Immobilization Technology Section
Savannah River Technology Center
Westinghouse Savannah River Company

WSRC-TR-2000-00358
Rev. 0

September 15, 2000

REDUCTION OF CONSTRAINTS:

Applicability of the Homogeneity Constraint for Macrobatch 3 (U)

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PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC09-96SR18500

This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U.S. Department of Energy.

DISCLAIMER

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This report was prepared by Westinghouse Savannah River Company (WSRC) for the United States Department of Energy under Contract No. DE-AC09-96SR18500 and is an account of work performed under that contract.

Task Title: Reduction in Durability Constraints (U)		TTR Number: HLW/DWPF/TTR-00-0023, Rev. 0	TTR Date: 03/20/00
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EXECUTIVE SUMMARY

This study provides the technical bases to relax the homogeneity measurement uncertainty requirement ***for macro-batch 3*** (MB3) as long as the following criteria are satisfied:

Criterion (1)

- use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add a sum of alkali[1] (ΣM_2O) constraint with an upper limit of 19.3 wt% (i.e., $\Sigma M_2O < 19.3$ wt%), **or**

Criterion (2)

- adjust the lower limit on the alumina constraint to 4 wt% (i.e., $Al_2O_3 \geq$ 4.0 wt%).

Measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina constraint and/or the coupled alumina and alkali constraint, if used. These constraints are applicable over the composition region evaluated for MB3 which was based on a pool of candidate glasses for each sludge type: Tank 40 only and a blend of Tank 8 and Tank 40. These constraints should not be applied to compositional envelopes outside that tested until data are generated to support their use.[2] The use of these constraints to relax the homogeneity measurement uncertainty *for any new macro-batch* would require a similar study of the feasible compositions.

1 Alkali included in this sum are Na_2O, Li_2O, Cs_2O, and K_2O (in wt%).

2 For example, these constraints may not be applicable to glasses with high B_2O_3 and/or low Fe_2O_3 concentrations as discussed in this document.

ACRONYMS

ADS	Analytical Development Services
ARM	Approved Reference Material
ASTM	American Society for Testing and Materials
CELS	Corning Engineering Laboratory Services
EA	Environmental Assessment
ICP-AES	inductively coupled plasma – atomic emission spectroscopy
MAR	Measurement Acceptability Region
MB	macrobatch
PAR	Property Acceptability Region
PCCS	Product Composition Control System
PCT	product consistency test (ASTM C 1285)
RC	reduction of constraints
SEM/EDS	scanning electron microscopy / energy dispersive spectroscopy
SME	Slurry Mix Evaporator
SRTC	Savannah River Technology Center
SRTC-ML	Savannah River Technology Center – Mobile Laboratory
T_g	glass transition temperature
T_L	liquidus temperature
THERMO	Thermodynamic Hydration Energy Reaction Model
TTR	technical task request
WCP	Waste Compliance Plan
XRD	x-ray diffraction

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1.0 INTRODUCTION

The Product Composition Control System (PCCS) is used to determine the acceptability of each batch of Defense Waste Processing Facility (DWPF) melter feed in the Slurry Mix Evaporator (SME). This control system imposes several constraints on the composition of the contents of the SME to define acceptability. These constraints relate process or product properties to composition via prediction models. A SME batch is deemed acceptable if its sample composition measurements lead to acceptable property predictions after accounting for modeling, measurement and analytic uncertainties. The baseline document guiding the use of these data and models is "SME Acceptability Determination for DWPF Process Control (U)" by Brown and Postles [1996].

A minimum of three PCCS constraints support the prediction of the glass durability from a given SME batch. The Savannah River Technology Center (SRTC) is reviewing all of the PCCS constraints associated with durability. The purpose of this review is to revisit these constraints in light of the additional knowledge gained since the beginning of radioactive operations at DWPF and to identify any supplemental studies needed to amplify this knowledge so that redundant or overly conservative constraints can be eliminated or replaced by more appropriate constraints.

One of the specific PCCS constraints currently being evaluated is the homogeneity constraint which is used to discriminate compositions that are likely to result in a phase separated glasses from compositions that are likely to be homogeneous. Phase separation referring to the development of amorphous or glass-in-glass phase separation; not crystallization. The homogeneity constraint is a linear function of parameters representing sludge and frit. This function was obtained from a discriminate analysis of 110 glasses (88 homogeneous and 22 phase-separated) in sludge versus frit composition space [Brown and Edwards 1995, Jantzen et. al 1995]. A homogeneity constraint is needed to prevent phase separated glasses from being produced. The technical basis for implementing a phase separation discriminator into PCCS is based on the fact that durability of phase-separated glasses is unpredictable.

For a given macrobatch, PCCS determines acceptability after optimizing the target glass composition to maximize waste loading while ensuring processibility and durability of the final product. Since the decision regarding acceptability is based on the underlying models (e.g., liquidus, durability, viscosity and homogeneity) within PCCS as well as single-component concentration constraints (e.g., Al_2O_3), waste loadings are usually limited by one of the model predictions (taking into account their expected uncertainties).[3] For example, application of the homogeneity constraint at the Measurement Acceptability Region (MAR) limit for MB2 eliminated much of the potential composition region from the DWPF window of operability [Edwards and Brown 1998]. To address this issue, a variability study for macro-batch 2 (MB2) was conducted by the Savannah River Technology Center (SRTC) and the results from that study were reported by Edwards and Brown [1998] and Edwards [1999].

The MB2 results, supplemented by an evaluation of an existing property-composition database, led to the formation of two new options for PCCS: a new limit for the alumina constraint or the

[3] Waste loadings are typically limited by one of the model predictions since their uncertainty (both measured and predicted) will likely be much larger than that of an individual component.

introduction of a new sum of alkali constraint coupled with the existing Al_2O_3 constraint.[4] The latter of these options to PCCS allowed DWPF to relax the homogeneity constraint from a measured acceptance criterion to a property acceptance criterion for MB2. The technical basis developed by Edwards and Brown [1998] for relaxing the homogeneity constraint to the Property Acceptability Region (PAR) coupled with the implementation of one of the proposed equivalent constraints provided compositional flexibility (e.g., increased the composition operational window) for MB2 operations without compromising product quality or melter processing considerations.

The technical basis for this MB2 decision is briefly discussed in this report to establish a technical baseline for the potential application of these equivalent constraints to MB3. Edwards and Brown [1998] provide a more detailed discussion for the MB2 technical basis.

As noted above, application of the homogeneity constraint at the MAR had a significant (negative) impact on the compositional operational window for MB2. To address this issue, Edwards and Brown [1998] hypothesized that one could reduce the application of the homogeneity constraint to the PAR given the implementation of one of two constraints:

(1) use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add a sum of alkali constraint with an upper limit of 19.3 wt% (i.e., $\Sigma M_2O < 19.3$ wt%), **or**
(2) adjust the lower limit on the alumina constraint to 4 wt% (i.e., $Al_2O_3 \geq 4.0$ wt%).

This hypothesis was based on the fact that Al_2O_3 is known to suppress the formation of amorphous phase separation in borosilicate glasses [Volf 1974, Jantzen et al. 1995, Jantzen and Brown 2000, Hrma et al. 1994] and that sufficient quantities of Al_2O_3 have a positive impact on durability (usually independent of any homogeneity classification). It is also well known that relatively high quantities of alkali metal oxides typically result in a reduction in durability for borosilicate glasses [Volf 1974 and Jantzen et al. 1995]. Criteria (1) constrains the glass composition in a durability region where the strong base – weak acids are balanced in the leachate [Jantzen et al. 1995]. Criteria (2) does not impose an upper alkali constraint but either constraint should only be applied over the compositional envelopes evaluated.

Figure 1 shows the impact of Al_2O_3 and the ΣM_2O on the durability for the glasses used to define the discriminator and the Tank 42 variability study glasses. Glasses predicted to be phase separated are labeled with the common logarithm of their PCT results (log NL [B] in g/L) as is the EA glass (log NL [B] = 1.22). Glasses with high PCT leach values (> 1.0 in log space)[5] are located in the high alkali / low alumina quadrant (i.e., lower right) of the figure. Edwards and Brown [1998] also noted that the current PCCS constraint for Al_2O_3 (i.e., ≥ 3.0 wt%) is not sufficient to keep DWPF from compositions that may be near the homogeneity PAR that have unacceptable PCT values. The latter is shown by the presence of glasses with log NL [B] > 1.0 above the Al_2O_3 = 3.0 wt% limit (as denoted by the dotted line). This agrees well with the maximum of ~4.0 wt% defined by Jantzen et al. [1995]. However, the data from the Tank 42 variability study do suggest that the assurance of producing a durable product is increased by either:

4 Jantzen et al. [1995; see Figure 32] delineated a compositional difference between homogeneous and phase separated glasses when examined in the Al_2O_3-B_2O_3-ΣM_2O-Fe_2O_3 quaternary. This analysis indicated that the phase separated glasses are low in Al_2O_3 relative to homogeneous glasses.

5 log NL [B] > 1.0 is used as a conservative metric relative to a lower bound for EA leaching.

(1) adding a constraint on the ΣM_2O (upper limit of ~19.3 wt%) along with the current alumina constraint (≥ 3.0 wt%) OR
(2) increasing the limit on alumina ≥ 4.0 wt% (without limiting alkali content over the range that was evaluated).

Therefore, by relaxing the homogeneity constraint (to the PAR) and imposing one of the two equivalent constraints, the operational window for MB2 was increased dramatically.[6] It should also be noted that the upper limit on the sum of alkali (ΣM_2O = 19.3 wt%) and lower limit on Al_2O_3 (≥ 3 wt%) was defined by the homogeneous WCP Purex (PX) glass (label of 0.45).

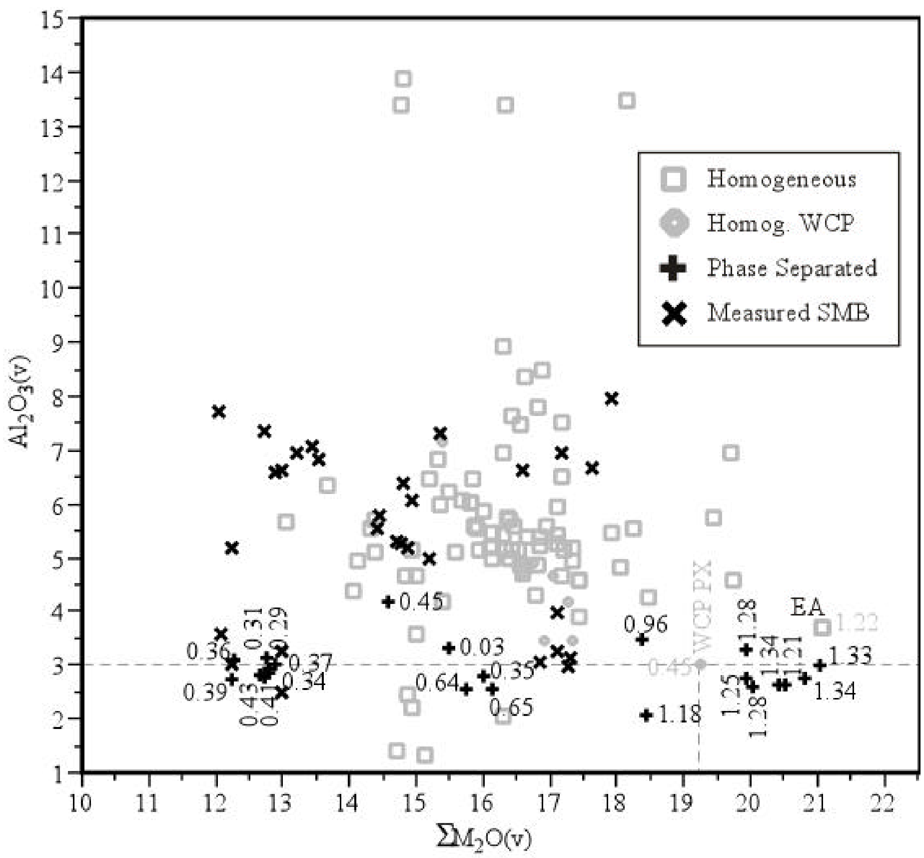

Figure 1. Al_2O_3 (wt%) versus SM_2O (wt%) for the Glasses Used to Define the Discriminator and the Tank 42 Variability Study Glasses.
(from Edwards and Brown [1998] where the SM_2O = Na_2O + Li_2O + Cs_2O + K_2O wt%)

[6] It should be noted that the homogeneity PAR was still required for MB2 because the data used to develop these constraints were from quenched glasses. The effect of kinetics (i.e., slow thermal cool down) were not included and the impact on durability was not known.

Prior to recommending this potential change to DWPF, Edwards and Brown [1998] evaluated these potential criteria from a larger, existing database (> 1300 data points) to gain a better understanding of the relationship between the alumina and sum of alkali and the leaching behavior. This evaluation tested the application of one of the equivalent criteria over a larger compositional window and provided some measure of confidence for their application. The database (at that time) consisted of the data used for THERMO model development and validation [Jantzen et al. 1995], the sludge-only processing glasses of the Tank 51 variability study [Peeler 1996a, Peeler 1996b], two pour stream samples from macrobatch 1 [Edwards 1997], the PNNL CVS glasses [Hrma et al. 1994], and the glasses from the Tank 42 variability study [Edwards and Brown 1998, Edwards 1999].[7] It should be noted that the majority of property-composition data in the database were based on glasses that had been quenched from the melt temperature.

Figure 2 provides a plot of alumina versus ΣM_2O (wt%) content for the glasses in the compiled database. In Figure 3, the data for only those glasses having log NL [B] > 1.0 are shown. When applying either of the proposed constraints (in conjunction with relaxing the homogeneity constraint to the PAR), all but six glasses would be eliminated from potential processing. As noted by Edwards and Brown [1998], these six glasses were outside the feasible composition range for glasses expected to be produced during the processing of MB2. More specifically, these glasses contained either low concentrations of Fe_2O_3 (< 2.5 wt%) or high concentrations of B_2O_3 (> 19.6 wt%). All other glasses that were evaluated within the compositional region of interest with Al_2O_3 exceeding 3 wt% and the ΣM_2O less than 19.3 wt% provide PCT results for boron significantly better than those for the EA standard glass [Jantzen et al. 1993]. The data also indicated that if the lower limit for Al_2O_3 were increased to 4.0 wt% there may not be a need for the addition of an upper sum of alkali constraint (over the composition range tested) to avoid glasses that may leach as poorly as EA.

Based on analysis of the compiled database, Edwards and Brown [1998] determined that the imposition of the measurement uncertainty requirement on the homogeneity constraint (necessary to assure reliable durability prediction) unnecessarily restricted DWPF operation for expected macrobatch 2 glass compositions. These data indicated that it was possible to relax the homogeneity measurement uncertainty requirement (to the PAR) for macrobatch 2 as long as the following criteria were satisfied:

- use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add an sum of alkali constraint with an upper limit of 19.3 wt% (i.e., $\Sigma M_2O < 19.3$ wt%), **or**

- adjust the lower limit on the alumina constraint to 4 wt% (i.e., $Al_2O_3 \geq 4.0$ wt%).

As noted by Edwards and Brown [1998], measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina constraint and/or the coupled alumina and alkali constraint, if used.[8]

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7 Over 3900 data points (average of the logs from triplicate analysis) formed the extensive database.

8 The application of these two constraints applies only to MB3 compositional envelope evaluated which was based on a pool of candidate glasses for each sludge type: Tank 40 only and a blend of Tank 8 and Tank 40. More specifically, these constraints should not be applied to glasses outside this envelope such as high B_2O_3 glasses.

These recommendations were transmitted to DWPF for MB2. Radioactive glasses produced at DWPF have been analyzed and have found to be consistent with the results discussed above [Fellinger and Bibler 2000]. The analysis by Edwards and Brown [1998] led to a larger compositional window for MB2 without compromising product quality or processing considerations.

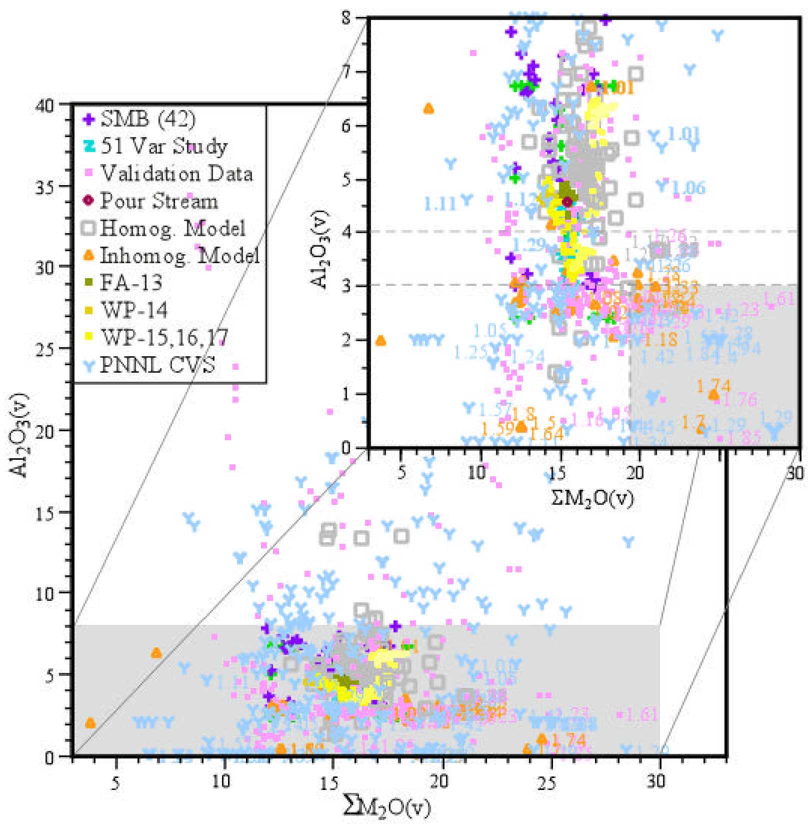

Figure 2. Al_2O_3 (wt%) versus SM_2O (wt%) for the Existing Database.
(from Edwards and Brown [1998] where the SM_2O = Na_2O + Li_2O + Cs_2O + K_2O wt%)

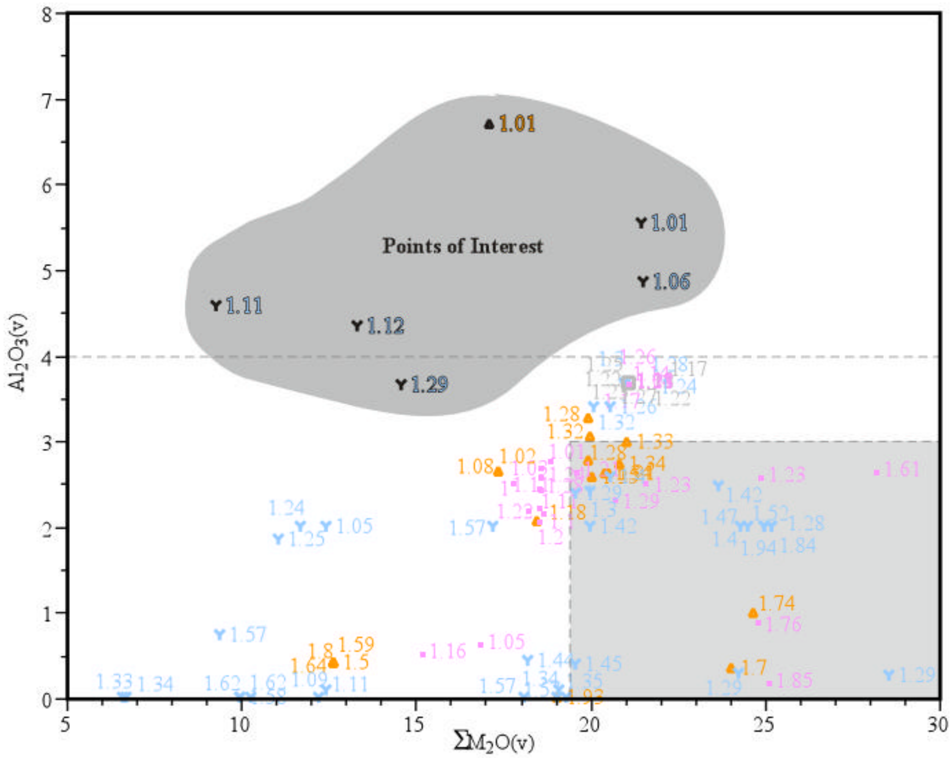

Figure 3. Al_2O_3 (wt%) versus ΣM_2O (wt%) for Glasses with log NL [B] > 1 (g/L).
(from Edwards and Brown [1998] where the $\Sigma M_2O = Na_2O + Li_2O + Cs_2O + K_2O$ wt%)

Given the effectiveness of applying the new constraints associated with homogeneity for MB2 and the inherent limitations of the application of the homogeneity discriminator for MB3 (and other sludge-only glasses), an investigation into the application of these constraints is warranted. In this report, data are generated to support the use of a relaxed homogeneity constraint (to the PAR) coupled with application of one of the equivalent constraints for MB3. This work has been prepared to address technical issues discussed in Technical Task Request HLW/DWPF/TTR-00-0023, Rev. 0 [Ray 2000], and in accordance with the Task Technical and QA Plan (WSRC-RP-2000-00302) [Harbour 2000a] and the associated Analytical Study Plan (WSRC-RP-2000-00321) [Harbour 2000b]. The scope to support this objective was integrated with the MB3 variability study [Harbour 2000c].

2.0 OBJECTIVE STATEMENT

The objective of this research is to provide the technical bases to relax the homogeneity measurement uncertainty requirement ***for macro-batch 3*** as long as the following criteria are satisfied:

Criterion (1)

- use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add an sum of alkali[9] constraint with an upper limit of 19.3 wt% (i.e., $\Sigma M_2O < 19.3$ wt%), **or**

Criterion (2)

- adjust the lower limit on the alumina constraint to 4 wt% (i.e., $Al_2O_3 \geq 4.0$ wt%).

3.0 SELECTING THE REDUCTION OF CONSTRAINTS (RC) GLASS COMPOSITIONS

A detailed discussion of the strategy for selecting glass compositions for the RC glasses has been described by Edwards and Brown (see Appendix A). In general, glass compositions to support the reduction of constraints task were selected from a pool of candidate glasses (for each sludge type: Tank 40 only and a blend of Tank 8 and Tank 40) developed as part of the MB3 variability study [Harbour 2000c]. The pool of candidate glasses from which to select was not restricted by DWPF's product or process constraints. The systematic glass selection process was focused specifically to support the reduction of constraints objective(s) which would allow for the examination of the conservatism in the homogeneity constraint. More specifically, all glasses selected were predicted to be outside the homogeneous property acceptance region (PAR)[10] based upon the current homogeneity constraint.

Statistical design algorithms were then used to select 12 compositions that satisfied each of the constraints listed in Section 2.0 (Criterion (1) and Criterion (2)). While selecting compositions to satisfy criterion (2), glasses with at least 4 wt% Al_2O_3 which challenged the criteria associated with the sum of alkali (19.3 wt%) were the focus. For the sludge option consisting only of Tank 40, there were only three loadings that generated compositions that were predicted to be inhomogeneous. For the Tank 8 and 40 (blend) sludge option, there were candidate compositions at each waste loading from 20 to 30% from which to select.

Glasses were selected from the MB3 compositional pool that challenge criteria (1) and (2) over a broad compositional region. This was accomplished by using the D-optimality routines of JMP® Version 3.2.2 [SAS 1994] to select 12 compositions from the set of compositions that were predicted to be inhomogeneous but which satisfied criterion (1). These 12 compositions were selected using 100 iterations of the JMP routines to optimize the fitting of a mixture model comprised of 11 linear terms for Al_2O_3, B_2O_3, CaO, Fe_2O_3, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2, and U_3O_8. Although no modeling is desired for these results, this approach did provide an opportunity to assess the (linear) effects of each of these oxides and, thus, provided coverage of

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9 Alkali included in this sum are Na_2O, Li_2O, Cs_2O, and K_2O.

10 The PAR for a constraint represents the region in composition space whereby that constraint is satisfied after the prediction uncertainties for the constraint are taken into account.

the composition space spanned by this set of compositions (i.e., those compositions that were predicted to fall outside of the homogeneity PAR, that have Al_2O_3 content of at least 3.0 wt%, and that have no more than 19.3 wt% alkali content).

An additional 12 compositions were selected from the set of compositions that fell outside of the homogeneity PAR, that had an Al_2O_3 content of at least 4.0 wt%, and that had more than 19.3 wt% alkali content. The 12 compositions so generated were then combined with the first set of 12 for a total of 24 compositions. The combined set of twenty-four compositions are shown in Table I. The sludge type and sludge loading values are also provided in this table.

Given the composition similarities of the 6 "outlier" glasses with log NL [B] > 1.0 (see Figure 3), the potential range of these components for MB3 are of interest. Based on the analysis performed by Edwards and Brown (see Appendix A), it is evident that the B_2O_3 content within the MB3 composition space (and for the candidate glasses to support the reduction of constraints task) never exceeds ~ 11 wt% and that the Fe_2O_3 concentrations are always greater than 7 wt% regardless of the blending scenario. Therefore, as with MB2, the MB3 composition regions implicitly avoid the problematic compositional regions in terms of application of the equivalent criteria even though the candidate glasses are predicted to be inhomogeneous (at the PAR limit).

Table I. Reduction of Constraints (RC) Target Glass Compositions (wt%).

ID	Sludge	Loading (%)	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	U_3O_8
RC01	Tank 40 Only	20	4.07	9.00	0.71	08.35	4.40	1.44	0.30	15.11	0.00	55.27	1.35
RC02	Tanks 8 and 40	26	4.25	8.33	0.75	9.20	3.33	1.34	0.58	16.20	0.61	51.13	4.28
RC03	Tanks 8 and 40	24	4.62	9.69	0.69	8.49	4.18	1.78	0.54	15.84	0.56	52.51	1.10
RC04	Tanks 8 and 40	30	4.13	7.88	0.90	10.61	3.15	1.66	0.99	16.92	0.43	48.39	4.94
RC05	Tanks 8 and 40	26	4.26	8.33	0.75	9.20	3.33	1.74	0.86	16.20	0.61	53.53	1.19
RC06	Tank 40 Only	20	3.07	10.20	1.86	8.35	3.60	1.87	0.30	15.11	0.00	55.27	0.37
RC07	Tank 40 Only	20	4.76	9.00	0.71	8.35	4.40	1.87	0.30	11.56	0.00	57.70	1.35
RC08	Tanks 8 and 40	22	3.03	8.78	0.63	7.78	3.51	1.82	0.49	13.61	0.51	56.22	3.62
RC09	Tanks 8 and 40	22	3.03	9.95	0.63	7.78	4.29	1.40	0.73	14.37	0.32	53.88	3.62
RC10	Tanks 8 and 40	24	3.31	8.55	1.79	8.49	4.18	1.37	0.79	14.99	0.56	54.87	1.10
RC11	Tanks 8 and 40	22	5.19	9.95	1.72	7.78	3.51	1.82	0.73	10.14	0.32	55.22	3.62
RC12	Tanks 8 and 40	22	5.19	9.95	0.63	7.78	3.51	1.40	0.73	15.41	0.51	53.88	1.01
RC13	Tanks 8 and 40	20	3.19	10.20	0.57	10.00	4.40	1.86	0.66	10.18	0.47	57.56	0.91
RC14	Tanks 8 and 40	22	5.19	8.78	1.72	7.78	4.29	1.40	0.49	10.14	0.51	56.08	3.62
RC15	Tanks 8 and 40	22	3.03	9.95	0.63	10.99	3.51	1.40	0.49	10.14	0.32	55.92	3.62
RC16	Tanks 8 and 40	30	4.13	8.93	0.86	10.61	3.85	1.66	0.67	15.26	0.70	48.39	4.94
RC17	Tanks 8 and 40	20	4.10	10.20	0.57	7.07	4.40	1.43	0.66	15.11	0.29	55.26	0.91
RC18	Tanks 8 and 40	20	4.00	9.00	1.65	7.07	4.40	1.86	0.45	15.11	0.29	55.26	0.91
RC19	Tanks 8 and 40	24	4.02	8.55	0.69	8.49	4.18	1.37	0.54	15.84	0.35	54.87	1.10
RC20	Tanks 8 and 40	22	5.19	8.78	0.63	7.78	4.29	1.82	0.73	15.48	0.32	53.88	1.10
RC21	Tanks 8 and 40	30	4.13	7.88	0.86	10.61	3.85	1.66	0.99	15.99	0.70	48.39	4.94
RC22	Tanks 8 and 40	22	5.19	9.95	0.63	7.78	3.87	1.40	0.49	15.48	0.32	53.88	1.01
RC23	Tanks 8 and 40	22	4.23	8.82	1.72	7.97	4.29	1.37	0.73	15.48	0.51	53.88	1.01
RC24	Tanks 8 and 40	30	4.13	7.88	0.86	10.61	3.15	1.66	0.99	14.51	0.43	50.84	4.94

Property predictions for these compositions are provided in Table II. It is noted the selection of these glasses was not limited by any property prediction with the exception of homogeneity. For example, 8 glasses are predicted to be non-durable (ΔG_P values < -12.75). However, to support the test objectives, all of the RC compositions are predicted to be inhomogeneous based on target compositions.

Table II. Sum of Alkalis and Property Predictions for the RC Glasses.

ID	ΣM_2O	ΔG_P	Homo	T_L	$\eta_{1150°C}$	Satisfies PAR
RC01	0.1951	-12.392	208.5	927.7	52.2	Durable; Visc; T_L; Not Homo
RC02	0.1953	-12.669	206.9	953.5	45.8	Durable; Visc; T_L; Not Homo
RC03	0.2002	-13.037	209.8	939.4	41.5	Not Durable; Visc; T_L; Not Homo
RC04	0.2007	-13.423	210.7	986.9	33.3	Not Durable; Visc; T_L; Not Homo
RC05	0.1953	-12.578	210.8	946.1	54.2	Durable; Visc; T_L; Not Homo
RC06	0.1871	-12.622	210.0	924.4	55.6	Durable; Visc; T_L; Not Homo
RC07	0.1596	-9.002	210.6	924.1	97.2	Durable; Visc; T_L; Not Homo
RC08	0.1712	-10.899	196.3	914.0	80.2	Durable; Visc; T_L; Not Homo
RC09	0.1866	-12.526	196.9	919.2	48.4	Durable; Visc; T_L; Not Homo
RC10	0.1917	-12.752	209.2	928.2	52.5	Not Durable; Visc; T_L; Not Homo
RC11	0.1365	-7.723	209.4	923.1	128.5	Durable; Not Visc; T_L; Not Homo
RC12	0.1892	-11.916	209.5	926.5	61.5	Durable; Visc; T_L; Not Homo
RC13	0.1458	-8.512	209.7	942.5	88.3	Durable; Visc; T_L; Not Homo
RC14	0.1443	-7.965	210.1	921.0	117.2	Durable; Not Visc; T_L; Not Homo
RC15	0.1365	-7.762	210.3	960.4	97.2	Durable; Visc; T_L; Not Homo
RC16	0.1911	-12.601	210.7	986.9	32.1	Durable; Visc; T_L; Not Homo
RC17	0.1951	-12.752	202.6	908.8	52.0	Not Durable; Visc; T_L; Not Homo
RC18	0.1951	-12.872	206.2	908.6	55.2	Not Durable; Visc; T_L; Not Homo
RC19	0.2002	-12.863	208.3	930.7	49.8	Not Durable; Visc; T_L; Not Homo
RC20	0.1977	-12.500	209.0	926.5	53.0	Durable; Visc; T_L; Not Homo
RC21	0.1984	-13.179	210.1	986.9	30.9	Not Durable; Visc; T_L; Not Homo
RC22	0.1935	-12.184	210.2	926.5	55.5	Durable; Visc; T_L; Not Homo
RC23	0.1977	-13.029	210.8	926.0	48.7	Not Durable; Visc; T_L; Not Homo
RC24	0.1766	-11.184	210.6	977.0	56.0	Durable; Visc; T_L; Not Homo

4.0 EXPERIMENTAL

The data generated for the study were performed according to the applicable DOE/RW-0333P Quality Assurance Criteria [11]. This section describes the experimental procedures, test equipment, and application of standards used to generate the required data in support of the test objective(s).

4.1 GLASS FABRICATION

Table I identified the 24 glasses prepared for this study as well as the unique nomenclatures used (i.e., RC series). Each batch was prepared (to produce 100 grams of glass[12]) from the proper proportions of reagent grade chemicals using SRTC technical procedure "Glass Batch Preparation Procedure – GTOP-3-003" [SRTC 1996a]. Weigh sheets were filled out as the materials were weighed.[13] Once batched, these glasses were melted in accordance with the technical procedure "Glass Melting Procedure – GTOP-3-004" [SRTC 1996b]. In general, the raw materials were thoroughly mixed and placed into a Platinum / 5% Gold 250 mL crucible. The batch was subsequently placed into a high temperature furnace and the temperature was increased at ~10°C/minute to 1150°C. After an isothermal hold at 1150°C for 4 h, the crucible was removed and the glass was poured onto a clean stainless steel plate and allowed to air cool. Batching and melting were performed in random order according to the guidance defined by Edwards and Brown (see Appendix A).

Approximately 90 grams of glass were removed (poured) from the crucible while ~10 grams remained in the crucible along the walls.[14] The pour patty was used as a sampling stock for the various heat treatments and property measurements (i.e., chemical composition, crystallinity, and durability) in accordance with the analytical plan [Harbour 2000b]. Glasses were stored in marked containers (using the unique RC nomenclature as defined by Edwards and Brown (see Appendix A)).

To bound the effects of thermal history on the product performance, approximately 25 grams of each RC glasses was heat treated to simulate cooling along the centerline of a DWPF-type canister [Marra and Jantzen 1993]. This cooling regime is commonly referred to as the centerline canister cooling (clc) curve. This terminology will be utilized in this report to differentiate samples from different cooling regimes (quenched versus clc). Again it is noted that the evaluation of criterion (1) and criterion (2) for MB2 application (see Section 1.0) was based on primarily quenched glasses.

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11 As defined by the DOE/RW-0333P Quality Assurance Program and implemented through the L1 manual.

12 This would produce enough glass from which all processing and product performance properties could be measured.

13 Weigh sheets can be found in the WSRC-NB-99-00236, pp. 18 – 23.

14 Visual observations of homogeneity were documented in WSRC-NB-99-00236 for both the pour patty and the residual crucible glass. No visual signs of undissolved solids or compositional inhomogeneities were observed.

4.2 PROPERTY MEASUREMENTS

4.2.1 CHEMICAL COMPOSITION ANALYSIS

To confirm that the as-fabricated glasses corresponded to the target compositions (as shown in Table I), a representative sample from each as-fabricated RC glass was submitted to the SRTC Mobile Laboratory (SRTC-ML) for chemical analysis. Edwards provided an analytical plan (see Appendix B) that accompanied these samples. This plan identified the cations to be analyzed and the dissolution techniques (i.e., sodium peroxide fusion or lithium-metaborate flux) to be used. Each glass was prepared in duplicate by each of the dissolution techniques. Concentrations (as weight %) for the following cations were measured by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP – AES): aluminum, boron, calcium, iron, lithium, magnesium, manganese, nickel, sodium, silicon, and uranium. The analytical plan was developed in such a way as to provide the opportunity to evaluate potential sources of error. The results were evaluated to confirm that the target glass compositions were adequately met. To assess the performance of the ICP over the course of these analyses and for potential bias-correction needs, standard glasses (including the Waste Compliance Plan (WCP) Batch 1 standard and a Corning Engineering Laboratory Services (CELS) uranium-containing glass standard) were intermittently run.

4.2.2 CRYSTALLINITY

Although visual observations for crystallization were performed and documented[15], a representative sample from each RC glass (both quenched and clc versions) was submitted to SRTC Analytical Development Section (ADS) for X-ray diffraction (XRD) analysis. This analysis would be used to confirm visual observations of crystallinity within a given detection limit based on the run conditions of the diffractometer. Samples were run under conditions allowing an approximate 1.0 vol% detection limit. That is, if crystals (or undissolved solids) are present at 1.0 vol% (or greater), the diffractometer will not only be able to detect these crystals but will also allow a qualitative measure (i.e., determine the type of crystal present). Otherwise, a characteristic high background devoid of crystalline spectral lines indicates that the glass product is amorphous.

4.2.3 DURABILITY

The Product Consistency Test (PCT) was performed on each glass to assess chemical durability using technical procedure "Nuclear Waste Glass Product Consistency Test (PCT) Method – GTOP-3-025" [ASTM 1997]. The PCT was conducted in triplicate for each RC glass (both quenched and CLC versions).[16] Also included in this experimental test matrix were the Environmental Assessment (EA) glass [Jantzen et al. 1993], the Approved Reference Material (ARM-1) glass, and blanks. Samples were ground, washed, and prepared according to procedure. Fifteen (15) mL of Type I ASTM water was added to 1.5 grams of glass in stainless steel vessels.

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15 For visual observations of crystallization, refer to WSRC-NB-99-00236, pp. 18 – 22.

16 Due to the number of glasses to be tested (48 glasses as a result of 24 glasses with two heat treatments – not including blanks and standards), 12 RC glasses were randomly selected as defined as Set #1 while the remaining 12 RC glasses defined Set #2. It should be noted that blanks and standards were run in both sets. See WSRC-NB-99-00236, Appendix C, and Appendix D for more details.

The vessels were closed, sealed, and placed in an oven at 90 ± 2°C. Samples were left at 90°C ± 2°C for 7 days. The resulting solutions (once cooled) were sampled (filtered and acidified), labeled (according to the analytical plan), and analyzed. Edwards provided analytical plans for the SRTC-ML analysis (see Appendices C and D – due to the large number of vessels two groups of tests were initiated). The overall philosophy of these plans were to provide an opportunity to assess the consistency (repeatability) of the PCT and analytical procedures in the effort to evaluate chemical durability of the RC glasses. Normalized release rates were calculated based on target, measured and bias-corrected compositions using the average of the logs.

5.0 RESULTS AND DISCUSSION

This section provides a detailed discussion and analysis of the measured RC glass compositions, homogeneity evaluation via XRD, and the PCT results.

5.1 CHEMICAL COMPOSITION

Target and measured compositions of the RC glasses are provided, and comparisons are made, in this section. The chemical composition measurements for these glasses were conducted as part of a larger study[17] by the SRTC-ML. Two dissolution methods were utilized: samples prepared by lithium metaborate ($LiBO_2$) dissolution were used to measure calcium (Ca), iron (Fe), magnesium (Mg), sodium (Na), silicon (Si), and uranium (U) and samples prepared by sodium peroxide fusion (Na_2O_2) dissolution were used to measure aluminum (Al), boron (B), lithium (Li), manganese (Mn), and nickel (Ni). For each of these cations, two measurements were obtained on each of two samples prepared by the given dissolution method. All of the prepared samples were analyzed by ICP-AES.

Table E1 in Appendix E provides the cation concentration measurements obtained from the samples prepared using $LiBO_2$, and Table E2 in Appendix E provides cation concentration measurements derived from the samples prepared using Na_2O_2. Included in these tables are the measurements from all of the glasses covered by the analytical plan in Appendix B. Measurements for the two standards (Batch 1 and a uranium standard glass) that were included in the SRTC-ML analytical blocks along with the RC glasses are also provided in these tables. The measurements for these standards and the RC glasses are discussed below. The cation concentrations were converted to oxide concentrations by multiplying the concentrations for each cation by the gravimetric factor for the corresponding oxide. During this process, a cation concentration, that was determined to be below the detection limit of the analytical procedures, was reduced to half of the detection limit (as indicated by a "<" in Appendix E), as the corresponding oxide concentration was determined.

17 In addition to the 24 glasses batched as part of the reduction of constraints task, ten MB3 Phase 3 glasses were included in the analytical plan executed by the SRTC-ML. The analytical plan is provided in Appendix B.

5.1.1. WCP Batch 1 and CELS Uranium Standard

In this section, the SRTC-ML measured chemical compositions for the samples of WCP Batch 1 and the CELS uranium standard (U_{std}) glasses are reviewed and compared to their reference values, which are provided in Table III. A dash ("-") in Table III indicates that corresponding oxide is not present in this glass. Also note that these glasses contain oxides that are outside the scope of this work and, thus, are not measured or accounted for in this study.

Table III. Oxide Compositions of WCP Batch 1 and CELS Uranium Standard Glasses (wt%).

Oxide	WCP Batch 1 (wt%)	CELS U_{std} (wt%)
Al_2O_3	4.877	4.1
B_2O_3	7.777	9.209
BaO	0.151	-
CaO	1.220	1.301
Cr_2O_3	0.107	-
Cs_2O	0.060	-
CuO	0.399	-
Fe_2O_3	12.839	13.196
K_2O	3.327	2.999
Li_2O	4.429	3.057
MgO	1.419	1.21
MnO	1.726	2.892
Na_2O	9.003	11.795
Nd_2O_3	0.147	-
NiO	0.751	1.12
RuO_2	0.0214	-
SiO_2	50.22	45.353
TiO_2	0.677	1.049
U_3O_8	-	2.406
ZrO_2	0.098	-

Three WCP Batch 1 samples and two CELS U_{std} samples were included in each of the analytical blocks for peroxide fusion and for lithium metaborate. For each analytical block, there were two ICP calibration blocks, and the results over these blocks were investigated for biases due to calibration effects.

5.1.2. WCP Batch 1 and CELS U_{std} Results by Analytical Block

The chemical composition measurements of the WCP Batch 1 and CELS U_{std} samples utilized in the analytical plan are investigated in this section. Plots of the measurements for these standards by analytical block for each oxide are plotted in Exhibits E1 and E2 of Appendix E. Exhibit E1 covers the results from samples prepared by $LiBO_2$, and Exhibit E2 covers samples prepared by Na_2O_2. Line segments have been added to these plots connecting the means of the analytical blocks for each of the two standards for each oxide. The behaviors of the line plots for the two standards mimic each other for many of the oxides. This implies that all of the measurements derived from the same calibration of the ICP may be influenced in a similar manner.

WCP Batch 1 measurements generated from samples prepared by $LiBO_2$ are analyzed by analytical block in Exhibits E3 and E4 in Appendix E, and those generated from samples prepared by Na_2O_2 are shown in Exhibits E5 and E6. These exhibits include statistical tests for differences among the block averages for each oxide.[18] At the 5% significance level, differences in these block averages are indicated for Cr_2O_3, Fe_2O_3, and MgO (note that there is no uranium in Batch 1) for samples prepared using $LiBO_2$. For samples prepared using Na_2O_2 (at the 5% significance level), the oxides B_2O_3, Li_2O, MnO, and NiO indicate statistically significant differences in the averages of the ICP calibration blocks.

Similar information for the Ustd results is provided in Exhibits E7 through E10 of Appendix E. At the 5% significance level, differences in the block averages are indicated only for Fe_2O_3 for samples prepared using $LiBO_2$. For the samples prepared using Na_2O_2, only for NiO is there an indication of statistically significant differences in the averages of the ICP calibration blocks.

These results suggest that it may be helpful to bias-correct the oxide measurements for the RC glasses. When there are statistically significant differences among the WCP Batch 1 measurements over the analytical blocks for some of the oxides, bias correcting the measurements of the study glasses for these differences should help reduce the variability of these measurements. Reducing the variability increases the power for detecting real differences among the study glasses when they exist. For the discussion that follows, comparisons are made that consider both the original and bias-corrected measurements.

5.1.3. Bias-Correction Using the WCP Batch 1 Results

The basis for bias correcting the oxide concentration values for the RC glasses is provided in Table IV, which provides the average oxide concentrations by analytical block for both WCP Batch 1 and CELS U_{std}. The WCP Batch 1 values were used to adjust the compositions of study glasses for all oxides except uranium. The CELS U_{std} results were used to adjust the uranium measurements for the study glasses.

18 These exhibits include analysis of variance (ANOVA) tests for differences among the analytical blocks. If the value of **Prob>F** is less than or equal to 0.05 for an oxide, then the null hypothesis of no differences among the analytical block means for this oxide is rejected in favor of the alternate hypothesis (that there are differences among these means) at the 5% significance level.

Table IV. Reference Values for and Average Measurements of Standards by Block and Associated Statistical Comparisons.

WCP Batch 1	Reference Value	Prep Method	Block 1 ICP Block 1 N=3*	Block 1 ICP Block 2 N=3	Block 2 ICP Block 1 N=3	Block 2 ICP Block 2 N=3	Block 3 ICP Block 1 N=3	Block 3 ICP Block 2 N=3	Statistical Difference Between Avg. Meas. and Ref Value
Al_2O_3 (wt%)	4.877	Na_2O_2	4.667	4.699	4.806	4.862	4.793	4.825	Yes
B_2O_3 (wt%)	7.777	Na_2O_2	7.470	7.706	7.814	7.985	7.749	7.803	No
CaO (wt%)	1.22	$LiBO_2$	1.218	1.229	1.201	1.209	1.226	1.215	No
Cr_2O_3 (wt%)	0.107	$LiBO_2$	0.095	0.099	0.096	0.092	0.095	0.100	Yes
Fe_2O_3 (wt%)	12.839	$LiBO_2$	13.229	12.920	13.044	12.958	12.810	12.762	No
Li_2O (wt%)	4.429	Na_2O_2	4.291	4.220	4.342	4.335	4.356	4.370	Yes
MgO (wt%)	1.419	$LiBO_2$	1.383	1.412	1.430	1.432	1.396	1.457	No
MnO (wt%)	1.726	Na_2O_2	1.691	1.765	1.674	1.730	1.644	1.683	No
Na_2O (wt%)	9.003	$LiBO_2$	8.883	8.883	8.892	9.090	8.946	8.816	No
NiO (wt%)	0.751	Na_2O_2	0.708	0.773	0.682	0.687	0.699	0.717	Yes
SiO_2 (wt%)	50.22	$LiBO_2$	50.701	50.060	50.345	50.131	49.703	49.489	No
U_3O_8 (wt%)	0	$LiBO_2$	0.057	0.057	0.057	0.057	0.057	0.057	N/A
Sum of Oxides (wt%)	94.37		94.40	93.82	94.38	94.57	93.47	93.30	No

CELS U_{std}	Reference Value	Prep Method	Block 1 ICP Block 1 N=2	Block 1 ICP Block 2 N=2	Block 2 ICP Block 1 N=2	Block 2 ICP Block 2 N=2	Block 3 ICP Block 1 N=2	Block 3 ICP Block 2 N=2	Statistical Difference Between Avg. Meas. and Ref Value
Al_2O_3 (wt%)	4.1	Na_2O_2	4.006	3.873	3.949	3.817	4.015	3.930	Yes
B_2O_3 (wt%)	9.209	Na_2O_2	8.903	8.565	8.790	8.710	9.000	8.758	Yes
CaO (wt%)	1.301	$LiBO_2$	1.426	1.429	1.295	1.308	1.428	1.350	Yes
Cr_2O_3 (wt%)	0	$LiBO_2$	0.233	0.241	0.232	0.230	0.226	0.237	Yes
Fe_2O_3 (wt%)	13.196	$LiBO_2$	13.246	13.067	13.118	13.010	12.746	12.724	No
Li_2O (wt%)	3.057	Na_2O_2	2.917	2.820	2.853	2.766	2.917	2.885	Yes
MgO (wt%)	1.21	$LiBO_2$	1.156	1.157	1.166	1.171	1.128	1.180	Yes
MnO (wt%)	2.892	Na_2O_2	2.705	2.776	2.634	2.660	2.724	2.679	Yes
Na_2O (wt%)	11.795	$LiBO_2$	10.771	11.168	11.424	11.343	11.188	10.791	Yes
NiO (wt%)	1.12	Na_2O_2	1.017	1.043	0.978	0.953	1.013	0.997	Yes
SiO_2 (wt%)	45.353	$LiBO_2$	45.567	45.460	46.209	45.246	44.925	44.497	No
U_3O_8 (wt%)	2.406	$LiBO_2$	1.969	2.305	2.364	2.046	2.229	2.264	Yes
Sum of Oxides (wt%)	95.64		93.92	93.91	95.01	93.26	93.54	92.29	Yes

* "N" refers to the number (sample size) of WCP Batch 1 or CELS U_{std} standard glasses in each ICP block

Before tackling the process of the bias correction, consider the statistical comparisons of the WCP Batch 1 and CELS U_{std} results provided in Table IV. Significant differences (at a 5% significance level) between the average measurements and the WCP Batch 1 reference values are indicated for Al_2O_3, Cr_2O_3, Li_2O, and NiO in the statistical comparisons in Table IV. For the CELS U_{std} standard, the references values are not as well known as they are for WCP Batch 1, and the average measurements for all of the oxides, except Fe_2O_3 and SiO_2, differ from the reference values at a 5% significance level.

How was the bias correction conducted? For each dissolution method, let $\bar{a}_{ij}$ be the average measurement for the i^{th} oxide at analytical block j for WCP Batch 1 (or CELS U_{std} for uranium), and let t_i be the reference value for the i^{th} oxide for WCP Batch 1. (The averages and reference values are provided in Table IV for each oxide of interest.) Let $\bar{c}_{ijk}$ be the average measurement for the i^{th} oxide at analytical block j for the k^{th} glass prepared by the given dissolution method. The bias adjustment was conducted as follows for each of the two dissolution methods

$$\bar{c}_{ijk} \bullet \left(1 - \frac{\bar{a}_{ij} - t_i}{\bar{a}_{ij}}\right) = \bar{c}_{ijk} \bullet \frac{t_i}{\bar{a}_{ij}}$$

Bias corrected (relative) measurements are indicated by additional "bc" suffix, and such adjustments were performed for all of the oxides and both of the dissolution methods of this study. Both measured and measured "bc" values for both dissolution methods are included in the discussion that follows.

5.1.4. Results in Analytical Sequence

All of the composition data generated by the SRTC-ML in the measurement of the glass samples (including the two standards WCP Batch 1 and CELS U_{std} and the reduction of constraint glasses) are plotted in analytical sequence by oxide in Exhibits E11 through E14 in Appendix E. Plots are provided for the original and the bias-corrected (bc) measurements for each oxide. In these plots, a small square is used to represent WCP Batch 1, an open square is used to represent CELS U_{std}, a "x" is used to represent each of the RC glasses, and an "+" is used to represent each of the other glasses included in the same analytical plan. The results presented in these plots by analytical sequence are investigated in more detail below.

5.1.5. Composition Measurements by Glass ID

Exhibits E15 through E20 in Appendix E provide plots of the oxide concentrations by glass ID (including the WCP Batch 1 and CELS U_{std} glasses) for the original and bias-corrected measurements of the glasses. As discussed in Section 5.1.6, these plots indicate reasonably close agreement among the measurements for each oxide for each glass.

5.1.6. Measured versus Target Compositions

A closer look at the measured versus target compositions for the glasses of this study is provided in this section. Exhibits E21 through E26 in Appendix E provide plots by glass ID by oxide of the average measured, average bias-corrected measured, and target concentrations. Exhibit E27 in Appendix E provides a similar plot for the sum of oxides by glass ID.

Some observations from these exhibits include:

- the B_2O_3, Li_2O, and Na_2O measurements (original and bias-corrected) fall short of the targets for most of the RC glasses, and

- the average SiO_2 measurements (original and bias-corrected) for rc22 appear to be higher than targeted for that glass while the SiO_2 values for the other RC glasses tend to fall short of their targets.

Comparisons for the study glasses and the two standard glasses are also provided in Table E3 through Table E6 in Appendix E. The measurements, the bias-corrected measurements, and the target values for the various oxides for each glass are shown. Differences (measured values minus targets) are also given as percentages of the target values. As suggested by the exhibits, the differences between the measured and targeted values for B_2O_3 are all negative. Also, the measured values for rc22 fall at least 5% short of their corresponding targets for all oxides except SiO_2. For this oxide, rc22's measured values are 5% above target. The sums of oxides for all of the glasses are within the interval 95 to 105 wt%, which is typically used to assess acceptable laboratory performance for chemical analysis of glasses [Jantzen et al. 1995].

In the discussion that follows, three different representations (targeted, measured, and measured bias-corrected) of the compositions of these glasses will be explored to demonstrate that the conclusions presented in this document are robust (or insensitive) to which of these representations is most accurate.

5.2 CRYSTALLIZATION

A representative sample of each as-fabricated (quenched) and thermally heat treated (i.e., clc) RC glass was submitted for X-ray diffraction (XRD) to confirm visual observations of crystallization or lack thereof. All 24 RC glasses were amorphous based on the XRD results after both heat treatments.[19] As an example, the XRD pattern for rc18-clc is shown in Figure 4. The XRD pattern shows the characteristic high background devoid of crystalline spectral lines indicative of an amorphous (non-crystalline) product. That is, if undissolved solids and/or crystallization were present in the sample in sufficient quantity, well-defined or distinct spectral lines would be observed which could be used to identify the crystalline phase. It should be noted that the X-ray diffractometer used in this study has a detection limit of approximately 1.0 vol% in glass. Undissolved solids and/or crystallization present below this limit remain undetected by the XRD unit.

19 XRD patterns for all 24 RC glasses (quenched and clc) are characterized by high background devoid of crystalline spectral lines indicative of an amorphous (non-crystalline) product within the detection limits (~ 1 vol%) of the X-ray diffractometer (see Appendix F for clc results). Note, the absence of well defined spectral lines does not provide an indication of chemical homogeneity, but simply demonstrates the absence of crystalline material.

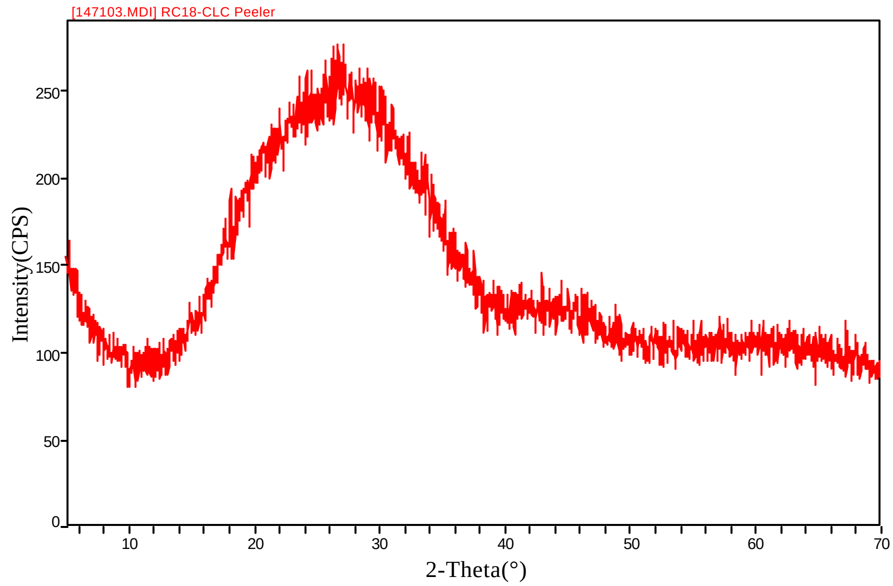

Figure 4. XRD Analysis of rc18-clc.

5.3 DURABILITY AS MEASURED BY THE PCT

The 24 RC glasses, after being batched and fabricated, were subjected to the 7-day Product Consistency Test (PCT) as an assessment of their durabilities. More specifically, Method A of the PCT [ASTM 1997] was used for these measurements. All 24 glasses were both quenched and centerline-cooled (clc) with both versions of the glass being subjected to the PCT. Durability is the critical product quality metric for the glass produced by DWPF. PCTs were conducted in triplicate for each version (heat treatment) of the glasses. To facilitate this experimental work, the glasses were split into two groups for testing durability. For each group, PCTs were also conducted in triplicate for samples of the EA glass and for samples of the ARM-1 glass. Blanks (samples consisting only of ASTM Type I water) were also submitted for the PCT as part of each group.

An analytical plan was provided to the SRTC-ML to support the measurement of the compositions of the solutions resulting from the PCTs for each group. Appendix C provides the plan for the first group of PCT's; Appendix D provides the plan for the second group. The elements measured as part of these plans were expanded (beyond the four recommended in the PCT: B, Li, Na, and Si) to include Al, B, Ca, Cr, Fe, Li, Mg, Mn, Na, Ni, Si, and U. Samples of a multi-element standard solution were also included in each analytical plan (as a check on the accuracy of the ICP–AES used for these measurements) per the PCT procedure. The results from all of the measurements as reported by the SRTC-ML are given in Table G1 of Appendix G. Any measurement in the as-reported (ar) columns of Table G1 determined to be below detection (as indicated by a "<" in the table) was replaced by ½ of the detection limit in determining the parts per million (ppm) columns that appear in Table G2. The ppm values in Table G2 were compiled by adjusting for the dilution factors: the values in the as-reported columns of Table G1 were multiplied by 1.6667 for the study and ARM glasses and by 16.667 for the EA glass to determine the ppm values.[20] In the discussion that follows, only the results for B, Li, Na, and Si are discussed.

Per the PCT procedure, the SRTC technicians conducting the tests assessed the water weight loss of each individual PCT solution. This process resulted in the following PCTs being discarded as inaccurate[21]: rc02-1 (F21), rc07-clc-1 (F48), rc14-clc-3 (F25), and rc05-3 (H14). The SRTC-ML measurements for these PCTs are provided (and have been shaded) in Table G2, but none of these values participates in the discussion that follows.

Exhibit G1 in Appendix G provides a plot of the leachate concentrations of interest (i.e., B, Li, Na, and Si) in analytical sequence by group that were reported by the SRTC-ML including all of the standards. The values from the EA PCT's expand the scales of these plots making it difficult to distinguish among the results of the other analyses. Exhibit G2 in Appendix G provides a revised plot of these results excluding the EA values. No trends or problems are seen in the two exhibits.

Exhibits G3 and G4 in Appendix G provide plots of the leachate concentrations for each type of submitted solution: the standards, EA, ARM, and the glasses. The results for EA are excluded in Exhibits G5 and G6 in Appendix G. Exhibits G7 and G8 in Appendix G plot results from only the RC glasses. A shortened version of the Glass ID is used to identify the results in these exhibits. This shortened version utilizes just the glass number for the glasses and adds an asterisk to this number to represent "clc" results for each glass. There appears to be good repeatability among the three results for each glass with the exception of rc18-clc. One of the PCT triplicates for this glass appears to have yielded much lower concentrations of B, Li, Na, and Si in the leachate than the other two PCT's for this glass.[22]

Table V provides the results from the three analyses of the multi-element standard solution that were included in each of the SRTC-ML's analytical blocks for each of the testing groups. These results also indicate reasonably consistent and accurate results from SRTC-ML's measurement process.

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[20] Six (6) mL of leachate was diluted with 4 mL of 0.4M HNO_3 (a 6:10 volume to volume dilution) before being submitted to the SRTC-ML for analysis. The EA leachates were further diluted (1:10 volume to volume) with deionized water.

[21] Per ASTM C 1285 (Section 21.4.9), if the mass loss is calculated to be greater than 5% of the original leachant mass, disregard the results of that test and use the remaining test results (minimum of two). The details of these measurements and other related information are recorded in SRTC laboratory notebook WSRC-NB-99-00236.

[22] If one discards the "flier", log normalized release values (g/L) for B, Li, Na, and Si based on measured compositions are 0.5682, 0.5045, 0.4901, and 0.2086, respectively. Based on target compositions, log NL values for B, Li, Na, and Si are 0.5543, 0.4940, 0.4678, and 0.1944, respectively. For measured bias corrected compositions, log NL values for B, Li, Na, and Si are 0.5681, 0.4981, 0.4842, and 0.2032, respectively. These values can be compared to those using the triplicate values as reported in Table VI. The discussion and conclusions in this report are based on all three results for rc-18 clc. Conclusions do not change if the "flier" is discarded.

Table V. Measurements of Multi-Element PCT Solution Standard.

	First Group of PCTs					Second Group of PCTs			
Block	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)	Block	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	21.5	9.8	80.0	49.8	1	21.6	10.6	85.6	53.1
1	21.9	10.0	79.4	51.9	1	21.4	10.5	85.8	52.5
1	22.0	10.0	79.8	53.2	1	21.8	10.7	86.3	53.6
Average	21.8	9.9	79.7	51.6	Average	21.6	10.6	85.9	53.1
2	22.7	9.7	82.0	49.0	2	21.4	10.3	85.5	51.8
2	20.8	9.6	79.7	48.7	2	21.3	10.4	85.5	52.0
2	21.4	9.8	80.8	48.5	2	20.8	10.3	81.9	51.8
Average	21.6	9.7	80.8	48.7	Average	21.2	10.3	84.3	51.9
3	21.8	9.8	80.2	48.8	3	21.0	10.0	81.8	51.9
3	20.3	9.6	77.8	47.3	3	20.9	10.2	82.2	51.6
3	19.5	9.8	80.6	43.8	3	20.8	10.0	84.8	51.7
Average	20.5	9.7	79.5	51.7	Average	20.9	10.1	82.9	51.7
Overall Average	21.3	9.8	80.0	50.7	Overall Average	21.2	10.3	84.4	52.2
Reference Value[23]	20.0	10.0	81.0	50.0	Reference Value	20.0	10.0	81.0	50.0
% Difference	6.61%	-2.16%	-1.19%	1.38%	% Difference	6.11%	3.33%	4.17%	4.44%

5.3.1 NORMALIZED PCT RESULTS

Each PCT leachate concentration is typically normalized using the cation composition (expressed as a weight percent) in the glass to obtain a grams-per-liter (g/L) leachate concentration. The normalization of the PCTs is preferentially conducted using the measured compositions of the glasses. In the discussion that follows, the measured as well as the target and bias-corrected, measured cation compositions will be used to conduct the normalization.

To express leachate concentration, the common logarithm of the normalized PCT (normalized leachate, NL) for each element of interest will be determined and used for comparisons. To accomplish this computation for the measured composition, one must

Step 1. Determine the common logarithm of the elemental parts per million (ppm) leachate concentration of each of the triplicates for each of the elements of interest (these values are provided in Table G2 of the Appendix),

Step 2. Average the common logarithms over the triplicates for each element of interest, and then

Step 3. Subtract a quantity equal to 1 plus the common logarithm of the average cation measured concentration, expressed as a weight percent in the glass, from the average computed in Step 2.

Normalizing a PCT based upon the target composition or a bias-corrected composition measurement of the glass is handled in a similar fashion.

Table VI provides the results from the normalization process using the information in Tables E4-E6 and Table G2 in the appendices.

[23] WSRC Custom Multi-Element ICP Standard was produced by High Purity Chemicals in Charleston, South Carolina. Reference values reported in Table V are within ± 0.5% μg/ml in 2% HNO_3 as supplied by the manufacturer.

Table VI. Normalized PCTs for the RC Glasses.

Composition	Glass ID	log NL [B (g/L)]	Log NL [Li (g/L)]	Log NL [Na (g/L)]	log NL [Si (g/L)]	NL B (g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
ARM-1	reference	-0.3322	-0.3122	-0.3897	-0.6580	0.465	0.487	0.408	0.220
ARM-1	reference	-0.2203	-0.1751	-0.2376	-0.5109	0.602	0.668	0.579	0.308
EA	reference	1.2605	0.9655	1.1268	0.5800	18.217	9.236	13.391	3.802
EA	reference	1.3324	1.0371	1.1981	0.6541	21.497	10.892	15.780	4.509
rc01	measured	0.4299	0.3394	0.3478	0.0509	2.691	2.185	2.227	1.124
rc01	measured bc	0.4299	0.3329	0.3419	0.0455	2.691	2.152	2.197	1.110
rc01	target	0.3977	0.3128	0.3205	0.0375	2.498	2.055	2.091	1.090
rc01-clc	measured	0.3722	0.2996	0.2918	0.0142	2.356	1.994	1.958	1.033
rc01-clc	measured bc	0.3721	0.2931	0.2860	0.0088	2.356	1.964	1.932	1.021
rc01-clc	target	0.3399	0.2731	0.2645	0.0008	2.187	1.875	1.839	1.002
rc02	measured	0.1568	0.0508	0.1455	-0.1241	1.435	1.124	1.398	0.751
rc02	measured bc	0.1567	0.0442	0.1396	-0.1295	1.434	1.107	1.379	0.742
rc02	target	0.1362	0.0287	0.1273	-0.1417	1.368	1.068	1.341	0.722
rc02-clc	measured	0.1200	0.0434	0.0901	-0.1573	1.318	1.105	1.231	0.696
rc02-clc	measured bc	0.1199	0.0368	0.0842	-0.1627	1.318	1.089	1.214	0.687
rc02-clc	target	0.0994	0.0213	0.0719	-0.1749	1.257	1.050	1.180	0.668
rc03	measured	0.4449	0.3593	0.3773	0.0647	2.785	2.287	2.384	1.161
rc03	measured bc	0.4517	0.3504	0.3767	0.0648	2.829	2.241	2.381	1.161
rc03	target	0.4471	0.3522	0.3698	0.0572	2.800	2.250	2.343	1.141
rc03-clc	measured	0.3804	0.3173	0.3115	0.0301	2.401	2.076	2.049	1.072
rc03-clc	measured bc	0.3873	0.3083	0.3109	0.0302	2.439	2.034	2.046	1.072
rc03-clc	target	0.3827	0.3101	0.3040	0.0226	2.414	2.042	2.014	1.053
rc04	measured	0.1388	0.0042	0.1372	-0.1198	1.377	1.010	1.371	0.759
rc04	measured bc	0.1388	-0.0023	0.1365	-0.1197	1.376	0.995	1.369	0.759
rc04	target	0.1217	-0.0118	0.1194	-0.1241	1.323	0.973	1.317	0.752
rc04-clc	measured	0.0983	0.0086	0.0837	-0.1432	1.254	1.020	1.212	0.719
rc04-clc	measured bc	0.0982	0.0021	0.0831	-0.1430	1.254	1.005	1.211	0.719
rc04-clc	target	0.0811	-0.0075	0.0659	-0.1474	1.205	0.983	1.164	0.712
rc05	measured	0.2984	0.1926	0.2363	-0.0646	1.988	1.558	1.723	0.862
rc05	measured bc	0.2983	0.1860	0.2357	-0.0645	1.988	1.535	1.721	0.862
rc05	target	0.2765	0.1690	0.2228	-0.0711	1.890	1.476	1.670	0.849
rc05-clc	measured	0.2707	0.1938	0.2021	-0.0754	1.865	1.562	1.593	0.841
rc05-clc	measured bc	0.2707	0.1873	0.2015	-0.0752	1.865	1.539	1.590	0.841
rc05-clc	target	0.2489	0.1702	0.1886	-0.0819	1.774	1.480	1.544	0.828
rc06	measured	0.6574	0.5633	0.5443	0.2296	4.544	3.659	3.502	1.697
rc06	measured bc	0.6574	0.5568	0.5437	0.2298	4.543	3.604	3.497	1.697
rc06	target	0.6327	0.5401	0.5352	0.2257	4.293	3.468	3.429	1.681
rc06-clc	measured	0.6359	0.5511	0.5172	0.1998	4.324	3.557	3.290	1.584
rc06-clc	measured bc	0.6359	0.5446	0.5166	0.1999	4.324	3.504	3.285	1.585
rc06-clc	target	0.6112	0.5279	0.5080	0.1958	4.085	3.372	3.221	1.570
rc07	measured	-0.0507	-0.0537	-0.1341	-0.2864	0.890	0.884	0.734	0.517
rc07	measured bc	-0.0439	-0.0626	-0.1400	-0.2918	0.904	0.866	0.724	0.511
rc07	target	-0.0654	-0.0702	-0.1417	-0.2990	0.860	0.851	0.722	0.502
rc07-clc	measured	-0.0963	-0.0941	-0.1660	-0.3316	0.801	0.805	0.682	0.466
rc07-clc	measured bc	-0.0895	-0.1031	-0.1720	-0.3371	0.814	0.789	0.673	0.460
rc07-clc	target	-0.1109	-0.1106	-0.1736	-0.3442	0.775	0.775	0.670	0.453
rc08	measured	0.2860	0.2215	0.2150	-0.0450	1.932	1.665	1.641	0.902
rc08	measured bc	0.2928	0.2125	0.2091	-0.0505	1.962	1.631	1.618	0.890
rc08	target	0.2768	0.1995	0.1982	-0.0573	1.892	1.583	1.578	0.876
rc08-clc	measured	0.2614	0.2062	0.1839	-0.0675	1.826	1.608	1.527	0.856
rc08-clc	measured bc	0.2682	0.1972	0.1780	-0.0729	1.855	1.575	1.507	0.845
rc08-clc	target	0.2523	0.1842	0.1671	-0.0797	1.788	1.528	1.469	0.832

Table VI. Normalized PCTs for the RC Glasses.

(continued)

Composition	Glass ID	log NL [B (g/L)]	Log NL [Li (g/L)]	Log NL [Na (g/L)]	log NL [Si (g/L)]	NL B (g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
rc09	measured	0.6329	0.5662	0.5276	0.2456	4.295	3.683	3.370	1.760
rc09	measured bc	0.6397	0.5572	0.5217	0.2402	4.362	3.608	3.324	1.739
rc09	target	0.6283	0.5596	0.5179	0.2376	4.249	3.627	3.295	1.728
rc09-clc	measured	0.5643	0.4931	0.4525	0.1820	3.667	3.113	2.834	1.521
rc09-clc	measured bc	0.5711	0.4842	0.4466	0.1766	3.724	3.049	2.796	1.502
rc09-clc	target	0.5597	0.4865	0.4428	0.1740	3.628	3.066	2.772	1.493
rc10	measured	0.6421	0.5575	0.5369	0.2381	4.386	3.610	3.443	1.730
rc10	measured bc	0.6487	0.5486	0.5310	0.2327	4.453	3.537	3.396	1.709
rc10	target	0.6129	0.5259	0.5181	0.2283	4.101	3.356	3.297	1.692
rc10-clc	measured	0.5717	0.5022	0.4708	0.1778	3.730	3.178	2.957	1.506
rc10-clc	measured bc	0.5783	0.4932	0.4649	0.1724	3.787	3.113	2.917	1.487
rc10-clc	target	0.5424	0.4705	0.4521	0.1680	3.487	2.955	2.832	1.472
rc11	measured	-0.1766	-0.1366	-0.2816	-0.4145	0.666	0.730	0.523	0.385
rc11	measured bc	-0.1766	-0.1431	-0.2823	-0.4143	0.666	0.719	0.522	0.385
rc11	target	-0.2268	-0.1523	-0.2960	-0.4177	0.593	0.704	0.506	0.382
rc11-clc	measured	-0.1680	-0.1886	-0.3017	-0.4326	0.679	0.648	0.499	0.369
rc11-clc	measured bc	-0.1681	-0.1951	-0.3023	-0.4324	0.679	0.638	0.499	0.369
rc11-clc	target	-0.2183	-0.2043	-0.3160	-0.4357	0.605	0.625	0.483	0.367
rc12	measured	0.1961	0.0983	0.1268	-0.2011	1.571	1.254	1.339	0.629
rc12	measured bc	0.1960	0.0917	0.1262	-0.2010	1.571	1.235	1.337	0.630
rc12	target	0.1811	0.0887	0.1208	-0.2013	1.517	1.227	1.321	0.629
rc12-clc	measured	0.1378	0.0708	0.0662	-0.2210	1.373	1.177	1.165	0.601
rc12-clc	measured bc	0.1377	0.0643	0.0656	-0.2208	1.373	1.160	1.163	0.601
rc12-clc	target	0.1228	0.0613	0.0602	-0.2212	1.327	1.152	1.149	0.601
rc13	measured	0.1442	0.1160	0.0352	-0.1799	1.394	1.306	1.084	0.661
rc13	measured bc	0.1509	0.1070	0.0346	-0.1798	1.416	1.279	1.083	0.661
rc13	target	0.1337	0.1016	0.0261	-0.1841	1.361	1.264	1.062	0.655
rc13-clc	measured	0.1248	0.0831	0.0154	-0.1883	1.333	1.211	1.036	0.648
rc13-clc	measured bc	0.1316	0.0741	0.0147	-0.1881	1.354	1.186	1.034	0.648
rc13-clc	target	0.1144	0.0688	0.0062	-0.1924	1.301	1.172	1.014	0.642
rc14	measured	-0.1713	-0.1285	-0.2514	-0.3854	0.674	0.744	0.560	0.412
rc14	measured bc	-0.1646	-0.1374	-0.2574	-0.3908	0.684	0.729	0.553	0.407
rc14	target	-0.1928	-0.1509	-0.2810	-0.3961	0.642	0.707	0.524	0.402
rc14-clc	measured	-0.2698	-0.3030	-0.4114	-0.5476	0.537	0.498	0.388	0.283
rc14-clc	measured bc	-0.2631	-0.3119	-0.4173	-0.5531	0.546	0.488	0.383	0.280
rc14-clc	target	-0.2913	-0.3254	-0.4409	-0.5584	0.511	0.473	0.362	0.276
rc15	measured	-0.0156	0.0009	-0.1467	-0.2575	0.965	1.002	0.713	0.553
rc15	measured bc	-0.0087	-0.0081	-0.1526	-0.2629	0.980	0.982	0.704	0.546
rc15	target	-0.0339	-0.0310	-0.1660	-0.2790	0.925	0.931	0.682	0.526
rc15-clc	measured	-0.0350	-0.0358	-0.1612	-0.2826	0.923	0.921	0.690	0.522
rc15-clc	measured bc	-0.0281	-0.0448	-0.1671	-0.2880	0.937	0.902	0.681	0.515
rc15-clc	target	-0.0533	-0.0677	-0.1805	-0.3041	0.885	0.856	0.660	0.496
rc16	measured	0.1125	0.0179	0.1013	-0.1293	1.296	1.042	1.263	0.743
rc16	measured bc	0.1192	0.0089	0.0953	-0.1347	1.316	1.021	1.245	0.733
rc16	target	0.1017	0.0079	0.0858	-0.1393	1.264	1.018	1.218	0.726
rc16-clc	measured	0.1350	0.0622	0.1043	-0.1283	1.365	1.154	1.271	0.744
rc16-clc	measured bc	0.1417	0.0533	0.0984	-0.1337	1.386	1.130	1.254	0.735
rc16-clc	target	0.1242	0.0522	0.0889	-0.1383	1.331	1.128	1.227	0.727

Table VI. Normalized PCTs for the RC Glasses.
(continued)

Composition	Glass ID	log NL [B (g/L)]	Log NL [Li (g/L)]	Log NL [Na (g/L)]	log NL [Si (g/L)]	NL B (g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
rc17	measured	0.7066	0.6162	0.5693	0.2603	5.089	4.132	3.709	1.821
rc17	measured bc	0.7065	0.6096	0.5687	0.2605	5.088	4.070	3.704	1.822
rc17	target	0.6880	0.5980	0.5601	0.2551	4.875	3.963	3.632	1.799
rc17-clc	measured	0.6280	0.5542	0.4991	0.2089	4.247	3.583	3.156	1.618
rc17-clc	measured bc	0.6280	0.5477	0.4985	0.2091	4.246	3.529	3.151	1.618
rc17-clc	target	0.6094	0.5361	0.4899	0.2038	4.069	3.436	3.090	1.599
rc18	measured	0.6793	0.5921	0.5842	0.2904	4.779	3.909	3.839	1.952
rc18	measured bc	0.6792	0.5856	0.5783	0.2850	4.778	3.851	3.787	1.928
rc18	target	0.6655	0.5816	0.5619	0.2762	4.629	3.816	3.647	1.889
rc18-clc[24]	measured	0.3853	0.2890	0.2173	0.0558	2.429	1.945	1.649	1.137
rc18-clc	measured bc	0.3853	0.2825	0.2114	0.0504	2.428	1.916	1.627	1.123
rc18-clc	target	0.3715	0.2785	0.1950	0.0416	2.352	1.899	1.567	1.101
rc19	measured	0.4998	0.4150	0.4262	0.1373	3.161	2.600	2.668	1.372
rc19	measured bc	0.4998	0.4085	0.4204	0.1319	3.160	2.561	2.633	1.355
rc19	target	0.4797	0.3940	0.4044	0.1209	3.018	2.477	2.538	1.321
rc19-clc	measured	0.4485	0.3767	0.3657	0.0976	2.808	2.380	2.321	1.252
rc19-clc	measured bc	0.4484	0.3701	0.3599	0.0922	2.808	2.345	2.290	1.237
rc19-clc	target	0.4283	0.3557	0.3439	0.0813	2.681	2.268	2.208	1.206
rc20	measured	0.3378	0.2467	0.2722	-0.0518	2.177	1.765	1.871	0.888
rc20	measured bc	0.3377	0.2402	0.2715	-0.0516	2.176	1.739	1.869	0.888
rc20	target	0.2970	0.2091	0.2394	-0.0502	1.982	1.619	1.736	0.891
rc20-clc	measured	0.2453	0.1702	0.1701	-0.1193	1.759	1.480	1.480	0.760
rc20-clc	measured bc	0.2453	0.1637	0.1695	-0.1191	1.759	1.458	1.478	0.760
rc20-clc	target	0.2046	0.1326	0.1374	-0.1177	1.602	1.357	1.372	0.763
rc21	measured	0.1590	0.0587	0.1640	-0.0966	1.442	1.145	1.459	0.801
rc21	measured bc	0.1589	0.0522	0.1634	-0.0964	1.442	1.128	1.457	0.801
rc21	target	0.1455	0.0449	0.1506	-0.1037	1.398	1.109	1.414	0.788
rc21-clc	measured	0.1465	0.0682	0.1249	-0.1003	1.401	1.170	1.333	0.794
rc21-clc	measured bc	0.1464	0.0617	0.1242	-0.1002	1.401	1.153	1.331	0.794
rc21-clc	target	0.1330	0.0545	0.1114	-0.1075	1.358	1.134	1.292	0.781
rc22	measured	0.2974	0.2051	0.1475	-0.1874	1.983	1.604	1.404	0.650
rc22	measured bc	0.3041	0.1962	0.1472	-0.1872	2.014	1.571	1.403	0.650
rc22	target	0.2351	0.1429	0.1702	-0.1653	1.718	1.390	1.480	0.683
rc22-clc	measured	0.2458	0.1806	0.0903	-0.1947	1.761	1.516	1.231	0.639
rc22-clc	measured bc	0.2525	0.1717	0.0900	-0.1945	1.789	1.485	1.230	0.639
rc22-clc	target	0.1836	0.1184	0.1130	-0.1726	1.526	1.313	1.297	0.672
rc23	measured	0.4170	0.3397	0.3487	0.0553	2.612	2.186	2.232	1.136
rc23	measured bc	0.4236	0.3308	0.3481	0.0555	2.652	2.142	2.229	1.136
rc23	target	0.3859	0.3127	0.3378	0.0451	2.432	2.055	2.177	1.109
rc23-clc	measured	0.3168	0.2548	0.2506	-0.0271	2.074	1.798	1.781	0.939
rc23-clc	measured bc	0.3234	0.2458	0.2499	-0.0270	2.105	1.761	1.778	0.940
rc23-clc	target	0.2857	0.2278	0.2397	-0.0373	1.931	1.690	1.737	0.918
rc24	measured	0.0690	0.0134	0.0449	-0.2002	1.172	1.031	1.109	0.631
rc24	measured bc	0.0758	0.0044	0.0390	-0.2056	1.191	1.010	1.094	0.623
rc24	target	0.0397	-0.0240	0.0300	-0.2125	1.096	0.946	1.071	0.613
rc24-clc	measured	0.0470	0.0121	0.0095	-0.2184	1.114	1.028	1.022	0.605
rc24-clc	measured bc	0.0537	0.0031	0.0037	-0.2238	1.132	1.007	1.008	0.597
rc24-clc	target	0.0176	-0.0253	-0.0054	-0.2307	1.041	0.943	0.988	0.588

24 Values reported are based on triplicate analysis for rc-18 clc; even though one appears to have been a “flier”. Refer to Section 5.3 and footnote #22 for log NL values when the “flier” is discarded.

Exhibits G9 through G11 in Appendix G provide correlations and scatter plots of the results in Table VI by compositional view (targeted, measured, and measured bias-corrected). These scatter plots afford the opportunity to investigate congruent leaching among the elements of interest for the glasses of this study. This consistency is typically demonstrated by a high degree of correlation among the normalized leachate concentrations. Such a high degree of correlation is seen for the PCTs normalized using any of the three compositions of these glasses. None of these scatter plots includes the results for EA and ARM.

5.3.2 PROPERTY PREDICTIONS

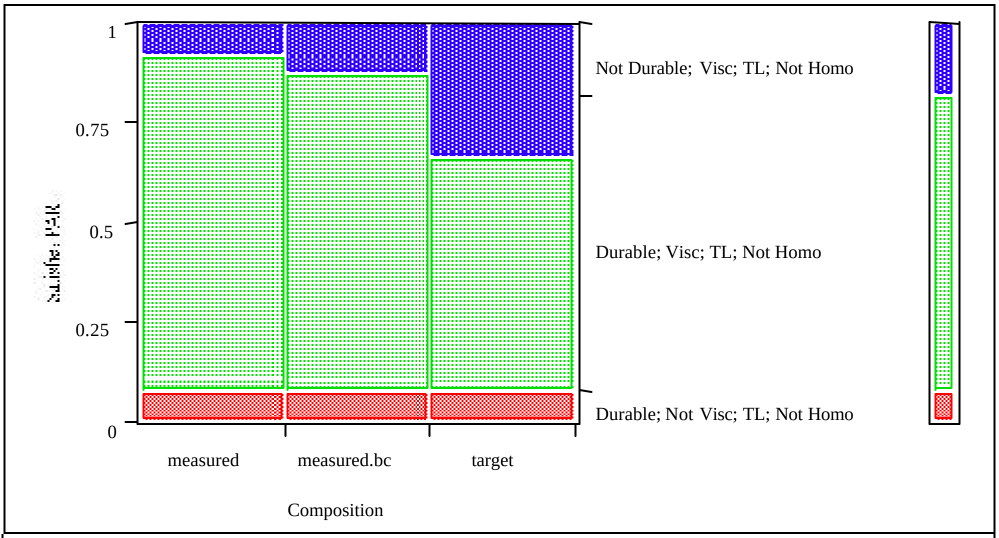
The property predictions for these RC glasses based upon each of the three possible composition views are provided in Table VII.

Table VII. Property Predictions for the RC Glasses
Based Upon Target, Measured, and Bias-Corrected Composition Views.

	Target Composition						Measured Compositions						Measured, Bias-Corrected Composition					
Glass ID	Al_2O_3 (wt%)	ΔG_p (kcal/100 g glass)	Homo (wt%)	T_L (°C)	Visc Poise	Alkalis (wt%)	Al_2O_3 (wt%)	ΔG_p (kcal/100 g glass)	Homo (wt%)	T_L (°C)	Visc Poise	Alkalis (wt%)	Al_2O_3 (wt%)	ΔG_p (kcal/100 g glass)	Homo (wt%)	T_L (°C)	Visc Poise	Alkalis (wt%)
rc01	4.07	-12.39	208.50	927.73	52.18	19.51	3.85	-11.45	201.1	930.3	57.5	18.3	3.90	-11.61	203.12	929.23	57.76	18.58
rc02	4.25	-12.67	206.86	953.55	45.84	19.53	4.20	-12.03	200.7	958.5	46.4	18.7	4.26	-12.20	202.67	957.21	46.69	18.96
rc03	4.62	-13.04	209.78	939.38	41.53	20.02	4.70	-12.77	209.1	944.8	40.9	19.7	4.74	-12.83	208.68	943.31	40.46	19.79
rc04	4.13	-13.42	210.74	986.90	33.31	20.07	4.04	-12.73	208.9	992.1	36.5	19.3	4.10	-12.80	208.57	990.13	36.28	19.35
rc05	4.26	-12.58	210.76	946.06	54.22	19.53	4.23	-11.98	207.9	949.3	58.5	18.9	4.29	-12.04	207.70	947.79	58.12	18.93
rc06	3.07	-12.62	209.99	924.43	55.63	18.71	3.02	-12.12	207.6	927.3	60.1	18.2	3.07	-12.18	207.47	925.94	59.57	18.28
rc07	4.76	-9.00	210.60	924.13	97.24	15.96	4.69	-8.79	206.6	928.1	96.1	15.6	4.73	-8.91	208.35	927.05	96.59	15.84
rc08	3.03	-10.90	196.29	914.03	80.23	17.12	3.03	-10.36	192.1	916.4	82.9	16.4	3.06	-10.50	193.69	915.43	83.47	16.68
rc09	3.03	-12.53	196.88	919.21	48.37	18.66	3.03	-12.19	195.7	924.2	47.8	18.3	3.06	-12.35	197.31	923.13	48.11	18.56
rc10	3.31	-12.75	209.19	928.22	52.50	19.17	3.27	-11.96	202.9	927.6	59.0	18.2	3.30	-12.12	204.57	926.56	59.28	18.52
rc11	5.19	-7.72	209.35	923.05	128.54	13.65	5.13	-7.16	205.6	924.3	143.2	13.2	5.20	-7.22	205.67	923.10	142.42	13.26
rc12	5.19	-11.92	209.50	926.47	61.52	18.92	5.18	-11.59	208.8	927.9	65.3	18.6	5.25	-11.65	208.77	926.68	64.80	18.71
rc13	3.19	-8.51	209.75	942.48	88.31	14.58	3.28	-8.15	208.4	944.4	92.9	14.2	3.31	-8.22	207.82	942.79	92.11	14.33
rc14	5.19	-7.97	210.11	920.96	117.16	14.43	5.13	-7.23	203.4	919.9	129.8	13.5	5.18	-7.33	205.13	918.91	130.32	13.76
rc15	3.03	-7.76	210.25	960.39	97.18	13.65	3.05	-7.28	203.0	966.0	97.9	13.0	3.07	-7.38	204.58	964.65	98.87	13.16
rc16	4.13	-12.60	210.66	986.90	32.11	19.11	4.05	-12.13	206.9	990.6	32.7	18.5	4.09	-12.31	208.49	988.94	32.92	18.77
rc17	4.10	-12.75	202.55	908.85	52.02	19.51	4.01	-12.32	200.2	912.0	54.9	19.0	4.06	-12.39	200.14	910.87	54.22	19.10
rc18	4.00	-12.87	206.17	908.56	55.16	19.51	3.91	-12.22	200.6	911.4	56.2	18.7	3.96	-12.38	202.53	910.50	56.44	18.91
rc19	4.02	-12.86	208.35	930.66	49.83	20.02	3.96	-12.13	201.0	931.6	52.1	19.0	4.02	-12.30	202.98	930.57	52.39	19.31
rc20	5.19	-12.50	208.99	926.47	53.04	19.77	4.94	-11.17	205.4	927.6	69.1	18.3	5.01	-11.23	205.39	926.36	68.51	18.37
rc21	4.13	-13.18	210.15	986.90	30.94	19.84	4.11	-12.66	207.6	991.0	32.5	19.2	4.17	-12.74	207.39	989.13	32.20	19.31
rc22	5.19	-12.18	210.19	926.47	55.45	19.35	4.63	-12.27	206.5	909.7	72.0	19.7	4.68	-12.32	206.13	908.58	71.57	19.74
rc23	4.23	-13.04	210.86	926.05	48.67	19.77	4.04	-12.51	207.3	933.3	50.5	19.1	4.08	-12.58	206.94	931.91	49.94	19.24
rc24	4.13	-11.18	210.58	976.98	56.00	17.66	3.85	-10.64	204.3	980.0	59.0	16.9	3.89	-10.79	205.96	978.47	59.47	17.16

* Property limits at the PAR are: Homo > 210.9203, T_L > 1024.9462, ΔG_P > -12.7178, and 21.5308 < η (Poise) < 105.4437

A crosstabs table of property predictions based upon measured, bias-corrected measured, and target compositions is provided in Figure 5. Property predictions were generated as part of the selection process for the RC study glasses, and these predictions were actively involved in that process (see the selection document provided in Appendix A). Figure 5 provides a graphical representation of the number of glasses whose predictions fall within and outside of the property acceptance region (PAR) for the various properties. Once again, the critical property for this variability study is durability (as predicted by the ΔG_p models and as measured by the PCT).



Crosstabs: Satisfies @ PAR Count	Composition Measured	measured, bc	target	Row Totals
Durable; Not Visc; T_L; Not Homogeneous	4	4	4	12
Durable; Visc; T_L; Not Homogeneous	40	38	28	106
Not Durable; Visc; T_L; Not Homogeneous	4	6	16	26
Column Totals	48	48	48	144

Figure 5. Property Predictions Versus Property Acceptance Regions.

As seen from Figure 5, all of the glasses selected for this study were predicted to fall outside of the PAR for homogeneity. Sixteen glasses were predicted (based on target compositions) not only to be non-homogeneous (e.g., phase separated) but also non-durable (these glasses were predicted to meet both the viscosity and T_L constraints). Based on measured and measured bias-corrected compositions, only 4 and 6 glasses, respectively, actually feel into the non-durable, phase separated category. Likewise, 28 glasses were predicted (based on target compositions) to be phase separated (non-homogeneous) while meeting the durability, viscosity and T_L constraints. Based on measured and measured bias-corrected compositions, the number of glasses falling into this category increased to 40 and 38, respectively.

It should be noted all RC glasses (regardless of thermal history) had normalized release rates for B (as well as Na, Li, and Si as shown in Table VI) significantly less than the EA values. The highest NL [B] release observed from the RC glasses (regardless of thermal history) was 5.089

g/L (log NL [B] = 0.7066 g/L) from rc17. The EA limit for NL [B] is 16.695 g/L (or log NL[B] = 1.22 g/L) [Jantzen et al. 1993].

5.3.3 POTENTIAL IMPACTS OF CRYSTALLIZATION ON DURABILITY

The effect of thermal history on the resulting glass microstructure (e.g., the formation of crystallization and/or amorphous phase separation) and its ultimate impact on durability of DWPF- and Hanford-type HLW glasses have been previously studied. As the glass is poured into the canister, the radial temperature distribution is virtually parabolic with approximately 400°C difference in temperature at the centerline and the wall [Edwards 1987, Lee 1989]. The temperature history of the centerline glass is most favorable for the formation of crystalline phases. As the new phase precipitates, it affects the glass matrix, in which it is embedded, both chemically and mechanically. Other chemical or mechanical factors, such as concentration gradients and mechanical stresses, played a secondary role. These changes may impact the rate of glass dissolution in water, and thus change its chemical durability.

Figure 6 shows a plot of log NL [B] (in g/L) for the quenched versus clc RC glasses. Based on statistical analysis, there is a statistically significant difference (at the 0.05% level) between the quenched and clc NL [B] release values (Prob > $|t|$ = 0.0001). The quenched glasses had on average a 0.056 g/L larger release than their clc counterparts. Although this difference is statistically significant, there does not appear to be any practical difference between the releases for the two thermal histories. If rc18 is not considered in the analysis (an obvious outlier), there is still a significant difference between the two thermal histories but the average difference is reduced to 0.045 g/L. It should be noted that rc18-clc glass was determined to be amorphous based on visual observations which was confirmed by XRD analysis (see Figure 4) at the detection limit of the XRD unit. Scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) was also performed on the clc version of rc18 and confirmed both visual and XRD analysis regarding the lack of crystallinity.

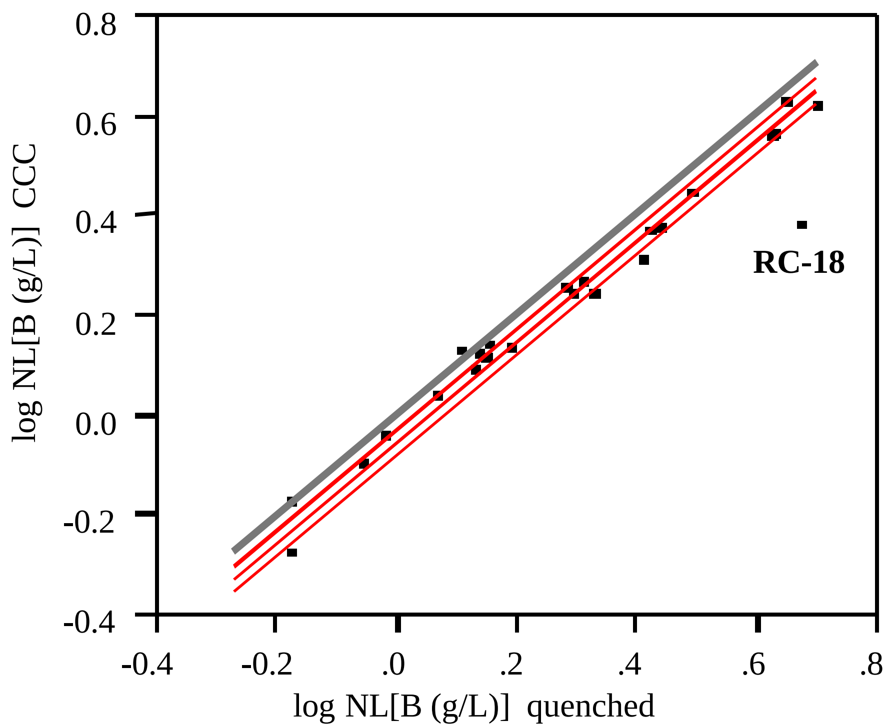


Figure 6. log NL [B] (in g/L) for Quenched Versus CLC RC Glasses.
(points along the bold 45° line indicate no difference in NL [B] based on thermal history)

5.3.4 PREDICTION OF DURABILITY VIA ΔG_P

Figure 7 presents the log NL [B] (g/L) results for all RC glasses (both quenched and clc versions) versus computed ΔG_P predictions (based on target compositions for the current THERMO [Jantzen et al. 1995] model) with 95% prediction intervals. With the exception of a limited number of glasses at the more positive ΔG_P's[25], all glasses are well predicted by the model and are acceptable relative to the EA. It should also be noted that a limited number of RC glasses have a predicted (based on target compositions) ΔG_P < -12.7178 which is the SME cutoff between "durable" and "non-durable" glasses [Brown and Postels 1996]. Although the current durability constraint in PCCS would eliminate these glasses from acceptability, they are well behaved in terms of prediction (and are very durable). As shown in Table II, eight of the RC glasses (rc03, rc04, rc10, rc17, rc18, rc19, rc21, and rc23) were predicted to be non-durable based on target compositions.

Figure 8 presents the log NL [B] (g/L) results for all RC glasses (both quenched and clc version presented) versus computed ΔG_P predictions (based on measured compositions for the current THERMO [Jantzen et al. 1995] model) with 95% prediction intervals. Again, with the exception of a limited number of glasses at the more positive ΔG_P's, all glasses are well predicted by the model and are acceptable relative to the EA.

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25 Those glasses with the most positive ΔG_P values were underpredicted by the model which is a phenomena that has been observed in previous studies.

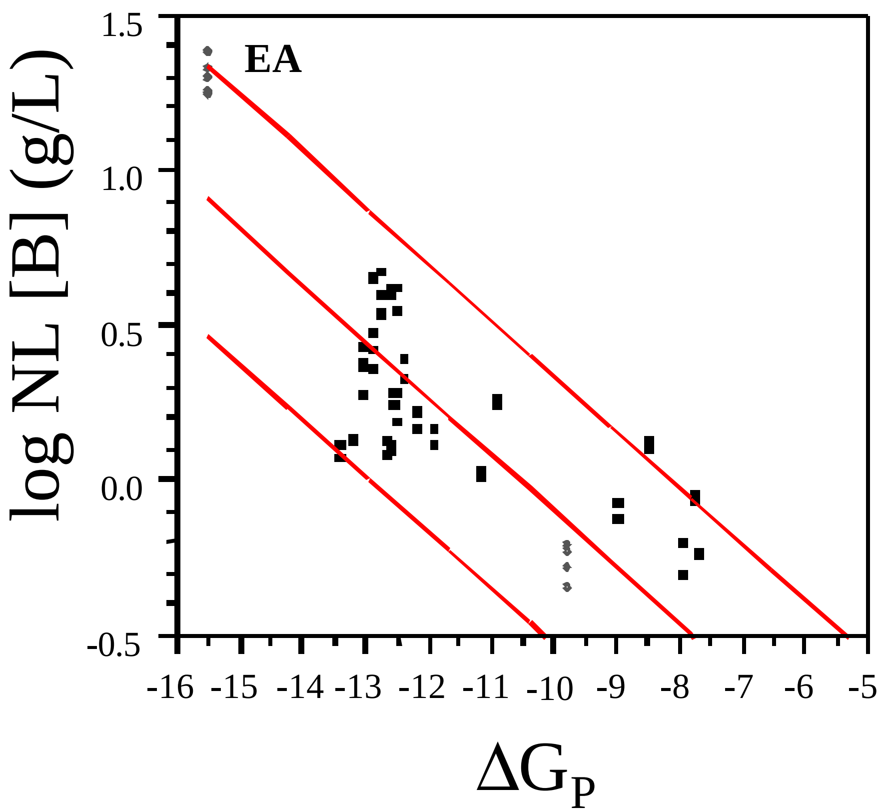

Figure 7. log NL [B] (g/L) Versus ΔG$_P$ (based on target composition) for all RC Glasses (quenched and CLC).

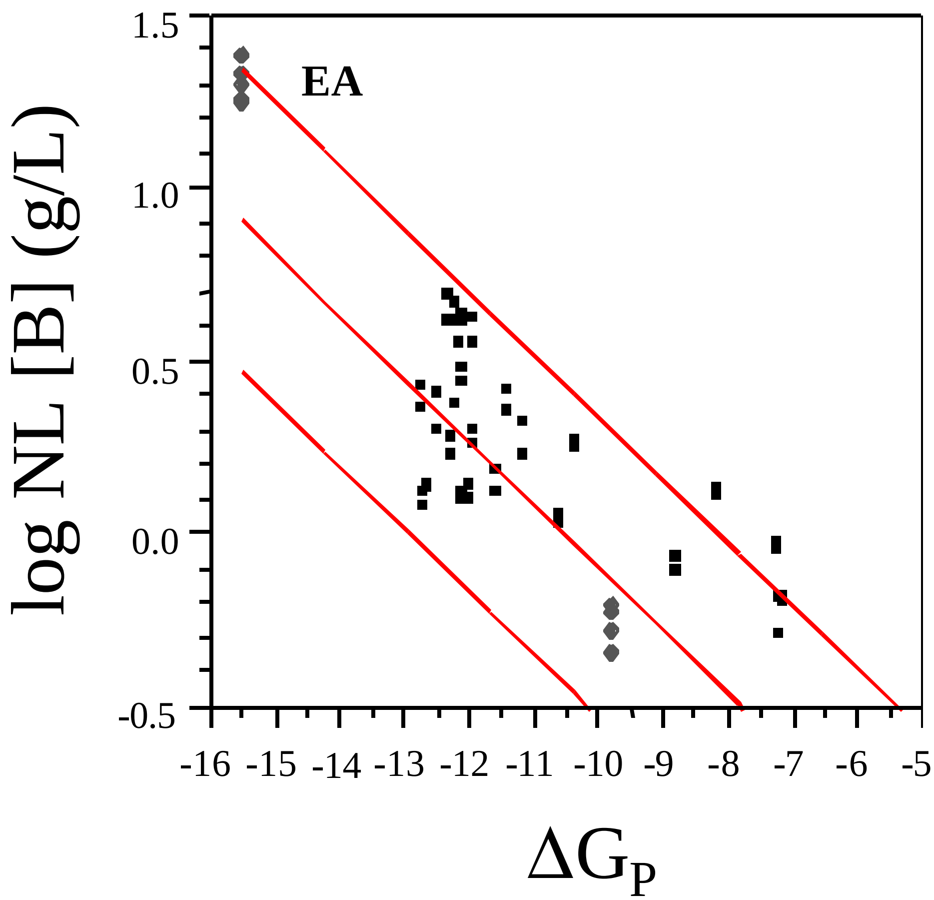

Figure 8. log NL [B] (g/L) Versus ΔG_P (based on measured composition) for all RC Glasses (quenched and CLC).

5.4 APPLICATION OF EQUIVALENT CONSTRAINTS FOR MB3

The primary objective of this research is again to provide the technical bases to relax the homogeneity measurement uncertainty requirement ***for MB3*** as long as the following criteria are satisfied:

Criterion (1)

- use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add an alkali constraint with an upper limit of 19.3 wt%, **or**

Criterion (2)

- adjust the lower limit on the alumina constraint to 4 wt%.

Figure 9 provides a view of the log NL [B] (g/L) for the RC glasses as a function of Al_2O_3 concentration (wt% in glass based on target compositions) versus ΣM_2O.[26] Each of the RC glasses has been classified based on a range of log NL [B] release values. The nomenclature used for these classifications is:

■; log NL [B] > 1.0
✖; 0.5 < log NL [B] < 1.0
■; 0.25 < log NL [B] < 0.5
♦; 0.0 < log NL [B] < 0.25
♦; log NL [B] < 0.0

Imposing either Criterion (1) or Criterion (2), durable glass products can be expected over the MB3 compositional region. As previously noted, all RC glasses (regardless of thermal history) have log NL [B] < 1.0 (g/L). The only data point with log NL [B] > 1.0 is that for EA (which is labeled "■").

The data suggest that as the Al_2O_3 concentration approaches the lower limit of 3.0 wt% (in glass) and the sum of alkali content increases (up to ~ 20 wt%), durability (noted as log NL [B]) trends to higher release values (or lower durability). Again, it is noted that all the RC glasses are significantly more durable than EA. The effects of Al_2O_3 and sum of alkali concentrations on durability trends are presented in Figure 10. Durability contours indicated that more durable glasses are produced at higher Al_2O_3 and lower ΣM_2O concentrations for these glasses.

If the data from the MB3 variability study [Harbour 2000c] are included, a similar trend in durability response is observed as a function of Al_2O_3 and ΣM_2O concentration (Figure 11) as well as the predicted durability contours (Figure 12). Figure 11 (legend the same as in Figure 9) supports the technical bases for imposing either of the two equivalent constraints as a means of assuring a durable product will be produced for MB3. As previously noted, all RC and MB3 glasses (regardless of thermal history) have log NL [B] << 1.0 (g/L) – significantly less than EA.

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26 Similar figures (see Figures 2 – 3) were used as the basis of relaxing the homogeneity constraint to the PAR for MB2.

In Figure 12, the durability contours become more refined with the use of the additional MB3 data – particularly the region of high alkali concentrations. In this compositional region, the projected region of high release glasses (log NL [B] > 1.0 g/L) is very limited.

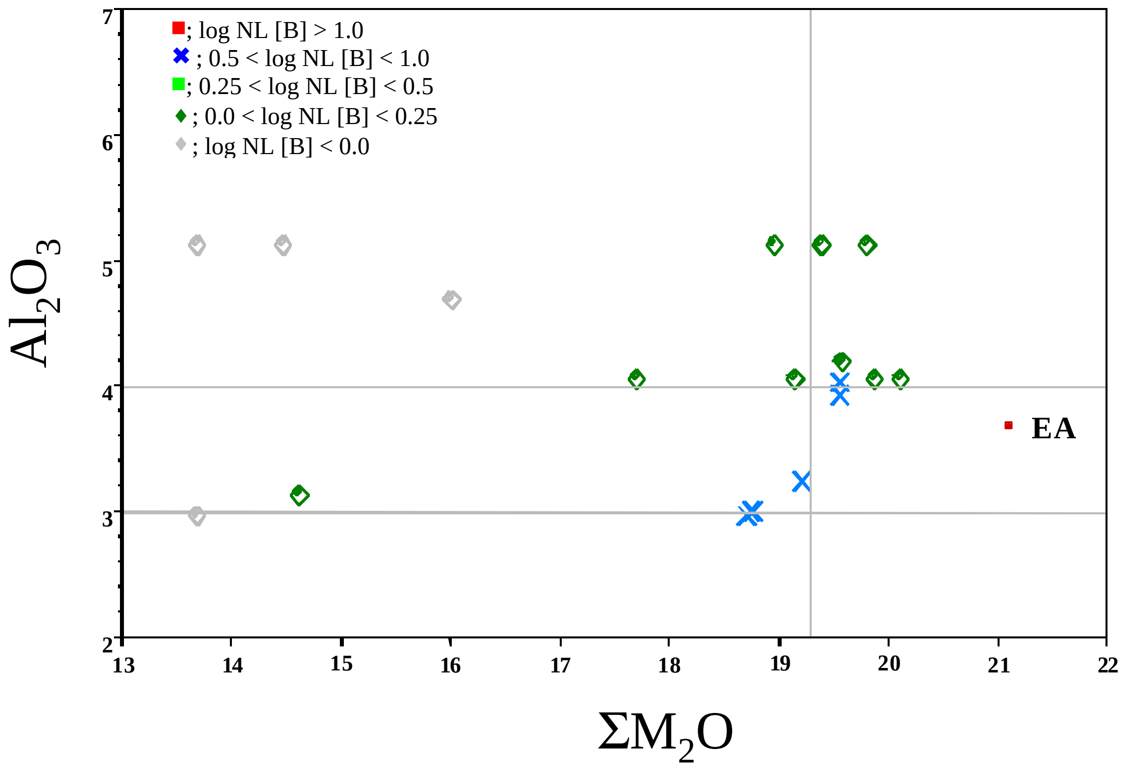

Figure 9. Al_2O_3 Versus ΣM_2O for the RC Glasses.
(based on target compositions)

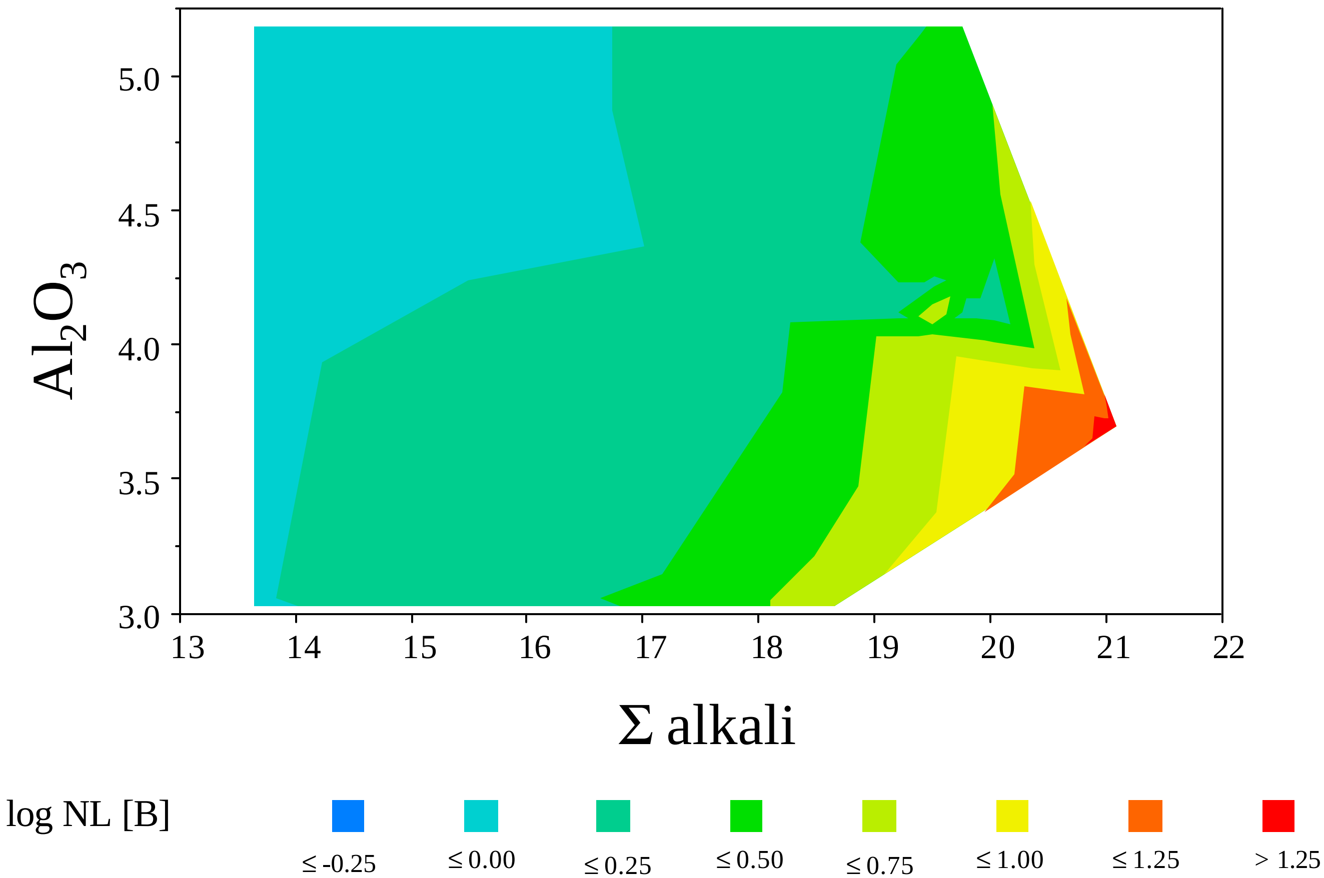

Figure 10. Durability Contours Based Only on the 24 RC Glasses.

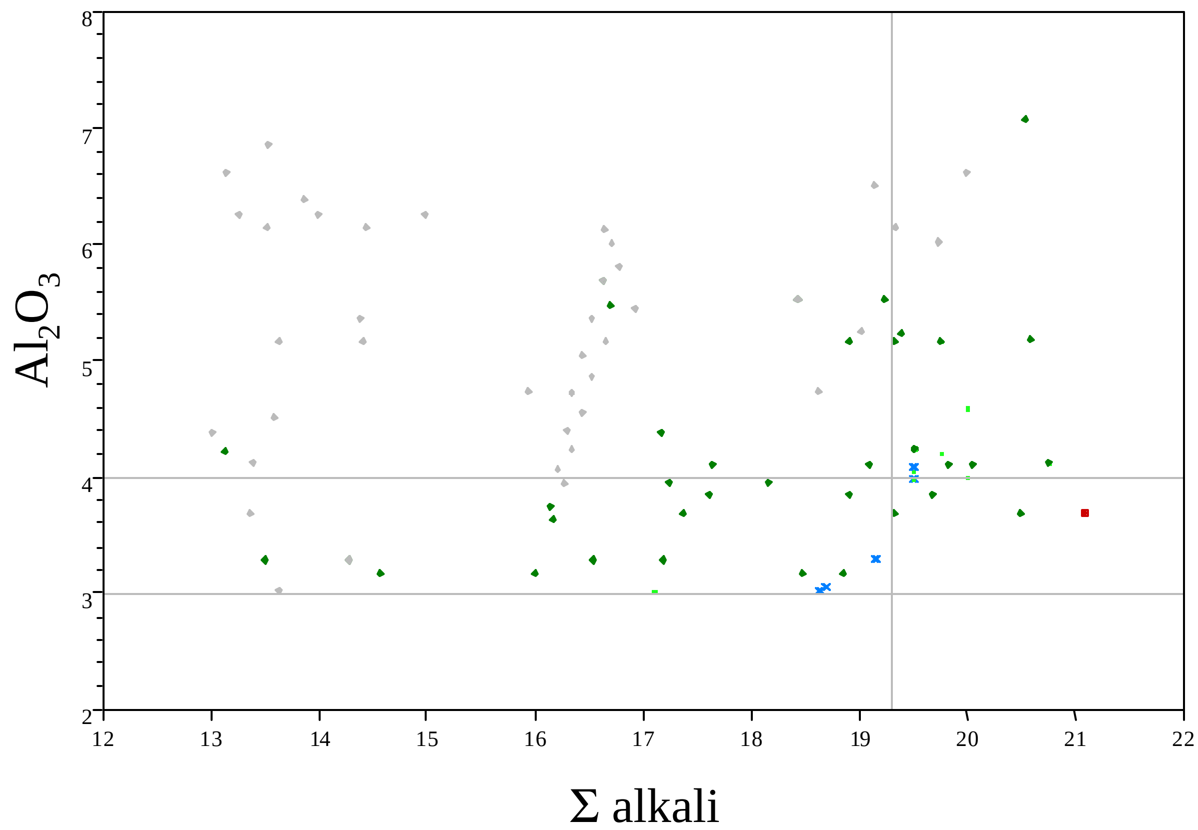

Figure 11. Al_2O_3 Versus ΣM_2O for the RC and MB3 Glasses.
(based on target compositions)

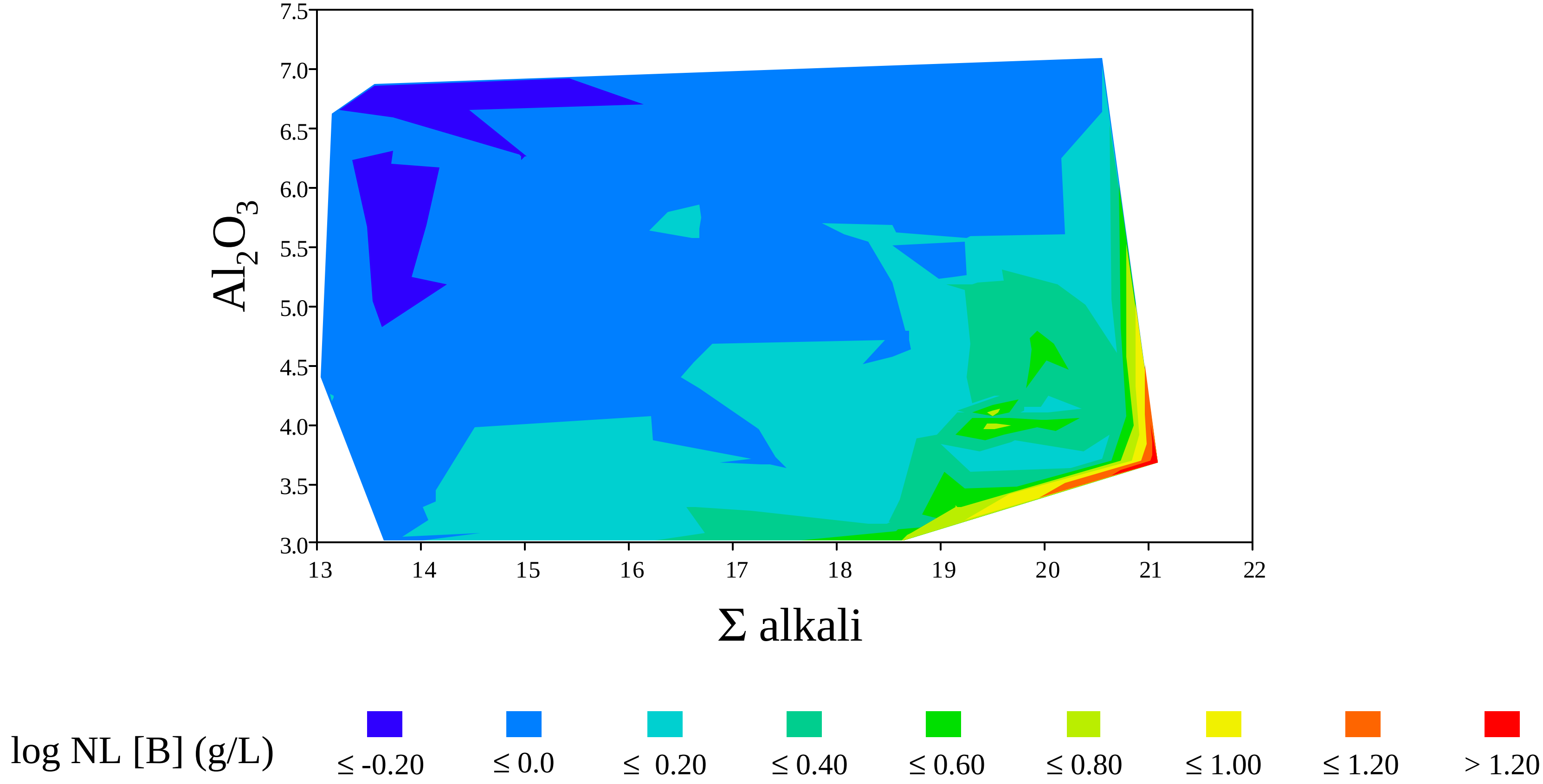

Figure 12. Durability Contours Based on the RC and MB3 Glasses.

6.0 SUMMARY

Given the effectiveness of the application of the constraints associated with homogeneity for MB2, and the inherent limitations of the application of the homogeneity discriminator for MB3, an investigation into the application of these constraints to MB3 has been performed. The objective of this research is to provide the technical bases to relax the homogeneity measurement uncertainty requirement ***for macro-batch 3***. To accomplish this reduction of constraints objective, glass compositions were selected from a pool of candidate glasses (for each sludge type: Tank 40 only and a blend of Tank 8 and Tank 40) developed as part of the MB3 variability study. The systematic glass selection process (see Appendix A) was focused specifically to support the reduction of constraints objective which would allow for the examination of the conservatism in the homogeneity constraint. More specifically, all 24 RC glasses selected were predicted to be outside the homogeneous property acceptance region (PAR) based upon the current homogeneity constraint using targeted compositions.

Glasses were fabricated, heat treated, and tested using standard technical procedures. To bound the effects of thermal history on durability, each glasses was heat treated to simulate cooling along the centerline of a DWPF-type canister (clc). Visual observations of crystallization (after both quenching and clc) were confirmed by XRD.

The Product Consistency Test (PCT) was performed on each glass to assess chemical durability (for both quenched and clc versions). All RC glasses (regardless of thermal history) have log NL [B] < 1.0 (g/L). The PCT data indicated that as Al_2O_3 concentration approached the lower limit of 3.0 wt% (in glass) and the sum of alkali content increase (up to ~20 wt%), durability tends to higher release values (or lower durability). Again, it is noted that all the RC glasses are significantly more durable than EA.

The performance of the homogeneity constraint for the compositions tested for both the RC and MB3 glasses provides strong evidence that the imposition of the measurement uncertainty for this constraint unnecessarily restricts the DWPF operational window.

Based on the results of this study, the technical bases to relax the homogeneity measurement uncertainty requirement ***for macro-batch 3*** has been established as long as the following criteria are satisfied:

Criterion (1)

- use the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **and** add an sum of alkali[27] constraint with an upper limit of 19.3 wt% (i.e., $\Sigma M_2O < 19.3$ wt%),

OR

Criterion (2)

- adjust the lower limit on the alumina constraint to 4 wt% (i.e., $Al_2O_3 \geq 4.0$ wt%).

Regardless, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina constraint or the alkali constraint, if used, and the use of these constraints to relax the homogeneity MAR for any new macro-batch would require a similar study of the feasible compositions.

[27] Alkali included in this sum are Na_2O, Li_2O, Cs_2O, and K_2O.

7.0 FUTURE WORK

In FY01, a joint DWPF (EM-40) and Tanks Focus Area (EM-50) task will be initiated to evaluate the use of the equivalent constraints for a generic sludge-only flowsheet. This task will require various inputs prior to establishing the specific testing program to be utilized. These inputs include (but are not limited to):

(1) definition of future sludge batch compositions,
(2) the role of pretreatment (e.g., washing) and its impact on Al_2O_3 and/or Na_2O concentration, and
(3) potential blending strategies.

Another goal of this joint program will be to evaluate the potential to eliminate the homogeneity constraint for MB3 as well as future sludge-only macrobatches.

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APPENDIX A

GLASS SELECTION DOCUMENT
(SRT-SCS-2000-00030)

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OSR 31-688 (Rev 11-20-97)
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WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2000-00030

June 23, 2000

To: D. K. Peeler, 773-43A

cc: D. A. Crowley, 773-43A
J. R. Harbour, 773-43A
E. W. Holtzscheiter, 773-A
C. M. Jantzen, 773-A
S. L. Marra, 704-1T
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R. C. Tuckfield, 773-42A

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

K. G. Brown, 704-1T (7-7799)
Immobilization Technology Section

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J. R. Harbour, Technical Reviewer — Date
Immobilization Technology Section

________________________ ________________________
R. C. Tuckfield, Manager — Date
Statistical Consulting Section

________________________ ________________________
S. L. Marra, Manager — Date
Immobilization Technology Section

SELECTING GLASSES IN SUPPORT OF PHASE 1 OF THE REDUCTION OF CONSTRAINTS TASK (U)

INTRODUCTION

The Savannah River Technology Center (SRTC) is currently conducting a Macro-Batch 3 (MB3) variability study for the Defense Waste Processing Facility (DWPF) [1]. There is an additional task underway at SRTC that has a bearing on this MB3 study. This second task is an effort to reduce the constraints associated with durability prediction in order to increase DWPF's window of operability [2]. These are complex tasks with decision points involving SRTC and/or the DWPF and with a need for integration using information exchanges between the two tasks.

The purpose of this memorandum is to provide a set of glass compositions within the MB3 composition regions (as there are two sludge types being considered for this macro-batch) which supports the efforts to reduce the number of durability constraints associated with DWPF batch acceptability for MB3. Additional work is planned to support the reduction of constraints associated with durability for sludge-only operation in general; however, this work is outside the scope of this memorandum.

DISCUSSION

The variability study for macro-batch 2 (MB2) [3] included an evaluation of the impact of the homogeneity constraint [4], one of the constraints associated with durability prediction [5], on the composition region of that macro-batch. Based upon this evaluation, the application of the homogeneity constraint to batch acceptability decisions for MB2 was modified.[1] This modification involved the relaxation of the measurement uncertainty requirement for the homogeneity constraint, and it was possible (for MB2) as long as one of the following criteria was satisfied:

Criterion (1)

- Continue to use the alumina constraint as implemented in PCCS (i.e., $Al_2O_3 \geq 3.0$ wt%) and add an alkali ($Cs_2O+K_2O+Li_2O+Na_2O$) constraint with an upper limit of 19.3 wt%

or

Criterion (2)

- Adjust the lower limit on the alumina constraint to 4.0 wt%.

These criteria are referred to as criterion (1) and criterion (2) in the discussion that follows.

One objective of the reduction of constraints task is to pursue a similar modification to the application of the homogeneity constraint for MB3: specifically, to relax or to eliminate the need for the homogeneity constraint for this MB3.[2]

Glass compositions to support the MB3 variability study were previously selected [6]. The selection of these compositions was not restricted by DWPF's product or process constraints. The job of intentionally selecting glasses within MB3's composition regions that allow for the examination of the

1 Subsequent to the MB2 variability study, an investigation into another constraint associated with durability, the low frit constraint, was conducted. This investigation led to the elimination of this constraint for DWPF operations. See "Relaxation of the Lower Frit Loading Constraint for DWPF Process Control (U)," WSRC-RP-99-00355, Revision 0, issued by K.G. Brown on May 6, 1999.

2 The scope of the reduction in constraints task includes the full set of constraints associated with durability. Based upon previous variability studies and other investigations (such as the low frit study), there is a general belief that there is excessive conservatism in one or more of these constraints and that leads to unnecessary restrictions on DWPF operations. The effort supported by this memorandum is focused on the conservatism of the homogeneity constraint.

conservatism in the homogeneity constraint was left as part of the reduction of constraints task and is accomplished by this memorandum.

The approach used to select these glasses may be framed as follows:

- The starting place is the set of glass compositions generated as candidates during the MB3 selection process for each sludge type [1].
- From this set of glasses, select those compositions that are predicted to be outside the homogeneous property acceptance region (PAR)[3] based upon the homogeneity constraint.
- Group these compositions by criteria (1) and (2) above.
- Use statistical design algorithms to select compositions from each of these two groups. In selecting compositions that satisfy criterion (2), select only from that set of compositions that satisfy criterion (2) but not criterion (1).

Table 1 provides a count of the number of candidate compositions that are predicted to be within the homogeneity PAR and the number that are not at each sludge loading considered for each sludge type.

TABLE 1. INFORMATION ON THE MB3 CANDIDATE COMPOSITIONS

Sludge Type	Sludge Loading	Homo (PAR)	Not Homo (PAR)	Not Homo PAR – Satisfy (1)	Not Homo PAR – Satisfy (2)	Not Homo PAR – $Al_2O_3 \geq 4.0\%$; alkalis > 19.3%
Tank 40 Only	0.2	1140	455	140	29	2
Tank 40 Only	0.22	1426	161	11	0	0
Tank 40 Only	0.24	1574	10	6	0	0
Tank 40 Only	0.26	1582	0	0	0	0
Tank 40 Only	0.28	1570	0	0	0	0
Tank 40 Only	0.3	1572	0	0	0	0
Tank 40 Only	0.32	1574	0	0	0	0
Tank 40 Only	0.34	1576	0	0	0	0
Tanks 8 and 40	0.2	709	1933	846	614	49
Tanks 8 and 40	0.22	1271	1356	1132	546	60
Tanks 8 and 40	0.24	1831	765	607	244	8
Tanks 8 and 40	0.26	2158	416	214	50	6
Tanks 8 and 40	0.28	2374	188	89	9	5
Tanks 8 and 40	0.3	2519	49	28	49	21
Tanks 8 and 40	0.32	2529	0	0	0	0
Tanks 8 and 40	0.34	2528	0	0	0	0

Thus, for the sludge option consisting only of Tank 40, there are just three loadings that generate compositions that are predicted to be inhomogeneous. For the Tank 8 and 40 sludge option there are candidate compositions at each waste-loading from 20 to 30%. The fifth column of Table 1 provides the number of glass compositions that do not fall within the homogeneity PAR but that do satisfy criterion (1) (i.e., their Al_2O_3 values are greater than or equal to 3.0 wt% and their alkali values are less than or equal to 19.3 wt%). The sixth column of Table 1 provides the number of glass compositions that do not fall within the homogeneity PAR but that do satisfy criterion (2) (i.e., their Al_2O_3 values are greater than or equal to 4.0 wt%). The last column of Table 1 provides the number of glass compositions that do not fall within the homogeneity PAR, that do not satisfy criterion (1), but that do satisfy criterion (2) (i.e., their Al_2O_3 values are greater than or equal to 4.0 wt% and their alkali values are greater than 19.3 wt%).

3 The PAR for a constraint represents the region in composition space whereby that constraint is satisfied after the prediction uncertainties for the constraint are taken into account.

Exhibit 1 provides plots of these data of interest. Included in this exhibit are scatterplots for Al_2O_3, B_2O_3, Fe_2O_3, and alkali value for each loading and sludge type of interest. As indicated earlier, the Al_2O_3 and alkali components were instrumental in the relaxation of the homogeneity constraint for MB2. Since the B_2O_3 and Fe_2O_3 components were considered in the discussion supporting that variability study and are known to fundamentally change the behavior of the glass system, the B_2O_3 and Fe_2O_3 components are also considered in this discussion. In these plots, the darker shaded points are those that satisfy criterion (1) above. The lighter shaded points do not satisfy this criterion. For criterion (2), the only restriction is the Al_2O_3 content. If Al_2O_3 is at least 4.0 wt% of the glass, criterion (2) is met.

From these scatter plots, it is evident that the B_2O_3 content in these glasses never gets above ~ 11% and that the Fe_2O_3 content is always greater than 7% regardless of scenario. Thus, there should be no problems in low-Fe_2O_3 or high-B_2O_3 space [3] for these MB3 glasses. Thus, the MB3 composition regions shown on these scatter plots implicitly avoid these problems even though these glass compositions are predicted to be inhomogeneous (at the PAR limit).

As the next step, glasses are selected from these MB3 compositions that challenge criteria (1) and (2) over a broad compositional region. This is accomplished by using the D-optimality routines of JMP® Version 3.2.2 [7] to select 12 compositions from the set of compositions that are predicted to be inhomogeneous but which satisfy criterion (1). These 12 compositions were selected using 100 iterations of the JMP routines to optimize the fitting of a mixture model comprised of 11 linear terms for Al_2O_3, B_2O_3, CaO, Fe_2O_3, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2, and U_3O_8. Although no modeling is desired for these results, this approach does provide an opportunity to see the (linear) effects of each of these oxides and, thus, does provide coverage of the composition space spanned by this set of compositions (i.e., those compositions that are predicted to fall outside of the homogeneity PAR, that have Al_2O_3 content of at least 3.0 wt%, and that have no more than 19.3 wt% alkali content).

An additional 12 compositions were selected from the set of compositions represented by the last column of Table 1 using this same approach. This set consists of compositions that fall outside of the homogeneity PAR, that have Al_2O_3 content of at least 4.0 wt%, and that have more than 19.3 wt% alkali content. Thus, the compositions represented by the last column of Table 1 satisfy criterion (2) but do not satisfy criterion (1). The 12 compositions so generated were then combined with the first set of 12 for a total of 24 compositions. These compositions are provided in Table 2. The sludge type and sludge loading values are also provided in this table.

TABLE 2. COMPOSITIONS OF GLASSES FOR PHASE 1 OF THE REDUCTION OF CONSTRAINTS TASK

ID	Sludge	Loading	Al2O3	B2O3	CaO	Fe2O3	Li2O	MgO	MnO	Na2O	NiO	SiO2	U3O8
rc01	Tank 40 Only	0.2	0.0407	0.0900	0.0071	0.0835	0.0440	0.0144	0.0030	0.1511	0.0000	0.5527	0.0135
rc02	Tanks 8 and 40	0.26	0.0425	0.0833	0.0075	0.0920	0.0333	0.0134	0.0058	0.1620	0.0061	0.5113	0.0428
rc03	Tanks 8 and 40	0.24	0.0462	0.0969	0.0069	0.0849	0.0418	0.0178	0.0054	0.1584	0.0056	0.5251	0.0110
rc04	Tanks 8 and 40	0.3	0.0413	0.0788	0.0090	0.1061	0.0315	0.0166	0.0099	0.1692	0.0043	0.4839	0.0494
rc05	Tanks 8 and 40	0.26	0.0426	0.0833	0.0075	0.0920	0.0333	0.0174	0.0086	0.1620	0.0061	0.5353	0.0119
rc06	Tank 40 Only	0.2	0.0307	0.1020	0.0186	0.0835	0.0360	0.0187	0.0030	0.1511	0.0000	0.5527	0.0037
rc07	Tank 40 Only	0.2	0.0476	0.0900	0.0071	0.0835	0.0440	0.0187	0.0030	0.1156	0.0000	0.5770	0.0135
rc08	Tanks 8 and 40	0.22	0.0303	0.0878	0.0063	0.0778	0.0351	0.0182	0.0049	0.1361	0.0051	0.5622	0.0362
rc09	Tanks 8 and 40	0.22	0.0303	0.0995	0.0063	0.0778	0.0429	0.0140	0.0073	0.1437	0.0032	0.5388	0.0362
rc10	Tanks 8 and 40	0.24	0.0331	0.0855	0.0179	0.0849	0.0418	0.0137	0.0079	0.1499	0.0056	0.5487	0.0110
rc11	Tanks 8 and 40	0.22	0.0519	0.0995	0.0172	0.0778	0.0351	0.0182	0.0073	0.1014	0.0032	0.5522	0.0362
rc12	Tanks 8 and 40	0.22	0.0519	0.0995	0.0063	0.0778	0.0351	0.0140	0.0073	0.1541	0.0051	0.5388	0.0101
rc13	Tanks 8 and 40	0.2	0.0319	0.1020	0.0057	0.1000	0.0440	0.0186	0.0066	0.1018	0.0047	0.5756	0.0091
rc14	Tanks 8 and 40	0.22	0.0519	0.0878	0.0172	0.0778	0.0429	0.0140	0.0049	0.1014	0.0051	0.5608	0.0362
rc15	Tanks 8 and 40	0.22	0.0303	0.0995	0.0063	0.1099	0.0351	0.0140	0.0049	0.1014	0.0032	0.5592	0.0362
rc16	Tanks 8 and 40	0.3	0.0413	0.0893	0.0086	0.1061	0.0385	0.0166	0.0067	0.1526	0.0070	0.4839	0.0494
rc17	Tanks 8 and 40	0.2	0.0410	0.1020	0.0057	0.0707	0.0440	0.0143	0.0066	0.1511	0.0029	0.5526	0.0091
rc18	Tanks 8 and 40	0.2	0.0400	0.0900	0.0165	0.0707	0.0440	0.0186	0.0045	0.1511	0.0029	0.5526	0.0091
rc19	Tanks 8 and 40	0.24	0.0402	0.0855	0.0069	0.0849	0.0418	0.0137	0.0054	0.1584	0.0035	0.5487	0.0110
rc20	Tanks 8 and 40	0.22	0.0519	0.0878	0.0063	0.0778	0.0429	0.0182	0.0073	0.1548	0.0032	0.5388	0.0110
rc21	Tanks 8 and 40	0.3	0.0413	0.0788	0.0086	0.1061	0.0385	0.0166	0.0099	0.1599	0.0070	0.4839	0.0494
rc22	Tanks 8 and 40	0.22	0.0519	0.0995	0.0063	0.0778	0.0387	0.0140	0.0049	0.1548	0.0032	0.5388	0.0101
rc23	Tanks 8 and 40	0.22	0.0423	0.0882	0.0172	0.0797	0.0429	0.0137	0.0073	0.1548	0.0051	0.5388	0.0101
rc24	Tanks 8 and 40	0.3	0.0413	0.0788	0.0086	0.1061	0.0315	0.0166	0.0099	0.1451	0.0043	0.5084	0.0494

The property predictions for these compositions are provided in Table 3. Note that none of the properties restricted the selection of the glasses for this study except for homogeneity. All of the compositions are predicted to be inhomogeneous.

TABLE 3: SUM OF ALKALIS AND PROPERTY PREDICTIONS FOR PHASE 1 GLASSES

ID	Alkalis	ΔGp	Homo	T_L	Visc	Satisfies PAR	Random Sequence for Batching and/or Testing
rc01	0.1951	-12.392	208.5	927.7	52.2	Durable; Visc; TL; Not Homo	4
rc02	0.1953	-12.669	206.9	953.5	45.8	Durable; Visc; TL; Not Homo	2
rc03	0.2002	-13.037	209.8	939.4	41.5	Not Durable; Visc; TL; Not Homo	13
rc04	0.2007	-13.423	210.7	986.9	33.3	Not Durable; Visc; TL; Not Homo	8
rc05	0.1953	-12.578	210.8	946.1	54.2	Durable; Visc; TL; Not Homo	17
rc06	0.1871	-12.622	210.0	924.4	55.6	Durable; Visc; TL; Not Homo	10
rc07	0.1596	-9.002	210.6	924.1	97.2	Durable; Visc; TL; Not Homo	11
rc08	0.1712	-10.899	196.3	914.0	80.2	Durable; Visc; TL; Not Homo	21
rc09	0.1866	-12.526	196.9	919.2	48.4	Durable; Visc; TL; Not Homo	14
rc10	0.1917	-12.752	209.2	928.2	52.5	Not Durable; Visc; TL; Not Homo	24
rc11	0.1365	-7.723	209.4	923.1	128.5	Durable; Not Visc; TL; Not Homo	6
rc12	0.1892	-11.916	209.5	926.5	61.5	Durable; Visc; TL; Not Homo	18
rc13	0.1458	-8.512	209.7	942.5	88.3	Durable; Visc; TL; Not Homo	20
rc14	0.1443	-7.965	210.1	921.0	117.2	Durable; Not Visc; TL; Not Homo	9
rc15	0.1365	-7.762	210.3	960.4	97.2	Durable; Visc; TL; Not Homo	12
rc16	0.1911	-12.601	210.7	986.9	32.1	Durable; Visc; TL; Not Homo	3
rc17	0.1951	-12.752	202.6	908.8	52.0	Not Durable; Visc; TL; Not Homo	5
rc18	0.1951	-12.872	206.2	908.6	55.2	Not Durable; Visc; TL; Not Homo	15
rc19	0.2002	-12.863	208.3	930.7	49.8	Not Durable; Visc; TL; Not Homo	16
rc20	0.1977	-12.500	209.0	926.5	53.0	Durable; Visc; TL; Not Homo	1
rc21	0.1984	-13.179	210.1	986.9	30.9	Not Durable; Visc; TL; Not Homo	7
rc22	0.1935	-12.184	210.2	926.5	55.5	Durable; Visc; TL; Not Homo	22
rc23	0.1977	-13.029	210.8	926.0	48.7	Not Durable; Visc; TL; Not Homo	19
rc24	0.1766	-11.184	210.6	977.0	56.0	Durable; Visc; TL; Not Homo	23

The batching and testing of these glasses should be conducted in a random order and under the guidance of the analytical study plan [8]. To facilitate this, a random ordering is provided in the last column of Table 3.

Scatter plots of these glass compositions are provided in Exhibit 2 of the Appendix. These plots are provided to show the coverage of the compositional region offered by this selection of 16 points. Three of the compositions are from the option of Tank 40 only sludge: 2 of these meeting criterion (1) and the other challenging criterion (2). The other 13 compositions are from the Tank 8 and 40 option: 9 of these meeting criterion (1) and the other 4 challenging criterion (2).

CONCLUDING COMMENTS

Twenty-four glass compositions were selected for Phase 1 of the reduction of constraints task. The compositions were selected from a set of candidates covering both sludge options for MB3. All of these candidate compositions were predicted to be inhomogeneous. The batching and testing of these glasses should provide data that complement the results from the glasses being investigated as part of the MB3 variability study and that allow for the relaxation and/or elimination of the homogeneity constraint for MB3 processing.

These results should also contribute to the glass database being complied as part of the reduction of constraints task and to the determination of a pathforward for this task.

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[1] Harbour, J. R. and T. B. Edwards, "Technical Task and QA Plan: Macrobatch 3 Variability Study," WSRC-RP-2000-00301, Revision 0, April 2000.

[2] Harbour, J. R. and T. B. Edwards, "Technical Task and QA Plan: Reduction in Durability Constraints," WSRC-RP-2000-00302, Revision 0, March 2000.

[3] Edwards, T. B. and K. G. Brown, "Evaluating the Glasses Batched for the Tank 42 Variability Study," SRT-SCS-98-0017, May 11, 1998.

[4] Brown, K. G. and T. B. Edwards, "Definition of the DWPF Predictability Constraint (U)," WSRC-TR-95-0060, Revision 0, January 31, 1995.

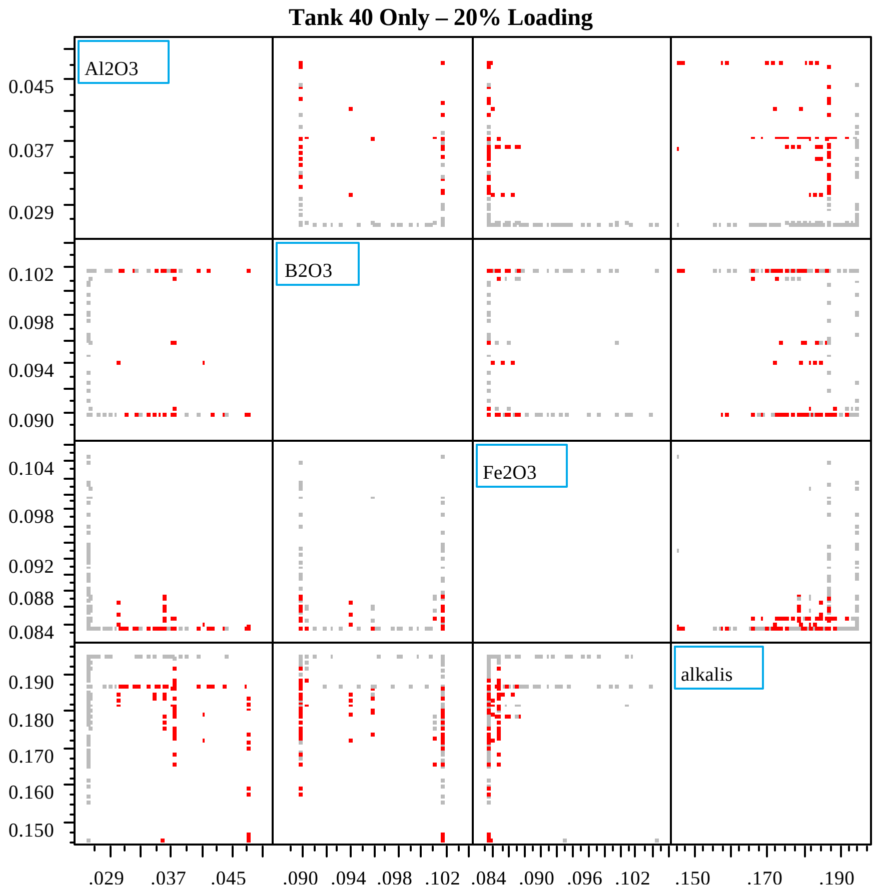
[5] Brown, K. G. and R. L. Postles, "SME Acceptability Determination for DWPF Process Control (U)," WSRC-TR-95-0364, Revision 3, February 21, 1996.

[6] Edwards, T. B. and K. G. Brown, "Selecting Glass Compositions to Support the MB3 Variability Study (U)," SRT-SCS-2000-00012, April 27, 2000.

[7] SAS Institute, Inc., **JMP Statistics and Graphics Guide**, Version 3, SAS Institute, Inc., Cary, NC, 1994.

[8] Harbour, J. R. and T. B. Edwards, "Analytical Study Plan: Reduction in Constraints," WSRC-RP-2000-00321, Revision 0, April 2000.

Exhibit 1. Scatter plots of Key Components of Glasses Predicted to be Inhomogeneous by Sludge Type and Waste-Loading



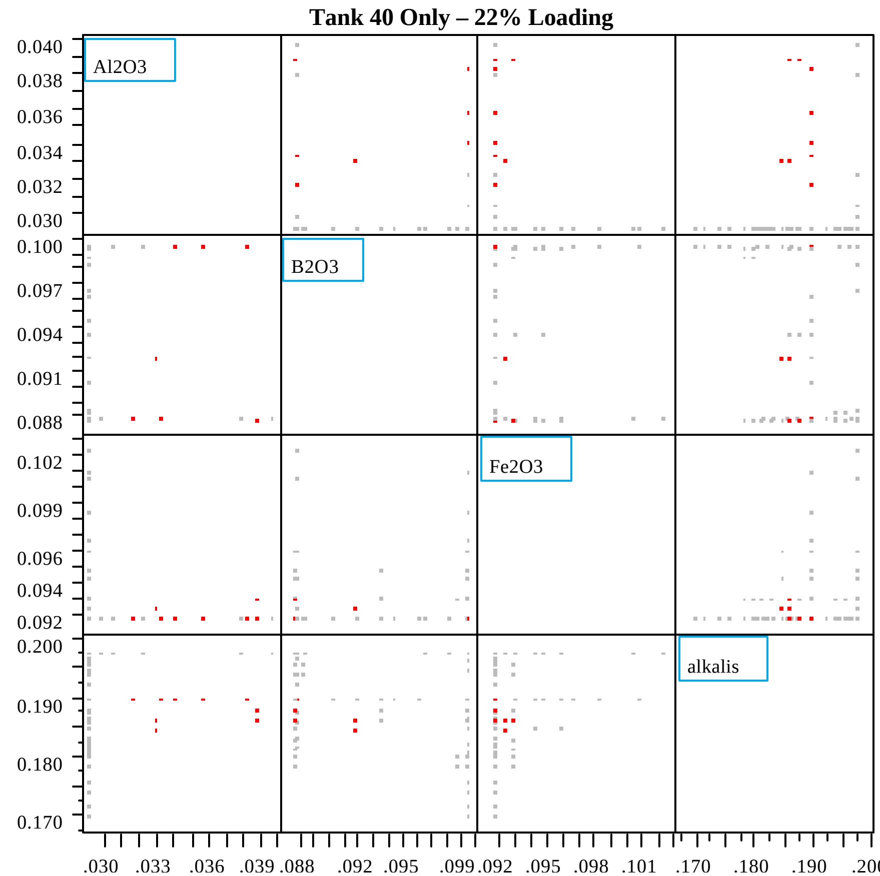
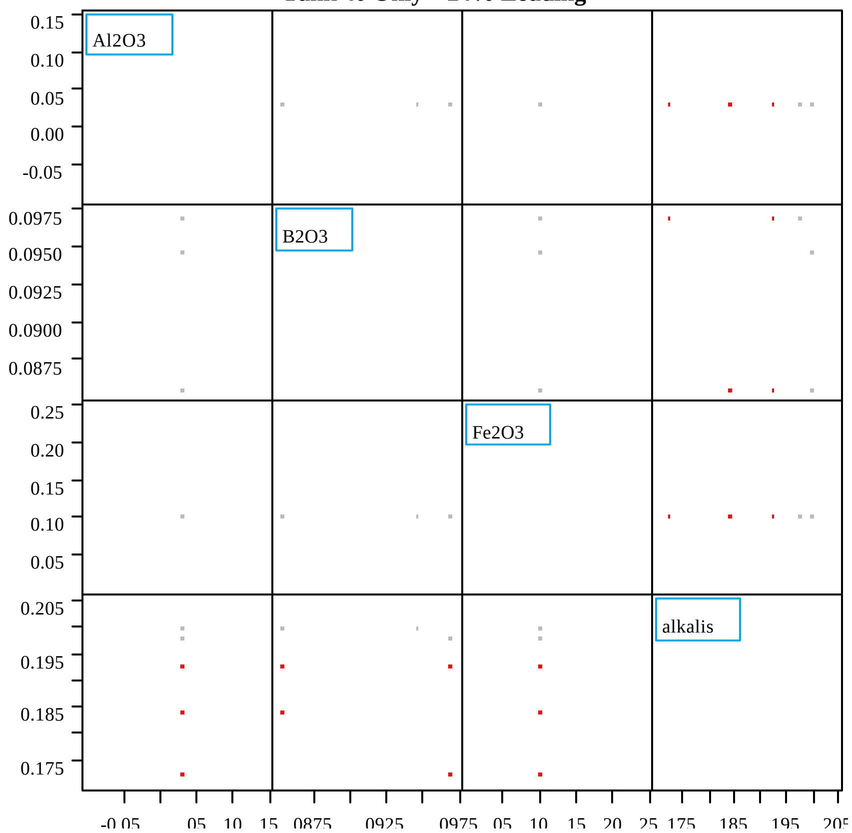


Exhibit 1. Scatter plots of Key Components of Glasses Predicted to be Inhomogeneous by Sludge Type and Waste-Loading (continued)

Tank 40 Only – 24% Loading



Tank 8 and 40– 20% Loading

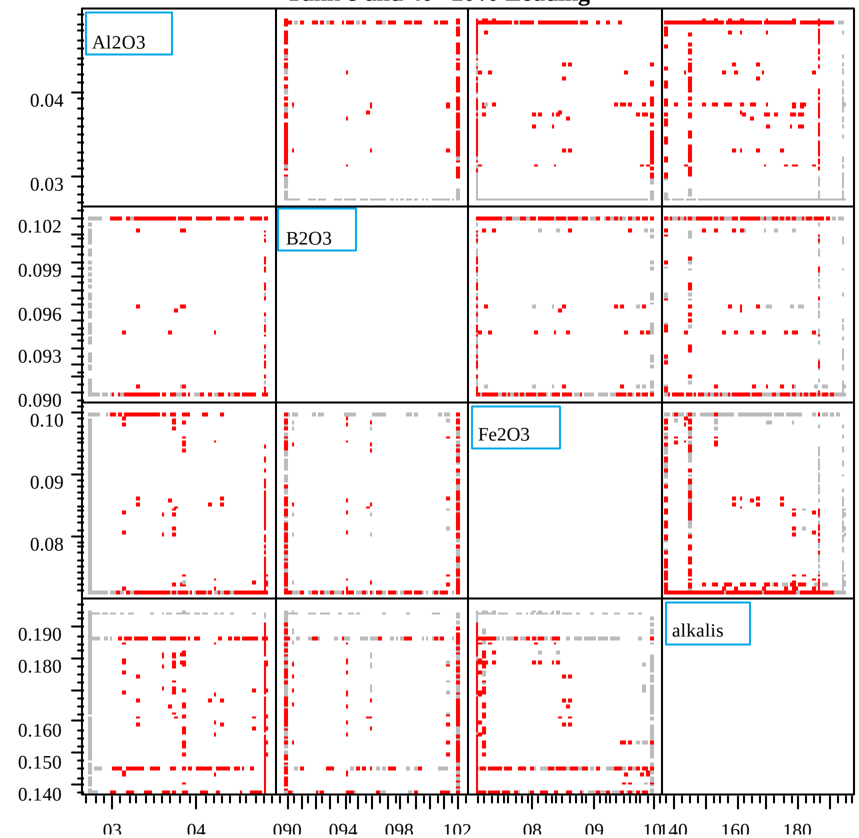
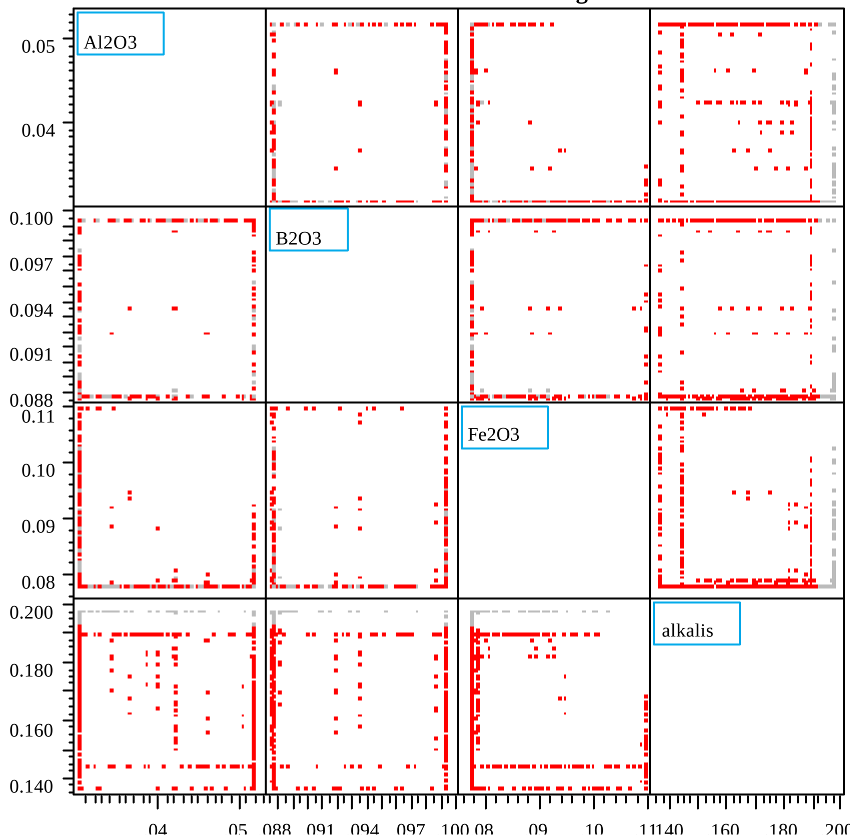


Exhibit 1. Scatter plots of Key Components of Glasses Predicted to be Inhomogeneous by Sludge Type and Waste-Loading (continued)

Tank 8 and 40– 22% Loading



Tank 8 and 40– 24% Loading

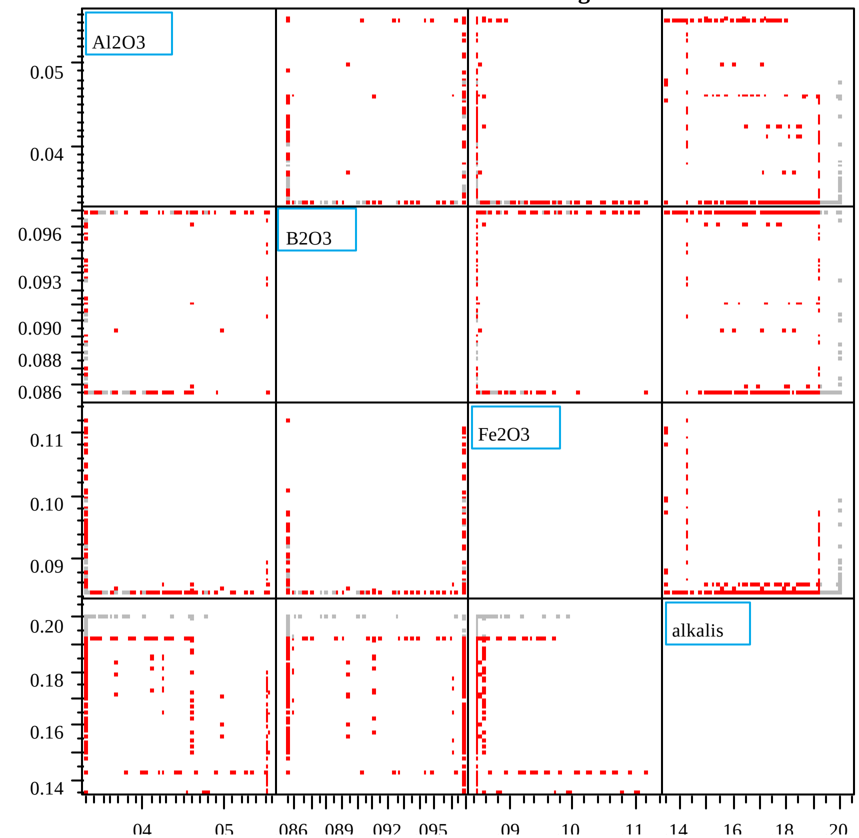
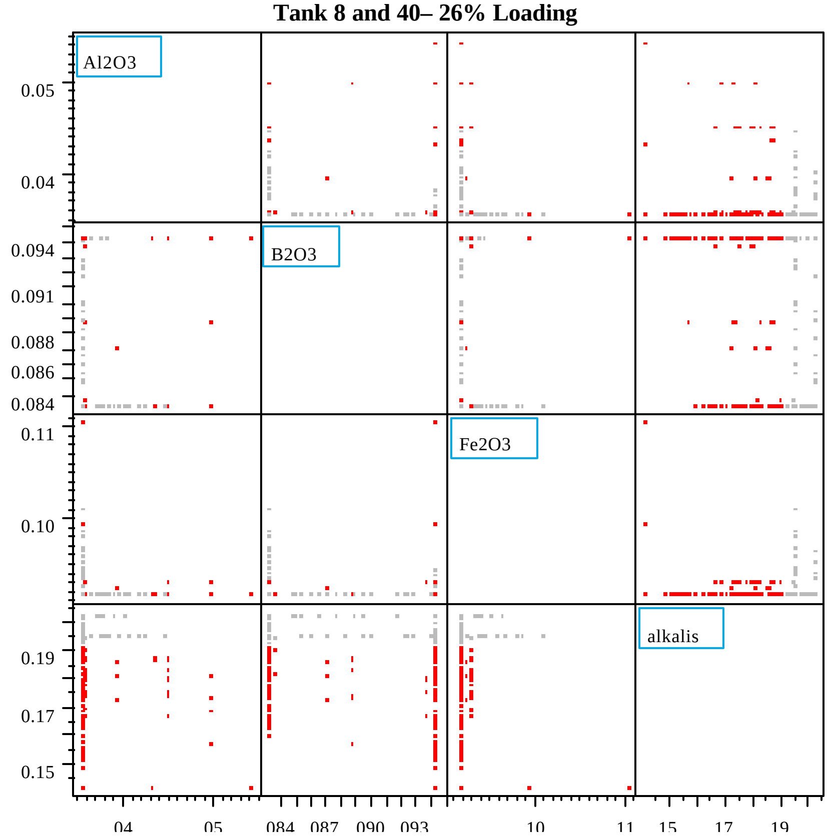


Exhibit 1. Scatter plots of Key Components of Glasses Predicted to be Inhomogeneous by Sludge Type and Waste-Loading (continued)

Tank 8 and 40– 26% Loading



Tank 8 and 40– 28% Loading

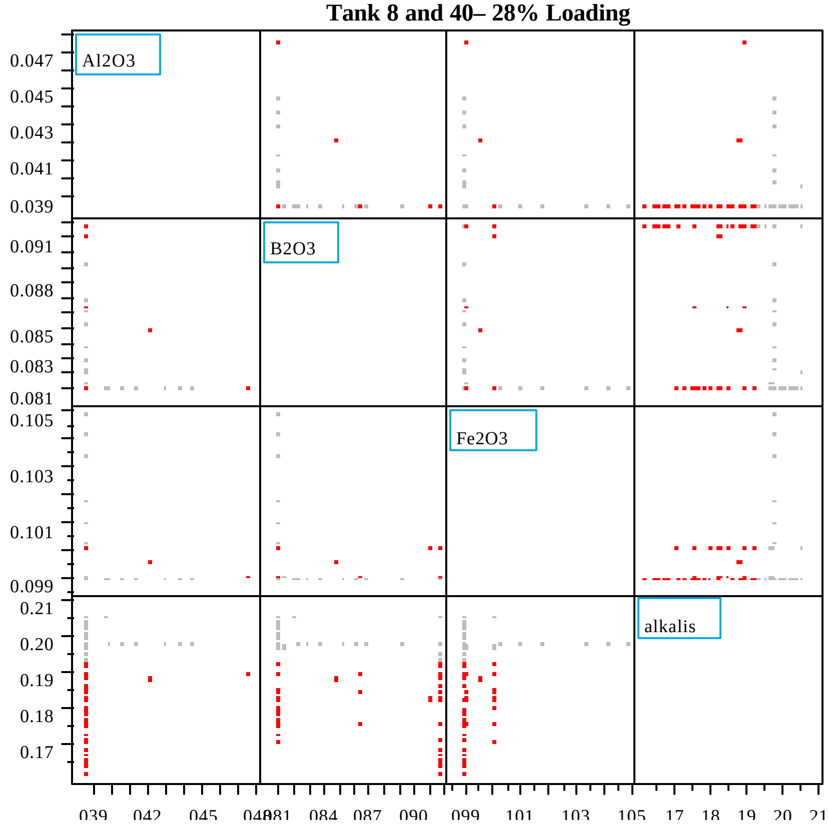


Exhibit 1. Scatter plots of Key Components of Glasses Predicted to be Inhomogeneous by Sludge Type and Waste-Loading (continued)

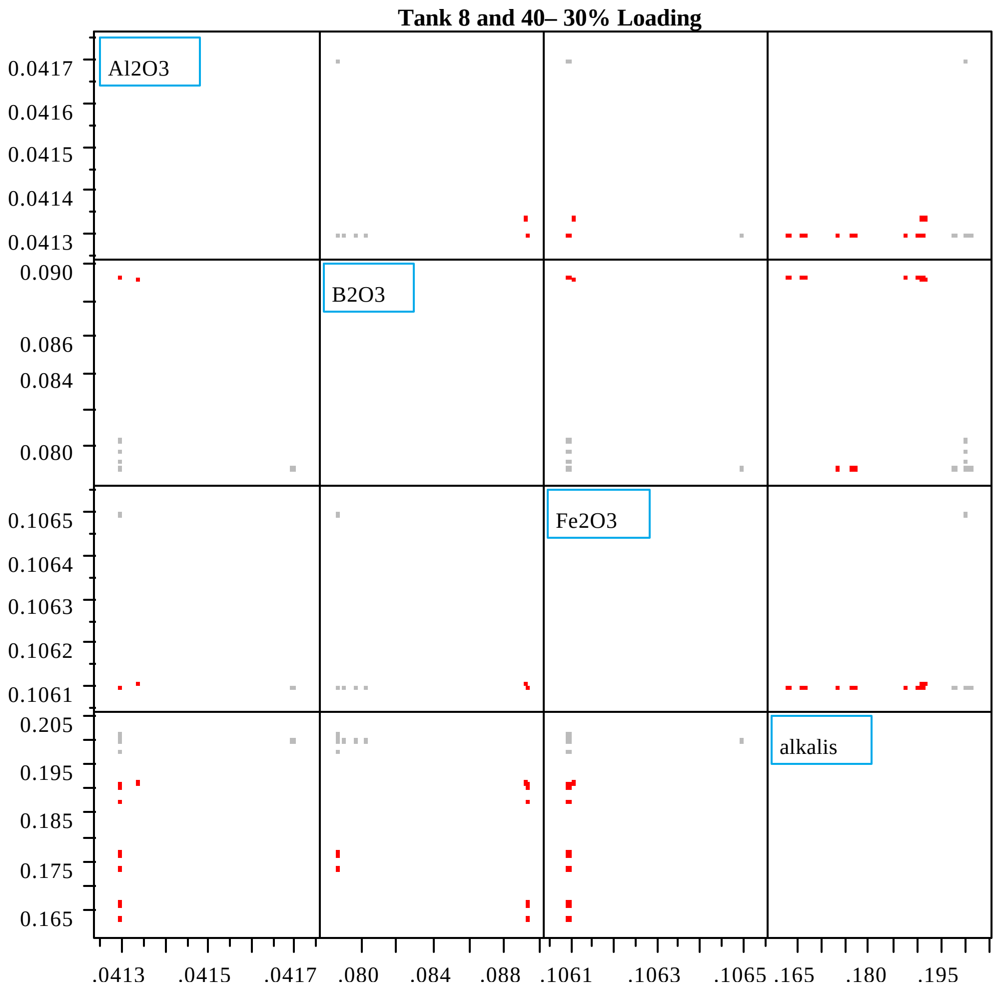
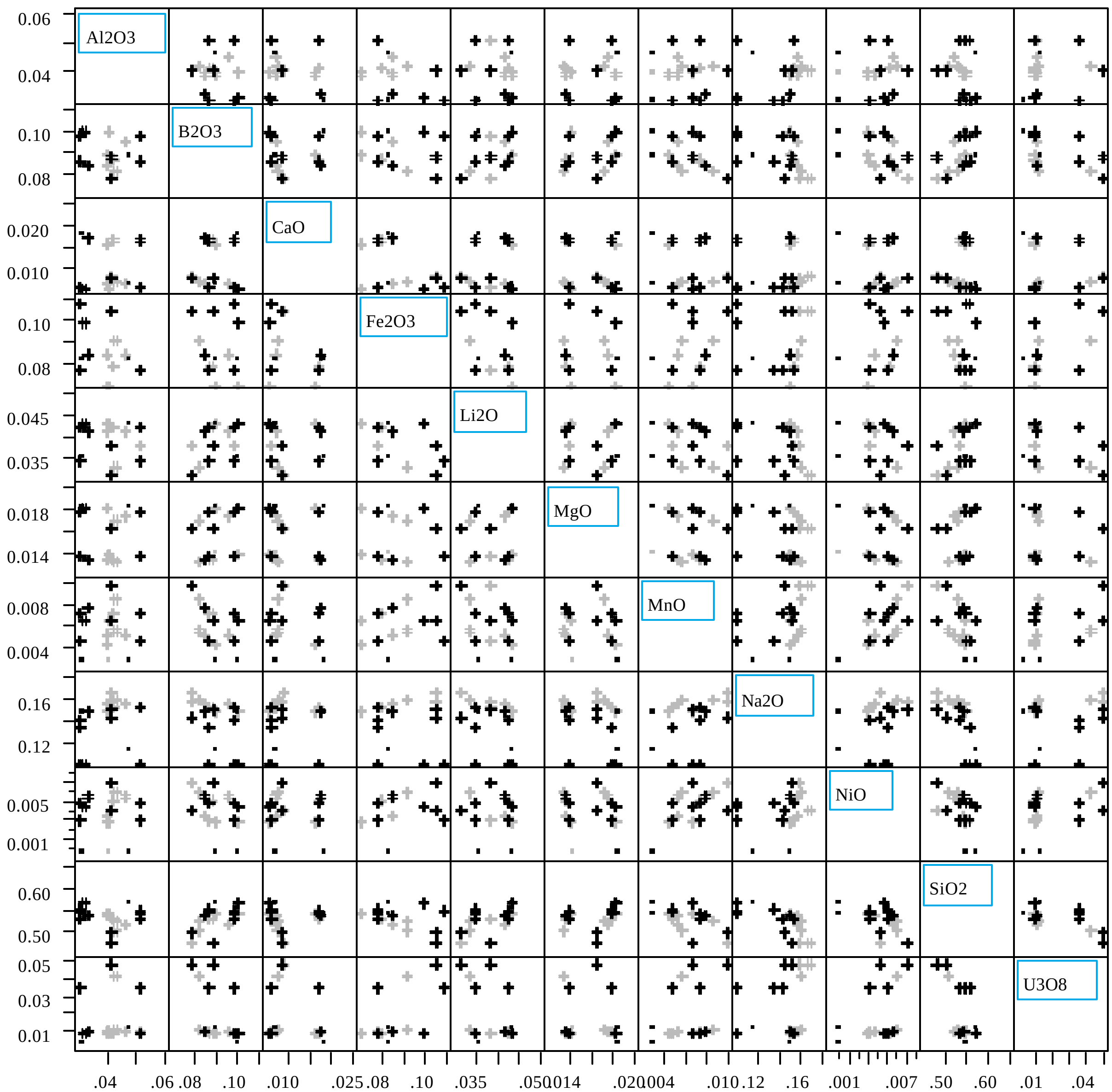


Exhibit 2. Scatterplot Matrix for Phase 1 Glasses
Small Squares – Tank 40 Only Sludge; Pluses – Tank 8 and 40
Lighter Shaded Points – Criterion 1; Darker Shaded Points – Criterion 2



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Appendix B

Analytical Plan supporting the Measurement of Chemical Compositions by the SRTC-ML

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OSR 31-688 (Rev 11-20-97)
Stores: 26-8910.00

WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2000-00038

July 17, 2000

To: J. R. Harbour, 773-43A
D. K. Peeler, 773-43A

cc: K. G. Brown, 704-1T
D. R. Best, 773-A
E. W. Holtzscheiter, 773-A
C. M. Jantzen, 773-A
S. L. Marra, 704-T
I. A.Reamer, 773-A
R. H. Spires, 773-A
R. C. Tuckfield, 773-42A
J. H. Weber, 773-42A
R.J. Workman, 773-A

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

J. H. Weber, Technical Reviewer — Date

R. C. Tuckfield, Manager
Statistical Consulting Section — Date

AN ANALYTICAL PLAN FOR THE SRTC MOBILE LABORATORY TO FOLLOW IN MEASURING THE CHEMICAL COMPOSITIONS OF ADDITIONAL GLASSES REPRESENTATIVE OF MB3(U)

EXECUTIVE SUMMARY

Two sets of glasses, whose compositions are targeted to be within the regions of interest for DWPF's macrobatch 3 (MB3) have recently been batched and fabricated as part of two studies being conducted by SRTC. The first set, which consists of ten glasses, supports the MB3 variability study, and the second set, which consists of twenty-four glasses, supports the reduction of constraints task. This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the chemical compositions of these 34 glasses.

INTRODUCTION

Task technical and quality assurance (TT&QA) plans and analytical study plans have been prepared to direct activities associated with the macrobatch 3 (MB3) variability study ([1] and [2], respectively) and those associated with a reduction of constraints task ([3] and [4], respectively) for the Defense Waste Processing Facility (DWPF). Ten glasses have been batched and fabricated as part of the third phase of the MB3 variability study, and twenty-four glasses were batched and fabricated for the reduction of constraints task [5]. The compositions of these thirty-four glasses are to be determined by the SRTC Mobile Laboratory (SRTC-ML). This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the compositions of these 34 glasses.

DISCUSSION

Table 1 provides the identifiers to be used by the SRTC-ML in analyzing and reporting the chemical compositions of the glasses covered by this plan. The first two columns of this table identify the samples of the MB3 variability study glasses and the last two columns identify the samples of the reduction-of-constraints glasses.

Table 1: Sample Identifiers for Use by the SRTC-ML

Glass ID	Sample ID	Glass ID	Sample ID
St04	V07	rc01	V28
St07	V03	rc02	V20
St31	V33	rc03	V13
St37	V12	rc04	V05
St39	V19	rc05	V11
St41	V23	rc06	V02
St43	V18	rc07	V01
St47	V27	rc08	V10
St56	V21	rc09	V06
St59	V29	rc10	V25
		rc11	V16
		rc12	V32
		rc13	V09
		rc14	V24
		rc15	V08
		rc16	V34
		rc17	V30
		rc18	V26
		rc19	V17
		rc20	V14
		rc21	V04
		rc22	V31
		rc23	V22
		rc24	V15

In the next section, these glass identifiers are modified to designate preparation and measurement information.

PREPARATION OF THE SAMPLES

The analytical procedures used by the SRTC-ML to determine cation concentrations for a glass sample include steps for sample preparation and for calibration of the Inductively Coupled Plasma (ICP) – Emission Spectrometer. These procedural steps are of primary concern in the development of this analytical plan.

Two dissolution methods will be used by the SRTC-ML to complete this compositional study: peroxide fusion (pf) and lithium metaborate (mb). The cation concentrations (as weight percents of the submitted sample) for the following elements are to be measured: aluminum (Al), boron (B), calcium (Ca), chromium (Cr), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), nickel (Ni), sodium (Na), silicon (Si), and uranium (U). Peroxide fusion is to be used to prepare samples for which all of these cation concentrations except that for Na are to be measured, and lithium metaborate is to be used to prepare samples for which all of these cation concentrations are to be determined except those of B and Li.

Each of the 34 samples submitted to the SRTC-ML is to be prepared twice by each of the two dissolution methods, and the pair of prepared samples are to be read twice by Inductively Coupled Plasma – Emission Spectroscopy, with the instrument being calibrated before each of these two readings (for each of the prepared samples). This will lead to 4 measurements for each cation of interest (by each preparation method employed for that cation) for each of the 34 samples submitted to the lab. Table 2 provides a (random) sequencing scheme for conducting the dissolutions (two blocks per method) required for these analyses.

Table 1: Randomized Preparation Blocks

Peroxide Fusion		Lithium Metaborate	
1	**2**	**1**	**2**
V07pf1	V26pf1	V05mb1	V29mb1
V25pf1	V01pf1	V13mb1	V07mb1
V24pf1	V04pf1	V09mb1	V27mb1
V18pf1	V26pf2	V26mb1	V18mb1
V29pf1	V28pf1	V05mb2	V08mb1
V30pf1	V22pf1	V04mb1	V33mb1
V08pf1	V02pf1	V09mb2	V20mb1
V21pf1	V05pf1	V13mb2	V08mb2
V33pf1	V13pf1	V31mb1	V29mb2
V30pf2	V14pf1	V15mb1	V23mb1
V33pf2	V16pf1	V16mb1	V21mb1
V32pf1	V31pf1	V34mb1	V24mb1
V07pf2	V34pf1	V26mb2	V20mb2
V11pf1	V06pf1	V14mb1	V32mb1
V25pf2	V05pf2	V14mb2	V25mb1
V29pf2	V16pf2	V01mb1	V07mb2
V24pf2	V09pf1	V28mb1	V03mb1
V03pf1	V09pf2	V15mb2	V12mb1
V27pf1	V04pf2	V22mb1	V11mb1
V18pf2	V15pf1	V01mb2	V23mb2
V19pf1	V06pf2	V17mb1	V30mb1
V20pf1	V17pf1	V06mb1	V18mb2
V23pf1	V28pf2	V31mb2	V24mb2
V12pf1	V17pf2	V10mb1	V19mb1
V21pf2	V15pf2	V02mb1	V27mb2
V32pf2	V10pf1	V06mb2	V03mb2
V11pf2	V22pf2	V28mb2	V30mb2
V08pf2	V31pf2	V04mb2	V25mb2
V12pf2	V13pf2	V16mb2	V33mb2
V27pf2	V01pf2	V34mb2	V11mb2
V20pf2	V02pf2	V22mb2	V21mb2
V23pf2	V34pf2	V02mb2	V32mb2
V03pf2	V14pf2	V17mb2	V12mb2
V19pf2	V10pf2	V10mb2	V19mb2

In Table 2, the sample identifier has been modified with a suffix consisting of a two-letter indicator for the preparation method ("pf" for peroxide fusion and "mb" for lithium metaborate) and a 1-digit indicator for preparation number.

Measuring the Samples with the ICP

The samples prepared by each of the two dissolution methods are to be analyzed using ICP instrumentation calibrated for the particular preparation method. After the initial set of cation concentration measurements has been completed for a set of samples, the ICP instrumentation is to be recalibrated and a second set of concentration measurements for the appropriate cations determined.

Two additional glasses are included in this analytical plan to provide an opportunity for checking the performance of the ICP instrumentation over the course of these analyses and for possible bias-correction of the measurements of the other glasses. One of these glasses is the standard, Batch 1, whose composition is provided in Table 3.

Table 3: Reference Composition of Batch 1 in Weight Percent (wt%)

Oxide	Wt%	Oxide	Wt%	Oxide	Wt%
Al_2O_3	4.877	Fe_2O_3	12.839	NiO	0.751
B_2O_3	7.777	K_2O	3.327	RuO_2	0.0214
BaO	0.151	Li_2O	4.429	SiO_2	50.22
CaO	1.220	MgO	1.419	TiO_2	0.677
Cr_2O_3	0.107	MnO	1.726	ZrO_2	0.098
Cs2O	0.060	Na_2O	9.003		
CuO	0.399	Nd_2O_3	0.147		

The second glass that will be used as a standard for these measurements is a uranium glass that is to be provided to the SRTC-ML along with the other glass samples.

A randomized plan for measuring cation concentrations in the prepared samples by each dissolution method is provided in Tables 4-5. Each ICP calibration required for these analyses is identified by specifying the cations to be measured for that set of ICP calibration blocks.

In these tables, the sample identifiers have been modified by the addition of a one-digit suffix to indicate whether the measurement is to be made during the first or second ICP calibration block for that sample. Samples of the standards, Batch 1 and the uranium-bearing glasses, which are to be prepared using the appropriate dissolution method, have been added to Tables 4 and 5. The identifiers for the Batch 1 standard samples begin with the 1-letter designation "b" followed by the 2-letter dissolution indicator, then the 2-digit ICP block number, and finally, a number 1 through 3 for the three replicates of this glass per block. The identifiers for the uranium standard samples begin with the 1-letter designation "u" followed by the 2-letter dissolution indicator, then the 2-digit ICP block number, and finally, a number 1 through 2 for the duplicate measurements per block of this glass.

**Table 4: ICP Blocks for Cation Concentration Measurements
For Samples Prepared Using Peroxide Fusion Method**

1-1	1-2	2-1	2-2	3-1	3-2
bpf111	bpf121	bpf211	bpf221	bpf311	bpf321
V19pf21	V03pf12	V08pf21	V24pf12	V26pf21	V26pf22
V18pf21	V27pf12	V01pf21	V15pf22	V16pf11	V16pf12
V33pf11	V19pf12	V09pf21	V22pf12	V17pf21	V17pf22
V33pf21	V29pf22	V15pf11	V09pf22	V26pf11	V26pf12
V21pf11	V12pf22	V10pf21	V31pf22	V02pf11	V02pf12
upf111	upf121	V31pf21	V34pf22	V28pf11	V28pf12
V23pf21	V23pf22	upf211	upf221	upf311	upf321
V18pf11	V18pf12	V06pf21	V25pf22	V30pf11	V30pf12
V27pf11	V33pf22	V08pf11	V13pf22	V14pf11	V14pf12
V12pf11	V07pf12	V15pf21	V25pf12	V20pf11	V20pf12
V07pf21	V07pf22	V22pf11	V01pf12	V11pf21	V11pf22
bpf112	bpf122	V13pf11	V15pf12	V05pf11	V05pf12
V27pf21	V33pf12	V25pf21	V31pf12	V28pf21	V28pf22
V29pf21	V21pf12	bpf212	bpf222	bpf312	bpf322
V29pf11	V19pf22	V34pf21	V01pf22	V16pf21	V16pf22
V03pf21	V18pf22	V34pf11	V09pf12	V32pf21	V32pf22
V12pf21	V23pf12	V31pf11	V06pf12	V30pf21	V30pf22
upf112	upf122	V06pf11	V10pf12	V02pf21	V02pf22
V03pf11	V03pf22	V24pf11	V13pf12	V14pf21	V14pf22
V23pf11	V21pf22	V25pf11	V08pf22	V04pf11	V04pf12
V07pf11	V12pf12	upf212	upf222	upf312	upf322
V19pf11	V27pf22	V01pf11	V10pf22	V04pf21	V04pf22
V21pf21	V29pf12	V09pf11	V22pf22	V20pf21	V20pf22
bpf113	bpf123	V10pf11	V34pf12	V11pf11	V11pf12
		V24pf21	V06pf22	V17pf11	V17pf12
		V22pf21	V24pf22	V32pf11	V32pf12
		V13pf21	V08pf12	V05pf21	V05pf22
		bpf213	bpf223	bpf313	bpf323

Table 5: ICP Blocks for Cation Concentration Measurements For Samples Prepared Using Lithium Metaborate Method

1-1	1-2	2-1	2-2	3-1	3-2
bmb111	bmb121	bmb211	bmb221	bmb311	bmb321
V19mb11	V12mb22	V11mb11	V22mb12	V26mb21	V10mb12
V07mb21	V19mb12	V14mb11	V11mb22	V01mb21	V06mb22
V03mb11	V18mb22	V09mb21	V16mb22	V08mb21	V15mb12
V27mb21	V07mb12	V02mb21	V22mb22	V08mb11	V01mb22
V33mb11	V23mb12	V32mb21	V30mb22	V10mb11	V24mb12
umb111	umb121	V13mb11	V31mb22	V06mb11	V26mb22
V33mb21	V19mb22	umb211	umb221	umb311	umb321
V21mb11	V12mb12	V04mb11	V14mb12	V24mb11	V24mb22
V12mb11	V07mb22	V22mb21	V04mb22	V25mb11	V34mb22
V21mb21	V29mb22	V04mb21	V31mb12	V20mb11	V15mb22
V12mb21	V03mb22	V16mb11	V32mb12	V26mb11	V10mb22
bmb112	bmb122	V09mb11	V11mb12	V34mb11	V17mb22
V29mb21	V27mb22	V11mb21	V16mb12	V01mb11	V06mb12
V23mb11	V03mb12	bmb212	bmb222	bmb312	bmb322
V23mb21	V27mb12	V31mb21	V09mb12	V24mb21	V34mb12
V18mb21	V29mb12	V02mb11	V02mb12	V06mb21	V20mb22
V03mb21	V18mb12	V14mb21	V13mb12	V17mb11	V17mb12
umb112	umb122	V32mb11	V14mb22	V10mb21	V08mb12
V18mb11	V21mb12	V16mb21	V04mb12	V25mb21	V25mb12
V27mb11	V33mb22	V13mb21	V02mb22	V15mb11	V01mb12
V29mb11	V21mb22	umb212	umb222	umb312	umb322
V07mb11	V23mb22	V31mb11	V05mb22	V15mb21	V20mb12
V19mb21	V33mb12	V05mb21	V09mb22	V28mb11	V25mb22
bmb113	bmb123	V30mb11	V32mb22	V20mb21	V08mb22
		V30mb21	V30mb12	V28mb21	V26mb12
		V22mb11	V13mb22	V34mb21	V28mb22
		V05mb11	V05mb12	V17mb21	V28mb12
		bmb213	bmb223	bmb313	bmb323

CONCLUDING COMMENTS

In summary, this analytical plan identifies 4 preparation blocks in Table 2 and 12 ICP calibration blocks in Tables 4-5 to assist in the chemical analyses of the thirty-four glasses that support the MB3 variability study and the reduction of constraints task. The sequencing of the activities associated with each of these steps in the analytical procedures has been randomized in these tables. The size of each of these blocks is such that it should be completed in a single work shift.

If for some reason the measurements are not conducted in the sequences presented in this memorandum, the actual order used should be recorded along with any explanative comments.

The analytical plan provided in the preceding tables should be modified by the personnel of SRTC-ML to include any calibration check standards and/or other standards that are part of their routine operating procedures.

REFERENCES

[1] Harbour, J. R. and T. B. Edwards, “Technical Task and QA Plan: Macrobatch 3 Variability Study,” WSRC-RP-2000-00301, Revision 0, April 2000.

[2] Harbour, J. R. and T. B. Edwards, “Analytical Study Plan: Macrobatch 3 Variability Study,” WSRC-RP-2000-00320, Revision 0, April 2000.

[3] Harbour, J. R., T. B. Edwards, and K. G. Brown, “Technical Task and QA Plan: Reduction in Durability Constraints,” WSRC-RP-2000-00302, Revision 0, March 2000.

[4] Harbour, J. R. and T. B. Edwards, “Analytical Study Plan: Reduction in Constraints,” WSRC-RP-2000-00321, Revision 0, April 2000.

[5] Edwards, T. B. and K. G. Brown, “Selecting Glasses in Support of Phase 1 of the Reduction of Constraints Task (U),” SRT-SCS-2000-00030, June 23, 2000.

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APPENDIX C

ANALYTICAL PLAN SUPPORTING THE MEASUREMENT OF PCT SOLUTIONS FROM GROUP 1 BY THE SRTC-ML

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OSR 31-688 (Rev 11-20-97)
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WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2000-00043

July 31, 2000

To: D. K. Peeler, 773-43A (wi)

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wi - with sample identifiers
es - executive summary only

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

____________________ ____________________
S. P. Harris, Technical Reviewer Date

____________________ ____________________
R. C. Tuckfield, Manager Date
Statistical Consulting Section

AN ANALYTICAL PLAN FOR THE SRTC MOBILE LABORATORY TO FOLLOW IN MEASURING THE FIRST SET OF PCT SOLUTIONS FOR PHASE 1 GLASSES OF THE REDUCTION OF CONSTRAINTS TASK (U)

1.0 EXECUTIVE SUMMARY

A task technical and quality assurance (TT&QA) plan and an analytical study plan have been prepared to direct activities associated with the reduction of constraints task being conducted by SRTC for DWPF. Twenty-four glass compositions were batched as Phase 1 of this study. All of these glasses were cooled by both quenching and center-line-cooling, resulting in forty-eight glasses, which are to be tested for this phase of the study.

Durability is a critical product quality characteristic that is to be measured for these glasses. The Product Consistency Test, or PCT, is used as a measure of glass durability, and its requirements are described in ASTM C1285-97 (Method A). Each PCT results in a leachate solution whose elemental concentrations must be measured to complete the determination of glass durability. The PCT is to be conducted in triplicate for each glass. Due to space limitations, the PCTs of the Phase 1 glasses must be conducted in two sets. The quenched and center-lined-cooled versions of twelve glasses were randomly selected to comprise the first set, and this memorandum covers the PCTs for these glasses. (A subsequent memorandum will provide an analytical plan for the second set of PCTs.) In addition to the test glasses, PCTs are to be conducted (in triplicate) on samples of the Approved Reference Material (ARM) glass and of Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests.

The Savannah River Technology Center-Mobile Laboratory (SRTC-ML) is to be used to measure elemental concentrations of the resulting leachate solutions from these PCTs. This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the compositions of the leachate solutions resulting from the PCT procedures for the glasses.

2.0 INTRODUCTION

A task technical and quality assurance (TT&QA) plan [1] and an analytical study plan [2] have been prepared to direct activities associated with the reduction of constraints task for the Defense Waste Processing Facility (DWPF). Twenty-four glass compositions were batched as Phase 1 of this study [3]. All of these glasses were cooled both by quenching and center-line-cooling, which resulted in forty-eight glasses. The durabilities of these forty-eight glasses are to be measured using the Product Consistency Test, or PCT. Its requirements are described in ASTM C1285-97 (Method A) [4]. Due to the large number of samples involved, the tests are to be conducted in two sets. The quenched and center-lined-cooled versions of twelve glasses were randomly selected to comprise the first set. In addition to these test glasses, PCTs are to be conducted (in triplicate) on samples of the Approved Reference Material (ARM) glass and of Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests.

This memorandum provides an analytical plan for the Savannah River Technology Center's Mobile Laboratory (SRTC-ML) to follow in measuring the compositions of the PCT leachate solutions for the MB3 glasses.

3.0 DISCUSSION

Twenty-four glasses batched and fabricated as part of Phase 1 of the reduction of constraints study are to be subjected to the PCT. Each of these tests is to be conducted in triplicate. In addition to these test glasses, triplicate PCTs are to be conducted on a sample of ARM glass and a sample of the EA glass. Two reagent blank samples are also to be included in these tests. This results in 80 sample solutions being required to complete these PCTs.

The leachates from these tests will be diluted by adding 4 mL of 0.4 M HNO_3 to 6 mL of the leachate (a 6:10 volume to volume, v:v, dilution) before being submitted to the Mobile Laboratory. The EA leachates will be further diluted (1:10 v:v) with deionized water prior to submission to the SRTC-ML in order to prevent problems with the nebulizer.

Table 1 enumerates the glasses comprising this phase of the reduction of constraints study and presents identifying codes, f01 through f80, for the individual solutions required for the PCTs of the test glasses and of the standards (EA, ARM, and blanks). This provides a naming convention that is to be used by the SRTC-ML in analyzing these solutions and reporting the relevant concentration measurements.[4] The center-line-cooled glasses are identified by the "-clc" suffix.

4 Renaming these samples ensures that they will be processed as blind samples by the SRTC-ML. This table is complete only for those on the distribution list with a "wi" following their names.

Table 1: Assignment of Solution Identifiers

Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier
rc02	f21	rc14	f71	rc03clc	f45	rc16clc	f10
rc02	f56	rc15	f62	rc03clc	f40	rc16clc	f19
rc02	f09	rc15	f43	rc04clc	f68	rc16clc	f55
rc03	f76	rc15	f65	rc04clc	f69	rc18clc	f07
rc03	f75	rc16	f77	rc04clc	f44	rc18clc	f80
rc03	f49	rc16	f31	rc06clc	f15	rc18clc	f51
rc04	f72	rc16	f53	rc06clc	f60	rc20clc	f33
rc04	f22	rc18	f27	rc06clc	f37	rc20clc	f11
rc04	f78	rc18	f08	rc07clc	f48	rc20clc	f26
rc06	f13	rc18	f47	rc07clc	f46	rc21clc	f73
rc06	f16	rc20	f28	rc07clc	f17	rc21clc	f36
rc06	f12	rc20	f59	rc11clc	f79	rc21clc	f57
rc07	f67	rc20	f05	rc11clc	f66	EA	f20
rc07	f30	rc21	f38	rc11clc	f01	EA	f34
rc07	f32	rc21	f06	rc14clc	f24	EA	f04
rc11	f18	rc21	f63	rc14clc	f61	ARM	f70
rc11	f41	rc02clc	f02	rc14clc	f25	ARM	f23
rc11	f42	rc02clc	f74	rc15clc	f39	ARM	f14
rc14	f50	rc02clc	f29	rc15clc	f64	blank	f58
rc14	f03	rc03clc	f35	rc15clc	f54	blank	f52

4.0 ANALYTICAL PLAN

The analytical plan for the SRTC-ML is provided in this section. Each of the solution samples submitted to the SRTC-ML is to be analyzed only once for each of the following: aluminum (Al), boron (B), calcium (Ca), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), and uranium (U). These measurements are to be made in parts per million (ppm). The analytical procedure used by the SRTC-ML to determine the concentrations utilizes an Inductively Coupled Plasma (ICP) – Emission Spectrometer. The PCT solutions (as identified in Table 1) are grouped in three ICP blocks for processing by the SRTC-ML in Table 2. Each block requires a different calibration of the ICP.

Table 2: ICP Calibration Blocks for Leachate Measurements

1	2	3
std-b1-1	std-b2-1	std-b3-1
f18	f45	f71
f28	f16	f05
f10	f66	f44
f13	f43	f51
f33	f41	f78
f76	f31	f53
f35	f30	f42
f48	f34	f25
f73	f22	f57
f24	f69	f32
f20	f11	f65
f50	f06	f12
f67	f03	f01
std-b1-2	std-b2-2	std-b3-2
f27	f36	f09
f15	f75	f26
f62	f60	f37
f38	f61	f04
f39	f23	f29
f07	f80	f47
f21	f08	f54
f02	f19	f49
f70	f64	f14
f72	f74	f40
f77	f56	f55
f58	f46	f52
f68	f59	f63
f79	std-b2-3	f17
std-b1-3		std-b3-3

A multi-element solution standard (denoted by "std-bi-j" where i=1, 2, and 3 represents the block number and j=1, 2, 3 represents the position in the block) was added at the beginning, middle, and end of each of the three blocks. This standard may be useful in checking for and correcting bias in the concentration measurements arising from the ICP calibrations.

5.0 SUMMARY

In summary, this analytical plan provides identifiers for the PCT solutions in Table 1 and three ICP calibration blocks in Table 2 for the SRTC-ML to use in conducting the aluminum (Al), boron (B), calcium (Ca), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), and uranium (U) concentration measurements for the PCT study of the first set of Phase 1 glasses of the reduction of constraints task. The sequencing of the activities associated with each of these steps in the analytical procedure has been randomized. The size of these blocks was selected so that the block could be completed in a single work shift. If for some reason the measurements are not conducted in the sequence presented in this memorandum, the actual order should be recorded along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of the SRTC-ML to include any calibration check standards and/or other standards that are part of their standard operating procedures.

6.0 REFERENCES

[1] Harbour, J. R., T. B. Edwards, and K. G. Brown, "Technical Task and QA Plan: Reduction in Durability Constraints," WSRC-RP-2000-00302, Revision 0, March 2000.

[2] Harbour, J. R. and T. B. Edwards, "Analytical Study Plan: Reduction in Constraints," WSRC-RP-2000-00321, Revision 0, April 2000.

[3] Edwards, T. B. and K. G. Brown, "Selecting Glasses in Support of Phase 1 of the Reduction of Constraints Task (U)," SRT-SCS-2000-0030, June 23, 2000.

[4] ASTM C1285-97, "Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT)," 1997.

APPENDIX D

ANALYTICAL PLAN SUPPORTING THE MEASUREMENT OF PCT SOLUTIONS FROM GROUP 2 BY THE SRTC-ML

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OSR 31-688 (Rev 11-20-97)
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WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2000-00044

August 2, 2000

To: D. K. Peeler, 773-43A (wi)

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R. J. Workman, 773-A (wi)

wi - with sample identifiers
es - executive summary only

From: T. B. Edwards, 773-42A (5-5148)
Statistical Consulting Section

________________________ __________________
S. P. Harris, Technical Reviewer Date

________________________ __________________
R. C. Tuckfield, Manager Date
Statistical Consulting Section

AN ANALYTICAL PLAN FOR THE SRTC MOBILE LABORATORY TO FOLLOW IN MEASURING THE SECOND SET OF PCT SOLUTIONS FOR PHASE 1 GLASSES OF THE REDUCTION OF CONSTRAINTS TASK (U)

1.0 EXECUTIVE SUMMARY

A task technical and quality assurance (TT&QA) plan and an analytical study plan have been prepared to direct activities associated with the reduction of constraints task being conducted by SRTC for DWPF. Twenty-four glass compositions were batched as Phase 1 of this study. All of these glasses were cooled by both quenching and center-line-cooling, resulting in forty-eight glasses, which are to be tested for this phase of the study.

Durability is a critical product quality characteristic that is to be measured for these glasses. The Product Consistency Test, or PCT, is used as a measure of glass durability, and its requirements are described in ASTM C1285-97 (Method A). Each PCT results in a leachate solution whose elemental concentrations must be measured to complete the determination of glass durability. The PCT is to be conducted in triplicate for each glass. Due to space limitations, the PCTs of the Phase 1 glasses must be conducted in two sets. The original 24 glasses were randomly placed into two groups, and the quenched and center-lined-cooled versions for the first group of glasses comprised the first set. An earlier memorandum provided an analytical plan for the PCTs for these glasses. The current memorandum provides an analytical plan for the second set of PCTs (those conducted for the quenched and center-lined-cooled versions of the second group of glasses). In addition to the test glasses, PCTs are to be conducted (in triplicate) on samples of the Approved Reference Material (ARM) glass and of Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests.

The Savannah River Technology Center-Mobile Laboratory (SRTC-ML) is to be used to measure elemental concentrations of the resulting leachate solutions from these PCTs. This memorandum provides an analytical plan for the SRTC-ML to follow in measuring the compositions of the leachate solutions resulting from the PCT procedures for the glasses.

2.0 INTRODUCTION

A task technical and quality assurance (TT&QA) plan [1] and an analytical study plan [2] have been prepared to direct activities associated with the reduction of constraints task for the Defense Waste Processing Facility (DWPF). Twenty-four glass compositions were batched as Phase 1 of this study [3]. All of these glasses were cooled both by quenching and center-line-cooling, which resulted in forty-eight glasses (2 different thermal histories for each of the 24 glasses). The durabilities of these forty-eight glasses are to be measured in triplicate using the Product Consistency Test, or PCT. Its requirements are described in ASTM C1285-97 (Method A) [4]. Due to the large number of samples involved, the tests are to be conducted in two sets. The quenched and center-lined-cooled versions of twelve glasses were randomly selected to comprise the first set. An earlier memorandum provided an analytical plan for the PCTs for these glasses [5]. The current memorandum provides an analytical plan for the second set of PCTs (those conducted for the quenched and center-lined-cooled versions of the second group of twelve glasses). In addition to these test glasses, PCTs are to be conducted (in triplicate) on samples of the Approved Reference Material (ARM) glass and of Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests.

This memorandum provides an analytical plan for the Savannah River Technology Center's Mobile Laboratory (SRTC-ML) to follow in measuring the compositions of the PCT leachate solutions for these glasses.

3.0 DISCUSSION

The quenched and center-line-cooled versions of the second set of twelve Phase 1 glasses of the reduction of constraints study are to be subjected to the PCT. These 2 different thermal histories for each of the 12 batched glasses lead to 24 glasses that are to be measured (in triplicate) using the PCT. In addition to the test glasses, triplicate PCTs are to be conducted on a sample of ARM glass and a sample of the EA glass. Two reagent blank samples are also to be included in these tests. This results in 80 sample solutions being required to complete these PCTs.

The leachates from these tests will be diluted by adding 4 mL of 0.4 M HNO_3 to 6 mL of the leachate (a 6:10 volume to volume, v:v, dilution) before being submitted to the Mobile Laboratory. The EA leachates will be further diluted (1:10 v:v) with deionized water prior to submission to the SRTC-ML in order to prevent problems with the nebulizer.

Table 1 enumerates the glasses comprising this phase of the reduction of constraints study and presents identifying codes, h01 through h80, for the individual solutions required for the PCTs of the test glasses and of the standards (EA, ARM, and blanks). This provides a naming convention that is to be used by the SRTC-ML in analyzing these solutions and reporting the relevant concentration measurements.[5] The center-line-cooled glasses are identified by the "-clc" suffix.

5 Renaming these samples ensures that they will be processed as blind samples by the SRTC-ML. This table is complete only for those on the distribution list with a "wi" following their names.

Table 1: Assignment of Solution Identifiers

Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier
rc01	h06	rc13	h15	rc05clc	h32	rc19clc	h73
rc01	h01	rc17	h38	rc05clc	h51	rc19clc	h59
rc01	h29	rc17	h46	rc08clc	h44	rc19clc	h62
rc05	h37	rc17	h52	rc08clc	h61	rc22clc	h25
rc05	h43	rc19	h19	rc08clc	h56	rc22clc	h76
rc05	h14	rc19	h03	rc09clc	h27	rc22clc	h40
rc08	h65	rc19	h02	rc09clc	h79	rc23clc	h35
rc08	h30	rc22	h05	rc09clc	h31	rc23clc	h12
rc08	h21	rc22	h64	rc10clc	h42	rc23clc	h39
rc09	h23	rc22	h63	rc10clc	h60	rc24clc	h75
rc09	h13	rc23	h10	rc10clc	h04	rc24clc	h28
rc09	h20	rc23	h68	rc12clc	h57	rc24clc	h33
rc10	h07	rc23	h11	rc12clc	h16	EA	h34
rc10	h70	rc24	h72	rc12clc	h66	EA	h09
rc10	h71	rc24	h18	rc13clc	h80	EA	h24
rc12	h69	rc24	h77	rc13clc	h36	ARM	h58
rc12	h26	rc01clc	h47	rc13clc	h67	ARM	h49
rc12	h41	rc01clc	h78	rc17clc	h54	ARM	h53
rc13	h55	rc01clc	h50	rc17clc	h74	blank	h45
rc13	h17	rc05clc	h08	rc17clc	h48	blank	h22

4.0 ANALYTICAL PLAN

The analytical plan for the SRTC-ML is provided in this section. Each of the solution samples submitted to the SRTC-ML is to be analyzed only once for each of the following: aluminum (Al), boron (B), calcium (Ca), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), and uranium (U). These measurements are to be made in parts per million (ppm). The analytical procedure used by the SRTC-ML to determine the concentrations utilizes an Inductively Coupled Plasma (ICP) – Emission Spectrometer. The PCT solutions (as identified in Table 1) are grouped in three ICP blocks for processing by the SRTC-ML in Table 2. Each block requires a different calibration of the ICP.

Table 2: ICP Calibration Blocks for Leachate Measurements

1	2	3
std-b1-1	std-b2-1	std-b3-1
h38	h71	h79
h27	h20	h74
h05	h67	h01
h72	h48	h36
h23	h33	h26
h69	h31	h13
h55	h14	h60
h19	h21	h76
h80	h50	h09
h06	h15	h30
h35	h40	h12
h34	h66	h70
h25	h41	h16
std-b1-2	std-b2-2	std-b3-2
h65	h53	h78
h42	h52	h18
h47	h63	h46
h45	h02	h22
h08	h77	h17
h73	h29	h28
h10	h04	h49
h58	h11	h59
h57	h51	h43
h37	h56	h64
h75	h39	h68
h07	h24	h32
h54	h62	h61
h44	std-b2-3	h03
std-b1-3		std-b3-3

A multi-element solution standard (denoted by "std-bi-j" where i=1, 2, and 3 represents the block number and j=1, 2, and 3 represents the position in the block) was added at the beginning, middle, and end of each of the three blocks. This standard may be useful in checking for and correcting bias in the concentration measurements arising from the ICP calibrations.

5.0 SUMMARY

In summary, this analytical plan provides identifiers for the PCT solutions in Table 1 and three ICP calibration blocks in Table 2 for the SRTC-ML to use in conducting the aluminum (Al), boron (B), calcium (Ca), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), silicon (Si), and uranium (U) concentration measurements for the PCT study of the second set of Phase 1 glasses of the reduction of constraints task. The sequencing of the activities associated with each of these steps in the analytical procedure has been randomized. The size of these blocks was selected so that the block could be completed in a single work shift. If for some reason the measurements are not conducted in the sequence presented in this memorandum, the actual order should be recorded along with any explanative comments.

The analytical plan indicated in the preceding tables should be modified by the personnel of the SRTC-ML to include any calibration check standards and/or other standards that are part of their standard operating procedures.

6.0 REFERENCES

[1] Harbour, J. R., T. B. Edwards, and K. G. Brown, “Technical Task and QA Plan: Reduction in Durability Constraints,” WSRC-RP-2000-00302, Revision 0, March 2000.

[2] Harbour, J. R. and T. B. Edwards, “Analytical Study Plan: Reduction in Constraints,” WSRC-RP-2000-00321, Revision 0, April 2000.

[3] Edwards, T. B. and K. G. Brown, “Selecting Glasses in Support of Phase 1 of the Reduction of Constraints Task (U),” SRT-SCS-2000-0030, June 23, 2000.

[4] ASTM C1285-97, “Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT),” 1997.

[5] Edwards, T. B., “An Analytical Plan for the SRTC Mobile Laboratory to Follow in Measuring the First Set of PCT Solutions for Phase 1 Glasses of the Reduction of Constraints Task (U),” SRT-SCS-2000-00043, July 31, 2000.

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APPENDIX E

CHEMICAL COMPOSITION DATA FOR THE RC GLASSES

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Table E1. SRTC-ML Elemental Concentration Measurements (wt%) for Samples Prepared Using Lithium Metaborate ($LiBO_2$)

Glass ID	Prep Method	Block	ICP Calibration	Analytical Sequence	Sample ID	Ca	Cr	Fe	Mg	Na	Si	U
Batch 1	LiBO2	1	1	1	bmb111	0.878	0.065	9.15	0.840	6.67	23.5	<0.097
st39	LiBO2	1	1	2	v19mb11	0.483	<0.010	5.95	0.784	10.7	24.6	0.834
st04	LiBO2	1	1	3	v07mb21	1.07	<0.010	9.15	0.918	9.23	24.2	0.847
st07	LiBO2	1	1	4	v03mb11	1.26	<0.010	11.4	0.864	9.50	22.3	0.988
st47	LiBO2	1	1	5	v27mb21	1.32	<0.010	9.56	0.745	8.92	23.0	0.973
st31	LiBO2	1	1	6	v33mb11	0.768	<0.010	6.06	0.950	8.70	25.4	1.43
Ustd	LiBO2	1	1	7	umb111	0.939	0.160	9.24	0.693	7.90	21.3	1.87
st31	LiBO2	1	1	8	v33mb21	0.771	<0.010	6.12	0.968	8.58	26.2	1.46
st56	LiBO2	1	1	9	v21mb11	1.37	<0.010	8.75	0.711	11.7	22.8	0.987
st37	LiBO2	1	1	10	v12mb11	1.04	<0.010	9.83	0.856	9.49	22.5	2.28
st56	LiBO2	1	1	11	v21mb21	1.39	<0.010	8.83	0.716	11.6	23.2	1.00
st37	LiBO2	1	1	12	v12mb21	1.06	<0.010	9.89	0.883	9.87	22.8	2.33
Batch 1	LiBO2	1	1	13	bmb112	0.865	0.064	9.16	0.825	6.70	23.5	<0.097
st59	LiBO2	1	1	14	v29mb21	1.43	<0.010	10.9	0.902	10.1	22.2	1.22
st41	LiBO2	1	1	15	v23mb11	1.23	<0.010	8.11	1.00	7.15	24.7	3.04
st41	LiBO2	1	1	16	v23mb21	1.24	<0.010	8.20	0.997	7.04	24.9	3.04
st43	LiBO2	1	1	17	v18mb21	0.489	<0.010	8.36	0.762	7.08	25.4	2.98
st07	LiBO2	1	1	18	v03mb21	1.22	<0.010	11.6	0.842	9.22	22.3	0.963
Ustd	LiBO2	1	1	19	umb112	1.10	0.159	9.29	0.701	8.08	21.3	1.87
st43	LiBO2	1	1	20	v18mb11	0.479	<0.010	8.40	0.767	7.31	25.6	2.95
st47	LiBO2	1	1	21	v27mb11	1.36	<0.010	9.78	0.742	9.01	23.7	0.971
st59	LiBO2	1	1	22	v29mb11	1.41	<0.010	11.0	0.906	9.85	22.1	1.21
st04	LiBO2	1	1	23	v07mb11	1.06	<0.010	9.42	0.901	8.98	24.5	0.839
st39	LiBO2	1	1	24	v19mb21	0.478	<0.010	6.18	0.783	10.4	25.2	0.817
Batch 1	LiBO2	1	1	25	bmb113	0.869	0.065	9.45	0.838	6.40	24.1	<0.097
Batch 1	LiBO2	1	2	1	bmb121	0.881	0.067	8.99	0.853	6.56	23.3	<0.097
st37	LiBO2	1	2	2	v12mb22	1.07	<0.010	9.64	0.890	9.76	22.3	2.33
st39	LiBO2	1	2	3	v19mb12	0.482	<0.010	5.91	0.779	10.9	24.7	0.823
st43	LiBO2	1	2	4	v18mb22	0.494	<0.010	8.06	0.773	7.04	24.6	3.00
st04	LiBO2	1	2	5	v07mb12	1.08	<0.010	8.93	0.909	8.99	23.7	0.852
st41	LiBO2	1	2	6	v23mb12	1.25	<0.010	7.98	1.01	7.31	24.4	3.05
Ustd	LiBO2	1	2	7	umb121	0.932	0.164	9.05	0.684	8.18	21.0	1.86
st39	LiBO2	1	2	8	v19mb22	0.477	<0.010	5.88	0.790	10.6	24.6	0.821
st37	LiBO2	1	2	9	v12mb12	1.05	<0.010	9.70	0.868	9.55	22.4	2.31
st04	LiBO2	1	2	10	v07mb22	1.06	<0.010	9.10	0.910	9.19	24.2	0.850
st59	LiBO2	1	2	11	v29mb22	1.42	<0.010	10.8	0.910	10.0	21.9	1.21
st07	LiBO2	1	2	12	v03mb22	1.22	<0.010	11.3	0.851	9.35	21.9	0.974
Batch 1	LiBO2	1	2	13	bmb122	0.873	0.067	9.06	0.847	6.67	23.4	<0.097
st47	LiBO2	1	2	14	v27mb22	1.34	<0.010	9.51	0.750	9.08	23.2	0.968
st07	LiBO2	1	2	15	v03mb12	1.25	<0.010	11.5	0.856	9.44	22.3	0.982
st47	LiBO2	1	2	16	v27mb12	1.36	<0.010	9.49	0.761	8.93	23.0	0.982
st59	LiBO2	1	2	17	v29mb12	1.43	<0.010	10.8	0.910	10.1	21.8	1.21
st43	LiBO2	1	2	18	v18mb12	0.485	<0.010	8.28	0.780	7.41	25.1	2.98
Ustd	LiBO2	1	2	19	umb122	1.11	0.166	9.23	0.712	8.39	21.5	1.87
st56	LiBO2	1	2	20	v21mb12	1.38	<0.010	8.73	0.721	11.9	23.0	0.995
st31	LiBO2	1	2	21	v33mb22	0.768	<0.010	6.09	0.973	8.82	26.5	1.46
st56	LiBO2	1	2	22	v21mb22	1.41	<0.010	8.79	0.726	12.0	23.1	1.01
st41	LiBO2	1	2	23	v23mb22	1.28	<0.010	8.10	1.02	7.31	24.7	3.08
st31	LiBO2	1	2	24	v33mb12	0.782	<0.010	6.01	0.953	8.72	25.3	1.43
Batch 1	LiBO2	1	2	25	bmb123	0.882	0.069	9.06	0.854	6.54	23.5	<0.097
Batch 1	LiBO2	2	1	1	bmb211	0.862	0.065	9.02	0.858	6.7	23.4	<0.097
rc05	LiBO2	2	1	2	v11mb11	0.529	<0.010	6.4	1	11.5	24.3	0.912
rc20	LiBO2	2	1	3	v14mb11	0.491	<0.010	5.48	1.03	10.5	25	0.761
rc13	LiBO2	2	1	4	v09mb21	0.4	<0.010	6.93	1.07	7.42	26.6	0.703
rc06	LiBO2	2	1	5	v02mb21	1.29	<0.010	5.88	1.11	11	25.5	0.307
rc12	LiBO2	2	1	6	v32mb21	0.44	<0.010	5.53	0.821	11.2	25.4	0.782
rc03	LiBO2	2	1	7	v13mb11	0.497	<0.010	6.05	1.1	11.7	24.1	0.861
Ustd	LiBO2	2	1	8	umb211	0.916	0.156	9.15	0.691	8.48	21.5	1.86
rc21	LiBO2	2	1	9	v04mb11	0.618	<0.010	7.48	0.997	11.6	22.3	3.91
rc23	LiBO2	2	1	10	v22mb21	1.19	<0.010	5.79	0.864	11.2	24.8	0.783
rc21	LiBO2	2	1	11	v04mb21	0.608	<0.010	7.44	0.981	11.4	22.3	3.86
rc11	LiBO2	2	1	12	v16mb11	1.18	<0.010	5.5	1.05	7.22	25.9	2.56
rc13	LiBO2	2	1	13	v09mb11	0.411	<0.010	7.08	1.07	7.36	27	0.717
rc05	LiBO2	2	1	14	v11mb21	0.539	<0.010	6.57	1.02	11.9	25.2	0.933
Batch 1	LiBO2	2	1	15	bmb212	0.868	0.065	9.12	0.855	6.6	23.5	<0.097
rc22	LiBO2	2	1	16	v31mb21	0.412	<0.010	5.09	0.763	10.3	26.6	0.718
rc06	LiBO2	2	1	17	v02mb11	1.29	<0.010	5.99	1.12	11	26	0.305
rc20	LiBO2	2	1	18	v14mb21	0.489	<0.010	5.63	1.06	10.7	25.6	0.77
rc12	LiBO2	2	1	19	v32mb11	0.434	<0.010	5.49	0.816	11.3	25.2	0.778

rc11	LiBO2	2	1	20	v16mb21	1.16	<0.010	5.48	1.07	7.29	25.8	2.54
rc03	LiBO2	2	1	21	v13mb21	0.479	<0.010	6.03	1.11	11.3	24.1	0.855
Ustd	LiBO2	2	1	22	umb212	0.935	0.161	9.2	0.715	8.47	21.7	1.86
rc22	LiBO2	2	1	23	v31mb11	0.403	<0.010	5.07	0.779	12.1	26.8	0.711
rc04	LiBO2	2	1	24	v05mb21	0.642	<0.010	7.66	1.03	12.2	22.7	3.76
rc17	LiBO2	2	1	25	v30mb11	0.394	<0.010	5.09	0.872	11	25.7	0.743
rc17	LiBO2	2	1	26	v30mb21	0.401	<0.010	5.06	0.881	10.9	25.8	0.757
rc23	LiBO2	2	1	27	v22mb11	1.2	<0.010	5.86	0.837	11.3	24.9	0.788
rc04	LiBO2	2	1	28	v05mb11	0.621	<0.010	7.53	1.01	11.8	22.3	3.74
Batch 1	LiBO2	2	1	29	bmb213	0.846	0.067	9.23	0.875	6.49	23.7	<0.097
Batch 1	LiBO2	2	2	1	bmb221	0.861	0.063	8.97	0.868	6.62	23.2	<0.097
rc23	LiBO2	2	2	2	v22mb12	1.21	<0.010	5.69	0.823	11.2	24.2	0.785
rc05	LiBO2	2	2	3	v11mb22	0.532	<0.010	6.44	1.02	11.6	24.6	0.93

Table E1. SRTC-ML Elemental Concentration Measurements (wt%) for Samples Prepared Using Lithium Metaborate ($LiBO_2$) - continued

Glass ID	Prep Method	Block	ICP Calibration	Analytical Sequence	Sample ID	Ca	Cr	Fe	Mg	Na	Si	U
rc11	LiBO2	2	2	4	v16mb22	1.17	<0.010	5.37	1.07	7.37	25.2	2.55
rc23	LiBO2	2	2	5	v22mb22	1.21	<0.010	5.8	0.874	11.1	24.5	0.789
rc17	LiBO2	2	2	6	v30mb22	0.396	<0.010	4.97	0.864	10.9	25.4	0.757
rc22	LiBO2	2	2	7	v31mb22	0.407	<0.010	5.05	0.773	14.2	26.4	0.73
Ustd	LiBO2	2	2	8	umb221	0.91	0.157	9.08	0.705	8.32	21	1.88
rc20	LiBO2	2	2	9	v14mb12	0.475	<0.010	5.53	1.04	10.6	25.1	0.753
rc21	LiBO2	2	2	10	v04mb22	0.604	<0.010	7.37	0.997	11.3	22	3.9
rc22	LiBO2	2	2	11	v31mb12	0.4	<0.010	5.02	0.773	11.8	26.2	0.71
rc12	LiBO2	2	2	12	v32mb12	0.432	<0.010	5.47	0.811	11.4	25	0.784
rc05	LiBO2	2	2	13	v11mb12	0.522	<0.010	6.5	1	11.6	24.5	0.923
rc11	LiBO2	2	2	14	v16mb12	1.18	<0.010	5.5	1.07	7.23	25.6	2.56
Batch 1	LiBO2	2	2	15	bmb222	0.854	0.063	9.05	0.868	6.92	23.5	<0.097
rc13	LiBO2	2	2	16	v09mb12	0.401	<0.010	7.04	1.09	7.26	26.5	0.711
rc06	LiBO2	2	2	17	v02mb12	1.3	<0.010	5.91	1.12	10.8	25.4	0.305
rc03	LiBO2	2	2	18	v13mb12	0.484	<0.010	6.03	1.1	11.7	24.1	0.867
rc20	LiBO2	2	2	19	v14mb22	0.479	<0.010	5.58	1.06	10.8	25.4	0.77
rc21	LiBO2	2	2	20	v04mb12	0.609	<0.010	7.52	1.01	11.7	22.4	3.91
rc06	LiBO2	2	2	21	v02mb22	1.29	<0.010	5.93	1.11	11.1	25.5	0.304
Ustd	LiBO2	2	2	22	umb222	0.959	0.158	9.12	0.708	8.51	21.3	1.88
rc04	LiBO2	2	2	23	v05mb22	0.649	<0.010	7.58	1.01	12.2	22.5	3.78
rc13	LiBO2	2	2	24	v09mb22	0.394	<0.010	6.95	1.08	7.54	26.5	0.712
rc12	LiBO2	2	2	25	v32mb22	0.434	<0.010	5.53	0.828	11.2	25.1	0.791
rc17	LiBO2	2	2	26	v30mb12	0.397	<0.010	5.04	0.856	11.1	25.2	0.751
rc03	LiBO2	2	2	27	v13mb22	0.481	<0.010	6.06	1.1	11.5	24.2	0.865
rc04	LiBO2	2	2	28	v05mb12	0.628	<0.010	7.5	0.992	12	22.1	3.79
Batch 1	LiBO2	2	2	29	bmb223	0.878	0.063	9.17	0.855	6.69	23.6	<0.097
Batch 1	LiBO2	3	1	1	bmb311	0.871	0.066	8.98	0.849	6.68	23.4	<0.097
rc18	LiBO2	3	1	2	v26mb21	1.15	<0.010	4.88	1.07	10.9	25	0.662
rc07	LiBO2	3	1	3	v01mb21	0.53	<0.010	5.8	1.33	8.58	26.1	1.01
rc15	LiBO2	3	1	4	v08mb21	0.45	<0.010	7.56	0.791	7.26	24.6	2.89
rc15	LiBO2	3	1	5	v08mb11	0.448	<0.010	7.46	0.78	7.26	25.2	2.87
rc08	LiBO2	3	1	6	v10mb11	0.477	<0.010	5.37	0.979	9.76	25.4	2.74
rc09	LiBO2	3	1	7	v06mb11	0.464	<0.010	5.44	0.787	10.3	24.3	2.6
Ustd	LiBO2	3	1	8	umb311	0.981	0.151	8.88	0.661	8.25	20.8	1.85
rc14	LiBO2	3	1	9	v24mb11	1.18	<0.010	5.21	0.774	6.85	25.4	2.64
rc10	LiBO2	3	1	10	v25mb11	1.23	<0.010	5.69	0.758	10.5	24.8	0.898
rc02	LiBO2	3	1	11	v20mb11	0.528	<0.010	6.41	0.735	11.6	22.8	3.36
rc18	LiBO2	3	1	12	v26mb11	1.17	<0.010	4.92	1.06	11	25.3	0.664
rc16	LiBO2	3	1	13	v34mb11	0.616	<0.010	7.34	1.02	11	22	3.7
rc07	LiBO2	3	1	14	v01mv11	0.501	<0.010	5.84	1.07	8.42	26.3	0.976
Batch 1	LiBO2	3	1	15	bmb312	0.878	0.065	8.85	0.848	6.57	23	<0.097
rc14	LiBO2	3	1	16	v24mb21	1.17	<0.010	5.24	0.796	7.14	25.5	2.63
rc09	LiBO2	3	1	17	v06mb21	0.492	<0.010	5.72	0.811	10.9	25.4	0.96
rc19	LiBO2	3	1	18	v17mb11	0.493	<0.010	5.73	0.787	11.5	24.7	0.869
rc08	LiBO2	3	1	19	v10mb21	0.455	<0.010	5.4	0.999	9.77	25.7	2.69
rc10	LiBO2	3	1	20	v25mb21	1.24	<0.010	5.81	0.785	11.1	25.4	0.893
rc24	LiBO2	3	1	21	v15mb11	0.613	<0.010	7.36	0.944	10.6	23.3	3.73
Ustd	LiBO2	3	1	22	umb312	1.06	0.158	8.95	0.699	8.35	21.2	1.87
rc24	LiBO2	3	1	23	v15mb21	0.62	<0.010	7.41	0.974	10.6	23.1	3.78
rc01	LiBO2	3	1	24	v28mb11	0.508	<0.010	5.88	0.828	10.8	25.6	0.985
rc02	LiBO2	3	1	25	v20mb21	0.551	<0.010	6.34	0.746	11.8	23.4	3.43
rc01	LiBO2	3	1	26	v28mb21	0.497	<0.010	5.72	0.798	10.6	25	0.967
rc16	LiBO2	3	1	27	v34mb21	0.624	<0.010	7.42	1.01	11.1	22.3	3.73
rc19	LiBO2	3	1	28	v17mb21	0.494	<0.010	5.8	0.775	11.4	25.2	0.868
Batch 1	LiBO2	3	1	29	bmb313	0.879	0.064	9.05	0.829	6.66	23.3	<0.097
Batch 1	LiBO2	3	2	1	bmb321	0.861	0.069	8.89	0.886	6.52	23.2	<0.097
rc08	LiBO2	3	2	2	v10mb12	0.463	<0.010	5.38	1.04	9.65	25.4	2.73
rc09	LiBO2	3	2	3	v06mb22	0.492	<0.010	5.65	0.851	10.4	24.8	0.984
rc24	LiBO2	3	2	4	v15mb12	0.601	<0.010	7.34	0.986	10.1	23	3.76
rc07	LiBO2	3	2	5	v01mb22	0.525	<0.010	5.91	1.35	8.57	26.4	1.01
rc14	LiBO2	3	2	6	v24mb12	1.14	<0.010	5.34	0.829	7.07	26	2.68
rc18	LiBO2	3	2	7	v26mb22	1.17	<0.010	4.89	1.08	10.5	24.9	0.675
Ustd	LiBO2	3	2	8	umb321	0.99	0.161	8.87	0.706	8.19	20.9	1.88
rc14	LiBO2	3	2	9	v24mb22	1.17	<0.010	5.22	0.809	7.05	25.4	2.66
rc16	LiBO2	3	2	10	v34mb22	0.614	<0.010	7.39	1.07	10.8	22	3.75
rc24	LiBO2	3	2	11	v15mb22	0.605	<0.010	7.4	0.977	10.3	23	3.71
rc08	LiBO2	3	2	12	v10mb22	0.451	<0.010	5.42	1.05	9.67	25.7	2.73
rc19	LiBO2	3	2	13	v17mb22	0.482	<0.010	5.7	0.798	10.9	24.5	0.862
rc09	LiBO2	3	2	14	v06mb12	0.447	<0.010	5.44	0.848	10.1	24.4	2.6

Batch 1	LiBO2	3	2	15	bmb322	0.873	0.069	8.92	0.879	6.56	23	<0.097
rc16	LiBO2	3	2	16	v34mb12	0.599	<0.010	7.42	1.08	10.8	22.1	3.76
rc02	LiBO2	3	2	17	v20mb22	0.52	<0.010	6.3	0.777	11.1	22.9	3.4
rc19	LiBO2	3	2	18	v17mb12	0.481	<0.010	5.76	0.805	10.9	24.4	0.868
rc15	LiBO2	3	2	19	v08mb12	0.433	<0.010	7.47	0.824	6.95	25	2.88
rc10	LiBO2	3	2	20	v25mb12	1.2	<0.010	5.74	0.803	10.4	24.8	0.902
rc07	LiBO2	3	2	21	v01mb12	0.495	<0.010	5.86	1.14	8.14	26	0.998
Ustd	LiBO2	3	2	22	umb322	0.939	0.163	8.93	0.717	7.82	20.7	1.86
rc02	LiBO2	3	2	23	v20mb12	0.518	<0.010	6.38	0.781	11.6	22.7	3.44
rc10	LiBO2	3	2	24	v25mb22	1.25	<0.010	5.85	0.815	10.6	25.3	0.914
rc15	LiBO2	3	2	25	v08mb22	0.431	<0.010	7.69	0.819	7.31	24.7	2.86
rc18	LiBO2	3	2	26	v26mb12	1.17	<0.010	4.95	1.1	10.2	24.8	0.677
rc01	LiBO2	3	2	27	v28mb22	0.486	<0.010	5.71	0.834	10.5	24.4	0.965
rc01	LiBO2	3	2	28	v28mb12	0.486	<0.010	5.87	0.843	10.2	25.2	0.962
Batch 1	LiBO2	3	2	29	bmb323	0.872	0.068	8.97	0.872	6.54	23.2	<0.097

Table E2. SRTC-ML Elemental Concentration Measurements (wt%) for Samples Prepared Using Peroxide Fusion (Na_2O_2)

Glass ID	Prep Method	Block	ICP Calibration	Analytical Sequence	Sample ID	Al	B	Li	Mn	Ni
Batch 1	Na2O2	1	1	1	bpf111	2.5	2.34	2	1.3	0.552
st39	Na2O2	1	1	2	v19pf21	3.01	2.87	1.55	0.594	0.239
st43	Na2O2	1	1	3	v18pf21	1.77	2.57	1.87	0.607	0.256
st31	Na2O2	1	1	4	v33pf11	1.99	2.81	1.79	0.408	0.274
st31	Na2O2	1	1	5	v33pf21	2.03	2.81	1.8	0.42	0.272
st56	Na2O2	1	1	6	v21pf11	2.11	2.28	1.69	0.733	0.493
Ustd	Na2O2	1	1	7	upf111	2.11	2.78	1.36	2.08	0.796
st41	Na2O2	1	1	8	v23pf21	1.79	2.88	1.51	0.407	0.246
st43	Na2O2	1	1	9	v18pf11	1.75	2.52	1.86	0.601	0.255
st47	Na2O2	1	1	10	v27pf11	2.31	2.54	1.35	0.796	0.548
st37	Na2O2	1	1	11	v12pf11	2.89	2.43	1.53	0.687	0.441
st04	Na2O2	1	1	12	v07pf21	2.54	2.73	1.72	0.275	<0.010
Batch 1	Na2O2	1	1	13	bpf112	2.43	2.31	1.99	1.3	0.554
st47	Na2O2	1	1	14	v27pf21	3.24	2.39	1.79	0.477	0.307
st59	Na2O2	1	1	15	v29pf21	2.34	2.59	1.35	0.81	0.546
st59	Na2O2	1	1	16	v29pf11	2.31	2.55	1.34	0.803	0.543
st07	Na2O2	1	1	17	v03pf21	2.8	2.33	1.51	0.461	<0.010
st37	Na2O2	1	1	18	v12pf21	2.88	2.33	1.5	0.68	0.44
Ustd	Na2O2	1	1	19	upf112	2.13	2.75	1.35	2.11	0.803
st07	Na2O2	1	1	20	v03pf11	3.16	2.43	1.54	0.468	<0.010
st41	Na2O2	1	1	21	v23pf11	1.8	2.84	1.52	0.415	0.257
st04	Na2O2	1	1	22	v07pf11	2.49	2.59	1.64	0.388	<0.010
st39	Na2O2	1	1	23	v19pf11	2.97	2.83	1.52	0.601	0.244
st56	Na2O2	1	1	24	v21pf21	2.03	2.2	1.61	0.721	0.496
Batch 1	Na2O2	1	1	25	bpf113	2.48	2.31	1.99	1.33	0.562
Batch 1	Na2O2	1	2	1	bpf121	2.51	2.46	1.98	1.37	0.613
st07	Na2O2	1	2	2	v03pf12	3.07	2.42	1.51	0.478	0.011
st47	Na2O2	1	2	3	v27pf12	2.27	2.5	1.31	0.823	0.578
st39	Na2O2	1	2	4	v19pf12	2.82	2.71	1.46	0.605	0.257
st59	Na2O2	1	2	5	v29pf22	2.26	2.51	1.31	0.823	0.581
st37	Na2O2	1	2	6	v12pf22	2.79	2.33	1.47	0.695	0.458
Ustd	Na2O2	1	2	7	upf121	2.07	2.68	1.32	2.15	0.82
st41	Na2O2	1	2	8	v23pf22	1.76	2.78	1.46	0.415	0.275
st43	Na2O2	1	2	9	v18pf12	1.71	2.46	1.81	0.62	0.283
st31	Na2O2	1	2	10	v33pf22	1.98	2.72	1.74	0.425	0.299
st04	Na2O2	1	2	11	v07pf12	2.39	2.48	1.58	0.391	0.02
st04	Na2O2	1	2	12	v07pf22	2.44	2.61	1.66	0.276	0.012
Batch 1	Na2O2	1	2	13	bpf122	2.46	2.37	1.96	1.37	0.598
st31	Na2O2	1	2	14	v33pf12	1.95	2.67	1.72	0.415	0.292
st56	Na2O2	1	2	15	v21pf12	2.05	2.21	1.62	0.752	0.517
st39	Na2O2	1	2	16	v19pf22	2.86	2.76	1.48	0.61	0.261
st43	Na2O2	1	2	17	v18pf22	1.75	2.51	1.82	0.628	0.275
st41	Na2O2	1	2	18	v23pf12	1.76	2.83	1.48	0.42	0.285
Ustd	Na2O2	1	2	19	upf122	2.03	2.64	1.3	2.15	0.819
st07	Na2O2	1	2	20	v03pf22	2.7	2.34	1.47	0.473	<0.010
st56	Na2O2	1	2	21	v21pf22	1.99	2.14	1.55	0.731	0.519
st37	Na2O2	1	2	22	v12pf12	2.76	2.32	1.47	0.7	0.47
st47	Na2O2	1	2	23	v27pf22	3.13	2.4	1.74	0.486	0.329
st59	Na2O2	1	2	24	v29pf12	2.25	2.47	1.3	0.817	0.573
Batch 1	Na2O2	1	2	25	bpf123	2.49	2.35	1.94	1.36	0.611
Batch 1	Na2O2	2	1	1	bpf211	2.59	2.5	2.04	1.33	0.554
rc15	Na2O2	2	1	2	v08pf21	1.59	2.91	1.51	0.34	0.212
rc07	Na2O2	2	1	3	v01pf21	2.43	2.67	1.93	0.186	<0.010
rc13	Na2O2	2	1	4	v09pf21	1.71	3	1.93	0.475	0.321
rc24	Na2O2	2	1	5	v15pf11	2.07	2.3	1.35	0.721	0.291
rc08	Na2O2	2	1	6	v10pf21	1.55	2.56	1.52	0.337	0.355
rc22	Na2O2	2	1	7	v31pf21	2.43	2.68	1.55	0.305	0.187
Ustd	Na2O2	2	1	8	upf211	2.14	2.76	1.34	2.07	0.779
rc09	Na2O2	2	1	9	v06pf21	1.59	2.96	1.93	0.552	0.218
rc15	Na2O2	2	1	10	v08pf11	1.59	2.88	1.49	0.332	0.206
rc24	Na2O2	2	1	11	v15pf21	2.06	2.3	1.36	0.719	0.286
rc23	Na2O2	2	1	12	v22pf11	2.08	2.45	1.82	0.495	0.337
rc03	Na2O2	2	1	13	v13pf11	2.4	2.87	1.85	0.379	0.38
rc10	Na2O2	2	1	14	v25pf21	1.75	2.52	1.82	0.558	0.387
Batch 1	Na2O2	2	1	15	bpf212	2.45	2.33	1.98	1.27	0.53
rc16	Na2O2	2	1	16	v34pf21	2.13	2.67	1.74	0.487	0.493
rc16	Na2O2	2	1	17	v34pf11	2.2	2.81	1.79	0.503	0.512
rc22	Na2O2	2	1	18	v31pf11	2.52	2.77	1.62	0.316	0.193
rc09	Na2O2	2	1	19	v06pf11	1.62	3.1	2	0.55	0.221

rc14	Na2O2	2	1	20	v24pf11	2.64	2.55	1.86	0.328	0.343
rc10	Na2O2	2	1	21	v25pf11	1.77	2.59	1.85	0.566	0.397
Ustd	Na2O2	2	1	22	upf212	2.04	2.7	1.31	2.01	0.758
rc07	Na2O2	2	1	23	v01pf11	2.48	2.68	1.98	0.186	<0.010
rc13	Na2O2	2	1	24	v09pf11	1.77	3.15	2.01	0.488	0.329
rc08	Na2O2	2	1	25	v10pf11	1.63	2.67	1.57	0.344	0.368
rc14	Na2O2	2	1	26	v24pf21	2.9	2.77	2.04	0.362	0.381
rc23	Na2O2	2	1	27	v22pf21	2.34	2.81	2.06	0.556	0.382
rc03	Na2O2	2	1	28	v13pf21	2.51	3.04	1.94	0.394	0.39
Batch 1	Na2O2	2	1	29	bpf213	2.59	2.45	2.03	1.29	0.524
Batch 1	Na2O2	2	2	1	bpf221	2.57	2.47	2.01	1.34	0.547
rc14	Na2O2	2	2	2	v24pf12	2.58	2.41	1.8	0.319	0.327
rc24	Na2O2	2	2	3	v15pf22	2.02	2.26	1.34	0.716	0.277

Table E2. SRTC-ML Elemental Concentration Measurements (wt%) for Samples Prepared Using Peroxide Fusion (Na_2O_2) - continued

Glass ID	Prep Method	Block	ICP Calibration	Analytical Sequence	Sample ID	Al	B	Li	Mn	Ni
rc23	Na2O2	2	2	4	v22pf12	2.05	2.43	1.8	0.493	0.323
rc13	Na2O2	2	2	5	v09pf22	1.65	2.86	1.88	0.465	0.305
rc22	Na2O2	2	2	6	v31pf22	2.23	2.41	1.42	0.277	0.16
rc16	Na2O2	2	2	7	v34pf22	2.09	2.63	1.71	0.487	0.481
Ustd	Na2O2	2	2	8	upf221	2.08	2.77	1.33	2.11	0.762
rc10	Na2O2	2	2	9	v25pf22	1.7	2.43	1.78	0.555	0.375
rc03	Na2O2	2	2	10	v13pf22	2.45	2.99	1.87	0.385	0.376
rc10	Na2O2	2	2	11	v25pf12	1.7	2.39	1.77	0.558	0.37
rc07	Na2O2	2	2	12	v01pf12	2.55	2.77	2.02	0.192	<0.010
rc24	Na2O2	2	2	13	v15pf12	2	2.29	1.32	0.705	0.274
rc22	Na2O2	2	2	14	v31pf12	2.63	2.85	1.64	0.325	0.183
Batch 1	Na2O2	2	2	15	bpf222	2.56	2.48	2.02	1.33	0.528
rc07	Na2O2	2	2	16	v01pf22	2.46	2.69	1.94	0.184	<0.010
rc13	Na2O2	2	2	17	v09pf12	1.82	3.36	2.09	0.514	0.338
rc09	Na2O2	2	2	18	v06pf12	1.67	3.23	2.05	0.568	0.214
rc08	Na2O2	2	2	19	v10pf12	1.68	2.82	1.61	0.358	0.371
rc03	Na2O2	2	2	20	v13pf12	2.59	3.2	1.98	0.407	0.397
rc15	Na2O2	2	2	21	v08pf22	1.62	3.02	1.52	0.344	0.235
Ustd	Na2O2	2	2	22	upf222	1.96	2.64	1.24	2.01	0.736
rc08	Na2O2	2	2	23	v10pf22	1.55	2.63	1.5	0.338	0.347
rc23	Na2O2	2	2	24	v22pf22	2.08	2.51	1.81	0.513	0.342
rc16	Na2O2	2	2	25	v34pf12	2.16	2.71	1.75	0.511	0.505
rc09	Na2O2	2	2	26	v06pf22	1.54	2.94	1.87	0.547	0.204
rc14	Na2O2	2	2	27	v24pf22	2.74	2.65	1.87	0.339	0.348
rc15	Na2O2	2	2	28	v08pf12	1.65	3.04	1.54	0.346	0.201
Batch 1	Na2O2	2	2	29	bpf223	2.59	2.49	2.01	1.35	0.545
Batch 1	Na2O2	3	1	1	bpf311	2.54	2.42	2.03	1.28	0.551
rc18	Na2O2	3	1	2	v26pf21	2.08	2.73	2.01	0.299	0.217
rc11	Na2O2	3	1	3	v16pf11	2.73	2.74	1.57	0.507	0.22
rc19	Na2O2	3	1	4	v17pf21	2.08	2.53	1.85	0.361	0.258
rc18	Na2O2	3	1	5	v26pf11	2.06	2.71	1.98	0.302	0.218
rc06	Na2O2	3	1	6	v02pf11	1.6	2.98	1.58	0.169	<0.010
rc01	Na2O2	3	1	7	v28pf11	2.03	2.62	1.92	0.168	<0.010
Ustd	Na2O2	3	1	8	upf311	2.13	2.81	1.36	2.11	0.792
rc17	Na2O2	3	1	9	v30pf11	2.14	3.05	1.97	0.466	0.205
rc20	Na2O2	3	1	10	v14pf11	2.63	2.47	1.82	0.507	0.205
rc02	Na2O2	3	1	11	v20pf11	2.24	2.48	1.47	0.397	0.441
rc05	Na2O2	3	1	12	v11pf21	2.23	2.47	1.46	0.622	0.44
rc04	Na2O2	3	1	13	v05pf11	2.15	2.36	1.4	0.733	0.309
rc01	Na2O2	3	1	14	v28pf21	2.04	2.58	1.92	0.165	<0.010
Batch 1	Na2O2	3	1	15	bpf312	2.52	2.38	2.01	1.26	0.544
rc11	Na2O2	3	1	16	v16pf21	2.72	2.75	1.56	0.511	0.219
rc12	Na2O2	3	1	17	v32pf21	2.76	3.04	1.61	0.529	0.387
rc17	Na2O2	3	1	18	v30pf21	2.14	3.08	1.98	0.464	0.201
rc06	Na2O2	3	1	19	v02pf21	1.59	3.02	1.59	0.168	<0.010
rc20	Na2O2	3	1	20	v14pf21	2.64	2.51	1.84	0.512	0.21
rc21	Na2O2	3	1	21	v04pf11	2.17	2.37	1.73	0.732	0.501
Ustd	Na2O2	3	1	22	upf312	2.12	2.78	1.35	2.11	0.8
rc21	Na2O2	3	1	23	v04pf21	2.2	2.39	1.73	0.738	0.503
rc02	Na2O2	3	1	24	v20pf21	2.22	2.45	1.46	0.391	0.427
rc05	Na2O2	3	1	25	v11pf11	2.26	2.48	1.47	0.61	0.451
rc19	Na2O2	3	1	26	v17pf11	2.15	2.61	1.88	0.367	0.237
rc12	Na2O2	3	1	27	v32pf11	2.74	2.98	1.59	0.51	0.373
rc04	Na2O2	3	1	28	v05pf21	2.17	2.36	1.42	0.732	0.313
Batch 1	Na2O2	3	1	29	bpf313	2.55	2.42	2.03	1.28	0.552
Batch 1	Na2O2	3	2	1	bpf321	2.57	2.43	2.04	1.3	0.568
rc18	Na2O2	3	2	2	v26pf22	2.07	2.69	1.99	0.327	0.223
rc11	Na2O2	3	2	3	v16pf12	2.71	2.77	1.59	0.537	0.224
rc19	Na2O2	3	2	4	v17pf22	2.05	2.47	1.82	0.392	0.264
rc18	Na2O2	3	2	5	v26pf12	2.06	2.7	2	0.333	0.228
rc06	Na2O2	3	2	6	v02pf12	1.59	2.95	1.58	0.199	<0.010
rc01	Na2O2	3	2	7	v28pf12	2.05	2.6	1.94	0.196	<0.010
Ustd	Na2O2	3	2	8	upf321	2.08	2.72	1.34	2.07	0.782
rc17	Na2O2	3	2	9	v30pf12	2.1	3.02	1.95	0.489	0.211
rc20	Na2O2	3	2	10	v14pf12	2.59	2.45	1.82	0.532	0.215
rc02	Na2O2	3	2	11	v20pf12	2.22	2.48	1.48	0.418	0.429
rc05	Na2O2	3	2	12	v11pf22	2.24	2.47	1.48	0.634	0.435
rc04	Na2O2	3	2	13	v05pf12	2.11	2.32	1.4	0.747	0.32
rc01	Na2O2	3	2	14	v28pf22	2.02	2.58	1.91	0.199	<0.010

Batch 1	Na2O2	3	2	15	bpf322	2.52	2.4	2.01	1.3	0.561
rc11	Na2O2	3	2	16	v16pf22	2.7	2.75	1.57	0.541	0.228
rc12	Na2O2	3	2	17	v32pf22	2.78	3.01	1.61	0.555	0.387
rc17	Na2O2	3	2	18	v30pf22	2.1	2.99	1.94	0.489	0.206
rc06	Na2O2	3	2	19	v02pf22	1.62	3.02	1.59	0.2	<0.010
rc20	Na2O2	3	2	20	v14pf22	2.59	2.5	1.83	0.542	0.221
rc21	Na2O2	3	2	21	v04pf12	2.14	2.32	1.72	0.748	0.504
Ustd	Na2O2	3	2	22	upf322	2.08	2.72	1.34	2.08	0.785
rc21	Na2O2	3	2	23	v04pf22	2.2	2.41	1.75	0.763	0.508
rc02	Na2O2	3	2	24	v20pf22	2.22	2.46	1.47	0.416	0.434
rc05	Na2O2	3	2	25	v11pf12	2.22	2.42	1.45	0.624	0.443
rc19	Na2O2	3	2	26	v17pf12	2.1	2.53	1.85	0.396	0.243
rc12	Na2O2	3	2	27	v32pf12	2.68	2.91	1.57	0.539	0.378
rc04	Na2O2	3	2	28	v05pf22	2.13	2.37	1.42	0.755	0.319
Batch 1	Na2O2	3	2	29	bpf323	2.57	2.44	2.04	1.31	0.561

Table E3: Composition Comparisons for Al_2O_3, B_2O_3, CaO, and Cr_2O_3 by Glass ID

Glass ID	Al2O3 (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	B2O3 (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	4.877	4.683	4.877	-4.0%	0.0%	7.777	7.588	7.777	-2.4%	0.0%
Ustd	4.100	3.940	4.103	-3.9%	0.1%	9.209	8.734	8.956	-5.2%	-2.7%
rc01	4.070	3.845	3.900	-5.5%	-4.2%	9.000	8.356	8.357	-7.2%	-7.1%
rc02	4.250	4.204	4.264	-1.1%	0.3%	8.330	7.945	7.946	-4.6%	-4.6%
rc03	4.620	4.700	4.742	1.7%	2.6%	9.690	9.740	9.588	0.5%	-1.1%
rc04	4.130	4.044	4.101	-2.1%	-0.7%	7.880	7.575	7.576	-3.9%	-3.9%
rc05	4.260	4.228	4.288	-0.8%	0.6%	8.330	7.921	7.922	-4.9%	-4.9%
rc06	3.070	3.023	3.066	-1.5%	-0.1%	10.200	9.636	9.637	-5.5%	-5.5%
rc07	4.760	4.686	4.728	-1.6%	-0.7%	9.000	8.702	8.567	-3.3%	-4.8%
rc08	3.030	3.028	3.055	-0.1%	0.8%	8.780	8.597	8.463	-2.1%	-3.6%
rc09	3.030	3.033	3.060	0.1%	1.0%	9.950	9.845	9.692	-1.1%	-2.6%
rc10	3.310	3.269	3.298	-1.2%	-0.4%	8.550	7.993	7.873	-6.5%	-7.9%
rc11	5.190	5.130	5.203	-1.2%	0.2%	9.950	8.863	8.864	-10.9%	-10.9%
rc12	5.190	5.177	5.251	-0.2%	1.2%	9.950	9.611	9.613	-3.4%	-3.4%
rc13	3.190	3.283	3.312	2.9%	3.8%	10.200	9.958	9.804	-2.4%	-3.9%
rc14	5.190	5.130	5.176	-1.2%	-0.3%	8.780	8.356	8.229	-4.8%	-6.3%
rc15	3.030	3.047	3.074	0.6%	1.4%	9.950	9.539	9.390	-4.1%	-5.6%
rc16	4.130	4.053	4.089	-1.9%	-1.0%	8.930	8.710	8.577	-2.5%	-4.0%
rc17	4.100	4.006	4.063	-2.3%	-0.9%	10.200	9.772	9.774	-4.2%	-4.2%
rc18	4.000	3.907	3.962	-2.3%	-1.0%	9.000	8.718	8.719	-3.1%	-3.1%
rc19	4.020	3.959	4.015	-1.5%	-0.1%	8.550	8.162	8.164	-4.5%	-4.5%
rc20	5.190	4.936	5.006	-4.9%	-3.5%	8.780	7.993	7.995	-9.0%	-8.9%
rc21	4.130	4.114	4.173	-0.4%	1.0%	7.880	7.639	7.640	-3.1%	-3.0%
rc22	5.190	4.634	4.676	-10.7%	-9.9%	9.950	8.621	8.490	-13.4%	-14.7%
rc23	4.230	4.039	4.076	-4.5%	-3.6%	8.820	8.211	8.087	-6.9%	-8.3%
rc24	4.130	3.850	3.885	-6.8%	-5.9%	7.880	7.366	7.253	-6.5%	-8.0%

Glass ID	CaO (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	Cr2O3 (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	1.220	1.224	1.220	0.3%	0.0%	0.107	0.097	0.107	-9.6%	-0.3%
Ustd	1.301	1.428	1.423	9.7%	9.4%	0.000	0.237	0.262	N/A	N/A
rc01	0.71	0.692	0.691	-2.6%	-2.6%	0.000	0.007	0.008	N/A	N/A
rc02	0.75	0.741	0.740	-1.3%	-1.3%	0.000	0.007	0.008	N/A	N/A
rc03	0.69	0.679	0.687	-1.6%	-0.4%	0.000	0.007	0.008	N/A	N/A
rc04	0.9	0.888	0.900	-1.3%	-0.1%	0.000	0.007	0.008	N/A	N/A
rc05	0.75	0.742	0.752	-1.0%	0.2%	0.000	0.007	0.008	N/A	N/A
rc06	1.86	1.808	1.831	-2.8%	-1.6%	0.000	0.007	0.008	N/A	N/A
rc07	0.71	0.717	0.717	1.0%	1.0%	0.000	0.007	0.008	N/A	N/A
rc08	0.63	0.646	0.645	2.5%	2.5%	0.000	0.007	0.008	N/A	N/A
rc09	0.63	0.663	0.663	5.2%	5.2%	0.000	0.007	0.008	N/A	N/A
rc10	1.79	1.721	1.720	-3.9%	-3.9%	0.000	0.007	0.008	N/A	N/A
rc11	1.72	1.641	1.661	-4.6%	-3.4%	0.000	0.007	0.008	N/A	N/A
rc12	0.63	0.609	0.616	-3.4%	-2.2%	0.000	0.007	0.008	N/A	N/A
rc13	0.57	0.562	0.569	-1.4%	-0.2%	0.000	0.007	0.008	N/A	N/A
rc14	1.72	1.630	1.629	-5.2%	-5.3%	0.000	0.007	0.008	N/A	N/A
rc15	0.63	0.616	0.616	-2.2%	-2.2%	0.000	0.007	0.008	N/A	N/A
rc16	0.86	0.858	0.858	-0.2%	-0.3%	0.000	0.007	0.008	N/A	N/A
rc17	0.57	0.555	0.562	-2.5%	-1.3%	0.000	0.007	0.008	N/A	N/A
rc18	1.65	1.630	1.629	-1.2%	-1.2%	0.000	0.007	0.008	N/A	N/A
rc19	0.69	0.682	0.682	-1.1%	-1.2%	0.000	0.007	0.008	N/A	N/A
rc20	0.63	0.677	0.685	7.4%	8.7%	0.000	0.007	0.008	N/A	N/A
rc21	0.86	0.853	0.864	-0.8%	0.4%	0.000	0.007	0.008	N/A	N/A
rc22	0.63	0.567	0.574	-9.9%	-8.8%	0.000	0.007	0.008	N/A	N/A
rc23	1.72	1.683	1.703	-2.2%	-1.0%	0.000	0.007	0.008	N/A	N/A
rc24	0.86	0.853	0.853	-0.8%	-0.8%	0.000	0.007	0.008	N/A	N/A

Table E4: Composition Comparisons for Fe_2O_3, Li_2O, MgO, and MnO by Glass ID

Glass ID	Fe2O3 (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	Li2O (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	12.839	13.075	12.839	1.8%	0.0%	4.429	4.256	4.429	-3.9%	0.0%
Ustd	13.196	13.157	12.921	-0.3%	-2.1%	3.057	2.869	2.985	-6.2%	-2.3%
rc01	8.350	8.285	8.319	-0.8%	-0.4%	4.400	4.139	4.202	-5.9%	-4.5%
rc02	9.200	9.089	9.127	-1.2%	-0.8%	3.330	3.165	3.213	-5.0%	-3.5%
rc03	8.490	8.639	8.531	1.8%	0.5%	4.180	4.112	4.198	-1.6%	0.4%
rc04	10.610	10.819	10.684	2.0%	0.7%	3.150	3.036	3.082	-3.6%	-2.2%
rc05	9.200	9.261	9.146	0.7%	-0.6%	3.330	3.154	3.202	-5.3%	-3.9%
rc06	8.350	8.475	8.369	1.5%	0.2%	3.600	3.412	3.464	-5.2%	-3.8%
rc07	8.350	8.367	8.402	0.2%	0.6%	4.400	4.236	4.324	-3.7%	-1.7%
rc08	7.780	7.710	7.742	-0.9%	-0.5%	3.510	3.337	3.407	-4.9%	-2.9%
rc09	7.780	7.953	7.986	2.2%	2.6%	4.290	4.225	4.313	-1.5%	0.5%
rc10	8.490	8.253	8.287	-2.8%	-2.4%	4.180	3.886	3.967	-7.0%	-5.1%
rc11	7.780	7.810	7.712	0.4%	-0.9%	3.510	3.385	3.437	-3.5%	-2.1%
rc12	7.780	7.870	7.772	1.2%	-0.1%	3.510	3.434	3.486	-2.2%	-0.7%
rc13	10.000	10.008	9.883	0.1%	-1.2%	4.400	4.257	4.346	-3.2%	-1.2%
rc14	7.780	7.509	7.541	-3.5%	-3.1%	4.290	4.074	4.159	-5.0%	-3.0%
rc15	10.990	10.787	10.832	-1.8%	-1.4%	3.510	3.262	3.330	-7.1%	-5.1%
rc16	10.610	10.569	10.613	-0.4%	0.0%	3.850	3.762	3.841	-2.3%	-0.2%
rc17	7.070	7.206	7.116	1.9%	0.6%	4.400	4.220	4.284	-4.1%	-2.6%
rc18	7.070	7.020	7.049	-0.7%	-0.3%	4.400	4.295	4.360	-2.4%	-0.9%
rc19	8.490	8.217	8.251	-3.2%	-2.8%	4.180	3.983	4.043	-4.7%	-3.3%
rc20	7.780	7.942	7.843	2.1%	0.8%	4.290	3.934	3.994	-8.3%	-6.9%
rc21	10.610	10.655	10.522	0.4%	-0.8%	3.850	3.730	3.786	-3.1%	-1.7%
rc22	7.780	7.231	7.141	-7.1%	-8.2%	3.870	3.353	3.423	-13.4%	-11.5%
rc23	7.970	8.271	8.168	3.8%	2.5%	4.290	4.031	4.115	-6.0%	-4.1%
rc24	10.610	10.548	10.591	-0.6%	-0.2%	3.150	2.890	2.951	-8.2%	-6.3%

Glass ID	MgO (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	MnO (wt%) Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	1.419	1.398	1.419	-1.5%	0.0%	1.726	1.728	1.726	0.1%	0.0%
Ustd	1.210	1.157	1.174	-4.4%	-2.9%	2.892	2.741	2.738	-5.2%	-5.3%
rc01	1.440	1.369	1.362	-4.9%	-5.4%	0.300	0.235	0.244	-21.7%	-18.8%
rc02	1.340	1.260	1.253	-6.0%	-6.5%	0.580	0.524	0.543	-9.7%	-6.4%
rc03	1.780	1.828	1.813	2.7%	1.8%	0.540	0.505	0.512	-6.4%	-5.1%
rc04	1.660	1.676	1.661	0.9%	0.1%	0.990	0.958	0.994	-3.3%	0.4%
rc05	1.740	1.675	1.661	-3.8%	-4.6%	0.860	0.804	0.834	-6.5%	-3.0%
rc06	1.870	1.849	1.833	-1.1%	-2.0%	0.300	0.238	0.246	-20.8%	-17.9%
rc07	1.870	2.027	2.016	8.4%	7.8%	0.300	0.241	0.245	-19.5%	-18.4%
rc08	1.820	1.686	1.677	-7.3%	-7.8%	0.490	0.444	0.451	-9.3%	-8.0%
rc09	1.400	1.367	1.359	-2.4%	-2.9%	0.730	0.716	0.726	-2.0%	-0.6%
rc10	1.370	1.310	1.303	-4.4%	-4.9%	0.790	0.722	0.733	-8.6%	-7.3%
rc11	1.820	1.766	1.751	-3.0%	-3.8%	0.730	0.677	0.702	-7.3%	-3.9%
rc12	1.400	1.358	1.347	-3.0%	-3.8%	0.730	0.689	0.714	-5.7%	-2.2%
rc13	1.860	1.787	1.772	-3.9%	-4.8%	0.660	0.627	0.636	-5.0%	-3.7%
rc14	1.400	1.330	1.323	-5.0%	-5.5%	0.490	0.435	0.442	-11.2%	-9.9%
rc15	1.400	1.332	1.325	-4.8%	-5.3%	0.490	0.440	0.446	-10.3%	-9.0%
rc16	1.660	1.733	1.723	4.4%	3.8%	0.670	0.642	0.651	-4.2%	-2.8%
rc17	1.430	1.440	1.428	0.7%	-0.2%	0.660	0.616	0.639	-6.7%	-3.2%
rc18	1.860	1.787	1.778	-3.9%	-4.4%	0.450	0.407	0.422	-9.5%	-6.2%
rc19	1.370	1.312	1.305	-4.2%	-4.7%	0.540	0.489	0.508	-9.4%	-6.0%
rc20	1.820	1.737	1.722	-4.6%	-5.4%	0.730	0.676	0.701	-7.4%	-4.0%
rc21	1.660	1.652	1.638	-0.5%	-1.3%	0.990	0.962	0.998	-2.8%	0.8%
rc22	1.400	1.280	1.269	-8.6%	-9.3%	0.490	0.395	0.401	-19.4%	-18.3%
rc23	1.370	1.409	1.397	2.8%	2.0%	0.730	0.664	0.674	-9.0%	-7.7%
rc24	1.660	1.609	1.601	-3.1%	-3.6%	0.990	0.924	0.937	-6.7%	-5.4%

Table E5: Composition Comparisons for Na_2O, NiO, SiO_2, and U_3O_8 by Glass ID

	Na2O (wt%)					NiO (wt%)				
Glass ID	Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	9.003	8.883	9.003	-1.3%	0.0%	0.751	0.740	0.751	-1.4%	0.0%
Ustd	11.795	10.969	11.118	-7.0%	-5.7%	1.120	1.030	1.046	-8.0%	-6.6%
rc01	15.110	14.188	14.382	-6.1%	-4.8%	0.000	0.006	0.007	N/A	N/A
rc02	16.200	15.536	15.748	-4.1%	-2.8%	0.610	0.551	0.584	-9.7%	-4.2%
rc03	15.840	15.569	15.591	-1.7%	-1.6%	0.560	0.491	0.539	-12.3%	-3.8%
rc04	16.920	16.243	16.266	-4.0%	-3.9%	0.430	0.401	0.426	-6.7%	-1.0%
rc05	16.200	15.704	15.728	-3.1%	-2.9%	0.610	0.563	0.597	-7.7%	-2.1%
rc06	15.110	14.794	14.816	-2.1%	-1.9%	0.000	0.006	0.007	N/A	N/A
rc07	11.560	11.360	11.516	-1.7%	-0.4%	0.000	0.006	0.007	N/A	N/A
rc08	13.610	13.092	13.272	-3.8%	-2.5%	0.510	0.458	0.503	-10.1%	-1.4%
rc09	14.370	14.053	14.245	-2.2%	-0.9%	0.320	0.273	0.299	-14.8%	-6.5%
rc10	14.990	14.356	14.553	-4.2%	-2.9%	0.560	0.486	0.534	-13.1%	-4.7%
rc11	10.140	9.810	9.824	-3.3%	-3.1%	0.320	0.283	0.301	-11.4%	-6.0%
rc12	15.410	15.199	15.220	-1.4%	-1.2%	0.510	0.485	0.515	-4.9%	0.9%
rc13	10.180	9.968	9.983	-2.1%	-1.9%	0.470	0.411	0.451	-12.5%	-4.0%
rc14	10.140	9.473	9.604	-6.6%	-5.3%	0.510	0.445	0.488	-12.7%	-4.2%
rc15	10.140	9.699	9.832	-4.4%	-3.0%	0.320	0.272	0.298	-15.1%	-6.9%
rc16	15.260	14.727	14.929	-3.5%	-2.2%	0.700	0.633	0.695	-9.5%	-0.7%
rc17	15.110	14.794	14.815	-2.1%	-1.9%	0.290	0.262	0.278	-9.7%	-4.2%
rc18	15.110	14.356	14.551	-5.0%	-3.7%	0.290	0.282	0.299	-2.8%	3.1%
rc19	15.840	15.064	15.269	-4.9%	-3.6%	0.350	0.319	0.338	-8.9%	-3.4%
rc20	15.480	14.356	14.376	-7.3%	-7.1%	0.320	0.271	0.287	-15.4%	-10.3%
rc21	15.990	15.502	15.525	-3.1%	-2.9%	0.700	0.641	0.680	-8.4%	-2.8%
rc22	15.480	16.311	16.321	5.4%	5.4%	0.320	0.230	0.252	-28.1%	-21.1%
rc23	15.480	15.098	15.120	-2.5%	-2.3%	0.510	0.440	0.483	-13.7%	-5.3%
rc24	14.510	14.019	14.211	-3.4%	-2.1%	0.430	0.359	0.394	-16.5%	-8.4%

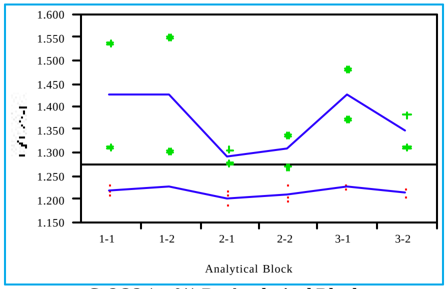
	SiO2 (wt%)					U3O8 (wt%)				
Glass ID	Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)	Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	50.220	50.381	50.220	0.3%	0.0%	0.000	0.057	0.062	N/A	N/A
Ustd	45.353	45.318	45.451	-0.1%	0.2%	2.406	2.202	2.407	-8.5%	0.0%
rc01	55.270	53.589	54.263	-3.0%	-1.8%	1.350	1.144	1.252	-15.3%	-7.3%
rc02	51.130	49.097	49.714	-4.0%	-2.8%	4.280	4.018	4.398	-6.1%	2.8%
rc03	52.510	51.611	51.592	-1.7%	-1.7%	1.100	1.016	1.109	-7.6%	0.8%
rc04	48.390	47.920	47.903	-1.0%	-1.0%	4.940	4.443	4.848	-10.1%	-1.9%
rc05	53.530	52.734	52.715	-1.5%	-1.5%	1.190	1.090	1.190	-8.4%	0.0%
rc06	55.270	54.766	54.746	-0.9%	-0.9%	0.370	0.360	0.393	-2.7%	6.2%
rc07	57.700	56.050	56.755	-2.9%	-1.6%	1.350	1.177	1.289	-12.8%	-4.5%
rc08	56.220	54.659	55.347	-2.8%	-1.6%	3.620	3.210	3.514	-11.3%	-2.9%
rc09	53.880	52.894	53.559	-1.8%	-0.6%	3.620	2.106	2.305	-41.8%	-36.3%
rc10	54.870	53.643	54.318	-2.2%	-1.0%	1.100	1.063	1.164	-3.3%	5.8%
rc11	55.220	54.820	54.799	-0.7%	-0.8%	3.620	3.010	3.284	-16.9%	-9.3%
rc12	53.880	53.857	53.837	0.0%	-0.1%	1.010	0.924	1.008	-8.5%	-0.2%
rc13	57.560	57.012	56.991	-1.0%	-1.0%	0.910	0.838	0.915	-7.9%	0.5%
rc14	56.080	54.713	55.402	-2.4%	-1.2%	3.620	3.128	3.424	-13.6%	-5.4%
rc15	55.920	53.215	53.885	-4.8%	-3.6%	3.620	3.390	3.711	-6.3%	2.5%
rc16	48.390	47.279	47.873	-2.3%	-1.1%	4.940	4.404	4.821	-10.8%	-2.4%
rc17	55.260	54.606	54.585	-1.2%	-1.2%	0.910	0.887	0.968	-2.6%	6.3%
rc18	55.260	53.483	54.155	-3.2%	-2.0%	0.910	0.789	0.864	-13.2%	-5.0%
rc19	54.870	52.841	53.505	-3.7%	-2.5%	1.100	1.022	1.119	-7.1%	1.7%
rc20	53.880	54.071	54.052	0.4%	0.3%	1.100	0.900	0.982	-18.2%	-10.7%
rc21	48.390	47.599	47.582	-1.6%	-1.7%	4.940	4.593	5.012	-7.0%	1.5%
rc22	53.880	56.691	56.670	5.2%	5.2%	1.010	0.846	0.923	-16.3%	-8.6%
rc23	53.880	52.627	52.607	-2.3%	-2.4%	1.010	0.927	1.012	-8.2%	0.2%
rc24	50.840	49.418	50.039	-2.8%	-1.6%	4.940	4.416	4.834	-10.6%	-2.1%

Table E6: Composition Comparisons for Sum of Oxides by Glass ID

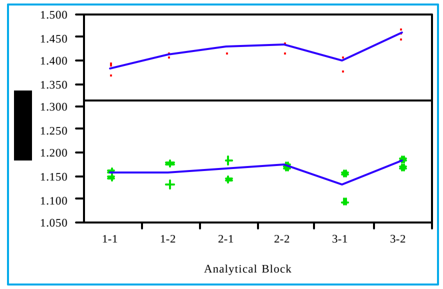
	Sum of Oxides (wt%)				
Glass ID	Target	Measured	Measured Bias-Corrected (bc)	% Relative Difference Measured	% Relative Difference Measured (bc)
Batch 1	94.368	94.109	94.431	-0.3%	0.1%
Ustd	95.639	93.976	94.503	-1.7%	-1.2%
rc01	100.000	95.855	96.985	-4.1%	-3.0%
rc02	100.000	96.136	97.539	-3.9%	-2.5%
rc03	100.000	98.898	98.911	-1.1%	-1.1%
rc04	100.000	98.010	98.448	-2.0%	-1.6%
rc05	100.000	97.883	98.041	-2.1%	-2.0%
rc06	100.000	98.374	98.417	-1.6%	-1.6%
rc07	100.000	97.578	98.575	-2.4%	-1.4%
rc08	100.000	96.876	98.084	-3.1%	-1.9%
rc09	100.000	97.134	98.215	-2.9%	-1.8%
rc10	100.000	96.711	97.758	-3.3%	-2.2%
rc11	100.000	97.201	97.546	-2.8%	-2.5%
rc12	100.000	99.220	99.388	-0.8%	-0.6%
rc13	100.000	98.719	98.670	-1.3%	-1.3%
rc14	100.000	96.230	97.425	-3.8%	-2.6%
rc15	100.000	95.606	96.746	-4.4%	-3.3%
rc16	100.000	97.377	98.678	-2.6%	-1.3%
rc17	100.000	98.370	98.519	-1.6%	-1.5%
rc18	100.000	96.680	97.797	-3.3%	-2.2%
rc19	100.000	96.057	97.206	-3.9%	-2.8%
rc20	100.000	97.500	97.652	-2.5%	-2.3%
rc21	100.000	97.949	98.429	-2.1%	-1.6%
rc22	100.000	100.167	100.149	0.2%	0.1%
rc23	100.010	97.406	97.450	-2.6%	-2.6%
rc24	100.000	96.258	97.555	-3.7%	-2.4%

Exhibit E1: Batch 1 Measurements by Analytical Block for Al_2O_3 and B_2O_3

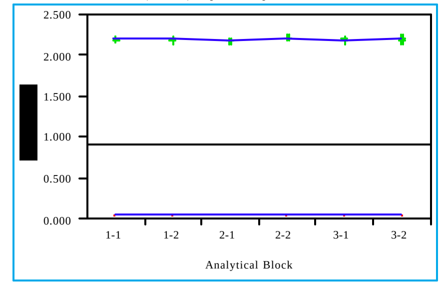
CaO (wt%) By Analytical Block



MgO (wt%) By Analytical Block

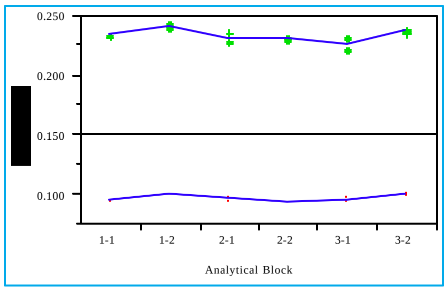


U3O8 (wt%) By Analytical Block

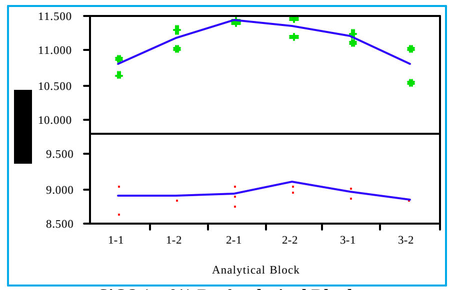


Small Square–Batch 1 and Plus–Ustd

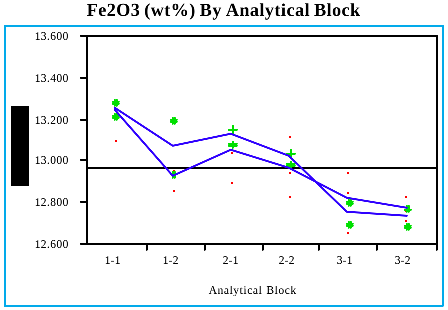
Cr2O3 (wt%) By Analytical Block



Na2O (wt%) By Analytical Block



Fe2O3 (wt%) By Analytical Block



SiO2 (wt%) By Analytical Block

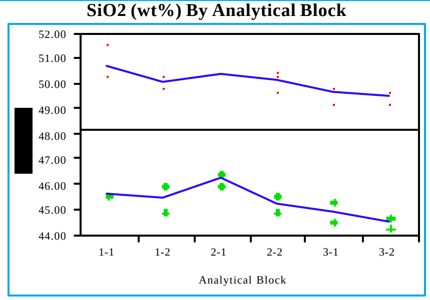
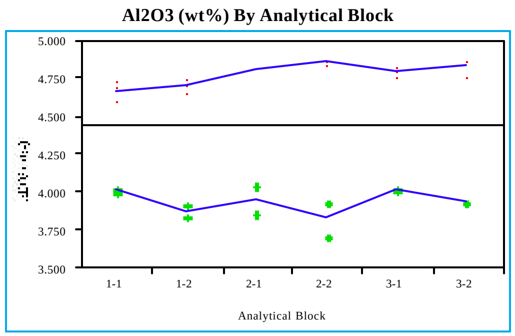
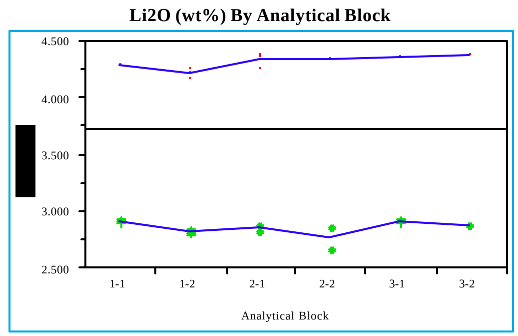
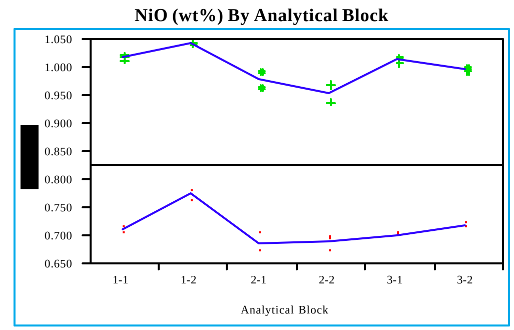
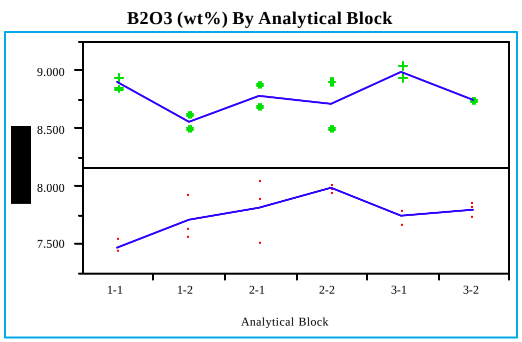


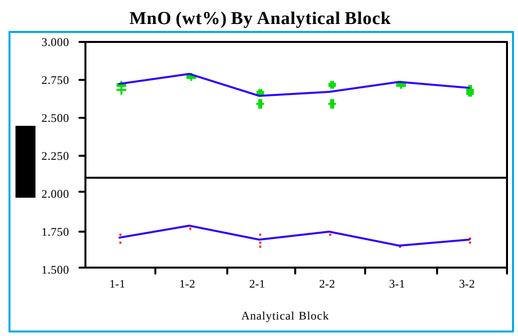
Exhibit E2: Batch 1 and Ustd Measurements by Analytical Block[6] for Al_2O_3, B_2O_3, Li_2O, MnO, and NiO for Samples Prepared Using Na_2O_2











Small Square–Batch 1 and Plus–Ustd

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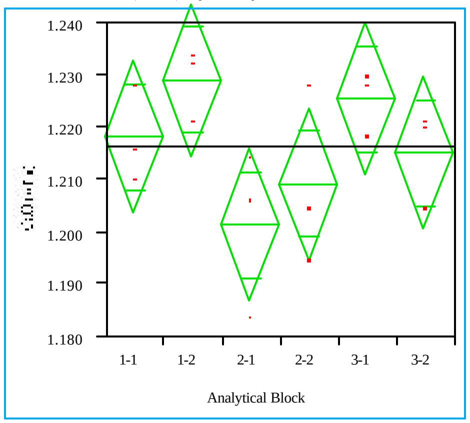
6 Only blocks 2-1 through 3-2 were used to conduct the chemical composition measurements for the 24 RC glasses. The other blocks are being shown as part of these plots for completeness. The additional blocks also help convey the similarity of behaviors of the two standards over the analytical process.

Exhibit E3: Batch 1 Measurements by Analytical Block for CaO, Cr_2O_3, and Fe_2O_3 for Samples Prepared Using $LiBO_2$

CaO (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.496909
RSquare Adj	0.287288
Root Mean Square Error	0.011618
Mean of Response	1.216604
Observations (or Sum Wgts)	18

Analysis of Variance

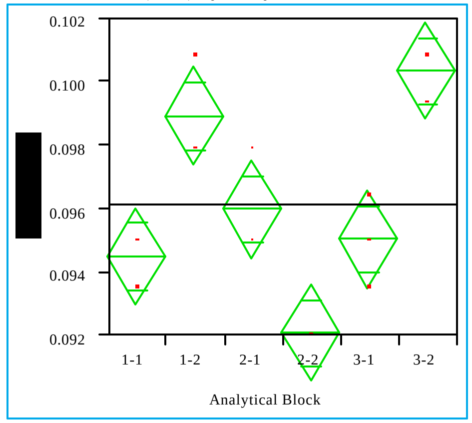
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00159982	0.000320	2.3705
Error	12	0.00161972	0.000135	**Prob>F**
C Total	17	0.00321954	0.000189	0.1024

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	1.21824	0.00671
1-2	3	1.22943	0.00671
2-1	3	1.20145	0.00671
2-2	3	1.20938	0.00671
3-1	3	1.22570	0.00671
3-2	3	1.21544	0.00671

Std Error uses a pooled estimate of error variance

Cr2O3 (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.881459
RSquare Adj	0.832067
Root Mean Square Error	0.001242
Mean of Response	0.096141
Observations (or Sum Wgts)	18

Analysis of Variance

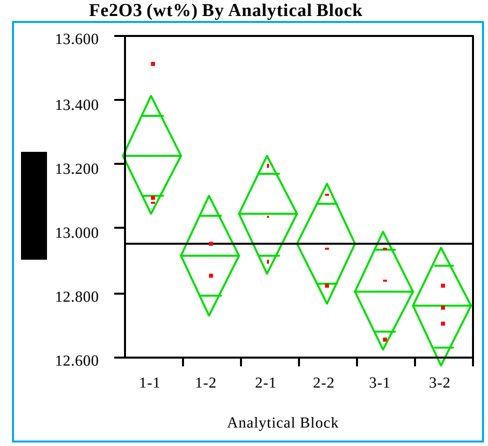
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00013767	0.000028	17.8462
Error	12	0.00001851	0.000002	**Prob>F**
C Total	17	0.00015619	0.000009	<.0001

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	0.094517	0.00072
1-2	3	0.098902	0.00072
2-1	3	0.095978	0.00072
2-2	3	0.092081	0.00072
3-1	3	0.095004	0.00072
3-2	3	0.100363	0.00072

Std Error uses a pooled estimate of error variance

Fe2O3 (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.621219
RSquare Adj	0.463394
Root Mean Square Error	0.147389
Mean of Response	12.95388
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.42753411	0.085507	3.9361
Error	12	0.26068350	0.021724	**Prob>F**
C Total	17	0.68821762	0.040483	0.0241

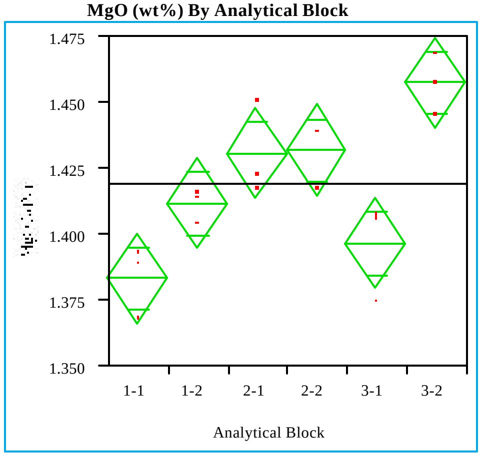
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	13.2295	0.08510
1-2	3	12.9197	0.08510
2-1	3	13.0436	0.08510
2-2	3	12.9578	0.08510
3-1	3	12.8101	0.08510
3-2	3	12.7625	0.08510

Std Error uses a pooled estimate of error variance

Exhibit E4: Batch 1 Measurements by Analytical Block for MgO, Na_2O, and SiO_2 for Samples Prepared Using $LiBO_2$

MgO (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.821576
RSquare Adj	0.747232
Root Mean Square Error	0.014026
Mean of Response	1.418505
Observations (or Sum Wgts)	18

Analysis of Variance

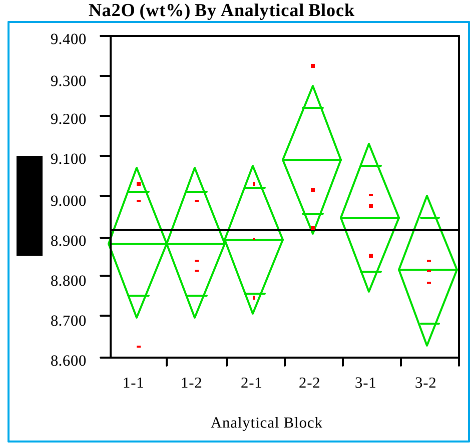
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.01087026	0.002174	11.0511
Error	12	0.00236073	0.000197	**Prob>F**
C Total	17	0.01323099	0.000778	0.0004

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	1.38341	0.00810
1-2	3	1.41160	0.00810
2-1	3	1.43039	0.00810
2-2	3	1.43205	0.00810
3-1	3	1.39612	0.00810
3-2	3	1.45747	0.00810

Std Error uses a pooled estimate of error variance

Na2O (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.335581
RSquare Adj	0.05874
Root Mean Square Error	0.147358
Mean of Response	8.918518
Observations (or Sum Wgts)	18

Analysis of Variance

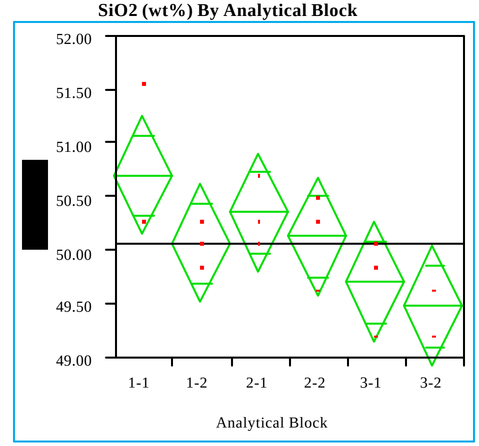
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.13160880	0.026322	1.2122
Error	12	0.26057271	0.021714	**Prob>F**
C Total	17	0.39218152	0.023070	0.3610

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	8.88332	0.08508
1-2	3	8.88332	0.08508
2-1	3	8.89231	0.08508
2-2	3	9.09001	0.08508
3-1	3	8.94623	0.08508
3-2	3	8.81592	0.08508

Std Error uses a pooled estimate of error variance

SiO2 (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.551402
RSquare Adj	0.364486
Root Mean Square Error	0.439584
Mean of Response	50.07151
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	2.8502076	0.570042	2.9500
Error	12	2.3188129	0.193234	**Prob>F**
C Total	17	5.1690205	0.304060	0.0579

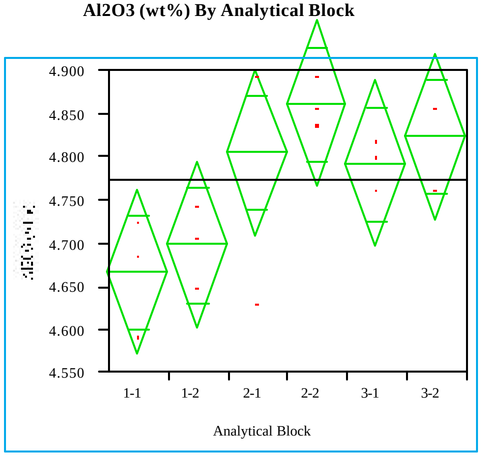
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	50.7014	0.25379
1-2	3	50.0596	0.25379
2-1	3	50.3449	0.25379
2-2	3	50.1309	0.25379
3-1	3	49.7031	0.25379
3-2	3	49.4891	0.25379

Std Error uses a pooled estimate of error variance

Exhibit E5: Batch 1 Measurements by Analytical Block for Al_2O_3, B_2O_3, and Li_2O for Samples Prepared Using Na_2O_2

Al2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.553637
RSquare Adj	0.367653
Root Mean Square Error	0.076233
Mean of Response	4.775186
Observations (or Sum Wgts)	18

Analysis of Variance

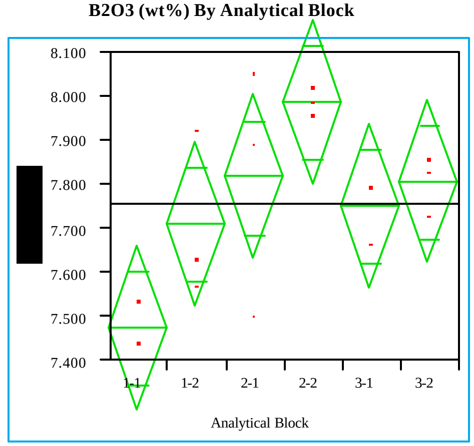
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.08649826	0.017300	2.9768
Error	12	0.06973811	0.005812	**Prob>F**
C Total	17	0.15623637	0.009190	0.0564

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	4.66707	0.04401
1-2	3	4.69856	0.04401
2-1	3	4.80563	0.04401
2-2	3	4.86231	0.04401
3-1	3	4.79303	0.04401
3-2	3	4.82452	0.04401

Std Error uses a pooled estimate of error variance

B2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.623518
RSquare Adj	0.46665
Root Mean Square Error	0.146575
Mean of Response	7.754592
Observations (or Sum Wgts)	18

Analysis of Variance

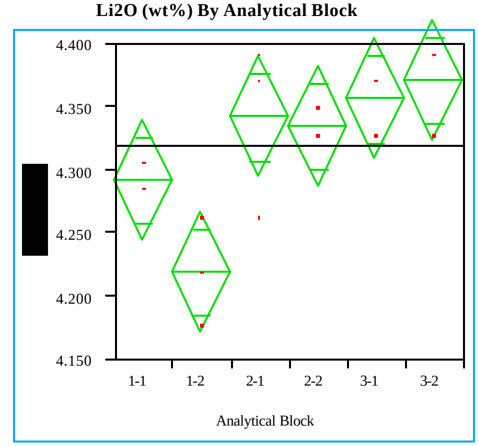
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.42697875	0.085396	3.9748
Error	12	0.25781153	0.021484	**Prob>F**
C Total	17	0.68479028	0.040282	0.0233

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	7.47017	0.08463
1-2	3	7.70629	0.08463
2-1	3	7.81362	0.08463
2-2	3	7.98535	0.08463
3-1	3	7.74923	0.08463
3-2	3	7.80289	0.08463

Std Error uses a pooled estimate of error variance

Li2O (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.72037
RSquare Adj	0.603857
Root Mean Square Error	0.038646
Mean of Response	4.318957
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.04616953	0.009234	6.1828
Error	12	0.01792192	0.001493	**Prob>F**
C Total	17	0.06409145	0.003770	0.0047

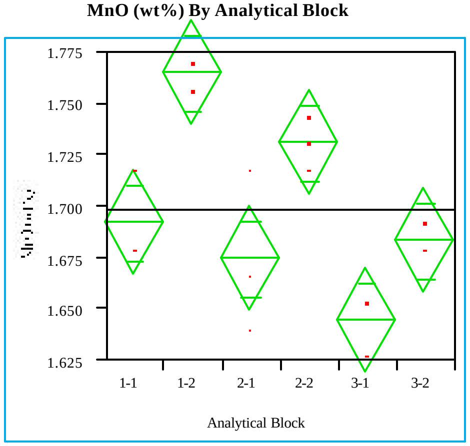
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	4.29145	0.02231
1-2	3	4.21968	0.02231
2-1	3	4.34168	0.02231
2-2	3	4.33451	0.02231
3-1	3	4.35603	0.02231
3-2	3	4.37039	0.02231

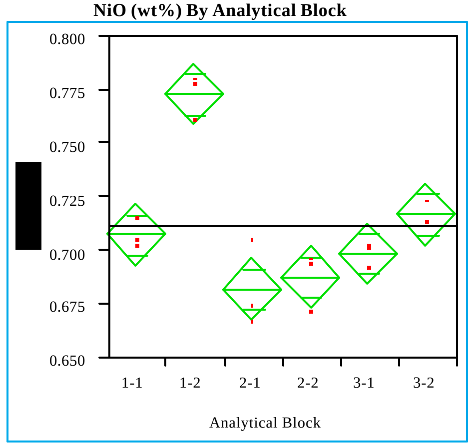
Std Error uses a pooled estimate of error variance

Exhibit E6: Batch 1 Measurements by Analytical Block for MnO and NiO for Samples Prepared Using Na_2O_2

MnO (wt%) By Analytical Block



NiO (wt%) By Analytical Block



MnO

Oneway Anova

Summary of Fit

RSquare	0.843936
RSquare Adj	0.778909
Root Mean Square Error	0.020641
Mean of Response	1.697928
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.02764769	0.005530	12.9783
Error	12	0.00511274	0.000426	**Prob>F**
C Total	17	0.03276043	0.001927	0.0002

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	1.69147	0.01192
1-2	3	1.76464	0.01192
2-1	3	1.67426	0.01192
2-2	3	1.73021	0.01192
3-1	3	1.64413	0.01192
3-2	3	1.68286	0.01192

Std Error uses a pooled estimate of error variance

NiO

Oneway Anova

Summary of Fit

RSquare	0.911113
RSquare Adj	0.874077
Root Mean Square Error	0.011507
Mean of Response	0.710833
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.01628801	0.003258	24.6007
Error	12	0.00158903	0.000132	**Prob>F**
C Total	17	0.01787704	0.001052	<.0001

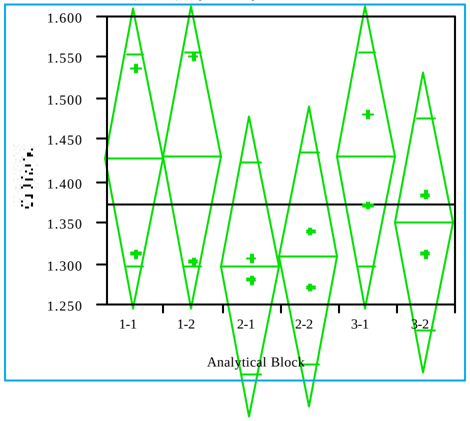
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	3	0.707510	0.00664
1-2	3	0.772832	0.00664
2-1	3	0.682060	0.00664
2-2	3	0.687150	0.00664
3-1	3	0.698602	0.00664
3-2	3	0.716842	0.00664

Std Error uses a pooled estimate of error variance

Exhibit E7: Ustd Measurements by Analytical Block for CaO, Cr_2O_3, and Fe_2O_3 for Samples Prepared Using $LiBO_2$

CaO (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.369898
RSquare Adj	-0.15519
Root Mean Square Error	0.10626
Mean of Response	1.372499
Observations (or Sum Wgts)	12

Analysis of Variance

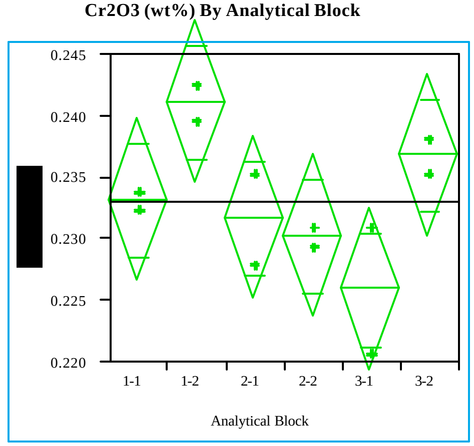
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.03977077	0.007954	0.7045
Error	6	0.06774733	0.011291	**Prob>F**
C Total	11	0.10751809	0.009774	0.6412

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	1.42648	0.07514
1-2	2	1.42858	0.07514
2-1	2	1.29496	0.07514
2-2	2	1.30755	0.07514
3-1	2	1.42788	0.07514
3-2	2	1.34953	0.07514

Std Error uses a pooled estimate of error variance

Cr2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.76
RSquare Adj	0.56
Root Mean Square Error	0.003867
Mean of Response	0.233125
Observations (or Sum Wgts)	12

Analysis of Variance

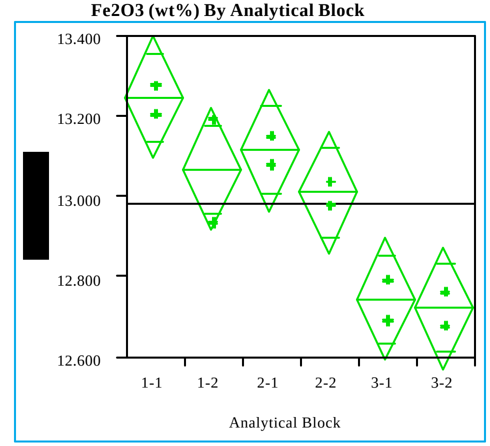
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00028412	0.000057	3.8000
Error	6	0.00008972	0.000015	**Prob>F**
C Total	11	0.00037385	0.000034	0.0674

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	0.233125	0.00273
1-2	2	0.241164	0.00273
2-1	2	0.231664	0.00273
2-2	2	0.230202	0.00273
3-1	2	0.225817	0.00273
3-2	2	0.236779	0.00273

Std Error uses a pooled estimate of error variance

Fe2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.899968
RSquare Adj	0.816609
Root Mean Square Error	0.08995
Mean of Response	12.98525
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.43676069	0.087352	10.7962
Error	6	0.04854600	0.008091	**Prob>F**
C Total	11	0.48530669	0.044119	0.0058

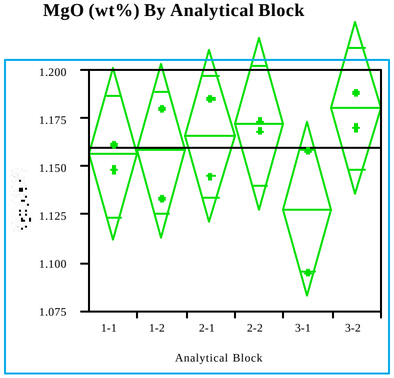
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	13.2462	0.06360
1-2	2	13.0675	0.06360
2-1	2	13.1175	0.06360
2-2	2	13.0103	0.06360
3-1	2	12.7458	0.06360
3-2	2	12.7243	0.06360

Std Error uses a pooled estimate of error variance

Exhibit E8: Ustd Measurements by Analytical Block for MgO, MnO, Na_2O, and NiO for Samples Prepared Using $LiBO_2$

MgO (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.44206
RSquare Adj	-0.02289
Root Mean Square Error	0.026208
Mean of Response	1.159565
Observations (or Sum Wgts)	12

Analysis of Variance

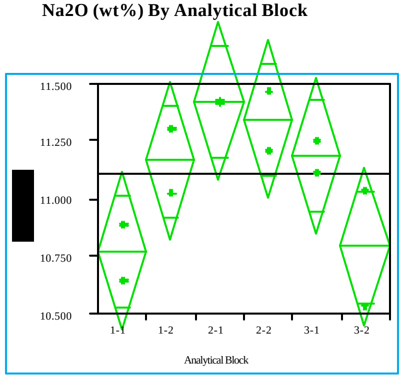
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00326525	0.000653	0.9508
Error	6	0.00412119	0.000687	**Prob>F**
C Total	11	0.00738644	0.000671	0.5119

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	1.15570	0.01853
1-2	2	1.15735	0.01853
2-1	2	1.16564	0.01853
2-2	2	1.17145	0.01853
3-1	2	1.12751	0.01853
3-2	2	1.17974	0.01853

Std Error uses a pooled estimate of error variance

Na2O (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.763095
RSquare Adj	0.565675
Root Mean Square Error	0.198268
Mean of Response	11.11426
Observations (or Sum Wgts)	12

Analysis of Variance

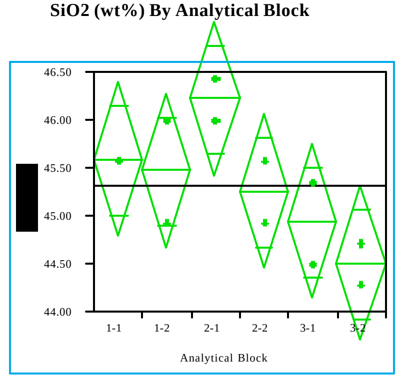
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.75973118	0.151946	3.8653
Error	6	0.23586010	0.039310	**Prob>F**
C Total	11	0.99559128	0.090508	0.0651

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	10.7705	0.14020
1-2	2	11.1682	0.14020
2-1	2	11.4243	0.14020
2-2	2	11.3434	0.14020
3-1	2	11.1884	0.14020
3-2	2	10.7907	0.14020

Std Error uses a pooled estimate of error variance

SiO2 (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.720257
RSquare Adj	0.487138
Root Mean Square Error	0.470322
Mean of Response	45.31751
Observations (or Sum Wgts)	12

Analysis of Variance

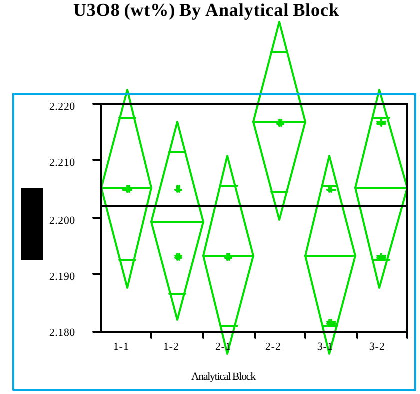
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	3.4171980	0.683440	3.0897
Error	6	1.3272153	0.221203	**Prob>F**
C Total	11	4.7444133	0.431310	0.1011

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	45.5671	0.33257
1-2	2	45.4601	0.33257
2-1	2	46.2089	0.33257
2-2	2	45.2462	0.33257
3-1	2	44.9253	0.33257
3-2	2	44.4974	0.33257

Std Error uses a pooled estimate of error variance

U3O8 (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.560976
RSquare Adj	0.195122
Root Mean Square Error	0.010212
Mean of Response	2.202156
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00079954	0.000160	1.5333
Error	6	0.00062573	0.000104	**Prob>F**
C Total	11	0.00142528	0.000130	0.3069

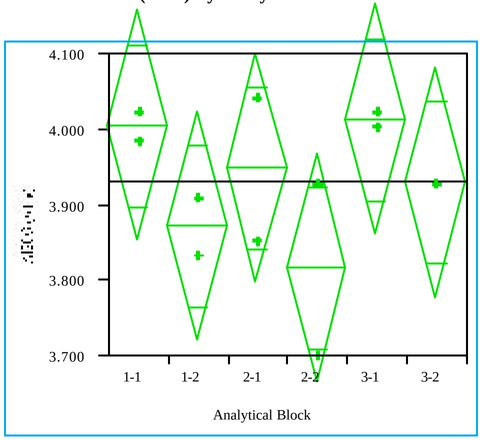
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	2.20510	0.00722
1-2	2	2.19921	0.00722
2-1	2	2.19331	0.00722
2-2	2	2.21690	0.00722
3-1	2	2.19331	0.00722
3-2	2	2.20510	0.00722

Std Error uses a pooled estimate of error variance

Exhibit E9: Ustd Measurements by Analytical Block for Al_2O_3, B_2O_3, and Li_2O for Samples Prepared Using Na_2O_2

Al2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.553747
RSquare Adj	0.181869
Root Mean Square Error	0.088793
Mean of Response	3.931735
Observations (or Sum Wgts)	12

Analysis of Variance

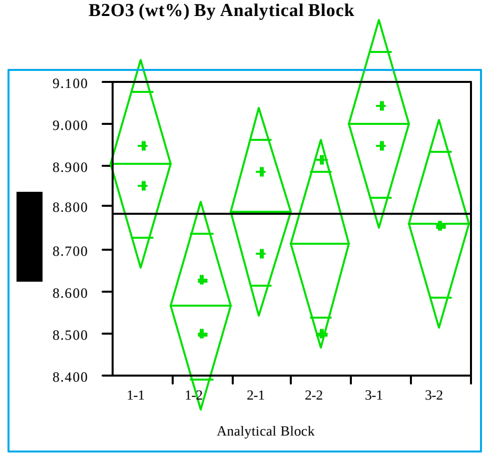
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.05870021	0.011740	1.4891
Error	6	0.04730529	0.007884	**Prob>F**
C Total	11	0.10600549	0.009637	0.3185

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	4.00574	0.06279
1-2	2	3.87348	0.06279
2-1	2	3.94905	0.06279
2-2	2	3.81679	0.06279
3-1	2	4.01519	0.06279
3-2	2	3.93016	0.06279

Std Error uses a pooled estimate of error variance

B2O3 (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.649474
RSquare Adj	0.35737
Root Mean Square Error	0.143698
Mean of Response	8.787644
Observations (or Sum Wgts)	12

Analysis of Variance

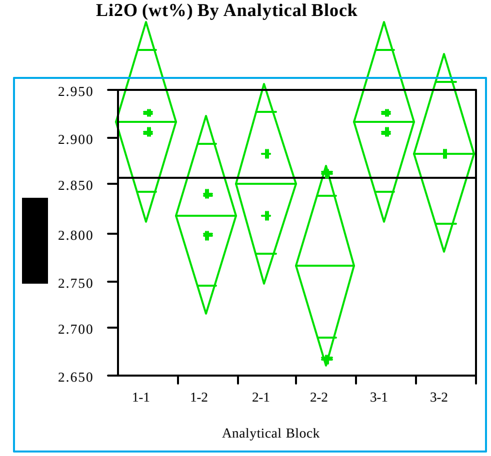
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.22955940	0.045912	2.2234
Error	6	0.12389468	0.020649	**Prob>F**
C Total	11	0.35345408	0.032132	0.1794

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	8.90302	0.10161
1-2	2	8.56493	0.10161
2-1	2	8.79033	0.10161
2-2	2	8.70983	0.10161
3-1	2	8.99962	0.10161
3-2	2	8.75813	0.10161

Std Error uses a pooled estimate of error variance

Li2O (wt%) By Analytical Block



Oneway Anova
Summary of Fit

RSquare	0.61186
RSquare Adj	0.28841
Root Mean Square Error	0.060893
Mean of Response	2.859769
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.03507134	0.007014	1.8917
Error	6	0.02224790	0.003708	**Prob>F**
C Total	11	0.05731923	0.005211	0.2300

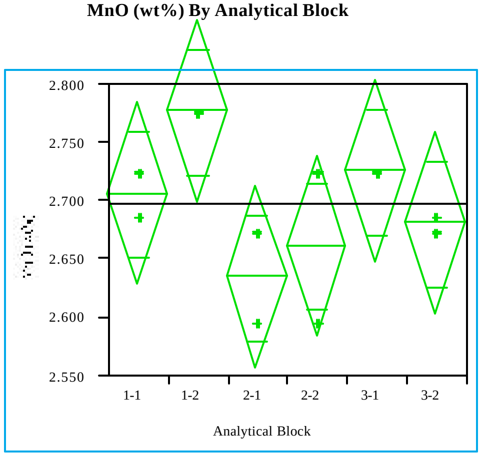
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	2.91718	0.04306
1-2	2	2.82030	0.04306
2-1	2	2.85259	0.04306
2-2	2	2.76648	0.04306
3-1	2	2.91718	0.04306
3-2	2	2.88489	0.04306

Std Error uses a pooled estimate of error variance

Exhibit E10: Ustd Measurements by Analytical Block for MnO and NiO for Samples Prepared Using Na_2O_2

MnO (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.676514
RSquare Adj	0.406942
Root Mean Square Error	0.045038
Mean of Response	2.696456
Observations (or Sum Wgts)	12

Analysis of Variance

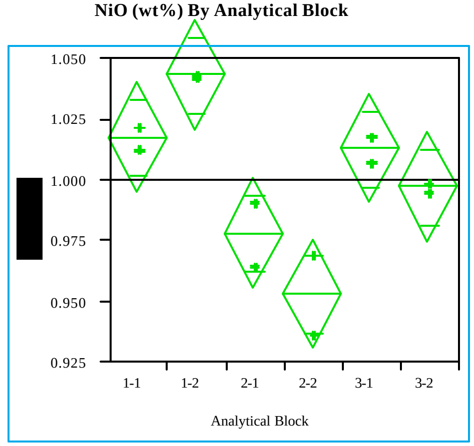
Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.02545255	0.005091	2.5096
Error	6	0.01217054	0.002028	**Prob>F**
C Total	11	0.03762309	0.003420	0.1468

Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	2.70506	0.03185
1-2	2	2.77608	0.03185
2-1	2	2.63405	0.03185
2-2	2	2.65987	0.03185
3-1	2	2.72443	0.03185
3-2	2	2.67924	0.03185

Std Error uses a pooled estimate of error variance

NiO (wt%) By Analytical Block



Oneway Anova

Summary of Fit

RSquare	0.908716
RSquare Adj	0.832646
Root Mean Square Error	0.012935
Mean of Response	1.000185
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	5	0.00999405	0.001999	11.9458
Error	6	0.00100394	0.000167	**Prob>F**
C Total	11	0.01099799	0.001000	0.0045

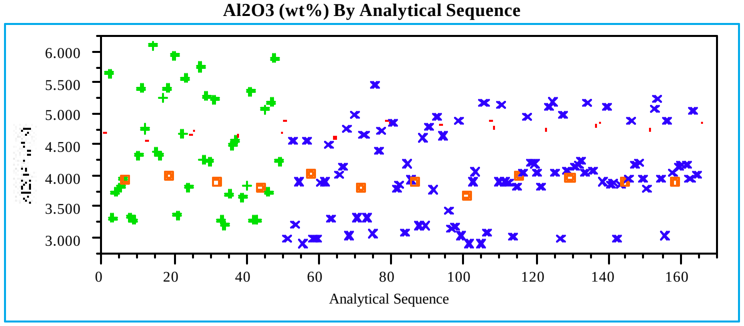
Means for Oneway Anova

Level	Number	Mean	Std Error
1-1	2	1.01736	0.00915
1-2	2	1.04281	0.00915
2-1	2	0.97792	0.00915
2-2	2	0.95310	0.00915
3-1	2	1.01291	0.00915
3-2	2	0.99700	0.00915

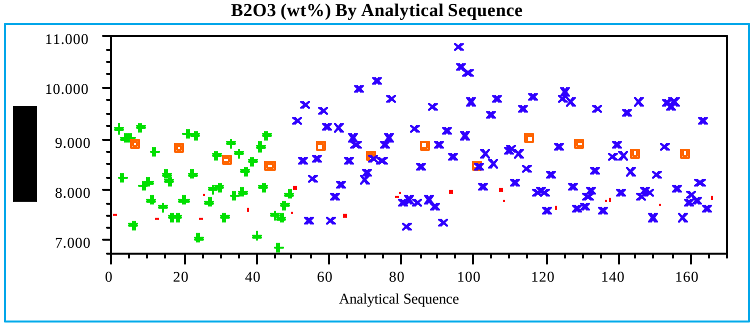
Std Error uses a pooled estimate of error variance

Exhibit E11: Al_2O_3, B_2O_3, CaO, Cr_2O_3, Fe_2O_3 and Li_2O Measurements In Analytical Sequence (Glasses from Other Study +'s; Ustd Open Squares; Batch 1 Small Squares; RC x's)

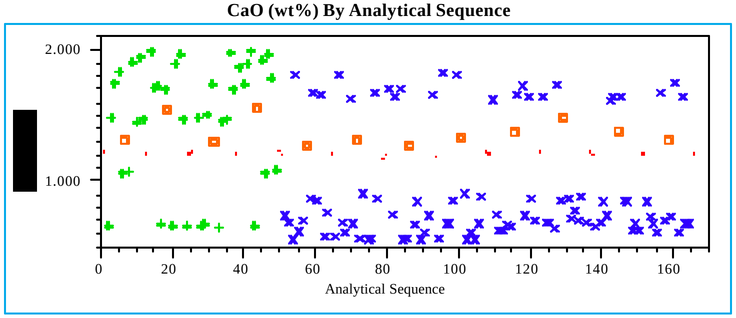
Al2O3 (wt%) By Analytical Sequence



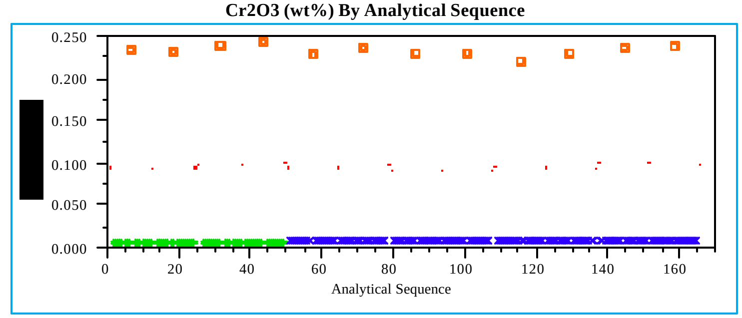
B2O3 (wt%) By Analytical Sequence



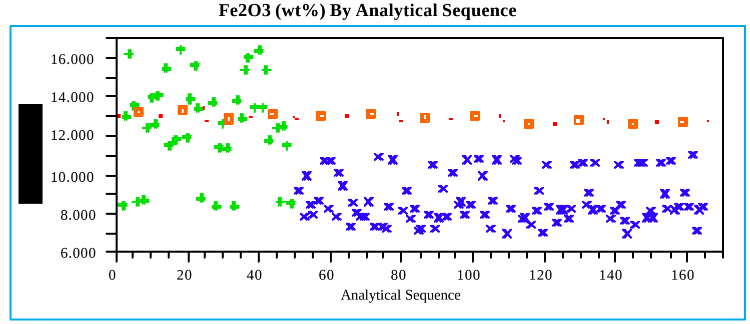
CaO (wt%) By Analytical Sequence



Cr2O3 (wt%) By Analytical Sequence



Fe2O3 (wt%) By Analytical Sequence



Li2O (wt%) By Analytical Sequence

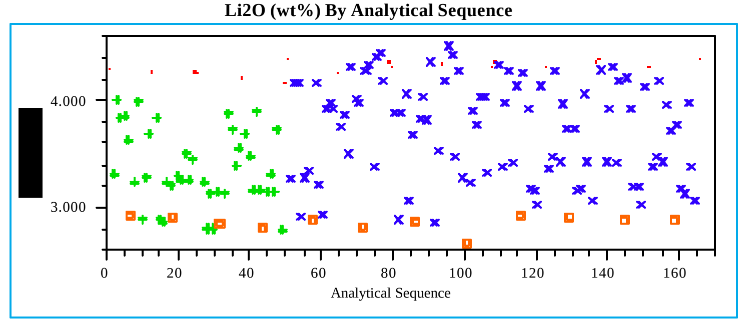
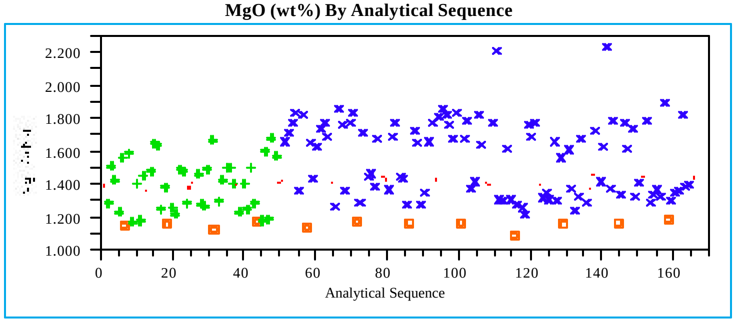
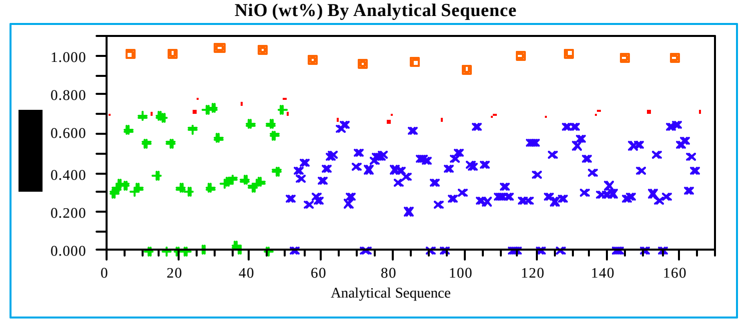


Exhibit E12: MgO, MnO, Na_2O, NiO, SiO_2, and U_3O_8 Measurements In Analytical Sequence (Glasses from Other Study +'s; Ustd Open Squares; Batch 1 Small Squares; RC x's)

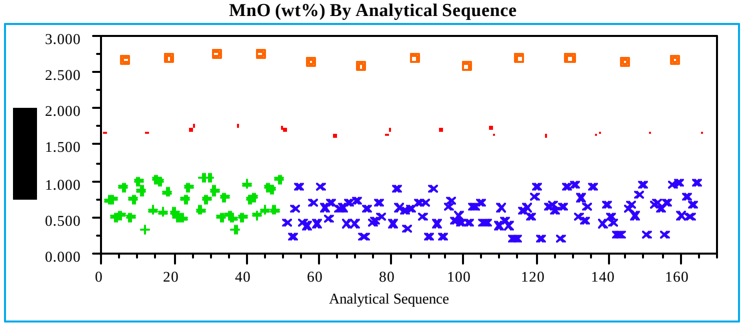
MgO (wt%) By Analytical Sequence



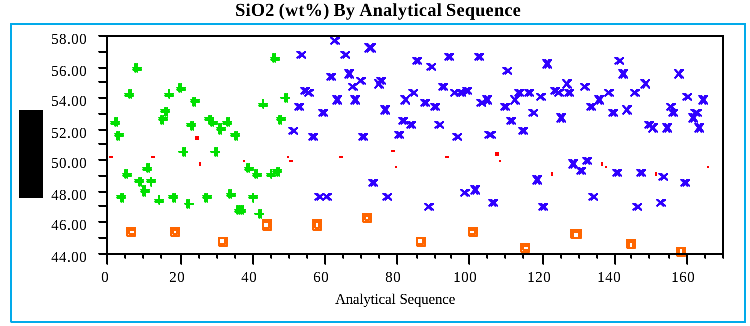
NiO (wt%) By Analytical Sequence



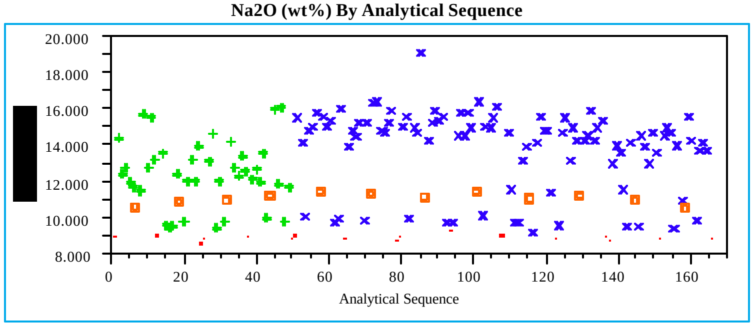
MnO (wt%) By Analytical Sequence



SiO2 (wt%) By Analytical Sequence



Na2O (wt%) By Analytical Sequence



U3O8 (wt%) By Analytical Sequence

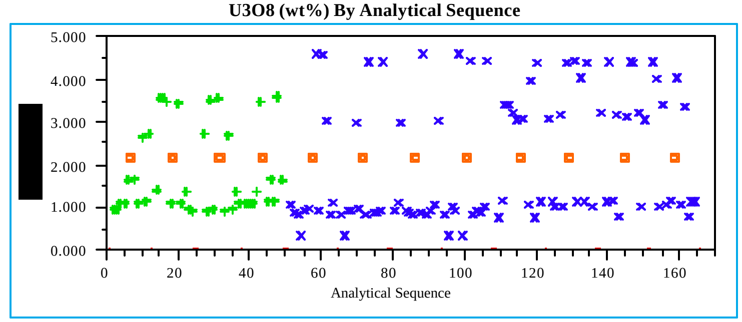
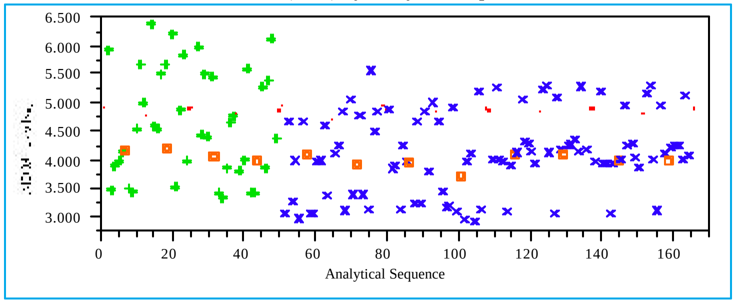
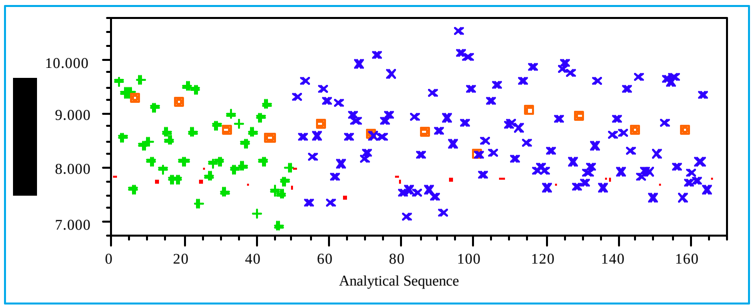


Exhibit E13: Al_2O_3, B_2O_3, CaO, Cr_2O_3, Fe_2O_3 and Li_2O Bias-Corrected, Measurements In Analytical Sequence (Glasses from Other Study +'s; Ustd Open Squares; Batch 1 Small Squares; RC x's)

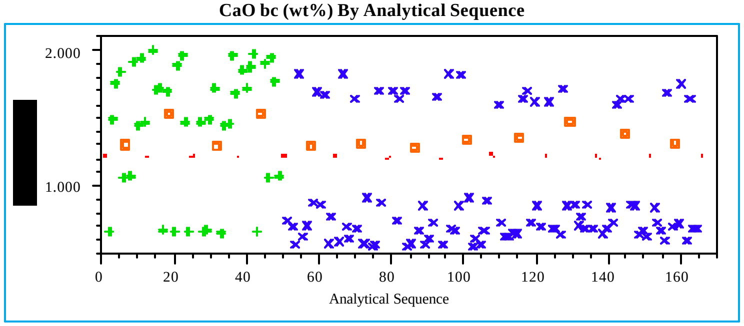
Al2O3 bc (wt%) By Analytical Sequence



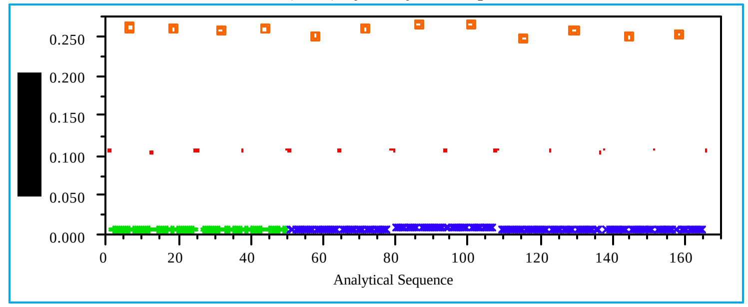
B2O3 bc (wt%) By Analytical Sequence



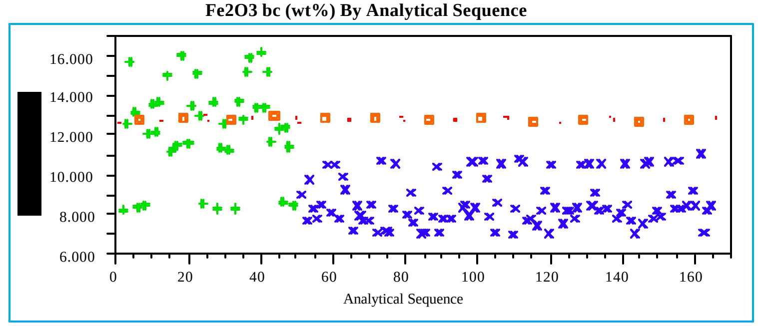
CaO bc (wt%) By Analytical Sequence



Cr2O3 bc (wt%) By Analytical Sequence



Fe2O3 bc (wt%) By Analytical Sequence



Li2O bc (wt%) By Analytical Sequence

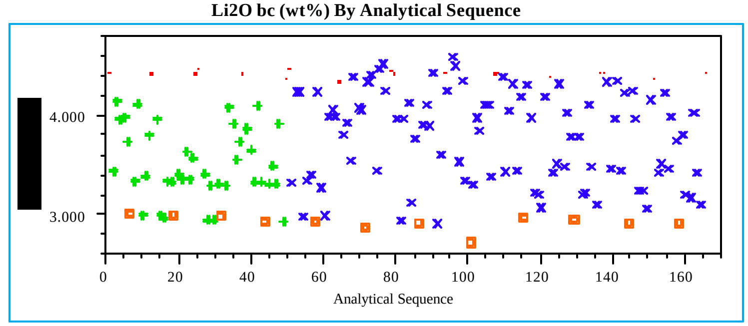
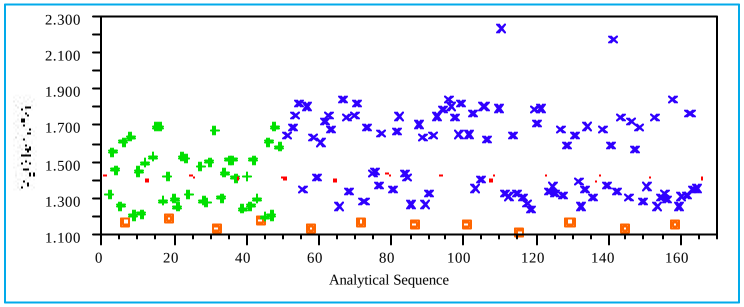
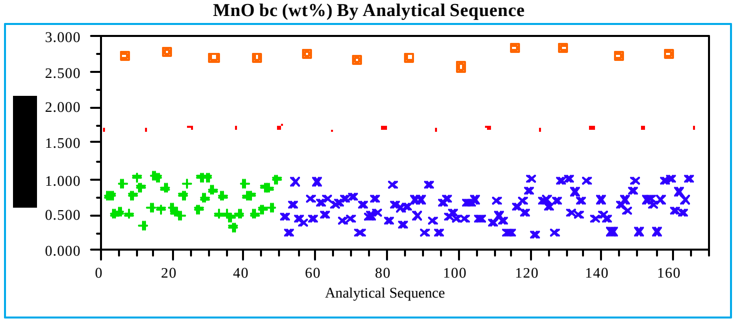


Exhibit E14: MgO, MnO, Na_2O, NiO, SiO_2, and U_3O_8 Bias-Corrected, Measurements In Analytical Sequence (Glasses from Other Study +'s; Ustd Open Squares; Batch 1 Small Squares; RC x's)

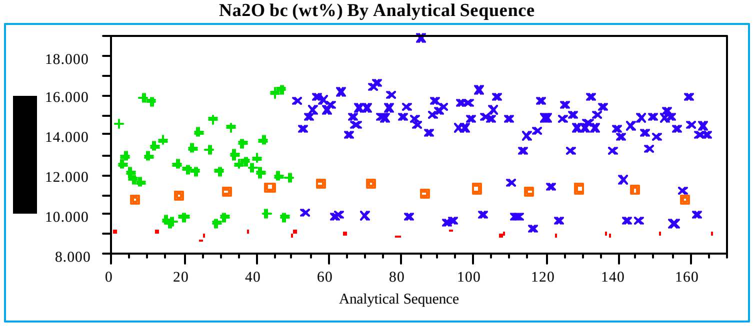
MgO bc (wt%) By Analytical Sequence



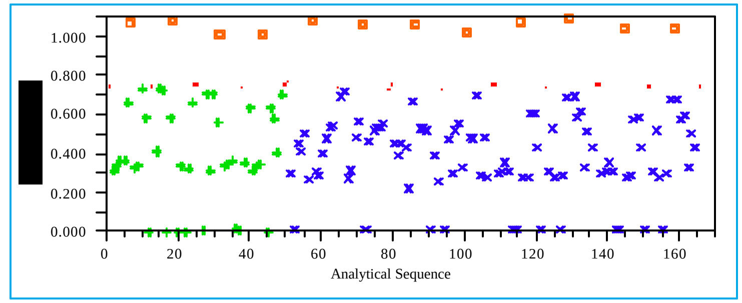
MnO bc (wt%) By Analytical Sequence



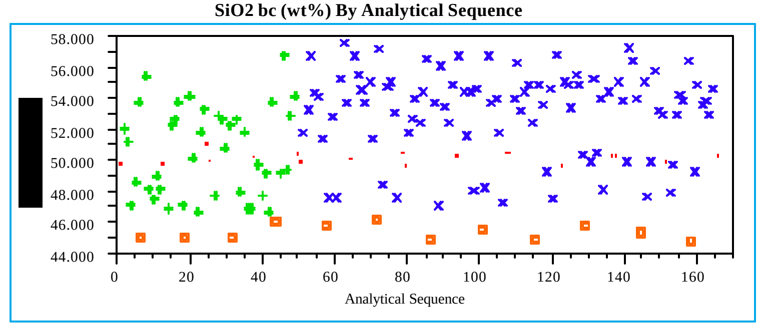
Na2O bc (wt%) By Analytical Sequence



NiO bc (wt%) By Analytical Sequence



SiO2 bc (wt%) By Analytical Sequence



U3O8 bc (wt%) By Analytical Sequence

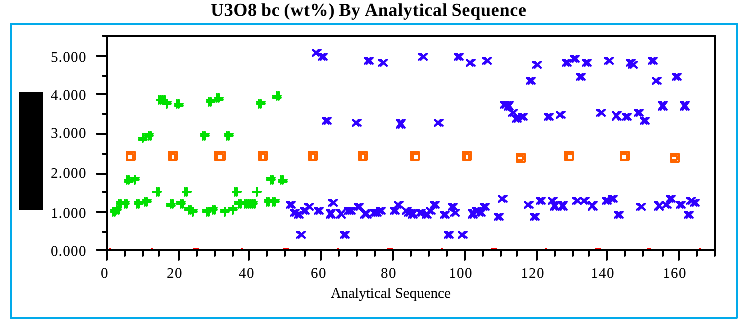
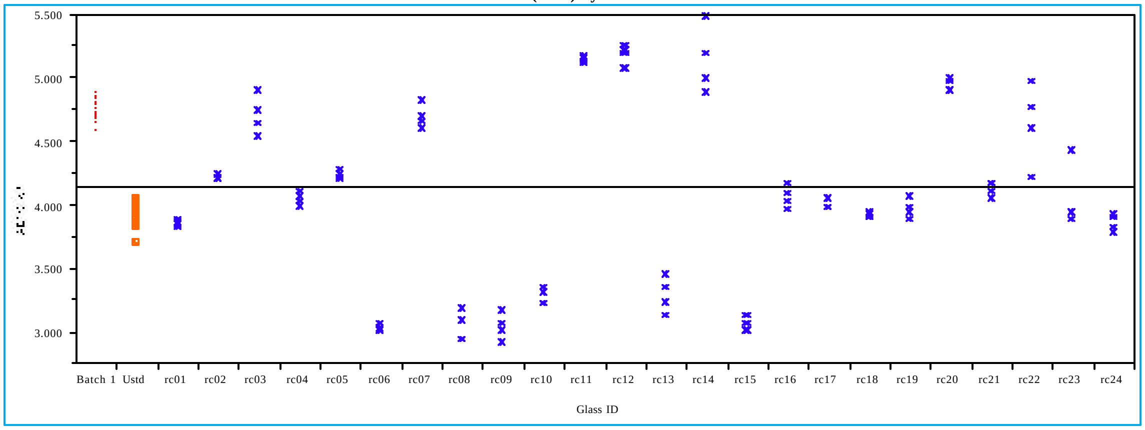
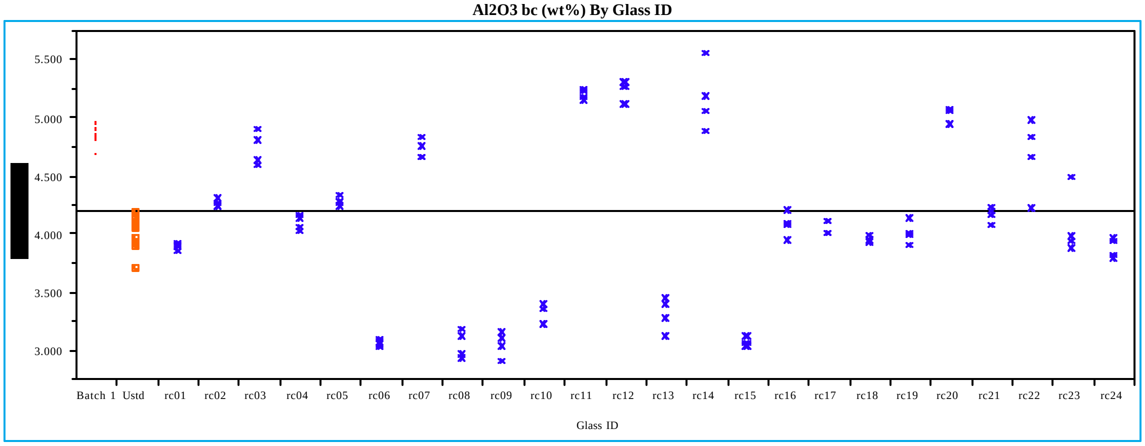


Exhibit E15: Al_2O_3 and B_2O_3 Measurements (original and bias-corrected) by Glass ID

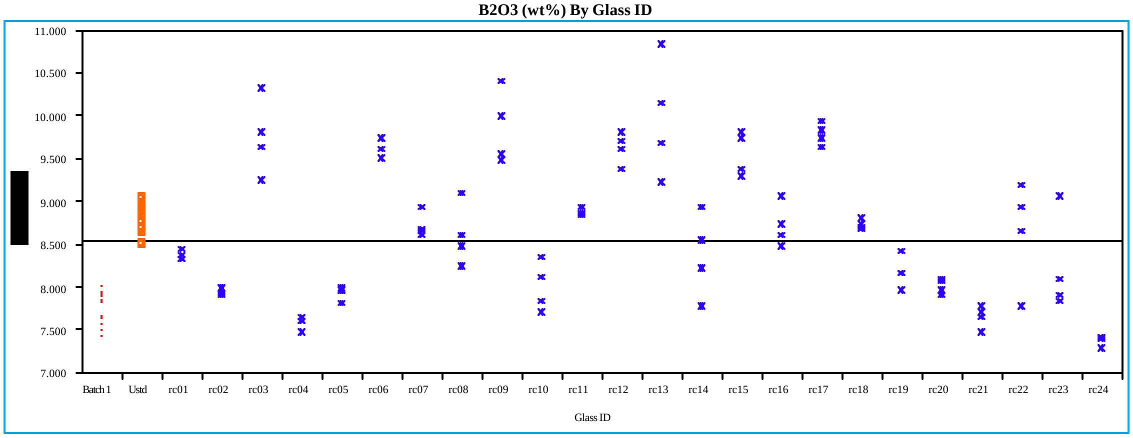
Al2O3 (wt%) By Glass ID



Al2O3 bc (wt%) By Glass ID



B2O3 (wt%) By Glass ID



B2O3 bc (wt%) By Glass ID

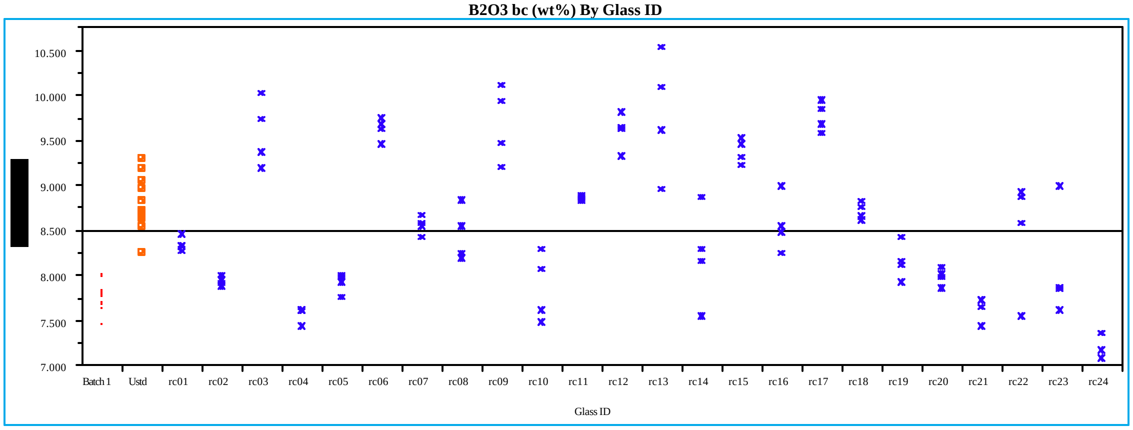
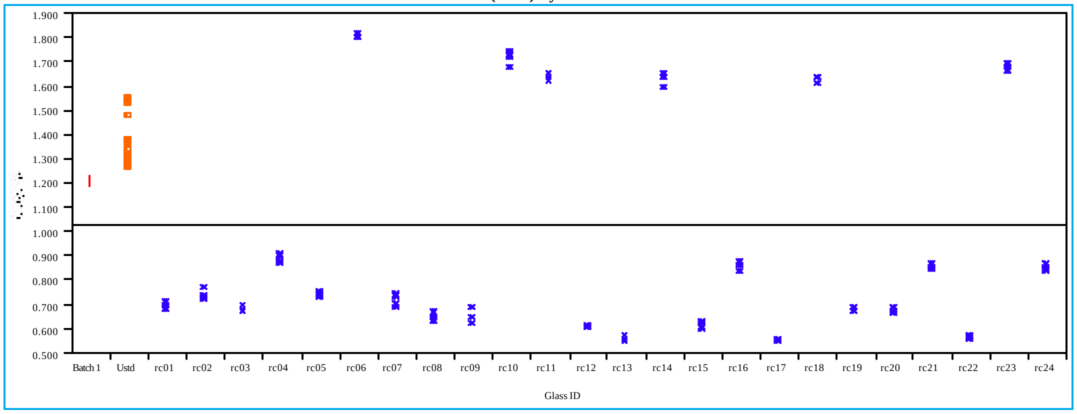
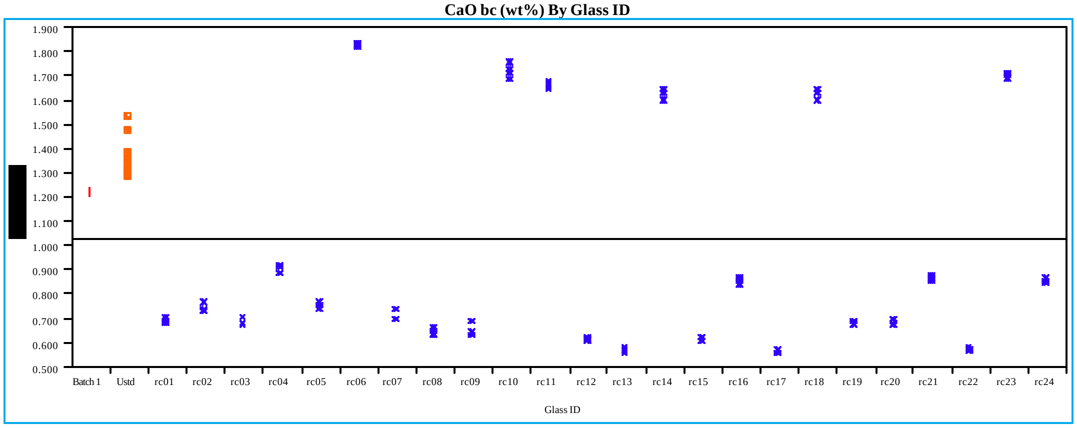


Exhibit E16: CaO and Cr_2O_3 Measurements (original and bias-corrected) by Glass ID

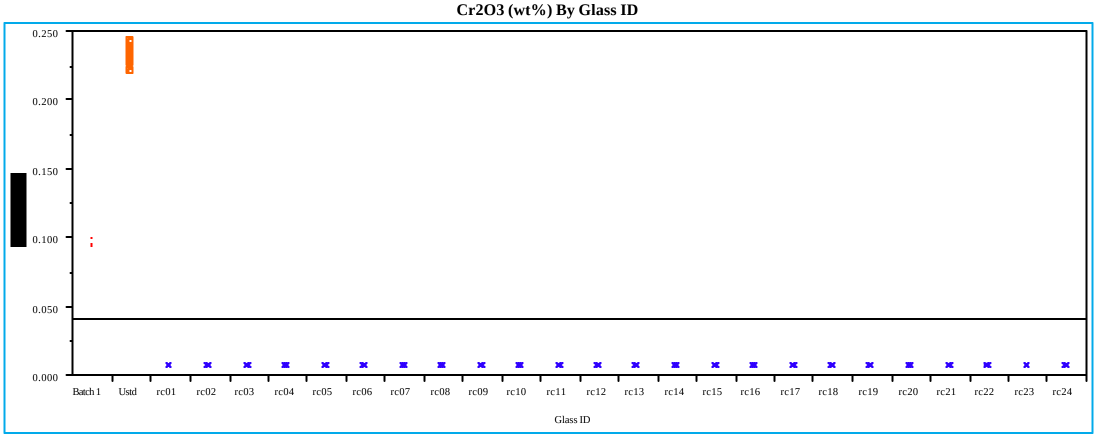
CaO (wt%) By Glass ID



CaO bc (wt%) By Glass ID



Cr2O3 (wt%) By Glass ID



Cr2O3 bc (wt%) By Glass ID

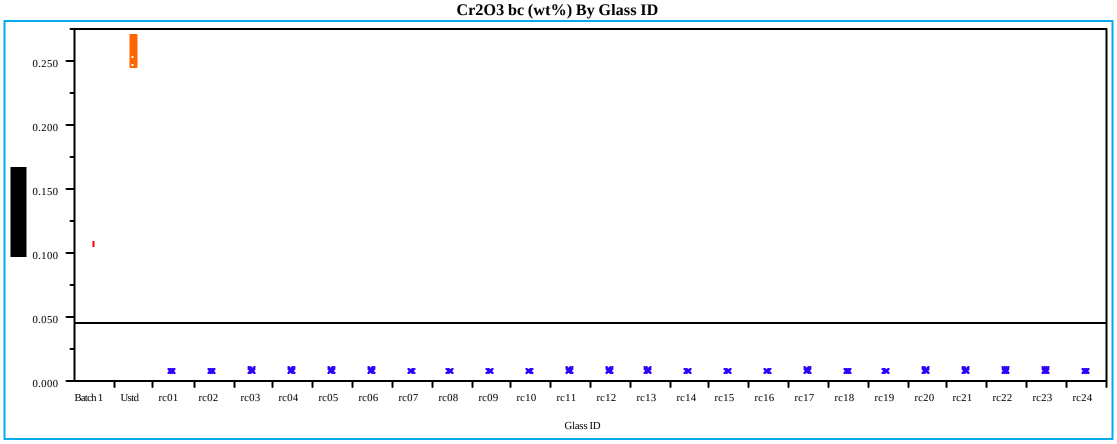
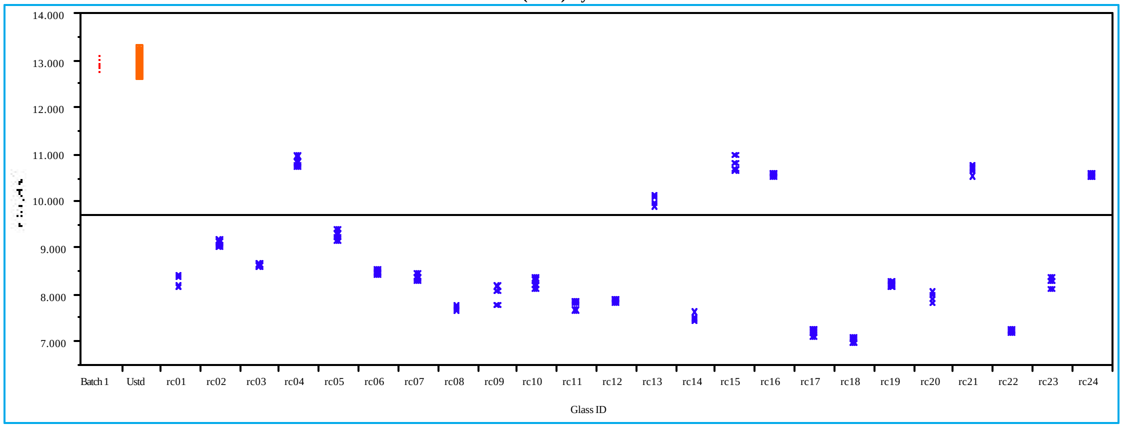
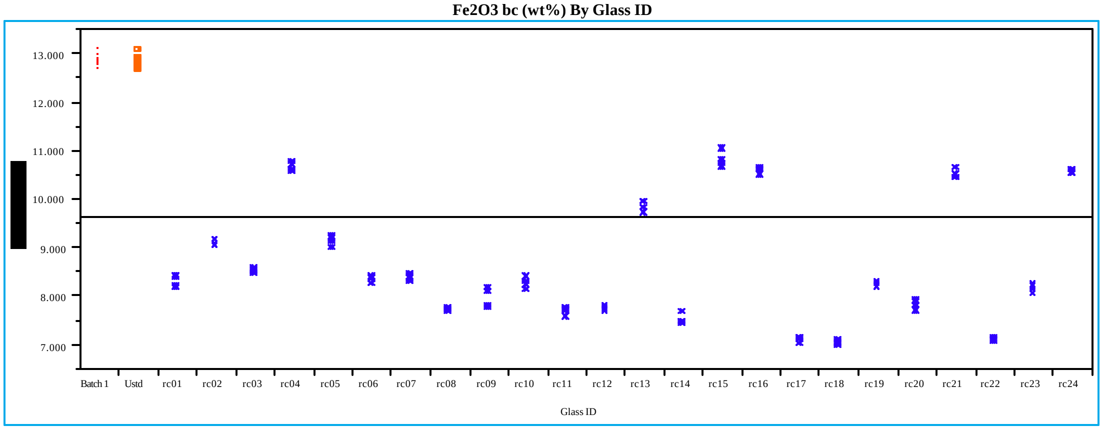


Exhibit E17: Fe_2O_3 and Li_2O Measurements (original and bias-corrected) by Glass ID

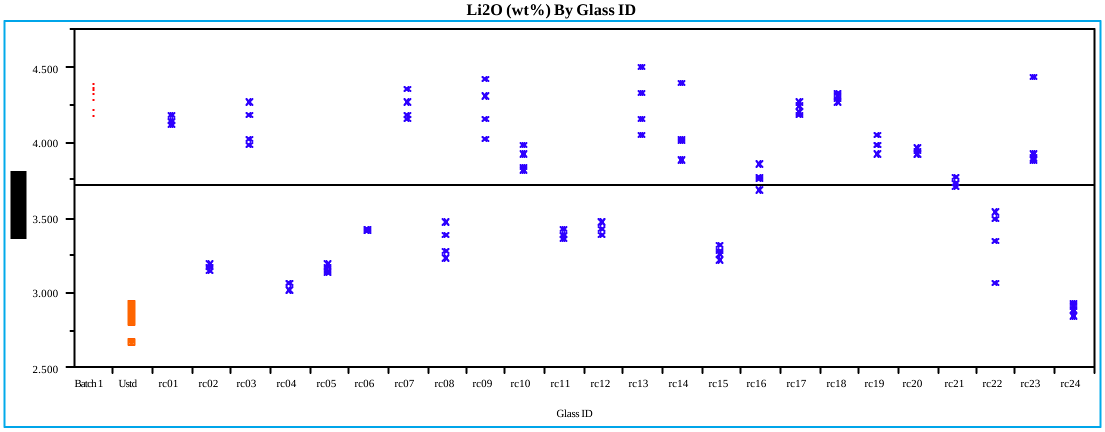
Fe2O3 (wt%) By Glass ID



Fe2O3 bc (wt%) By Glass ID



Li2O (wt%) By Glass ID



Li2O bc (wt%) By Glass ID

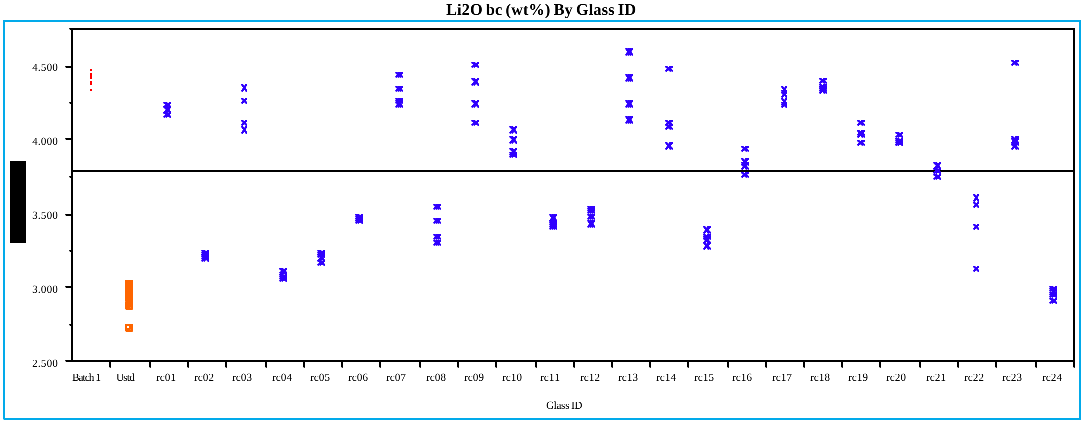
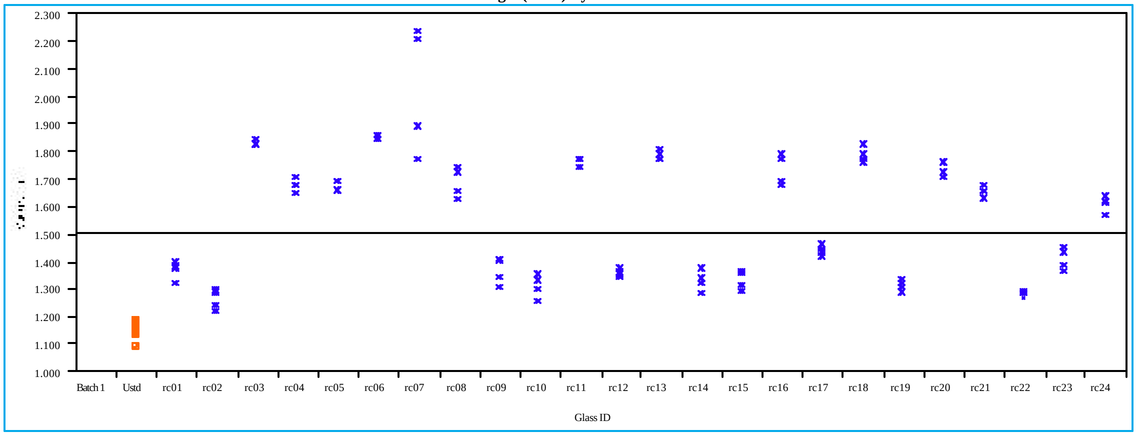
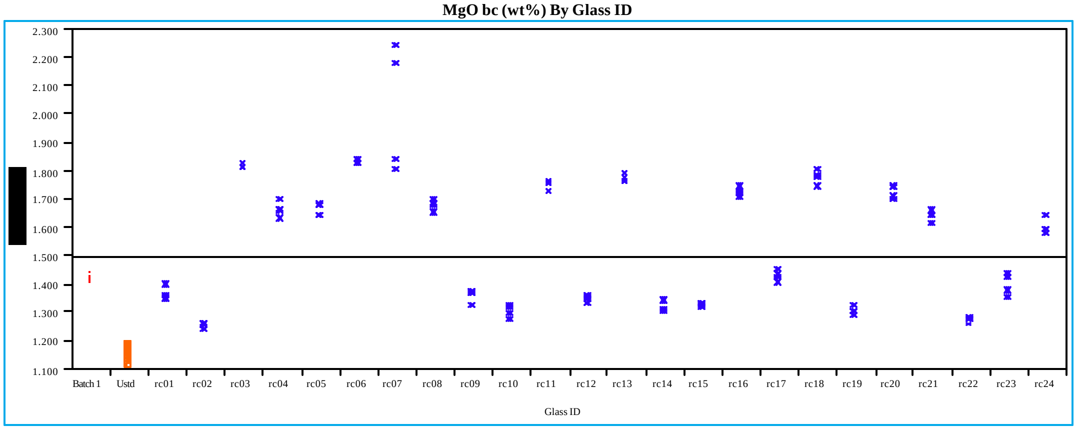


Exhibit E18: MgO and MnO Measurements (original and bias-corrected) by Glass ID

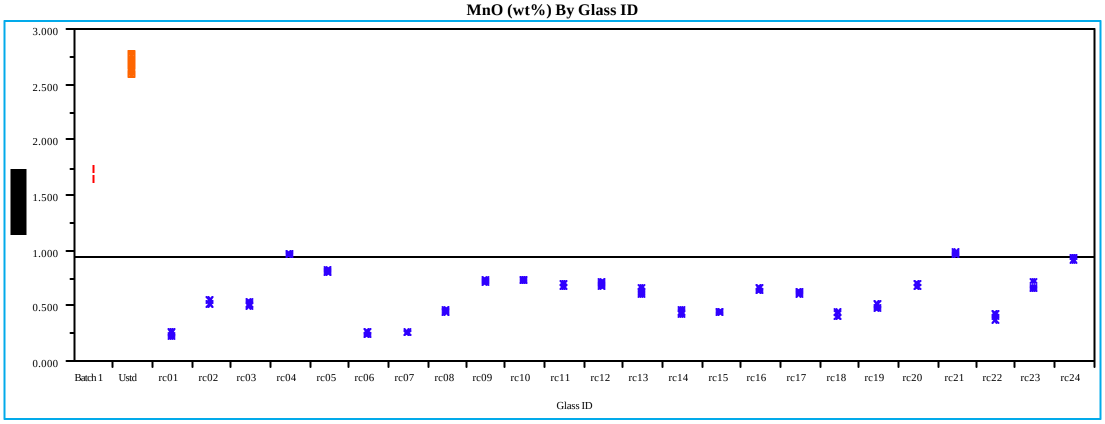
MgO (wt%) By Glass ID



MgO bc (wt%) By Glass ID



MnO (wt%) By Glass ID



MnO bc (wt%) By Glass ID

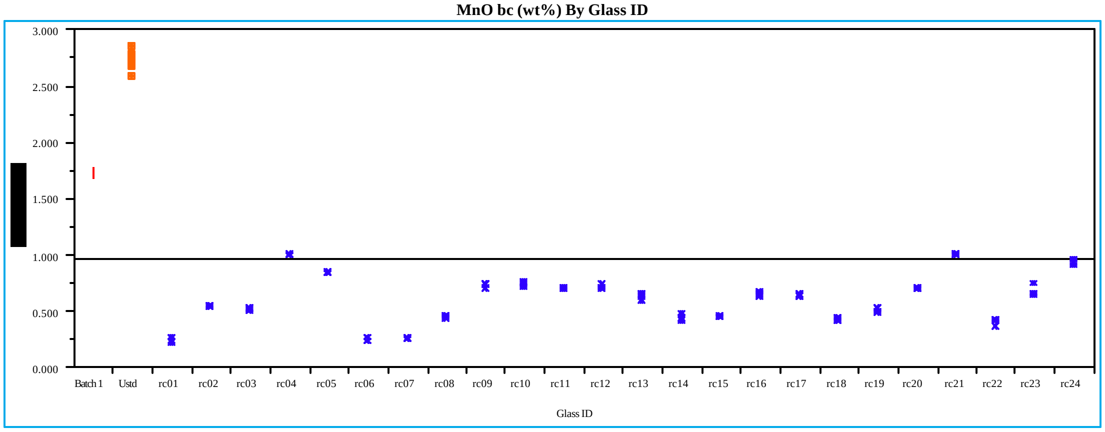
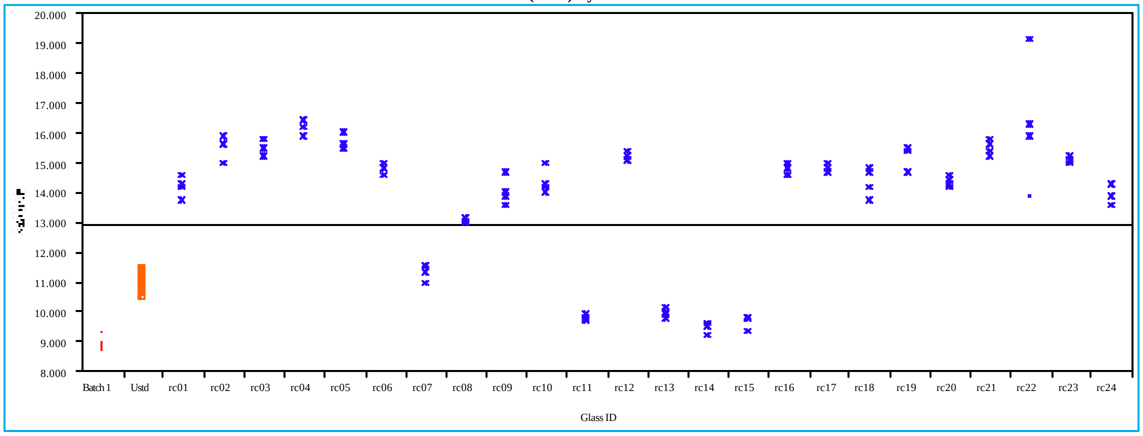
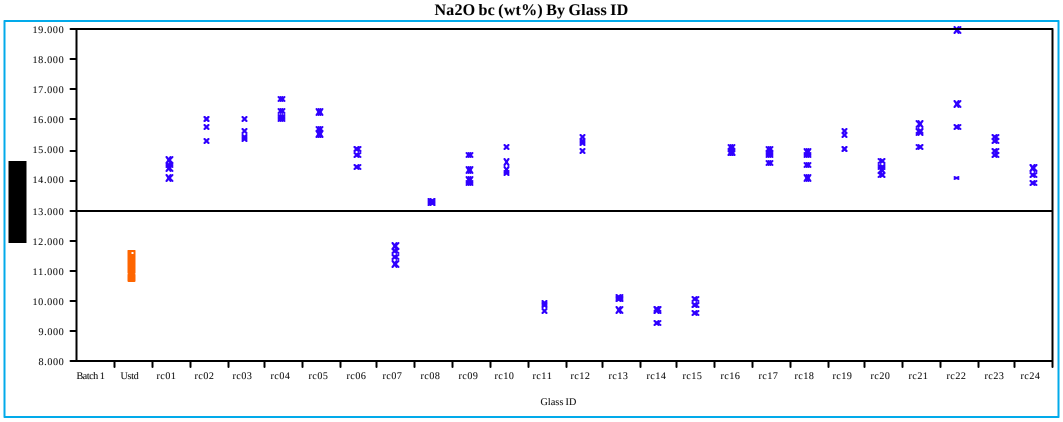


Exhibit E19: Na_2O and NiO Measurements (original and bias-corrected) by Glass ID

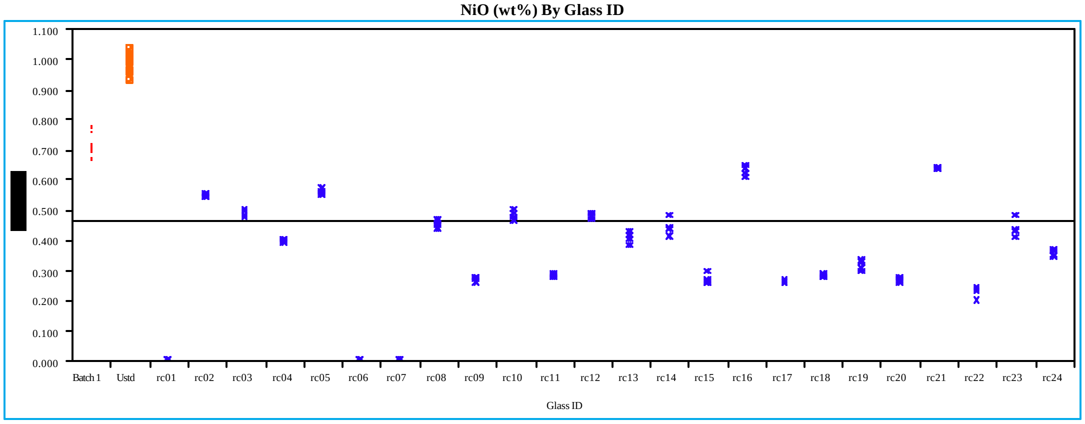
Na2O (wt%) By Glass ID



Na2O bc (wt%) By Glass ID



NiO (wt%) By Glass ID



NiO bc (wt%) By Glass ID

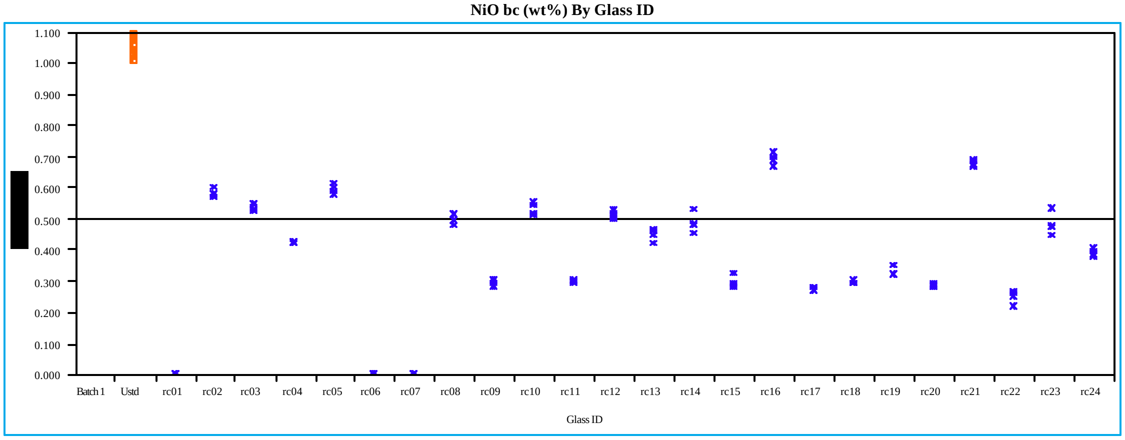
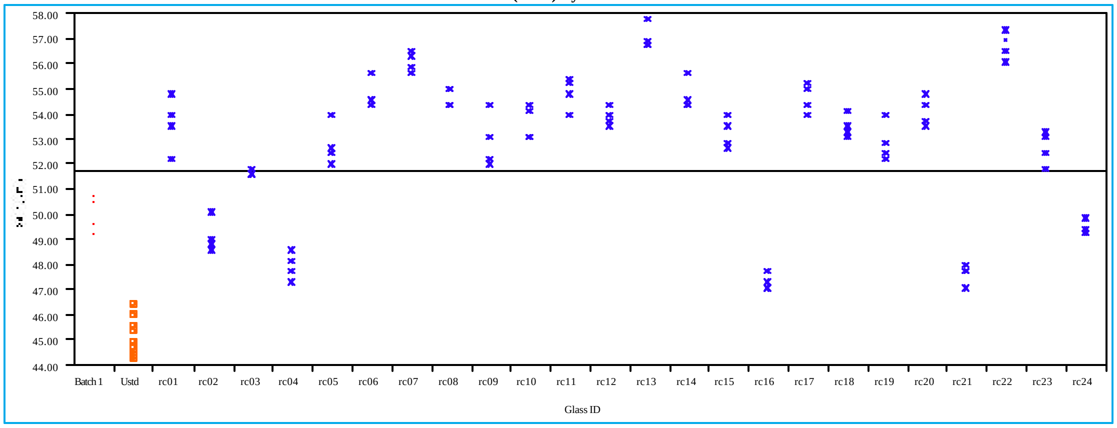
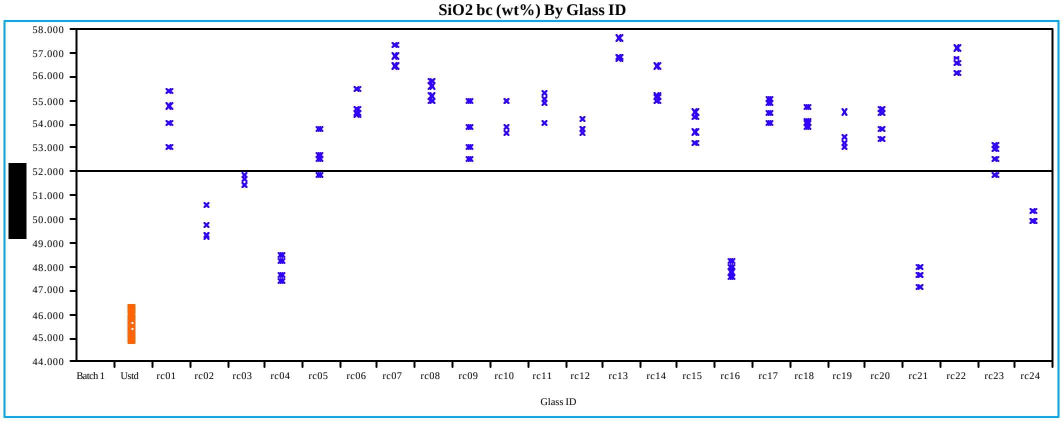


Exhibit E20: SiO_2 and U_3O_8 Measurements (original and bias-corrected) by Glass ID

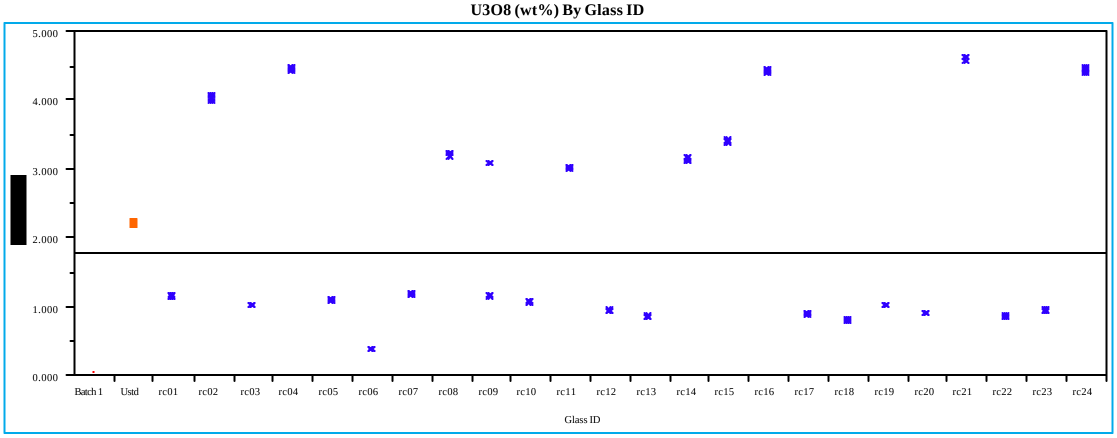
SiO2 (wt%) By Glass ID



SiO2 bc (wt%) By Glass ID



U3O8 (wt%) By Glass ID



U3O8 bc (wt%) By Glass ID

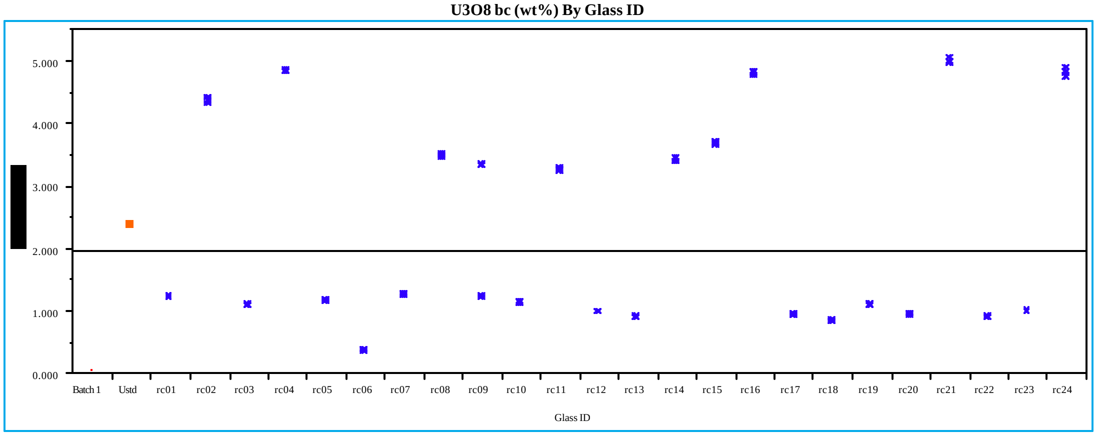
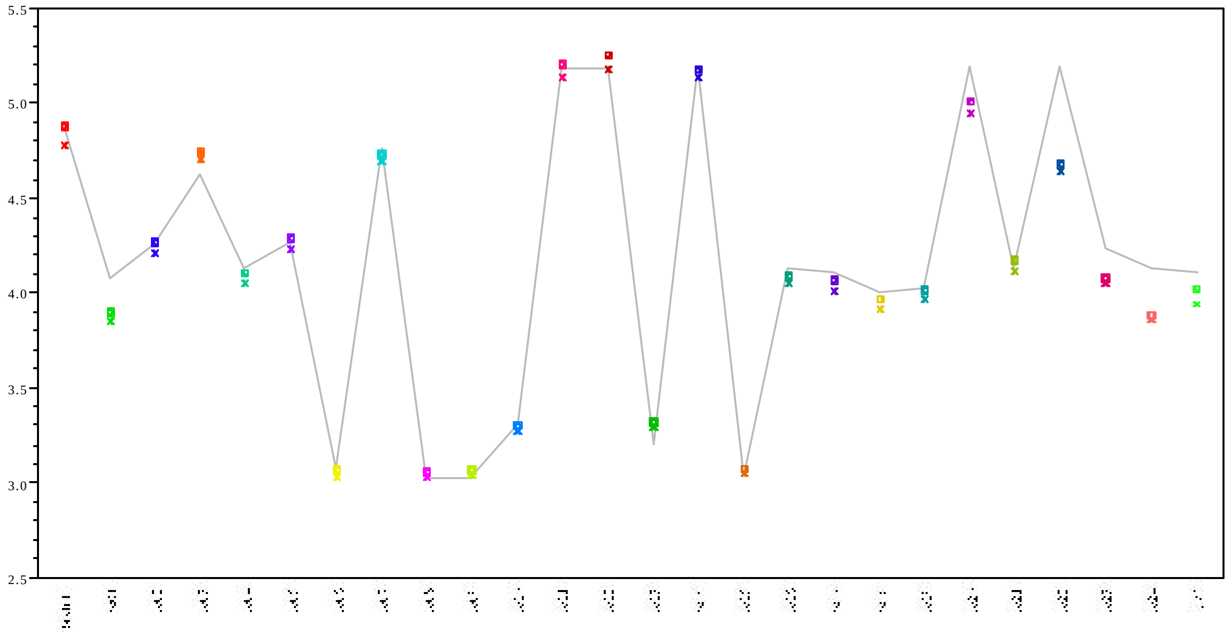


Exhibit E21: Al_2O_3 and B_2O_3 Concentrations by Glass ID

Average Al2O3 (wt%) by Glass ID



Average B2O3 (wt%) by Glass ID

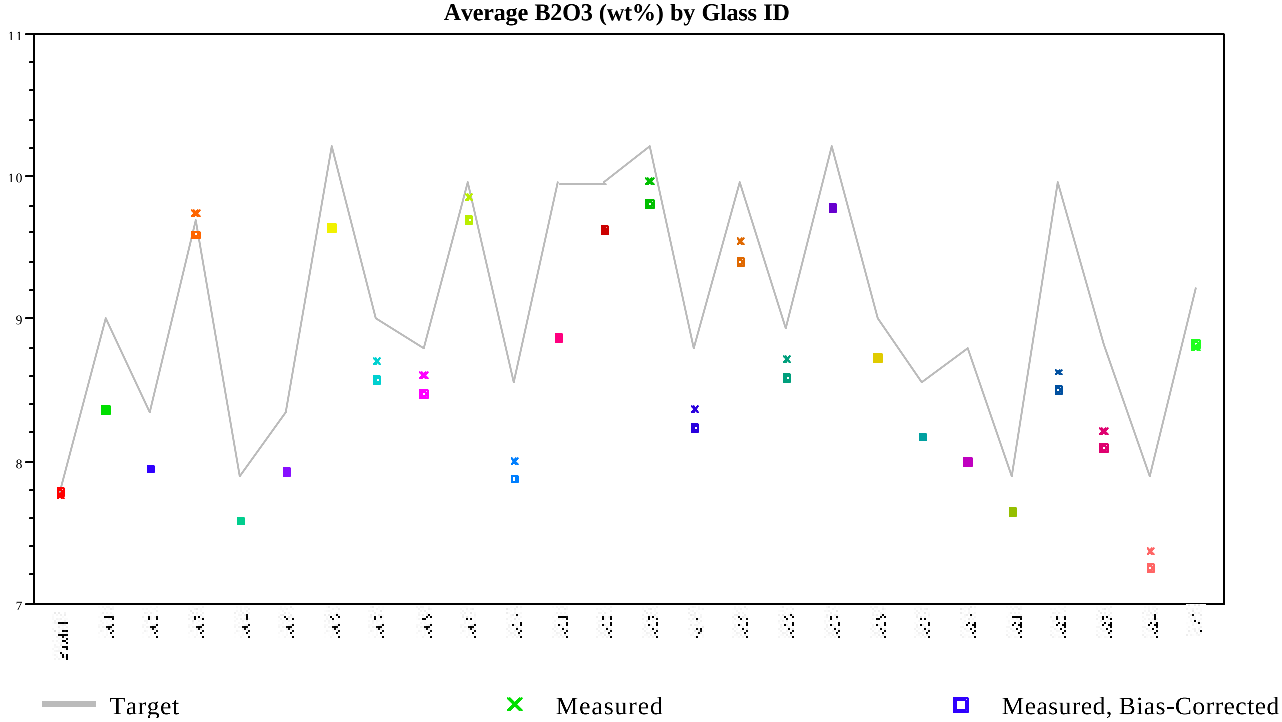
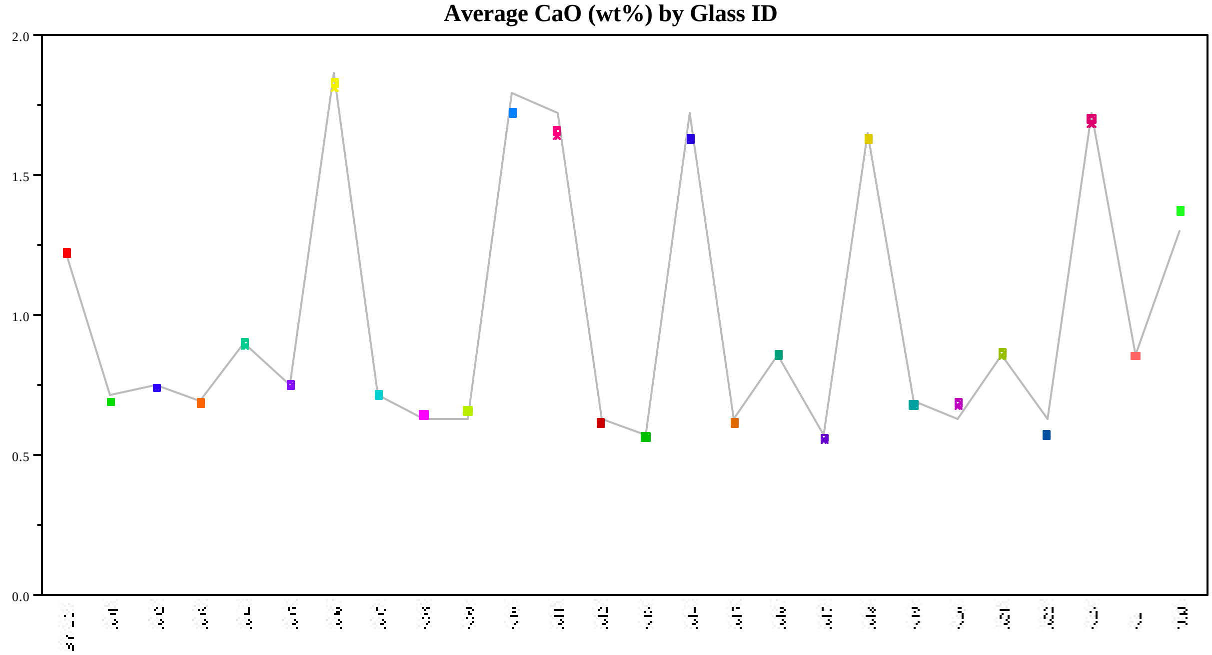
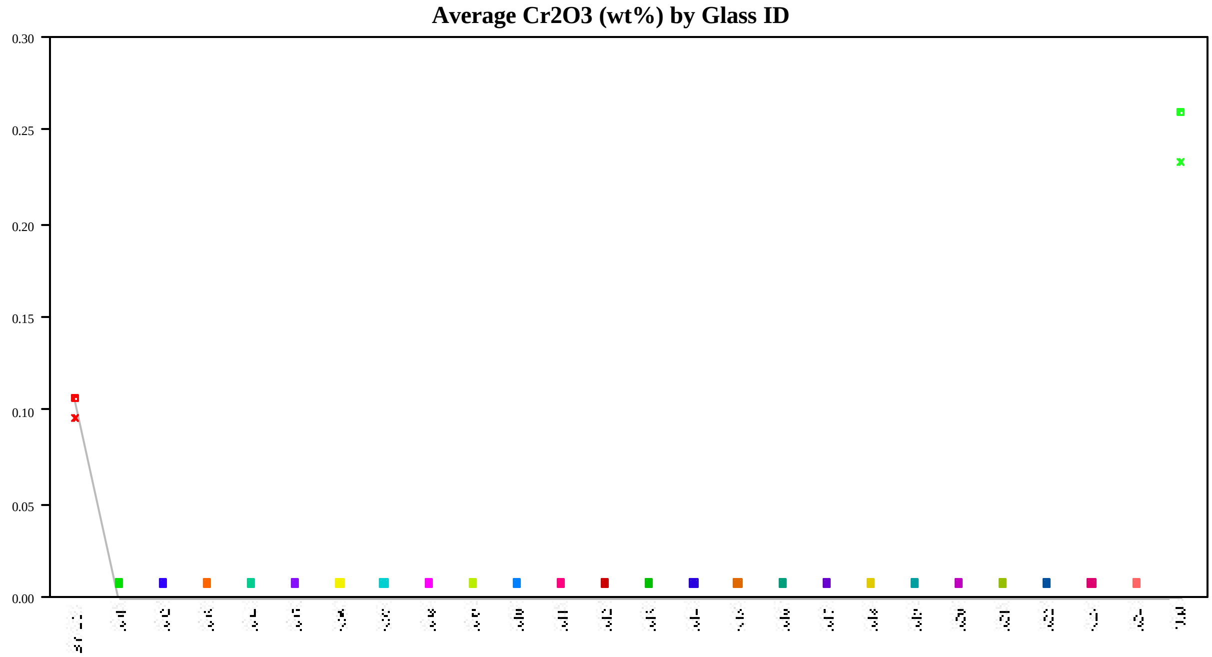


Exhibit E22: CaO and Cr_2O_3 Concentrations by Glass ID

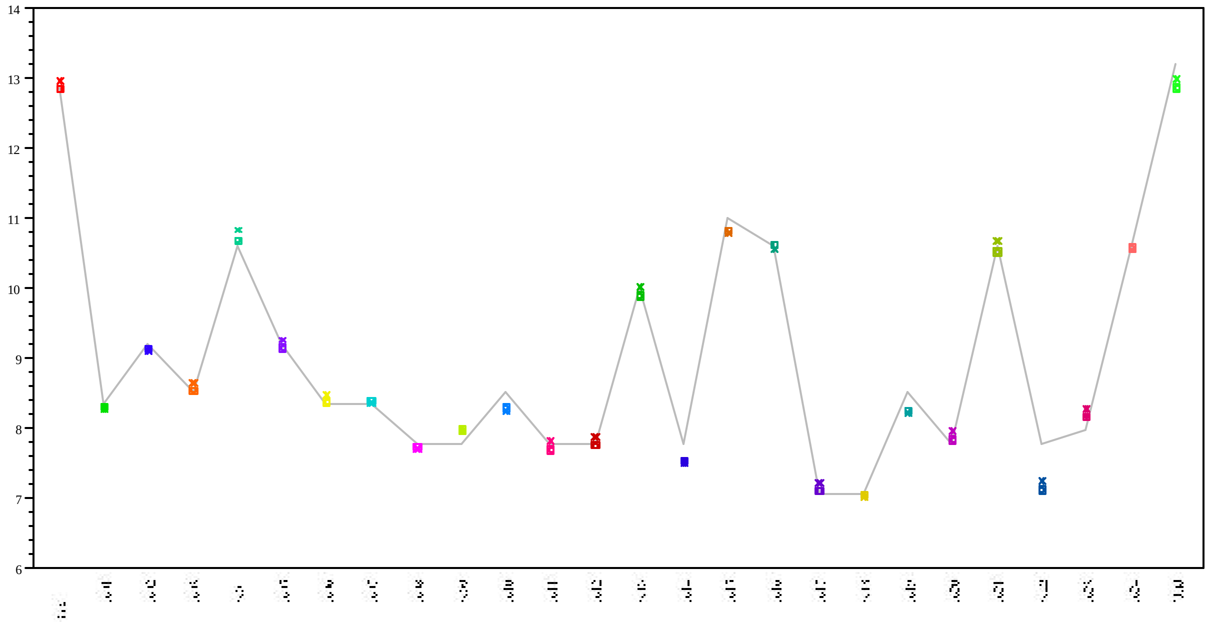




Target   × Measured   □ Measured, Bias-Corrected

Exhibit E23: Fe_2O_3 and Li_2O Concentrations by Glass ID

Average Fe2O3 (wt%) by Glass ID



Average Li2O (wt%) by Glass ID

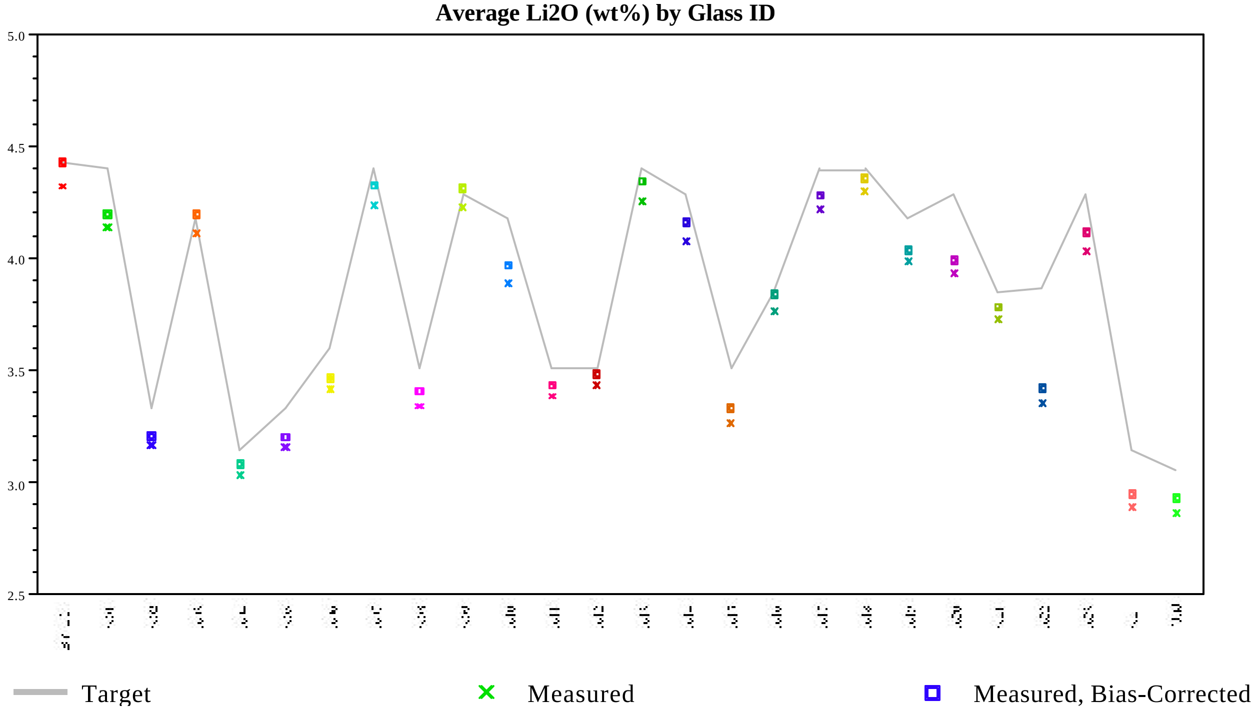
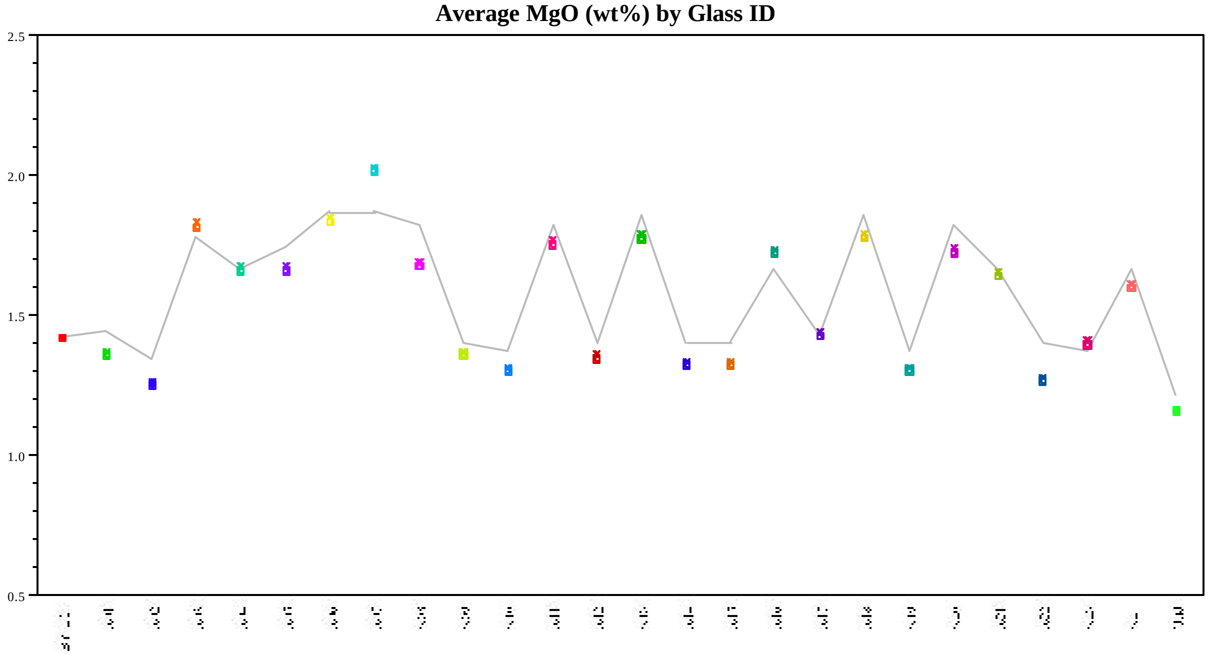


Exhibit E24: MgO and MnO Concentrations by Glass ID



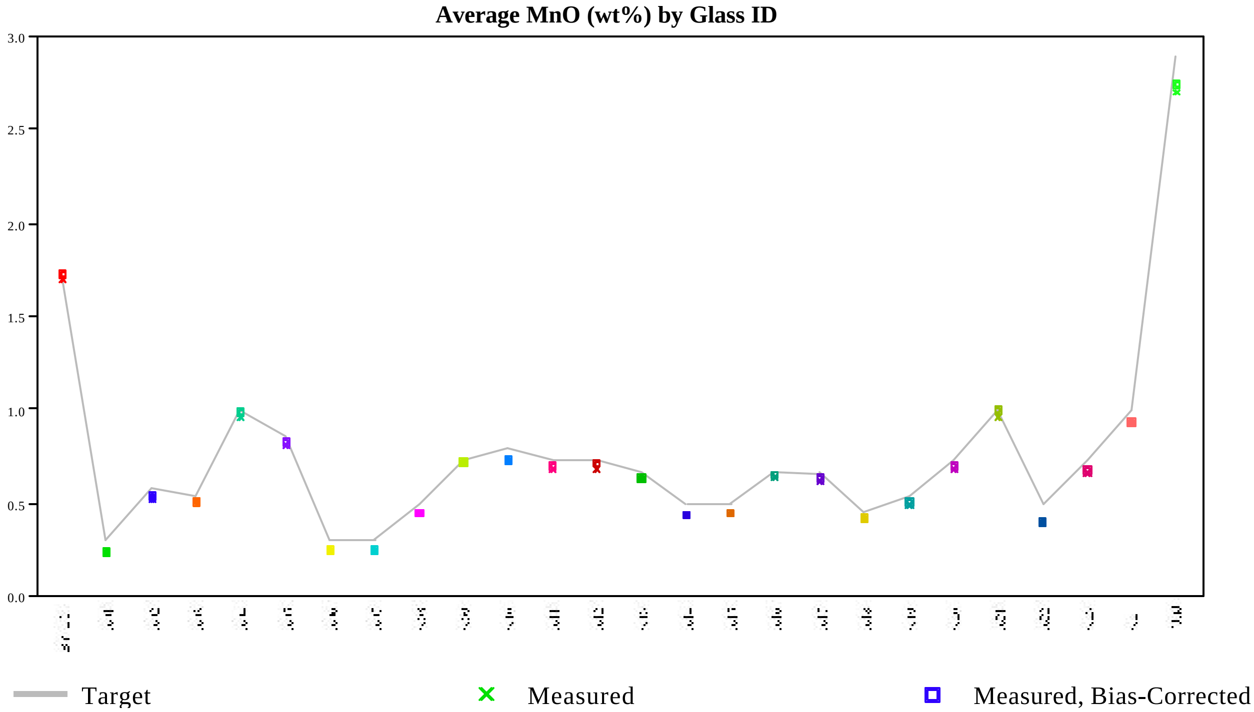
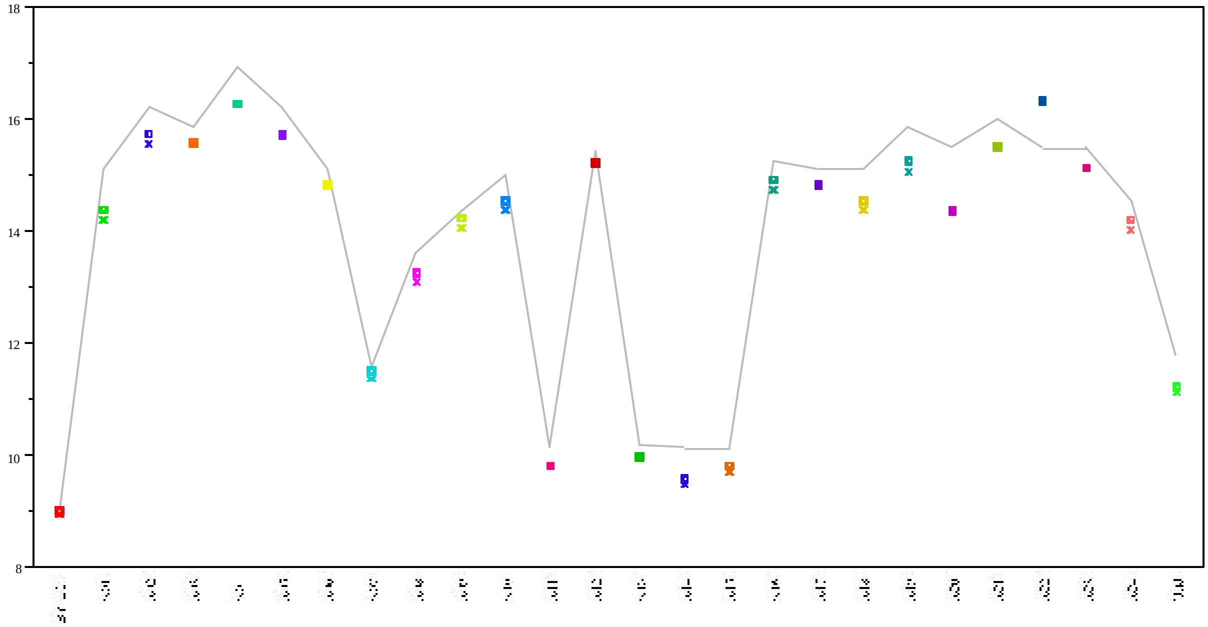
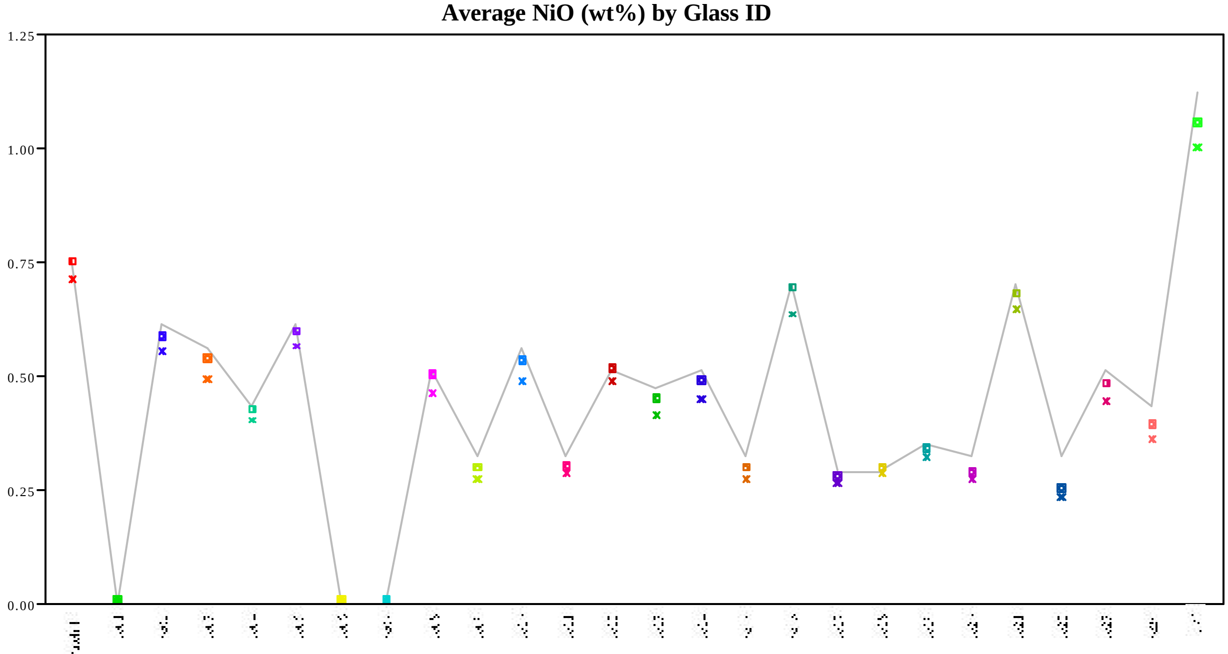


Exhibit E25: Na_2O and NiO Concentrations by Glass ID

Average Na2O (wt%) by Glass ID

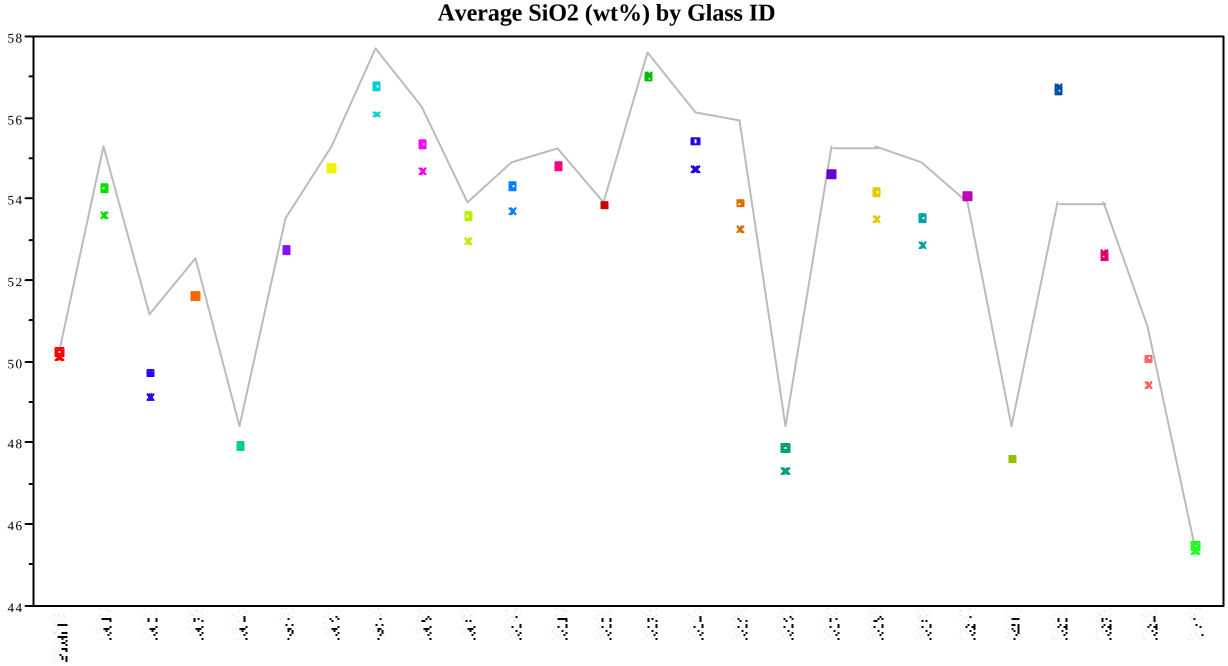


Average NiO (wt%) by Glass ID



Target Measured Measured, Bias-Corrected

Exhibit E26: SiO_2 and U_3O_8 Concentrations by Glass ID



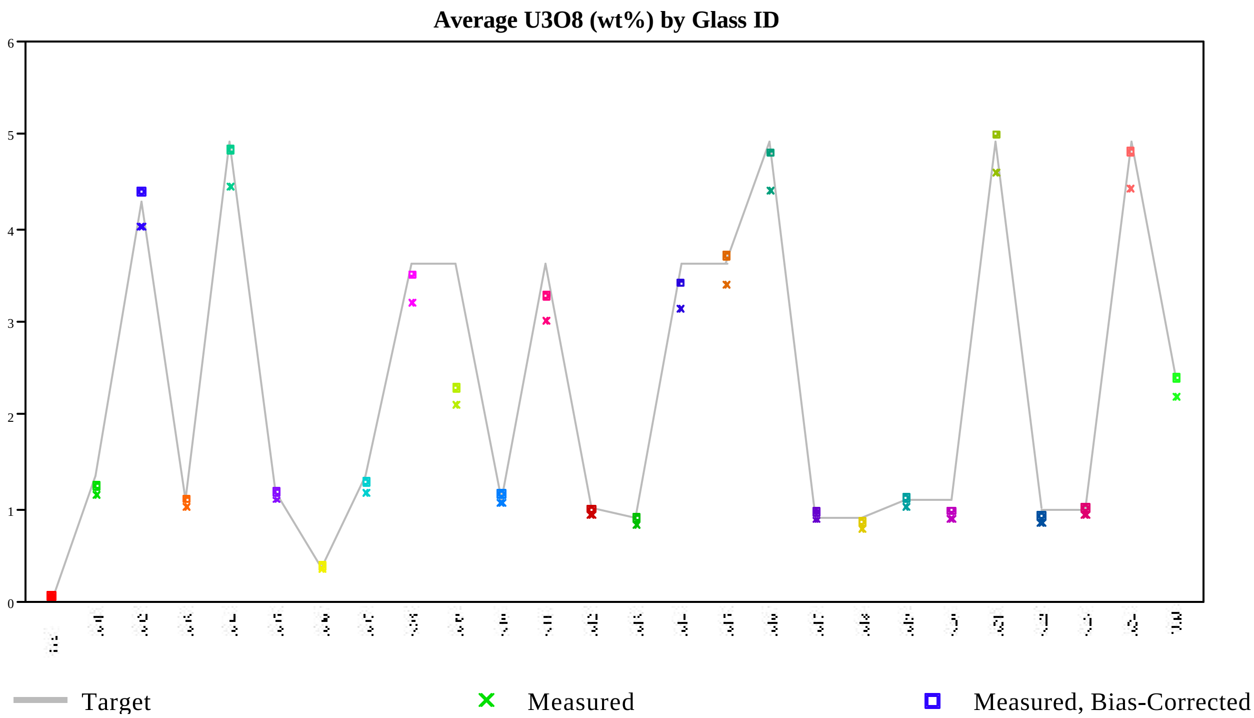
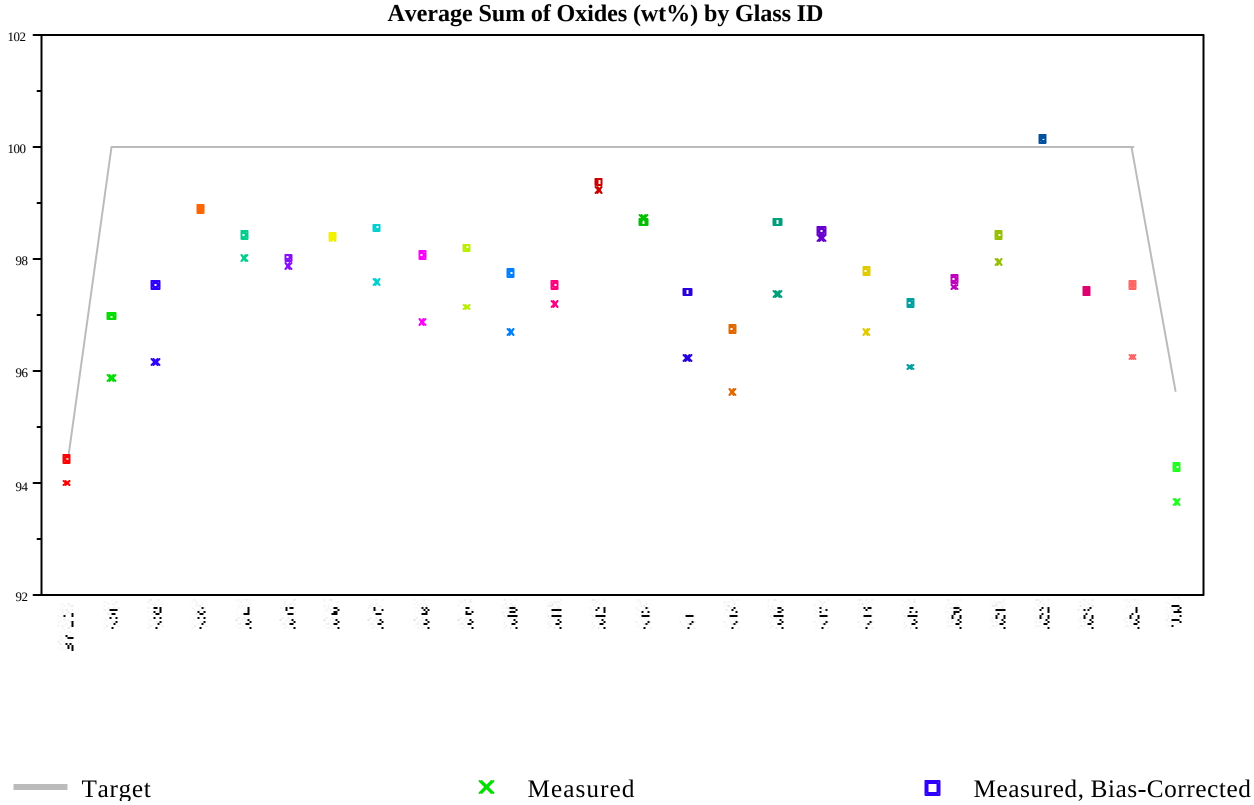


Exhibit E27: Sum of Oxides by Glass ID



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Appendix F

X-Ray Diffraction Analysis
for the RC Glasses After CLC

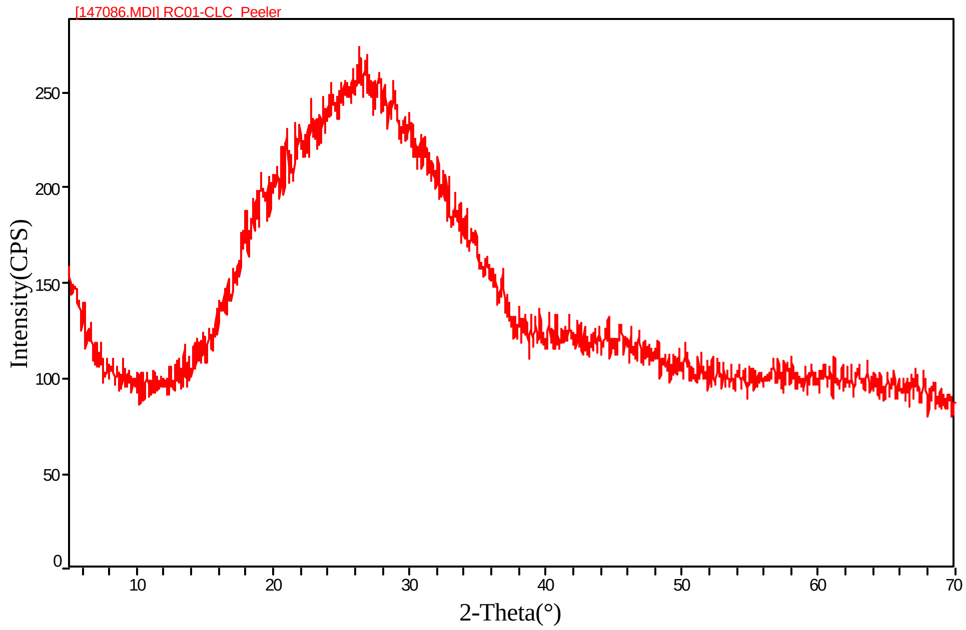

Exhibit F.1: XRD Results for RC-01 CLC.

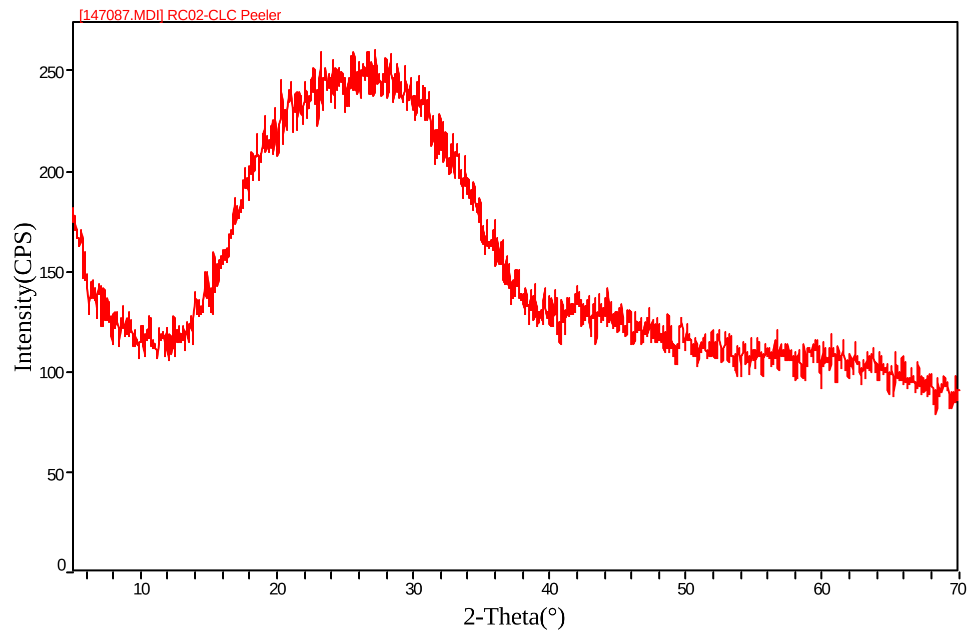

Exhibit F.2: XRD Results for RC-02 CLC.

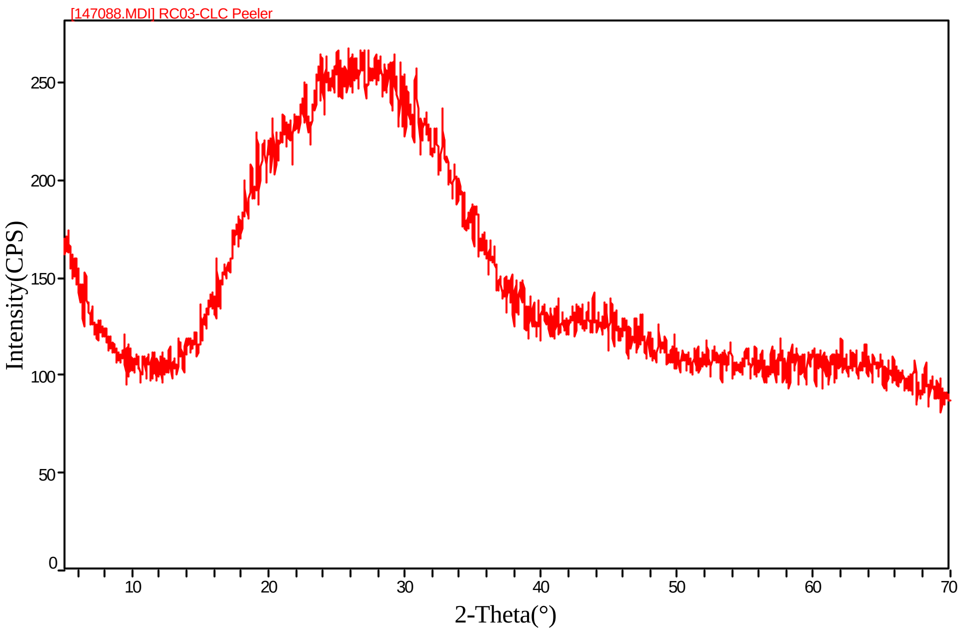

Exhibit F.3: XRD Results for RC-03 CLC.

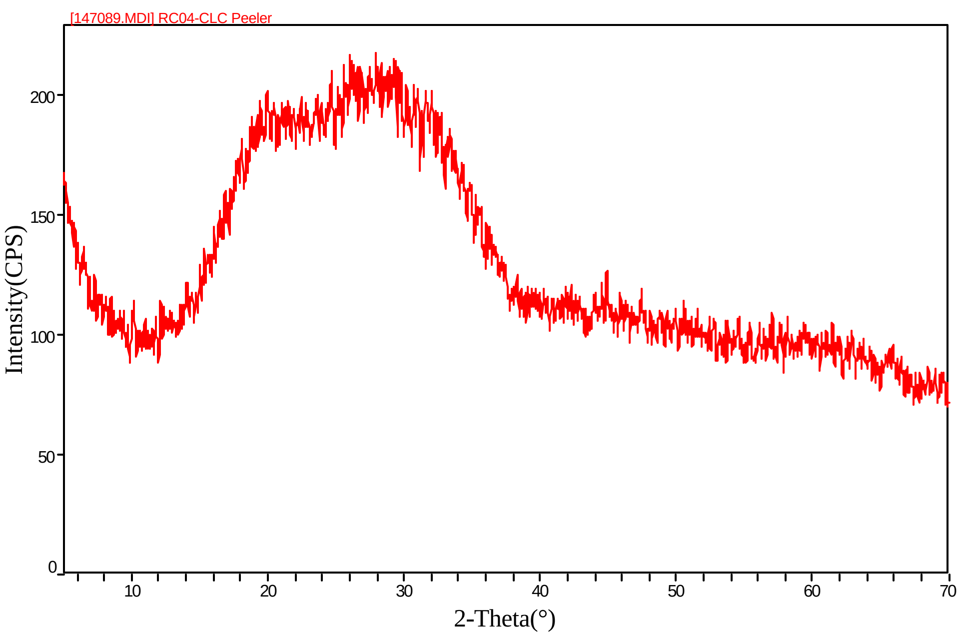

Exhibit F.4: XRD Results for RC-04 CLC.

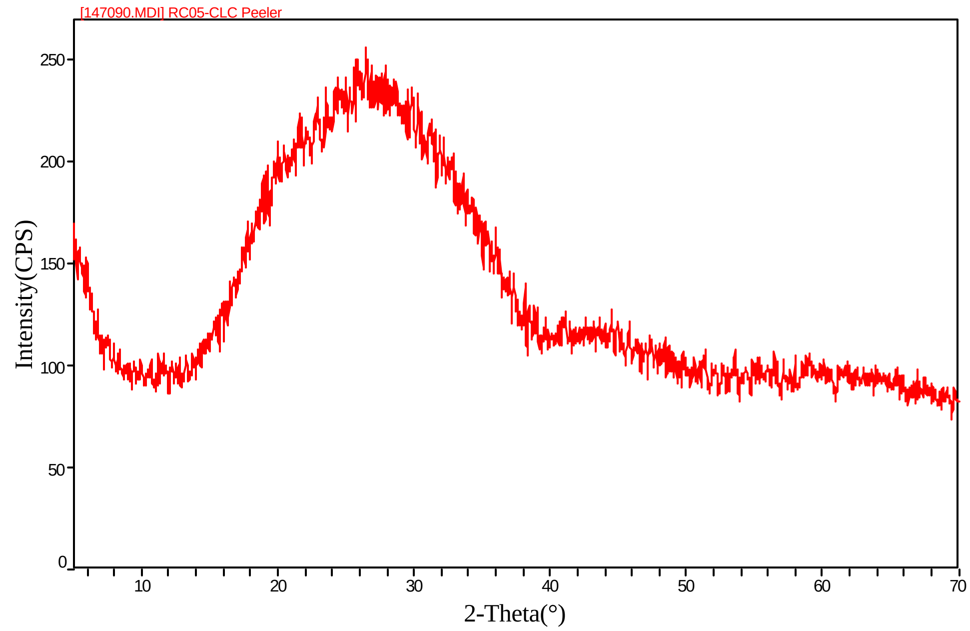

Exhibit F.5: XRD Results for RC-05 CLC.

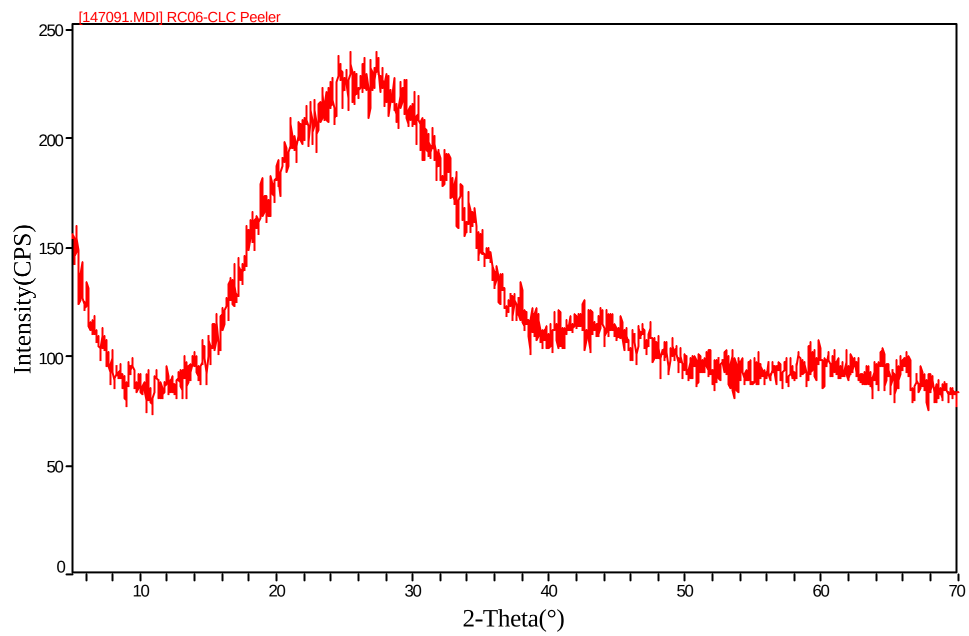

Exhibit F.6: XRD Results for RC-06 CLC.

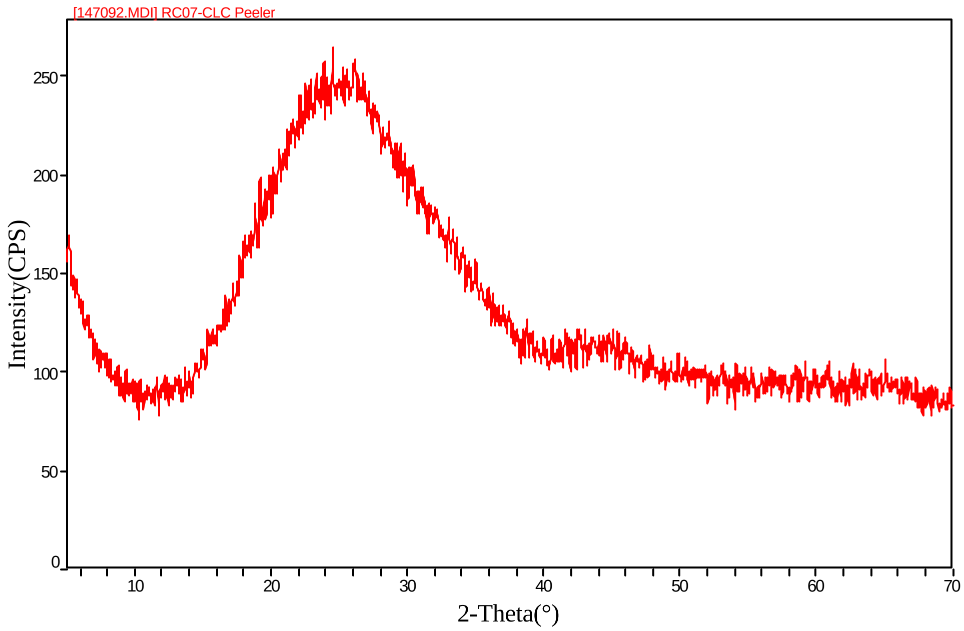

Exhibit F.7: XRD Results for RC-07 CLC.

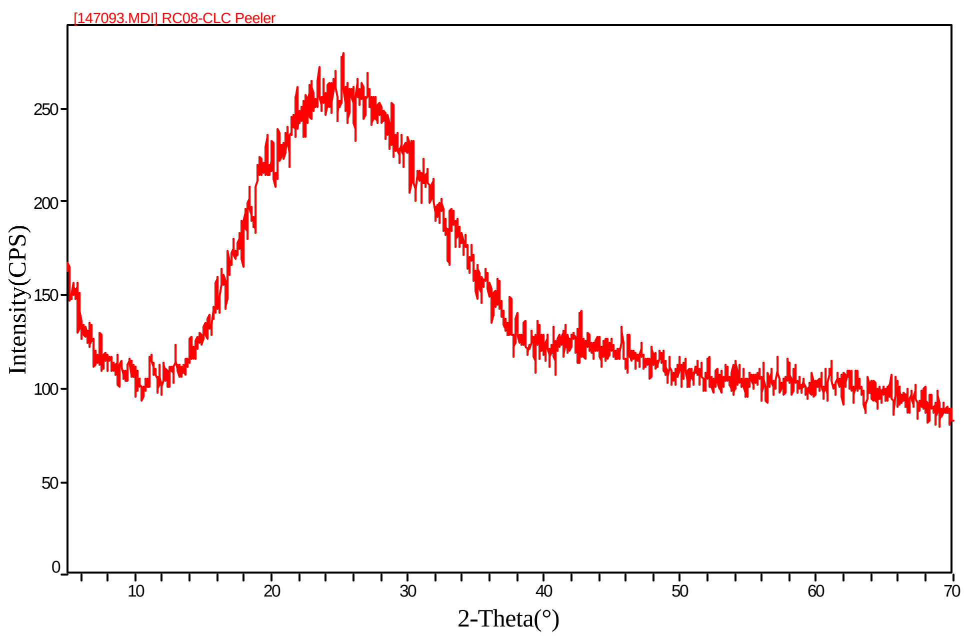

Exhibit F.8: XRD Results for RC-08 CLC.

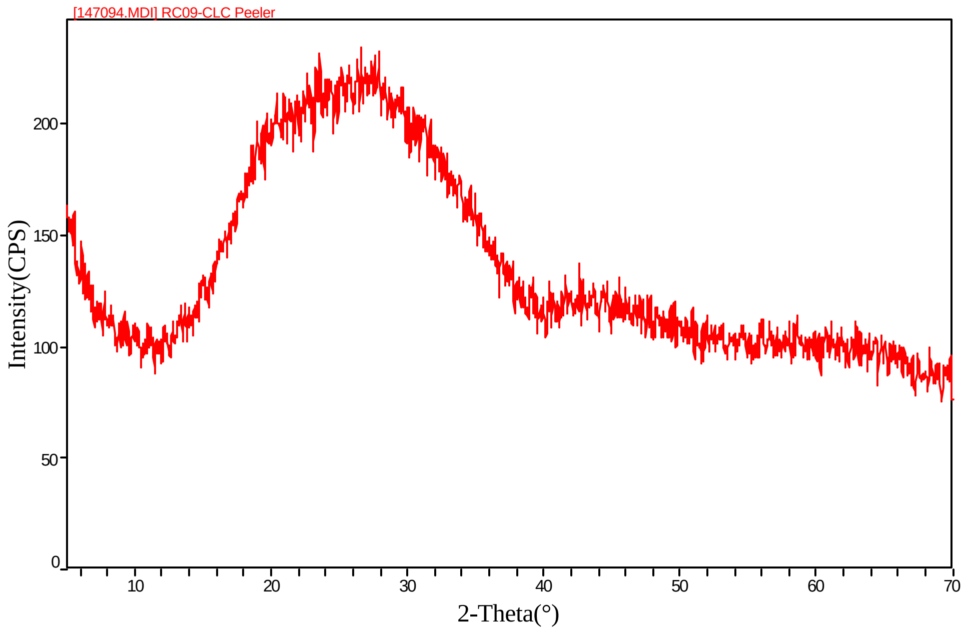

Exhibit F.9: XRD Results for RC-09 CLC.

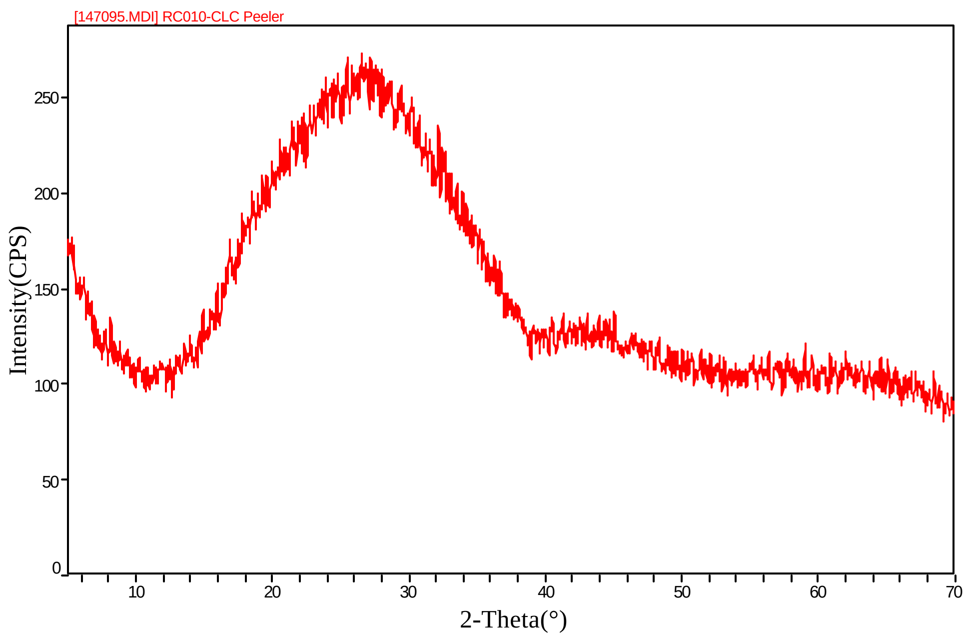

Exhibit F.10: XRD Results for RC-10 CLC.

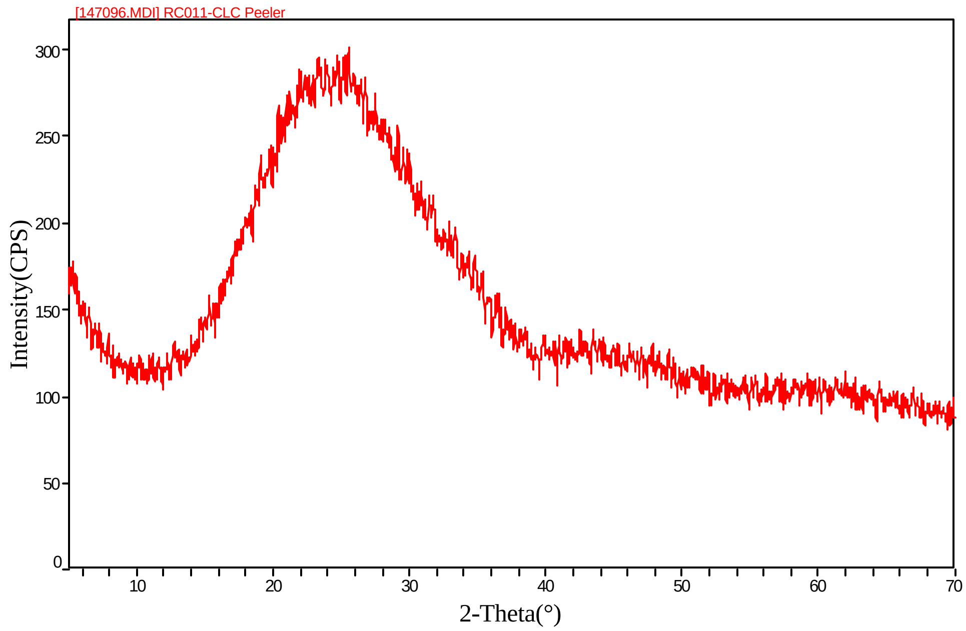

Exhibit F.11: XRD Results for RC-11 CLC.

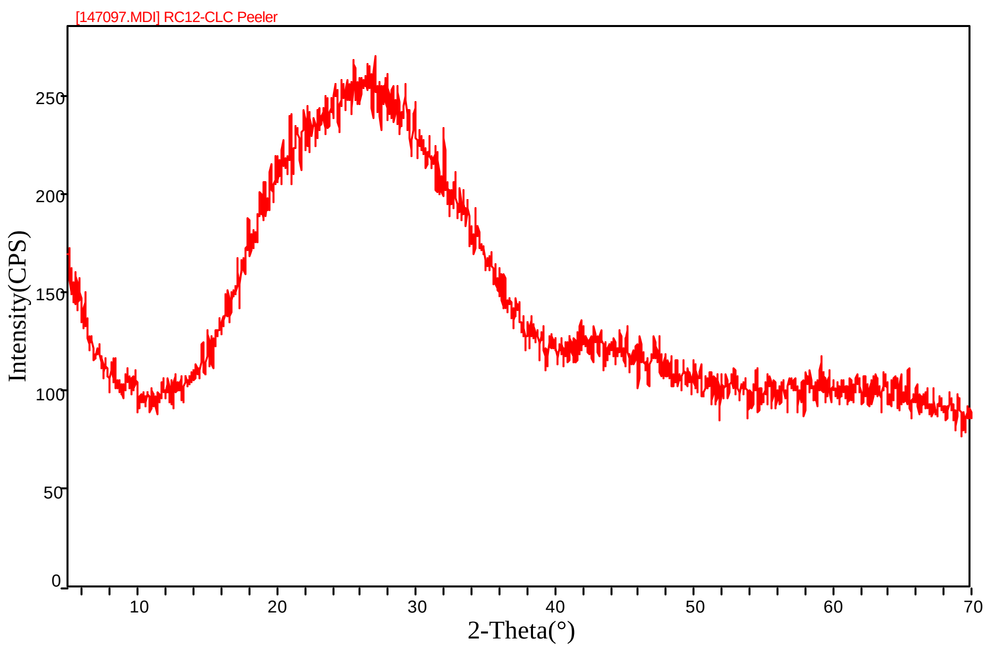

Exhibit F.12: XRD Results for RC-12 CLC.

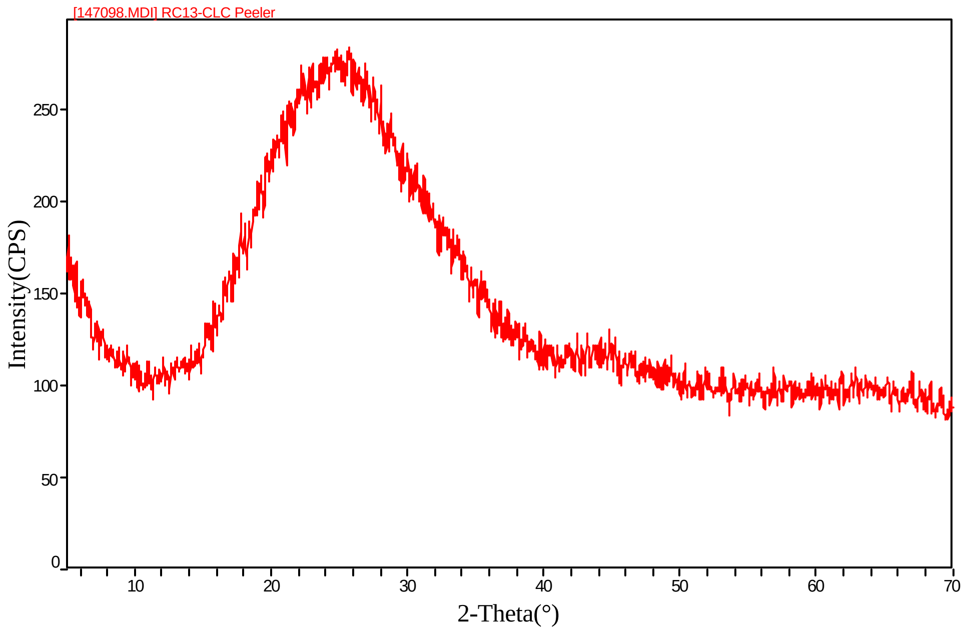

Exhibit F.13: XRD Results for RC-13 CLC.

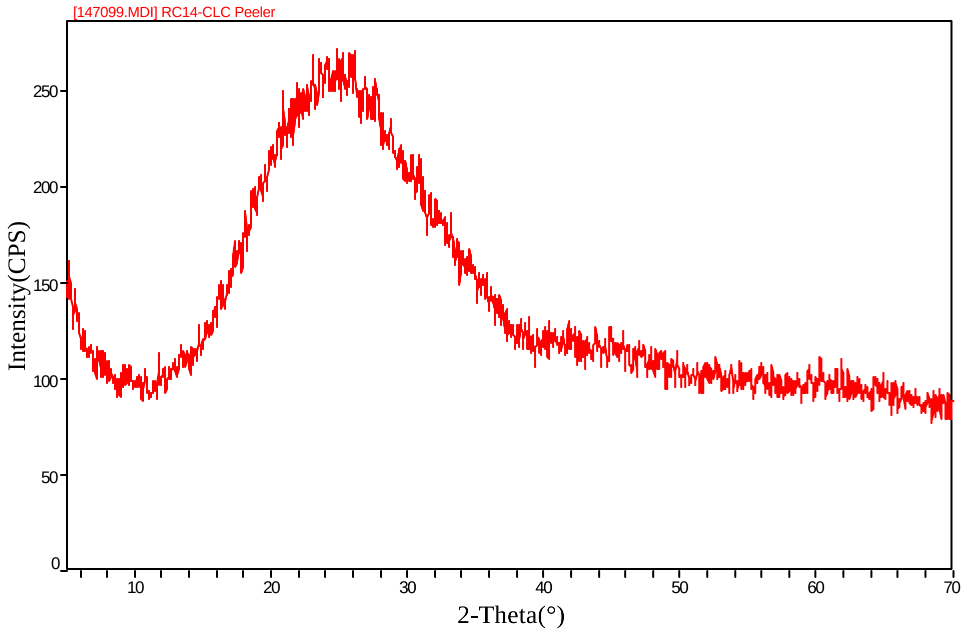

Exhibit F.14: XRD Results for RC-14 CLC.

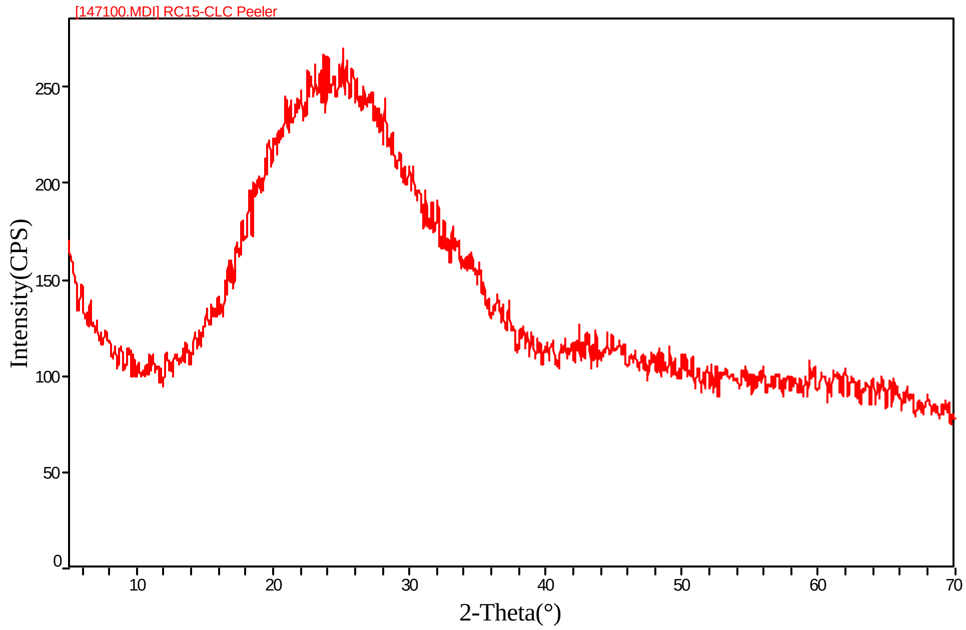

Exhibit F.15: XRD Results for RC-15 CLC.

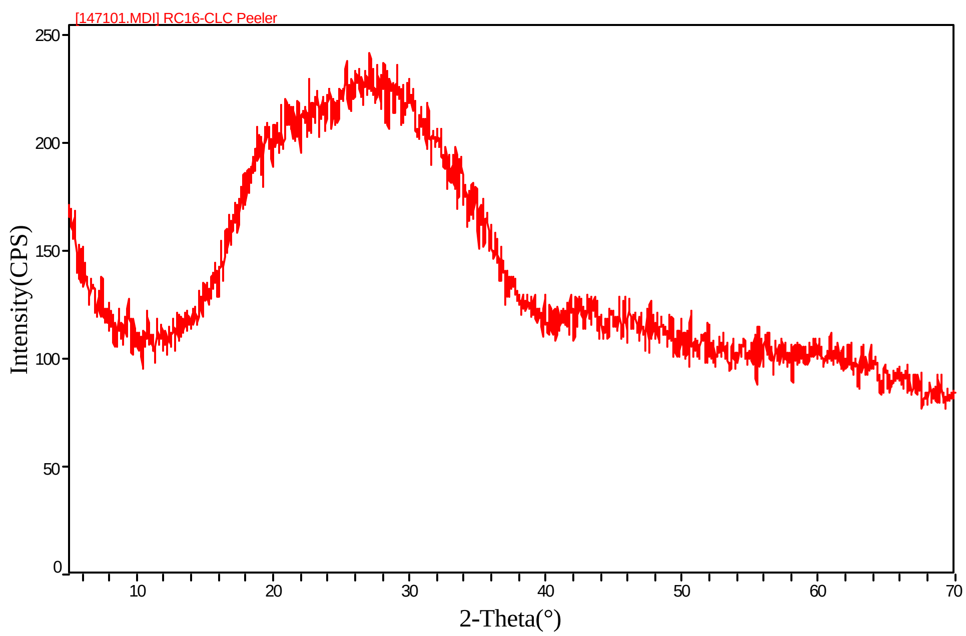

Exhibit F.16: XRD Results for RC-16 CLC.

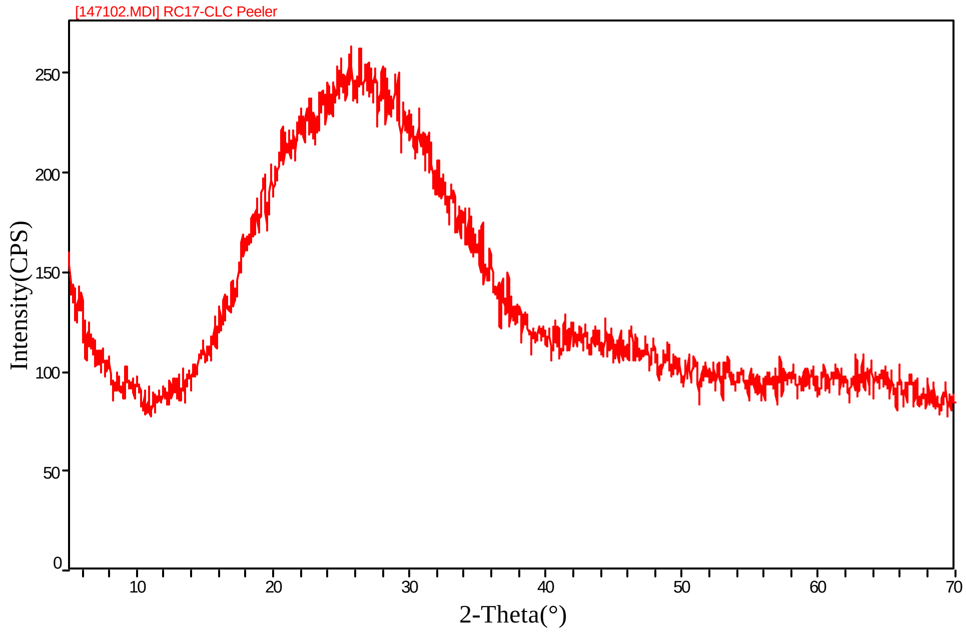

Exhibit F.17: XRD Results for RC-17 CLC.

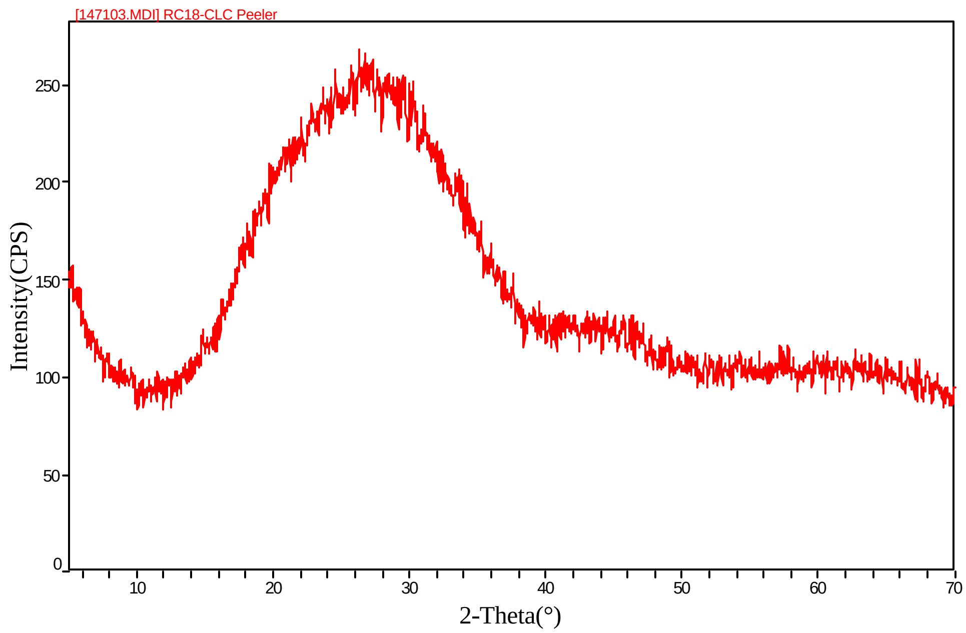

Exhibit F.18: XRD Results for RC-18 CLC.

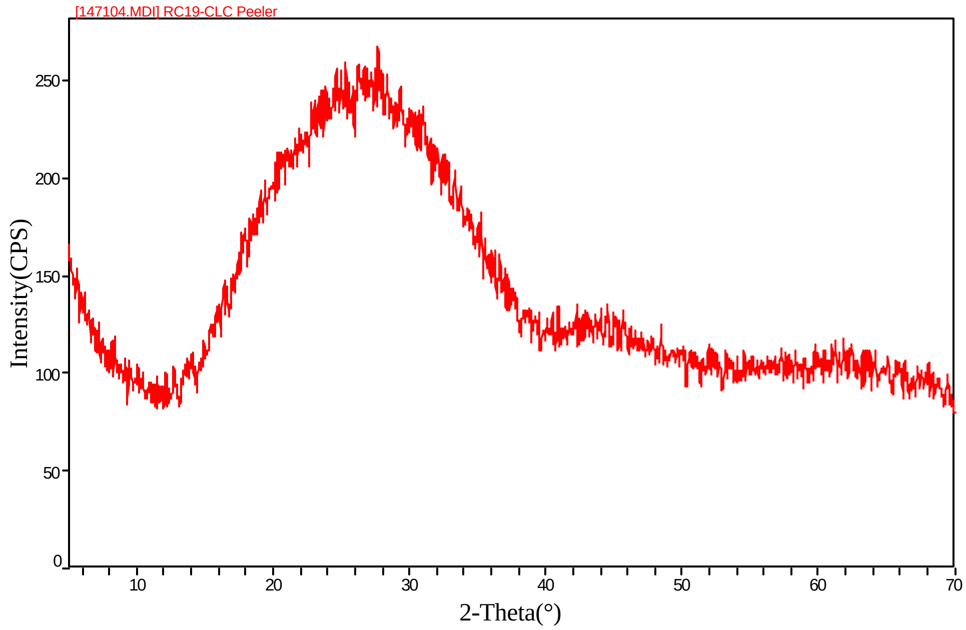

Exhibit F.19: XRD Results for RC-19 CLC.

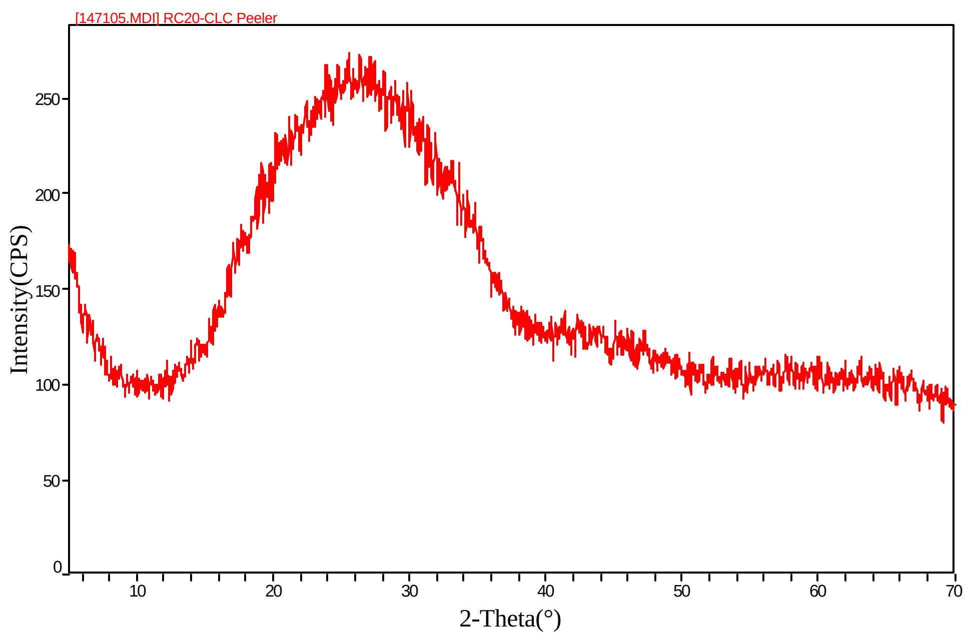

Exhibit F.20: XRD Results for RC-20 CLC.

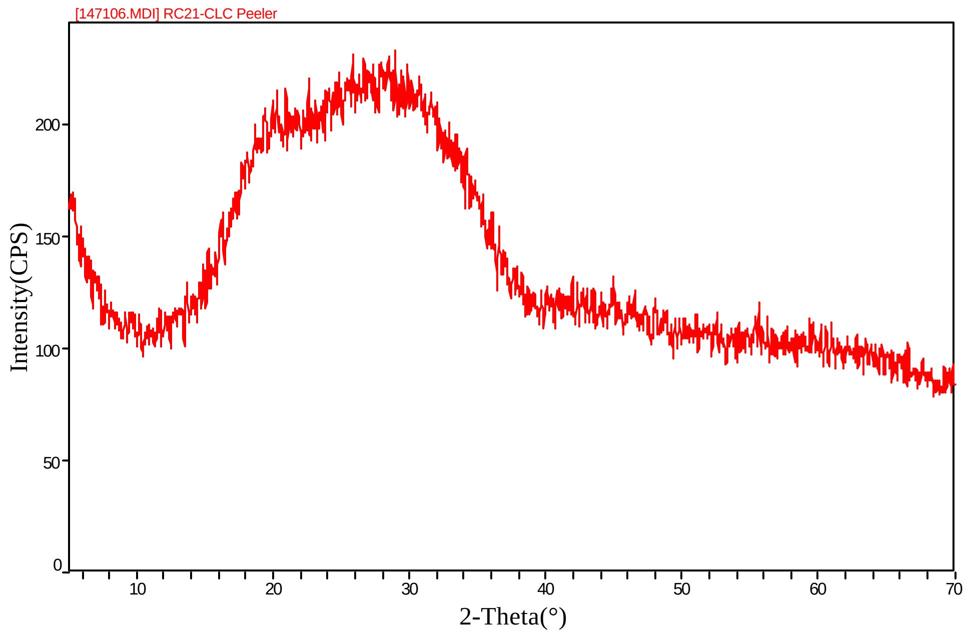

Exhibit F.21: XRD Results for RC-21 CLC.

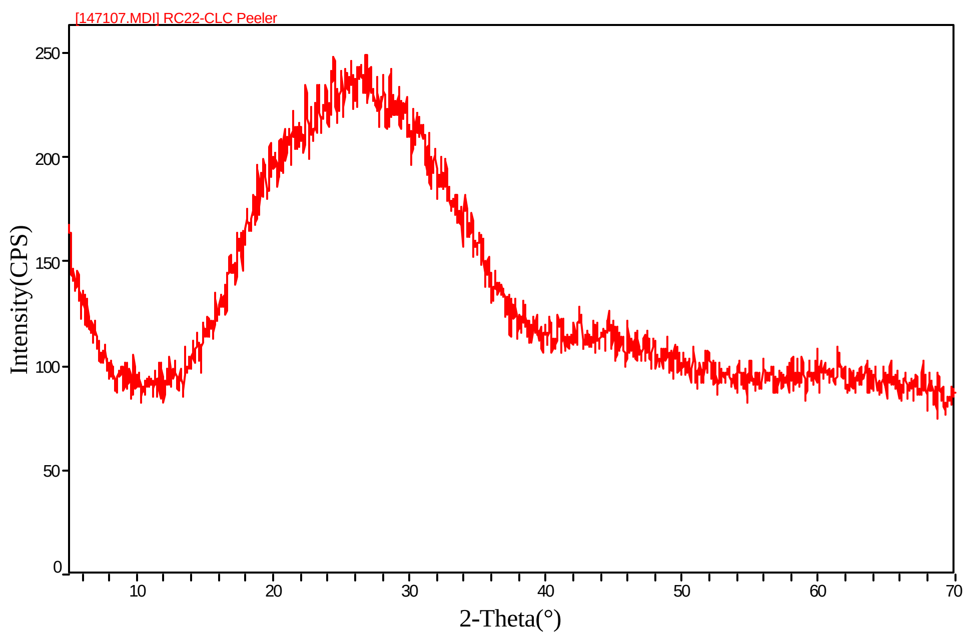

Exhibit F.22: XRD Results for RC-22 CLC.

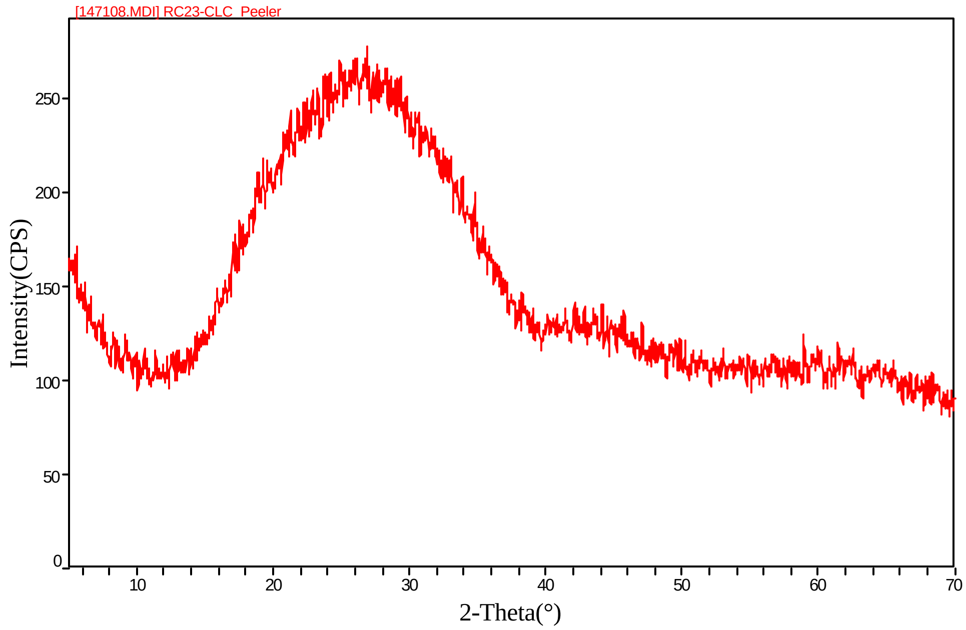

Exhibit F.23: XRD Results for RC-23 CLC.

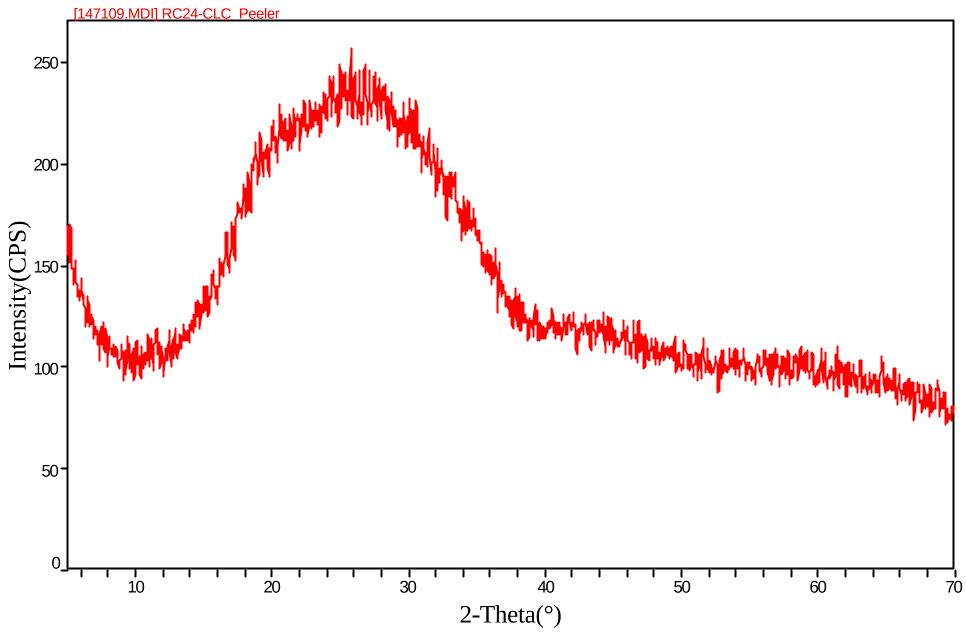

Exhibit F.24: XRD Results for RC-24 CLC.

Appendix G

PCT Raw Data and Analysis

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Table G1: Measurements of PCT Solutions As Reported by SRTC-ML

	Glass	Analytical		SRTC-ML	(as reported parts per million {ppm})										
Group	ID	Block	Sequence	ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
1	soln-std	1	1	std-b1-1	4.18	21.5	<0.100	4.36	9.81	<0.100	<0.100	80.0	0.282	49.8	<0.870
1	rc11	1	2	F18	4.03	11.3	<0.100	1.70	7.02	<0.100	<0.100	22.4	0.345	62	1.02
1	rc20	1	3	F28	5.10	31.6	<0.100	7.31	18.5	0.701	0.858	115	0.572	131	3.06
1	rc16clc	1	4	F10	5.00	21.0	<0.100	5.95	11.4	<0.010	0.190	78.3	0.524	97.2	1.84
1	rc06	1	5	F13	2.02	80.7	<0.100	11.2	34.1	3.61	0.643	224	0.298	266	0.828
1	rc20clc	1	6	F33	5.03	28.0	<0.100	5.57	16.9	<0.100	0.449	97.5	0.490	122	3.18
1	rc03	1	7	F76	4.18	54.8	<0.100	7.81	27.6	0.206	0.482	172	0.694	183	3.60
1	rc03clc	1	8	F35	3.79	46.5	<0.100	7.17	24.6	0.139	0.455	144	0.721	166	3.31
1	rc07clc	1	9	F48	4.31	14.9	<0.100	3.39	10.1	<0.100	<0.100	36.2	0.297	82.9	2.62
1	rc21clc	1	10	F73	5.25	21.0	<0.100	6.89	12.5	<0.100	0.417	92.6	0.531	108	2.01
1	rc14clc	1	11	F24	4.06	10.1	<0.100	2.00	7.83	<0.100	<0.100	22.1	0.323	62.2	0.958
1	EA	1	12	F20	0.238	40.4	<0.100	0.175	11.2	<0.100	<0.100	101	0.314	56.2	<0.870
1	rc14	1	13	F50	4.34	10.9	<0.100	1.89	8.75	<0.100	<0.100	23.5	0.390	66.4	1.21
1	rc07	1	14	F67	4.40	14.9	<0.100	3.60	10.6	<0.100	<0.100	37.1	0.297	84.7	2.75
1	soln-std	1	15	STD-B1-2	4.10	21.9	<0.100	4.76	9.98	<0.100	<0.100	79.4	0.286	51.9	<0.870
1	rc18	1	16	F27	1.22	79.5	<0.100	1.18	46.0	<0.100	<0.100	238	0.333	294	0.991
1	rc06clc	1	17	F15	1.53	81.1	<0.100	7.69	34.1	2.15	0.426	217	0.304	239	0.526
1	rc15	1	18	F62	2.42	18.2	<0.100	4.70	9.28	<0.100	0.0283	30.4	0.373	86.2	3.08
1	rc21	1	19	F38	5.23	21.7	<0.100	7.89	12.1	<0.100	0.522	100	0.573	112	1.84
1	rc15clc	1	20	F39	2.38	16.5	<0.100	4.79	8.40	<0.100	0.0407	28.5	0.374	82.9	3.10
1	rc18clc	1	21	F07	2.46	17.0	<0.100	4.74	8.63	<0.100	0.038	30.0	0.382	84.4	3.22
1	rc02	1	22	F21	1.71	61.4	<0.100	3.61	33.6	<0.100	0.205	131	0.414	249	1.49
1	rc02clc	1	23	F02	4.64	20.5	<0.100	5.54	9.93	<0.100	0.197	86.0	0.514	100	1.82
1	ARM	1	24	F70	3.40	12.5	<0.100	0.190	8.80	<0.100	<0.100	21.7	0.290	40.7	<0.870
1	rc04	1	25	F72	5.13	19.0	<0.100	6.53	8.39	<0.100	0.382	96.5	0.427	103	1.87
1	rc16	1	26	F77	5.75	21.1	<0.100	10.3	10.7	0.328	0.574	80.3	0.795	102	1.91
1	blank	1	27	F58	0.130	0.892	<0.100	0.223	0.399	<0.100	<0.100	<0.010	0.303	<0.790	<0.870
1	rc04clc	1	28	F68	5.56	17.9	<0.100	8.84	8.77	<0.100	0.699	86.5	0.560	101	2.23
1	rc11clc	1	29	F79	3.81	10.8	<0.100	1.52	6.30	<0.100	<0.100	21.9	0.327	60.8	0.870
1	soln-std	1	30	STD-B1-3	4.17	22.0	<0.100	4.77	10.0	<0.100	<0.100	79.8	0.286	53.2	<0.870
1	soln-std	2	1	STD-B2-1	3.82	22.7	<0.100	3.88	9.74	<0.100	<0.100	82.0	<0.100	49.0	<0.870
1	rc03clc	2	2	F45	2.96	43	<0.100	4.69	23.1	<0.100	<0.100	138	<0.100	153	2.88
1	rc06	2	3	F16	0.400	85.4	<0.100	1.03	35.5	<0.100	<0.100	236	<0.100	255	0.251
1	rc11clc	2	4	F66	3.36	12.1	<0.100	0.863	6.08	<0.100	<0.100	21.9	<0.100	56.5	0.847
1	rc15	2	5	F43	2.02	17.0	<0.100	3.89	8.96	<0.100	<0.100	30.7	<0.100	81.4	2.89
1	rc11	2	6	F41	3.41	10.9	<0.100	0.952	6.72	<0.100	<0.100	22.7	<0.100	58.4	0.809
1	rc16	2	7	F31	5.05	20.5	<0.100	8.22	10.6	<0.100	<0.100	81.7	0.0703	95.9	1.79
1	rc07	2	8	F30	3.95	14.5	<0.100	2.89	10.3	<0.100	<0.100	36.8	<0.100	80.4	2.59
1	EA	2	9	F34	<0.100	38.7	<0.100	<0.100	10.8	<0.100	<0.100	99.7	<0.100	52.9	<0.870
1	rc04	2	10	F22	5.18	19.7	<0.100	7.27	8.56	<0.100	<0.100	100	<0.100	103	1.78
1	rc04clc	2	11	F69	5.01	17.7	<0.100	7.29	8.45	<0.100	0.025	87.4	<0.100	95.2	1.74
1	rc20clc	2	12	F11	4.07	25.4	<0.100	4.10	15.7	<0.100	<0.100	92.8	<0.100	111	2.68
1	rc21	2	13	F06	4.77	21.2	<0.100	6.33	11.9	<0.100	<0.100	101	<0.100	109	1.55
1	rc14	2	14	F03	3.88	10.4	<0.100	1.25	8.40	<0.100	<0.100	23.5	<0.100	63.2	1.19
1	soln-std	2	15	STD-B2-2	3.71	20.8	<0.100	3.78	9.60	<0.100	<0.100	79.7	<0.100	48.7	<0.870
1	rc21clc	2	16	F36	4.87	20.2	<0.100	6.31	12.2	<0.100	<0.100	93.8	<0.100	108	1.66
1	rc03	2	17	F75	3.87	48.7	<0.100	7.97	25.1	0.093	0.046	157	0.134	165	3.20
1	rc06clc	2	18	F60	1.08	79.5	<0.100	6.19	34.2	1.05	<0.100	220	<0.100	249	0.363
1	rc14clc	2	19	F61	0.719	6.93	<0.100	0.214	4.08	<0.100	<0.100	12.1	<0.100	30.4	<0.870
1	ARM	2	20	F23	0.364	6.72	<0.100	<0.100	4.47	<0.100	<0.100	11.8	<0.100	18.2	<0.870
1	rc18clc	2	21	F80	1.33	60.5	<0.100	2.03	37.9	<0.100	<0.100	196	<0.100	241	1.40
1	rc18	2	22	F08	1.64	79.2	<0.100	3.93	47.9	<0.100	<0.100	248	<0.100	307	1.39
1	rc16clc	2	23	F19	5.70	26.8	<0.100	6.40	14.0	<0.100	<0.100	95.9	<0.100	115	2.00

1	rc15clc	2	24	F64	2.14	16.5	<0.100	3.85	8.33	<0.100	<0.100	30.5	<0.100	77.9	2.96
1	rc02clc	2	25	F74	4.25	19.6	<0.100	4.92	9.69	<0.100	<0.100	85.4	<0.100	97.1	1.83
1	rc02	2	26	F56	4.91	21.9	<0.100	6.01	10.1	<0.100	<0.100	99.3	<0.100	106	1.64
1	rc07clc	2	27	F46	3.77	13.5	<0.100	2.55	9.42	<0.100	<0.100	34.8	<0.100	76.0	2.37
1	rc20	2	28	F59	4.26	32.1	<0.100	5.07	19.2	<0.100	<0.100	118	<0.100	133	3.03
1	soln-std	2	29	STD-B2-3	3.78	21.4	<0.100	3.78	9.75	<0.100	<0.100	80.8	<0.100	48.5	<0.870
1	soln-std	3	1	STD-B3-1	4.30	21.8	<0.100	3.99	9.79	<0.100	<0.100	80.2	<0.100	48.8	<0.870

Table G1: Measurements of PCT Solutions As Reported by SRTC-ML *(continued)*

Group	Glass ID	Analytical Block	Analytical Sequence	SRTC-ML ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
					(as reported parts per million {ppm})										
1	rc14	3	2	F71	4.37	10.2	<0.100	1.69	8.2	<0.100	<0.100	23.9	<0.100	60.1	1.46
1	rc20	3	3	F05	5.16	33.6	<0.100	5.86	20.4	<0.100	0.064	126	<0.100	140	3.44
1	rc04clc	3	4	F44	5.53	17.5	<0.100	7.51	8.67	<0.100	0.157	89.1	<0.100	93.9	2.21
1	rc18clc	3	5	F51	1.98	59.7	<0.100	2.59	38.6	<0.100	<0.100	199	<0.100	244	1.91
1	rc04	3	6	F78	5.49	19.6	<0.100	5.97	8.68	<0.100	<0.100	101	<0.100	100	2.20
1	rc16	3	7	F53	5.48	21.5	<0.100	6.59	11.5	<0.100	<0.100	86.4	<0.100	97.6	2.16
1	rc11	3	8	F42	3.97	10.8	<0.100	1.09	6.93	<0.100	<0.100	23.4	<0.100	57.3	1.15
1	rc14clc	3	9	F25	4.16	9.57	<0.100	1.38	7.85	<0.100	<0.100	24.0	<0.100	59.1	1.35
1	rc21clc	3	10	F57	5.94	18.7	<0.100	8.93	11.8	<0.100	0.296	89.6	0.108	102	2.05
1	rc07	3	11	F32	4.51	13.9	<0.100	2.91	10.4	<0.100	<0.100	37.5	<0.100	78.9	2.96
1	rc15	3	12	F65	2.58	16.3	<0.100	3.71	9.09	<0.100	<0.100	31.3	<0.100	80.0	3.30
1	rc06	3	13	F12	2.13	78.8	<0.100	9.78	34.8	2.70	0.124	232	<0.100	261	0.952
1	rc11clc	3	14	F01	3.74	10.8	<0.100	0.963	5.96	<0.100	<0.100	21.6	<0.100	53.3	0.995
1	soln-std	3	15	STD-B3-2	4.20	20.3	<0.100	3.90	9.63	<0.100	<0.100	77.8	<0.100	47.3	<0.870
1	rc02	3	16	F09	5.13	20.6	<0.100	5.81	9.73	<0.100	<0.100	94.1	<0.100	101	2.02
1	rc20clc	3	17	F26	4.60	25.3	<0.100	3.94	16.1	<0.100	<0.100	93.4	<0.100	113	2.99
1	rc06clc	3	18	F37	1.55	72.6	<0.100	6.13	33.2	0.986	<0.100	213	<0.100	242	0.697
1	EA	3	19	F04	0.274	36.1	<0.100	<0.100	10.9	<0.100	<0.100	99.7	<0.100	47.2	<0.870
1	rc02clc	3	20	F29	4.77	18.5	<0.100	5.33	9.62	<0.100	<0.100	83.9	<0.100	90.7	1.91
1	rc18	3	21	F47	1.17	74.3	<0.100	0.284	46.5	<0.100	<0.100	250	<0.100	278	1.11
1	rc15clc	3	22	F54	2.67	16.2	<0.100	3.89	8.38	<0.100	<0.100	30.4	<0.100	73.1	3.04
1	rc03	3	23	F49	3.65	48.4	<0.100	5.52	26.0	<0.100	<0.100	167	<0.100	157	3.35
1	ARM	3	24	F14	3.54	11.2	<0.100	<0.100	8.35	<0.100	<0.100	21.1	<0.100	31.8	<0.870
1	rc03clc	3	25	F40	3.49	41.4	<0.100	5.23	23.7	<0.100	<0.100	144	<0.100	147	3.13
1	rc16clc	3	26	F55	4.74	19.3	<0.100	4.85	11.1	<0.100	<0.100	77.1	<0.100	86.0	1.65
1	blank	3	27	F52	0.201	0.550	<0.100	<0.100	0.363	<0.100	<0.100	<0.010	<0.100	<0.790	<0.870
1	rc21	3	28	F63	5.86	18.8	<0.100	9.03	11.7	<0.100	<0.100	101	0.129	100	2.42
1	rc07clc	3	29	F17	4.42	12.5	<0.100	2.72	9.59	<0.100	<0.100	34.2	<0.100	70.6	2.56
1	soln-std	3	30	STD-B3-3	4.09	19.5	<0.100	3.84	9.76	<0.100	<0.100	80.6	<0.100	43.8	<0.870
2	soln-std	1	1	STD-B1-1	4.06	21.6	<0.100	4.30	10.3	<0.100	<0.100	85.3	<0.100	51	<0.870
2	rc17	1	2	H38	1.24	90.1	<0.100	3.26	46.2	<0.100	0.220	238	<0.100	268	1.70
2	rc09clc	1	3	H27	2.01	70.3	<0.100	13.3	38.2	1.66	1.70	183	0.116	234	9.26
2	rc22	1	4	H05	4.52	30.5	<0.100	4.91	14.4	<0.100	<0.100	97.2	<0.100	100	2.64
2	rc24	1	5	H72	3.82	15.4	<0.100	3.99	8.02	<0.100	<0.100	65.9	<0.100	85.2	1.69
2	rc09	1	6	H23	2.74	82.5	<0.100	19.2	46.9	4.04	2.96	225	0.355	285	12.9
2	rc12	1	7	H69	4.34	28.4	<0.100	3.88	12.1	<0.100	<0.100	91.1	<0.100	96.7	2.51
2	rc13	1	8	H55	1.39	25.4	<0.100	2.11	15.3	<0.100	<0.100	47.5	<0.100	106	2.34
2	rc19	1	9	H19	2.44	47.4	<0.100	7.46	28.6	<0.100	0.196	174	<0.100	204	3.23
2	rc13clc	1	10	H80	1.25	24.7	<0.100	2.01	14.4	<0.100	<0.100	45.8	<0.100	103	2.17
2	rc01	1	11	H06	2.36	42.4	<0.100	5.74	25.5	<0.100	<0.100	142	<0.100	169	3.82
2	rc23clc	1	12	H35	2.87	31.0	<0.100	3.52	20.0	<0.100	<0.100	119	<0.100	137	2.47
2	EA	1	13	H34	<0.100	45.7	<0.100	<0.100	13.1	<0.100	<0.100	119	<0.100	62.7	<0.870
2	rc22clc	1	14	H25	3.89	27.9	<0.100	4.06	14.0	<0.100	<0.100	87.5	<0.100	101	2.49
2	soln-std	1	15	STD-B1-2	4.06	21.4	<0.100	4.30	10.1	<0.100	<0.100	81.9	<0.100	51.1	<0.870
2	rc08	1	16	H65	1.28	32.5	<0.100	3.03	16.4	<0.100	<0.100	101	<0.100	147	4.72
2	rc10clc	1	17	H42	2.07	57.4	<0.100	6.67	35.9	<0.100	0.763	195	<0.100	236	2.52
2	rc01clc	1	18	H47	2.50	36.0	<0.100	5.42	22.9	<0.100	<0.100	122	<0.100	155	4.12
2	blank	1	19	H45	<0.100	0.121	<0.100	<0.100	0.321	<0.100	<0.100	<0.100	<0.100	<0.100	<0.870
2	rc05clc	1	20	H08	2.92	27.0	<0.100	3.56	13.6	<0.100	<0.100	112	<0.100	124	3.37
2	rc19clc	1	21	H73	2.49	44.4	<0.100	6.85	27.3	<0.100	0.141	159	<0.100	194	3.31
2	rc23	1	22	H10	2.65	40.2	<0.100	3.88	25.0	<0.100	<0.100	151	<0.100	171	2.58
2	ARM	1	23	H58	3.00	13.1	<0.100	<0.100	9.80	<0.100	<0.100	25.8	<0.100	42	<0.870

2	rc12clc	1	24	H57	3.81	25.0	<0.100	3.13	11.5	<0.100	<0.100	80.4	<0.100	93.5	2.35
2	rc05	1	25	H37	2.85	30.1	<0.100	3.87	14.1	<0.100	<0.100	124	<0.100	131	3.16
2	rc24clc	1	26	H75	3.72	14.7	<0.100	3.46	8.14	<0.100	<0.100	62.0	<0.100	82.7	1.78
2	rc10	1	27	H07	2.13	65.6	<0.100	8.82	39.5	0.685	1.29	222	0.203	264	2.69
2	rc17clc	1	28	H54	2.63	77.9	<0.100	10.8	42.9	2.37	1.81	208	<0.100	255	2.54
2	rc08clc	1	29	H44	1.34	29.1	<0.100	3.36	14.8	<0.100	<0.100	87.6	<0.100	131	4.75
2	soln-std	1	30	STD-B1-3	4.03	21.1	<0.100	4.32	10.1	<0.100	<0.100	82.2	<0.100	50.2	<0.870
2	soln-std	2	1	STD-B2-1	4.02	22.3	<0.100	4.29	10.0	<0.100	<0.100	83.4	<0.100	50.7	<0.870

Table G1: Measurements of PCT Solutions As Reported by SRTC-ML *(continued)*

	Glass	Analytical		SRTC-ML	(as reported parts per million {ppm})										
Group	ID	Block	Sequence	ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
2	rc10	2	2	H71	2.17	65.6	<0.100	8.98	39.1	1.50	1.42	222	0.609	258	2.32
2	rc09	2	3	H20	2.52	78.1	<0.100	15.7	42.0	3.65	2.51	206	0.626	251	11.1
2	rc13clc	2	4	H67	1.41	24.8	<0.100	2.57	14.2	<0.100	<0.100	46.2	<0.100	102	2.00
2	rc17clc	2	5	H48	2.66	81.2	<0.100	11.0	43.7	3.17	1.94	219	0.529	256	2.21
2	rc24clc	2	6	H33	4.19	15.3	<0.100	5.29	8.06	<0.100	0.143	64.2	<0.100	83.1	1.62
2	rc09clc	2	7	H31	2.09	65.4	<0.100	13.0	35.8	2.58	1.90	175	0.545	219	9.34
2	rc05	2	8	H14	2.94	30.9	<0.100	4.86	14.2	<0.100	0.225	128	0.194	131	3.03
2	rc08	2	9	H21	1.44	30.6	<0.100	3.43	15.2	<0.100	<0.100	95.1	<0.100	135	4.29
2	rc01clc	2	10	H50	2.48	35.8	<0.100	5.49	22.5	<0.100	<0.100	123	<0.100	152	3.73
2	rc13	2	11	H15	1.71	26.7	<0.100	3.17	16.0	<0.100	<0.100	50.0	<0.100	107	2.19
2	rc22clc	2	12	H40	4.51	29.0	<0.100	5.32	14.5	<0.100	<0.100	93.8	0.149	104	2.54
2	rc12clc	2	13	H66	3.62	24.3	<0.100	3.32	11.1	<0.100	<0.100	78.9	0.144	89.3	1.88
2	rc12	2	14	H41	4.39	27.9	<0.100	4.54	11.9	<0.100	0.201	91.5	0.212	93.3	2.22
2	soln-std	2	15	STD-B2-2	3.98	23.2	<0.100	4.16	10.5	<0.100	<0.100	87.8	<0.100	49.5	<0.870
2	ARM	2	16	H53	2.96	13.3	<0.100	<0.100	9.62	<0.100	<0.100	25.8	<0.100	41.2	<0.870
2	rc17	2	17	H52	2.53	96.3	<0.100	9.84	51.1	2.44	1.64	252	0.46	289	2.31
2	rc22	2	18	H63	5.07	34.1	<0.100	5.94	15.9	<0.100	0.137	110	0.348	108	2.73
2	rc19	2	19	H02	2.77	50.1	<0.100	8.26	29.7	<0.100	0.395	187	0.303	207	3.28
2	rc24	2	20	H77	4.30	16.8	<0.100	4.73	8.55	<0.100	<0.100	73.3	<0.100	90.4	1.62
2	rc01	2	21	H29	2.34	41.7	<0.100	5.88	25.1	<0.100	<0.100	141	<0.100	169	3.63
2	rc10clc	2	22	H04	1.88	54.5	<0.100	6.97	33.7	0.532	0.937	188	0.449	221	2.30
2	rc23	2	23	H11	2.77	39.7	<0.100	4.79	24.4	<0.100	0.365	151	0.283	166	2.35
2	rc05clc	2	24	H51	2.89	27.9	<0.100	4.60	13.7	<0.100	0.115	112	0.14	125	2.80
2	rc08clc	2	25	H56	1.46	28.0	<0.100	4.32	14.2	<0.100	<0.100	85.8	0.185	125	4.20
2	rc23clc	2	26	H39	2.51	32.4	<0.100	2.95	20.4	<0.100	<0.100	121	0.144	140	2.00
2	EA	2	27	H24	<0.100	44.5	<0.100	<0.100	12.6	<0.100	<0.100	117	<0.100	60.9	<0.870
2	rc19clc	2	28	H62	2.36	41.5	<0.100	6.52	25.5	<0.100	0.256	152	0.202	178	2.85
2	soln-std	2	29	STD-B2-2	3.90	23.5	<0.100	4.26	10.6	<0.100	<0.100	88.4	<0.100	49.1	<0.870
2	soln-std	3	1	STD-B3-1	3.88	21.1	<0.100	4.26	9.96	<0.100	<0.100	80.5	<0.100	49.7	<0.870
2	rc09clc	3	2	H79	1.99	66.2	<0.100	12.5	36.0	2.20	1.72	174	0.247	224	9.86
2	rc17clc	3	3	H74	1.55	73.1	<0.100	5.17	39.9	<0.100	0.418	197	<0.100	233	2.33
2	rc01	3	4	H01	2.40	41.6	<0.100	5.59	25.0	<0.100	<0.100	139	<0.100	169	3.95
2	rc13clc	3	5	H36	1.40	24.7	<0.100	2.28	14.5	<0.100	<0.100	45.9	<0.100	106	2.38
2	rc12	3	6	H26	4.30	28.1	<0.100	4.05	12.0	<0.100	<0.100	89.2	<0.100	95.2	2.66
2	rc09	3	7	H13	2.26	75.9	<0.100	14.5	41.4	3.09	2.23	202	0.336	249	10.9
2	rc10clc	3	8	H60	1.75	54.8	<0.100	6.43	33.7	0.281	0.82	184	0.213	223	2.56
2	rc22clc	3	9	H76	3.77	28.0	<0.100	4.00	14.0	<0.100	<0.100	87.0	<0.100	99.7	2.60
2	EA	3	10	H09	<0.100	45.6	<0.100	<0.100	13.1	<0.100	<0.100	118	<0.100	61.3	<0.870
2	rc08	3	11	H30	1.32	29.8	<0.100	2.62	14.9	<0.100	<0.100	91.0	<0.100	133	4.43
2	rc23clc	3	12	H12	2.81	31.8	<0.100	2.56	20.2	<0.100	<0.100	119	<0.100	139	2.39
2	rc10	3	13	H70	2.19	64.8	<0.100	9.06	38.7	1.40	1.39	216	0.411	259	2.82
2	rc12clc	3	14	H16	3.46	24.5	<0.100	2.92	11.2	<0.100	<0.100	77.1	<0.100	89.7	2.33
2	soln-std	3	15	STD-B3-2	3.87	21.2	<0.100	4.22	10.0	<0.100	<0.100	81.0	<0.100	50.0	<0.870
2	rc01clc	3	16	H78	2.51	38.3	<0.100	4.74	23.6	<0.100	<0.100	126	<0.100	159	4.28
2	rc24	3	17	H18	4.03	16.1	<0.100	3.91	8.36	<0.100	<0.100	68.6	<0.100	86.7	1.90
2	rc17	3	18	H46	2.19	91.7	<0.100	8.16	48.6	1.46	1.22	243	0.111	280	2.59
2	blank	3	19	H22	<0.100	0.672	<0.100	<0.100	0.402	<0.100	<0.100	<0.100	<0.100	<0.100	<0.870
2	rc13	3	20	H17	1.55	25.5	<0.100	2.24	15.2	<0.100	<0.100	46.9	<0.100	104	2.43
2	rc24clc	3	21	H28	3.96	15.9	<0.100	3.33	8.66	<0.100	<0.100	65.2	<0.100	85.7	2.11
2	ARM	3	22	H49	2.74	11.7	<0.100	<0.100	8.98	<0.100	<0.100	23.2	<0.100	37.6	<0.870
2	rc19clc	3	23	H59	2.33	42.3	<0.100	5.78	26.5	<0.100	<0.100	156	<0.100	185	3.32
2	rc05	3	24	H43	3.11	28.6	<0.100	5.20	13.3	<0.100	0.292	117	<0.100	124	3.26

2	rc22	3	25	H64	4.69	31.1	<0.100	4.87	14.7	<0.100	<0.100	99.1	<0.100	102	2.82
2	rc23	3	26	H68	2.81	40.0	<0.100	4.60	24.3	<0.100	0.303	148	<0.100	166	2.69
2	rc05clc	3	27	H32	2.41	27.7	<0.100	3.00	13.9	<0.100	<0.100	110	<0.100	124	3.14
2	rc08clc	3	28	H61	1.37	30.7	<0.100	3.03	15.9	<0.100	<0.100	93.8	<0.100	138	4.79
2	rc19	3	29	H03	2.66	46.8	<0.100	7.60	28.3	<0.100	0.290	176	<0.100	199	3.44
2	soln-std	3	30	STDB3-3	3.93	21.6	<0.100	4.22	10.1	<0.100	<0.100	82.4	<0.100	52.1	<0.870

Table G2: PCT Measurements for RC Glasses

	Glass	Analytical		SRTC-ML	Values are given in parts per million (ppm)										
Group	ID	Block	Sequence	ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
1	soln-std	1	1	std-b1-1	4.180	21.500	0.050	4.360	9.810	0.050	0.050	80.000	0.282	49.800	0.435
1	rc11	1	2	F18	6.717	18.834	0.083	2.833	11.700	0.083	0.083	37.334	0.575	103.335	1.700
1	rc20	1	3	F28	8.500	52.668	0.083	12.184	30.834	1.168	1.430	191.671	0.953	218.338	5.100
1	rc16clc	1	4	F10	8.334	35.001	0.083	9.917	19.000	0.008	0.317	130.503	0.873	162.003	3.067
1	rc06	1	5	F13	3.367	134.503	0.083	18.667	56.834	6.017	1.072	373.341	0.497	443.342	1.380
1	rc20clc	1	6	F33	8.384	46.668	0.083	9.284	28.167	0.083	0.748	162.503	0.817	203.337	5.300
1	rc03	1	7	F76	6.967	91.335	0.083	13.017	46.001	0.343	0.803	286.672	1.157	305.006	6.000
1	rc03clc	1	8	F35	6.317	77.502	0.083	11.950	41.001	0.232	0.758	240.005	1.202	276.672	5.517
1	rc07clc	1	9	F48	7.183	24.834	0.083	5.650	16.834	0.083	0.083	60.335	0.495	138.169	4.367
1	rc21clc	1	10	F73	8.750	35.001	0.083	11.484	20.834	0.083	0.695	154.336	0.885	180.004	3.350
1	rc14clc	1	11	F24	6.767	16.834	0.083	3.333	13.050	0.083	0.083	36.834	0.538	103.669	1.597
1	EA	1	12	F20	3.967	673.347	0.833	2.917	186.670	0.833	0.833	1683.367	5.233	936.685	7.250
1	rc14	1	13	F50	7.233	18.167	0.083	3.150	14.584	0.083	0.083	39.167	0.650	110.669	2.017
1	rc07	1	14	F67	7.333	24.834	0.083	6.000	17.667	0.083	0.083	61.835	0.495	141.170	4.583
1	soln-std	1	15	STD-B1-2	4.100	21.900	0.050	4.760	9.980	0.050	0.050	79.400	0.286	51.900	0.435
1	rc18	1	16	F27	2.033	132.503	0.083	1.967	76.668	0.083	0.083	396.675	0.555	490.010	1.652
1	rc06clc	1	17	F15	2.550	135.169	0.083	12.817	56.834	3.583	0.710	361.674	0.507	398.341	0.877
1	rc15	1	18	F62	4.033	30.334	0.083	7.833	15.467	0.083	0.047	50.668	0.622	143.670	5.133
1	rc21	1	19	F38	8.717	36.167	0.083	13.150	20.167	0.083	0.870	166.670	0.955	186.670	3.067
1	rc15clc	1	20	F39	3.967	27.501	0.083	7.983	14.000	0.083	0.068	47.501	0.623	138.169	5.167
1	rc18clc	1	21	F07	4.100	28.334	0.083	7.900	14.384	0.083	0.063	50.001	0.637	140.670	5.367
1	rc02	1	22	F21	2.850	102.335	0.083	6.017	56.001	0.083	0.342	218.338	0.690	415.008	2.483
1	rc02clc	1	23	F02	7.733	34.167	0.083	9.234	16.550	0.083	0.328	143.336	0.857	166.670	3.033
1	ARM	1	24	F70	5.667	20.834	0.083	0.317	14.667	0.083	0.083	36.167	0.483	67.835	0.725
1	rc04	1	25	F72	8.550	31.667	0.083	10.884	13.984	0.083	0.637	160.837	0.712	171.670	3.117
1	rc16	1	26	F77	9.584	35.167	0.083	17.167	17.834	0.547	0.957	133.836	1.325	170.003	3.183
1	blank	1	27	F58	0.217	1.487	0.083	0.372	0.665	0.083	0.083	0.008	0.505	0.658	0.725
1	rc04clc	1	28	F68	9.267	29.834	0.083	14.734	14.617	0.083	1.165	144.170	0.933	168.337	3.717
1	rc11clc	1	29	F79	6.350	18.000	0.083	2.533	10.500	0.083	0.083	36.501	0.545	101.335	1.450
1	soln-std	1	30	STD-B1-3	4.170	22.000	0.050	4.770	10.000	0.050	0.050	79.800	0.286	53.200	0.435
1	soln-std	2	1	STD-B2-1	3.820	22.700	0.050	3.880	9.740	0.050	0.050	82.000	0.050	49.000	0.435
1	rc03clc	2	2	F45	4.933	71.668	0.083	7.817	38.501	0.083	0.083	230.005	0.083	255.005	4.800
1	rc06	2	3	F16	0.667	142.336	0.083	1.717	59.168	0.083	0.083	393.341	0.083	425.009	0.418
1	rc11clc	2	4	F66	5.600	20.167	0.083	1.438	10.134	0.083	0.083	36.501	0.083	94.169	1.412
1	rc15	2	5	F43	3.367	28.334	0.083	6.483	14.934	0.083	0.083	51.168	0.083	135.669	4.817
1	rc11	2	6	F41	5.683	18.167	0.083	1.587	11.200	0.083	0.083	37.834	0.083	97.335	1.348
1	rc16	2	7	F31	8.417	34.167	0.083	13.700	17.667	0.083	0.083	136.169	0.117	159.837	2.983
1	rc07	2	8	F30	6.583	24.167	0.083	4.817	17.167	0.083	0.083	61.335	0.083	134.003	4.317
1	EA	2	9	F34	0.833	645.013	0.833	0.833	180.004	0.833	0.833	1661.700	0.833	881.684	7.250
1	rc04	2	10	F22	8.634	32.834	0.083	12.117	14.267	0.083	0.083	166.670	0.083	171.670	2.967
1	rc04clc	2	11	F69	8.350	29.501	0.083	12.150	14.084	0.083	0.042	145.670	0.083	158.670	2.900
1	rc20clc	2	12	F11	6.783	42.334	0.083	6.833	26.167	0.083	0.083	154.670	0.083	185.004	4.467
1	rc21	2	13	F06	7.950	35.334	0.083	10.550	19.834	0.083	0.083	168.337	0.083	181.670	2.583
1	rc14	2	14	F03	6.467	17.334	0.083	2.083	14.000	0.083	0.083	39.167	0.083	105.335	1.983
1	soln-std	2	15	STD-B2-2	3.710	20.800	0.050	3.780	9.600	0.050	0.050	79.700	0.050	48.700	0.435
1	rc21clc	2	16	F36	8.117	33.667	0.083	10.517	20.334	0.083	0.083	156.337	0.083	180.004	2.767
1	rc03	2	17	F75	6.450	81.168	0.083	13.284	41.834	0.155	0.077	261.672	0.223	275.006	5.333
1	rc06clc	2	18	F60	1.800	132.503	0.083	10.317	57.001	1.750	0.083	366.674	0.083	415.008	0.605
1	rc14clc	2	19	F61	1.198	11.550	0.083	0.357	6.800	0.083	0.083	20.167	0.083	50.668	0.725
1	ARM	2	20	F23	0.607	11.200	0.083	0.083	7.450	0.083	0.083	19.667	0.083	30.334	0.725
1	rc18clc	2	21	F80	2.217	100.835	0.083	3.383	63.168	0.083	0.083	326.673	0.083	401.675	2.333
1	rc18	2	22	F08	2.733	132.003	0.083	6.550	79.835	0.083	0.083	413.342	0.083	511.677	2.317

1	rc16clc	2	23	F19	9.500	44.668	0.083	10.667	23.334	0.083	0.083	159.837	0.083	191.671	3.333
1	rc15clc	2	24	F64	3.567	27.501	0.083	6.417	13.884	0.083	0.083	50.834	0.083	129.836	4.933
1	rc02clc	2	25	F74	7.083	32.667	0.083	8.200	16.150	0.083	0.083	142.336	0.083	161.837	3.050
1	rc02	2	26	F56	8.183	36.501	0.083	10.017	16.834	0.083	0.083	165.503	0.083	176.670	2.733
1	rc07clc	2	27	F46	6.283	22.500	0.083	4.250	15.700	0.083	0.083	58.001	0.083	126.669	3.950
1	rc20	2	28	F59	7.100	53.501	0.083	8.450	32.001	0.083	0.083	196.671	0.083	221.671	5.050
1	soln-std	2	29	STD-B2-3	3.780	21.400	0.050	3.780	9.750	0.050	0.050	80.800	0.050	48.500	0.435
1	soln-std	3	1	STD-B3-1	4.300	21.800	0.050	3.990	9.790	0.050	0.050	80.200	0.050	48.800	0.435

Shaded rows highlight PCTs with water loss problems.

Table G2: PCT Measurements for RC Glasses *(continued)*

	Glass	Analytical		SRTC-ML	Values are given in parts per million (ppm)										
Group	ID	Block	Sequence	ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
1	rc14	3	2	F71	7.283	17.000	0.083	2.817	13.667	0.083	0.083	39.834	0.083	100.169	2.433
1	rc20	3	3	F05	8.600	56.001	0.083	9.767	34.001	0.083	0.107	210.004	0.083	233.338	5.733
1	rc04clc	3	4	F44	9.217	29.167	0.083	12.517	14.450	0.083	0.262	148.503	0.083	156.503	3.683
1	rc18clc	3	5	F51	3.300	99.502	0.083	4.317	64.335	0.083	0.083	331.673	0.083	406.675	3.183
1	rc04	3	6	F78	9.150	32.667	0.083	9.950	14.467	0.083	0.083	168.337	0.083	166.670	3.667
1	rc16	3	7	F53	9.134	35.834	0.083	10.984	19.167	0.083	0.083	144.003	0.083	162.670	3.600
1	rc11	3	8	F42	6.617	18.000	0.083	1.817	11.550	0.083	0.083	39.001	0.083	95.502	1.917
1	rc14clc	3	9	F25	6.933	15.950	0.083	2.300	13.084	0.083	0.083	40.001	0.083	98.502	2.250
1	rc21clc	3	10	F57	9.900	31.167	0.083	14.884	19.667	0.083	0.493	149.336	0.180	170.003	3.417
1	rc07	3	11	F32	7.517	23.167	0.083	4.850	17.334	0.083	0.083	62.501	0.083	131.503	4.933
1	rc15	3	12	F65	4.300	27.167	0.083	6.183	15.150	0.083	0.083	52.168	0.083	133.336	5.500
1	rc06	3	13	F12	3.550	131.336	0.083	16.300	58.001	4.500	0.207	386.674	0.083	435.009	1.587
1	rc11clc	3	14	F01	6.233	18.000	0.083	1.605	9.934	0.083	0.083	36.001	0.083	88.835	1.658
1	soln-std	3	15	STD-B3-2	4.200	20.300	0.050	3.900	9.630	0.050	0.050	77.800	0.050	47.300	0.435
1	rc02	3	16	F09	8.550	34.334	0.083	9.684	16.217	0.083	0.083	156.837	0.083	168.337	3.367
1	rc20clc	3	17	F26	7.667	42.168	0.083	6.567	26.834	0.083	0.083	155.670	0.083	188.337	4.983
1	rc06clc	3	18	F37	2.583	121.002	0.083	10.217	55.334	1.643	0.083	355.007	0.083	403.341	1.162
1	EA	3	19	F04	4.567	601.679	0.833	0.833	181.670	0.833	0.833	1661.700	0.833	786.682	7.250
1	rc02clc	3	20	F29	7.950	30.834	0.083	8.884	16.034	0.083	0.083	139.836	0.083	151.170	3.183
1	rc18	3	21	F47	1.950	123.836	0.083	0.473	77.502	0.083	0.083	416.675	0.083	463.343	1.850
1	rc15clc	3	22	F54	4.450	27.001	0.083	6.483	13.967	0.083	0.083	50.668	0.083	121.836	5.067
1	rc03	3	23	F49	6.083	80.668	0.083	9.200	43.334	0.083	0.083	278.339	0.083	261.672	5.583
1	ARM	3	24	F14	5.900	18.667	0.083	0.083	13.917	0.083	0.083	35.167	0.083	53.001	0.725
1	rc03clc	3	25	F40	5.817	69.001	0.083	8.717	39.501	0.083	0.083	240.005	0.083	245.005	5.217
1	rc16clc	3	26	F55	7.900	32.167	0.083	8.083	18.500	0.083	0.083	128.503	0.083	143.336	2.750
1	blank	3	27	F52	0.335	0.917	0.083	0.083	0.605	0.083	0.083	0.008	0.083	0.658	0.725
1	rc21	3	28	F63	9.767	31.334	0.083	15.050	19.500	0.083	0.083	168.337	0.215	166.670	4.033
1	rc07clc	3	29	F17	7.367	20.834	0.083	4.533	15.984	0.083	0.083	57.001	0.083	117.669	4.267
1	soln-std	3	30	STD-B3-3	4.090	19.500	0.050	3.840	9.760	0.050	0.050	80.600	0.050	43.800	0.435
2	soln-std	1	1	STD-B1-1	4.060	21.600	0.050	4.300	10.300	0.050	0.050	85.300	0.050	51.000	0.435
2	rc17	1	2	H38	2.067	150.170	0.083	5.433	77.002	0.083	0.367	396.675	0.083	446.676	2.833
2	rc09clc	1	3	H27	3.350	117.169	0.083	22.167	63.668	2.767	2.833	305.006	0.193	390.008	15.434
2	rc22	1	4	H05	7.533	50.834	0.083	8.183	24.000	0.083	0.083	162.003	0.083	166.670	4.400
2	rc24	1	5	H72	6.367	25.667	0.083	6.650	13.367	0.083	0.083	109.836	0.083	142.003	2.817
2	rc09	1	6	H23	4.567	137.503	0.083	32.001	78.168	6.733	4.933	375.008	0.592	475.010	21.500
2	rc12	1	7	H69	7.233	47.334	0.083	6.467	20.167	0.083	0.083	151.836	0.083	161.170	4.183
2	rc13	1	8	H55	2.317	42.334	0.083	3.517	25.501	0.083	0.083	79.168	0.083	176.670	3.900
2	rc19	1	9	H19	4.067	79.002	0.083	12.434	47.668	0.083	0.327	290.006	0.083	340.007	5.383
2	rc13clc	1	10	H80	2.083	41.167	0.083	3.350	24.000	0.083	0.083	76.335	0.083	171.670	3.617
2	rc01	1	11	H06	3.933	70.668	0.083	9.567	42.501	0.083	0.083	236.671	0.083	281.672	6.367
2	rc23clc	1	12	H35	4.783	51.668	0.083	5.867	33.334	0.083	0.083	198.337	0.083	228.338	4.117
2	EA	1	13	H34	0.833	761.682	0.833	0.833	218.338	0.833	0.833	1983.373	0.833	1045.021	7.250
2	rc22clc	1	14	H25	6.483	46.501	0.083	6.767	23.334	0.083	0.083	145.836	0.083	168.337	4.150
2	soln-std	1	15	STD-B1-2	4.060	21.400	0.050	4.300	10.100	0.050	0.050	81.900	0.050	51.100	0.435
2	rc08	1	16	H65	2.133	54.168	0.083	5.050	27.334	0.083	0.083	168.337	0.083	245.005	7.867
2	rc10clc	1	17	H42	3.450	95.669	0.083	11.117	59.835	0.083	1.272	325.007	0.083	393.341	4.200
2	rc01clc	1	18	H47	4.167	60.001	0.083	9.034	38.167	0.083	0.083	203.337	0.083	258.339	6.867
2	blank	1	19	H45	0.083	0.202	0.083	0.083	0.535	0.083	0.083	0.083	0.083	0.083	0.725
2	rc05clc	1	20	H08	4.867	45.001	0.083	5.933	22.667	0.083	0.083	186.670	0.083	206.671	5.617
2	rc19clc	1	21	H73	4.150	74.001	0.083	11.417	45.501	0.083	0.235	265.005	0.083	323.340	5.517
2	rc23	1	22	H10	4.417	67.001	0.083	6.467	41.668	0.083	0.083	251.672	0.083	285.006	4.300
2	ARM	1	23	H58	5.000	21.834	0.083	0.083	16.334	0.083	0.083	43.001	0.083	70.001	0.725

2	rc12clc	1	24	H57	6.350	41.668	0.083	5.217	19.167	0.083	0.083	134.003	0.083	155.837	3.917
2	rc05	1	25	H37	4.750	50.168	0.083	6.450	23.500	0.083	0.083	206.671	0.083	218.338	5.267
2	rc24clc	1	26	H75	6.200	24.500	0.083	5.767	13.567	0.083	0.083	103.335	0.083	137.836	2.967
2	rc10	1	27	H07	3.550	109.336	0.083	14.700	65.835	1.142	2.150	370.007	0.338	440.009	4.483
2	rc17clc	1	28	H54	4.383	129.836	0.083	18.000	71.501	3.950	3.017	346.674	0.083	425.009	4.233
2	rc08clc	1	29	H44	2.233	48.501	0.083	5.600	24.667	0.083	0.083	146.003	0.083	218.338	7.917
2	soln-std	1	30	STD-B1-3	4.030	21.100	0.050	4.320	10.100	0.050	0.050	82.200	0.050	50.200	0.435
2	soln-std	2	1	STD-B2-1	4.020	22.300	0.050	4.290	10.000	0.050	0.050	83.400	0.050	50.700	0.435

Shaded rows highlight PCTs with water loss problems.

Table G2: PCT Measurements for RC Glasses *(continued)*

	Glass	Analytical		SRTC-ML	Values are given in parts per million (ppm)										
Group	ID	Block	Sequence	ID	Al	B	Ca	Fe	Li	Mg	Mn	Na	Ni	Si	U
2	rc10	2	2	H71	3.617	109.336	0.083	14.967	65.168	2.500	2.367	370.007	1.015	430.009	3.867
2	rc09	2	3	H20	4.200	130.169	0.083	26.167	70.001	6.083	4.183	343.340	1.043	418.342	18.500
2	rc13clc	2	4	H67	2.350	41.334	0.083	4.283	23.667	0.083	0.083	77.002	0.083	170.003	3.333
2	rc17clc	2	5	H48	4.433	135.336	0.083	18.334	72.835	5.283	3.233	365.007	0.882	426.675	3.683
2	rc24clc	2	6	H33	6.983	25.501	0.083	8.817	13.434	0.083	0.238	107.002	0.083	138.503	2.700
2	rc09clc	2	7	H31	3.483	109.002	0.083	21.667	59.668	4.300	3.167	291.673	0.908	365.007	15.567
2	rc05	2	8	H14	4.900	51.501	0.083	8.100	23.667	0.083	0.375	213.338	0.323	218.338	5.050
2	rc08	2	9	H21	2.400	51.001	0.083	5.717	25.334	0.083	0.083	158.503	0.083	225.005	7.150
2	rc01clc	2	10	H50	4.133	59.668	0.083	9.150	37.501	0.083	0.083	205.004	0.083	253.338	6.217
2	rc13	2	11	H15	2.850	44.501	0.083	5.283	26.667	0.083	0.083	83.335	0.083	178.337	3.650
2	rc22clc	2	12	H40	7.517	48.334	0.083	8.867	24.167	0.083	0.083	156.337	0.248	173.337	4.233
2	rc12clc	2	13	H66	6.033	40.501	0.083	5.533	18.500	0.083	0.083	131.503	0.240	148.836	3.133
2	rc12	2	14	H41	7.317	46.501	0.083	7.567	19.834	0.083	0.335	152.503	0.353	155.503	3.700
2	soln-std	2	15	STD-B2-2	3.980	23.200	0.050	4.160	10.500	0.050	0.050	87.800	0.050	49.500	0.435
2	ARM	2	16	H53	4.933	22.167	0.083	0.083	16.034	0.083	0.083	43.001	0.083	68.668	0.725
2	rc17	2	17	H52	4.217	160.503	0.083	16.400	85.168	4.067	2.733	420.008	0.767	481.676	3.850
2	rc22	2	18	H63	8.450	56.834	0.083	9.900	26.501	0.083	0.228	183.337	0.580	180.004	4.550
2	rc19	2	19	H02	4.617	83.502	0.083	13.767	49.501	0.083	0.658	311.673	0.505	345.007	5.467
2	rc24	2	20	H77	7.167	28.001	0.083	7.883	14.250	0.083	0.083	122.169	0.083	150.670	2.700
2	rc01	2	21	H29	3.900	69.501	0.083	9.800	41.834	0.083	0.083	235.005	0.083	281.672	6.050
2	rc10clc	2	22	H04	3.133	90.835	0.083	11.617	56.168	0.887	1.562	313.340	0.748	368.341	3.833
2	rc23	2	23	H11	4.617	66.168	0.083	7.983	40.667	0.083	0.608	251.672	0.472	276.672	3.917
2	rc05clc	2	24	H51	4.817	46.501	0.083	7.667	22.834	0.083	0.192	186.670	0.233	208.338	4.667
2	rc08clc	2	25	H56	2.433	46.668	0.083	7.200	23.667	0.083	0.083	143.003	0.308	208.338	7.000
2	rc23clc	2	26	H39	4.183	54.001	0.083	4.917	34.001	0.083	0.083	201.671	0.240	233.338	3.333
2	EA	2	27	H24	0.833	741.682	0.833	0.833	210.004	0.833	0.833	1950.039	0.833	1015.020	7.250
2	rc19clc	2	28	H62	3.933	69.168	0.083	10.867	42.501	0.083	0.427	253.338	0.337	296.673	4.750
2	soln-std	2	29	STD-B2-2	3.900	23.500	0.050	4.260	10.600	0.050	0.050	88.400	0.050	49.100	0.435
2	soln-std	3	1	STD-B3-1	3.880	21.100	0.050	4.260	9.960	0.050	0.050	80.500	0.050	49.700	0.435
2	rc09clc	3	2	H79	3.317	110.336	0.083	20.834	60.001	3.667	2.867	290.006	0.412	373.341	16.434
2	rc17clc	3	3	H74	2.583	121.836	0.083	8.617	66.501	0.083	0.697	328.340	0.083	388.341	3.883
2	rc01	3	4	H01	4.000	69.335	0.083	9.317	41.668	0.083	0.083	231.671	0.083	281.672	6.583
2	rc13clc	3	5	H36	2.333	41.167	0.083	3.800	24.167	0.083	0.083	76.502	0.083	176.670	3.967
2	rc12	3	6	H26	7.167	46.834	0.083	6.750	20.000	0.083	0.083	148.670	0.083	158.670	4.433
2	rc09	3	7	H13	3.767	126.503	0.083	24.167	69.001	5.150	3.717	336.673	0.560	415.008	18.167
2	rc10clc	3	8	H60	2.917	91.335	0.083	10.717	56.168	0.468	1.367	306.673	0.355	371.674	4.267
2	rc22clc	3	9	H76	6.283	46.668	0.083	6.667	23.334	0.083	0.083	145.003	0.083	166.170	4.333
2	EA	3	10	H09	0.833	760.015	0.833	0.833	218.338	0.833	0.833	1966.706	0.833	1021.687	7.250
2	rc08	3	11	H30	2.200	49.668	0.083	4.367	24.834	0.083	0.083	151.670	0.083	221.671	7.383
2	rc23clc	3	12	H12	4.683	53.001	0.083	4.267	33.667	0.083	0.083	198.337	0.083	231.671	3.983
2	rc10	3	13	H70	3.650	108.002	0.083	15.100	64.501	2.333	2.317	360.007	0.685	431.675	4.700
2	rc12clc	3	14	H16	5.767	40.834	0.083	4.867	18.667	0.083	0.083	128.503	0.083	149.503	3.883
2	soln-std	3	15	STD-B3-2	3.870	21.200	0.050	4.220	10.000	0.050	0.050	81.000	0.050	50.000	0.435
2	rc01clc	3	16	H78	4.183	63.835	0.083	7.900	39.334	0.083	0.083	210.004	0.083	265.005	7.133
2	rc24	3	17	H18	6.717	26.834	0.083	6.517	13.934	0.083	0.083	114.336	0.083	144.503	3.167
2	rc17	3	18	H46	3.650	152.836	0.083	13.600	81.002	2.433	2.033	405.008	0.185	466.676	4.317
2	blank	3	19	H22	0.083	1.120	0.083	0.083	0.670	0.083	0.083	0.083	0.083	0.083	0.725
2	rc13	3	20	H17	2.583	42.501	0.083	3.733	25.334	0.083	0.083	78.168	0.083	173.337	4.050
2	rc24clc	3	21	H28	6.600	26.501	0.083	5.550	14.434	0.083	0.083	108.669	0.083	142.836	3.517
2	ARM	3	22	H49	4.567	19.500	0.083	0.083	14.967	0.083	0.083	38.667	0.083	62.668	0.725
2	rc19clc	3	23	H59	3.883	70.501	0.083	9.634	44.168	0.083	0.083	260.005	0.083	308.340	5.533
2	rc05	3	24	H43	5.183	47.668	0.083	8.667	22.167	0.083	0.487	195.004	0.083	206.671	5.433

2	rc22	3	25	H64	7.817	51.834	0.083	8.117	24.500	0.083	0.083	165.170	0.083	170.003	4.700
2	rc23	3	26	H68	4.683	66.668	0.083	7.667	40.501	0.083	0.505	246.672	0.083	276.672	4.483
2	rc05clc	3	27	H32	4.017	46.168	0.083	5.000	23.167	0.083	0.083	183.337	0.083	206.671	5.233
2	rc08clc	3	28	H61	2.283	51.168	0.083	5.050	26.501	0.083	0.083	156.337	0.083	230.005	7.983
2	rc19	3	29	H03	4.433	78.002	0.083	12.667	47.168	0.083	0.483	293.339	0.083	331.673	5.733
2	soln-std	3	30	STDB3-3	3.930	21.600	0.050	4.220	10.100	0.050	0.050	82.400	0.050	52.100	0.435

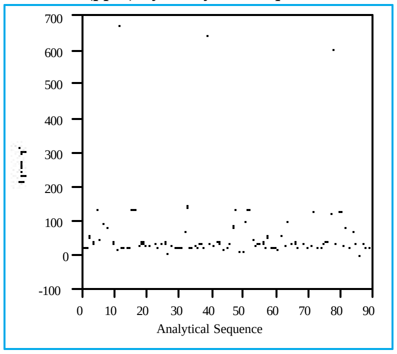
Shaded rows highlight PCTs with water loss problems.

Exhibit G1: SRTC-ML PCT Measurements By Group in Analytical Sequence Including All RC Glasses, EA, ARM, blank, and Samples of the Solution Standard

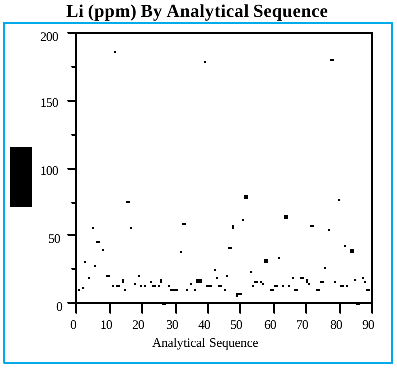
(PCTs experiencing water loss problems are not included)

Group 1

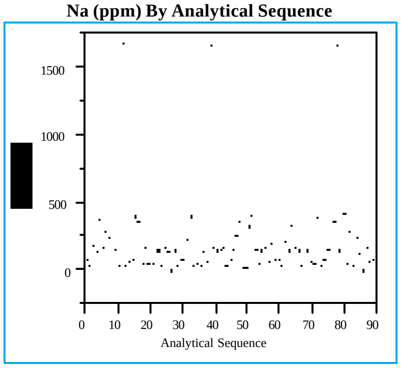
B (ppm) By Analytical Sequence



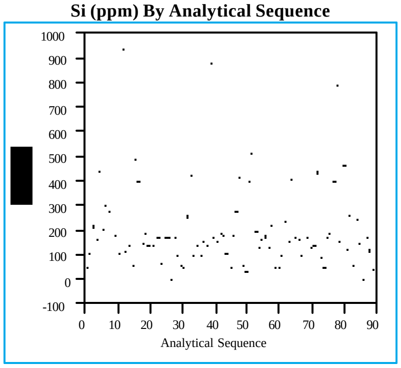
Li (ppm) By Analytical Sequence



Na (ppm) By Analytical Sequence

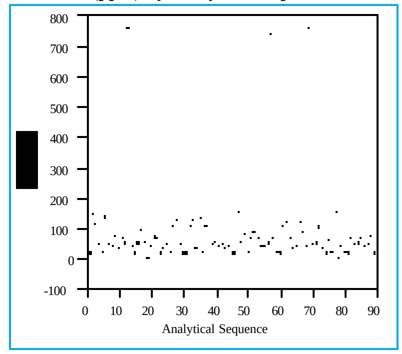


Si (ppm) By Analytical Sequence

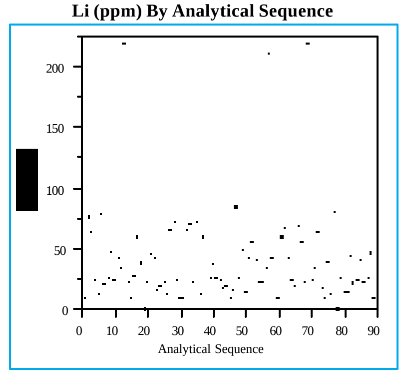


Group 2

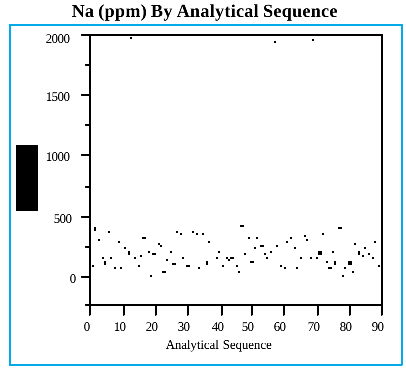
B (ppm) By Analytical Sequence



Li (ppm) By Analytical Sequence



Na (ppm) By Analytical Sequence



Si (ppm) By Analytical Sequence

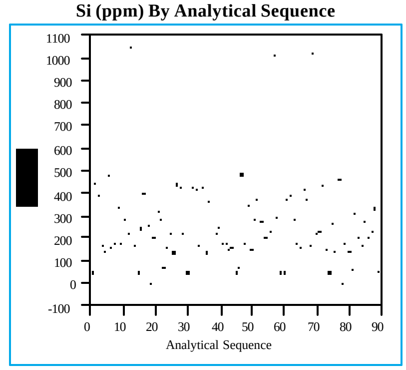
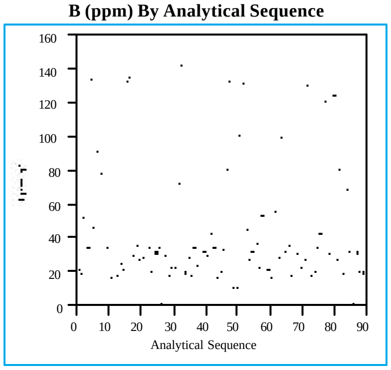


Exhibit G2: SRTC-ML PCT Measurements By Group in Analytical Sequence Including All RC Glasses, and Samples of the Solution Standard but excluding EA

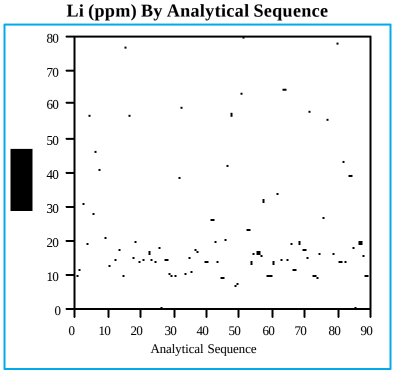
(PCTs experiencing water loss problems are not included)

Group 1

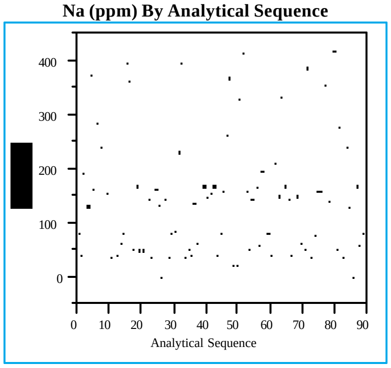
B (ppm) By Analytical Sequence



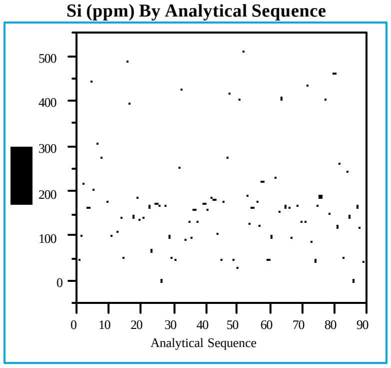
Li (ppm) By Analytical Sequence



Na (ppm) By Analytical Sequence

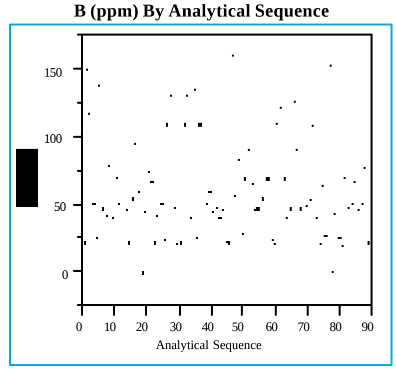


Si (ppm) By Analytical Sequence

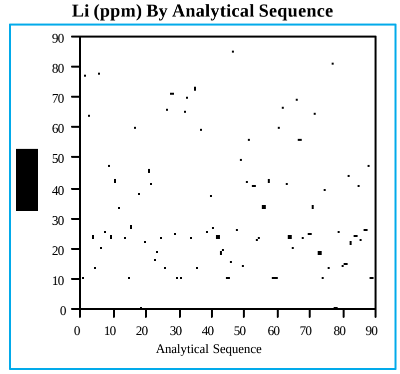


Group 2

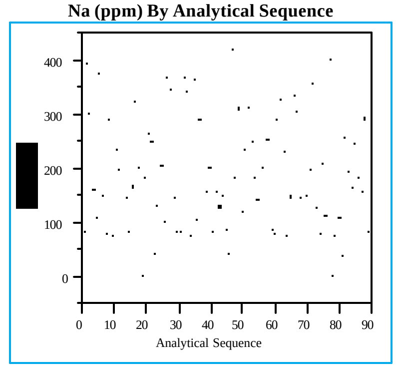
B (ppm) By Analytical Sequence



Li (ppm) By Analytical Sequence



Na (ppm) By Analytical Sequence



Si (ppm) By Analytical Sequence

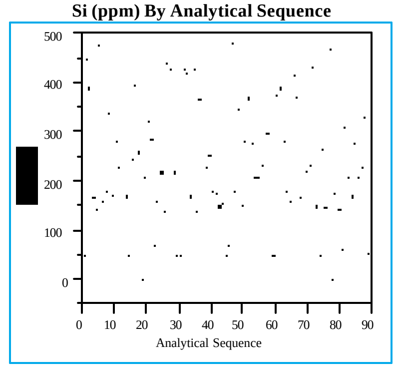
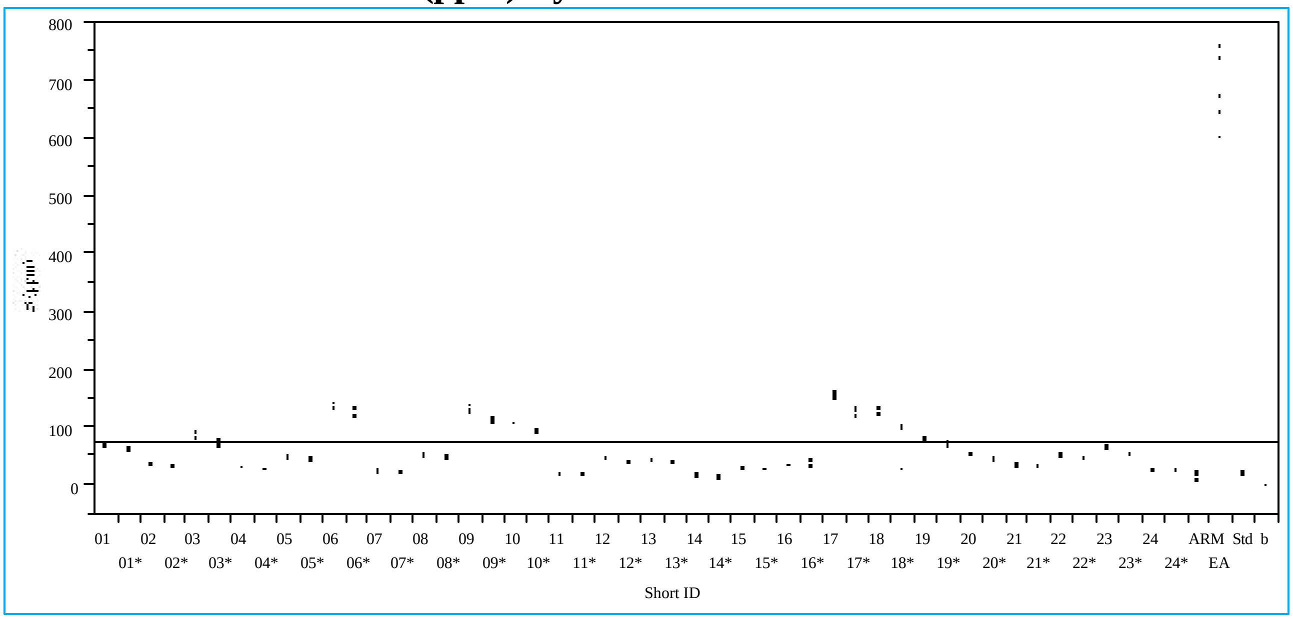


Exhibit G3: SRTC-ML PCT Measurements for Boron and Lithium from All RC Glasses, EA, ARM, blank, and Samples of the Solution Standard

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

B (ppm) By Short ID



Li (ppm) By Short ID

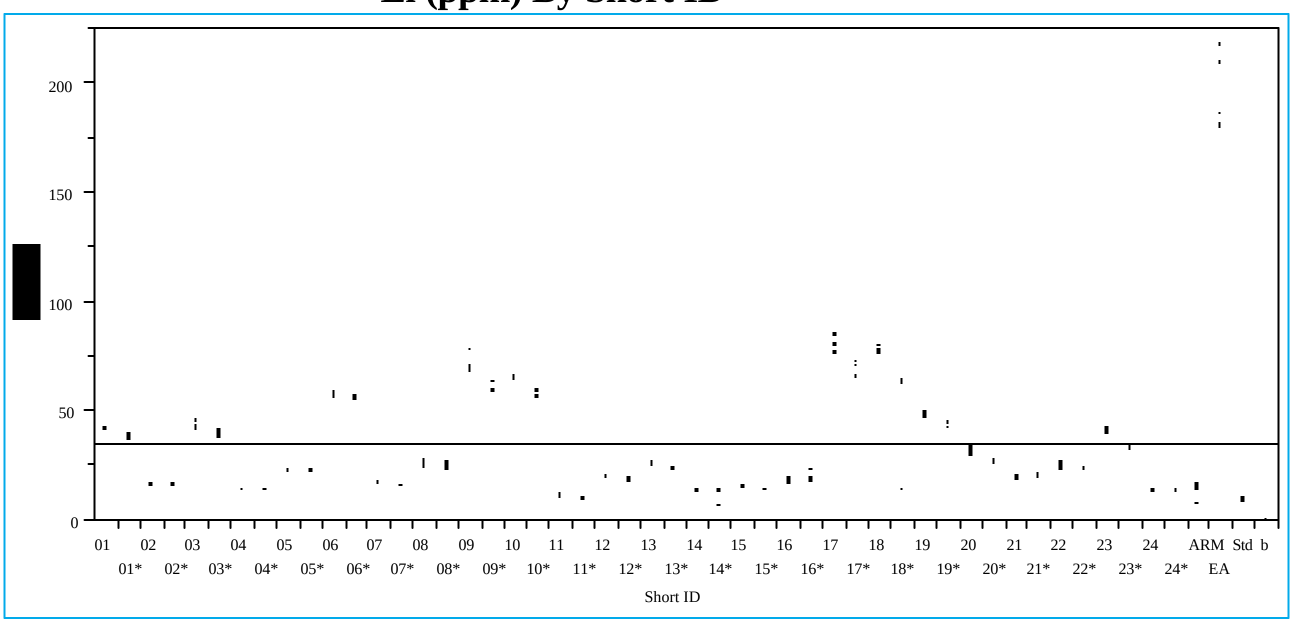
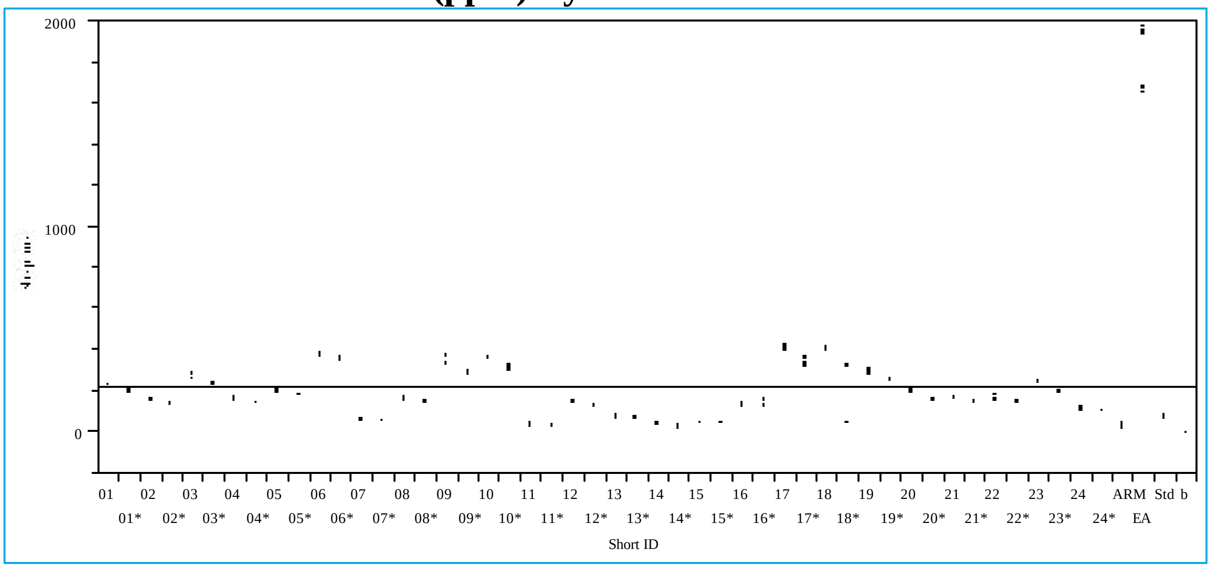


Exhibit G4: SRTC-ML PCT Measurements for Sodium and Silicon from All RC Glasses, EA, ARM, blank, and Samples of the Solution Standard

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

Na (ppm) By Short ID



Si (ppm) By Short ID

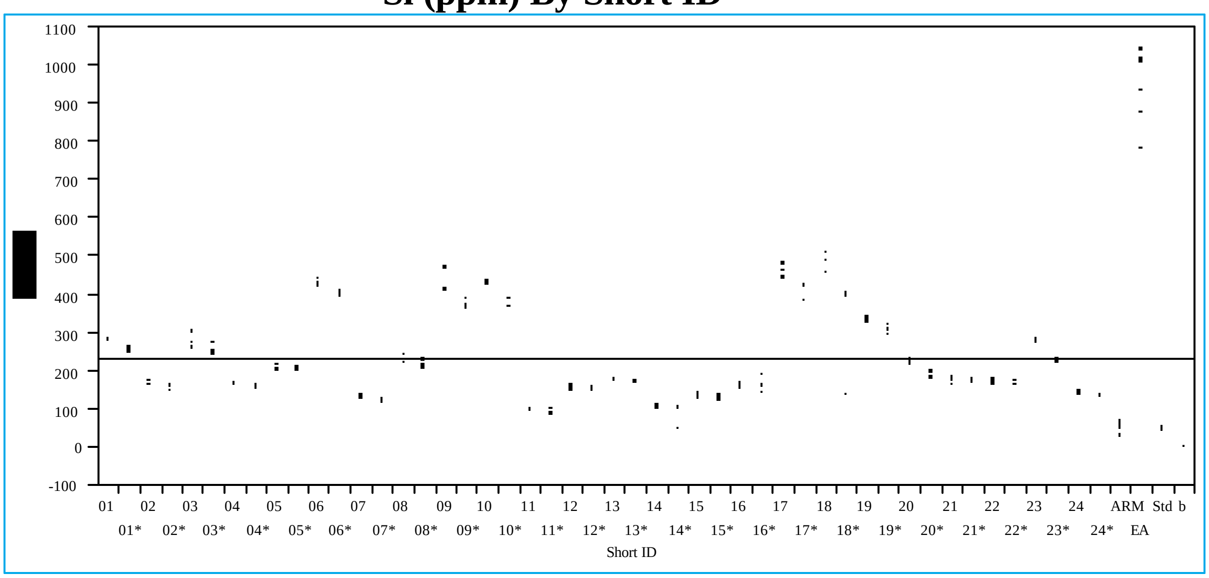
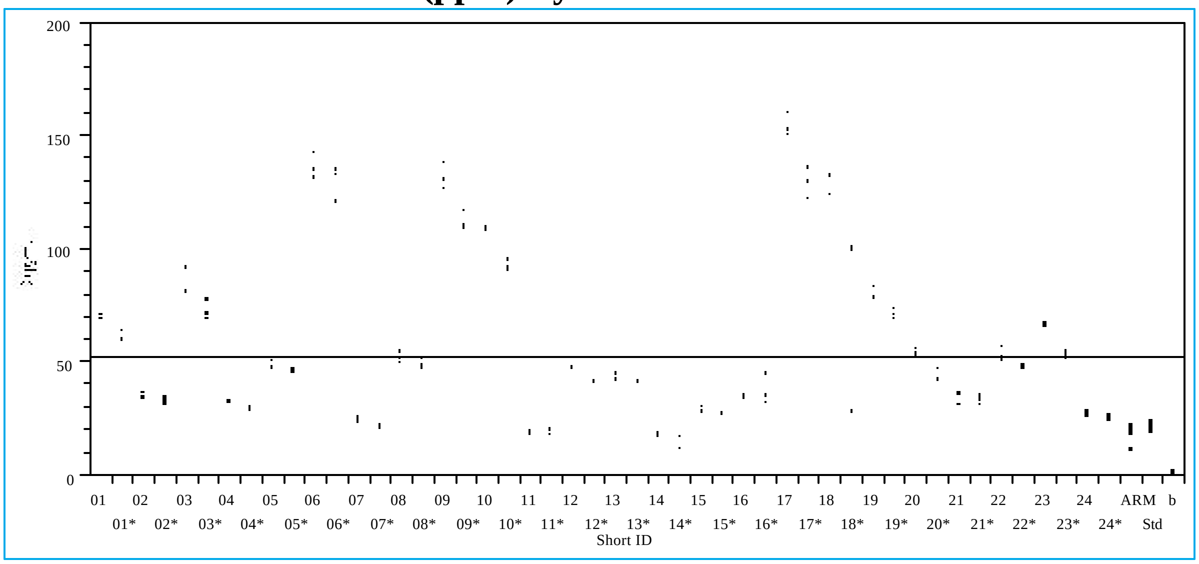


Exhibit G5: SRTC-ML PCT Measurements for Boron and Lithium from All RC Glasses, ARM, blank, and Samples of the Solution Standard, but excluding EA

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

B (ppm) By Short ID



Li (ppm) By Short ID

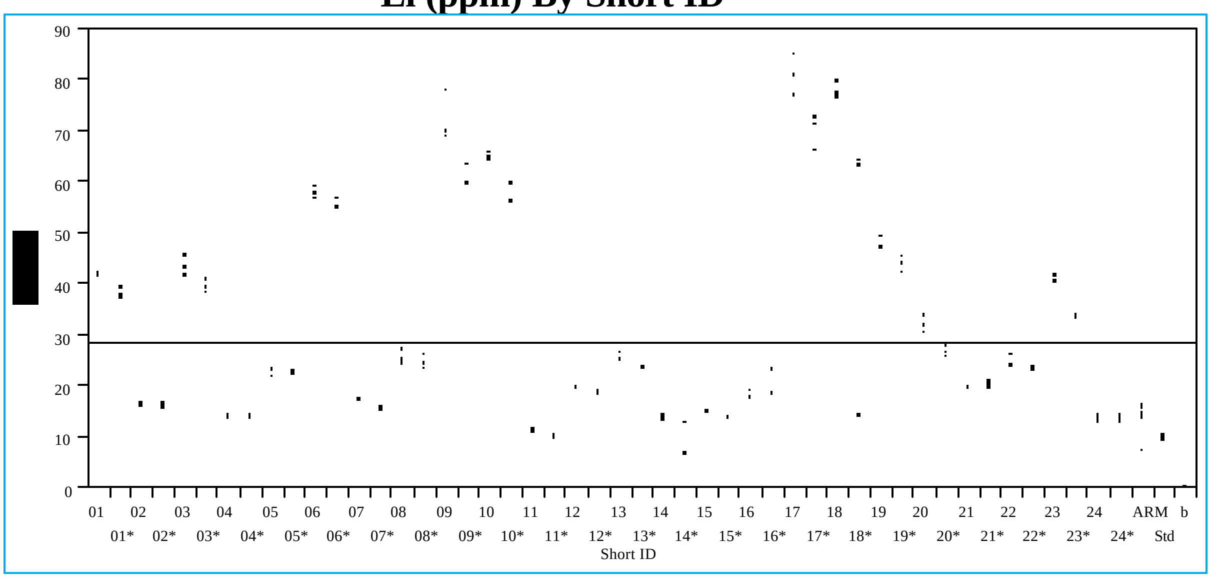
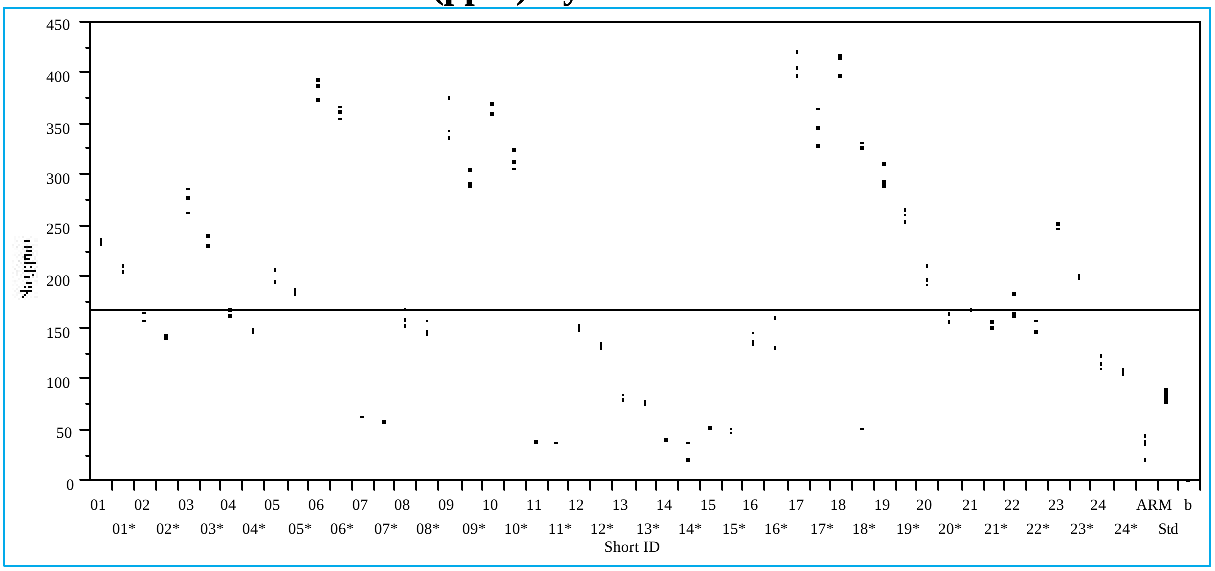


Exhibit G6: SRTC-ML PCT Measurements for Sodium and Silicon from All RC Glasses, ARM, blank, and Samples of the Solution Standard, but excluding EA

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

Na (ppm) By Short ID



Si (ppm) By Short ID

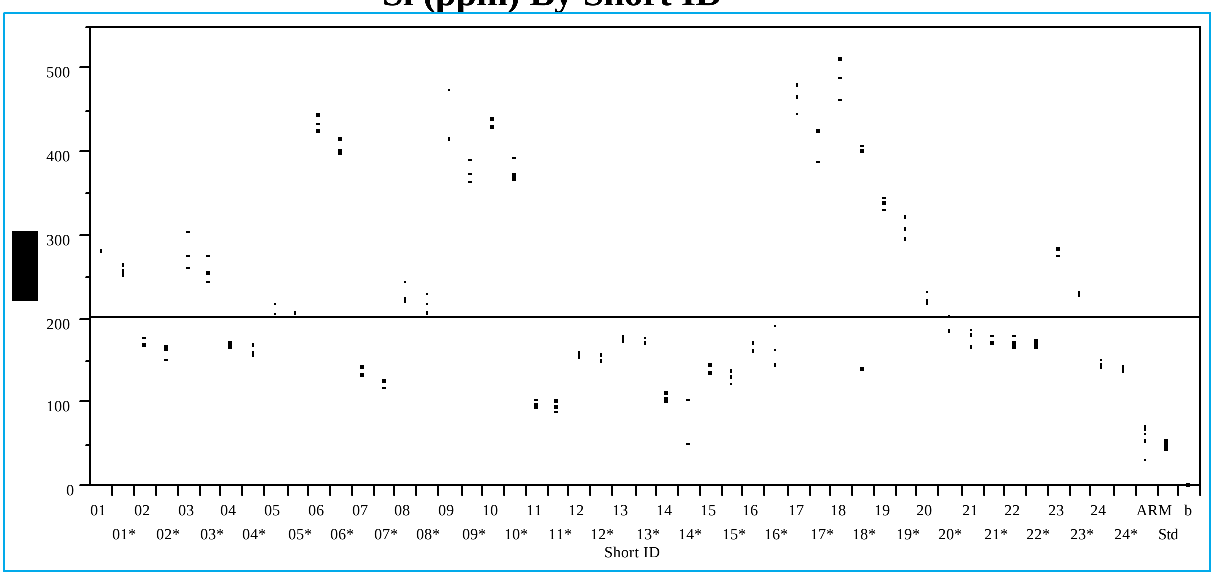
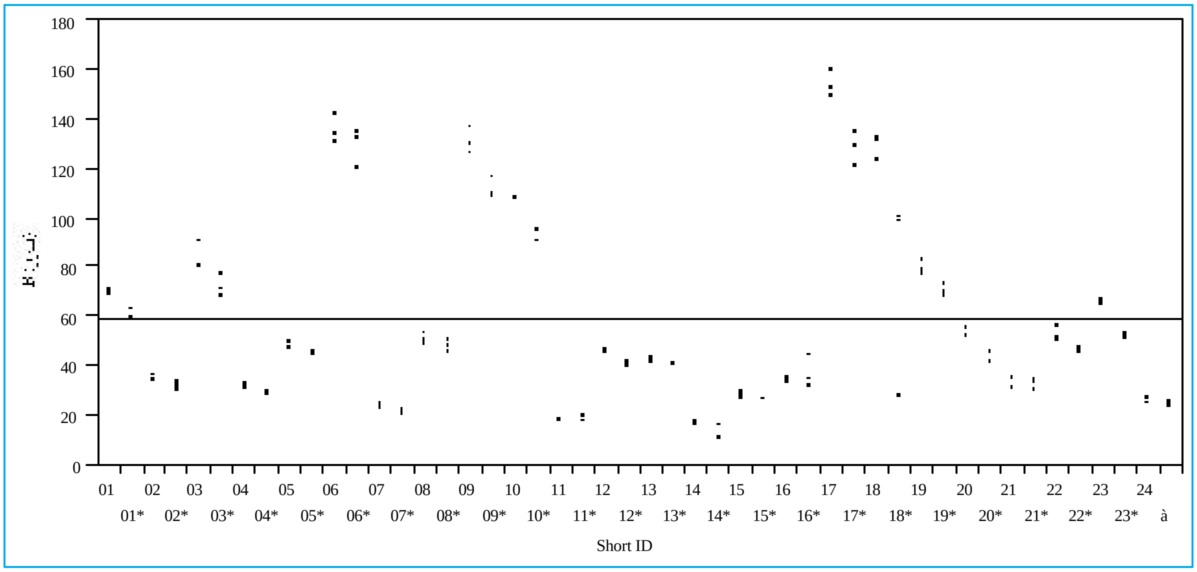


Exhibit G7: SRTC-ML PCT Measurements for Boron and Lithium from Only the RC Glasses

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

B (ppm) By Short ID



Li (ppm) By Short ID

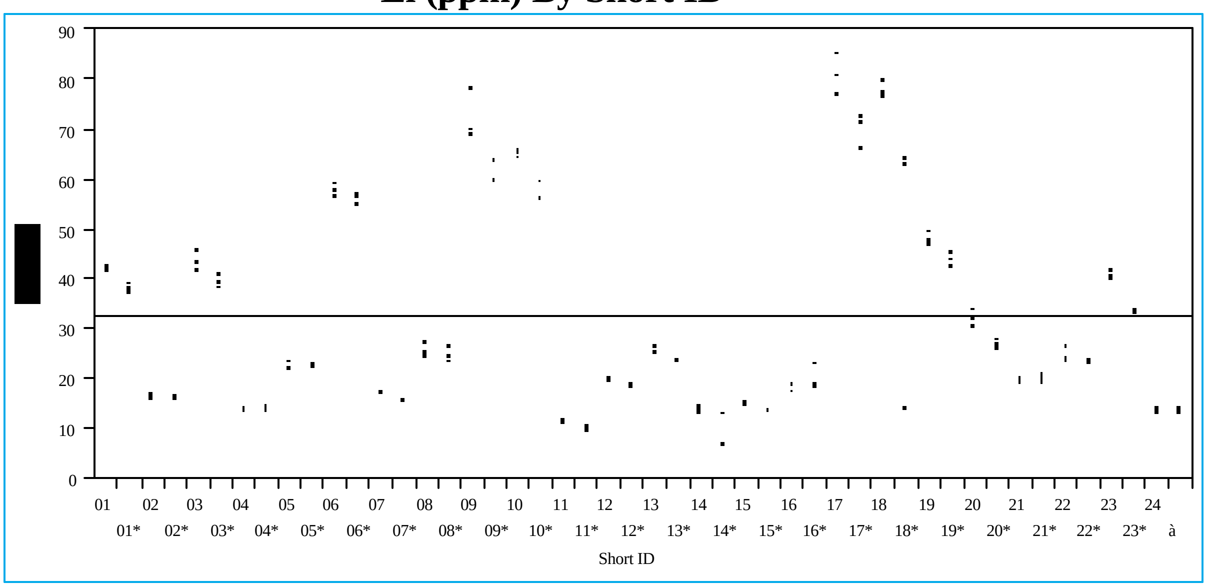
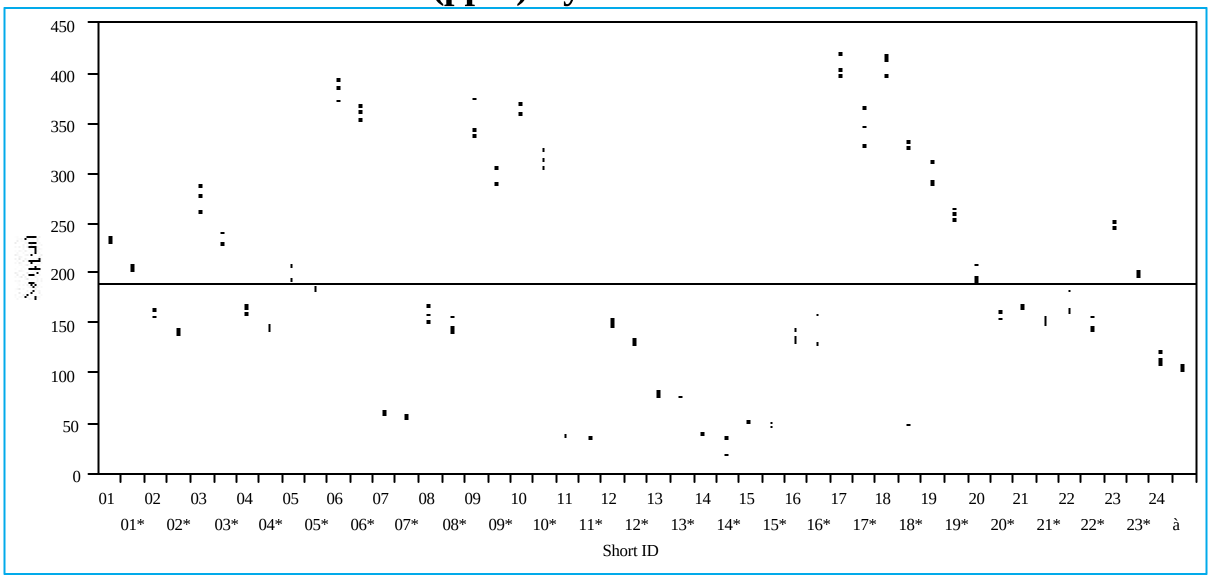


Exhibit G8: SRTC-ML PCT Measurements for Sodium and Silicon from Only the RC Glasses

(Short Glass ID utilizes glass number, * implies clc version; and PCTs experiencing water loss problems are not included)

Na (ppm) By Short ID



Si (ppm) By Short ID

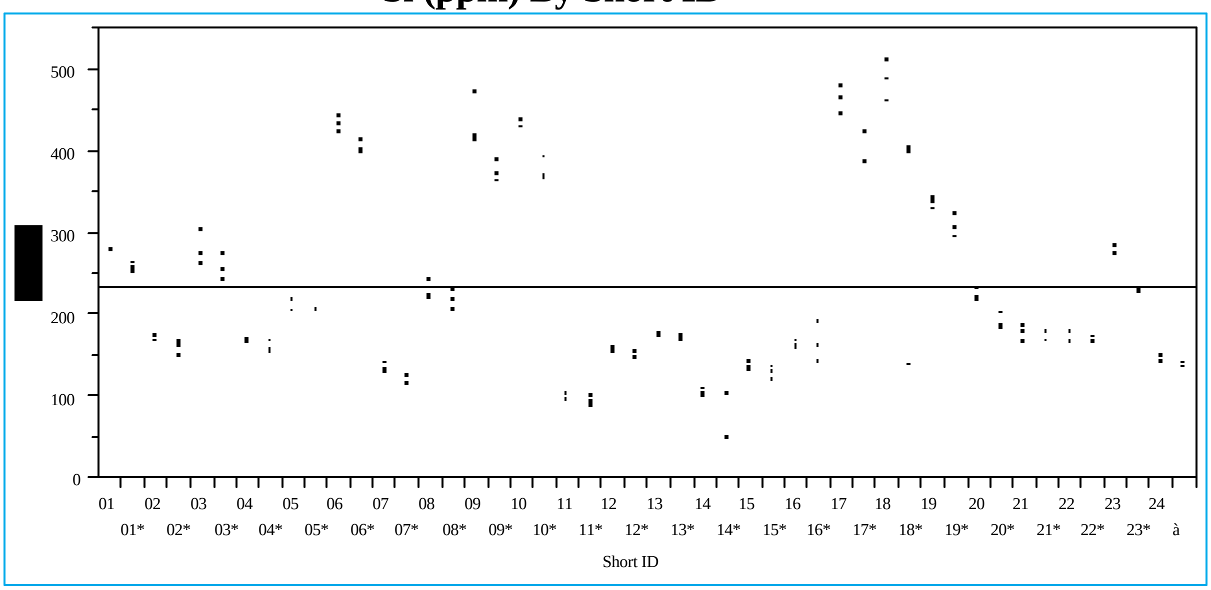


Exhibit G9: Correlations and Scatter Plots of Normalized PCTs Based Upon Target Compositions

(Excluding EA and ARM)

Correlations

Variable	log NL[B (g/L)]	log NL[Li (g/L)]	log NL[Na (g/L)]	log NL[Si (G/L)]
log NL[B (g/L)]	1.0000	0.9911	0.9877	0.9883
log NL[Li (g/L)]	0.9911	1.0000	0.9669	0.9796
log NL[Na (g/L)]	0.9877	0.9669	1.0000	0.9852
log NL[Si (G/L)]	0.9883	0.9796	0.9852	1.0000

Scatterplot Matrix

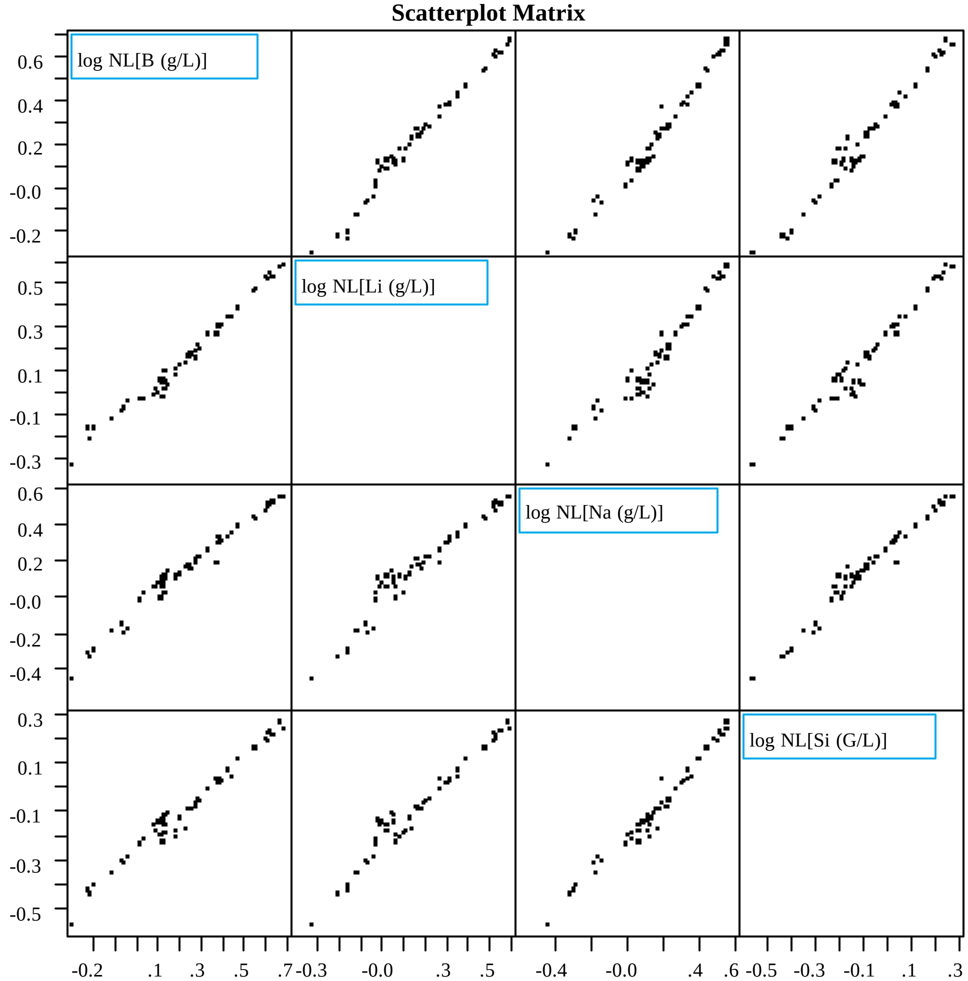


Exhibit G10: Correlations and Scatter Plots of Normalized PCTs Based Upon Measured Compositions
(Excluding EA and ARM)

Correlations

Variable	log NL[B (g/L)]	log NL[Li (g/L)]	log NL[Na (g/L)]	log NL[Si (G/L)]
log NL[B (g/L)]	1.0000	0.9917	0.9858	0.9790
log NL[Li (g/L)]	0.9917	1.0000	0.9656	0.9716
log NL[Na (g/L)]	0.9858	0.9656	1.0000	0.9838
log NL[Si (G/L)]	0.9790	0.9716	0.9838	1.0000

Scatterplot Matrix

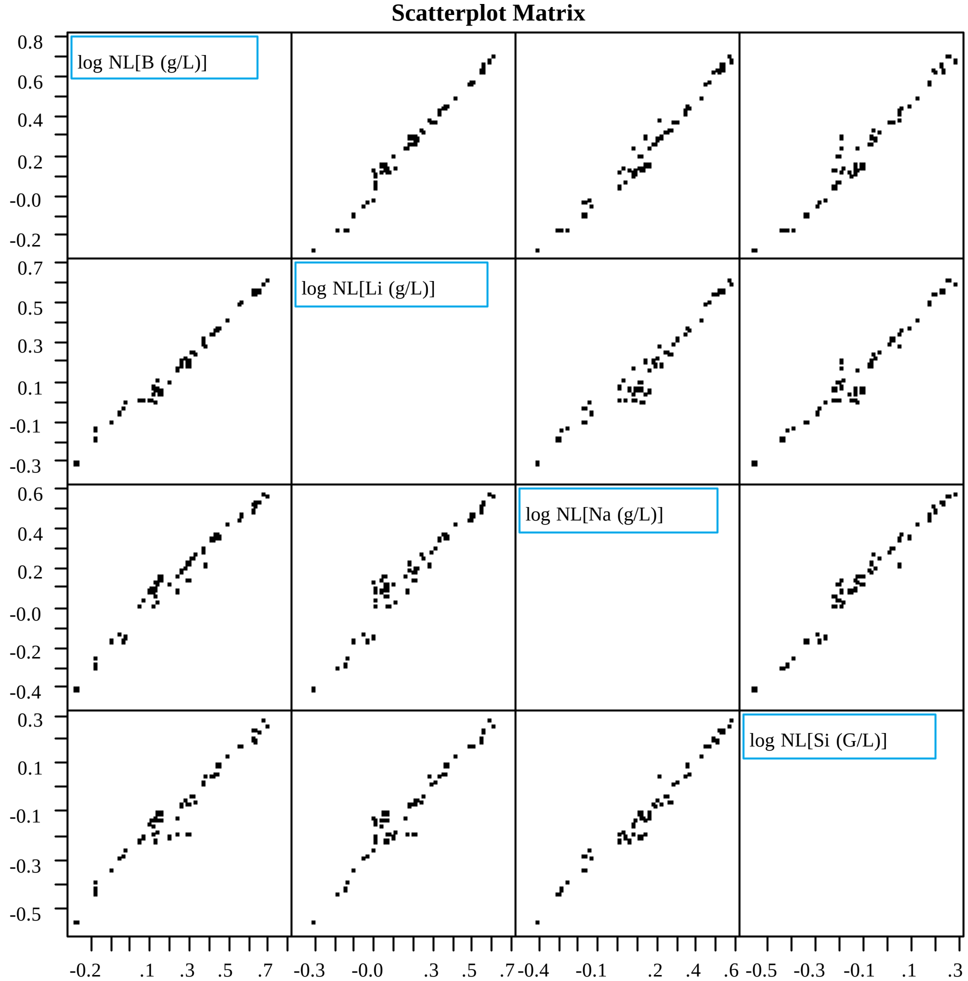


Exhibit G11: Correlations and Scatter Plots of Normalized PCTs Based Upon Measured, Bias-Corrected Compositions

(Excluding EA and ARM)

Correlations

Variable	log NL[B (g/L)]	log NL[Li (g/L)]	log NL[Na (g/L)]	log NL[Si (G/L)]
log NL[B (g/L)]	1.0000	0.9925	0.9852	0.9799
log NL[Li (g/L)]	0.9925	1.0000	0.9657	0.9726
log NL[Na (g/L)]	0.9852	0.9657	1.0000	0.9840
log NL[Si (G/L)]	0.9799	0.9726	0.9840	1.0000

Scatterplot Matrix