WSRC-TR-2001-00511
Revision: 0
October 31, 2001
WSRC-TR-2001-00511
Revision: 0

October 31, 2001

Keywords: Tank 40, Tank 8, DWPF,
Sludge Batch 2, PCCS, PCT

Retention Time: Permanent

SUMMARY OF RESULTS FOR EXPANDED MACROBATCH 3 VARIABILITY STUDY (U)

C.C. Herman
T. B. Edwards
D.M. Marsh

Westinghouse Savannah River Company
Savannah River Technology Center
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
SRS
SAVANNAH RIVER SITE

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

Summary of Results for Expanded Macrobatch 3 Variability Study (U)

Document Approvals

C.C. Herman, Author Immobilization Technology Section	12/10/01 Date
T. B. Edwards, Author Statistical Consulting Section	12/10/01 Date
D.M. Marsh, Author Immobilization Technology Section	12/10/01 Date
K. G. Brown, Technical Review Immobilization Technology Section	12/10/2001 Date
D. K. Peeler, Technical Review Immobilization Technology Section	12/10/2001 Date
S. L. Marra, Manager Glass Formulation and Process Development Group Immobilization Technology Section	12/12/01 Date
E. W. Holtzscheiter, Manager Immobilization Technology Section Authorized Derivative Classifier	12/11/01 Date
R. C. Tuckfield, Manager Statistical Consulting Section	12/12/01 Date

TABLE OF CONTENTS

SUMMARY AND CONCLUSIONS

A variability study has already been performed for DWPF Macrobatch 3 (MB3) using estimates for the Sludge Batch 2 (SB2) composition and Frit 200. Since that time, a change in the frit for MB3 was recommended via report WSRC-TR-2001-00131, "Melt Rate Improvement for DWPF information on the composition of SB2 has been obtained. Frit 320 was the recommended frit for MB3 based on the results of the melt rate studies. The frit change initiated a new variability study that was enhanced to reflect the SB2 compositional changes to include other components and/or to extend oxide ranges beyond those originally tested. This study addressed the extended processing region for the use of Frit 320 and also considered changes in the processing region due to updates in the sludge composition. As part of the sludge composition update, the processing region for the use of Frit 200 was also re-examined. Three glasses were fabricated to expand the Frit 200 processing region, while eighteen glasses were fabricated to cover the Frit 320 processing region.

The results from testing with both frits demonstrate that acceptable (durable as defined by the Product Consistency Test (PCT)) glass can be produced based on the most recent SB2 compositional analyses. All of the glasses produced in this study have PCT release rates for B, Na, and Li that are significantly less than the release rates for the corresponding elements from the Environmental Assessment (EA) glass. The EA limit for B release is 16.695 g/L, while the highest release rate measured for B in this study was 3.83 g/L for one of the Frit 200 glasses. The release rates for the canister centerline-cooled (ccc) glasses were comparable to or less than the quenched glasses, therefore no detrimental affect on performance was seen due to centerline cooling. All of the glasses selected were within the 95% prediction intervals of the THERMO Models in the Product Composition Control System (PCCS). Therefore, this study demonstrated that PCCS adequately predicts durability for glasses produced from this sludge batch (within the sludge composition bounds) with either Frit 200 or Frit 320 over the waste loading range tested (i.e., 25 to 35 wt% for Frit 200 and 25 to 40 wt% for Frit 320).

The homogeneity constraint was not used to limit the selection of glasses for this study. Some of the glasses were specifically selected to demonstrate that the homogeneity constraint could be relaxed for MB3 regardless of the choice between Frit 200 and Frit 320. For the Frit 320 glasses, the constraint was easily met except at lower waste loadings, and selecting glasses to challenge the constraint was difficult. An effort to relax or remove the homogeneity constraint for future sludge-only processing at the DWPF is being investigated in parallel. Five of the glasses selected for this study were predicted to be inhomogeneous, with two coming from the Frit 200 group and three from the Frit 320 group. The PCT responses for all selected glasses (including those that were predicted to be inhomogeneous) fell within the 95% prediction intervals for the durability models. This was true for both the quenched and canister center cooled versions of these glasses. Even though the response of NS01[1], which was a Frit 200 glass that was predicted to be inhomogeneous, was significantly different from the rest of the glasses tested in this variability study, it too fell within the prediction limits. No attempts were made to analyze this glass for amorphous phase separation. This glass was fabricated to be a high MgO and low MnO Frit 200 glass and also had a very low Al_2O_3 content. This combination of glass components has not been extensively tested for DWPF processing and presents a glass composition region that may be of interest in future glass testing for DWPF. The results demonstrate that the homogeneity constraint may be relaxed for MB3 with the use of either Frit 200 or Frit 320 in a manner similar to that utilized for Macrobatch 2 (MB2).

[1] The glasses for this study are denoted NS01 through NS21. This nomenclature was used throughout the study to identify the glasses for batching, melting, and analyses.

From a processing point of view, viscosity measurements were not made for any of the NS glasses; however, all of the target compositions selected for the variability study generated viscosity predictions (using the PCCS model) that fell within the property acceptability region (PAR) for this property except for NS06. NS06 was selected intentionally to help explore the impact of higher waste loadings (40 wt%) with Frit 320. Once this glass was fabricated, viscosity predictions for the measured and bias-corrected compositions of NS06 were both within the PAR. Liquidus temperature (T_L) is also a processing parameter of interest, although no T_L measurements were conducted as part of this variability study. Two models were used to predict T_L for the compositions of this study: the original T_L model and a new liquidus model. The NS glass compositions selected for this study (except for NS06) were predicted to have an acceptable liquidus temperature for at least one of the two T_L models. Once, again, NS06 is the centroid for the SB2/Frit 320 processing region at 40 wt%.

X-Ray Diffraction (XRD) analyses and Scanning Electron Microscopy (SEM) were performed on selected glasses from the study to confirm visual observations of homogeneity (after both quenching and ccc) or to determine the type of crystals present. Eight of the ten glasses submitted were determined to be amorphous based on the two analyses. The other two glasses, which were rapidly quenched, had very small peaks of unidentified material (by XRD), which were determined to be small amounts of nickel-iron spinel and ruthenium based on SEM analysis. The amounts of crystals were not quantified since the scope of this task was focused mainly on glass durability. In general, the crystals did not appear to affect the glass durability and were consistent with crystalline species found in other DWPF glasses.

INTRODUCTION

The Immobilization Technology Section (ITS) of the Savannah River Technology Center (SRTC) was requested [1] by the Defense Waste Processing Facility (DWPF) to perform an expanded variability study for Sludge Batch 2 (SB2) based on updated sludge composition information and the use of Frit 320. This study is necessary to meet the requirements of the DWPF Glass Product Control Program (GPCP) [2] and must be completed before DWPF can vitrify this sludge batch with Frit 320. The current proposed DWPF plan for SB2 is to begin processing with Frit 200 and then transition to Frit 320 after the necessary testing and procurement is completed [3]. Frit 200 and SB2 will constitute the feed for Macrobatch 3 (MB3) at DWPF and Frit 320 and SB2 will constitute either the next Macrobatch or a subpart of MB3.

Since the performance of the original MB3 variability study [4], the High Level Waste Division has combined the contents of Tanks 8 and 40 to define SB2, which was one of the SB2 options considered in the original variability study, and the SRTC has recommended the use of Frit 320 for SB2 [5]. Preliminary analyses of the tank contents by SRTC indicated that the composition was not bounded by the compositions used in the original variability study; specifically, the Al content was lower and Mg and Mn were present in greater quantities than were obtained from historical data [6,7]. Therefore, the expanded variability study had to include not only Frit 320, but also some glasses with Frit 200 to supplement the existing MB3 and Frit 200 data [4] and to ensure that the processing region was adequately covered based on the new sludge composition data. In the study, two phases of testing were planned, but only the first was necessary. The first phase used the available data on the sludge composition and involved the twenty-one glasses that were tested in this study. The second phase would have been performed if major differences in the SB2 composition had been seen for the waste acceptance sample analyses of Tank 40, which was to be washed to an endpoint of 0.55 M Na in the supernate per the task technical request (TTR) covering the waste acceptance sample [8]. Since the composition of the waste acceptance

sample was within the bounds of the SB2 composition range, no additional glasses were necessary.[2] For ease of presentation, the conclusions for the Frit 200 glasses are presented independently from the Frit 320 conclusions.

Due to the need to start the variability study as soon as possible and the unavailability of the nominally washed sludge composition at the beginning of the test, a range of sludge compositions was used to select the SB2 sludge composition boundaries. The SB2 composition boundaries were selected from the preliminary data on once washed Tank 40 sludge [6], preliminary data on twice washed Tank 40 sludge [9], estimates of the sludge composition when washed to the nominal levels, and historical data on the chemical compositions for Tanks 8, 40, and a 50/50 blend of the tanks [7]. Based on the TTR [1], a technical task and quality assurance plan [10] for the variability study was written, approved by DWPF, and issued.

As directed by the task plan and using the compositions from the above mentioned documents [6,7,9], a report on the selection of glasses for both Frit 200 and Frit 320 was issued for the variability study [11]. The glasses were selected based on the current PAR limits for homogeneity, durability, liquidus temperature, and viscosity. The limits are given in Table 1. In selecting these glasses, both the original and new liquidus models [12] were used. The PAR limit for the new T_L model was conservatively set at 1010°C [11]. Also, note in Table 1 that the durability model PAR is related to a measure of the free energy of hydration (ΔG_P) for a given glass composition [13].

Table 1: Summary of Constraint PARs

Constraint	Units	PAR Limit(s)
Homogeneity	wt%	> 210.92034
Durability (ΔG_P)	kcal/mol	> -12.7178
Liquidus Temperature (T_L) – Original Model	°C	≤ 1024.9°C
Viscosity at 1150°C ($\eta_{1150°C}$)	Poise	$21.5308 \leq \eta_{1150°C} \geq 105.4437$
Liquidus Temperature (T_L) – New Model	°C	≤ 1010°C

In the previous MB3 variability study, no attempt was made to address the minor components of the sludge. During the glass selection process for the current study, minor sludge components including those that facilitate crystal formation were included so that the glasses would be available for T_L measurements in the future.

Three glasses were identified based on the Frit 200 portion and eighteen glasses were identified for the Frit 320 portion of the study. For the Frit 200 glasses, the new SB2 ranges extended the upper limits of MgO and MnO, causing the SB2 region to extend to values beyond those for the glasses from the original SB2 region [11]. Therefore, a limited number of glasses were selected to explore the extended glass composition region [11]. The set of extreme vertices from the outer layer of the new SB2 region was combined with the nominal Frit 200 for waste loadings of 25, 30, and 35 wt%. Candidate glasses were then selected using the following strategy [11]:

[2] The chemical composition of the waste acceptance sample of Tank 40 was received via e-mail from T. L. Fellinger on October 15,2001: *Tank 40 SRAT Product Composition for SME Blending Calculations (U).* The set of measurements was adjusted to reflect the sludge oxide contribution to the glass composition, and the resulting values were compared to the oxide ranges used to bound the SB2 region. For the major oxides, only SiO_2 did not fall within the SB2 bounds. The SiO_2 value was slightly higher than the upper bound used for SB2 (2.7 vs 2.4 wt%). Since the SiO_2 contribution is primarily from the frit, this slight difference was not deemed to be of practical concern. It is worth noting that even the measured values of the minor components (e.g., Cr_2O_3 and P_2O_5) fell within the intervals used to define SB2.

- At 25% sludge loading, a glass (NS01) at the low end of the MnO and high end of the MgO range that had the most negative ΔG_p value;
- At 30% sludge loading, a glass (NS02) at the high end of the MnO and low end of the MgO range that had the most negative ΔG_p value; and
- At 35% sludge loading, a glass (NS03) at the high end of the MnO and high end of the MgO range that had the most negative ΔG_p value.

Both NS01 (25% loading) and NS02 (30% loading) did not meet the homogeneity constraint, so they provided an opportunity to assess the applicability of the homogeneity constraint within the extended SB2 composition region for Frit 200. The higher loading glass, NS03, failed the existing T_L model but met the constraint based on the new T_L model, so this glass provided the opportunity to assess the applicability of the durability models for an expanded compositional region assuming implementation of the new T_L model. The overall objective of these three glass compositions was to demonstrate that the higher concentrations of MnO and MgO did not have a detrimental impact on the viability of the predictions generated by the current PCCS durability models.

For the Frit 320 glasses, the sludge composition layers were used to define the centroid of the sludge outer layer combined with Frit 320 at waste loadings from 25 to 40%. Model predictions for these glasses showed that all constraints were met for waste loadings up to 31%. With the new liquidus model, the DWPF operating window may be opened even further, possibly up to 39% [11]. To help support the understanding of the impact of higher waste loadings with Frit 320 for DWPF operations, the sludge outer layer centroids at 30, 35, and 40% waste loading were selected for testing. These glasses were identified as NS04 through NS06, respectively. The three sludge layers (i.e., outer, middle, and inner) were then used to predict properties of glasses with Frit 320 at waste loadings of: 25, 27.5, 30, 32.5, 35, 37.5, and 40% [11].

Glasses were then selected based on the following criteria:
- Compositions that satisfied all of the constraint PARs;
- Compositions that satisfied all constraints except the homogeneity PAR; and
- Compositions that satisfied all constraints except the current T_L model PAR.

Over the loading interval of interest, ten groups were generated that satisfied these criteria and five compositions with the most negative ΔG_p values in each group were selected [11]. The D-Optimality routine available in JMP Version 3.2.2 [14] was then used to select fifteen of the fifty resulting compositions for testing. These glasses were identified as NS07 through NS21. Glasses NS09 through NS11 (at 25 wt% waste loading) did not meet the homogeneity PAR, while glasses NS13 and NS14 (at 30 wt% waste loading) and glasses NS16 through NS21 (at waste loadings from 35 to 40 wt%) did not meet the original T_L constraint. All other constraints were met for the Frit 320 glasses. Provisions in the task plan [10] were also made for producing more glasses if the washed SB2 waste acceptance composition was not covered by the sludge composition range selected for the glasses. However, this was not necessary since the composition was within the SB2 composition range studied (see footnote 1).

The objective of the variability study was to demonstrate the applicability of the PCT/chemical composition correlations utilized by DWPF to the new compositional region for SB2. As stated earlier, the variability study must be performed for each macrobatch to ensure that the requirements of the Glass Product Control Program [2] are met. The suitability of the current composition/property models within the expanded compositional space was evaluated. The

models were used to predict durability, homogeneity, viscosity, and liquidus for each of the glasses in the matrix. Both the existing and new liquidus models were used for predicting liquidus. However, the primary goal of the variability study was to demonstrate that the durability model in PCCS could provide assurance that glass produced during that macrobatch will meet the acceptance criterion defined in Waste Acceptance Product Specification 1.3.1 [15].

Compliance with the acceptance criteria as part of the variability study was accomplished in two ways. First, the PCT responses for each of the glasses selected for both frit portions of the variability study were measured. The normalized leach rates for B, Li, and Na were then compared to the mean EA values for these elements provided in Table 2 [16]. Silicon is also reported in Table 1 for completeness, but is not part of the acceptance criteria. Compliance will be realized if the leach rates are less than the mean leach rates of the EA glass [16].

Table 2: Mean Values for Product Consistency of Environmental Assessment (EA) Glass [16]

EA	B (g/L)	Li (g/L)	Na (g/L)	Si (g/L)
Mean	16.695	9.565	13.346	3.922

The second method of compliance for the variability study was to demonstrate that the durability, as measured by the PCT, could be predicted from the chemical composition using the THERMO ΔG_P model [13]. In this report, the prediction is based on 95% two-sided confidence intervals for an individual PCT. Therefore, a comparison is made of the predictions for each glass using the THERMO model in PCCS versus the actual leaching performance as determined by the PCT. Applicability of the PCT/chemical composition model will be demonstrated if the leach rates are successfully predicted by PCCS.

The efforts of this variability study also included demonstrating the viability of relaxing the homogeneity constraint for the expanded SB2/Frit 200 and for the SB2/Frit 320 glass regions. In a parallel effort to the original (SB2/Frit 200) variability study [4], Peeler, et. al. [17] focused on the role of the homogeneity constraint for that glass composition region. Based upon the results from that study and the study for MB2 [18], there was strong evidence that the imposition of the homogeneity Measurement Acceptance Region (MAR) criterion might unnecessarily restrict the DWPF operational window for SB2. The relaxation of the homogeneity constraint from the MAR to the PAR limit for acceptability is conditioned on one of the following two criteria being met:

Criterion (1)

- Use of the alumina constraint as currently implemented in PCCS (i.e., $Al_2O_3 \geq 3$ wt%) **AND** add a sum of alkali[3] 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., $Al_2O_3 \geq 4$ wt%)

Regardless, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina or the new alkali constraint, if used, as it is for the current alumina constraint.

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

The homogeneity constraint was not used to limit the selection of glasses for this study. To the contrary, some of the glasses were specifically selected to demonstrate that the homogeneity constraint could be relaxed for MB3 regardless of the choice between Frit 200 and Frit 320. For the Frit 320 glasses, the constraint was easily met except at lower waste loadings and selecting glasses to challenge the constraint was difficult. An effort to relax or remove the homogeneity constraint for future sludge-only processing at the DWPF is being investigated in parallel. Five of the glasses selected for this study were predicted to be inhomogeneous, with two coming from the Frit 200 group and three from the Frit 320 group.

Processing parameters are also crucial for operation of the DWPF but are not directly waste affecting. Therefore, viscosity and liquidus temperature were not measured as part of this task, but they were predicted using current PCCS models [19] and the new liquidus temperature model [12] for each of the glasses. The predicted viscosities and liquidus temperatures are provided in this report.

EXPERIMENTAL

Due to the presence of depleted uranium in these glasses, this work was performed in laboratory C-114 of 773-A. The glasses were melted at 1150°C for four hours in 95% platinum – 5% gold crucibles and rapidly cooled by pouring onto a clean stainless steel plate according to GTOP-3-003 and GTOP-3-004, latest revisions. All of the glasses fabricated for this study were tested using the PCT-method A procedure [20]. To provide additional assurance and as directed in the TTR [1], all glasses were cooled in the furnace following the canister centerline cooling (ccc) curve for a prototypically filled DWPF canister [21]. This was accomplished by adding approximately 25 grams of the quenched glass to a 100-ml platinum gold crucible, placing the crucible into the furnace at 1150°C, and cooling the glass following the ccc profile [21]. The ccc glasses were also subjected to the PCT to determine the affect of cooling on durability.

Requirements for analyses of the glasses, the PCT leachates, and for mineralogy were stated in an Analytical Study Plan [22]. A discussion of the dissolution methods, measurements of the chemical composition and PCT leachates, and statistical blocking requirements for the chemical composition and PCT samples has been documented by Edwards [23,24]. Chemical composition analyses were performed on the quenched glasses to verify that the target glass compositions were adequately met. Chemical composition measurements from the two dissolution methods used by the SRTC-Mobile Lab (SRTC-ML) for these glasses were bias-corrected for possible ICP calibration effects [23]. These efforts led to three different ways of representing the chemical compositions of these glasses (targeted, measured, and bias-corrected compositions). These compositional representations were then used to normalize the PCT results for each glass.

XRD and SEM measurements were performed by ADS in routine modes using ADS procedures. Several glasses, spanning the region of glasses tested, were analyzed by XRD and SEM to monitor for crystallization. The glasses selected were also based on physical appearance and when the PCT results showed discrepancies between quenched and ccc versions of the same glass (where differences in quenched vs. ccc PCT releases have been linked to the presence of crystallization primarily in the ccc glass).

RESULTS AND DISCUSSION

Selection of Glasses. Twenty-one glasses were selected for the study with three using Frit 200 and the rest using Frit 320 [11]. The predictions of durability (given in terms of ΔG_p), homogeneity, liquidus temperature, and viscosity for each glass are presented in Table 3 as a function of the targeted, measured, and bias-corrected (bc) measured compositions.

Chemical Compositions. The twenty-one glasses were dissolved and analyzed for chemical composition by the SRTC-ML according to analytical plans [22,23]. The statistical analysis of these results has been performed and the results along with the chemical compositions for these twenty-one glasses are presented in Appendix A. The measured and bias-corrected (bc) measured results compare quite well with the targeted compositions with the measurements (original and bias corrected) for most of the major oxides (i.e., those with targeted concentrations greater than 0.5 wt%) falling within approximately 5% of the targeted values. Bias-correction was performed for all of the oxides of this study except P_2O_5 and ZrO_2, which were at concentrations in the standards of less than 0.1 wt% (see Appendix A). All of the sums of oxides (both measured and bias-corrected) fall within the interval of 95 to 105% except the bias-corrected sums of oxides for NS04 (94.1%), NS13 (94.7%), and the uranium standard glass (94.8%). However, the targeted sum of oxides for the uranium standard glass was only 96.5 wt%, which suggests that the 94.8 wt% recovery attained in the bias-corrected measurements for this standard glass is not a problem. The uranium standard glass contains ~3 wt% K_2O, which was not measured in this study so this accounts for a portion of the oxide sum difference. A more complete discussion of the chemical composition measurement comparison is given in Appendix A. The target, measured, and bias-corrected compositions of NS05, the centroid of the SB2 sludge region at a 35% loading, is provided in Table 4 as an example of the SB2 with Frit 320 glass region. Due to the "Others" components in the glasses that were not analyzed, the totals for the glass do not sum to 100.

Table 3: Process and Property Predictions Based on Compositional View

Glass ID	Compositional View	Al2O3 wt fraction	alkalis wt fraction	Viscosity (Poise)	Homogeneity (wt%)	DG_p	Current TL (°C)	New TL (°C)	Assessment Against PAR Limits
NS01	Measured	0.0319	0.1801	57.0	204.2	-11.985	934.7	815.5	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS01	Measured bc	0.0324	0.1751	57.6	200.7	-11.567	936.6	822.3	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS01	Targeted	0.0303	0.1779	54.9	201.7	-11.886	937.7	822.4	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS02	Measured	0.0348	0.1824	44.4	215.0	-12.316	980.7	870.0	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS02	Measured bc	0.0353	0.1766	43.7	209.5	-11.875	984.0	877.1	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS02	Targeted	0.0332	0.1819	40.3	208.7	-12.438	978.4	864.7	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS03	Measured	0.0414	0.1836	30.9	215.8	-12.525	1029.0	957.5	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS03	Measured bc	0.0421	0.1786	30.7	211.5	-12.120	1032.6	963.2	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS03	Targeted	0.0407	0.1855	30.3	215.8	-12.702	1028.9	970.1	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS04	Measured	0.0442	0.1822	36.2	216.8	-11.009	1005.4	867.7	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS04	Measured bc	0.0449	0.1779	34.6	211.6	-10.688	1009.6	872.5	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS04	Targeted	0.0454	0.1900	35.5	223.4	-11.522	1008.2	870.0	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS05	Measured	0.0526	0.1832	28.7	233.9	-10.871	1079.1	948.4	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS05	Measured bc	0.0533	0.1784	28.9	230.5	-10.475	1084.0	955.9	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS05	Targeted	0.0530	0.1884	28.1	233.9	-11.265	1069.1	944.1	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS06	Measured	0.0608	0.1859	24.4	243.6	-10.961	1125.7	988.9	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS06	Measured bc	0.0617	0.1806	23.7	238.3	-10.561	1133.8	996.0	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS06	Targeted	0.0606	0.1867	21.5	244.5	-11.009	1145.4	1011.0	Durable; Not Visc; Not TL; Homo; Not New TL; Al2O3 ; alkali
NS07	Measured	0.0310	0.1863	38.8	209.4	-11.702	968.0	778.2	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS07	Measured bc	0.0316	0.1826	37.5	204.9	-11.415	970.2	782.5	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS07	Targeted	0.0313	0.1913	39.9	213.0	-12.005	967.8	785.6	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS08	Measured	0.0321	0.1911	37.1	218.2	-11.847	984.4	788.7	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS08	Measured bc	0.0327	0.1863	36.6	213.5	-11.496	986.9	794.5	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS08	Targeted	0.0313	0.1920	39.5	213.2	-11.980	967.8	765.9	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS09	Measured	0.0458	0.1956	42.5	213.9	-12.217	952.9	795.6	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; Not alkali
NS09	Measured bc	0.0466	0.1906	42.1	209.5	-11.828	955.3	802.3	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS09	Targeted	0.0460	0.1928	49.4	210.5	-11.946	939.5	782.5	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS10	Measured	0.0463	0.1912	50.1	212.2	-11.833	940.6	787.2	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS10	Measured bc	0.0470	0.1858	48.9	207.0	-11.437	943.3	792.9	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS10	Targeted	0.0460	0.1912	49.6	210.0	-11.848	940.0	793.6	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS11	Measured	0.0430	0.1878	48.8	213.5	-11.280	958.0	791.8	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS11	Measured bc	0.0437	0.1825	47.6	208.4	-10.905	961.1	798.8	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS11	Targeted	0.0423	0.1930	46.3	210.1	-11.823	946.8	776.4	Durable; Visc; TL ; Not Homo; New TL ; Al2O3 ; alkali
NS12	Measured	0.0327	0.1991	29.8	237.0	-12.362	1029.7	847.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali
NS12	Measured bc	0.0331	0.1938	30.1	233.3	-11.935	1032.9	856.0	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali
NS12	Targeted	0.0304	0.1928	32.3	219.4	-12.109	999.9	826.0	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS13	Measured	0.0315	0.1733	46.6	217.2	-10.492	999.0	836.6	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS13	Measured bc	0.0320	0.1691	45.5	212.6	-10.196	1001.7	841.0	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS13	Targeted	0.0332	0.1899	29.2	226.9	-11.941	1027.6	854.3	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS14	Measured	0.0333	0.1871	27.6	227.4	-11.598	1039.0	891.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS14	Measured bc	0.0339	0.1825	26.9	222.7	-11.260	1042.4	897.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS14	Targeted	0.0332	0.1917	28.7	227.1	-11.905	1027.6	880.1	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali

Table 3: Process and Property Predictions Based on Compositional View *(continued)*

Glass ID	Compositional View	Al2O3 wt fraction	alkalis wt fraction	Viscosity (Poise)	Homogeneity (wt%)	DG_p	Current TL (°C)	New TL (°C)	Assessment Against PAR Limits
NS15	Measured	0.0585	0.1916	37.0	228.4	-11.747	1015.6	881.4	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS15	Measured bc	0.0593	0.1873	37.1	224.9	-11.346	1019.4	888.0	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS15	Targeted	0.0597	0.1929	36.9	226.0	-11.805	1010.6	882.1	Durable; Visc; TL ; Homo; New TL ; Al2O3 ; alkali
NS16	Measured	0.0392	0.1864	25.7	232.8	-11.611	1069.2	894.0	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS16	Measured bc	0.0398	0.1817	24.5	227.1	-11.261	1074.5	900.7	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS16	Targeted	0.0388	0.1905	21.9	238.7	-11.892	1089.8	911.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS17	Measured	0.0414	0.1941	25.3	238.8	-12.002	1072.5	902.6	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; Not alkali
NS17	Measured bc	0.0420	0.1891	25.4	235.3	-11.595	1076.8	910.1	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS17	Targeted	0.0388	0.1908	21.7	236.0	-11.838	1089.8	921.0	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS18	Measured	0.0693	0.1916	37.8	230.5	-11.475	1040.5	947.6	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS18	Measured bc	0.0703	0.1866	36.7	225.5	-11.076	1046.7	952.1	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS18	Targeted	0.0689	0.1921	28.8	232.7	-11.566	1075.2	979.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS19	Measured	0.0691	0.1919	26.7	239.9	-11.552	1099.8	967.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS19	Measured bc	0.0703	0.1875	26.3	235.5	-11.165	1106.4	973.0	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS19	Targeted	0.0677	0.1924	22.8	242.1	-11.593	1125.4	987.5	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS20	Measured	0.0736	0.1906	28.0	237.3	-11.598	1091.2	977.6	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS20	Measured bc	0.0746	0.1861	28.4	233.9	-11.163	1097.4	985.2	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS20	Targeted	0.0735	0.1913	25.8	240.7	-11.529	1113.7	1002.3	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS21	Measured	0.0656	0.1867	30.5	230.9	-11.117	1080.7	969.8	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS21	Measured bc	0.0665	0.1815	31.3	227.7	-10.663	1086.3	978.7	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali
NS21	Targeted	0.0677	0.1925	23.1	240.5	-11.508	1123.9	998.7	Durable; Visc; Not TL; Homo; New TL ; Al2O3 ; alkali

Table 4: Chemical Composition of NS05 Glass Based on the Targeted Composition

NS05 Oxide	Target %Oxide in Glass	Measured % Oxide in Glass	Bias Corrected % Oxide in Glass
Al_2O_3	5.301	5.262	5.334
B_2O_3	5.214	5.104	5.029
CaO	1.323	1.459	1.367
Cr_2O_3	0.128	0.103	0.094
Fe_2O_3	14.482	14.765	14.624
Li_2O	5.271	5.108	5.081
MgO	0.823	0.899	0.860
MnO	1.429	1.411	1.393
Na_2O	13.567	13.207	12.759
NiO	0.673	0.607	0.624
P_2O_5	0.485	0.362	0.362
SiO_2	47.503	46.744	45.785
TiO_2	0.014	0.009	0.009
U_3O_8	3.410	3.378	3.514
ZrO_2	0.046	0.024	0.024
Total	99.669	98.442	96.859

PCT Results. The SRTC-ML analyzed the PCT leachates according to the approved analytical plans [22,24]. The PCT results for the twenty-one NS glasses and the associated standard samples are presented in Appendix B. These data include the results from both the rapidly quenched and ccc glasses. Table 5 highlights the normalized PCT release for boron for the three Frit 200 glasses.

Table 5: Normalized PCT Response for B Using Bias-Corrected Compositions for Normalization

Wt% Oxide	Glass ID	PCT, Boron g/L
25	**NS01**	3.83
30	**NS02**	1.94
35	**NS03**	1.64

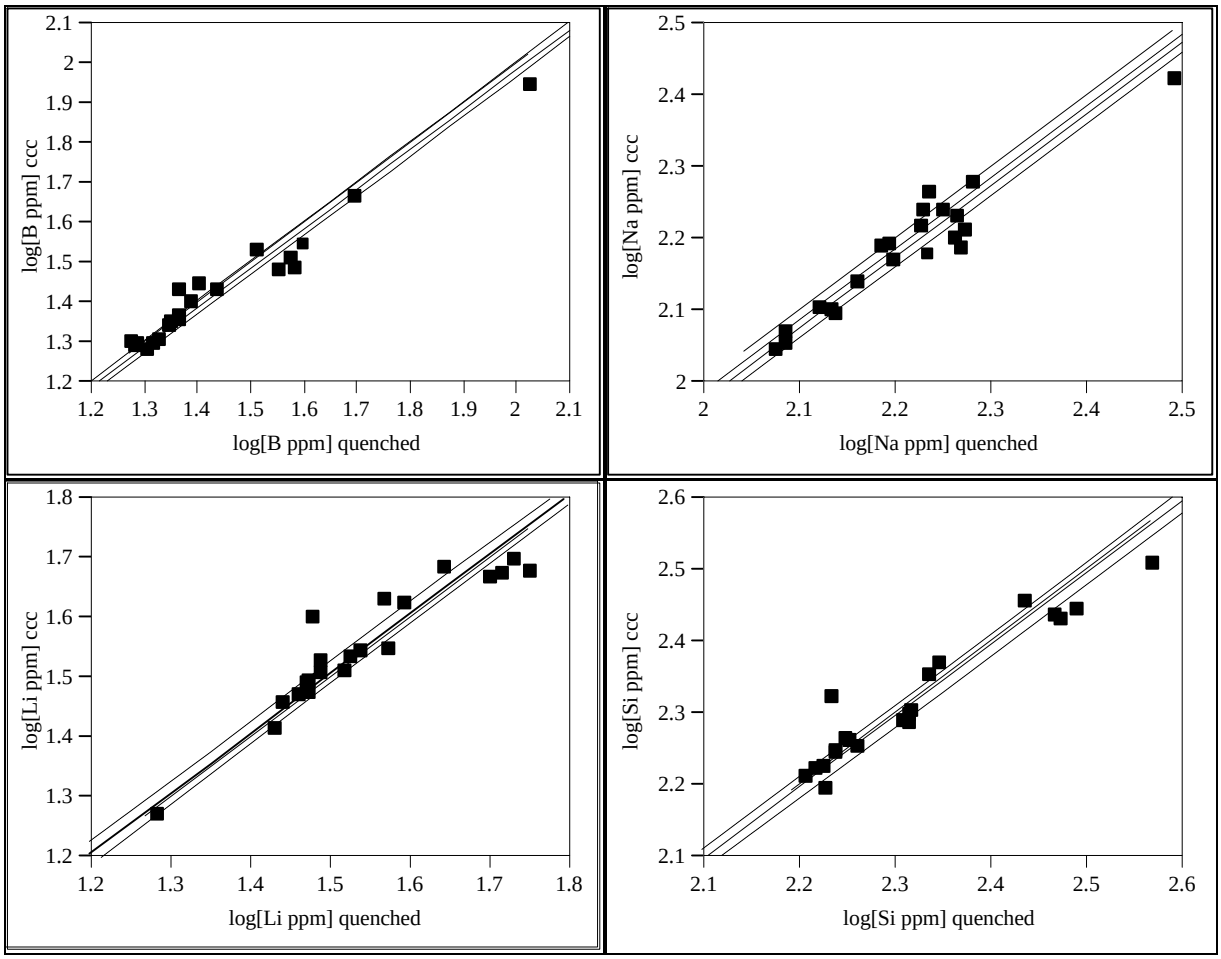
It is evident from Table 5 and Appendix B that all of the measured PCT values, determined by normalization with the targeted, measured, and bias-corrected (bc) compositions, are well below (i.e., satisfy) the EA values provided in Table 2. The maximum average values for release for B, Na, Li, and Si for the twenty-one glasses was from NS01 (a Frit 200 based glass) and its results are presented in Table 6.

Table 6: Maximum Normalized PCT Release as Exhibited by Glass NS01

Element	Release (g/L)
B	3.83
Li	3.19
Na	3.04
Si	1.50

The PCT results for the ccc glasses are plotted in Figure 1 against the PCT results for the glasses of the same composition (i.e., same batch) that had been rapidly quenched. The diagonal, bold line in the figure is the theoretical line for no difference between leaching for the quenched vs. ccc glasses. The pair of dashed lines shown on the plot forms a 95% confidence interval around the line representing the average difference between the PCTs of the two heat treatments. If the dashed lines contain the diagonal line, then there is no statistically significant (at the 5% significance level) difference between the PCTs from the two heat treatments. Appendix B provides a more complete description of the statistical comparisons, which are conducted in ppm and log[ppm]. The statistical tests of the average differences due to heat treatment indicate statistically significant (at the 5% level) differences between the PCTs for the two heat treatments for Na (both for the ppm and log[ppm] results). On average, the Na leachate concentrations for the PCTs of the quenched glasses is 10.6 ppm greater than the centerline-cooled counterparts (0.027 greater in log[ppm]). No statistically significant difference due to heat treatment was seen for the PCT data for B, Li, and Si.

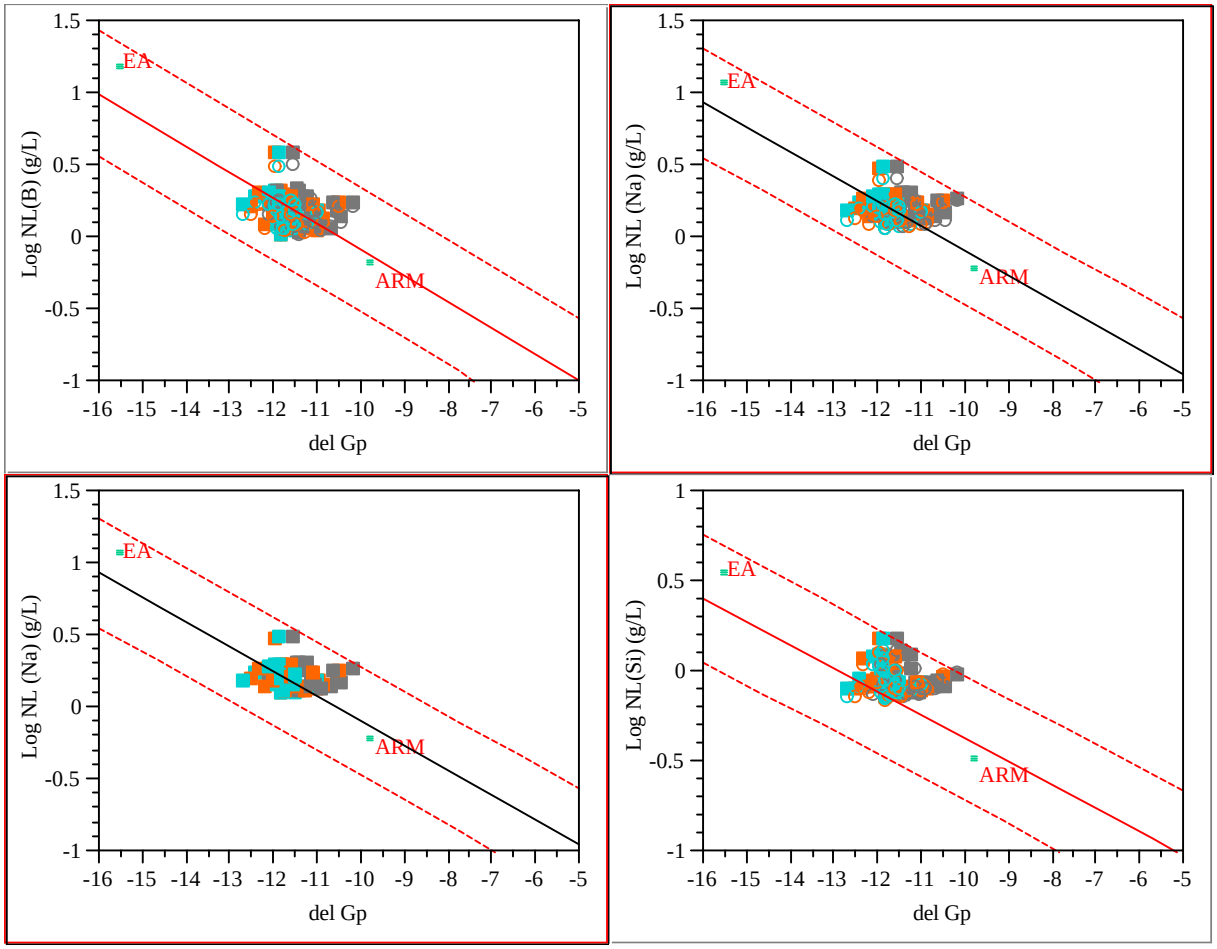
Figure 1: PCTs for Quenched Glasses versus Centerline Canister Cooled (ccc) Glasses in log[ppm] releases for B, Li, Na, and Si



Homogeneity. The homogeneity constraint was evaluated for each of the study glasses using targeted, measured, and bias-corrected compositions. As stated earlier, several of the glasses were intentionally selected to challenge homogeneity for the SB2/Frit 200 and SB2/Frit 320 glass regions. The target compositions of these glasses failed to satisfy the homogeneity PAR. In the discussion of the previous section, the acceptability of all of the NS glasses was established including the glasses that failed the homogeneity PAR. In the following section, the predictability of the glasses is considered.

Predictability. Figure 2 presents the B, Li, Na, and Si normalized PCT values for the glasses in the context of the current THERMO models for these releases [13], shown with 95% prediction limits. This figure also contains the results for the ccc (shown as squares) and quenched (shown as rings) glasses and for the ARM and EA glasses. Different colors are used in these plots to represent the different compositional views (measured, bias corrected, and targeted). All three compositional views are presented as part of Figure 2. Also note that, in this figure, ΔG_p is represented by del G_p. More information and associated plots are presented as part of the discussion of Appendix B.

Figure 2: DG_p (or del Gp) Model Predictions versus Normalized PCT Measurements Based upon For All Compositions Views and Quenched and ccc Glasses



These data provide evidence that the models [13] adequately predict the leaching performance of these glasses (as determined by the PCT) using credible compositions and waste loadings for SB2 with Frit 200 and Frit 320. The measured PCTs readily fall within the 95% prediction limits of the model.

By the nature of the selection process for glasses, there are a number of glasses that are significantly distant in composition from the centroids. That is, the extreme vertices from the statistical approach identify glasses that will provide information on the effect of variation in the amount of each component of the glass on the properties. However, the likelihood of or in some cases even the possibility of, producing glasses of such compositions is remote.

As discussed above under the homogeneity section of this report, several glasses were predicted to be inhomogeneous; NS01, NS02, NS09, NS10, and NS11. The predicted release rates for all of these glasses were within the 95% prediction interval of the model, and data for these glasses are given in Table 7. One of the glasses predicted to be inhomogeneous had relatively high release rates; glass NS01, which is the 25 wt% oxide loaded centroid for Frit 200 with high MgO and low MnO and also low Al_2O_3. At only 25 wt% loading, glass NS01 would not likely be processed at the DWPF. On the other hand, the predicted release rates were still within the 95% prediction interval of the model and well below the EA mean release rates. This combination of

glass components has not been extensively tested for DWPF processing and presents a glass compositional region that may be of interest in future glass testing for DWPF.

Table 7: Normalized PCT Response for B Using the Bias-Corrected Compositions for Normalization

Glass ID	Del Gp	Homogeneity	PCT Release B (g/L)
NS01	-11.567	200.7	3.83
NS02	-11.875	209.5	1.94
NS09	-11.828	209.5	1.22
NS10	-11.437	207.0	1.04
NS11	-10.905	208.4	1.15

Relaxation of the Homogeneity MAR. Based upon the results from this and from the Peeler, et. al. [17] studies with Frit 200 (and the effectiveness of the relaxation of the homogeneity constraint from the MAR to the PAR for MB2 acceptability), there is strong evidence in support of the relaxation of the homogeneity constraint from the MAR to the PAR limit for acceptability for both the SB2/Frit 200 and the SB2/Frit 320 glass regions. This relaxation is conditioned on one of the following two criteria being met:

Criterion (1)

- Use of 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

Criterion (2)

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

Note that in Table 3, all of the glasses included in this study, except for NS12, satisfy one or both of these criteria. Glass NS12 was targeted to meet the criteria, but the measured and bias-corrected compositions did not meet criterion (1) because the sum of alkali was >19.3 wt%. This glass, however, was acceptable and predictable from a durability perspective, which may indicate the need for further evaluation of the sum of alkali limit.

Regardless of which criterion is used by the DWPF, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina or the new alkali constraint, if used, as it is for the current alumina constraint.

Viscosity. Only one of the twenty-one glasses failed the viscosity constraint using the targeted compositions to predict viscosity. This glass, NS06 was the 40 wt% centroid glass for Frit 320, had a predicted viscosity of 21.50 Poise at 1150°C using the targeted composition as seen in Table 3. Using the bias-corrected composition for this glass, the predicted viscosity for NS06 was 23.7 Poise, which meets the PAR. The viscosities predicted using the measured compositions for all glasses ranged from 24.4 to 57.0 Poise at 1150°C and for the bias-corrected compositions the viscosity prediction ranged from 23.7 to 57.6 Poise (see Table 3). The general trend for the Frit 320 glasses was that predicted viscosity decreased with increasing waste loading, with the centroid at 40 wt% pushing the viscosity lower limit.

Liquidus Temperature. The original liquidus model was developed for glasses that contain Ni and form Trevorite as the primary crystalline phase. Trevorite is a nickel iron spinel that has

been observed in DWPF type glasses. The glasses for this expanded variability study contained nickel oxide. The new T_L model being developed for the DWPF was also used to evaluate the glasses for this study. This model is based on crystalline phase-like precursors in the melt.[12]

Selection of the twenty-one glasses was not constrained by T_L predictions determined for the original model. Thus, eleven of the twenty-one glasses, based upon targeted compositions, were predicted to fall outside of the T_L PAR for the original model, while only one, NS06, fell outside the conservative PAR used for the new model. For the measured compositions, the T_L predictions from the original model range from 934.7 to 1125.7°C, while the T_L predictions from the new model range from 778.2 to 988.9°C. For the bias-corrected compositions, the T_L predictions from the original model range from 936.6 to 1133.8°C, while the T_L predictions from the new model range from 782.5 to 996.0°C. The PAR limits for the original and new T_L models used in this study were 1024.9 and 1010°C, respectively. Measurements of liquidus temperature were not made for the glasses in this study, and no assessment of primary phases in the compositional region were made.

Crystallinity. XRD measurements were carried out on a number of the quenched glasses. A sample of the ccc NS01 glass was also analyzed due to the higher than normal PCT results. Some of these same samples were also submitted for SEM to verify the XRD results and to confirm or identify the chemical constituents of the crystalline phases that were unidentifiable by XRD. Table 8 presents the results of the XRD and SEM measurements. Two of the samples had unidentified peaks by XRD, but the amounts present were very small and the crystals were identified with SEM.

Table 8: Summary of XRD Results
(to the detection limit of XRD which is ~ 0.5 wt%)

Glass	XRD Submitted	XRD Detected	SEM Submitted	SEM Detected
NS01	Yes	Unidentified species	Yes	Ru, Spinel (Ni, Fe, Mn)
NS01 ccc	Yes	No crystals	No	No crystals
NS02	Yes	No crystals	No	No crystals
NS05	Yes	No crystals	No	No crystals
NS06	Yes	No crystals	No	No crystals
NS10	Yes	No crystals	No	No crystals
NS13	Yes	No crystals	No	No crystals
NS17	Yes	No crystals	Yes	Ru
NS18	Yes	No crystals	Yes	Ru
NS20	Yes	Unidentified species	Yes	Spinel (Ni, Fe, Mn)

A couple of the higher waste loading glasses (specifically NS16 through NS21) contained unreacted material in the crucibles after the samples were poured during the rapid quenching process. The quantity of the material was relatively small, and the overall measured glass compositions were acceptable compared to the target glass compositions. Therefore, the presence of this material did not affect the overall composition of the glass matrix, nor should it have affected the properties of the glass. Samples of this unreacted material were also submitted for SEM to identify what species were not becoming incorporated in the glass matrix. For glasses NS17 and NS18, crystals containing high levels of iron were detected. The SEM data suggested that the relative intensity of the iron in the matrix of the unreacted material itself was much higher than for the normal glass matrix. For glass NS20, the unreacted material contained mostly uranium, chromium, nickel and iron. Crystals of uranium oxide and spinel (iron-nickel-

chromium) were specifically detected. As stated above, the glass compositions did not appear to be affected by the presence of this unreacted material.

CONCLUSIONS – FRIT 200

The results from the glasses made using the Frit 200 composition demonstrate that, for the compositional region targeted, acceptable (durable) glasses will be produced. All of the glasses produced in this study met the acceptance criterion of having PCT leach rates significantly less than the EA glass mean values. The EA limit for B release is 16.695 g/L, while the highest release rate measured for B from any of the three Frit 200 glasses in this study was 3.83 g/L. The glasses were all within the 95% prediction intervals for individuals of the THERMO models in PCCS. Therefore, it has been demonstrated, based on this expanded processing region, that the durability models in PCCS adequately predict durability for glasses likely to be produced for SB2 with Frit 200. However, one of the glasses, NS01, did have an usually high release rate compared to the remaining glasses. This glass was the 25 wt% centroid with high MgO and low MnO and also contained a low amount of Al_2O_3. The effects of this combination of components should be further investigated for future DWPF sludge batches, since the reason for the high release is not understood.

The homogeneity constraint was not used to limit the selection of glasses for this study. Two glasses that were predicted to be inhomogeneous, NS01 and NS02, both had leach rates, both quenched and center-line cooled, that fell within the 95% prediction intervals for the durability models. These results, coupled with the results from Peeler et al [17], support the relaxation of the homogeneity constraint from the MAR to the PAR limit with Frit 200. This relaxation is conditioned on one of the following two criteria being met:

Criterion (1)

- Use of 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

Criterion (2)

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

Regardless of which criterion is used by the DWPF, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina or the new alkali constraint, if used, as it is for the current alumina constraint.

From a processing point of view, predicted viscosity (using the PCCS model) was not a concern for these Frit 200 glasses. Another processing parameter is liquidus temperature. The original liquidus temperature model assumes a nickel iron spinel (Trevorite) as the primary crystalline phase, and one of the glasses, NS03, with a 35 wt% sludge oxide loading was predicted to not have an acceptable liquidus temperature based on this original model. No problems with liquidus were predicted by the new model and liquidus temperature does not appear to be a problem based on past SB2 and Frit 200 studies [4] where isothermal holds at 1050°C were performed.

XRD results revealed that unidentified crystalline phases were seen in the NS01 quenched glass, while no crystals were detected in this glass after being subjected to the ccc profile. SEM of this glass identified ruthenium and spinel crystals. No crystalline species were detected in the other Frit 200 glass analyzed.

CONCLUSIONS – FRIT 320

The results for the SB2 variability study with Frit 320 demonstrate that, for the composition region targeted, glasses meeting durability limits will be produced. All of the glasses produced in this study met the acceptance criterion of having PCT leach rates less than the EA glass mean values. The EA limit for B release is 16.695 g/L while the highest release rate measured for B from any of the eighteen Frit 320 glasses (quenched and ccc) was 2.13 g/L. The glasses tested were all within the 95% prediction intervals for individuals of the THERMO Models in PCCS. Therefore, it has been demonstrated, based on these glasses, that the models in PCCS will adequately predict durability for this sludge batch.

The homogeneity constraint was not used to limit the selection of the Frit 320 glasses for this study. To the contrary, some of the glasses were specifically selected to demonstrate that the homogeneity constraint could be relaxed for MB3 with Frit 320. For the Frit 320 glasses, the constraint was easily met except at lower waste loadings and selecting glasses to challenge the constraint was difficult. Three of the Frit 320 glasses selected for this study were predicted to be inhomogeneous. The normalized releases for these glasses, both quenched and center-line cooled, fell within the 95% prediction intervals for the durability models. These results support, along with other information in this report and for MB2 [18], the relaxation of the homogeneity constraint from the MAR to the PAR limit. This relaxation is conditioned on one of the following two criteria being met:

Criterion (1)

- Use of 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

Criterion (2)

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

Regardless of which criterion is used by the DWPF, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina or the new alkali constraint, if used, as it is for the current alumina constraint.

From a processing point of view, the viscosity prediction was a concern for one glass, NS06 which was the 40 wt% waste loading centroid. The viscosity prediction for the targeted composition of this glass was just below the lower PAR limit, while the viscosity predictions for the measured and bias-corrected compositions satisfied the viscosity PAR.

Another processing parameter is liquidus temperature. The selection of the eighteen glasses was not constrained by the liquidus predictions for the original liquidus model. Consequently, ten of the eighteen glasses were predicted to not have an acceptable liquidus temperature based on the original liquidus model using bias-corrected glass compositions, while none of the glasses fell outside the PAR used for the new model using measured or bias-corrected glass compositions.

XRD results revealed that unidentified crystals were seen in one of the glasses, the quenched NS20 glass. SEM identified the crystals to be spinel, but no attempts were made in this study to evaluate the liquidus temperature of this glass to determine if the spinel formation was directly linked to liquidus temperature. No crystals were detected in the remaining glasses analyzed. Several of the higher loading glasses also contained unreacted material after rapid quenching.

This unreacted material was found to contain crystals of iron oxide, spinel, and uranium oxide, but the compositional measurements indicated no significant deviation from targeted values.

OVERALL CONCLUSIONS

The results from the Sludge Batch 2 expanded variability studies with Frit 200 and Frit 320 and the most recent sludge composition data demonstrate that the current DWPF models can be used to produce acceptable (durable) glass from both of these frits and this sludge batch. All of the glasses produced in this study have PCT release rates for B, Na, and Li that are significantly less than the release rates for the corresponding elements from the EA glass. The glasses for both frit options were within the 95% prediction intervals of the THERMO Models in PCCS. Therefore, this study demonstrates, based on the glasses tested, that the THERMO Models in PCCS adequately predict durability for glasses produced from this sludge batch using Frit 200 or Frit 320 over the waste loading range tested.

These results support the relaxation of the homogeneity constraint from the MAR to the PAR limit for these glass regions. This relaxation is conditioned on one of the following two criteria being met:

Criterion (1)

- Use of 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

Criterion (2)

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

Regardless of which criterion is used by the DWPF, measurement uncertainty (at the 95% confidence limit) should be applied to the new alumina or the new alkali constraint, if used, as it is for the current alumina constraint.

REFERENCES

[1] Sproull, J.F., "Technical Task Request: Expanded Glass Variability Study for Sludge Batch 2 (Macro-Batch 3) (U)", HLW/DWPF/TTR-01-0020, Rev. 0, May 17, 2001.

[2] Plodinec, M. J, K. G. Brown, S. L. Marra, C. M. Jantzen, and T. B. Edwards, "Technical Bases for the DWPF Glass Product Control Program (U)", WSRC-IM-91-116-5, Rev. 1, December 1995.

[3] Norton, M.R., "Engineering Position, SRTC Work to Support the Frit Selection for Macrobatch 3", HLW-DEN-2001-00136, May 21, 2001.

[4] Harbour, J.R., T.B. Edwards, and R.J. Workman, "Summary of Results for Macrobatch 3 Variability Study", WSRC-TR-2000-00351, September 13, 2000.

[5] Peeler, D.K., T.B. Edwards, T. H. Lorier, K.G. Brown, D.F. Bickford, I.A. Reamer, D.C. Witt, J.D. Vienna, and R.J. Workman, "Melt Rate Improvement for DWPF MB3: Frit Development and Model Assessment", WSRC-TR-2001-00131, March 30, 2001.

[6] Fellinger, T.L., and N.E. Bibler, "Results of a Laboratory Washing Study Using the March 2001 Tank 40 Radioactive Slurry Samples – Original Composition and Over-Washed Composition", SRT-GPD-2001-00059, June 21, 2001.

[7] Elder, H. H., "Sludge Batch 2 Qualification Strategy and Simulant Composition (U)," HLW-SDT-2000-00128, Rev. 0, April 18, 2000.

[8] Bumgardner, D.C., "Technical Task Request: Tank 40 Sludge Batch 2 Washing/Glass Qualification", HLE-TTR-2001-055, Rev. 0, May 17, 2001.

[9] Swingle, R. F. and T. B. Edwards, "Task Technical and Quality Assurance Plan for Qualification of the Sludge Batch 2 Acceptance Sample," WSRC-RP-2001-00754, Rev. 0, July 26, 2001.

[10] Herman, C.C, "Task Technical & QA Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)", WSRC-RP-2001-00756, July 31, 2001.

[11] Brown, K.G., T.B. Edwards, C.C. Herman, and D.K. Peeler, "Selecting Glass Compositions for the DWPF SB2/Frit 320 Variability Study", WSRC-RP-2001-00775, July 31, 2001.

[12] Brown, K.G., C.M. Jantzen, and G. Ritzhaupt, "Relating Liquidus Temperature to Composition for Defense Waste Processing Facility (DWPF) Process Control", WSRC-TR-2001-00520, October 25, 2001.

[13] Jantzen, C. M., J. B. Pickett, K. G. Brown, T. B. Edwards, and D. C. Beam, "Process/Product Models for the Defense Waste Processing Facility (DWPF): Part I. Predicting Glass Durability from Composition Using a Thermodynamic Hydration Energy Reaction Model (THERMO) (U)," WSRC-TR-93-672, Rev. 1, September 28, 1995.

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

[15] Office of Environmental Management, **Waste Acceptance Product Specifications for Vitrified High-Level Waste Forms**, Revision 2, USDOE Document DOE/EM-0093, December 1996.

[16] Jantzen, C. M., N. E. Bibler, D. C. Beam, C. L. Crawford, and M. A. Pickett, "Characterization of the DWPF Environmental Assessment (EA) Glass Standard Reference Material (U)" WSRC-TR-92-346, Rev.1, June 1, 1993.

[17] Peeler, D. K., T. B. Edwards, K. G. Brown, R. J. Workman, and I. A. Reamer, "Reduction of Constraints: Applicability of the Homogeneity Constraint for Macrobatch 3 (U)," WSRC-TR-2000-00358, September 15, 2000.

[18] Cicero-Herman, C.A., M.K. Andrews, T.B. Edwards, 'Results of the Tank 42 (Batch 1B) Variability Study", WSRC-TR-98-00180, June 5, 1998.

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

[20] ASTM C 1285-97, "Standard Test Methods for Determining Chemical Durability of Nuclear Waste Glasses: The Product Consistency Test (PCT) (U)", 1997.

[21] Edwards. R.E. "SGM Run 8 - Canister and Glass Temperature During Filling and DPST-87-801, Savannah River Laboratory, Aiken, South Carolina, 1987.

[22] Herman, C.C., "Analytical Study Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)", WSRC-RP-2001-00702, August 22, 2001.

[23] Edwards, T. B, "An Analytical Plan for Measuring the Chemical Compositions of Glasses for the Expanded MB3 Variability Study," SRT-SCS-2001-00034, August 21, 2001.

[24] Edwards, T. B, "An Analytical Plan for Measuring PCT Solutions for the Glasses Supporting the Expanded MB3 Variability Study," SRT-SCS-2001-00038, August 24, 2001.

[25] SAS Institute, Inc., **JMP® Statistics and Graphics Guide**, Version 4, SAS Institute, Inc., Cary, NC, 2000.

This page intentionally left blank.

APPENDICES

Appendix A. **A Statistical Review of the Chemical Composition Measurements.**

Appendix B. **A Statistical Review of the PCT Measurements.**

Appendix C. **Analytical Plan for the Measurement of Chemical Compositions.**

Appendix D. **Analytical Plan for the Measurement of PCT Leachates.**

This page intentionally left blank.

Appendix A:

A Statistical Review of the Chemical Composition Measurements

In this appendix, the measured versus target compositions of the 21 study glasses are presented and compared. The targeted compositions for these glasses are provided in Table A.1.[4] The chemical composition measurements for these glasses were conducted by the SRTC-Mobile Laboratory (SRTC-ML) following the analytical plan provided as Appendix C. Two dissolution methods were utilized: samples prepared by lithium metaborate (LM) dissolution were used to measure elemental concentrations of aluminum (Al), calcium (Ca), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), phosphorous (P), silicon (Si), titanium (Ti), uranium (U), and zirconium (Zr), while samples prepared by peroxide fusion (PF) dissolution were used to measure elemental concentrations of boron (B) and lithium (Li). Notice that beyond the minor components of Cr, P, Ti, and Zr, there is an "Others" grouping of additional minor components whose concentrations were not measured. For each study glass, measurements were obtained from samples prepared in duplicate by each of these dissolution methods. All of the prepared samples were analyzed (twice for each element of interest) by Inductively Coupled Plasma – Emission Spectroscopy (ICP-ES) (with the instrumentation being re-calibrated between the duplicate analyses).

Table A.2 provides the elemental concentration measurements derived from the samples prepared using LM and Table A.3 provides the measurements derived from the sample prepared using PF. Measurements for two standards (Batch 1 and a uranium standard, U Std, glass), that were included in the SRTC-ML analytical plan along with the NS glasses, are also provided in these two tables.

The elemental concentrations were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During this process, an elemental concentration that was determined to be below the detection limit of the analytical procedures used by the SRTC-ML was reduced to half of that detection limit as the oxide concentration was determined.

In the sections that follow, the analytical sequence of the measurements is explored, the measurements of the standards are investigated and used for bias correction, the measurements for each glass are reviewed, the average chemical composition (measured and bias-corrected) for each glass are determined, and comparisons are made between these measurements and the targeted compositions for these glasses. The statistical analyses presented in this appendix were conducted using JMP® Version 4 from SAS Institute, Inc. [25].

Measurements in Analytical Sequence

Exhibit A.1 provides plots of the measurements generated by the SRTC-ML from samples prepared using the LM method. These plots are in analytical sequence with different symbols and colors being used to represent each of the NS and standard glasses. Similar plots for the samples prepared using the PF method are provided in Exhibit A.2.

[4] All tables and exhibits for this appendix appear at the end of this appendix.

A review of these plots indicates no significant patterns or trends in the analytical process over the course of these measurements, and there appear to be no obvious outliers in these chemical composition measurements.

Batch 1 and Uranium Standard Results

In this section of the appendix, the SRTC-ML measurements of the chemical compositions of the Batch 1 and uranium standard (U std) glasses are reviewed. These measurements are investigated across the ICP analytical blocks, and the results are used to bias correct the measurements for the NS glasses.

Exhibit A.3 provides statistical analyses of the Batch 1 and U std results generated by the LM prep method by analytical block. The results of an analysis of variance (ANOVA) investigation looking for statistically significant differences among the block means for each of the standards. The results from these statistical tests may be summarized as follows: for the Batch 1 standard – the Fe, Na, Si, and Zr measurements indicate a significant ICP calibration effect at the 5% significance level and for the U std – the Ca, Fe, Na, and Si measurements indicate a significant ICP calibration effect at the 5% significance level. Also, note that there is similarity between the patterns of behavior for the measurements of the two standards over the analytical blocks for many of the elements. The reference values for the oxide concentrations of the two standards are given in the header for each set of measurements in the exhibit.

Exhibit A.4 provides a similar set of analyses for the B_2O_3 and Li_2O measurements derived from samples prepared via the PF method. In this exhibit, only the Li_2O data for Batch 1 show a statistically significant (at the 5% significance level) difference among the ICP analytical/calibration blocks.

The results suggest that it may be helpful to bias correct the oxide measurements of the NS glasses for the effect of the ICP calibration on each of the analytical blocks. The basis for this bias correction is presented as part of Exhibits A.3 and A.4 – the average measurement for Batch 1 for each ICP block for Al, Ca, Cr, Fe, Mg, Mn, Na, Ni, P, Si, Ti, and Zr and the average measurement for U std for each ICP block for U. The Batch 1 results served as the basis for bias correcting all of the oxides except uranium. The U std results were used to bias correct for uranium. For the other oxides, the Batch 1 results were used to conduct the bias correction as long as the reference value for the oxide concentration in the Batch 1 glass was greater than or equal to 0.1 wt%. Thus, applying this approach and based upon the information in the exhibits, the Batch 1 results were used to bias correct the Al, Ca, Cr, Fe, Mg, Mn, Na, Ni, Si, and Ti measurements. No bias correction was conducted for P or Zr.

The bias correction was conducted as follows. For each oxide, let $\bar{a}_{ij}$ be the average measurement for the i^{th} oxide at analytical block j for Batch 1 (or U std for uranium), and let t_i be the reference value for the i^{th} oxide for Batch 1 (or for U std if uranium). (The averages and reference values are provided in Exhibits A.3 and A.4.) Let $\bar{c}_{ijk}$ be the average measurement for the i^{th} oxide at analytical block j for the k^{th} glass. The bias adjustment was conducted as follows

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

Bias-corrected measurements are indicated by a "bc" suffix, and such adjustments were performed for all of the oxides of this study except P_2O_5 and ZrO_2. Both measured and measured "bc" values are included in the discussion that follows. In these discussions bias-corrected values for P_2O_5 and ZrO_2 are included for completeness (e.g., to allow a sum of oxides to be computed for the bias-corrected results). These bias-corrected values are the same as the original P_2O_5 and ZrO_2 values (i.e., once again, no bias correction was performed for these two oxides).

Composition Measurements by Glass Number

Exhibits A.5 and A.6 provide plots of the oxide concentration measurements by Glass ID (including both the Batch 1, labeled as glass number 0, and U std, labeled as glass number 100, glasses) for the measured and bias-corrected (bc) values for the LM and PF preparation methods, respectively. These plots show the individual measurements across the duplicates of each preparation method and the two ICP calibrations. A review of the plots presented in these exhibits reveals the repeatability of the four individual, oxide values for each glass.

Some observations from these exhibits are provided. The variation among the four measurements appears to be greater for some of the glasses than for other glasses for several of the oxides. The Fe_2O_3 measurements demonstrate such variation as do the Na_2O and SiO_2 values. Each of these is a primary component of the NS glasses. The measurements for P_2O_5, although only a minor component of this study, reveal more variation for several of the glasses as compared to the variation. Where the variation is greater, there appears to be one measurement that has a much smaller value than the others do. This observation prompted a request that the SRTC-ML re-measure several of the prepared samples for their P_2O_5 content. Display 1 was prepared from the data generated by the SRTC-ML in response to this request:

Display 1: Select Phosphorous Re-Measurements

Glass ID	Sample ID	P Elemental Wt%	
		Original	Re-Measured
NS18	Q02LM12	0.144	0.232
NS14	Q06LM21	0.069	0.089
NS06	Q07LM12	0.166	0.184
NS02	Q08LM22	0.163	0.191
NS19	Q13LM21	0.057	0.143
NS01	Q17LM12	0.056	0.073
NS03	Q18LM21	0.085	0.211
NS09	Q20LM21	0.000	0.064

These re-measurements are more in line with the other 3 results originally generated by the SRTC-ML for the glass samples. However, the re-measured data of Display 1 are used in the following discussions even though these data suggest that the average P_2O_5 concentration for each of the NS glasses listed in the above table computed using the four original measurements generated by the SRTC-ML may be slightly biased low. More detailed discussions of the average, measured chemical compositions of the NS glasses are provided in the sections that follow.

The observations discussed here indicate no problems of practical significance in using the chemical composition measurements or the bias-corrected values, which are presented in the plots of Exhibits A.5 and A.6, for this variability study.

Measured versus Targeted Compositions

The four measurements for each oxide for each glass (over both preparation methods) were averaged to determine a representative chemical composition for each glass. These

determinations were conducted for the measured and bias-corrected data. A sum of oxides was also computed for each glass based upon both the measured and bias-corrected values. Table A.4 provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. Notice that the targeted sums of oxides for the glasses do not sum to 100% due to the "Others" component of the NS glasses and an incomplete coverage of the oxides in the Batch 1 and U std glasses. All of the sums of oxides (both measured and bias-corrected) fall within the interval of 95 to 105 wt% except the bias-corrected sums of oxides for NS04 (94.1%), NS13 (94.7%), and the U std glass (94.8%). However, the targeted sum of oxides for the U std glass was only 96.5 wt% which suggests that the 94.8 wt% recovery attained in the bias-corrected measurements is not a problem.

Entries in Table A.4 show the relative differences between the measured or bias-corrected values and the targeted values for those oxides with a targeted concentration > 0.5 wt%. These differences are shaded when they are greater than or equal to 5%. To help highlight the comparisons among the measured, bias-corrected, and targeted values, Exhibit A.7 provides comparison plots for each glass for each oxide.

As seen in Table A.4 and the plots of Exhibit A.7, the CaO measured values are, on average, slightly higher than their targeted values. Bias correction appears to move the measured values closer to their targets. For most of the NS glasses, the measured and bias-corrected Cr_2O_3 values are slightly less than their respective targets. The Fe_2O_3 values miss their respective targets for several of the NS glasses with the misses being both above and below the targeted values. See for example glass numbers 8, 12, 13, 16, and 18 through 21. The Li_2O results look very good with only NS13 missing its Li_2O target (low) by more than 5%. For the Na_2O results, the bias-corrected values appear to miss the Na_2O targets more than the original measurements with the measured values for a couple of the glasses (see NS04 and NS13) missing the targeted values by more than 5%. The P_2O_5 values appear to fall below targeted values for all of the NS glasses even for glasses that were not part of the set that was re-measured by the SRTC-ML. The SiO_2 results miss their respective targets both high and low, but none of the differences between the measured or bias-corrected values and the targeted values is as great as 5%. Finally, the comparisons for the U_3O_8 results show good agreement between the measurements and targeted values.

Overall, these comparisons between the measured and targeted compositions suggest that there were no significant problems in the batching or fabrication of the NS study glasses.

Table A.1: Targeted Compositions (in oxides) for the NS Glasses

Glass ID	% Waste Loading	Frit	Oxide Concentrations (in weight fractions)														
			Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	P_2O_5	SiO_2	TiO_2	U_3O_8	ZrO_2	Others
NS01	25	200	0.030250	0.09007	0.011200	0.000591	0.088850	0.03783	0.025950	0.005780	0.140050	0.005680	0.002242	0.530880	0.000067	0.028850	0.000214	0.004630
NS02	30	200	0.033210	0.08417	0.013440	0.001470	0.106620	0.03582	0.014540	0.017310	0.146060	0.006810	0.005578	0.495880	0.000166	0.034620	0.000532	0.011520
NS03	35	200	0.040670	0.07819	0.010710	0.001715	0.124390	0.03346	0.028330	0.020200	0.152070	0.007950	0.006508	0.463230	0.000194	0.027370	0.000621	0.013440
NS04	30	320	0.045430	0.05612	0.011340	0.001096	0.124130	0.05661	0.007050	0.012250	0.133430	0.005770	0.004159	0.510030	0.000124	0.029230	0.000397	0.008590
NS05	35	320	0.053010	0.05214	0.013230	0.001279	0.144820	0.05271	0.008230	0.014290	0.135670	0.006730	0.004852	0.475030	0.000144	0.034100	0.000463	0.010020
NS06	40	320	0.060580	0.04816	0.015120	0.001462	0.165510	0.04881	0.009400	0.016340	0.137900	0.007700	0.005549	0.440040	0.000165	0.038970	0.000529	0.011460
NS07	25	320	0.031330	0.06008	0.008360	0.000717	0.111550	0.06040	0.008850	0.012700	0.130890	0.004300	0.002721	0.544520	0.000081	0.021410	0.000260	0.005620
NS08	25	320	0.031330	0.06008	0.008360	0.000717	0.111550	0.06040	0.002550	0.012700	0.131610	0.004300	0.002721	0.544520	0.000081	0.026990	0.000260	0.005620
NS09	25	320	0.045950	0.06007	0.011200	0.000591	0.088850	0.06033	0.010950	0.014430	0.132500	0.005680	0.002242	0.545880	0.000067	0.019550	0.000214	0.004630
NS10	25	320	0.045950	0.06014	0.011200	0.001225	0.088850	0.06068	0.010950	0.014430	0.130530	0.003950	0.004648	0.544180	0.000138	0.019550	0.000444	0.009600
NS11	25	320	0.042300	0.06012	0.008360	0.001099	0.094530	0.06061	0.002550	0.012700	0.132380	0.005330	0.004169	0.545540	0.000124	0.026990	0.000398	0.008610
NS12	27.5	320	0.030440	0.05815	0.008420	0.001347	0.128950	0.05875	0.000500	0.015870	0.134030	0.006240	0.005113	0.526590	0.000152	0.021510	0.000488	0.010560
NS13	30	320	0.033210	0.05617	0.013440	0.001470	0.140670	0.05682	0.000540	0.017310	0.133110	0.004740	0.005578	0.509010	0.000166	0.023460	0.000532	0.011520
NS14	30	320	0.033210	0.05608	0.013440	0.000708	0.140670	0.05639	0.013140	0.006930	0.135300	0.006810	0.002687	0.509010	0.000080	0.023460	0.000256	0.005550
NS15	32.5	320	0.059740	0.05409	0.014560	0.000768	0.115510	0.05443	0.014240	0.018750	0.138490	0.005140	0.002915	0.493640	0.000087	0.025420	0.000278	0.006020
NS16	35	320	0.038750	0.05209	0.015680	0.000827	0.164120	0.05246	0.000630	0.020200	0.138060	0.007950	0.003138	0.476230	0.000093	0.027370	0.000299	0.006480
NS17	35	320	0.038750	0.05219	0.010710	0.001715	0.164120	0.05296	0.000630	0.020200	0.137890	0.005530	0.006508	0.476230	0.000194	0.027370	0.000621	0.013440
NS18	37.5	320	0.068930	0.05021	0.011480	0.001837	0.133280	0.05102	0.016430	0.021640	0.141110	0.005930	0.006972	0.456260	0.000207	0.029330	0.000665	0.014400
NS19	40	320	0.067670	0.04813	0.016780	0.001148	0.151240	0.04864	0.014160	0.020310	0.143710	0.006870	0.004358	0.439220	0.000130	0.034260	0.000416	0.009000
NS20	40	320	0.073520	0.04811	0.017920	0.000946	0.142160	0.04853	0.017520	0.023080	0.142720	0.009080	0.003588	0.438680	0.000107	0.031280	0.000342	0.007410
NS21	40	320	0.067670	0.04813	0.013380	0.001148	0.151240	0.04864	0.014160	0.020310	0.143830	0.008530	0.004358	0.440860	0.000130	0.034260	0.000416	0.009000

Table A.2: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Lithium Metaborate

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	Al	Ca	Cr	Fe	Mg	Mn	Na	Ni	P	Si	Ti	U	Zr
BCHLM111	Batch 1	1	1	1	2.55	0.922	0.082	9.19	0.898	1.350	7.03	0.576	0.000	24.5	0.412	0.00	0.061
UGLM111	U Std	1	1	2	2.10	0.970	0.167	9.12	0.738	2.080	8.61	0.792	0.000	22.2	0.571	1.97	0.001
Q10LM11	NS04	1	1	3	2.33	0.840	0.085	8.33	0.414	0.920	9.49	0.407	0.130	23.5	0.007	2.36	0.018
Q09LM11	NS11	1	1	4	2.22	0.632	0.062	7.01	0.143	0.949	9.43	0.383	0.134	25.4	0.006	2.22	0.019
Q04LM21	NS16	1	1	5	2.13	1.230	0.051	11.13	0.024	1.560	10.37	0.577	0.101	23.4	0.009	2.35	0.025
Q08LM21	NS02	1	1	6	1.84	1.030	0.094	7.81	0.893	1.360	10.89	0.515	0.189	24.2	0.009	2.97	0.032
Q02LM21	NS18	1	1	7	3.67	0.873	0.105	8.69	1.020	1.710	10.51	0.437	0.240	22.8	0.011	2.50	0.047
Q02LM11	NS18	1	1	8	3.64	0.885	0.104	8.68	1.000	1.690	11.21	0.427	0.231	22.8	0.010	2.49	0.045
Q10LM21	NS04	1	1	9	2.33	0.843	0.060	8.51	0.411	0.913	9.44	0.406	0.126	23.7	0.005	2.35	0.019
BCHLM112	Batch 1	1	1	10	2.54	0.958	0.082	9.35	0.891	1.340	7.13	0.576	0.000	24.8	0.409	0.00	0.060
UGLM112	U Std	1	1	11	2.09	0.964	0.168	9.41	0.735	2.070	8.75	0.787	0.000	22.7	0.569	1.98	0.002
Q07LM11	NS06	1	1	12	3.21	1.200	0.079	11.52	0.568	1.270	10.35	0.543	0.187	21.5	0.011	3.31	0.030
Q04LM11	NS16	1	1	13	2.02	1.180	0.051	10.68	0.021	1.500	10.06	0.555	0.098	22.5	0.009	2.22	0.025
Q08LM11	NS02	1	1	14	1.85	1.050	0.094	7.98	0.904	1.380	11.43	0.524	0.186	24.8	0.008	2.99	0.028
Q12LM21	NS10	1	1	15	2.47	0.901	0.069	6.48	0.678	1.150	9.93	0.294	0.151	26.6	0.008	1.60	0.022
Q07LM21	NS06	1	1	16	3.21	1.210	0.079	11.32	0.568	1.280	10.46	0.548	0.185	21.6	0.008	3.30	0.029
Q12LM11	NS10	1	1	17	2.44	0.850	0.068	6.38	0.677	1.160	9.81	0.297	0.150	26.2	0.007	1.60	0.023
Q09LM21	NS11	1	1	18	2.33	0.679	0.062	7.40	0.149	0.973	10.03	0.392	0.136	26.8	0.007	2.29	0.019
BCHLM113	Batch 1	1	1	19	2.53	0.955	0.081	9.34	0.884	1.330	7.07	0.570	0.000	25.1	0.405	0.00	0.061
UGLM113	U Std	1	1	20	2.10	0.972	0.167	9.38	0.730	2.060	8.68	0.783	0.000	22.7	0.565	1.98	0.002
BCHLM121	Batch 1	1	2	1	2.55	0.930	0.081	9.12	0.890	1.350	6.85	0.575	0.000	23.8	0.409	0.00	0.060
UGLM121	U Std	1	2	2	2.10	0.959	0.167	8.96	0.729	2.100	8.22	0.789	0.000	21.4	0.568	1.92	0.001
Q07LM22	NS06	1	2	3	3.23	1.190	0.078	10.87	0.565	1.300	9.91	0.550	0.190	20.5	0.009	3.30	0.028
Q04LM22	NS16	1	2	4	2.14	1.220	0.049	10.76	0.023	1.560	10.13	0.575	0.105	22.4	0.010	2.37	0.024
Q07LM12	NS06	1	2	5	3.22	1.230	0.078	10.95	0.566	1.280	9.86	0.547	0.166	20.3	0.012	3.34	0.029
Q08LM12	NS02	1	2	6	1.85	1.040	0.093	7.59	0.904	1.390	10.68	0.527	0.189	23.2	0.009	3.02	0.027
Q08LM22	NS02	1	2	7	1.83	1.110	0.093	7.62	0.882	1.370	10.62	0.515	0.163	23.1	0.010	2.53	0.031
Q02LM12	NS18	1	2	8	3.67	0.878	0.101	8.44	0.992	1.690	10.10	0.427	0.144	21.6	0.011	2.53	0.043
Q10LM22	NS04	1	2	9	2.35	0.844	0.059	8.32	0.407	0.910	9.14	0.406	0.128	22.7	0.006	2.35	0.018
BCHLM122	Batch 1	1	2	10	2.55	0.933	0.080	9.07	0.882	1.350	6.77	0.573	0.000	23.8	0.411	0.00	0.059

Table A.2: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Lithium Metaborate *(continued)*

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	Al	Ca	Cr	Fe	Mg	Mn	Na	Ni	P	Si	Ti	U	Zr
UGLM122	U Std	1	2	11	2.11	0.963	0.166	8.97	0.727	2.080	8.24	0.788	0.000	21.4	0.565	2.04	0.001
Q02LM22	NS18	1	2	12	3.69	0.870	0.103	8.48	1.000	1.700	10.36	0.436	0.226	21.9	0.012	2.52	0.045
Q12LM22	NS10	1	2	13	2.45	0.894	0.068	6.18	0.674	1.160	9.48	0.296	0.154	25.1	0.009	1.66	0.021
Q04LM12	NS16	1	2	14	2.01	1.170	0.050	10.16	0.020	1.500	9.47	0.555	0.099	21.1	0.010	2.26	0.023
Q09LM22	NS11	1	2	15	2.32	0.668	0.060	7.09	0.147	0.971	9.47	0.393	0.123	25.1	0.008	2.35	0.018
Q12LM12	NS10	1	2	16	2.45	0.841	0.066	6.11	0.672	1.160	9.30	0.297	0.155	24.6	0.008	1.65	0.021
Q09LM12	NS11	1	2	17	2.24	0.632	0.061	6.87	0.140	0.949	9.25	0.382	0.127	24.4	0.007	2.27	0.018
Q10LM12	NS04	1	2	18	2.35	0.840	0.083	8.18	0.405	0.911	9.34	0.403	0.130	22.9	0.008	2.45	0.017
BCHLM123	Batch 1	1	2	19	2.54	0.907	0.080	8.92	0.875	1.340	6.76	0.572	0.000	23.7	0.407	0.00	0.059
UGLM123	U Std	1	2	20	2.09	0.954	0.165	8.94	0.722	2.060	8.31	0.783	0.000	21.4	0.565	2.04	0.000
BCHLM211	Batch 1	2	1	1	2.53	0.948	0.083	9.10	0.892	1.360	6.94	0.581	0.000	24.1	0.411	0.00	0.059
UGLM211	U Std	2	1	2	2.09	0.969	0.169	9.10	0.736	2.090	8.46	0.799	0.000	21.8	0.566	1.95	0.000
Q16LM21	NS08	2	1	3	1.69	0.643	0.046	8.33	0.164	1.010	9.71	0.324	0.089	25.0	0.007	2.18	0.037
Q11LM11	NS07	2	1	4	1.69	0.674	0.030	7.84	0.566	1.030	9.69	0.328	0.060	25.7	0.059	1.76	0.038
Q13LM11	NS19	2	1	5	3.66	1.290	0.070	9.98	0.850	1.610	10.87	0.522	0.134	21.3	0.008	2.87	0.017
Q06LM11	NS14	2	1	6	1.72	0.999	0.038	9.93	0.833	0.543	9.67	0.492	0.090	23.0	0.007	1.84	0.010
Q06LM21	NS14	2	1	7	1.80	1.040	0.041	10.38	0.866	0.568	10.17	0.516	0.069	24.0	0.008	1.92	0.009
Q16LM11	NS08	2	1	8	1.71	0.698	0.049	8.60	0.169	1.040	9.97	0.335	0.093	25.6	0.008	2.20	0.015
Q18LM11	NS03	2	1	9	2.21	0.856	0.095	8.90	1.700	1.590	11.70	0.592	0.234	22.4	0.008	2.24	0.029
BCHLM212	Batch 1	2	1	10	2.56	0.937	0.082	9.18	0.889	1.360	7.05	0.579	0.000	24.4	0.411	0.00	0.059
UGLM212	U Std	2	1	11	2.09	0.973	0.169	9.12	0.736	2.090	8.61	0.796	0.000	22.1	0.566	1.89	0.000
Q20LM11	NS09	2	1	12	2.46	0.864	0.039	6.85	0.722	1.190	10.34	0.451	0.074	25.8	0.002	1.63	0.005
Q20LM21	NS09	2	1	13	2.35	0.831	0.044	6.58	0.692	1.130	9.95	0.430	0.000	24.8	0.003	1.60	0.003
Q05LM11	NS13	2	1	14	1.68	0.989	0.076	8.94	0.014	1.240	9.20	0.327	0.171	24.8	0.006	1.83	0.022
Q13LM21	NS19	2	1	15	3.56	1.270	0.067	9.96	0.819	1.550	10.91	0.499	0.057	21.2	0.010	2.83	0.017
Q18LM21	NS03	2	1	16	2.14	0.831	0.092	8.17	1.620	1.520	10.74	0.563	0.085	20.5	0.007	2.22	0.027
Q11LM21	NS07	2	1	17	1.57	0.617	0.026	7.46	0.504	0.931	9.37	0.292	0.051	24.5	0.052	1.65	0.032
Q05LM21	NS13	2	1	18	1.61	0.916	0.072	8.88	0.012	1.160	9.11	0.297	0.160	24.6	0.007	1.79	0.020
BCHLM213	Batch 1	2	1	19	2.48	0.905	0.079	9.18	0.861	1.300	7.06	0.548	0.000	24.4	0.399	0.00	0.056
UGLM213	U Std	2	1	20	2.04	0.950	0.162	9.13	0.702	2.000	8.74	0.754	0.000	22.3	0.550	1.90	0.000
BCHLM221	Batch 1	2	2	1	2.54	0.937	0.081	9.15	0.899	1.360	6.88	0.580	0.000	24.2	0.409	0.00	0.062

Table A.2: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Lithium Metaborate *(continued)*

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	Al	Ca	Cr	Fe	Mg	Mn	Na	Ni	P	Si	Ti	U	Zr
UGLM221	U Std	2	2	2	2.09	0.975	0.168	9.10	0.740	2.100	8.54	0.796	0.000	21.9	0.569	1.99	0.001
Q16LM22	NS08	2	2	3	1.69	0.654	0.045	8.25	0.164	1.010	9.48	0.323	0.090	24.6	0.004	2.24	0.039
Q06LM22	NS14	2	2	4	1.77	1.080	0.040	10.24	0.872	0.560	9.87	0.507	0.090	23.5	0.006	1.98	0.011
Q18LM22	NS03	2	2	5	2.16	0.843	0.094	8.60	1.680	1.560	10.89	0.580	0.217	21.3	0.005	2.30	0.037
Q05LM22	NS13	2	2	6	1.66	0.951	0.074	8.81	0.014	1.210	8.88	0.314	0.169	24.2	0.004	1.86	0.024
Q16LM12	NS08	2	2	7	1.71	0.715	0.048	8.66	0.171	1.040	9.74	0.333	0.091	25.4	0.005	2.28	0.018
Q20LM22	NS09	2	2	8	2.38	0.847	0.043	6.58	0.699	1.140	9.55	0.431	0.073	24.4	0.000	1.62	0.007
Q11LM12	NS07	2	2	9	1.68	0.671	0.028	7.82	0.566	1.020	9.38	0.325	0.059	25.3	0.057	1.78	0.040
BCHLM222	Batch 1	2	2	10	2.55	0.931	0.081	9.12	0.895	1.360	6.73	0.579	0.000	23.9	0.409	0.00	0.061
UGLM222	U Std	2	2	11	2.11	0.988	0.166	9.05	0.742	2.090	8.23	0.799	0.000	21.5	0.570	1.95	0.002
Q20LM12	NS09	2	2	12	2.50	0.877	0.038	6.82	0.727	1.190	9.91	0.454	0.075	25.4	0.000	1.66	0.008
Q18LM12	NS03	2	2	13	2.25	0.867	0.095	8.88	1.710	1.590	11.22	0.593	0.234	22.0	0.005	2.29	0.031
Q06LM12	NS14	2	2	14	1.75	1.090	0.037	9.82	0.849	0.544	9.29	0.493	0.089	22.6	0.005	1.85	0.012
Q13LM12	NS19	2	2	15	3.73	1.320	0.069	9.91	0.857	1.610	10.38	0.524	0.156	20.7	0.005	2.90	0.019
Q05LM12	NS13	2	2	16	1.71	0.999	0.076	8.91	0.014	1.260	8.67	0.325	0.177	24.2	0.004	1.84	0.024
Q11LM22	NS07	2	2	17	1.63	0.653	0.026	7.37	0.533	0.972	8.92	0.307	0.053	24.0	0.051	1.67	0.038
Q13LM22	NS19	2	2	18	3.67	1.300	0.069	9.88	0.849	1.590	10.36	0.516	0.152	20.6	0.008	2.86	0.019
BCHLM223	Batch 1	2	2	19	2.55	0.947	0.081	9.14	0.896	1.360	6.75	0.579	0.000	23.8	0.409	0.00	0.061
UGLM223	U Std	2	2	20	2.13	0.992	0.167	9.11	0.738	2.100	8.26	0.797	0.000	21.6	0.566	1.95	0.001
BCHLM311	Batch 1	3	1	1	2.54	0.933	0.079	9.08	0.894	1.350	6.95	0.575	0.000	24.1	0.412	0.00	0.056
UGLM311	U Std	3	1	2	2.11	0.985	0.167	9.02	0.736	2.090	8.48	0.792	0.000	21.8	0.569	1.98	0.000
Q03LM21	NS21	3	1	3	3.52	1.020	0.076	9.61	0.824	1.540	10.61	0.613	0.143	21.4	0.005	2.70	0.035
Q14LM21	NS20	3	1	4	3.98	1.410	0.051	9.42	1.110	1.840	10.70	0.651	0.119	21.1	0.010	2.63	0.010
Q03LM11	NS21	3	1	5	3.44	0.980	0.065	9.31	0.803	1.500	10.22	0.599	0.133	20.8	0.005	2.63	0.033
Q14LM11	NS20	3	1	6	3.81	1.350	0.049	9.15	1.070	1.780	10.28	0.632	0.116	20.3	0.009	2.52	0.012
Q01LM11	NS15	3	1	7	3.04	1.110	0.042	8.23	0.852	1.450	10.07	0.368	0.092	23.0	0.003	2.07	0.010
Q19LM11	NS12	3	1	8	1.75	0.760	0.073	10.61	0.018	1.350	10.56	0.487	0.172	25.1	0.008	1.90	0.017
Q01LM21	NS15	3	1	9	3.12	1.160	0.044	8.40	0.858	1.480	10.42	0.377	0.097	23.3	0.003	2.12	0.011
BCHLM312	Batch 1	3	1	10	2.56	0.943	0.080	8.98	0.893	1.360	6.90	0.572	0.000	23.8	0.413	0.00	0.057
UGLM312	U Std	3	1	11	2.12	0.988	0.166	8.93	0.734	2.080	8.45	0.789	0.000	21.6	0.568	1.98	0.000
Q15LM21	NS17	3	1	12	2.20	0.886	0.102	11.06	0.026	1.620	10.56	0.429	0.231	23.0	0.010	2.38	0.030

Table A.2: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Lithium Metaborate *(continued)*

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	Al	Ca	Cr	Fe	Mg	Mn	Na	Ni	P	Si	Ti	U	Zr
Q17LM21	NS01	3	1	13	1.70	0.881	0.035	6.11	1.545	0.463	10.56	0.416	0.076	25.2	0.005	2.47	0.003
Q17LM11	NS01	3	1	14	1.69	0.873	0.046	6.10	1.549	0.464	10.53	0.419	0.073	25.2	0.035	2.48	0.006
Q21LM21	NS05	3	1	15	2.75	1.020	0.070	10.14	0.534	1.070	9.64	0.469	0.156	21.5	0.006	2.85	0.016
Q19LM21	NS12	3	1	16	1.73	0.722	0.072	10.44	0.017	1.310	10.38	0.471	0.176	25.2	0.008	1.90	0.021
Q21LM11	NS05	3	1	17	2.82	1.040	0.070	10.45	0.549	1.100	10.03	0.481	0.160	22.1	0.007	2.92	0.018
Q15LM11	NS17	3	1	18	2.19	0.853	0.100	10.97	0.025	1.610	10.37	0.424	0.229	22.8	0.010	2.32	0.028
BCHLM313	Batch 1	3	1	19	2.56	0.930	0.080	9.06	0.891	1.350	6.93	0.571	0.000	24.0	0.407	0.00	0.055
UGLM313	U Std	3	1	20	2.12	0.977	0.167	9.01	0.738	2.090	8.51	0.794	0.000	21.8	0.571	1.98	0.000
BCHLM321	Batch 1	3	2	1	2.53	0.916	0.080	9.16	0.897	1.360	6.93	0.576	0.000	24.1	0.405	0.00	0.057
UGLM321	U Std	3	2	2	2.10	0.968	0.167	9.07	0.733	2.090	8.39	0.792	0.000	21.8	0.567	1.93	0.000
Q15LM22	NS17	3	2	3	2.19	0.916	0.103	11.30	0.022	1.620	10.53	0.430	0.231	23.3	0.007	2.32	0.029
Q17LM22	NS01	3	2	4	1.68	0.857	0.036	6.19	1.550	0.462	10.46	0.418	0.072	25.1	0.001	2.43	0.004
Q21LM12	NS05	3	2	5	2.81	1.090	0.071	10.46	0.551	1.120	9.74	0.485	0.162	22.0	0.004	2.88	0.019
Q03LM12	NS21	3	2	6	3.42	0.958	0.066	9.30	0.803	1.500	10.01	0.598	0.136	20.6	0.002	2.62	0.034
Q19LM12	NS12	3	2	7	1.73	0.746	0.074	10.67	0.013	1.350	10.35	0.488	0.173	25.1	0.005	1.90	0.018
Q03LM22	NS21	3	2	8	3.51	0.998	0.076	9.62	0.819	1.530	10.49	0.612	0.144	21.3	0.017	2.69	0.036
Q15LM12	NS17	3	2	9	2.19	0.861	0.101	11.16	0.021	1.610	10.48	0.427	0.224	23.1	0.007	2.33	0.028
BCHLM322	Batch 1	3	2	10	2.54	0.935	0.080	9.07	0.894	1.350	6.89	0.573	0.000	23.9	0.408	0.00	0.055
UGLM322	U Std	3	2	11	2.11	0.971	0.167	9.06	0.733	2.080	8.51	0.791	0.000	21.9	0.565	1.94	0.011
Q14LM12	NS20	3	2	12	3.81	1.340	0.050	9.23	1.080	1.780	10.40	0.632	0.114	20.3	0.007	2.48	0.013
Q21LM22	NS05	3	2	13	2.76	1.020	0.071	10.26	0.534	1.080	9.78	0.472	0.154	21.8	0.004	2.81	0.017
Q14LM22	NS20	3	2	14	3.98	1.410	0.052	9.47	1.110	1.830	10.75	0.653	0.122	21.0	0.007	2.62	0.011
Q19LM22	NS12	3	2	15	1.71	0.721	0.073	10.54	0.013	1.310	10.44	0.477	0.176	25.2	0.005	1.86	0.020
Q17LM12	NS01	3	2	16	1.69	0.865	0.047	6.17	1.560	0.463	10.63	0.420	0.056	25.2	0.032	2.42	0.003
Q01LM12	NS15	3	2	17	3.08	1.100	0.042	8.26	0.846	1.450	10.11	0.367	0.096	22.8	0.000	2.06	0.011
Q01LM22	NS15	3	2	18	3.14	1.170	0.045	8.48	0.874	1.490	10.30	0.379	0.097	23.5	0.000	2.12	0.013
BCHLM323	Batch 1	3	2	19	2.55	0.925	0.081	9.05	0.895	1.350	6.88	0.576	0.000	23.9	0.406	0.00	0.055
UGLM323	U Std	3	2	20	2.11	0.967	0.167	9.03	0.735	2.090	8.45	0.793	0.000	21.7	0.566	1.96	0.000

Table A.3: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Peroxide Fusion

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	B	Li
BCHSP111	Batch 1	1	1	1	2.56	2.03
UGSP111	U Std	1	1	2	2.82	1.34
Q10SP11	NS04	1	1	3	1.77	2.57
Q04SP11	NS16	1	1	4	1.61	2.37
Q11SP21	NS07	1	1	5	1.94	2.81
Q13SP21	NS19	1	1	6	1.54	2.25
Q13SP11	NS19	1	1	7	1.54	2.25
Q02SP11	NS18	1	1	8	1.53	2.29
Q10SP21	NS04	1	1	9	1.77	2.59
BCHSP112	Batch 1	1	1	10	2.50	2.05
UGSP112	U Std	1	1	11	2.86	1.34
Q01SP11	NS15	1	1	12	1.69	2.46
Q11SP11	NS07	1	1	13	1.95	2.77
Q01SP21	NS15	1	1	14	1.75	2.48
Q04SP21	NS16	1	1	15	1.63	2.41
Q14SP11	NS20	1	1	16	1.59	2.27
Q02SP21	NS18	1	1	17	1.62	2.29
Q14SP21	NS20	1	1	18	1.58	2.23
BCHSP113	Batch 1	1	1	19	2.51	2.04
UGSP113	U Std	1	1	20	2.84	1.35
BCHSP121	Batch 1	1	2	1	2.50	2.08
UGSP121	U Std	1	2	2	2.78	1.35
Q10SP12	NS04	1	2	3	1.75	2.63
Q04SP12	NS16	1	2	4	1.62	2.41
Q11SP22	NS07	1	2	5	1.90	2.82
Q13SP22	NS19	1	2	6	1.49	2.24
Q13SP12	NS19	1	2	7	1.52	2.29
Q02SP12	NS18	1	2	8	1.54	2.31
Q10SP22	NS04	1	2	9	1.72	2.64
BCHSP122	Batch 1	1	2	10	2.56	2.12
UGSP122	U Std	1	2	11	2.89	1.36
Q01SP12	NS15	1	2	12	1.76	2.53
Q11SP12	NS07	1	2	13	1.90	2.83
Q01SP22	NS15	1	2	14	1.71	2.52
Q04SP22	NS16	1	2	15	1.62	2.38
Q14SP12	NS20	1	2	16	1.55	2.26
Q02SP22	NS18	1	2	17	1.56	2.30
Q14SP22	NS20	1	2	18	1.56	2.27
BCHSP123	Batch 1	1	2	19	2.51	2.07
UGSP123	U Std	1	2	20	2.82	1.36
BCHSP211	Batch 1	2	1	1	2.47	2.07
UGSP211	U Std	2	1	2	2.75	1.38
Q06SP11	NS14	2	1	3	1.73	2.59
Q17SP21	NS01	2	1	4	2.80	1.79
Q18SP11	NS03	2	1	5	2.45	1.58
Q05SP11	NS13	2	1	6	1.64	2.47
Q05SP21	NS13	2	1	7	1.64	2.44
Q21SP21	NS05	2	1	8	1.57	2.37
Q15SP21	NS17	2	1	9	1.63	2.45
BCHSP212	Batch 1	2	1	10	2.50	2.11
UGSP212	U Std	2	1	11	2.82	1.37
Q06SP21	NS14	2	1	12	1.78	2.60
Q18SP21	NS03	2	1	13	2.44	1.56
Q07SP11	NS06	2	1	14	1.56	2.31
Q17SP11	NS01	2	1	15	2.80	1.77
Q15SP11	NS17	2	1	16	1.66	2.46

Table A.3: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Peroxide Fusion *(continued)*

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	B	Li
Q21SP11	NS05	2	1	17	1.63	2.41
Q07SP21	NS06	2	1	18	1.52	2.30
BCHSP213	Batch 1	2	1	19	2.48	2.09
UGSP213	U Std	2	1	20	2.79	1.38
BCHSP221	Batch 1	2	2	1	2.52	2.07
UGSP221	U Std	2	2	2	2.74	1.32
Q06SP12	NS14	2	2	3	1.71	2.56
Q17SP22	NS01	2	2	4	2.76	1.75
Q18SP12	NS03	2	2	5	2.40	1.53
Q05SP12	NS13	2	2	6	1.61	2.41
Q05SP22	NS13	2	2	7	1.62	2.43
Q21SP22	NS05	2	2	8	1.54	2.32
Q15SP22	NS17	2	2	9	1.61	2.44
BCHSP222	Batch 1	2	2	10	2.42	2.07
UGSP222	U Std	2	2	11	2.83	1.36
Q06SP22	NS14	2	2	12	1.77	2.59
Q18SP22	NS03	2	2	13	2.45	1.55
Q07SP12	NS06	2	2	14	1.46	2.26
Q17SP12	NS01	2	2	15	2.84	1.74
Q15SP12	NS17	2	2	16	1.64	2.46
Q21SP12	NS05	2	2	17	1.60	2.39
Q07SP22	NS06	2	2	18	1.50	2.26
BCHSP223	Batch 1	2	2	19	2.47	2.09
UGSP213	U Std	2	2	20	2.80	1.35
BCHSP311	Batch 1	3	1	1	2.54	2.07
UGSP311	U Std	3	1	2	2.79	1.36
Q08SP21	NS02	3	1	3	2.61	1.67
Q12SP11	NS10	3	1	4	1.91	2.87
Q19SP21	NS12	3	1	5	1.80	2.71
Q20SP21	NS09	3	1	6	1.90	2.88
Q03SP21	NS21	3	1	7	1.49	2.23
Q19SP11	NS12	3	1	8	1.84	2.79
Q09SP11	NS11	3	1	9	1.86	2.79
BCHSP312	Batch 1	3	1	10	2.44	2.05
UGSP312	U Std	3	1	11	2.78	1.33
Q09SP21	NS11	3	1	12	1.84	2.72
Q08SP11	NS02	3	1	13	2.66	1.68
Q12SP21	NS10	3	1	14	1.92	2.87
Q20SP11	NS09	3	1	15	1.90	2.89
Q16SP21	NS08	3	1	16	1.85	2.80
Q16SP11	NS08	3	1	17	1.85	2.80
Q03SP11	NS21	3	1	18	1.52	2.22
BCHSP313	Batch 1	3	1	19	2.48	2.09
UGSP313	U Std	3	1	20	2.92	1.42
BCHSP321	Batch 1	3	2	1	2.51	2.05
UGSP321	U Std	3	2	2	2.76	1.32
Q08SP22	NS02	3	2	3	2.54	1.59
Q12SP12	NS10	3	2	4	1.86	2.79
Q19SP22	NS12	3	2	5	1.72	2.61
Q20SP22	NS09	3	2	6	1.83	2.83
Q03SP22	NS21	3	2	7	1.44	2.16
Q19SP12	NS12	3	2	8	1.80	2.76
Q09SP12	NS11	3	2	9	1.81	2.76
BCHSP322	Batch 1	3	2	10	2.44	2.04
UGSP322	U Std	3	2	11	2.80	1.34
Q09SP22	NS11	3	2	12	1.82	2.72

Table A.3: Measured Elemental Concentrations (wt%) for the NS Glasses Prepared Using Peroxide Fusion *(continued)*

SRTC-ML ID	Glass ID	Block	Sub-Block	Analytical Sequence	B	Li
Q08SP12	NS02	3	2	13	2.58	1.64
Q12SP22	NS10	3	2	14	1.90	2.87
Q20SP12	NS09	3	2	15	1.85	2.85
Q16SP22	NS08	3	2	16	1.80	2.76
Q16SP12	NS08	3	2	17	1.81	2.79
Q03SP12	NS21	3	2	18	1.44	2.20
BCHSP323	Batch 1	3	2	19	2.43	2.07
UGSP323	U Std	3	2	20	2.83	1.37

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std)

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
0	Al_2O_3	4.8025	4.8770	4.8770	-0.0745	0.0000	-1.5%	0.0%
0	B_2O_3	8.0211	7.7971	7.7770	0.2441	0.0201	3.1%	0.3%
0	CaO	1.3053	1.2200	1.2200	0.0853	0.0000	7.0%	0.0%
0	Cr_2O_3	0.1180	0.1070	0.1070	0.0110	0.0000		
0	Fe_2O_3	13.0468	12.8390	12.8390	0.2078	0.0000	1.6%	0.0%
0	Li_2O	4.4565	4.4424	4.4290	0.0275	0.0134	0.6%	0.3%
0	MgO	1.4753	1.4190	1.4190	0.0563	0.0000	4.0%	0.0%
0	MnO	1.7417	1.7260	1.7260	0.0157	0.0000	0.9%	0.0%
0	Na_2O	9.3237	9.0030	9.0030	0.3207	0.0000	3.6%	0.0%
0	NiO	0.7303	0.7510	0.7510	-0.0207	0.0000	-2.8%	0.0%
0	P_2O_5	0.0000	0.0000	0.0000	0.0000	0.0000		
0	SiO_2	51.6166	50.2200	50.2200	1.3966	0.0000	2.8%	0.0%
0	TiO_2	0.6813	0.6770	0.6770	0.0043	0.0000	0.6%	0.0%
0	U_3O_8	0.0000	0.0000	0.0000	0.0000	0.0000		
0	ZrO_2	0.0790	0.0790	0.0980	-0.0190	-0.0190		
	Sum of Oxides	97.3981	95.1575	95.1430	2.2551	0.0145	2.4%	0.0%
1	Al_2O_3	3.1933	3.2365	3.0250	0.1683	0.2115	5.6%	7.0%
1	B_2O_3	9.0157	8.8826	9.0070	0.0087	-0.1244	0.1%	-1.4%
1	CaO	1.2159	1.1396	1.1200	0.0959	0.0196	8.6%	1.7%
1	Cr_2O_3	0.0599	0.0548	0.0591	0.0008	-0.0043		
1	Fe_2O_3	8.7819	8.6981	8.8850	-0.1031	-0.1869	-1.2%	-2.1%
1	Li_2O	3.7945	3.7746	3.7830	0.0115	-0.0084	0.3%	-0.2%
1	MgO	2.5717	2.4618	2.5950	-0.0233	-0.1332	-0.9%	-5.1%
1	MnO	0.5978	0.5905	0.5780	0.0198	0.0125	3.4%	2.2%
1	Na_2O	14.2147	13.7325	14.0050	0.2097	-0.2725	1.5%	-1.9%
1	NiO	0.5322	0.5474	0.5680	-0.0358	-0.0206	-6.3%	-3.6%
1	P_2O_5	0.1587	0.1587	0.2242	-0.0655	-0.0655		
1	SiO_2	53.8569	52.7519	53.0880	0.7689	-0.3361	1.4%	-0.6%
1	TiO_2	0.0304	0.0302	0.0067	0.0237	0.0235		
1	U_3O_8	2.8890	3.0049	2.8850	0.0040	0.1199	0.1%	4.2%
1	ZrO_2	0.0054	0.0054	0.0214	-0.0160	-0.0160		
	Sum of Oxides	100.9180	99.0695	99.8504	1.0676	-0.7809	1.1%	-0.8%
2	Al_2O_3	3.4814	3.5331	3.3210	0.1604	0.2121	4.8%	6.4%
2	B_2O_3	8.3637	8.1579	8.4170	-0.0533	-0.2591	-0.6%	-3.1%
2	CaO	1.4797	1.3816	1.3440	0.1357	0.0376	10.1%	2.8%
2	Cr_2O_3	0.1367	0.1235	0.1470	-0.0103	-0.0235		
2	Fe_2O_3	11.0802	10.8560	10.6620	0.4182	0.1940	3.9%	1.8%
2	Li_2O	3.5415	3.5060	3.5820	-0.0405	-0.0760	-1.1%	-2.1%
2	MgO	1.4852	1.4335	1.4540	0.0312	-0.0205	2.1%	-1.4%
2	MnO	1.7754	1.7667	1.7310	0.0444	0.0357	2.6%	2.1%
2	Na_2O	14.6999	14.1560	14.6060	0.0939	-0.4500	0.6%	-3.1%
2	NiO	0.6620	0.6811	0.6810	-0.0190	0.0001	-2.8%	0.0%
2	P_2O_5	0.4165	0.4165	0.5578	-0.1413	-0.1413	-25.3%	-25.3%
2	SiO_2	50.9688	49.2648	49.5880	1.3808	-0.3232	2.8%	-0.7%
2	TiO_2	0.0150	0.0149	0.0166	-0.0016	-0.0017		
2	U_3O_8	3.3931	3.4828	3.4620	-0.0689	0.0208	-2.0%	0.6%
2	ZrO_2	0.0398	0.0398	0.0532	-0.0134	-0.0134		
	Sum of Oxides	101.5389	98.8142	99.6226	1.9163	-0.8084	1.9%	-0.8%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
3	Al_2O_3	4.1380	4.2133	4.0670	0.0710	0.1463	1.7%	3.6%
3	B_2O_3	7.8405	7.7250	7.8190	0.0215	-0.0940	0.3%	-1.2%
3	CaO	1.1883	1.1091	1.0710	0.1173	0.0381	11.0%	3.6%
3	Cr_2O_3	0.1374	0.1239	0.1715	-0.0341	-0.0476		
3	Fe_2O_3	12.3490	12.1266	12.4390	-0.0900	-0.3124	-0.7%	-2.5%
3	Li_2O	3.3478	3.3302	3.3460	0.0018	-0.0158	0.1%	-0.5%
3	MgO	2.7815	2.6786	2.8330	-0.0515	-0.1544	-1.8%	-5.5%
3	MnO	2.0207	2.0009	2.0200	0.0007	-0.0191	0.0%	-0.9%
3	Na_2O	15.0134	14.5307	15.2070	-0.1936	-0.6763	-1.3%	-4.4%
3	NiO	0.7406	0.7610	0.7950	-0.0544	-0.0340	-6.8%	-4.3%
3	P_2O_5	0.4411	0.4411	0.6508	-0.2097	-0.2097	-32.2%	-32.2%
3	SiO_2	46.1019	44.8478	46.3230	-0.2211	-1.4752	-0.5%	-3.2%
3	TiO_2	0.0104	0.0104	0.0194	-0.0090	-0.0090		
3	U_3O_8	2.6679	2.8083	2.7370	-0.0691	0.0713	-2.5%	2.6%
3	ZrO_2	0.0419	0.0419	0.0621	-0.0202	-0.0202		
	Sum of Oxides	98.8204	96.7488	99.5608	-0.7404	-2.8120	-0.7%	-2.8%
4	Al_2O_3	4.4214	4.4871	4.5430	-0.1216	-0.0559	-2.7%	-1.2%
4	B_2O_3	5.6429	5.3940	5.6120	0.0309	-0.2180	0.6%	-3.9%
4	CaO	1.1778	1.0995	1.1340	0.0438	-0.0345	3.9%	-3.0%
4	Cr_2O_3	0.1049	0.0948	0.1096	-0.0047	-0.0148		
4	Fe_2O_3	11.9165	11.6769	12.4130	-0.4965	-0.7361	-4.0%	-5.9%
4	Li_2O	5.6137	5.6471	5.6610	-0.0473	-0.0139	-0.8%	-0.2%
4	MgO	0.6786	0.6549	0.7050	-0.0264	-0.0501	-3.7%	-7.1%
4	MnO	1.1795	1.1737	1.2250	-0.0455	-0.0513	-3.7%	-4.2%
4	Na_2O	12.6072	12.1435	13.3430	-0.7358	-1.1995	-5.5%	-9.0%
4	NiO	0.5160	0.5308	0.5770	-0.0610	-0.0462	-10.6%	-8.0%
4	P_2O_5	0.2944	0.2944	0.4159	-0.1215	-0.1215		
4	SiO_2	49.6318	47.9837	51.0030	-1.3712	-3.0193	-2.7%	-5.9%
4	TiO_2	0.0108	0.0108	0.0124	-0.0016	-0.0016		
4	U_3O_8	2.8035	2.8768	2.9230	-0.1195	-0.0462	-4.1%	-1.6%
4	ZrO_2	0.0243	0.0243	0.0397	-0.0154	-0.0154		
	Sum of Oxides	96.6233	94.0923	99.7166	-3.0933	-5.6243	-3.1%	-5.6%
5	Al_2O_3	5.2623	5.3335	5.3010	-0.0387	0.0325	-0.7%	0.6%
5	B_2O_3	5.1035	5.0286	5.2140	-0.1105	-0.1854	-2.1%	-3.6%
5	CaO	1.4587	1.3672	1.3230	0.1357	0.0442	10.3%	3.3%
5	Cr_2O_3	0.1030	0.0943	0.1279	-0.0249	-0.0336		
5	Fe_2O_3	14.7652	14.6244	14.4820	0.2832	0.1424	2.0%	1.0%
5	Li_2O	5.1078	5.0809	5.2710	-0.1632	-0.1901	-3.1%	-3.6%
5	MgO	0.8987	0.8603	0.8230	0.0757	0.0373	9.2%	4.5%
5	MnO	1.4106	1.3934	1.4290	-0.0184	-0.0356	-1.3%	-2.5%
5	Na_2O	13.2070	12.7589	13.5670	-0.3600	-0.8081	-2.7%	-6.0%
5	NiO	0.6067	0.6239	0.6730	-0.0663	-0.0491	-9.9%	-7.3%
5	P_2O_5	0.3620	0.3620	0.4852	-0.1232	-0.1232		
5	SiO_2	46.7437	45.7847	47.5030	-0.7593	-1.7183	-1.6%	-3.6%
5	TiO_2	0.0088	0.0087	0.0144	-0.0056	-0.0057		
5	U_3O_8	3.3784	3.5140	3.4100	-0.0316	0.1040	-0.9%	3.0%
5	ZrO_2	0.0236	0.0236	0.0463	-0.0227	-0.0227		
	Sum of Oxides	98.4400	96.8584	99.6698	-1.2298	-2.8114	-1.2%	-2.8%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
6	Al_2O_3	6.0795	6.1698	6.0580	0.0215	0.1118	0.4%	1.8%
6	B_2O_3	4.8620	4.7911	4.8160	0.0460	-0.0249	1.0%	-0.5%
6	CaO	1.6895	1.5773	1.5120	0.1775	0.0653	11.7%	4.3%
6	Cr_2O_3	0.1147	0.1037	0.1462	-0.0315	-0.0425		
6	Fe_2O_3	15.9626	15.6388	16.5510	-0.5884	-0.9122	-3.6%	-5.5%
6	Li_2O	4.9140	4.8882	4.8810	0.0330	0.0072	0.7%	0.1%
6	MgO	0.9397	0.9070	0.9400	-0.0003	-0.0330	0.0%	-3.5%
6	MnO	1.6560	1.6478	1.6340	0.0220	0.0138	1.3%	0.8%
6	Na_2O	13.6755	13.1689	13.7900	-0.1145	-0.6211	-0.8%	-4.5%
6	NiO	0.6961	0.7161	0.7700	-0.0739	-0.0539	-9.6%	-7.0%
6	P_2O_5	0.4170	0.4170	0.5549	-0.1379	-0.1379	-24.9%	-24.9%
6	SiO_2	44.8718	43.3724	44.0040	0.8678	-0.6316	2.0%	-1.4%
6	TiO_2	0.0167	0.0166	0.0165	0.0002	0.0001		
6	U_3O_8	3.9061	4.0084	3.8970	0.0091	0.1114	0.2%	2.9%
6	ZrO_2	0.0392	0.0392	0.0529	-0.0137	-0.0137		
	Sum of Oxides	99.8404	97.4623	99.6235	0.2169	-2.1612	0.2%	-2.2%
7	Al_2O_3	3.1035	3.1599	3.1330	-0.0295	0.0269	-0.9%	0.9%
7	B_2O_3	6.1903	5.9172	6.0080	0.1823	-0.0908	3.0%	-1.5%
7	CaO	0.9147	0.8537	0.8360	0.0787	0.0177	9.4%	2.1%
7	Cr_2O_3	0.0402	0.0362	0.0717	-0.0315	-0.0355		
7	Fe_2O_3	10.8979	10.7015	11.1550	-0.2571	-0.4535	-2.3%	-4.1%
7	Li_2O	6.0443	6.0803	6.0400	0.0043	0.0403	0.1%	0.7%
7	MgO	0.8991	0.8658	0.8850	0.0141	-0.0192	1.6%	-2.2%
7	MnO	1.2760	1.2635	1.2700	0.0060	-0.0065	0.5%	-0.5%
7	Na_2O	12.5903	12.1830	13.0890	-0.4987	-0.9060	-3.8%	-6.9%
7	NiO	0.3983	0.4093	0.4300	-0.0317	-0.0207		
7	P_2O_5	0.1277	0.1277	0.2721	-0.1444	-0.1444		
7	SiO_2	53.2151	51.7626	54.4520	-1.2369	-2.6894	-2.3%	-4.9%
7	TiO_2	0.0913	0.0909	0.0081	0.0832	0.0828		
7	U_3O_8	2.0223	2.1290	2.1410	-0.1187	-0.0120	-5.5%	-0.6%
7	ZrO_2	0.0500	0.0500	0.0260	0.0240	0.0240		
	Sum of Oxides	97.8610	95.6306	99.8169	-1.9559	-4.1863	-2.0%	-4.2%
8	Al_2O_3	3.2122	3.2707	3.1330	0.0792	0.1377	2.5%	4.4%
8	B_2O_3	5.8844	5.7395	6.0080	-0.1236	-0.2685	-2.1%	-4.5%
8	CaO	0.9480	0.8848	0.8360	0.1120	0.0488	13.4%	5.8%
8	Cr_2O_3	0.0687	0.0619	0.0717	-0.0030	-0.0098		
8	Fe_2O_3	12.0953	11.8773	11.1550	0.9403	0.7223	8.4%	6.5%
8	Li_2O	6.0012	5.9406	6.0400	-0.0388	-0.0994	-0.6%	-1.6%
8	MgO	0.2769	0.2667	0.2550	0.0219	0.0117		
8	MnO	1.3235	1.3106	1.2700	0.0535	0.0406	4.2%	3.2%
8	Na_2O	13.1093	12.6870	13.1610	-0.0517	-0.4740	-0.4%	-3.6%
8	NiO	0.4183	0.4299	0.4300	-0.0117	-0.0001		
8	P_2O_5	0.2079	0.2079	0.2721	-0.0642	-0.0642		
8	SiO_2	53.8034	52.3360	54.4520	-0.6486	-2.1160	-1.2%	-3.9%
8	TiO_2	0.0100	0.0100	0.0081	0.0019	0.0019		
8	U_3O_8	2.6237	2.7617	2.6990	-0.0753	0.0627	-2.8%	2.3%
8	ZrO_2	0.0368	0.0368	0.0260	0.0108	0.0108		
	Sum of Oxides	100.0196	97.8214	99.8169	0.2027	-1.9955	0.2%	-2.0%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff	% diff
		Measured	Measured bc	Targeted			Meas.	Meas bc
9	Al_2O_3	4.5773	4.6605	4.5950	-0.0177	0.0655	-0.4%	1.4%
9	B_2O_3	6.0212	5.8731	6.0070	0.0142	-0.1339	0.2%	-2.2%
9	CaO	1.1960	1.1163	1.1200	0.0760	-0.0037	6.8%	-0.3%
9	Cr_2O_3	0.0599	0.0540	0.0591	0.0008	-0.0051		
9	Fe_2O_3	9.5897	9.4169	8.8850	0.7047	0.5319	7.9%	6.0%
9	Li_2O	6.1627	6.1005	6.0330	0.1297	0.0675	2.1%	1.1%
9	MgO	1.1773	1.1338	1.0950	0.0823	0.0388	7.5%	3.5%
9	MnO	1.5010	1.4864	1.4430	0.0580	0.0434	4.0%	3.0%
9	Na_2O	13.3958	12.9622	13.2500	0.1458	-0.2878	1.1%	-2.2%
9	NiO	0.5618	0.5773	0.5680	-0.0062	0.0093	-1.1%	1.6%
9	P_2O_5	0.1272	0.1272	0.2242	-0.0970	-0.0970		
9	SiO_2	53.6964	52.2312	54.5880	-0.8916	-2.3568	-1.6%	-4.3%
9	TiO_2	0.0021	0.0021	0.0067	-0.0046	-0.0046		
9	U_3O_8	1.9191	2.0203	1.9550	-0.0359	0.0653	-1.8%	3.3%
9	ZrO_2	0.0078	0.0078	0.0214	-0.0136	-0.0136		
	Sum of Oxides	99.9953	97.7696	99.8504	0.1449	-2.0808	0.1%	-2.1%
10	Al_2O_3	4.6340	4.7029	4.5950	0.0390	0.1079	0.8%	2.3%
10	B_2O_3	6.1098	5.9592	6.0140	0.0958	-0.0548	1.6%	-0.9%
10	CaO	1.2194	1.1383	1.1200	0.0994	0.0183	8.9%	1.6%
10	Cr_2O_3	0.0990	0.0895	0.1225	-0.0235	-0.0330		
10	Fe_2O_3	8.9892	8.8069	8.8850	0.1042	-0.0781	1.2%	-0.9%
10	Li_2O	6.1358	6.0739	6.0680	0.0678	0.0059	1.1%	0.1%
10	MgO	1.1196	1.0806	1.0950	0.0246	-0.0144	2.2%	-1.3%
10	MnO	1.4946	1.4872	1.4430	0.0516	0.0442	3.6%	3.1%
10	Na_2O	12.9812	12.5005	13.0530	-0.0718	-0.5525	-0.6%	-4.2%
10	NiO	0.3767	0.3875	0.3950	-0.0183	-0.0075		
10	P_2O_5	0.3494	0.3494	0.4648	-0.1154	-0.1154		
10	SiO_2	54.8196	52.9846	54.4180	0.4016	-1.4334	0.7%	-2.6%
10	TiO_2	0.0133	0.0132	0.0138	-0.0005	-0.0006		
10	U_3O_8	1.9191	1.9692	1.9550	-0.0359	0.0142	-1.8%	0.7%
10	ZrO_2	0.0294	0.0294	0.0444	-0.0150	-0.0150		
	Sum of Oxides	100.2901	97.5723	99.6865	0.6036	-2.1142	0.6%	-2.1%
11	Al_2O_3	4.3033	4.3673	4.2300	0.0733	0.1373	1.7%	3.2%
11	B_2O_3	5.9005	5.7551	6.0120	-0.1115	-0.2569	-1.9%	-4.3%
11	CaO	0.9133	0.8526	0.8360	0.0773	0.0166	9.2%	2.0%
11	Cr_2O_3	0.0895	0.0809	0.1099	-0.0204	-0.0290		
11	Fe_2O_3	10.1401	9.9354	9.4530	0.6871	0.4824	7.3%	5.1%
11	Li_2O	5.9151	5.8553	6.0610	-0.1459	-0.2057	-2.4%	-3.4%
11	MgO	0.2400	0.2316	0.2550	-0.0150	-0.0234		
11	MnO	1.2402	1.2341	1.2700	-0.0298	-0.0359	-2.3%	-2.8%
11	Na_2O	12.8667	12.3916	13.2380	-0.3713	-0.8464	-2.8%	-6.4%
11	NiO	0.4931	0.5073	0.5330	-0.0399	-0.0257	-7.5%	-4.8%
11	P_2O_5	0.2979	0.2979	0.4169	-0.1190	-0.1190		
11	SiO_2	54.3917	52.5752	54.5540	-0.1623	-1.9788	-0.3%	-3.6%
11	TiO_2	0.0117	0.0116	0.0124	-0.0007	-0.0008		
11	U_3O_8	2.6915	2.7619	2.6990	-0.0075	0.0629	-0.3%	2.3%
11	ZrO_2	0.0250	0.0250	0.0398	-0.0148	-0.0148		
	Sum of Oxides	99.5196	96.8828	99.7200	-0.2004	-2.8372	-0.2%	-2.8%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
12	Al_2O_3	3.2688	3.3130	3.0440	0.2248	0.2690	7.4%	8.8%
12	B_2O_3	5.7636	5.6219	5.8150	-0.0514	-0.1931	-0.9%	-3.3%
12	CaO	1.0316	0.9668	0.8420	0.1896	0.1248	22.5%	14.8%
12	Cr_2O_3	0.1067	0.0977	0.1347	-0.0280	-0.0370		
12	Fe_2O_3	15.1048	14.9607	12.8950	2.2098	2.0657	17.1%	16.0%
12	Li_2O	5.8505	5.7917	5.8750	-0.0245	-0.0833	-0.4%	-1.4%
12	MgO	0.0253	0.0242	0.0500	-0.0247	-0.0258		
12	MnO	1.7173	1.6963	1.5870	0.1303	0.1093	8.2%	6.9%
12	Na_2O	14.0630	13.5859	13.4030	0.6600	0.1829	4.9%	1.4%
12	NiO	0.6118	0.6292	0.6240	-0.0122	0.0052	-2.0%	0.8%
12	P_2O_5	0.3993	0.3993	0.5113	-0.1120	-0.1120	-21.9%	-21.9%
12	SiO_2	53.8034	52.6996	52.6590	1.1444	0.0406	2.2%	0.1%
12	TiO_2	0.0108	0.0108	0.0152	-0.0044	-0.0044		
12	U_3O_8	2.2287	2.3182	2.1510	0.0777	0.1672	3.6%	7.8%
12	ZrO_2	0.0257	0.0257	0.0488	-0.0231	-0.0231		
	Sum of Oxides	104.0113	102.1410	99.6550	4.3563	2.4860	4.4%	2.5%
13	Al_2O_3	3.1460	3.2031	3.3210	-0.1750	-0.1179	-5.3%	-3.6%
13	B_2O_3	5.2404	5.1634	5.6170	-0.3766	-0.4536	-6.7%	-8.1%
13	CaO	1.3485	1.2586	1.3440	0.0045	-0.0854	0.3%	-6.4%
13	Cr_2O_3	0.1089	0.0982	0.1470	-0.0381	-0.0488		
13	Fe_2O_3	12.7029	12.4740	14.0670	-1.3641	-1.5930	-9.7%	-11.3%
13	Li_2O	5.2477	5.2201	5.6820	-0.4343	-0.4619	-7.6%	-8.1%
13	MgO	0.0224	0.0216	0.0540	-0.0316	-0.0324		
13	MnO	1.5720	1.5565	1.7310	-0.1590	-0.1745	-9.2%	-10.1%
13	Na_2O	12.0848	11.6937	13.3110	-1.2262	-1.6173	-9.2%	-12.2%
13	NiO	0.4018	0.4129	0.4740	-0.0722	-0.0611		
13	P_2O_5	0.3878	0.3878	0.5578	-0.1700	-0.1700	-30.5%	-30.5%
13	SiO_2	52.3059	50.8778	50.9010	1.4049	-0.0232	2.8%	0.0%
13	TiO_2	0.0088	0.0087	0.0166	-0.0078	-0.0079		
13	U_3O_8	2.1579	2.2716	2.3460	-0.1881	-0.0744	-8.0%	-3.2%
13	ZrO_2	0.0304	0.0304	0.0532	-0.0228	-0.0228		
	Sum of Oxides	96.7662	94.6784	99.6226	-2.8564	-4.9442	-2.9%	-5.0%
14	Al_2O_3	3.3255	3.3861	3.3210	0.0045	0.0651	0.1%	2.0%
14	B_2O_3	5.6268	5.5439	5.6080	0.0188	-0.0641	0.3%	-1.1%
14	CaO	1.4723	1.3740	1.3440	0.1283	0.0300	9.5%	2.2%
14	Cr_2O_3	0.0570	0.0514	0.0708	-0.0138	-0.0194		
14	Fe_2O_3	14.4292	14.1692	14.0670	0.3622	0.1022	2.6%	0.7%
14	Li_2O	5.5652	5.5358	5.6390	-0.0738	-0.1032	-1.3%	-1.8%
14	MgO	1.4177	1.3653	1.3140	0.1037	0.0513	7.9%	3.9%
14	MnO	0.7150	0.7080	0.6930	0.0220	0.0150	3.2%	2.2%
14	Na_2O	13.1430	12.7184	13.5300	-0.3870	-0.8116	-2.9%	-6.0%
14	NiO	0.6388	0.6565	0.6810	-0.0422	-0.0245	-6.2%	-3.6%
14	P_2O_5	0.1936	0.1936	0.2687	-0.0751	-0.0751		
14	SiO_2	49.7922	48.4329	50.9010	-1.1088	-2.4681	-2.2%	-4.8%
14	TiO_2	0.0108	0.0108	0.0080	0.0028	0.0028		
14	U_3O_8	2.2375	2.3554	2.3460	-0.1085	0.0094	-4.6%	0.4%
14	ZrO_2	0.0142	0.0142	0.0256	-0.0114	-0.0114		
	Sum of Oxides	98.6388	96.5155	99.8171	-1.1783	-3.3016	-1.2%	-3.3%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
15	Al_2O_3	5.8480	5.9272	5.9740	-0.1260	-0.0468	-2.1%	-0.8%
15	B_2O_3	5.5624	5.3175	5.4090	0.1534	-0.0915	2.8%	-1.7%
15	CaO	1.5881	1.4885	1.4560	0.1321	0.0325	9.1%	2.2%
15	Cr_2O_3	0.0632	0.0579	0.0768	-0.0136	-0.0189		
15	Fe_2O_3	11.9273	11.8135	11.5510	0.3763	0.2625	3.3%	2.3%
15	Li_2O	5.3769	5.4089	5.4430	-0.0661	-0.0341	-1.2%	-0.6%
15	MgO	1.4218	1.3611	1.4240	-0.0022	-0.0629	-0.2%	-4.4%
15	MnO	1.8948	1.8716	1.8750	0.0198	-0.0034	1.1%	-0.2%
15	Na_2O	13.7833	13.3157	13.8490	-0.0657	-0.5333	-0.5%	-3.9%
15	NiO	0.4743	0.4878	0.5140	-0.0397	-0.0262	-7.7%	-5.1%
15	P_2O_5	0.2188	0.2188	0.2915	-0.0727	-0.0727		
15	SiO_2	49.5248	48.5087	49.3640	0.1608	-0.8553	0.3%	-1.7%
15	TiO_2	0.0025	0.0025	0.0087	-0.0062	-0.0062		
15	U_3O_8	2.4675	2.5667	2.5420	-0.0745	0.0247	-2.9%	1.0%
15	ZrO_2	0.0152	0.0152	0.0278	-0.0126	-0.0126		
	Sum of Oxides	100.1689	98.3616	99.8058	0.3631	-1.4442	0.4%	-1.4%
16	Al_2O_3	3.9207	3.9790	3.8750	0.0457	0.1040	1.2%	2.7%
16	B_2O_3	5.2162	4.9864	5.2090	0.0072	-0.2226	0.1%	-4.3%
16	CaO	1.6790	1.5674	1.5680	0.1110	-0.0006	7.1%	0.0%
16	Cr_2O_3	0.0734	0.0664	0.0827	-0.0093	-0.0163		
16	Fe_2O_3	15.2728	14.9634	16.4120	-1.1392	-1.4486	-6.9%	-8.8%
16	Li_2O	5.1508	5.1817	5.2460	-0.0952	-0.0643	-1.8%	-1.2%
16	MgO	0.0365	0.0352	0.0630	-0.0265	-0.0278		
16	MnO	1.9755	1.9659	2.0200	-0.0445	-0.0541	-2.2%	-2.7%
16	Na_2O	13.4901	12.9917	13.8060	-0.3159	-0.8143	-2.3%	-5.9%
16	NiO	0.7196	0.7403	0.7950	-0.0754	-0.0547	-9.5%	-6.9%
16	P_2O_5	0.2309	0.2309	0.3138	-0.0829	-0.0829		
16	SiO_2	47.8134	46.2163	47.6230	0.1904	-1.4067	0.4%	-3.0%
16	TiO_2	0.0158	0.0157	0.0093	0.0065	0.0064		
16	U_3O_8	2.7122	2.7831	2.7370	-0.0248	0.0461	-0.9%	1.7%
16	ZrO_2	0.0328	0.0328	0.0299	0.0029	0.0029		
	Sum of Oxides	98.3397	95.7562	99.7897	-1.4500	-4.0335	-1.5%	-4.0%
17	Al_2O_3	4.1427	4.1988	3.8750	0.2677	0.3238	6.9%	8.4%
17	B_2O_3	5.2645	5.1871	5.2190	0.0455	-0.0319	0.9%	-0.6%
17	CaO	1.2299	1.1528	1.0710	0.1589	0.0818	14.8%	7.6%
17	Cr_2O_3	0.1484	0.1358	0.1715	-0.0231	-0.0357		
17	Fe_2O_3	15.9018	15.7499	16.4120	-0.5102	-0.6621	-3.1%	-4.0%
17	Li_2O	5.2800	5.2519	5.2960	-0.0160	-0.0441	-0.3%	-0.8%
17	MgO	0.0390	0.0373	0.0630	-0.0240	-0.0257		
17	MnO	2.0853	2.0597	2.0200	0.0653	0.0397	3.2%	2.0%
17	Na_2O	14.1338	13.6544	13.7890	0.3448	-0.1346	2.5%	-1.0%
17	NiO	0.5440	0.5595	0.5530	-0.0090	0.0065	-1.6%	1.2%
17	P_2O_5	0.5242	0.5242	0.6508	-0.1266	-0.1266	-19.5%	-19.5%
17	SiO_2	49.3109	48.2992	47.6230	1.6879	0.6762	3.5%	1.4%
17	TiO_2	0.0142	0.0141	0.0194	-0.0052	-0.0053		
17	U_3O_8	2.7564	2.8671	2.7370	0.0194	0.1301	0.7%	4.8%
17	ZrO_2	0.0388	0.0388	0.0621	-0.0233	-0.0233		
	Sum of Oxides	101.4139	99.7306	99.5618	1.8521	0.1688	1.9%	0.2%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

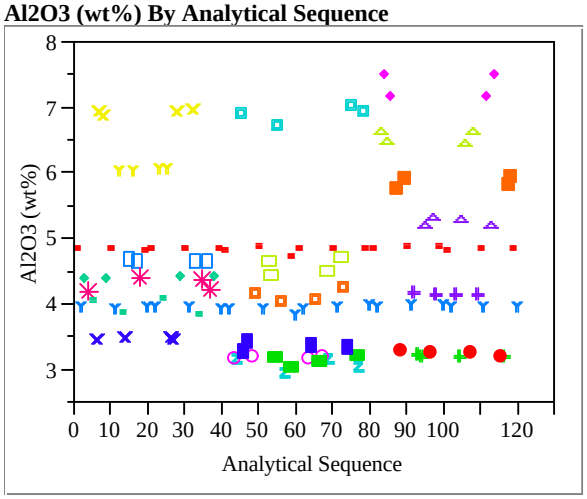
Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
18	Al_2O_3	6.9297	7.0327	6.8930	0.0367	0.1397	0.5%	2.0%
18	B_2O_3	5.0311	4.8093	5.0210	0.0101	-0.2117	0.2%	-4.2%
18	CaO	1.2264	1.1448	1.1480	0.0784	-0.0032	6.8%	-0.3%
18	Cr_2O_3	0.1509	0.1364	0.1837	-0.0328	-0.0473		
18	Fe_2O_3	12.2561	12.0091	13.3280	-1.0719	-1.3189	-8.0%	-9.9%
18	Li_2O	4.9463	4.9759	5.1020	-0.1557	-0.1261	-3.1%	-2.5%
18	MgO	1.6631	1.6051	1.6430	0.0201	-0.0379	1.2%	-2.3%
18	MnO	2.1918	2.1811	2.1640	0.0278	0.0171	1.3%	0.8%
18	Na_2O	14.2147	13.6869	14.1110	0.1037	-0.4241	0.7%	-3.0%
18	NiO	0.5494	0.5652	0.5930	-0.0436	-0.0278	-7.4%	-4.7%
18	P_2O_5	0.4818	0.4818	0.6972	-0.2154	-0.2154	-30.9%	-30.9%
18	SiO_2	47.6529	46.0644	45.6260	2.0269	0.4384	4.4%	1.0%
18	TiO_2	0.0183	0.0182	0.0207	-0.0024	-0.0025		
18	U_3O_8	2.9598	3.0372	2.9330	0.0268	0.1042	0.9%	3.6%
18	ZrO_2	0.0608	0.0608	0.0665	-0.0057	-0.0057		
	Sum of Oxides	100.3331	97.8089	99.5301	0.8030	-1.7212	0.8%	-1.7%
19	Al_2O_3	6.9061	7.0315	6.7670	0.1391	0.2645	2.1%	3.9%
19	B_2O_3	4.9023	4.6861	4.8130	0.0893	-0.1269	1.9%	-2.6%
19	CaO	1.8120	1.6912	1.6780	0.1340	0.0132	8.0%	0.8%
19	Cr_2O_3	0.1005	0.0906	0.1148	-0.0143	-0.0242		
19	Fe_2O_3	14.2005	13.9446	15.1240	-0.9235	-1.1794	-6.1%	-7.8%
19	Li_2O	4.8602	4.8892	4.8640	-0.0038	0.0252	-0.1%	0.5%
19	MgO	1.3990	1.3473	1.4160	-0.0170	-0.0687	-1.2%	-4.9%
19	MnO	2.0530	2.0329	2.0310	0.0220	0.0019	1.1%	0.1%
19	Na_2O	14.3292	13.8647	14.3710	-0.0418	-0.5063	-0.3%	-3.5%
19	NiO	0.6557	0.6737	0.6870	-0.0313	-0.0133	-4.6%	-1.9%
19	P_2O_5	0.2859	0.2859	0.4358	-0.1499	-0.1499		
19	SiO_2	44.8183	43.5934	43.9220	0.8963	-0.3286	2.0%	-0.7%
19	TiO_2	0.0129	0.0129	0.0130	-0.0001	-0.0001		
19	U_3O_8	3.3784	3.5566	3.4260	-0.0476	0.1306	-1.4%	3.8%
19	ZrO_2	0.0243	0.0243	0.0416	-0.0173	-0.0173		
	Sum of Oxides	99.7383	97.7249	99.7042	0.0341	-1.9793	0.0%	-2.0%
20	Al_2O_3	7.3596	7.4592	7.3520	0.0076	0.1072	0.1%	1.5%
20	B_2O_3	5.0552	4.8323	4.8110	0.2442	0.0213	5.1%	0.4%
20	CaO	1.9274	1.8065	1.7920	0.1354	0.0145	7.6%	0.8%
20	Cr_2O_3	0.0738	0.0676	0.0946	-0.0208	-0.0270		
20	Fe_2O_3	13.3212	13.1942	14.2160	-0.8948	-1.0218	-6.3%	-7.2%
20	Li_2O	4.8602	4.8892	4.8530	0.0072	0.0362	0.1%	0.7%
20	MgO	1.8115	1.7341	1.7520	0.0595	-0.0179	3.4%	-1.0%
20	MnO	2.3338	2.3053	2.3080	0.0258	-0.0027	1.1%	-0.1%
20	Na_2O	14.1978	13.7163	14.2720	-0.0742	-0.5557	-0.5%	-3.9%
20	NiO	0.8169	0.8402	0.9080	-0.0911	-0.0678	-10.0%	-7.5%
20	P_2O_5	0.2698	0.2698	0.3588	-0.0890	-0.0890		
20	SiO_2	44.2300	43.3226	43.8680	0.3620	-0.5454	0.8%	-1.2%
20	TiO_2	0.0138	0.0137	0.0107	0.0031	0.0030		
20	U_3O_8	3.0217	3.1431	3.1280	-0.1063	0.0151	-3.4%	0.5%
20	ZrO_2	0.0155	0.0155	0.0342	-0.0187	-0.0187		
	Sum of Oxides	99.3082	97.6096	99.7583	-0.4501	-2.1487	-0.5%	-2.2%

Table A.4: Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass Number (0 – Batch 1 and 100 – U std) *(continued)*

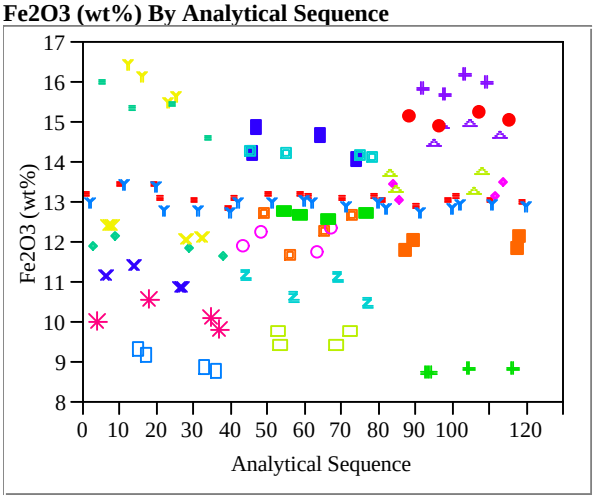
Glass #	Oxide	Composition (wt%)			Diff Meas.	Diff. bc	% diff Meas.	% diff Meas bc
		Measured	Measured bc	Targeted				
21	Al_2O_3	6.5613	6.6501	6.7670	-0.2057	-0.1169	-3.0%	-1.7%
21	B_2O_3	4.7413	4.6249	4.8130	-0.0717	-0.1881	-1.5%	-3.9%
21	CaO	1.3838	1.2969	1.3380	0.0458	-0.0411	3.4%	-3.1%
21	Cr_2O_3	0.1034	0.0947	0.1148	-0.0114	-0.0201		
21	Fe_2O_3	13.5250	13.3961	15.1240	-1.5990	-1.7279	-10.6%	-11.4%
21	Li_2O	4.7418	4.6940	4.8640	-0.1222	-0.1700	-2.5%	-3.5%
21	MgO	1.3468	1.2892	1.4160	-0.0692	-0.1268	-4.9%	-9.0%
21	MnO	1.9594	1.9354	2.0310	-0.0716	-0.0956	-3.5%	-4.7%
21	Na_2O	13.9282	13.4555	14.3830	-0.4548	-0.9275	-3.2%	-6.4%
21	NiO	0.7705	0.7925	0.8530	-0.0825	-0.0605	-9.7%	-7.1%
21	P_2O_5	0.3185	0.3185	0.4358	-0.1173	-0.1173		
21	SiO_2	44.9788	44.0560	44.0860	0.8928	-0.0300	2.0%	-0.1%
21	TiO_2	0.0121	0.0120	0.0130	-0.0009	-0.0010		
21	U_3O_8	3.1367	3.2627	3.4260	-0.2893	-0.1633	-8.4%	-4.8%
21	ZrO_2	0.0466	0.0466	0.0416	0.0050	0.0050		
	Sum of Oxides	97.5542	95.9251	99.7062	-2.1520	-3.7811	-2.2%	-3.8%
100	Al_2O_3	3.9690	4.0306	4.1000	-0.1310	-0.0694	-3.2%	-1.7%
100	B_2O_3	9.0551	8.8023	9.2090	-0.1539	-0.4067	-1.7%	-4.4%
100	CaO	1.3592	1.2704	1.3010	0.0582	-0.0306	4.5%	-2.4%
100	Cr_2O_3	0.2438	0.2211	0.0000	0.2438	0.2211		
100	Fe_2O_3	12.9872	12.7800	13.1960	-0.2088	-0.4160	-1.6%	-3.2%
100	Li_2O	2.9184	2.9093	3.0570	-0.1386	-0.1477	-4.5%	-4.8%
100	MgO	1.2145	1.1681	1.2100	0.0045	-0.0419	0.4%	-3.5%
100	MnO	2.6857	2.6615	2.8920	-0.2063	-0.2305	-7.1%	-8.0%
100	Na_2O	11.4161	11.0232	11.7950	-0.3789	-0.7718	-3.2%	-6.5%
100	NiO	1.0049	1.0333	1.1200	-0.1151	-0.0867	-10.3%	-7.7%
100	P_2O_5	0.0000	0.0000	0.0000	0.0000	0.0000		
100	SiO_2	46.7794	45.5124	45.3530	1.4264	0.1594	3.1%	0.4%
100	TiO_2	0.9448	0.9389	1.0490	-0.1042	-0.1101	-9.9%	-10.5%
100	U_3O_8	2.3145	2.4060	2.4060	-0.0915	0.0000	-3.8%	0.0%
100	ZrO_2	0.0017	0.0017	0.0000	0.0017	0.0017		
	Sum of Oxides	96.8943	94.7588	96.6880	0.2063	-1.9292	0.2%	-2.0%

Exhibit A.1: SRTC-ML Measurements for Samples Prepared Using the LM Method

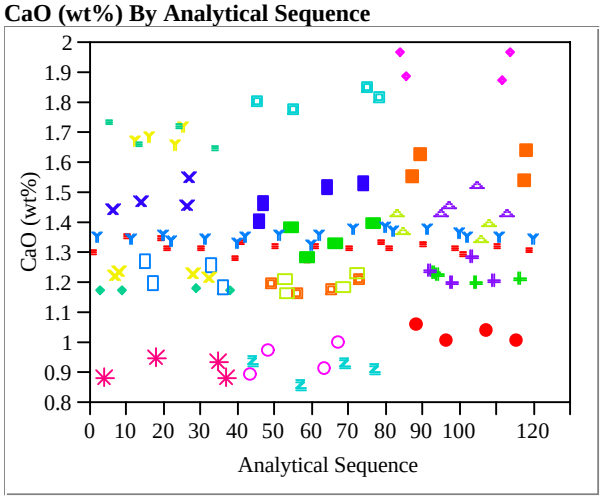
Al2O3 (wt%) By Analytical Sequence



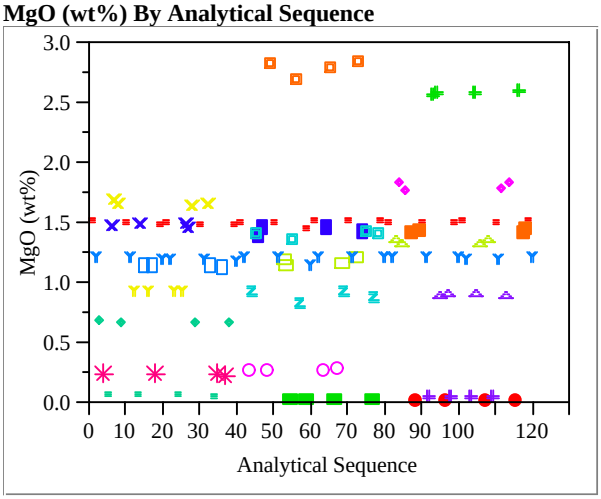
Fe2O3 (wt%) By Analytical Sequence



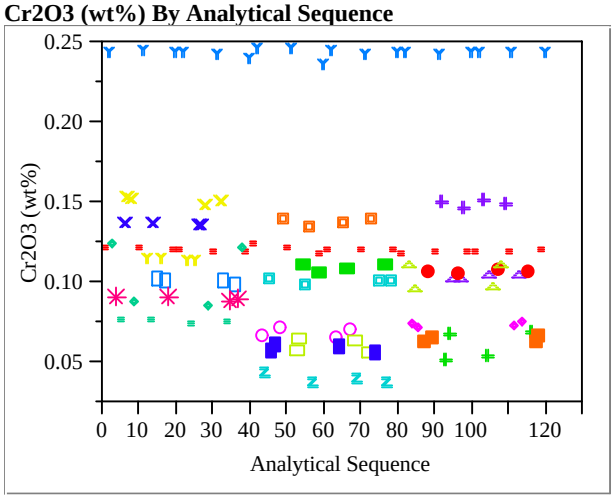
CaO (wt%) By Analytical Sequence



MgO (wt%) By Analytical Sequence



Cr2O3 (wt%) By Analytical Sequence



MnO (wt%) By Analytical Sequence

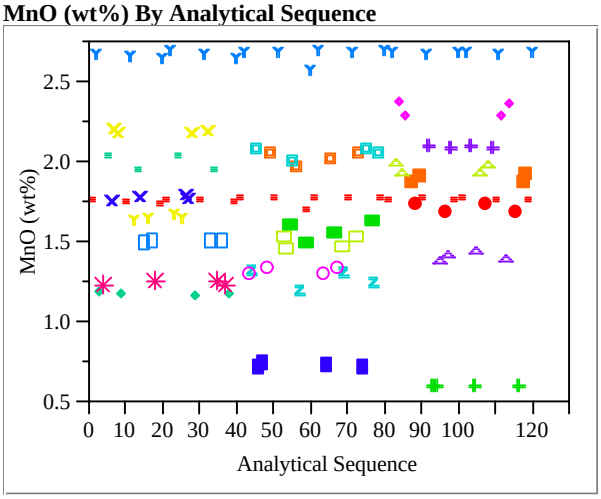
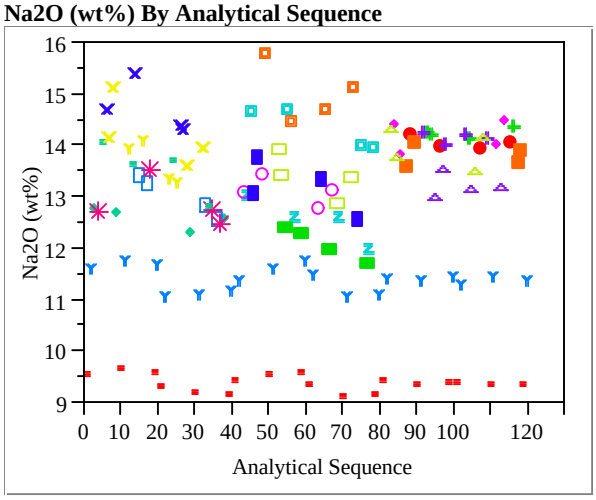
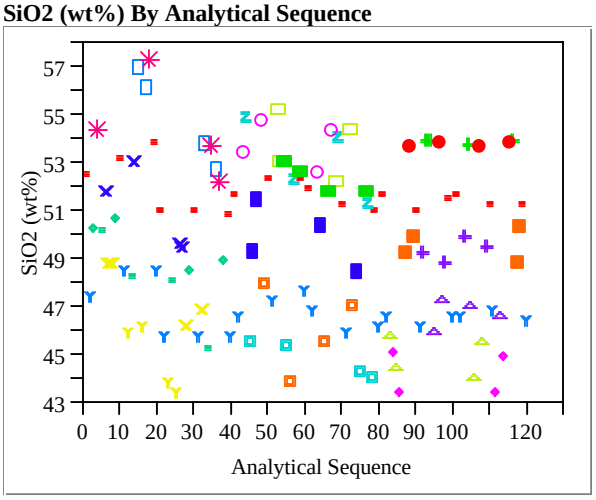


Exhibit A.1: SRTC-ML Measurements for Samples Prepared Using the LM Method *(continued)*

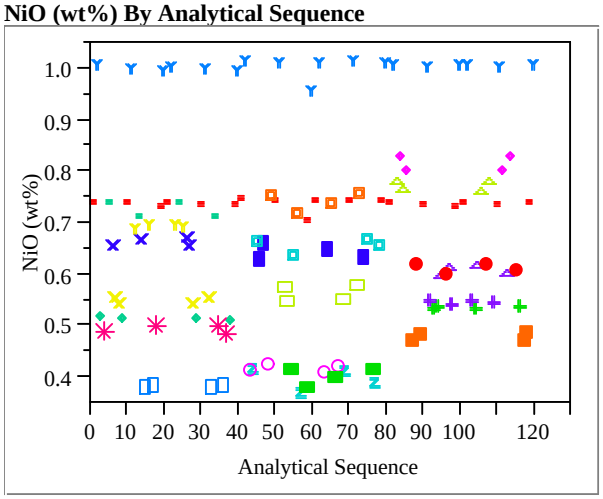
Na2O (wt%) By Analytical Sequence



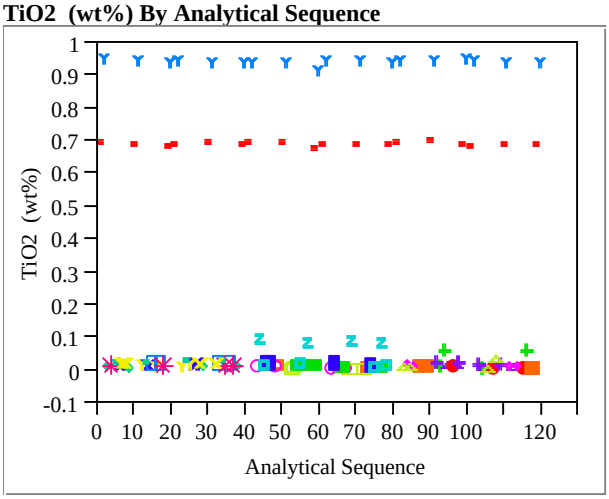
SiO2 (wt%) By Analytical Sequence



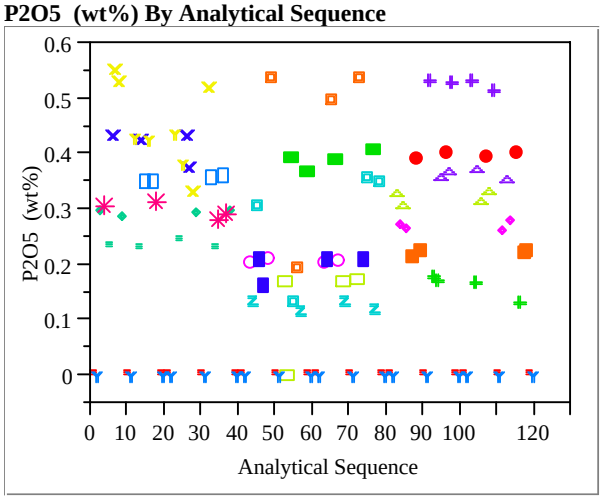
NiO (wt%) By Analytical Sequence



TiO2 (wt%) By Analytical Sequence



P2O5 (wt%) By Analytical Sequence



U3O8 (wt%) By Analytical Sequence

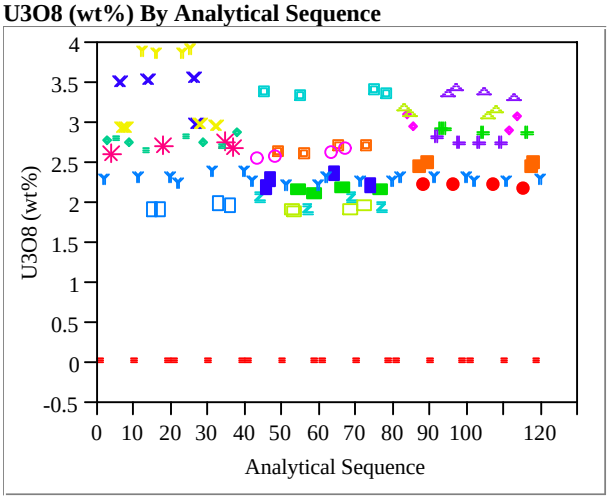


Exhibit A.1: SRTC-ML Measurements for Samples Prepared Using the LM Method *(continued)*

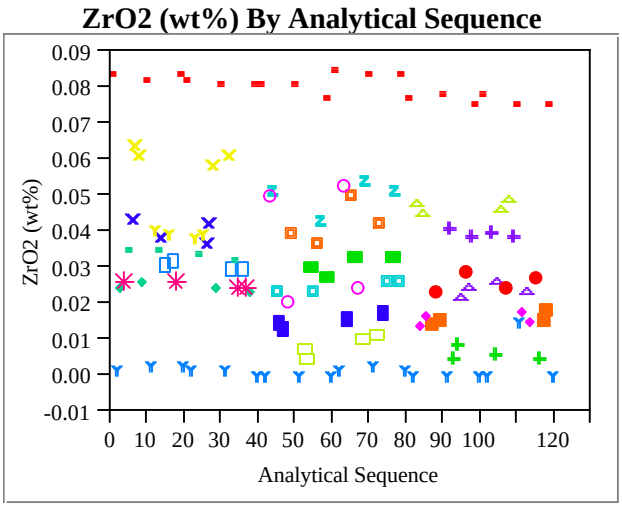
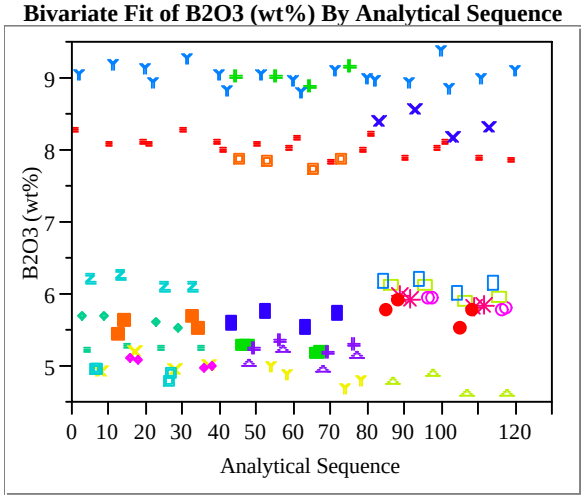


Exhibit A.2: SRTC-ML Measurements for Samples Prepared Using the PF Method

Bivariate Fit of B2O3 (wt%) By Analytical Sequence



Bivariate Fit of Li2O (wt%) By Analytical Sequence

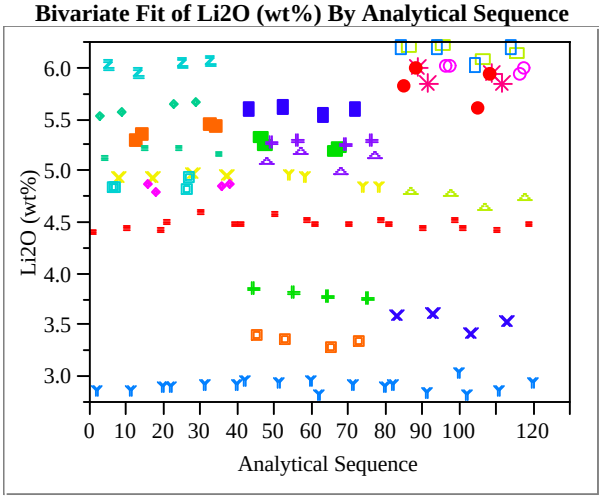
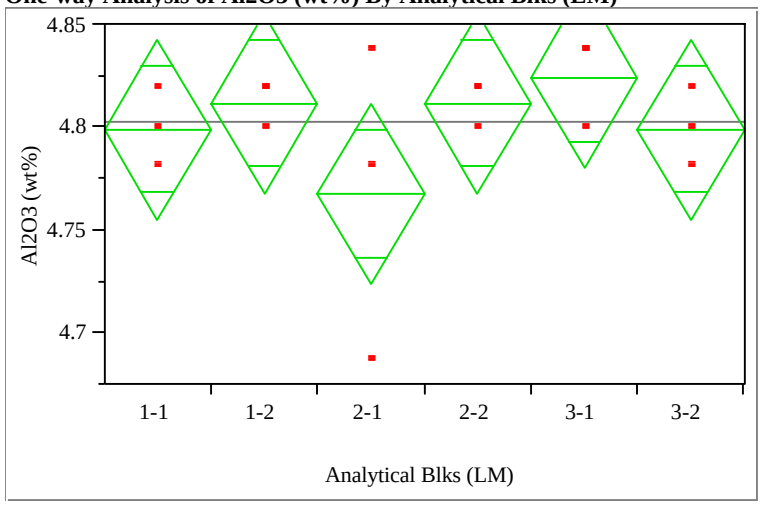


Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method

Batch 1 – reference value 4.8777 wt%

One-way Analysis of Al2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.280236
Adj Rsquare	-0.01967
Root Mean Square Error	0.034784
Mean of Response	4.802479
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00565283	0.001131	0.9344	0.4928
Error	12	0.01451886	0.001210		
C. Total	17	0.02017169			

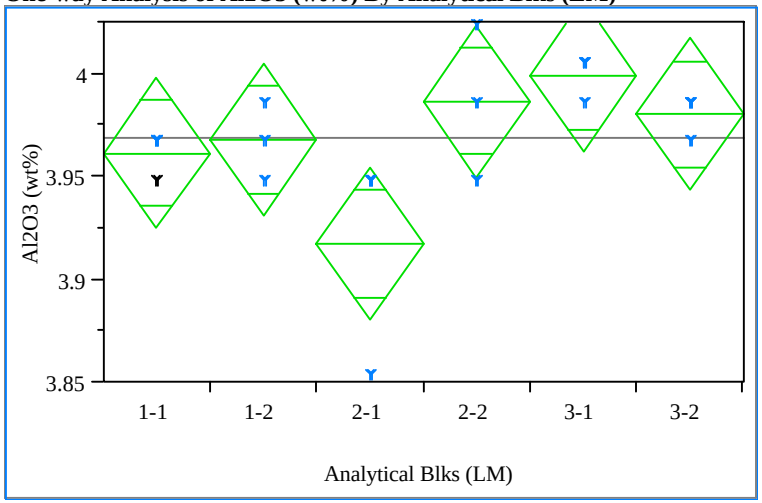
Means for One-way Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	4.79933	0.02008	4.7556	4.8431
1-2	3	4.81193	0.02008	4.7682	4.8557
2-1	3	4.76784	0.02008	4.7241	4.8116
2-2	3	4.81193	0.02008	4.7682	4.8557
3-1	3	4.82452	0.02008	4.7808	4.8683
3-2	3	4.79933	0.02008	4.7556	4.8431

Std Error uses a pooled estimate of error variance

U std – reference value 4.1 wt%

One-way Analysis of Al2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.544572
Adj Rsquare	0.35481
Root Mean Square Error	0.029204
Mean of Response	3.969
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.01223789	0.002448	2.8698	0.0625
Error	12	0.01023460	0.000853		
C. Total	17	0.02247249			

Means for One-way Anova

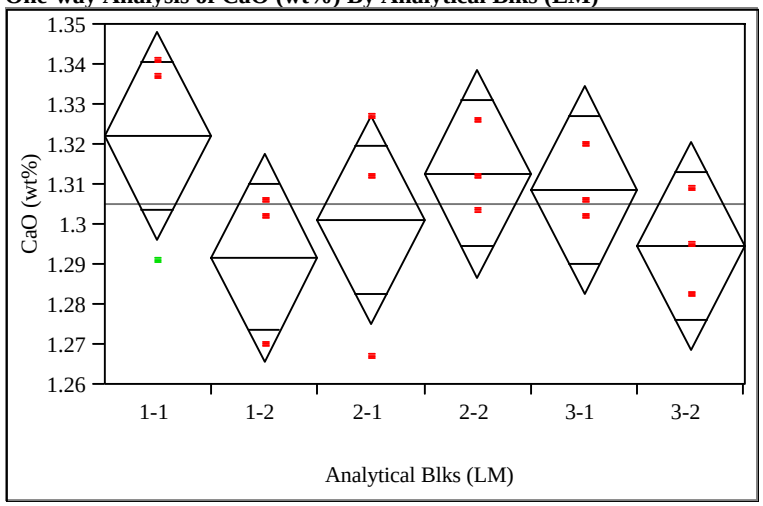
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	3.96165	0.01686	3.9249	3.9984
1-2	3	3.96795	0.01686	3.9312	4.0047
2-1	3	3.91756	0.01686	3.8808	3.9543
2-2	3	3.98685	0.01686	3.9501	4.0236
3-1	3	3.99944	0.01686	3.9627	4.0362
3-2	3	3.98055	0.01686	3.9438	4.0173

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 1.22 wt%

One-way Analysis of CaO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.280832
Adj Rsquare	-0.01882
Root Mean Square Error	0.020614
Mean of Response	1.305298
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00199126	0.000398	0.9372	0.4913
Error	12	0.00509931	0.000425		
C. Total	17	0.00709057			

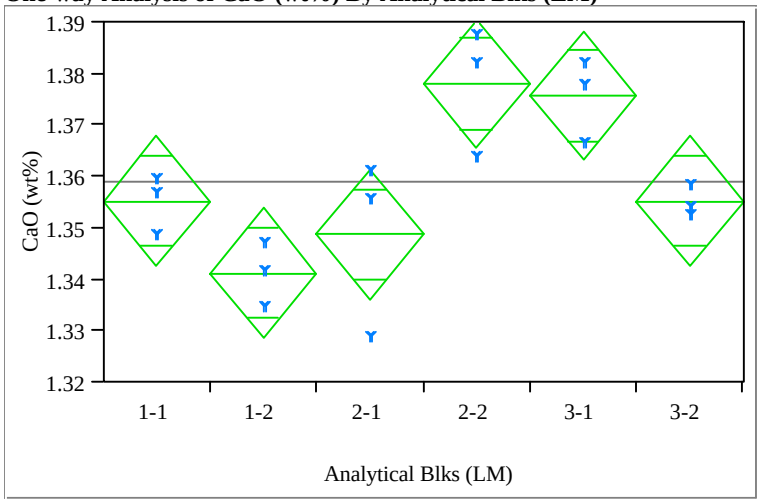
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.32224	0.01190	1.2963	1.3482
1-2	3	1.29193	0.01190	1.2660	1.3179
2-1	3	1.30126	0.01190	1.2753	1.3272
2-2	3	1.31292	0.01190	1.2870	1.3388
3-1	3	1.30872	0.01190	1.2828	1.3346
3-2	3	1.29473	0.01190	1.2688	1.3207

Std Error uses a pooled estimate of error variance

U std – reference value 1.301 wt%

One-way Analysis of CaO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.733774
Adj Rsquare	0.622846
Root Mean Square Error	0.009965
Mean of Response	1.359167
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00328436	0.000657	6.6149	0.0035
Error	12	0.00119162	0.000099		
C. Total	17	0.00447598			

Means for Oneway Anova

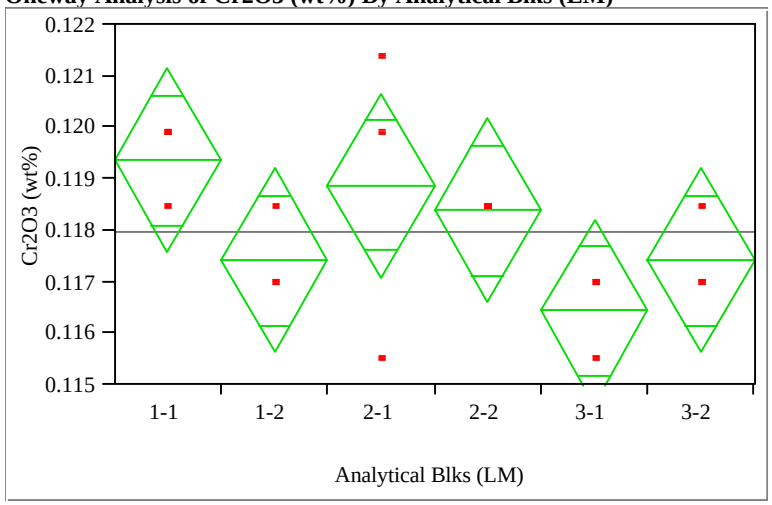
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.35536	0.00575	1.3428	1.3679
1-2	3	1.34137	0.00575	1.3288	1.3539
2-1	3	1.34883	0.00575	1.3363	1.3614
2-2	3	1.37821	0.00575	1.3657	1.3907
3-1	3	1.37588	0.00575	1.3633	1.3884
3-2	3	1.35536	0.00575	1.3428	1.3679

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 0.107 wt%

Oneway Analysis of Cr2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.422096
Adj Rsquare	0.181303
Root Mean Square Error	0.00142
Mean of Response	0.117984
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00001768	0.0000035	1.7529	0.1973
Error	12	0.00002421	0.000002		
C. Total	17	0.00004189			

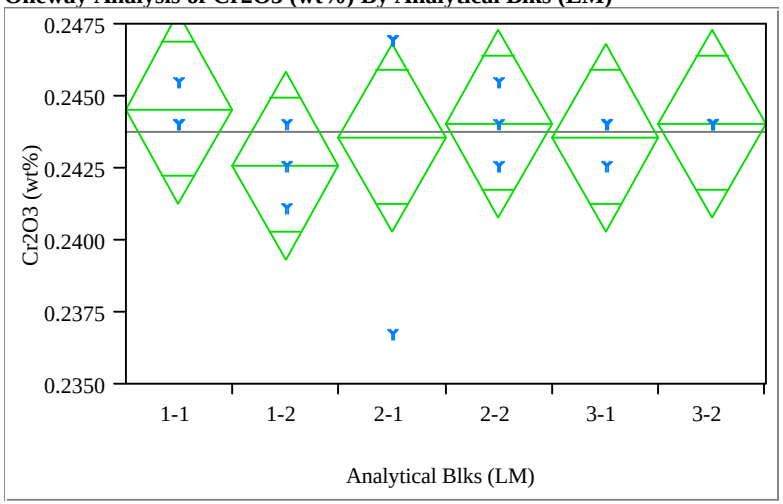
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.119364	0.00082	0.11758	0.12115
1-2	3	0.117415	0.00082	0.11563	0.11920
2-1	3	0.118877	0.00082	0.11709	0.12066
2-2	3	0.118390	0.00082	0.11660	0.12018
3-1	3	0.116441	0.00082	0.11465	0.11823
3-2	3	0.117415	0.00082	0.11563	0.11920

Std Error uses a pooled estimate of error variance

U std – reference value no defined

Oneway Analysis of Cr2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.075676
Adj Rsquare	-0.30946
Root Mean Square Error	0.002601
Mean of Response	0.243762
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00000665	0.0000013	0.1965	0.9579
Error	12	0.00008118	0.0000068		
C. Total	17	0.00008782			

Means for Oneway Anova

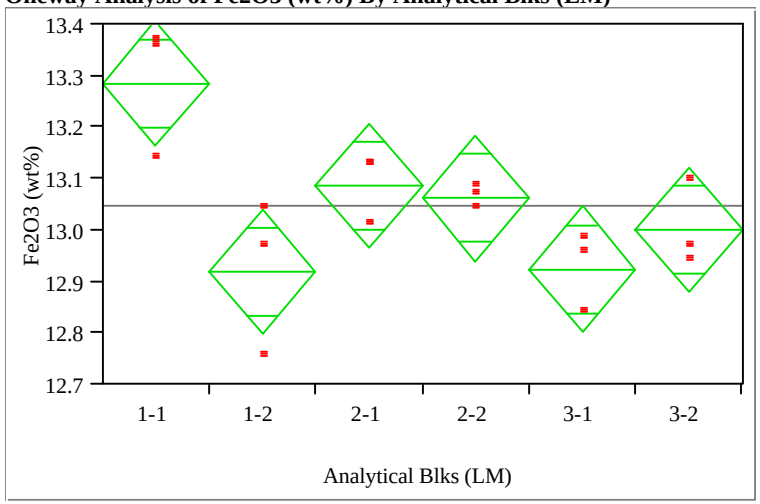
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.244574	0.00150	0.24130	0.24785
1-2	3	0.242626	0.00150	0.23935	0.24590
2-1	3	0.243600	0.00150	0.24033	0.24687
2-2	3	0.244087	0.00150	0.24082	0.24736
3-1	3	0.243600	0.00150	0.24033	0.24687
3-2	3	0.244087	0.00150	0.24082	0.24736

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 12.839 wt%

Oneway Analysis of Fe2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.712156
Adj Rsquare	0.592222
Root Mean Square Error	0.096732
Mean of Response	13.04681
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.27780803	0.055562	5.9379	0.0055
Error	12	0.11228605	0.009357		
C. Total	17	0.39009408			

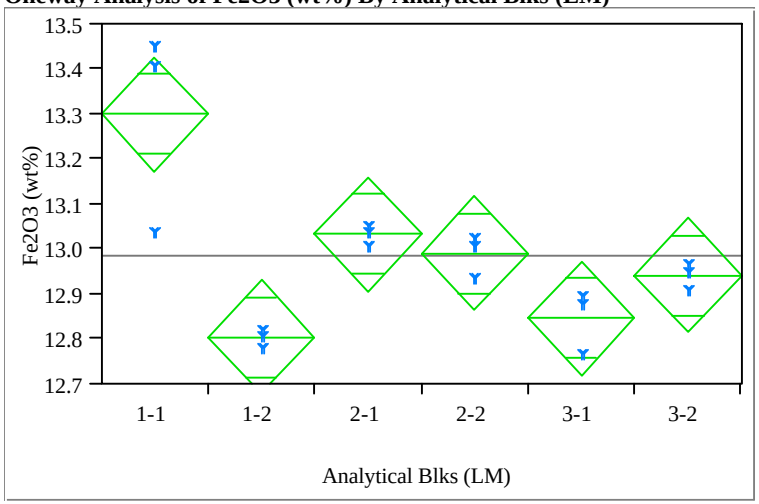
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	13.2867	0.05585	13.165	13.408
1-2	3	12.9197	0.05585	12.798	13.041
2-1	3	13.0865	0.05585	12.965	13.208
2-2	3	13.0627	0.05585	12.941	13.184
3-1	3	12.9245	0.05585	12.803	13.046
3-2	3	13.0007	0.05585	12.879	13.122

Std Error uses a pooled estimate of error variance

U std – reference value 13.196 wt%

Oneway Analysis of Fe2O3 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.792355
Adj Rsquare	0.705836
Root Mean Square Error	0.100758
Mean of Response	12.98724
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.46487195	0.092974	9.1582	0.0009
Error	12	0.12182491	0.010152		
C. Total	17	0.58669686			

Means for Oneway Anova

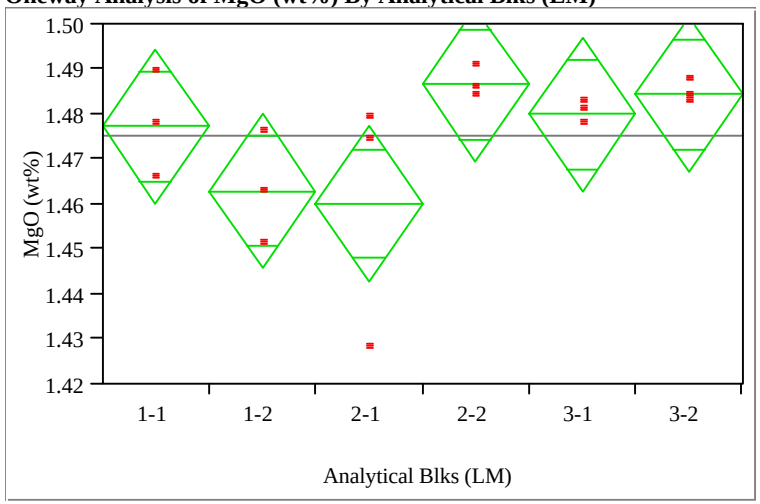
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	13.3010	0.05817	13.174	13.428
1-2	3	12.8053	0.05817	12.679	12.932
2-1	3	13.0341	0.05817	12.907	13.161
2-2	3	12.9912	0.05817	12.864	13.118
3-1	3	12.8482	0.05817	12.721	12.975
3-2	3	12.9436	0.05817	12.817	13.070

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 1.419 wt%

Oneway Analysis of MgO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.455276
Adj Rsquare	0.228308
Root Mean Square Error	0.013651
Mean of Response	1.475341
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00186891	0.000374	2.0059	0.1500
Error	12	0.00223609	0.000186		
C. Total	17	0.00410500			

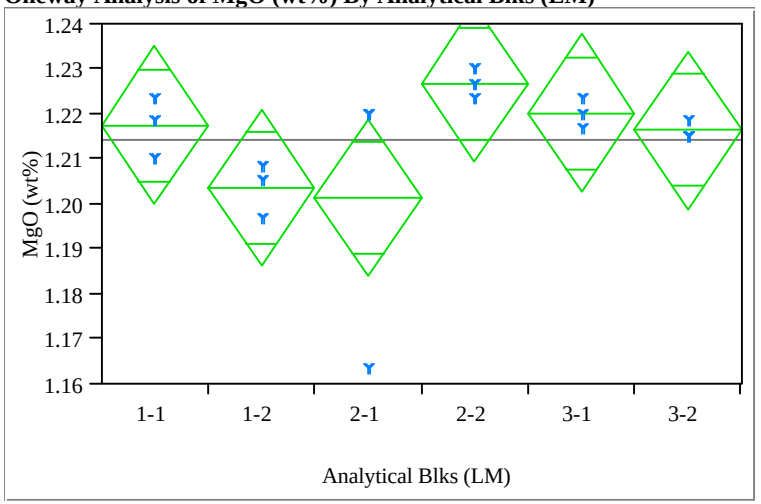
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.47737	0.00788	1.4602	1.4945
1-2	3	1.46300	0.00788	1.4458	1.4802
2-1	3	1.46023	0.00788	1.4431	1.4774
2-2	3	1.48676	0.00788	1.4696	1.5039
3-1	3	1.48013	0.00788	1.4630	1.4973
3-2	3	1.48455	0.00788	1.4674	1.5017

Std Error uses a pooled estimate of error variance

U std – reference value 1.21 wt%

Oneway Analysis of MgO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.384814
Adj Rsquare	0.128486
Root Mean Square Error	0.013939
Mean of Response	1.214466
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00145835	0.000292	1.5013	0.2607
Error	12	0.00233140	0.000194		
C. Total	17	0.00378975			

Means for Oneway Anova

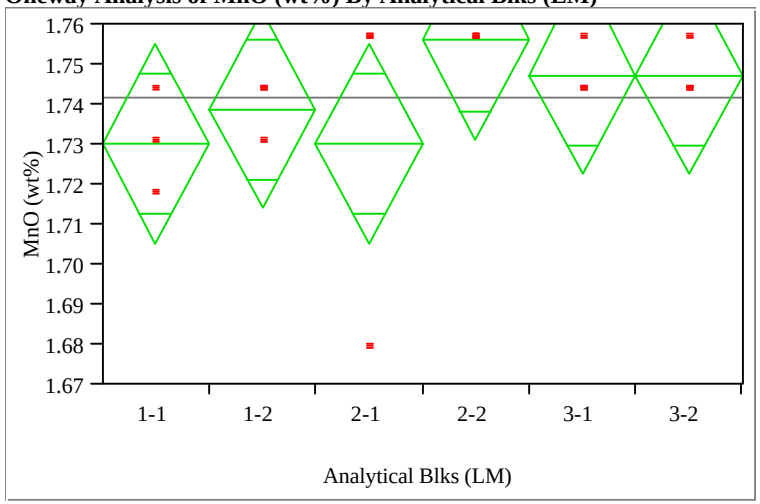
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.21760	0.00805	1.2001	1.2351
1-2	3	1.20378	0.00805	1.1862	1.2213
2-1	3	1.20157	0.00805	1.1840	1.2191
2-2	3	1.22699	0.00805	1.2095	1.2445
3-1	3	1.22036	0.00805	1.2028	1.2379
3-2	3	1.21649	0.00805	1.1990	1.2340

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 1.726 wt%

Oneway Analysis of MnO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.258824
Adj Rsquare	-0.05
Root Mean Square Error	0.019723
Mean of Response	1.741685
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00163015	0.000326	0.8381	0.5476
Error	12	0.00466815	0.000389		
C. Total	17	0.00629830			

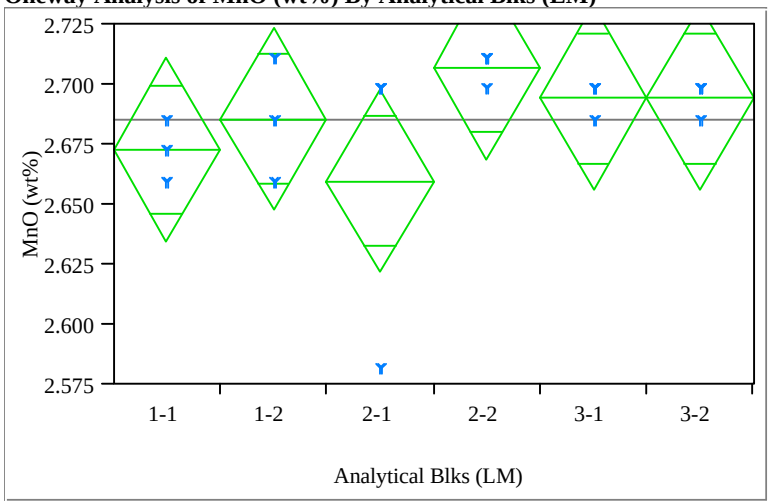
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.73021	0.01139	1.7054	1.7550
1-2	3	1.73882	0.01139	1.7140	1.7636
2-1	3	1.73021	0.01139	1.7054	1.7550
2-2	3	1.75603	0.01139	1.7312	1.7808
3-1	3	1.74742	0.01139	1.7226	1.7722
3-2	3	1.74742	0.01139	1.7226	1.7722

Std Error uses a pooled estimate of error variance

U std – reference value 2.892 wt%

Oneway Analysis of MnO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.282609
Adj Rsquare	-0.0163
Root Mean Square Error	0.030281
Mean of Response	2.685696
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00433471	0.000867	0.9455	0.4868
Error	12	0.01100350	0.000917		
C. Total	17	0.01533822			

Means for Oneway Anova

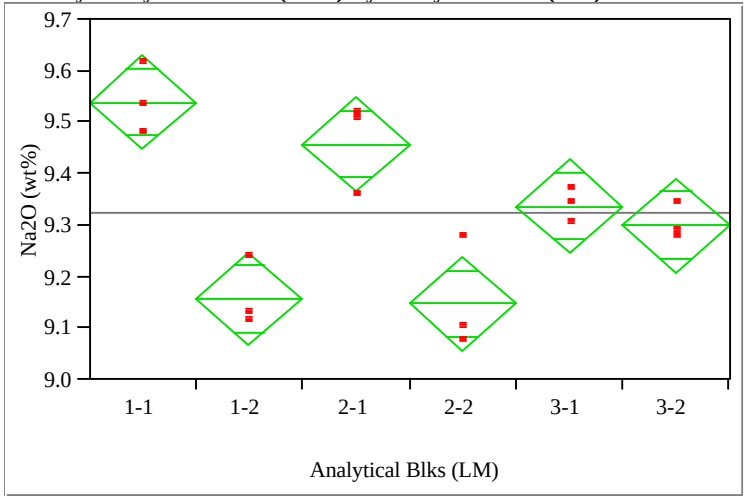
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	2.67278	0.01748	2.6347	2.7109
1-2	3	2.68570	0.01748	2.6476	2.7238
2-1	3	2.65987	0.01748	2.6218	2.6980
2-2	3	2.70722	0.01748	2.6691	2.7453
3-1	3	2.69430	0.01748	2.6562	2.7324
3-2	3	2.69430	0.01748	2.6562	2.7324

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 9.003 wt%

Oneway Analysis of Na2O (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.854672
Adj Rsquare	0.794119
Root Mean Square Error	0.072522
Mean of Response	9.323667
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.37117378	0.074235	14.1144	0.0001
Error	12	0.06311408	0.005260		
C. Total	17	0.43428786			

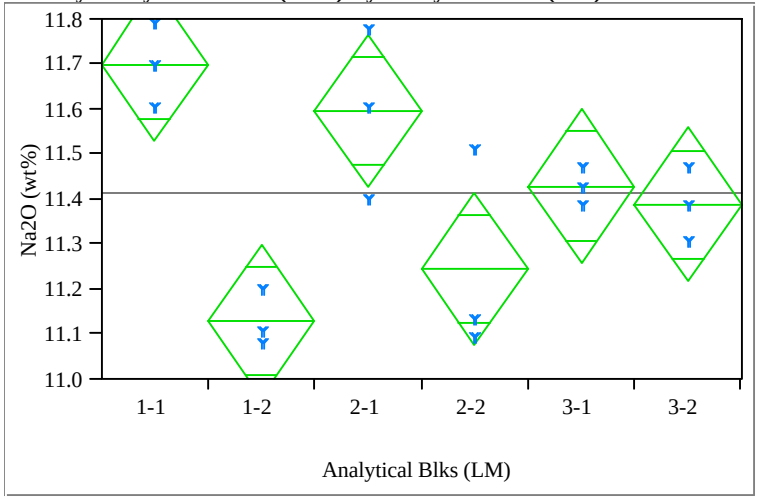
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	9.53935	0.04187	9.4481	9.6306
1-2	3	9.15741	0.04187	9.0662	9.2486
2-1	3	9.45847	0.04187	9.3672	9.5497
2-2	3	9.14843	0.04187	9.0572	9.2397
3-1	3	9.33715	0.04187	9.2459	9.4284
3-2	3	9.30120	0.04187	9.2100	9.3924

Std Error uses a pooled estimate of error variance

U std – reference value 11.795 wt%

Oneway Analysis of Na2O (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.754453
Adj Rsquare	0.652142
Root Mean Square Error	0.135361
Mean of Response	11.41606
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.67555889	0.135112	7.3741	0.0023
Error	12	0.21986958	0.018322		
C. Total	17	0.89542847			

Means for Oneway Anova

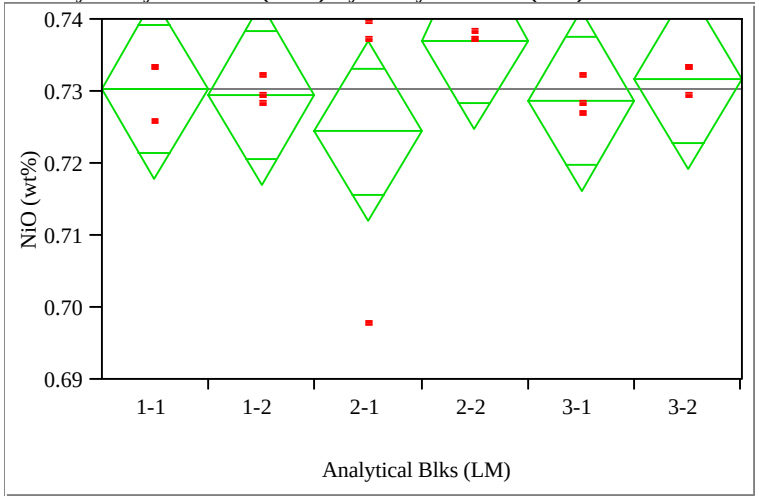
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	11.7006	0.07815	11.530	11.871
1-2	3	11.1300	0.07815	10.960	11.300
2-1	3	11.5973	0.07815	11.427	11.768
2-2	3	11.2468	0.07815	11.077	11.417
3-1	3	11.4310	0.07815	11.261	11.601
3-2	3	11.3906	0.07815	11.220	11.561

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference 0.751 wt%

Oneway Analysis of NiO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.180301
Adj Rsquare	-0.16124
Root Mean Square Error	0.009916
Mean of Response	0.730344
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00025953	0.000052	0.5279	0.7513
Error	12	0.00117990	0.000098		
C. Total	17	0.00143943			

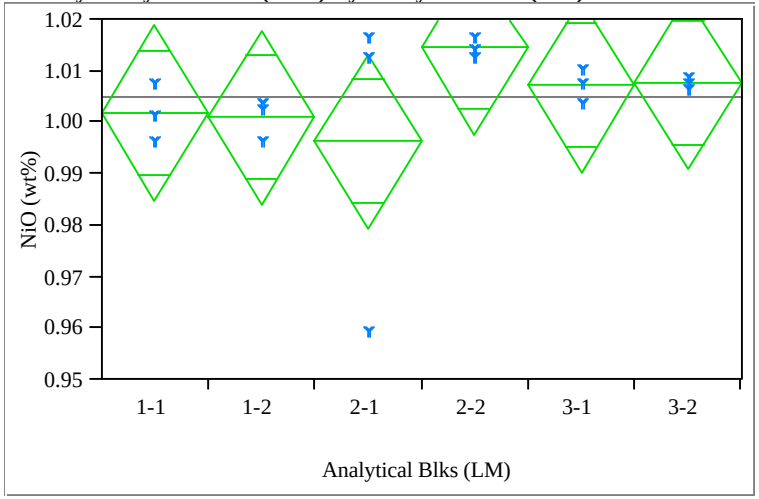
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.730415	0.00572	0.71794	0.74289
1-2	3	0.729567	0.00572	0.71709	0.74204
2-1	3	0.724477	0.00572	0.71200	0.73695
2-2	3	0.737202	0.00572	0.72473	0.74968
3-1	3	0.728718	0.00572	0.71624	0.74119
3-2	3	0.731687	0.00572	0.71921	0.74416

Std Error uses a pooled estimate of error variance

U std – reference value 1.12 wt%

Oneway Analysis of NiO (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.220679
Adj Rsquare	-0.10404
Root Mean Square Error	0.01348
Mean of Response	1.004851
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00061748	0.000123	0.6796	0.6474
Error	12	0.00218060	0.000182		
C. Total	17	0.00279807			

Means for Oneway Anova

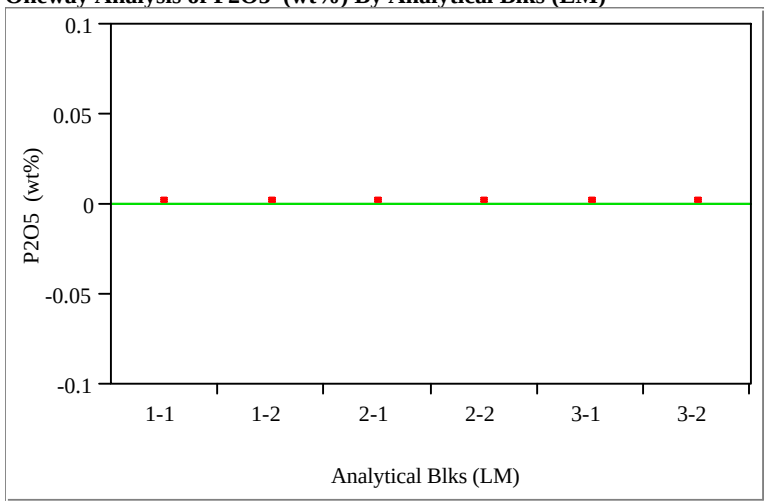
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	1.00188	0.00778	0.98492	1.0188
1-2	3	1.00103	0.00778	0.98408	1.0180
2-1	3	0.99637	0.00778	0.97941	1.0133
2-2	3	1.01461	0.00778	0.99765	1.0316
3-1	3	1.00740	0.00778	0.99044	1.0244
3-2	3	1.00782	0.00778	0.99086	1.0248

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value ~0 wt%

Oneway Analysis of P2O5 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0	0	.	-1.0000
Error	12	0	0		
C. Total	17	0			

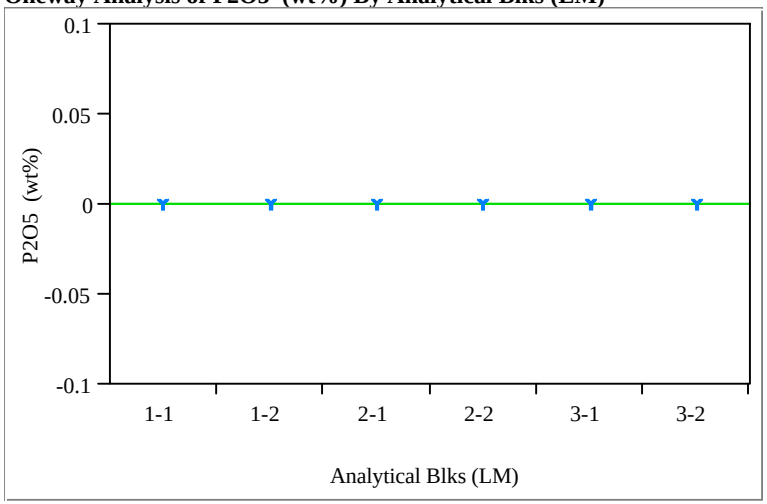
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0	0	0	0
1-2	3	0	0	0	0
2-1	3	0	0	0	0
2-2	3	0	0	0	0
3-1	3	0	0	0	0
3-2	3	0	0	0	0

Std Error uses a pooled estimate of error variance

U std – reference value ~0 wt%

Oneway Analysis of P2O5 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0	0	.	-1.0000
Error	12	0	0		
C. Total	17	0			

Means for Oneway Anova

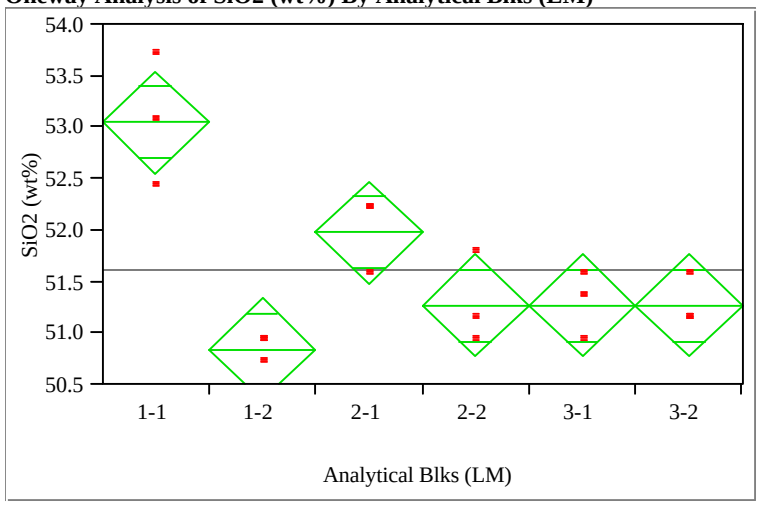
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0	0	0	0
1-2	3	0	0	0	0
2-1	3	0	0	0	0
2-2	3	0	0	0	0
3-1	3	0	0	0	0
3-2	3	0	0	0	0

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 50.22 wt %

Oneway Analysis of SiO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.835764
Adj Rsquare	0.767332
Root Mean Square Error	0.393822
Mean of Response	51.61655
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	9.471029	1.89421	12.2131	0.0002
Error	12	1.861152	0.15510		
C. Total	17	11.332181			

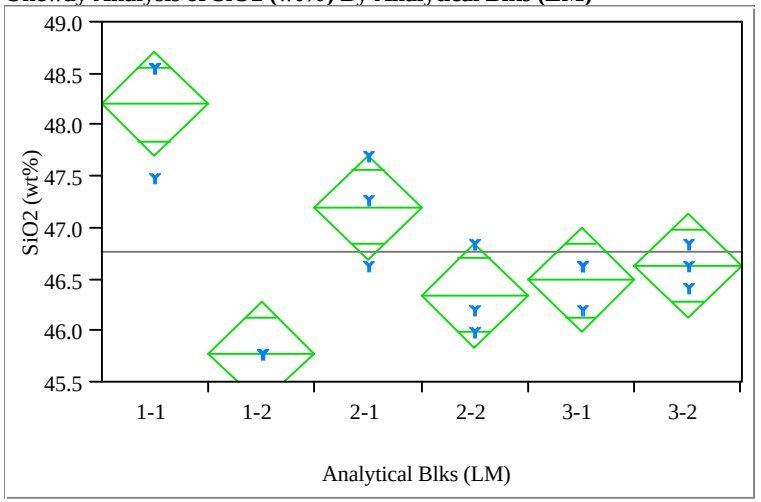
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	53.0546	0.22737	52.559	53.550
1-2	3	50.8440	0.22737	50.349	51.339
2-1	3	51.9850	0.22737	51.490	52.480
2-2	3	51.2719	0.22737	50.776	51.767
3-1	3	51.2719	0.22737	50.776	51.767
3-2	3	51.2719	0.22737	50.776	51.767

Std Error uses a pooled estimate of error variance

U std – reference value 45.353 wt%

Oneway Analysis of SiO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.843137
Adj Rsquare	0.777778
Root Mean Square Error	0.40339
Mean of Response	46.77936
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	10.495680	2.09914	12.9000	0.0002
Error	12	1.952685	0.16272		
C. Total	17	12.448364			

Means for Oneway Anova

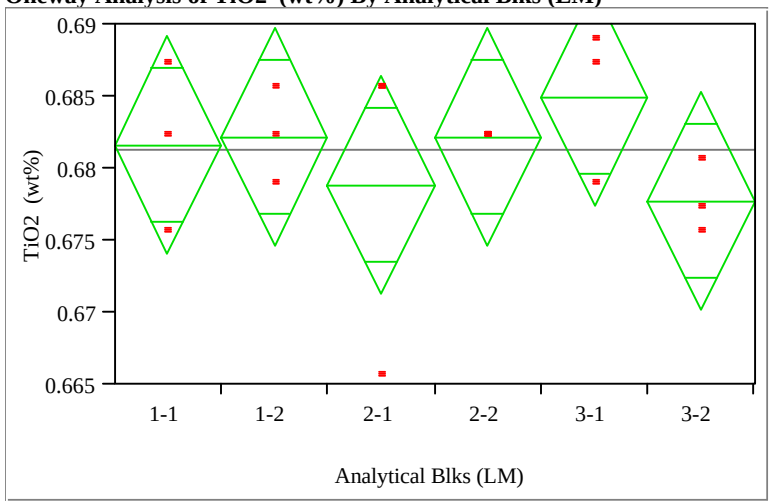
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	48.2056	0.23290	47.698	48.713
1-2	3	45.7810	0.23290	45.274	46.288
2-1	3	47.2072	0.23290	46.700	47.715
2-2	3	46.3515	0.23290	45.844	46.859
3-1	3	46.4941	0.23290	45.987	47.002
3-2	3	46.6367	0.23290	46.129	47.144

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 0.677 wt%

Oneway Analysis of TiO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.191365
Adj Rsquare	-0.14557
Root Mean Square Error	0.005975
Mean of Response	0.681285
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00010140	0.000020	0.5680	0.7234
Error	12	0.00042846	0.000036		
C. Total	17	0.00052986			

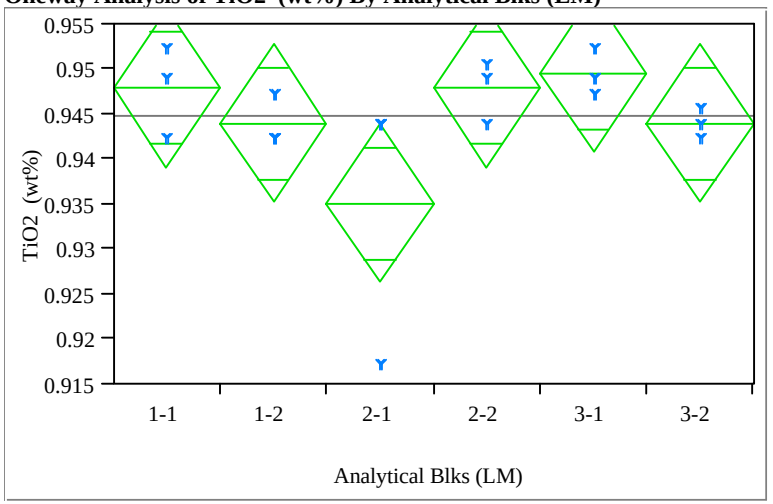
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.681656	0.00345	0.67414	0.68917
1-2	3	0.682212	0.00345	0.67470	0.68973
2-1	3	0.678876	0.00345	0.67136	0.68639
2-2	3	0.682212	0.00345	0.67470	0.68973
3-1	3	0.684992	0.00345	0.67748	0.69251
3-2	3	0.677764	0.00345	0.67025	0.68528

Std Error uses a pooled estimate of error variance

U std – reference value 1.049 wt%

Oneway Analysis of TiO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.412275
Adj Rsquare	0.16739
Root Mean Square Error	0.006989
Mean of Response	0.944829
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00041115	0.000082	1.6835	0.2129
Error	12	0.00058612	0.000049		
C. Total	17	0.00099727			

Means for Oneway Anova

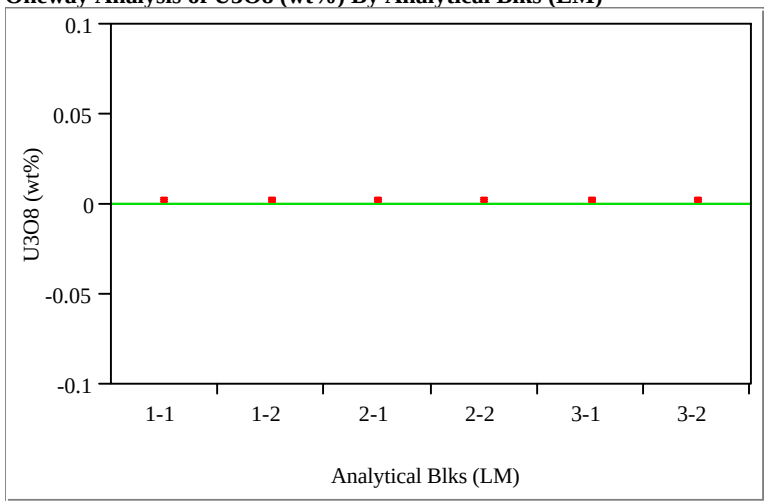
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.947980	0.00403	0.93919	0.95677
1-2	3	0.944088	0.00403	0.93530	0.95288
2-1	3	0.935192	0.00403	0.92640	0.94398
2-2	3	0.947980	0.00403	0.93919	0.95677
3-1	3	0.949648	0.00403	0.94086	0.95844
3-2	3	0.944088	0.00403	0.93530	0.95288

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 0 wt%

Oneway Analysis of U3O8 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0	0	.	-1.0000
Error	12	0	0		
C. Total	17	0			

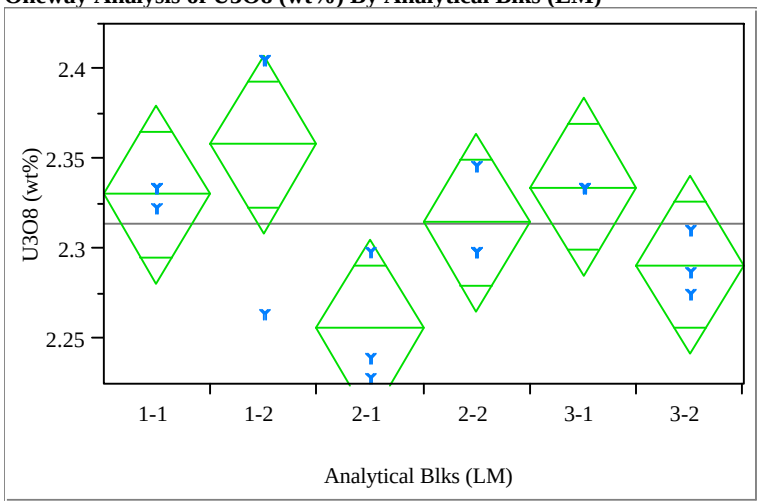
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0	0	0	0
1-2	3	0	0	0	0
2-1	3	0	0	0	0
2-2	3	0	0	0	0
3-1	3	0	0	0	0
3-2	3	0	0	0	0

Std Error uses a pooled estimate of error variance

U std – reference value 2.406 wt%

Oneway Analysis of U3O8 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.515127
Adj Rsquare	0.313096
Root Mean Square Error	0.039208
Mean of Response	2.314508
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.01959850	0.003920	2.5497	0.0855
Error	12	0.01844747	0.001537		
C. Total	17	0.03804597			

Means for Oneway Anova

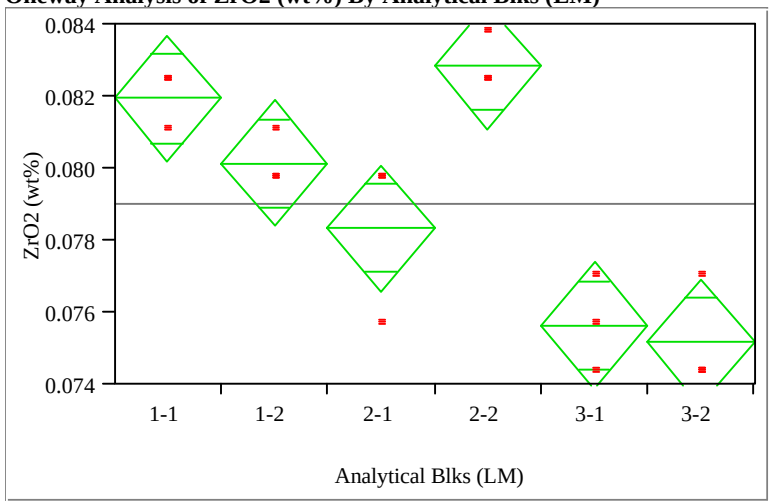
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	2.33089	0.02264	2.2816	2.3802
1-2	3	2.35840	0.02264	2.3091	2.4077
2-1	3	2.25620	0.02264	2.2069	2.3055
2-2	3	2.31516	0.02264	2.2658	2.3645
3-1	3	2.33482	0.02264	2.2855	2.3841
3-2	3	2.29158	0.02264	2.2423	2.3409

Std Error uses a pooled estimate of error variance

Exhibit A.3: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the LM Method *(continued)*

Batch 1 – reference value 0.098 wt%

Oneway Analysis of ZrO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.868739
Adj Rsquare	0.814047
Root Mean Square Error	0.001388
Mean of Response	0.079022
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00015297	0.000031	15.8842	<.0001
Error	12	0.00002311	0.000002		
C. Total	17	0.00017608			

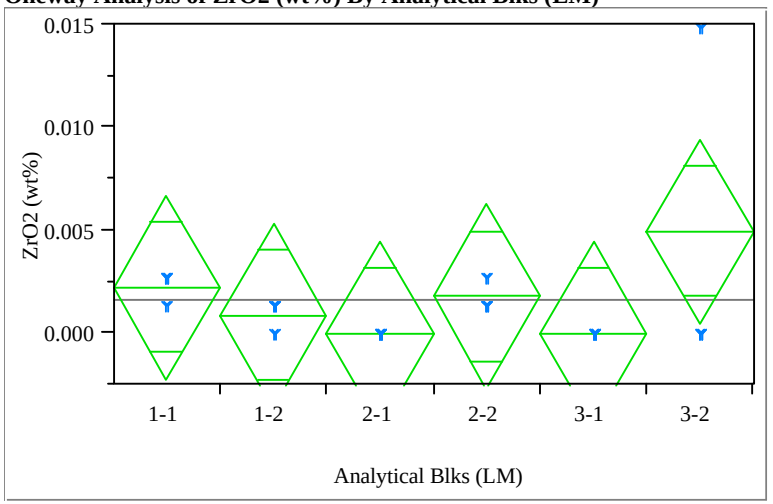
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.081949	0.00080	0.08020	0.08369
1-2	3	0.080147	0.00080	0.07840	0.08189
2-1	3	0.078346	0.00080	0.07660	0.08009
2-2	3	0.082849	0.00080	0.08110	0.08459
3-1	3	0.075645	0.00080	0.07390	0.07739
3-2	3	0.075195	0.00080	0.07345	0.07694

Std Error uses a pooled estimate of error variance

U std – reference value ~0 wt%

Oneway Analysis of ZrO2 (wt%) By Analytical Blks (LM)



Summary of Fit

Rsquare	0.256
Adj Rsquare	-0.054
Root Mean Square Error	0.003545
Mean of Response	0.001651
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Blks (LM)	5	0.00005190	0.000010	0.8258	0.5549
Error	12	0.00015084	0.000013		
C. Total	17	0.00020274			

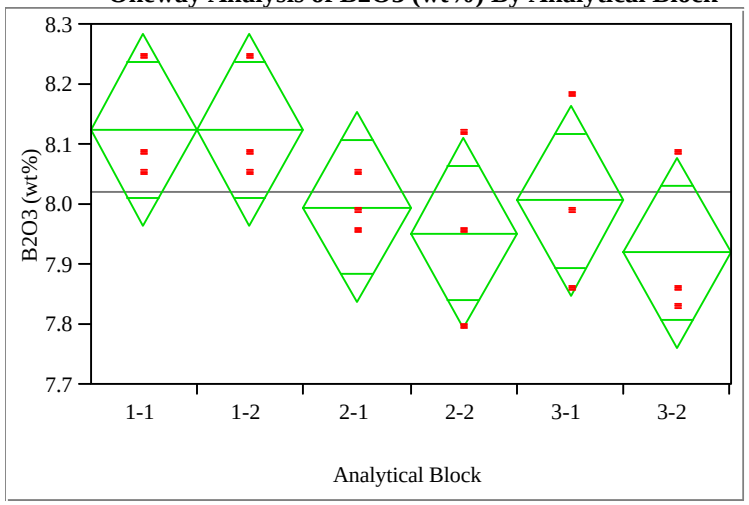
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	0.002251	0.00205	-0.0022	0.00671
1-2	3	0.000901	0.00205	-0.0036	0.00536
2-1	3	0.000000	0.00205	-0.0045	0.00446
2-2	3	0.001801	0.00205	-0.0027	0.00626
3-1	3	0.000000	0.00205	-0.0045	0.00446
3-2	3	0.004953	0.00205	0.00049	0.00941

Std Error uses a pooled estimate of error variance

Exhibit A.4: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method

Batch 1 – reference value 7.777 wt%



Summary of Fit

Rsquare	0.367098
Adj Rsquare	0.103389
Root Mean Square Error	0.126312
Mean of Response	8.021129
Observations (or Sum Wgts)	18

Analysis of Variance

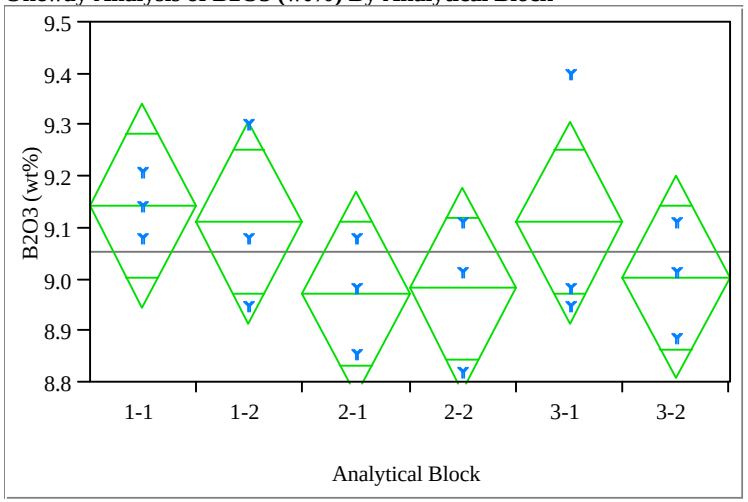
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Block	5	0.11105019	0.022210	1.3921	0.2947
Error	12	0.19145789	0.015955		
C. Total	17	0.30250808			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	8.12488	0.07293	7.9660	8.2838
1-2	3	8.12488	0.07293	7.9660	8.2838
2-1	3	7.99608	0.07293	7.8372	8.1550
2-2	3	7.95315	0.07293	7.7943	8.1120
3-1	3	8.00682	0.07293	7.8479	8.1657
3-2	3	7.92095	0.07293	7.7621	8.0798

Std Error uses a pooled estimate of error variance

U std – reference value 9.209 wt%



Summary of Fit

Rsquare	0.228208
Adj Rsquare	-0.09337
Root Mean Square Error	0.156459
Mean of Response	9.055074
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Block	5	0.08685876	0.017372	0.7096	0.6277
Error	12	0.29375309	0.024479		
C. Total	17	0.38061184			

Means for Oneway Anova

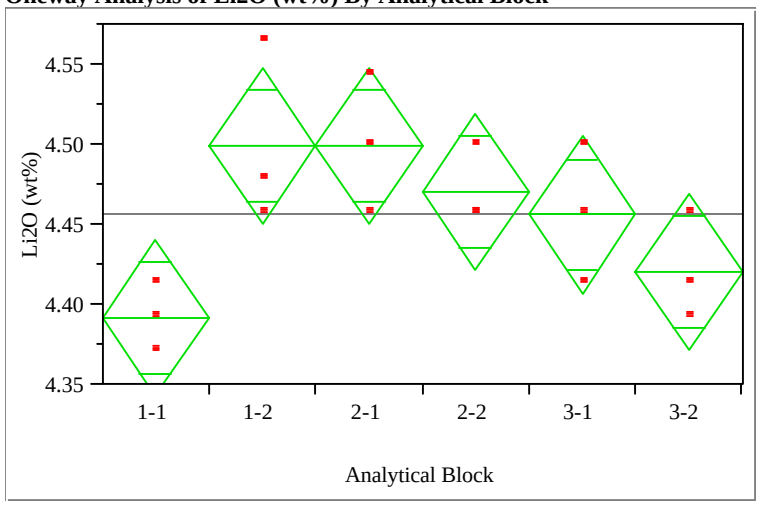
Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	9.14452	0.09033	8.9477	9.3413
1-2	3	9.11232	0.09033	8.9155	9.3091
2-1	3	8.97279	0.09033	8.7760	9.1696
2-2	3	8.98352	0.09033	8.7867	9.1803
3-1	3	9.11232	0.09033	8.9155	9.3091
3-2	3	9.00499	0.09033	8.8082	9.2018

Std Error uses a pooled estimate of error variance

Exhibit A.4: SRTC-ML Measurements by Analytical Block for Samples of the Standard Glasses Prepared Using the PF Method *(continued)*

Batch 1 – reference value 4.429 wt%

Oneway Analysis of Li2O (wt%) By Analytical Block



Summary of Fit

Rsquare	0.606667
Adj Rsquare	0.442778
Root Mean Square Error	0.038977
Mean of Response	4.456503
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Block	5	0.02811887	0.005624	3.7017	0.0294
Error	12	0.01823092	0.001519		
C. Total	17	0.04634978			

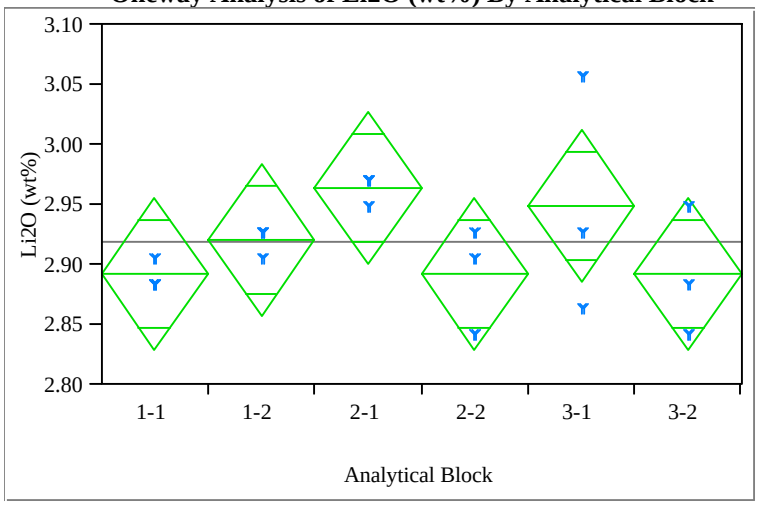
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	4.39192	0.02250	4.3429	4.4409
1-2	3	4.49956	0.02250	4.4505	4.5486
2-1	3	4.49956	0.02250	4.4505	4.5486
2-2	3	4.47086	0.02250	4.4218	4.5199
3-1	3	4.45650	0.02250	4.4075	4.5055
3-2	3	4.42062	0.02250	4.3716	4.4697

Std Error uses a pooled estimate of error variance

U std – reference value 3.057 wt%

Oneway Analysis of Li2O (wt%) By Analytical Block



Summary of Fit

Rsquare	0.336343
Adj Rsquare	0.059819
Root Mean Square Error	0.050234
Mean of Response	2.918376
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Analytical Block	5	0.01534693	0.003069	1.2163	0.3593
Error	12	0.03028186	0.002523		
C. Total	17	0.04562879			

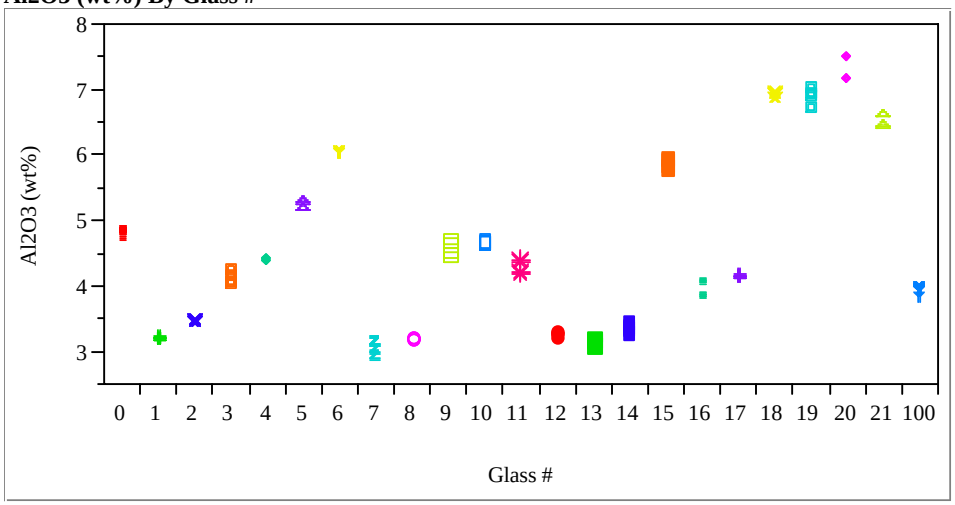
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1-1	3	2.89206	0.02900	2.8289	2.9553
1-2	3	2.92077	0.02900	2.8576	2.9840
2-1	3	2.96383	0.02900	2.9006	3.0270
2-2	3	2.89206	0.02900	2.8289	2.9553
3-1	3	2.94947	0.02900	2.8863	3.0127
3-2	3	2.89206	0.02900	2.8289	2.9553

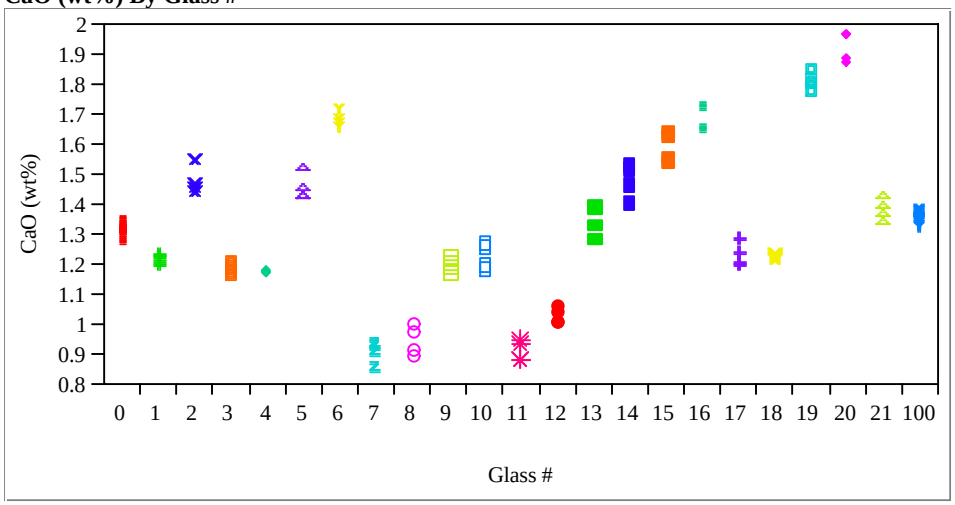
Std Error uses a pooled estimate of error varianc

Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method
(0 – Batch 1 and 100 – U std)

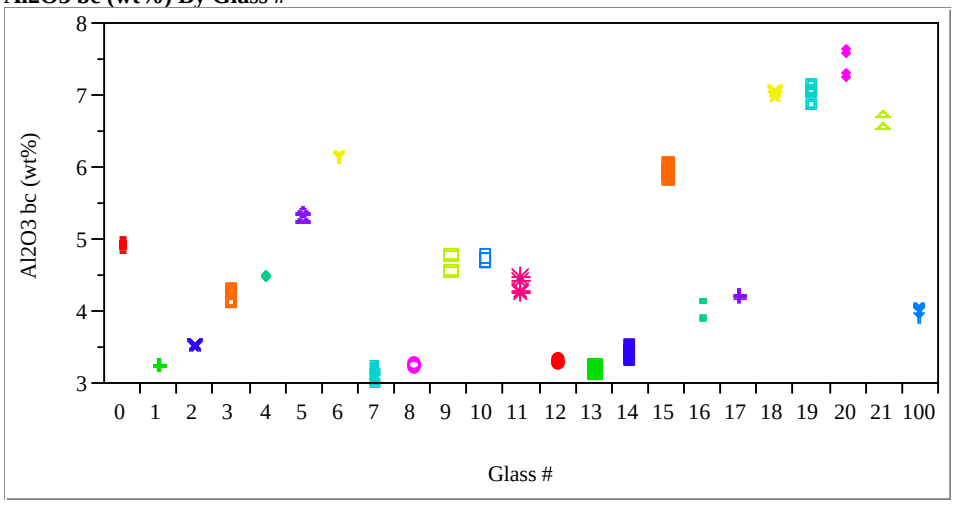
Al2O3 (wt%) By Glass #



CaO (wt%) By Glass #



Al2O3 bc (wt%) By Glass #



CaO bc (wt%) By Glass #

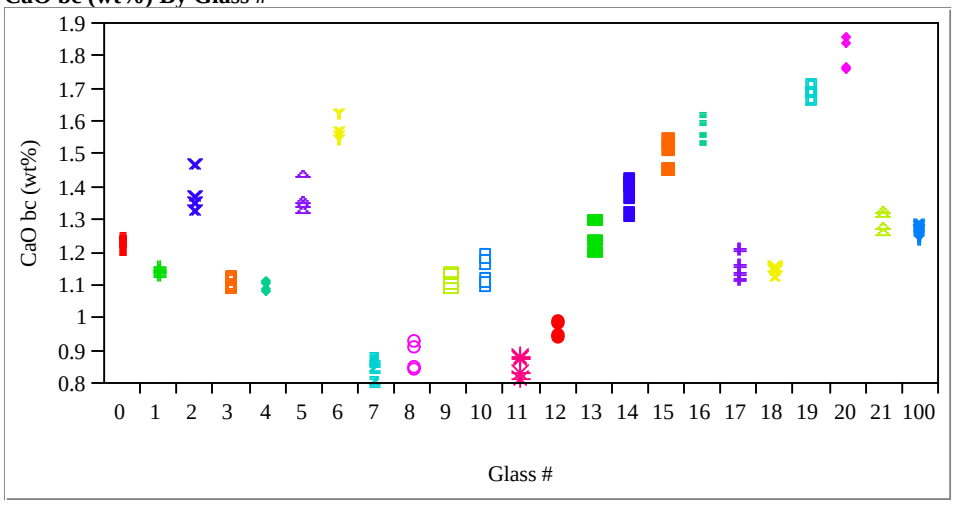
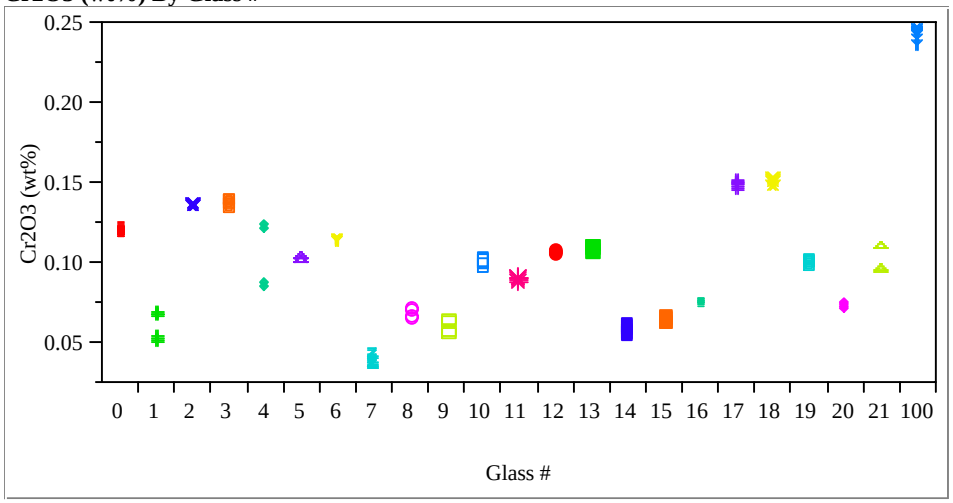
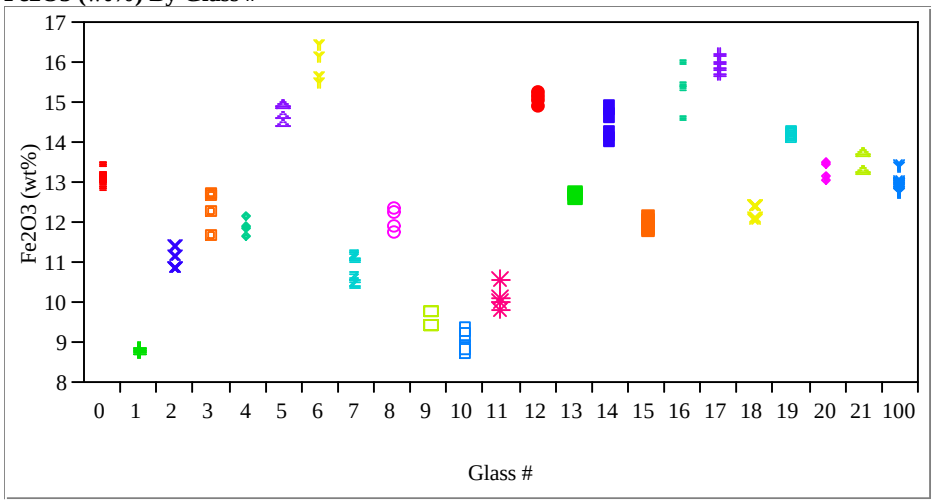


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)

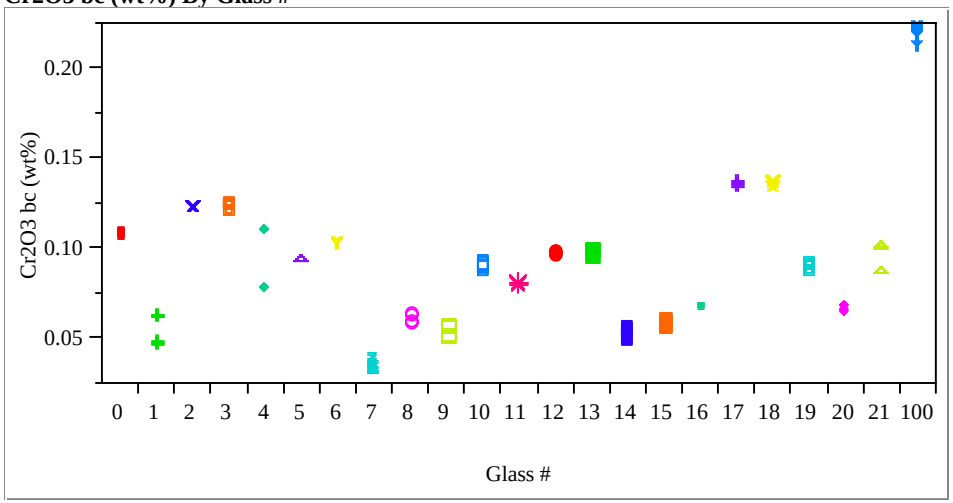
Cr2O3 (wt%) By Glass #



Fe2O3 (wt%) By Glass #



Cr2O3 bc (wt%) By Glass #



Fe2O3 bc (wt%) By Glass #

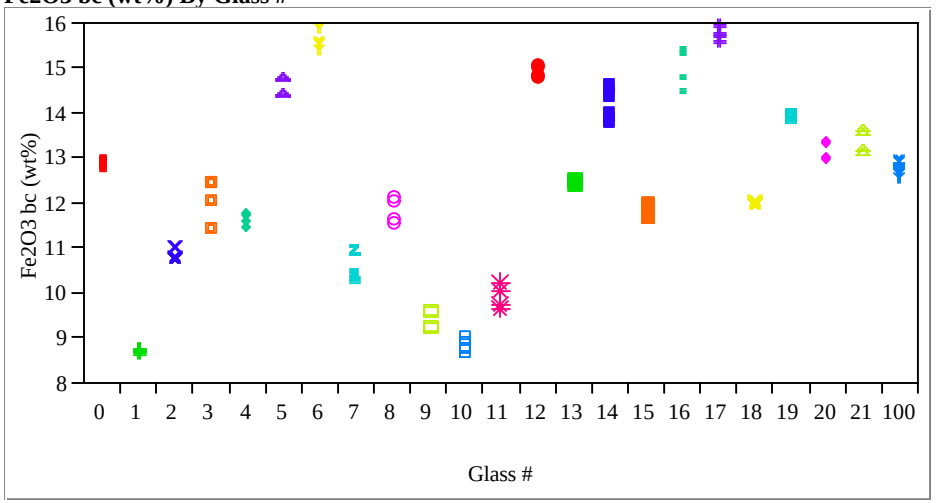
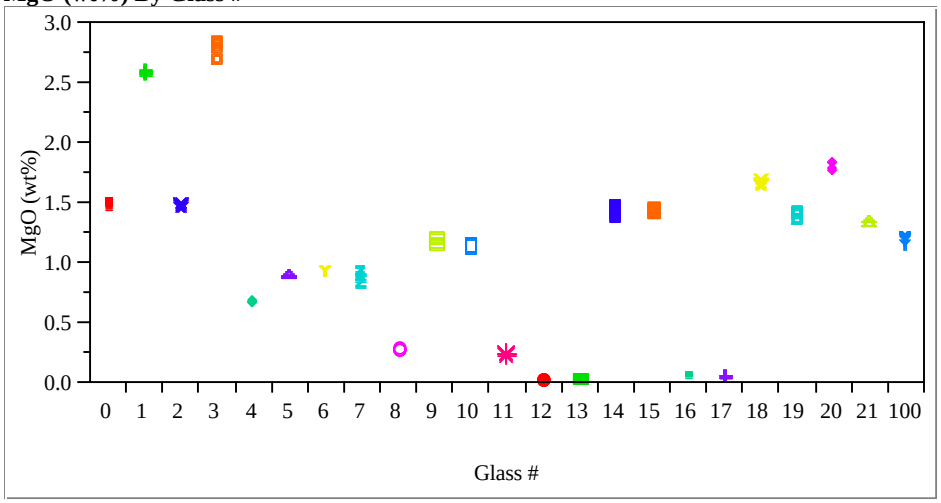
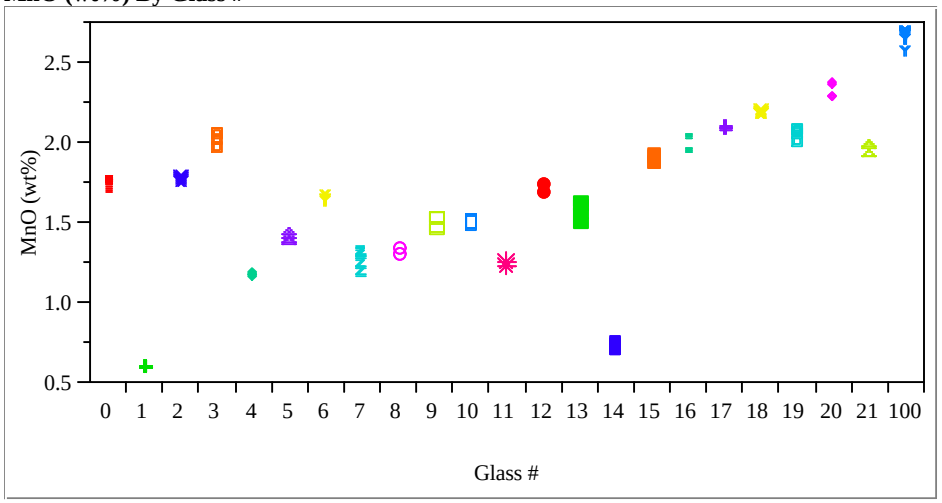


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)

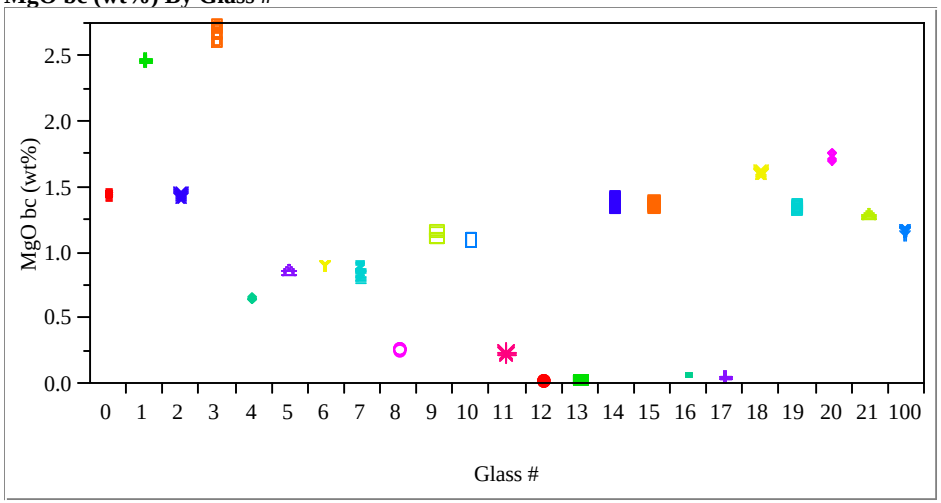
MgO (wt%) By Glass #



MnO (wt%) By Glass #



MgO bc (wt%) By Glass #



MnO bc (wt%) By Glass #

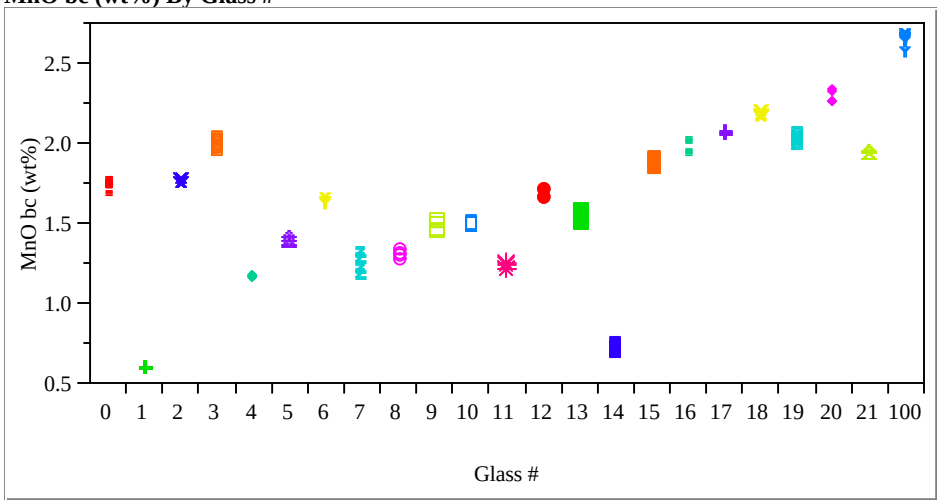
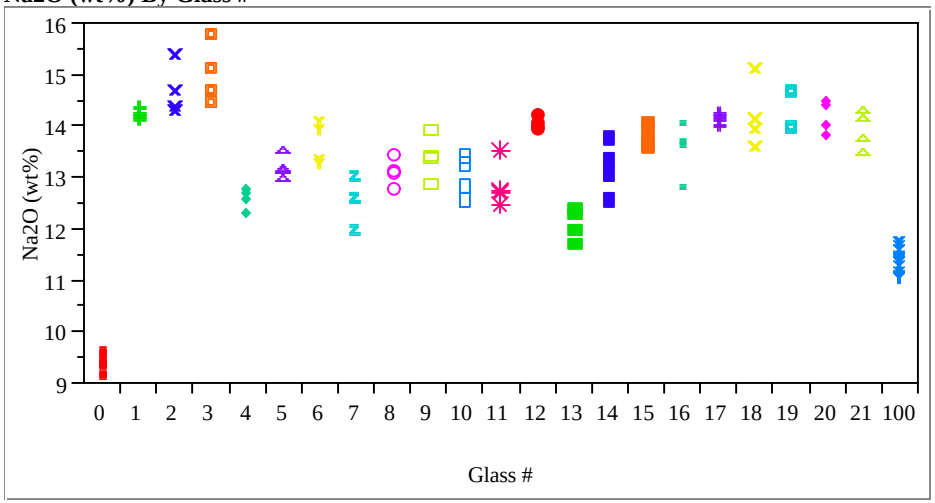
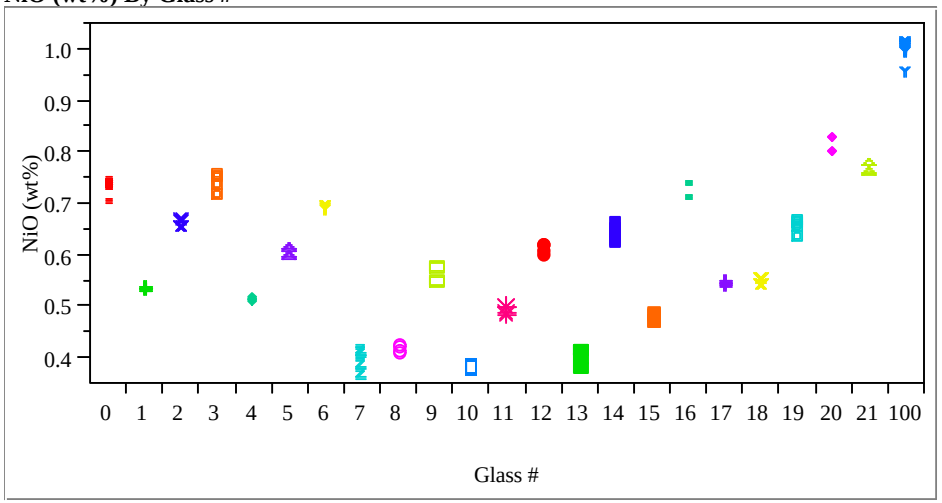


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)

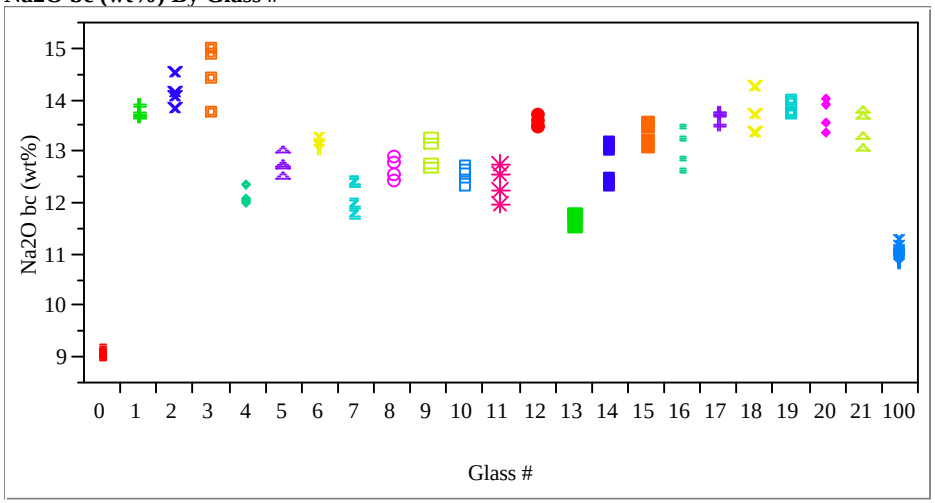
Na2O (wt%) By Glass #



NiO (wt%) By Glass #



Na2O bc (wt%) By Glass #



NiO bc (wt%) By Glass #

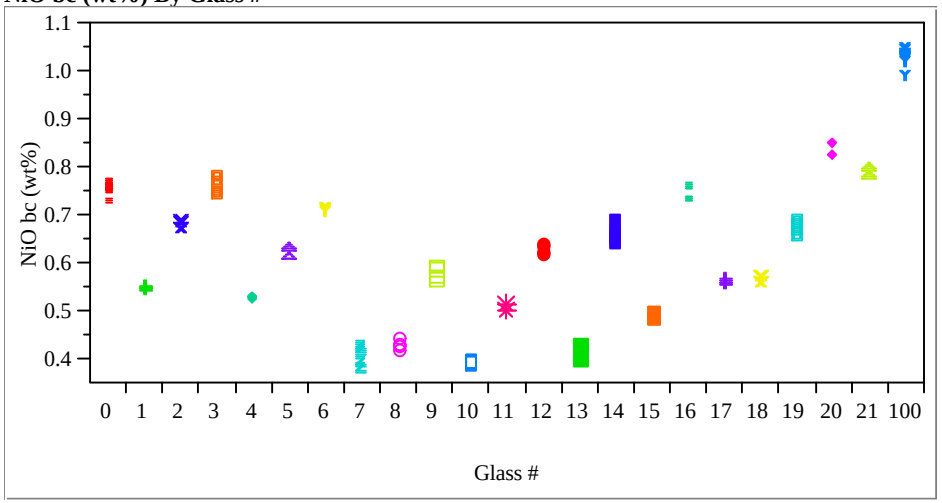
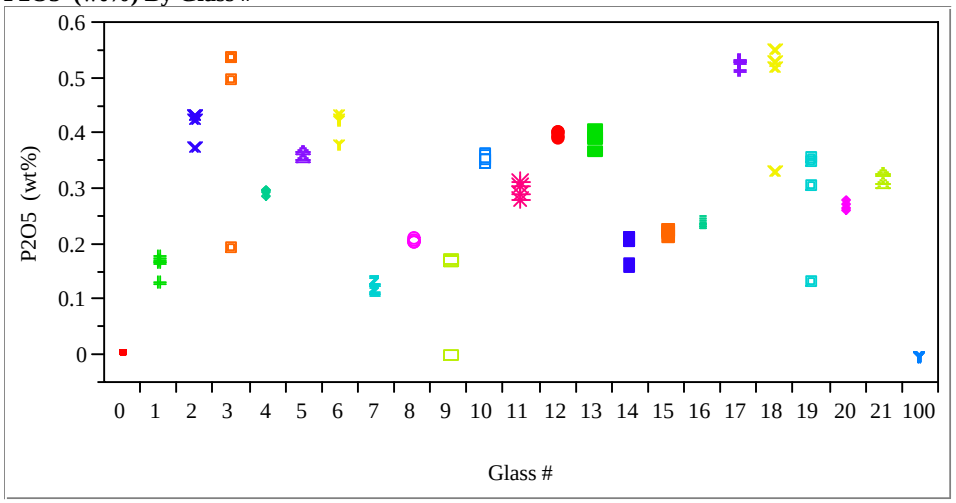
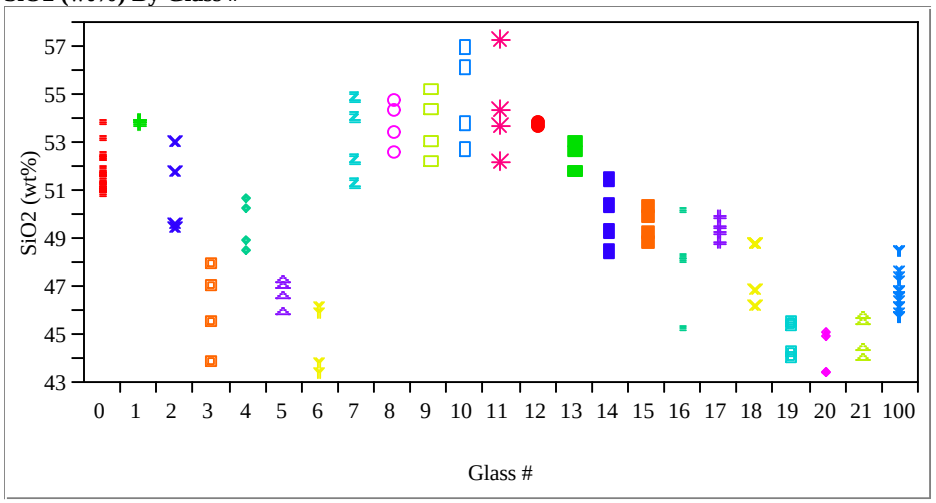


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)

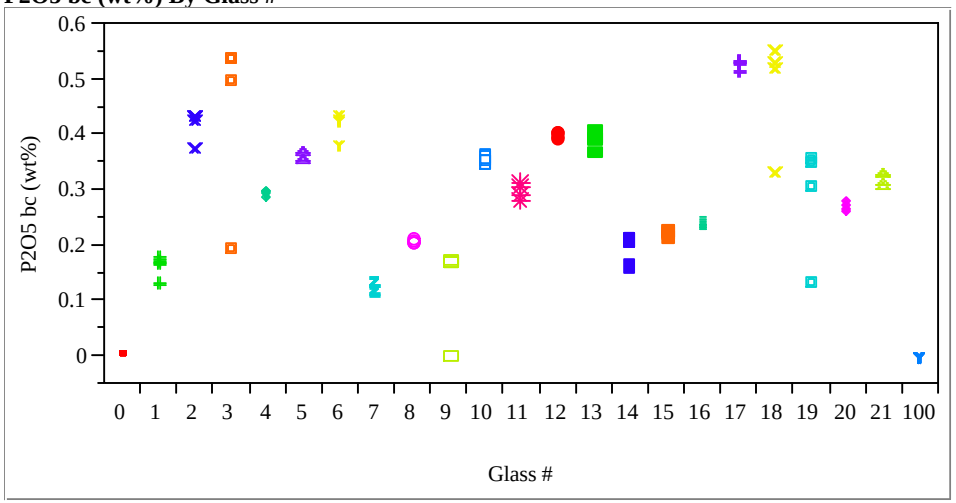
P2O5 (wt%) By Glass #



SiO2 (wt%) By Glass #



P2O5 bc (wt%) By Glass #



SiO2 bc (wt%) By Glass #

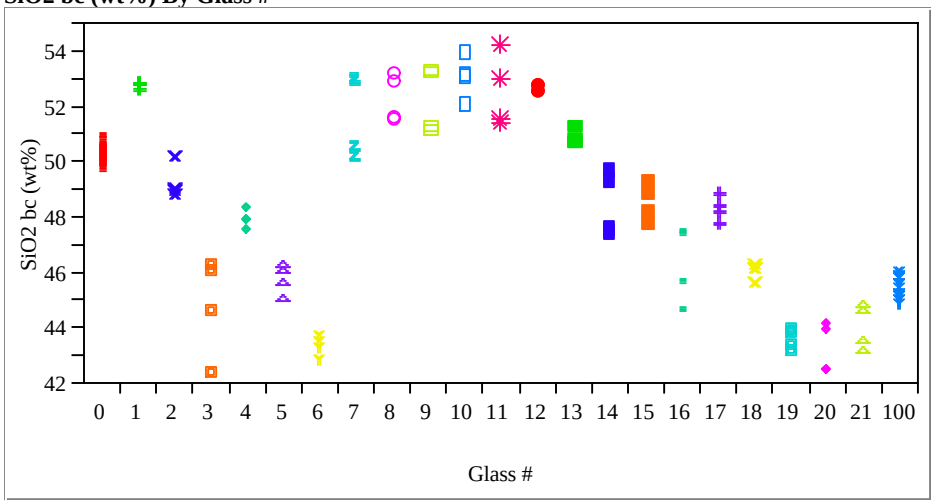
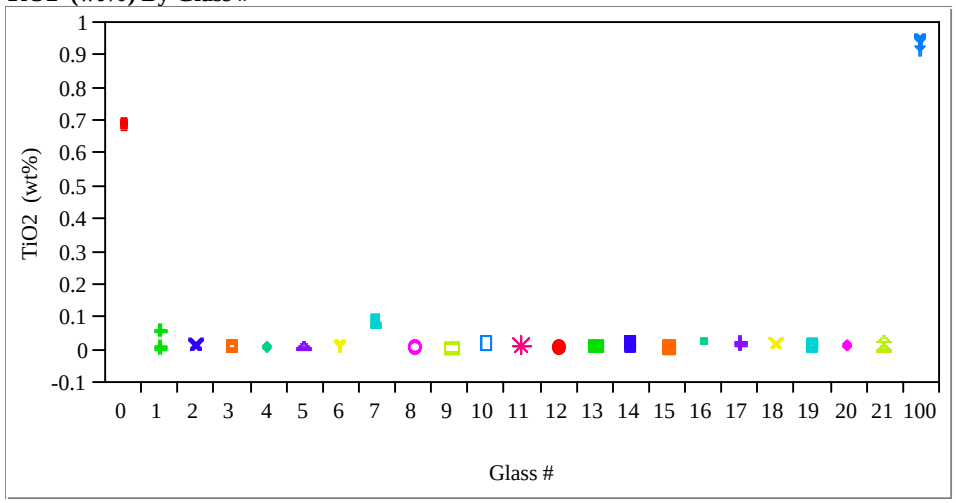
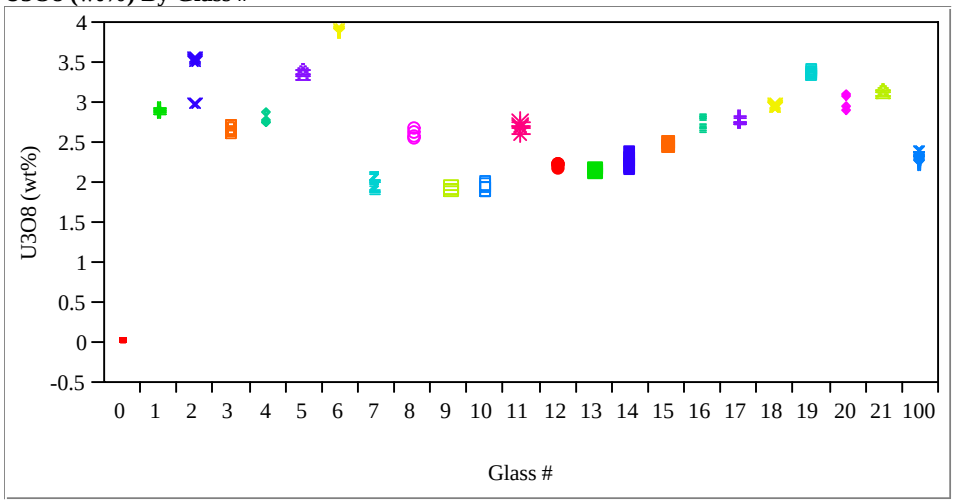


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)

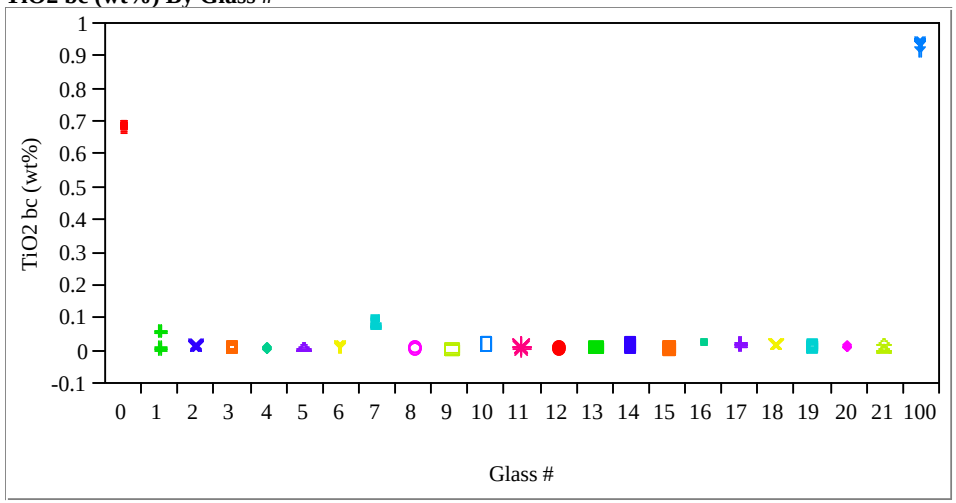
TiO2 (wt%) By Glass #



U3O8 (wt%) By Glass #



TiO2 bc (wt%) By Glass #



U3O8 bc (wt%) By Glass #

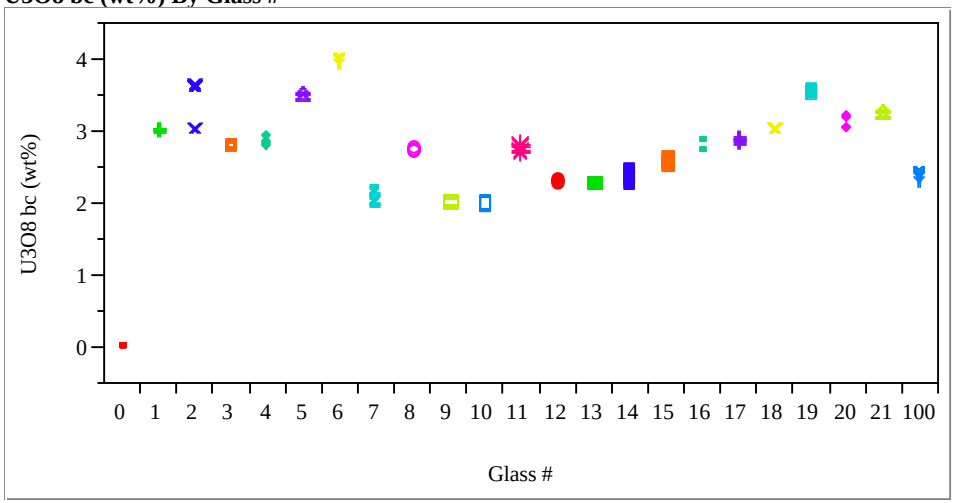
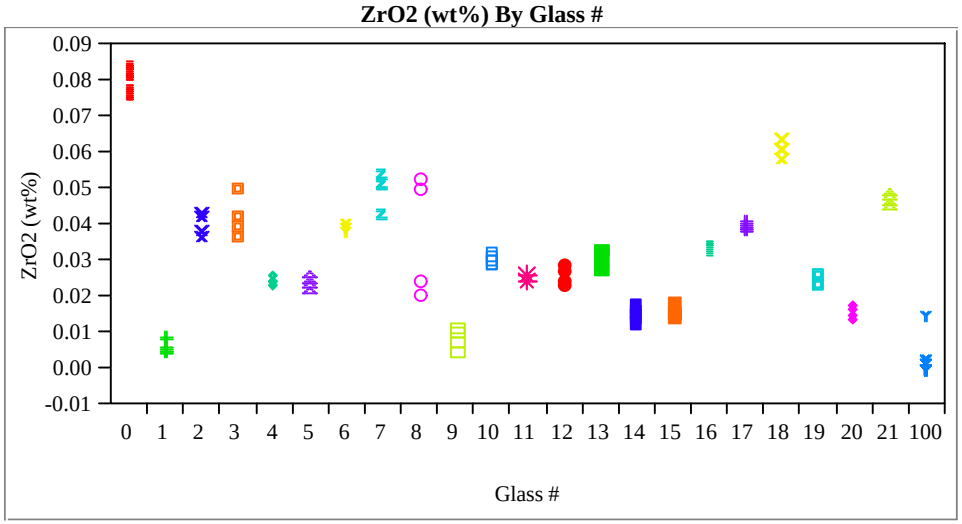


Exhibit A.5: SRTC-ML Measurements by Glass Number for Samples Prepared Using the LM Method *(continued)*
(0 – Batch 1 and 100 – U std)



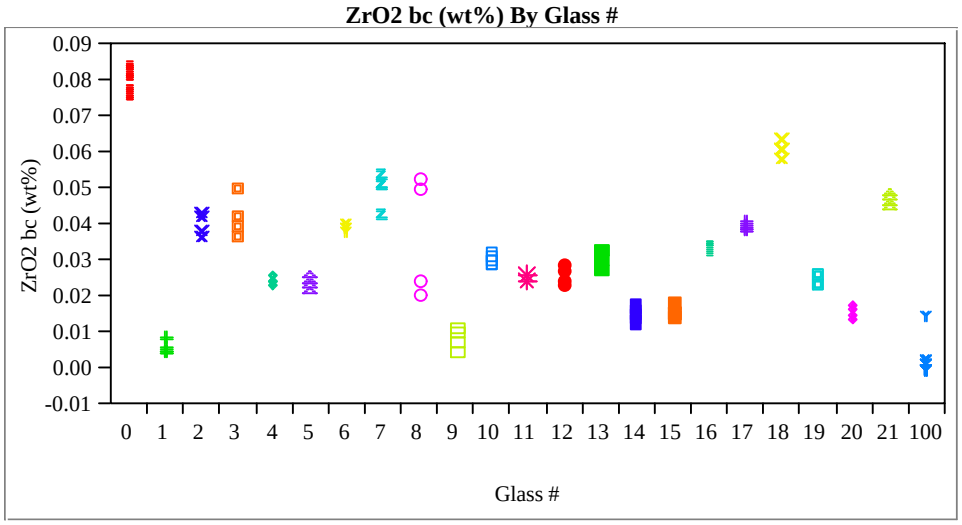
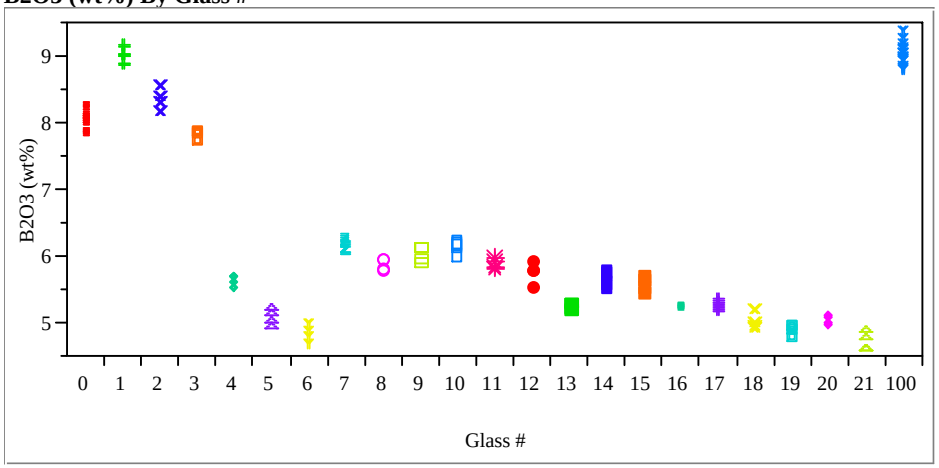
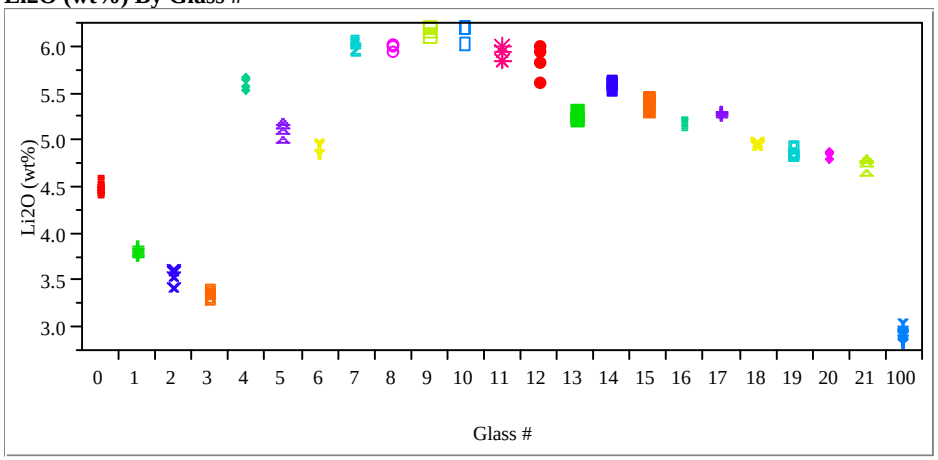


Exhibit A.6: SRTC-ML Measurements by Glass Number for Samples Prepared Using the PF Method
(0 – Batch 1 and 100 – U std)

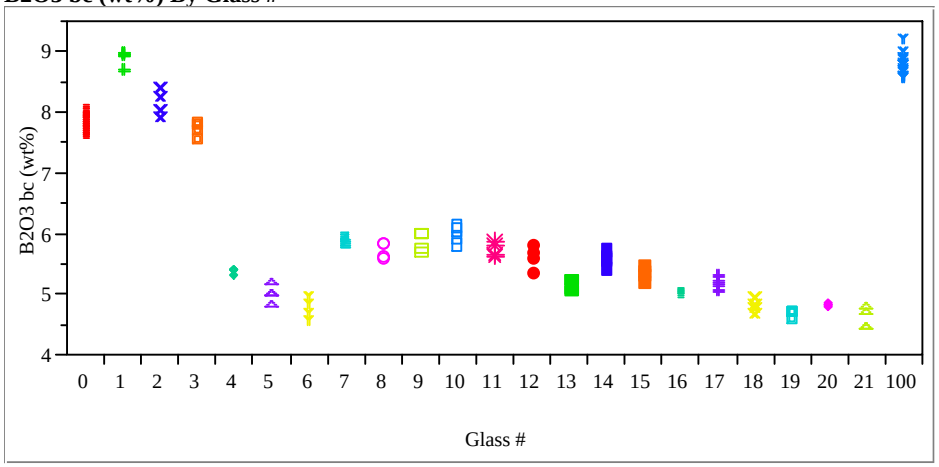
B2O3 (wt%) By Glass #



Li2O (wt%) By Glass #



B2O3 bc (wt%) By Glass #



Li2O bc (wt%) By Glass #

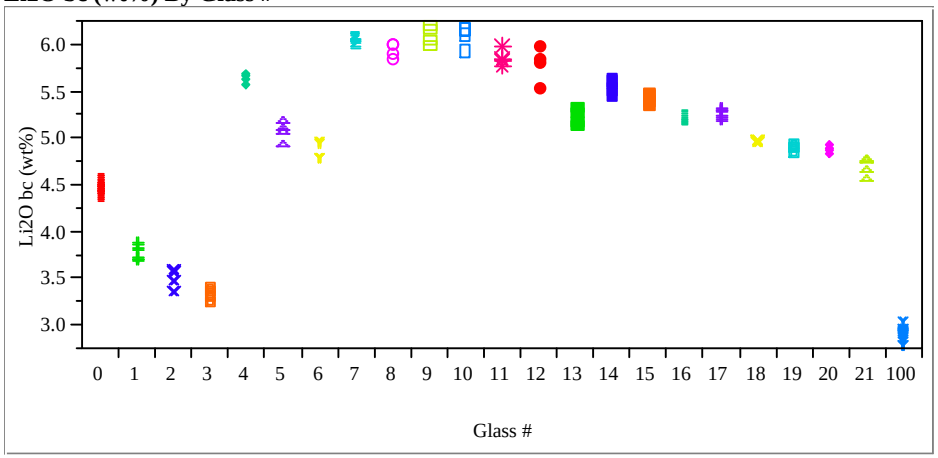
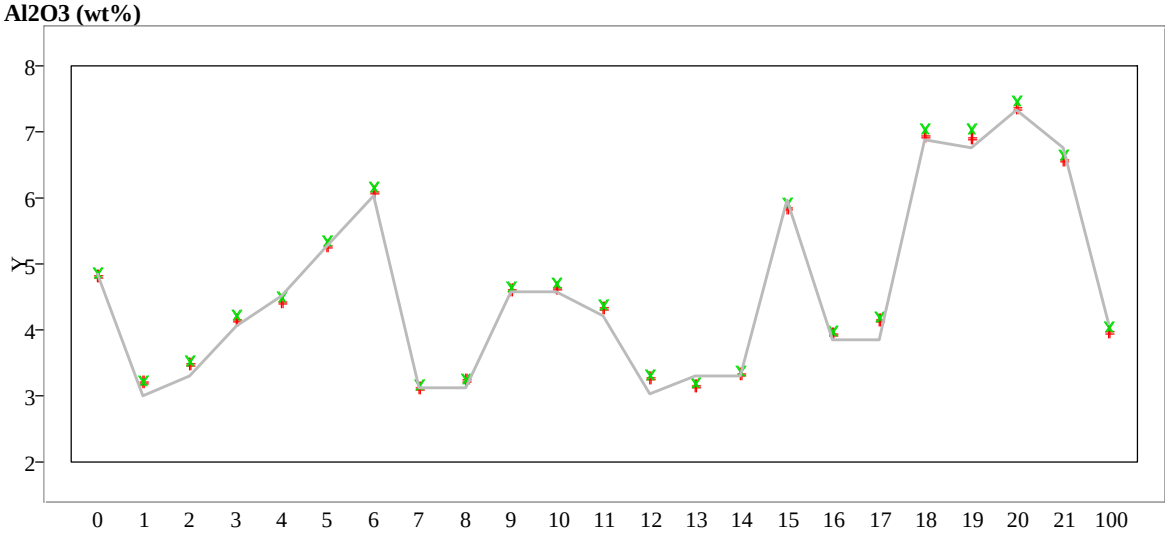


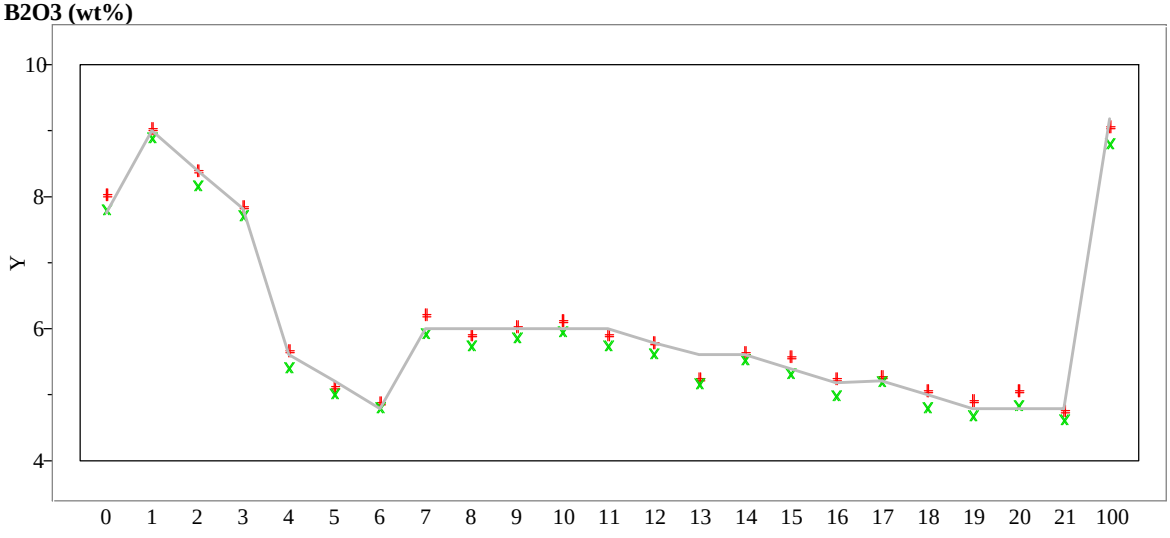
Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide

(0 – Batch 1 and 100 – U std)

Al2O3 (wt%)



B2O3 (wt%)



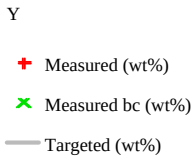
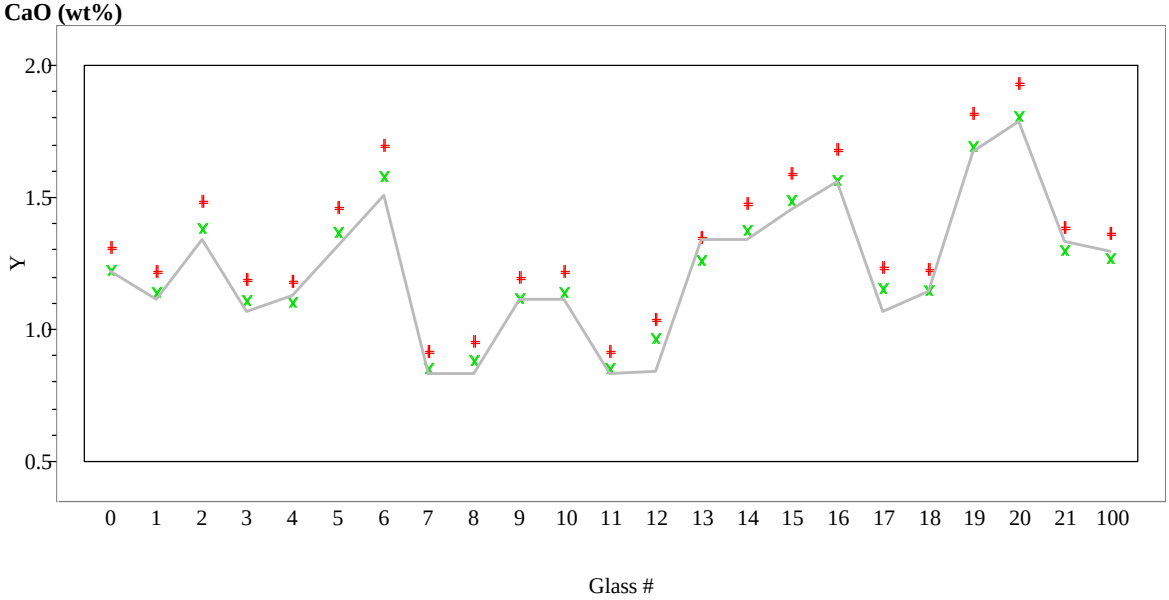


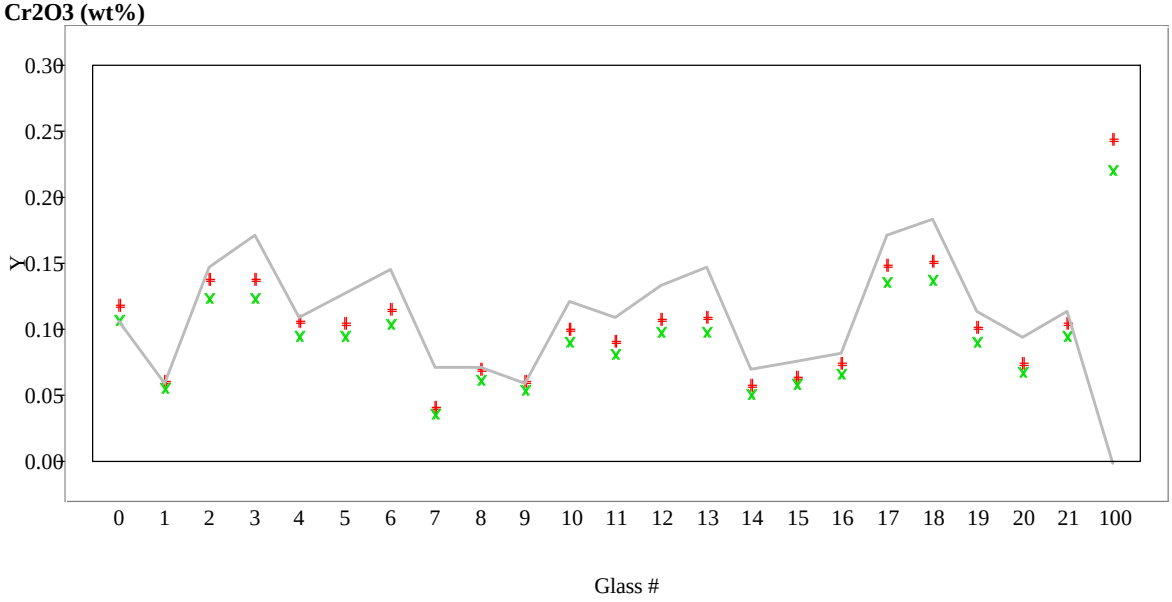
Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)

CaO (wt%)



Cr2O3 (wt%)



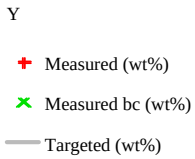
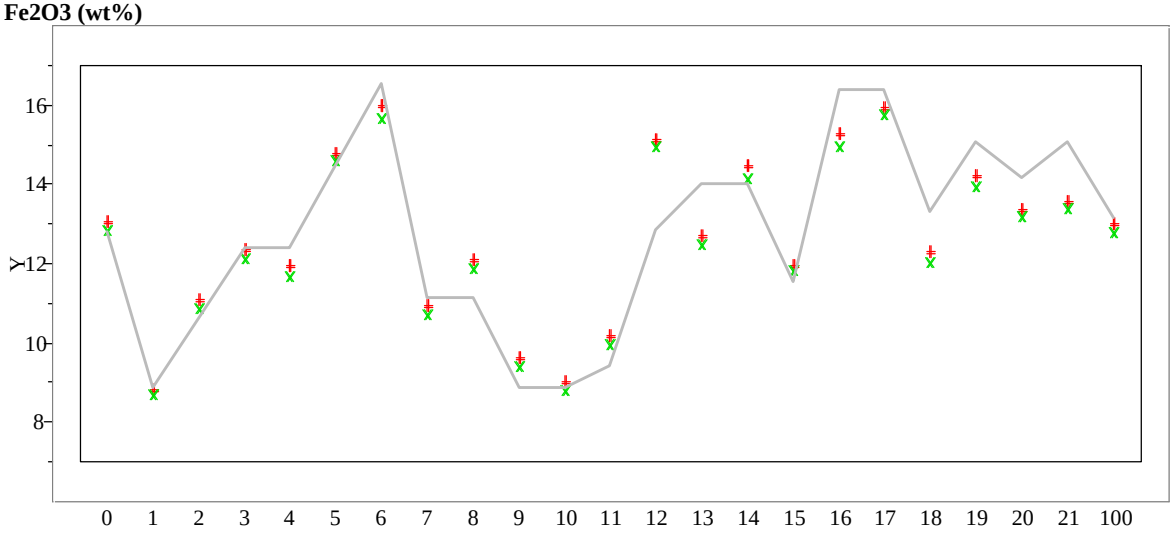


Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)

Fe2O3 (wt%)



Li2O (wt%)

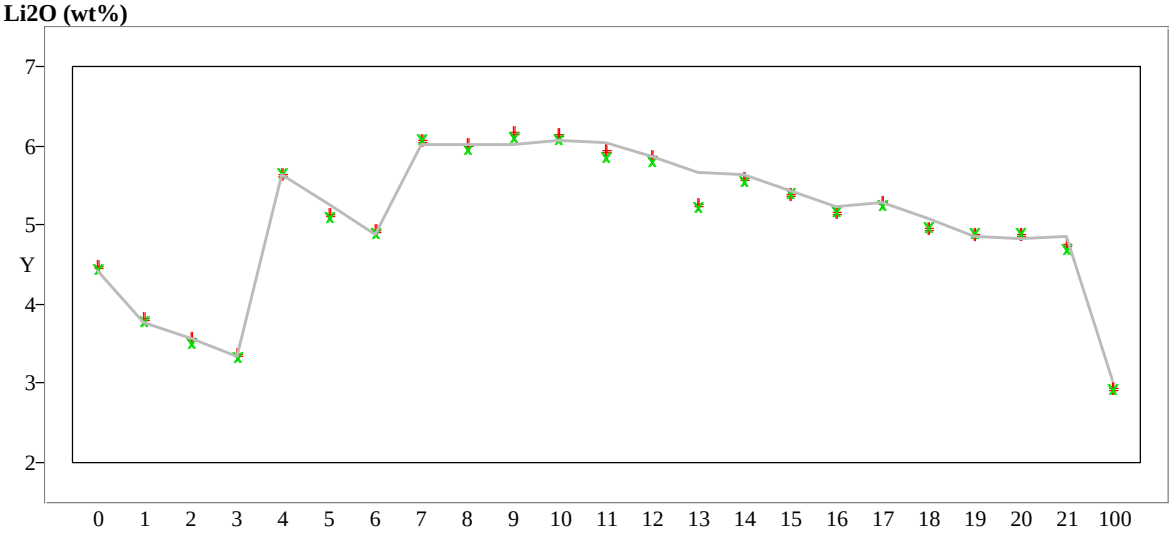
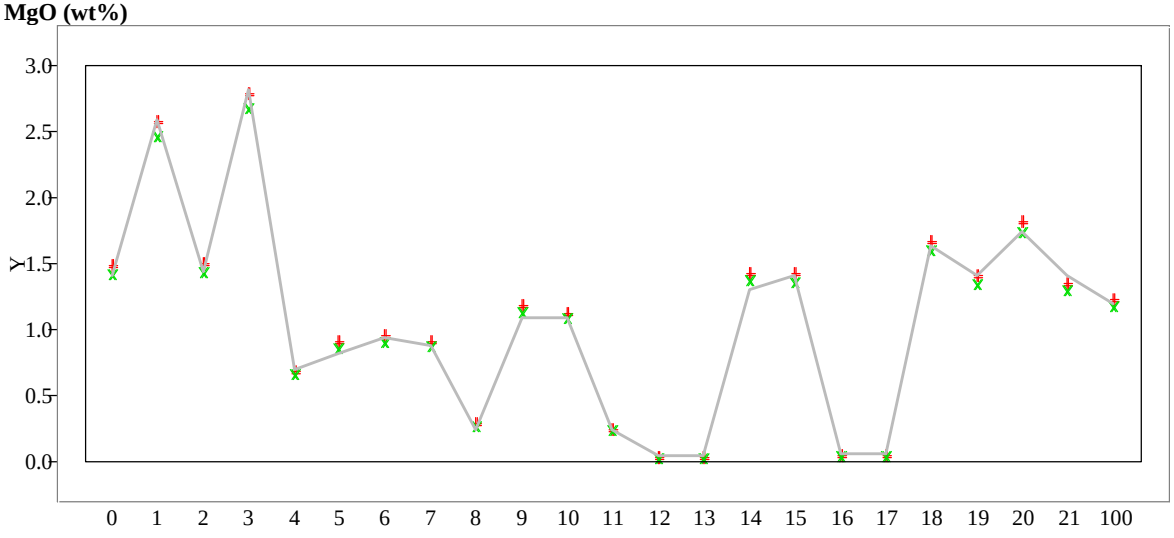


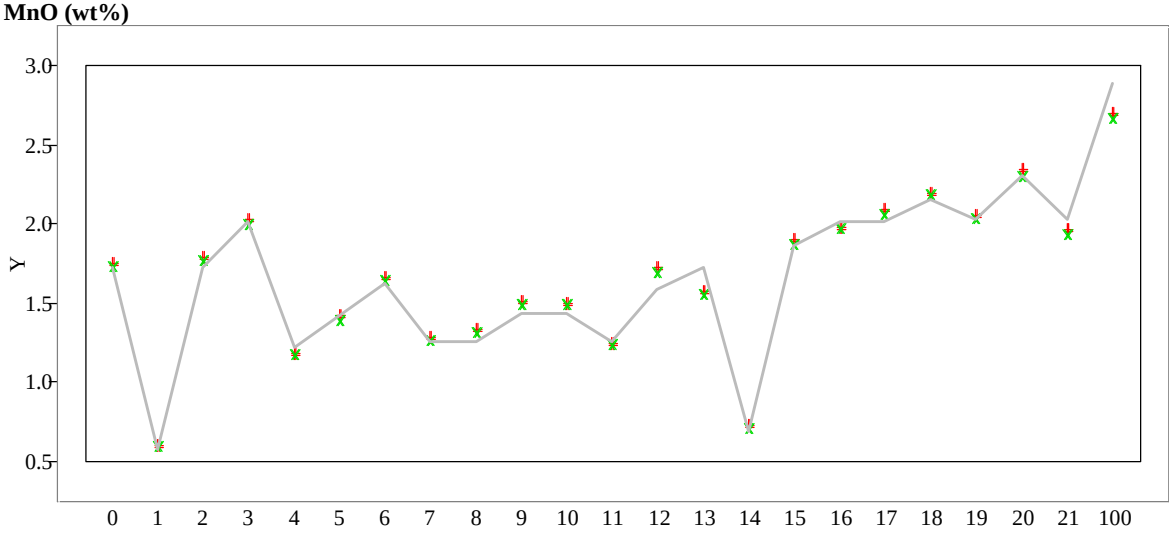
Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)

MgO (wt%)



MnO (wt%)



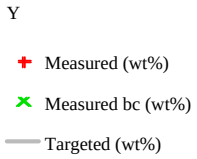
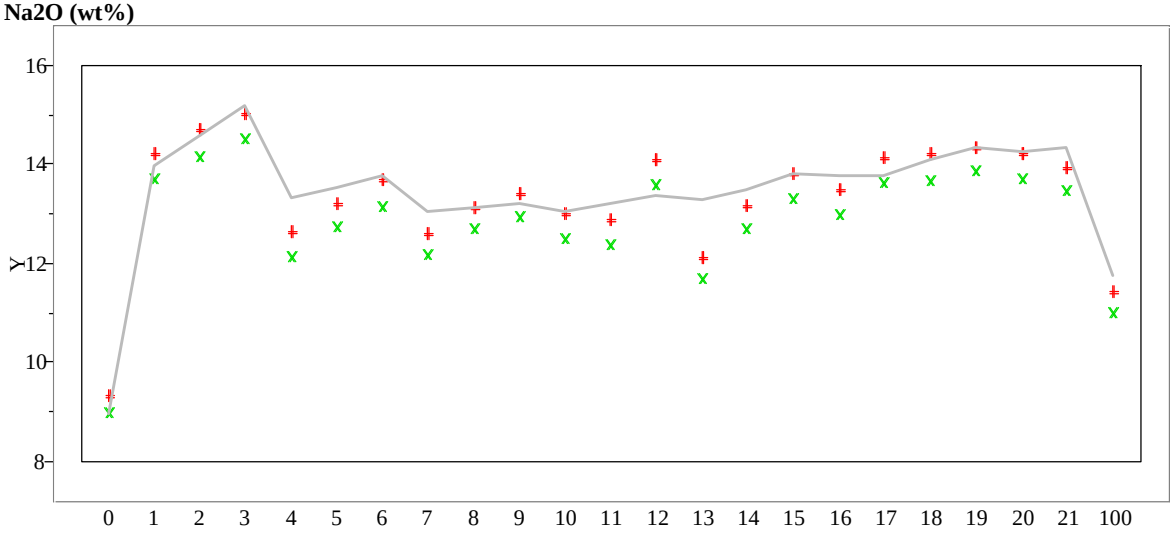


Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)

Na2O (wt%)



NiO (wt%)

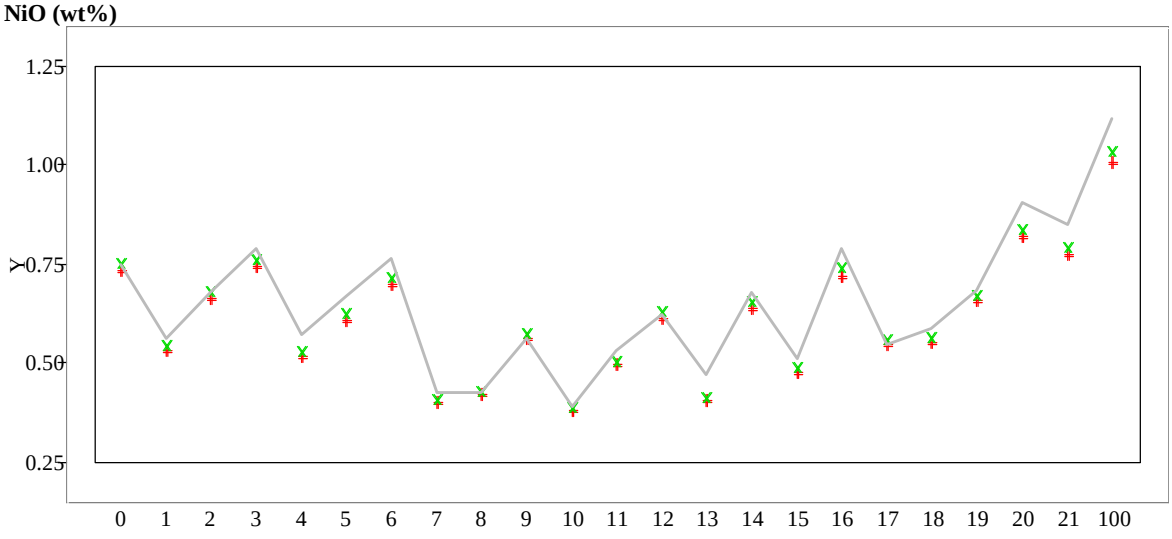
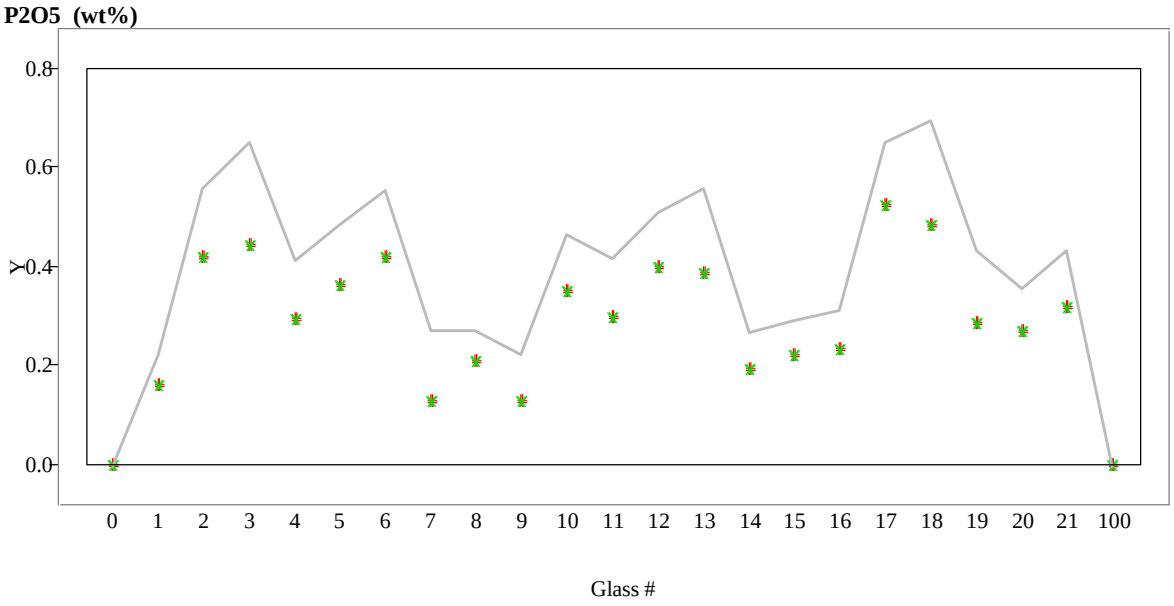
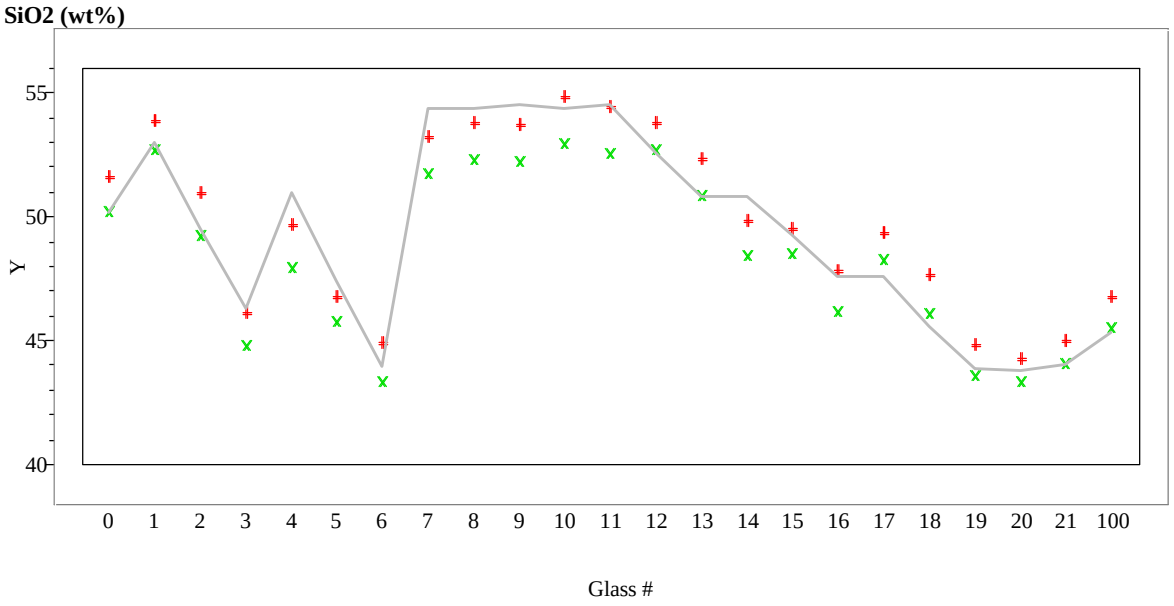


Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)





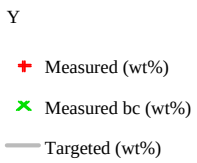
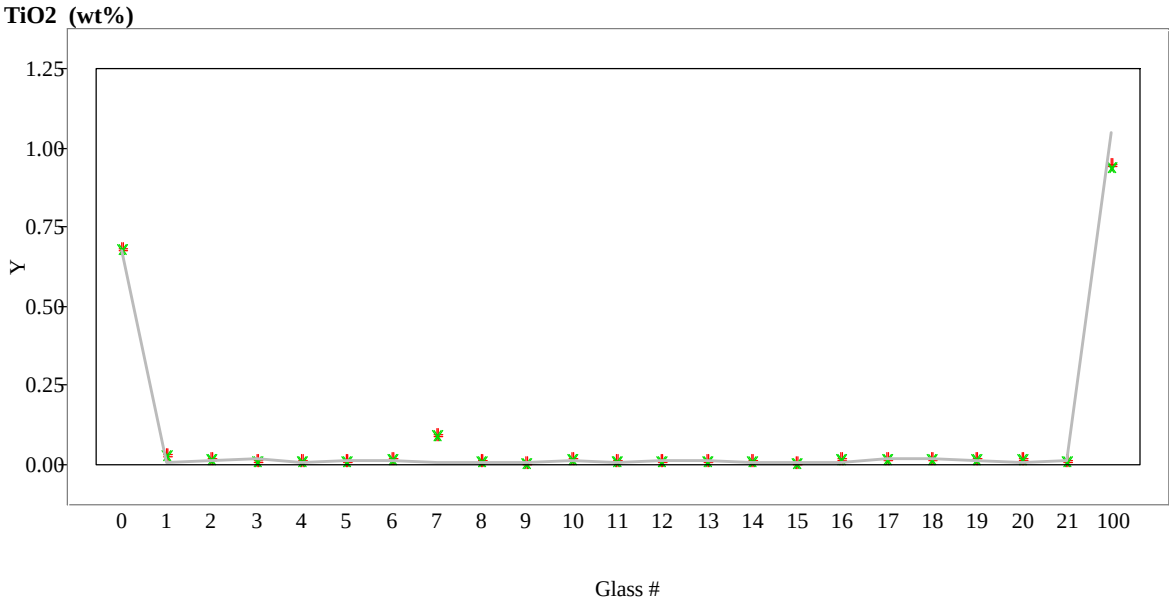


Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

(0 – Batch 1 and 100 – U std)



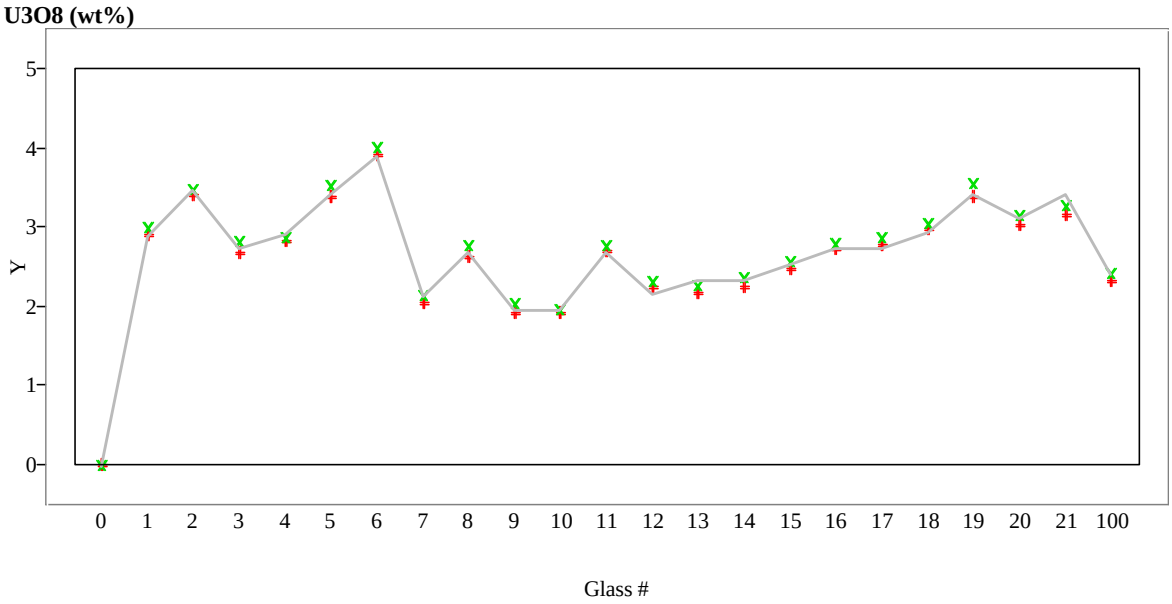
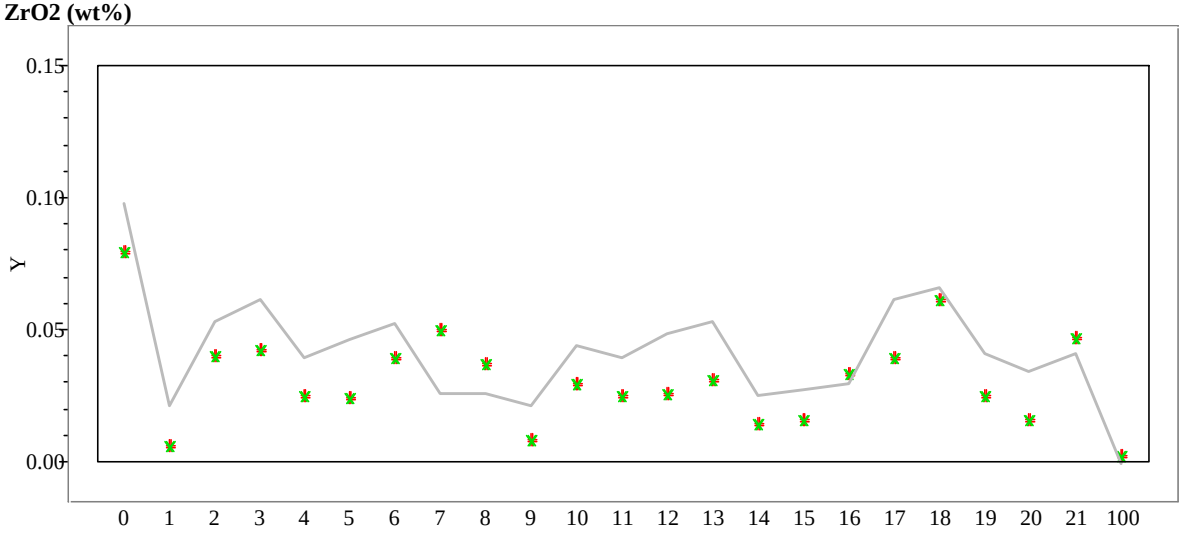


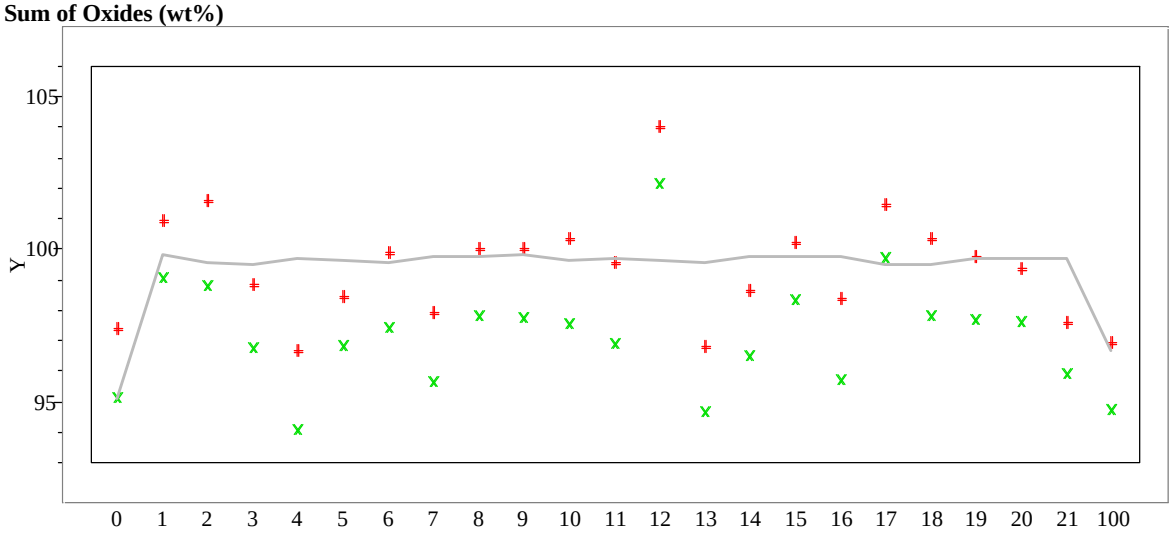
Exhibit A.7: Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass by Oxide
(continued)

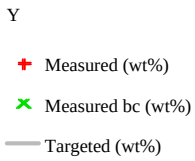
(0 – Batch 1 and 100 – U std)

ZrO2 (wt%)



Sum of Oxides (wt%)





Appendix B:
A Statistical Review of the PCT Measurements

The 21 "NS" 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 C1285-97 [ref 14]) was used for these measurements. A quenched and centerline-cooled version of each of these glasses was prepared as the glasses were fabricated, and both versions were subjected to the PCT. Durability is the critical product quality metric for DWPF variability studies. The PCTs were conducted in triplicate for both heat treatments (quenched and centerline-cooled) of each glass. In addition, PCTs were conducted in triplicate for samples of the Environmental Assessment (EA) glass and for samples of the Approved Reference Material (ARM) glass. Blanks (samples consisting only of ASTM Type I water) were also submitted for the PCT.

An analytical plan, provided in Appendix D, was provided to the SRTC-ML to support the measurement of the compositions of the solutions resulting from these PCTs. Samples of a multi-element, standard solution were also included in this analytical plan (as a check on the accuracy of the Inductively Coupled Plasma (ICP) – Emission Spectroscopy used for these measurements). In this appendix, the measurements generated by the SRTC-ML for these PCTs are presented and reviewed.

Table B.1 provides the elemental leachate concentration measurements determined by the SRTC-ML for the solution samples generated by the PCTs. Any measurement in the "As-Reported Concentrations" columns of Table B.1 below the detection limit of the analytical procedure (indicated by a "<") was replaced by ½ of the detection limit in the "Concentrations in ppm Adjusted for Dilution Factor" columns. In addition to adjustments for detection limits, these values were adjusted for the dilution factors [ref]: the values for the "NS", ARM, and EA[5] glasses in the as-reported columns were multiplied by 1.6667 to determine the ppm values.

In the sections that follow, the analytical sequence of the measurements is explored, the measurements of the standards are investigated and used to assess the overall accuracy of the ICP measurement process, the measurements for each glass are reviewed, the quenched versus centerline-cooled results are compared, the PCTs are normalized using the compositions (targeted, measured, and bias-corrected) presented in Appendix A, and the normalized PCTs are compared to durability predictions for these compositions generated from the current DWPF models [13].

Measurements in Analytical Sequence

Exhibit B.1 provides plots of the leachate concentrations in analytical sequence as generated by the SRTC-ML including all of the standards. The results for one set of PCTs are at much higher concentrations than the others, which distorts the scales of the plots. The higher leachate concentrations correspond to the EA PCTs. Exhibit B.2 provides the same plots with the EA results excluded. No problems are seen in these plots.

---

5 In the analytical plan [18], there was an indication that the EA solutions would be diluted by an additional factor of 10 before being submitted to the SRTC-ML. In the initial survey of the data and subsequent review of activities associated with this task, it was determined that this additional dilution was not completed. Therefore, no additional adjustments were warranted for the EA results.

Results for the Samples of the Multi-Element Solution Standard

Exhibit B.3 provides an analysis of the SRTC-ML measurements of the samples of the multi-element solution standard by ICP analytical (or calibration) block. An analysis of variance (ANOVA) investigating for statistically significant differences among the block averages for these samples for each element of interest is included in this exhibit. These results indicate a statistically significant (at the 5% level) difference among the Li, Na, and Si average measurements over these blocks. However, no bias correction of the PCT results for the study glasses was conducted. This approach was taken since the triplicate PCTs for a single study glass were placed in different ICP blocks. Averaging the ppm's for each set of triplicates helps to minimize the impact of the ICP effects.

Display 2 summarizes the average measurements and the reference values for the 4 elements. The results indicate consistent and accurate measurements from the SRTC-ML processes used to conduct these analyses.

Display 2: Results from Samples of the Multi-Element Solution Standard

Analytical Block	Avg B (ppm)	Avg Li (ppm)	Avg Na (ppm)	Avg Si (ppm)
1	21.0	9.9	82.1	52.2
2	20.5	9.6	82.4	50.5
3	20.7	9.7	80.0	50.2
4	20.7	9.6	80.2	50.9
5	20.3	9.7	82.5	50.5
6	20.4	9.7	83.7	50.5
Grand Average	20.6	9.7	81.8	50.8
Reference Value	20	10	81	50
% difference	2.9%	-3.0%	1.0%	1.6%

Measurements in Analytical Sequence

Exhibit B.4 provides plots of the leachate concentrations for each type of submitted sample: the standards (0 – multi-element solution standard, 100 – EA, 101 – ARM, and 102 – blanks), centerline-cooled "NS" glasses, and quenched "NS" glasses (with the "NS" glasses being identified by glass number). These plots allow for the assessment of the repeatability of the measurements, which suggests no obvious outliers among these data.

Quenched versus Centerline-Cooled Results

Exhibits B.5 and B.6 provide a closer look at the quenched versus centerline-cooled results for the "NS" glasses, including a statistical comparison of the average differences due to heat treatment for each element of interest. The statistical tests indicate statistically significant (at the 5% level) differences between the PCTs for the two heat treatments for both B and Na. On average, the B leachate concentrations for the PCTs of the quenched glasses is 1.9 ppm greater than their centerline-cooled counterparts. For Na, average difference is 10.6 ppm (quenched being greater than centerline cooled).

Normalized PCT Results

PCT leachate concentrations are 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 usually conducted using the measured compositions of the glasses. This is the preferred normalization process for the PCTs. For completeness, the targeted cation and the bias-corrected cation compositions will also be used to conduct this normalization.

As is the usual convention, the common logarithm of the normalized PCT (normalized leachate, NL) for each element of interest will be determined and used for comparison. To accomplish this computation, one must

1. Determine the common logarithm of the elemental parts per million (ppm) leachate concentration for each of the triplicates and each of the elements of interest (these values are provided in Table A.4 of Appendix A),

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

Normalizing Using Measured Composition (preferred method)

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

Or Normalizing Using Target Composition

3. Subtract a quantity equal to 1 plus the common logarithm of the target cation concentration (expressed as a weight percent of the glass) from the average computed in step 2.

Or Normalizing Using Measured Bias-Corrected Composition

3. Subtract a quantity equal to 1 plus the common logarithm of the measured bias-corrected cation concentration (expressed as a weight percent of the glass) from the average computed in step 2.

Exhibit B.7 provides scatter plots for these results (both quenched and centerline cooled) and offers an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. The consistency is typically demonstrated by a high degree of linear correlation among the values. PCT values normalized using targeted, measured, and bias-corrected compositions are investigated. A high degree of correlation is seen for these data for most pairs of the elements. The smallest correlation (~84%) is between B and Si for the centerline-cooled PCTs normalized using the bias-corrected compositions with most of the correlations being above 90%.

Display 3 summarizes the normalized PCTs for the glasses of this study.

Display 3: Normalized PCTs by Glass by Composition View by Heat Treatment

		Quenched								Centerline Cooled							
Glass ID	Composition	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)	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	Ref.	-0.2036	-0.1947	-0.2409	-0.5102	0.63	0.64	0.57	0.31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
EA	Ref.	1.1563	0.9166	1.0474	0.5303	14.33	8.25	11.15	3.39	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Meas.	0.5768	0.5016	0.4682	0.1672	3.77	3.17	2.94	1.47	0.4946	0.4285	0.3984	0.1057	3.12	2.68	2.50	1.28
NS01	Meas. bc	0.5832	0.5039	0.4832	0.1762	3.83	3.19	3.04	1.50	0.5010	0.4308	0.4133	0.1147	3.17	2.70	2.59	1.30
	Target	0.5772	0.5029	0.4746	0.1735	3.78	3.18	2.98	1.49	0.4950	0.4298	0.4048	0.1119	3.13	2.69	2.54	1.29
	Meas.	0.2776	0.2132	0.2256	-0.0644	1.90	1.63	1.68	0.86	0.2471	0.1950	0.1928	-0.0920	1.77	1.57	1.56	0.81
NS02	Meas. bc	0.2885	0.2176	0.2420	-0.0497	1.94	1.65	1.75	0.89	0.2579	0.1995	0.2092	-0.0772	1.81	1.58	1.62	0.84
	Target	0.2749	0.2082	0.2284	-0.0525	1.88	1.62	1.69	0.89	0.2444	0.1902	0.1956	-0.0800	1.76	1.55	1.57	0.83
	Meas.	0.2074	0.0907	0.1854	-0.1080	1.61	1.23	1.53	0.78	0.1569	0.0767	0.1297	-0.1405	1.44	1.19	1.35	0.72
NS03	Meas. bc	0.2138	0.0930	0.1996	-0.0960	1.64	1.24	1.58	0.80	0.1633	0.0790	0.1439	-0.1285	1.46	1.20	1.39	0.74
	Target	0.2086	0.0909	0.1799	-0.1100	1.62	1.23	1.51	0.78	0.1581	0.0769	0.1242	-0.1426	1.44	1.19	1.33	0.72
	Meas.	0.0312	0.0552	0.1124	-0.1143	1.07	1.14	1.30	0.77	0.0537	0.0750	0.0971	-0.1064	1.13	1.19	1.25	0.78
NS04	Meas. bc	0.0508	0.0526	0.1287	-0.0996	1.12	1.13	1.34	0.80	0.0733	0.0725	0.1133	-0.0917	1.18	1.18	1.30	0.81
	Target	0.0336	0.0516	0.0878	-0.1261	1.08	1.13	1.22	0.75	0.0561	0.0714	0.0724	-0.1182	1.14	1.18	1.18	0.76
	Meas.	0.1243	0.0970	0.1417	-0.1038	1.33	1.25	1.39	0.79	0.1030	0.0961	0.1077	-0.0951	1.27	1.25	1.28	0.80
NS05	Meas. bc	0.1307	0.0993	0.1567	-0.0948	1.35	1.26	1.43	0.80	0.1094	0.0984	0.1227	-0.0861	1.29	1.25	1.33	0.82
	Target	0.1150	0.0833	0.1300	-0.1108	1.30	1.21	1.35	0.77	0.0937	0.0824	0.0960	-0.1021	1.24	1.21	1.25	0.79
	Meas.	0.1673	0.1274	0.1783	-0.0843	1.47	1.34	1.51	0.82	0.1684	0.1450	0.1824	-0.0762	1.47	1.40	1.52	0.84
NS06	Meas. bc	0.1737	0.1297	0.1947	-0.0695	1.49	1.35	1.57	0.85	0.1748	0.1473	0.1989	-0.0614	1.50	1.40	1.58	0.87
	Target	0.1714	0.1303	0.1747	-0.0758	1.48	1.35	1.50	0.84	0.1726	0.1480	0.1788	-0.0677	1.49	1.41	1.51	0.86
	Meas.	0.2907	0.2663	0.2902	0.0765	1.95	1.85	1.95	1.19	0.2225	0.2237	0.2275	0.0338	1.67	1.67	1.69	1.08
NS07	Meas. bc	0.3103	0.2637	0.3045	0.0885	2.04	1.84	2.02	1.23	0.2421	0.2211	0.2418	0.0458	1.75	1.66	1.74	1.11
	Target	0.3037	0.2666	0.2734	0.0665	2.01	1.85	1.88	1.17	0.2354	0.2240	0.2106	0.0238	1.72	1.67	1.62	1.06
	Meas.	0.3179	0.2845	0.2806	0.0884	2.08	1.93	1.91	1.23	0.2198	0.2483	0.1978	0.0412	1.66	1.77	1.58	1.10
NS08	Meas. bc	0.3287	0.2889	0.2948	0.1004	2.13	1.94	1.97	1.26	0.2306	0.2527	0.2120	0.0532	1.70	1.79	1.63	1.13
	Target	0.3089	0.2817	0.2789	0.0832	2.04	1.91	1.90	1.21	0.2107	0.2455	0.1960	0.0360	1.62	1.76	1.57	1.09
	Meas.	0.0738	0.1140	0.1387	-0.0927	1.19	1.30	1.38	0.81	0.0672	0.0872	0.0955	-0.1134	1.17	1.22	1.25	0.77
NS09	Meas. bc	0.0846	0.1184	0.1530	-0.0807	1.22	1.31	1.42	0.83	0.0781	0.0916	0.1098	-0.1014	1.20	1.23	1.29	0.79
	Target	0.0748	0.1233	0.1435	-0.0999	1.19	1.33	1.39	0.79	0.0683	0.0965	0.1002	-0.1206	1.17	1.25	1.26	0.76
	Meas.	0.0044	0.0607	0.0894	-0.1495	1.01	1.15	1.23	0.71	0.0143	0.0540	0.0584	-0.1561	1.03	1.13	1.14	0.70
NS10	Meas. bc	0.0152	0.0651	0.1058	-0.1347	1.04	1.16	1.28	0.73	0.0252	0.0585	0.0747	-0.1413	1.06	1.14	1.19	0.72
	Target	0.0112	0.0655	0.0870	-0.1463	1.03	1.16	1.22	0.71	0.0212	0.0589	0.0560	-0.1529	1.05	1.15	1.14	0.70
	Meas.	0.0499	0.0851	0.1054	-0.0912	1.12	1.22	1.27	0.81	0.0315	0.0918	0.0707	-0.1091	1.08	1.24	1.18	0.78
NS11	Meas. bc	0.0607	0.0895	0.1217	-0.0764	1.15	1.23	1.32	0.84	0.0424	0.0962	0.0871	-0.0944	1.10	1.25	1.22	0.80
	Target	0.0417	0.0745	0.0930	-0.0925	1.10	1.19	1.24	0.81	0.0234	0.0812	0.0584	-0.1104	1.06	1.21	1.14	0.78
	Meas.	0.2959	0.2634	0.2526	0.0651	1.98	1.83	1.79	1.16	0.2267	0.2312	0.1921	0.0344	1.69	1.70	1.56	1.08
NS12	Meas. bc	0.3068	0.2677	0.2676	0.0741	2.03	1.85	1.85	1.19	0.2375	0.2356	0.2071	0.0434	1.73	1.72	1.61	1.11
	Target	0.2921	0.2615	0.2735	0.0744	1.96	1.83	1.88	1.19	0.2228	0.2294	0.2130	0.0437	1.67	1.70	1.63	1.11
	Meas.	0.2245	0.2041	0.2401	-0.0438	1.68	1.60	1.74	0.90	0.2143	0.2334	0.2382	-0.0214	1.64	1.71	1.73	0.95
NS13	Meas. bc	0.2310	0.2064	0.2544	-0.0318	1.70	1.61	1.80	0.93	0.2207	0.2357	0.2525	-0.0093	1.66	1.72	1.79	0.98
	Target	0.1944	0.1696	0.1981	-0.0320	1.56	1.48	1.58	0.93	0.1841	0.1989	0.1963	-0.0095	1.53	1.58	1.57	0.98
	Meas.	0.2679	0.2288	0.2910	0.0670	1.85	1.69	1.95	1.17	0.2839	0.2698	0.2872	0.0863	1.92	1.86	1.94	1.22
NS14	Meas. bc	0.2743	0.2311	0.3052	0.0791	1.88	1.70	2.02	1.20	0.2903	0.2720	0.3014	0.0983	1.95	1.87	2.00	1.25
	Target	0.2693	0.2231	0.2784	0.0575	1.86	1.67	1.90	1.14	0.2854	0.2640	0.2746	0.0767	1.93	1.84	1.88	1.19
	Meas.	0.0438	0.0624	0.1110	-0.1405	1.11	1.15	1.29	0.72	0.0524	0.0707	0.0907	-0.1405	1.13	1.18	1.23	0.72
NS15	Meas. bc	0.0633	0.0598	0.1260	-0.1315	1.16	1.15	1.34	0.74	0.0719	0.0681	0.1057	-0.1315	1.18	1.17	1.28	0.74
	Target	0.0559	0.0571	0.1090	-0.1390	1.14	1.14	1.29	0.73	0.0645	0.0654	0.0886	-0.1390	1.16	1.16	1.23	0.73
	Meas.	0.1912	0.1886	0.2273	-0.0147	1.55	1.54	1.69	0.97	0.2333	0.2490	0.2371	0.0027	1.71	1.77	1.73	1.01
NS16	Meas. bc	0.2108	0.1860	0.2436	0.0000	1.62	1.53	1.75	1.00	0.2529	0.2463	0.2535	0.0175	1.79	1.76	1.79	1.04
	Target	0.1918	0.1807	0.2172	-0.0130	1.56	1.52	1.65	0.97	0.2339	0.2410	0.2271	0.0045	1.71	1.74	1.69	1.01
	Meas.	0.1503	0.1474	0.1759	-0.0463	1.41	1.40	1.50	0.90	0.1406	0.1510	0.1488	-0.0604	1.38	1.42	1.41	0.87
NS17	Meas. bc	0.1567	0.1497	0.1909	-0.0373	1.43	1.41	1.55	0.92	0.1471	0.1533	0.1639	-0.0514	1.40	1.42	1.46	0.89
	Target	0.1541	0.1461	0.1866	-0.0312	1.43	1.40	1.54	0.93	0.1445	0.1497	0.1596	-0.0453	1.39	1.41	1.44	0.90
	Meas.	0.1107	0.0763	0.1360	-0.1421	1.29	1.19	1.37	0.72	0.0855	0.0928	0.1147	-0.1385	1.22	1.24	1.30	0.73
NS18	Meas. bc	0.1303	0.0737	0.1524	-0.1274	1.35	1.19	1.42	0.75	0.1051	0.0901	0.1312	-0.1237	1.27	1.23	1.35	0.75
	Target	0.1116	0.0629	0.1391	-0.1233	1.29	1.16	1.38	0.75	0.0863	0.0793	0.1179	-0.1196	1.22	1.20	1.31	0.76
	Meas.	0.1813	0.1235	0.2080	-0.0880	1.52	1.33	1.61	0.82	0.2452	0.2441	0.2364	0.0006	1.76	1.75	1.72	1.00
NS19	Meas. bc	0.2009	0.1209	0.2224	-0.0759	1.59	1.32	1.67	0.84	0.2648	0.2415	0.2507	0.0126	1.84	1.74	1.78	1.03
	Target	0.1892	0.1231	0.2068	-0.0792	1.55	1.33	1.61	0.83	0.2532	0.2438	0.2351	0.0094	1.79	1.75	1.72	1.02
	Meas.	0.1669	0.1162	0.2038	-0.1000	1.47	1.31	1.60	0.79	0.1648	0.1338	0.1925	-0.0952	1.46	1.36	1.56	0.80
NS20	Meas. bc	0.1865	0.1136	0.2188	-0.0910	1.54	1.30	1.66	0.81	0.1844	0.1312	0.2075	-0.0862	1.53	1.35	1.61	0.82
	Target	0.1884	0.1168	0.2016	-0.0964	1.54	1.31	1.59	0.80	0.1863	0.1344	0.1902	-0.0917	1.54	1.36	1.55	0.81
	Meas.	0.2189	0.1422	0.2343	-0.0756	1.66	1.39	1.72	0.84	0.2288	0.1806	0.2233	-0.0614	1.69	1.52	1.67	0.87
NS21	Meas. bc	0.2297	0.1466	0.2493	-0.0666	1.70	1.40	1.78	0.86	0.2396	0.1850	0.2382	-0.0524	1.74	1.53	1.73	0.89
	Target	0.2124	0.1311	0.2203	-0.0669	1.63	1.35	1.66	0.86	0.2222	0.1696	0.2093	-0.0527	1.67	1.48	1.62	0.89

Predicted versus Measured PCTs

As seen in the above table, the durabilities for all of the "NS" glasses are much better than that of EA. (This is indicated for each glass by its normalized leachate being much smaller than that of EA.) Exhibits B.8 through B.10 provide a closer look at these results based upon the three different representations of the glass chemical compositions: target, measured, and bias corrected. These exhibit provide plots of the DWPF models that relate the logarithm of the normalized PCT (for each element of interest) to a linear function of a free energy of hydration term (ΔG_p, kcal/100g glass) derived from the measured glass composition [19]. Prediction limits (at a 95% confidence) for an individual PCT result are also plotted along with the linear fit. The EA and ARM results are also indicated on these plots. Exhibit B.8 shows both quenched and centerline-cooled results together while Exhibit B.9 shows only the quenched and Exhibit B.10 shows only the centerline-cooled.

Note that the "NS" glasses reveal acceptable PCTs as compared to those of EA. Also, note that the "NS" glasses are predictable. Also note that the durabilities of glasses produced with both heat treatments are acceptable as compared to the results for EA and are predictable by the current DWPF models.

Table B.1: SRTC-ML Measurements of the PCT Solutions for the "NS" Glasses

Glass ID	Block	Sequence Number	Planning ID	SRTC-ML ID	As-Reported Concentrations (ppm) B	Li	Na	Si	Concentrations in ppm Corrected for Dilution Factor B	Li	Na	Si
std	1	1	soln std	std-b1-1	21.1	9.83	81.5	52.7	21.10	9.83	81.50	52.70
NS	1	2	NS02	p081	31.5	16.9	112	130	52.50	28.17	186.67	216.67
NS	1	3	NS15	p093	11.8	17.4	77.5	103	19.67	29.00	129.17	171.67
NS	1	4	NS21ccc	p119	15.5	20.5	104	117	25.83	34.17	173.34	195.00
NS	1	5	NS09	p106	13.5	22.6	81.2	125	22.50	37.67	135.34	208.34
NS	1	6	NS05ccc	p033	12.7	18.4	76.0	107	21.17	30.67	126.67	178.34
NS	1	7	NS18	p064	12.4	16.6	85.2	99.4	20.67	27.67	142.00	165.67
NS	1	8	NS05	p026	12.9	18.1	81.3	108	21.50	30.17	135.50	180.00
NS	1	9	NS08ccc	p080	19.1	30.5	92.6	173	31.83	50.83	154.34	288.34
NS	1	10	NS08	p123	23.0	32.4	110	189	38.33	54.00	183.34	315.01
NS	1	11	NS02ccc	p095	27.8	15.5	101	116	46.33	25.83	168.34	193.34
NS	1	12	NS16	p071	15.4	22.2	101	132	25.67	37.00	168.34	220.00
std	1	13	soln std	std-b1-2	20.8	9.83	81.9	51.6	20.80	9.83	81.90	51.60
EA	1	14	EA	p067	322	105	890	486	536.68	175.00	1483.36	810.02
ARM	1	15	ARM	p091	15.9	9.59	26.1	41.9	26.50	15.98	43.50	69.83
NS	1	16	NS18ccc	p100	12.4	17.1	81.9	98.1	20.67	28.50	136.50	163.50
NS	1	17	NS21	p019	15.3	18.3	105	106	25.50	30.50	175.00	176.67
NS	1	18	NS16ccc	p043	17.0	25.4	102	139	28.33	42.33	170.00	231.67
NS	1	19	NS13	p128	16.4	23.8	94.4	138	27.33	39.67	157.34	230.00
NS	1	20	NS13ccc	p047	16.6	25.2	92.1	142	27.67	42.00	153.50	236.67
NS	1	21	NS07ccc	p008	20.2	28.8	95.1	165	33.67	48.00	158.50	275.01
NS	1	22	NS07	p090	23.0	31.5	111	182	38.33	52.50	185.00	303.34
NS	1	23	NS15ccc	p054	12.3	17.8	76.3	105	20.50	29.67	127.17	175.00
NS	1	24	NS09ccc	p011	13.2	20.7	72.4	118	22.00	34.50	120.67	196.67
std	1	25	soln std	std-b1-3	21.1	9.90	82.8	52.4	21.10	9.90	82.80	52.40
std	2	1	soln std	std-b2-1	20.8	9.60	81.6	50.5	20.80	9.60	81.60	50.50
NS	2	2	NS05ccc	p092	12.1	17.7	76.2	104	20.17	29.50	127.00	173.34
NS	2	3	NS07	p132	22.7	31.1	109	175	37.83	51.83	181.67	291.67
NS	2	4	NS21ccc	p070	14.9	20.0	105	109	24.83	33.33	175.00	181.67
NS	2	5	NS02	p029	28.7	15.7	109	121	47.83	26.17	181.67	201.67
NS	2	6	NS18	p048	12.1	16.3	87.6	95.2	20.17	27.17	146.00	158.67
NS	2	7	NS13ccc	p068	16.0	25.2	94.5	139	26.67	42.00	157.50	231.67
NS	2	8	NS21	p034	14.3	18.2	106	104	23.83	30.33	176.67	173.34
NS	2	9	NS18ccc	p066	11.0	17.0	82.0	93.5	18.33	28.33	136.67	155.84
NS	2	10	NS02ccc	p077	27.7	15.5	103	115	46.17	25.83	171.67	191.67
NS	2	11	NS15	p133	11.4	17.4	80.2	100	19.00	29.00	133.67	166.67
NS	2	12	NS15ccc	p006	11.3	17.4	75.0	97.6	18.83	29.00	125.00	162.67
std	2	13	soln std	std-b2-2	20.3	9.67	82.7	50.7	20.30	9.67	82.70	50.70
NS	2	14	NS08ccc	p036	17.4	29.0	91.1	162	29.00	48.33	151.84	270.01
NS	2	15	NS16	p051	14.7	21.7	100	125	24.50	36.17	166.67	208.34
NS	2	16	NS07ccc	p062	18.3	27.4	92.2	158	30.50	45.67	153.67	263.34
EA	2	17	EA	p058	306	100	844	473	510.01	166.67	1406.69	788.35
NS	2	18	NS13	p005	17.5	23.3	93.3	131	29.17	38.83	155.50	218.34
ARM	2	19	ARM	p017	12.3	8.80	24.1	39.9	20.50	14.67	40.17	66.50
NS	2	20	NS05	p039	13.0	17.9	82.9	103	21.67	29.83	138.17	171.67
NS	2	21	NS09	p122	13.4	22.4	83.1	120	22.33	37.33	138.50	200.00
NS	2	22	NS09ccc	p078	13.3	21.5	76.0	116	22.17	35.83	126.67	193.34
NS	2	23	NS08	p020	23.1	32.4	112	184	38.50	54.00	186.67	306.67
NS	2	24	NS16ccc	p009	16.4	25.3	103	130	27.33	42.17	171.67	216.67
std	2	25	soln std	std-b2-3	20.4	9.65	83.0	50.4	20.40	9.65	83.00	50.40
std	3	1	soln std	std-b3-1	20.1	9.69	82.1	50.4	20.10	9.69	82.10	50.40
NS	3	2	NS09	p073	13.0	22.0	81.9	120	21.67	36.67	136.50	200.00
NS	3	3	NS09ccc	p103	12.8	20.8	74.5	114	21.33	34.67	124.17	190.00
ARM	3	4	ARM	p044	11.7	8.76	24.0	39.1	19.50	14.60	40.00	65.17
NS	3	5	NS18	p024	11.8	16.4	86.8	94.5	19.67	27.33	144.67	157.50
NS	3	6	NS08ccc	p097	18.1	29.4	92.3	163	30.17	49.00	153.84	271.67

Table B.1: SRTC-ML Measurements of the PCT Solutions for the "NS" Glasses (continued)

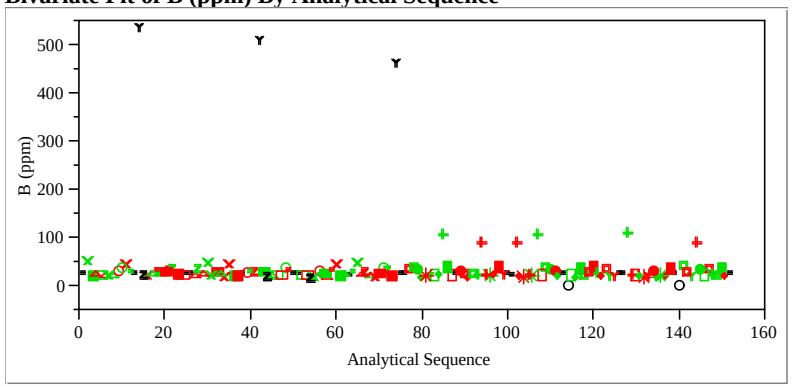
Glass ID	Block	Sequence Number	Planning ID	SRTC-ML ID	As-Reported Concentrations (ppm) B	Li	Na	Si	Concentrations in ppm Corrected for Dilution Factor B	Li	Na	Si
NS	3	7	NS13	p014	15.3	23.1	92.8	129	25.50	38.50	154.67	215.00
NS	3	8	NS05ccc	p052	11.4	17.2	73.8	105	19.00	28.67	123.00	175.00
NS	3	9	NS16ccc	p115	16.5	25.7	106	136	27.50	42.83	176.67	226.67
NS	3	10	NS02ccc	p031	27.1	15.4	102	116	45.17	25.67	170.00	193.34
NS	3	11	NS15	p063	11.2	17.1	80.0	98.6	18.67	28.50	133.34	164.34
NS	3	12	NS21	p055	14.3	18.5	108	108	23.83	30.83	180.00	180.00
std	3	13	soln std	std-b3-2	19.9	9.67	82.0	50.2	19.90	9.67	82.00	50.20
NS	3	14	NS16	p004	15.2	22.6	103	132	25.33	37.67	171.67	220.00
NS	3	15	NS02	p025	28.5	15.8	109	119	47.50	26.33	181.67	198.34
NS	3	16	NS21ccc	p079	14.5	19.6	102	103	24.17	32.67	170.00	171.67
NS	3	17	NS07ccc	p121	19.3	28.4	96.6	161	32.17	47.33	161.00	268.34
NS	3	18	NS05	p104	12.1	17.4	80.2	98.9	20.17	29.00	133.67	164.84
NS	3	19	NS18ccc	p038	10.9	17.1	83.3	100	18.17	28.50	138.84	166.67
NS	3	20	NS13ccc	p114	15.4	24.7	92.7	138	25.67	41.17	154.50	230.00
NS	3	21	NS08	p012	22.3	31.8	112	182	37.17	53.00	186.67	303.34
NS	3	22	NS07	p129	21.9	30.7	108	177	36.50	51.17	180.00	295.01
NS	3	23	NS15ccc	p130	11.5	17.7	75.5	99.1	19.17	29.50	125.84	165.17
EA	3	24	EA	p113	279	89.6	772	433	465.01	149.34	1286.69	721.68
std	3	25	soln std	std-b3-3	22.1	9.62	82.0	50.0	22.10	9.62	82.00	50.00
std	4	1	soln std	std-b4-1	20.8	9.53	79.3	50.5	20.80	9.53	79.30	50.50
NS	4	2	NS03ccc	p112	21.1	10.9	86.2	92.6	35.17	18.17	143.67	154.34
NS	4	3	NS03	p099	23.1	11.2	96.7	99.3	38.50	18.67	161.17	165.50
NS	4	4	NS12	p023	21.7	30.1	110	177	36.17	50.17	183.34	295.01
NS	4	5	NS04	p065	11.6	17.7	71.4	107	19.33	29.50	119.00	178.34
NS	4	6	NS11ccc	p001	12.5	20.8	67.4	119	20.83	34.67	112.34	198.34
NS	4	7	NS06	p069	13.8	17.9	91.1	102	23.00	29.83	151.84	170.00
NS	4	8	NS10	p085	11.5	19.5	69.2	109	19.17	32.50	115.34	181.67
NS	4	9	NS20	p028	14.0	17.5	98.2	99	23.33	29.17	163.67	165.00
NS	4	10	NS01	p056	63.4	33.4	181	223	105.67	55.67	301.67	371.67
NS	4	11	NS14	p016	20.0	26.4	112	167	33.33	44.00	186.67	278.34
NS	4	12	NS10ccc	p061	11.9	19.3	64.6	108	19.83	32.17	107.67	180.00
std	4	13	soln std	std-b4-2	20.8	9.67	80.0	51.3	20.80	9.67	80.00	51.30
NS	4	14	NS12ccc	p059	18.2	27.5	95.4	164	30.33	45.83	159.00	273.34
NS	4	15	NS19ccc	p057	15.8	23.1	104	134	26.33	38.50	173.34	223.34
NS	4	16	NS04ccc	p041	11.6	18.0	66.1	105	19.33	30.00	110.17	175.00
NS	4	17	NS19	p084	14.0	17.8	100	101	23.33	29.67	166.67	168.34
NS	4	18	NS17	p127	13.7	20.1	90.0	121	22.83	33.50	150.00	201.67
NS	4	19	NS01ccc	p027	52.8	28.5	157	195	88.00	47.50	261.67	325.01
NS	4	20	NS17ccc	p105	13.8	21.0	87.7	120	23.00	35.00	146.17	200.00
NS	4	21	NS11	p124	12.2	19.1	69.1	125	20.33	31.83	115.17	208.34
NS	4	22	NS20ccc	p101	14.0	18.3	96.3	97.3	23.33	30.50	160.50	162.17
NS	4	23	NS14ccc	p094	20.9	29.2	114	172	34.83	48.67	190.00	286.67
NS	4	24	NS06ccc	p007	14.2	18.3	94.9	101	23.67	30.50	158.17	168.34
std	4	25	soln std	std-b4-3	20.5	9.67	81.2	50.8	20.50	9.67	81.20	50.80
std	5	1	soln std	std-b5-1	19.9	9.65	82.5	50.1	19.90	9.65	82.50	50.10
NS	5	2	NS01ccc	p022	52.1	28.2	158	191	86.84	47.00	263.34	318.34
NS	5	3	NS04ccc	p083	12.0	18.9	71.7	111	20.00	31.50	119.50	185.00
NS	5	4	NS11ccc	p098	11.7	20.5	67.7	120	19.50	34.17	112.84	200.00
NS	5	5	NS17ccc	p045	13.1	20.7	88.0	120	21.83	34.50	146.67	200.00
NS	5	6	NS11	p086	12.3	20.3	73.3	122	20.50	33.83	122.17	203.34
NS	5	7	NS01	p120	62.4	33.3	185	220	104.00	55.50	308.34	366.67
NS	5	8	NS10ccc	p021	11.6	19.3	66.2	107	19.33	32.17	110.34	178.34
NS	5	9	NS03	p037	22.9	11.4	101	99.3	38.17	19.00	168.34	165.50
NS	5	10	NS12	p015	20.7	29.7	112	173.9	34.50	49.50	186.67	289.84
NS	5	11	NS12ccc	p111	18.0	27.9	97.8	164	30.00	46.50	163.00	273.34

Table B.1: SRTC-ML Measurements of the PCT Solutions for the "NS" Glasses (continued)

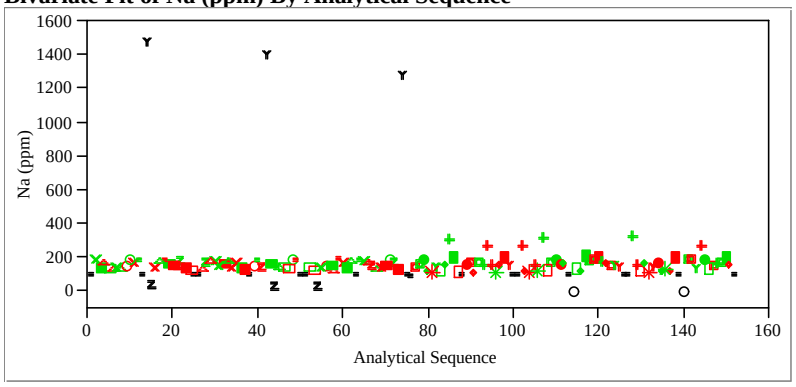
Glass ID	Block	Sequence Number	Planning ID	SRTC-ML ID	As-Reported Concentrations (ppm) B	Li	Na	Si	Concentrations in ppm Corrected for Dilution Factor B	Li	Na	Si
NS	5	12	NS20	p049	13.7	17.9	103	98.7	22.83	29.83	171.67	164.50
std	5	13	soln std	std-b5-2	20.2	9.74	82.1	51.0	20.20	9.74	82.10	51.00
blank	5	14	blank	p072	<0.150	0.366	<0.100	<0.790	0.13	0.61	0.08	0.66
NS	5	15	NS10	p002	11.4	20.0	71.6	112	19.00	33.33	119.34	186.67
NS	5	16	NS04	p118	11.1	18.0	73.5	109	18.50	30.00	122.50	181.67
NS	5	17	NS14	p018	19.0	26.4	116	164	31.67	44.00	193.34	273.34
NS	5	18	NS19	p087	13.8	18.3	106	105	23.00	30.50	176.67	175.00
NS	5	19	NS19ccc	p125	16.1	24.3	113	123	26.83	40.50	188.34	205.00
NS	5	20	NS14ccc	p107	20.1	29.1	115	169	33.50	48.50	191.67	281.67
NS	5	21	NS17	p116	14.0	21.3	99.3	128	23.33	35.50	165.50	213.34
NS	5	22	NS20ccc	p131	13.7	18.9	102	104	22.83	31.50	170.00	173.34
NS	5	23	NS03ccc	p102	20.8	11.3	91.5	94.3	34.67	18.83	152.50	157.17
NS	5	24	NS06	p075	13.8	18.7	98.4	106	23.00	31.17	164.00	176.67
NS	5	25	NS06ccc	p109	12.7	19.5	91.4	110	21.17	32.50	152.34	183.34
std	5	26	soln std	std-b5-2	20.7	9.65	83.0	50.5	20.70	9.65	83.00	50.50
std	6	1	soln std	std-b6-1	20.6	9.74	83.9	50.6	20.60	9.74	83.90	50.60
NS	6	2	NS01	p117	64.4	34.0	192	223	107.34	56.67	320.01	371.67
NS	6	3	NS17ccc	p032	13.8	20.8	90.2	121	23.00	34.67	150.34	201.67
NS	6	4	NS10ccc	p030	11.8	19.5	67.5	107	19.67	32.50	112.50	178.34
NS	6	5	NS20	p010	13.8	17.7	102	97.9	23.00	29.50	170.00	163.17
NS	6	6	NS11ccc	p060	11.3	19.8	67.1	117	18.83	33.00	111.84	195.00
NS	6	7	NS06ccc	p013	13.2	19.6	91.7	106	22.00	32.67	152.84	176.67
NS	6	8	NS12ccc	p126	18.1	27.9	99.1	162	30.17	46.50	165.17	270.01
NS	6	9	NS04	p108	11.2	17.6	73.2	105	18.67	29.33	122.00	175.00
NS	6	10	NS11	p082	12.5	20.8	76.8	124	20.83	34.67	128.00	206.67
NS	6	11	NS04ccc	p089	12.1	18.9	72.9	111	20.17	31.50	121.50	185.00
NS	6	12	NS14ccc	p046	19.5	28.3	111	170	32.50	47.17	185.00	283.34
std	6	13	soln std	std-b6-2	20.3	9.78	84.1	50.8	20.30	9.78	84.10	50.80
blank	6	14	blank	p042	0.122	0.353	0.136	0.066	0.20	0.59	0.23	0.11
NS	6	15	NS03	p088	24.7	11.9	110	104	41.17	19.83	183.34	173.34
NS	6	16	NS19ccc	p134	16.3	23.9	113	121	27.17	39.83	188.34	201.67
NS	6	17	NS06	p074	12.4	18.5	86.2	103	20.67	30.83	143.67	171.67
NS	6	18	NS01ccc	p040	52.5	28.4	160	192	87.50	47.33	266.67	320.01
NS	6	19	NS12	p076	21.3	29.9	114	175	35.50	49.83	190.00	291.67
NS	6	20	NS10	p096	11.6	19.5	72.2	106	19.33	32.50	120.34	176.67
NS	6	21	NS03ccc	p110	21.0	11.2	92.7	93.8	35.00	18.67	154.50	156.34
NS	6	22	NS17	p050	13.9	20.6	93.9	124	23.17	34.33	156.50	206.67
NS	6	23	NS19	p053	13.8	17.9	103	102	23.00	29.83	171.67	170.00
NS	6	24	NS14	p035	19.3	26.0	115	158	32.17	43.33	191.67	263.34
NS	6	25	NS20ccc	p003	13.6	18.1	97.1	97.7	22.67	30.17	161.84	162.84
std	6	26	soln std	std-b6-3	20.2	9.69	83.1	50.1	20.20	9.69	83.10	50.10

Exhibit B.1: SRTC-ML PCT Measurements in Analytical Sequence
Including All "NS" Glasses, EA, ARM, Blanks, and Samples of the Solution Standard

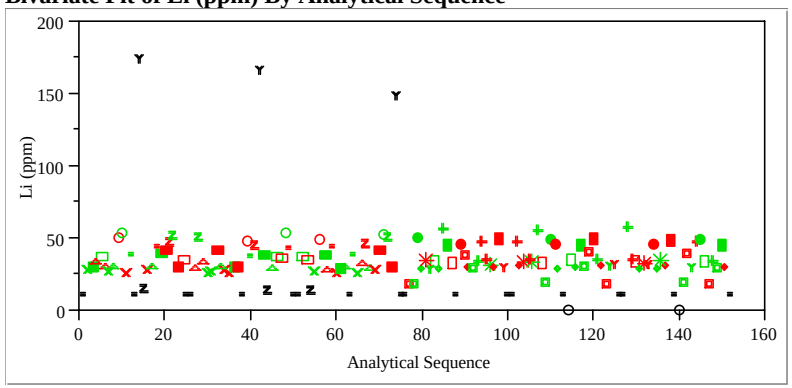
Bivariate Fit of B (ppm) By Analytical Sequence



Bivariate Fit of Na (ppm) By Analytical Sequence



Bivariate Fit of Li (ppm) By Analytical Sequence



Bivariate Fit of Si (ppm) By Analytical Sequence

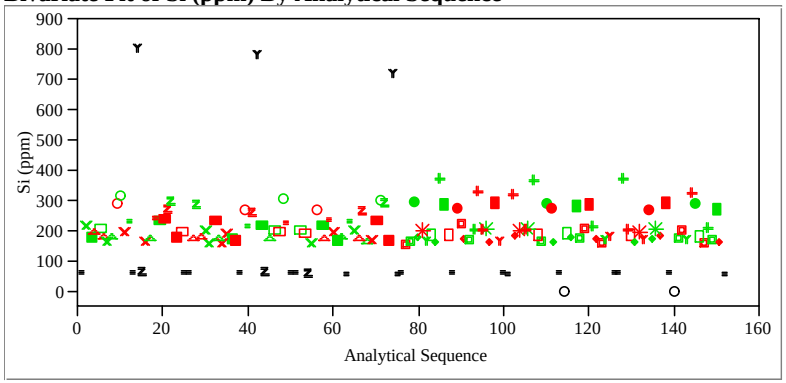
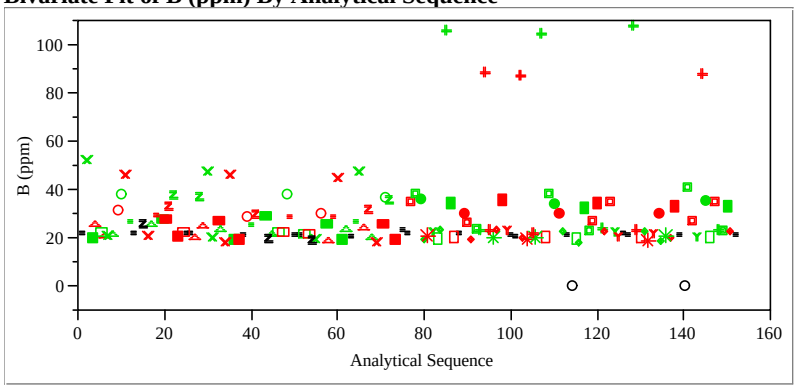
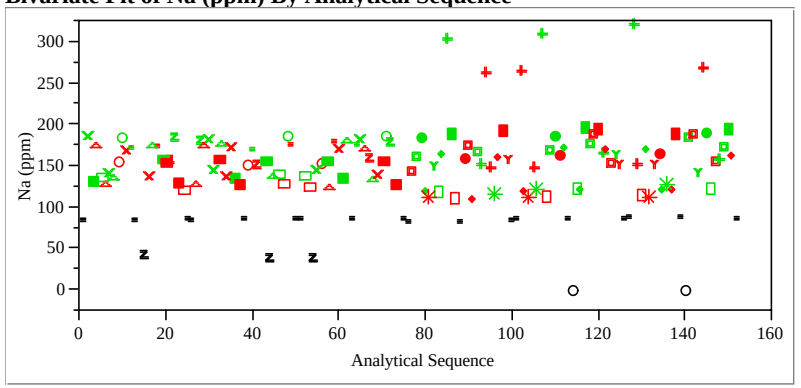


**Exhibit B.2: SRTC-ML PCT Measurements in Analytical Sequence
Including All "NS" Glasses, ARM, Blanks, and Samples of the Solution Standard but Excluding EA**

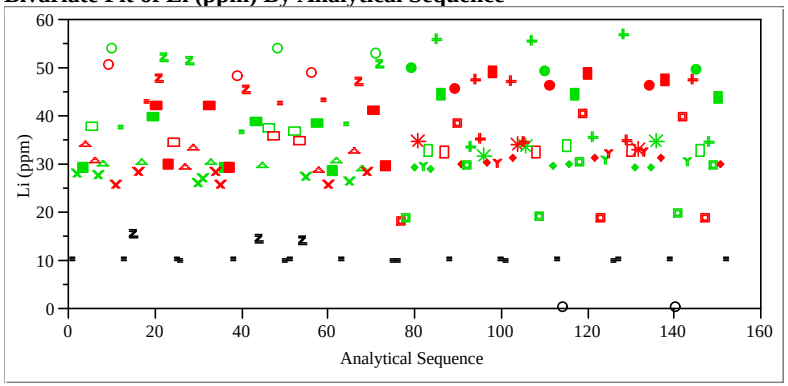
Bivariate Fit of B (ppm) By Analytical Sequence



Bivariate Fit of Na (ppm) By Analytical Sequence



Bivariate Fit of Li (ppm) By Analytical Sequence



Bivariate Fit of Si (ppm) By Analytical Sequence

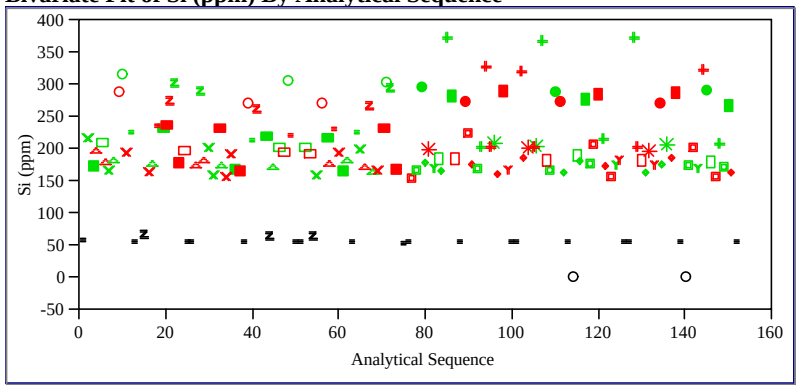
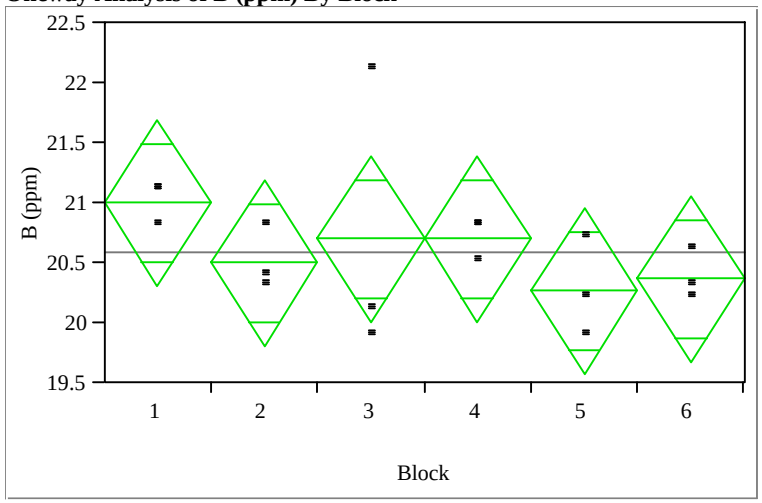


Exhibit B.3: Measurements of the Multi-Element Solution Standard by ICP Block

Oneway Analysis of B (ppm) By Block



Oneway Anova

Summary of Fit

Rsquare	0.226585
Adj Rsquare	-0.09567
Root Mean Square Error	0.550252
Mean of Response	20.58889
Observations (or Sum Wgts)	18

Analysis of Variance

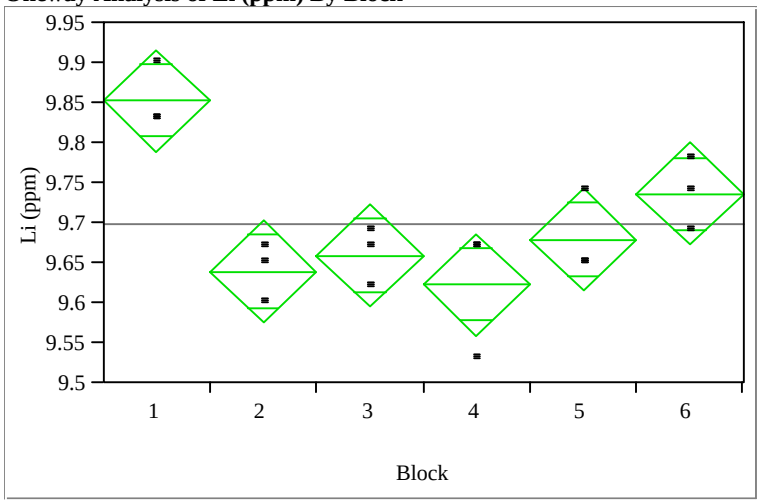
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	1.0644444	0.212889	0.7031	0.6319
Error	12	3.6333333	0.302778		
C. Total	17	4.6977778			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	21.0000	0.31769	20.308	21.692
2	3	20.5000	0.31769	19.808	21.192
3	3	20.7000	0.31769	20.008	21.392
4	3	20.7000	0.31769	20.008	21.392
5	3	20.2667	0.31769	19.574	20.959
6	3	20.3667	0.31769	19.674	21.059

Std Error uses a pooled estimate of error variance

Oneway Analysis of Li (ppm) By Block



Oneway Anova

Summary of Fit

Rsquare	0.778536
Adj Rsquare	0.68626
Root Mean Square Error	0.050827
Mean of Response	9.698889
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	0.10897778	0.021796	8.4370	0.0013
Error	12	0.03100000	0.002583		
C. Total	17	0.13997778			

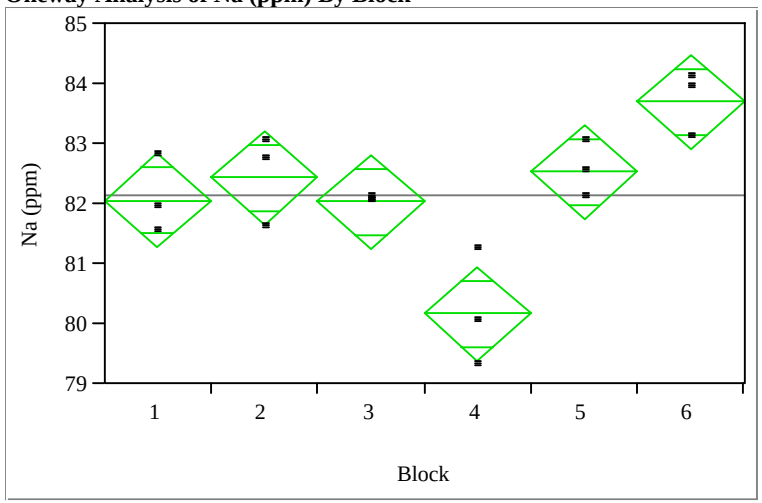
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	9.85333	0.02934	9.7894	9.9173
2	3	9.64000	0.02934	9.5761	9.7039
3	3	9.66000	0.02934	9.5961	9.7239
4	3	9.62333	0.02934	9.5594	9.6873
5	3	9.68000	0.02934	9.6161	9.7439
6	3	9.73667	0.02934	9.6727	9.8006

Std Error uses a pooled estimate of error variance

Exhibit B.3: Measurements of the Multi-Element Solution Standard by ICP Block *(continued)*

Oneway Analysis of Na (ppm) By Block



Oneway Anova

Summary of Fit

Rsquare	0.804708
Adj Rsquare	0.723336
Root Mean Square Error	0.632016
Mean of Response	82.15556
Observations (or Sum Wgts)	18

Analysis of Variance

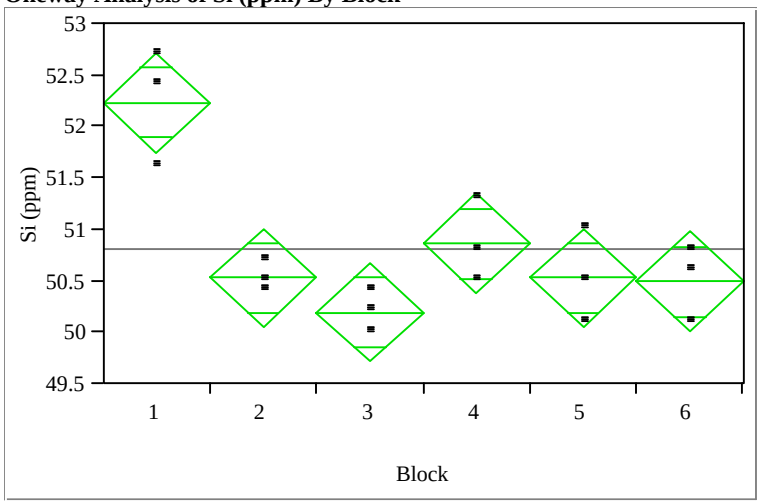
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	19.751111	3.95022	9.8893	0.0006
Error	12	4.793333	0.39944		
C. Total	17	24.544444			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	82.0667	0.36489	81.272	82.862
2	3	82.4333	0.36489	81.638	83.228
3	3	82.0333	0.36489	81.238	82.828
4	3	80.1667	0.36489	79.372	80.962
5	3	82.5333	0.36489	81.738	83.328
6	3	83.7000	0.36489	82.905	84.495

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Block



Oneway Anova

Summary of Fit

Rsquare	0.818203
Adj Rsquare	0.742454
Root Mean Square Error	0.383695
Mean of Response	50.81111
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	5	7.9511111	1.59022	10.8015	0.0004
Error	12	1.7666667	0.14722		
C. Total	17	9.7177778			

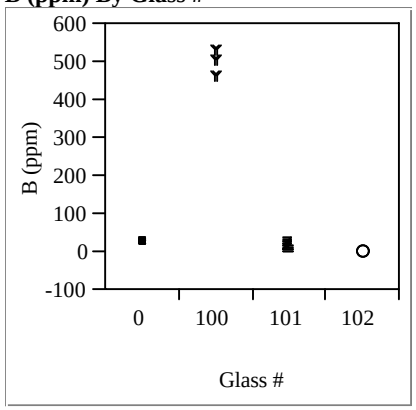
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	52.2333	0.22153	51.751	52.716
2	3	50.5333	0.22153	50.051	51.016
3	3	50.2000	0.22153	49.717	50.683
4	3	50.8667	0.22153	50.384	51.349
5	3	50.5333	0.22153	50.051	51.016
6	3	50.5000	0.22153	50.017	50.983

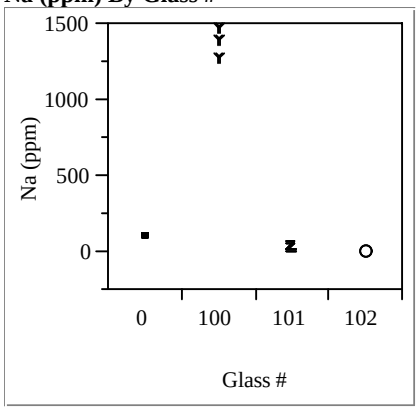
Std Error uses a pooled estimate of error variance

Exhibit B.4: SRTC-ML PCT Measurements by Glass Number Grouped by Standards, (0 –Solution Standard, 100 – EA, 101 – ARM, and 102 – Blanks), Centerline-Cooled (ccc), and Quenched Results

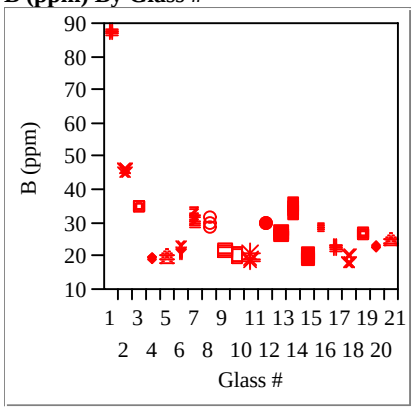
B (ppm) By Glass #



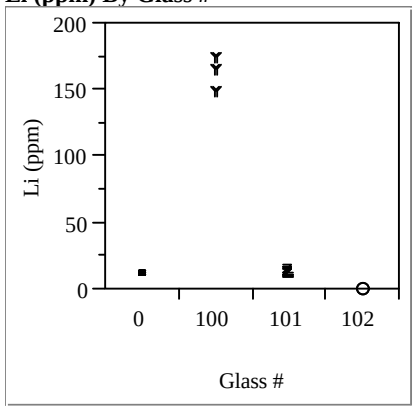
Na (ppm) By Glass #



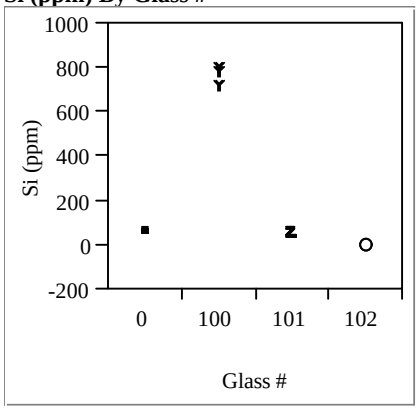
ccc
B (ppm) By Glass #



Li (ppm) By Glass #



Si (ppm) By Glass #



Li (ppm) By Glass #

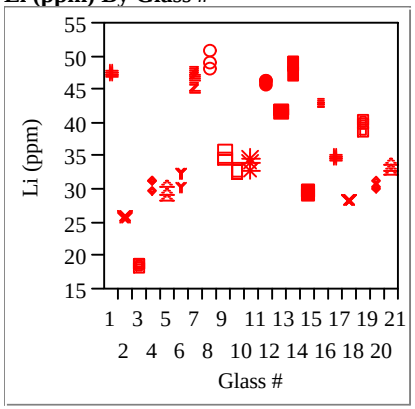
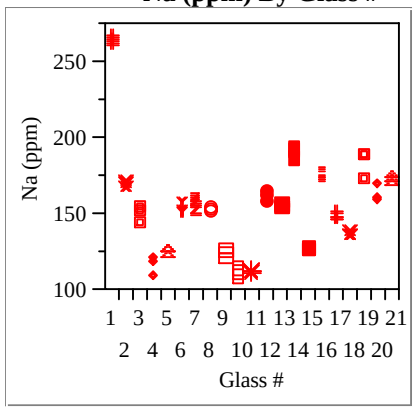
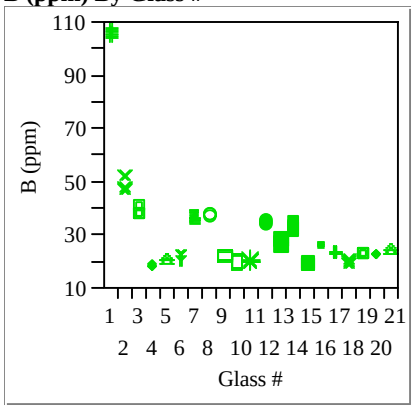


Exhibit B.4: SRTC-ML PCT Measurements by Glass Number Grouped by Standards, (0 –Solution Standard, 100 – EA, 101 – ARM, and 102 – Blanks), Centerline-Cooled (ccc), and Quenched Results

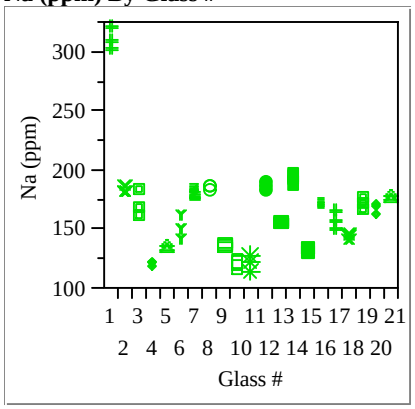
Na (ppm) By Glass #



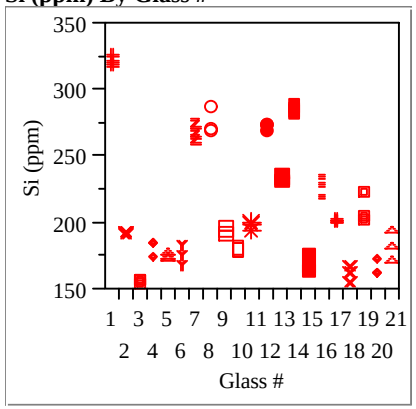
quenched
B (ppm) By Glass #



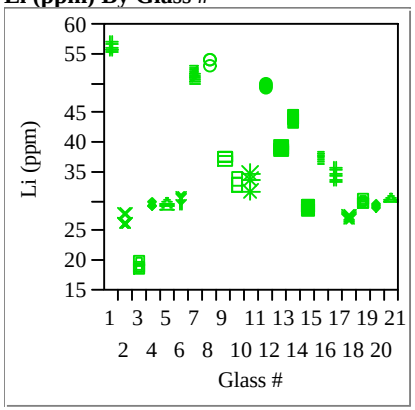
Na (ppm) By Glass #



Si (ppm) By Glass #



Li (ppm) By Glass #



Si (ppm) By Glass #

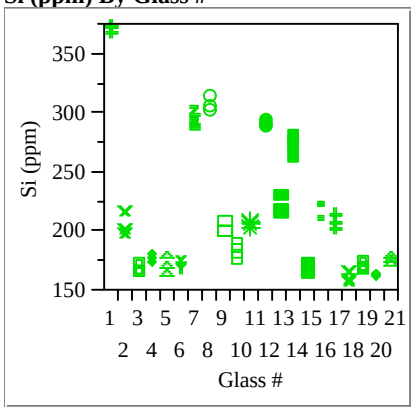
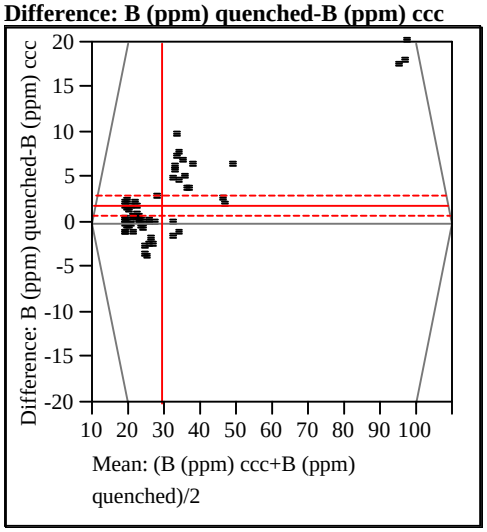


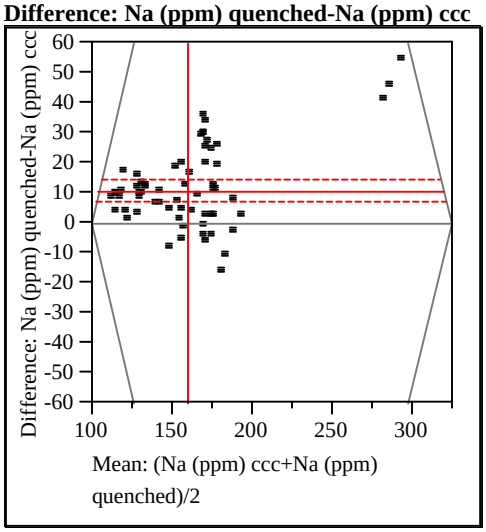
Exhibit B.5: Pairwise Comparisons between the PCTs for the Two Heat Treatments (Quenched and Centerline-Cooled)

Difference: B (ppm) quenched-B (ppm) ccc



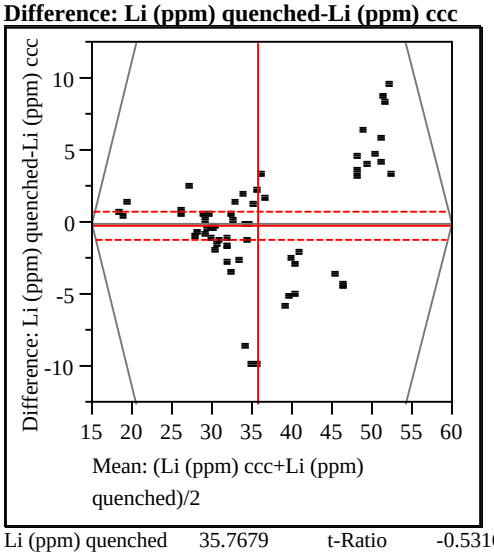
B (ppm) quenched	30.8128	t-Ratio	3.150932
B (ppm) ccc	28.9583	DF	62
Mean Difference	1.85453	Prob > |t|	0.0025
Std Error	0.58857	Prob > t	0.0013
Upper95%	3.03106	Prob < t	0.9987
Lower95%	0.67801		
N	63		
Correlation	0.9897		

Difference: Na (ppm) quenched-Na (ppm) ccc



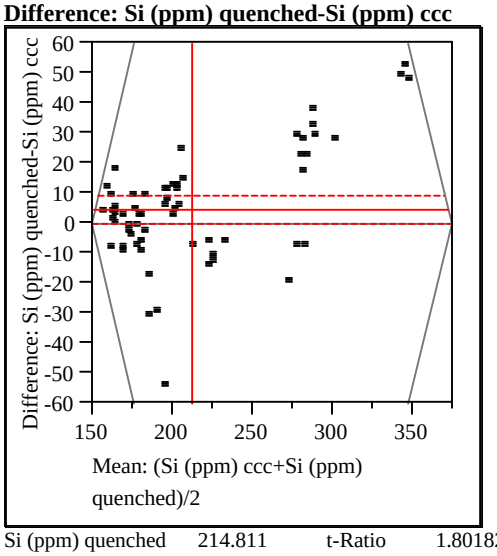
Na (ppm) quenched	165.334	t-Ratio	6.246312
Na (ppm) ccc	154.72	DF	62
Mean Difference	10.614	Prob > |t|	<.0001
Std Error	1.69924	Prob > t	<.0001
Upper95%	14.0107	Prob < t	1.0000
Lower95%	7.21724		
N	63		
Correlation	0.9482		

Difference: Li (ppm) quenched-Li (ppm) ccc



Li (ppm) quenched	35.7679	t-Ratio	-0.53164
Li (ppm) ccc	36.0272	DF	62
Mean Difference	-0.2593	Prob > |t|	0.5969
Std Error	0.48766	Prob > t	0.7016
Upper95%	0.71556	Prob < t	0.2984
Lower95%	-1.2341		
N	63		
Correlation	0.92002		

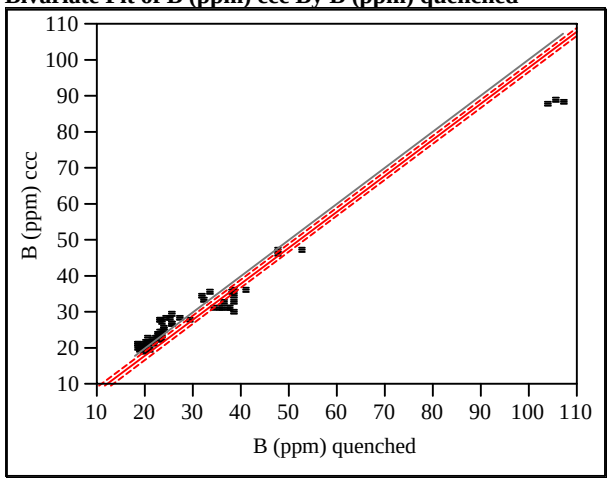
Difference: Si (ppm) quenched-Si (ppm) ccc



Si (ppm) quenched	214.811	t-Ratio	1.801828
Si (ppm) ccc	210.56	DF	62
Mean Difference	4.25141	Prob > |t|	0.0764
Std Error	2.3595	Prob > t	0.0382
Upper95%	8.96798	Prob < t	0.9618
Lower95%	-0.4652		
N	63		
Correlation	0.95687		

Exhibit B.6: Additional Comparisons between the PCTs for the Two Heat Treatments (Quenched and Centerline-Cooled)

Bivariate Fit of B (ppm) ccc By B (ppm) quenched



Linear Fit
B (ppm) ccc = -1.854534 + 1 B (ppm) quenched

Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	4.671605
Mean of Response	-1.85453
Observations (or Sum Wgts)	63

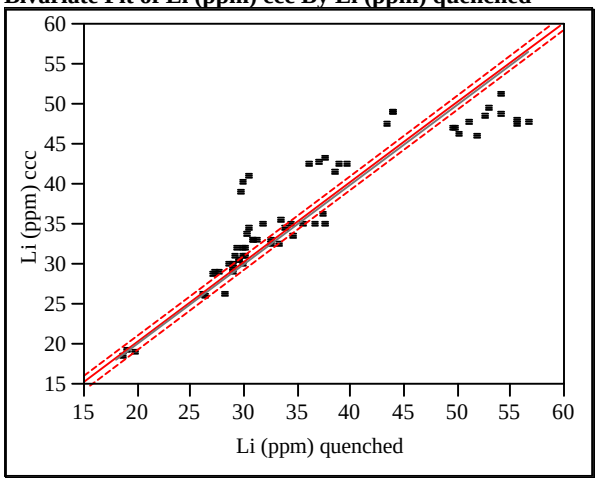
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	0	0.0000	0.0000	.
Error	62	1353.0815	21.8239	**Prob > F**
C. Total	62	1353.0815		.

Parameter Estimates

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		-1.854534	0.588567	-3.15	0.0025
B (ppm) quenched	Zeroed	1	0	.	.

Bivariate Fit of Li (ppm) ccc By Li (ppm) quenched



Linear Fit
Li (ppm) ccc = 0.2592644 + 1 Li (ppm) quenched

Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	3.870721
Mean of Response	0.259264
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	0	0.00000	0.0000	.
Error	62	928.91370	14.9825	**Prob > F**
C. Total	62	928.91370		.

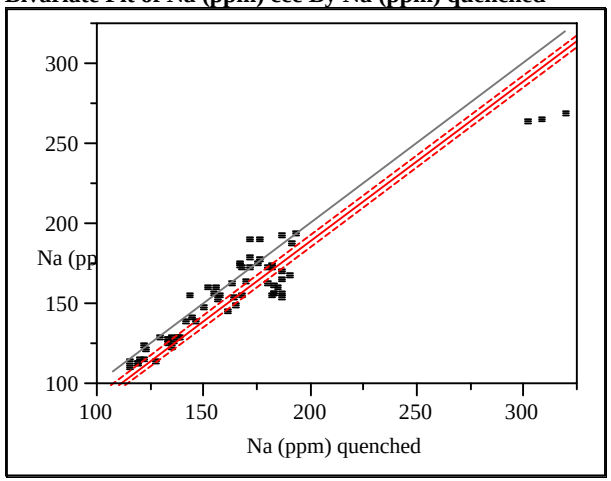
Parameter Estimates

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		0.2592644	0.487665	0.53	0.5969
Li (ppm) quenched	Zeroed	1	0	.	.

Exhibit B.6: Additional Comparisons between the PCTs for the Two Heat Treatments (Quenched and Centerline-Cooled)

(continued)

Bivariate Fit of Na (ppm) ccc By Na (ppm) quenched



Linear Fit

Na (ppm) ccc = -10.61397 + 1 Na (ppm) quenched

Summary of Fit

RSquare	0
RSquare Adj	0
Root Mean Square Error	13.48728
Mean of Response	-10.614
Observations (or Sum Wgts)	63

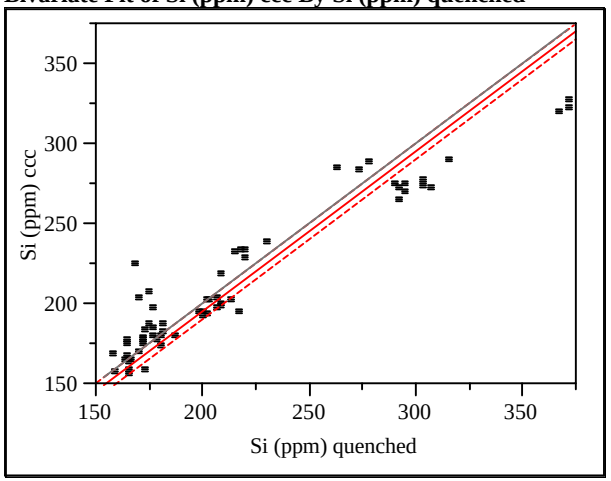
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	0	0.000	0.000	.
Error	62	11278.219	181.907	**Prob > F**
C. Total	62	11278.219		.

Parameter Estimates

Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		-10.61397	1.699238	-6.25	<.0001
Na (ppm) quenched	Zeroed	1	0	.	.

Bivariate Fit of Si (ppm) ccc By Si (ppm) quenched



Linear Fit

Si (ppm) ccc = -4.251408 + 1 Si (ppm) quenched

Summary of Fit

RSquare	2.22e-16
RSquare Adj	2.22e-16
Root Mean Square Error	18.72793
Mean of Response	-4.25141
Observations (or Sum Wgts)	63

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	0	0.000	0.000	.
Error	62	21745.585	350.735	**Prob > F**
C. Total	62	21745.585		.

Parameter Estimates

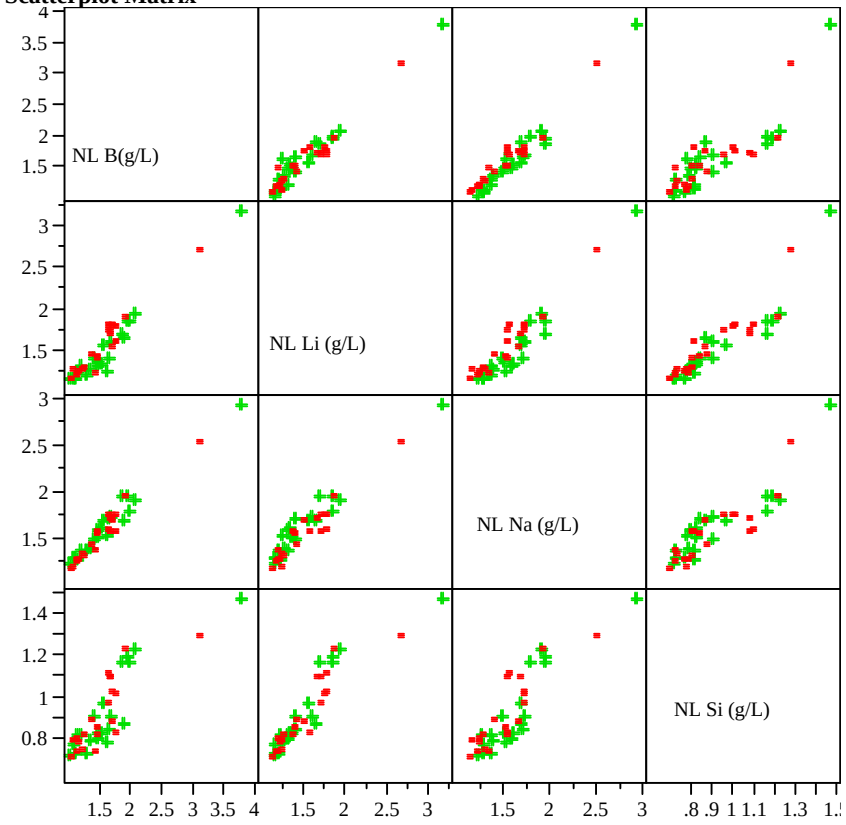
Term		Estimate	Std Error	t Ratio	Prob>|t|
Intercept		-4.251408	2.359497	-1.80	0.0764
Si (ppm) quenched	Zeroed	1	0	.	.

Exhibit B.7: Scatter Plots of Normalized PCTs by Compositional View

Measured Compositions both quenched and ccc
Correlations

	NL B(g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
NL B(g/L)	1.0000	0.9675	0.9726	0.8503
NL Li (g/L)	0.9675	1.0000	0.9523	0.9151
NL Na (g/L)	0.9726	0.9523	1.0000	0.8816
NL Si (g/L)	0.8503	0.9151	0.8816	1.0000

Scatterplot Matrix



Measured bc Compositions both quenched and ccc
Correlations

	NL B(g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
NL B(g/L)	1.0000	0.9676	0.9748	0.8491
NL Li (g/L)	0.9676	1.0000	0.9505	0.9127
NL Na (g/L)	0.9748	0.9505	1.0000	0.8779
NL Si (g/L)	0.8491	0.9127	0.8779	1.0000

Scatterplot Matrix

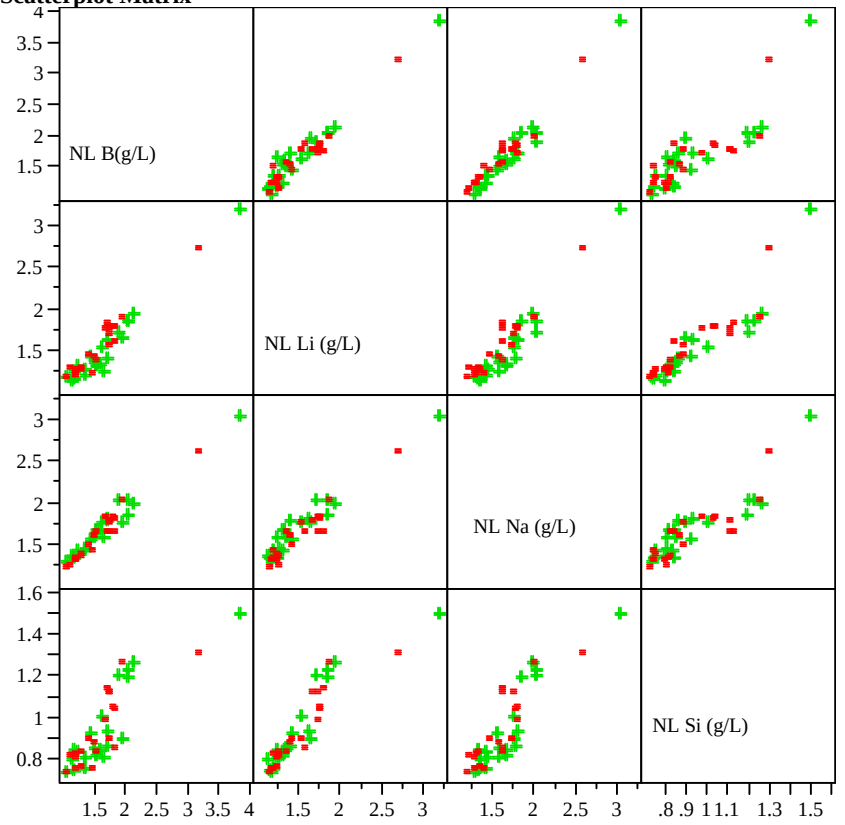


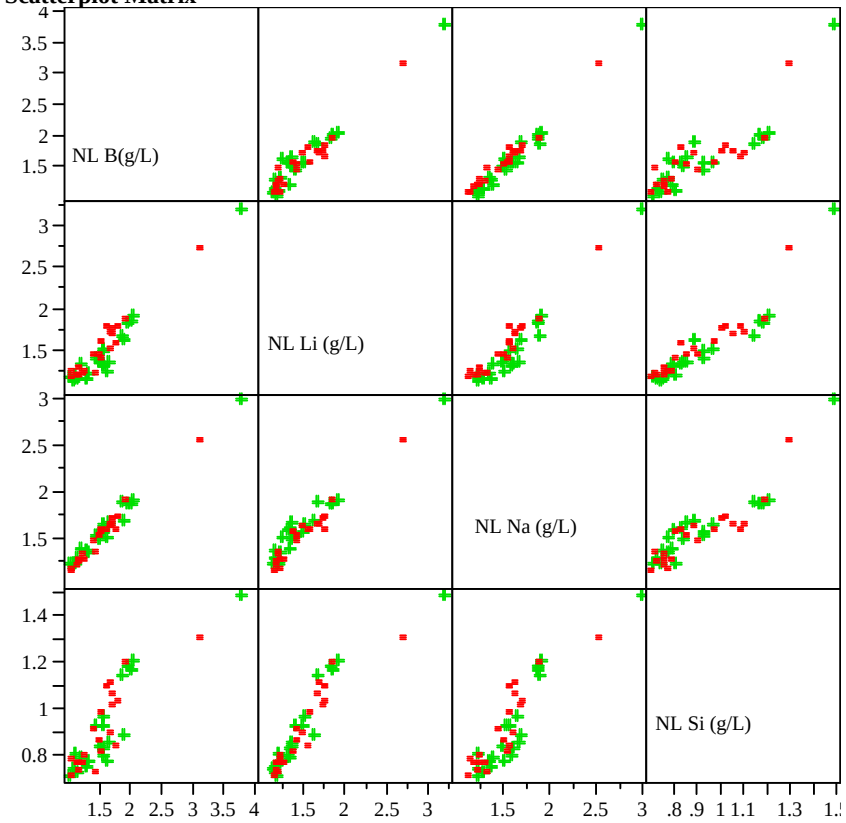
Exhibit B.7: Scatter Plots of Normalized PCTs by Compositional View *(continued)*

Targeted Compositions both quenched and ccc

Correlations

	NL B(g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
NL B(g/L)	1.0000	0.9660	0.9845	0.8671
NL Li (g/L)	0.9660	1.0000	0.9602	0.9298
NL Na (g/L)	0.9845	0.9602	1.0000	0.9003
NL Si (g/L)	0.8671	0.9298	0.9003	1.0000

Scatterplot Matrix



Measured bc Compositions for ccc only

Correlations

	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	0.9519	0.9762	0.8364
log NL[Li(g/L)]	0.9519	1.0000	0.9518	0.9304
log NL[Na (g/L)]	0.9762	0.9518	1.0000	0.8626
log NL[Si (g/L)]	0.8364	0.9304	0.8626	1.0000

Scatterplot Matrix

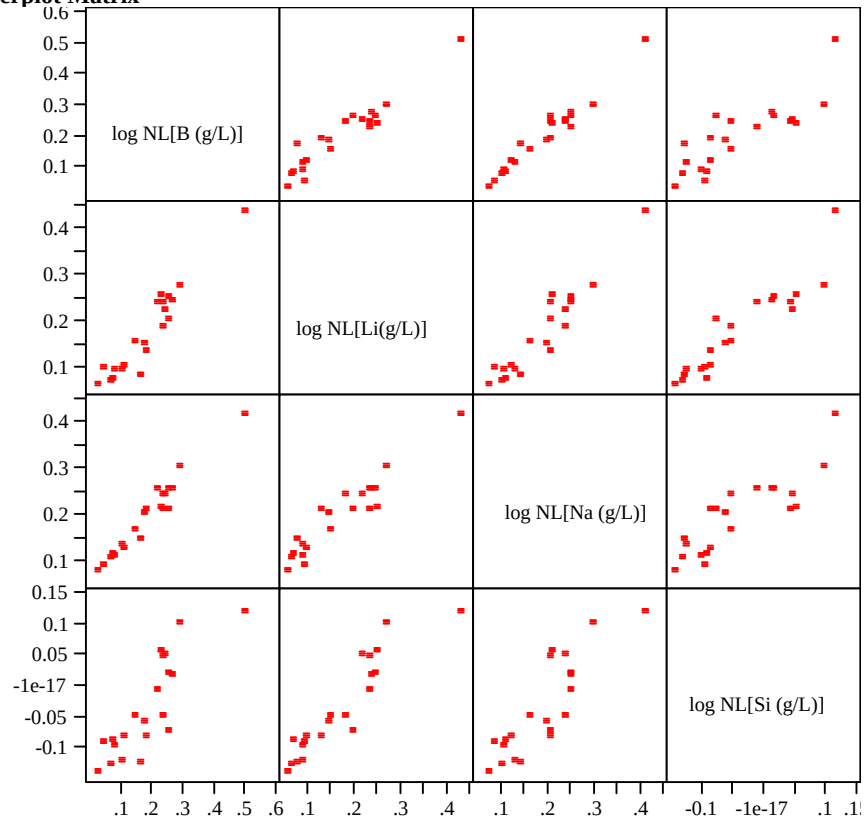


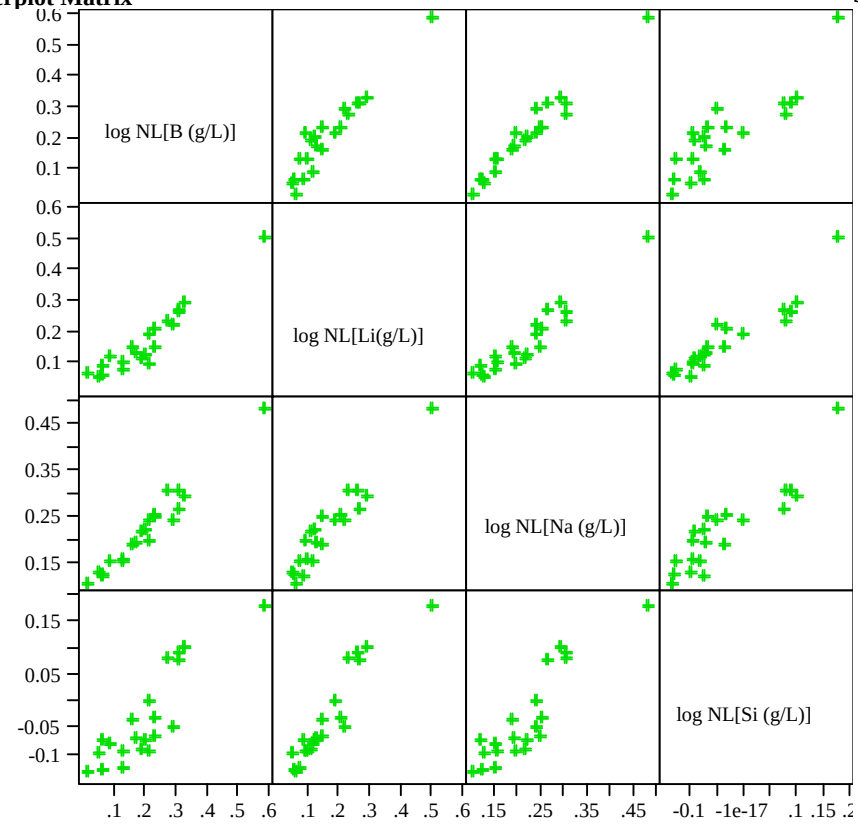
Exhibit B.7: Scatter Plots of Normalized PCTs by Compositional View *(continued)*

Measured bc Composition for quenched only

Correlations

	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	0.9483	0.9796	0.8692
log NL[Li(g/L)]	0.9483	1.0000	0.9534	0.9387
log NL[Na (g/L)]	0.9796	0.9534	1.0000	0.8974
log NL[Si (g/L)]	0.8692	0.9387	0.8974	1.0000

Scatterplot Matrix



Measured Compositions for ccc only

Correlations

	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	0.9518	0.9738	0.8381
log NL[Li(g/L)]	0.9518	1.0000	0.9553	0.9314
log NL[Na (g/L)]	0.9738	0.9553	1.0000	0.8660
log NL[Si (g/L)]	0.8381	0.9314	0.8660	1.0000

Scatterplot Matrix

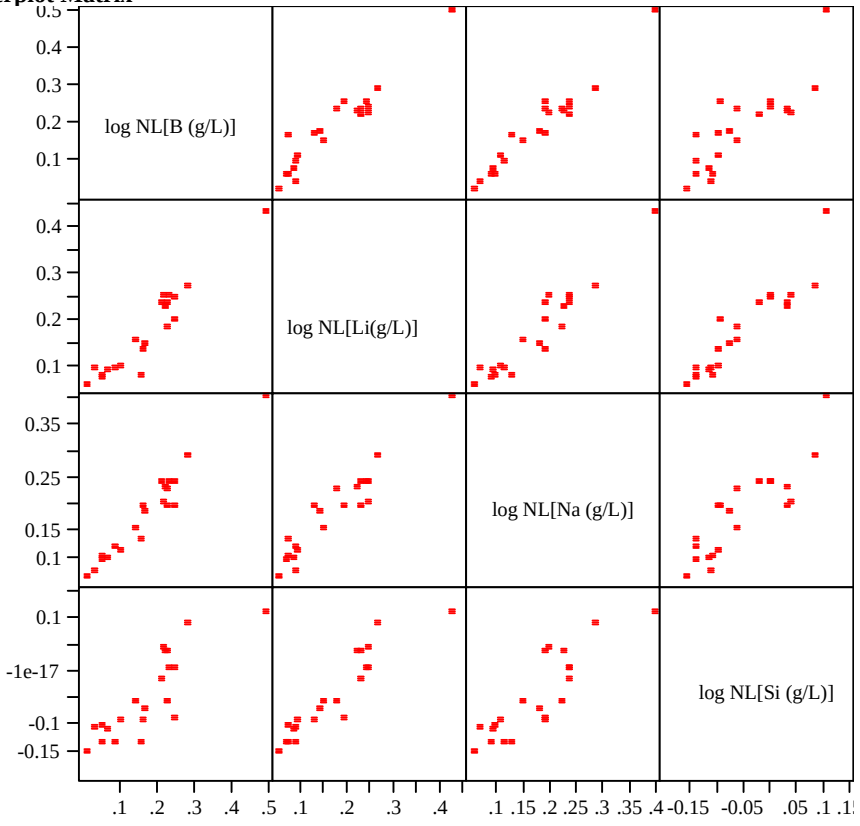
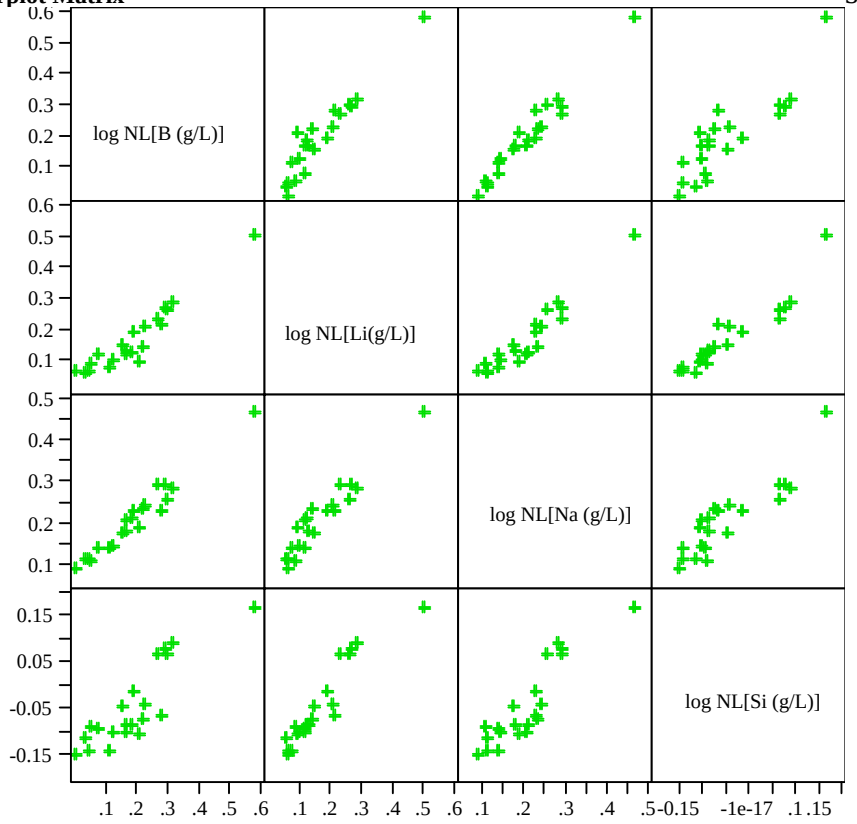


Exhibit B.7: Scatter Plots of Normalized PCTs by Compositional View *(continued)*

Measured Compositions for quenched only
Correlations

	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	0.9508	0.9775	0.8719
log NL[Li(g/L)]	0.9508	1.0000	0.9559	0.9404
log NL[Na (g/L)]	0.9775	0.9559	1.0000	0.9005
log NL[Si (g/L)]	0.8719	0.9404	0.9005	1.0000

Scatterplot Matrix



Targeted Compositions for ccc only
Correlations

	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	0.9479	0.9860	0.8505
log NL[Li(g/L)]	0.9479	1.0000	0.9613	0.9477
log NL[Na (g/L)]	0.9860	0.9613	1.0000	0.8882
log NL[Si (g/L)]	0.8505	0.9477	0.8882	1.0000

Scatterplot Matrix

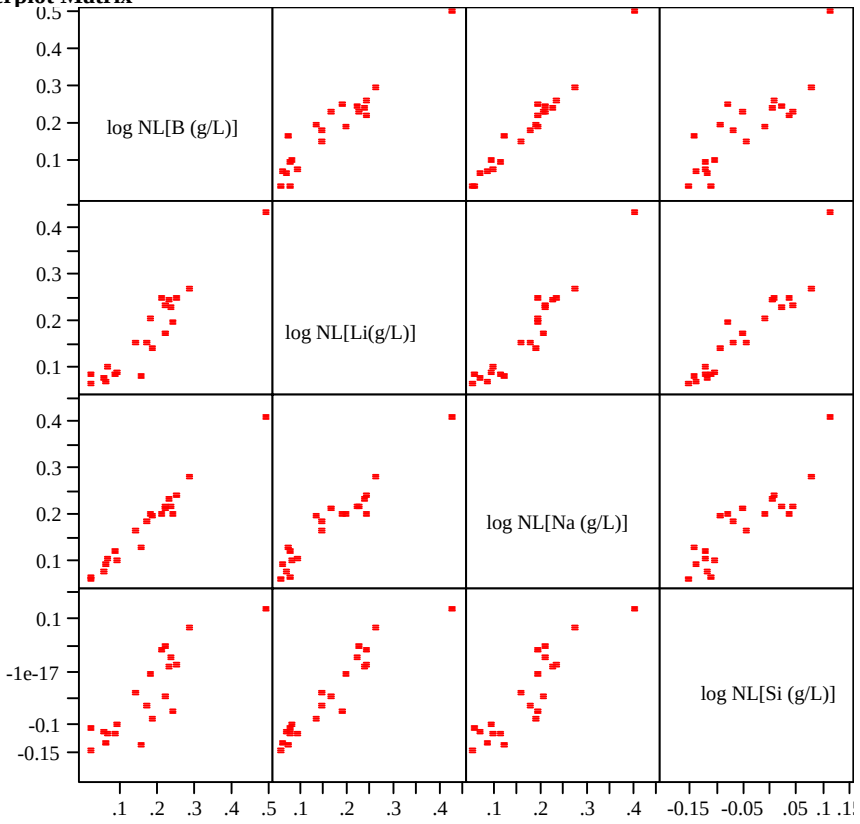


Exhibit B.7: Scatter Plots of Normalized PCTs by Compositional View *(continued)*

Targeted Compositions for quenched only
Multivariate
Correlations

	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	0.9449	0.9861	0.8891
log NL[Li(g/L)]	0.9449	1.0000	0.9614	0.9524
log NL[Na (g/L)]	0.9861	0.9614	1.0000	0.9185
log NL[Si (g/L)]	0.8891	0.9524	0.9185	1.0000

Scatterplot Matrix

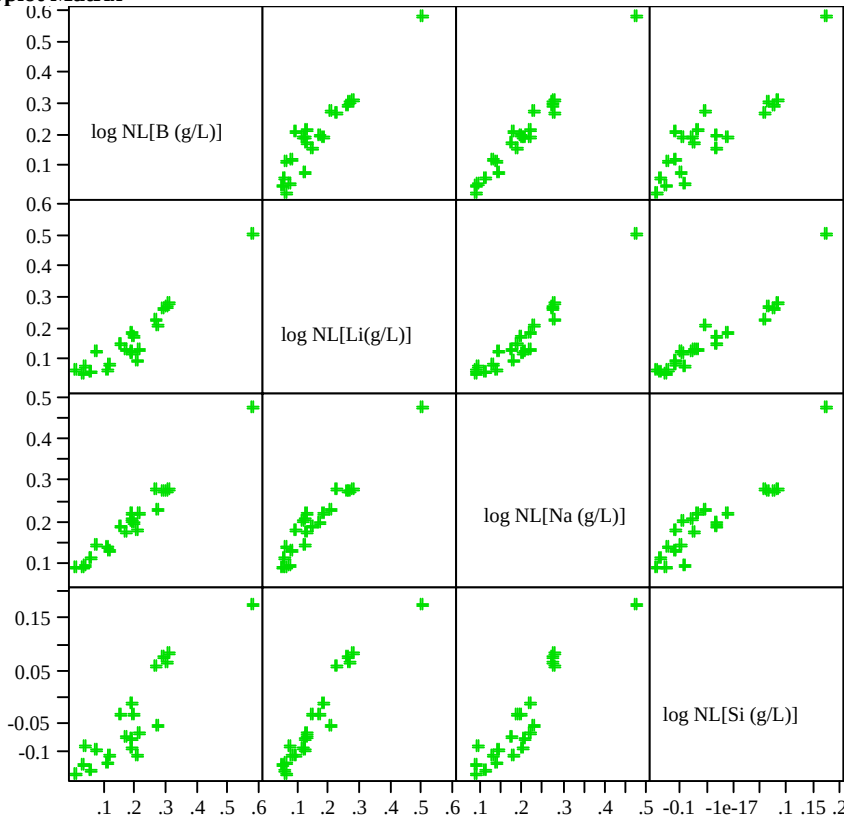
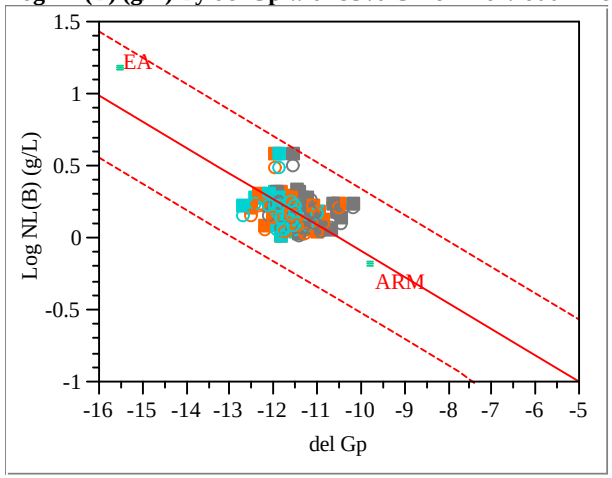
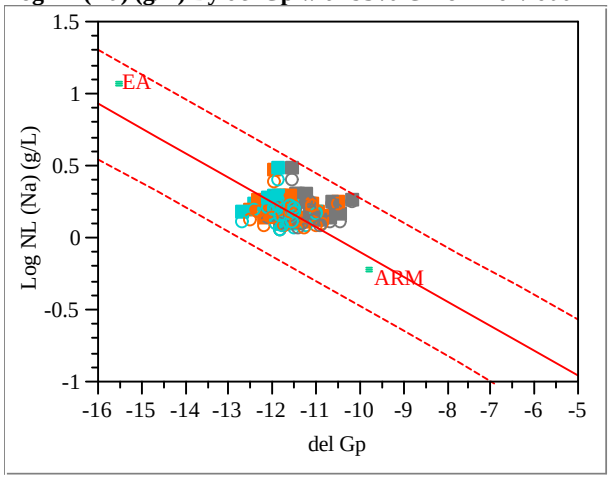


Exhibit B.8: del Gp (DG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si For Both Quenched and Centerline-Cooled Glasses Using All Compositional Views

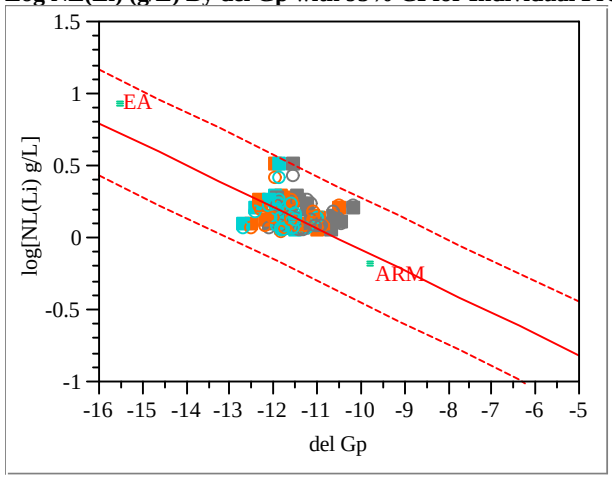
Log NL(B) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Na) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Li) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Si) (g/L) By del Gp with 95% CI for Individual Predictions

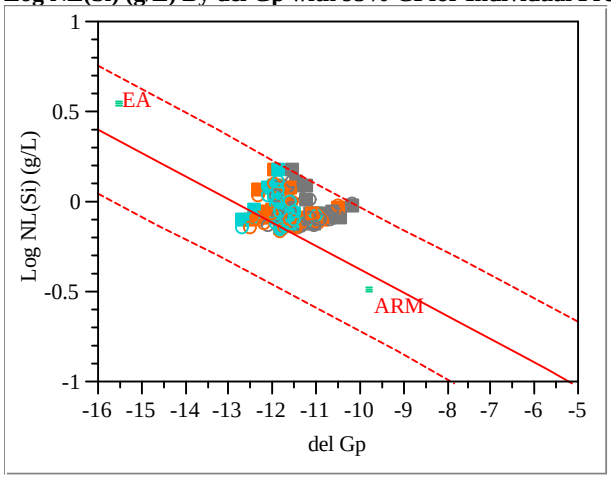
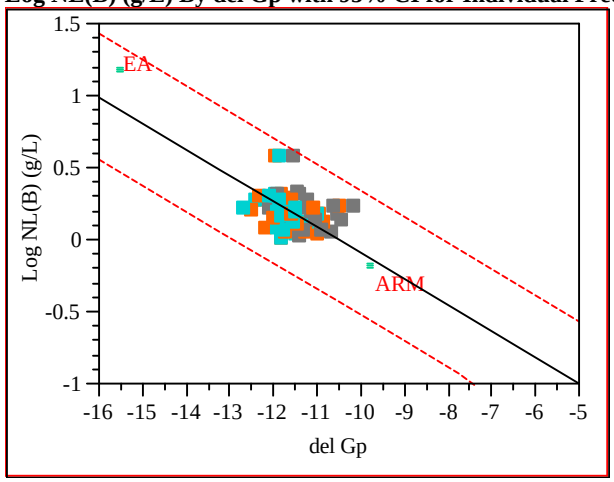
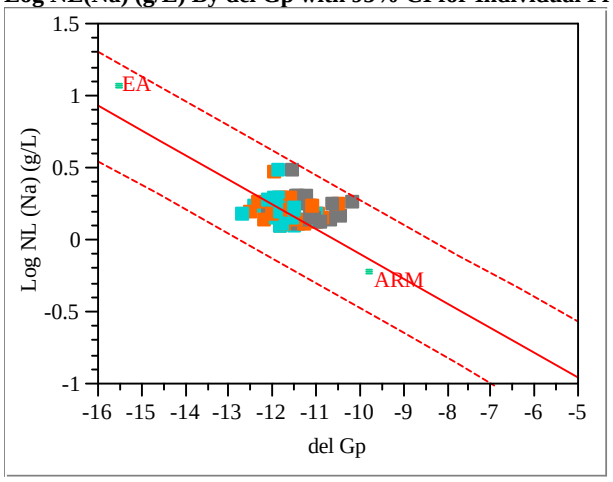


Exhibit B.9: del Gp (DG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si For Only Quenched Glasses Using All Compositional Views

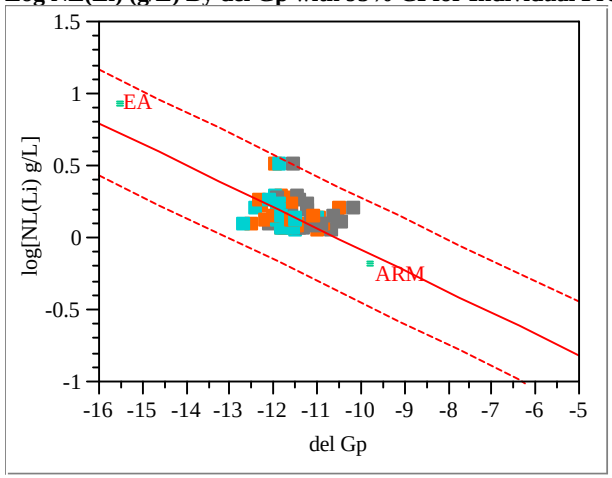
Log NL(B) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Na) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Li) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Si) (g/L) By del Gp with 95% CI for Individual Predictions

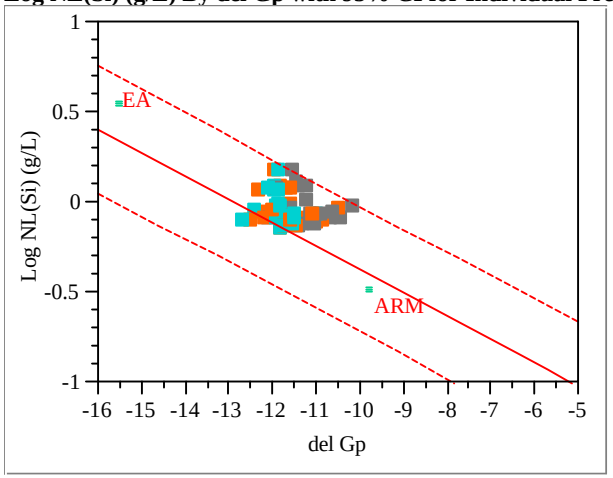
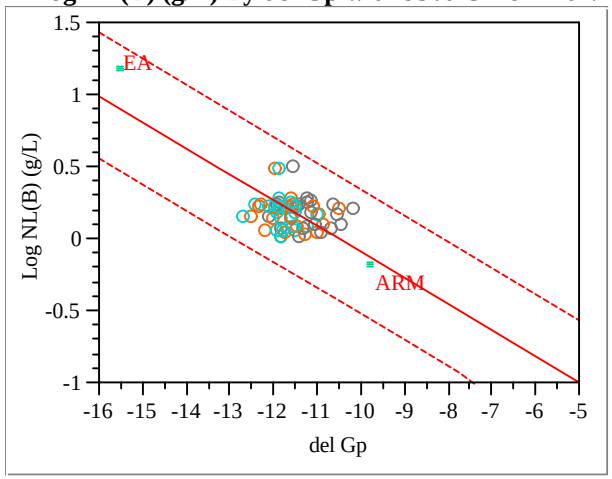
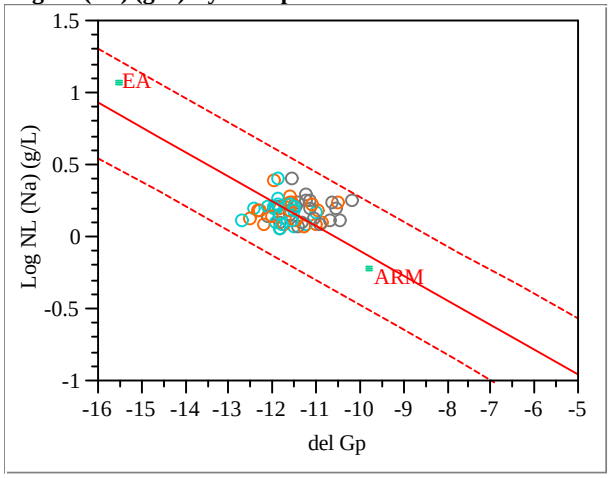


Exhibit B.10: del Gp (DG_p) Predictions versus Common Logarithm Normalized Leachate (log NL[.]) for B, Li, Na, and Si For Only Center-Cooled Glasses Using All Compositional Views

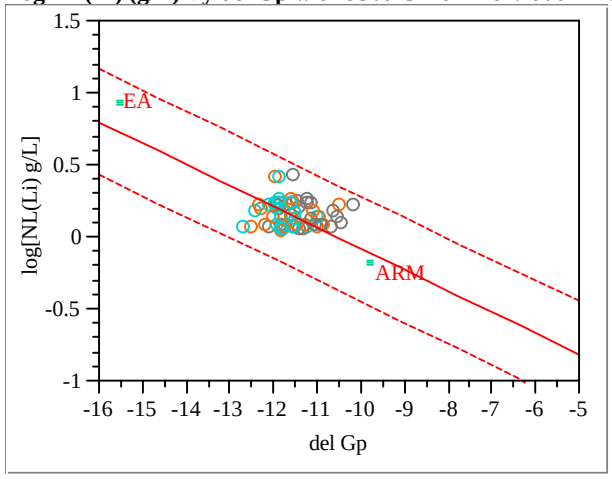
Log NL(B) (g/L) By del Gp with 95% CI for Individual Predictions



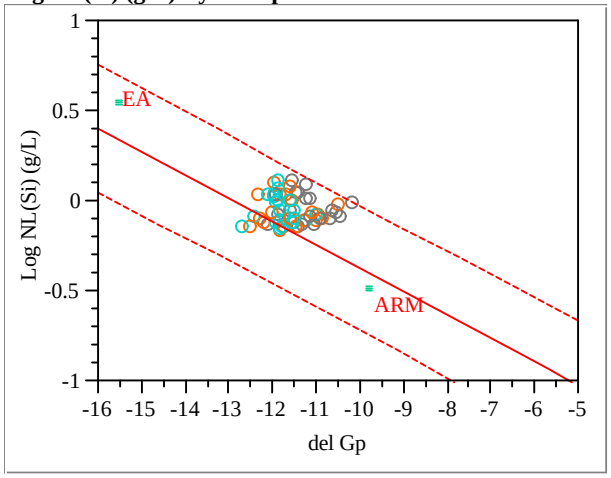
Log NL(Na) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Li) (g/L) By del Gp with 95% CI for Individual Predictions



Log NL(Si) (g/L) By del Gp with 95% CI for Individual Predictions



This page intentionally left blank.

Appendix C:
Analytical Plan for the Measurement of Chemical Compositions

SRS savannah river site™

WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2001-00034

August 21, 2001

To: C. C. Herman, 773-41A

cc: D. R. Best, 773-41A (wo)
K. G. Brown, 773-42A
E. W. Holtzscheiter, 773-A (es)
S. L. Marra, 704-1T
D. M. Marsh, 773-A
D. K. Peeler, 773-43A
E. P. Shine, 773-42A
R. C. Tuckfield, 773-42A

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

wo – without glass identifiers
es – executive summary only

E. P. Shine, Technical Reviewer — 8/21/01 Date

R. C. Tuckfield, Manager
Statistical Consulting Section — 8/21/01 Date

An Analytical Plan for Measuring the Chemical Compositions of Glasses for the Expanded MB3 Variability Study (U)

1.0 EXECUTIVE SUMMARY

An expanded macrobatch 3 (MB3) variability study is being conducted by the Savannah River Technology Center for the Defense Waste Processing Facility (DWPF). Twenty-one (21) glass compositions were selected for batching and testing to support this effort.

The chemical compositions of these study glasses are to be determined by the Savannah River Technology Center – Mobile Laboratory (SRTC-ML). This memorandum provides an analytical plan to direct and support these measurements at the SRTC-ML.

2.0 INTRODUCTION

An expanded macrobatch 3 (MB3) variability study ([1] and [2]) is being conducted by the Savannah River Technology Center for the Defense Waste Processing Facility (DWPF). Twenty-one (21) glass compositions were selected for batching and testing to support this effort [3].

The chemical compositions of these study glasses (referred to as "NS" glasses) are to be determined by the Savannah River Technology Center – Mobile Laboratory (SRTC-ML). This memorandum provides an analytical plan to direct and support these measurements at the SRTC-ML.

3.0 ANALYTICAL PLAN

The analytical procedures used by the SRTC-ML to determine cation concentrations for a glass sample include steps for sample preparation and for instrument calibration. Each glass is to be prepared in duplicate by each of two dissolution methods: lithium metaborate (LM) and sodium peroxide (SP).

The primary measurements of interest are to be acquired as follows: the samples prepared by lithium metaborate (LM) are to be measured for aluminum (Al), calcium (Ca), chromium (Cr), iron (Fe), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), phosphorous (P), silicon (Si), titanium (Ti), uranium (U), and zirconium (Zr) concentrations. Samples prepared by sodium peroxide (SP) are to be measured for boron (B) and lithium (Li). Samples dissolved by either of these two preparation methods are to be measured using Inductively Coupled Plasma (ICP) – Atomic Emission Spectrometry (AES). It should be noted that there are minor components associated with the NS glasses that will not be measured due to their concentration being below detection limits of the ICP. These minor components include Ba, Cd, Co, Cu, La, Mo, Pb, Ru, Sn, Sr, Th, V, and Zn.

Randomizing the preparation steps and blocking and randomizing the measurements for the ICP are of primary concern in the development of this analytical plan. The sources of uncertainty for the analytical procedure used by the SRTC-ML to determine the cation concentrations for the submitted glass samples primarily involve the dissolution step in the preparation of the sample and the calibrations of the ICP.

Samples of two standard glasses will be included in the analytical plan to provide an opportunity for checking the performance of the instrumentation over the course of the analyses and for potential bias correction. Specifically, several samples of Waste Compliance Plan (WCP) Batch 1 (BCH) [2] are included in this plan. A glass containing uranium (UST) will also be included in this analytical plan. The reference compositions of these glasses are provided in Table 1. These standards will be referred using the short identifier provided in Table 1 in the remainder of this memo.

Table 1: Oxide Compositions of WCP Batch 1 (BCH) and Uranium Standard (UST) Glasses (wt%).

Oxide/ Anion	BCH (wt%)	UST (wt%)
Al_2O_3	4.877	4.1
B_2O_3	7.777	9.209
BaO	0.151	0.00
CaO	1.220	1.301
CdO	0.00	0.00
Cl	0.00	0.00
Cr_2O_3	0.107	0.00
Cs_2O	0.060	0.00
CuO	0.399	0.00
F	0.00	0.00
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
MoO_3	0.00	0.00
Na_2O	9.003	11.795
Nd_2O_3	0.147	0.00
NiO	0.751	1.12
P_2O_5	0.00	0.00
PbO	0.00	0.00
RuO_2	0.0214	0.00
SiO_2	50.22	45.353
SnO_2	0.00	0.00
SO_3	0.00	0.00
TiO_2	0.677	1.049
U_3O_8	0.00	2.406
ZrO_2	0.098	0.00

Each glass sample submitted to the SRTC-ML will be prepared in duplicate by the LM and SP dissolution methods. Each sample prepared using LM or SP will be read twice by ICP-AES, with the instrument being calibrated before each of these two sets of readings. This will lead to four measurements for each cation of interest for each submitted glass.

Table 2 presents identifying codes, Q01 through Q21, for the 21 NS glasses batched as part of the expanded MB3 variability study. The table provides a naming convention that is to be used in analyzing the glasses and reporting the measurements of their compositions.[1]

[1] Renaming these samples helps to ensure that they will be processed as blind samples within the SRTC-ML. Table 2 is not shown in its entirety in those copies going to the SRTC-ML.

Table 2: Identifiers to Establish Blind Samples for the SRTC-ML

Glass ID	Sample ID	Glass ID	Sample ID
NS01	Q17	NS12	Q19
NS02	Q08	NS13	Q05
NS03	Q18	NS14	Q06
NS04	Q10	NS15	Q01
NS05	Q21	NS16	Q04
NS06	Q07	NS17	Q15
NS07	Q11	NS18	Q02
NS08	Q16	NS19	Q13
NS09	Q20	NS20	Q14
NS10	Q12	NS21	Q03
NS11	Q09		

3.1 PREPARATION OF THE SAMPLES

Each of the 21 NS glasses included in this analytical plan is to be prepared in duplicate by the LM and SP dissolution method. Thus, the total number of prepared glass samples is determined by $21 \cdot 2 \cdot 2 = 84$, not including the samples of the BCH and UST glass standards that are to be prepared.

Tables 3a-3b provide blocking and (random) sequencing schema for conducting the preparation steps of the analytical procedures. Two blocks of preparation work are provided for each preparation method to facilitate the scheduling of activities by work shift. The identifier for each of the prepared samples indicates the sample identifier (ID), preparation method, and duplicate number.

Table 3a: LM (Lithium Metaborate) Preparation Blocks

1	2
Q02LM1	Q09LM1
Q14LM1	Q04LM1
Q14LM2	Q01LM1
Q02LM2	Q09LM2
Q06LM1	Q05LM1
Q11LM1	Q05LM2
Q21LM1	Q20LM1
Q19LM1	Q03LM1
Q15LM1	Q08LM1
Q07LM1	Q01LM2
Q19LM2	Q04LM2
Q16LM1	Q10LM1
Q12LM1	Q03LM2
Q06LM2	Q13LM1
Q11LM2	Q17LM1
Q15LM2	Q13LM2
Q18LM1	Q20LM2
Q21LM2	Q10LM2
Q07LM2	Q08LM2
Q12LM2	Q17LM2
Q16LM2	
Q18LM2	

Table 3b: SP (Sodium Peroxide) Preparation Blocks

1	2
Q12SP1	Q11SP1
Q10SP1	Q03SP1
Q12SP2	Q13SP1
Q21SP1	Q03SP2
Q16SP1	Q13SP2
Q19SP1	Q06SP1
Q10SP2	Q11SP2
Q02SP1	Q18SP1
Q19SP2	Q01SP1
Q04SP1	Q18SP2
Q02SP2	Q15SP1
Q09SP1	Q05SP1
Q21SP2	Q14SP1
Q16SP2	Q01SP2
Q04SP2	Q06SP2
Q20SP1	Q07SP1
Q08SP1	Q15SP2
Q17SP1	Q14SP2
Q08SP2	Q05SP2
Q20SP2	Q07SP2
Q09SP2	
Q17SP2	

3.2 ICP Calibration Blocks

The glass samples prepared by LM and SP dissolution methods are to be analyzed using ICP instrumentation calibrated for the particular preparation method. After the initial set of cation concentration measurements, the ICP instrumentation is to be recalibrated and a second set of concentration measurements for the cations determined.

Randomized plans for measuring cation concentrations in the LM-prepared and SP-prepared samples are provided in Tables 4 and 5, respectively. The cations to be measured are specified in the header of each of these tables. In these tables, the sample identifiers for the 21 NS glasses have been modified by the addition of a suffix (a "1" or a "2") to indicate whether the measurement was made during the first or second (respectively) ICP calibration group. The identifiers for the BCH and UST samples have been modified to indicate that each of these prepared samples is to be read 3 times (mirrored in the corresponding suffix of 1, 2, or 3) per calibration block.

Table 4: ICP Blocks and Calibration Groups for Samples Prepared Using LM
(Used to Measure Elemental Al, Ca, Cr, Fe, Mg, Mn, Na, Ni, P, Si, Ti, U, and Zr)

ICP Block 1		ICP Block 2		ICP Block 3	
Calibration 1	**Calibration 2**	**Calibration 1**	**Calibration 2**	**Calibration 1**	**Calibration 2**
BCHLM111	BCHLM121	BCHLM211	BCHLM221	BCHLM311	BCHLM321
LRMLM111	LRMLM121	LRMLM211	LRMLM221	LRMLM311	LRMLM321
Q10LM11	Q07LM22	Q16LM21	Q16LM22	Q03LM21	Q15LM22
Q09LM11	Q04LM22	Q11LM11	Q06LM22	Q14LM21	Q17LM22
Q04LM21	Q07LM12	Q13LM11	Q18LM22	Q03LM11	Q21LM12
Q08LM21	Q08LM12	Q06LM11	Q05LM22	Q14LM11	Q03LM12
Q02LM21	Q08LM22	Q06LM21	Q16LM12	Q01LM11	Q19LM12
Q02LM11	Q02LM12	Q16LM11	Q20LM22	Q19LM11	Q03LM22
Q10LM21	Q10LM22	Q18LM11	Q11LM12	Q01LM21	Q15LM12
BCHLM112	BCHLM122	BCHLM212	BCHLM222	BCHLM312	BCHLM322
LRMLM112	LRMLM122	LRMLM212	LRMLM222	LRMLM312	LRMLM322
Q07LM11	Q02LM22	Q20LM11	Q20LM12	Q15LM21	Q14LM12
Q04LM11	Q12LM22	Q20LM21	Q18LM12	Q17LM21	Q21LM22
Q08LM11	Q04LM12	Q05LM11	Q06LM12	Q17LM11	Q14LM22
Q12LM21	Q09LM22	Q13LM21	Q13LM12	Q21LM21	Q19LM22
Q07LM21	Q12LM12	Q18LM21	Q05LM12	Q19LM21	Q17LM12
Q12LM11	Q09LM12	Q11LM21	Q11LM22	Q21LM11	Q01LM12
Q09LM21	Q10LM12	Q05LM21	Q13LM22	Q15LM11	Q01LM22
BCHLM113	BCHLM123	BCHLM213	BCHLM223	BCHLM313	BCHLM323
LRMLM113	LRMLM123	LRMLM213	LRMLM223	LRMLM313	LRMLM323

Table 5: ICP Blocks and Calibration Groups for Samples Prepared Using SP
(Used to Measure Elemental B and Li)

ICP Block 1		ICP Block 2		ICP Block 3	
Calibration 1	**Calibration 2**	**Calibration 1**	**Calibration 2**	**Calibration 1**	**Calibration 2**
BCHSP111	BCHSP121	BCHSP211	BCHSP221	BCHSP311	BCHSP321
LRMSP111	LRMSP121	LRMSP211	LRMSP221	LRMSP311	LRMSP321
Q10SP11	Q10SP12	Q06SP11	Q06SP12	Q08SP21	Q08SP22
Q04SP11	Q04SP12	Q17SP21	Q17SP22	Q12SP11	Q12SP12
Q11SP21	Q11SP22	Q18SP11	Q18SP12	Q19SP21	Q19SP22
Q13SP21	Q13SP22	Q05SP11	Q05SP12	Q20SP21	Q20SP22
Q13SP11	Q13SP12	Q05SP21	Q05SP22	Q03SP21	Q03SP22
Q02SP11	Q02SP12	Q21SP21	Q21SP22	Q19SP11	Q19SP12
Q10SP21	Q10SP22	Q15SP21	Q15SP22	Q09SP11	Q09SP12
BCHSP112	BCHSP122	BCHSP212	BCHSP222	BCHSP312	BCHSP322
LRMSP112	LRMSP122	LRMSP212	LRMSP222	LRMSP312	LRMSP322
Q01SP11	Q01SP12	Q06SP21	Q06SP22	Q09SP21	Q09SP22
Q11SP11	Q11SP12	Q18SP21	Q18SP22	Q08SP11	Q08SP12
Q01SP21	Q01SP22	Q07SP11	Q07SP12	Q12SP21	Q12SP22
Q04SP21	Q04SP22	Q17SP11	Q17SP12	Q20SP11	Q20SP12
Q14SP11	Q14SP12	Q15SP11	Q15SP12	Q16SP21	Q16SP22
Q02SP21	Q02SP22	Q21SP11	Q21SP12	Q16SP11	Q16SP12
Q14SP21	Q14SP22	Q07SP21	Q07SP22	Q03SP11	Q03SP12
BCHSP113	BCHSP123	BCHSP213	BCHSP223	BCHSP313	BCHSP323
LRMSP113	LRMSP123	LRMSP213	LRMSP223	LRMSP313	LRMSP323

4.0 CONCLUDING COMMENTS

In summary, this analytical plan identifies several ICP calibration blocks in Tables 4 – 5 as well as four preparation blocks in Tables 3a-3b for use by the SRTC-ML. The sequencing of the activities associated with each of the steps in the analytical procedures has been randomized. The size of each of the blocks was selected so that it could be completed in a single work shift.

In this plan, the identifiers of study and standard glass samples that contain uranium and/or thorium are marked with an asterisk as in Table 2. The scheme used to block these samples for preparation and measurement groups these samples together to facilitate the special handling that they require (as compared to the non-radioactive samples).

If during the process of measuring the samples in a calibration block a problem is discovered by the technician, the instrument should be re-calibrated and the block of samples re-measured in its entirety. If for some reason the measurements are not conducted in the sequences presented in this report, a record should be made of the actual order used along with any explanative comments.

The analytical plan indicated 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. It is also recommended that the solutions resulting from each of the prepared samples be archived for some period, considering the “shelf-life” of the solutions, in case questions arise during data analysis. This would allow for the solutions to be rerun without additional preparations, thus minimizing cost.

5.0 REFERENCES

[1] Herman, C. C., "Task Technical & QA Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)," WSRC-RP-2001-00756, July 31, 2001.

[2] Herman, C. C., "Analytical Study Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)," WSRC-RP-2001-00792, August 22, 2001.

[3] Brown, K. G., T. B. Edwards, C. C. Herman, D. K. Peeler, "Selecting Glass Compositions for the DWPF SB2/Frit 320 Variability Study," WSRC-RP-2001-00775, July 31, 2001.

Appendix D:
Analytical Plan for the Measurement of PCT Leachates

SRS savannah river site ™

WESTINGHOUSE SAVANNAH RIVER COMPANY
INTEROFFICE MEMORANDUM

SRT-SCS-2001-00038

August 24, 2001

To: C. C. Herman, 773-41A

cc: D. R. Best, 773-41A (wo)
K. G. Brown, 773-42A
E. W. Holtzscheiter, 773-A (es)
S. L. Marra, 704-1T
D. M. Marsh, 773-A
D. K. Peeler, 773-43A
D. J. Pittman, 786-1A (wo)
E. P. Shine, 773-42A
R. C. Tuckfield, 773-42A

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

wo – without glass identifiers
es – executive summary only

E. P. Shine, Technical Reviewer — 8/29/01 Date

R. C. Tuckfield, Manager — 8/29/01 Date
Statistical Consulting Section

An Analytical Plan for Measuring PCT Solutions for the Glasses Supporting the Expanded MB3 Variability Study (U)

1.0 EXECUTIVE SUMMARY

An expanded macrobatch 3 (MB3) variability study is being conducted by the Savannah River Technology Center for the Defense Waste Processing Facility (DWPF). Twenty-one (21) glass compositions were selected for batching and testing to support this effort. The glasses are to be cooled both by quenching and center-line-cooling, and the durabilities of the resulting forty-two glasses are to be measured in triplicate using the Product Consistency Test, or PCT. Its requirements are described in ASTM C1285-97 (Method A)

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

An expanded macrobatch 3 (MB3) variability study ([1] and [2]) is being conducted by the Savannah River Technology Center for the Defense Waste Processing Facility (DWPF). Twenty-one (21) glass compositions [3] were selected for batching and testing to support this effort.

The glasses for this study, which are designated as the "NS" glasses, are to be cooled both by quenching and center-line-cooling, and the durabilities of the resulting forty-two 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].

The "NS" identifiers presented in Table 1 are modified using a " centerline canister-cooled glass.

Table 1: Identifiers for the NS Glasses

Quenched	Centerline Canister Cooled	Quenched	Centerline Canister Cooled
NS01	NS01ccc	NS12	NS12ccc
NS02	NS02ccc	NS13	NS13ccc
NS03	NS03ccc	NS14	NS14ccc
NS04	NS04ccc	NS15	NS15ccc
NS05	NS05ccc	NS16	NS16ccc
NS06	NS06ccc	NS17	NS17ccc
NS07	NS07ccc	NS18	NS18ccc
NS08	NS08ccc	NS19	NS19ccc
NS09	NS09ccc	NS20	NS20ccc
NS10	NS10ccc	NS21	NS21ccc
NS11	NS11ccc		

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. In addition to the study glasses, PCTs are to be conducted (in triplicate) on samples of the Approved Reference Material (ARM) glass and the Environmental Assessment (EA) glass. Two reagent blank samples are also to be included in these tests.

3.0 DISCUSSION

The quenched and center-line-cooled versions of the "NS" glasses are to be subjected to the PCT. The 2 different thermal histories for each of the 21 glasses lead to 42 glasses that are to be measured (in triplicate) using the PCT. In addition to the study 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 134 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 SRTC-ML 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 2 presents identifying codes, p001 through p134, for the individual solutions required for the PCTs of the "NS" 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.[1] The centerline, canister-cooled glasses are identified by the "-ccc" suffix.

Table 2: Assignment of Solution Identifiers for SG Glasses

Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier	Original Sample	Solution Identifier
NS01	p056	NS06ccc	p109	NS12	p076	NS18	p064
NS01	p120	NS06ccc	p013	NS12ccc	p059	NS18	p048
NS01	p117	NS07	p090	NS12ccc	p111	NS18	p024
NS01ccc	p027	NS07	p132	NS12ccc	p126	NS18ccc	p100
NS01ccc	p022	NS07	p129	NS13	p128	NS18ccc	p066
NS01ccc	p040	NS07ccc	p008	NS13	p005	NS18ccc	p038
NS02	p081	NS07ccc	p062	NS13	p014	NS19	p084
NS02	p029	NS07ccc	p121	NS13ccc	p047	NS19	p087
NS02	p025	NS08	p123	NS13ccc	p068	NS19	p053
NS02ccc	p095	NS08	p020	NS13ccc	p114	NS19ccc	p057
NS02ccc	p077	NS08	p012	NS14	p016	NS19ccc	p125
NS02ccc	p031	NS08ccc	p080	NS14	p018	NS19ccc	p134
NS03	p099	NS08ccc	p036	NS14	p035	NS20	p028
NS03	p037	NS08ccc	p097	NS14ccc	p094	NS20	p049
NS03	p088	NS09	p106	NS14ccc	p107	NS20	p010
NS03ccc	p112	NS09	p122	NS14ccc	p046	NS20ccc	p101
NS03ccc	p102	NS09	p073	NS15	p093	NS20ccc	p131
NS03ccc	p110	NS09ccc	p011	NS15	p133	NS20ccc	p003
NS04	p065	NS09ccc	p078	NS15	p063	NS21	p019
NS04	p118	NS09ccc	p103	NS15ccc	p054	NS21	p034
NS04	p108	NS10	p085	NS15ccc	p006	NS21	p055
NS04ccc	p041	NS10	p002	NS15ccc	p130	NS21ccc	p119
NS04ccc	p083	NS10	p096	NS16	p071	NS21ccc	p070
NS04ccc	p089	NS10ccc	p061	NS16	p051	NS21ccc	p079
NS05	p026	NS10ccc	p021	NS16	p004	ARM	p091
NS05	p039	NS10ccc	p030	NS16ccc	p043	ARM	p017
NS05	p104	NS11	p124	NS16ccc	p009	ARM	p044
NS05ccc	p033	NS11	p086	NS16ccc	p115	EA	p067
NS05ccc	p092	NS11	p082	NS17	p127	EA	p058
NS05ccc	p052	NS11ccc	p001	NS17	p116	EA	p113
NS06	p069	NS11ccc	p098	NS17	p050	blank	p072
NS06	p075	NS11ccc	p060	NS17ccc	p105	blank	p042
NS06	p074	NS12	p023	NS17ccc	p045		
NS06ccc	p007	NS12	p015	NS17ccc	p032		

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: boron (B), lithium (Li), sodium (Na), and silicon (Si). The 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) – Atomic Emission Spectrometer. The PCT

[1] Renaming these samples ensures that they will be processed as blind samples by the SRTC-ML. This table does not contain the solution identifiers for those on the distribution list with a "

solutions (as identified in Table 2) are grouped in six ICP blocks for processing by the SRTC-ML in Table 3. Each block requires a different calibration of the ICP.

Table 3: ICP Calibration Blocks for Leachate Measurements for the NS Glasses

1	2	3	4	5	6
std-b1-1	std-b2-1	std-b3-1	std-b4-1	std-b5-1	std-b6-1
p081	p092	p073	p112	p022	p117
p093	p132	p103	p099	p083	p032
p119	p070	p044	p023	p098	p030
p106	p029	p024	p065	p045	p010
p033	p048	p097	p001	p086	p060
p064	p068	p014	p069	p120	p013
p026	p034	p052	p085	p021	p126
p080	p066	p115	p028	p037	p108
p123	p077	p031	p056	p015	p082
p095	p133	p063	p016	p111	p089
p071	p006	p055	p061	p049	p046
std-b1-2	std-b2-2	std-b3-2	std-b4-2	std-b5-2	std-b6-2
p067	p036	p004	p059	p072	p042
p091	p051	p025	p057	p002	p088
p100	p062	p079	p041	p118	p134
p019	p058	p121	p084	p018	p074
p043	p005	p104	p127	p087	p040
p128	p017	p038	p027	p125	p076
p047	p039	p114	p105	p107	p096
p008	p122	p012	p124	p116	p110
p090	p078	p129	p101	p131	p050
p054	p020	p130	p094	p102	p053
p011	p009	p113	p007	p075	p035
std-b1-3	std-b2-3	std-b3-3	std-b4-3	p109	p003
				std-b5-3	std-b6-3

A multi-element solution standard (denoted by "std-bi-j" where i=1, 2, and 6 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 six blocks. This standard may be useful in checking and correcting for 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 2 and six ICP calibration blocks in Table 3 for the SRTC-ML to use in conducting the boron (B), lithium (Li), sodium (Na), and silicon (Si) concentration measurements for the PCT study of the "NS" glasses for the expanded MB3 variability study. The sequencing of the activities associated with each of the steps in the analytical procedure has been randomized. The size of the 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] Herman, C. C., "Task Technical & QA Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)," WSRC-RP-2001-00756, July 31, 2001.

[2] Herman, C. C., "Analytical Study Plan: Expanded Glass Variability Study for Sludge Batch 2 (Macrobatch 3)," WSRC-RP-2001-00792, August 22, 2001.

[3] Brown, K. G., T. B. Edwards, C. C. Herman, D. K. Peeler, "Selecting Glass Compositions for the DWPF SB2/Frit 320 Variability Study," WSRC-RP-2001-00775, July 31, 2001.

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