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# Chemical Composition Analysis and Product Consistency Tests Supporting Refinement of the Nepheline Model for the High Aluminum Hanford Glass Composition Region

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# EXECUTIVE SUMMARY

In this report, Savannah River National Laboratory provides chemical analyses and Product Consistency Test (PCT) results for a series of simulated high level waste (HLW) glasses fabricated by Pacific Northwest National Laboratory (PNNL) as part of an ongoing nepheline crystallization study. The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

The measured chemical composition data are reported and compared with the targeted values for each component for each glass. A detailed review showed no indications of errors in the preparation or measurement of the study glasses. All of the measured sums of oxides for the study glasses fell within the interval of 98 to 101 wt %, indicating recovery of all components. Comparisons of the targeted and measured chemical compositions showed that the measured values for the glasses met the targeted concentrations within 10% for those components present at more than 5 wt %.

Several of the study glasses exhibited unusual appearances during preparation for, or after performance of, the Product Consistency Tests (PCTs). In some cases this may be linked to low chemical durability. Future studies should include thorough analysis of the glasses after the PCTs to provide further information regarding glass behavior in durability testing.

A detailed review showed no issues with performance of the PCTs. The quenched versions of all of the study glasses have normalized boron concentration ($NC_B$) values that are lower than the Environmental Assessment (EA) benchmark $NC_B$ value of 16.695 g/L. Many of the study glasses have higher normalized concentration values after the canister centerline cooled (CCC) heat treatment. This is likely indicative of crystallization or phase separation. Sixteen of the study glasses have $NC_B$ values that are below that of the EA benchmark for the quenched versions, but greater than that of the EA benchmark glass after the CCC heat treatment. These results can be combined with additional characterization, including X-ray diffraction, to determine the cause of the higher release rates.

Duplicate PCT testing was completed for a small subset of the study glasses to test reproducibility. Although limited in scope, the results of the duplicate tests indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AD | Acid Dissolution |
| AR | As Received |
| ARM | Approved Reference Material |
| BDL | Below Detection Limit |
| CCC | Canister Centerline Cooled |
| DOE | U.S. Department of Energy |
| EA | Environmental Assessment benchmark glass |
| HLW | High Level Waste |
| ICP-OES | Inductively Coupled Plasma – Optical Emission Spectroscopy |
| JHCM | Joule-Heated Ceramic Melter |
| LAW | Low Activity Waste |
| LRM | Low-level Reference Material |
| $NC_i$ | Normalized Concentration of element "*i*" |
| ORP | U.S. Department of Energy – Office of River Protection |
| PCT | Product Consistency Test |
| PF | Peroxide Fusion |
| PNNL | Pacific Northwest National Laboratory |
| RSD | Relative Standard Deviation |
| SRNL | Savannah River National Laboratory |
| TTQAP | Task Technical and Quality Assurance Plan |
| wt % | Weight Percent |
| WTP | Hanford Waste Treatment and Immobilization Plant |

## 1.0 Introduction

The U.S. Department of Energy (DOE) Office of River Protection (ORP) is building the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site in Washington to remediate 55 million gallons of radioactive waste that is temporarily stored in 177 underground tanks. The low-activity waste (LAW) fraction will be partitioned from the high-level waste (HLW). Both the LAW and HLW will then be vitrified in borosilicate glass with Joule-heated ceramic melters (JHCM).

Efforts are being made to increase the loading of Hanford tank wastes in glass while maintaining the ability to meet processing, regulatory compliance, and product quality requirements. DOE-ORP has requested that SRNL support the advancement of glass formulations and process control strategies in key technical areas, as defined in the Task Technical and Quality Assurance Plan (TTQAP).[1] One of these areas is the development of advanced, predictive models for the crystallization of nepheline in glasses formulated at high alumina concentrations.

The performance of HLW glass is generally quantified by its resistance to chemical degradation, or durability. The durability of a HLW glass is dependent upon its composition and its crystalline content. If crystalline phases form within a glass during cooling, the composition of the residual glass network is altered, potentially affecting the durability of the glass. Crystallization of nepheline ($NaAlSiO_4$) has been shown to adversely impact the durability of HLW glasses since it removes glass forming species (in this case, Al and Si) from the glass network.[2] The propensity for nepheline crystallization in a HLW glass increases with increasing concentrations of $Al_2O_3$ and $Na_2O$ in the glass.[3] Nepheline crystallization is therefore of concern for processing of HLW at WTP since a significant fraction of Hanford tank wastes is rich in $Al_2O_3$ and $Na_2O$. The ability to correctly predict the formation of nepheline as a function of glass composition will allow WTP to maximize the loading of $Al_2O_3$ and $Na_2O$ in glass while maintaining acceptable durability.

In this report, SRNL provides chemical analyses and Product Consistency Test (PCT) results for a series of simulated HLW glasses fabricated by Pacific Northwest National Laboratory (PNNL) as part of an ongoing nepheline crystallization study.[4,5] The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

## 2.0 Experimental Procedure

### 2.1 <u>Glasses Selected for Study</u>

PNNL fabricated 31 glasses for the analyses described in this report. The identifiers for these glasses are given in Table 2-1. Rapidly cooled (quenched) and Canister Centerline Cooled (CCC) versions of each glass were provided. The quenched glasses were used for chemical analyses. Both the quenched and the CCC glasses were used for the PCTs.

**Table 2-1. Identifiers for PNNL Nepheline Glasses Characterized in this Study**

| Glass Identifier | | Glass Identifier |
|---|---|---|
| BL3 | | NP-MC-AlBNa-1 |
| Neph-NN-1-12 | | NP-MC-AlBNa-2 |
| NP2 - High Al | | NP-MC-AlBSi-1 |
| NP2 - High B | | NP-MC-AlLi-1 |
| NP2 - High Li | | NP-MC-AlLi-2 |
| NP2 - High Na | | NP-MC-AlLiNa-1 |
| NP2 - High Si | | NP-MC-AlLiSi-1 |
| NP2 - Low Al | | NP-MC-AlNa-1 |
| NP2 - Low B | | NP-MC-AlSi-1 |
| NP2 - Low Li | | NP-MC-AlSi-2 |
| NP2 - Low Na | | NP-MC-BLiSi-1 |
| NP2 - Low Si | | NP-MC-BLiSi-2 |
| NP2 - Very High Al | | NP-MC-BNa-1 |
| NP2 - Very High Si | | NP-MC-BNaSi-1 |
| NP2 - Very Low Si | | NP-MC-BSi-1 |
| NP-MC-AlB-1 | | |

In the sections that follow, the methods used for measuring chemical composition and PCT performance are described and statistical reviews of the resulting data are provided. Detailed data from these analyses are included as appendices.

## 2.2 Compositional Analysis

Chemical analysis was performed under the auspices of an analytical plan[6] on a representative sample from the quenched version of each of the study glasses to allow for comparisons with the targeted compositions and normalization of the PCT data. Two preparation techniques, sodium peroxide fusion (PF) and acid dissolution (AD), were used to prepare the glass samples, in duplicate, for analysis. The PF method was selected for measurement of the major components of the glasses since SRNL experience has shown it to be an effective method for complete dissolution of simulated HLW glass samples.[7-9] Measurement of the minor components using samples prepared with this method is difficult due to the high concentration of salts in the resulting solutions. A 10x dilution is required before analysis of the PF prepared solutions to avoid issues with extinguishing the plasma in the Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) instrument. This dilution results in higher detection limits. The AD method was used for those components that could not be measured via the PF preparation due to interferences or low (minor) concentrations. The PF method is described in an SRNL procedure,[10] and the AD method is described in an earlier report.[11]

The preparation methods used for each of the reported glass components are summarized in Table 2-2. Note that additional preparation methods for some of the glass components were requested in the analytical plan[6] due to the potential for crystalline phases to be present in the study glasses and uncertainty regarding the dissolution of those phases. In these cases, the analytical data from each method were reviewed in order to select the most appropriate method, and the selected methods are listed in Table 2-2.

Fluorine concentrations were not measured since this would have required the use of an additional preparation method. Targeted fluorine concentrations were also low (approximately

0.3 wt %), such that they were likely to be near or below analytical detection limits. After discussion with PNNL, it was determined that the effort needed to measure fluorine was not worthwhile.

Each of the prepared samples was analyzed, twice for each element of interest, by ICP-OES. A glass standard was also intermittently measured to assess the performance of the ICP-OES instrument over the course of these analyses. Specifically, several samples of the low-level reference material (LRM)[12] were included as part of the analytical plan.

**Table 2-2. Preparation Methods Used in Reporting the Concentrations of Each of the Components of the Study Glasses.**

| Component | Preparation Method |
|---|---|
| Al | PF |
| B | PF |
| Bi | AD |
| Ca | AD |
| Cr | PF |
| F | Not analyzed |
| Fe | PF |
| Li | PF |
| Mn | PF |
| Na | AD |
| Ni | AD |
| P | AD |
| Ru | AD |
| S | AD |
| Si | PF |
| Zr | AD |

2.3 Product Consistency Test

The PCT Method-A[13] was performed in triplicate on each of the quenched and CCC versions of the study glasses to assess chemical durability. Also included in the experimental test matrix was the Approved Reference Material (ARM) glass[14] and blanks from the vessel cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.[13] 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. The vessels were then removed from the oven and cooled to ambient temperature. Once cooled, a small aliquot was used to determine the ambient temperature pH of the leachate. The remaining solutions were sampled (filtered and acidified), then labeled and analyzed by ICP-OES under the auspices of a series of analytical plans.[15-17] Samples of a multi-element, standard solution[a] were also included in the analytical plans as a check on the accuracy of the ICP-OES instrument used for these measurements. Normalized concentrations were calculated based on the targeted (provided by PNNL) and measured compositions using the average of the common logarithms of the leachate concentrations.

[a] ICP multi-element custom solution, product number SM-744-013, High Purity Standards, Charleston, SC

*2.3.1 PCT Reproducibility Testing*

During the course of the PCTs for this study, it was noted that normalized concentration values for some of the glasses were unusually high. It was postulated that these responses may be the result of inhomogeneous glasses. The PCT was therefore repeated in entirety for three of the study glasses in order to test the reproducibility of the normalized concentration results. The glasses selected for the reproducibility study were the CCC versions of:

- NP-MC-AlBNa-1
- NP-MC-AlLi-2
- NP-MC-AlNa-1

These glasses spanned a range of normalized concentration values in the first PCT group. Normalized concentrations were measured and calculated again for each of these glasses in the second group of PCTs. The results are discussed with the rest of the PCT outcomes later in this report.

2.4 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2. Laboratory data for this study were recorded in the SRNL Electronic Laboratory Notebook system, experiment C3489-00079-09.

## 3.0 Results and Discussion

3.1 Review and Evaluation of Chemical Composition Measurements

Table A-1 in Appendix A provides the elemental concentration measurements in wt % from the study glasses that were prepared by the AD method. Table A-2 in Appendix A provides the elemental concentration measurements in wt % from these glasses as prepared by the PF method. Elemental measurements for samples of the LRM standard glass are also provided in the tables of Appendix A. These unprocessed data are provided as appendices to this report so that the values are readily available should they be of interest for future reviews.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements of the LRM standard glass are investigated, the measurements for each glass are reviewed, the average chemical composition for each glass is determined, and comparisons are made between the measurements and the targeted compositions for the glasses. JMP Pro Version 11.2.1 (SAS Institute, Inc.)[18] was used to support these analyses.

*3.1.1 Treatment of Detection Limits*

The elemental concentrations in Table A-1 and Table A-2 were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During the process of converting to oxide concentrations, an elemental concentration that was reported to be below the detection limit of the analytical process used was set to the detection limit as the oxide concentration was determined for the purposes of statistical review and calculating a sum of oxides for each glass. Those oxides with measured concentrations that were below the associated detection limit will be denoted with a less than symbol (<) as the measured compositions are reported.

*3.1.2 Measurements in Analytical Sequence*

Exhibit A-1 in Appendix A provides plots of the wt % measurements generated for prepared samples by oxide and analytical block. The plots are in analytical sequence within each calibration block 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 Table A-1 and Table A-2, with each plotted point identified by its Lab ID. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instrument within and among calibration blocks. A review of these plots identified a slight, upward shift in the measurements of the second sub-block within the first block of $Cr_2O_3$ measurements. There is also a slight, upward shift in the measurements of the second sub-block within the first block of MnO measurements. These shifts may be the result of minor differences in instrument calibrations. One of the four measurements of the $Li_2O$ concentration in glass NP-MC-BLiSi-2 (Lab ID W12) is lower than the other three. There do not appear to be any other gross patterns or trends in the analytical process over the course of these measurements.

*3.1.3 Composition Measurements by Glass Identifier*

Exhibit A-2 in Appendix A provides plots of the oxide concentration measurements by the PNNL Glass ID (including the LRM reference glass) by Lab ID grouped by targeted concentration. 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 for each glass. Plotting the data in this format provides an opportunity to review the values for each individual glass as a function of the duplicate preparations and duplicate measurements. A review of the plots presented in these exhibits reveals the repeatability of the four individual values for each oxide for each glass and leads to the following observations:

- The measured $Bi_2O_3$ concentrations of the study glasses are generally low by about 10%, although the targeted concentrations of this oxide are less than 1 wt %.
- The measured CaO concentrations of the study glasses are generally lower than the targeted values, although the targeted concentrations of this oxide are less than 1 wt %.
- One of the measured values for $Li_2O$ in glass NP-MC-BLiSi-2 is low relative to the other three.
- The measured $Na_2O$ values appeared to be biased somewhat high.
- Measurements of $RuO_2$ were all below detection limits for the study glasses.
- Measurements of $SO_3$ in the LRM glass are below the consensus average value of 0.3 wt % reported in the reference document,[12] but are close to the batch target of 0.2 wt % for this glass. Measurements of $SO_3$ for the study glasses vary somewhat from the targeted values, depending on the individual glass composition.
- Measurements of $ZrO_2$ in glass NP2-High Na are consistently above the targeted value by about a factor of two. This component may have been inadvertently double batched in this glass.

None of the observations noted above from Exhibit A-2 indicated an error in preparation or measurement that had to be addressed in treatment of the data. Therefore, the entire set of measurement data was used in determining representative, measured compositions for all of the oxides for the study glasses.

*3.1.4 Results for the LRM Standard*

Exhibit A-3 in Appendix A provides a review of the LRM results against acceptability limits utilized by SRNL. The review is in the form of plots of the measurements arranged by preparation method and element, framed by upper and lower acceptability limits for the concentration of the element in question. The results show that all of the measurements for the elements present in the LRM standard glass were within the acceptability limits utilized by SRNL in conducting instrument and procedure assessments during the execution of these measurements. Note that as observed in the previous section, sodium measurements were elevated but were within acceptability limits.

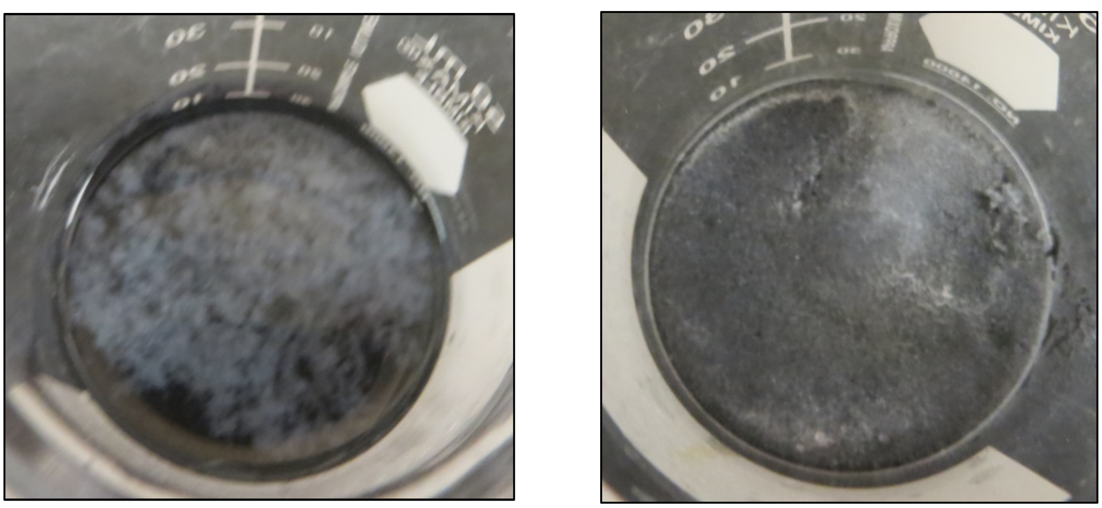
### *3.1.5 Measured versus Targeted Compositions*

From the discussion of Section 3.1.3, all of the measurements for each oxide for each glass (i.e., all of the measurements in Appendix A, Table A-1 and Table A-2), were averaged to determine a representative chemical composition for each glass. A sum of oxides was also computed for each glass based upon the measured values. Exhibit A-4 in Appendix A provides a graphical representation of the results for each glass for each oxide to allow PNNL to draw comparisons between the measured and targeted values.

Table A-3 in Appendix A provides a summary of the average compositions as well as the targeted compositions and some associated differences and relative differences. All of the measured sums of oxides for the study glasses fall within the interval of 98 to 101 wt %, indicating recovery of all components. Entries in Table A-3 show the relative differences between the measured values and the targeted values for the oxides with targeted values above 5 wt %. The relative differences are typically shaded if they are 10% or more.[a] The measurements of the glasses in this study all exceeded these criteria, thus there are no shaded values found in Table A-3.

## 3.2 Review and Evaluation of PCT Measurements

Unusual appearances were noted for some of the study glasses during performance of the PCTs. The CCC versions of glasses NP-MC-AlLiNa-1 and NP-MC-BNaSi-1 expressed a whitish material during the washing steps after grinding the glass for the PCT. Washing consisted of several ASTM Type I water washes, followed by several absolute ethanol washes per procedure. Photos of this material are shown in Figure 3-1. The material persisted until the final alcohol wash.



(a) (b)

**Figure 3-1. Photos of whitish material expressed from the CCC versions of glasses NP-MC-AlLiNa-1 (a) and NP-MC-BNaSi-1 (b) during washing for the PCT.**

[a] These criteria were selected arbitrarily for the purpose of highlighting differences from targeted concentrations that may be of practical concern.

Samples of the glasses shown in Figure 3-1 were collected and prepared for chemical composition analysis to identify changes to the glass composition that may have occurred during washing for the PCT. A sample of each glass was prepared once using the PF and AD methods described in Section 2.2. Each of the prepared samples was analyzed, twice for each element of interest, by ICP-OES. The average of the two values for each element was calculated, and the results are given in Table 3-1. Included in the table are the measured composition data for the quenched versions of these glasses, as described in Section 3.1 and reported in Table A-3 of Appendix A. The differences between the measured values for the quenched glasses and the measured values for the CCC versions of the glasses after washing for the PCT are also reported in the table. A review of these data shows that some changes occurred, either as a function of the CCC heat treatment, washing of the glass for the PCT, or both. Of most significance is the ~10% reduction in $B_2O_3$ concentration for these glasses after the CCC heat treatment and preparation for the PCT. The concentrations of $Li_2O$ and MnO are also reduced in these glasses after the CCC heat treatment and preparation for the PCT. The reduction in the concentrations of $B_2O_3$, $P_2O_5$, and $SO_3$ may be due in part to volatilization during the CCC heat treatment.

**Table 3-1. Measured Compositions of Two of the Study Glasses Before and After the CCC Heat Treatment and PCT Preparation**

| Oxide | NP-MC-BNaSi-1 (Quenched) | NP-MC-BNaSi-1 (CCC, After Washing for PCT) | Difference | | NP-MC-AlLiNa-1 (Quenched) | NP-MC-AlLiNa-1 (CCC, After Washing for PCT) | Difference |
|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 30.66 | 30.38 | -0.90% | | 30.94 | 29.55 | -4.49% |
| $B_2O_3$ | 14.21 | 12.80 | -9.89% | | 15.15 | 13.71 | -9.53% |
| $Bi_2O_3$ | 0.65 | 0.59 | -10.27% | | 0.52 | 0.47 | -8.89% |
| CaO | 0.66 | 0.70 | 5.63% | | 0.53 | 0.58 | 9.83% |
| $Cr_2O_3$ | 1.17 | 1.14 | -2.60% | | 0.88 | 0.95 | 7.61% |
| $Fe_2O_3$ | 2.72 | 2.44 | -10.36% | | 2.18 | 3.08 | 40.85% |
| $Li_2O$ | 5.31 | 5.00 | -5.83% | | 5.70 | 4.70 | -17.62% |
| MnO | 1.07 | 0.68 | -36.15% | | 0.82 | 0.55 | -32.86% |
| $Na_2O$ | 16.48 | 16.70 | 1.35% | | 15.70 | 16.44 | 4.68% |
| $P_2O_5$ | 0.71 | 0.66 | -6.15% | | 0.58 | 0.52 | -10.74% |
| $SO_3$ | 0.27 | 0.23 | -13.32% | | 0.24 | 0.20 | -16.31% |
| $SiO_2$ | 26.37 | 27.07 | 2.67% | | 26.47 | 26.39 | -0.32% |
| $ZrO_2$ | 0.26 | 0.27 | 5.24% | | 0.21 | 0.20 | -3.91% |

The technicians performing the PCTs noted that the leachates for glass NP2-Low-Si-CCC were difficult to pass through the syringe filter.

Although the scope of this study did not include any detailed observation or analysis of the leached glasses per Section 24.4.17 of the PCT ( °C), some observations of the leached glasses are discussed below. Most of the study glasses appeared uniform in color before and after the PCT. For example, a photo of ground NP2-Very-High-Si-CCC glass inside a PCT vessel after the test is shown in Figure 3-2. The photo in Figure 3-2 is generated after several steps following the PCT-A. These include removal of the sealed PCT vessels from the oven, cooling to ambient temperature, weighing and opening of the vessels, and removal of the leachate from the vessel. These steps leave the leached glass powder and some residual or interstitial leachate behind in the vessel. These 'damp' leached powders are then typically dried in an oven to render dried, leached glass powders that can be discarded. This process can produce visible solids on the leached glass powders.

Some of the study glasses had unusual appearances after the PCT was completed and the leached glasses containing various amounts of residual/interstitial amounts of leachate were dried in the vessels. The CCC versions of glasses NP-MC-AlB-1 and NP-MC-BLiSi-2 both had layers of whitish material on top of the ground glass. The layer could be broken to observe its thickness by gently tapping the PCT vessel, as shown in Figure 3-3.

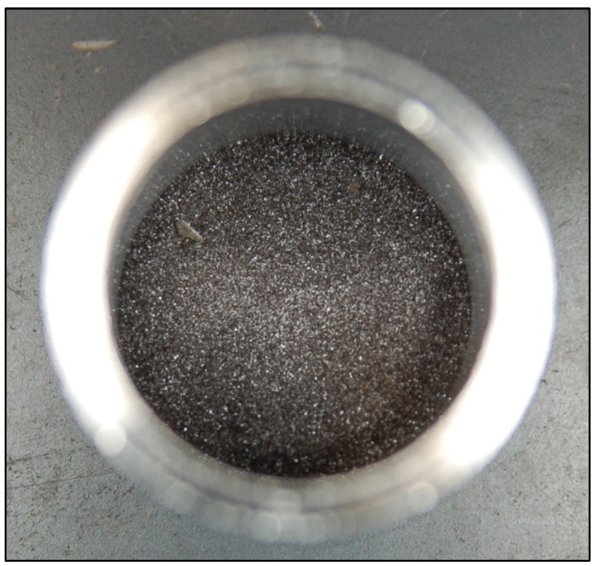
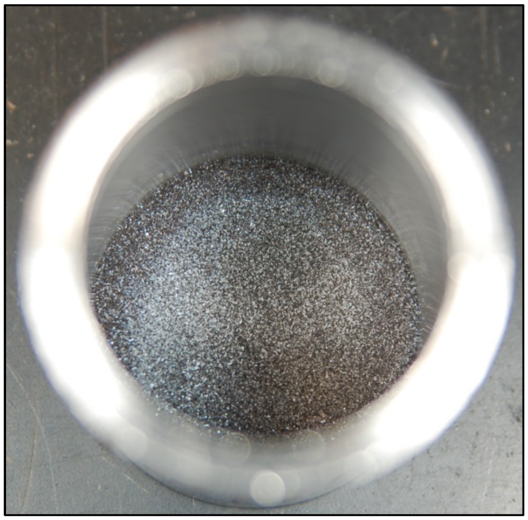
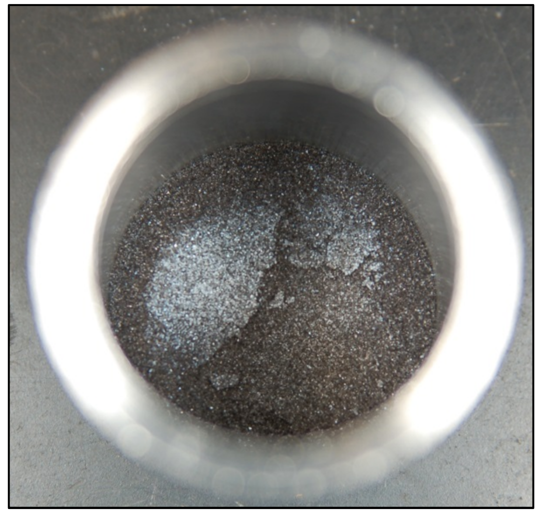


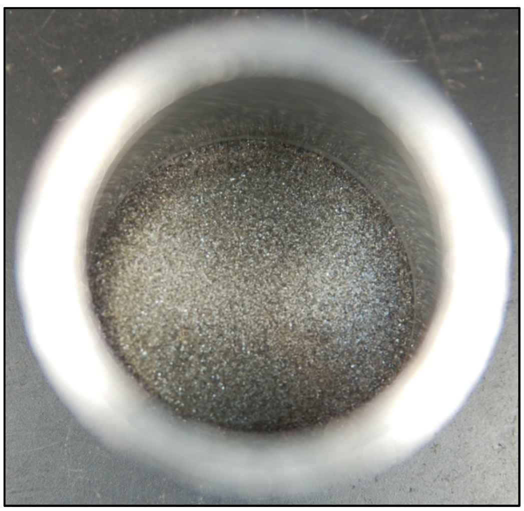
**Figure 3-2. Example of typical, uniform glass appearance after PCT.**



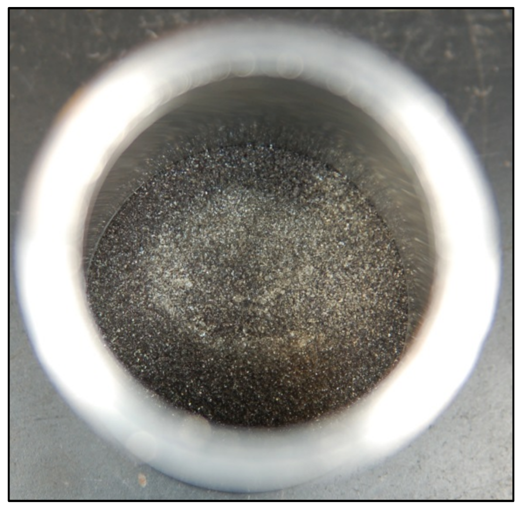
**(NP-MC-AlB-1-CCC)**



**(NP-MC-AlB-1-CCC, disturbed)**



**(NP-MC-BLiSi-2-CCC)**



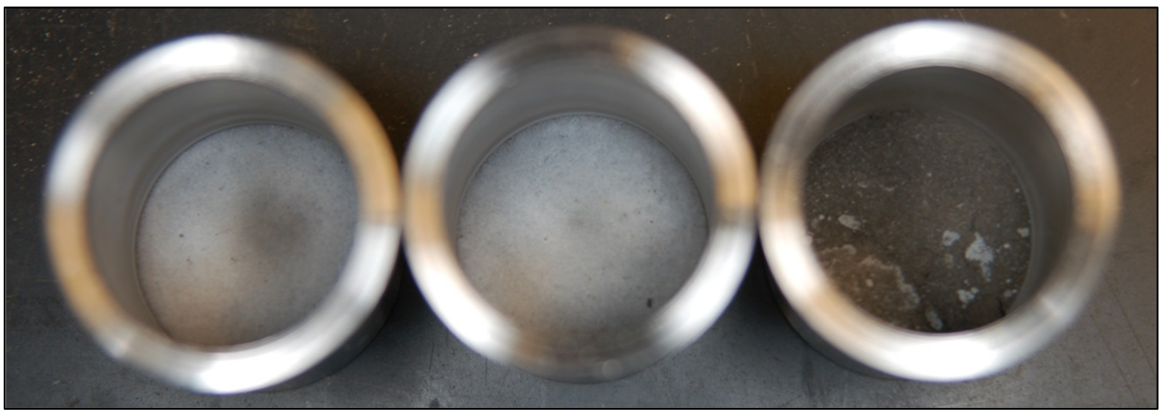
**(NP-MC-BLiSi-2-CCC, disturbed)**

**Figure 3-3. Photos of the CCC versions of glasses NP-MC-AlB-1 and NP-MC-BLiSi-2 after the PCT, showing whitish layer that could be broken by tapping the vessel.**

The CCC version of glass NP-MC-AlBNa-1 left a dark coating on the inner surface of each of the triplicate PCT vessels, as shown in Figure 3-4. The CCC versions of glasses NP-MC-AlLi-2 and NP-MC-AlNa-1 had relatively thick, whitish coatings on top of the ground glass after the PCT as shown in Figure 3-5. Each of the three replicate PCT vessels is shown in these photos, with the third vessel having been gently tapped to disturb the layer such that its thickness is visible. These observations will be discussed further in this report as normalized PCT data are presented and reviewed.

**Figure 3-4. Photos of a PCT vessel for the CCC version of glass NP-MC-AlBNa-1 (left), showing dark coating left on the vessel after the test. A clean vessel is shown for comparison (right).**

**(NP-MC-AlLi-2-CCC)**



**(NP-MC-AlNa-1-CCC)**

**Figure 3-5. Photos of the CCC versions of glasses NP-MC-AlLi-2 and NP-MC-AlNa-1 after the PCT showing thick, whitish layer on top of the ground glass.**

Table B-1 in Appendix B provides the elemental leachate concentration measurements for the solution samples generated by the PCTs for the study glasses and standards. The values for these measurements are given in the table as-received ("ar") from the laboratory analyses and after adjustments for the dilution factors. The measurements for the study glasses, blanks, and the ARM glass were multiplied by 1.6667 to determine the values in mg/L.

Based on the masses of the PCT vessels before and after the 7-day procedures, there were no samples that had water-loss issues. The ratio of leachant volume to the mass of ground glass was confirmed to be correct for each vessel. The measured concentrations of B, Li, Na, and Si in the leachates from the ARM glasses were compared to the control charts to demonstrate proper performance of the PCTs.[14] Two of the triplicate B values from the Group 1, Set 1 PCTs, three of the triplicate B values from the Group 1, Set 2 PCTs, and one of the triplicate B values from the Group 3, Set 1 PCTs fell outside the limits of the control chart. All of the measured Li, Na, and Si concentrations in the ARM glass leachates fell within the limits of the control charts. The expectation is that an error in the performance of a PCT would result in a consistent divergence of the concentrations of the analytes of the ARM glass away from the limits of the control charts. Since there were no consistent issues with the ARM values for any of the five sets of PCTs, the tests were considered to have been performed properly and no bias correction was performed.[a] The measured, ambient temperature pH values for each of the PCT leachates are provided in Table B-2 through Table B-6 of Appendix B for reference.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements for each glass are reviewed, the measurements of the multi-element solution standard are investigated, the normalized PCT results for each glass are determined, and comparisons are made between the PCT results for the two heat treatments of each glass. JMP Pro Version 11.2.1 (SAS Institute, Inc.)[18] was used to support these analyses.

### *3.2.1 Treatment of Detection Limits*

Some of the "ar" measurements (Table B-1 in Appendix B) were below the detection limit of 1 mg/L (prior to correction for dilution). These measurements (indicated by a "<" symbol in Table B-1) were replaced by their detection limits in subsequent analyses for the purposes of statistical review and calculating normalized leachate values. Those elements with measured concentrations that were below the associated detection limit will be denoted with a less than symbol (<) as the normalized leachate values are reported.

### *3.2.2 Results for the Samples of the Multi-Element Solution Standard*

Table B-7 through Table B-9 of Appendix B provide a review of the measurements of the solution standard samples that were included in the analytical blocks for the PCT analyses. For each analytical block, the mean, standard deviation, and percent relative standard deviation (%RSD) are determined for each element present in the standard. Following the guidance in ASTM C 1285 (PCT), there were two primary evaluations conducted for these summary statistics: the mean value for each analytical block was found to be less than 10% from the reference value (i.e., a percent relative bias less than 10%) for the element in question, and the %RSD was less than 10% for the element in question. The results in Table B-7 through Table B-9 of Appendix B satisfy these criteria, and thus, the results for the standard suggest no significant issues with the analytical outcomes for the measurements of the PCT solutions.

### *3.2.3 Measurements in Analytical Sequence*

Exhibit B-1 in Appendix B provides plots of the common logarithms of the leachate concentrations (mg/L) in analytical sequence by analytical block by analytical set. Each of the analytical sets corresponds to an oven run that was used to conduct the PCT measurements needed to support the analyses of the nepheline study glasses. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instrument within and among calibration blocks. A review of these plots identified an outlying silicon measurement for one of the replicates (lab identifier M29) of glass NP2-Low-Si-Q in PCT Group 3, Set 1. This measurement was about an order of magnitude lower than those for the other two replicates, and therefore it was excluded from the normalized concentration calculations. No other issues were observed in these plots.

### *3.2.4 Measurements by Glass Identifier*

Exhibit B-2 in Appendix B provides plots of the leachate concentrations for both the quenched and CCC version of each of the study glasses and for the standards for each analytical set. These plots are in common logarithms of the mg/L values and allow for the assessment of the repeatability of the measurements and any differences between the quenched and CCC version of a given glass. For some of the glasses, minor scatter among the triplicate values of some analytes

[a] Data are provided in Appendix B to support bias correction per ASTM C 1285, Section 25.2 if desired.

is observed. The outlier in the silicon measurements for one of the replicates of glass NP2-Low-Si-Q is again visible in these plots. In addition, there are differences in the PCT responses between the quenched and CCC versions of some of the study glasses. A closer look at the quenched and CCC outcomes is provided in the following sections.

### *3.2.5 Normalization of the PCT Results*

The PCT leachate data were used to determine normalized concentrations for each element of interest using both the targeted and measured compositions of the glasses following the expression given in ASTM C1285:

$$NC_i = \frac{c_i\left(sample\right)}{f_i}$$

where $NC_i$ is the normalized concentration in units of $g_{\text{waste form}}/L_{\text{leachant}}$, $c_i$ is the concentration of element "*i*" in the leachate in units of $g_i$/L, and $f_i$ is the mass fraction of element "*i*" in the unleached glass in units of $g_i/g_{\text{glass}}$.[a]

An equation was developed to allow for calculation of the $NC_i$ values using the units of measurement provided with the analytical results for this study, and to accommodate the triplicate leachate measurements for each of the study glasses. Note that the symbols in this second equation were kept consistent with those used in ASTM C1285, but the units of measurement differ. The common logarithm of the normalized concentration for each element "*i*" ($NC_i$) for each of the study glasses was determined using the equation:

$$\log_{10}\left(NC_i\right) = \overline{\log_{10} c_i} - \left[1 + \log_{10} f_i\right]$$

where $NC_i$ remains in units of $g_{\text{waste form}}/L_{\text{leachant}}$, $\overline{\log_{10} c_i}$ is the average of the common logarithms of the measured concentrations of element "*i*" in the triplicate leachates in units of mg/L, and $\log_{10} f_i$ is either the common logarithm of the targeted concentration of element "*i*" in the glass in units of wt %, or the common logarithm of the average measured concentration of element "*i*" in the glass in units of wt % (from Table A-3 of Appendix A). The calculated $NC_i$ values are discussed further in the following sections.

### *3.2.6 PCT Reproducibility Testing*

The PCT was repeated in its entirety for three of the study glasses in order to test reproducibility over a range of normalized concentration values. The results of the duplicate testing are shown in Table 3-2. The results for the ARM-1 glass are included for comparison, since samples of this reference glass were included in each of the five PCT groups and sets that composed this study. Each of the $NC_i$ (g/L) values shown in Table 3-2 is the average of a triplicate data set.

[a] Note that the waste forms in this study were assumed to be of similar density. The PCT-A reference volume of leachant to sample mass ratio was used, and the 100 to 200 mesh reference particle size was used. Thus, no adjustment for the density of the glasses was made in normalizing the PCT results. Data provided in the appendices of this report allow for the calculation of normalized elemental mass loss ($NL_i$) if glass densities are measured at a later date.

**Table 3-2. Results of PCT Reproducibility Testing**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 1/1 | ARM-1 | ref | ref | 0.443 | 0.559 | 0.461 | 0.259 |
| 1/2 | ARM-1 | ref | ref | 0.965 | 0.612 | 0.527 | 0.306 |
| 2/1 | ARM-1 | ref | ref | 0.476 | 0.573 | 0.493 | 0.257 |
| 3/1 | ARM-1 | ref | ref | 0.582 | 0.603 | 0.525 | 0.277 |
| 3/2 | ARM-1 | ref | ref | 0.523 | 0.597 | 0.507 | 0.277 |
| 1/2 | NP-MC-AlBNa-1 | CCC | measured | 1.384 | 1.158 | 0.623 | 0.627 |
| 2/1 | NP-MC-AlBNa-1 | CCC | measured | 1.026 | 1.054 | 0.597 | 0.539 |
| 1/2 | NP-MC-AlLi-2 | CCC | measured | 21.207 | 12.955 | 6.547 | 0.199 |
| 2/1 | NP-MC-AlLi-2 | CCC | measured | 21.514 | 13.113 | 6.624 | 0.194 |
| 1/2 | NP-MC-AlNa-1 | CCC | measured | 95.382 | 75.916 | 18.092 | 0.120 |
| 2/1 | NP-MC-AlNa-1 | CCC | measured | 95.576 | 78.893 | 18.714 | 0.117 |

A review of the data in Table 3-2 shows that the PCT responses for the three study glasses were consistent between the duplicate tests. The variation in the normalized concentration values is consistent with the variation seen in the responses for the ARM-1 glass. Although limited in scope, these results indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

### *3.2.7 Effects of Heat Treatments*

Exhibit B-3 in Appendix B provides plots of the normalized PCT responses for the two heat treatments for each of the study glasses as well as the responses for ARM-1. The results are grouped by compositional view. Note that an indicator is provided as part of these plots to show results involving below detection limit (bdl) values; however, all of the PCT results for the study glasses were above detection limits.

The plots of Exhibit B-3 provide a graphical comparison between the PCT responses for the two heat treatments of each study glass. Table 3-3 provides a listing of the normalized PCT responses in g/L. Values for the duplicate PCTs of the CCC versions of glasses NP-MC-AlBNa-1, NP-MC-AlLi-2, and NP-MC-AlNa-1 are included in the exhibit and table.

A review of the PCT data resulted in several observations:

- The use of either the targeted or measured compositions in calculating the normalized concentration values has little if any practical effect.
- The quenched versions of all of the study glasses have $NC_B$ values that are lower than the EA benchmark $NC_B$ value of 16.695 g/L.[19]
- Many of the study glasses have higher normalized concentration values after the CCC heat treatment. Note however that this is often not the case for Si; $NC_{Si}$ values tend to decrease after the CCC heat treatment.
- Five of the study glasses have normalized concentration values that are relatively unaffected by heat treatment and that are lower than the EA benchmark value for $NC_B$. These glasses are NP2-High-B, NP2-Very-High-Si, NP-MC-AlB-1, NP-MC-AlBNa-1, and NP-MC-BSi-1.
- Ten of the study glasses have more significant increases in normalized concentration values after the CCC heat treatment, although their $NC_B$ values after the CCC heat treatment remained below that of the EA benchmark glass. These glasses are NP2-Low-

Al, NP2-Low-Li, NP2-Low-Na, NP2-Low-Si, NP-MC-AlBNa-2, NP-MC-AlBSi-1, NP-MC-AlLi-1, NP-MC-AlLiSi-1, NP-MC-AlSi-2, and NP-MC-BLiSi-2.

- The remaining 16 glasses in the study have $NC_B$ values that are below that of the EA benchmark for the quenched versions, but after the CCC heat treatment, the $NC_B$ values for these glasses are greater than that of the EA benchmark glass. In some cases the $NC_B$ values are quite high, e.g., 95.58 g/L for the CCC version of glass NP-MC-AlNa-1. A value of this magnitude represents leaching of almost all of the boron from the glass (an $NC_i$ value of 100 g/L is equivalent to complete leaching).

The PCT results appear to be somewhat related to the observations that were noted earlier in Section 3.2, although they are not uniform or consistent. It is important to note that the observations of the dried glass powders are likely confounded by the presence of compounds remaining after evaporation of the leachate. The presence of a whitish material after washing the CCC versions of glasses NP-MC-AlLiNa-1 and NP-MC-BNaSi-1 for the PCT (see Figure 3-1), may be linked to the poor durability and high $NC_B$ values for these glasses (75.57 and 73.26 g/L, respectively, based on the measured compositions). Note also that the reduction in $B_2O_3$ concentration measured in these glasses after preparation for the PCT (see Section 3.2) means that the actual $NC_B$ values for these glasses are greater than reported since the measured compositions of the quenched glasses were used for normalizing the PCT data. The leachates that were difficult to filter, from the CCC version of glass NP2-Low-Si, led to an $NC_B$ value of 9.85 g/L, which is relatively low as compared to the other glasses in this study.

The glasses that exhibited a thin white layer after the PCT (including removal of the leachate and drying of the damp, leached glass powders), which were the CCC versions of glasses NP-MC-AlB-1 and NP-MC-BLiSi-2 (Figure 3-3), had relatively low $NC_B$ values of 4.01 and 6.63 g/L, respectively. Glass NP-MC-AlBNa-1, which left a dark coating on the inside of the PCT vessels (Figure 3-4), had a low $NC_B$ value of 1.03 g/L. Neither of these behaviors appears to have contributed to unusually poor durability.

The glasses that exhibited a thick white layer after the PCT (including removal of the leachate and drying of the damp, leached glass powders), which were the CCC versions of glasses NP-MC-AlLi-2 and NP-MC-AlNa-1 (Figure 3-5), had relatively high $NC_B$ values of 21.21 and 95.38 g/L, respectively. It appears that the thick white layer was indicative of poor leaching behavior. Future studies of the glasses after the PCT, if of interest, should include preparation of the leached glass per the ASTM procedure.

As noted earlier, the $NC_{Si}$ values for the study glasses were generally low, and in most cases were reduced for the CCC versions of the glasses where the other $NC_i$ values generally increased. Exhibit B-4 and Exhibit B-5 in Appendix B provide correlation factors and graphical representations of congruency among the $NC_i$ values (normalized using the measured compositions) for the quenched and CCC glasses, respectively. In both cases, the $NC_B$, $NC_{Li}$, and $NC_{Na}$ values are well correlated, but the $NC_{Si}$ values are inversely related to the others. This is unusual in that several earlier studies of nepheline crystallization in simulated HLW glasses showed generally good correlation of $NC_{Si}$ values with those of other elements of interest.[20-24] In addition, note that Section 26.1 of the ASTM PCT procedure[13] states that the elements best representing the extent of dissolution of the glass waste form are the most important.[a] Thus,

[a] "The most important elements to be analyzed in the leachate are those that best represent the extent of dissolution of the glass waste form. For example, elements that are not sequestered in alteration phases that participate in surface alteration reactions, and are also not solubility limited, are good indicators of glass waste form durability."[13]

boron is likely a better element to correlate the extent of glass dissolution in this study compared to either Na or Si, which could be sequestered in alteration phases such as zeolites or sodium aluminosilicates.

It is recommended that a more complete review of the influence of composition and heat treatment on the PCT responses of the glasses described in this report be performed in order to draw further conclusions. In particular, the cause of the inverse correlation in silicon dissolution should be investigated. Treatment of the leached glasses per the PCT procedure and additional characterization, such as examination by optical or scanning electron microscopy, and X-ray diffraction analysis to identify possible crystalline phases, would be beneficial for further interpretation of the PCT results.

**Table 3-3. Normalized PCT Results**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 3/1 | ARM-1 | ref | ref | 0.582 | 0.603 | 0.525 | 0.277 |
| 3/2 | ARM-1 | ref | ref | 0.523 | 0.597 | 0.507 | 0.277 |
| 2/1 | ARM-1 | ref | ref | 0.476 | 0.573 | 0.493 | 0.257 |
| 1/1 | ARM-1 | ref | ref | 0.443 | 0.559 | 0.461 | 0.259 |
| 1/2 | ARM-1 | ref | ref | 0.965 | 0.612 | 0.527 | 0.306 |
| 1/1 | BL3 | CCC | measured | 23.703 | 13.936 | 7.324 | 0.158 |
| 1/1 | BL3 | CCC | targeted | 22.974 | 13.396 | 7.735 | 0.159 |
| 3/1 | BL3 | quenched | measured | 1.888 | 1.848 | 1.095 | 0.502 |
| 3/1 | BL3 | quenched | targeted | 1.830 | 1.777 | 1.156 | 0.505 |
| 1/1 | Neph-NN-1-12 | CCC | measured | 83.722 | 66.472 | 15.095 | 0.087 |
| 1/1 | Neph-NN-1-12 | CCC | targeted | 83.965 | 64.550 | 16.176 | 0.087 |
| 3/1 | Neph-NN-1-12 | quenched | measured | 2.532 | 2.196 | 1.617 | 0.495 |
| 3/1 | Neph-NN-1-12 | quenched | targeted | 2.539 | 2.133 | 1.732 | 0.498 |
| 1/1 | NP2-High-Al | CCC | measured | 17.576 | 9.055 | 6.628 | 0.157 |
| 1/1 | NP2-High-Al | CCC | targeted | 17.574 | 8.689 | 7.051 | 0.159 |
| 3/1 | NP2-High-Al | quenched | measured | 1.984 | 2.034 | 1.151 | 0.428 |
| 3/1 | NP2-High-Al | quenched | targeted | 1.984 | 1.952 | 1.224 | 0.434 |
| 1/1 | NP2-High-B | CCC | measured | 4.288 | 3.651 | 2.296 | 0.387 |
| 1/1 | NP2-High-B | CCC | targeted | 4.147 | 3.651 | 2.403 | 0.391 |
| 3/1 | NP2-High-B | quenched | measured | 3.632 | 3.385 | 2.174 | 0.365 |
| 3/1 | NP2-High-B | quenched | targeted | 3.512 | 3.385 | 2.276 | 0.369 |
| 1/1 | NP2-High-Li | CCC | measured | 70.430 | 52.412 | 13.162 | 0.086 |
| 1/1 | NP2-High-Li | CCC | targeted | 71.251 | 50.354 | 14.099 | 0.087 |
| 3/1 | NP2-High-Li | quenched | measured | 1.961 | 1.901 | 1.186 | 0.507 |
| 3/1 | NP2-High-Li | quenched | targeted | 1.984 | 1.826 | 1.270 | 0.514 |
| 1/1 | NP2-High-Na | CCC | measured | 79.474 | 67.680 | 18.124 | 0.078 |
| 1/1 | NP2-High-Na | CCC | targeted | 79.265 | 64.633 | 19.230 | 0.079 |
| 3/1 | NP2-High-Na | quenched | measured | 2.418 | 2.113 | 1.567 | 0.431 |
| 3/1 | NP2-High-Na | quenched | targeted | 2.411 | 2.018 | 1.662 | 0.434 |
| 1/1 | NP2-High-Si | CCC | measured | 39.818 | 26.822 | 8.390 | 0.161 |
| 1/1 | NP2-High-Si | CCC | targeted | 39.147 | 26.010 | 8.897 | 0.163 |

**Table 3-3. Normalized PCT Results (continued)**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 3/1 | NP2-High-Si | quenched | measured | 0.944 | 1.122 | 0.564 | 0.510 |
| 3/1 | NP2-High-Si | quenched | targeted | 0.928 | 1.088 | 0.598 | 0.518 |
| 1/1 | NP2-Low-Al | CCC | measured | 7.875 | 5.876 | 2.423 | 0.225 |
| 1/1 | NP2-Low-Al | CCC | targeted | 7.776 | 5.597 | 2.485 | 0.226 |
| 3/1 | NP2-Low-Al | quenched | measured | 2.236 | 2.082 | 1.302 | 0.481 |
| 3/1 | NP2-Low-Al | quenched | targeted | 2.208 | 1.984 | 1.335 | 0.483 |
| 1/1 | NP2-Low-B | CCC | measured | 82.945 | 59.198 | 11.658 | 0.070 |
| 1/1 | NP2-Low-B | CCC | targeted | 81.649 | 58.199 | 12.379 | 0.072 |
| 3/1 | NP2-Low-B | quenched | measured | 1.457 | 1.472 | 0.905 | 0.529 |
| 3/1 | NP2-Low-B | quenched | targeted | 1.434 | 1.447 | 0.961 | 0.539 |
| 1/1 | NP2-Low-Li | CCC | measured | 3.535 | 2.537 | 1.518 | 0.274 |
| 1/1 | NP2-Low-Li | CCC | targeted | 3.509 | 2.410 | 1.605 | 0.278 |
| 3/1 | NP2-Low-Li | quenched | measured | 1.634 | 1.759 | 0.953 | 0.495 |
| 3/1 | NP2-Low-Li | quenched | targeted | 1.622 | 1.671 | 1.007 | 0.502 |
| 1/1 | NP2-Low-Na | CCC | measured | 4.506 | 3.168 | 1.802 | 0.333 |
| 1/1 | NP2-Low-Na | CCC | targeted | 4.384 | 2.949 | 1.932 | 0.335 |
| 3/1 | NP2-Low-Na | quenched | measured | 1.270 | 1.536 | 0.649 | 0.553 |
| 3/1 | NP2-Low-Na | quenched | targeted | 1.235 | 1.429 | 0.696 | 0.556 |
| 1/1 | NP2-Low-Si | CCC | measured | 9.853 | 6.043 | 4.770 | 0.020 |
| 1/1 | NP2-Low-Si | CCC | targeted | 9.855 | 5.928 | 4.834 | 0.020 |
| 3/1 | NP2-Low-Si | quenched | measured | 3.081 | 2.866 | 2.100 | 0.332 |
| 3/1 | NP2-Low-Si | quenched | targeted | 3.081 | 2.811 | 2.128 | 0.337 |
| 1/1 | NP2-Very-High-Al | CCC | measured | 42.040 | 25.872 | 12.498 | 0.160 |
| 1/1 | NP2-Very-High-Al | CCC | targeted | 41.979 | 24.597 | 13.349 | 0.162 |
| 3/1 | NP2-Very-High-Al | quenched | measured | 2.304 | 2.225 | 1.305 | 0.395 |
| 3/1 | NP2-Very-High-Al | quenched | targeted | 2.300 | 2.115 | 1.394 | 0.401 |
| 2/1 | NP2-Very-High-Si | CCC | measured | 0.705 | 0.859 | 0.350 | 0.441 |
| 2/1 | NP2-Very-High-Si | CCC | targeted | 0.712 | 0.823 | 0.365 | 0.447 |
| 3/1 | NP2-Very-High-Si | quenched | measured | 0.588 | 0.920 | 0.316 | 0.467 |
| 3/1 | NP2-Very-High-Si | quenched | targeted | 0.593 | 0.882 | 0.328 | 0.473 |

**Table 3-3. Normalized PCT Results (continued)**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 1/1 | NP2-Very-Low-Si | CCC | measured | 54.125 | 40.086 | 26.033 | 0.037 |
| 1/1 | NP2-Very-Low-Si | CCC | targeted | 53.596 | 39.828 | 27.400 | 0.038 |
| 3/1 | NP2-Very-Low-Si | quenched | measured | 15.534 | 9.000 | 12.038 | 0.098 |
| 3/1 | NP2-Very-Low-Si | quenched | targeted | 15.382 | 8.942 | 12.671 | 0.100 |
| 2/1 | NP-MC-AlB-1 | CCC | measured | 4.007 | 3.524 | 2.220 | 0.331 |
| 2/1 | NP-MC-AlB-1 | CCC | targeted | 3.966 | 3.385 | 2.298 | 0.337 |
| 3/1 | NP-MC-AlB-1 | quenched | measured | 4.180 | 3.863 | 2.363 | 0.373 |
| 3/1 | NP-MC-AlB-1 | quenched | targeted | 4.137 | 3.711 | 2.446 | 0.379 |
| 1/2 | NP-MC-AlBNa-1 | CCC | measured | 1.384 | 1.158 | 0.623 | 0.627 |
| 2/1 | NP-MC-AlBNa-1 | CCC | measured | 1.026 | 1.054 | 0.597 | 0.539 |
| 1/2 | NP-MC-AlBNa-1 | CCC | targeted | 1.344 | 1.149 | 0.662 | 0.631 |
| 2/1 | NP-MC-AlBNa-1 | CCC | targeted | 0.996 | 1.046 | 0.635 | 0.543 |
| 3/2 | NP-MC-AlBNa-1 | quenched | measured | 0.903 | 1.072 | 0.537 | 0.542 |
| 3/2 | NP-MC-AlBNa-1 | quenched | targeted | 0.877 | 1.064 | 0.571 | 0.546 |
| 1/2 | NP-MC-AlBNa-2 | CCC | measured | 12.012 | 7.933 | 6.232 | 0.034 |
| 1/2 | NP-MC-AlBNa-2 | CCC | targeted | 12.092 | 7.508 | 6.682 | 0.034 |
| 3/2 | NP-MC-AlBNa-2 | quenched | measured | 3.456 | 3.276 | 2.237 | 0.310 |
| 3/2 | NP-MC-AlBNa-2 | quenched | targeted | 3.479 | 3.101 | 2.399 | 0.313 |
| 1/2 | NP-MC-AlBSi-1 | CCC | measured | 3.634 | 3.162 | 2.209 | 0.025 |
| 1/2 | NP-MC-AlBSi-1 | CCC | targeted | 3.634 | 3.122 | 2.340 | 0.026 |
| 3/2 | NP-MC-AlBSi-1 | quenched | measured | 2.675 | 2.682 | 1.626 | 0.369 |
| 3/2 | NP-MC-AlBSi-1 | quenched | targeted | 2.675 | 2.648 | 1.723 | 0.381 |
| 1/2 | NP-MC-AlLi-1 | CCC | measured | 2.781 | 2.156 | 1.214 | 0.443 |
| 1/2 | NP-MC-AlLi-1 | CCC | targeted | 2.701 | 2.063 | 1.226 | 0.439 |
| 3/2 | NP-MC-AlLi-1 | quenched | measured | 1.950 | 1.847 | 1.131 | 0.442 |
| 3/2 | NP-MC-AlLi-1 | quenched | targeted | 1.895 | 1.767 | 1.142 | 0.438 |
| 1/2 | NP-MC-AlLi-2 | CCC | measured | 21.207 | 12.955 | 6.547 | 0.199 |
| 2/1 | NP-MC-AlLi-2 | CCC | measured | 21.514 | 13.113 | 6.624 | 0.194 |
| 1/2 | NP-MC-AlLi-2 | CCC | targeted | 20.848 | 12.377 | 6.943 | 0.200 |
| 2/1 | NP-MC-AlLi-2 | CCC | targeted | 21.149 | 12.528 | 7.025 | 0.195 |

**Table 3-3. Normalized PCT Results (continued)**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 3/2 | NP-MC-AlLi-2 | quenched | measured | 1.609 | 1.762 | 0.951 | 0.403 |
| 3/2 | NP-MC-AlLi-2 | quenched | targeted | 1.582 | 1.683 | 1.009 | 0.406 |
| 1/2 | NP-MC-AlLiNa-1 | CCC | measured | 75.566 | 55.417 | 23.508 | 0.034 |
| 1/2 | NP-MC-AlLiNa-1 | CCC | targeted | 75.117 | 53.718 | 24.384 | 0.035 |
| 3/2 | NP-MC-AlLiNa-1 | quenched | measured | 2.913 | 2.543 | 2.050 | 0.419 |
| 3/2 | NP-MC-AlLiNa-1 | quenched | targeted | 2.896 | 2.465 | 2.127 | 0.427 |
| 1/2 | NP-MC-AlLiSi-1 | CCC | measured | 14.101 | 9.621 | 6.459 | 0.183 |
| 1/2 | NP-MC-AlLiSi-1 | CCC | targeted | 14.128 | 9.270 | 6.863 | 0.185 |
| 3/2 | NP-MC-AlLiSi-1 | quenched | measured | 4.324 | 3.910 | 2.792 | 0.270 |
| 3/2 | NP-MC-AlLiSi-1 | quenched | targeted | 4.333 | 3.767 | 2.967 | 0.273 |
| 1/2 | NP-MC-AlNa-1 | CCC | measured | 95.382 | 75.916 | 18.092 | 0.120 |
| 2/1 | NP-MC-AlNa-1 | CCC | measured | 95.576 | 78.893 | 18.714 | 0.117 |
| 1/2 | NP-MC-AlNa-1 | CCC | targeted | 91.957 | 74.120 | 18.684 | 0.120 |
| 2/1 | NP-MC-AlNa-1 | CCC | targeted | 92.144 | 77.027 | 19.326 | 0.117 |
| 3/2 | NP-MC-AlNa-1 | quenched | measured | 2.782 | 2.291 | 1.753 | 0.426 |
| 3/2 | NP-MC-AlNa-1 | quenched | targeted | 2.682 | 2.237 | 1.811 | 0.426 |
| 1/2 | NP-MC-AlSi-1 | CCC | measured | 81.046 | 65.848 | 21.249 | 0.113 |
| 1/2 | NP-MC-AlSi-1 | CCC | targeted | 80.339 | 63.856 | 22.808 | 0.115 |
| 3/2 | NP-MC-AlSi-1 | quenched | measured | 4.264 | 3.807 | 2.726 | 0.368 |
| 3/2 | NP-MC-AlSi-1 | quenched | targeted | 4.227 | 3.692 | 2.926 | 0.375 |
| 1/2 | NP-MC-AlSi-2 | CCC | measured | 12.908 | 5.562 | 4.496 | 0.024 |
| 1/2 | NP-MC-AlSi-2 | CCC | targeted | 12.728 | 5.290 | 4.793 | 0.024 |
| 3/2 | NP-MC-AlSi-2 | quenched | measured | 0.827 | 1.317 | 0.410 | 0.489 |
| 3/2 | NP-MC-AlSi-2 | quenched | targeted | 0.816 | 1.253 | 0.437 | 0.494 |
| 1/2 | NP-MC-BLiSi-1 | CCC | measured | 86.483 | 55.250 | 9.651 | 0.111 |
| 1/2 | NP-MC-BLiSi-1 | CCC | targeted | 86.474 | 53.080 | 10.328 | 0.113 |
| 3/2 | NP-MC-BLiSi-1 | quenched | measured | 0.994 | 1.129 | 0.637 | 0.544 |
| 3/2 | NP-MC-BLiSi-1 | quenched | targeted | 0.994 | 1.084 | 0.682 | 0.554 |
| 2/1 | NP-MC-BLiSi-2 | CCC | measured | 6.634 | 5.998 | 3.654 | 0.310 |
| 2/1 | NP-MC-BLiSi-2 | CCC | targeted | 6.602 | 5.439 | 3.729 | 0.315 |

**Table 3-3. Normalized PCT Results (continued)**

| Group/Set | Glass ID | Heat Treatment | Comp. View | $NC_B$ (g/L) | $NC_{Li}$ (g/L) | $NC_{Na}$ (g/L) | $NC_{Si}$ (g/L) |
|---|---|---|---|---|---|---|---|
| 3/2 | NP-MC-BLiSi-2 | quenched | measured | 5.106 | 4.826 | 3.140 | 0.321 |
| 3/2 | NP-MC-BLiSi-2 | quenched | targeted | 5.082 | 4.377 | 3.204 | 0.327 |
| 1/2 | NP-MC-BNa-1 | CCC | measured | 81.479 | 65.450 | 14.125 | 0.055 |
| 1/2 | NP-MC-BNa-1 | CCC | targeted | 80.720 | 63.211 | 14.926 | 0.056 |
| 3/2 | NP-MC-BNa-1 | quenched | measured | 2.462 | 1.977 | 1.413 | 0.403 |
| 3/2 | NP-MC-BNa-1 | quenched | targeted | 2.439 | 1.909 | 1.493 | 0.411 |
| 1/2 | NP-MC-BNaSi-1 | CCC | measured | 73.258 | 53.334 | 22.720 | 0.034 |
| 1/2 | NP-MC-BNaSi-1 | CCC | targeted | 74.346 | 52.177 | 24.155 | 0.034 |
| 3/2 | NP-MC-BNaSi-1 | quenched | measured | 2.829 | 2.478 | 2.049 | 0.386 |
| 3/2 | NP-MC-BNaSi-1 | quenched | targeted | 2.871 | 2.424 | 2.179 | 0.392 |
| 2/1 | NP-MC-BSi-1 | CCC | measured | 2.170 | 1.974 | 1.087 | 0.403 |
| 2/1 | NP-MC-BSi-1 | CCC | targeted | 2.156 | 1.906 | 1.169 | 0.410 |
| 3/2 | NP-MC-BSi-1 | quenched | measured | 2.542 | 2.424 | 1.228 | 0.401 |
| 3/2 | NP-MC-BSi-1 | quenched | targeted | 2.525 | 2.341 | 1.321 | 0.408 |

## 4.0 Summary

In this report, SRNL provides chemical analyses and PCT results for a series of simulated HLW glasses fabricated by PNNL as part of an ongoing nepheline crystallization study.[4,5] The results of these analyses will be used to improve the ability to predict crystallization of nepheline as a function of composition and heat treatment for glasses formulated at high alumina concentrations.

The measured chemical composition data are reported and compared with the targeted values for each component for each glass. Fluorine concentrations were not measured since this species would have required the use of an additional preparation method and its measured values were likely to be near or below analytical detection limits. A detailed review showed no indications of errors in the preparation or measurement of the study glasses. All of the measured sums of oxides for the study glasses fell within the interval of 98 to 101 wt %, indicating recovery of all components. Comparisons of the targeted and measured chemical compositions showed that the measured values for the glasses met the targeted concentrations within 10% for those components present at more than 5 wt %. Sodium measurements were elevated but were within acceptability limits. Measurements of $ZrO_2$ in glass NP2-High Na were consistently above the targeted value by about a factor of two. This component may have been inadvertently double batched in this glass.

Several of the study glasses exhibited unusual appearances during preparation for, or after performance of, the PCTs. In some cases this may be linked to low chemical durability. Future studies should include thorough analysis of the glasses after the PCTs to provide further information regarding glass behavior in durability testing.

A detailed review showed no issues with performance of the PCTs. The PCT results were normalized to both the targeted and measured compositions of the study glasses. Several observations were made regarding the PCT results. The quenched versions of all of the study glasses have $NC_B$ values that are lower than the EA benchmark $NC_B$ value of 16.695 g/L.[19] Many of the study glasses have higher normalized concentration values after the CCC heat treatment. This is likely indicative of crystallization or phase separation. Sixteen of the study glasses have $NC_B$ values that are below that of the EA benchmark for the quenched versions, but greater than that of the EA benchmark glass after the CCC heat treatment. In some cases the $NC_B$ values are quite high, e.g., 95.58 g/L for the CCC version of glass NP-MC-AlNa-1. These results can be combined with additional characterization, including X-ray diffraction, to determine the cause of the higher release rates.

Duplicate PCT testing was completed for a small subset of the study glasses to test reproducibility. Although limited in scope, the results of the duplicate tests indicate reasonable reproducibility for the PCT responses of the study glasses over a broad range of normalized concentration values.

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# Appendix A Tables and Exhibits Supporting the Chemical Composition Measurements

## Table A-1. AD Measurements of the Nepheline Study Glasses

| Glass ID | Block | Sub-Blk | Sequence | Lab ID | Bi (wt%) | Ca (wt%) | Na (wt%) | Ni (wt%) | P (wt%) | Ru (wt%) | S (wt%) | Zr (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LRM | 1 | 1 | 1 | LRMAD111 | <0.100 | 0.341 | 15.7 | 0.135 | 0.231 | <0.100 | 0.089 | 0.728 |
| BL3 | 1 | 1 | 2 | W15AD11 | 0.545 | 0.436 | 9.72 | <0.100 | 0.296 | <0.100 | 0.105 | 0.189 |
| NP-MC-AlLi-2 | 1 | 1 | 3 | W07AD11 | 0.515 | 0.418 | 9.49 | <0.100 | 0.285 | <0.100 | 0.081 | 0.178 |
| NP2-Low-B | 1 | 1 | 4 | W27AD11 | 0.554 | 0.449 | 10.2 | <0.100 | 0.305 | <0.100 | 0.087 | 0.192 |
| NP2-Very-High-Al | 1 | 1 | 5 | W20AD11 | 0.495 | 0.401 | 9.18 | <0.100 | 0.270 | <0.100 | 0.085 | 0.173 |
| NP2-Low-B | 1 | 1 | 6 | W27AD21 | 0.562 | 0.452 | 10.1 | <0.100 | 0.311 | <0.100 | 0.093 | 0.195 |
| BL3 | 1 | 1 | 7 | W15AD21 | 0.537 | 0.432 | 9.54 | <0.100 | 0.290 | <0.100 | 0.103 | 0.186 |
| NP-MC-BNa-1 | 1 | 1 | 8 | W03AD21 | 0.531 | 0.434 | 12.1 | <0.100 | 0.290 | <0.100 | 0.105 | 0.187 |
| NP2-High-Li | 1 | 1 | 9 | W30AD21 | 0.527 | 0.435 | 9.64 | <0.100 | 0.290 | <0.100 | 0.110 | 0.188 |
| LRM | 1 | 1 | 10 | LRMAD112 | <0.100 | 0.341 | 16.1 | 0.134 | 0.221 | <0.100 | 0.094 | 0.715 |
| NP-MC-AlSi-1 | 1 | 1 | 11 | W17AD11 | 0.623 | 0.478 | 11.4 | <0.100 | 0.339 | <0.100 | 0.124 | 0.228 |
| NP2-High-Li | 1 | 1 | 12 | W30AD11 | 0.534 | 0.431 | 9.77 | <0.100 | 0.290 | <0.100 | 0.108 | 0.189 |
| NP-MC-AlSi-1 | 1 | 1 | 13 | W17AD21 | 0.614 | 0.483 | 11.4 | <0.100 | 0.338 | <0.100 | 0.126 | 0.226 |
| NP-MC-AlBNa-1 | 1 | 1 | 14 | W13AD21 | 0.599 | 0.479 | 8.56 | <0.100 | 0.330 | <0.100 | 0.107 | 0.209 |
| NP-MC-AlLi-2 | 1 | 1 | 15 | W07AD21 | 0.520 | 0.419 | 9.60 | <0.100 | 0.285 | <0.100 | 0.084 | 0.182 |
| NP-MC-BNa-1 | 1 | 1 | 16 | W03AD11 | 0.537 | 0.424 | 12.0 | <0.100 | 0.291 | <0.100 | 0.102 | 0.188 |
| NP-MC-AlBNa-1 | 1 | 1 | 17 | W13AD11 | 0.607 | 0.481 | 8.43 | <0.100 | 0.331 | <0.100 | 0.102 | 0.214 |
| NP2-Very-High-Al | 1 | 1 | 18 | W20AD21 | 0.490 | 0.404 | 8.94 | <0.100 | 0.266 | <0.100 | 0.081 | 0.172 |
| LRM | 1 | 1 | 19 | LRMAD113 | <0.100 | 0.343 | 16.2 | 0.136 | 0.220 | <0.100 | 0.093 | 0.717 |
| LRM | 1 | 2 | 1 | LRMAD121 | <0.100 | 0.339 | 16.0 | 0.135 | 0.228 | <0.100 | 0.092 | 0.731 |
| NP2-High-Li | 1 | 2 | 2 | W30AD22 | 0.531 | 0.432 | 10.0 | <0.100 | 0.288 | <0.100 | 0.105 | 0.188 |
| NP2-High-Li | 1 | 2 | 3 | W30AD12 | 0.524 | 0.429 | 9.91 | <0.100 | 0.287 | <0.100 | 0.108 | 0.187 |
| NP-MC-BNa-1 | 1 | 2 | 4 | W03AD22 | 0.529 | 0.434 | 12.2 | <0.100 | 0.287 | <0.100 | 0.109 | 0.186 |
| NP2-Very-High-Al | 1 | 2 | 5 | W20AD22 | 0.490 | 0.399 | 9.11 | <0.100 | 0.264 | <0.100 | 0.088 | 0.171 |
| NP2-Very-High-Al | 1 | 2 | 6 | W20AD12 | 0.498 | 0.407 | 9.06 | <0.100 | 0.267 | <0.100 | 0.089 | 0.174 |
| NP-MC-BNa-1 | 1 | 2 | 7 | W03AD12 | 0.536 | 0.431 | 12.3 | <0.100 | 0.288 | <0.100 | 0.100 | 0.186 |
| NP-MC-AlLi-2 | 1 | 2 | 8 | W07AD12 | 0.518 | 0.419 | 9.39 | <0.100 | 0.282 | <0.100 | 0.080 | 0.179 |
| NP-MC-AlSi-1 | 1 | 2 | 9 | W17AD12 | 0.615 | 0.483 | 11.6 | <0.100 | 0.335 | <0.100 | 0.123 | 0.227 |
| LRM | 1 | 2 | 10 | LRMAD122 | <0.100 | 0.337 | 16.0 | 0.135 | 0.230 | <0.100 | 0.087 | 0.731 |
| NP2-Low-B | 1 | 2 | 11 | W27AD12 | 0.552 | 0.446 | 10.3 | <0.100 | 0.300 | <0.100 | 0.096 | 0.193 |
| NP-MC-AlLi-2 | 1 | 2 | 12 | W07AD22 | 0.520 | 0.422 | 9.66 | <0.100 | 0.280 | <0.100 | 0.085 | 0.181 |
| BL3 | 1 | 2 | 13 | W15AD22 | 0.539 | 0.428 | 9.81 | <0.100 | 0.289 | <0.100 | 0.100 | 0.187 |
| NP-MC-AlBNa-1 | 1 | 2 | 14 | W13AD12 | 0.603 | 0.482 | 8.55 | <0.100 | 0.328 | <0.100 | 0.110 | 0.211 |
| NP2-Low-B | 1 | 2 | 15 | W27AD22 | 0.555 | 0.453 | 10.3 | <0.100 | 0.304 | <0.100 | 0.090 | 0.193 |
| NP-MC-AlBNa-1 | 1 | 2 | 16 | W13AD22 | 0.603 | 0.481 | 8.52 | <0.100 | 0.331 | <0.100 | 0.106 | 0.211 |
| NP-MC-AlSi-1 | 1 | 2 | 17 | W17AD22 | 0.613 | 0.489 | 11.4 | <0.100 | 0.333 | <0.100 | 0.124 | 0.227 |
| BL3 | 1 | 2 | 18 | W15AD12 | 0.542 | 0.431 | 10.1 | <0.100 | 0.288 | <0.100 | 0.102 | 0.190 |
| LRM | 1 | 2 | 19 | LRMAD123 | <0.100 | 0.341 | 16.3 | 0.136 | 0.229 | <0.100 | 0.092 | 0.729 |
| LRM | 2 | 1 | 1 | LRMAD211 | <0.100 | 0.339 | 16.0 | 0.136 | 0.225 | <0.100 | 0.084 | 0.710 |
| NP-MC-AlSi-2 | 2 | 1 | 2 | W24AD21 | 0.452 | 0.372 | 8.21 | <0.100 | 0.242 | <0.100 | 0.063 | 0.146 |
| NP2-Low-Li | 2 | 1 | 3 | W21AD11 | 0.551 | 0.437 | 9.63 | <0.100 | 0.292 | <0.100 | 0.089 | 0.178 |

**Table A-1. AD Measurements of the Nepheline Study Glasses (continued)**

| Glass ID | Block | Sub-Blk | Sequence | Lab ID | Bi (wt%) | Ca (wt%) | Na (wt%) | Ni (wt%) | P (wt%) | Ru (wt%) | S (wt%) | Zr (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NP2-Very-High-Si | 2 | 1 | 4 | W25AD11 | 0.483 | 0.394 | 8.47 | <0.100 | 0.257 | <0.100 | 0.078 | 0.156 |
| NP-MC-BNaSi-1 | 2 | 1 | 5 | W11AD11 | 0.592 | 0.470 | 12.0 | <0.100 | 0.313 | <0.100 | 0.104 | 0.193 |
| NP-MC-AlBNa-2 | 2 | 1 | 6 | W22AD11 | 0.486 | 0.392 | 10.8 | <0.100 | 0.258 | <0.100 | 0.082 | 0.157 |
| Neph-NN-1-12 | 2 | 1 | 7 | W26AD11 | 0.578 | 0.300 | 11.7 | 0.148 | 0.385 | <0.100 | 0.104 | <0.100 |
| NP2-Very-High-Si | 2 | 1 | 8 | W25AD21 | 0.478 | 0.393 | 8.54 | <0.100 | 0.253 | <0.100 | 0.075 | 0.153 |
| Neph-NN-1-12 | 2 | 1 | 9 | W26AD21 | 0.586 | 0.307 | 12.1 | 0.152 | 0.387 | <0.100 | 0.102 | <0.100 |
| LRM | 2 | 1 | 10 | LRMAD212 | <0.100 | 0.340 | 16.2 | 0.136 | 0.221 | <0.100 | 0.085 | 0.700 |
| NP-MC-AlBNa-2 | 2 | 1 | 11 | W22AD21 | 0.483 | 0.393 | 10.7 | <0.100 | 0.257 | <0.100 | 0.084 | 0.156 |
| NP2-Low-Li | 2 | 1 | 12 | W21AD21 | 0.549 | 0.455 | 9.90 | <0.100 | 0.290 | <0.100 | 0.092 | 0.178 |
| NP-MC-AlLiNa-1 | 2 | 1 | 13 | W14AD21 | 0.468 | 0.378 | 11.5 | <0.100 | 0.253 | <0.100 | 0.095 | 0.152 |
| NP-MC-AlLiNa-1 | 2 | 1 | 14 | W14AD11 | 0.472 | 0.380 | 11.5 | <0.100 | 0.254 | <0.100 | 0.095 | 0.153 |
| NP2-High-Na | 2 | 1 | 15 | W18AD21 | 0.524 | 0.422 | 12.1 | <0.100 | 0.277 | <0.100 | 0.107 | 0.344 |
| NP-MC-BNaSi-1 | 2 | 1 | 16 | W11AD21 | 0.587 | 0.473 | 12.2 | <0.100 | 0.307 | <0.100 | 0.106 | 0.191 |
| NP2-High-Na | 2 | 1 | 17 | W18AD11 | 0.516 | 0.416 | 12.1 | <0.100 | 0.271 | <0.100 | 0.103 | 0.336 |
| NP-MC-AlSi-2 | 2 | 1 | 18 | W24AD11 | 0.453 | 0.399 | 8.19 | <0.100 | 0.243 | <0.100 | 0.068 | 0.146 |
| LRM | 2 | 1 | 19 | LRMAD213 | <0.100 | 0.339 | 15.8 | 0.135 | 0.223 | <0.100 | 0.090 | 0.690 |
| LRM | 2 | 2 | 1 | LRMAD221 | <0.100 | 0.353 | 15.9 | 0.143 | 0.208 | <0.100 | 0.085 | 0.700 |
| NP2-Very-High-Si | 2 | 2 | 2 | W25AD22 | 0.470 | 0.392 | 8.69 | <0.100 | 0.249 | <0.100 | 0.082 | 0.152 |
| NP-MC-AlLiNa-1 | 2 | 2 | 3 | W14AD22 | 0.463 | 0.380 | 11.8 | <0.100 | 0.249 | <0.100 | 0.092 | 0.153 |
| NP-MC-AlSi-2 | 2 | 2 | 4 | W24AD12 | 0.451 | 0.396 | 8.47 | <0.100 | 0.240 | <0.100 | 0.065 | 0.148 |
| NP2-High-Na | 2 | 2 | 5 | W18AD22 | 0.516 | 0.420 | 12.3 | <0.100 | 0.274 | <0.100 | 0.105 | 0.348 |
| NP-MC-AlLiNa-1 | 2 | 2 | 6 | W14AD12 | 0.468 | 0.381 | 11.8 | <0.100 | 0.253 | <0.100 | 0.095 | 0.154 |
| NP2-Very-High-Si | 2 | 2 | 7 | W25AD12 | 0.476 | 0.399 | 8.74 | <0.100 | 0.254 | <0.100 | 0.078 | 0.157 |
| NP2-Low-Li | 2 | 2 | 8 | W21AD12 | 0.541 | 0.442 | 10.0 | <0.100 | 0.288 | <0.100 | 0.095 | 0.178 |
| Neph-NN-1-12 | 2 | 2 | 9 | W26AD12 | 0.565 | 0.303 | 11.9 | 0.149 | 0.377 | <0.100 | 0.099 | <0.100 |
| LRM | 2 | 2 | 10 | LRMAD222 | <0.100 | 0.374 | 16.0 | 0.152 | 0.203 | <0.100 | 0.084 | 0.700 |
| NP-MC-AlSi-2 | 2 | 2 | 11 | W24AD22 | 0.447 | 0.373 | 8.44 | <0.100 | 0.240 | <0.100 | 0.064 | 0.148 |
| NP-MC-AlBNa-2 | 2 | 2 | 12 | W22AD12 | 0.474 | 0.395 | 11.3 | <0.100 | 0.253 | <0.100 | 0.088 | 0.157 |
| NP2-High-Na | 2 | 2 | 13 | W18AD12 | 0.509 | 0.416 | 12.3 | <0.100 | 0.270 | <0.100 | 0.101 | 0.341 |
| NP-MC-BNaSi-1 | 2 | 2 | 14 | W11AD12 | 0.587 | 0.470 | 12.5 | <0.100 | 0.307 | <0.100 | 0.109 | 0.194 |
| NP-MC-BNaSi-1 | 2 | 2 | 15 | W11AD22 | 0.582 | 0.473 | 12.2 | <0.100 | 0.307 | <0.100 | 0.110 | 0.194 |
| Neph-NN-1-12 | 2 | 2 | 16 | W26AD22 | 0.568 | 0.307 | 12.0 | 0.150 | 0.380 | <0.100 | 0.101 | <0.100 |
| NP2-Low-Li | 2 | 2 | 17 | W21AD22 | 0.542 | 0.453 | 10.1 | <0.100 | 0.290 | <0.100 | 0.091 | 0.178 |
| NP-MC-AlBNa-2 | 2 | 2 | 18 | W22AD22 | 0.476 | 0.391 | 11.2 | <0.100 | 0.254 | <0.100 | 0.087 | 0.155 |
| LRM | 2 | 2 | 19 | LRMAD223 | <0.100 | 0.370 | 16.0 | 0.151 | 0.209 | <0.100 | 0.089 | 0.690 |
| LRM | 3 | 1 | 1 | LRMAD311 | <0.100 | 0.295 | 15.8 | 0.137 | 0.215 | <0.100 | 0.086 | 0.690 |
| NP-MC-BSi-1 | 3 | 1 | 2 | W06AD11 | 0.478 | 0.327 | 8.85 | <0.100 | 0.260 | <0.100 | 0.078 | 0.156 |
| NP2-Low-Na | 3 | 1 | 3 | W01AD21 | 0.566 | 0.382 | 7.61 | <0.100 | 0.302 | <0.100 | 0.071 | 0.186 |
| NP-MC-AlBSi-1 | 3 | 1 | 4 | W08AD21 | 0.442 | 0.296 | 8.05 | <0.100 | 0.242 | <0.100 | 0.067 | 0.148 |
| NP-MC-AlLiSi-1 | 3 | 1 | 5 | W19AD21 | 0.664 | 0.439 | 11.8 | <0.100 | 0.353 | <0.100 | 0.120 | 0.216 |
| NP-MC-BSi-1 | 3 | 1 | 6 | W06AD21 | 0.487 | 0.328 | 8.64 | <0.100 | 0.263 | <0.100 | 0.079 | 0.157 |
| NP2-High-Si | 3 | 1 | 7 | W23AD11 | 0.527 | 0.362 | 9.29 | <0.100 | 0.276 | <0.100 | 0.076 | 0.168 |

**Table A-1. AD Measurements of the Nepheline Study Glasses (continued)**

| Glass ID | Block | Sub-Blk | Sequence | Lab ID | Bi (wt%) | Ca (wt%) | Na (wt%) | Ni (wt%) | P (wt%) | Ru (wt%) | S (wt%) | Zr (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NP-MC-AlBSi-1 | 3 | 1 | 8 | W08AD11 | 0.442 | 0.316 | 7.84 | <0.100 | 0.241 | <0.100 | 0.065 | 0.146 |
| NP2-High-Al | 3 | 1 | 9 | W10AD21 | 0.521 | 0.364 | 9.35 | <0.100 | 0.281 | <0.100 | 0.088 | 0.172 |
| LRM | 3 | 1 | 10 | LRMAD312 | <0.100 | 0.314 | 15.8 | 0.137 | 0.213 | <0.100 | 0.088 | 0.710 |
| NP2-High-Al | 3 | 1 | 11 | W10AD11 | 0.522 | 0.368 | 9.35 | <0.100 | 0.283 | <0.100 | 0.087 | 0.173 |
| NP-MC-AlLiSi-1 | 3 | 1 | 12 | W19AD11 | 0.652 | 0.464 | 11.7 | <0.100 | 0.349 | <0.100 | 0.123 | 0.214 |
| NP2-High-Si | 3 | 1 | 13 | W23AD21 | 0.524 | 0.376 | 9.18 | <0.100 | 0.279 | <0.100 | 0.076 | 0.171 |
| NP2-Very-Low-Si | 3 | 1 | 14 | W31AD21 | 0.590 | 0.411 | 10.5 | <0.100 | 0.316 | <0.100 | 0.109 | 0.192 |
| NP2-Very-Low-Si | 3 | 1 | 15 | W31AD11 | 0.602 | 0.434 | 10.6 | <0.100 | 0.321 | <0.100 | 0.112 | 0.196 |
| NP-MC-BLiSi-1 | 3 | 1 | 16 | W05AD21 | 0.524 | 0.371 | 9.48 | <0.100 | 0.280 | <0.100 | 0.084 | 0.170 |
| NP2-Low-Na | 3 | 1 | 17 | W01AD11 | 0.566 | 0.395 | 7.48 | <0.100 | 0.301 | <0.100 | 0.069 | 0.185 |
| NP-MC-BLiSi-1 | 3 | 1 | 18 | W05AD11 | 0.521 | 0.371 | 9.66 | <0.100 | 0.280 | <0.100 | 0.083 | 0.171 |
| LRM | 3 | 1 | 19 | LRMAD313 | <0.100 | 0.317 | 16.1 | 0.140 | 0.216 | <0.100 | 0.082 | 0.720 |
| LRM | 3 | 2 | 1 | LRMAD321 | <0.100 | 0.310 | 16.3 | 0.136 | 0.223 | <0.100 | 0.091 | 0.720 |
| NP-MC-AlLiSi-1 | 3 | 2 | 2 | W19AD22 | 0.645 | 0.452 | 11.9 | <0.100 | 0.346 | <0.100 | 0.124 | 0.215 |
| NP2-Very-Low-Si | 3 | 2 | 3 | W31AD12 | 0.585 | 0.421 | 11.4 | <0.100 | 0.314 | <0.100 | 0.110 | 0.194 |
| NP-MC-BLiSi-1 | 3 | 2 | 4 | W05AD12 | 0.517 | 0.363 | 9.71 | <0.100 | 0.277 | <0.100 | 0.087 | 0.169 |
| NP-MC-BSi-1 | 3 | 2 | 5 | W06AD22 | 0.470 | 0.340 | 9.26 | <0.100 | 0.255 | <0.100 | 0.082 | 0.155 |
| NP2-High-Al | 3 | 2 | 6 | W10AD12 | 0.506 | 0.367 | 9.65 | <0.100 | 0.272 | <0.100 | 0.082 | 0.168 |
| NP-MC-BSi-1 | 3 | 2 | 7 | W06AD12 | 0.472 | 0.335 | 8.94 | <0.100 | 0.253 | <0.100 | 0.076 | 0.154 |
| NP-MC-AlLiSi-1 | 3 | 2 | 8 | W19AD12 | 0.632 | 0.445 | 11.8 | <0.100 | 0.336 | <0.100 | 0.121 | 0.208 |
| NP2-Low-Na | 3 | 2 | 9 | W01AD12 | 0.549 | 0.391 | 7.50 | <0.100 | 0.294 | <0.100 | 0.075 | 0.182 |
| LRM | 3 | 2 | 10 | LRMAD322 | <0.100 | 0.308 | 16.0 | 0.135 | 0.199 | <0.100 | 0.084 | 0.680 |
| NP-MC-AlBSi-1 | 3 | 2 | 11 | W08AD22 | 0.433 | 0.305 | 8.15 | <0.100 | 0.235 | <0.100 | 0.071 | 0.146 |
| NP2-Very-Low-Si | 3 | 2 | 12 | W31AD22 | 0.572 | 0.406 | 10.6 | <0.100 | 0.309 | <0.100 | 0.107 | 0.189 |
| NP2-High-Si | 3 | 2 | 13 | W23AD12 | 0.506 | 0.362 | 9.31 | <0.100 | 0.266 | <0.100 | 0.076 | 0.165 |
| NP-MC-BLiSi-1 | 3 | 2 | 14 | W05AD22 | 0.508 | 0.362 | 9.67 | <0.100 | 0.274 | <0.100 | 0.088 | 0.167 |
| NP2-High-Al | 3 | 2 | 15 | W10AD22 | 0.502 | 0.363 | 9.47 | <0.100 | 0.272 | <0.100 | 0.088 | 0.167 |
| NP2-High-Si | 3 | 2 | 16 | W23AD22 | 0.503 | 0.366 | 9.51 | <0.100 | 0.266 | <0.100 | 0.074 | 0.165 |
| NP2-Low-Na | 3 | 2 | 17 | W01AD22 | 0.545 | 0.391 | 7.64 | <0.100 | 0.289 | <0.100 | 0.071 | 0.182 |
| NP-MC-AlBSi-1 | 3 | 2 | 18 | W08AD12 | 0.430 | 0.313 | 8.25 | <0.100 | 0.231 | <0.100 | 0.066 | 0.145 |
| LRM | 3 | 2 | 19 | LRMAD323 | <0.100 | 0.306 | 16.1 | 0.134 | 0.199 | <0.100 | 0.087 | 0.680 |
| LRM | 4 | 1 | 1 | LRMAD411 | <0.100 | 0.305 | 15.1 | 0.136 | 0.206 | <0.100 | 0.084 | 0.711 |
| NP-MC-AlNa-1 | 4 | 1 | 2 | W28AD11 | 0.543 | 0.378 | 11.9 | <0.100 | 0.292 | <0.100 | 0.096 | 0.184 |
| NP2-Low-Si | 4 | 1 | 3 | W16AD21 | 0.567 | 0.392 | 9.52 | <0.100 | 0.302 | <0.100 | 0.089 | 0.194 |
| NP2-High-B | 4 | 1 | 4 | W29AD21 | 0.504 | 0.363 | 9.15 | <0.100 | 0.274 | <0.100 | 0.073 | 0.178 |
| NP2-High-B | 4 | 1 | 5 | W29AD11 | 0.504 | 0.362 | 9.05 | <0.100 | 0.274 | <0.100 | 0.077 | 0.179 |
| NP-MC-AlNa-1 | 4 | 1 | 6 | W28AD21 | 0.535 | 0.380 | 11.7 | <0.100 | 0.285 | <0.100 | 0.100 | 0.183 |
| NP-MC-BLiSi-2 | 4 | 1 | 7 | W12AD11 | 0.503 | 0.351 | 8.96 | <0.100 | 0.268 | <0.100 | 0.095 | 0.177 |
| NP-MC-AlB-1 | 4 | 1 | 8 | W02AD11 | 0.524 | 0.367 | 9.29 | <0.100 | 0.282 | <0.100 | 0.097 | 0.180 |
| NP2-Low-Al | 4 | 1 | 9 | W04AD21 | 0.558 | 0.416 | 9.77 | <0.100 | 0.298 | <0.100 | 0.097 | 0.197 |
| LRM | 4 | 1 | 10 | LRMAD412 | <0.100 | 0.306 | 15.1 | 0.134 | 0.203 | <0.100 | 0.083 | 0.710 |
| NP2-Low-Si | 4 | 1 | 11 | W16AD11 | 0.567 | 0.392 | 9.70 | <0.100 | 0.300 | <0.100 | 0.084 | 0.196 |

**Table A-1. AD Measurements of the Nepheline Study Glasses (continued)**

| Glass ID | Block | Sub-Blk | Sequence | Lab ID | Bi (wt%) | Ca (wt%) | Na (wt%) | Ni (wt%) | P (wt%) | Ru (wt%) | S (wt%) | Zr (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NP-MC-BLiSi-2 | 4 | 1 | 12 | W12AD21 | 0.508 | 0.378 | 8.89 | <0.100 | 0.270 | <0.100 | 0.094 | 0.179 |
| NP2-Low-Al | 4 | 1 | 13 | W04AD11 | 0.555 | 0.401 | 9.95 | <0.100 | 0.296 | <0.100 | 0.102 | 0.195 |
| NP-MC-AlLi-1 | 4 | 1 | 14 | W09AD11 | 0.572 | 0.396 | 9.33 | <0.100 | 0.307 | <0.100 | 0.099 | 0.204 |
| NP-MC-AlB-1 | 4 | 1 | 15 | W02AD21 | 0.516 | 0.362 | 9.03 | <0.100 | 0.279 | <0.100 | 0.092 | 0.179 |
| NP-MC-AlLi-1 | 4 | 1 | 16 | W09AD21 | 0.568 | 0.405 | 10.2 | <0.100 | 0.304 | <0.100 | 0.100 | 0.204 |
| LRM | 4 | 1 | 17 | LRMAD413 | <0.100 | 0.304 | 15.5 | 0.133 | 0.203 | <0.100 | 0.085 | 0.721 |
| LRM | 4 | 2 | 1 | LRMAD421 | <0.100 | 0.319 | 15.7 | 0.143 | 0.215 | <0.100 | 0.088 | 0.719 |
| NP2-High-B | 4 | 2 | 2 | W29AD12 | 0.514 | 0.355 | 9.19 | <0.100 | 0.280 | <0.100 | 0.073 | 0.181 |
| NP-MC-BLiSi-2 | 4 | 2 | 3 | W12AD12 | 0.515 | 0.355 | 9.17 | <0.100 | 0.277 | <0.100 | 0.099 | 0.180 |
| NP2-High-B | 4 | 2 | 4 | W29AD22 | 0.511 | 0.363 | 9.20 | <0.100 | 0.279 | <0.100 | 0.074 | 0.179 |
| NP2-Low-Al | 4 | 2 | 5 | W04AD12 | 0.563 | 0.409 | 9.80 | <0.100 | 0.308 | <0.100 | 0.098 | 0.197 |
| NP-MC-AlLi-1 | 4 | 2 | 6 | W09AD12 | 0.574 | 0.406 | 9.89 | <0.100 | 0.314 | <0.100 | 0.100 | 0.205 |
| NP-MC-BLiSi-2 | 4 | 2 | 7 | W12AD22 | 0.512 | 0.378 | 8.92 | <0.100 | 0.275 | <0.100 | 0.098 | 0.181 |
| NP-MC-AlNa-1 | 4 | 2 | 8 | W28AD12 | 0.545 | 0.372 | 11.8 | <0.100 | 0.292 | <0.100 | 0.103 | 0.186 |
| NP-MC-AlLi-1 | 4 | 2 | 9 | W09AD22 | 0.574 | 0.407 | 10.3 | <0.100 | 0.312 | <0.100 | 0.095 | 0.206 |
| LRM | 4 | 2 | 10 | LRMAD422 | <0.100 | 0.322 | 15.3 | 0.151 | 0.220 | <0.100 | 0.087 | 0.722 |
| NP2-Low-Al | 4 | 2 | 11 | W04AD22 | 0.563 | 0.422 | 10.1 | <0.100 | 0.305 | <0.100 | 0.104 | 0.200 |
| NP-MC-AlB-1 | 4 | 2 | 12 | W02AD12 | 0.527 | 0.374 | 9.42 | <0.100 | 0.285 | <0.100 | 0.100 | 0.181 |
| NP-MC-AlB-1 | 4 | 2 | 13 | W02AD22 | 0.528 | 0.366 | 9.39 | <0.100 | 0.285 | <0.100 | 0.095 | 0.181 |
| NP2-Low-Si | 4 | 2 | 14 | W16AD12 | 0.567 | 0.393 | 10.2 | <0.100 | 0.305 | <0.100 | 0.089 | 0.195 |
| NP-MC-AlNa-1 | 4 | 2 | 15 | W28AD22 | 0.540 | 0.384 | 12.1 | <0.100 | 0.288 | <0.100 | 0.099 | 0.184 |
| NP2-Low-Si | 4 | 2 | 16 | W16AD22 | 0.561 | 0.389 | 9.95 | <0.100 | 0.301 | <0.100 | 0.086 | 0.193 |
| LRM | 4 | 2 | 17 | LRMAD423 | <0.100 | 0.327 | 15.4 | 0.151 | 0.220 | <0.100 | 0.088 | 0.712 |

**Table A-2. PF Measurements of the Nepheline Study Glasses**

| ID | Block | Sub-Blk | Sequence | Lab ID | Al (wt%) | B (wt%) | Cr (wt%) | Fe (wt%) | Li (wt%) | Mn (wt%) | Si (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LRM | 1 | 1 | 1 | LRMPF111 | 5.02 | 2.50 | <0.100 | 0.980 | <0.100 | <0.100 | 25.2 |
| NP-MC-AlLiNa-1 | 1 | 1 | 2 | W14PF11 | 16.3 | 4.77 | 0.582 | 1.52 | 2.67 | 0.613 | 12.5 |
| NP2-Low-Na | 1 | 1 | 3 | W01PF11 | 15.5 | 5.45 | 0.673 | 1.81 | 2.33 | 0.733 | 14.4 |
| NP-MC-AlSi-2 | 1 | 1 | 4 | W24PF21 | 16.3 | 4.36 | 0.549 | 1.43 | 1.85 | 0.561 | 15.4 |
| NP-MC-BLiSi-1 | 1 | 1 | 5 | W05PF21 | 14.5 | 4.26 | 0.658 | 1.71 | 2.72 | 0.690 | 15.7 |
| NP2-High-Al | 1 | 1 | 6 | W10PF21 | 16.6 | 5.07 | 0.640 | 1.67 | 2.15 | 0.670 | 13.3 |
| NP2-High-Na | 1 | 1 | 7 | W18PF11 | 14.5 | 5.16 | 0.634 | 1.64 | 2.13 | 0.666 | 13.4 |
| NP2-Very-High-Al | 1 | 1 | 8 | W20PF11 | 18.2 | 4.97 | 0.591 | 1.53 | 1.98 | 0.612 | 12.8 |
| NP2-Low-Li | 1 | 1 | 9 | W21PF21 | 15.2 | 5.49 | 0.667 | 1.72 | 1.73 | 0.691 | 14.1 |
| LRM | 1 | 1 | 10 | LRMPF112 | 5.02 | 2.45 | <0.100 | 0.956 | <0.100 | <0.100 | 25.2 |
| NP2-High-Al | 1 | 1 | 11 | W10PF11 | 16.8 | 5.29 | 0.618 | 1.63 | 2.09 | 0.646 | 13.6 |
| NP-MC-AlSi-2 | 1 | 1 | 12 | W24PF11 | 16.7 | 4.60 | 0.540 | 1.41 | 1.81 | 0.554 | 15.9 |
| NP-MC-BLiSi-1 | 1 | 1 | 13 | W05PF11 | 14.4 | 4.36 | 0.624 | 1.62 | 2.60 | 0.653 | 15.6 |
| NP-MC-AlLiNa-1 | 1 | 1 | 14 | W14PF21 | 16.4 | 4.70 | 0.560 | 1.46 | 2.56 | 0.586 | 12.3 |
| NP2-Low-Na | 1 | 1 | 15 | W01PF21 | 14.9 | 5.19 | 0.648 | 1.75 | 2.24 | 0.706 | 13.9 |
| NP2-Very-High-Al | 1 | 1 | 16 | W20PF21 | 18.0 | 4.86 | 0.597 | 1.56 | 2.01 | 0.617 | 12.7 |
| NP2-High-Na | 1 | 1 | 17 | W18PF21 | 14.1 | 5.12 | 0.634 | 1.63 | 2.13 | 0.665 | 13.1 |
| NP2-Low-Li | 1 | 1 | 18 | W21PF11 | 14.9 | 5.35 | 0.662 | 1.71 | 1.73 | 0.687 | 14.0 |
| LRM | 1 | 1 | 19 | LRMPF113 | 5.10 | 2.51 | <0.100 | 0.947 | <0.100 | <0.100 | 25.7 |
| LRM | 1 | 2 | 1 | LRMPF121 | 5.12 | 2.55 | <0.100 | 1.00 | <0.100 | <0.100 | 25.8 |
| NP2-Low-Li | 1 | 2 | 2 | W21PF22 | 14.9 | 5.36 | 0.722 | 1.79 | 1.80 | 0.755 | 14.0 |
| NP2-High-Na | 1 | 2 | 3 | W18PF22 | 14.3 | 5.14 | 0.688 | 1.69 | 2.18 | 0.724 | 13.4 |
| NP2-High-Al | 1 | 2 | 4 | W10PF12 | 16.4 | 5.11 | 0.670 | 1.67 | 2.12 | 0.699 | 13.3 |
| NP2-Very-High-Al | 1 | 2 | 5 | W20PF22 | 18.0 | 4.81 | 0.662 | 1.65 | 2.07 | 0.689 | 12.7 |
| NP-MC-AlSi-2 | 1 | 2 | 6 | W24PF22 | 16.1 | 4.27 | 0.600 | 1.48 | 1.88 | 0.616 | 15.2 |
| NP2-Low-Na | 1 | 2 | 7 | W01PF12 | 15.7 | 5.47 | 0.717 | 1.83 | 2.33 | 0.774 | 14.6 |
| NP-MC-AlLiNa-1 | 1 | 2 | 8 | W14PF12 | 16.4 | 4.76 | 0.633 | 1.56 | 2.68 | 0.663 | 12.4 |
| NP-MC-AlSi-2 | 1 | 2 | 9 | W24PF12 | 16.7 | 4.52 | 0.607 | 1.49 | 1.90 | 0.623 | 15.8 |
| LRM | 1 | 2 | 10 | LRMPF122 | 5.05 | 2.42 | 0.102 | 1.02 | <0.100 | <0.100 | 25.4 |
| NP2-Very-High-Al | 1 | 2 | 11 | W20PF12 | 18.1 | 4.91 | 0.645 | 1.60 | 2.03 | 0.673 | 12.8 |
| NP2-Low-Na | 1 | 2 | 12 | W01PF22 | 15.2 | 5.39 | 0.652 | 1.61 | 2.04 | 0.678 | 14.2 |
| NP-MC-BLiSi-1 | 1 | 2 | 13 | W05PF12 | 14.5 | 4.38 | 0.691 | 1.71 | 2.70 | 0.722 | 15.7 |
| NP2-High-Al | 1 | 2 | 14 | W10PF22 | 16.3 | 5.00 | 0.689 | 1.71 | 2.18 | 0.720 | 13.1 |
| NP2-Low-Li | 1 | 2 | 15 | W21PF12 | 15.1 | 5.23 | 0.729 | 1.79 | 1.80 | 0.756 | 14.1 |
| NP-MC-AlLiNa-1 | 1 | 2 | 16 | W14PF22 | 16.4 | 4.59 | 0.634 | 1.57 | 2.68 | 0.663 | 12.3 |
| NP2-High-Na | 1 | 2 | 17 | W18PF12 | 14.6 | 5.16 | 0.672 | 1.66 | 2.13 | 0.703 | 13.5 |
| NP-MC-BLiSi-1 | 1 | 2 | 18 | W05PF22 | 14.6 | 4.39 | 0.688 | 1.71 | 2.69 | 0.720 | 15.8 |
| LRM | 1 | 2 | 19 | LRMPF123 | 5.03 | 2.38 | 0.102 | 1.02 | <0.100 | <0.100 | 25.2 |
| LRM | 2 | 1 | 1 | LRMPF211 | 5.09 | 2.53 | 0.114 | 1.03 | <0.100 | <0.100 | 25.6 |
| NP2-High-B | 2 | 1 | 2 | W29PF21 | 13.9 | 6.63 | 0.650 | 1.69 | 2.17 | 0.727 | 13.1 |
| NP-MC-AlBNa-1 | 2 | 1 | 3 | W13PF11 | 13.6 | 4.57 | 0.837 | 2.05 | 2.64 | 0.886 | 15.3 |

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

| ID | Block | Sub-Blk | Sequence | Lab ID | Al (wt%) | B (wt%) | Cr (wt%) | Fe (wt%) | Li (wt%) | Mn (wt%) | Si (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NP-MC-AlLi-1 | 2 | 1 | 4 | W09PF21 | 12.9 | 5.36 | 0.781 | 1.88 | 1.80 | 0.810 | 14.2 |
| NP-MC-AlBNa-1 | 2 | 1 | 5 | W13PF21 | 14.0 | 4.69 | 0.840 | 2.05 | 2.63 | 0.886 | 15.6 |
| NP2-High-B | 2 | 1 | 6 | W29PF11 | 14.0 | 6.62 | 0.681 | 1.75 | 2.24 | 0.756 | 13.0 |
| NP2-Low-Si | 2 | 1 | 7 | W16PF21 | 15.6 | 5.63 | 0.772 | 1.88 | 2.40 | 0.816 | 12.3 |
| NP-MC-AlLiSi-1 | 2 | 1 | 8 | W19PF11 | 13.2 | 6.42 | 0.862 | 2.07 | 1.75 | 0.908 | 12.2 |
| NP2-Low-Si | 2 | 1 | 9 | W16PF11 | 15.6 | 5.62 | 0.758 | 1.85 | 2.36 | 0.802 | 12.3 |
| LRM | 2 | 1 | 10 | LRMPF212 | 5.00 | 2.41 | 0.117 | 1.04 | <0.100 | <0.100 | 25.2 |
| NP-MC-AlLi-1 | 2 | 1 | 11 | W09PF11 | 13.0 | 5.50 | 0.770 | 1.87 | 1.79 | 0.810 | 14.4 |
| NP2-High-Si | 2 | 1 | 12 | W23PF21 | 14.0 | 4.80 | 0.677 | 1.67 | 2.13 | 0.721 | 15.5 |
| NP2-High-Li | 2 | 1 | 13 | W30PF11 | 14.9 | 5.27 | 0.709 | 1.71 | 2.69 | 0.740 | 13.8 |
| NP-MC-BSi-1 | 2 | 1 | 14 | W06PF11 | 13.2 | 6.18 | 0.649 | 1.60 | 2.02 | 0.682 | 14.9 |
| NP-MC-AlLiSi-1 | 2 | 1 | 15 | W19PF21 | 13.5 | 6.53 | 0.895 | 2.14 | 1.82 | 0.946 | 12.4 |
| NP-MC-BSi-1 | 2 | 1 | 16 | W06PF21 | 13.4 | 6.35 | 0.655 | 1.61 | 2.05 | 0.688 | 15.2 |
| NP2-High-Li | 2 | 1 | 17 | W30PF21 | 15.0 | 5.46 | 0.711 | 1.71 | 2.69 | 0.740 | 13.9 |
| NP2-High-Si | 2 | 1 | 18 | W23PF11 | 14.3 | 5.09 | 0.696 | 1.68 | 2.15 | 0.723 | 15.8 |
| LRM | 2 | 1 | 19 | LRMPF213 | 4.89 | 2.30 | 0.114 | 1.02 | <0.100 | <0.100 | 24.6 |
| LRM | 2 | 2 | 1 | LRMPF221 | 4.94 | 2.41 | 0.144 | 1.05 | <0.100 | <0.100 | 24.8 |
| NP-MC-AlLi-1 | 2 | 2 | 2 | W09PF12 | 13.1 | 5.61 | 0.786 | 1.86 | 1.77 | 0.821 | 14.6 |
| NP-MC-BSi-1 | 2 | 2 | 3 | W06PF22 | 13.3 | 6.35 | 0.668 | 1.59 | 2.00 | 0.695 | 15.2 |
| NP2-Low-Si | 2 | 2 | 4 | W16PF12 | 15.7 | 5.58 | 0.792 | 1.87 | 2.40 | 0.830 | 12.4 |
| NP2-High-B | 2 | 2 | 5 | W29PF22 | 14.1 | 6.62 | 0.700 | 1.74 | 2.22 | 0.769 | 13.2 |
| NP-MC-AlBNa-1 | 2 | 2 | 6 | W13PF22 | 14.0 | 4.67 | 0.828 | 1.97 | 2.53 | 0.863 | 15.6 |
| NP2-High-Li | 2 | 2 | 7 | W30PF22 | 14.7 | 5.30 | 0.745 | 1.74 | 2.71 | 0.767 | 13.7 |
| NP-MC-AlLiSi-1 | 2 | 2 | 8 | W19PF22 | 13.2 | 6.33 | 0.899 | 2.11 | 1.79 | 0.943 | 12.2 |
| NP-MC-BSi-1 | 2 | 2 | 9 | W06PF12 | 13.2 | 6.30 | 0.650 | 1.55 | 1.95 | 0.675 | 15.1 |
| LRM | 2 | 2 | 10 | LRMPF222 | 4.97 | 2.40 | 0.144 | 1.03 | <0.100 | <0.100 | 25.0 |
| NP2-High-Si | 2 | 2 | 11 | W23PF12 | 14.2 | 4.96 | 0.718 | 1.68 | 2.13 | 0.742 | 15.7 |
| NP-MC-AlBNa-1 | 2 | 2 | 12 | W13PF12 | 14.1 | 4.64 | 0.844 | 2.01 | 2.56 | 0.883 | 15.6 |
| NP2-High-B | 2 | 2 | 13 | W29PF12 | 14.1 | 6.56 | 0.671 | 1.67 | 2.12 | 0.734 | 13.0 |
| NP-MC-AlLi-1 | 2 | 2 | 14 | W09PF22 | 13.3 | 5.53 | 0.784 | 1.85 | 1.75 | 0.808 | 14.5 |
| NP2-Low-Si | 2 | 2 | 15 | W16PF22 | 15.7 | 5.56 | 0.793 | 1.88 | 2.39 | 0.831 | 12.4 |
| NP2-High-Si | 2 | 2 | 16 | W23PF22 | 14.2 | 5.07 | 0.703 | 1.68 | 2.13 | 0.741 | 15.7 |
| NP2-High-Li | 2 | 2 | 17 | W30PF12 | 14.8 | 5.36 | 0.718 | 1.68 | 2.62 | 0.742 | 13.7 |
| NP-MC-AlLiSi-1 | 2 | 2 | 18 | W19PF12 | 13.2 | 6.36 | 0.906 | 2.12 | 1.80 | 0.948 | 12.2 |
| LRM | 2 | 2 | 19 | LRMPF223 | 5.17 | 2.50 | 0.147 | 1.05 | <0.100 | <0.100 | 25.9 |
| LRM | 3 | 1 | 1 | LRMPF311 | 5.11 | 2.48 | <0.100 | 0.982 | <0.100 | <0.100 | 25.5 |
| NP-MC-AlNa-1 | 3 | 1 | 2 | W28PF21 | 13.4 | 5.39 | 0.666 | 1.71 | 2.23 | 0.704 | 14.0 |
| NP-MC-AlB-1 | 3 | 1 | 3 | W02PF11 | 13.3 | 6.92 | 0.628 | 1.61 | 2.07 | 0.650 | 13.4 |
| NP-MC-AlNa-1 | 3 | 1 | 4 | W28PF11 | 13.4 | 5.29 | 0.678 | 1.73 | 2.24 | 0.711 | 13.9 |
| NP-MC-AlBSi-1 | 3 | 1 | 5 | W08PF21 | 16.6 | 6.81 | 0.560 | 1.44 | 1.86 | 0.576 | 12.5 |
| NP2-Low-B | 3 | 1 | 6 | W27PF11 | 15.3 | 4.20 | 0.716 | 1.84 | 2.35 | 0.756 | 14.3 |
| NP-MC-BNa-1 | 3 | 1 | 7 | W03PF21 | 14.8 | 4.28 | 0.681 | 1.74 | 2.22 | 0.713 | 13.9 |

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

| ID | Block | Sub-Blk | Sequence | Lab ID | Al (wt%) | B (wt%) | Cr (wt%) | Fe (wt%) | Li (wt%) | Mn (wt%) | Si (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NP-MC-AlB-1 | 3 | 1 | 8 | W02PF21 | 13.2 | 6.71 | 0.654 | 1.75 | 2.13 | 0.679 | 13.5 |
| NP-MC-AlSi-1 | 3 | 1 | 9 | W17PF11 | 13.0 | 6.02 | 0.769 | 1.96 | 2.48 | 0.799 | 12.2 |
| LRM | 3 | 1 | 10 | LRMPF312 | 5.01 | 2.34 | <0.100 | 0.946 | <0.100 | <0.100 | 25.1 |
| BL3 | 3 | 1 | 11 | W15PF11 | 14.8 | 5.29 | 0.700 | 1.81 | 2.28 | 0.733 | 13.9 |
| NP-MC-AlSi-1 | 3 | 1 | 12 | W17PF21 | 13.3 | 6.18 | 0.794 | 2.04 | 2.57 | 0.831 | 12.4 |
| NP2-Very-Low-Si | 3 | 1 | 13 | W31PF11 | 16.1 | 5.78 | 0.747 | 1.89 | 2.44 | 0.776 | 10.3 |
| BL3 | 3 | 1 | 14 | W15PF21 | 14.5 | 5.10 | 0.656 | 1.69 | 2.15 | 0.683 | 13.5 |
| NP-MC-BNa-1 | 3 | 1 | 15 | W03PF11 | 14.8 | 4.18 | 0.671 | 1.73 | 2.18 | 0.700 | 13.9 |
| NP2-Very-Low-Si | 3 | 1 | 16 | W31PF21 | 16.5 | 5.78 | 0.775 | 1.97 | 2.51 | 0.802 | 10.6 |
| NP-MC-AlBSi-1 | 3 | 1 | 17 | W08PF11 | 16.6 | 6.75 | 0.596 | 1.53 | 1.96 | 0.616 | 12.5 |
| NP2-Low-B | 3 | 1 | 18 | W27PF21 | 15.6 | 4.39 | 0.712 | 1.83 | 2.34 | 0.752 | 14.7 |
| LRM | 3 | 1 | 19 | LRMPF313 | 5.03 | 2.34 | <0.100 | 1.01 | <0.100 | <0.100 | 25.2 |
| LRM | 3 | 2 | 1 | LRMPF321 | 4.96 | 2.24 | <0.100 | 0.970 | <0.100 | <0.100 | 25.0 |
| NP-MC-AlNa-1 | 3 | 2 | 2 | W28PF12 | 13.0 | 4.92 | 0.676 | 1.76 | 2.29 | 0.708 | 13.5 |
| NP-MC-AlB-1 | 3 | 2 | 3 | W02PF12 | 13.0 | 6.43 | 0.647 | 1.70 | 2.17 | 0.670 | 13.1 |
| BL3 | 3 | 2 | 4 | W15PF22 | 14.8 | 5.22 | 0.678 | 1.78 | 2.26 | 0.708 | 13.9 |
| NP2-Low-B | 3 | 2 | 5 | W27PF22 | 15.6 | 4.33 | 0.698 | 1.84 | 2.37 | 0.741 | 14.7 |
| NP-MC-BNa-1 | 3 | 2 | 6 | W03PF12 | 15.2 | 4.37 | 0.681 | 1.79 | 2.28 | 0.713 | 14.2 |
| NP-MC-AlB-1 | 3 | 2 | 7 | W02PF22 | 13.6 | 6.99 | 0.677 | 1.85 | 2.25 | 0.706 | 14.0 |
| NP-MC-AlBSi-1 | 3 | 2 | 8 | W08PF22 | 16.8 | 6.95 | 0.542 | 1.42 | 1.83 | 0.554 | 12.7 |
| NP-MC-AlSi-1 | 3 | 2 | 9 | W17PF12 | 13.3 | 6.18 | 0.795 | 2.07 | 2.62 | 0.833 | 12.5 |
| LRM | 3 | 2 | 10 | LRMPF322 | 5.00 | 2.30 | <0.100 | 0.993 | <0.100 | <0.100 | 25.1 |
| NP-MC-AlNa-1 | 3 | 2 | 11 | W28PF22 | 13.0 | 5.00 | 0.684 | 1.78 | 2.31 | 0.720 | 13.5 |
| BL3 | 3 | 2 | 12 | W15PF12 | 14.9 | 5.10 | 0.671 | 1.76 | 2.24 | 0.699 | 13.9 |
| NP2-Low-B | 3 | 2 | 13 | W27PF12 | 15.4 | 4.20 | 0.718 | 1.89 | 2.42 | 0.764 | 14.4 |
| NP2-Very-Low-Si | 3 | 2 | 14 | W31PF22 | 16.6 | 5.86 | 0.803 | 2.08 | 2.67 | 0.837 | 10.5 |
| NP-MC-BNa-1 | 3 | 2 | 15 | W03PF22 | 15.1 | 4.40 | 0.688 | 1.79 | 2.31 | 0.718 | 14.1 |
| NP-MC-AlBSi-1 | 3 | 2 | 16 | W08PF12 | 16.6 | 6.82 | 0.553 | 1.46 | 1.89 | 0.568 | 12.5 |
| NP2-Very-Low-Si | 3 | 2 | 17 | W31PF12 | 16.6 | 5.94 | 0.777 | 1.99 | 2.57 | 0.807 | 10.5 |
| NP-MC-AlSi-1 | 3 | 2 | 18 | W17PF22 | 13.4 | 5.99 | 0.817 | 2.12 | 2.69 | 0.857 | 12.5 |
| LRM | 3 | 2 | 19 | LRMPF323 | 4.99 | 2.14 | <0.100 | 0.999 | <0.100 | <0.100 | 24.8 |
| LRM | 4 | 1 | 1 | LRMPF411 | 5.02 | 2.29 | <0.100 | 1.00 | <0.100 | <0.100 | 24.8 |
| NP2-Very-High-Si | 4 | 1 | 2 | W25PF11 | 13.2 | 4.74 | 0.626 | 1.56 | 2.01 | 0.646 | 17.3 |
| NP2-Low-Al | 4 | 1 | 3 | W04PF21 | 13.3 | 5.64 | 0.765 | 1.85 | 2.37 | 0.780 | 14.5 |
| Neph-NN-1-12 | 4 | 1 | 4 | W26PF21 | 14.2 | 5.43 | 0.278 | 1.65 | 2.57 | 0.681 | 13.8 |
| NP-MC-AlBNa-2 | 4 | 1 | 5 | W22PF21 | 15.5 | 6.10 | 0.620 | 1.49 | 1.95 | 0.644 | 12.2 |
| NP-MC-BLiSi-2 | 4 | 1 | 6 | W12PF11 | 14.3 | 6.98 | 0.692 | 1.68 | 2.74 | 0.711 | 12.5 |
| Neph-NN-1-12 | 4 | 1 | 7 | W26PF11 | 13.8 | 5.30 | 0.286 | 1.65 | 2.58 | 0.687 | 13.5 |
| NP-MC-AlLi-2 | 4 | 1 | 8 | W07PF21 | 16.3 | 5.10 | 0.681 | 1.66 | 1.75 | 0.708 | 13.3 |
| NP-MC-AlLi-2 | 4 | 1 | 9 | W07PF11 | 16.3 | 4.95 | 0.694 | 1.70 | 1.79 | 0.723 | 13.3 |
| LRM | 4 | 1 | 10 | LRMPF412 | 5.00 | 2.28 | <0.100 | 0.990 | <0.100 | <0.100 | 24.8 |
| NP2-Very-High-Si | 4 | 1 | 11 | W25PF21 | 13.6 | 4.96 | 0.632 | 1.55 | 1.99 | 0.652 | 17.9 |

**Table A-2. PF Measurements of the Nepheline Study Glasses (continued)**

| ID | Block | Sub-Blk | Sequence | Lab ID | Al (wt%) | B (wt%) | Cr (wt%) | Fe (wt%) | Li (wt%) | Mn (wt%) | Si (wt%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NP-MC-BNaSi-1 | 4 | 1 | 12 | W11PF11 | 16.4 | 4.52 | 0.799 | 1.91 | 2.46 | 0.826 | 12.4 |
| NP-MC-AlBNa-2 | 4 | 1 | 13 | W22PF11 | 15.8 | 6.18 | 0.641 | 1.51 | 1.99 | 0.660 | 12.4 |
| NP-MC-BLiSi-2 | 4 | 1 | 14 | W12PF21 | 14.1 | 6.84 | 0.646 | 1.53 | 2.01 | 0.669 | 12.3 |
| NP-MC-BNaSi-1 | 4 | 1 | 15 | W11PF21 | 16.0 | 4.34 | 0.794 | 1.88 | 2.44 | 0.814 | 12.2 |
| NP2-Low-Al | 4 | 1 | 16 | W04PF11 | 13.1 | 5.38 | 0.748 | 1.79 | 2.30 | 0.764 | 14.2 |
| LRM | 4 | 1 | 17 | LRMPF413 | 5.03 | 2.27 | <0.100 | 1.01 | <0.100 | <0.100 | 25.0 |
| LRM | 4 | 2 | 1 | LRMPF421 | 5.08 | 2.40 | <0.100 | 1.02 | <0.100 | <0.100 | 25.2 |
| NP-MC-BLiSi-2 | 4 | 2 | 2 | W12PF22 | 14.0 | 6.64 | 0.667 | 1.64 | 2.67 | 0.692 | 12.2 |
| NP2-Very-High-Si | 4 | 2 | 3 | W25PF22 | 13.2 | 4.73 | 0.632 | 1.53 | 1.97 | 0.645 | 17.4 |
| Neph-NN-1-12 | 4 | 2 | 4 | W26PF12 | 14.0 | 5.23 | 0.279 | 1.63 | 2.55 | 0.681 | 13.6 |
| NP-MC-BNaSi-1 | 4 | 2 | 5 | W11PF22 | 16.2 | 4.40 | 0.807 | 1.92 | 2.49 | 0.830 | 12.3 |
| NP-MC-AlLi-2 | 4 | 2 | 6 | W07PF12 | 16.5 | 5.16 | 0.685 | 1.68 | 1.78 | 0.719 | 13.5 |
| NP-MC-AlBNa-2 | 4 | 2 | 7 | W22PF22 | 15.6 | 5.99 | 0.628 | 1.49 | 1.98 | 0.651 | 12.3 |
| NP-MC-AlLi-2 | 4 | 2 | 8 | W07PF22 | 16.5 | 5.16 | 0.690 | 1.67 | 1.78 | 0.719 | 13.5 |
| NP-MC-BLiSi-2 | 4 | 2 | 9 | W12PF12 | 14.2 | 6.74 | 0.675 | 1.63 | 2.69 | 0.695 | 12.4 |
| LRM | 4 | 2 | 10 | LRMPF422 | 5.00 | 2.28 | <0.100 | 1.03 | <0.100 | <0.100 | 24.8 |
| NP2-Low-Al | 4 | 2 | 11 | W04PF22 | 13.3 | 5.47 | 0.752 | 1.78 | 2.29 | 0.764 | 14.4 |
| NP2-Very-High-Si | 4 | 2 | 12 | W25PF12 | 13.3 | 4.81 | 0.629 | 1.52 | 1.97 | 0.644 | 17.5 |
| NP-MC-BNaSi-1 | 4 | 2 | 13 | W11PF12 | 16.3 | 4.39 | 0.805 | 1.91 | 2.48 | 0.831 | 12.4 |
| Neph-NN-1-12 | 4 | 2 | 14 | W26PF22 | 14.0 | 5.22 | 0.277 | 1.59 | 2.53 | 0.672 | 13.7 |
| NP-MC-AlBNa-2 | 4 | 2 | 15 | W22PF12 | 15.5 | 5.89 | 0.596 | 1.41 | 1.87 | 0.617 | 12.2 |
| NP2-Low-Al | 4 | 2 | 16 | W04PF12 | 13.2 | 5.49 | 0.736 | 1.75 | 2.26 | 0.748 | 14.4 |
| LRM | 4 | 2 | 17 | LRMPF423 | 5.08 | 2.38 | <0.100 | 0.969 | <0.100 | <0.100 | 25.3 |

**Table A-3. Comparison of Targeted and Measured Glass Compositions**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| BL3 | $Al_2O_3$ | | 27.870 | 28.500 | -0.630 | -2.2% |
| BL3 | $B_2O_3$ | | 16.671 | 17.200 | -0.529 | -3.1% |
| BL3 | $Bi_2O_3$ | | 0.603 | 0.650 | -0.047 | |
| BL3 | CaO | | 0.604 | 0.650 | -0.046 | |
| BL3 | $Cr_2O_3$ | | 0.988 | 1.100 | -0.112 | |
| BL3 | $Fe_2O_3$ | | 2.516 | 2.500 | 0.016 | |
| BL3 | $Li_2O$ | | 4.806 | 5.000 | -0.194 | -3.9% |
| BL3 | MnO | | 0.911 | 1.000 | -0.089 | |
| BL3 | $Na_2O$ | | 13.200 | 12.500 | 0.700 | 5.6% |
| BL3 | NiO | < | 0.127 | 0.000 | 0.127 | |
| BL3 | $P_2O_5$ | | 0.666 | 0.700 | -0.034 | |
| BL3 | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| BL3 | $SiO_2$ | | 29.522 | 29.350 | 0.172 | 0.6% |
| BL3 | $SO_3$ | | 0.256 | 0.250 | 0.006 | |
| BL3 | $ZrO_2$ | | 0.254 | 0.250 | 0.004 | |
| BL3 | Sum | | 99.128 | 99.700 | -0.572 | -0.6% |
| LRM | $Al_2O_3$ | | 9.503 | 9.510 | -0.007 | -0.1% |
| LRM | $B_2O_3$ | | 7.661 | 7.850 | -0.189 | -2.4% |
| LRM | $Bi_2O_3$ | < | 0.111 | 0.000 | 0.111 | |
| LRM | CaO | | 0.460 | 0.540 | -0.080 | |
| LRM | $Cr_2O_3$ | < | 0.157 | 0.190 | -0.033 | |
| LRM | $Fe_2O_3$ | | 1.433 | 1.380 | 0.053 | |
| LRM | $Li_2O$ | < | 0.215 | 0.110 | 0.105 | |
| LRM | MnO | < | 0.129 | 0.080 | 0.049 | |
| LRM | $Na_2O$ | | 21.366 | 20.030 | 1.336 | 6.7% |
| LRM | NiO | | 0.177 | 0.190 | -0.013 | |
| LRM | $P_2O_5$ | | 0.495 | 0.540 | -0.045 | |
| LRM | $RuO_2$ | < | 0.132 | 0.000 | 0.132 | |
| LRM | $SiO_2$ | | 53.857 | 54.200 | -0.343 | -0.6% |
| LRM | $SO_3$ | | 0.218 | 0.300 | -0.082 | |
| LRM | $ZrO_2$ | | 0.959 | 0.930 | 0.029 | |
| LRM | Sum | | 96.873 | 95.850 | 1.023 | 1.1% |
| Neph-NN-1-12 | $Al_2O_3$ | | 26.453 | 26.920 | -0.467 | -1.7% |
| Neph-NN-1-12 | $B_2O_3$ | | 17.049 | 17.000 | 0.049 | 0.3% |
| Neph-NN-1-12 | $Bi_2O_3$ | | 0.640 | 0.710 | -0.070 | |
| Neph-NN-1-12 | CaO | | 0.426 | 0.470 | -0.044 | |
| Neph-NN-1-12 | $Cr_2O_3$ | | 0.409 | 0.470 | -0.061 | |
| Neph-NN-1-12 | $Fe_2O_3$ | | 2.330 | 2.360 | -0.030 | |
| Neph-NN-1-12 | $Li_2O$ | | 5.506 | 5.670 | -0.164 | -2.9% |
| Neph-NN-1-12 | MnO | | 0.878 | 0.940 | -0.062 | |
| Neph-NN-1-12 | $Na_2O$ | | 16.075 | 15.000 | 1.075 | 7.2% |
| Neph-NN-1-12 | NiO | | 0.191 | 0.240 | -0.049 | |
| Neph-NN-1-12 | $P_2O_5$ | | 0.876 | 0.940 | -0.064 | |
| Neph-NN-1-12 | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| Neph-NN-1-12 | $SiO_2$ | | 29.201 | 28.990 | 0.211 | 0.7% |
| Neph-NN-1-12 | $SO_3$ | | 0.253 | 0.240 | 0.013 | |
| Neph-NN-1-12 | $ZrO_2$ | < | 0.135 | 0.000 | 0.135 | |
| Neph-NN-1-12 | Sum | | 100.555 | 100.000 | 0.555 | 0.6% |
| NP2-High-Al | $Al_2O_3$ | | 31.224 | 31.500 | -0.276 | -0.9% |
| NP2-High-Al | $B_2O_3$ | | 16.478 | 16.480 | -0.002 | 0.0% |
| NP2-High-Al | $Bi_2O_3$ | | 0.572 | 0.620 | -0.048 | |
| NP2-High-Al | CaO | | 0.511 | 0.620 | -0.109 | |
| NP2-High-Al | $Cr_2O_3$ | | 0.956 | 1.050 | -0.094 | |
| NP2-High-Al | $Fe_2O_3$ | | 2.388 | 2.400 | -0.012 | |
| NP2-High-Al | $Li_2O$ | | 4.596 | 4.790 | -0.194 | |
| NP2-High-Al | MnO | | 0.883 | 0.960 | -0.077 | |
| NP2-High-Al | $Na_2O$ | | 12.745 | 11.980 | 0.765 | 6.4% |
| NP2-High-Al | NiO | < | 0.127 | 0.000 | 0.127 | |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP2-High-Al | $P_2O_5$ | | 0.635 | 0.670 | -0.035 | |
| NP2-High-Al | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-High-Al | $SiO_2$ | | 28.506 | 28.120 | 0.386 | 1.4% |
| NP2-High-Al | $SO_3$ | | 0.215 | 0.240 | -0.025 | |
| NP2-High-Al | $ZrO_2$ | | 0.230 | 0.240 | -0.010 | |
| NP2-High-Al | Sum | | 100.198 | 99.720 | 0.478 | 0.5% |
| NP2-High-B | $Al_2O_3$ | | 26.500 | 26.850 | -0.350 | -1.3% |
| NP2-High-B | $B_2O_3$ | | 21.275 | 22.000 | -0.725 | -3.3% |
| NP2-High-B | $Bi_2O_3$ | | 0.567 | 0.610 | -0.043 | |
| NP2-High-B | CaO | | 0.505 | 0.610 | -0.105 | |
| NP2-High-B | $Cr_2O_3$ | | 0.987 | 1.040 | -0.053 | |
| NP2-High-B | $Fe_2O_3$ | | 2.448 | 2.360 | 0.088 | |
| NP2-High-B | $Li_2O$ | | 4.709 | 4.710 | -0.001 | |
| NP2-High-B | MnO | | 0.964 | 0.940 | 0.024 | |
| NP2-High-B | $Na_2O$ | | 12.331 | 11.780 | 0.551 | 4.7% |
| NP2-High-B | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-High-B | $P_2O_5$ | | 0.634 | 0.660 | -0.026 | |
| NP2-High-B | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-High-B | $SiO_2$ | | 27.971 | 27.650 | 0.321 | 1.2% |
| NP2-High-B | $SO_3$ | | 0.185 | 0.240 | -0.055 | |
| NP2-High-B | $ZrO_2$ | | 0.242 | 0.240 | 0.002 | |
| NP2-High-B | Sum | | 99.579 | 99.740 | -0.161 | -0.2% |
| NP2-High-Li | $Al_2O_3$ | | 28.059 | 28.200 | -0.141 | -0.5% |
| NP2-High-Li | $B_2O_3$ | | 17.218 | 17.020 | 0.198 | 1.2% |
| NP2-High-Li | $Bi_2O_3$ | | 0.590 | 0.640 | -0.050 | |
| NP2-High-Li | CaO | | 0.604 | 0.640 | -0.036 | |
| NP2-High-Li | $Cr_2O_3$ | | 1.053 | 1.090 | -0.037 | |
| NP2-High-Li | $Fe_2O_3$ | | 2.445 | 2.470 | -0.025 | |
| NP2-High-Li | $Li_2O$ | | 5.764 | 6.000 | -0.236 | -3.9% |
| NP2-High-Li | MnO | | 0.965 | 0.990 | -0.025 | |
| NP2-High-Li | $Na_2O$ | | 13.251 | 12.370 | 0.881 | 7.1% |
| NP2-High-Li | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-High-Li | $P_2O_5$ | | 0.662 | 0.690 | -0.028 | |
| NP2-High-Li | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-High-Li | $SiO_2$ | | 29.469 | 29.040 | 0.429 | 1.5% |
| NP2-High-Li | $SO_3$ | | 0.269 | 0.250 | 0.019 | |
| NP2-High-Li | $ZrO_2$ | | 0.254 | 0.250 | 0.004 | |
| NP2-High-Li | Sum | | 100.862 | 99.700 | 1.162 | 1.2% |
| NP2-High-Na | $Al_2O_3$ | | 27.162 | 27.520 | -0.358 | -1.3% |
| NP2-High-Na | $B_2O_3$ | | 16.566 | 16.610 | -0.044 | -0.3% |
| NP2-High-Na | $Bi_2O_3$ | | 0.576 | 0.630 | -0.054 | |
| NP2-High-Na | CaO | | 0.586 | 0.630 | -0.044 | |
| NP2-High-Na | $Cr_2O_3$ | | 0.960 | 1.060 | -0.100 | |
| NP2-High-Na | $Fe_2O_3$ | | 2.366 | 2.410 | -0.044 | |
| NP2-High-Na | $Li_2O$ | | 4.613 | 4.830 | -0.217 | |
| NP2-High-Na | MnO | | 0.890 | 0.970 | -0.080 | |
| NP2-High-Na | $Na_2O$ | | 16.446 | 15.500 | 0.946 | 6.1% |
| NP2-High-Na | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-High-Na | $P_2O_5$ | | 0.626 | 0.680 | -0.054 | |
| NP2-High-Na | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-High-Na | $SiO_2$ | | 28.560 | 28.340 | 0.220 | 0.8% |
| NP2-High-Na | $SO_3$ | | 0.260 | 0.240 | 0.020 | |
| NP2-High-Na | $ZrO_2$ | | 0.462 | 0.240 | 0.222 | |
| NP2-High-Na | Sum | | 100.330 | 99.710 | 0.620 | 0.6% |
| NP2-High-Si | $Al_2O_3$ | | 26.784 | 27.030 | -0.246 | -0.9% |
| NP2-High-Si | $B_2O_3$ | | 16.035 | 16.310 | -0.275 | -1.7% |
| NP2-High-Si | $Bi_2O_3$ | | 0.574 | 0.620 | -0.046 | |
| NP2-High-Si | CaO | | 0.513 | 0.620 | -0.107 | |
| NP2-High-Si | $Cr_2O_3$ | | 1.021 | 1.040 | -0.019 | |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP2-High-Si | $Fe_2O_3$ | | 2.398 | 2.370 | 0.028 | |
| NP2-High-Si | $Li_2O$ | | 4.596 | 4.740 | -0.144 | |
| NP2-High-Si | MnO | | 0.945 | 0.950 | -0.005 | |
| NP2-High-Si | $Na_2O$ | | 12.567 | 11.850 | 0.717 | 6.0% |
| NP2-High-Si | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-High-Si | $P_2O_5$ | | 0.623 | 0.660 | -0.037 | |
| NP2-High-Si | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-High-Si | $SiO_2$ | | 33.534 | 33.000 | 0.534 | 1.6% |
| NP2-High-Si | $SO_3$ | | 0.189 | 0.240 | -0.051 | |
| NP2-High-Si | $ZrO_2$ | | 0.226 | 0.240 | -0.014 | |
| NP2-High-Si | Sum | | 100.263 | 99.720 | 0.543 | 0.5% |
| NP2-Low-Al | $Al_2O_3$ | | 24.989 | 25.500 | -0.511 | -2.0% |
| NP2-Low-Al | $B_2O_3$ | | 17.693 | 17.920 | -0.227 | -1.3% |
| NP2-Low-Al | $Bi_2O_3$ | | 0.624 | 0.680 | -0.056 | |
| NP2-Low-Al | CaO | | 0.576 | 0.680 | -0.104 | |
| NP2-Low-Al | $Cr_2O_3$ | | 1.097 | 1.150 | -0.053 | |
| NP2-Low-Al | $Fe_2O_3$ | | 2.563 | 2.600 | -0.037 | |
| NP2-Low-Al | $Li_2O$ | | 4.962 | 5.210 | -0.248 | -4.8% |
| NP2-Low-Al | MnO | | 0.986 | 1.040 | -0.054 | |
| NP2-Low-Al | $Na_2O$ | | 13.352 | 13.020 | 0.332 | 2.5% |
| NP2-Low-Al | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Low-Al | $P_2O_5$ | | 0.691 | 0.730 | -0.039 | |
| NP2-Low-Al | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Low-Al | $SiO_2$ | | 30.752 | 30.580 | 0.172 | 0.6% |
| NP2-Low-Al | $SO_3$ | | 0.250 | 0.260 | -0.010 | |
| NP2-Low-Al | $ZrO_2$ | | 0.266 | 0.260 | 0.006 | |
| NP2-Low-Al | Sum | | 99.062 | 99.680 | -0.618 | -0.6% |
| NP2-Low-B | $Al_2O_3$ | | 29.240 | 29.600 | -0.360 | -1.2% |
| NP2-Low-B | $B_2O_3$ | | 13.781 | 14.000 | -0.219 | -1.6% |
| NP2-Low-B | $Bi_2O_3$ | | 0.620 | 0.680 | -0.060 | |
| NP2-Low-B | CaO | | 0.630 | 0.680 | -0.050 | |
| NP2-Low-B | $Cr_2O_3$ | | 1.039 | 1.140 | -0.101 | |
| NP2-Low-B | $Fe_2O_3$ | | 2.645 | 2.600 | 0.045 | |
| NP2-Low-B | $Li_2O$ | | 5.102 | 5.190 | -0.088 | -1.7% |
| NP2-Low-B | MnO | | 0.973 | 1.040 | -0.067 | |
| NP2-Low-B | $Na_2O$ | | 13.783 | 12.980 | 0.803 | 6.2% |
| NP2-Low-B | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Low-B | $P_2O_5$ | | 0.699 | 0.730 | -0.031 | |
| NP2-Low-B | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Low-B | $SiO_2$ | | 31.073 | 30.480 | 0.593 | 1.9% |
| NP2-Low-B | $SO_3$ | | 0.228 | 0.260 | -0.032 | |
| NP2-Low-B | $ZrO_2$ | | 0.261 | 0.260 | 0.001 | |
| NP2-Low-B | Sum | | 100.333 | 99.690 | 0.643 | 0.6% |
| NP2-Low-Li | $Al_2O_3$ | | 28.390 | 28.800 | -0.410 | -1.4% |
| NP2-Low-Li | $B_2O_3$ | | 17.251 | 17.380 | -0.129 | -0.7% |
| NP2-Low-Li | $Bi_2O_3$ | | 0.608 | 0.660 | -0.052 | |
| NP2-Low-Li | CaO | | 0.625 | 0.660 | -0.035 | |
| NP2-Low-Li | $Cr_2O_3$ | | 1.016 | 1.110 | -0.094 | |
| NP2-Low-Li | $Fe_2O_3$ | | 2.506 | 2.530 | -0.024 | |
| NP2-Low-Li | $Li_2O$ | | 3.800 | 4.000 | -0.200 | |
| NP2-Low-Li | MnO | | 0.933 | 1.010 | -0.077 | |
| NP2-Low-Li | $Na_2O$ | | 13.355 | 12.630 | 0.725 | 5.7% |
| NP2-Low-Li | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Low-Li | $P_2O_5$ | | 0.665 | 0.710 | -0.045 | |
| NP2-Low-Li | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Low-Li | $SiO_2$ | | 30.057 | 29.660 | 0.397 | 1.3% |
| NP2-Low-Li | $SO_3$ | | 0.229 | 0.250 | -0.021 | |
| NP2-Low-Li | $ZrO_2$ | | 0.240 | 0.250 | -0.010 | |
| NP2-Low-Li | Sum | | 99.933 | 99.700 | 0.233 | 0.2% |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP2-Low-Na | $Al_2O_3$ | | 28.957 | 29.480 | -0.523 | -1.8% |
| NP2-Low-Na | $B_2O_3$ | | 17.307 | 17.790 | -0.483 | -2.7% |
| NP2-Low-Na | $Bi_2O_3$ | | 0.620 | 0.670 | -0.050 | |
| NP2-Low-Na | CaO | | 0.545 | 0.670 | -0.125 | |
| NP2-Low-Na | $Cr_2O_3$ | | 0.983 | 1.140 | -0.157 | |
| NP2-Low-Na | $Fe_2O_3$ | | 2.502 | 2.590 | -0.088 | |
| NP2-Low-Na | $Li_2O$ | | 4.812 | 5.170 | -0.358 | -6.9% |
| NP2-Low-Na | MnO | | 0.933 | 1.030 | -0.097 | |
| NP2-Low-Na | $Na_2O$ | | 10.188 | 9.500 | 0.688 | 7.2% |
| NP2-Low-Na | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Low-Na | $P_2O_5$ | | 0.679 | 0.720 | -0.041 | |
| NP2-Low-Na | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Low-Na | $SiO_2$ | | 30.539 | 30.360 | 0.179 | 0.6% |
| NP2-Low-Na | $SO_3$ | | 0.179 | 0.260 | -0.081 | |
| NP2-Low-Na | $ZrO_2$ | | 0.248 | 0.260 | -0.012 | |
| NP2-Low-Na | Sum | | 98.750 | 99.690 | -0.940 | -0.9% |
| NP2-Low-Si | $Al_2O_3$ | | 29.571 | 29.850 | -0.279 | -0.9% |
| NP2-Low-Si | $B_2O_3$ | | 18.023 | 18.020 | 0.003 | 0.0% |
| NP2-Low-Si | $Bi_2O_3$ | | 0.630 | 0.680 | -0.050 | |
| NP2-Low-Si | CaO | | 0.548 | 0.680 | -0.132 | |
| NP2-Low-Si | $Cr_2O_3$ | | 1.138 | 1.150 | -0.012 | |
| NP2-Low-Si | $Fe_2O_3$ | | 2.674 | 2.620 | 0.054 | |
| NP2-Low-Si | $Li_2O$ | | 5.140 | 5.240 | -0.100 | -1.9% |
| NP2-Low-Si | MnO | | 1.058 | 1.050 | 0.008 | |
| NP2-Low-Si | $Na_2O$ | | 13.268 | 13.090 | 0.178 | 1.4% |
| NP2-Low-Si | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Low-Si | $P_2O_5$ | | 0.692 | 0.730 | -0.038 | |
| NP2-Low-Si | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Low-Si | $SiO_2$ | | 26.420 | 26.000 | 0.420 | 1.6% |
| NP2-Low-Si | $SO_3$ | | 0.217 | 0.260 | -0.043 | |
| NP2-Low-Si | $ZrO_2$ | | 0.263 | 0.260 | 0.003 | |
| NP2-Low-Si | Sum | | 99.901 | 99.680 | 0.221 | 0.2% |
| NP2-Very-High-Al | $Al_2O_3$ | | 34.153 | 34.500 | -0.347 | -1.0% |
| NP2-Very-High-Al | $B_2O_3$ | | 15.737 | 15.760 | -0.023 | -0.1% |
| NP2-Very-High-Al | $Bi_2O_3$ | | 0.550 | 0.600 | -0.050 | |
| NP2-Very-High-Al | CaO | | 0.564 | 0.600 | -0.036 | |
| NP2-Very-High-Al | $Cr_2O_3$ | | 0.912 | 1.010 | -0.098 | |
| NP2-Very-High-Al | $Fe_2O_3$ | | 2.266 | 2.290 | -0.024 | |
| NP2-Very-High-Al | $Li_2O$ | | 4.354 | 4.580 | -0.226 | |
| NP2-Very-High-Al | MnO | | 0.836 | 0.920 | -0.084 | |
| NP2-Very-High-Al | $Na_2O$ | | 12.230 | 11.450 | 0.780 | 6.8% |
| NP2-Very-High-Al | NiO | < | 0.127 | 0.000 | 0.127 | |
| NP2-Very-High-Al | $P_2O_5$ | | 0.611 | 0.640 | -0.029 | |
| NP2-Very-High-Al | $RuO_2$ | < | 0.132 | 0.050 | 0.082 | |
| NP2-Very-High-Al | $SiO_2$ | | 27.276 | 26.890 | 0.386 | 1.4% |
| NP2-Very-High-Al | $SO_3$ | | 0.214 | 0.230 | -0.016 | |
| NP2-Very-High-Al | $ZrO_2$ | | 0.233 | 0.230 | 0.003 | |
| NP2-Very-High-Al | Sum | | 100.195 | 99.750 | 0.445 | 0.4% |
| NP2-Very-High-Si | $Al_2O_3$ | | 25.178 | 25.410 | -0.232 | -0.9% |
| NP2-Very-High-Si | $B_2O_3$ | | 15.488 | 15.340 | 0.148 | 1.0% |
| NP2-Very-High-Si | $Bi_2O_3$ | | 0.531 | 0.580 | -0.049 | |
| NP2-Very-High-Si | CaO | | 0.552 | 0.580 | -0.028 | |
| NP2-Very-High-Si | $Cr_2O_3$ | | 0.920 | 0.980 | -0.0596 | |
| NP2-Very-High-Si | $Fe_2O_3$ | | 2.202 | 2.230 | -0.0283 | |
| NP2-Very-High-Si | $Li_2O$ | | 4.274 | 4.460 | -0.1865 | |
| NP2-Very-High-Si | MnO | | 0.835 | 0.890 | -0.0549 | |
| NP2-Very-High-Si | $Na_2O$ | | 11.606 | 11.150 | 0.4563 | 4.1% |
| NP2-Very-High-Si | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP2-Very-High-Si | $P_2O_5$ | | 0.580 | 0.620 | -0.0397 | |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP2-Very-High-Si | $RuO_2$ | < | 0.132 | 0.040 | 0.0917 | |
| NP2-Very-High-Si | $SiO_2$ | | 37.491 | 37.000 | 0.4912 | 1.3% |
| NP2-Very-High-Si | $SO_3$ | | 0.195 | 0.220 | -0.0246 | |
| NP2-Very-High-Si | $ZrO_2$ | | 0.209 | 0.220 | -0.0113 | |
| NP2-Very-High-Si | Sum | | 100.320 | 99.720 | 0.6003 | 0.6% |
| NP2-Very-Low-Si | $Al_2O_3$ | | 31.082 | 31.460 | -0.3777 | -1.2% |
| NP2-Very-Low-Si | $B_2O_3$ | | 18.804 | 18.990 | -0.1858 | -1.0% |
| NP2-Very-Low-Si | $Bi_2O_3$ | | 0.655 | 0.720 | -0.0653 | |
| NP2-Very-Low-Si | CaO | | 0.585 | 0.720 | -0.1351 | |
| NP2-Very-Low-Si | $Cr_2O_3$ | | 1.133 | 1.210 | -0.0765 | |
| NP2-Very-Low-Si | $Fe_2O_3$ | | 2.834 | 2.760 | 0.0744 | |
| NP2-Very-Low-Si | $Li_2O$ | | 5.485 | 5.520 | -0.0355 | -0.6% |
| NP2-Very-Low-Si | MnO | | 1.040 | 1.100 | -0.0599 | |
| NP2-Very-Low-Si | $Na_2O$ | | 14.525 | 13.800 | 0.7247 | 5.3% |
| NP2-Very-Low-Si | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP2-Very-Low-Si | $P_2O_5$ | | 0.722 | 0.770 | -0.0482 | |
| NP2-Very-Low-Si | $RuO_2$ | < | 0.132 | 0.060 | 0.0717 | |
| NP2-Very-Low-Si | $SiO_2$ | | 22.409 | 22.000 | 0.4092 | 1.9% |
| NP2-Very-Low-Si | $SO_3$ | | 0.273 | 0.280 | -0.0066 | |
| NP2-Very-Low-Si | $ZrO_2$ | | 0.260 | 0.280 | -0.0196 | |
| NP2-Very-Low-Si | Sum | | 100.067 | 99.670 | 0.3968 | 0.4% |
| NP-MC-AlB-1 | $Al_2O_3$ | | 25.083 | 25.500 | -0.4169 | -1.6% |
| NP-MC-AlB-1 | $B_2O_3$ | | 21.775 | 22.000 | -0.2254 | -1.0% |
| NP-MC-AlB-1 | $Bi_2O_3$ | | 0.584 | 0.630 | -0.0461 | |
| NP-MC-AlB-1 | CaO | | 0.514 | 0.630 | -0.1161 | |
| NP-MC-AlB-1 | $Cr_2O_3$ | | 0.952 | 1.060 | -0.1078 | |
| NP-MC-AlB-1 | $Fe_2O_3$ | | 2.470 | 2.420 | 0.0498 | |
| NP-MC-AlB-1 | $Li_2O$ | | 4.639 | 4.830 | -0.1905 | |
| NP-MC-AlB-1 | MnO | | 0.873 | 0.970 | -0.0968 | |
| NP-MC-AlB-1 | $Na_2O$ | | 12.513 | 12.090 | 0.4228 | 3.5% |
| NP-MC-AlB-1 | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlB-1 | $P_2O_5$ | | 0.648 | 0.680 | -0.0321 | |
| NP-MC-AlB-1 | $RuO_2$ | < | 0.132 | 0.050 | 0.0817 | |
| NP-MC-AlB-1 | $SiO_2$ | | 28.881 | 28.380 | 0.5006 | 1.8% |
| NP-MC-AlB-1 | $SO_3$ | | 0.240 | 0.240 | -0.0003 | |
| NP-MC-AlB-1 | $ZrO_2$ | | 0.243 | 0.240 | 0.0035 | |
| NP-MC-AlB-1 | Sum | | 99.673 | 99.720 | -0.0465 | 0.0% |
| NP-MC-AlBNa-1 | $Al_2O_3$ | | 26.311 | 26.800 | -0.4887 | -1.8% |
| NP-MC-AlBNa-1 | $B_2O_3$ | | 14.948 | 15.390 | -0.4416 | -2.9% |
| NP-MC-AlBNa-1 | $Bi_2O_3$ | | 0.672 | 0.730 | -0.0578 | |
| NP-MC-AlBNa-1 | CaO | | 0.673 | 0.730 | -0.0573 | |
| NP-MC-AlBNa-1 | $Cr_2O_3$ | | 1.224 | 1.240 | -0.0163 | |
| NP-MC-AlBNa-1 | $Fe_2O_3$ | | 2.888 | 2.810 | 0.0780 | |
| NP-MC-AlBNa-1 | $Li_2O$ | | 5.576 | 5.620 | -0.0440 | -0.8% |
| NP-MC-AlBNa-1 | MnO | | 1.136 | 1.120 | 0.0156 | |
| NP-MC-AlBNa-1 | $Na_2O$ | | 11.478 | 10.800 | 0.6782 | 6.3% |
| NP-MC-AlBNa-1 | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlBNa-1 | $P_2O_5$ | | 0.756 | 0.790 | -0.0338 | |
| NP-MC-AlBNa-1 | $RuO_2$ | < | 0.132 | 0.060 | 0.0717 | |
| NP-MC-AlBNa-1 | $SiO_2$ | | 33.213 | 33.000 | 0.2126 | 0.6% |
| NP-MC-AlBNa-1 | $SO_3$ | | 0.265 | 0.280 | -0.0147 | |
| NP-MC-AlBNa-1 | $ZrO_2$ | | 0.285 | 0.280 | 0.0054 | |
| NP-MC-AlBNa-1 | Sum | | 99.684 | 99.650 | 0.0345 | 0.0% |
| NP-MC-AlBNa-2 | $Al_2O_3$ | | 29.476 | 29.830 | -0.3538 | -1.2% |
| NP-MC-AlBNa-2 | $B_2O_3$ | | 19.448 | 19.320 | 0.1282 | 0.7% |
| NP-MC-AlBNa-2 | $Bi_2O_3$ | | 0.535 | 0.580 | -0.0452 | |
| NP-MC-AlBNa-2 | CaO | | 0.550 | 0.580 | -0.0305 | |
| NP-MC-AlBNa-2 | $Cr_2O_3$ | | 0.908 | 0.970 | -0.0620 | |
| NP-MC-AlBNa-2 | $Fe_2O_3$ | | 2.109 | 2.210 | -0.1012 | |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP-MC-AlBNa-2 | $Li_2O$ | | 4.193 | 4.430 | -0.2372 | |
| NP-MC-AlBNa-2 | MnO | | 0.830 | 0.890 | -0.0598 | |
| NP-MC-AlBNa-2 | $Na_2O$ | | 14.828 | 13.830 | 0.9980 | 7.2% |
| NP-MC-AlBNa-2 | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlBNa-2 | $P_2O_5$ | | 0.585 | 0.620 | -0.0345 | |
| NP-MC-AlBNa-2 | $RuO_2$ | < | 0.132 | 0.040 | 0.0917 | |
| NP-MC-AlBNa-2 | $SiO_2$ | | 26.260 | 26.000 | 0.2599 | 1.0% |
| NP-MC-AlBNa-2 | $SO_3$ | | 0.213 | 0.220 | -0.0071 | |
| NP-MC-AlBNa-2 | $ZrO_2$ | | 0.211 | 0.220 | -0.0089 | |
| NP-MC-AlBNa-2 | Sum | | 100.405 | 99.740 | 0.6648 | 0.7% |
| NP-MC-AlBSi-1 | $Al_2O_3$ | | 31.460 | 31.500 | -0.0398 | -0.1% |
| NP-MC-AlBSi-1 | $B_2O_3$ | | 22.000 | 22.000 | 0.0000 | 0.0% |
| NP-MC-AlBSi-1 | $Bi_2O_3$ | | 0.487 | 0.530 | -0.0431 | |
| NP-MC-AlBSi-1 | CaO | | 0.430 | 0.530 | -0.0997 | |
| NP-MC-AlBSi-1 | $Cr_2O_3$ | | 0.823 | 0.900 | -0.0775 | |
| NP-MC-AlBSi-1 | $Fe_2O_3$ | | 2.091 | 2.050 | 0.0409 | |
| NP-MC-AlBSi-1 | $Li_2O$ | | 4.058 | 4.110 | -0.0518 | |
| NP-MC-AlBSi-1 | MnO | | 0.747 | 0.820 | -0.0730 | |
| NP-MC-AlBSi-1 | $Na_2O$ | | 10.882 | 10.270 | 0.6117 | 6.0% |
| NP-MC-AlBSi-1 | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlBSi-1 | $P_2O_5$ | | 0.544 | 0.580 | -0.0364 | |
| NP-MC-AlBSi-1 | $RuO_2$ | < | 0.132 | 0.040 | 0.0917 | |
| NP-MC-AlBSi-1 | $SiO_2$ | | 26.848 | 26.000 | 0.8482 | 3.3% |
| NP-MC-AlBSi-1 | $SO_3$ | | 0.168 | 0.210 | -0.0421 | |
| NP-MC-AlBSi-1 | $ZrO_2$ | | 0.198 | 0.210 | -0.0124 | |
| NP-MC-AlBSi-1 | Sum | | 100.994 | 99.750 | 1.2439 | 1.2% |
| NP-MC-AlLi-1 | $Al_2O_3$ | | 24.705 | 25.500 | -0.7948 | -3.1% |
| NP-MC-AlLi-1 | $B_2O_3$ | | 17.709 | 18.230 | -0.5206 | -2.9% |
| NP-MC-AlLi-1 | $Bi_2O_3$ | | 0.638 | 0.690 | -0.0523 | |
| NP-MC-AlLi-1 | CaO | | 0.565 | 0.690 | -0.1254 | |
| NP-MC-AlLi-1 | $Cr_2O_3$ | | 1.140 | 1.170 | -0.0296 | |
| NP-MC-AlLi-1 | $Fe_2O_3$ | | 2.666 | 2.650 | 0.0164 | |
| NP-MC-AlLi-1 | $Li_2O$ | | 3.827 | 4.000 | -0.1732 | |
| NP-MC-AlLi-1 | MnO | | 1.049 | 1.060 | -0.0112 | |
| NP-MC-AlLi-1 | $Na_2O$ | | 13.386 | 13.250 | 0.1356 | 1.0% |
| NP-MC-AlLi-1 | NiO | < | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlLi-1 | $P_2O_5$ | | 0.709 | 0.740 | -0.0314 | |
| NP-MC-AlLi-1 | $RuO_2$ | < | 0.132 | 0.050 | 0.0817 | |
| NP-MC-AlLi-1 | $SiO_2$ | | 30.859 | 31.120 | -0.2606 | -0.8% |
| NP-MC-AlLi-1 | $SO_3$ | | 0.246 | 0.270 | -0.0241 | |
| NP-MC-AlLi-1 | $ZrO_2$ | | 0.277 | 0.270 | 0.0066 | |
| NP-MC-AlLi-1 | Sum | | 98.034 | 99.690 | -1.6556 | -1.7% |
| NP-MC-AlLi-2 | $Al_2O_3$ | | 30.988 | 31.500 | -0.5122 | -1.6% |
| NP-MC-AlLi-2 | $B_2O_3$ | | 16.397 | 16.680 | -0.2827 | -1.7% |
| NP-MC-AlLi-2 | $Bi_2O_3$ | | 0.578 | 0.630 | -0.0523 | |
| NP-MC-AlLi-2 | CaO | | 0.587 | 0.630 | -0.0430 | |
| NP-MC-AlLi-2 | $Cr_2O_3$ | | 1.005 | 1.070 | -0.0652 | |
| NP-MC-AlLi-2 | $Fe_2O_3$ | | 2.398 | 2.420 | -0.0217 | |
| NP-MC-AlLi-2 | $Li_2O$ | | 3.821 | 4.000 | -0.1786 | |
| NP-MC-AlLi-2 | MnO | | 0.926 | 0.970 | -0.0439 | |
| NP-MC-AlLi-2 | $Na_2O$ | | 12.853 | 12.120 | 0.7332 | 6.0% |
| NP-MC-AlLi-2 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlLi-2 | $P_2O_5$ | | 0.648 | 0.680 | -0.0315 | |
| NP-MC-AlLi-2 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-AlLi-2 | $SiO_2$ | | 28.667 | 28.470 | 0.1966 | 0.7% |
| NP-MC-AlLi-2 | $SO_3$ | | 0.206 | 0.240 | -0.0340 | |
| NP-MC-AlLi-2 | $ZrO_2$ | | 0.243 | 0.240 | 0.0031 | |
| NP-MC-AlLi-2 | Sum | | 99.577 | 99.700 | -0.1232 | -0.1% |
| NP-MC-AlLiNa-1 | $Al_2O_3$ | | 30.941 | 31.140 | -0.1994 | -0.6% |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP-MC-AlLiNa-1 | $B_2O_3$ | | 15.150 | 15.240 | -0.0904 | -0.6% |
| NP-MC-AlLiNa-1 | $Bi_2O_3$ | | 0.521 | 0.580 | -0.0586 | |
| NP-MC-AlLiNa-1 | CaO | | 0.531 | 0.580 | -0.0487 | |
| NP-MC-AlLiNa-1 | $Cr_2O_3$ | | 0.880 | 0.970 | -0.0898 | |
| NP-MC-AlLiNa-1 | $Fe_2O_3$ | | 2.184 | 2.210 | -0.0261 | |
| NP-MC-AlLiNa-1 | $Li_2O$ | | 5.700 | 5.880 | -0.1802 | -3.1% |
| NP-MC-AlLiNa-1 | MnO | | 0.815 | 0.890 | -0.0749 | |
| NP-MC-AlLiNa-1 | $Na_2O$ | | 15.704 | 15.140 | 0.5642 | 3.7% |
| NP-MC-AlLiNa-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlLiNa-1 | $P_2O_5$ | | 0.578 | 0.620 | -0.0420 | |
| NP-MC-AlLiNa-1 | $RuO_2$ | | 0.132 | 0.040 | 0.0917 | |
| NP-MC-AlLiNa-1 | $SiO_2$ | | 26.474 | 26.000 | 0.4738 | 1.8% |
| NP-MC-AlLiNa-1 | $SO_3$ | | 0.235 | 0.220 | 0.0153 | |
| NP-MC-AlLiNa-1 | $ZrO_2$ | | 0.207 | 0.220 | -0.0133 | |
| NP-MC-AlLiNa-1 | Sum | | 100.179 | 99.730 | 0.4489 | 0.5% |
| NP-MC-AlLiSi-1 | $Al_2O_3$ | | 25.083 | 25.500 | -0.4169 | -1.6% |
| NP-MC-AlLiSi-1 | $B_2O_3$ | | 20.640 | 20.600 | 0.0396 | 0.2% |
| NP-MC-AlLiSi-1 | $Bi_2O_3$ | | 0.723 | 0.780 | -0.0573 | |
| NP-MC-AlLiSi-1 | CaO | | 0.630 | 0.780 | -0.1504 | |
| NP-MC-AlLiSi-1 | $Cr_2O_3$ | | 1.302 | 1.320 | -0.0184 | |
| NP-MC-AlLiSi-1 | $Fe_2O_3$ | | 3.017 | 2.990 | 0.0267 | |
| NP-MC-AlLiSi-1 | $Li_2O$ | | 3.854 | 4.000 | -0.1463 | |
| NP-MC-AlLiSi-1 | MnO | | 1.209 | 1.200 | 0.0089 | |
| NP-MC-AlLiSi-1 | $Na_2O$ | | 15.906 | 14.970 | 0.9364 | 6.3% |
| NP-MC-AlLiSi-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlLiSi-1 | $P_2O_5$ | | 0.793 | 0.840 | -0.0472 | |
| NP-MC-AlLiSi-1 | $RuO_2$ | | 0.132 | 0.060 | 0.0717 | |
| NP-MC-AlLiSi-1 | $SiO_2$ | | 26.206 | 26.000 | 0.2064 | 0.8% |
| NP-MC-AlLiSi-1 | $SO_3$ | | 0.305 | 0.300 | 0.0046 | |
| NP-MC-AlLiSi-1 | $ZrO_2$ | | 0.288 | 0.300 | -0.0119 | |
| NP-MC-AlLiSi-1 | Sum | | 100.213 | 99.640 | 0.5730 | 0.6% |
| NP-MC-AlNa-1 | $Al_2O_3$ | | 24.941 | 25.500 | -0.5586 | -2.2% |
| NP-MC-AlNa-1 | $B_2O_3$ | | 16.582 | 17.200 | -0.6175 | -3.6% |
| NP-MC-AlNa-1 | $Bi_2O_3$ | | 0.603 | 0.650 | -0.0472 | |
| NP-MC-AlNa-1 | CaO | | 0.530 | 0.650 | -0.1204 | |
| NP-MC-AlNa-1 | $Cr_2O_3$ | | 0.988 | 1.100 | -0.1120 | |
| NP-MC-AlNa-1 | $Fe_2O_3$ | | 2.495 | 2.500 | -0.0052 | |
| NP-MC-AlNa-1 | $Li_2O$ | | 4.882 | 5.000 | -0.1183 | -2.4% |
| NP-MC-AlNa-1 | MnO | | 0.918 | 1.000 | -0.0823 | |
| NP-MC-AlNa-1 | $Na_2O$ | | 16.008 | 15.500 | 0.5075 | 3.3% |
| NP-MC-AlNa-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlNa-1 | $P_2O_5$ | | 0.663 | 0.700 | -0.0372 | |
| NP-MC-AlNa-1 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-AlNa-1 | $SiO_2$ | | 29.362 | 29.350 | 0.0119 | 0.0% |
| NP-MC-AlNa-1 | $SO_3$ | | 0.248 | 0.250 | -0.0016 | |
| NP-MC-AlNa-1 | $ZrO_2$ | | 0.249 | 0.250 | -0.0011 | |
| NP-MC-AlNa-1 | Sum | | 98.727 | 99.700 | -0.9730 | -1.0% |
| NP-MC-AlSi-1 | $Al_2O_3$ | | 25.036 | 25.500 | -0.4641 | -1.8% |
| NP-MC-AlSi-1 | $B_2O_3$ | | 19.617 | 19.790 | -0.1728 | -0.9% |
| NP-MC-AlSi-1 | $Bi_2O_3$ | | 0.687 | 0.750 | -0.0630 | |
| NP-MC-AlSi-1 | CaO | | 0.676 | 0.750 | -0.0738 | |
| NP-MC-AlSi-1 | $Cr_2O_3$ | | 1.160 | 1.270 | -0.1099 | |
| NP-MC-AlSi-1 | $Fe_2O_3$ | | 2.927 | 2.880 | 0.0473 | |
| NP-MC-AlSi-1 | $Li_2O$ | | 5.576 | 5.750 | -0.1740 | -3.0% |
| NP-MC-AlSi-1 | MnO | | 1.072 | 1.150 | -0.0783 | |
| NP-MC-AlSi-1 | $Na_2O$ | | 15.435 | 14.380 | 1.0546 | 7.3% |
| NP-MC-AlSi-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlSi-1 | $P_2O_5$ | | 0.770 | 0.810 | -0.0395 | |
| NP-MC-AlSi-1 | $RuO_2$ | | 0.132 | 0.060 | 0.0717 | |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP-MC-AlSi-1 | $SiO_2$ | | 26.527 | 26.000 | 0.5273 | 2.0% |
| NP-MC-AlSi-1 | $SO_3$ | | 0.310 | 0.290 | 0.0202 | |
| NP-MC-AlSi-1 | $ZrO_2$ | | 0.307 | 0.290 | 0.0166 | |
| NP-MC-AlSi-1 | Sum | | 100.360 | 99.670 | 0.6896 | 0.7% |
| NP-MC-AlSi-2 | $Al_2O_3$ | | 31.082 | 31.500 | -0.4177 | -1.3% |
| NP-MC-AlSi-2 | $B_2O_3$ | | 14.288 | 14.490 | -0.2017 | -1.4% |
| NP-MC-AlSi-2 | $Bi_2O_3$ | | 0.502 | 0.550 | -0.0475 | |
| NP-MC-AlSi-2 | CaO | | 0.539 | 0.550 | -0.0113 | |
| NP-MC-AlSi-2 | $Cr_2O_3$ | | 0.839 | 0.930 | -0.0910 | |
| NP-MC-AlSi-2 | $Fe_2O_3$ | | 2.077 | 2.110 | -0.0334 | |
| NP-MC-AlSi-2 | $Li_2O$ | | 4.004 | 4.210 | -0.2056 | |
| NP-MC-AlSi-2 | MnO | | 0.760 | 0.840 | -0.0801 | |
| NP-MC-AlSi-2 | $Na_2O$ | | 11.225 | 10.530 | 0.6955 | 6.6% |
| NP-MC-AlSi-2 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-AlSi-2 | $P_2O_5$ | | 0.553 | 0.590 | -0.0372 | |
| NP-MC-AlSi-2 | $RuO_2$ | | 0.132 | 0.040 | 0.0917 | |
| NP-MC-AlSi-2 | $SiO_2$ | | 33.320 | 33.000 | 0.3196 | 1.0% |
| NP-MC-AlSi-2 | $SO_3$ | | 0.162 | 0.210 | -0.0477 | |
| NP-MC-AlSi-2 | $ZrO_2$ | | 0.199 | 0.210 | -0.0114 | |
| NP-MC-AlSi-2 | Sum | | 99.809 | 99.760 | 0.0493 | 0.0% |
| NP-MC-BLiSi-1 | $Al_2O_3$ | | 27.398 | 27.650 | -0.2523 | -0.9% |
| NP-MC-BLiSi-1 | $B_2O_3$ | | 13.999 | 14.000 | -0.0015 | 0.0% |
| NP-MC-BLiSi-1 | $Bi_2O_3$ | | 0.577 | 0.630 | -0.0531 | |
| NP-MC-BLiSi-1 | CaO | | 0.513 | 0.630 | -0.1168 | |
| NP-MC-BLiSi-1 | $Cr_2O_3$ | | 0.972 | 1.070 | -0.0977 | |
| NP-MC-BLiSi-1 | $Fe_2O_3$ | | 2.413 | 2.430 | -0.0174 | |
| NP-MC-BLiSi-1 | $Li_2O$ | | 5.764 | 6.000 | -0.2356 | -3.9% |
| NP-MC-BLiSi-1 | MnO | | 0.899 | 0.970 | -0.0710 | |
| NP-MC-BLiSi-1 | $Na_2O$ | | 12.981 | 12.130 | 0.8512 | 7.0% |
| NP-MC-BLiSi-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-BLiSi-1 | $P_2O_5$ | | 0.636 | 0.680 | -0.0436 | |
| NP-MC-BLiSi-1 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-BLiSi-1 | $SiO_2$ | | 33.587 | 33.000 | 0.5870 | 1.8% |
| NP-MC-BLiSi-1 | $SO_3$ | | 0.213 | 0.240 | -0.0265 | |
| NP-MC-BLiSi-1 | $ZrO_2$ | | 0.229 | 0.240 | -0.0114 | |
| NP-MC-BLiSi-1 | Sum | | 100.440 | 99.720 | 0.7204 | 0.7% |
| NP-MC-BLiSi-2 | $Al_2O_3$ | | 26.736 | 27.060 | -0.3236 | -1.2% |
| NP-MC-BLiSi-2 | $B_2O_3$ | | 21.895 | 22.000 | -0.1047 | -0.5% |
| NP-MC-BLiSi-2 | $Bi_2O_3$ | | 0.568 | 0.620 | -0.0520 | |
| NP-MC-BLiSi-2 | CaO | | 0.511 | 0.620 | -0.1086 | |
| NP-MC-BLiSi-2 | $Cr_2O_3$ | | 0.979 | 1.040 | -0.0607 | |
| NP-MC-BLiSi-2 | $Fe_2O_3$ | | 2.316 | 2.370 | -0.0539 | |
| NP-MC-BLiSi-2 | $Li_2O$ | | 5.441 | 6.000 | -0.5585 | -9.3% |
| NP-MC-BLiSi-2 | MnO | | 0.893 | 0.950 | -0.0568 | |
| NP-MC-BLiSi-2 | $Na_2O$ | | 12.112 | 11.870 | 0.2418 | 2.0% |
| NP-MC-BLiSi-2 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-BLiSi-2 | $P_2O_5$ | | 0.624 | 0.660 | -0.0356 | |
| NP-MC-BLiSi-2 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-BLiSi-2 | $SiO_2$ | | 26.420 | 26.000 | 0.4204 | 1.6% |
| NP-MC-BLiSi-2 | $SO_3$ | | 0.241 | 0.240 | 0.0010 | |
| NP-MC-BLiSi-2 | $ZrO_2$ | | 0.242 | 0.240 | 0.0021 | |
| NP-MC-BLiSi-2 | Sum | | 99.240 | 99.720 | -0.4803 | -0.5% |
| NP-MC-BNa-1 | $Al_2O_3$ | | 28.295 | 28.580 | -0.2847 | -1.0% |
| NP-MC-BNa-1 | $B_2O_3$ | | 13.870 | 14.000 | -0.1303 | -0.9% |
| NP-MC-BNa-1 | $Bi_2O_3$ | | 0.594 | 0.650 | -0.0555 | |
| NP-MC-BNa-1 | CaO | | 0.603 | 0.650 | -0.0473 | |
| NP-MC-BNa-1 | $Cr_2O_3$ | | 0.994 | 1.100 | -0.1057 | |
| NP-MC-BNa-1 | $Fe_2O_3$ | | 2.520 | 2.510 | 0.0098 | |
| NP-MC-BNa-1 | $Li_2O$ | | 4.839 | 5.010 | -0.1714 | -3.4% |

**Table A-3. Comparison of Targeted and Measured Glass Compositions (continued)**

| Glass ID | Oxide | BDL (<) | Measured (wt%) | Targeted (wt%) | Difference of Measured versus Targeted | % Difference of Measured versus Targeted |
|---|---|---|---|---|---|---|
| NP-MC-BNa-1 | MnO | | 0.918 | 1.000 | -0.0820 | |
| NP-MC-BNa-1 | $Na_2O$ | | 16.378 | 15.500 | 0.8782 | 5.7% |
| NP-MC-BNa-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-BNa-1 | $P_2O_5$ | | 0.662 | 0.700 | -0.0378 | |
| NP-MC-BNa-1 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-BNa-1 | $SiO_2$ | | 30.004 | 29.430 | 0.5737 | 1.9% |
| NP-MC-BNa-1 | $SO_3$ | | 0.260 | 0.250 | 0.0097 | |
| NP-MC-BNa-1 | $ZrO_2$ | | 0.252 | 0.250 | 0.0023 | |
| NP-MC-BNa-1 | Sum | | 100.448 | 99.680 | 0.7679 | 0.8% |
| NP-MC-BNaSi-1 | $Al_2O_3$ | | 30.657 | 30.970 | -0.3129 | -1.0% |
| NP-MC-BNaSi-1 | $B_2O_3$ | | 14.208 | 14.000 | 0.2078 | 1.5% |
| NP-MC-BNaSi-1 | $Bi_2O_3$ | | 0.654 | 0.710 | -0.0556 | |
| NP-MC-BNaSi-1 | CaO | | 0.660 | 0.710 | -0.0503 | |
| NP-MC-BNaSi-1 | $Cr_2O_3$ | | 1.171 | 1.200 | -0.0289 | |
| NP-MC-BNaSi-1 | $Fe_2O_3$ | | 2.724 | 2.720 | 0.0036 | |
| NP-MC-BNaSi-1 | $Li_2O$ | | 5.312 | 5.430 | -0.1177 | -2.2% |
| NP-MC-BNaSi-1 | MnO | | 1.066 | 1.090 | -0.0244 | |
| NP-MC-BNaSi-1 | $Na_2O$ | | 16.479 | 15.500 | 0.9793 | 6.3% |
| NP-MC-BNaSi-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-BNaSi-1 | $P_2O_5$ | | 0.707 | 0.760 | -0.0531 | |
| NP-MC-BNaSi-1 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-BNaSi-1 | $SiO_2$ | | 26.367 | 26.000 | 0.3669 | 1.4% |
| NP-MC-BNaSi-1 | $SO_3$ | | 0.268 | 0.270 | -0.0022 | |
| NP-MC-BNaSi-1 | $ZrO_2$ | | 0.261 | 0.270 | -0.0093 | |
| NP-MC-BNaSi-1 | Sum | | 100.792 | 99.680 | 1.1121 | 1.1% |
| NP-MC-BSi-1 | $Al_2O_3$ | | 25.083 | 25.500 | -0.4169 | -1.6% |
| NP-MC-BSi-1 | $B_2O_3$ | | 20.269 | 20.400 | -0.1307 | -0.6% |
| NP-MC-BSi-1 | $Bi_2O_3$ | | 0.531 | 0.580 | -0.0485 | |
| NP-MC-BSi-1 | CaO | | 0.465 | 0.580 | -0.1148 | |
| NP-MC-BSi-1 | $Cr_2O_3$ | | 0.958 | 0.980 | -0.0219 | |
| NP-MC-BSi-1 | $Fe_2O_3$ | | 2.270 | 2.240 | 0.0296 | |
| NP-MC-BSi-1 | $Li_2O$ | | 4.317 | 4.470 | -0.1534 | |
| NP-MC-BSi-1 | MnO | | 0.884 | 0.890 | -0.0055 | |
| NP-MC-BSi-1 | $Na_2O$ | | 12.028 | 11.180 | 0.8475 | 7.6% |
| NP-MC-BSi-1 | NiO | | 0.127 | 0.000 | 0.1273 | |
| NP-MC-BSi-1 | $P_2O_5$ | | 0.591 | 0.630 | -0.0394 | |
| NP-MC-BSi-1 | $RuO_2$ | | 0.132 | 0.050 | 0.0817 | |
| NP-MC-BSi-1 | $SiO_2$ | | 32.303 | 31.780 | 0.5234 | 1.6% |
| NP-MC-BSi-1 | $SO_3$ | | 0.197 | 0.220 | -0.0234 | |
| NP-MC-BSi-1 | $ZrO_2$ | | 0.210 | 0.220 | -0.0100 | |
| NP-MC-BSi-1 | Sum | | 100.365 | 99.720 | 0.6450 | 0.6% |

**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

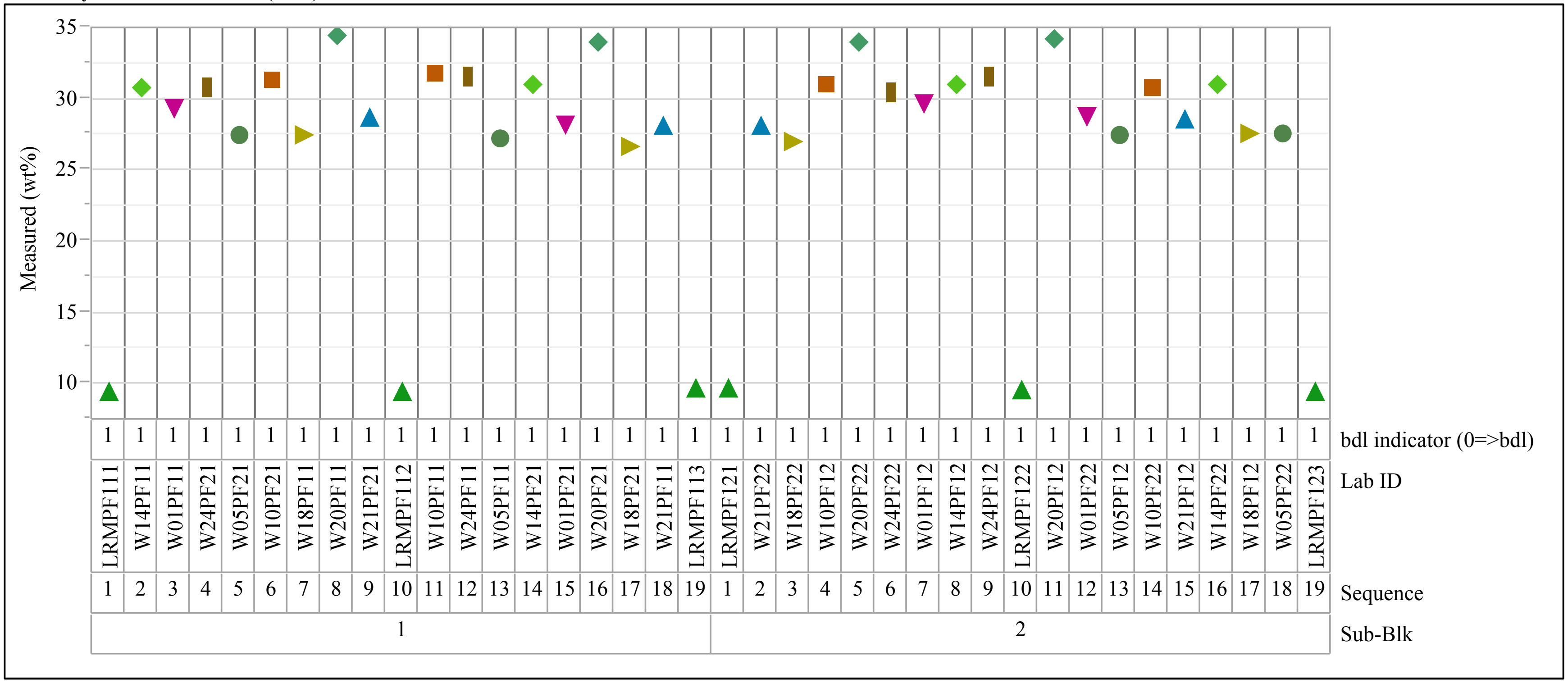


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

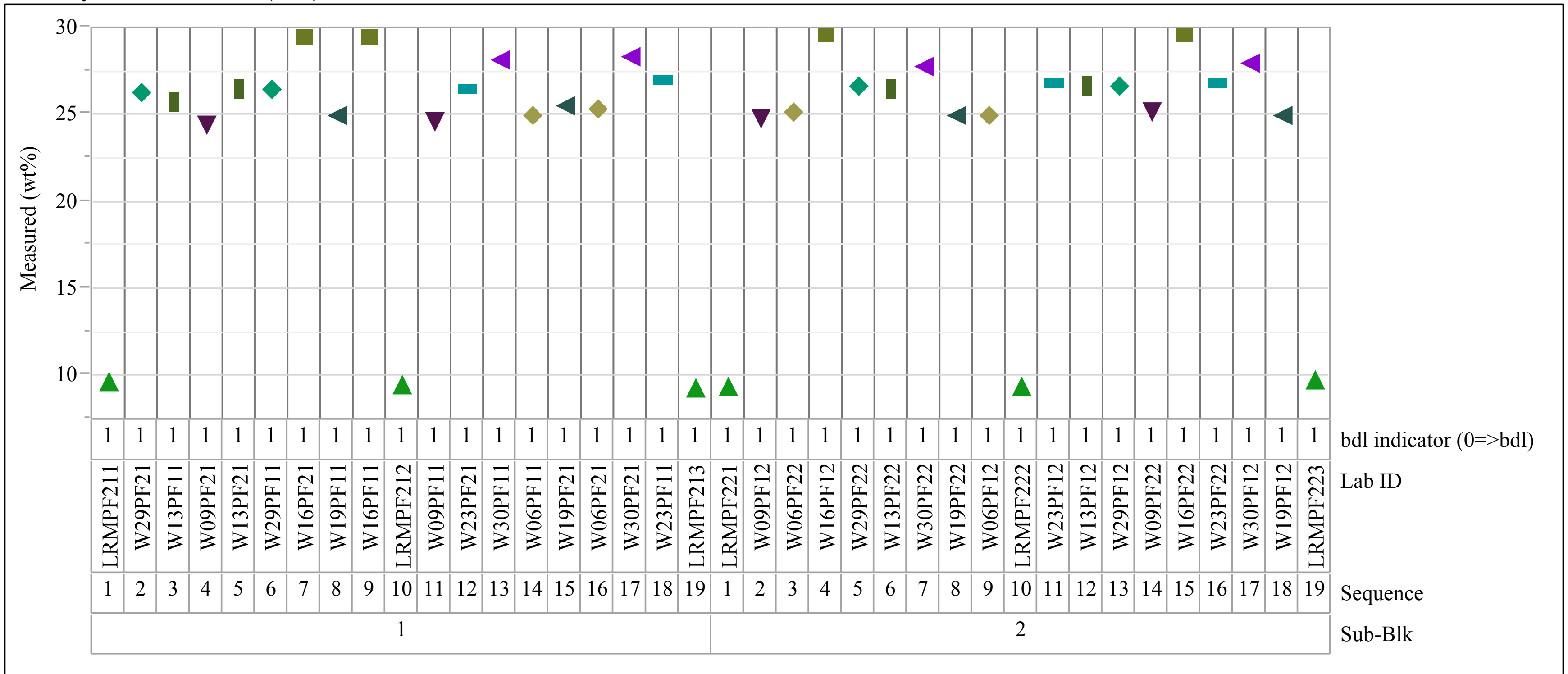


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

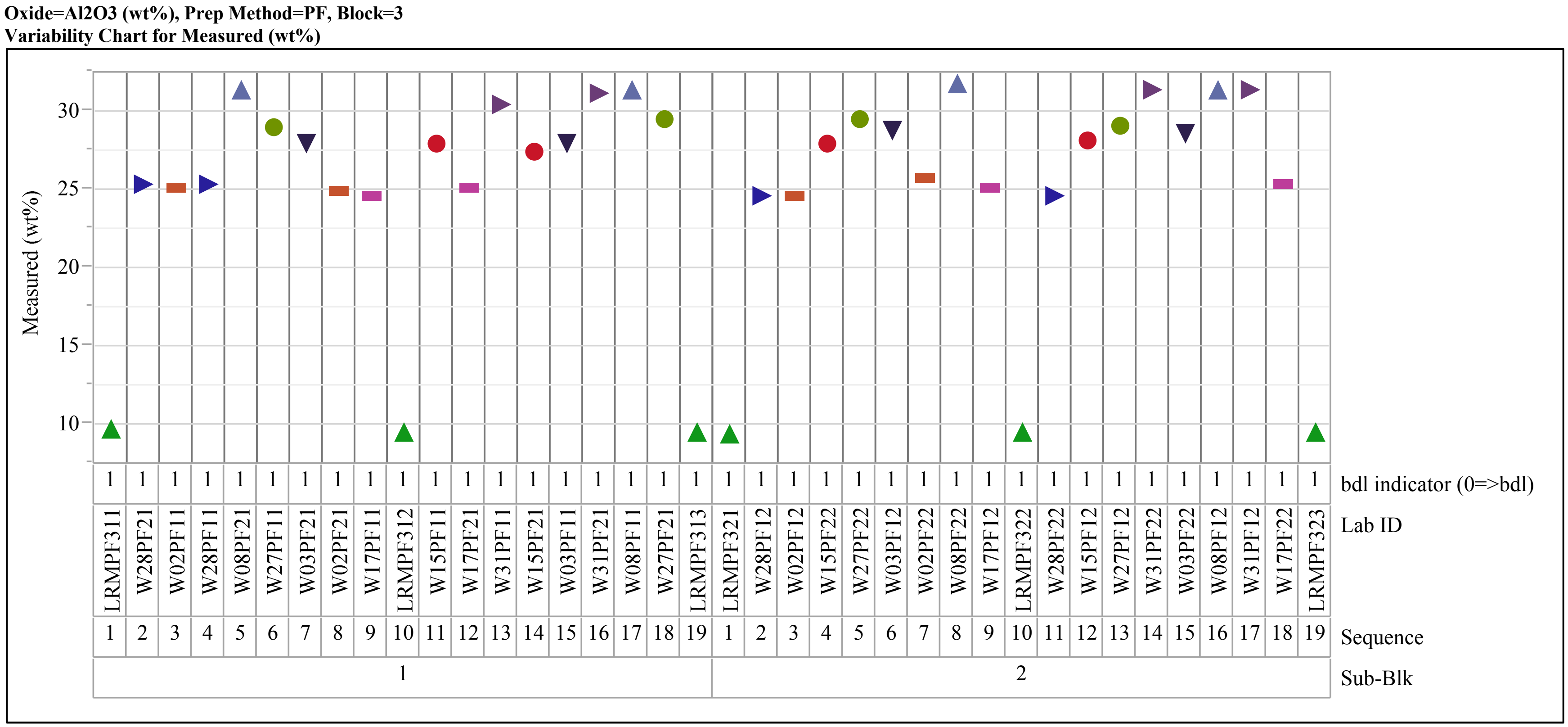


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

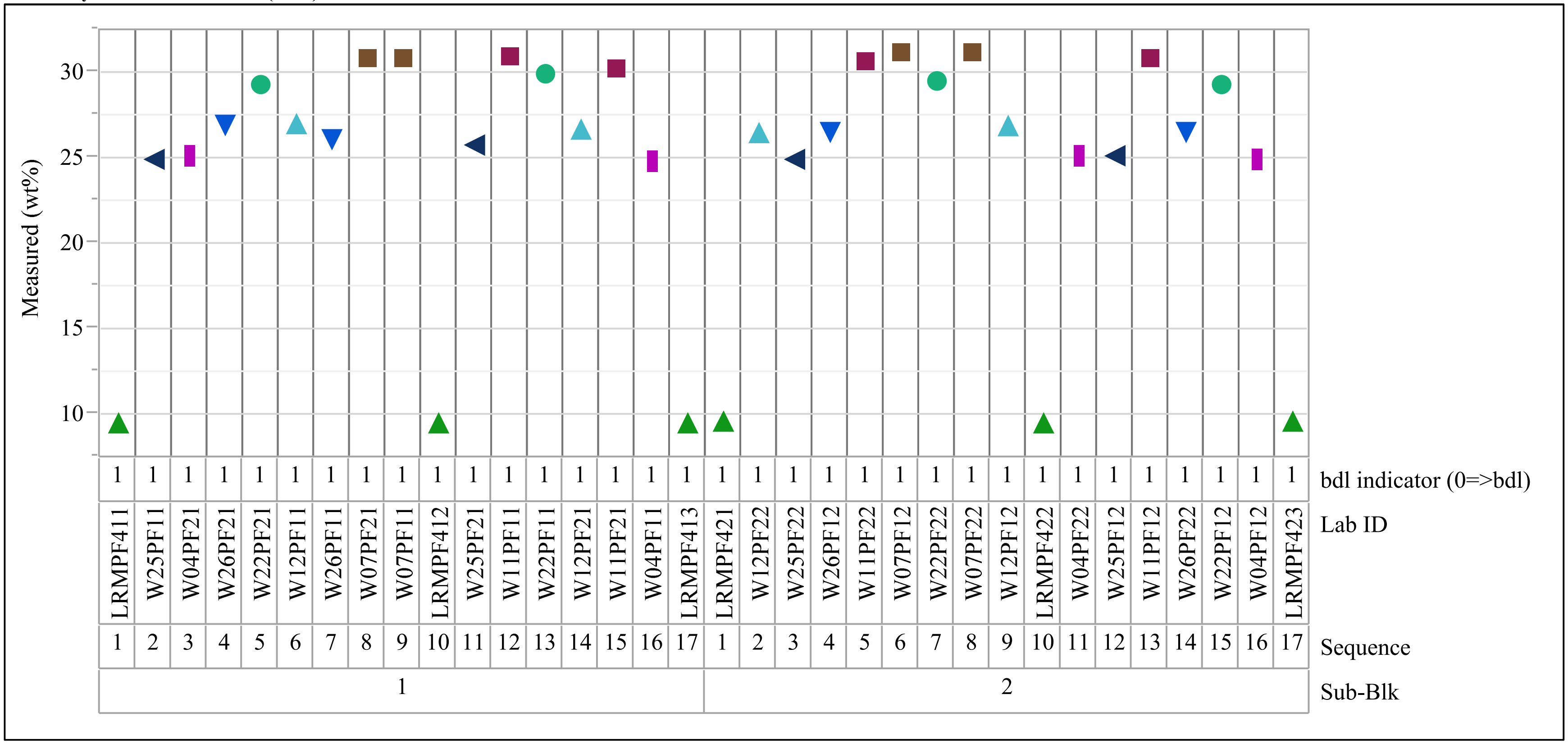


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

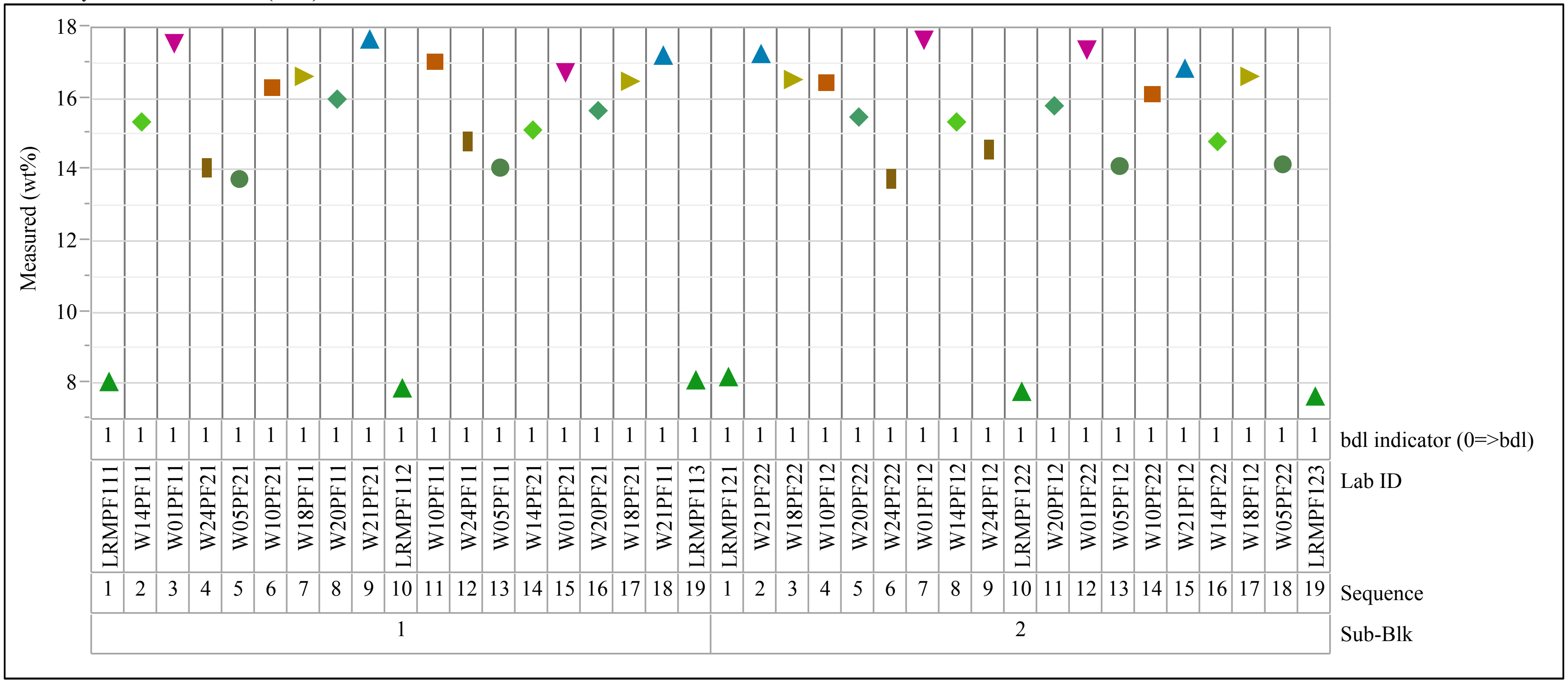


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

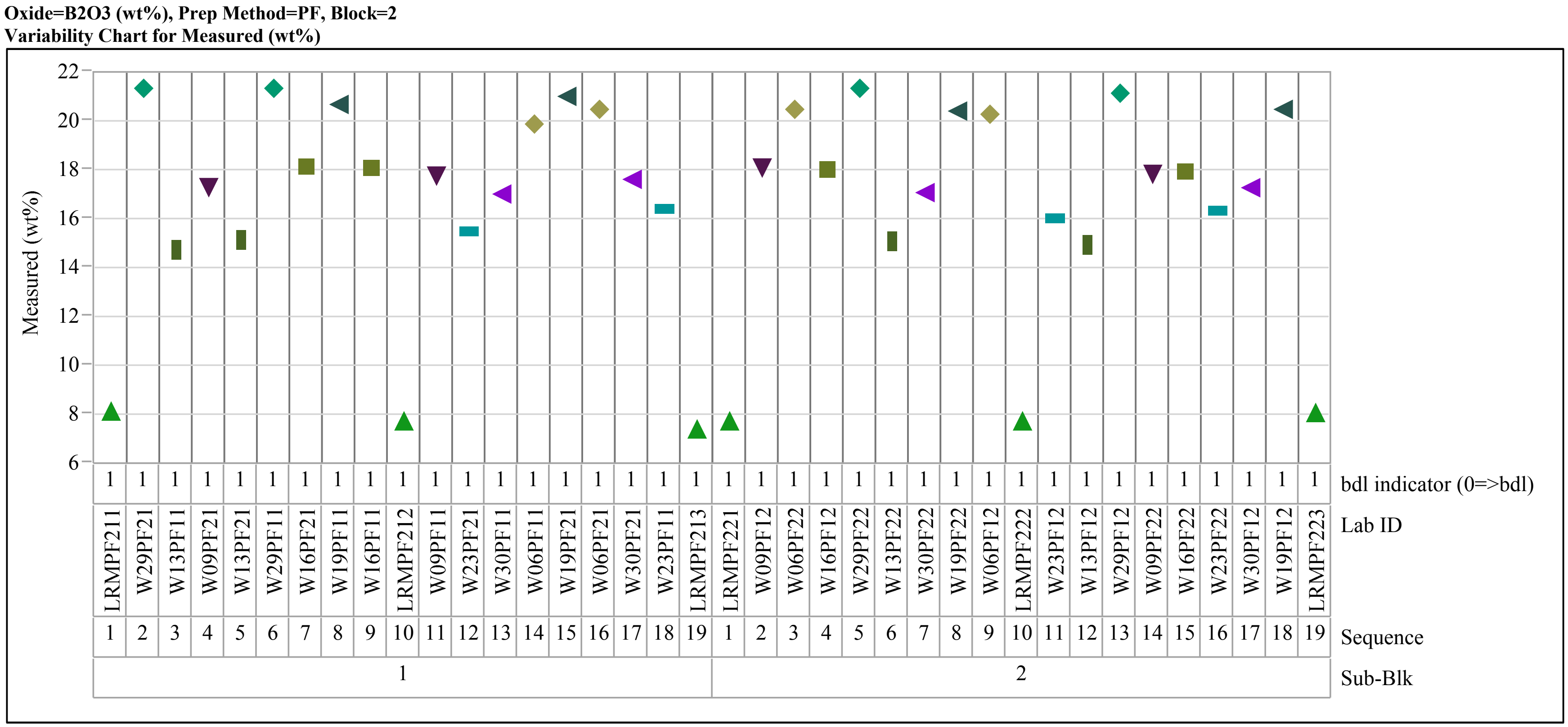


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

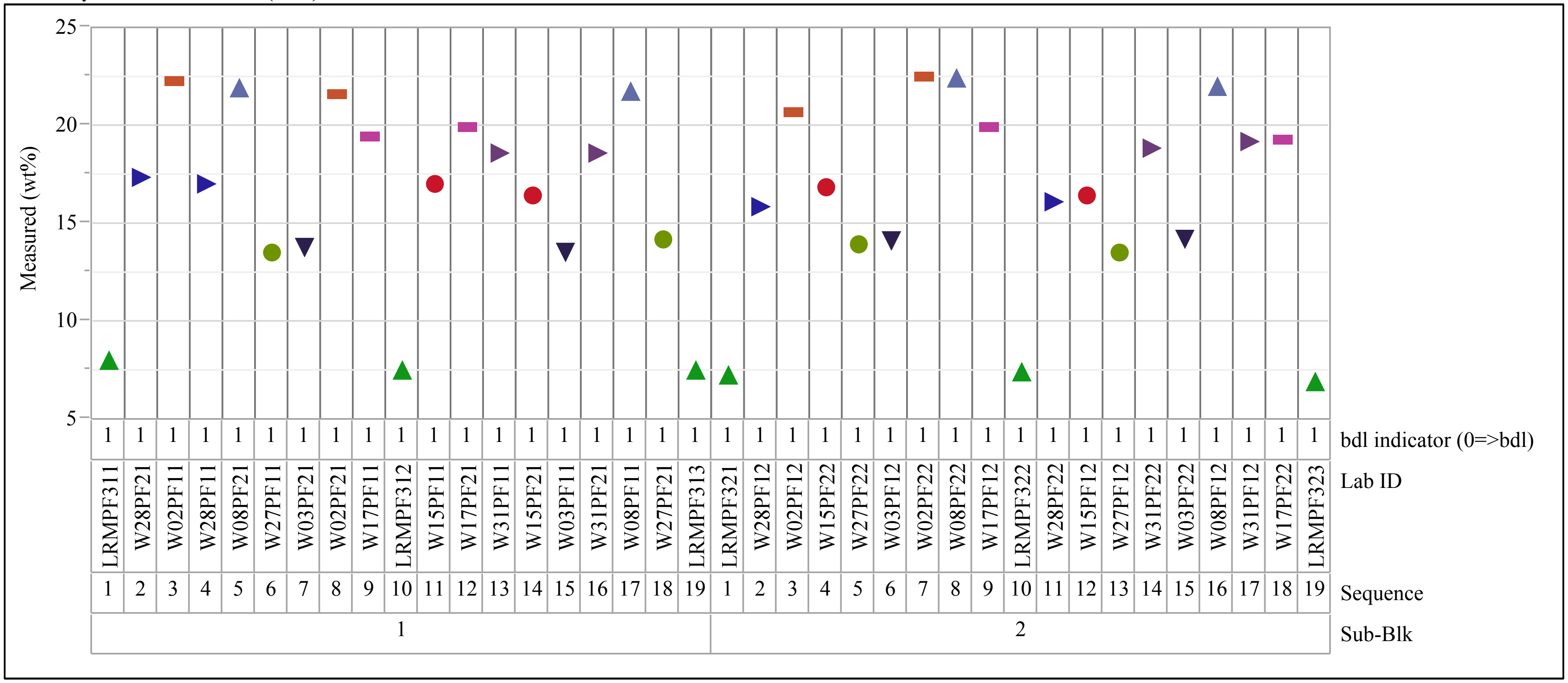


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

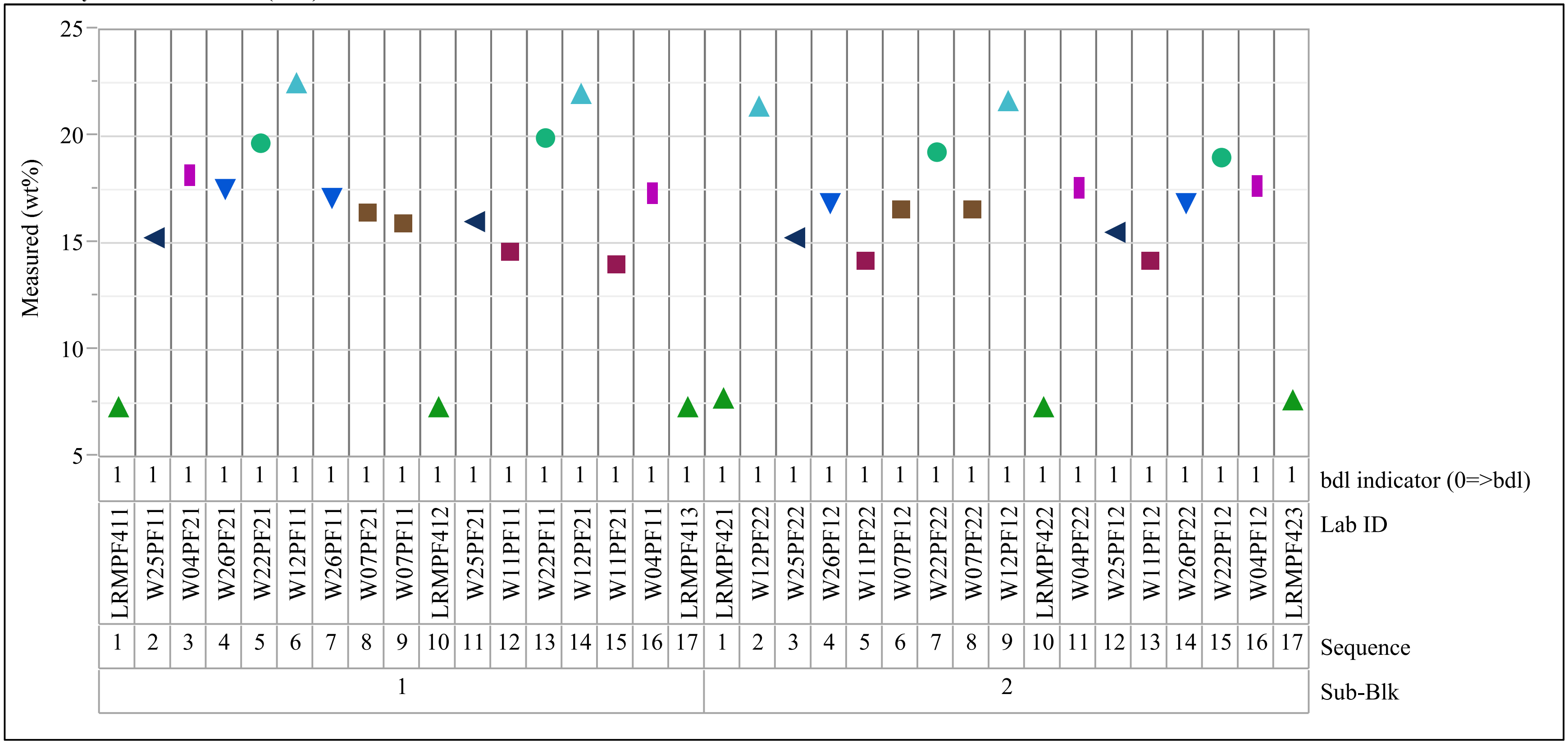


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

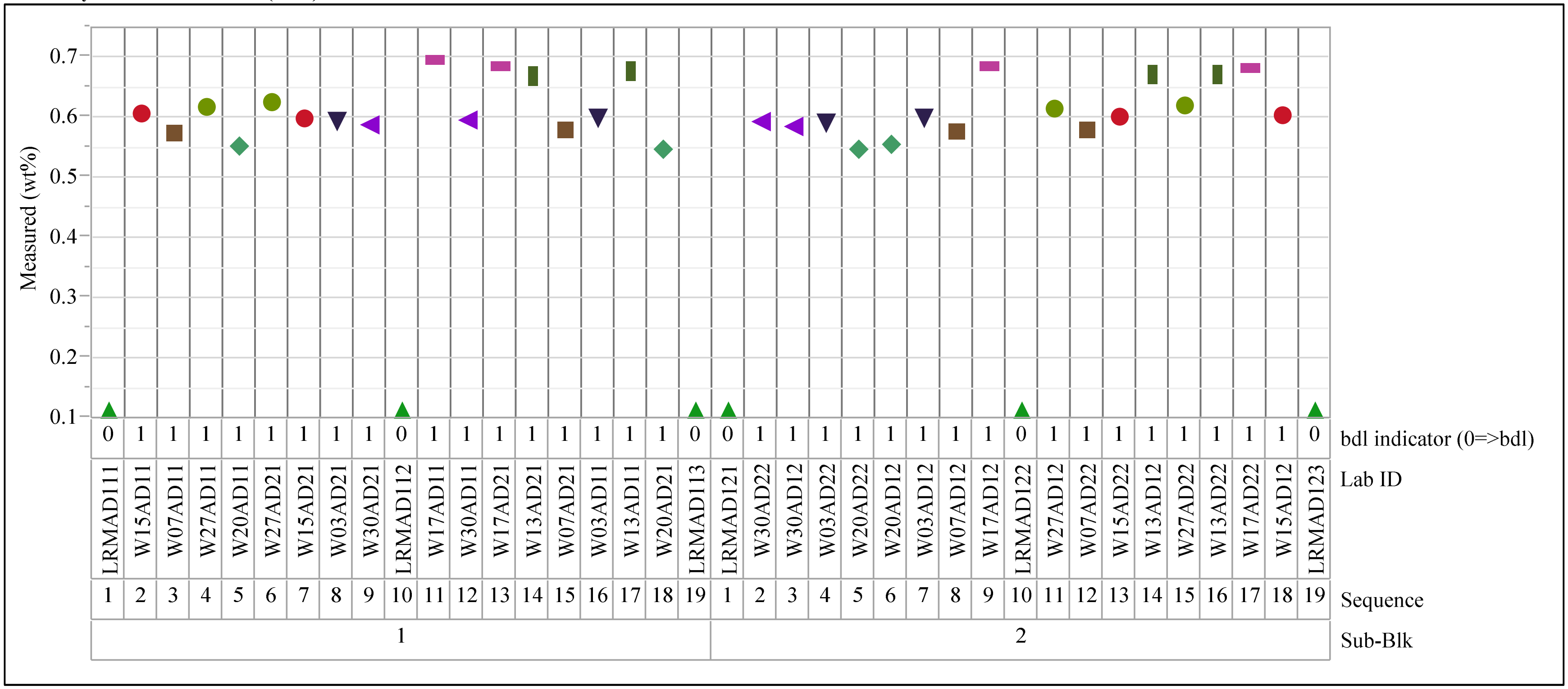


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

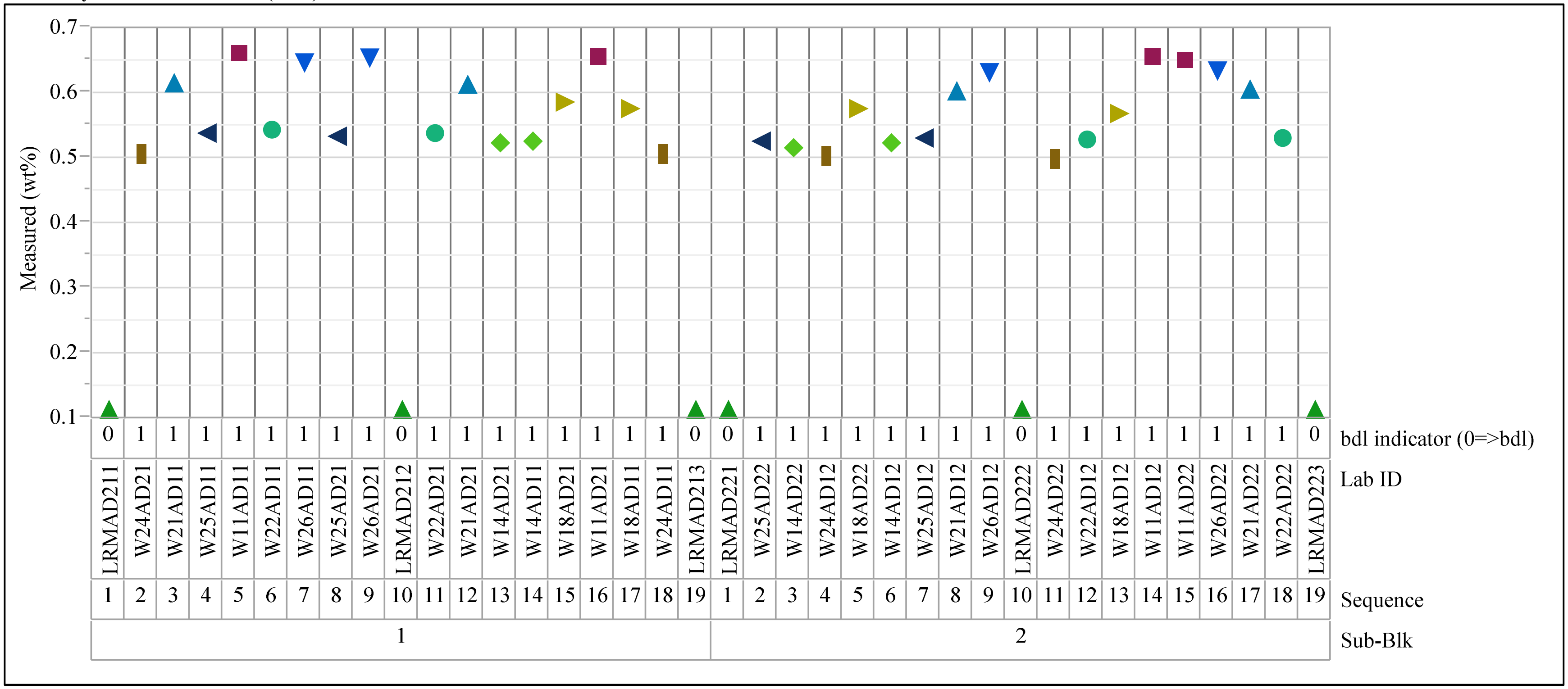


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

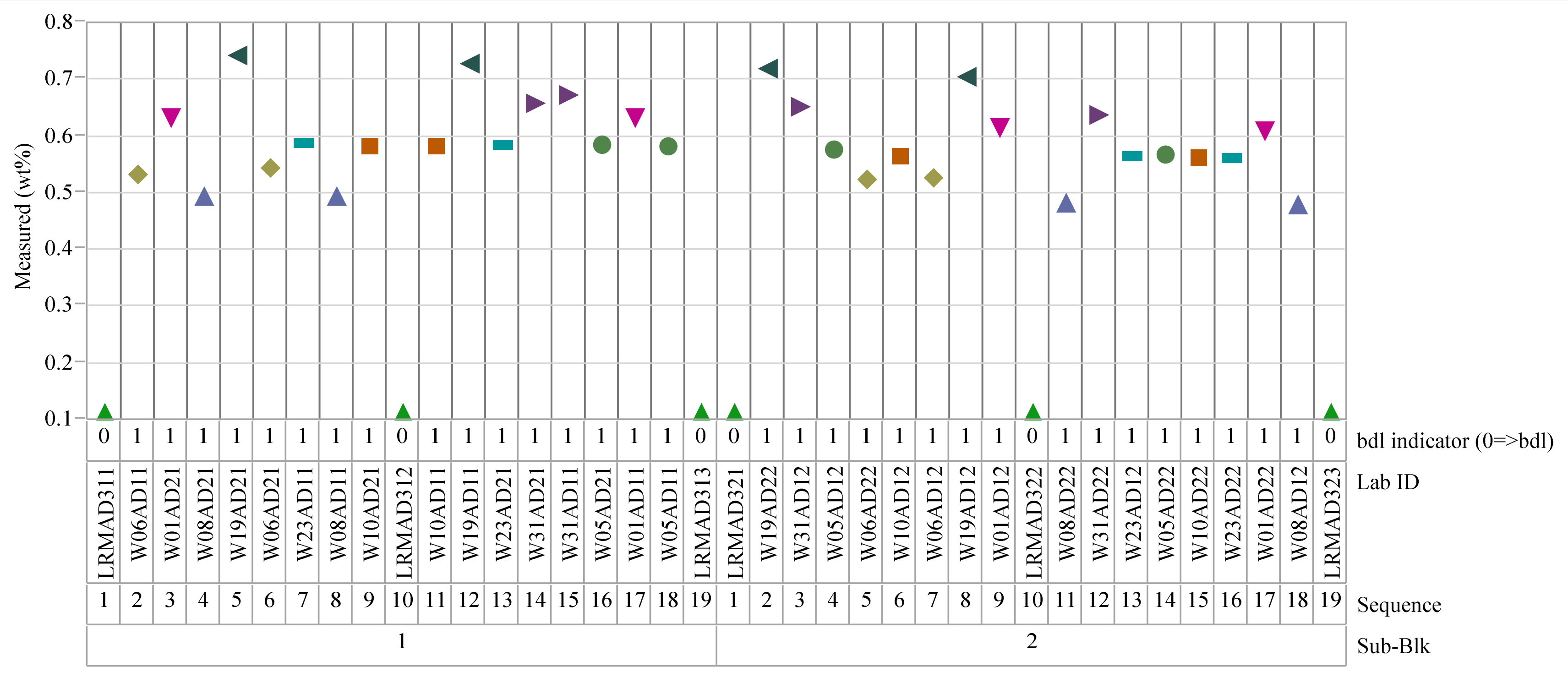


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

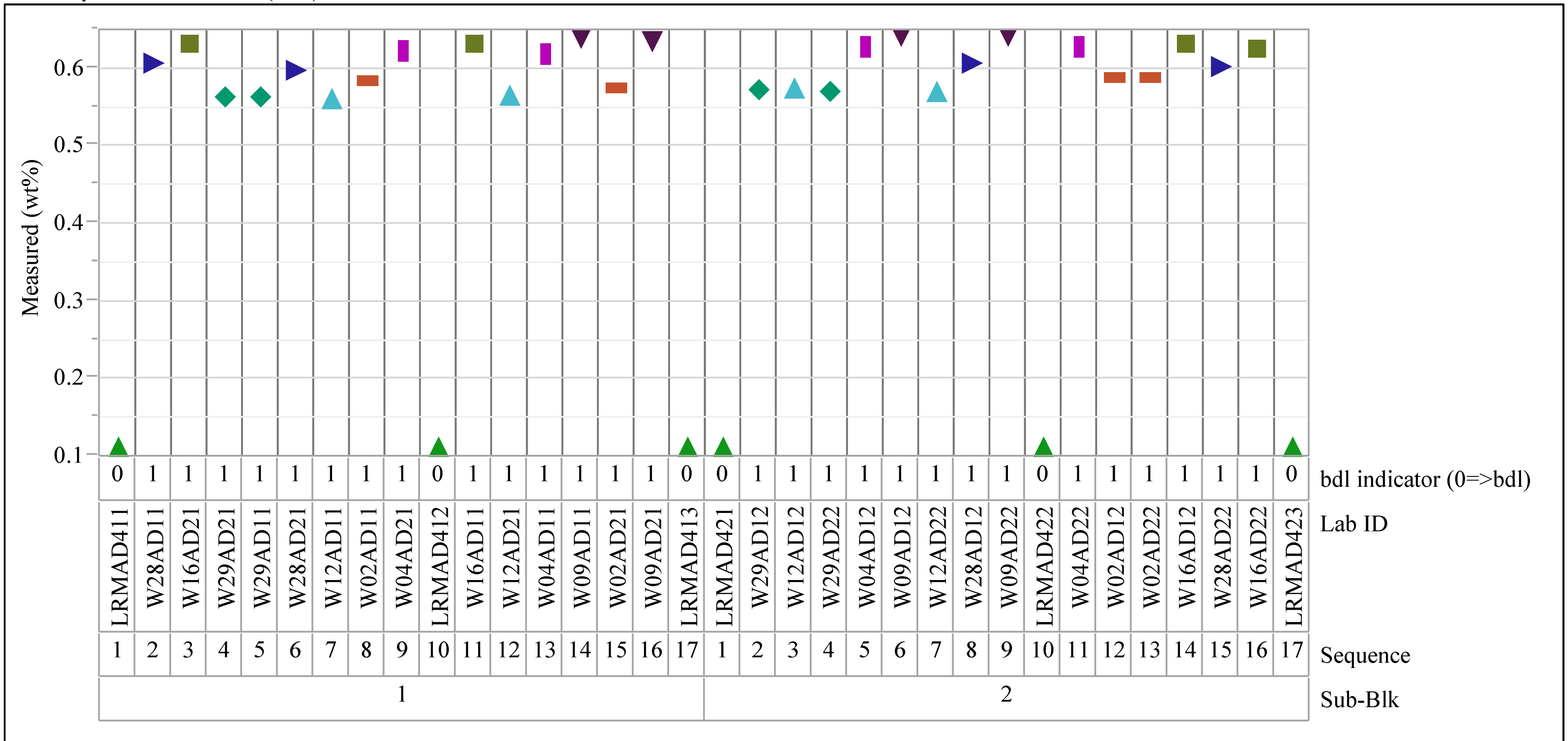


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

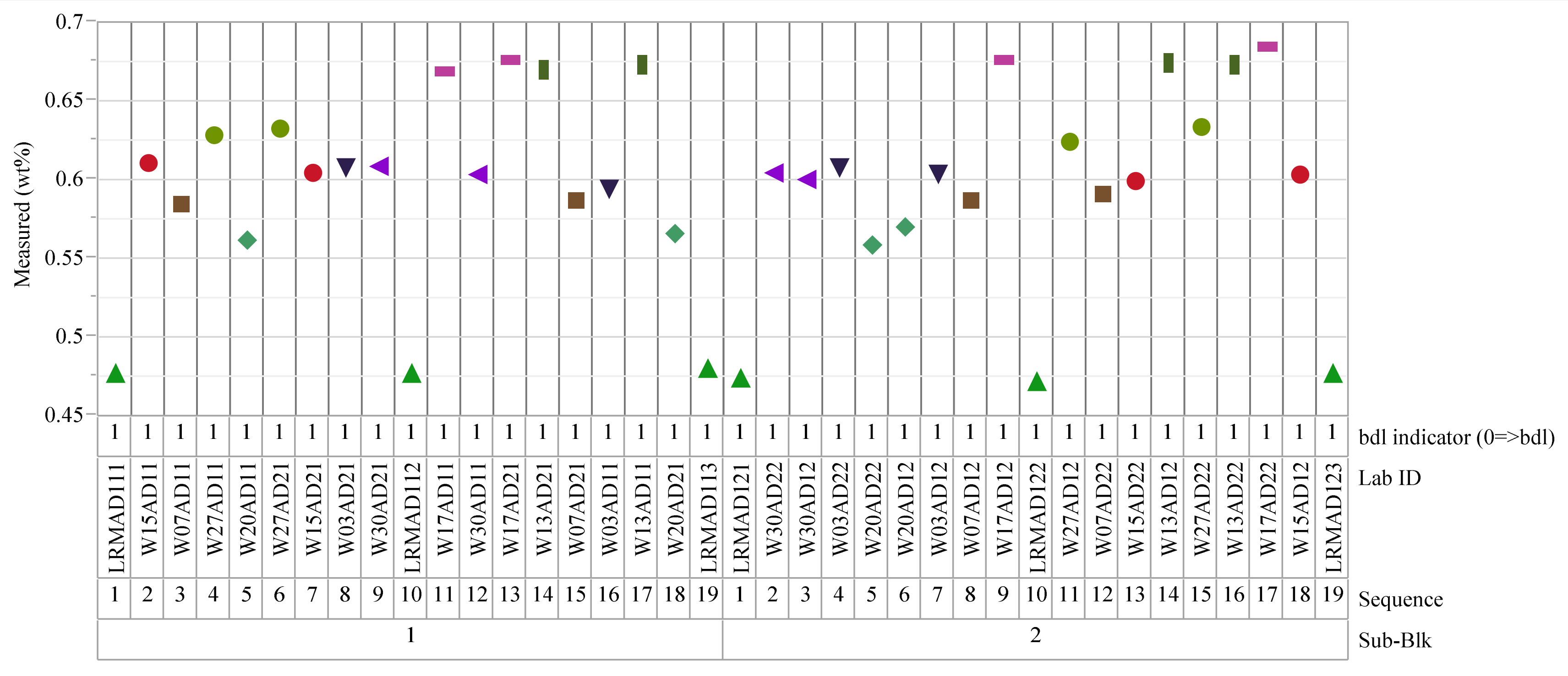


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

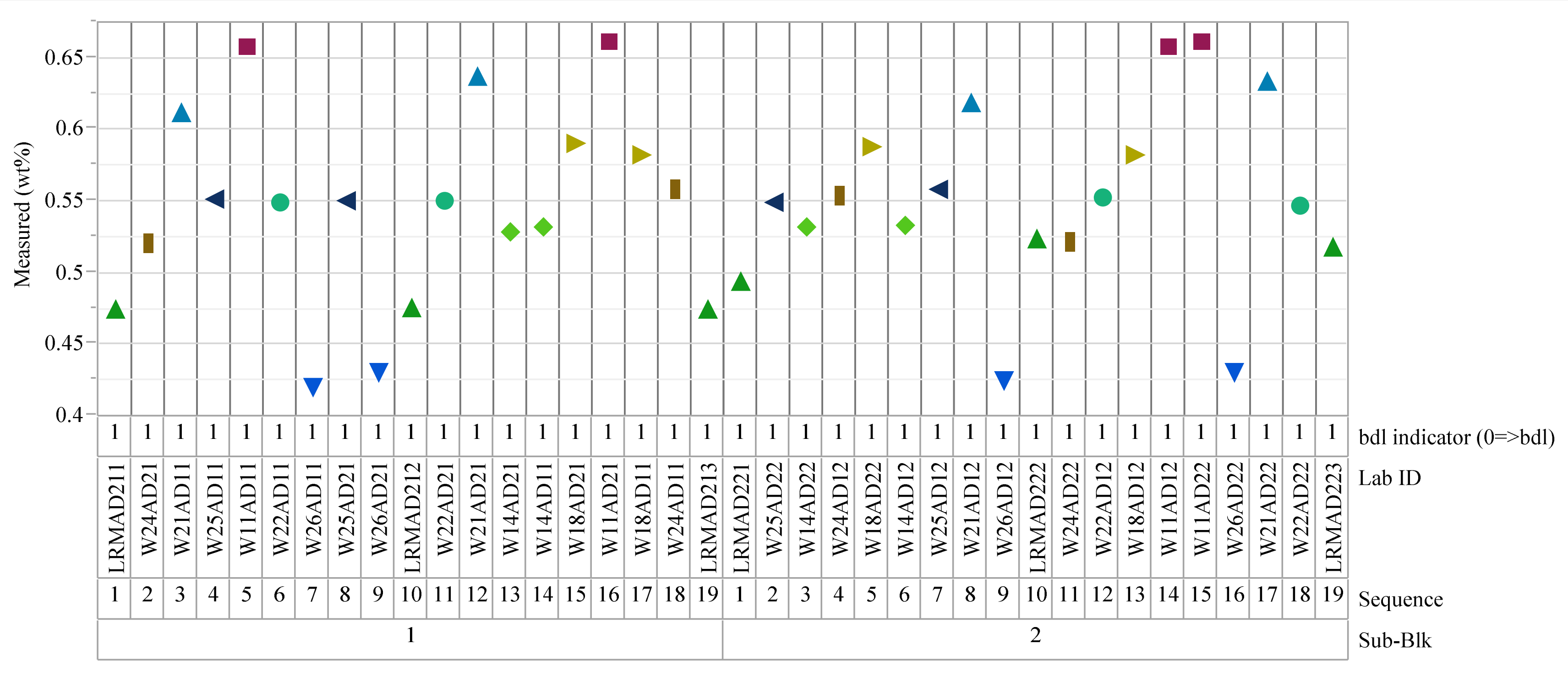


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

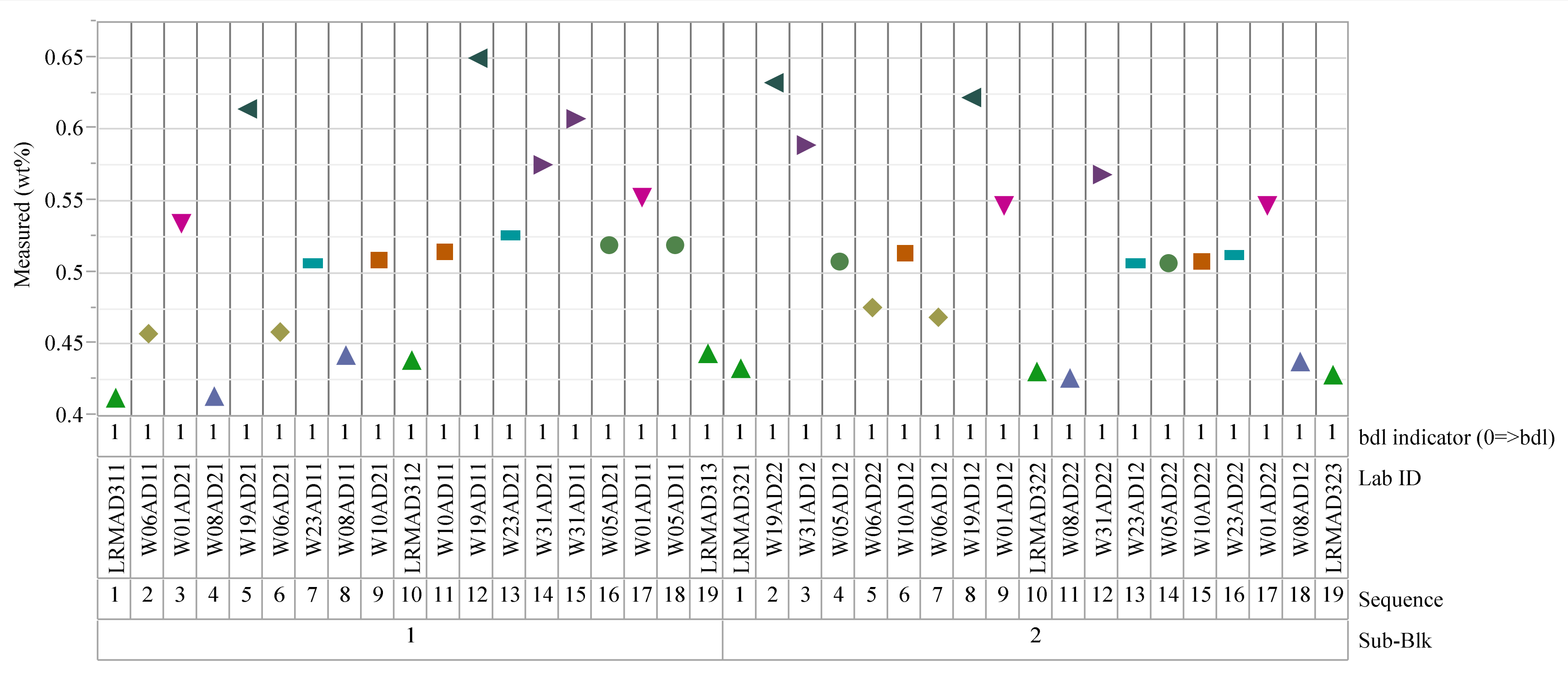


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

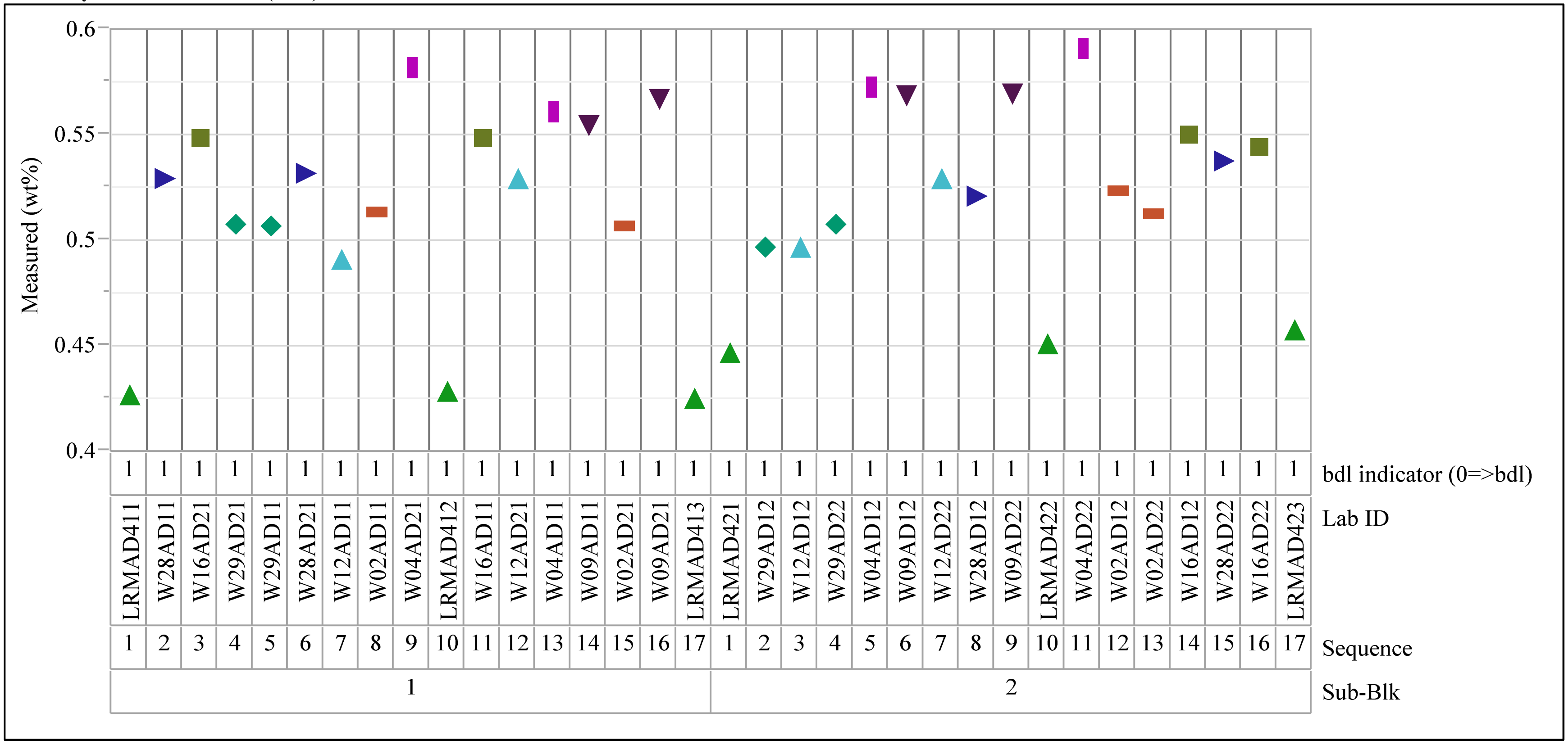


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

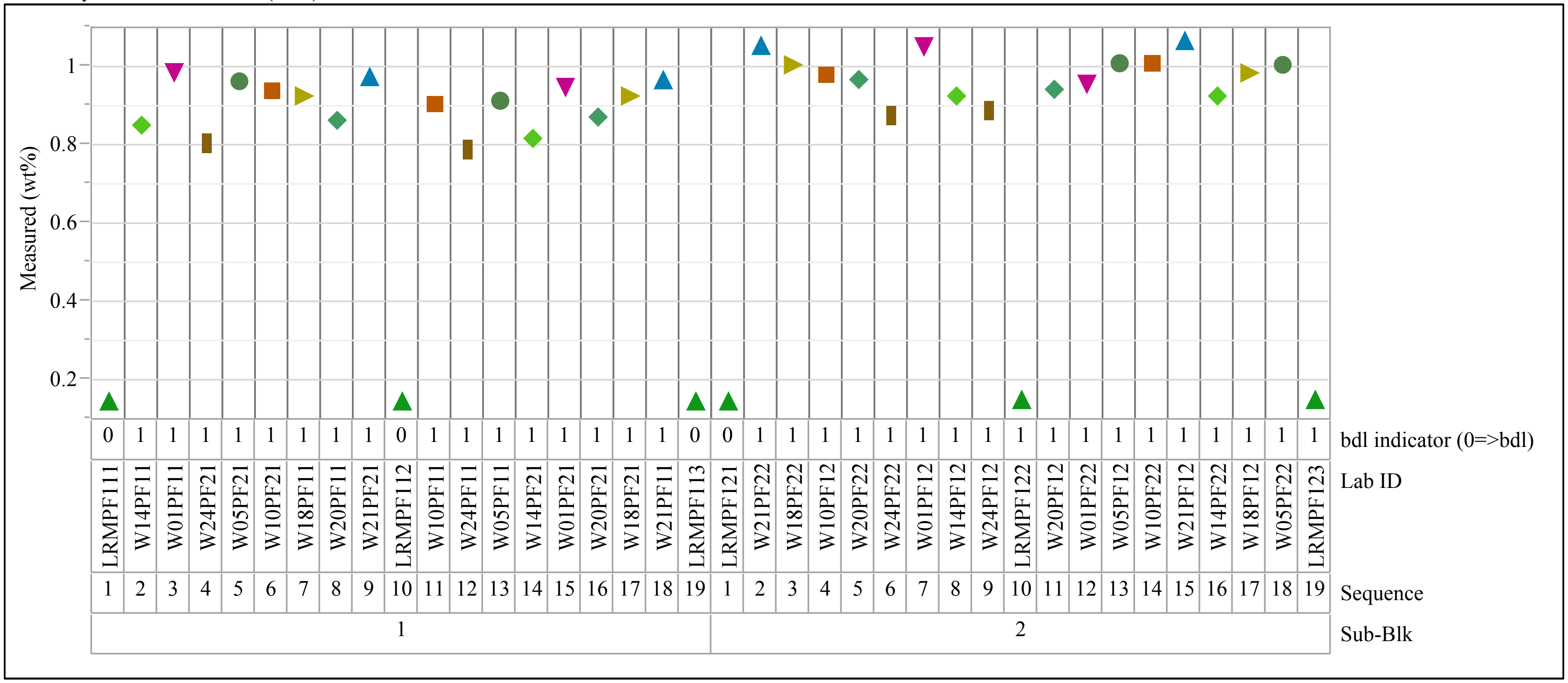


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

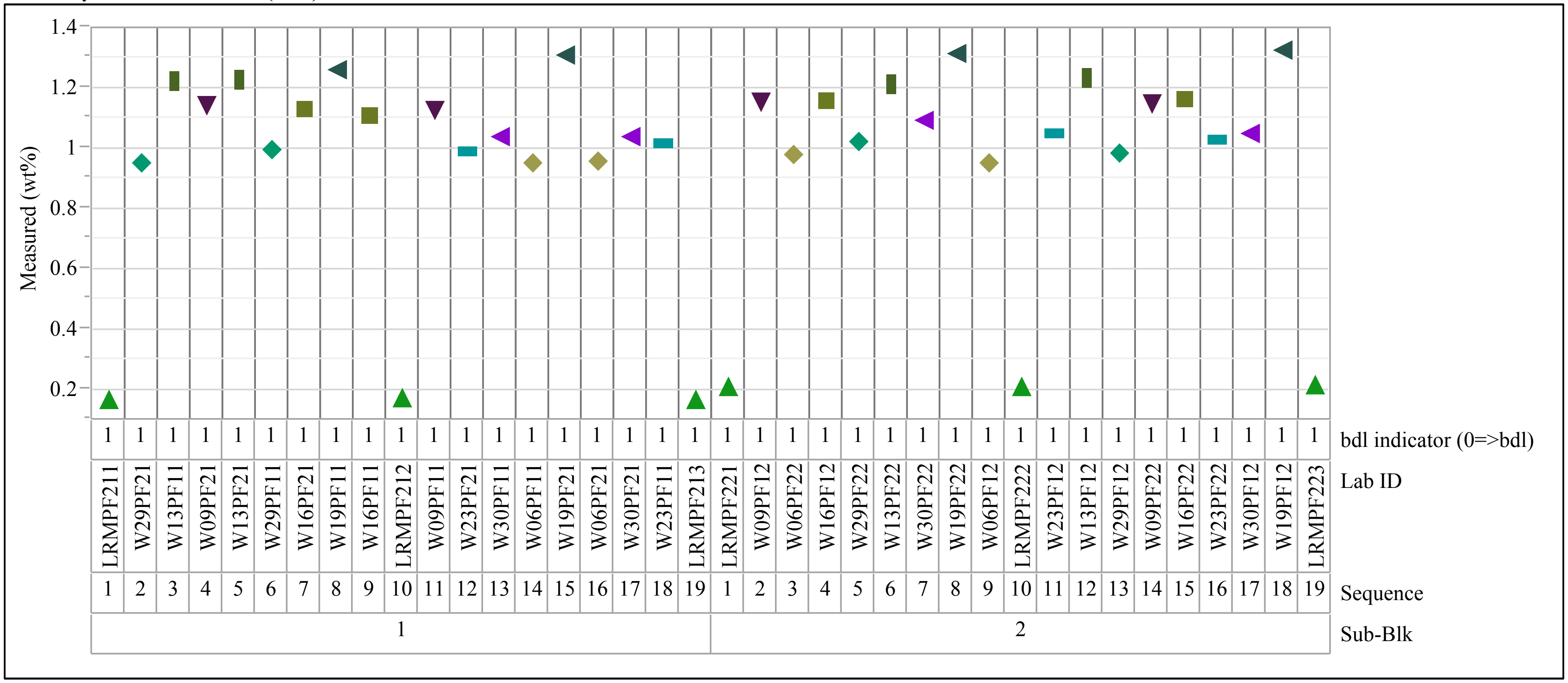


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

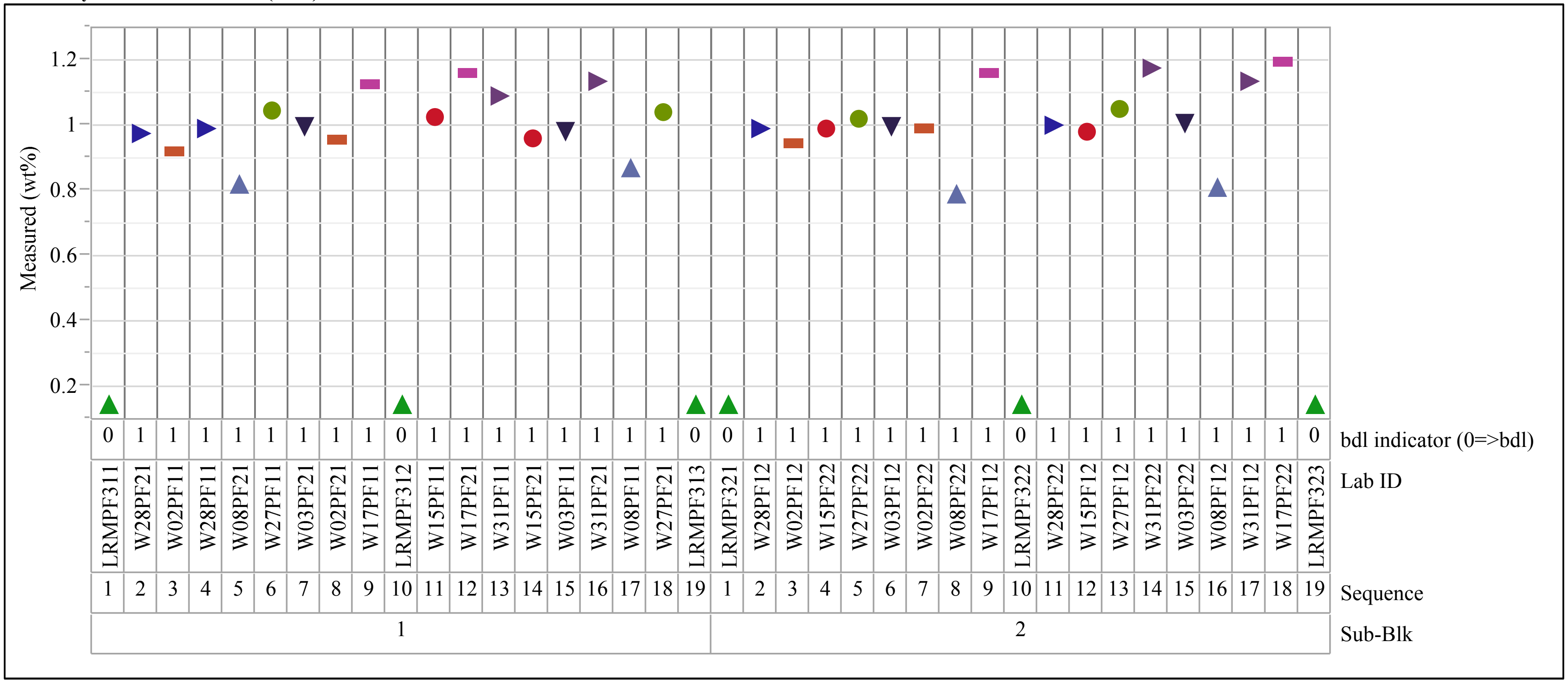


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

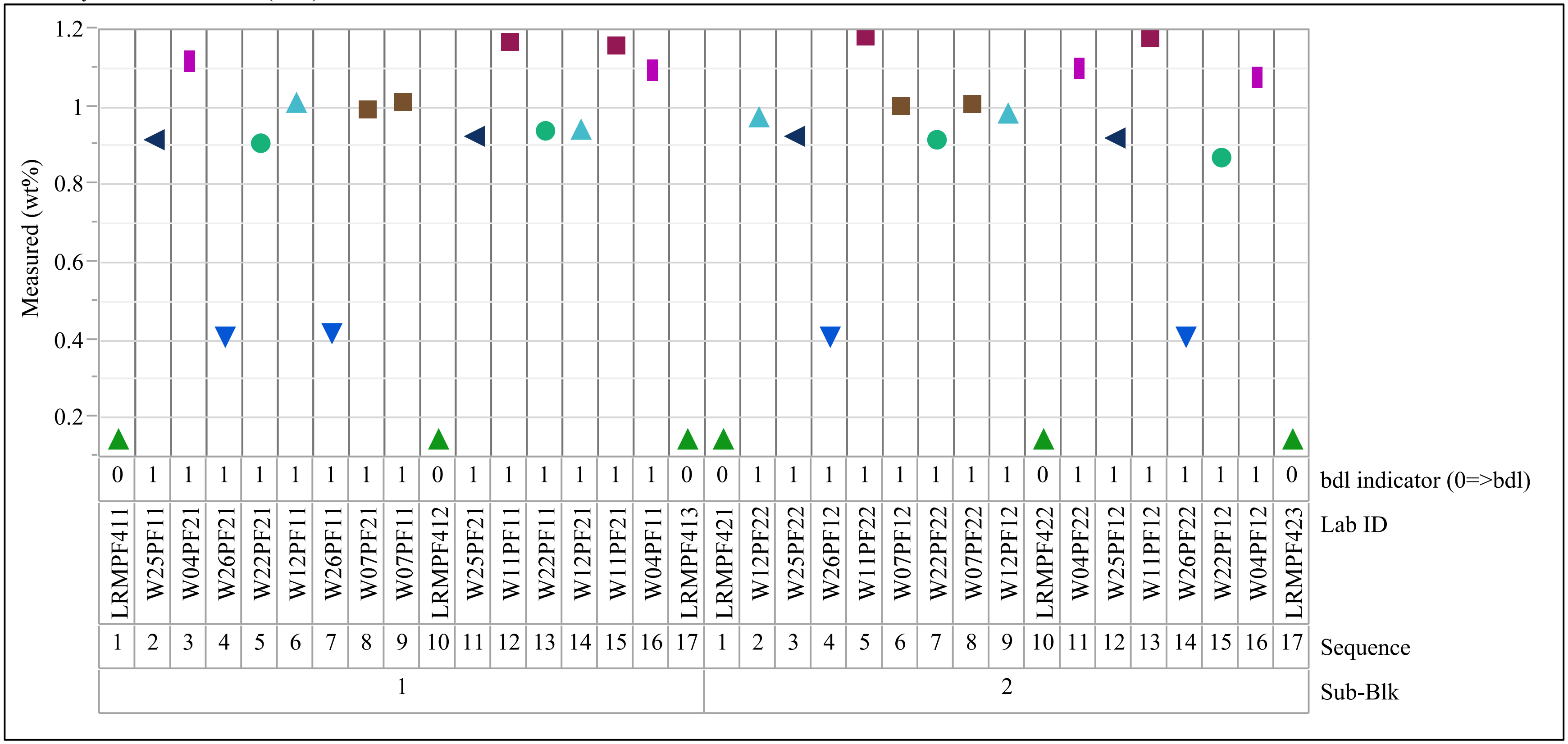


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

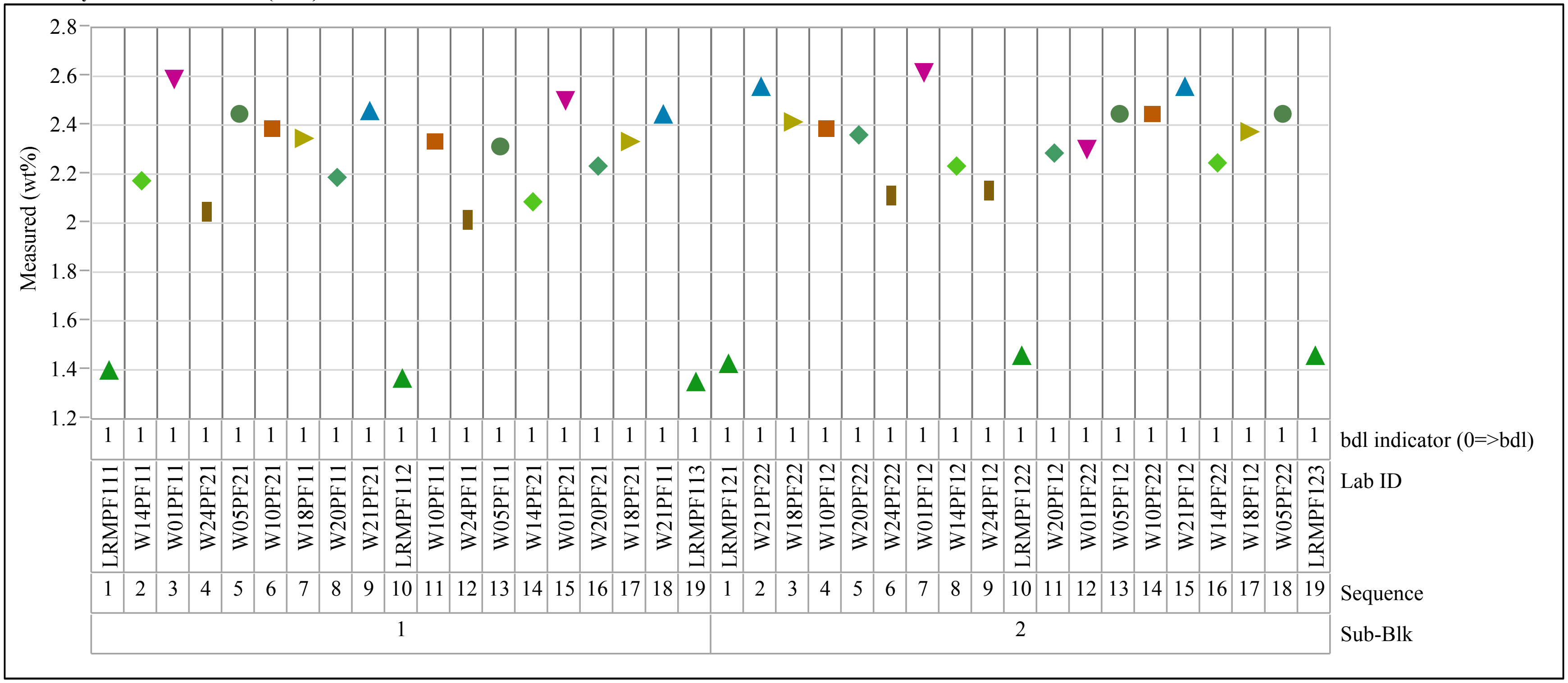
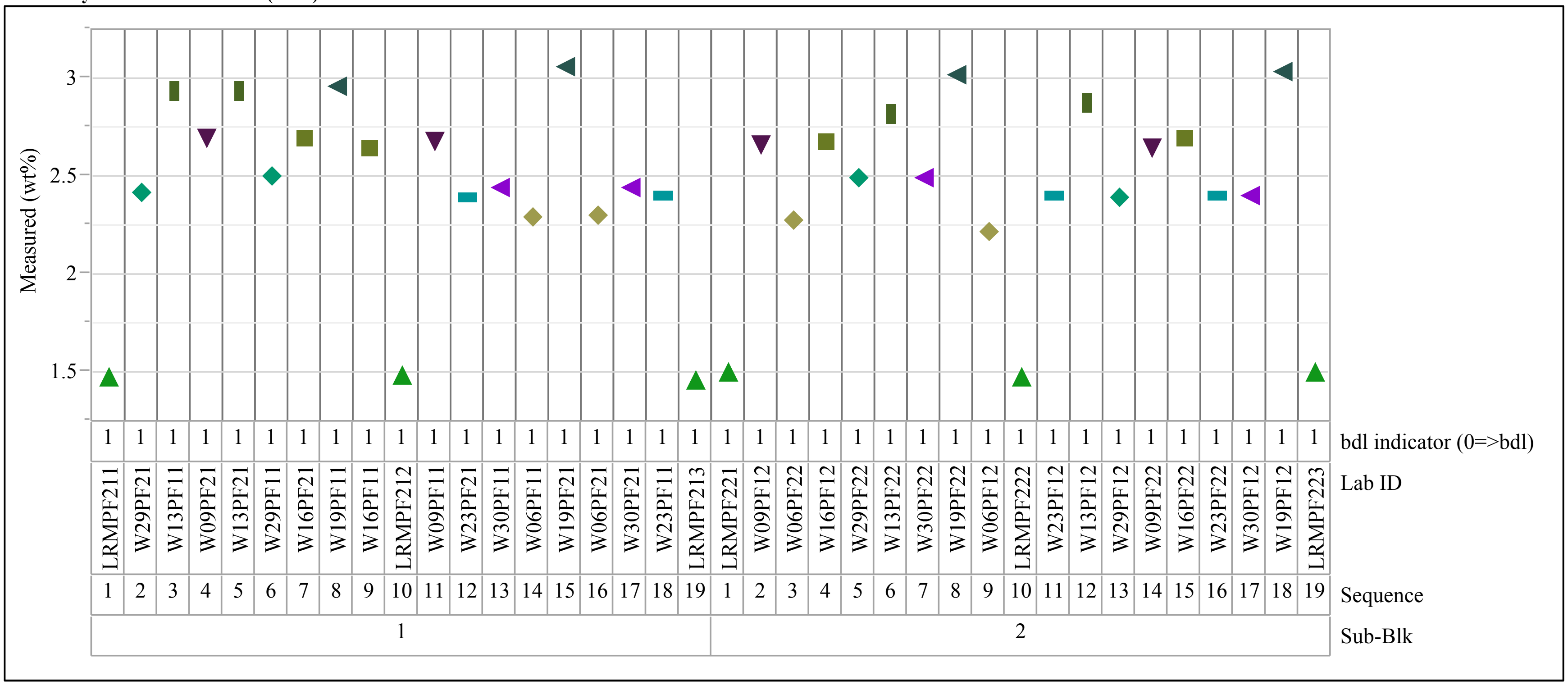


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

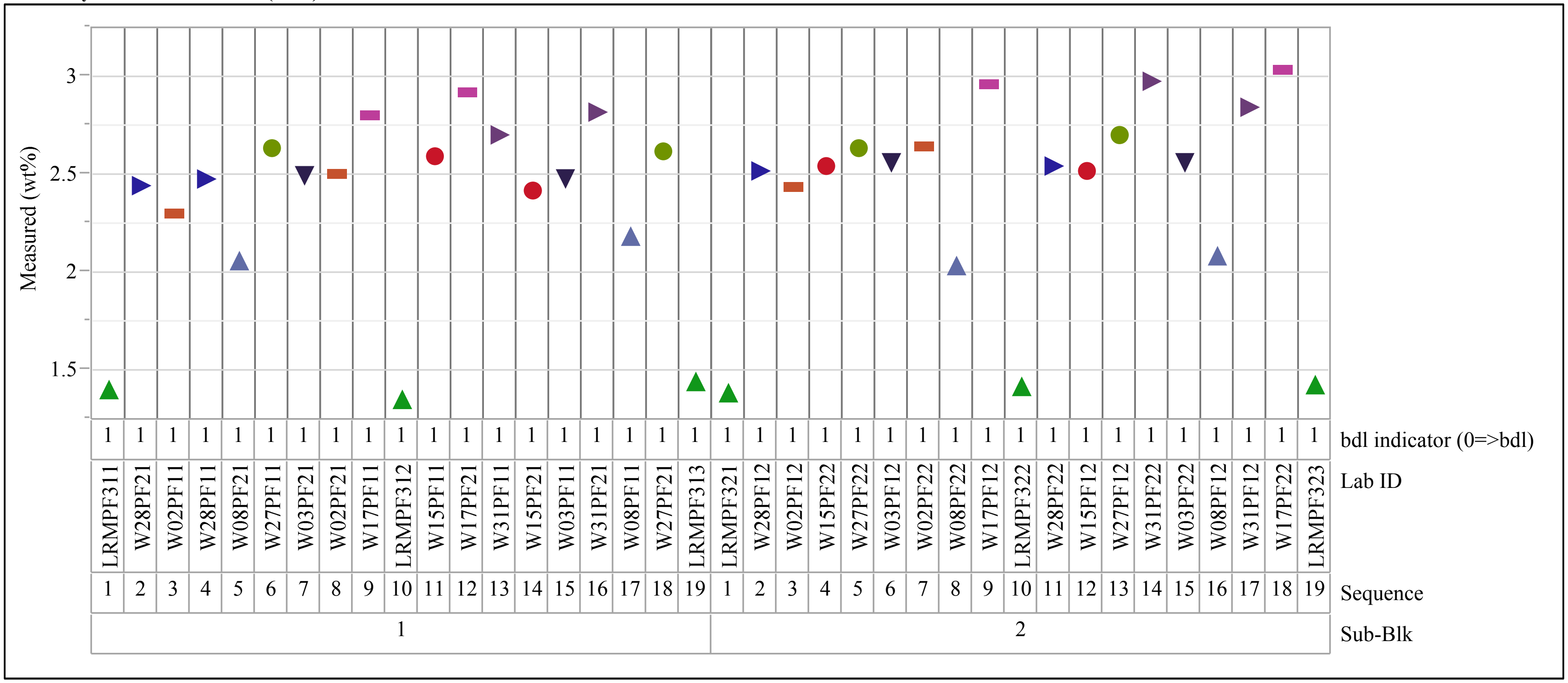


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

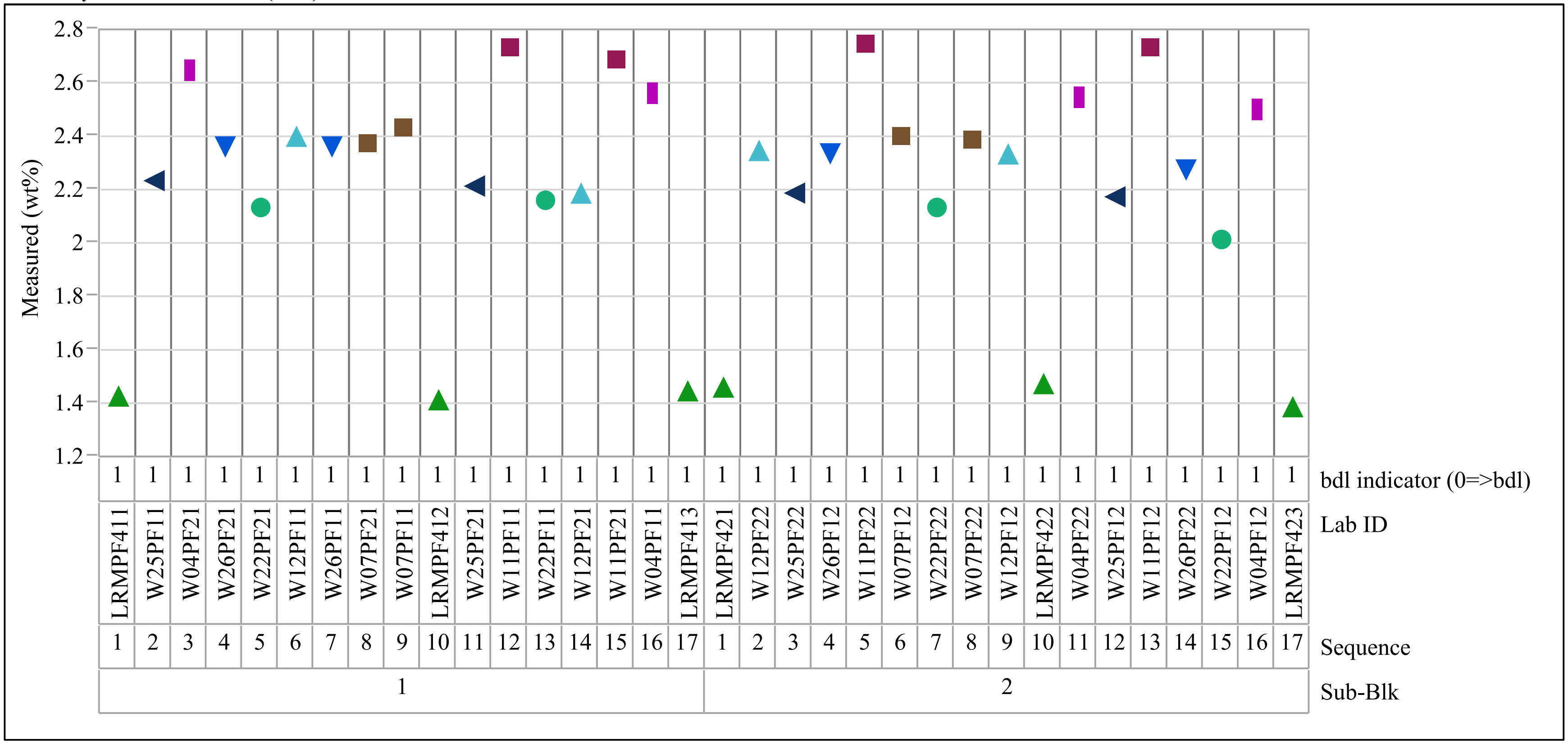


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

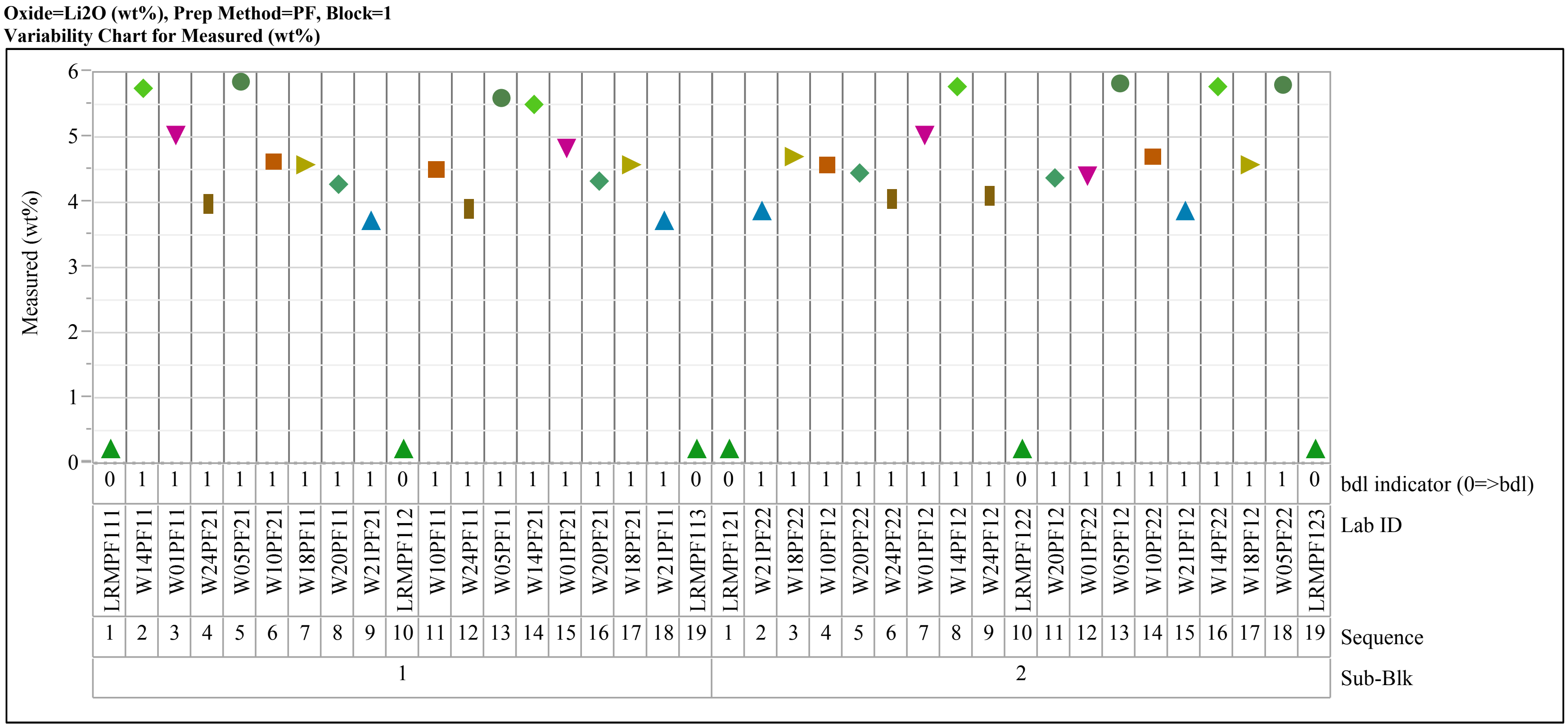


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

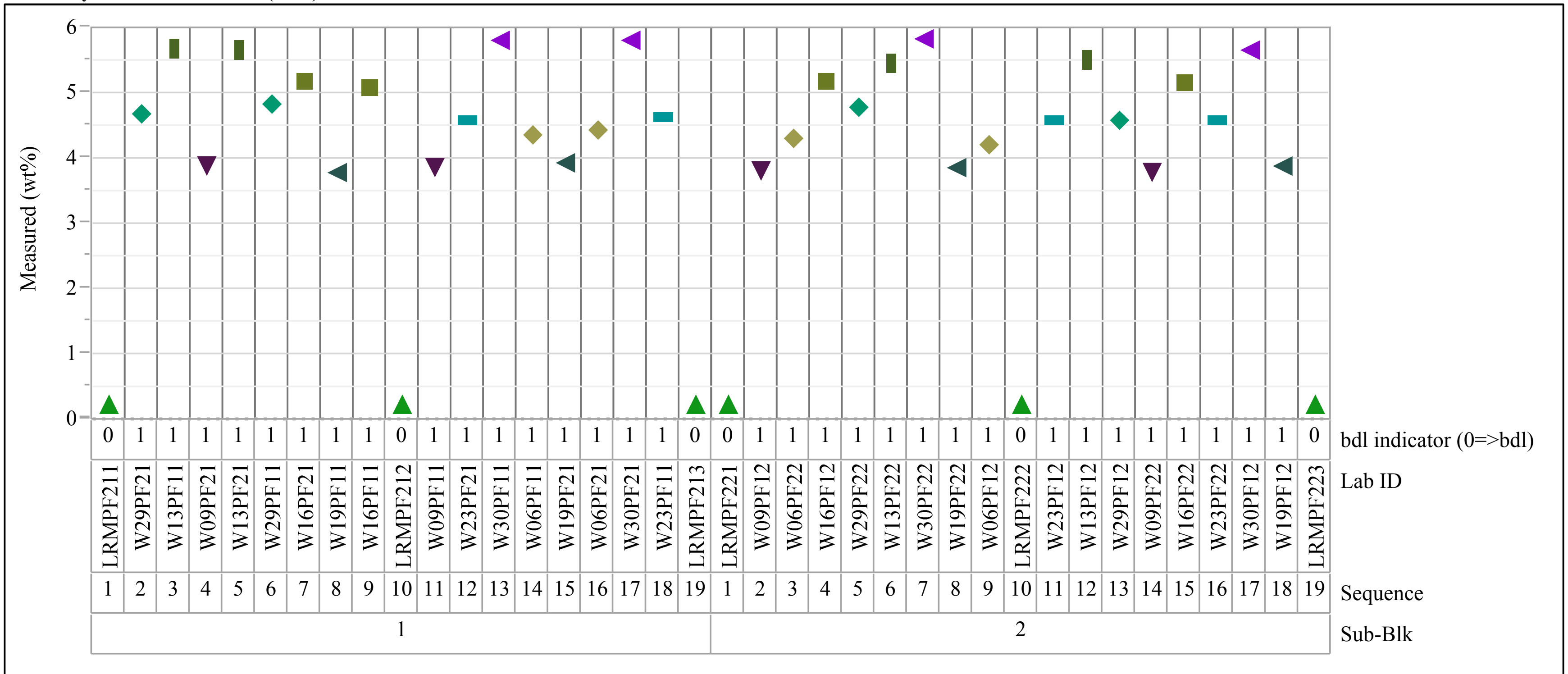


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

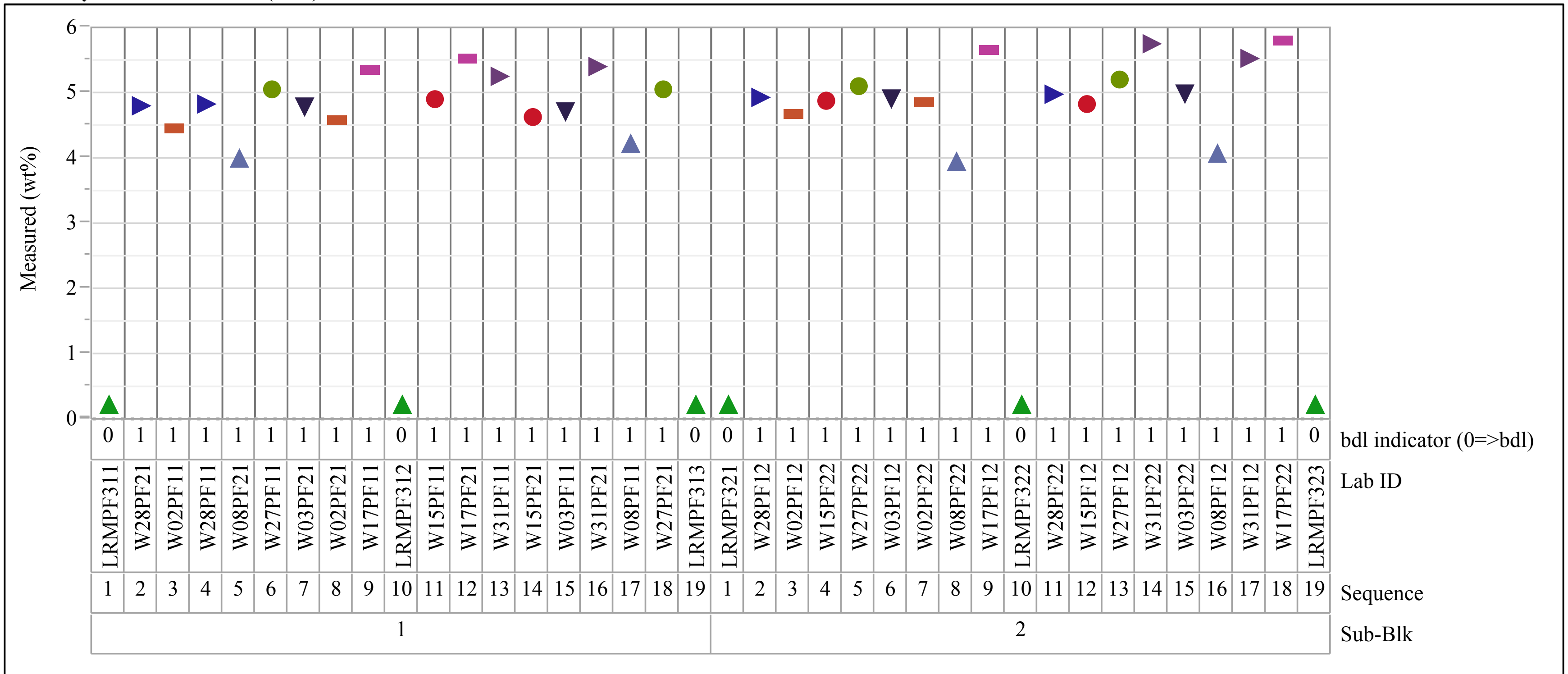


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

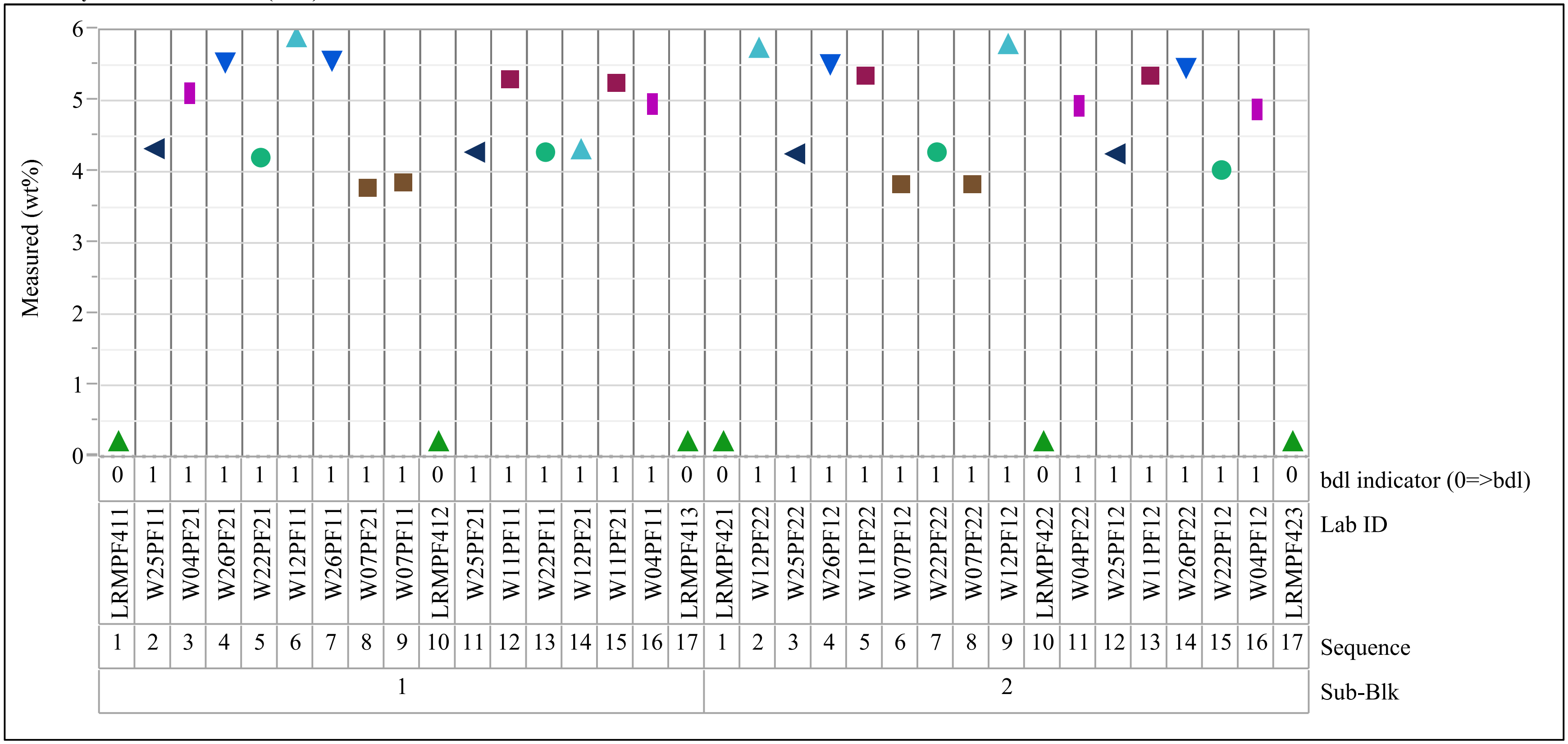


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

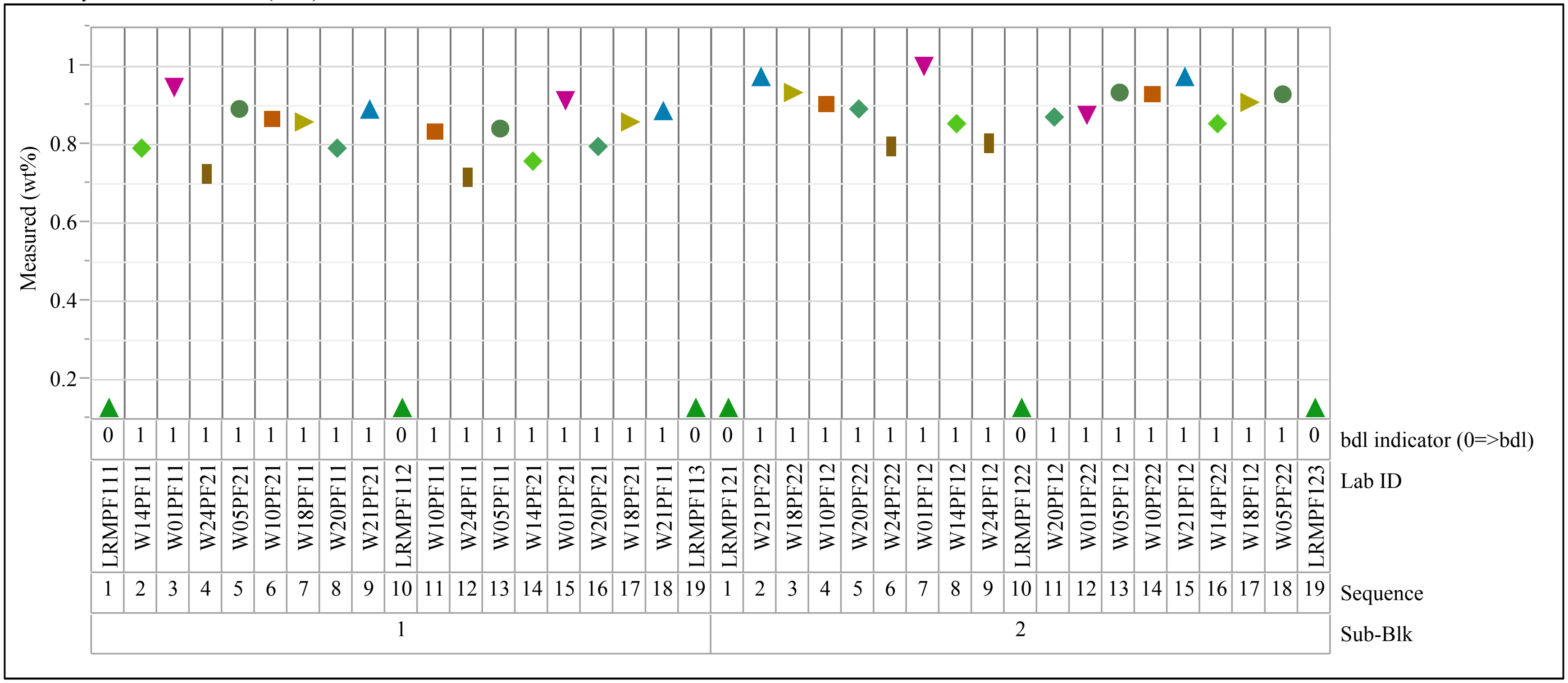


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

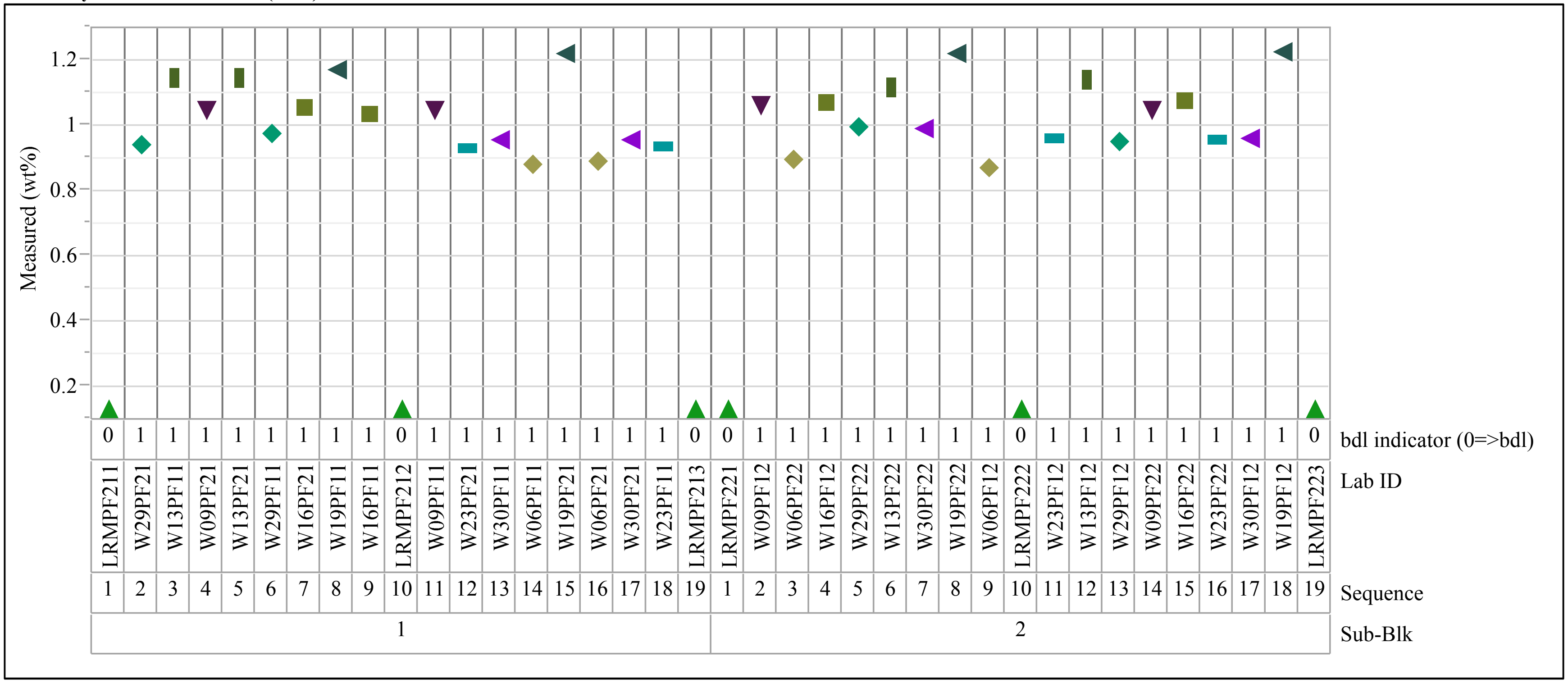


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

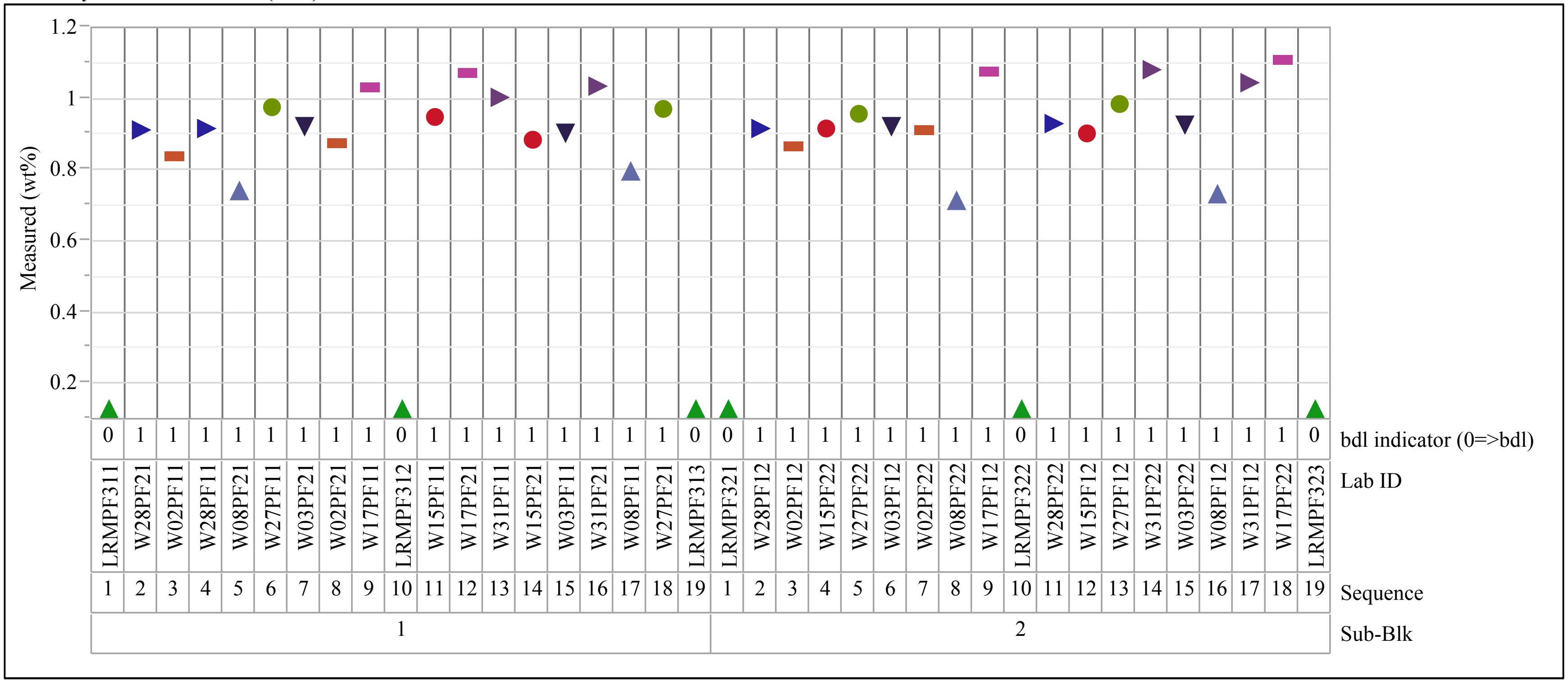


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

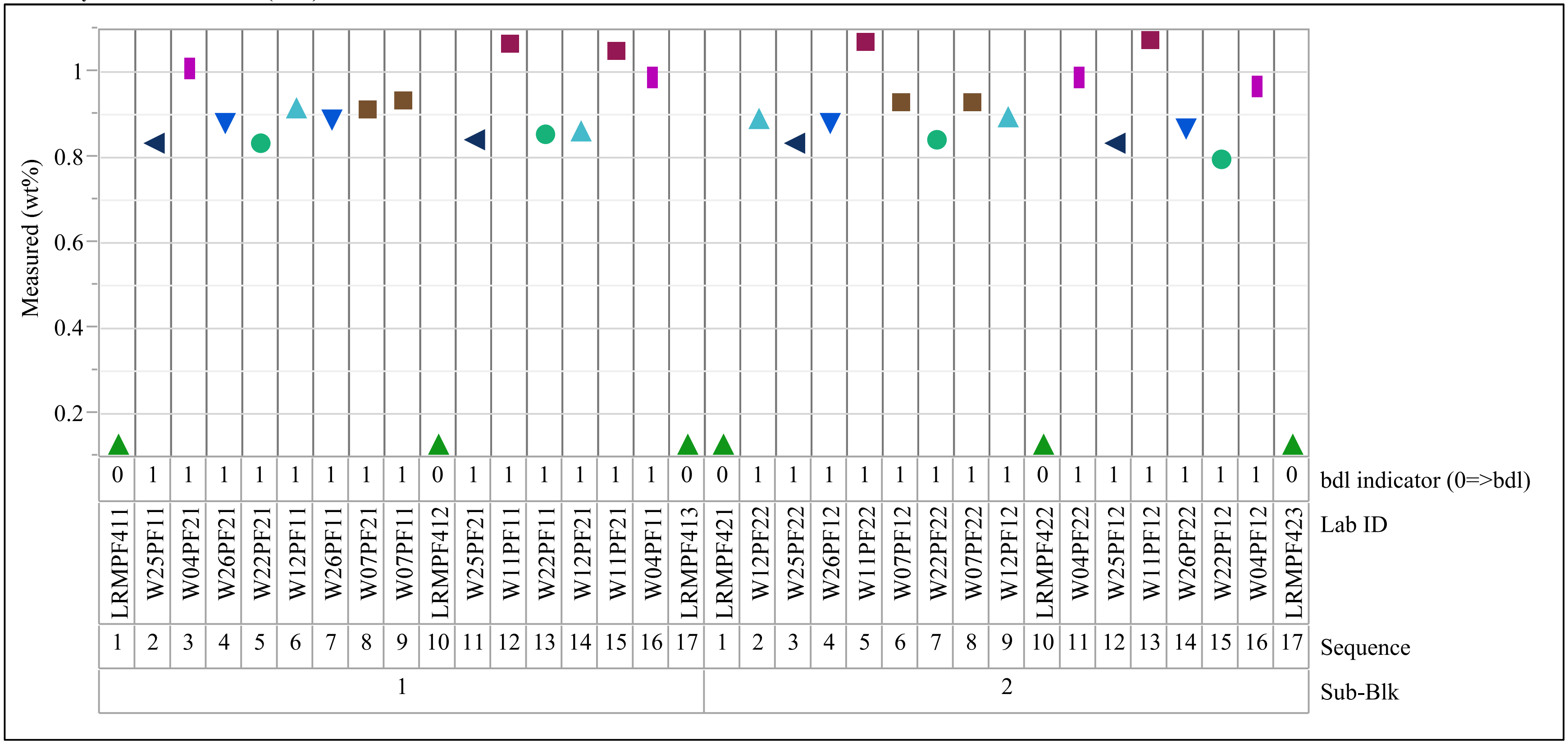
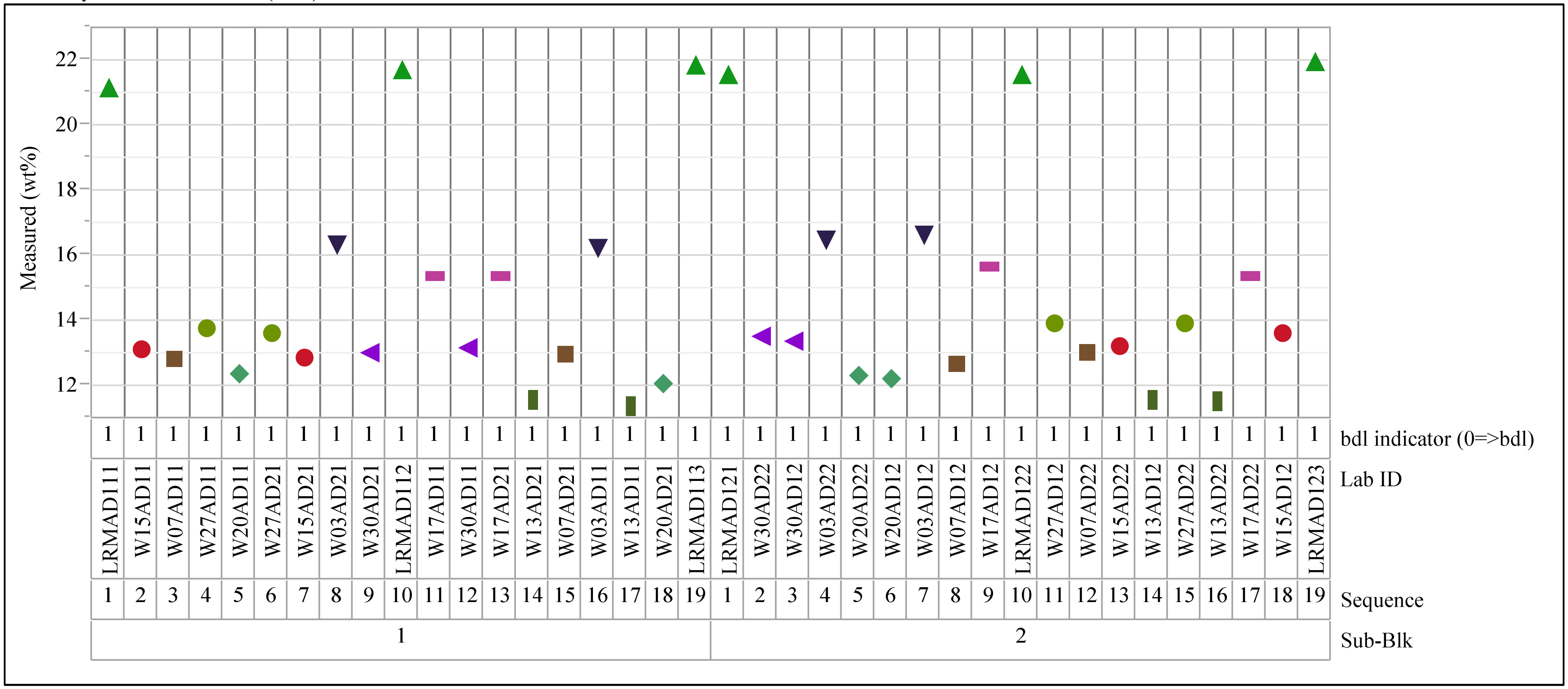


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**



## Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)

**Oxide=Na2O (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

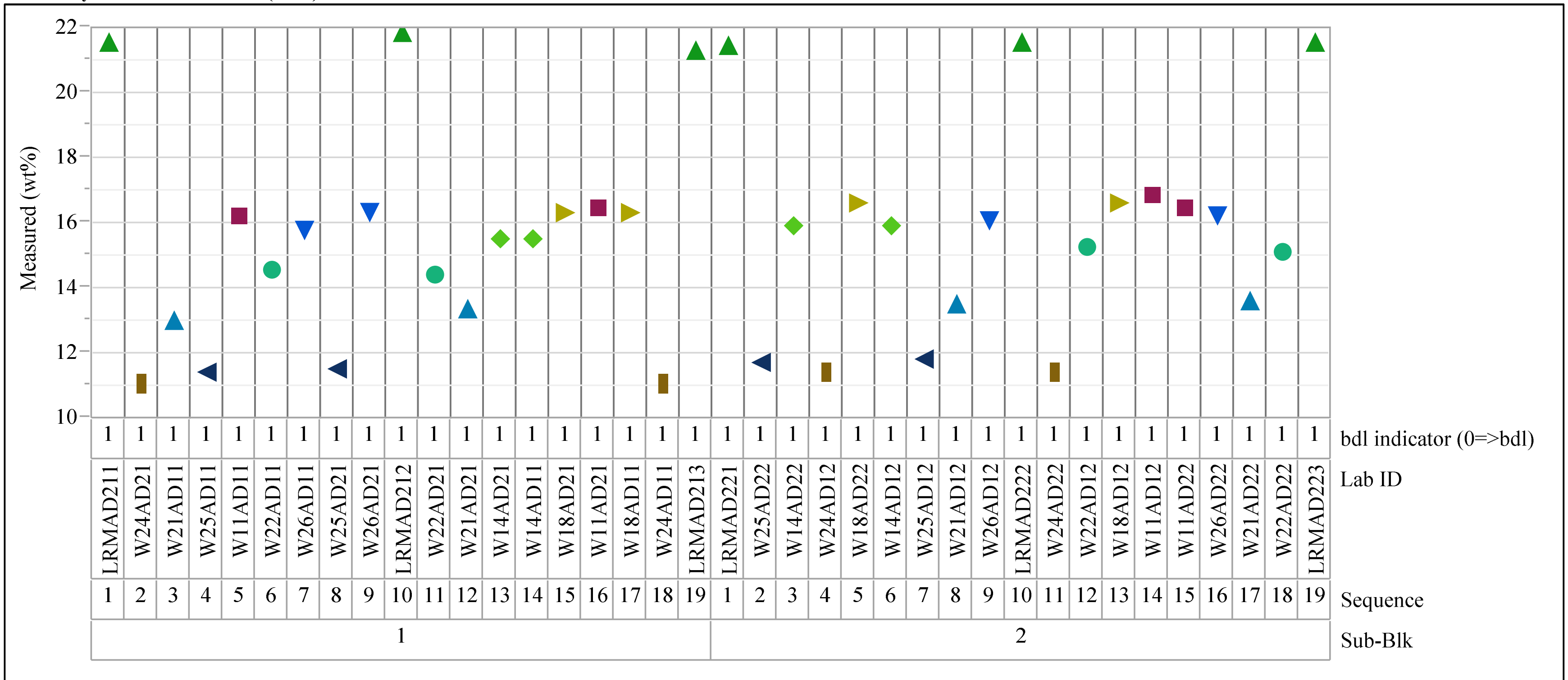


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

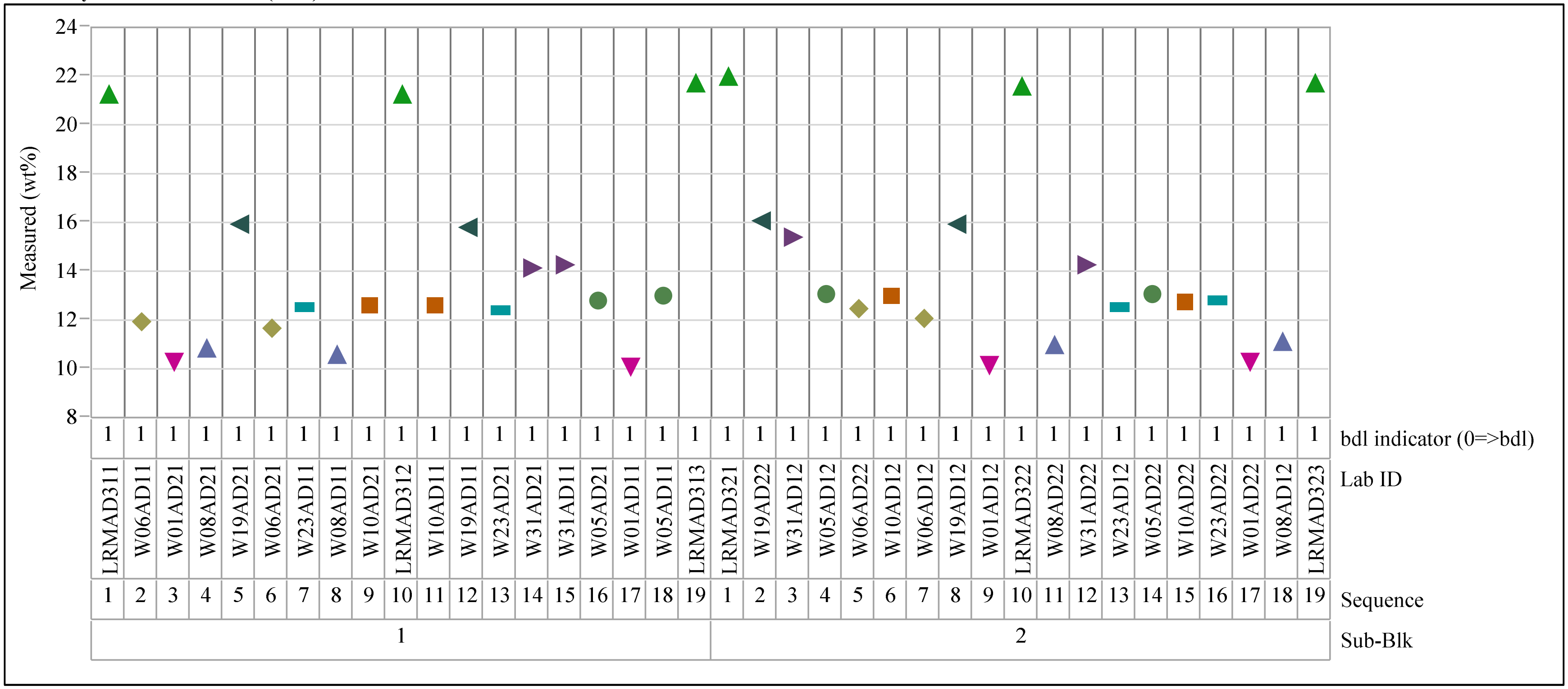


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

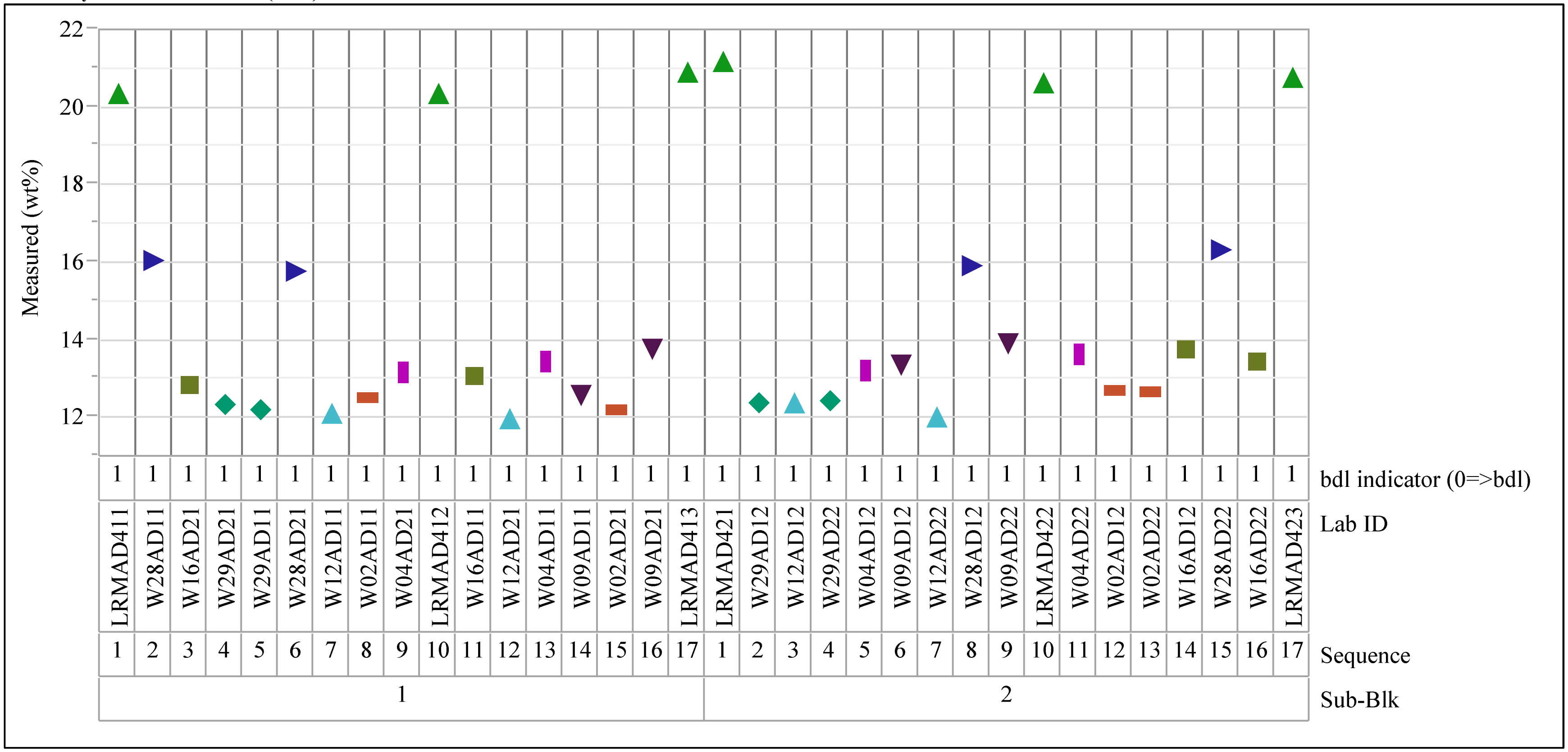


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

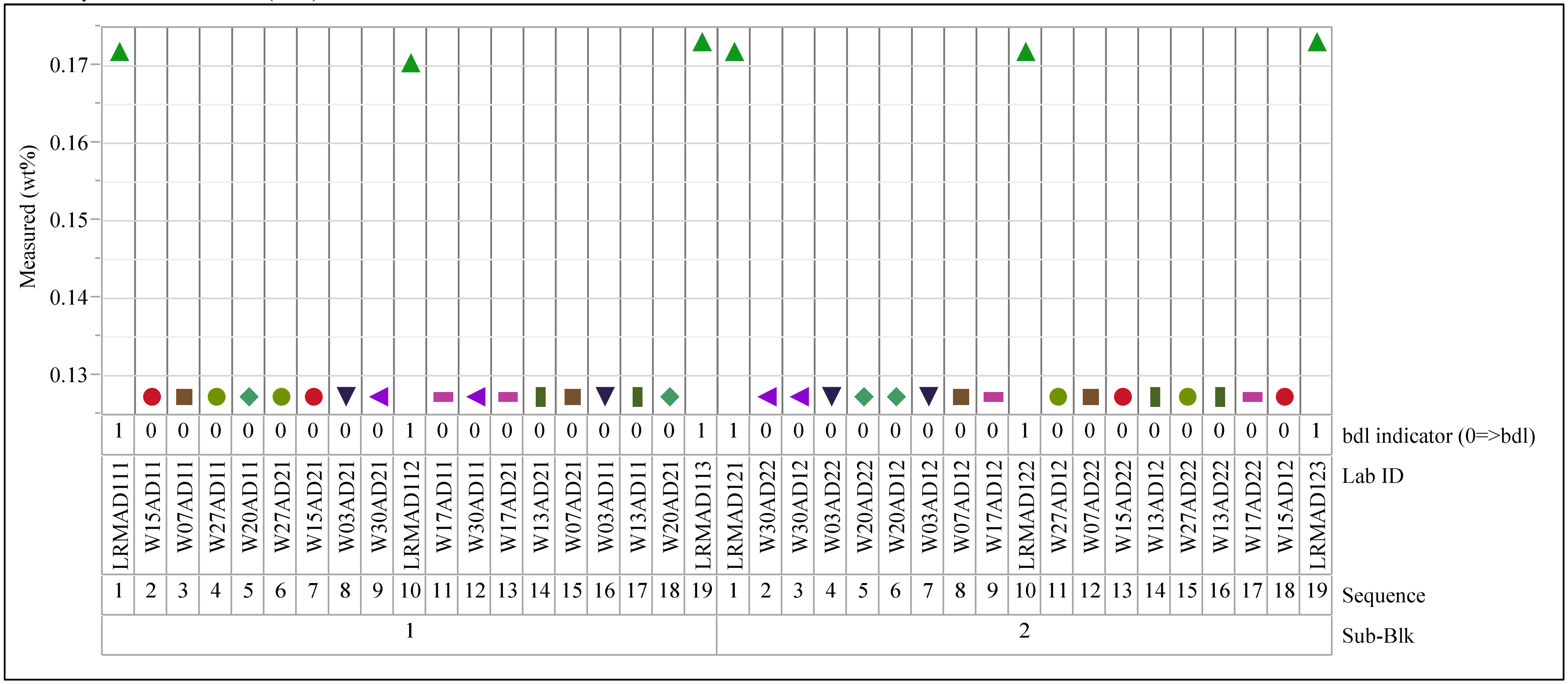


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

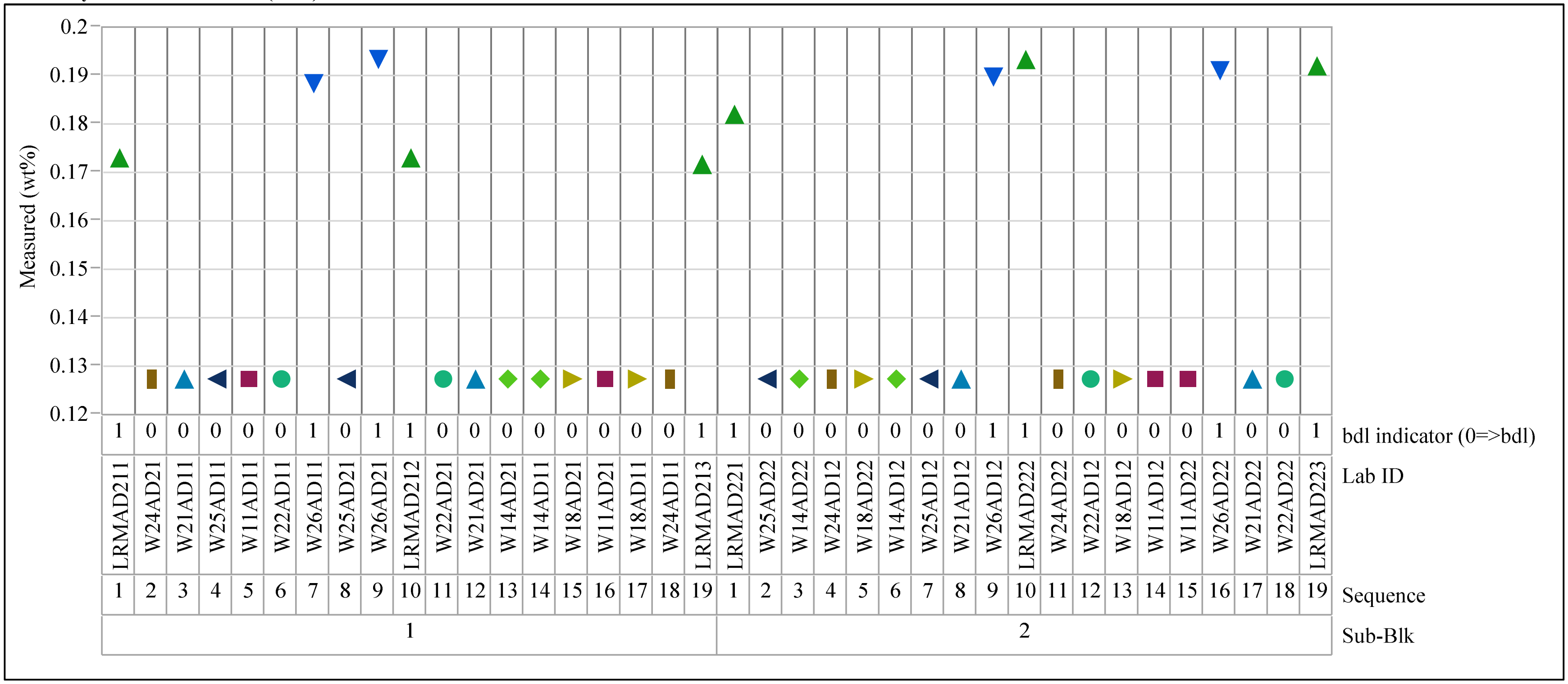


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

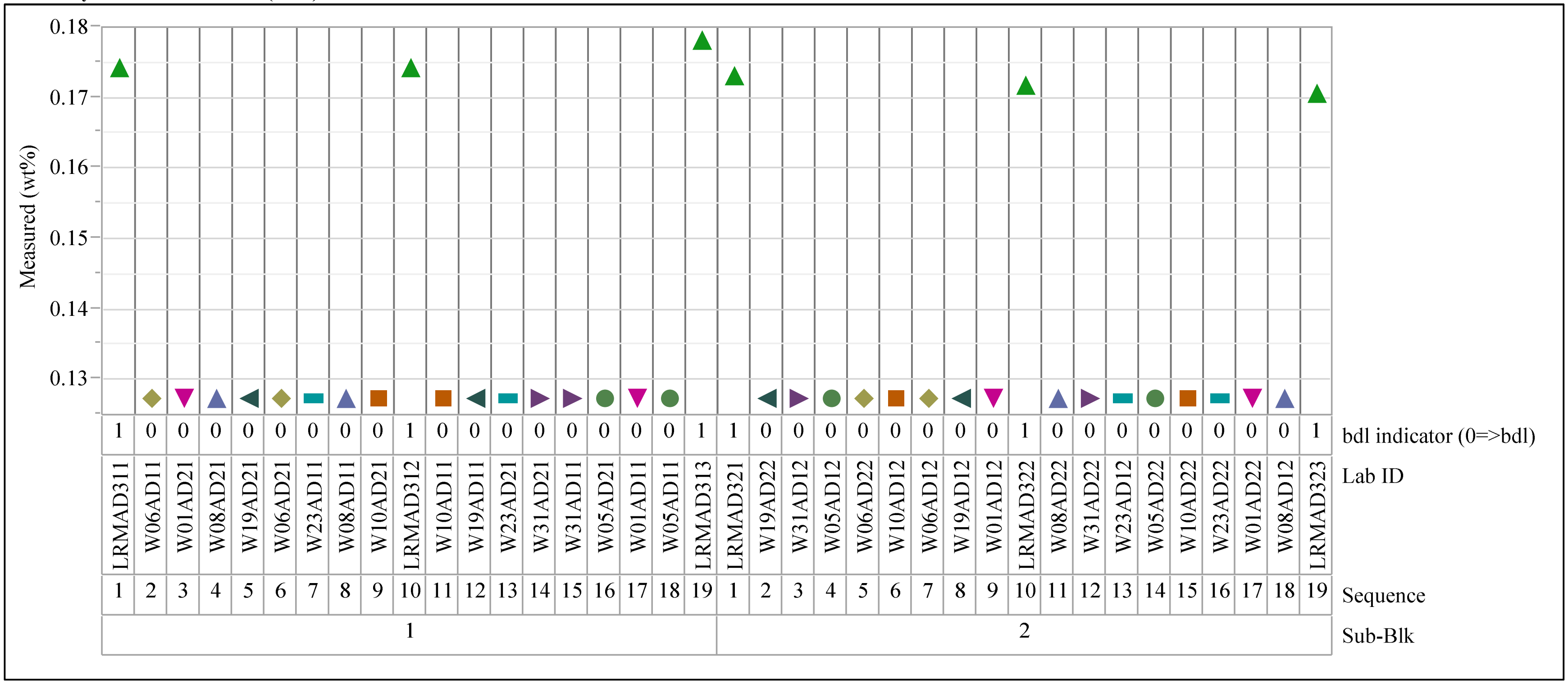


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

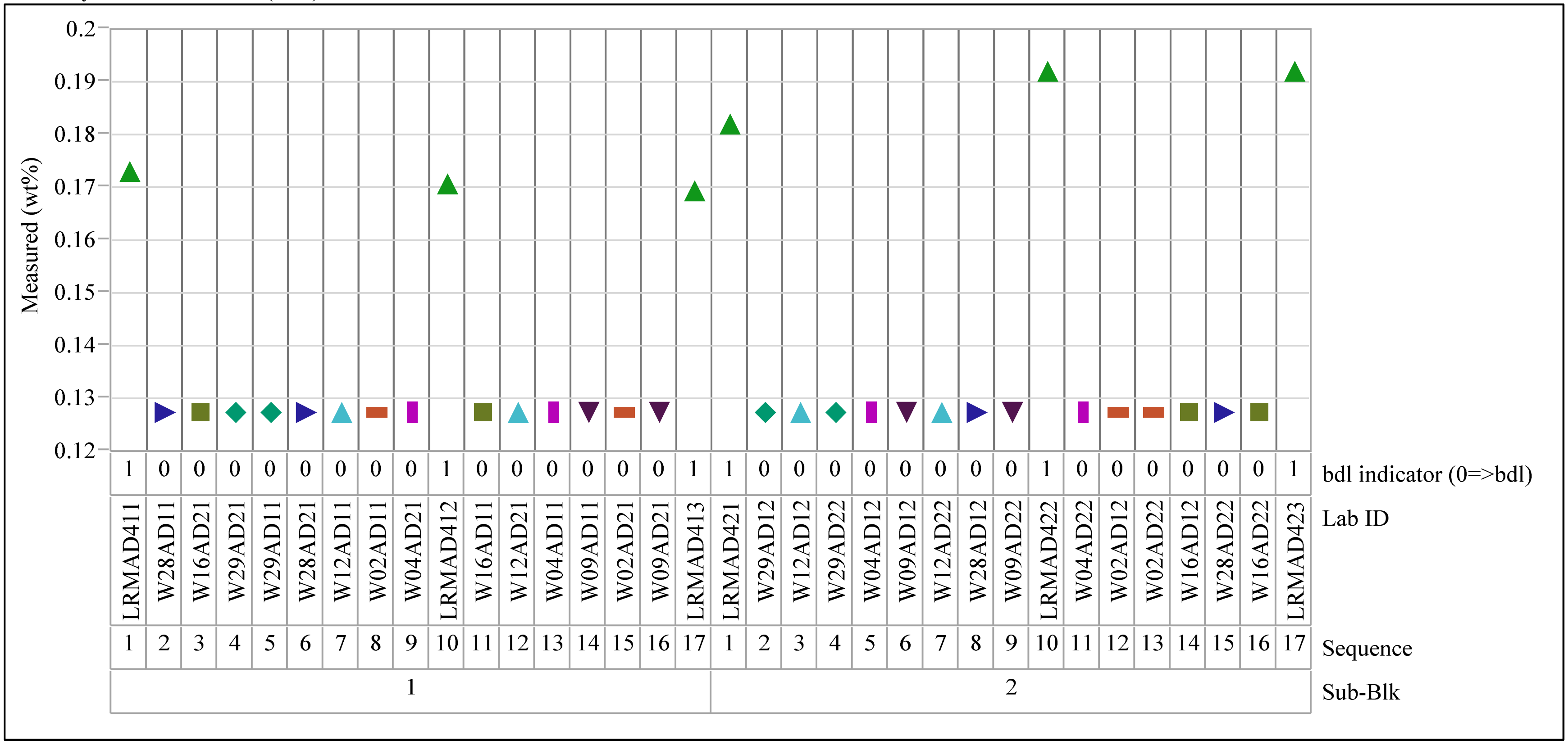


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

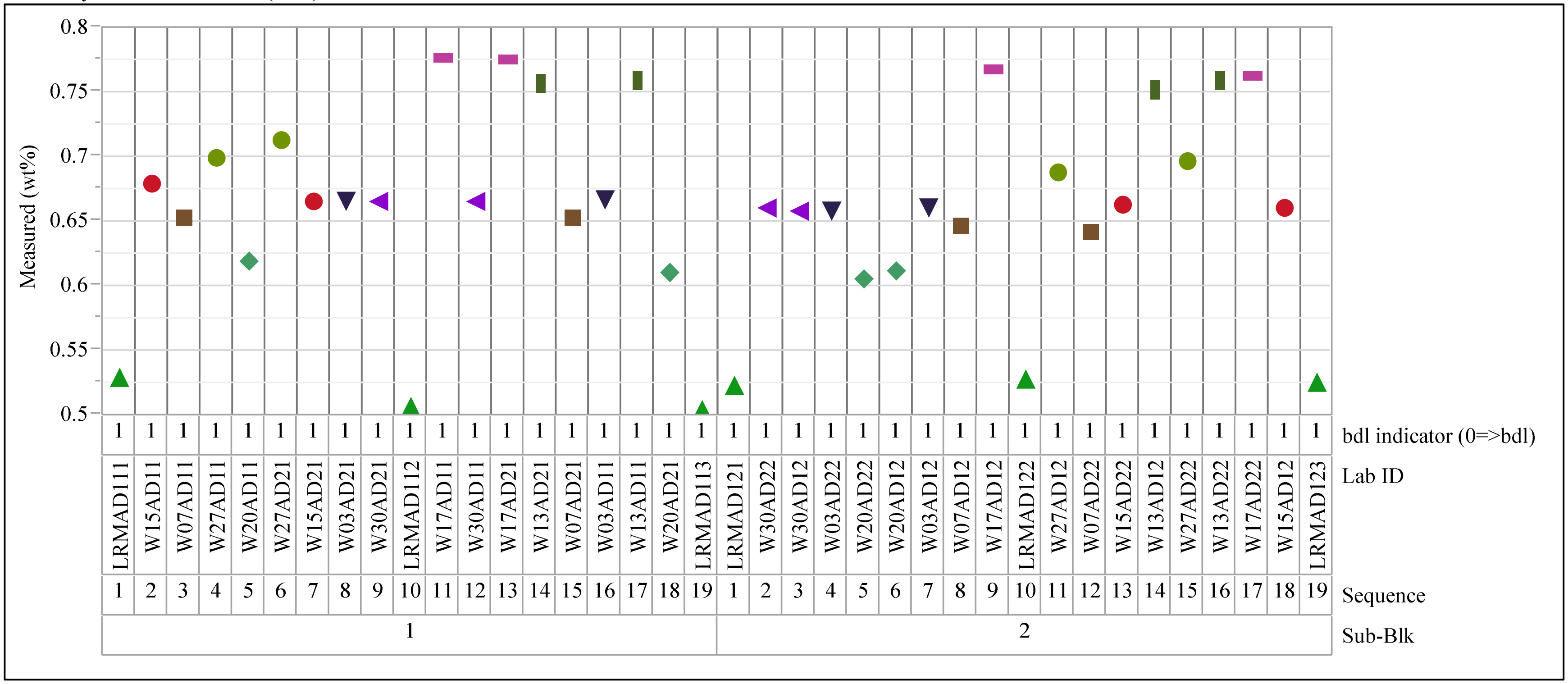


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

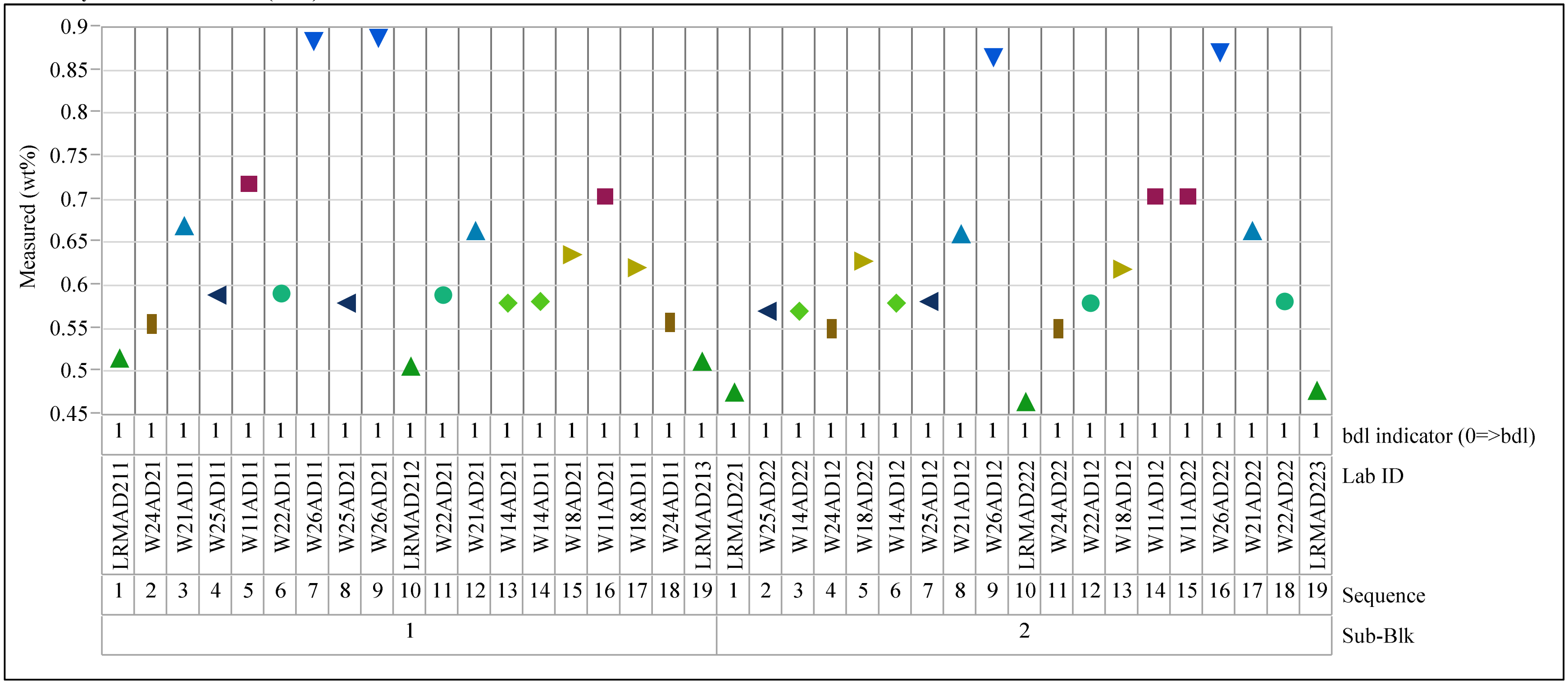


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

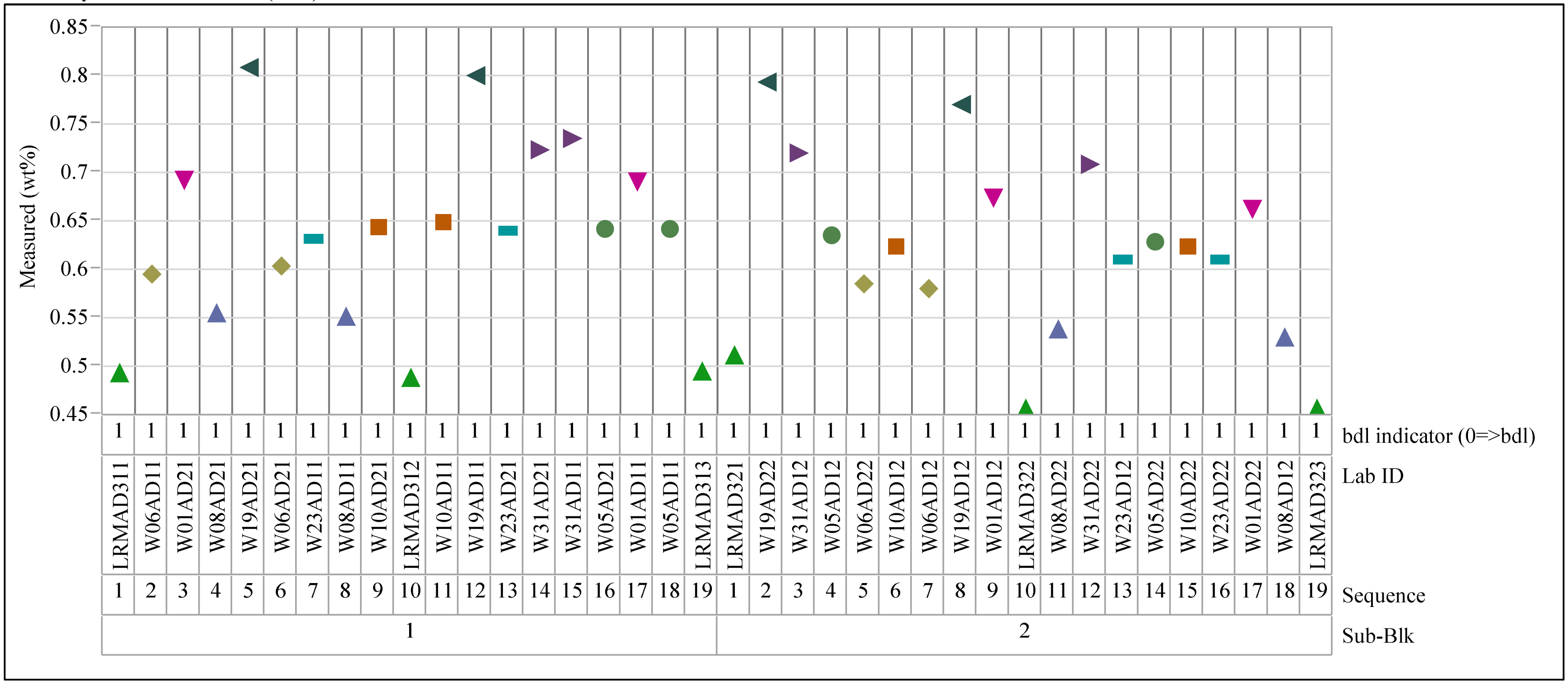


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

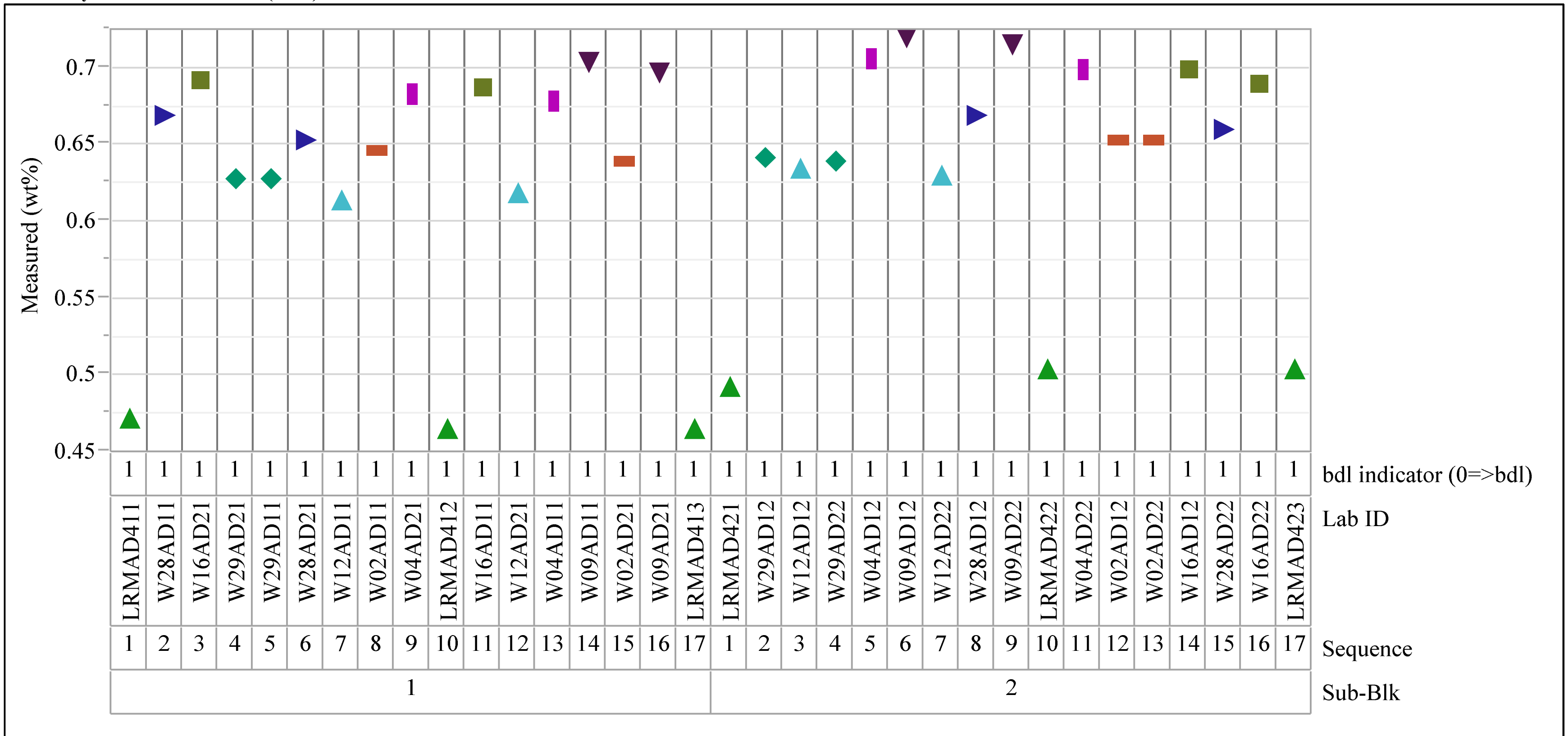


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

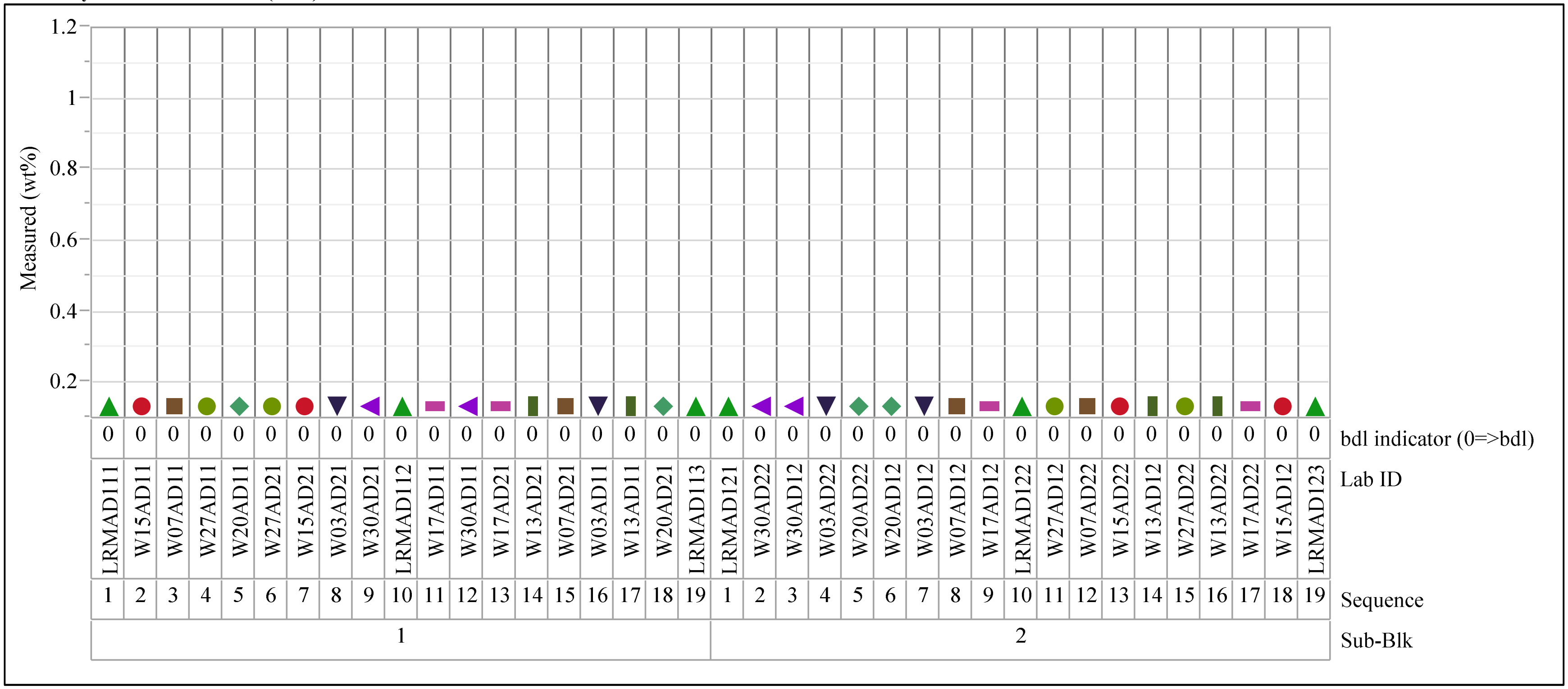


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

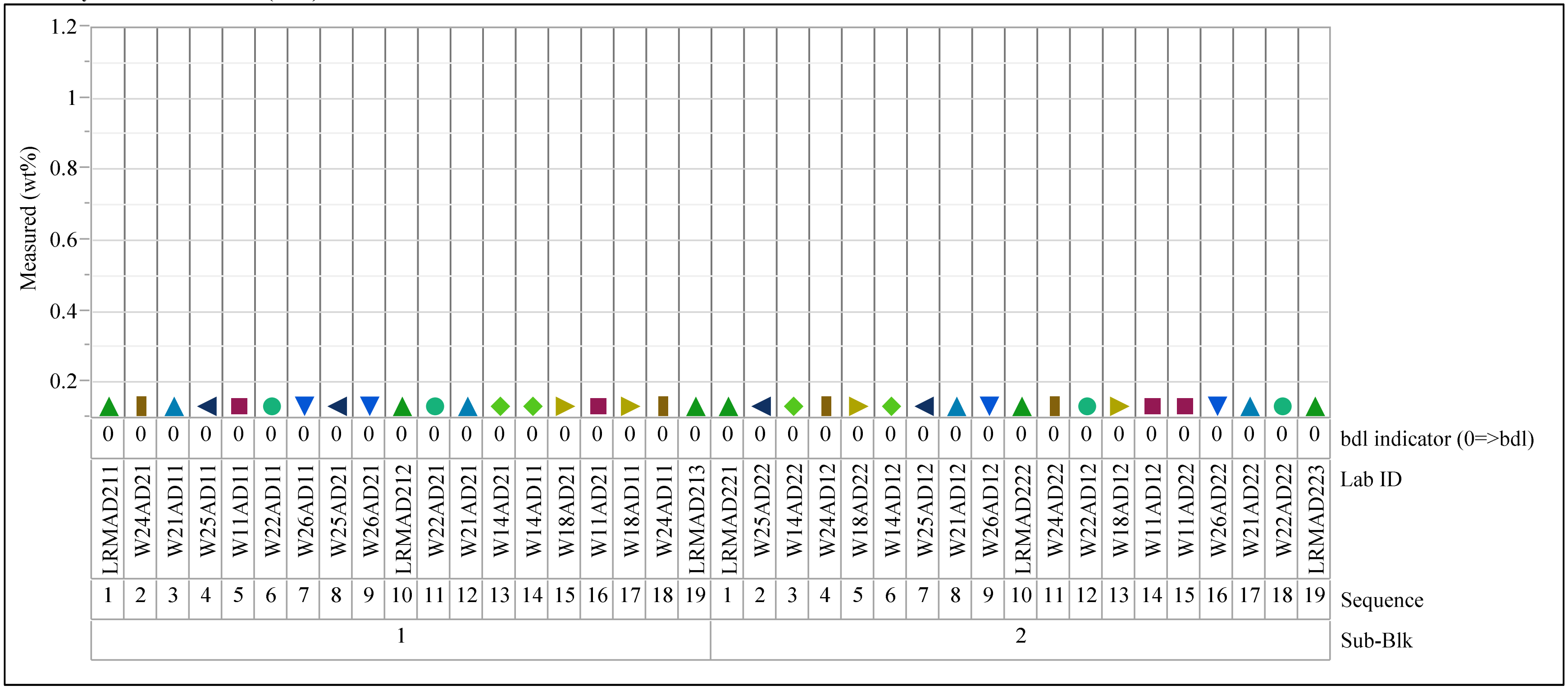


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

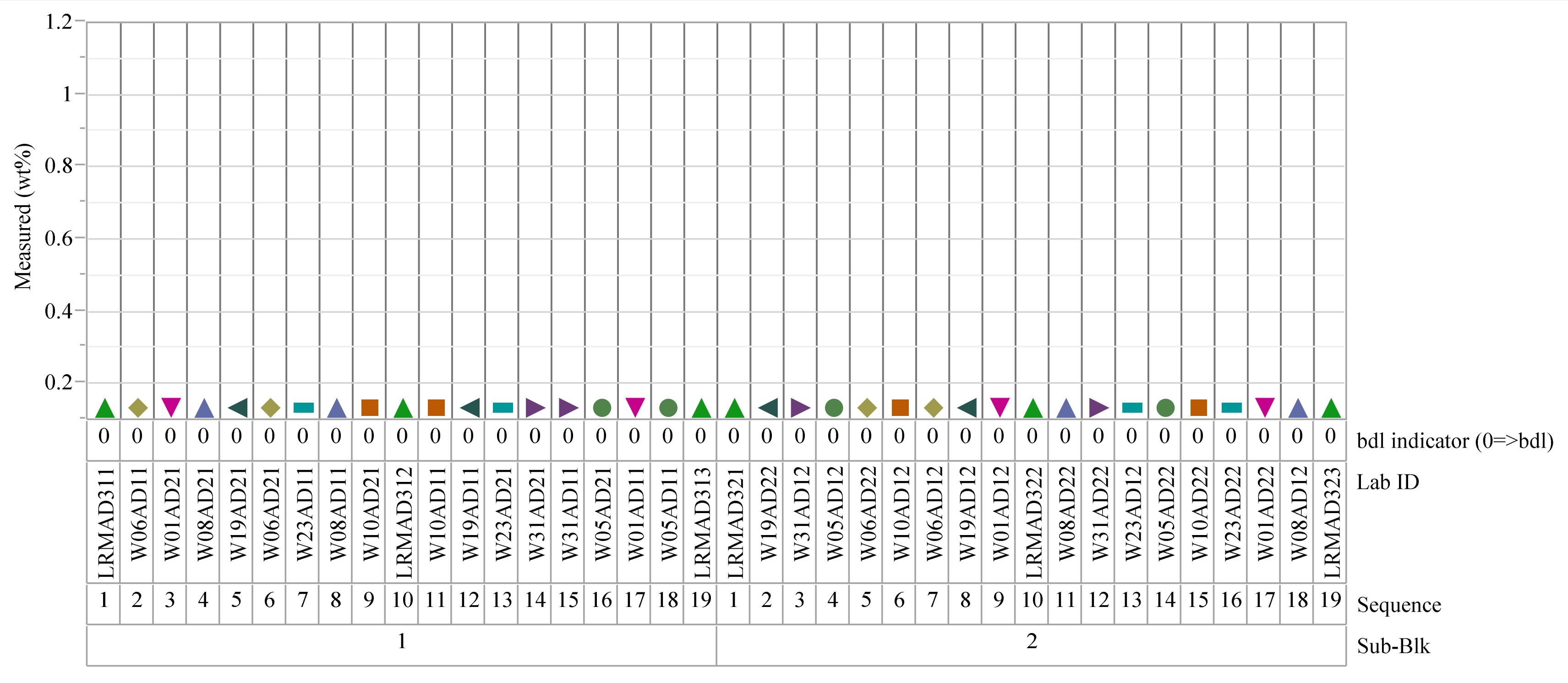


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

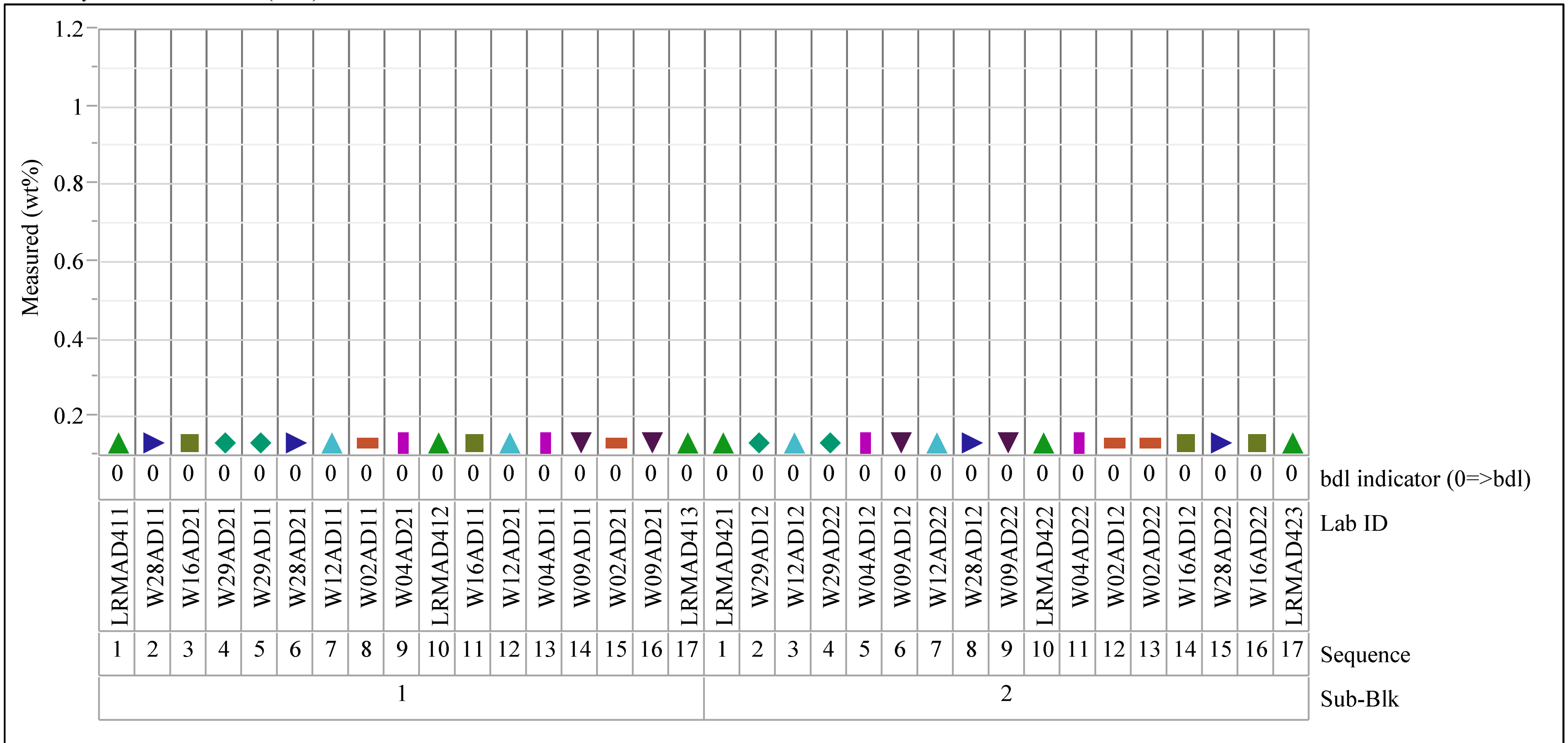


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

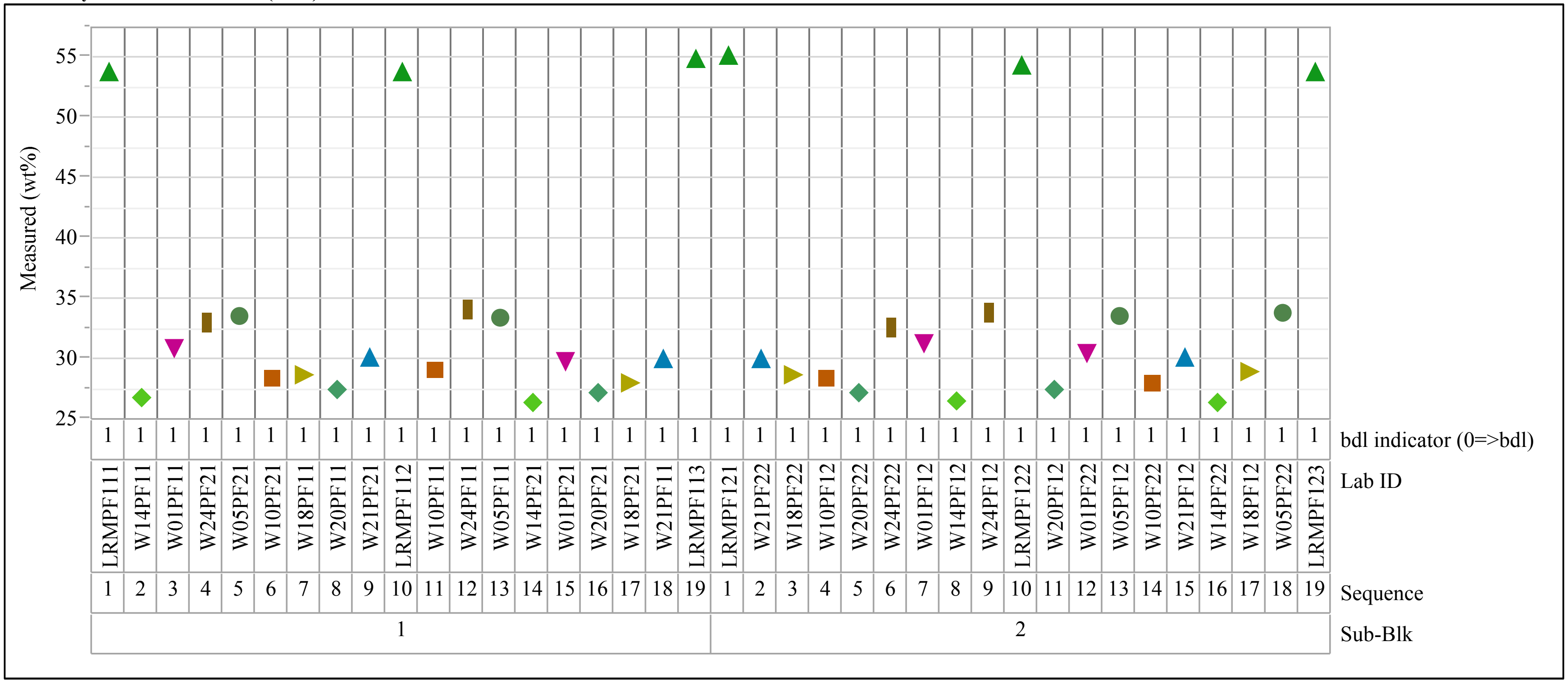


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

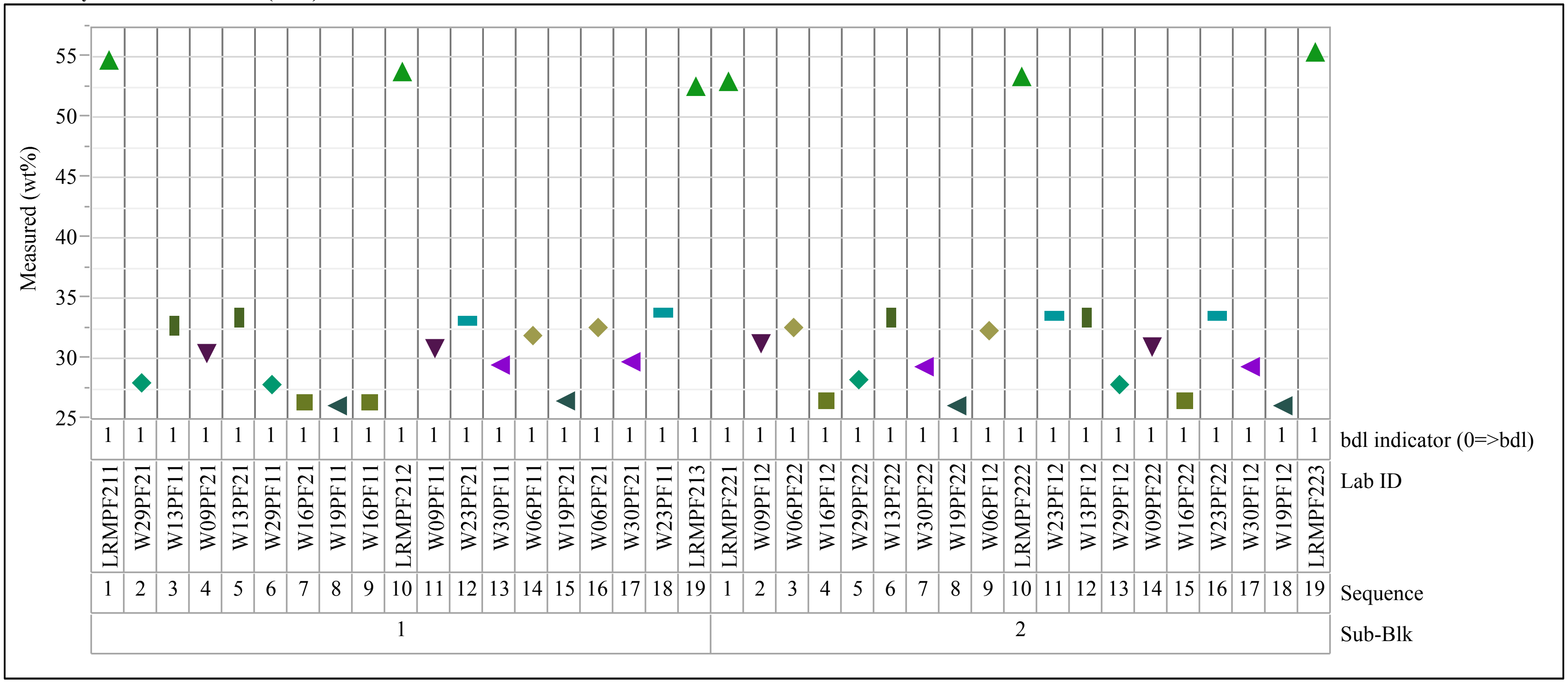


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

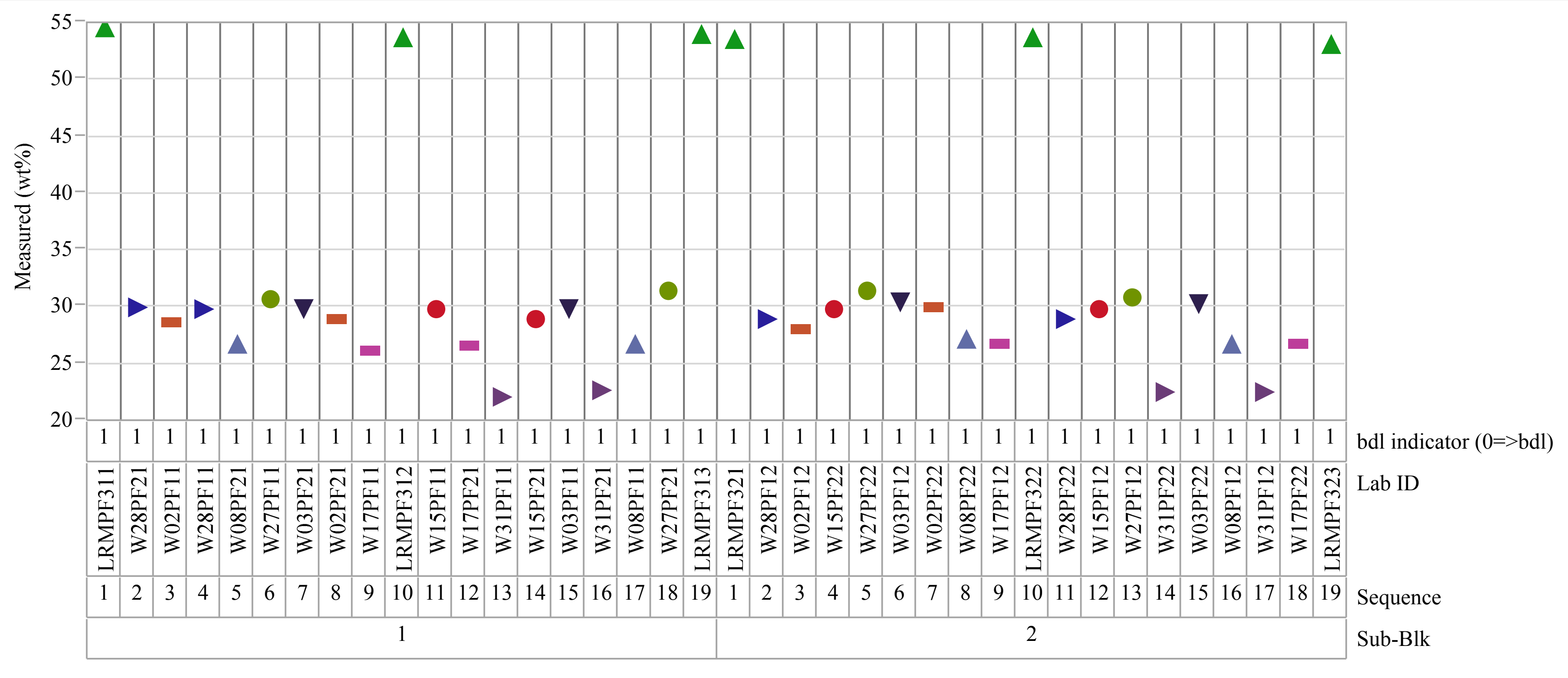


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

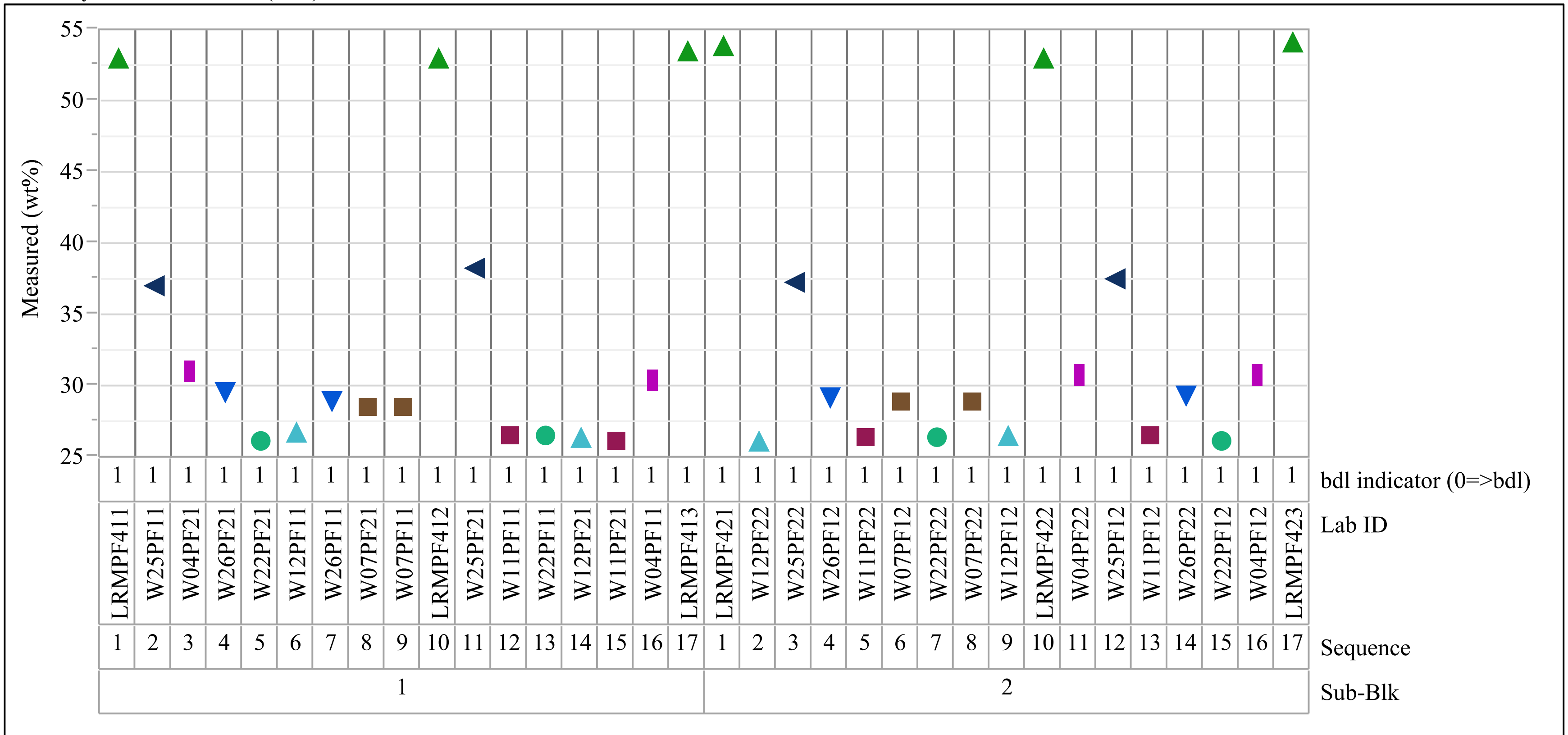


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

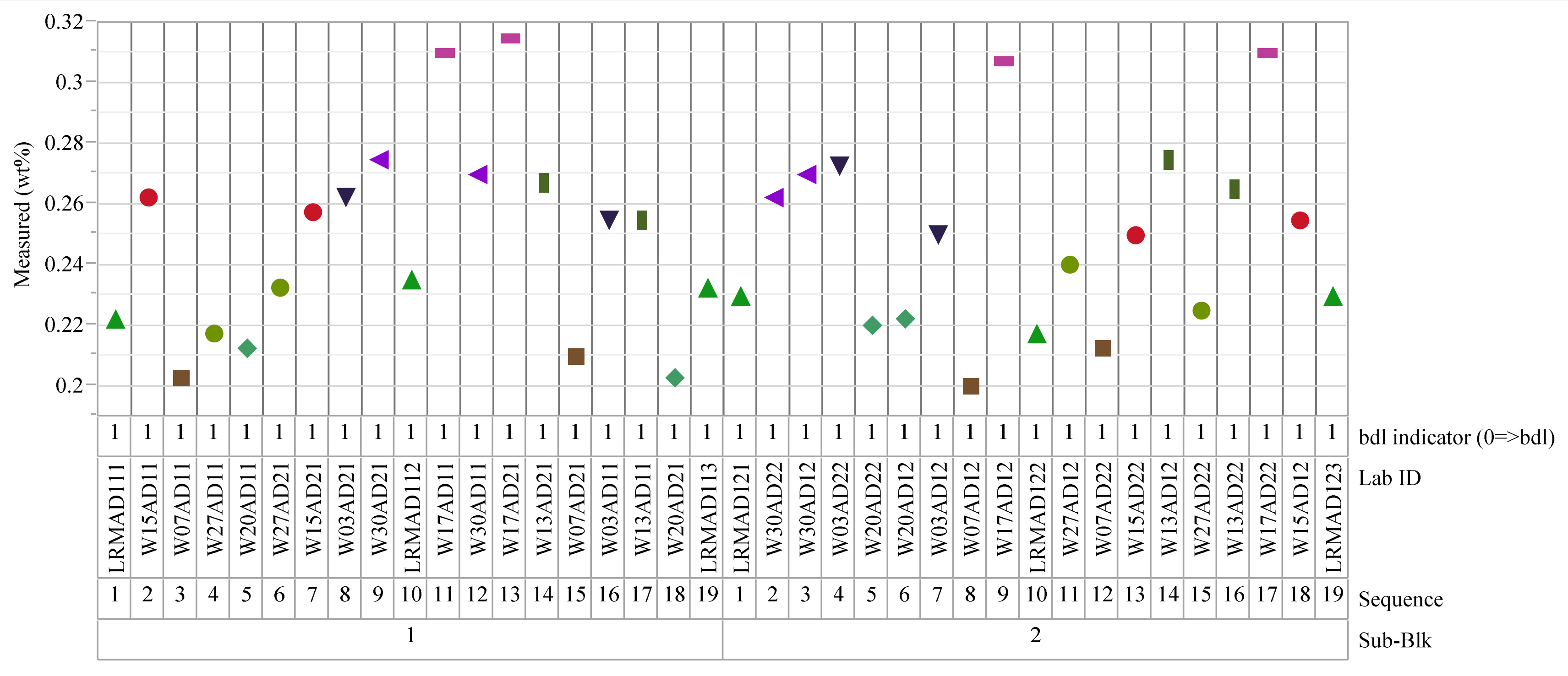


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

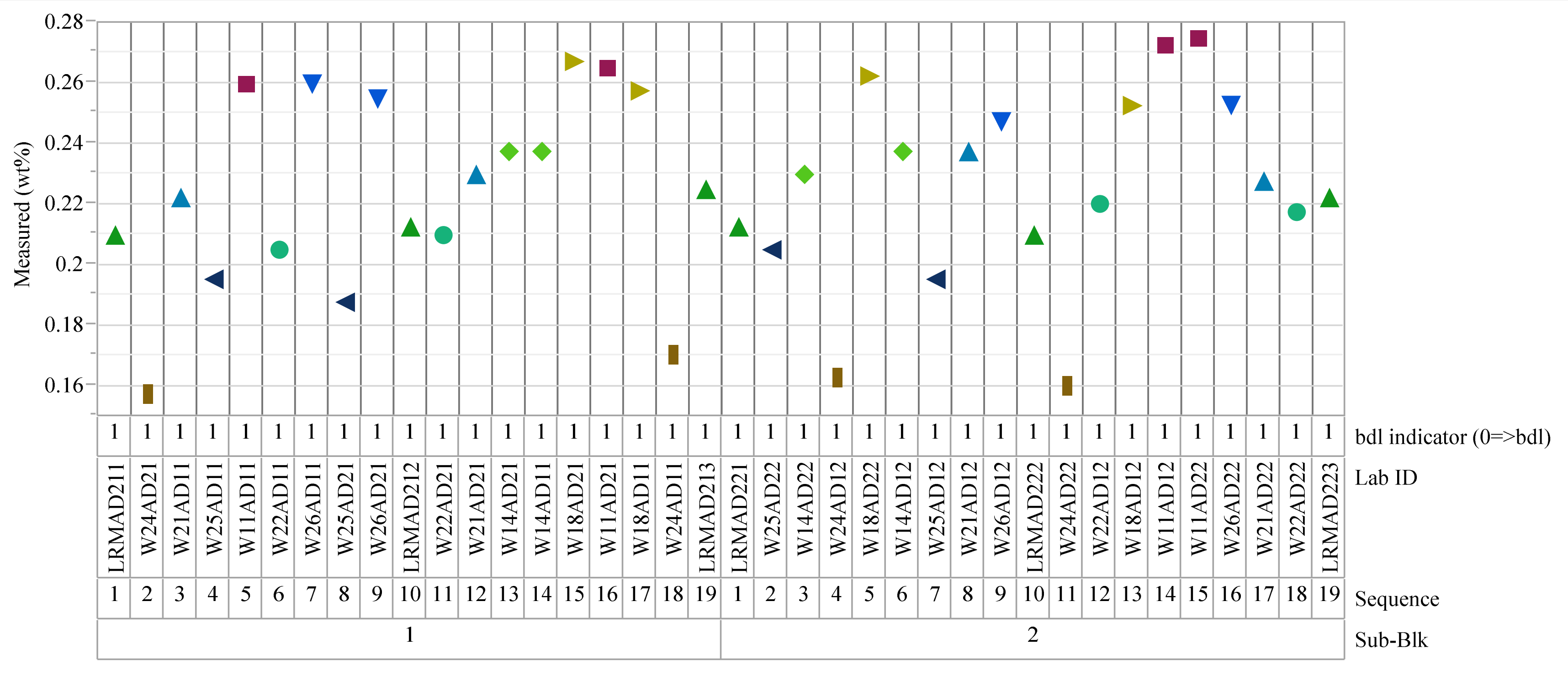


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

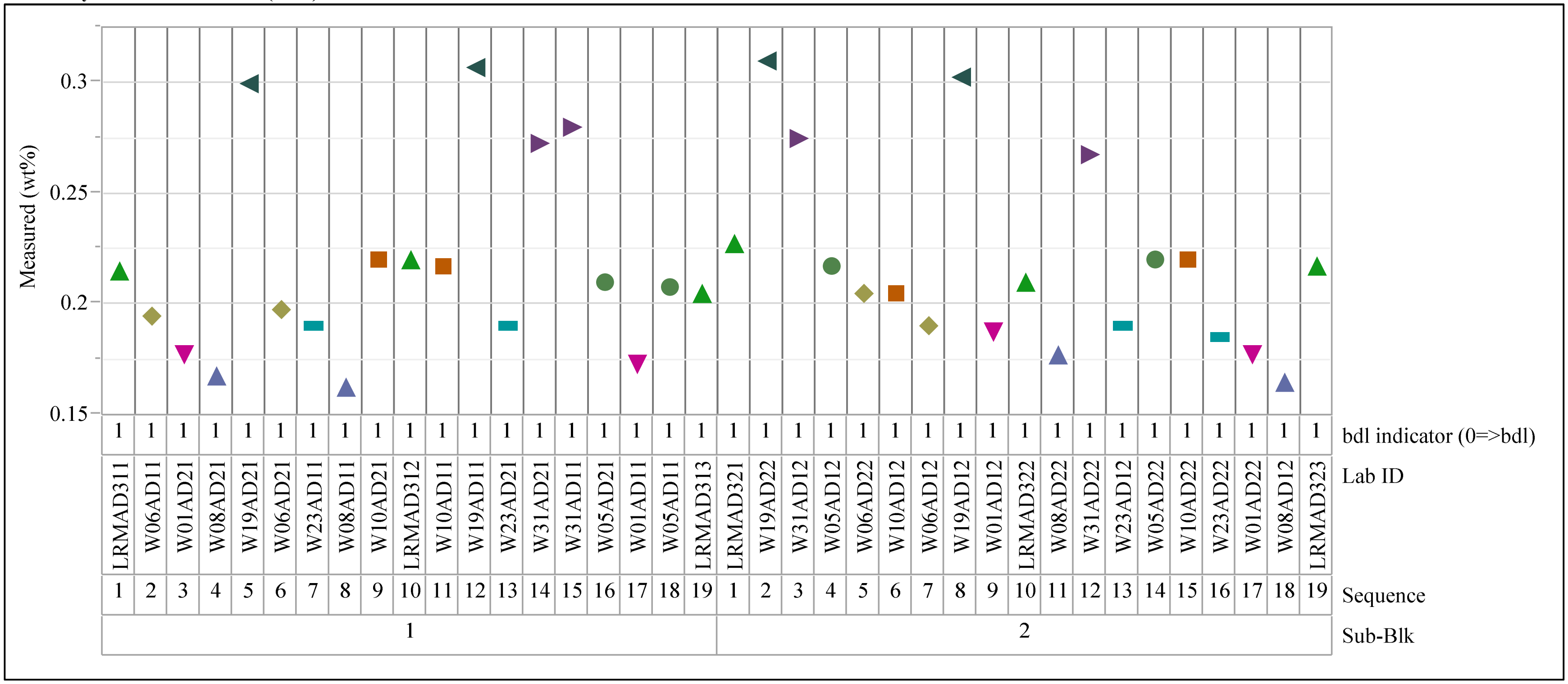


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

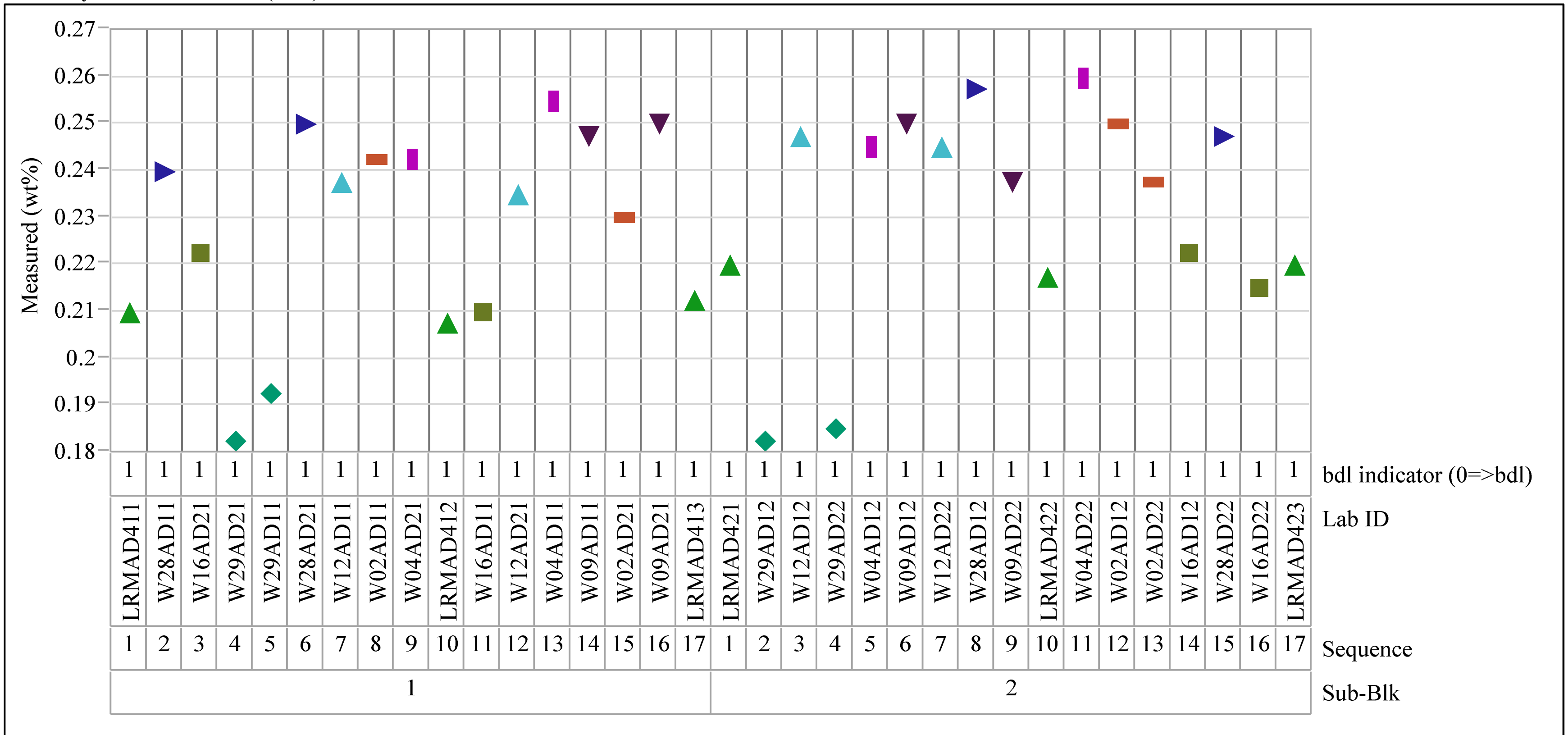


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

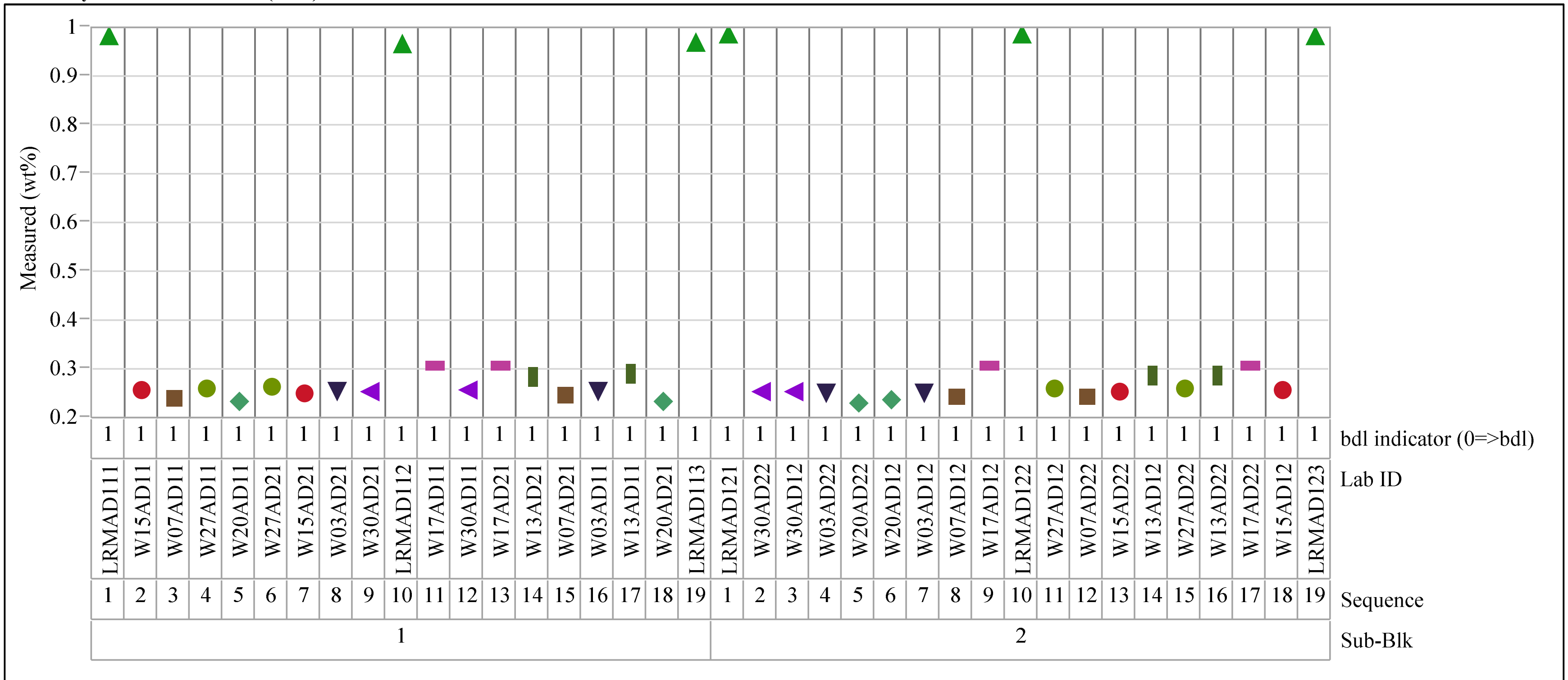


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

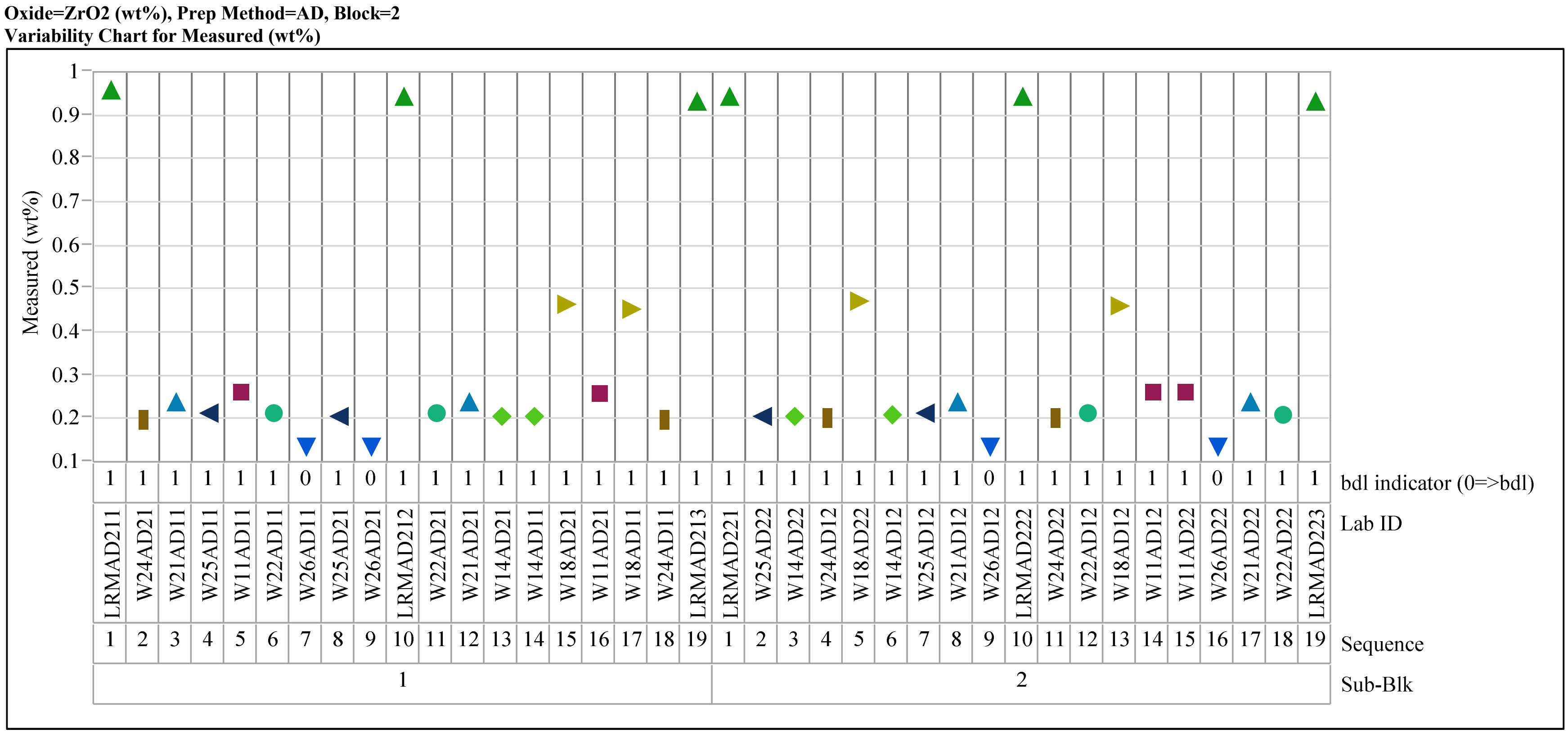


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

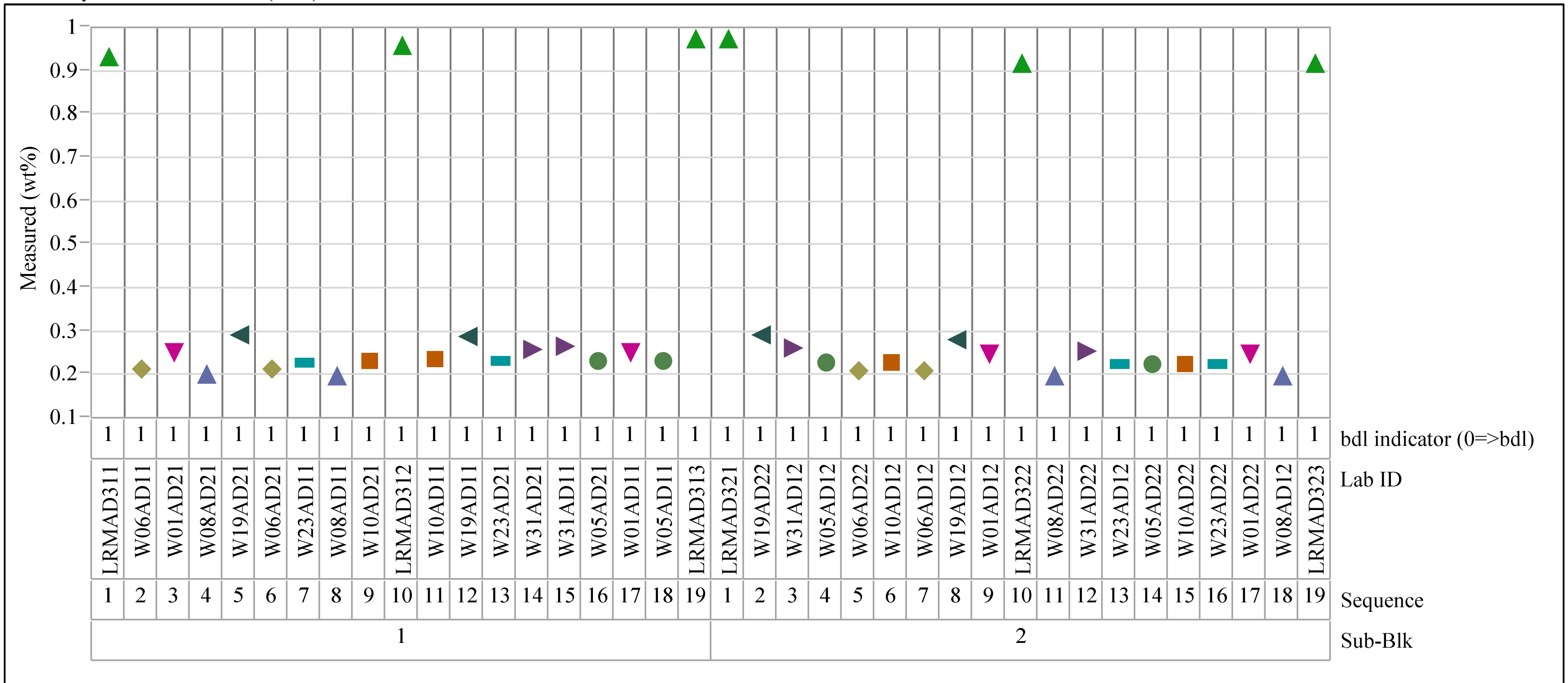


**Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

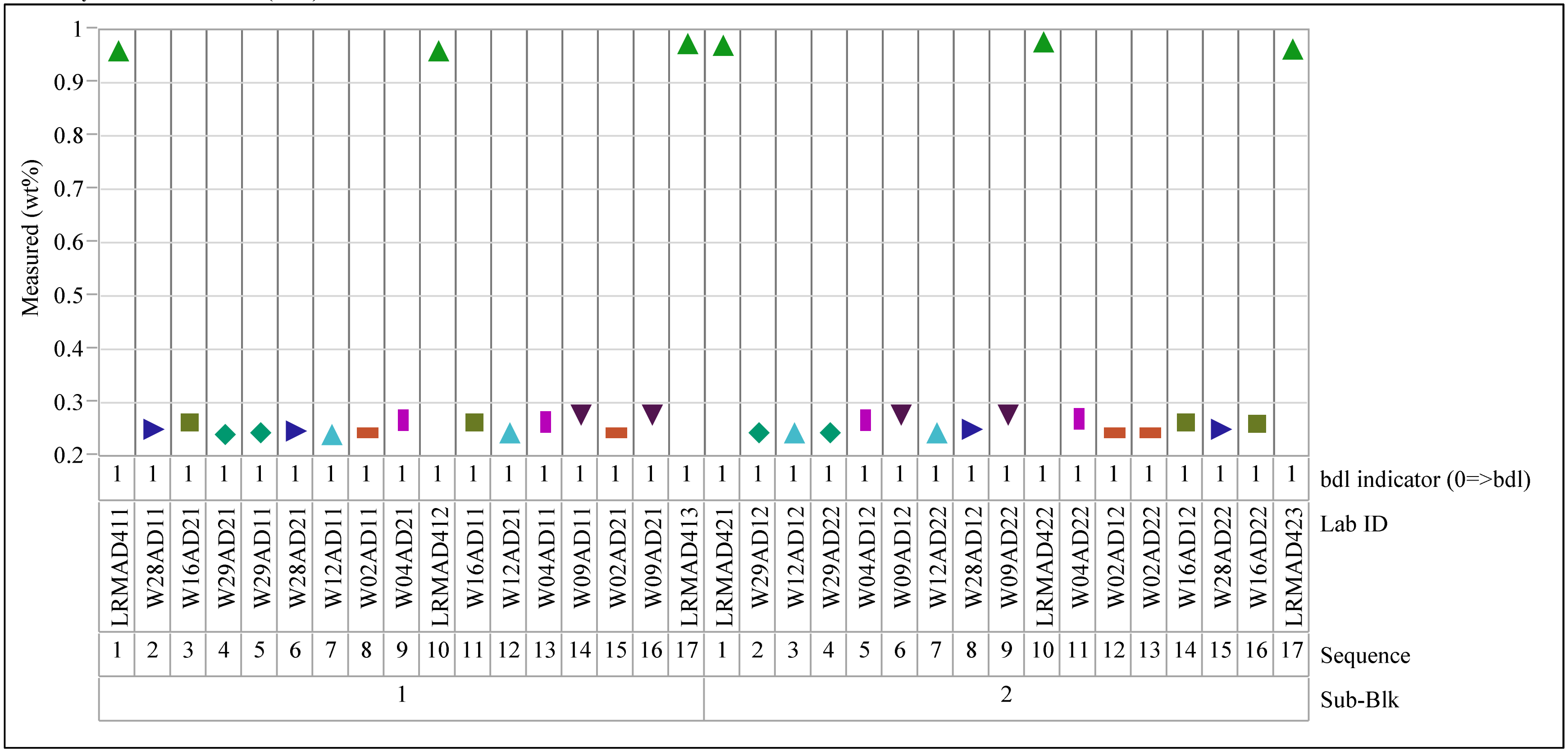


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

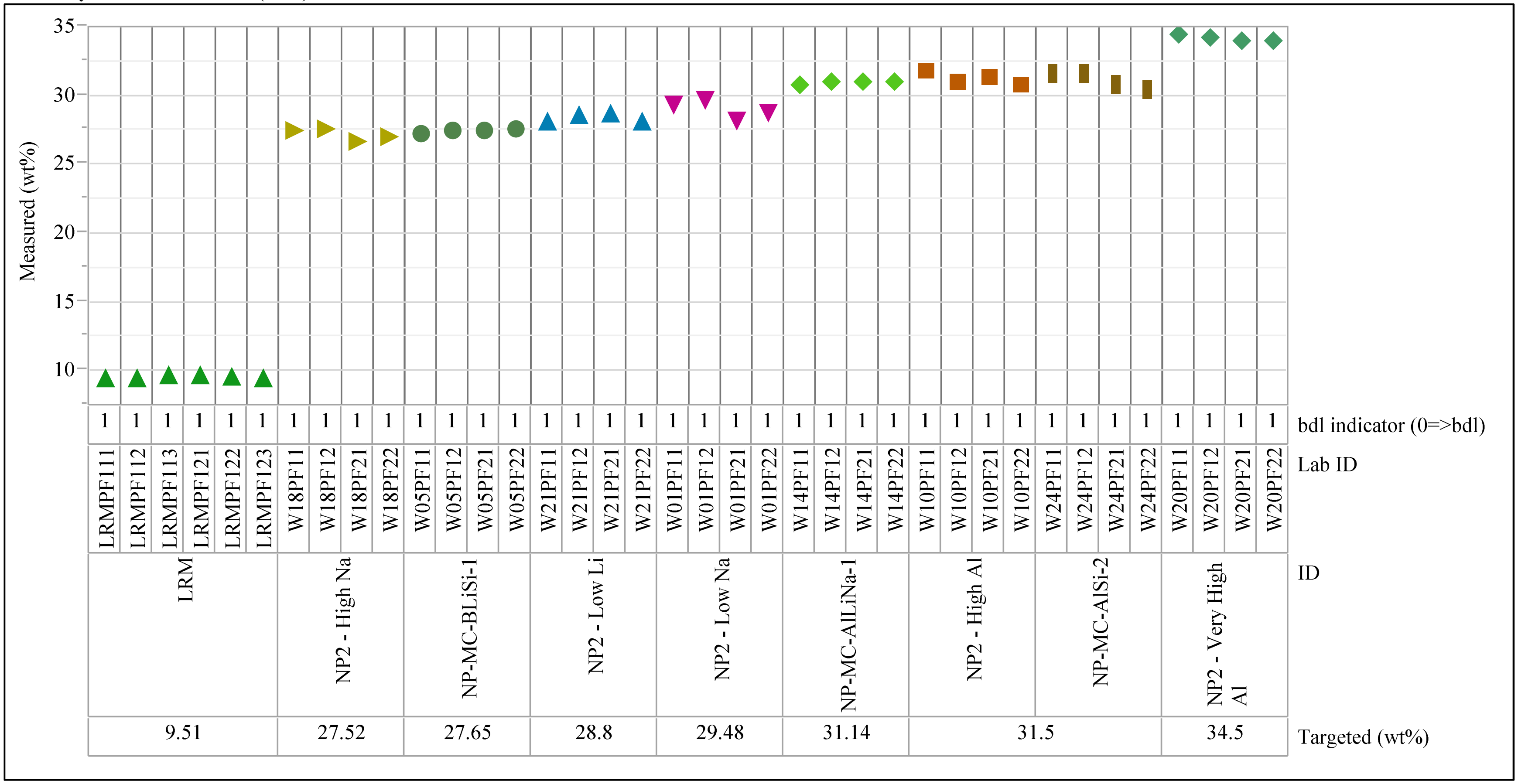


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

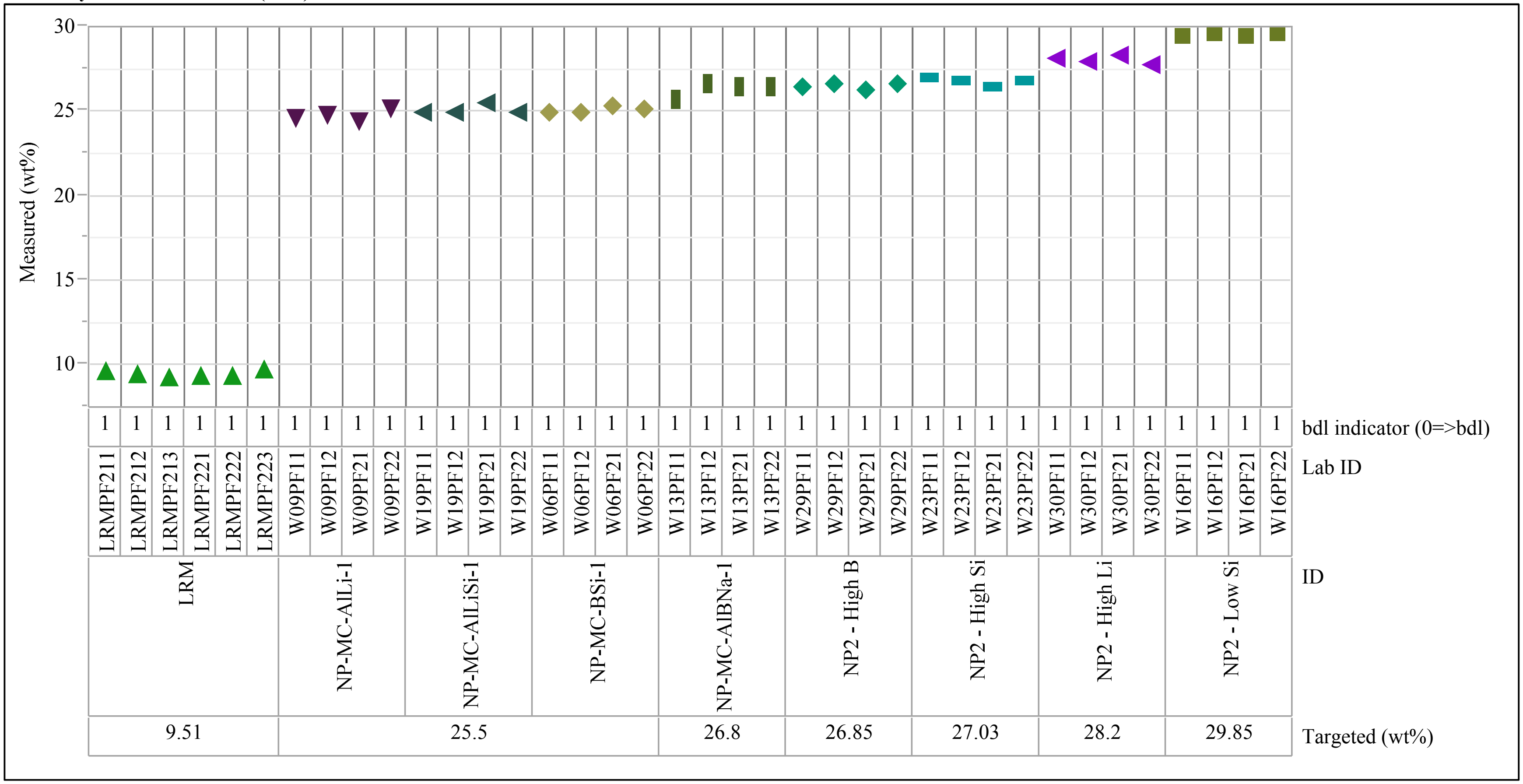


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

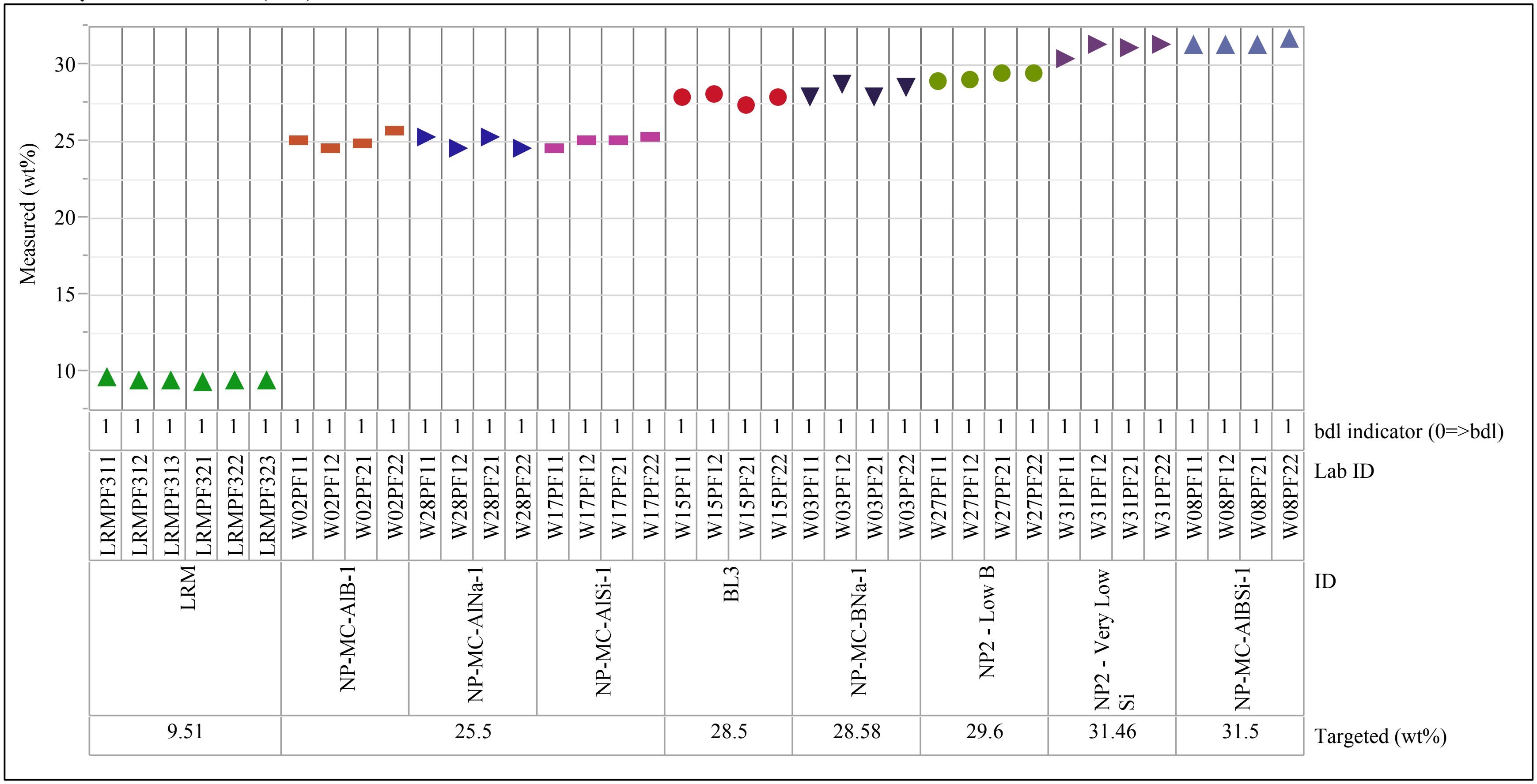


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Al2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

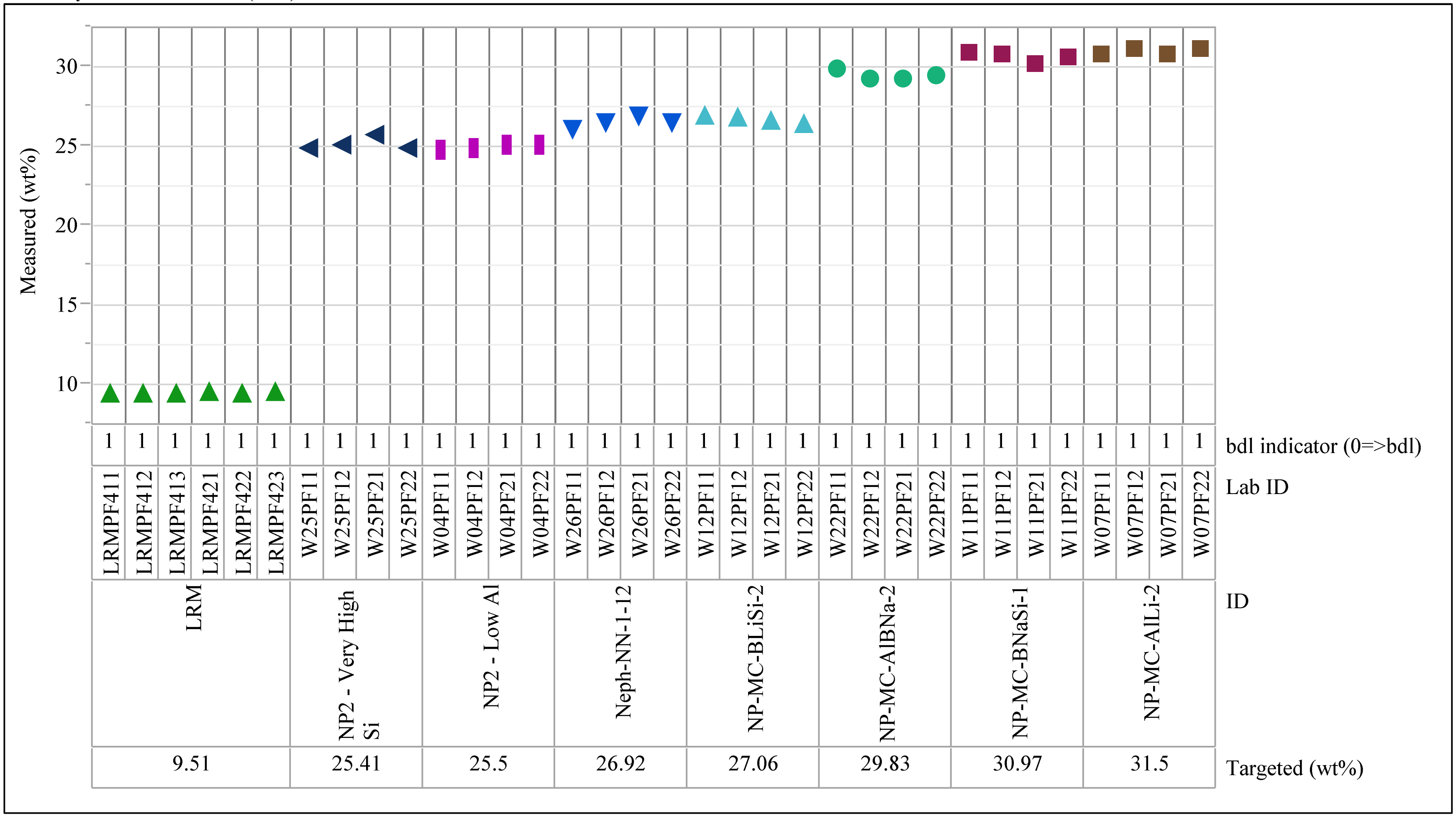


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

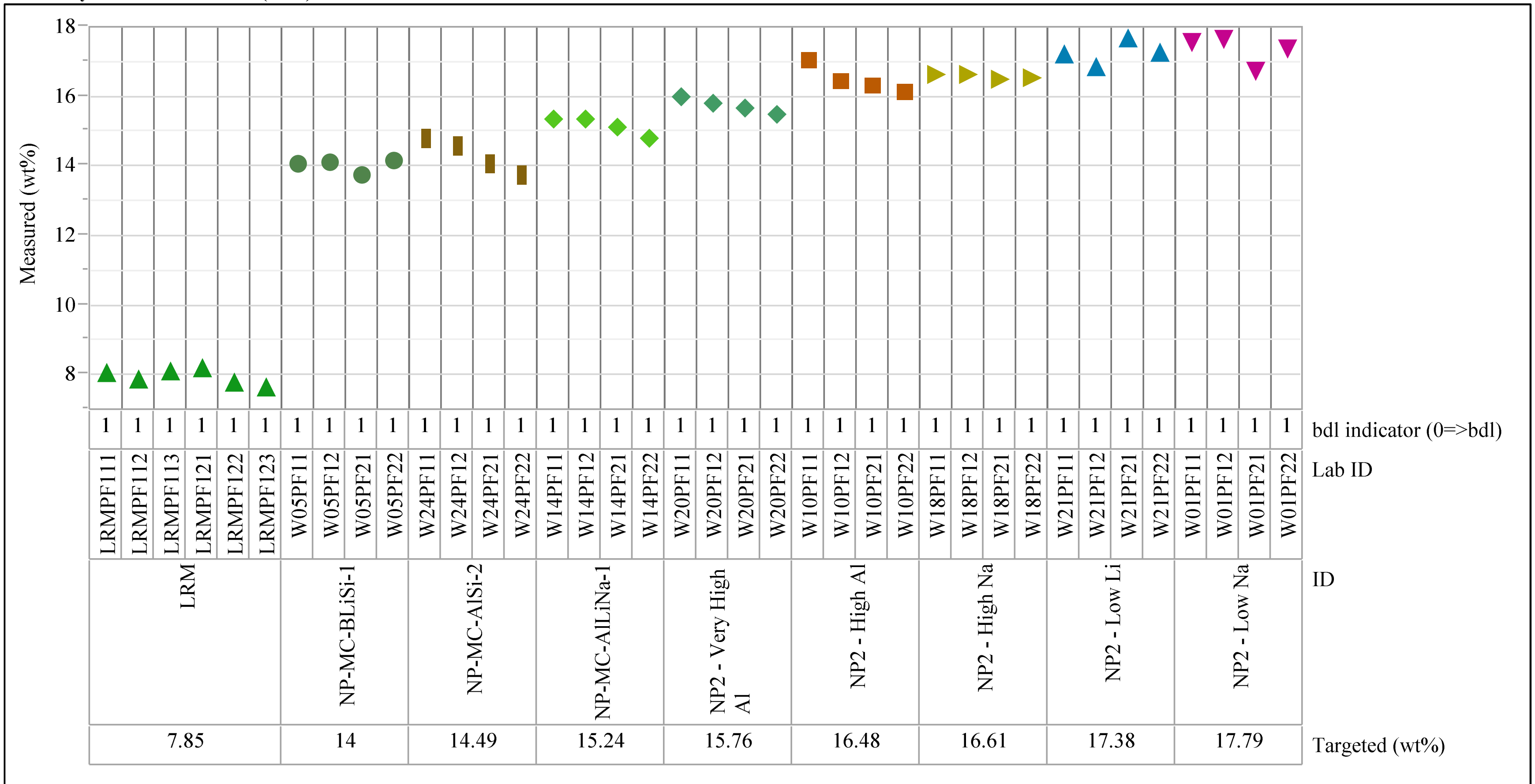


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

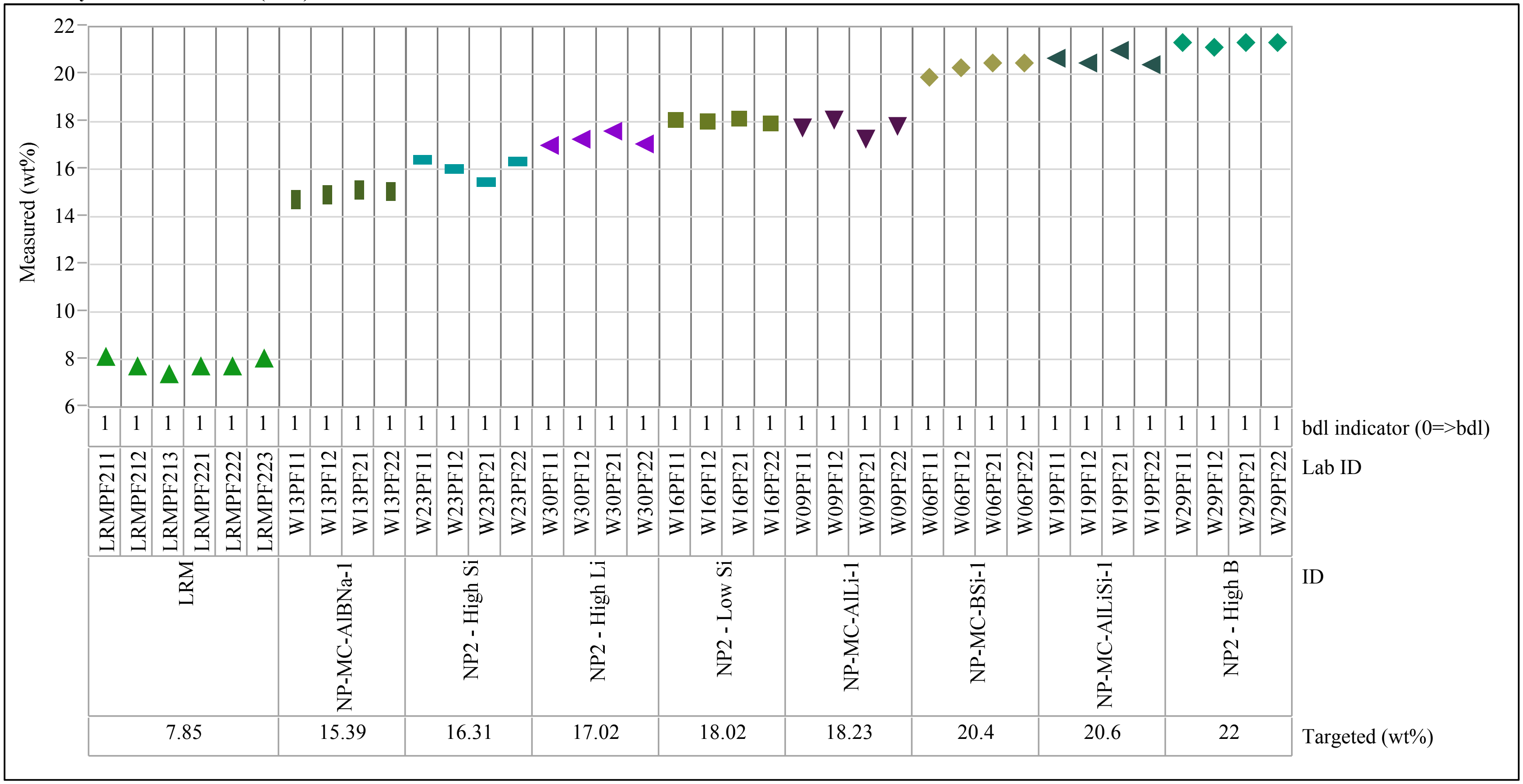


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

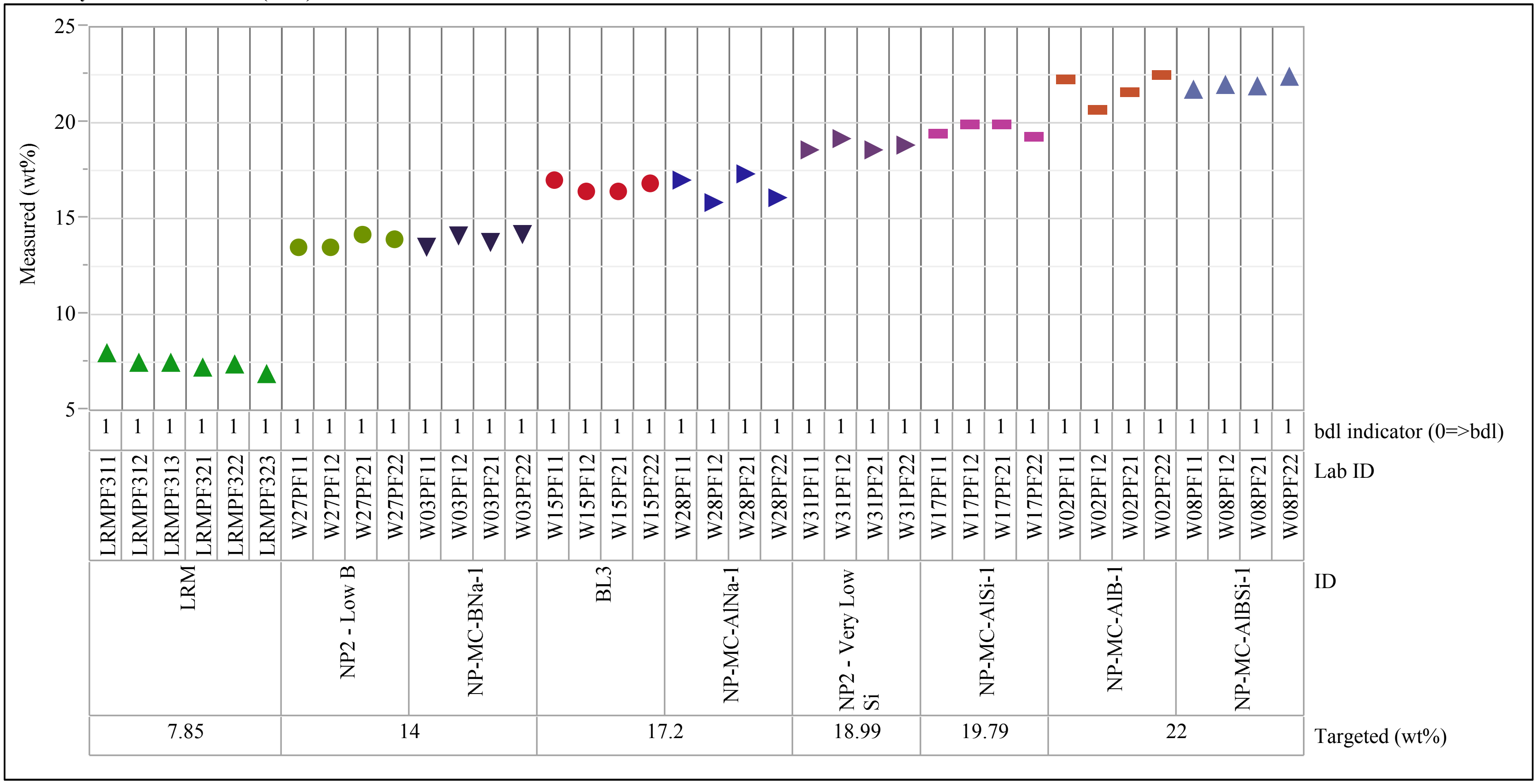


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=B2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

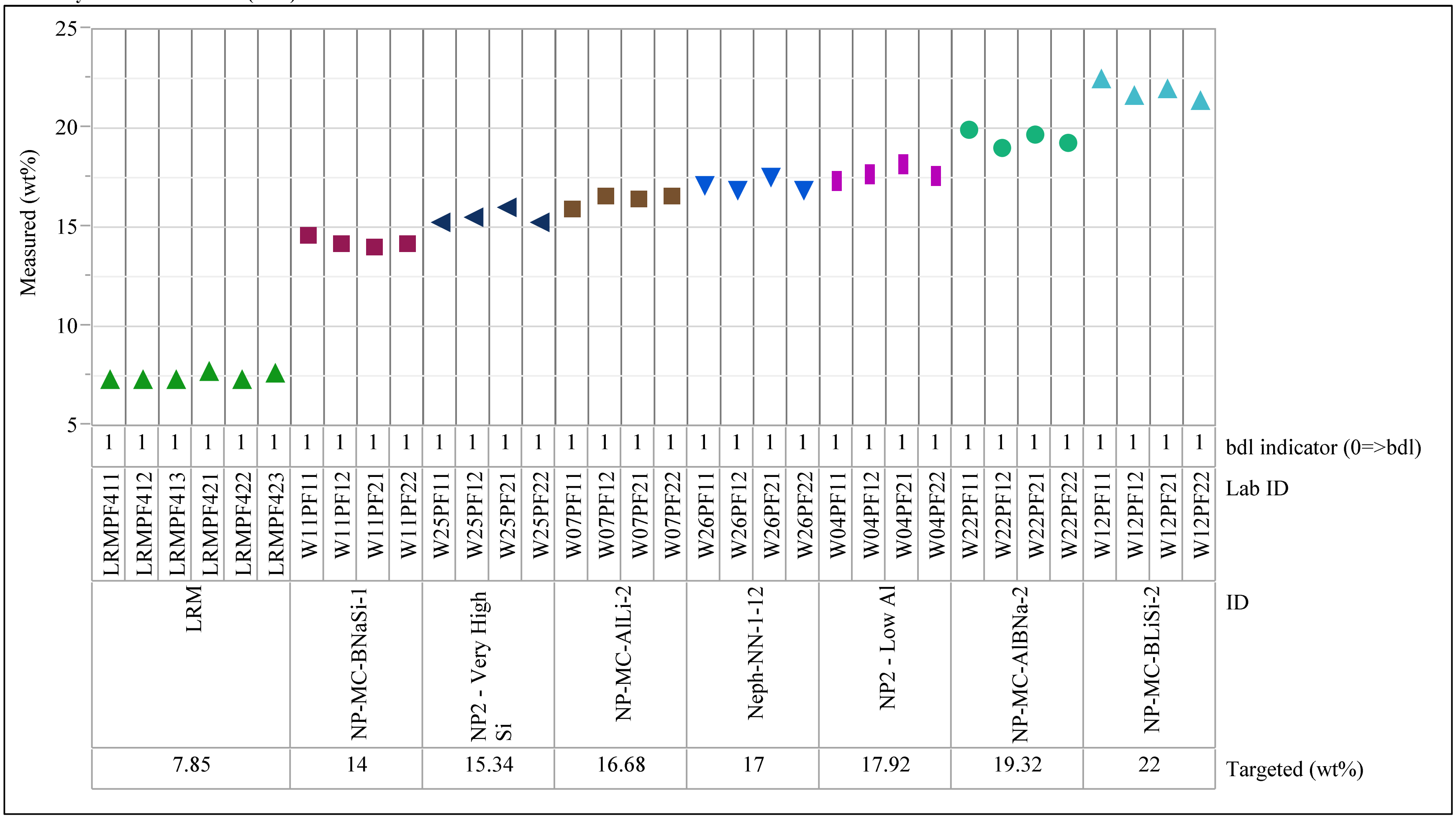


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

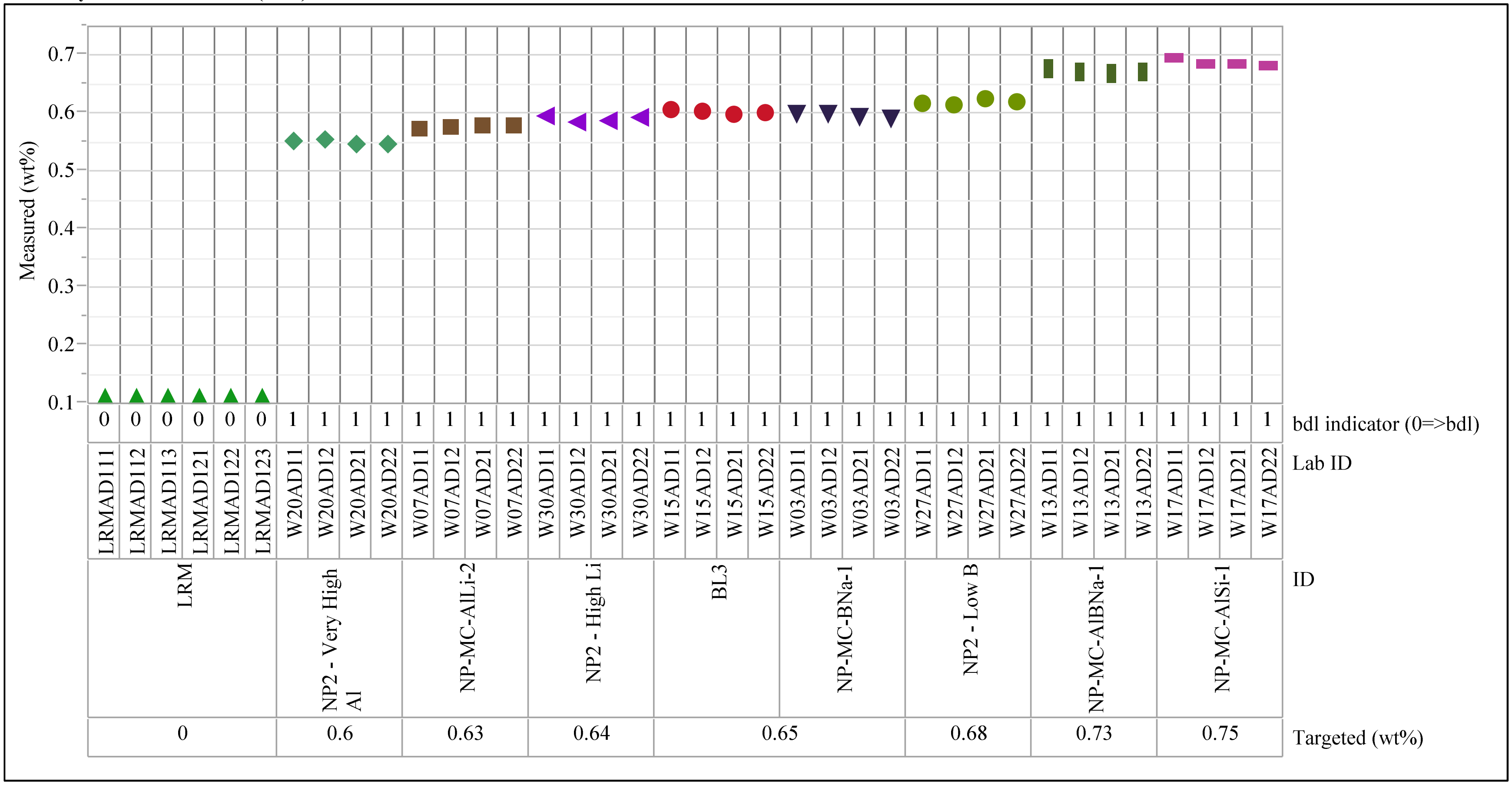


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

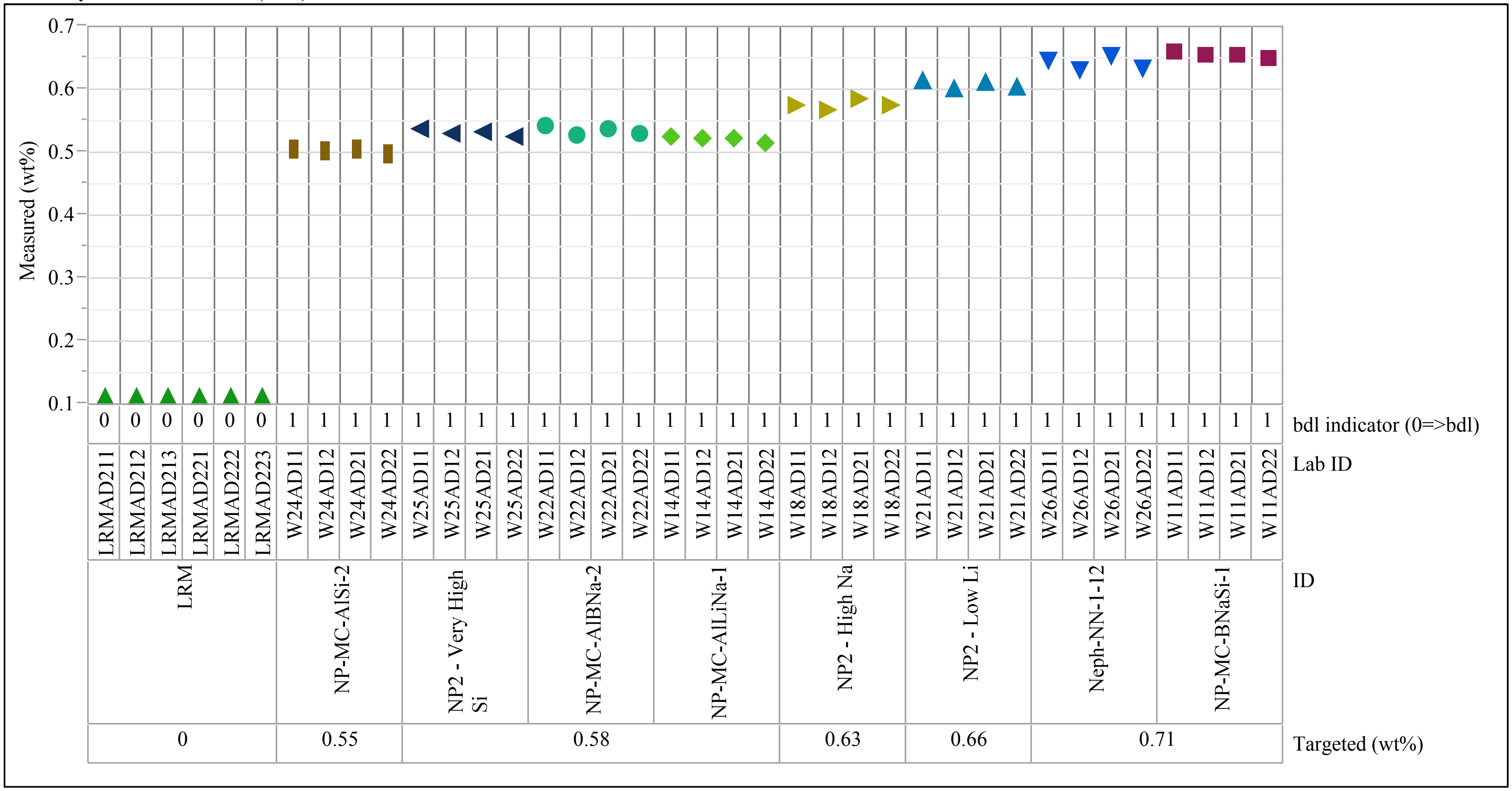


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

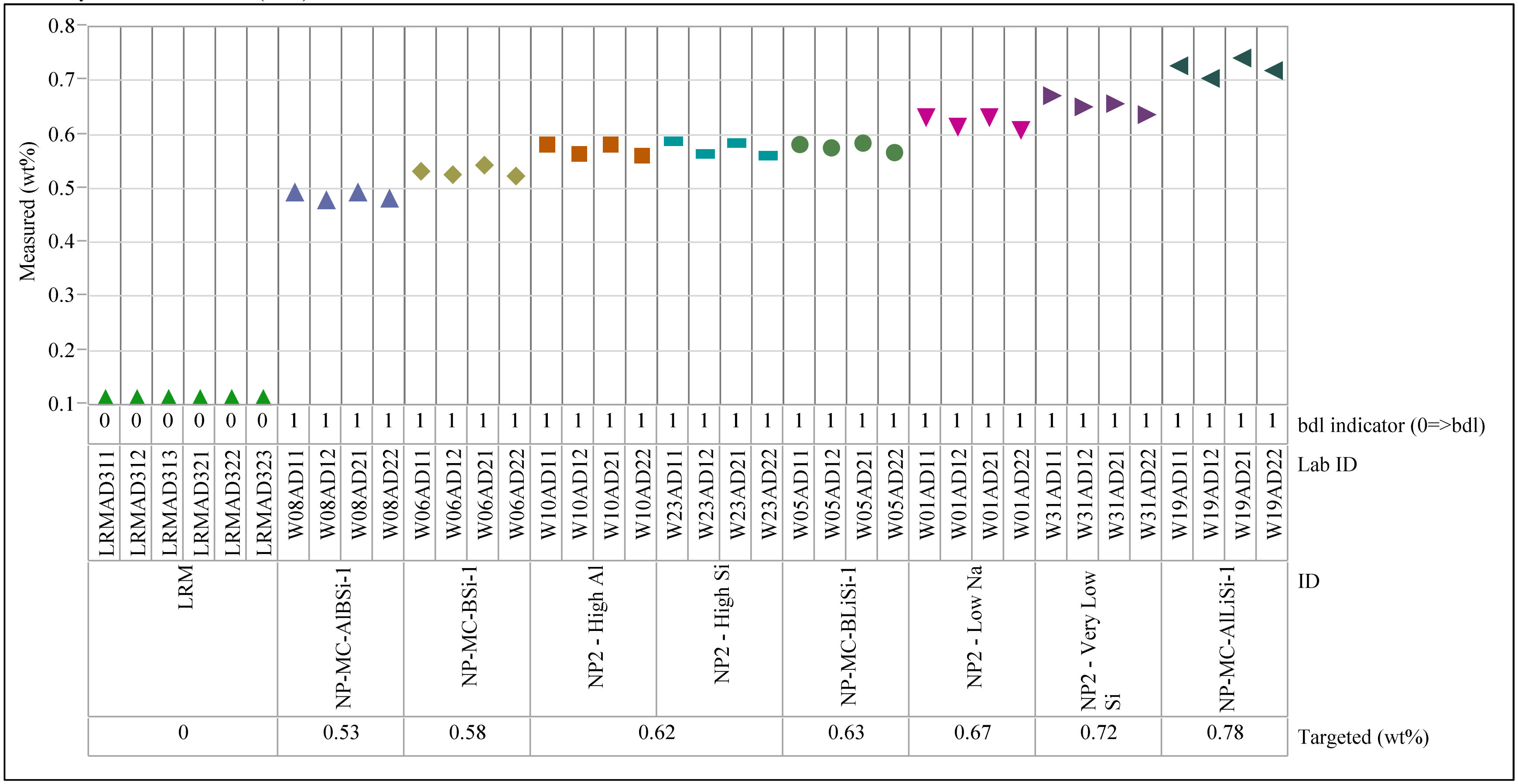


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Bi2O3 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

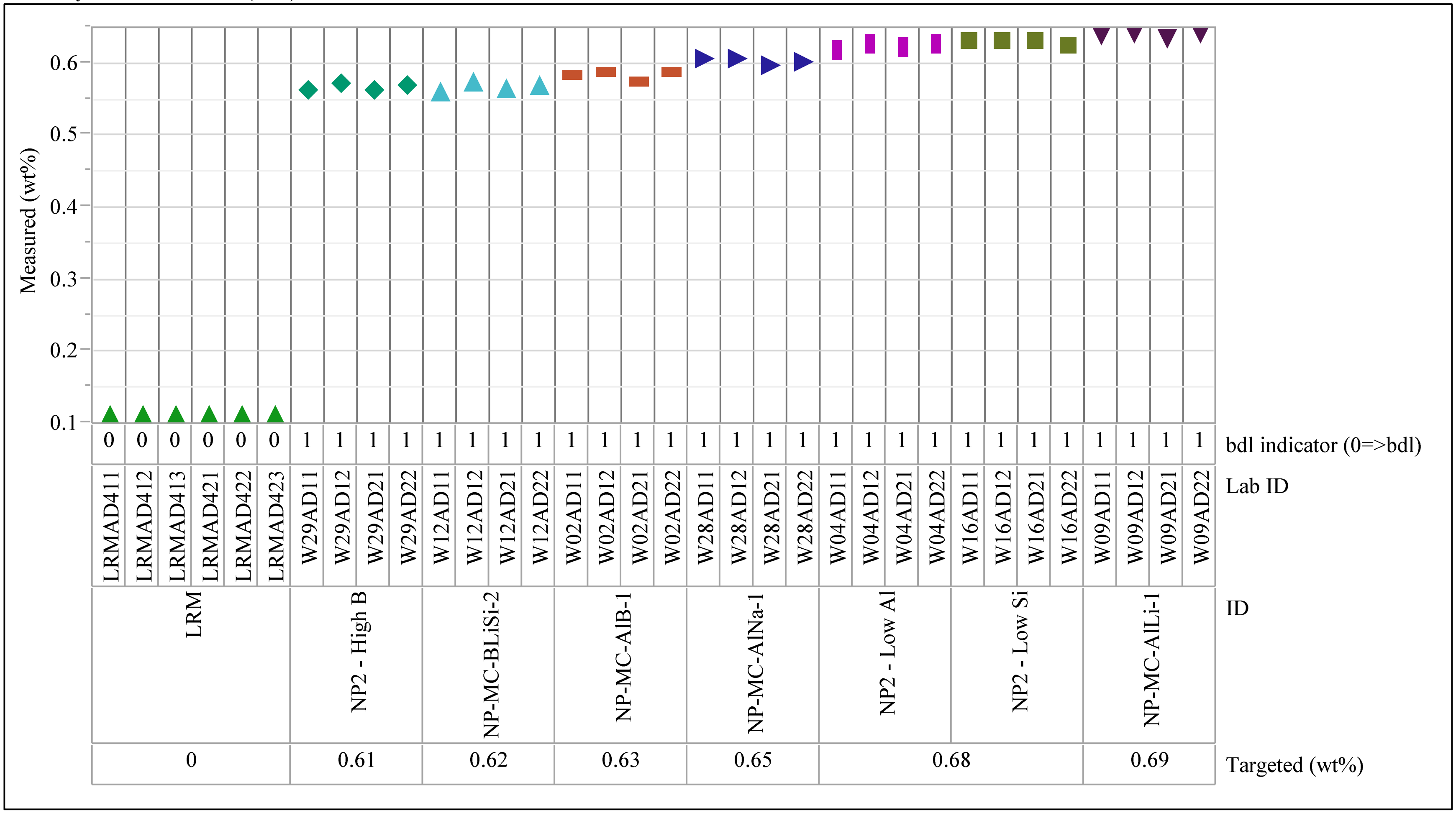


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

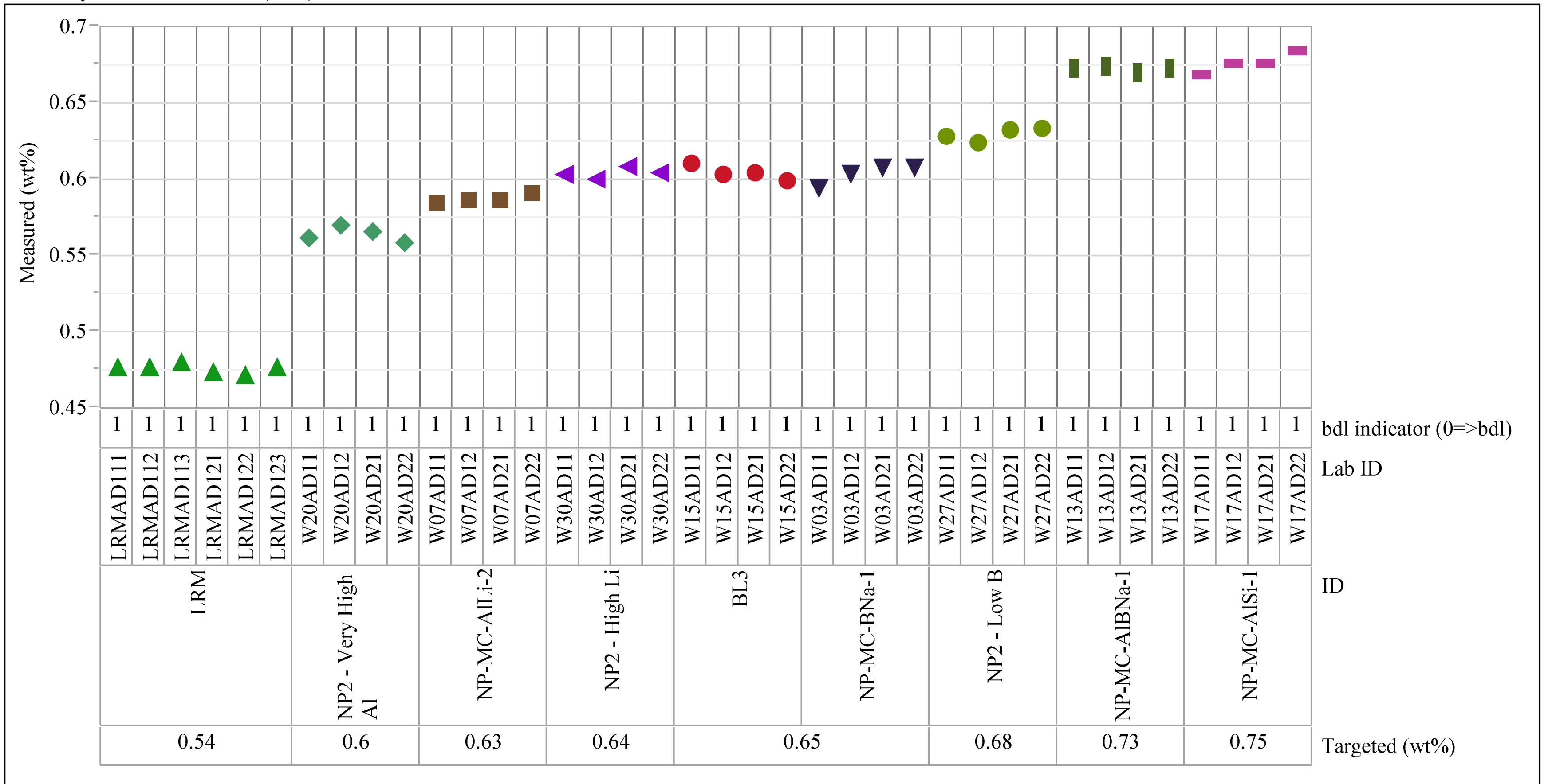


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

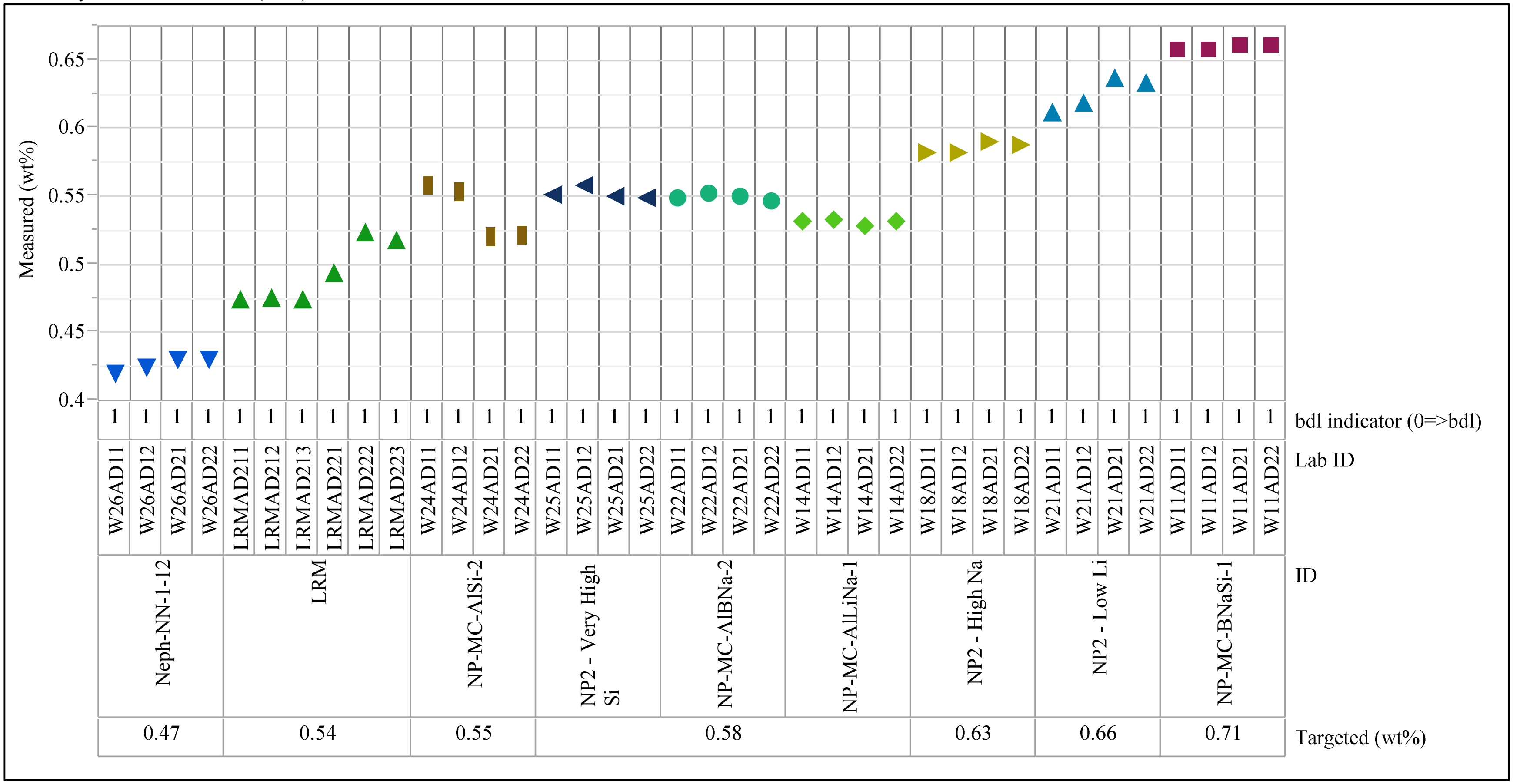


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

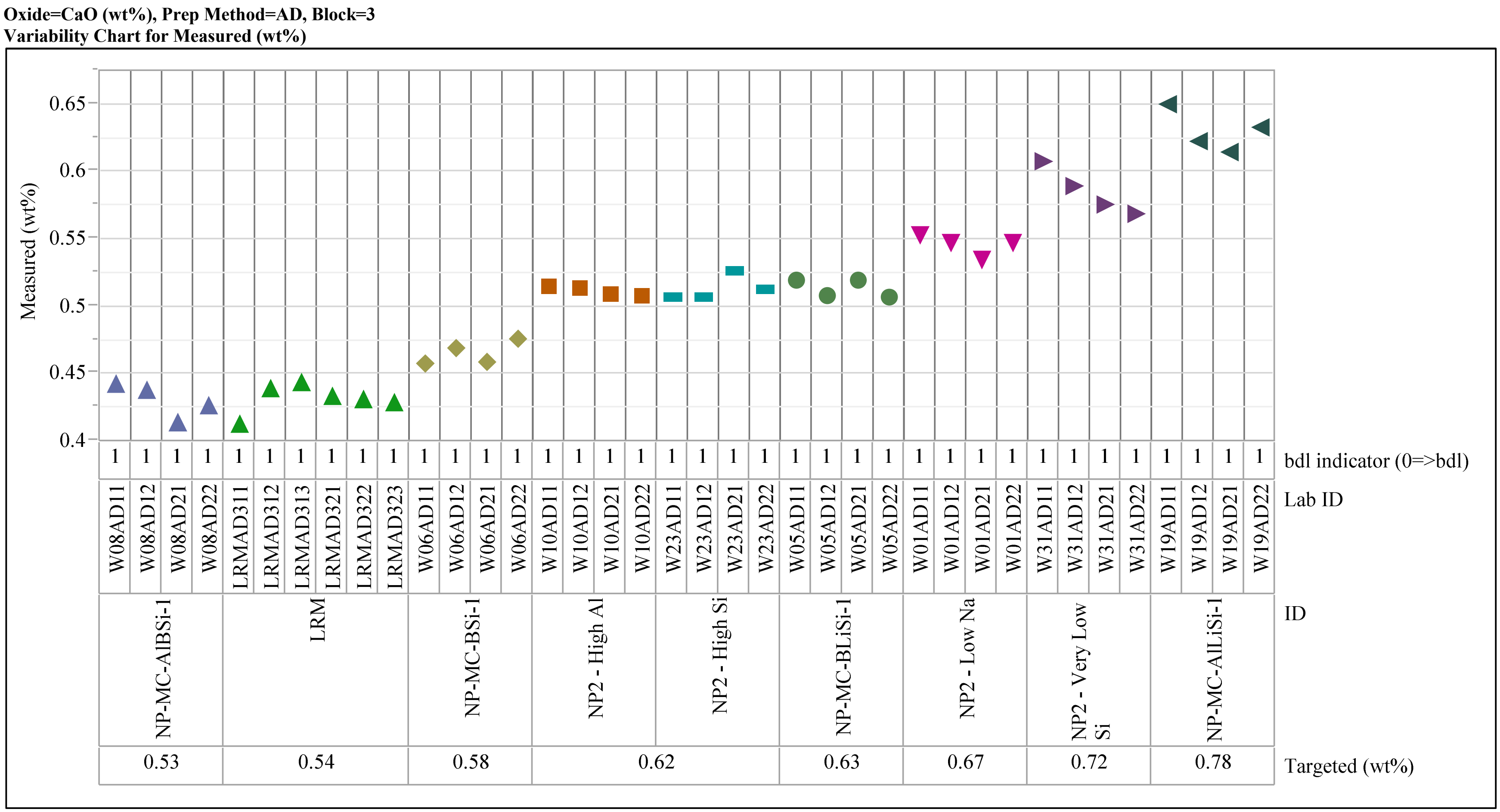


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=CaO (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

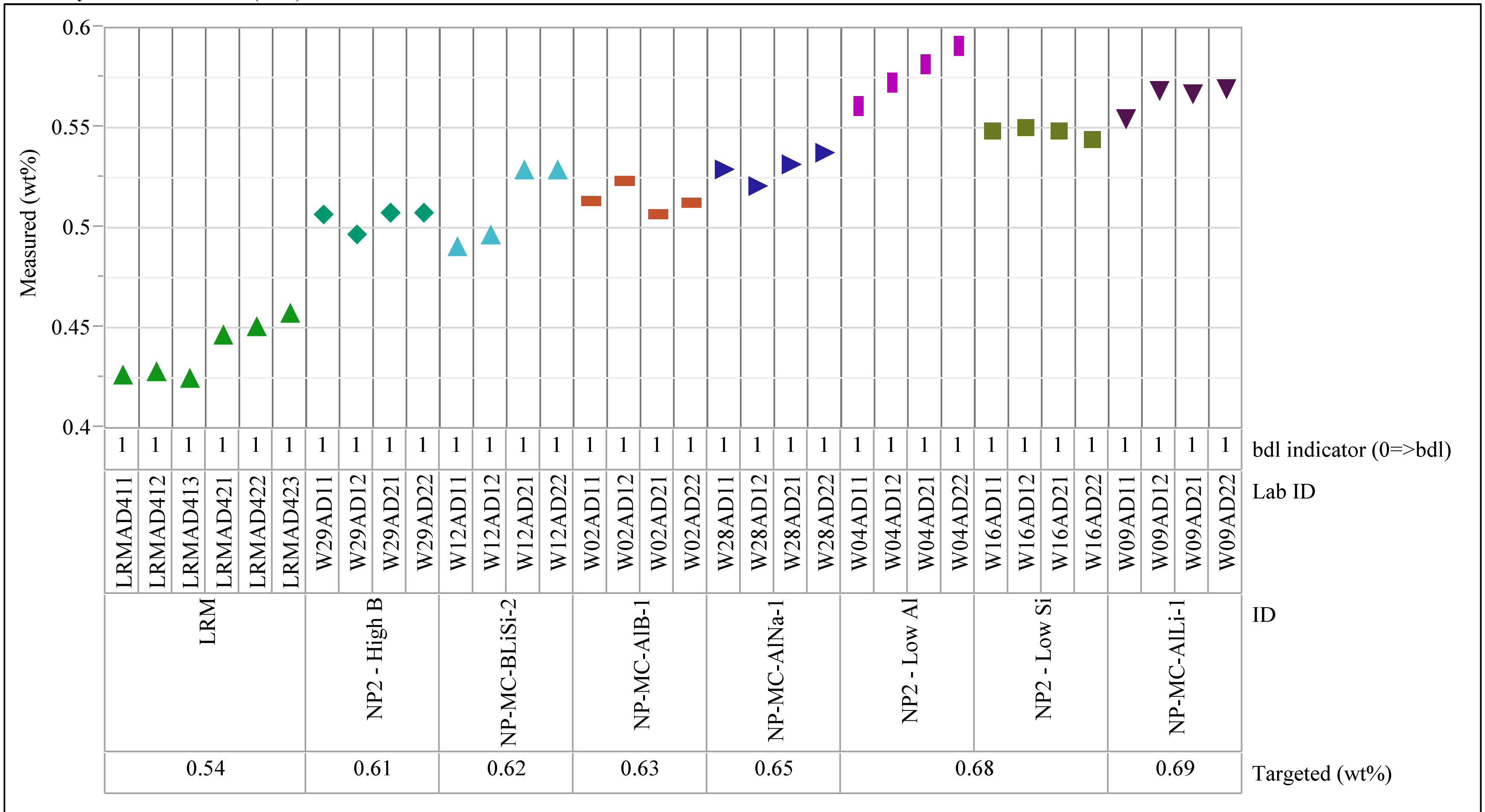


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

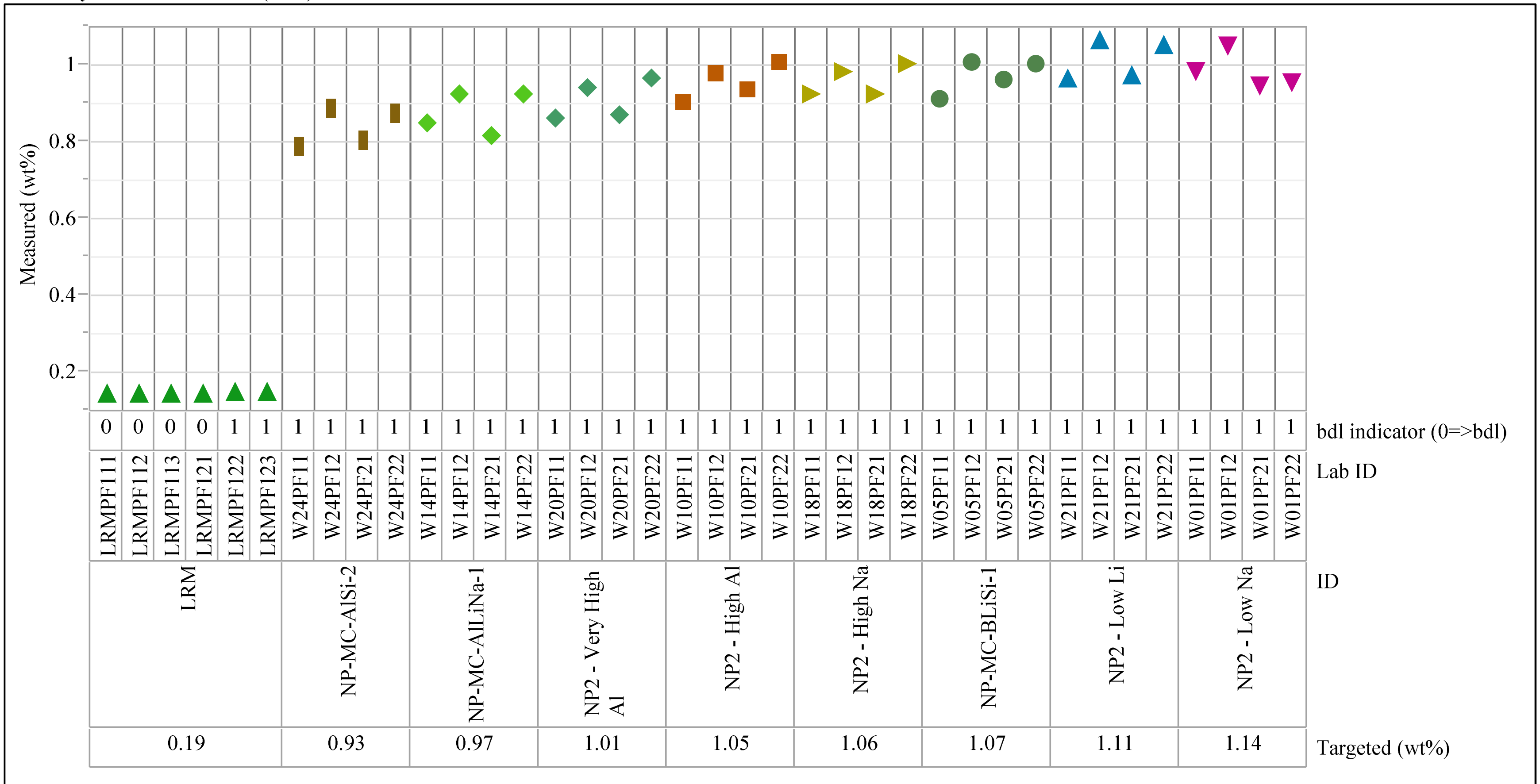


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

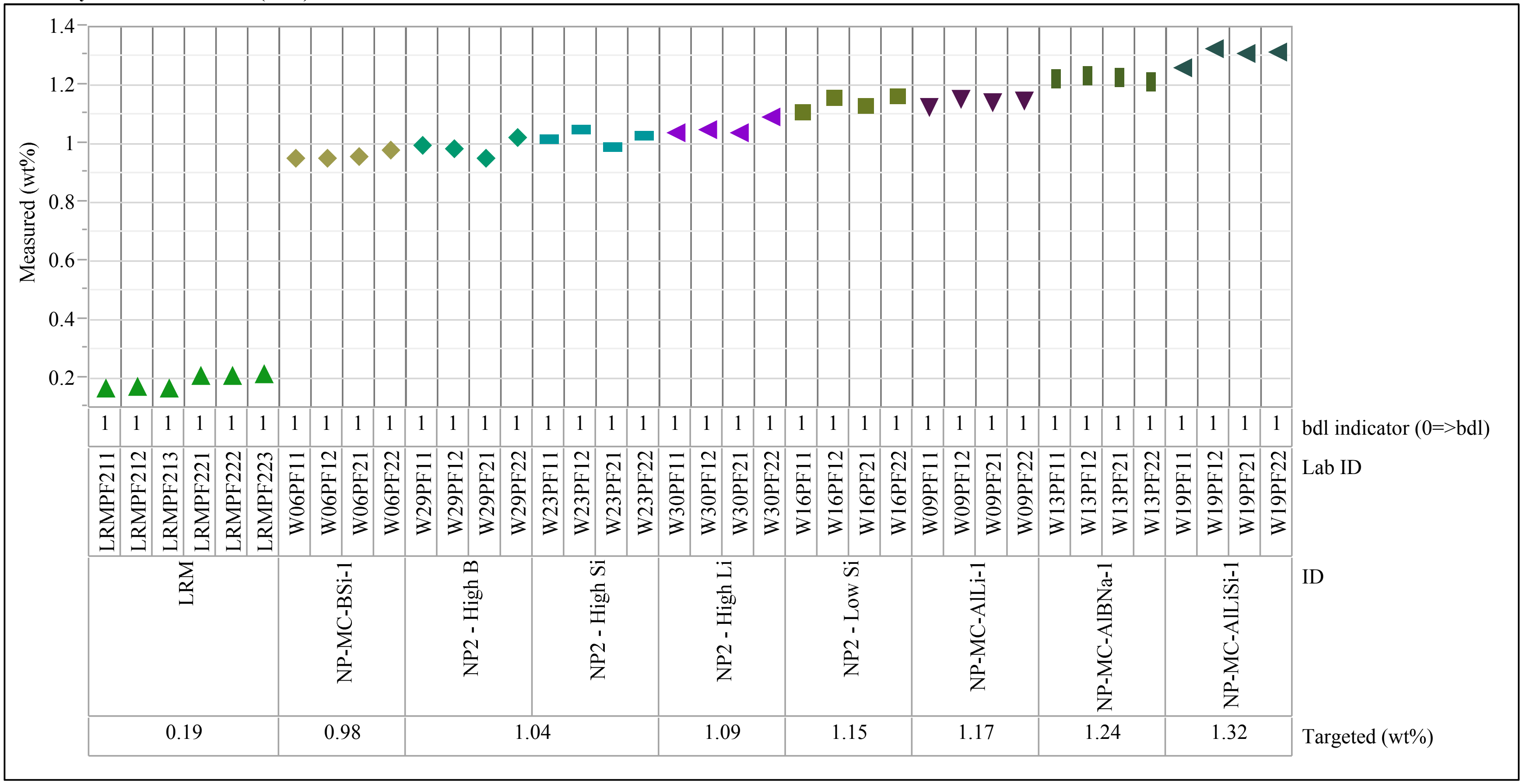


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

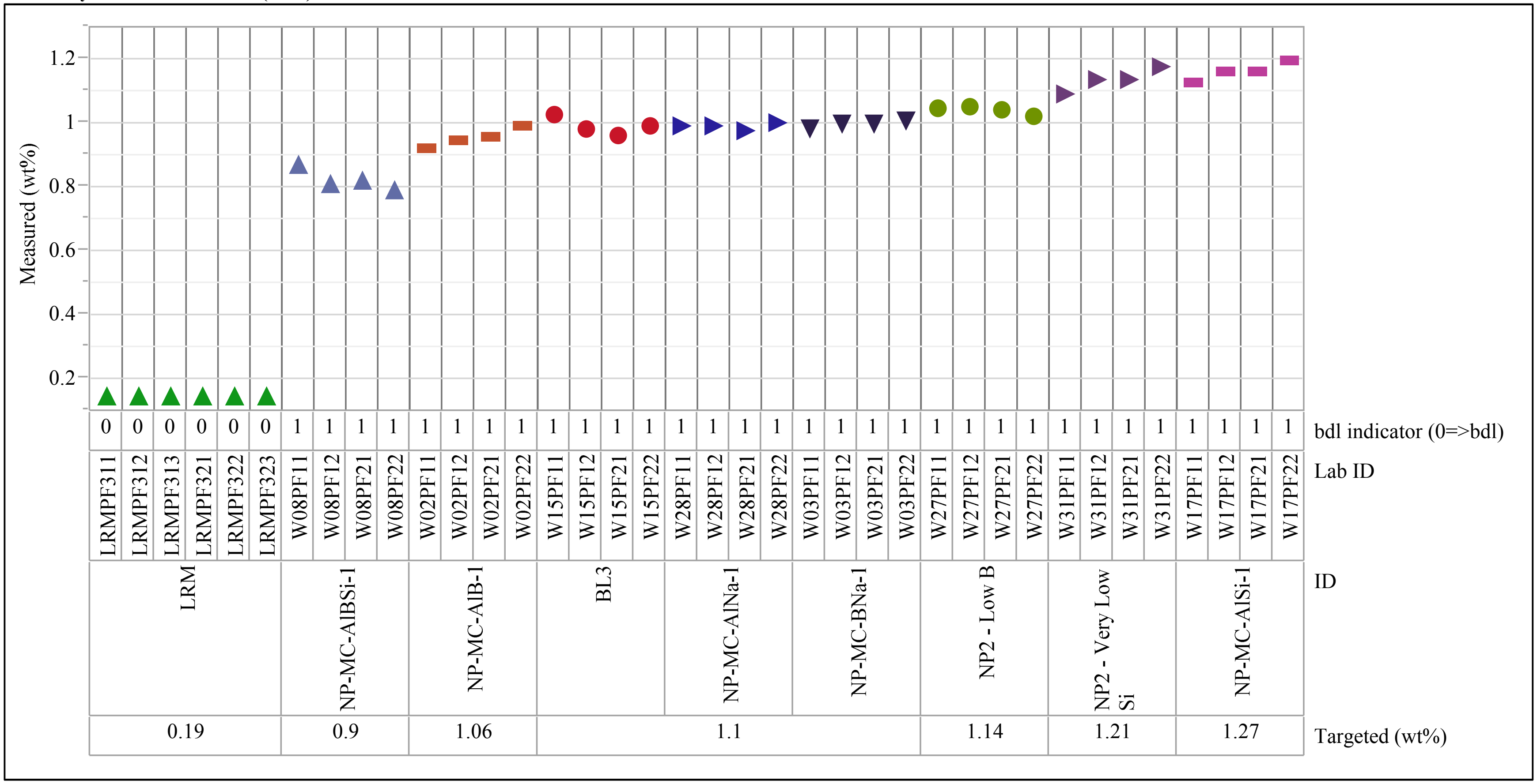


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Cr2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

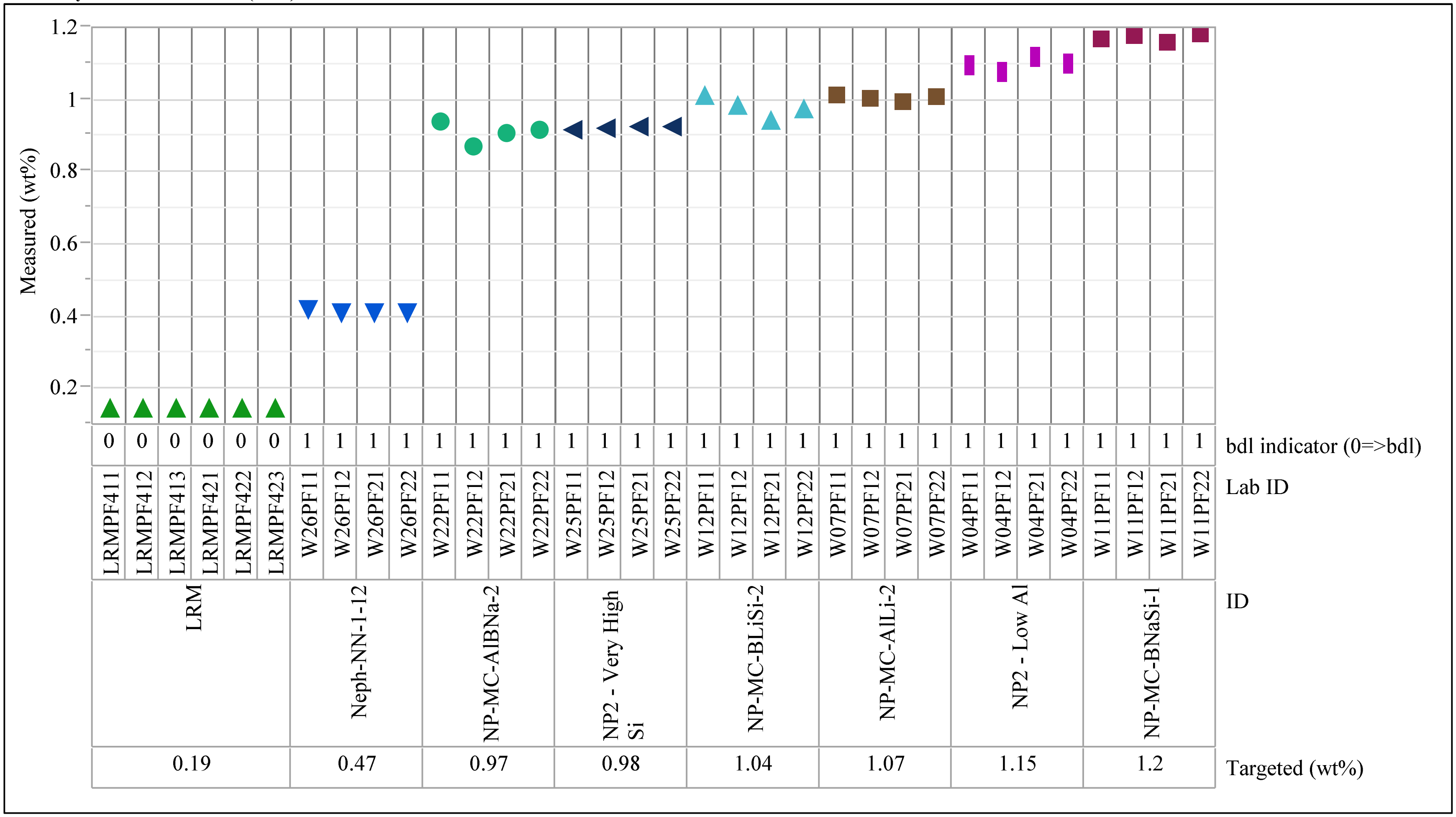


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

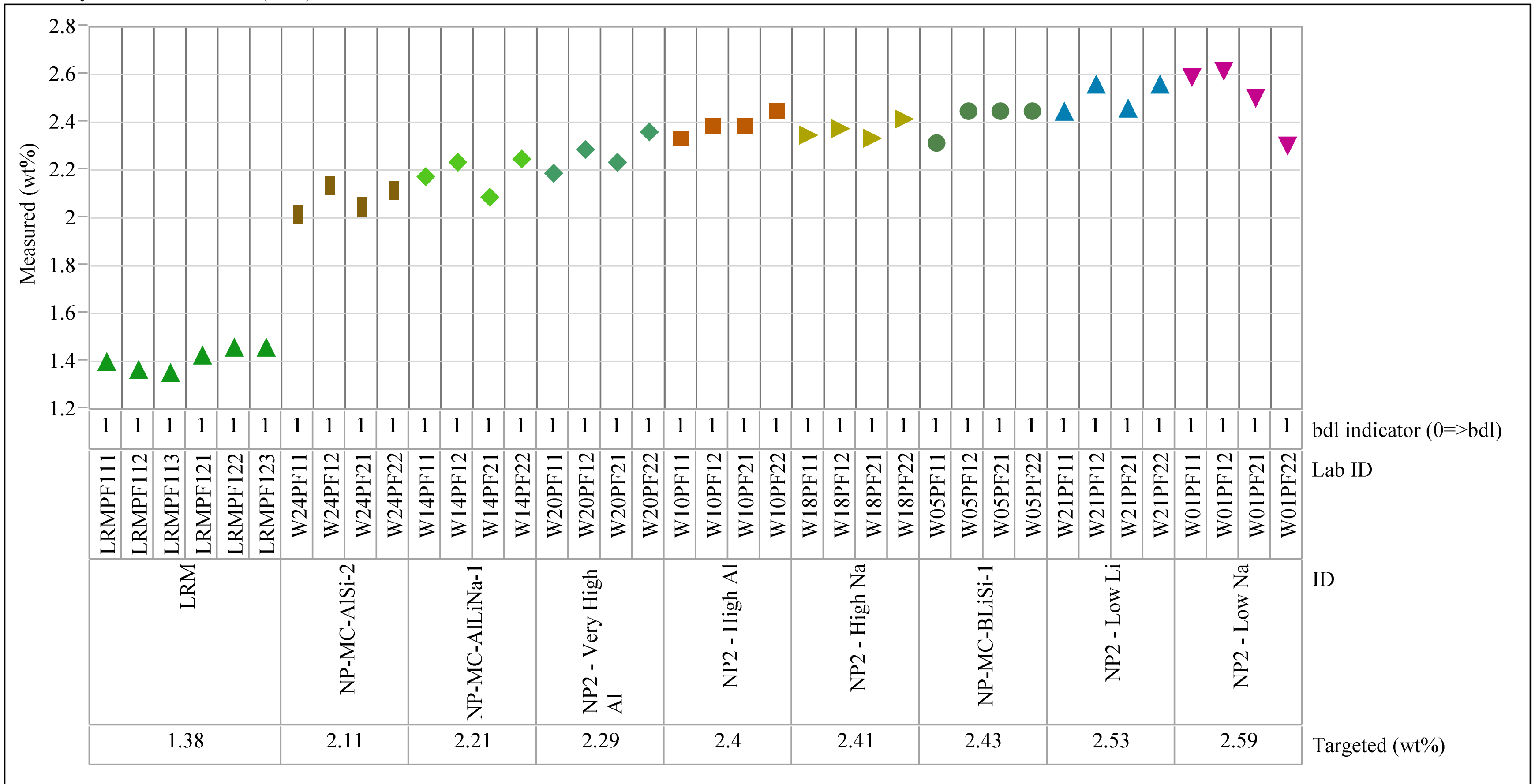


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

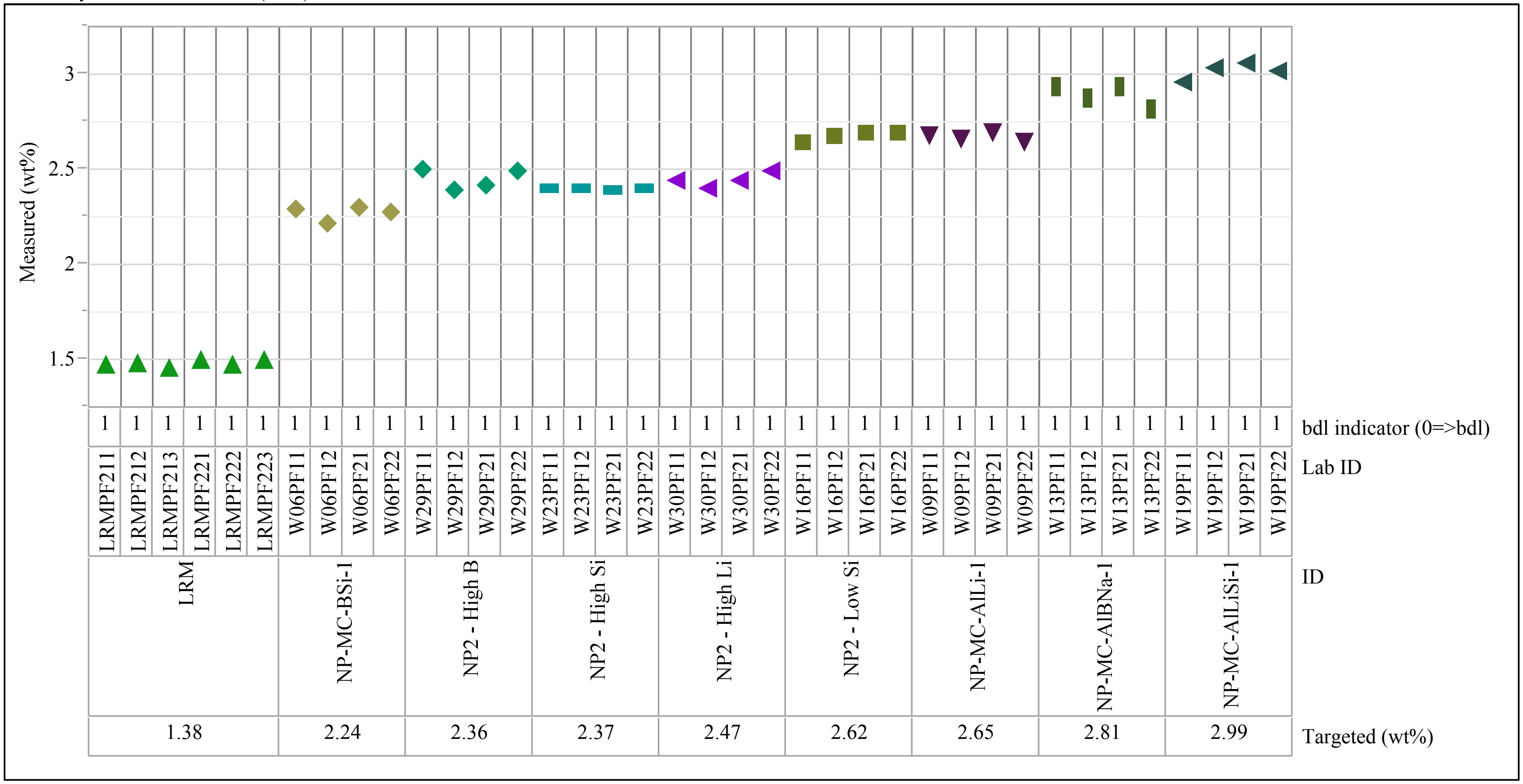


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

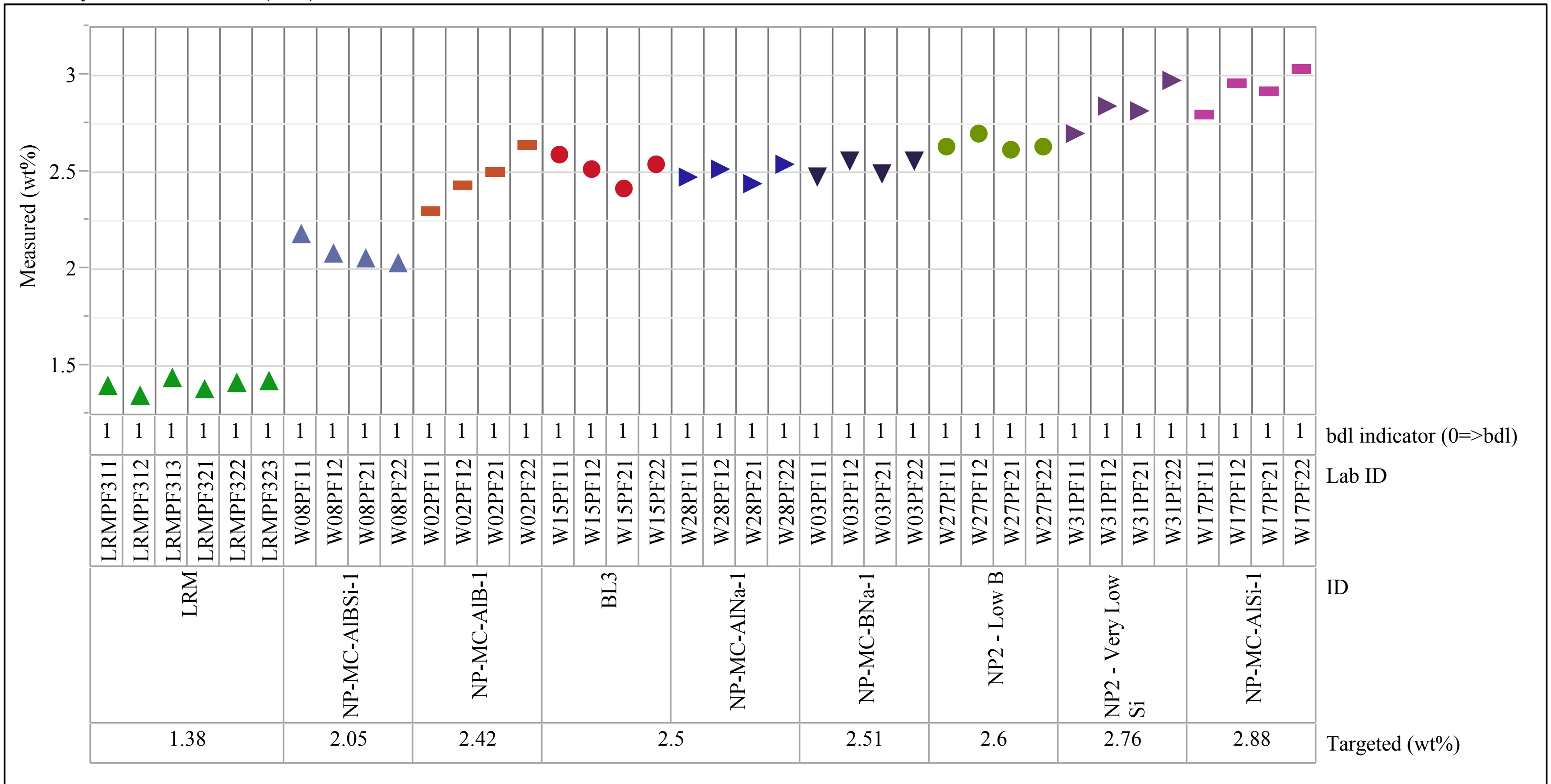


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Fe2O3 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

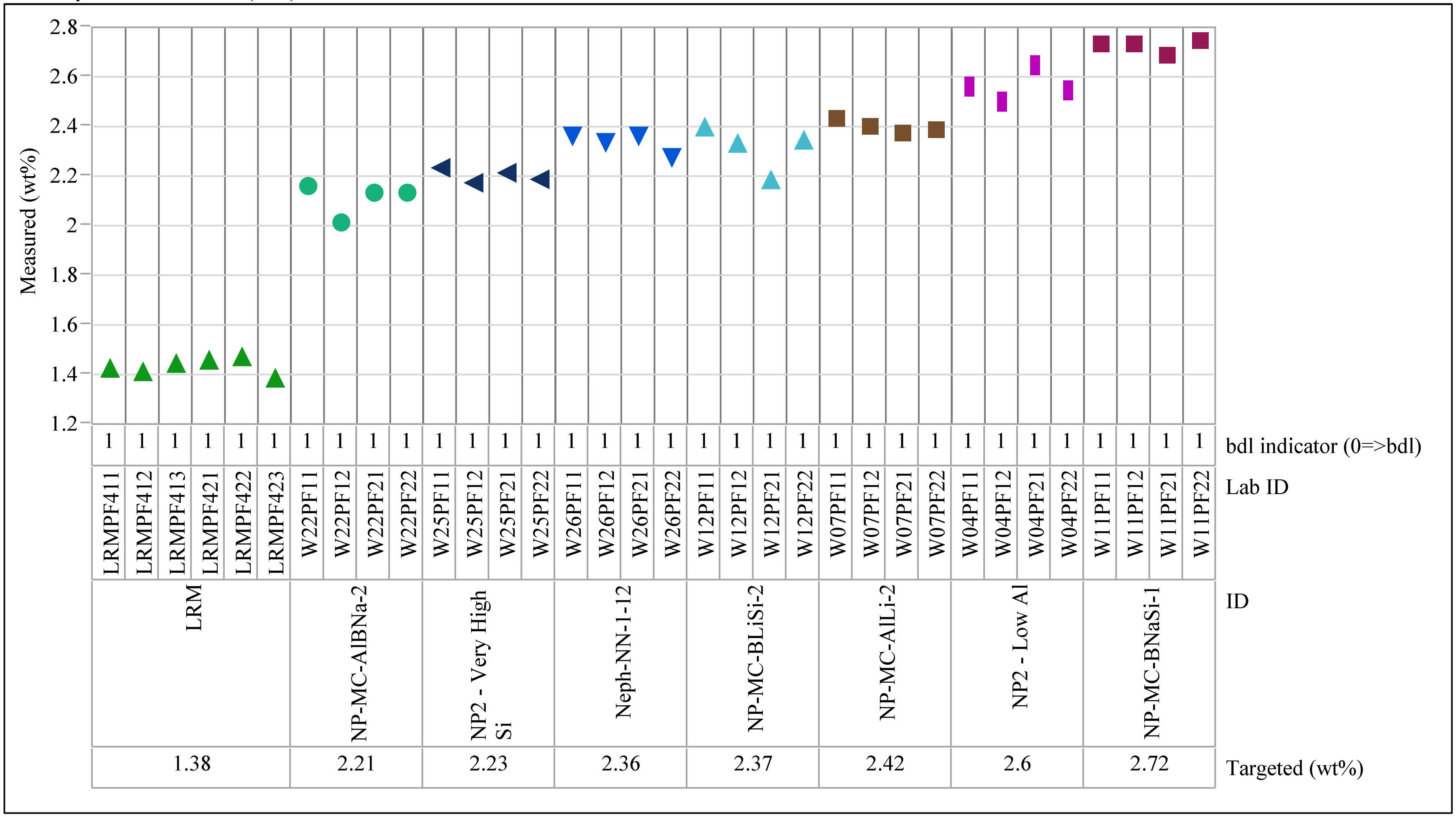


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

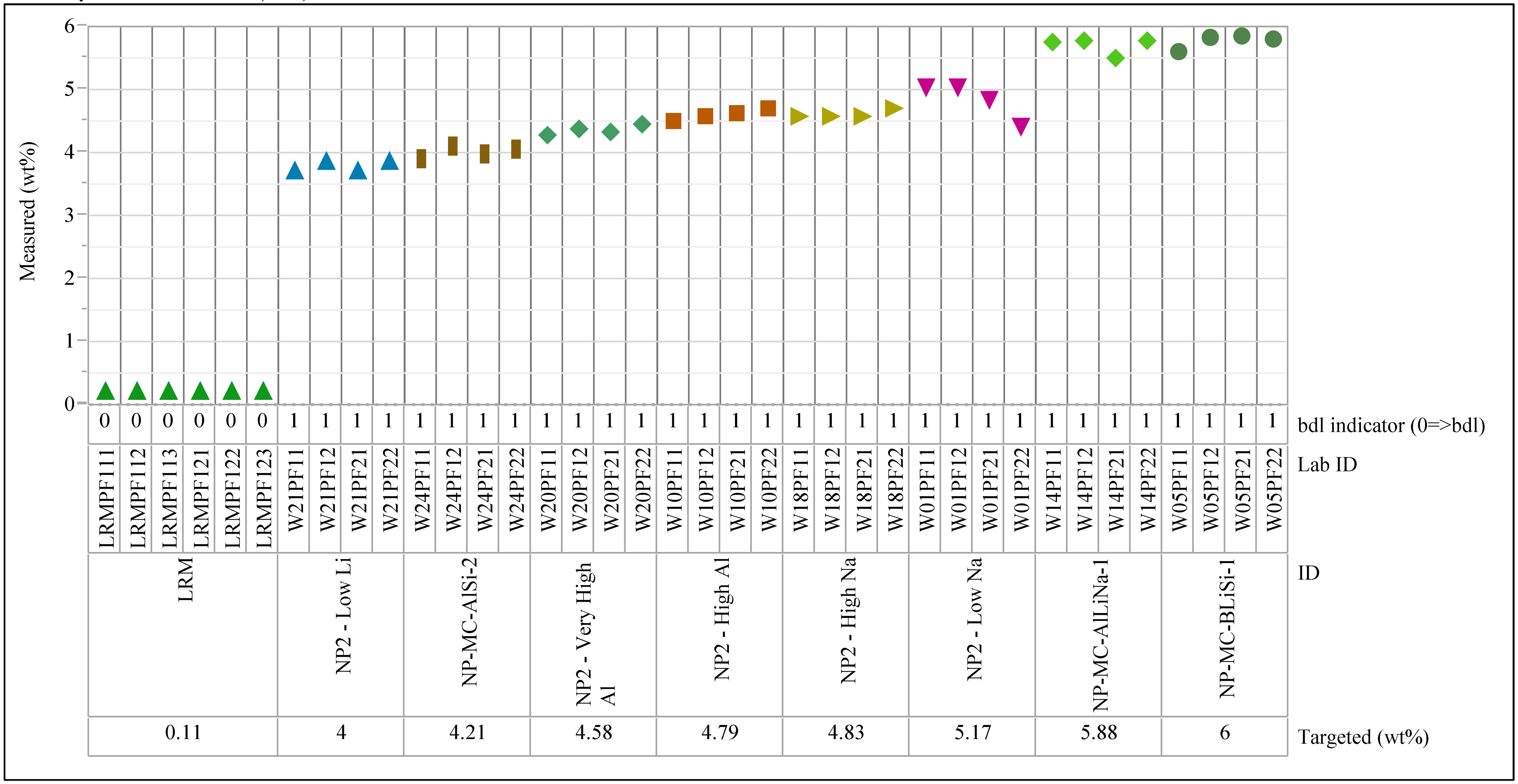


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

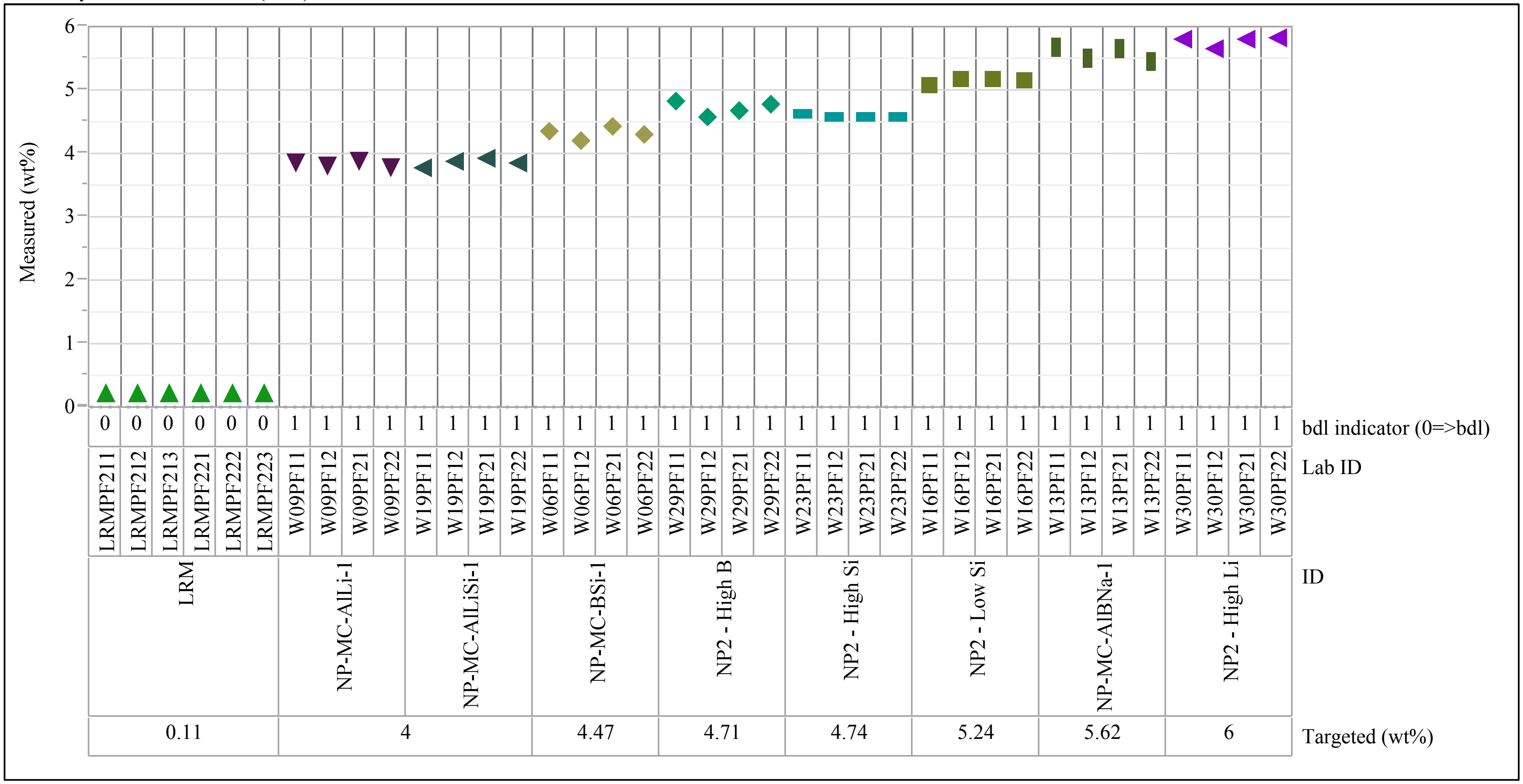


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

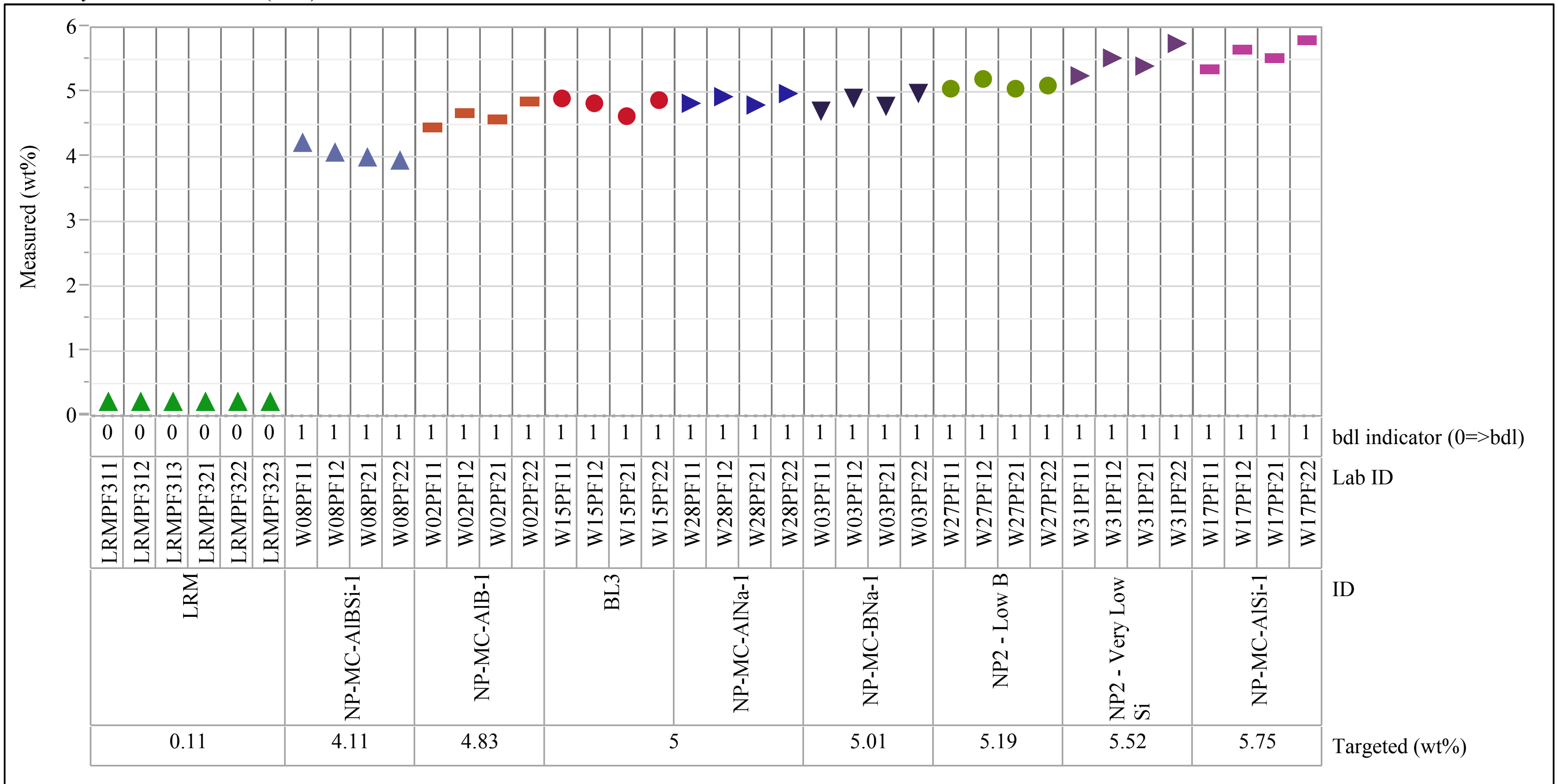


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Li2O (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

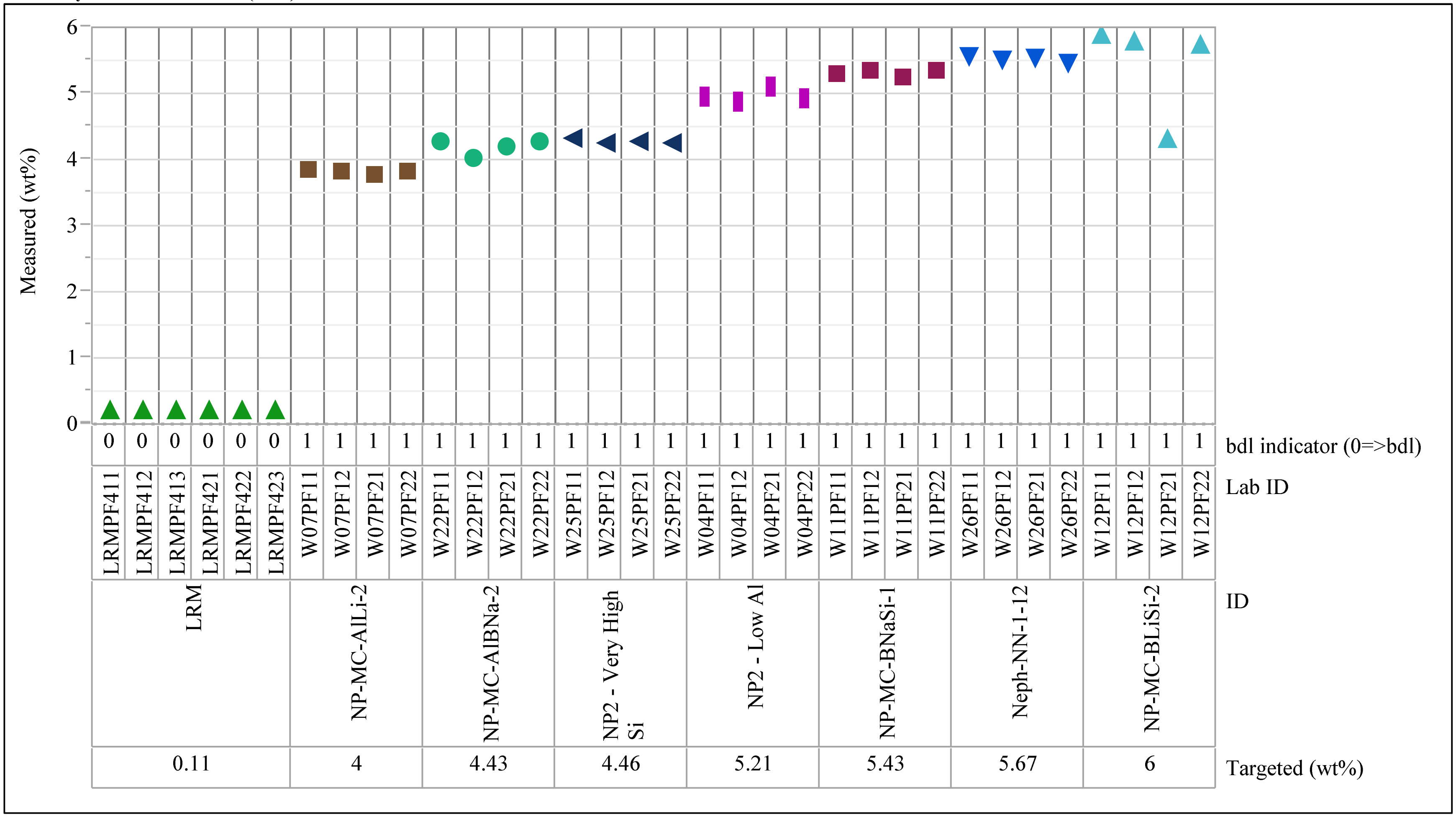


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

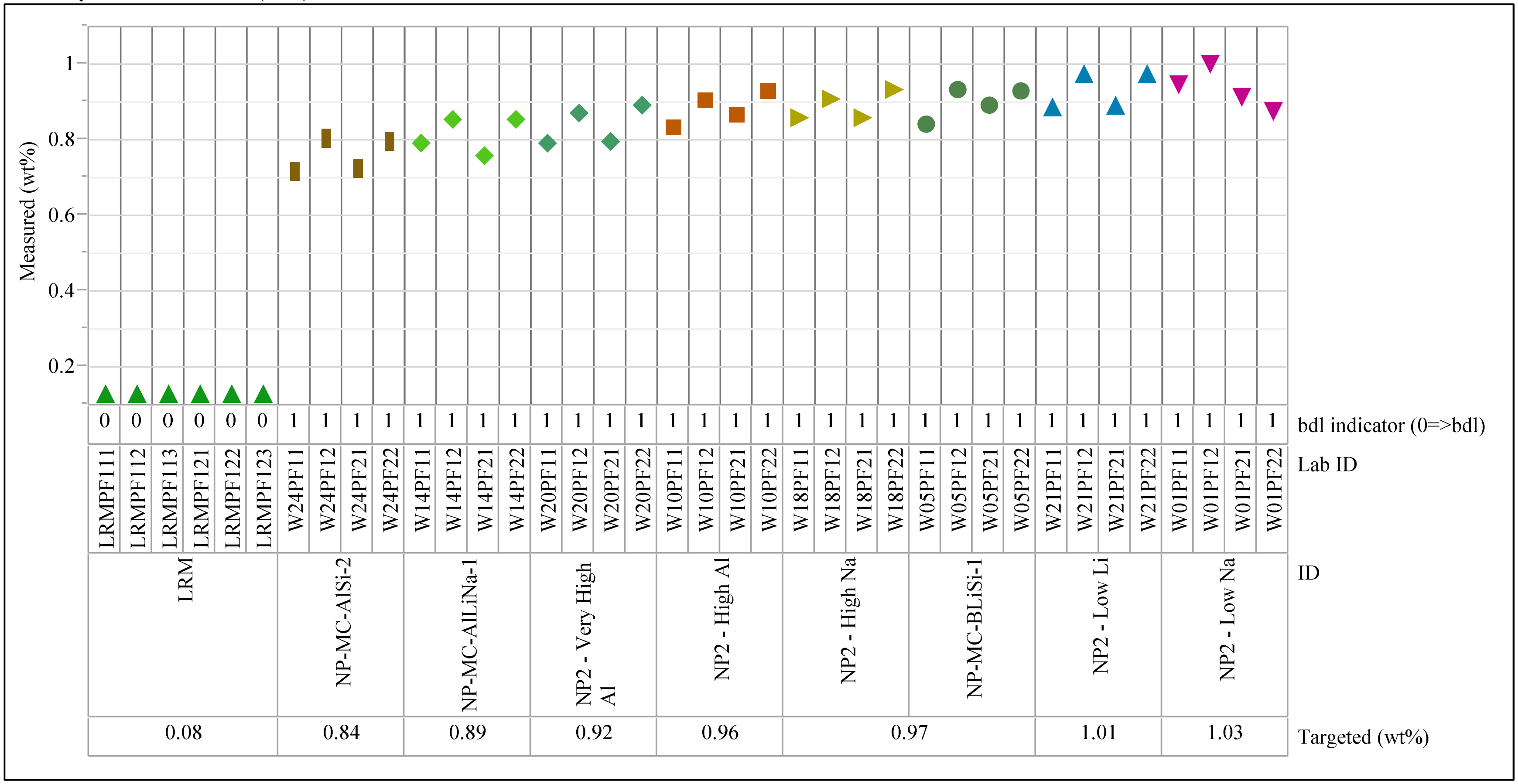


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

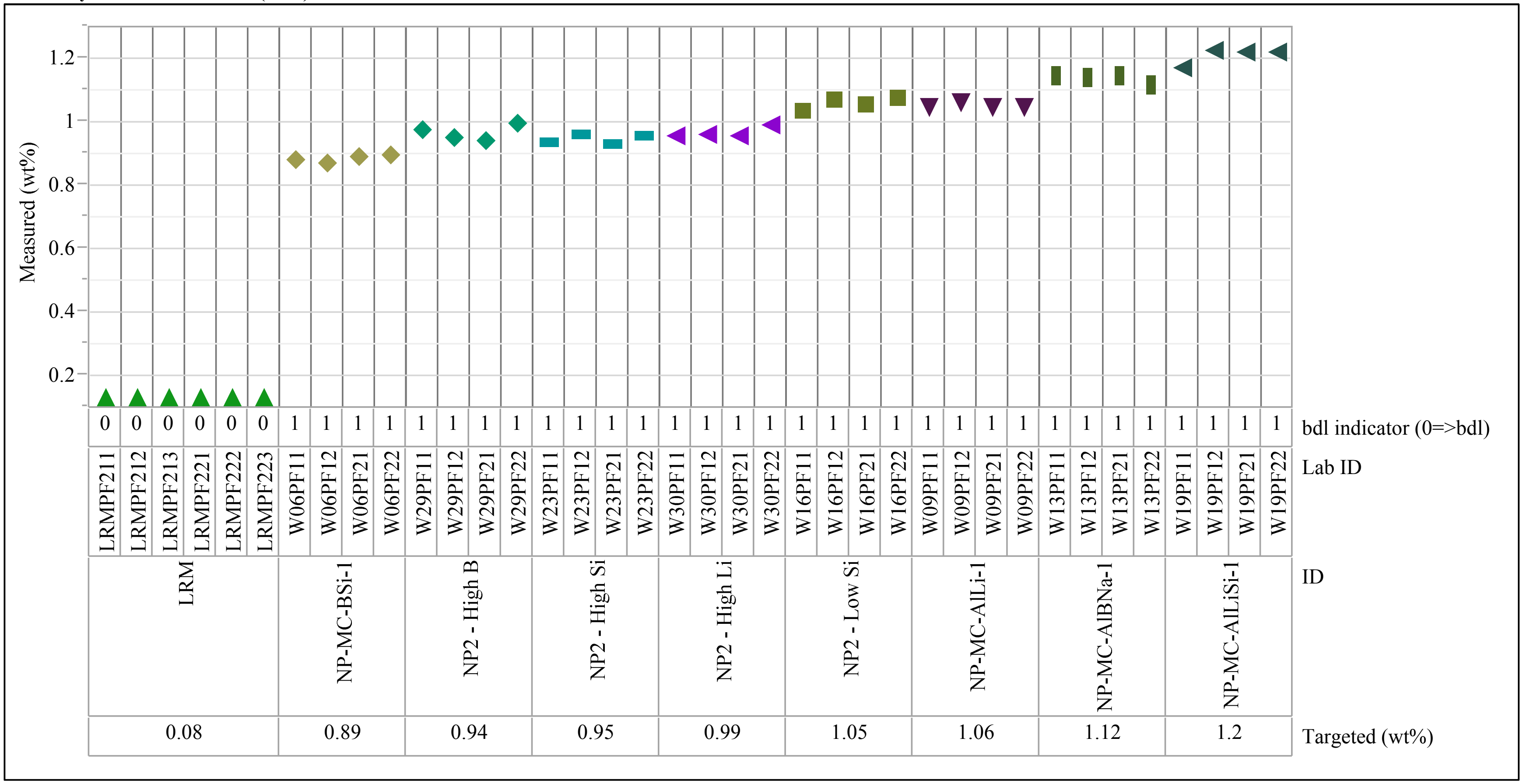


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

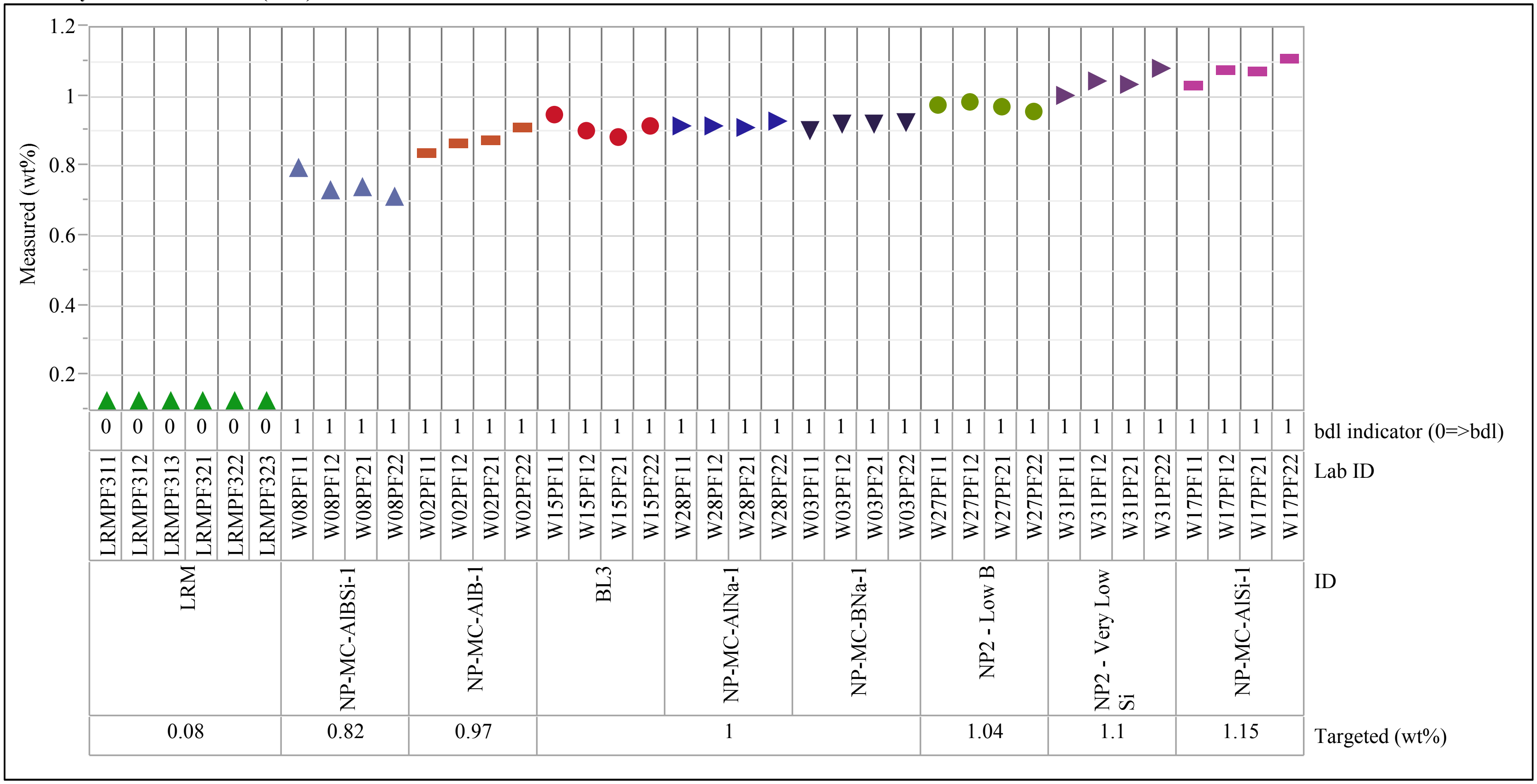


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=MnO (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

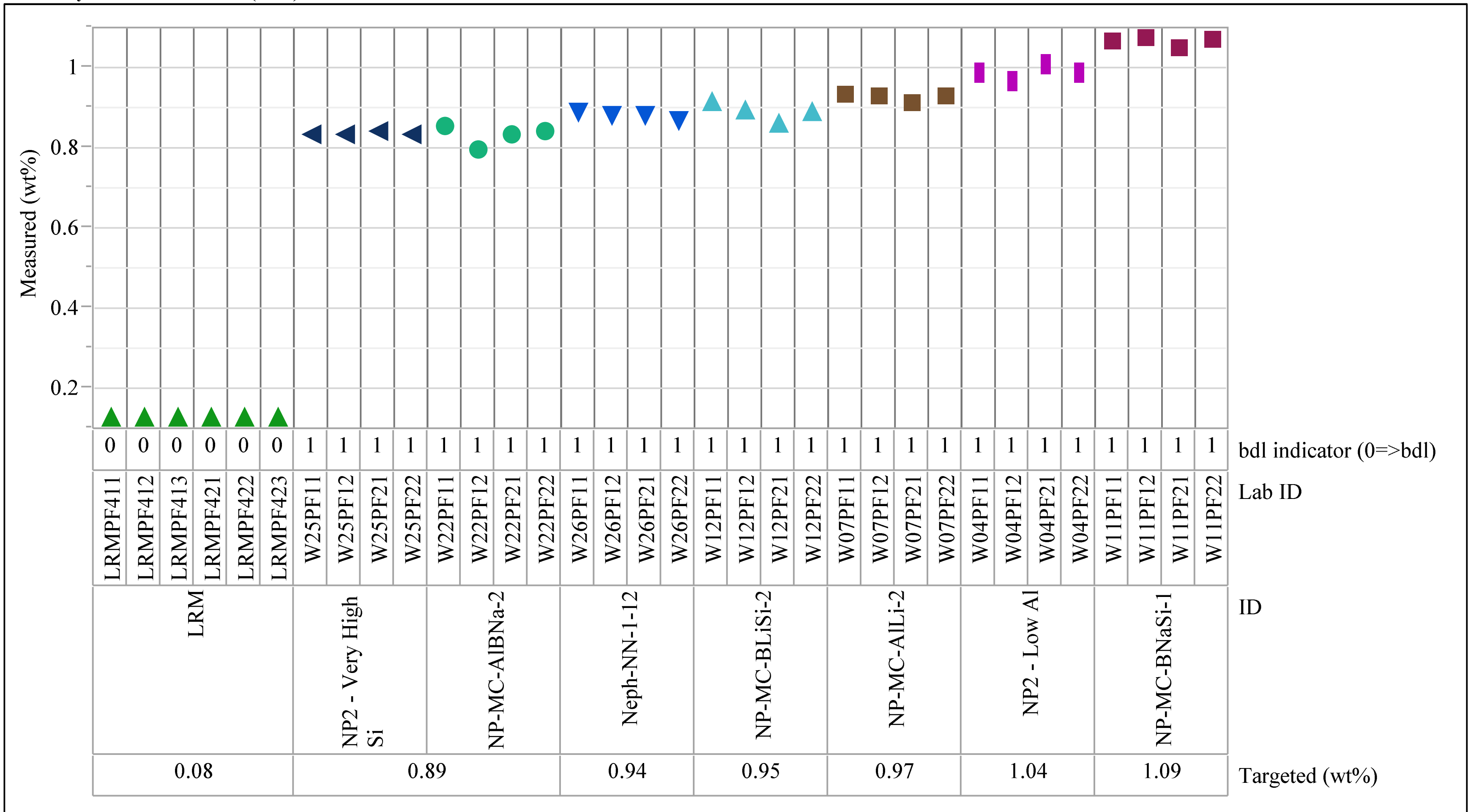


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

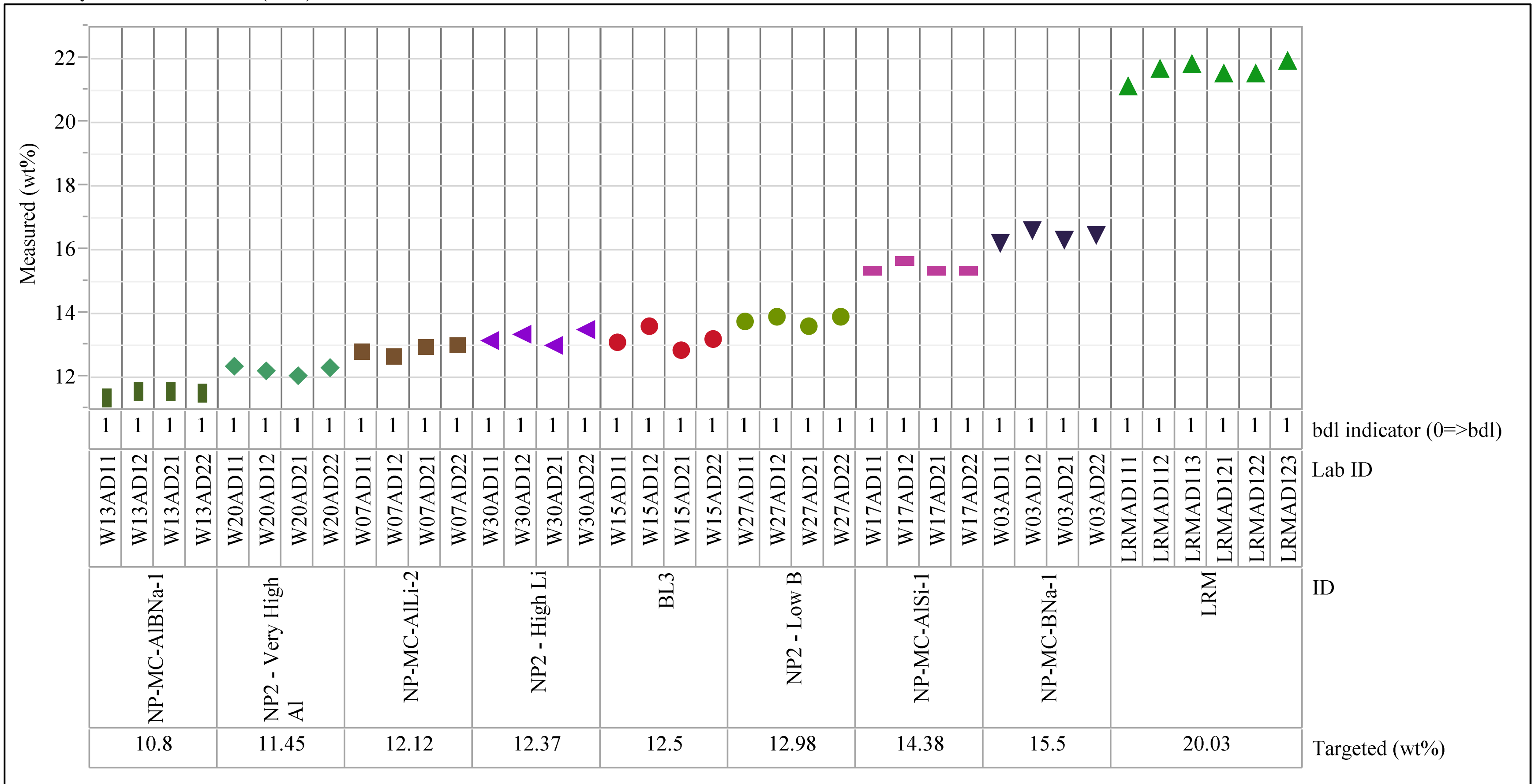


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

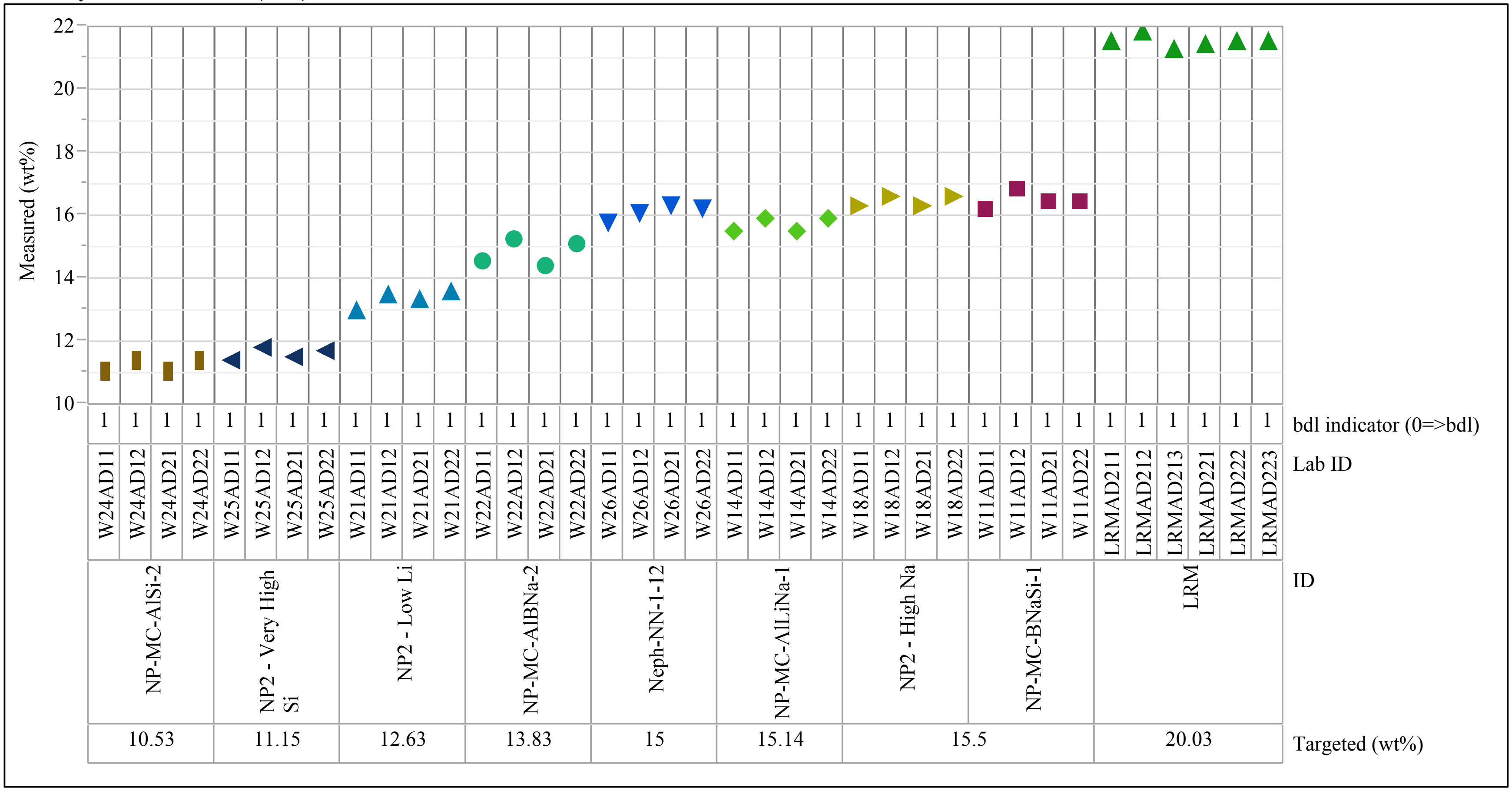


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

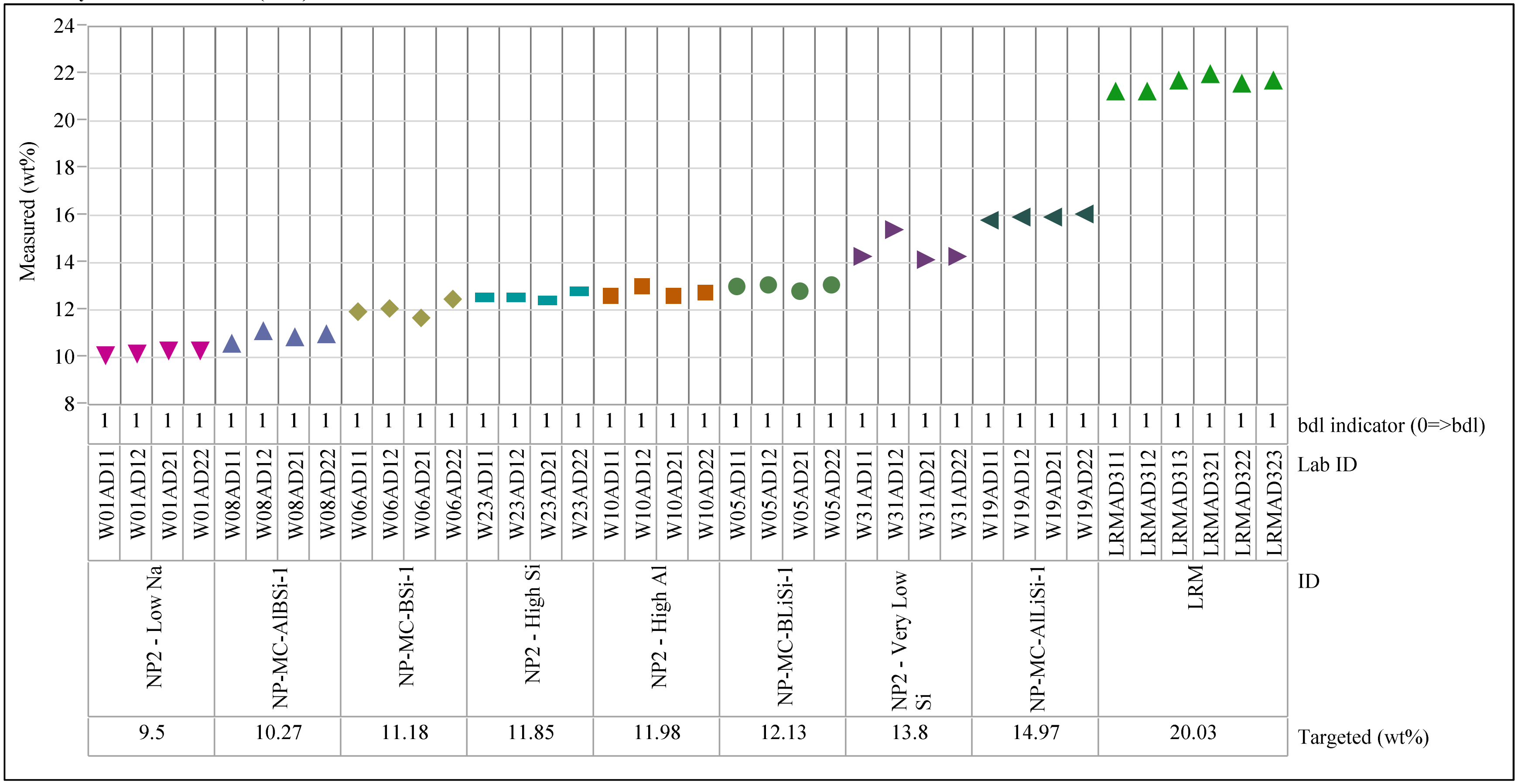


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=Na2O (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

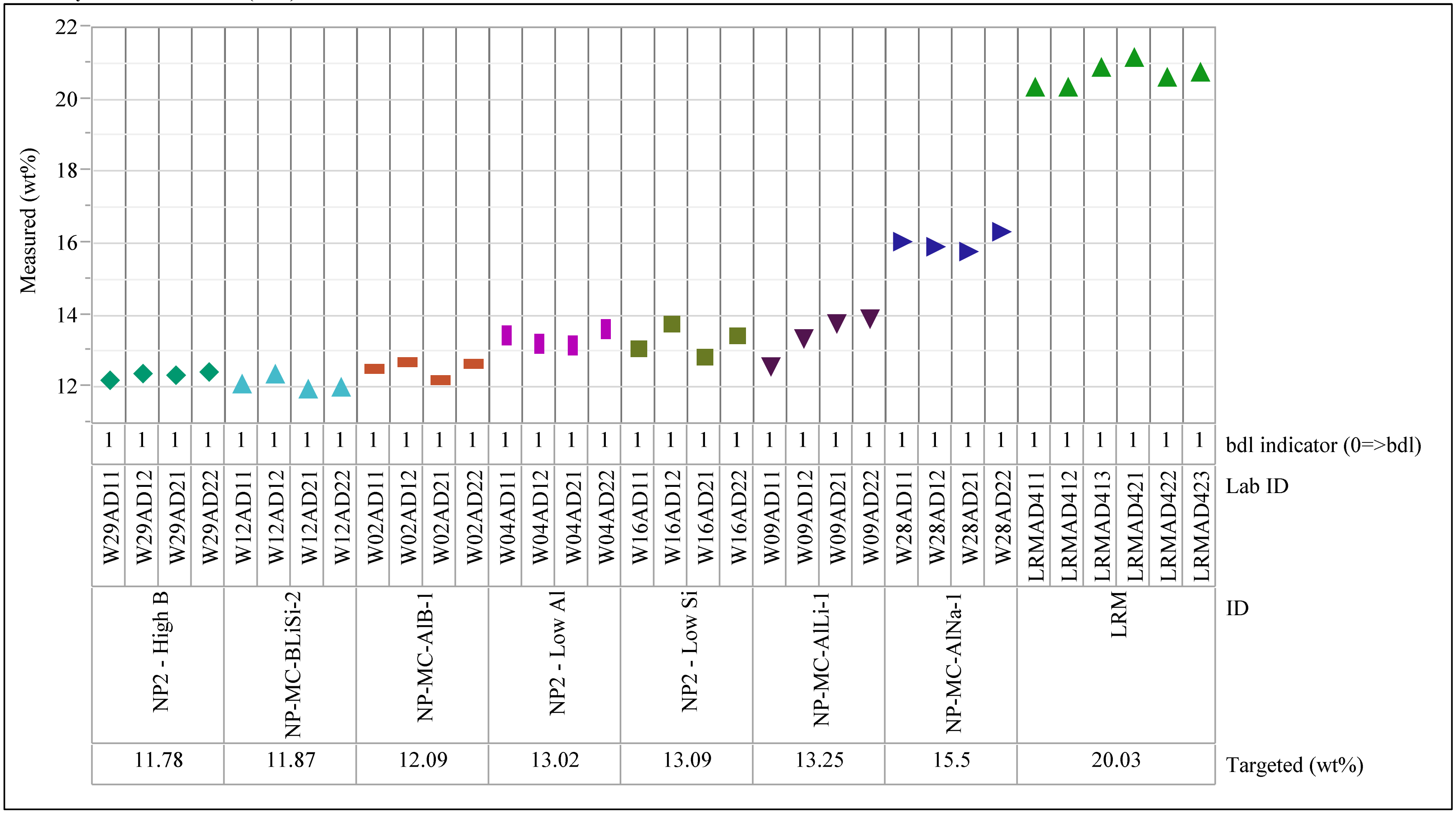


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

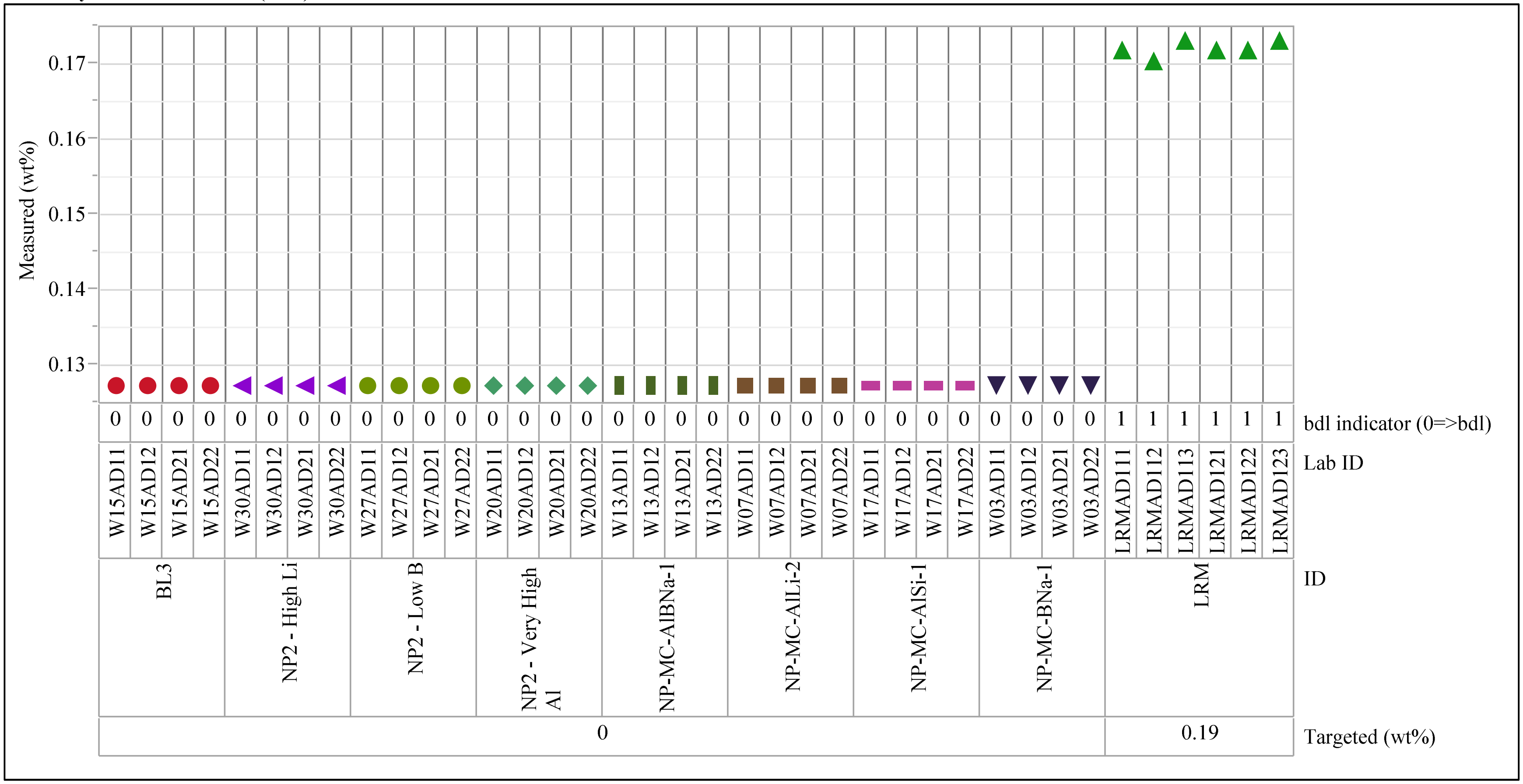


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

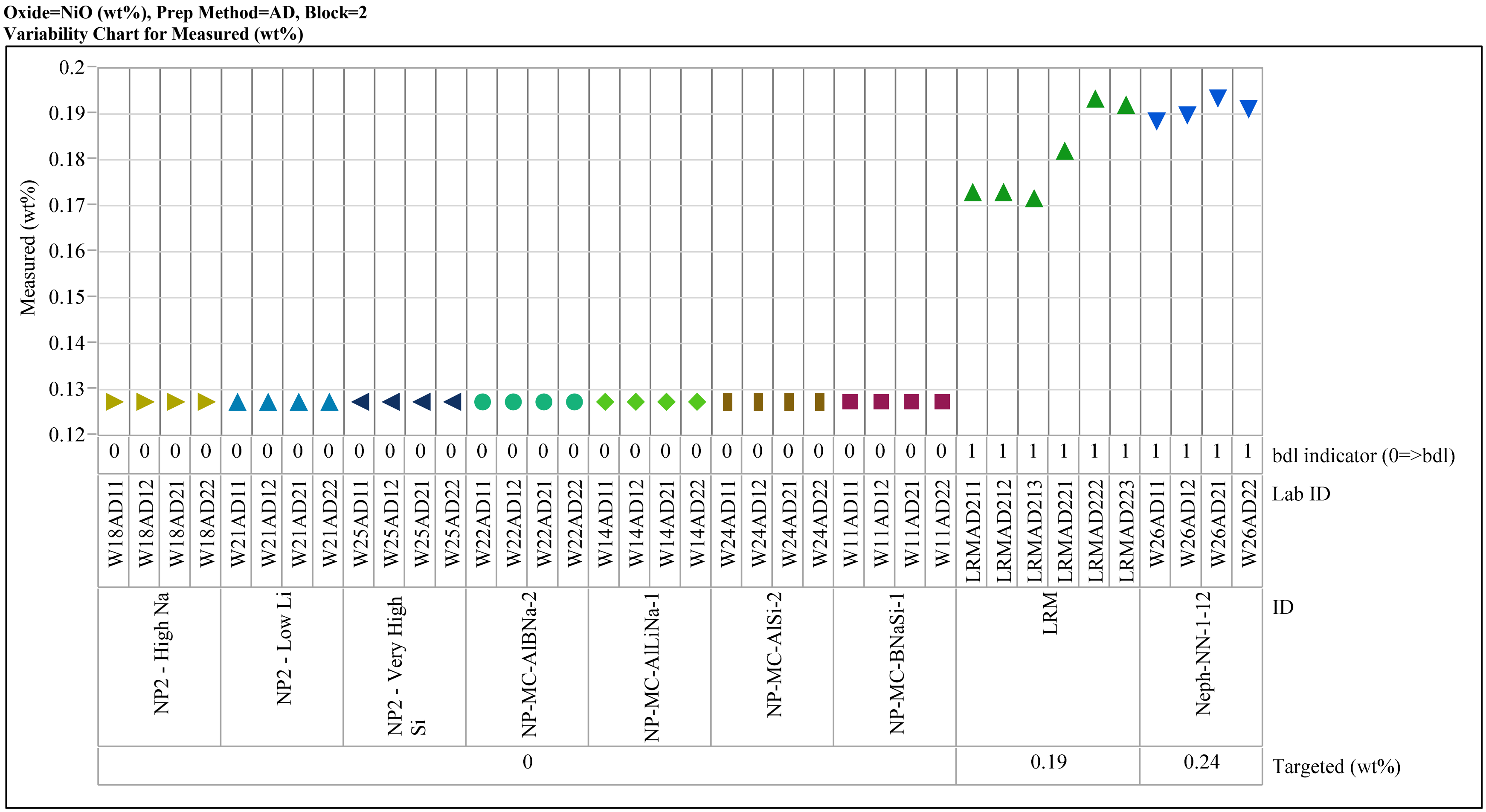


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

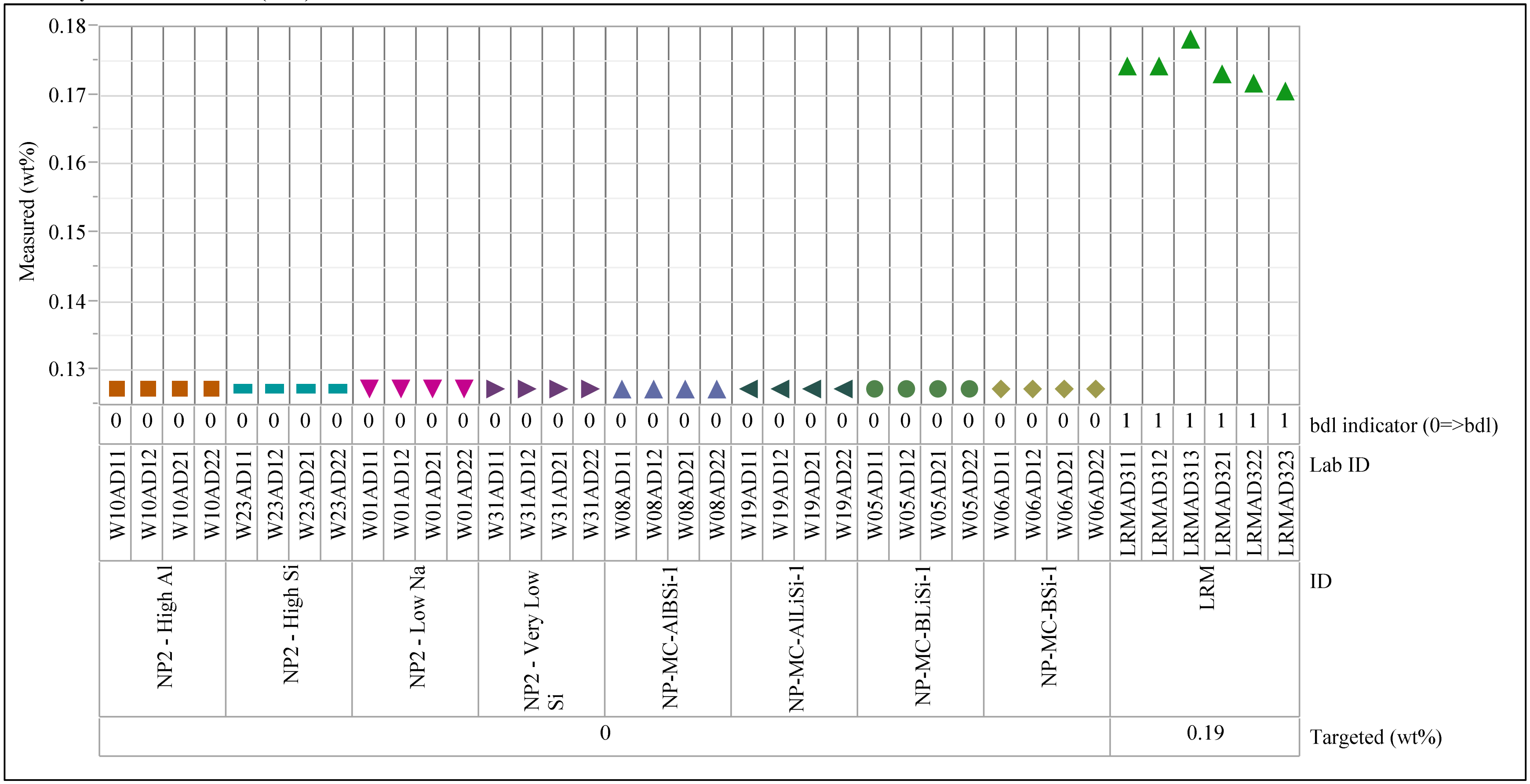


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=NiO (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

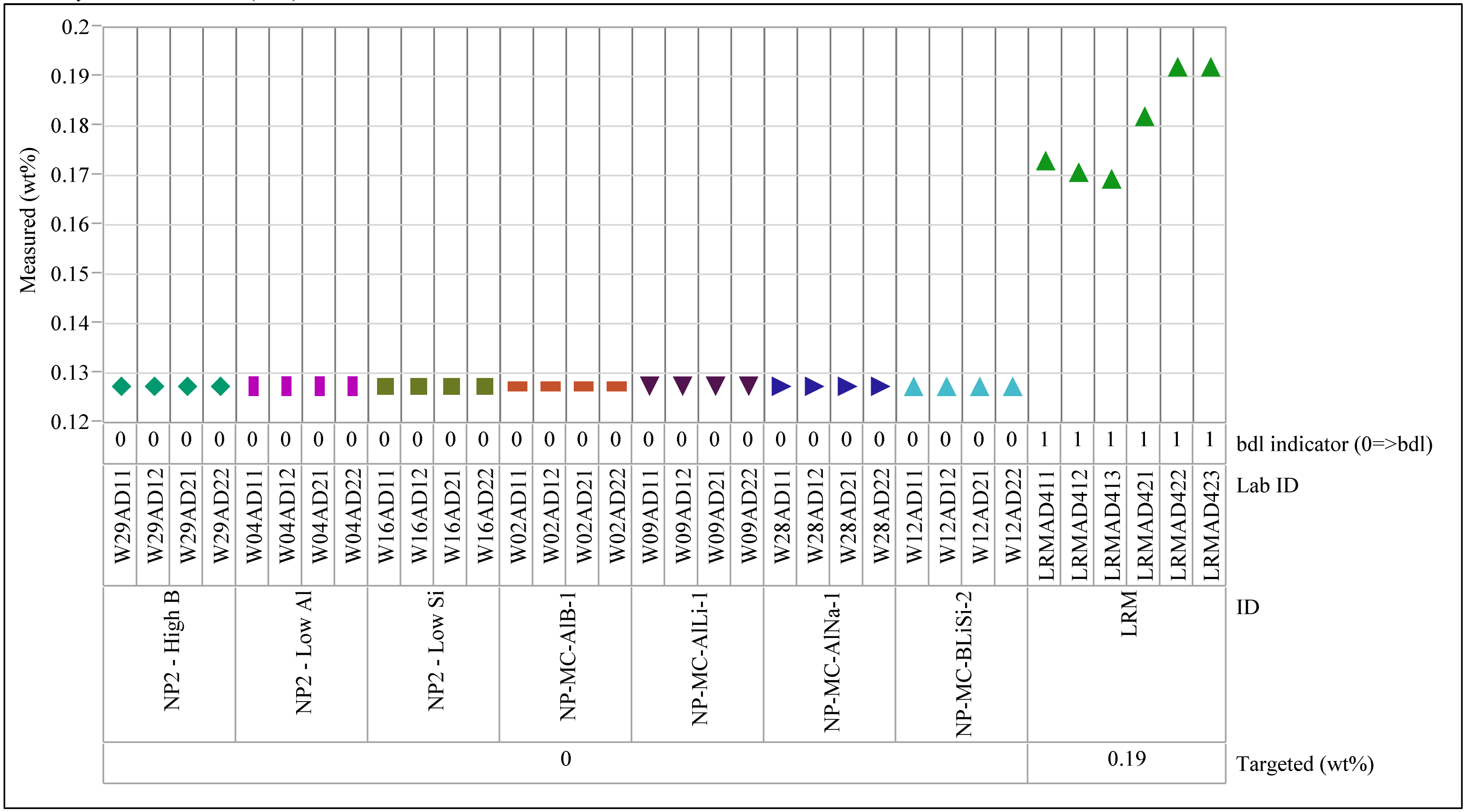


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

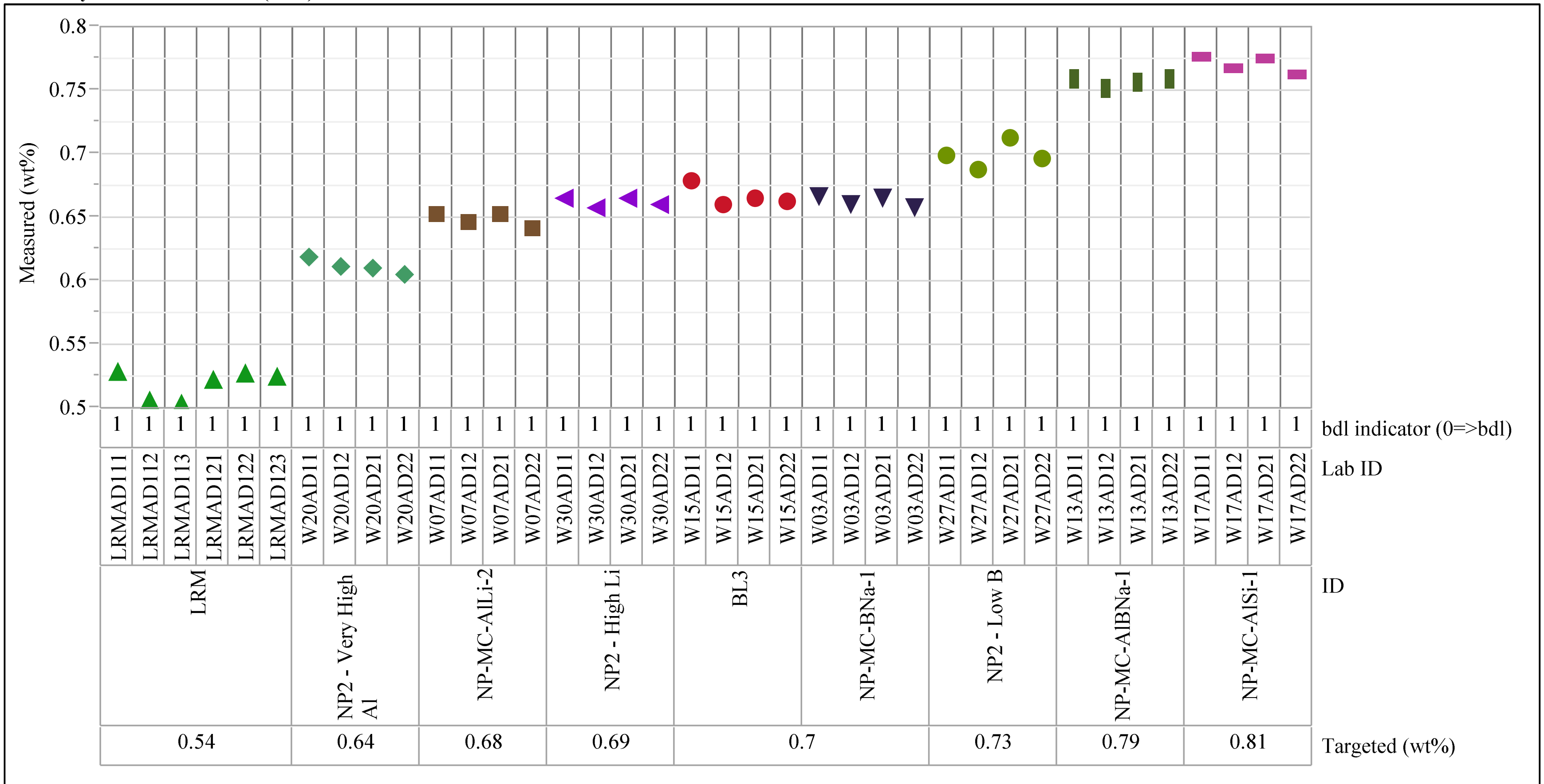


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

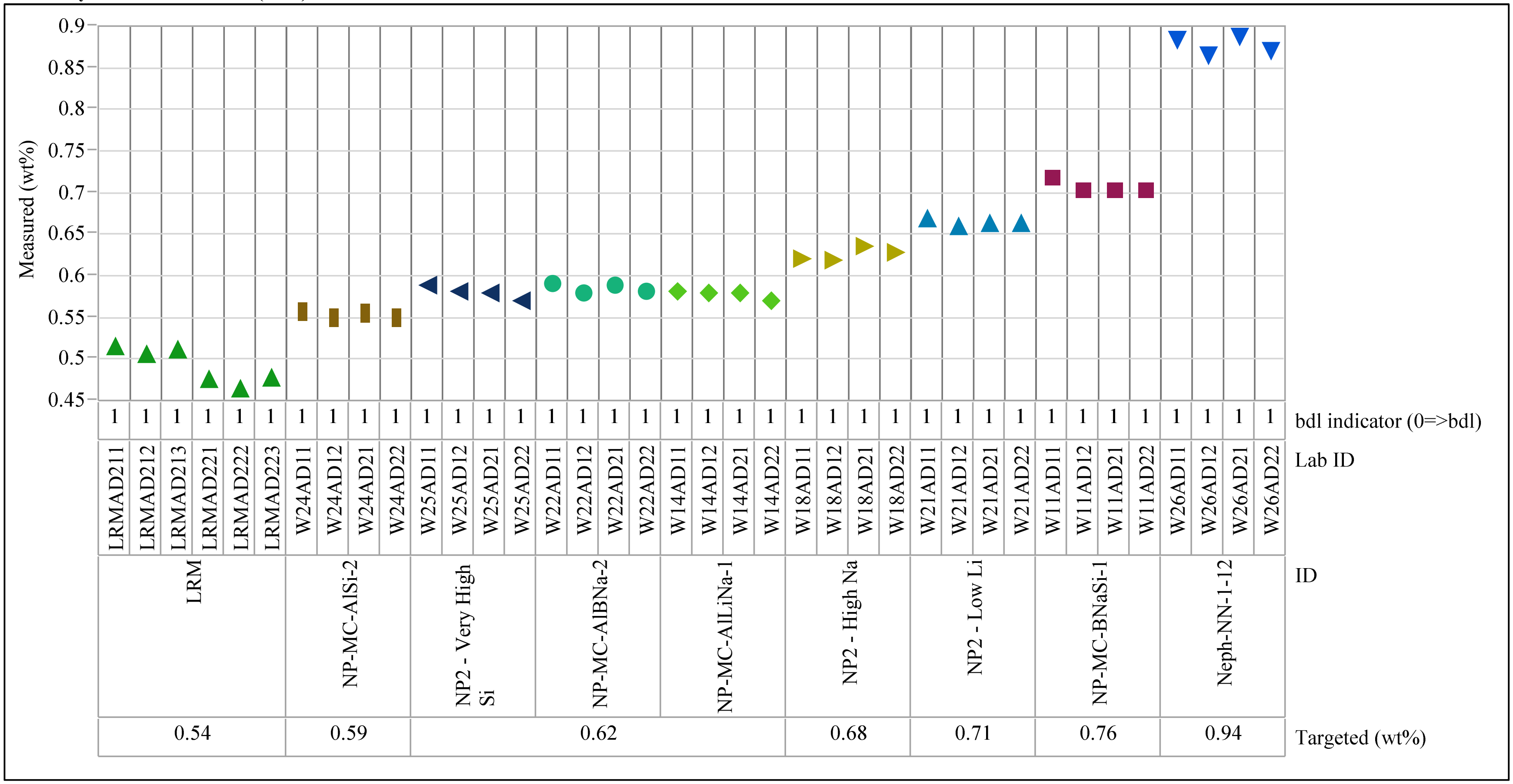


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

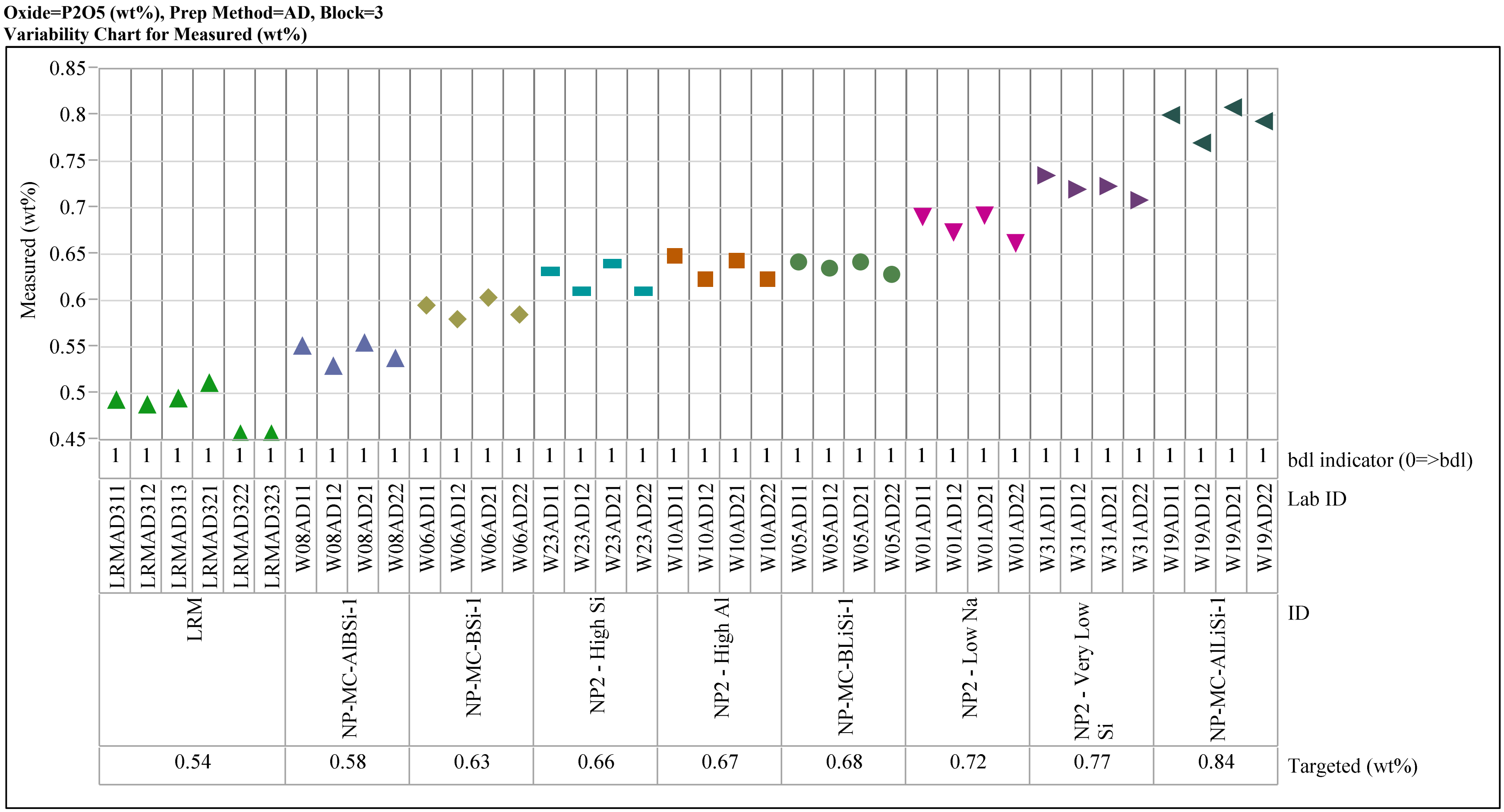


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=P2O5 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

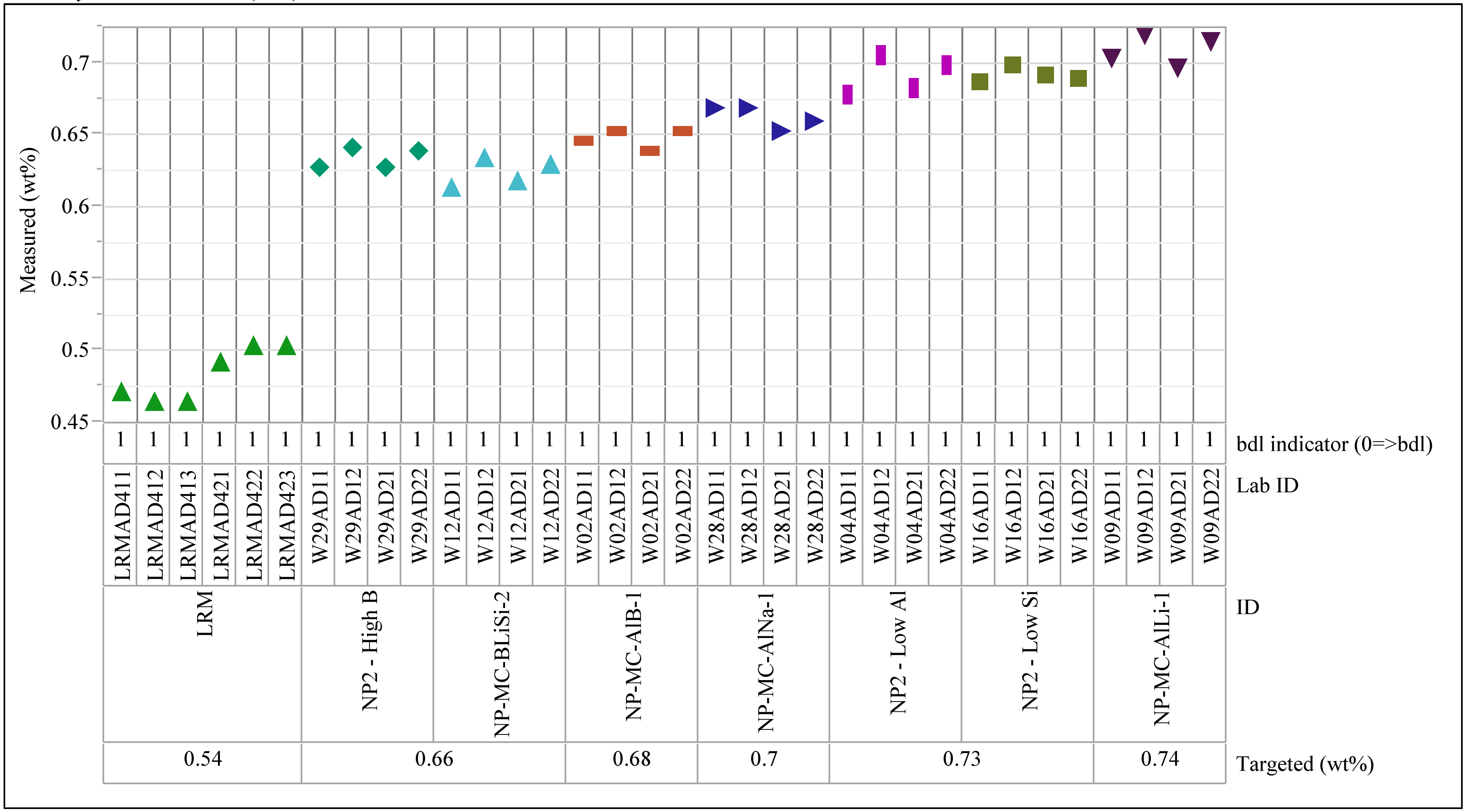


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

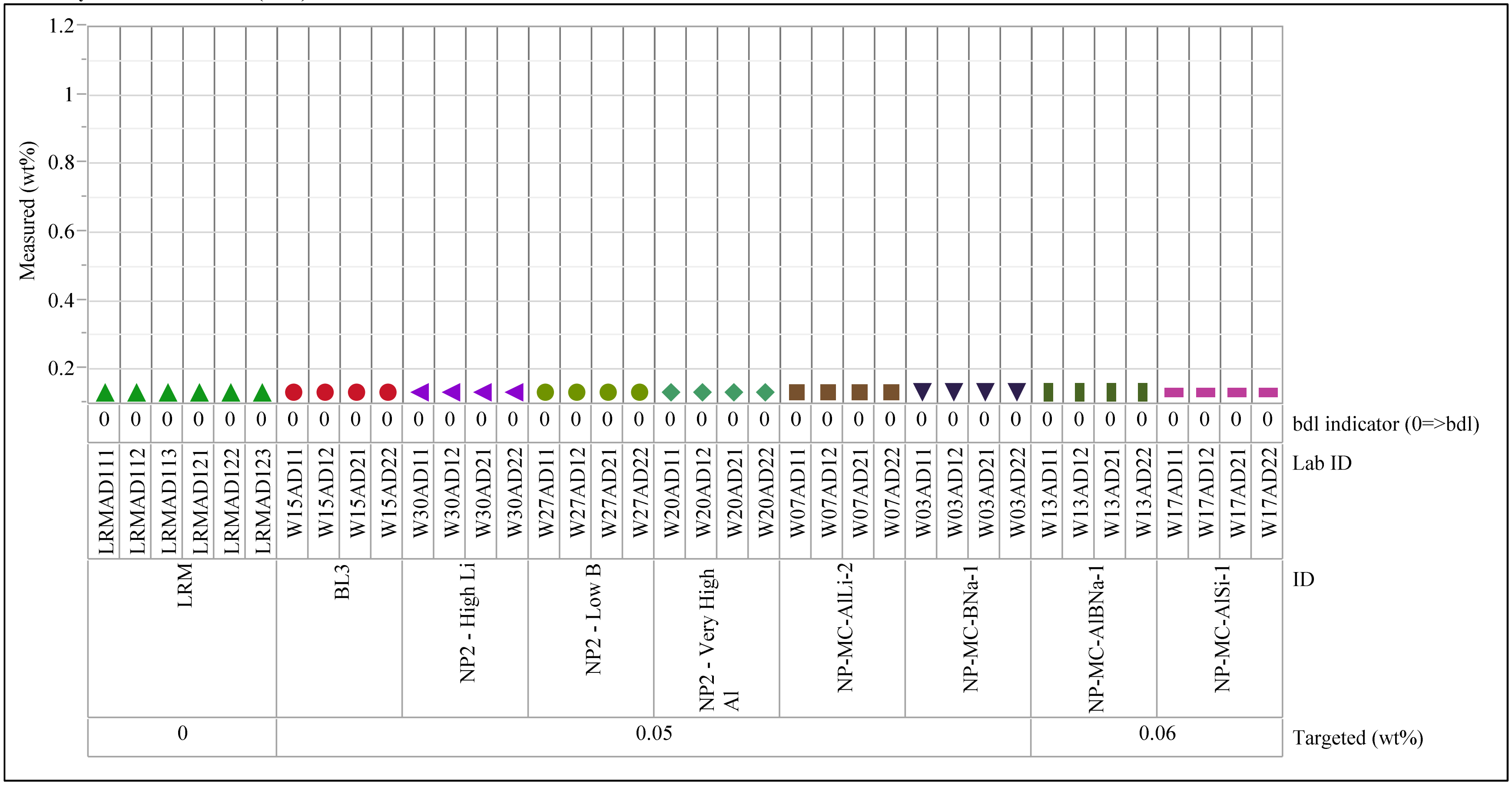


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

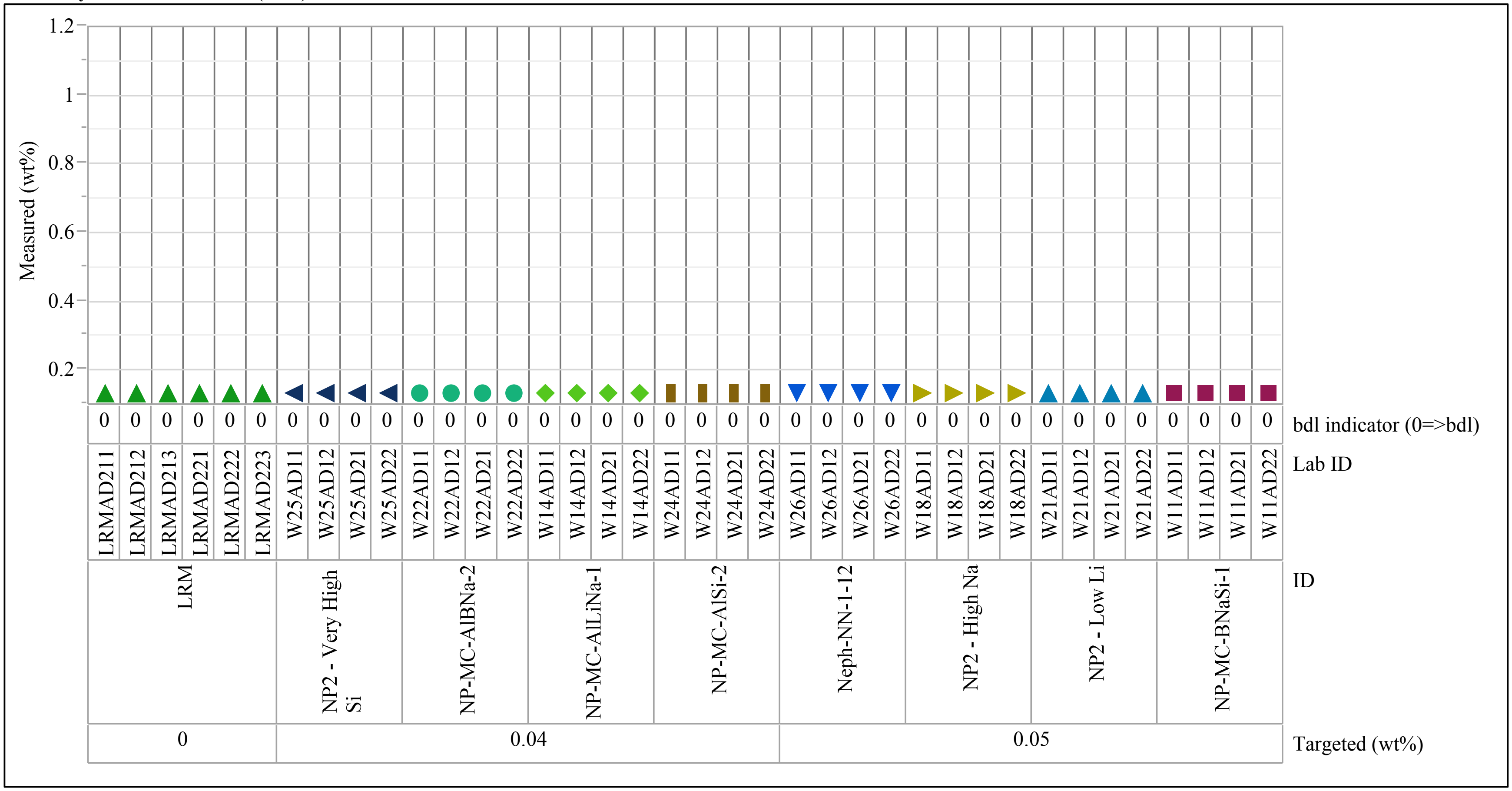


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

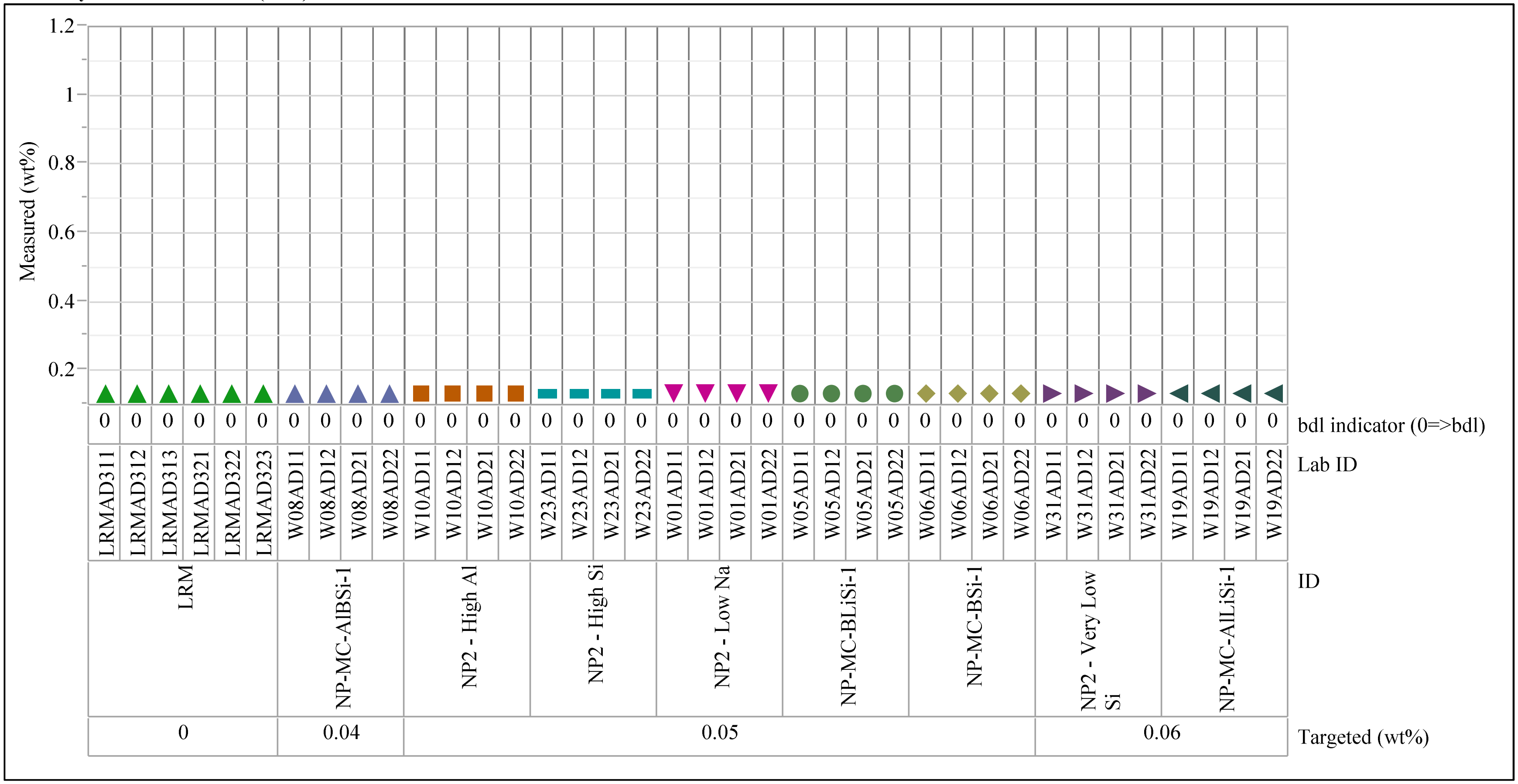


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=RuO2 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

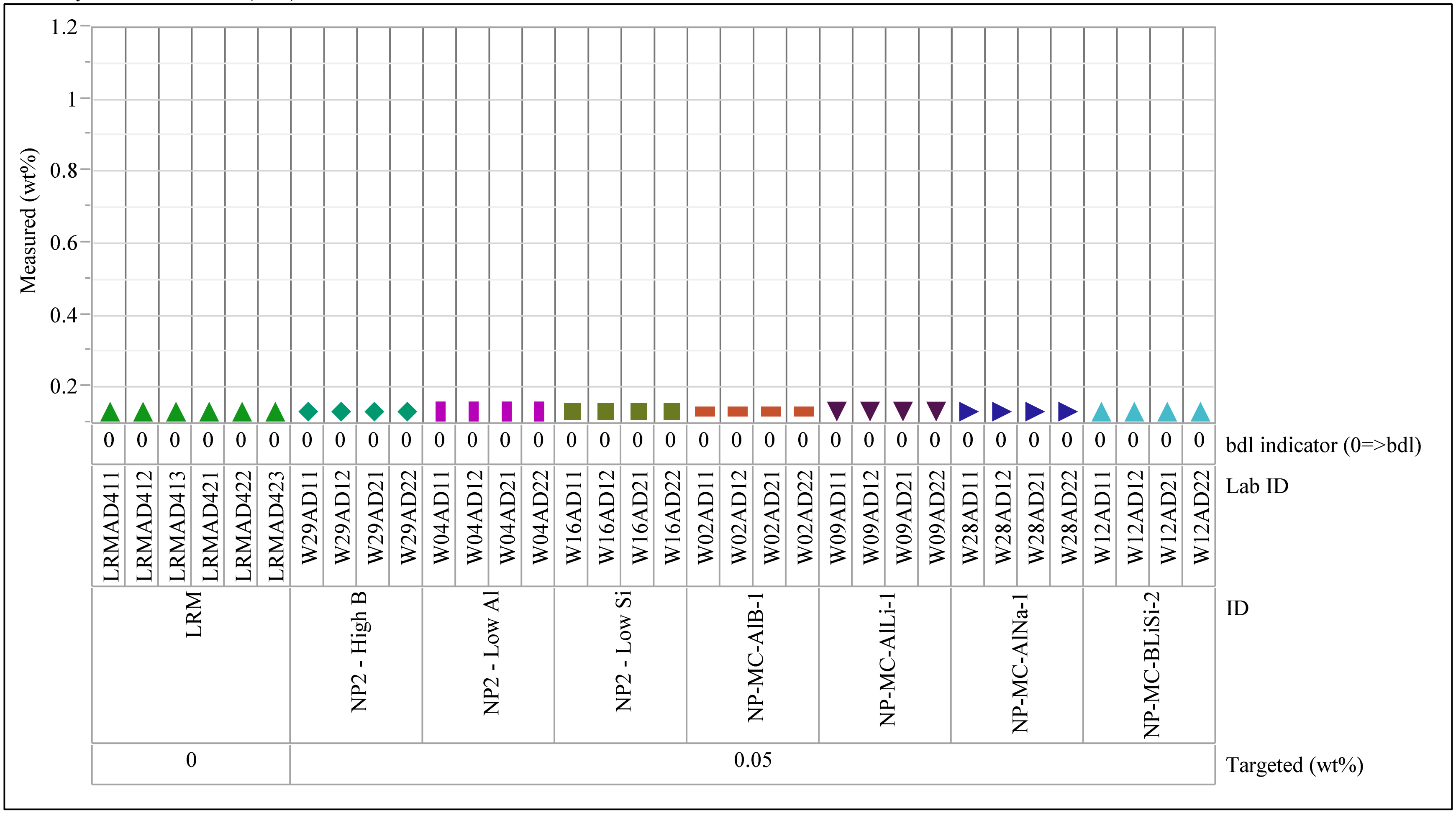


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=1**
**Variability Chart for Measured (wt%)**

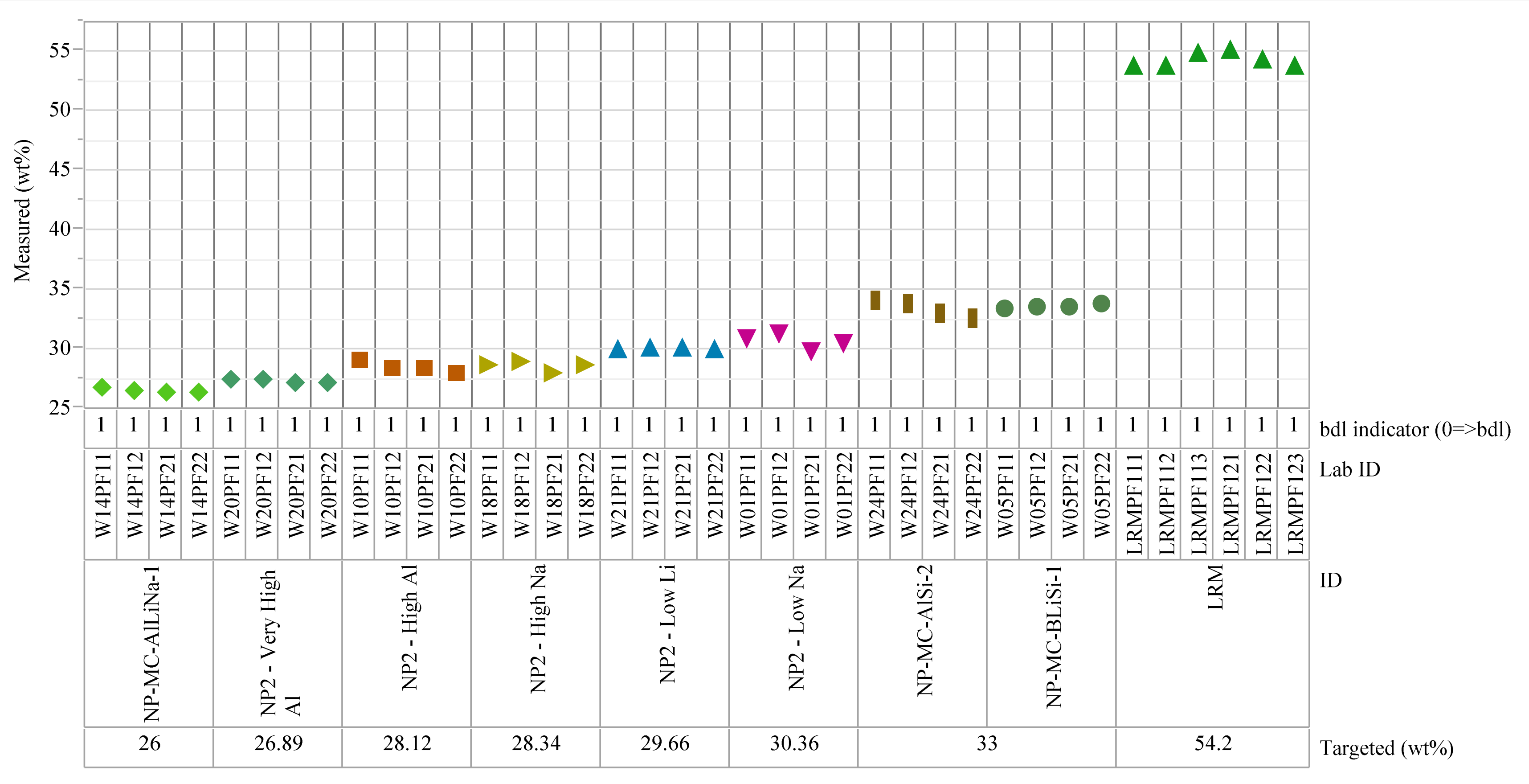


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=2**
**Variability Chart for Measured (wt%)**

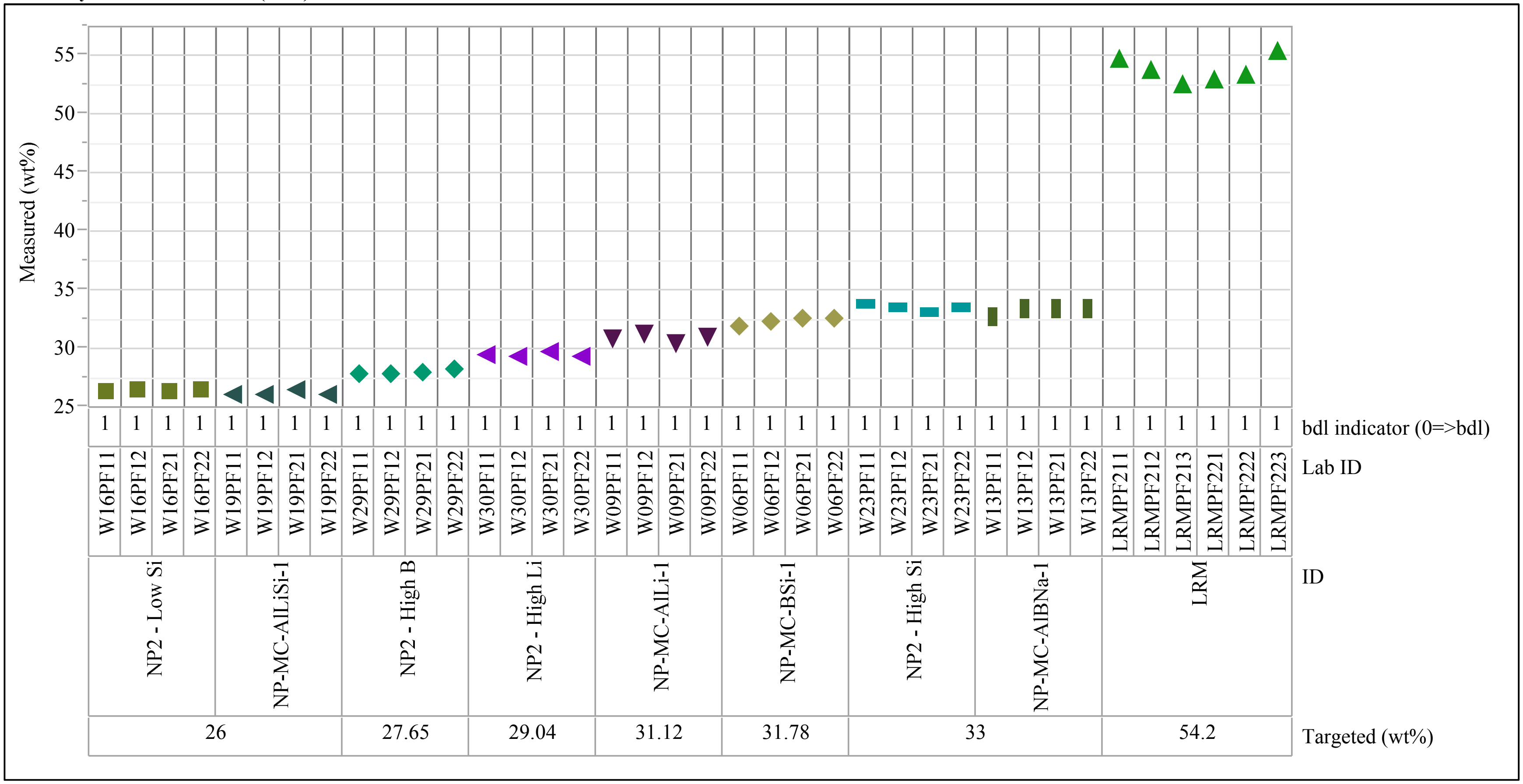


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=3**
**Variability Chart for Measured (wt%)**

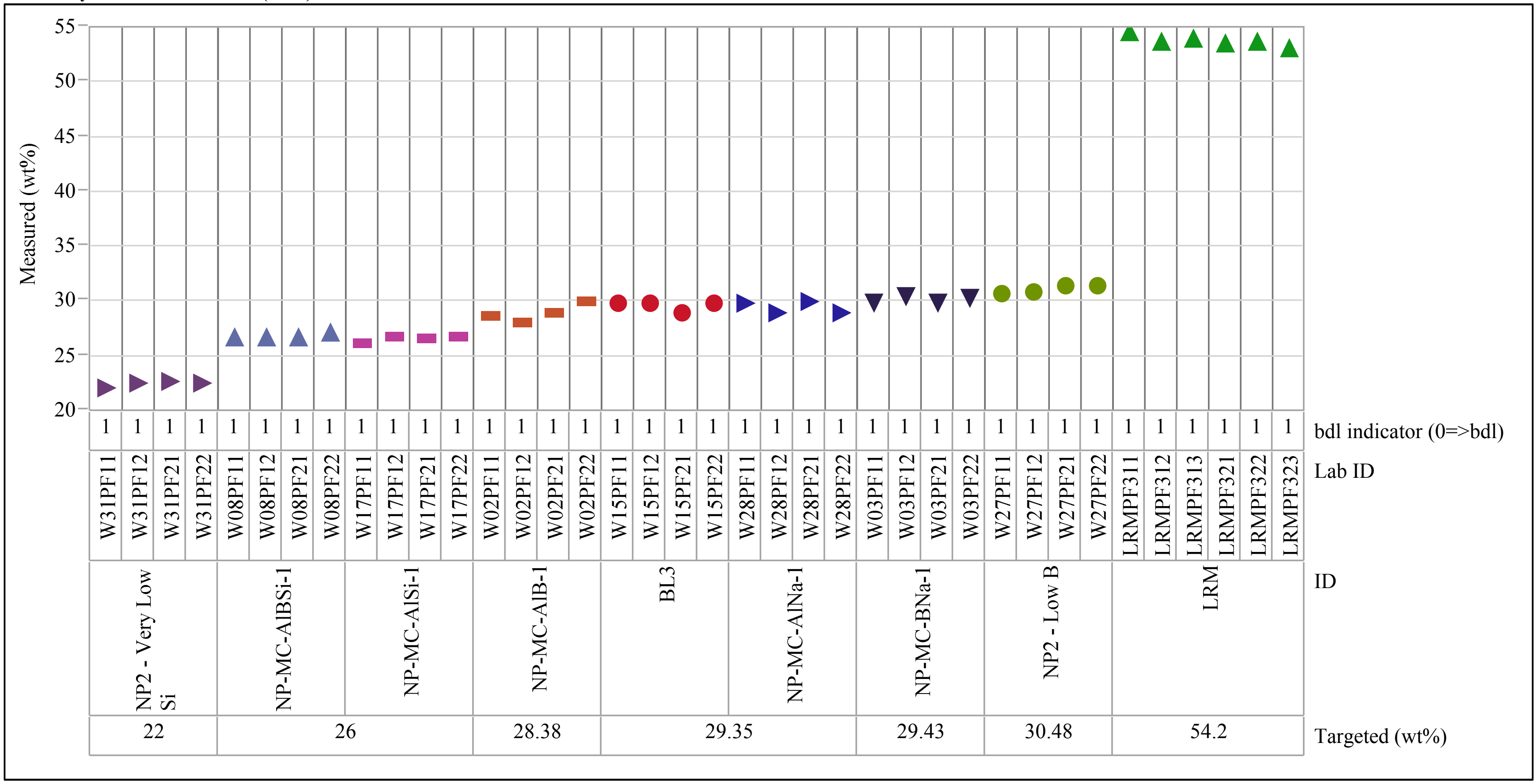


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SiO2 (wt%), Prep Method=PF, Block=4**
**Variability Chart for Measured (wt%)**

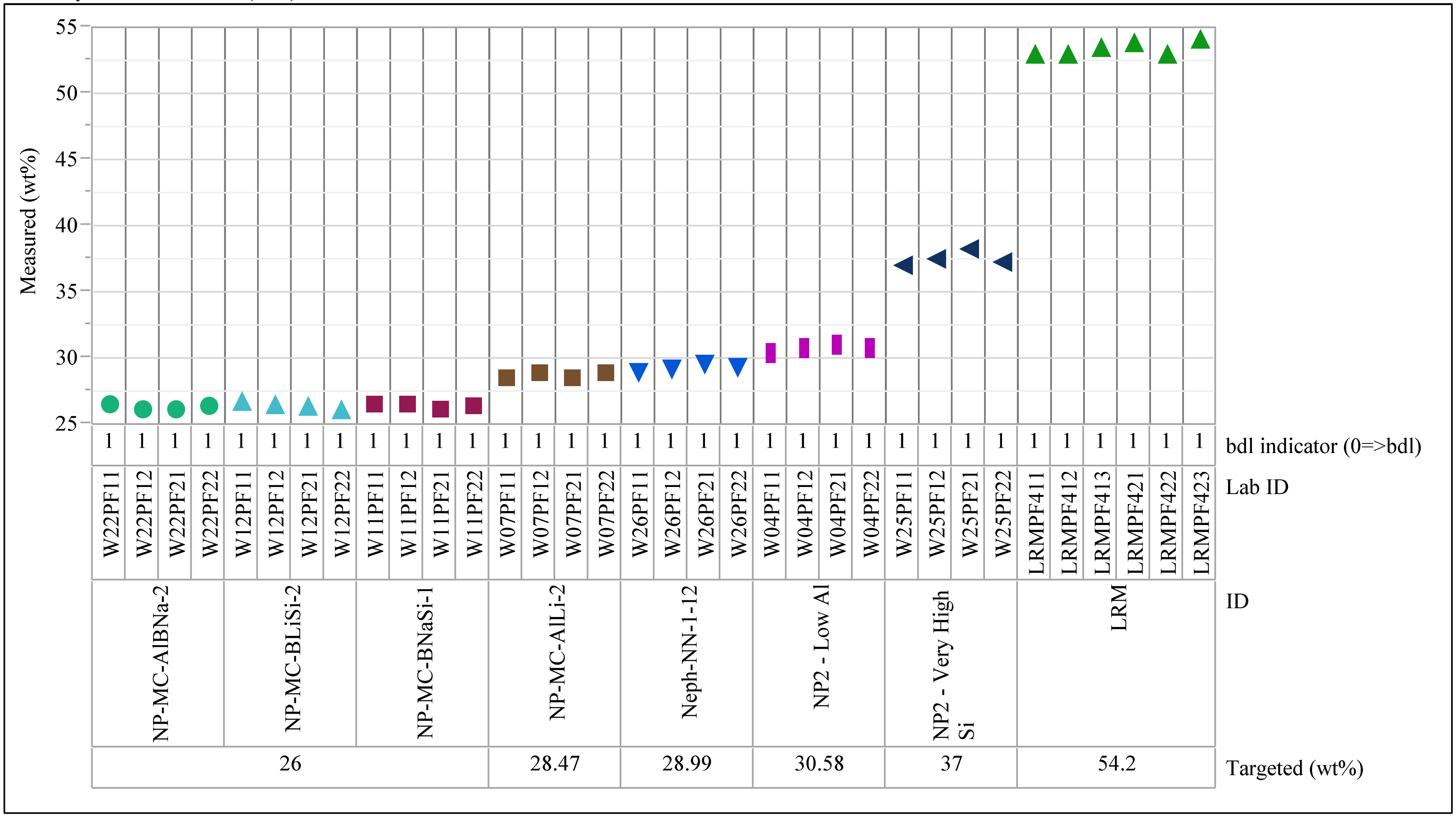


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

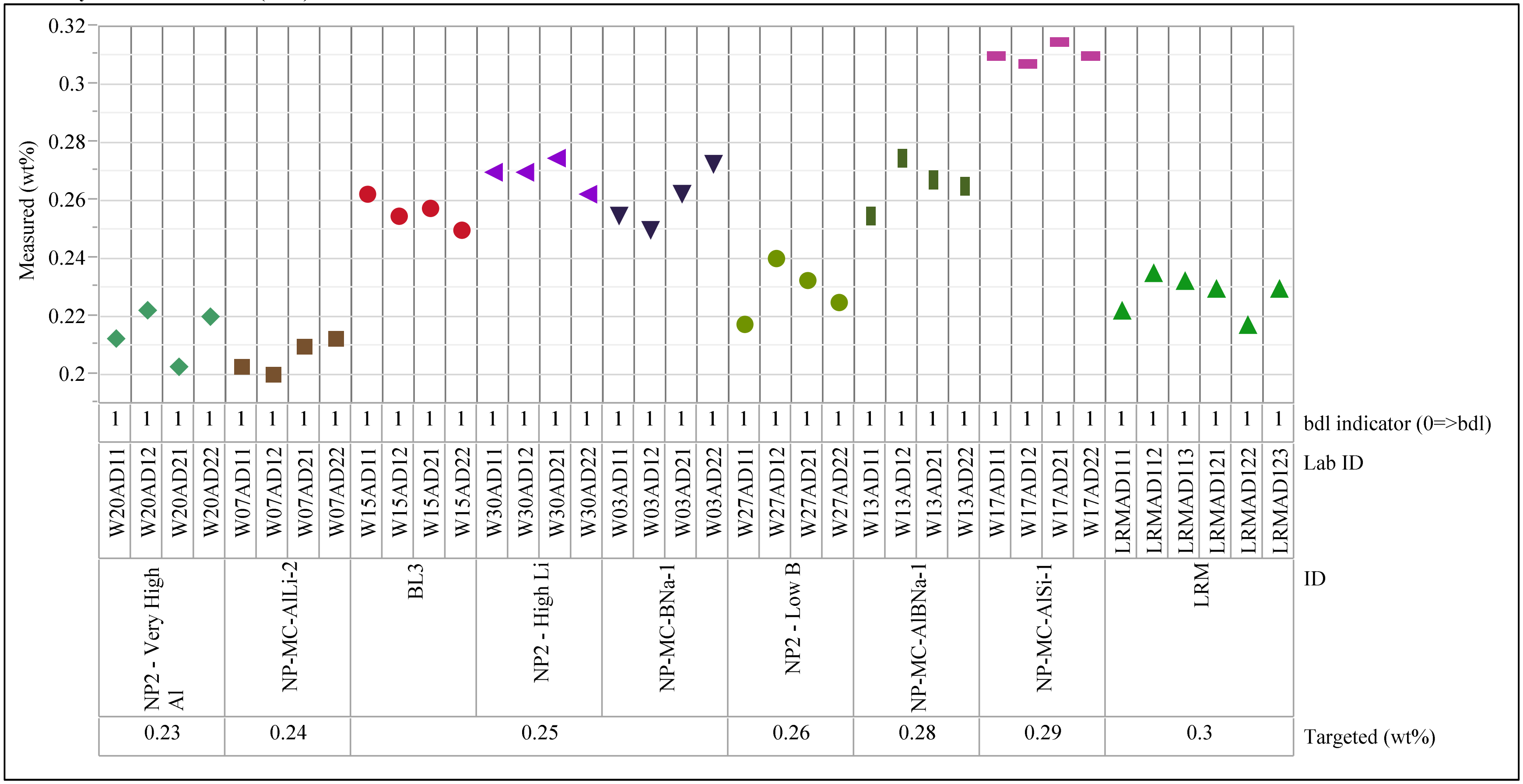


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

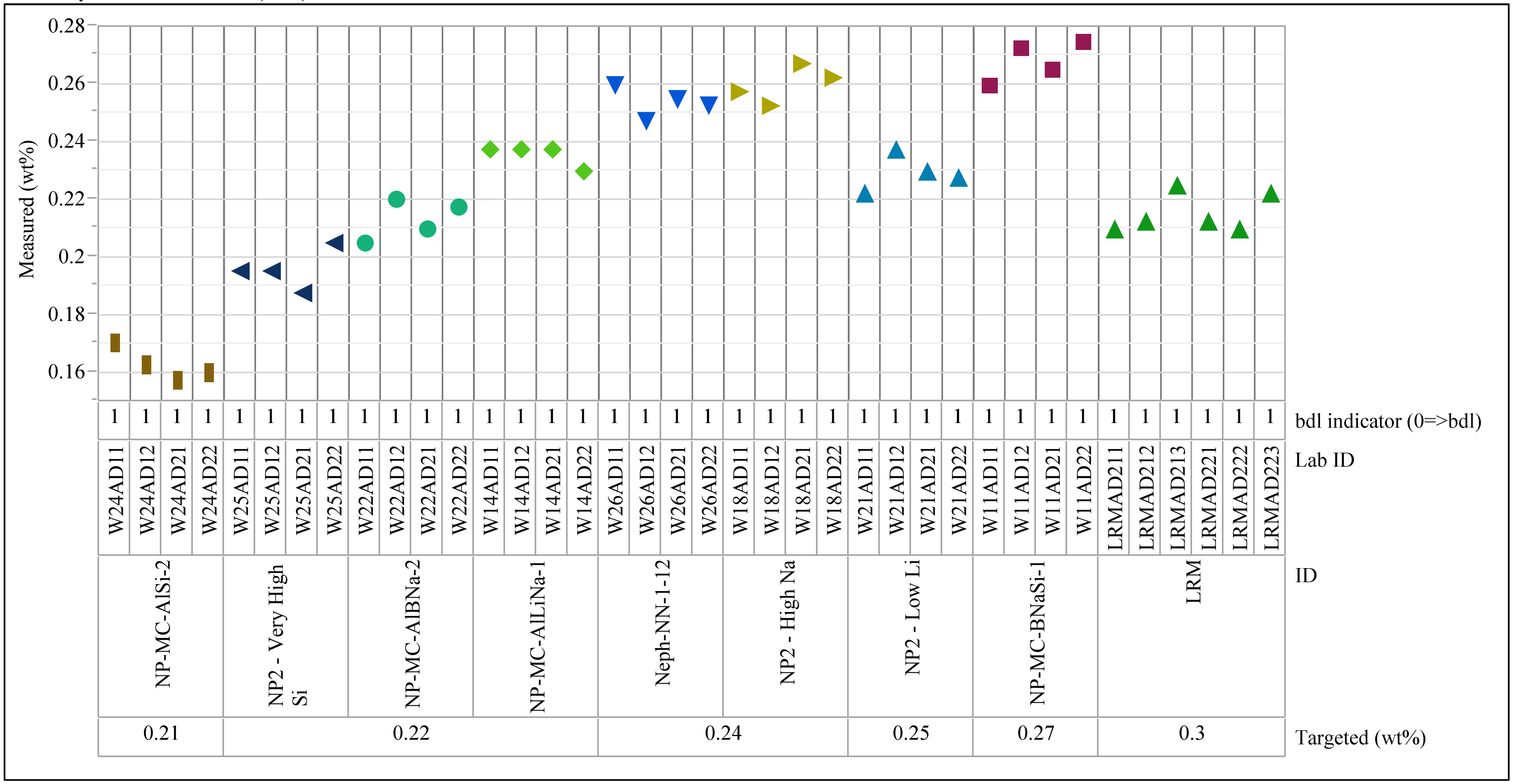


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

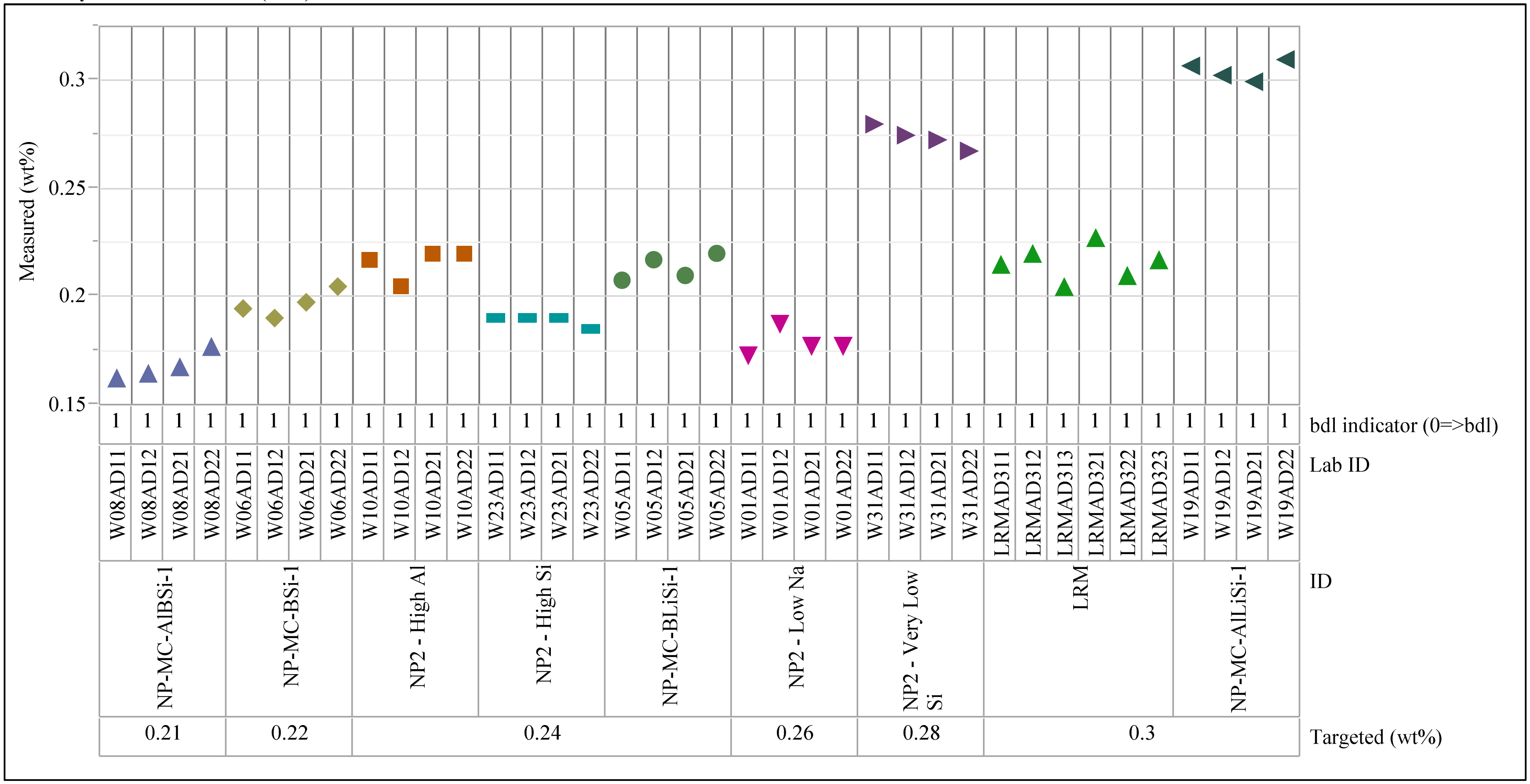


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=SO3 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

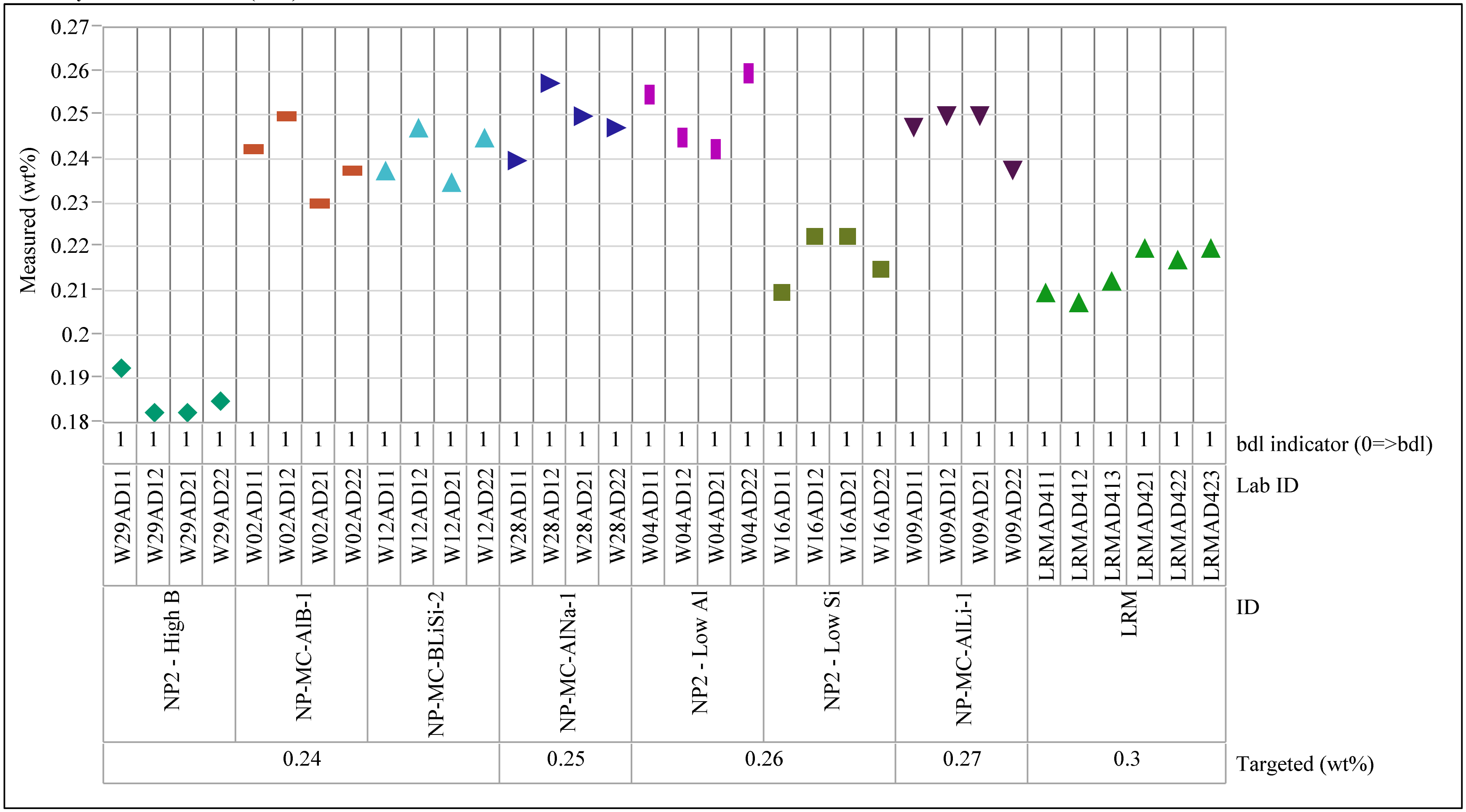


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=1**
**Variability Chart for Measured (wt%)**

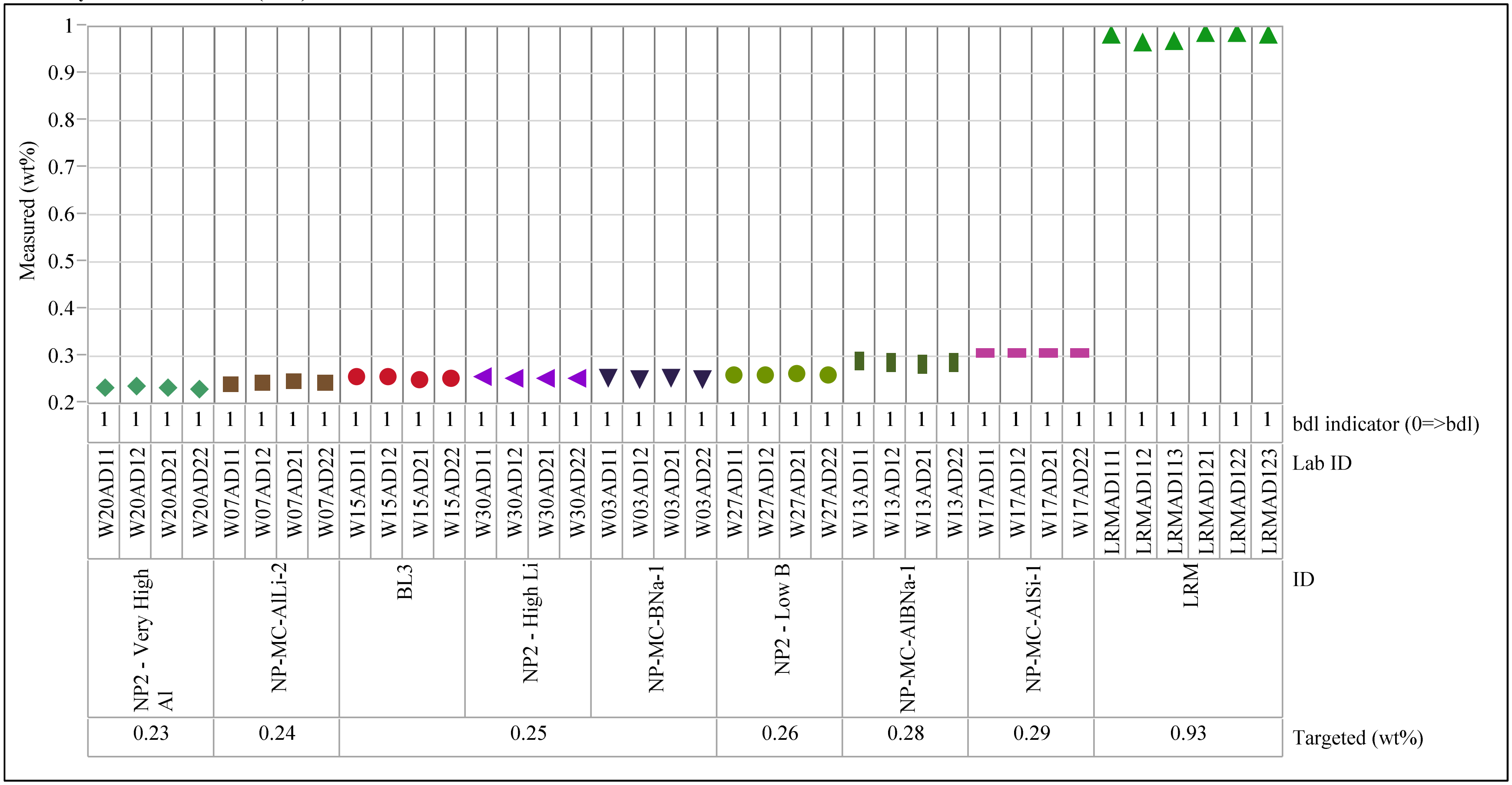


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=2**
**Variability Chart for Measured (wt%)**

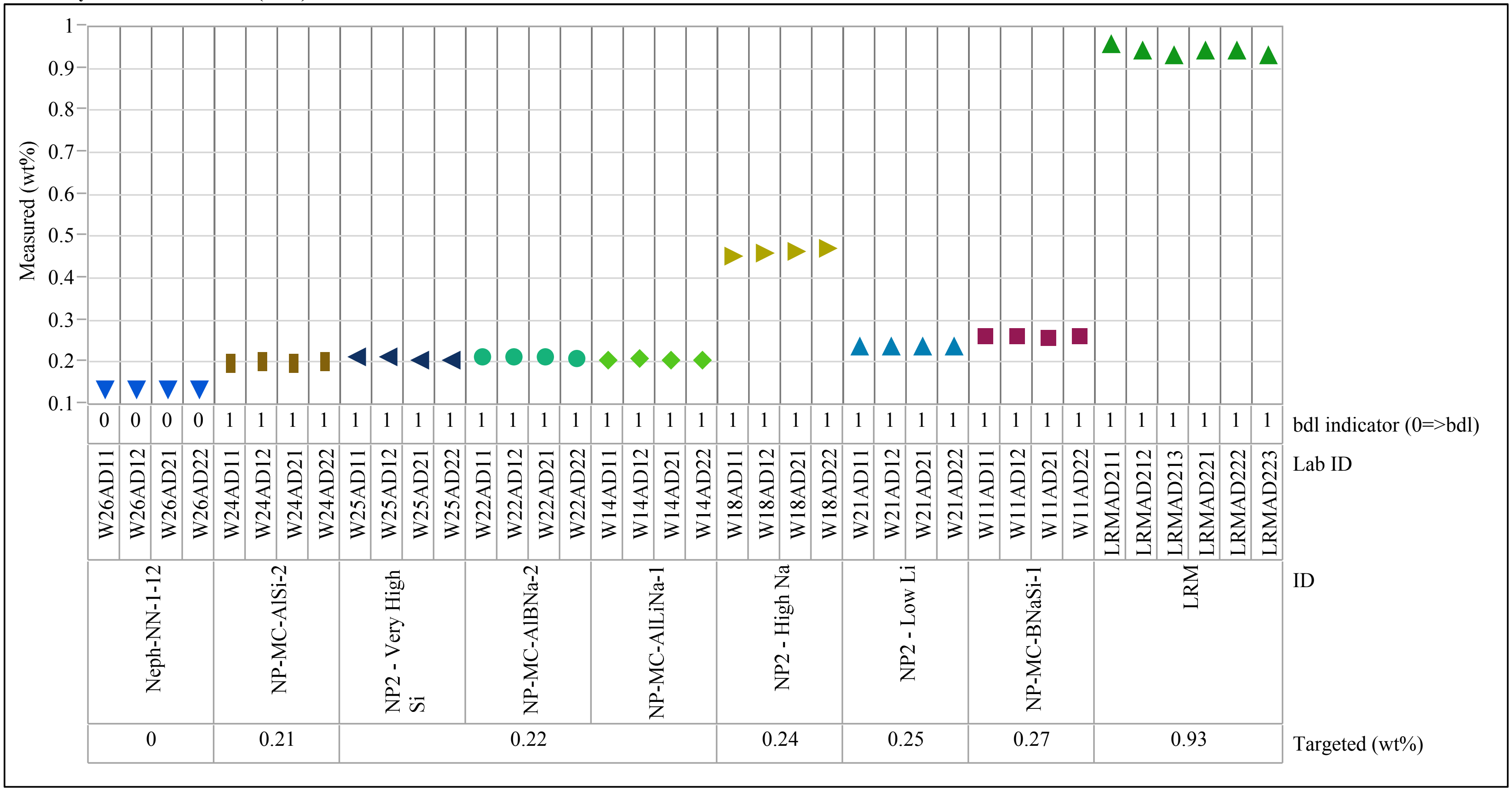


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=3**
**Variability Chart for Measured (wt%)**

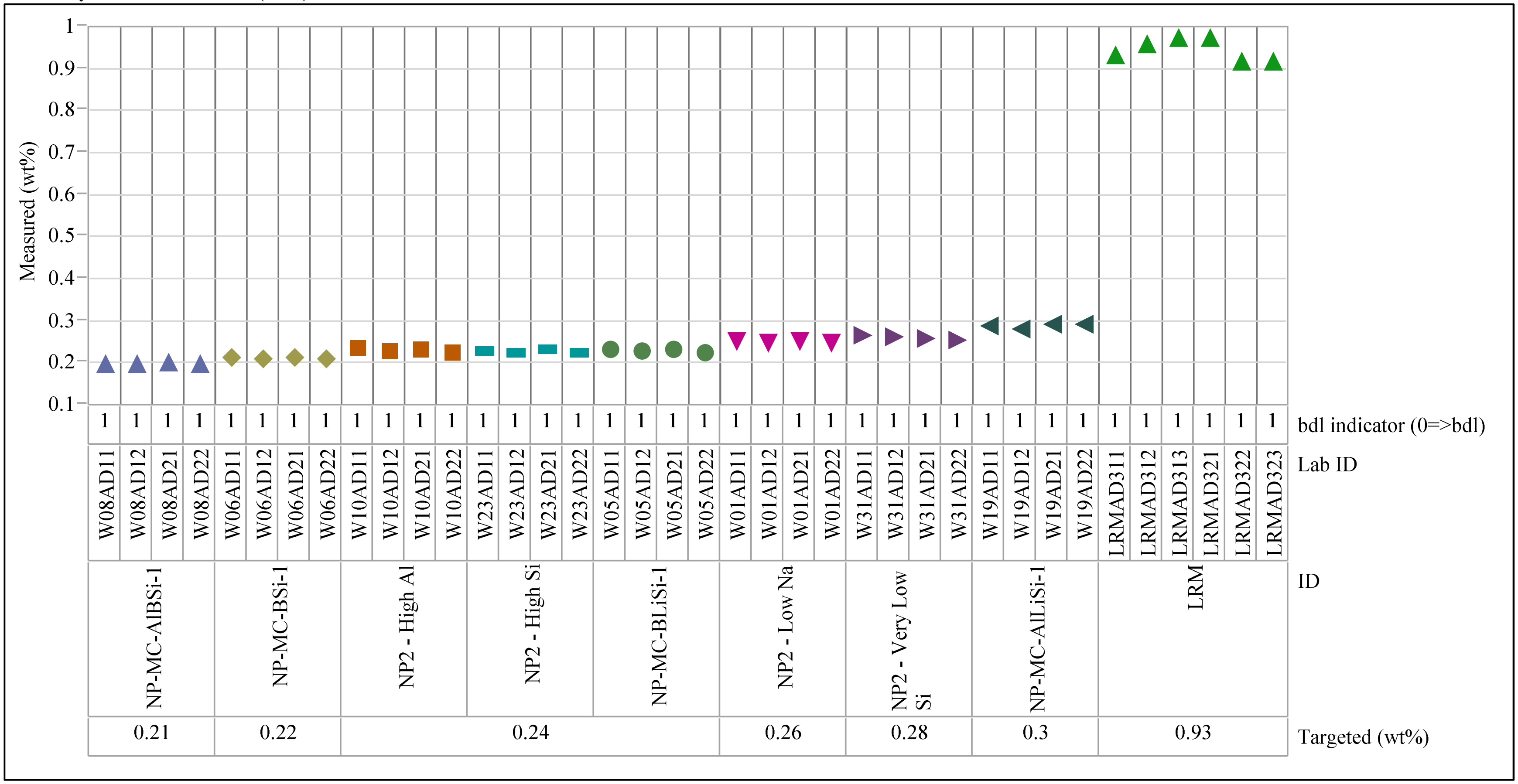


**Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Targeted Concentrations (continued)**

**Oxide=ZrO2 (wt%), Prep Method=AD, Block=4**
**Variability Chart for Measured (wt%)**

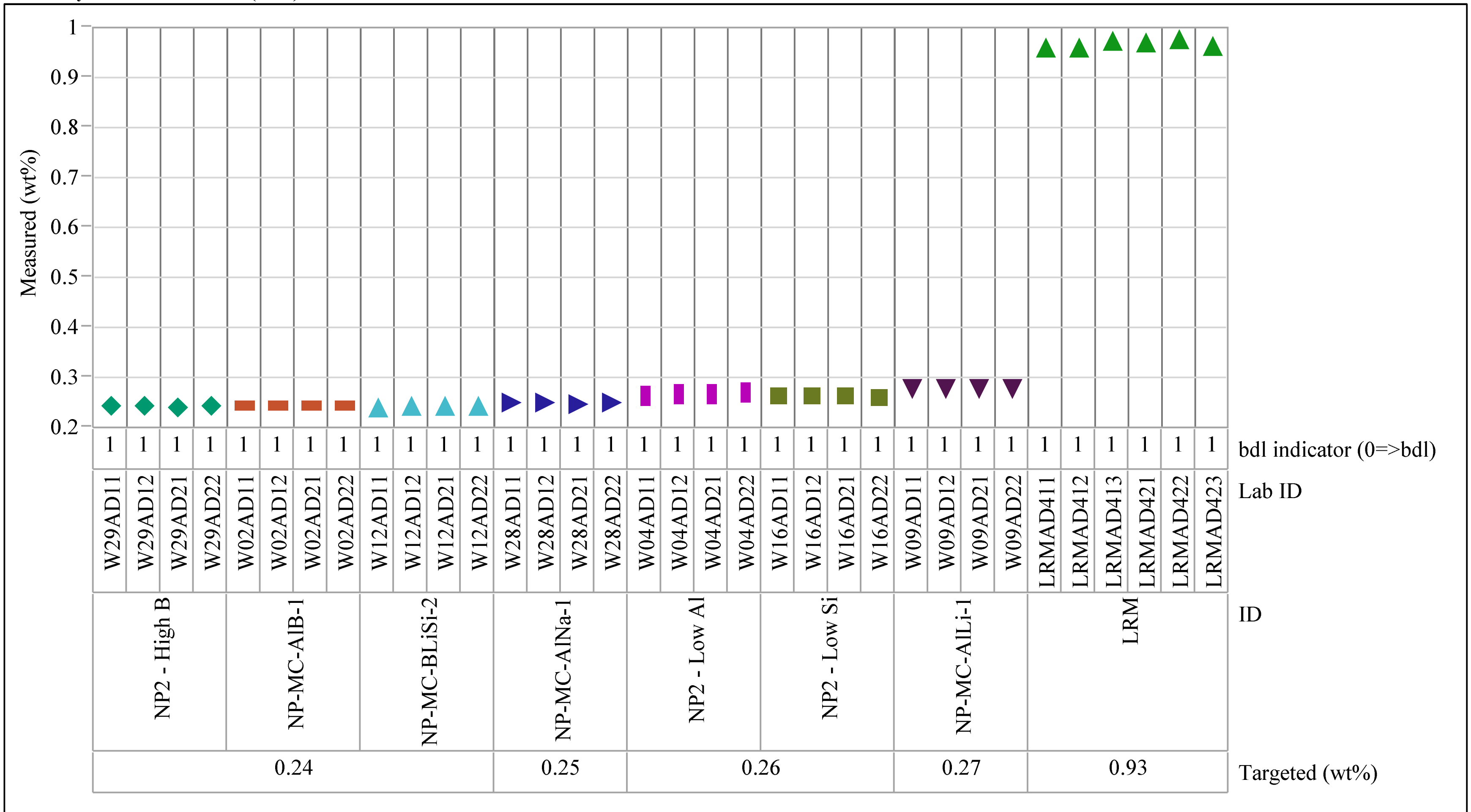


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass**

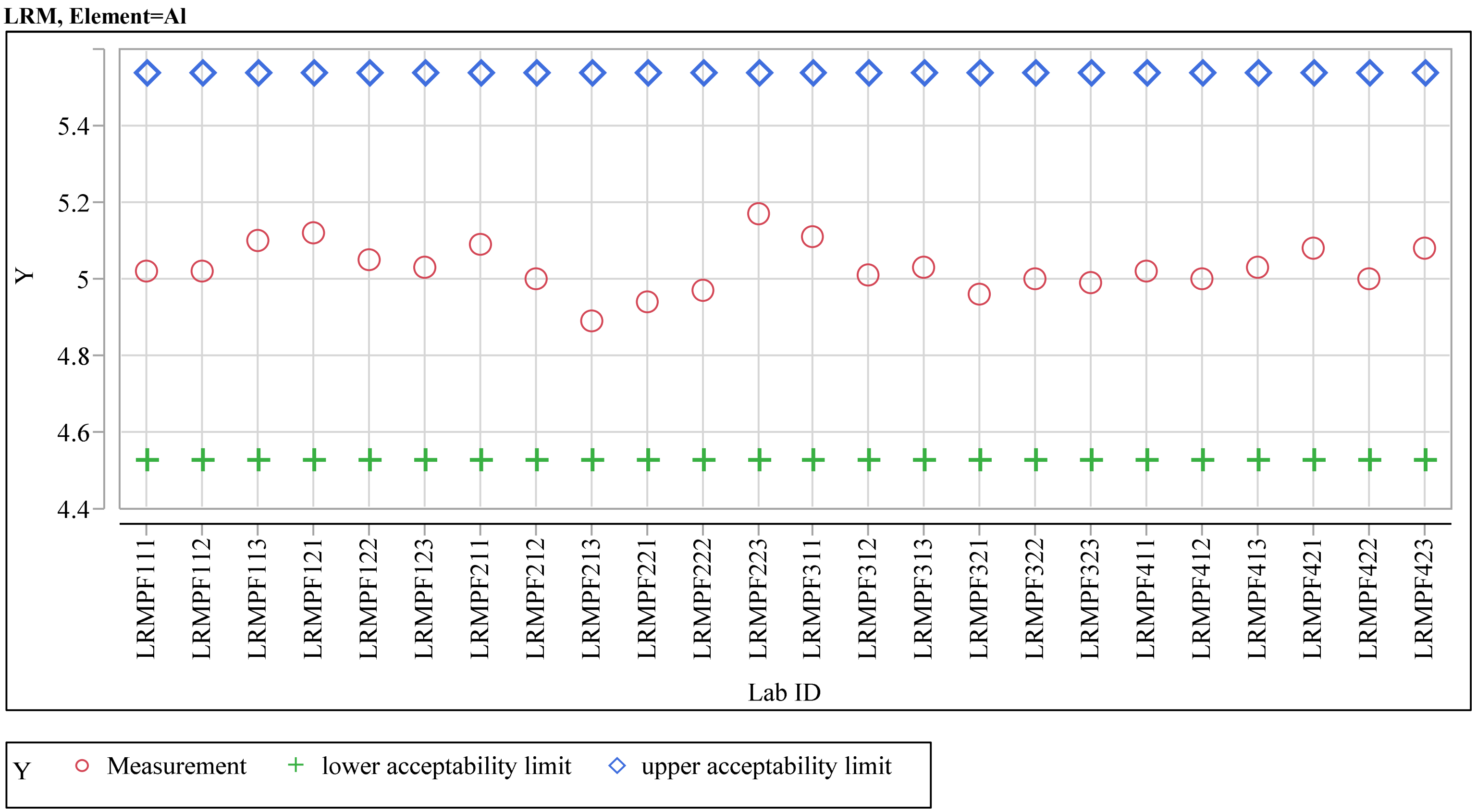


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

**LRM, Element=B**

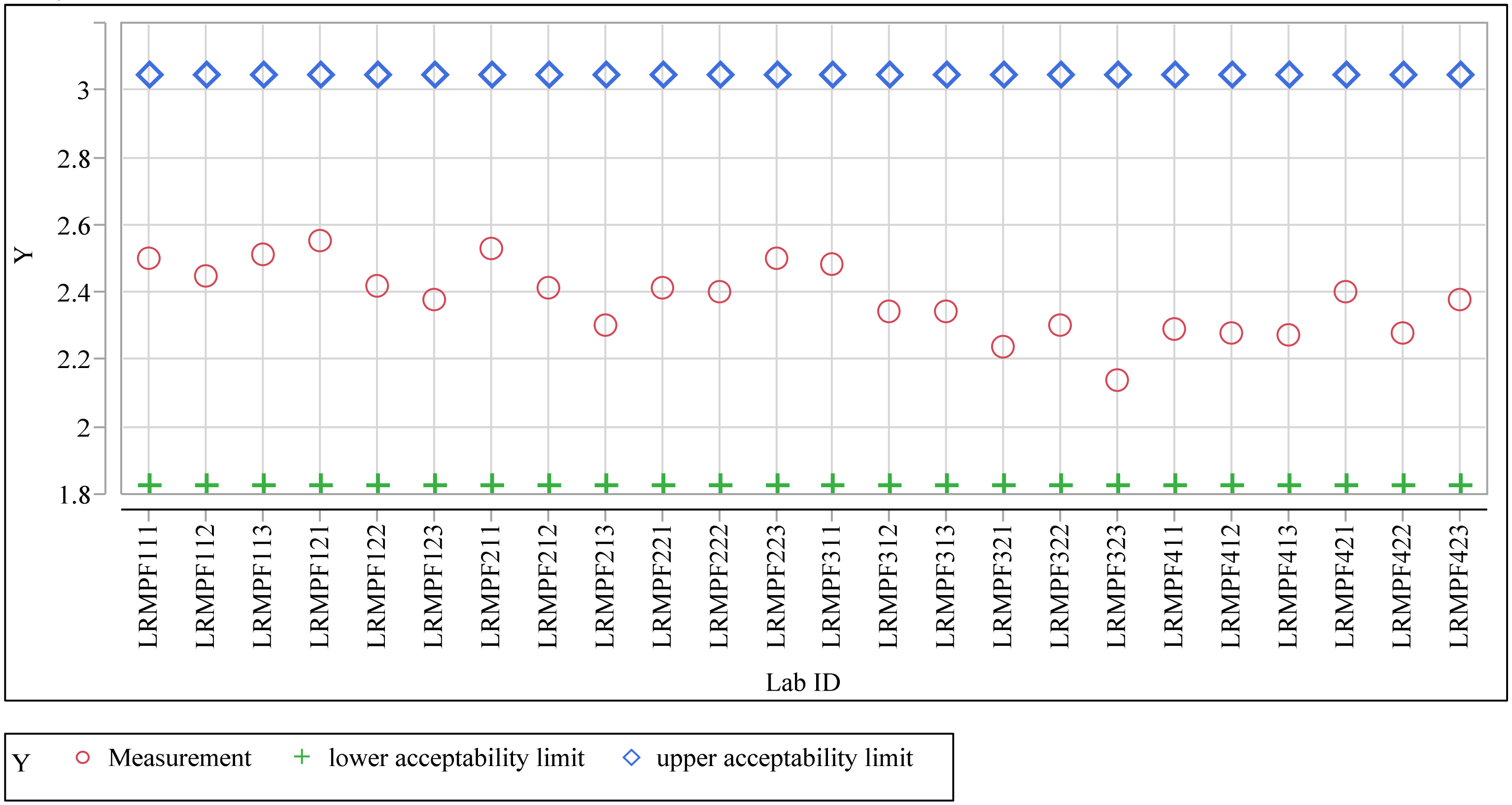


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

**LRM, Element=Fe**

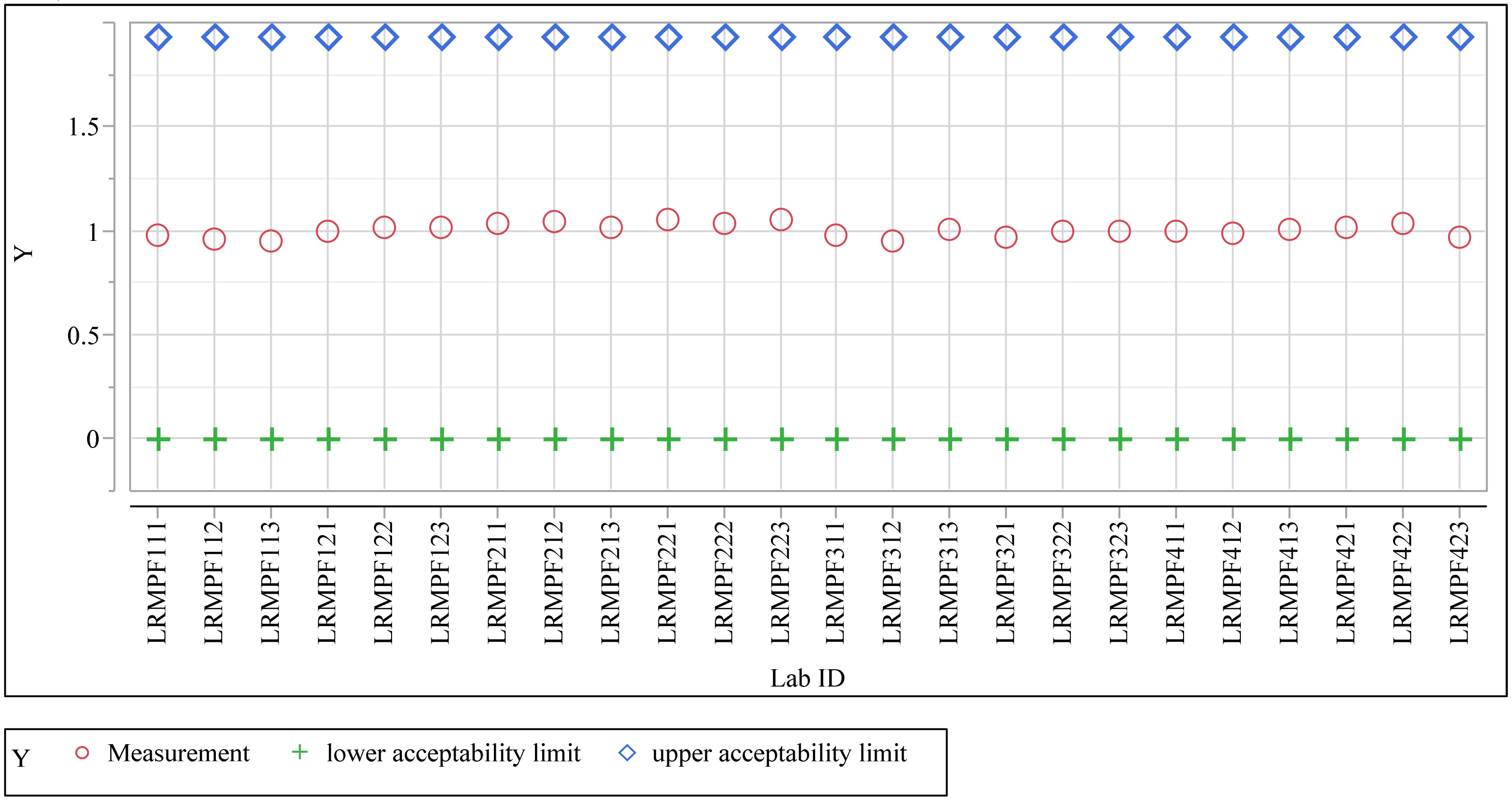


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

**LRM, Element=K**

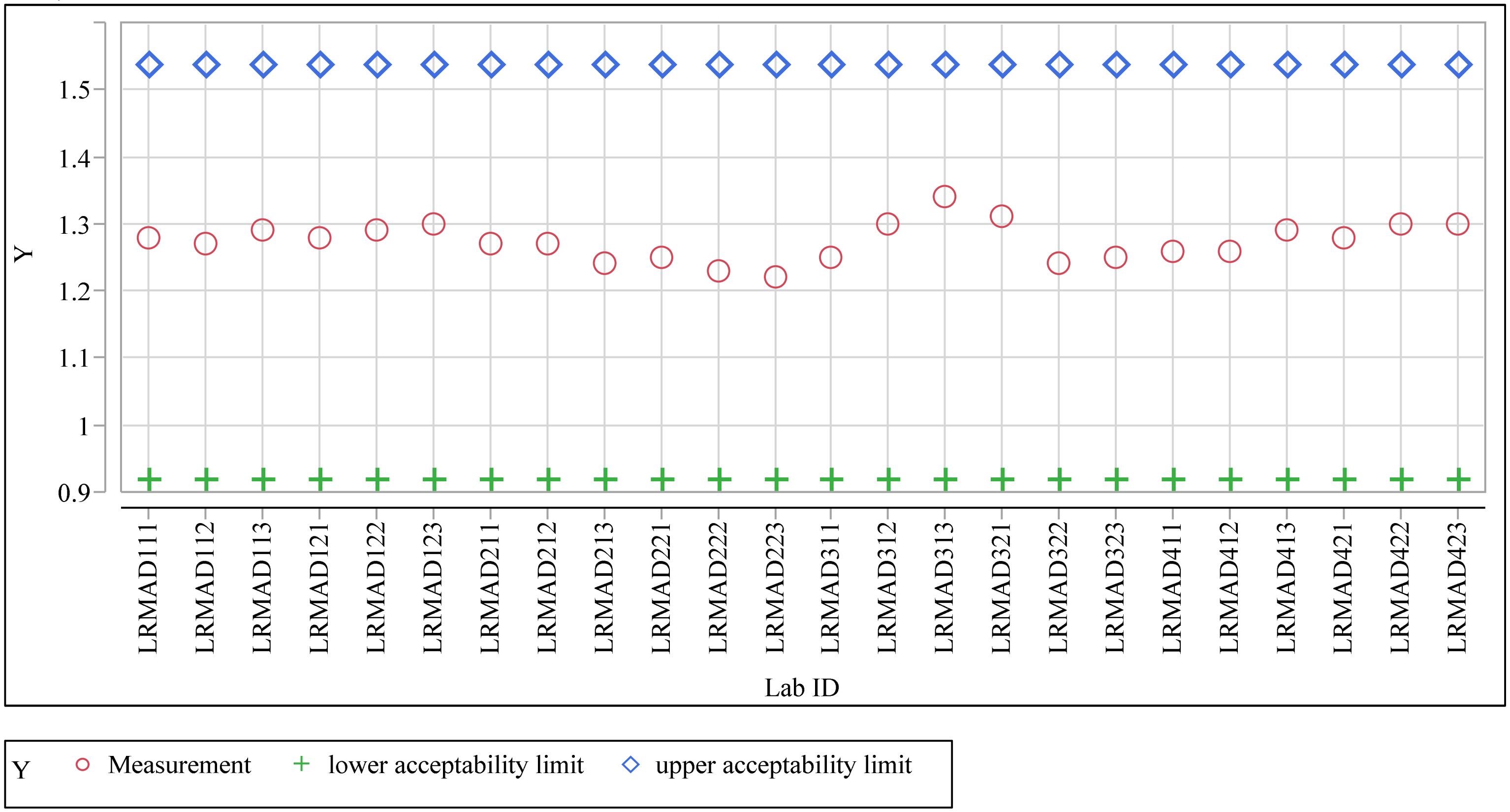


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

**LRM, Element=Na**

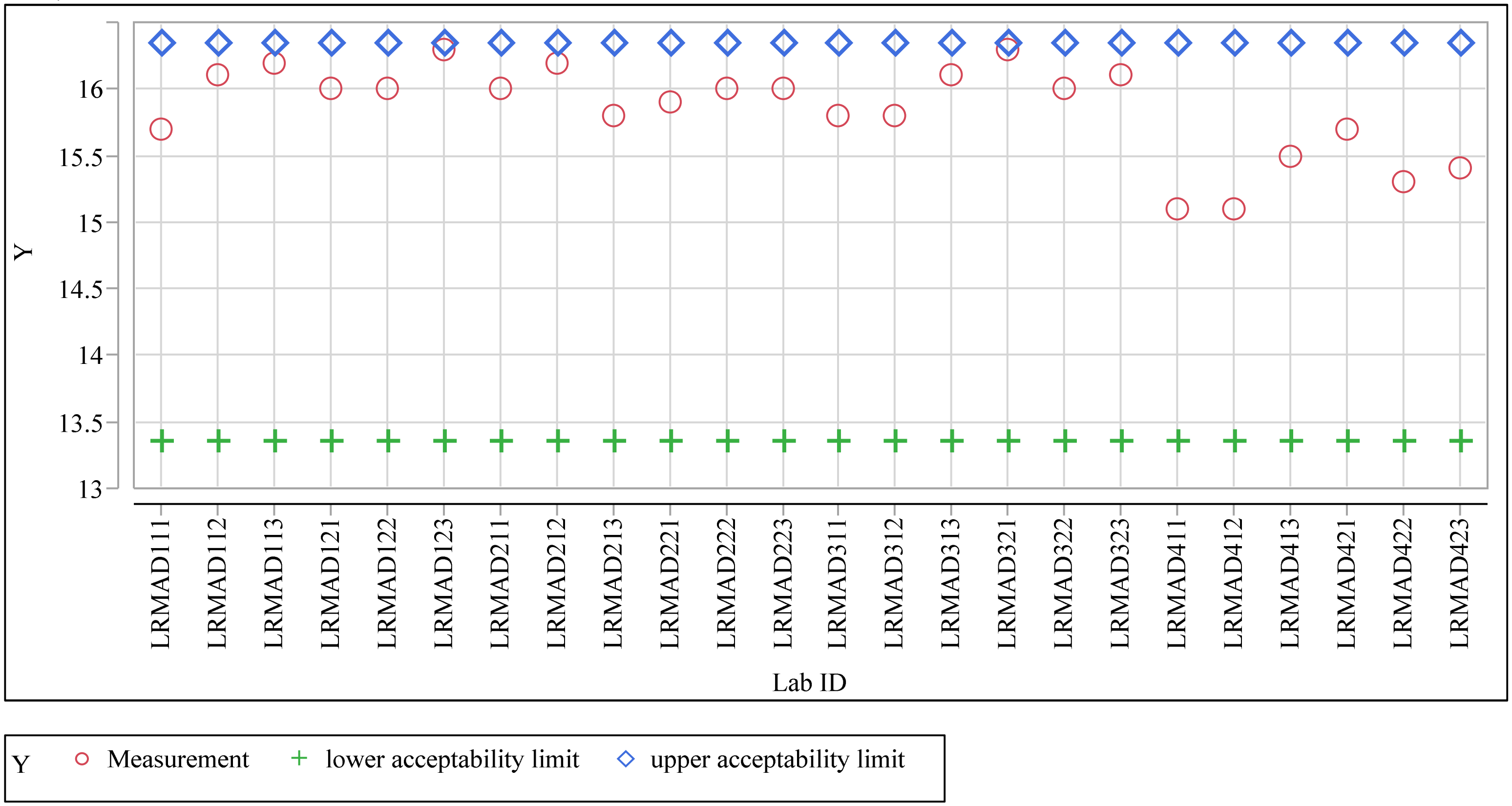


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

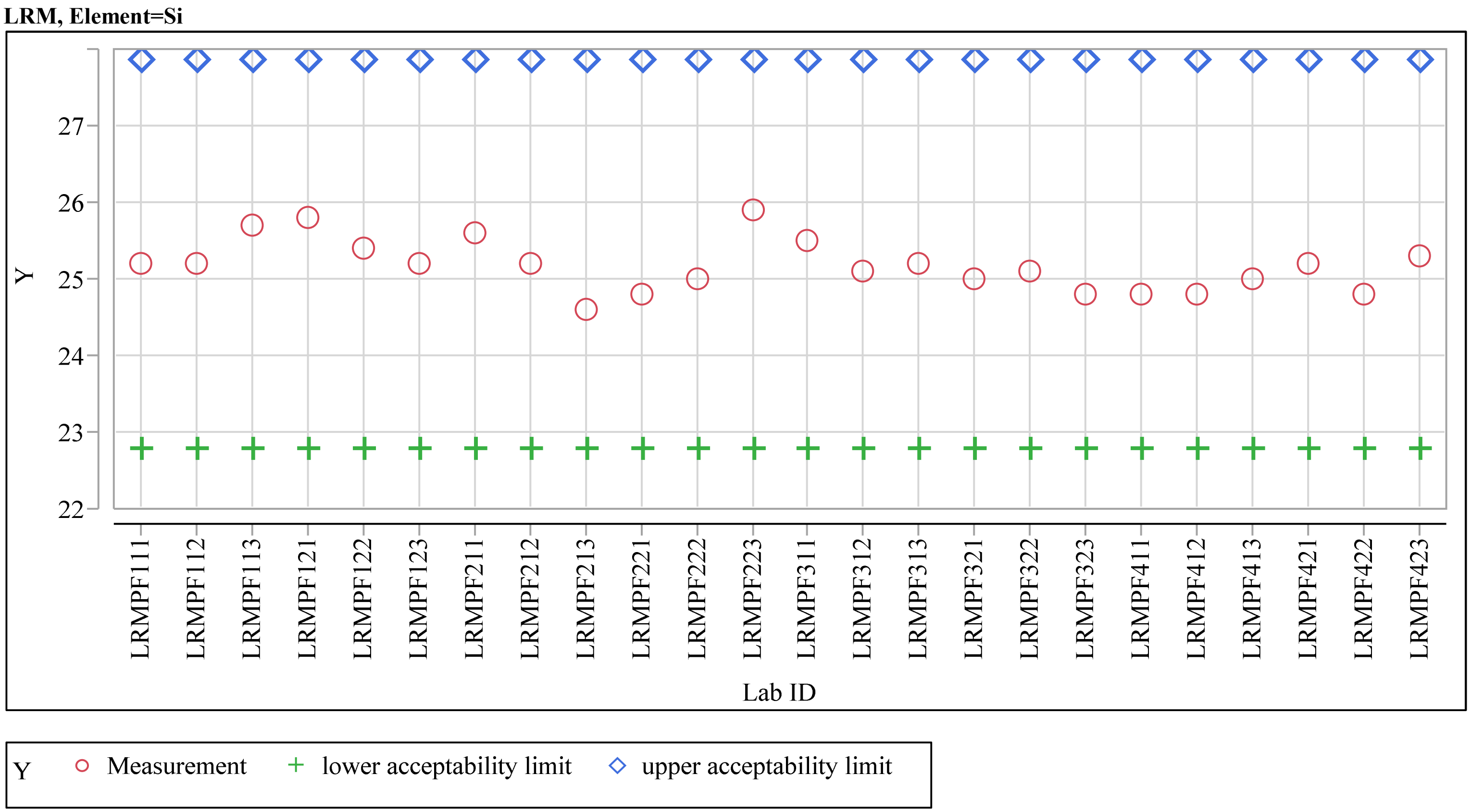


**Exhibit A-3. Acceptability Evaluation for Measurements of the LRM Standard Glass (continued)**

**LRM, Element=Zr**

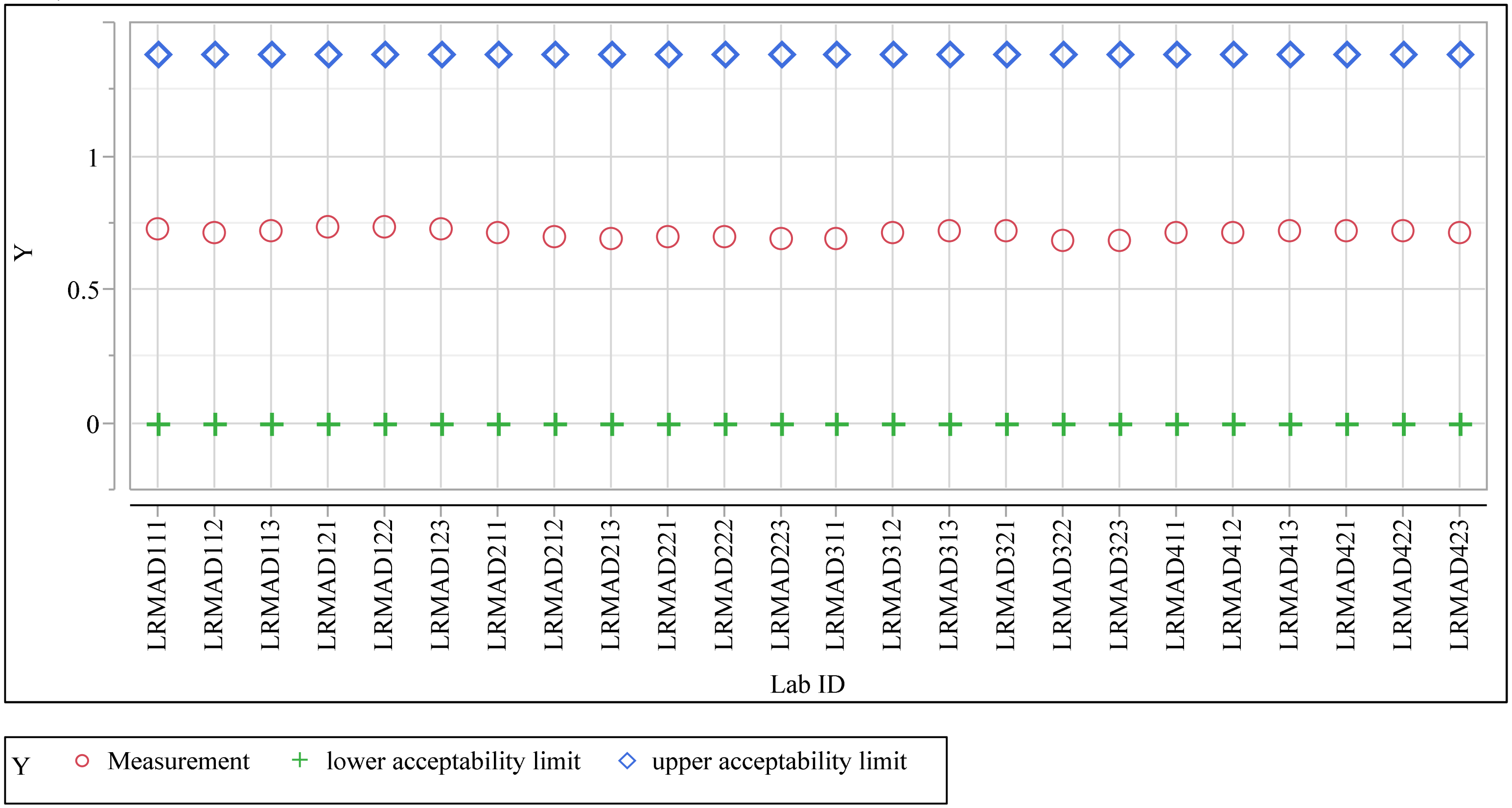


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide**

**Oxide=Al2O3 (wt%)**

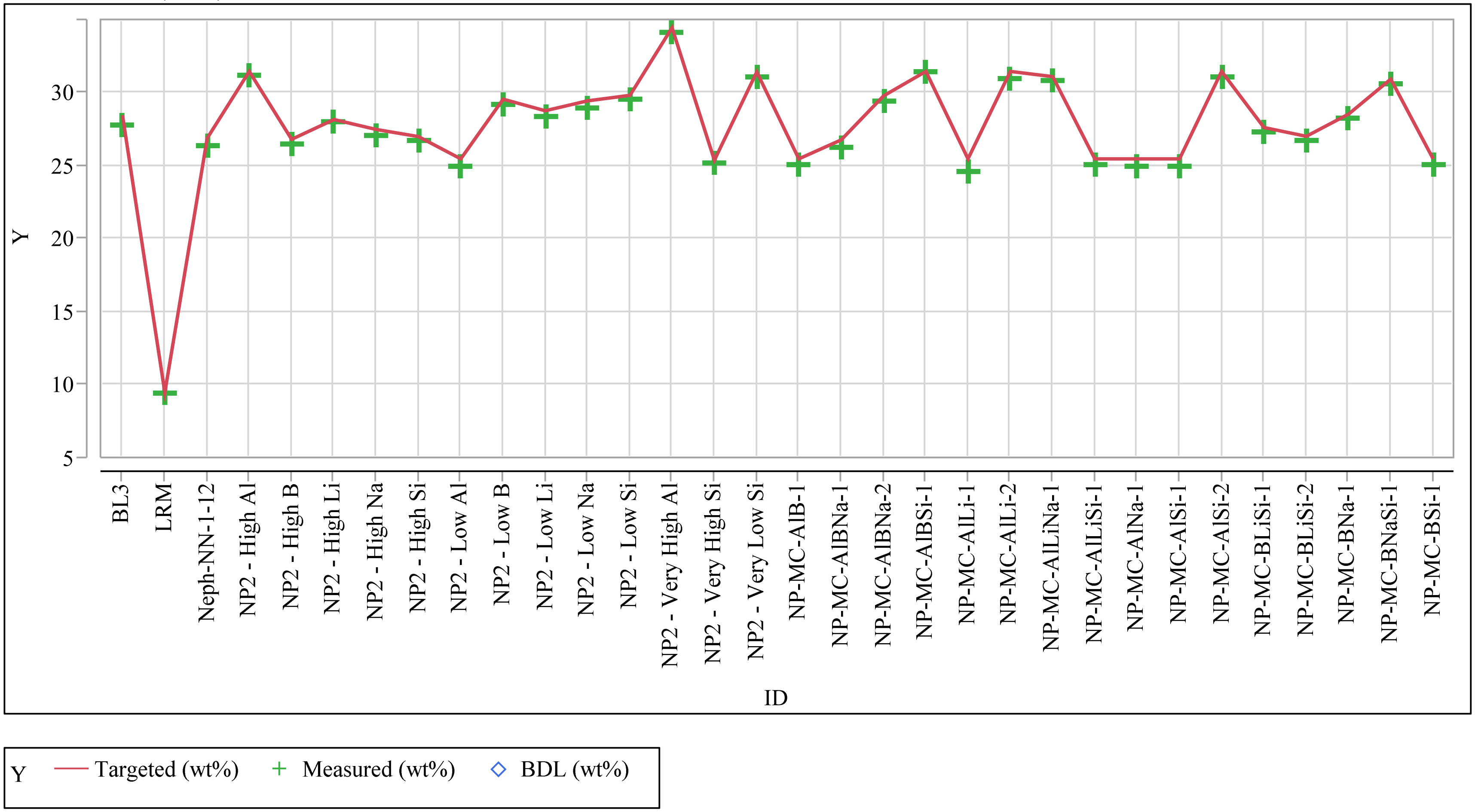


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=B2O3 (wt%)**

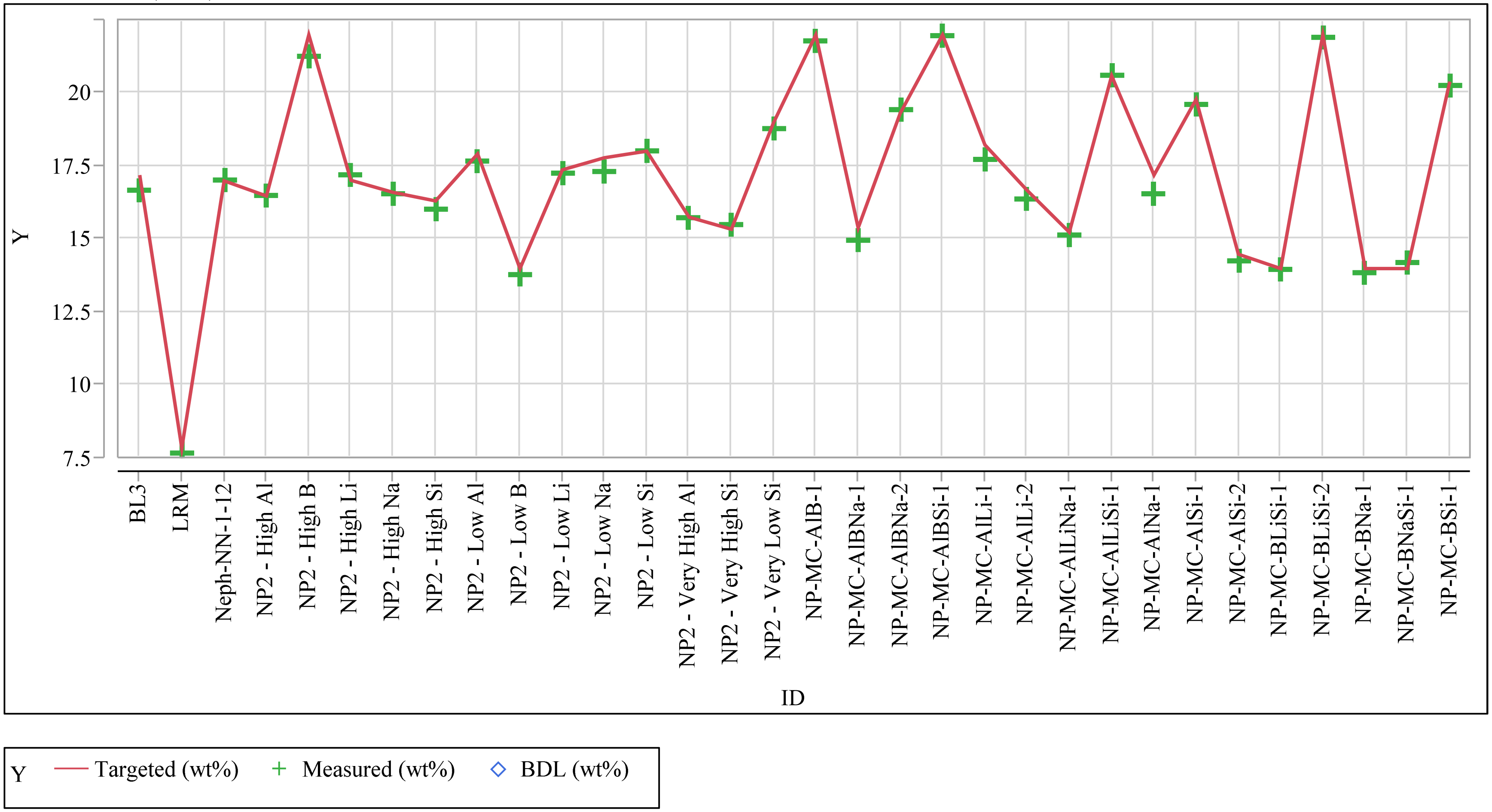


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Bi2O3 (wt%)**

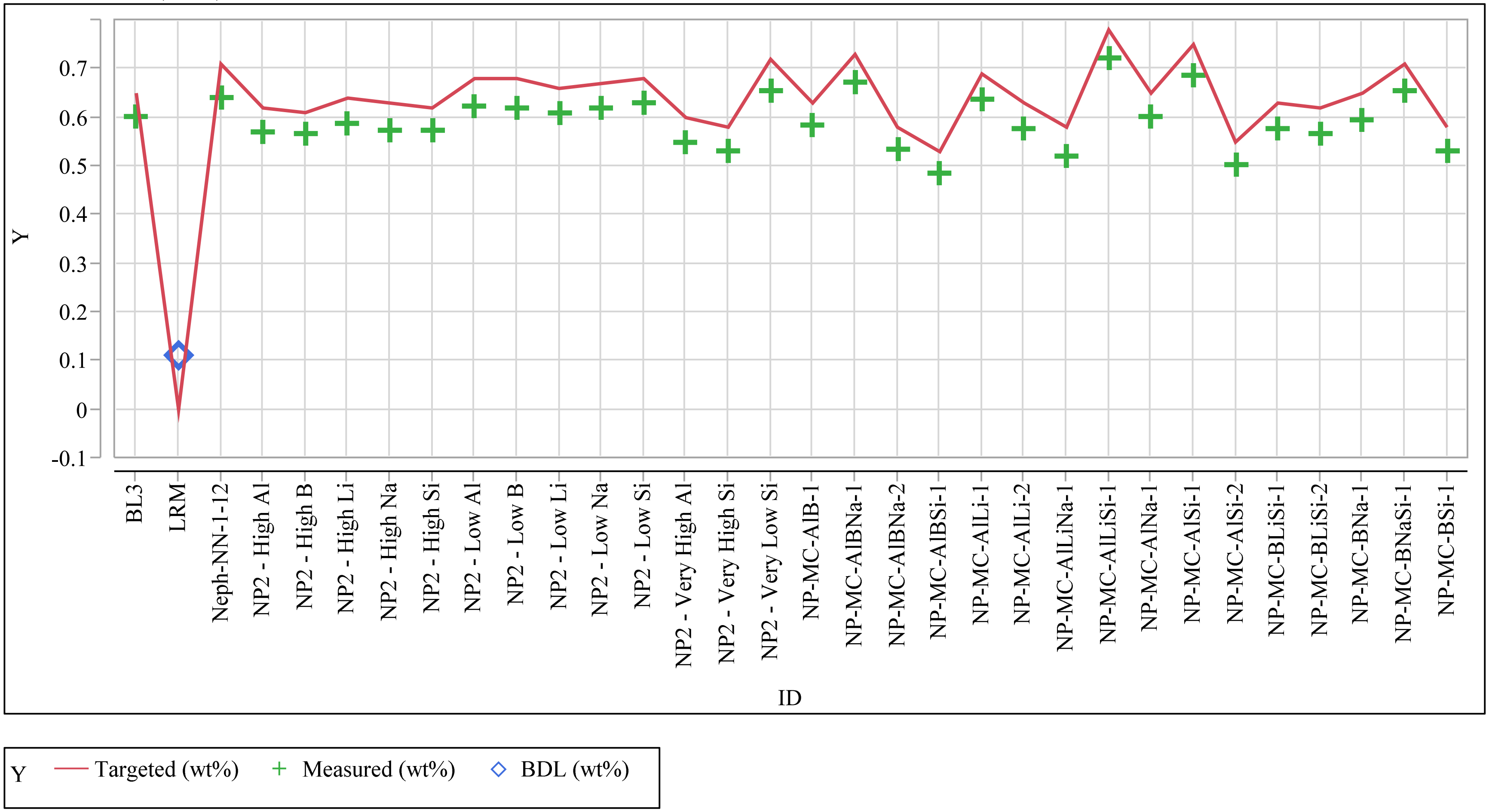


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=CaO (wt%)**

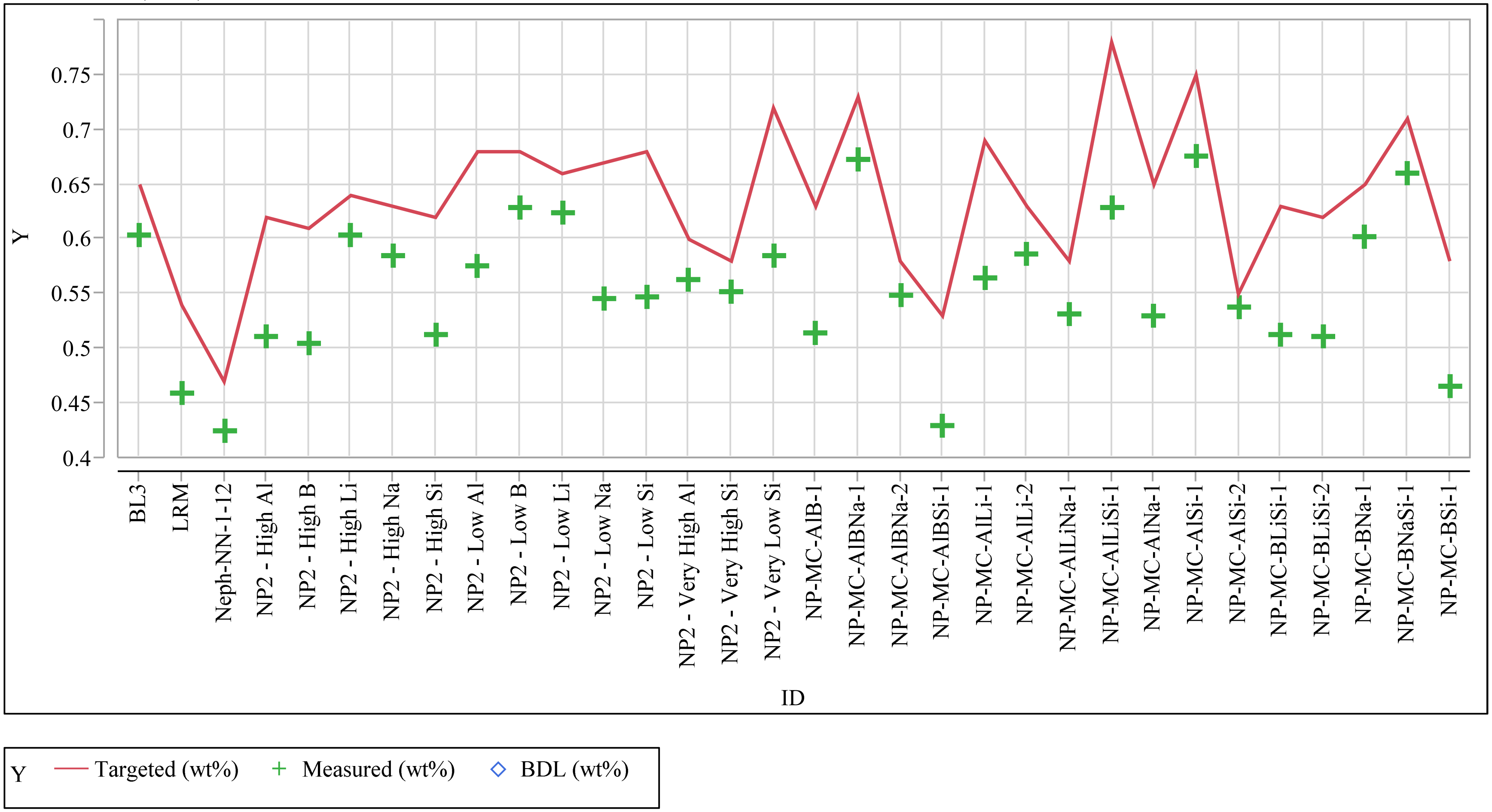


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Cr2O3 (wt%)**

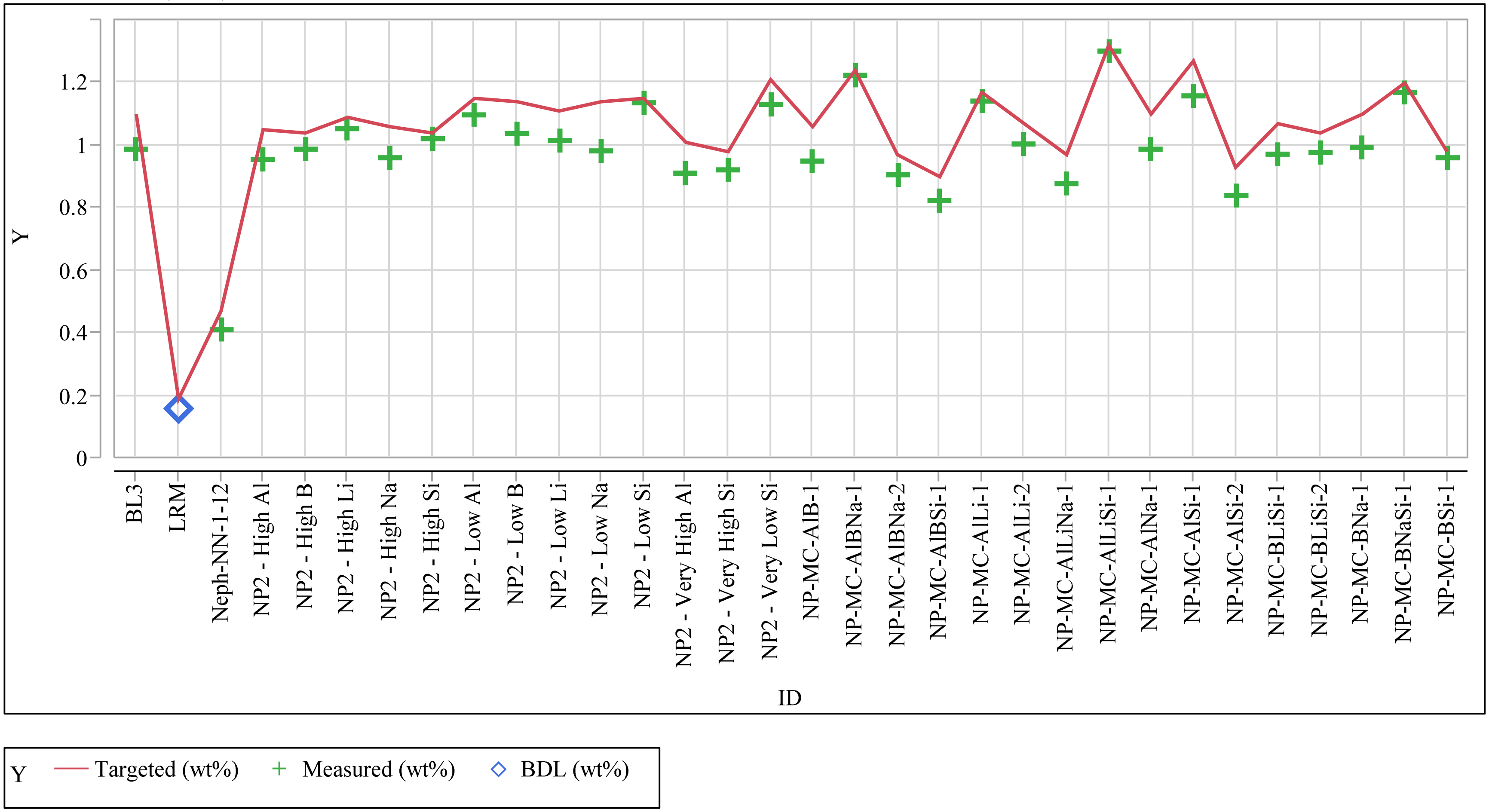


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Fe2O3 (wt%)**

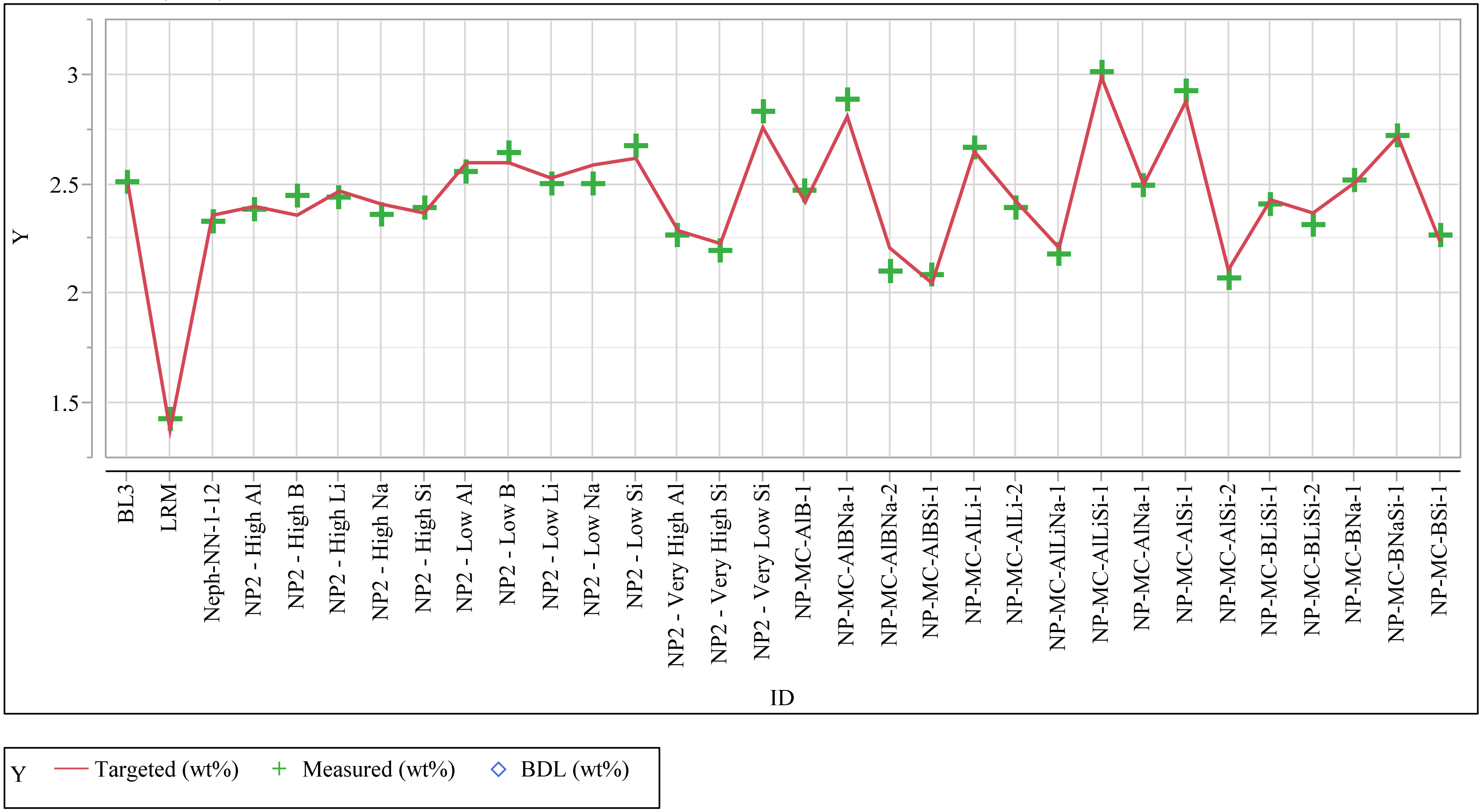


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Li2O (wt%)**

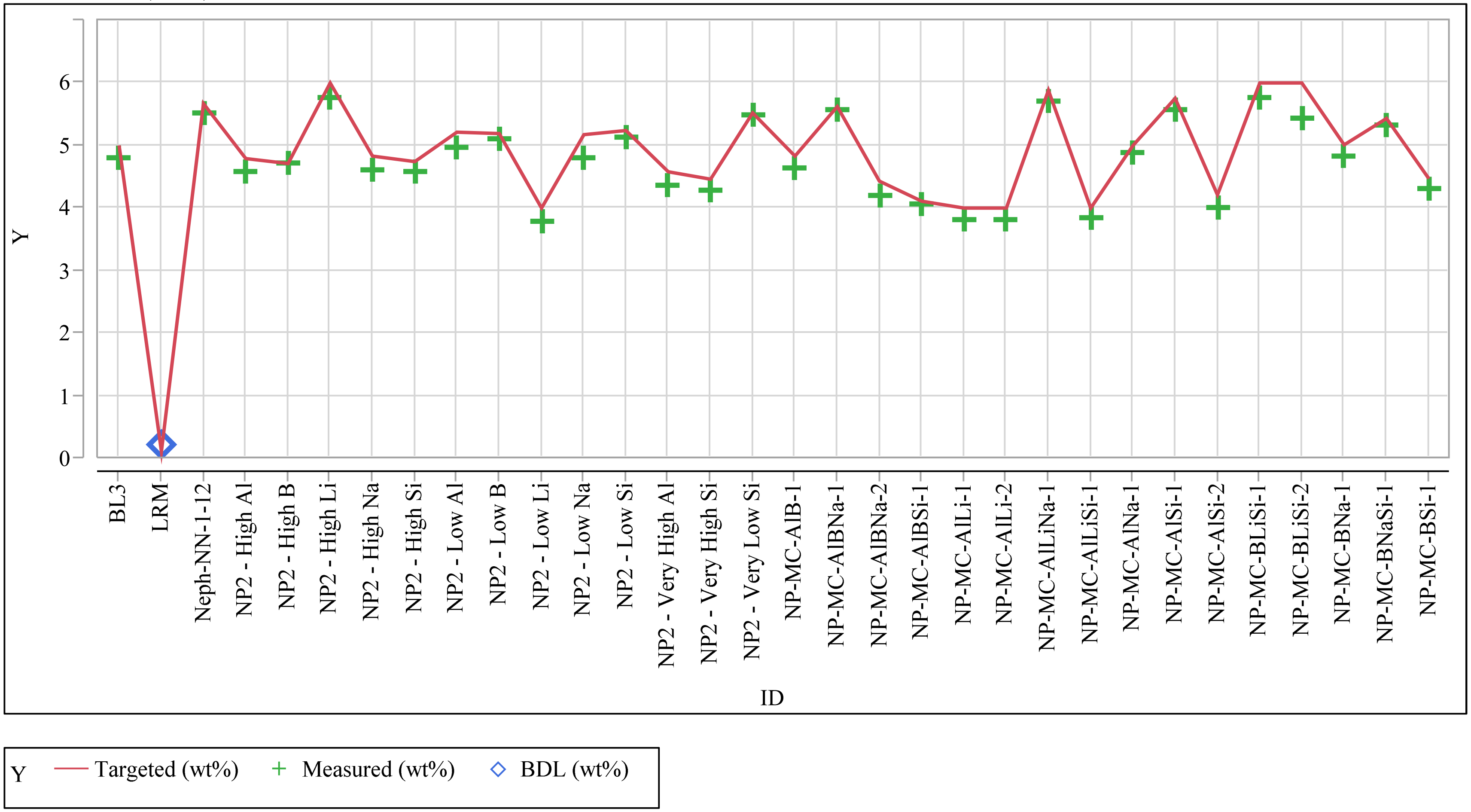


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=MnO (wt%)**

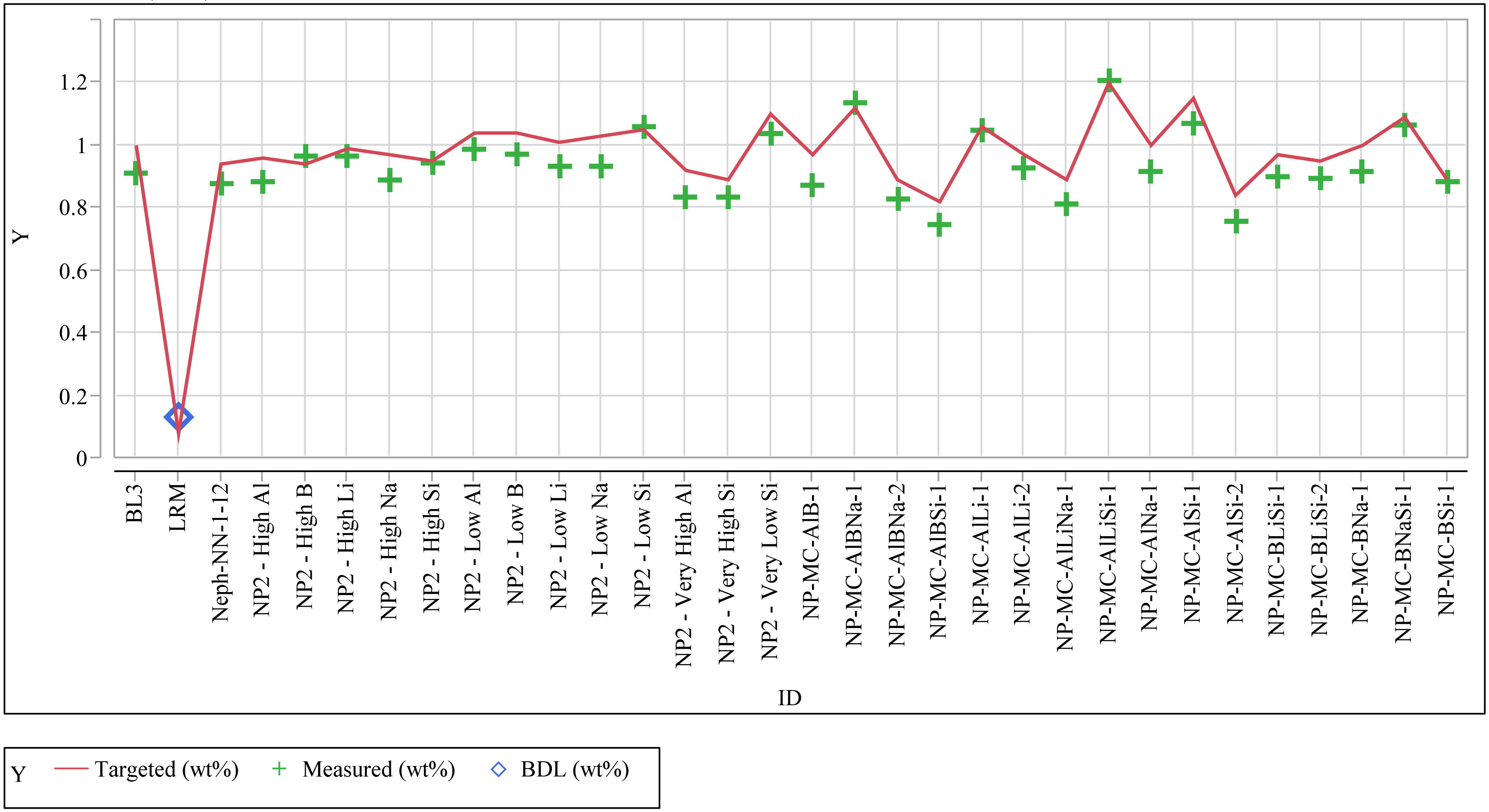


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Na2O (wt%)**

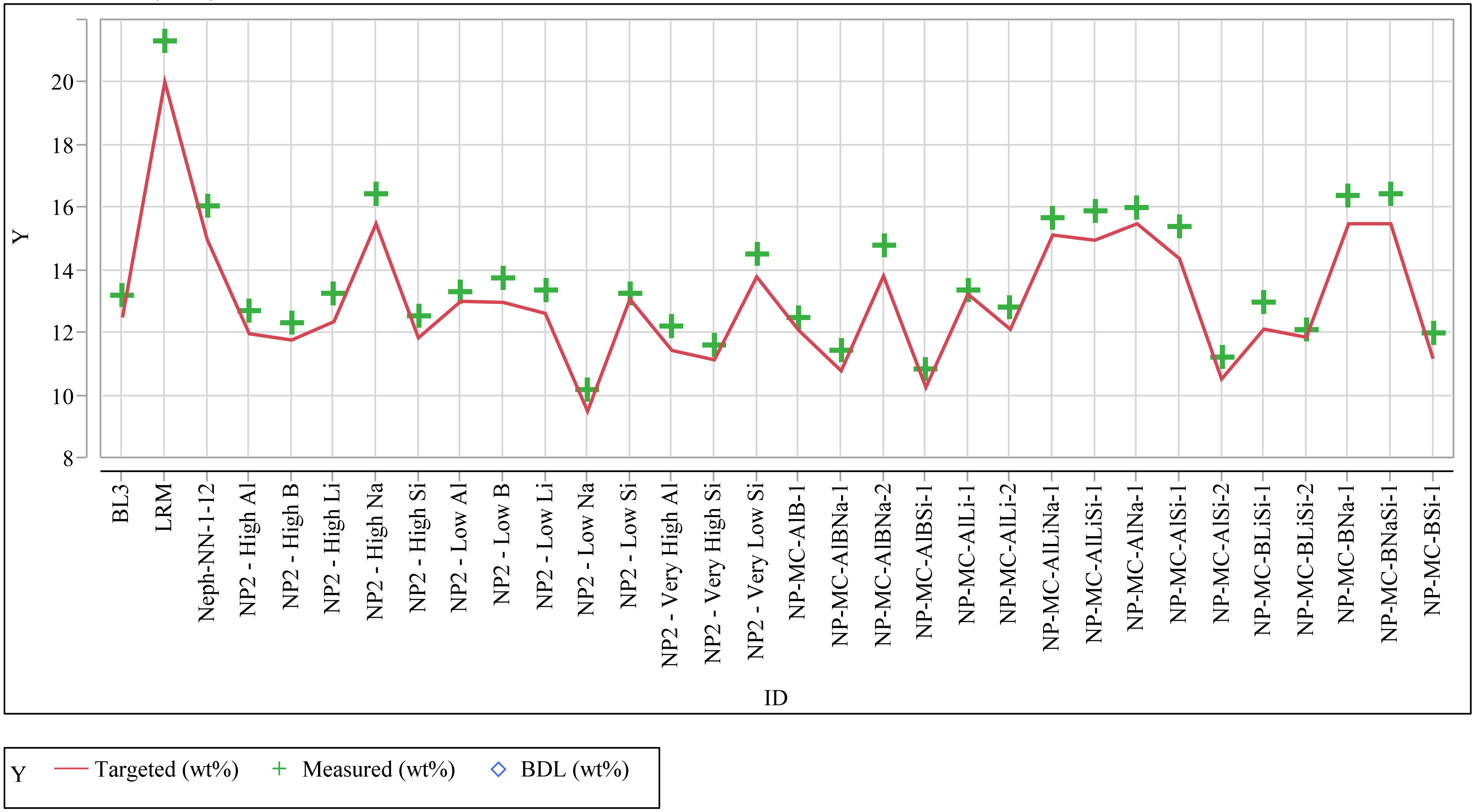


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=NiO (wt%)**

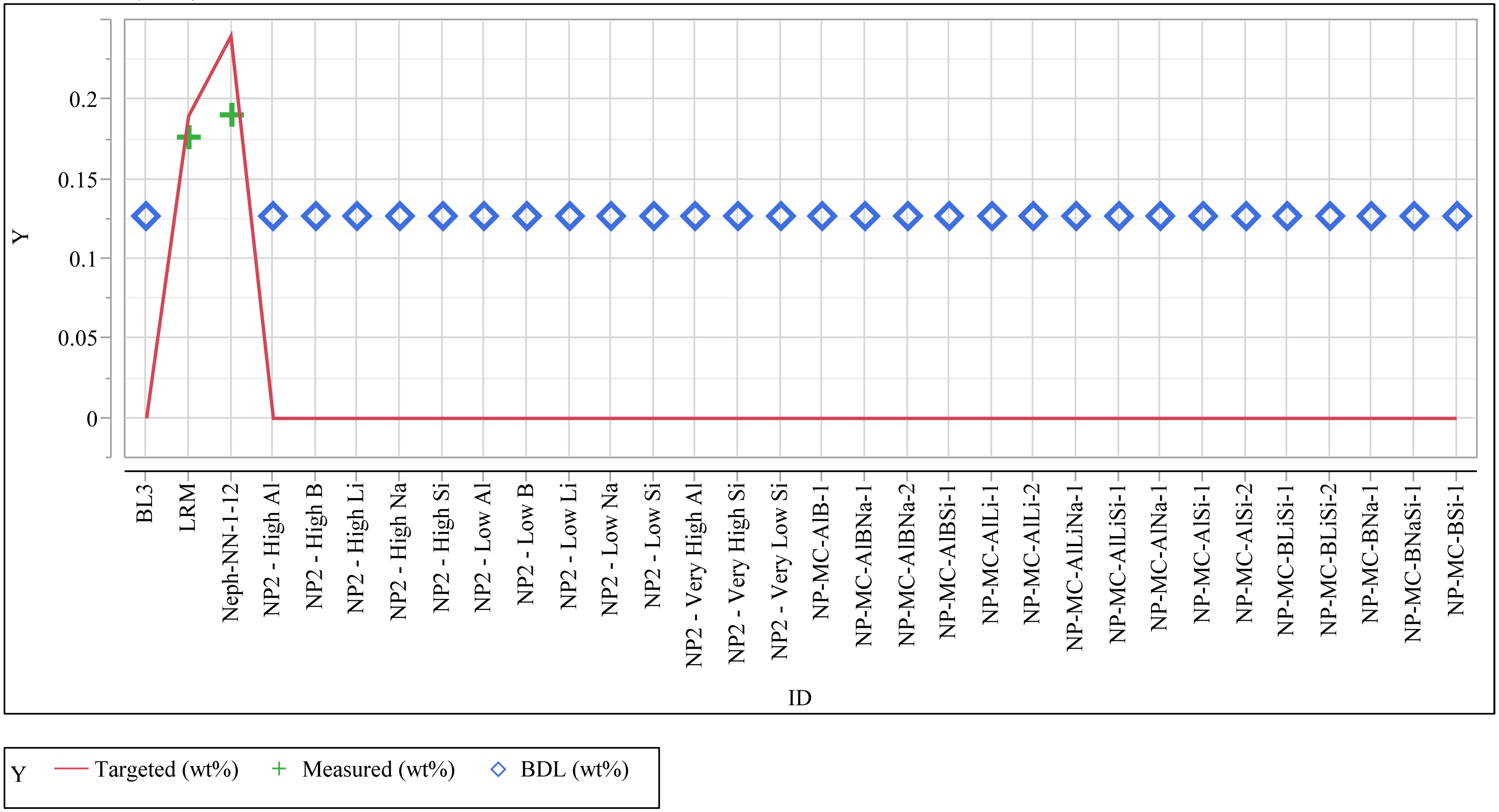


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=P2O5 (wt%)**

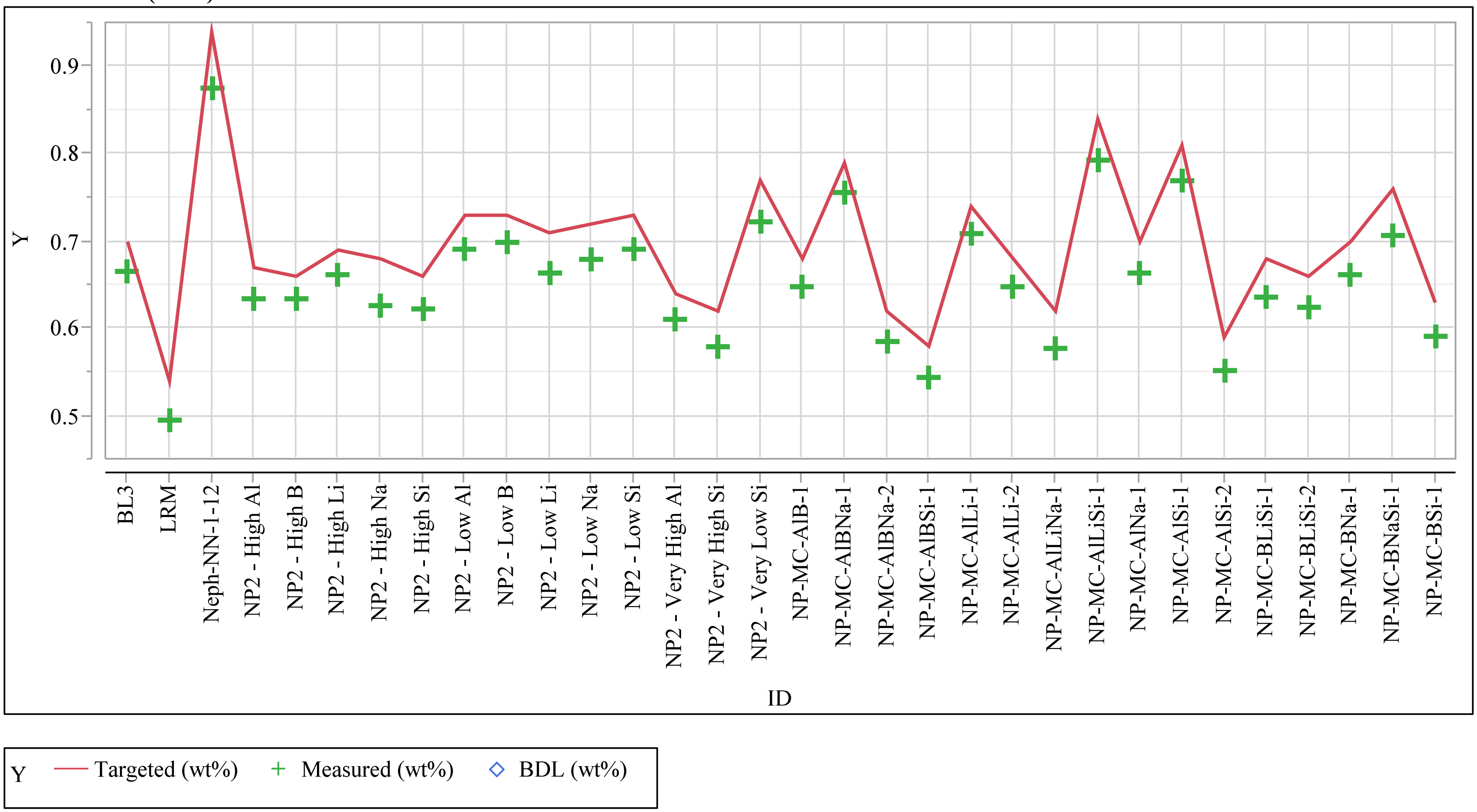


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=RuO2 (wt%)**

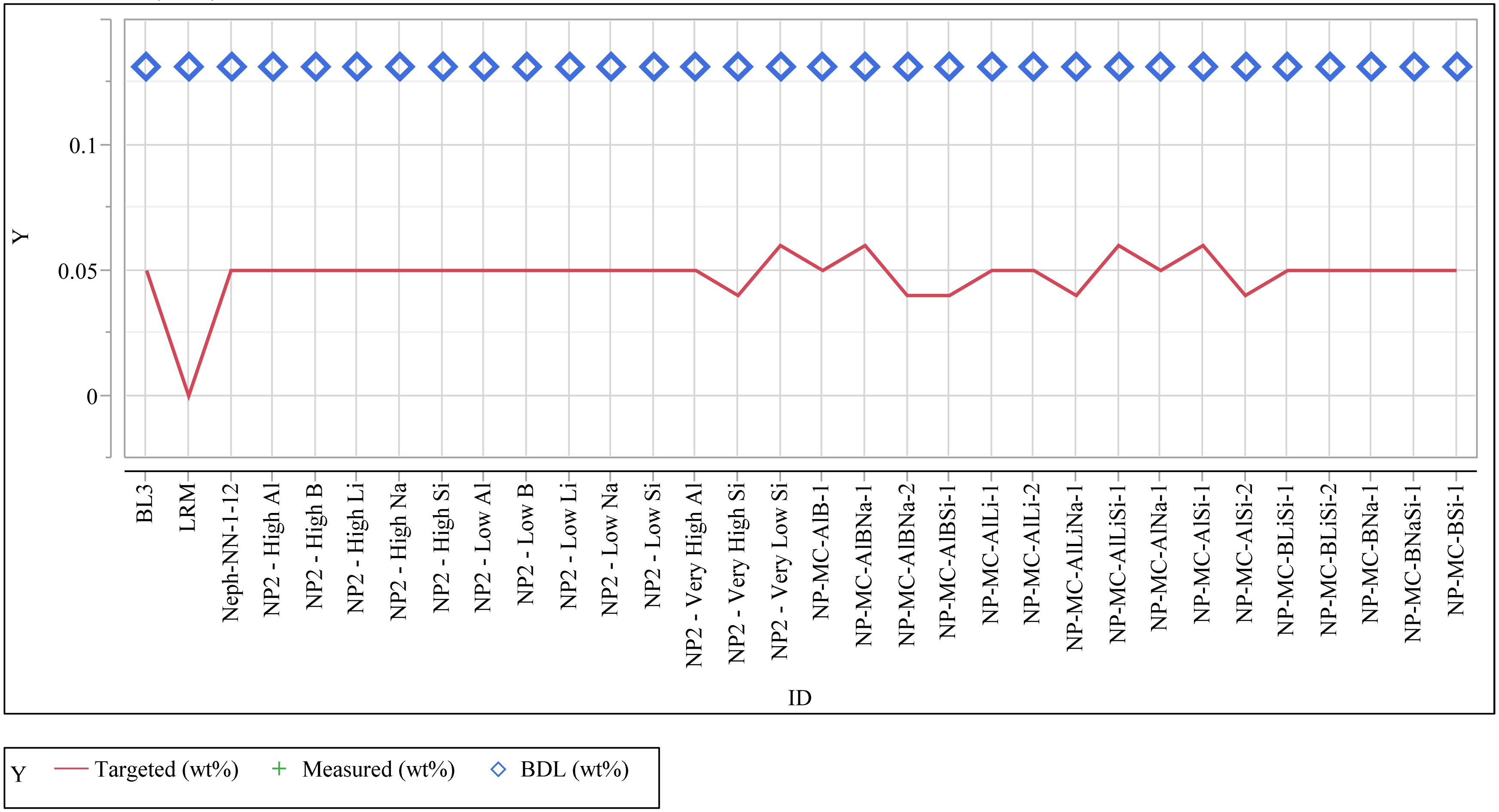


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=SiO2 (wt%)**

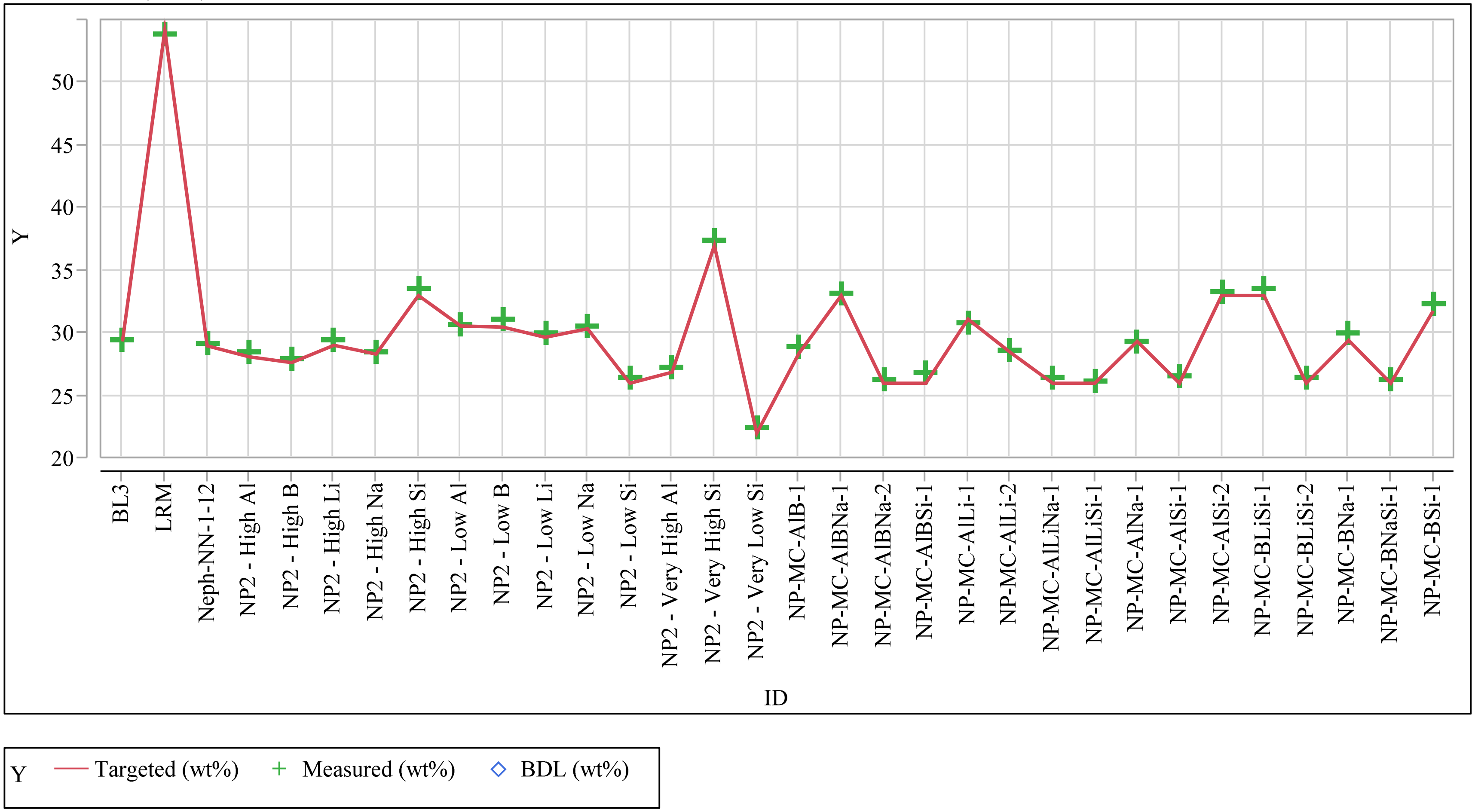


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=SO3 (wt%)**

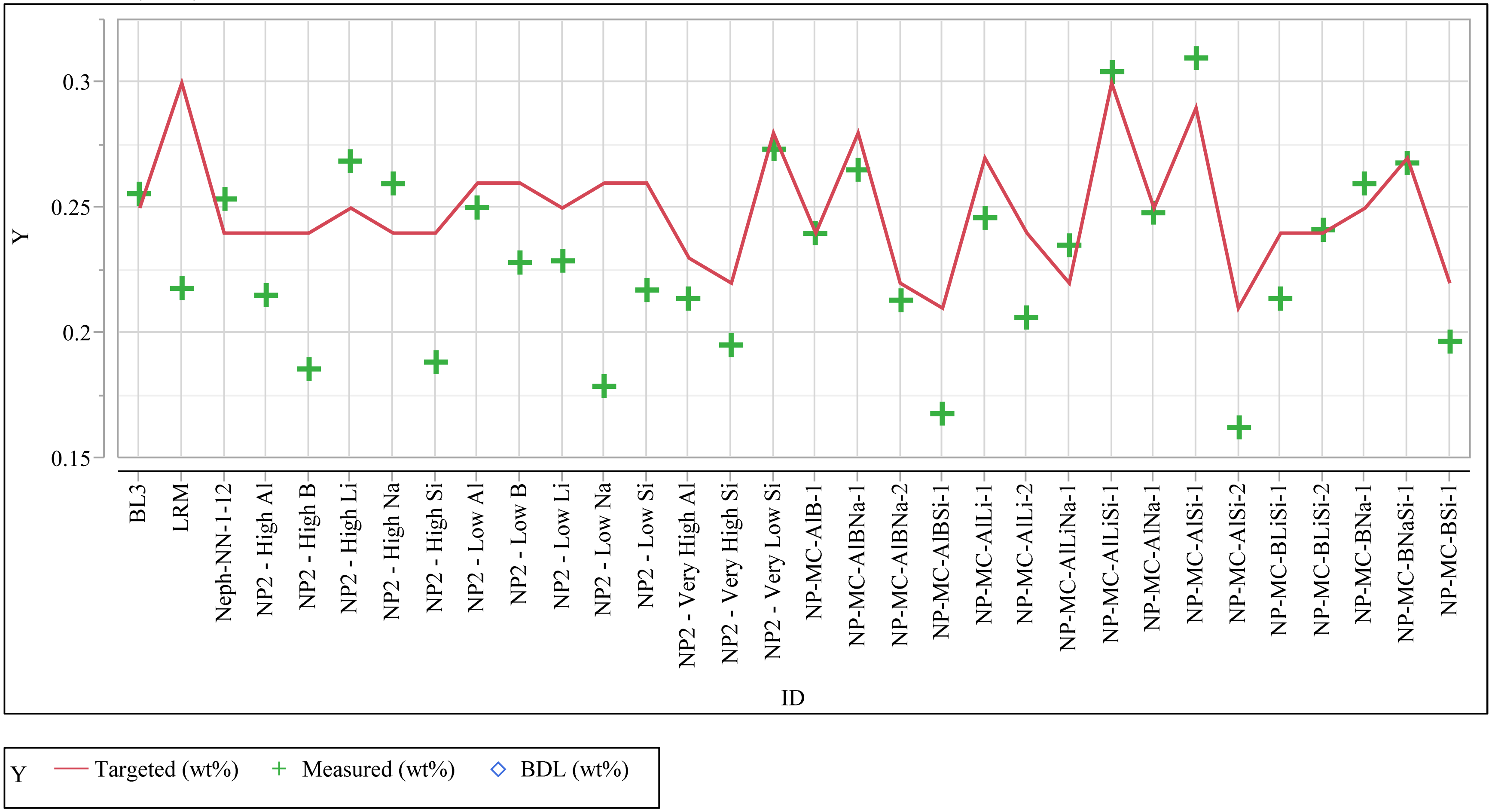


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=ZrO2 (wt%)**

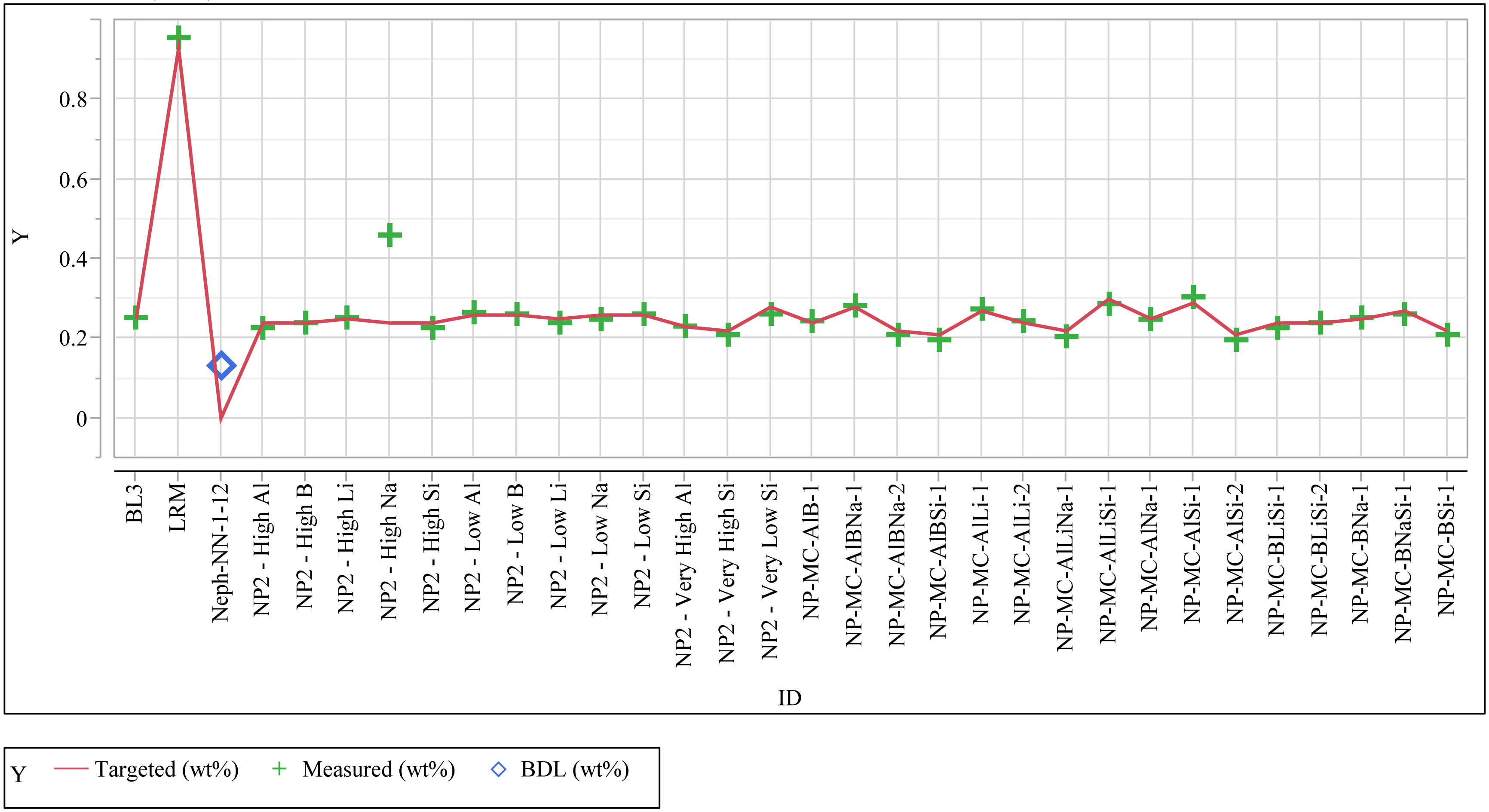
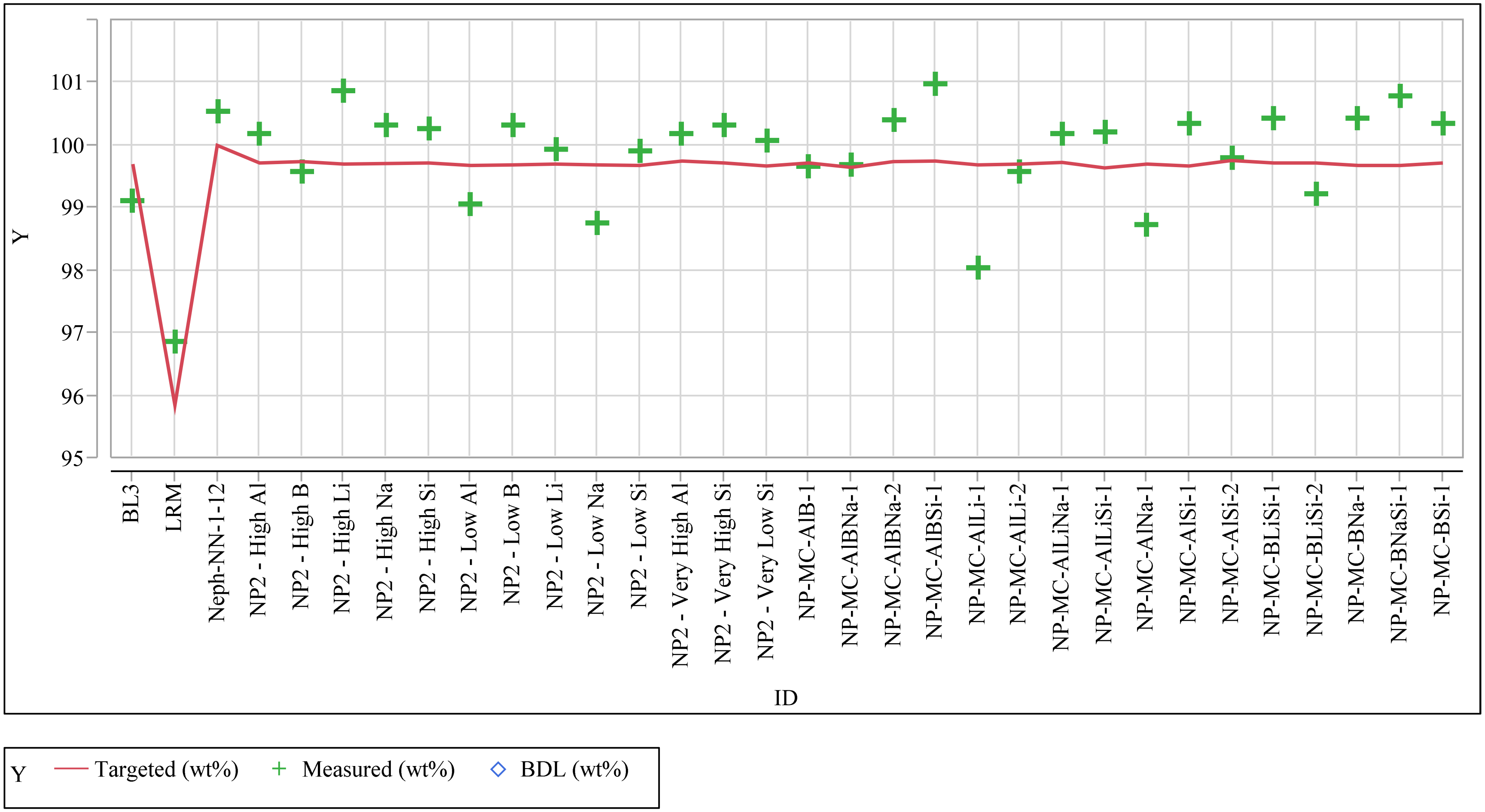


**Exhibit A-4. Measured versus Targeted Concentrations by Glass ID by Oxide (continued)**

**Oxide=Sum of Oxides**



# Appendix B Tables and Exhibits Supporting the PCT Results

## Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received)

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/1 | soln std | 1 | 1 | std-J1-1 | 19.1 | 9.73 | 79.7 | 49.3 | 19.100 | 9.730 | 79.700 | 49.300 |
| 1/1 | NP2-High-B-CCC | 1 | 2 | J26 | 171 | 49.1 | 126 | 30.6 | 285.006 | 81.835 | 210.004 | 51.001 |
| 1/1 | NP2-Low-Si-CCC | 1 | 3 | J27 | 321 | 86.3 | 279 | 1.63 | 535.011 | 143.836 | 465.009 | 2.717 |
| 1/1 | NP2-Low-Na-CCC | 1 | 4 | J44 | 144 | 44.0 | 87.0 | 30.2 | 240.005 | 73.335 | 145.003 | 50.334 |
| 1/1 | ARM-1 | 1 | 5 | J46 | 9.44 | 8.10 | 20.4 | 34.5 | 15.734 | 13.500 | 34.001 | 57.501 |
| 1/1 | blank | 1 | 6 | J09 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 1/1 | NP2-Very-High-Al-CCC | 1 | 7 | J04 | 1280 | 321 | 729 | 12.5 | 2133.376 | 535.011 | 1215.024 | 20.834 |
| 1/1 | NP2-High-Si-CCC | 1 | 8 | J30 | 1190 | 334 | 497 | 15.2 | 1983.373 | 556.678 | 828.350 | 25.334 |
| 1/1 | NP2-High-Li-CCC | 1 | 9 | J47 | 2270 | 843 | 784 | 7.09 | 3783.409 | 1405.028 | 1306.693 | 11.817 |
| 1/1 | soln std | 1 | 10 | std-J1-2 | 19.3 | 9.83 | 80.1 | 48.9 | 19.300 | 9.830 | 80.100 | 48.900 |
| 1/1 | NP2-Low-Al-CCC | 1 | 11 | J03 | 255 | 81.3 | 143 | 19.0 | 425.009 | 135.503 | 238.338 | 31.667 |
| 1/1 | NP2-Low-Li-CCC | 1 | 12 | J07 | 113 | 27.2 | 92.3 | 23.5 | 188.337 | 45.334 | 153.836 | 39.167 |
| 1/1 | NP2-Very-Low-Si-CCC | 1 | 13 | J19 | 1890 | 588 | 1670 | 2.56 | 3150.063 | 980.020 | 2783.389 | 4.267 |
| 1/1 | BL3-CCC | 1 | 14 | J18 | 739 | 186 | 430 | 13.1 | 1231.691 | 310.006 | 716.681 | 21.834 |
| 1/1 | NP2-High-Na-CCC | 1 | 15 | J32 | 2470 | 846 | 1330 | 6.29 | 4116.749 | 1410.028 | 2216.711 | 10.484 |
| 1/1 | NP2-High-Al-CCC | 1 | 16 | J20 | 537 | 115 | 374 | 12.9 | 895.018 | 191.671 | 623.346 | 21.500 |
| 1/1 | Neph-NN-1-12-CCC | 1 | 17 | J06 | 2660 | 1020 | 1080 | 7.29 | 4433.422 | 1700.034 | 1800.036 | 12.150 |
| 1/1 | NP2-Low-B-CCC | 1 | 18 | J01 | 2140 | 869 | 731 | 6.29 | 3566.738 | 1448.362 | 1218.358 | 10.484 |
| 1/1 | soln std | 1 | 19 | std-J1-3 | 19.9 | 9.77 | 79.5 | 49.0 | 19.900 | 9.770 | 79.500 | 49.000 |
| 1/1 | soln std | 2 | 1 | std-J2-1 | 19.5 | 9.86 | 80.5 | 48.9 | 19.500 | 9.860 | 80.500 | 48.900 |
| 1/1 | NP2-High-Na-CCC | 2 | 2 | J24 | 2440 | 919 | 1330 | 6.20 | 4066.748 | 1531.697 | 2216.711 | 10.334 |
| 1/1 | BL3-CCC | 2 | 3 | J13 | 742 | 188 | 433 | 12.9 | 1236.691 | 313.340 | 721.681 | 21.500 |
| 1/1 | NP2-Very-Low-Si-CCC | 2 | 4 | J38 | 1930 | 663 | 1730 | 2.11 | 3216.731 | 1105.022 | 2883.391 | 3.517 |
| 1/1 | NP2-Low-Si-CCC | 2 | 5 | J45 | 338 | 86.3 | 284 | 1.37 | 563.345 | 143.836 | 473.343 | 2.283 |
| 1/1 | NP2-Low-B-CCC | 2 | 6 | J37 | 2130 | 858 | 697 | 6.12 | 3550.071 | 1430.029 | 1161.690 | 10.200 |
| 1/1 | NP2-Very-High-Al-CCC | 2 | 7 | J42 | 1230 | 313 | 637 | 12.0 | 2050.041 | 521.677 | 1061.688 | 20.000 |
| 1/1 | NP2-High-Si-CCC | 2 | 8 | J11 | 1160 | 345 | 452 | 14.8 | 1933.372 | 575.012 | 753.348 | 24.667 |
| 1/1 | ARM-1 | 2 | 9 | J21 | 14.0 | 7.80 | 19.5 | 33.5 | 23.334 | 13.000 | 32.501 | 55.834 |
| 1/1 | soln std | 2 | 10 | std-J2-2 | 21.7 | 9.64 | 77.5 | 48.2 | 21.700 | 9.640 | 77.500 | 48.200 |
| 1/1 | Neph-NN-1-12-CCC | 2 | 11 | J14 | 2620 | 1020 | 1080 | 6.94 | 4366.754 | 1700.034 | 1800.036 | 11.567 |
| 1/1 | NP2-Low-Na-CCC | 2 | 12 | J41 | 148 | 41.2 | 77.5 | 28.1 | 246.672 | 68.668 | 129.169 | 46.834 |
| 1/1 | NP2-Low-Al-CCC | 2 | 13 | J02 | 261 | 81.6 | 146 | 19.4 | 435.009 | 136.003 | 243.338 | 32.334 |
| 1/1 | NP2-High-Li-CCC | 2 | 14 | J40 | 2210 | 834 | 765 | 6.83 | 3683.407 | 1390.028 | 1275.026 | 11.384 |
| 1/1 | NP2-Low-Li-CCC | 2 | 15 | J35 | 117 | 26.6 | 87.8 | 22.6 | 195.004 | 44.334 | 146.336 | 37.667 |
| 1/1 | NP2-High-B-CCC | 2 | 16 | J36 | 168 | 47.8 | 128 | 30.4 | 280.006 | 79.668 | 213.338 | 50.668 |
| 1/1 | NP2-High-Al-CCC | 2 | 17 | J29 | 539 | 116 | 373 | 12.4 | 898.351 | 193.337 | 621.679 | 20.667 |
| 1/1 | soln std | 2 | 18 | std-J2-3 | 21.4 | 9.71 | 77.9 | 49.1 | 21.400 | 9.710 | 77.900 | 49.100 |
| 1/1 | soln std | 3 | 1 | std-J3-1 | 18.8 | 9.79 | 80.8 | 49.6 | 18.800 | 9.790 | 80.800 | 49.600 |
| 1/1 | BL3-CCC | 3 | 2 | J08 | 728 | 186 | 428 | 13.2 | 1213.358 | 310.006 | 713.348 | 22.000 |
| 1/1 | NP2-Very-Low-Si-CCC | 3 | 3 | J12 | 1870 | 590 | 1650 | 2.30 | 3116.729 | 983.353 | 2750.055 | 3.833 |
| 1/1 | NP2-Low-Li-CCC | 3 | 4 | J16 | 111 | 26.8 | 90.6 | 23.2 | 185.004 | 44.668 | 151.003 | 38.667 |
| 1/1 | ARM-1 | 3 | 5 | J17 | 6.15 | 7.86 | 19.6 | 33.3 | 10.250 | 13.100 | 32.667 | 55.501 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/1 | NP2-Low-Al-CCC | 3 | 6 | J22 | 263 | 80.9 | 143 | 19.7 | 438.342 | 134.836 | 238.338 | 32.834 |
| 1/1 | NP2-High-Li-CCC | 3 | 7 | J34 | 2300 | 849 | 780 | 7.45 | 3833.410 | 1415.028 | 1300.026 | 12.417 |
| 1/1 | NP2-Low-Na-CCC | 3 | 8 | J05 | 144 | 42.3 | 80.9 | 27.3 | 240.005 | 70.501 | 134.836 | 45.501 |
| 1/1 | NP2-High-Si-CCC | 3 | 9 | J39 | 1220 | 352 | 460 | 15.4 | 2033.374 | 586.678 | 766.682 | 25.667 |
| 1/1 | soln std | 3 | 10 | std-J3-2 | 18.5 | 9.64 | 78.1 | 48.5 | 18.500 | 9.640 | 78.100 | 48.500 |
| 1/1 | Neph-NN-1-12-CCC | 3 | 11 | J25 | 2700 | 1020 | 1080 | 7.08 | 4500.090 | 1700.034 | 1800.036 | 11.800 |
| 1/1 | blank | 3 | 12 | J33 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 1/1 | NP2-High-Na-CCC | 3 | 13 | J43 | 2450 | 847 | 1320 | 6.24 | 4083.415 | 1411.695 | 2200.044 | 10.400 |
| 1/1 | NP2-High-B-CCC | 3 | 14 | J28 | 171 | 46.9 | 124 | 30.0 | 285.006 | 78.168 | 206.671 | 50.001 |
| 1/1 | NP2-High-Al-CCC | 3 | 15 | J10 | 543 | 117 | 381 | 12.4 | 905.018 | 195.004 | 635.013 | 20.667 |
| 1/1 | NP2-Low-Si-CCC | 3 | 16 | J23 | 334 | 87.1 | 282 | 1.45 | 556.678 | 145.170 | 470.009 | 2.417 |
| 1/1 | NP2-Low-B-CCC | 3 | 17 | J15 | 2120 | 800 | 718 | 5.98 | 3533.404 | 1333.360 | 1196.691 | 9.967 |
| 1/1 | NP2-Very-High-Al-CCC | 3 | 18 | J31 | 1190 | 308 | 678 | 12.2 | 1983.373 | 513.344 | 1130.023 | 20.334 |
| 1/1 | soln std | 3 | 19 | std-J3-3 | 18.5 | 9.72 | 78.6 | 48.8 | 18.500 | 9.720 | 78.600 | 48.800 |
| 1/2 | soln std | 1 | 1 | std-K1-1 | 20.9 | 9.84 | 82.6 | 51.1 | 20.900 | 9.840 | 82.600 | 51.100 |
| 1/2 | NP-MC-BLiSi-1-CCC | 1 | 2 | K01 | 2200 | 902 | 570 | 10.6 | 3666.740 | 1503.363 | 950.019 | 17.667 |
| 1/2 | NP-MC-BNaSi-1-CCC | 1 | 3 | K10 | 1930 | 799 | 1690 | 2.54 | 3216.731 | 1331.693 | 2816.723 | 4.233 |
| 1/2 | blank | 1 | 4 | K31 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 1/2 | NP-MC-AlLi-1-CCC | 1 | 5 | K04 | 80.0 | 23.2 | 73.0 | 38.5 | 133.336 | 38.667 | 121.669 | 64.168 |
| 1/2 | NP-MC-AlBNa-2-CCC | 1 | 6 | K29 | 435 | 93.3 | 417 | 2.45 | 725.015 | 155.503 | 695.014 | 4.083 |
| 1/2 | NP-MC-AlSi-1-CCC | 1 | 7 | K13 | 3000 | 1040 | 1490 | 8.24 | 5000.100 | 1733.368 | 2483.383 | 13.734 |
| 1/2 | NP-MC-AlBSi-1-CCC | 1 | 8 | K40 | 147 | 36.2 | 110 | 1.94 | 245.005 | 60.335 | 183.337 | 3.233 |
| 1/2 | NP-MC-AlNa-1-CCC | 1 | 9 | K23 | 3120 | 1080 | 1360 | 10.2 | 5200.104 | 1800.036 | 2266.712 | 17.000 |
| 1/2 | soln std | 1 | 10 | std-K1-2 | 20.6 | 9.80 | 81.2 | 51.1 | 20.600 | 9.800 | 81.200 | 51.100 |
| 1/2 | NP-MC-BNa-1-CCC | 1 | 11 | K39 | 2110 | 897 | 1060 | 4.63 | 3516.737 | 1495.030 | 1766.702 | 7.717 |
| 1/2 | NP-MC-AlLiSi-1-CCC | 1 | 12 | K35 | 540 | 103 | 462 | 13.5 | 900.018 | 171.670 | 770.015 | 22.500 |
| 1/2 | NP-MC-AlLi-2-CCC | 1 | 13 | K18 | 664 | 140 | 384 | 16.0 | 1106.689 | 233.338 | 640.013 | 26.667 |
| 1/2 | NP-MC-AlBNa-1-CCC | 1 | 14 | K11 | 35.7 | 18.2 | 32.2 | 57.9 | 59.501 | 30.334 | 53.668 | 96.502 |
| 1/2 | NP-MC-AlLiNa-1-CCC | 1 | 15 | K08 | 2110 | 888 | 1670 | 2.66 | 3516.737 | 1480.030 | 2783.389 | 4.433 |
| 1/2 | NP-MC-AlSi-2-CCC | 1 | 16 | K28 | 343 | 62.1 | 224 | 2.20 | 571.678 | 103.502 | 373.341 | 3.667 |
| 1/2 | ARM-1 | 1 | 17 | K17 | 17.6 | 8.84 | 23.3 | 40.3 | 29.334 | 14.734 | 38.834 | 67.168 |
| 1/2 | soln std | 1 | 18 | std-K-1-3 | 20.7 | 9.81 | 82.3 | 50.9 | 20.700 | 9.810 | 82.300 | 50.900 |
| 1/2 | soln std | 2 | 1 | std-K2-1 | 20.6 | 9.57 | 82.7 | 51.5 | 20.600 | 9.570 | 82.700 | 51.500 |
| 1/2 | NP-MC-BNa-1-CCC | 2 | 2 | K22 | 2030 | 866 | 1000 | 4.40 | 3383.401 | 1443.362 | 1666.700 | 7.333 |
| 1/2 | NP-MC-AlBNa-2-CCC | 2 | 3 | K33 | 439 | 91.9 | 405 | 2.29 | 731.681 | 153.170 | 675.014 | 3.817 |
| 1/2 | NP-MC-AlLiSi-1-CCC | 2 | 4 | K36 | 540 | 103 | 452 | 13.2 | 900.018 | 171.670 | 753.348 | 22.000 |
| 1/2 | NP-MC-AlSi-1-CCC | 2 | 5 | K27 | 2870 | 1010 | 1430 | 8.31 | 4783.429 | 1683.367 | 2383.381 | 13.850 |
| 1/2 | NP-MC-AlNa-1-CCC | 2 | 6 | K26 | 2810 | 1010 | 1240 | 9.52 | 4683.427 | 1683.367 | 2066.708 | 15.867 |
| 1/2 | NP-MC-AlLi-2-CCC | 2 | 7 | K02 | 618 | 134 | 363 | 16.7 | 1030.021 | 223.338 | 605.012 | 27.834 |
| 1/2 | NP-MC-AlSi-2-CCC | 2 | 8 | K16 | 344 | 61.7 | 222 | 1.96 | 573.345 | 102.835 | 370.007 | 3.267 |
| 1/2 | NP-MC-AlBNa-1-CCC | 2 | 9 | K12 | 40.8 | 17.6 | 31.5 | 57.9 | 68.001 | 29.334 | 52.501 | 96.502 |
| 1/2 | soln std | 2 | 10 | std-K2-2 | 19.4 | 9.49 | 81.3 | 50.9 | 19.400 | 9.490 | 81.300 | 50.900 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1/2 | NP-MC-BNaSi-1-CCC | 2 | 11 | K24 | 1890 | 774 | 1630 | 2.27 | 3150.063 | 1290.026 | 2716.721 | 3.783 |
| 1/2 | NP-MC-BLiSi-1-CCC | 2 | 12 | K41 | 2230 | 870 | 549 | 10.4 | 3716.741 | 1450.029 | 915.018 | 17.334 |
| 1/2 | NP-MC-AlLi-1-CCC | 2 | 13 | K43 | 102 | 23.4 | 74.5 | 38.8 | 170.003 | 39.001 | 124.169 | 64.668 |
| 1/2 | ARM-1 | 2 | 14 | K34 | 22.5 | 8.47 | 22.6 | 40.1 | 37.501 | 14.117 | 37.667 | 66.835 |
| 1/2 | NP-MC-AlLiNa-1-CCC | 2 | 15 | K14 | 2120 | 866 | 1610 | 2.35 | 3533.404 | 1443.362 | 2683.387 | 3.917 |
| 1/2 | NP-MC-AlBSi-1-CCC | 2 | 16 | K37 | 153 | 35.7 | 105 | 1.66 | 255.005 | 59.501 | 175.004 | 2.767 |
| 1/2 | soln std | 2 | 17 | std-K2-3 | 19.7 | 9.46 | 82.4 | 50.8 | 19.700 | 9.460 | 82.400 | 50.800 |
| 1/2 | soln std | 3 | 1 | std-k3-1 | 21.8 | 10.2 | 84.7 | 53.1 | 21.800 | 10.200 | 84.700 | 53.100 |
| 1/2 | NP-MC-AlLi-2-CCC | 3 | 2 | K03 | 663 | 140 | 377 | 15.3 | 1105.022 | 233.338 | 628.346 | 25.501 |
| 1/2 | NP-MC-AlBNa-1-CCC | 3 | 3 | K06 | 39.3 | 18.2 | 31.8 | 59.5 | 65.501 | 30.334 | 53.001 | 99.169 |
| 1/2 | NP-MC-AlSi-1-CCC | 3 | 4 | K09 | 3020 | 1020 | 1460 | 8.59 | 5033.434 | 1700.034 | 2433.382 | 14.317 |
| 1/2 | NP-MC-BNa-1-CCC | 3 | 5 | K25 | 2180 | 885 | 1030 | 4.88 | 3633.406 | 1475.030 | 1716.701 | 8.133 |
| 1/2 | NP-MC-AlBNa-2-CCC | 3 | 6 | K21 | 432 | 92.9 | 412 | 2.68 | 720.014 | 154.836 | 686.680 | 4.467 |
| 1/2 | NP-MC-AlLi-1-CCC | 3 | 7 | K30 | 94.7 | 22.4 | 69.5 | 37.7 | 157.836 | 37.334 | 115.836 | 62.835 |
| 1/2 | NP-MC-AlLiSi-1-CCC | 3 | 8 | K32 | 547 | 104 | 458 | 13.7 | 911.685 | 173.337 | 763.349 | 22.834 |
| 1/2 | blank | 3 | 9 | K42 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 1/2 | soln std | 3 | 10 | std-K3-2 | 21.7 | 9.89 | 79.8 | 51.0 | 21.700 | 9.890 | 79.800 | 51.000 |
| 1/2 | NP-MC-AlSi-2-CCC | 3 | 11 | K05 | 344 | 62.4 | 228 | 2.54 | 573.345 | 104.002 | 380.008 | 4.233 |
| 1/2 | ARM-1 | 3 | 12 | K07 | 21.2 | 8.67 | 22.2 | 39.3 | 35.334 | 14.450 | 37.001 | 65.501 |
| 1/2 | NP-MC-BLiSi-1-CCC | 3 | 13 | K44 | 2340 | 891 | 554 | 10.3 | 3900.078 | 1485.030 | 923.352 | 17.167 |
| 1/2 | NP-MC-AlLiNa-1-CCC | 3 | 14 | K15 | 2170 | 887 | 1650 | 2.64 | 3616.739 | 1478.363 | 2750.055 | 4.400 |
| 1/2 | NP-MC-AlNa-1-CCC | 3 | 15 | K20 | 2920 | 1010 | 1270 | 9.94 | 4866.764 | 1683.367 | 2116.709 | 16.567 |
| 1/2 | NP-MC-AlBSi-1-CCC | 3 | 16 | K38 | 147 | 35.4 | 106 | 2.10 | 245.005 | 59.001 | 176.670 | 3.500 |
| 1/2 | NP-MC-BNaSi-1-CCC | 3 | 17 | K19 | 2000 | 796 | 1680 | 2.66 | 3333.400 | 1326.693 | 2800.056 | 4.433 |
| 1/2 | soln std | 3 | 18 | std-K3-3 | 20.2 | 10.0 | 82.7 | 51.3 | 20.200 | 10.000 | 82.700 | 51.300 |
| 2/1 | soln std | 1 | 1 | std-1-1 | 19.4 | 10.2 | 84.8 | 50.9 | 19.400 | 10.200 | 84.800 | 50.900 |
| 2/1 | NP-MC-AlB-1-CCC | 1 | 2 | Y04 | 156 | 45.3 | 125 | 27.3 | 260.005 | 75.502 | 208.338 | 45.501 |
| 2/1 | blank | 1 | 3 | Y14 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 2/1 | NP2-Very-High-Si-CCC | 1 | 4 | Y18 | 15.0 | 10.3 | 18.3 | 46.5 | 25.001 | 17.167 | 30.501 | 77.502 |
| 2/1 | NP-MC-BSi-1-CCC | 1 | 5 | Y03 | 76.9 | 22.6 | 55.1 | 34.3 | 128.169 | 37.667 | 91.835 | 57.168 |
| 2/1 | NP-MC-AlLi-2-CCC | 1 | 6 | Y20 | 656 | 137 | 382 | 16.1 | 1093.355 | 228.338 | 636.679 | 26.834 |
| 2/1 | soln std | 1 | 7 | std-1-2 | 21.7 | 10.0 | 82.1 | 48.3 | 21.700 | 10.000 | 82.100 | 48.300 |
| 2/1 | NP-MC-AlBNa-1-CCC | 1 | 8 | Y12 | 27.9 | 16.9 | 31.4 | 51.6 | 46.501 | 28.167 | 52.334 | 86.002 |
| 2/1 | ARM-1 | 1 | 9 | Y19 | 9.39 | 8.21 | 21.4 | 33.7 | 15.650 | 13.684 | 35.667 | 56.168 |
| 2/1 | NP-MC-AlNa-1-CCC | 1 | 10 | Y05 | 2920 | 1070 | 1330 | 9.95 | 4866.764 | 1783.369 | 2216.711 | 16.584 |
| 2/1 | NP-MC-BLiSi-2-CCC | 1 | 11 | Y10 | 266 | 87.0 | 196 | 23.3 | 443.342 | 145.003 | 326.673 | 38.834 |
| 2/1 | soln std | 1 | 12 | std-1-3 | 20.6 | 10.6 | 85.7 | 48.7 | 20.600 | 10.600 | 85.700 | 48.700 |
| 2/1 | soln std | 2 | 1 | std-2-1 | 19.0 | 9.79 | 80.9 | 47.0 | 19.000 | 9.790 | 80.900 | 47.000 |
| 2/1 | NP-MC-AlB-1-CCC | 2 | 2 | Y01 | 169 | 46.6 | 124 | 27.2 | 281.672 | 77.668 | 206.671 | 45.334 |
| 2/1 | NP-MC-BSi-1-CCC | 2 | 3 | Y07 | 81.3 | 23.9 | 58.8 | 36.2 | 135.503 | 39.834 | 98.002 | 60.335 |
| 2/1 | ARM-1 | 2 | 4 | Y24 | 10.4 | 8.19 | 21.5 | 33.3 | 17.334 | 13.650 | 35.834 | 55.501 |
| 2/1 | NP-MC-AlBNa-1-CCC | 2 | 5 | Y02 | 25.5 | 15.4 | 28.8 | 47.1 | 42.501 | 25.667 | 48.001 | 78.502 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2/1 | NP-MC-AlLi-2-CCC | 2 | 6 | Y23 | 658 | 140 | 373 | 15.0 | 1096.689 | 233.338 | 621.679 | 25.001 |
| 2/1 | soln std | 2 | 7 | std-2-2 | 19.0 | 9.79 | 80.0 | 47.2 | 19.000 | 9.790 | 80.000 | 47.200 |
| 2/1 | NP-MC-AlNa-1-CCC | 2 | 8 | Y08 | 2960 | 1070 | 1330 | 8.65 | 4933.432 | 1783.369 | 2216.711 | 14.417 |
| 2/1 | NP2-Very-High-Si-CCC | 2 | 9 | Y21 | 27.8 | 10.2 | 18.1 | 46.0 | 46.334 | 17.000 | 30.167 | 76.668 |
| 2/1 | NP-MC-BLiSi-2-CCC | 2 | 10 | Y06 | 274 | 93.2 | 197 | 22.6 | 456.676 | 155.336 | 328.340 | 37.667 |
| 2/1 | soln std | 2 | 11 | std-2-3 | 18.4 | 9.80 | 80.8 | 46.6 | 18.400 | 9.800 | 80.800 | 46.600 |
| 2/1 | soln std | 3 | 1 | std-3-1 | 19.4 | 10.0 | 82.1 | 49.1 | 19.400 | 10.000 | 82.100 | 49.100 |
| 2/1 | NP-MC-AlNa-1-CCC | 3 | 2 | Y11 | 2980 | 1080 | 1340 | 10.3 | 4966.766 | 1800.036 | 2233.378 | 17.167 |
| 2/1 | NP-MC-BLiSi-2-CCC | 3 | 2 | Y13 | 272 | 92.8 | 198 | 23.1 | 453.342 | 154.670 | 330.007 | 38.501 |
| 2/1 | NP-MC-AlBNa-1-CCC | 3 | 3 | Y16 | 32.8 | 16.9 | 31.4 | 52.2 | 54.668 | 28.167 | 52.334 | 87.002 |
| 2/1 | NP-MC-AlLi-2-CCC | 3 | 4 | Y25 | 658 | 142 | 382 | 15.6 | 1096.689 | 236.671 | 636.679 | 26.001 |
| 2/1 | NP2-Very-High-Si-CCC | 3 | 6 | Y26 | 20.2 | 10.2 | 17.9 | 46.7 | 33.667 | 17.000 | 29.834 | 77.835 |
| 2/1 | soln std | 3 | 7 | std-3-2 | 21.6 | 9.79 | 80.3 | 47.9 | 21.600 | 9.790 | 80.300 | 47.900 |
| 2/1 | blank | 3 | 8 | Y09 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 2/1 | ARM-1 | 3 | 9 | Y22 | 10.3 | 7.95 | 20.8 | 33.5 | 17.167 | 13.250 | 34.667 | 55.834 |
| 2/1 | NP-MC-BSi-1-CCC | 3 | 10 | Y15 | 88.0 | 24.8 | 60.8 | 39.2 | 146.670 | 41.334 | 101.335 | 65.335 |
| 2/1 | NP-MC-AlB-1-CCC | 3 | 11 | Y17 | 163 | 44.8 | 122 | 26.0 | 271.672 | 74.668 | 203.337 | 43.334 |
| 2/1 | soln std | 3 | 12 | std-3-3 | 19.9 | 9.86 | 81.5 | 48.1 | 19.900 | 9.860 | 81.500 | 48.100 |
| 3/1 | soln std | 1 | 1 | std-M1-1 | 20.8 | 10.2 | 84.1 | 51.5 | 20.800 | 10.200 | 84.100 | 51.500 |
| 3/1 | ARM-1 | 1 | 2 | M25 | 11.2 | 8.75 | 22.9 | 37.1 | 18.667 | 14.584 | 38.167 | 61.835 |
| 3/1 | NP2-Very-High-Si-Q | 1 | 3 | M03 | 16.4 | 11.4 | 16.4 | 51.0 | 27.334 | 19.000 | 27.334 | 85.002 |
| 3/1 | NP2-High-Na-Q | 1 | 4 | M39 | 73.9 | 27.9 | 115 | 35.8 | 123.169 | 46.501 | 191.671 | 59.668 |
| 3/1 | BL3-Q | 1 | 5 | M12 | 58.5 | 25.7 | 65.3 | 42.4 | 97.502 | 42.834 | 108.836 | 70.668 |
| 3/1 | NP2-Very-Low-Si-Q | 1 | 6 | M10 | 549 | 145 | 792 | 6.45 | 915.018 | 241.672 | 1320.026 | 10.750 |
| 3/1 | NP2-Low-B-Q | 1 | 7 | M51 | 37.1 | 21.3 | 55.4 | 46.4 | 61.835 | 35.501 | 92.335 | 77.335 |
| 3/1 | Neph-NN-1-12-Q | 1 | 8 | M24 | 78.9 | 34.1 | 115 | 41.0 | 131.503 | 56.834 | 191.671 | 68.335 |
| 3/1 | NP2-High-Al-Q | 1 | 9 | M19 | 62.2 | 27.1 | 67.1 | 34.3 | 103.669 | 45.168 | 111.836 | 57.168 |
| 3/1 | NP2-Low-Li-Q | 1 | 10 | M42 | 53.4 | 19.3 | 57.7 | 43.4 | 89.002 | 32.167 | 96.169 | 72.335 |
| 3/1 | soln std | 1 | 11 | std-M1-2 | 20.9 | 10.2 | 83.7 | 52.1 | 20.900 | 10.200 | 83.700 | 52.100 |
| 3/1 | NP-MC-AlB-1-Q | 1 | 12 | M30 | 168 | 50.5 | 131 | 30.3 | 280.006 | 84.168 | 218.338 | 50.501 |
| 3/1 | NP2-Low-Al-Q | 1 | 13 | M37 | 74.2 | 28.7 | 76.0 | 41.7 | 123.669 | 47.834 | 126.669 | 69.501 |
| 3/1 | NP2-High-B-Q | 1 | 14 | M17 | 147 | 45.2 | 120 | 28.6 | 245.005 | 75.335 | 200.004 | 47.668 |
| 3/1 | NP2-High-Li-Q | 1 | 15 | M45 | 62.3 | 30.6 | 68.9 | 41.9 | 103.835 | 51.001 | 114.836 | 69.835 |
| 3/1 | blank | 1 | 16 | M14 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 3/1 | NP2-Low-Na-Q | 1 | 17 | M43 | 39.1 | 20.5 | 28.8 | 47.0 | 65.168 | 34.167 | 48.001 | 78.335 |
| 3/1 | NP2-Very-High-Al-Q | 1 | 18 | M32 | 67.1 | 27.2 | 71.2 | 30.0 | 111.836 | 45.334 | 118.669 | 50.001 |
| 3/1 | NP2-Low-Si-Q | 1 | 19 | M28 | 106 | 41.0 | 123 | 25.2 | 176.670 | 68.335 | 205.004 | 42.001 |
| 3/1 | NP2-High-Si-Q | 1 | 20 | M53 | 28.6 | 14.5 | 31.6 | 48.7 | 47.668 | 24.167 | 52.668 | 81.168 |
| 3/1 | soln std | 1 | 21 | std-M1-3 | 21.1 | 10.3 | 84.1 | 52.8 | 21.100 | 10.300 | 84.100 | 52.800 |
| 3/1 | soln std | 2 | 1 | std-M2-1 | 20.9 | 10.2 | 83.9 | 52.0 | 20.900 | 10.200 | 83.900 | 52.000 |
| 3/1 | NP2-High-Al-Q | 2 | 2 | M47 | 60.3 | 25.5 | 63.5 | 35.0 | 100.502 | 42.501 | 105.835 | 58.335 |
| 3/1 | NP2-Very-High-Al-Q | 2 | 3 | M40 | 66.3 | 26.5 | 69.9 | 29.9 | 110.502 | 44.168 | 116.502 | 49.834 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/1 | NP2-High-Li-Q | 2 | 4 | M16 | 62.3 | 30.5 | 69.9 | 42.4 | 103.835 | 50.834 | 116.502 | 70.668 |
| 3/1 | Neph-NN-1-12-Q | 2 | 5 | M01 | 81.3 | 33.8 | 117 | 40.8 | 135.503 | 56.334 | 195.004 | 68.001 |
| 3/1 | NP2-High-B-Q | 2 | 6 | M52 | 144 | 44.0 | 119 | 29.1 | 240.005 | 73.335 | 198.337 | 48.501 |
| 3/1 | NP2-Low-Si-Q | 2 | 7 | M48 | 101 | 41.1 | 125 | 24.0 | 168.337 | 68.501 | 208.338 | 40.001 |
| 3/1 | NP2-High-Na-Q | 2 | 8 | M44 | 74.6 | 27.0 | 115 | 34.3 | 124.336 | 45.001 | 191.671 | 57.168 |
| 3/1 | NP2-Very-High-Si-Q | 2 | 9 | M15 | 17.2 | 10.8 | 16.1 | 48.4 | 28.667 | 18.000 | 26.834 | 80.668 |
| 3/1 | NP2-Low-Na-Q | 2 | 10 | M35 | 43.7 | 21.2 | 30.2 | 47.8 | 72.835 | 35.334 | 50.334 | 79.668 |
| 3/1 | soln std | 2 | 11 | std-M2-2 | 20.3 | 10.2 | 82.9 | 51.1 | 20.300 | 10.200 | 82.900 | 51.100 |
| 3/1 | NP2-Low-Li-Q | 2 | 12 | M33 | 51.9 | 18.4 | 56.0 | 41.3 | 86.502 | 30.667 | 93.335 | 68.835 |
| 3/1 | NP2-High-Si-Q | 2 | 13 | M07 | 27.9 | 14.4 | 31.8 | 48.1 | 46.501 | 24.000 | 53.001 | 80.168 |
| 3/1 | ARM-1 | 2 | 14 | M11 | 11.9 | 8.54 | 22.5 | 36.0 | 19.834 | 14.234 | 37.501 | 60.001 |
| 3/1 | NP2-Low-Al-Q | 2 | 15 | M26 | 72.4 | 28.8 | 78.0 | 42.0 | 120.669 | 48.001 | 130.003 | 70.001 |
| 3/1 | NP2-Low-B-Q | 2 | 16 | M06 | 36.4 | 20.6 | 55.1 | 45.5 | 60.668 | 34.334 | 91.835 | 75.835 |
| 3/1 | BL3-Q | 2 | 17 | M23 | 59.7 | 24.8 | 64.8 | 41.4 | 99.502 | 41.334 | 108.002 | 69.001 |
| 3/1 | NP2-Very-Low-Si-Q | 2 | 18 | M36 | 547 | 136 | 769 | 6.18 | 911.685 | 226.671 | 1281.692 | 10.300 |
| 3/1 | NP-MC-AlB-1-Q | 2 | 19 | M41 | 165 | 48.2 | 127 | 29.3 | 275.006 | 80.335 | 211.671 | 48.834 |
| 3/1 | soln std | 2 | 20 | std-M2-3 | 20.4 | 10.2 | 83.1 | 51.5 | 20.400 | 10.200 | 83.100 | 51.500 |
| 3/1 | soln std | 3 | 1 | std-M3-1 | 19.8 | 9.92 | 81.7 | 50.3 | 19.800 | 9.920 | 81.700 | 50.300 |
| 3/1 | NP2-Low-B-Q | 3 | 2 | M31 | 38.8 | 20.9 | 56.0 | 46.3 | 64.668 | 34.834 | 93.335 | 77.168 |
| 3/1 | Neph-NN-1-12-Q | 3 | 3 | M49 | 81.1 | 33.2 | 115 | 39.8 | 135.169 | 55.334 | 191.671 | 66.335 |
| 3/1 | NP2-High-Si-Q | 3 | 4 | M22 | 28.1 | 14.2 | 31.2 | 47.0 | 46.834 | 23.667 | 52.001 | 78.335 |
| 3/1 | NP2-High-B-Q | 3 | 5 | M04 | 141 | 44.1 | 119 | 28.1 | 235.005 | 73.501 | 198.337 | 46.834 |
| 3/1 | NP2-Low-Si-Q | 3 | 6 | M29 | 103 | 35.8 | 123 | 3.35 | 171.670 | 59.668 | 205.004 | 5.583 |
| 3/1 | NP2-Low-Al-Q | 3 | 7 | M05 | 74.6 | 28.9 | 78.1 | 40.7 | 124.336 | 48.168 | 130.169 | 67.835 |
| 3/1 | NP2-High-Al-Q | 3 | 8 | M20 | 60.3 | 25.6 | 65.3 | 33.4 | 100.502 | 42.668 | 108.836 | 55.668 |
| 3/1 | NP-MC-AlB-1-Q | 3 | 9 | M13 | 176 | 51.2 | 137 | 31.0 | 293.339 | 85.335 | 228.338 | 51.668 |
| 3/1 | NP2-Low-Li-Q | 3 | 10 | M38 | 52.3 | 18.2 | 56.2 | 40.6 | 87.168 | 30.334 | 93.669 | 67.668 |
| 3/1 | soln std | 3 | 11 | std-M3-2 | 19.7 | 10.0 | 82.9 | 50.4 | 19.700 | 10.000 | 82.900 | 50.400 |
| 3/1 | NP2-Very-Low-Si-Q | 3 | 12 | M46 | 537 | 132 | 774 | 5.82 | 895.018 | 220.004 | 1290.026 | 9.700 |
| 3/1 | ARM-1 | 3 | 13 | M34 | 13.8 | 8.33 | 22.4 | 35.4 | 23.000 | 13.884 | 37.334 | 59.001 |
| 3/1 | NP2-Very-High-Al-Q | 3 | 14 | M27 | 69.3 | 27.3 | 72.1 | 30.8 | 115.502 | 45.501 | 120.169 | 51.334 |
| 3/1 | BL3-Q | 3 | 15 | M50 | 57.8 | 23.8 | 62.9 | 40.8 | 96.335 | 39.667 | 104.835 | 68.001 |
| 3/1 | NP2-High-Na-Q | 3 | 16 | M02 | 75.4 | 26.6 | 114 | 33.5 | 125.669 | 44.334 | 190.004 | 55.834 |
| 3/1 | NP2-Low-Na-Q | 3 | 17 | M08 | 40.2 | 20.1 | 29.3 | 47.2 | 67.001 | 33.501 | 48.834 | 78.668 |
| 3/1 | NP2-Very-High-Si-Q | 3 | 18 | M18 | 17.3 | 10.7 | 16.4 | 48.0 | 28.834 | 17.834 | 27.334 | 80.002 |
| 3/1 | NP2-High-Li-Q | 3 | 19 | M21 | 64.2 | 30.5 | 71.0 | 41.4 | 107.002 | 50.834 | 118.336 | 69.001 |
| 3/1 | blank | 3 | 20 | M09 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 3/1 | soln std | 3 | 21 | std-M3-3 | 19.8 | 10.1 | 83.6 | 50.5 | 19.800 | 10.100 | 83.600 | 50.500 |
| 3/2 | soln std | 1 | 1 | std-P1-1 | 20.6 | 10.3 | 82.6 | 51.6 | 20.600 | 10.300 | 82.600 | 51.600 |
| 3/2 | NP-MC-AlSi-2-Q | 1 | 2 | P37 | 21.8 | 14.7 | 20.4 | 47.4 | 36.334 | 24.500 | 34.001 | 79.002 |
| 3/2 | NP-MC-BSi-1-Q | 1 | 3 | P10 | 95.6 | 29.3 | 65.9 | 39.6 | 159.337 | 48.834 | 109.836 | 66.001 |
| 3/2 | NP-MC-AlLi-1-Q | 1 | 4 | P42 | 63.3 | 19.6 | 67.0 | 38.6 | 105.502 | 32.667 | 111.669 | 64.335 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/2 | NP-MC-AlNa-1-Q | 1 | 5 | P05 | 85.5 | 31.5 | 131 | 36.0 | 142.503 | 52.501 | 218.338 | 60.001 |
| 3/2 | NP-MC-AlBSi-1-Q | 1 | 6 | P48 | 108 | 30.1 | 77.3 | 29.5 | 180.004 | 50.168 | 128.836 | 49.168 |
| 3/2 | NP-MC-AlLi-2-Q | 1 | 7 | P07 | 45.8 | 18.1 | 52.2 | 33.3 | 76.335 | 30.167 | 87.002 | 55.501 |
| 3/2 | NP-MC-AlSi-1-Q | 1 | 8 | P31 | 149 | 56.5 | 183 | 28.2 | 248.338 | 94.169 | 305.006 | 47.001 |
| 3/2 | NP-MC-AlLiSi-1-Q | 1 | 9 | P15 | 163 | 40.6 | 197 | 21.7 | 271.672 | 67.668 | 328.340 | 36.167 |
| 3/2 | NP-MC-BNa-1-Q | 1 | 10 | P33 | 60.7 | 25.7 | 104 | 34.2 | 101.169 | 42.834 | 173.337 | 57.001 |
| 3/2 | soln std | 1 | 11 | std-P1-2 | 20.0 | 9.84 | 77.3 | 48.7 | 20.000 | 9.840 | 77.300 | 48.700 |
| 3/2 | NP-MC-AlBNa-1-Q | 1 | 12 | P49 | 24.9 | 16.5 | 27.0 | 52.2 | 41.501 | 27.501 | 45.001 | 87.002 |
| 3/2 | NP-MC-BNaSi-1-Q | 1 | 13 | P36 | 71.4 | 35.4 | 150 | 28.8 | 119.002 | 59.001 | 250.005 | 48.001 |
| 3/2 | NP-MC-BLiSi-1-Q | 1 | 14 | P44 | 25.6 | 18.2 | 37.2 | 53.4 | 42.668 | 30.334 | 62.001 | 89.002 |
| 3/2 | NP-MC-AlLiNa-1-Q | 1 | 15 | P19 | 82.6 | 40.3 | 146 | 32.0 | 137.669 | 67.168 | 243.338 | 53.334 |
| 3/2 | blank | 1 | 16 | P32 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |
| 3/2 | NP-MC-BLiSi-2-Q | 1 | 17 | P28 | 211 | 71.1 | 174 | 24.7 | 351.674 | 118.502 | 290.006 | 41.167 |
| 3/2 | ARM-1 | 1 | 18 | P16 | 11.4 | 8.64 | 21.9 | 37.2 | 19.000 | 14.400 | 36.501 | 62.001 |
| 3/2 | NP-MC-AlBNa-2-Q | 1 | 19 | P04 | 120 | 36.9 | 149 | 22.6 | 200.004 | 61.501 | 248.338 | 37.667 |
| 3/2 | soln std | 1 | 20 | std-P1-3 | 20.0 | 9.79 | 76.6 | 48.4 | 20.000 | 9.790 | 76.600 | 48.400 |
| 3/2 | soln std | 2 | 1 | std-P2-1 | 21.3 | 10.3 | 84.8 | 50.9 | 21.300 | 10.300 | 84.800 | 50.900 |
| 3/2 | NP-MC-AlLi-2-Q | 2 | 2 | P27 | 51.3 | 19.2 | 55.4 | 34.5 | 85.502 | 32.001 | 92.335 | 57.501 |
| 3/2 | NP-MC-BNa-1-Q | 2 | 3 | P03 | 66.5 | 27.6 | 104 | 36.8 | 110.836 | 46.001 | 173.337 | 61.335 |
| 3/2 | NP-MC-AlNa-1-Q | 2 | 4 | P12 | 87.8 | 31.3 | 123 | 36.1 | 146.336 | 52.168 | 205.004 | 60.168 |
| 3/2 | NP-MC-BNaSi-1-Q | 2 | 5 | P46 | 76.0 | 37.2 | 148 | 29.5 | 126.669 | 62.001 | 246.672 | 49.168 |
| 3/2 | NP-MC-AlLiSi-1-Q | 2 | 6 | P40 | 167 | 42.8 | 198 | 20.9 | 278.339 | 71.335 | 330.007 | 34.834 |
| 3/2 | NP-MC-AlSi-2-Q | 2 | 7 | P25 | 22.6 | 14.8 | 20.5 | 46.3 | 37.667 | 24.667 | 34.167 | 77.168 |
| 3/2 | NP-MC-AlLiNa-1-Q | 2 | 8 | P45 | 83.1 | 40.8 | 144 | 30.9 | 138.503 | 68.001 | 240.005 | 51.501 |
| 3/2 | NP-MC-AlSi-1-Q | 2 | 9 | P34 | 164 | 62.0 | 195 | 29.4 | 273.339 | 103.335 | 325.007 | 49.001 |
| 3/2 | ARM-1 | 2 | 10 | P30 | 11.7 | 8.61 | 22.4 | 37.3 | 19.500 | 14.350 | 37.334 | 62.168 |
| 3/2 | soln std | 2 | 11 | std-P2-2 | 20.9 | 10.1 | 81.8 | 49.8 | 20.900 | 10.100 | 81.800 | 49.800 |
| 3/2 | NP-MC-BLiSi-2-Q | 2 | 12 | P26 | 208 | 74.1 | 166 | 24.3 | 346.674 | 123.502 | 276.672 | 40.501 |
| 3/2 | NP-MC-AlBNa-2-Q | 2 | 13 | P43 | 131 | 39.5 | 149 | 22.9 | 218.338 | 65.835 | 248.338 | 38.167 |
| 3/2 | NP-MC-BSi-1-Q | 2 | 14 | P21 | 95.3 | 28.8 | 64.7 | 35.4 | 158.837 | 48.001 | 107.835 | 59.001 |
| 3/2 | NP-MC-BLiSi-1-Q | 2 | 15 | P06 | 25.7 | 18.0 | 36.4 | 51.1 | 42.834 | 30.001 | 60.668 | 85.168 |
| 3/2 | NP-MC-AlBSi-1-Q | 2 | 16 | P41 | 110 | 30.3 | 78.6 | 28.4 | 183.337 | 50.501 | 131.003 | 47.334 |
| 3/2 | NP-MC-AlBNa-1-Q | 2 | 17 | P24 | 26.5 | 17.1 | 28.0 | 52.0 | 44.168 | 28.501 | 46.668 | 86.668 |
| 3/2 | NP-MC-AlLi-1-Q | 2 | 18 | P35 | 65.6 | 19.8 | 67.6 | 37.4 | 109.336 | 33.001 | 112.669 | 62.335 |
| 3/2 | soln std | 2 | 19 | std-P2-3 | 21.2 | 10.0 | 81.4 | 48.9 | 21.200 | 10.000 | 81.400 | 48.900 |
| 3/2 | soln std | 3 | 1 | std-P3-1 | 19.8 | 9.81 | 79.2 | 48.3 | 19.800 | 9.810 | 79.200 | 48.300 |
| 3/2 | NP-MC-AlLi-1-Q | 3 | 2 | P39 | 64.2 | 19.7 | 67.5 | 38.8 | 107.002 | 32.834 | 112.502 | 64.668 |
| 3/2 | NP-MC-AlBNa-2-Q | 3 | 3 | P38 | 125 | 38.5 | 145 | 23.0 | 208.338 | 64.168 | 241.672 | 38.334 |
| 3/2 | NP-MC-AlLiNa-1-Q | 3 | 4 | P22 | 81.0 | 40.1 | 140 | 30.5 | 135.003 | 66.835 | 233.338 | 50.834 |
| 3/2 | ARM-1 | 3 | 5 | P01 | 10.0 | 8.10 | 21.2 | 34.0 | 16.667 | 13.500 | 35.334 | 56.668 |
| 3/2 | NP-MC-AlNa-1-Q | 3 | 6 | P29 | 84.6 | 30.7 | 121 | 33.2 | 141.003 | 51.168 | 201.671 | 55.334 |
| 3/2 | blank | 3 | 7 | P14 | <1.00 | <1.00 | <1.00 | <1.00 | <1.667 | <1.667 | <1.667 | <1.667 |

**Table B-1. PCT Measurements for the Nepheline Study Glasses (ar – as received) (continued)**

| Group/Set | Glass ID (w HT) | Block | Seq | Lab ID | B ar | Li ar | Na ar | Si ar | B (mg/L) | Li (mg/L) | Na (mg/L) | Si (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/2 | NP-MC-AlBNa-1-Q | 3 | 8 | P09 | 24.1 | 16.4 | 27.3 | 47.5 | 40.167 | 27.334 | 45.501 | 79.168 |
| 3/2 | NP-MC-AlSi-2-Q | 3 | 9 | P18 | 21.7 | 14.6 | 20.6 | 43.6 | 36.167 | 24.334 | 34.334 | 72.668 |
| 3/2 | NP-MC-BLiSi-2-Q | 3 | 10 | P08 | 206 | 74.4 | 168 | 22.5 | 343.340 | 124.002 | 280.006 | 37.501 |
| 3/2 | soln std | 3 | 11 | std-P3-2 | 19.8 | 9.75 | 79.6 | 45.1 | 19.800 | 9.750 | 79.600 | 45.100 |
| 3/2 | NP-MC-BNaSi-1-Q | 3 | 12 | P11 | 77.4 | 37.5 | 153 | 27.4 | 129.003 | 62.501 | 255.005 | 45.668 |
| 3/2 | NP-MC-BSi-1-Q | 3 | 13 | P50 | 97.1 | 29.4 | 66.6 | 34.3 | 161.837 | 49.001 | 111.002 | 57.168 |
| 3/2 | NP-MC-AlLi-2-Q | 3 | 14 | P20 | 50.6 | 19.0 | 55.7 | 29.7 | 84.335 | 31.667 | 92.835 | 49.501 |
| 3/2 | NP-MC-AlBSi-1-Q | 3 | 15 | P02 | 111 | 30.6 | 80.4 | 25.5 | 185.004 | 51.001 | 134.003 | 42.501 |
| 3/2 | NP-MC-BNa-1-Q | 3 | 16 | P23 | 63.8 | 26.7 | 101 | 31.0 | 106.335 | 44.501 | 168.337 | 51.668 |
| 3/2 | NP-MC-BLiSi-1-Q | 3 | 17 | P47 | 26.5 | 18.2 | 36.9 | 49.4 | 44.168 | 30.334 | 61.501 | 82.335 |
| 3/2 | NP-MC-AlSi-1-Q | 3 | 18 | P17 | 155 | 59.1 | 184 | 24.7 | 258.339 | 98.502 | 306.673 | 41.167 |
| 3/2 | NP-MC-AlLiSi-1-Q | 3 | 19 | P13 | 169 | 42.6 | 198 | 17.3 | 281.672 | 71.001 | 330.007 | 28.834 |
| 3/2 | soln std | 3 | 20 | std-P3-3 | 20.9 | 10.0 | 81.6 | 45.0 | 20.900 | 10.000 | 81.600 | 45.000 |

**Table B-2. Group 1, Set 1 PCT Leachate pH Values for the Nepheline Glasses**

| Identifier | pH | | Identifier | pH |
|---|---|---|---|---|
| BLANK-1 | 6.98 | | NP2-High-Si-CCC-1 | 9.29 |
| BLANK-2 | 6.91 | | NP2-High-Si-CCC-2 | 9.30 |
| ARM-1-1 | 10.16 | | NP2-High-Si-CCC-3 | 9.30 |
| ARM-1-2 | 10.15 | | NP2-Low-Al-CCC-1 | 9.31 |
| ARM-1-3 | 10.14 | | NP2-Low-Al-CCC-2 | 9.29 |
| BL3-CCC-1 | 9.31 | | NP2-Low-Al-CCC-3 | 9.31 |
| BL3-CCC-2 | 9.31 | | NP2-Low-B-CCC-1 | 9.67 |
| BL3-CCC-3 | 9.32 | | NP2-Low-B-CCC-2 | 9.70 |
| Neph-NN-1-12-CCC-1 | 9.93 | | NP2-Low-B-CCC-3 | 9.70 |
| Neph-NN-1-12-CCC-2 | 9.81 | | NP2-Low-Li-CCC-1 | 9.22 |
| Neph-NN-1-12-CCC-3 | 9.94 | | NP2-Low-Li-CCC-2 | 9.17 |
| NP2-High-Al-CCC-1 | 9.30 | | NP2-Low-Li-CCC-3 | 9.15 |
| NP2-High-Al-CCC-2 | 9.28 | | NP2-Low-Na-CCC-1 | 9.21 |
| NP2-High-Al-CCC-3 | 9.28 | | NP2-Low-Na-CCC-2 | 9.19 |
| Np2-High-B-CCC-1 | 9.28 | | NP2-Low-Na-CCC-3 | 9.18 |
| Np2-High-B-CCC-2 | 9.27 | | NP2-Low-Si-CCC-1 | 9.49 |
| Np2-High-B-CCC-3 | 9.25 | | NP2-Low-Si-CCC-2 | 9.50 |
| NP2-High-Li-CCC-1 | 9.70 | | NP2-Low-Si-CCC-3 | 9.49 |
| NP2-High-Li-CCC-2 | 9.71 | | NP2-Very-High-Al-CCC-1 | 9.37 |
| NP2-High-Li-CCC-3 | 9.72 | | NP2-Very-High-Al-CCC-2 | 9.39 |
| NP2-High-Na-CCC-1 | 9.87 | | NP2-Very-High-Al-CCC-3 | 9.39 |
| NP2-High-Na-CCC-2 | 9.88 | | NP2-Very-Low-Si-CCC-1 | 10.18 |
| NP2-High-Na-CCC-3 | 9.88 | | NP2-Very-Low-Si-CCC-2 | 10.20 |
| | | | NP2-Very-Low-Si-CCC-3 | 10.20 |

**Table B-3. Group 1, Set 2 PCT Leachate pH Values for the Nepheline Glasses**

| Identifier | pH | | Identifier | pH |
|---|---|---|---|---|
| BLANK-1 | 8.57 | | NP-MC-AlLiSi-1-CCC-1 | 9.49 |
| BLANK-2 | 8.15 | | NP-MC-AlLiSi-1-CCC-2 | 9.47 |
| ARM-1-1 | 10.24 | | NP-MC-AlLiSi-1-CCC-3 | 9.46 |
| ARM-1-2 | 10.26 | | NP-MC-AlNa-1-CCC-1 | 9.93 |
| ARM-1-3 | 10.25 | | NP-MC-AlNa-1-CCC-2 | 9.93 |
| NP-MC-AlBNa-1-CCC-1 | 9.34 | | NP-MC-AlNa-1-CCC-3 | 9.93 |
| NP-MC-AlBNa-1-CCC-2 | 9.28 | | NP-MC-AlSi-1-CCC-1 | 9.98 |
| NP-MC-AlBNa-1-CCC-3 | 9.28 | | NP-MC-AlSi-1-CCC-2 | 9.96 |
| NP-MC-AlBNa-2-CCC-1 | 9.50 | | NP-MC-AlSi-1-CCC-3 | 9.97 |
| NP-MC-AlBNa-2-CCC-2 | 9.51 | | NP-MC-AlSi-2-CCC-1 | 9.24 |
| NP-MC-AlBNa-2-CCC-3 | 9.50 | | NP-MC-AlSi-2-CCC-2 | 9.23 |
| NP-MC-AlBSi-1-CCC-1 | 9.32 | | NP-MC-AlSi-2-CCC-3 | 9.17 |
| NP-MC-AlBSi-1-CCC-2 | 9.30 | | NP-MC-BLiSi-1-CCC-1 | 9.71 |
| NP-MC-AlBSi-1-CCC-3 | 9.34 | | NP-MC-BLiSi-1-CCC-2 | 9.76 |
| NP-MC-AlLi-1-CCC-1 | 9.25 | | NP-MC-BLiSi-1-CCC-3 | 9.76 |
| NP-MC-AlLi-1-CCC-2 | 9.26 | | NP-MC-BNa-1-CCC-1 | 10.16 |
| NP-MC-AlLi-1-CCC-3 | 9.24 | | NP-MC-BNa-1-CCC-2 | 10.17 |
| NP-MC-AlLi-2-CCC-1 | 9.27 | | NP-MC-BNa-1-CCC-3 | 10.19 |
| NP-MC-AlLi-2-CCC-2 | 9.29 | | NP-MC-BNaSi-1-CCC-1 | 11.07 |
| NP-MC-AlLi-2-CCC-3 | 9.29 | | NP-MC-BNaSi-1-CCC-2 | 11.06 |
| NP-MC-AlLiNa-1-CCC-1 | 10.93 | | NP-MC-BNaSi-1-CCC-3 | 11.09 |
| NP-MC-AlLiNa-1-CCC-2 | 10.95 | | | |
| NP-MC-AlLiNa-1-CCC-3 | 10.96 | | | |

**Table B-4. Group 2 PCT Leachate pH Values for the Nepheline Glasses**

| Identifier | pH |
|---|---|
| blank-1 | 6.76 |
| blank-2 | 6.07 |
| ARM-1-1 | 10.14 |
| ARM-1-2 | 10.31 |
| ARM-1-3 | 10.29 |
| NP2-Very-High-Si-CCC-1 | 9.28 |
| NP2-Very-High-Si-CCC-2 | 9.21 |
| NP2-Very-High-Si-CCC-3 | 9.22 |
| NP-MC-AlB-1-CCC-1 | 9.55 |
| NP-MC-AlB-1-CCC-2 | 9.54 |
| NP-MC-AlB-1-CCC-3 | 9.54 |
| NP-MC-BLiSi-2-CCC-1 | 9.72 |
| NP-MC-BLiSi-2-CCC-2 | 9.73 |
| NP-MC-BLiSi-2-CCC-3 | 9.73 |
| NP-MC-Bsi-1-CCC-1 | 9.42 |
| NP-MC-Bsi-1-CCC-2 | 9.42 |
| NP-MC-Bsi-1-CCC-3 | 9.40 |
| NP-MC-AlBNa-1-CCC-1 | 9.39 |
| NP-MC-AlBNa-1-CCC-2 | 9.44 |
| NP-MC-AlBNa-1-CCC-3 | 9.41 |
| NP-MC-AlLi-2-CCC-1 | 9.41 |
| NP-MC-AlLi-2-CCC-2 | 9.44 |
| NP-MC-AlLi-2-CCC-3 | 9.45 |
| NP-MC-AlNa-1-CCC-1 | 10.05 |
| NP-MC-AlNa-1-CCC-2 | 10.08 |
| NP-MC-AlNa-1-CCC-3 | 10.07 |

**Table B-5. Group 3, Set 1 PCT Leachate pH Values for the Nepheline Glasses**

| Identifier | pH | Identifier | pH |
|---|---|---|---|
| BLANK-1 | 6.65 | NP2-Low-Al-Q-1 | 9.70 |
| BLANK-2 | 6.24 | NP2-Low-Al-Q-2 | 9.70 |
| ARM-1-1 | 10.33 | NP2-Low-Al-Q-3 | 9.67 |
| ARM-1-2 | 10.21 | NP2-Low-B-Q-1 | 9.55 |
| ARM-1-3 | 10.21 | NP2-Low-B-Q-2 | 9.52 |
| BL3-Q-1 | 9.48 | NP2-Low-B-Q-3 | 9.49 |
| BL3-Q-2 | 9.46 | NP2-Low-Li-Q-1 | 9.40 |
| BL3-Q-3 | 9.46 | NP2-Low-Li-Q-2 | 9.43 |
| Neph-NN-1-12-Q-1 | 10.41 | NP2-Low-Li-Q-3 | 9.45 |
| Neph-NN-1-12-Q-2 | 10.47 | NP2-Low-Na-Q-1 | 9.40 |
| Neph-NN-1-12-Q-3 | 10.45 | NP2-Low-Na-Q-2 | 9.40 |
| NP2-High-Al-Q-1 | 9.60 | NP2-Low-Na-Q-3 | 9.41 |
| NP2-High-Al-Q-2 | 9.55 | NP2-Low-Si-Q-1 | 9.77 |
| NP2-High-Al-Q-3 | 9.54 | NP2-Low-Si-Q-2 | 9.78 |
| NP2-High-B-Q-1 | 9.41 | NP2-Low-Si-Q-3 | 9.78 |
| NP2-High-B-Q-2 | 9.40 | NP2-Very-High-Al-Q-1 | 9.60 |
| NP2-High-B-Q-3 | 9.42 | NP2-Very-High-Al-Q-2 | 9.55 |
| NP2-High-Li-Q-1 | 9.71 | NP2-Very-High-Al-Q-3 | 9.55 |
| NP2-High-Li-Q-2 | 9.71 | NP2-Very-High-Si-Q-1 | 9.06 |
| NP2-High-Li-Q-3 | 9.70 | NP2-Very-High-Si-Q-2 | 9.00 |
| NP2-High-Na-Q-1 | 10.05 | NP2-Very-High-Si-Q-3 | 9.02 |
| NP2-High-Na-Q-2 | 10.05 | NP2-Very-Low-Si-Q-1 | 10.76 |
| NP2-High-Na-Q-3 | 10.04 | NP2-Very-Low-Si-Q-2 | 10.78 |
| NP2-High-Si-Q-1 | 9.30 | NP2-Very-Low-Si-Q-3 | 10.79 |
| NP2-High-Si-Q-2 | 9.22 | NP-MC-AlB-1-Q-1 | 9.48 |
| NP2-High-Si-Q-3 | 9.17 | NP-MC-AlB-1-Q-2 | 9.47 |
| | | NP-MC-AlB-1-Q-3 | 9.49 |

**Table B-6. Group 3, Set 2 PCT Leachate pH Values for the Nepheline Glasses**

| Identifier | pH | | Identifier | pH |
|---|---|---|---|---|
| BLANK-1 | 6.71 | | NP-MC-AlNa-1-Q-1 | 10.16 |
| BLANK-2 | 6.08 | | NP-MC-AlNa-1-Q-2 | 10.14 |
| ARM-1-1 | 10.02 | | NP-MC-AlNa-1-Q-3 | 10.11 |
| ARM-1-2 | 10.02 | | NP-MC-AlSi-1-Q-1 | 10.06 |
| ARM-1-3 | 10.00 | | NP-MC-AlSi-1-Q-2 | 10.07 |
| NP-MC-AlBNa-1-Q-1 | 9.22 | | NP-MC-AlSi-1-Q-3 | 10.09 |
| NP-MC-AlBNa-1-Q-2 | 9.27 | | NP-MC-AlSi-2-Q-1 | 9.25 |
| NP-MC-AlBNa-1-Q-3 | 9.26 | | NP-MC-AlSi-2-Q-2 | 9.23 |
| NP-MC-AlBNa-2-Q-1 | 9.51 | | NP-MC-AlSi-2-Q-3 | 9.22 |
| NP-MC-AlBNa-2-Q-2 | 9.49 | | NP-MC-BLiSi-1-Q-1 | 9.65 |
| NP-MC-AlBNa-2-Q-3 | 9.51 | | NP-MC-BLiSi-1-Q-2 | 9.67 |
| NP-MC-AlBSi-1-Q-1 | 9.20 | | NP-MC-BLiSi-1-Q-3 | 9.64 |
| NP-MC-AlBSi-1-Q-2 | 9.22 | | NP-MC-BLiSi-2-Q-1 | 9.52 |
| NP-MC-AlBSi-1-Q-3 | 9.21 | | NP-MC-BLiSi-2-Q-2 | 9.54 |
| NP-MC-AlLi-1-Q-1 | 9.30 | | NP-MC-BLiSi-2-Q-3 | 9.54 |
| NP-MC-AlLi-1-Q-2 | 9.32 | | NP-MC-BNa-1-Q-1 | 9.84 |
| NP-MC-AlLi-1-Q-3 | 9.33 | | NP-MC-BNa-1-Q-2 | 9.84 |
| NP-MC-AlLi-2-Q-1 | 9.35 | | NP-MC-BNa-1-Q-3 | 9.85 |
| NP-MC-AlLi-2-Q-2 | 9.34 | | NP-MC-BNaSi-1-Q-1 | 9.96 |
| NP-MC-AlLi-2-Q-3 | 9.32 | | NP-MC-BNaSi-1-Q-2 | 9.97 |
| NP-MC-AlLiNa-1-Q-1 | 9.90 | | NP-MC-BNaSi-1-Q-3 | 9.95 |
| NP-MC-AlLiNa-1-Q-2 | 9.93 | | NP-MC-BSi-1-Q-1 | 9.25 |
| NP-MC-AlLiNa-1-Q-3 | 9.94 | | NP-MC-BSi-1-Q-2 | 9.26 |
| NP-MC-AlLiSi-1-Q-1 | 9.55 | | NP-MC-BSi-1-Q-3 | 9.24 |
| NP-MC-AlLiSi-1-Q-2 | 9.55 | | | |
| NP-MC-AlLiSi-1-Q-3 | 9.55 | | | |

**Table B-7. Results from Samples of the Multi-Element Solution Standard for the Group 1 PCTs**

| Set | 1 | | | 2 | | | Reference values (mg/L) |
|---|---|---|---|---|---|---|---|
| **Block** | **1** | **2** | **3** | **1** | **2** | **3** | |
| **Mean (B (ppm))** | 19.43 | 20.87 | 18.60 | 20.73 | 19.90 | 21.23 | 20 |
| **Mean (Li (ppm))** | 9.78 | 9.74 | 9.72 | 9.82 | 9.51 | 10.03 | 10 |
| **Mean (Na (ppm))** | 79.77 | 78.63 | 79.17 | 82.03 | 82.13 | 82.40 | 81 |
| **Mean (Si (ppm))** | 49.07 | 48.73 | 48.97 | 51.03 | 51.07 | 51.80 | 50 |
| **% relative bias, B** | -2.8% | 4.3% | -7.0% | 3.7% | -0.5% | 6.2% | <10% per ASTM C 1285 |
| **% relative bias, Li** | -2.2% | -2.6% | -2.8% | -1.8% | -4.9% | 0.3% | |
| **% relative bias, Na** | -1.5% | -2.9% | -2.3% | 1.3% | 1.4% | 1.7% | |
| **% relative bias, Si** | -1.9% | -2.5% | -2.1% | 2.1% | 2.1% | 3.6% | |
| **Std Dev (B (ppm))** | 0.416 | 1.193 | 0.173 | 0.153 | 0.624 | 0.896 | |
| **Std Dev (Li (ppm))** | 0.050 | 0.112 | 0.075 | 0.021 | 0.057 | 0.157 | |
| **Std Dev (Na (ppm))** | 0.306 | 1.629 | 1.436 | 0.737 | 0.737 | 2.464 | |
| **Std Dev (Si (ppm))** | 0.208 | 0.473 | 0.569 | 0.115 | 0.379 | 1.136 | |
| **%RSD (B (ppm))** | 2.1% | 5.7% | 0.9% | 0.7% | 3.1% | 4.2% | <10% per ASTM C 1285 |
| **%RSD (Li (ppm))** | 0.5% | 1.2% | 0.8% | 0.2% | 0.6% | 1.6% | |
| **%RSD (Na (ppm))** | 0.4% | 2.1% | 1.8% | 0.9% | 0.9% | 3.0% | |
| **%RSD (Si (ppm))** | 0.4% | 1.0% | 1.2% | 0.2% | 0.7% | 2.2% | |

**Table B-8. Results from Samples of the Multi-Element Solution Standard for the Group 2 PCTs**

| Block | 1 | 2 | 3 | Reference values (mg/L) |
|---|---|---|---|---|
| **Mean (B (mg/L))** | 20.57 | 18.80 | 20.30 | 20 |
| **Mean (Li (mg/L))** | 10.27 | 9.79 | 9.88 | 10 |
| **Mean (Na (mg/L))** | 84.20 | 80.57 | 81.30 | 81 |
| **Mean (Si (mg/L))** | 49.30 | 46.93 | 48.37 | 50 |
| **% relavtive bias, B** | 2.8% | -6.0% | 1.5% | <10% per ASTM C 1285 |
| **% relavtive bias, Li** | 2.7% | -2.1% | -1.2% | |
| **% relavtive bias, Na** | 4.0% | -0.5% | 0.4% | |
| **% relavtive bias, Si** | -1.4% | -6.1% | -3.3% | |
| **Std Dev (B (mg/L))** | 1.150 | 0.346 | 1.153 | |
| **Std Dev (Li (mg/L))** | 0.306 | 0.006 | 0.107 | |
| **Std Dev (Na (mg/L))** | 1.873 | 0.493 | 0.917 | |
| **Std Dev (Si (mg/L))** | 1.400 | 0.306 | 0.643 | |
| **%RSD (B (mg/L))** | 5.6% | 1.8% | 5.7% | <10% per ASTM C 1285 |
| **%RSD (Li (mg/L))** | 3.0% | 0.1% | 1.1% | |
| **%RSD (Na (mg/L))** | 2.2% | 0.6% | 1.1% | |
| **%RSD (Si (mg/L))** | 2.8% | 0.7% | 1.3% | |

**Table B-9. Results from Samples of the Multi-Element Solution Standard for the Group 3 PCTs**

| Set | 1 | | | 2 | | | Reference values (mg/L) |
|---|---|---|---|---|---|---|---|
| Block | 1 | 2 | 3 | 1 | 2 | 3 | |
| Mean (B (mg/L)) | 20.93 | 20.53 | 19.77 | 20.20 | 21.13 | 20.17 | 20 |
| Mean (Li (mg/L)) | 10.23 | 10.20 | 10.01 | 9.98 | 10.13 | 9.85 | 10 |
| Mean (Na (mg/L)) | 83.97 | 83.30 | 82.73 | 78.83 | 82.67 | 80.13 | 81 |
| Mean (Si (mg/L)) | 52.13 | 51.53 | 50.40 | 49.57 | 49.87 | 46.13 | 50 |
| % relative bias, B | 4.7% | 2.7% | -1.2% | 1.0% | 5.7% | 0.8% | <10% per ASTM C 1285 |
| % relative bias, Li | 2.3% | 2.0% | 0.1% | -0.2% | 1.3% | -1.5% | |
| % relative bias, Na | 3.7% | 2.8% | 2.1% | -2.7% | 2.1% | -1.1% | |
| % relative bias, Si | 4.3% | 3.1% | 0.8% | -0.9% | -0.3% | -7.7% | |
| Std Dev (B (mg/L)) | 0.153 | 0.321 | 0.058 | 0.346 | 0.208 | 0.635 | |
| Std Dev (Li (mg/L)) | 0.058 | 0.000 | 0.090 | 0.281 | 0.153 | 0.131 | |
| Std Dev (Na (mg/L)) | 0.231 | 0.529 | 0.961 | 3.281 | 1.858 | 1.286 | |
| Std Dev (Si (mg/L)) | 0.651 | 0.451 | 0.100 | 1.767 | 1.002 | 1.877 | |
| %RSD (B (mg/L)) | 0.7% | 1.6% | 0.3% | 1.7% | 1.0% | 3.1% | <10% per ASTM C 1285 |
| %RSD (Li (mg/L)) | 0.6% | 0.0% | 0.9% | 2.8% | 1.5% | 1.3% | |
| %RSD (Na (mg/L)) | 0.3% | 0.6% | 1.2% | 4.2% | 2.2% | 1.6% | |
| %RSD (Si (mg/L)) | 1.2% | 0.9% | 0.2% | 3.6% | 2.0% | 4.1% | |

**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set**

**Group/Set=1/1, Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

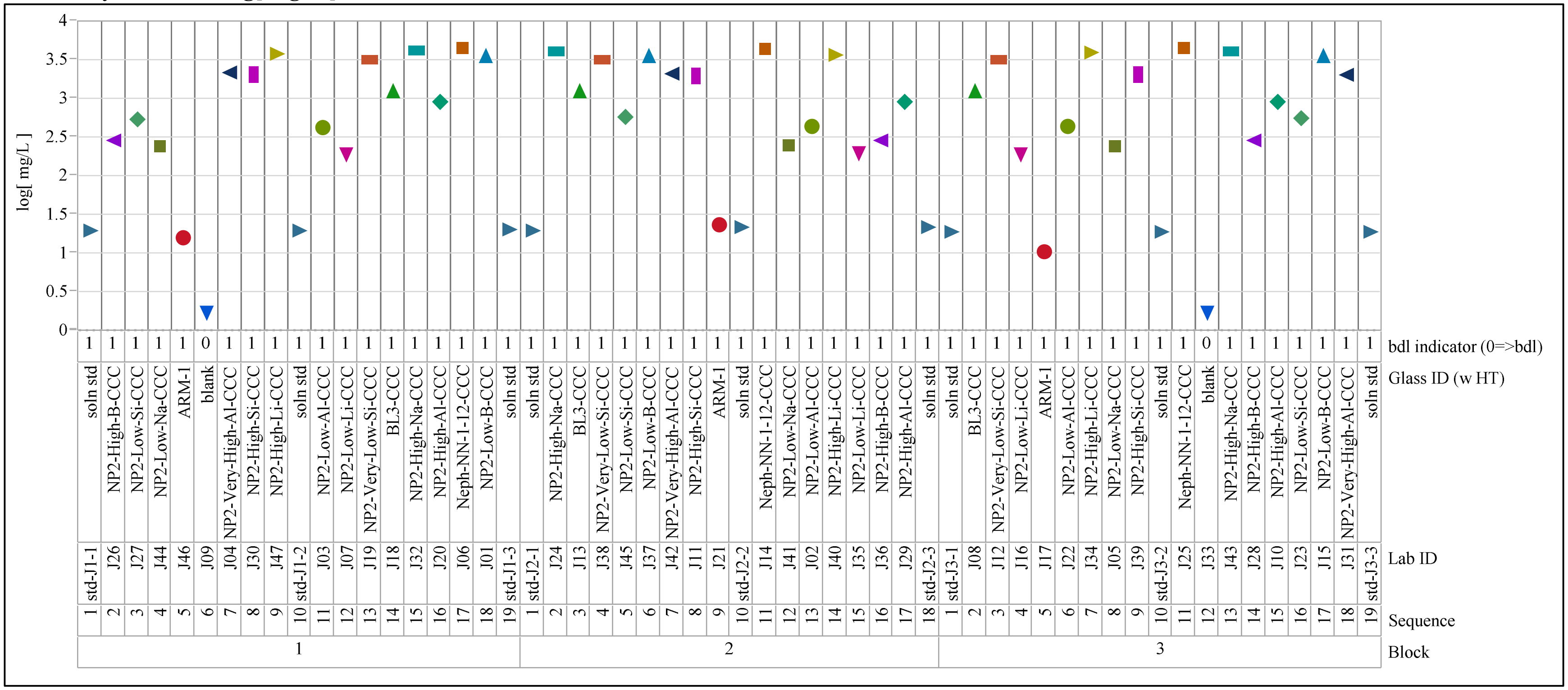


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/1, Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

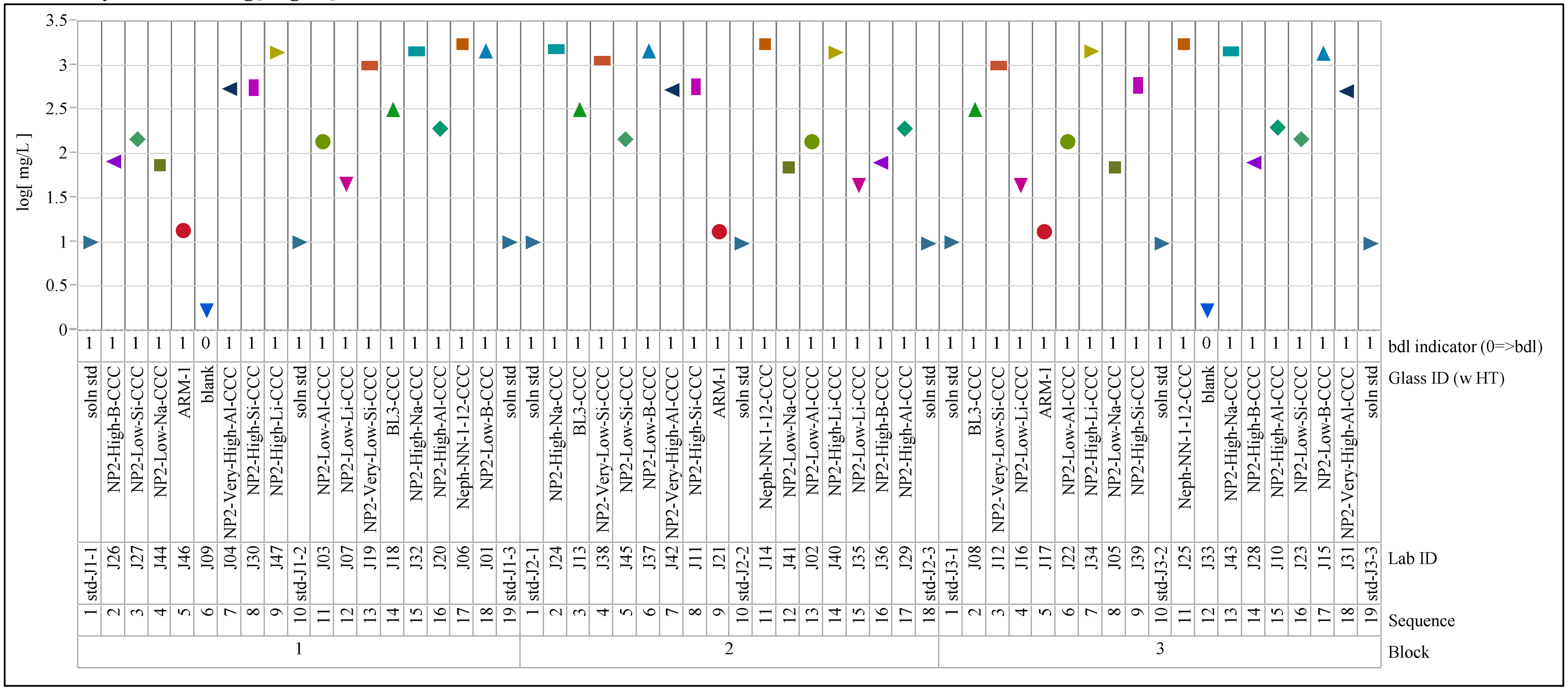


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/1, Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

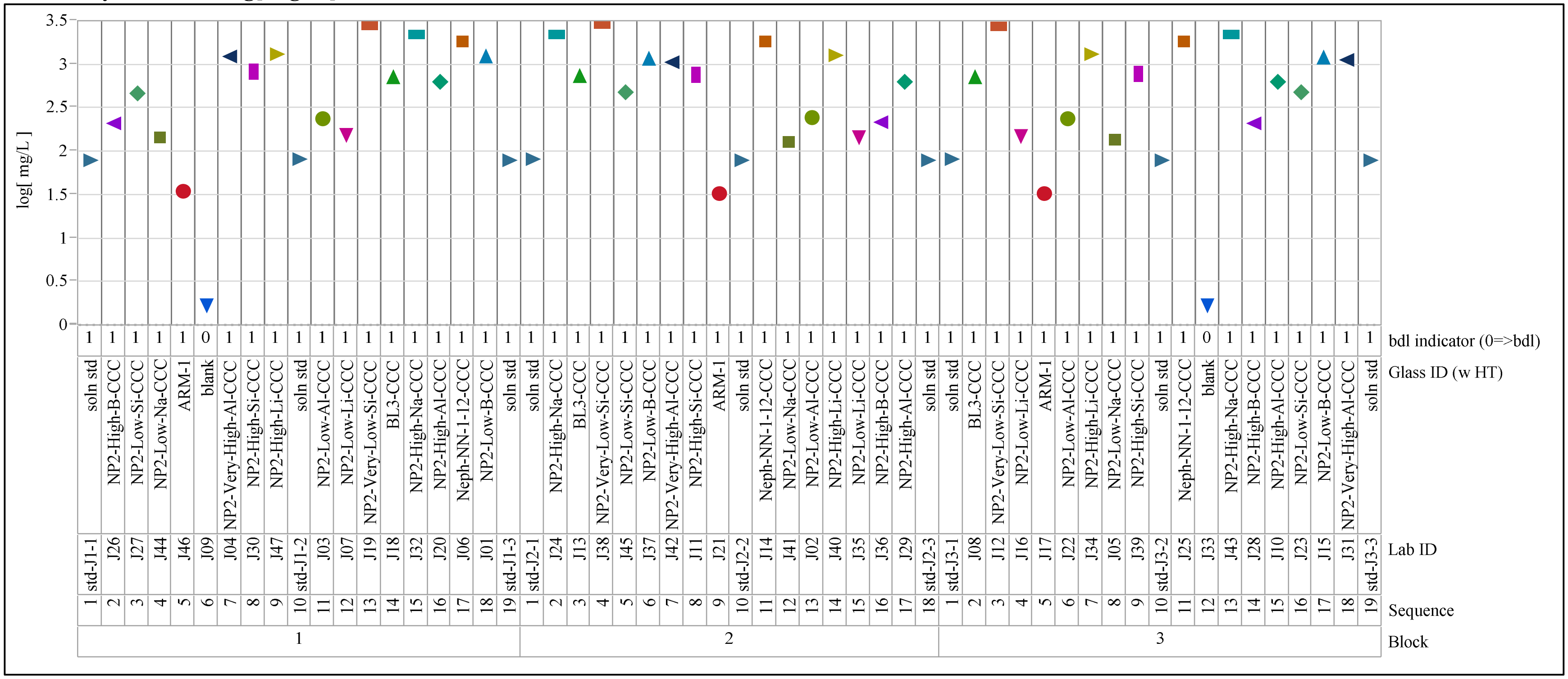


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/1, Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

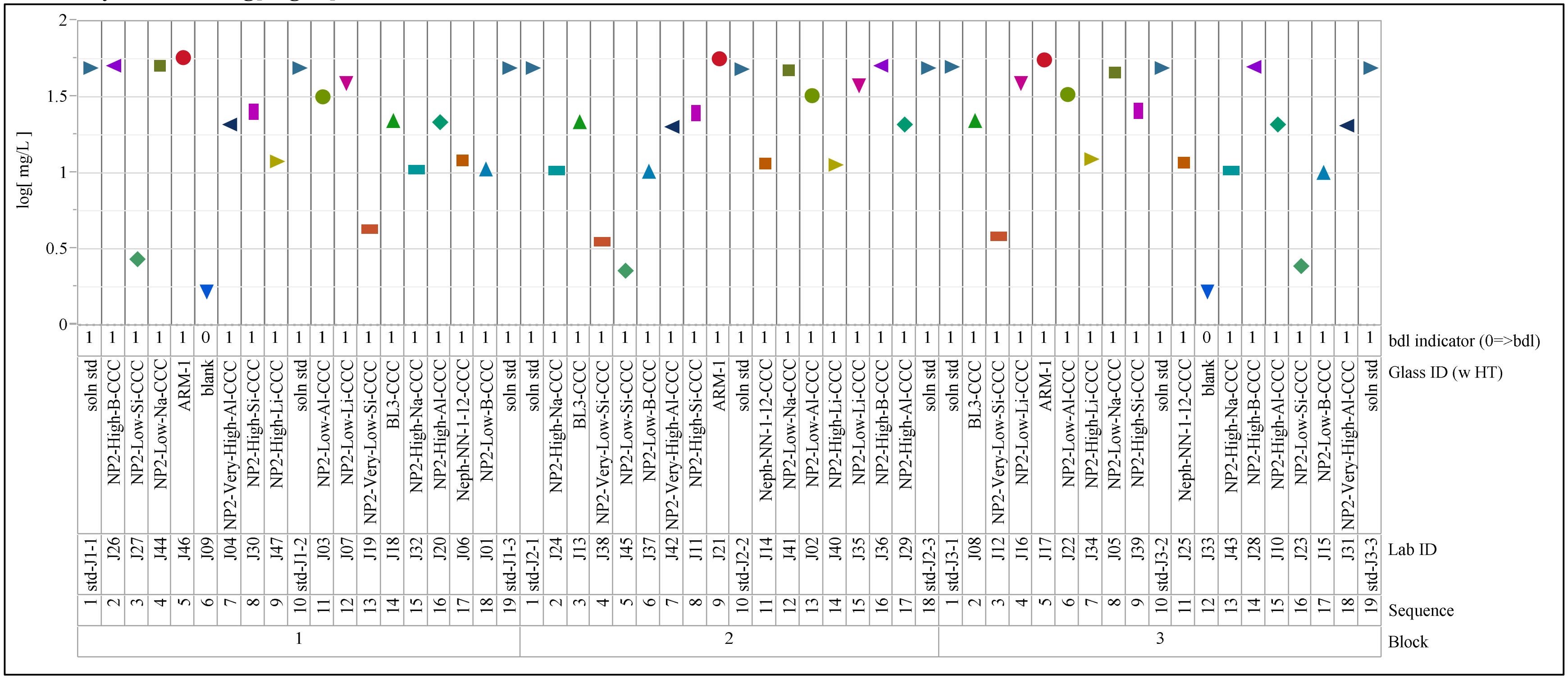


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/2, Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

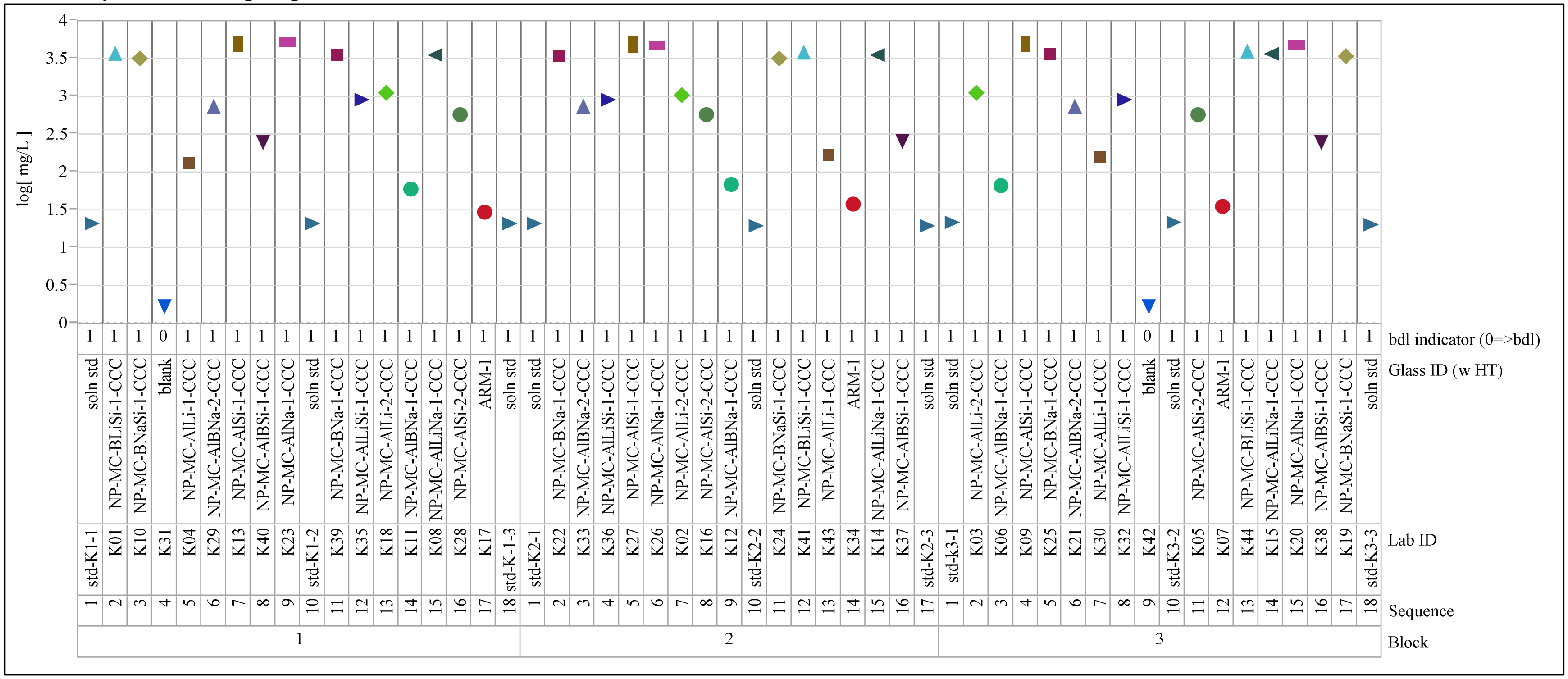


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/2, Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

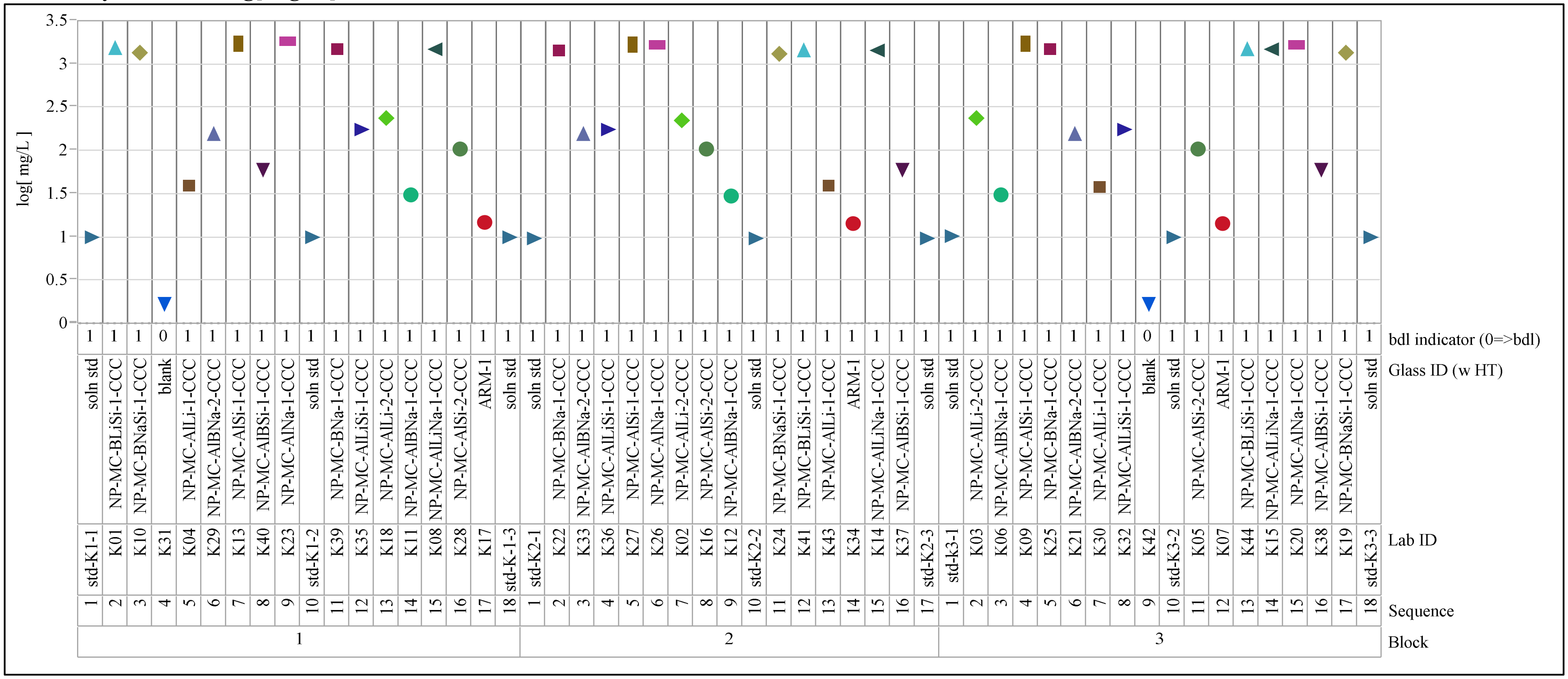


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/2, Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

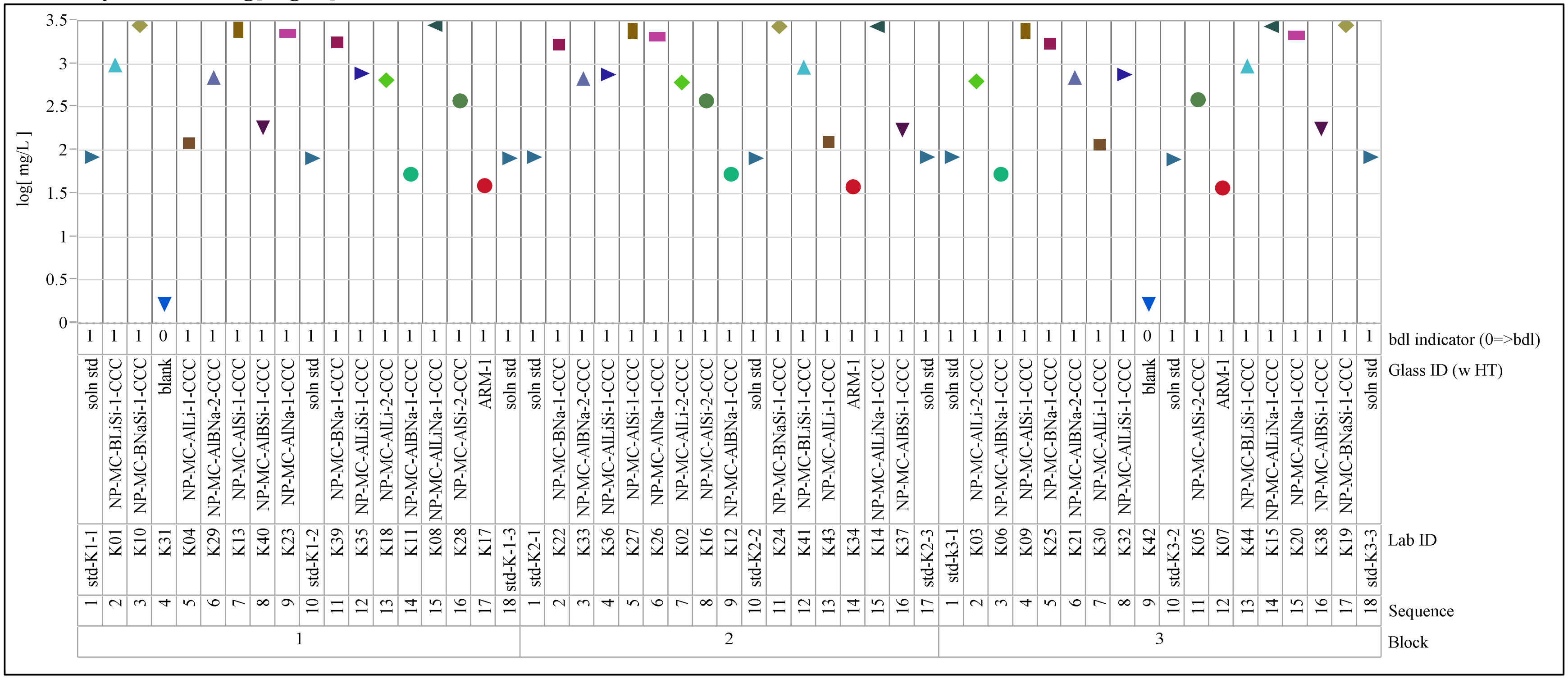


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=1/2, Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

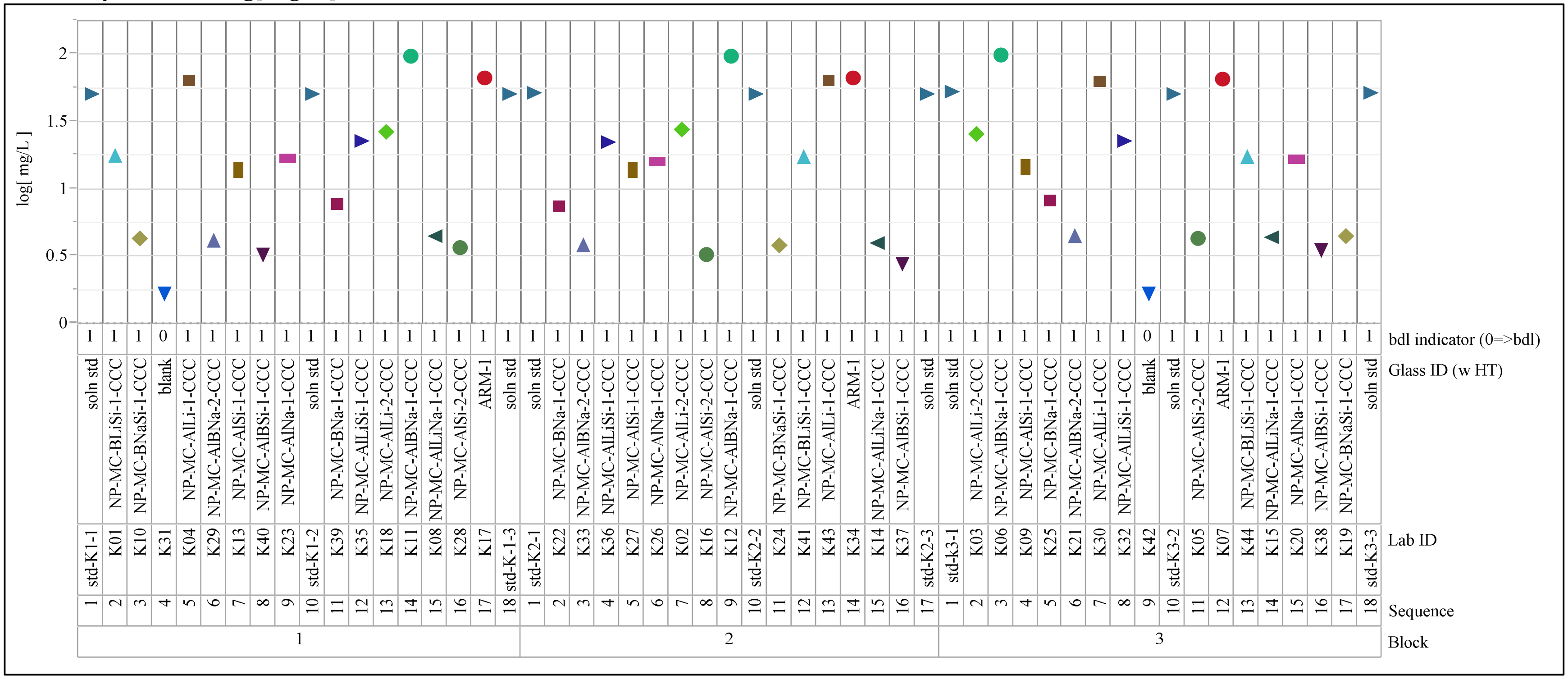


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=2, Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

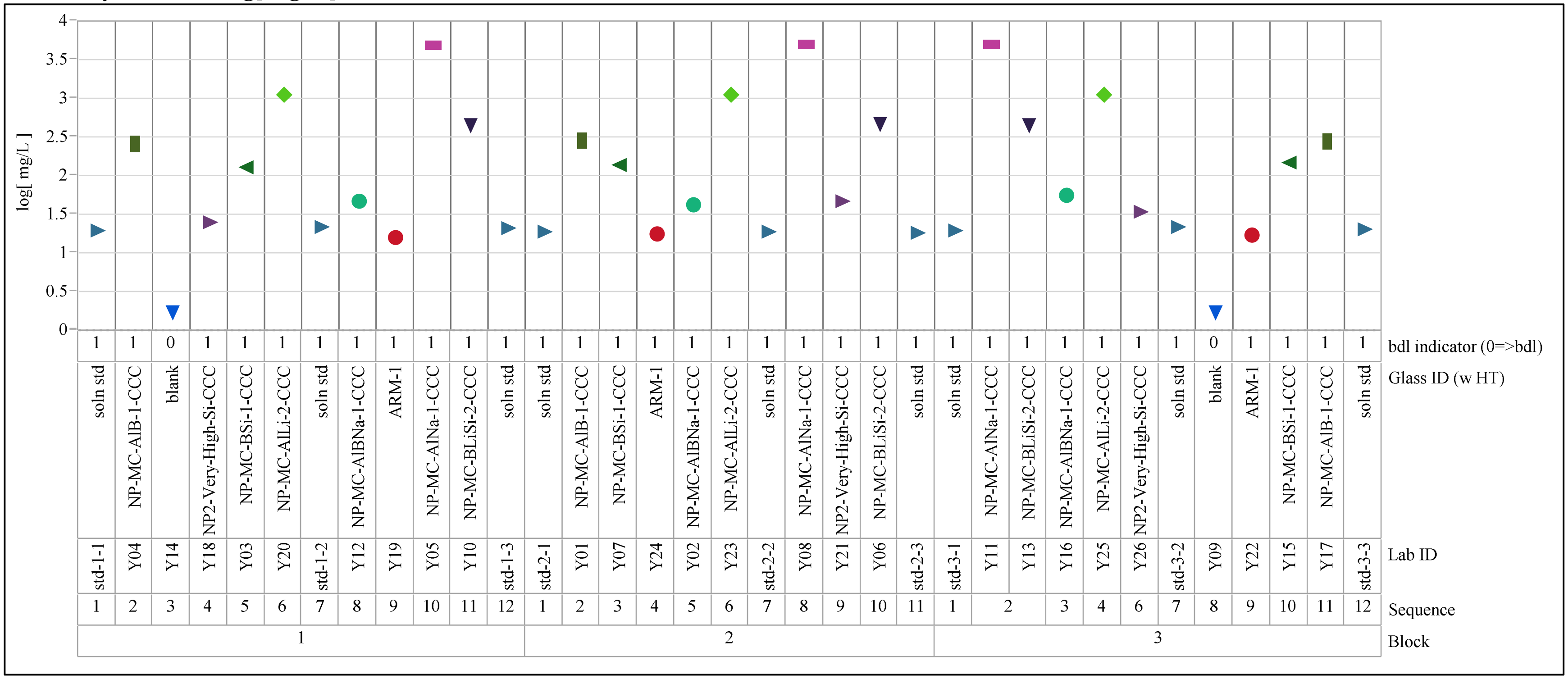


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=2, Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

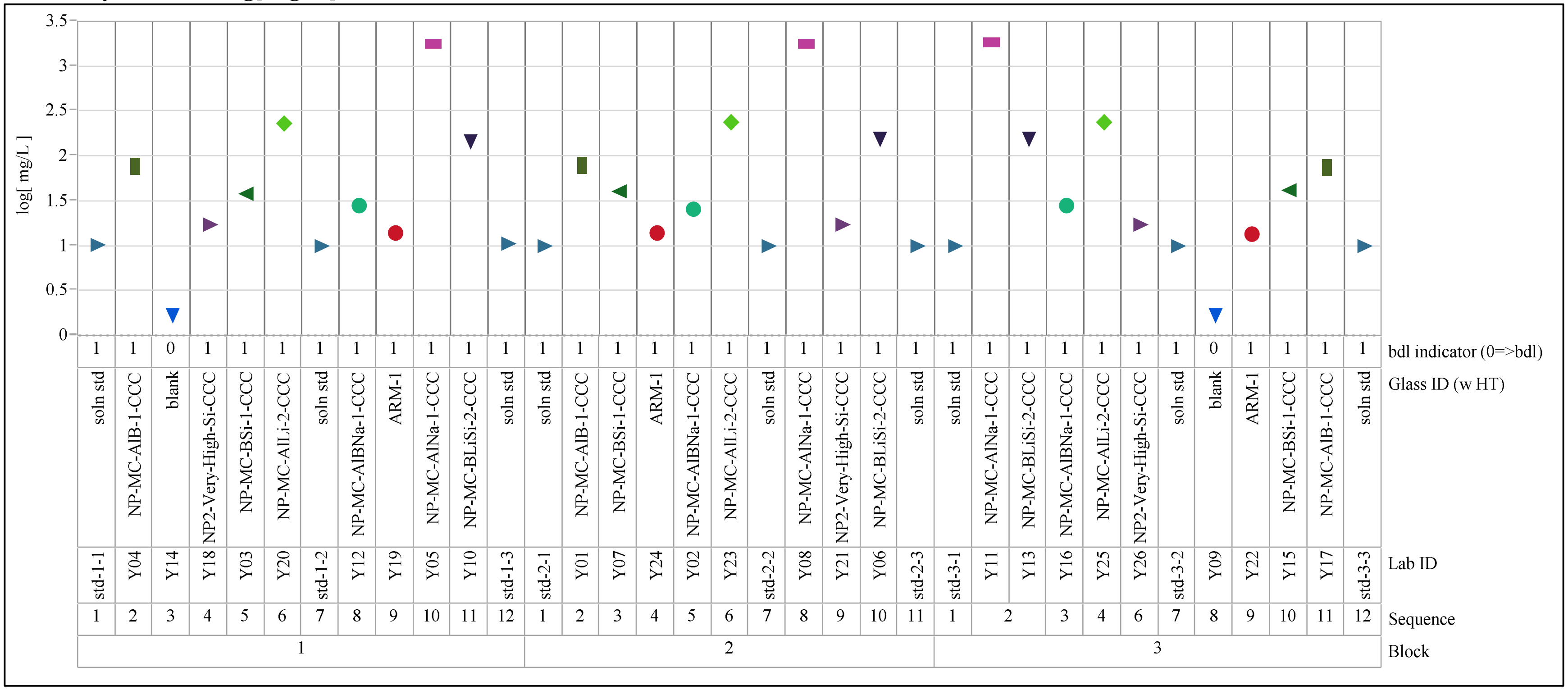


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=2, Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

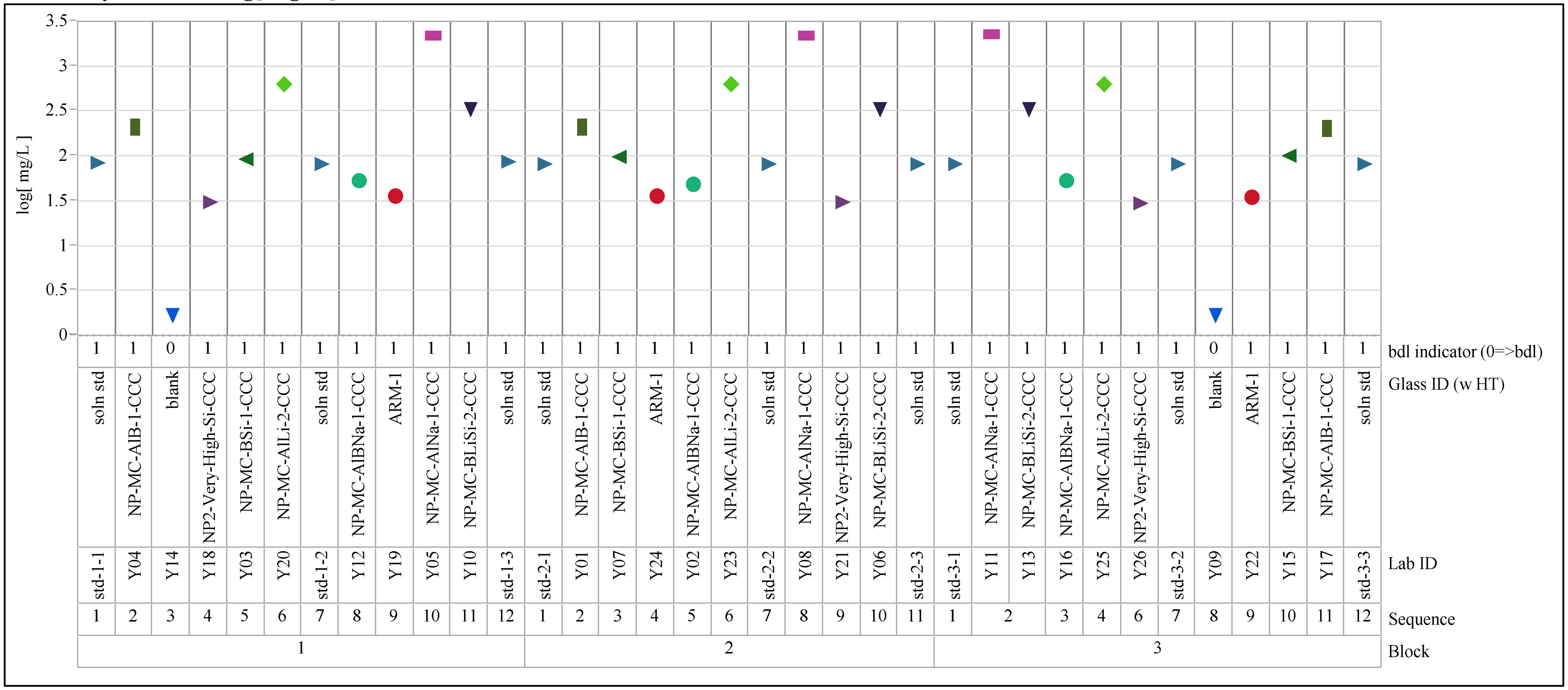


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=2, Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

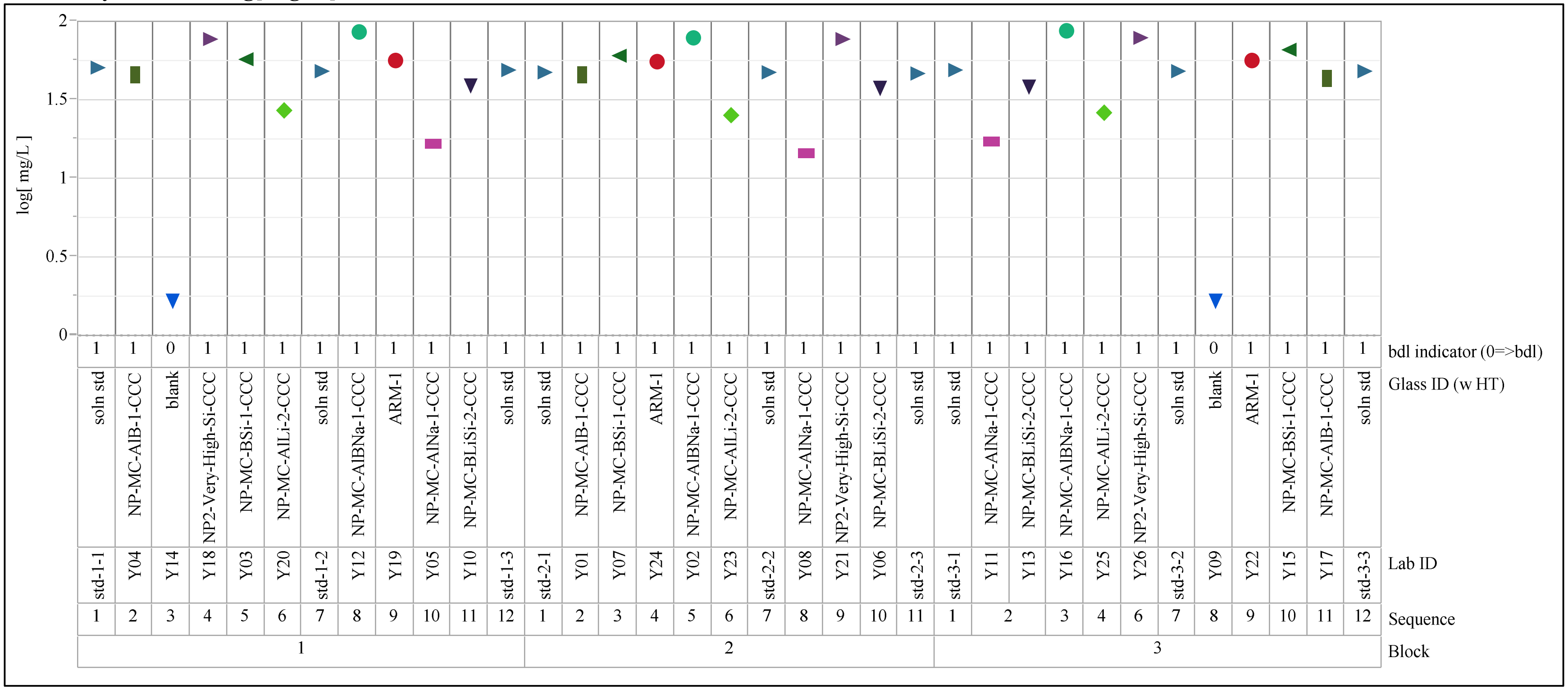


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/1, Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

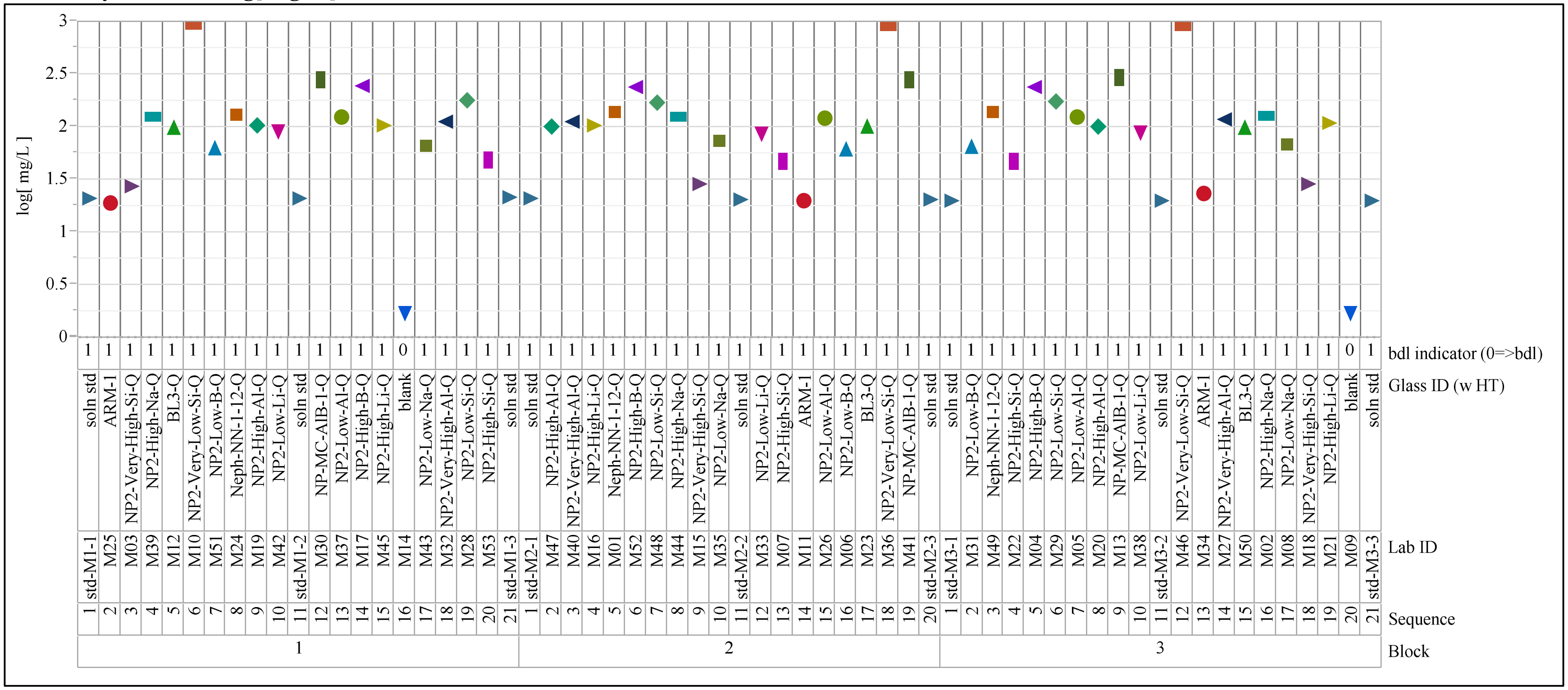


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/1, Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

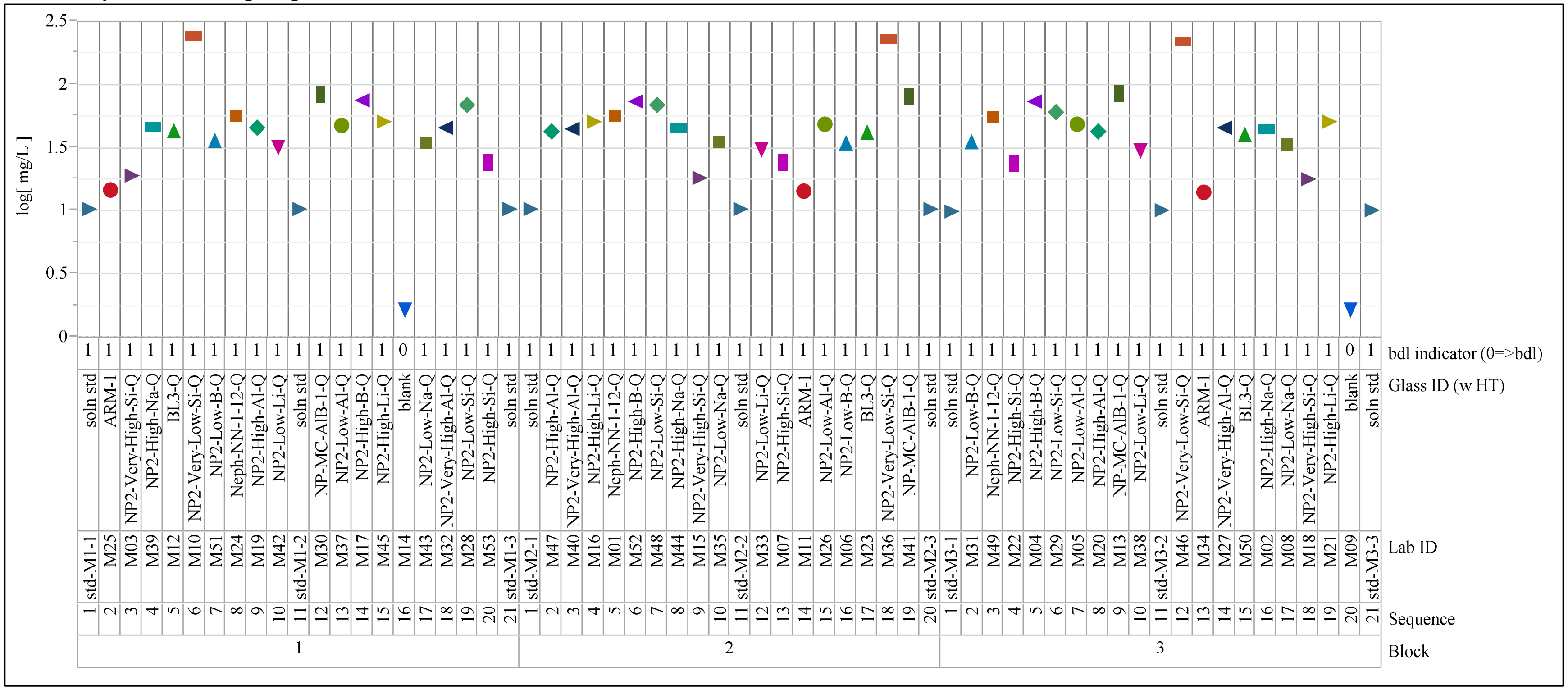


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/1, Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

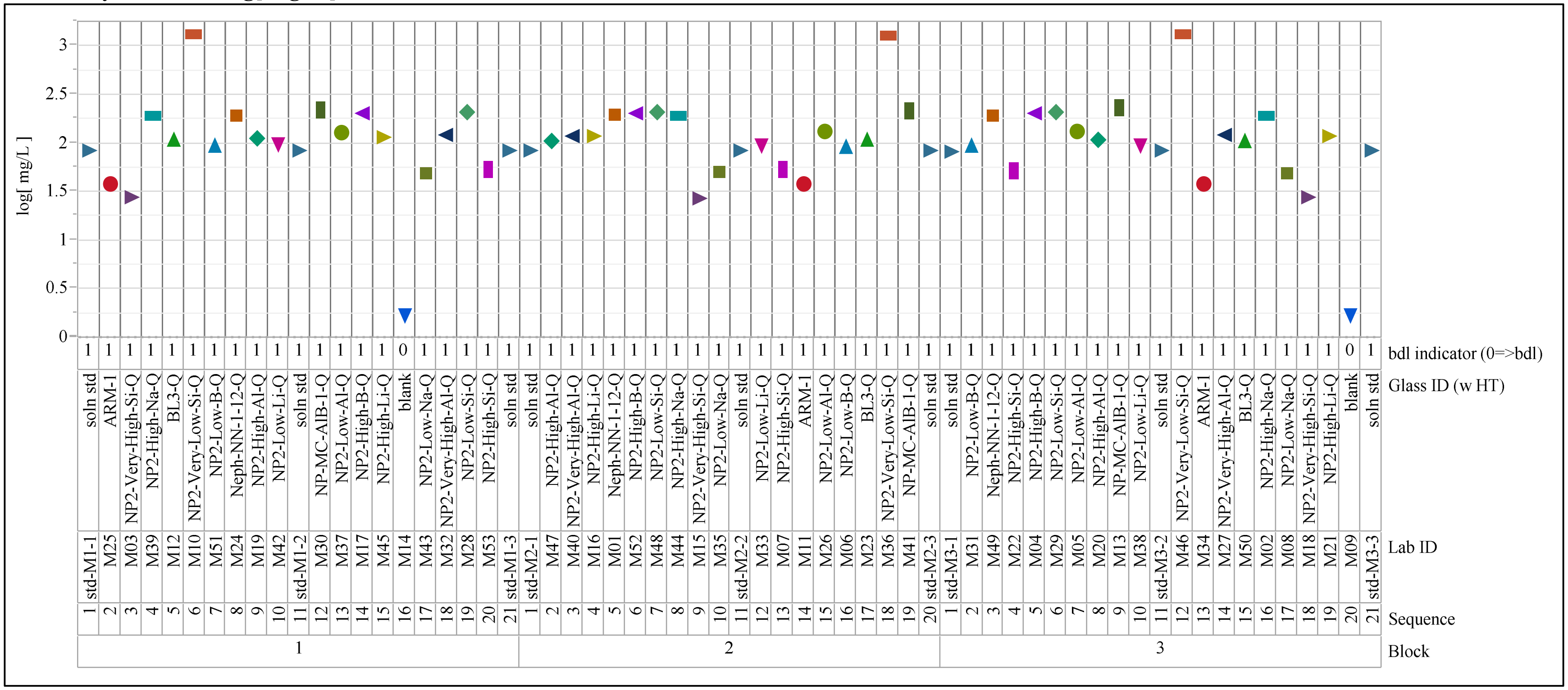


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/1, Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

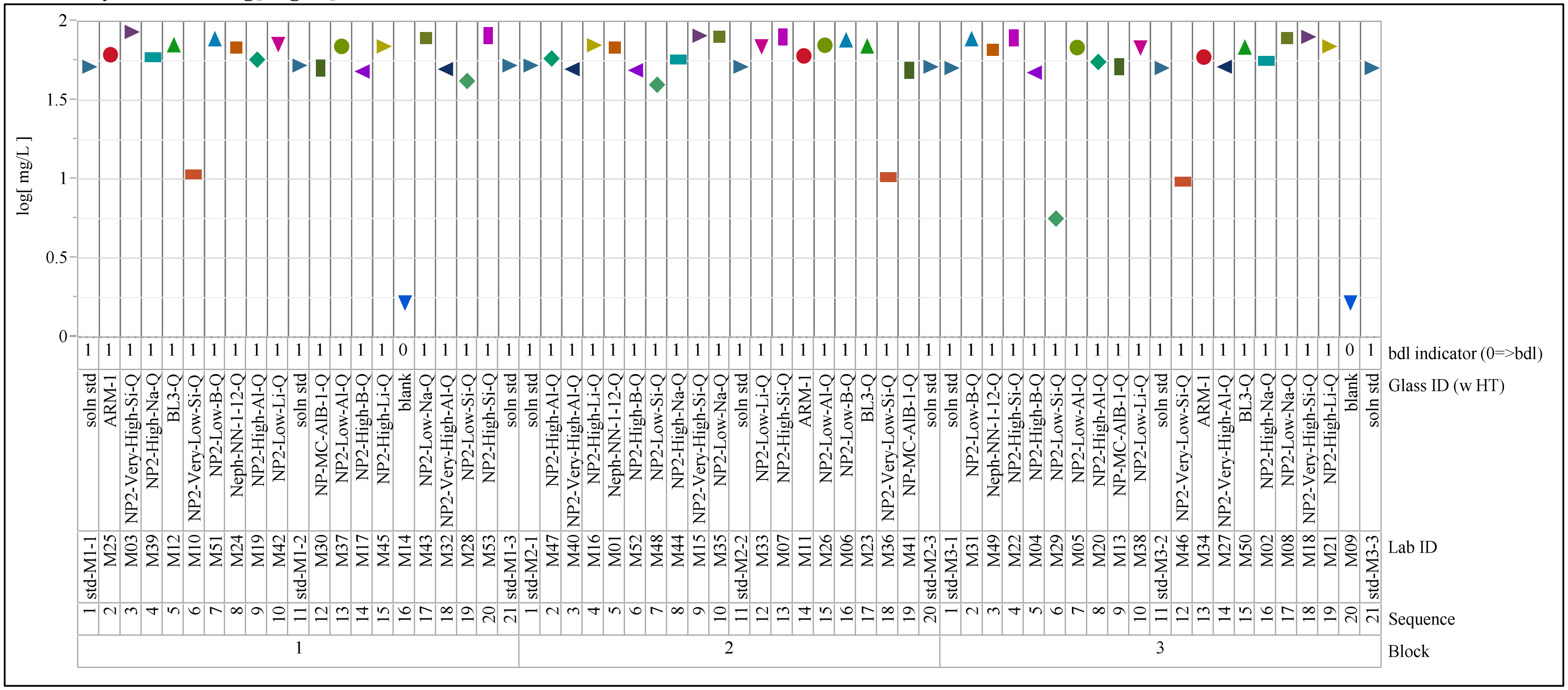


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/2, Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

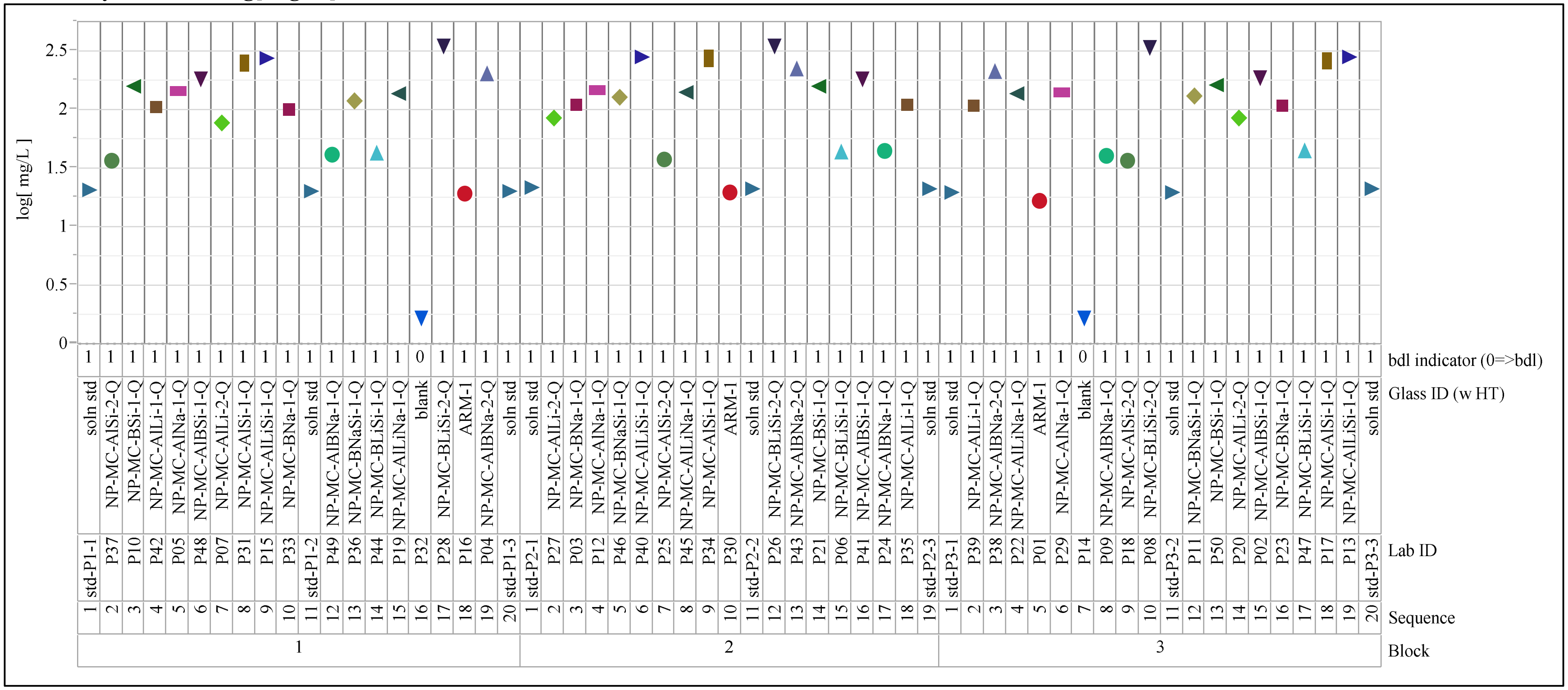


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/2, Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

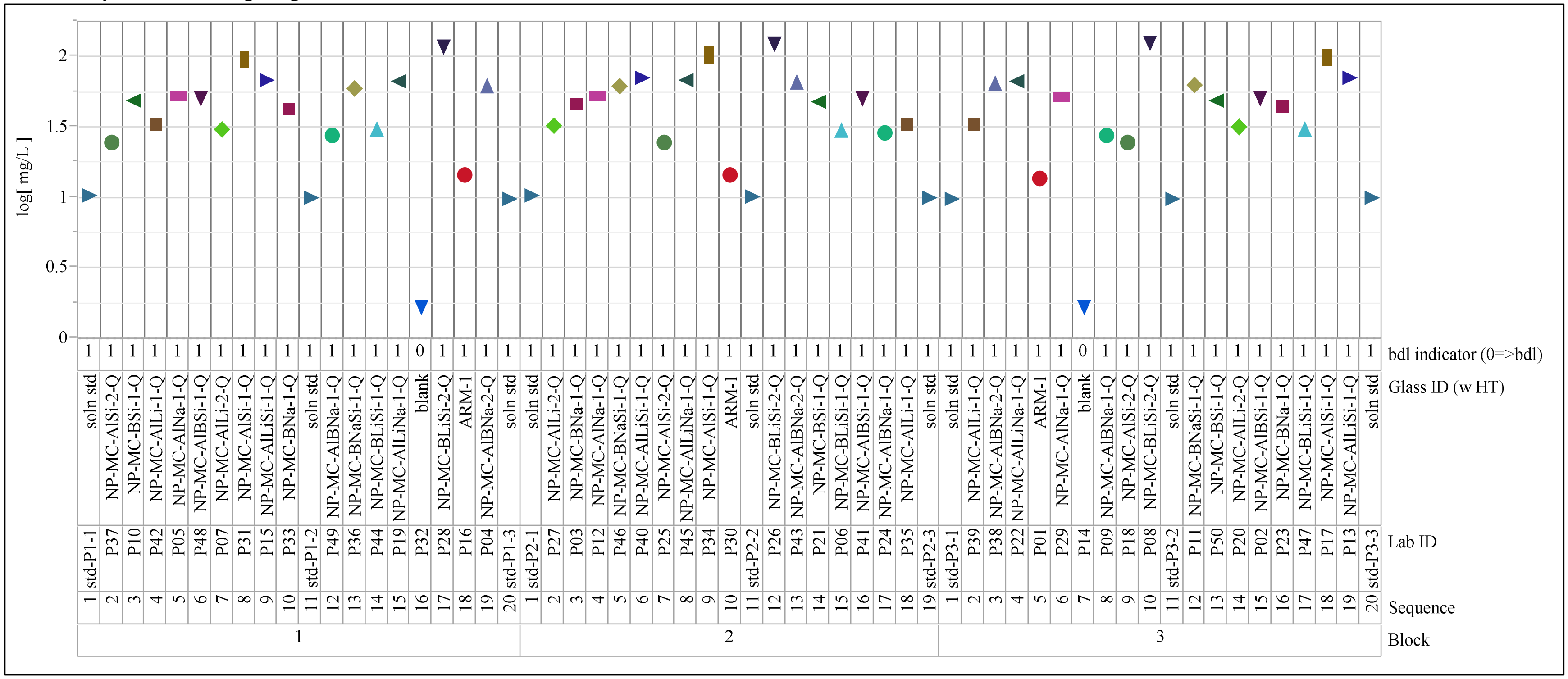


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/2, Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

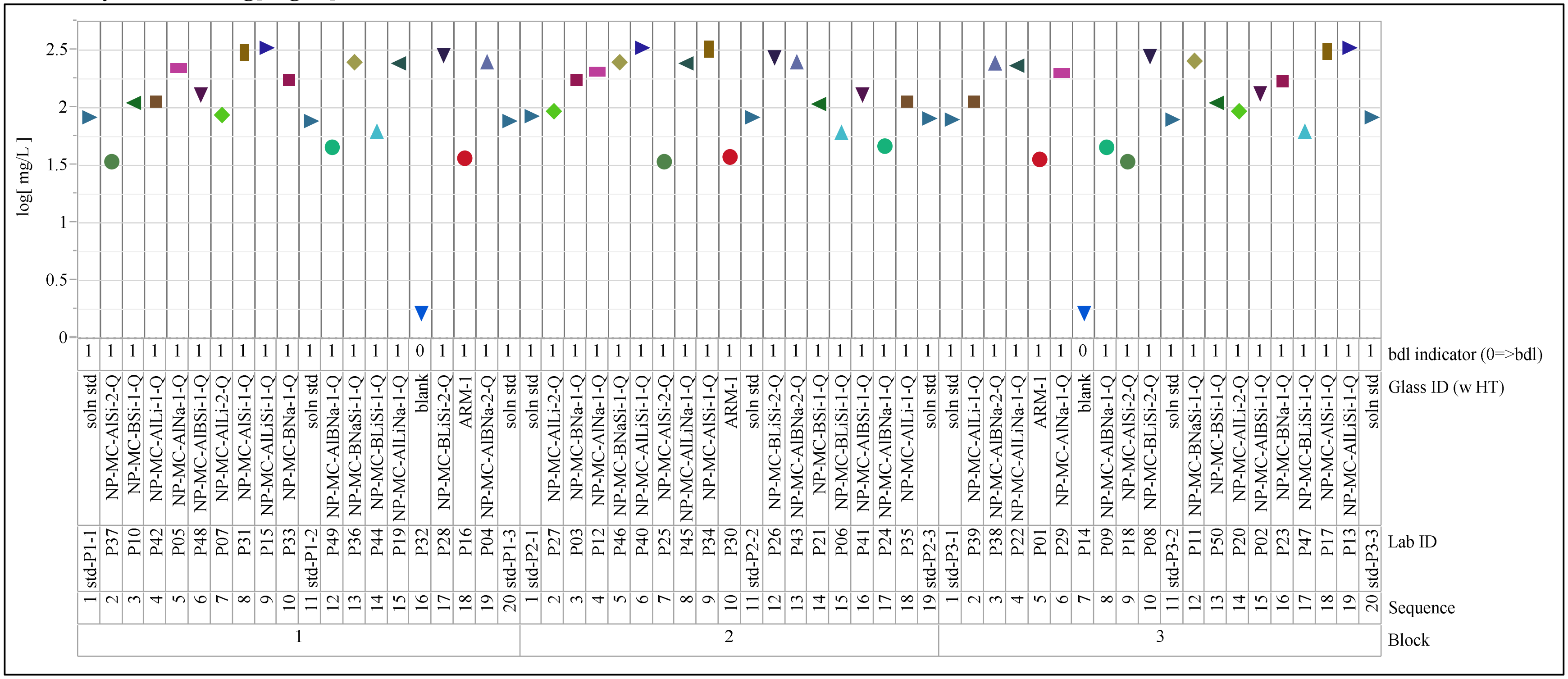


**Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Set (continued)**

**Group/Set=3/2, Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

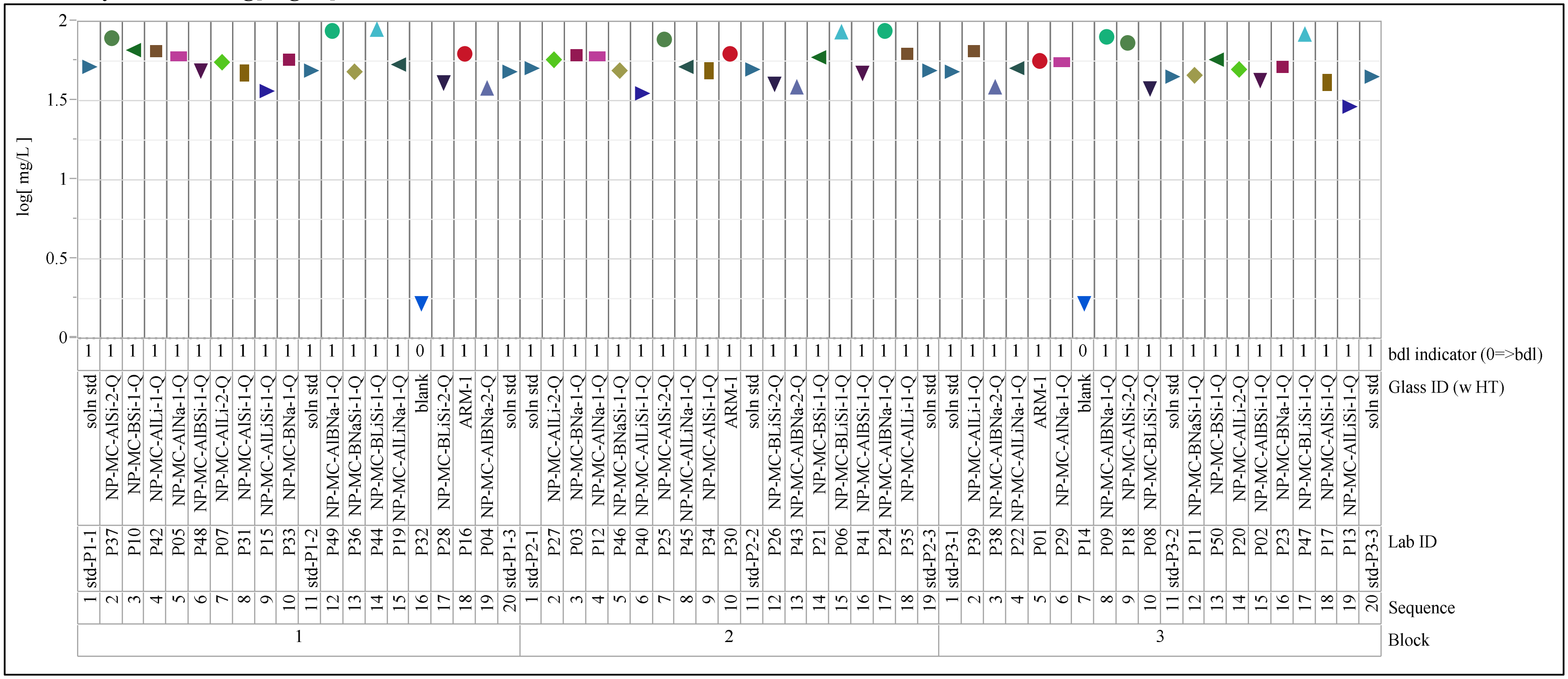


**Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses**

**Analyte=log[B mg/L]**
**Variability Chart for log[ mg/L ]**

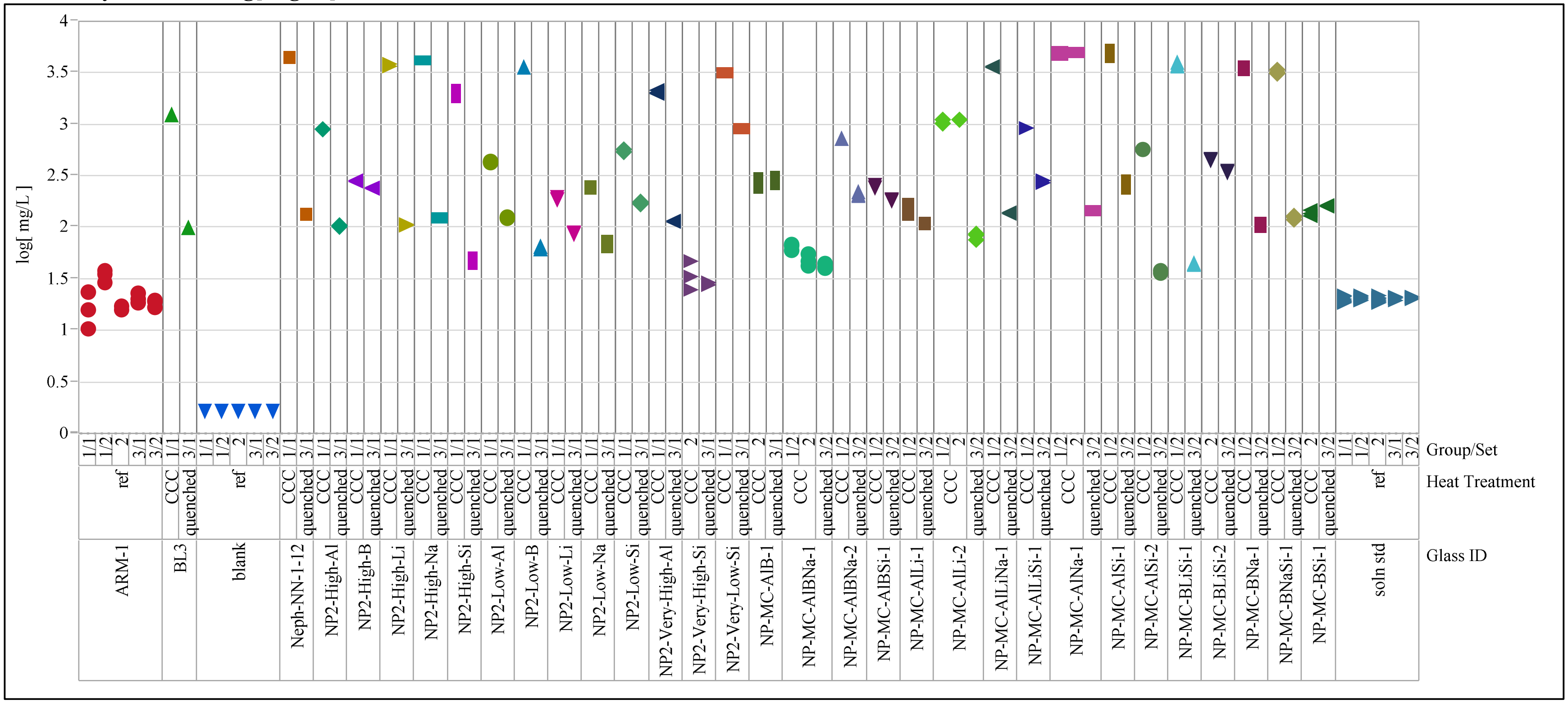


**Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)**

**Analyte=log[Li mg/L]**
**Variability Chart for log[ mg/L ]**

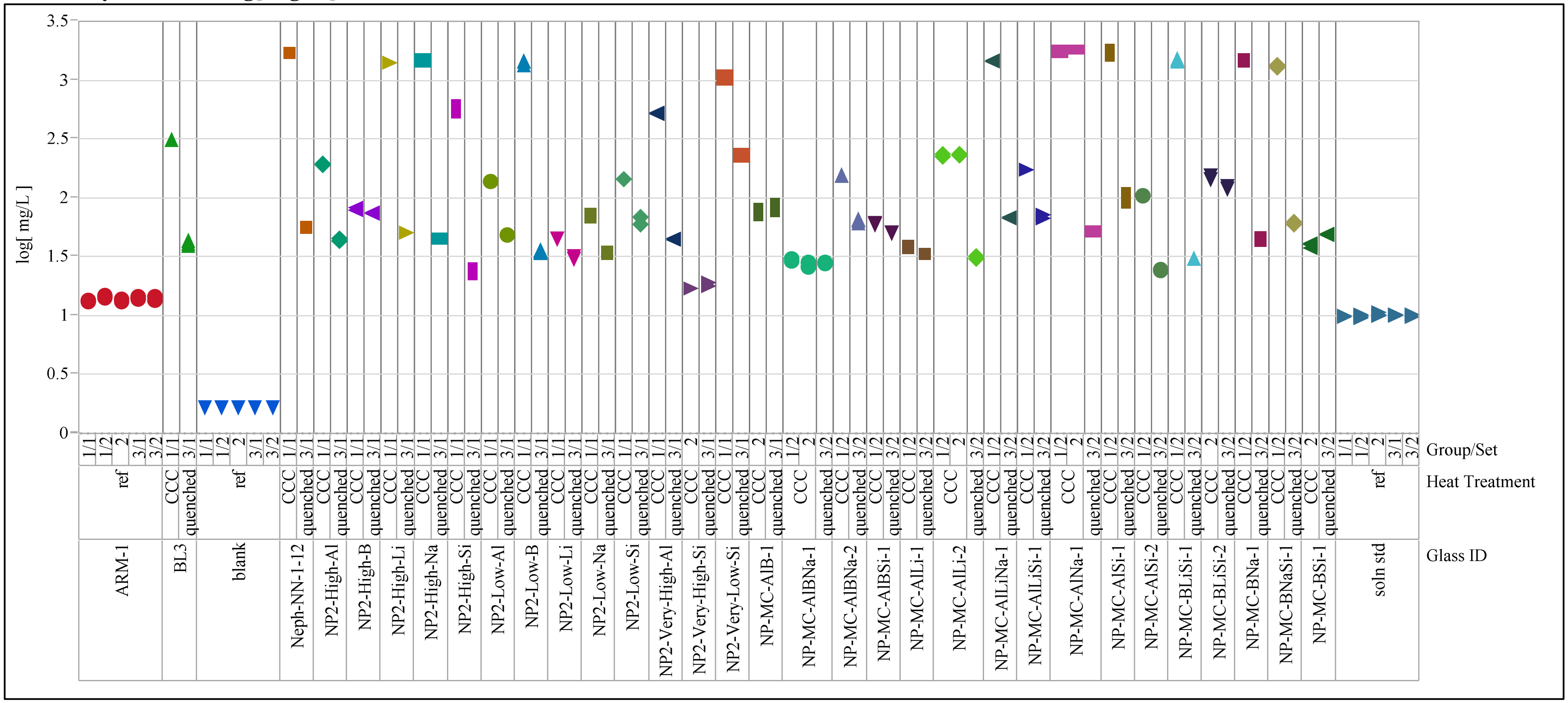


**Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)**

**Analyte=log[Na mg/L]**
**Variability Chart for log[ mg/L ]**

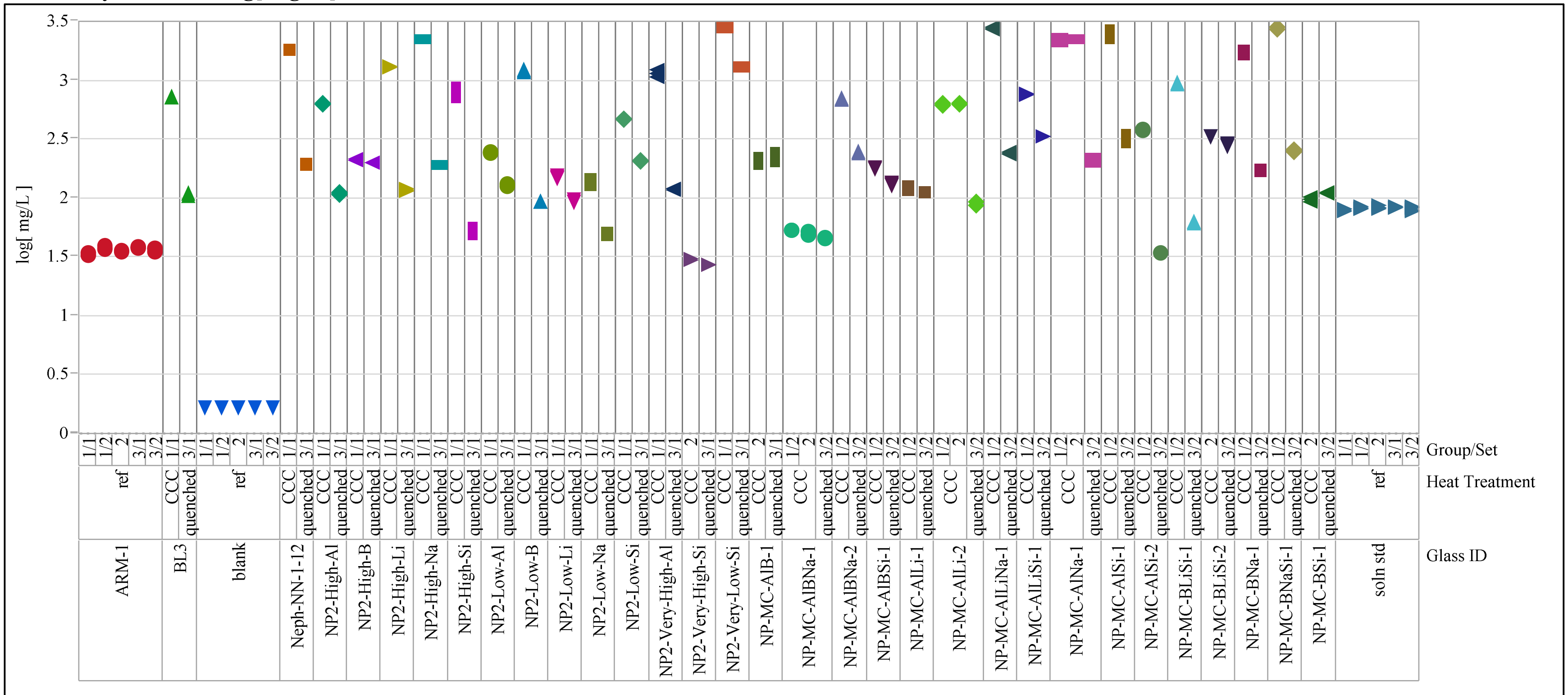


**Exhibit B-2. PCT Measurements for Each Set of Nepheline Study Glasses (continued)**

**Analyte=log[Si mg/L]**
**Variability Chart for log[ mg/L ]**

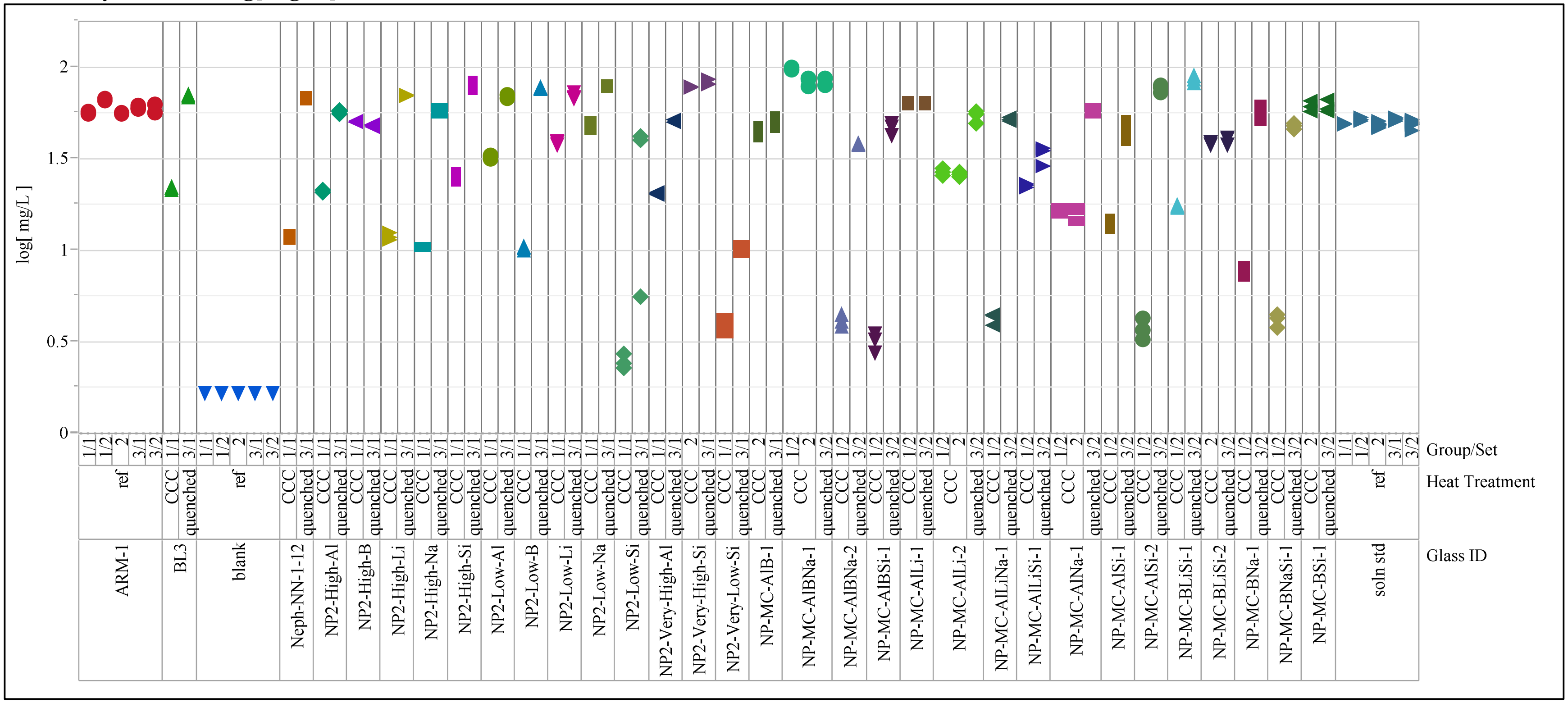


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass**

**Analyte=$NC_B$**
**Variability Chart for log [ (g/L) ]**

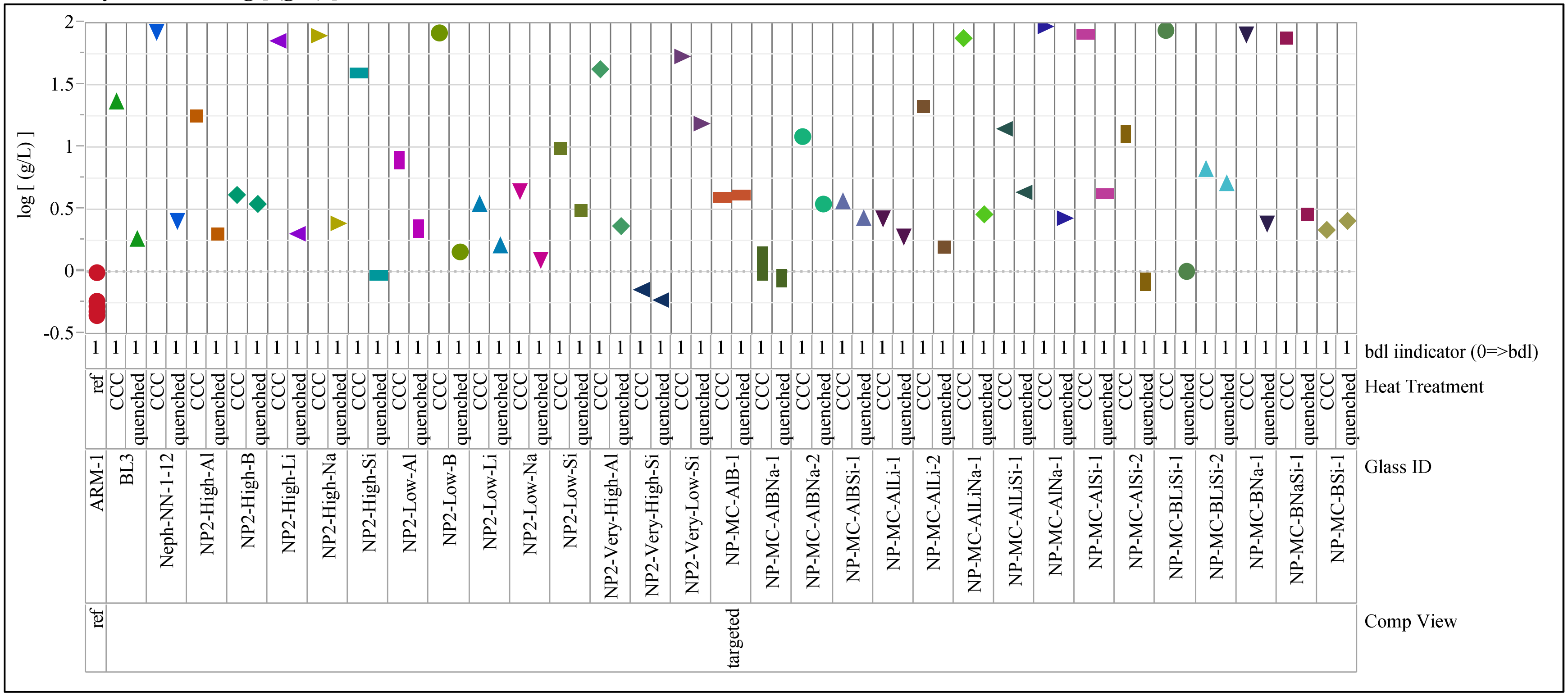


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_{Li}$**
**Variability Chart for log [ (g/L) ]**

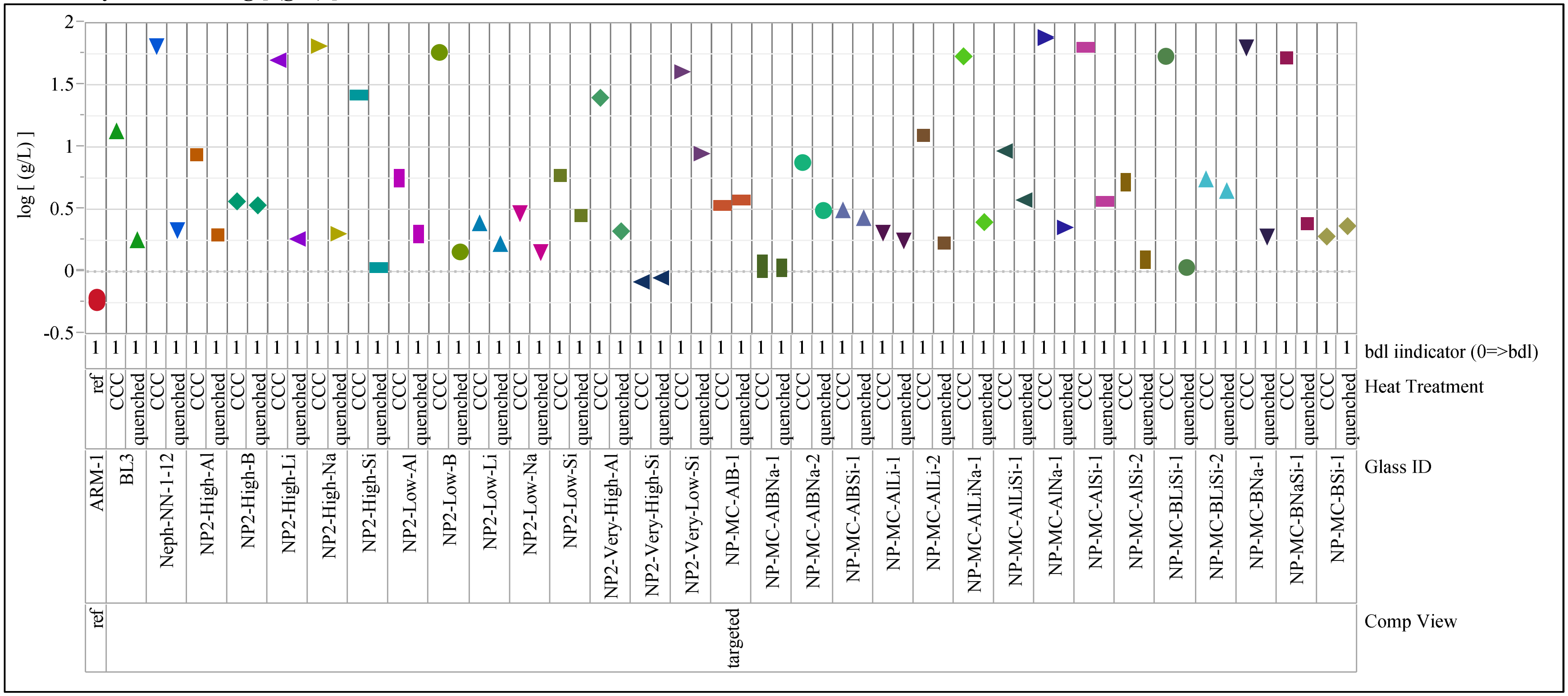


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_{Na}$**
**Variability Chart for log [ (g/L) ]**

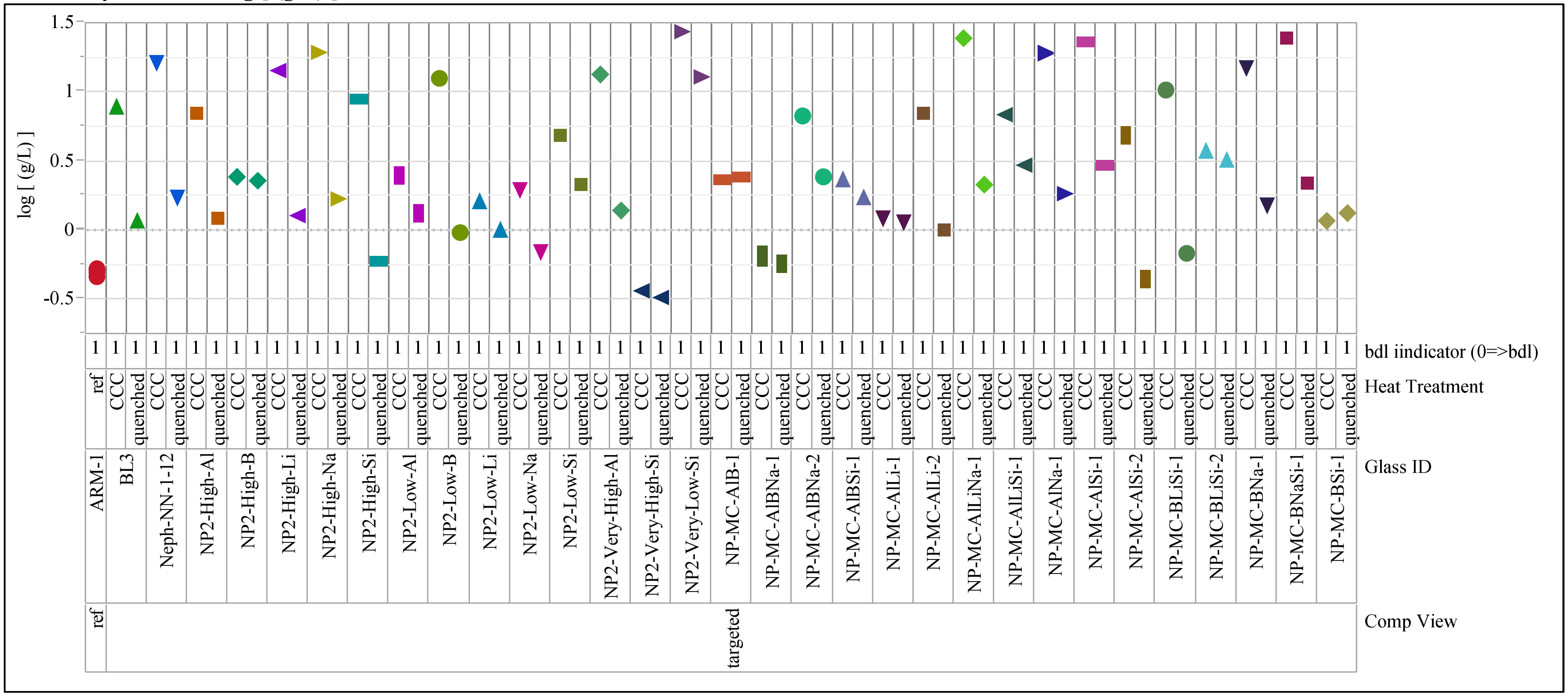


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_{Si}$**
**Variability Chart for log [ (g/L) ]**

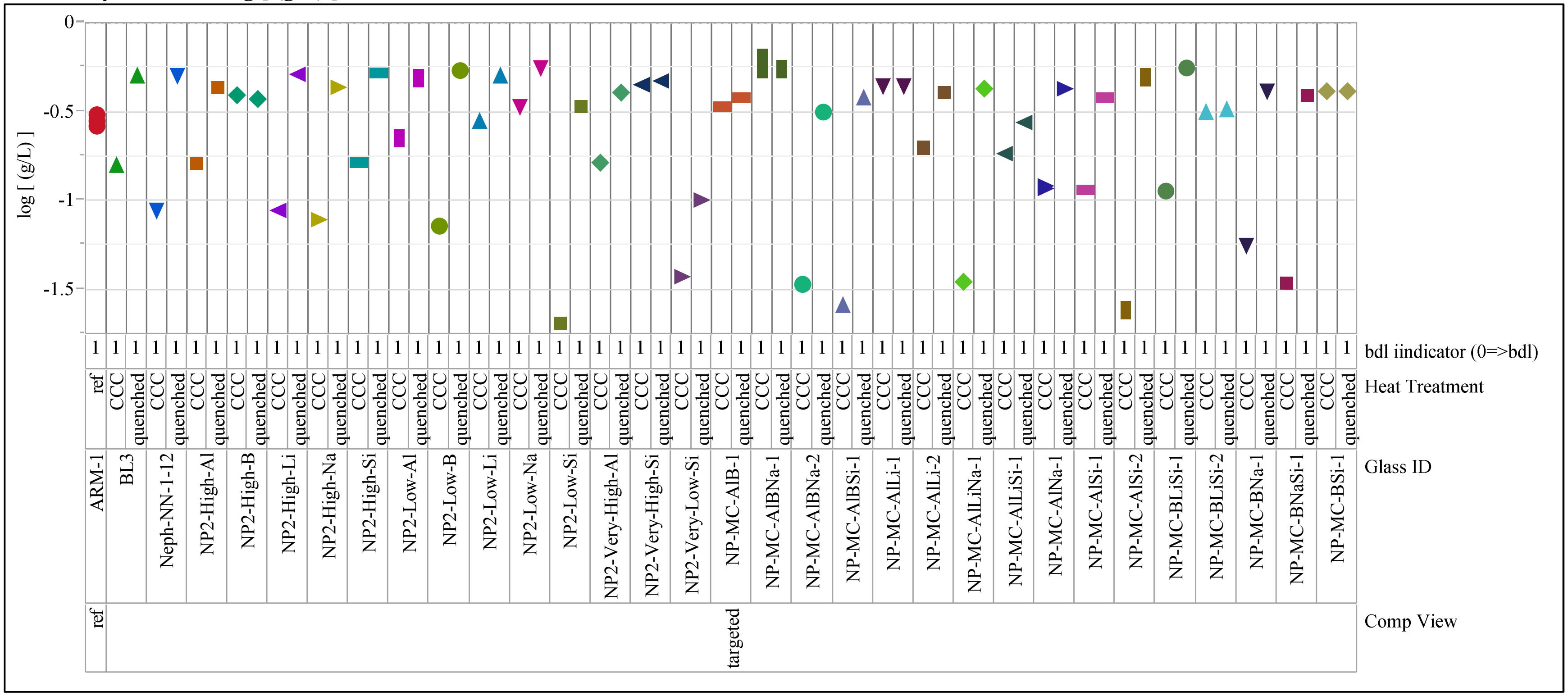


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_B$**
**Variability Chart for log [ (g/L) ]**

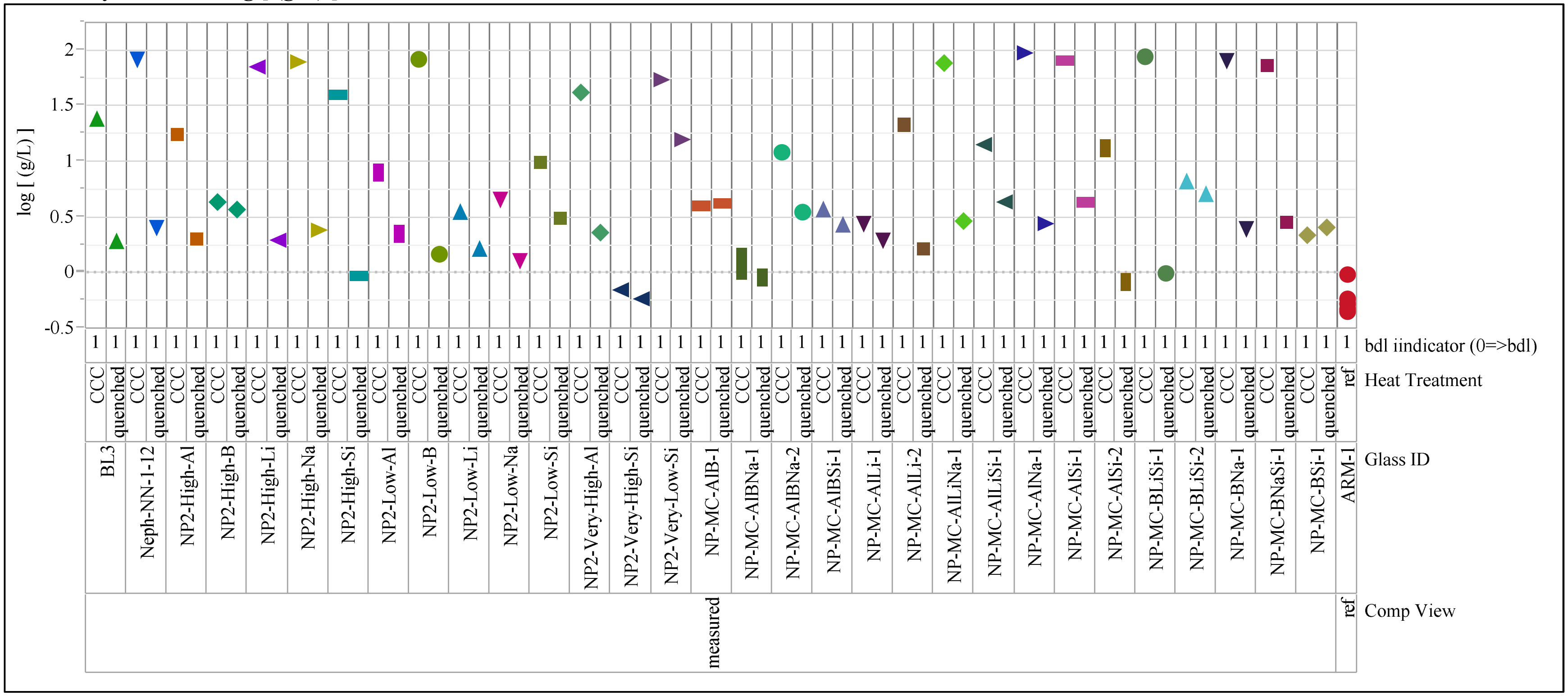


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_{Li}$**
**Variability Chart for log [ (g/L) ]**

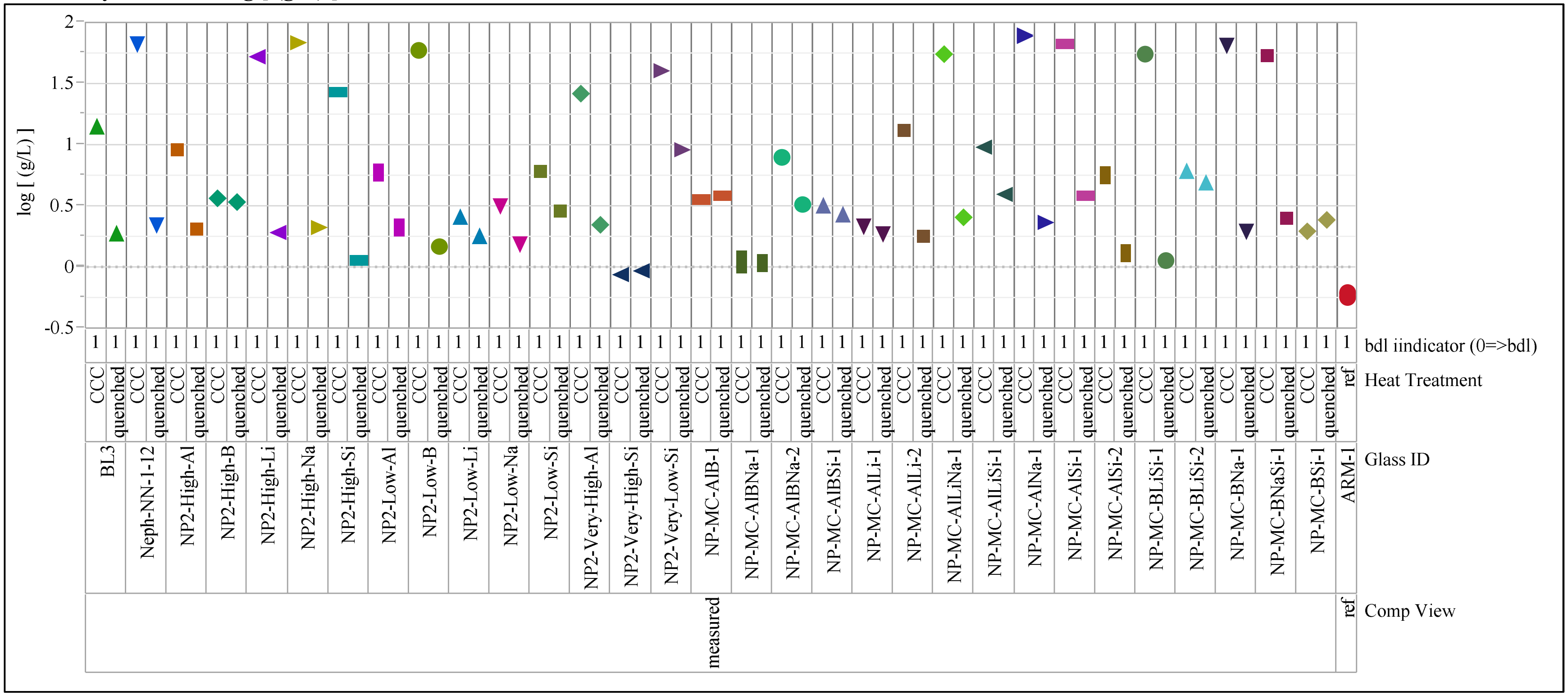


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=$NC_{Na}$**
**Variability Chart for log [ (g/L) ]**

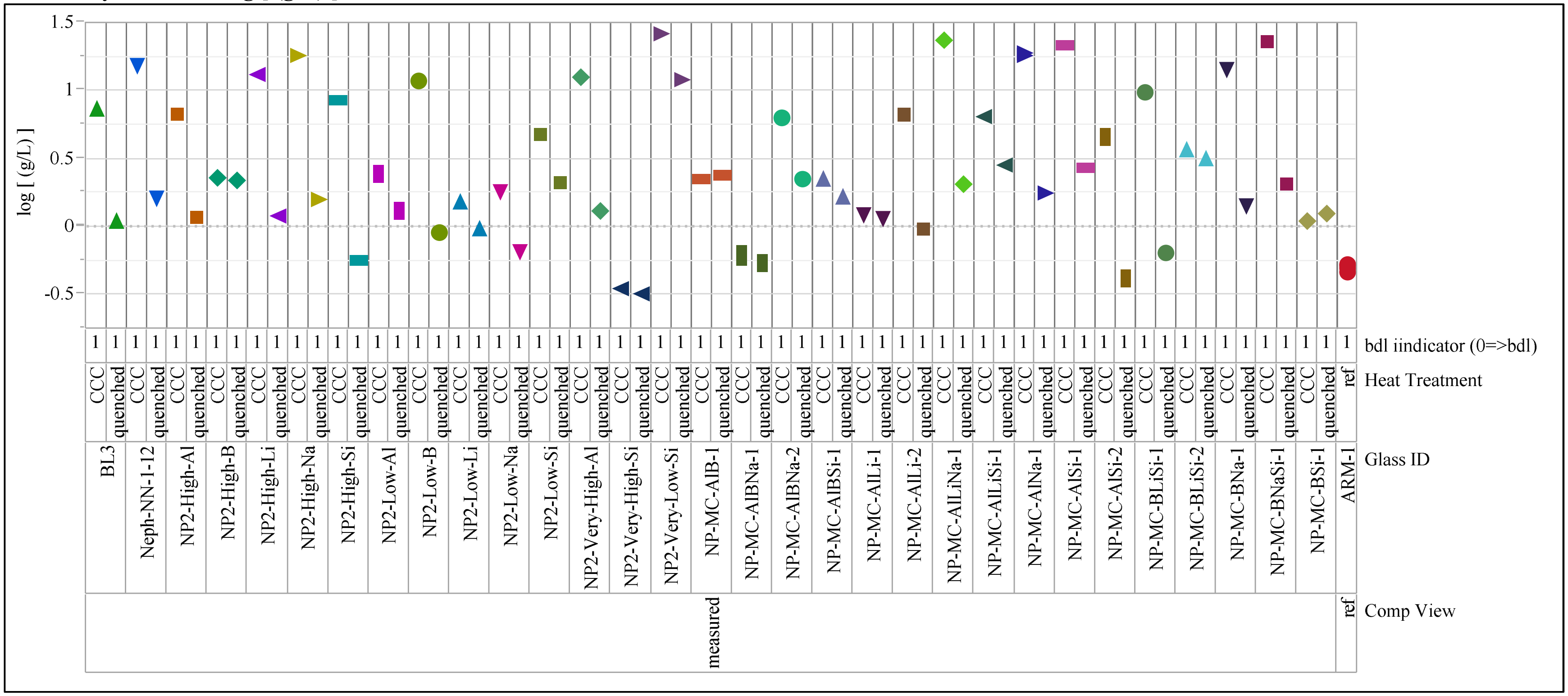


**Exhibit B-3. Normalized PCT Results by Heat Treatment by Compositional View for Each Glass (continued)**

**Analyte=*$NC_{Si}$***
**Variability Chart for log [ (g/L) ]**

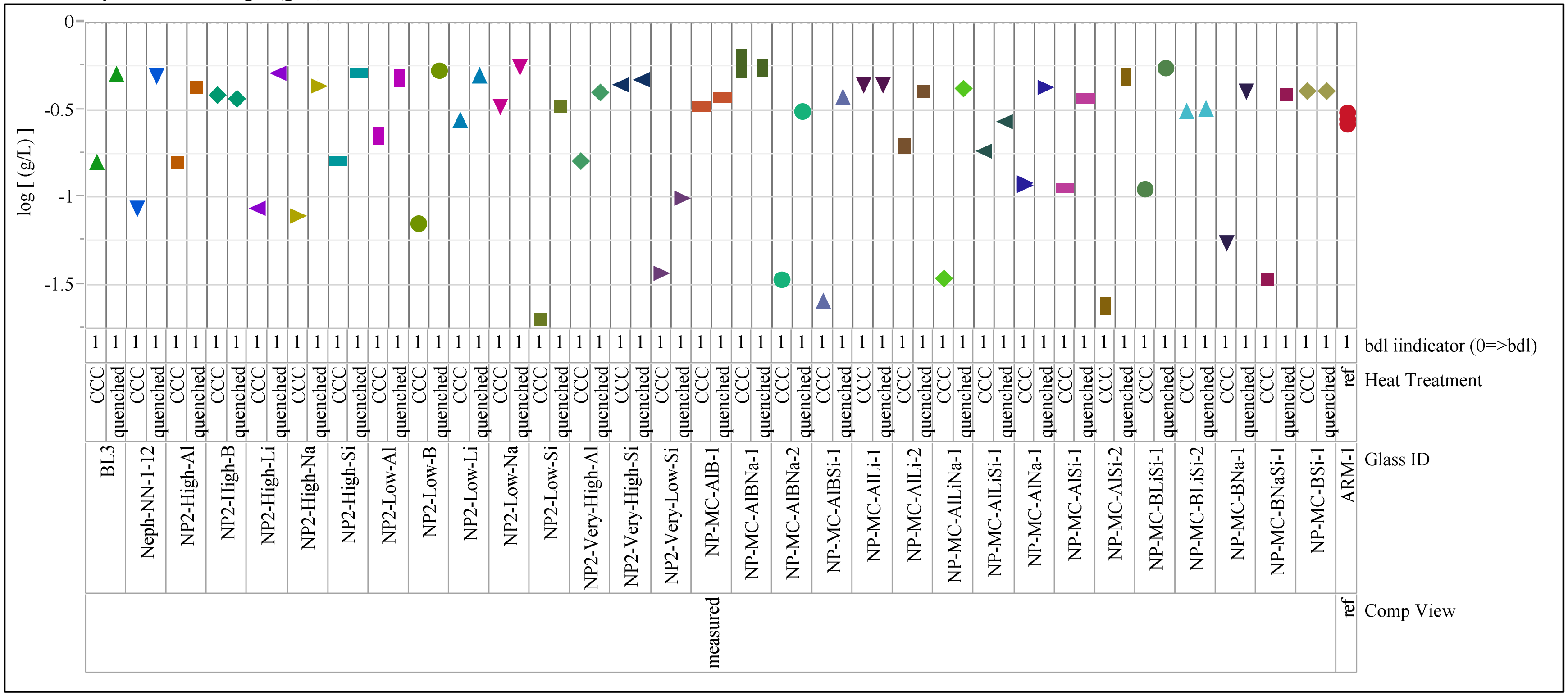


**Exhibit B-4. Congruent Leaching Analysis for the Quenched Versions of the Nepheline Glasses**

**Correlations**

| | log NC[B (g/L)] | log NC[Li(g/L)] | log NC[Na (g/L)] | log NC[Si (g/L)] |
|---|---|---|---|---|
| **log NC[B (g/L)]** | 1.0000 | 0.9829 | 0.9929 | -0.8258 |
| **log NC[Li(g/L)]** | 0.9829 | 1.0000 | 0.9674 | -0.8408 |
| **log NC[Na (g/L)]** | 0.9929 | 0.9674 | 1.0000 | -0.8294 |
| **log NC[Si (g/L)]** | -0.8258 | -0.8408 | -0.8294 | 1.0000 |

**Scatterplot Matrix**

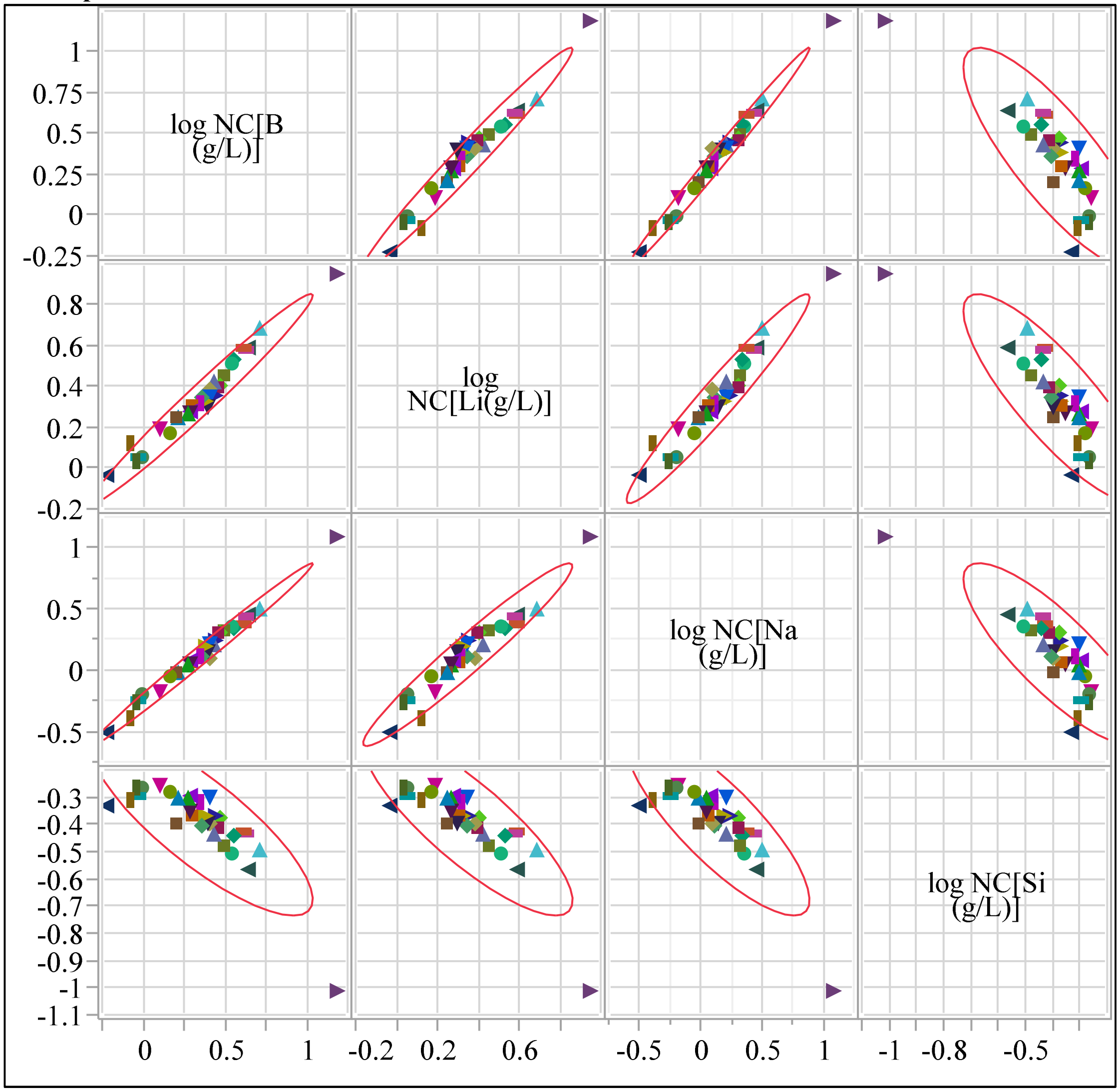
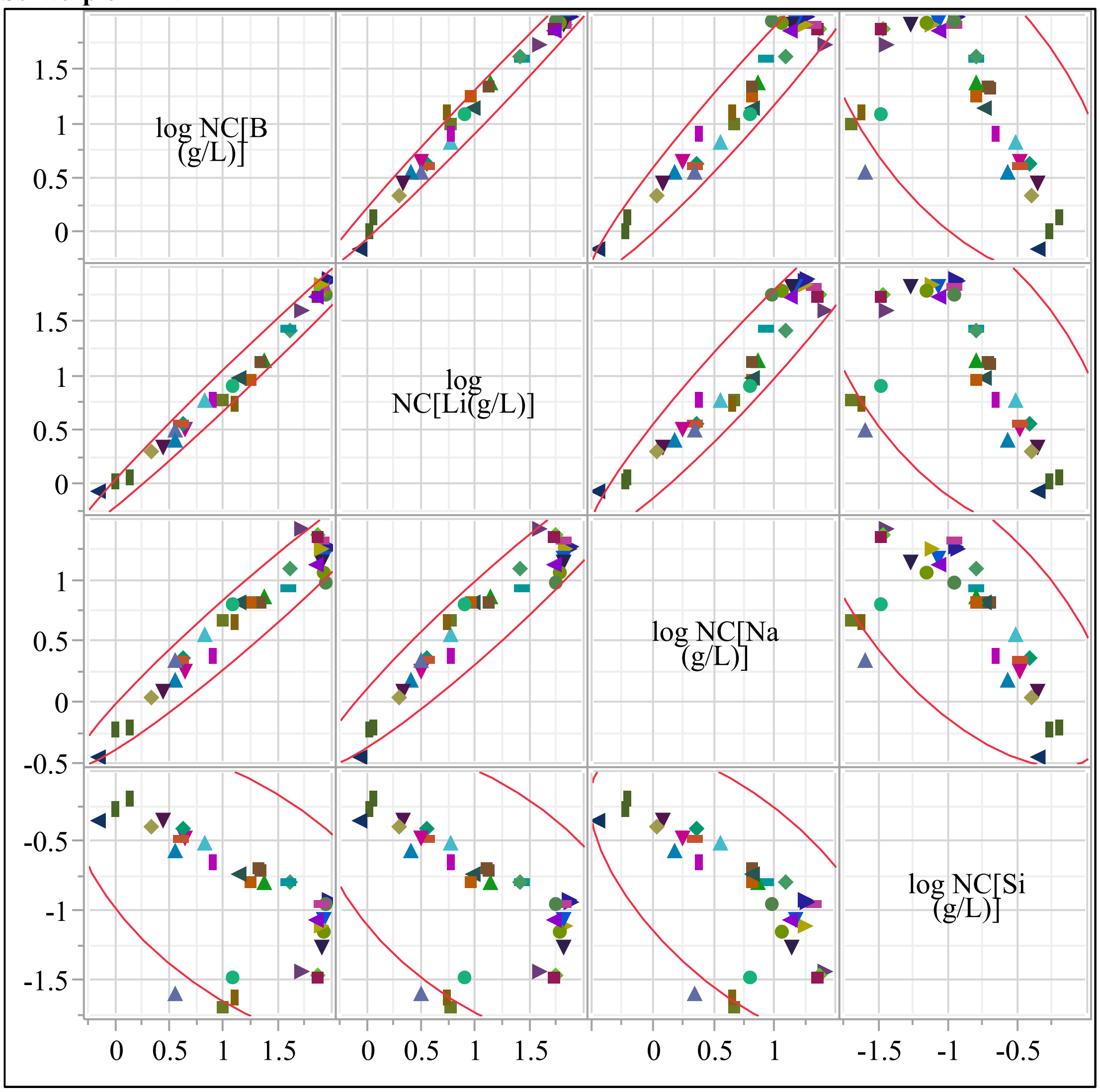


**Exhibit B-5. Congruent Leaching Analysis for the CCC Versions of the Nepheline Glasses**

**Correlations**

| | log NC[B (g/L)] | log NC[Li(g/L)] | log NC[Na (g/L)] | log NC[Si (g/L)] |
|---|---|---|---|---|
| **log NC[B (g/L)]** | 1.0000 | 0.9920 | 0.9730 | -0.5822 |
| **log NC[Li(g/L)]** | 0.9920 | 1.0000 | 0.9616 | -0.5502 |
| **log NC[Na (g/L)]** | 0.9730 | 0.9616 | 1.0000 | -0.6484 |
| **log NC[Si (g/L)]** | -0.5822 | -0.5502 | -0.6484 | 1.0000 |

**Scatterplot Matrix**



**Distribution:**

J. W. Amoroso, 999-W
T. B. Brown, 773-A
H. H. Burns, 773-41A
A. S. Choi, 999-W
Y. S. Chou, PNNL
A. D. Cozzi, 999-W
C. L. Crawford, 773-42A
J. V. Crum, PNNL
D. E. Dooley, 999-W
A. P. Fellinger. 773-42A
S. D. Fink, 773-A
K. M. Fox, 999-W
E. K. Hansen, 999-W
C. C. Herman, 773-A
E. N. Hoffman, 999-W
J. E. Hyatt, 773-A
C. M. Jantzen, 773-A
F. C. Johnson, 999-W
D. S. Kim, PNNL
A. A. Kruger, DOE-ORP
D. J. McCabe, 773-42A
D. L. McClane, 999-W
D. H. McGuire, 999-W
D. H. Miller, 999-W
D. K. Peeler, PNNL
F. M. Pennebaker, 773-42A
M. R. Poirier, 773-42A
M. J. Schweiger, PNNL
M. E. Stone, 999-W
C. L. Trivelpiece, 999-W
J. D. Vienna, PNNL
A. L. Washington II, 773-42A
W. R. Wilmarth, 773-A
Records Administration (EDWS)