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**FRIT DEVELOPMENT EFFORTS FOR SLUDGE  
BATCH 4 (SB4): OPERATING WINDOW  
ASSESSMENTS OF SCENARIOS LEADING UP TO  
THE SELECTED PREPARATION PLAN FOR SB4**

D.K. Peeler  
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January 2006

Process Science and Engineering Section  
Savannah River National Laboratory  
Aiken, SC 29808

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Prepared for the U.S. Department of Energy Under Contract Number  
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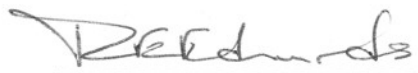
  
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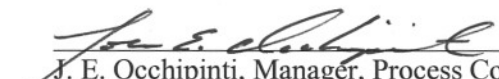
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## **EXECUTIVE SUMMARY**

The objective of this report is to document technical information that has been provided to Defense Waste Processing Facility (DWPF) and Closure Business Unit (CBU) personnel as part of the frit development support for Sludge Batch 4 (SB4). The information presented in this report includes projected operating windows (expressed in terms of waste loading) for various sludge blending and/or washing options coupled with candidate frits of interest. Although the Nominal Stage assessment serves as the primary tool for these evaluations, select systems were also evaluated using a Variation Stage assessment in which compositional variations were introduced. In addition, assessments of the impacts of nepheline formation potential and the  $\text{SO}_4^{=}$  solubility limit on the projected operating windows are also provided.

Although this information was used as part of the technical basis leading to CBU's development of the preferred SB4 preparation plan, none of the options presented in this report was selected as the preferred plan. Therefore, the information is presented without significant interpretation of the resulting operating windows, but the projected windows are provided so additional insight can be explored if desired. Detailed assessments of the projected operating windows (using both Nominal and Variation Stage assessments) of the preferred sludge preparation plan with candidate frits are to be documented elsewhere.

The information provided in this report is focused solely on model-based projections of the operating windows for various SB4 blending strategies of interest. Although nepheline formation potential is monitored via model predictions as a part of this assessment, experimental work investigating the impact of nepheline on glass quality is also being addressed in a parallel study. The results of this paper study and the experimental assessments of melt rate,  $\text{SO}_4$  solubility, and/or nepheline formation potential are all critical components of the inputs into the frit selection process for SB4.

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## LIST OF ACRONYMS

ARP	Actinide Removal Process
CBU	Closure Business Unit
CPC	Chemical Process Cell
DWPF	Defense Waste Processing Facility
EV	Extreme Vertices
$\Delta G_p$	preliminary glass dissolution estimator
HLW	High Level Waste
MAR	Measurement Acceptability Region
MCU	Modular Caustic Side Solvent Extraction Unit
PCCS	Product Composition Control System
PCT	Product Consistency Test
SB	sludge batch
SRNL	Savannah River National Laboratory
$T_L$	liquidus temperature
$\eta$	viscosity
WL	waste loading

## 1.0 INTRODUCTION

A preferred sludge preparation plan for the next sludge batch (Sludge Batch 4, SB4) of high-level waste (HLW) to be processed at the Savannah River Site's Defense Waste Processing Facility (DWPF) has been identified by the Closure Business Unit (CBU).<sup>1</sup> A progression of various blending and washing strategies was evaluated by the CBU as it made its decision on the SB4 preparation plan (Shah 2006). The Savannah River National Laboratory (SRNL) provided technical assessment support to the CBU during this process. This support included assessments of candidate SB4 projected compositions that were conducted by SRNL's frit development team. SRNL was asked to provide support for SB4 via a technical task request (Washburn 2004), and SRNL responded to the request by issuing a task technical and quality assurance plan (Peeler 2004) under whose auspices this report was prepared. The purpose of this report is to document the most recent assessments that were completed by the frit development team of SB4 options leading up to the preferred sludge preparation plan. The assessments were strictly paper studies driven by predictions from glass property/glass composition models most of which are currently used by DWPF to control its process and the quality (i.e., the durability) of its final product — no experimental work was conducted to support the assessments documented in this report.

Objectives of the SB4 frit development task are specified in Section 2.0. The set of projected SB4 nominal compositions for which assessments were conducted is provided in Section 3.0. Also discussed in Section 3.0 are the candidate frits and the strategy behind their use. Section 4.0 provides a brief overview of how sludge/frit glass systems are assessed. There are two stages to the assessment: a Nominal Stage (a screening tool applied to a large set of candidate frits) and a Variation Stage (a more thorough assessment applied to select sludge/frit systems). Both assessments use the same criteria to make acceptability decisions that lead to a projected operating window (an interval of waste loading over which all the criteria are simultaneously satisfied) that may be achieved for a specific sludge/frit glass system. Section 5.0 summarizes the results of the assessments conducted for the various SB4 options. Issues associated with a  $\text{SO}_4^{=}$  limit are also discussed in Section 5.0 with respect to how the limit may influence acceptable waste loading (WL) intervals. Section 6.0 provides a summary of this work that supported the CBU's decisions that led to the preferred SB4 preparation plan.

## 2.0 OBJECTIVE

SRNL has developed, and continues to enhance, its integrated capability to evaluate the impact of proposed sludge flowsheets on DWPF's operation for the CBU. The components of this support include frit development, Chemical Process Cell (CPC) flowsheet development, and melt rate assessment.

The objective of frit development is to identify a viable frit or frits for each sludge preparation option being contemplated. A frit is considered viable if its composition allows for economic fabrication and if, when it is combined with the sludge option under consideration, DWPF's property/composition models indicate that the combination has the potential for an operating window (a waste loading interval over which the sludge/frit glass system satisfies processability and durability constraints) that would allow DWPF to meet its goals for waste loading and canister production rate.

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<sup>1</sup> Due to tank settling and washing issues, the strategy outlined by the CBU has evolved into the definition of a sludge preparation plan for the tanks proposed for SB4 which now involves preparation as SB4 and Sludge Batch 5 (SB5). Typically, four options were provided for each candidate preparation plan, which included Batch 1, Blend 1, Batch 2, and Blend 2. "Batches" refer to projected sludge compositions (prior to blending) that would be qualified. "Blends" refer to projected sludge compositions (after blending with the heel of the previous sludge batch) that would be processed in DWPF. For simplicity purposes in this report, the authors will refer to SB4 only in the discussions that follow given none of the cases defines the preferred preparation plan.

The objective of this report is to document the results of SRNL's efforts to identify candidate frit compositions and corresponding predicted operating windows for various SB4 sludge preparation plan options that CBU entertained (Shah 2006) on its way to finalizing the SB4 preparation plan. The information provided in this report is a summary of and is limited to the model-based projections of operating windows that were provided to CBU for the candidate sludge preparation plans. Although this information was used as part of the technical basis from which the preferred SB4 preparation plan was selected, none of the options presented in this report is the preferred plan. Therefore the information is presented without significant interpretation but the details are provided so additional insight can be made if desired. Details regarding the evaluation of the preferred plan are provided by Peeler and Edwards (2006).

### **3.0 A PROGRESSION OF SB4 COMPOSITIONAL SCENARIOS**

The compositional scenarios under consideration for SB4 progressed to the point that some of the preparation plans developed by CBU involved up to two transfers to (or blends in) Tank 40 from Tank 51 and the qualification of two different batches of material in Tank 51 (Shah 2006). In the text that follows, the term "batch" refers to a projected nominal sludge composition that would be qualified (prior to blending with the heel of the previous sludge batch). The term "blend" refers to a projected nominal sludge composition of a blended sludge that would be processed in DWPF. The dual batches and/or blends are indicated by batch or blend number within a particular scenario in the discussion that follows. Frit assessments were conducted for three sets of SB4 scenarios. In this section, the nominal compositions defining each scenario are presented. The set of candidate frits that was used in the assessment of each of the sludge compositions is also presented in this section.

#### **3.1 Projected SB4 Compositions**

Shah (2006) provided the projected elemental compositions for the various sludge preparation options. To support the model based assessments, elemental concentrations were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide.  $\text{SO}_4^{=}$  concentrations were not provided by Shah (2006). However, CBU personnel did provide information as part of the washing scenarios and preparations plans that was used to derive estimates for the  $\text{SO}_4^{=}$  concentrations. These concentrations were added to the oxide list and the resulting oxide concentrations were then normalized to 100%. Tables 3-1 (Set 1) and 3-2 (Sets 2 and 3, which are revisions of the Set 1 projections based upon different mass limits for hydrogen generation and washing endpoints, respectively) provide the oxide compositions (in weight percent, wt%) of the SB4 scenarios being considered in this report. A Case 15C was also included as part of Set 3 and represents an iteration of Case 15B and Case 15 with mass adjustments for hydrogen retention and less washing, respectively. However, this case was selected as the preferred sludge preparation plan for SB4, and its evaluation is the subject of a separate report (Peeler and Edwards 2006). It should be noted that the projected sludge compositions presented in Tables 3-1 and 3-2 are sludge-only flowsheets and do not account for any potential secondary streams from the Actinide Removal Process (ARP) or the Modular Caustic Side Solvent Extraction Unit (MCU). The assessment of the preferred SB4 preparation plan, which is addressed in a separate document (Peeler and Edwards 2006), will include evaluations of the impact of auxiliary ARP streams. Based upon the results presented by Peeler et al. (2005a), the addition of a MCU stream is not expected to have an impact on the projected operating windows for SB4. As seen in Table 3-1 and 3-2, the projected sludge compositions are relatively high in  $\text{Al}_2\text{O}_3$ ,  $\text{Na}_2\text{O}$ , and  $\text{SO}_4^{=}$  and relatively low in  $\text{Fe}_2\text{O}_3$  (as compared to previous sludges processed in DWPF). In addition, the  $\text{SiO}_2$  content of the projected sludges typically ranges from 3 to 6.5 wt%, which is at higher concentrations than previous sludge batches (which were normally in the 1 – 2 wt% range).

**Table 3-1. Set 1 of SB4 Scenarios**

Oxide	Case 8 and 8A	Case 8	Case 8a	Case 7	Case 7	Case 7	Case 7	Case 15B	Case 15B	Case 15B	Case 15B	Case 16	Case 16	Case 16	Case 16
	Batch 1	Blend 1	Blend 1	Batch 1	Blend 1	Batch 2	Blend 2	Batch 1	Blend 1	Batch 2	Blend 2	Batch 1	Blend 1	Batch 2	Blend 2
Al <sub>2</sub> O <sub>3</sub>	28.765	23.017	25.706	31.877	18.764	33.940	30.842	41.321	19.092	32.634	29.940	6.364	14.104	37.481	31.658
BaO	0.151	0.148	0.149	0.132	0.143	0.141	0.140	0.091	0.138	0.145	0.143	0.219	0.172	0.113	0.127
CaO	1.679	2.161	1.923	1.622	2.593	1.726	1.887	1.550	2.665	1.726	1.896	2.184	2.903	1.517	1.847
Ce <sub>2</sub> O <sub>3</sub>	0.065	0.135	0.101	0.046	0.195	0.049	0.077	0.000	0.200	0.054	0.082	0.181	0.240	0.018	0.071
Cr <sub>2</sub> O <sub>3</sub>	0.217	0.222	0.219	0.204	0.225	0.217	0.218	0.179	0.223	0.219	0.219	0.266	0.254	0.191	0.206
CuO	0.035	0.059	0.047	0.025	0.079	0.026	0.037	0.000	0.080	0.029	0.039	0.096	0.101	0.010	0.032
Fe <sub>2</sub> O <sub>3</sub>	20.259	25.104	22.702	19.006	29.317	20.236	21.908	16.687	29.840	20.407	22.102	27.013	33.187	17.409	21.163
K <sub>2</sub> O	0.415	0.327	0.368	0.455	0.261	0.484	0.439	0.578	0.263	0.467	0.427	0.167	0.211	0.520	0.443
La <sub>2</sub> O <sub>3</sub>	0.095	0.102	0.098	0.095	0.109	0.102	0.103	0.101	0.111	0.100	0.102	0.092	0.115	0.097	0.101
MgO	1.473	2.305	1.899	1.250	3.013	1.331	1.651	0.739	3.085	1.385	1.700	3.484	3.737	0.797	1.507
MnO	5.152	5.712	5.426	4.652	6.142	4.953	5.162	3.589	6.105	5.054	5.231	8.285	7.384	3.910	4.737
Na <sub>2</sub> O	23.608	23.265	23.665	24.609	22.621	19.992	20.859	22.621	22.146	20.463	21.116	31.079	19.255	22.907	22.340
NiO	3.925	3.008	3.439	3.145	2.044	3.349	3.081	1.298	1.667	3.552	3.181	5.075	2.601	2.668	2.641
PbO	0.036	0.080	0.058	0.025	0.117	0.027	0.044	0.000	0.121	0.030	0.047	0.110	0.145	0.008	0.041
SO <sub>4</sub> <sup>=</sup>	1.121	1.138	1.124	0.965	1.124	0.766	0.833	1.649	1.246	0.867	0.934	0.302	0.725	1.174	1.060
SiO <sub>2</sub>	4.250	3.738	3.972	4.656	3.400	4.958	4.633	5.913	3.485	4.781	4.517	1.779	2.962	5.305	4.715
ThO <sub>2</sub>	0.075	0.058	0.066	0.087	0.045	0.093	0.083	0.121	0.047	0.088	0.080	0.000	0.028	0.106	0.087
TiO <sub>2</sub>	0.244	0.155	0.197	0.180	0.062	0.191	0.165	0.023	0.028	0.209	0.174	0.490	0.134	0.111	0.116
U <sub>3</sub> O <sub>8</sub>	8.140	8.919	8.518	6.709	9.360	7.143	7.541	3.359	9.073	7.506	7.770	12.324	11.277	5.446	6.837
ZnO	0.058	0.097	0.078	0.041	0.129	0.044	0.060	0.000	0.131	0.048	0.064	0.163	0.166	0.015	0.052
ZrO <sub>2</sub>	0.237	0.249	0.243	0.219	0.257	0.233	0.237	0.182	0.255	0.236	0.239	0.327	0.299	0.197	0.221
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

**Table 3-2. Sets 2 and 3 of SB4 Scenarios**

Oxide	Set 2	Set 2	Set 2	Set 2	Set 3	Set 3	Set 3	Set 3
	Case 15	Case 15	Case 15	Case 15	Case 7b	Case 7b	Case 7b	Case 7b
	Batch 1	Blend 1	Batch 2	Blend 2	Batch 1	Blend 1	Batch 2	Blend 2
Al <sub>2</sub> O <sub>3</sub>	44.265	25.362	28.491	27.705	30.874	20.810	32.933	30.114
BaO	0.097	0.129	0.149	0.144	0.128	0.140	0.136	0.136
CaO	1.660	2.441	1.663	1.814	1.571	2.396	1.675	1.825
Ce <sub>2</sub> O <sub>3</sub>	0.000	0.153	0.064	0.082	0.045	0.167	0.048	0.074
Cr <sub>2</sub> O <sub>3</sub>	0.192	0.217	0.215	0.215	0.197	0.219	0.211	0.211
CuO	0.000	0.061	0.035	0.040	0.024	0.069	0.026	0.035
Fe <sub>2</sub> O <sub>3</sub>	17.876	27.162	20.066	21.421	18.408	27.203	19.635	21.198
K <sub>2</sub> O	0.619	0.352	0.411	0.397	0.441	0.291	0.470	0.428
La <sub>2</sub> O <sub>3</sub>	0.108	0.111	0.094	0.097	0.092	0.105	0.099	0.100
MgO	0.791	2.551	1.458	1.675	1.211	2.675	1.291	1.588
MnO	3.845	5.603	5.103	5.180	4.506	5.814	4.806	5.003
Na <sub>2</sub> O	17.610	20.489	24.775	24.274	26.766	23.771	22.175	22.912
NiO	1.390	1.612	3.888	3.401	3.046	2.211	3.250	3.006
PbO	0.000	0.093	0.035	0.047	0.025	0.100	0.026	0.042
SO <sub>4</sub> <sup>=</sup>	1.264	1.210	0.671	0.778	1.149	1.161	0.933	0.975
SiO <sub>2</sub>	6.335	4.205	4.209	4.187	4.510	3.578	4.810	4.517
ThO <sub>2</sub>	0.130	0.067	0.075	0.073	0.084	0.052	0.090	0.081
TiO <sub>2</sub>	0.025	0.027	0.242	0.197	0.174	0.081	0.186	0.162
U <sub>3</sub> O <sub>8</sub>	3.599	7.812	8.063	7.971	6.498	8.796	6.931	7.306
ZnO	0.000	0.100	0.057	0.066	0.040	0.113	0.042	0.058
ZrO <sub>2</sub>	0.195	0.242	0.235	0.235	0.212	0.248	0.226	0.230
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

### 3.2 Candidate Frit Compositions

Table 3-3 provides the list of candidate frits and nominal compositions (weight % basis) considered in this assessment. A closer review of frits X1-1 through 422 (shaded in Table 3-3) indicates fixed concentrations of B<sub>2</sub>O<sub>3</sub> and Li<sub>2</sub>O at 8 wt% with only the Na<sub>2</sub>O and SiO<sub>2</sub> concentrations varying. In general, these frit compositions increase in Na<sub>2</sub>O by 1% and decrease respectively in SiO<sub>2</sub> proceeding from Frit X1-1 (the most refractory frit being considered) to Frit 422. This system has been referred to as a “sliding Na<sub>2</sub>O scale” concept which was developed to accommodate potential Na<sub>2</sub>O concentration differences in the sludge as a result of varying blending and/or washing strategies being considered (see Peeler and Edwards 2002 and 2005 for more details).

Frits 202 and 200 are historical frits that were developed to support both the coupled and sludge-only flowsheets. They are being carried forward in this assessment to provide insight into their potential use with the SB4 options. The “P-series” of frits have been developed to minimize the potential for nepheline formation given its impact on durability (Peeler et al. (2005b and 2006)). In general, these frits have lower Na<sub>2</sub>O than the “sliding scale series” with the difference being accounted for by an increase in Li<sub>2</sub>O and/or Fe<sub>2</sub>O<sub>3</sub>. Fe<sub>2</sub>O<sub>3</sub> was added as a “filler” given its inert effects on nepheline formation and its potentially advantageous effects on viscosity and/or melt rate.

**Table 3-3. Composition of Candidate Frits (oxide wt%)**

Frit	B <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	Li <sub>2</sub> O	MgO	Na <sub>2</sub> O	SiO <sub>2</sub>
X1-1	8	0	8	0	15	69
Y1-1	8	0	8	0	14	70
431	8	0	8	0	13	71
320	8	0	8	0	12	72
417	8	0	8	0	11	73
425	8	0	8	0	10	74
426	8	0	8	0	9	75
418	8	0	8	0	8	76
460	8	0	8	0	7	77
432	8	0	8	0	6	78
473	8	0	8	0	5	79
d1-1	8	0	8	0	4	80
422	8	0	8	0	3	81
202	8	0	7	2	6	77
200	12	0	5	2	11	70
P1-1	8	4	8	0	5	75
P2-1	8	4	10	0	5	73
P2-2	8	5	11	0	5	71
P2-3	8	3	10	0	6	73
P2-4	8	5	11	0	6	70
P2-5	8	5	10	0	7	70

## 4.0 THE APPROACH AND CRITERIA FOR ACCEPTABILITY

As stated in Section 2.0, the assessments conducted as part of this effort were strictly paper studies that were driven by predictions from glass property/glass composition models. However, the assessments do provide meaningful insight into the viability of sludge/frit glass systems since the models used in the assessment are the same as the models anticipated to be in DWPF's Product Composition Control System (PCCS) during the processing of SB4. The major property models included those for liquidus temperature ( $T_L$ ), viscosity ( $\eta$ ), and durability (as defined by the Product Consistency Test [PCT] [ASTM 2002] response in terms of the preliminary glass dissolution estimator ( $\Delta G_p$ ) (Jantzen et al. 1995)). It should be noted that the proposed durability limits by Edwards et al. (2003) and the new viscosity model developed by Jantzen (2005) were used in this assessment.<sup>2</sup> Jantzen et al. (1995) and Brown et al. (2001) provide more details on the development of the PCCS models. In addition, the potential for the formation of a nepheline primary crystalline phase was also included in the assessment using a nepheline discriminator function described by Li et al. (2003).<sup>3</sup> The nepheline discriminator model is currently not part of PCCS. However, based on recent experimental results (Peeler et al. 2005b and 2006), a strategy for controlling or limiting access to higher WLs in which nepheline formation can lead to detrimental effects on durability must be developed. Options for mitigating this potential include (but are not limited to) the implementation of the nepheline discriminator into PCCS or the use of an administrative control limit based on a fixed nepheline formation value.

There are two stages of investigation that may be used in the assessment of a candidate sludge: a Nominal Stage (a screening tool for the sludge that is typically applied to a large set of candidate frits such as that provided in Table 3-3) and a Variation Stage (a more thorough assessment of the sludge conducted for a select set of frits). These are discussed in Sections 4.2 and 4.3, respectively. For either stage, glass compositions were generated to represent combinations of the sludge/frit at waste loadings of interest. The acceptability of the model predictions for a particular glass composition for either stage was judged by employing the same criteria that are used by PCCS in its Measurement Acceptability Region (MAR) evaluations. Acceptable predicted properties for this assessment were based on satisfying their respective MAR limits. Brown, Postles, and Edwards (2002) provide a detailed discussion of how the MAR limits are utilized in PCCS. Thus, the value of the frit development effort in its assessment of a glass composition is that it mirrors the results that would be generated by the PCCS MAR for the same glass.

### 4.1 $\text{SO}_4^{=}$ Limitation

In the MAR assessments of the sludge compositions that follow (both Nominal and Variation Stages), the  $\text{SO}_4^{=}$  concentrations in glass will be calculated, but an assumed  $\text{SO}_4^{=}$  limit will not be used to restrict the projected operating windows. Given there is no MAR

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<sup>2</sup> It is assumed that the new durability limits and the new viscosity model will be implemented in DWPF to support SB4 processing. The durability limits remove excess conservatism in the current model without compromising product quality and provide access into higher alkali compositional regions which may improve melt rate and/or waste loading. The modifications to implement the new viscosity model in PCCS are described by Edwards and Peeler in the memorandum SRNL-SCS-2005-00054.

<sup>3</sup> Li et al. (2003) indicate that sodium aluminoborosilicate glasses are prone to nepheline crystallization if their compositions projected on the  $\text{Na}_2\text{O}-\text{Al}_2\text{O}_3-\text{SiO}_2$  ternary fall within the nepheline primary phase field. In particular, durable glasses with  $\text{SiO}_2/(\text{SiO}_2+\text{Na}_2\text{O}+\text{Al}_2\text{O}_3) > 0.62$ , where the oxides are expressed as mass fractions in the glass, do not precipitate nepheline as their primary phase.

uncertainty associated with the  $\text{SO}_4^{=}$  concentration, the maximum WL for each SB4 option can be determined as a function of an assumed  $\text{SO}_4^{=}$  solubility limit based strictly on mathematics (i.e., the assumed  $\text{SO}_4^{=}$  solubility limit divided by the  $\text{SO}_4^{=}$  concentration in sludge times 100). For example, if the  $\text{SO}_4^{=}$  concentration in sludge was 1.121 wt% (as it is for Case 8 and 8a Batch 1— see Table 3-1) and the assumed  $\text{SO}_4^{=}$  solubility limit was 0.4 wt% (in glass), then the maximum WL achievable (based strictly on the  $\text{SO}_4^{=}$  solubility limit) would be ~35.7 wt%. If the  $\text{SO}_4^{=}$  solubility limit were 0.5 wt% or 0.6 wt%, then the maximum achievable WLs (based strictly on the  $\text{SO}_4^{=}$  solubility limit) for this case would be 44.6% and 53.5%, respectively. Although one can easily calculate the maximum WL for a given  $\text{SO}_4^{=}$  solubility limit, properties other than  $\text{SO}_4^{=}$  solubility may restrict the upper WL prior to the assumed  $\text{SO}_4^{=}$  limit – especially when a 0.6 wt% limit is assumed which Lorier et al. (2005) have suggested was feasible for SB4 glasses. Although a nominal  $\text{SO}_4^{=}$  value has been added to each sludge option, an assumed  $\text{SO}_4^{=}$  solubility limit in PCCS was not activated during the model-based assessment. However, an assessment of the  $\text{SO}_4^{=}$  limit and its potential impact on the upper WL attainable for select options is provided in Section 5.1.

## 4.2 Overview of Nominal Assessment

In general, the Nominal Stage evaluation provides a quick assessment of the viability of a particular sludge option relative to a potentially large set of candidate frits. Only the nominal composition of the sludge is used in this stage of the evaluation — no sludge variation is accounted for in this phase. Glass compositions are generated for a sludge/frit system at waste loadings of 25 to 60% in increments of 1 percentage point. This leads to the generation of 36 glass compositions for each sludge/frit combination. Each of these glasses is evaluated against the PCCS MAR and its acceptability is determined. The resulting evaluation identifies a sub-interval within the 25 to 60% interval of WLs that defines the projected operating window in WL-space for the sludge/frit glass system. The evaluation also identifies the property model (e.g., viscosity or  $T_L$ ) that limits the operating window when the window is restricted at either or both ends of the 25 to 60% interval. The Nominal Stage evaluation combined each of the nominal sludge options of Tables 3-1 and 3-2 with each frit (listed in Table 3-3) at WLs from 25 through 60% (in increments of 1 wt%). The results from this assessment (i.e., the operating windows for each of these glass systems) are provided in Section 5.2.

## 4.3 Overview of Variation Stage Assessment

Since the Nominal Stage assessment does not account for any anticipated compositional variation in a sludge option, there is an increased risk with respect to processability or product quality if a decision were to be based solely on this assessment. The risk is lessened by the Variation Stage assessment, which is used to gain insight into the robustness of candidate frits with respect to sludge compositional variation. Of particular concern for SB4 is the potential impact of sludge variation on the operating windows of the glass system due to the nepheline constraint. As a result of this concern, an aggressive Variation Stage assessment was conducted for the Set 2 and 3 sludge options (see Table 3.2).<sup>4</sup>

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<sup>4</sup> The term “aggressive” refers to a change in the traditional approach by which the Variation Stage has previously been performed. Previous assessments have typically used a “standard”  $\pm$  5%, 7.5% or 10% variation around the nominal sludge composition to define the minimum and maximum values for each oxide of interest. Although effective, applying a set percentage to both major and minor components results in a limited range over which the minor components are assessed. In the “aggressive approach” a different strategy was taken for the minor components – which is described in Section 4.3.



Variation Stage assessments were not conducted on the compositions of Set 1 due to changes in the priorities of the work being conducted by the frit development team. As stated above, the results from the assessments that were completed and reviewed with CBU allowed them to make adjustments to their preparation plans that provided additional cases for consideration by the frit development team. The evaluation of these revised plans took precedent over any additional work on the compositions in Table 3-1 and Table 3-2 such as Variation Stage assessments for the Set 1 options.

Table 4-1 provides the framework for the Variation Stage assessments. These assessments replace the nominal value for each oxide in the sludge with an interval (defined by minimum (min) and maximum (max) values) of possible values. The top two rows indicate the types of variation that were introduced to determine the minimums and maximums: a variation of  $\pm 7.5\%$  of the nominal was placed around the nominal to determine the min's and max's for the major oxides (i.e.,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{Na}_2\text{O}$ ) and a  $\pm 1$  wt% variation was placed around the nominal value for each individually tracked minor oxide (i.e.,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{MnO}$ ,  $\text{NiO}$ ,  $\text{SiO}_2$ , and  $\text{U}_3\text{O}_8$ ) and for "Others". The "Others" term was used to allow for the inclusion of the minor oxides that were not tracked individually. The composition of the "Others" component of the sludge is provided (as weight percentages) in Table 4-2. This is seen as an aggressive approach in that the variation introduced for  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{MnO}$ ,  $\text{NiO}$ ,  $\text{SO}_4^{=}$ ,  $\text{SiO}_2$ ,  $\text{U}_3\text{O}_8$ , and "Others" is very large (when expressed as a percentage of the nominal values) as compared to the variation for the major oxides of  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ , and  $\text{Na}_2\text{O}$ . The variation applied to the nominal  $\text{SO}_4^{=}$  was  $\pm 0.25$  wt%. Also note that the rows of Tables 4-1 and 4-2 show that the Variation Stage assessments were conducted only for the sludge options corresponding to Case 15 and Case 7b as indicated above.

**Table 4-1. Developing Bounding Regions for Case 15 and Case 7b (as mass fractions)**

Variation (+/-)		7.5	1	7.5	1	1	7.5	1	0.25	1	1	1
Unit of Measure		%	wt%	%	wt%	wt%	%	wt%	wt%	wt%	wt%	wt%
Option		Al <sub>2</sub> O <sub>3</sub>	CaO	Fe <sub>2</sub> O <sub>3</sub>	MgO	MnO	Na <sub>2</sub> O	NiO	SO <sub>4</sub> <sup>=</sup>	SiO <sub>2</sub>	U <sub>3</sub> O <sub>8</sub>	Others
Case 15 Batch 1	min	0.40945	0.00660	0.16535	-0.00209 <sup>5</sup>	0.02845	0.16289	0.00390	0.01014	0.05335	0.02599	0.00366
	max	0.47585	0.02660	0.19217	0.01791	0.04845	0.18931	0.02390	0.01514	0.07335	0.04599	0.02366
Case 15 Blend 1	min	0.23460	0.01441	0.25125	0.01551	0.04603	0.18952	0.00612	0.00960	0.03205	0.06812	0.00552
	max	0.27264	0.03441	0.29199	0.03551	0.06603	0.22026	0.02612	0.01460	0.05205	0.08812	0.02552
Case 15 Batch 2	min	0.26354	0.00663	0.18561	0.00458	0.04103	0.22917	0.02888	0.00421	0.03209	0.07063	0.00612
	max	0.30628	0.02663	0.21571	0.02458	0.06103	0.26633	0.04888	0.00921	0.05209	0.09063	0.02612
Case 15 Blend 2	min	0.25627	0.00814	0.19814	0.00675	0.04180	0.22453	0.02401	0.00528	0.03187	0.06971	0.00593
	max	0.29783	0.02814	0.23028	0.02675	0.06180	0.26095	0.04401	0.01028	0.05187	0.08971	0.02593
Case 7b Batch 1	min	0.28559	0.00571	0.17027	0.00211	0.03506	0.24758	0.02046	0.00899	0.03510	0.05498	0.00462
	max	0.33190	0.02571	0.19789	0.02211	0.05506	0.28773	0.04046	0.01399	0.05510	0.07498	0.02462
Case 7b Blend 1	min	0.19250	0.01396	0.25163	0.01675	0.04814	0.21988	0.01211	0.00911	0.02578	0.07796	0.00584
	max	0.22371	0.03396	0.29244	0.03675	0.06814	0.25554	0.03211	0.01411	0.04578	0.09796	0.02584
Case 7b Batch 2	min	0.30463	0.00675	0.18163	0.00291	0.03806	0.20512	0.02250	0.00683	0.03810	0.05931	0.00559
	max	0.35403	0.02675	0.21108	0.02291	0.05806	0.23838	0.04250	0.01183	0.05810	0.07931	0.02559
Case 7b Blend 2	min	0.27855	0.00825	0.19608	0.00588	0.04003	0.21193	0.02006	0.00725	0.03517	0.06306	0.00557
	max	0.32372	0.02825	0.22788	0.02588	0.06003	0.24630	0.04006	0.01225	0.05517	0.08306	0.02557

<sup>5</sup> The 1 wt% variation around the nominal mass fraction concentration of 0.00791 for the Case 15 Batch 1 MgO drives the lower limit of the concentration for this oxide negative; a value of zero was used for this lower limit in the development of the EVs for Case 15 Batch 1.

**Table 4-2. Components (as weight percentages) of Others for Case 15 and Case 7b**

<b>Option</b>	<b>BaO</b>	<b>Ce<sub>2</sub>O<sub>3</sub></b>	<b>Cr<sub>2</sub>O<sub>3</sub></b>	<b>CuO</b>	<b>K<sub>2</sub>O</b>	<b>La<sub>2</sub>O<sub>3</sub></b>	<b>PbO</b>	<b>ThO<sub>2</sub></b>	<b>TiO<sub>2</sub></b>	<b>ZnO</b>	<b>ZrO<sub>2</sub></b>	<b>Others</b>
Case 15 Batch 1	7.10	0.00	14.06	0.00	45.31	7.91	0.00	9.52	1.83	0.00	14.28	100.00
Case 15 Blend 1	8.31	9.86	13.98	3.93	22.68	7.15	5.99	4.32	1.74	6.44	15.59	100.00
Case 15 Batch 2	9.24	3.97	13.34	2.17	25.50	5.83	2.17	4.65	15.01	3.54	14.58	100.00
Case 15 Blend 2	9.04	5.15	13.50	2.51	24.92	6.09	2.95	4.58	12.37	4.14	14.75	100.00
Case 7b Batch 1	8.75	3.06	13.51	1.64	30.14	6.32	1.68	5.77	11.91	2.71	14.50	100.00
Case 7b Blend 1	8.81	10.53	13.80	4.35	18.39	6.64	6.31	3.28	5.15	7.11	15.65	100.00
Case 7b Batch 2	8.75	3.06	13.51	1.64	30.14	6.32	1.68	5.77	11.91	2.71	14.50	100.00
Case 7b Blend 2	8.76	4.72	13.57	2.24	27.52	6.39	2.71	5.22	10.41	3.69	14.76	100.00

Consider one of the sludge options of Table 4-1. A sludge composition is in the region corresponding to this option if its concentration for each oxide is within the min and max interval for that oxide and the sum of the concentrations equals 1. Such a composition is a mixture of oxides at concentrations that correspond to one of the possible compositions for that sludge option as defined by Table 4-1. Algorithms are available in statistical software packages such as JMP (SAS 2002) to generate the compositions that bound the region defined by Table 4-1 for a particular sludge option — the bounding compositions are the extreme vertices (or “corner points”) of the region.

JMP Version 5.1.2 (SAS 2002) was used to generate the extreme vertices (EVs) or corner points of the sludge regions defined by Table 4-1 for the options of Case 15 and Case 7B. The centroid (or average of the EVs) for each region was also generated as it was tracked during the Variation Stage to ensure consistent results with the Nominal Stage assessment. For each sludge option, candidate frits were selected to be combined with the EVs generated by JMP at waste loadings from 25 to 60%. The resulting glass compositions were evaluated against the PCCS MAR criteria to determine their respective acceptability. A candidate frit is considered to demonstrate robustness to the variation in a sludge option if 100% of the EVs for that option meet the PCCS MAR criteria over a wide sub-interval of the 25 to 60% WL interval. In addition, where less than 100% of the EVs are acceptable, identifying the constraint or constraints that are not met (i.e., the constraint(s) that limit the operating window) is of interest.

Identification or selection of the candidate frits to be used in the Variation Stage assessment was primarily based on the results of the Nominal Stage assessments. Table 4-3 provides an overview of the glass systems that were evaluated as part of the Variation Stage. The number of EVs for each sludge option is also provided in Table 4-3. The results from this assessment (i.e., the operating windows for each of these glass systems) are provided in Section 5.3.

**Table 4-3. Glass Systems Evaluated During Variation Stage Assessments**

Case	Sludge Option	Number of EVs	Candidate Frits
15	Batch 1	2144	320
15	Blend 1	2464	418, 425, P3-1
15	Batch 2	2534	P3-1
15	Blend 2	2464	418, 425, P3-1
7B	Batch 1	2492	418, P3-1
7B	Blend 1	2464	418, 425, P3-1
7B	Batch 2	2464	418, P3-1
7B	Blend 2	2534	418, 425, P3-1

## 5.0 PROJECTED OPERATING WINDOWS FOR THE SB4 OPTIONS

In this section, the projected operating windows are presented for the Nominal and Variation Stage assessments. Prior to the discussion of these results, the impact of the  $\text{SO}_4^{=}$  solubility limit on the operating windows is discussed.

### 5.1 Impact of $\text{SO}_4^{=}$

The nominal  $\text{SO}_4^{=}$  concentration for SB4 is dependent on three primary inputs: (1) the wash endpoint for SB4, (2) the SB3 heel volume, and (3) the inclusion (or exclusion) of ARP streams. ARP is not included in the scope of this effort. From a historical SB4 perspective, Lorier et al. (2005) provided preliminary results that indicated that the 0.6 wt%  $\text{SO}_4^{=}$  solubility limit (defined for SB3) was applicable for select SB4 sludge (based on Lilliston 2005) – frit combinations. No salt layer formation was evident in any test (30% or 40% WL) with Frit 320 until  $\text{SO}_4^{=}$  concentrations of 0.8 wt% were targeted. Tests with Frit 418 showed that  $\text{SO}_4^{=}$  was apparent on the glass surface of tests at 40% WL and 0.6 wt%  $\text{SO}_4^{=}$  - indicating that a  $\text{SO}_4^{=}$  limit of 0.5 wt% may be required. The results suggested that the  $\text{SO}_4^{=}$  solubility limit was dependent on the overall glass composition – in general, the more refractory the frit, the lower the  $\text{SO}_4^{=}$  solubility.

Given Frit 320 and Frit 418 are somewhat bounding in terms of their  $\text{Na}_2\text{O}$  concentrations (for the “sliding  $\text{Na}_2\text{O}$  scale” series – see Table 3-3) and acknowledging the recent results from Lorier et al. (2005), an assessment of the maximum WLs that could be achieved prior to a specific system becoming  $\text{SO}_4^{=}$  limited at either 0.5 and 0.6 wt% is warranted. It should be noted that a formal experimental assessment of  $\text{SO}_4^{=}$  solubility based on the final SB4 preparation plan and candidate frit compositions will be addressed in a subsequent report.

Table 5-1 shows how much  $\text{SO}_4^{=}$  must be retained (assuming no volatilization occurs) in the glass at various WLs (by increments of 5 percentage points). Since there is no measurement uncertainty accounted for in the  $\text{SO}_4^{=}$  PCCS constraint, this table can be used as a basis for understanding how  $\text{SO}_4^{=}$  solubility might limit DWPF’s operating window (i.e., targeted WL) depending upon its solubility limit in the glass system. The cells highlighted in yellow indicate that the solubility limit would be exceeded assuming a 0.5 wt% limit in PCCS. Those cells highlighted in green represent conditions in which the solubility limit would be exceeded assuming a 0.6 wt% value. The mathematical WL limit at which the assumed solubility limit would be exceeded can easily be calculated (assuming no volatilization occurs).

Assuming a 0.6 wt%  $\text{SO}_4^{=}$  limit, Case 15B (both Batch 1 and Blend 1) and Case 15 (both Batch 1 and Blend 1) are the only sludge options that would exceed this limit at WLs at or below 50%. Case 15B Batch 1 being the “worst case” scenario as WLs would be limited to ~ 36% WL or lower. It should be noted that the Batch 1 composition reflects a qualification sample and thus the targeted WL may not be as critical. When considering the “blends” (i.e., sludges to be processed in DWPF), the maximum WLs for the Case 15B Blend 1 and Case 15 Blend 1 would be ~48% and 49% WL, respectively. The potential for the 0.6 wt%  $\text{SO}_4^{=}$  solubility limit to constrain DWPF processing is minimal as another constraint will likely restrict assess to these higher WLs.

Obviously, if one assumes a lower  $\text{SO}_4^{=}$  solubility limit (i.e., 0.5 wt%), the impact on select systems is more severe (especially the Blend 1 and Batch 1 sludges for Case 15 and Case 15B). In general, WLs of at least ~ 40 – 45% would be obtainable for most systems of interest. One interesting observation is the fact that none of the Blend 2 options (which would be processed in DWPF) are limited by  $\text{SO}_4^{=}$  even with the lower assumed 0.5 wt% limit. As previously mentioned, although these data provide insight into the

possible impact of  $\text{SO}_4^{=}$  solubility limits on the projected operating window, a formal experimental assessment of  $\text{SO}_4^{=}$  solubility based on the final SB4 preparation plan and candidate frit compositions will be addressed in a subsequent report.

**Table 5-1.  $\text{SO}_4^{=}$  Concentrations in the Glass for the Sludge Cases at Select WLs**

Set	Sludge Options	$\text{SO}_4^{=}$ wt%	%WL <sup>6</sup>				
			30	35	40	45	50
1	Case 8 and 8a - Batch 1	1.121	0.336	0.392	0.448	0.504	0.561
1	Case 8 - Blend 1	1.138	0.341	0.398	0.455	0.512	0.569
1	Case 8A - Blend 1	1.124	0.337	0.393	0.450	0.506	0.562
1	Case 7 Batch 1	0.965	0.290	0.338	0.386	0.434	0.483
1	Case 7 Blend 1	1.124	0.337	0.393	0.450	0.506	0.562
1	Case 7 Batch 2	0.766	0.230	0.268	0.306	0.345	0.383
1	Case 7 Blend 2	0.833	0.250	0.292	0.333	0.375	0.417
1	Case 15B - Batch 1	1.649	0.495	0.577	0.660	0.742	0.825
1	Case 15B - Blend 1	1.246	0.374	0.436	0.498	0.561	0.623
1	Case 15B - Batch 2	0.867	0.260	0.303	0.347	0.390	0.434
1	Case 15B - Blend 2	0.934	0.280	0.327	0.374	0.420	0.467
1	Case 16 - Batch 1	0.302	0.091	0.106	0.121	0.136	0.151
1	Case 16 - Blend 1	0.725	0.218	0.254	0.290	0.326	0.363
1	Case 16 - Batch 2	1.174	0.352	0.411	0.470	0.528	0.587
1	Case 16 - Blend 2	1.060	0.318	0.371	0.424	0.477	0.530
2	Case 15 Batch 1	1.264	0.379	0.442	0.506	0.569	0.632
2	Case 15 Blend 1	1.210	0.363	0.424	0.484	0.545	0.605
2	Case 15 Batch 2	0.671	0.201	0.235	0.268	0.302	0.336
2	Case 15 Blend 2	0.778	0.233	0.272	0.311	0.350	0.389
3	Case 7b Batch 1	1.149	0.345	0.402	0.460	0.517	0.575
3	Case 7b Blend 1	1.161	0.348	0.406	0.464	0.522	0.581
3	Case 7b Batch 2	0.933	0.280	0.327	0.373	0.420	0.467
3	Case 7b Blend 2	0.975	0.293	0.341	0.390	0.439	0.488

## 5.2 Results from the Nominal Stage Assessments

Exhibit A1 in the Appendix provides the details of the MAR and nepheline results at each WL for each sludge/frit glass system. Table 5-2 provides (in two parts)<sup>7</sup> the projected operating windows (defined in terms of minimum and maximum WLs) for each glass system based upon the MAR assessments and an activated nepheline constraint. It should be noted that a “-” in Table 5-2 indicates that there is no operating window for that frit – sludge combination based on the acceptance criteria used.

Obviously, numerous comparisons can be made among the SB4 scenarios for a specific frit, and, yet, even more when considering differences among the frits for the sludge options. Be that as it may, the authors have elected to provide a detailed assessment of one of the sludge options –

<sup>6</sup> The cells highlighted in yellow indicate that the solubility limit would be exceeded assuming a 0.5 wt% limit in PCCS. Those cells highlighted in green represent conditions in which the solubility limit would be exceeded assuming a 0.6 wt% value.

<sup>7</sup> The two parts are differentiated by the  $\text{Na}_2\text{O}$  concentration in frit. Part 1 shows the frits containing 3 – 6 wt%  $\text{Na}_2\text{O}$ ; Part 2 contains the frits with 7 – 15 wt%  $\text{Na}_2\text{O}$ .

specifically Frit 418 with Case 15 (see the yellow highlighted cells of part 2 in Table 5-2 and, for details, of part 3 of Exhibit A1 ). Frit 418 was selected given it is the current frit being used to process SB3 and a primary candidate for SB4 as well. Case 15 was selected given it was one of the sludge composition used in the limited Variation Stage assessment and will provide continuity in the transition from the discussion of the Nominal Stage results to the discussion of the Variation Stage results. The details associated with the Nominal Stage assessment of these cases are highlighted in Appendix A. The discussion of the Frit 418 – Case 15 flowsheet will provide a general understanding of how the table can be interpreted and applied to other systems that may be of interest to the reader.

For the Case 15 Batch 1 option, there is no projected operating window when Frit 418 is utilized. From Appendix A, predictions of high viscosity limit access to WLs of 25% to 39% with an additional constraint (nepheline formation potential) also becoming an issue at 40% and higher. Although Frit 418 could not be used to qualify this batch, other frits are available with operating windows (e.g., 425, 417, 320, 431, P2-2, and P2-4). Operating windows do exist for these alternative frits, but the maximum WL is typically in the low-to-mid-30's with nepheline predictions becoming the primary issue. Therefore, qualification of this batch would most likely be based on a relatively low WL (high 20's to low 30's) and possibly with a different frit than used to process the "blend" in DWPF. It should be noted that the  $\text{Fe}_2\text{O}_3$ -based frits (P2-2 and P2-4) provide operating windows of 25 – 38 and 39%, respectively, given the suppression of nepheline formation to higher WLs for these glass systems.

Coupling Frit 418 with Batch 2 (another qualification composition), yields a projected operating window of 25 – 43% WL. From Appendix A, nepheline becomes the limiting factor at 44% WL and higher. This sludge could be qualified with Frit 418 at reasonable WLs of interest.

When Frit 418 is used with Case 15 Blend 1 and Blend 2, the projected operating windows are 25 – 46% and 25 – 43% WL, respectively. Predictions of  $T_L$  limit access to WLs of 47% and higher in the Blend 1 system. Nepheline concerns limit access to WLs of 44% and higher in the Blend 2 system. With respect to DWPF processing, Frit 418 could be used with both Blend 1 and Blend 2 with a potential need to reduce the targeted WL for Blend 2. This latter statement assumes that the maximum waste throughput for Blend 1 would be achieved at WLs of 44% - 46%. Although historically maximum waste throughput has not been achieved at the maximum WL identified through the model based assessments (but at some intermediate WL), predictions of  $T_L$  would restrict WLs to 43% or lower for the Blend 2 system even if the higher WLs were realized for Blend 1.

Again, the number of comparisons within a specific flowsheet or among different flowsheets could be overwhelming. The summary in Table 5-2 coupled with the details in Appendix A provide a technical basis from which other comparisons can be made that may be of interest to the reader. Given the preferred preparation plan as defined by the CBU is not shown in this report, the discussions provided in this report have been held to a minimum.

**Table 5-2. Operating Windows from Nominal Assessments Expressed as WL Intervals (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

	Na <sub>2</sub> O (wt%) content	3	4	5	5	5	5	5	5	6	6	6	6	6
Set	Frit	422	d1-1	473	P1-1	P2-1	P2-2	P3-1	t1-1	202	432	P2-3	P2-4	P3-2
1	Case 15B - Batch 1	- <sup>8</sup>	-	-	-	25-39 neph	25-38 neph	25-40 neph	-	-	-	25-39 neph	25-37 neph	25-39 neph
1	Case 15B - Batch 2	-	-	-	-	25-37 TL	25-37 TL	25-42 TL	-	-	-	25-39 TL	25-38 TL	25-41 TL
1	Case 15B - Blend 1	hvisc 34-41 TL	hvisc 31-43 TL	hvisc 27-44 TL	25-39 TL	25-38 lvisc	25-31 lvisc	25-41 lvisc	25-42 TL	hvisc 28-40 TL	25-45 TL	25-37 lvisc	25-27 lvisc	25-41 lvisc
1	Case 15B - Blend 2	-	-	-	hvisc 31-35 TL	25-38 TL	25-38 TL	25-43 TL	hvisc 38-38 TL	-	hvisc 39-41 TL	25-40 TL	25-39 TL	25-42 TL
1	Case 16 - Batch 1	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Case 16 - Batch 2	-	-	-	-	25-41 neph	25-40 neph	25-42 neph	-	-	-	25-40 neph	25-39 neph	25-41 neph
1	Case 16 - Blend 1	hvisc 32-35 TL	hvisc 29-36 TL	hvisc 26-38 TL	25-34 TL	25-36 TL, lvisc	25-29 lvisc	25-39 lvisc	25-36 TL	hvisc 26-34 TL	25-39 TL	25-35 lvisc	25-26 lvisc	25-39 lvisc
1	Case 16 - Blend 2	-	-	hvisc 44-44 TL	hvisc 32-39 TL	25-42 TL	25-41 TL	25-44 neph	lvisc 39-42 TL	-	hvisc 39-44 neph	25-43 neph	25-41 neph	25-43 neph
1	Case 7 Batch 1	-	hvisc 45-45 neph	hvisc 41-44 neph	hvisc 29-42 TL	25-42 neph	25-41 neph	25-43 neph	hvisc 36-44 TL, neph	hvisc 42-43 TL, neph	hvisc 36-43 neph	25-41 neph	25-40 neph	25-42 neph
1	Case 7 Batch 2	-	-	-	-	25-37 TL	25-37 TL	25-42 TL	-	-	-	25-39 TL	25-38 TL	25-41 TL
1	Case 7 Blend 1	hvisc 33-41 TL	hvisc 30-42 TL	hvisc 27-43 TL	25-39 lvisc	25-38 lvisc	25-30 lvisc	25-40 lvisc	25-41 TL	hvisc 27-40 TL	25-45 TL	25-37 lvisc	25-27 lvisc	25-40 lvisc
1	Case 7 Blend 2	-	-	-	hvisc 33-35 TL	25-38 TL	25-38 TL	25-43 TL	-	-	hvisc 41-42 TL	25-40 TL	25-39 TL	25-42 TL
1	Case 8 - Blend 1	hvisc 37-40 TL	hvisc 34-41 TL	hvisc 30-42 TL	25-38 TL	25-40 TL	25-35 lvisc	25-45 TL, lvisc	hvisc 26-40 TL	hvisc 31-38 TL	hvisc 26-43 TL	25-41 lvisc	25-31 lvisc	25-45 TL, lvisc

<sup>8</sup> A “-” entry in a cell indicates no operating window for the corresponding glass system.



**Table 5-2. Operating Windows from Nominal Assessments Expressed as WL Intervals (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

	Na <sub>2</sub> O (wt%) content	3	4	5	5	5	5	5	5	6	6	6	6	6
Set	Frit	422	d1-1	473	P1-1	P2-1	P2-2	P3-1	t1-1	202	432	P2-3	P2-4	P3-2
1	Case 8 and 8a Batch 1	-	-	hvisc 38-42 TL	hvisc 26-37 TL	25-39 TL	25-39 TL	25-45 TL, neph	hvisc 33-39 TL	-	hvisc 33-43 TL	25-42 TL	25-39 lvisc	25-44 TL, neph
1	Case 8A - Blend 1	-	hvisc 37-41 TL	hvisc 33-42 TL	25-38 TL	25-40 TL	25-38 lvisc	25-45 TL	hvisc 28-40 TL	hvisc 34-38 TL	hvisc 29-43 TL	25-42 TL	25-34 lvisc	25-44 TL
2	Case 15 Batch 1	-	-	-	-	-	25-39 neph	-	-	-	-	-	25-38 neph	-
2	Case 15 Batch 2	-	hvisc 40-42 TL	hvisc 36-43 TL	25-38 TL	25-41 TL	25-41 TL, lvisc	25-45 neph	hvisc 31-41 TL	hvisc 37-39 TL	hvisc 31-45 TL, neph	25-43 TL, neph	25-36 lvisc	25-44 neph
2	Case 15 Blend 1	-	hvisc 39-41 TL	hvisc 35-42 TL	25-37 TL	25-40 TL	25-40 TL, lvisc	25-45 TL	hvisc 30-40 TL	hvisc 36-38 TL	hvisc 31-43 TL	25-42 TL	25-36 lvisc	25-44 TL
2	Case 15 Blend 2	-	hvisc 39-43 TL	hvisc 35-44 TL	25-39 TL	25-41 TL	25-40 lvisc	25-45 neph	hvisc 30-41 TL	hvisc 36-40 TL	hvisc 31-45 TL, neph	25-43 neph	25-35 lvisc	25-44 neph
3	Case 7b Batch 1	hvisc 44-45 neph	hvisc 40-45 neph	hvisc 36-44 neph	25-42 neph	25-42 neph	25-41 lvisc, neph	25-43 neph	hvisc 31-43 neph	hvisc 37-42 neph	hvisc 32-43 neph	25-41 neph	25-37 lvisc	25-42 neph
3	Case 7b Batch 2	-	-	-	hvisc 35-38 TL	25-40 TL	25-40 TL	25-44 neph	-	-	hvisc 44-44 TL, neph	25-42 TL, neph	25-41 TL, neph	25-43 neph
3	Case 7b Blend 1	hvisc 34-43 TL	hvisc 31-44 TL	hvisc 28-45 TL	25-40 TL	25-3 lvisc9	25-31 lvisc	25-41 lvisc	25-43 TL	hvisc 28-41 TL	25-46 TL	25-38 lvisc	25-28 lvisc	25-41 lvisc
3	Case 7b Blend 2	-	-	hvisc 41-44 TL	hvisc 28-39 TL	25-41 TL	25-41 TL	25-45 neph	hvisc 35-41 TL	-	hvisc 36-45 TL, neph	25-43 TL, neph	25-41 lvisc	25-44 neph

**Table 5-2. Operating Windows from Nominal Assessments Expressed as WL Intervals (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

	Na <sub>2</sub> O (wt%) content	7	7	7	7	8	9	10	11	11	12	13	14	15
Set	Frit	460	P2-5	P3-3	P3-4	418	426	425	200	417	320	431	Y1-1	X1-1
1	Case 15B - Batch 1	-	25-37 neph	25-38 neph	25-39 neph	-	-	25-36 neph	-	25-35 neph	25-34 neph	25-33 neph	25-32 neph	25-31 neph
1	Case 15B - Batch 2	hvisc 41-42 TL	25-38 TL	25-42 TL	25-43 TL, neph	hvisc 33-43 TL, neph	25-42 neph	25-41 neph	hvisc 26-38 neph	25-40 neph	25-39 neph	25-37 neph	25-36 neph	25-35 neph
1	Case 15B - Blend 1	25-46 TL	25-30 lvisc	25-38 lvisc	25-40 lvisc	25-46 lvisc	25-43 lvisc	25-41 lvisc	25-42 lvisc	25-38 lvisc	25-35 lvisc	-	-	-
1	Case 15B - Blend 2	hvisc 33-42 TL	25-39 TL	25-43 TL	25-44 TL, neph	25-43 TL	25-43 neph	25-42 neph	25-39 neph	25-41 neph	25-39 neph	25-38 neph	25-37 neph	Del GP 30-36 neph
1	Case 16 - Batch 1	-	-	-	-	-	-	-	-	-	-	-	-	-
1	Case 16 - Batch 2	-	25-38 neph	25-40 neph	25-40 neph	hvisc 40-40 neph	hvisc 28-39 neph	25-38 neph	hvisc 32-35 neph	25-37 neph	25-35 neph	25-34 neph	25-33 neph	25-32 neph
1	Case 16 - Blend 1	25-40 TL	25-28 lvisc	25-36 lvisc	25-38 lvisc	25-41 TL	25-41 lvisc	25-39 lvisc	25-38 TL	R20 30-36 lvisc	R20 30-33 lvisc	-	-	-
1	Case 16 - Blend 2	hvisc 33-44 neph	25-41 neph	25-42 neph	25-43 neph	26-43 neph	25-41 neph	25-40 neph	25-38 neph	25-39 neph	25-38 neph	25-37 neph	25-36 neph	Del GP 31-34 neph
1	Case 7 Batch 1	hvisc 31-42 neph	25-40 neph	25-41 neph	25-42 neph	25-41 neph	25-40 neph	25-39 neph	25-37 neph	25-38 neph	25-37 neph	25-36 neph	Del GP 30-35 neph	-
1	Case 7 Batch 2	-	25-38 TL	25-42 TL, neph	25-43 neph	hvisc 38-43 TL, neph	hvisc 26-42 neph	25-40 neph	hvisc 30-38 neph	25-39 neph	25-38 neph	25-37 neph	25-36 neph	25-34 neph
1	Case 7 Blend 1	25-46 TL	25-29 lvisc	25-37 lvisc	25-39 lvisc	25-45 lvisc	25-43 lvisc	25-40 lvisc	25-42 lvisc	25-37 lvisc	25-34 lvisc	-	-	-
1	Case 7 Blend 2	hvisc 35-43 TL	25-39 TL	25-43 TL, neph	25-44 TL, neph	27-44 TL, neph	25-43 neph	25-41 neph	25-39 neph	25-40 neph	25-39 neph	25-38 neph	25-37 neph	28-35 neph
1	Case 8 - Blend 1	25-45 TL	25-33 lvisc	25-42 lvisc	25-44 lvisc	25-46 TL, neph	25-45 neph	25-44 neph	25-42 TL, neph	25-42 lvisc	25-39 lvisc	Del GP 32-35 lvisc	-	-
1	Case 8 and 8a - Batch 1	hvisc 28-44 TL, neph	25-41 TL, neph	25-43 neph	25-43 neph	25-43 neph	25-42 neph	25-41 neph	25-39 neph	25-40 neph	25-39 neph	25-38 neph	33-36 neph	-

**Table 5-2. Operating Windows from Nominal Assessments Expressed as WL Intervals (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

	Na <sub>2</sub> O (wt%) content	7	7	7	7	8	9	10	11	11	12	13	14	15
Set	Frit	460	P2-5	P3-3	P3-4	418	426	425	200	417	320	431	Y1-1	X1-1
1	Case 8A - Blend 1	25-45 TL	25-36 lvisc	25-44 neph	25-45 neph	25-45 neph	25-44 neph	25-42 neph	25-40 neph	25-41 neph	25-40 neph	25-38 lvisc	-	-
2	Case 15 Batch 1	-	25-38 neph	-	-	-	-	-	-	-	25-33 hvisc	25-34 neph	25-33 neph	25-31 neph
2	Case 15 Batch 2	hvisc 26-44 neph	25-39 lvisc	25-43 neph	25-43 neph	25-43 neph	25-42 neph	25-41 neph	25-38 neph	25-39 neph	25-38 neph	25-37 neph	-	-
2	Case 15 Blend 1	hvisc 26-44 TL	25-39 lvisc	25-45 TL	25-46 TL	25-46 TL	25-46 neph	25-44 neph	25-42 TL, neph	25-43 neph	25-42 neph	25-41 lvisc, neph	25-36 lvisc	-
2	Case 15 Blend 2	25-44 neph	25-38 lvisc	25-43 neph	25-44 neph	25-43 neph	25-42 neph	25-41 neph	25-39 neph	25-40 neph	25-39 neph	25-38 neph	-	-
3	Case 7b Batch 1	hvisc 26-42 neph	25-39 neph	25-41 neph	25-41 neph	25-41 neph	25-40 neph	25-39 neph	25-36 neph	25-38 neph	25-36 neph	Del GP 31-35 neph	-	-
3	Case 7b Batch 2	hvisc 37-43 neph	25-40 neph	25-42 neph	25-42 neph	29-42 neph	25-41 neph	25-40 neph	25-37 neph	25-39 neph	25-38 neph	25-36 neph	25-35 neph	Del GP 29-34 neph
3	Case 7b Blend 1	25-47 TL	25-30 lvisc	25-38 lvisc	25-40 lvisc	25-46 lvisc	25-44 lvisc	25-41 lvisc	25-42 neph	25-38 lvisc	25-35 lvisc	-	-	-
3	Case 7b Blend 2	hvisc 30-44 neph	25-41 neph	25-43 neph	25-43 neph	25-43 neph	25-42 neph	25-41 neph	25-38 neph	25-40 neph	25-38 neph	25-37 neph	Del Gp 26-36 neph	-

### 5.3 Results of the Variation Stage Assessments

As described in Section 4.3, a small set of sludge/frit glass systems was selected for evaluation by the aggressive Variation Stage assessment. How are the results from these assessments to be summarized? The answer is the interval of waste loadings for which 100% of the region's EVs meet the MAR criteria for that frit. Table 5-3 through Table 5-6 provide the summaries of the results at each waste loading from 25 to 60% for the candidate frits for each of the glass systems studied. Note that the potential for nepheline formation was considered as part of this evaluation; those entries that are shaded yellow indicate the WLs at which the nepheline constraint indicated a potential problem for some of the EVs.

For continuity and to provide a roadmap for interpretation, consider Frit 418 – Case 15 Blend 1 option (see Table 5-3). The projected operating window for the centroid composition is 25 – 46% with a prediction of  $T_L$  limiting access to higher WLs. This is consistent with the Nominal Stage assessment as discussed in the previous section. The WL interval over which all 2464 EVs could be processed is 25 – 37% WL. This is a relatively large operating window which demonstrates the robustness of Frit 418 to potential variation (even with the aggressive approach) in sludge composition. At 38% WL, 2% (or approximately 49 EVs) are classified as not acceptable due to  $T_L$  predictions. Potential nepheline issues do not come into play until 45% WL (only a 3 WL point reduction from the centroid assessment). This suggests that the initial concerns of nepheline having a dramatic negative impact on the operating windows once compositional variation was applied did not materialize. Instead, the “aggressive” nature of the approach taken resulted in significant changes in  $T_L$  predictions to the point at which severe reductions in the operating windows occurred. More specifically, the  $\pm 1$  wt% value applied to NiO and MnO coupled with the 7.5% variation applied with  $Fe_2O_3$  resulted in significant changes to  $T_L$  predictions for the EVs. If the more “traditional” approach were to be taken in the Variation Stage assessment, the reduction in the operating window over which all the EVs could be processed would not be as severe and the window would possibly be limited based on nepheline as anticipated.

Although a detailed discussion is not provided for each system, an easy assessment to make is to assess the response of each frit to the same EVs that define a specific case. Consider Frit 425 and Frit P3-1 with the Case 15 Blend 1 option. Based on the % of EVs considered processable, there appears to be very little, if any, difference in the projected operating windows between Frit 418 and Frit 425. With a 2%  $Na_2O$  difference between the two frits, this is expected – given the significant impact of  $T_L$  predictions. The primary difference between the two frits can be seen in the centroid assessments where the additional 2%  $Na_2O$  in Frit 425 has a negative impact on the upper WL achievable given nepheline prediction issues. The  $Fe_2O_3$  addition to Frit P3-1 does not help the  $T_L$  issue for the centroid assessment as 1 WL point is lost as compared to the Frit 418 system. However, if one elects to suppress nepheline formation through strategic frit development efforts, Frit P3-1 does not appear to yield significant losses with respect to its ability to process the EVs.

**Table 5-3. Variation Stage MAR Results (as % of EVs) for Case 15 Batch 1 and Blend 1.**

% Waste	Case 15 Batch 1 <sup>9</sup>		Case 15 Blend 1					
	Frit 320	Frit 320	Frit 418	Frit 418	Frit 425	Frit 425	Frit p3-1	Frit p3-1
Loading	Centroid	% of EVs	Centroid	% of EVs	Centroid	% of EVs	Centroid	% of EVs
25		73		100		100		100
26		70		100		100		100
27		67		100		100		100
28		65		100		100		100
29		63		100		100		100
30		59		100		100		100
31		57		100		100		100
32		54		100		100		100
33		53		100		100		100
34		51		100		100		100
35	newhv	46		100		100		100
36	newhv Neph	39		100		100		100
37	newhv Neph	8		100		100		99.9
38	newhv Neph			98		98		98
39	newhv Neph			96		96		95
40	newhv Neph			91		91		91
41	newhv Neph			87		87		86
42	newhv Neph			80		80		80
43	newhv Neph			73		64		72
44	newhv Neph			64		46		63
45	newhv Neph			50	Neph	24		52
46	newhv Neph			35	Neph	5	TL	42
47	newhv Neph		TL	18	TL Neph	1	TL	25
48	newhv Neph		TL Neph	2	TL Neph		TL	11
49	newhv Neph		TL Neph	1	TL Neph		TL	4
50	newhv Neph		TL Neph		TL Neph		TL Neph	1
51	newhv Neph		TL Neph		TL Neph		TL newlv Neph	
52	newhv Neph		TL Neph		TL Neph		TL newlv Neph	
53	newhv Neph		TL Neph		TL Neph		TL newlv Neph	
54	newhv Neph		TL Neph		TL Neph		TL newlv Neph	
55	newhv Neph		TL Neph		TL Neph		TL newlv Neph	
56	TL newhv Neph		TL newlv Neph		TL newlv Neph		TL Ivisc newlv Neph	
57	TL newhv Neph		TL newlv Neph		TL newlv Neph		TL Ivisc newlv Neph	
58	TL newhv Neph		TL newlv Neph		TL newlv Neph		TL Ivisc newlv Neph	
59	TL newhv Neph		TL newlv Neph		TL newlv Neph		TL Ivisc newlv Neph	
60	TL newhv Neph		TL newlv Neph		TL newlv Neph		TL Ivisc newlv Neph	

<sup>9</sup> The shaded cells indicate that the potential for nepheline formation is predicted for some of the EVs using the 0.62 value for the constraint. Constraint not met: neph (nepheline), TL (liquidus temperature), Ivisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

**Table 5-4. Variation Stage MAR Results (as % of EVs) for Case 15 Batch 2 and Blend 2.**

% Waste	Case 15 Batch 2 <sup>10</sup>				Case 15 Blend 2					
	Frit 418	Frit 418	Frit p3-1	Frit p3-1	Frit 418	Frit 418	Frit 425	Frit 425	Frit p3-1	Frit p3-1
Loading	Centroid	% of EVs	Centroid	% of EVs	Centroid	% of EVs	Centroid	% of EVs	Centroid	% of EVs
25		93		100		100		100		100
26		100		100		100		100		100
27		100		100		100		100		100
28		100		100		100		100		100
29		100		100		100		100		100
30		100		100		100		100		100
31		100		100		100		100		100
32		100		100		100		100		100
33		100		100		100		100		100
34		100		100		100		100		100
35		100		100		100		100		100
36		100		100		100		100		100
37		100		100		100		100		100
38		99.8		99.7		99.9		100		99.9
39		98		96		98		100		98
40		93		93		94		91		94
41		89		88		90		76		90
42		69		83		77	Neph	31		85
43		50		71		61	Neph	11		81
44	Neph	9		54	Neph	31	Neph	5		61
45	Neph	3		29	Neph	6	Neph			41
46	Neph		Neph	4	Neph	2	Neph		Neph	15
47	Neph		TL Neph	1	Neph		Neph		Neph	3
48	TL Neph		TL Neph		TL Neph		Neph		TL Neph	1
49	TL Neph		TL Neph		TL Neph		Neph		TL Neph	
50	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
51	TL Neph		TL Neph		TL Neph		TL newlv Neph		TL newlv Neph	
52	TL Neph		TL newlv Neph		TL Neph		TL newlv Neph		TL newlv Neph	
53	TL Neph		TL newlv Neph		TL Neph		TL newlv Neph		TL newlv Neph	
54	TL Neph		TL newlv Neph		TL Neph		TL newlv Neph		TL newlv Neph	
55	TL Neph		TL newlv Neph		TL Neph		TL newlv Neph		TL newlv Neph	
56	TL Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
57	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
58	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
59	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
60	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	

<sup>10</sup> The shaded cells indicate that the potential for nepheline formation is predicted for some of the EVs using the 0.62 value for the constraint. Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

**Table 5-5. Variation Stage MAR Results (as % of EVs) for Case 7b Batch 1 and Blend 1.**

% Waste	Case 7b Batch 1 <sup>11</sup>				Case 7b Blend 1					
	Frit 418 Centroid	Frit 418 % of EVs	Frit p3-1 Centroid	Frit p3-1 % of EVs	Frit 418 Centroid	Frit 418 % of EVs	Frit 425 Centroid	Frit 425 % of EVs	Frit p3-1 Centroid	Frit p3-1 % of EVs
25		89		100		100		100		100
26		95		100		100		100		100
27		100		100		100		100		100
28		100		100		100		100		100
29		100		100		100		100		100
30		100		100		100		100		100
31		100		100		100		100		100
32		100		100		100		100		100
33		100		100		100		100		100
34		100		100		100		100		100
35		100		100		100		100		100
36		100		100		100		100		100
37		100		100		100		100		100
38		100		100		100		91		91
39		100		100		99.8		82		82
40		87		100		98		75		73
41		65		100		95		59		55
42	Neph	18		85		89	newlv	47	newlv	41
43	Neph	9		53		77	newlv	31	newlv	25
44	Neph		Neph	16		64	newlv	19	newlv	16
45	Neph		Neph	7		50	newlv	12	newlv	10
46	Neph		Neph			30	newlv Neph	1	newlv	4
47	Neph		Neph		newlv	16	newlv Neph		newlv	2
48	Neph		Neph		newlv Neph	6	newlv Neph		newlv	
49	Neph		Neph		TL newlv Neph		newlv Neph		TL newlv	
50	Neph		Neph		TL newlv Neph		newlv Neph		TL newlv Neph	
51	Neph		Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
52	Neph		Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
53	Neph		newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
54	Neph		newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
55	Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
56	TL Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
57	TL Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
58	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
59	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	
60	TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph		TL newlv Neph	

<sup>11</sup> The shaded cells indicate that the potential for nepheline formation is predicted for some of the EVs using the 0.62 value for the constraint. Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.

**Table 5-6. Variation Stage MAR Results (as % of EVs) for Case 7b Batch 2 and Blend 2.**

% Waste Loading	Case 7b Batch 2 <sup>12</sup>				Case 7b Blend 2					
	Frit 418 Centroid	Frit 418 % of EVs	Frit p3-1 Centroid	Frit p3-1 % of EVs	Frit 418 Centroid	Frit 418 % of EVs	Frit 425 Centroid	Frit 425 % of EVs	Frit p3-1 Centroid	Frit p3-1 % of EVs
25	newhv	31		100		67		100		100
26	newhv	34		100		70		100		100
27	newhv	39		100		77		100		100
28	newhv	42		100		80		100		100
29		50		100		88		100		100
30		58		100		91		100		100
31		60		100		93		100		100
32		65		100		97		100		100
33		66		100		100		100		100
34		68		100		100		100		100
35		70		100		100		100		100
36		73		100		100		100		100
37		78		100		100		100		100
38		79		99		99.9		100		99.9
39		79		95		98		100		98
40		77		91		94		85		93
41		65		86		90		63		90
42		45		81		72	Neph	18		84
43	Neph	22		60		51	Neph	7		80
44	Neph	5		40	Neph	10	Neph			57
45	Neph		Neph	14	Neph	5	Neph			40
46	Neph		Neph	1	Neph		Neph		Neph	6
47	TL Neph		TL Neph		Neph		Neph		Neph	2
48	TL Neph		TL Neph		TL Neph		Neph		TL Neph	
49	TL Neph		TL Neph		TL Neph		Neph		TL Neph	
50	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
51	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
52	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
53	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
54	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
55	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
56	TL Neph		TL Neph		TL Neph		TL Neph		TL Neph	
57	TL Neph		TL Neph		TL Neph		TL newlv Neph		TL newlv Neph	
58	TL Neph		TL Neph		TL Neph		TL newlv Neph		TL newlv Neph	
59	TL Neph		TL Neph		TL Neph		TL newlv Neph		TL newlv Neph	
60	TL Neph		TL Neph		TL Neph		TL newlv Neph		TL newlv Neph	

<sup>12</sup> The shaded cells indicate that the potential for nepheline formation is predicted for some of the EVs using the 0.62 value for the constraint. Constraint not met: neph (nepheline), TL (liquidus temperature), lvisc (low viscosity – new model), hvisc (high viscosity – new model), and Del GP – durability.



Table 5-7 provides a summary of these results for the EVs by showing the first constraint(s), using the same terms as used in Tables 5-3 through 5-6, that limit(s) the operating window at either end of the 25 to 60% interval of WLs.

**Table 5-7. Intervals with 100% EVs Acceptable and Limiting Constraint(s)**

Case	Sludge Option	Frit 320	Frit 418	Frit 425	Frit P3-1
15	Batch 1	-	N/A	N/A	N/A
15	Batch 2	N/A	hvisc 26 – 37 TL	N/A	25 – 37 TL
15	Blend 1	N/A	25 – 37 TL	25 – 37 TL	25 – 36 TL
15	Blend 2	-	25 – 37 TL	25 – 39 Neph, TL	25 – 37 TL
7B	Batch 1	N/A	hvisc 27 - 39 neph	N/A	25 – 41 neph
7B	Batch 2	N/A	-	-	25 – 37 TL
7B	Blend 1	N/A	25 – 38 TL	25 – 37 lvisc	25 – 37 lvisc
7B	Blend 2	N/A	hvisc 33 – 37 TL	25 – 39 TL, neph	25 – 37 TL

## 6.0 SUMMARY

The objective of this report is to document technical information that has been provided to CBU personnel as part of the frit development support for SB4. The information presented in this report includes the resulting projected operating windows (expressed in terms of waste loading) for various sludge blending and/or washing options when coupled with candidate frits of interest. Although the Nominal Stage assessment serves as the primary tool for these evaluations, select systems were also assessed using the Variation Stage in which compositional uncertainties were added. In addition, assessments of the impacts of nepheline formation potential and the  $\text{SO}_4^-$  solubility limit on the projected operating windows are also provided. Although this information was used as part of the technical basis from which the preferred SB4 preparation plan was selected, none of the options presented in this report is the preferred plan. Therefore, the information is presented without significant interpretation but the details are provided so additional insight can be made if desired. Details regarding the evaluation of the preferred preparation plan are documented in Peeler and Edwards (2006).

Although a detailed discussion is not provided, below are some high level observations from the datasets:

- (1) A comparison of the Nominal Stage assessments with the centroids from the Variation Stage assessments shows consistency between the two methods.
- (2) The impact of nepheline formation does not appear to be as significant (in terms of access to upper WLs) as anticipated once compositional variations are applied. In fact, the reduction in upper WLs between the nominal (or centroid) assessment and that for the EV-based evaluation was typically 1 – 3 percentage points. The more severe impact resulted from predictions associated with  $T_L$ .
- (3) The “aggressive” approach taken in the Variation Stage assessment appears to severely impact the WL interval over which all of the EVs could be processed. Applying the  $\pm 1$  wt% value to NiO and MnO coupled with the 7.5% variation applied to  $\text{Fe}_2\text{O}_3$  resulted in significant changes in

the  $T_L$  predictions for select EVs. If the more “traditional” approach were to be taken, the reduction in the operating windows over which all the EVs could be processed would not be as severe and possibly could be defined based on nepheline as anticipated.

- (4) It appears that the “P-series” of frits (i.e., the  $Fe_2O_3$  based) have the possibility to mitigate nepheline formation allowing access to higher WLs for select sludge systems. If true, then one may elect to utilize a  $Fe_2O_3$ -based frit to process one of the high  $Al_2O_3$ -based sludges. This latter statement assumes that there is no negative impact on melt rate and/or waste throughput – critical processing factors that were not addressed in this report.
- (5) With only one exception (i.e., Case 16), projected operating windows for all of the flowsheets considered could be identified using strategic frit development strategies. It is noted that some of the operating windows are relatively small and have maximum WLs that may not meet expectations – but windows do exist.

Frit selection will ultimately be dependent on the strategy (or risks) one elects to take for SB4. More specifically, a conservative (and potentially bounding) strategy would be to avoid nepheline formation altogether through strategic frit development efforts or at least suppress it to WLs of 50% or higher. At these higher WLs, the probability of another property limiting acceptability is extremely high – thus taking nepheline and its potential negative impact out of the SB4 picture. To do this, one may need to reduce the  $Na_2O$  content and/or increase the  $SiO_2$  content of the frit; both of which may lead to relatively slow melt rates. The other extreme would be to push the  $Na_2O$  concentrations in glass to the point at which WL and/or melt rate may be optimized, but this strategy could put DWPF on the edge of compromising product quality – a condition to be avoided. The answer or most appropriate strategy may lie somewhere between these two extremes. That is, one should attempt to balance the probability (or possibility) to mitigate nepheline formation while gaining as much advantage in melt rate and/or WL space as possible. To perform such a balancing act, more information than presented in this report is required (e.g., melt rate information will be critical). The concept of frit selection to meet processing goals is explored more thoroughly in Peeler and Edwards (2006).

## 7.0 REFERENCES

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# Appendix A

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
1	Case 15B - Batch 1	25	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	26	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	27	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	28	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	29	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	30	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	31	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	32	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	33	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	34	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	35	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	36	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	37	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	38	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 1	39	newhv	newhv	newhv	newhv		Neph	
1	Case 15B - Batch 1	40	newhv	newhv	newhv	newhv	Neph	Neph	
1	Case 15B - Batch 1	41	newhv	newhv	newhv	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	42	newhv	newhv	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	43	newhv	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	44	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	45	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	46	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	47	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	48	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	49	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	50	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	51	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	52	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	53	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	54	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	55	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	Neph	TL Neph	Neph
1	Case 15B - Batch 1	56	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 1	57	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 1	58	TL newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 1	59	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 1	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 2	25	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	26	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	27	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	28	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	29	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	30	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	31	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	32	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	33	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	34	newhv	newhv	newhv	newhv			
1	Case 15B - Batch 2	35	newhv	newhv	newhv	TL newhv			
1	Case 15B - Batch 2	36	newhv	newhv	newhv	TL newhv			
1	Case 15B - Batch 2	37	newhv	newhv	newhv	TL newhv			
1	Case 15B - Batch 2	38	TL newhv	newhv	newhv	TL newhv			
1	Case 15B - Batch 2	39	TL newhv	TL newhv	newhv	TL	TL	TL	
1	Case 15B - Batch 2	40	TL newhv	TL newhv	TL newhv	TL	TL	TL	

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 15B - Batch 2	41	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Batch 2	42	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Batch 2	43	TL newhv	TL newhv	TL newhv	TL	TL	TL	TL
1	Case 15B - Batch 2	44	TL newhv	TL newhv	TL newhv	TL	TL	TL Neph	TL
1	Case 15B - Batch 2	45	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL
1	Case 15B - Batch 2	46	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	47	TL newhv	TL newhv	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	48	TL newhv	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	49	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	51	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	52	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	53	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	54	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	55	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	56	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	57	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	58	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	59	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Batch 2	60	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 1	25	newhv	newhv	newhv				
1	Case 15B - Blend 1	26	newhv	newhv	newhv				
1	Case 15B - Blend 1	27	newhv	newhv					
1	Case 15B - Blend 1	28	newhv	newhv					
1	Case 15B - Blend 1	29	newhv	newhv					
1	Case 15B - Blend 1	30	newhv	newhv					
1	Case 15B - Blend 1	31	newhv						
1	Case 15B - Blend 1	32	newhv					newlv	
1	Case 15B - Blend 1	33	newhv					newlv	
1	Case 15B - Blend 1	34						newlv	
1	Case 15B - Blend 1	35						newlv	
1	Case 15B - Blend 1	36						newlv	
1	Case 15B - Blend 1	37						newlv	
1	Case 15B - Blend 1	38						newlv	
1	Case 15B - Blend 1	39					newlv	newlv	
1	Case 15B - Blend 1	40				TL	newlv	newlv	
1	Case 15B - Blend 1	41				TL	newlv	newlv	
1	Case 15B - Blend 1	42	TL			TL	newlv	newlv	newlv
1	Case 15B - Blend 1	43	TL			TL	TL newlv	TL newlv	newlv
1	Case 15B - Blend 1	44	TL	TL		TL	TL newlv	TL newlv	newlv
1	Case 15B - Blend 1	45	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 15B - Blend 1	46	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 15B - Blend 1	47	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 15B - Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 15B - Blend 1	49	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 15B - Blend 1	50	TL	TL	TL	TL newlv	TL newlv	TL newlv Neph	TL newlv
1	Case 15B - Blend 1	51	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv
1	Case 15B - Blend 1	52	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	53	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	54	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	55	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 15B - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	25	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	26	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	27	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	28	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	29	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	30	newhv	newhv	newhv	newhv			
1	Case 15B - Blend 2	31	newhv	newhv	newhv				
1	Case 15B - Blend 2	32	newhv	newhv	newhv				
1	Case 15B - Blend 2	33	newhv	newhv	newhv				
1	Case 15B - Blend 2	34	newhv	newhv	newhv				
1	Case 15B - Blend 2	35	newhv	newhv	newhv				
1	Case 15B - Blend 2	36	newhv	newhv	newhv	TL			
1	Case 15B - Blend 2	37	newhv	newhv	newhv	TL			
1	Case 15B - Blend 2	38	newhv	newhv	newhv	TL			
1	Case 15B - Blend 2	39	TL newhv	newhv	newhv	TL	TL	TL	
1	Case 15B - Blend 2	40	TL newhv	TL newhv	newhv	TL	TL	TL	
1	Case 15B - Blend 2	41	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Blend 2	42	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Blend 2	43	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Blend 2	44	TL newhv	TL newhv	TL	TL	TL	TL	TL
1	Case 15B - Blend 2	45	TL newhv	TL newhv	TL	TL	TL	TL Neph	TL
1	Case 15B - Blend 2	46	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL
1	Case 15B - Blend 2	47	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	48	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	49	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	50	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	51	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 15B - Blend 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Batch 1	25	A1203	A1203	A1203	A1203	A1203 R20	newlv A1203 R20	A1203 R20
1	Case 16 - Batch 1	26	A1203	A1203	A1203 R20	A1203	A1203 R20	Del Gp newlv A1203 R20	Del Gp A1203 R20
1	Case 16 - Batch 1	27	A1203	A1203	A1203	A1203	newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp A1203 R20
1	Case 16 - Batch 1	28	A1203	A1203	A1203	A1203	newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp A1203 R20
1	Case 16 - Batch 1	29	A1203	A1203	A1203	A1203	newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	30	A1203	A1203	A1203	A1203	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	31	A1203	A1203	A1203 R20	A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	32	A1203	A1203	A1203 R20	A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	33	A1203	A1203	A1203 R20	A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	34	A1203	A1203	A1203 R20	newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	35	A1203	A1203 R20	A1203 R20	newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20
1	Case 16 - Batch 1	36	A1203	A1203 R20	Del Gp A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20	Del Gp newlv A1203 R20





**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 16 - Batch 2	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	55	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	56	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	59	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 1	25	newhv	newhv	newhv				
1	Case 16 - Blend 1	26	newhv	newhv					
1	Case 16 - Blend 1	27	newhv	newhv					
1	Case 16 - Blend 1	28	newhv	newhv					
1	Case 16 - Blend 1	29	newhv						
1	Case 16 - Blend 1	30	newhv					newlv	
1	Case 16 - Blend 1	31	newhv					newlv	
1	Case 16 - Blend 1	32						newlv	
1	Case 16 - Blend 1	33						newlv	
1	Case 16 - Blend 1	34						newlv	
1	Case 16 - Blend 1	35				TL		newlv	
1	Case 16 - Blend 1	36	TL			TL		newlv	
1	Case 16 - Blend 1	37	TL	TL		TL	TL newlv	TL newlv	
1	Case 16 - Blend 1	38	TL	TL		TL	TL newlv	TL newlv	
1	Case 16 - Blend 1	39	TL	TL	TL	TL	TL newlv	TL newlv	
1	Case 16 - Blend 1	40	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 16 - Blend 1	41	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 16 - Blend 1	42	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	43	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	44	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	45	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	46	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	47	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	49	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	50	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	51	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	52	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	53	TL	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	54	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	55	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv
1	Case 16 - Blend 1	56	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv
1	Case 16 - Blend 1	57	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	58	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	59	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	25	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	26	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	27	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	28	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	29	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	30	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	31	newhv	newhv	newhv	newhv			
1	Case 16 - Blend 2	32	newhv	newhv	newhv				

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
1	Case 16 - Blend 2	33	newhv	newhv	newhv				
1	Case 16 - Blend 2	34	newhv	newhv	newhv				
1	Case 16 - Blend 2	35	newhv	newhv	newhv				
1	Case 16 - Blend 2	36	newhv	newhv	newhv				
1	Case 16 - Blend 2	37	newhv	newhv	newhv				
1	Case 16 - Blend 2	38	newhv	newhv	newhv				
1	Case 16 - Blend 2	39	newhv	newhv	newhv				
1	Case 16 - Blend 2	40	newhv	newhv	newhv	TL			
1	Case 16 - Blend 2	41	newhv	newhv	newhv	TL			
1	Case 16 - Blend 2	42	newhv	newhv	newhv	TL		TL	
1	Case 16 - Blend 2	43	TL newhv	newhv	newhv	TL	TL	TL Neph	
1	Case 16 - Blend 2	44	TL newhv	TL newhv	TL	TL	TL Neph	TL Neph	
1	Case 16 - Blend 2	45	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL Neph	Neph
1	Case 16 - Blend 2	46	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 16 - Blend 2	47	TL newhv	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 16 - Blend 2	48	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	49	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	50	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	51	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	52	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Blend 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	25	newhv	newhv	newhv	newhv			
1	Case 7 Batch 1	26	newhv	newhv	newhv	newhv			
1	Case 7 Batch 1	27	newhv	newhv	newhv	newhv			
1	Case 7 Batch 1	28	newhv	newhv	newhv	newhv			
1	Case 7 Batch 1	29	newhv	newhv	newhv				
1	Case 7 Batch 1	30	newhv	newhv	newhv				
1	Case 7 Batch 1	31	newhv	newhv	newhv				
1	Case 7 Batch 1	32	newhv	newhv	newhv				
1	Case 7 Batch 1	33	newhv	newhv	newhv				
1	Case 7 Batch 1	34	newhv	newhv	newhv				
1	Case 7 Batch 1	35	newhv	newhv	newhv				
1	Case 7 Batch 1	36	newhv	newhv	newhv				
1	Case 7 Batch 1	37	newhv	newhv	newhv				
1	Case 7 Batch 1	38	newhv	newhv	newhv				
1	Case 7 Batch 1	39	newhv	newhv	newhv				
1	Case 7 Batch 1	40	newhv	newhv	newhv				
1	Case 7 Batch 1	41	newhv	newhv	newhv				
1	Case 7 Batch 1	42	newhv	newhv				Neph	
1	Case 7 Batch 1	43	newhv	newhv		TL	Neph	Neph	
1	Case 7 Batch 1	44	newhv	newhv		TL Neph	Neph	Neph	Neph
1	Case 7 Batch 1	45	newhv		Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 7 Batch 1	46	TL newhv	Neph	Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 7 Batch 1	47	TL newhv Neph	TL Neph	Neph	TL Neph	TL Neph	TL newlv Neph	Neph
1	Case 7 Batch 1	48	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 7 Batch 1	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph
1	Case 7 Batch 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph
1	Case 7 Batch 1	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 2	25	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	26	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	27	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	28	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	29	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	30	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	31	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	32	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	33	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	34	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	35	newhv	newhv	newhv	newhv			
1	Case 7 Batch 2	36	newhv	newhv	newhv	TL newhv			
1	Case 7 Batch 2	37	newhv	newhv	newhv	TL newhv			
1	Case 7 Batch 2	38	TL newhv	newhv	newhv	TL newhv	TL	TL	
1	Case 7 Batch 2	39	TL newhv	newhv	newhv	TL newhv	TL	TL	
1	Case 7 Batch 2	40	TL newhv	TL newhv	newhv	TL newhv	TL	TL	
1	Case 7 Batch 2	41	TL newhv	TL newhv	TL newhv	TL newhv	TL	TL	
1	Case 7 Batch 2	42	TL newhv	TL newhv	TL newhv	TL newhv	TL	TL	
1	Case 7 Batch 2	43	TL newhv	TL newhv	TL newhv	TL newhv	TL	TL	TL
1	Case 7 Batch 2	44	TL newhv	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL
1	Case 7 Batch 2	45	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	46	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	47	TL newhv	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	48	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	49	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	51	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	52	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	55	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	56	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	59	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	60	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 1	25	newhv	newhv	newhv				
1	Case 7 Blend 1	26	newhv	newhv	newhv				
1	Case 7 Blend 1	27	newhv	newhv					
1	Case 7 Blend 1	28	newhv	newhv					

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 7 Blend 1	29	newhv	newhv					
1	Case 7 Blend 1	30	newhv						
1	Case 7 Blend 1	31	newhv					newlv	
1	Case 7 Blend 1	32	newhv					newlv	
1	Case 7 Blend 1	33						newlv	
1	Case 7 Blend 1	34						newlv	
1	Case 7 Blend 1	35						newlv	
1	Case 7 Blend 1	36						newlv	
1	Case 7 Blend 1	37						newlv	
1	Case 7 Blend 1	38						newlv	
1	Case 7 Blend 1	39					newlv	newlv	
1	Case 7 Blend 1	40				TL	newlv	newlv	
1	Case 7 Blend 1	41				TL	newlv	newlv	newlv
1	Case 7 Blend 1	42	TL			TL	newlv	newlv	newlv
1	Case 7 Blend 1	43	TL	TL		TL	TL newlv	TL newlv	newlv
1	Case 7 Blend 1	44	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 7 Blend 1	45	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 7 Blend 1	46	TL	TL	TL	TL	TL newlv	TL newlv	newlv
1	Case 7 Blend 1	47	TL	TL	TL	TL newlv	TL newlv	TL newlv	newlv
1	Case 7 Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 7 Blend 1	49	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 7 Blend 1	50	TL	TL	TL	TL newlv	TL newlv	TL newlv Neph	TL newlv
1	Case 7 Blend 1	51	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv
1	Case 7 Blend 1	52	TL	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	53	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	54	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	25	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	26	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	27	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	28	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	29	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	30	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	31	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	32	newhv	newhv	newhv	newhv			
1	Case 7 Blend 2	33	newhv	newhv	newhv				
1	Case 7 Blend 2	34	newhv	newhv	newhv				
1	Case 7 Blend 2	35	newhv	newhv	newhv				
1	Case 7 Blend 2	36	newhv	newhv	newhv	TL			
1	Case 7 Blend 2	37	newhv	newhv	newhv	TL			
1	Case 7 Blend 2	38	newhv	newhv	newhv	TL			
1	Case 7 Blend 2	39	TL newlv	newhv	newhv	TL	TL	TL	
1	Case 7 Blend 2	40	TL newlv	TL newlv	newhv	TL	TL	TL	
1	Case 7 Blend 2	41	TL newlv	TL newlv	TL newlv	TL	TL	TL	
1	Case 7 Blend 2	42	TL newlv	TL newlv	TL newlv	TL	TL	TL	
1	Case 7 Blend 2	43	TL newlv	TL newlv	TL newlv	TL	TL	TL	
1	Case 7 Blend 2	44	TL newlv	TL newlv	TL newlv	TL	TL	TL	TL

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
1	Case 7 Blend 2	45	TL newhv	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL
1	Case 7 Blend 2	46	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	47	TL newhv	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	48	TL newhv	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	49	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	50	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	51	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	52	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	53	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Blend 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	25	newhv	newhv	newhv				
1	Case 8 - Blend 1	26	newhv	newhv	newhv				
1	Case 8 - Blend 1	27	newhv	newhv	newhv				
1	Case 8 - Blend 1	28	newhv	newhv	newhv				
1	Case 8 - Blend 1	29	newhv	newhv	newhv				
1	Case 8 - Blend 1	30	newhv	newhv					
1	Case 8 - Blend 1	31	newhv	newhv					
1	Case 8 - Blend 1	32	newhv	newhv					
1	Case 8 - Blend 1	33	newhv	newhv					
1	Case 8 - Blend 1	34	newhv						
1	Case 8 - Blend 1	35	newhv						
1	Case 8 - Blend 1	36	newhv					newlv	
1	Case 8 - Blend 1	37						newlv	
1	Case 8 - Blend 1	38						newlv	
1	Case 8 - Blend 1	39				TL		newlv	
1	Case 8 - Blend 1	40				TL		newlv	
1	Case 8 - Blend 1	41	TL			TL	TL	TL newlv	
1	Case 8 - Blend 1	42	TL	TL		TL	TL	TL newlv	
1	Case 8 - Blend 1	43	TL	TL	TL	TL	TL newlv	TL newlv	
1	Case 8 - Blend 1	44	TL	TL	TL	TL	TL newlv	TL newlv	
1	Case 8 - Blend 1	45	TL	TL	TL	TL	TL newlv	TL newlv	
1	Case 8 - Blend 1	46	TL	TL	TL	TL	TL newlv	TL newlv	TL newlv
1	Case 8 - Blend 1	47	TL	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv
1	Case 8 - Blend 1	48	TL	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv
1	Case 8 - Blend 1	49	TL	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	50	TL	TL	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	51	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	57	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	58	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	59	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
1	Case 8 and 8a - Batch 1	25	newhv	newhv	newhv	newhv			
1	Case 8 and 8a - Batch 1	26	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	27	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	28	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	29	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	30	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	31	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	32	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	33	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	34	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	35	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	36	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	37	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	38	newhv	newhv		TL			
1	Case 8 and 8a - Batch 1	39	newhv	newhv		TL			
1	Case 8 and 8a - Batch 1	40	newhv	newhv		TL	TL	TL	
1	Case 8 and 8a - Batch 1	41	TL newhv	newhv		TL	TL	TL	
1	Case 8 and 8a - Batch 1	42	TL newhv	TL		TL	TL	TL	
1	Case 8 and 8a - Batch 1	43	TL newhv	TL	TL	TL	TL	TL	
1	Case 8 and 8a - Batch 1	44	TL newhv	TL	TL	TL	TL	TL newlv Neph	
1	Case 8 and 8a - Batch 1	45	TL newhv	TL	TL	TL	TL Neph	TL newlv Neph	
1	Case 8 and 8a - Batch 1	46	TL	TL	TL	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	47	TL	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	48	TL	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	25	newhv	newhv	newhv				
1	Case 8A - Blend 1	26	newhv	newhv	newhv				
1	Case 8A - Blend 1	27	newhv	newhv	newhv				
1	Case 8A - Blend 1	28	newhv	newhv	newhv				
1	Case 8A - Blend 1	29	newhv	newhv	newhv				
1	Case 8A - Blend 1	30	newhv	newhv	newhv				
1	Case 8A - Blend 1	31	newhv	newhv	newhv				
1	Case 8A - Blend 1	32	newhv	newhv	newhv				
1	Case 8A - Blend 1	33	newhv	newhv	newhv				
1	Case 8A - Blend 1	34	newhv	newhv	newhv				
1	Case 8A - Blend 1	35	newhv	newhv	newhv				
1	Case 8A - Blend 1	36	newhv	newhv	newhv				
1	Case 8A - Blend 1	37	newhv	newhv	newhv				
1	Case 8A - Blend 1	38	newhv	newhv	newhv				
1	Case 8A - Blend 1	39	newhv	newhv		TL		newlv	
1	Case 8A - Blend 1	40	newhv	newhv		TL		newlv	

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
1	Case 8A - Blend 1	41	TL			TL	TL	TL newlv	
1	Case 8A - Blend 1	42	TL	TL		TL	TL	TL newlv	
1	Case 8A - Blend 1	43	TL	TL	TL	TL	TL	TL newlv	
1	Case 8A - Blend 1	44	TL	TL	TL	TL	TL	TL newlv	
1	Case 8A - Blend 1	45	TL	TL	TL	TL	TL	TL newlv	
1	Case 8A - Blend 1	46	TL	TL	TL	TL	TL Neph	TL newlv Neph	TL
1	Case 8A - Blend 1	47	TL	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	48	TL	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	49	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	60	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 1	25	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	26	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	27	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	28	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	29	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	30	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	31	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	32	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	33	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	34	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	35	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	36	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	37	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	38	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	39	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	40	newhv	newhv	newhv	newhv	newhv	Neph	newhv
2	Case 15 Batch 1	41	newhv	newhv	newhv	newhv	newhv Neph	Neph	newhv
2	Case 15 Batch 1	42	newhv	newhv	newhv	newhv Neph	newhv Neph	Neph	newhv Neph
2	Case 15 Batch 1	43	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	newhv Neph	Neph	newhv Neph
2	Case 15 Batch 1	44	newhv	newhv Neph	newhv Neph	TL newhv Neph	newhv Neph	TL Neph	newhv Neph
2	Case 15 Batch 1	45	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	newhv Neph
2	Case 15 Batch 1	46	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	47	TL newhv Neph	newhv Neph	newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	48	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	49	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	51	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	52	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	55	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	56	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
2	Case 15 Batch 1	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	59	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 2	25	newhv	newhv	newhv				
2	Case 15 Batch 2	26	newhv	newhv	newhv				
2	Case 15 Batch 2	27	newhv	newhv	newhv				
2	Case 15 Batch 2	28	newhv	newhv	newhv				
2	Case 15 Batch 2	29	newhv	newhv	newhv				
2	Case 15 Batch 2	30	newhv	newhv	newhv				
2	Case 15 Batch 2	31	newhv	newhv	newhv				
2	Case 15 Batch 2	32	newhv	newhv	newhv				
2	Case 15 Batch 2	33	newhv	newhv	newhv				
2	Case 15 Batch 2	34	newhv	newhv	newhv				
2	Case 15 Batch 2	35	newhv	newhv	newhv				
2	Case 15 Batch 2	36	newhv	newhv					
2	Case 15 Batch 2	37	newhv	newhv					
2	Case 15 Batch 2	38	newhv	newhv					
2	Case 15 Batch 2	39	newhv	newhv		TL			
2	Case 15 Batch 2	40	newhv			TL			
2	Case 15 Batch 2	41	newhv			TL			
2	Case 15 Batch 2	42	TL newhv			TL	TL	TL newlv	
2	Case 15 Batch 2	43	TL	TL		TL	TL	TL newlv	
2	Case 15 Batch 2	44	TL	TL	TL	TL	TL Neph	TL newlv Neph	
2	Case 15 Batch 2	45	TL	TL	TL	TL Neph	TL Neph	TL newlv Neph	
2	Case 15 Batch 2	46	TL	TL	TL	TL Neph	TL Neph	TL newlv Neph	Neph
2	Case 15 Batch 2	47	TL	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	25	newhv	newhv	newhv				
2	Case 15 Blend 1	26	newhv	newhv	newhv				
2	Case 15 Blend 1	27	newhv	newhv	newhv				
2	Case 15 Blend 1	28	newhv	newhv	newhv				
2	Case 15 Blend 1	29	newhv	newhv	newhv				
2	Case 15 Blend 1	30	newhv	newhv	newhv				
2	Case 15 Blend 1	31	newhv	newhv	newhv				
2	Case 15 Blend 1	32	newhv	newhv	newhv				
2	Case 15 Blend 1	33	newhv	newhv	newhv				
2	Case 15 Blend 1	34	newhv	newhv	newhv				
2	Case 15 Blend 1	35	newhv	newhv					
2	Case 15 Blend 1	36	newhv	newhv					



**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
2	Case 15 Blend 1	37	newhv	newhv					
2	Case 15 Blend 1	38	newhv	newhv		TL			
2	Case 15 Blend 1	39	newhv			TL			
2	Case 15 Blend 1	40	newhv			TL			
2	Case 15 Blend 1	41	TL newhv			TL	TL	TL newlv	
2	Case 15 Blend 1	42	TL newhv	TL		TL	TL	TL newlv	
2	Case 15 Blend 1	43	TL	TL	TL	TL	TL	TL newlv	
2	Case 15 Blend 1	44	TL	TL	TL	TL	TL	TL newlv	
2	Case 15 Blend 1	45	TL	TL	TL	TL	TL	TL newlv	
2	Case 15 Blend 1	46	TL	TL	TL	TL	TL	TL newlv	TL
2	Case 15 Blend 1	47	TL	TL	TL	TL	TL	TL newlv	TL
2	Case 15 Blend 1	48	TL	TL	TL	TL	TL Neph	TL newlv Neph	TL
2	Case 15 Blend 1	49	TL	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL
2	Case 15 Blend 1	50	TL	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	51	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	25	newhv	newhv	newhv				
2	Case 15 Blend 2	26	newhv	newhv	newhv				
2	Case 15 Blend 2	27	newhv	newhv	newhv				
2	Case 15 Blend 2	28	newhv	newhv	newhv				
2	Case 15 Blend 2	29	newhv	newhv	newhv				
2	Case 15 Blend 2	30	newhv	newhv	newhv				
2	Case 15 Blend 2	31	newhv	newhv	newhv				
2	Case 15 Blend 2	32	newhv	newhv	newhv				
2	Case 15 Blend 2	33	newhv	newhv	newhv				
2	Case 15 Blend 2	34	newhv	newhv	newhv				
2	Case 15 Blend 2	35	newhv	newhv					
2	Case 15 Blend 2	36	newhv	newhv					
2	Case 15 Blend 2	37	newhv	newhv					
2	Case 15 Blend 2	38	newhv	newhv					
2	Case 15 Blend 2	39	newhv						
2	Case 15 Blend 2	40	newhv			TL			
2	Case 15 Blend 2	41	newhv			TL		newlv	
2	Case 15 Blend 2	42	TL newhv			TL	TL	TL newlv	
2	Case 15 Blend 2	43	TL			TL	TL	TL newlv	
2	Case 15 Blend 2	44	TL	TL		TL	TL	TL newlv Neph	
2	Case 15 Blend 2	45	TL	TL	TL	TL	TL Neph	TL newlv Neph	
2	Case 15 Blend 2	46	TL	TL	TL	TL Neph	TL Neph	TL newlv Neph	Neph
2	Case 15 Blend 2	47	TL	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph
2	Case 15 Blend 2	48	TL	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03 422	0.04 d1-1	0.05 473	0.05 P1-1	0.05 P2-1	0.05 P2-2	0.05 P3-1
2	Case 15 Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	25	newhv	newhv	newhv				
3	Case 7b Batch 1	26	newhv	newhv	newhv				
3	Case 7b Batch 1	27	newhv	newhv	newhv				
3	Case 7b Batch 1	28	newhv	newhv	newhv				
3	Case 7b Batch 1	29	newhv	newhv	newhv				
3	Case 7b Batch 1	30	newhv	newhv	newhv				
3	Case 7b Batch 1	31	newhv	newhv	newhv				
3	Case 7b Batch 1	32	newhv	newhv	newhv				
3	Case 7b Batch 1	33	newhv	newhv	newhv				
3	Case 7b Batch 1	34	newhv	newhv	newhv				
3	Case 7b Batch 1	35	newhv	newhv	newhv				
3	Case 7b Batch 1	36	newhv	newhv					
3	Case 7b Batch 1	37	newhv	newhv					
3	Case 7b Batch 1	38	newhv	newhv					
3	Case 7b Batch 1	39	newhv	newhv					
3	Case 7b Batch 1	40	newhv						
3	Case 7b Batch 1	41	newhv						
3	Case 7b Batch 1	42	newhv					newlv Neph	
3	Case 7b Batch 1	43	newhv			Neph	Neph	newlv Neph	
3	Case 7b Batch 1	44				Neph	Neph	newlv Neph	Neph
3	Case 7b Batch 1	45			Neph	Neph	Neph	newlv Neph	Neph
3	Case 7b Batch 1	46	Neph	Neph	Neph	Neph	Neph	newlv Neph	Neph
3	Case 7b Batch 1	47	Neph	Neph	Neph	TL Neph	Neph	newlv Neph	Neph
3	Case 7b Batch 1	48	Neph	Neph	Neph	TL Neph	Neph	newlv Neph	Neph
3	Case 7b Batch 1	49	Neph	Neph	Neph	TL Neph	TL Neph	TL newlv Neph	Neph
3	Case 7b Batch 1	50	TL Neph	Neph	Neph	TL Neph	TL newlv Neph	TL newlv Neph	Neph
3	Case 7b Batch 1	51	TL Neph	TL Neph	Neph	TL Neph	TL newlv Neph	TL newlv Neph	Neph
3	Case 7b Batch 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	Neph
3	Case 7b Batch 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	newlv Neph
3	Case 7b Batch 1	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	newlv Neph
3	Case 7b Batch 1	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL newlv Neph
3	Case 7b Batch 1	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL newlv Neph
3	Case 7b Batch 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	25	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	26	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	27	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	28	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	29	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	30	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	31	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	32	newhv	newhv	newhv	newhv			

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
3	Case 7b Batch 2	33	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	34	newhv	newhv	newhv	newhv			
3	Case 7b Batch 2	35	newhv	newhv	newhv				
3	Case 7b Batch 2	36	newhv	newhv	newhv				
3	Case 7b Batch 2	37	newhv	newhv	newhv				
3	Case 7b Batch 2	38	newhv	newhv	newhv				
3	Case 7b Batch 2	39	newhv	newhv	newhv	TL			
3	Case 7b Batch 2	40	newhv	newhv	newhv	TL			
3	Case 7b Batch 2	41	newhv	newhv	newhv	TL	TL	TL	
3	Case 7b Batch 2	42	TL newhv	newhv	newhv	TL	TL	TL	
3	Case 7b Batch 2	43	TL newhv	TL newhv	newhv	TL	TL	TL Neph	
3	Case 7b Batch 2	44	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	
3	Case 7b Batch 2	45	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	Neph
3	Case 7b Batch 2	46	TL newhv	TL newhv	TL newhv Neph	TL Neph	TL Neph	TL Neph	Neph
3	Case 7b Batch 2	47	TL newhv	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	48	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	49	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	51	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	52	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	53	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	54	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	55	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 2	56	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 1	25	newhv	newhv	newhv				
3	Case 7b Blend 1	26	newhv	newhv	newhv				
3	Case 7b Blend 1	27	newhv	newhv	newhv				
3	Case 7b Blend 1	28	newhv	newhv					
3	Case 7b Blend 1	29	newhv	newhv					
3	Case 7b Blend 1	30	newhv	newhv					
3	Case 7b Blend 1	31	newhv						
3	Case 7b Blend 1	32	newhv					newlv	
3	Case 7b Blend 1	33	newhv					newlv	
3	Case 7b Blend 1	34						newlv	
3	Case 7b Blend 1	35						newlv	
3	Case 7b Blend 1	36						newlv	
3	Case 7b Blend 1	37						newlv	
3	Case 7b Blend 1	38						newlv	
3	Case 7b Blend 1	39						newlv	
3	Case 7b Blend 1	40					newlv	newlv	
3	Case 7b Blend 1	41				TL	newlv	newlv	
3	Case 7b Blend 1	42				TL	newlv	newlv	newlv
3	Case 7b Blend 1	43				TL	newlv	newlv	newlv
3	Case 7b Blend 1	44	TL			TL	TL newlv	TL newlv	newlv
3	Case 7b Blend 1	45	TL	TL		TL	TL newlv	TL newlv	newlv
3	Case 7b Blend 1	46	TL	TL	TL	TL	TL newlv	TL newlv	newlv
3	Case 7b Blend 1	47	TL	TL	TL	TL	TL newlv	TL newlv	newlv
3	Case 7b Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv Neph	newlv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 1)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.03	0.04	0.05	0.05	0.05	0.05	0.05
			422	d1-1	473	P1-1	P2-1	P2-2	P3-1
3	Case 7b Blend 1	49	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv
3	Case 7b Blend 1	50	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	51	TL	TL	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	52	TL	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	53	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	54	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	55	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	25	newhv	newhv	newhv	newhv			
3	Case 7b Blend 2	26	newhv	newhv	newhv	newhv			
3	Case 7b Blend 2	27	newhv	newhv	newhv	newhv			
3	Case 7b Blend 2	28	newhv	newhv	newhv				
3	Case 7b Blend 2	29	newhv	newhv	newhv				
3	Case 7b Blend 2	30	newhv	newhv	newhv				
3	Case 7b Blend 2	31	newhv	newhv	newhv				
3	Case 7b Blend 2	32	newhv	newhv	newhv				
3	Case 7b Blend 2	33	newhv	newhv	newhv				
3	Case 7b Blend 2	34	newhv	newhv	newhv				
3	Case 7b Blend 2	35	newhv	newhv	newhv				
3	Case 7b Blend 2	36	newhv	newhv	newhv				
3	Case 7b Blend 2	37	newhv	newhv	newhv				
3	Case 7b Blend 2	38	newhv	newhv	newhv				
3	Case 7b Blend 2	39	newhv	newhv	newhv				
3	Case 7b Blend 2	40	newhv	newhv	newhv	TL			
3	Case 7b Blend 2	41	newhv	newhv	newhv	TL			
3	Case 7b Blend 2	42	TL newhv	newhv	newhv	TL	TL	TL	TL
3	Case 7b Blend 2	43	TL newhv	TL newhv	newhv	TL	TL	TL	TL
3	Case 7b Blend 2	44	TL newhv	TL newhv	newhv	TL	TL	TL Neph	
3	Case 7b Blend 2	45	TL newhv	TL	TL	TL Neph	TL Neph	TL Neph	
3	Case 7b Blend 2	46	TL newhv	TL	TL	TL Neph	TL Neph	TL Neph	Neph
3	Case 7b Blend 2	47	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph
3	Case 7b Blend 2	48	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 tl-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 15B - Batch 1	25	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	26	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	27	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	28	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	29	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	30	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	31	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	32	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	33	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	34	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	35	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	36	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	37	newhv	newhv	newhv				newhv
1	Case 15B - Batch 1	38	newhv	newhv	newhv		Neph		newhv
1	Case 15B - Batch 1	39	newhv	newhv	newhv		Neph		newhv
1	Case 15B - Batch 1	40	newhv	newhv	newhv	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	41	newhv	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	42	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	43	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	44	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	45	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	46	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	47	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	48	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	49	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	50	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	51	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	52	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	53	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	54	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	55	newhv Neph	newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	56	newhv Neph	TL newhv Neph	newhv Neph	Neph	Neph	Neph	newhv Neph
1	Case 15B - Batch 1	57	TL newhv Neph	TL newhv Neph	newhv Neph	Neph	TL Neph	Neph	newhv Neph
1	Case 15B - Batch 1	58	TL newhv Neph	TL newhv Neph	newhv Neph	Neph	TL Neph	Neph	newhv Neph
1	Case 15B - Batch 1	59	TL newhv Neph	TL newhv Neph	newhv Neph	TL Neph	TL Neph	Neph	newhv Neph
1	Case 15B - Batch 1	60	TL newhv Neph	TL newhv Neph	newhv Neph	TL Neph	TL Neph	Neph	newhv Neph
1	Case 15B - Batch 2	25	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	26	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	27	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	28	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	29	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	30	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	31	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	32	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	33	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	34	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	35	newhv	newhv	newhv				newhv
1	Case 15B - Batch 2	36	newhv	TL newhv	newhv				newhv
1	Case 15B - Batch 2	37	newhv	TL newhv	newhv				newhv
1	Case 15B - Batch 2	38	TL newhv	TL newhv	newhv				newhv
1	Case 15B - Batch 2	39	TL newhv	TL newhv	newhv		TL		newhv
1	Case 15B - Batch 2	40	TL newhv	TL newhv	newhv	TL	TL		newhv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 tl-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 15B - Batch 2	41	TL newhv	TL newhv	TL newhv	TL	TL		
1	Case 15B - Batch 2	42	TL newhv	TL newhv	TL newhv	TL	TL	TL	
1	Case 15B - Batch 2	43	TL newhv	TL newhv	TL newhv	TL	TL Neph	TL	TL
1	Case 15B - Batch 2	44	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL	TL
1	Case 15B - Batch 2	45	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	46	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	47	TL Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	48	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	49	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	50	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	51	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	52	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	53	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 1	25		newhv					
1	Case 15B - Blend 1	26		newhv					
1	Case 15B - Blend 1	27		newhv					
1	Case 15B - Blend 1	28					newlv		
1	Case 15B - Blend 1	29					newlv		
1	Case 15B - Blend 1	30					newlv		
1	Case 15B - Blend 1	31					newlv		
1	Case 15B - Blend 1	32					newlv		
1	Case 15B - Blend 1	33					newlv		
1	Case 15B - Blend 1	34					newlv		
1	Case 15B - Blend 1	35					newlv		
1	Case 15B - Blend 1	36					newlv		
1	Case 15B - Blend 1	37					newlv		
1	Case 15B - Blend 1	38				newlv	newlv		
1	Case 15B - Blend 1	39				newlv	newlv		
1	Case 15B - Blend 1	40				newlv	newlv		
1	Case 15B - Blend 1	41		TL		newlv	newlv		
1	Case 15B - Blend 1	42		TL		newlv	newlv	newlv	
1	Case 15B - Blend 1	43	TL	TL		newlv	newlv	newlv	
1	Case 15B - Blend 1	44	TL	TL		newlv	TL newlv	newlv	
1	Case 15B - Blend 1	45	TL	TL		TL newlv	TL newlv	newlv	
1	Case 15B - Blend 1	46	TL	TL	TL	TL newlv	TL newlv	newlv	
1	Case 15B - Blend 1	47	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 15B - Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 15B - Blend 1	49	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv	TL newlv
1	Case 15B - Blend 1	50	TL newlv	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv	TL newlv
1	Case 15B - Blend 1	51	TL newlv	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 15B - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	25	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	26	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	27	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	28	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	29	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	30	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	31	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	32	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	33	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	34	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	35	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	36	newhv	newhv	newhv				newhv
1	Case 15B - Blend 2	37	newhv	TL newhv	newhv				newhv
1	Case 15B - Blend 2	38		TL newhv	newhv				newhv
1	Case 15B - Blend 2	39	TL	TL newhv					TL
1	Case 15B - Blend 2	40	TL	TL newhv			TL		TL
1	Case 15B - Blend 2	41	TL	TL newhv		TL	TL		TL
1	Case 15B - Blend 2	42	TL	TL newhv	TL	TL	TL		TL
1	Case 15B - Blend 2	43	TL	TL newhv	TL	TL	TL	TL	TL
1	Case 15B - Blend 2	44	TL	TL newhv	TL	TL	TL Neph	TL	TL
1	Case 15B - Blend 2	45	TL	TL	TL	TL Neph	TL newlv Neph	TL	TL
1	Case 15B - Blend 2	46	TL	TL	TL	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Batch 1	25	A1203	A1203	A1203	A1203 R2O	Del Gp newlv A1203 R2O	A1203 R2O	A1203 R2O
1	Case 16 - Batch 1	26	A1203	A1203	A1203	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	A1203 R2O
1	Case 16 - Batch 1	27	A1203	A1203	A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	A1203 R2O
1	Case 16 - Batch 1	28	A1203	A1203	A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	A1203 R2O
1	Case 16 - Batch 1	29	A1203	A1203	A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	30	A1203	A1203	A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	31	A1203 R2O	A1203 R2O	A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	32	A1203 R2O	A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	33	A1203 R2O	A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	34	A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	35	A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	36	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O





**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 16 - Batch 2	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	55	TL Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	56	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	57	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	58	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	59	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	60	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 1	25		newhv					
1	Case 16 - Blend 1	26							
1	Case 16 - Blend 1	27					newlv		
1	Case 16 - Blend 1	28					newlv		
1	Case 16 - Blend 1	29					newlv		
1	Case 16 - Blend 1	30					newlv		
1	Case 16 - Blend 1	31					newlv		
1	Case 16 - Blend 1	32					newlv		
1	Case 16 - Blend 1	33					newlv		
1	Case 16 - Blend 1	34					newlv		
1	Case 16 - Blend 1	35		TL			newlv		
1	Case 16 - Blend 1	36		TL		newlv	newlv		
1	Case 16 - Blend 1	37	TL	TL		newlv	newlv		
1	Case 16 - Blend 1	38	TL	TL		newlv	newlv		
1	Case 16 - Blend 1	39	TL	TL		TL newlv	TL newlv		
1	Case 16 - Blend 1	40	TL	TL	TL	TL newlv	TL newlv	newlv	
1	Case 16 - Blend 1	41	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	42	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	43	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	44	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	45	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	46	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 16 - Blend 1	47	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	48	TL newlv	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	49	TL newlv	TL	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	50	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	51	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	52	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	53	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	54	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv	TL newlv
1	Case 16 - Blend 1	55	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv	TL newlv
1	Case 16 - Blend 1	56	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv
1	Case 16 - Blend 1	57	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	25	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	26	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	27	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	28	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	29	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	30	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	31	newhv	newhv	newhv				newhv
1	Case 16 - Blend 2	32	newhv	newhv	newhv				newhv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 tl-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 16 - Blend 2	33	newhv	newhv	newhv				
1	Case 16 - Blend 2	34	newhv	newhv	newhv				
1	Case 16 - Blend 2	35	newhv	newhv	newhv				
1	Case 16 - Blend 2	36	newhv	newhv	newhv				
1	Case 16 - Blend 2	37	newhv	newhv	newhv				
1	Case 16 - Blend 2	38	newhv	newhv	newhv				
1	Case 16 - Blend 2	39		newhv					
1	Case 16 - Blend 2	40		newhv					
1	Case 16 - Blend 2	41		TL newhv					
1	Case 16 - Blend 2	42		TL newhv			Neph		
1	Case 16 - Blend 2	43	TL	TL newhv			Neph		
1	Case 16 - Blend 2	44	TL	TL newhv		Neph	TL Neph	Neph	
1	Case 16 - Blend 2	45	TL	TL Neph	Neph	TL Neph	TL Neph	Neph	Neph
1	Case 16 - Blend 2	46	TL Neph	TL Neph	Neph	TL Neph	TL newlv Neph	Neph	Neph
1	Case 16 - Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	Neph
1	Case 16 - Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	25	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	26	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	27	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	28	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	29	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	30	newhv	newhv	newhv				newhv
1	Case 7 Batch 1	31	newhv	newhv	newhv				
1	Case 7 Batch 1	32	newhv	newhv	newhv				
1	Case 7 Batch 1	33	newhv	newhv	newhv				
1	Case 7 Batch 1	34	newhv	newhv	newhv				
1	Case 7 Batch 1	35	newhv	newhv	newhv				
1	Case 7 Batch 1	36		newhv					
1	Case 7 Batch 1	37		newhv					
1	Case 7 Batch 1	38		newhv					
1	Case 7 Batch 1	39		newhv					
1	Case 7 Batch 1	40		newhv					
1	Case 7 Batch 1	41		newhv					
1	Case 7 Batch 1	42					Neph		
1	Case 7 Batch 1	43				Neph	Neph		
1	Case 7 Batch 1	44		TL Neph	Neph	Neph	newlv Neph	Neph	Neph
1	Case 7 Batch 1	45	TL Neph	TL Neph	Neph	Neph	newlv Neph	Neph	Neph
1	Case 7 Batch 1	46	TL Neph	TL Neph	Neph	Neph	TL newlv Neph	Neph	Neph
1	Case 7 Batch 1	47	TL Neph	TL Neph	Neph	TL Neph	TL newlv Neph	Neph	Neph
1	Case 7 Batch 1	48	TL Neph	TL Neph	Neph	TL Neph	TL newlv Neph	Neph	Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 7 Batch 1	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph	Neph
1	Case 7 Batch 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Batch 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 2	25	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	26	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	27	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	28	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	29	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	30	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	31	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	32	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	33	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	34	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	35	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	36	newhv	newhv	newhv				newhv
1	Case 7 Batch 2	37	newhv	TL newhv	newhv				newhv
1	Case 7 Batch 2	38	TL newhv	TL newhv	newhv				newhv
1	Case 7 Batch 2	39	TL newhv	TL newhv	newhv		TL		newhv
1	Case 7 Batch 2	40	TL newhv	TL newhv	newhv	TL	TL		newhv
1	Case 7 Batch 2	41	TL newhv	TL newhv	newhv	TL	TL		newhv
1	Case 7 Batch 2	42	TL newhv	TL newhv	TL newhv	TL	TL	TL	newhv
1	Case 7 Batch 2	43	TL newhv	TL newhv	TL newhv	TL	TL Neph	TL	TL newhv
1	Case 7 Batch 2	44	TL newhv	TL newhv	TL newhv	TL Neph	TL Neph	TL Neph	TL newhv
1	Case 7 Batch 2	45	TL newhv	TL newhv Neph	TL newhv	TL Neph	TL Neph	TL Neph	TL newhv Neph
1	Case 7 Batch 2	46	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL newhv Neph
1	Case 7 Batch 2	47	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	48	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	49	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	51	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	52	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	53	TL Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	54	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	55	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	56	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	57	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	58	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	59	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 1	25		newhv					
1	Case 7 Blend 1	26		newhv					
1	Case 7 Blend 1	27							
1	Case 7 Blend 1	28				newlv			

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 7 Blend 1	29					newlv		
1	Case 7 Blend 1	30					newlv		
1	Case 7 Blend 1	31					newlv		
1	Case 7 Blend 1	32					newlv		
1	Case 7 Blend 1	33					newlv		
1	Case 7 Blend 1	34					newlv		
1	Case 7 Blend 1	35					newlv		
1	Case 7 Blend 1	36					newlv		
1	Case 7 Blend 1	37					newlv		
1	Case 7 Blend 1	38				newlv	newlv		
1	Case 7 Blend 1	39				newlv	newlv		
1	Case 7 Blend 1	40				newlv	newlv		
1	Case 7 Blend 1	41		TL		newlv	newlv	newlv	
1	Case 7 Blend 1	42	TL	TL		newlv	newlv	newlv	
1	Case 7 Blend 1	43	TL	TL		newlv	TL	newlv	
1	Case 7 Blend 1	44	TL	TL		newlv	TL newlv	newlv	
1	Case 7 Blend 1	45	TL	TL		TL newlv	TL newlv	newlv	
1	Case 7 Blend 1	46	TL	TL	TL	TL newlv	TL newlv	newlv	
1	Case 7 Blend 1	47	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL
1	Case 7 Blend 1	48	TL	TL	TL	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 7 Blend 1	49	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv	TL newlv
1	Case 7 Blend 1	50	TL newlv	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv	TL newlv
1	Case 7 Blend 1	51	TL newlv	TL	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	25	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	26	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	27	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	28	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	29	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	30	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	31	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	32	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	33	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	34	newhv	newhv	newhv				newhv
1	Case 7 Blend 2	35	newhv	newhv	newhv				
1	Case 7 Blend 2	36	newhv	newhv	newhv				
1	Case 7 Blend 2	37	newhv	newhv	newhv				
1	Case 7 Blend 2	38	newhv	TL newhv	newhv				
1	Case 7 Blend 2	39	TL newhv	TL newhv	newhv				
1	Case 7 Blend 2	40	TL	TL newhv	newhv		TL		
1	Case 7 Blend 2	41	TL	TL newhv		TL	TL		
1	Case 7 Blend 2	42	TL	TL newhv		TL	TL		
1	Case 7 Blend 2	43	TL	TL newhv	TL	TL	TL	TL	
1	Case 7 Blend 2	44	TL	TL newhv	TL	TL	TL Neph	TL	TL

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 7 Blend 2	45	TL	TL newhv	TL	TL Neph	TL Neph	TL Neph	TL
1	Case 7 Blend 2	46	TL	TL newhv Neph	TL	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 7 Blend 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 - Blend 1	25	newhv	newhv	newhv				
1	Case 8 - Blend 1	26		newhv					
1	Case 8 - Blend 1	27		newhv					
1	Case 8 - Blend 1	28		newhv					
1	Case 8 - Blend 1	29		newhv					
1	Case 8 - Blend 1	30		newhv					
1	Case 8 - Blend 1	31							
1	Case 8 - Blend 1	32					newlv		
1	Case 8 - Blend 1	33					newlv		
1	Case 8 - Blend 1	34					newlv		
1	Case 8 - Blend 1	35					newlv		
1	Case 8 - Blend 1	36					newlv		
1	Case 8 - Blend 1	37					newlv		
1	Case 8 - Blend 1	38					newlv		
1	Case 8 - Blend 1	39		TL			newlv		
1	Case 8 - Blend 1	40		TL			newlv		
1	Case 8 - Blend 1	41	TL	TL			newlv		
1	Case 8 - Blend 1	42	TL	TL		newlv	TL newlv		
1	Case 8 - Blend 1	43	TL	TL		TL newlv	TL newlv		
1	Case 8 - Blend 1	44	TL	TL	TL	TL newlv	TL newlv		
1	Case 8 - Blend 1	45	TL	TL	TL	TL newlv	TL newlv		
1	Case 8 - Blend 1	46	TL	TL	TL	TL newlv	TL newlv Neph	TL newlv	TL
1	Case 8 - Blend 1	47	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv	TL
1	Case 8 - Blend 1	48	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	49	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 - Blend 1	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	54	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	55	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 tl-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 8 and 8a - Batch 1	25	newhv	newhv	newhv				newhv
1	Case 8 and 8a - Batch 1	26	newhv	newhv	newhv				newhv
1	Case 8 and 8a - Batch 1	27	newhv	newhv	newhv				newhv
1	Case 8 and 8a - Batch 1	28	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	29	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	30	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	31	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	32	newhv	newhv	newhv				
1	Case 8 and 8a - Batch 1	33		newhv					
1	Case 8 and 8a - Batch 1	34		newhv					
1	Case 8 and 8a - Batch 1	35		newhv					
1	Case 8 and 8a - Batch 1	36		newhv					
1	Case 8 and 8a - Batch 1	37		newhv					
1	Case 8 and 8a - Batch 1	38		newhv					
1	Case 8 and 8a - Batch 1	39		TL					
1	Case 8 and 8a - Batch 1	40	TL	TL			newlv		
1	Case 8 and 8a - Batch 1	41	TL	TL			TL newlv		
1	Case 8 and 8a - Batch 1	42	TL	TL			TL newlv		
1	Case 8 and 8a - Batch 1	43	TL	TL		TL	TL newlv Neph		
1	Case 8 and 8a - Batch 1	44	TL	TL	TL	TL Neph	TL newlv Neph		
1	Case 8 and 8a - Batch 1	45	TL	TL	TL	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	46	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	25	newhv	newhv	newhv				
1	Case 8A - Blend 1	26	newhv	newhv	newhv				
1	Case 8A - Blend 1	27	newhv	newhv	newhv				
1	Case 8A - Blend 1	28		newhv	newhv				
1	Case 8A - Blend 1	29		newhv					
1	Case 8A - Blend 1	30		newhv					
1	Case 8A - Blend 1	31		newhv					
1	Case 8A - Blend 1	32		newhv					
1	Case 8A - Blend 1	33		newhv					
1	Case 8A - Blend 1	34							
1	Case 8A - Blend 1	35					newlv		
1	Case 8A - Blend 1	36					newlv		
1	Case 8A - Blend 1	37					newlv		
1	Case 8A - Blend 1	38					newlv		
1	Case 8A - Blend 1	39		TL			newlv		
1	Case 8A - Blend 1	40		TL			newlv		

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
1	Case 8A - Blend 1	41	TL	TL				newlv	
1	Case 8A - Blend 1	42	TL	TL				TL newlv	
1	Case 8A - Blend 1	43	TL	TL				TL newlv	
1	Case 8A - Blend 1	44	TL	TL	TL	TL		TL newlv	
1	Case 8A - Blend 1	45	TL	TL	TL	TL		TL newlv Neph	TL
1	Case 8A - Blend 1	46	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL Neph	TL
1	Case 8A - Blend 1	47	TL	TL Neph	TL	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8A - Blend 1	48	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
1	Case 8A - Blend 1	49	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	58	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	59	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 1	25	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	26	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	27	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	28	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	29	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	30	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	31	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	32	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	33	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	34	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	35	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	36	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	37	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	38	newhv	newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	39	newhv	newhv	newhv	newhv	Neph	newhv	newhv
2	Case 15 Batch 1	40	newhv	newhv	newhv	newhv	Neph	newhv	newhv
2	Case 15 Batch 1	41	newhv	newhv	newhv	newhv Neph	Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	42	newhv	newhv Neph	newhv Neph	newhv Neph	Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	43	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	44	newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	45	newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	TL Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	46	TL newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	TL Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	47	TL newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	TL Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	48	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph	TL Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	49	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph	TL Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	50	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL newhv Neph	newhv Neph
2	Case 15 Batch 1	51	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	52	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	55	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	56	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
2	Case 15 Batch 1	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	59	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 2	25	newhv	newhv	newhv				newhv
2	Case 15 Batch 2	26	newhv	newhv	newhv				
2	Case 15 Batch 2	27	newhv	newhv	newhv				
2	Case 15 Batch 2	28	newhv	newhv	newhv				
2	Case 15 Batch 2	29	newhv	newhv	newhv				
2	Case 15 Batch 2	30	newhv	newhv	newhv				
2	Case 15 Batch 2	31		newhv					
2	Case 15 Batch 2	32		newhv					
2	Case 15 Batch 2	33		newhv					
2	Case 15 Batch 2	34		newhv					
2	Case 15 Batch 2	35		newhv					
2	Case 15 Batch 2	36		newhv					
2	Case 15 Batch 2	37					newlv		
2	Case 15 Batch 2	38					newlv		
2	Case 15 Batch 2	39					newlv		
2	Case 15 Batch 2	40		TL			newlv		
2	Case 15 Batch 2	41		TL			newlv		
2	Case 15 Batch 2	42	TL	TL			newlv		
2	Case 15 Batch 2	43	TL	TL			TL newlv Neph		
2	Case 15 Batch 2	44	TL	TL		TL Neph	TL newlv Neph		
2	Case 15 Batch 2	45	TL	TL Neph		TL Neph	TL newlv Neph	Neph	Neph
2	Case 15 Batch 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	Neph
2	Case 15 Batch 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Batch 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Batch 2	49	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Batch 2	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Batch 2	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Batch 2	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	25	newhv	newhv	newhv				newhv
2	Case 15 Blend 1	26	newhv	newhv	newhv				
2	Case 15 Blend 1	27	newhv	newhv	newhv				
2	Case 15 Blend 1	28	newhv	newhv	newhv				
2	Case 15 Blend 1	29	newhv	newhv	newhv				
2	Case 15 Blend 1	30		newhv	newhv				
2	Case 15 Blend 1	31		newhv					
2	Case 15 Blend 1	32		newhv					
2	Case 15 Blend 1	33		newhv					
2	Case 15 Blend 1	34		newhv					
2	Case 15 Blend 1	35		newhv					
2	Case 15 Blend 1	36							



**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
2	Case 15 Blend 1	37						newlv	
2	Case 15 Blend 1	38						newlv	
2	Case 15 Blend 1	39		TL				newlv	
2	Case 15 Blend 1	40		TL				newlv	
2	Case 15 Blend 1	41	TL	TL				newlv	
2	Case 15 Blend 1	42	TL	TL				TL newlv	
2	Case 15 Blend 1	43	TL	TL		TL		TL newlv	
2	Case 15 Blend 1	44	TL	TL	TL	TL		TL newlv	
2	Case 15 Blend 1	45	TL	TL	TL	TL		TL newlv	TL
2	Case 15 Blend 1	46	TL	TL	TL	TL		TL newlv	TL
2	Case 15 Blend 1	47	TL	TL	TL	TL		TL newlv Neph	TL
2	Case 15 Blend 1	48	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL	TL
2	Case 15 Blend 1	49	TL	TL Neph	TL	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 1	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 1	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 1	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	60	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	25	newhv	newhv	newhv				
2	Case 15 Blend 2	26	newhv	newhv	newhv				
2	Case 15 Blend 2	27	newhv	newhv	newhv				
2	Case 15 Blend 2	28	newhv	newhv	newhv				
2	Case 15 Blend 2	29	newhv	newhv	newhv				
2	Case 15 Blend 2	30		newhv	newhv				
2	Case 15 Blend 2	31		newhv					
2	Case 15 Blend 2	32		newhv					
2	Case 15 Blend 2	33		newhv					
2	Case 15 Blend 2	34		newhv					
2	Case 15 Blend 2	35		newhv					
2	Case 15 Blend 2	36						newlv	
2	Case 15 Blend 2	37						newlv	
2	Case 15 Blend 2	38						newlv	
2	Case 15 Blend 2	39						newlv	
2	Case 15 Blend 2	40						newlv	
2	Case 15 Blend 2	41		TL				newlv	
2	Case 15 Blend 2	42	TL	TL				newlv	
2	Case 15 Blend 2	43	TL	TL				TL newlv Neph	
2	Case 15 Blend 2	44	TL	TL		Neph		TL newlv Neph	
2	Case 15 Blend 2	45	TL	TL		TL Neph	TL newlv Neph	Neph	Neph
2	Case 15 Blend 2	46	TL	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph	Neph
2	Case 15 Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 2	48	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Blend 2	49	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 2	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 2	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
2	Case 15 Blend 2	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	60	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	25	newhv	newhv	newhv				newhv
3	Case 7b Batch 1	26	newhv	newhv	newhv				
3	Case 7b Batch 1	27	newhv	newhv	newhv				
3	Case 7b Batch 1	28	newhv	newhv	newhv				
3	Case 7b Batch 1	29	newhv	newhv	newhv				
3	Case 7b Batch 1	30	newhv	newhv	newhv				
3	Case 7b Batch 1	31		newhv	newhv				
3	Case 7b Batch 1	32		newhv					
3	Case 7b Batch 1	33		newhv					
3	Case 7b Batch 1	34		newhv					
3	Case 7b Batch 1	35		newhv					
3	Case 7b Batch 1	36		newhv					
3	Case 7b Batch 1	37							
3	Case 7b Batch 1	38					newlv		
3	Case 7b Batch 1	39					newlv		
3	Case 7b Batch 1	40					newlv		
3	Case 7b Batch 1	41					newlv Neph		
3	Case 7b Batch 1	42				Neph	newlv Neph		
3	Case 7b Batch 1	43		Neph		Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	44	Neph	Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	45	Neph	Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	46	Neph	Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	47	Neph	Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	48	Neph	TL Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	49	Neph	TL Neph	Neph	Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	50	TL Neph	TL Neph	Neph	newlv Neph	newlv Neph	Neph	Neph
3	Case 7b Batch 1	51	TL Neph	TL Neph	Neph	newlv Neph	TL newlv Neph	Neph	Neph
3	Case 7b Batch 1	52	TL Neph	TL Neph	Neph	TL newlv Neph	TL newlv Neph	Neph	Neph
3	Case 7b Batch 1	53	TL Neph	TL Neph	Neph	TL newlv Neph	TL newlv Neph	newlv Neph	Neph
3	Case 7b Batch 1	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Neph
3	Case 7b Batch 1	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 1	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 1	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 1	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 1	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Batch 1	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	25	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	26	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	27	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	28	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	29	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	30	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	31	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	32	newhv	newhv	newhv				newhv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 tl-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
3	Case 7b Batch 2	33	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	34	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	35	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	36	newhv	newhv	newhv				newhv
3	Case 7b Batch 2	37	newhv	newhv	newhv				
3	Case 7b Batch 2	38	newhv	newhv	newhv				
3	Case 7b Batch 2	39	newhv	newhv	newhv				
3	Case 7b Batch 2	40	newhv	TL newhv	newhv				
3	Case 7b Batch 2	41	TL newhv	TL newhv	newhv				
3	Case 7b Batch 2	42	TL newhv	TL newhv	newhv		TL Neph		
3	Case 7b Batch 2	43	TL	TL newhv	newhv	TL Neph	TL Neph		
3	Case 7b Batch 2	44	TL	TL newhv		TL Neph	TL Neph	Neph	Neph
3	Case 7b Batch 2	45	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	Neph	Neph
3	Case 7b Batch 2	46	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	47	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	48	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	49	TL Neph	TL newhv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 1	25		newhv					
3	Case 7b Blend 1	26		newhv					
3	Case 7b Blend 1	27		newhv					
3	Case 7b Blend 1	28							
3	Case 7b Blend 1	29					newlv		
3	Case 7b Blend 1	30					newlv		
3	Case 7b Blend 1	31					newlv		
3	Case 7b Blend 1	32					newlv		
3	Case 7b Blend 1	33					newlv		
3	Case 7b Blend 1	34					newlv		
3	Case 7b Blend 1	35					newlv		
3	Case 7b Blend 1	36					newlv		
3	Case 7b Blend 1	37					newlv		
3	Case 7b Blend 1	38					newlv		
3	Case 7b Blend 1	39				newlv	newlv		
3	Case 7b Blend 1	40				newlv	newlv		
3	Case 7b Blend 1	41				newlv	newlv		
3	Case 7b Blend 1	42		TL		newlv	newlv	newlv	
3	Case 7b Blend 1	43		TL		newlv	newlv	newlv	
3	Case 7b Blend 1	44	TL	TL		newlv	newlv	newlv	
3	Case 7b Blend 1	45	TL	TL		newlv	TL newlv	newlv	
3	Case 7b Blend 1	46	TL	TL		TL newlv	TL newlv	newlv	
3	Case 7b Blend 1	47	TL	TL	TL	TL newlv	TL newlv Neph	newlv	
3	Case 7b Blend 1	48	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv	TL

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 2)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.05 t1-1	0.06 202	0.06 432	0.06 P2-3	0.06 P2-4	0.06 P3-2	0.07 460
3	Case 7b Blend 1	49	TL	TL	TL	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	51	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	52	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	25	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	26	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	27	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	28	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	29	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	30	newhv	newhv	newhv				newhv
3	Case 7b Blend 2	31	newhv	newhv	newhv				
3	Case 7b Blend 2	32	newhv	newhv	newhv				
3	Case 7b Blend 2	33	newhv	newhv	newhv				
3	Case 7b Blend 2	34	newhv	newhv	newhv				
3	Case 7b Blend 2	35		newhv	newhv				
3	Case 7b Blend 2	36		newhv	newhv				
3	Case 7b Blend 2	37		newhv					
3	Case 7b Blend 2	38		newhv					
3	Case 7b Blend 2	39		newhv					
3	Case 7b Blend 2	40		newhv					
3	Case 7b Blend 2	41		TL					
3	Case 7b Blend 2	42	TL	TL			newlv		
3	Case 7b Blend 2	43	TL	TL			TL newlv Neph		
3	Case 7b Blend 2	44	TL	TL		TL Neph	TL newlv Neph		
3	Case 7b Blend 2	45	TL	TL		TL Neph	TL newlv Neph	Neph	Neph
3	Case 7b Blend 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	Neph	Neph
3	Case 7b Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph
3	Case 7b Blend 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	60	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 15B - Batch 1	25				newhv	newhv		newhv
1	Case 15B - Batch 1	26				newhv	newhv		newhv
1	Case 15B - Batch 1	27				newhv	newhv		newhv
1	Case 15B - Batch 1	28				newhv	newhv		newhv
1	Case 15B - Batch 1	29				newhv	newhv		newhv
1	Case 15B - Batch 1	30				newhv	newhv		newhv
1	Case 15B - Batch 1	31				newhv	newhv		newhv
1	Case 15B - Batch 1	32				newhv	newhv		newhv
1	Case 15B - Batch 1	33				newhv	newhv		newhv
1	Case 15B - Batch 1	34				newhv	newhv		newhv
1	Case 15B - Batch 1	35				newhv	newhv		newhv Neph
1	Case 15B - Batch 1	36				newhv	newhv		newhv Neph
1	Case 15B - Batch 1	37				newhv	newhv	Neph	newhv Neph
1	Case 15B - Batch 1	38		Neph		newhv	newhv Neph	Neph	newhv Neph
1	Case 15B - Batch 1	39		Neph	Neph	newhv	newhv Neph	Neph	newhv Neph
1	Case 15B - Batch 1	40		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	41		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	42		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	43		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	44		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	45		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	46		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	47		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	48		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	49		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	50		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	51		Neph	Neph	Neph	newhv Neph	newhv Neph	Neph
1	Case 15B - Batch 1	52		Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	53		Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	54		Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	55		Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	56		Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	57		TL Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	58		TL Neph	Neph	Neph	newhv Neph	Neph	Neph
1	Case 15B - Batch 1	59		TL Neph	Neph	Neph	newhv Neph	Neph	TL Neph
1	Case 15B - Batch 1	60		TL Neph	Neph	Neph	newhv Neph	Neph	TL Neph
1	Case 15B - Batch 2	25				newhv			newhv
1	Case 15B - Batch 2	26				newhv			
1	Case 15B - Batch 2	27				newhv			
1	Case 15B - Batch 2	28				newhv			
1	Case 15B - Batch 2	29				newhv			
1	Case 15B - Batch 2	30				newhv			
1	Case 15B - Batch 2	31				newhv			
1	Case 15B - Batch 2	32				newhv			
1	Case 15B - Batch 2	33							
1	Case 15B - Batch 2	34							
1	Case 15B - Batch 2	35							
1	Case 15B - Batch 2	36							
1	Case 15B - Batch 2	37							
1	Case 15B - Batch 2	38							
1	Case 15B - Batch 2	39		TL					Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 15B - Batch 2	40	TL						TL Neph
1	Case 15B - Batch 2	41	TL						TL Neph
1	Case 15B - Batch 2	42	TL Neph					Neph	TL Neph
1	Case 15B - Batch 2	43	TL Neph	TL			Neph	Neph	TL Neph
1	Case 15B - Batch 2	44	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 15B - Batch 2	45	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	58	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	59	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Batch 2	60	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 1	25							
1	Case 15B - Blend 1	26							
1	Case 15B - Blend 1	27							
1	Case 15B - Blend 1	28							
1	Case 15B - Blend 1	29							
1	Case 15B - Blend 1	30							
1	Case 15B - Blend 1	31	newlv						
1	Case 15B - Blend 1	32	newlv						
1	Case 15B - Blend 1	33	newlv						
1	Case 15B - Blend 1	34	newlv						
1	Case 15B - Blend 1	35	newlv						
1	Case 15B - Blend 1	36	newlv						
1	Case 15B - Blend 1	37	newlv						
1	Case 15B - Blend 1	38	newlv						
1	Case 15B - Blend 1	39	newlv	newlv					
1	Case 15B - Blend 1	40	newlv	newlv					
1	Case 15B - Blend 1	41	newlv	newlv	newlv				
1	Case 15B - Blend 1	42	newlv	newlv	newlv			newlv	
1	Case 15B - Blend 1	43	newlv	newlv	newlv			newlv	newlv
1	Case 15B - Blend 1	44	TL newlv	newlv	newlv		newlv	newlv	TL newlv
1	Case 15B - Blend 1	45	TL newlv	newlv	newlv		newlv	newlv	TL newlv Neph
1	Case 15B - Blend 1	46	TL newlv	newlv	newlv		newlv	newlv	TL newlv Neph
1	Case 15B - Blend 1	47	TL newlv	newlv	newlv	newlv	newlv	newlv	TL newlv Neph
1	Case 15B - Blend 1	48	TL newlv Neph	TL newlv	newlv	TL newlv	newlv	newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	49	TL newlv Neph	TL newlv	TL newlv	TL newlv	TL newlv Neph	newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	50	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 15B - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	25							
1	Case 15B - Blend 2	26							
1	Case 15B - Blend 2	27							
1	Case 15B - Blend 2	28							
1	Case 15B - Blend 2	29							
1	Case 15B - Blend 2	30							
1	Case 15B - Blend 2	31							
1	Case 15B - Blend 2	32							
1	Case 15B - Blend 2	33							
1	Case 15B - Blend 2	34							
1	Case 15B - Blend 2	35							
1	Case 15B - Blend 2	36							
1	Case 15B - Blend 2	37							
1	Case 15B - Blend 2	38							
1	Case 15B - Blend 2	39							
1	Case 15B - Blend 2	40	TL						Neph
1	Case 15B - Blend 2	41	TL						TL Neph
1	Case 15B - Blend 2	42	TL						TL Neph
1	Case 15B - Blend 2	43	TL Neph					Neph	TL Neph
1	Case 15B - Blend 2	44	TL Neph	TL		TL	Neph	Neph	TL Neph
1	Case 15B - Blend 2	45	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 15B - Blend 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	49	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	50	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	51	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	52	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	53	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	55	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	56	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	57	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	58	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 15B - Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 16 - Batch 1	25	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	26	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	27	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	28	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	29	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O
1	Case 16 - Batch 1	30	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O
1	Case 16 - Batch 1	31	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O
1	Case 16 - Batch 1	32	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O
1	Case 16 - Batch 1	33	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O	Del Gp newlv A1203 R2O





**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 16 - Batch 2	49	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Batch 2	50	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Batch 2	51	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Batch 2	52	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Batch 2	53	TL Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph
1	Case 16 - Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 16 - Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 1	25							
1	Case 16 - Blend 1	26							
1	Case 16 - Blend 1	27							
1	Case 16 - Blend 1	28							
1	Case 16 - Blend 1	29		newlv					
1	Case 16 - Blend 1	30		newlv					
1	Case 16 - Blend 1	31		newlv					
1	Case 16 - Blend 1	32		newlv					
1	Case 16 - Blend 1	33		newlv					
1	Case 16 - Blend 1	34		newlv					
1	Case 16 - Blend 1	35		newlv					
1	Case 16 - Blend 1	36		newlv					
1	Case 16 - Blend 1	37		newlv	newlv				
1	Case 16 - Blend 1	38		newlv	newlv				
1	Case 16 - Blend 1	39		TL newlv	newlv	newlv			TL
1	Case 16 - Blend 1	40		TL newlv	newlv	newlv		newlv	TL
1	Case 16 - Blend 1	41		TL newlv	newlv	newlv		newlv	TL newlv
1	Case 16 - Blend 1	42		TL newlv	TL newlv	TL	newlv	newlv	TL newlv
1	Case 16 - Blend 1	43		TL newlv	TL newlv	TL	TL newlv	newlv	TL newlv
1	Case 16 - Blend 1	44		TL newlv	TL newlv	TL	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	45		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	46		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	47		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	48		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	49		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	50		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv
1	Case 16 - Blend 1	51		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph
1	Case 16 - Blend 1	52		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph
1	Case 16 - Blend 1	53		TL newlv	TL newlv	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	54		TL newlv Neph	TL newlv	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	55		TL newlv Neph	TL newlv Neph	TL newlv	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	56		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	57		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	58		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	59		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 1	60		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	25				newhv			
1	Case 16 - Blend 2	26							
1	Case 16 - Blend 2	27							

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 16 - Blend 2	28							
1	Case 16 - Blend 2	29							
1	Case 16 - Blend 2	30							
1	Case 16 - Blend 2	31							
1	Case 16 - Blend 2	32							
1	Case 16 - Blend 2	33							
1	Case 16 - Blend 2	34							
1	Case 16 - Blend 2	35							
1	Case 16 - Blend 2	36							
1	Case 16 - Blend 2	37							
1	Case 16 - Blend 2	38							
1	Case 16 - Blend 2	39							Neph
1	Case 16 - Blend 2	40							Neph
1	Case 16 - Blend 2	41						Neph	Neph
1	Case 16 - Blend 2	42	Neph				Neph	Neph	Neph
1	Case 16 - Blend 2	43	Neph	Neph			Neph	Neph	Neph
1	Case 16 - Blend 2	44	TL Neph	Neph	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Blend 2	45	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Blend 2	46	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Blend 2	47	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Blend 2	48	TL Neph	TL Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 16 - Blend 2	49	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph	Neph	Neph	TL Neph
1	Case 16 - Blend 2	50	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	51	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	52	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	53	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	55	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	56	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	57	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	59	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 16 - Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	25							
1	Case 7 Batch 1	26							
1	Case 7 Batch 1	27							
1	Case 7 Batch 1	28							
1	Case 7 Batch 1	29							
1	Case 7 Batch 1	30							
1	Case 7 Batch 1	31							
1	Case 7 Batch 1	32							
1	Case 7 Batch 1	33							
1	Case 7 Batch 1	34							
1	Case 7 Batch 1	35							
1	Case 7 Batch 1	36							
1	Case 7 Batch 1	37							
1	Case 7 Batch 1	38							Neph
1	Case 7 Batch 1	39							Neph
1	Case 7 Batch 1	40						Neph	Neph
1	Case 7 Batch 1	41	Neph				Neph	Neph	Neph
1	Case 7 Batch 1	42	Neph	Neph		Neph	Neph	Neph	Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 7 Batch 1	43	Neph	Neph	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 1	44	Neph	Neph	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 1	45	Neph	Neph	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 1	46	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 1	47	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 7 Batch 1	48	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 7 Batch 1	49	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 7 Batch 1	50	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 7 Batch 1	51	TL newlv Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph
1	Case 7 Batch 1	52	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 7 Batch 1	53	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 7 Batch 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 2	25				newhv	newhv		newhv
1	Case 7 Batch 2	26				newhv			newhv
1	Case 7 Batch 2	27				newhv			newhv
1	Case 7 Batch 2	28				newhv			newhv
1	Case 7 Batch 2	29				newhv			newhv
1	Case 7 Batch 2	30				newhv			
1	Case 7 Batch 2	31				newhv			
1	Case 7 Batch 2	32				newhv			
1	Case 7 Batch 2	33				newhv			
1	Case 7 Batch 2	34				newhv			
1	Case 7 Batch 2	35				newhv			
1	Case 7 Batch 2	36				newhv			
1	Case 7 Batch 2	37				newhv			
1	Case 7 Batch 2	38							
1	Case 7 Batch 2	39	TL						Neph
1	Case 7 Batch 2	40	TL						TL Neph
1	Case 7 Batch 2	41	TL					Neph	TL Neph
1	Case 7 Batch 2	42	TL Neph					Neph	TL Neph
1	Case 7 Batch 2	43	TL Neph	TL Neph			Neph	Neph	TL Neph
1	Case 7 Batch 2	44	TL Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph
1	Case 7 Batch 2	45	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 7 Batch 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 7 Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 1	25							
1	Case 7 Blend 1	26							
1	Case 7 Blend 1	27							
1	Case 7 Blend 1	28							
1	Case 7 Blend 1	29							
1	Case 7 Blend 1	30	newlv						
1	Case 7 Blend 1	31	newlv						
1	Case 7 Blend 1	32	newlv						
1	Case 7 Blend 1	33	newlv						
1	Case 7 Blend 1	34	newlv						
1	Case 7 Blend 1	35	newlv						
1	Case 7 Blend 1	36	newlv						
1	Case 7 Blend 1	37	newlv						
1	Case 7 Blend 1	38	newlv	newlv					
1	Case 7 Blend 1	39	newlv	newlv					
1	Case 7 Blend 1	40	newlv	newlv	newlv				
1	Case 7 Blend 1	41	newlv	newlv	newlv			newlv	
1	Case 7 Blend 1	42	newlv	newlv	newlv			newlv	
1	Case 7 Blend 1	43	newlv	newlv	newlv			newlv	newlv
1	Case 7 Blend 1	44	TL newlv	newlv	newlv		newlv	newlv	TL newlv
1	Case 7 Blend 1	45	TL newlv	newlv	newlv		newlv	newlv	TL newlv Neph
1	Case 7 Blend 1	46	TL newlv	newlv	newlv	newlv	newlv	newlv	TL newlv Neph
1	Case 7 Blend 1	47	TL newlv	newlv	newlv	newlv	newlv	newlv	TL newlv Neph
1	Case 7 Blend 1	48	TL newlv Neph	TL newlv	newlv	TL newlv	newlv	newlv Neph	TL newlv Neph
1	Case 7 Blend 1	49	TL newlv Neph	TL newlv	TL newlv	TL newlv	TL newlv Neph	newlv Neph	TL newlv Neph
1	Case 7 Blend 1	50	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	25				newhv			
1	Case 7 Blend 2	26				newhv			
1	Case 7 Blend 2	27							
1	Case 7 Blend 2	28							
1	Case 7 Blend 2	29							
1	Case 7 Blend 2	30							
1	Case 7 Blend 2	31							
1	Case 7 Blend 2	32							
1	Case 7 Blend 2	33							
1	Case 7 Blend 2	34							
1	Case 7 Blend 2	35							
1	Case 7 Blend 2	36							

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 7 Blend 2	37							
1	Case 7 Blend 2	38							
1	Case 7 Blend 2	39							
1	Case 7 Blend 2	40	TL						Neph
1	Case 7 Blend 2	41	TL						TL Neph
1	Case 7 Blend 2	42	TL					Neph	TL Neph
1	Case 7 Blend 2	43	TL Neph					Neph	TL Neph
1	Case 7 Blend 2	44	TL Neph	TL Neph			Neph	Neph	TL Neph
1	Case 7 Blend 2	45	TL Neph	TL Neph	TL Neph	TL Neph	Neph	Neph	TL Neph
1	Case 7 Blend 2	46	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 7 Blend 2	47	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	51	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	52	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	53	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	55	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	56	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	57	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	58	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	59	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Blend 2	60	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 - Blend 1	25							
1	Case 8 - Blend 1	26							
1	Case 8 - Blend 1	27							
1	Case 8 - Blend 1	28							
1	Case 8 - Blend 1	29							
1	Case 8 - Blend 1	30							
1	Case 8 - Blend 1	31							
1	Case 8 - Blend 1	32							
1	Case 8 - Blend 1	33							
1	Case 8 - Blend 1	34	newlv						
1	Case 8 - Blend 1	35	newlv						
1	Case 8 - Blend 1	36	newlv						
1	Case 8 - Blend 1	37	newlv						
1	Case 8 - Blend 1	38	newlv						
1	Case 8 - Blend 1	39	newlv						
1	Case 8 - Blend 1	40	newlv						
1	Case 8 - Blend 1	41	newlv						
1	Case 8 - Blend 1	42	newlv						
1	Case 8 - Blend 1	43	TL newlv	newlv					TL Neph
1	Case 8 - Blend 1	44	TL newlv	newlv					TL Neph
1	Case 8 - Blend 1	45	TL newlv Neph	newlv	newlv			Neph	TL Neph
1	Case 8 - Blend 1	46	TL newlv Neph	newlv	newlv		Neph	newlv Neph	TL Neph
1	Case 8 - Blend 1	47	TL newlv Neph	TL newlv Neph	newlv Neph	TL Neph	Neph	newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	48	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	49	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	50	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 8 - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	25							
1	Case 8 and 8a - Batch 1	26							
1	Case 8 and 8a - Batch 1	27							
1	Case 8 and 8a - Batch 1	28							
1	Case 8 and 8a - Batch 1	29							
1	Case 8 and 8a - Batch 1	30							
1	Case 8 and 8a - Batch 1	31							
1	Case 8 and 8a - Batch 1	32							
1	Case 8 and 8a - Batch 1	33							
1	Case 8 and 8a - Batch 1	34							
1	Case 8 and 8a - Batch 1	35							
1	Case 8 and 8a - Batch 1	36							
1	Case 8 and 8a - Batch 1	37							
1	Case 8 and 8a - Batch 1	38							
1	Case 8 and 8a - Batch 1	39							
1	Case 8 and 8a - Batch 1	40							Neph
1	Case 8 and 8a - Batch 1	41							Neph
1	Case 8 and 8a - Batch 1	42	TL Neph					Neph	TL Neph
1	Case 8 and 8a - Batch 1	43	TL newlv Neph				Neph	Neph	TL Neph
1	Case 8 and 8a - Batch 1	44	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 8 and 8a - Batch 1	45	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
1	Case 8 and 8a - Batch 1	46	TL newlv Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph
1	Case 8 and 8a - Batch 1	47	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 8 and 8a - Batch 1	48	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	49	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	50	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	51	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	52	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	53	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 8 and 8a - Batch 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8 and 8a - Batch 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	25							
1	Case 8A - Blend 1	26							
1	Case 8A - Blend 1	27							
1	Case 8A - Blend 1	28							
1	Case 8A - Blend 1	29							
1	Case 8A - Blend 1	30							

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
1	Case 8A - Blend 1	31							
1	Case 8A - Blend 1	32							
1	Case 8A - Blend 1	33							
1	Case 8A - Blend 1	34							
1	Case 8A - Blend 1	35							
1	Case 8A - Blend 1	36							
1	Case 8A - Blend 1	37		newlv					
1	Case 8A - Blend 1	38		newlv					
1	Case 8A - Blend 1	39		newlv					
1	Case 8A - Blend 1	40		newlv					
1	Case 8A - Blend 1	41		newlv					Neph
1	Case 8A - Blend 1	42		TL newlv					Neph
1	Case 8A - Blend 1	43		TL newlv				Neph	TL Neph
1	Case 8A - Blend 1	44		TL newlv Neph				Neph	TL Neph
1	Case 8A - Blend 1	45		TL newlv Neph	Neph		Neph	Neph	TL Neph
1	Case 8A - Blend 1	46		TL newlv Neph	newlv Neph	Neph	Neph	Neph	TL Neph
1	Case 8A - Blend 1	47		TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	Neph	TL Neph
1	Case 8A - Blend 1	48		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph
1	Case 8A - Blend 1	49		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph
1	Case 8A - Blend 1	50		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 8A - Blend 1	51		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 8A - Blend 1	52		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	53		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	54		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	55		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	56		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	57		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	58		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	59		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	60		TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 1	25		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	26		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	27		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	28		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	29		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	30		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	31		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	32		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	33		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	34		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	35		newhv	newhv	newhv	newhv	newhv	newhv
2	Case 15 Batch 1	36		newhv	newhv	newhv	newhv	newhv	newhv Neph
2	Case 15 Batch 1	37		newhv	newhv	newhv	newhv	newhv	newhv Neph
2	Case 15 Batch 1	38		newhv	newhv	newhv	newhv	newhv Neph	newhv Neph
2	Case 15 Batch 1	39		Neph	newhv	newhv	newhv	newhv Neph	newhv Neph
2	Case 15 Batch 1	40		Neph	newhv Neph	newhv	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	41		Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	42		Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	43		Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	44		Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	45		Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
2	Case 15 Batch 1	46	TL Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	47	TL Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph
2	Case 15 Batch 1	48	TL newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	49	TL newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	50	TL newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	51	TL newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	52	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	53	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	newhv Neph	TL newhv Neph
2	Case 15 Batch 1	54	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	55	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	56	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	59	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 2	25							
2	Case 15 Batch 2	26							
2	Case 15 Batch 2	27							
2	Case 15 Batch 2	28							
2	Case 15 Batch 2	29							
2	Case 15 Batch 2	30							
2	Case 15 Batch 2	31							
2	Case 15 Batch 2	32							
2	Case 15 Batch 2	33							
2	Case 15 Batch 2	34							
2	Case 15 Batch 2	35							
2	Case 15 Batch 2	36							
2	Case 15 Batch 2	37							
2	Case 15 Batch 2	38							
2	Case 15 Batch 2	39							Neph
2	Case 15 Batch 2	40	newlv						Neph
2	Case 15 Batch 2	41	newlv						Neph
2	Case 15 Batch 2	42	newlv Neph					Neph	Neph
2	Case 15 Batch 2	43	TL newlv Neph				Neph	Neph	Neph
2	Case 15 Batch 2	44	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Batch 2	45	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Batch 2	46	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Batch 2	47	TL newlv Neph	TL Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Batch 2	48	TL newlv Neph	TL Neph	TL Neph	TL Neph	Neph	Neph	TL Neph
2	Case 15 Batch 2	49	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
2	Case 15 Batch 2	50	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Batch 2	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Batch 2	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Batch 2	54	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph



**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
2	Case 15 Blend 1	25							
2	Case 15 Blend 1	26							
2	Case 15 Blend 1	27							
2	Case 15 Blend 1	28							
2	Case 15 Blend 1	29							
2	Case 15 Blend 1	30							
2	Case 15 Blend 1	31							
2	Case 15 Blend 1	32							
2	Case 15 Blend 1	33							
2	Case 15 Blend 1	34							
2	Case 15 Blend 1	35							
2	Case 15 Blend 1	36							
2	Case 15 Blend 1	37							
2	Case 15 Blend 1	38							
2	Case 15 Blend 1	39							
2	Case 15 Blend 1	40	newlv						
2	Case 15 Blend 1	41	newlv						
2	Case 15 Blend 1	42	TL newlv						
2	Case 15 Blend 1	43	TL newlv						TL Neph
2	Case 15 Blend 1	44	TL newlv						TL Neph
2	Case 15 Blend 1	45	TL newlv					Neph	TL Neph
2	Case 15 Blend 1	46	TL newlv Neph	TL				Neph	TL Neph
2	Case 15 Blend 1	47	TL newlv Neph	TL Neph	TL	TL	Neph	Neph	TL Neph
2	Case 15 Blend 1	48	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Blend 1	49	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Blend 1	50	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	25							
2	Case 15 Blend 2	26							
2	Case 15 Blend 2	27							
2	Case 15 Blend 2	28							
2	Case 15 Blend 2	29							
2	Case 15 Blend 2	30							
2	Case 15 Blend 2	31							
2	Case 15 Blend 2	32							
2	Case 15 Blend 2	33							
2	Case 15 Blend 2	34							
2	Case 15 Blend 2	35							
2	Case 15 Blend 2	36							
2	Case 15 Blend 2	37							
2	Case 15 Blend 2	38							
2	Case 15 Blend 2	39	newlv						

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
2	Case 15 Blend 2	40	newlv						Neph
2	Case 15 Blend 2	41	newlv						Neph
2	Case 15 Blend 2	42	newlv						Neph
2	Case 15 Blend 2	43	TL newlv Neph					Neph	Neph
2	Case 15 Blend 2	44	TL newlv Neph	Neph		Neph	Neph	Neph	TL Neph
2	Case 15 Blend 2	45	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Blend 2	46	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Blend 2	47	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
2	Case 15 Blend 2	48	TL newlv Neph	TL newlv Neph	Neph	TL Neph	Neph	Neph	TL Neph
2	Case 15 Blend 2	49	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
2	Case 15 Blend 2	50	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
2	Case 15 Blend 2	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
2	Case 15 Blend 2	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL Neph	TL Neph
2	Case 15 Blend 2	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	25							
3	Case 7b Batch 1	26							
3	Case 7b Batch 1	27							
3	Case 7b Batch 1	28							
3	Case 7b Batch 1	29							
3	Case 7b Batch 1	30							
3	Case 7b Batch 1	31							
3	Case 7b Batch 1	32							
3	Case 7b Batch 1	33							
3	Case 7b Batch 1	34							
3	Case 7b Batch 1	35							
3	Case 7b Batch 1	36							
3	Case 7b Batch 1	37							Neph
3	Case 7b Batch 1	38							Neph
3	Case 7b Batch 1	39							Neph
3	Case 7b Batch 1	40	Neph					Neph	Neph
3	Case 7b Batch 1	41	newlv Neph				Neph	Neph	Neph
3	Case 7b Batch 1	42	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	43	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	44	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	45	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	46	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	47	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	48	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	49	newlv Neph	Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	50	newlv Neph	newlv Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	51	TL newlv Neph	newlv Neph	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 1	52	TL newlv Neph	newlv Neph	newlv Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Batch 1	53	TL newlv Neph	newlv Neph	newlv Neph	Neph	Neph	newlv Neph	TL Neph
3	Case 7b Batch 1	54	TL newlv Neph	newlv Neph	newlv Neph	Neph	Neph	newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
3	Case 7b Batch 1	55	TL newlv Neph	TL newlv Neph	newlv Neph	Neph	newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Batch 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Batch 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	25				newhv			
3	Case 7b Batch 2	26				newhv			
3	Case 7b Batch 2	27				newhv			
3	Case 7b Batch 2	28				newhv			
3	Case 7b Batch 2	29							
3	Case 7b Batch 2	30							
3	Case 7b Batch 2	31							
3	Case 7b Batch 2	32							
3	Case 7b Batch 2	33							
3	Case 7b Batch 2	34							
3	Case 7b Batch 2	35							
3	Case 7b Batch 2	36							
3	Case 7b Batch 2	37							
3	Case 7b Batch 2	38							Neph
3	Case 7b Batch 2	39							Neph
3	Case 7b Batch 2	40							Neph
3	Case 7b Batch 2	41	Neph					Neph	Neph
3	Case 7b Batch 2	42	TL Neph				Neph	Neph	Neph
3	Case 7b Batch 2	43	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Batch 2	44	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Batch 2	45	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Batch 2	46	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Batch 2	47	TL Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph
3	Case 7b Batch 2	48	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
3	Case 7b Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	55	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	56	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	57	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	58	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	59	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Batch 2	60	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 1	25							
3	Case 7b Blend 1	26							
3	Case 7b Blend 1	27							
3	Case 7b Blend 1	28							
3	Case 7b Blend 1	29							
3	Case 7b Blend 1	30							
3	Case 7b Blend 1	31	newlv						
3	Case 7b Blend 1	32	newlv						
3	Case 7b Blend 1	33	newlv						

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
3	Case 7b Blend 1	34	newlv						
3	Case 7b Blend 1	35	newlv						
3	Case 7b Blend 1	36	newlv						
3	Case 7b Blend 1	37	newlv						
3	Case 7b Blend 1	38	newlv						
3	Case 7b Blend 1	39	newlv	newlv					
3	Case 7b Blend 1	40	newlv	newlv					
3	Case 7b Blend 1	41	newlv	newlv	newlv				
3	Case 7b Blend 1	42	newlv	newlv	newlv			newlv	
3	Case 7b Blend 1	43	newlv	newlv	newlv			newlv	Neph
3	Case 7b Blend 1	44	newlv	newlv	newlv			newlv	newlv Neph
3	Case 7b Blend 1	45	TL newlv	newlv	newlv		newlv	newlv	newlv Neph
3	Case 7b Blend 1	46	TL newlv Neph	newlv	newlv		newlv	newlv Neph	TL newlv Neph
3	Case 7b Blend 1	47	TL newlv Neph	newlv	newlv	newlv	newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Blend 1	48	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Blend 1	49	TL newlv Neph	TL newlv Neph	newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Blend 1	50	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph	TL newlv Neph
3	Case 7b Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	25							
3	Case 7b Blend 2	26							
3	Case 7b Blend 2	27							
3	Case 7b Blend 2	28							
3	Case 7b Blend 2	29							
3	Case 7b Blend 2	30							
3	Case 7b Blend 2	31							
3	Case 7b Blend 2	32							
3	Case 7b Blend 2	33							
3	Case 7b Blend 2	34							
3	Case 7b Blend 2	35							
3	Case 7b Blend 2	36							
3	Case 7b Blend 2	37							
3	Case 7b Blend 2	38							
3	Case 7b Blend 2	39							Neph
3	Case 7b Blend 2	40							Neph
3	Case 7b Blend 2	41							Neph
3	Case 7b Blend 2	42	Neph					Neph	Neph
3	Case 7b Blend 2	43	TL Neph				Neph	Neph	Neph
3	Case 7b Blend 2	44	TL Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Blend 2	45	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Blend 2	46	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Blend 2	47	TL newlv Neph	Neph	Neph	Neph	Neph	Neph	TL Neph
3	Case 7b Blend 2	48	TL newlv Neph	TL Neph	Neph	TL Neph	Neph	Neph	TL Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 3)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.07 P2-5	0.07 P3-3	0.07 P3-4	0.08 418	0.09 426	0.1 425	0.11 200
3	Case 7b Blend 2	49	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	Neph	TL Neph
3	Case 7b Blend 2	50	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	51	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	52	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	53	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	54	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	55	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL Neph	TL Neph
3	Case 7b Blend 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL Neph
3	Case 7b Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 15B - Batch 1	25	417	320	431	Y1-1	X1-1
1	Case 15B - Batch 1	26					
1	Case 15B - Batch 1	27					
1	Case 15B - Batch 1	28					
1	Case 15B - Batch 1	29					
1	Case 15B - Batch 1	30					
1	Case 15B - Batch 1	31					
1	Case 15B - Batch 1	32					Neph
1	Case 15B - Batch 1	33				Neph	Neph
1	Case 15B - Batch 1	34			Neph	Neph	Neph
1	Case 15B - Batch 1	35		Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	36	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	37	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	38	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	39	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	40	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	41	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	42	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	43	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	44	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	45	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	46	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	47	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	48	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	49	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	50	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	51	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	52	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	53	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	54	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	55	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	56	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	57	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	58	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	59	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 1	60	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	25					
1	Case 15B - Batch 2	26					
1	Case 15B - Batch 2	27					
1	Case 15B - Batch 2	28					
1	Case 15B - Batch 2	29					
1	Case 15B - Batch 2	30					
1	Case 15B - Batch 2	31					
1	Case 15B - Batch 2	32					
1	Case 15B - Batch 2	33					
1	Case 15B - Batch 2	34					
1	Case 15B - Batch 2	35					
1	Case 15B - Batch 2	36					Neph
1	Case 15B - Batch 2	37				Neph	Neph
1	Case 15B - Batch 2	38			Neph	Neph	Neph
1	Case 15B - Batch 2	39			Neph	Neph	Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 15B - Batch 2	40	417	320	431	Y1-1	X1-1
1	Case 15B - Batch 2	41	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	42	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	43	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	44	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	45	Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	46	TL Neph	Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	47	TL Neph	TL Neph	Neph	Neph	Neph
1	Case 15B - Batch 2	48	TL Neph	TL Neph	TL Neph	Neph	Neph
1	Case 15B - Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 15B - Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 15B - Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 15B - Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 15B - Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 15B - Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 15B - Batch 2	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Batch 2	56	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Batch 2	57	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Batch 2	58	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Batch 2	59	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Batch 2	60	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 1	25			Del Gp	Del Gp	Del Gp newlv
1	Case 15B - Blend 1	26			Del Gp	Del Gp	Del Gp newlv
1	Case 15B - Blend 1	27			Del Gp	Del Gp	Del Gp newlv
1	Case 15B - Blend 1	28			Del Gp	Del Gp	Del Gp newlv
1	Case 15B - Blend 1	29			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	30			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	31			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	32			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	33			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	34			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	35			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	36		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	37		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	38		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	39	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	40	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	41	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 15B - Blend 1	42	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv Neph
1	Case 15B - Blend 1	43	newlv	newlv	Del Gp newlv	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	44	newlv	newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	45	newlv	newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	46	newlv	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	47	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	48	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	49	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	50	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	51	TL newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	52	TL newlv Neph	TL newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 15B - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11 417	0.12 320	0.13 431	0.14 Y1-1	0.15 X1-1
1	Case 15B - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 15B - Blend 2	25					Del Gp
1	Case 15B - Blend 2	26					Del Gp
1	Case 15B - Blend 2	27					Del Gp
1	Case 15B - Blend 2	28					Del Gp
1	Case 15B - Blend 2	29					Del Gp
1	Case 15B - Blend 2	30					
1	Case 15B - Blend 2	31					
1	Case 15B - Blend 2	32					
1	Case 15B - Blend 2	33					
1	Case 15B - Blend 2	34					
1	Case 15B - Blend 2	35					
1	Case 15B - Blend 2	36					
1	Case 15B - Blend 2	37					Neph
1	Case 15B - Blend 2	38				Neph	Neph
1	Case 15B - Blend 2	39			Neph	Neph	Neph
1	Case 15B - Blend 2	40		Neph	Neph	Neph	Neph
1	Case 15B - Blend 2	41		Neph	Neph	Neph	newlv Neph
1	Case 15B - Blend 2	42	Neph	Neph	Neph	Neph	newlv Neph
1	Case 15B - Blend 2	43	Neph	Neph	Neph	Neph	newlv Neph
1	Case 15B - Blend 2	44	Neph	Neph	Neph	Neph	newlv Neph
1	Case 15B - Blend 2	45	Neph	Neph	Neph	Neph	newlv Neph
1	Case 15B - Blend 2	46	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 15B - Blend 2	47	TL Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 15B - Blend 2	48	TL Neph	TL Neph	Neph	newlv Neph	newlv Neph
1	Case 15B - Blend 2	49	TL Neph	TL Neph	TL Neph	newlv Neph	newlv Neph
1	Case 15B - Blend 2	50	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	newlv Neph
1	Case 15B - Blend 2	51	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	52	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	53	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	54	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	55	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	56	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	57	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 15B - Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Batch 1	25	Del Gp Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	26	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	27	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	28	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	29	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	30	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	31	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	32	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	33	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O



**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11 417	0.12 320	0.13 431	0.14 Y1-1	0.15 X1-1
1	Case 16 - Batch 1	34	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	35	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	36	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	37	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	38	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	39	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	40	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	41	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	42	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O
1	Case 16 - Batch 1	43	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	44	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	45	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	46	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	47	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	48	Del Gp newlv Al2O3 R2O	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	49	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	50	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph	Del Gp newlv Al2O3 R2O Neph
1	Case 16 - Batch 1	51	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	52	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	53	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	54	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	55	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	56	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	57	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	58	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	59	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 1	60	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph	Del Gp newlv R2O Neph
1	Case 16 - Batch 2	25					
1	Case 16 - Batch 2	26					
1	Case 16 - Batch 2	27					
1	Case 16 - Batch 2	28					
1	Case 16 - Batch 2	29					
1	Case 16 - Batch 2	30					
1	Case 16 - Batch 2	31					
1	Case 16 - Batch 2	32					
1	Case 16 - Batch 2	33					Neph
1	Case 16 - Batch 2	34				Neph	Neph
1	Case 16 - Batch 2	35			Neph	Neph	Neph
1	Case 16 - Batch 2	36		Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	37		Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	38	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	39	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	40	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	41	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	42	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	43	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	44	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	45	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	46	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	47	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	48	Neph	Neph	Neph	Neph	Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 16 - Batch 2	49	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	50	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	51	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	52	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	53	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	54	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	55	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	56	TL Neph	Neph	Neph	Neph	Neph
1	Case 16 - Batch 2	57	TL Neph	TL Neph	TL Neph	Neph	Neph
1	Case 16 - Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	newlv Neph
1	Case 16 - Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 16 - Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 16 - Blend 1	25	R2O	R2O	Del Gp R2O	Del Gp R2O	Del Gp newlv R2O
1	Case 16 - Blend 1	26	R2O	R2O	Del Gp R2O	Del Gp R2O	Del Gp newlv R2O
1	Case 16 - Blend 1	27	R2O	R2O	Del Gp R2O	Del Gp newlv R2O	Del Gp newlv R2O
1	Case 16 - Blend 1	28	R2O	R2O	Del Gp R2O	Del Gp newlv R2O	Del Gp newlv R2O
1	Case 16 - Blend 1	29	R2O	R2O	Del Gp R2O	Del Gp newlv R2O	Del Gp newlv R2O
1	Case 16 - Blend 1	30			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	31			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	32			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	33			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	34		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	35		newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	36		newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	37	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	38	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	39	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	40	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	41	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	42	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	43	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	44	newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	45	TL newlv	newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	46	TL newlv	TL newlv	newlv	Del Gp newlv	Del Gp newlv
1	Case 16 - Blend 1	47	TL newlv	TL newlv	TL newlv	Del Gp newlv	Del Gp newlv Neph
1	Case 16 - Blend 1	48	TL newlv	TL newlv	TL newlv	Del Gp TL newlv Neph	Del Gp newlv Neph
1	Case 16 - Blend 1	49	TL newlv	TL newlv	TL newlv	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	50	TL newlv	TL newlv	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	51	TL newlv	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 16 - Blend 2	25					Del Gp
1	Case 16 - Blend 2	26					Del Gp
1	Case 16 - Blend 2	27					Del Gp

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 16 - Blend 2	28	417	320	431	Y1-1	X1-1
1	Case 16 - Blend 2	29					Del Gp
1	Case 16 - Blend 2	30					Del Gp
1	Case 16 - Blend 2	31					Del Gp
1	Case 16 - Blend 2	32					
1	Case 16 - Blend 2	33					
1	Case 16 - Blend 2	34					
1	Case 16 - Blend 2	35					Neph
1	Case 16 - Blend 2	36					Neph
1	Case 16 - Blend 2	37				Neph	Neph
1	Case 16 - Blend 2	38			Neph	Neph	Neph
1	Case 16 - Blend 2	39		Neph	Neph	Neph	Neph
1	Case 16 - Blend 2	40	Neph	Neph	Neph	Neph	Neph
1	Case 16 - Blend 2	41	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	42	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	43	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	44	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	45	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	46	Neph	Neph	Neph	Neph	newlv Neph
1	Case 16 - Blend 2	47	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	48	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	49	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	50	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	51	TL Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	52	TL Neph	TL Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	53	TL Neph	TL Neph	TL newlv Neph	newlv Neph	newlv Neph
1	Case 16 - Blend 2	54	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	newlv Neph
1	Case 16 - Blend 2	55	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	56	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	57	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 16 - Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	25				Del Gp	Del Gp
1	Case 7 Batch 1	26				Del Gp	Del Gp
1	Case 7 Batch 1	27				Del Gp	Del Gp
1	Case 7 Batch 1	28				Del Gp	Del Gp
1	Case 7 Batch 1	29				Del Gp	Del Gp
1	Case 7 Batch 1	30					Del Gp
1	Case 7 Batch 1	31					Del Gp
1	Case 7 Batch 1	32					Del Gp
1	Case 7 Batch 1	33					Del Gp
1	Case 7 Batch 1	34					Del Gp Neph
1	Case 7 Batch 1	35					Del Gp Neph
1	Case 7 Batch 1	36				Neph	Del Gp Neph
1	Case 7 Batch 1	37			Neph	Neph	Del Gp Neph
1	Case 7 Batch 1	38		Neph	Neph	Neph	Del Gp newlv Neph
1	Case 7 Batch 1	39	Neph	Neph	Neph	Neph	Del Gp newlv Neph
1	Case 7 Batch 1	40	Neph	Neph	Neph	Neph	Del Gp newlv Neph
1	Case 7 Batch 1	41	Neph	Neph	Neph	Neph	Del Gp newlv Neph
1	Case 7 Batch 1	42	Neph	Neph	Neph	Neph	newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 7 Batch 1	43	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	44	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	45	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	46	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	47	Neph	Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	48	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	49	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	50	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	51	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	52	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	53	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	54	TL Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	55	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 7 Batch 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph
1	Case 7 Batch 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Batch 2	25					
1	Case 7 Batch 2	26					
1	Case 7 Batch 2	27					
1	Case 7 Batch 2	28					
1	Case 7 Batch 2	29					
1	Case 7 Batch 2	30					
1	Case 7 Batch 2	31					
1	Case 7 Batch 2	32					
1	Case 7 Batch 2	33					
1	Case 7 Batch 2	34					
1	Case 7 Batch 2	35					Neph
1	Case 7 Batch 2	36					Neph
1	Case 7 Batch 2	37				Neph	Neph
1	Case 7 Batch 2	38			Neph	Neph	Neph
1	Case 7 Batch 2	39		Neph	Neph	Neph	Neph
1	Case 7 Batch 2	40	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	41	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	42	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	43	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	44	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	45	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	46	Neph	Neph	Neph	Neph	Neph
1	Case 7 Batch 2	47	TL Neph	TL Neph	Neph	Neph	Neph
1	Case 7 Batch 2	48	TL Neph	TL Neph	TL Neph	Neph	Neph
1	Case 7 Batch 2	49	TL Neph	TL Neph	TL Neph	TL Neph	Neph
1	Case 7 Batch 2	50	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	51	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	52	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	53	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	54	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	55	TL Neph	TL Neph	TL Neph	TL Neph	TL Neph
1	Case 7 Batch 2	56	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 7 Batch 2	57	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
			417	320	431	Y1-1	X1-1
1	Case 7 Batch 2	58	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 7 Batch 2	59	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 7 Batch 2	60	TL Neph	TL Neph	TL Neph	TL Neph	TL newlv Neph
1	Case 7 Blend 1	25			Del Gp	Del Gp	Del Gp newlv
1	Case 7 Blend 1	26			Del Gp	Del Gp	Del Gp newlv
1	Case 7 Blend 1	27			Del Gp	Del Gp	Del Gp newlv
1	Case 7 Blend 1	28			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	29			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	30			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	31			Del Gp	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	32			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	33			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	34			Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	35		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	36		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	37		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	38	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	39	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	40	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
1	Case 7 Blend 1	41	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv Neph
1	Case 7 Blend 1	42	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv Neph
1	Case 7 Blend 1	43	newlv	newlv	Del Gp newlv	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	44	newlv	newlv	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	45	newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	46	newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	47	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	48	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	49	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	50	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	51	TL newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	52	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	53	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp newlv Neph
1	Case 7 Blend 1	54	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	55	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	56	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	57	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	58	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	59	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 1	60	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 7 Blend 2	25					Del Gp
1	Case 7 Blend 2	26					Del Gp
1	Case 7 Blend 2	27					Del Gp
1	Case 7 Blend 2	28					
1	Case 7 Blend 2	29					
1	Case 7 Blend 2	30					
1	Case 7 Blend 2	31					
1	Case 7 Blend 2	32					
1	Case 7 Blend 2	33					
1	Case 7 Blend 2	34					
1	Case 7 Blend 2	35					
1	Case 7 Blend 2	36					Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 7 Blend 2	37	417	320	431	Y1-1	X1-1
1	Case 7 Blend 2	38				Neph	Neph
1	Case 7 Blend 2	39			Neph	Neph	Neph
1	Case 7 Blend 2	40		Neph	Neph	Neph	Neph
1	Case 7 Blend 2	41	Neph	Neph	Neph	Neph	Neph
1	Case 7 Blend 2	42	Neph	Neph	Neph	Neph	Neph
1	Case 7 Blend 2	43	Neph	Neph	Neph	Neph	newlv Neph
1	Case 7 Blend 2	44	Neph	Neph	Neph	Neph	newlv Neph
1	Case 7 Blend 2	45	Neph	Neph	Neph	Neph	newlv Neph
1	Case 7 Blend 2	46	Neph	Neph	Neph	Neph	newlv Neph
1	Case 7 Blend 2	47	TL Neph	Neph	Neph	Neph	newlv Neph
1	Case 7 Blend 2	48	TL Neph	TL Neph	Neph	newlv Neph	newlv Neph
1	Case 7 Blend 2	49	TL Neph	TL Neph	TL Neph	newlv Neph	newlv Neph
1	Case 7 Blend 2	50	TL Neph	TL Neph	TL Neph	TL newlv Neph	newlv Neph
1	Case 7 Blend 2	51	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	53	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	54	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	55	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	56	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	57	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	58	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	59	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 7 Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 - Blend 1	25			Del Gp	Del Gp	Del Gp
1	Case 8 - Blend 1	26			Del Gp	Del Gp	Del Gp
1	Case 8 - Blend 1	27			Del Gp	Del Gp	Del Gp newlv
1	Case 8 - Blend 1	28			Del Gp	Del Gp	Del Gp newlv
1	Case 8 - Blend 1	29			Del Gp	Del Gp	Del Gp newlv
1	Case 8 - Blend 1	30			Del Gp	Del Gp	Del Gp newlv
1	Case 8 - Blend 1	31			Del Gp	Del Gp	Del Gp newlv
1	Case 8 - Blend 1	32				Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	33				Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	34				Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	35				Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	36			newlv	Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	37			newlv	Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	38			newlv	Del Gp newlv	Del Gp newlv
1	Case 8 - Blend 1	39			newlv	Del Gp newlv	Del Gp newlv Neph
1	Case 8 - Blend 1	40		newlv	newlv	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	41		newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	42		newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	43	newlv	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	44	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	45	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	46	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	47	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	48	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	49	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	50	TL newlv Neph	TL newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11 417	0.12 320	0.13 431	0.14 Y1-1	0.15 X1-1
1	Case 8 - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp newlv Neph
1	Case 8 - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8 and 8a - Batch 1	25				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	26				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	27				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	28				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	29				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	30				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	31				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	32				Del Gp	Del Gp
1	Case 8 and 8a - Batch 1	33					Del Gp
1	Case 8 and 8a - Batch 1	34					Del Gp
1	Case 8 and 8a - Batch 1	35					Del Gp newlv
1	Case 8 and 8a - Batch 1	36					Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	37				Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	38				Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	39			Neph	Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	40		Neph	Neph	newlv Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	41	Neph	Neph	Neph	newlv Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	42	Neph	Neph	Neph	newlv Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	43	Neph	Neph	Neph	newlv Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	44	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8 and 8a - Batch 1	45	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	46	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	47	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	48	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	49	TL Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	50	TL Neph	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	51	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph
1	Case 8 and 8a - Batch 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8 and 8a - Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	25				Del Gp	Del Gp
1	Case 8A - Blend 1	26				Del Gp	Del Gp
1	Case 8A - Blend 1	27				Del Gp	Del Gp
1	Case 8A - Blend 1	28				Del Gp	Del Gp
1	Case 8A - Blend 1	29				Del Gp	Del Gp
1	Case 8A - Blend 1	30				Del Gp	Del Gp newlv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
1	Case 8A - Blend 1	31	417	320	431	Y1-1	X1-1
1	Case 8A - Blend 1	32				Del Gp	Del Gp newlv
1	Case 8A - Blend 1	33				Del Gp	Del Gp newlv
1	Case 8A - Blend 1	34				Del Gp	Del Gp newlv
1	Case 8A - Blend 1	35				Del Gp newlv	Del Gp newlv
1	Case 8A - Blend 1	36				Del Gp newlv	Del Gp newlv
1	Case 8A - Blend 1	37				Del Gp newlv	Del Gp newlv Neph
1	Case 8A - Blend 1	38				Del Gp newlv	Del Gp newlv Neph
1	Case 8A - Blend 1	39			newlv	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	40			newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	41		Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	42	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	43	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	44	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	45	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	46	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	47	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	48	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	49	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	50	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph
1	Case 8A - Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8A - Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8A - Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8A - Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8A - Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
1	Case 8A - Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
1	Case 8A - Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 1	25	newhv				
2	Case 15 Batch 1	26	newhv				
2	Case 15 Batch 1	27	newhv				
2	Case 15 Batch 1	28	newhv				
2	Case 15 Batch 1	29	newhv				
2	Case 15 Batch 1	30	newhv				
2	Case 15 Batch 1	31	newhv				
2	Case 15 Batch 1	32	newhv				Neph
2	Case 15 Batch 1	33	newhv				Neph
2	Case 15 Batch 1	34	newhv	newhv		Neph	Neph
2	Case 15 Batch 1	35	newhv	newhv	Neph	Neph	Neph
2	Case 15 Batch 1	36	newhv	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	37	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	38	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	39	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	40	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	41	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	42	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	43	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	44	newhv Neph	newhv Neph	Neph	Neph	Neph
2	Case 15 Batch 1	45	newhv Neph	newhv Neph	newhv Neph	Neph	Neph



**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
2	Case 15 Batch 1	46	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	47	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	48	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	49	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	50	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	51	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	52	newhv Neph	newhv Neph	newhv Neph	Neph	Neph
2	Case 15 Batch 1	53	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph
2	Case 15 Batch 1	54	newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph
2	Case 15 Batch 1	55	TL newhv Neph	newhv Neph	newhv Neph	newhv Neph	Neph
2	Case 15 Batch 1	56	TL newhv Neph	TL newhv Neph	newhv Neph	newhv Neph	Neph
2	Case 15 Batch 1	57	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	Neph
2	Case 15 Batch 1	58	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL Neph
2	Case 15 Batch 1	59	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 1	60	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph	TL newhv Neph
2	Case 15 Batch 2	25				Del Gp	Del Gp
2	Case 15 Batch 2	26				Del Gp	Del Gp
2	Case 15 Batch 2	27				Del Gp	Del Gp
2	Case 15 Batch 2	28				Del Gp	Del Gp
2	Case 15 Batch 2	29				Del Gp	Del Gp
2	Case 15 Batch 2	30				Del Gp	Del Gp
2	Case 15 Batch 2	31				Del Gp	Del Gp
2	Case 15 Batch 2	32				Del Gp	Del Gp
2	Case 15 Batch 2	33				Del Gp	Del Gp newlv
2	Case 15 Batch 2	34				Del Gp	Del Gp newlv
2	Case 15 Batch 2	35				Del Gp	Del Gp newlv Neph
2	Case 15 Batch 2	36				Del Gp	Del Gp newlv Neph
2	Case 15 Batch 2	37				Del Gp Neph	Del Gp newlv Neph
2	Case 15 Batch 2	38			Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	39		Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	40	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	41	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	42	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	43	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	44	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	45	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	46	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	47	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	48	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	49	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	50	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	51	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph
2	Case 15 Batch 2	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
2	Case 15 Batch 2	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph
2	Case 15 Batch 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Batch 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
2	Case 15 Blend 1	25	417	320	431	Y1-1	X1-1
2	Case 15 Blend 1	26					Del Gp
2	Case 15 Blend 1	27					Del Gp
2	Case 15 Blend 1	28					Del Gp
2	Case 15 Blend 1	29					Del Gp
2	Case 15 Blend 1	30					Del Gp
2	Case 15 Blend 1	31					Del Gp
2	Case 15 Blend 1	32					Del Gp newlv
2	Case 15 Blend 1	33					Del Gp newlv
2	Case 15 Blend 1	34					Del Gp newlv
2	Case 15 Blend 1	35					newlv
2	Case 15 Blend 1	36					newlv
2	Case 15 Blend 1	37				newlv	newlv
2	Case 15 Blend 1	38				newlv	newlv
2	Case 15 Blend 1	39				newlv	newlv Neph
2	Case 15 Blend 1	40				newlv	newlv Neph
2	Case 15 Blend 1	41				newlv Neph	newlv Neph
2	Case 15 Blend 1	42			newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	43		Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	44	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	45	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	46	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	47	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	48	Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	49	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	50	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	51	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph
2	Case 15 Blend 1	52	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph
2	Case 15 Blend 1	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	25				Del Gp	Del Gp
2	Case 15 Blend 2	26				Del Gp	Del Gp
2	Case 15 Blend 2	27				Del Gp	Del Gp
2	Case 15 Blend 2	28				Del Gp	Del Gp
2	Case 15 Blend 2	29				Del Gp	Del Gp
2	Case 15 Blend 2	30				Del Gp	Del Gp
2	Case 15 Blend 2	31				Del Gp	Del Gp
2	Case 15 Blend 2	32				Del Gp	Del Gp newlv
2	Case 15 Blend 2	33				Del Gp	Del Gp newlv
2	Case 15 Blend 2	34				Del Gp	Del Gp newlv
2	Case 15 Blend 2	35				Del Gp	Del Gp newlv
2	Case 15 Blend 2	36				Del Gp	Del Gp newlv Neph
2	Case 15 Blend 2	37				Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	38				Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	39			Neph	Del Gp newlv Neph	Del Gp newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
			417	320	431	Y1-1	X1-1
2	Case 15 Blend 2	40		Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	41	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	42	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	43	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	44	Neph	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	45	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	46	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	47	Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	48	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	49	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	50	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	51	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	52	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	53	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph
2	Case 15 Blend 2	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
2	Case 15 Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 1	25			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	26			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	27			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	28			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	29			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	30			Del Gp	Del Gp	Del Gp
3	Case 7b Batch 1	31				Del Gp	Del Gp
3	Case 7b Batch 1	32				Del Gp	Del Gp
3	Case 7b Batch 1	33				Del Gp	Del Gp newlv
3	Case 7b Batch 1	34				Del Gp	Del Gp newlv Neph
3	Case 7b Batch 1	35				Del Gp Neph	Del Gp newlv Neph
3	Case 7b Batch 1	36			Neph	Del Gp Neph	Del Gp newlv Neph
3	Case 7b Batch 1	37		Neph	Neph	Del Gp Neph	Del Gp newlv Neph
3	Case 7b Batch 1	38		Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	39	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	40	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	41	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	42	Neph	Neph	Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	43	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	44	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	45	Neph	Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	46	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	47	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	48	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	49	Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	50	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	51	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	52	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	53	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	54	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
			417	320	431	Y1-1	X1-1
3	Case 7b Batch 1	55	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	56	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	57	newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	58	TL newlv Neph	newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	59	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 1	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph	Del Gp newlv Neph
3	Case 7b Batch 2	25					Del Gp
3	Case 7b Batch 2	26					Del Gp
3	Case 7b Batch 2	27					Del Gp
3	Case 7b Batch 2	28					Del Gp
3	Case 7b Batch 2	29					
3	Case 7b Batch 2	30					
3	Case 7b Batch 2	31					
3	Case 7b Batch 2	32					
3	Case 7b Batch 2	33					
3	Case 7b Batch 2	34					
3	Case 7b Batch 2	35					Neph
3	Case 7b Batch 2	36				Neph	Neph
3	Case 7b Batch 2	37			Neph	Neph	Neph
3	Case 7b Batch 2	38			Neph	Neph	Neph
3	Case 7b Batch 2	39		Neph	Neph	Neph	Neph
3	Case 7b Batch 2	40	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	41	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	42	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	43	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	44	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	45	Neph	Neph	Neph	Neph	Neph
3	Case 7b Batch 2	46	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Batch 2	47	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Batch 2	48	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Batch 2	49	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Batch 2	50	TL Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Batch 2	51	TL Neph	TL Neph	TL Neph	newlv Neph	newlv Neph
3	Case 7b Batch 2	52	TL Neph	TL Neph	TL Neph	TL newlv Neph	newlv Neph
3	Case 7b Batch 2	53	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	54	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	55	TL Neph	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	56	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	57	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	58	TL Neph	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	59	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Batch 2	60	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 1	25			Del Gp	Del Gp	Del Gp newlv
3	Case 7b Blend 1	26			Del Gp	Del Gp	Del Gp newlv
3	Case 7b Blend 1	27			Del Gp	Del Gp	Del Gp newlv
3	Case 7b Blend 1	28			Del Gp	Del Gp	Del Gp newlv
3	Case 7b Blend 1	29			Del Gp	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	30			Del Gp	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	31			Del Gp	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	32			Del Gp	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	33			Del Gp newlv	Del Gp newlv	Del Gp newlv

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

Set	Type	Na2O Sludge Loading (%)	0.11	0.12	0.13	0.14	0.15
			417	320	431	Y1-1	X1-1
3	Case 7b Blend 1	34			Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	35			Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	36		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	37		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	38		newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	39	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv
3	Case 7b Blend 1	40	newlv	newlv	Del Gp newlv	Del Gp newlv	Del Gp newlv Neph
3	Case 7b Blend 1	41	newlv	newlv	Del Gp newlv	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	42	newlv	newlv	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	43	newlv	newlv	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	44	newlv	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	45	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	46	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	47	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	48	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	49	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	50	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	51	newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	52	TL newlv Neph	newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	53	TL newlv Neph	TL newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	54	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	55	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp newlv Neph
3	Case 7b Blend 1	56	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
3	Case 7b Blend 1	57	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
3	Case 7b Blend 1	58	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
3	Case 7b Blend 1	59	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
3	Case 7b Blend 1	60	TL newlv Neph	TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph	Del Gp TL newlv Neph
3	Case 7b Blend 2	25				Del Gp	Del Gp
3	Case 7b Blend 2	26					Del Gp
3	Case 7b Blend 2	27					Del Gp
3	Case 7b Blend 2	28					Del Gp
3	Case 7b Blend 2	29					Del Gp
3	Case 7b Blend 2	30					Del Gp
3	Case 7b Blend 2	31					Del Gp
3	Case 7b Blend 2	32					Del Gp
3	Case 7b Blend 2	33					Del Gp
3	Case 7b Blend 2	34					Del Gp
3	Case 7b Blend 2	35					Del Gp
3	Case 7b Blend 2	36					Del Gp Neph
3	Case 7b Blend 2	37				Neph	Neph
3	Case 7b Blend 2	38			Neph	Neph	newlv Neph
3	Case 7b Blend 2	39		Neph	Neph	Neph	newlv Neph
3	Case 7b Blend 2	40		Neph	Neph	Neph	newlv Neph
3	Case 7b Blend 2	41	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Blend 2	42	Neph	Neph	Neph	Neph	newlv Neph
3	Case 7b Blend 2	43	Neph	Neph	Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	44	Neph	Neph	Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	45	Neph	Neph	Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	46	Neph	Neph	Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	47	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	48	Neph	Neph	newlv Neph	newlv Neph	newlv Neph

**Exhibit A1. Results for MAR Assessments of the Nominal Stage (part 4)**

Constraint not met: neph (nepheline), TL (liquidus temperature), newlv (low viscosity – new model), newhv (high viscosity – new model), and Del GP – durability

		Na2O	0.11	0.12	0.13	0.14	0.15
Set	Type	Sludge Loading (%)	417	320	431	Y1-1	X1-1
3	Case 7b Blend 2	49	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	50	Neph	Neph	newlv Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	51	TL Neph	newlv Neph	newlv Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	52	TL Neph	TL newlv Neph	TL newlv Neph	newlv Neph	newlv Neph
3	Case 7b Blend 2	53	TL Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	newlv Neph
3	Case 7b Blend 2	54	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	55	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	56	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	57	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	58	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	59	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph
3	Case 7b Blend 2	60	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph	TL newlv Neph

**Distribution:**

J.E. Marra, SRNL  
R.E. Edwards, SRNL  
D. A. Crowley, 999-W  
T. B. Calloway, 999-W  
N. E. Bibler, SRNL  
C.M. Jantzen, SRNL  
J. R. Harbour, 773-42A  
G. G. Wicks, SRNL  
R. C. Tuckfield, 773-42A  
D. K. Peeler, 999-W  
T. B. Edwards, 773-42A  
C. C. Herman, 773-42A  
M. E. Smith, 773-42A  
M. E. Stone, 999-W  
D. H. Miller, 999-W  
M. J. Barnes, 999-W  
K.M. Fox, SRNL  
M. S. Miller, 704-S  
J. E. Occhipinti, 704-S  
P. M. Patel, 704-27S  
H. H. Elder, 766-H  
J. F. Iaukea, 704-30S  
J. W. Ray, 704-S  
M. A. Rios-Armstrong, 766-H  
W. B. Van-Pelt, 704-S  
H. B. Shah, 766-H  
J. M. Gillam, 766-H  
B. A. Davis, 704-27S