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SB10 Frit Recommendation, and Evaluations of the Glass Variability Study and Cs-137 Concentrations in Strip Effluent Based on May 2021 Projections

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EXECUTIVE SUMMARY

The Defense Waste Processing Facility (DWPF) is currently preparing to initiate processing of Sludge Batch 10 (SB10), which is comprised of material from Tanks 11H, 13H, 15H, and 26F, Alternate Feed Stock-2 (AFS-2) and Sodium Reactor Experiment (SRE) material from H-Canyon. In support of SB10 qualification, frit development using 2020 Tank 40 blend projections and experimental work for the glass variability study were previously conducted. Frit 473 and Frit 209 were identified as candidate frits and both were included in the development of the variability study test matrix; however, a final frit recommendation was postponed until more information could be determined about the composition of SB10 after washing. In May 2021, Savannah River Remediation (SRR) reprojected SB10 based on the analytical results from the Tank 51 qualification sample that was washed in the Savannah River National Laboratory (SRNL) Shielded Cells Facility. The objectives of this task were to:

- Identify a viable frit for SB10 sludge-only (SO) and coupled operation with the Salt Waste Processing Facility (SWPF)
- Determine if any composition gaps exist between the already completed SB10 variability study and the reprojected SB10 glass composition region
- Compare the SB10 glass composition region to the DWPF Product Composition Control System (PCCS) model development and validation ranges to ensure that compositional gaps do not exist between the data sets

This report documents the results of these evaluations and an additional request for an analysis of the projected Cs_2O concentration in glass as a function of the assumed Cs-137 concentration in strip effluent (SE).

Calculation-based frit assessments were performed using the DWPF PCCS glass property models and their associated Measurement Acceptance Region (MAR) constraints. Frit 473 and Frit 209 were evaluated along with a large array of frits covering the B_2O_3-Li_2O-Na_2O-SiO_2 region. Based on MAR assessments of 1M Na wash endpoint Tank 40 blend projections, Frit 473 ($8B_2O_3$-$8Li_2O$-$5Na_2O$-$79SiO_2$ (wt.%)) is recommended for SB10 processing. A target waste loading (WL) of 36% ± 4 percentage points is possible for single strike coupled processing at a nominal Sludge Solids Receipt Tank (SSRT) transfer volume of ~2800 gallons. Increasing the single strike SSRT transfer volume to 4500 gallons demonstrates that there are only incremental reductions to maximum WLs and operating windows. Due to the compositional shifts for SO operation and double strike coupled processing, reductions in the maximum WL and operating window are observed for both of these scenarios.

The reprojected SB10 glass composition region generally overlaps the previously evaluated SB10 variability study composition region. Thus, the minor composition shift of SB10 in the May 2021 projections indicates that no additional glasses are necessary to demonstrate acceptability relative to the chemical durability of the Environmental Assessment (EA) benchmark glass and predictability using the current PCCS models for durability. Based on a comparison of the PCCS model development and validation data to the SB10 glass composition region, the viscosity and liquidus temperature models will reliably predict SB10 compositions. No additional glasses are necessary to demonstrate predictability of these models.

Total Cs becomes reportable in glass at 36% WL once the Cs-137 concentration reaches 14-34 Ci/gal in the SE based on the assumptions and inputs used for this evaluation. The concentration depends on the volume of the transfer (15,000 versus 22,000 gallons) and the extractant (BOBCalixC6 versus Next Generation Solvent).

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AFS-2	Alternate Feed Stock-2
BC	BOBCalixC6
DWPF	Defense Waste Processing Facility
EVs	extreme vertices
ISS	insoluble sludge solids
MAR	Measurement Acceptance Region
MST	monosodium titanate
NGS	Next Generation Solvent
PCCS	Product Composition Control System
SB10	Sludge Batch 10
SB9	Sludge Batch 9
SE	strip effluent
SEFT	Strip Effluent Feed Tank
SME	Slurry Mix Evaporator
SO	sludge-only
SRAT	Sludge Receipt and Adjustment Tank
SRE	Sodium Reactor Experiment
SRNL	Savannah River National Laboratory
SRR	Savannah River Remediation
SS	sludge solids
SSRT	Sludge Solids Receipt Tank
SWPF	Salt Waste Processing Facility
TTQAP	Task Technical and Quality Assurance Plan
TTR	Technical Task Request
WL	waste loading
wt.%	weight percent

1.0 Introduction

The Defense Waste Processing Facility (DWPF) is currently preparing to initiate processing of Sludge Batch 10 (SB10), which is comprised of material from Tanks 11H, 13H, 15H, and 26F, Alternate Feed Stock-2 (AFS-2) and Sodium Reactor Experiment (SRE) material from H-Canyon. In support of SB10 qualification, frit development using 2020 Tank 40 blend projections and experimental work for the glass variability study were previously conducted.[1,2] Frit 473 and Frit 209 were identified as candidate frits and both were included in the development of the variability study test matrix; however, a final frit recommendation was postponed until more information could be determined about the composition of SB10 after washing. In May 2021, Savannah River Remediation (SRR) reprojected SB10 based on the analytical results from the Tank 51 qualification sample that was washed in the Savannah River National Laboratory (SRNL) Shielded Cells Facility.[3] The objectives of this task were to:

- Identify a viable frit for SB10 sludge-only (SO) and coupled operation with the Salt Waste Processing Facility (SWPF)
- Determine if any composition gaps exist between the already completed SB10 variability study and the reprojected SB10 glass composition region
- Compare the SB10 glass composition region to the DWPF Product Composition Control System (PCCS) model development and validation ranges to ensure that compositional gaps do not exist between the data sets

This report documents the results of these evaluations and an additional analysis of the projected Cs_2O concentration in glass as a function of the assumed Cs-137 concentration in strip effluent (SE).

2.0 Quality Assurance

This work was requested via a Technical Task Request (TTR)[4] and directed by a Task Technical and Quality Assurance Plan (TTQAP).[5] The functional classification of the tasks covered by this report is Production Support. The variability study is waste form affecting and needs to follow the quality assurance requirements of RW-0333P.[6] Microsoft Excel and JMP Version 14.3.0 were used to support this work.[7,8] Requirements for performing reviews of technical reports and the extent of review are established in Manual E7, Procedure 2.60.[9] This document, including calculations, was reviewed by a Design Check. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.[10] The Design Checklists for this report are stored in electronic laboratory notebook experiment C7592-00311-38. Hence, all work was performed commensurate with the applicable quality assurance requirements.

3.0 Measurement Acceptance Region (MAR) Assessments

Calculation-based frit assessments were performed using the DWPF PCCS glass property models and their associated Measurement Acceptance Region (MAR) constraints. Note that iterative evaluations were completed, and the results are presented chronologically in Section 3.3.

3.1 Inputs and Assumptions

3.1.1 SB10 Projections

In May 2021, SRR System Planning provided SB10 Tank 40 blend projections for SO and coupled processing (on a calcine basis) for 0.9M and 1M Na wash endpoints.[3] The elemental concentrations were converted to oxides and normalized to 100 weight percent (wt.%) as shown in Appendix Table A-1. Projections representing coupled operation include the contribution of the monosodium titanate (MST) and sludge solids (SS) stream from the Sludge Solids Receipt Tank (SSRT) at SWPF.

3.1.2 SRNL Developed Inputs for Coupled Operation

Per a request from SRR,[11] SRNL also performed subsequent calculations with the SO projections in Appendix Table A-1 to estimate the composition in the Sludge Receipt and Adjustment Tank (SRAT) during coupled operation with SWPF. These calculations involved developing compositions for SE as well as the following four cases of MST/SS that were originally developed for SB9:[12-15]

- Case 1: Single strike operation with no entrained insoluble sludge solids (ISS). This case represents the baseline.
- Case 3A: Single strike operation, with 600 mg/L of entrained ISS, which were assumed to be SB9 sludge solids.[16]
- Case 3B: Single strike operation with 1200 mg/L of entrained ISS, which were assumed to be SB9 sludge solids.
- Case 4: Double strike operation with no entrained ISS.

Case 2 (single strike with no aluminum) and Case 5 (double strike with no aluminum) were eliminated as these cases were not applicable to SB10.[a]

Other pertinent inputs include:

- DWPF receives 5200, 5700 or 6000 gallons of sludge slurry from Tank 40 per SRAT batch[17]
- Single strike operation results in 2800 gallons of the SSRT effluent stream (MST/SS) and 4200 gallons for double strike operation per SRAT batch[12]
  - Incremental variation in these transfer volumes were initially requested for SB9,[12] which SRNL assumed to be ±400 gallons for these assessments; however, DWPF recently requested that 4500 gallons be evaluated for single strike operation[18]
- DWPF receives 15,000 or 22,000 gallons of SE per SRAT batch (BOBCalixC6 solvent[b] or Next Generation Solvent (NGS)[c])[12,17]
- Cs-137 concentration in SE is 66 Ci/gallon[19]

3.2 Methodology for the Variation Stage MAR Assessments

The approach taken for the Variation Stage MAR assessment[20] was to evaluate how robust candidate frit compositions were relative to expected variation in the composition of the SB10 SRAT material and the uncertainty in targeting the desired waste loading (WL). These uncertainties take effect as DWPF (i) conducts the blending process[d] to target the desired WL for the next Slurry Mix Evaporator (SME) batch, and (ii) subsequently evaluates the new SME batch for acceptability with PCCS, which is driven by the analysis of samples of the new SME batch.

Compositional variation (±) was applied to SRAT compositions to account for likely, but not necessarily bounding, differences that may be seen in the material that is transferred from Tank 40 and SWPF into the SRAT during the processing of SB10. The compositional variation for the individually tracked oxides was represented by the larger of 0.5 wt.% or 7.5%[21] of the nominal concentration. Those oxides not tracked individually were grouped into an "Others" component.[e] Extreme vertices (EVs) were generated using the oxide intervals for each SB10 scenario and were combined with frit compositions over the interval of 24-42% WL. Each of the resulting glass compositions was evaluated against the PCCS MAR criteria to

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[a] Per SRR-WSE-2018-00025, more conservative cases were developed for SB9 where the aluminum concentration in the SSRT effluent stream was set to 0 mg/L. SB10 has a much higher Al_2O_3 concentration than SB9, thus there is no concern with the Al_2O_3 concentration being too low in glass for SB10 and Cases 2 and 5 were eliminated.

[b] BOBCalixC6 is calix[4]arene-bis(tert-octylbenzo-crown-6) , which uses a nitric acid strip solution.

[c] NGS contains the extractant MaxCalix (1,3-alt-25,27-bis(3,7- dimethyloctyl-1-oxy) calix[4]arene-benzocrown-6), which uses a boric acid strip solution.

[d] Combining SRAT material with frit and the heel of the SME.

[e] The "Others" components typically include B_2O_3, BaO, Ce_2O_3, Cr_2O_3, CuO, K_2O, La_2O_3, Li_2O, MgO, PbO, SO_4^{2-}, ZnO, and ZrO_2; however, B_2O_3 is an individually tracked oxide when SE with NGS is evaluated.

determine whether the composition would pass the SME acceptability process.[22] An operating window of at least 9 percentage points (target of 36%WL ± 4 percentage points) was the primary success metric used to select a frit for SB10 processing.

3.3 Results and Discussion

3.3.1 Frit 473 and Frit 209

Based on the results of previous MAR assessments, Frit 473 and Frit 209 were two of the primary frits that were used as inputs to the development of the SB10 variability study test matrix.[1] These frits were evaluated against the 0.9M and 1M Na wash endpoint SO and coupled projections shown in Appendix Table A-1. Note that the coupled projections from System Planning were evaluated as-received. Table 3-1 presents a summary of the MAR assessment results. More detailed results are provided in Appendix Table A-2 and Table A-3.

Consider the 0.9M Na wash endpoint column for SO and Frit 473 as an example for the interpretation of the information provided. The frit composition and number of EVs are shown for reference. The operating window (WL interval over which all EVs pass the SME acceptability process) is 35-39%. At 34% WL, 11% of the EVs fail the high viscosity constraint and at 40% WL, 4.8% of the EVs fail the nepheline constraint.

Table 3-1. MAR Assessment Results with Frit 473 and Frit 209

Na Wash Endpoint	**0.9M**		**1M**	
Projection	**SO**	**Coupled**	**SO**	**Coupled**
Frit 473 ($8B_2O_3$-$8Li_2O$-$5Na_2O$-$79SiO_2$ (wt.%))				
Number of EVs	2079	2186	2037	2144
Operating Window	35-39	26-39	33-38	26-39
Lower WL Limiting Constraint	34% *highv* (11%)	25% *highv* (17%)	32% *highv* (8.9%)	25% *highv* (1.1%)
Upper WL Limiting Constraint	40% *neph* (4.8%)	40% *neph* (1%)	39% *neph* (0.5%)	40% *neph* (2.6%)
Frit 209 ($11B_2O_3$-$8Li_2O$-$5Na_2O$-$76SiO_2$ (wt.%))				
Number of EVs	2079	2186	2037	2144
Operating Window	27-38	24-37	25-37	24-37
Lower WL Limiting Constraint	26% *highv* (6.5%)	not evaluated	24% *highv* (11%)	not evaluated
Upper WL Limiting Constraint	39% *neph* (5.3%)	38% *lowv* (0.3%)	38% *neph* (0.5%)	38% *lowv* (17%)

highv: high viscosity *lowv*: low viscosity *neph*: nepheline

The failed nepheline constraint at higher waste loadings for some of the EVs is waste form affecting as it reduces the chemical durability of the waste form. Nepheline ($NaAlSiO_4$) is a crystalline phase that is prone to form in glass during slow cooling when higher concentrations of Al_2O_3 and Na_2O are present.[23] The formation of nepheline is controlled in the DWPF PCCS by the following expression:[22,24]

$$\frac{SiO_2}{Al_2O_3+Na_2O+SiO_2} > 0.62$$

where SiO_2, Na_2O, and Al_2O_3 are the concentrations in the glass as mass fractions. Nepheline is *not* predicted to form when the value is greater than 0.62.

While Frit 209 does offer operating windows of at least 9 percentage points for both SO and coupled operation, the maximum WLs is 37% for coupled operation. Alternatively; the maximum WL for Frit 473 for coupled operation is 39% WL; however, the SO operating window is 5-6 percentage points. Thus, SRR requested additional MAR assessments be completed to determine if an alternative frit composition would increase the maximum WL while still maintaining a sufficient operating window for SO and coupled operation.[25]

3.3.2 Alternative Frits

For this set of MAR assessments, SRR requested[11] the use of the SRNL-developed compositions for coupled operation as defined in Section 3.1.2. Due to the considerable number of variable inputs, a subset of the nominal inputs and coupled operation cases were selected for the initial frit development as shown below.

- Sludge-only
- Coupled operation (Cases 1 and 3A (single strike - 2800 gallons) and Case 4 (double strike - 4200 gallons)
- DWPF receives 5700 gallons of sludge slurry from Tank 40 per SRAT batch
- DWPF receives 15,000 gallons of SE per SRAT batch (NGS)

Nominal SRAT compositions representing coupled operations scenarios are shown in Appendix Table A-4 and Table A-5. Using the methodology described in Section 3.2, EVs were generated using the oxide intervals for these SB10 scenarios and were combined with a large array of frits covering the B_2O_3-Li_2O-Na_2O-SiO_2 region in the interval of 24-42% WL.

Table 3-2 and Table 3-3 present summaries of the MAR assessment results for the 0.9M and 1M Na wash endpoints, respectively, with alternative frits. A target WL of 36% is possible for single strike operation (Cases 1 and 3A). Double strike operation (Case 4) is limited by the maximum TiO_2 constraint[f] at 37-38% WL regardless of frit composition.[22] Two frit options are shown for each Na wash endpoint to demonstrate the sensitivity of the SO operating window as the Li_2O concentration in the frit is increased from 8 wt.% to 10 wt.%. To date, all frits used for DWPF processing have had ≤ 8 wt.% Li_2O and limited glass durability data exists in the SB10 composition region at higher Li_2O concentrations.[26] In addition, experimental testing would be required to measure the leaching of frit components from the frit slurry with water since the original testing evaluated frits up to 8 wt.% Li_2O.[27,28]

Table 3-2. 0.9M Na Wash Endpoint MAR Assessment Results for Alternative Frits

Case	Case 1 Single Strike	Case 3A Single Strike 600 ISS	Case 4 Double Strike	SO
Frit: $10B_2O_3$-$8Li_2O$-$4Na_2O$-$78SiO_2$ (wt.%)				
Operating Window	25-40	30-42	24-36	34-39
Frit: $8B_2O_3$-$10Li_2O$-$2Na_2O$-$80SiO_2$ (wt.%)				
Operating Window	24-40	28-42	24-36	33-41

[f] TiO_2 concentration must be ≤ 6 wt.% minus measurement uncertainty.

Table 3-3. 1M Na Wash Endpoint MAR Assessment Results for Alternative Frits

Case	Case 1 Single Strike	Case 3A Single Strike 600 ISS	Case 4 Double Strike	SO
Frit 473: $8B_2O_3$-$8Li_2O$-$5Na_2O$-$79SiO_2$ (wt.%)				
Operating Window	25-40	29-42	24-37	33-38
Frit: $9B_2O_3$-$10Li_2O$-$1Na_2O$-$80SiO_2$ (wt.%)				
Operating Window	25-40	29-42	24-37	33-41

In June 2021, SRR finalized the decision to proceed with the 1M Na wash endpoint and Frit 473 for SB10 based on the results in Table 3-2 and Table 3-3.[29] For informational purposes, Frit 473 and the 1M Na wash endpoint were evaluated with the remainder of the inputs listed in Section 3.1.2. Summaries of the operating windows are shown in Appendix Table A-6 and Table A-7 and more detailed MAR assessment results are shown in Appendix Table A-8-Table A-19. Note that the SO results are repeatedly shown in each of the tables for reference. Overall, a target WL of 36% ± 4 percentage points is possible for SB10 single strike coupled processing at a nominal SSRT transfer volume (~2800 gallons) for all of the evaluated scenarios (Cases 1, 3A and 3B). Increasing the SSRT transfer volume to 4500 gallons demonstrates that there are only incremental reductions to maximum WLs and operating windows for Case 1 and Case 3B; Case 3A is minimally impacted. The maximum WL for double strike operation (Case 4) is limited to 32-39% WL depending on the scenario due to the maximum TiO_2 constraint. Other high-level trends in the operating windows for the variable inputs for coupled operation are listed below.

- Tank 40 transfer volume (5200, 5700 and 6000 gallons) – There is minimal impact to the operating windows for single strike operation. For double strike operation, both the operating windows and maximum WL decrease as the Tank 40 transfer volume decreases.
- SSRT transfer volume – There is minimal or no impact to the operating windows for single strike operation as the SSRT transfer volume is increased from 2400 to 3200 gallons. At 4500 gallons of SSRT, the operating window is reduced to less than 9 percentage points. For double strike operation, the maximum WL and operating window decrease as SSRT transfer volume is increased from 3800 to 4600 gallons.
- ISS (assumed to be SB9 solids) – Increasing the ISS concentration from 600 to 1200 mg/L limits both high and lower WLs, but a 36% WL target is feasible at nominal SSRT transfer volumes.
- SE transfer volume – There is minimal or no impact on operating windows as the SE transfer volume is increased from 15,000 to 22,000 gallons.
- SE extractant – There is minimal or no difference in the operating windows between SE based on NGS or BOBCalixC6.

4.0 Variability Study Evaluation

The objective of the variability study is to demonstrate that the Product Consistency Test (PCT)[30] response of glass compositions *within* (not necessarily bounding) the glass system based on the projected sludge, salt effluents, and frit are acceptable relative to the chemical durability of the Environmental Assessment (EA) benchmark glass[31] and predictable by the DWPF PCCS models for durability.[22,32] Five of the SB10 variability glasses were not predictable with the PCCS durability models, but were acceptable compared to the EA benchmark glass when tested.[2] Two of these glasses had normalized PCT releases that fell slightly outside of the lower 95% confidence band, which demonstrates conservatism of the durability models. The other three glasses had normalized PCT releases that fell slightly outside the upper 95% confidence band at more positive ΔGp values where glasses are predicted to be more durable; however, these glasses have normalized PCT releases that were significantly lower than two standard deviations below the values of the EA benchmark glass[31,33] and are of no practical concern since the glass compositions are outside of the region where DWPF will operate. Based on these results, it was concluded that the PCCS durability models are applicable to the SB10 glass composition region evaluated in the variability study.

An evaluation of the reprojected SB10 glass composition region and previously developed SB10 variability study glass composition region is necessary to determine whether additional glasses would be needed to demonstrate that the reprojected SB10 glass composition region is acceptable and predictable.

Prior to developing the SB10 variability study test matrix, the ComPro™ database[34-36] was used to determine whether glasses from previous studies were already within the SB10 glass composition region of interest. As documented previously, eighty-five "model" entries were found to have compositions that simultaneously satisfied the oxide intervals of the search criteria.[g,1] These entries included glass compositions from the SB6,[37] SB7a,[38-40] and SB7b[41] variability studies. Thus, eight glasses were fabricated and tested for the SB10 variability study to supplement the existing durability data.[1,2]

Table 4-1 presents a comparison of the minimum and maximum nominal major[h] oxide concentrations of the reprojected SB10 glass composition region, and the composition region defined by the eighty-five ComPro™ entries and eight SB10 variability study test glasses. The reprojected SB10 composition region is based on Frit 473 and the 1M Na wash endpoint Tank 40 blend projection (Appendix Table A-1) over a WL interval of 32-40%. SO operation and the following coupled operation scenarios from Section 3.1.2 were evaluated:

- DWPF receives 5200, 5700 or 6000 gallons of sludge slurry from Tank 40 per SRAT batch
- Case 1 (single strike) and 3A (single strike with 600 mg/L of SB9 ISS) with SSRT transfer volumes of 2400, 2800 and 3200 gallons per SRAT batch
- 15,000 or 22,000 gallons of SE transferred per SRAT batch (both BobCalixC6 and NGS)

A numerical difference is shown in Table 4-1 only when the reprojected SB10 oxide concentration falls outside of the oxide interval defined by the SB10 variability study glasses and ComPro™ entries. The oxide intervals for the reprojected SB10 glass composition region are generally within the oxide intervals evaluated in the variability studies. Cs_2O has the highest difference (1.3 wt.%) and otherwise minor compositional differences exist for Fe_2O_3, U_3O_8 and TiO_2. The maximum reprojected Cs_2O concentration in glass (1.32 wt.%) is based on the following assumptions:

- 5200 gallons of Tank 40 per SRAT batch
- 22,000 gallons of SE per SRAT batch (BOBCalixC6) with a Cs-137 concentration of 66 Ci/gal

The maximum Cs_2O concentration in glass is reduced to ~0.85 wt.% for more nominal conditions (5700 gallons of Tank 40 and 15,000 gallons of SE per SRAT batch) and could be further reduced if the Cs-137 concentration is less than 66 Ci/gal. Thus, the Cs_2O concentration in glass is highly dependent on the operating parameters. The DWPF durability models have been validated to 1.62 wt.% Cs_2O,[42] so the expected variable concentrations for SB10 are still within the validated range although being outside of the SB10 variability study.

Despite minor compositional differences, the PCCS durability models[22] will reliably predict the durability of compositions within the reprojected SB10 glass region. Based on the slight compositional shifts of the reprojected SB10 glass region, no additional glasses are necessary to demonstrate acceptability relative to the chemical durability of the EA benchmark glass and predictability using the PCCS models for durability.[22,31,32]

[g] "Model" entries are results from studies that were conducted under quality assurance criteria that were RW-0333P compliant or criteria determined to be RW-0333P equivalent.

[h] Minor glass components having concentrations less than ~0.5 wt.% were not included in this evaluation (BaO, Ce_2O_3, Cr_2O_3, CuO, K_2O, La_2O_3, MgO, PbO, SO_4^{2-}, ZnO and ZrO_2).

Table 4-1. Comparison of Reprojected SB10 Glass Oxide Intervals and Previous SB10 Variability Study Oxide Intervals (wt.%)

	SB10 Variability Study and ComPro™ Entries		Reprojected SB10 Glass Composition Region		Difference	
	minimum	maximum	minimum	maximum	minimum	maximum
Al_2O_3	7.01	12.69	7.40	11.89	----	----
B_2O_3	4.37	7.45	4.81	5.87	----	----
CaO	0.27	0.84	0.29	0.49	----	----
Cs_2O	0.00	0.00	0.00	1.32	----	1.3
Fe_2O_3	5.08	10.09	4.69	7.85	-0.4	----
Li_2O	4.59	6.40	4.81	5.46	----	----
MnO	1.07	2.67	1.34	2.43	----	----
Na_2O	11.36	17.07	12.37	16.81	----	----
NiO	0.20	1.50	0.18	0.30	----	----
SiO_2	45.22	54.49	47.91	54.39	----	----
ThO_2	0.14	1.26	0.56	0.98	----	----
TiO_2	0.01	3.28	0.01	3.92	----	0.6
U_3O_8	1.06	2.88	0.91	1.53	-0.2	----

5.0 PCCS Models Evaluation

The DWPF PCCS is comprised of three composition-based glass property models, which include durability, viscosity and liquidus temperature.[22] Each of the DWPF PCCS glass property models have been developed and validated over specific oxide ranges.[42-44] While the variability study focuses on the waste-form affecting durability model and is performed for each sludge batch, the viscosity and liquidus temperature models are processing constraints and are not included.[32,45] The objective of this evaluation is to compare the SB10 composition regions shown in Table 4-1 to the PCCS model development ranges to ensure that compositional gaps do not exist between the data sets.

Table 5-1 shows a comparison of the reprojected SB10 glass composition region to the PCCS model development oxides ranges, and Table 5-2 shows the comparison for the combined SB10 variability study and ComPro™ ranges. Due to the methodology of the ComPro™ search used during the development of the SB10 variability study, the addition of the eighty five ComPro™ glasses stretches some of the oxide concentrations beyond the SB10 glass composition region.[1] Thus, Table 5-3 shows the comparison of only the SB10 variability study region to the PCCS model development ranges. As noted below each of the tables, the durability model ranges include both the model development data and SWPF validation data for ease of comparison since the model development ranges are more limited for some of the oxides.[42]

A numerical difference is only shown in Table 5-1 through Table 5-3 when the SB10 data falls outside of the ranges defined by the PCCS model data. The SB10 data generally fall within the PCCS model ranges and minor differences less than 0.4 wt.% exist for B_2O_3, Cr_2O_3, Cs_2O, CuO, P_2O_5, SO_4^{2-} and ThO_2. Table 5-2 indicates differences of 0.9 wt.% for SO_4^{2-}, but these differences are based on measured SO_4^{2-} concentrations from ComPro™ that were noted as being high in the corresponding variability study reports.[37,38,41] Ignoring these high measured values would result in minor differences of ~0.4 wt.%. The SB10 Na_2O concentration exceeds the liquidus temperature model development value by approximately 1 wt.%; however, the liquidus temperature model was validated up to 17.39 wt.%,[43] which provides sufficient coverage for SB10 processing.

Based on a comparison of the PCCS model development and validation data to the SB10 glass composition region, the viscosity and liquidus temperature models will reliably predict SB10 compositions. No additional glasses are necessary to demonstrate predictability of these models.

Table 5-1. Comparison of PCCS Model Development Data and Reprojected SB10 Glass Composition Region

	Model Development Ranges						Reprojected SB10 Glass Region		Durability Difference		Viscosity Difference		Liquidus Temp Difference	
	Durability*		Viscosity		Liquidus Temp									
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Al_2O_3	2.99	13.90	0	13.90	0.99	14.16	7.40	11.89	----	----	----	----	----	----
B_2O_3	4.57	13.30	4.57	12.20	4.57	12.65	4.81	5.87	----	----	----	----	----	----
BaO	0	0.66	0	0.31	0	0.29	0.02	0.03	----	----	----	----	----	----
CaO	0.22	2.23	0	2.05	0.23	2.01	0.29	0.49	----	----	----	----	----	----
Ce_2O_3	0	1.44	0	0.42	0	0.24	0.04	0.07	----	----	----	----	----	----
Cr_2O_3	0	0.55	0	0.19	0	0.30	0.06	0.12	----	----	----	----	----	----
Cs_2O	0	1.62	0	1.62	0	1.26	0	1.32	----	----	----	----	----	0.1
CuO	0	0.33	0	0.66	0	0.06	0.01	0.02	----	----	----	----	----	----
Fe_2O_3	0	15.51	0	15.51	3.43	16.98	4.69	7.85	----	----	----	----	----	----
K_2O	0	5.73	0	5.73	0	3.89	0.04	0.16	----	----	----	----	----	----
La_2O_3	0	0.42	0	0.36	0	0.36	0.01	0.02	----	----	----	----	----	----
Li_2O	1.05	6.81	1.05	6.96	2.26	6.81	4.81	5.46	----	----	----	----	----	----
MgO	0	3.24	0	2.92	0	2.65	0.11	0.19	----	----	----	----	----	----
MnO	0	4.08	0	4.08	0.74	4.08	1.34	2.43	----	----	----	----	----	----
Na_2O	6.42	18.14	5.80	18.14	5.99	15.81	12.37	16.81	----	----	----	----	----	1.0
NiO	0	1.99	0	2.97	0	3.05	0.18	0.30	----	----	----	----	----	----
P_2O_5	0	0.65	0	0	0	0	0	0.05	----	----	----	0.1	----	0.1
PbO	0	0.25	0	0.23	0	0.23	0.01	0.01	----	----	----	----	----	----
SO_4	0	0.37	0	0.37	0	0.34	0.41	0.66	----	0.3	----	0.3	----	0.3
SiO_2	39.80	57.00	40.00	77.04	40.10	58.23	47.91	54.39	----	----	----	----	----	----
ThO_2	0	0.95	0	0.95	0	0.95	0.56	0.98	----	0.03	----	0.03	----	0.03
TiO_2	0	5.85	0	5.85	0	5.85	0.01	3.92	----	----	----	----	----	----
U_3O_8	0	6.24	0	6.24	0	6.24	0.91	1.53	----	----	----	----	----	----
ZnO	0	1.46	0	0.20	0	0.20	0.01	0.01	----	----	----	----	----	----
ZrO_2	0	1.80	0	0.99	0	0.97	0.04	0.07	----	----	----	----	----	----

*The durability model ranges include both the model development data and the SWPF validation data.[42]

Table 5-2. Comparison of PCCS Model Development Data and SB10 Glass Composition Region Defined By Variability Study Glasses and ComPro™ Entries

	Model Development Data						SB10 VS and ComPro™ Entries		Durability Difference		Viscosity Difference		Liquidus Temp Difference	
	Durability*		Viscosity		Liquidus Temp									
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Al_2O_3	2.99	13.90	0	13.90	0.99	14.16	7.01	12.69	----	----	----	----	----	----
B_2O_3	4.57	13.30	4.57	12.20	4.57	12.65	4.37	7.45	-0.2	----	-0.2	----	-0.2	----
BaO	0	0.66	0	0.31	0	0.29	0	0.07	----	----	----	----	----	----
CaO	0.22	2.23	0	2.05	0.23	2.01	0.27	0.84	----	----	----	----	----	----
Ce_2O_3	0	1.44	0	0.42	0	0.24	0.01	0.17	----	----	----	----	----	----
Cr_2O_3	0	0.55	0	0.19	0	0.30	0.01	0.22	----	----	----	0.03	----	----
CuO	0	0.33	0	0.66	0	0.06	0.01	0.10	----	----	----	----	----	0.04
Fe_2O_3	0	15.51	0	15.51	3.43	16.98	5.08	10.09	----	----	----	----	----	----
K_2O	0	5.73	0	5.73	0	3.89	0.03	0.47	----	----	----	----	----	----
La_2O_3	0	0.42	0	0.36	0	0.36	0	0.04	----	----	----	----	----	----
Li_2O	1.05	6.81	1.05	6.96	2.26	6.81	4.59	6.40	----	----	----	----	----	----
MgO	0	3.24	0	2.92	0	2.65	0.03	0.46	----	----	----	----	----	----
MnO	0	4.08	0	4.08	0.74	4.08	1.07	2.67	----	----	----	----	----	----
Na_2O	6.42	18.14	5.80	18.14	5.99	15.81	11.36	17.07	----	----	----	----	----	1.3
NiO	0	1.99	0	2.97	0	3.05	0.20	1.50	----	----	----	----	----	----
P_2O_5	0	0.65	0	0	0	0	0	0.17	----	----	----	0.2	----	0.2
PbO	0	0.25	0	0.23	0	0.23	0	0.05	----	----	----	----	----	----
RuO_2	0	0.16	0	0.16	0	0.14	0	0.07	----	----	----	----	----	----
SO_4	0	0.37	0	0.37	0	0.34	0.32	1.23	----	0.9	----	0.9	----	0.9
SiO_2	39.80	57.00	40.00	77.04	40.10	58.23	45.22	54.49	----	----	----	----	----	----
ThO_2	0	0.95	0	0.95	0	0.95	0.14	1.26	----	0.3	----	0.3	----	0.3
TiO_2	0	5.85	0	5.85	0	5.85	0.01	3.28	----	----	----	----	----	----
U_3O_8	0	6.24	0	6.24	0	6.24	1.06	2.88	----	----	----	----	----	----
ZnO	0	1.46	0	0.20	0	0.20	0	0.04	----	----	----	----	----	----
ZrO_2	0	1.80	0	0.99	0	0.97	0.03	0.21	----	----	----	----	----	----

*The durability model ranges include both the model development data and the SWPF validation data.[42]

Table 5-3. Comparison of PCCS Model Development Data and SB10 Variability Study Glasses

	Model Development Data						SB10 Variability Study		Durability Difference		Viscosity Difference		Liquidus Temp Difference	
	Durability*		Viscosity		Liquidus Temp									
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
Al_2O_3	2.99	13.90	0	13.90	0.99	14.16	7.38	12.69	----	----	----	----	----	----
B_2O_3	4.57	13.30	4.57	12.20	4.57	12.65	5.00	7.45	----	----	----	----	----	----
BaO	0	0.66	0	0.31	0	0.29	0.04	0.07	----	----	----	----	----	----
CaO	0.22	2.23	0	2.05	0.23	2.01	0.44	0.72	----	----	----	----	----	----
Ce_2O_3	0	1.44	0	0.42	0	0.24	0.09	0.17	----	----	----	----	----	----
Cr_2O_3	0	0.55	0	0.19	0	0.30	0.10	0.19	----	----	----	----	----	----
CuO	0	0.33	0	0.66	0	0.06	0.02	0.04	----	----	----	----	----	----
Fe_2O_3	0	15.51	0	15.51	3.43	16.98	5.08	8.80	----	----	----	----	----	----
K_2O	0	5.73	0	5.73	0	3.89	0.04	0.08	----	----	----	----	----	----
La_2O_3	0	0.42	0	0.36	0	0.36	0.02	0.04	----	----	----	----	----	----
Li_2O	1.05	6.81	1.05	6.96	2.26	6.81	4.90	5.27	----	----	----	----	----	----
MgO	0	3.24	0	2.92	0	2.65	0.20	0.38	----	----	----	----	----	----
MnO	0	4.08	0	4.08	0.74	4.08	1.07	2.59	----	----	----	----	----	----
Na_2O	6.42	18.14	5.80	18.14	5.99	15.81	11.36	17.07	----	----	----	----	----	1.3
NiO	0	1.99	0	2.97	0	3.05	0.20	0.51	----	----	----	----	----	----
PbO	0	0.25	0	0.23	0	0.23	0.02	0.05	----	----	----	----	----	----
SO_4	0	0.37	0	0.37	0	0.34	0.32	0.60	----	0.2	----	0.2	----	0.3
SiO_2	39.80	57.00	40.00	77.04	40.10	58.23	45.92	54.49	----	----	----	----	----	----
ThO_2	0	0.95	0	0.95	0	0.95	0.58	1.09	----	0.1	----	0.1	----	0.1
TiO_2	0	5.85	0	5.85	0	5.85	0.03	3.28	----	----	----	----	----	----
U_3O_8	0	6.24	0	6.24	0	6.24	1.06	1.49	----	----	----	----	----	----
ZnO	0	1.46	0	0.20	0	0.20	0.01	0.02	----	----	----	----	----	----
ZrO_2	0	1.80	0	0.99	0	0.97	0.11	0.21	----	----	----	----	----	----

*The durability model ranges include both the model development data and the SWPF validation data.[42]

6.0 Sensitivity Analysis of SE Cs-137 Concentration

As shown in Section 3.1.2, the assumption for the Cs-137 concentration in SE is 66 Ci/gal for MAR assessments, which is based on guidance developed for SB9.[12,13] SB10 MAR assessments have repeatedly identified that this assumption results in a reportable Cs concentration in glass (> 0.5 wt.%[46]) at 36% WL.[47] Thus, SRR requested that SRNL perform a Cs-137 sensitivity analysis to determine the Cs-137 concentration in SE that corresponds to a reportable Cs concentration in glass.[29]

6.1 Inputs and Assumptions

The normalized 1M Na wash endpoint Tank 40 blend projection for SO operation (Appendix Table A-1) was selected for this evaluation based on the MAR assessment results in Section 3.3.2. Several baseline operating assumptions from Section 3.1.2 were also used as listed below.

- DWPF receives 5700 gallons of sludge slurry from Tank 40 per SRAT batch
- 15,000 or 22,000 gallons of SE transferred per SRAT batch (both BobCalixC6 and NGS)
- Case 1 (single strike) with an SSRT transfer volume of 2800 gallons per SRAT batch

SRAT compositions were generated using SRNL-developed inputs for coupled operation Case 1 (single strike – see Section 3.1.2) and variable SE compositions based on SE Cs-137 concentrations of 8, 16.5, 33, 49.5, and 66 Ci/gal. The SE compositions and properties are provided in Appendix Table B-1 and Table B-2. The methodology for developing the SE compositions was the same that was used for SB9.[14] The ratio of the Cs-137 mass to the total Cs mass was assumed to be 0.2 based on the SRNL analysis of samples of SRS sludge waste.[14,48,49] To convert the SRAT Cs_2O concentration to a glass Cs_2O concentration, a 36% WL was assumed and the gravimetric factor was used for the oxide to elemental conversion.

6.2 Results and Discussion

Appendix Figure B-1 through Figure B-4 show the Cs concentration in glass at 36% WL as a function of the SE Cs-137 concentration. Also shown on each figure is the equation for the exponential trendline and the R^2 value. The equations were used to approximate the SE Cs-137 concentrations that result in a reportable Cs concentration in glass (> 0.5 wt.%[46]) for the four different scenarios evaluated. Table 6-1 presents a summary of the results. Based on the assumptions and inputs used for this evaluation, Cs becomes reportable in glass at 36% WL once the Cs-137 concentration reaches 14-34 Ci/gal in the SE depending on the transfer volume and extractant. Increasing the SE transfer volume from 15,000 to 22,000 gallons[i] reduces the SE Cs-137 concentration at which Cs becomes reportable in glass. Slightly higher Cs-137 concentrations are possible with NGS since B_2O_3 is included in the composition and the Cs_2O is diluted relative to the BOBCalixC6 compositions (Appendix Table B-1).

Table 6-1. Approximate Cs-137 Concentration in SE Corresponding to Reportable Cs Concentration In Glass At 36% WL

SE Volume (gal)	15,000	15,000	22,000	22,000
SE Extractant	BOBCalixC6	NGS	BOBCalixC6	NGS
SE Cs-137 Concentration (Ci/gal)	27	34	14	20

7.0 Conclusions

Based on MAR assessments of 1M Na wash endpoint Tank 40 blend projections, Frit 473 ($8B_2O_3$-$8Li_2O$-$5Na_2O$-$79SiO_2$ (wt.%)) is recommended for SB10 processing. A target WL of 36% ± 4 percentage points

[i] Under typical processing conditions, 15,000 gallons represents 2 transfers from the Strip Effluent Feed Tank (SEFT), whereas 22,000 gallons represents 3 transfers from the SEFT and allows for flexibility if a processing upset occurs.

is possible for single strike coupled processing at a nominal SSRT transfer volume of ~2800 gallons. Increasing the single strike SSRT transfer volume to 4500 gallons demonstrates that there are only incremental reductions to maximum WLs and operating windows. Due to the compositional shifts for SO operation and double strike coupled processing, reductions in the maximum WL and operating window are observed for both of these scenarios.

The reprojected SB10 glass composition region generally overlaps the previously evaluated SB10 variability study composition region. Thus, the minor composition shift of SB10 in the May 2021 projections indicates that no additional glasses are necessary to demonstrate acceptability relative to the chemical durability of the EA benchmark glass and predictability using the current PCCS models for durability. Based on a comparison of the PCCS model development and validation data to the SB10 glass composition region, the viscosity and liquidus temperature models will reliably predict SB10 compositions. No additional glasses are necessary to demonstrate predictability of these models.

Total Cs becomes reportable in glass at 36% WL once the Cs-137 concentration reaches 14-34 Ci/gal in the SE based on the assumptions and inputs used for this evaluation. The concentration depends on the volume of the transfer (15,000 versus 22,000 gallons) and the extractant (BOBCalixC6 versus NGS).

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Appendix A. Supplementary Information and Results for MAR Assessments

Table A-1. Normalized SB10 Tank 40 Blend Projections (wt.%)

Na Wash Endpoint	0.9M		1M	
Projection	**SO**	**Coupled**	**SO**	**Coupled**
Al_2O_3	30.27	25.46	29.72	25.10
B_2O_3	0.04	0.03	0.03	0.03
BaO	0.08	0.07	0.08	0.07
CaO	1.25	1.05	1.22	1.03
Ce_2O_3	0.19	0.16	0.19	0.16
Cr_2O_3	0.30	0.25	0.30	0.25
CuO	0.06	0.05	0.06	0.05
Fe_2O_3	20.15	16.95	19.64	16.58
K_2O	0.11	0.09	0.11	0.09
La_2O_3	0.04	0.04	0.04	0.03
Li_2O	0.05	0.04	0.05	0.04
MgO	0.49	0.42	0.48	0.41
MnO	5.76	4.84	5.61	4.74
Na_2O	30.43	33.49	31.83	34.60
NiO	0.76	0.64	0.74	0.63
PbO	0.03	0.03	0.03	0.03
SO_4^{2-}	1.54	1.50	1.64	1.58
SiO_2	1.77	1.49	1.72	1.45
ThO_2	2.52	2.12	2.45	2.07
TiO_2	0.03	7.57	0.03	7.41
U_3O_8	3.92	3.54	3.82	3.47
ZnO	0.04	0.03	0.03	0.03
ZrO_2	0.19	0.16	0.18	0.15

Table A-2. Complete 0.9M and 1M Na Wash Endpoint MAR Assessment Results for Frit 473

Na Wash Endpoint	0.9M		1M	
Projection	SO	Coupled	SO	Coupled
Number of EVs	2079	2186	2037	2144
24, %WL	highv(100%)	highv(40%)	highv(92%)	highv(23%)
25	highv(92%)	highv(17%)	highv(67%)	highv(1.1%)
26	highv(76%)		highv(56%)	
27	highv(59%)		highv(52%)	
28	highv(53%)		highv(50%)	
29	highv(50%)		highv(45%)	
30	highv(48%)		highv(36%)	
31	highv(41%)		highv(21%)	
32	highv(34%)		highv(8.9%)	
33	highv(21%)			
34	highv(11%)			
35				
36				
37				
38				
39			Neph(0.54%)	
40	Neph(4.8%)	Neph(1.0%)	Neph(8.1%)	Neph(2.6%)
41	Neph(48%)	Neph(9.6%)	Neph(78%)	lowv Neph(3.5%) Neph(24%)
42	Neph(90%)	lowv Neph(6.5%) Neph(62%)	Neph(94%)	lowv Neph(28%) Neph(59%)

highv: high viscosity
Neph: nepheline
lowv: low viscosity

Note that the coupled projections from System Planning (Appendix Table A-1) were evaluated as-received.

Table A-3. Complete 0.9M and 1M Na Wash Endpoint MAR Assessment Results for Frit 209

Na Wash Endpoint	0.9M		1M	
Projection	SO	Coupled	SO	Coupled
Number of EVs	2079	2186	2037	2144
24, %WL	highv(34%)		highv(11%)	
25	highv(19%)			
26	highv(6.5%)			
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38		lowv(0.32%)	Neph(0.54%)	lowv(17%)
39	Neph(5.3%)	lowv(19%) Neph(1.0%)	Neph(10%)	lowv(40%) lowv Neph(0.28%) Neph(2.8%)
40	Neph(48%)	lowv(38%) lowv Neph(3.2%) Neph(7.7%)	Neph(80%)	lowv(25%) lowv Neph(23%) Neph(9.0%)
41	Neph(92%)	lowv(6.1%) lowv Neph(41%) Neph(28%)	Neph(96%)	lowv(4.3%) lowv Neph(47%) Neph(44%)
42	Neph(99%)	lowv(1.0%) lowv Neph(50%) Neph(47%)	Neph(100%)	lowv(1.1%) lowv Neph(54%) Neph(45%)

highv: high viscosity
Neph: nepheline
lowv: low viscosity

Note that the coupled projections from System Planning (Appendix Table A-1) were evaluated as-received.

Table A-4. SRNL-Developed SRAT Compositions for Coupled Operation for the 0.9M Na Wash Endpoint

Case	Case 1 Single Strike	Case 3A Single Strike 600 mg/L ISS	Case 4 Double Strike
Tank 40 Volume (gal)	5700	5700	5700
SSRT Volume (gal)	2800	2800	4200
ISS Concentration (mg/L)	0	600	0
SE Volume (gal)	15,000	15,000	15,000
Al_2O_3	24.74	24.92	22.24
B_2O_3	0.88	0.75	0.78
BaO	0.06	0.05	0.06
CaO	0.99	1.18	0.88
Ce_2O_3	0.15	0.18	0.13
Cr_2O_3	0.24	0.20	0.21
Cs_2O	2.10	1.77	1.86
CuO	0.05	0.04	0.04
Fe_2O_3	15.92	19.55	14.14
K_2O	0.31	0.26	0.31
La_2O_3	0.03	0.03	0.03
Li_2O	0.04	0.03	0.04
MgO	0.39	0.42	0.35
MnO	4.55	6.05	4.04
Na_2O	32.70	27.65	32.57
NiO	0.60	0.74	0.53
P_2O_5	0.00	0.11	0.00
PbO	0.03	0.02	0.02
SO_4^{2-}	1.26	1.43	1.13
SiO_2	1.40	2.06	1.24
ThO_2	1.99	1.89	1.77
TiO_2	8.30	7.01	14.71
U_3O_8	3.10	3.49	2.75
ZnO	0.03	0.02	0.02
ZrO_2	0.15	0.12	0.13

Table A-5. SRNL-Developed SRAT Compositions for Coupled Operation for the 1M Na Wash Endpoint

Case	Case 1 Single Strike	Case 3A Single Strike 600 mg/L ISS	Case 4 Double Strike
Tank 40 Volume (gal)	5700	5700	5700
SSRT Volume (gal)	2800	2800	4200
ISS Concentration (mg/L)	0	600	0
SE Volume (gal)	15,000	15,000	15,000
Al_2O_3	24.42	24.64	22.00
B_2O_3	0.86	0.73	0.77
BaO	0.06	0.05	0.06
CaO	0.97	1.16	0.86
Ce_2O_3	0.15	0.18	0.13
Cr_2O_3	0.23	0.20	0.21
Cs_2O	2.05	1.74	1.83
CuO	0.05	0.04	0.04
Fe_2O_3	15.61	19.22	13.89
K_2O	0.31	0.26	0.31
La_2O_3	0.03	0.03	0.03
Li_2O	0.04	0.03	0.03
MgO	0.38	0.41	0.34
MnO	4.46	5.95	3.97
Na_2O	33.77	28.65	33.52
NiO	0.59	0.73	0.53
P_2O_5	0.00	0.11	0.00
PbO	0.02	0.02	0.02
SO_4^{2-}	1.34	1.50	1.21
SiO_2	1.37	2.03	1.22
ThO_2	1.95	1.86	1.73
TiO_2	8.12	6.89	14.44
U_3O_8	3.04	3.43	2.70
ZnO	0.03	0.02	0.02
ZrO_2	0.14	0.12	0.13

Table A-6. Summary of Operating Windows for 1M Na Wash Endpoint (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-40	25-39	24-39	24-37	29-42	29-42	29-42	28-42	33-41	33-40	33-40	34-38	24-37	24-34	24-32	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	25-40	25-39	24-39	24-37	29-42	29-42	29-42	28-42	33-42	33-41	33-40	33-38	24-38	24-35	24-33	33-38
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-40	25-40	25-39	24-38	30-42	29-42	29-42	29-42	33-42	33-41	33-40	34-38	24-38	24-37	24-34	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	26-40	25-40	25-39	24-38	29-42	29-42	29-42	28-42	33-42	33-41	33-41	33-39	24-38	24-37	24-35	33-38
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-40	26-40	25-39	24-38	30-41	30-42	29-42	29-42	33-42	33-41	33-40	34-39	24-38	24-38	24-36	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	26-40	25-40	25-39	24-38	29-42	29-42	29-42	28-42	33-42	33-42	33-41	33-39	24-38	24-38	24-36	33-38

Table A-7. Summary of Operating Windows for 1M Na Wash Endpoint (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-39	25-39	24-39	24-37	29-42	29-42	29-42	28-42	33-41	33-40	33-40	34-38	24-37	24-34	24-32	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	25-40	25-39	24-39	24-37	29-42	29-42	29-42	28-42	33-42	33-41	33-40	33-38	24-37	24-35	24-32	33-38
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-39	25-39	25-39	24-38	30-41	29-42	29-42	29-42	33-42	33-41	33-40	34-38	24-38	24-36	24-34	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	26-40	25-40	25-39	24-38	29-42	29-42	29-42	28-42	33-42	33-41	33-40	33-38	24-38	24-37	24-34	33-38
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	---
SE Volume (gal)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	0
Operating Window (%WL)	26-39	26-39	25-39	24-38	30-41	30-42	29-42	29-42	33-42	33-41	33-40	34-38	24-39	24-38	24-35	33-38
SE Volume (gal)	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	0
Operating Window (%WL)	26-40	25-40	25-39	24-38	30-41	29-42	29-42	28-42	33-42	33-41	33-41	33-39	24-39	24-38	24-36	33-38

Table A-8. Detailed MAR Assessment Results for 5200 Gallons of Tank 40 and 15,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	----
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	9378	9162	9522	9284	9408	9534	9534	9685	9768	9768	9768	9811	9284	9284	9284	2037
%WL, 24	highv(18%)	highv(1.3%)			highv(58%)	highv(58%)	highv(57%)	highv(50%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(0.09%)				highv(47%)	highv(46%)	highv(44%)	highv(38%)	highv(87%)	highv(90%)	highv(92%)	highv(98%)				highv(67%)
26					highv(39%)	highv(38%)	highv(36%)	highv(25%)	highv(68%)	highv(70%)	highv(72%)	highv(80%)				highv(56%)
27					highv(27%)	highv(23%)	highv(17%)	highv(3.9%)	highv(60%)	highv(62%)	highv(63%)	highv(68%)				highv(52%)
28					highv(6.8%)	highv(3.8%)	highv(0.90%)		highv(44%)	highv(47%)	highv(49%)	highv(57%)				highv(50%)
29									highv(36%)	highv(37%)	highv(37%)	highv(39%)				highv(45%)
30									highv(28%)	highv(29%)	highv(30%)	highv(31%)				highv(36%)
31									highv(13%)	highv(15%)	highv(16%)	highv(18%)				highv(21%)
32									highv(2.0%)	highv(3.3%)	highv(4.2%)	highv(6.1%)				highv(8.9%)
33												highv(0.16%)			maxTi(45%)	
34															maxTi(46%)	
35														maxTi(45%)	maxTi(50%)	
36														maxTi(45%)	maxTi(50%)	
37														maxTi(50%)	maxTi(55%)	
38				lowv(0.84%)									maxTi(45%)	lowv maxTi(0.14%) maxTi(50%)	lowv(1.1%) lowv maxTi(3.7%) maxTi(51%)	
39				lowv(27%)								TL(0.45%)	lowv(2.7%) lowv maxTi(4.2%) maxTi(43%)	lowv(8.8%) lowv maxTi(12%) maxTi(41%)	lowv maxTi(32%) maxTi(68%)	Neph(0.54%)
40		lowv(0.38%)	lowv(8.8%)	lowv(41%)								TL(5.3%)	lowv(19%) lowv maxTi(14%) maxTi(36%)	lowv(21%) lowv maxTi(18%) maxTi(37%)	lowv maxTi(45%) maxTi(55%)	Neph(8.1%)
41	lowv(4.7%) Neph(6.3%)	lowv(20%) Neph(4.7%)	lowv(34%) lowv Neph(0.13%) Neph(6.3%)	lowv(44%) lowv Neph(5.5%) Del Gp lowv(0.43%)						TL(0.01%)	TL(0.89%)	TL(16%)	lowv(27%) lowv maxTi(18%) maxTi(32%)	lowv maxTi(49%) maxTi(51%)	lowv maxTi(53%) maxTi(47%)	Neph(78%)
42	lowv(1.4%) lowv Neph(30%) Neph(19%)	lowv(5.2%) lowv Neph(35%) Neph(14%)	lowv(8.5%) lowv Neph(35%) Neph(12%)	lowv(26%) lowv Neph(27%) Neph(2.7%) Del Gp lowv(2.2%) Del Gp lowv Neph(3.8%)					TL(0.07%)	TL(1.4%)	TL(5.5%)	TL(25%)	lowv(22%) lowv maxTi(22%) lowv maxTi Neph(1.0%) lowv Neph(7.2%) maxTi(29%) Neph(0.59%)	lowv maxTi(51%) lowv maxTi Neph(7.6%) maxTi(41%)	lowv maxTi(58%) lowv maxTi Neph(6.1%) maxTi(36%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-9. Detailed MAR Assessment Results for 5200 Gallons of Tank 40 and 22,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	9378	9162	9522	9284	9618	9534	9534	9685	9768	9768	9775	9895	9284	9284	9284	2037
%WL, 24	highv(12%)	highv(0.38%)			highv(58%)	highv(56%)	highv(55%)	highv(48%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25					highv(46%)	highv(44%)	highv(42%)	highv(36%)	highv(82%)	highv(85%)	highv(89%)	highv(96%)				highv(67%)
26					highv(38%)	highv(36%)	highv(34%)	highv(21%)	highv(65%)	highv(67%)	highv(69%)	highv(76%)				highv(56%)
27					highv(21%)	highv(16%)	highv(12%)	highv(1.5%)	highv(58%)	highv(59%)	highv(61%)	highv(66%)				highv(52%)
28					highv(2.8%)	highv(0.83%)	highv(0.17%)		highv(41%)	highv(43%)	highv(44%)	highv(52%)				highv(50%)
29									highv(34%)	highv(35%)	highv(35%)	highv(36%)				highv(45%)
30									highv(23%)	highv(24%)	highv(26%)	highv(29%)				highv(36%)
31									highv(8.3%)	highv(10%)	highv(11%)	highv(15%)				highv(21%)
32									highv(0.26%)	highv(0.61%)	highv(1.1%)	highv(3.8%)				highv(8.9%)
33																
34															maxTi(45%)	
35															maxTi(50%)	
36														maxTi(45%)	maxTi(50%)	
37														maxTi(48%)	maxTi(54%)	
38				lowv(1.4%)										lowv maxTi(0.38%) maxTi(50%)	lowv(1.8%) lowv maxTi(4.7%) maxTi(50%)	
39				lowv(29%)								TL(0.25%)	lowv(4.6%) lowv maxTi(4.8%) maxTi(41%)	lowv(12%) lowv maxTi(11%) maxTi(39%)	lowv maxTi(33%) maxTi(67%)	Neph(0.54%)
40		lowv(0.73%)	lowv(12%)	lowv(43%)								TL(2.7%)	lowv(20%) lowv maxTi(14%) maxTi(34%)	lowv(21%) lowv maxTi(18%) maxTi(36%)	lowv maxTi(46%) maxTi(54%)	Neph(8.1%)
41	lowv(7.7%) Neph(3.8%)	lowv(25%) Neph(3.3%)	lowv(36%) Neph(5.1%)	lowv(45%) lowv Neph(3.9%) Del Gp lowv(2.1%)							TL(0.29%)	TL(13%)	lowv(28%) lowv maxTi(18%) maxTi(32%)	lowv(28%) lowv maxTi(22%) maxTi(33%)	lowv maxTi(54%) maxTi(46%)	Neph(78%)
42	lowv(16%) lowv Neph(18%) Neph(13%)	lowv(22%) lowv Neph(19%) Neph(10%)	lowv(25%) lowv Neph(20%) Neph(8.4%) Del Gp lowv(0.04%) Del Gp lowv Neph(0.2%)	lowv(35%) lowv Neph(13%) Neph(0.50%) Del Gp lowv(11%) Del Gp lowv Neph(0.6%)						TL(0.51%)	TL(3.0%)	TL(22%)	lowv(26%) lowv maxTi(21%) lowv maxTi Neph(0.4%) lowv Neph(5.7%) maxTi(28%)	lowv maxTi(54%) lowv maxTi Neph(5.5%) maxTi(40%)	lowv maxTi(61%) lowv maxTi Neph(4.5%) maxTi(35%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-10. Detailed MAR Assessment Results for 5700 Gallons of Tank 40 and 15,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	---
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	9378	9378	9162	9284	9408	9408	9534	9433	9660	9768	9768	9811	9284	9284	9284	2037
%WL, 24	highv(31%)	highv(11%)	highv(0.41%)		highv(59%)	highv(58%)	highv(58%)	highv(53%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(2.9%)				highv(49%)	highv(47%)	highv(46%)	highv(40%)	highv(85%)	highv(89%)	highv(91%)	highv(98%)				highv(67%)
26					highv(40%)	highv(39%)	highv(38%)	highv(30%)	highv(67%)	highv(69%)	highv(71%)	highv(78%)				highv(56%)
27					highv(31%)	highv(26%)	highv(22%)	highv(7.6%)	highv(59%)	highv(61%)	highv(62%)	highv(66%)				highv(52%)
28					highv(11%)	highv(6.3%)	highv(3.2%)	highv(0.03%)	highv(44%)	highv(47%)	highv(49%)	highv(56%)				highv(50%)
29					highv(0.15%)				highv(37%)	highv(37%)	highv(37%)	highv(38%)				highv(45%)
30									highv(29%)	highv(30%)	highv(30%)	highv(31%)				highv(36%)
31									highv(13%)	highv(15%)	highv(16%)	highv(18%)				highv(21%)
32									highv(2.2%)	highv(3.3%)	highv(4.3%)	highv(6.1%)				highv(8.0%)
33												highv(0.16%)				
34																
35															maxTi(45%)	
36															maxTi(46%)	
37															maxTi(50%)	
38														maxTi(45%)	lowv maxTi(0.13%) maxTi(50%)	
39				lowv(13%)								TL(0.12%)	lowv(0.43%)	lowv(2.9%) lowv maxTi(4.7%) maxTi(44%)	lowv(8.4%) lowv maxTi(12%) maxTi(42%)	Neph(0.54%)
40			lowv(0.90%)	lowv(36%)								TL(2.3%)	lowv(23%)	lowv(20%) lowv maxTi(14%) maxTi(36%)	lowv(21%) lowv maxTi(18%) maxTi(37%)	Neph(8.1%)
41	lowv(0.51%) Neph(7.5%)	lowv(9.9%) Neph(6.3%)	lowv(25%) lowv Neph(0.01%) Neph(6.5%)	lowv(43%) lowv Neph(4.1%) Neph(2.0%)							TL(0.19%)	TL(10%)	lowv(24%) lowv maxTi(16%) maxTi(31%)	lowv(25%) lowv maxTi(19%) maxTi(32%)	lowv maxTi(49%) maxTi(51%)	Neph(78%)
42	lowv(0.01%) lowv Neph(20%) Neph(33%)	lowv(2.3%) lowv Neph(33%) Neph(17%)	lowv(6.1%) lowv Neph(36%) Neph(13%)	lowv(13%) lowv Neph(38%) Neph(6.5%) Del Gp lowv Neph(1.8%)						TL(0.30%)	TL(2.2%)	TL(21%)	lowv(24%) lowv maxTi(18%) lowv maxTi Neph(0.7%) lowv Neph(5.5%) maxTi(29%) maxTi Neph(0.3%) Neph(2.3)	lowv(22%) lowv maxTi(22%) lowv maxTi Neph(1.4%) lowv Neph(6.9%) maxTi(31%) Neph(0.5%)	lowv maxTi(50%) lowv maxTi Neph(8.2%) maxTi(42%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-11. Detailed MAR Assessment Results for 5700 Gallons of Tank 40 and 22,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	9378	9378	9162	9284	9408	9534	9534	9433	9660	9768	9768	9895	9284	9284	9284	2037
%WL, 24	highv(24%)	highv(5.9%)	highv(0.05%)		highv(58%)	highv(57%)	highv(56%)	highv(51%)	highv(99%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(0.68%)				highv(47%)	highv(46%)	highv(44%)	highv(39%)	highv(81%)	highv(85%)	highv(88%)	highv(95%)				highv(67%)
26					highv(39%)	highv(37%)	highv(36%)	highv(26%)	highv(65%)	highv(67%)	highv(68%)	highv(75%)				highv(56%)
27					highv(26%)	highv(21%)	highv(16%)	highv(4.1%)	highv(57%)	highv(59%)	highv(61%)	highv(65%)				highv(52%)
28					highv(5.6%)	highv(2.5%)	highv(0.84%)		highv(42%)	highv(43%)	highv(44%)	highv(51%)				highv(50%)
29									highv(35%)	highv(35%)	highv(36%)	highv(36%)				highv(45%)
30									highv(24%)	highv(25%)	highv(26%)	highv(29%)				highv(36%)
31									highv(9.0%)	highv(10%)	highv(11%)	highv(15%)				highv(21%)
32									highv(0.49%)	highv(0.71%)	highv(1.2%)	highv(3.7%)				highv(8.0%)
33																
34																
35																
36															maxTi(45%)	
37															maxTi(50%)	
38														maxTi(45%)	lowv maxTi(0.31%) maxTi(50%)	
39				lowv(16%)									lowv(0.89%)	lowv(4.0%) lowv maxTi(5.6%) maxTi(42%)	lowv(11%) lowv maxTi(11%) maxTi(39%)	Neph(0.54%)
40			lowv(2.1%)	lowv(37%)								TL(1.2%)	lowv(25%)	lowv(21%) lowv maxTi(14%) maxTi(36%)	lowv(21%) lowv maxTi(18%) maxTi(36%)	Neph(8.1%)
41	lowv(1.3%) Neph(4.0%)	lowv(13%) Neph(4.0%)	lowv(29%) Neph(4.1%)	lowv(43%) lowv Neph(4.1%) Neph(1.2%) Del Gp lowv(0.25%)								TL(7.2%)	lowv(26%) lowv maxTi(15%) maxTi(31%)	lowv(28%) lowv maxTi(18%) maxTi(32%)	lowv(28%) lowv maxTi(22%) maxTi(33%)	Neph(78%)
42	lowv(7.1%) lowv Neph(17%) Neph(16%)	lowv(17%) lowv Neph(21%) Neph(13%)	lowv(22%) lowv Neph(21%) Neph(10%)	lowv(27%) lowv Neph(22%) Neph(2.8%) Del Gp lowv(2.2%) Del Gp lowv Neph(2.9%)						TL(0.13%)	TL(1.3%)	TL(17%)	lowv(25%) lowv maxTi(19%) lowv maxTi Neph(0.7%) lowv Neph(5.1%) maxTi(28%) maxTi Neph(0.2%) Neph(0.7%)	lowv(24%) lowv maxTi(24%) lowv maxTi Neph(0.4%) lowv Neph(5.7%) maxTi(28%)	lowv maxTi(54%) lowv maxTi Neph(5.5%) maxTi(40%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-12. Detailed MAR Assessment Results for 6000 Gallons of Tank 40 and 15,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	----
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	9378	9378	9162	9270	9408	9408	9534	9433	9408	9768	9768	9811	9284	9284	9284	2037
%WL, 24	highv(35%)	highv(18%)	highv(2.8%)		highv(60%)	highv(59%)	highv(58%)	highv(54%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(7.1%)	highv(0.10%)			highv(50%)	highv(48%)	highv(47%)	highv(41%)	highv(84%)	highv(88%)	highv(90%)	highv(97%)				highv(67%)
26					highv(41%)	highv(39%)	highv(39%)	highv(32%)	highv(65%)	highv(69%)	highv(70%)	highv(77%)				highv(56%)
27					highv(32%)	highv(28%)	highv(24%)	highv(10%)	highv(58%)	highv(61%)	highv(62%)	highv(66%)				highv(52%)
28					highv(13%)	highv(7.9%)	highv(4.9%)	highv(0.10%)	highv(45%)	highv(46%)	highv(48%)	highv(55%)				highv(50%)
29					highv(0.51%)	highv(0.01%)			highv(38%)	highv(37%)	highv(37%)	highv(38%)				highv(45%)
30									highv(29%)	highv(30%)	highv(30%)	highv(31%)				highv(36%)
31									highv(14%)	highv(15%)	highv(16%)	highv(18%)				highv(21%)
32									highv(2.3%)	highv(3.4%)	highv(4.3%)	highv(6.1%)				highv(8.9%)
33												highv(0.15%)				
34																
35																
36																
37															maxTi(45%)	
38															maxTi(50%)	
39				lowv(5.9%)									lowv(0.01%)	lowv(0.80%) lowv maxTi(1.5%) maxTi(44%)	lowv(5.4%) lowv maxTi(7.3%) maxTi(43%)	Neph(0.54%)
40			lowv(0.11%)	lowv(33%)								TL(1.2%)	lowv(16%)	lowv(16%) lowv maxTi(13%) maxTi(35%)	lowv(19%) lowv maxTi(17%) maxTi(36%)	Neph(8.1%)
41	Neph(7.5%)	lowv(4.7%) Neph(7.5%)	lowv(18%) Neph(6.5%)	lowv(41%) lowv Neph(2.2%) Neph(4.4%)							TL(0.06%)	TL(7.5%)	lowv(37%)	lowv(24%) lowv maxTi(17%) maxTi(33%)	lowv(26%) lowv maxTi(21%) maxTi(34%)	Neph(78%)
42	lowv Neph(15%) Neph(38%)	lowv(0.79%) lowv Neph(30%) Neph(21%)	lowv(4.8%) lowv Neph(35%) Neph(14%)	lowv(12%) lowv Neph(38%) Neph(7.4%) Del Gp lowv Neph(0.7%)	Neph(3.2%)					TL(0.15%)	TL(1.6%)	TL(17%)	lowv(25%) lowv maxTi(16%) lowv maxTi Neph(0.7%) lowv Neph(5.5%) maxTi(28%) maxTi Neph(0.4%) Neph(3.6%)	lowv(24%) lowv maxTi(19%) lowv maxTi Neph(0.9%) lowv Neph(6.6%) maxTi(30%) maxTi Neph(0.2%) Neph(1.2%)	lowv maxTi(46%) lowv maxTi Neph(8.7%) maxTi(45%) maxTi Neph(0.16%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-13. Detailed MAR Assessment Results for 6000 Gallons of Tank 40 and 22,000 Gallons of SE (NGS) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	NGS	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	9378	9378	9162	9270	9408	9408	9534	9433	9408	9768	9768	9895	9284	9284	9284	2037
%WL, 24	highv(31%)	highv(13%)	highv(0.73%)		highv(58%)	highv(57%)	highv(57%)	highv(52%)	highv(99%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(3.6%)				highv(48%)	highv(46%)	highv(45%)	highv(40%)	highv(80%)	highv(84%)	highv(87%)	highv(95%)				highv(67%)
26					highv(39%)	highv(38%)	highv(37%)	highv(29%)	highv(64%)	highv(66%)	highv(68%)	highv(75%)				highv(56%)
27					highv(28%)	highv(23%)	highv(19%)	highv(5.8%)	highv(56%)	highv(59%)	highv(60%)	highv(64%)				highv(52%)
28					highv(7.3%)	highv(4.4%)	highv(1.7%)		highv(43%)	highv(43%)	highv(44%)	highv(50%)				highv(50%)
29									highv(36%)	highv(35%)	highv(36%)	highv(36%)				highv(45%)
30									highv(25%)	highv(25%)	highv(26%)	highv(29%)				highv(36%)
31									highv(9.8%)	highv(10%)	highv(11%)	highv(15%)				highv(21%)
32									highv(0.52%)	highv(0.81%)	highv(1.2%)	highv(3.8%)				highv(8.9%)
33																
34																
35																
36																
37															maxTi(45%)	
38															maxTi(48%)	
39				lowv(7.9%)									lowv(0.13%)	lowv(3.7%)	lowv(6.8%) lowv maxTi(7.9%) maxTi(42%)	Neph(0.54%)
40			lowv(0.40%)	lowv(34%)								TL(0.51%)	lowv(18%)	lowv(19%) lowv maxTi(11%) maxTi(34%)	lowv(22%) lowv maxTi(15%) maxTi(35%)	Neph(8.1%)
41	lowv(0.15%) Neph(4.8%)	lowv(7.4%) Neph(4.0%)	lowv(22%) Neph(4.1%)	lowv(42%) lowv Neph(2.3%) Neph(3.0%) Del Gp lowv(0.02%)								TL(5.3%)	lowv(38%)	lowv(25%) lowv maxTi(17%) maxTi(31%)	lowv(27%) lowv maxTi(21%) maxTi(32%)	Neph(78%)
42	lowv(2.9%) lowv Neph(15%) Neph(20%)	lowv(14%) lowv Neph(20%) Neph(15%)	lowv(19%) lowv Neph(22%) Neph(12%)	lowv(26%) lowv Neph(23%) Neph(4.7%) Del Gp lowv(0.97%) Del Gp lowv Neph(1.7%)							TL(0.58%)	TL(15%)	lowv(42%) lowv Neph(5.8%) Neph(3.0%)	lowv(26%) lowv maxTi(20%) lowv maxTi Neph(0.4%) lowv Neph(5.5%) maxTi(30%) Neph(0.2%)	lowv(25%) lowv maxTi(25%) lowv maxTi Neph(0.8%) lowv Neph(5.3%) maxTi(28%)	Neph(94%)

NGS: Next Generation Solvent
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-14. Detailed MAR Assessment Results for 5200 Gallons of Tank 40 and 15,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	4356	4356	4356	4344	4500	4500	4500	4668	4644	4588	4574	4644	4568	4504	4516	2037
%WL, 24	highv(20%)	highv(2.6%)			highv(59%)	highv(58%)	highv(57%)	highv(51%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(0.16%)				highv(48%)	highv(46%)	highv(44%)	highv(38%)	highv(87%)	highv(89%)	highv(93%)	highv(98%)				highv(67%)
26					highv(40%)	highv(38%)	highv(36%)	highv(27%)	highv(69%)	highv(71%)	highv(74%)	highv(81%)				highv(56%)
27					highv(29%)	highv(23%)	highv(18%)	highv(6.1%)	highv(61%)	highv(61%)	highv(63%)	highv(67%)				highv(52%)
28					highv(8.6%)	highv(4.9%)	highv(1.6%)		highv(47%)	highv(49%)	highv(52%)	highv(58%)				highv(50%)
29									highv(38%)	highv(38%)	highv(38%)	highv(39%)				highv(45%)
30									highv(30%)	highv(30%)	highv(31%)	highv(31%)				highv(36%)
31									highv(15%)	highv(16%)	highv(16%)	highv(18%)				highv(21%)
32									highv(3.3%)	highv(4.8%)	highv(5.9%)	highv(7.6%)				highv(8.9%)
33												highv(0.28%)			maxTi(48%)	
34															maxTi(48%)	
35														maxTi(45%)	maxTi(52%)	
36														maxTi(48%)	maxTi(52%)	
37														maxTi(49%)	maxTi(52%)	
38				lowv(1.3%)									maxTi(48%)	lowv maxTi(0.07%) maxTi(52%)	lowv maxTi(2.6%) maxTi(97%)	
39				lowv(26%)								TL(0.43%)	lowv(2.3%) lowv maxTi(4.2%) maxTi(43%)	lowv(9.1%) lowv maxTi(9.5%) maxTi(43%)	lowv maxTi(29%) maxTi(71%)	Neph(0.54%)
40	Neph(1.5%)	lowv(0.02%)	lowv(7.1%)	lowv(42%)								TL(5.2%)	lowv(18%) lowv maxTi(16%) maxTi(34%)	lowv(20%) lowv maxTi(17%) maxTi(38%)	lowv maxTi(43%) maxTi(57%)	Neph(8.1%)
41	lowv(2.4%) Neph(9.5%)	lowv(18%) lowv Neph(0.02%) Neph(7.8%)	lowv(34%) lowv Neph(0.67%) Neph(6.8%)	lowv(44%) lowv Neph(4.5%) Neph(0.81%) Del Gp lowv(1.0%)						TL(0.15%)	TL(1.5%)	TL(16%)	lowv(25%) lowv maxTi(20%) maxTi(33%)	lowv maxTi(49%) maxTi(51%)	lowv maxTi(53%) maxTi(47%)	Neph(78%)
42	lowv(0.80%) lowv Neph(27%) Neph(37%)	lowv(3.2%) lowv Neph(36%) Neph(17%)	lowv(7.0%) lowv Neph(38%) Neph(14%)	lowv(15%) lowv Neph(34%) Neph(5.2%) Del Gp lowv Neph(8.0%)					TL(0.15%)	TL(1.7%)	TL(6.2%)	TL(25%)	lowv(23%) lowv maxTi(21%) lowv maxTi Neph(1.2%) lowv Neph(6.4%) maxTi(29%) maxTi Neph(0.3%) Neph(1.6%)	lowv maxTi(50%) lowv maxTi Neph(8.7%) maxTi(41%)	lowv maxTi(56%) lowv maxTi Neph(8.7%) maxTi(35%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-15. Detailed MAR Assessment Results for 5200 Gallons of Tank 40 and 22,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	4356	4356	4356	4344	4500	4500	4500	4724	4644	4644	4630	4686	4568	4516	4516	2037
%WL, 24	highv(16%)	highv(1.3%)			highv(57%)	highv(57%)	highv(55%)	highv(49%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25					highv(47%)	highv(45%)	highv(43%)	highv(37%)	highv(83%)	highv(87%)	highv(89%)	highv(97%)				highv(67%)
26					highv(39%)	highv(37%)	highv(35%)	highv(24%)	highv(67%)	highv(69%)	highv(71%)	highv(78%)				highv(56%)
27					highv(25%)	highv(19%)	highv(14%)	highv(3.4%)	highv(60%)	highv(61%)	highv(62%)	highv(66%)				highv(52%)
28					highv(5.8%)	highv(2.3%)	highv(0.53%)		highv(44%)	highv(46%)	highv(48%)	highv(56%)				highv(50%)
29									highv(36%)	highv(37%)	highv(37%)	highv(37%)				highv(45%)
30									highv(26%)	highv(28%)	highv(29%)	highv(30%)				highv(36%)
31									highv(11%)	highv(11%)	highv(13%)	highv(16%)				highv(21%)
32									highv(1.4%)	highv(1.7%)	highv(2.9%)	highv(4.8%)				highv(8.9%)
33															maxTi(43%)	
34															maxTi(48%)	
35															maxTi(48%)	
36														maxTi(48%)	maxTi(52%)	
37														maxTi(48%)	maxTi(52%)	
38				lowv(1.6%)									maxTi(45%)	lowv maxTi(0.16%) maxTi(52%)	lowv(0.44%) lowv maxTi(3.3%) maxTi(54%)	
39				lowv(27%)								TL(0.21%)	lowv(3.9%) lowv maxTi(5.3%) maxTi(42%)	lowv(11%) lowv maxTi(10%) maxTi(42%)	lowv maxTi(31%) maxTi(69%)	Neph(0.54%)
40		lowv(0.16%)	lowv(9.6%)	lowv(42%) Del Gp lowv(0.12%)								TL(3.4%)	lowv(22%) lowv maxTi(14%) maxTi(34%)	lowv(23%) lowv maxTi(15%) maxTi(37%)	lowv maxTi(45%) maxTi(55%)	Neph(8.1%)
41	lowv(4.9%) Neph(6.5%)	lowv(21%) Neph(6.5%)	lowv(36%) lowv Neph(0.16%) Neph(5.3%)	lowv(41%) lowv Neph(4.3%) Neph(0.69%) Del Gp lowv(4.5%)							TL(0.28%)	TL(13%)	lowv(26%) lowv maxTi(20%) maxTi(31%)	lowv maxTi(49%) maxTi(51%)	lowv maxTi(53%) maxTi(47%)	Neph(78%)
42	lowv(1.9%) lowv Neph(28%) Neph(21%)	lowv(6.6%) lowv Neph(34%) Neph(14%)	lowv(9.8%) lowv Neph(35%) Neph(11%) Del Gp lowv Neph(1.0%)	lowv(23%) lowv Neph(20%) Neph(2.0%) Del Gp lowv(6.2%) Del Gp lowv Neph(9.1%)						TL(1.2%)	TL(4.1%)	TL(22%)	lowv(24%) lowv maxTi(22%) lowv maxTi Neph(0.6%) lowv Neph(5.0%) maxTi(30%) Neph(0.5%)	lowv maxTi(52%) lowv maxTi Neph(7.8%) maxTi(40%)	lowv maxTi(58%) lowv maxTi Neph(7.4%) maxTi(35%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-16. Detailed MAR Assessment Results for 5700 Gallons of Tank 40 and 15,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	4356	4356	4356	4344	4356	4500	4500	4724	4588	4644	4588	4602	4568	4504	4504	2037
%WL, 24	highv(32%)	highv(14%)	highv(1.3%)		highv(59%)	highv(59%)	highv(58%)	highv(53%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(4.6%)				highv(50%)	highv(48%)	highv(46%)	highv(40%)	highv(87%)	highv(89%)	highv(91%)	highv(98%)				highv(67%)
26					highv(43%)	highv(40%)	highv(38%)	highv(30%)	highv(69%)	highv(70%)	highv(72%)	highv(79%)				highv(56%)
27					highv(34%)	highv(28%)	highv(22%)	highv(8.4%)	highv(61%)	highv(61%)	highv(62%)	highv(66%)				highv(52%)
28					highv(13%)	highv(7.6%)	highv(4.6%)	highv(0.02%)	highv(47%)	highv(49%)	highv(51%)	highv(57%)				highv(50%)
29					highv(0.32%)				highv(38%)	highv(38%)	highv(38%)	highv(38%)				highv(45%)
30									highv(31%)	highv(31%)	highv(31%)	highv(31%)				highv(36%)
31									highv(15%)	highv(16%)	highv(16%)	highv(18%)				highv(21%)
32									highv(3.3%)	highv(4.7%)	highv(5.6%)	highv(7.4%)				highv(8.9%)
33												highv(0.20%)				
34																
35															maxTi(45%)	
36															maxTi(48%)	
37														maxTi(45%)	maxTi(49%)	
38														maxTi(48%)	lowv maxTi(0.07%) maxTi(52%)	
39				lowv(13%)								TL(0.11%)	lowv(0.46%)	lowv(2.8%) lowv maxTi(4.7%) maxTi(43%)	lowv(8.6%) lowv maxTi(9.0%) maxTi(43%)	Neph(0.54%)
40	Neph(1.7%)	Neph(1.5%)	lowv(0.55%)	lowv(37%)								TL(2.9%)	lowv(13%) lowv maxTi(11%) maxTi(34%)	lowv(19%) lowv maxTi(16%) maxTi(35%)	lowv(20%) lowv maxTi(17%) maxTi(38%)	Neph(8.1%)
41	Neph(11%)	lowv(6.7%) Neph(9.5%)	lowv(23%) lowv Neph(0.02%) Neph(7.8%)	lowv(43%) lowv Neph(3.7%) Neph(2.6%)							TL(0.24%)	TL(12%)	lowv(24%) lowv maxTi(16%) lowv maxTi Neph(.02%) maxTi(32%) maxTi Neph(0.04%) Neph(2.2%)	lowv(26%) lowv maxTi(19%) maxTi(33%)	lowv maxTi(48%) maxTi(52%)	Neph(78%)
42	lowv Neph(17%) Neph(52%)	lowv(0.83%) lowv Neph(32%) Neph(31%)	lowv(4.3%) lowv Neph(37%) Neph(16%)	lowv(12%) lowv Neph(37%) Neph(8.3%) Del Gp lowv Neph(3.2%)	Neph(2.8%)					TL(0.39%)	TL(3.5%)	TL(21%)	lowv(25%) lowv maxTi(18%) lowv maxTi Neph(0.9%) lowv Neph(5.1%) maxTi(28%) maxTi Neph(0.5%) Neph(3.0)	lowv(23%) lowv maxTi(21%) lowv maxTi Neph(1.2%) lowv Neph(6.6%) maxTi(30%) maxTi Neph(0.3%) Neph(1.5%)	lowv maxTi(48%) lowv maxTi Neph(11%) maxTi(41%) maxTi Neph(0.11%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-17. Detailed MAR Assessment Results for 5700 Gallons of Tank 40 and 22,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700	5700
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	4356	4356	4356	4344	4356	4500	4500	4724	4588	4644	4644	4644	4568	4568	4504	2037
%WL, 24	highv(29%)	highv(9.4%)	highv(0.16%)		highv(57%)	highv(57%)	highv(57%)	highv(51%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(1.7%)				highv(49%)	highv(47%)	highv(45%)	highv(38%)	highv(84%)	highv(86%)	highv(89%)	highv(96%)				highv(67%)
26					highv(42%)	highv(38%)	highv(37%)	highv(27%)	highv(67%)	highv(68%)	highv(70%)	highv(77%)				highv(56%)
27					highv(30%)	highv(24%)	highv(18%)	highv(6.2%)	highv(60%)	highv(60%)	highv(61%)	highv(65%)				highv(52%)
28					highv(8.7%)	highv(4.8%)	highv(1.7%)		highv(45%)	highv(45%)	highv(47%)	highv(55%)				highv(50%)
29									highv(37%)	highv(37%)	highv(37%)	highv(37%)				highv(45%)
30									highv(27%)	highv(29%)	highv(29%)	highv(30%)				highv(36%)
31									highv(11%)	highv(12%)	highv(14%)	highv(16%)				highv(21%)
32									highv(1.4%)	highv(2.0%)	highv(2.9%)	highv(5.0%)				highv(8.9%)
33																
34																
35															maxTi(43%)	
36															maxTi(48%)	
37															maxTi(48%)	
38														maxTi(48%)	lowv maxTi(0.11%) maxTi(52%)	
39				lowv(14%)								TL(0.11%)	lowv(1.3%)	lowv(4.1%) lowv maxTi(6.1%) maxTi(42%)	lowv(10%) lowv maxTi(9.7%) maxTi(43%)	Neph(0.54%)
40			lowv(1.3%)	lowv(37%)								TL(1.6%)	lowv(27%)	lowv(20%) lowv maxTi(16%) maxTi(34%)	lowv(22%) lowv maxTi(16%) maxTi(37%)	Neph(8.1%)
41	lowv(0.21%) Neph(7.8%)	lowv(9.6%) Neph(7.5%)	lowv(25%) lowv Neph(0.05%) Neph(6.4%)	lowv(43%) lowv Neph(3.4%) Neph(1.9%) Del Gp lowv(0.99%)							TL(0.15%)	TL(8.9%)	lowv(25%) lowv maxTi(16%) maxTi(31%)	lowv(26%) lowv maxTi(20%) maxTi(32%)	lowv maxTi(49%) maxTi(51%)	Neph(78%)
42	lowv(0.34%) lowv Neph(19%) Neph(32%)	lowv(2.5%) lowv Neph(33%) Neph(17%)	lowv(6.1%) lowv Neph(35%) Neph(14%)	lowv(14%) lowv Neph(31%) Neph(6.2%) Del Gp lowv Neph(7.7%)						TL(0.24%)	TL(1.8%)	TL(18%)	lowv(25%) lowv maxTi(18%) lowv maxTi Neph(0.9%) lowv Neph(5.1%) maxTi(28%) maxTi Neph(0.5%) Naph(2.1%)	lowv(24%) lowv maxTi(22%) lowv maxTi Neph(0.6%) lowv Neph(5.1%) maxTi(29%) Neph(0.4%)	lowv maxTi(51%) lowv maxTi Neph(8.6%) maxTi(41%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-18. Detailed MAR Assessment Results for 6000 Gallons of Tank 40 and 15,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	0
Number of EVs	4356	4356	4356	4344	4356	4500	4500	4724	4588	4476	4588	4602	4568	4568	4504	2037
%WL, 24	highv(35%)	highv(20%)	highv(3.7%)		highv(59%)	highv(59%)	highv(58%)	highv(54%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(8.6%)	highv(0.16%)			highv(51%)	highv(49%)	highv(47%)	highv(40%)	highv(87%)	highv(91%)	highv(89%)	highv(97%)				highv(67%)
26					highv(44%)	highv(41%)	highv(39%)	highv(31%)	highv(69%)	highv(72%)	highv(72%)	highv(78%)				highv(56%)
27					highv(35%)	highv(30%)	highv(25%)	highv(11%)	highv(61%)	highv(63%)	highv(62%)	highv(66%)				highv(52%)
28					highv(14%)	highv(9.1%)	highv(6.4%)	highv(0.15%)	highv(47%)	highv(50%)	highv(50%)	highv(56%)				highv(50%)
29					highv(0.78%)	highv(0.02%)			highv(39%)	highv(40%)	highv(38%)	highv(38%)				highv(45%)
30									highv(31%)	highv(32%)	highv(31%)	highv(31%)				highv(36%)
31									highv(15%)	highv(16%)	highv(16%)	highv(18%)				highv(21%)
32									highv(3.3%)	highv(4.9%)	highv(5.6%)	highv(7.3%)				highv(8.9%)
33												highv(0.20%)				
34																
35																
36															maxTi(45%)	
37															maxTi(48%)	
38															maxTi(48%)	
39				lowv(4.6%)								TL(0.09%)		lowv(0.24%) lowv maxTi(1.5%) maxTi(45%)	lowv(5.9%) lowv maxTi(7.9%) maxTi(44%)	Neph(0.54%)
40	Neph(1.7%)	Neph(1.7%)	Neph(1.5%)	lowv(32%)								TL(1.5%)	lowv(15%)	lowv(16%) lowv maxTi(13%) maxTi(35%)	lowv(21%) lowv maxTi(16%) maxTi(36%)	Neph(8.1%)
41	Neph(11%)	lowv(3.2%) Neph(11%)	lowv(15%) lowv Neph(0.02%) Neph(9.4%)	lowv(41%) lowv Neph(3.2%) Neph(4.1%)							TL(0.15%)	TL(8.7%)	lowv(38%) Neph(2.3%)	lowv(24%) lowv maxTi(19%) lowv maxTi Neph(.02%) lowv Neph(0.1%) maxTi(31%) Neph(1.2%)	lowv(26%) lowv maxTi(21%) maxTi(32%)	Neph(78%)
42	lowv Neph(11%) Neph(58%)	lowv Neph(28%) Neph(39%)	lowv(2.5%) lowv Neph(35%) Neph(18%)	lowv(11%) lowv Neph(38%) Neph(10%) Del Gp lowv Neph(1.5%)	Neph(2.8%)					TL(0.27%)	TL(1.8%)	TL(18%)	lowv(23%) lowv maxTi(17%) lowv maxTi Neph(0.9%) lowv Neph(5.4%) maxTi(27%) maxTi Neph(0.8%) Neph(4.3%)	lowv(23%) lowv maxTi(21%) lowv maxTi Neph(1.1%) lowv Neph(5.6%) maxTi(30%) maxTi Neph(0.5%) Neph(2.4%)	lowv maxTi(45%) lowv maxTi Neph(7.5%) maxTi(46%) maxTi Neph(1.1%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Table A-19. Detailed MAR Assessment Results for 6000 Gallons of Tank 40 and 22,000 Gallons of SE (BOBCalixC6) with Frit 473

Case	Case 1 Single Strike				Case 3A Single Strike with 600 mg/L ISS				Case 3B Single Strike 1200 mg/L ISS				Case 4 Double Strike			Sludge-only
Tank 40 Volume (gal)	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
SSRT Volume (gal)	2400	2800	3200	4500	2400	2800	3200	4500	2400	2800	3200	4500	3800	4200	4600	0
SE Extractant	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	BC	----
SE Volume (gal)	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	0
Number of EVs	4356	4356	4356	4344	4356	4500	4500	4724	4588	4644	4644	4644	4568	4568	4504	2037
%WL, 24	highv(34%)	highv(16%)	highv(2.4%)		highv(58%)	highv(58%)	highv(57%)	highv(52%)	highv(100%)	highv(100%)	highv(100%)	highv(100%)				highv(92%)
25	highv(6.6%)				highv(50%)	highv(47%)	highv(46%)	highv(39%)	highv(83%)	highv(86%)	highv(88%)	highv(96%)				highv(67%)
26					highv(42%)	highv(39%)	highv(38%)	highv(30%)	highv(67%)	highv(68%)	highv(70%)	highv(77%)				highv(56%)
27					highv(32%)	highv(26%)	highv(21%)	highv(8.1%)	highv(60%)	highv(60%)	highv(61%)	highv(65%)				highv(52%)
28					highv(10%)	highv(6.6%)	highv(3.4%)		highv(45%)	highv(45%)	highv(47%)	highv(54%)				highv(50%)
29					highv(0.05%)				highv(37%)	highv(37%)	highv(37%)	highv(37%)				highv(45%)
30									highv(27%)	highv(29%)	highv(29%)	highv(30%)				highv(36%)
31									highv(11%)	highv(12%)	highv(14%)	highv(16%)				highv(21%)
32									highv(1.4%)	highv(2.0%)	highv(2.9%)	highv(5.0%)				highv(8.9%)
33																
34																
35																
36																
37															maxTi(48%)	
38															maxTi(48%)	
39				lowv(5.8%)										lowv(0.46%) lowv maxTi(1.7%) maxTi(44%)	lowv(5.9%) lowv maxTi(8.3%) maxTi(42%)	Neph(0.54%)
40			lowv(0.02%)	lowv(34%)								TL(1.2%)	lowv(17%)	lowv(17%) lowv maxTi(13%) maxTi(35%)	lowv(21%) lowv maxTi(16%) maxTi(36%)	Neph(8.1%)
41	Neph(7.8%)	lowv(4.7%) Neph(7.5%)	lowv(18%) lowv Neph(0.02%) Neph(7.5%)	lowv(43%) lowv Neph(2.5%) Neph(2.9%) Del Gp lowv(0.28%)								TL(5.7%)	lowv(39%)	lowv(26%) lowv maxTi(17%) maxTi(31%)	lowv(27%) lowv maxTi(20%) maxTi(32%)	Neph(78%)
42	lowv Neph(14%) Neph(37%)	lowv(1.5%) lowv Neph(29%) Neph(23%)	lowv(4.7%) lowv Neph(34%) Neph(16%)	lowv(12%) lowv Neph(33%) Neph(8.6%) Del Gp lowv Neph(5.0%)	Neph(2.8%)					TL(0.15%)	TL(1.6%)	TL(17%)	lowv(24%) lowv maxTi(18%) lowv maxTi Neph(0.7%) lowv Neph(4.9%) maxTi(26%) maxTi Neph(0.6%) Neph(3.3%)	lowv(23%) lowv maxTi(21%) lowv maxTi Neph(0.4%) lowv Neph(5.5%) maxTi(29%) maxTi Neph(0.02%) Neph(1.7%)	lowv(22%) lowv maxTi(25%) lowv maxTi Neph(0.6%) lowv Neph(5.4%) maxTi(29%) Neph(0.2%)	Neph(94%)

BC: BOBCalixC6
highv: high viscosity
lowv: low viscosity
Neph: nepheline
TL: liquidus temperature
maxTi: maximum TiO_2

Appendix B. Supplementary Information and Results for the SE Cs-137 Sensitivity Analysis

Table B-1. SE Compositions (wt.%) as a Function of Cs-137 Concentration

	Cs-137 Concentration (Ci/gallon)				
	66	**49.5**	**33**	**16.5**	**8**
SE Extractant: BOBCalixC6					
Cs_2O	71.30	65.07	55.40	38.31	23.14
K_2O	4.83	5.88	7.51	10.38	12.93
Na_2O	23.87	29.05	37.09	51.31	63.92
SE Extractant: NGS					
B_2O_3	22.53	26.14	31.12	38.46	43.78
Cs_2O	55.24	48.07	38.16	23.58	13.01
K_2O	3.74	4.34	5.17	6.39	7.27
Na_2O	18.49	21.45	25.55	31.57	35.94

Table B-2. Other SE Properties

SE Extractant	**BOBCalixC6**	**NGS**
Calcined Solids (g oxide/L)	1.50	1.93
Density (g/mL)	1.01	1.01

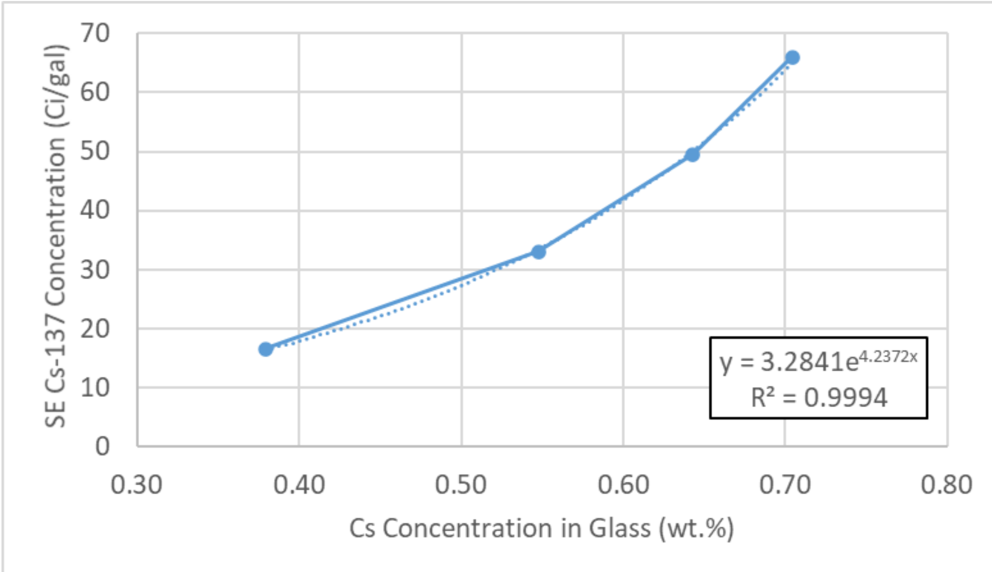

Figure B-1. Cs concentration in glass at 36% WL after a 15,000 gallon SE transfer (BOBCalixC6) as a function of various assumed SE Cs-137 concentrations.

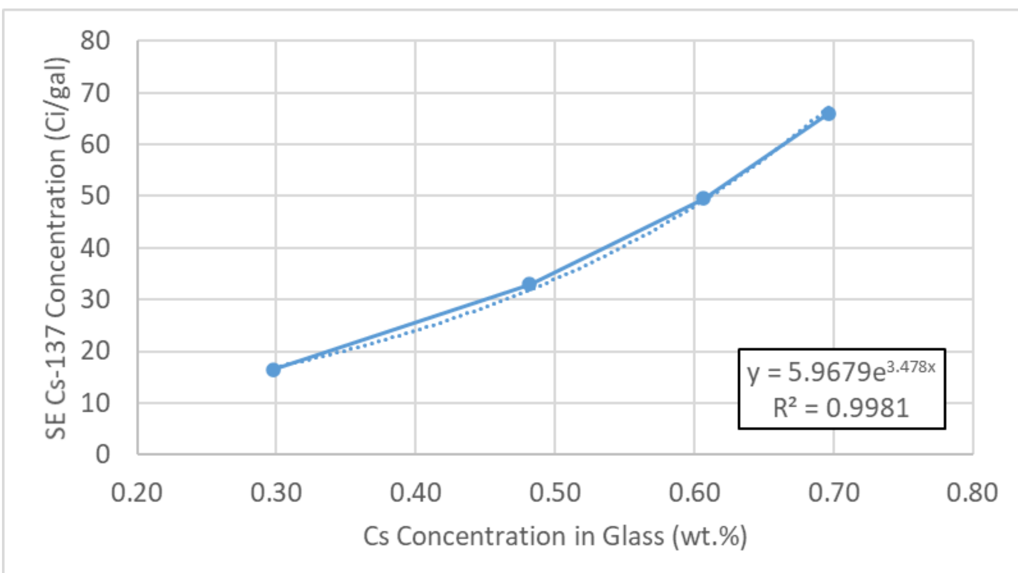

Figure B-2. Cs concentration in glass at 36% WL after a 15,000 gallon SE transfer (NGS) as a function of various assumed SE Cs-137 concentrations.

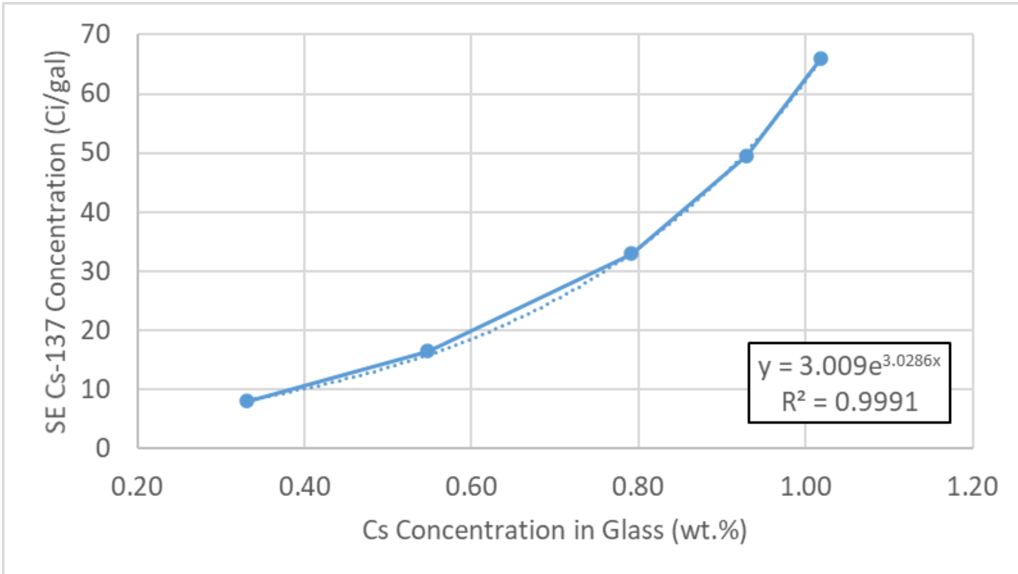

Figure B-3. Cs concentrations in glass at 36% WL after a 22,000 gallon SE transfer (BOBCalixC6) as a function of various assumed SE Cs-137 concentrations.

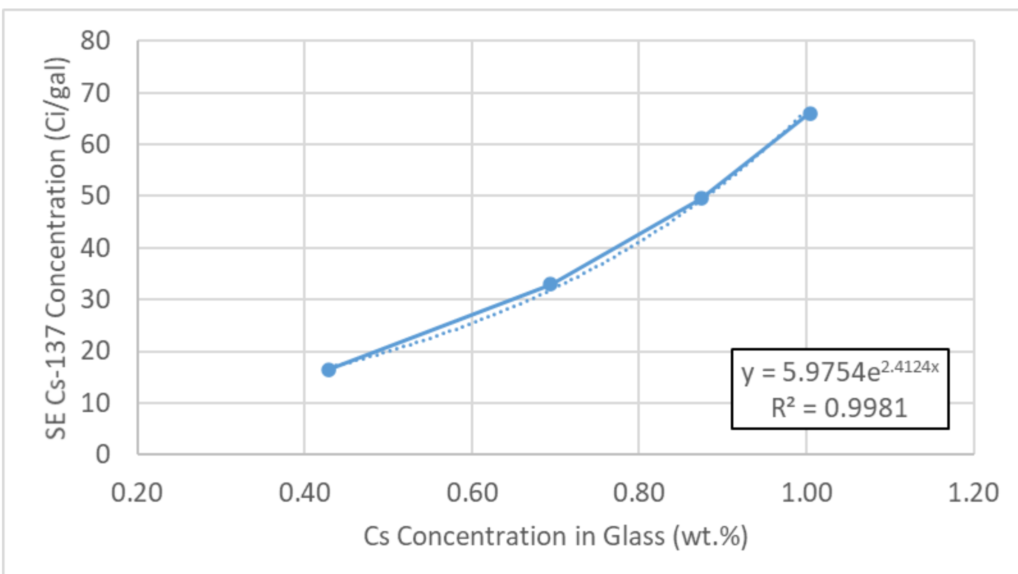

Figure B-4. Cs concentration in glass at 36% WL after a 22,000 gallon SE transfer (NGS) as a function of various assumed SE Cs-137 concentrations.