The Impact of a Tank 40H Decant on the Projected Operating Windows for SB4 and Glass Selection Strategy in Support of the Variability Study

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Process Science and Engineering Section
Savannah River National Laboratory
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EXECUTIVE SUMMARY

The Liquid Waste Organization (LWO) has requested that the Savannah River National Laboratory (SRNL) to assess the impact of a 100K gallon decant volume from Tank 40H on the existing sludge-only Sludge Batch 4 (SB4) – Frit 510 flowsheet and the coupled operations flowsheet (SB4 with the Actinide Removal Process (ARP)). Another potential SB4 flowsheet modification of interest includes the addition of 3 wt% sodium (on a calcined oxide basis) to a decanted sludge-only or coupled operations flowsheet. These potential SB4 flowsheet modifications could result in significant compositional shifts to the SB4 system. This paper study provides an assessment of the impact of these compositional changes to the projected glass operating windows and to the variability study for the Frit 510 – SB4 system. The influence of the compositional changes on melt rate was not assessed in this study nor was it requested.

Nominal Stage paper study assessments were completed using the projected compositions for the various flowsheet options coupled with Frit 510 (i.e., variation was *not* applied to the sludge and frit compositions). In order to gain insight into the impacts of sludge variation and/or frit variation (due to the procurement specifications) on the projected operating windows, three versions of the Variation Stage assessment were performed: (1) the traditional Variation Stage assessment in which the nominal Frit 510 composition was coupled with the extreme vertices (EVs) of each sludge, (2) an assessment of the impact of possible frit variation (within the accepted frit specification tolerances) on each nominal SB4 option, and (3) an assessment of the impact of possible variation in the Frit 510 composition due to the vendor's acceptance specifications coupled with the EVs of each sludge case.

The results of the Nominal Stage assessment indicate very little difference among the various flowsheet options. All of the flowsheets provide DWPF with the possibility of targeting waste loadings (WLs) from the low 30s to the low 40s with Frit 510. In general, the Tank 40H decant has a slight negative impact on the operating window, but DWPF still has the ability to target current WLs (34%) and higher WLs if needed. While the decant does not affect practical WL targets in DWPF, melt rate could be reduced due to the lower Na_2O content. If true, the addition of 3 wt% Na_2O to the glass system may regain melt rate, assuming that the source of alkali is independent of the impact on melt rate. Coupled operations with Frit 510 via the addition of ARP to the decanted SB4 flowsheet also appears to be viable based on the projected operating windows. The addition of both ARP and 3 wt% Na_2O to a decanted Tank 40H sludge may be problematic using Frit 510.

Although the Nominal Stage assessments provide reasonable operating windows for the SB4 flowsheets being considered with Frit 510, introduction of potential sludge and/or frit compositional variation does have a negative impact. The magnitude of the impact on the projected operating windows is dependent on the specific flowsheet options as well as the applied variation (e.g., frit specification, sludge variation, or both). The results of the traditional Variation Stage assessments indicate that the three proposed Tank 40H decanted flowsheet options (Case #2 – 100K gallon decant, Case #3 – 100K gallon decant and 3 wt% Na_2O addition and Case #4 – 100K gallon decant and ARP) demonstrate a relatively high degree of robustness to possible sludge variation over WLs of interest with Frit 510. However, the case where the addition of both ARP and 3 wt% Na_2O is considered was problematic during the traditional Variation Stage assessment. The impact of coupling the frit specifications with the nominal SB4 flowsheet options on the projected operating windows is highly dependent on whether the upper WLs are low viscosity or liquidus temperature limited in the Nominal Stage assessments. Systems that are liquidus temperature limited exhibit a high degree of robustness to the applied frit and sludge variation, while those that are low viscosity limited show significant reductions (6 percentage points) in the upper WLs that can be obtained. When both frit

and sludge variations are applied, the paper study results indicate that DWPF could be severely restricted in terms of projected operating windows for the ARP and Na_2O addition options.

An experimental variability study was not performed using the final SB4 composition and Frit 510 since glasses in the ComPro™ data base were identified that bounded the potential operating window of this system. The bounding ARP case was not considered in that assessment. After the flowsheet cases were identified, an electronic search of ComPro™ identified approximately 12 historical glasses within the compositional regions defined by at least one of the five flowsheet options, but the compositional coverage did not appear adequate to bound all cases. Therefore, SRNL recommends that a supplemental, experimental variability study be performed to support the various SB4 flowsheet options that may be implemented for future SB4 operations in DWPF. To support this recommendation, eighteen glasses have been selected based on the nominal sludge projections representing the current and proposed flowsheets over a WL interval of interest to DWPF (32 – 42%). These eighteen glasses will be fabricated and characterized to demonstrate that the glasses are both acceptable and predictable by the current process control models for durability. SRNL will then be able to confirm the recommendation for the decant or NaOH addition based on applicability of the glass models and will also be able to confirm the processing window for coupled operations with Frit 510.

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LIST OF ABBREVIATIONS

ARP	Actinide Removal Process
CPC	Chemical Process Cell
DWPF	Defense Waste Processing Facility
EV	Extreme Vertice
LWO	Liquid Waste Organization
MAR	Measurement Acceptability Region
MCU	Modular Caustic-Side Solvent Extraction Unit
MST	Monosodium Titanate
NL [B]	Normalized Leachate for Boron
PCCS	Product Composition Control System
PCT	Product Consistency Test
QA	Quality Assurance
SB4	Sludge Batch 4
SME	Slurry Mix Evaporator
SRAT	Sludge Receipt and Adjustment Tank
SRNL	Savannah River National Laboratory
T_L	Liquidus Temperature
TTR	Technical Task Request
η	Viscosity
WAPS	Waste Acceptance Product Specifications
WL	Waste Loading (weight percent)
WT	Waste Throughput

1.0 Introduction

Sludge Batch 4 (SB4) is currently being processed in the Defense Waste Processing Facility (DWPF) using Frit 510. The slurry pumps in Tank 40H are experiencing in-leakage of bearing water, which is causing the sludge slurry feed in Tank 40H to become dilute at a rapid rate. Currently, the DWPF is removing this dilution water by performing caustic boiling during the Sludge Receipt and Adjustment Tank (SRAT) cycle. In order to alleviate prolonged SRAT cycle times, which may eventually impact canister production rates, decant scenarios of varying amounts of supernate have been proposed for Tank 40H. The Savannah River National Laboratory (SRNL) has issued a preliminary assessment evaluating the possible downstream impacts of three (100, 150, and 200 kilogallon) decant scenarios on DWPF glass formulation and Chemical Processing Cell (CPC) issues.[1] Based on the results of the preliminary assessment, the Liquid Waste Organization (LWO) issued a Technical Task Request (TTR) for SRNL to perform a more detailed evaluation using updated SB4 compositional information.[2] As defined in the TTR, LWO has requested SRNL to validate the existing sludge-only SB4 flowsheet and coupled operations[a] flowsheet for a 100K gallon decant volume. Another potential SB4 flowsheet modification of interest to LWO included the addition of 3 wt% sodium (on a calcined oxide basis) to a decanted sludge-only or coupled operations flowsheet.

These potential SB4 flowsheet modifications (i.e., 100K gallon decant, potential additions of Na_2O, and/or transitioning to a coupled operations flowsheet) could result in significant compositional shifts to the SB4 system. To meet the objectives of the TTR, SRNL performed an assessment of the impact of these compositional changes to the projected glass operating windows and to the variability study for the Frit 510 – SB4 system as defined in the Task Technical and Quality Assurance (QA) Plan.[3,b]

2.0 Objectives

The objectives of the current report are:

(1) To provide feedback to LWO regarding the impact of the proposed SB4 flowsheet changes (Tank 40H decant, Na_2O addition, and/or transition to coupled operations) to the projected operating windows for the SB4 – Frit 510 system. The projected operating windows will be defined as the waste loading (WL) interval over which glasses are classified as acceptable based on current DWPF process control models and their associated acceptance constraints. The results presented in this report are solely based on model predictions and do not include any experimental work (such as melt rate assessments).

(2) To determine if a supplementary variability study is needed for the new compositional regions developed by the proposed SB4 flowsheet changes. The newly defined glass compositional regions will be compared to existing glass data (i.e., historical glasses) within the ComPro™ database.[4,5] If sufficient historical glasses are found within the compositional regions defined by the revised SB4 – Frit 510 flowsheet, then an experimental study may not be required. If an adequate number of historical glasses bounding the compositional range are not found, then an experimental study will be designed and implemented to support the Waste Acceptance Product Specifications (WAPS) requirements. A variability study will determine if the Product Consistency Test (PCT)/chemical composition correlation (i.e., ΔG_P

[a] SB4 coupled with the Actinide Removal Process (ARP) / monosodium titanate (MST) and/or Modular Caustic-Side Solvent Extraction (CSSX) Unit (MCU) strip effluent.
[b] As defined in the Task Technical and QA Plan, there are supplemental studies to evaluate the impact of these potential flowsheet changes on the CPC. These issues are not addressed in this report but will be documented elsewhere.

model) currently utilized by DWPF applies to the modified SB4 glass composition region of interest.[6,7]

3.0 Measurement Acceptability Region (MAR) Assessments

In order to perform the model-based MAR assessments, two critical inputs are required: (1) projected sludge compositions for the proposed flowsheet changes (i.e., decant, Na_2O addition, and/or transition to coupled operations) and (2) candidate frit compositions. Given these two inputs, glass compositional regions of interest can be defined and evaluated against existing Product Composition and Control System (PCCS) criteria to establish projected operating windows for the glass systems of interest.[8] The results of the MAR assessment will provide insight into the viability of the various flowsheet changes being considered for DWPF operations.[9] The following sections will discuss and provide the nominal sludge composition projections, the nominal composition of Frit 510 (including major oxide specifications), and a high-level summary of the MAR assessment criteria utilized.

3.1 Projected Sludge Compositions

To support the MAR assessments, the nominal (baseline) SB4 composition, compositional projections of SB4 with the 100K gallon decant, and SB4 with the 100K gallon decant and a 3 wt% Na_2O addition have been provided by LWO.[c] SRNL subsequently added the ARP/MCU stream[d] to these compositions to assess the scenarios that were presented in the TTR. The following five nominal SB4 sludges were identified to support this study:

Case #1: SB4 Nominal
Case #2: SB4 after the 100K gallon decant
Case #3: SB4 after the 100K gallon decant with a 3 wt% Na_2O addition
Case #4: SB4 after the 100K gallon decant and with addition of ARP J
Case #5: SB4 after the 100K gallon decant with the addition of 3 wt% Na_2O and ARP J

Table 1 summarizes the nominal compositions of the five sludge options, which will be referred to as Case #1 through Case #5 throughout the remainder of this report.

3.2 Candidate Frit Compositions

Currently, Frit 510 is being used to process SB4. The nominal or targeted composition of Frit 510 (wt% oxide basis) is listed in Table 2, as well as specifications of the four major oxides placed on the frit vendor for acceptance.[10,11] It should be noted that this study does not consider additional oxide/halide impurities or their concentrations that are also a part of the specification.[e]

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[c] Compositional projections received on 1-4-08 via personal communication (email) from H.H. Elder. Note: SO_4 values were not reported by LWO. The value reported during analysis of the WAPS sample (1.336 wt% on a calcined oxide basis) was used for the nominal SB4 composition (prior to Tank 40H decant and/or addition of Na_2O). The SO_4 value after decanting was assumed to be ~ 25% less based on information reported by LWO in November 2007. Although the addition of NaOH to regain 3 wt% Na_2O in sludge would result in a small dilution in SO_4 content of the decanted 3 wt% Na_2O projected composition, the SO_4 content was not changed.

[d] Compositional information for Appendix J was obtained from X-CLC-S-00113, Rev 0, Actinide Removal Process Material Balance Calculation with Low Curie Salt Feed, S.G. Subosits, 9/24/04, Appendix J.

[e] In this report, an assessment is made to evaluate the impact of the compositional specifications for the four major oxides on projected operating windows. A supplemental study is being performed in parallel to this task in order to assess the possible impact of an "out of spec" frit (either major oxides or impurity levels outside of the current acceptance specification) on the projected operating windows for the five SB4 cases of interest. The results will be documented in a separate report.

Table 1. Nominal Compositions of the Five SB4 Cases

	Case #1	Case #2	Case #3	Case #4	Case #5
	SB4 Baseline	SB4 after 100K Decant	SB4 after 100K Decant with Sodium Added	SB4 after 100K Decant + ARP J	SB4 after 100K Decant + Sodium Added + ARP J
Al_2O_3	24.894	25.958	25.015	24.988	24.091
BaO	0.074	0.077	0.075	0.078	0.075
CaO	2.730	2.857	2.753	2.765	2.666
Ce_2O_3	0.065	0.068	0.066	0.073	0.070
Cr_2O_3	0.155	0.162	0.156	0.160	0.154
CuO	0.057	0.060	0.058	0.059	0.057
Fe_2O_3	28.294	29.602	28.526	28.747	27.724
K_2O	0.350	0.366	0.353	0.354	0.341
La_2O_3	0.049	0.051	0.049	0.052	0.050
MgO	2.685	2.809	2.707	2.676	2.579
MnO	5.682	5.945	5.729	5.878	5.673
Na_2O	20.521	17.319	20.289	18.448	21.272
NiO	1.574	1.647	1.587	1.633	1.576
PbO	0.062	0.065	0.063	0.068	0.066
SO_4	1.319	0.992	0.992	1.086	1.086
SiO_2	2.662	2.785	2.683	2.681	2.585
TiO_2	0.038	0.040	0.039	1.337	1.336
U_3O_8	8.633	9.032	8.704	8.747	8.435
ZnO	0.077	0.081	0.078	0.081	0.078
ZrO_2	0.079	0.083	0.080	0.088	0.086

Table 2. Frit 510 Nominal Composition and Major Oxide Acceptance Specifications

Oxide	wt%	Specification (± wt%)
B_2O_3	14	0.85
Na_2O	8	0.55
Li_2O	8	0.55
SiO_2	70	1.30

4.0 Nominal and Variation Stage Assessments

Paper study assessments of sludge/frit systems are typically completed in a two-step process. The Nominal Stage assessment is a screening tool that is typically applied to a large set of candidate frits and/or sludge compositions to identify candidate flowsheets for further study, whereas the Variation Stage is a more thorough assessment of the sludge and is conducted for a select set of flowsheet options. Utilization of both of these stages allows for a detailed assessment of the impacts of sludge and/or frit variation on the projected operating windows of the system.

In each stage, glass compositions were generated to represent combinations of each sludge and Frit 510 at waste loadings of interest. The acceptability of the model predictions for a particular glass composition for either stage was judged by employing the same criteria that are used by the PCCS during Slurry Mix Evaporator (SME) acceptability decisions implemented in DWPF.[9] Properties predicted for this assessment were determined to be acceptable by satisfying their respective MAR limits. This assessment is valuable because it mirrors the process used by DWPF for the same glass during SME acceptability decisions for future facility operations.

4.1 Nominal Stage Assessment

In this assessment the nominal sludge compositions were coupled with the nominal Frit 510 composition over WLs of 25 – 50% in increments of 1 percentage point resulting in 26 glasses for each system of interest. Projected operating windows were identified as the WL interval over which the glasses met all PCCS MAR criteria. For each glass, the property predictions assessed included those for liquidus temperature (T_L), viscosity (η), durability (normalized leachate for boron, NL[B]), Al_2O_3 and/or sum of alkali and their associated constraints[f], high viscosity (highv), low viscosity (lowv), high chromia concentration (Cr_2O_3), high sulfate concentration (SO_4^{2-}) and nepheline formation. The MAR assessments were based on the current version of PCCS.[9]

Table 3 summarizes the Nominal Stage assessment for each of the five flowsheet options of interest. To aid in the interpretation of Table 3, consider Case #1; nominal Frit 510 coupled with nominal (or baseline) SB4 prior to the decant. This option reflects current operations at DWPF. The projected operating window is 27 – 42% WL with both low η and nepheline formation predictions limiting access to WLs greater than 42%. Homogeneity restricts access to the lower WLs (25 – 26%); however, this is of no practical concern.

The "Constraint at Higher WLs" column of Table 3 has been included to provide the LWO and DWPF with the WL at which nepheline formation is predicted to become an issue for the flowsheets of interest. It should be noted that for Case #1, nepheline is a *primary* constraint (in addition to low viscosity) and dictates the upper WL of the projected operating window. T_L predictions become restrictive at higher WLs (greater than 45%) for this system. Although not a concern from an

[f] For sludge-only processing, the Al_2O_3 and sum of alkali constraints can be used to replace the homogeneity constraint and its auxiliary constraints (low frit, high frit) (Herman et al. (2002)). Although DWPF is currently operating a sludge-only flowsheet, the algorithms in PCCS still contain homogeneity (at the PAR) and the auxiliary constraints. Although there is a high probability that the Al_2O_3 and sum of alkali could also replace homogeneity and the auxiliary constraints for coupled operations, this report utilized the exact algorithms currently imposed in PCCS to assess the projected operating windows. It should be noted that this does create a potentially conservative evaluation on the projected operating windows for those systems found to be homogeneity limited at lower WLs or where predicted issues associated with its auxiliary constraints occur at other WLs of interest. The application of the current PCCS system will not have an impact on the results or conclusions from this study.

operational perspective, WLs of 42% or greater would not be targeted based on nepheline formation issues for Case #1. The projected operating windows for the remaining sludge options (Case #2 – Case #5) are not nepheline limited. Identifying the WL at which nepheline predictions become restrictive helps LWO and DWPF to recognize when durability related concerns may become an issue. This information essentially provides insight into the "WL cushion" available between the upper WL defined by the process control models and the WL at which nepheline formation could potentially impact durability or SME acceptability decisions.

Table 3. Nominal Stage MAR Assessment

SB4 Option	Projected Operating Window (WL)	Constraint at Higher WLs
Case #1	homog 27 – 42% low η / nepheline	T_L at 46%
Case #2	25 – 41% T_L	Nepheline at 45%
Case #3	homog 26 – 42% low η	Nepheline at 44%
Case #4	homog 27 – 42% T_L	Nepheline at 45%
Case #5	homog 28 – 40% low η	Nepheline at 43%

A few general comments regarding the results of the Nominal Stage assessments are provided below for each case.

4.1.1 Case #1: SB4 Baseline

Based on the nominal compositions, current operations in DWPF have a projected operating window of 27 – 42% WL, which is limited at 43% WL by both low viscosity and nepheline. At the current WL target of ~34%, none of the current process or product performance properties are challenged. Although current DWPF operations at this WL are exceeding initial production expectations, there is some interest to assess the impact of WL on melt rate in an attempt to identify the WL which provides the maximum waste throughput for this flowsheet. The results of the MAR assessment indicate that DWPF has an opportunity to target WLs in the high 30s to low 40s in order to increase waste throughput; however, targeting higher WLs increases the risk of nepheline formation based on model predictions when coupled with the uncertainties associated with measuring or targeting WL in DWPF.

4.1.2 Case #2: SB4 + 100K Gallon Decant

Implementation of the Tank 40H decant reduces the total Na_2O in the sludge, which results in a lower Na_2O content (total) in the glass and thus increased T_L predictions, assuming the same WL. The projected operating window is 25 – 41%, but becomes limited by T_L at 42% due to the shift in the glass composition. Even though the projected operating window is slightly smaller than the Case #1 baseline, the lower Na_2O concentration suppresses nepheline formation to higher WLs (45%) and increases viscosity predictions (at a fixed WL). These results indicate that the Tank 40H decant not only allows DWPF to continue to target the nominal 34% WL, but provides access to WLs up to 41% WL without the risk of nepheline formation. Even if DWPF targeted 40% WL and due to uncertainties the WL was actually 42%, the system would only be limited by T_L and risk-based decisions could be made to continue processing because there would be no durability concerns.

Although the lower Na_2O content of this system could be advantageous for higher WLs, the impact of the Tank 40H decant on melt rate is unknown (even at the nominal 34% WL target of current operations). Historical trends have shown that glass systems with a higher Na_2O content typically have higher melt rates (at a fixed WL) than those with a lower Na_2O content; however, for SB4, the primary driver for melt rate has been linked to the increased B_2O_3 content of Frit 510. While the influence of Na_2O on melt rate is potentially of lesser importance for higher Al-based sludges, operational data from DWPF would be beneficial to SRNL for future frit development activities.

4.1.3 Case #3: SB4 + 100K Gallon Decant + 3 wt% Na_2O Addition

Preliminary assessments[g] of the Tank 40H decant suggested a negative impact on the projected operating window.[1] As a result, DWPF is interested in the option of adding Na_2O back to the glass forming system after the decant through NaOH additions.[2] As shown in Table 3, a 3 wt% Na_2O addition to the decanted SB4 flowsheet re-establishes the baseline flowsheet (Case #1) in terms of projected operating windows. The projected operating window for Case #3 is 26 – 42% WL with predictions of low viscosity limiting access to higher WLs. For Case #3, nepheline formation is predicted at WLs of 44% and greater, which could be advantageous for operations if higher WLs are warranted. If the Tank 40H decant is performed (Case #2) and DWPF operations indicate that melt rate is reduced due to the lower Na_2O content of the glass, this option (Case #3) does provide the opportunity to increase melt rate through NaOH additions. This latter statement assumes that the source of NaOH does not affect how the sodium impacts melt rate and that CPC related issues (acid consumption, rheology, etc.) were addressed.

4.1.4 Case #4: SB4 + 100K Gallon Decant + ARP

The addition of ARP to the decanted Tank 40H SB4 system yields a projected operating window of 27 – 42% WL that is restricted by T_L. This operating window is very similar to Case #1 and Case #3. Nepheline is not predicted to become an issue until 45% WL. ARP not only adds TiO_2 to the glass systems, but also provides additional Na_2O. This additional Na_2O replaces the Na_2O removed during the decant (similar to the use of NaOH in Case #3), resulting in a sludge composition similar (the primary exception being TiO_2 content) to the baseline flowsheet (Case #1). Increased concentrations of TiO_2 in the glass increase T_L predictions, which for a T_L limited system, may decrease the projected operating window. Because projected operating windows of Case #4 and Case #1 are identical, it appears that the negative effects of TiO_2 are offset by the Na_2O from ARP, which generally lowers T_L predictions. Although there is no significant impact on the projected operating window, the MAR assessment provides no insight into the potential impacts of ARP on melt rate.

[g] The results of the preliminary study resulted in projected operating windows for the SB4 baseline (pre-decant) and SB4 post-decant of 26 – 43% and 25 – 38% WL, respectively. Although the 38% upper WL for the post-decanted option would allow for continued operations at 34% WL, higher WLs may not be allowed.

4.1.5 Case #5: SB4 + 100K Gallon Decant + 3 wt% Na_2O Addition + ARP

Case #5 represents the addition of both ARP and 3 wt% Na_2O to a decanted SB4 flowsheet. Based on the previous discussions, this flowsheet provides two sources of Na_2O to replace the Na_2O in the glass removed by the decant. It is possible that the additional Na_2O could improve melt rate, assuming that the system is not overwhelmed by the increased alkali content to the point that it leads to primary concerns associated with durability, nepheline, or low viscosity. The results of the MAR assessments suggest a relatively large operating window (28 – 40% WL), which becomes limited by low viscosity at 41% WL and nepheline at 43% WL. Although this is a viable flowsheet based on nominal compositions, this option may become less attractive from a glass formulation perspective once variation is applied due to the presence of "excessive" alkali from the ARP and 3 wt% Na_2O addition.

4.2 Variation Stage Assessment

Variation was applied to the nominal concentration of each sludge component based on its projected value. For the major oxides (Al_2O_3, Fe_2O_3, Na_2O, and U_3O_8), a variation of ±7.5% was applied. A ±0.25 wt% variation was applied to CaO, MgO, MnO, and NiO. The variation applied to the nominal SO_4^{2-} value was ±0.10 wt%, while a ±0.5 wt% variation was applied to SiO_2 and TiO_2. The remaining sludge components were grouped into a category called 'Others'. A variation of 0.25 wt % was applied to the total concentration of the 'Others' components. The compositions (minimum and maximum values) of SB4 Cases #1 – #5 with the applied variation are listed in Table 4.

Algorithms available in the statistical software package JMP™ Version 6.0.3 were used to determine the extreme vertices (EVs) or bounding compositions of the sludge region for each case.[12] Frit 510 was then combined with each of the EVs generated for each flowsheet option at WLs from 25 to 50%. The resulting glass compositions were determined to be acceptable if the properties satisfied the current PCCS MAR criteria, which is consistent with the Nominal Stage assessment.

In this report, three versions of the Variation Stage assessment were performed: (1) the traditional Variation Stage assessment in which the nominal Frit 510 composition was coupled with the EVs of each sludge, (2) an assessment of the impact of possible frit variation (within the accepted frit specification tolerances) on each nominal SB4 option, and (3) an assessment of the impact of possible variation in the Frit 510 composition (within the accepted frit specification tolerances) coupled with the EVs of each sludge case. For cases (2) and (3), EVs defined by the frit procurement specifications were developed by applying the same statistical algorithms used for defining sludge EVs.

Table 4. Variation Stage Bounding Regions for Various SB4 Cases

Component	Variation	Case 1		Case 2		Case 3		Case 4		Case 5	
		Min. (wt%)	Max. (wt%)	Min. (wt%)	Max. (wt%)	Min. (wt%)	Max. (wt%)	Min. (wt%)	Max. (wt%)	Min. (wt%)	Max. (wt%)
Al_2O_3	7.50%	23.03	26.76	24.01	27.91	23.14	26.89	23.11	26.86	22.28	25.90
CaO	0.25 wt%	2.48	2.98	2.61	3.11	2.50	3.00	2.52	3.02	2.42	2.92
Fe_2O_3	7.50%	26.17	30.42	27.38	31.82	26.39	30.67	26.59	30.90	25.64	29.80
MgO	0.25 wt%	2.44	2.94	2.56	3.06	2.46	2.96	2.43	2.93	2.33	2.83
MnO	0.25 wt%	5.43	5.93	5.70	6.20	5.48	5.98	5.63	6.13	5.42	5.92
Na_2O	7.50%	18.98	22.06	16.02	18.62	18.77	21.81	17.06	19.83	19.68	22.87
NiO	0.25 wt%	1.32	1.82	1.40	1.90	1.34	1.84	1.38	1.88	1.33	1.83
SO_4	0.1 wt%	1.22	1.42	0.89	1.09	0.89	1.09	0.99	1.19	0.99	1.19
SiO_2	0.5 wt%	2.16	3.16	2.29	3.29	2.18	3.18	2.18	3.18	2.09	3.09
TiO_2	0.5 wt%	-	-	-	-	-	-	0.84	1.84	0.84	1.84
U_3O_8	7.50%	7.99	9.28	8.36	9.71	8.05	9.36	8.09	9.40	7.80	9.07
Others	0.25 wt%	0.76	1.26	0.80	1.30	0.77	1.27	0.76	1.26	0.73	1.23

4.2.1 Traditional Variation Stage Assessment

Table 5 summarizes the results of the traditional Variation Stage assessment (i.e., nominal Frit 510 coupled with each set of sludge EVs). As expected, the projected operating windows are reduced when variation is applied to the sludge composition as compared to the Nominal Stage assessment. A general discussion of the traditional Variation Stage results for each case is provided below.

Table 5. Variation Stage (Sludge Variation Only) MAR Assessment

SB4 Option	Variation Stage	Projected Operating Window (WL)	Constraints at Higher WLs
Case #1	Nominal Frit	homog 29 – 36 low η	Nepheline limited at 42%
Case #2	Nominal Frit	homog 28 – 37 T_L	Low η limited at 42%, nepheline limited at 43%
Case #3	Nominal Frit	homog 29 – 37 low η	T_L limited at 41%, nepheline limited at 42%
Case #4	Nominal Frit	homog 30 – 38 T_L	Low η limited at 40%, nepheline limited at 43%
Case #5	Nominal Frit	homog 31 – 35 low η	Nepheline limited at 42% and T_L limited at 43%

4.2.1.a Case #1: SB4 Baseline

Applying sludge variation to current DWPF SB4 operations causes a significant reduction in the projected operating window to 29 – 36% WL over which all EVs can be processed; a 27 – 42% WL interval was determined for the nominal SB4 composition (see Table 3). Current DWPF operations have not experienced any limitations based on the 34% WL target; however, if variation in the incoming sludge is experienced (prior to the decant), then higher WLs may be restricted unless management decides to accept failing the process related constraint (low η) for the specific SME batch. Note that nepheline formation for any of the EVs is not predicted to be an issue until WLs of 42% or higher.

4.2.1.b Case #2: SB4 + 100K Gallon Decant

The projected operating window over which all of the EVs could be processed for Case #2 is 28 – 37%. At 38% WL and higher, some of the EVs become limited by T_L, indicating that Frit 510 has a high degree of robustness to potential sludge variation from the Tank 40 decant. Low viscosity and nepheline predictions become limiting at 42 and 43% WL, respectively, for some of the EVs. The projected Variation Stage processing window after the Tank 40H decant is slightly larger than the baseline SB4 system prior to the decant. If higher WLs are of interest to potentially improve waste throughput, DWPF may be limited by T_L predictions (between 38 – 41%WL), but a risk-based management decision could be made to process the specific SME batch. Nepheline formation should not be an issue for this system because it is suppressed to 43% WL and higher for these EVs.

4.2.1.c Case #3: SB4 + 100K Gallon Decant + 3 wt% Na_2O Addition

The addition of 3 wt% Na_2O to SB4 after the Tank 40H decant reduces the projected operating window to 29 – 37% WL; a 26 – 42% WL window was determined in the Nominal Stage assessment. T_L and nepheline formation predictions do not become limiting until 41 and 42% WL, respectively. Based on the projected operating window alone, the 3 wt% Na_2O addition offers no significant advantage to DWPF; once sludge variation is applied, the projected operating windows for Case #2 (Tank 40H decant) and Case #3 (3 wt% Na_2O addition) are essentially the same. Unless a significant reduction in melt rate is observed once the Tank 40 decant is performed (Case #2), addition of Na_2O to the system through NaOH additions to improve melt rate may not be warranted. Note that the impacts of the Tank 40H decant or additions of NaOH on melt rate were not requested as part of this study.

4.2.1.d Case #4: SB4 + 100K Gallon Decant + ARP

Because the Tank 40H decant is likely to occur and initiation of coupled operations (incorporation of ARP) is anticipated prior to the completion of SB4 processing, it is highly probable that this flowsheet option will be implemented in the facility. The addition of ARP after the Tank 40H decant has a projected operating window of 29 – 37% WL in which all the EVs could be processed. T_L predictions once again limit access to WLs greater than 37%. The homogeneity constraint, which is important to a coupled operations flowsheet, limits WLs from 25 – 29%; however, these lower WLs are of no practical concern. From a DWPF operating window perspective, Case #4 is relatively similar to Case #2 or Case #3. More specifically, there is a 1 percentage point increase in WL over which all of the EVs could be processed with this option, which implies that Frit 510 would provide a little more flexibility for DWPF operations. The increased in the upper WL that defines the operating window as a result of ARP additions is consistent with previous results.[13] The additional Na_2O in the glass from ARP appears to reduce T_L predictions. Conversely, TiO_2 from the ARP increases T_L predictions. The MAR results suggest that the ability of Na_2O to lower T_L predictions overcomes the increase in T_L by TiO_2. The impact of ARP addition on melt rate is not addressed in this paper study.

4.2.1.e Case #5: SB4 + 100K Gallon Decant + 3 wt% Na_2O Addition + ARP

Addition of ARP and 3 wt% Na_2O to SB4 after the decant results in a very narrow projected operating window over which all of the EVs can be processed (31 – 35% WL). Based on the inability of Frit 510 to demonstrate compositional robustness to this flowsheet option, SRNL does not recommend this option. This recommendation may change once more formal compositional information is obtained after decanting or if ARP additions are modified (i.e., Na associated with cleaning the filters and transferring ARP is less than anticipated). Additional assessments could be performed to re-evaluate the feasibility of this option with the use of Frit 510 assuming significant compositional shifts are observed.

4.2.2 Frit 510 Specifications coupled with the Nominal Sludge Options

During the processing of SB4, analyses of select Frit 510 lots from the vendor have indicated that the levels of some of the major oxides and the impurity levels of other critical oxides are outside of the compositional tolerances. A previous MAR assessment of an “out of spec” Frit 510 suggests that there is little or no impact on the operating window when coupled with the current nominal SB4 baseline composition.[14] This result was based on the use of a single frit composition (Frit 510 Lot 006), which was low in B_2O_3 content (12.3% measured versus 14% target) and contained 1.37 wt% Al_2O_3 as an impurity. In this section, EVs defined by the Frit 510 procurement specifications were used with the nominal SB4 sludge options to evaluate the impact on the projected operating windows.Table 7 summarizes the impact of possible frit variation (within the current frit procurement specifications) to each of the nominal SB4 processing options being considered in this study. In order to assess the impact of potential variation in the Frit 510 composition on the projected operating windows, the results of the Nominal Stage assessment (nominal Frit 510 and nominal sludge compositions) will be used as a baseline (see Table 3).

Table 6. MAR Assessment of Frit 510 Specifications Coupled with Nominal SB4 Compositions.

SB4 Option	Variation Stage	Projected Operating Window (WL)	Constraints at Higher WLs
Case #1	Frit Specifications	homog 27 – 36 low η	nepheline limited at 42% T_L limited at 45%
Case #2	Frit Specifications	25 – 40 T_L	low η limited at 42%, nepheline limited at 44%
Case #3	Frit Specifications	homog 26 – 36 low η	nepheline limited at 43%, T_L limited at 44%
Case #4	Frit Specifications	homog 27 – 39 low η	T_L limited at 42%, nepheline limited at 44%
Case #5	Frit Specifications	homog 28 – 34 low η	nepheline limited at 42%, T_L limited at 47%

The magnitude of the impact of these compositional extremes in the frit on the projected operating windows appears to be flowsheet dependent. Application of the potential frit variation to the nominal Frit 510 flowsheet options that are low viscosity limited (Case #1, Case #3 and Case #5 – see Table 3) generally leads to a considerable reduction (6 percentage points) in the upper WLs that can be attained. For example, consider the Frit 510 – Case #1 scenario in Table 3, in which the projected operating window is 27 – 42% WL. Both low viscosity and nepheline limit access to higher WLs. Application of the frit procurement specifications to the nominal Case #1 sludge results in a projected operating window of 27 – 36% with predictions of low viscosity being the limiting constraint. These results suggest that even within the procurement specifications, there are combinations of frit components that could lead to severe negative impacts on the projected operating windows.

For Case #2 and Case #4 (Table 3), which are initially T_L limited, the application of the frit specifications has less of an impact resulting in a 1 – 3 percentage point reduction. For example, consider the Frit 510 – Case #2 scenario. The Nominal Stage assessment indicates that this option has a projected operating window of 25 – 41% and is limited by predictions of T_L at higher WLs. Application of the frit procurement specifications to the nominal Case #2 sludge results in a projected operating window, which is only reduced by 1 percentage point (25 – 40%). As in the Nominal Stage assessment, access to higher WLs is limited by predictions of T_L.

4.2.3 Frit 510 Specifications coupled with Sludge Variation

This section addresses the impacts of both sludge variation and frit variation on the projected operating windows. More specifically, each of the EVs defined by the frit procurement specifications was coupled with each of the EVs defined by the applied sludge variation. Although the application of "double variation"[h] could be viewed as an aggressive approach, the results do provide insight into the potential SME acceptability issues during future processing of SB4 after the Tank 40H decant (where sludge compositional uncertainties are greater) coupled with possible frit compositional variation (within the procurement specifications).

As shown in Table 7, the projected operating windows of DWPF could be severely restricted if substantial variation in the sludge composition were realized when coupled with variation in Frit 510 (even within the current specifications). All of the projected operating windows are extremely small or non-existent, as in Case #5. Based on recent processing of SB4 (Case #1), it is unlikely that this situation will be experienced prior to the Tank 40H decant and it is doubtful that DWPF will experience the extreme variations in sludge applied in this assessment. Processing SB4 prior to the Tank 40H decant will more likely be impacted by variation in the frit composition (see Section 4.2.2). It should be noted that the assessments in Section 4.2.2 only apply the frit procurement specifications. DWPF has recently received frits that are not only outside the specifications, but have impurity concentrations exceeding specific requirements. A supplemental memo will address the impact of larger frit procurement specification uncertainties and/or the inclusion of significant impurity concentrations (Al_2O_3 and/or ZrO_2) on the projected operating windows for the various flowsheet options.

Table 7. MAR Assessment of Frit 510 Specifications Coupled with Sludge Variation

SB4 Option	Variation Stage	Projected Operating Window (WL)	Constraints at Higher WLs
Case #1	Frit Specifications	homog 29 – 31 low η	T_L limited at 40% WL, nepheline limited at 41%
Case #2	Frit Specifications	homog 28 – 35 low η	T_L limited at 37% WL, nepheline limited at 42%
Case #3	Frit Specifications	homog 29 – 31 low η	T_L limited at 40% WL, nepheline limited at 41%
Case #4	Frit Specifications	homog 30 – 33 low η	T_L limited at 38% WL, nepheline limited at 42%
Case #5	Frit Specifications	No window	low η limited from 31 – 40% WL, T_L and nepheline limited at 41%

[h] The term "double variation" refers to the application of both sludge variation (as defined in Table 4) and the variation associated with the frit procurement specifications. It should be noted that the variation in the sludge (as shown in Table 4) has not been doubled but the standard variation applied to the sludge has been added to the variation in the frit composition as defined by the frit procurement specifications.

5.0 Impact of the SB4 Flowsheet Changes on the SB4 Variability Study

In order to satisfy the WAPS requirements a variability study must be conducted to demonstrate that the PCT/chemical composition correlation (i.e., ΔG_P model) currently utilized by DWPF applies to the SB4 glass composition region to be processed in DWPF.[6,7] Prior to the initiation of a formal experimental study, the ComPro™ database is first reviewed to determine if historical glasses are located within the compositional regions of interest for the different cases.[4,5] If a sufficient number of historical glasses are found within the compositional regions defined by the revised SB4 – Frit 510 flowsheet modifications, then an experimental study may not be required. If an adequate number of historical glasses are *not* found, then an experimental study needs to be designed and implemented to support the WAPS requirements.

Based on the Nominal and Traditional Variation assessments, LWO may elect to implement one or more of these options as the results suggest that all of the flowsheet options are viable (some caution should be exercised if Case #5 is to be pursued). Therefore, a series of "if then" statements was developed for JMP™ to search the ComPro™ database for historical glasses that may exist within the compositional regions defined by the various flowsheets.[4,5] The "if then" statements were developed to capture not only the potential variation in sludge (as shown in Table 4), but also the possible frit variation (bounded by the specification limits for the major frit oxides) over WLs of interest (in line with the "double variation" concept developed in Section 4.2.3).

Based on this electronic search, approximately 12 glasses were identified that are located within at least one of the five glass regions. These historical glasses are primarily from the previous SB4 variability study (using Frit 503 and Frit 418) and the PCT responses from both the quenched and centerline canister cooled glasses are acceptable[i] and predictable by the current durability model.[15-17] While these glasses meet the intent of the variability study requirements for SB4 current operations, the extent of the coverage that these glasses have in the newly defined glass regions is of concern. Therefore, SRNL is recommending that and has initiated a supplemental experimental variability study be performed to support the various SB4 flowsheet options that may be implemented for future SB4 operations in DWPF.

Given the compositional range of the historical glasses and the acceptable durability response of the historical SB4 glasses, the use of EVs to define or develop the supplementary SB4 study is not deemed warranted. Therefore, the nominal compositions of the five cases of interest in this study will be used to define specific glasses to fabricate and characterize.

The glass selection process utilized two primary inputs: (1) the projected operating windows over which acceptable glasses would be produced (results of the Nominal Stage MAR assessments reported in Section 4.1) and (2) a review of the five nominal sludge compositions to determine compositional similarities. A review of the projected sludge compositions (Table 1) and the Nominal Stage assessment (Table 3) indicates that Case #1 and Case #3 are very similar. Due to the compositional similarities, six glasses were selected using both sludge options over a WL interval of interest to both systems (32 – 42% WL) in "alternating" 4% WL increments; when coupled with Frit 510, Case #1 targeted 34, 38, and 42% WL and Case #3 targeted WLs of 32, 36, and 40%.[j] Table 7

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[i] < 1.6 g/L normalized boron release compared to 16.695 g/L for the Environmental Assessment (EA) glass.

[j] Although lower than the 34% WL target of current SB4 operations, 32% WL was chosen as a "bounding" composition in case lower WLs are observed due to blending uncertainties and/or the need to lower WLs for future SB4 operations. The glass with a target of 42% WL could also be viewed as a "bounding" case.

summarizes the nominal projected compositions of these six glasses. The study of these glasses provides an opportunity to assess the entire WL interval of interest to DWPF as well as an opportunity to identify any issues related to the slight differences in the nominal sludge compositions of Case #1 and Case #3, although none would be anticipated.

Case #2 represents a relatively unique sludge as it has the lowest Na_2O content of the options being evaluated. Based on the Nominal Stage projected operating window for this system (25 – 41% WL), four Frit 510 based glasses were selected targeting WLs of 32, 35, 38, and 41% as shown in Table 9. Again, this WL interval spans the operating window of interest and will provide insight into any potential durability issues associated with the Tank 40H decant option.

The addition of TiO_2 from ARP makes Cases #4 and #5 unique from the "sludge-only" options. Although the TiO_2 concentrations in both nominal sludge projections are essentially identical, the addition of the 3% Na_2O to the coupled flowsheet makes Case #5 unique unto itself. Therefore, four glasses were selected for Case #4 and four were selected for Case #5 targeting 32, 35, 38, and 41% WL. Although the Case #5 glass is limited by low viscosity at the nominal 41% WL, it will provide additional support to the variability study. Table 10 summarizes the nominal projected compositions of these Case #4 and Case #5 based glasses.

The eighteen glasses will be fabricated and characterized according to the Task Technical and QA plan to demonstrate that the glasses are both acceptable and predictable by the current process control models for durability.[3] The results will be reported in a subsequent report.

Table 8. Target Glass Compositions (wt%) for Case #1 and Case #3

	Case #1			Case #3		
Glass ID	**SB4VAR11**	**SB4VAR12**	**SB4VAR13**	**SB4VAR31**	**SB4VAR32**	**SB4VAR33**
Frit	510	510	510	510	510	510
WL	34	38	42	32	36	40
Al_2O_3	8.46	9.46	10.46	8.00	9.01	10.01
B_2O_3	9.24	8.68	8.12	9.52	8.96	8.40
BaO	0.03	0.03	0.03	0.02	0.03	0.03
CaO	0.93	1.04	1.15	0.88	0.99	1.10
Ce_2O_3	0.02	0.02	0.03	0.02	0.02	0.03
Cr_2O_3	0.05	0.06	0.07	0.05	0.06	0.06
CuO	0.02	0.02	0.02	0.02	0.02	0.02
Fe_2O_3	9.62	10.75	11.88	9.13	10.27	11.41
K_2O	0.12	0.13	0.15	0.11	0.13	0.14
La_2O_3	0.02	0.02	0.02	0.02	0.02	0.02
Li_2O	5.28	4.96	4.64	5.44	5.12	4.80
MgO	0.91	1.02	1.13	0.87	0.97	1.08
MnO	1.93	2.16	2.39	1.83	2.06	2.29
Na_2O	12.26	12.76	13.26	11.93	12.42	12.92
NiO	0.54	0.60	0.66	0.51	0.57	0.63
PbO	0.02	0.02	0.03	0.02	0.02	0.03
SO_4	0.45	0.50	0.55	0.32	0.36	0.40
SiO_2	47.10	44.41	41.72	48.46	45.77	43.07
TiO_2	0.01	0.01	0.02	0.01	0.01	0.02
U_3O_8	2.94	3.28	3.63	2.79	3.13	3.48
ZnO	0.03	0.03	0.03	0.02	0.03	0.03
ZrO_2	0.03	0.03	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00	100.00	100.00

Table 9. Target Glass Compositions (wt%) for Case #2

	Case #2			
	SB4VAR21	**SB4VAR22**	**SB4VAR23**	**SB4VAR24**
Frit	510	510	510	510
WL	32	35	38	41
Al_2O_3	8.31	9.09	9.86	10.64
B_2O_3	9.52	9.10	8.68	8.26
BaO	0.02	0.03	0.03	0.03
CaO	0.91	1.00	1.09	1.17
Ce_2O_3	0.02	0.02	0.03	0.03
Cr_2O_3	0.05	0.06	0.06	0.07
CuO	0.02	0.02	0.02	0.02
Fe_2O_3	9.47	10.36	11.25	12.14
K_2O	0.12	0.13	0.14	0.15
La_2O_3	0.02	0.02	0.02	0.02
Li_2O	5.44	5.20	4.96	4.72
MgO	0.90	0.98	1.07	1.15
MnO	1.90	2.08	2.26	2.44
Na_2O	10.98	11.26	11.54	11.82
NiO	0.53	0.58	0.63	0.68
PbO	0.02	0.02	0.02	0.03
SO_4	0.32	0.35	0.38	0.41
SiO_2	48.49	46.47	44.46	42.44
TiO_2	0.01	0.01	0.02	0.02
U_3O_8	2.89	3.16	3.43	3.70
ZnO	0.03	0.03	0.03	0.03
ZrO_2	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00

Table 10. Target Glass Compositions (wt%) for Case #4 and Case #5

	Case #4				Case #5			
	SB4VAR41	**SB4VAR42**	**SB4VAR43**	**SB4VAR44**	**SB4VAR51**	**SB4VAR52**	**SB4VAR53**	**SB4VAR54**
Frit	510	510	510	510	510	510	510	510
WL	32	35	38	41	32	35	38	41
Al_2O_3	8.00	8.75	9.50	10.25	7.71	8.43	9.15	9.88
B_2O_3	9.52	9.10	8.68	8.26	9.52	9.10	8.68	8.26
BaO	0.02	0.03	0.03	0.03	0.02	0.03	0.03	0.03
CaO	0.88	0.97	1.05	1.13	0.85	0.93	1.01	1.09
Ce_2O_3	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03
Cr_2O_3	0.05	0.06	0.06	0.07	0.05	0.05	0.06	0.06
CuO	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Fe_2O_3	9.20	10.06	10.92	11.79	8.87	9.70	10.53	11.37
K_2O	0.11	0.12	0.13	0.15	0.11	0.12	0.13	0.14
La_2O_3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Li_2O	5.44	5.20	4.96	4.72	5.44	5.20	4.96	4.72
MgO	0.86	0.94	1.02	1.10	0.83	0.90	0.98	1.06
MnO	1.88	2.06	2.23	2.41	1.82	1.99	2.16	2.33
Na_2O	11.34	11.66	11.97	12.28	12.25	12.65	13.04	13.44
NiO	0.52	0.57	0.62	0.67	0.50	0.55	0.60	0.65
PbO	0.02	0.02	0.03	0.03	0.02	0.02	0.02	0.03
SO_4	0.35	0.38	0.41	0.45	0.35	0.38	0.41	0.45
SiO_2	48.46	46.44	44.42	42.40	48.43	46.40	44.38	42.36
TiO_2	0.43	0.47	0.51	0.55	0.43	0.47	0.51	0.55
U_3O_8	2.80	3.06	3.32	3.59	2.70	2.95	3.21	3.46
ZnO	0.03	0.03	0.03	0.03	0.02	0.03	0.03	0.03
ZrO_2	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

6.0 Summary

SB4 is currently being processed in the DWPF using Frit 510. The slurry pumps in Tank 40H are experiencing in-leakage of bearing water, which is causing the sludge slurry feed in Tank 40H to become dilute at a rapid rate. At the present time, the DWPF is removing this dilution water by performing caustic boiling during the SRAT cycle. In order to alleviate prolonged SRAT cycle times, which may eventually impact canister production rates, decant scenarios of varying amounts of supernate have been proposed for Tank 40H. These potential SB4 flowsheet modifications (i.e., 100K gallon decant, potential additions of Na_2O, or transferring to a coupled operations flowsheet) could result in significant compositional shifts in the SB4 system. This study provided an assessment of the impact of these compositional changes to the projected glass operating windows and to the variability study for the Frit 510 – SB4 system. The influence of the compositional changes on melt rate was not requested or assessed in this study.

6.1 Nominal and Variation Stage Assessments

Based on the projected compositions, both Nominal and Variation Stage assessments were utilized to determine the impact on DWPF projected operation windows. The results of the Nominal Stage assessment indicate very little difference among the various flowsheet options. All of the flowsheets provide DWPF with the possibility of targeting WLs from the low 30s to low 40s with Frit 510. In general, the Tank 40H decant has a slightly negative impact on the operating window, but DWPF still has the ability to target current WLs (34%) and higher WLs if needed. While the decant does not affect practical WL targets in DWPF, melt rate could be reduced due to the lower Na_2O content. If true, the addition of 3 wt% Na_2O to the glass system may regain melt rate, assuming that the source of alkali does not affect the impact of the alkali on melt rate. Addition of ARP to a decanted SB4 flowsheet also appears to be viable based on the projected operating windows. The addition of both ARP and 3 wt% Na_2O to a decanted Tank 40 sludge may be problematic due to the high sodium content.

Although the Nominal Stage assessment provides reasonable operating windows, introduction of potential sludge and/or frit compositional variation has a significant negative impact. The magnitude of the impact of frit compositional extremes (defined by the frit procurement specifications) on the projected operating windows appears to be flowsheet dependent. The more severe impacts (a 6 percentage point reduction in the upper WLs that can be achieved relative to the Nominal Stage window) occur with systems that are low viscosity limited. For those cases which are T_L limited, only a 1 – 2 percentage point reduction is projected.

When both frit and sludge variations are applied, the paper study results indicate that DWPF processing could be severely restricted. The projected operating windows are extremely small or non-existent, as in Case #5. Although the application of “double variation” could be viewed as an aggressive approach, the results do provide insight into the potential SME acceptability issues during future processing of SB4 after the Tank 40H decant (where sludge compositional uncertainties are greater) coupled with possible frit compositional variation (within the procurement specifications).

6.2 Impact of the SB4 Flowsheet Changes on the SB4 Variability Study

Based on an electronic search of ComPro™, approximately 12 historical glasses were identified that are located within at least one of the five glass regions defined by the proposed SB4 flowsheet options. These historical glasses are primarily from the previous SB4 variability studies (using Frit 503 or Frit 418), and the PCT responses from both the quenched and centerline canister cooled glasses are acceptable and predictable by the current durability model.[15-17] While these glasses meet the requirements of the variability study for SB4 current operations, there is some concern over the coverage that these glasses provide in the newly defined glass regions. Therefore, SRNL recommends that a supplemental, experimental variability study be performed to support the various SB4 flowsheet options that may be implemented for future SB4 operations in DWPF. Eighteen glasses have been selected based on nominal sludge projections representing the current as well as the proposed flowsheets over a WL interval of interest to DWPF (32 – 42%). These eighteen glasses will be fabricated and characterized to demonstrate that the glasses are both acceptable and predictable by the current process control models for durability.

7.0 References

1. M.E. Stone, F.C. Raszewski, B.R. Pickenheim, T.B. Edwards, and D.K. Peeler, "Impacts of a Tank 40 Supernate Decant to DWPF Glass Formulation and CPC Processing: A Preliminary Assessment for SB4," Savannah River National Laboratory, Aiken, SC, Report No. SRNL-PSE-2007-00257, November 2007.

2. B.A. Davis, "SB4 Flowsheet and Variability Studies for Tank 40H 100,000 Gallon Decant Technical Task Request," Liquid Waste Organization, Aiken, SC, Report No. HLW-DWPF-TTR-2008-0009, Rev. 0, December 2007.

3. F.C. Raszewski and M.E. Stone, "SB4 Flowsheet and Variability Studies for Tank 40H 100,000 Gallon Decant Task Technical and QA Plan," Savannah River National Laboratory, Aiken, SC, Report No. WSRC-STI-2007-00700 Rev. 0, January 2008.

4. K.M. Fox, D.K. Peeler, and T.B. Edwards, "Request for QA Approval of Nepheline Database," Washington Savannah River Company, Aiken, SC, Report No. SRNL-PSE-2006-00053, 2006.

5. A.S. Taylor, T.B. Edwards, J.C. George, T.K. Snyder, and D.K. Peeler, "The SRNL Composition - Properties (ComPro™) Database," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-RP-2004-00704, Revision 0, 2004.

6. "Standard Test Methods for Determining Chemical Durability of Nuclear, Hazardous, and Mixed Waste Glasses and Multiphase Glass Ceramics: The Product Consistency Test (PCT)," ASTM International, West Conshohocken, PA, Report No. ASTM C 1285-02, 2002.

7. C.M. Jantzen, J.B. Picket, K.G. Brown, T.B. Edwards, and D.C. Beam, "Process/Product Models for the Defense Waste Processing Facility (DWPF): Part I. Predicting Glass Durability from Composition Using a Thermodynamic Hydration Energy Reaction Model (THERMO)," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-TR-93-672, Rev. 1, September 1995.

8. J.W. Ray, A.V. Staub, M.J. Plodinec, and S.L. Marra, "DWPF Glass Product Control Program," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-IM-91-116-6, Rev. 5, 1995.

9. K.G. Brown, R.L. Postles, and T.B. Edwards, "SME Acceptability Determination for DWPF Process Control," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-TR-95-00364, Rev. 5, 2006.

10. P.L. Bovan, "Glass Analyses and Physical Property Measurements for DWPF Frit," Washington Savannah River Company, Aiken, SC, Report No. X-SOW-S-00001, Rev. 0, May 2007.

11. P.L. Bovan, "Specification for Procurement of DWPF Frit," Washington Savannah River Company, Aiken, Report No. X-SPP-S-00018, Rev. 7, December 2007.

12. JMP™ Version 6.0.3, SAS Institute Inc., Cary, NC, 2005.

13. D.K. Peeler and T.B. Edwards, "The Impact of the Actinide Removal Process (ARP) on the Sludge Batch 4 Projected Operating Windows," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-TR-2005-00123, Revision 0, 2005.

14. D.K. Peeler, to P. L. Bovan, "Ferro Frit 510 Lot 006 - Out of Spec Results Path Forward," January 14, 2008, Email.

15. K.M. Fox, T.B. Edwards, D.K. Peeler, D.R. Best, I.A. Reamer, and R.J. Workman, "High Level Waste (HLW) Sludge Batch 4 (SB4) Variability Study," Washington Savannah River Company, Aiken, SC, Report No. WSRC-STI-2006-00204, Revision 0, 2006.

16. K.M. Fox, T.B. Edwards, D.K. Peeler, D.R. Best, I.A. Reamer, and R.J. Workman, "High Level Waste (HLW) Sludge Batch 4 (SB4) with Frit 418: Results of a Phase II Variability Study," Washington Savannah River Company, Aiken, SC, Report No. WSRC-STI-2006-00329, Revision 0, 2006.

17. S.L. Marra and C.M. Jantzen, "Characterization of Projected DWPF Glass Heat Treated to Simulate Canister Centerline Cooling," Westinghouse Savannah River Company, Aiken, SC, Report No. WSRC-TR-92-142, Revision 1, 1993.

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