies that if WTP uses a higher temperature in loading the SRF resin, it will obtain a lower equilibrium Cs loading level.

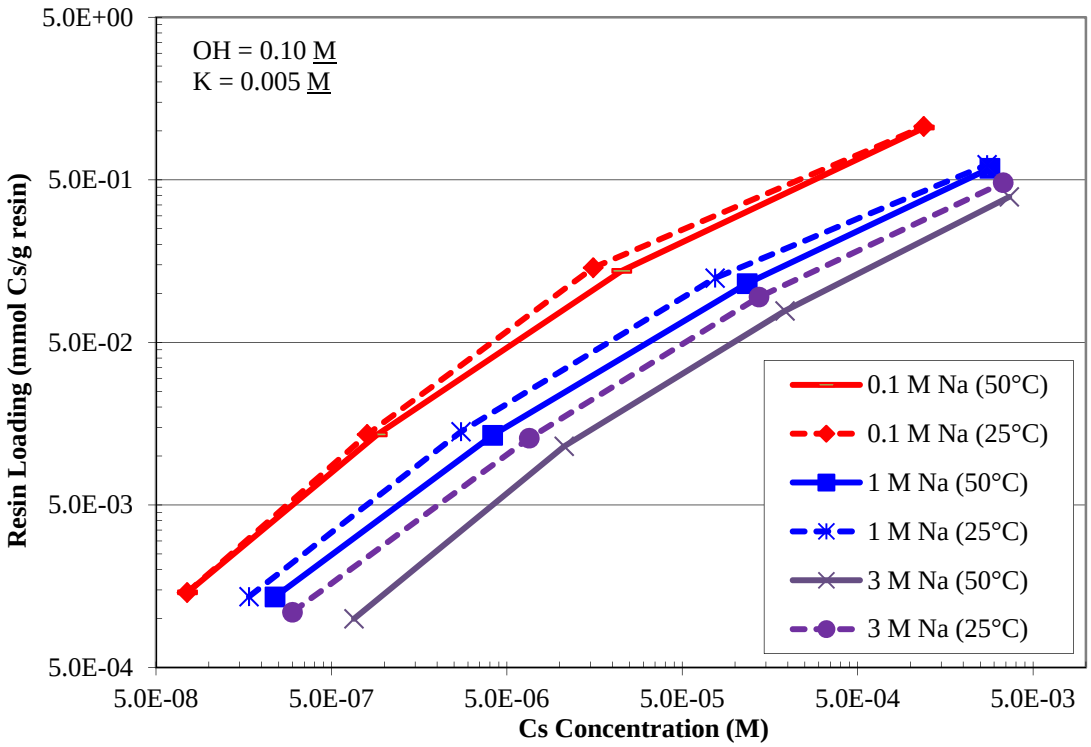

Figure 4.24. Temperature Effect of Na on Cs Loading at 0.1 M OH and 0.005 M K

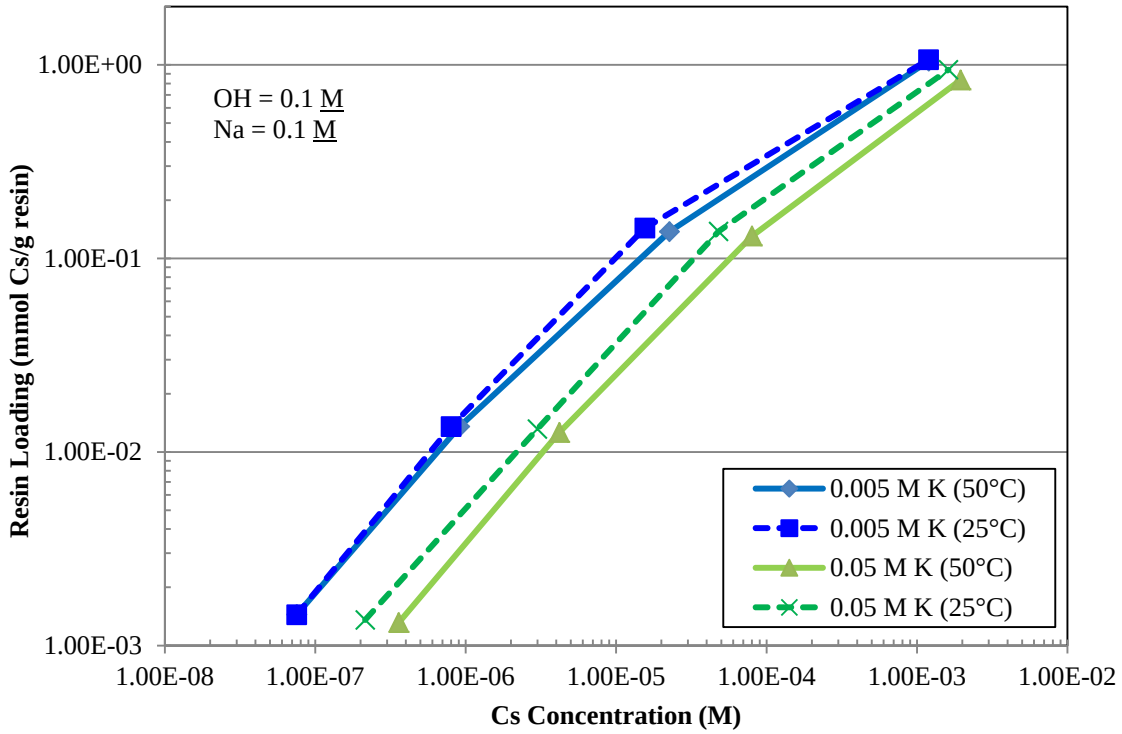

Figure 4.25. Temperature Effect of K on Cs Loading at 0.1 M OH and 0.1 M Na

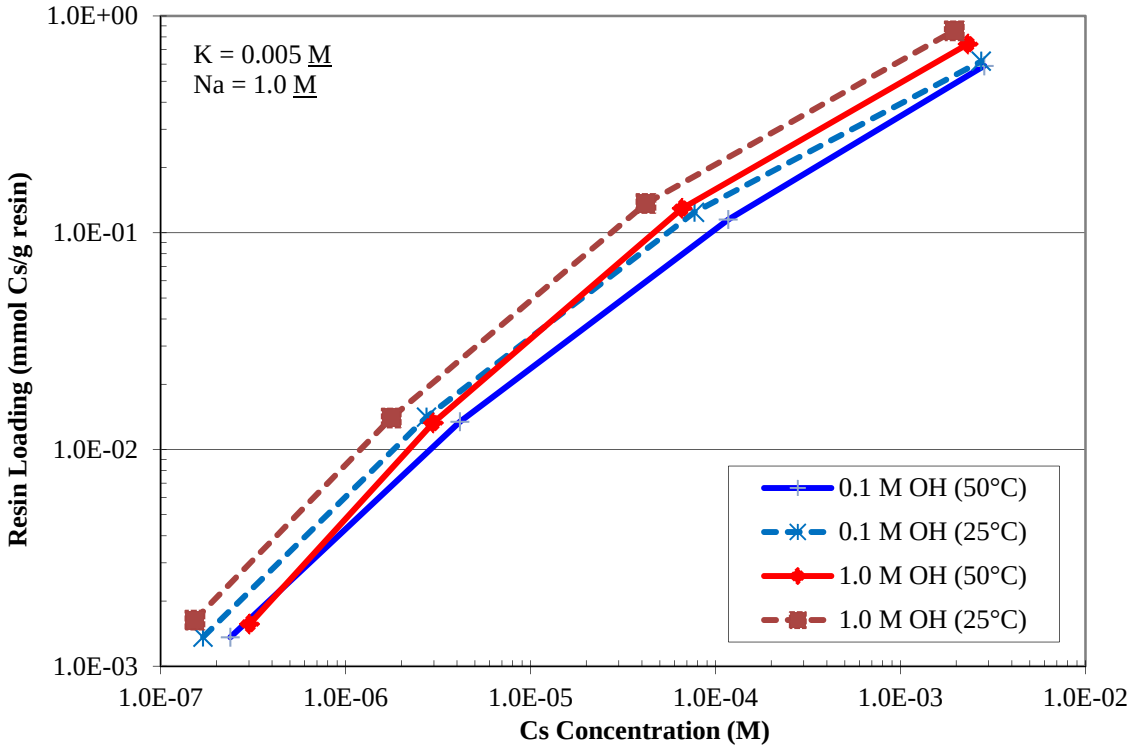

Figure 4.26. Temperature Effect of OH on Cs Loading at 1.0 M Na and 0.005 M K

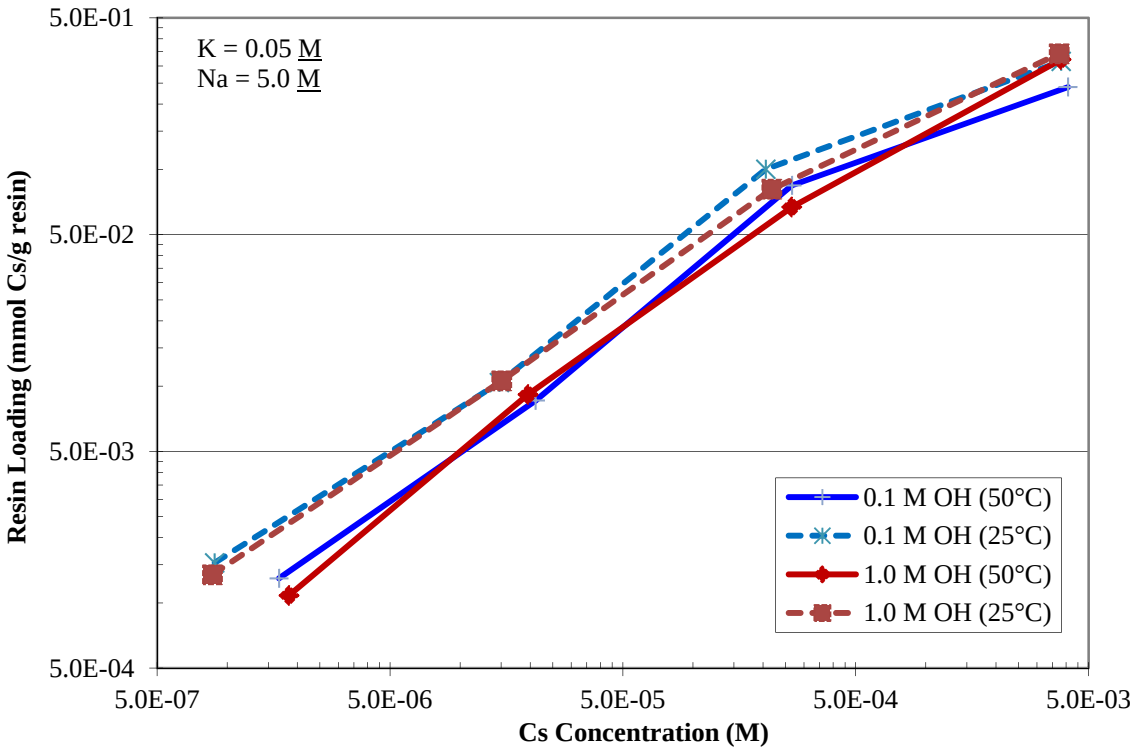

Figure 4.27. Temperature Effect of OH on Cs Loading at 5.0 M Na and 0.05 M K

5.0 Conclusions

Conclusions from the column testing include the following:

- Linear load velocity did not have a significant effect on the Cs loading kinetics at temperatures of 25, 30, 40, and 45°C. Previous work (Russell et al. 2012) showed a greater effect of the loading velocity on the Cs loading. The decrease in the impact of velocity with decreasing temperature is somewhat expected. As temperature is decreased, the kinetics of the sorption process will decrease. It would appear that below 45°C, the sorption process becomes the dominant factor in the Cs loading in place of the mass transfer process, which results in velocity not having a significant effect.
- Temperature had a negligible effect on the Cs loading kinetics. Temperature had a slight effect, with the Cs loading kinetics increasing slightly with increasing temperature. The 25 and 30°C test results were essentially the same and the 40 and 45°C test results were essentially the same. However, there may have been a slight increase in Cs loading kinetics between the 30 and 40°C tests. These results indicate that WTP should be able to perform the ion exchange process at up to 45°C without significant kinetics and Cs loading effects. In each extended test, regardless of temperature, Cs loading peaked after approximately72 hr. At the lower temperatures (45°C and 50°), the Cs loading remained stable within experimental error after 72 hr. However at the higher temperatures (55°C and 60°C) there was a loading decrease of ~9% and 16%, respectively, even after accounting for evaporation of the feed solution. Previous work on Cs loading over a period of time also showed that Cs loading peaked after approximately 72 hr and then began to decrease (Russell et al. 2012). These results indicate that the resin loses Cs loading ability over time and with increased temperature making it unable to hold the Cs over a long period of time at elevated temperatures. Therefore, it follows that WTP will lose resin Cs loading ability at an increased rate if the ion exchange process is performed above 25°C for an extended period of time. This indicates that the IX process should be operated at the minimum temperature within the range of 25-45°C that is consistent with minimizing the risk of post-filtration precipitation.
- Column plugging was observed in each extended test conducted above 45°C. Plugging occurred at 336 hr for tests conducted at 55 and 60°C and at 600 hr for the test conducted at 50°C. This presents a significant risk in that the plug could be difficult to remove in a hot cell environment.

Conclusions from the batch testing include the following:

- The Na concentration has a significant effect on Cs loading; the more Na is present the less Cs is loaded. Previous work also observed this effect (Nash et al. 2006 and Russell et al. 2012). Therefore, the lower the Na level that the PTF processes, the better Cs loading the WTP should obtain on the SRF resin.
- The K concentration appears to have a varying effect on Cs loading. The K effect is greater at lower Cs concentrations, with a Cs loading reduction of about 40 percent at 0.1 M Na, which is attributable to competition for the resin sites between the K and the Cs. The K effect is lower at higher Cs concentrations; at the highest Cs concentration tested (0.005 M), no significant K effect was observed (approximately 5 percent). Previous studies observed this trend and determined that above a Cs concentration of 0.001 M, Cs adsorption was more favorable at higher K concentrations (Nash and Isom 2010). Higher concentrations of Cs were not tested here because Hanford waste does not

contain those levels of Cs. There was also an inverse effect between Na and K with higher Na bringing less K effect.

- The OH concentration does not have a significant effect on the resin Cs loading. OH concentration may have a slightly positive effect at higher Cs concentrations and lower Na concentrations due to the rapid de-protonation of resin sites. This conclusion was reached in previous work (Nash and Isom 2010; Nash et al. 2006). Therefore, the presence of OH in the WTP feed may slightly help resin Cs loading but should not make a notable difference, especially in the presence of high Na and K concentrations.
- The temperature effect on the resin Cs loading appears to be dependent on the Na concentration with the effect being greater at higher Na concentrations. Previous work observed an almost linear effect of temperature on the loading at 4 and 6 M Na (Nash et al. 2006). Higher Na concentration resulted in less Cs loading at higher temperatures.
- No discernible difference in Cs loading was seen between 25 and 35°C. However, higher temperatures resulted in lower equilibrium Cs loading on the SRF resin. Increasing the temperature from 25 to 50°C resulted in a decrease in Cs removed from the simulant solution, with the percent decrease dependent on the presence of the other ions. This was also observed in previous work (Nash et al. 2006) and implies that if WTP uses a higher temperature in loading the SRF resin, it will obtain a lower equilibrium Cs loading level.

Based on the batch and column tests the following overall recommendations are provided:

- It is recommended that maximum routine operating of the SRF columns be limited to less than 45°C. This is primarily based on the hard resin clumps that formed and plugged the columns during the extended loading tests conducted above 45°C. It was not determined exactly what caused these clumps and the column plugging and might have been an artifact of the experimental set-up (e.g., polyethylene buildup from the simulant reservoir) and not be a factor in plant operation. The fact that plugging occurred at 336 hr for tests conducted at 55 and 60°C and occurred at 600 hr for the 50°C test suggests that some limited operation up to 55°C may be feasible. However the risk of a column plug that would be difficult to remove in a hot cell environment makes this a risky scenario and should be taken into account until the cause can be definitively proven. The other reason for limiting the routine operating temperature to a maximum of 45°C is that the resin degradation appears to increase with temperature.
- It is recommended that the IX process be operated at the minimum temperature within the range of 25-45°C that is consistent with minimizing the risk of post-filtration precipitation. The benefits to a lower operating temperature include: increased resin lifetime as result of a slower rate of resin degradation, increased Cs loading on the column due to more favorable equilibrium behavior, and less nitric acid for elution. One slight disadvantage is that a lower temperature results in slightly slower Cs ion exchange rates which will slightly increase the Cs breakthrough from the columns. This disadvantage is mitigated in the WTP by the use of two columns in series.

6.0 References

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Appendix A

Column Sampling Information

Appendix A

Column Sampling Information

Table A.1. Datasheet for Column A1 Pretreatment, Loading, and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A1-PT-DIW1	20	25	0.09	2/5/12 14:05	2/5/12 17:20	1.10	dark red	25.4	8.57	23.68	15.11	NA	NA	NA
A1-PT-ACID	20	25	0.09	2/6/12 9:16	2/6/12 12:51	1.00	orange	25.7	8.44	25.27	16.83	NA	NA	NA
A1-PT-DIW2	20	25	0.09	2/6/10 13:00	2/6/10 14:00	0.90	orange	24.8	8.53	13.19	4.66	NA	NA	NA
A1-PT-NaOH	20	25	0.09	2/6/10 14:10	2/6/10 16:25	1.25	dark red	25.6	8.51	19.85	11.34	NA	NA	NA
A1-LD-0	20	45	NA	2/13/12 6:47	2/13/12 6:47	1.25	dark red	55.2	NA	NA	NA	8.47	14.82	6.35
Loading (LD) Phase Start Date/Time:				2/13/12 6:52										
A1-LD-006	20	45	10.62	2/13/12 6:58	2/13/12 6:58	NA	dark red	52.2	NA	NA	NA	8.54	12.99	4.45
A1-LD-012	20	45	10.62	2/13/12 7:04	2/13/12 7:04	NA	dark red	48.0	NA	NA	NA	8.41	12.39	3.98
A1-LD-018	20	45	10.62	2/13/12 7:10	2/13/12 7:10	NA	dark red	46.4	NA	NA	NA	8.54	12.76	4.22
A1-LD-024	20	45	10.62	2/13/12 7:16	2/13/12 7:16	NA	dark red	45.1	NA	NA	NA	8.53	12.77	4.24
A1-LD-036	20	45	10.62	2/13/12 7:28	2/13/12 7:28	NA	dark red	44.0	NA	NA	NA	8.49	12.75	4.26
A1-LD-048	20	45	10.62	2/13/12 7:40	2/13/12 7:40	NA	dark red	44.3	NA	NA	NA	8.59	12.78	4.19
A1-LD-060	20	45	10.62	2/13/12 7:52	2/13/12 7:52	NA	dark red	44.4	NA	NA	NA	8.49	12.49	4.00
A1-LD-080	20	45	10.62	2/13/12 8:12	2/13/12 8:12	NA	dark red	45.3	NA	NA	NA	8.56	12.52	3.96
A1-LD-120	20	45	10.62	2/13/12 8:52	2/13/12 8:52	NA	dark red	44.9	NA	NA	NA	8.41	12.80	4.39
A1-LD-180	20	45	10.62	2/13/12 9:52	2/13/12 9:52	NA	dark red	44.8	NA	NA	NA	8.49	12.71	4.22
A1-LD-240	20	45	10.62	2/13/12 10:52	2/13/12 10:52	NA	dark red	45.2	NA	NA	NA	8.44	12.27	3.83
A1-LD-600	20	45	10.62	2/13/12 16:52	2/13/12 16:52	NA	dark red	45.1	NA	NA	NA	8.46	12.77	4
A1-FD-CP	20	45	0.09	2/13/12 17:10	2/13/12 19:40	NA	dark red	45.2	8.51	22.65	14.14	NA	NA	NA
A1-FDI-CP	20	45	0.09	2/13/12 20:05	2/13/12 22:35	1.25	dark red	26.1	8.38	20.90	12.52	NA	NA	NA
A1-AN-CP	20	45	0.09	2/13/12 22:40	2/13/12 23:40	1.25	dark red	25.3	8.65	13.29	4.64	NA	NA	NA

Table A.2. Datasheet for Column A1 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/14/12 6:50										
A1-EL-CP	60	25	0.08	2/14/12 6:50	2/14/12 16:50	1.05	orange	25.4	14.79	60.84	46.05	8.47	19.35	10.88
A1-EDI-CP	20	25	0.09	2/14/12 17:10	2/14/12 18:10	1.05	orange	25.0	8.50	13.32	4.82	NA	NA	NA
A1-RG-CP	20	25	0.09	2/14/12 18:17	2/14/12 20:47	1.25	dark red	26.5	8.57	20.75	12.18	NA	NA	NA

Table A.3. Datasheet for Column A2 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A2-LD-0	20	45	NA	2/15/12 6:47	2/15/12 6:47	1.25	dark red	55.1	NA	NA	NA	8.56	12.93	4.37
Loading (LD) Phase Start Date/Time:				2/15/12 6:50										
A2-LD-006	20	45	14.16	2/15/12 6:56	2/15/12 6:56	NA	dark red	49.5	NA	NA	NA	8.39	12.53	4.14
A2-LD-012	20	45	14.16	2/15/12 7:02	2/15/12 7:02	NA	dark red	46.8	NA	NA	NA	8.58	12.97	4.39
A2-LD-018	20	45	14.16	2/15/12 7:08	2/15/12 7:08	NA	dark red	45.1	NA	NA	NA	8.46	12.84	4.38
A2-LD-024	20	45	14.16	2/15/12 7:14	2/15/12 7:14	NA	dark red	44.0	NA	NA	NA	8.39	12.64	4.25
A2-LD-036	20	45	14.16	2/15/12 7:26	2/15/12 7:26	NA	dark red	43.8	NA	NA	NA	8.50	13.05	4.55
A2-LD-048	20	45	14.16	2/15/12 7:38	2/15/12 7:38	NA	dark red	44.3	NA	NA	NA	8.54	13.06	4.52
A2-LD-060	20	45	14.16	2/15/12 7:50	2/15/12 7:50	NA	dark red	44.8	NA	NA	NA	8.48	12.88	4.40
A2-LD-080	20	45	14.16	2/15/12 8:10	2/15/12 8:10	NA	dark red	45.1	NA	NA	NA	8.44	12.83	4.39
A2-LD-120	20	45	14.16	2/15/12 8:50	2/15/12 8:50	NA	dark red	45.2	NA	NA	NA	8.42	12.95	4.53
A2-LD-180	20	45	14.16	2/15/12 9:50	2/15/12 9:50	NA	dark red	45.1	NA	NA	NA	8.50	13.04	4.54
A2-LD-240	20	45	14.16	2/15/12 10:50	2/15/12 10:50	NA	dark red	45.0	NA	NA	NA	8.50	12.92	4.42
A2-LD-600	20	45	14.16	2/15/12 16:50	2/15/12 16:50	NA	dark red	45.2	NA	NA	NA	8.55	13.12	4.57
A2-FD-CP	20	45	0.09	2/15/12 17:07	2/15/12 19:37	1.25	dark red	45.2	8.44	22.44	14.00	NA	NA	NA
A2-FDI-CP	20	25	0.09	2/15/12 19:50	2/15/12 22:20	1.25	dark red	25.7	8.47	20.84	12.37	NA	NA	NA
A2-AN-CP	20	25	0.09	2/15/12 22:25	2/15/12 23:25	1.25	dark red	25.4	8.60	13.47	4.87	NA	NA	NA

Table A.4. Datasheet for Column A2 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/16/12 6:44										
A2-EL-CP	60	25	0.08	2/16/12 6:44	2/16/12 17:14	1.10	orange	25.9	14.90	60.83	45.93	8.46	16.76	8.30
A2-EDI-CP	20	25	0.09	2/16/12 17:27	2/16/12 18:27	1.10	orange	25.1	8.51	13.31	4.80	NA	NA	NA
A2-RG-CP	20	25	0.09	2/16/12 18:33	2/16/12 21:03	1.25	dark red	25.5	8.62	20.59	11.97	NA	NA	NA

Table A.5. Datasheet for Column A3 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A3-LD-0	20	45	NA	2/21/12 6:51	2/21/12 6:51	1.35	dark red	52.2	NA	NA	NA	8.54	13.11	4.57
Loading (LD) Phase Start Date/Time:				2/21/12 6:55										
A3-LD-006	20	45	7.08	2/21/12 7:01	2/21/12 7:01	NA	dark red	48.6	NA	NA	NA	8.51	12.87	4.36
A3-LD-012	20	45	7.08	2/21/12 7:07	2/21/12 7:07	NA	dark red	46.8	NA	NA	NA	8.66	13.12	4.46
A3-LD-018	20	45	7.08	2/21/12 7:13	2/21/12 7:13	NA	dark red	45.6	NA	NA	NA	8.68	13.36	4.68
A3-LD-024	20	45	7.08	2/21/12 7:19	2/21/12 7:19	NA	dark red	44.8	NA	NA	NA	8.61	13.02	4.41
A3-LD-036	20	45	7.08	2/21/12 7:31	2/21/12 7:31	NA	dark red	44.6	NA	NA	NA	8.68	12.79	4.11
A3-LD-048	20	45	7.08	2/21/12 7:43	2/21/12 7:43	NA	dark red	44.8	NA	NA	NA	8.58	12.39	3.81
A3-LD-060	20	45	7.08	2/21/12 7:55	2/21/12 7:55	NA	dark red	44.9	NA	NA	NA	8.49	13.04	4.55
A3-LD-080	20	45	7.08	2/21/12 8:15	2/21/12 8:15	NA	dark red	44.9	NA	NA	NA	8.67	13.43	4.76
A3-LD-120	20	45	7.08	2/21/12 8:55	2/21/12 8:55	NA	dark red	44.8	NA	NA	NA	8.50	12.99	4.49
A3-LD-180	20	45	7.08	2/21/12 9:55	2/21/12 9:55	NA	dark red	44.9	NA	NA	NA	8.46	13.02	4.56
A3-LD-240	20	45	7.08	2/21/12 10:55	2/21/12 10:55	NA	dark red	44.9	NA	NA	NA	8.61	12.63	4.02
A3-LD-600	20	45	7.08	2/21/12 16:55	2/21/12 16:55	NA	dark red	45.1	NA	NA	NA	8.61	13.01	4.40
A3-FD-CP	20	45	0.09	2/21/12 17:08	2/21/12 19:38	NA	dark red	44.9	8.49	22.39	13.90	NA	NA	NA
A3-FDI-CP	20	25	0.09	2/21/12 19:45	2/21/12 22:15	NA	dark red	25.6	8.45	20.97	12.52	NA	NA	NA
A3-AN-CP	20	25	0.09	2/21/12 22:22	2/21/12 23:17	NA	dark red	25.5	8.46	13.07	4.61	NA	NA	NA

Table A.6. Datasheet for Column A3 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/22/12 6:47										
A3-EL-CP	60	25	0.08	2/22/12 6:47	2/22/12 16:50	1.30	orange	26.4	14.63	58.95	44.32	8.66	19.22	10.56
A3-EDI-CP	20	25	0.09	2/22/12 17:01	2/22/12 18:01	1.30	orange red	25.3	8.61	13.27	4.66	NA	NA	NA
A3-RG-CP	20	25	0.09	2/22/12 18:07	2/22/12 20:47	1.35	dark red	26.2	8.51	21.29	12.78	NA	NA	NA

Table A.7. Datasheet for Column A4 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A4-LD-0	20	45	NA	2/23/12 6:47	2/23/12 6:47	1.35	dark red	51.8	NA	NA	NA	8.52	13.10	4.58
Loading (LD) Phase Start Date/Time:				2/23/12 6:50										
A4-LD-006	20	45	10.62	2/23/12 6:56	2/23/12 6:56	NA	dark red	47.9	NA	NA	NA	8.58	12.97	4.39
A4-LD-012	20	45	10.62	2/23/12 7:02	2/23/12 7:02	NA	dark red	45.2	NA	NA	NA	8.69	12.81	4.12
A4-LD-018	20	45	10.62	2/23/12 7:08	2/23/12 7:08	NA	dark red	44.1	NA	NA	NA	8.66	13.01	4.35
A4-LD-024	20	45	10.62	2/23/12 7:14	2/23/12 7:14	NA	dark red	44.1	NA	NA	NA	8.44	12.83	4.39
A4-LD-036	20	45	10.62	2/23/12 7:26	2/23/12 7:26	NA	dark red	44.9	NA	NA	NA	8.51	12.67	4.16
A4-LD-048	20	45	10.62	2/23/12 7:38	2/23/12 7:38	NA	dark red	45.2	NA	NA	NA	8.56	13.01	4.45
A4-LD-060	20	45	10.62	2/23/12 7:50	2/23/12 7:50	NA	dark red	45.2	NA	NA	NA	8.62	13.11	4.49
A4-LD-080	20	45	10.62	2/23/12 8:10	2/23/12 8:10	NA	dark red	44.8	NA	NA	NA	8.66	13.01	4.35
A4-LD-120	20	45	10.62	2/23/12 8:50	2/23/12 8:50	NA	dark red	44.5	NA	NA	NA	8.63	13.01	4.38
A4-LD-180	20	45	10.62	2/23/12 9:50	2/23/12 9:50	NA	dark red	44.8	NA	NA	NA	8.53	13.07	4.54
A4-LD-240	20	45	10.62	2/23/12 10:50	2/23/12 10:50	NA	dark red	44.5	NA	NA	NA	8.55	13.00	4.45
A4-LD-600	20	45	10.62	2/23/12 16:50	2/23/12 16:50	NA	dark red	45.3	NA	NA	NA	8.58	12.95	4.37
A4-FD-CP	20	45	0.09	2/23/12 17:06	2/23/12 19:36	NA	dark red	45.3	8.46	22.63	14.17	NA	NA	NA
A4-FDI-CP	20	25	0.09	2/23/12 19:54	2/23/12 21:54	NA	dark red	25.7	8.58	18.87	10.29	NA	NA	NA

Table A.8. Datasheet for Column A4B Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A4B-LD-0	20	60	NA	2/29/12 8:47	2/29/12 8:47	1.30	dark red	59.8	NA	NA	NA	8.41	12.66	4.25
Loading (LD) Phase Start Date/Time:				2/29/12 9:00										
A4B-LD-004	20	60	0.08	2/29/12 13:00	2/29/12 13:00	NA	dark red	60.0	NA	NA	NA	8.42	12.41	3.99
A4B-LD-008	20	60	0.08	2/29/12 17:00	2/29/12 17:00	NA	dark red	60.1	NA	NA	NA	8.51	13.05	4.54
A4B-LD-012	20	60	0.08	2/29/12 21:00	2/29/12 21:00	NA	dark red	60.1	NA	NA	NA	8.49	12.92	4.43
A4B-LD-024	20	60	0.08	3/1/12 9:00	3/1/12 9:00	NA	dark red	60.1	NA	NA	NA	8.36	12.91	4.55
A4B-LD-072	20	60	0.08	3/3/12 9:00	3/3/12 9:00	NA	dark red	60.1	NA	NA	NA	8.54	13.03	4.49
A4B-LD-120	20	60	0.08	3/5/12 9:00	3/5/12 9:00	NA	dark red	60.0	NA	NA	NA	8.46	12.97	4.51
A4B-LD-168	20	60	0.08	3/7/12 9:00	3/7/12 9:00	NA	dark red	59.8	NA	NA	NA	8.49	13.14	4.65
A4B-LD-336	20	60	0.08	3/14/12 9:00	3/14/12 9:00	NA	dark red	60.5	NA	NA	NA	8.43	12.85	4.42
A4B-FD-CP	20	60	0.08	3/15/12 9:20	3/15/12 11:50	NA	dark red	60.4	8.40	20.88	12.48	NA	NA	NA
A4B-FDI-CP	20	25	0.09	3/15/12 12:10	3/15/12 14:42	NA	dark red	26.3	8.45	21.23	12.78	NA	NA	NA
A4B-AN-CP	20	25	0.09	3/15/12 14:52	3/15/12 15:53	NA	dark red	26.9	8.47	13.64	5.17	NA	NA	NA

Table A.9. Datasheet for Column A4B Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/19/12 6:40										
A4B-EL-CP	60	25	0.08	3/19/12 6:40	3/19/12 17:40	1.50	orange	26.5	14.72	63.38	48.66	8.48	18.19	9.71
A4B-EDI-CP	20	25	0.09	3/19/12 17:55	3/19/12 18:55	1.40	orange red	25.1	8.47	13.20	4.73	NA	NA	NA
A4B-RG-CP	20	25	0.09	3/19/12 19:05	3/19/12 22:05	1.50	dark red	24.8	8.43	23.39	14.96	NA	NA	NA

Table A.10. Datasheet for Column A5 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
A5-LD-0	20	45	NA	3/20/12 6:41	3/20/12 6:41	1.50	dark red	50.6	NA	NA	NA	8.47	12.89	4.42
Loading (LD) Phase Start Date/Time:				3/20/12 6:45										
A5-LD-006	20	45	10.62	3/20/12 6:51	3/20/12 6:51	NA	dark red	46.6	NA	NA	NA	8.43	12.62	4.19
A5-LD-012	20	45	10.62	3/20/12 6:57	3/20/12 6:57	NA	dark red	44.6	NA	NA	NA	8.41	12.72	4.31
A5-LD-018	20	45	10.62	3/20/12 7:03	3/20/12 7:03	NA	dark red	43.8	NA	NA	NA	8.44	13.00	4.56
A5-LD-024	20	45	10.62	3/20/12 7:09	3/20/12 7:09	NA	dark red	43.6	NA	NA	NA	8.52	12.89	4.37
A5-LD-036	20	45	10.62	3/20/12 7:21	3/20/12 7:21	NA	dark red	43.9	NA	NA	NA	8.50	13.01	4.51
A5-LD-048	20	45	10.62	3/20/12 7:33	3/20/12 7:33	NA	dark red	44.4	NA	NA	NA	8.48	12.89	4.41
A5-LD-060	20	45	10.62	3/20/12 7:45	3/20/12 7:45	NA	dark red	44.8	NA	NA	NA	8.49	12.93	4.44
A5-LD-080	20	45	10.62	3/20/12 8:05	3/20/12 8:05	NA	dark red	45.0	NA	NA	NA	8.47	12.89	4.42
A5-LD-120	20	45	10.62	3/20/12 8:45	3/20/12 8:45	NA	dark red	45.0	NA	NA	NA	8.58	12.98	4.40
A5-LD-180	20	45	10.62	3/20/12 9:45	3/20/12 9:45	NA	dark red	45.0	NA	NA	NA	8.44	12.85	4.41
A5-LD-240	20	45	10.62	3/20/12 10:45	3/20/12 10:45	NA	dark red	45.0	NA	NA	NA	8.38	12.74	4.36
A5-LD-600	20	45	10.62	3/20/12 16:45	3/20/12 16:45	NA	dark red	44.8	NA	NA	NA	8.29	12.51	4.22
A5-FD-CP	20	45	0.09	3/20/12 16:56	3/20/12 19:26	1.50	dark red	45.0	8.38	22.71	14.33	NA	NA	NA
A5-FDI-CP	20	25	0.09	3/20/12 19:58	3/20/12 22:28	1.50	dark red	25.5	8.47	21.27	12.80	NA	NA	NA
A5-AN-CP	20	25	0.09	3/20/12 22:31	3/20/12 23:31	1.50	dark red	24.8	8.48	13.54	5.06	NA	NA	NA

Table A.11. Datasheet for Column A5 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/21/12 6:40										
A5-EL-CP	60	25	0.08	3/21/12 6:40	3/21/12 17:40	1.45	orange	26.0	14.64	63.21	48.57	8.43	14.59	6.16
A5-EDI-CP	20	25	0.09	3/21/12 17:47	3/21/12 18:47	1.45	orange	25.7	8.50	13.22	4.72	NA	NA	NA

Table A.12. Datasheet for Column B1 Pretreatment, Loading, and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B1-PT-DIW1	20	25	0.09	2/5/12 14:05	2/5/12 17:20	1.15	dark red	24.5	8.44	25.21	16.77	NA	NA	NA
B1-PT-ACID	20	25	0.09	2/6/12 9:16	2/6/12 12:16	1.10	orange	24.9	8.44	22.86	14.42	NA	NA	NA
B1-PT-DIW2	20	25	0.09	2/6/12 13:00	2/6/12 14:00	1.00	orange	23.9	8.33	13.18	4.85	NA	NA	NA
B1-PT-NaOH	20	25	0.09	2/6/12 14:10	2/6/12 16:30	1.30	dark red	24.3	8.50	20.33	11.83	NA	NA	NA
B1-LD-0	20	50.1	NA	2/13/12 6:50	2/13/12 6:50	1.30	dark red	50.1	NA	NA	NA	8.49	14.41	5.92
Loading (LD) Phase Start Date/Time:				2/13/12 6:55										
B1-LD-006	20	40	10.62	2/13/12 7:01	2/13/12 7:01	NA	dark red	45.9	NA	NA	NA	8.38	12.64	4.26
B1-LD-012	20	40	10.62	2/13/12 7:07	2/13/12 7:07	NA	dark red	43.7	NA	NA	NA	8.41	12.74	4.33
B1-LD-018	20	40	10.62	2/13/12 7:13	2/13/12 7:13	NA	dark red	42.1	NA	NA	NA	8.43	12.50	4.07
B1-LD-024	20	40	10.62	2/13/12 7:19	2/13/12 7:19	NA	dark red	41.0	NA	NA	NA	8.53	12.69	4.16
B1-LD-036	20	40	10.62	2/13/12 7:31	2/13/12 7:31	NA	dark red	39.8	NA	NA	NA	8.41	12.58	4.17
B1-LD-048	20	40	10.62	2/13/12 7:43	2/13/12 7:43	NA	dark red	39.3	NA	NA	NA	8.43	12.66	4.23
B1-LD-060	20	40	10.62	2/13/12 7:55	2/13/12 7:55	NA	dark red	39.5	NA	NA	NA	8.40	12.49	4.09
B1-LD-080	20	40	10.62	2/13/12 8:15	2/13/12 8:15	NA	dark red	39.8	NA	NA	NA	8.45	12.65	4.20
B1-LD-120	20	40	10.62	2/13/12 8:55	2/13/12 8:55	NA	dark red	39.8	NA	NA	NA	8.51	12.03	3.52
B1-LD-180	20	40	10.62	2/13/12 9:55	2/13/12 9:55	NA	dark red	39.9	NA	NA	NA	8.44	12.31	3.87
B1-LD-240	20	40	10.62	2/13/12 10:55	2/13/12 10:55	NA	dark red	39.8	NA	NA	NA	8.58	13.05	4.47
B1-LD-600	20	40	10.62	2/13/12 16:55	2/13/12 16:55	NA	dark red	40.1	NA	NA	NA	8.59	12.98	4.39
B1-FD-CP	20	40	0.09	2/13/12 17:12	2/13/12 19:42	NA	dark red	39.2	8.56	23.34	14.78	NA	NA	NA
B1-FDI-CP	20	25	0.09	2/13/12 20:07	2/13/12 22:37	1.30	dark red	24.9	8.54	21.63	13.09	NA	NA	NA
B1-AN-CP	20	25	0.09	2/13/12 22:41	2/13/12 23:41	1.30	dark red	24.1	8.45	13.26	4.81	NA	NA	NA

Table A.13. Datasheet for Column B1 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/14/12 6:50										
B1-EL-CP	60	25	0.08	2/14/12 6:50	2/14/12 16:50	1.15	orange	24.6	14.88	64.86	49.98	8.42	18.91	10.49
B1-EDI-CP	20	25	0.09	2/14/12 17:12	2/14/12 18:12	1.15	orange	24.2	8.41	13.57	5.16	NA	NA	NA
B1-RG-CP	20	25	0.09	2/14/12 18:17	2/14/12 20:47	1.30	dark red	25.3	8.62	12.21	3.59 (vial spilled)	NA	NA	NA

Table A.14. Datasheet for Column B2 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B2-LD-0	20	40	NA	2/15/12 6:49	2/15/12 6:49	1.30	dark red	50.0	NA	NA	NA	8.47	12.71	4.24
Loading (LD) Phase Start Date/Time:				2/15/12 6:53										
B2-LD-006	20	40	14.16	2/15/12 6:59	2/15/12 6:59	NA	dark red	45.3	NA	NA	NA	8.90	13.04	4.14
B2-LD-012	20	40	14.16	2/15/12 7:05	2/15/12 7:05	NA	dark red	43.0	NA	NA	NA	8.65	13.07	4.42
B2-LD-018	20	40	14.16	2/15/12 7:11	2/15/12 7:11	NA	dark red	41.5	NA	NA	NA	8.48	12.85	4.37
B2-LD-024	20	40	14.16	2/15/12 7:17	2/15/12 7:17	NA	dark red	40.3	NA	NA	NA	8.90	13.40	4.50
B2-LD-036	20	40	14.16	2/15/12 7:29	2/15/12 7:29	NA	dark red	39.0	NA	NA	NA	8.64	13.09	4.45
B2-LD-048	20	40	14.16	2/15/12 7:41	2/15/12 7:41	NA	dark red	38.8	NA	NA	NA	8.56	13.01	4.45
B2-LD-060	20	40	14.16	2/15/12 7:53	2/15/12 7:53	NA	dark red	39.0	NA	NA	NA	8.60	12.59	3.99
B2-LD-080	20	40	14.16	2/15/12 8:13	2/15/12 8:13	NA	dark red	39.2	NA	NA	NA	8.64	12.97	4.33
B2-LD-120	20	40	14.16	2/15/12 8:53	2/15/12 8:53	NA	dark red	39.4	NA	NA	NA	8.62	12.90	4.28
B2-LD-180	20	40	14.16	2/15/12 9:53	2/15/12 9:53	NA	dark red	39.6	NA	NA	NA	8.56	13.08	4.52
B2-LD-240	20	40	14.16	2/15/12 10:53	2/15/12 10:53	NA	dark red	39.3	NA	NA	NA	8.62	13.21	4.59
B2-LD-600	20	40	14.16	2/15/12 16:53	2/15/12 16:53	NA	dark red	39.9	NA	NA	NA	8.58	12.95	4.37
B2-FD-CP	20	40	0.09	2/15/12 17:07	2/15/12 19:37	1.30	dark red	40.4	8.58	23.44	14.86	NA	NA	NA
B2-FDI-CP	20	25	0.09	2/15/12 19:50	2/15/12 22:20	1.30	dark red	24.8	8.69	22.10	13.41	NA	NA	NA
B2-AN-CP	20	25	0.09	2/15/12 22:25	2/15/12 23:25	1.30	dark red	24.9	8.64	13.79	5.15	NA	NA	NA

Table A.15. Datasheet for Column B2 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/16/12 6:44										
B2-EL-CP	60	25	0.08	2/16/12 6:44	2/16/12 17:14	1.15	orange	25.0	14.91	64.54	49.63	8.51	18.15	9.64
B2-EDI-CP	20	25	0.09	2/16/12 17:27	2/16/12 18:27	1.15	orange	24.3	8.65	13.90	5.25	NA	NA	NA
B2-RG-CP	20	25	0.09	2/16/12 18:33	2/16/12 21:03	1.30	dark red	24.9	8.67	21.59	12.92	NA	NA	NA

Table A.16. Datasheet for Column B3 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B3-LD-0	20	40	NA	2/21/12 6:53	2/21/12 6:53	1.30	dark red	49.1	NA	NA	NA	8.61	12.76	4.15
Loading (LD) Phase Start Date/Time:				2/21/12 6:58										
B3-LD-006	20	40	7.08	2/21/12 7:04	2/21/12 7:04	NA	dark red	45.9	NA	NA	NA	8.58	13.01	4.43
B3-LD-012	20	40	7.08	2/21/12 7:10	2/21/12 7:10	NA	dark red	44.0	NA	NA	NA	8.50	13.02	4.52
B3-LD-018	20	40	7.08	2/21/12 7:16	2/21/12 7:16	NA	dark red	42.6	NA	NA	NA	8.62	13.09	4.47
B3-LD-024	20	40	7.08	2/21/12 7:22	2/21/12 7:22	NA	dark red	41.7	NA	NA	NA	8.52	13.00	4.48
B3-LD-036	20	40	7.08	2/21/12 7:34	2/21/12 7:34	NA	dark red	40.5	NA	NA	NA	8.41	12.90	4.49
B3-LD-048	20	40	7.08	2/21/12 7:46	2/21/12 7:46	NA	dark red	40.0	NA	NA	NA	8.51	12.94	4.43
B3-LD-060	20	40	7.08	2/21/12 7:58	2/21/12 7:58	NA	dark red	39.7	NA	NA	NA	8.62	13.17	4.55
B3-LD-080	20	40	7.08	2/21/12 8:18	2/21/12 8:18	NA	dark red	39.7	NA	NA	NA	8.83	13.12	4.29
B3-LD-120	20	40	7.08	2/21/12 8:58	2/21/12 8:58	NA	dark red	39.8	NA	NA	NA	8.50	13.00	4.50
B3-LD-180	20	50	7.08	2/21/12 9:58	2/21/12 9:58	NA	dark red	40.0	NA	NA	NA	8.46	13.00	4.54
B3-LD-240	20	50	7.08	2/21/12 10:58	2/21/12 10:58	NA	dark red	39.9	NA	NA	NA	8.63	12.97	4.34
B3-LD-600	20	50	7.08	2/21/12 16:58	2/21/12 16:58	NA	dark red	39.9	NA	NA	NA	8.54	12.82	4.28
B3-FD-CP	20	50	0.09	2/21/12 17:08	2/21/12 19:38	NA	dark red	39.8	8.60	23.32	14.72	NA	NA	NA
B3-FDI-CP	20	25	0.09	2/21/12 19:45	2/21/12 22:15	NA	dark red	25.1	8.48	21.88	13.40	NA	NA	NA
B3-AN-CP	20	25	0.09	2/21/12 22:22	2/21/12 23:17	NA	dark red	24.9	8.83	13.69	4.86	NA	NA	NA

Table A.17. Datasheet for Column B3 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				2/22/12 6:47										
B3-EL-CP	60	25	0.08	2/22/12 6:47	2/22/12 16:50	1.25	orange red	25.6	14.66	62.18	47.52	8.56	18.05	9.49
B3-EDI-CP	20	25	0.09	2/22/12 17:01	2/22/12 18:01	1.25	orange red	24.3	8.52	13.73	5.21	NA	NA	NA
B3-RG-CP	20	25	0.09	2/22/12 18:07	2/22/12 20:47	1.30	dark red	25.3	8.52	22.48	13.96	NA	NA	NA

Table A.18. Datasheet for Column B4 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B4-LD-0	20	40	NA	2/23/12 6:48	2/23/12 6:48	1.30	dark red	46.0	NA	NA	NA	8.66	13.14	4.48
Loading (LD) Phase Start Date/Time:				2/23/12 6:53										
B4-LD-006	20	40	10.62	2/23/12 6:59	2/23/12 6:59	NA	dark red	42.6	NA	NA	NA	8.64	13.11	4.47
B4-LD-012	20	40	10.62	2/23/12 7:05	2/23/12 7:05	NA	dark red	41.0	NA	NA	NA	8.58	13.04	4.46
B4-LD-018	20	40	10.62	2/23/12 7:11	2/23/12 7:11	NA	dark red	40.0	NA	NA	NA	8.61	13.14	4.53
B4-LD-024	20	40	10.62	2/23/12 7:17	2/23/12 7:17	NA	dark red	39.6	NA	NA	NA	8.73	13.18	4.45
B4-LD-036	20	40	10.62	2/23/12 7:29	2/23/12 7:29	NA	dark red	40.2	NA	NA	NA	8.69	12.98	4.29
B4-LD-048	20	40	10.62	2/23/12 7:41	2/23/12 7:41	NA	dark red	40.1	NA	NA	NA	8.51	13.06	4.55
B4-LD-060	20	40	10.62	2/23/12 7:53	2/23/12 7:53	NA	dark red	39.8	NA	NA	NA	8.57	13.10	4.53
B4-LD-080	20	40	10.62	2/23/12 8:13	2/23/12 8:13	NA	dark red	39.6	NA	NA	NA	8.52	13.00	4.48
B4-LD-120	20	40	10.62	2/23/12 8:53	2/23/12 8:53	NA	dark red	39.7	NA	NA	NA	8.51	12.91	4.40
B4-LD-180	20	40	10.62	2/23/12 9:53	2/23/12 9:53	NA	dark red	39.8	NA	NA	NA	8.67	13.21	4.54
B4-LD-240	20	40	10.62	2/23/12 10:53	2/23/12 10:53	NA	dark red	39.5	NA	NA	NA	8.44	12.81	4.37
B4-LD-600	20	40	10.62	2/23/12 16:53	2/23/12 16:53	NA	dark red	40.0	NA	NA	NA	8.62	12.92	4.30
B4-FD-CP	20	40	0.09	2/23/12 17:06	2/23/12 19:36	NA	dark red	40.8	8.48	23.10	14.62	NA	NA	NA
B4-FDI-CP	20	25	0.09	2/23/12 19:54	2/23/12 21:54	NA	dark red	25.0	8.53	20.52	11.99	NA	NA	NA

Table A.19. Datasheet for Column B4B Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B4B-LD-0	20	55	NA	2/29/12 9:00	2/29/12 9:00	1.30	dark red	34.8	NA	NA	NA	8.44	12.93	4.49
Loading (LD) Phase Start Date/Time:				2/29/12 9:03										
B4B-LD-004	20	55	0.08	2/29/12 13:03	2/29/12 13:03	NA	dark red	54.9	NA	NA	NA	8.43	12.79	4.36
B4B-LD-008	20	55	0.08	2/29/12 17:03	2/29/12 17:03	NA	dark red	55.0	NA	NA	NA	8.52	12.96	4.44
B4B-LD-012	20	55	0.08	2/29/12 21:03	2/29/12 21:03	NA	dark red	55.1	NA	NA	NA	8.40	12.48	4.08
B4B-LD-024	20	55	0.08	3/1/12 9:03	3/1/12 9:03	NA	dark red	55.2	NA	NA	NA	8.46	12.61	4.15
B4B-LD-072	20	55	0.08	3/3/12 9:03	3/3/12 9:03	NA	dark red	55.0	NA	NA	NA	8.47	13.15	4.68
B4B-LD-120	20	55	0.08	3/5/12 9:03	3/5/12 9:03	NA	dark red	54.9	NA	NA	NA	8.36	12.65	4.29
B4B-LD-168	20	55	0.08	3/7/12 9:03	3/7/12 9:03	NA	dark red	54.6	NA	NA	NA	8.48	12.82	4.34
B4B-LD-336	20	55	0.08	3/14/12 9:03	3/14/12 9:03	NA	dark red	55.6	NA	NA	NA	8.48	13.26	4.78
B4B-FD-CP	20	55	0.08	3/18/12 9:20	3/18/12 11:50	NA	dark red	54.8	8.29	19.34	11.05	NA	NA	NA
B4B-FDI-CP	20	25	0.09	3/18/12 12:10	3/18/12 14:42	NA	dark red	25.4	8.38	21.79	13.41	NA	NA	NA
B4B-AN-CP	20	25	0.09	3/18/12 14:52	3/18/12 15:53	1.45	dark red	25.8	8.40	13.78	5.38	NA	NA	NA

Table A.20. Datasheet for Column B4B Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/19/12 6:42										
B4B-EL-CP	60	25	0.08	3/19/12 6:42	3/19/12 17:42	1.45	dark red	25.2	14.69	65.36	50.67	8.48	14.43	5.95
B4B-EDI-CP	20	25	0.09	3/19/12 17:55	3/19/12 18:55	1.45	orange red	24.3	8.37	NA (spilled)	NA (spilled)	NA	NA	NA
B4B-RG-CP	20	25	0.09	3/19/12 19:05	3/19/12 22:05	1.50	dark red	23.6	8.39	24.05	15.66	NA	NA	NA

Table A.21. Datasheet for Column B5 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
B5-LD-0	20	40	NA	3/20/12 6:42	3/20/12 6:42	1.50	dark red	45.3	NA	NA	NA	8.47	12.53	4.06
Loading (LD) Phase Start Date/Time:				3/20/12 6:48										
B5-LD-006	20	40	10.62	3/20/12 6:54	3/20/12 6:54	NA	dark red	42.2	NA	NA	NA	8.39	12.86	4.47
B5-LD-012	20	40	10.62	3/20/12 7:00	3/20/12 7:00	NA	dark red	40.7	NA	NA	NA	8.39	12.37	3.98
B5-LD-018	20	40	10.62	3/20/12 7:06	3/20/12 7:06	NA	dark red	39.8	NA	NA	NA	8.43	12.90	4.47
B5-LD-024	20	40	10.62	3/20/12 7:12	3/20/12 7:12	NA	dark red	39.4	NA	NA	NA	8.41	12.90	4.49
B5-LD-036	20	40	10.62	3/20/12 7:24	3/20/12 7:24	NA	dark red	39.6	NA	NA	NA	8.45	11.78	3.33
B5-LD-048	20	40	10.62	3/20/12 7:36	3/20/12 7:36	NA	dark red	39.9	NA	NA	NA	8.46	12.98	4.52
B5-LD-060	20	40	10.62	3/20/12 7:48	3/20/12 7:48	NA	dark red	40.2	NA	NA	NA	8.48	12.89	4.41
B5-LD-080	20	40	10.62	3/20/12 8:08	3/20/12 8:08	NA	dark red	40.2	NA	NA	NA	8.43	12.98	4.55
B5-LD-120	20	40	10.62	3/20/12 8:48	3/20/12 8:48	NA	dark red	40.0	NA	NA	NA	8.43	12.94	4.51
B5-LD-180	20	40	10.62	3/20/12 9:48	3/20/12 9:48	NA	dark red	40.0	NA	NA	NA	8.52	12.96	4.44
B5-LD-240	20	40	10.62	3/20/12 10:48	3/20/12 10:48	NA	dark red	40.0	NA	NA	NA	8.46	12.90	4.44
B5-LD-600	20	40	10.62	3/20/12 16:48	3/20/12 16:48	NA	dark red	39.8	NA	NA	NA	8.44	12.65	4.21
B5-FD-CP	20	40	0.09	3/20/12 16:56	3/20/12 19:26	1.50	dark red	40.7	8.41	22.73	14.32	NA	NA	NA
B5-FDI-CP	20	25	0.09	3/20/12 19:58	3/20/12 22:28	1.50	dark red	24.4	8.52	21.58	13.06	NA	NA	NA
B5-AN-CP	20	25	0.09	3/20/12 22:31	3/20/12 23:31	1.50	dark red	25.1	8.55	13.58	5.03	NA	NA	NA

Table A.22. Datasheet for Column B5 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/21/12 6:40										
B5-EL-CP	60	25	0.08	3/21/12 6:40	3/21/12 17:40	1.15	orange	24.6	14.62	64.96	50.34	8.43	15.64	7.21
B5-EDI-CP	20	25	0.09	3/21/12 17:47	3/21/12 18:47	1.15	orange	24.4	8.49	13.52	5.03	NA	NA	NA

Table A.23. Datasheet for Column C1 Pretreatment, Loading, and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C1-PT-DIW1	20	25	0.09	3/26/12 13:05	3/26/12 15:35	1.10	dark red	23.6	8.44	20.45	12.01	NA	NA	NA
C1-PT-ACID	20	25	0.09	3/27/12 8:53	3/27/12 13:17	0.95	orange	23.4	8.50	36.27	27.77	NA	NA	NA
C1-PT-DIW2	20	25	0.09	3/27/12 13:40	3/27/12 14:40	0.95	orange	23.5	8.43	13.27	4.84	NA	NA	NA
C1-PT-NaOH	20	25	0.09	3/27/12 14:48	3/27/12 17:03	1.00	dark red	23.4	8.55	25.06	16.51	NA	NA	NA
C1-LD-0	20	30	NA	3/28/12 6:43	3/28/12 6:43	1.00	dark red	32.6	NA	NA	NA	8.46	12.94	4.48
Loading (LD) Phase Start Date/Time:				3/28/12 6:45										
C1-LD-006	20	30	10.62	3/28/12 6:51	3/28/12 6:51	NA	dark red	31.2	NA	NA	NA	8.45	12.98	4.53
C1-LD-012	20	30	10.62	3/28/12 6:57	3/28/12 6:57	NA	dark red	30.5	NA	NA	NA	8.43	12.92	4.49
C1-LD-018	20	30	10.62	3/28/12 7:03	3/28/12 7:03	NA	dark red	29.9	NA	NA	NA	8.52	13.26	4.74
C1-LD-024	20	30	10.62	3/28/12 7:09	3/28/12 7:09	NA	dark red	29.6	NA	NA	NA	8.39	12.47	4.08
C1-LD-036	20	30	10.62	3/28/12 7:21	3/28/12 7:21	NA	dark red	29.9	NA	NA	NA	8.45	12.99	4.54
C1-LD-048	20	30	10.62	3/28/12 7:33	3/28/12 7:33	NA	dark red	29.9	NA	NA	NA	8.42	12.89	4.47
C1-LD-060	20	30	10.62	3/28/12 7:45	3/28/12 7:45	NA	dark red	30.0	NA	NA	NA	8.41	13.04	4.63
C1-LD-080	20	30	10.62	3/28/128:05	3/28/128:05	NA	dark red	29.8	NA	NA	NA	8.50	13.20	4.70
C1-LD-120	20	30	10.62	3/28/12 8:45	3/28/12 8:45	NA	dark red	29.7	NA	NA	NA	8.36	12.92	4.56
C1-LD-180	20	30	10.62	3/28/12 9:45	3/28/12 9:45	NA	dark red	29.6	NA	NA	NA	8.39	12.97	4.58
C1-LD-240	20	30	10.62	3/28/12 10:45	3/28/12 10:45	NA	dark red	30.0	NA	NA	NA	8.43	12.91	4.48
C1-LD-600	20	30	10.62	3/28/12 16:46	3/28/12 16:46	1.00	dark red	30.1	NA	NA	NA	8.53	13.13	4.60
C1-FD-CP	20	30	0.09	3/28/12 17:00	3/28/12 19:30	1.00	dark red	30.1	8.44	22.54	14.10	NA	NA	NA
C1-FDI-CP	20	25	0.09	3/28/12 19:37	3/28/12 22:07	1.00	dark red	25.8	8.54	20.76	12.22	NA	NA	NA
C1-AN-CP	20	25	0.09	3/28/12 22:12	3/28/12 23:12	1.00	dark red	23.7	8.48	13.33	4.85	NA	NA	NA

Table A.24. Datasheet for Column C1 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/29/12 6:37										
C1-EL-CP	60	25	0.08	3/29/12 6:37	3/29/12 16:37	1.00	orange	26.1	14.58	58.03	43.45	8.43	16.29	7.86
C1-EDI-CP	20	25	0.09	3/29/12 16:43	3/29/12 17:45	0.95	orange	25.1	8.38	13.11	4.73	NA	NA	NA
C1-RG-CP	20	25	0.09	3/29/12 18:00	3/29/12 20:30	1.10	dark red	24.4	8.46	20.20	11.74	NA	NA	NA

Table A.25. Datasheet for Column C2 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C2-LD-0	20	30	NA	4/2/12 6:26	4/2/12 6:26	1.10	dark red	38.0	NA	NA	NA	8.48	12.94	4.46
Loading (LD) Phase Start Date/Time:				4/2/12 6:30										
C2-LD-006	20	30	14.16	4/2/12 6:36	4/2/12 6:36	NA	dark red	35.0	NA	NA	NA	8.54	12.45	3.91
C2-LD-012	20	30	14.16	4/2/12 6:42	4/2/12 6:42	NA	dark red	33.7	NA	NA	NA	8.54	13.11	4.57
C2-LD-018	20	30	14.16	4/2/12 6:48	4/2/12 6:48	NA	dark red	32.7	NA	NA	NA	8.67	13.27	4.60
C2-LD-024	20	30	14.16	4/2/12 6:54	4/2/12 6:54	NA	dark red	32.0	NA	NA	NA	8.57	12.84	4.27
C2-LD-036	20	30	14.16	4/2/12 7:06	4/2/12 7:06	NA	dark red	30.8	NA	NA	NA	8.61	13.22	4.61
C2-LD-048	20	30	14.16	4/2/12 7:18	4/2/12 7:18	NA	dark red	30.2	NA	NA	NA	8.87	13.06	4.19
C2-LD-060	20	30	14.16	4/2/12 7:30	4/2/12 7:30	NA	dark red	30.1	NA	NA	NA	8.52	13.18	4.66
C2-LD-080	20	30	14.16	4/2/12 7:50	4/2/12 7:50	NA	dark red	29.8	NA	NA	NA	8.55	13.24	4.69
C2-LD-120	20	30	14.16	4/2/12 8:30	4/2/12 8:30	NA	dark red	30.0	NA	NA	NA	8.62	13.31	4.69
C2-LD-180	20	30	14.16	4/2/12 9:30	4/2/12 9:30	NA	dark red	29.9	NA	NA	NA	8.64	13.48	4.84
C2-LD-240	20	30	14.16	4/2/12 10:30	4/2/12 10:30	NA	dark red	30.0	NA	NA	NA	8.63	13.39	4.76
C2-LD-600	20	30	14.16	4/2/12 16:30	4/2/12 16:30	NA	dark red	29.9	NA	NA	NA	8.57	13.04	4.47
C2-FD-CP	20	30	0.09	4/2/12 16:42	4/2/12 19:12	NA	dark red	29.9	8.57	22.37	13.80	NA	NA	NA
C2-FDI-CP	20	25	0.09	4/2/12 19:20	4/2/12 21:50	NA	dark red	24.1	8.53	20.93	12.40	NA	NA	NA
C2-AN-CP	20	25	0.09	4/2/12 21:54	4/2/12 22:54	1.10	dark red	24.2	8.68	13.50	4.82	NA	NA	NA

Table A.26. Datasheet for Column C2 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				4/3/12 6:22										
C2-EL-CP	60	25	0.08	4/3/12 6:22	4/3/12 16:22	1.05	orange	24.4	14.65	57.96	43.31	8.75	16.60	7.85
C2-EDI-CP	20	25	0.09	4/3/12 16:30	4/3/12 17:30	1.05	orange	23.9	8.60	13.25	4.65	NA	NA	NA
C2-RG-CP	20	25	0.09	4/3/12 17:35	4/3/12 20:05	1.15	dark red	24.2	8.64	20.51	11.87	NA	NA	NA

Table A.27. Datasheet for Column C3 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C3-LD-0	20	30	NA	4/4/12 6:31	4/4/12 6:31	1.15	dark red	30.9	NA	NA	NA	8.59	13.31	4.72
Loading (LD) Phase Start Date/Time:				4/4/12 6:35										
C3-LD-006	20	30	7.08	4/4/12 6:41	4/4/12 6:41	NA	dark red	30.0	NA	NA	NA	8.61	13.37	4.76
C3-LD-012	20	30	7.08	4/4/12 6:47	4/4/12 6:47	NA	dark red	29.6	NA	NA	NA	8.65	13.11	4.46
C3-LD-018	20	30	7.08	4/4/12 6:53	4/4/12 6:53	NA	dark red	29.6	NA	NA	NA	8.61	13.57	4.96
C3-LD-024	20	30	7.08	4/4/12 6:59	4/4/12 6:59	NA	dark red	29.7	NA	NA	NA	8.64	13.45	4.81
C3-LD-036	20	30	7.08	4/4/12 7:11	4/4/12 7:11	NA	dark red	30.1	NA	NA	NA	8.56	13.51	4.95
C3-LD-048	20	30	7.08	4/4/12 7:23	4/4/12 7:23	NA	dark red	30.0	NA	NA	NA	8.56	13.30	4.74
C3-LD-060	20	30	7.08	4/4/12 7:35	4/4/12 7:35	NA	dark red	30.0	NA	NA	NA	8.64	13.40	4.76
C3-LD-080	20	30	7.08	4/4/12 7:55	4/4/12 7:55	NA	dark red	29.9	NA	NA	NA	8.67	13.34	4.67
C3-LD-120	20	30	7.08	4/4/12 8:35	4/4/12 8:35	NA	dark red	29.8	NA	NA	NA	8.47	13.23	4.76
C3-LD-180	20	30	7.08	4/4/12 9:35	4/4/12 9:35	NA	dark red	29.8	NA	NA	NA	8.53	13.35	4.82
C3-LD-240	20	30	7.08	4/4/12 10:35	4/4/12 10:35	NA	dark red	29.6	NA	NA	NA	8.51	13.09	4.58
C3-LD-600	20	30	7.08	4/4/12 16:35	4/4/12 16:35	NA	dark red	30.0	NA	NA	NA	8.67	13.47	4.80
C3-FD-CP	20	30	0.09	4/4/12 16:47	4/4/12 19:17	NA	dark red	30.1	8.69	22.99	14.30	NA	NA	NA
C3-FDI-CP	20	25	0.09	4/4/12 19:22	4/4/12 21:52	NA	dark red	24.8	8.57	21.07	12.50	NA	NA	NA
C3-AN-CP	20	25	0.09	4/4/12 21:56	4/4/12 22:56	1.15	dark red	24.6	8.63	13.47	4.84	NA	NA	NA

Table A.28. Datasheet for Column C3 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				4/5/12 6:28										
C3-EL-CP	60	25	0.08	4/5/12 6:28	4/5/12 16:28	1.05	orange	26.3	14.87	58.10	43.23	8.50	17.54	9.04
C3-EDI-CP	20	25	0.09	4/5/12 16:45	4/5/12 17:45	1.05	orange	25.1	8.56	13.32	4.76	NA	NA	NA
C3-RG-CP	20	25	0.09	4/5/12 17:50	4/5/12 20:20	1.15	dark red	25.8	8.66	20.65	11.99	NA	NA	NA

Table A.29. Datasheet for Column C4 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C4-LD-0	20	30	NA	4/9/12 6:39	4/9/12 6:39	1.10	dark red	32.5	NA	NA	NA	8.70	13.43	4.73
Loading (LD) Phase Start Date/Time:				4/9/12 6:40										
C4-LD-006	20	30	10.62	4/9/12 6:46	4/9/12 6:46	NA	dark red	30.8	NA	NA	NA	8.52	13.22	4.70
C4-LD-012	20	30	10.62	4/9/12 6:52	4/9/12 6:52	NA	dark red	29.9	NA	NA	NA	8.65	13.47	4.82
C4-LD-018	20	30	10.62	4/9/12 6:58	4/9/12 6:58	NA	dark red	29.6	NA	NA	NA	8.40	12.92	4.52
C4-LD-024	20	30	10.62	4/9/12 7:05	4/9/12 7:05	NA	dark red	29.6	NA	NA	NA	8.49	13.17	4.68
C4-LD-036	20	30	10.62	4/9/12 7:16	4/9/12 7:16	NA	dark red	30.0	NA	NA	NA	8.54	13.33	4.79
C4-LD-048	20	30	10.62	4/9/12 7:28	4/9/12 7:28	NA	dark red	29.8	NA	NA	NA	8.63	13.29	4.66
C4-LD-060	20	30	10.62	4/9/12 7:40	4/9/12 7:40	NA	dark red	29.8	NA	NA	NA	8.61	13.35	4.74
C4-LD-080	20	30	10.62	4/9/12 8:00	4/9/12 8:00	NA	dark red	29.9	NA	NA	NA	8.67	13.47	4.80
C4-LD-120	20	30	10.62	4/9/12 8:40	4/9/12 8:40	NA	dark red	30.0	NA	NA	NA	8.78	13.44	4.66
C4-LD-180	20	30	10.62	4/9/12 9:40	4/9/12 9:40	NA	dark red	29.6	NA	NA	NA	8.59	13.26	4.67
C4-LD-240	20	30	10.62	4/9/12 10:40	4/9/12 10:40	NA	dark red	29.3	NA	NA	NA	8.59	13.42	4.83
C4-LD-600	20	30	10.62	4/9/12 16:41	4/9/12 16:41	NA	dark red	30.2	NA	NA	NA	8.67	13.40	4.73
C4-FD-CP	20	25	0.09	4/9/12 17:03	4/9/12 19:33	NA	dark red	25.7	8.48	22.47	13.99	NA	NA	NA
C4-FDI-CP	20	25	0.09	4/9/12 19:36	4/9/12 22:06	NA	dark red	26.3	8.57	20.95	12.38	NA	NA	NA

Table A.30. Datasheet for Column C4B Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C4B-LD-0	20	50	NA	4/11/12 8:55	4/11/12 8:55	1.1	dark red	49.9	NA	NA	NA	8.51	13.23	4.72
Loading (LD) Phase Start Date/Time:				4/11/12 9:00										
C4B-LD-004	20	50	0.08	4/11/12 13:15	4/11/12 13:15	NA	dark red	50.1	NA	NA	NA	8.72	13.28	4.56
C4B-LD-008	20	50	0.08	4/11/12 17:11	4/11/12 17:11	NA	dark red	50.0	NA	NA	NA	8.65	13.20	4.55
C4B-LD-012	20	50	0.08	4/11/12 21:01	4/11/12 21:01	NA	dark red	50.0	NA	NA	NA	8.66	12.83	4.17
C4B-LD-024	20	50	0.08	4/12/12 9:00	4/12/12 9:00	NA	dark red	50.0	NA	NA	NA	8.71	13.37	4.66
C4B-LD-072	20	50	0.08	4/14/12 9:00	4/14/12 9:00	NA	almost black	50.0	NA	NA	NA	8.67	13.16	4.49
C4B-LD-120	20	50	0.08	4/16/12 9:00	4/16/12 9:00	NA	dark red	49.8	NA	NA	NA	8.70	13.20	4.50
C4B-LD-168	20	50	0.08	4/18/12 9:00	4/18/12 9:00	NA	dark red	49.9	NA	NA	NA	8.65	13.10	4.54
C4B-LD-336	20	50	0.08	4/25/12 9:00	4/25/12 9:00	NA	dark red	49.9	NA	NA	NA	8.71	13.08	4.37
C4B-LD-504	20	50	0.08	5/2/12 9:00	5/2/12 9:00	NA	dark red	49.2	NA	NA	NA	8.50	13.00	4.50
C4B-FD-CP	20	50	0.08	5/11/12 9:31	5/11/12 13:21	NA	dark red	50.4	8.76	22.32	13.56	NA	NA	NA
C4B-FDI-CP	20	25	0.09	5/11/12 13:25	5/11/12 15:55	1.1	dark red	22.8	8.70	22.40	13.70	NA	NA	NA
C4B-AN-CP	20	25	0.09	5/11/12 16:00	5/11/12 17:00	1.1	dark red	22.8	8.52	12.88	4.36	NA	NA	NA

Table A.31. Datasheet for Column C4B Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/14/12 6:55										
C4B-EL-CP	60	25	0.08	5/14/12 6:55	5/14/12 17:25	1.1	orange	19.7	14.74	58.14	43.40	8.64	18.58	9.94
C4B-EDI-CP	20	25	0.09	5/14/12 17:32	5/14/12 18:32	1.1	orange	20.3	8.53	13.70	5.17	NA	NA	NA
C4B-RG-CP	20	25	0.09	5/14/12 18:49	5/14/12 21:19	1.3	dark red	20.2	8.75	19.89	11.14	NA	NA	NA

Table A.32. Datasheet for Column C5 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
C5-LD-0	20	30	NA	5/15/12 6:41	5/15/12 6:41	1.2	dark red	29.9	NA	NA	NA	8.45	12.82	4.37
Loading (LD) Phase Start Date/Time:				5/15/12 6:45										
C5-LD-006	20	30	10.62	5/15/12 6:51	5/15/12 6:51	NA	dark red	29.2	NA	NA	NA	8.47	12.76	4.29
C5-LD-012	20	30	10.62	5/15/12 6:57	5/15/12 6:57	NA	dark red	29.3	NA	NA	NA	8.46	12.94	4.48
C5-LD-018	20	30	10.62	5/15/12 7:03	5/15/12 7:03	NA	dark red	29.9	NA	NA	NA	8.59	12.94	4.35
C5-LD-024	20	30	10.62	5/15/12 7:09	5/15/12 7:09	NA	dark red	30.2	NA	NA	NA	8.71	13.17	4.46
C5-LD-036	20	30	10.62	5/15/12 7:21	5/15/12 7:21	NA	dark red	30.2	NA	NA	NA	8.69	12.98	4.29
C5-LD-048	20	30	10.62	5/15/12 7:33	5/15/12 7:33	NA	dark red	29.9	NA	NA	NA	8.66	12.95	4.29
C5-LD-060	20	30	10.62	5/15/12 7:45	5/15/12 7:45	NA	dark red	29.9	NA	NA	NA	8.54	13.35	4.81
C5-LD-080	20	30	10.62	5/15/12 8:05	5/15/12 8:05	NA	dark red	29.8	NA	NA	NA	8.74	13.36	4.62
C5-LD-120	20	30	10.62	5/15/12 8:45	5/15/12 8:45	NA	dark red	30.1	NA	NA	NA	8.63	13.25	4.62
C5-LD-180	20	30	10.62	5/15/12 9:45	5/15/12 9:45	NA	dark red	29.6	NA	NA	NA	8.57	12.86	4.29
C5-LD-240	20	30	10.62	5/15/12 10:45	5/15/12 10:45	NA	dark red	29.2	NA	NA	NA	8.66	13.03	4.37
C5-LD-600	20	30	10.62	5/15/12 16:46	5/15/12 16:46	NA	dark red	29.9	NA	NA	NA	8.77	13.07	4.30
C5-FD-CP	20	30	0.09	5/15/12 17:05	5/15/12 19:35	NA	dark red	29.8	8.79	22.40	13.61	NA	NA	NA
C5-FDI-CP	20	25	0.09	5/15/12 19:45	5/15/12 21:15	NA	dark red	18.8	8.62	20.38	11.76	NA	NA	NA
C5-AN-CP	20	25	0.09	5/15/12 22:20	5/15/12 23:20	NA	dark red	18.9	8.65	13.29	4.64	NA	NA	NA

Table A.33. Datasheet for Column C5 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/16/12 7:00										
C5-EL-CP	60	25	0.08	5/16/12 7:00	5/16/12 17:00	1.15	orange	21.4	14.82	55.95	41.13	8.61	16.86	8.25
C5-EDI-CP	20	25	0.09	5/16/12 17:15	5/16/12 18:15	1.15	orange	21.3	8.67	13.30	4.63	NA	NA	NA

Table A.34. Datasheet for Column D1 Pretreatment, Loading, and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D1-PT-DIW1	20	25	0.09	3/26/12 13:05	3/26/12 15:35	1.30	dark red	23.8	8.60	21.36	12.76	NA	NA	NA
D1-PT-ACID	20	25	0.09	3/27/12 8:53	3/27/12 12:33	1.10	orange	23.7	8.39	29.69	21.30	NA	NA	NA
D1-PT-DIW2	20	25	0.09	3/27/12 13:40	3/27/12 14:40	1.10	orange	23.8	8.47	13.28	4.81	NA	NA	NA
D1-PT-NaOH	20	25	0.09	3/27/12 14:48	3/27/12 17:03	1.30	dark red	24.1	8.50	24.53	16.03	NA	NA	NA
D1-LD-0	20	25	NA	3/28/12 6:45	3/28/12 6:45	1.30	dark red	25.3	NA	NA	NA	8.41	12.74	4.33
Loading (LD) Phase Start Date/Time:				3/28/12 6:48										
D1-LD-006	20	25	10.62	3/28/12 6:53	3/28/12 6:53	NA	dark red	25.2	NA	NA	NA	8.49	12.97	4.48
D1-LD-012	20	25	10.62	3/28/12 7:00	3/28/12 7:00	NA	dark red	25.1	NA	NA	NA	8.44	13.03	4.59
D1-LD-018	20	25	10.62	3/28/12 7:06	3/28/12 7:06	NA	dark red	25.0	NA	NA	NA	8.49	12.94	4.45
D1-LD-024	20	25	10.62	3/28/12 7:12	3/28/12 7:12	NA	dark red	24.9	NA	NA	NA	8.40	12.92	4.52
D1-LD-036	20	25	10.62	3/28/12 7:24	3/28/12 7:24	NA	dark red	24.9	NA	NA	NA	8.49	13.72	5.23
D1-LD-048	20	25	10.62	3/28/12 7:36	3/28/12 7:36	NA	dark red	24.8	NA	NA	NA	8.48	13.00	4.52
D1-LD-060	20	25	10.62	3/28/12 7:48	3/28/12 7:48	NA	dark red	25.0	NA	NA	NA	8.56	12.75	4.19
D1-LD-080	20	25	10.62	3/28/12 8:08	3/28/12 8:08	NA	dark red	25.0	NA	NA	NA	8.46	12.77	4.31
D1-LD-120	20	25	10.62	3/28/12 8:48	3/28/12 8:48	NA	dark red	25.0	NA	NA	NA	8.52	13.19	4.67
D1-LD-180	20	25	10.62	3/28/12 9:48	3/28/12 9:48	NA	dark red	24.9	NA	NA	NA	8.47	13.23	4.76
D1-LD-240	20	25	10.62	3/28/12 10:48	3/28/12 10:48	NA	dark red	25.0	NA	NA	NA	8.46	12.72	4.26
D1-LD-600	20	25	10.62	3/28/12 16:48	3/28/12 16:48	1.30	dark red	25.0	NA	NA	NA	8.45	13.06	4.61
D1-FD-CP	20	25	0.09	3/28/12 17:00	3/28/12 19:30	1.30	dark red	25.8	8.37	22.69	14.32	NA	NA	NA
D1-FDI-CP	20	25	0.09	3/28/12 19:37	3/28/12 22:07	1.30	dark red	24.7	8.38	21.09	12.71	NA	NA	NA
D1-AN-CP	20	25	0.09	3/28/12 22:12	3/28/12 23:12	1.30	dark red	24.6	8.46	13.64	5.18	NA	NA	NA

Table A.35. Datasheet for Column D1 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				3/29/12 6:37										
D1-EL-CP	60	25	0.08	3/29/12 6:37	3/29/12 16:37	1.30	orange	24.8	14.62	59.76	45.14	8.38	16.32	7.94
D1-EDI-CP	20	25	0.09	3/29/12 16:43	3/29/12 17:43	1.10	orange	24.3	8.47	13.45	4.98	NA	NA	NA
D1-RG-CP	20	25	0.09	3/29/12 18:00	3/29/12 20:30	1.30	dark red	24.0	8.49	20.93	12.44	NA	NA	NA

Table A.36. Datasheet for Column D2 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D2-LD-0	20	25	NA	4/2/12 6:28	4/2/12 6:28	1.10	dark red	25.6	NA	NA	NA	8.41	13.06	4.65
Loading (LD) Phase Start Date/Time:				4/2/12 6:33										
D2-LD-006	20	25	14.16	4/2/12 6:39	4/2/12 6:39	NA	dark red	25.3	NA	NA	NA	8.49	12.84	4.35
D2-LD-012	20	25	14.16	4/2/12 6:45	4/2/12 6:45	NA	dark red	25.2	NA	NA	NA	8.51	13.02	4.51
D2-LD-018	20	25	14.16	4/2/12 6:51	4/2/12 6:51	NA	dark red	25.2	NA	NA	NA	8.45	13.24	4.79
D2-LD-024	20	25	14.16	4/2/12 6:57	4/2/12 6:57	NA	dark red	25.2	NA	NA	NA	8.49	13.02	4.53
D2-LD-036	20	25	14.16	4/2/12 7:09	4/2/12 7:09	NA	dark red	25.0	NA	NA	NA	8.43	12.99	4.56
D2-LD-048	20	25	14.16	4/2/12 7:21	4/2/12 7:21	NA	dark red	24.9	NA	NA	NA	8.43	13.11	4.68
D2-LD-060	20	25	14.16	4/2/12 7:33	4/2/12 7:33	NA	dark red	25.0	NA	NA	NA	8.40	12.98	4.58
D2-LD-080	20	25	14.16	4/2/12 7:53	4/2/12 7:53	NA	dark red	24.9	NA	NA	NA	8.34	12.75	4.41
D2-LD-120	20	25	14.16	4/2/12 8:33	4/2/12 8:33	NA	dark red	24.9	NA	NA	NA	8.38	12.98	4.60
D2-LD-180	20	25	14.16	4/2/12 9:33	4/2/12 9:33	NA	dark red	24.8	NA	NA	NA	8.46	13.18	4.72
D2-LD-240	20	25	14.16	4/2/12 10:33	4/2/12 10:33	NA	dark red	24.9	NA	NA	NA	8.48	13.20	4.72
D2-LD-600	20	25	14.16	4/2/12 16:33	4/2/12 16:33	NA	dark red	24.8	NA	NA	NA	8.42	13.10	4.68
D2-FD-CP	20	25	0.09	4/2/12 16:42	4/2/12 19:12	NA	dark red	25.4	8.42	22.28	13.86	NA	NA	NA
D2-FDI-CP	20	25	0.09	4/2/12 19:20	4/2/12 21:50	NA	dark red	24.0	8.46	20.92	12.46	NA	NA	NA
D2-AN-CP	20	25	0.09	4/2/12 21:54	4/2/12 22:54	1.10	dark red	24.1	8.52	13.37	4.85	NA	NA	NA

Table A.37. Datasheet for Column D2 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				4/3/12 6:22										
D2-EL-CP	60	25	0.08	4/3/12 6:22	4/3/12 16:22	1.10	orange	24.4	14.69	57.74	43.05	8.36	16.98	8.62
D2-EDI-CP	20	25	0.09	4/3/12 16:30	4/3/12 17:30	1.10	orange	24.2	8.40	13.32	4.92	NA	NA	NA
D2-RG-CP	20	25	0.09	4/3/12 17:35	4/3/12 20:05	1.30	dark red	24.0	8.48	20.48	12.00	NA	NA	NA

Table A.38. Datasheet for Column D3 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D3-LD-0	20	25	NA	4/4/12 6:34	4/4/12 6:34	1.25	dark red	25.5	NA	NA	NA	8.44	13.33	4.89
Loading (LD) Phase Start Date/Time:				4/4/12 6:38										
D3-LD-006	20	25	7.08	4/4/12 6:44	4/4/12 6:44	NA	dark red	25.2	NA	NA	NA	8.48	13.31	4.83
D3-LD-012	20	25	7.08	4/4/12 6:50	4/4/12 6:50	NA	dark red	25.1	NA	NA	NA	8.56	13.20	4.64
D3-LD-018	20	25	7.08	4/4/12 6:56	4/4/12 6:56	NA	dark red	25.0	NA	NA	NA	8.49	13.05	4.56
D3-LD-024	20	25	7.08	4/4/12 7:02	4/4/12 7:02	NA	dark red	25.0	NA	NA	NA	8.54	13.26	4.72
D3-LD-036	20	25	7.08	4/4/12 7:14	4/4/12 7:14	NA	dark red	24.9	NA	NA	NA	8.55	12.99	4.44
D3-LD-048	20	25	7.08	4/4/12 7:26	4/4/12 7:26	NA	dark red	24.9	NA	NA	NA	8.50	13.40	4.90
D3-LD-060	20	25	7.08	4/4/12 7:38	4/4/12 7:38	NA	dark red	24.8	NA	NA	NA	8.53	13.19	4.66
D3-LD-080	20	25	7.08	4/4/12 7:58	4/4/12 7:58	NA	dark red	24.9	NA	NA	NA	8.58	13.42	4.84
D3-LD-120	20	25	7.08	4/4/12 8:38	4/4/12 8:38	NA	dark red	24.9	NA	NA	NA	8.57	13.24	4.67
D3-LD-180	20	25	7.08	4/4/12 9:38	4/4/12 9:38	NA	dark red	24.8	NA	NA	NA	8.48	13.26	4.78
D3-LD-240	20	25	7.08	4/4/12 10:38	4/4/12 10:38	NA	dark red	24.9	NA	NA	NA	8.47	12.81	4.34
D3-LD-600	20	25	7.08	4/4/12 16:38	4/4/12 16:38	NA	dark red	25.0	NA	NA	NA	8.62	13.14	4.52
D3-FD-CP	20	25	0.09	4/4/12 16:47	4/4/12 19:17	NA	dark red	25.8	8.47	22.51	14.04	NA	NA	NA
D3-FDI-CP	20	25	0.09	4/4/12 19:22	4/4/12 21:52	NA	dark red	26.1	8.50	21.14	12.64	NA	NA	NA
D3-AN-CP	20	25	0.09	4/4/12 21:56	4/4/12 22:56	1.25	dark red	24.9	8.49	13.34	4.85	NA	NA	NA

Table A.39. Datasheet for Column C3 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				4/5/12 6:28										
D3-EL-CP	60	25	0.08	4/5/12 6:28	4/5/12 16:28	1.10	orange	25.0	14.90	59.45	44.55	8.46	18.41	9.95
D3-EDI-CP	20	25	0.09	4/5/12 16:45	4/5/12 17:45	1.10	orange	24.2	8.49	13.45	4.96	NA	NA	NA
D3-RG-CP	20	25	0.09	4/5/12 17:50	4/5/12 20:20	1.30	dark red	24.7	8.43	20.81	12.38	NA	NA	NA

Table A.40. Datasheet for Column D4 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D4-LD-0	20	25	NA	4/9/12 6:41	4/9/12 6:41	1.25	dark red	25.9	NA	NA	NA	8.52	13.30	4.78
Loading (LD) Phase Start Date/Time:				4/9/12 6:43										
D4-LD-006	20	25	10.62	4/9/12 6:49	4/9/12 6:49	NA	dark red	25.6	NA	NA	NA	8.49	13.27	4.78
D4-LD-012	20	25	10.62	4/9/12 6:55	4/9/12 6:55	NA	dark red	25.5	NA	NA	NA	8.55	13.25	4.70
D4-LD-018	20	25	10.62	4/9/12 7:01	4/9/12 7:01	NA	dark red	25.3	NA	NA	NA	8.50	13.29	4.79
D4-LD-024	20	25	10.62	4/9/12 7:07	4/9/12 7:07	NA	dark red	25.3	NA	NA	NA	8.43	13.09	4.66
D4-LD-036	20	25	10.62	4/9/12 7:20	4/9/12 7:20	NA	dark red	25.1	NA	NA	NA	8.45	13.16	4.71
D4-LD-048	20	25	10.62	4/9/12 7:31	4/9/12 7:31	NA	dark red	25.1	NA	NA	NA	8.47	13.13	4.66
D4-LD-060	20	25	10.62	4/9/12 7:43	4/9/12 7:43	NA	dark red	25.0	NA	NA	NA	8.56	13.46	4.90
D4-LD-080	20	25	10.62	4/9/12 8:03	4/9/12 8:03	NA	dark red	25.0	NA	NA	NA	8.45	13.19	4.74
D4-LD-120	20	25	10.62	4/9/12 8:43	4/9/12 8:43	NA	dark red	24.9	NA	NA	NA	8.48	13.35	4.87
D4-LD-180	20	25	10.62	4/9/12 9:43	4/9/12 9:43	NA	dark red	24.9	NA	NA	NA	8.48	13.32	4.84
D4-LD-240	20	25	10.62	4/9/12 10:43	4/9/12 10:43	NA	dark red	25.0	NA	NA	NA	8.44	13.08	4.64
D4-LD-600	20	25	10.62	4/9/12 16:43	4/9/12 16:43	NA	dark red	25.3	NA	NA	NA	8.35	13.15	4.80
D4-FD-CP	20	25	0.09	4/9/12 17:03	4/9/12 19:33	NA	dark red	24.9	8.46	23.20	14.74	NA	NA	NA
D4-FDI-CP	20	25	0.09	4/9/12 19:36	4/9/12 22:06	NA	dark red	24.8	8.47	21.58	13.11	NA	NA	NA

Table A.41. Datasheet for Column D4B Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D4B-LD-0	20	45	NA	4/11/12 8:57	4/11/12 8:57	1.15	dark red	45.1	NA	NA	NA	8.51	13.12	4.61
Loading (LD) Phase Start Date/Time:				4/11/12 9:03										
D4B-LD-004	20	45	0.08	4/11/12 13:16	4/11/12 13:16	NA	dark red	45.0	NA	NA	NA	8.54	12.94	4.40
D4B-LD-008	20	45	0.08	4/11/12 17:12	4/11/12 17:12	NA	dark red	45.0	NA	NA	NA	8.57	13.06	4.49
D4B-LD-012	20	45	0.08	4/11/12 21:03	4/11/12 21:03	NA	dark red	45.0	NA	NA	NA	8.52	12.91	4.39
D4B-LD-024	20	45	0.08	4/12/12 9:03	4/12/12 9:03	NA	dark red	45.0	NA	NA	NA	8.61	13.09	4.48
D4B-LD-072	20	45	0.08	4/14/12 9:03	4/14/12 9:03	NA	almost black	44.8	NA	NA	NA	8.51	13.10	4.59
D4B-LD-120	20	45	0.08	4/16/12 9:03	4/16/12 9:03	NA	dark red	44.7	NA	NA	NA	8.59	13.00	4.41
D4B-LD-168	20	45	0.08	4/18/12 9:03	4/18/12 9:03	NA	dark red	44.8	NA	NA	NA	8.59	13.14	4.55
D4B-LD-336	20	45	0.08	4/25/12 9:03	4/25/12 9:03	NA	dark red	44.6	NA	NA	NA	8.54	13.15	4.61
D4B-LD-504	20	45	0.08	5/2/12 9:03	5/2/12 9:03	NA	dark red	44.0	NA	NA	NA	8.43	12.96	4.53
D4B-LD-672	20	45	0.08	5/9/12 9:03	5/9/12 9:03	NA	dark red	45.8	NA	NA	NA	8.61	13.34	4.73
D4B-LD-720	20	45	0.08	5/11/12 9:10	5/11/12 9:10	NA	dark red	44.3	NA	NA	NA	8.51	13.35	4.84
D4B-FD-CP	20	45	0.09	5/11/12 9:37	5/11/12 12:07	NA	dark red	45.1	8.64	23.45	14.81	NA	NA	NA
D4B-FDI-CP	20	25	0.09	5/11/12 13:25	5/11/12 15:55	1.15	dark red	22.6	8.59	21.70	13.11	NA	NA	NA
D4B-AN-CP	20	25	0.09	5/11/12 16:00	5/11/12 17:00	1.15	dark red	22.7	8.52	13.07	4.55	NA	NA	NA

Table A.42. Datasheet for Column D4B Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/14/12 6:55										
D4B-EL-CP	60	25	0.08	5/14/12 6:55	5/14/12 16:55	1.15	orange	19.8	14.85	60.83	45.98	8.48	16.69	8.21
D4B-EDI-CP	20	25	0.09	5/14/12 17:32	5/14/12 18:32	1.15	orange	20.4	8.52	13.35	4.83	NA	NA	NA
D4B-RG-CP	20	25	0.09	5/14/12 18:49	5/14/12 21:19	1.15	dark red	20.3	8.45	20.83	12.38	NA	NA	NA

Table A.43. Datasheet for Column D5 Loading and Rinsing Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
D5-LD-0	20	25	NA	5/15/12 6:43	5/15/12 6:43	1.15	dark red	23.2	NA	NA	NA	8.50	12.99	4.49
Loading (LD) Phase Start Date/Time:				5/15/12 6:48										
D5-LD-006	20	25	10.62	5/15/12 6:54	5/15/12 6:54	NA	dark red	23.8	NA	NA	NA	8.51	12.73	4.22
D5-LD-012	20	25	10.62	5/15/12 7:00	5/15/12 7:00	NA	dark red	24.5	NA	NA	NA	8.55	12.09	3.54
D5-LD-018	20	25	10.62	5/15/12 7:06	5/15/12 7:06	NA	dark red	25.0	NA	NA	NA	8.48	13.07	4.59
D5-LD-024	20	25	10.62	5/15/12 7:12	5/15/12 7:12	NA	dark red	25.3	NA	NA	NA	8.53	13.20	4.67
D5-LD-036	20	25	10.62	5/15/12 7:24	5/15/12 7:24	NA	dark red	25.3	NA	NA	NA	8.46	13.18	4.72
D5-LD-048	20	25	10.62	5/15/12 7:36	5/15/12 7:36	NA	dark red	24.9	NA	NA	NA	8.60	12.76	4.16
D5-LD-060	20	25	10.62	5/15/12 7:48	5/15/12 7:48	NA	dark red	24.8	NA	NA	NA	8.45	13.12	4.67
D5-LD-080	20	25	10.62	5/15/12 8:08	5/15/12 8:08	NA	dark red	24.8	NA	NA	NA	8.62	13.14	4.52
D5-LD-120	20	25	10.62	5/15/12 8:48	5/15/12 8:48	NA	dark red	25.1	NA	NA	NA	8.39	13.21	4.82
D5-LD-180	20	25	10.62	5/15/12 9:48	5/15/12 9:48	NA	dark red	24.7	NA	NA	NA	8.55	13.09	4.54
D5-LD-240	20	25	10.62	5/15/12 10:48	5/15/12 10:48	NA	dark red	24.3	NA	NA	NA	8.56	12.72	4.16
D5-LD-600	20	25	10.62	5/15/12 16:48	5/15/12 16:48	NA	dark red	24.9	NA	NA	NA	8.65	13.28	4.63
D5-FD-CP	20	25	0.09	5/15/12 17:05	5/15/12 19:35	NA	dark red	25.5	8.40	22.97	14.57	NA	NA	NA
D5-FDI-CP	20	25	0.09	5/15/12 19:45	5/15/12 21:15	NA	dark red	18.9	8.46	21.20	12.74	NA	NA	NA
D5-AN-CP	20	25	0.09	5/15/12 22:20	5/15/12 23:20	NA	dark red	19.0	8.58	13.59	5.01	NA	NA	NA

Table A.44. Datasheet for Column D5 Elution, Rinsing, and Regeneration Information

Sample	Bottle	Temp	Pump	Sampling	Sampling	Resin	Resin	Temp	Effluent Bottle Weight, g			Sample Vial Weight, g		
ID No.	Size (mL)	Set (°C)	Setting (mL/min)	Start Time	Stop Time	Height (cm)	Color	(°C)	Tare	Gross	Net	Tare	Gross	Net
Elution (EL) Phase Start Date/Time:				5/16/12 7:00										
D5-EL-CP	60	25	0.08	5/16/12 7:00	5/16/12 17:00	1.1	orange	20.2	14.82	58.69	43.87	8.45	15.78	7.33
D5-EDI-CP	20	25	0.08	5/16/12 17:15	5/16/12 18:15	1.1	orange	20.1	8.50	13.45	4.95	NA	NA	NA

Table A.45. Datasheet for 50°C Batch Loading Tests

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-LL-1	1A	0.2189	24.8113	3/16/12 9:12	49.5	3/19/12 9:12	50.0	8.48	14.13	5.65
Test-5-Na-LL-2	2A	0.2204	25.5372	3/16/12 9:14	49.5	3/19/12 9:14	50.0	8.53	14.22	5.69
Test-5-Na-LL-3	3A	0.2205	25.8469	3/16/12 9:16	49.8	3/19/12 9:16	50.1	8.38	14.29	5.91
Test-5-Na-LL-4	4A	0.2206	26.1507	3/16/12 9:18	49.6	3/19/12 9:18	50.2	8.51	14.39	5.88
Test-5-Na-LL-5	5A	0.2219	28.7257	3/16/12 9:21	49.8	3/19/12 9:21	50.3	8.51	14.65	6.14
Test-5-Na-LL-6	6A	0.2193	31.3679	3/16/12 9:23	49.9	3/19/12 9:23	50.0	8.40	15.21	6.81
Test-5-Na-MM-1	7A	0.2220	25.0646	3/16/12 9:27	49.4	3/19/12 9:28	49.9	8.51	14.65	6.14
Test-5-Na-MM-2	8A	0.2215	25.5566	3/16/12 9:28	49.4	3/19/12 9:28	49.8	8.49	14.07	5.58
Test-5-Na-MM-3	9A	0.2202	25.8741	3/16/12 9:30	49.8	3/19/12 9:30	49.9	8.45	14.24	5.79
Test-5-Na-MM-4	10A	0.2187	26.1595	3/16/12 9:31	49.8	3/19/12 9:31	49.8	8.55	14.26	5.71
Test-5-Na-MM-5	11A	0.2241	28.7331	3/16/12 9:32	49.3	3/19/12 9:32	49.5	8.45	14.54	6.09
Test-5-Na-MM-6	12A	0.2224	31.2936	3/16/12 9:34	49.4	3/19/12 9:34	50.0	8.42	15.33	6.91
Test-5-Na-NN-1	13A	0.2225	26.0848	3/16/12 9:35	49.8	3/19/12 9:35	49.3	8.35	14.27	5.92
Test-5-Na-NN-2	14A	0.2278	28.5587	3/16/12 9:37	50.0	3/19/12 9:37	49.7	8.42	15.21	6.79
Test-5-Na-NN-3	15A	0.2216	31.0837	3/16/12 9:38	50.0	3/19/12 9:38	49.5	8.36	15.17	6.81
Test-5-Na-OO-1	16A	0.2205	25.8754	3/16/12 9:41	50.1	3/19/12 9:41	50.0	8.36	14.15	5.79
Test-5-Na-OO-2	17A	0.2180	28.3813	3/16/12 9:42	50.0	3/19/12 9:42	49.9	8.57	14.75	6.18
Test-5-Na-OO-3	18A	0.2208	30.8050	3/16/12 9:43	49.7	3/19/12 9:43	50.0	8.39	15.14	6.75
Test-5-Na-A-1	1	0.2169	24.8207	2/14/12 10:07	49.7	2/17/12 10:06	50.0	8.54	14.17	5.63
Test-5-Na-A-2	2	0.2197	25.6030	2/10/12 10:04	49.9	2/13/12 10:04	50.6	8.59	14.35	5.76
Test-5-Na-A-3	3	0.2173	25.7820	2/14/12 10:09	49.5	2/17/12 10:08	50.0	8.61	14.27	5.66
Test-5-Na-A-4	4	0.2216	26.2668	2/14/12 10:11	48.9	2/17/12 10:10	50.3	8.57	14.51	5.94
Test-5-Na-A-5	5	0.2232	28.7178	2/14/12 10:13	48.8	2/17/12 10:12	50.3	8.43	14.40	5.97
Test-5-Na-A-6	6	0.2202	31.1913	2/14/12 10:15	49.8	2/17/12 10:15	50.2	8.54	15.59	7.05
Test-5-Na-B-1	7	0.2234	25.0270	2/14/12 10:16	49.5	2/17/12 10:17	50.4	8.47	14.31	5.84
Test-5-Na-B-2	8	0.2219	25.6131	2/10/12 10:05	49.0	2/13/12 10:05	49.6	8.69	14.30	5.61
Test-5-Na-B-3	9	0.2196	25.9791	2/14/12 10:18	49.2	2/17/12 10:18	50.0	8.54	14.63	6.09
Test-5-Na-B4	10	0.2222	26.1587	2/14/12 10:19	48.0	2/17/12 10:19	50.4	8.56	14.78	6.22
Test-5-Na-B-5	11	0.2201	28.8143	2/14/12 10:22	48.7	2/17/12 10:21	50.3	8.65	15.43	6.78

Table A.45. (contd)

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-B-6	12	0.2212	31.5647	2/14/12 10:24	49.2	2/17/12 10:23	50.5	8.52	15.51	6.99
Test-5-Na-C-1	13	0.2212	25.7480	2/14/12 10:26	49.1	2/17/12 10:25	50.7	8.52	14.21	5.69
Test-5-Na-C-2	14	0.2207	28.5969	2/14/12 10:27	48.1	2/17/12 10:27	50.3	8.53	15.24	6.71
Test-5-Na-C-3	15	0.2229	30.7547	2/10/12 10:08	48.2	2/13/12 10:06	49.6	8.63	14.27	5.64
Test-5-Na-D-1	16	0.2210	25.7644	2/14/12 10:30	48.8	2/17/12 10:29	50.1	8.59	14.70	6.11
Test-5-Na-D-2	17	0.2217	28.3663	2/14/12 10:32	49.2	2/17/12 10:31	50.2	8.56	14.91	6.35
Test-5-Na-D-3	18	0.2257	30.8073	2/10/12 10:10	47.8	2/13/12 10:08	49.2	8.63	15.07	6.44
Test-5-Na-Q-1	37	0.2225	24.8396	2/28/12 9:45	48.8	3/2/12 9:45	48.4	8.56	14.71	6.15
Test-5-Na-Q-2	38	0.2198	25.3875	2/10/12 10:15	50.1	2/13/12 10:14	51.0	8.57	13.83	5.26
Test-5-Na-Q-3	39	0.2186	25.7891	2/28/12 9:46	49.0	3/2/12 9:46	50.2	8.57	13.91	5.34
Test-5-Na-Q-4	40	0.2195	26.0198	2/28/12 9:48	49.7	3/2/12 9:48	50.8	8.67	14.63	5.96
Test-5-Na-Q-5	41	0.2224	28.6569	2/28/12 9:49	49.6	3/2/12 9:49	50.2	8.51	14.93	6.42
Test-5-Na-Q-6	42	0.2221	31.1025	2/28/12 9:51	49.9	3/2/12 9:51	50.3	8.56	15.38	6.82
Test-5-Na-R-1	43	0.2207	24.9493	2/28/12 9:53	49.8	3/2/12 9:52	50.3	8.56	13.86	5.30
Test-5-Na-R-2	44	0.2253	25.5213	2/10/12 10:19	49.7	2/13/12 10:17	51.1	8.60	14.24	5.64
Test-5-Na-R-3	45	0.2203	26.0104	2/28/12 9:55	49.2	3/2/12 9:54	50.4	8.59	14.41	5.82
Test-5-Na-R-4	46	0.2213	26.2770	2/28/12 9:57	49.3	3/2/12 9:57	50.2	8.55	14.51	5.96
Test-5-Na-R-5	47	0.2206	28.7751	2/28/12 9:58	48.9	3/2/12 9:58	50.2	8.58	15.01	6.43
Test-5-Na-R-6	48	0.2184	31.2205	2/28/12 10:00	49.2	3/2/12 9:59	49.9	8.55	16.50	7.95
Test-5-Na-S-1	49	0.2196	25.9241	3/2/12 12:57	49.6	3/5/12 12:56	49.9	8.61	13.75	5.14
Test-5-Na-S-2	50	0.2207	28.5037	3/2/12 12:58	49.3	3/5/12 12:57	49.9	8.57	14.69	6.12
Test-5-Na-S-3	51	0.2208	30.7745	2/10/12 10:21	50.1	2/13/12 10:19	50.9	8.54	15.69	7.15
Test-5-Na-T-1	52	0.2227	25.8485	3/2/12 13:00	49.3	3/5/12 12:59	49.9	8.56	14.19	5.63
Test-5-Na-T-2	53	0.2241	28.5346	2/10/12 10:22	50.1	2/13/12 10:20	50.9	8.55	14.92	6.37
Test-5-Na-T-3	54	0.2224	30.9574	2/10/12 10:24	50.1	2/13/12 10:22	50.8	8.57	14.68	6.11
Test-5-Na-Y-1	55	0.2231	25.0438	3/2/12 13:01	49.1	3/5/12 13:00	49.9	8.63	14.15	5.52
Test-5-Na-Y-2	56	0.2219	25.4408	2/10/12 10:25	50.1	2/13/12 10:24	50.4	8.63	14.28	5.65
Test-5-Na-Y-3	57	0.2214	25.8376	3/2/12 13:02	49.1	3/5/12 13:02	50.0	8.48	13.90	5.42
Test-5-Na-Y-4	58	0.2199	26.1558	3/2/12 13:04	49.1	3/5/12 13:03	50.2	8.54	14.19	5.65

Table A.45. (contd)

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-Y-5	59	0.2214	28.7729	3/2/12 13:07	49.2	3/5/12 13:06	50.3	8.52	14.81	6.29
Test-5-Na-Y-6	60	0.2232	31.2851	3/2/12 13:08	48.9	3/5/12 13:07	50.2	8.52	15.58	7.06
Test-5-Na-Z-1	61	0.2243	24.9957	3/2/12 13:11	48.8	3/5/12 13:11	50.2	8.52	13.95	5.43
Test-5-Na-Z-2	62	0.2191	25.4883	2/10/12 10:27	50.4	2/13/12 10:26	50.8	8.53	14.14	5.61
Test-5-Na-Z-3	63	0.2227	25.8878	3/2/12 13:13	49.8	3/5/12 13:12	50.3	8.58	14.29	5.71
Test-5-Na-Z-4	64	0.2216	26.2032	3/2/12 13:15	49.2	3/5/12 13:14	50.3	8.52	14.32	5.80
Test-5-Na-Z-5	65	0.2226	28.8929	3/2/12 13:16	49.2	3/5/12 13:15	50.2	8.57	14.59	6.02
Test-5-Na-Z-6	66	0.2216	31.2591	3/2/12 13:18	50.0	3/5/12 13:17	50.6	8.45	15.44	6.99
Test-5-Na-AA-1	67	0.2212	25.9060	3/2/12 13:20	50.2	3/5/12 13:19	50.2	8.43	14.15	5.72
Test-5-Na-AA-2	68	0.2189	28.3724	3/2/12 13:21	50.1	3/5/12 13:21	50.3	8.44	14.77	6.33
Test-5-Na-AA-3	69	0.2202	30.8017	2/10/12 10:29	50.3	2/13/12 10:28	50.9	8.53	15.33	6.80
Test-5-Na-BB-1	70	0.2217	26.0996	3/2/12 13:22	49.5	3/5/12 13:22	50.2	8.59	14.54	5.95
Test-5-Na-BB-2	71	0.2225	28.2844	2/10/12 10:30	50.2	2/13/12 10:29	50.8	8.62	14.62	6.00
Test-5-Na-BB-3	72	0.2218	31.0622	2/10/12 10:32	50.0	2/13/12 10:30	50.6	8.45	14.79	6.34

Table A.46. Datasheet for 25°C Batch Loading Tests

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-QQ-1	1A	0.2193	24.7812	3/16/12 9:46	23.6	3/19/12 9:46	25.1	NA	13.85	NA
Test-5-Na-QQ-2	2A	0.2185	25.5703	3/16/12 9:48	23.2	3/19/12 9:48	25.1	8.57	14.21	5.64
Test-5-Na-QQ-3	3A	0.2226	25.7690	3/16/12 9:50	23.0	3/19/12 9:50	25.1	8.52	14.39	5.87
Test-5-Na-QQ-4	4A	0.2224	26.0461	3/16/12 9:52	23.2	3/19/12 9:52	25.1	8.52	14.25	5.73
Test-5-Na-QQ-5	5A	0.2238	28.7336	3/16/12 9:54	23.1	3/19/12 9:54	25.1	8.51	15.06	6.55
Test-5-Na-QQ-6	6A	0.2209	31.3590	3/16/12 9:56	23.0	3/19/12 9:56	25.0	8.43	15.53	7.10
Test-5-Na-RR-1	7A	0.2208	24.9527	3/16/12 9:57	23.1	3/19/12 9:58	25.0	8.45	13.83	5.38
Test-5-Na-RR-2	8A	0.2206	25.3683	3/16/12 9:59	23.3	3/19/12 9:59	25.0	8.40	14.11	5.71
Test-5-Na-RR-3	9A	0.2201	25.8808	3/16/12 10:01	23.2	3/19/12 10:01	25.0	8.44	14.31	5.87

Table A.46. (contd)

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-RR-4	10A	0.2197	26.3019	3/16/12 10:04	23.3	3/19/12 10:04	25.0	8.45	13.93	5.48
Test-5-Na-RR-5	11A	0.2205	28.8853	3/16/12 10:06	23.3	3/19/12 10:06	25.0	8.53	15.02	6.49
Test-5-Na-RR-6	12A	0.2212	31.3175	3/16/12 10:07	23.2	3/19/12 10:07	25.0	8.51	15.53	7.02
Test-5-Na-SS-1	13A	0.2176	25.9331	3/16/12 10:09	23.3	3/19/12 10:09	25.0	8.46	14.16	5.70
Test-5-Na-SS-2	14A	0.2206	28.5491	3/16/12 10:10	23.2	3/19/12 10:10	25.0	8.58	15.09	6.51
Test-5-Na-SS-3	15A	0.2194	30.8957	3/16/12 10:12	23.0	3/19/12 10:12	25.0	8.45	15.56	7.11
Test-5-Na-TT-1	16A	0.2215	25.9330	3/16/12 10:13	23.0	3/19/12 10:13	25.0	8.41	14.11	5.70
Test-5-Na-TT-2	17A	0.2196	28.4645	3/16/12 10:15	23.1	3/19/12 10:15	25.0	8.51	14.81	6.30
Test-5-Na-TT-3	18A	0.2228	30.8095	3/16/12 10:17	23.4	3/19/12 10:17	25.0	8.52	15.14	6.62
Test-5-Na-E-1	1	0.2182	24.9162	2/14/12 10:43	23.8	2/17/12 10:43	25.0	8.62	14.06	5.44
Test-5-Na-E-2	2	0.2220	25.5521	2/10/12 10:36	23.2	2/13/12 10:33	25.2	8.63	13.99	5.36
Test-5-Na-E-3	3	0.2229	25.7614	2/14/12 10:45	23.6	2/17/12 10:45	25.0	8.55	14.37	5.82
Test-5-Na-E-4	4	0.2166	26.2079	2/14/12 10:46	23.4	2/17/12 10:46	25.0	8.50	14.01	5.51
Test-5-Na-E-5	5	0.2179	28.6561	2/14/12 10:49	23.4	2/17/12 10:48	25.0	8.58	15.31	6.73
Test-5-Na-E-6	6	0.2218	31.1121	2/14/12 10:51	23.2	2/17/12 10:50	25.0	8.59	15.64	7.05
Test-5-Na-F-1	7	0.2206	25.0860	2/14/12 10:52	23.4	2/17/12 10:51	25.0	8.66	14.08	5.42
Test-5-Na-F-2	8	0.2183	25.6015	2/10/12 10:37	23.0	2/13/12 10:33	25.2	8.67	14.01	5.34
Test-5-Na-F-3	9	0.2190	26.0098	2/14/12 10:55	23.5	2/17/12 10:54	25.0	8.53	14.32	5.79
Test-5-Na-F-4	10	0.2196	26.1329	2/14/12 10:56	23.6	2/17/12 10:55	25.0	8.66	14.83	6.17
Test-5-Na-F-5	11	0.2172	28.7954	2/14/12 10:58	23.6	2/17/12 10:57	25.0	8.54	14.76	6.22
Test-5-Na-F-6	12	0.2205	31.3886	2/14/12 11:00	23.3	2/17/12 10:59	25.0	8.56	15.69	7.13
Test-5-Na-G-1	13	0.2160	25.8255	2/14/12 11:03	23.1	2/17/12 11:02	25.0	8.51	14.61	6.10
Test-5-Na-G-2	14	0.2181	28.5630	2/14/12 11:05	23.2	2/17/12 11:04	25.0	8.57	14.43	5.86
Test-5-Na-G-3	15	0.2229	30.7148	2/10/12 10:40	23.4	2/13/12 10:35	25.2	8.62	15.28	6.66
Test-5-Na-H-1	16	0.2194	25.9236	2/14/12 11:08	23.3	2/17/12 11:08	25.0	8.57	14.22	5.65
Test-5-Na-H-2	17	0.2206	28.4521	2/14/12 11:10	23.3	2/17/12 11:10	25.0	8.65	15.08	6.43
Test-5-Na-H-3	18	0.2226	30.9054	2/10/12 10:41	23.4	2/13/12 10:36	25.2	8.50	15.42	6.92
Test-5-Na-U-1	37	0.2180	25.0587	2/24/12 13:59	23.6	2/27/12 13:58	25.0	8.53	13.86	5.33
Test-5-Na-U-2	38	0.2202	25.6184	2/10/12 10:50	23.2	2/13/12 10:41	25.2	8.54	13.28	4.74

Table A.46. (contd)

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-U-3	39	0.2215	25.6966	2/24/12 14:02	23.3	2/27/12 14:02	25.0	8.46	14.24	5.78
Test-5-Na-U-4	40	0.2238	26.0473	2/24/12 14:04	23.4	2/27/12 14:03	25.0	8.40	14.19	5.79
Test-5-Na-U-5	41	0.2201	28.7124	2/24/12 14:05	23.5	2/27/12 14:05	25.0	8.49	14.64	6.15
Test-5-Na-U-6	42	0.2215	31.0854	2/24/12 14:09	23.3	2/27/12 14:08	25.0	8.52	15.30	6.78
Test-5-Na-V-1	43	0.2230	24.8652	2/24/12 14:11	23.4	2/27/12 14:10	25.0	8.41	13.62	5.21
Test-5-Na-V-2	44	0.2211	25.8312	2/10/12 10:52	23.1	2/13/12 10:42	25.2	8.63	14.03	5.40
Test-5-Na-V-3	45	0.2240	25.9351	2/24/12 14:13	23.4	2/27/12 14:11	25.0	8.37	14.55	6.18
Test-5-Na-V-4	46	0.2201	26.2559	2/24/12 14:15	23.3	2/27/12 14:16	25.0	8.43	14.21	5.78
Test-5-Na-V-5	47	0.2201	28.6834	2/24/12 14:18	23.2	2/27/12 14:17	25.0	8.43	15.05	6.62
Test-5-Na-V-6	48	0.2217	31.1638	2/24/12 14:19	23.3	2/27/12 14:18	25.0	8.55	16.44	7.89
Test-5-Na-W-1	49	0.2191	25.8934	3/2/12 13:25	23.1	3/5/12 13:24	24.9	8.45	14.16	5.71
Test-5-Na-W-2	50	0.2200	28.4822	3/2/12 13:27	23.1	3/5/12 13:26	24.9	8.47	14.85	6.38
Test-5-Na-W-3	51	0.2233	30.7264	2/10/12 10:54	23.0	2/13/12 10:43	25.2	8.46	14.70	6.24
Test-5-Na-X-1	52	0.2199	25.9427	3/2/12 13:28	23.1	3/5/12 13:27	24.9	8.52	14.24	5.72
Test-5-Na-X-2	53	0.2213	28.3615	2/10/12 10:56	23.4	2/13/12 10:44	25.2	8.52	14.93	6.41
Test-5-Na-X-3	54	0.2208	30.9159	2/10/12 10:57	23.6	2/13/12 10:44	25.2	8.42	15.40	6.98
Test-5-Na-CC-1	55	0.2197	25.0134	3/2/12 13:30	23.0	3/5/12 13:29	25.0	8.46	14.38	5.92
Test-5-Na-CC-2	56	0.2218	25.4572	2/10/12 10:59	23.5	2/13/12 10:45	25.2	8.57	14.60	6.03
Test-5-Na-CC-3	57	0.2196	25.8235	3/2/12 13:31	23.1	3/5/12 13:31	25.0	8.49	14.05	5.56
Test-5-Na-CC-4	58	0.2207	26.2880	3/2/12 13:33	23.0	3/5/12 13:32	25.0	8.53	14.02	5.49
Test-5-Na-CC-5	59	0.2191	28.8083	3/2/12 13:36	23.0	3/5/12 13:36	25.0	8.40	15.05	6.65
Test-5-Na-CC-6	60	0.2204	31.3754	3/2/12 13:39	23.0	3/5/12 13:38	25.0	8.46	15.48	7.02
Test-5-Na-DD-1	61	0.2215	25.0416	3/2/12 13:40	22.9	3/5/12 13:40	25.0	8.45	13.68	5.23
Test-5-Na-DD-2	62	0.2237	25.4940	2/10/12 11:02	23.2	2/13/12 10:46	25.2	8.59	14.01	5.42
Test-5-Na-DD-3	63	0.2181	25.9740	3/2/12 13:41	23.0	3/5/12 13:41	25.0	8.47	14.20	5.73
Test-5-Na-DD-4	64	0.2220	26.1801	3/2/12 13:43	22.9	3/5/12 13:42	25.0	8.44	14.00	5.56
Test-5-Na-DD-5	65	0.2190	28.7919	3/2/12 13:45	22.8	3/5/12 13:45	25.0	8.49	15.22	6.73
Test-5-Na-DD-6	66	0.2229	31.3991	3/2/12 13:46	22.8	3/5/12 13:46	25.1	8.36	15.31	6.95
Test-5-Na-EE-1	67	0.2190	25.8682	3/2/12 13:48	22.9	3/5/12 13:48	25.1	8.55	14.37	5.82

Table A.46. (contd)

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-EE-2	68	0.2217	28.4064	3/2/12 13:49	22.9	3/5/12 13:49	25.1	8.40	15.01	6.61
Test-5-Na-EE-3	69	0.2211	30.7135	2/10/12 11:05	23.1	2/13/12 10:48	25.2	8.42	15.74	7.32
Test-5-Na-FF-1	70	0.2196	25.9979	3/2/12 13:51	22.9	3/5/12 13:50	25.1	8.42	14.46	6.04
Test-5-Na-FF-2	71	0.2198	28.4892	2/10/12 11:06	23.3	2/13/12 10:49	25.2	8.50	15.07	6.57
Test-5-Na-FF-3	72	0.2216	30.9601	2/10/12 11:07	23.3	2/13/12 10:50	25.2	8.56	15.78	7.22

Table A.47. Datasheet for 35°C Batch Loading Tests

Sample	Simulant ID Used	Resin Added	Simulant Added	Resin Added	Temp When Added	Resin Removed	Temp When Removed	Sample Vial Weight, g		
ID No.		(g)	(g)	Date/Time	(°C)	Date/Time	(°C)	Tare	Gross	Net
Test-5-Na-GG-1	72	0.2214	30.6308	2/3/12 10:41	35.0	2/6/12 10:41	34.8	8.54	14.81	6.27
Test-5-Na-GG-2	54	0.2253	30.7515	2/3/12 10:43	34.8	2/6/12 10:43	35.2	8.48	16.36	7.88
Test-5-Na-GG-3	36	0.2170	30.7809	2/3/12 10:44	34.9	2/6/12 10:44	35.0	8.64	16.83	8.19
Test-5-Na-PP-1	18	0.2222	30.8588	3/12/12 9:35	34.7	3/15/12 9:38	34.9	8.56	14.82	6.26
Test-5-Na-HH-1	69	0.2199	30.6352	2/3/12 10:47	35.2	2/6/12 10:46	34.9	8.48	16.92	8.44
Test-5-Na-HH-2	51	0.2167	30.7031	2/3/12 10:52	35.1	2/6/12 10:47	35.7	8.46	16.74	8.28
Test-5-Na-HH-3	33	0.2208	30.7555	2/3/12 10:53	35.5	2/6/12 10:48	35.5	8.56	16.78	8.22
Test-5-Na-PP-2	15	0.2196	30.7681	3/12/12 9:36	34.7	3/15/12 9:39	34.8	8.47	15.28	6.81
Test-5-Na-II-1	62	0.2262	25.5009	2/3/12 10:55	35.0	2/6/12 10:50	35.3	8.53	15.41	6.88
Test-5-Na-II-2	44	0.2194	25.6125	2/3/12 10:57	35.0	2/6/12 10:51	35.2	8.56	15.98	7.42
Test-5-Na-II-3	26	0.2193	25.5171	2/3/12 10:58	35.3	2/6/12 10:53	35.7	8.60	15.56	6.96
Test-5-Na-PP-3	8	0.2192	25.6220	3/12/12 9:38	34.8	3/15/12 9:40	34.8	8.45	14.20	5.75
Test-5-Na-JJ-1	56	0.2208	25.3575	2/3/12 11:01	35.4	2/6/12 10:55	35.6	8.61	15.02	6.41
Test-5-Na-JJ-2	38	0.2221	25.3418	2/3/12 11:03	34.6	2/6/12 10:56	35.2	8.60	16.12	7.52
Test-5-Na-JJ-3	20	0.2227	25.3067	2/3/12 11:06	35.3	2/6/12 10:58	34.9	8.54	15.28	6.74
Test-5-Na-PP-4	2	0.2192	25.5606	3/12/12 9:39	34.7	3/15/12 9:41	34.9	8.39	13.78	5.39
Test-5-Na-KK-1	53	0.2243	28.4964	2/3/12 11:10	35.4	2/6/12 11:00	35.3	8.51	16.65	8.14
Test-5-Na-KK-2	71	0.2284	28.3653	2/3/12 11:12	35.2	2/6/12 11:01	35.4	8.95	16.53	7.58

Appendix B

Analytical Data

Appendix B

Analytical Data

Table B.1. Column A1 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min, Simulant Used = 180.1 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A1-LD-00	0	5.19	3490	93700	1030	1.52	2.21	<64.1	23000	9290	308	873	1210	8065	417
A1-LD-06	6	4.87	3470	90500	1010	1.50	2.18	<64.8	22700	9060	302	865	1190	8010	415
A1-LD-12	12	3.38	3370	87900	962	1.47	2.13	<64.7	22500	8990	322	824	1120	7905	405
A1-LD-18	18	3.06	3470	89100	966	1.47	2.13	<65.4	22700	9060	300	838	1150	7905	394
A1-LD-24	24	2.77	3270	89900	964	1.47	2.14	<64.8	22200	8860	295	828	1130	8100	422
A1-LD-36	36	2.28	3410	87300	984	1.46	2.14	<64.7	21400	8990	295	839	1150	8010	412
A1-LD-48	48	1.95	3470	88900	974	1.47	2.16	<64.7	22700	9030	282	819	1110	7990	421
A1-LD-60	60	1.66	3270	87600	965	1.48	2.15	<65.0	22700	9090	291	831	1140	8220	414
A1-LD-80	80	1.41	3400	90100	959	1.46	2.12	<65.0	22300	8910	283	822	1110	7890	419
A1-LD-120	120	1.13	3360	88900	981	1.47	2.13	<64.9	22200	8870	293	826	1130	8065	424
A1-LD-180	180	0.899	3370	90400	983	1.47	2.14	<64.9	22200	8890	293	835	1140	7795	409
A1-LD-240	240	0.795	3380	87900	959	1.46	2.13	<64.6	22200	8890	296	832	1140	7795	411
A1-LD-600	600	0.676	3410	89100	960	1.47	2.13	<65.0	22500	9020	285	821	1110	7835	418
A1-FD-CP	Feed Displacement	0.498	2200	60100	644	0.884	0.962	<72.6	13900	6160	193	533	750	4735	264
A1-EL-CP	Elution	14.5	4.41	1320	65.5	<0.05	<0.05	<82.0	2450	<82.0	<82.0	<82.0	<82.0	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.2. Column A2 Test Analytical Data (T = 45°C, Flow rate = 14.16 mL/min, Simulant Used = 173.7 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A2-LD-00	0	5.11	3470	93600	1050	1.50	2.18	<64.3	23100	9220	317	857	1230	7930	428
A2-LD-06	6	4.00	3430	91200	989	1.45	2.10	<64.5	22200	8860	298	804	1150	7585	412
A2-LD-12	12	3.39	3430	92700	1020	1.45	2.11	<64.5	22600	9120	295	808	1140	7780	413
A2-LD-18	18	2.86	3320	89800	963	1.44	2.11	<64.1	22400	8940	294	800	1140	7620	409
A2-LD-24	24	2.61	3260	90200	988	1.45	2.10	<63.9	22300	9010	297	829	1160	7660	412
A2-LD-36	36	2.09	3300	90200	970	1.45	2.11	<64.1	21400	8900	295	813	1150	7765	408
A2-LD-48	48	1.79	3340	90200	973	1.45	2.10	<63.8	22400	8950	291	812	1130	7605	416
A2-LD-60	60	1.60	3390	91600	987	1.44	2.10	<63.7	22500	9060	284	799	1110	7505	409
A2-LD-80	80	1.35	3380	91700	1000	1.44	2.11	<63.9	22800	9090	289	809	1120	7835	413
A2-LD-120	120	1.06	3270	90100	969	1.44	2.10	<64.1	22000	8890	297	811	1150	7675	410
A2-LD-180	180	0.884	3270	89500	971	1.45	2.11	<64.3	22400	8840	300	811	1130	7595	414
A2-LD-240	240	0.840	3390	90900	983	1.44	2.09	<64.7	22500	9070	294	816	1150	7580	411
A2-LD-600	600	0.753	3350	90300	974	1.44	2.09	<63.6	22500	9050	290	821	1140	7740	424
A2-FD-CP	Feed Displacement	0.531	2090	58800	638	0.905	1.27	<69.6	13200	5770	189	493	714	4385	272
A2-EL-CP	Elution	11.1	4.36	1340	61.3	<0.05	<0.05	<78.0	3110	<78.0	<78.0	<78.0	<78.0	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.3. Column A3 Test Analytical Data (T = 45°C, Flow rate = 7.08 mL/min, Simulant Used = 171.1 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A3-LD-00	0	5.27	3610	96100	1080	1.52	2.20	<32.1	23200	9210	318	872	1250	8065	450
A3-LD-06	6	4.57	3550	94300	1040	1.47	2.13	<32.4	22400	8830	307	852	1210	7715	423
A3-LD-12	12	3.89	3290	90900	1020	1.47	2.15	<32.3	22600	8900	307	857	1250	8025	421
A3-LD-18	18	3.44	3370	91400	1020	1.44	2.11	<32.4	22200	8800	301	843	1190	7625	412
A3-LD-24	24	3.11	3460	92300	1010	1.46	2.12	<32.4	22900	9080	309	852	1210	7720	414
A3-LD-36	36	2.57	3540	91600	1020	1.45	2.13	<32.5	21000	9270	293	844	1180	8110	418
A3-LD-48	48	2.18	3290	91100	1010	1.46	2.13	<32.9	22600	8970	293	839	1150	7955	426
A3-LD-60	60	1.92	3490	91700	997	1.45	2.11	<32.4	22600	8950	300	855	1190	7930	421
A3-LD-80	80	1.60	3470	92400	997	1.45	2.12	<32.6	22900	9070	299	872	1120	7960	421
A3-LD-120	120	1.24	3290	91100	1020	1.44	2.12	<32.4	22200	8750	310	868	1150	7810	419
A3-LD-180	180	1.02	3570	92200	1020	1.46	2.12	<32.5	22200	8790	303	849	1190	7755	418
A3-LD-240	240	0.942	3510	92800	1030	1.44	2.12	<32.3	22300	8850	301	853	1180	8040	425
A3-LD-600	600	0.842	3530	91200	1000	1.44	2.11	<32.4	21700	8720	298	852	1220	7735	426
A3-FD-CP	Feed Displacement	0.624	2100	58300	634	0.775	1.28	<36.1	13100	5420	190	507	744	4250	285
A3-EL-CP	Elution	20.4	2.99	1500	65.3	<0.05	<0.05	<39.8	3110	<39.8	<39.8	<39.8	<39.8	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.4. Column A4 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min, Simulant Used = 170.5 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A4-LD-00	0	5.37	3430	97100	1040	1.58	2.66	<19.4	24000	9710	313	897	1310	7845	424
A4-LD-06	6	4.47	3540	93000	1040	1.46	2.14	<27.2	22600	9190	290	835	1190	7540	412
A4-LD-12	12	3.63	3390	93900	1010	1.44	2.12	<40.8	22300	9150	303	838	1180	7550	407
A4-LD-18	18	3.19	3720	92800	999	1.46	2.12	<27.0	22900	9170	291	849	1210	7705	401
A4-LD-24	24	2.89	3570	94300	1030	1.46	2.16	<34.2	22900	9340	298	861	1220	7610	409
A4-LD-36	36	2.24	3170	88700	981	1.39	2.04	<36.6	21500	8820	277	821	1130	7640	409
A4-LD-48	48	2.00	3420	94200	1060	1.47	2.17	<30.9	23100	9380	293	869	1200	7550	408
A4-LD-60	60	1.69	3310	90700	960	1.54	2.28	<30.9	23100	9460	320	871	1210	7420	403
A4-LD-80	80	1.39	3270	90300	980	1.40	2.08	<26.3	22100	9020	276	839	1140	7680	425
A4-LD-120	120	1.09	3440	90300	994	1.36	1.99	<27.7	22300	8950	294	838	1200	7590	385
A4-LD-180	180	0.932	3370	91600	1010	1.42	2.08	<27.5	22100	8930	283	825	1160	7485	415
A4-LD-240	240	0.865	3410	91400	1040	1.45	2.12	<29.4	22400	9030	288	842	1180	7535	407
A4-LD-600	600	0.805	3370	90900	1010	1.55	2.30	<28.7	22100	8980	275	817	1120	7545	431
A4-FD-CP	Feed Displacement	0.542	2100	55800	622	0.847	1.22	<33.0	12800	5370	211	491	726	4100	266
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.5. Column A4B Test Analytical Data (T = 60°C, Flow rate = 0.08 mL/min, Simulant Used = 198.6 mL)

Sample ID	Loading Time (hr)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A4B-LD-00	0	5.19	3590	94400	1090	1.49	2.17	<32.7	22400	9320	298	797	1110	8065	421
A4B-LD-04	4	4.86	3490	90700	1050	1.42	2.09	<33.1	21700	9120	292	786	1110	7835	410
A4B-LD-08	8	4.60	3440	91600	1030	1.43	2.10	<33.1	21700	9030	284	789	1130	7675	410
A4B-LD-12	12	4.38	3510	93400	1060	1.43	2.10	<32.6	21500	8830	276	805	1150	8055	415
A4B-LD-24	24	3.73	3530	91400	1090	1.44	2.11	<32.7	21800	9060	282	785	1120	8135	406
A4B-LD-72	72	2.65	3630	95400	1110	1.47	2.16	<32.9	22500	9450	285	805	995	8215	421
A4B-LD-120	120	2.88	3620	95400	1090	1.51	2.22	<32.7	22600	9260	290	817	1060	8415	447
A4B-LD-168	168	2.99	3780	99100	1140	1.54	2.26	<32.5	23400	9560	289	833	843	8985	458
A4B-LD-336	336	3.21	3900	102000	1160	1.62	2.39	<33.7	24600	10200	308	884	794	8795	351
A4B-FD-CP	Feed Displacement	2.00	2240	62400	2240	0.998	1.41	<36.4	14200	6320	190	512	796	4705	369
A4B-EL-CP	Elution	20.0	38.9	1270	39.5	<0.05	<0.05	<40.1	3020	<40.1	<40.1	<40.1	<40.1	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.6. Column A5 Test Analytical Data (T = 45°C, Flow rate = 10.62 mL/min, Simulant Used = 170.1 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
A5-LD-00	0	5.15	3520	92900	1070	1.49	2.18	<32.4	22500	9160	275	805	814	8065	346
A5-LD-06	6	4.18	3520	90200	1020	1.45	2.11	<32.7	21600	8820	265	772	811	7875	336
A5-LD-12	12	3.53	3380	90000	1010	1.45	2.09	<33.2	21600	8850	269	780	814	7555	337
A5-LD-18	18	3.12	3460	89900	1010	1.43	2.10	<32.9	21400	9180	259	778	826	7525	325
A5-LD-24	24	2.83	3480	90600	1020	1.45	2.11	<32.6	21400	8740	260	759	767	7740	326
A5-LD-36	36	2.24	3490	90000	1010	1.45	2.10	<33.1	21400	8900	266	778	785	7655	323
A5-LD-48	48	1.90	3390	88500	1000	1.42	2.09	<32.8	21400	8880	256	781	805	7440	325
A5-LD-60	60	1.69	3440	90800	990	1.43	2.08	<33.1	21200	8800	262	769	802	7400	330
A5-LD-80	80	1.45	3400	89500	994	1.43	2.09	<32.7	21600	8980	264	776	776	7675	327
A5-LD-120	120	1.19	3380	87800	990	1.43	2.09	<32.8	21600	8910	270	772	818	7510	324
A5-LD-180	180	1.03	3410	87600	980	1.43	2.10	<32.7	21500	9090	263	774	823	7685	325
A5-LD-240	240	1.01	3520	89600	1000	1.43	2.07	<32.8	21700	9040	257	772	813	7690	330
A5-LD-600	600	0.977	3460	90400	997	1.43	2.09	<32.7	21700	8850	256	773	786	7415	336
A5-FD-CP	Feed Displacement	0.734	2150	59100	650	0.926	1.32	<36.2	13400	5610	192	479	510	4465	234
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.7. Column B1 Test Analytical Data (T = 40°C, Flow rate = 10.62 mL/min, Simulant Used = 178.9 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B1-LD-00	0	5.24	3570	96400	1030	1.50	2.19	<64.2	22900	9160	311	835	1190	7980	426
B1-LD-06	6	4.05	3500	91400	952	1.46	2.13	<65.0	22500	8980	306	821	1180	7820	409
B1-LD-12	12	3.53	3480	92900	975	1.46	2.13	<64.7	22300	8930	303	829	1170	7965	412
B1-LD-18	18	3.03	3550	92600	974	1.46	2.13	<32.4	21700	8800	286	815	1140	7965	409
B1-LD-24	24	2.63	3370	91800	983	1.47	2.13	<64.9	22400	8970	293	806	1140	8060	416
B1-LD-36	36	2.15	3440	91000	961	1.46	2.13	<65.3	22200	8910	296	814	1130	7885	415
B1-LD-48	48	1.86	3510	95300	971	1.46	2.12	<64.9	22200	8860	294	815	1140	8075	414
B1-LD-60	60	1.62	3510	95800	985	1.46	2.13	<65.0	22300	9040	293	823	1140	7755	406
B1-LD-80	80	1.38	3510	93200	973	1.46	2.13	<65.5	22200	8850	294	835	1150	7915	413
B1-LD-120	120	1.09	3460	91900	963	1.45	2.12	<65.1	22500	8990	292	810	1150	8415	413
B1-LD-180	180	0.877	3490	93400	972	1.44	2.11	<65.0	22300	8930	302	825	1160	7880	411
B1-LD-240	240	0.768	3610	96600	976	1.46	2.12	<65.3	22300	8930	294	823	1170	7840	415
B1-LD-600	600	0.657	3340	92300	953	1.46	2.13	<65.6	22300	8940	288	821	1150	8020	412
B1-FD-CP	Feed Displacement	0.415	1920	53700	560	0.720	0.832	<73.8	12100	5300	169	458	659	4010	223
B1-EL-CP	Elution	13.3	<2.00	1200	60.5	<0.05	<0.05	<79.7	2430	<79.7	<79.7	<79.7	<79.7	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.8. Column B2 Test Analytical Data (T = 40°C, Flow rate = 14.16 mL/min, Simulant Used = 174.8 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B2-LD-00	0	5.22	3590	92900	1020	1.49	2.18	<63.5	23200	9300	297	834	1180	8130	413
B2-LD-06	6	4.09	3350	88600	974	1.45	2.10	<64.2	22100	8850	287	802	1100	7620	400
B2-LD-12	12	3.38	3430	87900	1030	1.44	2.10	<63.7	22000	8800	284	809	1110	7565	402
B2-LD-18	18	3.00	3620	90800	984	1.45	2.11	<63.7	22400	8970	287	806	1110	7475	399
B2-LD-24	24	2.62	3320	89300	994	1.45	2.11	<63.6	22400	8970	289	820	1110	7500	404
B2-LD-36	36	2.17	3530	89900	986	1.44	2.10	<63.7	21000	8910	281	802	1090	7635	403
B2-LD-48	48	1.83	3430	90500	983	1.45	2.10	<63.9	21900	8860	267	790	1070	7725	395
B2-LD-60	60	1.62	3470	90600	969	1.45	2.09	<63.8	21900	8740	282	816	1090	7585	392
B2-LD-80	80	1.37	3590	90300	1000	1.43	2.09	<63.8	22200	9040	276	809	1090	7555	396
B2-LD-120	120	1.08	3460	89500	972	1.45	2.11	<64.0	22200	8860	281	794	1090	7570	396
B2-LD-180	180	0.888	3510	89500	979	1.45	2.10	<63.6	22500	9000	268	786	1070	7660	399
B2-LD-240	240	0.803	3460	90500	957	1.44	2.09	<63.8	22200	8850	283	812	1110	7710	402
B2-LD-600	600	0.695	3430	89400	982	1.44	2.10	<64.6	22000	8800	320	814	1110	7755	397
B2-FD-CP	Feed Displacement	0.426	1940	52500	556	0.707	0.822	<70.5	11900	5100	162	446	621	3900	210
B2-EL-CP	Elution	16.1	4.33	1320	64.5	<0.05	<0.05	<78.7	3000	<78.7	<78.7	<78.7	<78.7	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.9. Column B3 Test Analytical Data (T = 40°C, Flow rate = 7.08 mL/min, Simulant Used = 172.2 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B3-LD-00	0	5.48	3650	96800	1100	1.51	2.19	<32.3	23700	9550	367	868	1200	8000	433
B3-LD-06	6	4.56	3500	93200	1040	1.45	2.11	<32.2	22800	9220	318	807	1540	7860	421
B3-LD-12	12	3.95	3480	91900	1020	1.45	2.10	<32.4	22800	9210	300	841	1180	8185	425
B3-LD-18	18	3.52	3430	93000	1070	1.46	2.12	<32.7	22800	9240	317	839	1170	8015	423
B3-LD-24	24	3.16	3570	93700	1040	1.46	2.12	<32.5	22500	9080	293	836	1160	7685	414
B3-LD-36	36	2.59	3570	93800	1050	1.44	2.11	<32.4	22300	9000	293	841	1190	7940	423
B3-LD-48	48	2.17	3620	92300	1030	1.44	2.11	<32.5	22900	9210	287	829	1130	7845	413
B3-LD-60	60	1.91	3380	92200	977	1.45	2.10	<32.1	22400	9020	286	833	1130	8155	420
B3-LD-80	80	1.57	3530	93000	1030	1.45	2.11	<32.3	22500	9080	282	833	1120	7985	418
B3-LD-120	120	1.19	3490	92800	1040	1.44	2.11	<32.3	22600	9170	296	840	1160	7855	418
B3-LD-180	180	0.926	3420	91900	1050	1.46	2.12	<34.7	22600	9140	302	847	1220	8070	420
B3-LD-240	240	0.821	3540	92400	1020	1.45	2.11	<31.8	22300	9010	290	825	1130	7820	429
B3-LD-600	600	0.698	3460	92900	1050	1.46	2.12	<32.2	22400	9040	295	834	1150	8035	433
B3-FD-CP	Feed Displacement	0.442	1860	53300	575	0.697	1.14	<36.6	11900	4990	180	465	665	3745	219
B3-EL-CP	Elution	17.3	2.39	1360	64.9	<0.05	<0.05	<39.7	3250	<39.7	<39.7	<39.7	<39.7	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.10. Column B4 Test Analytical Data (T = 40°C, Flow rate = 10.62 mL/min, Simulant Used = 170.4 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B4-LD-00	0	5.20	3640	94700	1080	1.49	2.17	<48.8	22700	9180	369	851	1200	7960	426
B4-LD-06	6	4.18	3410	90200	1020	1.45	2.10	<49.8	22400	9080	303	843	1220	7585	413
B4-LD-12	12	3.59	3340	93500	1030	1.43	2.10	<49.4	22400	9120	301	820	1170	7515	405
B4-LD-18	18	3.12	3410	93000	1030	1.45	2.10	<49.3	22000	8910	287	809	1150	7640	404
B4-LD-24	24	2.75	3510	92700	1020	1.46	2.11	<48.5	21700	8830	292	819	1150	7775	406
B4-LD-36	36	2.27	3520	93500	1010	1.43	2.10	<49.2	22000	8930	296	838	1160	7720	403
B4-LD-48	48	1.90	3390	93600	1040	1.44	2.09	<49.4	22400	9080	291	835	1170	7655	407
B4-LD-60	60	1.67	3430	91900	1050	1.44	2.09	<49.3	22300	9120	281	829	1080	7570	407
B4-LD-80	80	1.40	3550	93900	1070	1.44	2.09	<49.5	22000	8950	281	817	1120	7710	409
B4-LD-120	120	1.09	3520	92900	1010	1.44	2.09	<49.8	22100	8950	298	833	1170	7710	412
B4-LD-180	180	0.891	3690	93400	1020	1.44	2.09	<49.0	22100	8940	294	832	1180	7840	410
B4-LD-240	240	0.800	3480	93500	1030	1.45	2.11	<49.7	22200	9000	295	843	1160	7940	411
B4-LD-600	600	0.728	3490	92300	1030	1.41	2.04	<49.3	21700	8830	282	825	1120	7940	408
B4-FD-CP	Feed Displacement	0.418	1790	50800	536	0.640	1.07	<55.6	11000	4670	190	420	626	3800	210
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.11. Column B4B Test Analytical Data (T = 55°C, Flow rate = 0.08 mL/min, Simulant Used = 196.6 mL)

Sample ID	Loading Time (hr)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B4B-LD-00	0	5.25	3630	93600	1090	1.48	2.15	<32.8	22100	9370	280	814	1110	8050	403
B4B-LD-04	4	4.86	3460	91700	1050	1.42	2.08	<32.8	21600	8950	272	793	1130	7995	398
B4B-LD-08	8	4.60	3590	93800	1090	1.41	2.07	<32.7	21400	8870	269	777	1090	8035	403
B4B-LD-12	12	4.27	3520	90400	1050	1.43	2.11	<32.8	21600	9200	261	783	1070	8070	399
B4B-LD-24	24	3.49	3480	91500	1050	1.42	2.08	<33.2	21800	8930	264	790	1050	7865	411
B4B-LD-72	72	2.29	3520	93400	1060	1.46	2.15	<34.1	22000	9050	278	806	1110	8085	419
B4B-LD-120	120	2.67	3680	96700	1120	1.49	2.19	<32.6	22800	9690	273	825	1100	8520	441
B4B-LD-168	168	2.76	3730	94800	1120	1.54	2.25	<32.4	23200	9420	276	830	1010	8385	462
B4B-LD-336	336	3.12	4300	107000	1240	1.82	2.64	<31.6	28100	11000	419	1000	1350	9725	545
B4B-FD-CP	Feed Displacement	2.38	2970	79700	905	1.32	1.88	<33.4	20200	7900	315	731	1600	6530	607
B4B-EL-CP	Elution	27.1	18.8	1310	47.0	<0.05	<0.05	<39.7	3190	<39.7	<39.7	<39.7	<39.7	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.12. Column B5 Test Analytical Data (T = 40°C, Flow rate = 10.62 mL/min, Simulant Used = 172.0 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
B5-LD-00	0	5.13	3640	91400	1050	1.49	2.17	<32.5	23800	9350	345	852	909	7980	338
B5-LD-06	6	4.07	3490	88600	984	1.43	2.08	<32.8	22700	8920	313	832	895	7400	327
B5-LD-12	12	3.43	3430	89100	985	1.43	2.09	<32.9	22800	8910	307	844	919	7515	328
B5-LD-18	18	3.02	3470	89000	973	1.45	2.12	<32.8	23000	9030	348	808	919	8030	328
B5-LD-24	24	2.61	3330	88800	977	1.43	2.07	<32.7	22300	8800	313	839	922	7620	318
B5-LD-36	36	2.09	3420	91600	988	1.44	2.10	<32.8	22700	8780	337	810	894	7725	324
B5-LD-48	48	1.78	3430	89600	1010	1.44	2.09	<32.8	22700	8870	304	814	850	7695	338
B5-LD-60	60	1.55	3430	88000	981	1.44	2.10	<32.9	23300	9040	341	843	907	7475	329
B5-LD-80	80	1.32	3990	89100	977	1.44	2.10	<32.6	23200	9060	311	821	873	8005	338
B5-LD-120	120	1.06	3440	88700	969	1.45	2.11	<32.9	22700	8830	304	811	859	7730	323
B5-LD-180	180	0.876	3400	87300	962	1.44	2.09	<33.0	22200	8900	284	827	884	7535	320
B5-LD-240	240	0.813	3450	89200	993	1.44	2.09	<32.8	22500	8870	318	837	875	7840	336
B5-LD-600	600	0.741	3440	88200	973	1.42	2.08	<32.9	22700	8850	331	837	901	7725	329
B5-FD-CP	Feed Displacement	0.504	2000	54600	584	0.879	1.24	<35.3	13400	5360	230	482	533	4125	195
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.13. Column C1 Test Analytical Data (T = 30°C, Flow rate = 10.62 mL/min, Simulant Used = 164.7 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C1-LD-00	0	4.94	3360	92600	1080	1.48	2.15	<32.8	23700	9240	341	844	861	8045	301
C1-LD-06	6	4.05	3040	88100	979	1.44	2.09	<33.1	22900	8890	359	809	800	7550	288
C1-LD-12	12	3.63	3190	89600	1010	1.42	2.07	<32.9	22500	8810	310	816	789	7750	286
C1-LD-18	18	3.25	3170	89000	1020	1.43	2.08	<32.8	22800	8890	342	802	806	7575	288
C1-LD-24	24	2.94	3260	89800	1010	1.44	2.10	<33.0	22700	8860	282	808	776	7750	288
C1-LD-36	36	2.47	3180	88500	999	1.43	2.09	<33.1	22000	8840	342	809	808	7625	286
C1-LD-48	48	2.17	3090	89100	1000	1.42	2.08	<33.1	22700	8820	338	823	759	7445	285
C1-LD-60	60	1.92	3160	89900	1030	1.42	2.07	<32.8	22600	8840	330	812	741	7650	287
C1-LD-80	80	1.63	3180	89300	1010	1.44	2.11	<33.0	22500	8720	297	845	852	7695	287
C1-LD-120	120	1.25	3190	90200	1020	1.42	2.09	<32.9	22700	8840	343	831	801	7470	284
C1-LD-180	180	0.933	3070	89000	1010	1.43	2.08	<32.8	23000	8960	319	789	773	7445	287
C1-LD-240	240	0.822	3230	90100	1030	1.42	2.07	<32.8	22700	8830	299	850	797	7610	288
C1-LD-600	600	0.583	3190	89000	1010	1.41	2.06	<32.9	22500	8770	304	831	783	7750	285
C1-FD-CP	Feed Displacement	0.370	1860	55100	612	0.868	1.23	<47.9	13400	5300	192	470	505	4125	208
C1-EL-CP	Elution	15.2	4.29	1260	64.6	<0.05	<0.05	<40.2	3340	<40.2	<40.2	<40.2	<40.2	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.14. Column C2 Test Analytical Data (T = 30°C, Flow rate = 14.16 mL/min, Simulant Used = 151.3 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C2-LD-00	0	5.07	3470	92300	1110	1.48	2.17	<32.5	23500	9150	306	877	856	7995	292
C2-LD-06	6	4.10	3290	90900	1040	1.43	2.09	<32.8	22800	8820	303	795	812	7735	290
C2-LD-12	12	3.53	3310	90800	1040	1.43	2.10	<32.8	22800	8840	315	821	827	7815	287
C2-LD-18	18	3.17	3470	92200	1050	1.51	2.24	<32.6	24000	9220	347	842	811	8430	308
C2-LD-24	24	2.83	3330	91100	1040	1.44	2.10	<32.9	23000	8910	282	827	796	7905	286
C2-LD-36	36	2.33	3380	91000	1050	1.44	2.11	<32.8	22500	8930	294	824	771	8160	290
C2-LD-48	48	1.97	3350	89900	1030	1.44	2.11	<32.9	22800	8820	315	814	757	7885	291
C2-LD-60	60	1.73	3380	89600	1020	1.44	2.08	<32.8	23000	8890	293	806	754	7555	286
C2-LD-80	80	1.44	3300	89300	1020	1.44	2.10	<32.6	22900	8890	271	825	796	7755	284
C2-LD-120	120	1.09	3290	88800	1000	1.42	2.08	<34.0	22700	8900	284	823	762	7855	287
C2-LD-180	180	0.874	3370	89800	1020	1.44	2.08	<32.9	22800	8800	322	817	789	8005	293
C2-LD-240	240	0.768	3350	89700	1020	1.42	2.07	<32.8	22800	8930	290	815	775	7875	287
C2-LD-600	600	0.606	3320	90000	1040	1.43	2.08	<32.5	22800	8880	283	825	754	7655	288
C2-FD-CP	Feed Displacement	0.370	1970	57000	610	0.879	1.24	42.8	13400	5230	179	492	591	4195	220
C2-EL-CP	Elution	13.8	6.72	1230	63.6	<0.05	<0.05	<40.2	3230	<40.2	<40.2	<40.2	<40.2	<25.0	13.7
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.15. Column C3 Test Analytical Data (T = 30°C, Flow rate = 7.08 mL/min, Simulant Used = 151.4 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C3-LD-00	0	5.14	3670	93200	1090	1.49	2.16	<32.7	23500	9110	306	851	787	7950	289
C3-LD-06	6	4.42	3410	89900	1020	1.42	2.06	<32.8	22500	8770	292	810	773	7625	280
C3-LD-12	12	3.89	3380	89500	989	1.42	2.08	<33.0	22600	8790	291	818	815	7460	275
C3-LD-18	18	3.50	3460	88600	991	1.42	2.07	<31.7	22800	8870	301	854	780	7775	285
C3-LD-24	24	3.25	3320	90300	1040	1.43	2.10	<33.2	22400	8680	297	870	802	7550	277
C3-LD-36	36	2.67	3290	88500	999	1.43	2.07	<32.8	22500	8740	275	796	739	7295	272
C3-LD-48	48	2.34	3370	89500	1020	1.43	2.09	<33.1	22700	8820	294	812	731	7710	282
C3-LD-60	60	1.98	3270	87400	991	1.42	2.06	<32.8	22300	8660	283	781	744	7245	272
C3-LD-80	80	1.66	3170	88200	1010	1.43	2.09	<32.8	22300	8640	288	803	733	7700	278
C3-LD-120	120	1.21	3400	88800	997	1.41	2.07	<32.9	22400	8730	301	805	743	7590	273
C3-LD-180	180	0.930	3360	89600	998	1.41	2.06	<32.8	22500	8770	308	814	778	7590	275
C3-LD-240	240	0.780	3370	88900	975	1.41	2.07	<32.8	22500	8760	312	803	754	7190	274
C3-LD-600	600	0.578	3340	88200	1010	1.42	2.06	<32.8	22700	8800	276	812	727	7685	274
C3-FD-CP	Feed Displacement	0.279	1870	53600	571	0.827	1.17	<36.1	12500	5030	172	453	490	3850	154
C3-EL-CP	Elution	14.2	5.52	1260	60.8	<0.05	<0.05	<39.9	3290	<39.9	<39.9	<39.9	<39.9	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.16. Column C4 Test Analytical Data (T = 30°C, Flow rate = 10.62 mL/min, Simulant Used = 149.7 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C4-LD-00	0	5.01	3440	94700	1120	1.51	2.20	<32.4	24500	9510	322	864	796	8080	291
C4-LD-06	6	4.12	3260	90500	1050	1.44	2.10	<32.8	23300	9050	294	833	763	7520	303
C4-LD-12	12	3.68	3260	91300	1060	1.43	2.08	<32.8	23100	8970	290	808	745	7895	280
C4-LD-18	18	3.23	3250	89900	1040	1.44	2.10	<32.9	23400	9080	287	841	750	7960	358
C4-LD-24	24	2.92	3310	91800	1080	1.43	2.11	<32.7	23400	9050	312	835	755	7980	279
C4-LD-36	36	2.45	3210	89700	1020	1.44	2.09	<32.8	23200	8980	277	830	747	7675	276
C4-LD-48	48	2.20	3350	95000	1070	1.51	2.23	<32.7	24200	9330	284	857	762	8020	295
C4-LD-60	60	1.83	3200	90100	1040	1.45	2.10	<33.0	23300	9040	323	843	819	7565	281
C4-LD-80	80	1.50	3260	91500	1070	1.47	2.16	<34.4	24100	9320	329	892	848	8315	452
C4-LD-120	120	1.07	3270	90800	1040	1.42	2.08	<33.2	23200	9000	292	831	750	8100	282
C4-LD-180	180	0.822	3290	90600	1030	1.43	2.10	<32.8	23200	9010	279	812	731	7890	278
C4-LD-240	240	0.710	3240	89700	1010	1.41	2.05	<32.9	22800	8780	284	816	746	7910	273
C4-LD-600	600	0.586	3150	88900	1040	1.40	2.05	38.0	23200	8960	324	827	769	7840	285
C4-FD-CP	Feed Displacement	0.366	2050	57800	639	0.898	1.28	43.3	14500	5690	202	523	479	4385	188
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.17. Column C4B Test Analytical Data (T = 50°C, Flow rate = 0.08 mL/min, Simulant Used = 159.4 mL)

Sample ID	Loading Time (hr)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C4B-LD-00	0	5.10	3530	98400	1160	1.49	2.17	<32.8	24000	9300	328	878	820	7840	285
C4B-LD-04	4	5.52	3980	107000	1100	1.32	1.87	<32.7	25900	10000	329	951	836	7190	294
C4B-LD-08	8	4.09	3220	89000	1050	1.41	2.08	<32.4	23300	9070	304	835	778	8040	278
C4B-LD-12	12	3.82	3260	90300	1060	1.41	2.07	<32.8	23400	9090	297	822	774	7865	277
C4B-LD-24	24	3.11	3300	91900	1080	1.43	2.09	<32.7	23400	9050	305	829	761	7875	277
C4B-LD-72	72	2.19	3340	91900	1090	1.46	2.14	230	23800	9250	319	878	785	8350	285
C4B-LD-120	120	2.23	3410	95000	1130	1.45	2.13	<32.6	24000	9310	314	862	806	8070	297
C4B-LD-168	168	2.44	3740	104000	1110	1.32	1.95	<43.4	26300	10300	348	952	853	7355	302
C4B-LD-336	336	2.43	3110	87300	1090	1.50	2.19	<33.3	24700	9210	336	866	849	8205	351
C4B-LD-504	504	2.55	3190	90000	1130	1.58	2.35	<33.2	26000	9770	369	919	913	9215	392
C4B-FD-CP	Feed Displacement	1.87	2280	71400	809	1.13	1.59	<39.1	17800	6680	256	675	631	6050	370
C4B-EL-CP	Elution	18.8	93.4	1240	38.2	<0.05	<0.05	<40.0	3220	<40.0	<40.0	<40.0	<40.0	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.18. Column C5 Test Analytical Data (T = 30°C, Flow rate = 10.62 mL/min, Simulant Used = 205.4 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
C5-LD-00	0	5.08	3040	90500	1070	1.46	2.15	<32.5	23900	8900	326	847	956	7970	331
C5-LD-06	6	4.46	2980	89600	1030	1.44	2.11	<32.6	23300	8720	311	814	1160	7750	400
C5-LD-12	12	3.92	2960	89400	1010	1.44	2.09	<32.5	23200	8730	318	827	1180	7805	397
C5-LD-18	18	3.72	2990	89400	1030	1.43	2.07	<32.9	23300	8710	303	818	1150	7735	395
C5-LD-24	24	3.43	2970	85000	1040	1.44	2.11	<32.9	23300	8760	299	837	1170	7715	398
C5-LD-36	36	3.04	3040	92300	1020	1.44	2.09	<32.8	23200	8710	290	832	1210	7780	397
C5-LD-48	48	2.72	3010	89100	1030	1.43	2.09	<33.0	23300	8750	296	825	1160	7770	402
C5-LD-60	60	2.46	2940	89200	1020	1.44	2.10	<32.9	23300	8760	308	823	1150	7795	395
C5-LD-80	80	2.14	2990	79000	1010	1.44	2.10	<32.8	23100	8660	281	832	1140	7840	391
C5-LD-120	120	1.80	2980	88700	1020	1.44	2.09	<33.2	23800	8910	324	839	1170	7830	403
C5-LD-180	180	1.52	2980	87500	1040	1.44	2.09	<32.8	23200	8710	337	809	1170	7770	399
C5-LD-240	240	1.35	2980	85500	1020	1.44	2.10	<32.9	23400	8770	307	815	1160	7650	404
C5-LD-600	600	1.13	2990	89600	1010	1.44	2.10	<32.8	23300	8720	292	826	1170	7630	438
C5-FD-CP	Feed Displacement	0.797	2020	56900	663	0.923	1.31	<35.6	14600	5510	193	519	773	4605	273
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.19. Column D1 Test Analytical Data (T = 25°C, Flow rate = 10.62 mL/min, Simulant Used = 171.4 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D1-LD-00	0	4.97	3470	92200	1060	1.47	2.14	<32.8	23500	9160	342	830	819	7745	295
D1-LD-06	6	4.28	3330	89700	1010	1.40	2.05	<32.8	22500	8760	352	793	835	7555	302
D1-LD-12	12	3.64	3520	89900	1000	1.43	2.03	<32.8	22400	8740	341	790	781	7410	284
D1-LD-18	18	3.29	3390	89200	1000	1.42	2.07	<32.9	22700	8840	283	813	793	7715	277
D1-LD-24	24	2.99	3370	90200	994	1.42	2.08	<32.6	22500	8780	304	841	809	7560	289
D1-LD-36	36	2.46	3430	89500	998	1.42	2.07	<32.6	22800	8820	275	791	754	7485	282
D1-LD-48	48	2.13	3450	89400	997	1.42	2.06	<32.9	22600	8790	350	840	768	7360	284
D1-LD-60	60	1.88	3510	89100	995	1.42	2.09	<32.9	22600	8850	328	824	753	7635	287
D1-LD-80	80	1.57	3370	88700	985	1.44	2.08	<32.7	22500	8720	293	826	784	7695	284
D1-LD-120	120	1.20	3340	90300	1010	1.43	2.09	<32.9	22600	8870	300	813	779	7545	287
D1-LD-180	180	0.922	3470	89400	997	1.42	2.07	<32.8	22700	8720	279	823	777	7465	285
D1-LD-240	240	0.791	3420	89200	988	1.42	2.07	<32.9	22600	8820	332	818	798	7560	292
D1-LD-600	600	0.563	3480	90200	1000	1.42	2.06	<32.9	22600	8830	291	801	752	7840	287
D1-FD-CP	Feed Displacement	0.315	1950	53600	576	0.827	1.18	<36.5	12700	5070	176	465	498	3940	172
D1-EL-CP	Elution	15.8	7.16	1240	68.5	<0.05	<0.05	<39.9	3410	<39.9	<39.9	<39.9	<39.9	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.20. Column D2 Test Analytical Data (T = 25°C, Flow rate = 14.16 mL/min, Simulant Used = 154.2 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D2-LD-00	0	5.03	3570	93300	1080	1.48	2.15	<32.7	24100	9320	318	836	849	7990	286
D2-LD-06	6	4.25	3370	89700	1000	1.42	2.08	<33.1	23300	9070	320	833	841	7735	291
D2-LD-12	12	3.66	3320	87200	1000	1.41	2.06	<33.1	23400	9080	312	827	836	7745	284
D2-LD-18	18	3.20	3390	88800	995	1.42	2.07	<33.3	23300	9060	303	824	834	7875	283
D2-LD-24	24	2.96	3390	89500	1010	1.42	2.07	<33.0	22500	8770	309	818	798	7755	309
D2-LD-36	36	2.52	3470	92200	1050	1.42	2.08	<33.2	21900	9120	291	831	795	7860	286
D2-LD-48	48	2.12	3400	88000	1020	1.42	2.07	<33.4	23100	8960	306	826	806	7730	275
D2-LD-60	60	1.81	3350	87300	995	1.42	2.07	<33.3	23300	9010	308	822	792	7575	290
D2-LD-80	80	1.52	3500	88400	1020	1.42	2.07	<33.2	22700	8740	308	812	780	8080	289
D2-LD-120	120	1.16	3420	90200	1020	1.42	2.08	<33.1	23300	9060	306	825	825	7890	296
D2-LD-180	180	0.873	3290	87700	997	1.42	2.07	<33.2	23300	9120	302	825	805	7205	287
D2-LD-240	240	0.752	3230	87800	998	1.42	2.05	<32.8	23300	9050	307	822	795	7760	296
D2-LD-600	600	0.549	3440	87300	1020	1.41	2.06	<32.9	23100	8990	296	823	792	7915	280
D2-FD-CP	Feed Displacement	0.297	1830	52400	555	0.749	1.07	<37.1	12700	5030	186	462	573	3745	174
D2-EL-CP	Elution	16.5	4.98	1310	72.6	<0.05	<0.05	<40.2	3400	<40.2	<40.2	<40.2	<40.2	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.21. Column D3 Test Analytical Data (T = 25°C, Flow rate = 7.08 mL/min, Simulant Used = 148.3 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D3-LD-00	0	5.38	3480	93200	1060	1.48	2.09	<32.7	24200	9390	321	851	821	8005	281
D3-LD-06	6	4.67	3520	90400	1020	1.42	2.08	<32.7	23200	9000	295	812	788	7855	266
D3-LD-12	12	4.10	3580	90300	1010	1.42	2.07	<32.8	23200	9010	310	819	793	7800	268
D3-LD-18	18	3.66	3530	88800	982	1.42	2.07	<32.9	23400	9060	282	796	760	7975	279
D3-LD-24	24	3.28	3380	87800	972	1.40	2.06	<32.8	23200	9030	304	815	778	7720	266
D3-LD-36	36	2.83	3300	89600	994	1.41	2.06	48.6	23300	8970	307	828	776	7770	269
D3-LD-48	48	2.34	3420	87400	976	1.42	2.07	<32.8	22700	8800	292	821	768	7430	265
D3-LD-60	60	2.03	3330	90800	995	1.41	2.06	<32.9	23000	8910	289	807	744	7770	281
D3-LD-80	80	1.68	3470	88700	990	1.41	2.05	<32.9	23100	8990	281	821	760	7840	289
D3-LD-120	120	1.21	3430	88300	968	1.42	2.08	<32.8	23200	8990	299	824	784	7870	263
D3-LD-180	180	0.913	3500	88600	977	1.41	2.06	<32.9	23300	9050	292	1070	787	7740	269
D3-LD-240	240	0.752	3460	88700	992	1.40	2.04	<32.9	23100	9070	293	813	762	7855	261
D3-LD-600	600	0.528	3400	88700	996	1.40	2.05	<32.7	23200	9000	279	806	747	7680	266
D3-FD-CP	Feed Displacement	0.381	2010	55500	591	0.848	1.21	43.3	13200	5220	198	495	502	4370	176
D3-EL-CP	Elution	15.5	4.25	1250	66.0	<0.05	<0.05	<39.7	3610	<39.7	<39.7	<39.7	<39.7	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.22. Column D4 Test Analytical Data (T = 25°C, Flow rate = 10.62 mL/min, Simulant Used = 147.7 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D4-LD-00	0	5.03	3310	92100	1070	1.48	2.15	<32.4	24200	9400	315	863	800	7590	289
D4-LD-06	6	4.09	3160	87900	1010	1.43	2.07	<33.1	23100	8930	315	864	788	7700	288
D4-LD-12	12	3.62	3140	88200	1010	1.42	2.07	<33.1	23200	8990	295	815	738	7650	273
D4-LD-18	18	3.29	3660	91100	1030	1.45	2.11	<49.5	23000	8850	316	818	812	7635	290
D4-LD-24	24	2.86	3520	89200	1020	1.41	2.08	<49.4	23000	8860	325	813	780	7700	275
D4-LD-36	36	2.36	3380	87900	1000	1.41	2.07	<49.6	23100	8950	301	811	792	7790	280
D4-LD-48	48	2.02	3460	88300	1030	1.41	2.06	<50.3	22900	8870	302	811	777	7710	279
D4-LD-60	60	1.76	3440	90100	1000	1.43	2.08	<49.4	23000	8850	295	804	765	7700	281
D4-LD-80	80	1.43	3490	88300	1010	1.43	2.07	<52.7	23000	8880	302	839	764	7705	281
D4-LD-120	120	1.08	3180	89500	1000	1.42	2.08	<32.8	23300	9030	293	837	767	7705	284
D4-LD-180	180	0.826	3570	87600	998	1.42	2.07	<49.4	22800	8830	306	834	785	7620	285
D4-LD-240	240	0.721	3490	88300	1000	1.41	2.07	<49.5	22900	8880	311	821	787	7340	280
D4-LD-600	600	0.539	3610	89200	1020	1.43	2.09	<48.9	23000	8870	309	818	762	7670	285
D4-FD-CP	Feed Displacement	0.293	1860	58500	580	0.827	1.16	<37.0	14000	5520	185	496	478	4135	166
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.23. Column D4B Test Analytical Data (T = 45°C, Flow rate = 0.08 mL/min, Simulant Used = 159.9 mL)

Sample ID	Loading Time (hr)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D4B-LD-00	0	5.07	3300	93300	1100	1.51	2.20	<32.6	24600	9480	327	846	807	8200	304
D4B-LD-04	4	4.69	3250	91400	1070	1.42	2.09	<32.8	23600	9100	312	860	782	7745	276
D4B-LD-08	8	4.17	3180	89900	1040	1.42	2.05	<32.7	23600	9160	316	848	784	7735	277
D4B-LD-12	12	3.95	3260	92400	1090	1.43	2.09	<32.9	23600	9130	318	849	785	7625	280
D4B-LD-24	24	2.98	3190	90400	1050	1.42	2.09	<32.5	23400	9110	307	850	775	7815	280
D4B-LD-72	72	1.90	3190	93400	1110	1.42	2.08	<32.6	23200	9000	300	865	798	7960	285
D4B-LD-120	120	3.79	3220	90900	1060	1.46	2.13	36.9	23900	9280	319	878	792	7990	294
D4B-LD-168	168	2.04	3310	92300	1100	1.48	2.17	<32.7	24400	9440	327	871	795	8025	305
D4B-LD-336	336	2.02	3450	89600	1040	1.48	2.18	<33.8	24400	8890	329	852	823	8320	336
D4B-LD-504	504	2.19	3760	90100	1130	1.57	2.34	<32.8	25600	9460	343	898	871	9140	372
D4B-LD-672	672					1.88	2.79	<32.5	30100	11100	430	1120	1020	10750	434
D4B-LD-720	720					1.91	2.83	<32.5	30000	11100	405	1050	969	10750	437
D4B-FD-CP	Feed Displacement	1.74	2730	69500	844	1.20	1.74	<38.8	18600	7200	277	673	896	6055	397
D4B-EL-CP	Elution	25.9	58.7	1220	46.3	<0.05	<0.05	<39.8	3630	<39.8	<39.8	<39.8	<39.8	<25.0	<10.0
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.24. Column D5 Test Analytical Data (T = 25°C, Flow rate = 10.62 mL/min, Simulant Used = 203.7 mL)

Sample ID	Loading Time (min)	Cs (mg/kg)	Al (mg/kg)	Na (mg/kg)	K (mg/kg)	OH-Free (meq/mL)	OH-Total (meq/mL)	Cl (mg/kg)	NO_3 as N (mg/kg)	NO_2 as N (mg/kg)	PO_4 as P (mg/kg)	SO_4 (mg/kg)	C_2O_4 (mg/kg)	TIC (mg/L)	TOC (mg/L)
D5-LD-00	0	5.07	3410	89300	1020	1.47	2.14	<32.7	24500	8960	319	838	1020	7870	343
D5-LD-06	6	4.39	3380	85500	998	1.44	2.09	<32.7	23600	8640	308	825	1140	7835	411
D5-LD-12	12	3.99	3200	77100	942	1.47	2.13	<32.9	23000	8870	312	836	1190	6425	349
D5-LD-18	18	3.66	3420	78500	975	1.45	2.11	<32.8	23500	8610	305	807	1140	7720	391
D5-LD-24	24	3.35	3390	85800	992	1.43	2.08	<33.3	23300	8500	293	834	1150	7705	399
D5-LD-36	36	2.94	2990	87700	988	1.43	2.09	<33.1	23500	8520	312	825	1180	7585	388
D5-LD-48	48	2.57	3400	86800	976	1.48	2.15	<26.8	23600	9110	330	849	1150	6490	407
D5-LD-60	60	2.37	3460	88400	1020	1.42	2.08	<33.1	23700	8620	324	827	1110	7695	394
D5-LD-80	80	2.00	3430	87000	1000	1.42	2.08	<32.8	23500	8540	320	827	1140	7875	411
D5-LD-120	120	1.63	3490	79300	1010	1.44	2.09	<32.9	22900	8790	308	817	1170	8035	396
D5-LD-180	180	1.29	3470	79800	1010	1.43	2.10	<33.0	23400	8520	308	820	1140	7795	396
D5-LD-240	240	1.10	3360	83100	967	1.45	2.11	<33.0	23400	8580	341	817	1160	7725	407
D5-LD-600	600	0.817	3480	82600	1000	1.44	2.09	<32.4	23300	8470	300	829	1160	8110	444
D5-FD-CP	Feed Displacement	0.496	1900	50300	558	0.843	1.19	<36.8	13100	4930	181	490	672	4085	249
Target	--	4.86	3280	93200	951	1.20	2.01	0	23100	9430	326	856	1210	7960	408

Table B.25. Datasheet for 50°C Batch Loading Tests

					Initial Concentrations					Final Concentrations				
Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-LL-1	1A	0.2189	24.8113	1.00	0.679	2340	193	0.101	72.3	0.0100	2370	137	0.0947	72.2
Test-5-Na-LL-2	2A	0.2204	25.5372	1.02	0.653	11300	191	0.100	5280	0.0184	11400	172	0.0953	5480
Test-5-Na-LL-3	3A	0.2205	25.8469	1.04	0.677	16400	193	0.100	8640	0.0266	17000	179	0.0950	8670
Test-5-Na-LL-4	4A	0.2206	26.1507	1.05	0.631	21600	189	0.100	12000	0.0301	22500	181	0.0951	12100
Test-5-Na-LL-5	5A	0.2219	28.7257	1.15	0.481	47800	148	0.101	36600	0.0775	61200	188	0.0941	36700
Test-5-Na-LL-6	6A	0.2193	31.3679	1.25	0.580	90200	442	0.100	55200	0.132	92300	448	0.0931	54600
Test-5-Na-MM-1	7A	0.2220	25.0646	1.01	0.657	2310	1870	0.101	687	0.0474	2490	1670	0.0966	696
Test-5-Na-MM-2	8A	0.2215	25.5566	1.03	0.656	11300	1880	0.100	5910	0.0633	11700	1850	0.0958	6020
Test-5-Na-MM-3	9A	0.2202	25.8741	1.04	0.658	16300	1880	0.101	9080	0.0757	17400	1870	0.0958	9110
Test-5-Na-MM-4	10A	0.2187	26.1595	1.05	0.643	21900	1900	0.101	12500	0.0801	22600	1850	0.0957	12500
Test-5-Na-MM-5	11A	0.2241	28.7331	1.16	0.607	58300	1810	0.100	36600	0.136	61200	1890	0.0942	36900
Test-5-Na-MM-6	12A	0.2224	31.2936	1.26	0.659	107000	2080	0.0997	55200	0.176	93000	1780	0.0928	55100
Test-5-Na-NN-1	13A	0.2225	26.0848	1.04	0.738	21600	199	0.993	71.6	0.0388	22600	185	0.983	70.9
Test-5-Na-NN-2	14A	0.2278	28.5587	1.14	0.030	59400	191	0.988	25100	<0.00879	59500	188	0.978	25300
Test-5-Na-NN-3	15A	0.2216	31.0837	1.24	0.596	92100	181	0.993	46000	0.118	84300	185	0.978	46800
Test-5-Na-OO-1	16A	0.2205	25.8754	1.04	0.793	21600	1890	0.993	659	0.0890	22500	1870	0.978	662
Test-5-Na-OO-2	17A	0.2180	28.3813	1.14	0.613	58400	1840	0.993	25800	0.134	60800	1870	0.978	25900
Test-5-Na-OO-3	18A	0.2208	30.8050	1.24	0.604	90500	1720	0.993	47200	0.198	93500	1780	0.972	47300
Test-5-Na-A-1	1	0.2169	24.8207	1.00	6.32	2300	177	0.0954	68.0	0.121	2310	141	0.0964	68.4
Test-5-Na-A-2	2	0.2197	25.6030	1.02	6.39	10800	181	0.100	5630	0.289	10700	166	0.0988	5820
Test-5-Na-A-3	3	0.2173	25.7820	1.04	6.31	16400	187	0.0985	8210	0.412	16600	179	0.0953	7750
Test-5-Na-A-4	4	0.2216	26.2668	1.05	6.45	22200	190	0.0990	11300	0.524	22200	176	0.0947	11100
Test-5-Na-A-5	5	0.2232	28.7178	1.16	5.89	59100	187	0.0979	35400	1.22	58500	179	0.0931	35300
Test-5-Na-A-6	6	0.2202	31.1913	1.26	0.00371	88600	178	0.0983	54800	<0.003	89400	178	0.0926	54500
Test-5-Na-B-1	7	0.2234	25.0270	1.00	6.45	2230	1860	0.0982	653	0.555	2490	1690	0.0963	644
Test-5-Na-B-2	8	0.2219	25.6131	1.03	6.64	10900	1850	0.101	6310	0.777	10500	1750	0.0976	6520

Table B.25. (contd)

Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Initial Concentrations					Final Concentrations				
					Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-B-3	9	0.2196	25.9791	1.04	6.33	16500	1870	0.0976	8720	1.02	17000	1820	0.0941	8690
Test-5-Na-B-4	10	0.2222	26.1587	1.05	6.02	21700	1840	0.0983	11200	1.08	22200	1800	0.0958	11700
Test-5-Na-B-5	11	0.2201	28.8143	1.16	5.59	58200	1770	0.0979	35600	1.68	59500	1720	0.0940	35500
Test-5-Na-B-6	12	0.2212	31.5647	1.25	5.38	89800	1680	0.0982	55000	2.23	90800	1650	0.0933	55200
Test-5-Na-C-1	13	0.2212	25.7480	1.04	6.35	22000	188	0.998	69.1	0.382	22200	174	0.998	68.5
Test-5-Na-C-2	14	0.2207	28.5969	1.14	5.84	59900	182	0.993	24200	1.07	60600	177	0.983	21700
Test-5-Na-C-3	15	0.2229	30.7547	1.24	5.39	87100	168	0.998	46500	1.59	87000	168	0.979	44700
Test-5-Na-D-1	16	0.2210	25.7644	1.04	6.46	22700	1920	0.993	624	0.803	22200	1810	0.988	619
Test-5-Na-D-2	17	0.2217	28.3663	1.14	5.97	59900	1810	0.993	24800	1.58	61000	1810	0.983	24700
Test-5-Na-D-3	18	0.2257	30.8073	1.25	5.60	88100	1690	0.995	46100	2.09	87700	1630	0.974	45600
Test-5-Na-Q-1	37	0.2195	24.8167	1.00	67.5	2280	186	0.0982	90.2	3.00	2270	145	0.0850	69.9
Test-5-Na-Q-2	38	0.2198	25.3875	1.02	58.8	11000	183	0.0988	5660	7.62	11100	176	0.0968	5580
Test-5-Na-Q-3	39	0.2167	25.6805	1.04	67.5	16600	190	0.0981	8110	12.6	16900	189	0.0953	8180
Test-5-Na-Q-4	40	0.2208	26.1055	1.05	65.6	22000	189	0.0984	11100	14.8	21600	183	0.0953	11200
Test-5-Na-Q-5	41	0.2216	28.5678	1.16	53.8	58000	197	0.0980	33900	22.1	57400	191	0.0939	33700
Test-5-Na-Q-6	42	0.2200	31.0579	1.26	59.0	89300	178	0.0974	53600	33.2	89300	175	0.0934	54000
Test-5-Na-R-1	43	0.2182	24.8804	1.00	71.1	2270	1900	0.0986	656	10.6	2360	1690	0.0971	693
Test-5-Na-R-2	44	0.2253	25.5213	1.03	79.0	10700	1840	0.0951	6310	18.6	11000	1790	0.0925	6180
Test-5-Na-R-3	45	0.2184	26.0430	1.04	65.4	16600	1930	0.0984	8710	17.4	16600	1840	0.0961	8730
Test-5-Na-R-4	46	0.2183	26.2110	1.05	66.7	21700	1890	0.0985	11700	20.4	21500	1850	0.0943	11700
Test-5-Na-R-5	47	0.2158	28.5280	1.16	69.5	58600	1840	0.0978	34700	34.2	58500	1820	0.0946	33900
Test-5-Na-R-6	48	0.2195	31.0752	1.26	59.0	89600	1740	0.0977	53900	28.1	87500	1720	0.0937	54700
Test-5-Na-S-1	49	0.2196	25.9241	1.04	65.9	21900	187	0.988	68.1	8.47	21700	164	0.972	68.1
Test-5-Na-S-2	50	0.2207	28.5037	1.14	66.2	58200	204	0.988	23400	23.3	58800	198	0.983	23400
Test-5-Na-S-3	51	0.2208	30.7745	1.24	55.8	87900	174	0.989	46300	28.5	90100	174	0.979	42700
Test-5-Na-T-1	52	0.2227	25.8485	1.04	63.3	21500	1920	0.993	624	12.7	21500	1800	0.983	655

Table B.25. (contd)

Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Initial Concentrations					Final Concentrations				
					Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-T-2	53	0.2241	28.5346	1.14	60.2	57500	1750	0.995	25900	24.5	58800	1750	0.984	23300
Test-5-Na-T-3	54	0.2224	30.9574	1.24	53.6	88600	1660	0.995	47200	28.4	89200	1690	0.979	42600
Test-5-Na-Y-1	55	0.2231	25.0438	1.00	647	2230	190	0.101	134	159	2340	160	0.0978	131
Test-5-Na-Y-2	56	0.2219	25.4408	1.03	637	10800	179	0.0945	5750	317	11000	171	0.0898	5660
Test-5-Na-Y-3	57	0.2214	25.8376	1.04	637	16600	195	0.101	8050	340	16700	185	0.0964	8250
Test-5-Na-Y-4	58	0.2199	26.1558	1.05	617	21400	186	0.101	11100	358	21700	181	0.0960	11100
Test-5-Na-Y-5	59	0.2214	28.7729	1.16	578	58000	189	0.100	34300	420	57700	181	0.0944	34000
Test-5-Na-Y-6	60	0.2232	31.2851	1.26	536	89600	183	0.100	53500	424	88600	178	0.0932	52200
Test-5-Na-Z-1	61	0.2243	24.9957	1.01	651	2170	1880	0.0986	713	258	2370	1690	0.0955	748
Test-5-Na-Z-2	62	0.2191	25.4883	1.03	629	10800	1860	0.0990	6330	350	11300	1840	0.0905	6240
Test-5-Na-Z-3	63	0.2227	25.8878	1.04	639	16300	1930	0.101	8810	359	16200	1790	0.0960	8620
Test-5-Na-Z-4	64	0.2216	26.2032	1.05	622	21500	1950	0.101	11600	385	21200	1840	0.0969	11700
Test-5-Na-Z-5	65	0.2226	28.8929	1.16	560	58000	1850	0.100	34700	405	57600	1780	0.0942	34600
Test-5-Na-Z-6	66	0.2216	31.2591	1.26	519	89600	1780	0.100	54000	430	89600	1710	0.0940	53200
Test-5-Na-AA-1	67	0.2212	25.9060	1.04	629	21100	192	0.993	129	297	22900	197	0.978	123
Test-5-Na-AA-2	68	0.2189	28.3724	1.13	574	57600	189	0.983	23300	500	75200	235	0.972	23600
Test-5-Na-AA-3	69	0.2202	30.8017	1.24	521	88300	183	0.989	46200	391	86200	178	0.979	44100
Test-5-Na-BB-1	70	0.2217	26.0996	1.04	628	21200	1910	0.988	712	330	23000	1970	0.983	719
Test-5-Na-BB-2	71	0.2225	28.2844	1.15	562	52800	1740	0.995	25600	404	56900	1700	0.979	24100
Test-5-Na-BB-3	72	0.2218	31.0622	1.24	528	88700	1690	0.995	47300	408	86300	1630	0.979	44500

Table B.26. Datasheet for 25°C Batch Loading Tests

					Initial Concentrations					Final Concentrations				
Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-QQ-1	1A	0.2193	24.7812	1.00	0.679	2340	193	0.101	72.3	<0.00997	2260	132	0.0969	71.6
Test-5-Na-QQ-2	2A	0.2185	25.5703	1.02	0.653	11300	191	0.100	5280	0.0183	11000	167	0.0955	5330
Test-5-Na-QQ-3	3A	0.2226	25.7690	1.04	0.677	16400	193	0.100	8640	0.0178	16600	171	0.0948	8490
Test-5-Na-QQ-4	4A	0.2224	26.0461	1.05	0.631	21600	189	0.100	12000	0.0214	22100	181	0.0945	11700
Test-5-Na-QQ-5	5A	0.2238	28.7336	1.15	0.481	47800	148	0.101	36600	0.0345	59300	183	0.0937	41900
Test-5-Na-QQ-6	6A	0.2209	31.3590	1.25	0.580	90200	442	0.100	55200	0.0658	92200	438	0.0921	67700
Test-5-Na-RR-1	7A	0.2208	24.9527	1.01	0.657	2310	1870	0.101	687	0.0284	2390	1620	0.0863	853
Test-5-Na-RR-2	8A	0.2206	25.3683	1.03	0.656	11300	1880	0.100	5910	0.0386	11000	1770	0.0951	5690
Test-5-Na-RR-3	9A	0.2201	25.8808	1.04	0.658	16300	1880	0.101	9080	0.0381	16500	1780	0.0942	9060
Test-5-Na-RR-4	10A	0.2197	26.3019	1.05	0.643	21900	1900	0.101	12500	0.0530	22200	1830	0.0945	12600
Test-5-Na-RR-5	11A	0.2205	28.8853	1.16	0.607	58300	1810	0.100	36600	0.0745	58100	1780	0.0928	36000
Test-5-Na-RR-6	12A	0.2212	31.3175	1.26	0.659	107000	2080	0.0997	55200	0.0931	89300	1670	0.0920	54600
Test-5-Na-SS-1	13A	0.2176	25.9331	1.04	0.738	21600	199	0.993	71.6	0.0196	21600	174	0.983	72.4
Test-5-Na-SS-2	14A	0.2206	28.5491	1.14	0.030	59400	191	0.988	25100	<0.00878	59300	184	0.972	24800
Test-5-Na-SS-3	15A	0.2194	30.8957	1.24	0.596	92100	181	0.993	46000	0.0696	89800	177	0.978	46300
Test-5-Na-TT-1	16A	0.2215	25.9330	1.04	0.793	21600	1890	0.993	659	0.0689	22200	1820	0.983	661
Test-5-Na-TT-2	17A	0.2196	28.4645	1.14	0.613	58400	1840	0.993	25800	0.0655	58300	1800	0.993	25600
Test-5-Na-TT-3	18A	0.2228	30.8095	1.24	0.604	90500	1720	0.993	47200	0.0929	90400	1760	0.978	46400
Test-5-Na-E-1	1	0.2182	24.9162	1.00	6.32	2300	177	0.0954	68.0	0.106	2330	133	0.0984	67.0
Test-5-Na-E-2	2	0.2220	25.5521	1.02	6.39	10800	181	0.100	5630	0.303	10800	167	0.0972	5850
Test-5-Na-E-3	3	0.2229	25.7614	1.04	6.31	16400	187	0.0985	8210	0.252	16200	169	0.0952	8190
Test-5-Na-E-4	4	0.2166	26.2079	1.05	6.45	22200	190	0.0990	11300	0.346	21900	176	0.0951	11300
Test-5-Na-E-5	5	0.2179	28.6561	1.16	5.89	59100	187	0.0979	35400	0.770	58200	173	0.0932	35300
Test-5-Na-E-6	6	0.2218	30.8073	1.26	0.00371	88600	178	0.0983	54800	0.00321	92600	178	0.0926	55100
Test-5-Na-F-1	7	0.2206	24.9162	1.00	6.45	2230	1860	0.0982	653	0.397	2380	1670	0.0947	630
Test-5-Na-F-2	8	0.2183	25.5521	1.03	6.64	10900	1850	0.101	6310	0.537	10600	1720	0.0969	6400

Table B.26. (contd)

Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Initial Concentrations					Final Concentrations				
					Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-F-3	9	0.2190	26.0098	1.04	6.33	16500	1870	0.0976	8720	0.605	16100	1830	0.0945	8780
Test-5-Na-F-4	10	0.2196	26.1329	1.05	6.02	21700	1840	0.0983	11200	0.661	21400	1820	0.0953	11700
Test-5-Na-F-5	11	0.2172	28.7954	1.16	5.59	58200	1770	0.0979	35600	1.17	58100	1770	0.0939	35300
Test-5-Na-F-6	12	0.2205	31.3886	1.26	5.38	89800	1680	0.0982	55000	1.56	89400	1700	0.0933	55100
Test-5-Na-G-1	13	0.2160	25.8255	1.04	6.35	22200	188	0.998	69.1	0.226	22000	176	0.978	67.3
Test-5-Na-G-2	14	0.2181	28.5630	1.14	5.84	59900	182	0.993	24200	0.556	58000	169	0.978	24000
Test-5-Na-G-3	15	0.2229	30.7148	1.25	5.39	87100	168	0.998	46500	1.22	87200	168	0.974	44600
Test-5-Na-H-1	16	0.2194	25.9236	1.04	6.46	22700	1920	0.993	624	0.521	22200	1840	0.978	626
Test-5-Na-H-2	17	0.2206	28.4521	1.14	5.97	59900	1810	0.993	24800	0.941	58800	1770	0.978	24600
Test-5-Na-H-3	18	0.2226	30.9054	1.25	5.60	88100	1690	0.995	46100	1.61	86600	1640	0.979	45300
Test-5-Na-U-1	37	0.2180	25.0587	1.00	67.5	2280	186	0.0982	90.2	2.06	2290	132	0.0963	76.8
Test-5-Na-U-2	38	0.2202	25.6184	1.02	58.8	11000	183	0.0988	5660	5.13	11100	174	0.0915	5610
Test-5-Na-U-3	39	0.2215	25.6966	1.04	67.5	16600	190	0.0981	8110	8.39	16900	180	0.0930	8030
Test-5-Na-U-4	40	0.2238	26.0473	1.05	65.6	22000	189	0.0984	11100	9.72	22100	183	0.0932	11100
Test-5-Na-U-5	41	0.2201	28.7124	1.16	53.8	58000	197	0.0980	33900	15.7	58700	188	0.0934	34000
Test-5-Na-U-6	42	0.2215	31.0854	1.26	59.0	89300	178	0.0974	53600	29.3	106000	199	0.0926	53500
Test-5-Na-V-1	43	0.2230	24.8652	1.00	71.1	2270	1900	0.0986	656	6.35	2300	1580	0.0957	709
Test-5-Na-V-2	44	0.2211	25.8312	1.03	79.0	10700	1840	0.0951	6310	14.1	11100	1760	0.0900	6090
Test-5-Na-V-3	45	0.2240	25.9351	1.04	65.4	16600	1930	0.0984	8710	11.7	16800	1820	0.0927	8650
Test-5-Na-V-4	46	0.2201	26.2559	1.05	66.7	21700	1890	0.0985	11700	15.3	22500	1860	0.0936	11500
Test-5-Na-V-5	47	0.2201	28.6834	1.16	69.5	58600	1840	0.0978	34700	26.7	58300	1780	0.0925	34900
Test-5-Na-V-6	48	0.2217	31.1638	1.26	59.0	89600	1740	0.0977	53900	21.7	91200	1710	0.0922	53700
Test-5-Na-W-1	49	0.2191	25.8934	1.04	65.9	21900	187	0.988	68.1	5.39	21300	163	0.972	67.0
Test-5-Na-W-2	50	0.2200	28.4822	1.14	66.2	58200	204	0.988	23400	18.1	57800	189	0.978	23300
Test-5-Na-W-3	51	0.2233	30.7264	1.24	55.8	87900	174	0.989	46300	21.8	90200	171	0.979	44400

Table B.26. (contd)

Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Initial Concentrations					Final Concentrations				
					Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-X-1	52	0.2199	25.9427	1.04	63.3	21500	1920	0.993	624	8.67	21600	1770	0.983	651
Test-5-Na-X-2	53	0.2213	28.3615	1.14	60.2	57500	1750	0.995	25900	19.0	57900	1710	0.979	24400
Test-5-Na-X-3	54	0.2208	30.9159	1.24	53.6	88600	1660	0.995	47200	23.3	88700	1650	0.979	45100
Test-5-Na-CC-1	55	0.2197	25.0134	1.00	647	2230	190	0.101	134	158	2380	171	0.0972	127
Test-5-Na-CC-2	56	0.2218	25.4572	1.03	637	10800	179	0.0945	5750	284	11000	172	0.0949	5960
Test-5-Na-CC-3	57	0.2196	25.8235	1.04	637	16600	195	0.101	8050	326	16700	189	0.0951	8170
Test-5-Na-CC-4	58	0.2207	26.2880	1.05	617	21400	186	0.101	11100	345	22000	189	0.0947	11300
Test-5-Na-CC-5	59	0.2191	28.8083	1.16	578	58000	189	0.100	34300	387	59100	191	0.0950	34400
Test-5-Na-CC-6	60	0.2204	31.3754	1.26	536	89600	183	0.100	53500	396	91000	182	0.0945	53800
Test-5-Na-DD-1	61	0.2215	25.0416	1.01	651	2170	1880	0.0986	713	214	2360	1970	0.0953	752
Test-5-Na-DD-2	62	0.2237	25.4940	1.03	629	10800	1860	0.0990	6330	314	10500	1760	0.0948	6480
Test-5-Na-DD-3	63	0.2181	25.9740	1.04	639	16300	1930	0.101	8810	343	17100	1960	0.0962	8720
Test-5-Na-DD-4	64	0.2220	26.1801	1.05	622	21500	1950	0.101	11600	348	21200	1910	0.0947	11700
Test-5-Na-DD-5	65	0.2190	28.7919	1.16	560	58000	1850	0.100	34700	387	60100	1890	0.0944	33700
Test-5-Na-DD-6	66	0.2229	31.3991	1.26	519	89600	1780	0.100	54000	402	90800	1840	0.0943	53700
Test-5-Na-EE-1	67	0.2190	25.8682	1.04	629	21100	192	0.993	129	250	22000	191	0.983	123
Test-5-Na-EE-2	68	0.2217	28.4064	1.13	574	57600	189	0.983	23300	353	60700	193	0.983	23700
Test-5-Na-EE-3	69	0.2211	30.7135	1.24	521	88300	183	0.989	46200	377	86900	180	0.974	44900
Test-5-Na-FF-1	70	0.2196	25.9979	1.04	628	21200	1910	0.988	712	306	22000	1940	0.978	714
Test-5-Na-FF-2	71	0.2198	28.4892	1.15	562	52800	1740	0.995	25600	377	56400	1720	0.979	24800
Test-5-Na-FF-3	72	0.2216	30.9601	1.24	528	88700	1690	0.995	47300	400	87600	1680	0.979	46000

Table B.27. Datasheet for 35°C Batch Loading Tests

					Initial Concentrations					Final Concentrations				
Sample ID	Simulant ID Used	Resin Wt Added (g)	Feed Solution Added (g)	Density (g/mL)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)	Cs (mg/kg)	Na (mg/kg)	K (mg/kg)	OH (M)	NO_3 as N (mg/kg)
Test-5-Na-GG-1	72	0.2214	30.6308	1.24	528	88700	1690	0.995	47300	389	86300	1650	0.982	46600
Test-5-Na-GG-2	54	0.2253	30.7515	1.24	53.6	88600	1660	0.995	47200	23.2	89800	1680	0.989	47200
Test-5-Na-GG-3	36	0.2170	30.7809	1.24	54.5	87900	1670	0.995	46200	26.0	89300	1680	0.979	46900
Test-5-Na-PP-1	18A	0.2222	30.8588	1.24	0.604	90500	1720	0.993	47200	0.120	90200	1730	0.978	46800
Test-5-Na-HH-1	69	0.2199	30.6352	1.24	521	88300	183	0.989	46200	370	88900	180	0.979	46200
Test-5-Na-HH-2	51	0.2167	30.7031	1.24	55.8	87900	174	0.989	46300	25.0	88700	171	0.984	46100
Test-5-Na-HH-3	33	0.2208	30.7555	1.24	54.6	88700	170	0.995	45100	23.1	89100	167	0.979	45800
Test-5-Na-PP-2	15A	0.2196	30.7681	1.24	0.596	92100	181	0.993	46000	0.0668	90600	175	0.983	46400
Test-5-Na-II-1	62	0.2262	25.5009	1.03	629	10800	1860	0.0990	6330	306	10700	1760	0.0948	6300
Test-5-Na-II-2	44	0.2194	25.6125	1.03	79.0	10700	1840	0.0951	6310	17.1	11100	1780	0.0917	6260
Test-5-Na-II-3	26	0.2193	25.5171	1.03	64.4	10800	1840	0.0955	6190	12.9	10900	1770	0.0905	6260
Test-5-Na-PP-3	8A	0.2192	25.6220	1.03	0.656	11300	1880	0.100	5910	0.0490	11000	1770	0.0954	6030
Test-5-Na-JJ-1	56	0.2208	25.3575	1.03	637	10800	179	0.0945	5750	286	10900	167	0.0894	5750
Test-5-Na-JJ-2	38	0.2221	25.3418	1.02	58.8	11000	183	0.0988	5660	5.40	10800	166	0.0884	5690
Test-5-Na-JJ-3	20	0.2227	25.3067	1.02	64.9	10700	180	0.0983	5680	6.97	10900	168	0.0880	5730
Test-5-Na-PP-4	2A	0.2192	25.5606	1.02	0.653	11300	191	0.100	5280	0.0192	11100	170	0.0963	5450
Test-5-Na-KK-1	53	0.2243	28.4964	1.14	60.2	57500	1750	0.995	25900	20.5	56700	1700	0.979	25300
Test-5-Na-KK-2	71	0.2284	28.3653	1.15	562	52800	1740	0.995	25600	381	57900	1730	0.984	25600

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