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Refinement of the Nepheline Discriminator: Results of a Phase II Study

K. M. Fox
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October 2008

Environmental & Chemical Process Technology
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EXECUTIVE SUMMARY

Twenty five glass compositions were selected for a Phase II study to assess the potential for reducing the conservatism in the nepheline discriminator. The glass compositions were restricted to regions that fell within the validation ranges of the DWPF PCCS models. In addition, the liquidus temperature model was used to restrict the glass compositions so that they could all be melted at the same temperature. The nepheline discriminator was used to force the glass compositions into regions where nepheline formation was predicted to occur. The glasses were fabricated in the laboratory and characterized for crystallization and chemical durability after both quenching and slow cooling.

Chemical analysis showed that the fabricated glasses met the target compositions. Nepheline was identified in one of the quenched glasses and several of the CCC glasses. There was no clear relationship between the types of crystallization that occurred in a particular glass and its location on the Al_2O_3-Na_2O-SiO_2 ternary diagram. A partitioning algorithm was used to identify trends in crystallization behavior based on glass composition. Generally, for the CCC glasses MnO influenced the crystallization of spinels and B_2O_3 and SiO_2 influenced the crystallization of nepheline. Measured durability responses varied from acceptable to unacceptable depending on the glass composition and type and extent of crystallization that occurred. It was not possible to identify any linear effects of composition on chemical durability performance for this set of study glasses. The results were not sufficient to recommend modification of the current nepheline discriminator at this time.

It is recommended that the next series of experiments continue to focus not only on compositional regions where the PCCS models are considered applicable (i.e., the model validation ranges), but also be restricted to compositional regions where acceptable glasses are predicted to be produced but are disallowed by the current nepheline discriminator. This may help identify a path for gaining access to glass compositions that are limited by only the nepheline constraint. Dependencies on cooling rates should also be evaluated. A better understanding of these regions, as well as the impacts of B_2O_3 and CaO on nepheline crystallization, may allow for relaxation or refinement of the nepheline constraint and subsequently allow for higher Al_2O_3 concentrations.

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LIST OF ABBREVIATIONS

AD	Analytical Development
ANOVA	ANalysis Of Variance
ARM	Approved Reference Material
bc	Bias-corrected
CCC	Canister Centerline Cooled
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
HLW	High-Level Waste
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
LM	Lithium Metaborate fusion
PCCS	Product Composition Control System
PCT	Product Consistency Test
PF	Peroxide Fusion
PSAL	Process Science Analytical Laboratory
SB5	Sludge Batch 5
SRS	Savannah River Site
XRD	X-ray Diffraction

1.0 Introduction

Nepheline crystallization is of concern for high-level nuclear waste (HLW) glasses because its formation reduces the chemical durability of the waste form. Waste compositions containing higher concentrations of Al_2O_3 and Na_2O are more prone to nepheline ($NaAlSiO_4$) crystallization,[1] particularly upon slow cooling.

Currently, a 'nepheline discriminator' is included as a process control constraint at the Defense Waste Processing Facility (DWPF) at the Savannah River Site (SRS).[2] This constraint uses the inequality that was first proposed by Li[1] and later verified as applicable to DWPF-type glasses.[3-7] The nepheline discriminator is given as Equation 1, and relates the concentrations of SiO_2, Na_2O and Al_2O_3 (as weight percentages in glass) to a critical value of 0.62.

$$\frac{SiO_2}{SiO_2 + Na_2O + Al_2O_3} > 0.62 \qquad (1)$$

This equation defines a boundary line on the SiO_2-Na_2O-Al_2O_3 ternary diagram above which (or toward the SiO_2 corner of the ternary, see Figure 1-1) nepheline is not predicted to crystallize in the glass upon quenching or slow cooling.

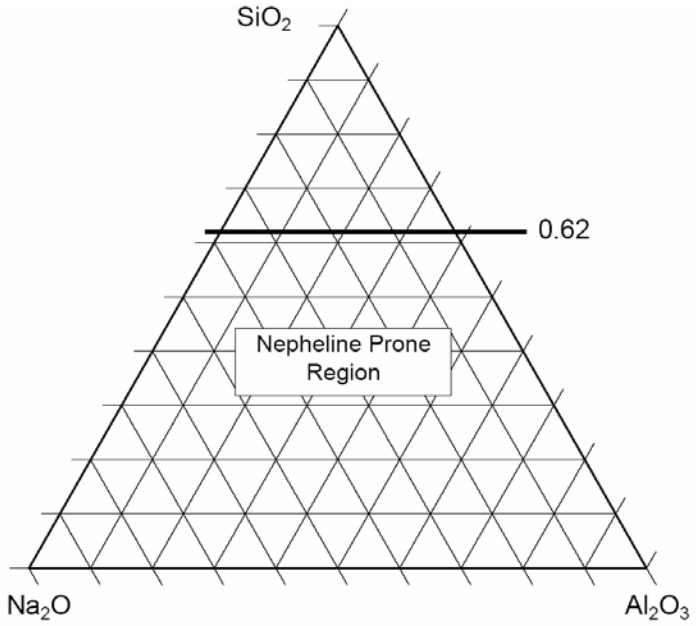

Figure 1-1. Ternary SiO_2-Na_2O-Al_2O_3 diagram (wt %) showing the location of the current nepheline discriminator. Glasses below the 0.62 line are considered prone to nepheline crystallization.

The current equation uses only the concentrations of the SiO_2, Na_2O and Al_2O_3 components in the glass in predicting whether or not nepheline is likely to crystallize. However, several other components have been shown to impact the propensity for nepheline crystallization, including B_2O_3 and CaO (potential DWPF frit components), among others.[1, 4, 8-10] Therefore, the potential exists to further refine the nepheline discriminator to include these components. Refining the nepheline discriminator to include other important components and to reduce conservatism may

provide access to high Al_2O_3 concentration glass compositions for the DWPF, which could in turn allow access to higher waste loadings, decreased washing and improved waste throughput.

A Phase I study confirmed that some conservatism exists in the current nepheline discriminator.[11] Several glass compositions, particularly compositions that targeted higher Al_2O_3 concentrations, were shown to be very durable (i.e., durability responses that were more than an order of magnitude better than that of the Environmental Assessment (EA) benchmark glass) while their nepheline discriminator values were well below the current nepheline discriminator limit of 0.62. Increased concentrations of B_2O_3 and CaO were shown to improve durability responses and suppress the formation of nepheline. These results provide incentive to revise the nepheline discriminator to reduce some of this conservatism and incorporate the influence of B_2O_3. The Phase I study suggested that a second phase be undertaken to provide additional data in support of this revision.[11]

The objective of this Phase II study was to develop and characterize a series of HLW glass compositions that were restricted to regions where DWPF could potentially process waste. That is, the compositions all fall within the validation ranges of the DWPF process control models. The glass compositions were also constrained by liquidus temperature predictions and nepheline discriminator values. Glasses were fabricated and characterized to determine the impacts of composition and heat treatment on the types of crystalline phases that formed.

This study is performed in response to Technical Task Request HLW-DWPF-TTR-2007-0007,[12] under Task Technical and Quality Assurance Plan WSRC-STI-2006-00321.[13]

2.0 Experimental Procedure

2.1 Glass Selection Strategy

Glass compositions for Phase II of the nepheline study were restricted to regions where DWPF could potentially process waste based on model validation ranges. The validation ranges for the predictive models in the Product Composition Control System (PCCS) were used to guide the concentration ranges of the major glass components, including Al_2O_3, B_2O_3, CaO, Cr_2O_3, Fe_2O_3, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2 and TiO_2. Table 2-1 provides bounding intervals for the major oxides considered. Glass compositions for this study had to fall within the region defined by this table. The glass compositions were also constrained by liquidus temperature predictions. Only glass compositions with a predicted liquidus temperature of 1100 °C or less were selected so that all of the study glasses could be melted at 1150 °C. Finally, the nepheline discriminator was used to constrain the glass compositions in two ways during the glass selection process. Twelve glass compositions were limited to nepheline discriminator values of 0.66 or less (Glass IDs NP2-01 through NP2-12), while another twelve glass compositions were limited to nepheline discriminator values of 0.60 or less (Glass IDs NP2-13 through NP2-24).

Table 2-1. Validation Ranges for Major Oxides within the Outer Layer of the Compositional Region of Interest.

Oxide	Minimum Concentration (wt % in glass)	Maximum Concentration (wt % in glass)
Al_2O_3	3.5	18
B_2O_3	4.5	14
CaO	0	4
Cr_2O_3	0	0.2
Fe_2O_3	5	20
Li_2O	4	7
MgO	0	1.5
MnO	0.5	5.5
Na_2O	10	18
NiO	0	2.5
SiO_2	35	55
TiO_2	0	2

For each of the two constraining values of the nepheline discriminator, the coordinate-exchange algorithm of JMP Version 6.0.3[14] was used to develop a constrained mixture experimental design over the 12 oxides of Table 2-1 from which the selection of the 12 glass compositions was accomplished. This allows for the investigation of linear effect of glass composition on the measured glass properties. The average of these 24 compositions, or the centroid (Glass ID NP2-25), was also determined and added as an additional glass composition. The 25 glass compositions selected through this process are given in Table 2-2.

Table 2-2. Target Glass Compositions (wt %) for the Nepheline Phase II Study.

Glass ID	Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2	Nepheline Discriminator	Predicted T_L (°C)
NP2-01	16.40	5.10	2.33	0.00	5.00	4.41	0.00	3.29	11.23	0.84	51.40	0.00	0.6504	1100.03
NP2-02	7.22	14.00	0.00	0.20	5.00	4.00	0.00	0.62	18.00	0.00	48.96	2.00	0.6600	656.51
NP2-03	8.37	4.70	0.18	0.20	14.82	7.00	0.15	1.87	15.12	0.20	45.39	2.00	0.6590	958.48
NP2-04	14.18	12.34	4.00	0.20	5.61	4.93	1.50	0.50	11.15	0.44	43.14	2.00	0.6300	1021.47
NP2-05	8.73	4.50	0.13	0.02	15.36	4.44	1.50	5.50	14.78	0.08	42.96	2.00	0.6464	1039.22
NP2-06	10.57	4.50	4.00	0.00	18.01	4.26	0.00	0.50	18.00	0.00	38.16	2.00	0.5719	1001.27
NP2-07	9.02	12.05	0.27	0.09	15.14	4.40	0.33	1.74	12.26	1.39	41.31	2.00	0.6600	1099.98
NP2-08	6.97	13.32	4.00	0.00	5.00	7.00	0.00	3.62	15.38	0.00	42.70	2.00	0.6564	626.53
NP2-09	5.52	5.90	4.00	0.20	13.81	4.88	0.96	4.80	16.12	1.98	41.83	0.00	0.6591	1083.36
NP2-10	10.65	10.17	0.95	0.00	13.64	5.16	0.68	0.50	13.43	0.00	44.82	0.00	0.6504	948.90
NP2-11	18.00	14.00	0.00	0.20	5.85	6.97	0.00	4.65	15.33	0.00	35.00	0.00	0.5122	895.40
NP2-12	10.64	6.68	0.83	0.02	6.17	7.00	1.50	0.50	18.00	2.50	44.15	2.00	0.6066	955.63
NP2-13	17.27	14.00	0.00	0.20	5.00	4.00	1.50	5.50	10.00	0.00	40.90	1.63	0.6000	1079.91
NP2-14	15.58	10.93	1.79	0.18	11.49	4.36	0.00	0.50	13.32	0.33	41.53	0.00	0.5897	1077.75
NP2-15	18.00	14.00	0.00	0.00	5.00	4.00	1.50	0.50	18.00	2.50	35.00	1.50	0.4930	1073.98
NP2-16	13.61	5.19	1.97	0.00	14.70	4.00	0.32	2.86	14.82	0.17	42.36	0.00	0.5984	1093.39
NP2-17	8.62	14.00	4.00	0.00	6.67	7.00	0.00	5.50	14.71	2.50	35.00	2.00	0.6000	914.85
NP2-18	12.85	4.97	0.00	0.00	11.04	7.00	0.49	1.41	17.18	0.00	45.05	0.00	0.6000	880.73
NP2-19	9.30	5.27	0.00	0.20	18.10	4.00	0.00	5.50	17.39	0.64	37.61	2.00	0.5849	1100.00
NP2-20	16.19	4.50	0.00	0.01	5.22	7.00	1.00	0.50	15.74	2.50	47.33	0.00	0.5971	1100.02
NP2-21	18.00	4.50	4.00	0.20	5.80	7.00	0.00	5.50	18.00	0.00	35.00	2.00	0.4930	949.21
NP2-22	13.97	4.50	0.02	0.02	7.09	4.87	0.00	1.58	18.00	0.20	47.75	2.00	0.5990	885.89
NP2-23	12.28	4.50	4.00	0.20	7.22	4.00	1.50	1.19	18.00	0.17	44.94	2.00	0.5975	947.99
NP2-24	14.06	7.04	1.51	0.00	16.15	6.16	0.31	0.90	12.31	0.01	39.55	2.00	0.5999	1093.48
NP2-25	12.33	8.36	1.58	0.09	9.87	5.33	0.55	2.48	15.26	0.69	42.16	1.30	0.6044	982.67

2.2 Glass Fabrication

Each of the study glasses was prepared from the proper proportions of reagent-grade metal oxides, carbonates, and boric acid in 150 g batches.[15] The raw materials were thoroughly mixed and placed into platinum/gold, 250 ml crucibles. The batch was placed into a high-temperature furnace at the target melt temperature of 1150°C.[16] The crucible was removed from the furnace after an isothermal hold at the melt temperature for 1 hour. The glass was poured onto a clean, stainless steel plate and allowed to air cool (quench). The glass pour patty was used as a sampling stock for the various property measurements, including chemical composition and durability testing.

Approximately 25 g of each glass was heat-treated to simulate cooling along the centerline of a DWPF-type canister[17] to gauge the effects of thermal history on the product performance. This cooling schedule is referred to as the centerline canister cooling (CCC) curve. Visual observations of both quenched and CCC glasses were documented.

2.3 Property Measurements

This section provides a general discussion of the chemical composition, crystallization and durability analyses of the study glasses.

2.3.1 *Compositional Analysis*

To confirm that the as-fabricated glasses met the target compositions, a representative sample from each quenched glass was submitted to the SRNL Process Science Analytical Laboratory (PSAL) for chemical analysis under the auspices of an analytical plan.[18] The plan identified the cations to be analyzed and the two dissolution techniques, sodium peroxide fusion (PF) and lithium-metaborate fusion (LM), to be used. Each glass was prepared in duplicate for each of the two cation dissolution techniques. All of the prepared samples were analyzed twice for each element of interest by Inductively Coupled Plasma – Atomic Emission Spectroscopy (ICP-AES), with the instrumentation being re-calibrated between the duplicate analyses. The analytical plan was developed in such a way as to provide the opportunity to evaluate potential sources of bias and error. Glass standards were also intermittently measured to assess the performance of the ICP-AES instrument over the course of these analyses.

2.3.2 *X-Ray Diffraction Analysis*

Representative samples of each quenched and CCC glass were submitted to SRNL Analytical Development (AD) for X-ray diffraction (XRD) analysis. Samples were run under conditions providing a detection limit of approximately 0.5 vol %. That is, if crystals (or undissolved batch material) were present at 0.5 vol % or greater, the diffractometer would not only be capable of detecting the crystals but would also allow a qualitative determination of the type of crystal(s) present. Otherwise, a characteristically high background signal (amorphous hump) devoid of crystalline spectral peaks indicates that the glass product is free of crystallization, suggesting either a completely amorphous product or that the degree of crystallization is below the detection limit.

2.3.3 *Product Consistency Test*

The PCT Method-A[19] was performed in triplicate on each quenched and CCC glass to assess chemical durability. Also included in the experimental test matrix was the EA benchmark glass,[20] the Approved Reference Material (ARM) glass, and blanks from the sample cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.[19] Fifteen milliliters of Type-I ASTM water were added to 1.5 g of glass in stainless steel vessels. The

vessels were closed, sealed, and placed in an oven at 90 ± 2 °C where the samples were maintained at temperature for 7 days. Once cooled, the resulting solutions were sampled (filtered and acidified), then labeled and analyzed by PSAL under the auspices of an analytical plan.[21] The aim of the plan was to provide an opportunity to assess the consistency (repeatability) of the PCT and analytical procedures in evaluating the chemical durability of the glasses. Normalized release rates were calculated based on target, measured, and bias-corrected (bc) compositions using the average of the common logarithms of the leachate concentrations.

3.0 Results and Discussion

3.1 A Statistical Review of the Chemical Composition Measurements

In this section, the measured versus targeted compositions of the 25 glasses supporting Phase II of the Nepheline Study are presented and compared. The identifiers and targeted compositions for these glasses are provided in Table A1 of Appendix A, as well as in Table 2-2.

Table A2 in Appendix A provides the elemental concentration measurements from both analytical sets derived from the samples prepared using LM, and Table A3 in Appendix A provides the measurements from both sets derived from the samples prepared using PF. Measurements for samples of the standard (Batch 1) that were included in the PSAL analytical plans along with the study 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 PSAL was reduced to half of that detection limit as the oxide concentration was determined.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the standards are investigated and used for bias correction, the measurements for each glass are reviewed, the average chemical compositions (measured and bias-corrected) for each glass are determined, and comparisons are made between the measurements and the targeted compositions of the glasses.

3.1.1 *Measurements in Analytical Sequence*

Exhibit A1 in Appendix A provides plots of the measurements generated by the PSAL for samples by preparation method (i.e., LM and PF). The plots are in analytical sequence over the two sets of measurements with different symbols and colors being used to represent each of the study and standard glasses. These plots include all of the measurement data from Tables A2 and A3. While looking for patterns in these plots is difficult, there do not appear to be any gross patterns or trends in the analytical process over the course of these measurements. A better opportunity for a review of the measurements for each glass is provided in the discussions that follow.

3.1.2 *Composition Measurements by Glass Identifier*

Exhibit A2 in Appendix A provides plots of the oxide concentration measurements by Glass ID (including Batch 1) by analytical solution or Lab ID for the LM and PF preparation methods, respectively. Different symbols and colors are used to represent the different glasses. These plots show the individual measurements across the duplicates of each preparation method and the two instrument calibrations within each analytical set. A review of the plots presented in these exhibits reveals the repeatability of the four individual values for each oxide for each glass. A further review of these plots suggests that:

- There is one CaO value (Lab ID Y11LM12) for glass NP2-02 that appears to be much higher than the other CaO measurements for this study glass.
- There is a great deal of scatter in the Na_2O values for glasses NP2-03 and NP2-07.
- There is also a great deal of scatter in the SiO_2 measurements for several of the study glasses. More will be said regarding some of these observations in the discussions below.

3.1.3 *Batch 1 Standard Results*

In this section, the PSAL measurements of the chemical compositions of the Batch 1 samples are reviewed. The measurements are investigated across the analytical blocks over the two sets of analyses for each of the preparation methods.

Exhibit A3 in Appendix A provides statistical analyses of these Batch 1 results generated for each oxide of interest for each prep method. The results include analysis of variance (ANOVA) investigations looking for statistically significant differences between the means of these groups for each of the oxides. The results from the statistical tests for the Batch 1 standard may be summarized as follows: for the LM prep, Al_2O_3, Cr_2O_3, Fe_2O_3, MgO, MnO, Na_2O, and NiO have measurements that indicate a significant instrument calibration effect on the block averages at the 5% significance level and for the PF prep, Li_2O and SiO_2 have measurements that indicate a significant instrument calibration effect on the block averages at the 5% significance level. The reference values for the oxide concentrations of the standard are given in the header for each set of measurements in the exhibit.

Thus, some of the results from the statistical analyses of the Batch 1 measurements provide incentive for adjusting the measurements by the effects of the instrument calibration. Therefore, the oxide measurements of the study glasses were bias corrected for the effect of the instrument calibration on each of the analytical blocks and sub-blocks. The basis for this bias correction is presented as part of Exhibit A3 – the average measurement for Batch 1 for each block/sub-block for Al_2O_3, B_2O_3, CaO, Cr_2O_3, Fe_2O_3, Li_2O, MgO, MnO, Na_2O, NiO, SiO_2, and TiO_2.

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, and let t_i be the reference value for the i^{th} oxide for Batch 1. (The averages and reference values are provided in Exhibits A3 and A4.) 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. Both measured and measured "bc" values are included in the discussions that follow.

3.1.4 *Composition Measurements by Glass Identifier with Targeted Compositions*

To gain insight into the measurements of the compositions of the study glasses, Exhibit A4 in Appendix A was prepared. The exhibit provides plots of the oxide concentration measurements by Glass ID (including Batch 1) by oxide. The plots show the individual measurements across the duplicates of each preparation method and the replicate instrument calibrations. The targeted concentration for each of the oxides for each of the study glasses and the reference values for the standards are also provided as part of these exhibits. The plots presented in these exhibits reveal the repeatability of the individual, oxide values for each glass as well as how close the measured values fell to the targeted or reference concentrations. The major conclusion from a review of these plots is that glasses NP2-14 and NP2-15 were unintentionally exchanged prior to their being submitted for chemical analysis and durability testing. In the subsequent analyses, the measurements are corrected for this problem.

3.1.5 *Measured versus Targeted Compositions*

The measurements for each oxide for each glass were averaged to determine a representative chemical composition for each glass. These determinations were conducted both for the measured and for the bias-corrected data. A sum of oxides was also computed for each glass based upon both the measured and bias-corrected values. Exhibit A5 in Appendix A provides plots showing results for each glass for each oxide to help highlight the comparisons among the measured, bias-corrected, and targeted values. Upon a review of the plots of Exhibit A5, there appear to have been very few difficulties in meeting the targeted compositions for the study glasses.

Table A4 in Appendix A 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 Batch 1 do not sum to 100% due to an incomplete coverage of the oxides in the Batch 1 glasses. All of the sums of oxides (both measured and bias-corrected) for the study glasses fall within the interval of 95 to 105 wt%. Entries in Table A4 show the relative differences between the measured or bias-corrected values and the targeted values. These differences are shaded when they are greater than or equal to 5%. Overall, these comparisons between the measured and targeted compositions suggest only minor difficulties in meeting the targeted compositions for some of the oxides for some of the glasses, none of which are expected to impact the outcome of the study.

3.2 Crystallization

Visual observations were recorded for each glass after melting and quenching, and also after completion of the CCC heat treatment. The surface of the glass pour patty and the glass remaining in the crucible were observed for the quenched glasses. Both the surface and a cross-sectional fracture surface (described as 'bulk') were observed for the CCC versions of the glasses. In describing the appearance of the glasses, terms such as black and shiny, clean, or homogeneous indicate that the glass was free of any visible crystallization. Terms such as milky, silvery, dull or hazy are used to describe crystallization visible on the surface of the glasses. The visual observations for all of the glasses are summarized in Table 3-1.

Any crystalline phases identified by XRD are also listed in Table 3-1. Glasses that were found to contain nepheline, or crystalline phases that are expected to have an impact on durability similar to that of nepheline, are highlighted in the table. The significance of these crystalline phases will be discussed further in the following sections.

Table 3-1. Summary of the Visual Observations and XRD Results for the Nepheline Phase II Glasses.

Glass ID	Heat Treatment	Visual Observations	XRD Phase Identification
NP2-01	quenched	patty: black and shiny, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	milky haze on surface, bulk clean	amorphous
NP2-02	quenched	patty: dark brown and shiny, clean, homogeneous; crucible: clean	amorphous
	CCC	surface and bulk both clean	amorphous
NP2-03	quenched	patty: black and shiny, clean; crucible: clean with air bubbles	amorphous
	CCC	milky haze on surface, crystals along melt line, bulk clean	Lithium silicate [Li_2SiO_3], Sodium aluminum silicate [$Na_{1.15}Al_{1.15}Si_{0.85}O_4$]
NP2-04	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	surface and bulk clean	amorphous
NP2-05	quenched	patty: tiny silver streaks on surface; crucible: small spots of undissolved material	amorphous
	CCC	milky haze with crystals on surface, crystals in bulk	Magnetite [$Fe^{+2}Fe_2^{+3}O_4$]
NP2-06	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	golden/ bronze crystals across surface; bulk devitrified	Trevorite [$NiFe_2O_4$], Nepheline [$NaAlSiO_4$]
NP2-07	quenched	patty: black and shiny, clean; crucible: tiny spots of undissolved material	amorphous
	CCC	crystals across surface and throughout bulk	Magnetite [$Fe^{+2}Fe_2^{+3}O_4$], Trevorite [$NiFe_2O_4$], Hematite [Fe_2O_3]
NP2-08	quenched	patty: black and shiny, clean, homogeneous, very fluid; crucible: clean	amorphous
	CCC	surface and bulk clean	amorphous
NP2-09	quenched	patty: milky haze on surface, bulk clean; crucible: clean with air bubbles	amorphous
	CCC	silvery haze with crystals across surface, crystals in bulk	Trevorite [$NiFe_2O_4$]

Table 3-1. Summary of the Visual Observations and XRD Results for the Nepheline Phase II Glasses. (continued)

Glass ID	Heat Treatment	Visual Observations	XRD Phase Identification
NP2-10	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	gold splotches across surface, bottom and sides golden/ copper colored, bulk clean	amorphous
NP2-11	quenched	patty: black and shiny, clean, homogeneous, very fluid; crucible: clean with air bubbles	amorphous
	CCC	dull matte, crusty, crystals across surface (1/8 inch thick layer across top, bottom, sides), middle layer (1/4 inch) black, shiny and glassy	Nepheline [$NaAlSiO_4$]
NP2-12	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	dull matte surface, surface and bottom dark brown, middle (bulk) reddish-brown color and devitrified	Bunsenite [NiO], Lithium silicate [Li_2SiO_3]
NP2-13	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	swirls of crystals on surface, bulk appeared devitrified	Jacobsite [$MnFe_2O_4$]
NP2-14	quenched	patty: dark brown with lighter chocolate brown streaks across surface, bulk crystallized chocolate brown; crucible: spots of undissolved material, air bubbles	Bunsenite [NiO]
	CCC	crusty, dull matte surface, crystals in bulk	Trevorite [$NiFe_2O_4$], Bunsenite [NiO], Nepheline [$NaAlSiO_4$]
NP2-15	quenched	patty: black and shiny, bulk possibly devitrified; crucible: clean with air bubbles	amorphous
	CCC	shiny surface with spots of silver material, bulk clean	Nepheline [$NaAlSiO_4$]
NP2-16	quenched	patty: black and shiny, clean, homogeneous; crucible: clean	amorphous
	CCC	dull matte surface, crusty surface and bottom, bulk devitrified	Nepheline [$NaAlSiO_4$], Hematite [Fe_2O_3], Magnetite [$Fe^{+2}Fe_2^{+3}O_4$], Lithium silicate [Li_2SiO_3]

Table 3-1. Summary of the Visual Observations and XRD Results for the Nepheline Phase II Glasses. (continued)

Glass ID	Heat Treatment	Visual Observations	XRD Phase Identification
NP2-17	quenched	patty: extremely fluid, silver with chocolate brown swirls on surface, bulk possibly devitrified; crucible: clean	amorphous
	CCC	surface crystallized with splotches of crystals, crystals in bulk	Magnetite [$Fe^{+2}Fe_2^{+3}O_4$]
NP2-18	quenched	patty: black and shiny, clean, homogeneous; crucible: clean	amorphous
	CCC	surface matte and crystallized, bottom crusty, glassy center with silver crystals in bulk layer	Lithium silicate [Li_2SiO_3], Nepheline [$NaAlSiO_4$], Bunsenite [NiO]
NP2-19	quenched	patty: chocolate brown with silver/ purple swirls on surface, bulk possible devitrified	Magnetite [$Fe^{+2}Fe_2^{+3}O_4$]
	CCC	shiny surface with crystals, bulk crystallized	Magnetite [$Fe^{+2}Fe_2^{+3}O_4$]
NP2-20	quenched	patty: small amount of silver crystals on surface, bulk clean; crucible: clean with air bubbles	amorphous
	CCC	dull matte, crystallized crusty surface and bottom, center layer glassy with silver bubbles	Lithium silicate [Li_2SiO_3], Nepheline [$NaAlSiO_4$]
NP2-21	quenched	patty: dull silvery surface, chocolate brown bulk, possible devitrified; crucible: chocolate brown with air bubbles	Sodium aluminum silicate [$Na_{1.55}Al_{1.55}Si_{0.45}O_4$], Lithium Nickel Oxide [$Li_{0.301}Ni_{1.699}O_2$]
	CCC	surface dull matte/ crystallized, bright red color, bulk devitrified	Nepheline [$NaAlSiO_4$], Gregoryte [Na_2CO_3], Lithium Iron Oxide [$LiFeO_2$], Lithium silicate [Li_2SiO_3]
NP2-22	quenched	patty: clean; crucible: clean with air bubbles	amorphous
	CCC	dull haze across surface with patches of crystals, bulk clean	Nepheline [$NaAlSiO_4$]
NP2-23	quenched	patty: black and shiny, clean, homogeneous; crucible: clean with air bubbles	amorphous
	CCC	dull haze across surface with patches of crystals, bulk clean	Nepheline [$NaAlSiO_4$]
NP2-24	quenched	patty: black and shiny, clean, homogeneous; crucible: small spots of undissolved material	amorphous
	CCC	dull matte across surface, bulk devitrified	Nepheline [$NaAlSiO_4$], Magnetite [$Fe^{+2}Fe_2^{+3}O_4$], Trevorite [$NiFe_2O_4$]

Table 3-1. Summary of the Visual Observations and XRD Results for the Nepheline Phase II Glasses. (continued)

Glass ID	Heat Treatment	Visual Observations	XRD Phase Identification
NP2-25	quenched	patty: black and shiny, clean, homogeneous; crucible: clean	amorphous
	CCC	dull haze across surface with patches of crystals, bulk clean	amorphous

In general, the visual observations indicate that the amount of crystallization increased as the nepheline discriminator value of the glasses decreased. In some cases (e.g., the quenched versions of NP2-15, NP2-17, etc.), crystallization was noted during visual observation of the glasses but not identified by XRD. This is likely due to the volume fraction of crystallization being lower than what was detectible via XRD.

Nepheline or other crystalline phases that are expected to have the same impact on durability as nepheline (e.g., sodium aluminum silicate [$Na_{1.15}Al_{1.15}Si_{0.85}O_4$]), were detected in several of the glasses and are highlighted in Table 3-1. Several of the other crystalline phases detected, such as trevorite and magnetite, have been shown to have little impact on the durability of DWPF-type glasses[22] and are not of concern to this study. Further discussion on the glasses that contained nepheline will be provided below in combination with the PCT results.

3.3 A Statistical Review of the PCT Results

Table B1 in Appendix B provides the elemental leachate concentration measurements determined by the PSAL for the solution samples generated by the PCTs. One of the quality control checkpoints for the PCT procedure is solution weight-loss over the course of the 7-day test. None of these PCT results indicated a solution weight-loss problem. Any measurement in Table B1 below the detection limit of the analytical procedure (indicated by a "<") was replaced by one half of the detection limit in subsequent analyses. In addition to adjustments for detection limits, the values were adjusted for the dilution factors: the values for the study glasses, the blanks, and the ARM glass in Table B1 were multiplied by 1.6667 to determine the values in parts per million (ppm) and the values for EA were multiplied by 16.6667. Table B2 in Appendix B provides the resulting measurements.

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 measurement process, the measurements for each glass are reviewed, plots are provided that explore the effects of heat treatment on the PCT results for these glasses, the PCT results are normalized using the compositions (targeted, measured, and bias-corrected) presented in Table A4, and the normalized PCT results are compared to durability predictions for these compositions generated from the current DWPF models.[23]

3.3.1 *Measurements in Analytical Sequence*

Exhibit B1 in Appendix B provides plots of the leachate concentrations in analytical sequence as generated by the PSAL for all of the data and for the data from only the study glasses. A different color and symbol are used for each study glass or standard. No problems are seen in these plots.

3.3.2 *Results for the Samples of the Multi-Element Solution Standard*

Exhibit B2 in Appendix B provides analyses of the PSAL measurements of the samples of the multi-element solution standard by analytical set and instrument calibration block. An ANOVA investigating for statistically significant differences among the block averages for these samples for each element of interest is included in this exhibit. There was no indication of a statistically significant (at a 5% level) difference among the averages of these measurements for any of the elements of interest except for Si. However, averaging the ppm values for each set of triplicates helps to minimize the impact of any potential instrument calibration effects.

Table 3-2 summarizes the average measurements and the reference values for the four elements of interest. The results indicate consistent and accurate measurements from the PSAL processes used to conduct these analyses.

Table 3-2. Results from Samples of the Multi-Element Solution Standard

Analytical Set	Analytical Block	Avg B (ppm)	Avg Li (ppm)	Avg Na (ppm)	Avg Si (ppm)
1	1	21.3	9.9	83.3	46.0
1	2	22.3	10.0	80.0	51.1
1	3	21.7	10.0	80.6	50.5
2	1	20.6	9.6	80.0	48.9
2	2	20.8	9.9	80.6	50.1
2	3	21.4	9.9	81.2	50.0
	Grand Average	21.3	9.9	80.9	49.4
	Reference Value	20	10	81	50
	% difference	6.67%	-1.18%	-0.07%	-1.16%

3.3.3 *Measurements by Glass Identifier*

Exhibit B3 in Appendix B provides plots of the leachate concentrations for each type of submitted sample: the study glasses by heat treatment and the standards (EA, ARM, the multi-element solution standard, and blanks). These plots allow for an assessment of the repeatability of the measurements, which suggests some scatter in the triplicate values for some analytes for some of the glasses. Also, note the large differences between the values for the two heat treatments for some of the study glasses. More will be said regarding comparisons between the heat treatments in the discussions that follow. The average measurements for the ARM glass fall within the control chart values.[23]

3.3.4 *Normalized PCT Results*

PCT leachate concentrations are normalized using the cation concentration in the glass. 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 were also used to conduct this normalization.

One additional point of concern was the PCT responses for NP2-14 and NP2-15. Since it was determined earlier that the glasses had been switched prior to the measurement of their chemical composition, a question arose regarding whether the glasses had been switched prior to glass samples being submitted for PCTs. Remaining samples of the glasses, both quenched and CCC, were submitted to PSAL for a compositional analysis. Table 3-3 provides the results from some key analytes. The results indicate that the glasses were also switched prior to their being sampled for PCT analyses. Therefore, as the normalization process was conducted the PCT responses were corrected for NP2-14 and NP2-15.

Table 3-3. Additional Measurements (wt %) of Glass Samples Used for PCTs.

Sample ID	Al_2O_3	B_2O_3	CaO	Fe_2O_3	Li_2O	SiO_2
NP2-14	18.7	13.9	0.0	4.40	4.09	35.3
NP2-14 CCC	18.7	13.8	0.0	4.78	4.15	35.7
NP2-15	13.2	8.77	1.67	8.94	3.61	34.9
NP2-15 CCC	13.3	8.76	1.72	8.94	3.59	35.3

As is the usual convention, the common logarithm of the normalized PCT (normalized leachate, NL) for each element of interest was 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 B2 of Appendix B),

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 B4 in Appendix B provides scatter plots for these results and offers an opportunity to investigate the consistency in the leaching across the elements for the glasses of this study. All combinations of the normalizations of the PCTs (i.e., those generated using the targeted, measured, and bias-corrected compositional views) and both heat treatments are represented in the series of scatter plots. Consistency in the leaching across the elements is typically demonstrated by a high degree of linear correlation among the values for pairs of these elements. The smallest correlation in this plot is that for Li and Si, with a value of ~89%, indicating relatively good correlation.

Table 3-4 summarizes the normalized PCTs for the study glasses. The quenched version of each of the study glasses had an NL [B] value below that of the EA benchmark glass (16.695 g/L).[20] However, several of the CCC glasses had NL [B] values that were greater than that of the EA glass. This response can be related to crystallization that occurred during the CCC heat treatment, as will be discussed in the following sections.

Table 3-4. Normalized PCT Results for the Study Glasses.

Glass ID	Heat Treatment	Compositional View	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	reference	-0.3022	-0.2561	-0.3329	-0.5688	0.499	0.554	0.465	0.270
ARM	ref	reference	-0.3022	-0.2561	-0.3329	-0.5688	0.499	0.554	0.465	0.270
EA	ref	reference	1.2864	0.9910	1.1529	0.6019	19.339	9.795	14.219	3.999
EA	ref	reference	1.2864	0.9910	1.1529	0.6019	19.339	9.795	14.219	3.999
NP2-01	CCC	targeted	-0.3154	-0.3504	-0.5666	-0.6988	0.484	0.446	0.271	0.200
NP2-02	CCC	targeted	0.7213	0.6132	0.5274	-0.0937	5.263	4.104	3.369	0.806
NP2-03	CCC	targeted	0.7406	0.5843	0.5060	0.1739	5.503	3.839	3.206	1.492
NP2-04	CCC	targeted	-0.3060	-0.2962	-0.3812	-0.6599	0.494	0.506	0.416	0.219
NP2-05	CCC	targeted	0.1123	0.0515	0.0819	-0.1552	1.295	1.126	1.207	0.700
NP2-06	CCC	targeted	1.7529	1.5090	1.4108	0.9150	56.606	32.288	25.753	8.222
NP2-07	CCC	targeted	-0.0758	-0.1051	-0.1665	-0.3676	0.840	0.785	0.682	0.429
NP2-08	CCC	targeted	0.5526	0.4901	0.4247	-0.0291	3.570	3.091	2.659	0.935
NP2-09	CCC	targeted	0.2577	0.3009	0.2888	-0.0302	1.810	2.000	1.944	0.933
NP2-10	CCC	targeted	-0.0115	-0.0587	-0.1286	-0.3267	0.974	0.874	0.744	0.471
NP2-11	CCC	targeted	1.8174	1.6689	1.2887	0.3840	65.674	46.657	19.442	2.421
NP2-12	CCC	targeted	0.3440	0.3551	0.2977	0.0735	2.208	2.265	1.985	1.184
NP2-13	CCC	targeted	-0.2767	-0.1833	-0.4269	-0.4312	0.529	0.656	0.374	0.371
NP2-14	CCC	targeted	0.5757	0.4959	0.1456	-0.2649	3.764	3.133	1.398	0.543
NP2-15	CCC	targeted	1.2350	1.1131	0.8544	-0.0022	17.178	12.975	7.152	0.995
NP2-16	CCC	targeted	1.2984	1.0222	0.8172	0.3784	19.880	10.525	6.564	2.390
NP2-17	CCC	targeted	0.5325	0.5123	0.4799	-0.0088	3.408	3.253	3.019	0.980
NP2-18	CCC	targeted	1.2131	0.7840	0.7368	0.3003	16.333	6.081	5.456	1.996
NP2-19	CCC	targeted	0.3450	0.2624	0.2912	0.0181	2.213	1.830	1.955	1.042
NP2-20	CCC	targeted	1.3886	0.9219	0.7669	0.3825	24.468	8.353	5.847	2.413
NP2-21	CCC	targeted	0.5497	0.6264	0.8373	0.0611	3.545	4.231	6.875	1.151
NP2-22	CCC	targeted	0.3077	0.2647	0.1481	-0.0751	2.031	1.840	1.406	0.841
NP2-23	CCC	targeted	-0.0880	0.0123	0.0523	-0.3575	0.817	1.029	1.128	0.439
NP2-24	CCC	targeted	0.8731	0.7205	0.3893	0.1516	7.466	5.254	2.451	1.418
NP2-25	CCC	targeted	0.0351	-0.0115	-0.0192	-0.2716	1.084	0.974	0.957	0.535
NP2-01	quenched	targeted	-0.5089	-0.3290	-0.5669	-0.6894	0.310	0.469	0.271	0.204
NP2-02	quenched	targeted	0.7941	0.6872	0.6271	-0.0641	6.224	4.866	4.238	0.863
NP2-03	quenched	targeted	0.1368	0.0733	0.1763	-0.0941	1.370	1.184	1.501	0.805
NP2-04	quenched	targeted	-0.3130	-0.2814	-0.3807	-0.6460	0.486	0.523	0.416	0.226

Table 3-4. Normalized PCT Results for the Study Glasses. (continued)

Glass ID	Heat Treatment	Compositional View	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)
NP2-05	quenched	targeted	0.1575	0.0043	0.0687	-0.2012	1.437	1.010	1.171	0.629
NP2-06	quenched	targeted	0.2199	0.1799	0.2665	-0.1380	1.659	1.513	1.847	0.728
NP2-07	quenched	targeted	-0.1130	-0.1203	-0.1873	-0.3887	0.771	0.758	0.650	0.409
NP2-08	quenched	targeted	0.6180	0.5595	0.5014	0.0567	4.150	3.626	3.172	1.139
NP2-09	quenched	targeted	0.6735	0.4855	0.6025	0.1256	4.715	3.059	4.004	1.335
NP2-10	quenched	targeted	-0.1673	-0.1711	-0.1786	-0.3687	0.680	0.674	0.663	0.428
NP2-11	quenched	targeted	0.5928	0.4853	0.3710	-0.1065	3.916	3.057	2.350	0.783
NP2-12	quenched	targeted	0.2380	0.1054	0.2635	-0.0529	1.730	1.275	1.835	0.885
NP2-13	quenched	targeted	-0.2596	-0.1634	-0.4391	-0.4854	0.550	0.686	0.364	0.327
NP2-14	quenched	targeted	-0.3168	-0.2458	-0.3017	-0.4683	0.482	0.568	0.499	0.340
NP2-15	quenched	targeted	0.2128	0.0764	0.0920	-0.3583	1.632	1.192	1.236	0.438
NP2-16	quenched	targeted	-0.1091	-0.1517	-0.0962	-0.3704	0.778	0.705	0.801	0.426
NP2-17	quenched	targeted	0.6139	0.5475	0.5623	0.0249	4.110	3.527	3.650	1.059
NP2-18	quenched	targeted	0.0349	0.0326	0.2052	-0.1009	1.084	1.078	1.604	0.793
NP2-19	quenched	targeted	0.0890	0.0222	0.1365	-0.1629	1.227	1.052	1.369	0.687
NP2-20	quenched	targeted	-0.1427	-0.1504	0.0135	-0.2557	0.720	0.707	1.032	0.555
NP2-21	quenched	targeted	0.6674	0.3302	0.7600	0.0468	4.650	2.139	5.754	1.114
NP2-22	quenched	targeted	-0.2169	-0.2187	0.0122	-0.2915	0.607	0.604	1.028	0.511
NP2-23	quenched	targeted	-0.1292	-0.1018	0.0644	-0.3711	0.743	0.791	1.160	0.425
NP2-24	quenched	targeted	-0.0289	-0.0538	-0.0833	-0.2892	0.936	0.883	0.826	0.514
NP2-25	quenched	targeted	-0.1081	-0.1522	-0.0585	-0.3183	0.780	0.704	0.874	0.480
NP2-01	CCC	measured	-0.3123	-0.3513	-0.5567	-0.6789	0.487	0.445	0.278	0.209
NP2-02	CCC	measured	0.7223	0.6069	0.5424	-0.0863	5.276	4.045	3.487	0.820
NP2-03	CCC	measured	0.7288	0.5848	0.5047	0.1747	5.355	3.844	3.197	1.495
NP2-04	CCC	measured	-0.2896	-0.2934	-0.3687	-0.6509	0.513	0.509	0.428	0.223
NP2-05	CCC	measured	0.0986	0.0525	0.0814	-0.1599	1.255	1.129	1.206	0.692
NP2-06	CCC	measured	1.7384	1.5071	1.4175	0.9153	54.748	32.145	26.151	8.228
NP2-07	CCC	measured	-0.0658	-0.1080	-0.2127	-0.3612	0.859	0.780	0.613	0.435
NP2-08	CCC	measured	0.5499	0.4876	0.4366	-0.0370	3.548	3.073	2.733	0.918
NP2-09	CCC	measured	0.2431	0.3109	0.2854	-0.0194	1.750	2.046	1.929	0.956
NP2-10	CCC	measured	-0.0075	-0.0588	-0.1254	-0.3256	0.983	0.873	0.749	0.472
NP2-11	CCC	measured	1.8314	1.6716	1.3042	0.3843	67.826	46.947	20.146	2.423
NP2-12	CCC	measured	0.3497	0.3647	0.3085	0.0959	2.237	2.316	2.035	1.247
NP2-13	CCC	measured	-0.2604	-0.1761	-0.4289	-0.4192	0.549	0.667	0.373	0.381

Table 3-4. Normalized PCT Results for the Study Glasses. (continued)

Glass ID	Heat Treatment	Compositional View	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)
NP2-14	CCC	measured	0.5834	0.5014	0.1497	-0.2612	3.831	3.172	1.412	0.548
NP2-15	CCC	measured	1.2542	1.1203	0.8644	-0.0085	17.954	13.191	7.318	0.981
NP2-16	CCC	measured	1.3182	1.0200	0.8259	0.3823	20.807	10.471	6.698	2.412
NP2-17	CCC	measured	0.5497	0.5257	0.4894	0.0008	3.545	3.355	3.086	1.002
NP2-18	CCC	measured	1.2248	0.7940	0.7453	0.3077	16.779	6.222	5.562	2.031
NP2-19	CCC	measured	0.3369	0.2619	0.2971	0.0213	2.172	1.828	1.982	1.050
NP2-20	CCC	measured	1.3786	0.9274	0.7717	0.3974	23.913	8.461	5.911	2.497
NP2-21	CCC	measured	0.5512	0.6412	0.8472	0.0762	3.558	4.377	7.035	1.192
NP2-22	CCC	measured	0.3275	0.2622	0.1614	-0.0712	2.126	1.829	1.450	0.849
NP2-23	CCC	measured	-0.0769	0.0141	0.0639	-0.3501	0.838	1.033	1.158	0.447
NP2-24	CCC	measured	0.8789	0.7245	0.3951	0.1578	7.566	5.303	2.484	1.438
NP2-25	CCC	measured	0.0378	-0.0030	-0.0117	-0.2591	1.091	0.993	0.974	0.551
NP2-01	quenched	measured	-0.5057	-0.3299	-0.5570	-0.6695	0.312	0.468	0.277	0.214
NP2-02	quenched	measured	0.7951	0.6809	0.6421	-0.0567	6.239	4.796	4.386	0.878
NP2-03	quenched	measured	0.1249	0.0738	0.1750	-0.0932	1.333	1.185	1.496	0.807
NP2-04	quenched	measured	-0.2965	-0.2785	-0.3682	-0.6370	0.505	0.527	0.428	0.231
NP2-05	quenched	measured	0.1438	0.0053	0.0683	-0.2059	1.392	1.012	1.170	0.622
NP2-06	quenched	measured	0.2054	0.1780	0.2731	-0.1377	1.605	1.507	1.876	0.728
NP2-07	quenched	measured	-0.1030	-0.1232	-0.2336	-0.3823	0.789	0.753	0.584	0.415
NP2-08	quenched	measured	0.6153	0.5570	0.5133	0.0488	4.124	3.606	3.261	1.119
NP2-09	quenched	measured	0.6589	0.4956	0.5992	0.1363	4.559	3.130	3.974	1.369
NP2-10	quenched	measured	-0.1634	-0.1713	-0.1754	-0.3676	0.686	0.674	0.668	0.429
NP2-11	quenched	measured	0.6068	0.4880	0.3865	-0.1062	4.044	3.076	2.435	0.783
NP2-12	quenched	measured	0.2437	0.1150	0.2744	-0.0305	1.753	1.303	1.881	0.932
NP2-13	quenched	measured	-0.2433	-0.1562	-0.4411	-0.4735	0.571	0.698	0.362	0.336
NP2-14	quenched	measured	-0.3091	-0.2404	-0.2975	-0.4647	0.491	0.575	0.504	0.343
NP2-15	quenched	measured	0.2320	0.0836	0.1020	-0.3646	1.706	1.212	1.265	0.432
NP2-16	quenched	measured	-0.0893	-0.1539	-0.0874	-0.3666	0.814	0.702	0.818	0.430
NP2-17	quenched	measured	0.6310	0.5609	0.5718	0.0346	4.275	3.638	3.731	1.083
NP2-18	quenched	measured	0.0466	0.0426	0.2137	-0.0935	1.113	1.103	1.636	0.806
NP2-19	quenched	measured	0.0809	0.0217	0.1425	-0.1596	1.205	1.051	1.388	0.692
NP2-20	quenched	measured	-0.1527	-0.1448	0.0182	-0.2407	0.704	0.716	1.043	0.574
NP2-21	quenched	measured	0.6690	0.3450	0.7699	0.0619	4.667	2.213	5.888	1.153
NP2-22	quenched	measured	-0.1971	-0.2212	0.0255	-0.2877	0.635	0.601	1.060	0.516

Table 3-4. Normalized PCT Results for the Study Glasses. (continued)

Glass ID	Heat Treatment	Compositional View	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)
NP2-23	quenched	measured	-0.1181	-0.0999	0.0761	-0.3637	0.762	0.795	1.191	0.433
NP2-24	quenched	measured	-0.0231	-0.0498	-0.0774	-0.2830	0.948	0.892	0.837	0.521
NP2-25	quenched	measured	-0.1053	-0.1436	-0.0510	-0.3059	0.785	0.718	0.889	0.494
NP2-01	CCC	measured bc	-0.3105	-0.3500	-0.5784	-0.6890	0.489	0.447	0.264	0.205
NP2-02	CCC	measured bc	0.7278	0.6096	0.5207	-0.0918	5.344	4.070	3.317	0.810
NP2-03	CCC	measured bc	0.7344	0.5875	0.4830	0.1693	5.425	3.868	3.041	1.477
NP2-04	CCC	measured bc	-0.2878	-0.2921	-0.3904	-0.6610	0.515	0.510	0.407	0.218
NP2-05	CCC	measured bc	0.1044	0.0552	0.0706	-0.1652	1.272	1.135	1.176	0.684
NP2-06	CCC	measured bc	1.7439	1.5098	1.4067	0.9098	55.450	32.345	25.508	8.125
NP2-07	CCC	measured bc	-0.0641	-0.1067	-0.2236	-0.3713	0.863	0.782	0.598	0.425
NP2-08	CCC	measured bc	0.5555	0.4903	0.4149	-0.0424	3.593	3.093	2.600	0.907
NP2-09	CCC	measured bc	0.2448	0.3122	0.2746	-0.0296	1.757	2.052	1.882	0.934
NP2-10	CCC	measured bc	-0.0021	-0.0562	-0.1362	-0.3311	0.995	0.879	0.731	0.467
NP2-11	CCC	measured bc	1.8331	1.6729	1.2825	0.3741	68.097	47.082	19.164	2.367
NP2-12	CCC	measured bc	0.3515	0.3660	0.2977	0.0858	2.246	2.323	1.984	1.218
NP2-13	CCC	measured bc	-0.2586	-0.1748	-0.4397	-0.4294	0.551	0.669	0.363	0.372
NP2-14	CCC	measured bc	0.5849	0.4931	0.1428	-0.2806	3.845	3.112	1.389	0.524
NP2-15	CCC	measured bc	1.2559	1.1120	0.8575	-0.0280	18.027	12.942	7.202	0.938
NP2-16	CCC	measured bc	1.3103	1.0146	0.8190	0.3687	20.431	10.341	6.592	2.337
NP2-17	CCC	measured bc	0.5417	0.5203	0.4854	-0.0128	3.481	3.314	3.057	0.971
NP2-18	CCC	measured bc	1.2168	0.7885	0.7384	0.2941	16.476	6.145	5.475	1.968
NP2-19	CCC	measured bc	0.3386	0.2536	0.2931	0.0019	2.181	1.793	1.964	1.004
NP2-20	CCC	measured bc	1.3807	0.9191	0.7647	0.3780	24.027	8.301	5.818	2.388
NP2-21	CCC	measured bc	0.5531	0.6329	0.8403	0.0568	3.574	4.295	6.923	1.140
NP2-22	CCC	measured bc	0.3196	0.2568	0.1573	-0.0848	2.087	1.806	1.437	0.823
NP2-23	CCC	measured bc	-0.0849	0.0087	0.0598	-0.3637	0.822	1.020	1.148	0.433
NP2-24	CCC	measured bc	0.8709	0.7191	0.3911	0.1441	7.429	5.237	2.461	1.394
NP2-25	CCC	measured bc	0.0395	-0.0113	-0.0157	-0.2785	1.095	0.974	0.964	0.527
NP2-01	quenched	measured bc	-0.5040	-0.3286	-0.5787	-0.6797	0.313	0.469	0.264	0.209
NP2-02	quenched	measured bc	0.8007	0.6836	0.6204	-0.0621	6.319	4.826	4.173	0.867
NP2-03	quenched	measured bc	0.1306	0.0765	0.1533	-0.0986	1.351	1.193	1.423	0.797
NP2-04	quenched	measured bc	-0.2948	-0.2773	-0.3899	-0.6471	0.507	0.528	0.407	0.225
NP2-05	quenched	measured bc	0.1496	0.0080	0.0574	-0.2113	1.411	1.019	1.141	0.615
NP2-06	quenched	measured bc	0.2109	0.1807	0.2623	-0.1431	1.625	1.516	1.830	0.719

Table 3-4. Normalized PCT Results for the Study Glasses. (continued)

Glass ID	Heat Treatment	Compositional View	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)
NP2-07	quenched	measured bc	-0.1013	-0.1219	-0.2444	-0.3924	0.792	0.755	0.570	0.405
NP2-08	quenched	measured bc	0.6209	0.5597	0.4917	0.0434	4.177	3.628	3.102	1.105
NP2-09	quenched	measured bc	0.6606	0.4969	0.5884	0.1262	4.577	3.139	3.876	1.337
NP2-10	quenched	measured bc	-0.1580	-0.1686	-0.1862	-0.3731	0.695	0.678	0.651	0.424
NP2-11	quenched	measured bc	0.6086	0.4893	0.3648	-0.1164	4.060	3.085	2.316	0.765
NP2-12	quenched	measured bc	0.2454	0.1163	0.2635	-0.0407	1.760	1.307	1.835	0.911
NP2-13	quenched	measured bc	-0.2415	-0.1550	-0.4520	-0.4836	0.573	0.700	0.353	0.328
NP2-14	quenched	measured bc	-0.3076	-0.2487	-0.3045	-0.4841	0.493	0.564	0.496	0.328
NP2-15	quenched	measured bc	0.2338	0.0753	0.0951	-0.3841	1.713	1.189	1.245	0.413
NP2-16	quenched	measured bc	-0.0973	-0.1593	-0.0943	-0.3802	0.799	0.693	0.805	0.417
NP2-17	quenched	measured bc	0.6230	0.5554	0.5678	0.0209	4.198	3.593	3.696	1.049
NP2-18	quenched	measured bc	0.0387	0.0372	0.2067	-0.1071	1.093	1.089	1.610	0.781
NP2-19	quenched	measured bc	0.0826	0.0134	0.1384	-0.1790	1.209	1.031	1.375	0.662
NP2-20	quenched	measured bc	-0.1507	-0.1531	0.0113	-0.2602	0.707	0.703	1.026	0.549
NP2-21	quenched	measured bc	0.6709	0.3367	0.7630	0.0424	4.687	2.171	5.795	1.103
NP2-22	quenched	measured bc	-0.2050	-0.2266	0.0215	-0.3013	0.624	0.593	1.051	0.500
NP2-23	quenched	measured bc	-0.1261	-0.1053	0.0720	-0.3773	0.748	0.785	1.180	0.419
NP2-24	quenched	measured bc	-0.0311	-0.0553	-0.0815	-0.2966	0.931	0.881	0.829	0.505
NP2-25	quenched	measured bc	-0.1036	-0.1519	-0.0550	-0.3253	0.788	0.705	0.881	0.473

3.3.5 *Effect of Heat Treatment on PCTs*

Exhibit B5 in Appendix B provides a series of plots and statistical comparisons that show the effects of heat treatment on the responses of interest of the triplicate PCTs for each element for each study glass. The CCC version of a given glass yielded measurements indicating a significantly (at the 5% significance level) different mean response as compared to the quenched version of the glass for a given element if the **Prob>|t|** value in the exhibit is 0.05 or smaller. Table 3-5 provides a summary of these statistical evaluations, and these results indicate that the CCC versions of the glasses often led to statistically poorer PCT responses.

Table 3-5. Indicated Heat Treatment had a Statistically Larger Mean

Glass ID	NL [B]	NL [Li]	NL [Na]	NL [Si]
NP2-01				
NP2-02	Q	Q	Q	Q
NP2-03	CCC	CCC	CCC	CCC
NP2-04				
NP2-05		CCC	CCC	
NP2-06	CCC	CCC	CCC	CCC
NP2-07				
NP2-08	Q	Q	Q	Q
NP2-09	Q	Q	Q	Q
NP2-10	CCC	CCC	CCC	
NP2-11	CCC	CCC	CCC	CCC
NP2-12		CCC	CCC	CCC
NP2-13		Q		
NP2-14	CCC	CCC	CCC	CCC
NP2-15	CCC	CCC	CCC	CCC
NP2-16	CCC	CCC	CCC	CCC
NP2-17			Q	
NP2-18	CCC	CCC	CCC	CCC
NP2-19	CCC	CCC	CCC	CCC
NP2-20	CCC	CCC	CCC	CCC
NP2-21	Q	Q	Q	
NP2-22	CCC	CCC	CCC	CCC
NP2-23		CCC		
NP2-24	CCC	CCC	CCC	CCC
NP2-25	CCC	CCC		

Exhibit B6 in Appendix B provides a series of plots that show the effects of heat treatment on the normalized PCT response for each of the study glasses (as well as ARM and EA) over all three compositional views: measured, measured bias-corrected, and targeted. These plots allow for an assessment of the differences in PCT responses from a practical perspective, and they show some significant differences due to heat treatment.

3.4 Composition – Property Relationships

Some insight into the composition dependent crystallization behavior of the study glasses can be gained by plotting the XRD results as a function of the location of each glass composition on the Al_2O_3-Na_2O-SiO_2 ternary diagram. Figure 3-1 shows the crystallization data for the quenched glasses plotted on the ternary diagram. The closed circles represent glass compositions that were amorphous by XRD, the open circles represent glass compositions where transition metal oxides or spinels were detected by XRD, and the crossed lines represent a glass composition where nepheline was detected by XRD. Only one of the quenched glasses was found to contain nepheline (NP2-21). This glass has a nepheline discriminator value of 0.49, which falls far below the current limit of 0.62. The data suggest that, for the range of compositions studied here, access to higher concentrations of Al_2O_3 in glass is possible without the formation of nepheline as long as the cooling rate is relatively rapid.

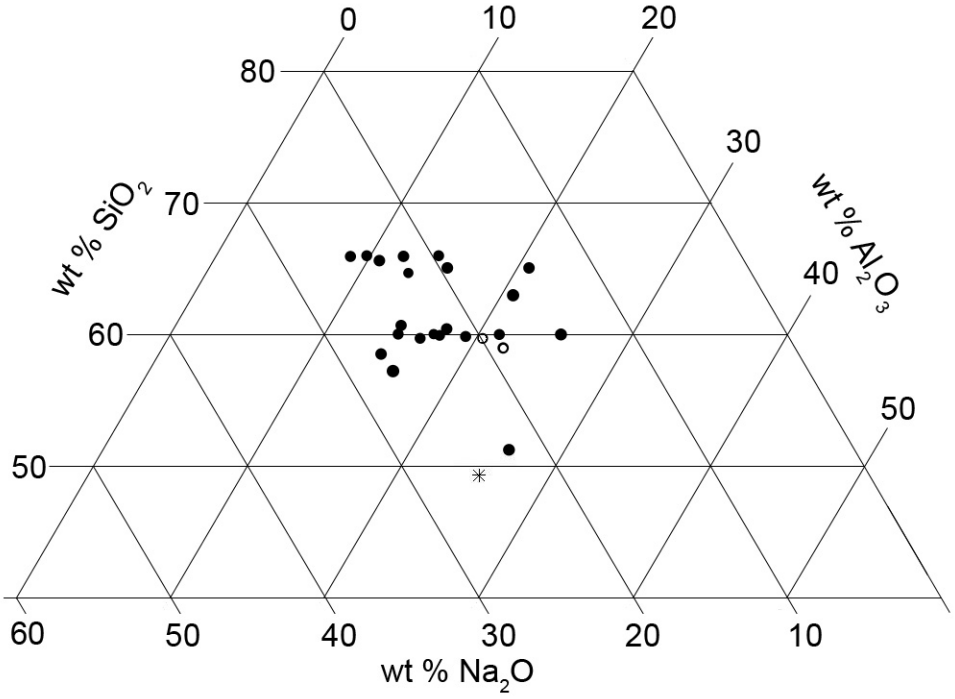

Figure 3-1. Portion of the Al_2O_3-Na_2O-SiO_2 ternary diagram showing the locations of the quenched study glasses and the types of crystallization that were identified by XRD.

Nepheline crystallization occurred in several of the glasses after they were subjected to the CCC heat treatment. Figure 3-2 shows the crystallization data for the quenched glasses plotted on the Al_2O_3-Na_2O-SiO_2 ternary diagram. The closed circles represent glass compositions that were amorphous by XRD, the open circles represent glass compositions where transition metal oxides or spinels were detected by XRD, and the crossed lines represent glass compositions where nepheline or a similarly detrimental crystalline phase (e.g., Li_2SiO_3) was detected by XRD.

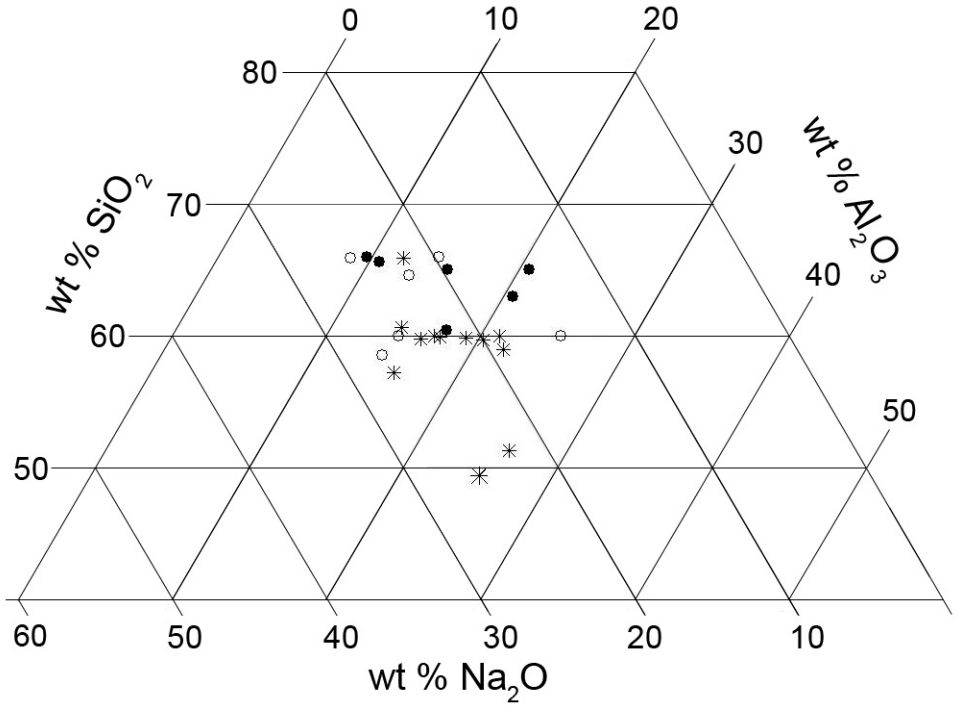

Figure 3-2. Portion of the Al_2O_3-Na_2O-SiO_2 ternary diagram showing the locations of the CCC study glasses and the types of crystallization that were identified by XRD.

For the most part, the CCC glasses that fall below the 0.62 nepheline discriminator value contained nepheline. Also notable is that one glass composition, NP2-03, contained nepheline even though its nepheline discriminator value is 0.66. This may indicate some lack of conservatism for the current nepheline discriminator in this particular composition region. It may be possible that glass compositions closer to the Al_2O_3 corner of the ternary diagram can remain free of nepheline after the CCC heat treatment (for example, the open circle at 60 wt % SiO_2 and 25 wt % Al_2O_3), although additional data are needed.

A second method of identifying compositional trends leading to each type of crystallization in the slowly cooled glasses was attempted, which involved using the partitioning function available in JMP™ statistical analysis software.[14] For this method, the types of crystallization identified in the CCC glasses were split into three groups: amorphous, nepheline and spinel. The XRD results and the measured bc composition data were fed into the JMP™ algorithm which partitioned the glasses based on the oxide components that were calculated to have the largest impact on crystallization behavior. The results of this process are given in Figure 3-3.

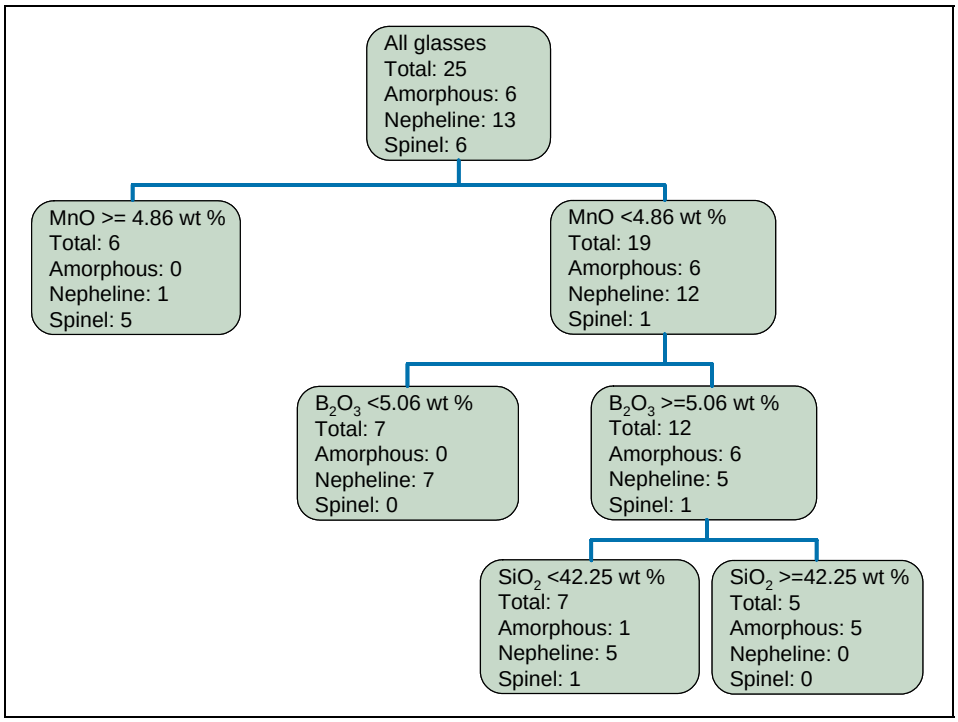

Figure 3-3. Partitioning of the crystallization behavior of the CCC glasses based on measured compositions.

The partitioning algorithm first split the glasses into two groups based on their concentrations of MnO. Glasses with MnO concentrations greater than or equal to 4.86 wt % typically contained spinels (with one exception). For the glasses with less than 4.86 wt % MnO, the partitioning next identified B_2O_3 concentration as a factor in crystallization, with those glasses containing less than 5.06 wt % B_2O_3 crystallizing nepheline. Finally, for the glasses with B_2O_3 concentrations greater than or equal to 5.06 wt %, SiO_2 concentration was the next partitioning step. Glasses with less than 42.25 wt % SiO_2 were generally prone to nepheline crystallization, while the glasses with SiO_2 concentrations greater than or equal to 42.25 wt % were amorphous. These results appear reasonable in that MnO is typically a component of the spinels that form in HLW glasses, B_2O_3 has been seen to hinder nepheline crystallization in previous studies, and higher SiO_2 concentrations increase the value of the nepheline discriminator.

4.0 Conclusions

Twenty five glass compositions were selected for a Phase II study on reduction of conservatism in the nepheline discriminator. The glass compositions were restricted to regions that fell within the validation ranges of the DWPF PCCS models. The glasses were fabricated in the laboratory and characterized for crystallization and chemical durability after both quenching and slow cooling.

Chemical analysis showed that the fabricated glasses met the target compositions. Nepheline was identified in one of the quenched glasses and several of the CCC glasses. There was no clear relationship between the types of crystallization that occurred in a particular glass and its location on the Al_2O_3-Na_2O-SiO_2 ternary diagram. A partitioning algorithm was used to identify trends in crystallization behavior based on glass composition. Generally, for the slowly cooled glasses MnO influenced the crystallization of spinels and B_2O_3 and SiO_2 influenced the crystallization of nepheline. Durability responses varied from acceptable to unacceptable depending on the glass composition and type and extent of crystallization that occurred. It was not possible to identify any linear effects of composition on chemical durability performance for this set of study glasses. The results were not sufficient to recommend modification of the current nepheline discriminator at this time.

It is recommended that the next series of experiments continue to focus not only on compositional regions where the PCCS models are considered applicable (i.e., the model validation ranges), but also be restricted to compositional regions where acceptable glasses are predicted to be produced but are disallowed by the current nepheline discriminator. This may help identify a path for gaining access to glass compositions that are limited by only the nepheline constraint. Dependencies on cooling rates should also be evaluated. A better understanding of these regions, as well as the impacts of B_2O_3 and CaO on nepheline crystallization, may allow for relaxation or refinement of the nepheline constraint and subsequently allow for higher Al_2O_3 concentrations.

5.0 References

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Appendix A

Tables and Exhibits Supporting the Analysis of the Chemical Composition Measurements of the Nepheline Phase II Study Glasses

Table A1. Targeted Oxide Concentrations (wt%) for the Nepheline Phase 2 Study Glasses.

Glass ID	Al_2O_3	B_2O_3	CaO	Cr_2O_3	Fe_2O_3	Li_2O	MgO	MnO	Na_2O	NiO	SiO_2	TiO_2
NP2-01	16.400	5.100	2.330	0.000	5.000	4.410	0.000	3.290	11.230	0.840	51.400	0.000
NP2-02	7.220	14.000	0.000	0.200	5.000	4.000	0.000	0.620	18.000	0.000	48.960	2.000
NP2-03	8.370	4.700	0.180	0.200	14.820	7.000	0.150	1.870	15.120	0.200	45.390	2.000
NP2-04	14.180	12.340	4.000	0.200	5.610	4.930	1.500	0.500	11.150	0.440	43.140	2.000
NP2-05	8.730	4.500	0.130	0.020	15.360	4.440	1.500	5.500	14.780	0.080	42.960	2.000
NP2-06	10.570	4.500	4.000	0.000	18.010	4.260	0.000	0.500	18.000	0.000	38.160	2.000
NP2-07	9.020	12.050	0.270	0.090	15.140	4.400	0.330	1.740	12.260	1.390	41.310	2.000
NP2-08	6.970	13.320	4.000	0.000	5.000	7.000	0.000	3.620	15.380	0.000	42.700	2.000
NP2-09	5.520	5.900	4.000	0.200	13.810	4.880	0.960	4.800	16.120	1.980	41.830	0.000
NP2-10	10.650	10.170	0.950	0.000	13.640	5.160	0.680	0.500	13.430	0.000	44.820	0.000
NP2-11	18.000	14.000	0.000	0.200	5.850	6.970	0.000	4.650	15.330	0.000	35.000	0.000
NP2-12	10.640	6.680	0.830	0.020	6.170	7.000	1.500	0.500	18.000	2.500	44.150	2.000
NP2-13	17.270	14.000	0.000	0.200	5.000	4.000	1.500	5.500	10.000	0.000	40.900	1.630
NP2-14	15.580	10.930	1.790	0.180	11.490	4.360	0.000	0.500	13.320	0.330	41.530	0.000
NP2-15	18.000	14.000	0.000	0.000	5.000	4.000	1.500	0.500	18.000	2.500	35.000	1.500
NP2-16	13.610	5.190	1.970	0.000	14.700	4.000	0.320	2.860	14.820	0.170	42.360	0.000
NP2-17	8.620	14.000	4.000	0.000	6.670	7.000	0.000	5.500	14.710	2.500	35.000	2.000
NP2-18	12.850	4.970	0.000	0.000	11.040	7.000	0.490	1.410	17.180	0.000	45.050	0.000
NP2-19	9.300	5.270	0.000	0.200	18.100	4.000	0.000	5.500	17.390	0.640	37.610	2.000
NP2-20	16.190	4.500	0.000	0.010	5.220	7.000	1.000	0.500	15.740	2.500	47.330	0.000
NP2-21	18.000	4.500	4.000	0.200	5.800	7.000	0.000	5.500	18.000	0.000	35.000	2.000
NP2-22	13.970	4.500	0.020	0.020	7.090	4.870	0.000	1.580	18.000	0.200	47.750	2.000
NP2-23	12.280	4.500	4.000	0.200	7.220	4.000	1.500	1.190	18.000	0.170	44.940	2.000
NP2-24	14.060	7.040	1.510	0.000	16.150	6.160	0.310	0.900	12.310	0.010	39.550	2.000
NP2-25	12.330	8.360	1.580	0.090	9.870	5.330	0.550	2.480	15.260	0.690	42.160	1.300

Table A2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate.

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Fe (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	Ti (wt%)
1	Batch 1	1	1	1	BCHLM11 11	2.45	0.818	0.075	8.67	0.827	1.31	6.49	0.559	0.393
1	NP2-13	1	1	2	Y08LM21	9.1	0.015	0.106	3.24	0.86	4.28	7.37	<0.010	0.931
1	NP2-05	1	1	3	Y09LM11	4.58	0.108	0.019	10.1	0.852	4.28	10.9	0.056	1.19
1	NP2-10	1	1	4	Y07LM11	5.64	0.631	<0.010	9.29	0.409	0.389	9.95	<0.010	<0.010
1	NP2-07	1	1	5	Y12LM12	4.7	0.197	0.05	9.96	0.198	1.37	9.05	0.926	1.2
1	NP2-05	1	1	6	Y09LM21	4.62	0.107	0.019	10.1	0.868	4.3	10.9	0.057	1.2
1	NP2-09	1	1	7	Y06LM11	2.97	3	0.12	9.19	0.559	3.76	12.1	1.39	<0.010
1	NP2-06	1	1	8	Y04LM21	5.53	2.98	<0.010	12.3	<0.010	0.396	13.3	<0.010	1.22
1	Batch 1	1	1	9	BCHLM1112	2.48	0.805	0.074	8.68	0.815	1.31	6.61	0.553	0.387
1	NP2-09	1	1	10	Y06LM21	2.97	3	0.119	9.09	0.553	3.73	12.1	1.38	<0.010
1	NP2-07	1	1	11	Y12LM11	5.58	0.242	0.051	10.1	0.223	1.38	11.2	0.899	1.2
1	NP2-06	1	1	12	Y04LM11	5.51	2.93	<0.010	12.2	<0.010	0.401	13.1	<0.010	1.21
1	NP2-10	1	1	13	Y07LM21	5.64	0.622	<0.010	9.25	0.407	0.385	9.92	<0.010	<0.010
1	NP2-12	1	1	14	Y03LM11	5.57	0.545	0.024	4.39	0.871	0.388	13	1.9	1.19
1	NP2-12	1	1	15	Y03LM21	5.59	0.571	0.021	4.2	0.877	0.389	13.1	1.84	1.2
1	NP2-13	1	1	16	Y08LM11	9.17	0.019	0.106	3.28	0.854	4.33	7.46	<0.010	0.925
1	Batch 1	1	1	17	BCHLM1113	2.49	0.811	0.074	8.71	0.818	1.31	6.64	0.554	0.389
1	Batch 1	1	2	1	BCHLM1121	2.41	0.799	0.072	8.65	0.812	1.31	6.29	0.551	0.387
1	NP2-10	1	2	2	Y07LM22	5.57	0.624	<0.010	9.24	0.408	0.388	9.69	<0.010	<0.010
1	NP2-06	1	2	3	Y04LM22	5.46	2.9	<0.010	12.3	<0.010	0.393	13	<0.010	1.21
1	NP2-12	1	2	4	Y03LM22	5.57	0.569	0.02	4.24	0.887	0.394	13	1.86	1.21
1	NP2-09	1	2	5	Y06LM12	3	2.99	0.119	9.28	0.558	3.79	12	1.41	<0.010
1	NP2-05	1	2	6	Y09LM12	4.68	0.106	0.018	10.3	0.859	4.35	11	0.056	1.21
1	NP2-09	1	2	7	Y06LM22	2.98	2.99	0.119	9.17	0.558	3.76	12	1.4	<0.010
1	NP2-05	1	2	8	Y09LM22	4.72	0.107	0.019	10.2	0.876	4.36	11.1	0.057	1.22
1	Batch 1	1	2	9	BCHLM1122	2.47	0.813	0.073	8.75	0.811	1.33	6.53	0.551	0.389
1	NP2-12	1	2	10	Y03LM12	5.58	0.547	0.023	4.43	0.87	0.39	13	1.92	1.21
1	NP2-13	1	2	11	Y08LM12	9.17	0.017	0.105	3.3	0.851	4.36	7.46	<0.010	0.927
1	NP2-07	1	2	12	Y12LM12	5.64	0.24	0.049	10.2	0.223	1.41	11.2	0.898	1.21
1	NP2-06	1	2	13	Y04LM12	5.6	2.93	<0.010	12.4	<0.010	0.404	13.2	<0.010	1.23
1	NP2-13	1	2	14	Y08LM22	9.31	0.014	0.106	3.32	0.865	4.4	7.52	<0.010	0.944
1	NP2-10	1	2	15	Y07LM12	5.7	0.625	<0.010	9.36	0.409	0.388	10	<0.010	<0.010
1	NP2-07	1	2	16	Y12LM22	4.7	0.194	0.049	9.97	0.198	1.38	9.02	0.923	1.2
1	Batch 1	1	2	17	BCHLM1123	2.47	0.809	0.073	8.72	0.821	1.32	6.53	0.554	0.39
1	Batch 1	2	1	1	BCHLM1211	2.39	0.796	0.073	8.59	0.816	1.32	6.3	0.549	0.387
1	NP2-01	2	1	2	Y05LM11	8.58	1.65	0.01	3.37	<0.010	2.65	8.19	0.633	<0.010
1	NP2-02	2	1	3	Y11LM11	3.81	0.011	0.122	3.41	<0.010	0.476	13	<0.010	1.2
1	NP2-04	2	1	4	Y01LM21	7.4	2.88	0.114	3.78	0.879	0.389	8.08	0.328	1.19

Table A2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate. (continued)

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Fe (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	Ti (wt%)
1	NP2-04	2	1	5	Y01LM11	7.48	2.94	0.115	3.83	0.881	0.387	8.12	0.326	1.2
1	NP2-11	2	1	6	Y02LM11	9.28	0.013	0.131	4.09	<0.010	3.64	11	<0.010	<0.010
1	NP2-03	2	1	7	Y10LM11	4.34	0.129	0.131	9.74	0.089	1.49	10.7	0.136	1.19
1	NP2-02	2	1	8	Y11LM21	3.78	0.011	0.121	3.39	<0.010	0.473	12.8	<0.010	1.18
1	Batch 1	2	1	9	BCHLM1212	2.43	0.806	0.073	8.75	0.821	1.34	6.36	0.549	0.391
1	NP2-03	2	1	10	Y10LM12	4.8	0.128	0.131	9.87	0.091	1.5	11.8	0.137	1.21
1	NP2-01	2	1	11	Y05LM21	8.56	1.65	0.01	3.38	<0.010	2.67	8.16	0.636	<0.010
1	NP2-11	2	1	12	Y02LM21	9.33	0.012	0.131	4	<0.010	3.65	11.1	<0.010	<0.010
1	NP2-08	2	1	13	Y13LM11	3.69	2.91	<0.010	3.63	<0.010	2.9	11.2	<0.010	1.22
1	NP2-08	2	1	14	Y13LM21	3.72	2.96	<0.010	3.48	<0.010	2.91	11.3	<0.010	1.22
1	Batch 1	2	1	15	BCHLM1213	2.45	0.86	0.073	8.75	0.821	1.34	6.46	0.549	0.405
1	Batch 1	2	2	1	BCHLM1221	2.43	0.797	0.074	8.55	0.814	1.3	6.34	0.549	0.386
1	NP2-01	2	2	2	Y05LM22	8.48	1.67	0.01	3.34	<0.010	2.61	8.13	0.64	<0.010
1	NP2-08	2	2	3	Y13LM12	3.62	2.9	<0.010	3.57	<0.010	2.82	10.9	<0.010	1.19
1	NP2-11	2	2	4	Y02LM12	9.18	0.014	0.131	4.04	<0.010	3.55	10.9	<0.010	<0.010
1	NP2-03	2	2	5	Y10LM12	4.34	0.129	0.131	9.65	0.089	1.46	10.9	0.136	1.19
1	NP2-03	2	2	6	Y10LM22	4.7	0.129	0.132	9.69	0.092	1.46	11.6	0.137	1.19
1	NP2-02	2	2	7	Y11LM22	3.75	0.011	0.121	3.36	<0.010	0.475	12.8	<0.010	1.18
1	NP2-08	2	2	8	Y13LM22	3.64	2.93	<0.010	3.44	<0.010	2.84	11	<0.010	1.2
1	Batch 1	2	2	9	BCHLM1222	2.39	0.801	0.073	8.57	0.813	1.3	6.29	0.551	0.389
1	NP2-01	2	2	10	Y05LM12	8.47	1.65	0.01	3.35	<0.010	2.63	8.09	0.631	<0.010
1	NP2-02	2	2	11	Y11LM12	3.8	0.801	0.12	3.38	<0.010	0.472	13	<0.010	1.19
1	NP2-04	2	2	12	Y01LM22	7.21	2.83	0.112	3.71	0.861	0.381	7.93	0.321	1.17
1	NP2-04	2	2	13	Y01LM12	7.3	2.91	0.114	3.76	0.866	0.384	8.02	0.322	1.19
1	NP2-11	2	2	14	Y02LM22	9.15	0.013	0.129	3.94	<0.010	3.57	10.9	<0.010	<0.010
1	Batch 1	2	2	15	BCHLM1123	2.43	0.851	0.073	8.63	0.807	1.31	6.37	0.545	0.386
2	Batch 1	1	1	1	BCHLM2111	2.41	0.814	0.075	8.7	0.816	1.32	6.63	0.553	0.389
2	NP2-19	1	1	2	Z02LM11	4.86	0.018	0.112	12	<0.010	4.3	12.6	0.399	1.21
2	NP2-22	1	1	3	Z05LM11	7.28	0.021	0.021	4.84	<0.010	1.27	12.8	0.149	1.21
2	NP2-25	1	1	4	Z08LM21	6.56	1.14	0.062	6.79	0.335	2.04	11.2	0.493	0.737
2	NP2-22	1	1	5	Z05LM21	7.2	0.021	0.02	4.8	<0.010	1.27	12.8	0.148	1.2
2	NP2-24	1	1	6	Z10LM21	7.44	0.982	<0.010	11	0.194	0.723	9.02	<0.010	1.22
2	NP2-23	1	1	7	Z09LM11	6.54	2.89	0.116	4.96	0.858	0.95	13.1	0.123	1.22
2	Batch 1	1	1	8	BCHLM2112	2.47	0.817	0.076	8.75	0.831	1.33	6.51	0.56	0.388
2	NP2-17	1	1	9	Z03LM21	4.49	2.86	<0.010	4.59	<0.010	4.26	10.7	1.85	1.21
2	NP2-25	1	1	10	Z08LM11	6.5	1.13	0.063	6.69	0.34	2.01	11.1	0.504	0.742
2	NP2-24	1	1	11	Z10LM11	7.39	1.06	<0.010	11	0.201	0.719	8.97	<0.010	1.23
2	NP2-17	1	1	12	Z03LM11	4.51	2.87	<0.010	4.63	<0.010	4.32	10.6	1.86	1.21
2	NP2-23	1	1	13	Z09LM21	6.42	2.84	0.118	4.9	0.875	0.94	12.9	0.129	1.21

Table A2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate. (continued)

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Fe (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	Ti (wt%)
2	NP2-19	1	1	14	Z02LM21	4.99	0.017	0.12	12.3	<0.010	4.42	12.8	0.427	1.24
2	Batch 1	1	1	15	BCHLM2113	2.53	0.826	0.077	8.99	0.834	1.37	6.64	0.566	0.391
2	Batch 1	1	2	1	BCHLM2121	2.52	0.809	0.075	8.91	0.823	1.36	6.64	0.551	0.388
2	NP2-23	1	2	2	Z09LM12	6.53	2.91	0.115	4.95	0.852	0.946	13.2	0.123	1.21
2	NP2-22	1	2	3	Z05LM12	7.35	0.019	0.021	4.8	<0.010	1.26	13.1	0.149	1.2
2	NP2-17	1	2	4	Z03LM22	4.53	2.92	<0.010	4.56	<0.010	4.27	10.7	1.84	1.19
2	NP2-24	1	2	5	Z10LM22	7.44	1.09	<0.010	10.9	0.196	0.711	9.03	<0.010	1.21
2	NP2-23	1	2	6	Z09LM22	6.38	2.88	0.118	4.81	0.877	0.919	12.8	0.127	1.18
2	NP2-17	1	2	7	Z03LM12	4.53	2.93	<0.010	4.53	<0.010	4.24	10.7	1.82	1.19
2	Batch 1	1	2	8	BCHLM2122	2.5	0.803	0.076	8.81	0.826	1.34	6.59	0.558	0.393
2	NP2-25	1	2	9	Z08LM12	6.49	1.15	0.063	6.6	0.336	1.98	11.2	0.495	0.743
2	NP2-19	1	2	10	Z02LM22	4.92	0.015	0.119	12.1	<0.010	4.33	12.7	0.424	1.2
2	NP2-24	1	2	11	Z10LM12	7.38	1.07	<0.010	10.9	0.198	0.708	9.02	0.008	1.2
2	NP2-25	1	2	12	Z08LM22	6.46	1.14	0.061	6.56	0.331	1.97	11	0.486	0.733
2	NP2-22	1	2	13	Z05LM22	7.38	0.02	0.02	4.76	<0.010	1.25	13.1	0.148	1.19
2	NP2-19	1	2	14	Z02LM12	4.94	0.016	0.112	11.9	<0.010	4.28	12.8	0.399	1.2
2	Batch 1	1	2	15	BCHLM2123	2.54	0.805	0.076	8.89	0.83	1.36	6.69	0.556	0.392
2	Batch 1	2	1	1	BCHLM22 11	2.52	0.807	0.074	8.93	0.814	1.36	6.62	0.544	0.387
2	NP2-14	2	1	2	Z06LM11	9.47	0.011	<0.010	3.35	0.835	0.38	13.2	1.76	0.833
2	NP2-15	2	1	3	Z07LM11	8.19	1.27	0.086	7.55	<0.010	0.372	9.79	0.236	<0.010
2	NP2-18	2	1	4	Z11LM21	6.8	0.01	<0.010	7.59	0.305	1.11	12.8	<0.010	<0.010
2	NP2-18	2	1	5	Z11LM11	6.68	<0.010	<0.010	7.49	0.298	1.09	12.5	<0.010	<0.010
2	NP2-14	2	1	6	Z06LM21	9.52	<0.010	<0.010	3.38	0.848	0.381	13.4	1.78	0.851
2	NP2-16	2	1	7	Z12LM21	7.15	1.41	<0.010	9.97	0.187	2.31	10.9	<0.010	<0.010
2	Batch 1	2	1	8	BCHLM2212	2.48	0.795	0.074	8.76	0.813	1.33	6.51	0.543	0.382
2	NP2-21	2	1	9	Z04LM21	9.52	2.88	0.126	4.06	<0.010	4.35	13.3	0.018	1.21
2	NP2-21	2	1	10	Z04LM11	9.47	2.86	0.125	4	<0.010	4.32	13.1	<0.010	1.2
2	NP2-16	2	1	11	Z12LM11	7.38	1.46	<0.010	10.2	0.193	2.37	11.2	<0.010	<0.010
2	NP2-15	2	1	12	Z07LM21	8.41	1.3	0.087	7.77	<0.010	0.384	10.1	0.252	<0.010
2	NP2-20	2	1	13	Z01LM11	8.72	0.03	0.012	3.63	0.574	0.38	11.8	1.84	<0.010
2	NP2-20	2	1	14	Z01LM21	8.75	0.014	0.013	3.65	0.589	0.383	11.8	1.86	<0.010
2	Batch 1	2	1	15	BCHLM2213	2.47	0.795	0.075	8.76	0.819	1.33	6.58	0.547	0.368
2	Batch 1	2	2	1	BCHLM2221	2.55	0.806	0.075	8.86	0.817	1.36	6.67	0.549	0.388
2	NP2-14	2	2	2	Z06LM12	9.29	0.01	<0.010	3.32	0.83	0.392	12.9	1.76	0.84
2	NP2-21	2	2	3	Z04LM22	9.39	2.87	0.127	4	<0.010	4.28	12.9	0.018	1.2
2	NP2-18	2	2	4	Z11LM12	6.65	<0.010	<0.010	7.5	0.303	1.11	12.5	<0.010	<0.010
2	NP2-21	2	2	5	Z04LM12	9.3	2.84	0.125	3.92	<0.010	4.25	12.9	<0.010	1.19
2	NP2-18	2	2	6	Z11LM22	6.61	0.01	<0.010	7.53	0.301	1.11	12.2	<0.010	<0.010
2	NP2-15	2	2	7	Z07LM12	8	1.27	0.084	7.52	<0.010	0.385	9.53	0.231	<0.010

Table A2. Measured Elemental Concentrations (wt%) for Samples Prepared Using Lithium Metaborate. (continued)

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	Al (wt%)	Ca (wt%)	Cr (wt%)	Fe (wt%)	Mg (wt%)	Mn (wt%)	Na (wt%)	Ni (wt%)	Ti (wt%)
2	Batch 1	2	2	8	BCHLM2222	2.51	0.809	0.074	8.89	0.813	1.36	6.57	0.546	0.388
2	NP2-20	2	2	9	Z01LM22	8.38	0.013	0.012	3.57	0.587	0.388	11.3	1.84	<0.010
2	NP2-14	2	2	10	Z06LM22	9.18	<0.010	<0.010	3.33	0.857	0.39	12.7	1.75	0.867
2	NP2-16	2	2	11	Z12LM12	6.92	1.38	<0.010	9.86	0.191	2.29	10.4	0.012	<0.010
2	NP2-16	2	2	12	Z12LM22	7.03	1.42	<0.010	9.9	0.186	2.31	10.6	<0.010	<0.010
2	NP2-20	2	2	13	Z01LM12	8.39	0.029	0.011	3.57	0.569	0.386	11.3	1.83	<0.010
2	NP2-15	2	2	14	Z07LM22	8.17	1.29	0.085	7.68	<0.010	0.393	9.73	0.25	<0.010
2	Batch 1	2	2	15	BCHLM2223	2.49	0.806	0.074	8.83	0.819	1.35	6.49	0.545	0.389

Table A3. Measured Elemental Concentrations (wt%) for Samples Prepared Using Peroxide Fusion.

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Li (wt%)	Si (wt%)
1	Batch 1	1	1	1	BCHPF11 11	2.44	2.06	23.3
1	NP2-01	1	1	2	Y05PF21	1.58	2.07	23.1
1	NP2-04	1	1	3	Y01PF11	3.71	2.31	19.7
1	NP2-13	1	1	4	Y08PF11	4.08	1.81	18
1	NP2-12	1	1	5	Y03PF11	2.01	3.17	19.2
1	NP2-04	1	1	6	Y01PF21	3.61	2.28	19.3
1	NP2-09	1	1	7	Y06PF11	1.91	2.28	19.4
1	NP2-13	1	1	8	Y08PF21	4.23	1.88	18.8
1	Batch 1	1	1	9	BCHPF1112	2.43	2.11	22.8
1	NP2-09	1	1	10	Y06PF21	1.91	2.21	18.5
1	NP2-01	1	1	11	Y05PF11	1.55	2.08	22.2
1	NP2-07	1	1	12	Y12PF21	3.61	2.08	18.5
1	NP2-11	1	1	13	Y02PF11	4.22	3.22	16.4
1	NP2-12	1	1	14	Y03PF21	2.1	3.21	19.8
1	NP2-11	1	1	15	Y02PF21	4.27	3.26	16.5
1	NP2-07	1	1	16	Y12PF11	3.64	2.09	18.9
1	Batch 1	1	1	17	BCHPF1113	2.39	2.1	22.5
1	Batch 1	1	2	1	BCHPF1121	2.51	2.05	23.1
1	NP2-09	1	2	2	Y06PF12	1.89	2.24	19.5
1	NP2-07	1	2	3	Y12PF12	3.73	2.06	19.6
1	NP2-11	1	2	4	Y02PF12	4.17	3.2	16.2
1	NP2-12	1	2	5	Y03PF22	2.02	3.16	19.4
1	NP2-11	1	2	6	Y02PF22	4.18	3.19	16.3
1	NP2-09	1	2	7	Y06PF22	1.87	2.13	18.9
1	NP2-13	1	2	8	Y08PF22	4.2	1.82	18.8
1	Batch 1	1	2	9	BCHPF1122	2.39	2.02	22.8
1	NP2-01	1	2	10	Y05PF12	1.62	2.06	23.6
1	NP2-07	1	2	11	Y12PF22	3.65	2	19.1
1	NP2-01	1	2	12	Y05PF22	1.54	2	22.9
1	NP2-04	1	2	13	Y01PF12	3.69	2.24	19.8
1	NP2-13	1	2	14	Y08PF12	4.24	1.8	18.8
1	NP2-04	1	2	15	Y01PF22	3.75	2.27	20.2
1	NP2-12	1	2	16	Y03PF12	2.06	3.18	20
1	Batch 1	1	2	17	BCHPF1123	2.39	2.04	23.1
1	Batch 1	2	1	1	BCHPF1211	2.54	2.1	23.2
1	NP2-06	2	1	2	Y04PF21	1.47	1.99	17.7
1	NP2-02	2	1	3	Y11PF11	4.31	1.89	22.2
1	NP2-08	2	1	4	Y13PF11	4.11	3.24	19.9
1	NP2-06	2	1	5	Y04PF11	1.44	1.97	17.6
1	NP2-10	2	1	6	Y07PF21	3.06	2.39	20.5
1	NP2-03	2	1	7	Y10PF21	1.5	3.23	20.9
1	NP2-10	2	1	8	Y07PF11	3.14	2.38	20.8
1	Batch 1	2	1	9	BCHPF1212	2.38	2	22.7
1	NP2-02	2	1	10	Y11PF21	4.42	1.87	22.9
1	NP2-03	2	1	11	Y10PF11	1.57	3.27	21.7
1	NP2-05	2	1	12	Y09PF11	1.52	2.06	20.8
1	NP2-05	2	1	13	Y09PF21	1.49	2.1	20.8
1	NP2-08	2	1	14	Y13PF21	4.25	3.3	20.8
1	Batch 1	2	1	15	BCHPF1213	2.54	2.1	24
1	Batch 1	2	2	1	BCHPF1221	2.52	2.09	23.3
1	NP2-06	2	2	2	Y04PF12	1.47	2	18.2
1	NP2-02	2	2	3	Y11PF12	4.31	1.89	22.3
1	NP2-08	2	2	4	Y13PF22	4.16	3.28	20.4
1	NP2-10	2	2	5	Y07PF12	3.18	2.4	21.1
1	NP2-03	2	2	6	Y10PF12	1.47	3.26	21.1
1	NP2-05	2	2	7	Y09PF22	1.37	2.05	19.8
1	NP2-05	2	2	8	Y09PF12	1.39	2.02	19.8
1	Batch 1	2	2	9	BCHPF1222	2.37	2.07	23

Table A3. Measured Elemental Concentrations (wt%) for Samples Prepared Using Peroxide Fusion. (continued)

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Li (wt%)	Si (wt%)
1	NP2-02	2	2	10	Y11PF22	4.31	1.89	22.6
1	NP2-08	2	2	11	Y13PF12	4.13	3.26	20.2
1	NP2-10	2	2	12	Y07PF22	3.14	2.42	21.2
1	NP2-06	2	2	13	Y04PF22	1.4	1.99	17.8
1	NP2-03	2	2	14	Y10PF22	1.46	3.23	21
1	Batch 1	2	2	15	BCHPF1123	2.33	2.06	22.9
2	Batch 1	1	1	1	BCHPF2111	2.57	2	22
2	NP2-25	1	1	2	Z08PF11	2.64	2.42	19
2	NP2-20	1	1	3	Z01PF11	1.44	3.22	21.6
2	NP2-21	1	1	4	Z04PF11	1.43	3.15	16.1
2	NP2-15	1	1	5	Z07PF21	3.32	1.99	19
2	NP2-19	1	1	6	Z02PF11	1.68	1.85	17.3
2	NP2-19	1	1	7	Z02PF21	1.69	1.86	17.5
2	Batch 1	1	1	8	BCHPF2112	2.37	2.01	22.3
2	NP2-20	1	1	9	Z01PF21	1.59	3.18	21.2
2	NP2-25	1	1	10	Z08PF21	2.6	2.42	19.1
2	NP2-14	1	1	11	Z06PF21	4.19	1.82	16.8
2	NP2-21	1	1	12	Z04PF21	1.46	3.12	15.7
2	NP2-15	1	1	13	Z07PF11	3.3	2	19.7
2	NP2-14	1	1	14	Z06PF11	4.28	1.85	16.7
2	Batch 1	1	1	15	BCHPF2113	2.46	2.05	22.5
2	Batch 1	1	2	1	BCHPF2121	2.54	2.01	22.7
2	NP2-19	1	2	2	Z02PF22	1.68	1.86	17.7
2	NP2-25	1	2	3	Z08PF12	2.57	2.43	19.2
2	NP2-25	1	2	4	Z08PF22	2.51	2.44	19.3
2	NP2-19	1	2	5	Z02PF12	1.62	1.87	17.3
2	NP2-20	1	2	6	Z01PF12	1.32	3.21	21.4
2	NP2-14	1	2	7	Z06PF12	4.06	1.82	16.5
2	Batch 1	1	2	8	BCHPF2122	2.32	2.02	22.7
2	NP2-15	1	2	9	Z07PF12	3.41	2	19.4
2	NP2-15	1	2	10	Z07PF22	3.31	2.01	18.9
2	NP2-20	1	2	11	Z01PF22	1.37	3.23	21.3
2	NP2-14	1	2	12	Z06PF22	4.11	1.82	16.4
2	NP2-21	1	2	13	Z04PF22	1.35	3.14	15.6
2	NP2-21	1	2	14	Z04PF12	1.33	3.16	15.8
2	Batch 1	1	2	15	BCHPF2123	2.29	2.02	22.5
2	Batch 1	2	1	1	BCHPF2211	2.52	2.02	22.7
2	NP2-23	2	1	2	Z09PF11	1.43	1.83	20.6
2	NP2-18	2	1	3	Z11PF11	1.51	3.2	20.6
2	NP2-17	2	1	4	Z03PF11	4.13	3.15	15.9
2	NP2-18	2	1	5	Z11PF21	1.5	3.15	20.5
2	NP2-23	2	1	6	Z09PF21	1.36	1.87	20.6
2	NP2-16	2	1	7	Z12PF21	1.55	1.86	19.6
2	Batch 1	2	1	8	BCHPF2212	2.29	2.03	22.6
2	NP2-24	2	1	9	Z10PF11	2.26	2.86	18.3
2	NP2-17	2	1	10	Z03PF21	4.26	3.16	15.9
2	NP2-22	2	1	11	Z05PF21	1.39	2.24	22
2	NP2-22	2	1	12	Z05PF11	1.32	2.27	21.5
2	NP2-24	2	1	13	Z10PF21	2.08	2.84	18
2	NP2-16	2	1	14	Z12PF11	1.52	1.86	19.1
2	Batch 1	2	1	15	BCHPF2213	2.27	2.02	22.4
2	Batch 1	2	2	1	BCHPF2221	2.54	2.05	23.1
2	NP2-18	2	2	2	Z11PF12	1.57	3.23	21.1
2	NP2-16	2	2	3	Z12PF12	1.54	1.92	20.1
2	NP2-22	2	2	4	Z05PF12	1.31	2.34	22.5
2	NP2-23	2	2	5	Z09PF12	1.3	1.87	20.9
2	NP2-17	2	2	6	Z03PF22	4.18	3.17	16.2
2	NP2-22	2	2	7	Z05PF22	1.32	2.25	22.5
2	Batch 1	2	2	8	BCHPF2222	2.28	2.04	22.9

Table A3. Measured Elemental Concentrations (wt%) for Samples Prepared Using Peroxide Fusion. (continued)

Set	Glass ID	Block	Sub-Block	Sequence	Lab ID	B (wt%)	Li (wt%)	Si (wt%)
2	NP2-24	2	2	9	Z10PF22	2.22	2.81	18.2
2	NP2-23	2	2	10	Z09PF22	1.36	1.83	20.5
2	NP2-16	2	2	11	Z12PF22	1.55	1.83	19.7
2	NP2-18	2	2	12	Z11PF22	1.43	3.13	20.6
2	NP2-24	2	2	13	Z10PF12	2.07	2.83	18.4
2	NP2-17	2	2	14	Z03PF12	4.15	3.13	16
2	Batch 1	2	2	15	BCHPF2223	2.33	2.03	22.8

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID.

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
Batch 1	Al_2O_3	4.6671	4.8770	4.8770	-0.2099	0.0000	-4.3%	0.0%
Batch 1	B_2O_3	7.7828	7.7770	7.7770	0.0058	0.0000	0.1%	0.0%
Batch 1	CaO	1.1344	1.2200	1.2200	-0.0856	0.0000	-7.0%	0.0%
Batch 1	Cr_2O_3	0.1085	0.1070	0.1070	0.0015	0.0000	1.4%	0.0%
Batch 1	Fe_2O_3	12.5158	12.8390	12.8390	-0.3232	0.0000	-2.5%	0.0%
Batch 1	Li_2O	4.4045	4.4290	4.4290	-0.0245	0.0000	-0.6%	0.0%
Batch 1	MgO	1.3578	1.4190	1.4190	-0.0612	0.0000	-4.3%	0.0%
Batch 1	MnO	1.7200	1.7260	1.7260	-0.0060	0.0000	-0.3%	0.0%
Batch 1	Na_2O	8.7817	9.0030	9.0030	-0.2213	0.0000	-2.5%	0.0%
Batch 1	NiO	0.7016	0.7510	0.7510	-0.0494	0.0000	-6.6%	0.0%
Batch 1	SiO_2	48.8384	50.2200	50.2200	-1.3816	0.0000	-2.8%	0.0%
Batch 1	TiO_2	0.6479	0.6770	0.6770	-0.0291	0.0000	-4.3%	0.0%
Batch 1	Sum	92.6603	95.0450	95.0450	-2.3847	0.0000	-2.5%	0.0%
NP2-01	Al_2O_3	16.1033	17.1752	16.4000	-0.2967	0.7752	-1.8%	4.7%
NP2-01	B_2O_3	5.0633	5.0430	5.1000	-0.0367	-0.0570	-0.7%	-1.1%
NP2-01	CaO	2.3157	2.4669	2.3300	-0.0143	0.1369	-0.6%	5.9%
NP2-01	Cr_2O_3	0.0146	0.0146	0.0000	0.0146	0.0146		
NP2-01	Fe_2O_3	4.8038	4.9930	5.0000	-0.1962	-0.0070	-3.9%	-0.1%
NP2-01	Li_2O	4.4188	4.4059	4.4100	0.0088	-0.0041	0.2%	-0.1%
NP2-01	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-01	MnO	3.4088	3.4565	3.2900	0.1188	0.1665	3.6%	5.1%
NP2-01	Na_2O	10.9761	11.5383	11.2300	-0.2539	0.3083	-2.3%	2.7%
NP2-01	NiO	0.8080	0.8692	0.8400	-0.0320	0.0292	-3.8%	3.5%
NP2-01	SiO_2	49.0969	50.2550	51.4000	-2.3031	-1.1450	-4.5%	-2.2%
NP2-01	TiO_2	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-01	Sum	97.0259	100.2349	100.0000	-2.9741	0.2349	-3.0%	0.2%
NP2-02	Al_2O_3	7.1518	7.6279	7.2200	-0.0682	0.4079	-0.9%	5.6%
NP2-02	B_2O_3	13.9663	13.7895	14.0000	-0.0337	-0.2105	-0.2%	-1.5%
NP2-02	CaO	0.0154	0.0164	0.0000	0.0154	0.0164		
NP2-02	Cr_2O_3	0.1769	0.1770	0.2000	-0.0231	-0.0230	-11.6%	-11.5%
NP2-02	Fe_2O_3	4.8395	5.0302	5.0000	-0.1605	0.0302	-3.2%	0.6%
NP2-02	Li_2O	4.0582	4.0332	4.0000	0.0582	0.0332	1.5%	0.8%
NP2-02	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-02	MnO	0.6120	0.6206	0.6200	-0.0080	0.0006	-1.3%	0.1%
NP2-02	Na_2O	17.3892	18.2801	18.0000	-0.6108	0.2801	-3.4%	1.6%
NP2-02	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-02	SiO_2	48.1343	48.7404	48.9600	-0.8257	-0.2196	-1.7%	-0.4%
NP2-02	TiO_2	1.9808	2.0580	2.0000	-0.0193	0.0580	-1.0%	2.9%
NP2-02	Sum	98.3390	100.3888	100.0000	-1.6610	0.3888	-1.7%	0.4%
NP2-03	Al_2O_3	8.5878	9.1594	8.3700	0.2178	0.7894	2.6%	9.4%
NP2-03	B_2O_3	4.8299	4.7674	4.7000	0.1299	0.0674	2.8%	1.4%
NP2-03	CaO	0.1801	0.1919	0.1800	0.0001	0.0119	0.1%	6.6%
NP2-03	Cr_2O_3	0.1918	0.1919	0.2000	-0.0082	-0.0081	-4.1%	-4.0%
NP2-03	Fe_2O_3	13.9217	14.4698	14.8200	-0.8983	-0.3502	-6.1%	-2.4%
NP2-03	Li_2O	6.9915	6.9484	7.0000	-0.0085	-0.0516	-0.1%	-0.7%
NP2-03	MgO	0.1497	0.1571	0.1500	-0.0003	0.0071	-0.2%	4.7%
NP2-03	MnO	1.9077	1.9344	1.8700	0.0377	0.0644	2.0%	3.4%
NP2-03	Na_2O	15.1650	15.9420	15.1200	0.0450	0.8220	0.3%	5.4%
NP2-03	NiO	0.1737	0.1868	0.2000	-0.0263	-0.0132	-13.2%	-6.6%
NP2-03	SiO_2	45.2997	45.8693	45.3900	-0.0903	0.4793	-0.2%	1.1%
NP2-03	TiO_2	1.9933	2.0710	2.0000	-0.0067	0.0710	-0.3%	3.5%
NP2-03	Sum	99.3919	101.8895	100.0000	-0.6081	1.8895	-0.6%	1.9%
NP2-04	Al_2O_3	13.8831	14.8071	14.1800	-0.2969	0.6271	-2.1%	4.4%
NP2-04	B_2O_3	11.8814	11.8337	12.3400	-0.4586	-0.5063	-3.7%	-4.1%
NP2-04	CaO	4.0437	4.3076	4.0000	0.0437	0.3076	1.1%	7.7%
NP2-04	Cr_2O_3	0.1663	0.1664	0.2000	-0.0337	-0.0336	-16.9%	-16.8%
NP2-04	Fe_2O_3	5.3900	5.6021	5.6100	-0.2200	-0.0079	-3.9%	-0.1%
NP2-04	Li_2O	4.8978	4.8836	4.9300	-0.0322	-0.0464	-0.7%	-0.9%

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID. (continued)

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
NP2-04	MgO	1.4456	1.5172	1.5000	-0.0544	0.0172	-3.6%	1.1%
NP2-04	MnO	0.4974	0.5044	0.5000	-0.0026	0.0044	-0.5%	0.9%
NP2-04	Na_2O	10.8346	11.3894	11.1500	-0.3155	0.2394	-2.8%	2.1%
NP2-04	NiO	0.4126	0.4438	0.4400	-0.0274	0.0038	-6.2%	0.9%
NP2-04	SiO_2	42.2512	43.2478	43.1400	-0.8888	0.1078	-2.1%	0.2%
NP2-04	TiO_2	1.9808	2.0579	2.0000	-0.0193	0.0579	-1.0%	2.9%
NP2-04	Sum	97.6844	100.7610	99.9900	-2.3056	0.7710	-2.3%	0.8%
NP2-05	Al_2O_3	8.7862	9.2132	8.7300	0.0562	0.4832	0.6%	5.5%
NP2-05	B_2O_3	4.6447	4.5831	4.5000	0.1447	0.0831	3.2%	1.8%
NP2-05	CaO	0.1497	0.1613	0.1300	0.0197	0.0313	15.2%	24.1%
NP2-05	Cr_2O_3	0.0274	0.0273	0.0200	0.0074	0.0073	37.0%	36.5%
NP2-05	Fe_2O_3	14.5472	15.0214	15.3600	-0.8128	-0.3386	-5.3%	-2.2%
NP2-05	Li_2O	4.4296	4.4023	4.4400	-0.0104	-0.0377	-0.2%	-0.8%
NP2-05	MgO	1.4324	1.4996	1.5000	-0.0676	-0.0004	-4.5%	0.0%
NP2-05	MnO	5.5812	5.6734	5.5000	0.0812	0.1734	1.5%	3.2%
NP2-05	Na_2O	14.7943	15.1688	14.7800	0.0143	0.3888	0.1%	2.6%
NP2-05	NiO	0.0719	0.0766	0.0800	-0.0081	-0.0034	-10.1%	-4.2%
NP2-05	SiO_2	43.4278	43.9698	42.9600	0.4678	1.0098	1.1%	2.4%
NP2-05	TiO_2	2.0099	2.0963	2.0000	0.0099	0.0963	0.5%	4.8%
NP2-05	Sum	99.9023	101.8931	100.0000	-0.0977	1.8931	-0.1%	1.9%
NP2-06	Al_2O_3	10.4395	10.9463	10.5700	-0.1305	0.3763	-1.2%	3.6%
NP2-06	B_2O_3	4.6528	4.5938	4.5000	0.1528	0.0938	3.4%	2.1%
NP2-06	CaO	4.1067	4.4251	4.0000	0.1067	0.4251	2.7%	10.6%
NP2-06	Cr_2O_3	0.0073	0.0073	0.0000	0.0073	0.0073		
NP2-06	Fe_2O_3	17.5853	18.1586	18.0100	-0.4247	0.1486	-2.4%	0.8%
NP2-06	Li_2O	4.2789	4.2525	4.2600	0.0189	-0.0075	0.4%	-0.2%
NP2-06	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-06	MnO	0.5145	0.5231	0.5000	0.0145	0.0231	2.9%	4.6%
NP2-06	Na_2O	17.7262	18.1729	18.0000	-0.2738	0.1729	-1.5%	1.0%
NP2-06	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-06	SiO_2	38.1330	38.6156	38.1600	-0.0270	0.4556	-0.1%	1.2%
NP2-06	TiO_2	2.0308	2.1180	2.0000	0.0308	0.1180	1.5%	5.9%
NP2-06	Sum	99.4896	101.8286	100.0000	-0.5104	1.8286	-0.5%	1.8%
NP2-07	Al_2O_3	9.7404	10.2133	9.0200	0.7204	1.1933	8.0%	13.2%
NP2-07	B_2O_3	11.7768	11.7295	12.0500	-0.2732	-0.3205	-2.3%	-2.7%
NP2-07	CaO	0.3054	0.3291	0.2700	0.0354	0.0591	13.1%	21.9%
NP2-07	Cr_2O_3	0.0727	0.0724	0.0900	-0.0173	-0.0176	-19.2%	-19.5%
NP2-07	Fe_2O_3	14.3792	14.8480	15.1400	-0.7608	-0.2920	-5.0%	-1.9%
NP2-07	Li_2O	4.4296	4.4165	4.4000	0.0296	0.0165	0.7%	0.4%
NP2-07	MgO	0.3491	0.3655	0.3300	0.0191	0.0355	5.8%	10.7%
NP2-07	MnO	1.7883	1.8179	1.7400	0.0483	0.0779	2.8%	4.5%
NP2-07	Na_2O	13.6384	13.9825	12.2600	1.3784	1.7225	11.2%	14.1%
NP2-07	NiO	1.1599	1.2364	1.3900	-0.2301	-0.1536	-16.6%	-11.1%
NP2-07	SiO_2	40.7002	41.6597	41.3100	-0.6098	0.3497	-1.5%	0.8%
NP2-07	TiO_2	2.0058	2.0919	2.0000	0.0058	0.0919	0.3%	4.6%
NP2-07	Sum	100.3457	102.7626	100.0000	0.3457	2.7626	0.3%	2.8%
NP2-08	Al_2O_3	6.9297	7.3910	6.9700	-0.0403	0.4210	-0.6%	6.0%
NP2-08	B_2O_3	13.4028	13.2336	13.3200	0.0828	-0.0864	0.6%	-0.6%
NP2-08	CaO	4.0927	4.3598	4.0000	0.0927	0.3598	2.3%	9.0%
NP2-08	Cr_2O_3	0.0073	0.0073	0.0000	0.0073	0.0073		
NP2-08	Fe_2O_3	5.0468	5.2455	5.0000	0.0468	0.2455	0.9%	4.9%
NP2-08	Li_2O	7.0400	6.9966	7.0000	0.0400	-0.0034	0.6%	0.0%
NP2-08	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-08	MnO	3.7025	3.7541	3.6200	0.0825	0.1341	2.3%	3.7%
NP2-08	Na_2O	14.9628	15.7288	15.3800	-0.4172	0.3488	-2.7%	2.3%
NP2-08	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-08	SiO_2	43.4813	44.0291	42.7000	0.7813	1.3291	1.8%	3.1%
NP2-08	TiO_2	2.0141	2.0925	2.0000	0.0141	0.0925	0.7%	4.6%

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID. (continued)

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
NP2-08	Sum	100.6947	102.8538	99.9900	0.7047	2.8638	0.7%	2.9%
NP2-09	Al_2O_3	5.6307	5.9041	5.5200	0.1107	0.3841	2.0%	7.0%
NP2-09	B_2O_3	6.1017	6.0774	5.9000	0.2017	0.1774	3.4%	3.0%
NP2-09	CaO	4.1906	4.5156	4.0000	0.1906	0.5156	4.8%	12.9%
NP2-09	Cr_2O_3	0.1743	0.1736	0.2000	-0.0257	-0.0264	-12.9%	-13.2%
NP2-09	Fe_2O_3	13.1282	13.5562	13.8100	-0.6818	-0.2538	-4.9%	-1.8%
NP2-09	Li_2O	4.7687	4.7545	4.8800	-0.1113	-0.1255	-2.3%	-2.6%
NP2-09	MgO	0.9237	0.9670	0.9600	-0.0363	0.0070	-3.8%	0.7%
NP2-09	MnO	4.8549	4.9352	4.8000	0.0549	0.1352	1.1%	2.8%
NP2-09	Na_2O	16.2434	16.6527	16.1200	0.1234	0.5327	0.8%	3.3%
NP2-09	NiO	1.7751	1.8923	1.9800	-0.2049	-0.0877	-10.3%	-4.4%
NP2-09	SiO_2	40.8071	41.7705	41.8300	-1.0229	-0.0595	-2.4%	-0.1%
NP2-09	TiO_2	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-09	Sum	98.6068	101.2079	100.0000	-1.3932	1.2079	-1.4%	1.2%
NP2-10	Al_2O_3	10.6521	11.1691	10.6500	0.0021	0.5191	0.0%	4.9%
NP2-10	B_2O_3	10.0783	9.9533	10.1700	-0.0917	-0.2167	-0.9%	-2.1%
NP2-10	CaO	0.8752	0.9431	0.9500	-0.0748	-0.0069	-7.9%	-0.7%
NP2-10	Cr_2O_3	0.0073	0.0073	0.0000	0.0073	0.0073		
NP2-10	Fe_2O_3	13.2748	13.7076	13.6400	-0.3652	0.0676	-2.7%	0.5%
NP2-10	Li_2O	5.1616	5.1297	5.1600	0.0016	-0.0303	0.0%	-0.6%
NP2-10	MgO	0.6770	0.7088	0.6800	-0.0030	0.0288	-0.4%	4.2%
NP2-10	MnO	0.5003	0.5086	0.5000	0.0003	0.0086	0.1%	1.7%
NP2-10	Na_2O	13.3317	13.6676	13.4300	-0.0983	0.2376	-0.7%	1.8%
NP2-10	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-10	SiO_2	44.7114	45.2777	44.8200	-0.1086	0.4577	-0.2%	1.0%
NP2-10	TiO_2	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-10	Sum	99.2843	101.0882	100.0000	-0.7157	1.0882	-0.7%	1.1%
NP2-11	Al_2O_3	17.4495	18.6110	18.0000	-0.5505	0.6110	-3.1%	3.4%
NP2-11	B_2O_3	13.5558	13.5018	14.0000	-0.4442	-0.4982	-3.2%	-3.6%
NP2-11	CaO	0.0182	0.0194	0.0000	0.0182	0.0194		
NP2-11	Cr_2O_3	0.1907	0.1908	0.2000	-0.0093	-0.0092	-4.6%	-4.6%
NP2-11	Fe_2O_3	5.7438	5.9700	5.8500	-0.1062	0.1200	-1.8%	2.1%
NP2-11	Li_2O	6.9270	6.9070	6.9700	-0.0430	-0.0630	-0.6%	-0.9%
NP2-11	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-11	MnO	4.6515	4.7165	4.6500	0.0015	0.0665	0.0%	1.4%
NP2-11	Na_2O	14.7943	15.5520	15.3300	-0.5357	0.2220	-3.5%	1.4%
NP2-11	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-11	SiO_2	34.9776	35.8046	35.0000	-0.0224	0.8046	-0.1%	2.3%
NP2-11	TiO_2	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-11	Sum	98.3314	101.2973	100.0000	-1.6686	1.2973	-1.7%	1.3%
NP2-12	Al_2O_3	10.5387	11.0502	10.6400	-0.1013	0.4102	-1.0%	3.9%
NP2-12	B_2O_3	6.5927	6.5664	6.6800	-0.0873	-0.1136	-1.3%	-1.7%
NP2-12	CaO	0.7808	0.8413	0.8300	-0.0492	0.0113	-5.9%	1.4%
NP2-12	Cr_2O_3	0.0322	0.0320	0.0200	0.0122	0.0120	60.8%	60.1%
NP2-12	Fe_2O_3	6.1692	6.3703	6.1700	-0.0008	0.2003	0.0%	3.2%
NP2-12	Li_2O	6.8462	6.8268	7.0000	-0.1538	-0.1732	-2.2%	-2.5%
NP2-12	MgO	1.4531	1.5213	1.5000	-0.0469	0.0213	-3.1%	1.4%
NP2-12	MnO	0.5039	0.5122	0.5000	0.0039	0.0122	0.8%	2.4%
NP2-12	Na_2O	17.5577	18.0005	18.0000	-0.4423	0.0005	-2.5%	0.0%
NP2-12	NiO	2.3923	2.5501	2.5000	-0.1077	0.0501	-4.3%	2.0%
NP2-12	SiO_2	41.9303	42.9203	44.1500	-2.2197	-1.2297	-5.0%	-2.8%
NP2-12	TiO_2	2.0058	2.0919	2.0000	0.0058	0.0919	0.3%	4.6%
NP2-12	Sum	96.8027	99.2835	99.9900	-3.1873	-0.7065	-3.2%	-0.7%
NP2-13	Al_2O_3	17.3598	18.2030	17.2700	0.0898	0.9330	0.5%	5.4%
NP2-13	B_2O_3	13.4833	13.4292	14.0000	-0.5167	-0.5708	-3.7%	-4.1%
NP2-13	CaO	0.0227	0.0245	0.0000	0.0227	0.0245		
NP2-13	Cr_2O_3	0.1546	0.1540	0.2000	-0.0454	-0.0460	-22.7%	-23.0%
NP2-13	Fe_2O_3	4.6966	4.8497	5.0000	-0.3034	-0.1503	-6.1%	-3.0%

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID. (continued)

Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
NP2-13	Li_2O	3.9344	3.9229	4.0000	-0.0656	-0.0771	-1.6%	-1.9%
NP2-13	MgO	1.4220	1.4888	1.5000	-0.0780	-0.0112	-5.2%	-0.7%
NP2-13	MnO	5.6070	5.6996	5.5000	0.1070	0.1996	1.9%	3.6%
NP2-13	Na_2O	10.0460	10.3001	10.0000	0.0460	0.3001	0.5%	3.0%
NP2-13	NiO	0.0064	0.0068	0.0000	0.0064	0.0068		
NP2-13	SiO_2	39.7910	40.7298	40.9000	-1.1090	-0.1702	-2.7%	-0.4%
NP2-13	TiO_2	1.5542	1.6209	1.6300	-0.0758	-0.0091	-4.7%	-0.6%
NP2-13	Sum	98.0779	100.4292	100.0000	-1.9221	0.4292	-1.9%	0.4%
NP2-14	Al_2O_3	15.4797	15.9622	15.5800	-0.1003	0.3822	-0.6%	2.5%
NP2-14	B_2O_3	10.7384	10.6999	10.9300	-0.1916	-0.2301	-1.8%	-2.1%
NP2-14	CaO	1.7945	1.9486	1.7900	0.0045	0.1586	0.2%	8.9%
NP2-14	Cr_2O_3	0.1250	0.1231	0.1800	-0.0550	-0.0569	-30.6%	-31.6%
NP2-14	Fe_2O_3	10.9086	11.0839	11.4900	-0.5814	-0.4061	-5.1%	-3.5%
NP2-14	Li_2O	4.3058	4.3888	4.3600	-0.0542	0.0288	-1.2%	0.7%
NP2-14	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-14	MnO	0.4952	0.4909	0.5000	-0.0048	-0.0091	-1.0%	-1.8%
NP2-14	Na_2O	13.1936	13.4053	13.3200	-0.1265	0.0853	-0.9%	0.6%
NP2-14	NiO	0.3083	0.3334	0.3300	-0.0217	0.0034	-6.6%	1.0%
NP2-14	SiO_2	41.1815	43.0664	41.5300	-0.3485	1.5364	-0.8%	3.7%
NP2-14	TiO_2	0.0083	0.0088	0.0000	0.0083	0.0088		
NP2-14	Sum	98.5471	101.5200	100.0100	-1.4629	1.5100	-1.5%	1.5%
NP2-15	Al_2O_3	17.6952	18.2468	18.0000	-0.3048	0.2468	-1.7%	1.4%
NP2-15	B_2O_3	13.3948	13.3410	14.0000	-0.6052	-0.6590	-4.3%	-4.7%
NP2-15	CaO	0.0108	0.0118	0.0000	0.0108	0.0118		
NP2-15	Cr_2O_3	0.0073	0.0072	0.0000	0.0073	0.0072		
NP2-15	Fe_2O_3	4.7823	4.8592	5.0000	-0.2177	-0.1408	-4.4%	-2.8%
NP2-15	Li_2O	3.9344	4.0102	4.0000	-0.0656	0.0102	-1.6%	0.3%
NP2-15	MgO	1.3971	1.4654	1.5000	-0.1029	-0.0346	-6.9%	-2.3%
NP2-15	MnO	0.4981	0.4938	0.5000	-0.0019	-0.0062	-0.4%	-1.2%
NP2-15	Na_2O	17.5914	17.8738	18.0000	-0.4086	-0.1262	-2.3%	-0.7%
NP2-15	NiO	2.2428	2.4258	2.5000	-0.2572	-0.0742	-10.3%	-3.0%
NP2-15	SiO_2	35.5124	37.1389	35.0000	0.5124	2.1389	1.5%	6.1%
NP2-15	TiO_2	1.4140	1.4960	1.5000	-0.0860	-0.0040	-5.7%	-0.3%
NP2-15	Sum	98.4807	101.3698	100.0000	-1.5193	1.3698	-1.5%	1.4%
NP2-16	Al_2O_3	13.4532	13.8731	13.6100	-0.1568	0.2631	-1.2%	1.9%
NP2-16	B_2O_3	4.9586	5.0499	5.1900	-0.2314	-0.1401	-4.5%	-2.7%
NP2-16	CaO	1.9834	2.1538	1.9700	0.0134	0.1838	0.7%	9.3%
NP2-16	Cr_2O_3	0.0073	0.0072	0.0000	0.0073	0.0072		
NP2-16	Fe_2O_3	14.2720	14.5015	14.7000	-0.4280	-0.1985	-2.9%	-1.4%
NP2-16	Li_2O	4.0205	4.0711	4.0000	0.0205	0.0711	0.5%	1.8%
NP2-16	MgO	0.3138	0.3292	0.3200	-0.0062	0.0092	-1.9%	2.9%
NP2-16	MnO	2.9956	2.9701	2.8600	0.1356	0.1101	4.7%	3.8%
NP2-16	Na_2O	14.5247	14.7579	14.8200	-0.2953	-0.0621	-2.0%	-0.4%
NP2-16	NiO	0.0086	0.0093	0.1700	-0.1614	-0.1607	-94.9%	-94.5%
NP2-16	SiO_2	41.9838	43.3196	42.3600	-0.3762	0.9596	-0.9%	2.3%
NP2-16	TiO_2	0.0083	0.0088	0.0000	0.0083	0.0088		
NP2-16	Sum	98.5299	101.0515	100.0000	-1.4701	1.0515	-1.5%	1.1%
NP2-17	Al_2O_3	8.5311	8.8261	8.6200	-0.0889	0.2061	-1.0%	2.4%
NP2-17	B_2O_3	13.4592	13.7073	14.0000	-0.5408	-0.2927	-3.9%	-2.1%
NP2-17	CaO	4.0507	4.3485	4.0000	0.0507	0.3485	1.3%	8.7%
NP2-17	Cr_2O_3	0.0073	0.0071	0.0000	0.0073	0.0071		
NP2-17	Fe_2O_3	6.5445	6.6472	6.6700	-0.1255	-0.0228	-1.9%	-0.3%
NP2-17	Li_2O	6.7870	6.8725	7.0000	-0.2130	-0.1275	-3.0%	-1.8%
NP2-17	MgO	0.0083	0.0086	0.0000	0.0083	0.0086		
NP2-17	MnO	5.5167	5.4762	5.5000	0.0167	-0.0238	0.3%	-0.4%
NP2-17	Na_2O	14.3899	14.5251	14.7100	-0.3201	-0.1849	-2.2%	-1.3%
NP2-17	NiO	2.3446	2.4827	2.5000	-0.1554	-0.0173	-6.2%	-0.7%
NP2-17	SiO_2	34.2288	35.3201	35.0000	-0.7712	0.3201	-2.2%	0.9%

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID. (continued)

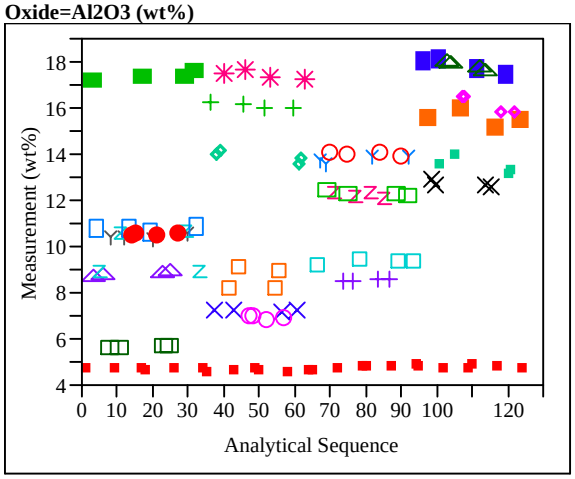
Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
NP2-17	TiO_2	2.0016	2.0822	2.0000	0.0016	0.0822	0.1%	4.1%
NP2-17	Sum	97.8696	100.3036	100.0000	-2.1304	0.3036	-2.1%	0.3%
NP2-18	Al_2O_3	12.6313	13.0247	12.8500	-0.2187	0.1747	-1.7%	1.4%
NP2-18	B_2O_3	4.8379	4.9271	4.9700	-0.1321	-0.0429	-2.7%	-0.9%
NP2-18	CaO	0.0105	0.0114	0.0000	0.0105	0.0114		
NP2-18	Cr_2O_3	0.0073	0.0072	0.0000	0.0073	0.0072		
NP2-18	Fe_2O_3	10.7621	10.9349	11.0400	-0.2779	-0.1051	-2.5%	-1.0%
NP2-18	Li_2O	6.8408	6.9270	7.0000	-0.1592	-0.0730	-2.3%	-1.0%
NP2-18	MgO	0.5004	0.5248	0.4900	0.0104	0.0348	2.1%	7.1%
NP2-18	MnO	1.4268	1.4145	1.4100	0.0168	0.0045	1.2%	0.3%
NP2-18	Na_2O	16.8500	17.1204	17.1800	-0.3300	-0.0596	-1.9%	-0.3%
NP2-18	NiO	0.0064	0.0069	0.0000	0.0064	0.0069		
NP2-18	SiO_2	44.2835	45.6950	45.0500	-0.7665	0.6450	-1.7%	1.4%
NP2-18	TiO_2	0.0083	0.0088	0.0000	0.0083	0.0088		
NP2-18	Sum	98.1653	100.6027	99.9900	-1.8247	0.6127	-1.8%	0.6%
NP2-19	Al_2O_3	9.3105	9.6327	9.3000	0.0105	0.3327	0.1%	3.6%
NP2-19	B_2O_3	5.3692	5.3483	5.2700	0.0992	0.0783	1.9%	1.5%
NP2-19	CaO	0.0231	0.0248	0.0000	0.0231	0.0248		
NP2-19	Cr_2O_3	0.1692	0.1633	0.2000	-0.0308	-0.0367	-15.4%	-18.3%
NP2-19	Fe_2O_3	17.2636	17.5347	18.1000	-0.8364	-0.5653	-4.6%	-3.1%
NP2-19	Li_2O	4.0044	4.0816	4.0000	0.0044	0.0816	0.1%	2.0%
NP2-19	MgO	0.0083	0.0086	0.0000	0.0083	0.0086		
NP2-19	MnO	5.5941	5.5532	5.5000	0.0941	0.0532	1.7%	1.0%
NP2-19	Na_2O	17.1533	17.3144	17.3900	-0.2367	-0.0756	-1.4%	-0.4%
NP2-19	NiO	0.5246	0.5555	0.6400	-0.1154	-0.0845	-18.0%	-13.2%
NP2-19	SiO_2	37.3308	39.0368	37.6100	-0.2792	1.4268	-0.7%	3.8%
NP2-19	TiO_2	2.0225	2.1039	2.0000	0.0225	0.1039	1.1%	5.2%
NP2-19	Sum	98.7735	101.3579	100.0100	-1.2365	1.3479	-1.2%	1.3%
NP2-20	Al_2O_3	16.1741	16.6789	16.1900	-0.0159	0.4889	-0.1%	3.0%
NP2-20	B_2O_3	4.6045	4.5827	4.5000	0.1045	0.0827	2.3%	1.8%
NP2-20	CaO	0.0301	0.0327	0.0000	0.0301	0.0327		
NP2-20	Cr_2O_3	0.0175	0.0173	0.0100	0.0075	0.0073	75.4%	72.7%
NP2-20	Fe_2O_3	5.1541	5.2370	5.2200	-0.0659	0.0170	-1.3%	0.3%
NP2-20	Li_2O	6.9108	7.0440	7.0000	-0.0892	0.0440	-1.3%	0.6%
NP2-20	MgO	0.9614	1.0084	1.0000	-0.0386	0.0084	-3.9%	0.8%
NP2-20	MnO	0.4961	0.4919	0.5000	-0.0039	-0.0081	-0.8%	-1.6%
NP2-20	Na_2O	15.5694	15.8193	15.7400	-0.1706	0.0793	-1.1%	0.5%
NP2-20	NiO	2.3446	2.5359	2.5000	-0.1554	0.0359	-6.2%	1.4%
NP2-20	SiO_2	45.7275	47.8189	47.3300	-1.6025	0.4889	-3.4%	1.0%
NP2-20	TiO_2	0.0083	0.0088	0.0000	0.0083	0.0088		
NP2-20	Sum	97.9985	101.2757	99.9900	-1.9915	1.2857	-2.0%	1.3%
NP2-21	Al_2O_3	17.7991	18.3534	18.0000	-0.2009	0.3534	-1.1%	2.0%
NP2-21	B_2O_3	4.4837	4.4642	4.5000	-0.0163	-0.0358	-0.4%	-0.8%
NP2-21	CaO	4.0052	4.3492	4.0000	0.0052	0.3492	0.1%	8.7%
NP2-21	Cr_2O_3	0.1838	0.1810	0.2000	-0.0162	-0.0190	-8.1%	-9.5%
NP2-21	Fe_2O_3	5.7117	5.8035	5.8000	-0.0883	0.0035	-1.5%	0.1%
NP2-21	Li_2O	6.7655	6.8959	7.0000	-0.2345	-0.1041	-3.4%	-1.5%
NP2-21	MgO	0.0083	0.0087	0.0000	0.0083	0.0087		
NP2-21	MnO	5.5522	5.5049	5.5000	0.0522	0.0049	0.9%	0.1%
NP2-21	Na_2O	17.5914	17.8737	18.0000	-0.4086	-0.1263	-2.3%	-0.7%
NP2-21	NiO	0.0146	0.0158	0.0000	0.0146	0.0158		
NP2-21	SiO_2	33.8009	35.3483	35.0000	-1.1991	0.3483	-3.4%	1.0%
NP2-21	TiO_2	2.0016	2.1179	2.0000	0.0016	0.1179	0.1%	5.9%
NP2-21	Sum	97.9180	100.9165	100.0000	-2.0820	0.9165	-2.1%	0.9%
NP2-22	Al_2O_3	13.7981	14.2745	13.9700	-0.1719	0.3045	-1.2%	2.2%
NP2-22	B_2O_3	4.2986	4.3781	4.5000	-0.2014	-0.1219	-4.5%	-2.7%
NP2-22	CaO	0.0283	0.0304	0.0200	0.0083	0.0104	41.7%	52.0%
NP2-22	Cr_2O_3	0.0300	0.0289	0.0200	0.0100	0.0089	49.8%	44.6%

Table A4. Average Measured and Bias-Corrected Chemical Compositions Versus Targeted Compositions by Oxide by Glass ID. (continued)

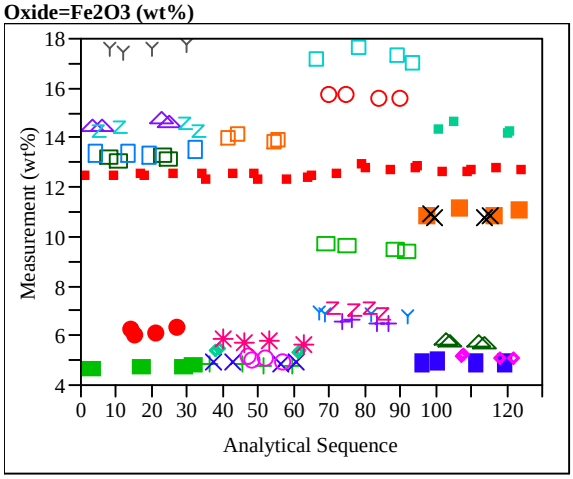
Glass ID	Oxide	Measured (wt%)	Measured Bias-Corrected (wt%)	Targeted (wt%)	Diff of Measured	Diff of Meas. bc	% Diff of Measured	% Diff of Meas bc
NP2-22	Fe_2O_3	6.8626	6.9703	7.0900	-0.2274	-0.1197	-3.2%	-1.7%
NP2-22	Li_2O	4.8978	4.9594	4.8700	0.0278	0.0894	0.6%	1.8%
NP2-22	MgO	0.0083	0.0086	0.0000	0.0083	0.0086		
NP2-22	MnO	1.6301	1.6182	1.5800	0.0501	0.0382	3.2%	2.4%
NP2-22	Na_2O	17.4566	17.6200	18.0000	-0.5434	-0.3800	-3.0%	-2.1%
NP2-22	NiO	0.1890	0.2001	0.2000	-0.0110	0.0001	-5.5%	0.1%
NP2-22	SiO_2	47.3320	48.8368	47.7500	-0.4180	1.0868	-0.9%	2.3%
NP2-22	TiO_2	2.0016	2.0822	2.0000	0.0016	0.0822	0.1%	4.1%
NP2-22	Sum	98.5330	101.0074	100.0000	-1.4670	1.0074	-1.5%	1.0%
NP2-23	Al_2O_3	12.2203	12.6436	12.2800	-0.0597	0.3636	-0.5%	3.0%
NP2-23	B_2O_3	4.3871	4.4684	4.5000	-0.1129	-0.0316	-2.5%	-0.7%
NP2-23	CaO	4.0297	4.3258	4.0000	0.0297	0.3258	0.7%	8.1%
NP2-23	Cr_2O_3	0.1706	0.1647	0.2000	-0.0294	-0.0353	-14.7%	-17.6%
NP2-23	Fe_2O_3	7.0127	7.1227	7.2200	-0.2073	-0.0973	-2.9%	-1.3%
NP2-23	Li_2O	3.9829	4.0330	4.0000	-0.0171	0.0330	-0.4%	0.8%
NP2-23	MgO	1.4353	1.4857	1.5000	-0.0647	-0.0143	-4.3%	-1.0%
NP2-23	MnO	1.2121	1.2032	1.1900	0.0221	0.0132	1.9%	1.1%
NP2-23	Na_2O	17.5240	17.6887	18.0000	-0.4760	-0.3113	-2.6%	-1.7%
NP2-23	NiO	0.1597	0.1691	0.1700	-0.0103	-0.0009	-6.1%	-0.5%
NP2-23	SiO_2	44.1765	45.5864	44.9400	-0.7635	0.6464	-1.7%	1.4%
NP2-23	TiO_2	2.0099	2.0909	2.0000	0.0099	0.0909	0.5%	4.5%
NP2-23	Sum	98.3209	100.9824	100.0000	-1.6791	0.9824	-1.7%	1.0%
NP2-24	Al_2O_3	14.0059	14.4908	14.0600	-0.0541	0.4308	-0.4%	3.1%
NP2-24	B_2O_3	6.9469	7.0751	7.0400	-0.0931	0.0351	-1.3%	0.5%
NP2-24	CaO	1.4699	1.5782	1.5100	-0.0401	0.0682	-2.7%	4.5%
NP2-24	Cr_2O_3	0.0073	0.0071	0.0000	0.0073	0.0071		
NP2-24	Fe_2O_3	15.6552	15.9009	16.1500	-0.4948	-0.2491	-3.1%	-1.5%
NP2-24	Li_2O	6.1035	6.1805	6.1600	-0.0565	0.0205	-0.9%	0.3%
NP2-24	MgO	0.3271	0.3386	0.3100	0.0171	0.0286	5.5%	9.2%
NP2-24	MnO	0.9235	0.9168	0.9000	0.0235	0.0168	2.6%	1.9%
NP2-24	Na_2O	12.1455	12.2596	12.3100	-0.1645	-0.0504	-1.3%	-0.4%
NP2-24	NiO	0.0073	0.0078	0.0100	-0.0027	-0.0022	-26.8%	-22.5%
NP2-24	SiO_2	38.9887	40.2325	39.5500	-0.5613	0.6825	-1.4%	1.7%
NP2-24	TiO_2	2.0266	2.1083	2.0000	0.0266	0.1083	1.3%	5.4%
NP2-24	Sum	98.6075	101.0959	100.0000	-1.3925	1.0959	-1.4%	1.1%
NP2-25	Al_2O_3	12.2865	12.7123	12.3300	-0.0435	0.3823	-0.4%	3.1%
NP2-25	B_2O_3	8.3073	8.2743	8.3600	-0.0527	-0.0857	-0.6%	-1.0%
NP2-25	CaO	1.5951	1.7123	1.5800	0.0151	0.1323	1.0%	8.4%
NP2-25	Cr_2O_3	0.0910	0.0878	0.0900	0.0010	-0.0022	1.1%	-2.4%
NP2-25	Fe_2O_3	9.5218	9.6715	9.8700	-0.3482	-0.1985	-3.5%	-2.0%
NP2-25	Li_2O	5.2262	5.3269	5.3300	-0.1038	-0.0031	-1.9%	-0.1%
NP2-25	MgO	0.5564	0.5759	0.5500	0.0064	0.0259	1.2%	4.7%
NP2-25	MnO	2.5824	2.5636	2.4800	0.1024	0.0836	4.1%	3.4%
NP2-25	Na_2O	14.9965	15.1376	15.2600	-0.2635	-0.1224	-1.7%	-0.8%
NP2-25	NiO	0.6293	0.6663	0.6900	-0.0607	-0.0237	-8.8%	-3.4%
NP2-25	SiO_2	40.9676	42.8390	42.1600	-1.1924	0.6790	-2.8%	1.6%
NP2-25	TiO_2	1.2322	1.2819	1.3000	-0.0678	-0.0181	-5.2%	-1.4%
NP2-25	Sum	97.9922	100.8494	100.0000	-2.0078	0.8494	-2.0%	0.8%

Exhibit A1. Measurements in Analytical Sequence for Samples by Oxide by Prep Method.

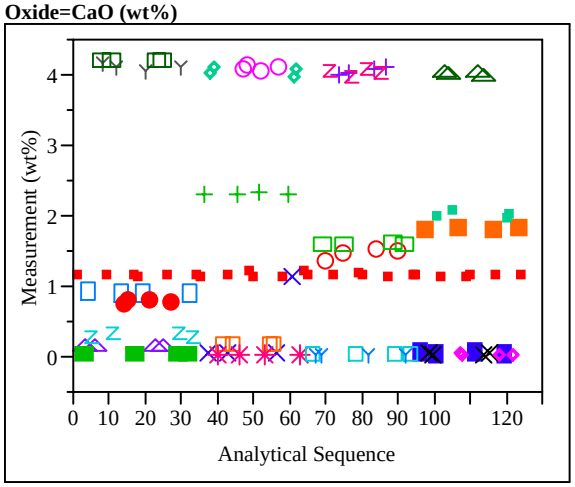
Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=Al2O3 (wt%)



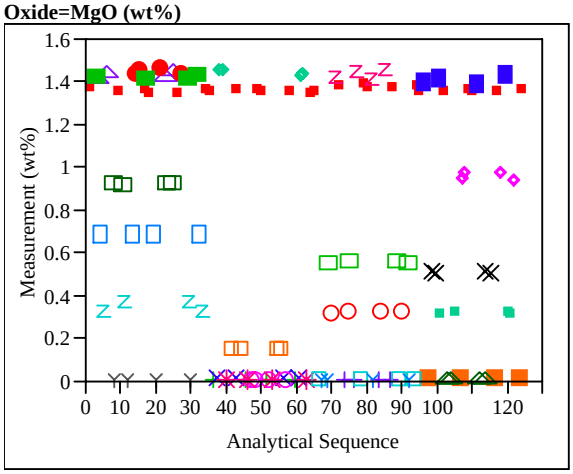
Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=Fe2O3 (wt%)



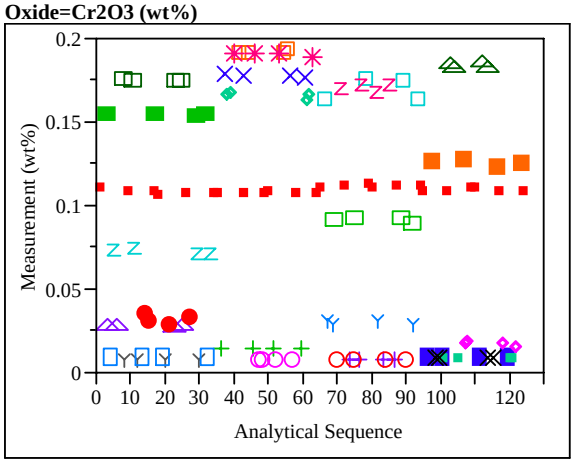
Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=CaO (wt%)



Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=MgO (wt%)



Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=Cr2O3 (wt%)



Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=MnO (wt%)

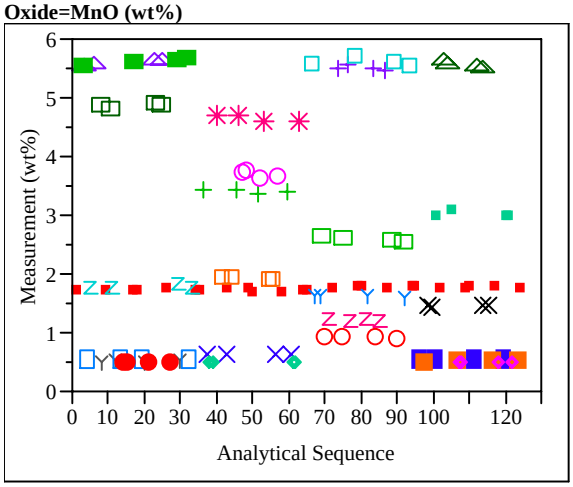
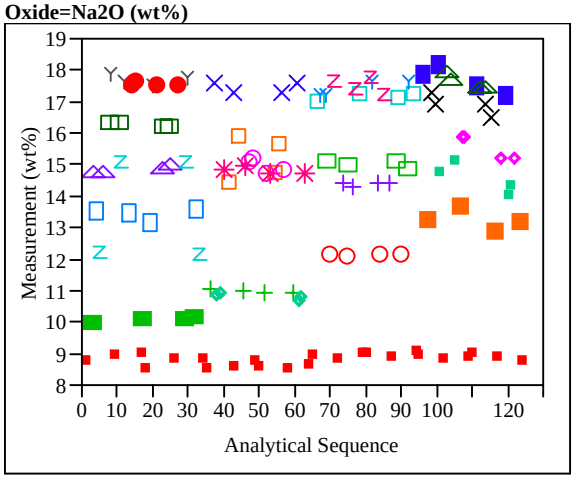
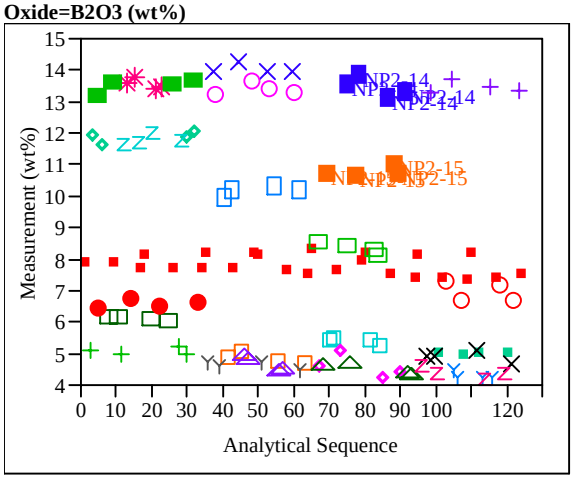


Exhibit A1. Measurements in Analytical Sequence for Samples by Oxide by Prep Method. (continued)

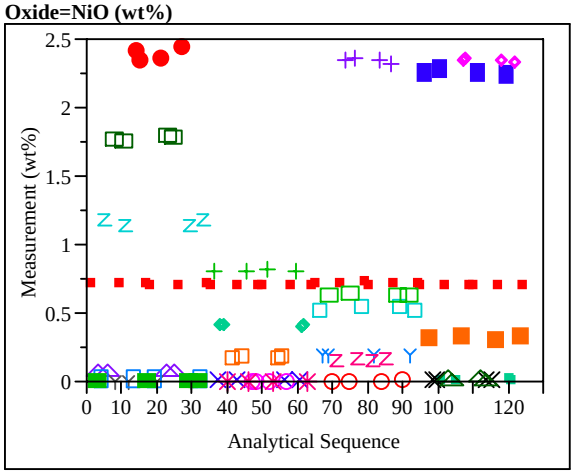
Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=Na2O (wt%)



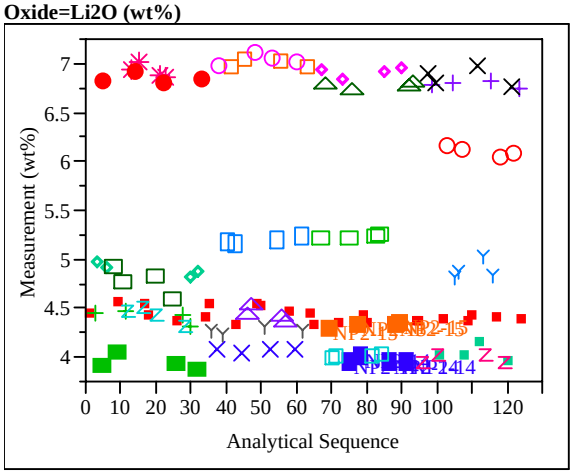
Measurement (wt%) By Analytical Sequence Prep=PF, Oxide=B2O3 (wt%)



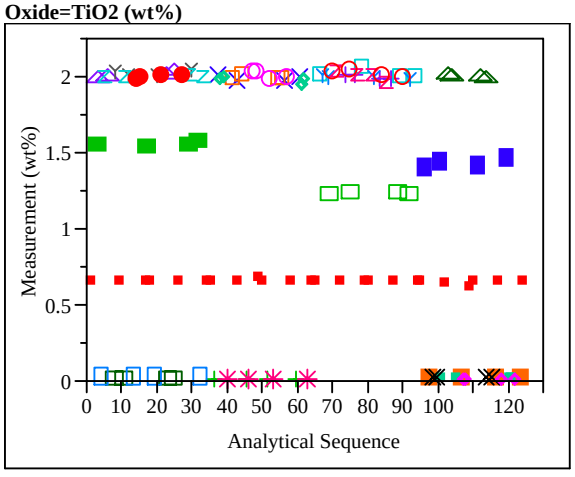
Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=NiO (wt%)



Measurement (wt%) By Analytical Sequence Prep=PF, Oxide=Li2O (wt%)



Measurement (wt%) By Analytical Sequence Prep=LM, Oxide=TiO2 (wt%)



Measurement (wt%) By Analytical Sequence Prep=PF, Oxide=SiO2 (wt%)

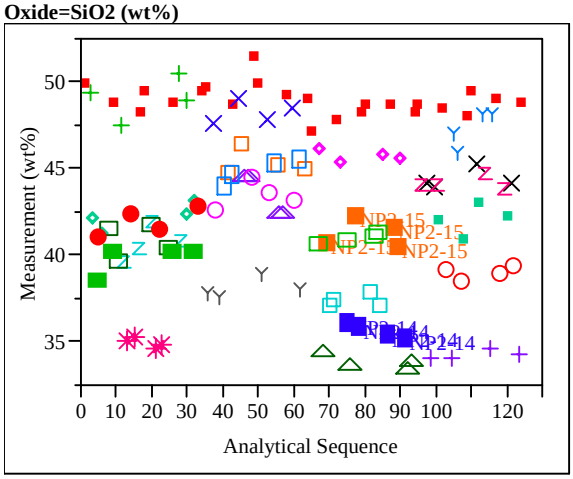
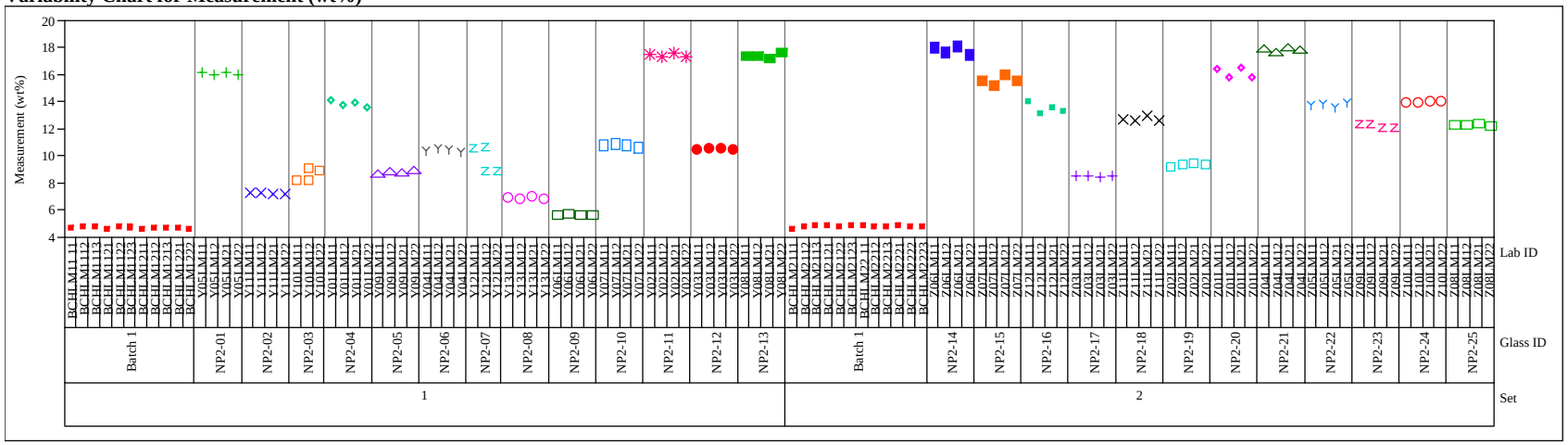


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method.

Prep=LM, Oxide=Al2O3 (wt%)
Variability Chart for Measurement (wt%)



Prep=LM, Oxide=CaO (wt%)
Variability Chart for Measurement (wt%)

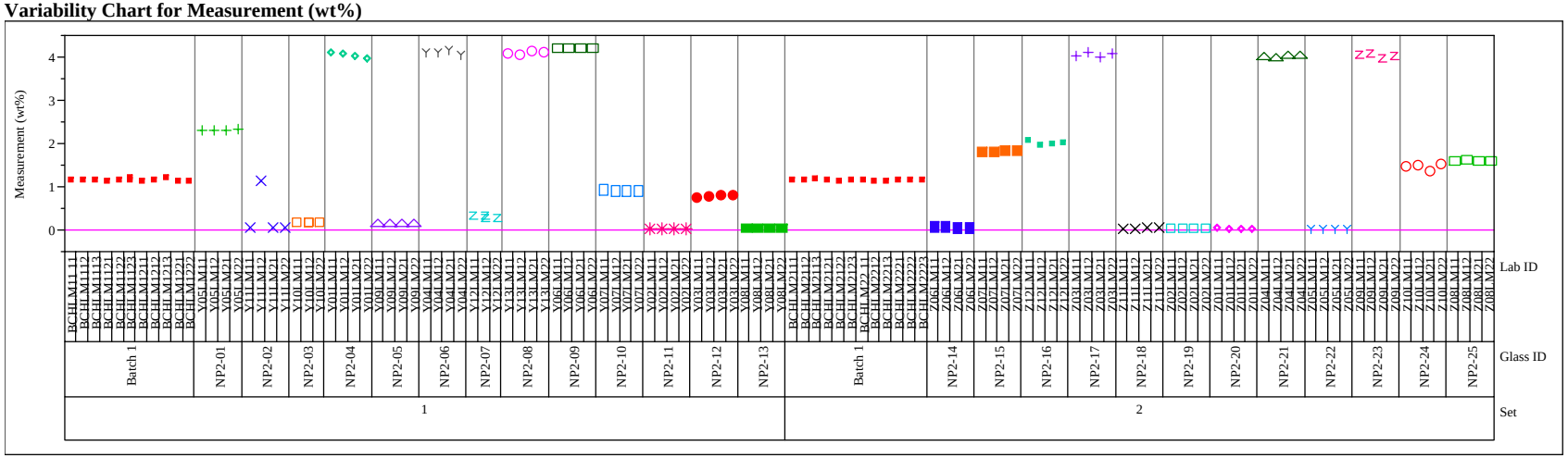
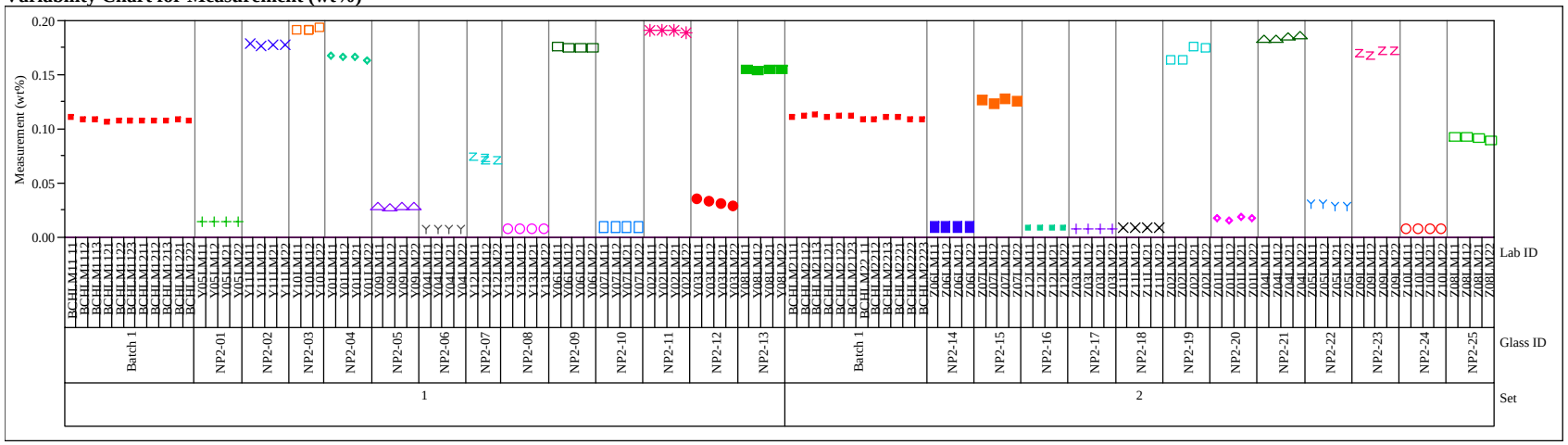


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method. (continued)

Prep=LM, Oxide=Cr2O3 (wt%)
Variability Chart for Measurement (wt%)



Prep=LM, Oxide=Fe2O3 (wt%)
Variability Chart for Measurement (wt%)

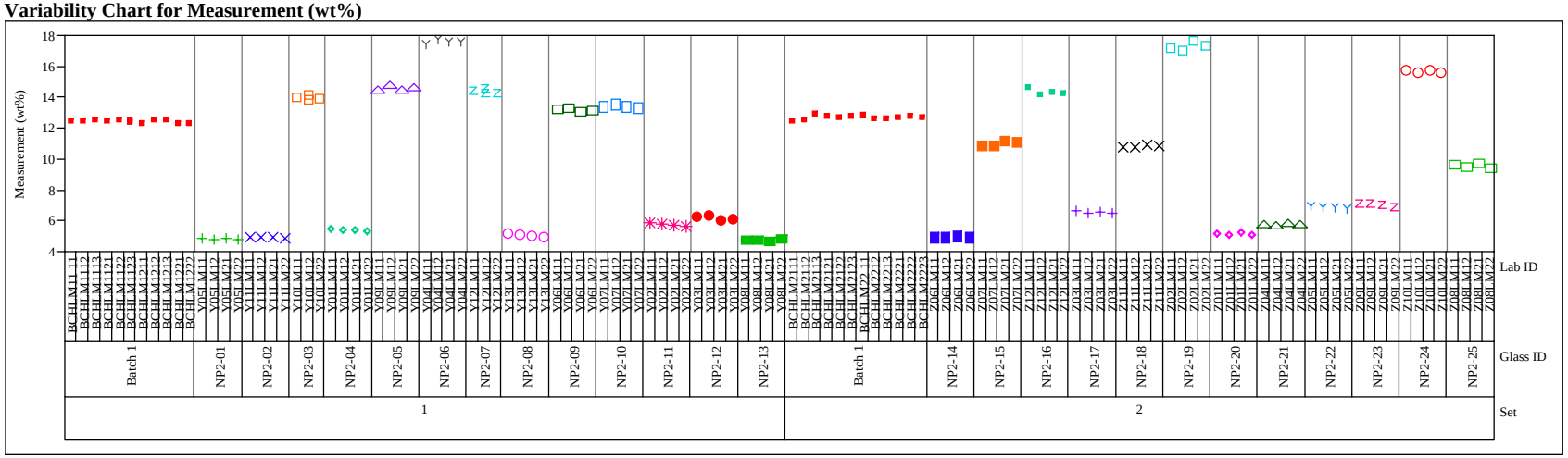
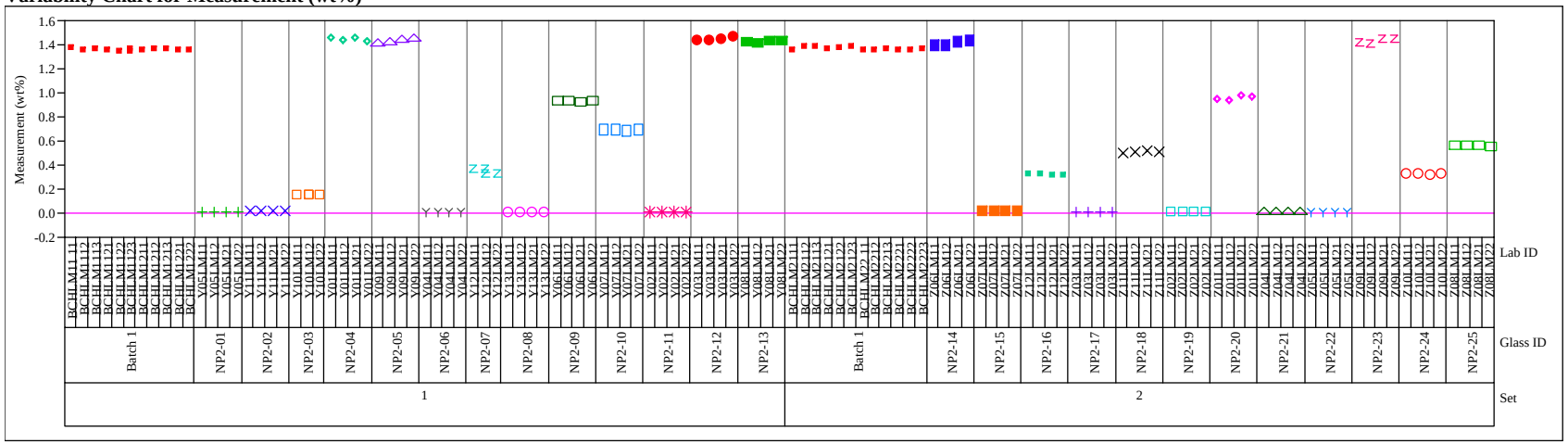


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method. (continued)

Prep=LM, Oxide=MgO (wt%)
Variability Chart for Measurement (wt%)



Prep=LM, Oxide=MnO (wt%)
Variability Chart for Measurement (wt%)

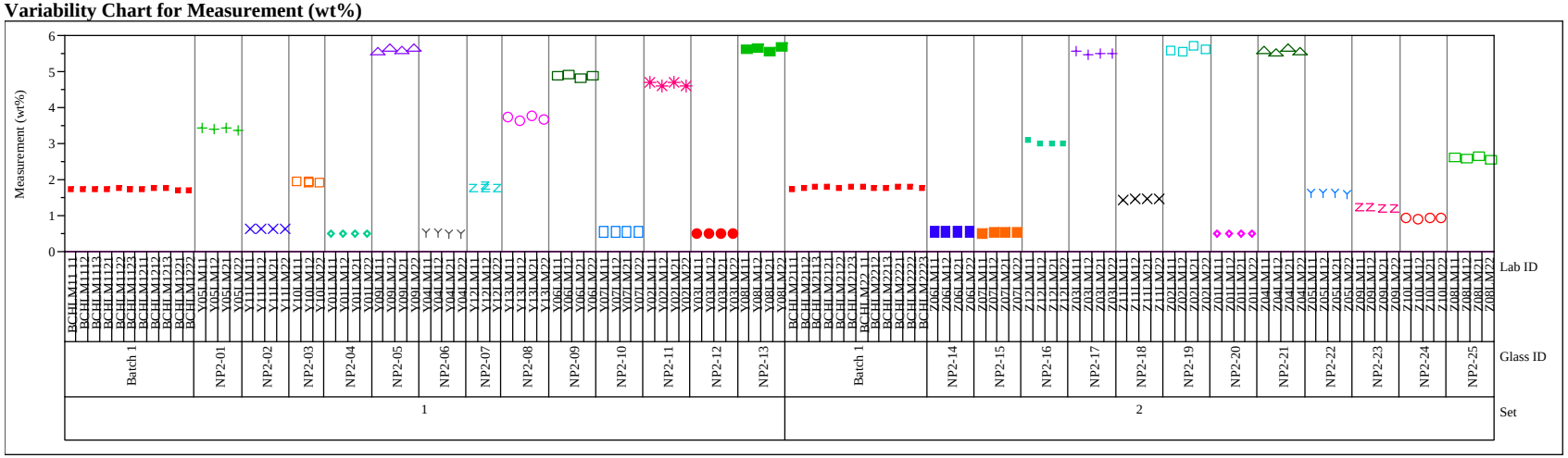
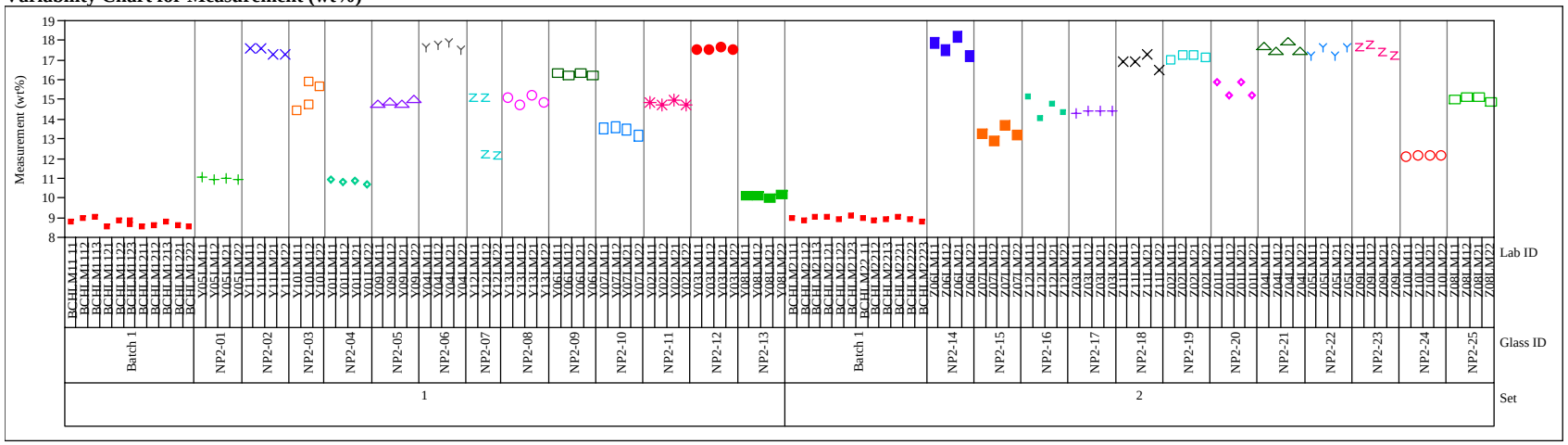


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method. (continued)

Prep=LM, Oxide=Na2O (wt%)
Variability Chart for Measurement (wt%)



Prep=LM, Oxide=NiO (wt%)
Variability Chart for Measurement (wt%)

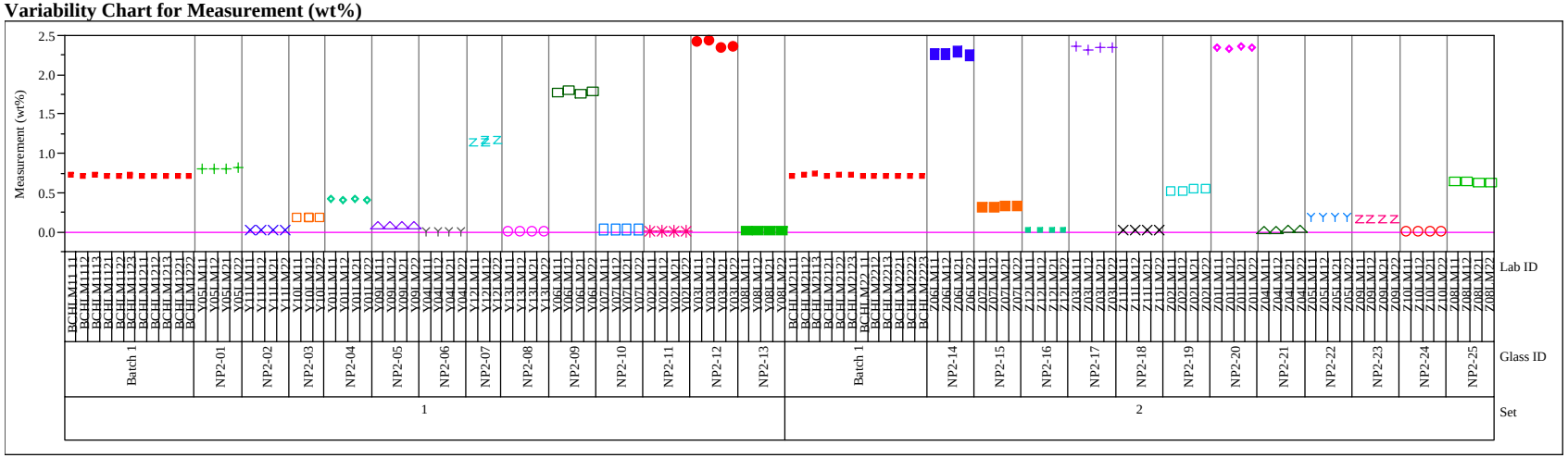
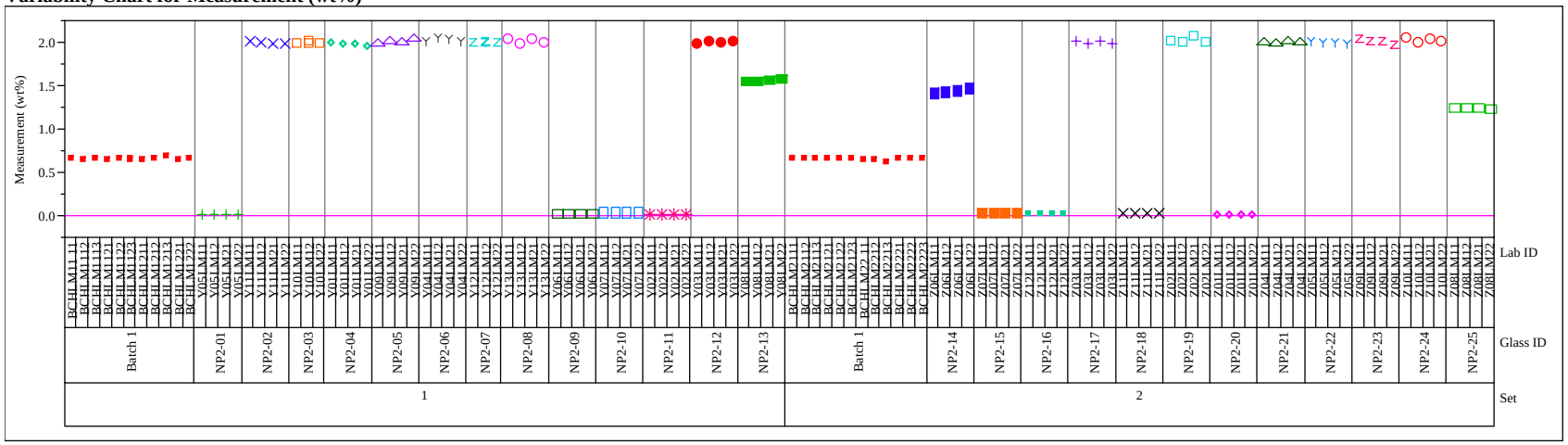


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method. (continued)

Prep=LM, Oxide=TiO2 (wt%)
Variability Chart for Measurement (wt%)



Prep=PF, Oxide=B2O3 (wt%)
Variability Chart for Measurement (wt%)

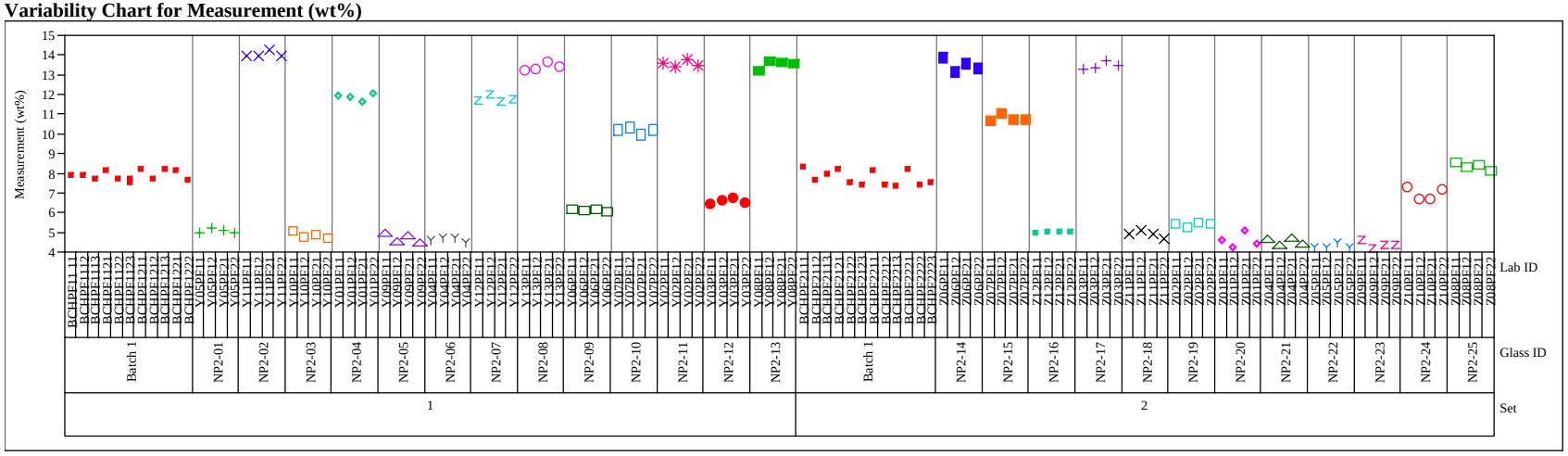
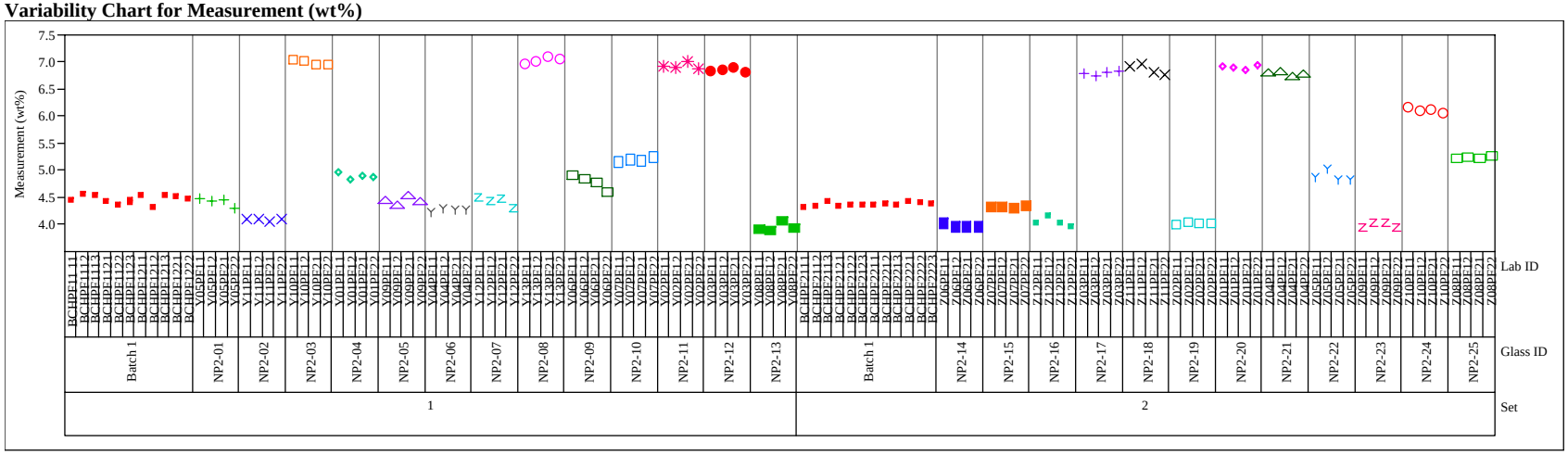


Exhibit A2. Measurements by Lab ID within Glass ID for Samples by Oxide and by Prep Method. (continued)

Prep=PF, Oxide=Li2O (wt%)
Variability Chart for Measurement (wt%)



Prep=PF, Oxide=SiO2 (wt%)
Variability Chart for Measurement (wt%)

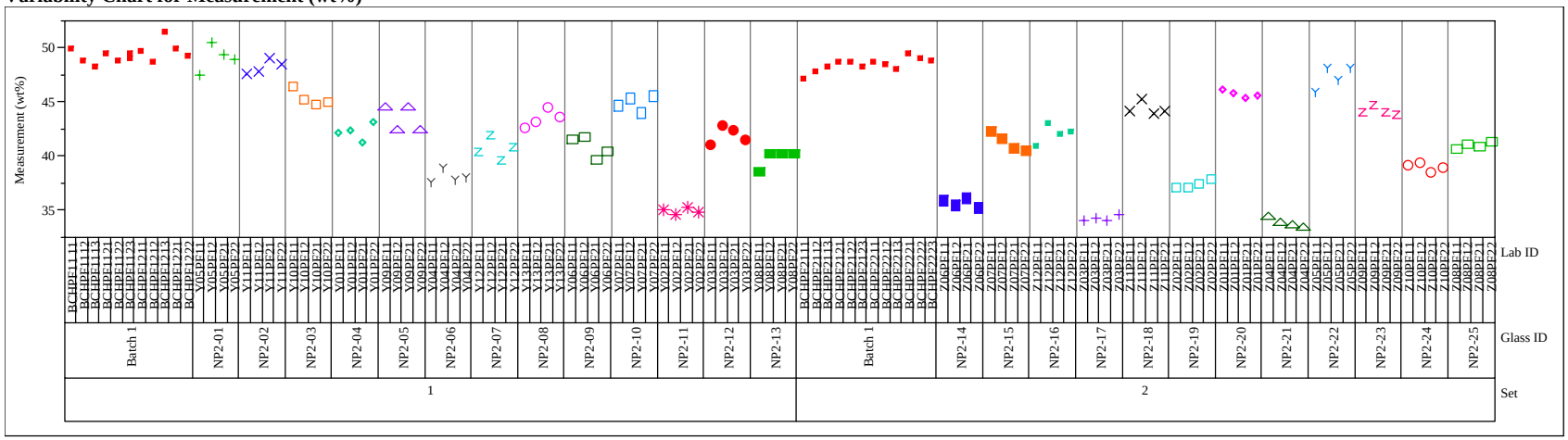
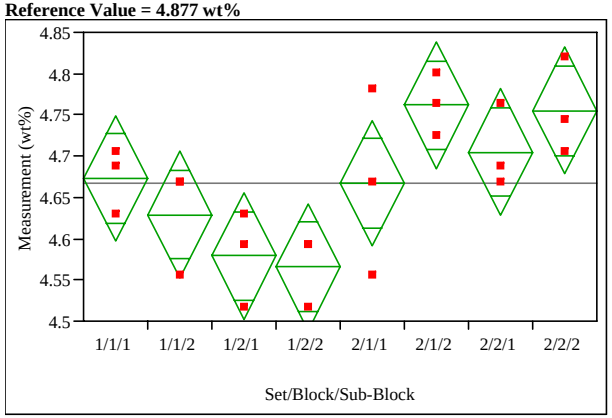


Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method.

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=Al2O3 (wt%), Glass ID=Batch 1
Reference Value = 4.877 wt%



Oneway Anova
Summary of Fit

Rsquare	0.643537
Adj Rsquare	0.487585
Root Mean Square Error	0.06243
Mean of Response	4.667065
Observations (or Sum Wgts)	24

Analysis of Variance

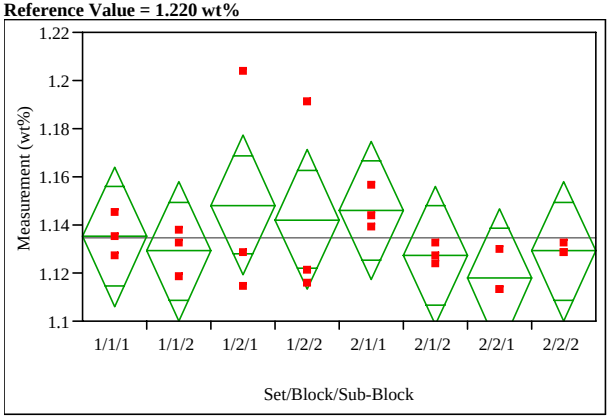
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.11258063	0.016083	4.1265	0.0090
Error	16	0.06235967	0.003897		
C. Total	23	0.17494030			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	4.67336	0.03604	4.5970	4.7498
1/1/2	3	4.62928	0.03604	4.5529	4.7057
1/2/1	3	4.57889	0.03604	4.5025	4.6553
1/2/2	3	4.56629	0.03604	4.4899	4.6427
2/1/1	3	4.66707	0.03604	4.5907	4.7435
2/1/2	3	4.76154	0.03604	4.6851	4.8379
2/2/1	3	4.70486	0.03604	4.6284	4.7813
2/2/2	3	4.75524	0.03604	4.6788	4.8317

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=CaO (wt%), Glass ID=Batch 1
Reference Value = 1.220 wt%



Oneway Anova
Summary of Fit

Rsquare	0.203857
Adj Rsquare	-0.14446
Root Mean Square Error	0.023644
Mean of Response	1.134401
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.00229025	0.000327	0.5853	0.7584
Error	16	0.00894436	0.000559		
C. Total	23	0.01123461			

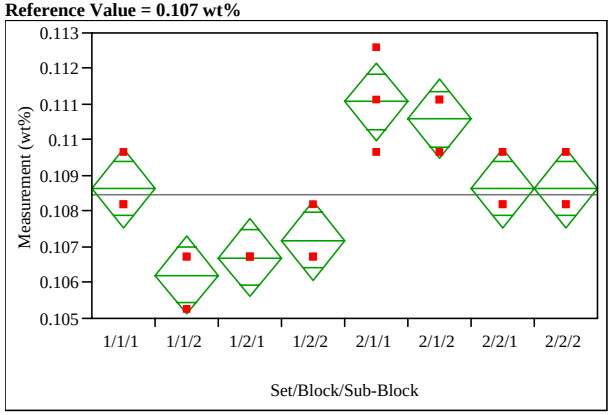
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	1.13522	0.01365	1.1063	1.1642
1/1/2	3	1.12915	0.01365	1.1002	1.1581
1/2/1	3	1.14828	0.01365	1.1193	1.1772
1/2/2	3	1.14221	0.01365	1.1133	1.1712
2/1/1	3	1.14594	0.01365	1.1170	1.1749
2/1/2	3	1.12729	0.01365	1.0984	1.1562
2/2/1	3	1.11796	0.01365	1.0890	1.1469
2/2/2	3	1.12915	0.01365	1.1002	1.1581

Std Error uses a pooled estimate of error variance

Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method. (continued)

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=Cr2O3 (wt%), Glass ID=Batch 1
Reference Value = 0.107 wt%



Oneway Anova
Summary of Fit

Rsquare	0.83314
Adj Rsquare	0.760139
Root Mean Square Error	0.000895
Mean of Response	0.108463
Observations (or Sum Wgts)	24

Analysis of Variance

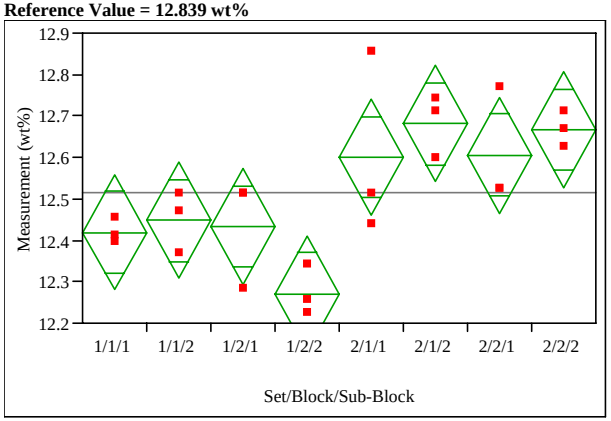
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.00006400	9.1427e-6	11.4127	<.0001
Error	16	0.00001282	8.011e-7		
C. Total	23	0.00007682			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	0.108646	0.00052	0.10755	0.10974
1/1/2	3	0.106210	0.00052	0.10511	0.10731
1/2/1	3	0.106697	0.00052	0.10560	0.10779
1/2/2	3	0.107184	0.00052	0.10609	0.10828
2/1/1	3	0.111082	0.00052	0.10999	0.11218
2/1/2	3	0.110594	0.00052	0.10950	0.11169
2/2/1	3	0.108646	0.00052	0.10755	0.10974
2/2/2	3	0.108646	0.00052	0.10755	0.10974

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=Fe2O3 (wt%), Glass ID=Batch 1
Reference Value = 12.839 wt%



Oneway Anova
Summary of Fit

Rsquare	0.678486
Adj Rsquare	0.537824
Root Mean Square Error	0.113816
Mean of Response	12.51583
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.43739094	0.062484	4.8235	0.0044
Error	16	0.20726587	0.012954		
C. Total	23	0.64465681			

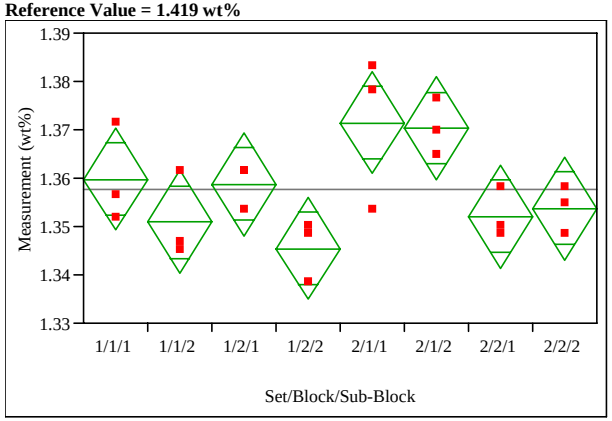
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	12.4193	0.06571	12.280	12.559
1/1/2	3	12.4479	0.06571	12.309	12.587
1/2/1	3	12.4336	0.06571	12.294	12.573
1/2/2	3	12.2716	0.06571	12.132	12.411
2/1/1	3	12.6004	0.06571	12.461	12.740
2/1/2	3	12.6814	0.06571	12.542	12.821
2/2/1	3	12.6052	0.06571	12.466	12.744
2/2/2	3	12.6671	0.06571	12.528	12.806

Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method. (continued)

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=MgO (wt%), Glass ID=Batch 1
Reference Value = 1.419 wt%



Oneway Anova
Summary of Fit

Rsquare	0.599616
Adj Rsquare	0.424447
Root Mean Square Error	0.008637
Mean of Response	1.357802
Observations (or Sum Wgts)	24

Analysis of Variance

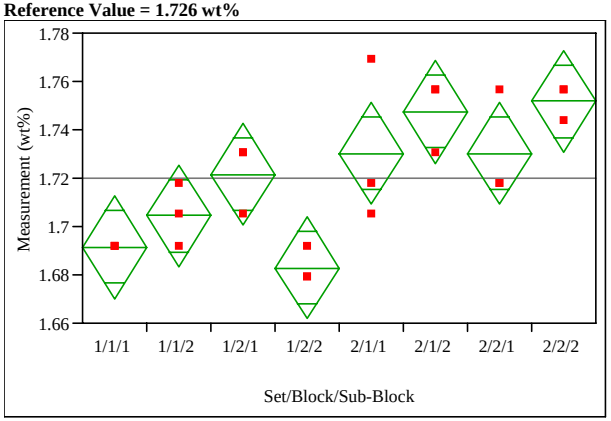
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.00178736	0.000255	3.4231	0.0197
Error	16	0.00119348	0.000075		
C. Total	23	0.00298084			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	1.35981	0.00499	1.3492	1.3704
1/1/2	3	1.35096	0.00499	1.3404	1.3615
1/2/1	3	1.35870	0.00499	1.3481	1.3693
1/2/2	3	1.34543	0.00499	1.3349	1.3560
2/1/1	3	1.37141	0.00499	1.3608	1.3820
2/1/2	3	1.37031	0.00499	1.3597	1.3809
2/2/1	3	1.35207	0.00499	1.3415	1.3626
2/2/2	3	1.35373	0.00499	1.3432	1.3643

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=MnO (wt%), Glass ID=Batch 1
Reference Value = 1.726 wt%



Oneway Anova
Summary of Fit

Rsquare	0.734465
Adj Rsquare	0.618294
Root Mean Square Error	0.017283
Mean of Response	1.719986
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.01321949	0.001888	6.3223	0.0011
Error	16	0.00477930	0.000299		
C. Total	23	0.01799879			

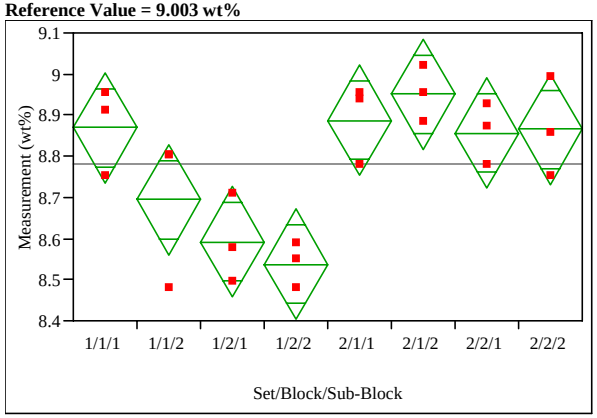
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	1.69147	0.00998	1.6703	1.7126
1/1/2	3	1.70438	0.00998	1.6832	1.7255
1/2/1	3	1.72160	0.00998	1.7004	1.7428
1/2/2	3	1.68286	0.00998	1.6617	1.7040
2/1/1	3	1.73021	0.00998	1.7091	1.7514
2/1/2	3	1.74742	0.00998	1.7263	1.7686
2/2/1	3	1.73021	0.00998	1.7091	1.7514
2/2/2	3	1.75173	0.00998	1.7306	1.7729

Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method. (continued)

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=Na2O (wt%), Glass ID=Batch 1
Reference Value = 9.003 wt%



Oneway Anova
Summary of Fit

Rsquare	0.719734
Adj Rsquare	0.597118
Root Mean Square Error	0.109339
Mean of Response	8.781658
Observations (or Sum Wgts)	24

Analysis of Variance

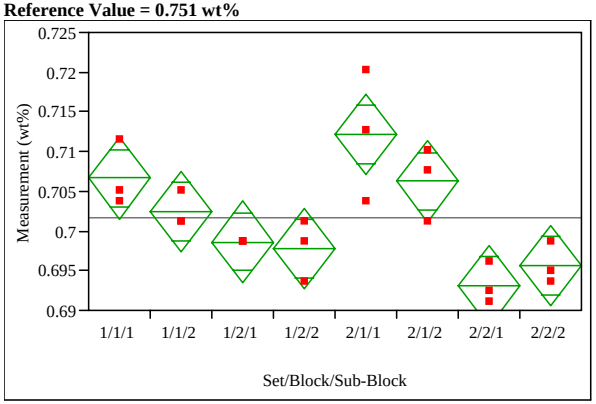
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.49121621	0.070174	5.8698	0.0017
Error	16	0.19128048	0.011955		
C. Total	23	0.68249669			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	8.86984	0.06313	8.7360	9.0037
1/1/2	3	8.69460	0.06313	8.5608	8.8284
1/2/1	3	8.59125	0.06313	8.4574	8.7251
1/2/2	3	8.53733	0.06313	8.4035	8.6712
2/1/1	3	8.88781	0.06313	8.7540	9.0216
2/1/2	3	8.95072	0.06313	8.8169	9.0845
2/2/1	3	8.85636	0.06313	8.7225	8.9902
2/2/2	3	8.86535	0.06313	8.7315	8.9992

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=NiO (wt%), Glass ID=Batch 1
Reference Value = 0.751 wt%



Oneway Anova
Summary of Fit

Rsquare	0.757009
Adj Rsquare	0.650701
Root Mean Square Error	0.004188
Mean of Response	0.701572
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.00087440	0.000125	7.1209	0.0006
Error	16	0.00028067	0.000018		
C. Total	23	0.00115507			

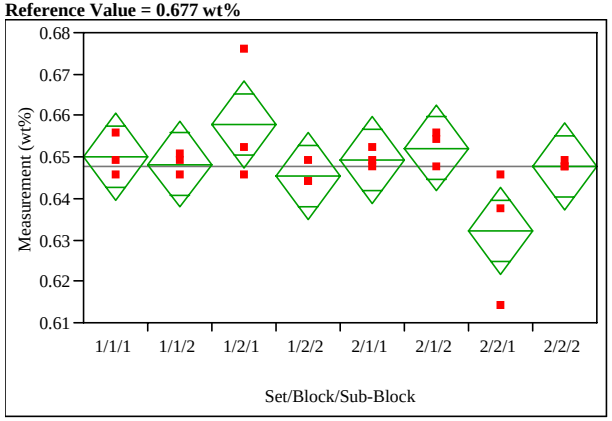
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	0.706662	0.00242	0.70154	0.71179
1/1/2	3	0.702420	0.00242	0.69729	0.70755
1/2/1	3	0.698603	0.00242	0.69348	0.70373
1/2/2	3	0.697754	0.00242	0.69263	0.70288
2/1/1	3	0.712176	0.00242	0.70705	0.71730
2/1/2	3	0.706238	0.00242	0.70111	0.71136
2/2/1	3	0.693088	0.00242	0.68796	0.69821
2/2/2	3	0.695633	0.00242	0.69051	0.70076

Std Error uses a pooled estimate of error variance

Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method. (continued)

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=LM, Oxide=TiO2 (wt%), Glass ID=Batch 1
Reference Value = 0.677 wt%



Oneway Anova
Summary of Fit

Rsquare	0.489808
Adj Rsquare	0.266599
Root Mean Square Error	0.00856
Mean of Response	0.647879
Observations (or Sum Wgts)	24

Analysis of Variance

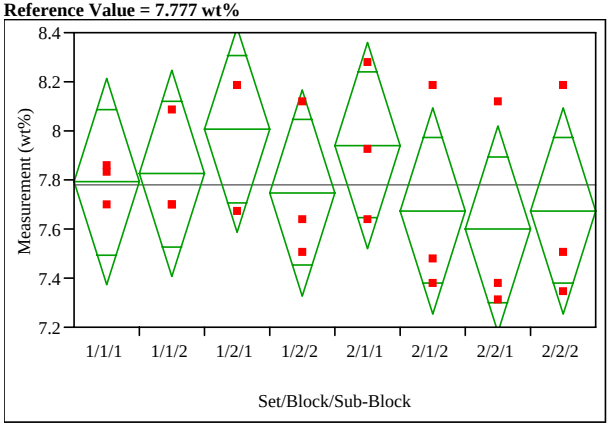
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.00112541	0.000161	2.1944	0.0915
Error	16	0.00117224	0.000073		
C. Total	23	0.00229765			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	0.649964	0.00494	0.63949	0.66044
1/1/2	3	0.648296	0.00494	0.63782	0.65877
1/2/1	3	0.657748	0.00494	0.64727	0.66822
1/2/2	3	0.645516	0.00494	0.63504	0.65599
2/1/1	3	0.649408	0.00494	0.63893	0.65988
2/1/2	3	0.652188	0.00494	0.64171	0.66266
2/2/1	3	0.632172	0.00494	0.62170	0.64265
2/2/2	3	0.647740	0.00494	0.63726	0.65822

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=PF, Oxide=B2O3 (wt%), Glass ID=Batch 1
Reference Value = 7.777 wt%



Oneway Anova
Summary of Fit

Rsquare	0.177712
Adj Rsquare	-0.18204
Root Mean Square Error	0.34354
Mean of Response	7.782767
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.4081008	0.058300	0.4940	0.8254
Error	16	1.8883140	0.118020		
C. Total	23	2.2964148			

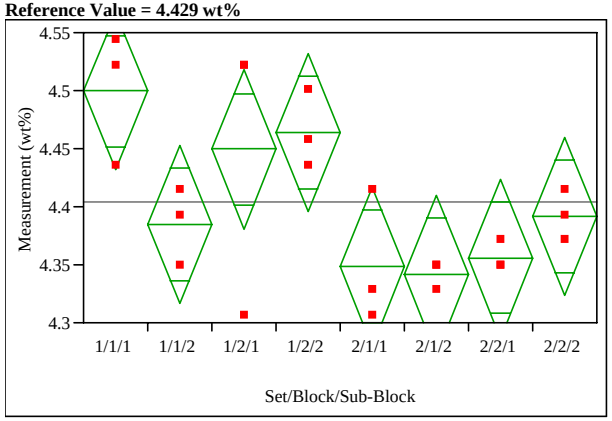
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	7.79216	0.19834	7.3717	8.2126
1/1/2	3	7.82436	0.19834	7.4039	8.2448
1/2/1	3	8.00682	0.19834	7.5864	8.4273
1/2/2	3	7.74923	0.19834	7.3288	8.1697
2/1/1	3	7.94242	0.19834	7.5220	8.3629
2/1/2	3	7.67410	0.19834	7.2536	8.0946
2/2/1	3	7.59896	0.19834	7.1785	8.0194
2/2/2	3	7.67410	0.19834	7.2536	8.0946

Std Error uses a pooled estimate of error variance

Exhibit A3. PSAL Measurements by Analytical Set, Block, and Sub-Block for Samples of the Batch 1 Standard by Oxide by Prep Method. (continued)

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=PF, Oxide=Li2O (wt%), Glass ID=Batch 1
Reference Value = 4.429 wt%



Oneway Anova
Summary of Fit

Rsquare	0.596238
Adj Rsquare	0.419592
Root Mean Square Error	0.055761
Mean of Response	4.404475
Observations (or Sum Wgts)	24

Analysis of Variance

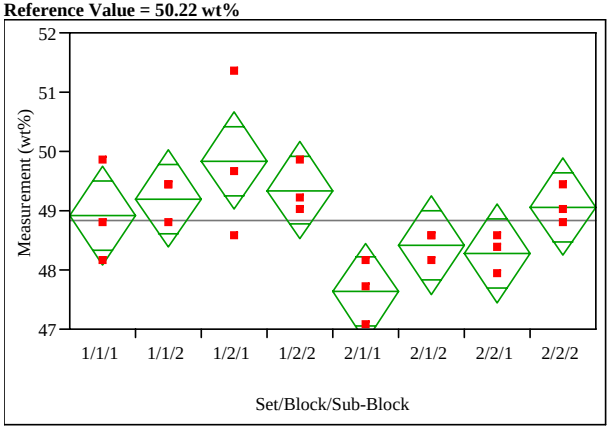
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	0.07346441	0.010495	3.3753	0.0208
Error	16	0.04974877	0.003109		
C. Total	23	0.12321318			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	4.49956	0.03219	4.4313	4.5678
1/1/2	3	4.38474	0.03219	4.3165	4.4530
1/2/1	3	4.44933	0.03219	4.3811	4.5176
1/2/2	3	4.46368	0.03219	4.3954	4.5319
2/1/1	3	4.34886	0.03219	4.2806	4.4171
2/1/2	3	4.34168	0.03219	4.2734	4.4099
2/2/1	3	4.35603	0.03219	4.2878	4.4243
2/2/2	3	4.39192	0.03219	4.3237	4.4602

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measurement (wt%) By Set/Block/Sub-Block
Prep=PF, Oxide=SiO2 (wt%), Glass ID=Batch 1
Reference Value = 50.22 wt%



Oneway Anova
Summary of Fit

Rsquare	0.585256
Adj Rsquare	0.403806
Root Mean Square Error	0.672265
Mean of Response	48.83844
Observations (or Sum Wgts)	24

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block/Sub-Block	7	10.203921	1.45770	3.2254	0.0248
Error	16	7.231035	0.45194		
C. Total	23	17.434956			

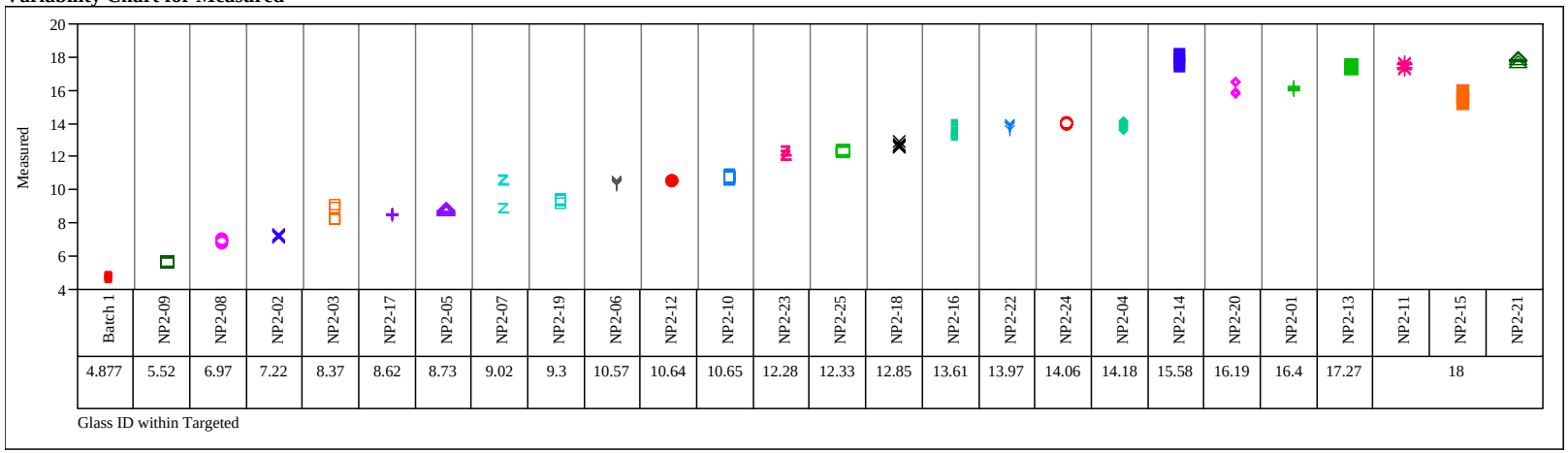
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1/1	3	48.9187	0.38813	48.096	49.741
1/1/2	3	49.2039	0.38813	48.381	50.027
1/2/1	3	49.8457	0.38813	49.023	50.668
1/2/2	3	49.3465	0.38813	48.524	50.169
2/1/1	3	47.6351	0.38813	46.812	48.458
2/1/2	3	48.4195	0.38813	47.597	49.242
2/2/1	3	48.2769	0.38813	47.454	49.100
2/2/2	3	49.0613	0.38813	48.238	49.884

Std Error uses a pooled estimate of error variance

Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps.

Prep=LM, Oxide=Al2O3 (wt%)
Variability Chart for Measured



Prep=LM, Oxide=Al2O3 (wt%)
Variability Chart for Measured bc

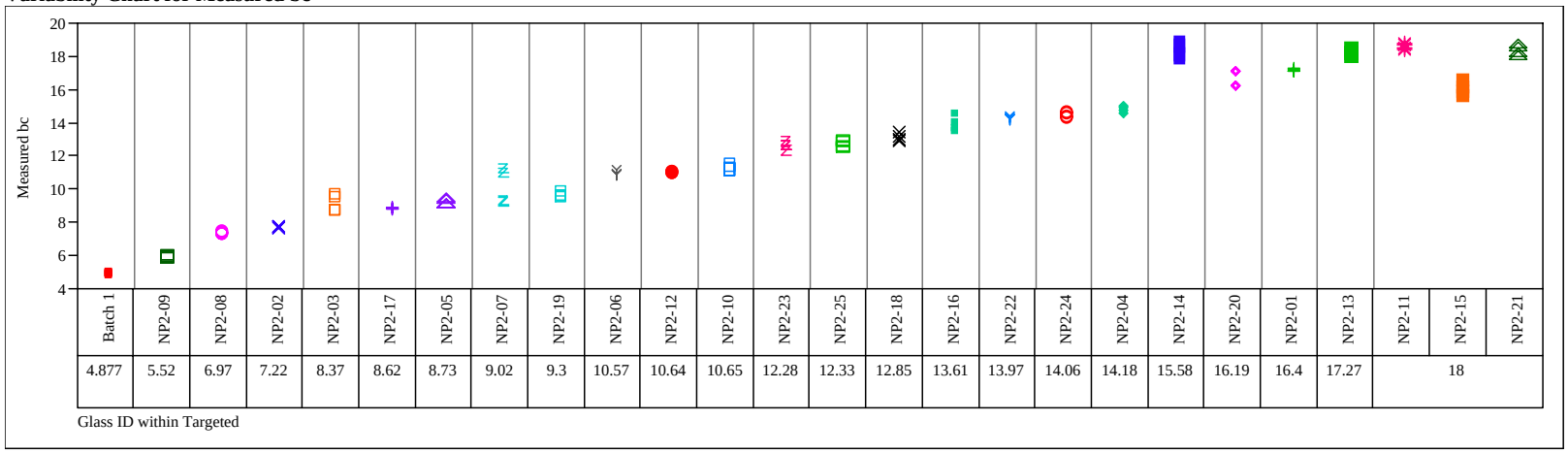
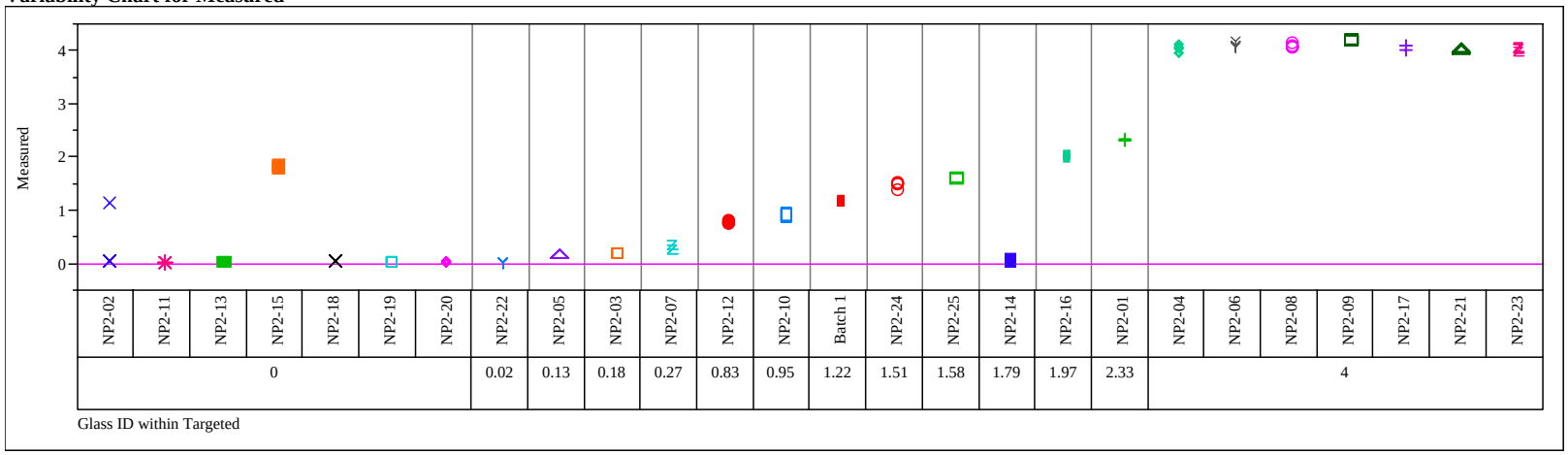


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=CaO (wt%)
Variability Chart for Measured



Prep=LM, Oxide=CaO (wt%)
Variability Chart for Measured bc

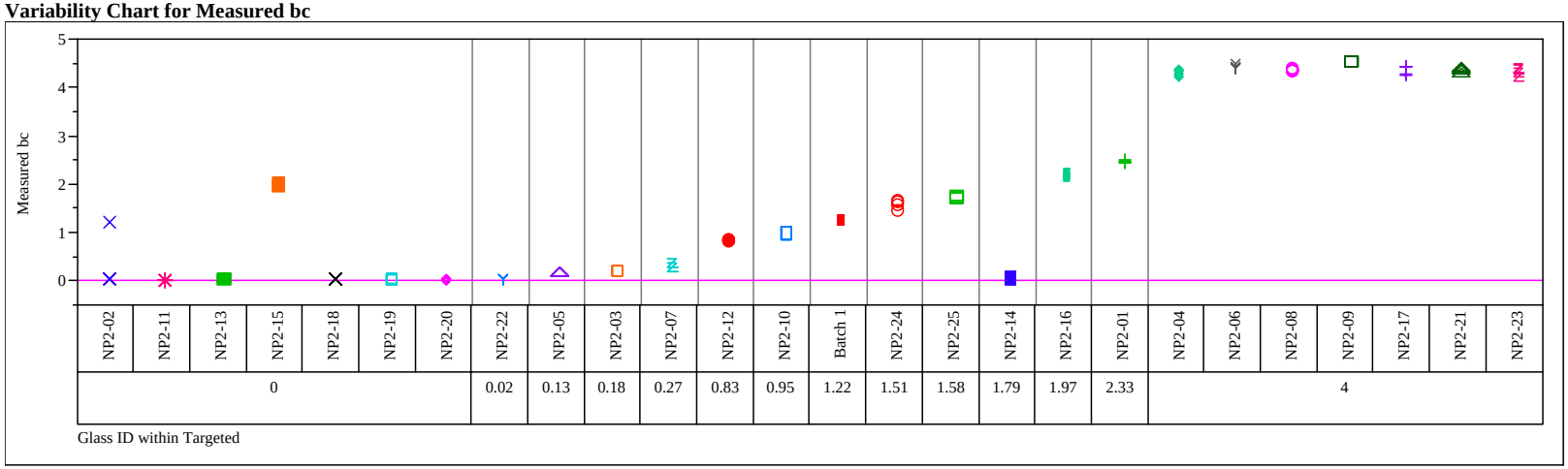
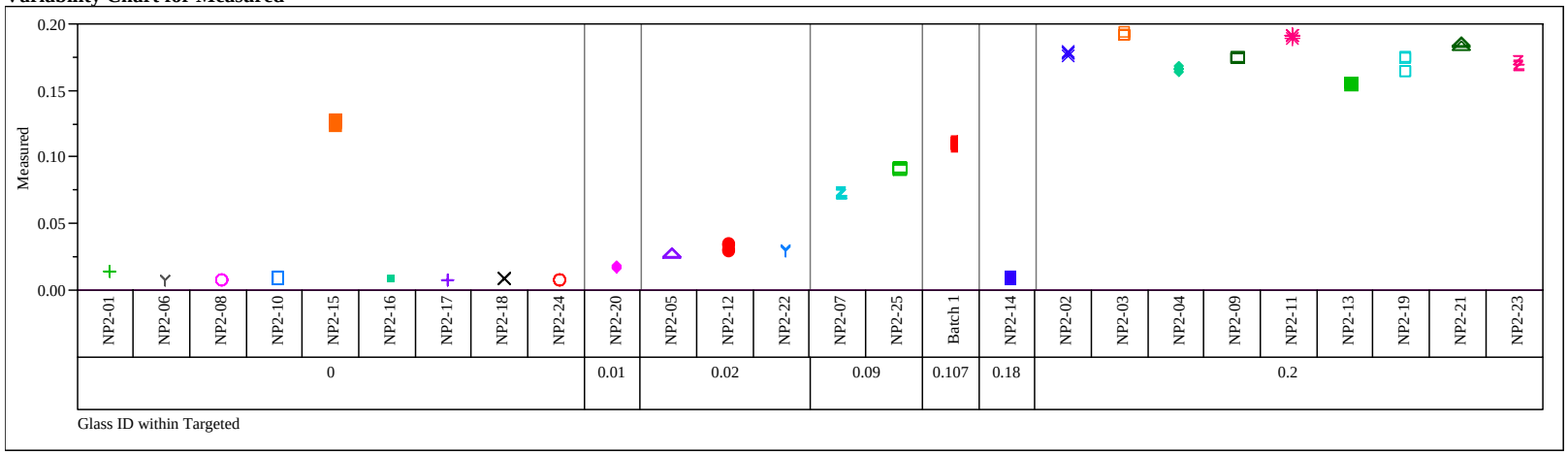


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=Cr2O3 (wt%)
Variability Chart for Measured



Prep=LM, Oxide=Cr2O3 (wt%)
Variability Chart for Measured bc

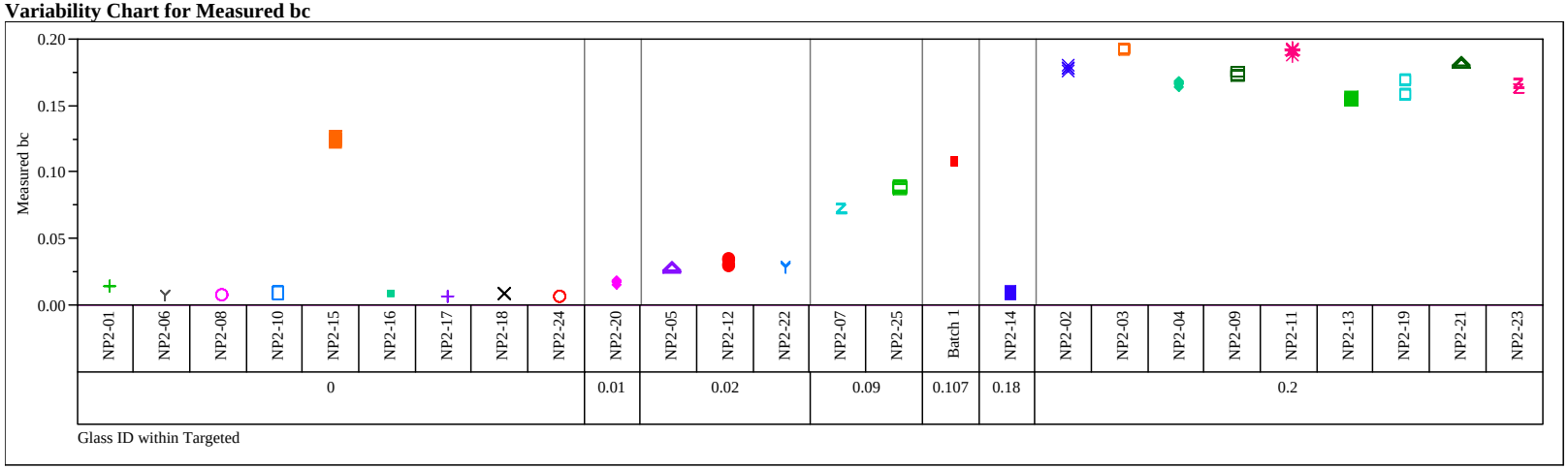
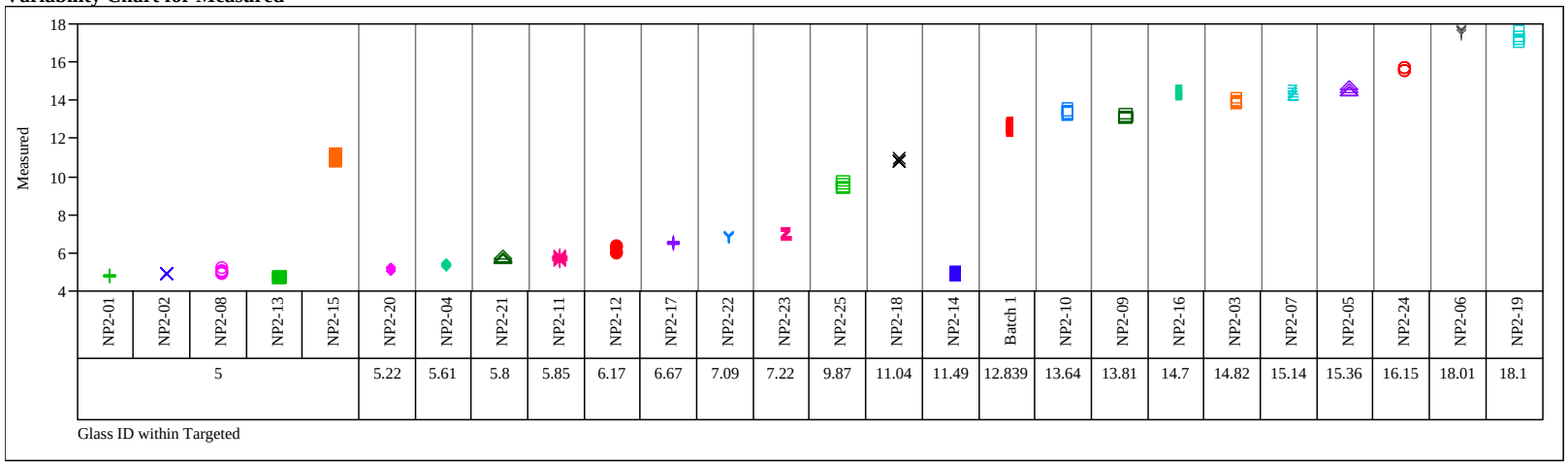


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=Fe2O3 (wt%)
Variability Chart for Measured



Prep=LM, Oxide=Fe2O3 (wt%)
Variability Chart for Measured bc

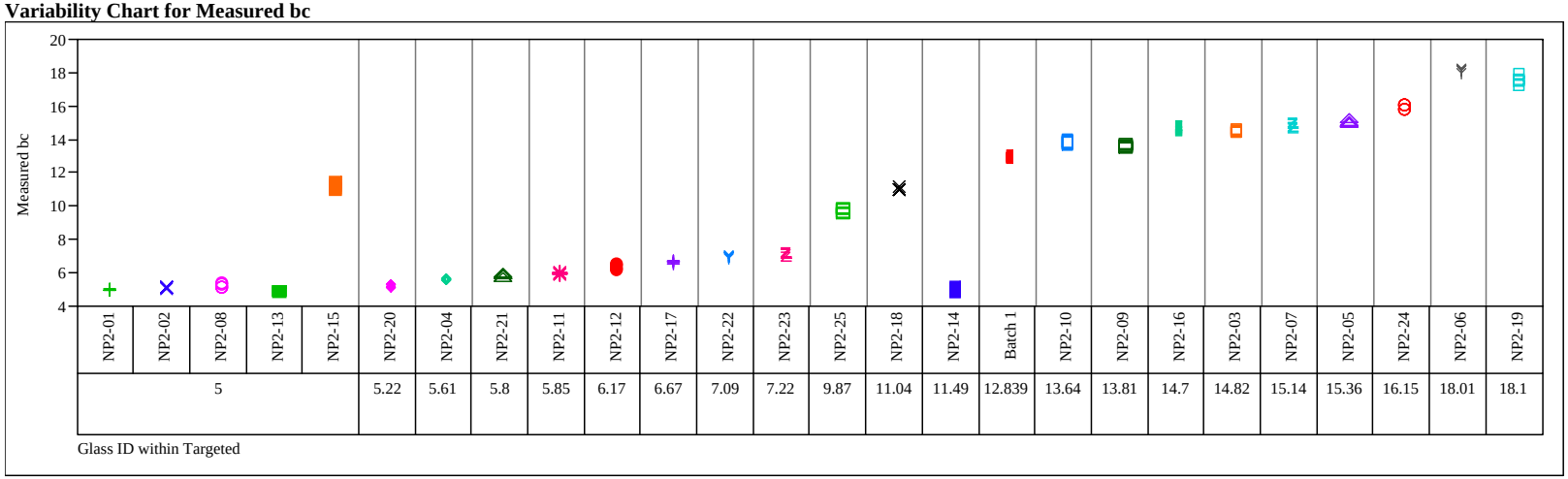
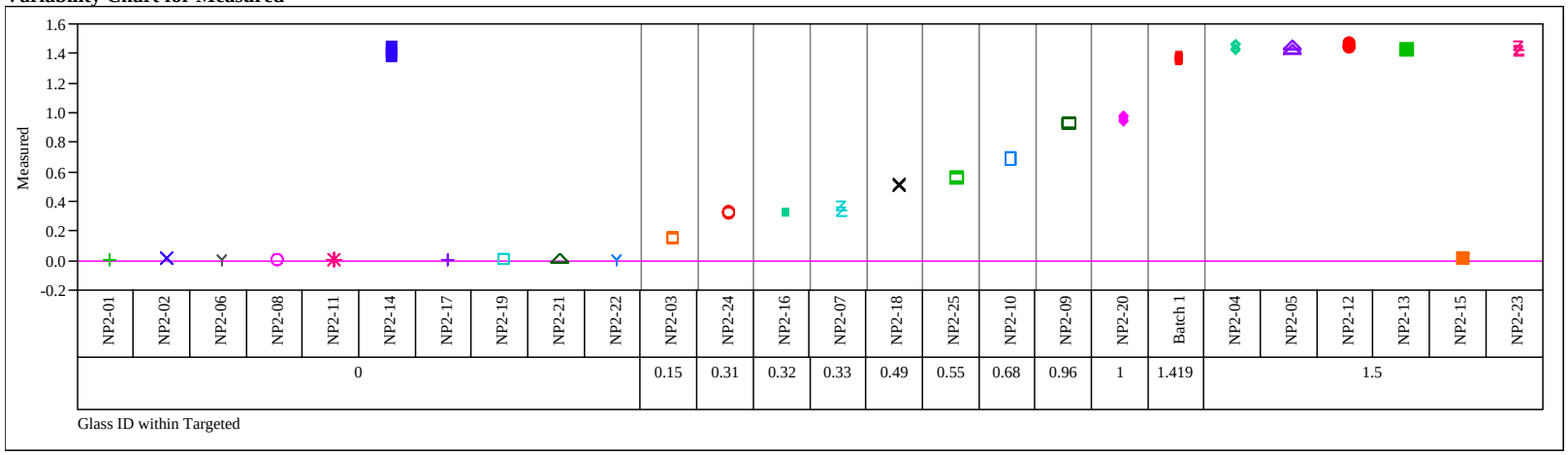


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=MgO (wt%)
Variability Chart for Measured



Prep=LM, Oxide=MgO (wt%)
Variability Chart for Measured bc

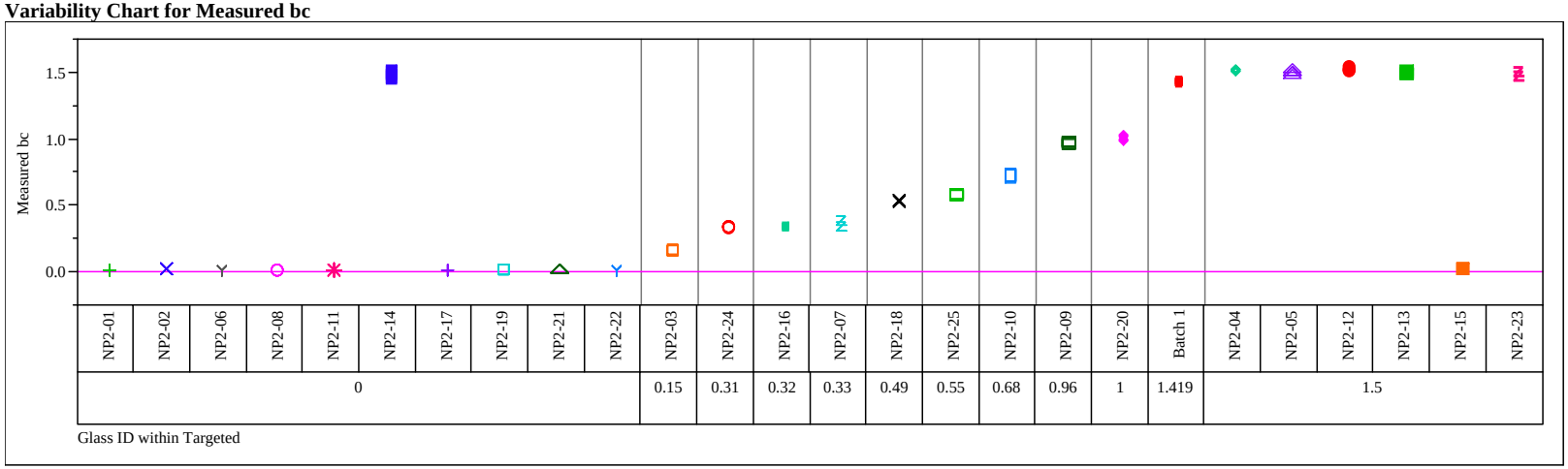
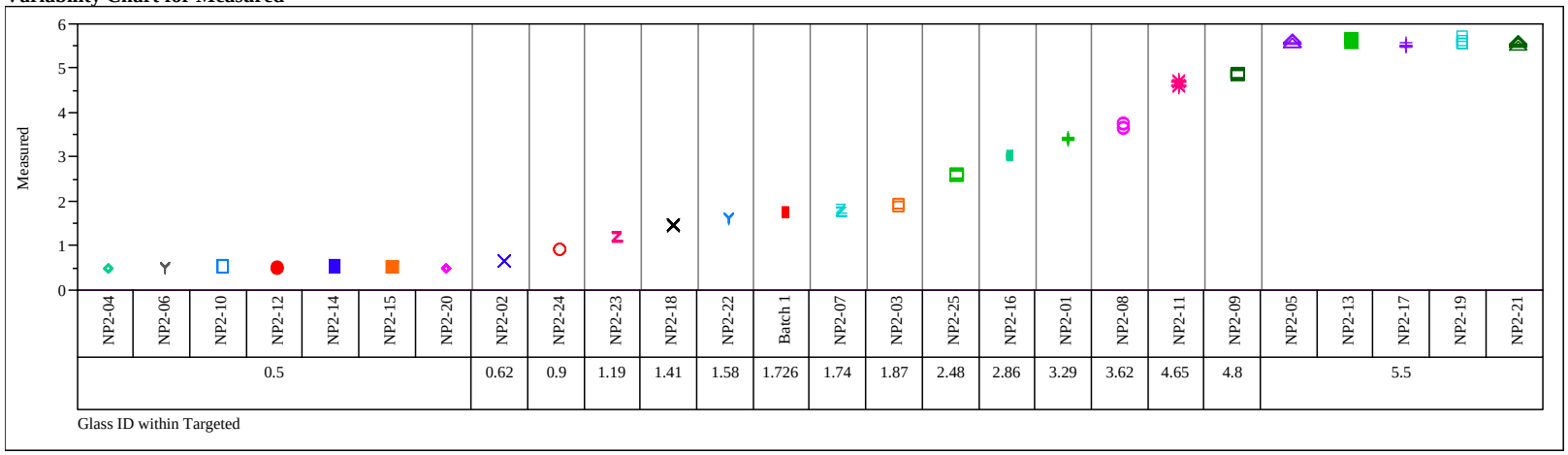


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=MnO (wt%)
Variability Chart for Measured



Prep=LM, Oxide=MnO (wt%)
Variability Chart for Measured bc

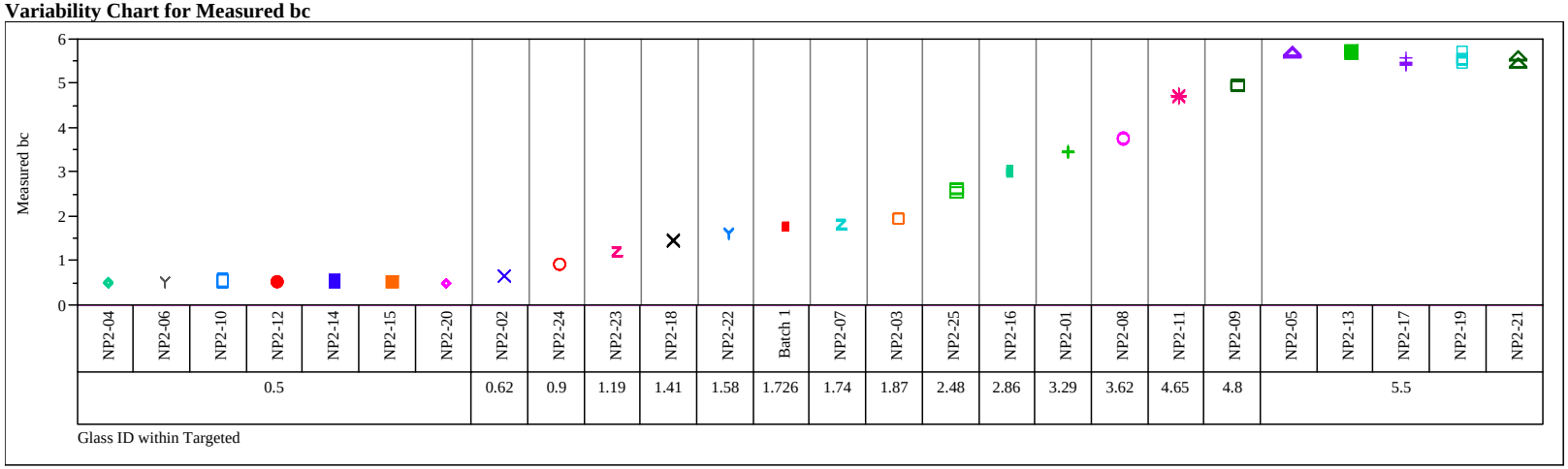
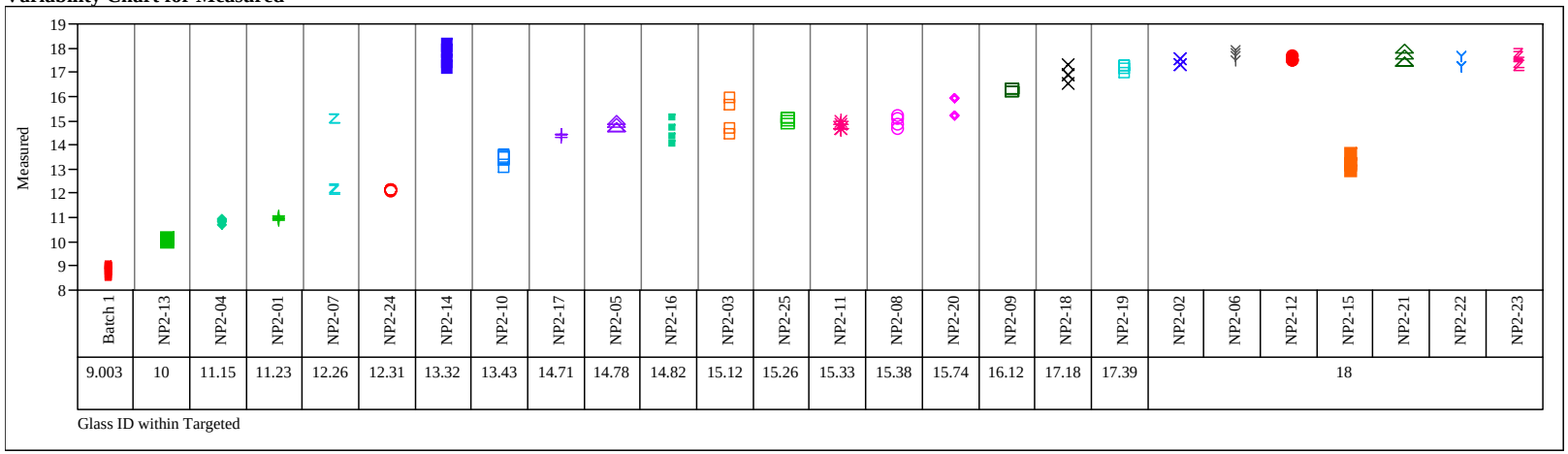


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=Na2O (wt%)
Variability Chart for Measured



Prep=LM, Oxide=Na2O (wt%)
Variability Chart for Measured bc

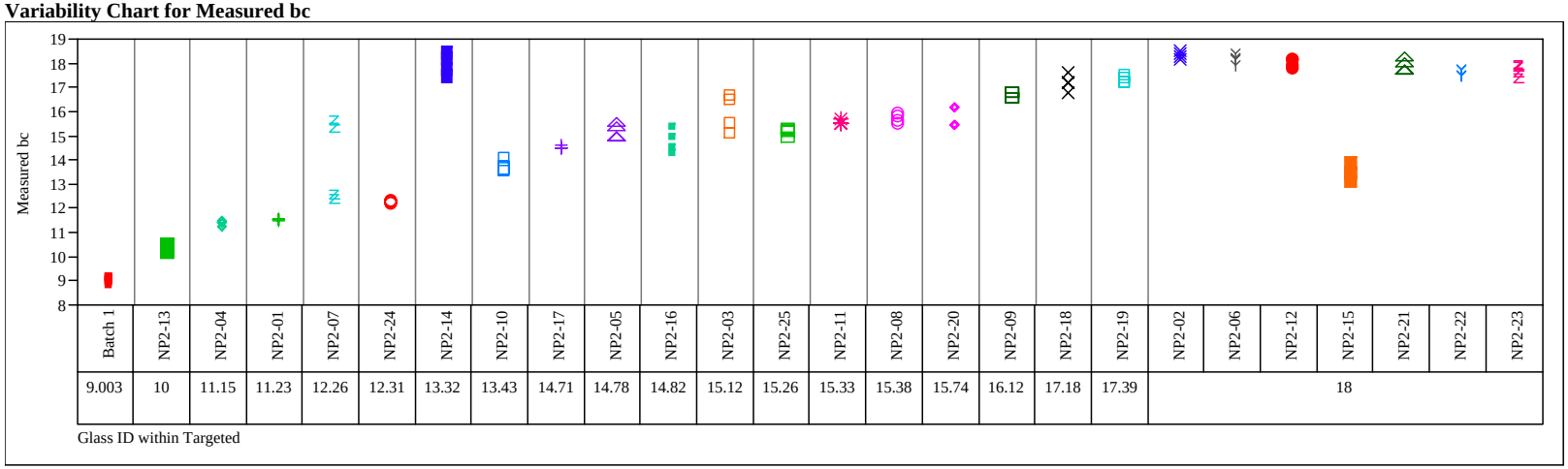
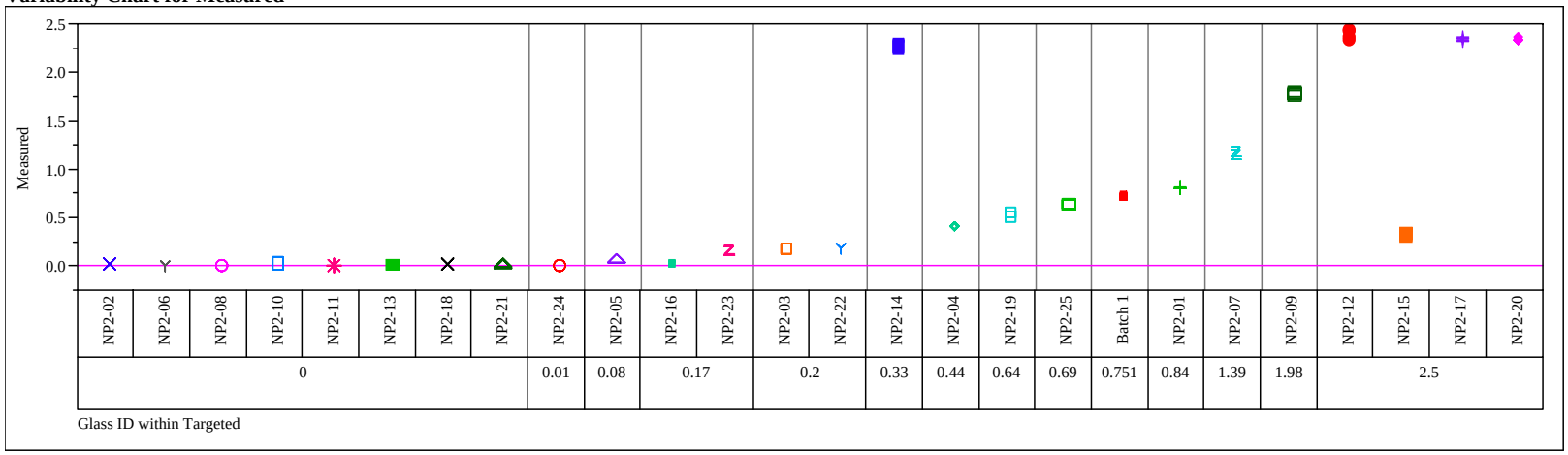


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=NiO (wt%)
Variability Chart for Measured



Prep=LM, Oxide=NiO (wt%)
Variability Chart for Measured bc

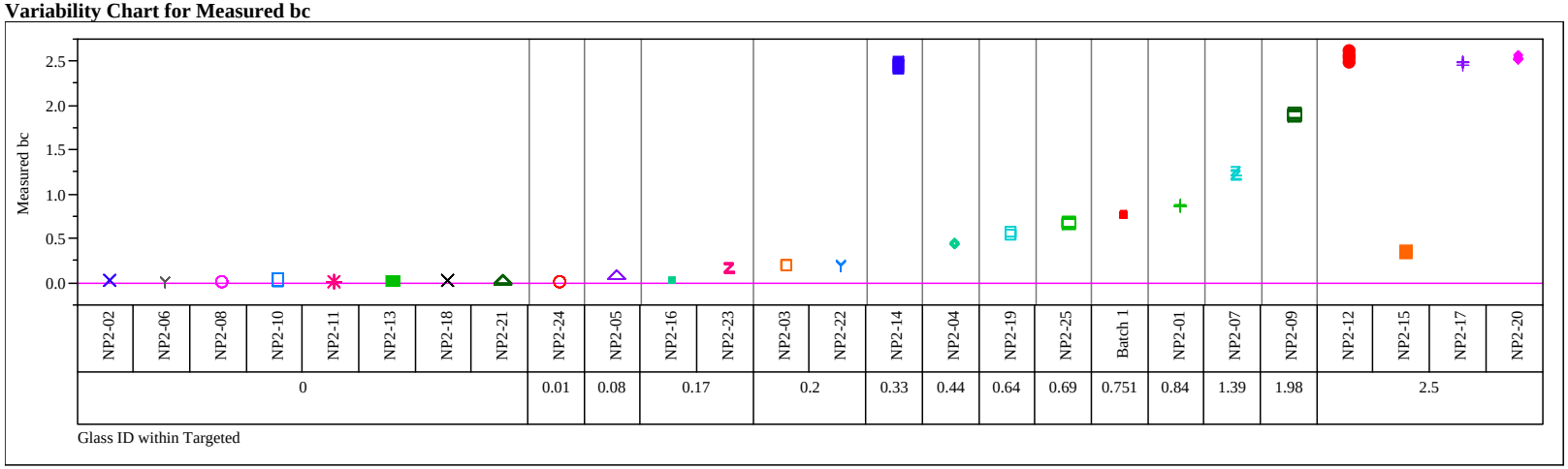
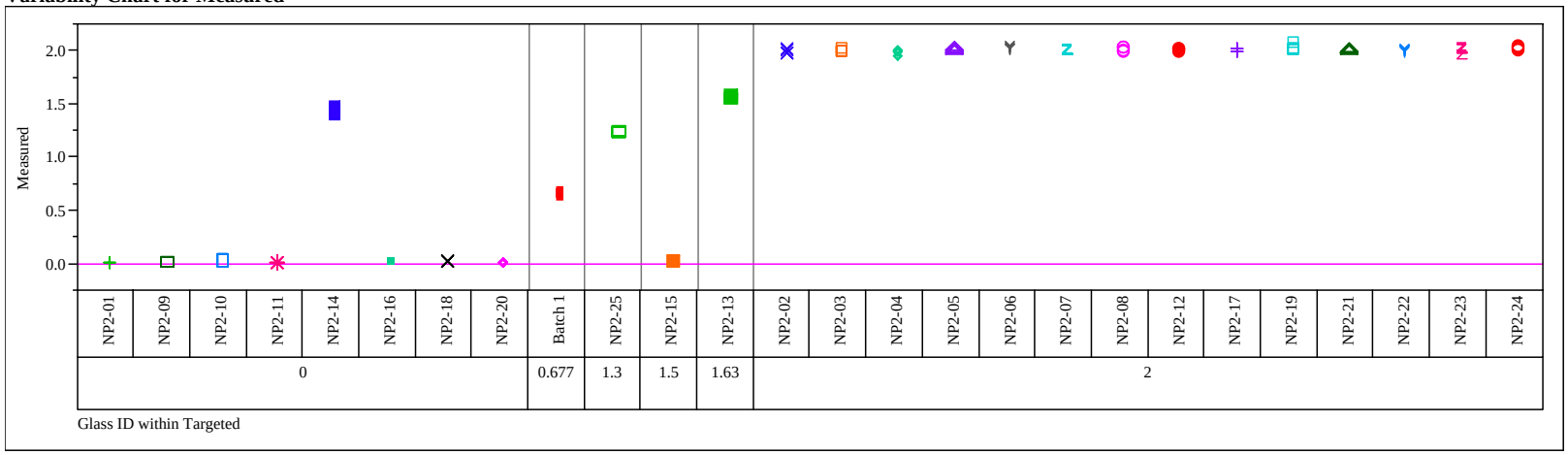


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=LM, Oxide=TiO2 (wt%)
Variability Chart for Measured



Prep=LM, Oxide=TiO2 (wt%)
Variability Chart for Measured bc

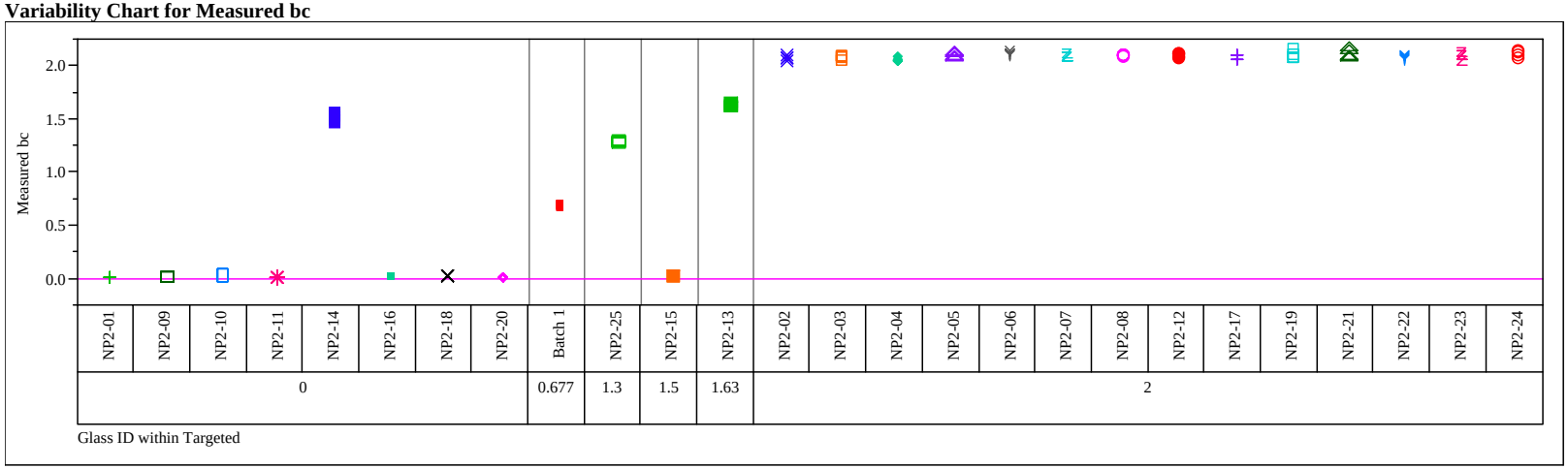
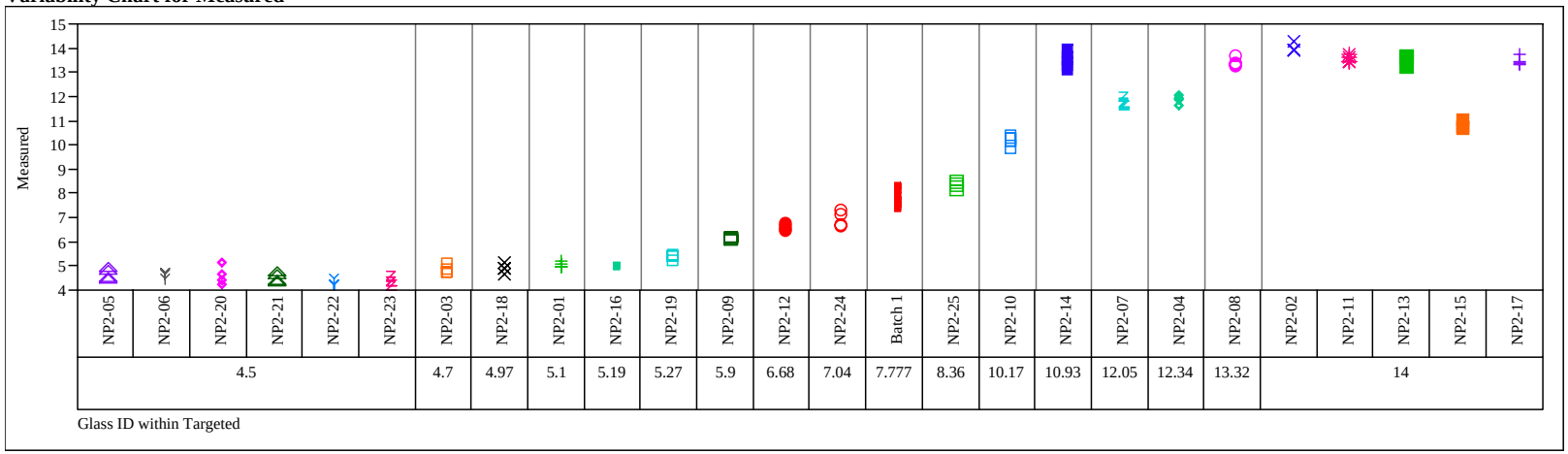


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=PF, Oxide=B2O3 (wt%)
Variability Chart for Measured



Prep=PF, Oxide=B2O3 (wt%)
Variability Chart for Measured bc

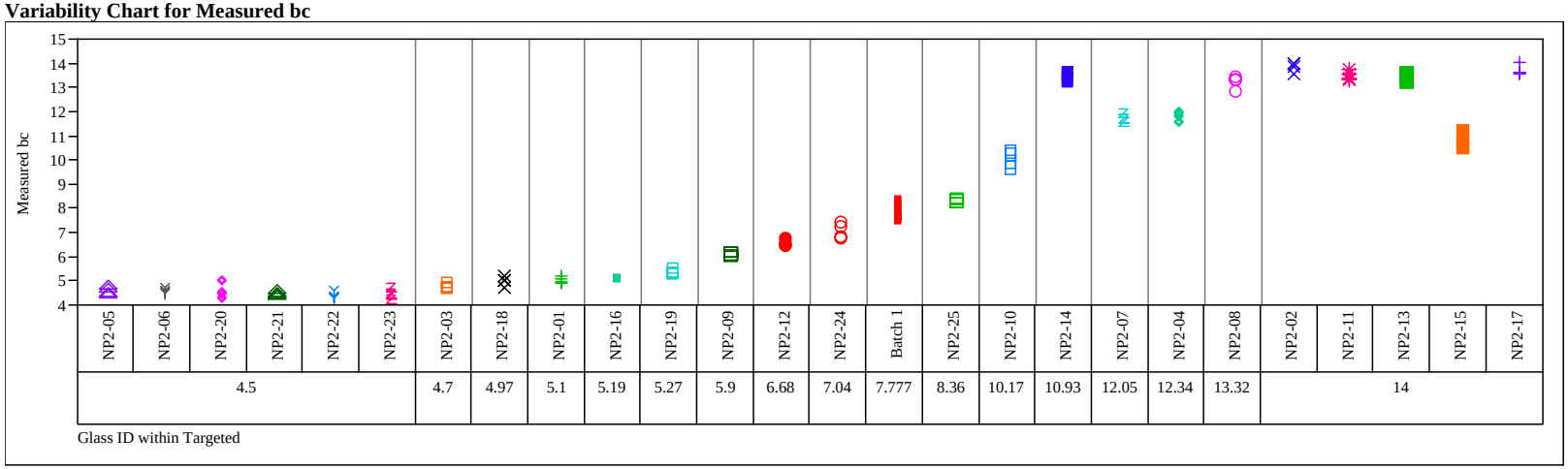
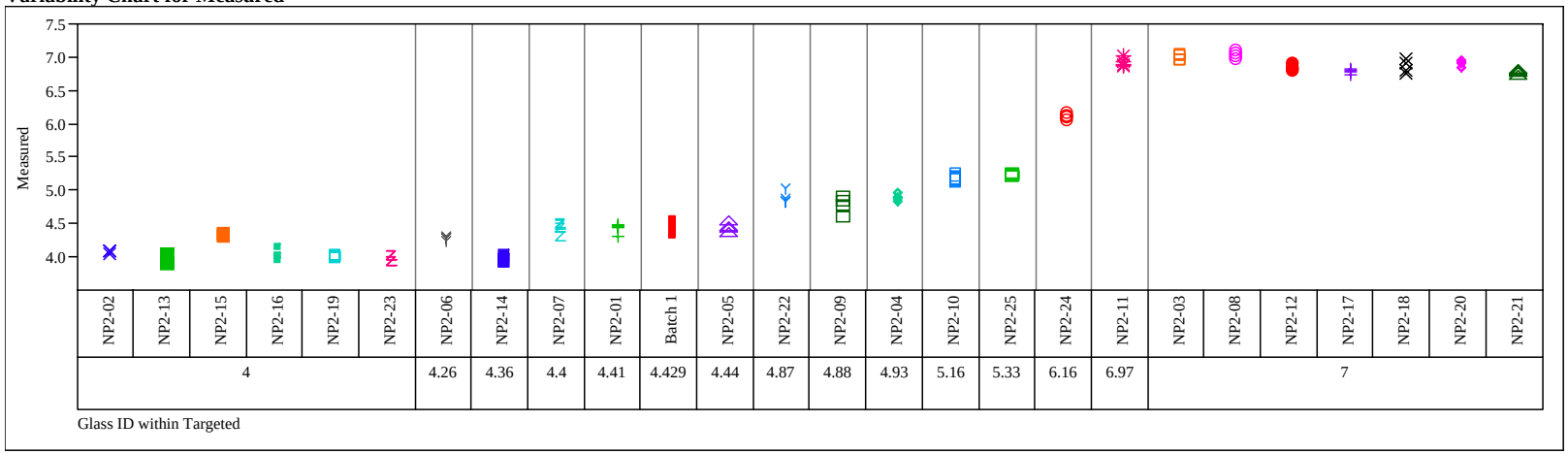


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=PF, Oxide=Li2O (wt%)
Variability Chart for Measured



Prep=PF, Oxide=Li2O (wt%)
Variability Chart for Measured bc

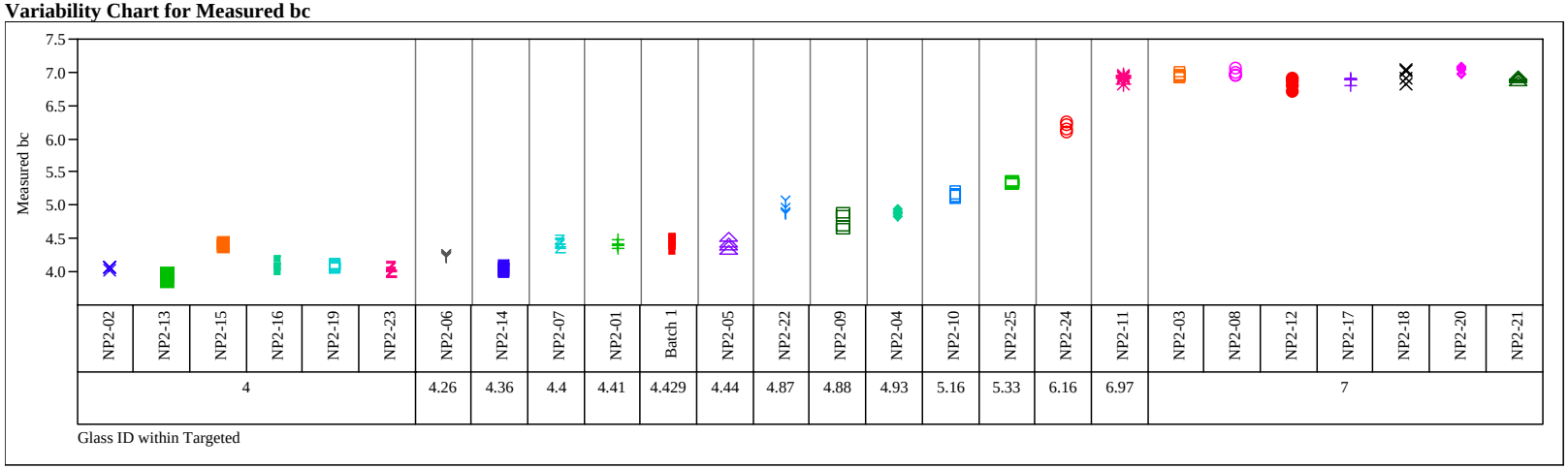
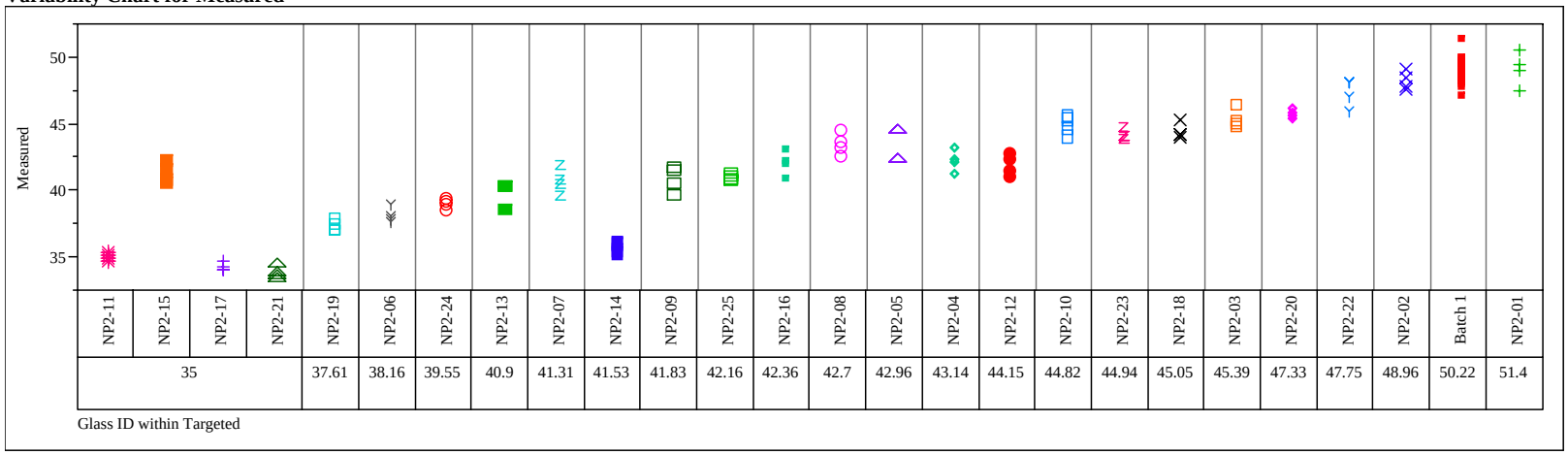


Exhibit A4. Oxide Measurements by Lab ID within Glass ID by Targeted Concentration over Both Preps. (continued)

Prep=PF, Oxide=SiO2 (wt%)
Variability Chart for Measured



Prep=PF, Oxide=SiO2 (wt%)
Variability Chart for Measured bc

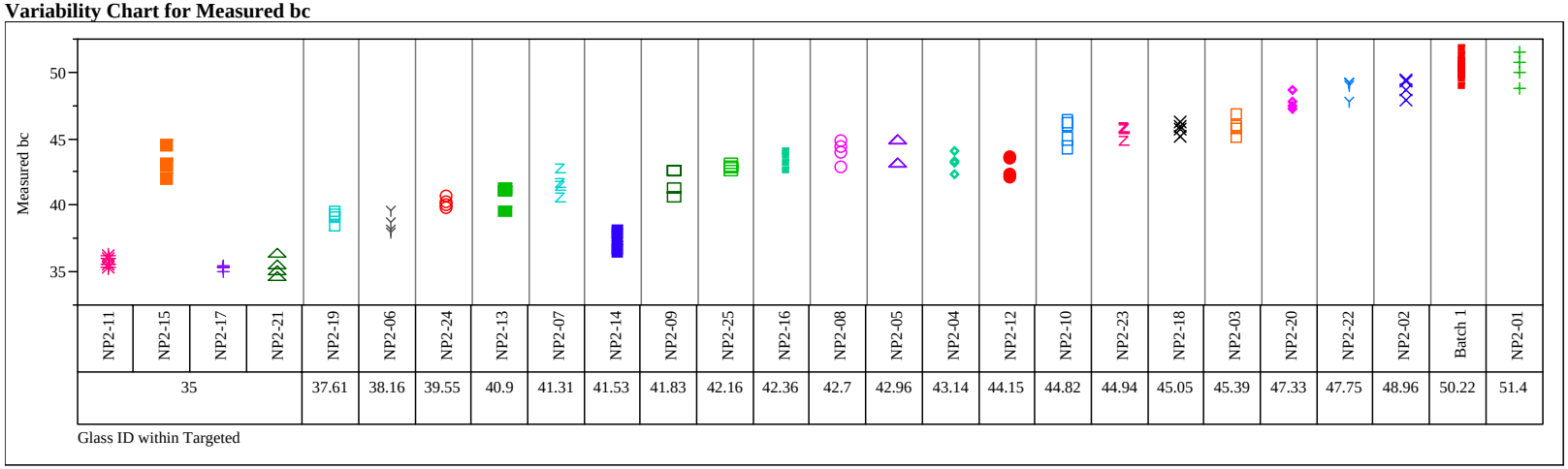
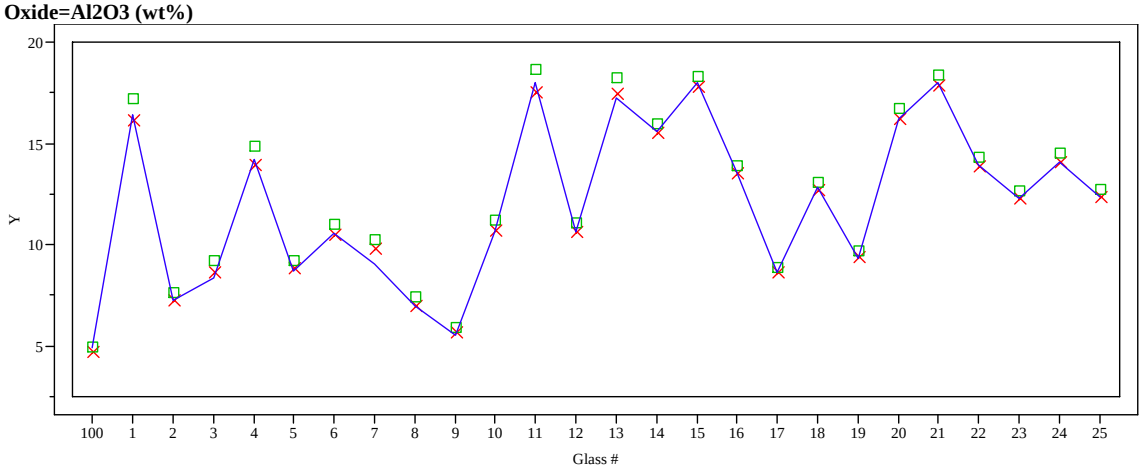
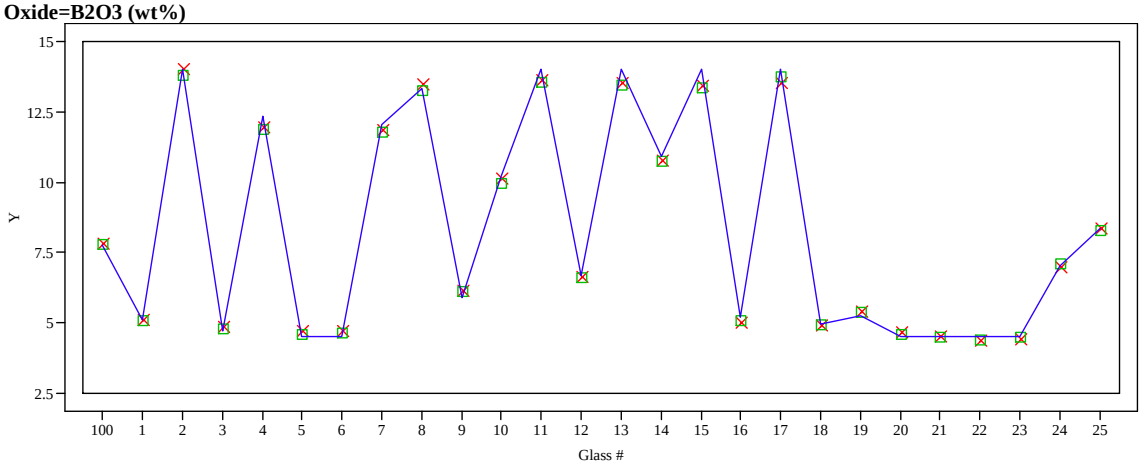


Exhibit A5. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Oxide.

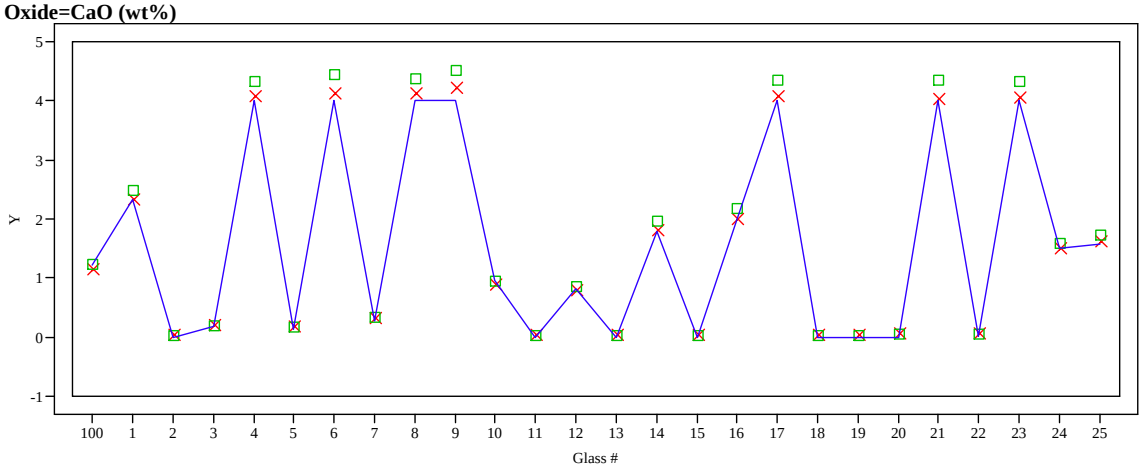
Oxide=Al2O3 (wt%)



Oxide=B2O3 (wt%)



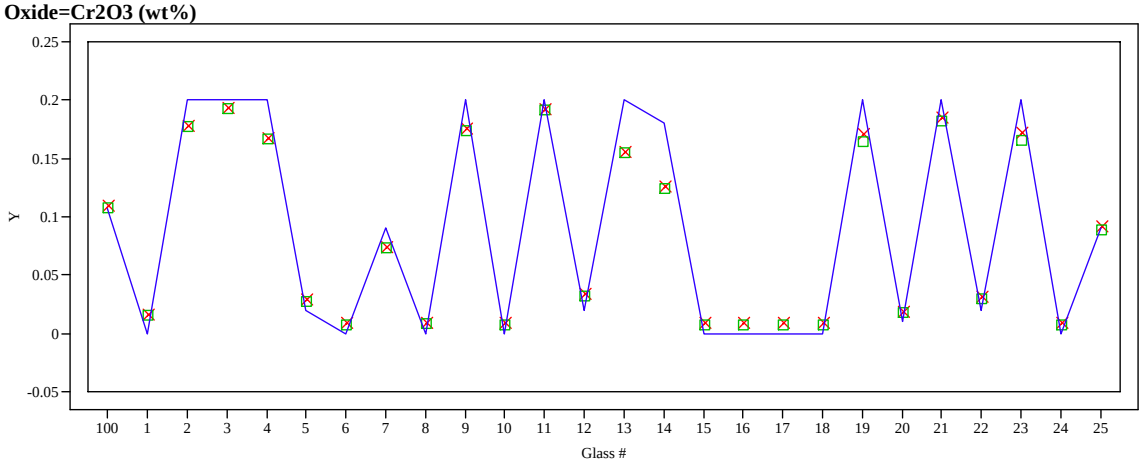
Oxide=CaO (wt%)



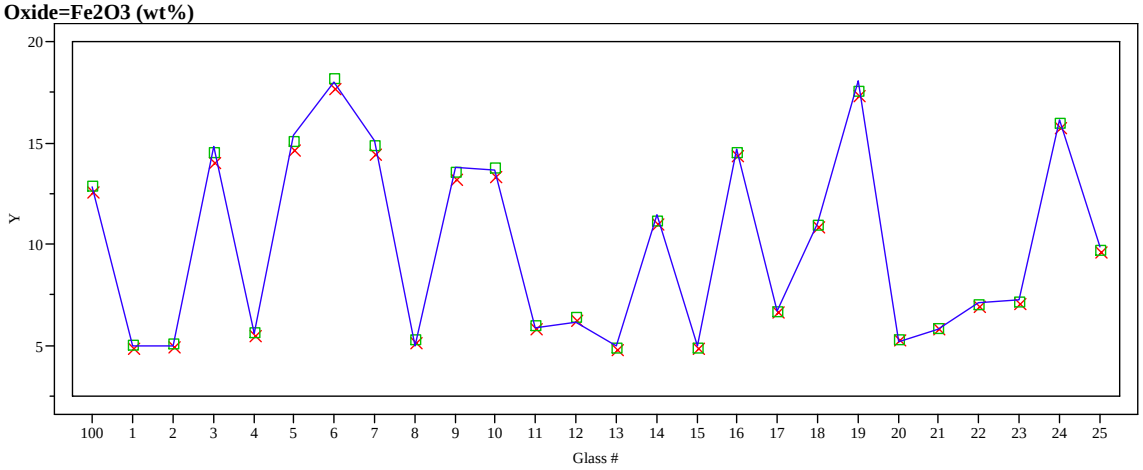
Y Measured Measured bc Targeted

Exhibit A5. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Oxide. (continued)

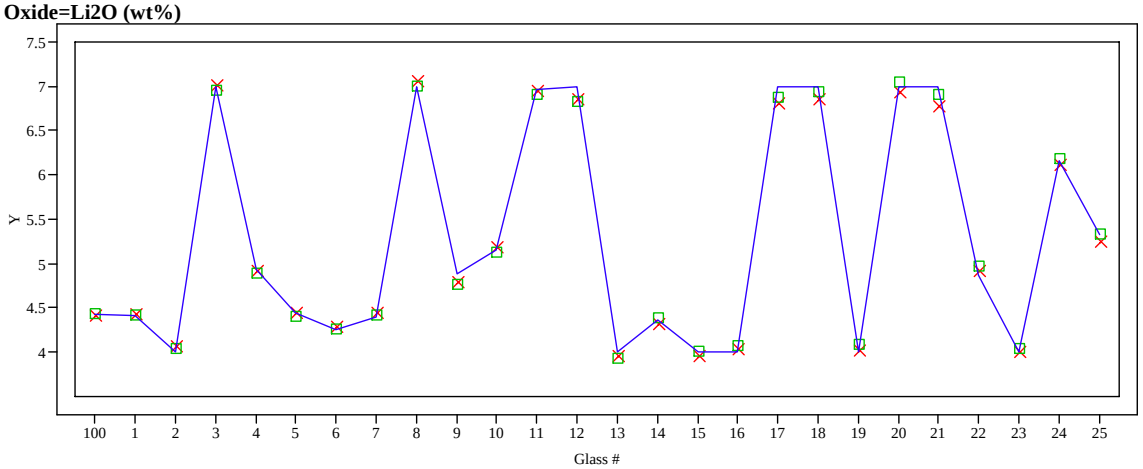
Oxide=Cr2O3 (wt%)



Oxide=Fe2O3 (wt%)



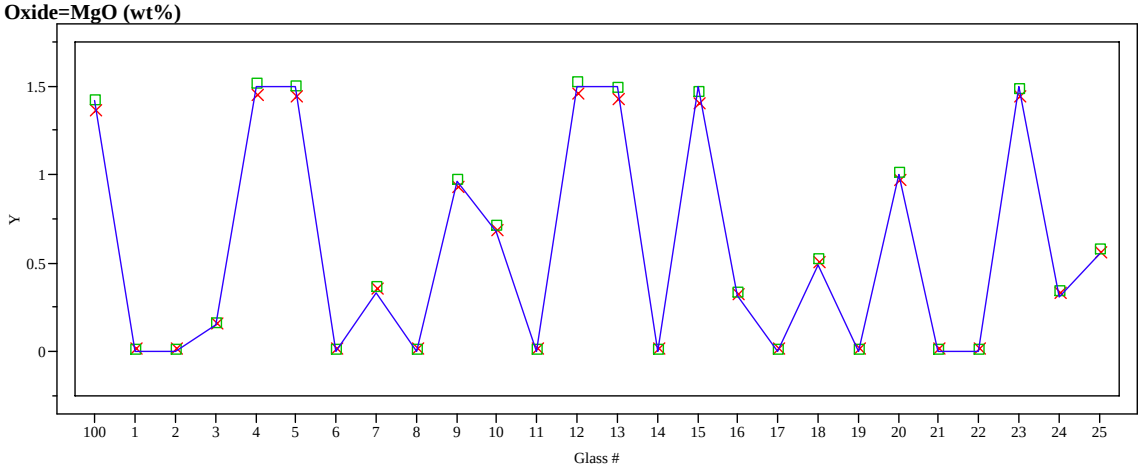
Oxide=Li2O (wt%)



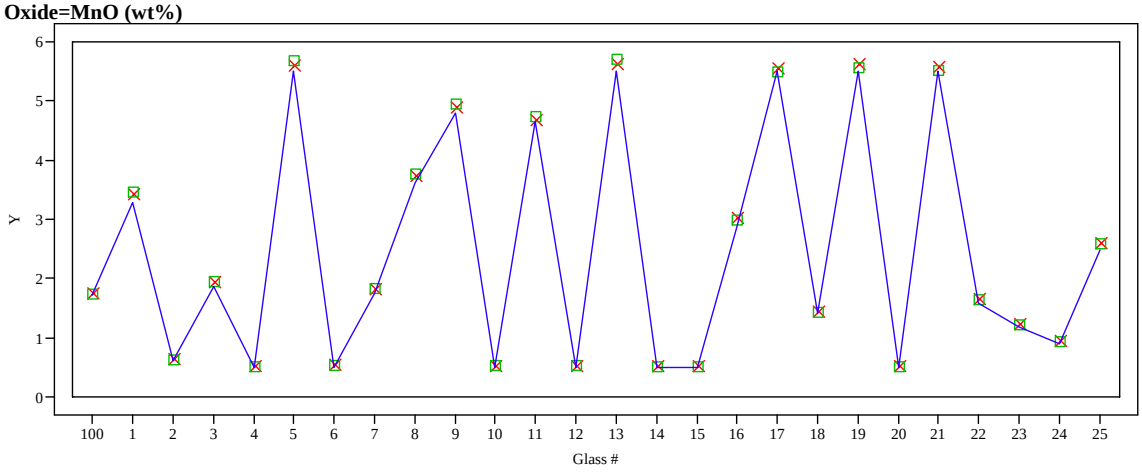
Y Measured Measured bc Targeted

Exhibit A5. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Oxide. (continued)

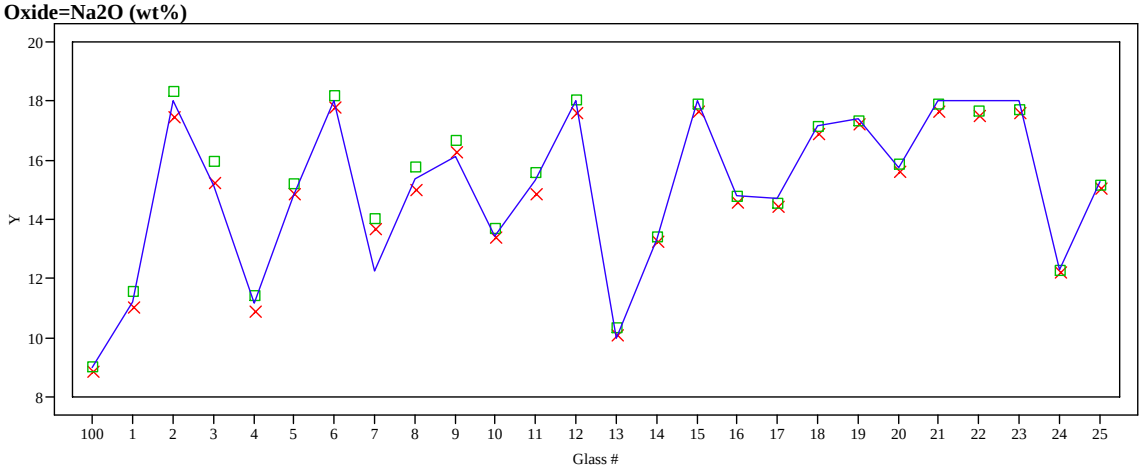
Oxide=MgO (wt%)



Oxide=MnO (wt%)



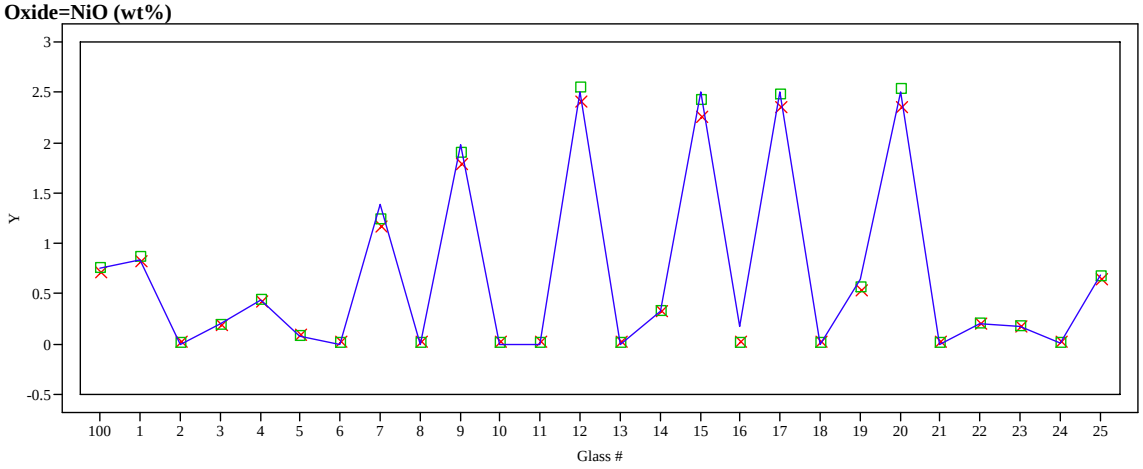
Oxide=Na2O (wt%)



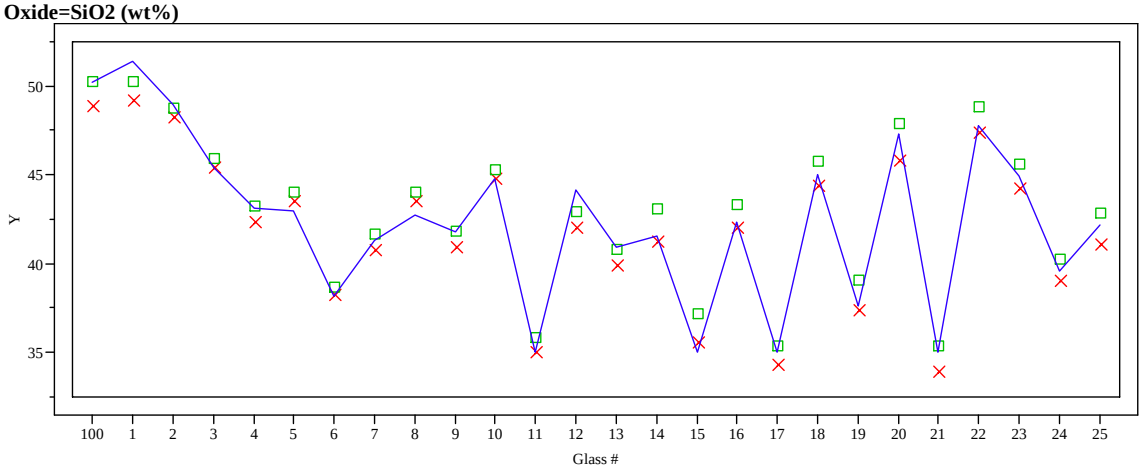
Y ✕ Measured ▫ Measured bc — Targeted

Exhibit A5. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Oxide. (continued)

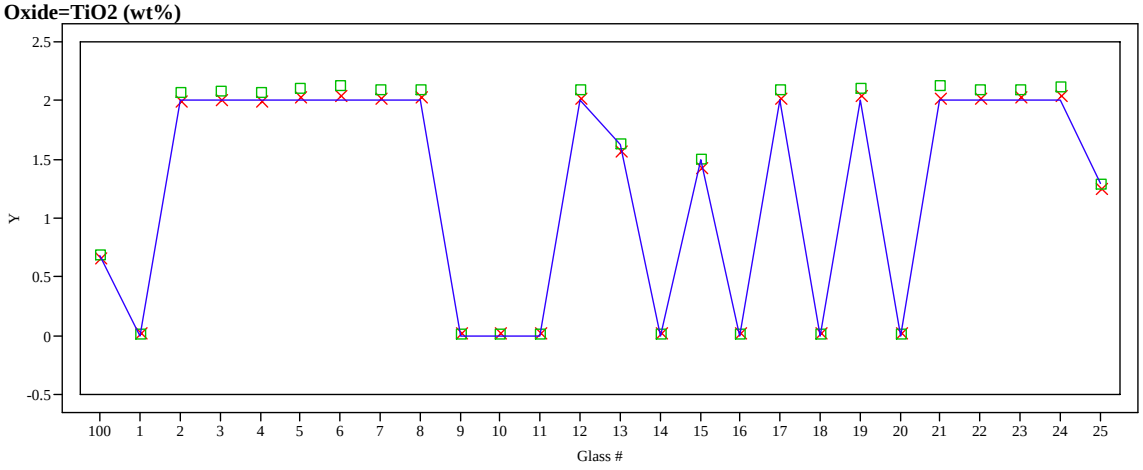
Oxide=NiO (wt%)



Oxide=SiO2 (wt%)



Oxide=TiO2 (wt%)



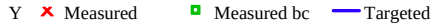
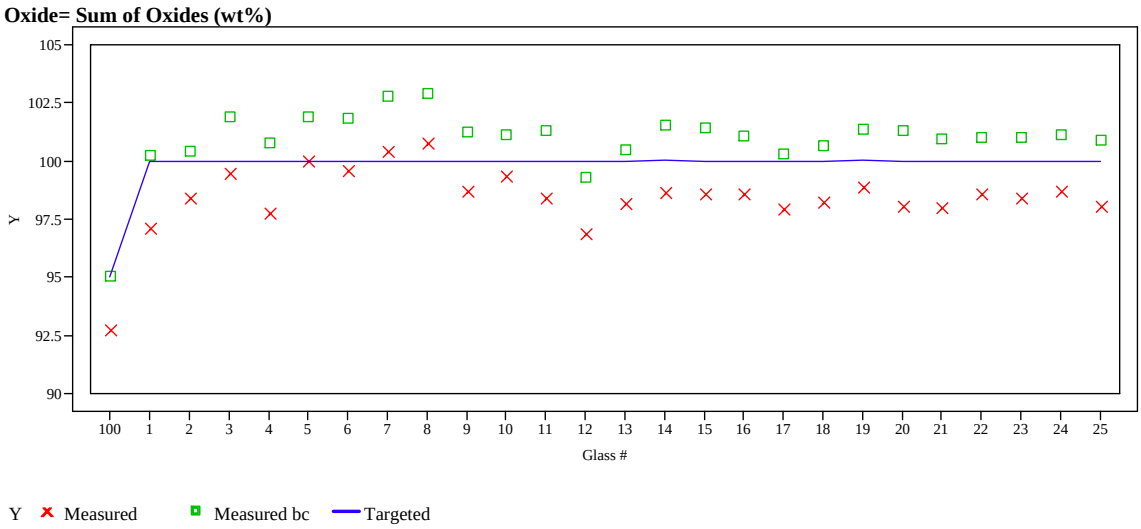


Exhibit A5. Average Measured and Bias-Corrected (bc) Versus Targeted Compositions by Glass ID by Oxide. (continued)



Appendix B

Tables and Exhibits Supporting the Analysis of the PCT Results
or Phase II of the Nepheline Study

Table B1. PSAL Measurements of the PCT Solutions As-Received (ar) and After Appropriate Adjustments (in ppm).

Set	Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	Soln Std	ref	1	1	STD-11-1	21	9.86	79.8	47.5	21.00	9.86	79.80	47.50
1	NP2-01	quenched	1	2	W32	2.89	5.58	13.4	27.4	4.82	9.30	22.33	45.67
1	NP2-07	quenched	1	3	W24	16.3	9.11	37	43.2	27.17	15.18	61.67	72.00
1	ARM-1	ref	1	4	W86	9.57	7.54	20.6	30.9	15.95	12.57	34.33	51.50
1	NP2-09	ccc	1	5	W76	16.7	25.6	138.5	92.2	27.83	42.67	230.84	153.67
1	NP2-02	ccc	1	6	W06	135	44.3	290	110	225.00	73.83	483.34	183.34
1	NP2-05	quenched	1	7	W44	10.2	12.1	76.5	69.3	17.00	20.17	127.50	115.50
1	NP2-13	ccc	1	8	W21	13.5	7.21	17.3	39.4	22.50	12.02	28.83	65.67
1	NP2-03	quenched	1	9	W59	10	22.6	102	96.4	16.67	37.67	170.00	160.67
1	EA	ref	1	10	W36	37.7	11.2	105	49.9	628.33	186.67	1750.00	831.67
1	blank	ref	1	11	W51	<1.00	<1.00	<0.100	<0.100	0.83	0.83	0.08	0.08
1	NP2-06	ccc	1	12	W67	472	385	2080	877	786.68	641.68	3466.74	1461.70
1	NP2-03	ccc	1	13	W23	49	74.6	206	187	81.67	124.34	343.34	311.67
1	NP2-05	ccc	1	14	W38	11.3	13.6	79.4	77.6	18.83	22.67	132.34	129.34
1	Soln Std	ref	1	15	STD-11-2	21.3	9.86	83.3	45.1	21.30	9.86	83.30	45.10
1	NP2-04	quenched	1	16	W27	10	6.96	21.6	24.3	16.67	11.60	36.00	40.50
1	NP2-08	quenched	1	17	W83	92.8	67.1	230	131	154.67	111.84	383.34	218.34
1	NP2-01	ccc	1	18	W54	3.97	5.29	13.9	25.8	6.62	8.82	23.17	43.00
1	NP2-11	quenched	1	19	W48	95.8	57.6	162	69.6	159.67	96.00	270.01	116.00
1	NP2-10	ccc	1	20	W65	17.4	12.1	45.6	53.1	29.00	20.17	76.00	88.50
1	NP2-09	quenched	1	21	W35	43.4	41.1	292	155	72.33	68.50	486.68	258.34
1	NP2-10	quenched	1	22	W04	12.3	9.38	41.1	48.4	20.50	15.63	68.50	80.67
1	NP2-13	quenched	1	23	W50	13.6	7.45	16.8	33.5	22.67	12.42	28.00	55.83
1	NP2-02	quenched	1	24	W10	156	53.3	338	116	260.01	88.84	563.34	193.34
1	NP2-12	ccc	1	25	W12	26.6	43.2	160	137	44.33	72.00	266.67	228.34
1	NP2-06	quenched	1	26	W09	13.2	17.7	151	72.3	22.00	29.50	251.67	120.50
1	NP2-04	ccc	1	27	W25	9.71	6.87	22.4	24.1	16.18	11.45	37.33	40.17
1	NP2-07	ccc	1	28	W58	18.1	9.35	37.9	45.3	30.17	15.58	63.17	75.50
1	NP2-11	ccc	1	29	W74	1690	895	1310	234	2816.72	1491.70	2183.38	390.01
1	NP2-12	quenched	1	30	W43	30.8	24.8	148	105	51.33	41.33	246.67	175.00
1	NP2-08	ccc	1	31	W63	88.6	60.3	182	112	147.67	100.50	303.34	186.67
1	Soln Std	ref	1	32	STD-11-3	21.6	10	86.9	45.3	21.60	10.00	86.90	45.30
1	Soln Std	ref	2	1	STD-12-1	21	9.89	79	50.1	21.00	9.89	79.00	50.10
1	NP2-07	quenched	2	2	W31	17.2	9.33	34.9	49.9	28.67	15.55	58.17	83.17
1	NP2-10	ccc	2	3	W34	17.8	12.9	43.8	64.2	29.67	21.50	73.00	107.00
1	NP2-13	quenched	2	4	W66	14.2	7.75	15.7	40.4	23.67	12.92	26.17	67.33
1	NP2-03	quenched	2	5	W81	10.8	24	101	114	18.00	40.00	168.34	190.00
1	NP2-11	ccc	2	6	W42	1720	906	1320	237	2866.72	1510.03	2200.04	395.01
1	NP2-09	quenched	2	7	W46	57.4	42	285	156	95.67	70.00	475.01	260.01
1	NP2-01	quenched	2	8	W77	10	5.95	13.4	32.6	16.67	9.92	22.33	54.33
1	NP2-04	ccc	2	9	W70	13.5	6.92	19.8	27.7	22.50	11.53	33.00	46.17
1	NP2-06	ccc	2	10	W71	480	385	2070	885	800.02	641.68	3450.07	1475.03
1	ARM-1	ref	2	11	W85	15.4	7.83	20	35.5	25.67	13.05	33.33	59.17
1	EA	ref	2	12	W29	43.9	11.9	107	57.8	731.67	198.33	1783.34	963.34
1	NP2-08	ccc	2	13	W79	83.9	58.8	192	121	139.84	98.00	320.01	201.67
1	NP2-02	quenched	2	14	W03	169	55.2	341	121	281.67	92.00	568.34	201.67
1	Soln Std	ref	2	15	STD-12-2	22.6	9.88	79.1	50.3	22.60	9.88	79.10	50.30
1	NP2-02	ccc	2	16	W15	136	45.6	286	110	226.67	76.00	476.68	183.34
1	NP2-10	quenched	2	17	W19	13.5	9.87	39.1	57	22.50	16.45	65.17	95.00
1	NP2-07	ccc	2	18	W05	19.1	9.7	37.3	52.1	31.83	16.17	62.17	86.84
1	NP2-08	quenched	2	19	W75	103	71.9	237	140	171.67	119.84	395.01	233.34
1	NP2-05	ccc	2	20	W17	10.9	14	80.2	88.1	18.17	23.33	133.67	146.84
1	NP2-06	quenched	2	21	W68	13.6	18.1	147	81.3	22.67	30.17	245.00	135.50
1	NP2-01	ccc	2	22	W49	3.32	5.54	13.9	30.9	5.53	9.23	23.17	51.50
1	NP2-05	quenched	2	23	W53	10.4	12.7	78.3	79.5	17.33	21.17	130.50	132.50
1	NP2-12	ccc	2	24	W84	28.1	44.9	158	157	46.83	74.83	263.34	261.67
1	NP2-03	ccc	2	25	W82	48	75.3	204	194	80.00	125.50	340.01	323.34

Table B1. PSAL Measurements of the PCT Solutions As-Received (ar) and After Appropriate Adjustments (in ppm). (continued)

Set	Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
1	NP2-12	quenched	2	26	W40	18	25	149	112	30.00	41.67	248.34	186.67
1	NP2-13	ccc	2	27	W18	14.3	7.42	16.8	44.6	23.83	12.37	28.00	74.33
1	NP2-09	ccc	2	28	W28	20.1	27.8	140	113	33.50	46.33	233.34	188.34
1	NP2-04	quenched	2	29	W37	10.6	7.38	20.3	29.6	17.67	12.30	33.83	49.33
1	NP2-11	quenched	2	30	W60	107	60.4	159	80.9	178.34	100.67	265.01	134.84
1	Soln Std	ref	2	31	STD-12-3	23.3	10.3	81.8	52.8	23.30	10.30	81.80	52.80
1	Soln Std	ref	3	1	STD-13-1	21.3	10	79.6	50.6	21.30	10.00	79.60	50.60
1	NP2-11	ccc	3	2	W30	1730	918	1350	242	2883.39	1530.03	2250.05	403.34
1	NP2-09	quenched	3	3	W39	55.9	41.7	285	159	93.17	69.50	475.01	265.01
1	NP2-05	quenched	3	4	W56	16.5	12.7	76.4	79.1	27.50	21.17	127.34	131.84
1	NP2-01	ccc	3	5	W61	7.37	5.63	12.9	30.1	12.28	9.38	21.50	50.17
1	NP2-02	quenched	3	6	W78	174	55.8	340	123	290.01	93.00	566.68	205.00
1	NP2-04	quenched	3	7	W73	13.2	7.23	20.1	28.4	22.00	12.05	33.50	47.33
1	NP2-06	ccc	3	8	W45	472	380	2040	878	786.68	633.35	3400.07	1463.36
1	NP2-02	ccc	3	9	W16	141	47.4	237	112	235.00	79.00	395.01	186.67
1	NP2-03	quenched	3	10	W52	14.4	23.6	100	109	24.00	39.33	166.67	181.67
1	NP2-10	ccc	3	11	W02	20.3	12.7	44	61	33.83	21.17	73.33	101.67
1	NP2-06	quenched	3	12	W22	15	18.1	146	80.4	25.00	30.17	243.34	134.00
1	NP2-04	ccc	3	13	W13	11.2	7.05	19.8	27.8	18.67	11.75	33.00	46.33
1	NP2-08	quenched	3	14	W14	103	69.6	199	133	171.67	116.00	331.67	221.67
1	Soln Std	ref	3	15	STD-13-2	22.9	10.1	80.7	51	22.90	10.10	80.70	51.00
1	NP2-13	quenched	3	16	W64	15.3	7.76	16.1	39	25.50	12.93	26.83	65.00
1	NP2-11	quenched	3	17	W26	104	60.2	160	80.5	173.34	100.34	266.67	134.17
1	NP2-09	ccc	3	18	W11	19.7	26.6	139	106	32.83	44.33	231.67	176.67
1	NP2-07	quenched	3	19	W20	18.5	9.45	34.5	49.2	30.83	15.75	57.50	82.00
1	blank	ref	3	20	W47	<1.00	<1.00	<0.100	0.195	0.83	0.83	0.08	0.33
1	NP2-05	ccc	3	21	W07	10.4	14.2	78.7	87.6	17.33	23.67	131.17	146.00
1	NP2-07	ccc	3	22	W33	19.4	9.84	36.4	52	32.33	16.40	60.67	86.67
1	NP2-12	quenched	3	23	W72	18	24.8	144	112	30.00	41.33	240.00	186.67
1	EA	ref	3	24	W41	40.8	11.8	107	56.6	680.00	196.67	1783.34	943.34
1	ARM-1	ref	3	25	W08	10.5	7.85	20	35.2	17.50	13.08	33.33	58.67
1	NP2-13	ccc	3	26	W69	13.6	7.3	15.9	43.7	22.67	12.17	26.50	72.83
1	NP2-10	quenched	3	27	W55	12.9	9.85	38.7	56.4	21.50	16.42	64.50	94.00
1	NP2-12	ccc	3	28	W62	28.4	45.2	158	157	47.33	75.33	263.34	261.67
1	NP2-01	quenched	3	29	W01	3	5.95	13.7	31.7	5.00	9.92	22.83	52.83
1	NP2-03	ccc	3	30	W57	47.4	75.2	226	193	79.00	125.34	376.67	321.67
1	NP2-08	ccc	3	31	W80	83.1	58.7	183	123	138.50	97.84	305.01	205.00
1	Soln Std	ref	3	32	STD-13-3	20.9	9.94	81.5	50	20.90	9.94	81.50	50.00
2	Soln Std	ref	1	1	STD-21-1	21.5	10	81.3	52	21.50	10.00	81.30	52.00
2	NP2-24	ccc	1	2	X30	100	90.9	137	162	166.67	151.50	228.34	270.01
2	NP2-16	ccc	1	3	X55	200	119	430	290	333.34	198.34	716.68	483.34
2	NP2-25	quenched	1	4	X36	12.8	10.3	58.1	57.2	21.33	17.17	96.84	95.34
2	NP2-22	ccc	1	5	X02	17.1	24.8	113	113	28.50	41.33	188.34	188.34
2	NP2-21	ccc	1	6	X06	29.1	82.6	572	126	48.50	137.67	953.35	210.00
2	NP2-23	quenched	1	7	X16	6.08	8.68	91.8	53.5	10.13	14.47	153.00	89.17
2	NP2-20	ccc	1	8	X31	216	168	416	331	360.01	280.01	693.35	551.68
2	NP2-15	ccc	1	9	X64	76.6	38	82.6	63	127.67	63.33	137.67	105.00
2	NP2-14	ccc	1	10	X71	461	148	575	96.3	768.35	246.67	958.35	160.50
2	NP2-16	quenched	1	11	X50	10.2	7.64	52.4	49.7	17.00	12.73	87.34	82.83
2	NP2-24	quenched	1	12	X53	13.1	15.1	45.1	57	21.83	25.17	75.17	95.00
2	blank	ref	1	13	X67	1.37	<1.00	<0.100	<0.100	2.28	0.83	0.08	0.08
2	Soln Std	ref	1	14	STD-21-2	20.3	9.39	78.8	47.6	20.30	9.39	78.80	47.60
2	NP2-17	ccc	1	15	X77	87.2	62.8	197	94.7	145.34	104.67	328.34	157.84
2	NP2-19	quenched	1	16	X18	12	11.5	105	71.5	20.00	19.17	175.00	119.17
2	NP2-21	quenched	1	17	X73	37.9	40.9	462	112	63.17	68.17	770.02	186.67
2	EA	ref	1	18	X74	36.7	10.8	99.3	51.3	611.67	180.00	1655.00	855.00
2	NP2-15	quenched	1	19	X29	10.4	6.8	29.6	38.3	17.33	11.33	49.33	63.83
2	NP2-20	quenched	1	20	X10	5.92	13.5	72.2	71.4	9.87	22.50	120.34	119.00

Table B1. PSAL Measurements of the PCT Solutions As-Received (ar) and After Appropriate Adjustments (in ppm). (continued)

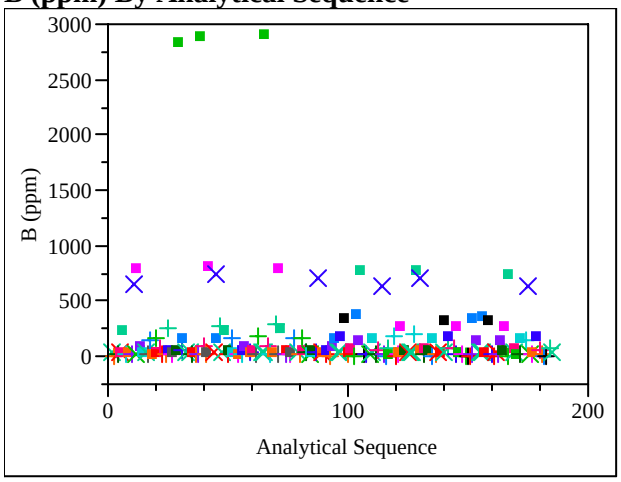
Set	Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
2	NP2-14	quenched	1	21	X27	41.2	12.9	97	42.1	68.67	21.50	161.67	70.17
2	NP2-23	ccc	1	22	X28	6.53	11.5	90.8	56.1	10.88	19.17	151.34	93.50
2	NP2-17	quenched	1	23	X76	112	71.2	251	107	186.67	118.67	418.34	178.34
2	NP2-22	quenched	1	24	X75	5.35	8.02	82.1	67.1	8.92	13.37	136.84	111.84
2	NP2-18	quenched	1	25	X80	9.91	20.6	122	97.5	16.52	34.33	203.34	162.50
2	NP2-25	ccc	1	26	X21	15	13.1	59.6	57.9	25.00	21.83	99.34	96.50
2	NP2-18	ccc	1	27	X65	158	123	433	262	263.34	205.00	721.68	436.68
2	NP2-19	ccc	1	28	X35	21.5	19.9	150	106	35.83	33.17	250.01	176.67
2	ARM-1	ref	1	29	X54	10.2	7.64	20.9	33.4	17.00	12.73	34.83	55.67
2	Soln Std	ref	1	30	STD-21-3	19.9	9.43	80	47	19.90	9.43	80.00	47.00
2	Soln Std	ref	2	1	STD-22-1	20.9	9.95	81.1	51.1	20.90	9.95	81.10	51.10
2	NP2-17	quenched	2	2	X08	119	73.7	246	108	198.34	122.84	410.01	180.00
2	NP2-14	ccc	2	3	X68	454	145	576	99.3	756.68	241.67	960.02	165.50
2	EA	ref	2	4	X57	41.4	11.2	98.5	54.8	690.00	186.67	1641.67	913.34
2	NP2-25	ccc	2	5	X59	19	15.3	67.9	67.1	31.67	25.50	113.17	111.84
2	NP2-19	quenched	2	6	X32	12.8	11.9	106	73.7	21.33	19.83	176.67	122.84
2	NP2-21	ccc	2	7	X47	30.3	83.1	538	108	50.50	138.50	896.68	180.00
2	NP2-19	ccc	2	8	X66	21.8	20.5	151	111	36.33	34.17	251.67	185.00
2	NP2-20	quenched	2	9	X38	6.45	14	71.8	76.2	10.75	23.33	119.67	127.00
2	NP2-17	ccc	2	10	X12	91.5	64.2	197	98.6	152.50	107.00	328.34	164.34
2	NP2-25	quenched	2	11	X49	12.5	10.8	60.6	58.6	20.83	18.00	101.00	97.67
2	ARM-1	ref	2	12	X09	11.2	8.36	22.1	37.4	18.67	13.93	36.83	62.33
2	NP2-22	ccc	2	13	X43	16.5	25.2	113	113	27.50	42.00	188.34	188.34
2	Soln Std	ref	2	14	STD-22-2	20.5	9.86	79.8	50	20.50	9.86	79.80	50.00
2	NP2-16	ccc	2	15	X45	190	117	435	284	316.67	195.00	725.01	473.34
2	NP2-14	quenched	2	16	X42	45.5	13.9	103	44.7	75.83	23.17	171.67	74.50
2	NP2-24	ccc	2	17	X37	95	87	129	150	158.34	145.00	215.00	250.01
2	NP2-21	quenched	2	18	X17	40	42.1	458	108	66.67	70.17	763.35	180.00
2	NP2-24	quenched	2	19	X25	11.2	15.1	45.4	55.9	18.67	25.17	75.67	93.17
2	NP2-18	ccc	2	20	X78	148	116	406	248	246.67	193.34	676.68	413.34
2	NP2-23	ccc	2	21	X34	7.21	11.4	88.9	55.2	12.02	19.00	148.17	92.00
2	NP2-18	quenched	2	22	X24	10.1	21.3	124	102	16.83	35.50	206.67	170.00
2	NP2-23	quenched	2	23	X63	5.86	8.8	92.9	52.8	9.77	14.67	154.84	88.00
2	NP2-16	quenched	2	24	X33	6.54	7.96	52.4	51.1	10.90	13.27	87.34	85.17
2	NP2-22	quenched	2	25	X07	4.56	8.2	81.7	67.5	7.60	13.67	136.17	112.50
2	NP2-15	quenched	2	26	X26	9.34	6.89	29.3	39.6	15.57	11.48	48.83	66.00
2	NP2-20	ccc	2	27	X44	196	159	402	314	326.67	265.01	670.01	523.34
2	NP2-15	ccc	2	28	X70	76.6	37.9	82.5	62.7	127.67	63.17	137.50	104.50
2	Soln Std	ref	2	29	STD-22-3	20.9	9.83	80.8	49.1	20.90	9.83	80.80	49.10
2	Soln Std	ref	3	1	STD-23-1	20.7	9.94	81.4	50.9	20.70	9.94	81.40	50.90
2	NP2-20	ccc	3	2	X46	204	162	411	316	340.01	270.01	685.01	526.68
2	NP2-22	ccc	3	3	X20	17.5	24.9	112	112	29.17	41.50	186.67	186.67
2	NP2-16	ccc	3	4	X79	187	116	434	278	311.67	193.34	723.35	463.34
2	NP2-24	quenched	3	5	X14	12.6	15.3	45.2	58.1	21.00	25.50	75.33	96.84
2	NP2-22	quenched	3	6	X19	5.4	8.39	83.4	70.8	9.00	13.98	139.00	118.00
2	ARM-1	ref	3	7	X62	11.3	8.44	22.6	37.9	18.83	14.07	37.67	63.17
2	NP2-15	quenched	3	8	X69	9.75	7.01	29.9	41	16.25	11.68	49.83	68.33
2	NP2-15	ccc	3	9	X03	76.8	38.3	83.6	64.2	128.00	63.83	139.34	107.00
2	NP2-19	ccc	3	10	X61	21.9	20.8	153	113	36.50	34.67	255.01	188.34
2	NP2-18	ccc	3	11	X11	148	117	413	247	246.67	195.00	688.35	411.67
2	NP2-23	quenched	3	12	X13	6.78	8.98	94.1	54.6	11.30	14.97	156.84	91.00
2	NP2-14	ccc	3	13	X04	430	141	568	97.4	716.68	235.00	946.69	162.34
2	Soln Std	ref	3	14	STD-23-2	23.3	9.8	81.2	49.6	23.30	9.80	81.20	49.60
2	NP2-21	ccc	3	15	X41	29.8	81.9	543	106	49.67	136.50	905.02	176.67
2	NP2-23	ccc	3	16	X23	6.82	11.5	91.4	54.7	11.37	19.17	152.34	91.17
2	NP2-19	quenched	3	17	X56	11.4	11.8	107	72.3	19.00	19.67	178.34	120.50
2	NP2-17	ccc	3	18	X58	88.1	63.4	199	95.3	146.84	105.67	331.67	158.84
2	NP2-17	quenched	3	19	X15	92.5	62.1	221	97.2	154.17	103.50	368.34	162.00

Table B1. PSAL Measurements of the PCT Solutions As-Received (ar) and After Appropriate Adjustments (in ppm). (continued)

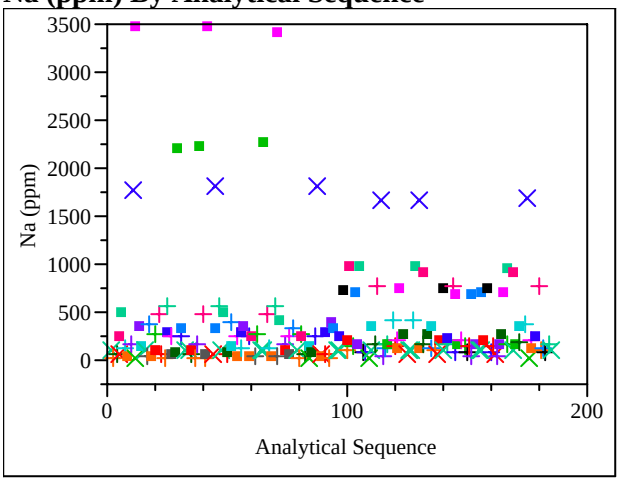
Set	Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
2	EA	ref	3	20	X51	37.3	11	99.9	52.5	621.67	183.33	1665.00	875.00
2	blank	ref	3	21	X22	0.387	<1.00	<0.100	<0.100	0.65	0.83	0.08	0.08
2	NP2-18	quenched	3	22	X39	10.1	21.2	122	101	16.83	35.33	203.34	168.34
2	NP2-25	ccc	3	23	X52	16.9	15.1	67.8	65.2	28.17	25.17	113.00	108.67
2	NP2-24	ccc	3	24	X01	98.9	92.8	137	160	164.84	154.67	228.34	266.67
2	NP2-21	quenched	3	25	X40	39.1	42.2	463	108	65.17	70.33	771.68	180.00
2	NP2-25	quenched	3	26	X05	11.2	10.3	59.4	54.7	18.67	17.17	99.00	91.17
2	NP2-20	quenched	3	27	X60	5.76	13.9	72.8	73.5	9.60	23.17	121.34	122.50
2	NP2-16	quenched	3	28	X72	6.38	7.99	53.8	51.1	10.63	13.32	89.67	85.17
2	NP2-14	quenched	3	29	X48	41.2	13.1	97.2	42.3	68.67	21.83	162.00	70.50
2	Soln Std	ref	3	30	STD-23-3	20.1	9.85	80.9	49.6	20.10	9.85	80.90	49.60

Exhibit B1. Laboratory PCT Measurements in Analytical Sequence over both Analytical Plans.

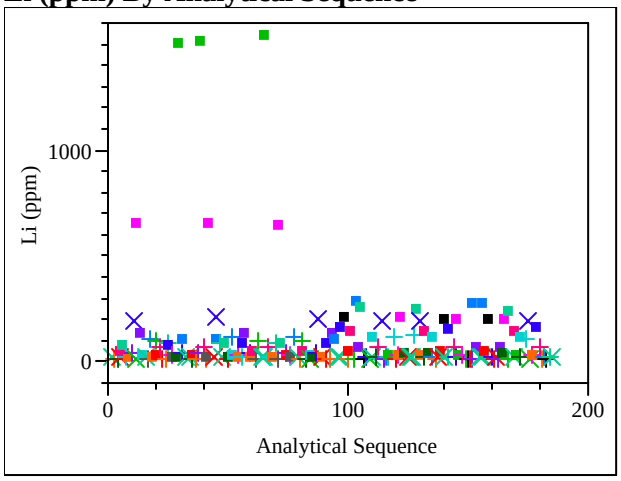
B (ppm) By Analytical Sequence



Na (ppm) By Analytical Sequence



Li (ppm) By Analytical Sequence



Si (ppm) By Analytical Sequence

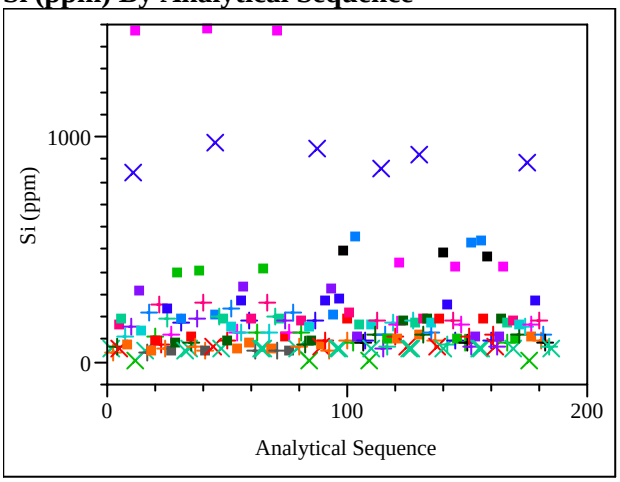
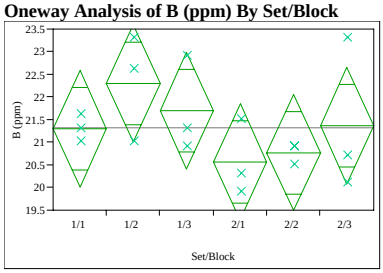


Exhibit B2. Measurements of the Multi-Element Solution Standard by ICP Block.

Oneway Analysis of B (ppm) By Set/Block



Oneway Anova
Summary of Fit

Rsquare	0.322476
Adj Rsquare	0.040174
Root Mean Square Error	1.019804
Mean of Response	21.33333
Observations (or Sum Wgts)	18

Analysis of Variance

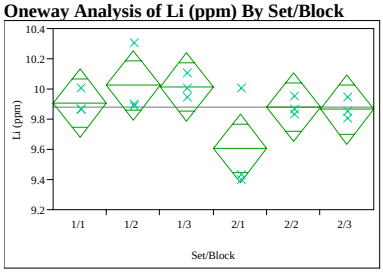
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block	5	5.940000	1.18800	1.1423	0.3906
Error	12	12.480000	1.04000		
C. Total	17	18.420000			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	21.3000	0.58878	20.017	22.583
1/2	3	22.3000	0.58878	21.017	23.583
1/3	3	21.7000	0.58878	20.417	22.983
2/1	3	20.5667	0.58878	19.284	21.850
2/2	3	20.7667	0.58878	19.484	22.050
2/3	3	21.3667	0.58878	20.084	22.650

Std Error uses a pooled estimate of error variance

Oneway Analysis of Li (ppm) By Set/Block



Oneway Anova
Summary of Fit

Rsquare	0.466093
Adj Rsquare	0.243632
Root Mean Square Error	0.180678
Mean of Response	9.882222
Observations (or Sum Wgts)	18

Analysis of Variance

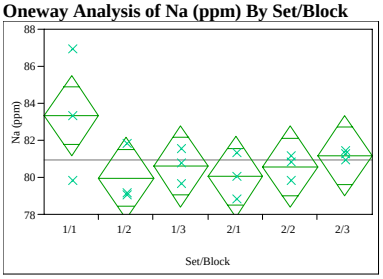
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block	5	0.34197778	0.068396	2.0952	0.1364
Error	12	0.39173333	0.032644		
C. Total	17	0.73371111			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	9.9067	0.10431	9.6794	10.134
1/2	3	10.0233	0.10431	9.7961	10.251
1/3	3	10.0133	0.10431	9.7861	10.241
2/1	3	9.6067	0.10431	9.3794	9.834
2/2	3	9.8800	0.10431	9.6527	10.107
2/3	3	9.8633	0.10431	9.6361	10.091

Std Error uses a pooled estimate of error variance

Oneway Analysis of Na (ppm) By Set/Block



Oneway Anova
Summary of Fit

Rsquare	0.39238
Adj Rsquare	0.139204
Root Mean Square Error	1.738134
Mean of Response	80.94444
Observations (or Sum Wgts)	18

Analysis of Variance

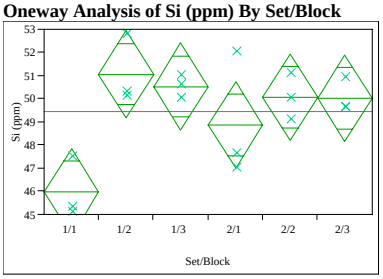
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block	5	23.411111	4.68222	1.5498	0.2470
Error	12	36.253333	3.02111		
C. Total	17	59.664444			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	83.3333	1.0035	81.147	85.520
1/2	3	79.9667	1.0035	77.780	82.153
1/3	3	80.6000	1.0035	78.414	82.786
2/1	3	80.0333	1.0035	77.847	82.220
2/2	3	80.5667	1.0035	78.380	82.753
2/3	3	81.1667	1.0035	78.980	83.353

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Set/Block



Oneway Anova
Summary of Fit

Rsquare	0.656743
Adj Rsquare	0.513719
Root Mean Square Error	1.489407
Mean of Response	49.42222
Observations (or Sum Wgts)	18

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Set/Block	5	50.931111	10.1862	4.5918	0.0142
Error	12	26.620000	2.2183		
C. Total	17	77.551111			

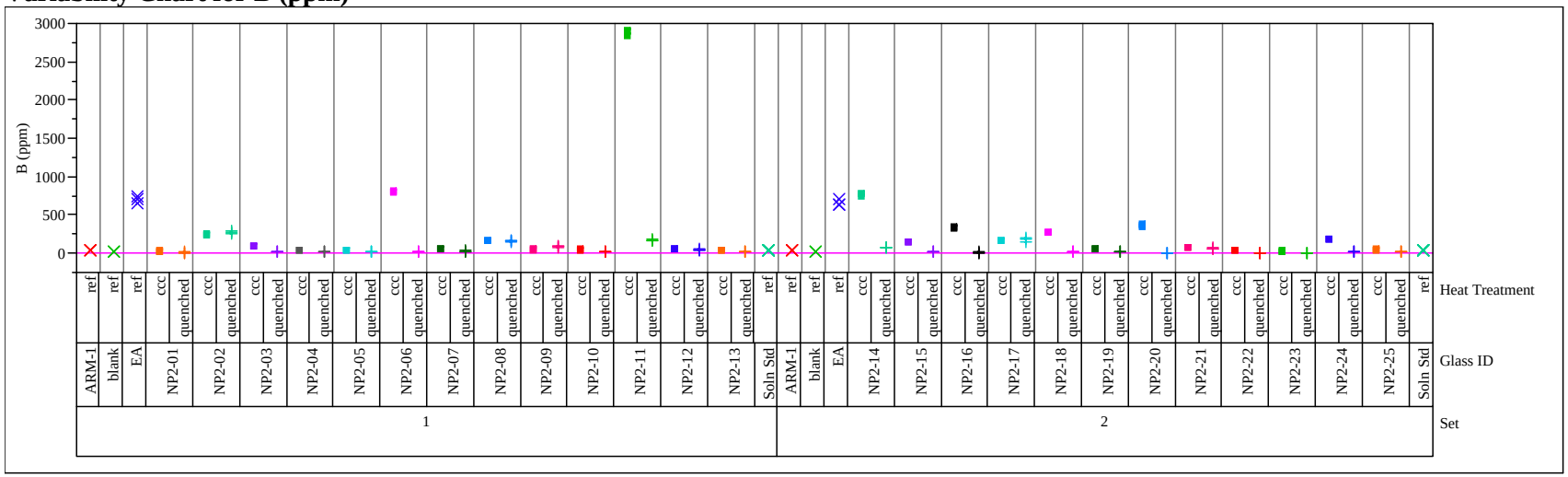
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1/1	3	45.9667	0.85991	44.093	47.840
1/2	3	51.0667	0.85991	49.193	52.940
1/3	3	50.5333	0.85991	48.660	52.407
2/1	3	48.8667	0.85991	46.993	50.740
2/2	3	50.0667	0.85991	48.193	51.940
2/3	3	50.0333	0.85991	48.160	51.907

Std Error uses a pooled estimate of error variance

Exhibit B3. Laboratory PCT Measurements by Glass Identifier for Study Glasses and Standards.

Variability Chart for B (ppm)



Variability Chart for Li (ppm)

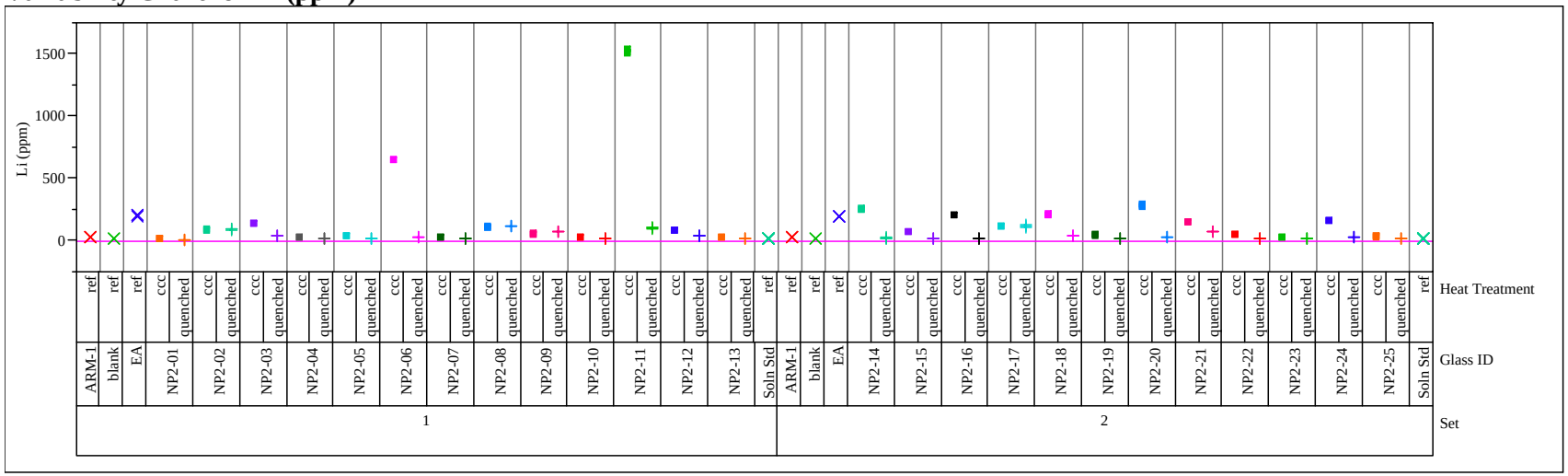
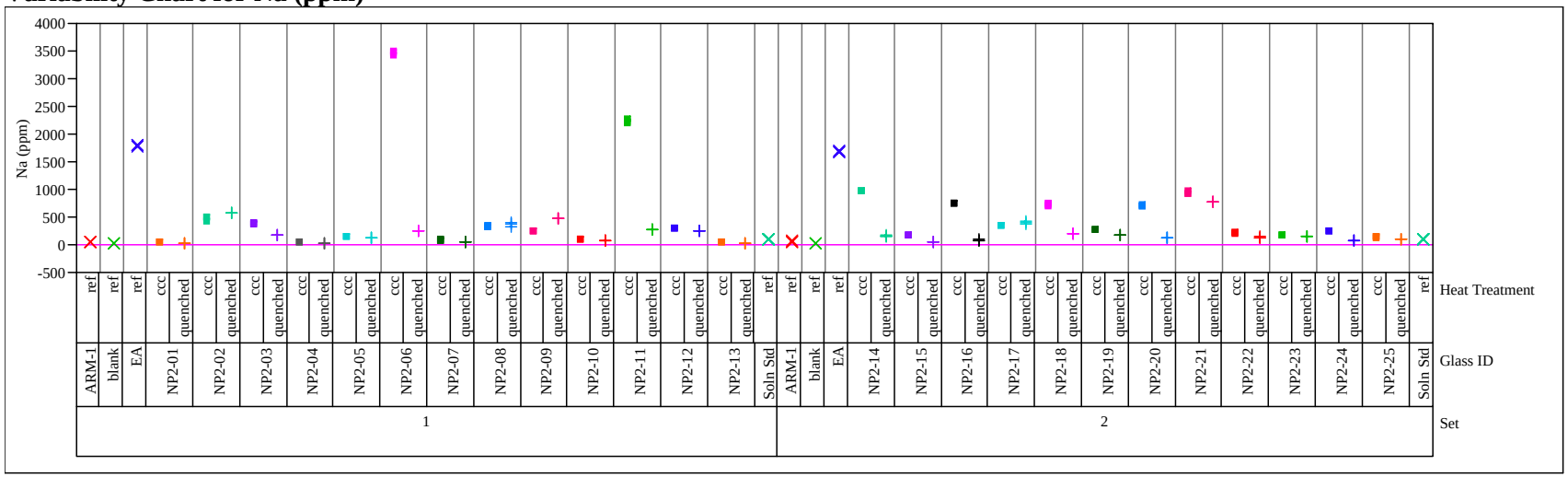


Exhibit B3. Laboratory PCT Measurements by Glass Identifier for Study Glasses and Standards. (continued)

Variability Chart for Na (ppm)



Variability Chart for Si (ppm)

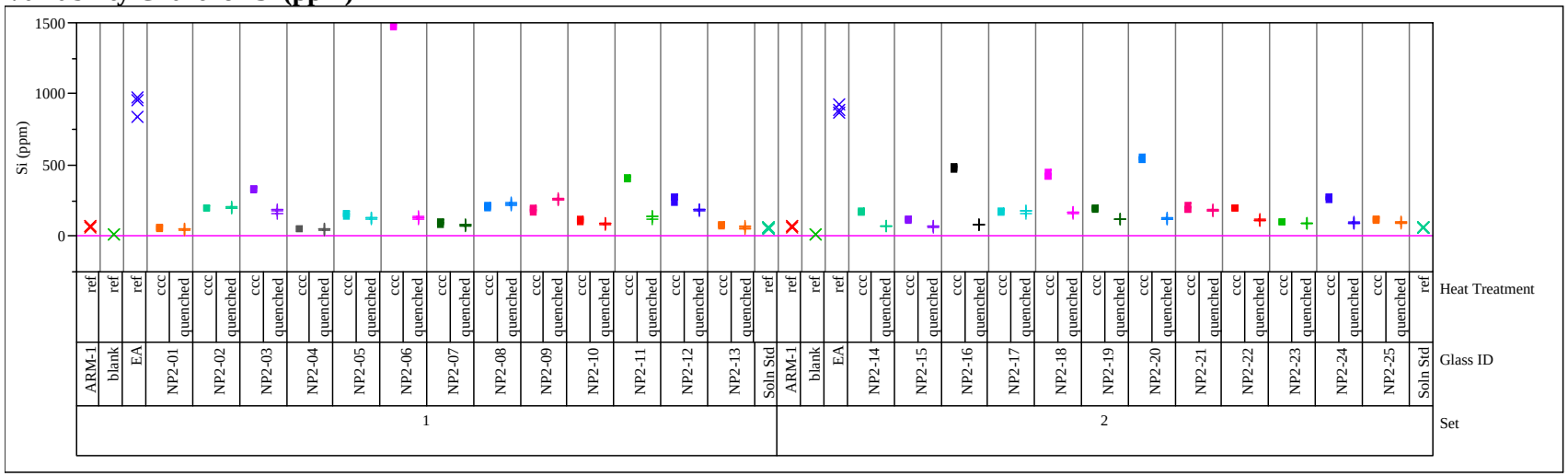
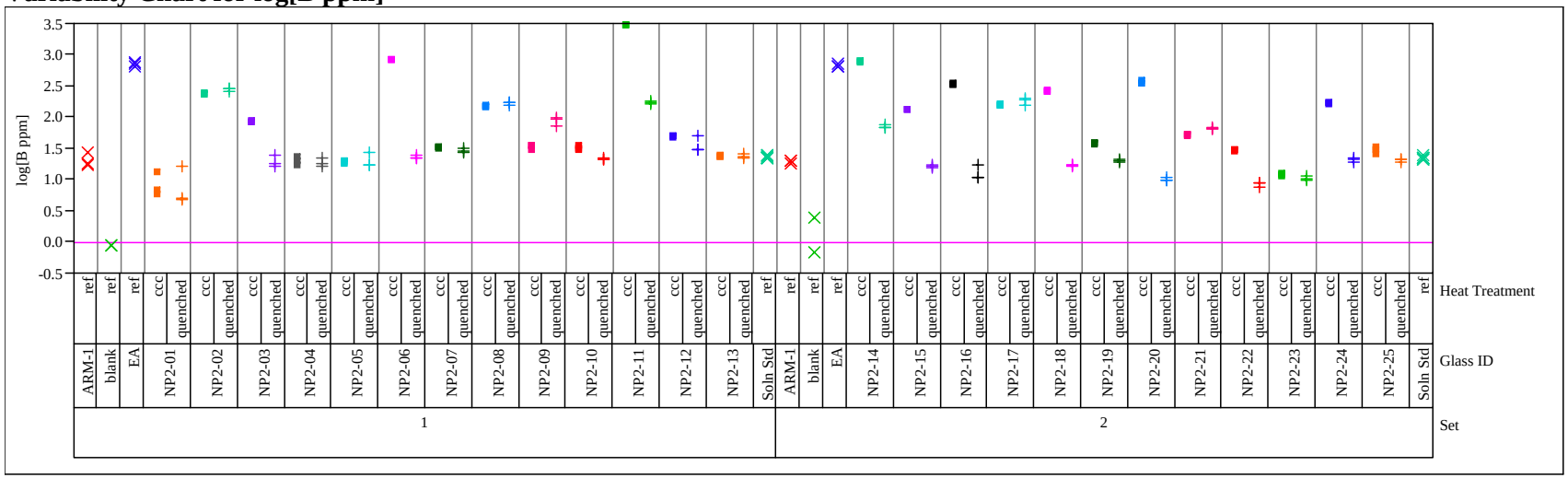


Exhibit B3. Laboratory PCT Measurements by Glass Identifier for Study Glasses and Standards. (continued)

Variability Chart for log[B ppm]



Variability Chart for log[Li ppm]

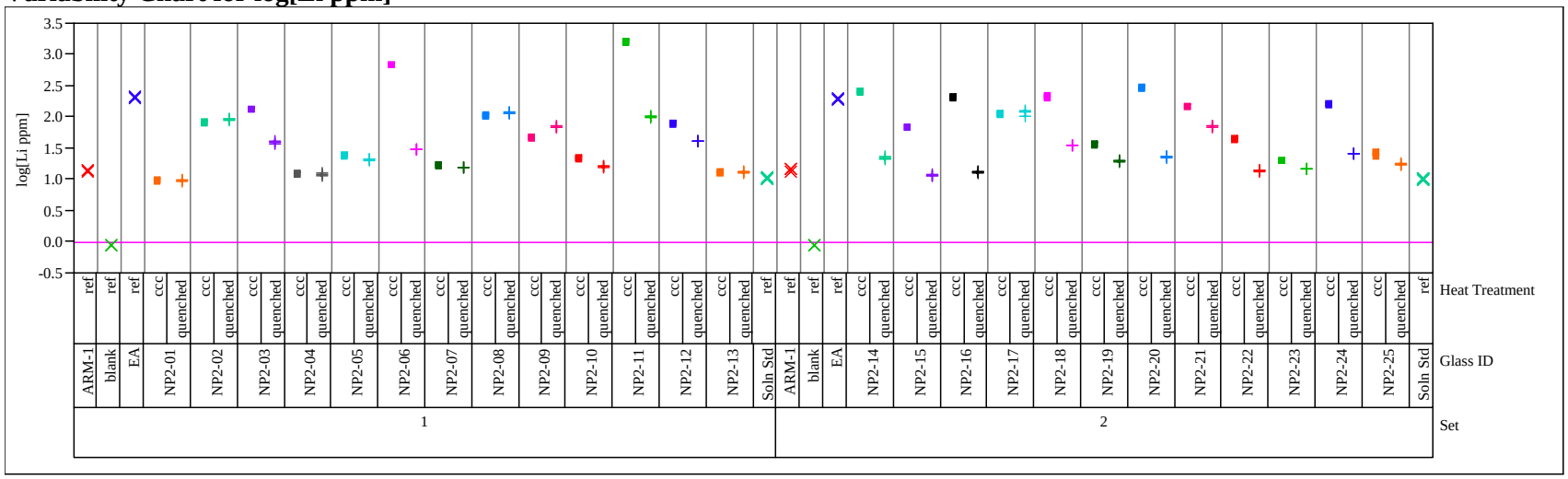
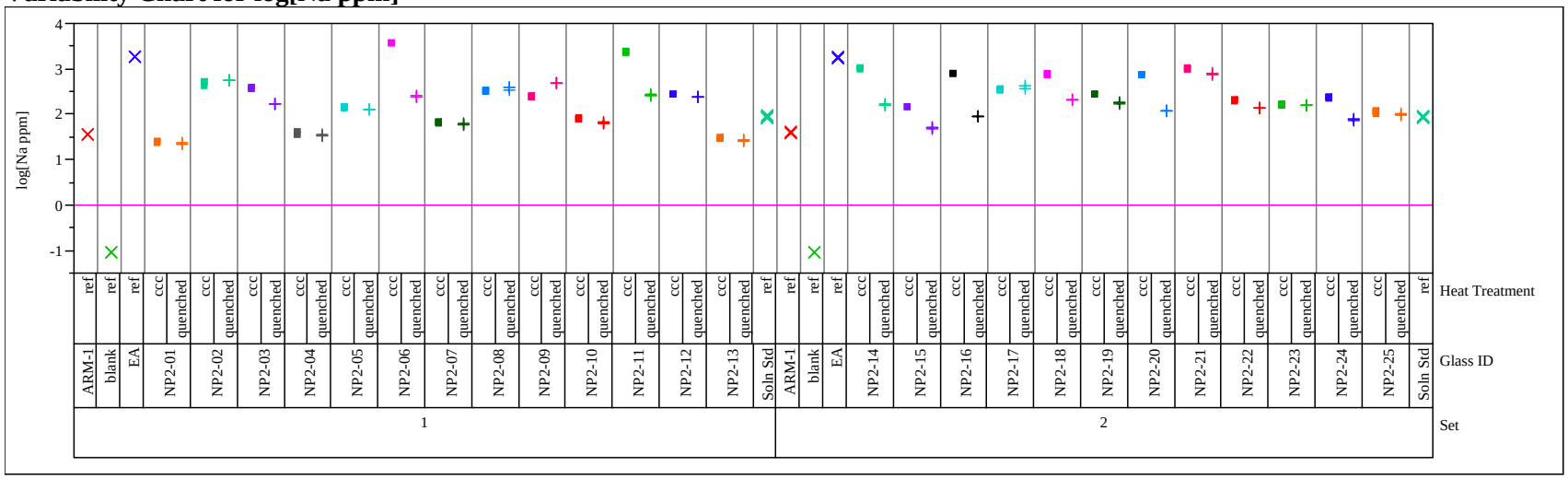


Exhibit B3. Laboratory PCT Measurements by Glass Identifier for Study Glasses and Standards. (continued)

Variability Chart for log[Na ppm]



Variability Chart for log[Si ppm]

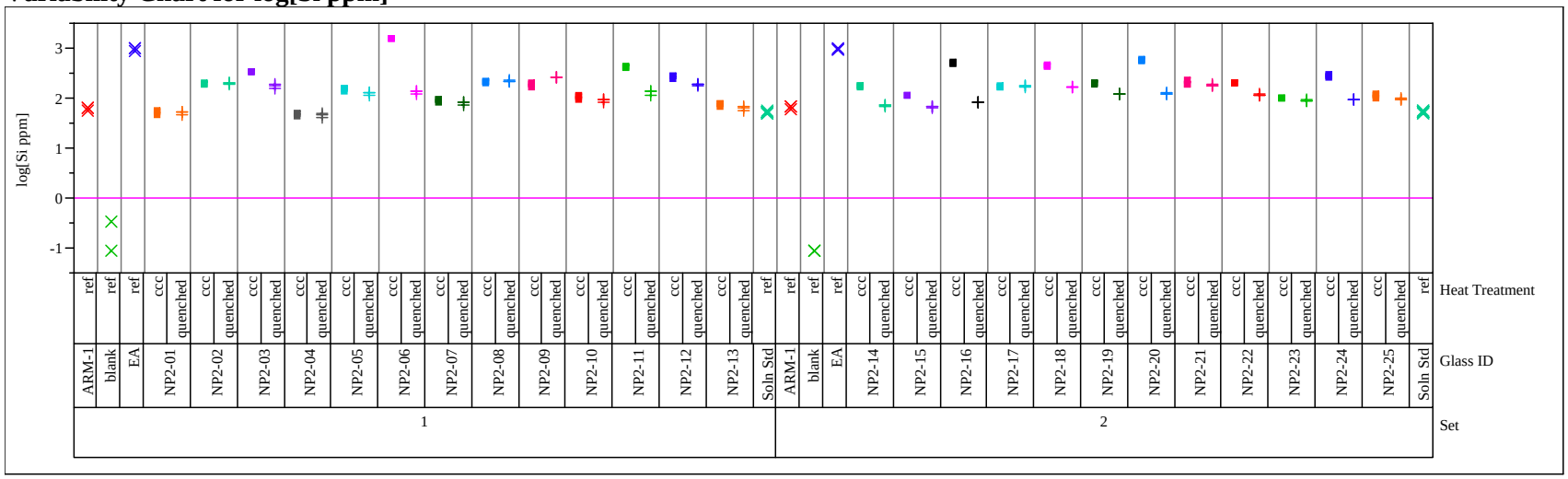
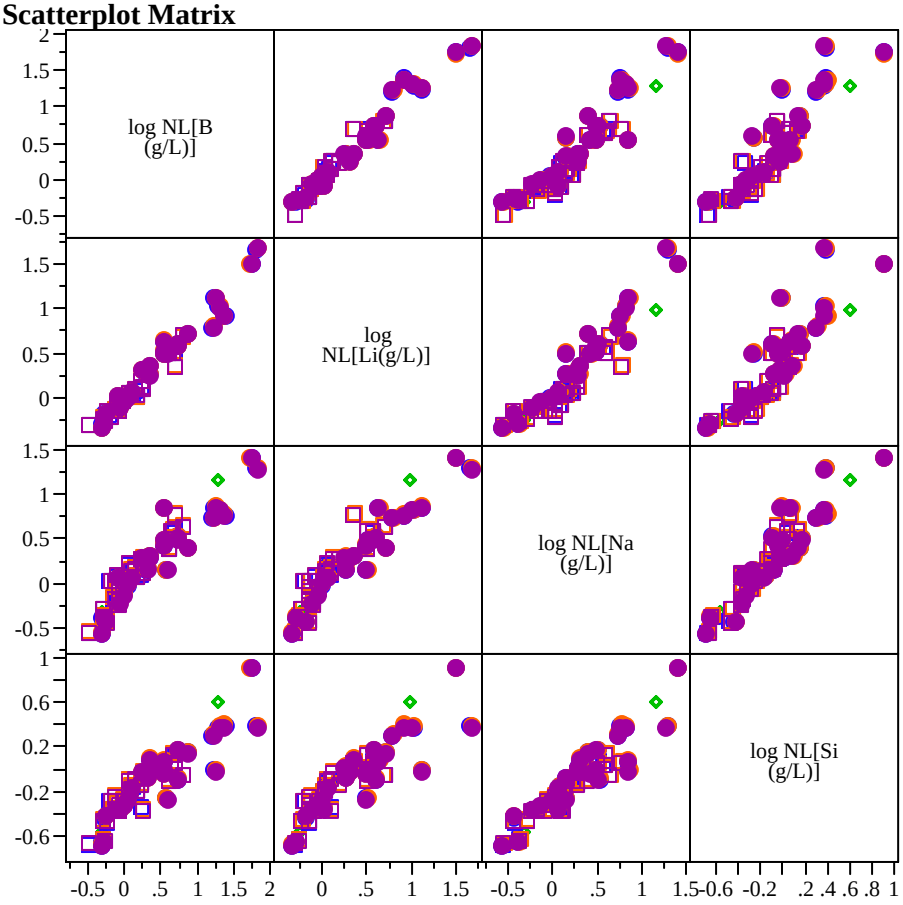


Exhibit B4. Correlations and Scatter Plots of Normalized PCTs Over All Compositional Views and Heat Treatments.

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	0.9852	0.9431	0.9081
log NL[Li(g/L)]	0.9852	1.0000	0.9413	0.8925
log NL[Na (g/L)]	0.9431	0.9413	1.0000	0.9337
log NL[Si (g/L)]	0.9081	0.8925	0.9337	1.0000

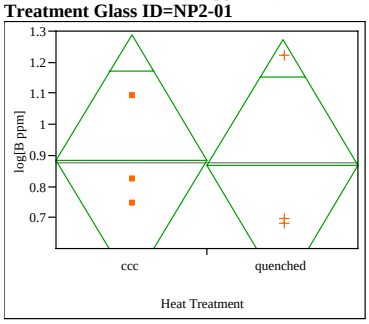
Scatterplot Matrix



EA and ARM are both represented by "◊."

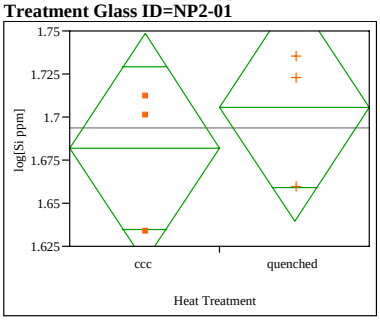
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses.

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-01



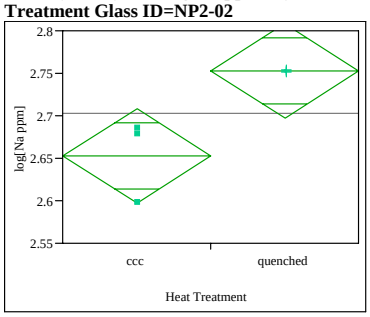
Difference	-0.01646	t Ratio	-0.07997
Std Err Dif	0.20581	DF	4
Upper CL Dif	0.55497	Prob > |t|	0.9401
Lower CL Dif	-0.58789	Prob > t	0.5299
Confidence	0.95	Prob < t	0.4701

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-01



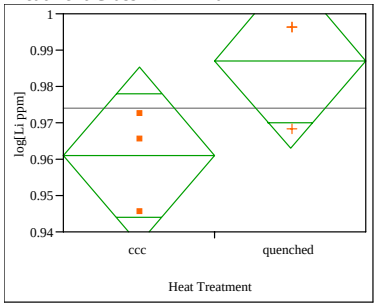
Difference	0.02396	t Ratio	0.708287
Std Err Dif	0.03383	DF	4
Upper CL Dif	0.11789	Prob > |t|	0.5179
Lower CL Dif	-0.06996	Prob > t	0.2589
Confidence	0.95	Prob < t	0.7411

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-02



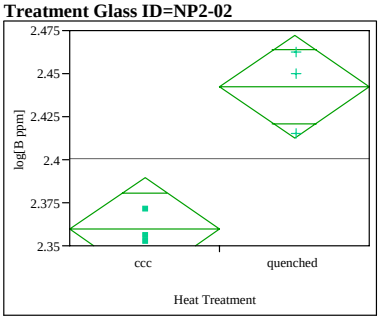
Difference	0.099879	t Ratio	3.530869
Std Err Dif	0.028287	DF	4
Upper CL Dif	0.178418	Prob > |t|	0.0242
Lower CL Dif	0.021341	Prob > t	0.0121
Confidence	0.95	Prob < t	0.9879

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-01



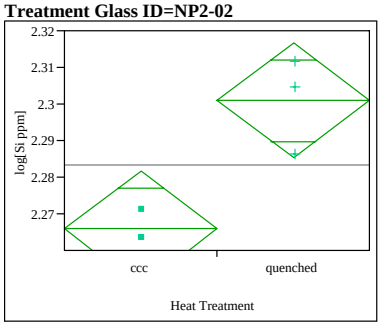
Difference	0.02606	t Ratio	2.1134
Std Err Dif	0.01233	DF	4
Upper CL Dif	0.06031	Prob > |t|	0.1021
Lower CL Dif	-0.00818	Prob > t	0.0510
Confidence	0.95	Prob < t	0.9490

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-02



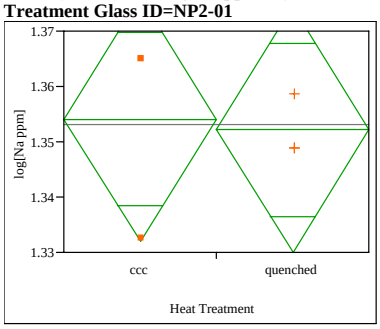
Difference	0.082823	t Ratio	5.402363
Std Err Dif	0.015331	DF	4
Upper CL Dif	0.125388	Prob > |t|	0.0057
Lower CL Dif	0.040258	Prob > t	0.0028
Confidence	0.95	Prob < t	0.9972

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-02



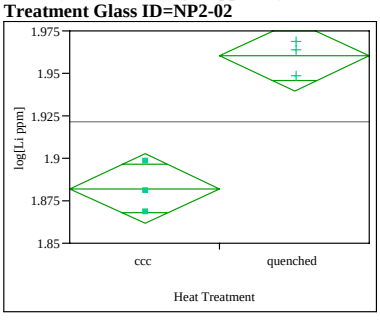
Difference	0.035048	t Ratio	4.372302
Std Err Dif	0.008016	DF	4
Upper CL Dif	0.057304	Prob > |t|	0.0119
Lower CL Dif	0.012792	Prob > t	0.0060
Confidence	0.95	Prob < t	0.9940

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-01



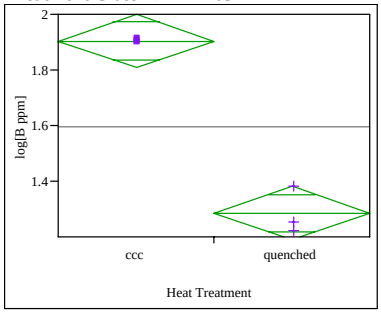
Difference	-0.00190	t Ratio	-0.16821
Std Err Dif	0.01127	DF	4
Upper CL Dif	0.02940	Prob > |t|	0.8746
Lower CL Dif	-0.03320	Prob > t	0.5627
Confidence	0.95	Prob < t	0.4373

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-02



Difference	0.078051	t Ratio	7.493007
Std Err Dif	0.010417	DF	4
Upper CL Dif	0.106972	Prob > |t|	0.0017
Lower CL Dif	0.049130	Prob > t	0.0008
Confidence	0.95	Prob < t	0.9992

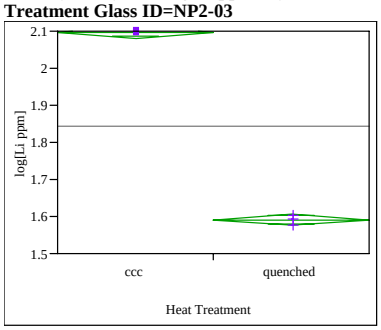
Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-03



Difference	-0.61848	t Ratio	-12.7849
Std Err Dif	0.04838	DF	4
Upper CL Dif	-0.48416	Prob > |t|	0.0002
Lower CL Dif	-0.75279	Prob > t	0.9999
Confidence	0.95	Prob < t	0.0001

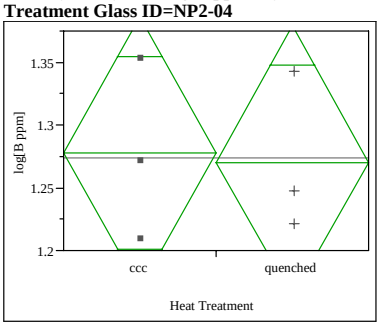
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-03



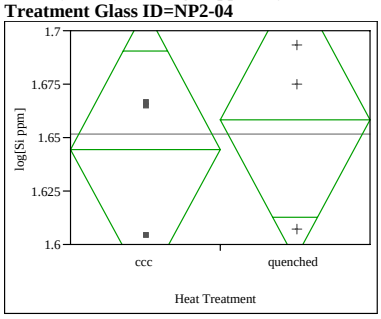
Difference	-0.50617	t Ratio	-64.2525
Std Err Dif	0.00788	DF	4
Upper CL Dif	-0.48430	Prob > |t|	<.0001
Lower CL Dif	-0.52805	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-04



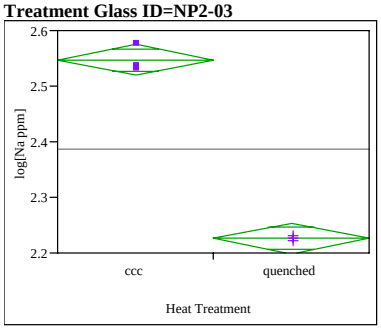
Difference	-0.00696	t Ratio	-0.1258
Std Err Dif	0.05536	DF	4
Upper CL Dif	0.14673	Prob > |t|	0.9060
Lower CL Dif	-0.16066	Prob > t	0.5470
Confidence	0.95	Prob < t	0.4530

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-04



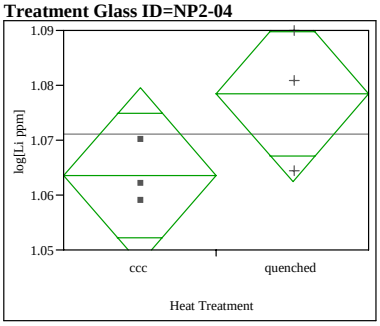
Difference	0.01389	t Ratio	0.419317
Std Err Dif	0.03313	DF	4
Upper CL Dif	0.10587	Prob > |t|	0.6965
Lower CL Dif	-0.07809	Prob > t	0.3483
Confidence	0.95	Prob < t	0.6517

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-03



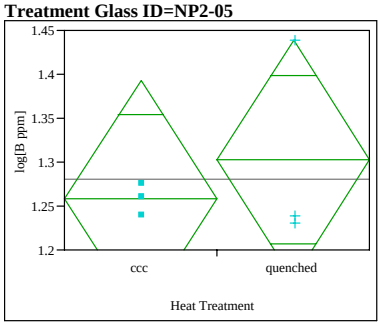
Difference	-0.32156	t Ratio	-22.3484
Std Err Dif	0.01439	DF	4
Upper CL Dif	-0.28161	Prob > |t|	<.0001
Lower CL Dif	-0.36151	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-04



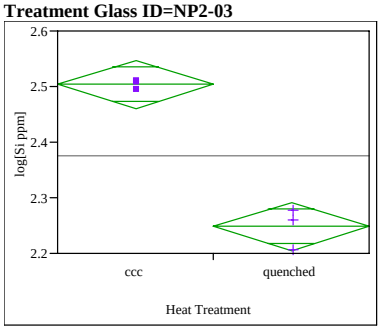
Difference	0.01485	t Ratio	1.817525
Std Err Dif	0.00817	DF	4
Upper CL Dif	0.03754	Prob > |t|	0.1433
Lower CL Dif	-0.00784	Prob > t	0.0716
Confidence	0.95	Prob < t	0.9284

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-05



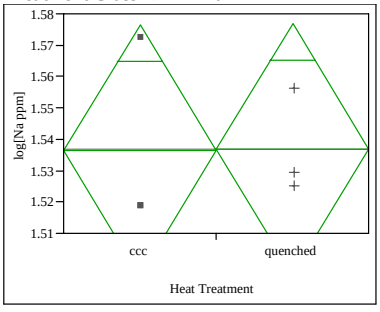
Difference	0.04519	t Ratio	0.654414
Std Err Dif	0.06906	DF	4
Upper CL Dif	0.23693	Prob > |t|	0.5486
Lower CL Dif	-0.14654	Prob > t	0.2743
Confidence	0.95	Prob < t	0.7257

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-03



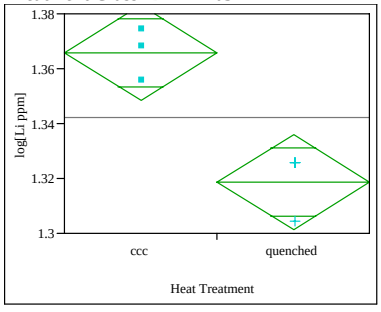
Difference	-0.25560	t Ratio	-11.4451
Std Err Dif	0.02233	DF	4
Upper CL Dif	-0.19359	Prob > |t|	0.0003
Lower CL Dif	-0.31760	Prob > t	0.9998
Confidence	0.95	Prob < t	0.0002

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-04



Difference	0.00052	t Ratio	0.025657
Std Err Dif	0.02036	DF	4
Upper CL Dif	0.05706	Prob > |t|	0.9808
Lower CL Dif	-0.05602	Prob > t	0.4904
Confidence	0.95	Prob < t	0.5096

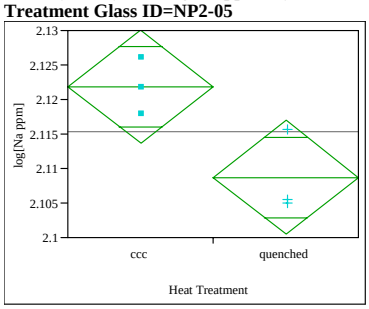
Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-05



Difference	-0.04719	t Ratio	-5.29133
Std Err Dif	0.00892	DF	4
Upper CL Dif	-0.02243	Prob > |t|	0.0061
Lower CL Dif	-0.07195	Prob > t	0.9969
Confidence	0.95	Prob < t	0.0031

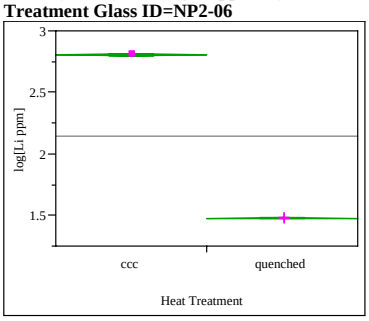
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-05



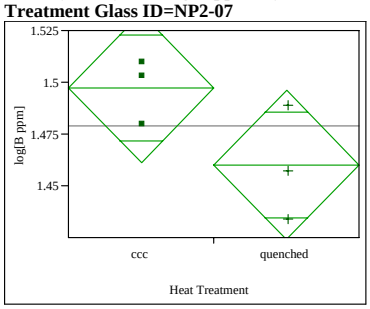
Difference	-0.01315	t Ratio	-3.1331
Std Err Dif	0.00420	DF	4
Upper CL Dif	-0.00150	Prob > |t|	0.0351
Lower CL Dif	-0.02481	Prob > t	0.9825
Confidence	0.95	Prob < t	0.0175

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-06



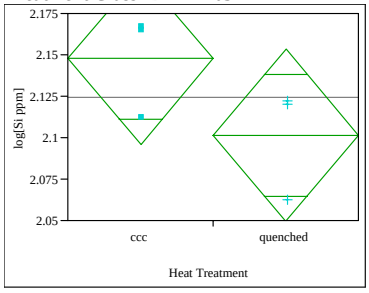
Difference	-1.3291	t Ratio	-354.629
Std Err Dif	0.0037	DF	4
Upper CL Dif	-1.3187	Prob > |t|	<.0001
Lower CL Dif	-1.3395	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-07



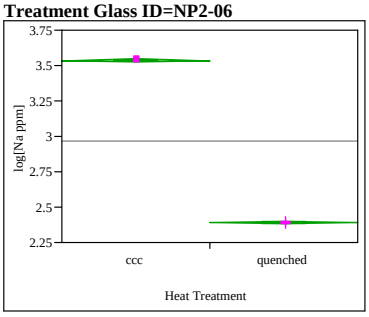
Difference	-0.03721	t Ratio	-2.02655
Std Err Dif	0.01836	DF	4
Upper CL Dif	0.01377	Prob > |t|	0.1127
Lower CL Dif	-0.08819	Prob > t	0.9437
Confidence	0.95	Prob < t	0.0563

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-05



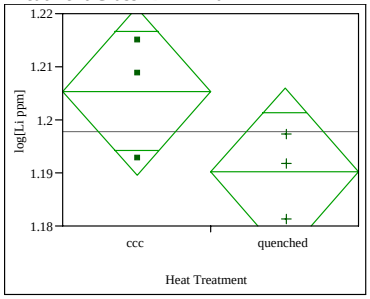
Difference	-0.04602	t Ratio	-1.73426
Std Err Dif	0.02654	DF	4
Upper CL Dif	0.02766	Prob > |t|	0.1579
Lower CL Dif	-0.11970	Prob > t	0.9211
Confidence	0.95	Prob < t	0.0789

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-06



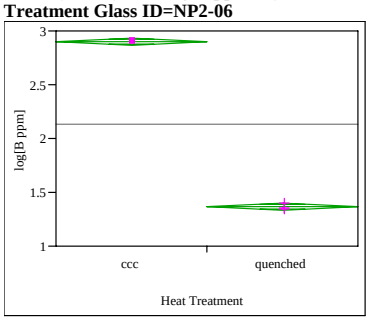
Difference	-1.1443	t Ratio	-222.929
Std Err Dif	0.0051	DF	4
Upper CL Dif	-1.1301	Prob > |t|	<.0001
Lower CL Dif	-1.1586	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-07



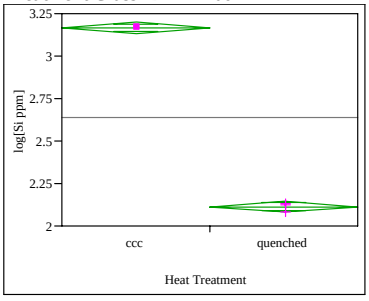
Difference	-0.01525	t Ratio	-1.88576
Std Err Dif	0.00809	DF	4
Upper CL Dif	0.00720	Prob > |t|	0.1324
Lower CL Dif	-0.03770	Prob > t	0.9338
Confidence	0.95	Prob < t	0.0662

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-06



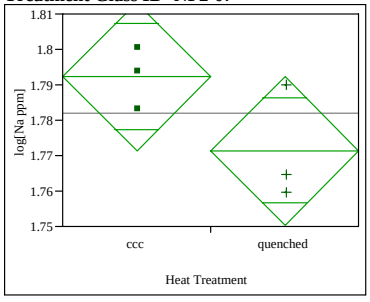
Difference	-1.5330	t Ratio	-90.4752
Std Err Dif	0.0169	DF	4
Upper CL Dif	-1.4859	Prob > |t|	<.0001
Lower CL Dif	-1.5800	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-06



Difference	-1.0530	t Ratio	-64.6569
Std Err Dif	0.0163	DF	4
Upper CL Dif	-1.0078	Prob > |t|	<.0001
Lower CL Dif	-1.0982	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

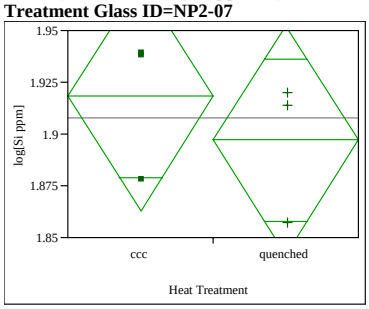
Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-07



Difference	-0.02087	t Ratio	-1.95053
Std Err Dif	0.01070	DF	4
Upper CL Dif	0.00884	Prob > |t|	0.1229
Lower CL Dif	-0.05057	Prob > t	0.9386
Confidence	0.95	Prob < t	0.0614

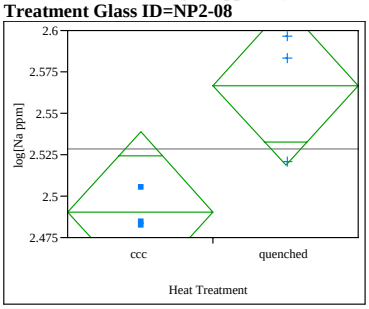
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-07



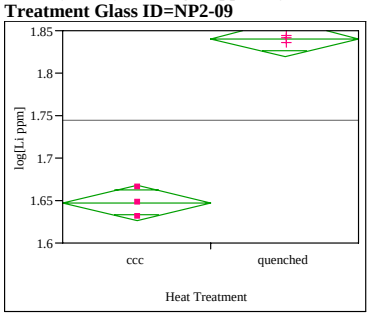
Difference	-0.02113	t Ratio	-0.74635
Std Err Dif	0.02831	DF	4
Upper CL Dif	0.05747	Prob > |t|	0.4969
Lower CL Dif	-0.09973	Prob > t	0.7515
Confidence	0.95	Prob < t	0.2485

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-08



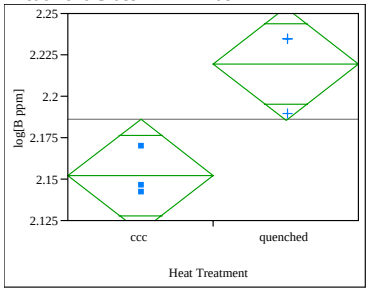
Difference	0.076502	t Ratio	3.114123
Std Err Dif	0.024566	DF	4
Upper CL Dif	0.144708	Prob > |t|	0.0357
Lower CL Dif	0.008295	Prob > t	0.0179
Confidence	0.95	Prob < t	0.9821

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-09



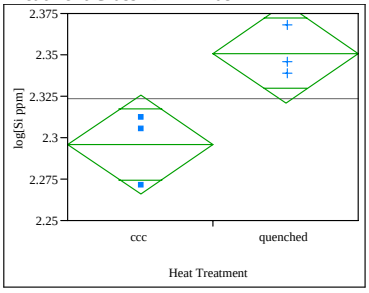
Difference	0.193354	t Ratio	18.05664
Std Err Dif	0.010708	DF	4
Upper CL Dif	0.223084	Prob > |t|	<.0001
Lower CL Dif	0.163623	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-08



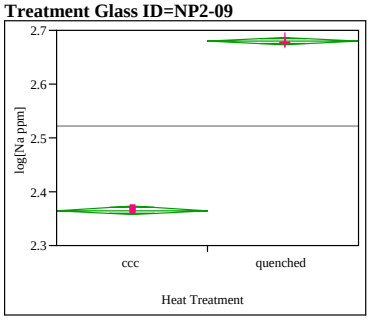
Difference	0.067475	t Ratio	3.876153
Std Err Dif	0.017408	DF	4
Upper CL Dif	0.115807	Prob > |t|	0.0179
Lower CL Dif	0.019143	Prob > t	0.0089
Confidence	0.95	Prob < t	0.9911

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-08



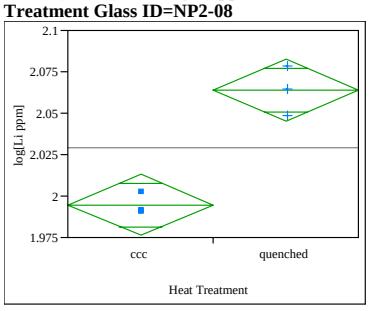
Difference	0.055114	t Ratio	3.60586
Std Err Dif	0.015285	DF	4
Upper CL Dif	0.097551	Prob > |t|	0.0226
Lower CL Dif	0.012677	Prob > t	0.0113
Confidence	0.95	Prob < t	0.9887

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-09



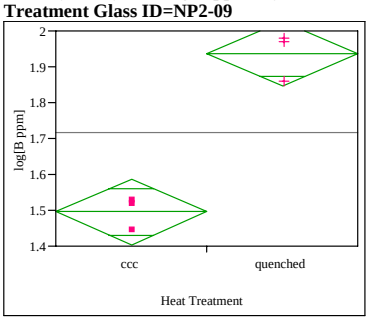
Difference	0.314827	t Ratio	83.46045
Std Err Dif	0.003772	DF	4
Upper CL Dif	0.325300	Prob > |t|	<.0001
Lower CL Dif	0.304353	Prob > t	<.0001
Confidence	0.95	Prob < t	1.0000

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-08



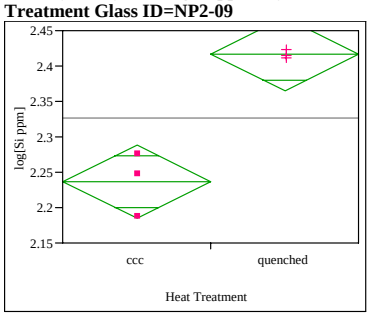
Difference	0.069243	t Ratio	7.324249
Std Err Dif	0.009454	DF	4
Upper CL Dif	0.095491	Prob > |t|	0.0018
Lower CL Dif	0.042994	Prob > t	0.0009
Confidence	0.95	Prob < t	0.9991

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-09



Difference	0.441145	t Ratio	9.518938
Std Err Dif	0.046344	DF	4
Upper CL Dif	0.569816	Prob > |t|	0.0007
Lower CL Dif	0.312474	Prob > t	0.0003
Confidence	0.95	Prob < t	0.9997

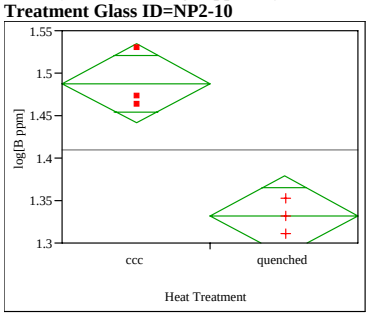
Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-09



Difference	0.180579	t Ratio	6.867741
Std Err Dif	0.026294	DF	4
Upper CL Dif	0.253583	Prob > |t|	0.0024
Lower CL Dif	0.107576	Prob > t	0.0012
Confidence	0.95	Prob < t	0.9988

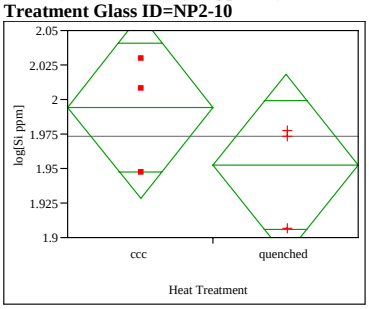
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-10



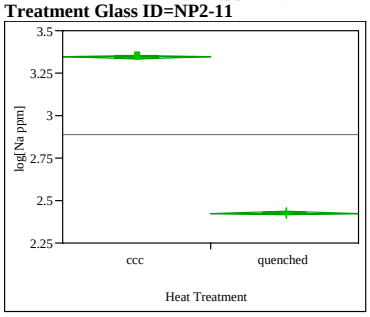
Difference	-0.15588	t Ratio	-6.5198
Std Err Dif	0.02391	DF	4
Upper CL Dif	-0.08950	Prob > |t|	0.0029
Lower CL Dif	-0.22226	Prob > t	0.9986
Confidence	0.95	Prob < t	0.0014

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-10



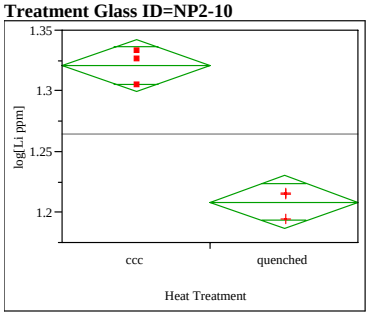
Difference	-0.04199	t Ratio	-1.24727
Std Err Dif	0.03366	DF	4
Upper CL Dif	0.05148	Prob > |t|	0.2803
Lower CL Dif	-0.13545	Prob > t	0.8598
Confidence	0.95	Prob < t	0.1402

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-11



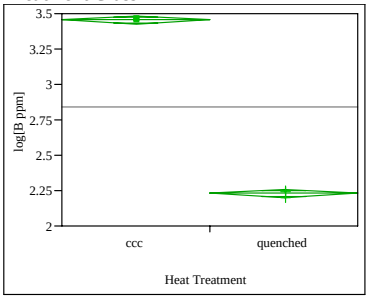
Difference	-0.91772	t Ratio	-199.942
Std Err Dif	0.00459	DF	4
Upper CL Dif	-0.90497	Prob > |t|	<.0001
Lower CL Dif	-0.93046	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-10



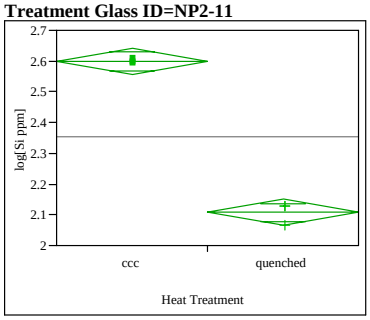
Difference	-0.11241	t Ratio	-10.164
Std Err Dif	0.01106	DF	4
Upper CL Dif	-0.08170	Prob > |t|	0.0005
Lower CL Dif	-0.14311	Prob > t	0.9997
Confidence	0.95	Prob < t	0.0003

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-11



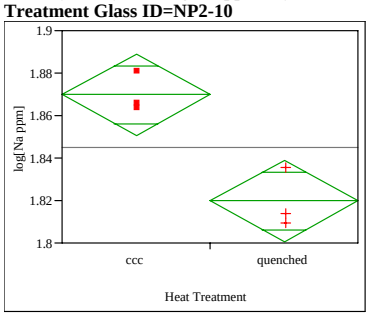
Difference	-1.2246	t Ratio	-83.2092
Std Err Dif	0.0147	DF	4
Upper CL Dif	-1.1837	Prob > |t|	<.0001
Lower CL Dif	-1.2654	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-11



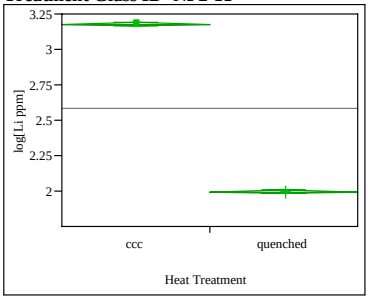
Difference	-0.49048	t Ratio	-22.449
Std Err Dif	0.02185	DF	4
Upper CL Dif	-0.42981	Prob > |t|	<.0001
Lower CL Dif	-0.55114	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-10



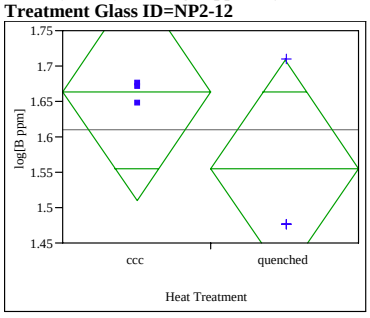
Difference	-0.05005	t Ratio	-5.11661
Std Err Dif	0.00978	DF	4
Upper CL Dif	-0.02289	Prob > |t|	0.0069
Lower CL Dif	-0.07722	Prob > t	0.9965
Confidence	0.95	Prob < t	0.0035

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-11



Difference	-1.1836	t Ratio	-160.66
Std Err Dif	0.0074	DF	4
Upper CL Dif	-1.1631	Prob > |t|	<.0001
Lower CL Dif	-1.2040	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

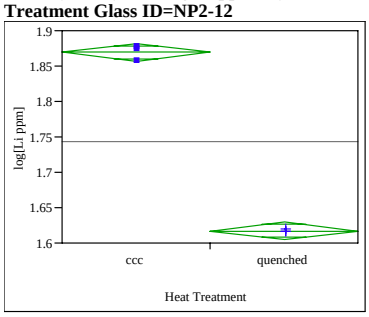
Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-12



Difference	-0.10927	t Ratio	-1.3963
Std Err Dif	0.07826	DF	4
Upper CL Dif	0.10801	Prob > |t|	0.2351
Lower CL Dif	-0.32655	Prob > t	0.8824
Confidence	0.95	Prob < t	0.1176

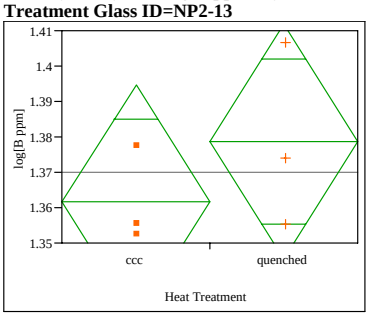
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-12



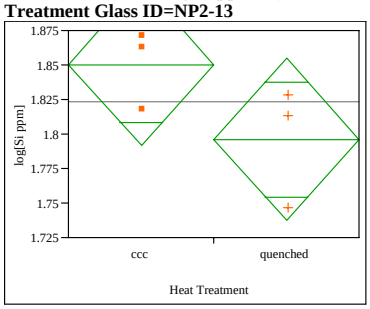
Difference	-0.25201	t Ratio	-40.4115
Std Err Dif	0.00624	DF	4
Upper CL Dif	-0.23469	Prob > |t|	<.0001
Lower CL Dif	-0.26932	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-13



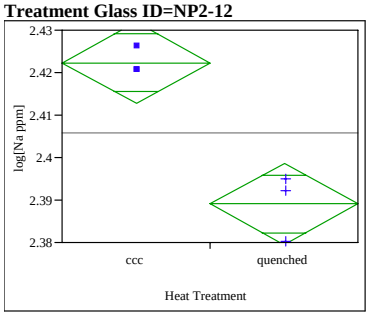
Difference	0.01710	t Ratio	1.013253
Std Err Dif	0.01688	DF	4
Upper CL Dif	0.06397	Prob > |t|	0.3682
Lower CL Dif	-0.02976	Prob > t	0.1841
Confidence	0.95	Prob < t	0.8159

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-13



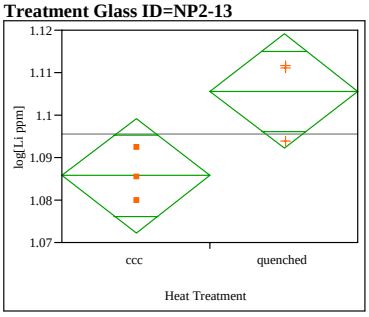
Difference	-0.05427	t Ratio	-1.8086
Std Err Dif	0.03001	DF	4
Upper CL Dif	0.02904	Prob > |t|	0.1448
Lower CL Dif	-0.13759	Prob > t	0.9276
Confidence	0.95	Prob < t	0.0724

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-12



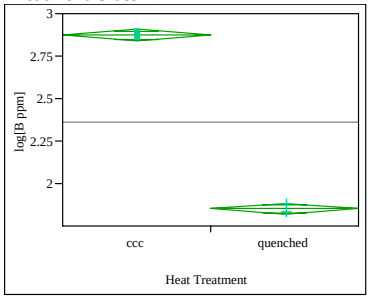
Difference	-0.03321	t Ratio	-6.79764
Std Err Dif	0.00489	DF	4
Upper CL Dif	-0.01964	Prob > |t|	0.0024
Lower CL Dif	-0.04677	Prob > t	0.9988
Confidence	0.95	Prob < t	0.0012

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-13



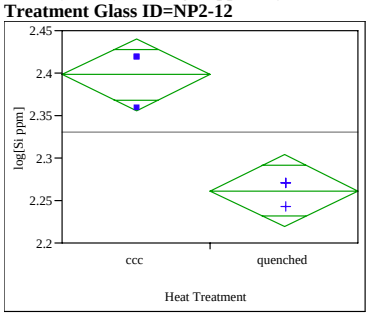
Difference	0.019886	t Ratio	2.906852
Std Err Dif	0.006841	DF	4
Upper CL Dif	0.038880	Prob > |t|	0.0438
Lower CL Dif	0.000892	Prob > t	0.0219
Confidence	0.95	Prob < t	0.9781

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-14



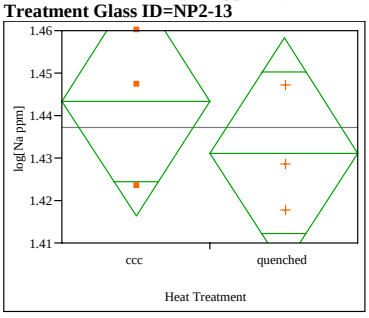
Difference	-1.0221	t Ratio	-59.9522
Std Err Dif	0.0170	DF	4
Upper CL Dif	-0.9748	Prob > |t|	<.0001
Lower CL Dif	-1.0695	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-12



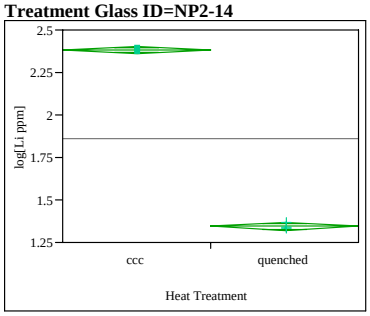
Difference	-0.13630	t Ratio	-6.24447
Std Err Dif	0.02183	DF	4
Upper CL Dif	-0.07570	Prob > |t|	0.0034
Lower CL Dif	-0.19690	Prob > t	0.9983
Confidence	0.95	Prob < t	0.0017

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-13



Difference	-0.01224	t Ratio	-0.89013
Std Err Dif	0.01375	DF	4
Upper CL Dif	0.02594	Prob > |t|	0.4237
Lower CL Dif	-0.05042	Prob > t	0.7882
Confidence	0.95	Prob < t	0.2118

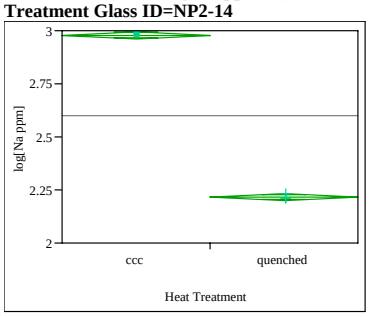
Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-14



Difference	-1.0367	t Ratio	-89.2536
Std Err Dif	0.0116	DF	4
Upper CL Dif	-1.0044	Prob > |t|	<.0001
Lower CL Dif	-1.0689	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

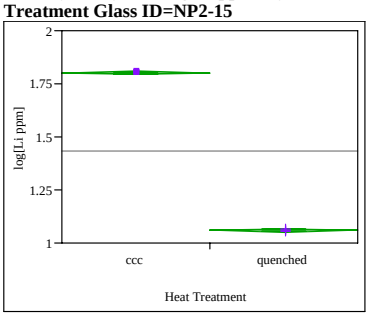
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-14



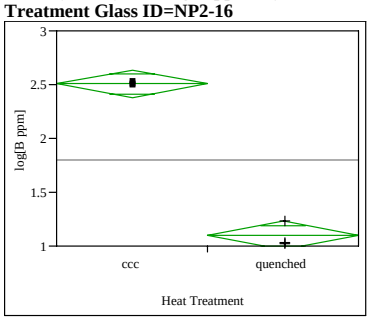
Difference	-0.76239	t Ratio	-87.0851
Std Err Dif	0.00875	DF	4
Upper CL Dif	-0.73808	Prob > |t|	<.0001
Lower CL Dif	-0.78669	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-15



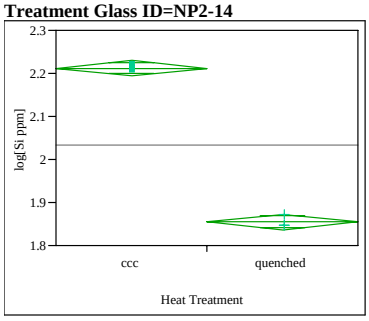
Difference	-0.74173	t Ratio	-182.575
Std Err Dif	0.00406	DF	4
Upper CL Dif	-0.73045	Prob > |t|	<.0001
Lower CL Dif	-0.75300	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-16



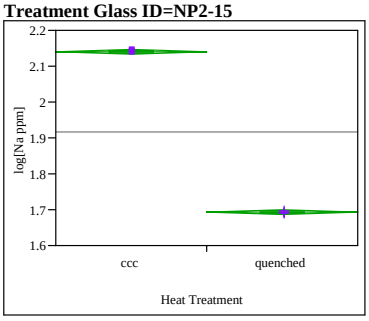
Difference	-1.4075	t Ratio	-21.0743
Std Err Dif	0.0668	DF	4
Upper CL Dif	-1.2221	Prob > |t|	<.0001
Lower CL Dif	-1.5930	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-14



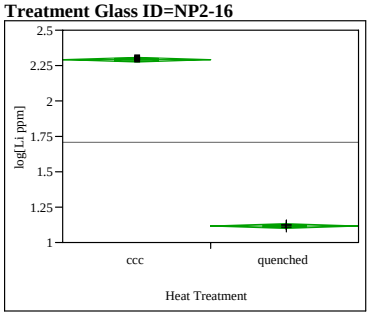
Difference	-0.35607	t Ratio	-38.6436
Std Err Dif	0.00921	DF	4
Upper CL Dif	-0.33049	Prob > |t|	<.0001
Lower CL Dif	-0.38165	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-15



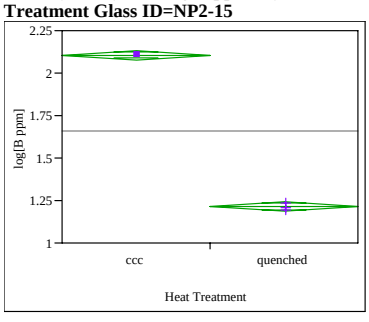
Difference	-0.44727	t Ratio	-142.659
Std Err Dif	0.00314	DF	4
Upper CL Dif	-0.43857	Prob > |t|	<.0001
Lower CL Dif	-0.45597	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-16



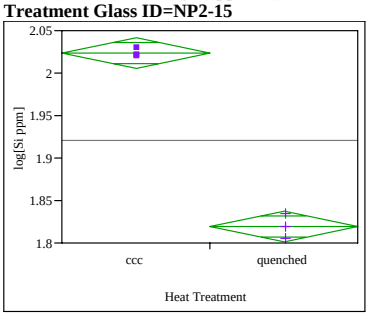
Difference	-1.1739	t Ratio	-166.97
Std Err Dif	0.0070	DF	4
Upper CL Dif	-1.1544	Prob > |t|	<.0001
Lower CL Dif	-1.1934	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-15



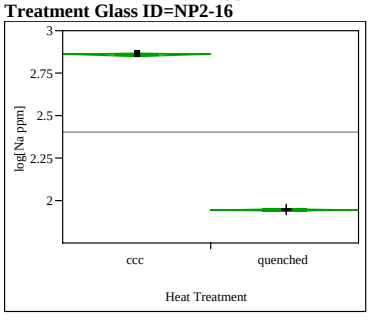
Difference	-0.89248	t Ratio	-65.7555
Std Err Dif	0.01357	DF	4
Upper CL Dif	-0.85479	Prob > |t|	<.0001
Lower CL Dif	-0.93016	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-15



Difference	-0.20349	t Ratio	-22.366
Std Err Dif	0.00910	DF	4
Upper CL Dif	-0.17823	Prob > |t|	<.0001
Lower CL Dif	-0.22875	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

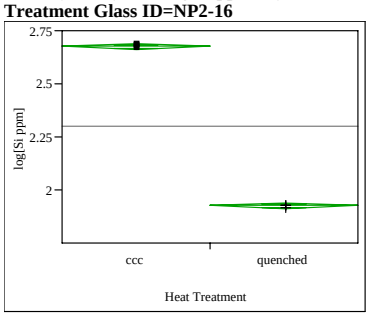
Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-16



Difference	-0.91333	t Ratio	-222.014
Std Err Dif	0.00411	DF	4
Upper CL Dif	-0.90191	Prob > |t|	<.0001
Lower CL Dif	-0.92476	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

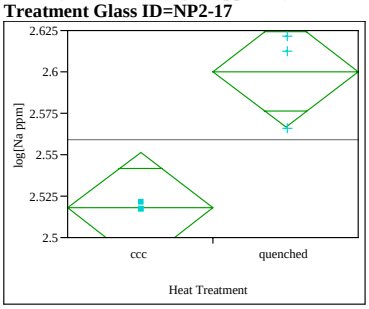
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-16



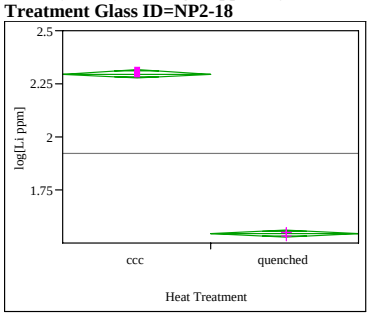
Difference	-0.74885	t Ratio	-112.583
Std Err Dif	0.00665	DF	4
Upper CL Dif	-0.73039	Prob > |t|	<.0001
Lower CL Dif	-0.76732	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-17



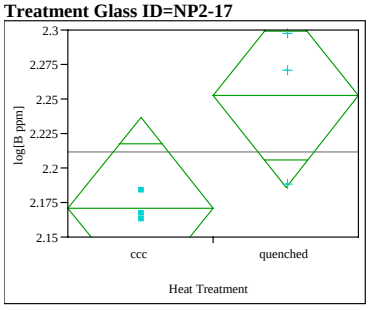
Difference	0.082405	t Ratio	4.785608
Std Err Dif	0.017219	DF	4
Upper CL Dif	0.130214	Prob > |t|	0.0087
Lower CL Dif	0.034597	Prob > t	0.0044
Confidence	0.95	Prob < t	0.9956

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-18



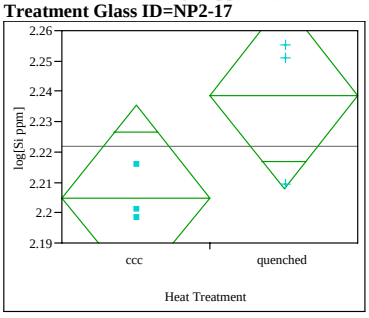
Difference	-0.75132	t Ratio	-82.2092
Std Err Dif	0.00914	DF	4
Upper CL Dif	-0.72595	Prob > |t|	<.0001
Lower CL Dif	-0.77670	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-17



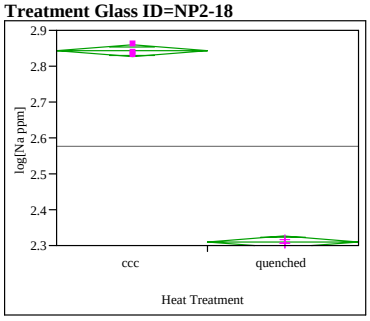
Difference	0.08133	t Ratio	2.42233
Std Err Dif	0.03358	DF	4
Upper CL Dif	0.17455	Prob > |t|	0.0726
Lower CL Dif	-0.01189	Prob > t	0.0363
Confidence	0.95	Prob < t	0.9637

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-17



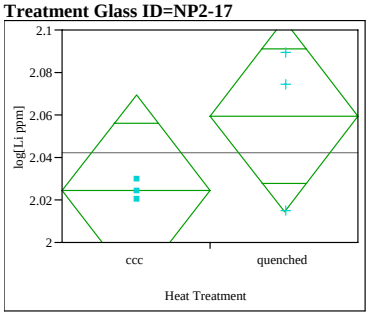
Difference	0.03372	t Ratio	2.160615
Std Err Dif	0.01561	DF	4
Upper CL Dif	0.07705	Prob > |t|	0.0968
Lower CL Dif	-0.00961	Prob > t	0.0484
Confidence	0.95	Prob < t	0.9516

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-18



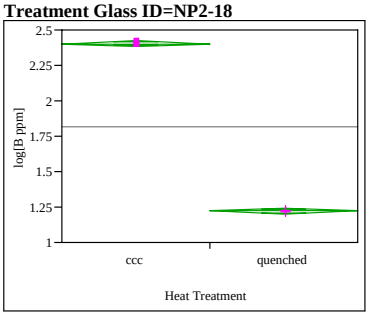
Difference	-0.53161	t Ratio	-61.1919
Std Err Dif	0.00869	DF	4
Upper CL Dif	-0.50749	Prob > |t|	<.0001
Lower CL Dif	-0.55573	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-17



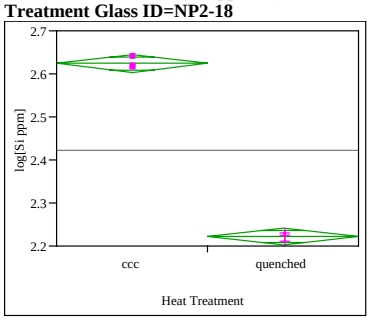
Difference	0.03515	t Ratio	1.536443
Std Err Dif	0.02288	DF	4
Upper CL Dif	0.09867	Prob > |t|	0.1992
Lower CL Dif	-0.02837	Prob > t	0.0996
Confidence	0.95	Prob < t	0.9004

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-18



Difference	-1.1782	t Ratio	-119.533
Std Err Dif	0.0099	DF	4
Upper CL Dif	-1.1508	Prob > |t|	<.0001
Lower CL Dif	-1.2055	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

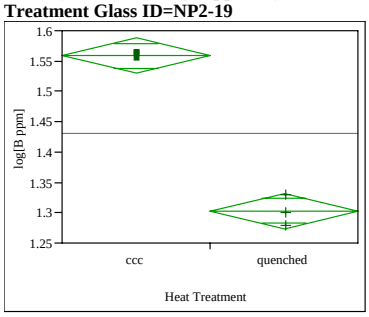
Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-18



Difference	-0.40117	t Ratio	-39.4189
Std Err Dif	0.01018	DF	4
Upper CL Dif	-0.37292	Prob > |t|	<.0001
Lower CL Dif	-0.42943	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

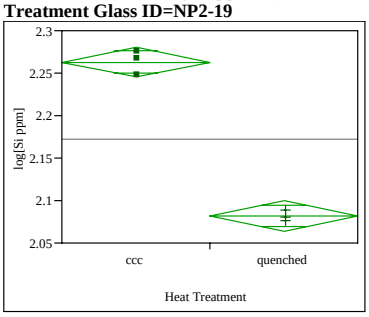
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-19



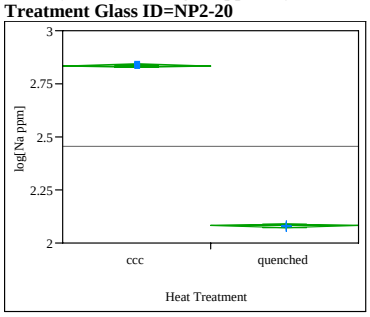
Difference	-0.25601	t Ratio	-17.3556
Std Err Dif	0.01475	DF	4
Upper CL Dif	-0.21506	Prob > |t|	<.0001
Lower CL Dif	-0.29697	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-19



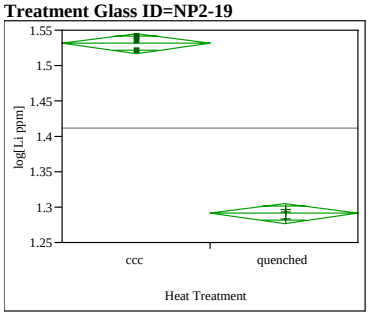
Difference	-0.18093	t Ratio	-19.8327
Std Err Dif	0.00912	DF	4
Upper CL Dif	-0.15560	Prob > |t|	<.0001
Lower CL Dif	-0.20626	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-20



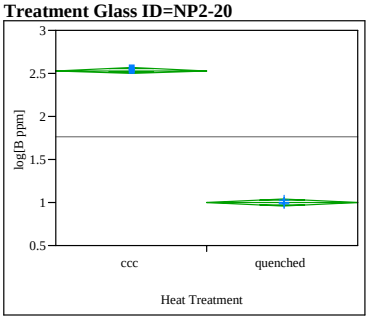
Difference	-0.75346	t Ratio	-160.658
Std Err Dif	0.00469	DF	4
Upper CL Dif	-0.74044	Prob > |t|	<.0001
Lower CL Dif	-0.76648	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-19



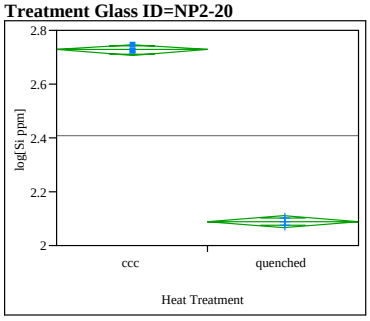
Difference	-0.24018	t Ratio	-33.3376
Std Err Dif	0.00720	DF	4
Upper CL Dif	-0.22018	Prob > |t|	<.0001
Lower CL Dif	-0.26018	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-20



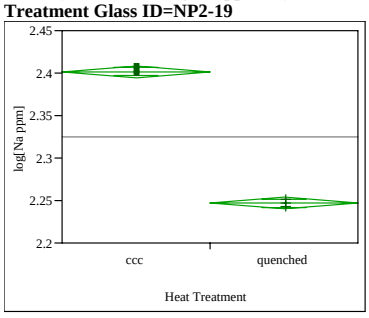
Difference	-1.5313	t Ratio	-79.722
Std Err Dif	0.0192	DF	4
Upper CL Dif	-1.4780	Prob > |t|	<.0001
Lower CL Dif	-1.5847	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-20



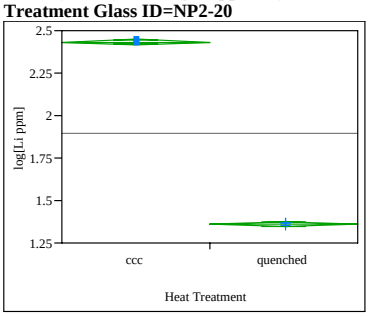
Difference	-0.63817	t Ratio	-58.5281
Std Err Dif	0.01090	DF	4
Upper CL Dif	-0.60789	Prob > |t|	<.0001
Lower CL Dif	-0.66844	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-19



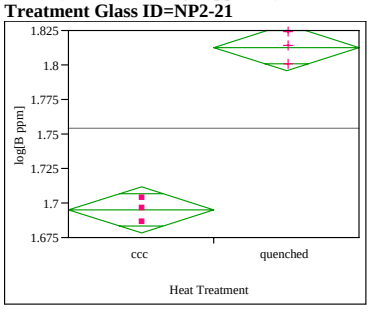
Difference	-0.15463	t Ratio	-44.671
Std Err Dif	0.00346	DF	4
Upper CL Dif	-0.14502	Prob > |t|	<.0001
Lower CL Dif	-0.16424	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-20



Difference	-1.0722	t Ratio	-125.827
Std Err Dif	0.0085	DF	4
Upper CL Dif	-1.0486	Prob > |t|	<.0001
Lower CL Dif	-1.0959	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

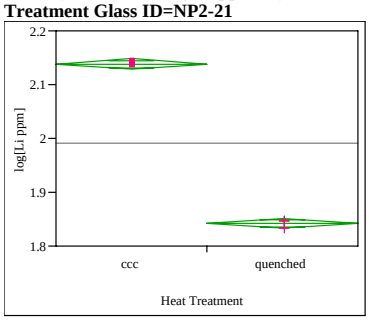
Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-21



Difference	0.117775	t Ratio	13.87851
Std Err Dif	0.008486	DF	4
Upper CL Dif	0.141336	Prob > |t|	0.0002
Lower CL Dif	0.094213	Prob > t	<.0001
Confidence	0.95	Prob < t	0.9999

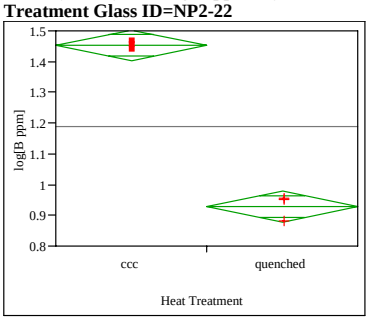
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-21



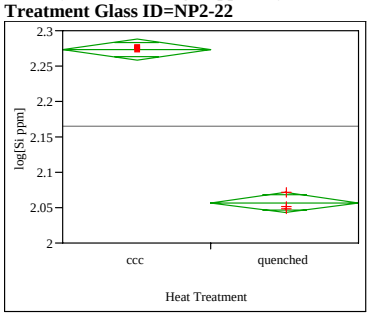
Difference	-0.29618	t Ratio	-62.5267
Std Err Dif	0.00474	DF	4
Upper CL Dif	-0.28303	Prob > |t|	<.0001
Lower CL Dif	-0.30933	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-22



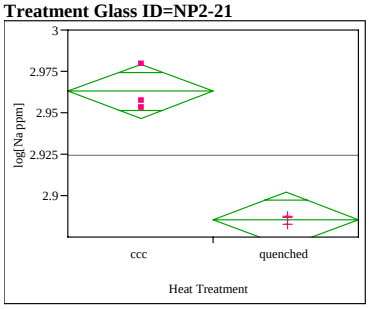
Difference	-0.52460	t Ratio	-21.0145
Std Err Dif	0.02496	DF	4
Upper CL Dif	-0.45529	Prob > |t|	<.0001
Lower CL Dif	-0.59391	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-22



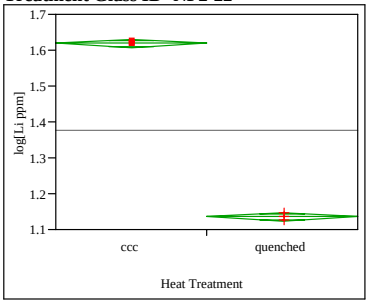
Difference	-0.21644	t Ratio	-28.9003
Std Err Dif	0.00749	DF	4
Upper CL Dif	-0.19565	Prob > |t|	<.0001
Lower CL Dif	-0.23723	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-21



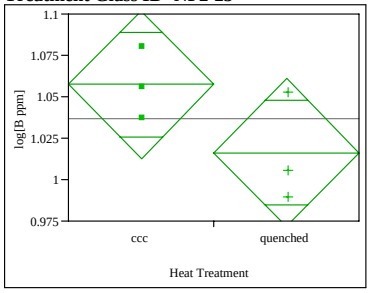
Difference	-0.07730	t Ratio	-9.19358
Std Err Dif	0.00841	DF	4
Upper CL Dif	-0.05395	Prob > |t|	0.0008
Lower CL Dif	-0.10064	Prob > t	0.9996
Confidence	0.95	Prob < t	0.0004

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-22



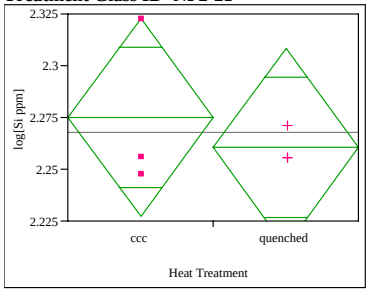
Difference	-0.48343	t Ratio	-80.2048
Std Err Dif	0.00603	DF	4
Upper CL Dif	-0.46670	Prob > |t|	<.0001
Lower CL Dif	-0.50017	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-23



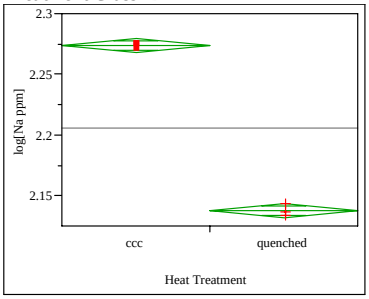
Difference	-0.04120	t Ratio	-1.81286
Std Err Dif	0.02273	DF	4
Upper CL Dif	0.02190	Prob > |t|	0.1441
Lower CL Dif	-0.10430	Prob > t	0.9280
Confidence	0.95	Prob < t	0.0720

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-21



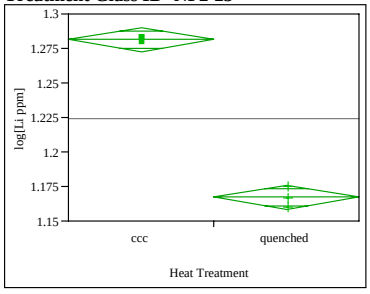
Difference	-0.01434	t Ratio	-0.58887
Std Err Dif	0.02436	DF	4
Upper CL Dif	0.05329	Prob > |t|	0.5876
Lower CL Dif	-0.08198	Prob > t	0.7062
Confidence	0.95	Prob < t	0.2938

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-22



Difference	-0.13588	t Ratio	-45.4551
Std Err Dif	0.00299	DF	4
Upper CL Dif	-0.12758	Prob > |t|	<.0001
Lower CL Dif	-0.14418	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

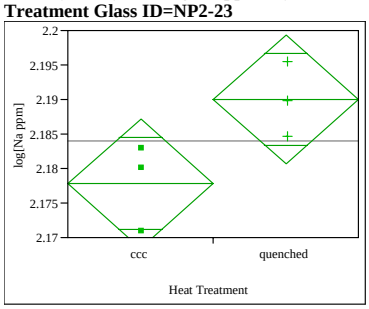
Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-23



Difference	-0.11401	t Ratio	-25.5135
Std Err Dif	0.00447	DF	4
Upper CL Dif	-0.10160	Prob > |t|	<.0001
Lower CL Dif	-0.12641	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

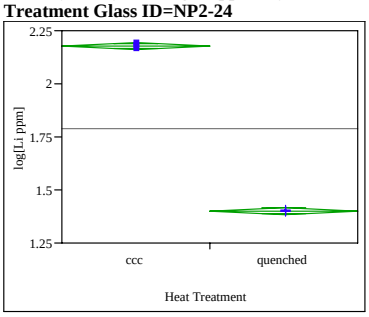
Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-23



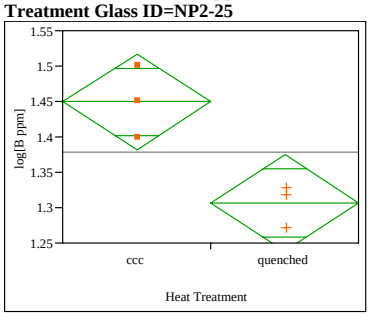
Difference	0.01217	t Ratio	2.547398
Std Err Dif	0.00478	DF	4
Upper CL Dif	0.02544	Prob > |t|	0.0635
Lower CL Dif	-0.00109	Prob > t	0.0317
Confidence	0.95	Prob < t	0.9683

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-24



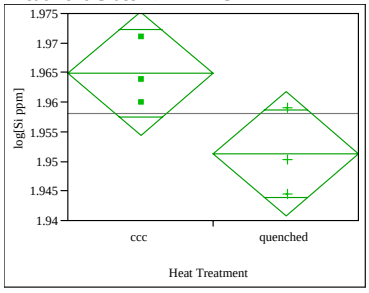
Difference	-0.77433	t Ratio	-91.3143
Std Err Dif	0.00848	DF	4
Upper CL Dif	-0.75078	Prob > |t|	<.0001
Lower CL Dif	-0.79787	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-25



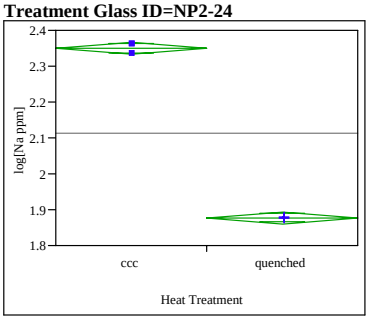
Difference	-0.14313	t Ratio	-4.1363
Std Err Dif	0.03460	DF	4
Upper CL Dif	-0.04706	Prob > |t|	0.0144
Lower CL Dif	-0.23921	Prob > t	0.9928
Confidence	0.95	Prob < t	0.0072

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-23



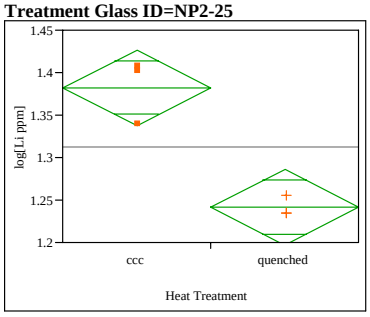
Difference	-0.01357	t Ratio	-2.55377
Std Err Dif	0.00531	DF	4
Upper CL Dif	0.00118	Prob > |t|	0.0631
Lower CL Dif	-0.02832	Prob > t	0.9685
Confidence	0.95	Prob < t	0.0315

Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-24



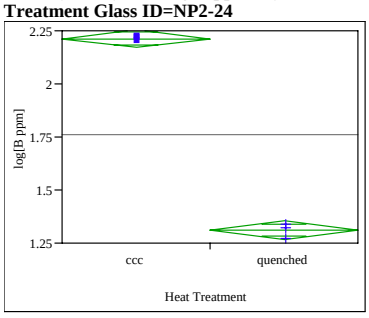
Difference	-0.47255	t Ratio	-53.9981
Std Err Dif	0.00875	DF	4
Upper CL Dif	-0.44826	Prob > |t|	<.0001
Lower CL Dif	-0.49685	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Li ppm] By Heat Treatment Glass ID=NP2-25



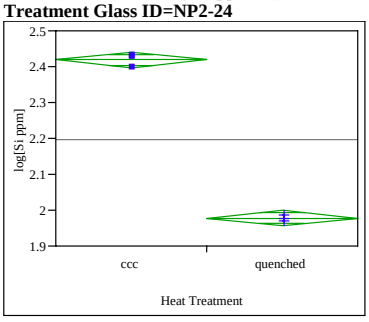
Difference	-0.14061	t Ratio	-6.20848
Std Err Dif	0.02265	DF	4
Upper CL Dif	-0.07773	Prob > |t|	0.0034
Lower CL Dif	-0.20350	Prob > t	0.9983
Confidence	0.95	Prob < t	0.0017

Oneway Analysis of log[B ppm] By Heat Treatment Glass ID=NP2-24



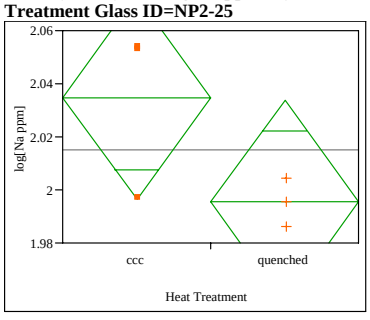
Difference	-0.90202	t Ratio	-41.86
Std Err Dif	0.02155	DF	4
Upper CL Dif	-0.84219	Prob > |t|	<.0001
Lower CL Dif	-0.96185	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-24



Difference	-0.44075	t Ratio	-38.5462
Std Err Dif	0.01143	DF	4
Upper CL Dif	-0.40901	Prob > |t|	<.0001
Lower CL Dif	-0.47250	Prob > t	1.0000
Confidence	0.95	Prob < t	<.0001

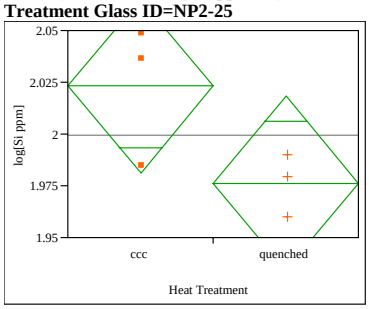
Oneway Analysis of log[Na ppm] By Heat Treatment Glass ID=NP2-25



Difference	-0.03930	t Ratio	-2.01573
Std Err Dif	0.01950	DF	4
Upper CL Dif	0.01483	Prob > |t|	0.1141
Lower CL Dif	-0.09344	Prob > t	0.9430
Confidence	0.95	Prob < t	0.0570

Exhibit B5. Effects of Heat Treatment on PCT log(ppm)-Response of Study Glasses. (continued)

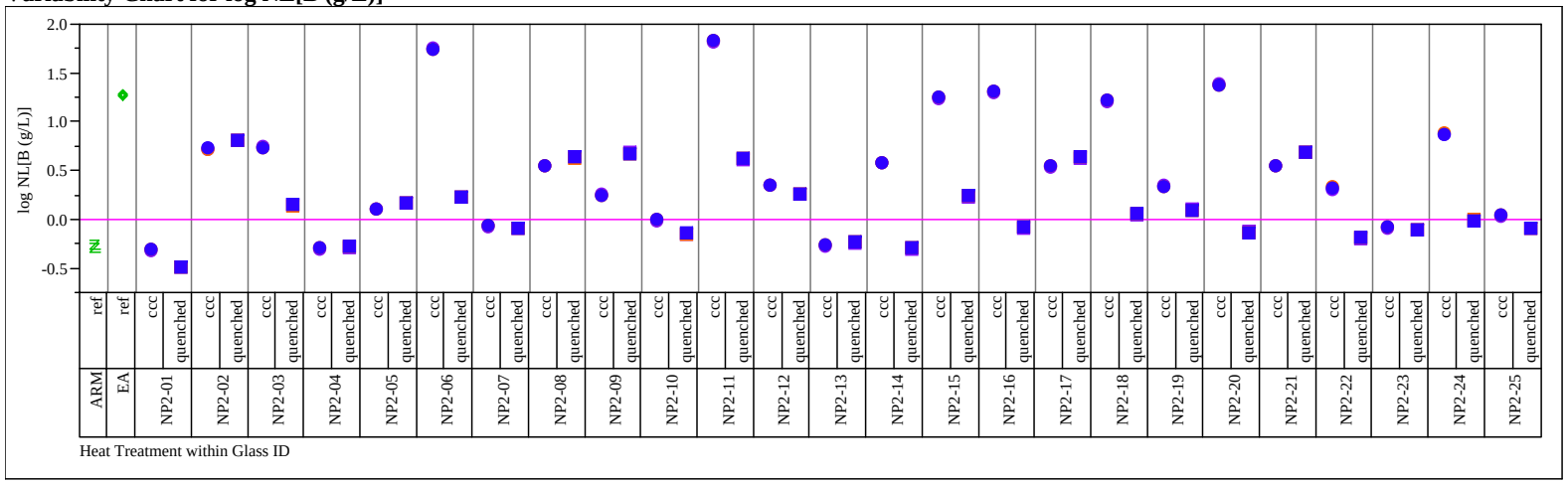
Oneway Analysis of log[Si ppm] By Heat Treatment Glass ID=NP2-25



Difference	-0.04679	t Ratio	-2.17916
Std Err Dif	0.02147	DF	4
Upper CL Dif	0.01282	Prob > |t|	0.0948
Lower CL Dif	-0.10640	Prob > t	0.9526
Confidence	0.95	Prob < t	0.0474

Exhibit B6. Effects of Heat Treatment for Study Glasses Over All Compositional Views.

Variability Chart for log NL[B (g/L)]



Variability Chart for log NL[Li (g/L)]

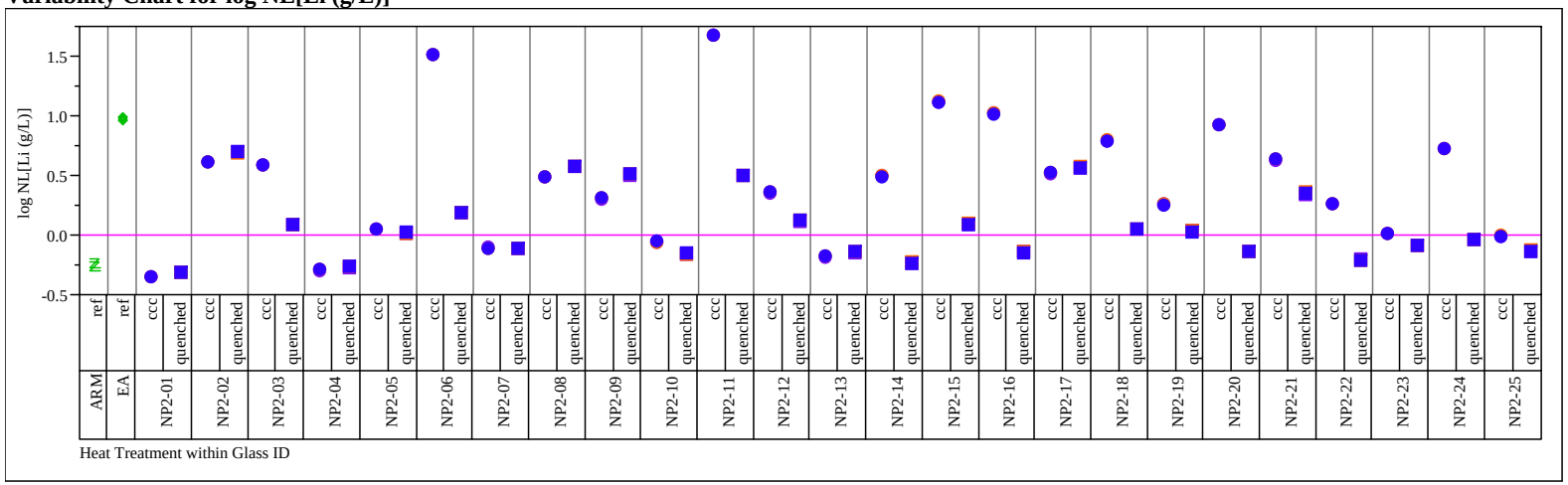
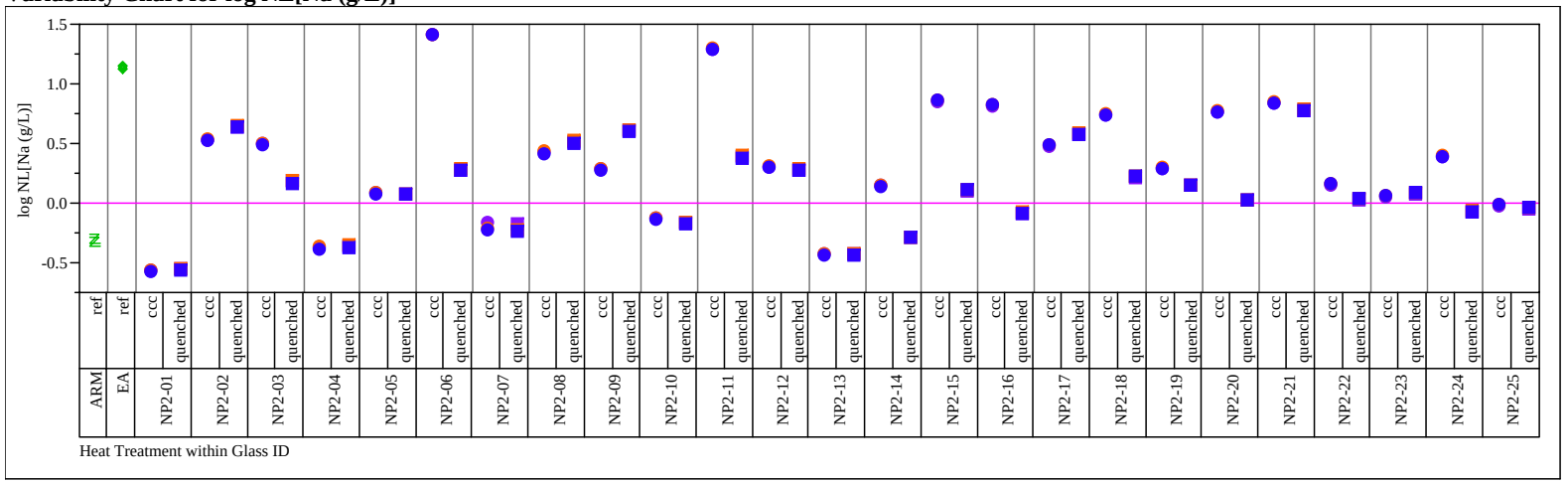
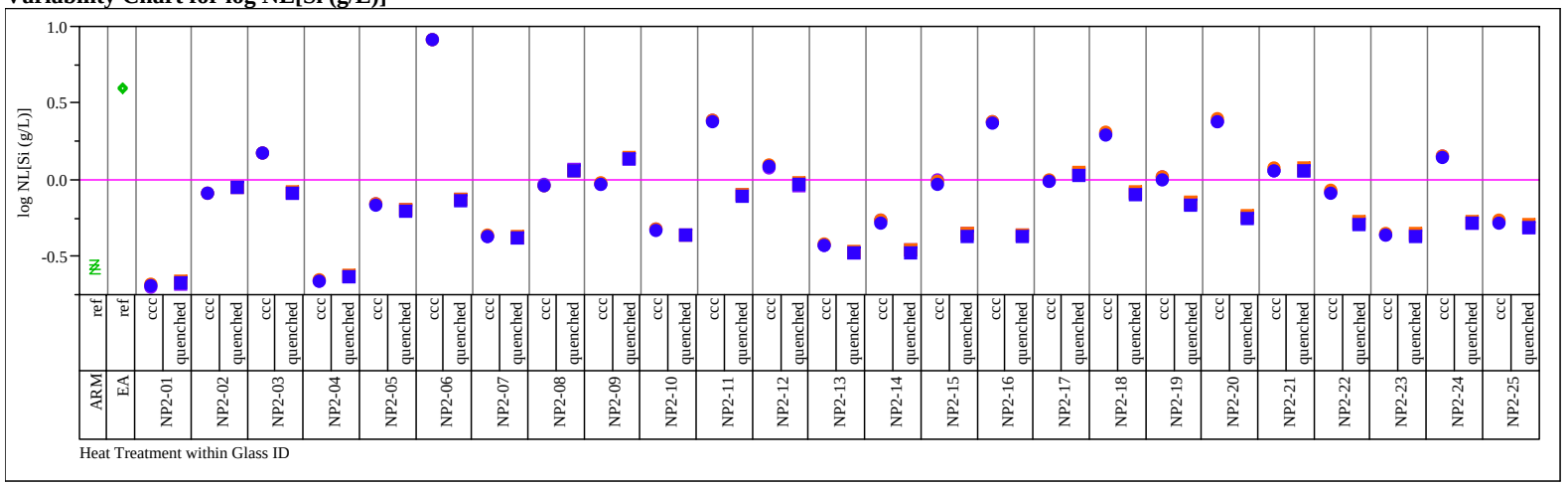


Exhibit B6. Effects of Heat Treatment for Study Glasses Over All Compositional Views. (continued)

Variability Chart for log NL[Na (g/L)]



Variability Chart for log NL[Si (g/L)]



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Distribution:

A.B. Barnes, 999-W
D.R. Best, 786-1A
N.E. Bibler, 773-A
A.L. Billings, 999-W
D.A. Crowley, 999-W
B.A. Davis, 704-27S
T.B. Edwards, 999-W
S.D. Fink, 773-A
K.M. Fox, 999-W
B.J. Giddings, 786-5A
J.M. Gillam, 766-H
J.C. Griffin, 773-A
B.A. Hamm, 766-H
C.C. Herman, 999-W
J.F. Iaukea, 704-30S
C.M. Jantzen, 773-A
T.M. Jones, 999-W
J.E. Marra, 773-A
R.T. McNew, 704-27S
D.H. Miller, 999-W
T.A. Nance, 773-42A
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