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Impact of Reducing the 100°C Liquidus Temperature Offset on Waste Loading Targets

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EXECUTIVE SUMMARY

The objective of this report is to assess the potential impact of reducing conservatism in the implementation of the current liquidus temperature (T_L) model in the Product Composition Control System (PCCS) on the ability to target higher waste loadings (WLs) for future sludge batches. No changes to the T_L model or the associated uncertainties (model or measurement) are proposed, rather only changes in the magnitude of the offset used between the nominal melt pool temperature (1150°C) and the Property Acceptance Region (PAR) value (1050°C). This strategy is consistent with that outlined and initially assessed by Brown et al. (2001). In that report, the authors stated even a fairly conservative change in this safety factor could have a significant impact on waste loading.

The results of this study clearly indicate that the implementation of an 1100°C T_L PAR criterion (which translates into a reduction in the T_L offset from 100°C to 50°C) can have significantly positive impacts on the ability to gain access to WLs exceeding 45%. This is especially true for those frit and sludge systems that are T_L limited using the current 1050°C T_L criterion, and are not limited by a second constraint (such as viscosity, nepheline, or durability) until much higher WLs. Examples of various glass forming systems are provided that are currently limited to maximum WLs in the mid-40s, but could be processed in the lower 50s through implementation of this new strategy. One example is in the Sludge Batch 10 (SB10) system, where for a specific glass forming system the projected operating window of 38-41% WL (using the current constraints) became 38-52% WL with the use of an 1100°C T_L PAR value. This change both provided access to significantly higher WLs, and transitioned a once infeasible flowsheet to a system that could potentially be processed in the Defense Waste Processing Facility (DWPF). This potential change in the T_L constraint also provides access to frit compositions (or glass forming regions) that are not accessible under the current limitations. These new composition regions not only provide access to higher WLs, but may also allow frit development efforts to target other specific properties to support enhanced melter operations.

It should be noted that under certain flowsheet conditions, the implementation of the 1100°C T_L PAR must be accompanied by a shifting categorization of what is deemed an acceptable operating window for DWPF operation. For example, the use of a 50°C offset may not be effective if access to WLs < 30% are still required. Assuming the intent of implementing the 1100°C PAR criterion is to gain access to higher WLs (> 45%), the need to identify frit and sludge systems that are predicted to form acceptable glasses at these lower WLs (< 30%) should no longer be of concern.

Although this strategy could have a significant impact on DWPF's ability to target higher WLs (> 45%), its implementation is not risk free. The reduction in the T_L offset does reduce the conservatism currently implemented, which is aimed at minimizing or eliminating the potential for massive devitrification within the melt pool. Prior to implementation of this alternative strategy, DWPF should perform a risk-based assessment or review of this alternative approach to ensure it aligns with needs and processing strategies.

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LIST OF ABBREVIATIONS

CPC	Chemical Processing Cell
DOE	Department of Energy
DWPF	Defense Waste Processing Facility
EM	Environmental Management
HLW	High Level Waste
MAR	Measurement Acceptance Limit
PAR	Property Acceptance Region
PCCS	Product Composition Control System
SB	Sludge Batch
SME	Slurry Mix Evaporator
SRNL	Savannah River National Laboratory
T_L	Liquidus Temperature
WL	Waste Loading
WTP	Waste Treatment and Immobilization Plant

1.0 Introduction

High-level waste (HLW) throughput (i.e., the amount of waste processed per unit time) is a function of two critical parameters: waste loading (WL) and melt rate. For the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site and the Defense Waste Processing Facility (DWPF) at the Savannah River Site (SRS), increasing HLW throughput would significantly reduce the overall mission life cycle costs for the Department of Energy (DOE).

Significant increases in waste throughput were achieved at DWPF for Sludge Batch 3 (SB3) and Sludge Batch 4 (SB4) through key technical and operational initiatives that included improving or maximizing facility attainment, improving the Chemical Processing Cell (CPC) flowsheet, improving the process control models, and strategic glass formulation efforts (i.e., customizing or tailoring frit formulations for specific sludge batches). With respect to strategic glass formulation efforts, frit development has shifted from a global "one frit fits all" concept to a focused effort on optimizing or compositionally tailoring frits for specific sludge batches. In addition, a new liquidus temperature model (T_L) (Brown et al. 2001) and a revised strategy for approaching the durability limits was developed and implemented (Edwards et al. 2003). These strategy shifts and model upgrades have allowed DWPF to target higher WLs while maintaining or improving melt rate which in turn has been a significant contributor to the improved waste throughputs obtained in the facility.

As a result of these key initiatives, DWPF increased WLs from a nominal 28% (with Sludge Batch 2 (SB2)) to approximately 38% WL while maintaining or improving canister fill times for SB3 and SB4.[1] Although significant improvements in waste loading and waste throughput were obtained, even higher waste loadings (> 40%) could have been targeted based on the Product Composition Control System (PCCS) models. More specifically, the models that predict the properties of a glass based on its composition indicated that WLs greater than 40% could have been targeted for these glass systems while continuing to satisfy both melter processing and product performance constraints. Higher WLs were not targeted during the processing of these previous sludge batches due to experimental and actual facility data demonstrating that melt rate is significantly reduced as higher WLs are targeted, which in turn adversely impacts waste throughput. Therefore, during processing of a specific sludge batch, DWPF will evaluate melt rate as a function of WL to determine the WL that yields the maximum waste throughput. Optimum waste throughput has historically been demonstrated at a WL significantly lower than the maximum allowed by the current process control models. Narrowing or eliminating this WL gap is of primary interest for continual improvements in the DWPF process.

Transformational changes in waste loading, melt rate, and ultimately waste throughput are still possible through the development of advanced silicate glasses, implementation of alternative melter technologies, or continued improvement in the process control system that ultimately dictates what glass systems can be processed through the melter. For example, DWPF has implemented a bubbler technology into the melter to enhance melt rate which could potentially minimize (if not eliminate) the historical trends between melt rate and waste loading. If this occurs, there will be a fundamental shift in the technical or process control criteria that will limit DWPF's ability to target higher WLs for future operations. It is the belief of the authors that the

[1] It should be noted that fissile loading constraints limited waste loadings for SB5 to the lower 30's on a percentage basis. Reduction of the fissile content associated with SB6 will allow higher WLs to be targeted.

process control models (or the implementation strategy of those models) underpinning the Slurry Mix Evaporator (SME) acceptability process will become that critical limitation, rather than the current limitation of reduced melt rate as WL is increased.[2] Therefore, the Savannah River National Laboratory (SRNL) has focused on three key initiatives to continue to enhance waste loading for the DWPF: (1) nepheline formation, (2) model applicability for advanced silicate glasses and (3) the potential impact of reducing conservatism the way select models are implemented (without compromising product quality). Although DWPF is used as a platform for these assessments, the strategies and/or results of these three initiatives could be applied to WTP as warranted. However, it is recognized that there are differences in how WTP approaches implementation of some of the process control strategies (e.g., T_L versus vol% crystallization approach).

The objective of this report is to assess the potential impact of reducing conservatism in the implementation of the current liquidus temperature (T_L) model in the PCCS. It should be noted that in this study, there are no changes made to the T_L model or the associated uncertainties (property or measurement). The only change is in the magnitude of the offset used between the nominal melt pool temperature (approximately 1150°C) and the Property Acceptance Region (PAR) value (1050°C) that is currently implemented in PCCS (i.e., a 100°C offset). The current implementation of the T_L model is such that the T_L prediction for a given glass composition must be below the PAR by a margin that reflects model and measurement uncertainty. These uncertainties are added prior to judging whether a specific glass composition would be classified as acceptable from a T_L prediction perspective. For glass systems in which T_L predictions limit access to higher WLs, reducing the offset (e.g., 50°C instead of 100°C) may have a significant impact on the projected operating window while keeping the risk of massive devitrification within the melt pool extremely low. This strategy is consistent with that outlined and initially assessed by Brown et al. (2001). In that report, the authors stated “even a fairly conservative change of 25°C in this safety factor from 1050 to 1075°C has a very significant potential impact on waste loading.”

Prior to the specific discussion of the potential impact of reducing this offset on the ability to access higher WLs, additional background information is provided on historical trends in melt rate and WL. This information illustrates the need for continued development of other technologies and strategies to support transformational gains in waste throughput within the DOE Environmental Management (EM) complex.

1.1 Melt Rate as a Function of WL

The Frit 418 – Sludge Batch 3 (SB3) system will be used to support discussions of historical trends in melt rate and waste loading (Lorier and Smith 2004 and Smith and Miller 2005). Although this system is highlighted in this report, the same trends have been observed for subsequent sludge batches either through experimental studies at SRNL (Smith et al. 2004, Smith et al. 2007, Miller et al. 2008) and/or DWPF operations. The general trend of melt rate versus WL is conceptually shown in Figure 1. The projected operating window (i.e., the WL interval over which the glass is classified as acceptable based on model predictions) for the Frit 418 - SB3 system was approximately 25 – 45% WL, as indicated in Figure 1. That is, if one were to

[2] There is also an assumption that an increase in melt rate can be supported by feed preparation unit operations (i.e., the Sludge Receipt and Adjustment Tank (SRAT) and SME). That is, SRAT and SME processing as well as analytical confirmation of the SME product are efficient enough to continually provide melter feed and that the rheology of the feed does not negatively impact melt rate.

compute the overall glass composition based on the compositions of Frit 418 and SB3 at 25% WL and compare the predicted properties (T_L, viscosity, durability, etc) of that glass to the current constraints, that glass would be deemed acceptable for melter processing. The glass system would also be deemed acceptable at 26% WL, 27% WL, and so on up to 45% WL. At 46% WL, model predictions associated with T_L exceed the associated PCCS constraint and thus the glass system would be classified as non-processable. With respect to DWPF operations, targeted WLs up to 45% could be achieved for this particular system based strictly on PCCS assessments. SRNL laboratory testing (Lorier and Smith 2004 and Smith and Miller 2005) and subsequent radioactive operations at DWPF evaluated melt rate as a function of WL for this system and found a gradual decrease in melt rate with increased WL (approximated by the red line in Figure 1). The maximum waste throughput (the amount of waste process per unit time) was determined to be at approximately 38% WL for the Frit 418 – SB3 system (represented by the "peak" in the blue line of Figure 1). Although the process control models allowed WLs up to 45% to be targeted, the severely negative impact on melt rate at higher WLs resulted in a reduction of the targeted WL to 38% in order to maximize waste throughput. Therefore, during SB3 processing, a seven percentage point WL interval (39 to 45% WL – see shaded area in Figure 1) was not targeted due to significant reductions in melt rate. Although WLs could have been higher, targeting these higher WLs would have lead to a prolonged processing time for the SB3 system (possibly extending mission life). It is this seven percentage point WL gap that is being targeted through strategic technology development efforts within the DOE Technology Development program.

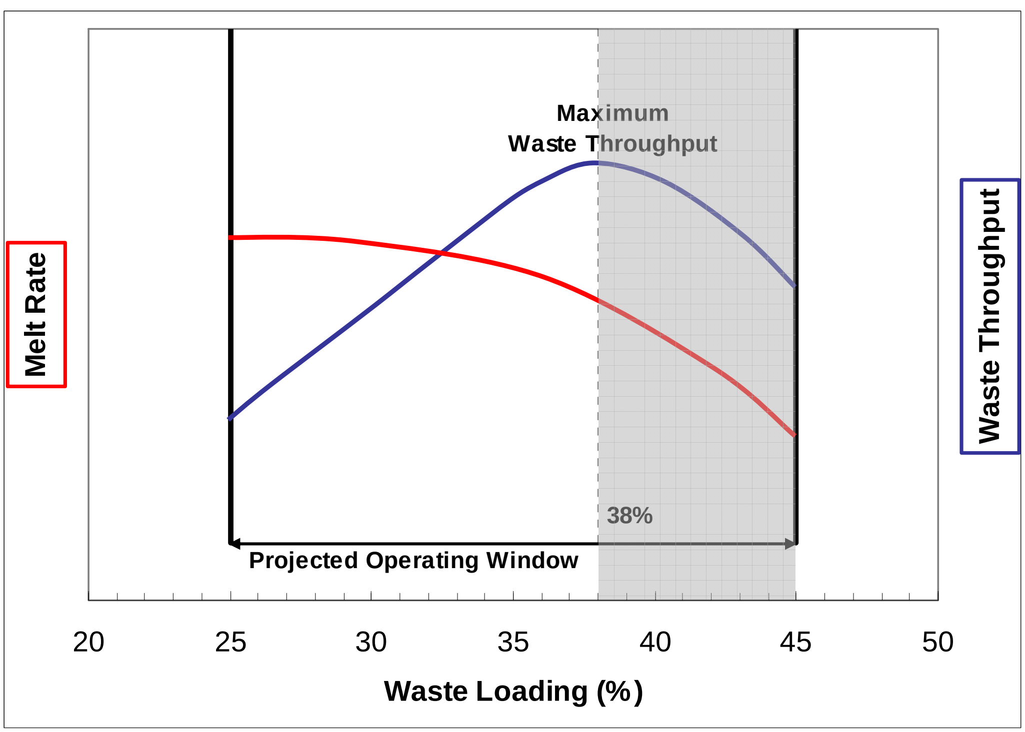

Figure 1. Melt rate and waste throughput as a function of waste loading for SB3. The shaded region indicates waste loadings where acceptable glasses are predicted, but decreased melt rate would hinder waste throughput.

It should be noted that if one were only concerned with minimizing the number of canisters produced, glasses targeting the highest WL allowed by the process control models would achieve that goal (e.g., for the Frit 418 – SB3 system, WLs of 45% would have met this objective). Based on this strategy and historical melt rate trends, canister fill times would increase, leading to a longer mission life. On the other hand, targeting maximum waste throughput should allow both Tank Farm and DWPF operations to be terminated sooner; however, this latter strategy does not minimize the canister count. This dilemma forces the DOE and/or the operating facility to make business decisions regarding minimizing canister count or reducing mission life – both having significant impacts to the overall life cycle costs.

1.2 Waste Throughput Improvements

Although processing SB3 at 38% WL (point of maximum waste throughput) was a significant improvement over the nominal 28% WL during DWPF's planning or early processing, the ability to access higher WLs has become a critical focus area for continuous improvement. Use of alternative approaches to attain higher waste throughputs, either chemically through frit development and CPC enhancements (feed properties) or physically by a change in the melter, have the potential to reduce (or eliminate) the negative trends observed in melt rate at higher WLs. These alternative approaches are conceptually presented and discussed below because they provide the basis for the focus on the 100°C T_L offset in this study.

1.2.1 *Strategic Glass Formulation*

Figure 2 provides a conceptual view of strategic glass formulation efforts which shift the maximum waste throughput from 38% WL to some higher WL value for the SB3 system. In this example, an alternative frit has been developed which reduces (but does not eliminate) the negative impact of higher WLs on melt rate. This specific frit and sludge system has an operating window of 25 – 45% WL – consistent with the Frit 418 system previously discussed. The dashed red line represents the improved relationship between melt rate and WL which shifts the maximum throughput "peak" to 42% WL. Based on this strategic glass formulation effort, DWPF could then shift its WL target to 42% WL, thus gaining access to a portion of the seven percentage point WL gap (as shown by the shaded region in Figure 2), which is defined by waste throughput restrictions rather than a process control model prediction. In this scenario (again this is a conceptual example), higher waste throughputs could be obtained, thus reducing overall mission life. Although this scenario does not completely eliminate the seven percentage point restricted WL window, shifting the throughput peak two to four percentage points in WL would have a significant impact on overall mission life. Although the example is presented conceptually, during SB2 processing DWPF transitioned from Frit 200 to Frit 320 (a tailored frit for SB2) which allowed DWPF to not only target higher WL (i.e., transition from 28% WL up to ~ 34% WL) without having a negative impact on melt rate. This led to a significant increase in waste throughput for DWPF.

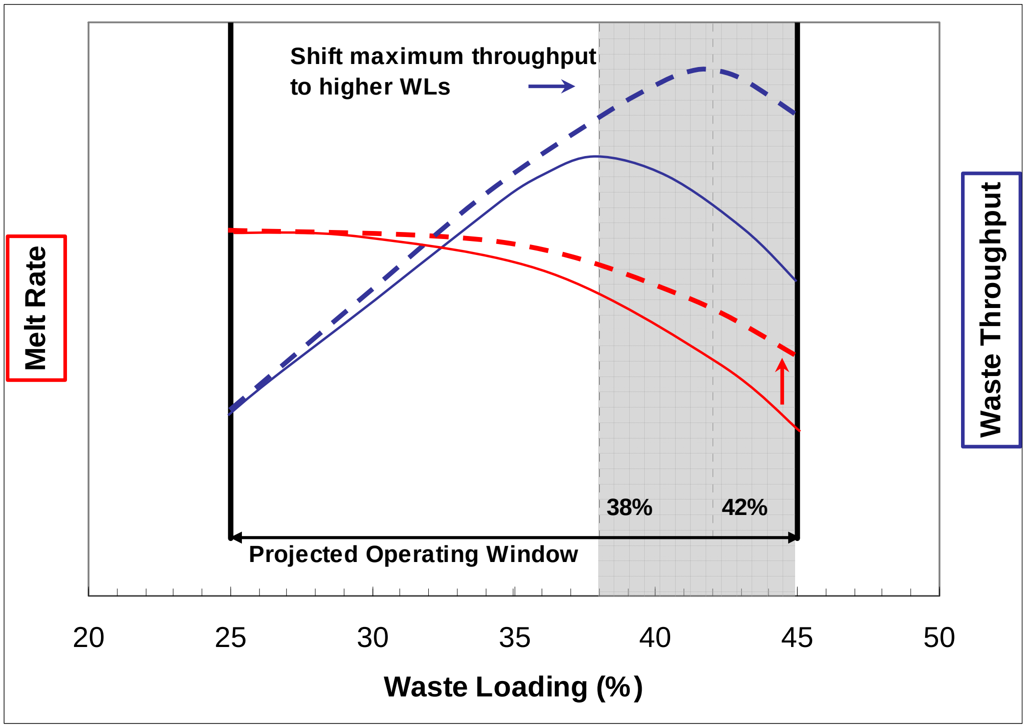

Figure 2. Conceptual waste throughput improvements due to strategic glass formulation.

1.2.2 *Alternative Melter Technology*

Another option to improve waste throughput would be to implement a new melter technology. New melter technologies could be viewed as the bubbler system was implemented into DWPF in the fall of 2010, or as a completely different technology such as the Cold Crucible Induction Melter (CCIM), that is being evaluated by the DOE's EM-31 Technology Development program. Given the implementation of a bubbler system in DWPF, the discussion in this section assumes that the bubbler technology (through forced convection within the melter) eliminates the dependence of melt rate on WL (including any impact of feed rheology) that has been historically observed. This is represented by the flat dashed red line shown in Figure 3, which is not only flat but has been shifted up to represent an overall increase in melt rate. If true, DWPF could conceptually target 45% WL for this system to maximize waste throughput. At this point, DWPF would not only be processing the maximum amount of waste per unit time, but would also be minimizing the number of canisters produced under the limitations of the product control models – leading to significant reductions in the overall life cycle costs. Although significant improvements in waste throughput could be demonstrated by targeting 45% WL, the driver for targeting even higher WLs would shift from being melt rate or waste throughput limited to restrictions based on the process control models or the criteria implemented for specific glass properties. That is, one or more of the current models supporting the SME acceptability process would become the limiting factor restricting access to higher WLs. Under this scenario, options to gain further improvement in waste throughput would fall into at least three categories: (a) reducing conservatism or uncertainties in the existing models, (b) developing and implementing new models, and (c) developing new process or product performance criteria or an alternative implementation or control strategy.

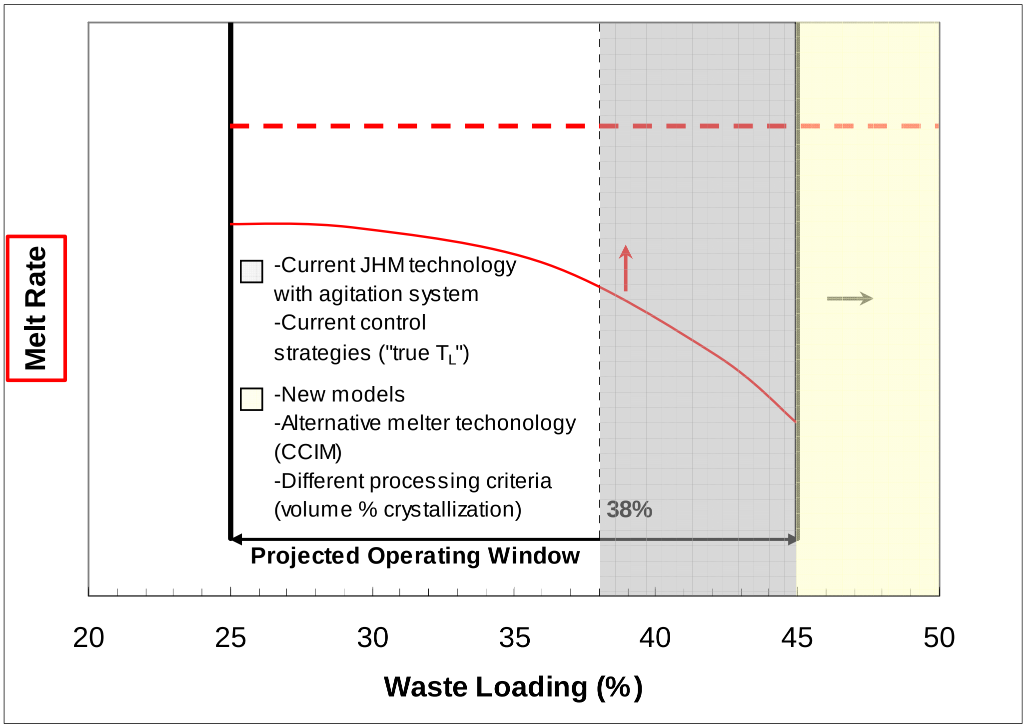

Figure 3. Potential melt rate improvements as a result of alternative melter technologies.

1.2.3 *Possible Impact of T_L Implementation Strategy Change*

In the Frit 418 – SB3 conceptual example (Figure 3), access to higher WLs (≥ 46%) is limited by predictions of liquidus temperature relative to the acceptance criteria (Measurement Acceptance Region (MAR) limit). That is, T_L predictions exceed the T_L MAR criterion which is based on a nominal 1050°C value onto which model and measurement uncertainties are applied. The resulting MAR criteria for acceptance (which is compositionally dependent) may be on the order of 1015°C. Therefore, if the predicted T_L is greater than 1015°C, the glass composition would be deemed unacceptable from a process perspective and would not be processed in the DWPF. It should be recognized that the assumed predicted T_L for this system is approximately 135°C below the nominal melt pool temperature.

If faced with this situation, one of the options listed in Section 1.2.1 was to develop new process or product performance criteria or implementation strategy as a potential method to gain access to higher WLs (i.e., the yellow shaded region in Figure 3) without compromising product quality or durability. One example of this strategy would be to evaluate the potential impacts of reducing the 100°C offset between the nominal melt pool temperature (1150°C) and the 1050°C T_L PAR criterion (without uncertainties added) on the ability to increase the operating windows for T_L - limited systems. The real question is: What would be the magnitude of the impact knowing that allowing slightly higher predicted T_L systems to be acceptable will result in access to higher WLs? If significant increases in WL could be gained through the use of a 50°C offset (1100°C instead of the 1050°C currently used), then decisions to implement this approach would need to balance the positive impacts of higher WLs on the overall mission life against the risk of a reduction in conservatism associated with melt pool crystallization. The magnitude of this impact will also be influenced by the WL at which the next product or performance constraint becomes a limiting factor. For example, the Frit 418 – SB3 system is T_L limited at 46% WL but predictions of either low viscosity (< 20 Poise at 1150°C without uncertainties applied) or predictions of nepheline formation do not becoming a limiting factor until 50% WL. This places a potential upper limit on the relief that implementation of a 50°C offset would have on this system. Assuming the 50°C T_L offset would allow WLs up to 52% to be achieved, WLs less than 50% would be required due to one of the other constraints (low viscosity or nepheline).

2.0 Objective

The objective of this study is to evaluate the potential impacts of implementing a new T_L PAR criterion of 1100°C as compared to the current PAR constraint of 1050°C. This objective will be met based on a paper study assessment in which the current PCCS algorithms (including the 1050°C T_L constraint) are used to assess the projected operating windows of future sludge batches projected in Revision 15 of the DWPF High Level Waste Systems Plan (Chew and Hamm 2009). Use of the current constraints will not only identify specific glass forming systems whose projected operating windows are T_L-limited at higher WLs, but will also provide a baseline from which comparisons can be made once the 1100°C T_L criterion is used (keeping all other constraints as currently implemented). In addition, specific glass forming systems are identified as examples. It should be noted that this assessment is based strictly on a change in the T_L criterion to which property and measurement uncertainties will be applied using the T_L model currently implemented (i.e., there is no change to the form of the model or its coefficients). An additional assumption being made is that the models contained within the PCCS algorithms are applicable to the compositional regions (especially the higher WLs) being explored.

3.0 Composition Basis

As previously mentioned, the nominal projections for future sludge batches (SB8 through SB17) provided in Revision 15 of the HLW System Plan (Chew and Hamm 2009) served as the basis for this study. It should be noted that this assessment did not account for secondary or auxiliary streams such as the Actinide Removal Process (ARP), Salt Waste Processing Facility (SWPF), and/or Small column Ion Exchange (SCIX). Based on historical assessments, these streams will have an impact on the operating window for specific systems and must ultimately be accounted for during frit development efforts. Lack of their use in this study is not significant given the focus is strictly on identifying the possible impact of reducing the 100°C offset by 50°C for T_L limited systems – regardless of the specific blending strategy or flowsheet.

In order to identify glass forming systems which are T_L-limited, candidate frit compositions were needed to couple with each nominal sludge projection over an interval of WLs. This was accomplished by defining a frit composition array which included B_2O_3, Fe_2O_3, Li_2O, Na_2O, and SiO_2. Table 1 shows the composition range (minimum and maximum wt%) and wt% increments within each range used to establish the frit array. For SiO_2, increment and levels are not shown given its composition range was defined by subtracting the percentage of the other frit oxide combinations from 100% (i.e., the SiO_2 value varied based on the total percent of the other four frit component combination values). Using this array, 7371 unique frits were defined based on the various combinations of each oxide.

Table 1. Compositional Ranges Defining the Frit Array.

Oxide	Min (wt%)	Max (wt%)	Increment	Levels
B_2O_3	8	20	1%	13
Fe_2O_3	0	4	2%	3
Li_2O	4	12	1%	9
Na_2O	0	20	1%	21
SiO_2	44	88	-	-

4.0 Measurement Acceptability Region (MAR) Assessments

Nominal Stage MAR assessments (developed by Peeler and Edwards 2005) were performed by coupling the 7371 different frit compositions with each of the nominal sludge batch projections. For each frit and sludge system, glass compositions were calculated over a waste loading interval of 25 – 60%. Each glass composition was then assessed against the current PCCS MAR criteria (including the 1050°C T_L PAR constraint) for acceptability. In this assessment it was assumed that the T_L model (and other models) was applicable to the glass composition regions being explored. The key output of this assessment was the size of the projected operating window (i.e., the WL interval over which the glass compositions satisfied all of the process and product performance constraints) for each frit and sludge system. The Nominal Stage assessment was then repeated using all the frit and sludge systems with the exception that the T_L PAR criterion of 1050°C was increased to 1100°C. This second assessment provided information regarding the size of the projected operating windows that could be compared to those based on the 1050°C criterion.

Given the large amount of information resulting from both assessments, it was required to define metrics from which to judge or compare the possible impact of the smaller T_L offset on the size of the operating window, not only for one frit and sludge system, but for multiple frits (7173 defined by the array) within each sludge batch and among sludge batches. The primary metric used in this study to support such comparisons was the number of frits that provided various WL point increases when the 1100°C criterion was used (relative to its counterpart 1050°C offset). The projected operating windows must have been at least (as low as) 35% to at least (as high as) 45% or 50% WL to be considered. The use of a projected operating window of 35% to 45% WL is somewhat arbitrary but is generally centered around the anticipated DWPF target WL of 40% based on current contractual agreements. Tracking the difference in the number of frits for the 35-50% WL interval based on the use of the two T_L constraints will provide insight into the ability to target higher WLs. However, based on the large number of systems to be evaluated, this approach is likely to show general trends (i.e., number of frits that increase the window size given the implementation of a less conservative constraint), but it will not provide any specifics regarding the potential magnitude. Therefore, a second approach was defined and used from which the magnitude of using an 1100°C PAR limit could be demonstrated or quantified. In this assessment, specific glass forming systems that would allow significantly higher WLs (> 45%) to be targeted if the T_L offset were relaxed are identified and discussed.

5.0 Results and Discussion

5.1 Number of Frits as a Function of Operating Window Size

Table 2 provides an initial assessment of the potential impact of the less conservative T_L PAR criterion on the ability to attain various projected operating windows for SB8 through SB17. The two projected operating windows shown are 35-45% WL and 35-50% WL, with each using both a 1050°C and a 1100°C T_L PAR to support the assessment. The values shown in the cells below each T_L PAR criterion are the number of frits that provide the stated projected operating window for each sludge batch.[3] To aid the reader in interpreting the table, the results of two sludge batches (SB8 and SB11) will be discussed. First, consider the SB8 system. The MAR assessments indicate that only 4 of the 7173 frits will provide an operating window of at least 35% to 45% WL when the current 1050°C T_L PAR is used. By replacing the current T_L PAR value with 1100°C, 116 frits of the 7173 now provide that same 35 to 45% WL window. Next consider the results of the SB11 system. The MAR assessments indicate that 75 of the 7173 frits will provide an operating window of at least 35% to 45% WL when the current 1050°C T_L PAR is used. By replacing the current T_L PAR value with 1100°C, 368 frits of the 7173 now provide that same 35 to 45% WL window. In addition, if a projected operating window of 35-50% is desired, implementation of the 1100°C T_L PAR would be required. More specifically, there are no frits that provide access to this larger operating windows with the 1050°C constraint but if the 1100°C T_L PAR is used, 25 frits provide access to WLs up to at least 50%.

For all future sludge batch projections, the number of frits available that provide access to a 35-45% operating window with the implementation of a less conservative T_L constraint increases. An increase in the number of frits available that provide access to an operating window of 35-45% WL has significant advantages. The primary advantage is that it provides more compositional flexibility to frit development efforts to not only provide DWPF with an operating window centered around it the target of 40% WL, but the larger number of candidate frits should provide compositional flexibility to overcome minor component (e.g., SO_4) solubility issues, and to select tailored frits that provide optimum processing properties (such as melt rate).

Implementation of the 1100°C T_L PAR has a significant impact on the number of frits available for processing SB8 and SB17 projections (assuming a 35-45% WL window is required). Based on current PCCS models and constraints, only 4 and 7 frits would be available to process SB8 and SB17, respectively. These numbers increase to 116 and 145 with implementation of the 1100°C T_L PAR.

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[3] It should be noted that the projected operating windows could be limited by constraints other than T_L (all constraints were active). That is, the ability to attain a 35-45% or 35-50% WL operating windows could be limited by predictions of low viscosity, nepheline, or durability.

Table 2. Number of Frits that Yield Projected Operating Windows of 35-45% and 35-50% and a Function of T_L PAR Criteria.

Sludge Batch	35-45% WL		35-50% WL	
	1050°C PAR	1100°C PAR	1050°C PAR	1100°C PAR
SB8	4	116	0	0
SB9	164	371	0	28
SB10	170	326	0	14
SB11	75	368	0	25
SB12	509	962	10	202
SB13	607	1032	17	189
SB14	362	779	13	174
SB15	495	604	67	151
SB16	39	289	0	7
SB17	7	145	0	1

Based strictly on the number of available frits, the benefits of implementing a 50°C offset to attain a 35-45% WL operating window do appear attractive and, as previously mentioned, will increase the compositional flexibility of available frits. However, given the large number of frits available for most sludge batches using the current 1050°C constraint, there may not be a significant driver to reduce the conservatism just to increase the size of the pool of candidate frits. There would need to be other specific and significant drivers in place to change the current strategy.

If higher WLs are desired (i.e., > 45% WL) or to account for sludge variation when targeting higher WLs, there would then be a significant initiative to use the 1100°C T_L PAR for future sludge batches based strictly on the number of frits providing access to an operating window of 35-50% WL (see Table 2). Reviewing the information listed under the "35-50% WL, 1050°C T_L PAR" column, there are only 4 of the 10 sludge batches that provide access to WLs up to 50% WL. With the possible exception of SB15, the number of frits available is very limited and may not provide a sufficient composition range to account for other glass property needs (e.g., SO_4 solubility). For the remaining sludge batches, none of the 7173 frits provide access to WLs up to 50% when the 1050°C T_L PAR is used.

Introduction of the 1100°C T_L PAR does provide some relief not only for those sludge batches which could not be accessed with a 1050°C constraint, but also the general trend is to increase the number of frits available for those systems that were rather limited with the current T_L constraint. For example, consider SB12 in which only 10 frits were identified that allowed WLs up to 50% if the current 1050°C PAR is used. When the 1100°C PAR is used, the number of frits that provide access up to 50% WL increases to 202 which could allow compositional flexibility to increase SO_4 solubility, melt rate, and/or identify a frit with enhanced robustness to sludge composition variation (and still provide access to high WLs). It should be noted that SB8, SB16, and SB17 are still problematic with respect to accessing WLs up to 50%, even with a 50°C offset. SRR should re-evaluate the blending strategy for these tanks.

The information presented in Table 2 provides some general guidance on the impact of the two T_L PAR values on the number of frits available for specific operating window sizes. Although of value, it is difficult to gauge the specific magnitude of the impact. That is, the use of at least (as low as) 35% and at least (as high as) 45% in the previous assessment is generalized.

Table 3 summarizes the number of frits that provide at least a five percentage point WL increase when a 50°C offset is used (relative to its counterpart 100°C assessment) for those systems which have a projected operating window of at least (as low as) 35% to at least (as high as) 45% WL with the 1100°C PAR. The left hand column identifies the specific sludge batch of interest. The shaded row of numbers (5 through 11) represents the increase in WL points if one were to apply the 50°C offset. The last two columns represent the number of frits that provide at least a five and eight point increase in the upper WL, respectively, with the application of the 50°C offset. The numbers associated with each sludge batch represent the number of frits meeting specific operating window size increases or widths (i.e., the number of frits that provide a certain WL point increase in the achievable upper WL).

Table 3. Increase in Operating Window Width Using a 50°C Offset.

Sludge Batch	Increase in Operating Window Width								
	5	6	7	8	9	10	11	At Least 5	At Least 8
SB8	13	57	13	-	-	-	-	83	0
SB9	23	27	22	23	34	34	3	166	94
SB10	20	18	16	13	14	15	17	113	59
SB11	38	25	30	105	40	-	-	238	145
SB12	51	60	55	57	153	32	-	408	242
SB13	63	63	53	53	131	21	-	384	205
SB14	46	54	151	141	-	-	-	392	141
SB15	19	20	19	14	8	15	8	103	45
SB16	25	50	122	10	-	-	-	207	10
SB17	18	48	46	-	-	-	-	112	0

A few examples are provided to aid the reader in interpreting Table 3. First consider the information presented in the SB8 row. The value (13) listed under the "5" indicates that there are 13 frits that provide a 5 point increase in the upper WL with the application of a 50°C offset (or 1100°C). These 13 frits provide a projected operating window of at least 35% to 45% WL. There are 57 and 13 frits that provide an increased upper WL of 6 and 7 points, respectively, for the SB8 system (with at least a 35 to 45% WL operating window). The "-" shown in the columns listed as "8", "9", "10", and "11" indicate that there are no frits (out of the 7173 candidates) that increase the upper WL at least 8 points or greater. The information presented in the "At Least 5" column identifies the number of frits that provide at least a 5 point increase in the upper WL for the SB8 system. Based on this assessment, there are 83 frits that provide at least a 5 point increase when the 1100°C criterion is used as compared to the 1050°C value. The last column ("At Least 8") provides the number of frits that provide at least an 8 point increase in the upper WL. For SB8, none of the 7173 frits evaluated will provide at least an 8 point WL increase, even with the T_L PAR of 1100°C.

Most of the other sludge batches show even more significant gains in maximum WL. The results for the SB10 system suggest that there are 113 frits that provide at least a 5 point increase in the upper WL. Perhaps more impressive is that 59 frits will provide at least an 8 point increase in the upper WL that could be achieved. Again, the projected operating windows for these systems range from at least 35% to 45% WL. In general, the information shown in Table 3 suggests that the implementation of a 1100°C T_L PAR could lead to significant increases in the number of frits that could provide access to higher WLs. For most sludge batches, the use of a 50°C offset relative to the current 100°C offset provides the opportunity to gain access to higher WLs (by 5 to 8 WL points) for those systems that are T_L limited. Perhaps more importantly, when this information is coupled with that shown in Table 2, the increased number of frits with the less conservative T_L constraint provides access to compositional regions in frit space that may be required to optimize other process or product performance properties or technically resolve specific limitations (e.g., SO_4 retention).

5.2 Impact (or Magnitude) of the 1100°C PAR for Specific Frit and Sludge Systems

In this section, specific glass forming systems are identified to show not only the potential but the magnitude of applying the 50°C offset to allow access to WLs exceeding 45%. There are two approaches used to demonstrate the potential impact that relaxing this constraint may have on future operations. The first approach is based on the use of what may be considered an "acceptable" WL interval for targeting the nominal 40% WL currently considered the contractual target for future sludge batches. The second approach does not restrict systems to being "acceptable" at lower WLs (i.e., < 38%), but they must provide acceptable windows that would allow higher WLs to be targeted (e.g., > 45%) while still providing enough flexibility to account for sludge variation.

5.2.1 *"Standard" Acceptable Operating Windows*

In the first approach, all of the glass forming systems were screened based on the ability to provide an operating window of as least (as low as) 30 to at least (as high as) 45% WL using the current T_L PAR of 1050°C. This screening process provides a set of glass forming systems from which a search was performed to identify the number of frits that provide the maximum increase in the upper WL while still requiring acceptability of the lower WL range (at least 30% WL). Table 4 summarizes the results of this approach. To aid the reader in interpreting the information, consider the data presented in the row associated with SB8. Only one frit (8% B_2O_3, 4% Li_2O, 10% Na_2O, and 78% SiO_2) which provides a projected operating window from 27 – 45% WL with the current T_L PAR provides access to higher WLs for the 1100°C T_L PAR. Specifically, if the T_L PAR were relaxed to 1100°C, there is only a 1 percentage point increase in the operating window from at least (as low as) 30% WL up to 46% WL. For this sludge batch, implementation of the 50°C offset does not appear to be viable. More specifically, why increase risk associated with melter processing (by reducing the current 100°C offset) for a 1 percentage point increase in WL? More insight or perspective into this question is given in Section 5.2.2.

Although the 50°C offset was not favorable for the SB8 projections, there are sludge batch systems that do provide access to significantly higher WLs even when maintaining access to lower WLs is required. For example, consider SB12, SB13, and SB14. For SB12, there is an opportunity to provide an 8 percentage point increase in the operating window (from 30-45% WL to 30-53% WL). For SB13 and SB14, a 7 and 6 percentage point increase is available (maximum WLs of 52 and 51%, respectively) with the implementation of the 1100°C T_L PAR. Again, the extension of the operating window to higher WLs was at this point still considered to require access to the lower WL acceptance limit (i.e., WLs of 30% or less are still required).

It should be noted that there is not an entry in Table 4 for SB10. Based on the metric being used to support this assessment, there were no systems in which the implementation of the 1100°C T_L PAR increased the projected operating window. Again, this latter statement is made based on limiting the acceptable WL interval to 30% or less which could be extremely conservative if WLs > 45% are being targeted.

Table 4. Number of Frits that Provide the Maximum Increase in Projected Operating Window for Each Sludge Batch.

(lower WLs are fixed to provide at least (as low as) 30% WL)

		1050°C T_L PAR		1100°C T_L PAR	
Sludge Batch	**Frit**	**Min (% WL)**	**Max (% WL)**	**Min (% WL)**	**Max (% WL)**
SB8	B-8;Li-4;Na-10;Si-78	27	45	27	46
SB9	B-10;Li-8;Si-82	30	45	30	48
SB9	B-11;Li-7;Na-1;Si-81	30	45	30	48
SB11	B-8;Li-7;Na-3;Si-82	30	45	30	49
SB12	B-11;Li-9;Si-80	30	45	30	53
SB13	B-14;Li-9;Si-77	26	45	26	52
SB13	B-13;Li-9;Si-78	28	45	28	52
SB13	B-12;Li-9;Si-79	30	45	30	52
SB14	B-8;Fe-2;Li-7;Na-4;Si-79	30	45	30	51
SB14	B-9;Fe-2;Li-6;Na-5;Si-78	30	45	30	51
SB15	B-8;Fe-4;Li-8;Si-80	30	45	30	49
SB15	B-9;Fe-4;Li-7;Na-1;Si-79	30	45	30	49
SB16	B-8;Li-6;Na-6;Si-80	29	45	29	48
SB16	B-10;Li-4;Na-8;Si-78	30	45	30	48
SB16	B-9;Li-5;Na-7;Si-79	30	45	30	48
SB17	B-8;Li-4;Na-10;Si-78	28	45	28	47

5.2.2 *Shifting the "Acceptable" Operating Window*

In the previous section, implementation of the 1100°C criterion had to result in an extension of the projected operating window to higher WLs while maintaining access to lower WLs (as least as low as 30%) before the use of a 50°C offset was considered viable. Application of this metric to gauge the effectiveness of the change in T_L offset may have provided an overly conservative view, especially if higher WLs (> 45%) are being considered. That is, access to WLs of 30% or less may be of no concern for a facility targeting WLs of 45% or higher. If a 50°C offset is considered for implementation to gain access to higher WLs, a different metric for an acceptable WL interval should be developed and applied prior to decisions regarding viability of the 50°C offset. A transformational shift in targeting WLs should not use current strategies or metrics to define acceptability. In this section, a WL interval of at least (as low as) 38% up to at least (as high as) 52% was set as the metric to demonstrate the potential impact of the 50°C offset. For example, if a WL target of 45% was being considered, there would be a 7 percentage point buffer around that nominal target to account for compositional variation in sludge, which typically reduces the width of the projected operating window by at least 4 percentage points.

As in the previous section, the glass forming systems were screened, but in this case using an operating window of at least (as low as) 38% up to at least (as high as) 52% WL. Glass forming systems which provided the maximum increase in upper WL with the implementation of the 1100°C T_L PAR were then identified for each sludge batch. This information is summarized in Table 5. It should be noted that there may have been more than one frit that provided the maximum increase for a specific sludge, but only one is shown in Table 5. In addition, there are other frit and sludge systems that provide significant increases (just not the maximum increase) in WL with the implementation of the 1100°C T_L PAR that are not shown strictly due to the amount of information that would need to be listed.

A high-level review of the information shown in Table 5 is provided below. First consider the information associated with SB9 (the first row in Table 5); it indicates that with the current 1050°C T_L PAR, the operating window (for a specific frit (8 wt% B_2O_3, 7 wt% Li_2O, 85 wt% SiO_2)) is 36 to 44% WL). If DWPF were targeting 40% WL, this operating window may not be acceptable given there is not an adequate WL interval to account for potential sludge variation. However, implementation of the 1100°C T_L PAR yields an operating window of at least (as low as) 38% with an upper WL limit of 52% WL ("Max (%WL) 1100°C T_L"). This is an eight percentage point increase in the operating window and with the shift in the acceptance criterion for the operating window, a significant increase in WL could be attained (e.g., at least (as low as) 38% WL up to 52% WL for the SB9 system).

Table 5. Impact of a Shifting "Acceptable" Operating Window and the 1100°C T_L PAR Constraint on Various Glass Forming Systems.

(lower WLs are fixed to provide at least (as low as) 38% WL)

			1050°C T_L PAR		1100°C T_L PAR	
Sludge Batch	**Frit**	**N Rows**	**Min (% WL)**	**Max (% WL)**	**N Rows**	**Max (% WL)**
SB9	B-8;Li-7;Si-85	9	36	44	8	52
SB10	B-8;Fe-2;Li-5;Na-1;Si-84	4	38	41	11	52
SB11	B-8;Li-5;Na-4;Si-83	9	36	44	8	52
SB12	B-9;Li-9;Si-82	12	34	45	9	54
SB13	B-8;Fe-2;Li-10;Si-80	17	28	44	9	53
SB14	B-8;Li-6;Na-4;Si-82	10	37	46	8	54
SB15	B-14;Fe-2;Li-4;Na-1;Si-79	4	38	41	11	52

Next, consider the impact of the shift in acceptance metrics and application of the 50°C offset for SB10. In the previous section, there were no frits available that would increase the operating window with a change in the T_L offset having fixed the acceptable WL interval to at least (as low as) 30% (i.e., no entry for SB10 in Table 4). With a shift in that metric toward higher WLs, implementation of the 50°C offset now provides candidate frits that would allow projected operating windows of at least (as low as) 38% up to 52% WL. This result suggests the application of a 50°C offset should also be accompanied by a shift in the WL interval over which acceptability would be defined.

Table 6 provides the MAR assessment results for this specific SB10 system. The first column (% WL) represents the WL interval from 25 to 60%. The second column (MAR w 1050 T_L PAR) summarizes the MAR results with the current 1050°C T_L PAR. The information shown in this column indicates the property (or properties) that fail their respective MAR criterion at each WL. For example, at 25 and 26% WL, predictions of high viscosity (highv) and inadequate Al_2O_3 content fail their respective MAR criteria. At 27%, only predictions of high viscosity fail, which is the case through a WL of 37%. The dashes ("-") from 38% WL to 41% WL indicate that all of the properties for those glasses pass the MAR criteria and are acceptable for DWPF processing. At 42% WL, predictions of T_L exceed the 1050°C constraint (after uncertainties are applied), and thus the system is limited only by T_L predictions up through 52% WL, where low viscosity and T_L become the co-limiting constraints at 53% WL. This glass forming system illustrates the impact of reducing the 100°C offset to 50°C to gain access to higher WLs. The WL interval from 42% to 52% is only restricted by T_L predictions based on the use of the 1050°C PAR. Therefore, it is not surprising that once the 1050°C T_L constraint is relaxed to 1100°C, the projected operating window size increases to 38 – 52% WL. This is a gain in access to 11 percentage points in WL space for this system, and would allow DWPF to target WLs in the upper 40s or low 50s.

Tables 7 and 8 show other examples of the impact that relaxing the T_L PAR criterion has on gaining access to significantly higher WLs for various sludge batch systems. In these examples, specific frits have been coupled with each nominal sludge batch composition and evaluated using both the 1050°C and 1100°C T_L PAR criteria. Each of the systems is T_L limited when the 1050°C T_L PAR is applied. When the T_L PAR is relaxed, access to higher WLs (from 8 to 11 WL points) occurs for all systems with upper WLs in the low 50s being acceptable. These two tables, along with Table 5, show the potential impact of relaxing the TL PAR criterion from 1050°C to 1100°C for future sludge batch operations. It is noted that SB8, SB16, and SB17 are not shown in Table 5, Table 7 or Table 8. This could be the result of those systems not allowing access up to 52% WL, which was the minimum upper WL that was used to screen the initial glass forming systems.

Table 6. Table AR Assessments for the SB10 and a Candidate Frit with a 1050 and 1100°C T_L Constraint.

($8\%\ B_2O_3$, $2\%\ Fe_2O_3$, $5\%\ Li_2O$, $1\%\ Na_2O$, $84\%\ SiO_2$)

% WL	MAR w 1050 T_L PAR	MAR T_L PAR at 1100
25	highv Al_2O_3	highv Al_2O_3
26	highv Al_2O_3	highv Al_2O_3
27	highv	highv
28	highv	highv
29	highv	highv
30	highv	highv
31	highv	highv
32	highv	highv
33	highv	highv
34	highv	highv
35	highv	highv
36	highv	highv
37	highv	highv
38	-	-
39	-	-
40	-	-
41	-	-
42	T_L	-
43	T_L	-
44	T_L	-
45	T_L	-
46	T_L	-
47	T_L	-
48	T_L	-
49	T_L	-
50	T_L	-
51	T_L	-
52	T_L	-
53	T_L, lowv	T_L, lowv
54	T_L, lowv	T_L, lowv
55	T_L, lowv	T_L, lowv
56	T_L, lowv	T_L, lowv
57	T_L lowv, Neph	T_L lowv, Neph
58	T_L lowv, Neph	T_L lowv, Neph
59	T_L lowv, Neph	T_L lowv, Neph
60	T_L lowv, Neph	T_L lowv, Neph

Table 7. MAR Assessments for the SB9, SB11, and SB12 and a Candidate Frit with a 1050 and 1100°C T_L Constraint.

	SB9		SB11		SB12	
% WL	1050 T_L PAR	1100°C T_L PAR	1050 T_L PAR	1100°C T_L PAR	1050 T_L PAR	1100°C T_L PAR
25	highv	highv	highv	highv	highv	highv
26	highv	highv	highv	highv	highv	highv
27	highv	highv	highv	highv	highv	highv
28	highv	highv	highv	highv	highv	highv
29	highv	highv	highv	highv	highv	highv
30	highv	highv	highv	highv	highv	highv
31	highv	highv	highv	highv	highv	highv
32	highv	highv	highv	highv	highv	highv
33	highv	highv	highv	highv	highv	highv
34	highv	highv	highv	highv	-	-
35	highv	highv	highv	highv	-	-
36	-	-	-	-	-	-
37	-	-	-	-	-	-
38	-	-	-	-	-	-
39	-	-	-	-	-	-
40	-	-	-	-	-	-
41	-	-	-	-	-	-
42	-	-	-	-	-	-
43	-	-	-	-	-	-
44	-	-	-	-	-	-
45	T_L	-	T_L	-	-	-
46	T_L	-	T_L	-	T_L	-
47	T_L	-	T_L	-	T_L	-
48	T_L	-	T_L	-	T_L	-
49	T_L	-	T_L	-	T_L	-
50	T_L	-	T_L	-	T_L	-
51	T_L	-	T_L	-	T_L	-
52	T_L	-	T_L	-	T_L	-
53	T_L, lowv	lowv	T_L, lowv	T_L, lowv	T_L	-
54	T_L, lowv	T_L lowv	T_L, lowv	T_L, lowv	T_L	-
55	T_L, lowv	T_L lowv	T_L, lowv	T_L, lowv	T_L Neph	T_L Neph
56	T_L lowv	T_L lowv	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
57	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
58	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
59	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
60	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph

Table 8. MAR Assessments for the SB13, SB14, and SB15 and a Candidate Frit with a 1050 and 1100°C T_L Constraint.

	SB13		SB14		SB15	
% WL	1050 T_L PAR	1100°C T_L PAR	1050 T_L PAR	1100°C T_L PAR	1050 T_L PAR	1100°C T_L PAR
25	highv	highv	highv	highv	highv Al_2O_3	highv Al_2O_3
26	highv	highv	highv	highv	highv Al_2O_3	highv Al_2O_3
27	highv	highv	highv	highv	highv	highv
28	-	-	highv	highv	highv	highv
29	-	-	highv	highv	highv	highv
30	-	-	highv	highv	highv	highv
31	-	-	highv	highv	highv	highv
32	-	-	highv	highv	highv	highv
33	-	-	highv	highv	highv	highv
34	-	-	highv	highv	highv	highv
35	-	-	highv	highv	highv	highv
36	-	-	highv	highv	highv	highv
37	-	-	-	-	highv	highv
38	-	-	-	-	-	-
39	-	-	-	-	-	-
40	-	-	-	-	-	-
41	-	-	-	-	-	-
42	-	-	-	-	T_L	-
43	-	-	-	-	T_L	-
44	-	-	-	-	T_L	-
45	T_L	-	-	-	T_L	-
46	T_L	-	-	-	T_L	-
47	T_L	-	T_L	-	T_L	-
48	T_L	-	T_L	-	T_L	-
49	T_L	-	T_L	-	T_L	-
50	T_L	-	T_L	-	T_L	-
51	T_L	-	T_L	-	T_L	-
52	T_L	-	T_L	-	T_L	-
53	T_L	-	T_L	-	T_L	T_L
54	T_L lowv Neph	T_L lowv Neph	T_L	-	T_L lowv	T_L lowv
55	T_L lowv Neph	T_L lowv Neph	T_L	T_L	T_L lowv	T_L lowv
56	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
57	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
58	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
59	T_L lowv Cr_2O_3 Neph	T_L lowv Cr_2O_3 Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph
60	T_L lowv Cr_2O_3 Neph	T_L lowv Cr_2O_3 Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph	T_L lowv Neph

6.0 Conclusions

High-level waste throughput (i.e., the amount of waste processed per unit time) is a function of two critical parameters: WL and melt rate. For the WTP at the Hanford Site and the DWPF at the Savannah River Site (SRS), increasing HLW throughput would significantly reduce the overall mission life cycle costs for DOE.

Although significant improvements in waste loading and waste throughput have been previously obtained in DWPF, even higher nominal waste loadings (> 40%) could have been targeted based on the PCCS models, but were not due to the negative impact of melt rate at higher WLs and its ultimate impact on waste throughput. With the implementation of a bubbler technology into the melter to enhance melt rate, the historical trends between melt rate and waste loading could be minimized (if not eliminated). If this occurs, there will be a fundamental shift in the technical or process control criteria that will limit the ability of DWPF to target higher WLs for future operations. It is the belief of the authors that the process control models (or the implementation strategy of those models) underpinning the SME acceptability process will become that critical limitation.

The objective of this report is to assess the potential impact of reducing conservatism in the implementation of the current T_L model in the PCCS on the ability to target higher WLs for future sludge batches. It should be noted that in this study, there are no changes made to the T_L model or to the associated uncertainties (property or measurement). The only change is in the magnitude of the offset used between the nominal melt pool temperature (1150°C) and the PAR value (1050°C) from which other uncertainties are added prior to judging whether a specific glass composition would be classified as acceptable from a T_L perspective.

The results of this study clearly indicate that the implementation of an 1100°C T_L PAR criterion can have significantly positive impacts on the ability to gain access to WLs exceeding 45%. This is especially true for those frit and sludge systems that are T_L limited using the current 1050°C T_L criterion, and are not limited by a second constraint (such as viscosity, nepheline, or durability) until much higher WLs. Examples of various glass forming systems were provided that are currently limited to maximum WLs in the mid-40s, but could be processed in the lower 50s through implementation of this new strategy. One example was in the SB10 system, where for a specific glass forming system the projected operating window of 38-41% WL (using the current constraints) became 38-52% WL with the use of an 1100°C T_L PAR value. This change both provided access to significantly higher WLs, and transitioned a once infeasible flowsheet to a system that could potentially be processed in DWPF. This potential change in the T_L constraint also provides access to frit compositions (or glass forming regions) that are not accessible under the current limitations. These new compositional regions not only provide access to higher WLs, but may also allow frit development efforts to target other specific properties to support enhanced melter operations.

It should be noted that under certain flowsheet conditions, the implementation of the 1100°C T_L PAR must be accompanied by a shifting categorization of what is deemed an acceptable operating window for DWPF operation. For example, the use of a 50°C offset may not be effective if access to WLs < 30% are still required. Assuming the intent of implementing the 1100°C PAR criterion is to gain access to higher WLs (> 45%), the need to identify frit and sludge systems that are predicted to form acceptable glasses at these lower WLs (< 30%) should no longer be of concern.

7.0 Recommendations

Based on the results of this study, if there are contractual drivers to target significantly higher WLs (> 45%), one option that could be extremely beneficial to DWPF would be to consider implementation of an 1100°C T_L PAR criterion (which translates into a reduction in the T_L offset from 100°C to 50°C). This option would not require changes to existing models or development of new models, but simply a change in PCCS coding. Decisions regarding implementation would need to balance the opportunity to increase WLs significantly for certain future sludge batches with the increased risk associated with melter operation, given some of the "T_L buffer" will have been removed from the SME acceptability process. With respect to the "T_L buffer", it should be mentioned that no changes are required to the model (thus the model predictions for T_L remain the same) and model and measurement uncertainties are still being applied – just to a smaller T_L PAR. Prior to implementation of this alternative strategy, DWPF should perform a risk-based assessment or review of this alternative approach to ensure it aligns with needs and processing strategies

8.0 References

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