Results of SRNL High Level Waste Glass Round Robin Testing: Question 1 at Time Interval 2

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EXECUTIVE SUMMARY

The U.S. Department of Energy – Office of River Protection (DOE-ORP) is administering a high level waste (HLW) round robin glass property evaluation among three laboratories. The objectives of this round robin study are: 1) to determine whether the properties of glasses produced in melter tests performed at two different locations match within appropriate uncertainties, and 2) to determine whether the results of simulated Hanford HLW glass properties measured at multiple laboratories match within appropriate uncertainties.

The data described in this report were collected to address the first question of the round robin study: Are the results of glass produced in melters at two different laboratories the same within uncertainty?

SRNL measured the chemical composition of two glass samples provided by the Pacific Northwest National Laboratory (PNNL). Four sub-samples were taken from each of the two glass samples for the chemical composition analysis. The resulting data are reviewed and presented in this report.

SRNL also measured the chemical durability of the two glass samples using the ASTM Product Consistency Test (PCT). Portions of each of the two glass samples were heat treated following the canister centerline cooling (CCC) profile for Hanford Waste Treatment and Immobilization Plant (WTP) HLW canisters. Four sub-samples were taken from each of the two glass samples for each of the two heat treatments (as-received and CCC) for the chemical durability analysis. The resulting PCT data are reviewed and presented in this report.

PNNL will compile these data, along with data generated at other laboratories, and conduct statistical evaluations to answer the first round robin question.

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LIST OF ABBREVIATIONS

%RSD	Percent Relative Standard Deviation
ar	As Received
ARM-1	Approved Reference Material – 1
CCC	Canister Centerline Cooled
CUA	Catholic University of America
DOE-ORP	U.S. Department of Energy – Office of River Protection
EA	Environmental Assessment reference glass
HLW	High Level Waste
IC	Ion Chromatography
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectrometry
KH	Potassium Hydroxide Fusion
LM	Lithium Metaborate Fusion
LRM	Low-level Reference Material
PCT	Product Consistency Test
PF	Sodium Peroxide Fusion
PNNL	Pacific Northwest National Laboratory
SRNL	Savannah River National Laboratory
VSL	Vitreous State Laboratory
WTP	Hanford Waste Treatment and Immobilization Plant

1.0 Introduction

The U.S. Department of Energy – Office of River Protection (DOE-ORP) is administering a high level waste (HLW) round robin glass property evaluation among three laboratories: Pacific Northwest National Laboratory (PNNL), the Catholic University of America (CUA) Vitreous State Laboratory (VSL), and Savannah River National Laboratory (SRNL). The objectives of this round robin study are: 1) to determine whether the properties of glasses produced in melter tests performed at PNNL and VSL match within appropriate uncertainties, and 2) to determine whether the results of simulated Hanford HLW glass properties measured at PNNL, VSL, and SRNL match within appropriate uncertainties.

The round robin study was designed by PNNL to answer the following questions:

1. VSL and PNNL each ran a melter test processing HLW-HCr-16 glass; are the results between the laboratories the same within uncertainty?
2. If PNNL, SRNL, or VSL characterize glass(es) at laboratory scale, are the results among the laboratories the same within uncertainty?
3. Each laboratory will test the glass in approximately 6 month intervals for approximately 18 months. If each laboratory tests glass(es) over time, are the results the same each time within uncertainty?

VSL formulated a glass composition designated HLW-HCr-16 for the round robin study, which contains high concentrations of waste-loading limiting components such as Cr_2O_3 and Al_2O_3.[1] Melter feed was prepared in one large batch by Noah Technologies (San Antonio, TX) using the composition submitted by VSL. The feed was then divided into requested quantities for PNNL and VSL. PNNL and VSL each performed a melter run using this feed producing glass of the targeted composition. The glass was sampled after the melters had reached steady-state (usually after 3 melter turnovers), ensuring the final composition was obtained. The VSL glass sample (~10 kg) was shipped to PNNL.

The HLW-HCr-16 glass samples from both the VSL and PNNL melter tests were staged and prepared for analysis by PNNL. The VSL and PNNL glasses were separately crushed in a jaw crusher and systematically sampled.[1] Both of these glasses were then distributed by PNNL to SRNL for analysis to answer the first round robin question shown above. One of these glasses will later be chosen and distributed among the three laboratories for analyses to answer the second and third questions shown above. SRNL heat treated a portion of the as-received glasses following the simulated WTP HLW canister centerline cooling (CCC) temperature profile.[2] The CCC heat treated glass was divided into random samples for characterization at SRNL and shipment to PNNL.

The focus of this report is the results of measurements completed at SRNL to address Question 1 at Time Interval 2.[a] To address Question 1, PNNL and SRNL agreed to measure specific properties of representative glass samples from both the PNNL and VSL melter runs. PNNL was to measure crystal fraction of the as-received glass, viscosity, electrical conductivity, crystal fraction as a function of temperature, and crystal fraction of a CCC heat treated glass. SRNL was to measure the durability of both the as-received and CCC heat treated versions of the glass samples and chemical composition of the as-received glasses. Questions 2 and 3 will be addressed at a later date.

The work performed at SRNL is controlled by a Task Technical and Quality Assurance Plan.[3] SRNL is responsible for supplying the requested data to PNNL for further analysis. SRNL is not expected to provide statistical support with respect to data analysis, determining whether the objectives of the testing program have been met, or determining the number of replicates needed to answer the round robin questions.[3]

[a] Characterization of the glasses at Time Interval 1 was performed only at VSL.

2.0 Experimental Procedure

2.1 Glass Samples

PNNL provided two glass samples to SRNL for use in addressing Question 1 at Time Interval 2. The glasses were labeled HLW-HCr-16-X (II) and HLW-HCr-16-Y (I). SRNL heat treated portions of each of the two glasses following the simulated WTP HLW canister CCC temperature profile.[2] The as-received glasses were used for chemical analyses. Both the as-received and the CCC glasses were used for the Product Consistency Test (PCT). SRNL was instructed by PNNL to provide four measurements of chemical composition for each of the as-received glasses, and four measurements of PCT performance for each of the glasses for both the as-received and CCC heat treated versions. In the sections that follow, the methods used for measuring chemical composition and PCT performance are described and 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[4] on four representative samples from each of the two as-received glasses. Two preparation techniques, sodium peroxide fusion (PF) and lithium metaborate fusion (LM), were used to prepare the glass samples in duplicate for analysis. Each of the samples was analyzed, twice for each element of interest, by Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES). An additional preparation technique, potassium hydroxide fusion (KH), was used to prepare the glass samples in duplicate for analysis of fluorine concentration by Ion Chromatography (IC). Glass standards were intermittently measured to assess the performance of the analytical instruments over the course of these analyses. Specifically, several samples of the Waste Compliance Plan Batch 1 glass[5] were included as part of the analytical plan for ICP-OES analysis, and several samples of the low-level reference material (LRM)[6] were included as part of the analytical plan for IC analysis. The preparation method used for each of the reported glass components is listed in Table 2-1.

Table 2-1. Preparation Method Used in Reporting the Concentrations of Each of the Components of the Study Glasses.

Component	Preparation Method
Al	PF
B	PF
Bi	LM
Ca	LM
Cr	LM
F	KH
Fe	PF
K	LM
Li	PF
Mn	PF
Na	LM
Ni	LM
P	LM
Pb	LM
Si	PF
W	LM

2.3 Product Consistency Test

The PCT Method-A[7] was performed in triplicate on four samples of each of the two glasses, both as-received and heat treated following the CCC profile, to assess chemical durability. Also included in the experimental test matrix was the Environmental Assessment (EA) benchmark glass,[8] the Approved Reference Material (ARM-1) glass,[9] and blanks from the sample cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.[7] Fifteen milliliters of Type-I ASTM water were added to 1.5 g of glass in stainless steel vessels. The vessels were closed, sealed, and placed in an oven at 90 ± 2 °C where the samples were maintained at temperature for 7 days. Once cooled, the resulting solutions were sampled (filtered and acidified), then labeled and analyzed by ICP-OES under the auspices of an analytical plan.[10] Samples of a multi-element, standard solution were also included in the analytical plans as a check on the accuracy of the ICP-OES instrument used for these measurements.

2.4 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in Savannah River Site Manual E7, Procedure 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.

3.0 Results and Discussion

3.1 Review and Evaluation of Chemical Composition Measurements

Table A-1, Table A-2, and Table A-3 in Appendix A provide the elemental concentration measurements in wt % from the round robin study glasses that were prepared by the PF, LM, and KH methods, respectively. Elemental measurements for samples of the Batch 1 and LRM reference glasses are also provided in these tables. 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 standard glasses are investigated, the measurements for each glass are reviewed, and the average chemical composition for each glass is determined. JMP Version 11.1.1 (SAS Institute, Inc.)[11] was used to support these analyses.

3.1.1 Treatment of Detection Limits

The elemental concentrations in Table A-1 through Table A-3 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 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 the study glasses 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 through Table A-3, 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 for sodium in the second block. As will be shown in Section 3.1.4, the measured sodium values for all of the Batch 1 reference glass samples were within the acceptability limits, so this minor shift in sodium measurements is considered insignificant. There do not

appear to be any other patterns or trends in the analytical process over the course of the composition measurements.

3.1.3 Composition Measurements by Glass Identifier

Exhibit A-2 in Appendix A provides plots of the oxide concentration measurements by the round robin ID (including the Batch 1 and LRM reference glasses), by Lab ID, and grouped by glass sub-sample. 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. No observations from Exhibit A-2 indicate an error in preparation or measurement. Therefore, the entire set of measurement data was used in determining representative, measured compositions for each sub-sample of the study glasses.

3.1.4 Results for the Batch 1 and LRM Reference Glasses

Exhibit A-3 in Appendix A provides a review of the Batch 1 and LRM results against acceptability limits.[12] The review is in the form of a plot of the measurements arranged by reference glass and element. The preparation method is indicated on each plot. The plotted measurements are framed by upper and lower acceptability limits for the element in question. The results show that all of the measurements for the elements present in the Batch 1 and LRM reference glasses were within the acceptability limits.

3.1.5 Summary of the Measured Compositions

Given that no issues were identified with the measured values, all of the measurements for each oxide for each glass sample (i.e., all of the measurements in Appendix A, Table A-1 through Table A-3) were averaged to determine a representative chemical composition for each glass sample. The resulting values are provided in Table 3-1. A sum of oxides was also computed for each glass based upon the measured values. All of the measured sums of oxides for the study glasses fall within the interval of 98.3 to 99.6 wt %, indicating excellent recovery of all components.

Table 3-1. Measured Compositions (wt %) for Each Glass Sample

Oxide	HLW-HCr-16-X (II) (1st sub-sample)	HLW-HCr-16-X (II) (2nd sub-sample)	HLW-HCr-16-X (II) (3rd sub-sample)	HLW-HCr-16-X (II) (4th sub-sample)	HLW-HCr-16-Y (I) (1st sub-sample)	HLW-HCr-16-Y (I) (2nd sub-sample)	HLW-HCr-16-Y (I) (3rd sub-sample)	HLW-HCr-16-Y (I) (4th sub-sample)
Al_2O_3	19.37	19.46	19.51	19.46	19.73	19.12	19.27	19.11
B_2O_3	14.51	14.31	14.48	14.59	14.25	14.37	14.77	14.39
Bi_2O_3	0.71	0.70	0.69	0.70	0.71	0.72	0.72	0.71
CaO	0.83	0.84	0.83	0.83	0.81	0.81	0.82	0.80
Cr_2O_3	1.68	1.58	1.45	1.71	1.66	1.64	1.71	1.67
F	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fe_2O_3	5.17	5.14	5.17	5.12	5.32	5.29	5.41	5.33
K_2O	6.05	6.02	6.11	6.05	5.92	5.96	5.90	5.93
Li_2O	3.84	3.82	3.83	3.96	3.77	3.77	3.79	3.79
MnO	1.23	1.22	1.22	1.22	1.19	1.20	1.24	1.20
Na_2O	9.66	9.63	9.76	9.66	9.73	9.77	9.70	9.74
NiO	0.26	0.25	0.24	0.26	0.28	0.27	0.28	0.28
P_2O_5	0.36	0.36	0.36	0.36	0.37	0.37	0.37	0.37
PbO	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
SiO_2	34.66	34.55	34.39	34.39	34.55	34.82	35.25	34.76
WO_3	0.09	0.08	0.09	0.09	0.08	0.09	0.09	0.08
Sum of oxides	98.72	98.28	98.44	98.67	98.69	98.51	99.63	98.46

3.2 Review and Evaluation of PCT Measurements

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 and after adjustments for the dilution factors. The measurements for the study glasses, blanks, and the ARM-1 glass were multiplied by 1.6667 to adjust for dilution, and the measurements for EA were multiplied by 16.6667 to adjust for dilution.

Based on the masses of the PCT vessels before and after the 7-day procedures, there were no samples that had water-loss issues per ASTM C 1285. The ratio of leachant volume to the mass of ground glass was confirmed to be correct for each vessel. All of the measurements of the ARM glass fell within the control ranges established by SRNL.[9] Measurements of the elements of interest from the blank leachates were all below the analytical detection limits. The measured pH values for each of the PCT leachates are provided in Table B-2 in Appendix B for reference.

In the sections that follow, the analytical sequences of the measurements are explored, the measurements for each glass are reviewed, and the measurements of the multi-element solution standard are investigated. The results are provided for the two heat treatments of each glass sample: as-received and CCC. JMP Version 11.1.1 (SAS Institute, Inc.)[11] was used to support these analyses.

3.2.1 Treatment of Detection Limits

Some of the "ar" measurements in Table B-1 were below the detection limit of 1 ppm (or 0.1 ppm for Cr) 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. Those elements with measured concentrations that were below their associated detection limit will be denoted with a less than symbol (<) as the values are reported.

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

The measurements of the solution standard samples that were included in the analytical blocks for the PCT analyses were reviewed. For each analytical block, the mean, standard deviation, and percent relative standard deviation (%RSD) were determined for each element present in the standard. Following the guidance in ASTM C 1285, there were two primary evaluations conducted for these summary statistics: the mean value for each element in each analytical block was confirmed to be less than 10% from the reference value (i.e., a percent relative bias less than 10% (absolute)), and the %RSD for each element in each analytical block was confirmed to be less than 10%. The results in Table 3-2 summarize the analyses of the solution standard measurements and demonstrate that they meet the criteria set by ASTM C 1285. Thus, there are no issues with the analytical outcomes for the measurements of the PCT solutions.

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

Analytical Block	1	2	3	Reference values (ppm)
Mean(Al (ppm))	3.73	3.76	3.67	4
Mean(B (ppm))	19.83	20.37	20.47	20
Mean(Cr (ppm))	<0.1	<0.1	<0.1	0
Mean(Fe (ppm))	4.11	3.89	3.86	4
Mean(Li (ppm))	9.67	9.71	9.61	10
Mean(Na (ppm))	83.23	85.03	85.33	81
Mean(Si (ppm))	50.90	50.07	50.93	50
% relative bias, Al	-6.8%	-5.9%	-8.2%	<10% absolute per ASTM C 1285
% relative bias, B	-0.8%	1.8%	2.3%	
% relative bias, Cr	na	na	na	
% relative bias, Fe	2.8%	-2.8%	-3.6%	
% relative bias, Li	-3.3%	-2.9%	-3.9%	
% relative bias, Na	2.8%	5.0%	5.3%	
% relative bias, Si	1.8%	0.1%	1.9%	
Std Dev(Al (ppm))	0.046	0.147	0.023	
Std Dev(B (ppm))	0.651	0.551	0.404	
Std Dev(Cr (ppm))	na	na	na	
Std Dev(Fe (ppm))	0.040	0.141	0.038	
Std Dev(Li (ppm))	0.062	0.276	0.101	
Std Dev(Na (ppm))	1.436	3.057	0.814	
Std Dev(Si (ppm))	0.964	2.354	1.097	
%RSD(Al (ppm))	1.23%	3.92%	0.63%	<10% absolute per ASTM C 1285
%RSD(B (ppm))	3.28%	2.70%	1.97%	
%RSD(Cr (ppm))	na	na	na	
%RSD(Fe (ppm))	0.97%	3.63%	0.98%	
%RSD(Li (ppm))	0.65%	2.84%	1.05%	
%RSD(Na (ppm))	1.73%	3.59%	0.95%	
%RSD(Si (ppm))	1.89%	4.70%	2.15%	

3.2.3 Measurements in Analytical Sequence

Exhibit B-1 in Appendix B provides plots of the common logarithms of the leachate (ppm) concentrations in analytical sequence by analytical block. Plotting the data in this format provides an opportunity to identify gross trends in performance of the analytical instrument within and among calibration blocks. No issues were observed in these plots.

3.2.4 Measurements by Glass Sample Identifier

Exhibit B-2 in Appendix B provides plots of the leachate concentrations for both the as-received and CCC version of each of the study glasses and for the reference glasses for each analytical set. These plots are in common logarithms of the ppm values and allow for the assessment of the repeatability of the measurements and any differences between the as-received and CCC versions of a given glass. For some of the glasses, minor scatter among the triplicate values of some analytes is observed. In addition, there are differences in the PCT responses between the as-received and CCC versions of some of the study glasses. Table 3-3 provides a summary of the PCT responses.

Table 3-3. PCT Leachate Data for Round Robin Glasses

Glass ID	Heat Treatment	Al (ppm)	B (ppm)	Cr (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
ARM-1	ref	6.02	16.83	<0.17	<1.67	12.70	34.67	58.34
ARM-1	ref	5.93	19.83	<0.17	<1.67	14.28	39.67	62.50
ARM-1	ref	6.07	17.83	<0.17	<1.67	13.33	37.33	61.67
blank	ref	<1.67	<1.67	<0.17	<1.67	<1.67	<1.67	<1.67
blank	ref	<1.67	<1.67	<0.17	<1.67	<1.67	<1.67	<1.67
EA	ref	<16.67	315.00	<1.67	<16.67	126.67	921.67	578.33
EA	ref	<16.67	318.33	<1.67	<16.67	114.00	990.00	591.67
EA	ref	<16.67	386.67	<1.67	<16.67	129.50	1101.67	695.00
HLW-HCr-16-X (II) (1st sub-sample)	as-received	33.50	47.50	<0.17	5.85	18.33	57.83	48.50
HLW-HCr-16-X (II) (1st sub-sample)	as-received	34.67	50.83	<0.17	5.72	18.67	58.84	49.17
HLW-HCr-16-X (II) (1st sub-sample)	as-received	35.50	48.50	<0.17	5.62	17.33	56.50	50.83
HLW-HCr-16-X (II) (1st sub-sample)	CCC	17.17	301.67	<0.17	<1.67	103.84	183.34	44.83
HLW-HCr-16-X (II) (1st sub-sample)	CCC	17.17	303.34	<0.17	<1.67	105.34	188.34	42.00
HLW-HCr-16-X (II) (1st sub-sample)	CCC	17.33	306.67	<0.17	<1.67	104.17	185.00	43.83
HLW-HCr-16-X (II) (2nd sub-sample)	as-received	35.33	51.50	<0.17	5.98	19.00	59.34	52.17
HLW-HCr-16-X (II) (2nd sub-sample)	as-received	33.33	47.67	<0.17	5.30	18.00	56.67	46.83
HLW-HCr-16-X (II) (2nd sub-sample)	as-received	35.83	53.67	<0.17	5.68	19.00	60.17	51.50
HLW-HCr-16-X (II) (2nd sub-sample)	CCC	16.83	303.34	<0.17	<1.67	105.34	183.34	44.00
HLW-HCr-16-X (II) (2nd sub-sample)	CCC	17.50	318.34	<0.17	<1.67	109.17	195.00	43.83
HLW-HCr-16-X (II) (2nd sub-sample)	CCC	17.00	326.67	<0.17	<1.67	107.34	190.00	43.67
HLW-HCr-16-X (II) (3rd sub-sample)	as-received	34.83	49.33	<0.17	6.15	18.50	58.00	50.50
HLW-HCr-16-X (II) (3rd sub-sample)	as-received	36.17	52.50	<0.17	6.03	19.00	60.84	51.17
HLW-HCr-16-X (II) (3rd sub-sample)	as-received	33.17	46.33	<0.17	5.37	17.67	56.00	47.17
HLW-HCr-16-X (II) (3rd sub-sample)	CCC	16.83	306.67	<0.17	<1.67	107.17	188.34	44.67
HLW-HCr-16-X (II) (3rd sub-sample)	CCC	17.83	318.34	<0.17	<1.67	108.17	191.67	43.67
HLW-HCr-16-X (II) (3rd sub-sample)	CCC	16.20	306.67	<0.17	<1.67	104.17	183.34	42.17
HLW-HCr-16-X (II) (4th sub-sample)	as-received	34.67	47.00	<0.17	6.13	18.33	57.33	49.33
HLW-HCr-16-X (II) (4th sub-sample)	as-received	33.50	46.50	<0.17	5.57	17.83	57.17	46.50
HLW-HCr-16-X (II) (4th sub-sample)	as-received	35.83	51.50	<0.17	5.97	18.67	59.34	51.50
HLW-HCr-16-X (II) (4th sub-sample)	CCC	17.00	298.34	<0.17	<1.67	107.34	188.34	43.33
HLW-HCr-16-X (II) (4th sub-sample)	CCC	17.33	310.01	<0.17	<1.67	108.50	193.34	41.83
HLW-HCr-16-X (II) (4th sub-sample)	CCC	17.17	325.01	<0.17	<1.67	106.34	188.34	44.00
HLW-HCr-16-Y (I) (1st sub-sample)	as-received	36.33	65.50	<0.17	6.85	24.00	71.84	55.00
HLW-HCr-16-Y (I) (1st sub-sample)	as-received	35.00	62.50	<0.17	6.40	23.33	71.00	51.00
HLW-HCr-16-Y (I) (1st sub-sample)	as-received	35.33	65.67	<0.17	6.13	23.50	71.34	52.33

Table 3-3. PCT Leachate Data for Round Robin Glasses (continued)

Glass ID	Heat Treatment	Al (ppm)	B (ppm)	Cr (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
HLW-HCr-16-Y (I) (1st sub-sample)	CCC	32.83	59.50	<0.17	4.78	23.00	67.17	52.17
HLW-HCr-16-Y (I) (1st sub-sample)	CCC	34.67	65.00	<0.17	4.53	24.50	71.84	51.67
HLW-HCr-16-Y (I) (1st sub-sample)	CCC	34.17	69.34	<0.17	4.52	24.50	72.67	53.17
HLW-HCr-16-Y (I) (2nd sub-sample)	as-received	34.83	60.84	<0.17	6.70	23.00	69.00	52.67
HLW-HCr-16-Y (I) (2nd sub-sample)	as-received	35.67	61.17	<0.17	6.62	22.50	68.84	50.50
HLW-HCr-16-Y (I) (2nd sub-sample)	as-received	36.33	67.34	<0.17	6.58	23.50	72.34	54.17
HLW-HCr-16-Y (I) (2nd sub-sample)	CCC	33.50	62.67	<0.17	4.92	24.00	69.50	53.17
HLW-HCr-16-Y (I) (2nd sub-sample)	CCC	33.17	66.17	<0.17	4.53	24.33	71.84	52.17
HLW-HCr-16-Y (I) (2nd sub-sample)	CCC	33.00	64.17	<0.17	4.37	23.83	70.50	51.83
HLW-HCr-16-Y (I) (3rd sub-sample)	as-received	34.50	56.67	<0.17	6.92	21.33	65.00	50.83
HLW-HCr-16-Y (I) (3rd sub-sample)	as-received	35.67	59.50	<0.17	6.65	21.83	67.00	52.33
HLW-HCr-16-Y (I) (3rd sub-sample)	as-received	34.83	61.67	<0.17	6.23	22.17	68.67	51.50
HLW-HCr-16-Y (I) (3rd sub-sample)	CCC	34.67	66.17	<0.17	5.10	25.00	72.50	54.83
HLW-HCr-16-Y (I) (3rd sub-sample)	CCC	33.17	66.17	<0.17	4.53	23.67	69.50	52.67
HLW-HCr-16-Y (I) (3rd sub-sample)	CCC	32.50	63.50	<0.17	4.28	23.17	68.00	52.50
HLW-HCr-16-Y (I) (4th sub-sample)	as-received	35.33	61.67	<0.17	6.65	22.17	67.67	54.00
HLW-HCr-16-Y (I) (4th sub-sample)	as-received	35.83	63.50	<0.17	6.68	22.67	69.50	52.50
HLW-HCr-16-Y (I) (4th sub-sample)	as-received	35.67	64.67	<0.17	6.38	22.33	68.84	53.50
HLW-HCr-16-Y (I) (4th sub-sample)	CCC	33.83	63.84	<0.17	4.98	23.83	69.34	54.67
HLW-HCr-16-Y (I) (4th sub-sample)	CCC	33.17	61.50	<0.17	4.50	23.33	69.17	52.17
HLW-HCr-16-Y (I) (4th sub-sample)	CCC	31.83	58.00	<0.17	4.27	21.50	63.50	49.83

4.0 Summary

The results of SRNL chemical composition measurements (Table 3-1) and PCTs (Table 3-3) of the two glasses provided by PNNL for addressing Question 1 at Time Interval 2 of the round robin study are presented in this report. No issues were identified in a review of the chemical composition data. All of the measurements for the elements present in the Batch 1 and LRM reference glasses were within the acceptability limits. It is recommended that these data be reviewed to determine whether there are statistically significant differences among the chemical compositions of the two glasses.

A review of the PCT data identified no issues with the performance of the tests. Measurements of the solution standard samples met the criteria in ASTM C 1285, the ARM-1 measurements were within the control ranges utilized by SRNL, the ratios of leachant volume to the mass of ground glass were correct, and there were no issues with water loss. While outside the scope of this report, it is interesting to note that differences were observed in the PCT responses of glass HLW-HCr-16-X (II) as a function of heat treatment (as-received vs. CCC). The leachate concentrations for some elements (B, Li, and Na) were higher in the CCC version of this glass as compared to the as-received version, while some other elements (Al and Fe) were present in the leachates at higher concentrations for the as-received version of this glass as compared to the CCC version. It is recommended that these differences be evaluated, along with the data produced by the other round robin participants, to determine whether there are statistically significant differences among the PCT responses of the two glasses.

5.0 References

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Appendix A Tables and Exhibits Supporting the Chemical Composition Measurements

Table A-1. PF Measurements of the Study Glasses

ID	Block	Sequence	Lab ID	Al (wt%)	B (wt%)	Fe (wt%)	Li (wt%)	Mn (wt%)	Si (wt%)
Batch 1	1	1	BCHPF11	2.41	2.42	9.07	2.04	1.29	23.9
HLW-HCr-16-X (II) (3rd sub-sample)	1	2	RR01PF11	10.5	4.56	3.65	1.81	0.938	16.4
HLW-HCr-16-X (II) (2nd sub-sample)	1	3	RR05PF11	10.2	4.49	3.60	1.79	0.932	16.4
HLW-HCr-16-Y (I) (4th sub-sample)	1	4	RR07PF21	10.0	4.50	3.75	1.77	0.920	16.6
HLW-HCr-16-X (II) (1st sub-sample)	1	5	RR03PF21	10.2	4.49	3.63	1.79	0.940	16.4
HLW-HCr-16-Y (I) (2nd sub-sample)	1	6	RR04PF21	10.2	4.46	3.73	1.77	0.920	16.5
HLW-HCr-16-Y (I) (3rd sub-sample)	1	7	RR02PF11	10.1	4.46	3.73	1.77	0.918	16.5
HLW-HCr-16-X (II) (1st sub-sample)	1	8	RR03PF11	10.4	4.49	3.63	1.79	0.942	16.4
HLW-HCr-16-Y (I) (2nd sub-sample)	1	9	RR04PF11	10.2	4.37	3.68	1.74	0.909	16.3
Batch 1	1	10	BCHPF12	2.45	2.31	9.09	2.03	1.30	23.7
HLW-HCr-16-Y (I) (1st sub-sample)	1	11	RR08PF11	10.8	4.37	3.72	1.74	0.907	16.1
HLW-HCr-16-X (II) (2nd sub-sample)	1	12	RR05PF21	10.5	4.40	3.59	1.78	0.935	16.2
HLW-HCr-16-Y (I) (3rd sub-sample)	1	13	RR02PF21	10.2	4.82	4.02	1.80	1.01	16.6
HLW-HCr-16-X (II) (3rd sub-sample)	1	14	RR01PF21	10.5	4.40	3.60	1.77	0.931	16.1
HLW-HCr-16-X (II) (4th sub-sample)	1	15	RR06PF21	10.5	4.57	3.60	1.91	0.933	16.3
HLW-HCr-16-Y (I) (4th sub-sample)	1	16	RR07PF11	10.3	4.37	3.70	1.75	0.907	16.1
HLW-HCr-16-Y (I) (1st sub-sample)	1	17	RR08PF21	10.3	4.39	3.71	1.76	0.908	16.2
HLW-HCr-16-X (II) (4th sub-sample)	1	18	RR06PF11	10.4	4.39	3.56	1.77	0.925	16.1
Batch 1	1	19	BCHPF13	2.55	2.29	9.00	2.02	1.29	23.4
Batch 1	2	1	BCHPF21	2.61	2.52	9.25	2.07	1.36	24.2
HLW-HCr-16-X (II) (2nd sub-sample)	2	2	RR05PF22	10.5	4.43	3.62	1.78	0.968	16.2
HLW-HCr-16-Y (I) (3rd sub-sample)	2	3	RR02PF12	10.4	4.48	3.72	1.76	0.949	16.3
HLW-HCr-16-Y (I) (3rd sub-sample)	2	4	RR02PF22	10.1	4.59	3.66	1.72	0.969	16.5
HLW-HCr-16-Y (I) (1st sub-sample)	2	5	RR08PF12	10.8	4.45	3.74	1.75	0.941	16.1
HLW-HCr-16-X (II) (3rd sub-sample)	2	6	RR01PF22	10.2	4.41	3.53	1.73	0.945	15.6
HLW-HCr-16-Y (I) (4th sub-sample)	2	7	RR07PF22	10.3	4.49	3.72	1.76	0.945	16.1
HLW-HCr-16-X (II) (1st sub-sample)	2	8	RR03PF12	10.4	4.48	3.58	1.77	0.958	15.9
HLW-HCr-16-Y (I) (2nd sub-sample)	2	9	RR04PF12	10.3	4.45	3.67	1.74	0.936	16.1
Batch 1	2	10	BCHPF22	2.58	2.40	9.11	2.05	1.34	23.8
HLW-HCr-16-X (II) (4th sub-sample)	2	11	RR06PF22	10.2	4.57	3.52	1.87	0.941	15.7
HLW-HCr-16-X (II) (2nd sub-sample)	2	12	RR05PF12	10.0	4.46	3.56	1.75	0.952	15.8
HLW-HCr-16-Y (I) (1st sub-sample)	2	13	RR08PF22	9.86	4.49	3.72	1.76	0.944	16.2
HLW-HCr-16-X (II) (1st sub-sample)	2	14	RR03PF22	10.0	4.57	3.63	1.79	0.974	16.1
HLW-HCr-16-X (II) (4th sub-sample)	2	15	RR06PF12	10.1	4.59	3.63	1.80	0.977	16.2
HLW-HCr-16-Y (I) (4th sub-sample)	2	16	RR07PF12	9.85	4.51	3.73	1.76	0.949	16.2
HLW-HCr-16-Y (I) (2nd sub-sample)	2	17	RR04PF22	9.77	4.57	3.72	1.76	0.949	16.2
HLW-HCr-16-X (II) (3rd sub-sample)	2	18	RR01PF12	10.1	4.62	3.68	1.80	0.978	16.2
Batch 1	2	19	BCHPF23	2.42	2.40	9.02	2.02	1.32	23.6

Table A-2. LM Measurements of the Study Glasses

ID	Block	Sequence	Lab ID	Bi (wt%)	Ca (wt%)	Cr (wt%)	K (wt%)	Na (wt%)	Ni (wt%)	P (wt%)	Pb (wt%)	W (wt%)
Batch 1	1	1	BCHLM11	<0.010	0.793	0.057	2.86	6.58	0.545	<0.100	<0.100	<0.010
HLW-HCr-16-Y (I) (3rd sub-sample)	1	2	RR02LM11	0.634	0.582	1.19	5.00	7.24	0.221	0.160	0.241	0.074
HLW-HCr-16-Y (I) (1st sub-sample)	1	3	RR08LM11	0.639	0.575	1.10	4.84	7.08	0.216	0.161	0.239	0.068
HLW-HCr-16-X (II) (4th sub-sample)	1	4	RR06LM21	0.624	0.584	1.15	4.90	6.99	0.200	0.156	0.243	0.069
HLW-HCr-16-Y (I) (2nd sub-sample)	1	5	RR04LM21	0.631	0.577	1.16	4.90	7.11	0.218	0.164	0.241	0.068
HLW-HCr-16-X (II) (4th sub-sample)	1	6	RR06LM11	0.609	0.573	1.14	4.96	7.04	0.195	0.155	0.239	0.068
HLW-HCr-16-Y (I) (4th sub-sample)	1	7	RR07LM21	0.629	0.563	1.13	4.81	7.07	0.215	0.159	0.238	0.068
HLW-HCr-16-X (II) (2nd sub-sample)	1	8	RR05LM11	0.620	0.583	0.994	4.92	7.02	0.192	0.155	0.241	0.067
HLW-HCr-16-X (II) (3rd sub-sample)	1	9	RR01LM21	0.609	0.580	0.925	4.96	7.05	0.181	0.155	0.238	0.068
Batch 1	1	10	BCHLM12	<0.010	0.776	0.056	2.80	6.48	0.536	<0.100	<0.100	<0.010
HLW-HCr-16-X (II) (1st sub-sample)	1	11	RR03LM11	0.624	0.584	1.11	4.92	7.02	0.198	0.156	0.240	0.074
HLW-HCr-16-Y (I) (2nd sub-sample)	1	12	RR04LM11	0.637	0.571	1.05	4.90	7.13	0.208	0.160	0.241	0.069
HLW-HCr-16-Y (I) (3rd sub-sample)	1	13	RR02LM21	0.629	0.562	1.14	4.82	7.06	0.216	0.156	0.238	0.068
HLW-HCr-16-Y (I) (1st sub-sample)	1	14	RR08LM21	0.625	0.559	1.13	4.80	7.08	0.215	0.153	0.236	0.067
HLW-HCr-16-Y (I) (4th sub-sample)	1	15	RR07LM11	0.625	0.563	1.13	4.91	7.16	0.214	0.158	0.236	0.066
HLW-HCr-16-X (II) (3rd sub-sample)	1	16	RR01LM11	0.609	0.580	1.03	5.07	7.19	0.192	0.152	0.237	0.066
HLW-HCr-16-X (II) (1st sub-sample)	1	17	RR03LM21	0.621	0.580	1.16	5.02	7.16	0.199	0.155	0.237	0.068
HLW-HCr-16-X (II) (2nd sub-sample)	1	18	RR05LM21	0.621	0.589	1.13	4.96	7.03	0.198	0.157	0.242	0.067
Batch 1	1	19	BCHLM13	<0.010	0.774	0.055	2.80	6.43	0.535	<0.100	<0.100	<0.010
Batch 1	2	1	BCHLM21	<0.010	0.829	0.057	2.88	6.68	0.567	<0.100	<0.100	<0.010
HLW-HCr-16-Y (I) (3rd sub-sample)	2	2	RR02LM12	0.650	0.598	1.19	4.90	7.26	0.225	0.164	0.246	0.071
HLW-HCr-16-Y (I) (2nd sub-sample)	2	3	RR04LM12	0.657	0.588	1.08	4.95	7.34	0.214	0.165	0.246	0.066
HLW-HCr-16-Y (I) (4th sub-sample)	2	4	RR07LM12	0.645	0.587	1.16	5.01	7.37	0.222	0.162	0.245	0.066
HLW-HCr-16-X (II) (1st sub-sample)	2	5	RR03LM22	0.635	0.595	1.18	5.09	7.29	0.204	0.160	0.244	0.066
HLW-HCr-16-Y (I) (1st sub-sample)	2	6	RR08LM12	0.639	0.580	1.13	4.92	7.25	0.218	0.162	0.241	0.065
HLW-HCr-16-X (II) (4th sub-sample)	2	7	RR06LM22	0.622	0.596	1.20	5.12	7.33	0.203	0.159	0.244	0.067
HLW-HCr-16-X (II) (2nd sub-sample)	2	8	RR05LM22	0.640	0.607	1.16	5.03	7.21	0.203	0.162	0.246	0.066
HLW-HCr-16-Y (I) (4th sub-sample)	2	9	RR07LM22	0.645	0.585	1.16	4.95	7.30	0.221	0.165	0.246	0.065
Batch 1	2	10	BCHLM22	<0.010	0.803	0.057	2.86	6.71	0.553	<0.100	<0.100	<0.010
HLW-HCr-16-Y (I) (2nd sub-sample)	2	11	RR04LM22	0.639	0.585	1.21	5.04	7.40	0.219	0.164	0.242	0.071
HLW-HCr-16-X (II) (3rd sub-sample)	2	12	RR01LM12	0.627	0.600	1.06	5.17	7.44	0.199	0.158	0.243	0.068
HLW-HCr-16-X (II) (2nd sub-sample)	2	13	RR05LM12	0.634	0.608	1.03	5.07	7.32	0.197	0.161	0.245	0.067
HLW-HCr-16-Y (I) (3rd sub-sample)	2	14	RR02LM22	0.651	0.590	1.17	4.87	7.22	0.226	0.165	0.246	0.066
HLW-HCr-16-X (II) (1st sub-sample)	2	15	RR03LM12	0.648	0.613	1.14	5.05	7.19	0.206	0.162	0.248	0.067
HLW-HCr-16-X (II) (3rd sub-sample)	2	16	RR01LM22	0.644	0.620	0.956	5.10	7.27	0.189	0.160	0.249	0.067
HLW-HCr-16-X (II) (4th sub-sample)	2	17	RR06LM12	0.637	0.609	1.18	5.10	7.29	0.203	0.162	0.247	0.065
HLW-HCr-16-Y (I) (1st sub-sample)	2	18	RR08LM22	0.658	0.594	1.19	5.10	7.47	0.225	0.162	0.247	0.065
Batch 1	2	19	BCHLM23	<0.010	0.816	0.058	2.94	6.84	0.559	<0.100	<0.100	<0.010

Table A-3. KH Measurements of the Study Glasses

ID	Block	Sequence	Lab ID	F (wt%)
LRM	1	1	LRMKH11	0.792
HLW-HCr-16-X (II) (4th sub-sample)	1	2	RR06KH21	<0.050
HLW-HCr-16-X (II) (3rd sub-sample)	1	3	RR01KH11	<0.050
HLW-HCr-16-X (II) (1st sub-sample)	1	4	RR03KH11	<0.050
HLW-HCr-16-X (II) (4th sub-sample)	1	5	RR06KH11	<0.050
HLW-HCr-16-X (II) (3rd sub-sample)	1	6	RR01KH21	<0.050
HLW-HCr-16-Y (I) (2nd sub-sample)	1	7	RR04KH11	<0.050
HLW-HCr-16-X (II) (2nd sub-sample)	1	8	RR05KH21	<0.050
HLW-HCr-16-Y (I) (4th sub-sample)	1	9	RR07KH11	<0.050
LRM	1	10	LRMKH12	0.797
HLW-HCr-16-Y (I) (1st sub-sample)	1	11	RR08KH11	<0.050
HLW-HCr-16-X (II) (2nd sub-sample)	1	12	RR05KH11	<0.050
HLW-HCr-16-Y (I) (4th sub-sample)	1	13	RR07KH21	<0.050
HLW-HCr-16-Y (I) (3rd sub-sample)	1	14	RR02KH11	<0.050
HLW-HCr-16-Y (I) (3rd sub-sample)	1	15	RR02KH21	<0.050
HLW-HCr-16-X (II) (1st sub-sample)	1	16	RR03KH21	<0.050
HLW-HCr-16-Y (I) (1st sub-sample)	1	17	RR08KH21	<0.050
HLW-HCr-16-Y (I) (2nd sub-sample)	1	18	RR04KH21	<0.050
LRM	1	19	LRMKH13	0.804
LRM	2	1	LRMKH21	0.805
HLW-HCr-16-X (II) (3rd sub-sample)	2	2	RR01KH22	<0.050
HLW-HCr-16-Y (I) (3rd sub-sample)	2	3	RR02KH12	<0.050
HLW-HCr-16-X (II) (4th sub-sample)	2	4	RR06KH22	<0.050
HLW-HCr-16-Y (I) (4th sub-sample)	2	5	RR07KH12	<0.050
HLW-HCr-16-X (II) (2nd sub-sample)	2	6	RR05KH22	<0.050
HLW-HCr-16-X (II) (4th sub-sample)	2	7	RR06KH12	<0.050
HLW-HCr-16-Y (I) (1st sub-sample)	2	8	RR08KH12	<0.050
HLW-HCr-16-Y (I) (2nd sub-sample)	2	9	RR04KH12	<0.050
LRM	2	10	LRMKH22	0.811
HLW-HCr-16-X (II) (2nd sub-sample)	2	11	RR05KH12	<0.050
HLW-HCr-16-Y (I) (2nd sub-sample)	2	12	RR04KH22	<0.050
HLW-HCr-16-Y (I) (4th sub-sample)	2	13	RR07KH22	<0.050
HLW-HCr-16-X (II) (1st sub-sample)	2	14	RR03KH12	<0.050
HLW-HCr-16-X (II) (3rd sub-sample)	2	15	RR01KH12	<0.050
HLW-HCr-16-X (II) (1st sub-sample)	2	16	RR03KH22	<0.050
HLW-HCr-16-Y (I) (3rd sub-sample)	2	17	RR02KH22	<0.050
HLW-HCr-16-Y (I) (1st sub-sample)	2	18	RR08KH22	<0.050
LRM	2	19	LRMKH23	0.814

Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block

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

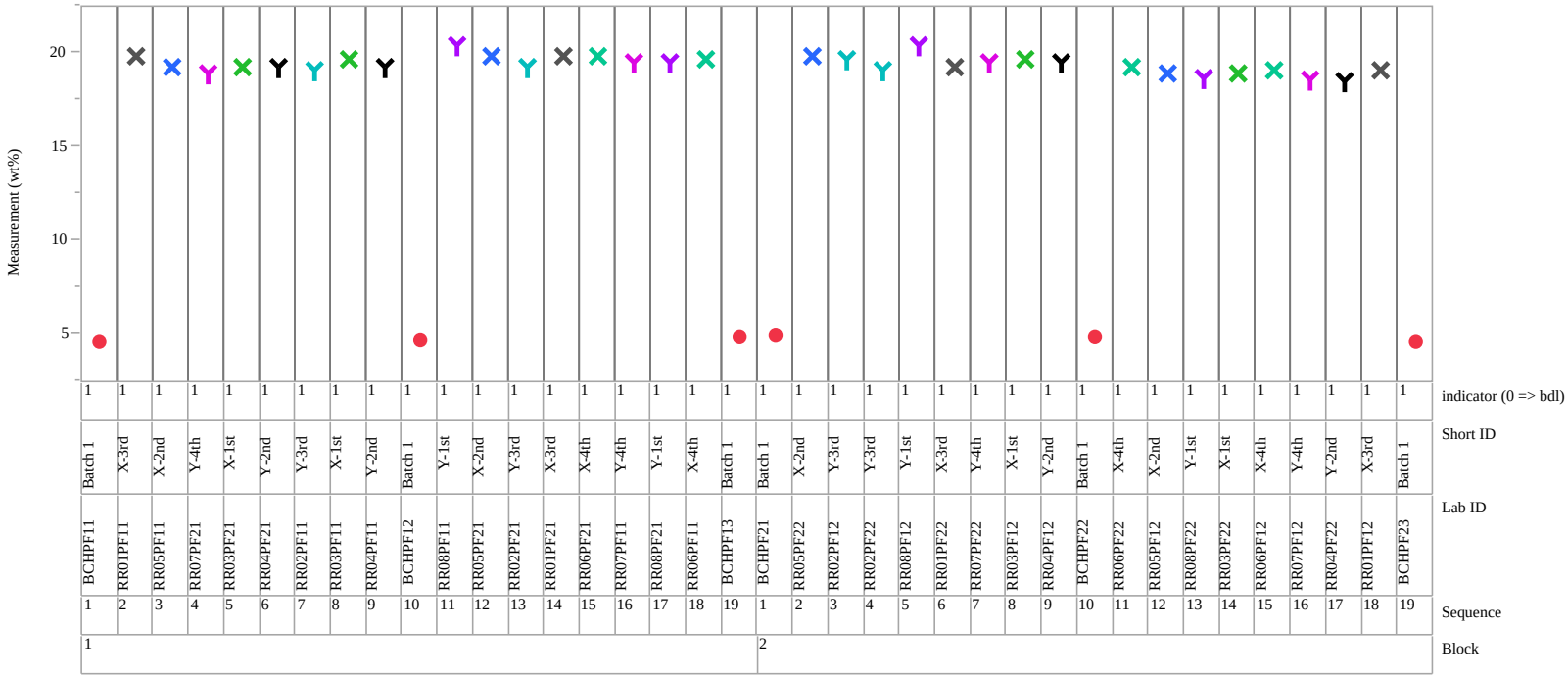


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

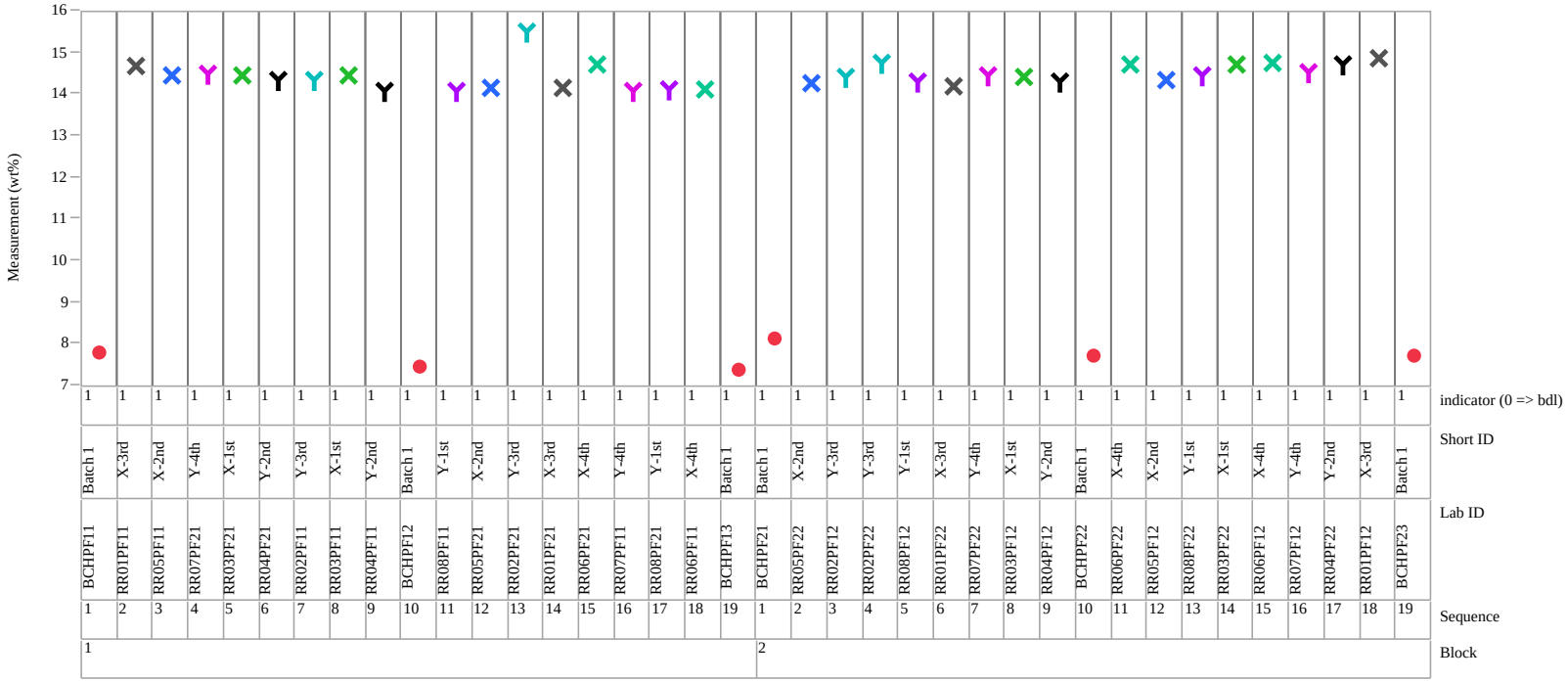


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

Oxide=Bi2O3 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

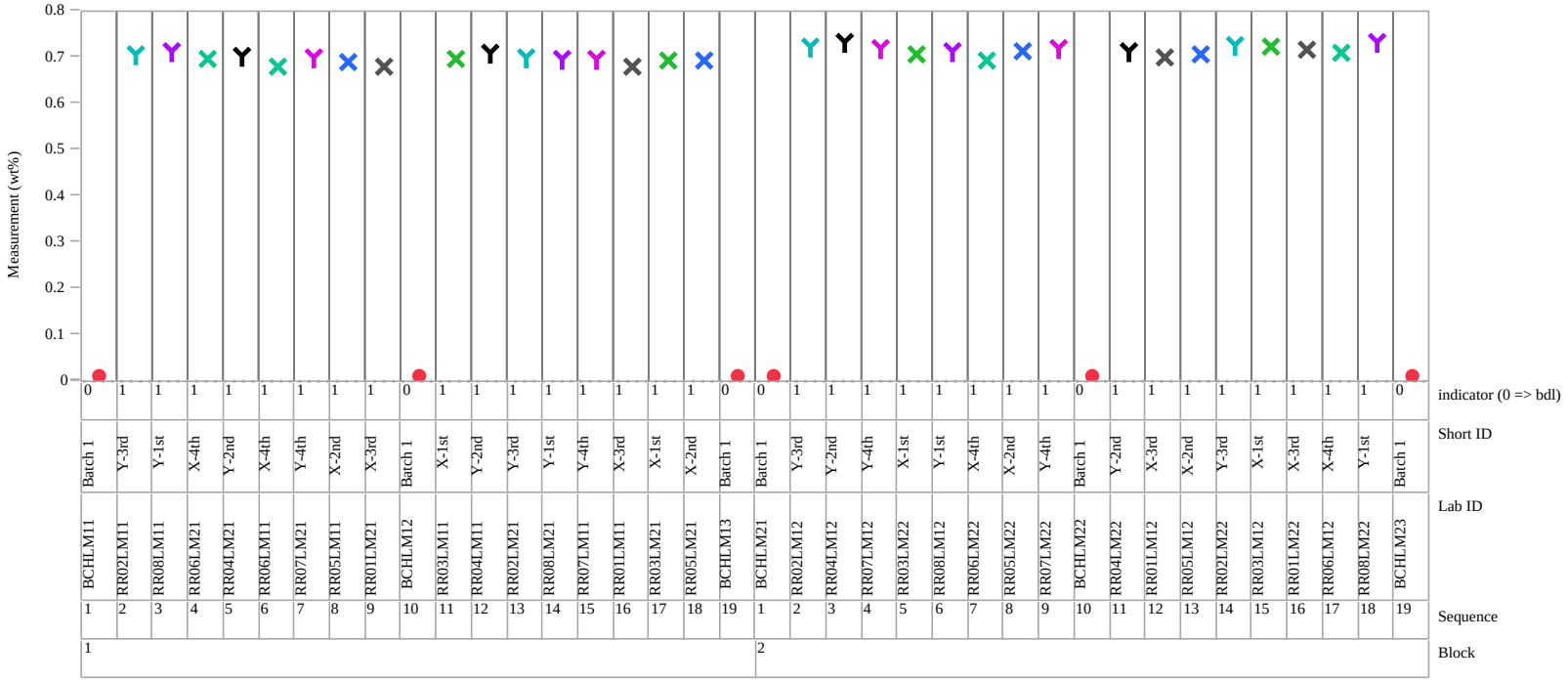


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

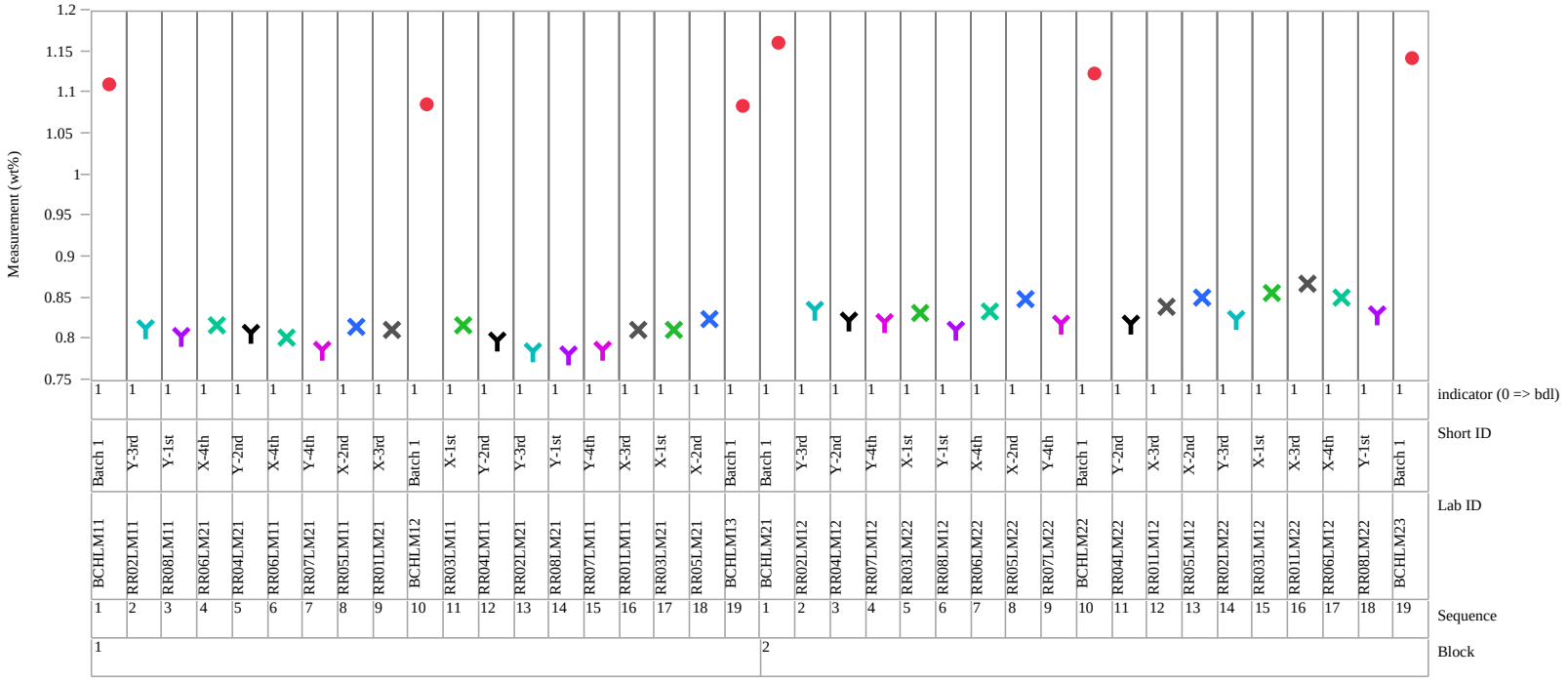


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

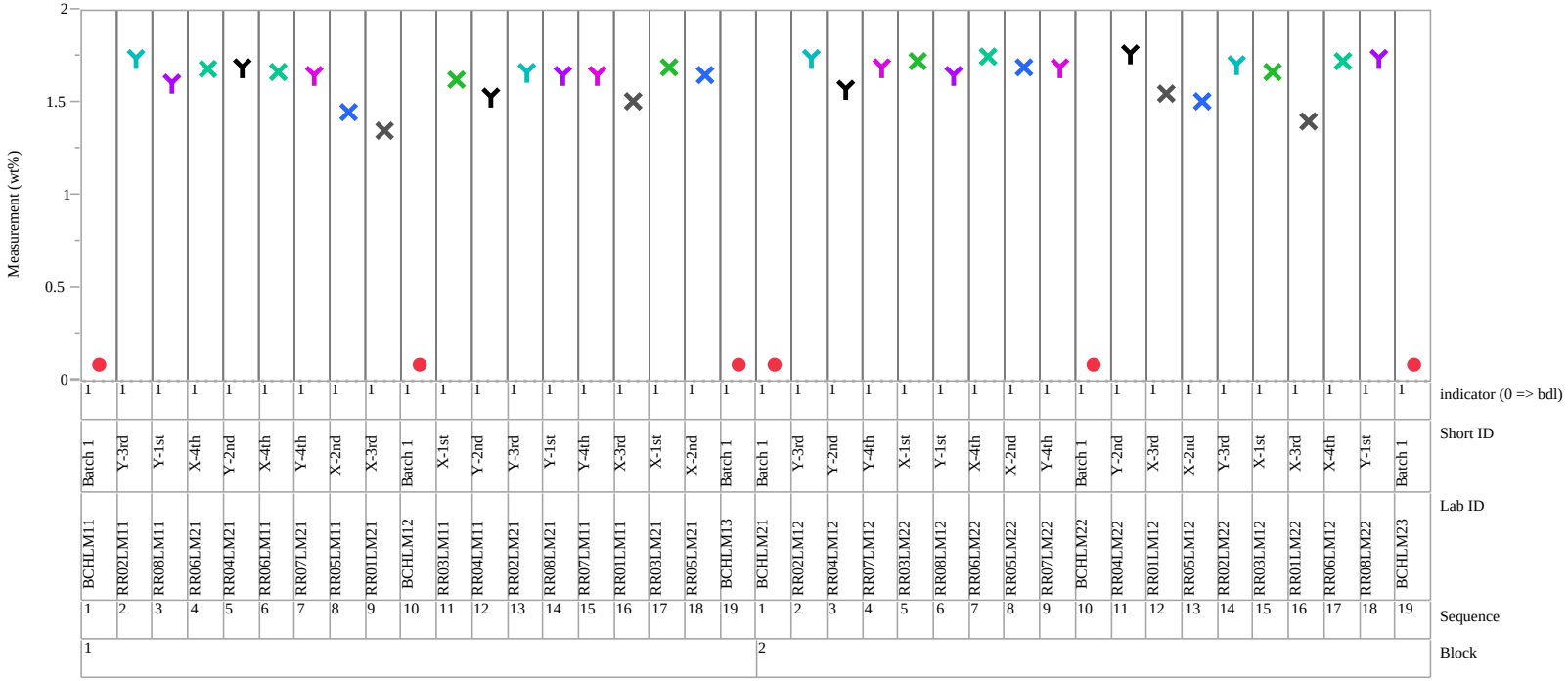


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

Element=F (wt%), Prep Method=KH
Variability Chart for Measurement (wt%)

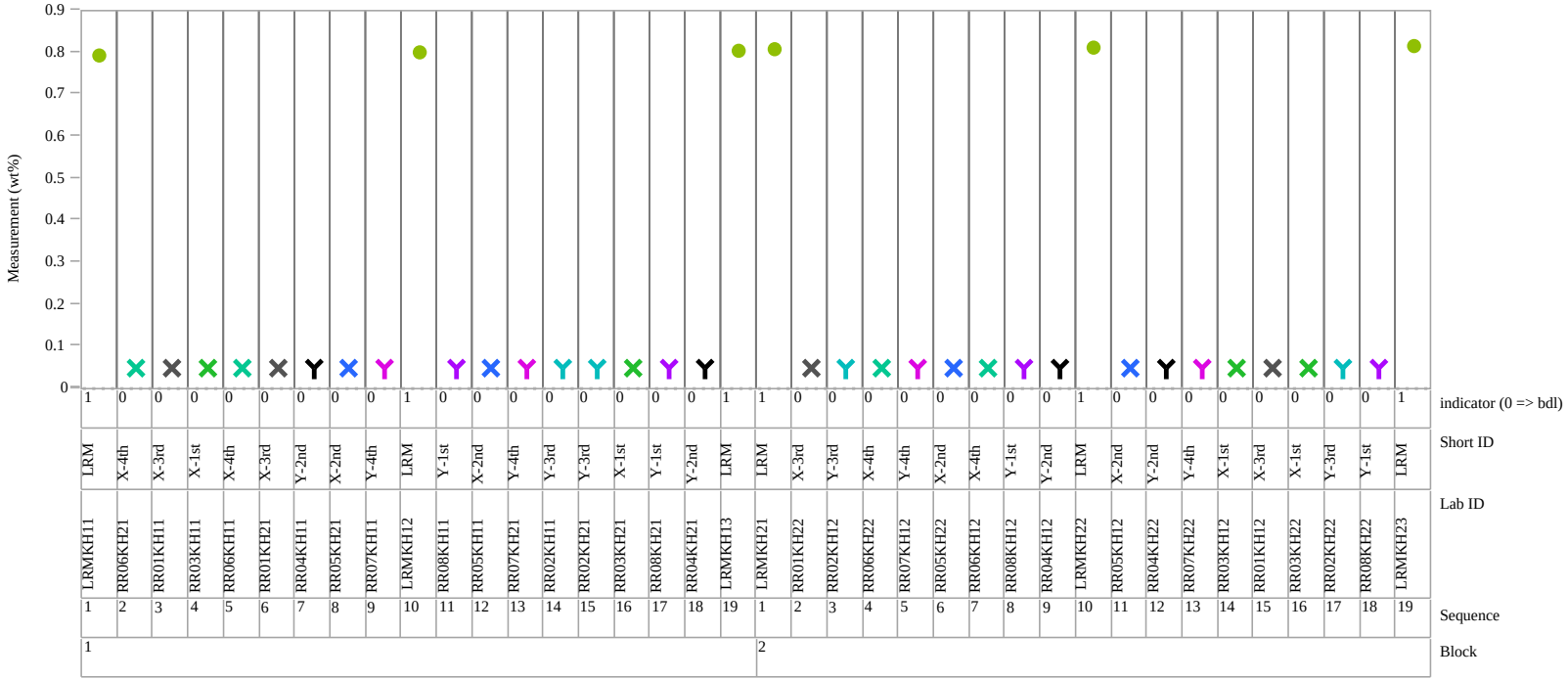


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

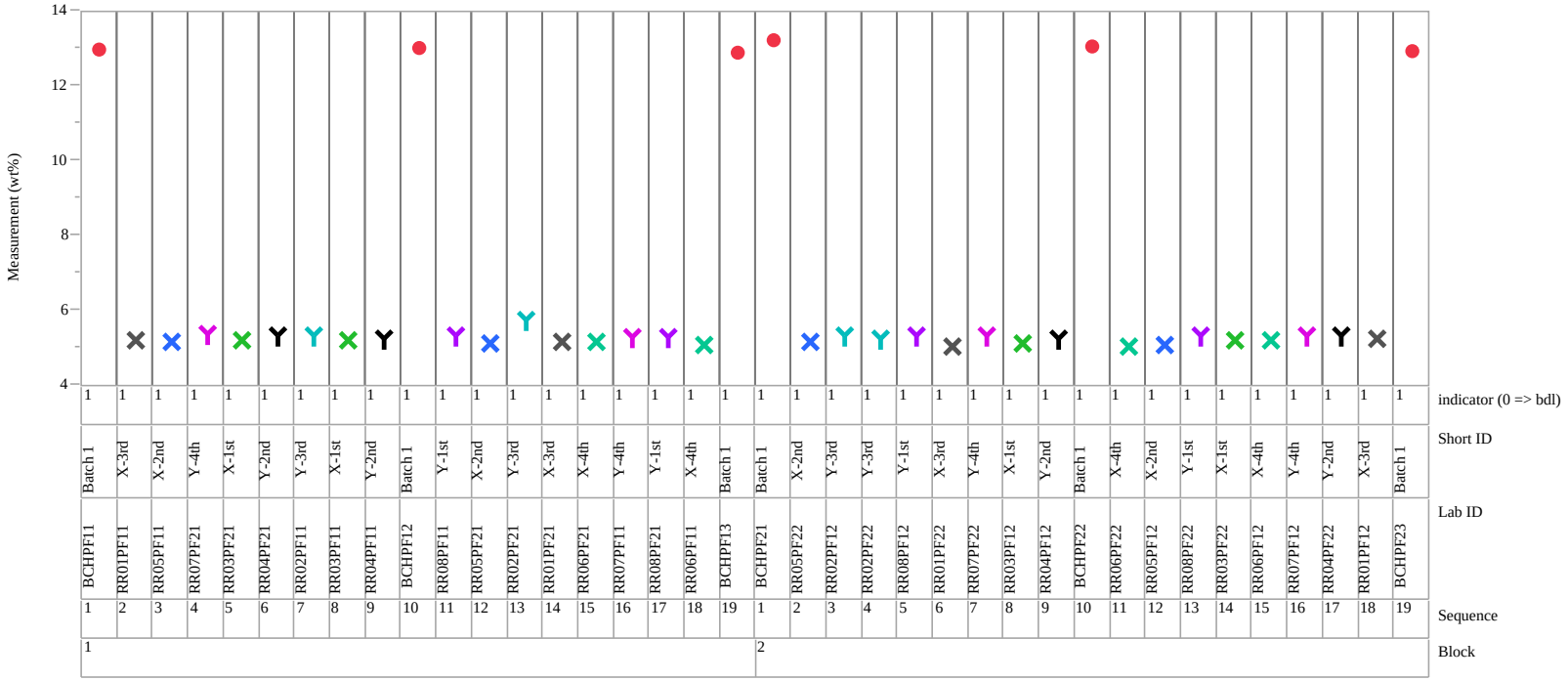


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

Oxide=K2O (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

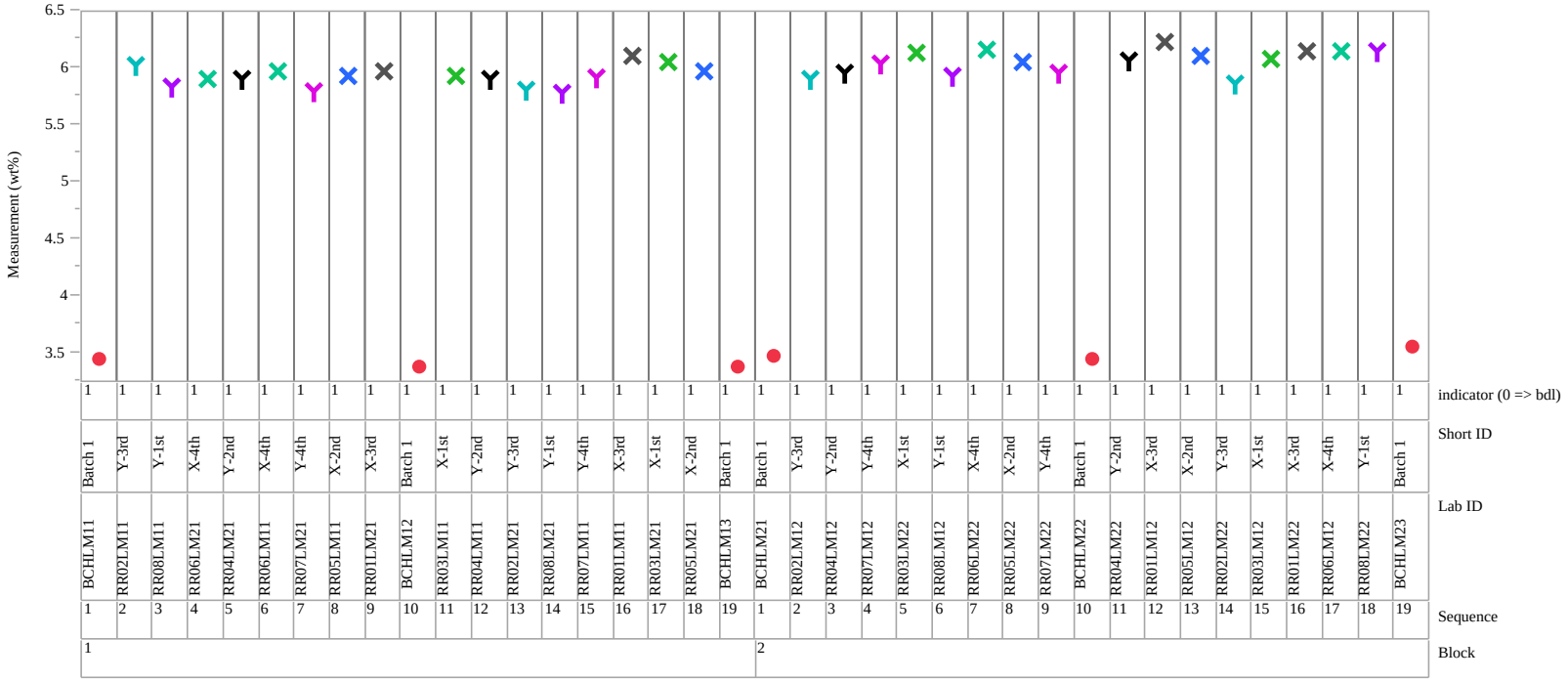


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

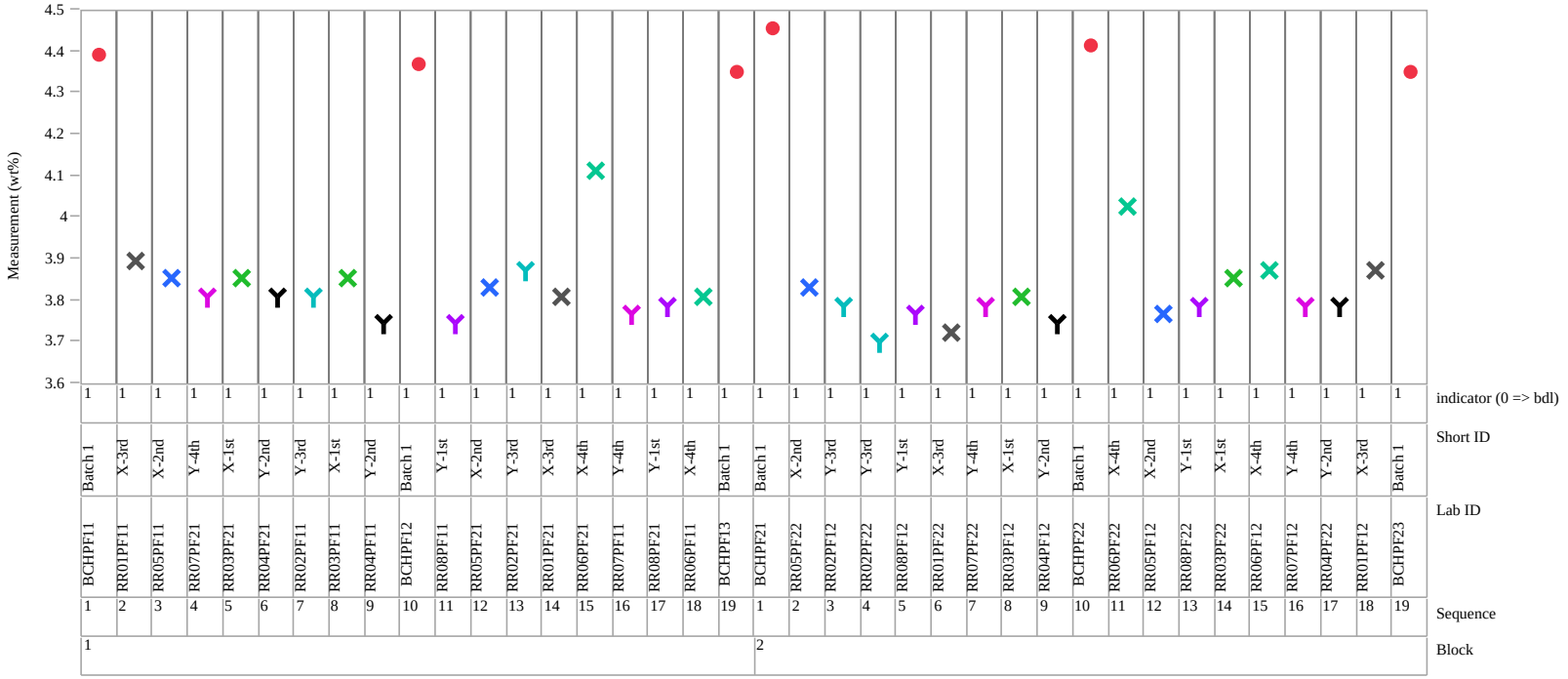


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

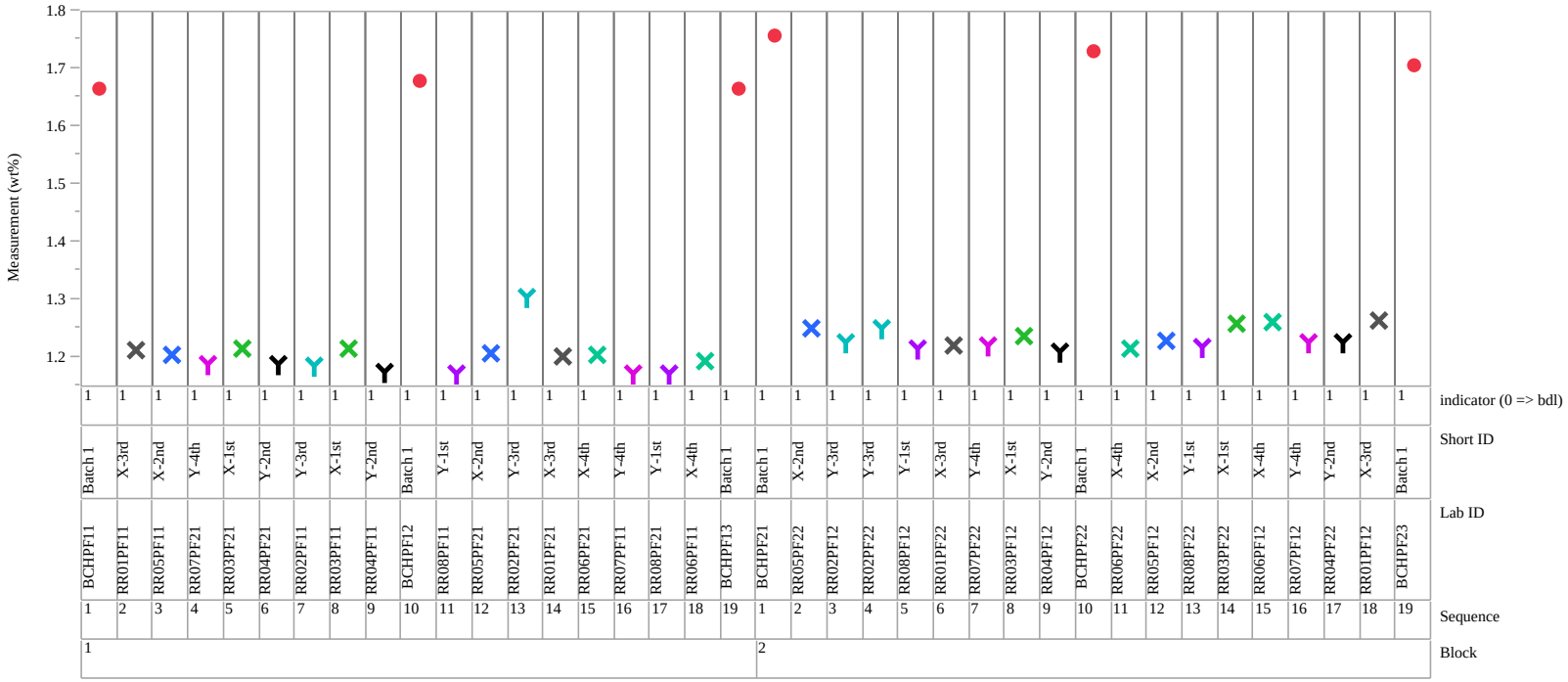


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

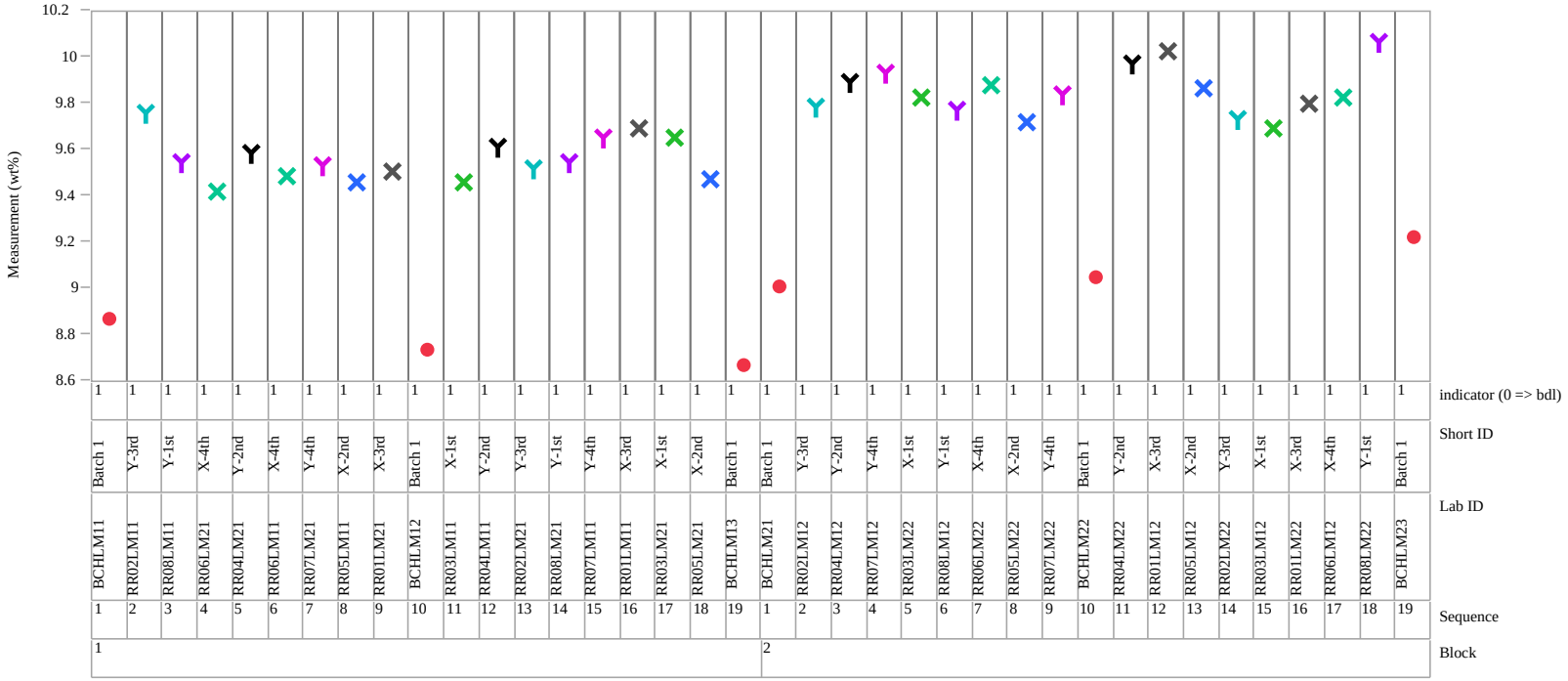


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

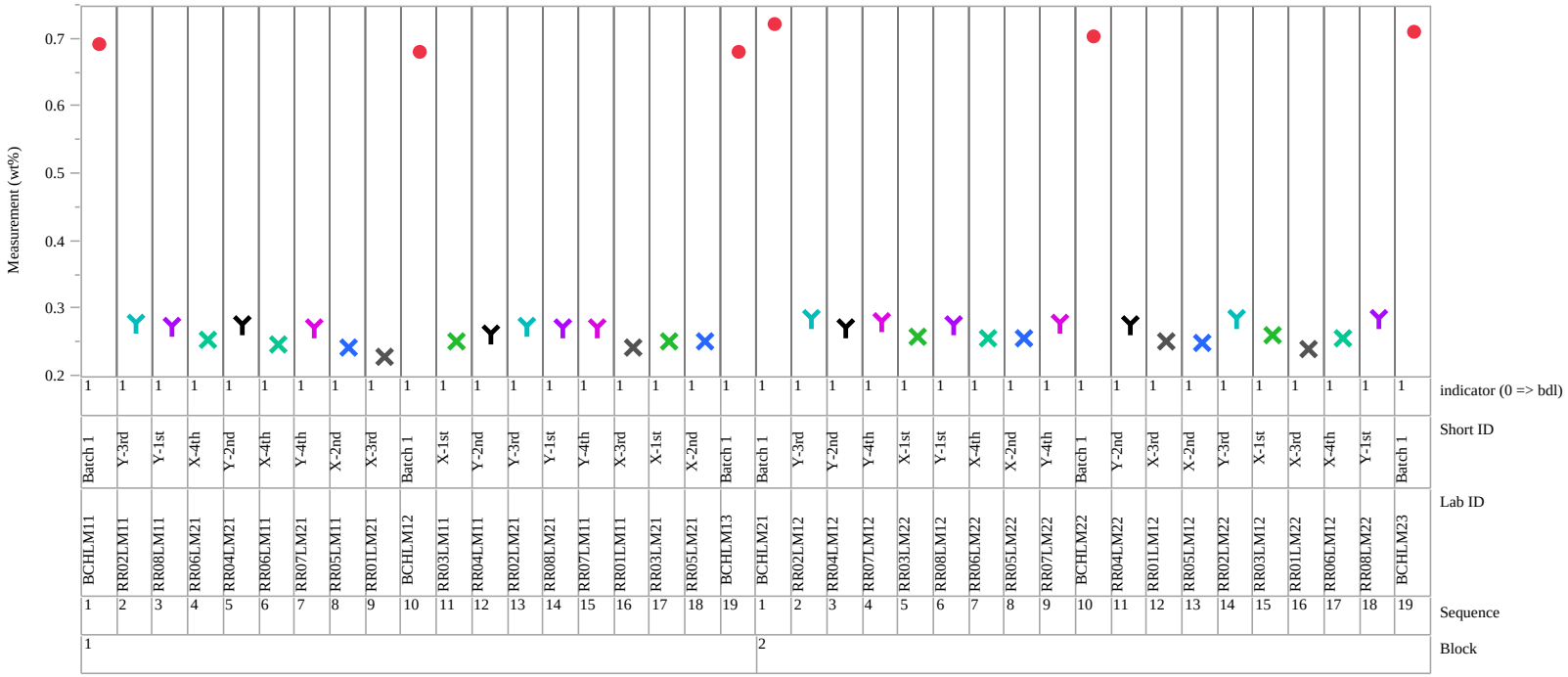


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

Oxide=P2O5 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

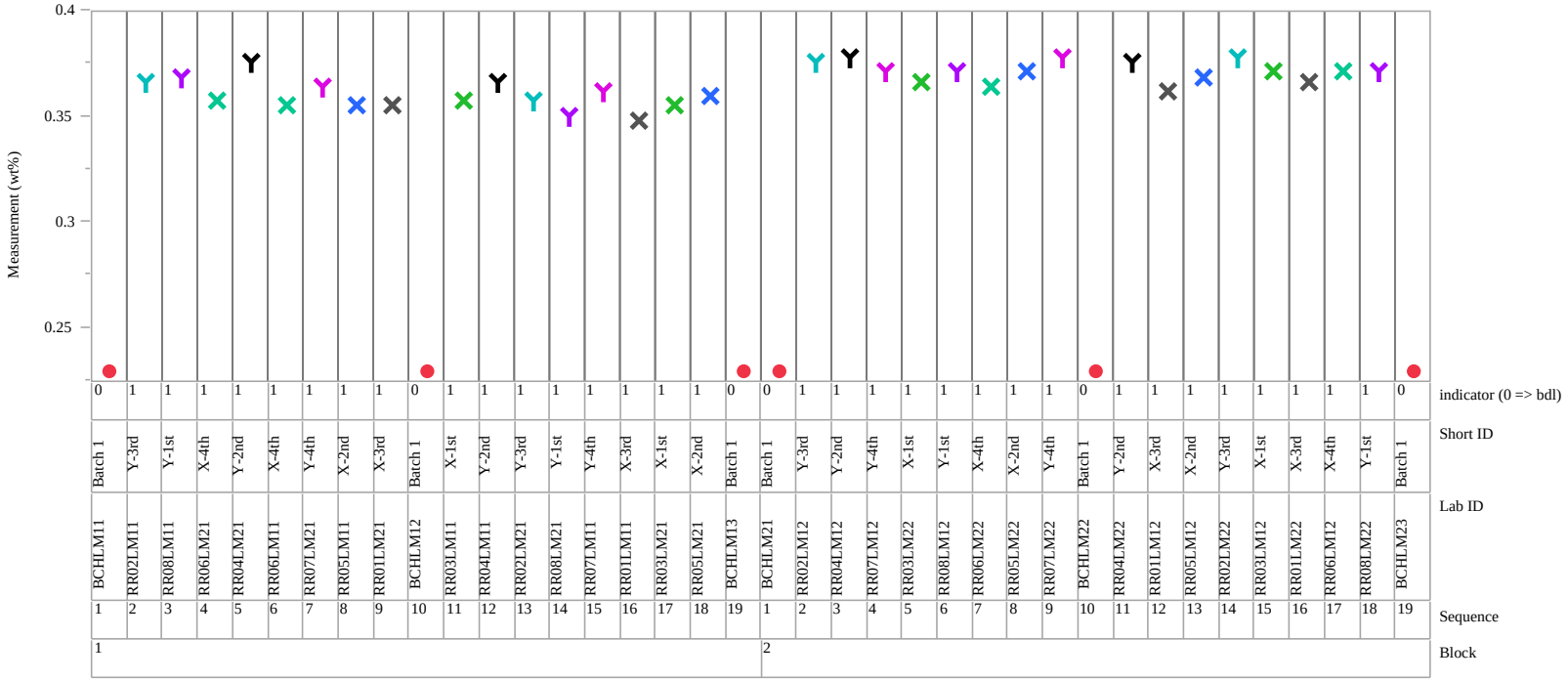


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

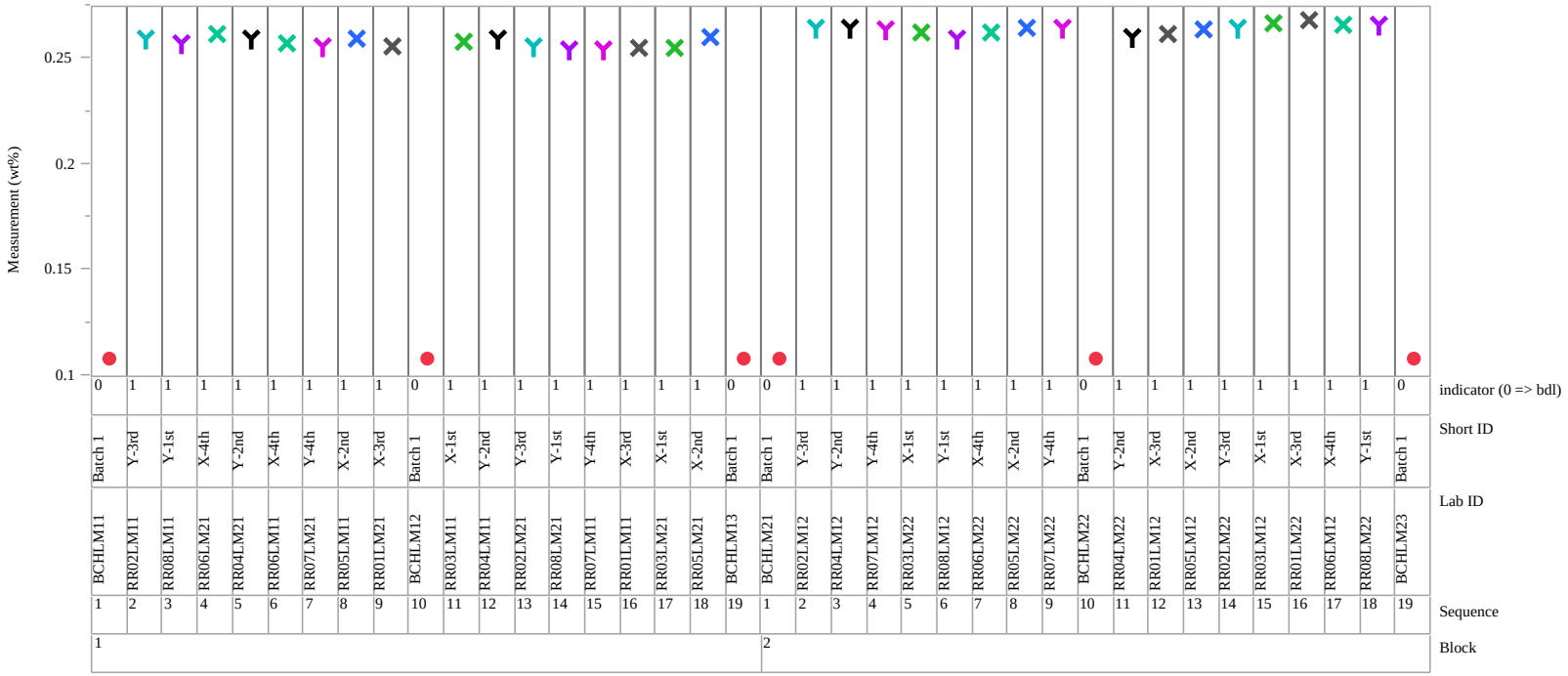


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

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

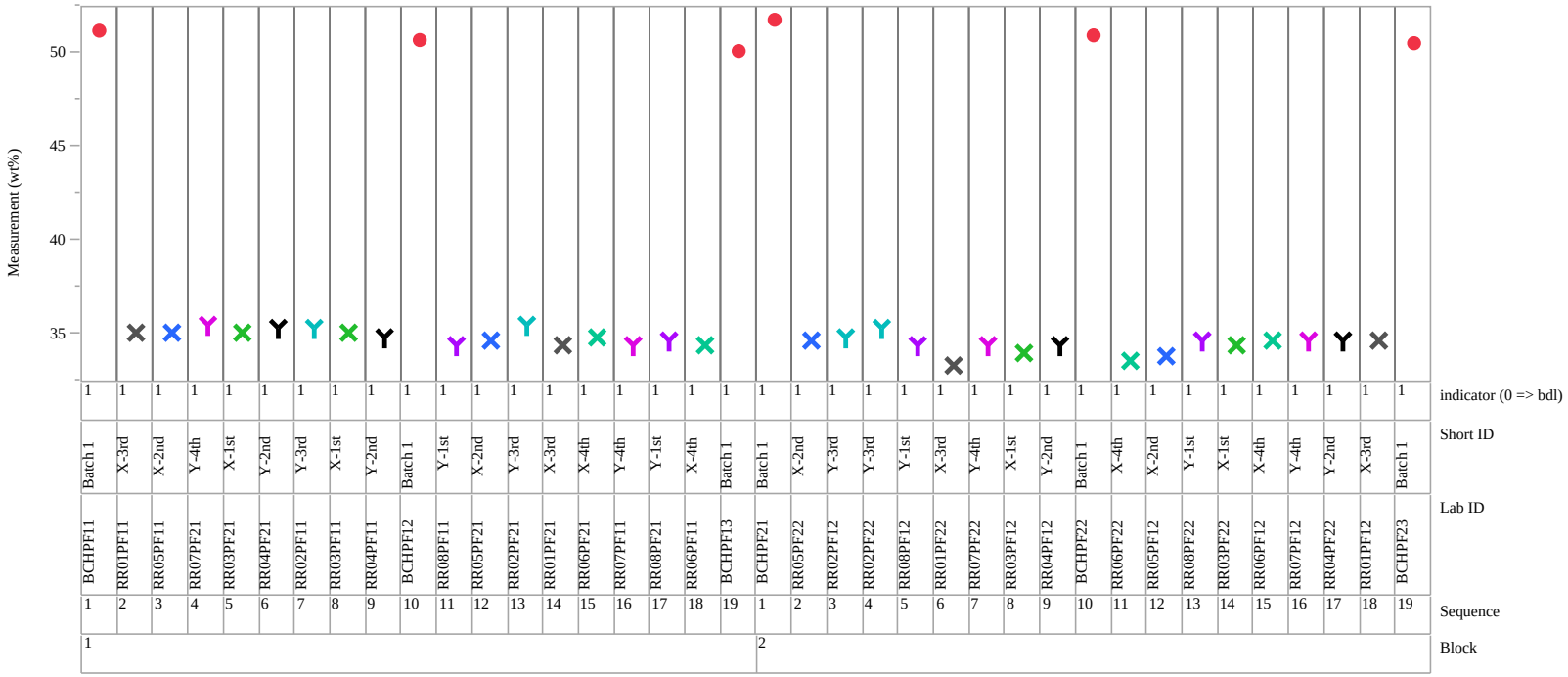


Exhibit A-1. Plots of Oxide Measurements in Analytical Sequence Grouped by Analytical Block (continued)

Oxide=WO3 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

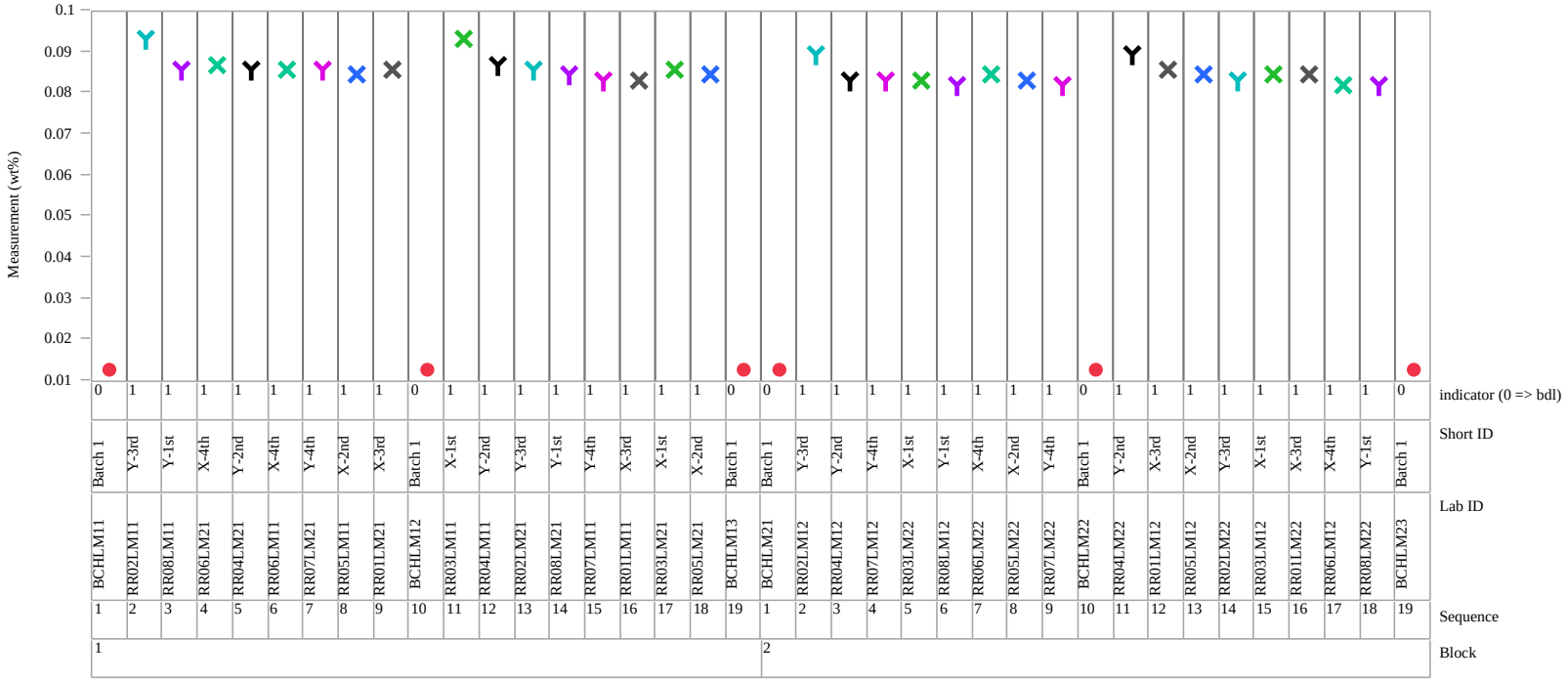


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample

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

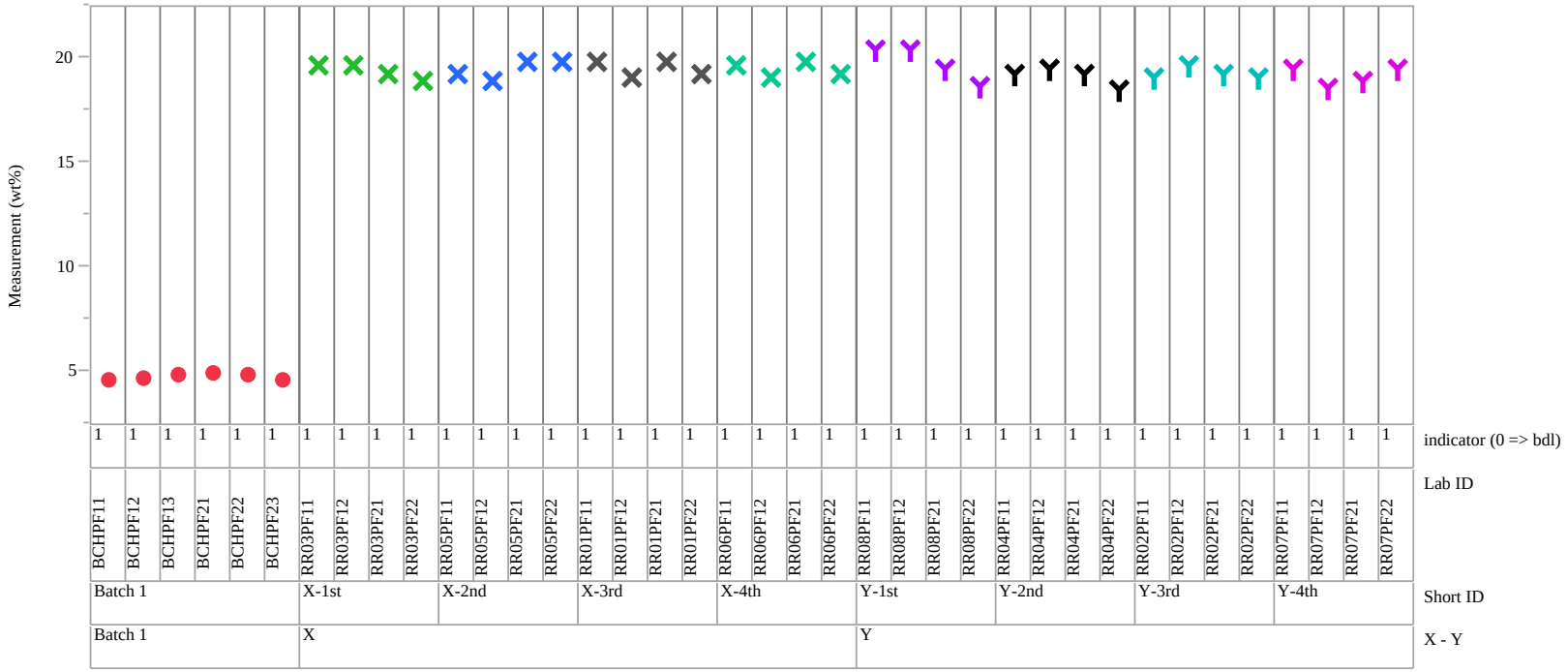


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

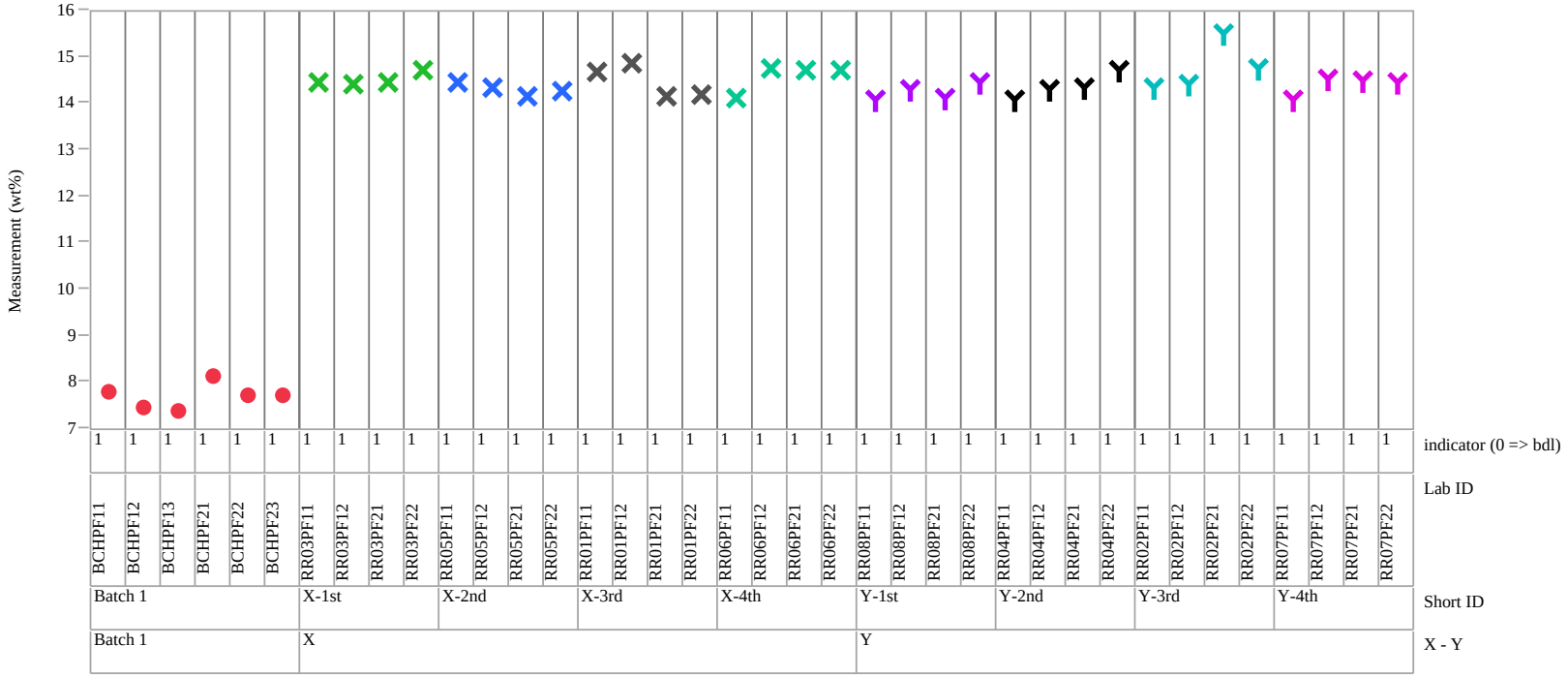


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

Oxide=Bi2O3 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

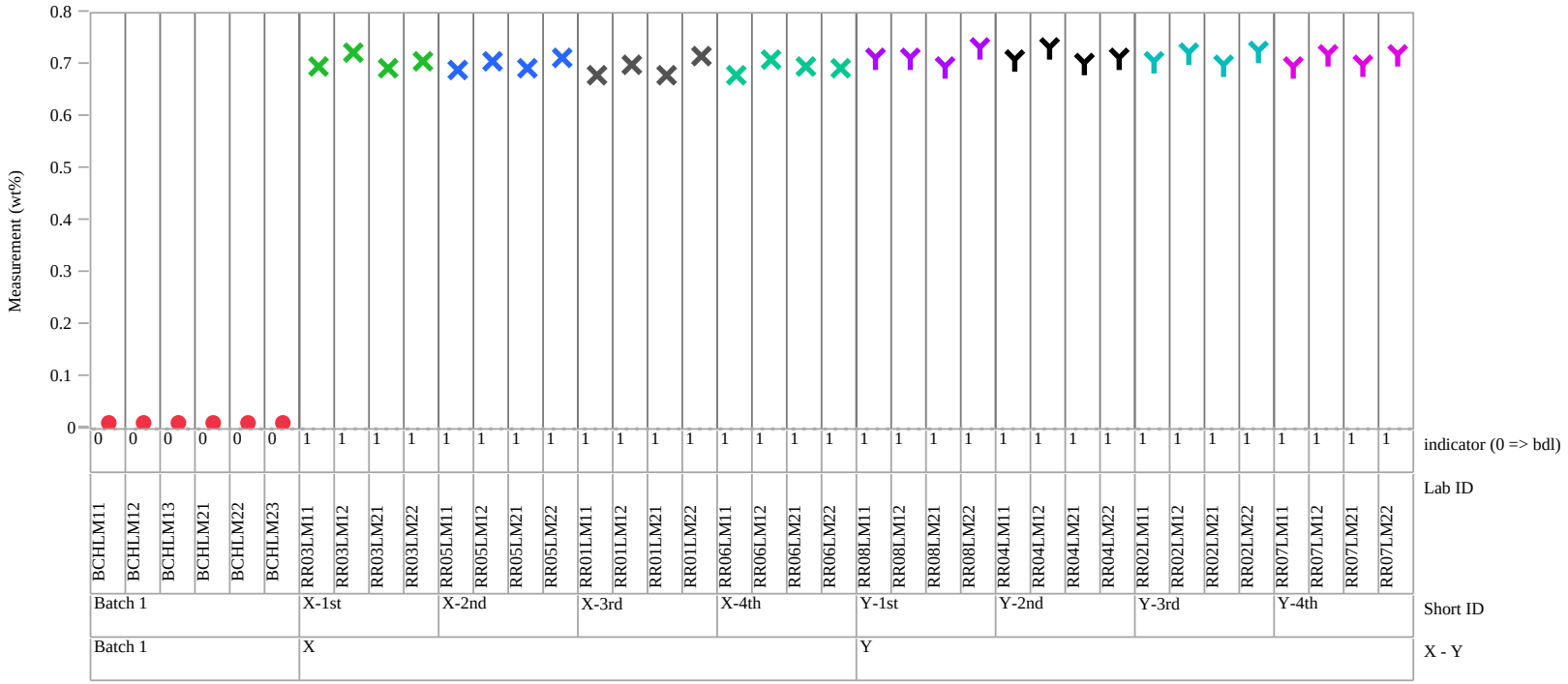


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

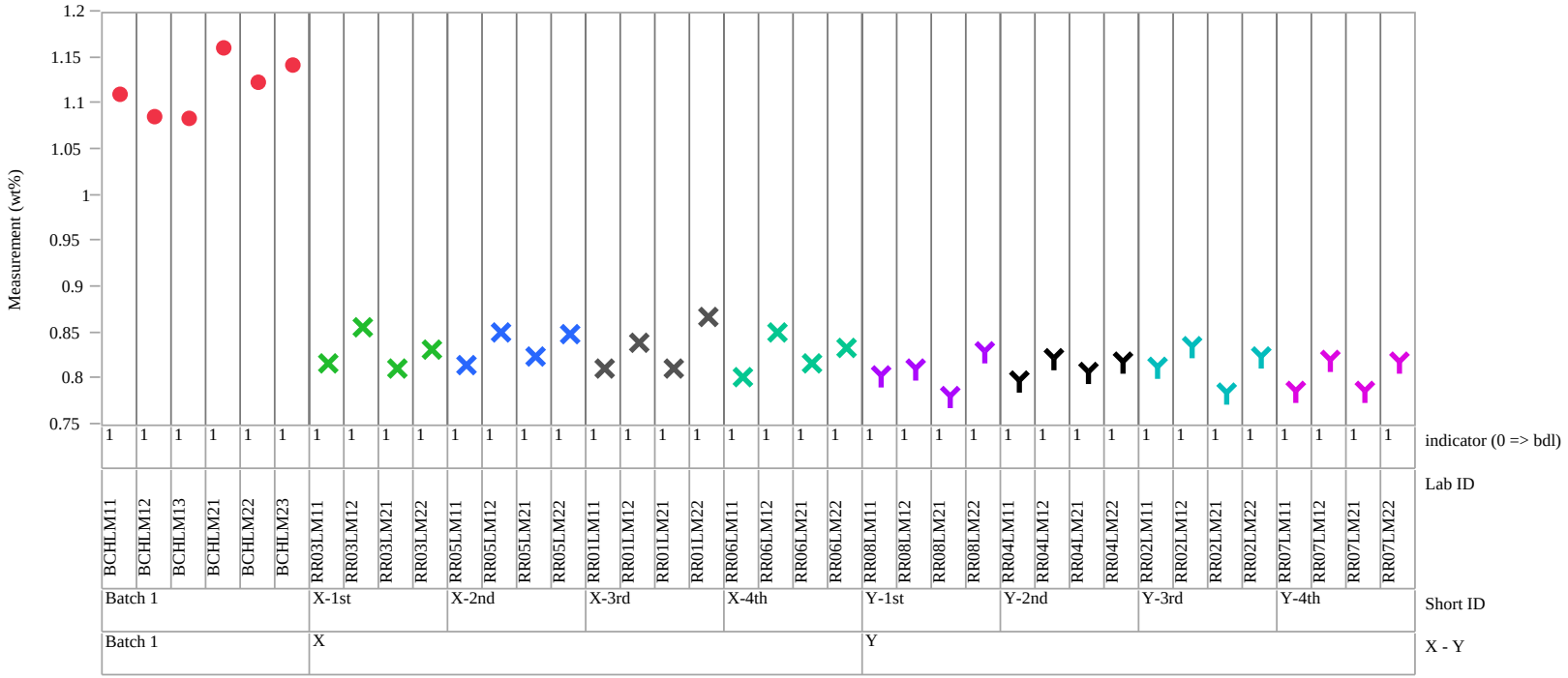


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

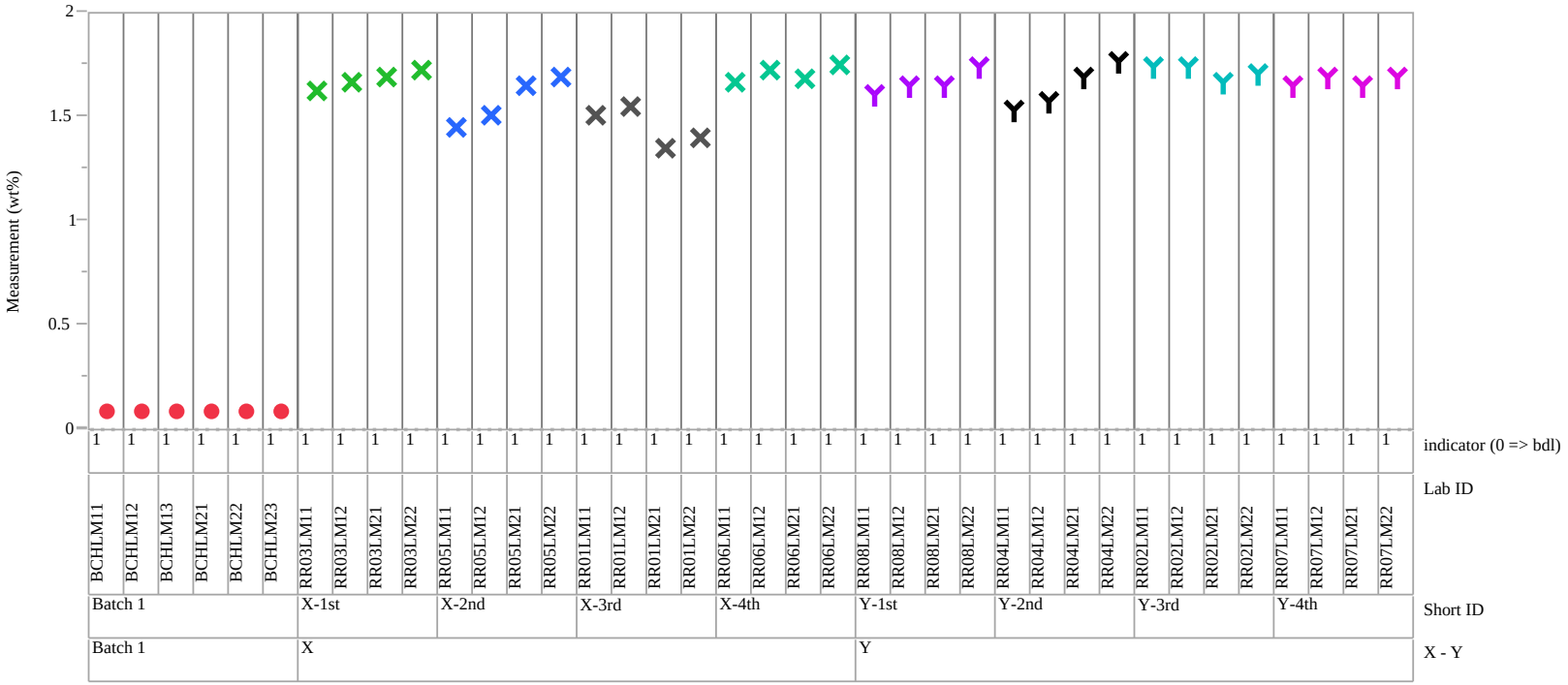


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

Element=F (wt%), Prep Method=KH
Variability Chart for Measurement (wt%)

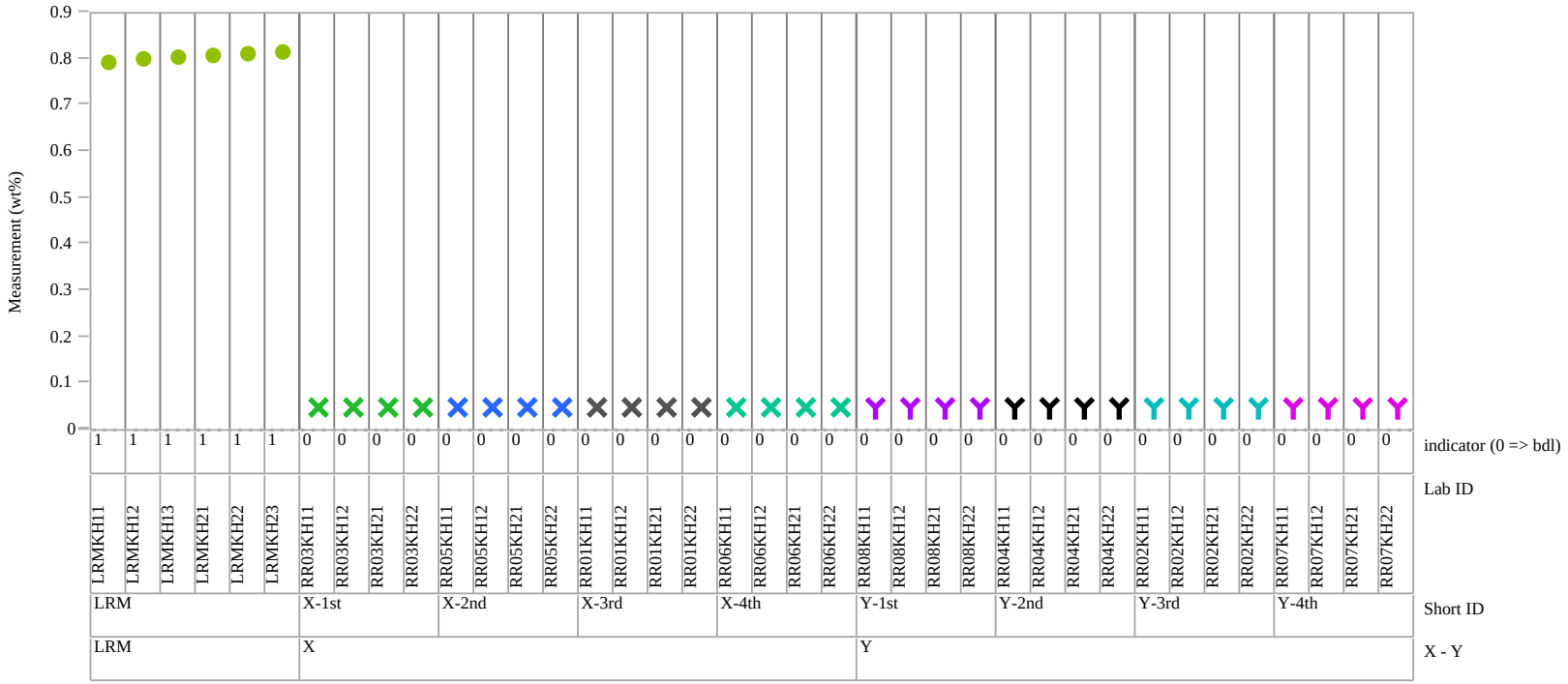


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

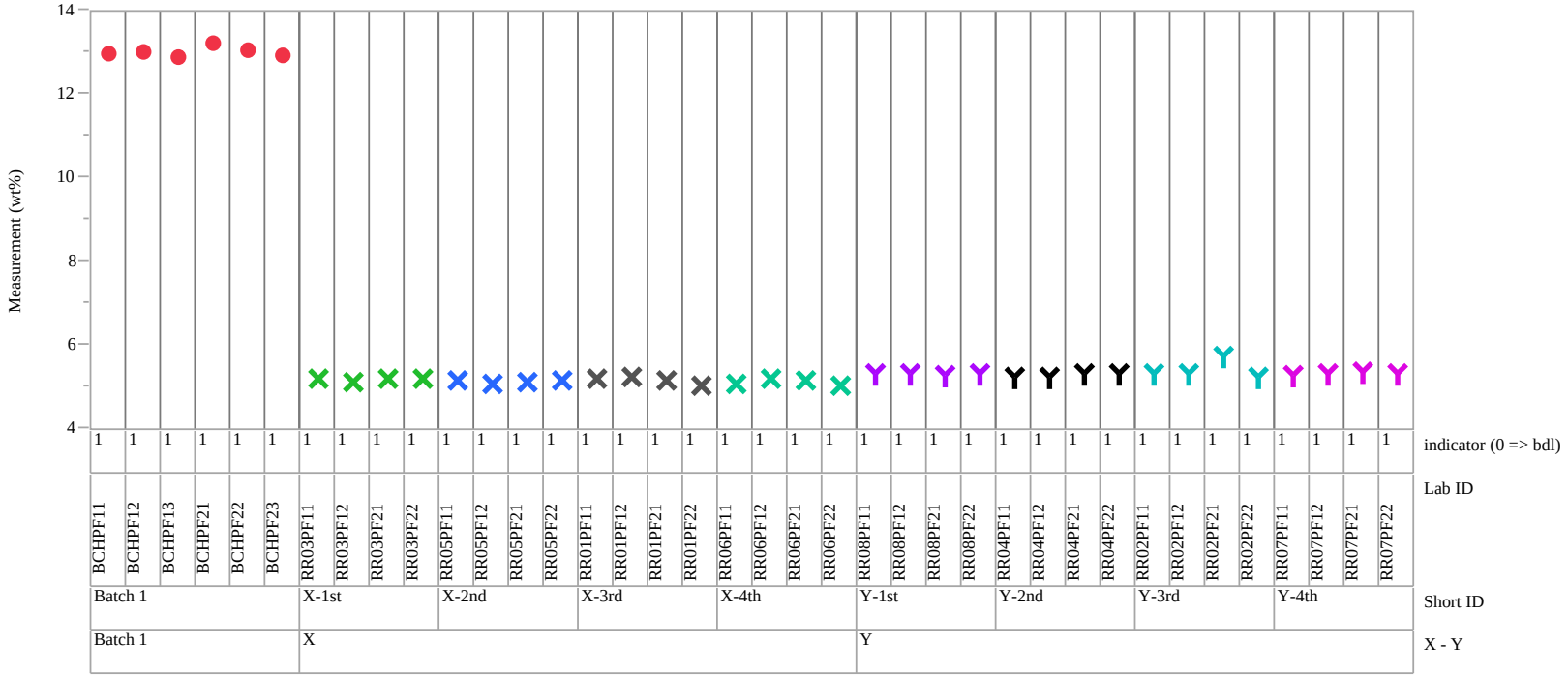


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

Oxide=K2O (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

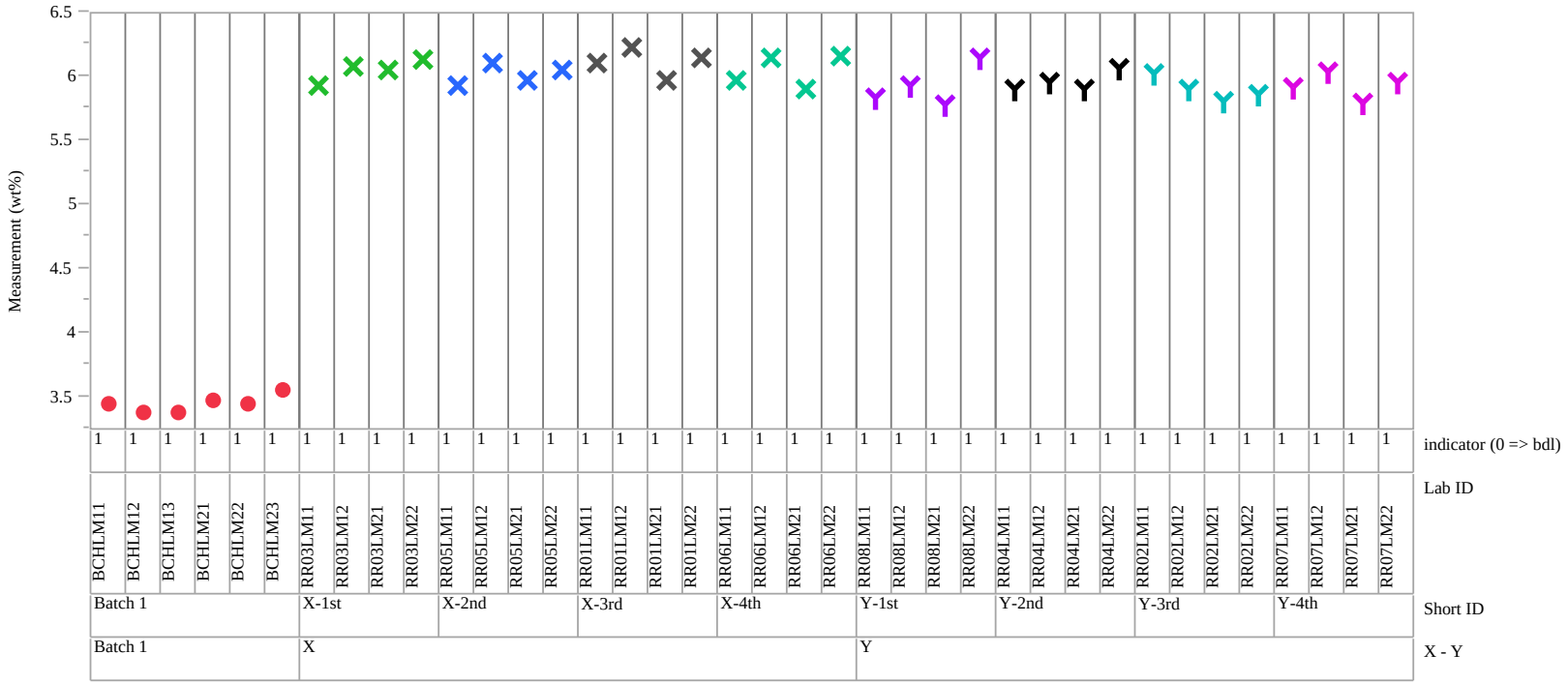


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

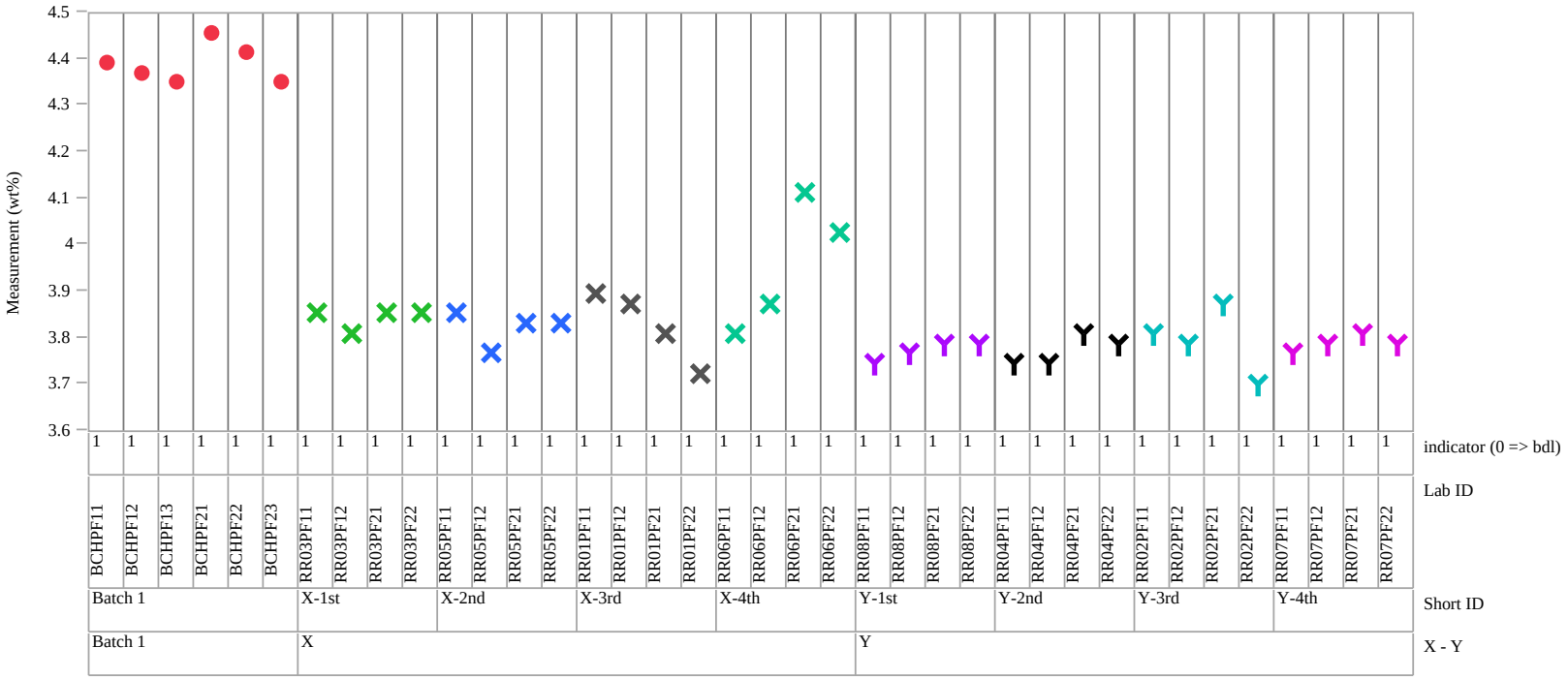


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

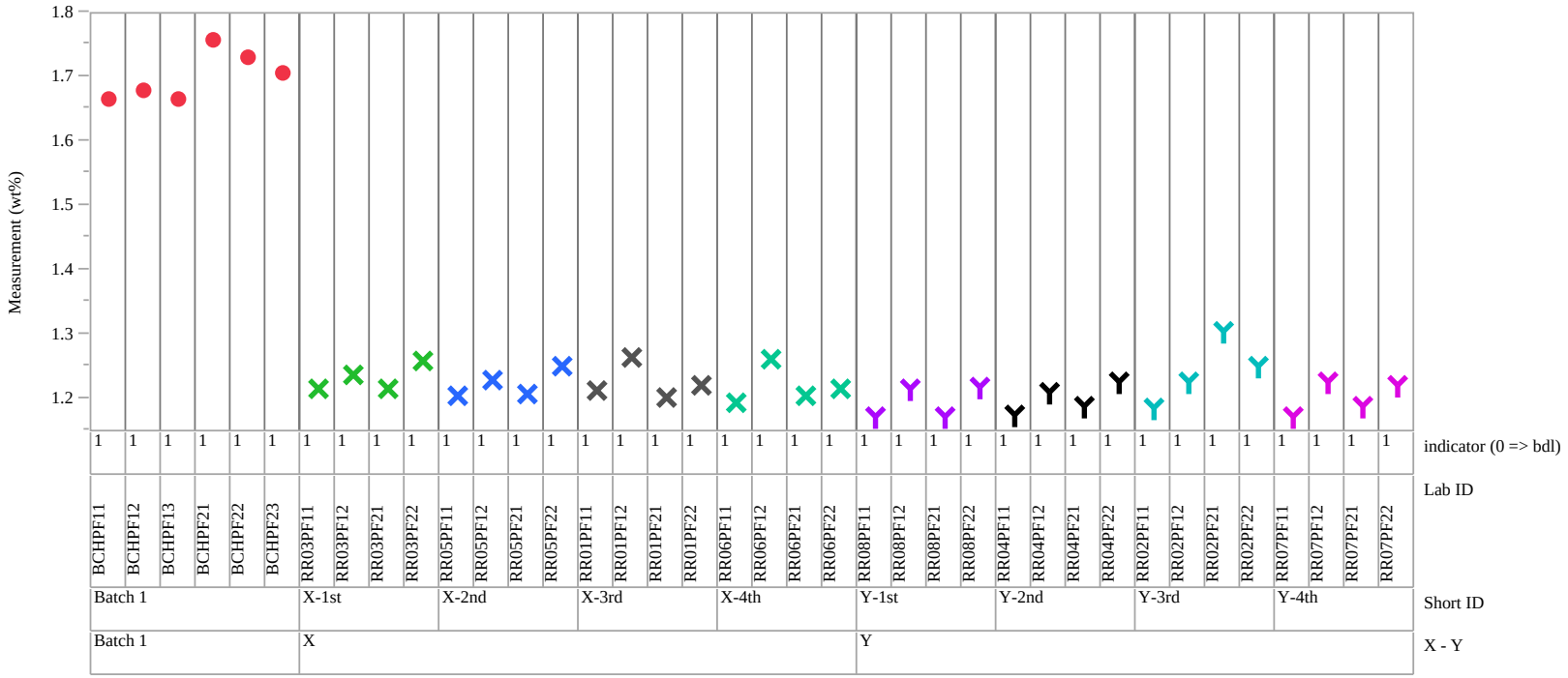


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

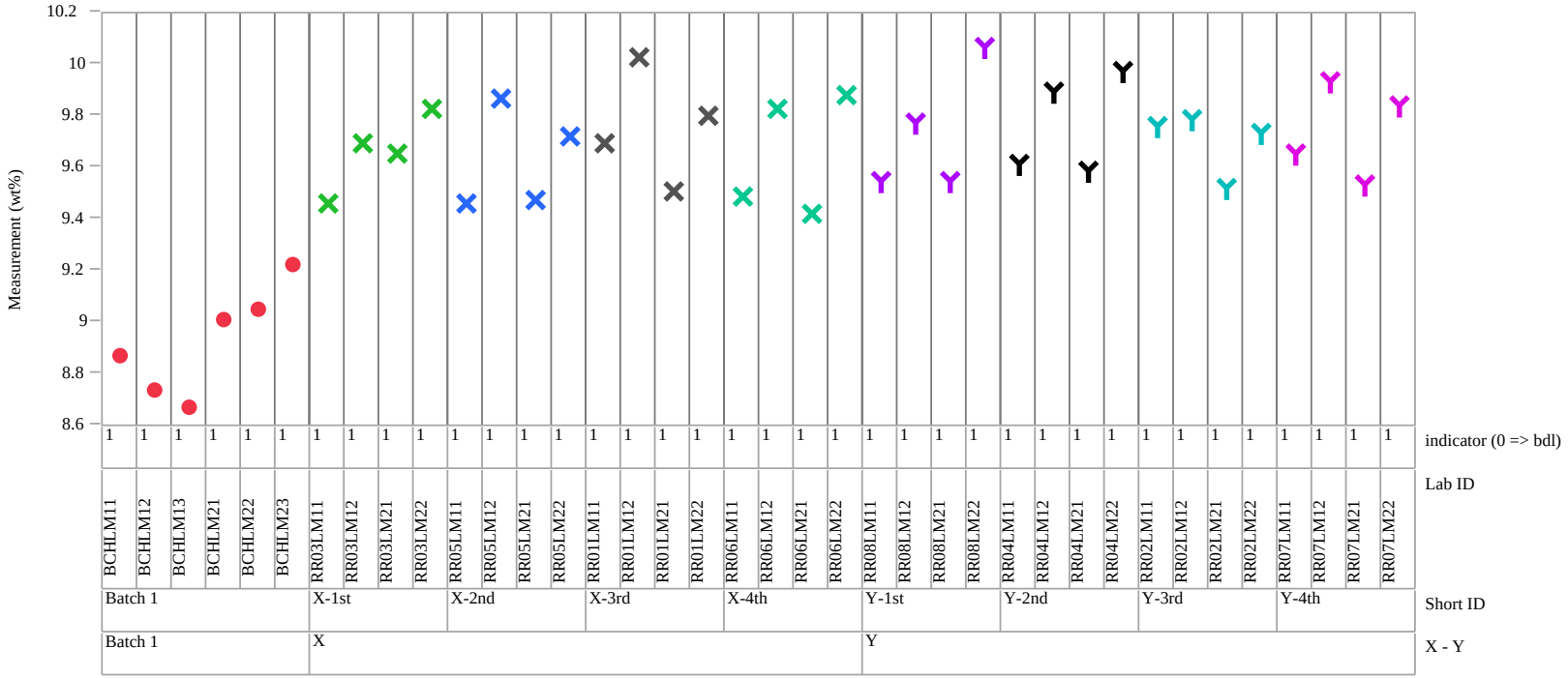


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

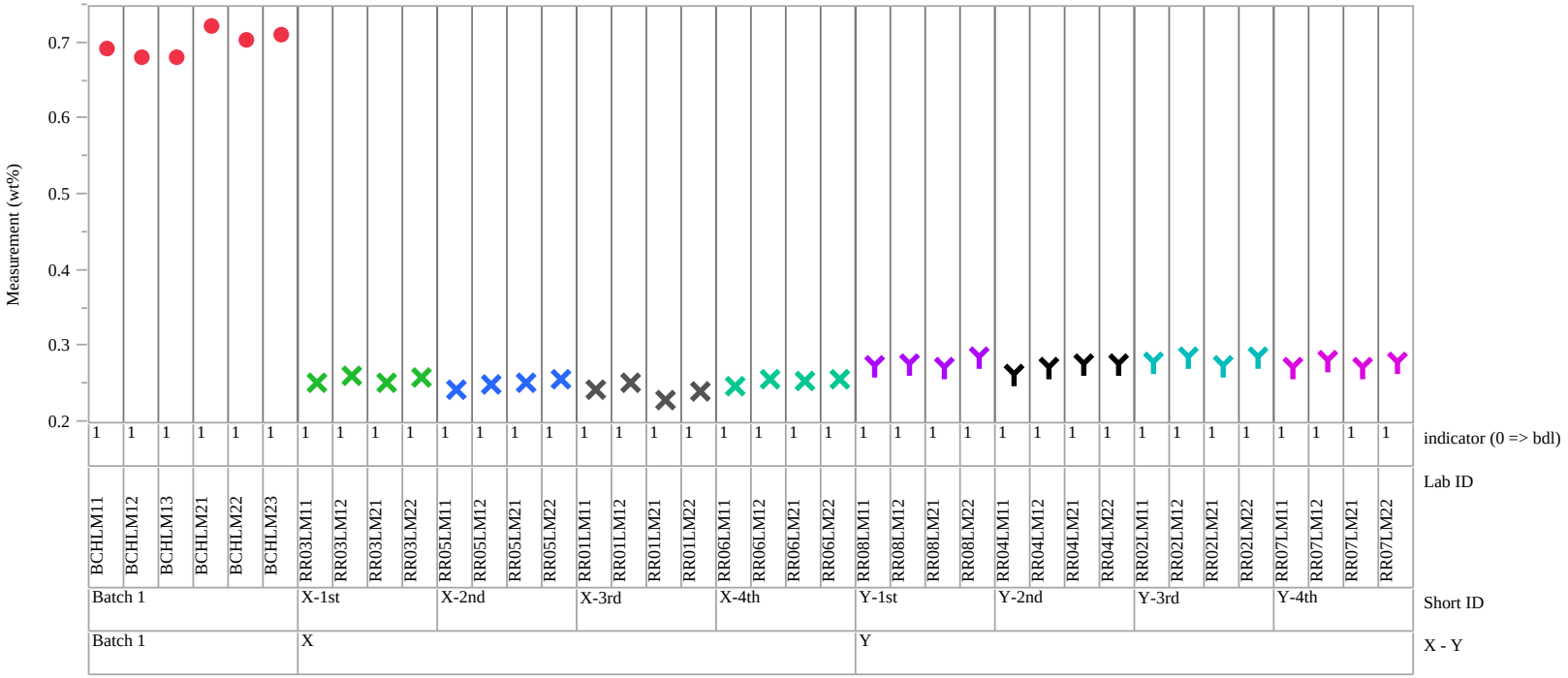


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

Oxide=P2O5 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

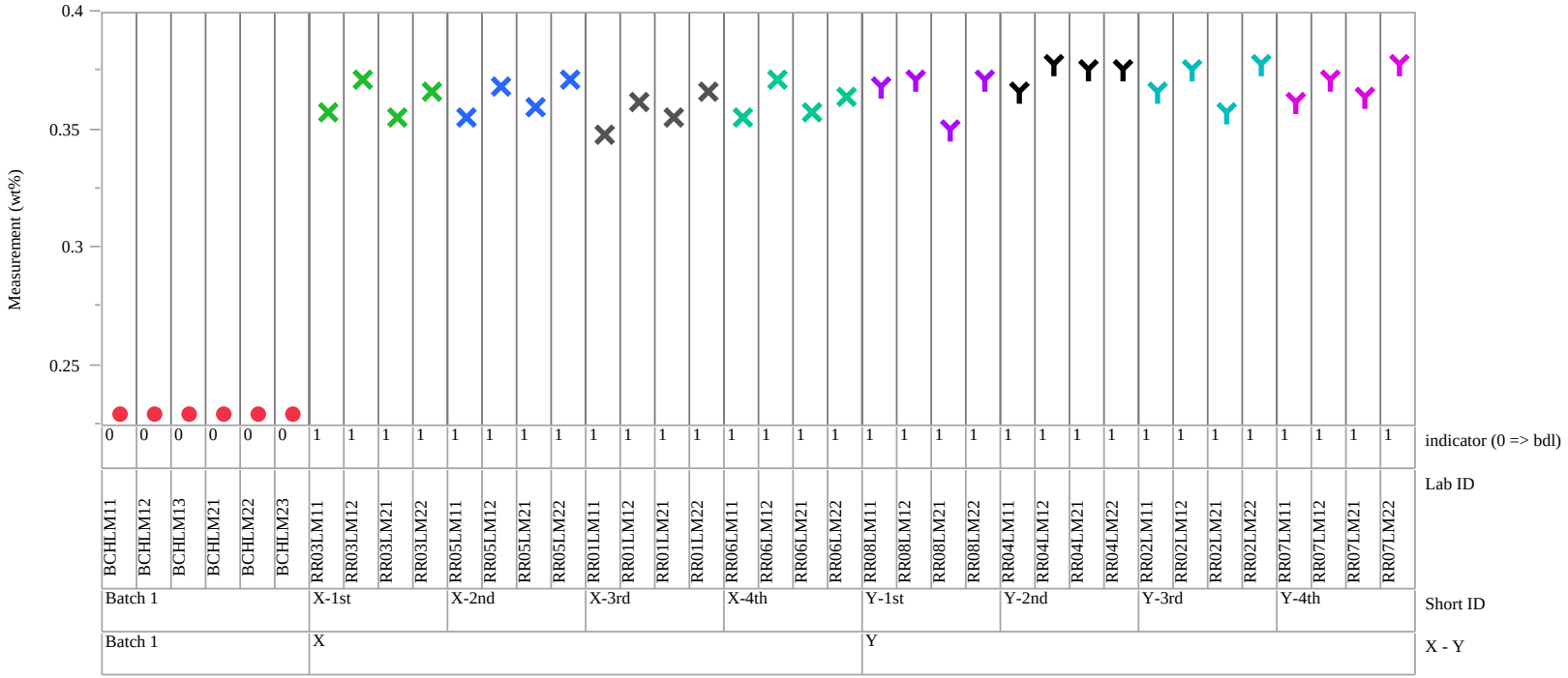


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

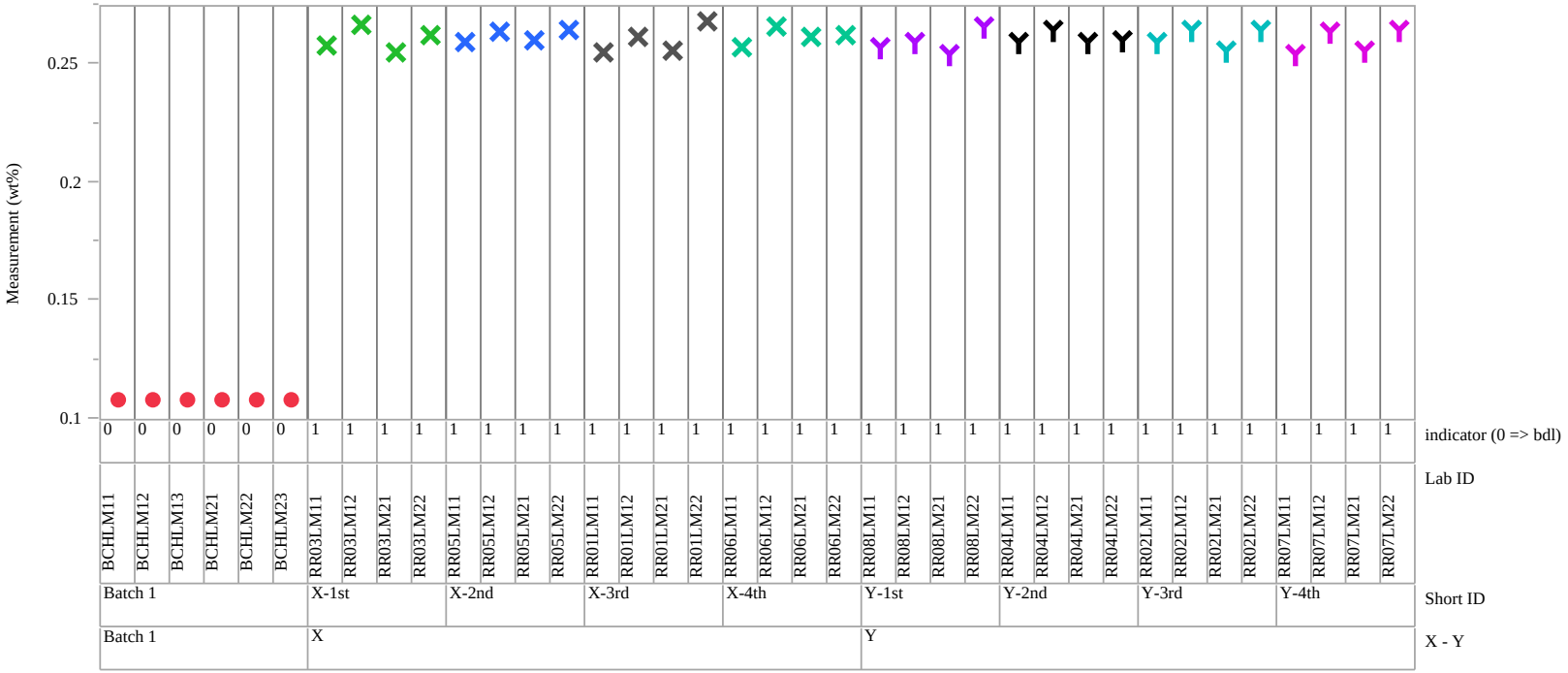


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

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

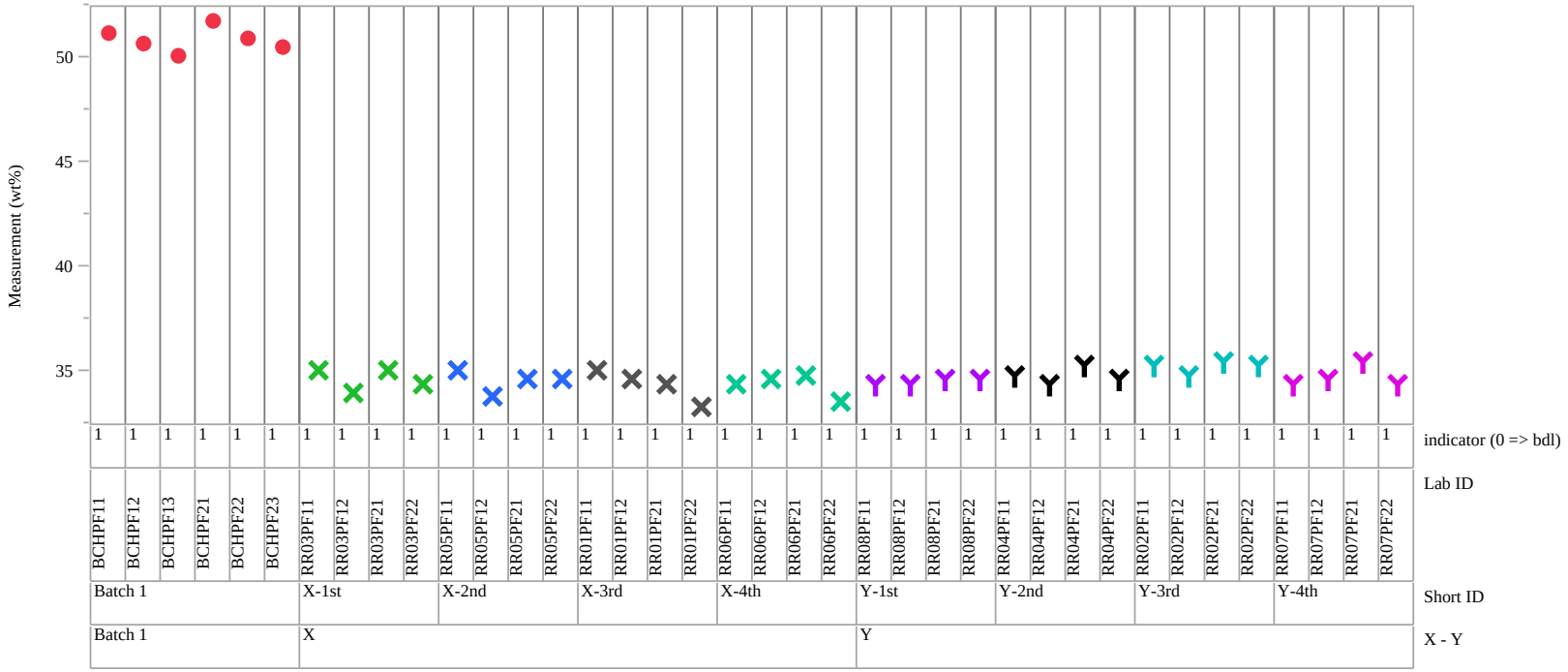


Exhibit A-2. Plots of Oxide Measurements by Glass Identifier Grouped by Glass Sub-Sample (continued)

Oxide=WO3 (wt%), Prep Method=LM
Variability Chart for Measurement (wt%)

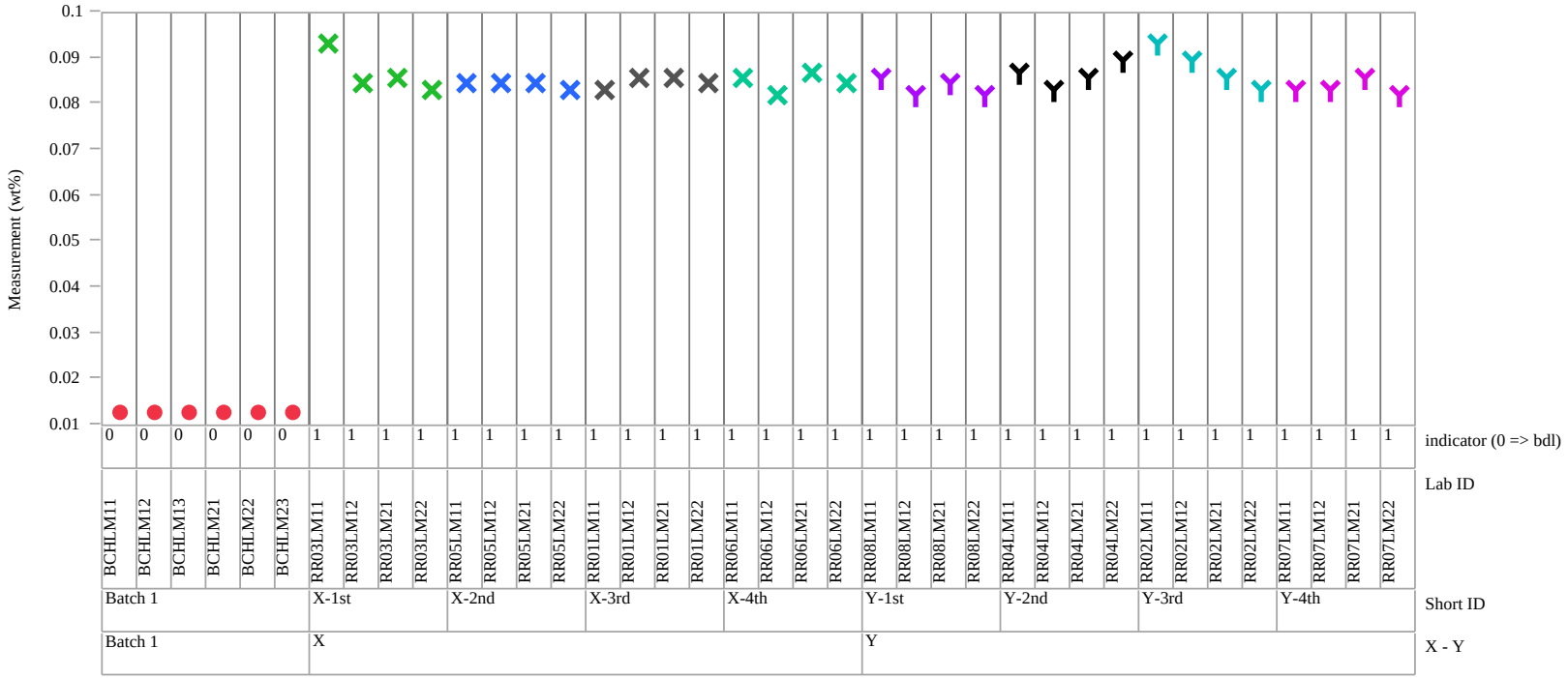
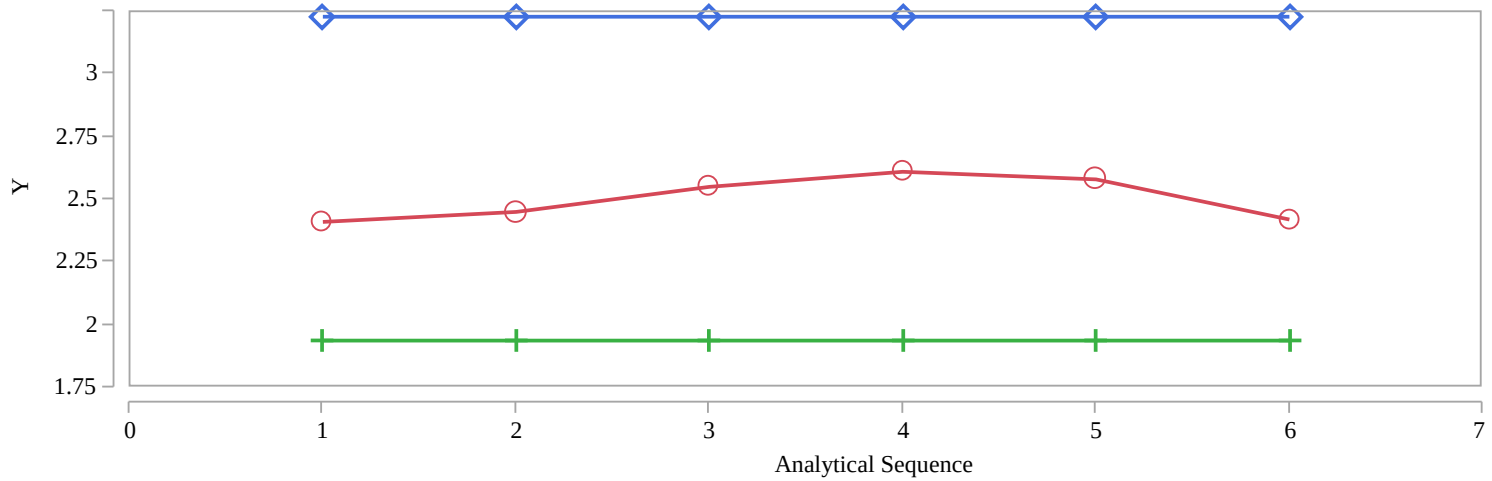


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element

Overlay Plot ID=Batch 1, Element=Al, Prep Method=PF



Overlay Plot ID=Batch 1, Element=B, Prep Method=PF

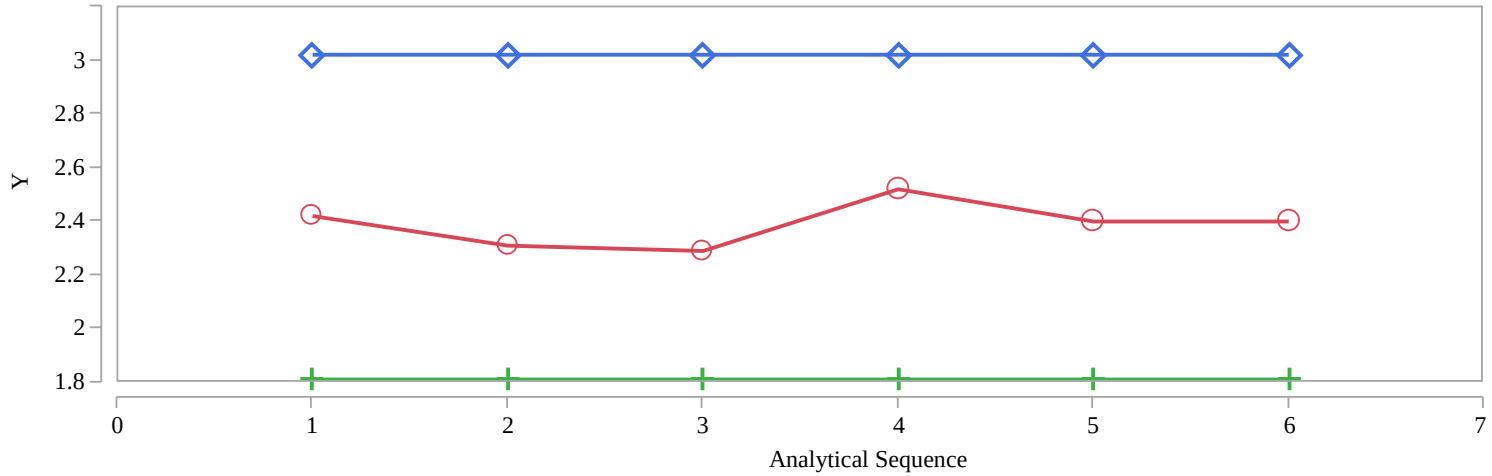
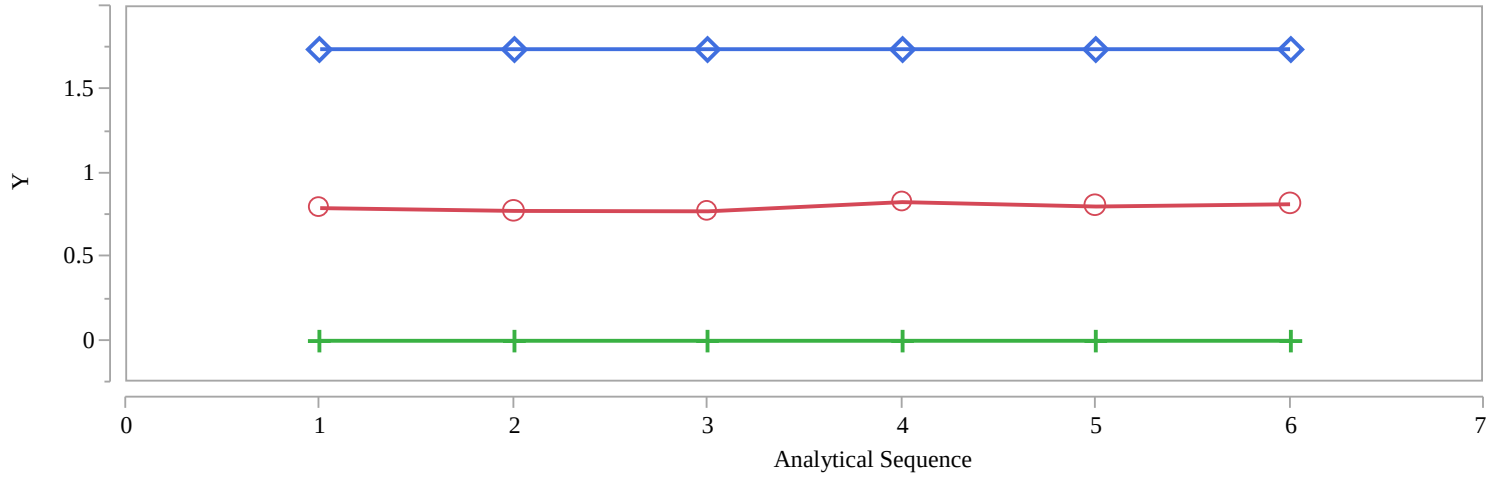


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element (continued)

Overlay Plot ID=Batch 1, Element=Ca, Prep Method=LM



Overlay Plot ID=Batch 1, Element=Fe, Prep Method=PF

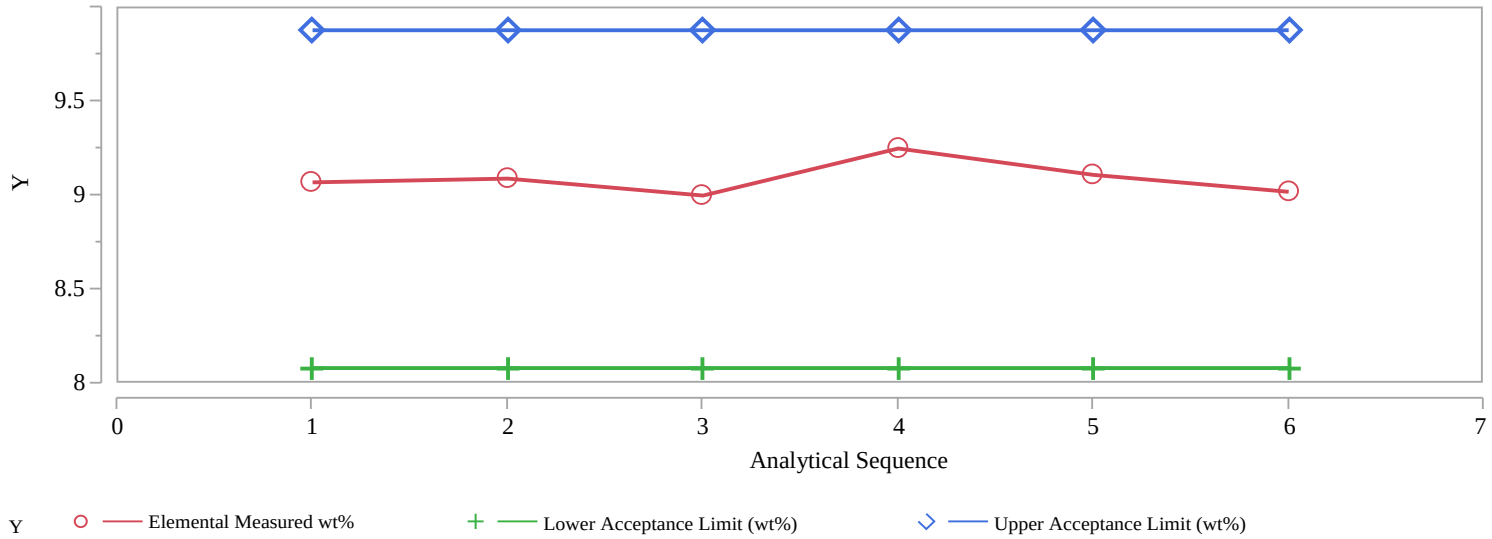
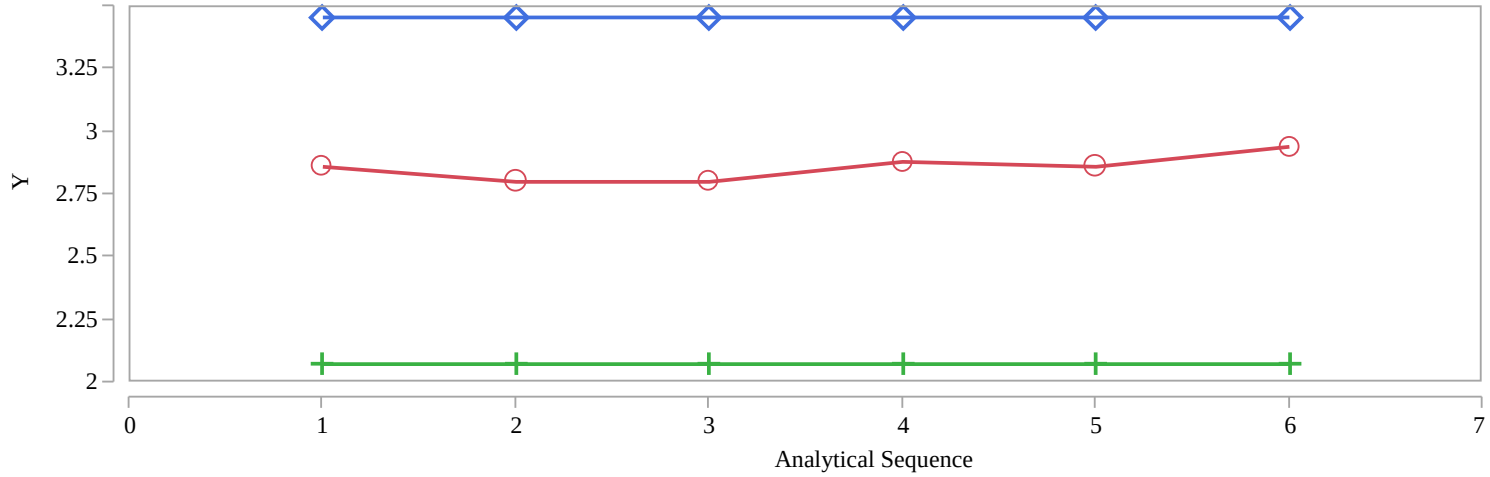


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element (continued)

Overlay Plot ID=Batch 1, Element=K, Prep Method=LM



Overlay Plot ID=Batch 1, Element=Li, Prep Method=PF

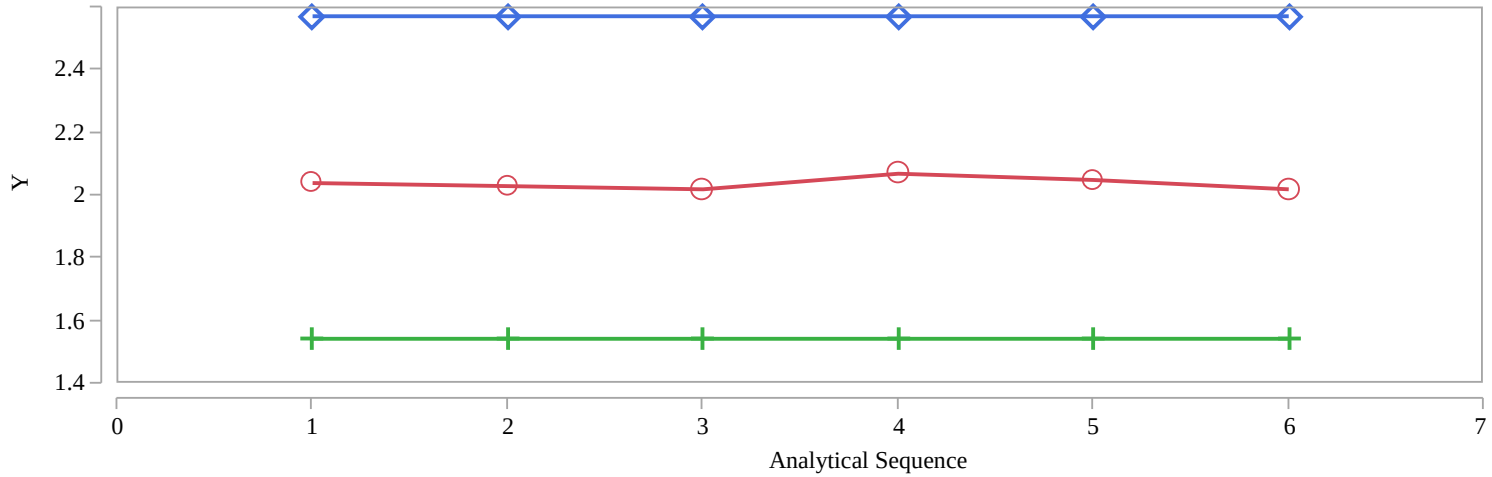
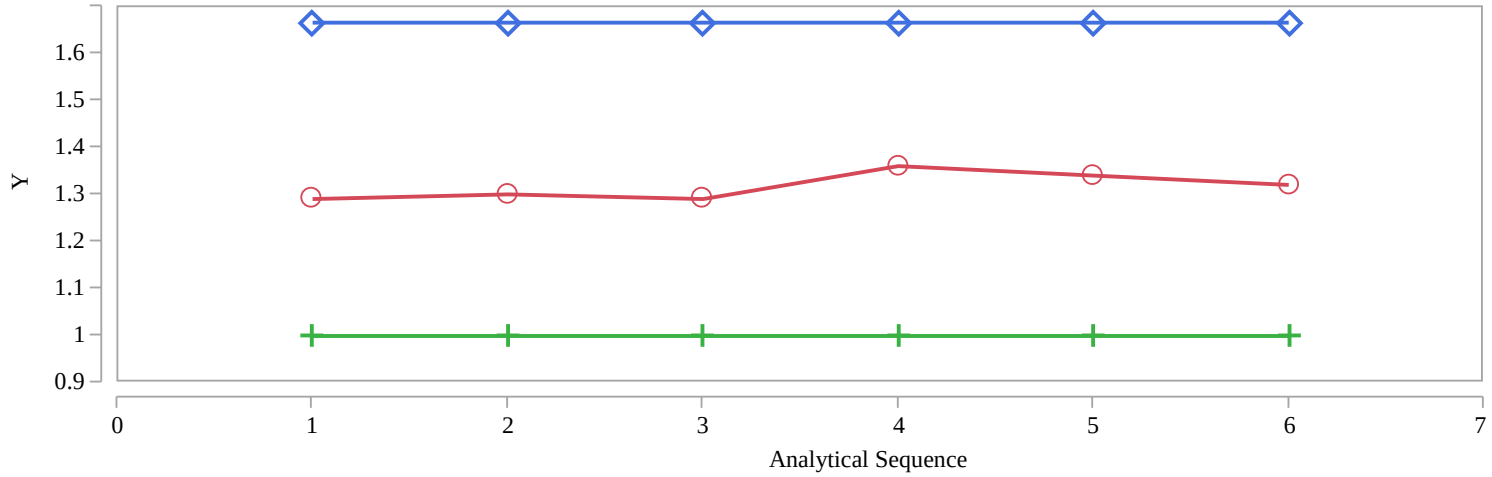


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element (continued)

Overlay Plot ID=Batch 1, Element=Mn, Prep Method=PF



Overlay Plot ID=Batch 1, Element=Na, Prep Method=LM

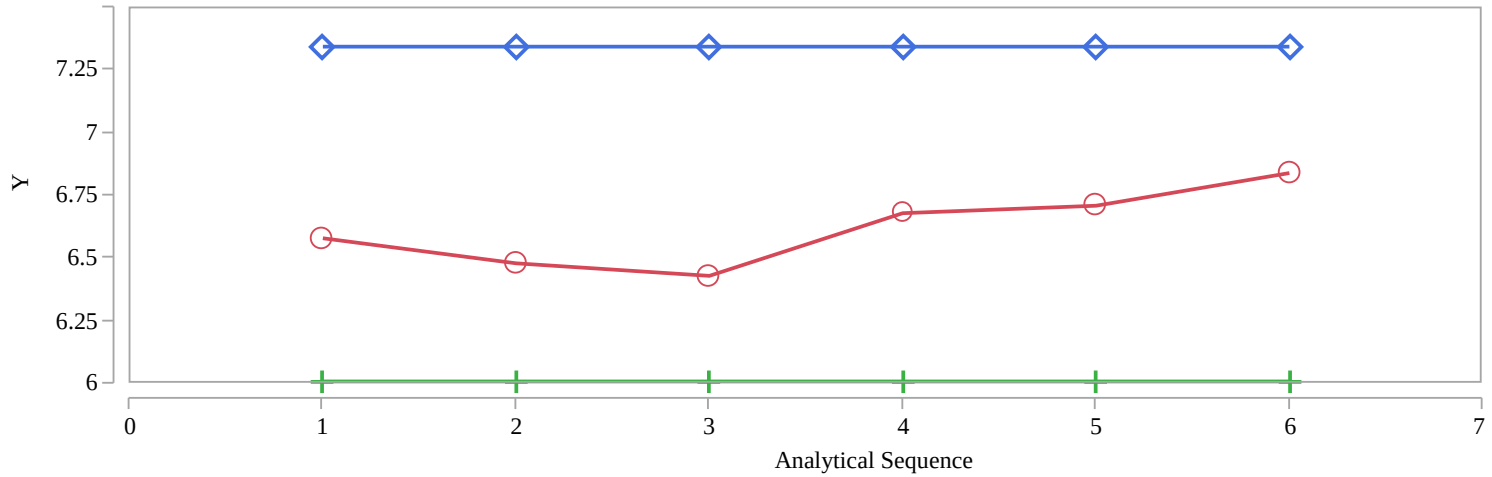
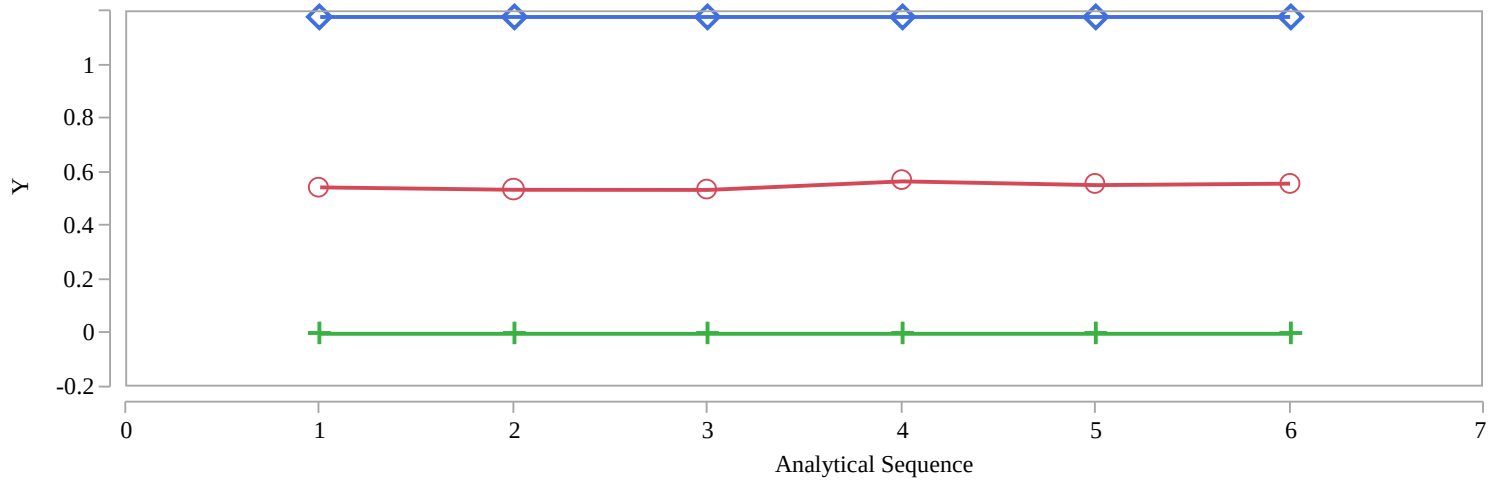


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element (continued)

Overlay Plot ID=Batch 1, Element=Ni, Prep Method=LM



Overlay Plot ID=Batch 1, Element=Si, Prep Method=PF

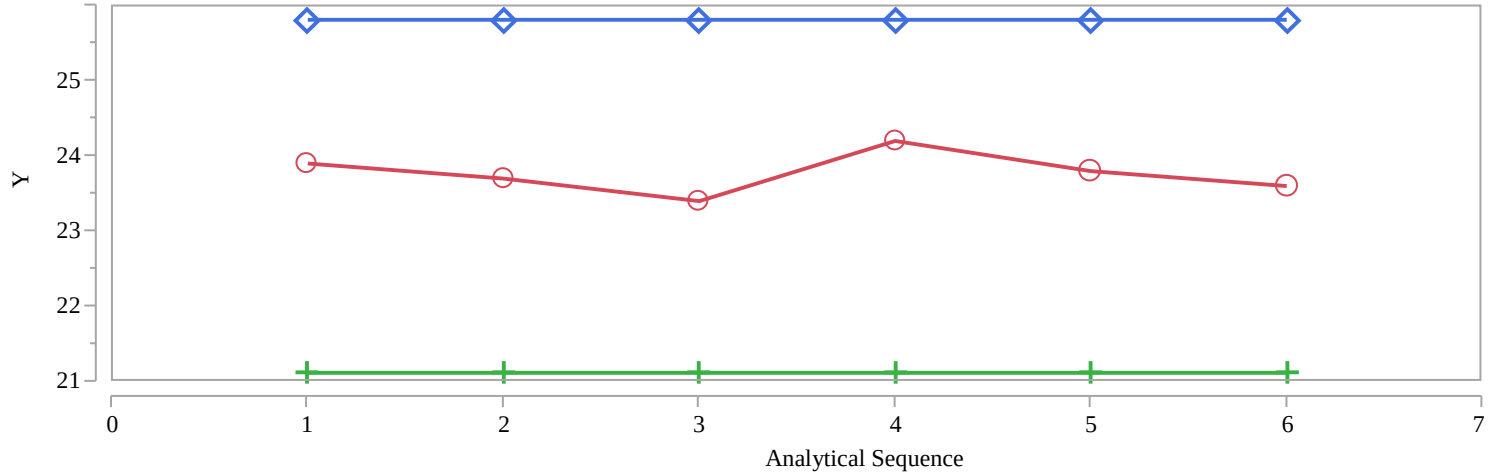
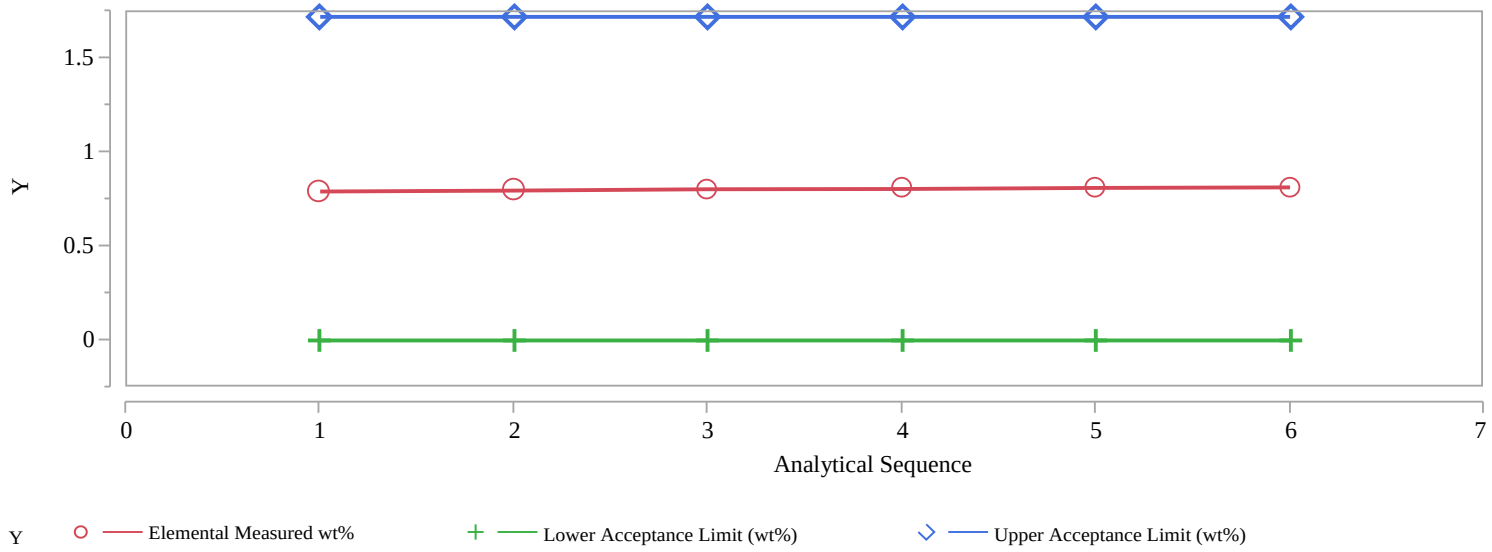


Exhibit A-3. Measurements of the Batch 1 and LRM Standards by Glass by Element (continued)

Overlay Plot ID=LRM, Element=F, Prep Method=KH



Appendix B Tables and Exhibits Supporting the PCT Results

Table B-1. PCT Measurements for Round Robin Glasses (ar – as received)

Glass ID (w HT)	Heat Treatment	Block	Seq	Lab ID	Al ar	B ar	Cr ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Cr (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
std-1-1	ref	1	1	std-1-1	3.77	20.5	<0.100	4.15	9.72	84.3	52.0	3.77	20.50	<0.10	4.15	9.72	84.30	52.00
HLW-HCr-16-X (II) (CCC) (1st sub-sample)	ccc	1	2	Z21	10.3	181	<0.100	<1.00	62.3	110	26.9	17.17	301.67	<0.17	<1.67	103.84	183.34	44.83
HLW-HCr-16-Y (I) (Q) (4th sub-sample)	ar	1	3	Z27	21.2	37.0	<0.100	3.99	13.3	40.6	32.4	35.33	61.67	<0.17	6.65	22.17	67.67	54.00
HLW-HCr-16-X (II) (Q) (2nd sub-sample)	ar	1	4	Z08	21.2	30.9	<0.100	3.59	11.4	35.6	31.3	35.33	51.50	<0.17	5.98	19.00	59.33	52.17
HLW-HCr-16-Y (I) (Q) (2nd sub-sample)	ar	1	5	Z19	20.9	36.5	<0.100	4.02	13.8	41.4	31.6	34.83	60.83	<0.17	6.70	23.00	69.00	52.67
HLW-HCr-16-X (II) (Q) (1st sub-sample)	ar	1	6	Z32	20.1	28.5	<0.100	3.51	11.0	34.7	29.1	33.50	47.50	<0.17	5.85	18.33	57.83	48.50
HLW-HCr-16-Y (I) (CCC) (4th sub-sample)	ccc	1	7	Z20	20.3	38.3	<0.100	2.99	14.3	41.6	32.8	33.83	63.83	<0.17	4.98	23.83	69.33	54.67
HLW-HCr-16-X (II) (CCC) (3rd sub-sample)	ccc	1	8	Z46	10.1	184	<0.100	<1.00	64.3	113	26.8	16.83	306.67	<0.17	<1.67	107.17	188.34	44.67
EA	ref	1	9	Z16	<1.00	18.9	<0.100	<1.00	7.6	55.3	34.7	<16.67	315.00	<1.67	<16.67	126.67	921.67	578.33
HLW-HCr-16-Y (I) (Q) (1st sub-sample)	ar	1	10	Z35	21.8	39.3	<0.100	4.11	14.4	43.1	33.0	36.33	65.50	<0.17	6.85	24.00	71.83	55.00
HLW-HCr-16-X (II) (CCC) (2nd sub-sample)	ccc	1	11	Z47	10.1	182	<0.100	<1.00	63.2	110	26.4	16.83	303.34	<0.17	<1.67	105.34	183.34	44.00
std-1-2	ref	1	12	std-1-2	3.68	19.8	<0.100	4.07	9.6	81.6	50.5	3.68	19.80	<0.10	4.07	9.60	81.60	50.50
HLW-HCr-16-Y (I) (CCC) (2nd sub-sample)	ccc	1	13	Z38	20.1	37.6	<0.100	2.95	14.4	41.7	31.9	33.50	62.67	<0.17	4.92	24.00	69.50	53.17
HLW-HCr-16-Y (I) (Q) (3rd sub-sample)	ar	1	14	Z11	20.7	34.0	<0.100	4.15	12.8	39.0	30.5	34.50	56.67	<0.17	6.92	21.33	65.00	50.83
HLW-HCr-16-Y (I) (CCC) (1st sub-sample)	ccc	1	15	Z42	19.7	35.7	<0.100	2.87	13.8	40.3	31.3	32.83	59.50	<0.17	4.78	23.00	67.17	52.17
HLW-HCr-16-Y (I) (CCC) (3rd sub-sample)	ccc	1	16	Z03	20.8	39.7	<0.100	3.06	15.0	43.5	32.9	34.67	66.17	<0.17	5.10	25.00	72.50	54.83
HLW-HCr-16-X (II) (CCC) (4th sub-sample)	ccc	1	17	Z10	10.2	179	<0.100	<1.00	64.4	113	26.0	17.00	298.34	<0.17	<1.67	107.34	188.34	43.33
HLW-HCr-16-X (II) (Q) (3rd sub-sample)	ar	1	18	Z41	20.9	29.6	<0.100	3.69	11.1	34.8	30.3	34.83	49.33	<0.17	6.15	18.50	58.00	50.50
ARM-1	ref	1	19	Z50	3.61	10.1	<0.100	<1.00	7.62	20.8	35.0	6.02	16.83	<0.17	<1.67	12.70	34.67	58.33
blank	ref	1	20	Z45	<1.00	<1.00	<0.100	<1.00	<1.00	<1.00	<1.00	<1.67	<1.67	<0.17	<1.67	<1.67	<1.67	<1.67
HLW-HCr-16-X (II) (Q) (4th sub-sample)	ar	1	21	Z06	20.8	28.2	<0.100	3.68	11.0	34.4	29.6	34.67	47.00	<0.17	6.13	18.33	57.33	49.33
std-1-3	ref	1	22	std-1-3	3.74	19.2	<0.100	4.11	9.69	83.8	50.2	3.74	19.20	<0.10	4.11	9.69	83.80	50.20
std-2-1	ref	2	1	std-2-1	3.93	21.0	<0.100	4.04	10.0	88.2	52.5	3.93	21.00	<0.10	4.04	10.00	88.20	52.50
HLW-HCr-16-Y (I) (CCC) (2nd sub-sample)	ccc	2	2	Z36	19.9	39.7	<0.100	2.72	14.6	43.1	31.3	33.17	66.17	<0.17	4.53	24.33	71.83	52.17
HLW-HCr-16-Y (I) (CCC) (4th sub-sample)	ccc	2	3	Z05	19.9	36.9	<0.100	2.70	14.0	41.5	31.3	33.17	61.50	<0.17	4.50	23.33	69.17	52.17
EA	ref	2	4	Z15	<1.00	19.1	<0.100	<1.00	6.84	59.4	35.5	<16.67	318.33	<1.67	<16.67	114.00	990.00	591.67
HLW-HCr-16-X (II) (CCC) (2nd sub-sample)	ccc	2	5	Z40	10.5	191	<0.100	<1.00	65.5	117	26.3	17.50	318.34	<0.17	<1.67	109.17	195.00	43.83
HLW-HCr-16-Y (I) (CCC) (3rd sub-sample)	ccc	2	6	Z54	19.9	39.7	<0.100	2.72	14.2	41.7	31.6	33.17	66.17	<0.17	4.53	23.67	69.50	52.67
HLW-HCr-16-X (II) (Q) (1st sub-sample)	ar	2	7	Z12	20.8	30.5	<0.100	3.43	11.2	35.3	29.5	34.67	50.83	<0.17	5.72	18.67	58.83	49.17
HLW-HCr-16-X (II) (Q) (2nd sub-sample)	ar	2	8	Z01	20.0	28.6	<0.100	3.18	10.8	34.0	28.1	33.33	47.67	<0.17	5.30	18.00	56.67	46.83
HLW-HCr-16-Y (I) (Q) (3rd sub-sample)	ar	2	9	Z02	21.4	35.7	<0.100	3.99	13.1	40.2	31.4	35.67	59.50	<0.17	6.65	21.83	67.00	52.33
HLW-HCr-16-X (II) (CCC) (1st sub-sample)	ccc	2	10	Z28	10.3	182	<0.100	<1.00	63.2	113	25.2	17.17	303.34	<0.17	<1.67	105.34	188.34	42.00
ARM-1	ref	2	11	Z07	3.56	11.9	<0.100	<1.00	8.57	23.8	37.5	5.93	19.83	<0.17	<1.67	14.28	39.67	62.50
std-2-2	ref	2	12	std-2-2	3.71	20.1	<0.100	3.87	9.68	84.8	49.9	3.71	20.10	<0.10	3.87	9.68	84.80	49.90
HLW-HCr-16-X (II) (CCC) (3rd sub-sample)	ccc	2	13	Z37	10.7	191	<0.100	<1.00	64.9	115	26.2	17.83	318.34	<0.17	<1.67	108.17	191.67	43.67
HLW-HCr-16-Y (I) (Q) (4th sub-sample)	ar	2	14	Z51	21.5	38.1	<0.100	4.01	13.6	41.7	31.5	35.83	63.50	<0.17	6.68	22.67	69.50	52.50
HLW-HCr-16-Y (I) (Q) (1st sub-sample)	ar	2	15	Z29	21.0	37.5	<0.100	3.84	14.0	42.6	30.6	35.00	62.50	<0.17	6.40	23.33	71.00	51.00

Table B-1. PCT Measurements for Round Robin Glasses (ar – as received) (continued)

Glass ID (w HT)	Heat Treatment	Block	Seq	Lab ID	Al ar	B ar	Cr ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Cr (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
HLW-HCr-16-X (II) (Q) (4th sub-sample)	ar	2	16	Z56	20.1	27.9	<0.100	3.34	10.7	34.3	27.9	33.50	46.50	<0.17	5.57	17.83	57.17	46.50
HLW-HCr-16-X (II) (Q) (3rd sub-sample)	ar	2	17	Z48	21.7	31.5	<0.100	3.62	11.4	36.5	30.7	36.17	52.50	<0.17	6.03	19.00	60.83	51.17
HLW-HCr-16-Y (I) (CCC) (1st sub-sample)	ccc	2	18	Z34	20.8	39.0	<0.100	2.72	14.7	43.1	31.0	34.67	65.00	<0.17	4.53	24.50	71.83	51.67
HLW-HCr-16-X (II) (CCC) (4th sub-sample)	ccc	2	19	Z26	10.4	186	<0.100	<1.00	65.1	116	25.1	17.33	310.01	<0.17	<1.67	108.50	193.34	41.83
HLW-HCr-16-Y (I) (Q) (2nd sub-sample)	ar	2	20	Z39	21.4	36.7	<0.100	3.97	13.5	41.3	30.3	35.67	61.17	<0.17	6.62	22.50	68.83	50.50
std-2-3	ref	2	21	std-2-3	3.65	20.0	<0.100	3.76	9.45	82.1	47.8	3.65	20.00	<0.10	3.76	9.45	82.10	47.80

Table B-1. PCT Measurements for Round Robin Glasses (ar – as received) (continued)

X-Y	Short ID	Glass ID (w HT)	Heat Treatment	Block	Seq	Lab ID	Al ar	B ar	Cr ar	Fe ar	Li ar	Na ar	Si ar	Al (ppm)	B (ppm)	Cr (ppm)	Fe (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
soln std	soln std	std-3-1	ref	3	1	std-3-1	3.70	20.9	<0.100	3.90	9.72	85.9	52.2	3.70	20.90	<0.10	3.90	9.72	85.90	52.20
Y	Y-3rd	HLW-HCr-16-Y (I) (CCC) (3rd sub-sample)	ccc	3	2	Z31	19.5	38.1	<0.100	2.57	13.9	40.8	31.5	32.50	63.50	<0.17	4.28	23.17	68.00	52.50
X	X-1st	HLW-HCr-16-X (II) (CCC) (1st sub-sample)	ccc	3	3	Z30	10.4	184	<0.100	<1.00	62.5	111	26.3	17.33	306.67	<0.17	<1.67	104.17	185.00	43.83
X	X-3rd	HLW-HCr-16-X (II) (CCC) (3rd sub-sample)	ccc	3	4	Z49	9.72	184	<0.100	<1.00	62.5	110	25.3	16.20	306.67	<0.17	<1.67	104.17	183.34	42.17
Y	Y-2nd	HLW-HCr-16-Y (I) (Q) (2nd sub-sample)	ar	3	5	Z14	21.8	40.4	<0.100	3.95	14.1	43.4	32.5	36.33	67.33	<0.17	6.58	23.50	72.33	54.17
ARM-1	ARM-1	ARM-1	ref	3	6	Z25	3.64	10.7	<0.100	<1.00	8.00	22.4	37.0	6.07	17.83	<0.17	<1.67	13.33	37.33	61.67
Y	Y-3rd	HLW-HCr-16-Y (I) (Q) (3rd sub-sample)	ar	3	7	Z13	20.9	37.0	<0.100	3.74	13.3	41.2	30.9	34.83	61.67	<0.17	6.23	22.17	68.67	51.50
blank	blank	blank	ref	3	8	Z33	<1.00	<1.00	<0.100	<1.00	<1.00	<1.00	<1.00	<1.67	<1.67	<0.17	<1.67	<1.67	<1.67	<1.67
X	X-4th	HLW-HCr-16-X (II) (Q) (4th sub-sample)	ar	3	9	Z55	21.5	30.9	<0.100	3.58	11.2	35.6	30.9	35.83	51.50	<0.17	5.97	18.67	59.33	51.50
X	X-2nd	HLW-HCr-16-X (II) (CCC) (2nd sub-sample)	ccc	3	10	Z24	10.2	196	<0.100	<1.00	64.4	114	26.2	17.00	326.67	<0.17	<1.67	107.34	190.00	43.67
X	X-4th	HLW-HCr-16-X (II) (CCC) (4th sub-sample)	ccc	3	11	Z22	10.3	195	<0.100	<1.00	63.8	113	26.4	17.17	325.01	<0.17	<1.67	106.34	188.34	44.00
soln std	soln std	std-3-2	ref	3	12	std-3-2	3.66	20.4	<0.100	3.84	9.52	84.4	50.3	3.66	20.40	<0.10	3.84	9.52	84.40	50.30
EA	EA	EA	ref	3	13	Z53	<1.00	23.2	<0.100	<1.00	7.77	66.1	41.7	<16.67	386.67	<1.67	<16.67	129.50	1101.67	695.00
Y	Y-2nd	HLW-HCr-16-Y (I) (CCC) (2nd sub-sample)	ccc	3	14	Z23	19.8	38.5	<0.100	2.62	14.3	42.3	31.1	33.00	64.17	<0.17	4.37	23.83	70.50	51.83
X	X-3rd	HLW-HCr-16-X (II) (Q) (3rd sub-sample)	ar	3	15	Z44	19.9	27.8	<0.100	3.22	10.6	33.6	28.3	33.17	46.33	<0.17	5.37	17.67	56.00	47.17
Y	Y-1st	HLW-HCr-16-Y (I) (CCC) (1st sub-sample)	ccc	3	16	Z09	20.5	41.6	<0.100	2.71	14.7	43.6	31.9	34.17	69.33	<0.17	4.52	24.50	72.67	53.17
X	X-2nd	HLW-HCr-16-X (II) (Q) (2nd sub-sample)	ar	3	17	Z18	21.5	32.2	<0.100	3.41	11.4	36.1	30.9	35.83	53.67	<0.17	5.68	19.00	60.17	51.50
Y	Y-1st	HLW-HCr-16-Y (I) (Q) (1st sub-sample)	ar	3	18	Z04	21.2	39.4	<0.100	3.68	14.1	42.8	31.4	35.33	65.67	<0.17	6.13	23.50	71.33	52.33
Y	Y-4th	HLW-HCr-16-Y (I) (CCC) (4th sub-sample)	ccc	3	19	Z17	19.1	34.8	<0.100	2.56	12.9	38.1	29.9	31.83	58.00	<0.17	4.27	21.50	63.50	49.83
Y	Y-4th	HLW-HCr-16-Y (I) (Q) (4th sub-sample)	ar	3	20	Z43	21.4	38.8	<0.100	3.83	13.4	41.3	32.1	35.67	64.67	<0.17	6.38	22.33	68.83	53.50
X	X-1st	HLW-HCr-16-X (II) (Q) (1st sub-sample)	ar	3	21	Z52	21.3	29.1	<0.100	3.37	10.4	33.9	30.5	35.50	48.50	<0.17	5.62	17.33	56.50	50.83
soln std	soln std	std-3-3	ref	3	22	std-3-3	3.66	20.1	<0.100	3.83	9.60	85.7	50.3	3.66	20.10	<0.10	3.83	9.60	85.70	50.30

Table B-2. PCT Leachate pH Values

Identifier	pH		Identifier	pH
Blank-1	6.75		HCr-16-X(II)Q-3rd-3	9.73
Blank-2	6.70		HCr-16-X(II)Q-4th-1	9.73
ARM-1-1	10.05		HCr-16-X(II)Q-4th-2	9.74
ARM-1-2	10.04		HCr-16-X(II)Q-4th-3	9.74
ARM-1-3	10.08		HCr-16-Y(I)CCC-1st-1	9.72
EA-1	11.43		HCr-16-Y(I)CCC-1st-2	9.75
EA-2	11.47		HCr-16-Y(I)CCC-1st-3	9.78
EA-3	11.46		HCr-16-Y(I)CCC-2nd-1	9.77
HCr-16-X(II)CCC-1st-1	9.57		HCr-16-Y(I)CCC-2nd-2	9.69
HCr-16-X(II)CCC-1st-2	9.55		HCr-16-Y(I)CCC-2nd-3	9.76
HCr-16-X(II)CCC-1st-3	9.54		HCr-16-Y(I)CCC-3rd-1	9.77
HCr-16-X(II)CCC-2nd-1	9.57		HCr-16-Y(I)CCC-3rd-2	9.77
HCr-16-X(II)CCC-2nd-2	9.57		HCr-16-Y(I)CCC-3rd-3	9.76
HCr-16-X(II)CCC-2nd-3	9.58		HCr-16-Y(I)CCC-4th-1	9.75
HCr-16-X(II)CCC-3rd-1	9.59		HCr-16-Y(I)CCC-4th-2	9.76
HCr-16-X(II)CCC-3rd-2	9.58		HCr-16-Y(I)CCC-4th-3	9.76
HCr-16-X(II)CCC-3rd-3	9.58		HCr-16-Y(I)Q-1st-1	9.78
HCr-16-X(II)CCC-4th-1	9.70		HCr-16-Y(I)Q-1st-2	9.81
HCr-16-X(II)CCC-4th-2	9.62		HCr-16-Y(I)Q-1st-3	9.81
HCr-16-X(II)CCC-4th-3	9.62		HCr-16-Y(I)Q-2nd-1	9.82
HCr-16-X(II)Q-1st-1	9.71		HCr-16-Y(I)Q-2nd-2	9.80
HCr-16-X(II)Q-1st-2	9.71		HCr-16-Y(I)Q-2nd-3	9.80
HCr-16-X(II)Q-1st-3	9.72		HCr-16-Y(I)Q-3rd-1	9.79
HCr-16-X(II)Q-2nd-1	9.74		HCr-16-Y(I)Q-3rd-2	9.79
HCr-16-X(II)Q-2nd-2	9.73		HCr-16-Y(I)Q-3rd-3	9.80
HCr-16-X(II)Q-2nd-3	9.71		HCr-16-Y(I)Q-4th-1	9.78
HCr-16-X(II)Q-3rd-1	9.73		HCr-16-Y(I)Q-4th-2	9.79
HCr-16-X(II)Q-3rd-2	9.67		HCr-16-Y(I)Q-4th-3	9.78

Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block

Analyte=log[Al ppm]
Variability Chart for Measurement (log ppm)

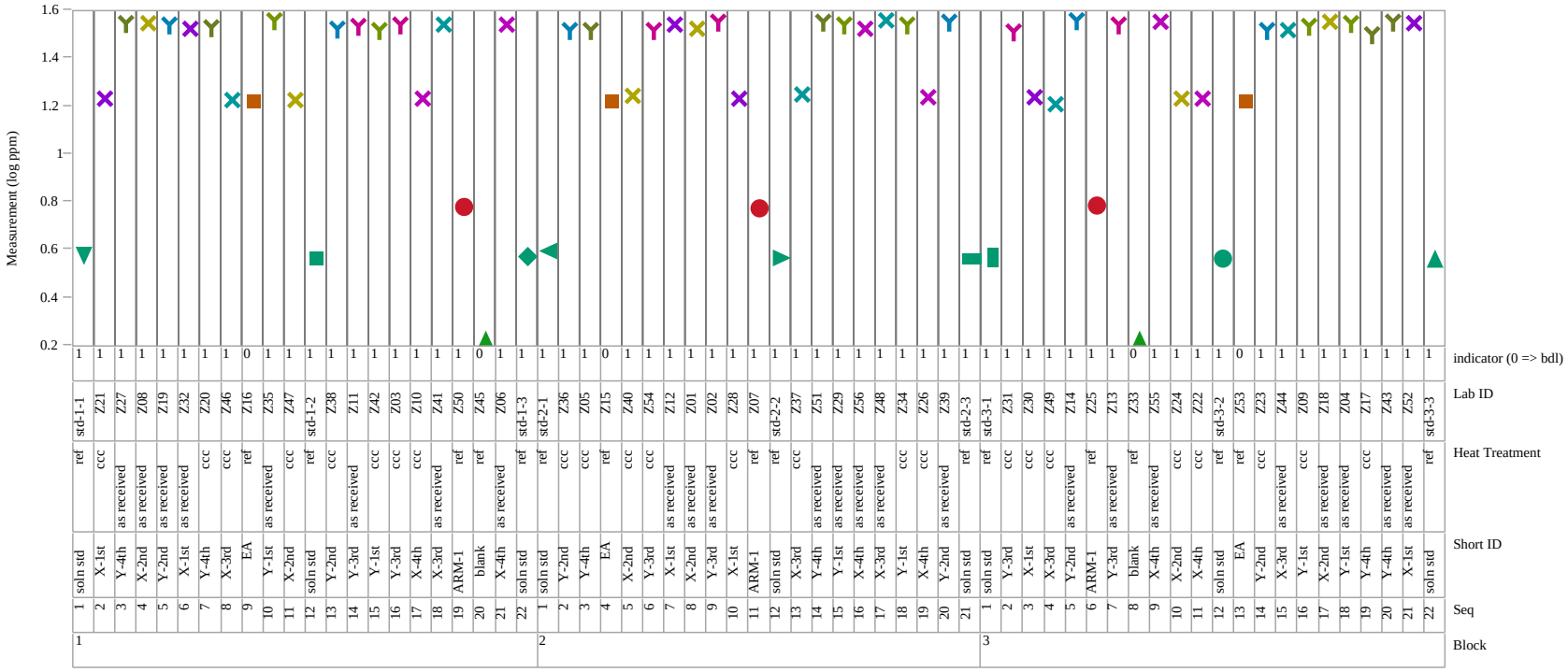


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[B ppm]
Variability Chart for Measurement (log ppm)

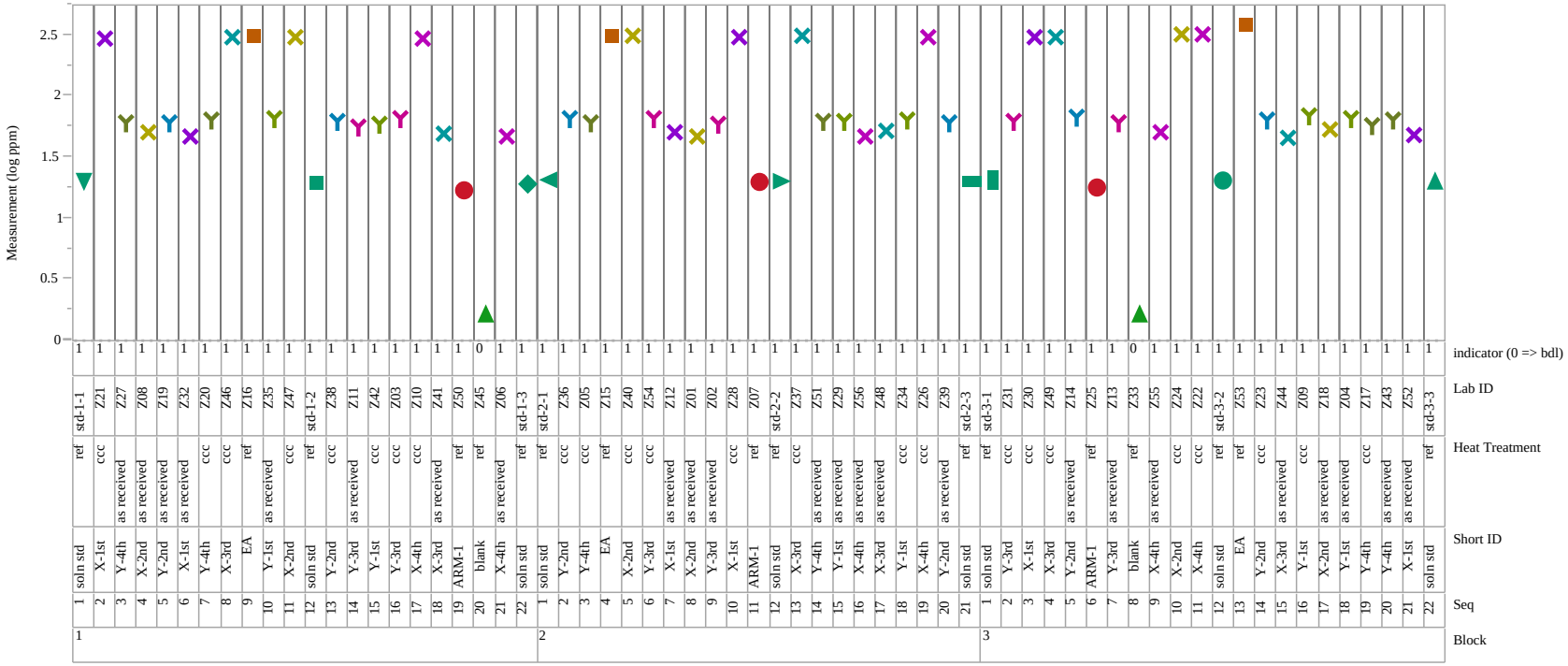


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[Cr ppm]
Variability Chart for Measurement (log ppm)

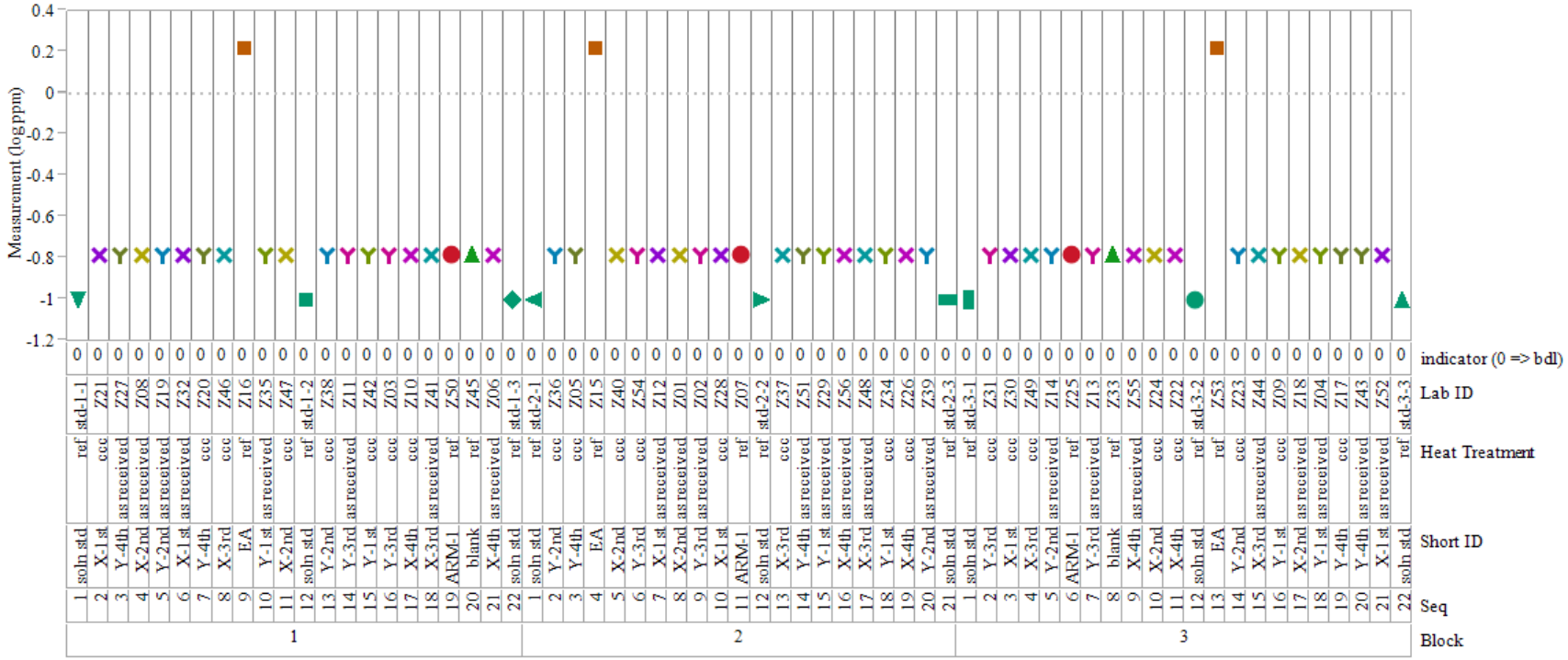


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[Fe ppm]
Variability Chart for Measurement (log ppm)

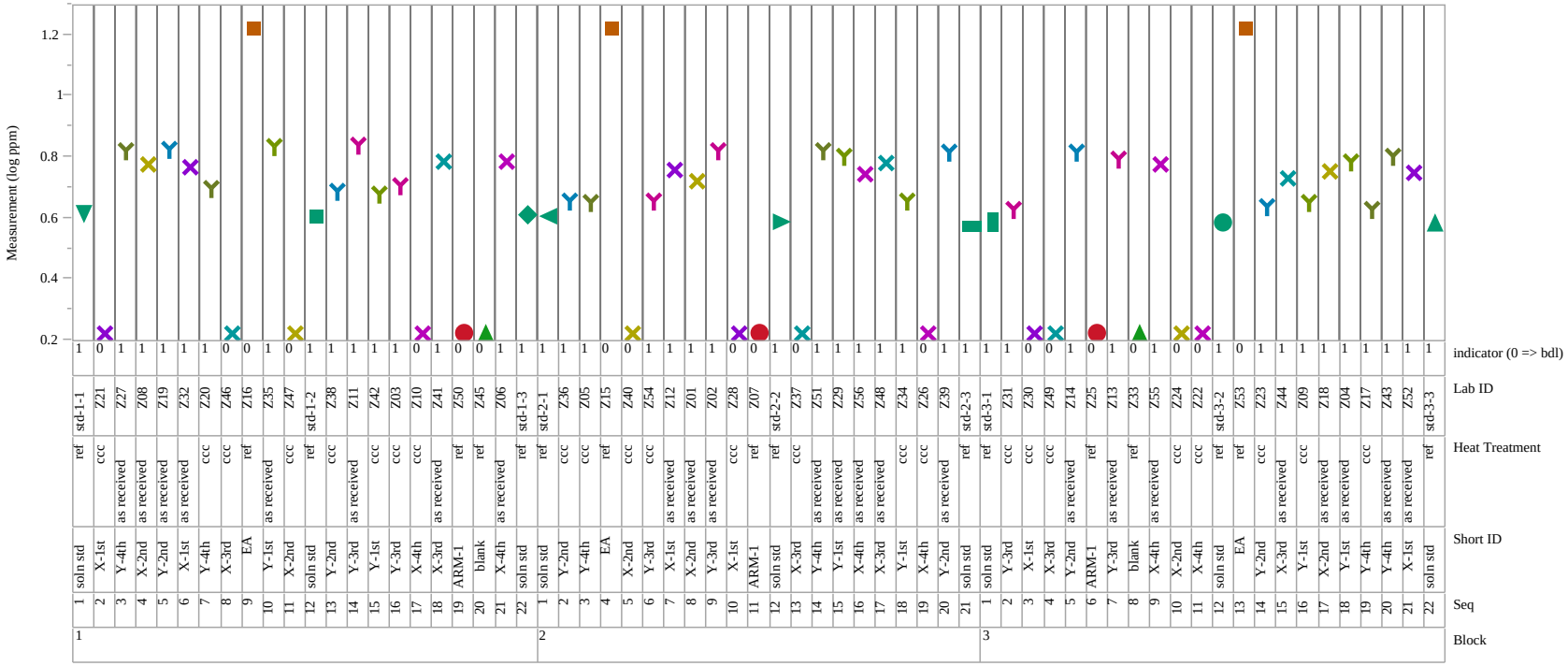


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[Li ppm]
Variability Chart for Measurement (log ppm)

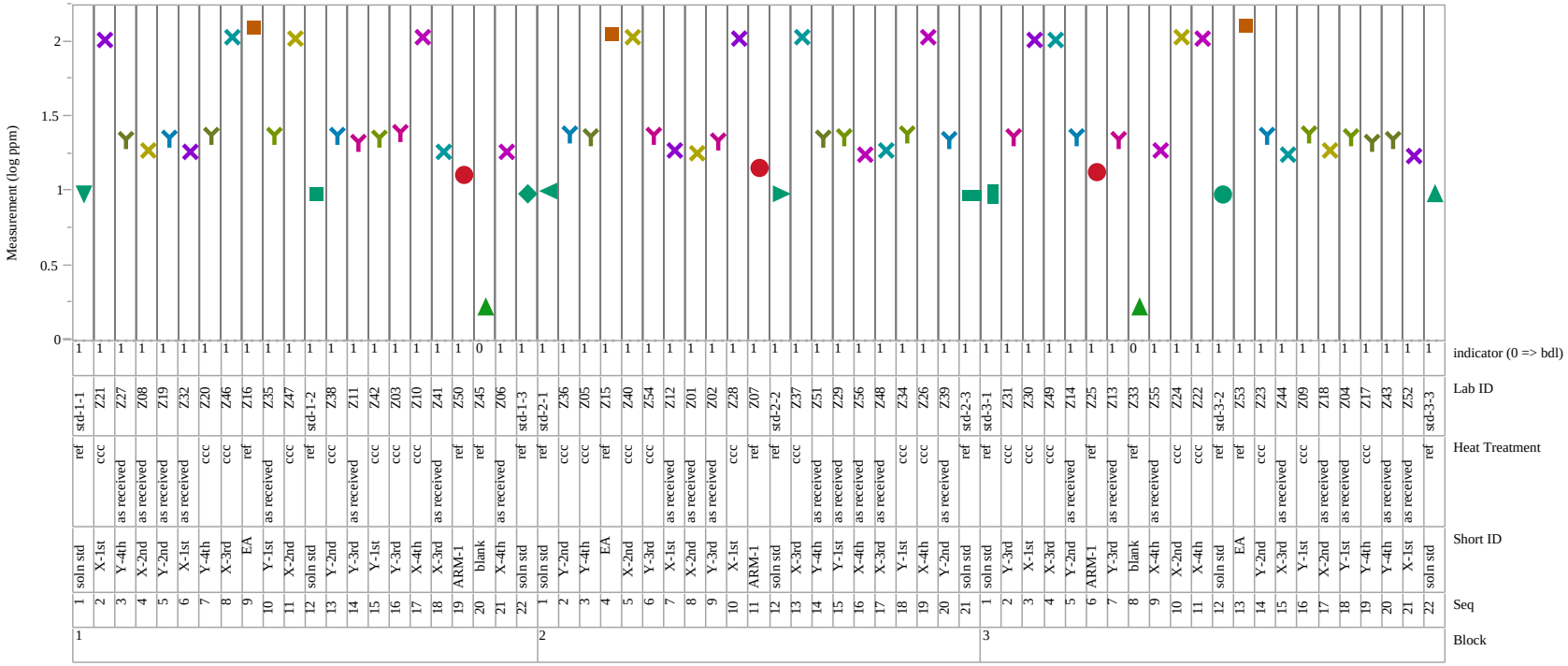


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[Na ppm]
Variability Chart for Measurement (log ppm)

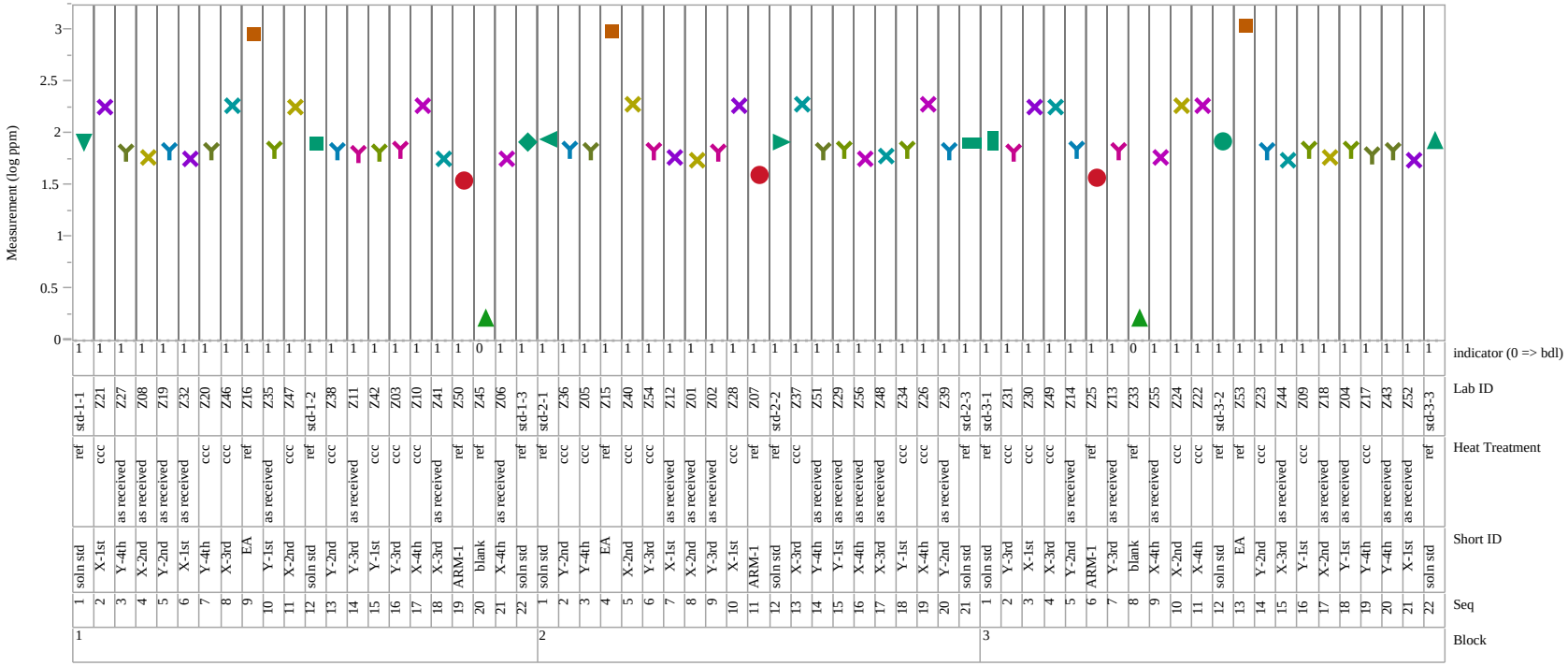


Exhibit B-1. PCT Measurements in Analytical Sequence by Analytical Block (continued)

Analyte=log[Si ppm]
Variability Chart for Measurement (log ppm)

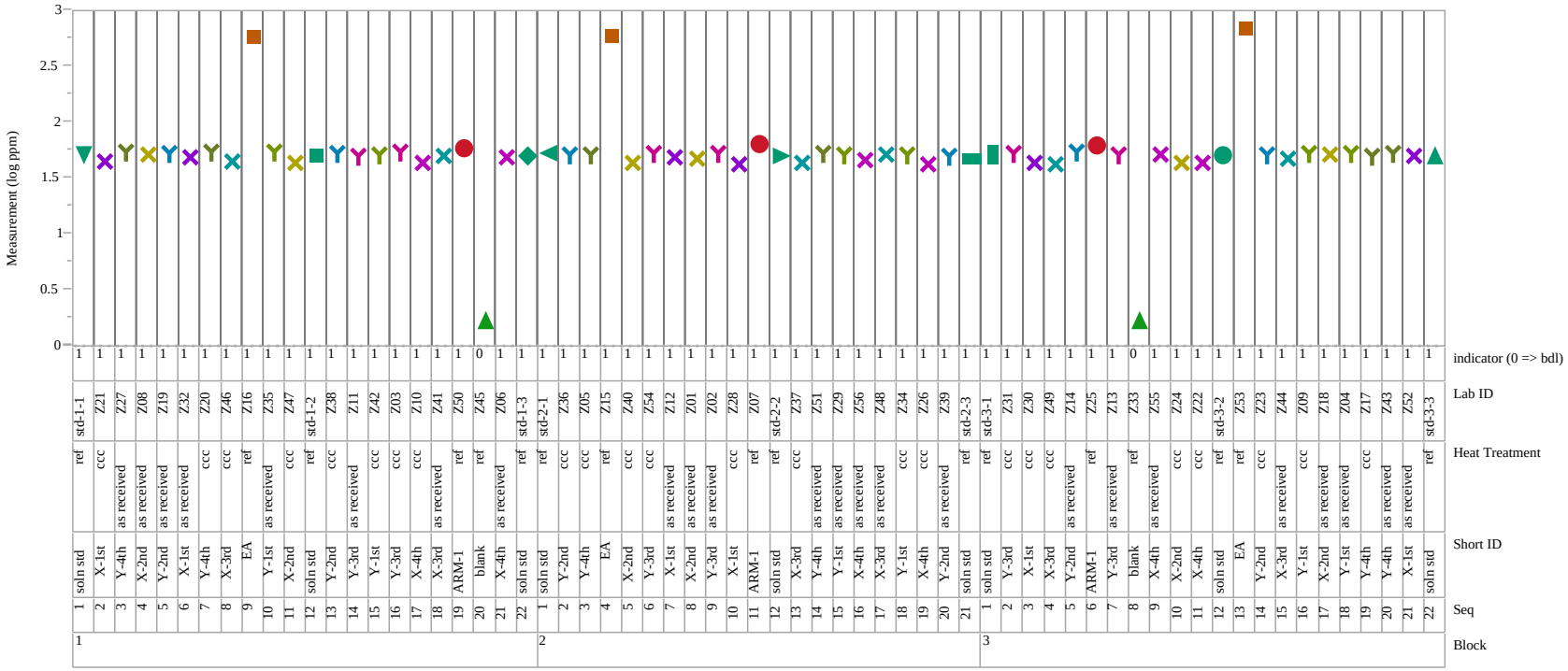


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment

Analyte=log[Al ppm]
Variability Chart for Measurement (log ppm)

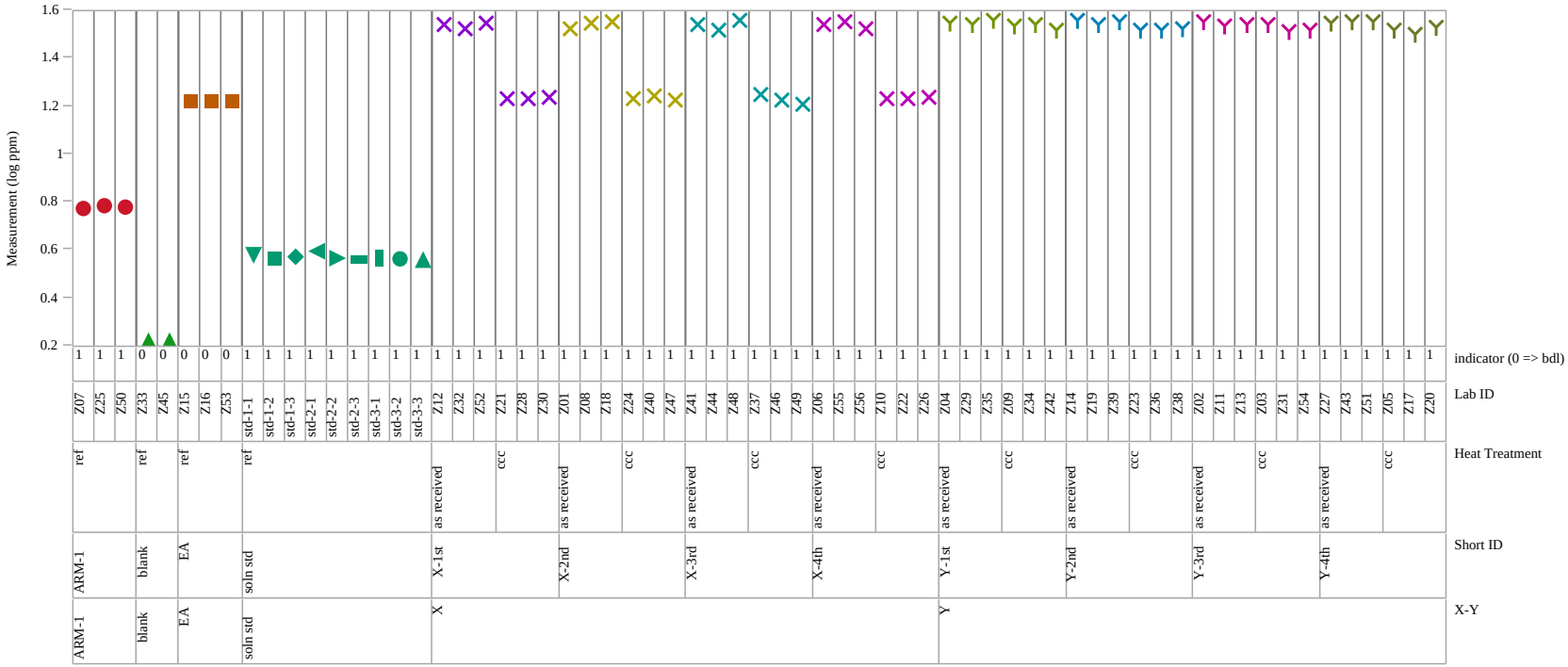


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[B ppm]
Variability Chart for Measurement (log ppm)

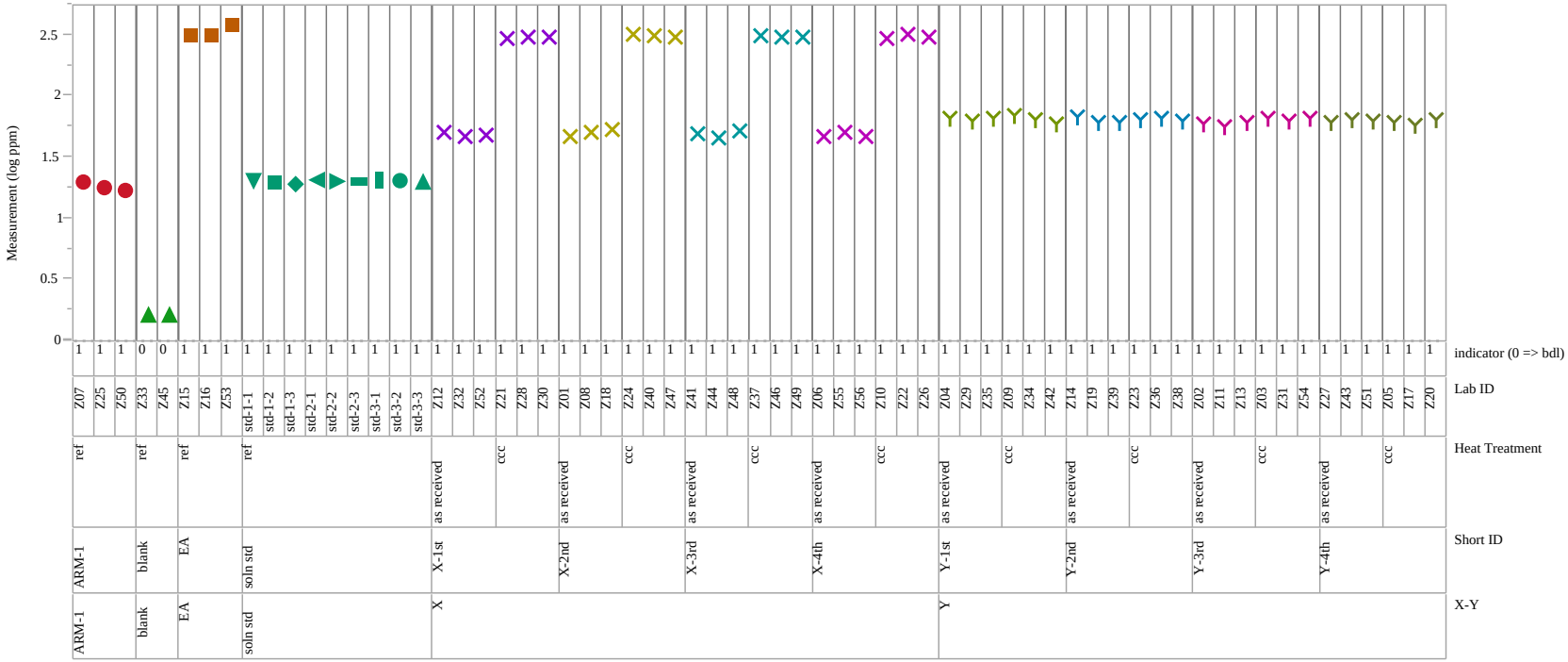


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[Cr ppm]
Variability Chart for Measurement (log ppm)

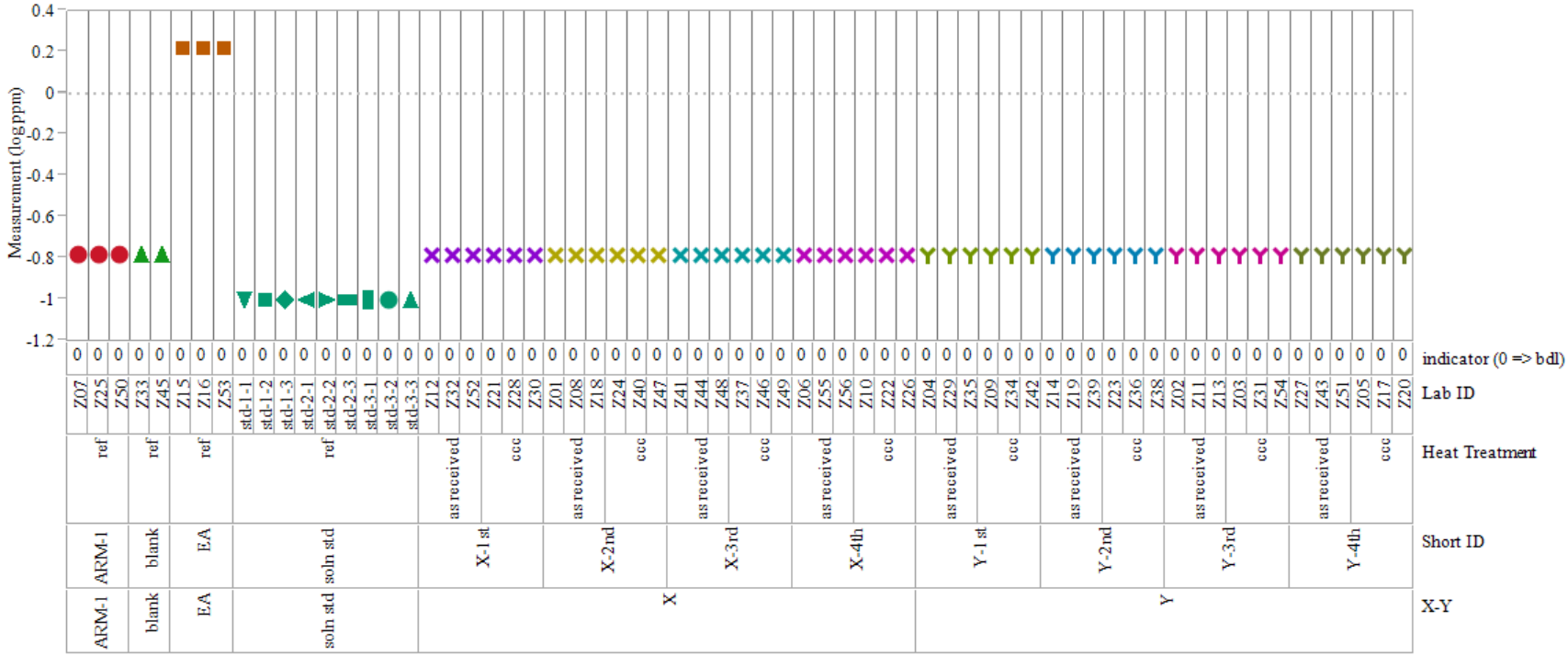


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[Fe ppm]
Variability Chart for Measurement (log ppm)

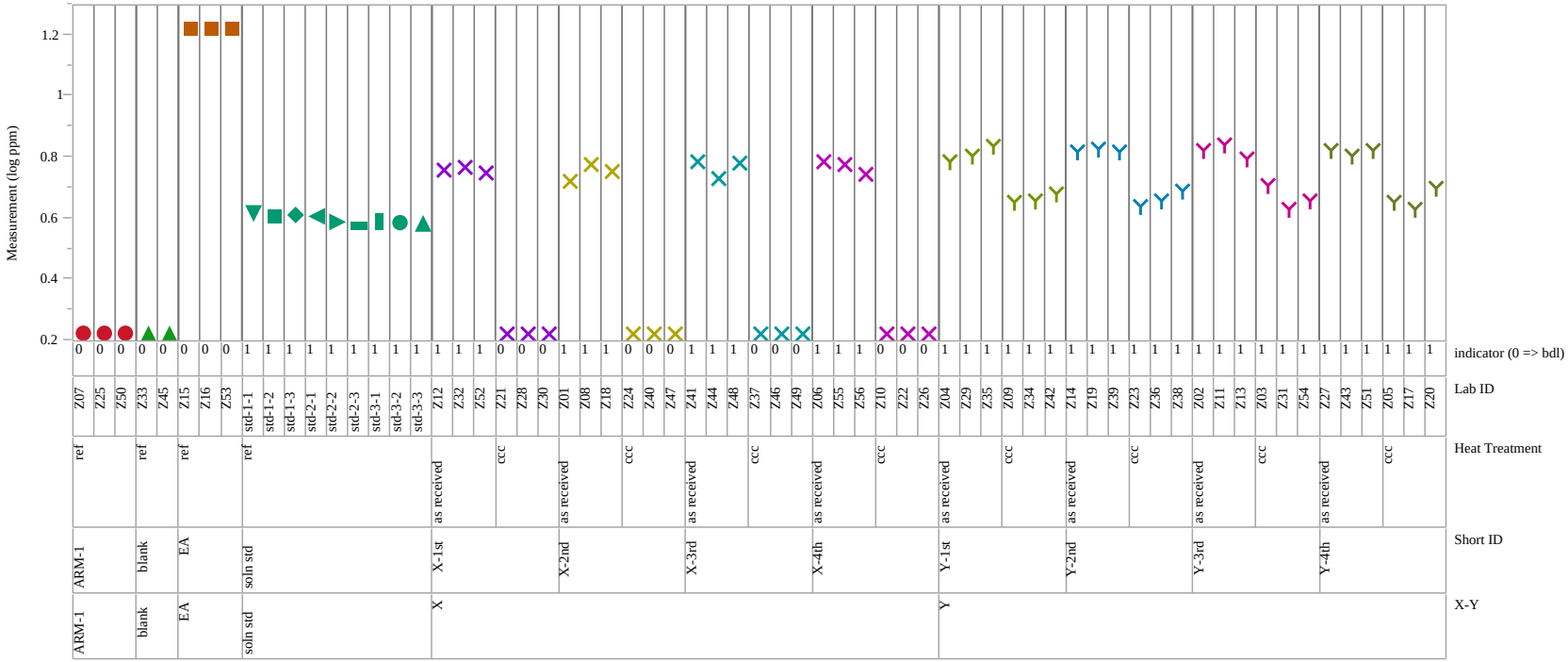


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[Li ppm]
Variability Chart for Measurement (log ppm)

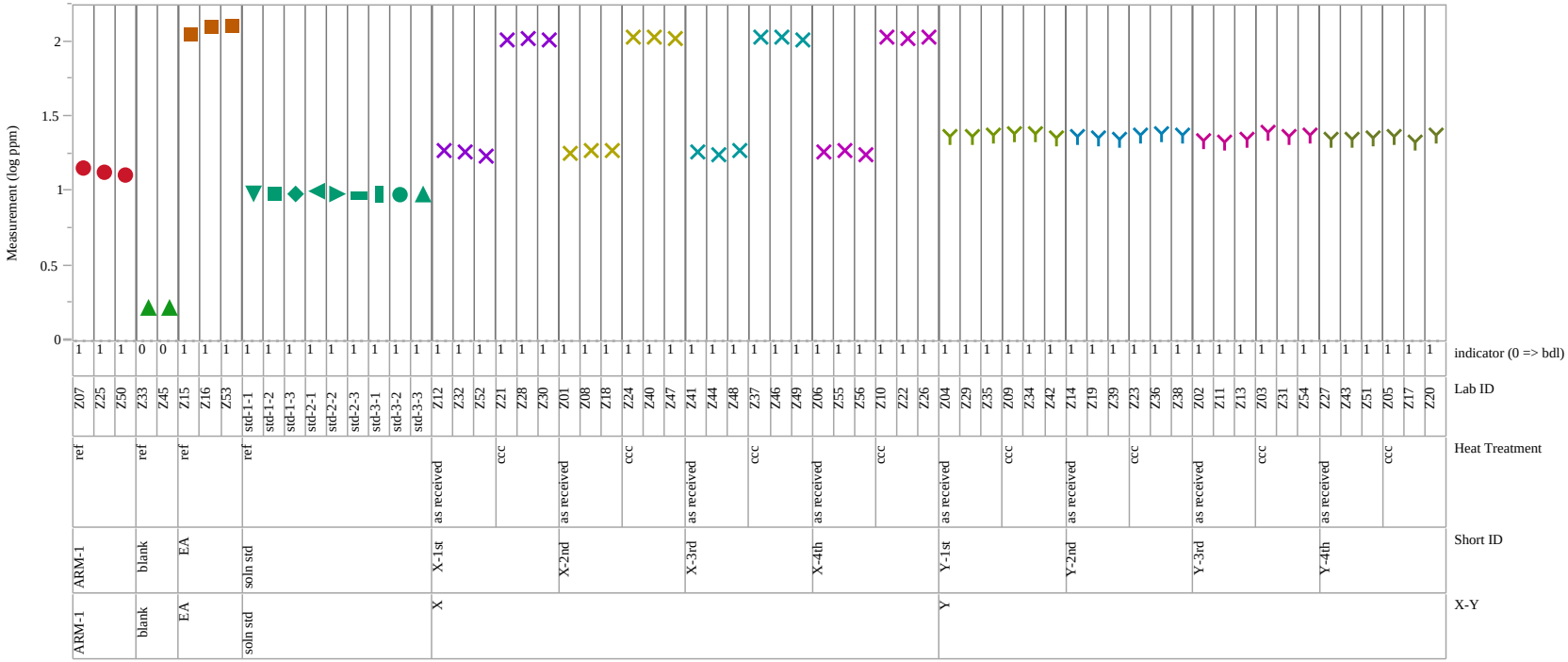


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[Na ppm]
Variability Chart for Measurement (log ppm)

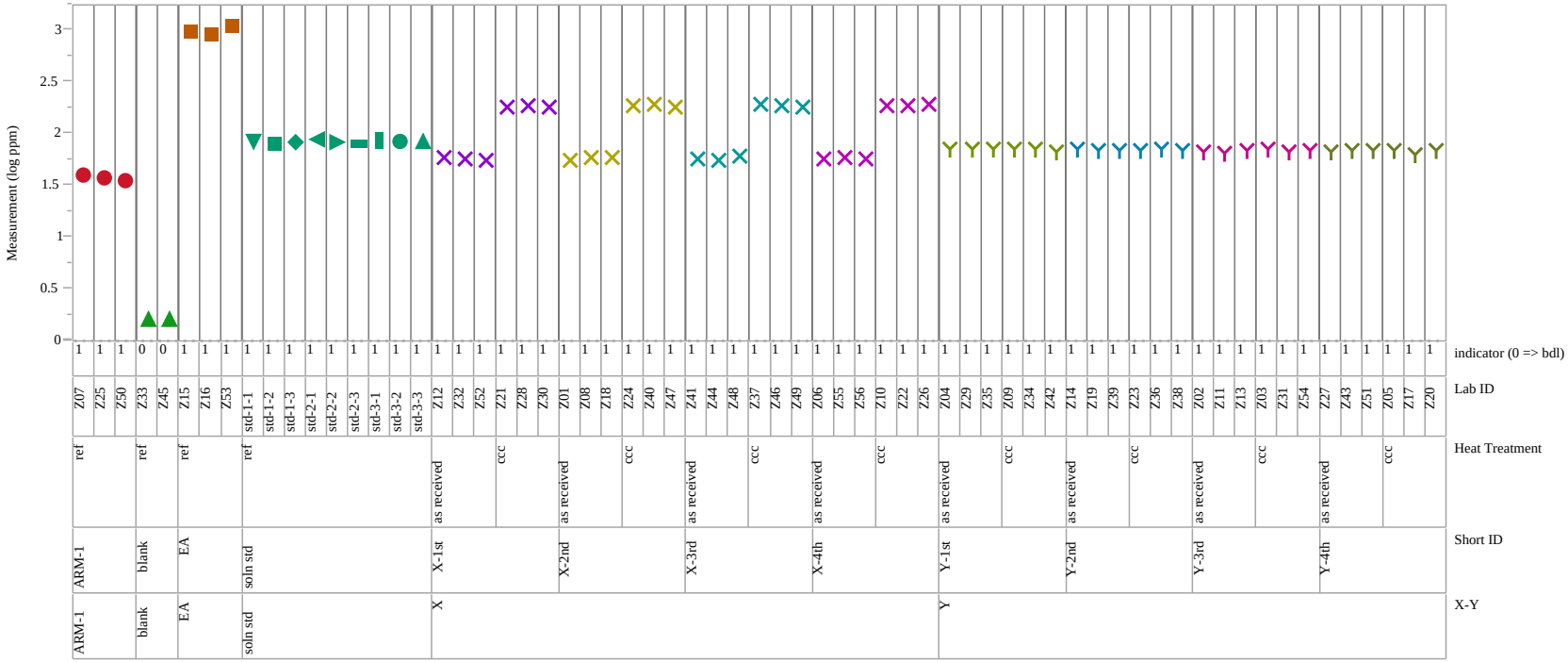
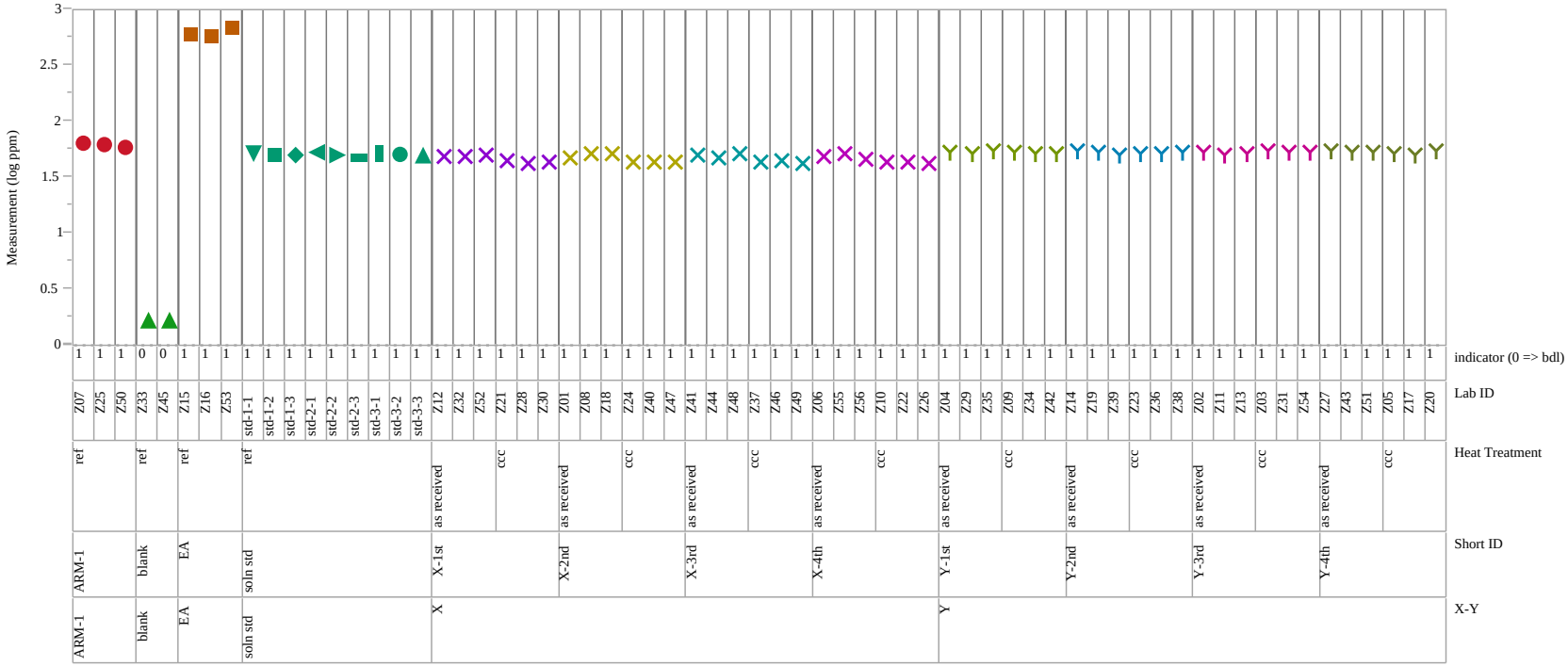


Exhibit B-2. PCT Measurements for Each Glass Grouped by Heat Treatment (continued)

Analyte=log[Si ppm]
Variability Chart for Measurement (log ppm)



Distribution:

J. W. Amoroso, 999-W
T. B. Brown, 773-A
J. H. Christian, 999-W
J. V. Crum, PNNL
W. A. Drown, 773-41A
T. B. Edwards, 999-W
S. D. Fink, 773-A
K. M. Fox, 999-W
C. C. Herman, 773-A
E. N. Hoffman, 999-W
F. C. Johnson, 999-W
D. S. Kim, PNNL
A. A. Kruger, DOE-ORP
S. L. Marra, 773-A
J. Matyáš, PNNL
B. P. McCarthy, PNNL
D. H. McGuire, 999-W
D. K. Peeler, 999-W
F. M. Pennebaker, 773-42A
R. L. Russell, PNNL
M. J. Schweiger, PNNL
J. D. Vienna, PNNL
W. R. Wilmarth, 773-A
Records Administration (EDWS)