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SLUDGE BATCH 2/3 CASE #6 AND CASE #7 WASHING AND BLENDING STRATEGIES:

A Model-Based Assessment for Projected Operating Windows

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Executive Summary

The decision on a baseline washing and/or blending strategy for the Sludge Batch 2/Sludge Batch 3 (SB2/SB3) combination with Np and Pu is not limited by the requirement to make an acceptable glass product. Model based assessments indicate that judicious selection of the frit can yield processable and durable products at attractive waste loadings for all scenarios assessed. If no other glass-related (e.g., anion solubility) or process-related (e.g., H_2 generation, redox control, or rheological control) restrictions are identified, then selecting a baseline flowsheet that minimizes unit operations (e.g., washing or decants) does have its potential advantages. The assessments supporting these statements are based solely on predictions generated by the glass property models as implemented in the Product Composition Control System (PCCS). Even though melt rate was not included in this assessment, it should be part of the integrated testing methodology and final frit selection process.

1.0 Introduction

The Defense Waste Processing Facility (DWPF) is currently processing Sludge Batch 2 (SB2). The radioactive glass is being produced as a "sludge-only" composition by combining SB2 with Frit 320 and melting. In preparation for the qualification and receipt of SB3, development and definition of the baseline flowsheet have been initiated (Rios-Armstrong 2002a and 2002b). In support of that effort, the Savannah River Technology Center (SRTC) recently developed frit compositions for SB3 (Peeler and Edwards 2002) and assessed melt rate for various frit/SB3 combinations (Lorier et al. 2003). Additional Pu and Np, which are being collected in H-Canyon storage vessels, are also being considered for blending with SB3. Disposal of both Pu and Np is in support of the site accelerated closure mission. In addition, recent blending strategies have contemplated combining SB3 with the remainder of SB2 once SB3 is qualified and ready for facility receipt. In support of this strategy, SRTC has been requested to assess the various SB2/SB3 washing/blending strategies in terms of potential frit development capabilities.

Seven washing strategies or cases were developed by the Closure Division and provided to SRTC. Based on the seven cases, Peeler and Edwards (2003) performed a model-based assessment in which candidate frit compositions were identified and projected operational windows were determined. The results of that assessment indicated that an acceptable glass product could be produced from the seven washing and/or blending strategies for the Sludge Batch 2/Sludge Batch 3 (SB2/SB3) combination with Np and Pu. More specifically, this parameter will not constrain the washing or blending strategy. The model-based assessments indicate that judicious selection of the frit could yield processable and durable products at attractive waste loadings for all scenarios assessed.

Recently, Process Support personnel have evaluated alternative washing scenarios for the washing strategies that have been termed the "baseline" and "alternative" flowsheets (Case #6 and Case #7).[1] The alternative cases proposed by Process Support were primarily focused on the degree of washing to control transfer volumes and to address tank farm space required for wash water. These results were then transmitted to Program Development & Integration who provided revised compositional estimates for the various SB2/SB3 washing strategies of interest.

This report summarizes the assessments of four derivatives of the potential SB2/SB3 "baseline" and "alternative" washing scenarios that were provided by Program Development & Integration. For each of the four derivatives, two options were provided based on the timing in which SB3 would be blended with SB2. The first option (referred to as the "110 canister" option) assumes an additional 110 canisters will be produced with SB2 prior to blending SB3.[2] The second option (referred to as the "250 canister" option) is based on the assumption that an additional 250 canisters will be produced with SB2 prior to SB3 blending. These two cases were assessed for the four different derivatives of the washing strategies resulting in 8 different or individual cases. Candidate frits were identified based on a review of each projected sludge composition and assessed using model-based predictions to project operational windows. Frits indicating promising results based on the Nominal Stage assessments were carried forward to the Variation Stage. This second stage introduced variation around the nominal SB2/SB3 compositions in an effort to gain insight into the robustness or tolerance of a candidate frit to anticipated

[1] Personal communication from Jeff Gillam on 6/5/03.
[2] The "additional" number of canisters to be produced from SB2 is based on a start date of May 1, 2003. It does not represent a total number of canisters produced from SB2.

compositional variation. Comparisons among these select frits were conducted using objective metrics developed and described by Peeler and Edwards (2002). The information resulting from these efforts will provide part of the technical basis for selecting a washing and blending strategy for SB2/SB3 processing.[3] It should be noted that a parallel activity is being performed to address other operational issues associated with Sludge Receipt and Adjustment Tank (SRAT) / Slurry Mix Evaporator (SME) processing (e.g., H_2 generation issues and acid addition and redox control strategies). Therefore, the results from both tasks should be considered prior to formalizing a decision regarding a baseline flowsheet.

It should also be noted that the frit compositions provided in this study may not be optimized with respect to providing maximum operational flexibility due to the short duration of this task. However, the frits do provide guidance in terms of targeting a baseline washing and blending strategy. Additional frit development activities would only enhance the reported operational windows and, when coupled with an assessment of melt rate (including the acid addition and redox control strategies), would provide a more thorough assessment of the baseline SB2/SB3 flowsheet. This report provides the detailed analysis that is referenced in Lilliston et al. (2003) with respect to the frit development efforts.

Objectives for this task are specified in Section 2.0. In Section 3.0, a brief review of the strategy or approach for developing and assessing new or existing frits is provided. In Section 4.0, the property acceptance criteria are established that will be used to classify properties predicted from models as acceptable or unacceptable as projected operational windows are defined. Projected SB2/SB3 nominal compositions are summarized in Section 5.0 from which assessments will be founded. Section 6.0 summarizes the Nominal and Variation Stage assessments for the eight washing and blending scenarios. Section 7.0 provides a summary of these assessments. Based on the results of this assessment, recommendations are made in Section 8.0.

[3] Lilliston et al. (2003) cited a personal communication in that report referencing the frit development efforts. The information presented in this report supports (and supplements) the information provided to Process Support, the Closure Division, and DWPF as they finalized the washing and blending strategy document.

2.0 Objective

The objective of this task is to provide technical information to the Closure Division from which a business decision can be made in terms of identifying a baseline SB2/SB3 flowsheet. The information provided in this report is solely focused on model-based projections of the Product Composition Control System (PCCS) operational windows and the robustness of candidate frits to sludge variation anticipated for various SB2/SB3 washing and blending strategies of interest. Experimental assessments of frittability and melt rate are not addressed.

3.0 The Strategy or Approach Supporting the Paper Study

Two stages proposed by Peeler and Edwards (2002) were used to assess various frit/sludge combinations: the Nominal Stage and the Variation Stage. The Nominal Stage utilized nominal SB2/SB3 compositions representing potential washing/blending scenarios. In general, this stage assessed candidate frit compositions with respect to their ability to provide a relatively large operational window based solely on a specific nominal composition – no sludge variation was accounted for in this phase. Assessments were made using predictions from models currently implemented in the DWPF over the waste loading (WL) interval of interest (25 – 60 wt%). The primary property predictions assessed included those for liquidus temperature (T_L), viscosity (η), and durability (normalized boron release – NL[B]).

It is recognized that the Nominal Stage assessments do not account for anticipated compositional variation. Therefore, an increased risk would result with respect to processability or product quality if a decision were based solely on this assessment without accounting for compositional variation. The intent or focus of the Variation Stage assessment was to gain insight into the robustness of candidate frits with respect to compositional variation. In this assessment, ±10% variation about both nominal Case #6 options (110- and 250-canister options) sludge compositions was used to assess specific frit/sludge systems. More specifically, ±10% around each nominal Case #6b-110 canister option and Case #6b-250 canister option was calculated. The minimum and maximum values for each major oxide over both canister options were selected and used to bound the anticipated compositional region of interest for the Variation Stage.

Statistical mixture experimental design methods were used to obtain an initial set of feasible compositions for each sludge region. These methods include algorithms that can be used to determine the extreme vertices (EVs) of a sludge region (the bounding compositions), such as that defined in the preceding paragraph. These algorithms are available in many statistical software packages. One such package, JMP Version 5.0 (SAS 2002), was used to generate the EVs for the mixture region of interest for this study.[4] An additional composition, the centroid, was computed for the set of EVs generated during this study. The centroid of a sludge region is determined by averaging all of the EVs for that sludge region and this composition was included along with the EVs in the assessments described below.

Once the EVs were determined for the sludge region developed to bound the options for Case #6b, assessments were made using models currently implemented in the DWPF over the waste loading interval of interest (25 – 60 wt%) for select frits – see Section 4.0 for a more detailed discussion of the models and Property Acceptability Region (PAR) limits. To obtain insight into the robustness of candidate frits to this sludge variation, the three metrics developed by Peeler and Edwards (2002) were utilized.

The assessments are also a function of the underlying assumptions made with respect to the impacts of sludge washing and blending on the ultimate compositions of the SB2/SB3 options

[4] The extreme vertices (EVs) for a particular sludge view are the "corner points" of the region determined by applying the ± 10% variation about the nominal composition for that sludge view. The corresponding centroid for the sludge view is simply the arithmetic average of these EVs.

provided. It should also be noted that an additional underlying assumption is being made with respect to the projected operational windows by the use of centroid and EV compositions. The assumption is that the property predictions for a sludge region of interest are bounded by the predictions generated from the EVs and that compositions lying between the EVs (i.e., such as the centroid) would yield property predictions that are acceptable if those from the EVs were acceptable. This assumption is valid when the property behavior is expected to be linear over the compositional region of interest. This assumption adds minimum risk to the projected operational windows with the highest concern being predictions of T_L that has a non-linear model form (Brown et al. 2001).

4.0 Property Acceptability Region (PAR) Limits Used for Assessments

The property predictions assessed in this study included durability (Product Consistency Test [PCT] [ASTM 2002] response in terms of the preliminary glass dissolution estimator (ΔG_P) (Jantzen et al. 1995)), viscosity at 1150°C ($\eta_{1150°C}$), T_L (new model), homogeneity, and Al_2O_3 and alkali concentrations. Jantzen et al. (1995) and Brown et al. (2001) provide a more detailed discussion on the development of these models. To establish or project operational windows for sludge/frit scenarios of interest, the predicted properties must be assessed relative to established acceptance criteria. Acceptable predicted properties for this assessment are based on satisfying their respective PAR limit values (see Table 4-1)—not the more restrictive Measurement Acceptability Region (MAR) limits. Brown, Postles, and Edwards (2002) provide a detailed discussion of how the MAR limits are utilized in PCCS. Because the PAR limit for the new T_L model is compositionally dependent (Brown et al. 2001), the PAR limit was conservatively set at 1010ºC to allow for a quick assessment. In fact, Brown et al. (2001) have demonstrated that the PAR limits for the new model will not be this restrictive (in terms of limiting the projected compositional operating window) for various glass-forming systems. Therefore, in the assessment discussions that follow, if the new T_L model limits the projected operational window, one must remember the use of this conservatively set PAR limit. More specifically, failing this constraint (as currently defined) does not necessarily mean that it would be an unacceptable glass given the conservative 1010ºC PAR limit.

Although the homogeneity constraint is calculated, Herman et al. (2002) have provided the technical basis to remove this constraint. More specifically, the homogeneity constraint can be replaced via application of the Al_2O_3 and sum of alkali constraints without compromising product quality while providing more flexibility for DWPF operations. Since this recommendation has not been implemented in the DWPF, homogeneity values were calculated. However, if the conditions established by Herman et al. (2002) with respect to Al_2O_3 and sum of alkali are met, the homogeneity constraint was not used to limit projected operational windows.

Table 4-1. PAR Limits for Various Properties

Property	PAR Limit
T_L (new)	< 1010°C
ΔG_P (durability)	> -12.7178 kcal/mol
$\eta_{1150°C}$ (melt viscosity)	21.5–105.4 Poise
Homogeneity	> 210.92
Al_2O_3	≥ 3.0 wt% (in glass)
Σalkali[5]	< 19.3 wt% (in glass)

[5] Alkalis included in this sum are Na_2O, Li_2O, Cs_2O, and K_2O.

5.0 Basis for SB2/3 Compositional Scenarios

Two primary inputs are required to assess the projected operational windows, the waste loading intervals, and the robustness. These inputs are: sludge or waste stream composition(s) and frit composition(s). Given the focus of this study is to develop and assess frit compositions for SB2/SB3, defining the nominal SB2/SB3 waste stream(s) and representing its (their) variation are the only required inputs. For a given waste stream composition, one can select candidate frit compositions and ultimately assess or define glass compositional regions or operating windows based on established acceptance criteria (see Section 4.0).

Various alternative washing strategies or cases were developed by Process Support personnel. The cases are:

6. 4 decants + Pu + 1 decant + Np (Baseline Case)
   a. 3 decants + 381 kgallon decant + Pu + 172 kgallon decant + Np
   b. 3 decants + 172 kgallon decant + Pu + 381 kgallon decant + Np
7. 4 decants + Pu + 1 decant with wash + Np (Alternate Case)
   a. 3 decants + 381 kgallon decant + Pu + IW + 515 kgallon decant + Np
   b. 3 decants + 381 kgallon decant + Pu + IW + 381 kgallon decant + Np
   c. 3 decants + 575 kgallon decant + Pu + IW + 380 kgallon decant + Np
   d. 3 decants + 381 kgallon decant + Pu + 171 kgallon decant + IW + 380 kgallon decant + Np
   e. 3 decants + 381 kgallon decant + Pu + IW + 380 kgallon decant + IW + 380 kgallon decant + Np

It should be noted that Case 6 (Baseline) and Case 7 (Alternate) were previously described in Peeler and Edwards (2003) and were the primarily focus of that report. The cases of interest in this report are essentially variations around Case 6 and Case 7. Lilliston et al. (2003) indicated that six criteria were used to provide guidance on determining the most ideal washing strategy. Upon application of these criteria to the various washing strategies, five of the cases were identified as primary candidates. These cases were 6a, 6b, 7c, 7d, and 7e. The remaining two washing cases were analyzed and determined to be "inappropriate" due to the four washes already occurring to SB3 and the ability to meet all six criteria previously mentioned.[6]

Elder provided the compositional estimates for the specific strategies of interest.[7] The elemental concentrations provided were converted to an oxide basis (by multiplying by the appropriate gravimetric factor) and these data are presented in Table 5-1. These nominal compositions form the basis for assessments as described in Section 6.0.

It should be noted that anions were not reported as part of the calcined elemental concentrations – only as part of the supernate information. Therefore no assessment of the potential to exceed the anion solubility limits could be made as a function of WL. Part of the SME acceptability process is to evaluate "single component" limits (e.g., SO_4, NaCl, NaF) to ensure they are not exceeded. As higher WLs are targeted, these components could limit upper WLs if their concentration in sludge is significant.

[6] Case 6a was not specifically assessed in this report given the compositional projections were very similar to Case 6b.
[7] Personal communication with H.H. Elder via email dated 6/11/03. Appendix A provides the data transmitted in the personal communication (elemental wt%, calcine basis).

Those sludge components shown in bold in Table 5-1 were classified as major oxides (> 0.5 wt% in glass once WL is accounted for). The remaining components were considered to be minor components in glass as their individual contributions to the glass will be < 0.5 wt% at WLs of 60% or less. The minor components were grouped into a single component (henceforth referred to as "Others") to aid in the model based assessments. The "Others" composition used for all assessments was the average composition for all eight cases. Appendix B summarizes the average "Others" composition. Although the "Others" group is constant in terms of its components and percentages, the quantity of "Others" will be varied in the Variation Stage assessment.

Table 5-1. Projected SB2/SB3 Compositions (oxide basis, wt%).

	7aLJD4-250	7aLJD4-110	7aPuWsWs-250	7aPuWsWs-110	7aPuDeWs-250	7aPuDeWs-110	6b-250	6b-110
	7c-250	7c-110	7e-250	7e-110	7d-250	7d-110	6b-250	6b-110
Al_2O_3	14.814	14.757	15.229	15.135	14.965	14.889	14.228	14.247
BaO	0.223	0.223	0.223	0.234	0.223	0.223	0.212	0.212
CaO	2.896	3.022	2.980	3.092	2.924	3.050	2.784	2.924
Ce_2O_3	0.328	0.340	0.328	0.340	0.328	0.340	0.316	0.328
Cr_2O_3	0.322	0.322	0.322	0.336	0.322	0.322	0.307	0.307
CuO	0.163	0.175	0.175	0.175	0.175	0.175	0.163	0.163
Fe_2O_3	34.785	35.585	35.800	36.457	35.156	35.871	33.441	34.341
K_2O	0.362	0.362	0.374	0.374	0.362	0.374	0.349	0.349
La_2O_3	0.203	0.216	0.216	0.216	0.203	0.216	0.203	0.203
MgO	3.001	3.101	3.084	3.184	3.018	3.134	2.885	3.001
MnO	7.502	7.153	7.721	7.334	7.579	7.218	7.205	6.908
Na_2O	20.220	19.398	17.901	17.416	19.384	18.710	23.334	22.202
NiO	1.438	1.489	1.476	1.527	1.451	1.502	1.387	1.438
PbO	0.259	0.269	0.269	0.269	0.269	0.269	0.248	0.259
SiO_2	1.754	1.776	1.797	1.818	1.776	1.776	1.669	1.711
ThO_2	0.125	0.125	0.137	0.125	0.125	0.125	0.125	0.125
U_3O_8	10.129	10.153	10.424	10.412	10.235	10.247	9.740	9.799
ZnO	0.336	0.349	0.349	0.361	0.349	0.349	0.324	0.336
ZrO_2	0.640	0.653	0.653	0.666	0.640	0.653	0.614	0.627
Total	99.499	99.466	99.458	99.472	99.484	99.442	99.534	99.481

6.0 Assessment of Nominal and Variation Stages

Using the available PCCS models, various frits were assessed for each of the SB2/SB3 washing/blending strategies. Evaluating the predicted impacts and projected operating windows for candidate frits will provide guidance to the Closure Division in terms of identifying and selecting a baseline SB2/SB3 flowsheet. It is not the intent of this study to recommend a frit to DWPF for SB2/SB3. In this section, both the Nominal and Variation Stage assessments are discussed. It should be noted that the Variation Stage assessment was not performed for each specific frit/sludge case. The Variation Stage was only performed for the Case #6 options (110 and 250 options) given successful SRAT/SME runs indicated that H_2 should not be an issue. It should be noted that if melt rate assessments indicate a need for a more advanced washed sludge, a separate report will be issued that provides a more detailed analysis of the Case #7 options.

6.1 Frit Development

Model-based scoping studies were performed to identify primary frit candidates from which the Nominal and Variation Stage assessments were based. The scoping studies evaluated operational windows as a function of frit composition for each SB2/SB3 blending/washing scenario provided. The results of this preliminary study are not reported in this document.[8] Table 6-1 summarizes the nominal frit compositions that were carried forward. The primary compositional difference is an adjustment in alkali concentration (both the ratio of Na_2O and Li_2O and/or the total quantity) to compensate for the varying Na_2O levels among the four cases evaluated.

Jantzen (1988) developed Frit 202 for the "coupled" operations flowsheet. Peeler et al. (2001) developed Frit 320 specifically to improve melt rate for SB2. With the exception of Frit 432, the "400 series frits" were developed for various washing strategies associated with SB3 (Peeler and Edwards 2002) or during previous assessments of SB2/SB3 flowsheet options (Peeler and Edwards 2003). As previously mentioned, the frits listed in Table 6-1 may not be optimized with respect to maximizing operational window sizes or the degree of robustness to compositional variation. It is felt that the frits listed provide ample insight or guidance to the Closure Division as it defines a baseline SB2/SB3 flowsheet.

Table 6-1. Nominal Compositions of the Primary Frits.

Oxide	Frit 202	Frit 320	Frit 416	Frit 417	Frit 418	Frit 430	Frit 432
Al_2O_3	-	-	1	-	-	-	-
B_2O_3	8	8	8	8	8	8	8
Li_2O	7	8	8	8	8	8	8
Na_2O	6	12	11	11	8	10	6
SiO_2	77	72	72	73	76	74	78
MgO	2	-	-	-	-	-	-
Total	100	100	100	100	100	100	100

[8] The results of the preliminary assessment can be found in WSRC-NB-2001-00061.

6.2 Nominal Stage Assessment

Projected operating windows for nominal SB2/SB3 washing/blending scenarios are presented in Table 6-2 for candidate frit compositions over the WL interval of interest (25 – 60 wt%). The acceptable WL intervals are based on the PAR criteria. Detailed information regarding the predicted properties is provided in Appendix C. The nomenclature used in Appendix C is consistent with that used by Peeler and Edwards (2002), and for a detailed discussion, the reader is referred to that report. In addition to the PAR-based projected WL interval, the property that restricts access to higher WLs is also provided in parenthesis.

Nominal Stage assessments for each SB2/SB3 option were completed using both Frit 202 and Frit 320 given previous interest in these frits. In general, these two frits compositionally bound the frit region of interest. Although they are potential candidates for select sludge options, they may not be optimal in terms of the projected operational windows or with respect to melt rate. More specifically, Frit 202 provides operational windows for all washing strategies covered in this report.

Frit 320 provides operational windows for approximately one-half of the cases being considered. The exceptions are those sludges whose Na_2O concentrations are relatively high: Case #6b (both 110 and 250 canister options) and Case #7c (or 7aLJD4) (250 canister option only). When Frit 320 is coupled with these high Na_2O sludges, PCT predictions limit the WL interval classified as acceptable.

A more detailed discussion of the Case #6 and Case #7 options is provided below. Initially consider Case #6b that is based on an additional 110 canisters being produced from SB2 prior to blending with SB3. The projected operational window when Frit 202 is used is 25 – 38% WL with T_L limiting access to WLs of 39% or greater. When Frit 418 is coupled with the Case #6b, 110 canister option, the projected WL interval is 25 – 45% with both low η and T_L predictions limiting access to higher waste loadings. The transition from a T_L-limited system to a low η- and T_L-limited system is due to compositional adjustments made to the frit to compensate for the shift in sludge alkali. More specifically, Frit 202 has a total alkali content of 13% while Frit 418 contains 16% total alkali. The use of the higher alkali frit results in a shift to a higher maximum WL at which this nominal sludge can be processed and could translate into an enhanced melt rate given the trends reported by Lambert et al. (2001). Use of Frit 416 (19% total alkali) results in a PCT-limited system with a projected operating window of only 25 – 33% WL. The high alkali content of this frit coupled with the high alkali content of the sludge drastically reduces the projected operational window. Further increases in the frit alkali content (e.g., Frit 320 and Frit 417) result in a complete restriction of the operational window due to predictions of durability. Projected operational windows for Frit 430 and Frit 432 are 25 – 41% and 25 – 43%, respectively. It should be noted that given the Frit 432- and Frit 202-based systems are T_L limited, the use of the 1010°C "conservative" PAR limit may unnecessarily restrict access to higher WLs.

Table 6-2. Summary of Nominal Stage PAR Assessments for Various SB2/SB3 Cases (waste loading ranges are in wt% on a calcined, oxide basis).

		Frit 202	Frit 320	Frit 416	Frit 417	Frit 418	Frit 430	Frit 432
Case #6b	110	25 – 38 (T_L)	- (PCT)	25 – 33 (PCT)	- (PCT)	25 – 45 (low η/ T_L)	25 – 41 (low η)	25 – 43 (T_L)
	250	25 – 40 (T_L)	- (PCT)	- (PCT)	- (PCT)	25 – 44 (low η)	29 – 34 (PCT)	25 – 45 (T_L)
Case #7c	110	27 – 35 (low η)	28 – 39 (low η)	25 – 41 (low η)	25 – 41 (low η)	25 – 42 (T_L)	25 – 43 (low η)	25 – 39 (T_L)
(7aLJD4)	250	26 – 36 (T_L)	- (PCT)	25 – 41 (low η)	28 – 41 (low η)	25 – 43 (T_L)	25 – 43 (low η)	25 – 41 (T_L)
Case #7d	110	27 – 34 (T_L)	27 – 39 (low η)	25 – 42 (low η)	25 – 42 (low η)	25 – 41 (T_L)	25 – 43 (T_L)	25 – 39 (T_L)
(PuDeWs)	250	27 – 35 (T_L)	30 – 39 (low η)	25 – 41 (low η)	25 – 41 (low η)	25 – 42 (T_L)	25 – 44 (low η/ T_L)	25 – 40 (T_L)
Case #7e	110	28 – 32 (T_L)	27 – 41 (low η)	25 – 41 (T_L)	25 – 42 (T_L)	25 – 39 (T_L)	25 – 41 (T_L)	25 – 37 (T_L)
(PuWsWs)	250	28 – 33 (T_L)	27 – 40 (low η)	25 – 42 (T_L)	25 – 43 (low η/T_L)	25 – 40 (T_L)	25 – 42 (T_L)	25 – 38 (T_L)

The projected operational windows for the Case #6b, 250 canister option are very comparable to their Case #6b, 110 canister counterparts for the most part. Based on the higher alkali sludge, the allowable upper WLs are extended (relative to the Case #6, 110 canister option) to 40% and 45% for those systems which were (and remain) T_L limited (e.g., the more refractory frits 202 and 432). Given the higher alkali content in the sludge, when Frit 418 is used the result is a lower viscosity as compared to the Case #6b, 110 canister option at the same WL. The impact on the operational window is a 1% reduction to 44% WL compared to 45% for the 110 canister option. The impact to the operational window when Frit 430 is used is quite dramatic. The 110-canister option was low η limited but transitions to a PCT-limited system with the higher alkali-based sludge. Predictions of PCT limit access to WLs of 35 % or higher – down from 41% for the 110-canister option. The Frit 416, Case #6b 250-canister option is completely restricted by PCT predictions. This is not surprising given both the sludge and the frit are relatively high in alkali. PCT predictions also restrict the use of Frit 320 and Frit 417 for this case.

Of the seven frits being assessed, only one is restricted from use with any of the Case #7 options. Specifically, predictions of PCT restrict the use of Frit 320 with the Case #7c, 250-canister option. There are numerous comparisons that could be made from the results presented in Table 6-2. Given the classification of Case #6 as the baseline by Lilliston et al. (2003), a detailed discussion of each of the Case #7 options is not provided. Of particular importance to this assessment is to provide technical information to the Closure Division from which a business decision can be made in terms of identifying a baseline SB2/SB3 flowsheet. To accomplish this, this assessment simply needs to demonstrate (not optimize) the ability to develop a frit composition to provide acceptable WL ranges (for both the nominal and anticipated sludge variation) that result in adequate operational flexibility for DWPF.

The first step in this process is discussed below. In general, the WL intervals over which the nominal compositions could be processed typically range from mid-to-high 20's (lower WLs) to the high 30's to low/mid 40's (upper WLs). Indications are that the lower washed sludges could provide slightly higher waste loadings with the frits evaluated (e.g., Case #6b 250-cansiter option which is based on 3 decants + 172 kgallon decant + Pu + 381 kgallon decant + Np resulting in a 45% WL upper limit with Frit 432). It should be noted that alternative frits could be developed (just not developed herein due to the expedited schedule to which this task was working) to narrow the potential WL differences or advantages. However, if no other processing issues are identified, then selecting a baseline flowsheet that minimizes unit operations (e.g., washing or decants) does have its advantages. These statements and the results summarized in Table 6-2 indicate that frits can be developed that provide large operational windows for each of the eight cases developed by the Closure Division when considering nominal compositions.

Although of secondary importance, it is noted that approximately half of the frit/sludge systems evaluated are T_L limited at the upper WL. In an attempt to enhance melt rate or waste throughput, higher alkali based systems should be targeted. The latter statement is based on the trends observed by Lambert et al. (2001). As the alkali content in glass increases, one of two constraints will likely limit the projected operational window: low viscosity or PCT. It is not specifically known if the source of alkali, either stemming from a less washed sludge or enhanced alkali concentrations in the frit, makes a difference in the impact on melt rate. Given this argument, primary frits of interest for the Case #6b options include: Frit 418 and Frit 430.

The use of the PAR criteria allows an efficient, "one-to-one" comparison in an effort to assess the impact of frit compositional changes on properties such as viscosity, homogeneity, durability, and T_L (which ultimately dictate projected operating windows). Given SME acceptability decisions and targeted WLs will ultimately be based on the MAR (Brown, Postles, and Edwards 2002), assessments for Case #6b, 250-cansiter option were performed to demonstrate that the operational windows would not collapse or be significantly reduced once measurement uncertainty was applied. Table 6-3 summarizes the MAR based assessments for the Case #6b, 250-cansiter option. Appendix D provides a detailed evaluation of the MAR assessments. Based on the results of the Nominal Stage PAR assessments, Frit 202, Frit 418, Frit 430 and Frit 432 were used for the Case #6b MAR assessment. It should be noted that due to the labor intensive nature of the MAR assessments, the WL range over which the MAR was performed was reduced to 30 – 47%. The lower limit was set strictly due to WLs of less than 30% are not of interest. The upper WL of 47% was based on the PAR information. The highest upper WL in the PAR assessment was 45% for the Frit 432, Case #6b, 250-canister option. With this system being T_L limited, the use of the 1010°C conservative PAR constraint may have unnecessarily restricted the upper WL. Historical results suggest that for T_L-limited systems, the MAR-based upper WL will remain the same as the PAR or be 1- 2% higher than the PAR. Therefore, the upper WL at which the MAR-based assessments were performed was set at 47%. The 30 – 47% WL interval should cover the range of interest as well as eliminate unnecessary calculations. Frit 320, Frit 416 and Frit 417 were not assessed at the MAR given there was no operational window at the PAR for the Case #6b-250 canister option.

Table 6-3. Summary of Nominal Stage MAR Assessments for Case #6b, 250-Canister Option. (waste loading ranges are in wt% on a calcined, oxide basis).

	Results Presented are from a Waste Loading Interval of 25% to 60%			
	Frit 202	**Frit 418**	**Frit 430**	**Frit 432**
Case #6b, 250-canister	30 – 41 (T_L)	30 – 42 (low η)	- (PCT)	30 – 46 (T_L/low η)

Initially, consider the use of Frit 202. The projected operational window when using the PAR criteria was 25 – 40% (T_L limited) (see Table 6-2). The MAR assessments for the Case #6b, 250-canister option with Frit 202 projected an operational window from 30 – 41% WL with T_L still limiting WLs of 42% or greater. As previously noted, the use of the 1010°C PAR constraint was "conservative" as the maximum obtainable WL allowed increased 1% from the PAR to the MAR (for the Case #6b, 250-cansiter option). The other T_L-limited system occurred when Frit 432 was utilized. Again, the use of the 1010°C PAR was conservative since the allowable upper WL increased from 45% (PAR-based) to 46% (MAR-based). Given low η limits the Frit 418 system (44% WL using the PAR criteria), it is not surprising that application of the measurement uncertainty reduces the upper WL to 42% (see Table 6-3). The most interesting system is based on Frit 430. The PAR assessments indicated that the projected operational window was 29 – 34% with PCT limiting access to higher WLs. Application of the measurement uncertainty not only reduced, but also completely eliminated, the projected operational window. This result lowers the classification of Frit 430 as a primary frit for the Case #6b, 250-caniser option.

The MAR-based assessments indicate that the decisions based on the PAR-based operational windows are of value. Once the MAR criteria were applied, the operational windows are not significantly altered with the exception of the Frit 430-based system.

6.3 Variation Stage Assessment

In Section 6.2, the model-based Nominal Stage assessments indicated large operational windows do exist for all SB2/SB3 cases being considered when coupled with specific frit compositions. In addition, there was evidence that the operational windows based on the PAR criteria were not overly optimistic given that the application of the MAR resulted in very similar window sizes for most systems. However, the assessments in Section 6.2 were based solely on nominal sludge compositions. In this section, a ±10% compositional variation was applied to the projected compositional estimates of Case #6b (both 110 and 250 canister options) to gain insight into the robustness of candidate frits. More specifically, a 10% compositional variation was initially applied to each nominal Case #6b sludge (both the 110- and 250-canister options). Then the minimum and maximum values for each major component were identified to bound the sludge compositional region of interest. JMP Version 5 was used to generate 932 extreme vertices and a centroid (for a total of 933 sludge compositions) for this region. Although the use of the minimum and maximum values from each of the options did result in a slightly larger compositional region than if the streams were considered individually, the authors feel that the larger compositional region is still valid to provide insight into the robustness of candidate frits to compositional variation.

Based on the PAR and MAR assessments, the following frits were carried forward in the Variation Stage assessment: Frit 202, Frit 320, Frit 418, Frit 430, and Frit 432. It should be noted that Frit 320 is being evaluated strictly given interest in its potential use. The PAR- and MAR-based assessments were not encouraging given PCT predictions.

Table 6-4 summarizes the response of the Variation Stage assessment using the PAR criteria with the various frits. Also provided in Table 6-4 are the PAR-based WL intervals projected under the Nominal Stage assessment (labeled as "WL Nominal") for the Case #6b-250 canister option. Appendix E provides the details supporting the summary shown in Table 6-4.

Table 6-4. Summary of Variation Stage PAR Assessments Based on both the Case #6b 110- and 250-canister Options. (waste loading ranges are in wt% on a calcined, oxide basis)

	Results Presented are from a Waste Loading Interval Of 25% to 60%				
Metrics	**Frit 202**	**Frit 320**	**Frit 418**	**Frit 430**	**Frit 432**
WL Nominal[9]	25 – 40	None	25 – 44	29 – 34	25 – 45
WL all EVs	28 – 33	None	25 – 35	None	25 – 37
% EVs at some WL	100%	16.4%	100%	65.9%	100%
WL of 5% or Greater	100%	14.9%	100%	54.6%	100%
Min. WL Range	7%	-	11%	-	13%

For the Frit 202, Case #6b, 250 canister option, the nominal WL interval was projected to be 25 – 40% WL (with T_L limiting access to WLs of 41% or greater). When ±10% variation around the Case #6b major sludge components is applied (resulting in 933 EVs including the centroid), the

[9] Nominal WL ranges are based solely on the Case #6b, 250-canister option (see Table 6-2).

WL interval over which all of the EVs can be processed is 28 – 33%. Predictions of T_L limit 36 of the 932 EVs at 34% WL. The second and third metrics ("% EVs at some WL" and "WL of 5% or Greater") indicate that all of the EVs can be processed at some WL and that all of the EVs have a minimum operation window of 5% or greater. In fact, the last metric shown in Table 6-4 ("Min. WL Range") indicates that the minimum WL interval over which each EV can be processed is 7%. In summary, when Frit 202 is coupled with the Case #6b, 110/250-based EVs, the projected operational window is extremely large and demonstrates a high degree of robustness.

The use of Frit 418 with the Case #6b, 110/250 based EVs results in a projected operational window of 25 – 35% WL over which all of the EVs can be processed. At 36% WL, 27 of the 933 EVs fail the PCT PAR. The minimum WL range over which each EV can be processed is 11% which demonstrates a high degree of robustness to the applied sludge variation. If the general trend of "increased alkali leads to an enhanced melt rate" holds, then Frit 418 should have a higher melt rate than Frit 202.

One of the primary candidates for further consideration is Frit 432. The projected operating window at the PAR for the nominal Case #6b, 250-canister option was 25 – 45% WL. Once the compositional uncertainty is applied, the operational window is projected to be 25 – 37%. This is not only the largest WL interval demonstrated but also allows for the highest WL. Perhaps the only disadvantage of Frit 432 relative to Frit 418 is the lower total alkali in the frit. With 14% total alkali, Frit 432 may not result in a higher relative melt rate when compared to Frit 418 (containing 16% total alkali). Although melt rate and WL are goals to support the accelerated mission efforts, total waste throughput should be the primary focus. In fact, Lorier and McGrier (2002) have demonstrated that melt rate and WL can be competing in the sense that as WL is increased, melt rate decreases. However, it was shown that total waste throughput increased up to a critical WL after which further increases in WL provided no advantage over the "baseline" case in the Frit 320/SB2 system. The effect of WL, melt rate, and total waste throughput will be assessed for the Case #6b, 250-cansiter option for various frits as a part of this integrated program.

It should be noted that Frit 320 has a very poor response to the EVs generated by the applied compositional variation. This is not surprising given the response to both nominal Case #6b options (see Table 6-2); that is, predictions of PCT restrict the use of Frit 320 with both options. The metrics for the Frit 320-based glasses indicate that there is no window over which all the EVs could be processed. The second metric indicates that only 16.4% of the EVs could be processed at some WL. The 16.4% of "processable" combinations are a result of coupling Frit 320 with the low alkali, EV-based sludges. This suggests that frit development should focus on less alkali rich frits in order to compensate for the higher alkali EVs. The third metric suggests that there are only 14.9% of the EVs with a WL interval of 5% or greater. For those EVs that are processable (16.4%), almost all have a minimum WL interval of 5%. Given the results of this assessment, Frit 320 is not a primary candidate for the Case #6b options.

Frit 430, with 18% total alkali, also has a poor response to the applied variation (see Table 6-4). There is no WL or WL interval over which all the EVs are processable and only 65.9% of the EVs are processable at some WL. Although a relatively poor response in comparison to other frits shown in Table 6-4, the metrics suggest that as frits with less alkali are considered, the response to the applied variation increases. That is, as one transitions from an alkali-rich frit to an alkali-poor frit, the projected operational window for the EVs increases. However, there does appear to be a "maximum or peak" in the robustness of the operational window which appears to occur with a 14% alkali containing frit (e.g., Frit 432). In general, the “robustness” or responses based on model predictions tails off with higher and lower alkali containing frits. Again, it should be mentioned that the frits being used in this assessment may not be optimized. Based on the results of the Variation Stage assessment, the primary frit candidates are: Frit 202, Frit 418, and Frit 432.

7.0 Summary

This assessment was performed to provide technical information to the Closure Division from which a business decision can be made in terms of identifying a baseline SB2/SB3 flowsheet. To accomplish this, the assessment demonstrated (not optimized) the ability of candidate SB2/SB3 frit compositions to provide acceptable WL intervals that provide operational flexibility to DWPF to account for anticipated sludge variation. This objective was met by utilizing an existing frit development and assessment methodology proven effective for previous frit development activities.

The following statements can be made to summarize this assessment:

- The model-based predictions indicated that judicious selection of the frit can yield processable and durable products at attractive waste loadings for all scenarios assessed. Based on this statement, the selection of a baseline flowsheet should not be limited by the ability to produce acceptable glass products within the compositional region assessed. If no other processing issues are identified, then selecting a baseline flowsheet that minimizes unit operations (e.g., washing or decants) does have its potential advantages.
- The MAR-based assessments for the Case #6b, 250-canister option indicated that the operational windows based on the PAR criteria were not overly optimistic. This statement being made based on the fact that once the measurement (MAR) uncertainties were applied to select SB2/SB3 systems the size of the operational window was very similar to that projected using the PAR.
- The results of the Variation Stage assessment indicate that frits can be used that demonstrate (via model based predictions) a high degree of robustness to the applied compositional variation.

As previously noted, the model-based assessments (Nominal and Variation Stage) were performed to provide guidance for the targeted washing and blending strategy – no experimental assessment of glass properties, melt rate or waste throughput was performed. The latter being a critical portion of the integrated approach to reduce the risk of defining a flowsheet which on paper looks attractive (e.g., large operating windows and relatively high projected waste loadings), but once implemented in the facility does not process according to expectations.

8.0 Path Forward

Based on the results of this assessment the following recommendations are made:

- Assess melt rate for the Case #6b, 250-canister option nominal sludge with Frit 202, Frit 418, and Frit 432 (at a minimum). The melt rate testing methodology should include both the dry-fed melt rate furnace (MRF) and the slurry-fed melt rate furnace (SMRF).

- The integrated testing program should address the following issues:
  (1) What is the effect of increasing WL on melt rate and total waste throughput? This issue could be addressed via the MRF test (as previously performed for the Frit 320/SB2 system). However, it is recommended that consideration be given to perform a SMRF test with the primary flowsheet at two (at least two) different waste loadings. One of the two targeted waste loadings should be the defined MAR-based upper limit for that system.
  (2) From a melt rate and/or total waste throughput perspective, is there an advantage for a more advanced washed sludge? Assuming the melt rate and/or total waste throughputs for the Case #6b, 250-canister option are not "acceptable", the melt rate program should assess the melt rate of a more advanced washed sludge (e.g., Case #7). This assessment would provide insight into the lingering question of if the source of alkali (either sludge or frit) makes a difference in melt rate. Even if the Case #6b melt rate assessments are positive, an evaluation of a Case #7 option should be highly considered.

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Appendix A

Nominal Decant Compositions
(Personal Communications with H.H. Elder)

Table A.1 Elemental Concentrations for Various SB2/SB3 Case #6 and Case #7 Options.[10]

	Units are wt % elemental, calcine basis							
Element	7a LJD4-250	7a LJD4-110	7aPuWs Ws-250	7aPuWs Ws-110	7aPuDe Ws-250	7aPuDe Ws-110	6b-250	6b-110
	7c-250	7c-110	7e-250	7e-110	7d-250	7d-110	6b-250	6b-110
Al	7.84	7.81	8.06	8.01	7.92	7.88	7.53	7.54
Ba	0.20	0.20	0.20	0.21	0.20	0.20	0.19	0.19
Ca	2.07	2.16	2.13	2.21	2.09	2.18	1.99	2.09
Ce	0.28	0.29	0.28	0.29	0.28	0.29	0.27	0.28
Cr	0.22	0.22	0.22	0.23	0.22	0.22	0.21	0.21
Cu	0.13	0.14	0.14	0.14	0.14	0.14	0.13	0.13
Fe	24.33	24.89	25.04	25.50	24.59	25.09	23.39	24.02
K	0.30	0.30	0.31	0.31	0.30	0.31	0.29	0.29
La	0.16	0.17	0.17	0.17	0.16	0.17	0.16	0.16
Mg	1.81	1.87	1.86	1.92	1.82	1.89	1.74	1.81
Mn	5.81	5.54	5.98	5.68	5.87	5.59	5.58	5.35
Na	15.00	14.39	13.28	12.92	14.38	13.88	17.31	16.47
Ni	1.13	1.17	1.16	1.20	1.14	1.18	1.09	1.13
Pb	0.24	0.25	0.25	0.25	0.25	0.25	0.23	0.24
Si	0.82	0.83	0.84	0.85	0.83	0.83	0.78	0.80
Th	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11
U	8.59	8.61	8.84	8.83	8.68	8.69	8.26	8.31
Zn	0.27	0.28	0.28	0.29	0.28	0.28	0.26	0.27
Zr	0.49	0.50	0.50	0.51	0.49	0.50	0.47	0.48

[10] Personal communication with H.H. Elder via email dated 6/11/03. Lilliston et al. (2003) renamed these cases as 6b-110, 6b-250, 7c-110, 7c-250, 7d-110, 7d-250, 7e-110, and 7e-250.

Appendix B

Average "Others" Composition

Table B-1. Average "Others" Composition (wt% basis)

Oxide	
BaO	0.222
Ce_2O_3	0.331
Cr_2O_3	0.320
CuO	0.171
K_2O	0.363
La_2O_3	0.210
PbO	0.264
ThO_2	0.127
ZnO	0.344
ZrO_2	0.643
Total	2.995

Appendix C

Nominal Stage Assessments Using the PAR Criteria

Table C-1. Summary of the Nominal Stage Assessments for Various Case #6b and Case #7 Options.

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
6b-110	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	6	25	30
6b-110	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	8	31	38
6b-110	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	39	50
6b-110	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	10	51	60
6b-110	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	4	25	28
6b-110	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	29	29
6b-110	320	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	7	30	36
6b-110	320	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	13	37	49
6b-110	320	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	50	60
6b-110	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
6b-110	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6	28	33
6b-110	416	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	5	34	38
6b-110	416	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10	39	48
6b-110	416	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
6b-110	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	1	25	25
6b-110	417	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	3	26	28
6b-110	417	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	29	29
6b-110	417	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	9	30	38
6b-110	417	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	11	39	49
6b-110	417	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	50	60
6b-110	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5	25	29
6b-110	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16	30	45
6b-110	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
6b-110	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5	25	29
6b-110	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	12	30	41
6b-110	430	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	42	45
6b-110	430	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	3	46	48
6b-110	430	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
6b-110	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5	25	29
6b-110	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	30	43
6b-110	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	5	44	48
6b-110	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
6b-250	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	7	25	31
6b-250	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	9	32	40
6b-250	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	41	49
6b-250	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	50	60
6b-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	4	25	28
6b-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	29	30
6b-250	320	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	5	31	35
6b-250	320	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	17	36	52

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
6b-250	320	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	8	53	60
6b-250	416	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
6b-250	416	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10	29	38
6b-250	416	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	12	39	50
6b-250	416	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	10	51	60
6b-250	417	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	4	25	28
6b-250	417	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	29	30
6b-250	417	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	8	31	38
6b-250	417	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	13	39	51
6b-250	417	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	52	60
6b-250	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	6	25	30
6b-250	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	31	44
6b-250	418	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	45	48
6b-250	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	5	49	53
6b-250	418	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	54	60
6b-250	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	4	25	28
6b-250	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	29	30
6b-250	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	4	31	34
6b-250	430	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6	35	40
6b-250	430	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10	41	50
6b-250	430	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	10	51	60
6b-250	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	6	25	30
6b-250	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	31	45
6b-250	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	3	46	48
6b-250	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
7aLJD4-110	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aLJD4-110	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	27	29
7aLJD4-110	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6	30	35
7aLJD4-110	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	36	52
7aLJD4-110	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	8	53	60
7aLJD4-110	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	3	25	27
7aLJD4-110	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	28	28
7aLJD4-110	320	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	11	29	39
7aLJD4-110	320	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	7	40	46
7aLJD4-110	320	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	14	47	60
7aLJD4-110	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aLJD4-110	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	27	41
7aLJD4-110	416	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	3	42	44
7aLJD4-110	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aLJD4-110	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-110	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	13	29	41
7aLJD4-110	417	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	42	45
7aLJD4-110	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aLJD4-110	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
7aLJD4-110	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	29	42
7aLJD4-110	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	6	43	48
7aLJD4-110	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
7aLJD4-110	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-110	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	29	43
7aLJD4-110	430	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1	44	44
7aLJD4-110	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aLJD4-110	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-110	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	11	29	39
7aLJD4-110	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	40	51
7aLJD4-110	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	52	60
7aLJD4-250	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	25	25
7aLJD4-250	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5	26	30
7aLJD4-250	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6	31	36
7aLJD4-250	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	37	52
7aLJD4-250	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	8	53	60
7aLJD4-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	3	25	27
7aLJD4-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	28	28
7aLJD4-250	320	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10	29	38
7aLJD4-250	320	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	9	39	47
7aLJD4-250	320	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	13	48	60
7aLJD4-250	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aLJD4-250	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	28	41
7aLJD4-250	416	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	42	45
7aLJD4-250	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aLJD4-250	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	3	25	27
7aLJD4-250	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	28	28
7aLJD4-250	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	13	29	41
7aLJD4-250	417	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	5	42	46
7aLJD4-250	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	14	47	60
7aLJD4-250	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-250	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	29	43
7aLJD4-250	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	4	44	47
7aLJD4-250	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	13	48	60
7aLJD4-250	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-250	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	29	43
7aLJD4-250	430	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	2	44	45
7aLJD4-250	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aLJD4-250	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aLJD4-250	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	13	29	41
7aLJD4-250	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	10	42	51
7aLJD4-250	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	52	60
7aPuDeWs-110	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuDeWs-110	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	27	29

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
7aPuDeWs-110	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	5	30	34
7aPuDeWs-110	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	19	35	53
7aPuDeWs-110	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	54	60
7aPuDeWs-110	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	2	25	26
7aPuDeWs-110	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	27	28
7aPuDeWs-110	320	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	11	29	39
7aPuDeWs-110	320	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	6	40	45
7aPuDeWs-110	320	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aPuDeWs-110	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuDeWs-110	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16	27	42
7aPuDeWs-110	416	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1	43	43
7aPuDeWs-110	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuDeWs-110	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-110	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	29	42
7aPuDeWs-110	417	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	2	43	44
7aPuDeWs-110	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aPuDeWs-110	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-110	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	13	29	41
7aPuDeWs-110	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	42	48
7aPuDeWs-110	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
7aPuDeWs-110	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-110	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	29	43
7aPuDeWs-110	430	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	1	44	44
7aPuDeWs-110	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aPuDeWs-110	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-110	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	11	29	39
7aPuDeWs-110	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	13	40	52
7aPuDeWs-110	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	8	53	60
7aPuDeWs-250	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuDeWs-250	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	27	29
7aPuDeWs-250	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6	30	35
7aPuDeWs-250	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	18	36	53
7aPuDeWs-250	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	54	60
7aPuDeWs-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	2	25	26
7aPuDeWs-250	320	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	27	28
7aPuDeWs-250	320	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	1	29	29
7aPuDeWs-250	320	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10	30	39
7aPuDeWs-250	320	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	7	40	46
7aPuDeWs-250	320	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	14	47	60
7aPuDeWs-250	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuDeWs-250	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	27	41
7aPuDeWs-250	416	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	3	42	44
7aPuDeWs-250	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aPuDeWs-250	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
7aPuDeWs-250	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	13	29	41
7aPuDeWs-250	417	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	42	45
7aPuDeWs-250	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aPuDeWs-250	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-250	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	29	42
7aPuDeWs-250	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	6	43	48
7aPuDeWs-250	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	12	49	60
7aPuDeWs-250	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-250	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16	29	44
7aPuDeWs-250	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aPuDeWs-250	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuDeWs-250	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	12	29	40
7aPuDeWs-250	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	41	51
7aPuDeWs-250	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	52	60
7aPuWsWs-110	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-110	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	28	28
7aPuWsWs-110	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	4	29	32
7aPuWsWs-110	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	23	33	55
7aPuWsWs-110	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	5	56	60
7aPuWsWs-110	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	2	25	26
7aPuWsWs-110	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	1	27	27
7aPuWsWs-110	320	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	28	41
7aPuWsWs-110	320	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	2	42	43
7aPuWsWs-110	320	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuWsWs-110	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuWsWs-110	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	27	41
7aPuWsWs-110	416	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	2	42	43
7aPuWsWs-110	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuWsWs-110	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-110	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	28	42
7aPuWsWs-110	417	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	1	43	43
7aPuWsWs-110	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuWsWs-110	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-110	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	12	28	39
7aPuWsWs-110	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	40	50
7aPuWsWs-110	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	10	51	60
7aPuWsWs-110	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-110	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	28	41
7aPuWsWs-110	430	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	5	42	46
7aPuWsWs-110	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	14	47	60
7aPuWsWs-110	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-110	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10	28	37
7aPuWsWs-110	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	38	53
7aPuWsWs-110	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	54	60

Type	Frit ID	Status of Glass Properties Predictions vs PAR Limits	N Rows	Min(WL) (%)	Max(WL) (%)
7aPuWsWs-250	202	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3	25	27
7aPuWsWs-250	202	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	28	29
7aPuWsWs-250	202	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	4	30	33
7aPuWsWs-250	202	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	21	34	54
7aPuWsWs-250	202	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	6	55	60
7aPuWsWs-250	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	2	25	26
7aPuWsWs-250	320	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	27	28
7aPuWsWs-250	320	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	12	29	40
7aPuWsWs-250	320	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4	41	44
7aPuWsWs-250	320	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	16	45	60
7aPuWsWs-250	416	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2	25	26
7aPuWsWs-250	416	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16	27	42
7aPuWsWs-250	416	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	1	43	43
7aPuWsWs-250	416	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuWsWs-250	417	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuWsWs-250	417	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	15	29	43
7aPuWsWs-250	417	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17	44	60
7aPuWsWs-250	418	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuWsWs-250	418	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	12	29	40
7aPuWsWs-250	418	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	9	41	49
7aPuWsWs-250	418	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	11	50	60
7aPuWsWs-250	430	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuWsWs-250	430	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	14	29	42
7aPuWsWs-250	430	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	3	43	45
7aPuWsWs-250	430	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	46	60
7aPuWsWs-250	432	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	4	25	28
7aPuWsWs-250	432	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10	29	38
7aPuWsWs-250	432	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	15	39	53
7aPuWsWs-250	432	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	7	54	60

Appendix D

MAR Based Assessments

Table D-1. MAR Results for Case #6b, 250-Canister Option with Select Frits

SB2-3 Case 6b 250 w Frit	% WL	Durability	T_L	Visc	Frit	Homog	Al_2O_3	alkali	T_L	Visc	ΔGp	Homog	Frit
202	30	-	-	-	-	NO	4.27	16.21	899.3	79.30	-9.695	208.60	76.21
202	31	-	-	-	-	NO	4.41	16.32	910.7	75.48	-9.781	210.32	75.48
202	32	-	-	-	-	-	4.55	16.42	921.9	71.73	-9.867	212.03	74.76
202	33	-	-	-	-	-	4.70	16.53	932.8	68.07	-9.953	213.75	74.03
202	34	-	-	-	-	-	4.84	16.64	943.4	64.50	-10.040	215.46	73.30
202	35	-	-	-	-	-	4.98	16.74	953.7	61.02	-10.126	217.18	72.58
202	36	-	-	-	-	-	5.12	16.85	963.7	57.63	-10.212	218.89	71.85
202	37	-	-	-	-	-	5.26	16.96	973.6	54.33	-10.298	220.61	71.13
202	38	-	-	-	-	-	5.41	17.06	983.2	51.13	-10.385	222.32	70.40
202	39	-	-	-	-	-	5.55	17.17	992.6	48.02	-10.471	224.04	69.67
202	40	-	-	-	-	-	5.69	17.28	1001.7	45.01	-10.557	225.76	68.95
202	41	-	-	-	-	-	5.83	17.39	1010.7	42.10	-10.643	227.47	68.22
202	42	-	NO	-	-	-	5.98	17.49	1019.5	39.29	-10.730	229.19	67.49
202	43	-	NO	-	-	-	6.12	17.60	1028.0	36.59	-10.816	230.90	66.77
202	44	-	NO	-	-	-	6.26	17.71	1036.4	33.98	-10.902	232.62	66.04
202	45	-	NO	-	-	-	6.40	17.81	1044.6	31.48	-10.989	234.33	65.31
202	46	-	NO	-	-	-	6.54	17.92	1052.6	29.09	-11.075	236.05	64.59
202	47	-	NO	-	-	-	6.69	18.03	1060.5	26.80	-11.161	237.76	63.86
418	30	-	-	-	-	NO	4.27	18.31	812.7	52.89	-11.276	210.85	77.61
418	31	-	-	-	-	-	4.41	18.39	825.6	50.31	-11.340	212.53	76.86
418	32	-	-	-	-	-	4.55	18.46	838.2	47.79	-11.403	214.21	76.12
418	33	-	-	-	-	-	4.70	18.54	850.6	45.33	-11.467	215.90	75.37
418	34	-	-	-	-	-	4.84	18.62	862.7	42.93	-11.531	217.58	74.62
418	35	-	-	-	-	-	4.98	18.69	874.5	40.59	-11.594	219.26	73.88
418	36	-	-	-	-	-	5.12	18.77	886.0	38.31	-11.658	220.95	73.13
418	37	-	-	-	-	-	5.26	18.85	897.4	36.10	-11.722	222.63	72.39
418	38	-	-	-	-	-	5.41	18.92	908.4	33.95	-11.785	224.31	71.64
418	39	-	-	-	-	-	5.55	19.00	919.3	31.87	-11.849	226.00	70.89
418	40	-	-	-	-	-	5.69	19.08	929.9	29.86	-11.913	227.68	70.15

SB2-3 Case 6b 250 w Frit	% WL	Durability	T_L	Visc	Frit	Homog	Al_2O_3	alkali	T_L	Visc	ΔGp	Homog	Frit
418	41	-	-	-	-	-	5.83	19.16	940.3	27.91	-11.976	229.36	69.40
418	42	-	-	-	-	-	5.98	19.23	950.6	26.03	-12.040	231.05	68.65
418	43	-	-	Low	-	-	6.12	19.31	960.6	24.22	-12.104	232.73	67.91
418	44	-	-	Low	-	-	6.26	19.39	970.4	22.49	-12.167	234.41	67.16
418	45	-	-	Low	-	-	6.40	19.46	980.0	20.82	-12.231	236.10	66.41
418	46	-	-	Low	-	-	6.54	19.54	989.4	19.22	-12.295	237.78	65.67
418	47	-	-	Low	-	-	6.69	19.62	998.7	17.69	-12.359	239.46	64.92
430	30	NO	-	-	-	NO	4.27	19.71	789.1	40.00	-12.570	210.85	77.61
430	31	NO	-	-	-	-	4.41	19.77	802.1	38.01	-12.615	212.53	76.86
430	32	NO	-	-	-	-	4.55	19.82	814.9	36.06	-12.660	214.21	76.12
430	33	NO	-	-	-	-	4.70	19.88	827.5	34.16	-12.705	215.90	75.37
430	34	NO	-	-	-	-	4.84	19.94	839.7	32.31	-12.750	217.58	74.62
430	35	NO	-	-	-	-	4.98	19.99	851.7	30.51	-12.796	219.26	73.88
430	36	NO	-	-	-	-	5.12	20.05	863.5	28.76	-12.841	220.95	73.13
430	37	NO	-	-	-	-	5.26	20.11	875.0	27.06	-12.886	222.63	72.39
430	38	NO	-	-	-	-	5.41	20.16	886.3	25.41	-12.931	224.31	71.64
430	39	NO	-	Low	-	-	5.55	20.22	897.4	23.82	-12.976	226.00	70.89
430	40	NO	-	Low	-	-	5.69	20.28	908.3	22.28	-13.022	227.68	70.15
430	41	NO	-	Low	-	-	5.83	20.34	919.0	20.79	-13.067	229.36	69.40
430	42	NO	-	Low	-	-	5.98	20.39	929.5	19.36	-13.112	231.05	68.65
430	43	NO	-	Low	-	-	6.12	20.45	939.8	17.98	-13.157	232.73	67.91
430	44	NO	-	Low	-	-	6.26	20.51	949.9	16.66	-13.202	234.41	67.16
430	45	NO	-	Low	-	-	6.40	20.56	959.9	15.40	-13.248	236.10	66.41
430	46	NO	-	Low	-	-	6.54	20.62	969.6	14.19	-13.293	237.78	65.67
430	47	NO	-	Low	-	-	6.69	20.68	979.2	13.04	-13.338	239.46	64.92
432	30	-	-	-	-	NO	4.27	16.91	837.9	68.93	-9.982	210.85	77.61
432	31	-	-	-	-	-	4.41	17.01	850.7	65.65	-10.065	212.53	76.86
432	32	-	-	-	-	-	4.55	17.10	863.1	62.44	-10.147	214.21	76.12
432	33	-	-	-	-	-	4.70	17.20	875.3	59.30	-10.229	215.90	75.37
432	34	-	-	-	-	-	4.84	17.30	887.1	56.23	-10.311	217.58	74.62
432	35	-	-	-	-	-	4.98	17.39	898.7	53.23	-10.393	219.26	73.88
432	36	-	-	-	-	-	5.12	17.49	910.0	50.31	-10.475	220.95	73.13

SB2-3 Case 6b 250 w Frit	% WL	Durability	T_L	Visc	Frit	Homog	Al_2O_3	alkali	T_L	Visc	ΔGp	Homog	Frit
432	37	-	-	-	-	-	5.26	17.59	921.0	47.47	-10.557	222.63	72.39
432	38	-	-	-	-	-	5.41	17.68	931.8	44.71	-10.640	224.31	71.64
432	39	-	-	-	-	-	5.55	17.78	942.4	42.03	-10.722	226.00	70.89
432	40	-	-	-	-	-	5.69	17.88	952.7	39.43	-10.804	227.68	70.15
432	41	-	-	-	-	-	5.83	17.98	962.8	36.92	-10.886	229.36	69.40
432	42	-	-	-	-	-	5.98	18.07	972.7	34.49	-10.968	231.05	68.65
432	43	-	-	-	-	-	6.12	18.17	982.4	32.14	-11.051	232.73	67.91
432	44	-	-	-	-	-	6.26	18.27	991.9	29.89	-11.133	234.41	67.16
432	45	-	-	-	-	-	6.40	18.36	1001.2	27.72	-11.215	236.10	66.41
432	46	-	-	-	-	-	6.54	18.46	1010.2	25.64	-11.297	237.78	65.67
432	47	-	NO	Low	-	-	6.69	18.56	1019.2	23.65	-11.379	239.46	64.92

Appendix E

Variation Stage Assessments

Table E.1 Variation Stage Assessment of Frit 202, Case #6b EVs

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
202	25	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	205
202	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	728
202	26	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	80
202	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	853
202	27	Durable; Not H Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5
202	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16
202	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	912
202	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	102
202	28	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	831
202	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	235
202	29	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	698
202	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	428
202	30	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	505
202	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	505
202	31	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	428
202	32	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	549
202	32	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	384
202	33	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	735
202	33	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	198
202	34	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	819
202	34	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	36
202	34	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	78
202	35	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	751
202	35	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	136
202	35	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	46
202	36	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	635
202	36	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	295
202	36	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	3
202	37	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	533
202	37	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	400
202	38	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	479
202	38	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	454
202	39	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	466
202	39	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	467
202	40	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	457
202	40	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	476
202	41	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	451
202	41	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	482
202	42	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	439
202	42	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	494
202	43	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	400
202	43	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	533
202	44	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	328
202	44	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	605
202	45	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	233
202	45	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	700
202	46	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	3
202	46	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	124
202	46	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	806
202	47	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	3
202	47	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	69
202	47	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	58
202	47	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	803
202	48	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10
202	48	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	137
202	48	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	10
202	48	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	756
202	48	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	6
202	48	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	14
202	49	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
202	49	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	203
202	49	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	674
202	49	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	3
202	49	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	52
202	50	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	401
202	50	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	445
202	50	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	87
202	51	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	585
202	51	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	236
202	51	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	112
202	52	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	655
202	52	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	140
202	52	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	138
202	53	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	698
202	53	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	59
202	53	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	176
202	54	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	678
202	54	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	6
202	54	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	249
202	55	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	646
202	55	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	287
202	56	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	616
202	56	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	317
202	57	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	556
202	57	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	377
202	58	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	533
202	58	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	400
202	59	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	521
202	59	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	412
202	60	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	510
202	60	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	423

N Rows	N Rows 2	% of Total
7	1	0.10718114
8	48	5.14469453
9	88	9.43193998
10	79	8.46730975
11	114	12.2186495
12	78	8.36012862
13	47	5.0375134
14	13	1.39335477
15	11	1.1789925
16	9	0.96463023
17	8	0.85744909
18	40	4.28724544
19	69	7.39549839
20	95	10.1822079
21	109	11.6827438
22	66	7.07395498
23	48	5.14469453
24	10	1.07181136

Table E.2 Variation Stage Assessment of Frit 320, Case #6b EVs.

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
320	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	110
320	25	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	823
320	26	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	4
320	26	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	31
320	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	9
320	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	73
320	26	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	1
320	26	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	491
320	26	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	324
320	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	3
320	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	91
320	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	2
320	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	25
320	27	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	11
320	27	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	9
320	27	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	456
320	27	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	336
320	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	118
320	28	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	5
320	28	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	158
320	28	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	43
320	28	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	287
320	28	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	322
320	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	127
320	29	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	244
320	29	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	69
320	29	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	179
320	29	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	314
320	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	132
320	30	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	269
320	30	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	124
320	30	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	129
320	30	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	279
320	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	135
320	31	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	272
320	31	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	200
320	31	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	102
320	31	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	224
320	32	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	136
320	32	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	679
320	32	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	118
320	33	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	137
320	33	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	22
320	33	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	708
320	33	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	66
320	34	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	141
320	34	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	118
320	34	Not Durable; Not L Visc; ; Not Homo; New TL ; Al2O3 ; alkali	2
320	34	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	640
320	34	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	32
320	35	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	145
320	35	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	214
320	35	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	574
320	36	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	147
320	36	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	467
320	36	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	319
320	37	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
320	37	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	149
320	37	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	674
320	37	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	109

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
320	38	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	41
320	38	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	112
320	38	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	723
320	38	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	57
320	39	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	138
320	39	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	19
320	39	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	735
320	39	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	41
320	40	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	162
320	40	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	765
320	40	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6
320	41	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	165
320	41	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	768
320	42	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	168
320	42	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	765
320	43	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	171
320	43	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	762
320	44	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	170
320	44	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	2
320	44	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	761
320	45	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	136
320	45	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	39
320	45	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	758
320	46	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	66
320	46	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	109
320	46	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	734
320	46	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	24
320	47	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	16
320	47	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	164
320	47	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	633
320	47	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	120
320	48	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	2
320	48	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	178
320	48	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	546
320	48	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	207
320	49	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	180
320	49	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	486
320	49	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	267
320	50	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	183
320	50	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	470
320	50	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	280
320	51	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	186
320	51	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	459
320	51	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	288
320	52	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	187
320	52	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	454
320	52	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	292
320	53	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	189
320	53	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	444
320	53	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	300
320	54	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	192
320	54	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	418
320	54	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	323
320	55	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	192
320	55	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	364
320	55	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	377
320	56	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	194
320	56	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	265
320	56	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	474
320	57	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	195
320	57	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	167
320	57	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	571

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
320	58	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	195
320	58	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	80
320	58	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	658
320	59	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	195
320	59	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	38
320	59	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	700
320	60	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	196
320	60	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10
320	60	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	727

N Rows	N Rows 2	% of Total
0	780	83.6012862
1	3	0.32154341
2	4	0.42872454
3	4	0.42872454
4	3	0.32154341
5	2	0.21436227
6	1	0.10718114
7	2	0.21436227
8	1	0.10718114
9	6	0.64308682
10	7	0.75026795
11	7	0.75026795
12	22	2.35798499
13	82	8.78885316
14	9	0.96463023

Table E.3 Variation Stage Assessment of Frit 418, Case #6b EVs.

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
418	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	933
418	26	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	36
418	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	897
418	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	114
418	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	819
418	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	319
418	28	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	614
418	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	440
418	29	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	493
418	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	525
418	30	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	408
418	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	607
418	31	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	326
418	32	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	815
418	32	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	118
418	33	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	867
418	33	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	66
418	34	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	899
418	34	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	34
418	35	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	933
418	36	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	906
418	36	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	27
418	37	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	865
418	37	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	68
418	38	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	835
418	38	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	98
418	39	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	811
418	39	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	122
418	40	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	777
418	40	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	1
418	40	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	155
418	41	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
418	41	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	668
418	41	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	38
418	41	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	226
418	42	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
418	42	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	521
418	42	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	134
418	42	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	60
418	42	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	217
418	43	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	16
418	43	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	331
418	43	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	285
418	43	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	142
418	43	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	159
418	44	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	52
418	44	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	5
418	44	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	134
418	44	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	383
418	44	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	193
418	44	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	166
418	45	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	44
418	45	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	49
418	45	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	44
418	45	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	400
418	45	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	390
418	45	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6
418	46	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	38
418	46	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	250
418	46	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	23

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
418	46	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	215
418	46	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	407
418	47	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	34
418	47	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	338
418	47	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6
418	47	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	136
418	47	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	419
418	48	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	29
418	48	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	421
418	48	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	59
418	48	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	424
418	49	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	19
418	49	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	480
418	49	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	6
418	49	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	427
418	49	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	1
418	50	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	5
418	50	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	493
418	50	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	413
418	50	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	22
418	51	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	494
418	51	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	365
418	51	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	74
418	52	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	492
418	52	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	266
418	52	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	175
418	53	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	486
418	53	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	166
418	53	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	281
418	54	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	483
418	54	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	85
418	54	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	365
418	55	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	482
418	55	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	38
418	55	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	413
418	56	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	477
418	56	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10
418	56	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	446
418	57	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	474
418	57	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
418	57	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	458
418	58	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	472
418	58	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	461
418	59	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	470
418	59	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	463
418	60	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	467
418	60	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	466

N Rows	N Rows 2	% of Total
11	27	2.89389068
12	41	4.39442658
13	30	3.21543408
14	24	2.57234727
15	34	3.64415863
16	109	11.6827438
17	147	15.755627
18	190	20.3644159
19	197	21.1146838
20	90	9.64630225
21	21	2.25080386
22	17	1.82207931

Table E.4 Variation Stage Assessment of Frit 430, Case #6b EVs.

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
430	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	180
430	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	472
430	25	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	281
430	26	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	36
430	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	15
430	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	565
430	26	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	204
430	26	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	113
430	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	114
430	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	17
430	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	419
430	27	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	183
430	27	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	200
430	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	21
430	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	298
430	28	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	208
430	28	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	172
430	28	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	234
430	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	24
430	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	408
430	29	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	80
430	29	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	4
430	29	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	4
430	29	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	157
430	29	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	256
430	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	26
430	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	447
430	30	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	36
430	30	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	26
430	30	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	26
430	30	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	127
430	30	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	245
430	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	30
430	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	447
430	31	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	24
430	31	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; Not alkali	44
430	31	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	86
430	31	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; Not alkali	102
430	31	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	200
430	32	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	489
430	32	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	6
430	32	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	326
430	32	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	112
430	33	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	493
430	33	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	374
430	33	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	66
430	34	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	487
430	34	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	412
430	34	Not Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	34
430	35	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	483
430	35	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	450
430	36	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	482
430	36	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	451
430	37	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	477
430	37	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
430	37	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	455
430	38	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	473
430	38	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	61
430	38	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	399
430	39	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
430	39	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	462
430	39	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	150
430	39	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	311
430	40	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	34
430	40	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	436
430	40	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	224
430	40	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	239
430	41	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	68
430	41	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	398
430	41	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	421
430	41	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	46
430	42	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	250
430	42	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	212
430	42	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	448
430	42	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	23
430	43	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	302
430	43	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	25
430	43	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	120
430	43	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	12
430	43	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	468
430	43	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	6
430	44	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	292
430	44	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	119
430	44	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	43
430	44	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	5
430	44	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	474
430	45	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	180
430	45	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	273
430	45	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	3
430	45	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	477
430	46	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	70
430	46	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	383
430	46	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	480
430	47	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	10
430	47	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	439
430	47	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	478
430	47	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	6
430	48	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	446
430	48	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	470
430	48	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	17
430	49	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	444
430	49	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	459
430	49	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	30
430	50	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	444
430	50	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	454
430	50	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	35
430	51	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	442
430	51	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	447
430	51	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	44
430	52	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	439
430	52	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	422
430	52	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	72
430	53	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	436
430	53	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	370
430	53	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	127
430	54	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	432
430	54	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	274
430	54	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	227
430	55	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	430
430	55	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	170
430	55	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	333
430	56	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	429

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
430	56	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	88
430	56	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	416
430	57	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	428
430	57	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	44
430	57	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	461
430	58	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	428
430	58	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	11
430	58	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	494
430	59	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	426
430	59	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	1
430	59	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	506
430	60	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	424
430	60	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	509

N Rows	N Rows 2	% of Total
0	318	34.0836013
1	65	6.96677385
2	23	2.46516613
3	15	1.60771704
4	3	0.32154341
5	8	0.85744909
6	7	0.75026795
7	2	0.21436227
8	5	0.53590568
9	6	0.64308682
10	4	0.42872454
11	5	0.53590568
12	5	0.53590568
13	4	0.42872454
14	3	0.32154341
15	24	2.57234727
16	38	4.07288317
17	186	19.9356913
18	92	9.86066452
19	77	8.25294748
20	40	4.28724544
21	3	0.32154341

Table E.5 Variation Stage Assessment of Frit 432, Case #6b, EVs.

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
432	25	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	933
432	26	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	36
432	26	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	897
432	27	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	114
432	27	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	819
432	28	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	319
432	28	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	614
432	29	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	440
432	29	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	493
432	30	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	525
432	30	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	408
432	31	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	607
432	31	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	326
432	32	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	815
432	32	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	118
432	33	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	867
432	33	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	66
432	34	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	899
432	34	Durable; Visc; ; Not Homo; New TL ; Al2O3 ; alkali	34
432	35	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	933
432	36	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	933
432	37	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	933
432	38	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	931
432	38	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	2
432	39	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	882
432	39	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	51
432	40	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	767
432	40	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	166
432	41	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	622
432	41	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	311
432	42	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	527
432	42	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	406
432	43	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	477
432	43	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	456
432	44	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	465
432	44	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	468
432	45	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	20
432	45	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	437
432	45	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	476
432	46	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	102
432	46	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	6
432	46	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	334
432	46	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	475
432	46	Not Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	16
432	47	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	116
432	47	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	26
432	47	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	274
432	47	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	467
432	47	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	50
432	48	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	215
432	48	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	81
432	48	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	105
432	48	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	448
432	48	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	84
432	49	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	225
432	49	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	256
432	49	Durable; Visc; ; Homo; New TL ; Al2O3 ; alkali	8
432	49	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	332
432	49	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	112
432	50	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	125

Frit ID	Sludge Loading (%)	Status of Glass Properties Predictions vs PAR Limits	N Rows
432	50	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	469
432	50	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	206
432	50	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	114
432	50	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	19
432	51	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	43
432	51	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	618
432	51	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	101
432	51	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	101
432	51	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	70
432	52	Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	4
432	52	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	655
432	52	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	30
432	52	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	65
432	52	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	179
432	53	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	647
432	53	Durable; Visc; ; Homo; Not New TL; Al2O3 ; alkali	1
432	53	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	28
432	53	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	257
432	54	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	623
432	54	Not Durable; Not L Visc; ; Homo; New TL ; Al2O3 ; alkali	6
432	54	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	304
432	55	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	563
432	55	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	370
432	56	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	535
432	56	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	398
432	57	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	523
432	57	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	410
432	58	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	511
432	58	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	422
432	59	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	509
432	59	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	424
432	60	Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	503
432	60	Not Durable; Not L Visc; ; Homo; Not New TL; Al2O3 ; alkali	430

N Rows	N Rows 2	% of Total
13	2	0.21436227
14	49	5.25187567
15	115	12.3258307
16	145	15.5412647
17	95	10.1822079
18	50	5.35905681
19	12	1.28617363
20	28	3.00107181
21	103	11.039657
22	60	6.43086817
23	169	18.113612
24	97	10.3965702
25	8	0.85744909