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Impacts of Small Column Ion Exchange Streams on DWPF Glass Formulation: KT07-Series Glass Compositions

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EXECUTIVE SUMMARY

This report is the third in a series of studies of the impacts of the addition of Crystalline Silicotitanate (CST) and Monosodium Titanate (MST) from the Small Column Ion Exchange (SCIX) process on the Defense Waste Processing Facility (DWPF) glass waste form and the applicability of the DWPF process control models. MST from the Salt Waste Processing Facility is also considered in the study. The KT07-series glasses were selected to evaluate any potential impacts of noble metals on their properties and performance. The glasses characterized thus far for the SCIX study have not included noble metals since they are not typically tracked in sludge batch composition projections. However, noble metals can act as nucleation sites in glass melts, leading to enhanced crystallization. This crystallization can potentially influence the properties and performance of the glass, such as chemical durability, viscosity, and liquidus temperature. The noble metals Ag, Pd, Rh, and Ru were added to the KT07-series glasses in concentrations based on recent measurements of Sludge Batch 6, which was considered to contain a high concentration of noble metals. The KT04-series glasses were used as the baseline compositions.

After fabrication, the glasses were characterized to determine their homogeneity, chemical composition, durability, and viscosity. Liquidus temperature measurements are also underway but were not complete at the time of this report. The liquidus temperature results for the KT07-series glasses, along with several of the earlier glasses in the SCIX study, will be documented separately. All of the KT07-series glasses, both quenched and slowly cooled, were found to be amorphous by X-ray diffraction. Chemical composition measurements showed that all of the glasses met their targeted compositions. The Product Consistency Test (PCT) results showed that all of the glasses had chemical durabilities that were far better than that of the Environmental Assessment benchmark glass. The measured PCT responses were well predicted by the current DWPF Product Composition Control System (PCCS) durability models. The measured viscosity values for each KT07-series glass were acceptable for DWPF processing and were well predicted by the current PCCS model.

Overall, the results show that the inclusion of relatively high concentrations of noble metals (in terms of expected values for a DWPF sludge batch) had no significant impact on the properties and performance of these glass compositions. There were no significant differences in the measured properties when compared to those of the KT04-series glasses, which did not contain noble metals. Liquidus temperature measurements are still underway and there may be an impact of the noble metals on those measurements. However, no adverse effects were noted in terms of crystallization after slow cooling.

At the completion of these studies, all of the data generated will be reviewed with regard to the applicability of the DWPF PCCS models and recommendations will be made as to whether the validation ranges of the current models can be extended, or whether some or all of the models need to be refit to allow for the incorporation of the SCIX streams. As changes are made to the projected sludge compositions and the volume of the SCIX material, additional evaluations should be performed.

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LIST OF ABBREVIATIONS

AD	Analytical Development
ANOVA	ANalysis Of VAriance
ARM	Approved Reference Material
CCC	Canister Centerline Cooled
CST	Crystalline Silicotitanate
DWPF	Defense Waste Processing Facility
EA	Environmental Assessment
HLW	High Level Waste
ICP-AES	Inductively Coupled Plasma – Atomic Emission Spectroscopy
LM	Lithium-Metaborate Fusion
MAR	Measurement Acceptability Region
MST	Monosodium Titanate
PCCS	Product Composition Control System
PCT	Product Consistency Test
PF	Sodium Peroxide Fusion
PSAL	Process Science Analytical Laboratory
RMF	Rotary Micro Filtration
SCIX	Small Column Ion Exchange
SRAT	Sludge Receipt and Adjustment Tank
SRS	Savannah River Site
SWPF	Salt Waste Processing Facility
T_L	Liquidus Temperature
XRD	X-ray Diffraction

1.0 Introduction

1.1 Background

The Savannah River Site (SRS) Liquid Waste contractor will begin a process referred to as Small Column Ion Exchange (SCIX) to disposition salt solution in fiscal year 2014. In the first step of the process, salt solution retrieved from various waste tanks will be struck with Monosodium Titanate (MST) to remove key actinides and Sr. The salt solution will then be processed using Rotary Micro Filtration (RMF) to remove the MST and any insoluble solids. The MST and insoluble solids will accumulate on the bottom of Tank 41. The filtrate from RMF will be fed to ion exchange columns, also in Tank 41, to remove the ^{137}Cs using Crystalline Silicotitanate (CST) resin. The decontaminated salt solution from SCIX will be sent to the Saltstone Facility for immobilization in grout. The ^{137}Cs-laden CST resin will be sluiced and ground for particle size reduction, then sent to the Defense Waste Processing Facility (DWPF) for immobilization in glass. These processes mirror the current disposition paths for streams associated with the Salt Waste Processing Facility (SWPF), which is under construction and will run concurrently with SCIX.

The MST and insoluble solids from Tank 41 will periodically be transferred to a sludge batch preparation tank (e.g., Tank 42 or Tank 51) as part of the High Level Waste (HLW) sludge batch preparation process for DWPF. The ground, ^{137}Cs-laden CST material (hereafter referred to simply as CST) from SCIX will be periodically transferred to Tank 40 prior to being processed at DWPF. Periodic additions of CST to Tank 40 would result in a changing composition of each sludge batch as it is processed since Tank 40 serves as the feed tank for the DWPF. Work is currently in progress to determine the feasibility of dropping the ground CST into Tank 41. If ground CST can be dropped into Tank 41 (depending on heat loading issues, among others), the CST would be sent to Tank 42 or Tank 51 using an existing transfer line. Therefore, the studies of SCIX impacts on DWPF glass formulation will encompass scenarios where the CST is sent to either Tank 40 or a sludge batch preparation tank. MST from the SWPF is also considered in the study.

This work was initiated by a DWPF Technical Task Request[1] and was performed following a Task Technical and Quality Assurance Plan.[2]

1.2 Potential Impacts of SCIX on DWPF Glass Formulation

The MST and CST from the SCIX process will significantly increase the concentrations of Nb_2O_5, TiO_2, and ZrO_2 in the DWPF feed. Other constituents of MST and CST – Na_2O and SiO_2 – are already present in high concentrations in DWPF glass; thus their influences are well understood. The increased concentrations of Nb_2O_5, TiO_2, and ZrO_2 will likely have some impact on the properties and performance of the DWPF glass product. Properties such as the liquidus temperature, viscosity, and rate of melting of the glass may be impacted. The performance of the glass, particularly its chemical durability as it pertains to repository acceptance requirements, may also be impacted. The DWPF uses a set of semi-empirical and first-principles models referred to as the Product Composition Control System (PCCS)[3] to predict the properties and performance of a glass based on its composition since it is not possible to measure these attributes during processing. The objective of this study is to evaluate the impacts of the SCIX streams on the properties and performance of the DWPF glass product and on the applicability of the current process control models.

This report is part of a series of studies on the potential impacts of SCIX on DWPF glass. Fox and Edwards recently performed a paper study evaluation using updated projections for sludge batch compositions and SCIX CST and MST addition rates.[4] This study found that, as a result of the updated composition projections, several viable options were predicted to be available for incorporation of the SCIX streams into either Tank 40 or a sludge batch preparation tank. Transfer of the CST to a sludge batch preparation tank was the preferred option since it allowed more compositional flexibility for frit development while maintaining sufficient projected operating windows. The report again identified several assumptions and limitations associated with the current PCCS models, and recommended that these be further evaluated.

The first report on experimental results in this series covered glass compositions identified as the KT01, KT02, KT03, and KT04-series.[5] The results presented in that report showed a reasonable ability to incorporate the anticipated SCIX streams into the DWPF-type glass compositions studied, with TiO_2 concentrations of 4-5 wt % in glass. The durability and viscosity models satisfactorily predicted the measured values for the study glasses with the exception of a small number of extreme compositions. It was shown that the liquidus temperature model may need to be adjusted to correctly predict the liquidus temperatures of glasses including the SCIX streams based on the data measured.

The second report on experimental results covered compositions identified as the KT05 and KT06-series.[6] The KT05-series glasses were selected, fabricated, and characterized to as a more fundamental study of glass compositions where iron titanate crystals had been previously found to form during a study of high waste loading glasses for future DWPF processing.[7] These glasses contained high TiO_2 concentrations, but may be outside the compositional region that is directly of interest to DWPF. Formation of these crystalline phases in these glasses was confirmed. However, the glass compositions from which these phases formed are different from the current projections for SCIX incorporation into DWPF sludge batches. Increased Na_2O concentrations had little if any impact on reducing the propensity for the formation of the iron titanate crystalline phases. The KT06-series glasses were selected, fabricated, and characterized to further study glass compositions that, while broader than the current projections for DWPF feeds with SCIX material, are potential candidates for future processing (i.e., the compositions are acceptable for processing by the PCCS with the exception of the current TiO_2 concentration constraint). Several of the KT06-series compositions had durability values that, while acceptable, were not correctly predicted by the current durability models. It was shown that for these high TiO_2 concentration glasses, relatively high Fe_2O_3 concentrations combined with relatively high Al_2O_3 concentrations led to durabilities that were unpredictable. Similar PCT responses (e.g., durability values that are acceptable but not predictable) have been observed in other DWPF studies. Several of the KT06-series glasses also had measured viscosity values that were not well predicted by the current model. A statistical partitioning routine showed that the measured viscosities became unpredictable by the current model when the Fe_2O_3 concentration in the glasses was less than about 8.2 wt % and TiO_2 concentrations were high. The current durability and viscosity models will have to be further evaluated should compositions in these regions become necessary for DWPF processing. Overall, the results for the KT05 and KT06-series glasses continued to show a reasonable ability to incorporate the anticipated SCIX streams into the DWPF-type glass compositions studied, with TiO_2 concentrations of approximately 6 wt % in glass.

The present report discusses the fabrication and characterization of the KT07-series glass compositions. As will be described below, these glasses were selected to evaluate any potential impacts of noble metals on their properties and performance. The glasses studied thus far for the SCIX work have not included noble metals since they are not typically tracked in sludge batch composition projections. However, noble metals can act as nucleation sites in glass melts, leading to enhanced crystallization. This crystallization can potentially influence the properties and performance of the glass, such as chemical durability, viscosity, and liquidus temperature.

2.0 Experimental Procedure

2.1 Selection of Glass Compositions

The KT07-series glass compositions were selected in order to evaluate any potential impacts of the inclusion of noble metals, along with the anticipated SCIX streams, on the properties and performance of simulated DWPF glasses. A set of glass compositions developed earlier in this study, the KT04-series, was used as the basis for the current work. The process of selecting the KT04-series glasses is described in detail elsewhere.[5] In brief, recent projections of Sludge Batches 8 through 17 were used, including anticipated material from SCIX and the SWPF, and with CST being added to Tank 40. An accelerated DWPF production rate was assumed, and the final Sludge Receipt and Adjustment Tank (SRAT) batch for each sludge batch was used since the final SRAT batches represent the highest concentrations of CST. Each of these ten sludge batch projections was combined with a frit that provided a PCCS Measurement Acceptability Region (MAR) acceptable glass composition (with the exception of the TiO_2 concentration constraint) at 40% waste loading. For the KT07-series glasses, ThO_2 and U_3O_8 were removed from these glass compositions and the noble metals Ag, Pd, Rh, and Ru were added, followed by a normalization of the remaining components to 100 wt %. The noble metals are not typically tracked in sludge batch projections, and were therefore not included in the KT04-series glasses. The concentrations of these metals were obtained from recent measurements of Sludge Batch 6, which was considered to contain a high concentration of noble metals.[8] The target concentrations for these metals in glass are given in Table 2-1. The resulting target compositions for the KT07-series glasses, as oxides, are given in Table 2-2.

Table 2-1. Target Noble Metals Concentrations (in Glass) for the KT07-Series Glasses.

Metal	(wt %)
Ag	0.015
Pd	0.007
Rh	0.02
Ru	0.11

Table 2-2. Target Compositions for the KT07-Series Glasses.

Oxides	KT07-01	KT07-02	KT07-03	KT07-04	KT07-05	KT07-06	KT07-07	KT07-08	KT07-09	KT07-10
Ag_2O	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Al_2O_3	5.737	5.131	4.435	4.914	6.805	7.228	5.620	5.011	5.460	5.609
B_2O_3	5.999	5.999	5.999	5.999	5.999	5.999	5.999	5.999	5.999	5.999
BaO	0.067	0.068	0.069	0.068	0.068	0.068	0.075	0.075	0.076	0.077
CaO	0.927	0.935	0.947	0.847	0.931	0.985	0.890	0.804	0.951	0.970
Ce_2O_3	0.282	0.285	0.252	0.213	0.142	0.108	0.078	0.079	0.199	0.244
Cr_2O_3	0.088	0.089	0.090	0.088	0.133	0.134	0.147	0.099	0.099	0.101
CuO	0.038	0.038	0.039	0.038	0.038	0.038	0.042	0.042	0.043	0.043
Fe_2O_3	11.971	11.423	11.391	12.027	9.554	9.017	9.378	9.131	12.289	13.576
K_2O	0.036	0.037	0.037	0.036	0.073	0.111	0.081	0.081	0.082	0.042
La_2O_3	0.106	0.071	0.072	0.071	0.071	0.036	0.039	0.040	0.080	0.081
Li_2O	3.599	3.599	3.599	3.599	3.599	3.599	3.599	3.599	3.599	3.599
MgO	0.150	0.151	0.153	0.151	0.150	0.102	0.111	0.112	0.113	0.115
MnO	1.906	1.687	1.788	1.055	1.015	1.186	0.735	0.960	0.570	0.403
Na_2O	13.101	13.950	14.230	13.671	13.631	13.645	14.508	15.411	14.023	13.505
Nb_2O_5	1.024	1.085	1.087	1.043	1.068	1.023	1.193	1.294	0.845	0.785
NiO	0.345	0.193	0.313	0.154	0.115	0.156	0.639	0.602	0.519	0.485
PbO	0.162	0.131	0.133	0.098	0.065	0.066	0.072	0.073	0.146	0.149
PdO	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Rh_2O_3	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010
RuO_2	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058	0.058
SiO_2	48.775	49.285	49.497	50.088	50.625	50.616	50.335	50.006	48.761	48.428
SO_4^{2-}	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400	0.400
TiO_2	4.296	4.329	4.350	4.361	4.416	4.373	4.846	4.932	4.824	4.505
ZnO	0.000	0.038	0.038	0.075	0.038	0.076	0.083	0.042	0.042	0.043
ZrO_2	0.913	0.999	1.004	0.927	0.986	0.956	1.054	1.130	0.802	0.762

2.2 Glass Fabrication

Each of the study glasses was prepared from the proper proportions of reagent-grade metal oxides, carbonates, and boric acid in 200 g batches. The raw materials were thoroughly mixed and placed into platinum/gold, 250 ml crucibles. The batch was placed into a high-temperature furnace at the melt temperature of 1150 °C. The crucible was removed from the furnace after an isothermal hold for 1 hour. The glass was poured onto a clean, stainless steel plate and allowed to air cool (quench). The glass pour patty was used as a sampling stock for the various property measurements described below.

Approximately 25 g of each glass was heat-treated to simulate cooling along the centerline of a DWPF-type canister[9] to gauge the effects of thermal history on the product performance. This cooling schedule is referred to as the CCC heat treatment. Visual observations of both quenched and CCC glasses were documented.

2.3 X-Ray Diffraction Analysis

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

2.4 Composition Analysis

To confirm that the as-fabricated glasses met the target compositions, a representative sample from each quenched glass in the KT07-series was submitted to the Process Science Analytical Laboratory (PSAL) for chemical analysis under the auspices of an analytical plan.[10] Two dissolution 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 – Atomic Emission Spectroscopy (ICP-AES). Glass standards (Batch 1) were also intermittently measured to assess the performance of the ICP-AES instrument over the course of these analyses.

2.5 Product Consistency Test

The Product Consistency Test (PCT) Method-A[11] was performed in triplicate on each KT07-series quenched and CCC glass to assess chemical durability. Also included in the experimental test matrix was the Environmental Assessment (EA) benchmark glass,[12] the Approved Reference Material (ARM) glass,[13] and blanks from the sample cleaning batch. Samples were ground, washed, and prepared according to the standard procedure.[11] 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 for 7 days. Once cooled, the resulting solutions were sampled (filtered and acidified), then labeled and analyzed by PSAL under the auspices of an analytical plan.[14] Samples of a multi-element, standard solution were also included in the analytical plan as a check on the accuracy of the ICP-AES instrument used for these measurements. Normalized release rates were calculated based on the target and measured compositions using the average of the common logarithms of the leachate concentrations.

2.6 Viscosity

The viscosities of the KT07-series glasses were measured following Procedure A of the ASTM C 965 standard.[15] An Orton high temperature rotating spindle viscometer was used with platinum crucibles and spindles. The crucible and spindle were specially designed to operate with small quantities of glass to support measurements of radioactive glasses when necessary.[16,17] A well characterized standard glass was used to determine the appropriate spindle constants.[17,18] Measurements were taken over a range of temperatures from 1050 to 1250 °C in 50 °C intervals. Measurements at 1150 °C were taken at three different times during the procedure to provide an opportunity to identify the effects of any crystallization or volatilization that may have occurred during the test. The data were fit to a Fulcher equation[19,20] to provide a measured viscosity value at the nominal DWPF melt temperature of 1150 °C.

2.7 Liquidus Temperature

Measurements of the liquidus temperatures (T_L) of the KT07-series glasses are underway at the time of this report. The data will be reported separately when the measurements are complete.

3.0 Results and Discussion

3.1 Homogeneity

The homogeneity of each glass sample was assessed via visual observations and XRD. Visual observations of the quenched versions of the KT07-series glasses identified no visible crystallization. All of the quenched glasses were also XRD amorphous. Minor surface crystallization was visible on the CCC versions of glasses KT07-01, -02, -03, -07, -09, and -10, although the bulk of these samples appeared to have remained amorphous. All of the CCC glasses were XRD amorphous, indicating that the volume fraction of the visible surface crystallization was very small.

3.2 Chemical Composition

In this section, the measured versus targeted compositions of the study glasses are presented and compared. Measurements for samples of the Batch 1 standard glass that were included in the analytical plan along with the study glasses are also discussed. The elemental concentrations were converted to oxide concentrations by multiplying the values for each element by the gravimetric factor for the corresponding oxide. During this process, an elemental concentration that was determined to be below the detection limit of the analytical procedures used was reduced to half of that detection limit as the oxide concentration was determined. In the discussion that follows, the analytical sequences of the measurements are explored, the measurements of the standard are investigated, the measurements for each glass are reviewed, the average chemical compositions for each glass are determined, and comparisons are made between the measurements and the targeted compositions of the glasses.

Table A-1 and Table A-2 in Appendix A provide the elemental concentration measurements from the KT07 glasses that were prepared using LM, and Table A-3 in Appendix A provides the measurements from the samples of these glasses prepared using PF. Measurements for samples of the standard Batch 1 glass that were included in the analytical plan along with the study glasses are also provided in these tables. Exhibit A-1 in Appendix A provides plots of the sample measurements generated by PSAL for each oxide over both preparation methods. The plots are in analytical sequence with different symbols and colors being used to represent each of the study glasses and the standard glass. In general, there do not appear to be any gross patterns or trends due to the analytical sequence. Further opportunity for a review of the measurements for each glass is provided in the discussions that follow.

Exhibit A-2 in Appendix A provides plots of the oxide concentration measurements by Glass ID (including the Batch 1 standard) by analytical solution or Lab ID for both preparation methods for the KT07-series. The different symbols and colors being used to represent the glasses are discernable in this exhibit. These plots show the individual measurements across the duplicates of each preparation method and the two ICP-AES calibrations for each glass for each oxide. The results are grouped by analytical block and arranged by targeted concentration to facilitate the interpretation of the measurements. A review of the plots presented in this exhibit reveals the repeatability of the four individual values for each oxide for each glass. There appears to be good repeatability of these measurements for each of the oxides for each of the glasses. There may be a minor preparation issue for the Cr_2O_3 measurements for glass KT07-03. There is some scatter in the B_2O_3, Li_2O, Na_2O, and SiO_2 measurements for several of the KT07 glasses. Overall, the data suggest no significant issues with the batching of the KT07 glasses or with the analytical process used to provide representative measurements of their compositions.

Exhibit A-3 in Appendix A provides statistical analyses of the results for the Batch 1 standard that was included with the KT07 glasses by analytical block/sub-block for each oxide of interest over both preparation methods. The results include analysis of variance (ANOVA) investigations looking for statistically significant differences among the means of these groups for each of the oxides. The reference values for the oxide concentrations of the standard are given in the header for each set of measurements in the exhibit. The results from the statistical tests for the Batch 1 standard included with the KT07 glasses may be summarized as follows: B_2O_3, BaO, CaO, Cr_2O_3, K_2O, MgO, Na_2O, NiO, and TiO_2 have measurements that indicate an ICP-AES calibration effect on the block averages at the 5% significance level. While statistically significant, the practical impact of these calibration effects is minimal.

All of the measurements for each oxide for each KT07 glass (i.e., all of the measurements in Appendix A Table A-1, Table A-2, and Table A-3) 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 plots showing results for each glass for each oxide to help highlight the comparisons among the measured and targeted values. Some observations from the plots of Exhibit A-4 are offered: Some of the measured Al_2O_3 values are slightly above the targets. There is minor scatter in the B_2O_3, Na_2O, and ZnO measurements. The measured values of BaO, La_2O_3, and Li_2O are slightly low for all of the glasses. All of the CaO and Cr_2O_3 measurements are slightly above the target values. Some of the measured Fe_2O_3, Nb_2O_5, PbO, SO_4, and ZrO_2 values are slightly low. The SiO_2 values and the sums of oxides are low for all of the study glasses and the Batch 1 standard. In general, there were only minor difficulties in meeting the targeted concentrations for the KT07 glasses, none of which will impact the outcome of the study.

Table A-4 in Appendix A provides a summary of the average measured compositions as well as the targeted compositions and the associated differences and relative differences. Note that the targeted sum of oxides for the Batch 1 standard does not sum to 100% due to an incomplete coverage of the oxides in this glass. All of the sums of oxides for the KT07 glasses fall within the PCCS acceptable interval of 95 to 105 wt%. Entries in Table A-4 show the relative differences between the measured values and the targeted values. These differences are shaded when they are greater than or equal to 5%. Overall, these comparisons between the measured and targeted compositions again suggest only minor difficulties in meeting the targeted compositions for the KT07 glasses. A MAR assessment using the measured compositions of the KT07 glasses showed that each composition was PCCS acceptable except for the current TiO_2 concentration constraint.

3.3 Durability

The measurements generated by the PCTs are presented and reviewed in this section. The analytical sequence of the measurements is explored, the measurements of the standards are investigated and used to assess the overall accuracy of the ICP-AES measurement process, the measurements for each glass are reviewed, plots are provided that explore the effects of heat treatment on the PCTs for these glasses, the PCTs are normalized using the compositions (targeted and measured) discussed in Section 3.2, and the normalized PCTs are compared to durability predictions for these compositions generated from the current DWPF models.[3]

One of the quality control checkpoints for the PCT procedure is solution mass loss over the course of the seven day test. The third replicate vessel for glass KT07-06 was found to have a solution mass loss issue at the completion of the PCT. Data from this vessel were excluded from further analyses; therefore the results of the PCT for glass KT07-06 are based on only two replicate vessels. There were no issues with solution mass loss for the other vessels in the PCT. The ratio of leachant volume to the mass of ground glass was also confirmed to be correct for each vessel. All of the measurements of the ARM glass fell within the control ranges.[13]

Table B-1 in Appendix B provides the elemental leachate concentration measurements determined by the PSAL for the solution samples generated by the PCTs for the KT07 glasses. The values were adjusted for the dilution factors: the values for the study glasses, the blanks, and the ARM glass in Table B-1 were multiplied by 1.6667 to determine the values in parts per million and the values for EA were multiplied by 16.6667. Table B-1 also provides the resulting ppm measurements.

Exhibit B-1 in Appendix B provides plots of the leachate (ppm) concentrations in analytical sequence as generated by the PSAL for all of the data from the KT07 PCTs. Different colors and symbols are used for each of the study glasses and standards. No issues are seen in these plots.

Exhibit B-2 in Appendix B provides analyses of the PSAL measurements of the samples of the multi-element standard solution by analytical set and ICP-AES calibration block for the KT07-series. An ANOVA investigating for statistically significant differences among the block averages for these samples for each element of interest is included in the exhibit. A statistically significant (at a 5% level) difference among the averages of these measurements was indicated for B and Li. However, no attempt was made to bias correct for these effects since averaging the measured concentrations for each set of triplicates in the PCT helps to minimize the impact of any potential ICP-AES bias effects. Table 3-1 summarizes the average measurements and the reference values for the four elements of interest in the multi-element standard solution. The results indicate consistent and accurate measurements from the PSAL processes used to conduct these analyses.

Table 3-1. Results form Samples of the Multi-Element Solution Standard.

Block	Number of Measurements	Mean (B (ppm))	Mean (Li (ppm))	Mean (Na (ppm))	Mean (Si (ppm))
1	3	21.3	10.4	85.1	50.6
2	3	19.8	10.1	84.9	49.4
3	3	20.1	10.0	84.1	49.4
		B (ppm)	**Li (ppm)**	**Na (ppm)**	**Si (ppm)**
Grand Average		20.4	10.2	84.7	49.8
Reference Value		20	10	81	50
Percent Difference		2.0	1.7	4.6	-0.4

Exhibit B-3 in Appendix B provides plots of the leachate concentrations for each type of submitted sample: the study glasses by heat treatment and the standards (EA, ARM, the multi-element solution standard, and blanks). The common logarithm plots allow for the assessment of the repeatability of the measurements, which suggest only minor scatter in the triplicate values for some analytes for some of the glasses. Note that the measurements for one of the replicates of glass KT07-06 (Lab ID h57), which was excluded from the analysis due to solution mass loss as discussed earlier, is denoted by a (■) symbol in this and these following plots in Appendix B.

The PCT leachate concentrations were normalized using the target and measured cation compositions of the glasses to obtain g/L leachate concentrations following the procedure.[11] Exhibit B-4 in Appendix B provides scatter plots for these results and offers an opportunity to investigate the consistency in the leaching across the elements for the KT07 glasses. All combinations of the normalizations of the PCTs (i.e., those generated using the targeted and measured compositional views) and both heat treatments are represented in the series of scatter plots. Consistency in the leaching across the elements is typically demonstrated by a high degree of linear correlation among the values for pairs of these elements. The smallest correlation in this plot is that for B and Si with a value of ~98%, indicating highly linear correlations for all of the element pairs.

Table B-2 in Appendix B summarizes the normalized PCTs for the KT07-series glasses. The PCTs are listed by heat treatment and compositional view for each glass. The KT07 glasses all had NL [B] values that were well below the 16.695 g/L value of the benchmark EA glass. The highest NL [B] value was for glass KT07-09, with values of 0.618 g/L and 0.565 g/L for the quenched and CCC versions of this glass, respectively, normalized to the measured composition.

Exhibit B-5 in Appendix B provides plots showing comparisons of the normalized PCT responses for the two heat treatments for each glass. A review of these plots shows only minor differences in normalized release for the KT07 glasses as a function of heat treatment.

The predictability of the KT07 PCT responses was evaluated using the DWPF durability models. The predicted PCT values, determined using the targeted and measured compositions of the KT07 glasses, were compared with the normalized PCT responses. Exhibit B-6 in Appendix B provides plots of the DWPF models for B, Li, Na, and Si that relate the logarithm of the normalized PCT value (for each element of interest) to a linear function of a free energy of hydration term (ΔG_p, in kcal/100 g glass) derived from all of the compositional views and heat treatments of the KT07 glasses. Prediction limits at a 95% confidence for an individual PCT result are also plotted along with the linear fit. The EA and ARM results are indicated on these plots as well. The plots show that all of the measured PCT responses for the KT07-series glasses are well predicted by the current DWPF PCCS durability models.

3.4 Viscosity

Viscosity data were collected for all of the glasses in the KT07-series. The measured viscosity at 1150 °C was determined by fitting the data for each glass to the Fulcher equation.[19,20] Complete data from the fitting of Fulcher equations are given in Exhibit C-1 in Appendix C. The results of the Fulcher fits of the measured data were used to calculate a viscosity value for each glass at 1150 °C. These values are given in Table C-1 in Appendix C. The measured values are displayed graphically versus the model predictions in Exhibit C-2 in Appendix C. The table and plot show that all of the measured viscosity values for the KT07-series glasses at 1150 °C are predictable by the current DWPF PCCS viscosity model.

4.0 Summary

This report discusses the fabrication and characterization of the KT07-series glass compositions. These glasses were selected to evaluate any potential impacts of noble metals on their properties and performance. The glasses characterized thus far for the study of potential impacts of the SCIX streams on DWPF glass have not included noble metals since they are not typically tracked in sludge batch composition projections. However, noble metals can act as nucleation sites in glass melts, leading to enhanced crystallization. This crystallization can potentially influence the properties and performance of the glass, such as chemical durability, viscosity, and liquidus temperature. A set of glass compositions developed earlier in the SCIX study, the KT04-series, was used as the basis for the current work. For the KT07-series glasses, the noble metals Ag, Pd, Rh, and Ru were added. The concentrations of these metals were obtained from recent measurements of Sludge Batch 6, which was considered to contain a high concentration of noble metals.[8]

After fabrication, the glasses were characterized to determine their crystalline content, chemical composition, durability, and viscosity. Liquidus temperature measurements are also underway but were not complete at the time of this report. The liquidus temperature results for the KT07-series glasses, along with several of the earlier glasses in the SCIX study, will be documented separately. All of the KT07-series glasses, both quenched and slowly cooled, were found to be amorphous by XRD. Chemical composition measurements showed that all of the glasses met their targeted compositions. The PCT results showed that all of the glasses had chemical durabilities that were far better than that of the EA benchmark glass. The measured PCT responses were well predicted by the current DWPF PCCS durability models. The measured viscosity values for each KT07-series glass were acceptable for DWPF processing and were well predicted by the current PCCS model.

Overall, the results show that the inclusion of relatively high concentrations of noble metals (in terms of expected values for a DWPF sludge batch) had no significant impact on the properties and performance of these glass compositions. The lack of crystallization in the KT07-series glasses, their measured PCT responses, and their measured viscosity values are very consistent with the KT04-series glasses, which did not contain noble metals. As previously mentioned, liquidus temperature measurements are still underway and there may be an impact of the noble metals on those measurements. However, no adverse effects were noted in terms of crystallization after slow cooling.

5.0 Recommendations and Path Forward

Liquidus temperature measurements for the KT07 and other KT-series glass compositions will continue, and the results will be presented in a separate technical report. The potential impacts of ThO_2 and U_3O_8 (as well as noble metals) on the properties and performance of glasses with increased TiO_2 concentrations will be investigated through the KT08-series glasses. The KT08-series glasses have been fabricated and characterization is now underway. A series of glasses designated KT09 will be fabricated and characterized to identify the potential influence of increased Al_2O_3 and K_2O concentrations on hindering the formation of titanium-containing crystalline phases. An additional series of glasses, KT10, will be fabricated to investigate the impacts of an increase of MST and CST over the current projected maximum concentrations using non-radioactive glasses.

At the completion of these studies, all of the data generated will be reviewed with regard to the applicability of the DWPF PCCS models and recommendations will be made as to whether the validation ranges of the current models can be extended, or whether some or all of the models need to be refit to allow for the incorporation of the SCIX streams. As changes are made to the projected sludge compositions and the volume of the SCIX material, additional evaluations should be performed.

6.0 References

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Appendix A. Data Supporting the Chemical Composition Measurements of the KT07-Series Glasses

Table A-1. PSAL Chemical Composition Measurements of the KT07-Series of Glasses Using LM Preparation Method. (part 1)

Glass ID	Block	Sub-Blk	Seq	Lab ID	Ag (wt%)	Al (wt%)	Ba (wt%)	Ca (wt%)	Ce (wt%)	Cr (wt%)	Cu (wt%)	Fe (wt%)	K (wt%)	La (wt%)	Mg (wt%)	Mn (wt%)
Batch 1	1	1	1	BCHLM111	<0.100	2.51	0.126	0.962	<0.010	0.073	0.314	8.72	2.61	<0.010	0.830	1.33
KT07-09	1	1	2	G10LM21	<0.100	2.94	0.058	0.688	0.155	0.071	0.028	8.33	0.073	0.050	0.061	0.427
KT07-07	1	1	3	G04LM11	<0.100	3.01	0.062	0.639	0.066	0.105	0.046	6.44	0.059	0.022	0.065	0.557
KT07-08	1	1	4	G02LM11	<0.100	2.67	0.064	0.677	0.068	0.073	0.034	6.32	0.057	0.025	0.068	0.740
KT07-03	1	1	5	G03LM11	<0.100	2.44	0.057	0.712	0.210	0.091	0.032	7.85	0.025	0.050	0.090	1.41
KT07-06	1	1	6	G06LM21	<0.100	3.87	0.054	0.699	0.093	0.093	0.033	6.30	0.096	0.022	0.057	0.916
Batch 1	1	1	7	BCHLM112	<0.100	2.51	0.126	0.942	<0.010	0.072	0.313	8.85	2.56	<0.010	0.836	1.34
KT07-07	1	1	8	G04LM21	<0.100	3.04	0.060	0.659	0.064	0.103	0.035	6.49	0.064	0.022	0.064	0.562
KT07-06	1	1	9	G06LM11	<0.100	3.92	0.054	0.694	0.092	0.094	0.038	6.33	0.090	0.021	0.057	0.917
KT07-08	1	1	10	G02LM21	<0.100	2.74	0.062	0.587	0.066	0.073	0.032	6.38	0.061	0.024	0.066	0.748
KT07-09	1	1	11	G10LM11	<0.100	2.94	0.062	0.681	0.165	0.069	0.030	8.37	0.058	0.053	0.065	0.430
KT07-03	1	1	12	G03LM21	<0.100	2.42	0.057	0.711	0.210	0.071	0.040	7.71	0.023	0.051	0.092	1.38
Batch 1	1	1	13	BCHLM113	<0.100	2.50	0.125	0.931	<0.010	0.072	0.305	8.59	2.53	<0.010	0.824	1.31
Batch 1	1	2	1	BCHLM121	<0.100	2.52	0.127	0.983	<0.010	0.074	0.320	8.80	2.65	<0.010	0.823	1.33
KT07-06	1	2	2	G06LM22	<0.100	3.93	0.056	0.738	0.094	0.096	0.036	6.36	0.105	0.023	0.060	0.924
KT07-06	1	2	3	G06LM12	<0.100	3.92	0.056	0.736	0.097	0.096	0.042	6.46	0.101	0.024	0.060	0.932
KT07-03	1	2	4	G03LM12	<0.100	2.36	0.058	0.736	0.216	0.092	0.035	7.92	0.028	0.052	0.093	1.41
KT07-07	1	2	5	G04LM12	<0.100	3.02	0.063	0.647	0.068	0.108	0.048	6.57	0.061	0.023	0.067	0.564
KT07-08	1	2	6	G02LM12	<0.100	2.66	0.066	0.679	0.070	0.076	0.036	6.34	0.058	0.026	0.071	0.739
Batch 1	1	2	7	BCHLM122	<0.100	2.48	0.127	0.972	<0.010	0.074	0.316	8.84	2.64	<0.010	0.828	1.33
KT07-08	1	2	8	G02LM22	<0.100	2.71	0.064	0.624	0.067	0.075	0.035	6.49	0.068	0.025	0.069	0.755
KT07-09	1	2	9	G10LM22	<0.100	2.92	0.062	0.753	0.167	0.077	0.035	8.52	0.078	0.054	0.065	0.434
KT07-03	1	2	10	G03LM22	<0.100	2.38	0.059	0.765	0.221	0.074	0.045	7.87	0.028	0.053	0.096	1.40
KT07-09	1	2	11	G10LM12	<0.100	2.87	0.065	0.743	0.177	0.074	0.036	8.50	0.067	0.056	0.069	0.431
KT07-07	1	2	12	G04LM22	<0.100	2.93	0.062	0.718	0.067	0.108	0.040	6.57	0.073	0.024	0.067	0.561
Batch 1	1	2	13	BCHLM123	<0.100	2.44	0.127	1.022	<0.010	0.075	0.330	8.82	2.76	<0.010	0.828	1.33
Batch 1	2	1	1	BCHLM211	<0.100	2.50	0.124	0.989	<0.010	0.073	0.316	8.93	2.62	<0.010	0.801	1.36
KT07-05	2	1	2	G01LM21	<0.100	3.63	0.055	0.819	0.124	0.094	0.040	6.74	0.063	0.051	0.092	0.801
KT07-10	2	1	3	G05LM21	<0.100	3.02	0.063	0.797	0.201	0.074	0.038	9.42	0.038	0.055	0.065	0.302
KT07-10	2	1	4	G05LM11	<0.100	3.01	0.065	0.704	0.209	0.077	0.037	9.38	0.030	0.058	0.068	0.303
KT07-02	2	1	5	G07LM21	<0.100	2.73	0.054	0.716	0.233	0.066	0.035	7.81	0.030	0.048	0.088	1.31
KT07-01	2	1	6	G08LM11	<0.100	2.93	0.055	0.742	0.238	0.066	0.045	8.09	0.028	0.075	0.088	1.47
Batch 1	2	1	7	BCHLM212	<0.100	2.43	0.125	0.994	<0.010	0.073	0.322	8.83	2.66	<0.010	0.809	1.34
KT07-01	2	1	8	G08LM21	<0.100	3.08	0.057	0.714	0.250	0.067	0.044	8.30	0.026	0.078	0.091	1.52
KT07-05	2	1	9	G01LM11	<0.100	3.74	0.057	0.753	0.129	0.095	0.041	6.75	0.057	0.052	0.095	0.805
KT07-04	2	1	10	G09LM11	<0.100	2.82	0.057	0.651	0.191	0.065	0.037	8.45	0.023	0.051	0.091	0.845
KT07-02	2	1	11	G07LM11	<0.100	2.96	0.055	0.696	0.245	0.067	0.039	7.93	0.028	0.049	0.090	1.35
KT07-04	2	1	12	G09LM21	<0.100	2.70	0.054	0.668	0.183	0.062	0.037	8.36	0.028	0.048	0.087	0.834
Batch 1	2	1	13	BCHLM213	<0.100	2.61	0.124	0.990	<0.010	0.073	0.318	9.02	2.63	<0.010	0.805	1.37
Batch 1	2	2	1	BCHLM221	<0.100	2.50	0.126	0.957	<0.010	0.075	0.310	8.70	2.51	<0.010	0.839	1.33
KT07-01	2	2	2	G08LM22	<0.100	3.13	0.057	0.697	0.248	0.067	0.043	8.18	0.025	0.077	0.092	1.50
KT07-05	2	2	3	G01LM22	<0.100	3.66	0.055	0.820	0.124	0.095	0.039	6.59	0.061	0.050	0.092	0.789
KT07-01	2	2	4	G08LM12	<0.100	3.08	0.054	0.733	0.235	0.063	0.044	8.12	0.028	0.073	0.086	1.49
KT07-10	2	2	5	G05LM12	<0.100	2.99	0.064	0.715	0.209	0.076	0.037	9.17	0.031	0.056	0.066	0.304
KT07-02	2	2	6	G07LM22	<0.100	2.78	0.053	0.719	0.233	0.064	0.035	7.78	0.031	0.046	0.085	1.31
Batch 1	2	2	7	BCHLM222	<0.100	2.58	0.125	0.990	<0.010	0.073	0.322	8.92	2.62	<0.010	0.815	1.36
KT07-04	2	2	8	G09LM12	<0.100	2.74	0.056	0.638	0.189	0.065	0.037	8.10	0.024	0.050	0.091	0.819
KT07-05	2	2	9	G01LM12	<0.100	3.84	0.057	0.746	0.127	0.096	0.041	6.66	0.055	0.051	0.096	0.801
KT07-04	2	2	10	G09LM22	<0.100	2.73	0.055	0.655	0.182	0.064	0.037	8.22	0.026	0.048	0.090	0.828
KT07-10	2	2	11	G05LM22	<0.100	3.17	0.064	0.783	0.201	0.075	0.038	9.39	0.036	0.055	0.066	0.309
KT07-02	2	2	12	G07LM12	<0.100	2.87	0.056	0.671	0.242	0.068	0.039	7.83	0.025	0.048	0.092	1.33
Batch 1	2	2	13	BCHLM223	<0.100	2.61	0.127	0.951	<0.010	0.074	0.312	8.05	2.52	<0.010	0.833	1.29

Table A-2. PSAL Chemical Composition Measurements of the KT07-Series of Glasses Using LM Preparation Method. (part 2)

Glass ID	Block	Sub-Blk	Seq	Lab ID	Na (wt%)	Nb (wt%)	Ni (wt%)	Pb (wt%)	Pd (wt%)	Rh (wt%)	Ru (wt%)	S (wt%)	Si (wt%)	Ti (wt%)	Zn (wt%)	Zr (wt%)
Batch 1	1	1	1	BCHLM111	6.93	<0.010	0.548	<0.010	<0.010	<0.010	<0.010	<0.100	22.9	0.400	<0.010	0.064
KT07-09	1	1	2	G10LM21	10.3	0.504	0.366	0.100	<0.010	<0.010	<0.010	0.116	21.8	2.83	0.028	0.523
KT07-07	1	1	3	G04LM11	10.5	0.828	0.492	0.061	<0.010	<0.010	<0.010	0.136	22.6	2.85	0.064	0.787
KT07-08	1	1	4	G02LM11	11.1	0.903	0.470	0.063	<0.010	<0.010	<0.010	0.126	22.4	2.90	0.035	0.823
KT07-03	1	1	5	G03LM11	10.2	0.734	0.241	0.113	<0.010	<0.010	<0.010	0.114	22.2	2.52	0.026	0.722
KT07-06	1	1	6	G06LM21	9.96	0.667	0.116	0.056	<0.010	<0.010	<0.010	0.122	22.6	2.53	0.056	0.674
Batch 1	1	1	7	BCHLM112	6.89	<0.010	0.546	<0.010	<0.010	<0.010	<0.010	<0.100	23.0	0.401	<0.010	0.066
KT07-07	1	1	8	G04LM21	10.7	0.743	0.477	0.068	<0.010	<0.010	<0.010	0.124	23.0	2.85	0.066	0.725
KT07-06	1	1	9	G06LM11	10.1	0.649	0.116	0.057	<0.010	<0.010	<0.010	0.118	22.6	2.54	0.056	0.666
KT07-08	1	1	10	G02LM21	11.4	0.872	0.452	0.060	<0.010	<0.010	<0.010	0.121	22.8	2.95	0.030	0.794
KT07-09	1	1	11	G10LM11	10.3	0.478	0.389	0.121	<0.010	<0.010	<0.010	0.113	21.9	2.83	0.031	0.547
KT07-03	1	1	12	G03LM21	10.5	0.704	0.243	0.112	<0.010	<0.010	<0.010	0.126	22.6	2.49	0.027	0.707
Batch 1	1	1	13	BCHLM113	6.95	<0.010	0.544	<0.010	<0.010	<0.010	<0.010	<0.100	22.7	0.394	<0.010	0.066
Batch 1	1	2	1	BCHLM121	6.81	<0.010	0.549	<0.010	<0.010	<0.010	<0.010	<0.100	23.1	0.405	<0.010	0.064
KT07-06	1	2	2	G06LM22	9.98	0.673	0.118	0.057	<0.010	<0.010	<0.010	0.125	23.2	2.58	0.058	0.682
KT07-06	1	2	3	G06LM12	9.97	0.658	0.118	0.057	<0.010	<0.010	<0.010	0.130	23.1	2.59	0.058	0.678
KT07-03	1	2	4	G03LM12	10.3	0.738	0.242	0.110	<0.010	<0.010	<0.010	0.126	22.8	2.55	0.028	0.727
KT07-07	1	2	5	G04LM12	10.4	0.821	0.491	0.062	<0.010	<0.010	<0.010	0.129	23.1	2.90	0.066	0.782
KT07-08	1	2	6	G02LM12	10.8	0.905	0.475	0.065	<0.010	<0.010	<0.010	0.136	22.6	2.91	0.037	0.836
Batch 1	1	2	7	BCHLM122	6.66	<0.010	0.551	<0.010	<0.010	<0.010	<0.010	<0.100	23.0	0.404	<0.010	0.068
KT07-08	1	2	8	G02LM22	11.0	0.887	0.459	0.063	<0.010	<0.010	<0.010	0.128	22.9	2.96	0.032	0.822
KT07-09	1	2	9	G10LM22	10.1	0.526	0.376	0.114	<0.010	<0.010	<0.010	0.126	22.0	2.87	0.032	0.556
KT07-03	1	2	10	G03LM22	10.1	0.719	0.248	0.116	<0.010	<0.010	<0.010	0.137	22.7	2.51	0.030	0.723
KT07-09	1	2	11	G10LM12	9.86	0.493	0.399	0.124	<0.010	<0.010	<0.010	0.130	22.0	2.85	0.033	0.570
KT07-07	1	2	12	G04LM22	10.0	0.765	0.486	0.069	<0.010	<0.010	<0.010	0.130	22.8	2.85	0.069	0.749
Batch 1	1	2	13	BCHLM123	6.48	<0.010	0.552	<0.010	<0.010	<0.010	<0.010	<0.100	22.7	0.401	<0.010	0.069
Batch 1	2	1	1	BCHLM211	6.59	<0.010	0.531	<0.010	<0.010	<0.010	<0.010	<0.100	23.0	0.417	<0.010	0.065
KT07-05	2	1	2	G01LM21	9.69	0.712	0.086	0.054	<0.010	<0.010	<0.010	0.122	23.0	2.58	0.043	0.717
KT07-10	2	1	3	G05LM21	9.80	0.510	0.346	0.123	<0.010	<0.010	<0.010	0.120	22.2	2.67	0.033	0.562
KT07-10	2	1	4	G05LM11	9.76	0.505	0.366	0.127	<0.010	<0.010	<0.010	0.120	21.5	2.67	0.031	0.534
KT07-02	2	1	5	G07LM21	9.99	0.687	0.137	0.105	<0.010	<0.010	<0.010	0.127	22.1	2.52	0.029	0.689
KT07-01	2	1	6	G08LM11	8.91	0.620	0.254	0.133	<0.010	<0.010	<0.010	0.129	21.0	2.44	<0.010	0.631
Batch 1	2	1	7	BCHLM212	6.37	<0.010	0.535	<0.010	<0.010	<0.010	<0.010	<0.100	22.5	0.408	<0.010	0.068
KT07-01	2	1	8	G08LM21	9.66	0.641	0.262	0.140	<0.010	<0.010	<0.010	0.124	21.5	2.54	<0.010	0.620
KT07-05	2	1	9	G01LM11	9.93	0.738	0.091	0.056	<0.010	<0.010	<0.010	0.119	23.5	2.62	0.051	0.756
KT07-04	2	1	10	G09LM11	10.2	0.653	0.119	0.085	<0.010	<0.010	<0.010	0.127	22.8	2.66	0.057	0.657
KT07-02	2	1	11	G07LM11	10.7	0.727	0.143	0.109	<0.010	<0.010	<0.010	0.114	23.4	2.65	0.028	0.709
KT07-04	2	1	12	G09LM21	9.81	0.642	0.112	0.081	<0.010	<0.010	<0.010	0.120	22.7	2.62	0.057	0.623
Batch 1	2	1	13	BCHLM213	6.92	<0.010	0.531	<0.010	<0.010	<0.010	<0.010	<0.100	23.7	0.424	<0.010	0.068
Batch 1	2	2	1	BCHLM221	6.88	<0.010	0.541	<0.010	<0.010	<0.010	<0.010	<0.100	22.9	0.413	<0.010	0.064
KT07-01	2	2	2	G08LM22	9.95	0.635	0.267	0.143	<0.010	<0.010	<0.010	0.129	21.7	2.52	<0.010	0.606
KT07-05	2	2	3	G01LM22	10.1	0.716	0.086	0.052	<0.010	<0.010	<0.010	0.130	23.1	2.55	0.042	0.725
KT07-01	2	2	4	G08LM12	10.1	0.616	0.251	0.130	<0.010	<0.010	<0.010	0.115	21.8	2.50	<0.010	0.611
KT07-10	2	2	5	G05LM12	9.98	0.507	0.365	0.124	<0.010	<0.010	<0.010	0.119	21.4	2.63	0.029	0.532
KT07-02	2	2	6	G07LM22	10.5	0.685	0.135	0.100	<0.010	<0.010	<0.010	0.123	22.3	2.53	0.027	0.689
Batch 1	2	2	7	BCHLM222	7.15	<0.010	0.538	<0.010	<0.010	<0.010	<0.010	<0.100	23.7	0.421	<0.010	0.067
KT07-04	2	2	8	G09LM12	10.5	0.656	0.119	0.085	<0.010	<0.010	<0.010	0.129	22.2	2.58	0.056	0.653
KT07-05	2	2	9	G01LM12	10.7	0.743	0.091	0.056	<0.010	<0.010	<0.010	0.127	23.8	2.61	0.050	0.747
KT07-04	2	2	10	G09LM22	10.4	0.657	0.114	0.084	<0.010	<0.010	<0.010	0.135	22.8	2.59	0.058	0.635
KT07-10	2	2	11	G05LM22	10.6	0.520	0.356	0.125	<0.010	<0.010	<0.010	0.119	22.9	2.71	0.033	0.570
KT07-02	2	2	12	G07LM12	10.8	0.729	0.146	0.111	<0.010	<0.010	<0.010	0.136	22.9	2.58	0.027	0.729
Batch 1	2	2	13	BCHLM223	7.16	<0.010	0.549	<0.010	<0.010	<0.010	<0.010	<0.100	23.0	0.408	<0.010	0.067

Table A-3. PSAL Chemical Composition Measurements of the KT07-Series of Glasses Using PF Preparation Method.

Glass ID	Block	Sub-Blk	Sequence	Lab ID	B (wt%)	Li (wt%)
Batch 1	1	1	1	BCHPF111	2.59	2.05
KT07-10	1	1	2	G05PF21	2.01	1.62
KT07-01	1	1	3	G08PF21	1.97	1.62
KT07-02	1	1	4	G07PF21	1.94	1.61
KT07-02	1	1	5	G07PF11	1.97	1.64
KT07-04	1	1	6	G09PF21	1.98	1.65
Batch 1	1	1	7	BCHPF112	2.51	2.11
KT07-10	1	1	8	G05PF11	2.09	1.65
KT07-01	1	1	9	G08PF11	2.04	1.65
KT07-03	1	1	10	G03PF11	2.00	1.64
KT07-03	1	1	11	G03PF21	1.98	1.61
KT07-04	1	1	12	G09PF11	1.98	1.63
Batch 1	1	1	13	BCHPF113	2.48	2.08
Batch 1	1	2	1	BCHPF121	2.47	2.03
KT07-03	1	2	2	G03PF12	1.69	1.58
KT07-10	1	2	3	G05PF12	1.76	1.60
KT07-04	1	2	4	G09PF22	1.75	1.61
KT07-04	1	2	5	G09PF12	1.72	1.60
KT07-01	1	2	6	G08PF22	1.71	1.59
Batch 1	1	2	7	BCHPF122	2.26	2.03
KT07-02	1	2	8	G07PF22	1.84	1.55
KT07-03	1	2	9	G03PF22	1.78	1.58
KT07-02	1	2	10	G07PF12	1.86	1.64
KT07-10	1	2	11	G05PF22	1.74	1.60
KT07-01	1	2	12	G08PF12	1.70	1.59
Batch 1	1	2	13	BCHPF123	2.31	1.99
Batch 1	2	1	1	BCHPF211	2.36	1.93
KT07-09	2	1	2	G10PF21	1.85	1.53
KT07-05	2	1	3	G01PF21	1.90	1.61
KT07-06	2	1	4	G06PF11	1.89	1.56
KT07-07	2	1	5	G04PF21	1.88	1.58
KT07-07	2	1	6	G04PF11	1.77	1.53
Batch 1	2	1	7	BCHPF212	2.32	1.96
KT07-08	2	1	8	G02PF11	1.91	1.56
KT07-05	2	1	9	G01PF11	1.91	1.59
KT07-08	2	1	10	G02PF21	1.87	1.62
KT07-09	2	1	11	G10PF11	1.93	1.61
KT07-06	2	1	12	G06PF21	1.72	1.48
Batch 1	2	1	13	BCHPF213	2.38	2.06
Batch 1	2	2	1	BCHPF221	2.49	2.05
KT07-08	2	2	2	G02PF12	1.89	1.61
KT07-05	2	2	3	G01PF12	1.86	1.60
KT07-09	2	2	4	G10PF22	1.82	1.59
KT07-07	2	2	5	G04PF12	1.78	1.59
KT07-06	2	2	6	G06PF12	1.85	1.61
Batch 1	2	2	7	BCHPF222	2.41	2.07
KT07-05	2	2	8	G01PF22	1.96	1.65
KT07-08	2	2	9	G02PF22	1.87	1.60
KT07-09	2	2	10	G10PF12	1.83	1.61
KT07-07	2	2	11	G04PF22	1.86	1.62
KT07-06	2	2	12	G06PF22	1.67	1.47
Batch 1	2	2	13	BCHPF223	2.37	2.09

Table A-4. Comparison of Measured versus Targeted Composition for the KT07-Series Glasses.

Glass ID	Oxide	Measured (wt %)	Targeted (wt %)	Difference (wt%) of Measured vs Targeted	% Difference of Measured vs Targeted
Batch 1	Al_2O_3	4.7537	4.8770	-0.1233	-2.5%
Batch 1	B_2O_3	7.7680	7.7770	-0.0090	-0.1%
Batch 1	BaO	0.1404	0.1510	-0.0106	-7.0%
Batch 1	CaO	1.3622	1.2200	0.1422	11.7%
Batch 1	Ce_2O_3	0.0059	0.0000	0.0059	
Batch 1	Cr_2O_3	0.1073	0.1070	0.0003	0.3%
Batch 1	CuO	0.3962	0.3990	-0.0028	-0.7%
Batch 1	Fe_2O_3	12.5182	12.8390	-0.3208	-2.5%
Batch 1	K_2O	3.1430	3.3270	-0.1840	-5.5%
Batch 1	La_2O_3	0.0059	0.0000	0.0059	
Batch 1	Li_2O	4.3865	4.4290	-0.0425	-1.0%
Batch 1	MgO	1.3641	1.4190	-0.0549	-3.9%
Batch 1	MnO	1.7238	1.7260	-0.0022	-0.1%
Batch 1	Na_2O	9.1877	9.0030	0.1847	2.1%
Batch 1	Nb_2O_5	0.0072	0.0000	0.0072	
Batch 1	NiO	0.6909	0.7510	-0.0601	-8.0%
Batch 1	PbO	0.0054	0.0000	0.0054	
Batch 1	SiO_2	49.2396	50.2200	-0.9804	-2.0%
Batch 1	SO_4	0.1498	0.0000	0.1498	
Batch 1	TiO_2	0.6805	0.6770	0.0035	0.5%
Batch 1	ZnO	0.0062	0.0000	0.0062	
Batch 1	ZrO_2	0.0896	0.0980	-0.0084	-8.6%
Batch 1	Sum	97.7320	99.0200	-1.2880	-1.3%
KT07-01	Al_2O_3	5.7724	5.7370	0.0354	0.6%
KT07-01	B_2O_3	5.9729	5.9990	-0.0261	-0.4%
KT07-01	BaO	0.0622	0.0670	-0.0048	-7.1%
KT07-01	CaO	1.0095	0.9270	0.0825	8.9%
KT07-01	Ce_2O_3	0.2843	0.2820	0.0023	0.8%
KT07-01	Cr_2O_3	0.0961	0.0880	0.0081	9.2%
KT07-01	CuO	0.0551	0.0380	0.0171	44.9%
KT07-01	Fe_2O_3	11.6842	11.9710	-0.2868	-2.4%
KT07-01	K_2O	0.0322	0.0360	-0.0038	-10.5%
KT07-01	La_2O_3	0.0888	0.1060	-0.0172	-16.2%
KT07-01	Li_2O	3.4716	3.5990	-0.1274	-3.5%
KT07-01	MgO	0.1480	0.1500	-0.0020	-1.3%
KT07-01	MnO	1.9303	1.9060	0.0243	1.3%
KT07-01	Na_2O	13.0149	13.1010	-0.0861	-0.7%
KT07-01	Nb_2O_5	0.8984	1.0240	-0.1256	-12.3%
KT07-01	NiO	0.3289	0.3450	-0.0161	-4.7%
KT07-01	PbO	0.1470	0.1620	-0.0150	-9.2%
KT07-01	SiO_2	45.9950	48.7750	-2.7801	-5.7%
KT07-01	SO_4	0.3722	0.4000	-0.0278	-6.9%
KT07-01	TiO_2	4.1700	4.2960	-0.1260	-2.9%
KT07-01	ZnO	0.0062	0.0000	0.0062	
KT07-01	ZrO_2	0.8334	0.9130	-0.0796	-8.7%
KT07-01	Sum	96.3739	99.9220	-3.5481	-3.6%
KT07-02	Al_2O_3	5.3567	5.1310	0.2257	4.4%
KT07-02	B_2O_3	6.1259	5.9990	0.1269	2.1%
KT07-02	BaO	0.0608	0.0680	-0.0072	-10.5%
KT07-02	CaO	0.9801	0.9350	0.0451	4.8%
KT07-02	Ce_2O_3	0.2791	0.2850	-0.0059	-2.1%
KT07-02	Cr_2O_3	0.0968	0.0890	0.0078	8.8%
KT07-02	CuO	0.0463	0.0380	0.0083	21.9%
KT07-02	Fe_2O_3	11.2053	11.4230	-0.2177	-1.9%
KT07-02	K_2O	0.0343	0.0370	-0.0027	-7.2%
KT07-02	La_2O_3	0.0560	0.0710	-0.0150	-21.1%
KT07-02	Li_2O	3.4662	3.5990	-0.1328	-3.7%
KT07-02	MgO	0.1472	0.1510	-0.0038	-2.5%
KT07-02	MnO	1.7108	1.6870	0.0238	1.4%

Table A-4. Comparison of Measured versus Targeted Composition for the KT07-Series Glasses. (continued)

Glass ID	Oxide	Measured (wt %)	Targeted (wt %)	Difference (wt%) of Measured vs Targeted	% Difference of Measured vs Targeted
KT07-02	Na_2O	14.1506	13.9500	0.2006	1.4%
KT07-02	Nb_2O_5	1.0114	1.0850	-0.0736	-6.8%
KT07-02	NiO	0.1785	0.1930	-0.0145	-7.5%
KT07-02	PbO	0.1145	0.1310	-0.0165	-12.6%
KT07-02	SiO_2	48.5086	49.2850	-0.7764	-1.6%
KT07-02	SO_4	0.3745	0.4000	-0.0255	-6.4%
KT07-02	TiO_2	4.2868	4.3290	-0.0422	-1.0%
KT07-02	ZnO	0.0345	0.0380	-0.0035	-9.1%
KT07-02	ZrO_2	0.9510	0.9990	-0.0480	-4.8%
KT07-02	Sum	99.1759	99.9230	-0.7471	-0.7%
KT07-03	Al_2O_3	4.5348	4.4350	0.0998	2.3%
KT07-03	B_2O_3	5.9971	5.9990	-0.0019	0.0%
KT07-03	BaO	0.0645	0.0690	-0.0045	-6.6%
KT07-03	CaO	1.0228	0.9470	0.0758	8.0%
KT07-03	Ce_2O_3	0.2510	0.2520	-0.0010	-0.4%
KT07-03	Cr_2O_3	0.1199	0.0900	0.0299	33.2%
KT07-03	CuO	0.0476	0.0390	0.0086	22.0%
KT07-03	Fe_2O_3	11.2053	11.3910	-0.1857	-1.6%
KT07-03	K_2O	0.0313	0.0370	-0.0057	-15.4%
KT07-03	La_2O_3	0.0604	0.0720	-0.0116	-16.1%
KT07-03	Li_2O	3.4500	3.5990	-0.1490	-4.1%
KT07-03	MgO	0.1538	0.1530	0.0008	0.5%
KT07-03	MnO	1.8077	1.7880	0.0197	1.1%
KT07-03	Na_2O	13.8507	14.2300	-0.3793	-2.7%
KT07-03	Nb_2O_5	1.0353	1.0870	-0.0517	-4.8%
KT07-03	NiO	0.3099	0.3130	-0.0031	-1.0%
KT07-03	PbO	0.1215	0.1330	-0.0115	-8.7%
KT07-03	SiO_2	48.2947	49.4970	-1.2023	-2.4%
KT07-03	SO_4	0.3767	0.4000	-0.0233	-5.8%
KT07-03	TiO_2	4.1992	4.3500	-0.1508	-3.5%
KT07-03	ZnO	0.0345	0.0380	-0.0035	-9.1%
KT07-03	ZrO_2	0.9722	1.0040	-0.0318	-3.2%
KT07-03	Sum	97.9408	99.9230	-1.9822	-2.0%
KT07-04	Al_2O_3	5.1914	4.9140	0.2774	5.6%
KT07-04	B_2O_3	5.9810	5.9990	-0.0180	-0.3%
KT07-04	BaO	0.0620	0.0680	-0.0060	-8.9%
KT07-04	CaO	0.9137	0.8470	0.0667	7.9%
KT07-04	Ce_2O_3	0.2182	0.2130	0.0052	2.4%
KT07-04	Cr_2O_3	0.0935	0.0880	0.0055	6.3%
KT07-04	CuO	0.0463	0.0380	0.0083	21.9%
KT07-04	Fe_2O_3	11.8415	12.0270	-0.1855	-1.5%
KT07-04	K_2O	0.0304	0.0360	-0.0056	-15.5%
KT07-04	La_2O_3	0.0578	0.0710	-0.0132	-18.6%
KT07-04	Li_2O	3.4931	3.5990	-0.1059	-2.9%
KT07-04	MgO	0.1488	0.1510	-0.0022	-1.4%
KT07-04	MnO	1.0736	1.0550	0.0186	1.8%
KT07-04	Na_2O	13.7867	13.6710	0.1157	0.8%
KT07-04	Nb_2O_5	0.9327	1.0430	-0.1103	-10.6%
KT07-04	NiO	0.1476	0.1540	-0.0064	-4.1%
KT07-04	PbO	0.0902	0.0980	-0.0078	-7.9%
KT07-04	SiO_2	48.4017	50.0880	-1.6863	-3.4%
KT07-04	SO_4	0.3827	0.4000	-0.0173	-4.3%
KT07-04	TiO_2	4.3577	4.3610	-0.0034	-0.1%
KT07-04	ZnO	0.0710	0.0750	-0.0040	-5.4%
KT07-04	ZrO_2	0.8672	0.9270	-0.0598	-6.4%
KT07-04	Sum	98.1886	99.9230	-1.7344	-1.7%
KT07-05	Al_2O_3	7.0242	6.8050	0.2192	3.2%
KT07-05	B_2O_3	6.1420	5.9990	0.1430	2.4%

Table A-4. Comparison of Measured versus Targeted Composition for the KT07-Series Glasses. (continued)

Glass ID	Oxide	Measured (wt %)	Targeted (wt %)	Difference (wt%) of Measured vs Targeted	% Difference of Measured vs Targeted
KT07-05	BaO	0.0625	0.0680	-0.0055	-8.1%
KT07-05	CaO	1.0977	0.9310	0.1667	17.9%
KT07-05	Ce_2O_3	0.1476	0.1420	0.0056	3.9%
KT07-05	Cr_2O_3	0.1389	0.1330	0.0059	4.4%
KT07-05	CuO	0.0504	0.0380	0.0124	32.6%
KT07-05	Fe_2O_3	9.5575	9.5540	0.0035	0.0%
KT07-05	K_2O	0.0711	0.0730	-0.0019	-2.6%
KT07-05	La_2O_3	0.0598	0.0710	-0.0112	-15.8%
KT07-05	Li_2O	3.4716	3.5990	-0.1274	-3.5%
KT07-05	MgO	0.1555	0.1500	0.0055	3.6%
KT07-05	MnO	1.0317	1.0150	0.0167	1.6%
KT07-05	Na_2O	13.6215	13.6310	-0.0095	-0.1%
KT07-05	Nb_2O_5	1.0403	1.0680	-0.0277	-2.6%
KT07-05	NiO	0.1126	0.1150	-0.0024	-2.1%
KT07-05	PbO	0.0587	0.0650	-0.0063	-9.7%
KT07-05	SiO_2	49.9527	50.6250	-0.6723	-1.3%
KT07-05	SO_4	0.3730	0.4000	-0.0270	-6.8%
KT07-05	TiO_2	4.3201	4.4160	-0.0959	-2.2%
KT07-05	ZnO	0.0579	0.0380	0.0199	52.3%
KT07-05	ZrO_2	0.9945	0.9860	0.0085	0.9%
KT07-05	Sum	99.5417	99.9220	-0.3803	-0.4%
KT07-06	Al_2O_3	7.3879	7.2280	0.1599	2.2%
KT07-06	B_2O_3	5.7395	5.9990	-0.2595	-4.3%
KT07-06	BaO	0.0614	0.0680	-0.0066	-9.7%
KT07-06	CaO	1.0029	0.9850	0.0179	1.8%
KT07-06	Ce_2O_3	0.1101	0.1080	0.0021	1.9%
KT07-06	Cr_2O_3	0.1385	0.1340	0.0045	3.3%
KT07-06	CuO	0.0466	0.0380	0.0086	22.7%
KT07-06	Fe_2O_3	9.0965	9.0170	0.0795	0.9%
KT07-06	K_2O	0.1181	0.1110	0.0071	6.4%
KT07-06	La_2O_3	0.0264	0.0360	-0.0096	-26.7%
KT07-06	Li_2O	3.2939	3.5990	-0.3051	-8.5%
KT07-06	MgO	0.0970	0.1020	-0.0050	-4.9%
KT07-06	MnO	1.1908	1.1860	0.0048	0.4%
KT07-06	Na_2O	13.4834	13.6450	-0.1616	-1.2%
KT07-06	Nb_2O_5	0.9466	1.0230	-0.0764	-7.5%
KT07-06	NiO	0.1489	0.1560	-0.0071	-4.6%
KT07-06	PbO	0.0611	0.0660	-0.0049	-7.4%
KT07-06	SiO_2	48.9365	50.6160	-1.6795	-3.3%
KT07-06	SO_4	0.3707	0.4000	-0.0293	-7.3%
KT07-06	TiO_2	4.2701	4.3730	-0.1029	-2.4%
KT07-06	ZnO	0.0710	0.0760	-0.0050	-6.6%
KT07-06	ZrO_2	0.9118	0.9560	-0.0442	-4.6%
KT07-06	Sum	97.5097	99.9220	-2.4123	-2.4%
KT07-07	Al_2O_3	5.6685	5.6200	0.0485	0.9%
KT07-07	B_2O_3	5.8683	5.9990	-0.1307	-2.2%
KT07-07	BaO	0.0689	0.0750	-0.0061	-8.1%
KT07-07	CaO	0.9315	0.8900	0.0415	4.7%
KT07-07	Ce_2O_3	0.0776	0.0780	-0.0004	-0.5%
KT07-07	Cr_2O_3	0.1549	0.1470	0.0079	5.4%
KT07-07	CuO	0.0529	0.0420	0.0109	25.9%
KT07-07	Fe_2O_3	9.3181	9.3780	-0.0599	-0.6%
KT07-07	K_2O	0.0774	0.0810	-0.0036	-4.4%
KT07-07	La_2O_3	0.0267	0.0390	-0.0123	-31.6%
KT07-07	Li_2O	3.4016	3.5990	-0.1974	-5.5%
KT07-07	MgO	0.1090	0.1110	-0.0020	-1.8%
KT07-07	MnO	0.7244	0.7350	-0.0106	-1.4%
KT07-07	Na_2O	14.0192	14.5080	-0.4888	-3.4%

Table A-4. Comparison of Measured versus Targeted Composition for the KT07-Series Glasses. (continued)

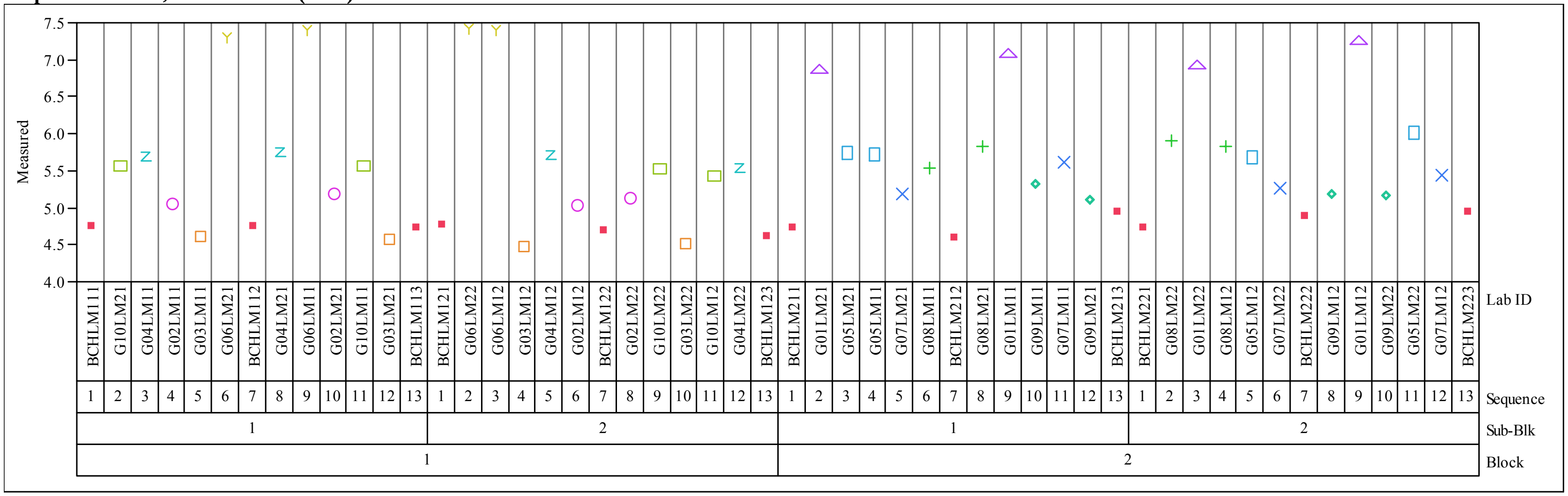
Glass ID	Oxide	Measured (wt %)	Targeted (wt %)	Difference (wt%) of Measured vs Targeted	% Difference of Measured vs Targeted
KT07-07	Nb_2O_5	1.1290	1.1930	-0.0640	-5.4%
KT07-07	NiO	0.6191	0.6390	-0.0199	-3.1%
KT07-07	PbO	0.0700	0.0720	-0.0020	-2.8%
KT07-07	SiO_2	48.9365	50.3350	-1.3985	-2.8%
KT07-07	SO_4	0.3887	0.4000	-0.0113	-2.8%
KT07-07	TiO_2	4.7747	4.8460	-0.0713	-1.5%
KT07-07	ZnO	0.0825	0.0830	-0.0005	-0.6%
KT07-07	ZrO_2	1.0276	1.0540	-0.0264	-2.5%
KT07-07	Sum	97.5270	99.9240	-2.3970	-2.4%
KT07-08	Al_2O_3	5.0922	5.0110	0.0812	1.6%
KT07-08	B_2O_3	6.0695	5.9990	0.0705	1.2%
KT07-08	BaO	0.0715	0.0750	-0.0035	-4.7%
KT07-08	CaO	0.8979	0.8040	0.0939	11.7%
KT07-08	Ce_2O_3	0.0794	0.0790	0.0004	0.5%
KT07-08	Cr_2O_3	0.1085	0.0990	0.0095	9.6%
KT07-08	CuO	0.0429	0.0420	0.0009	2.1%
KT07-08	Fe_2O_3	9.1251	9.1310	-0.0059	-0.1%
KT07-08	K_2O	0.0735	0.0810	-0.0075	-9.3%
KT07-08	La_2O_3	0.0293	0.0400	-0.0107	-26.7%
KT07-08	Li_2O	3.4393	3.5990	-0.1597	-4.4%
KT07-08	MgO	0.1136	0.1120	0.0016	1.4%
KT07-08	MnO	0.9626	0.9600	0.0026	0.3%
KT07-08	Na_2O	14.9291	15.4110	-0.4819	-3.1%
KT07-08	Nb_2O_5	1.2756	1.2940	-0.0184	-1.4%
KT07-08	NiO	0.5904	0.6020	-0.0116	-1.9%
KT07-08	PbO	0.0676	0.0730	-0.0054	-7.4%
KT07-08	SiO_2	48.5086	50.0060	-1.4974	-3.0%
KT07-08	SO_4	0.3827	0.4000	-0.0173	-4.3%
KT07-08	TiO_2	4.8872	4.9320	-0.0448	-0.9%
KT07-08	ZnO	0.0417	0.0420	-0.0003	-0.7%
KT07-08	ZrO_2	1.1060	1.1300	-0.0240	-2.1%
KT07-08	Sum	97.8942	99.9220	-2.0278	-2.0%
KT07-09	Al_2O_3	5.5126	5.4600	0.0526	1.0%
KT07-09	B_2O_3	5.9810	5.9990	-0.0180	-0.3%
KT07-09	BaO	0.0689	0.0760	-0.0071	-9.3%
KT07-09	CaO	1.0022	0.9510	0.0512	5.4%
KT07-09	Ce_2O_3	0.1944	0.1990	-0.0046	-2.3%
KT07-09	Cr_2O_3	0.1063	0.0990	0.0073	7.4%
KT07-09	CuO	0.0404	0.0430	-0.0026	-6.1%
KT07-09	Fe_2O_3	12.0524	12.2890	-0.2366	-1.9%
KT07-09	K_2O	0.0831	0.0820	0.0011	1.4%
KT07-09	La_2O_3	0.0625	0.0800	-0.0175	-21.9%
KT07-09	Li_2O	3.4123	3.5990	-0.1867	-5.2%
KT07-09	MgO	0.1078	0.1130	-0.0052	-4.6%
KT07-09	MnO	0.5559	0.5700	-0.0141	-2.5%
KT07-09	Na_2O	13.6687	14.0230	-0.3543	-2.5%
KT07-09	Nb_2O_5	0.7156	0.8450	-0.1294	-15.3%
KT07-09	NiO	0.4867	0.5190	-0.0323	-6.2%
KT07-09	PbO	0.1236	0.1460	-0.0224	-15.3%
KT07-09	SiO_2	46.9042	48.7610	-1.8568	-3.8%
KT07-09	SO_4	0.3633	0.4000	-0.0367	-9.2%
KT07-09	TiO_2	4.7455	4.8240	-0.0785	-1.6%
KT07-09	ZnO	0.0386	0.0420	-0.0034	-8.1%
KT07-09	ZrO_2	0.7416	0.8020	-0.0604	-7.5%
KT07-09	Sum	96.9675	99.9220	-2.9545	-3.0%
KT07-10	Al_2O_3	5.7583	5.6090	0.1493	2.7%
KT07-10	B_2O_3	6.1178	5.9990	0.1188	2.0%
KT07-10	BaO	0.0715	0.0770	-0.0055	-7.2%

Table A-4. Comparison of Measured versus Targeted Composition for the KT07-Series Glasses. (continued)

Glass ID	Oxide	Measured (wt %)	Targeted (wt %)	Difference (wt%) of Measured vs Targeted	% Difference of Measured vs Targeted
KT07-10	CaO	1.0491	0.9700	0.0791	8.1%
KT07-10	Ce_2O_3	0.2401	0.2440	-0.0039	-1.6%
KT07-10	Cr_2O_3	0.1104	0.1010	0.0094	9.3%
KT07-10	CuO	0.0469	0.0430	0.0039	9.2%
KT07-10	Fe_2O_3	13.3534	13.5760	-0.2226	-1.6%
KT07-10	K_2O	0.0407	0.0420	-0.0013	-3.2%
KT07-10	La_2O_3	0.0657	0.0810	-0.0153	-18.9%
KT07-10	Li_2O	3.4823	3.5990	-0.1167	-3.2%
KT07-10	MgO	0.1099	0.1150	-0.0051	-4.5%
KT07-10	MnO	0.3932	0.4030	-0.0098	-2.4%
KT07-10	Na_2O	13.5272	13.5050	0.0222	0.2%
KT07-10	Nb_2O_5	0.7303	0.7850	-0.0547	-7.0%
KT07-10	NiO	0.4559	0.4850	-0.0291	-6.0%
KT07-10	PbO	0.1344	0.1490	-0.0146	-9.8%
KT07-10	SiO_2	47.0646	48.4280	-1.3634	-2.8%
KT07-10	SO_4	0.3580	0.4000	-0.0420	-10.5%
KT07-10	TiO_2	4.4536	4.5050	-0.0514	-1.1%
KT07-10	ZnO	0.0392	0.0430	-0.0038	-8.8%
KT07-10	ZrO_2	0.7423	0.7620	-0.0197	-2.6%
KT07-10	Sum	98.3444	99.9210	-1.5766	-1.6%

Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide.

Prep Method=LM, Oxide=Al2O3 (wt%)



Prep Method=LM, Oxide=BaO (wt%)

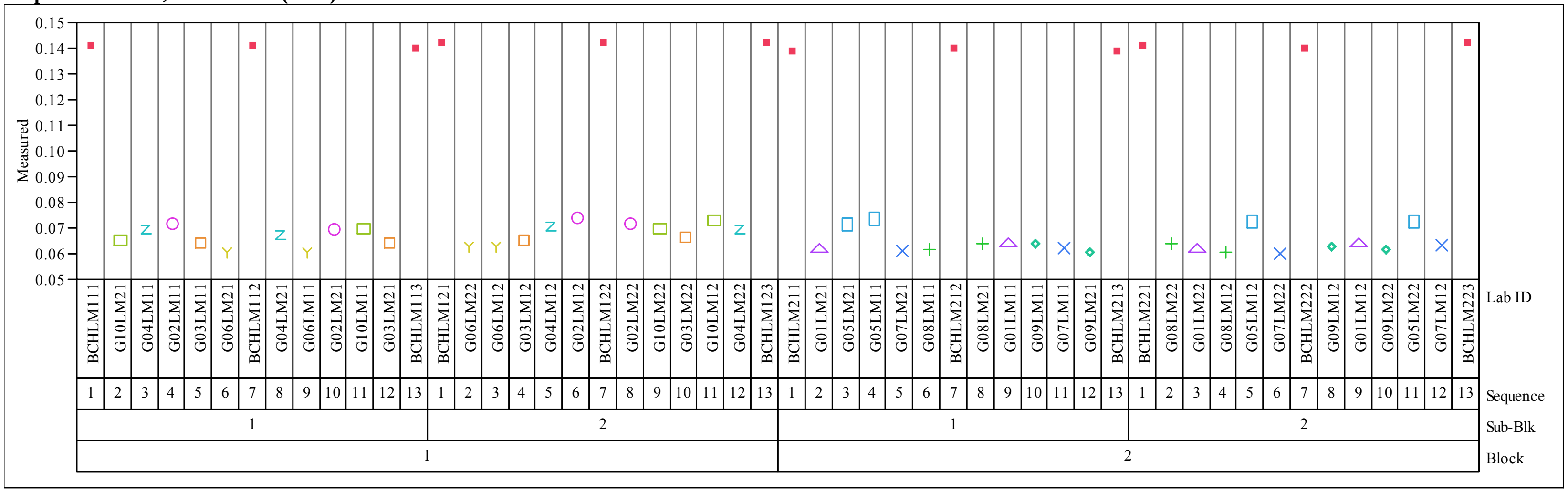
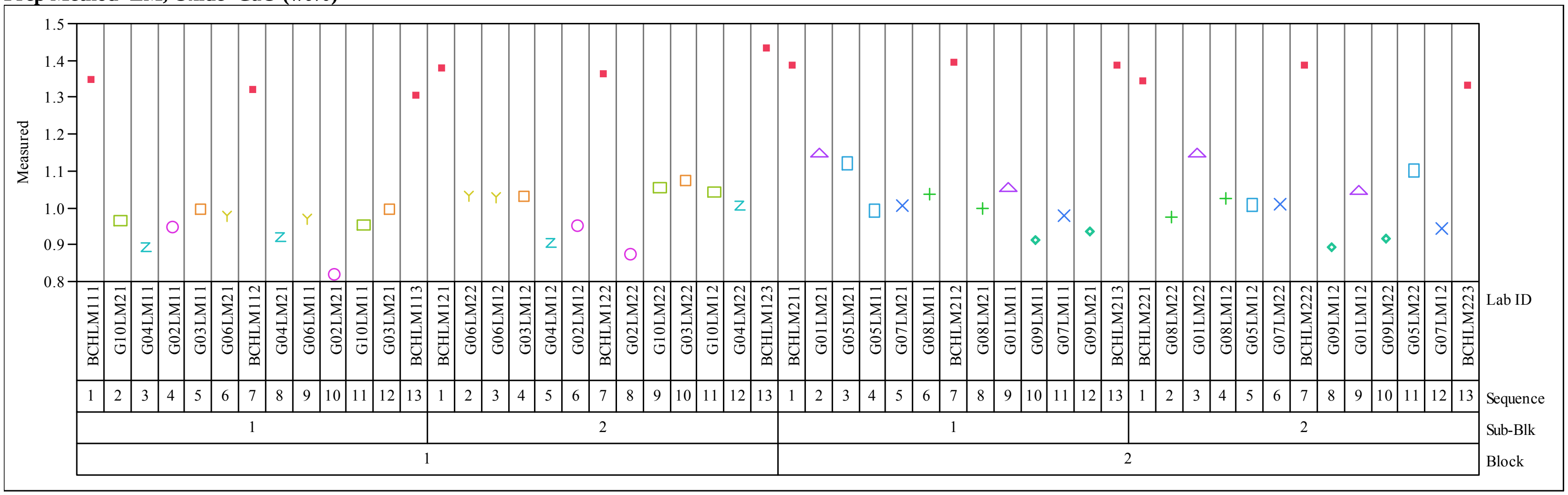


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=CaO (wt%)



Prep Method=LM, Oxide=Ce2O3 (wt%)

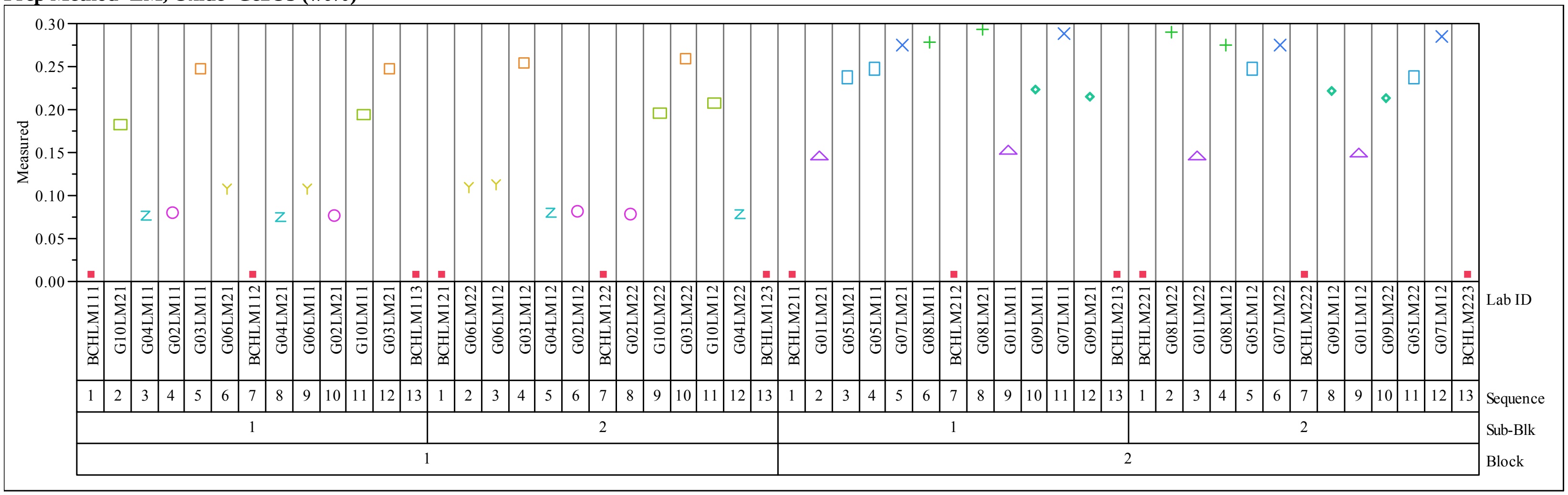
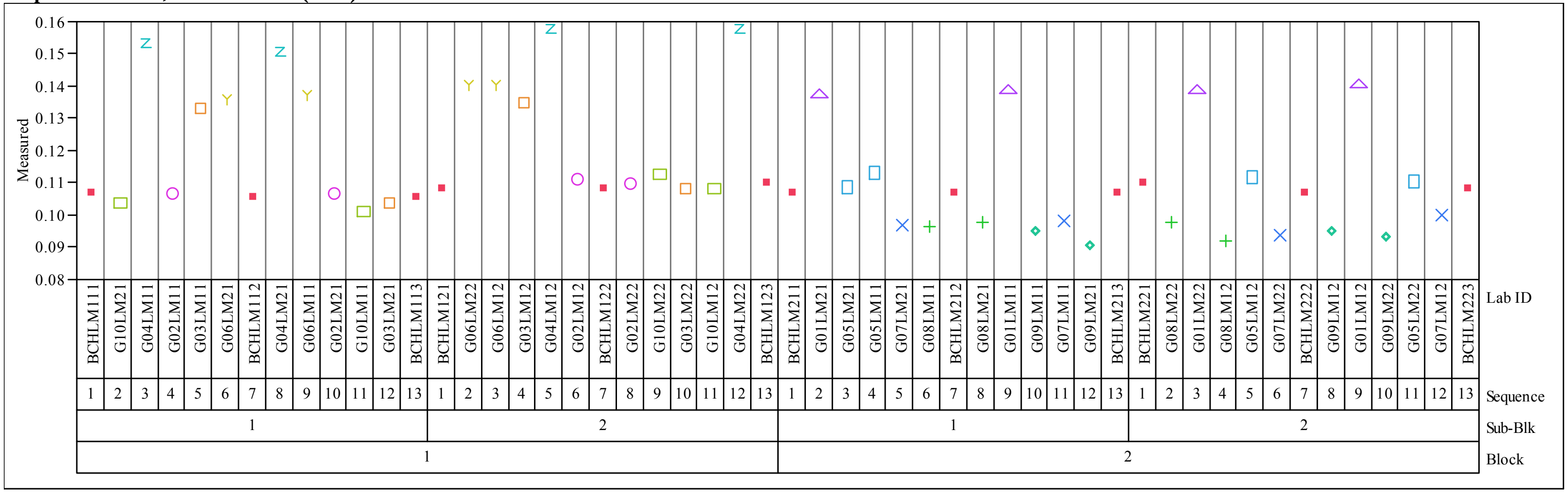


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Cr2O3 (wt%)



Prep Method=LM, Oxide=CuO (wt%)

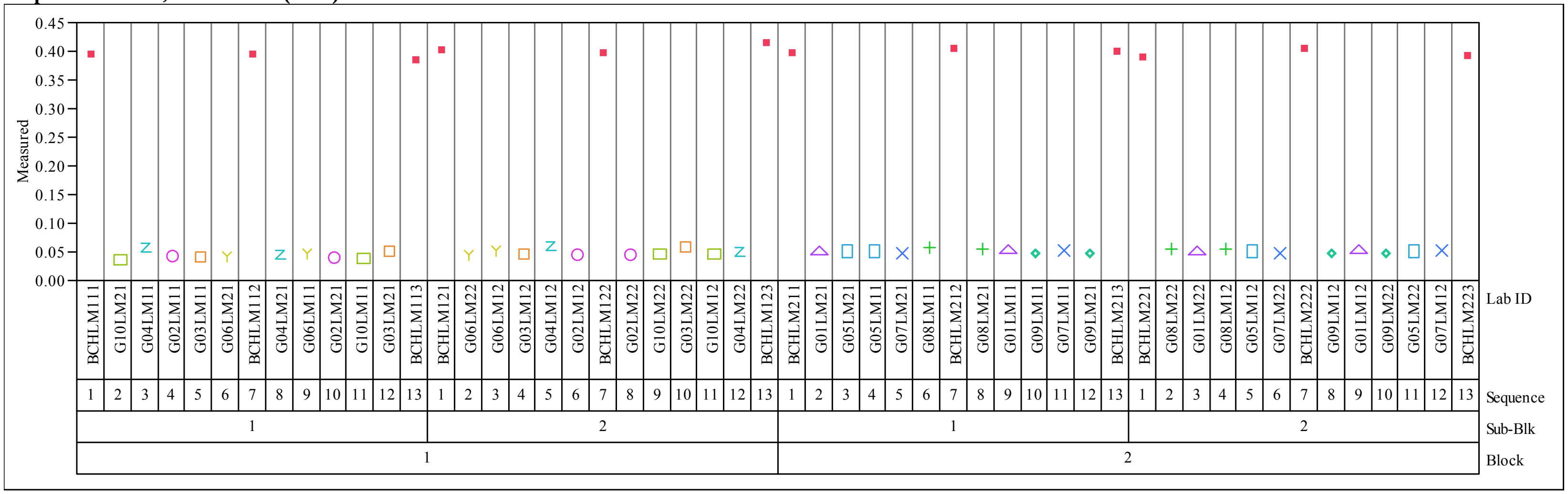
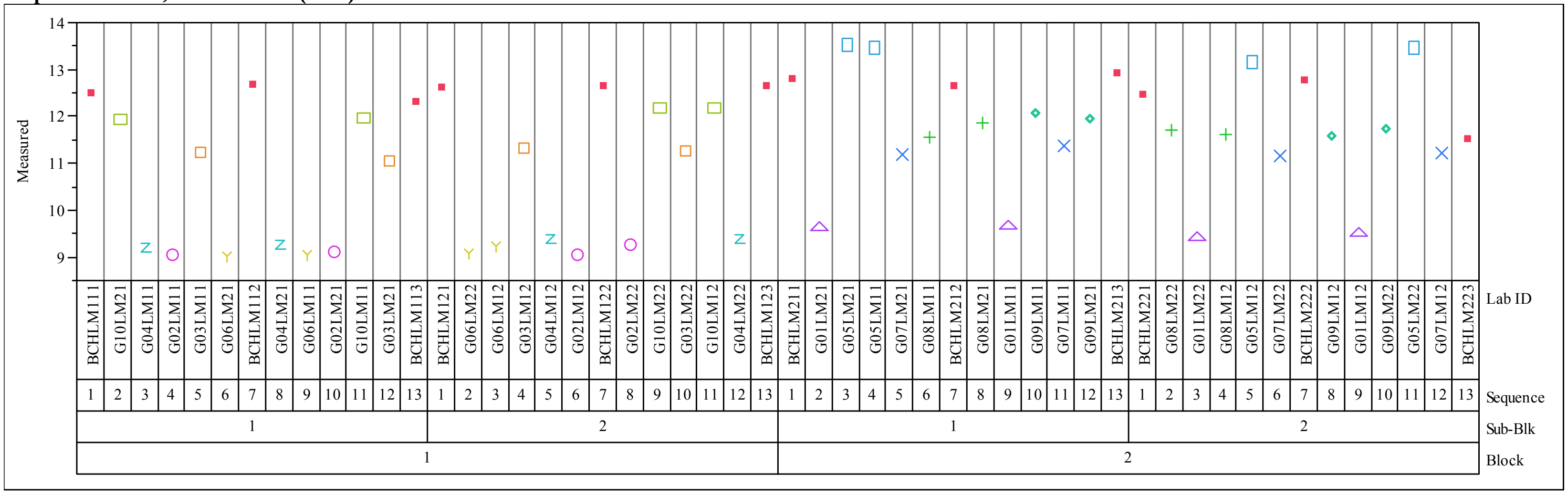


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Fe2O3 (wt%)



Prep Method=LM, Oxide=K2O (wt%)

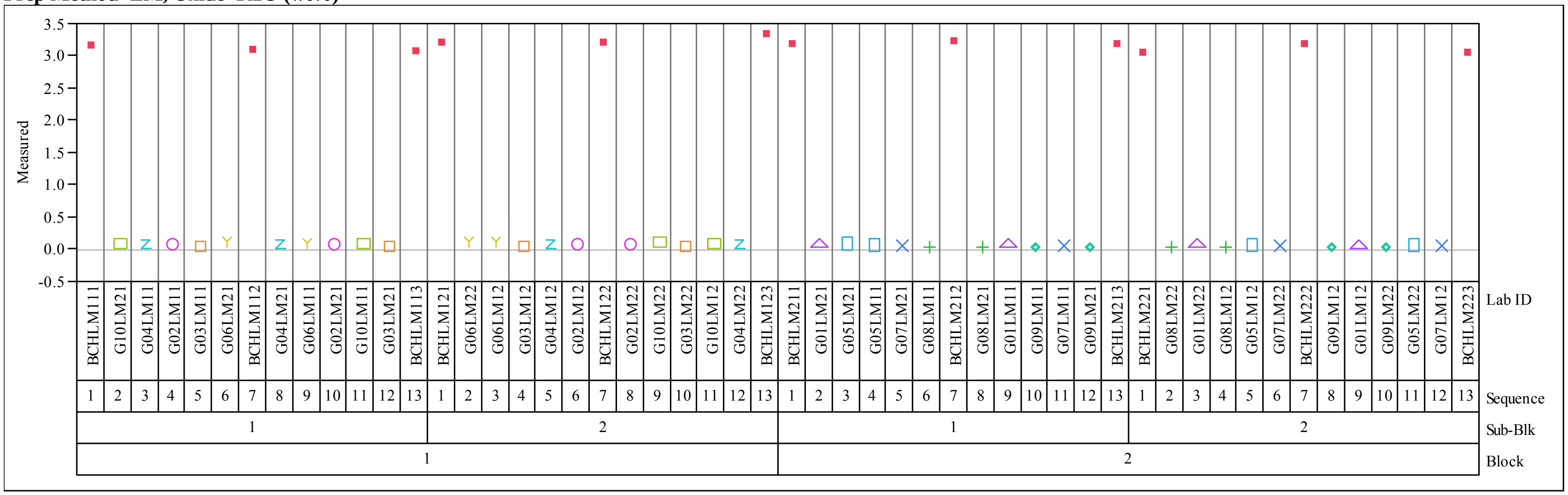
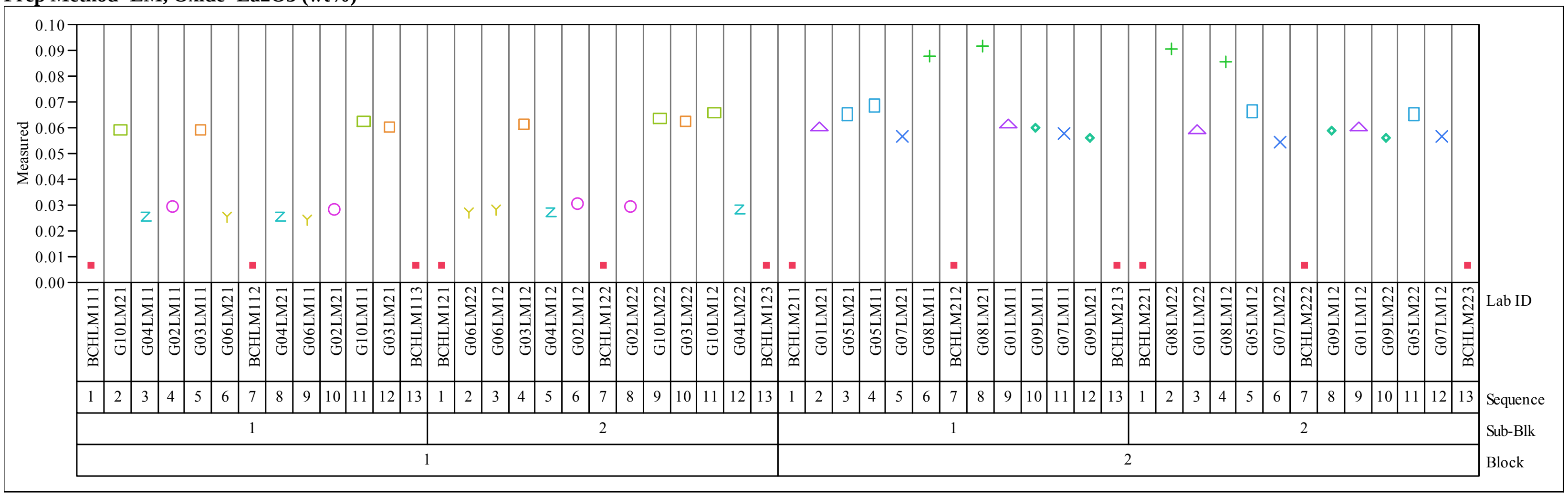


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=La2O3 (wt%)



Prep Method=LM, Oxide=MgO (wt%)

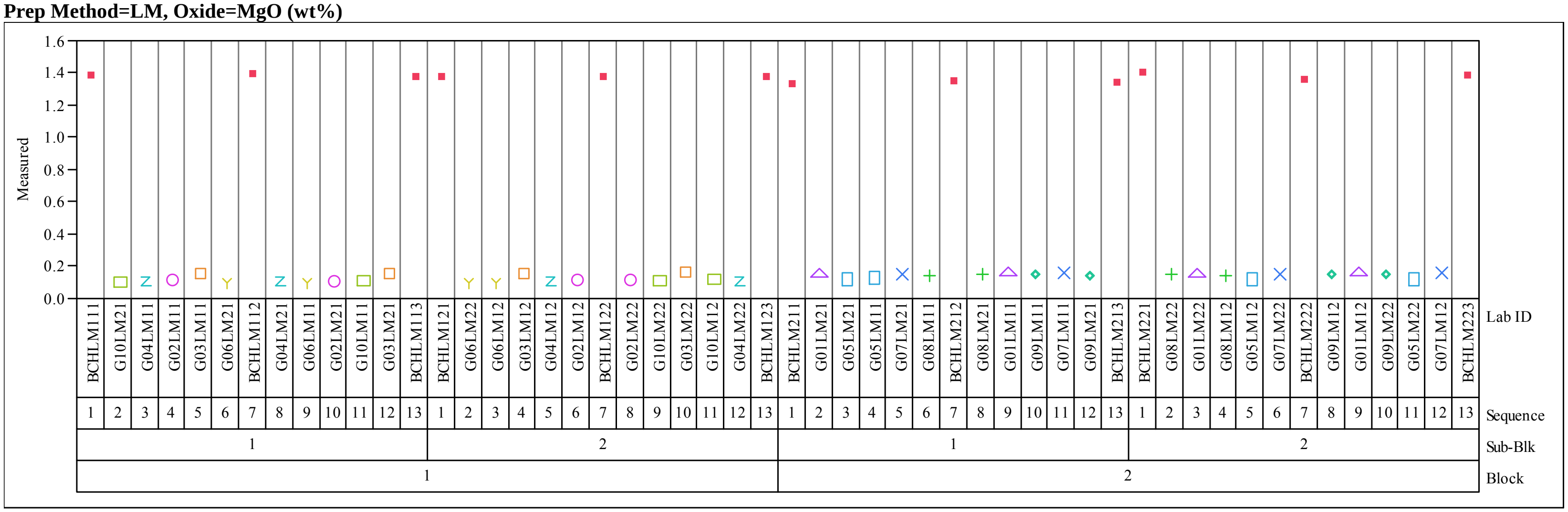
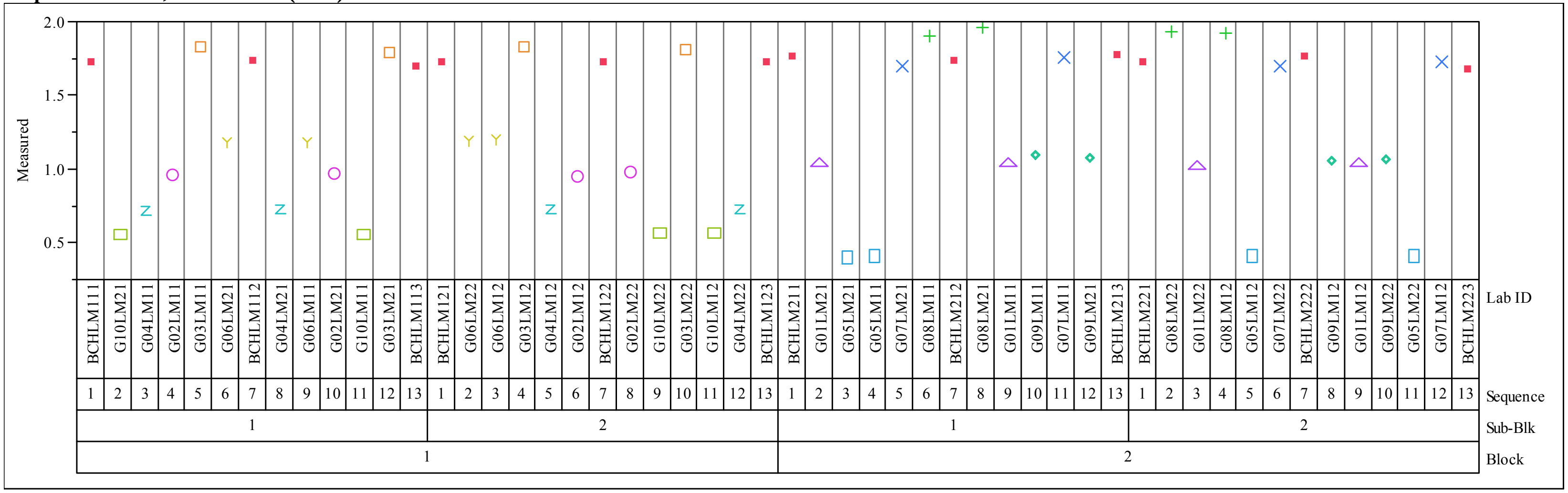


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=MnO (wt%)



Prep Method=LM, Oxide=Na2O (wt%)

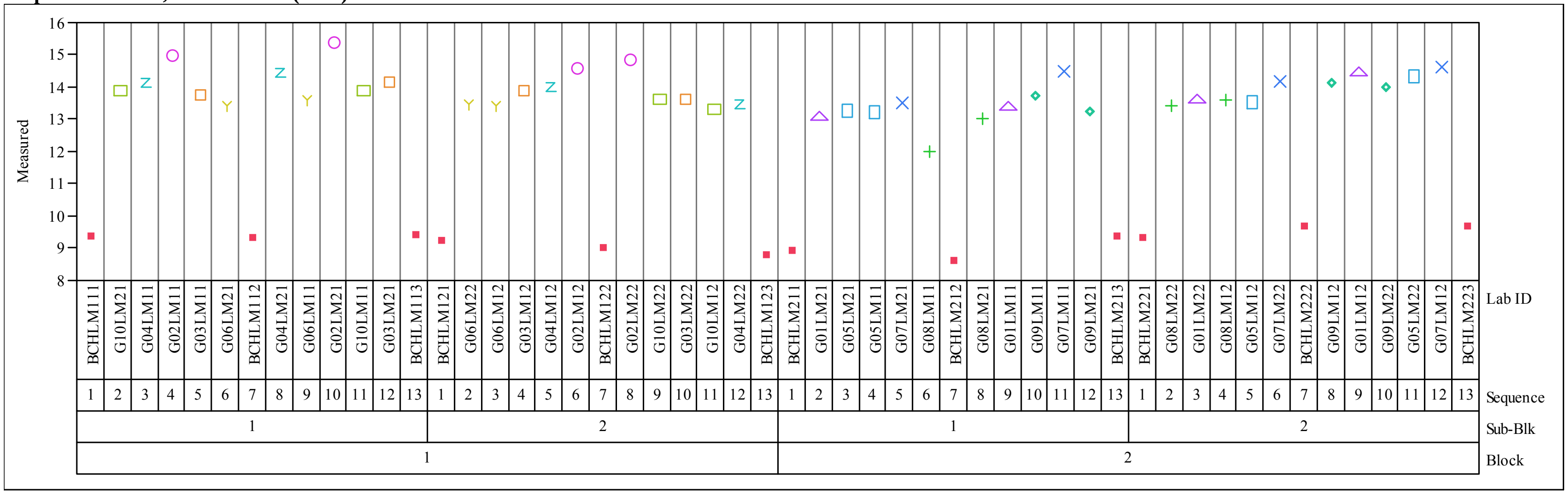
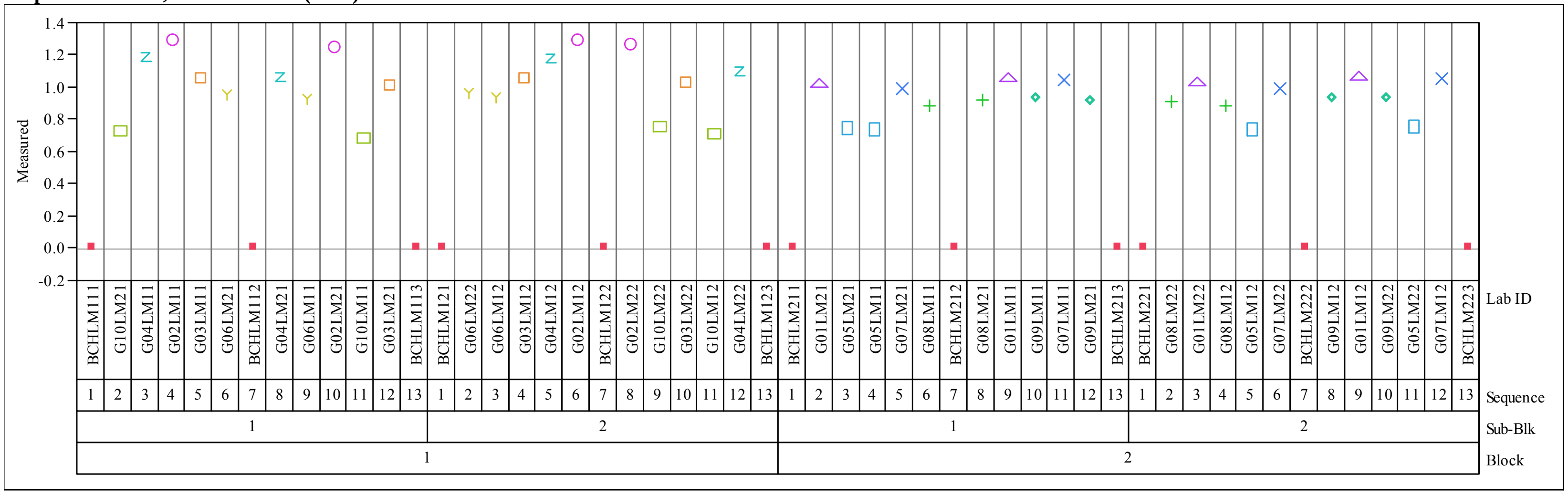


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Nb2O5 (wt%)



Prep Method=LM, Oxide=NiO (wt%)

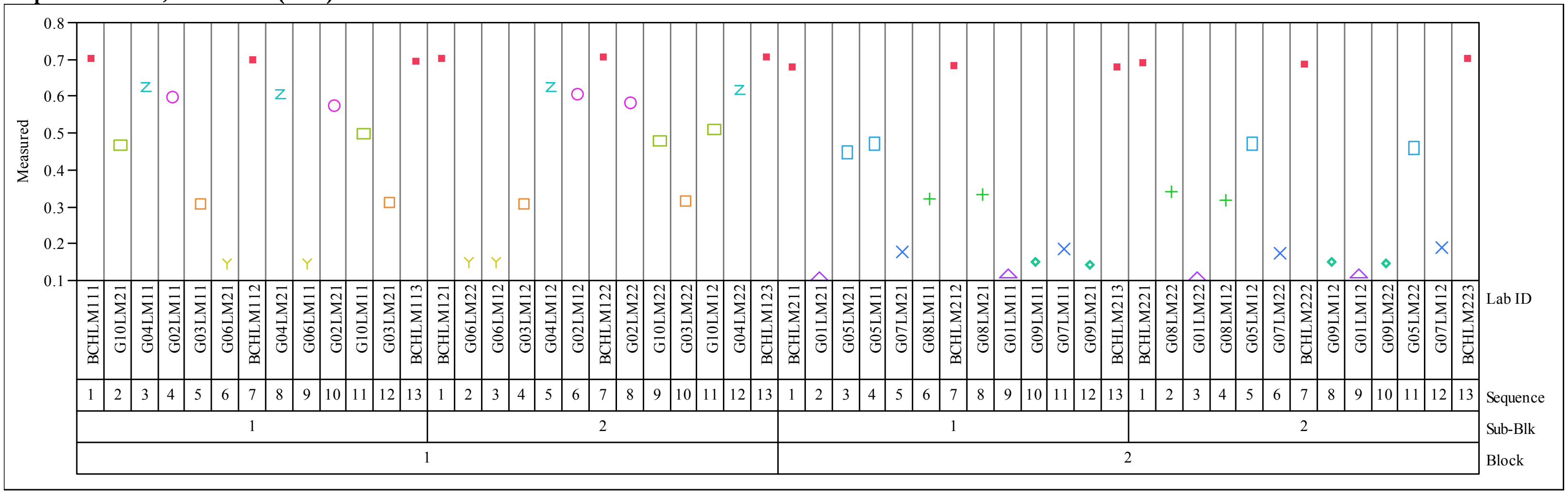
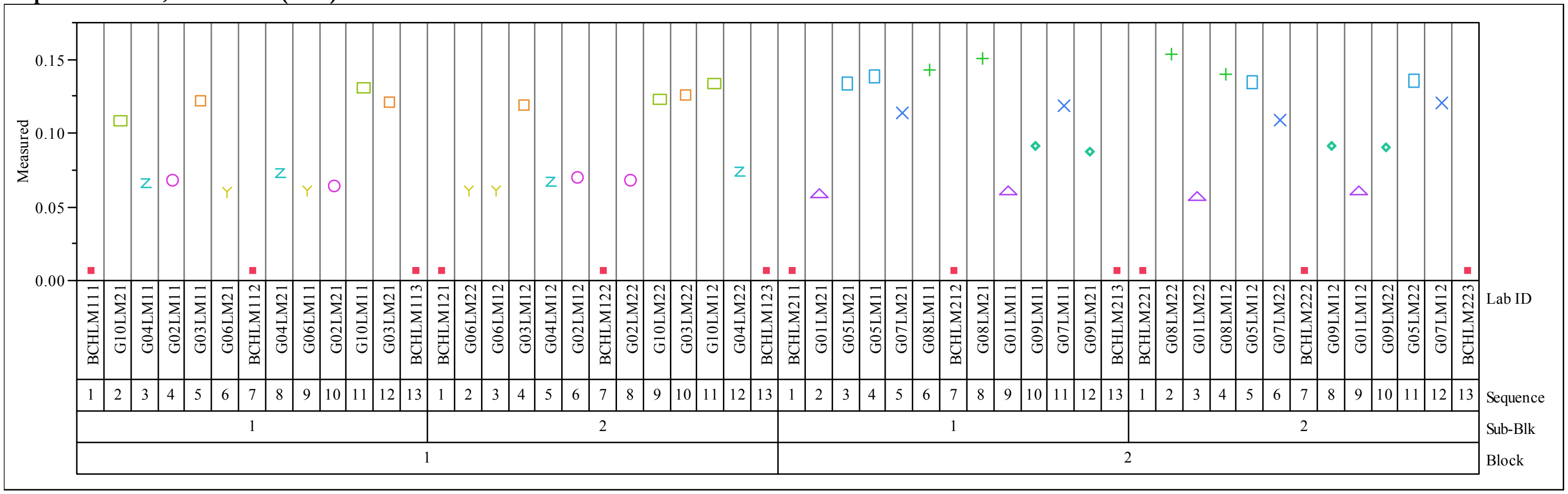


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=PbO (wt%)



Prep Method=LM, Oxide=SiO2 (wt%)

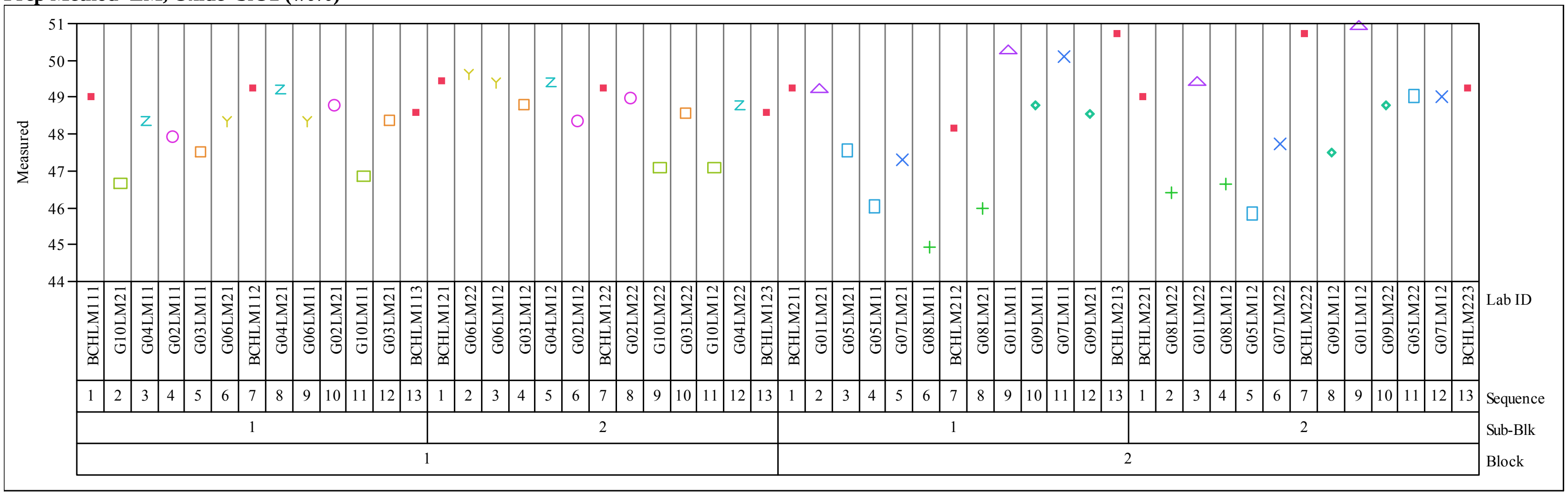
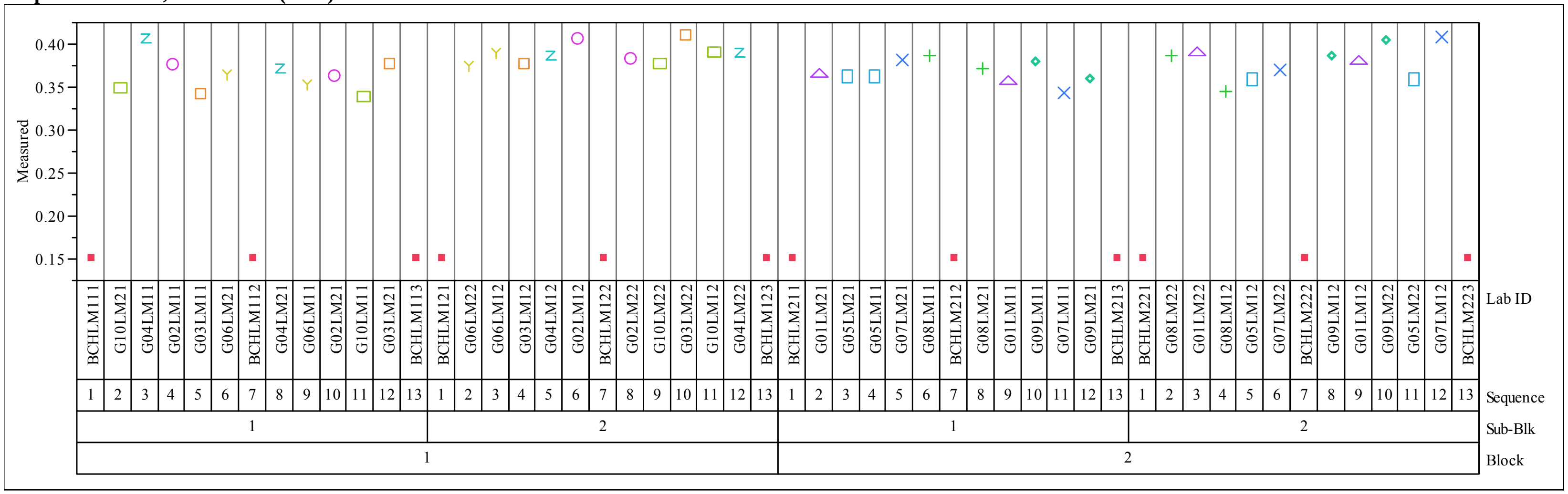


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=SO4 (wt%)



Prep Method=LM, Oxide=TiO2 (wt%)

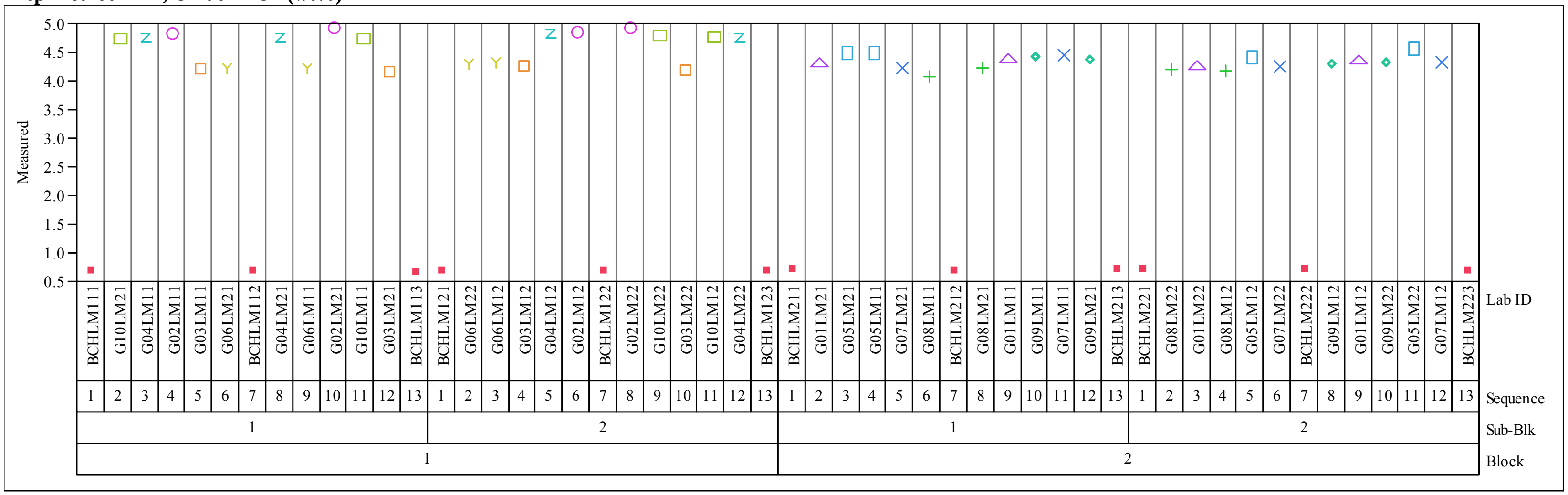
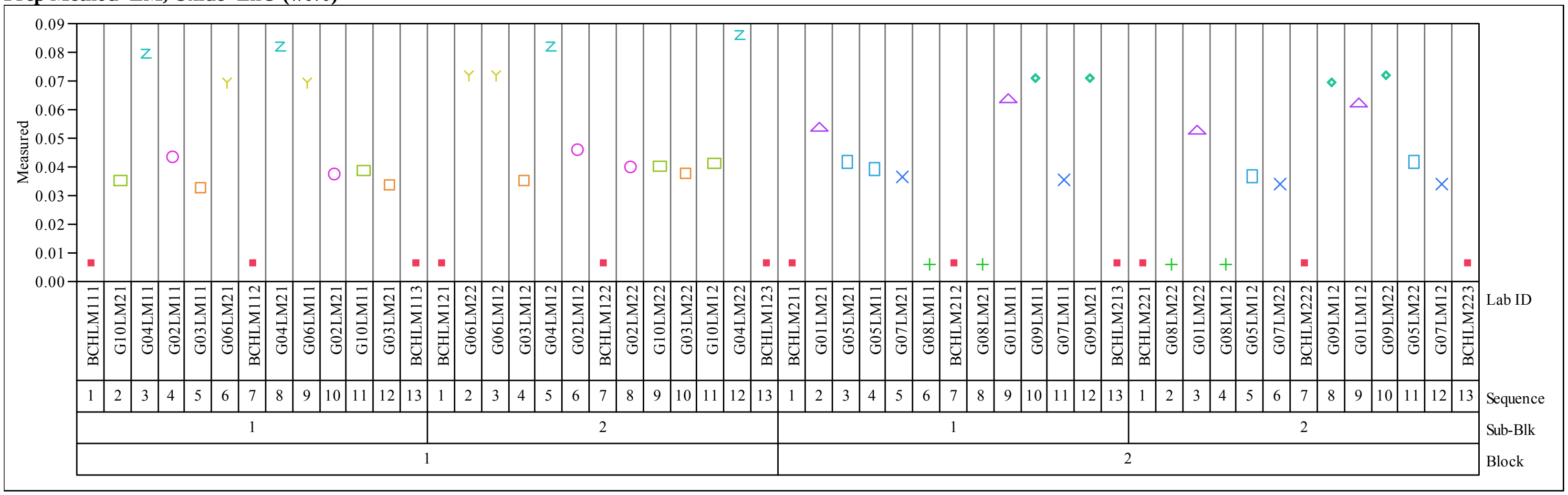


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=ZnO (wt%)



Prep Method=LM, Oxide=ZrO2 (wt%)

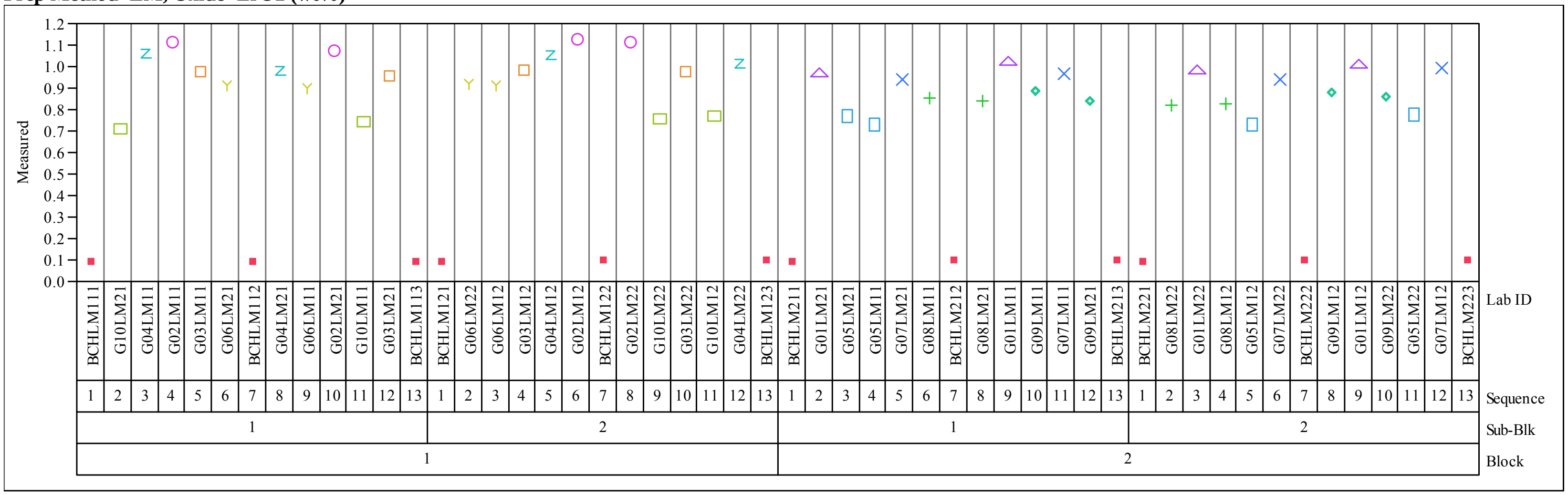
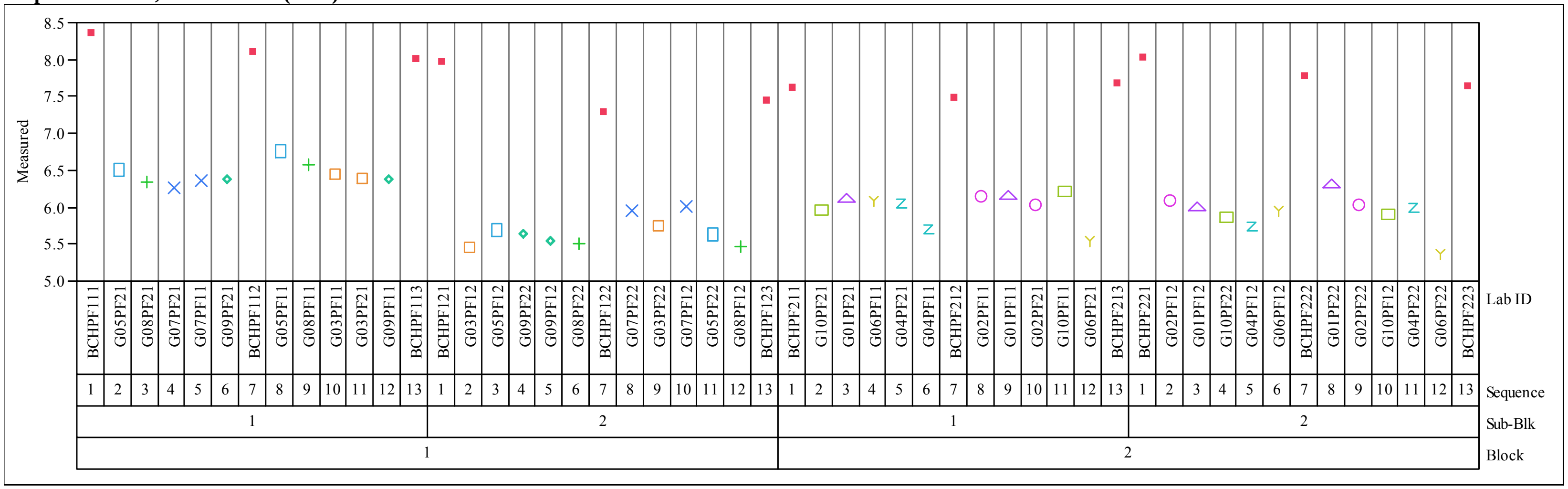


Exhibit A-1. Measurements in Analytical Sequence for the KT07-Series by Preparation Method by Oxide. (continued)

Prep Method=PF, Oxide=B2O3 (wt%)



Prep Method=PF, Oxide=Li2O (wt%)

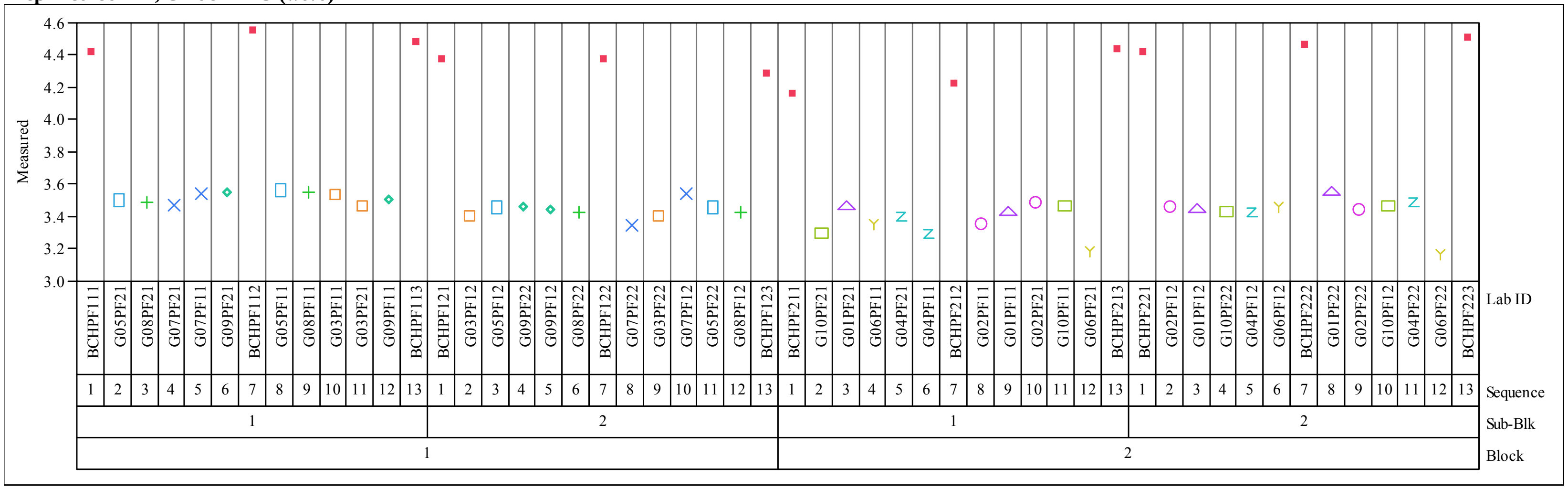
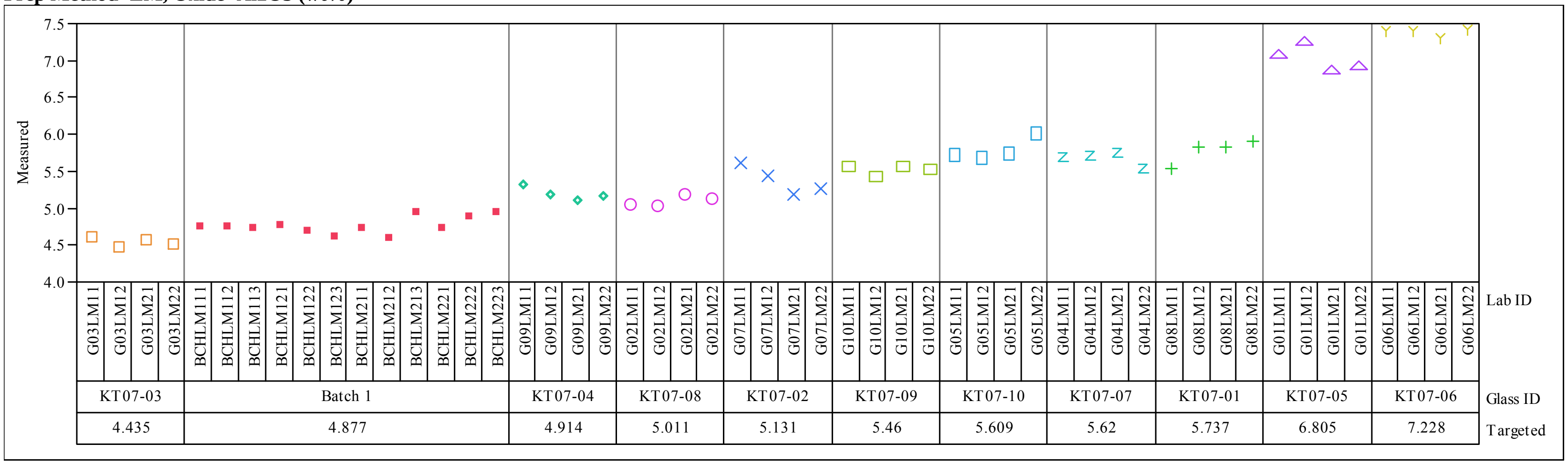


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide.

Prep Method=LM, Oxide=Al2O3 (wt%)



=Prep Method=LM, Oxide=BaO (wt%)

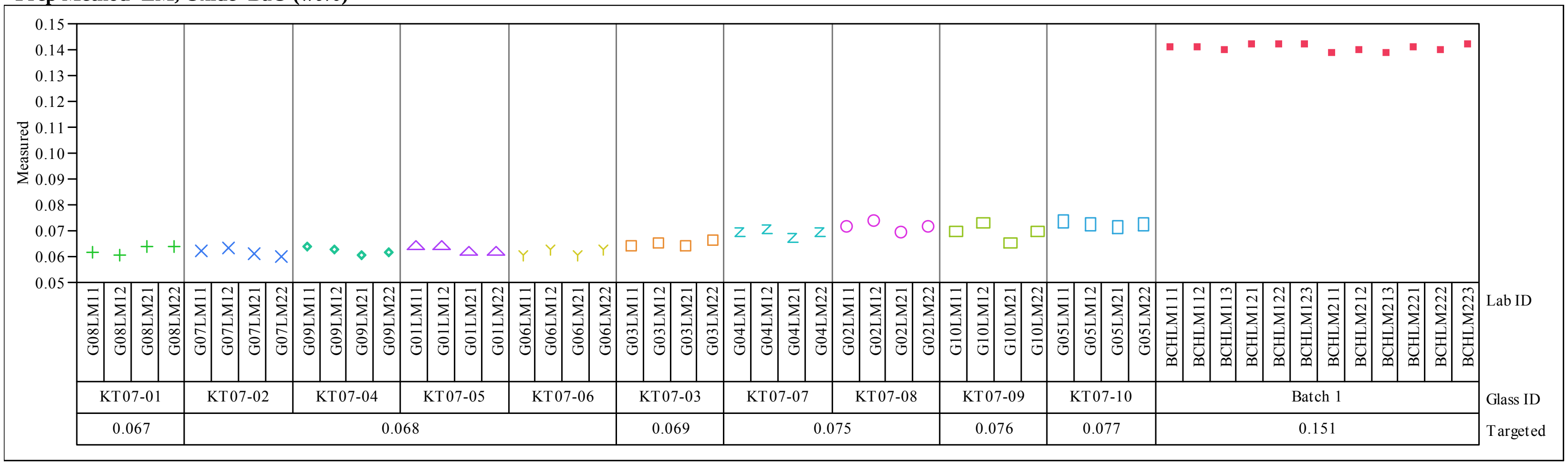
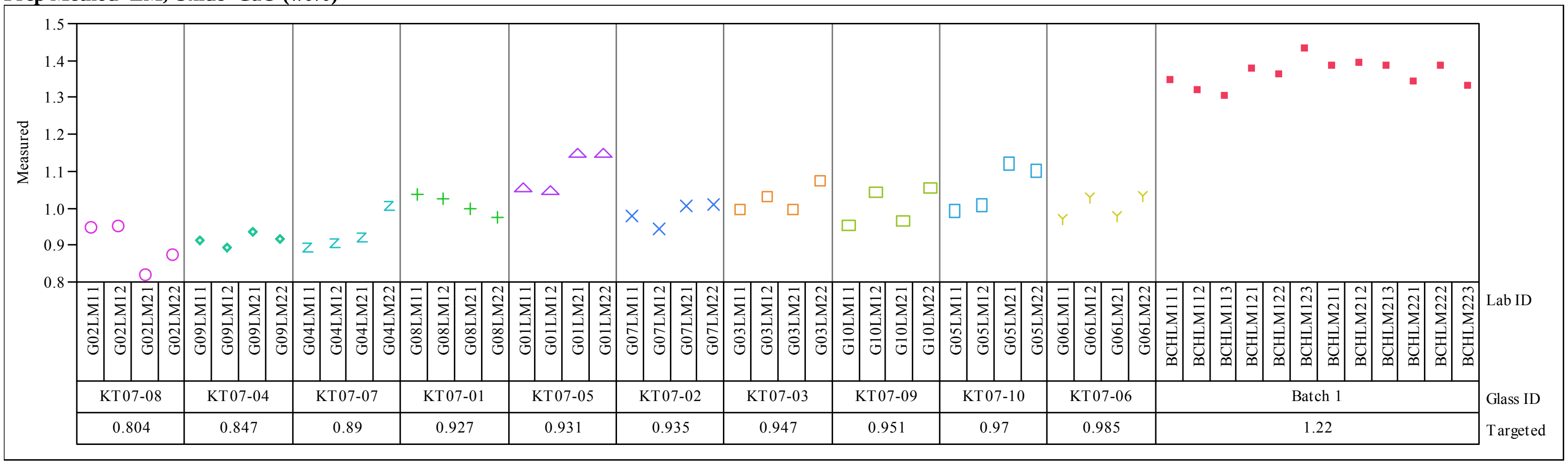


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=CaO (wt%)



Prep Method=LM, Oxide=Ce2O3 (wt%)

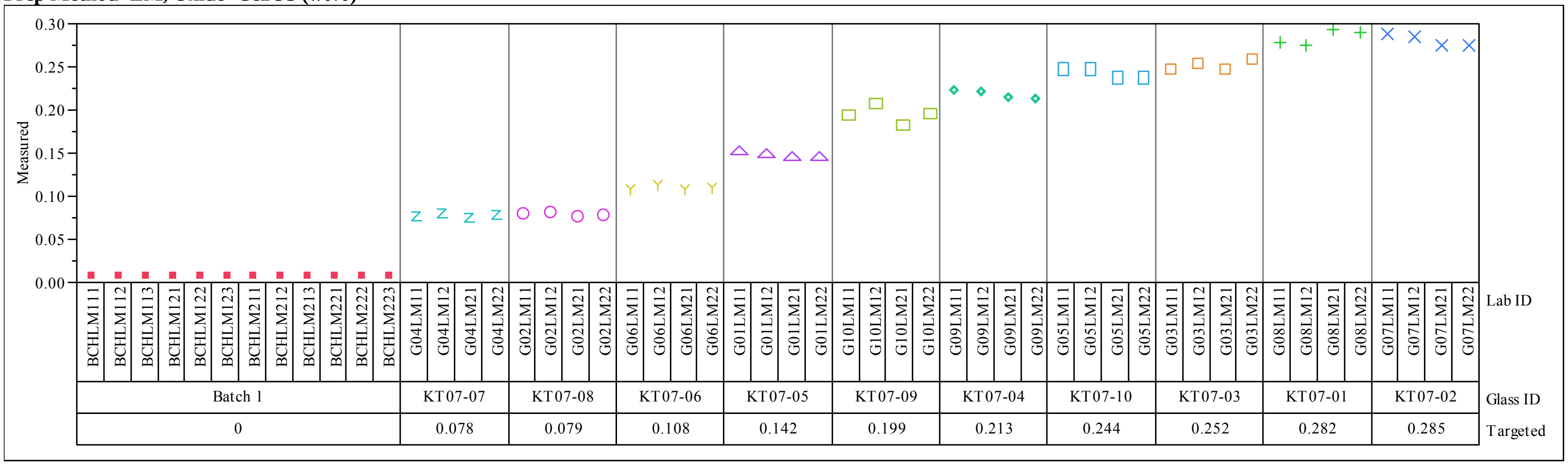
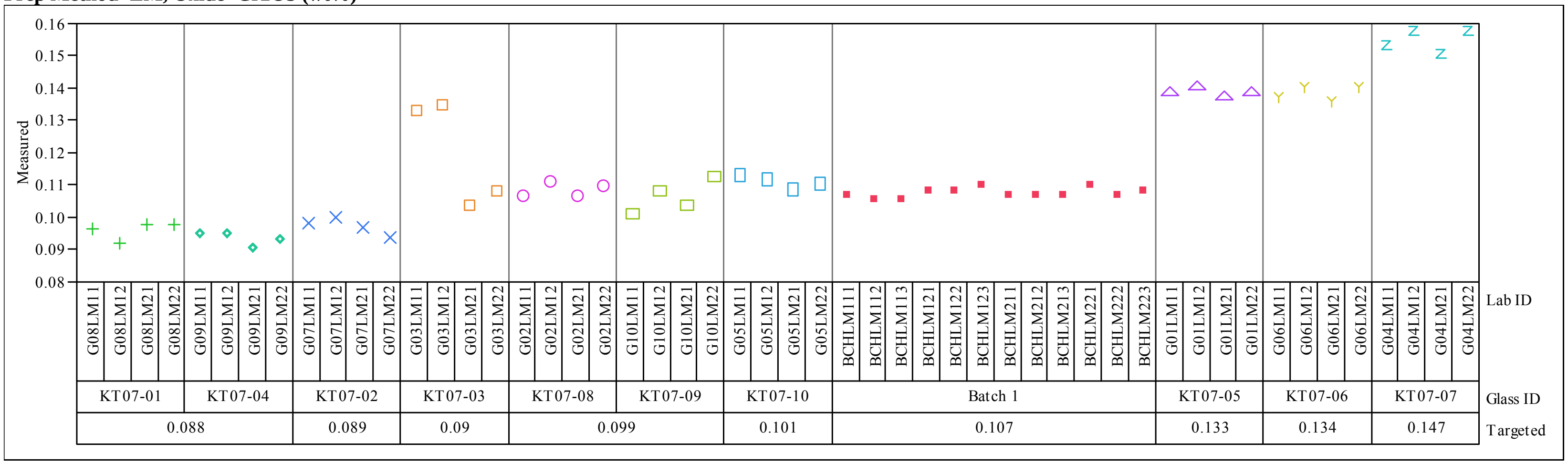


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Cr2O3 (wt%)



Prep Method=LM, Oxide=CuO (wt%)

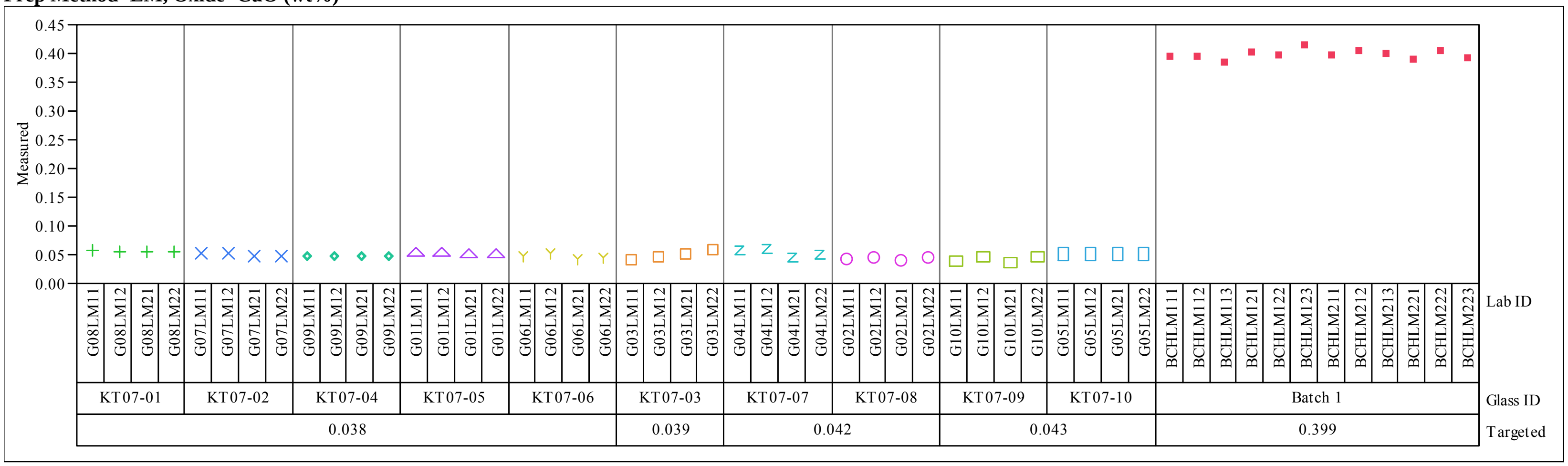
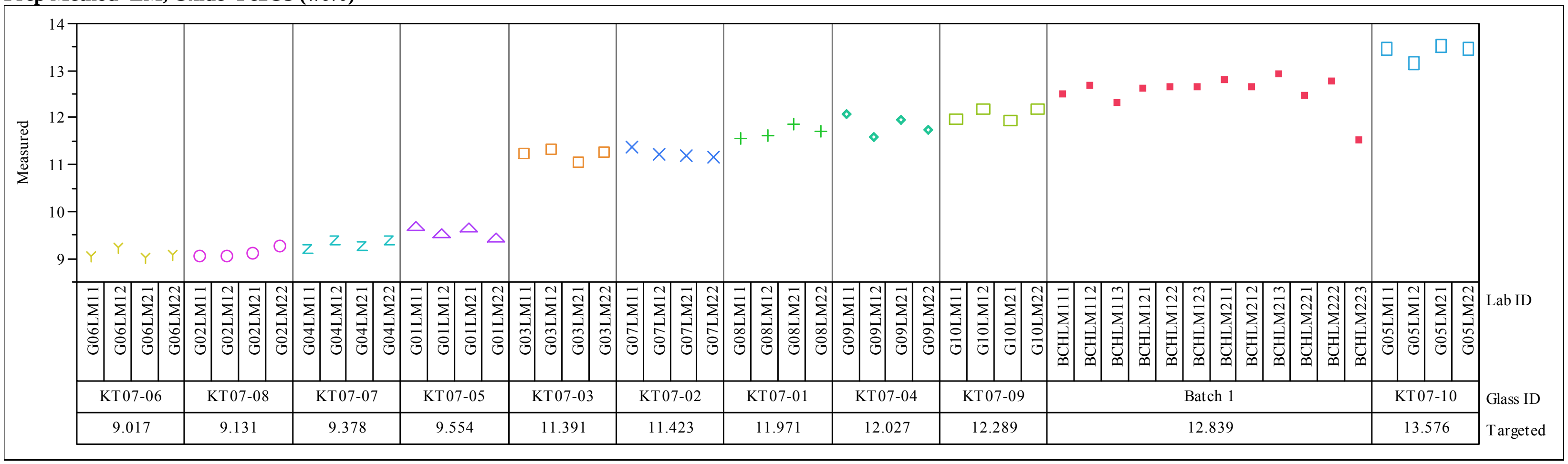


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Fe2O3 (wt%)



Prep Method=LM, Oxide=K2O (wt%)

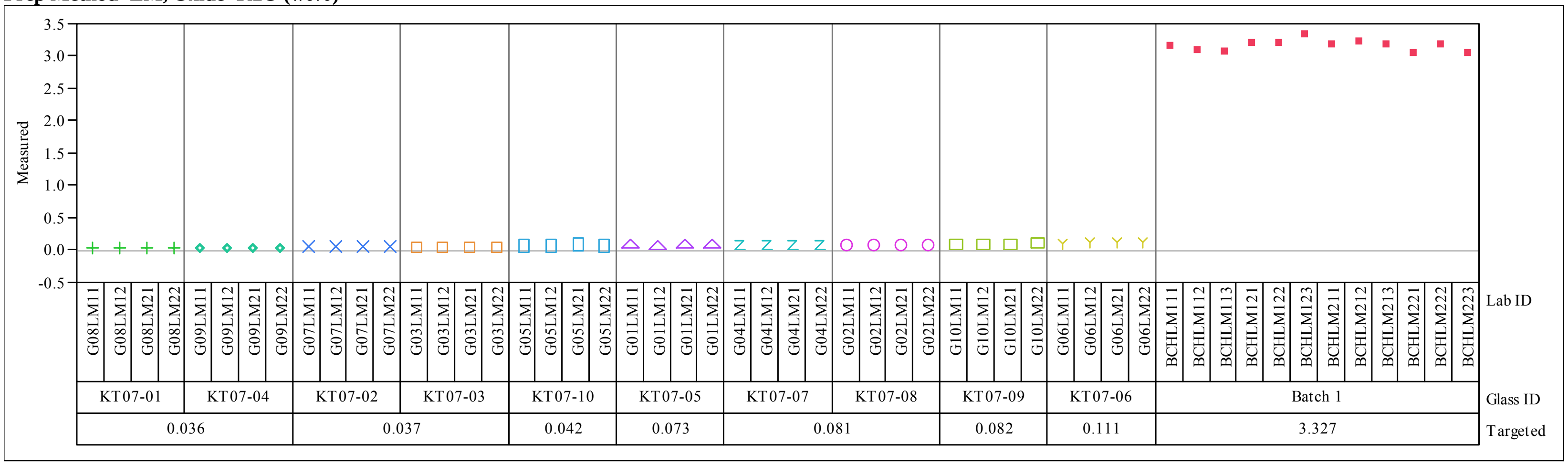
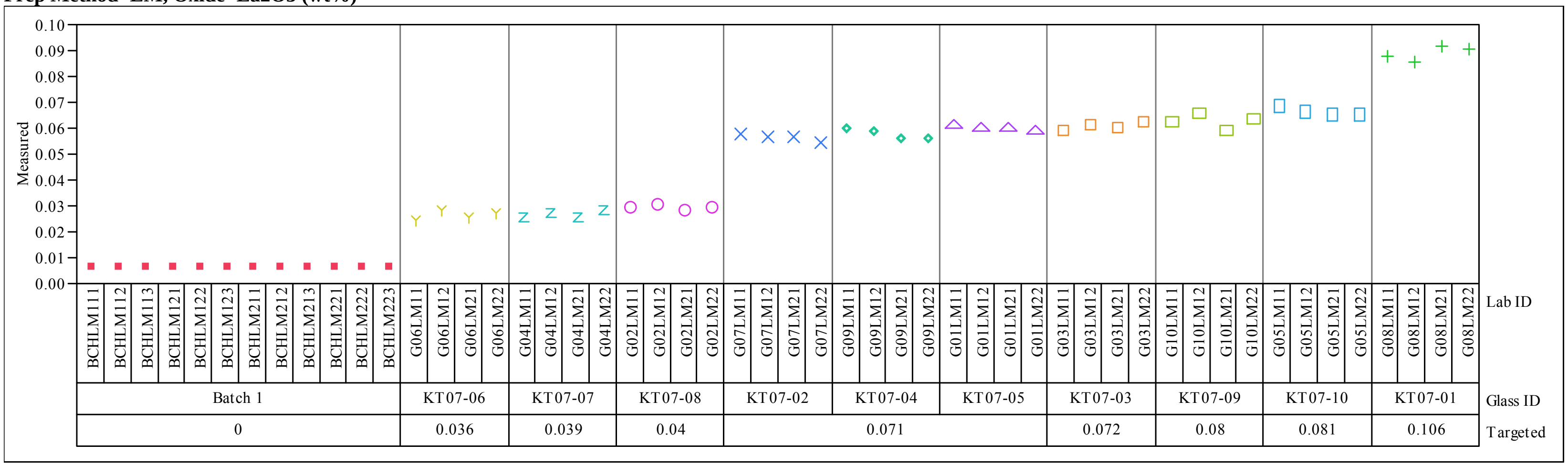


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=La2O3 (wt%)



Prep Method=LM, Oxide=MgO (wt%)

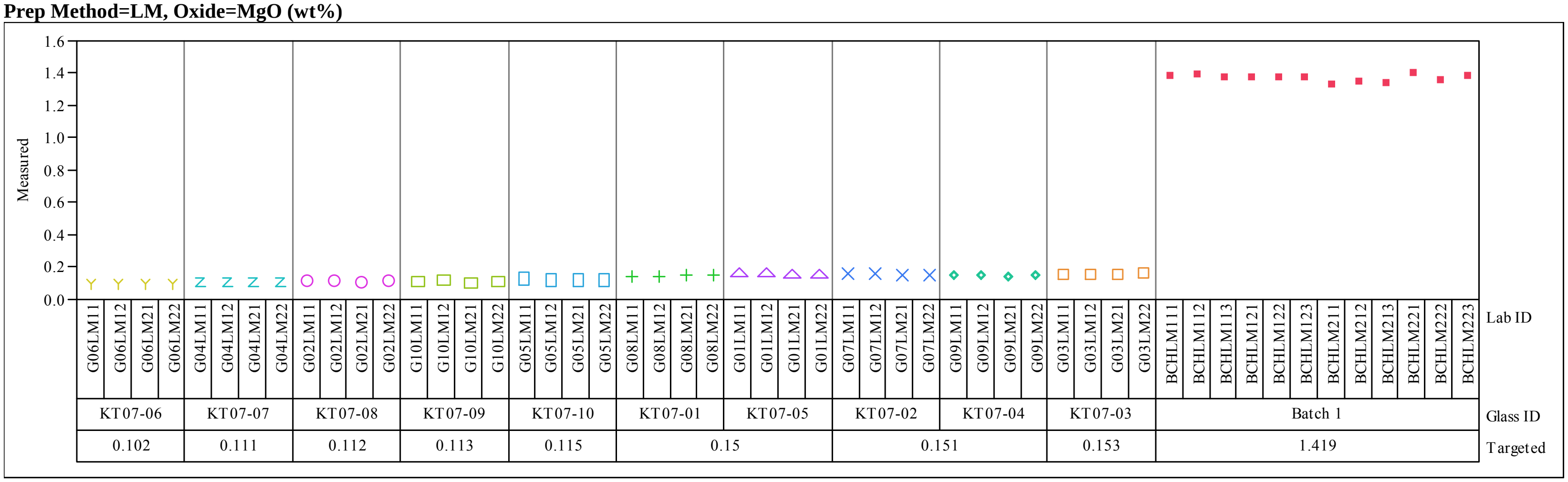
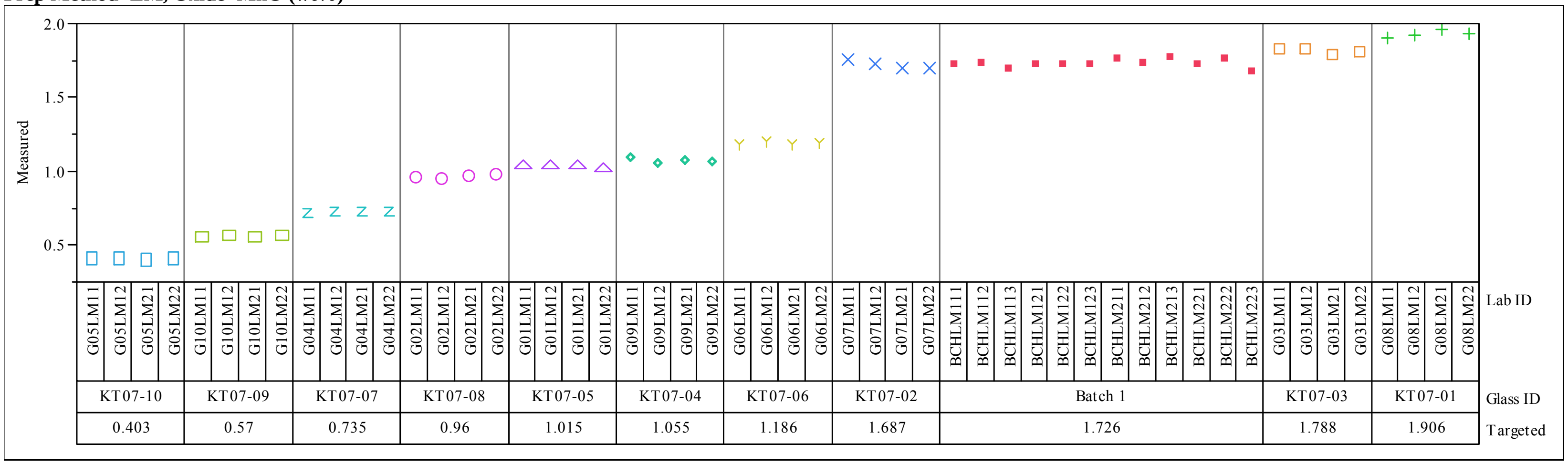


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=MnO (wt%)



Prep Method=LM, Oxide=Na2O (wt%)

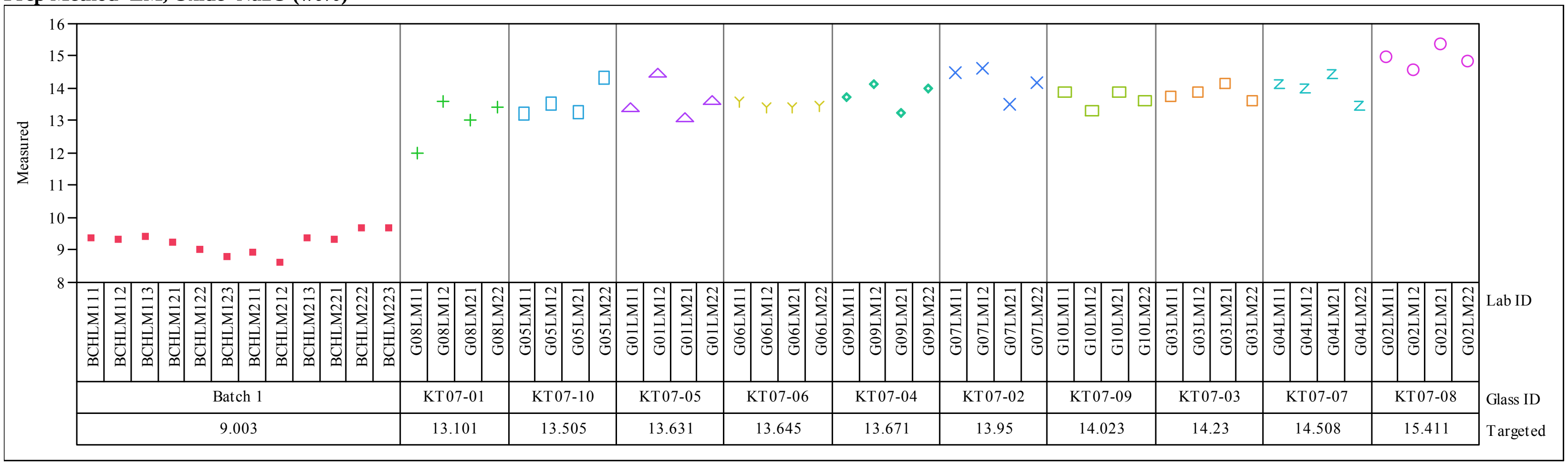
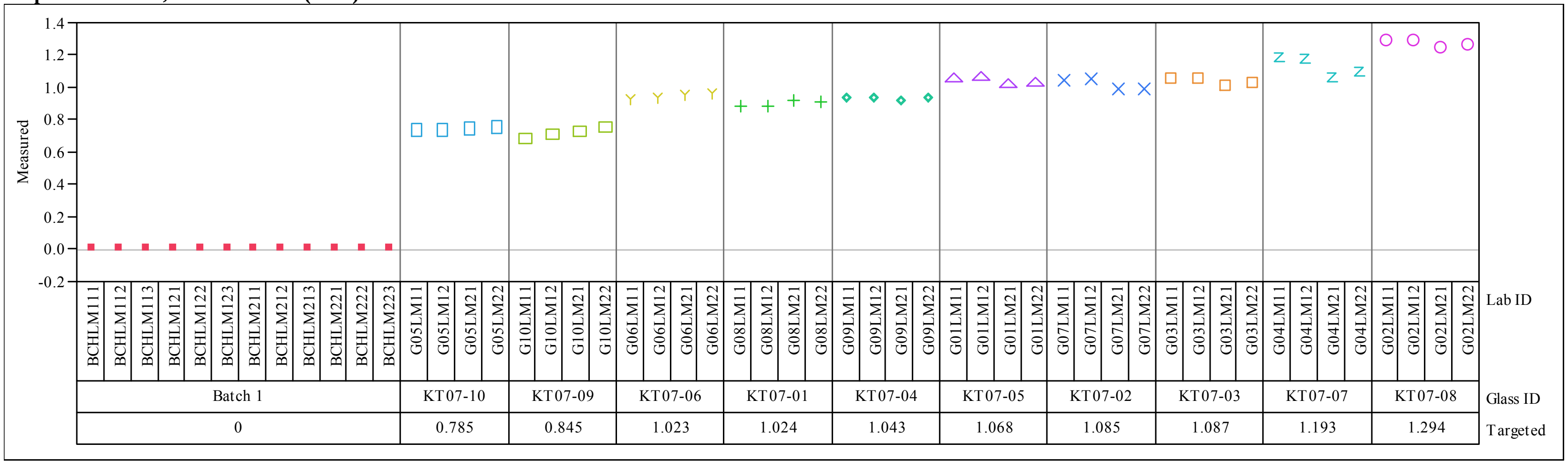


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=Nb2O5 (wt%)



Prep Method=LM, Oxide=NiO (wt%)

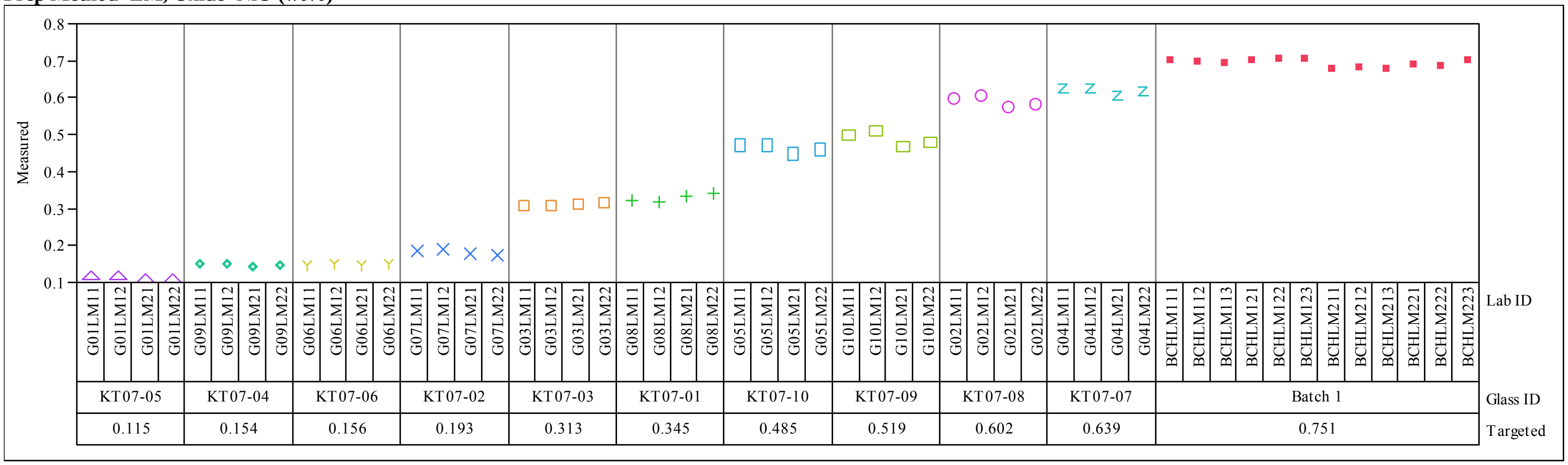
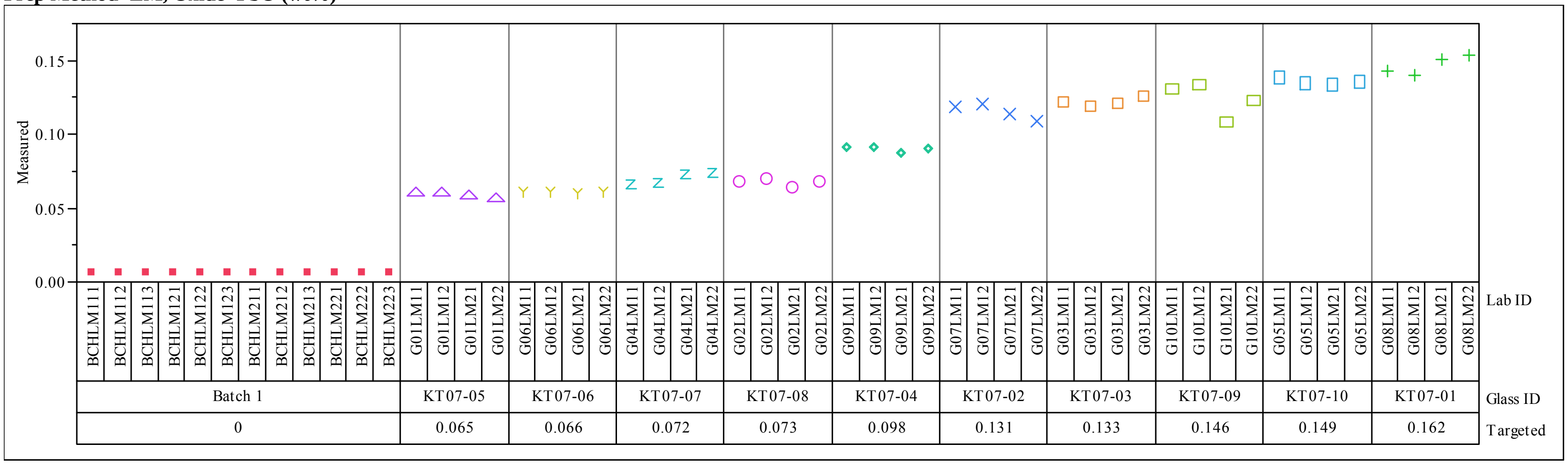


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=PbO (wt%)



Prep Method=LM, Oxide=SiO2 (wt%)

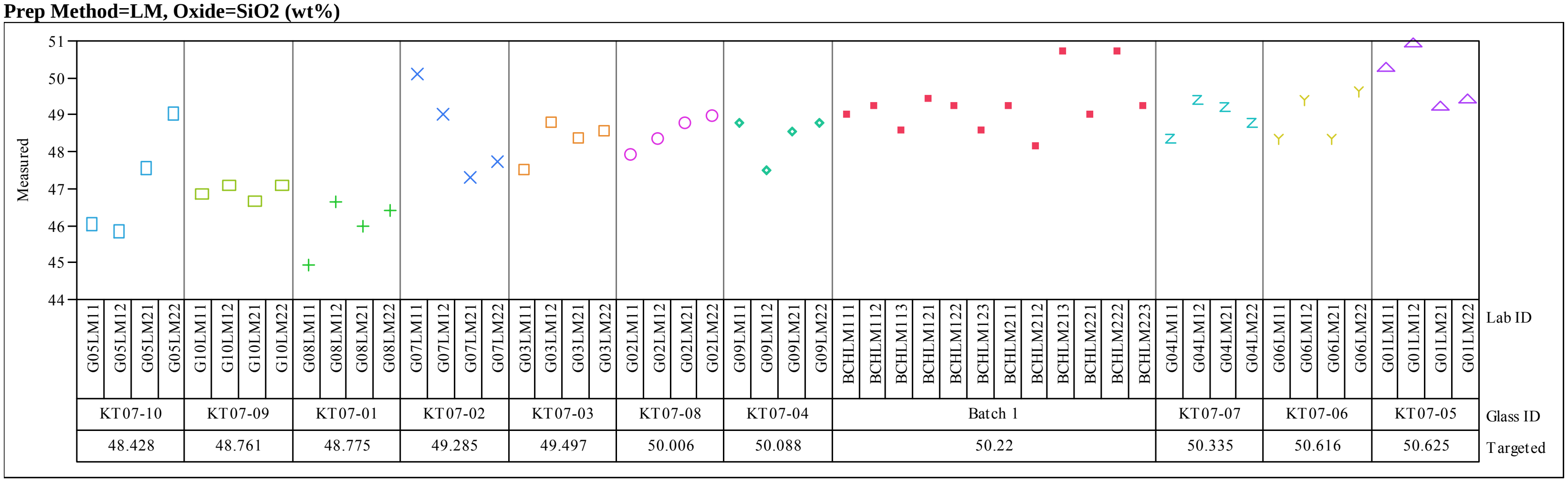
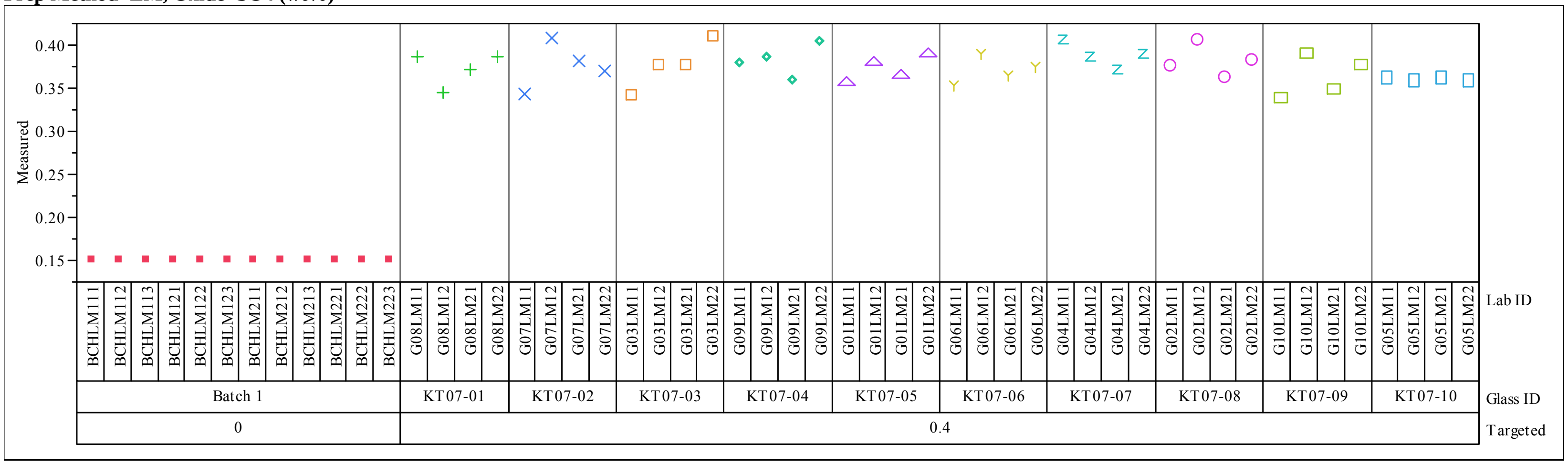


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=SO4 (wt%)



Prep Method=LM, Oxide=TiO2 (wt%)

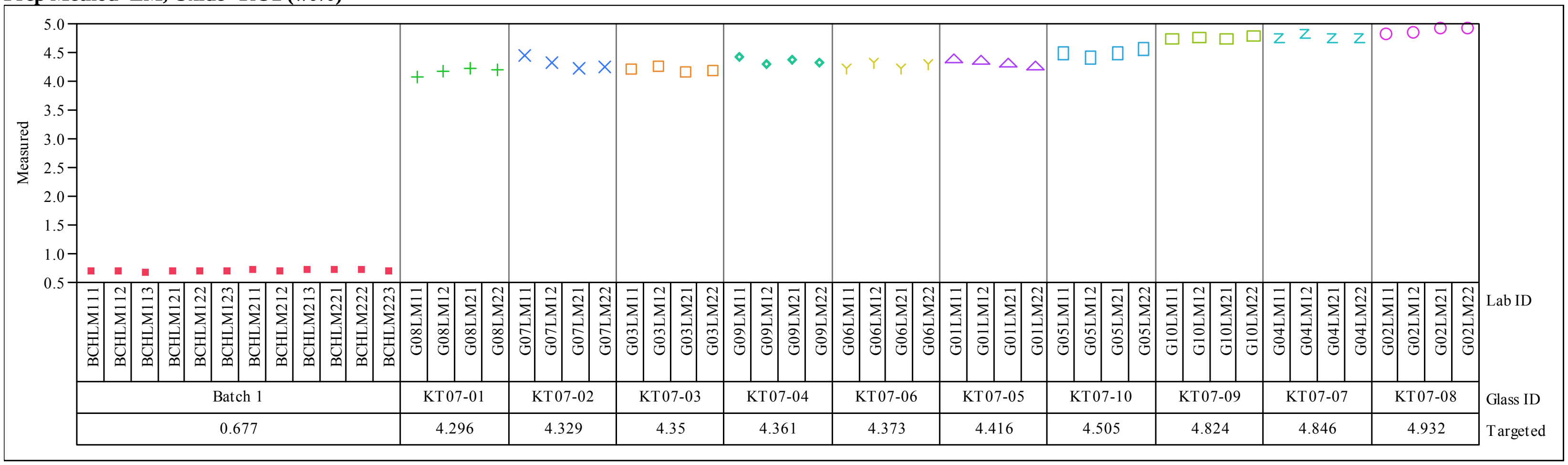
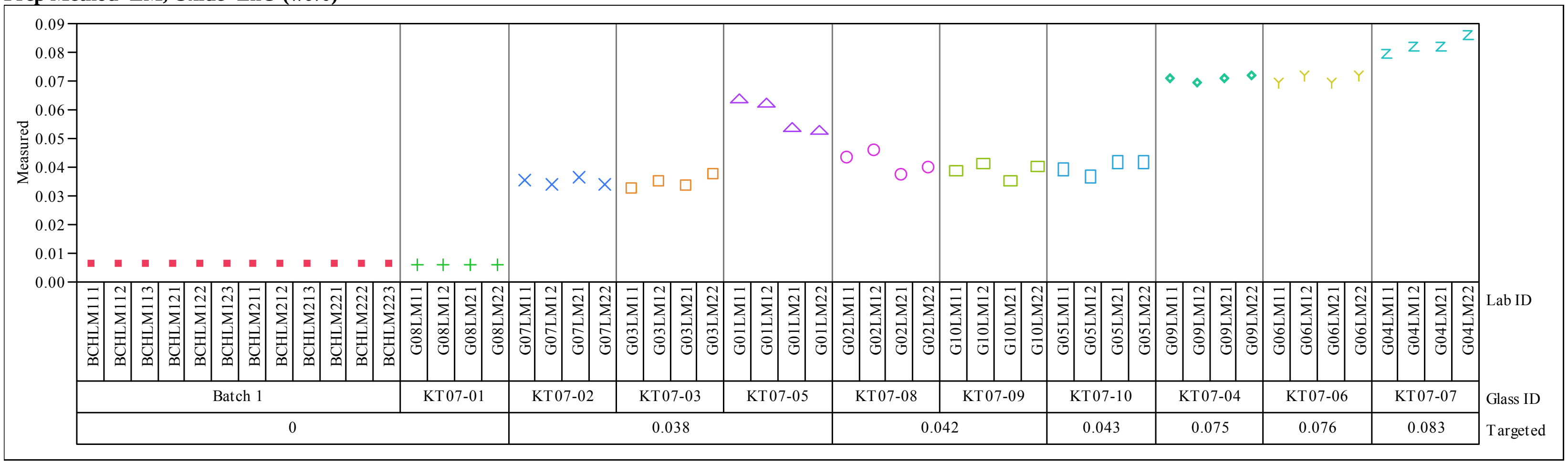


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=LM, Oxide=ZnO (wt%)



Prep Method=LM, Oxide=ZrO2 (wt%)

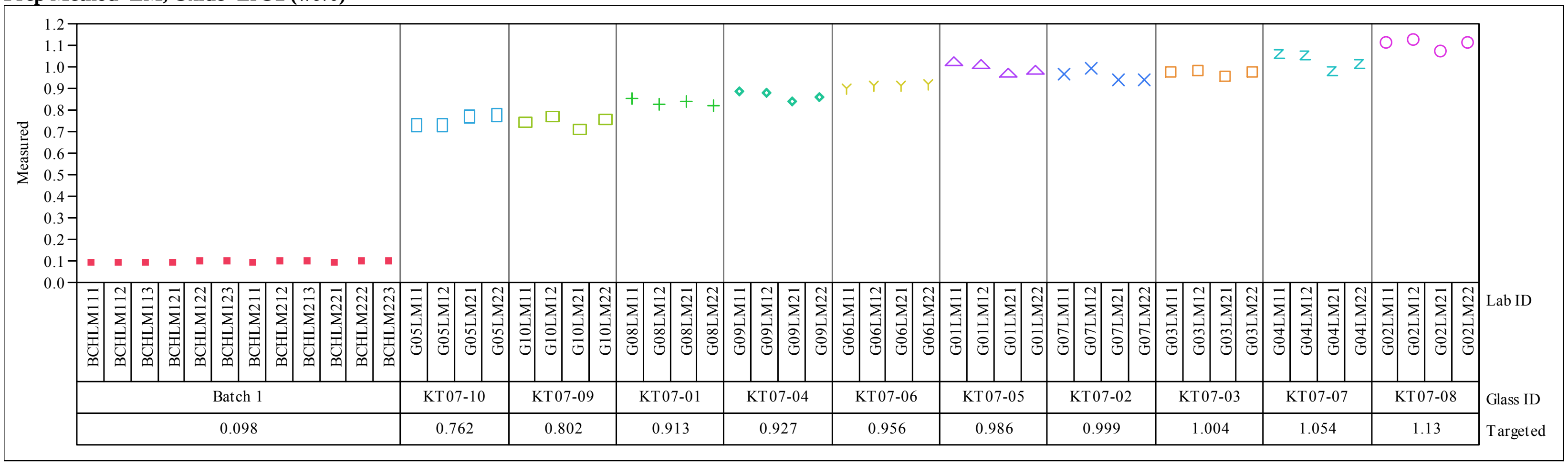
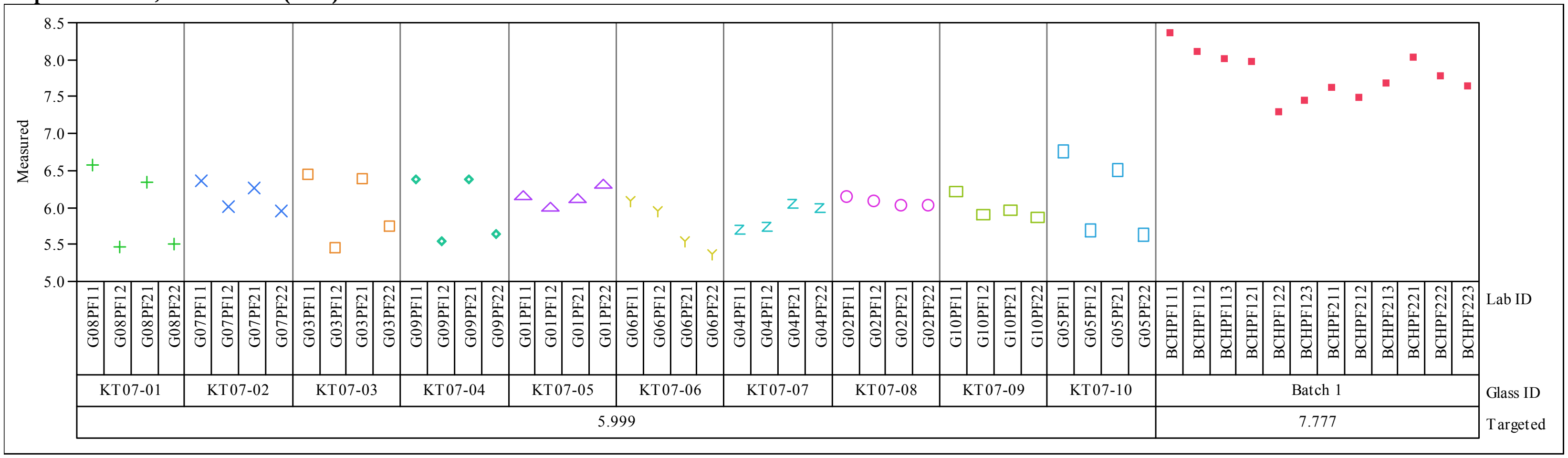


Exhibit A-2. Measurements for Each KT7-Series Glass ID by Preparation Method by Oxide. (continued)

Prep Method=PF, Oxide=B2O3 (wt%)



Prep Method=PF, Oxide=Li2O (wt%)

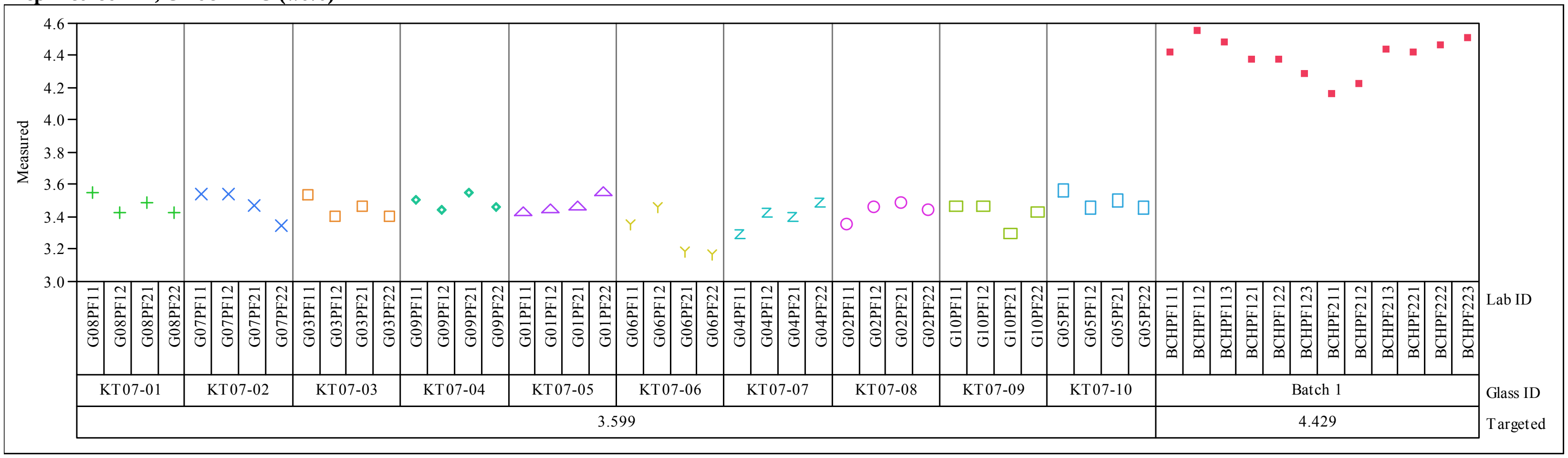
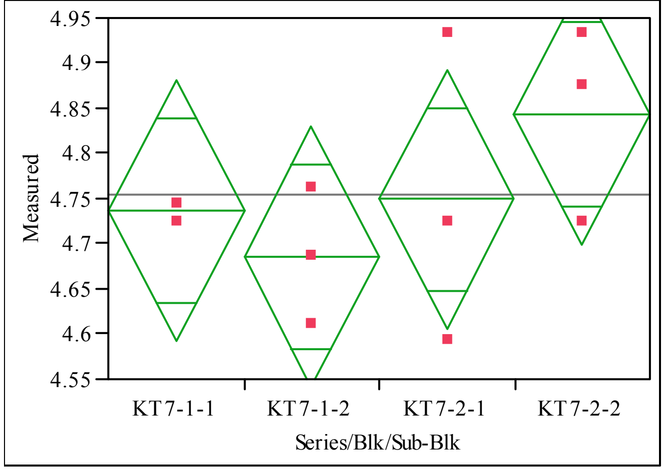


Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide.

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Al2O3 (wt%), Targeted=4.877



Oneway Anova
Summary of Fit

Rsquare	0.293642
Adj Rsquare	0.028758
Root Mean Square Error	0.108132
Mean of Response	4.753667
Observations (or Sum Wgts)	12

Analysis of Variance

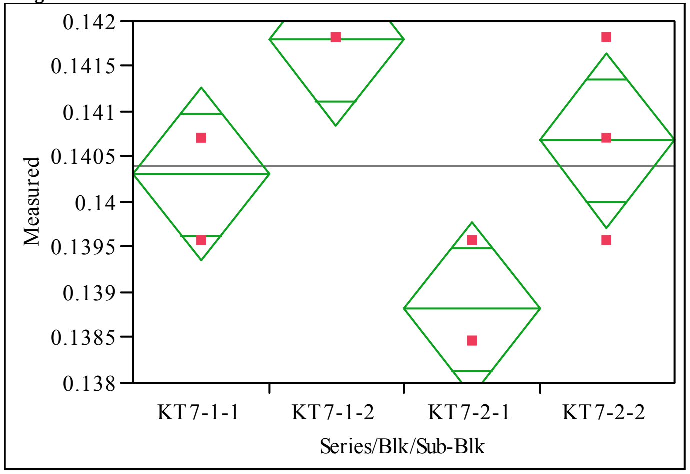
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.03888554	0.012962	1.1086	0.4008
Error	8	0.09353951	0.011692		
C. Total	11	0.13242505			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	4.73635	0.06243	4.5924	4.8803
KT7-1-2	3	4.68596	0.06243	4.5420	4.8299
KT7-2-1	3	4.74894	0.06243	4.6050	4.8929
KT7-2-2	3	4.84342	0.06243	4.6995	4.9874

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=BaO (wt%), Targeted=0.151



Oneway Anova
Summary of Fit

Rsquare	0.766082
Adj Rsquare	0.678363
Root Mean Square Error	0.000721
Mean of Response	0.1404
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00001361	4.5361e-6	8.7333	0.0066
Error	8	0.00000416	5.1941e-7		
C. Total	11	0.00001776			

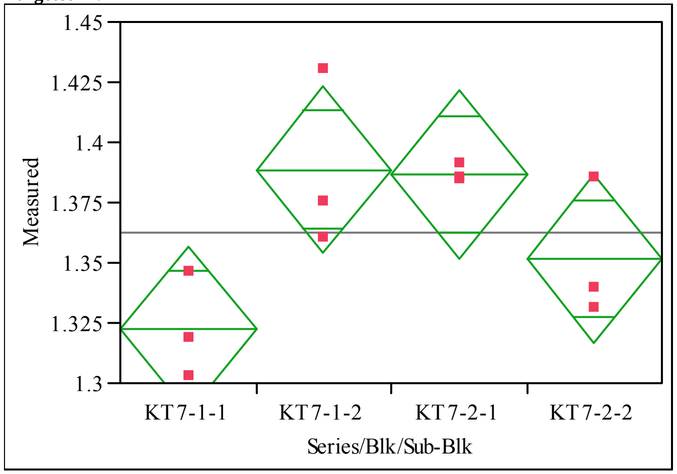
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.140307	0.00042	0.13935	0.14127
KT7-1-2	3	0.141796	0.00042	0.14084	0.14276
KT7-2-1	3	0.138818	0.00042	0.13786	0.13978
KT7-2-2	3	0.140679	0.00042	0.13972	0.14164

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=CaO (wt%), Targeted=1.22



Oneway Anova
Summary of Fit

Rsquare	0.623495
Adj Rsquare	0.482306
Root Mean Square Error	0.026039
Mean of Response	1.362238
Observations (or Sum Wgts)	12

Analysis of Variance

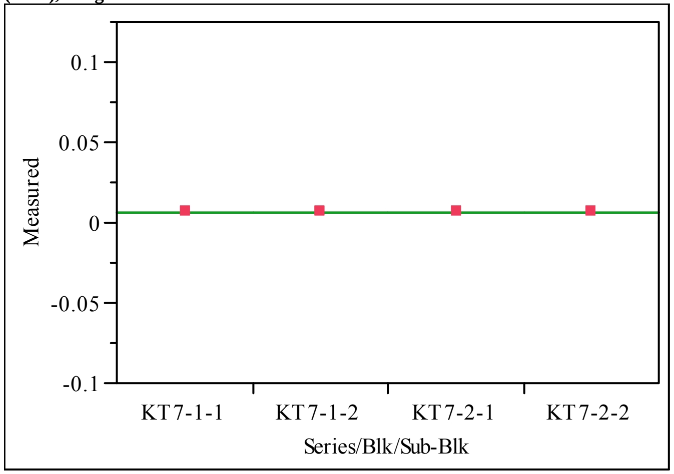
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00898270	0.002994	4.4160	0.0413
Error	8	0.00542430	0.000678		
C. Total	11	0.01440700			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	1.32224	0.01503	1.2876	1.3569
KT7-1-2	3	1.38847	0.01503	1.3538	1.4231
KT7-2-1	3	1.38661	0.01503	1.3519	1.4213
KT7-2-2	3	1.35163	0.01503	1.3170	1.3863

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Ce2O3 (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005857
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

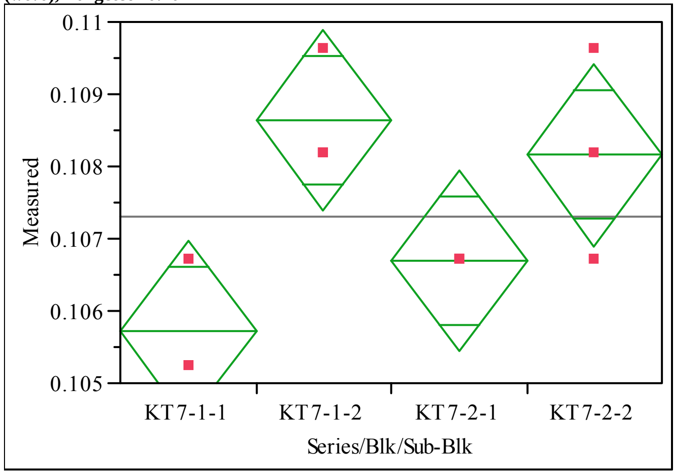
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.005857	0	0.00586	0.00586
KT7-1-2	3	0.005857	0	0.00586	0.00586
KT7-2-1	3	0.005857	0	0.00586	0.00586
KT7-2-2	3	0.005857	0	0.00586	0.00586

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Cr2O3 (wt%), Targeted=0.107



Oneway Anova
Summary of Fit

Rsquare	0.694656
Adj Rsquare	0.580153
Root Mean Square Error	0.000943
Mean of Response	0.107306
Observations (or Sum Wgts)	12

Analysis of Variance

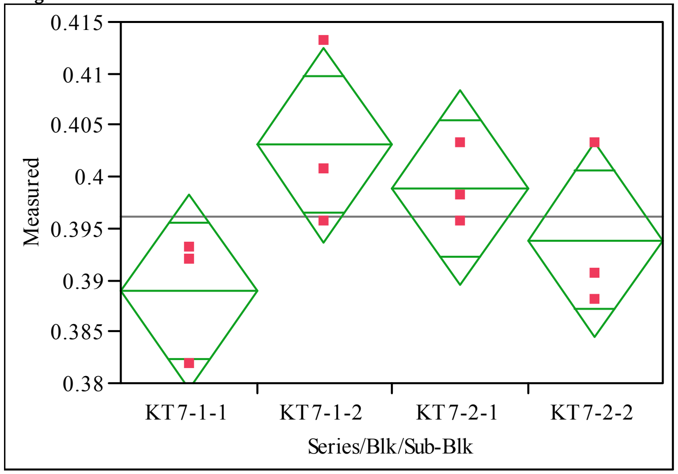
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00001620	0.0000054	6.0667	0.0186
Error	8	0.00000712	8.9011e-7		
C. Total	11	0.00002332			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.105722	0.00054	0.10447	0.10698
KT7-1-2	3	0.108646	0.00054	0.10739	0.10990
KT7-2-1	3	0.106697	0.00054	0.10544	0.10795
KT7-2-2	3	0.108158	0.00054	0.10690	0.10941

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=CuO (wt%), Targeted=0.399



Oneway Anova
Summary of Fit

Rsquare	0.460722
Adj Rsquare	0.258493
Root Mean Square Error	0.007054
Mean of Response	0.396195
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00034004	0.000113	2.2782	0.1565
Error	8	0.00039802	0.000050		
C. Total	11	0.00073806			

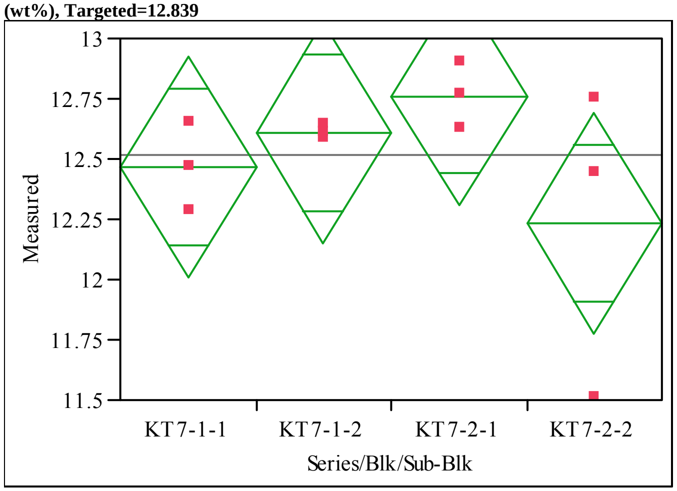
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.388893	0.00407	0.37950	0.39828
KT7-1-2	3	0.403080	0.00407	0.39369	0.41247
KT7-2-1	3	0.398907	0.00407	0.38952	0.40830
KT7-2-2	3	0.393900	0.00407	0.38451	0.40329

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Fe2O3 (wt%), Targeted=12.839



Oneway Anova
Summary of Fit

Rsquare	0.325341
Adj Rsquare	0.072344
Root Mean Square Error	0.34355
Mean of Response	12.51821
Observations (or Sum Wgts)	12

Analysis of Variance

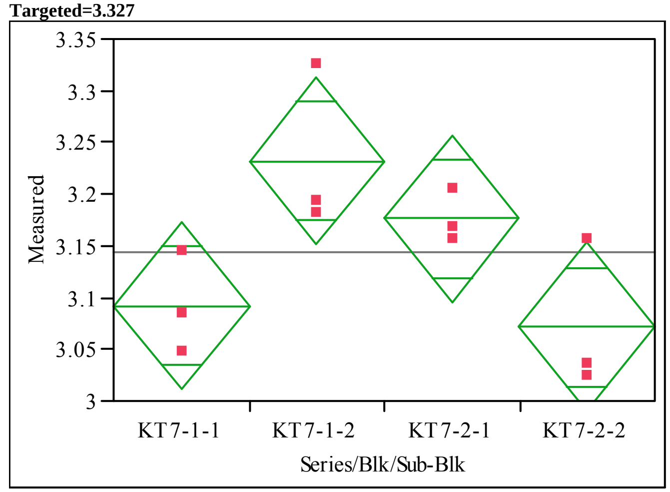
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.4553274	0.151776	1.2859	0.3436
Error	8	0.9442112	0.118026		
C. Total	11	1.3995386			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	12.4670	0.19835	12.010	12.924
KT7-1-2	3	12.6100	0.19835	12.153	13.067
KT7-2-1	3	12.7625	0.19835	12.305	13.220
KT7-2-2	3	12.2335	0.19835	11.776	12.691

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=K2O (wt%), Targeted=3.327



Oneway Anova
Summary of Fit

Rsquare	0.629708
Adj Rsquare	0.490849
Root Mean Square Error	0.060829
Mean of Response	3.143002
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.05033973	0.016780	4.5349	0.0388
Error	8	0.02960165	0.003700		
C. Total	11	0.07994138			

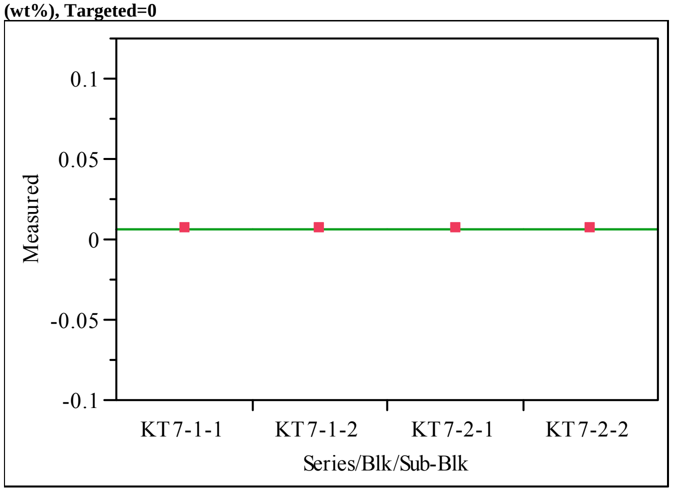
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	3.09181	0.03512	3.0108	3.1728
KT7-1-2	3	3.23234	0.03512	3.1514	3.3133
KT7-2-1	3	3.17613	0.03512	3.0951	3.2571
KT7-2-2	3	3.07173	0.03512	2.9907	3.1527

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=La2O3 (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.005864
Observations (or Sum Wgts)	12

Analysis of Variance

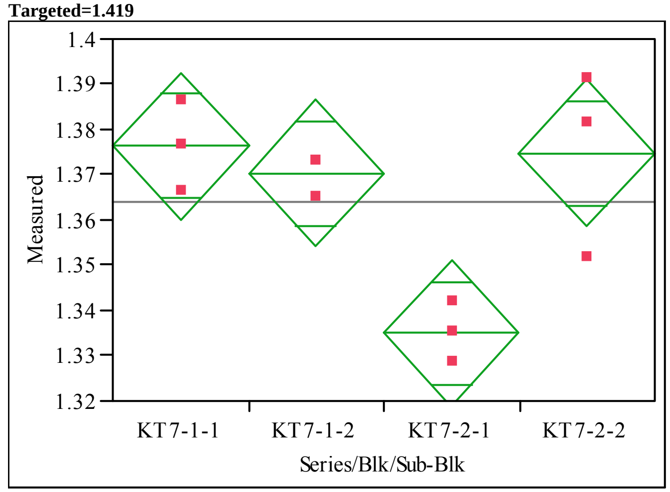
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.005864	0	0.00586	0.00586
KT7-1-2	3	0.005864	0	0.00586	0.00586
KT7-2-1	3	0.005864	0	0.00586	0.00586
KT7-2-2	3	0.005864	0	0.00586	0.00586

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=MgO (wt%), Targeted=1.419



Oneway Anova
Summary of Fit

Rsquare	0.744123
Adj Rsquare	0.648169
Root Mean Square Error	0.012195
Mean of Response	1.36409
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00346014	0.001153	7.7550	0.0094
Error	8	0.00118982	0.000149		
C. Total	11	0.00464995			

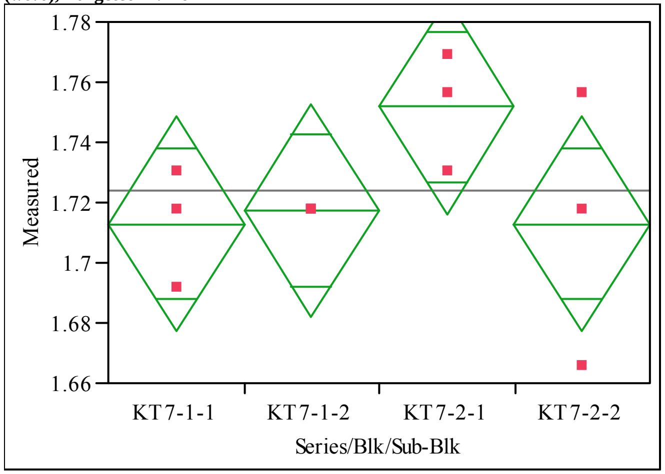
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	1.37639	0.00704	1.3602	1.3926
KT7-1-2	3	1.37031	0.00704	1.3541	1.3865
KT7-2-1	3	1.33493	0.00704	1.3187	1.3512
KT7-2-2	3	1.37473	0.00704	1.3585	1.3910

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=MnO (wt%), Targeted=1.726



Oneway Anova
Summary of Fit

Rsquare	0.358491
Adj Rsquare	0.117925
Root Mean Square Error	0.026619
Mean of Response	1.723752
Observations (or Sum Wgts)	12

Analysis of Variance

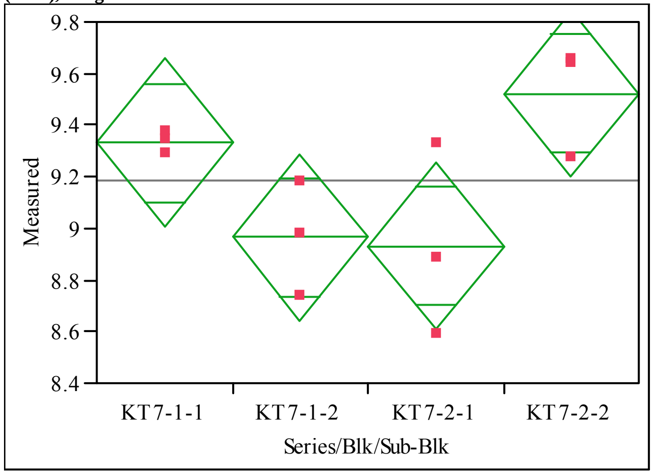
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00316768	0.001056	1.4902	0.2892
Error	8	0.00566847	0.000709		
C. Total	11	0.00883615			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	1.71299	0.01537	1.6776	1.7484
KT7-1-2	3	1.71730	0.01537	1.6819	1.7527
KT7-2-1	3	1.75173	0.01537	1.7163	1.7872
KT7-2-2	3	1.71299	0.01537	1.6776	1.7484

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Na2O (wt%), Targeted=9.003



Oneway Anova
Summary of Fit

Rsquare	0.610766
Adj Rsquare	0.464803
Root Mean Square Error	0.243108
Mean of Response	9.187743
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.7419084	0.247303	4.1844	0.0468
Error	8	0.4728105	0.059101		
C. Total	11	1.2147189			

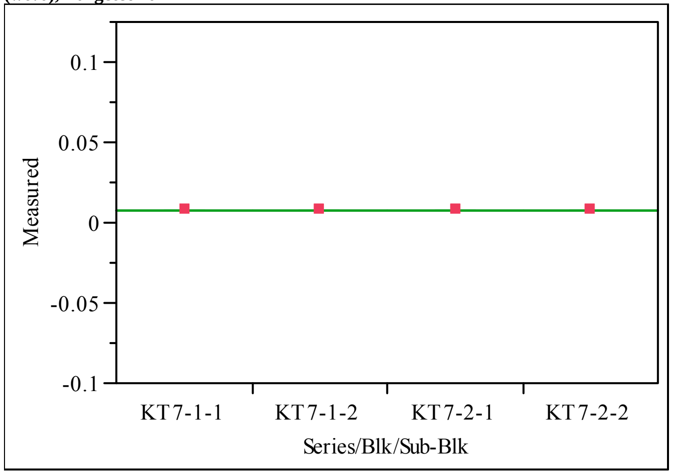
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	9.33265	0.14036	9.0090	9.6563
KT7-1-2	3	8.96420	0.14036	8.6405	9.2879
KT7-2-1	3	8.93275	0.14036	8.6091	9.2564
KT7-2-2	3	9.52137	0.14036	9.1977	9.8450

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=Nb2O5 (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	0
Adj Rsquare	-0.375
Root Mean Square Error	1.06e-18
Mean of Response	0.007153
Observations (or Sum Wgts)	12

Analysis of Variance

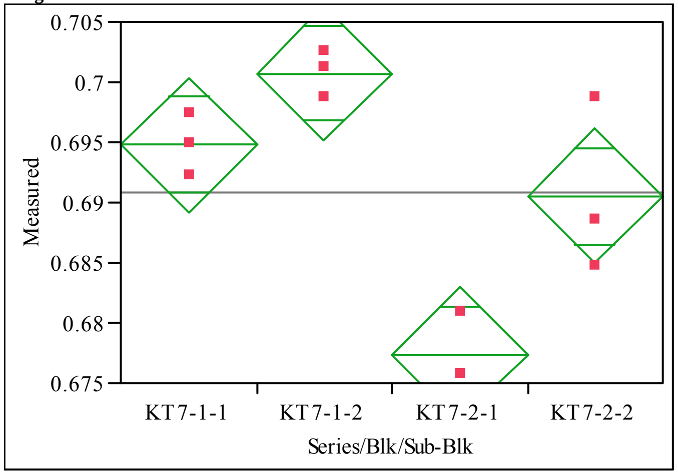
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	0.0000	1.0000
Error	8	9.0278e-36	1.128e-36		
C. Total	11	9.0278e-36			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.007153	6.133e-19	0.00715	0.00715
KT7-1-2	3	0.007153	6.133e-19	0.00715	0.00715
KT7-2-1	3	0.007153	6.133e-19	0.00715	0.00715
KT7-2-2	3	0.007153	6.133e-19	0.00715	0.00715

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=NiO (wt%), Targeted=0.751



Oneway Anova
Summary of Fit

Rsquare	0.860961
Adj Rsquare	0.808822
Root Mean Square Error	0.00422
Mean of Response	0.690861
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00088236	0.000294	16.5126	0.0009
Error	8	0.00014249	0.000018		
C. Total	11	0.00102485			

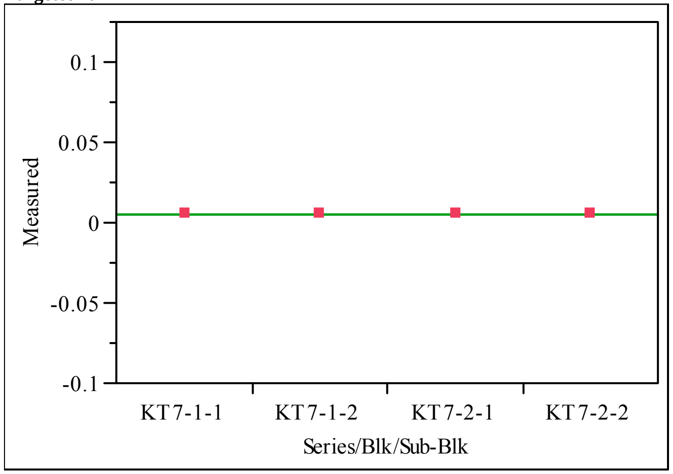
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.694785	0.00244	0.68917	0.70040
KT7-1-2	3	0.700723	0.00244	0.69510	0.70634
KT7-2-1	3	0.677394	0.00244	0.67178	0.68301
KT7-2-2	3	0.690543	0.00244	0.68492	0.69616

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=PbO (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	0
Adj Rsquare	-0.375
Root Mean Square Error	1.06e-18
Mean of Response	0.005386
Observations (or Sum Wgts)	12

Analysis of Variance

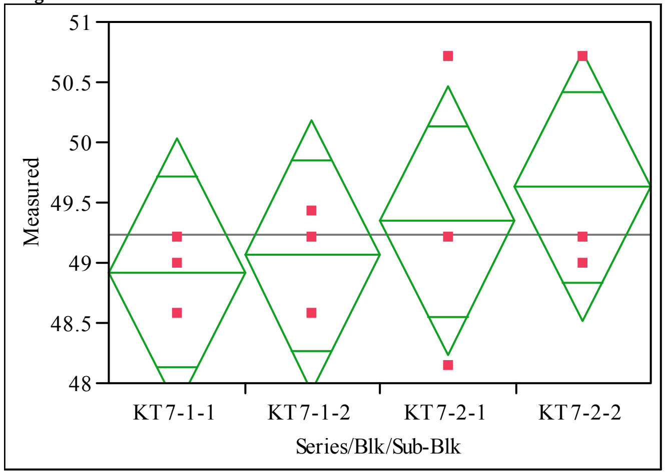
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	0.0000	1.0000
Error	8	9.0278e-36	1.128e-36		
C. Total	11	9.0278e-36			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.005386	6.133e-19	0.00539	0.00539
KT7-1-2	3	0.005386	6.133e-19	0.00539	0.00539
KT7-2-1	3	0.005386	6.133e-19	0.00539	0.00539
KT7-2-2	3	0.005386	6.133e-19	0.00539	0.00539

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=SiO2 (wt%), Targeted=50.22



Oneway Anova
Summary of Fit

Rsquare	0.136891
Adj Rsquare	-0.18677
Root Mean Square Error	0.842243
Mean of Response	49.23956
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.9000655	0.300022	0.4229	0.7418
Error	8	5.6749896	0.709374		
C. Total	11	6.5750551			

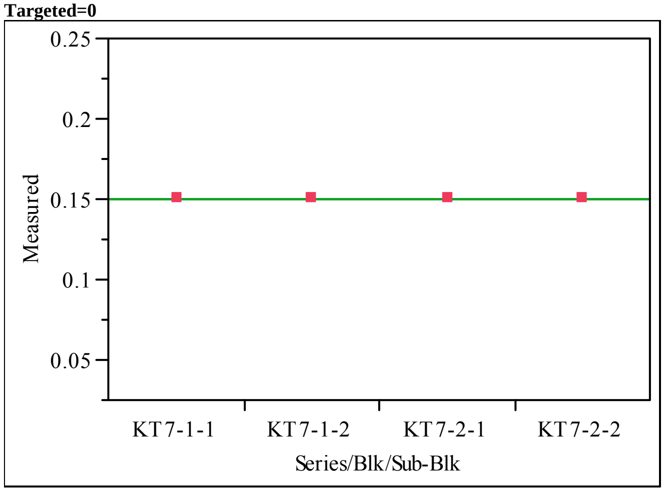
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	48.9187	0.48627	47.797	50.040
KT7-1-2	3	49.0613	0.48627	47.940	50.183
KT7-2-1	3	49.3465	0.48627	48.225	50.468
KT7-2-2	3	49.6318	0.48627	48.510	50.753

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=SO4 (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.149795
Observations (or Sum Wgts)	12

Analysis of Variance

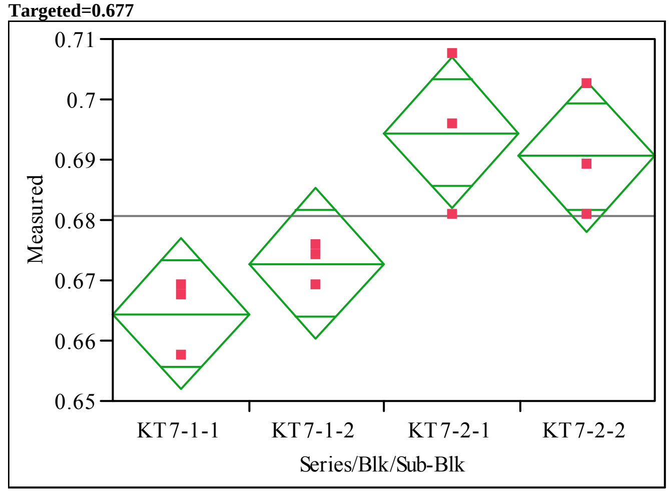
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.149795	0	0.14980	0.14980
KT7-1-2	3	0.149795	0	0.14980	0.14980
KT7-2-1	3	0.149795	0	0.14980	0.14980
KT7-2-2	3	0.149795	0	0.14980	0.14980

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=TiO2 (wt%), Targeted=0.677



Oneway Anova
Summary of Fit

Rsquare	0.724289
Adj Rsquare	0.620897
Root Mean Square Error	0.009362
Mean of Response	0.680544
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00184183	0.000614	7.0053	0.0125
Error	8	0.00070112	0.000088		
C. Total	11	0.00254295			

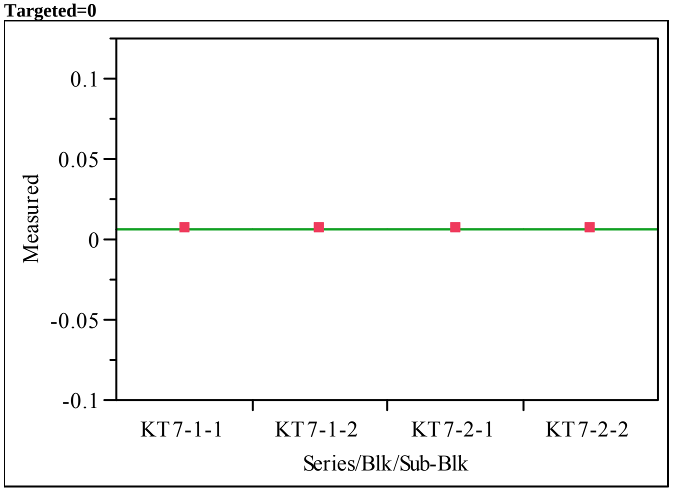
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.664420	0.00540	0.65196	0.67688
KT7-1-2	3	0.672760	0.00540	0.66030	0.68522
KT7-2-1	3	0.694444	0.00540	0.68198	0.70691
KT7-2-2	3	0.690552	0.00540	0.67809	0.70302

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=ZnO (wt%), Targeted=0



Oneway Anova
Summary of Fit

Rsquare	.
Adj Rsquare	.
Root Mean Square Error	0
Mean of Response	0.006224
Observations (or Sum Wgts)	12

Analysis of Variance

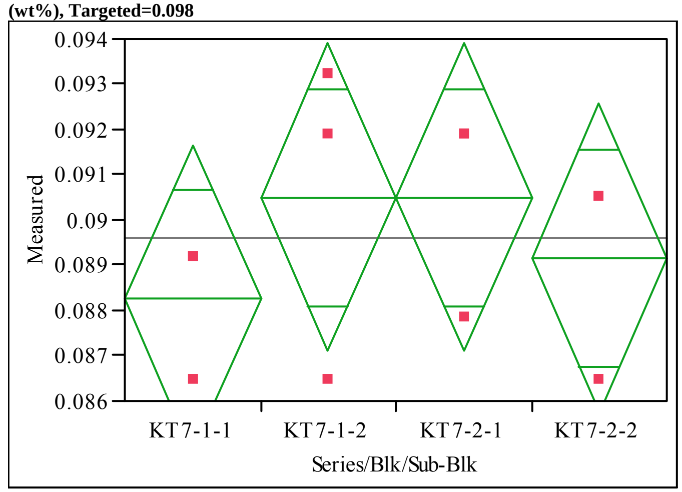
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0	0	.	.
Error	8	0	0		
C. Total	11	0			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.006224	0	0.00622	0.00622
KT7-1-2	3	0.006224	0	0.00622	0.00622
KT7-2-1	3	0.006224	0	0.00622	0.00622
KT7-2-2	3	0.006224	0	0.00622	0.00622

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=LM, Oxide=ZrO2 (wt%), Targeted=0.098



Oneway Anova
Summary of Fit

Rsquare	0.173077
Adj Rsquare	-0.13702
Root Mean Square Error	0.002557
Mean of Response	0.089603
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.00001095	3.6493e-6	0.5581	0.6573
Error	8	0.00005231	6.5384e-6		
C. Total	11	0.00006325			

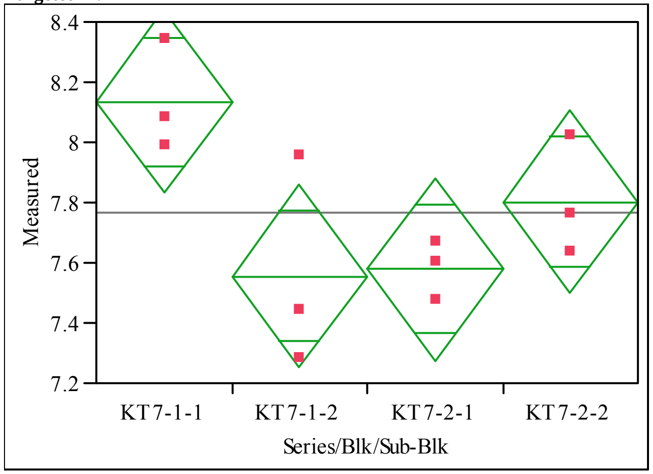
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	0.088252	0.00148	0.08485	0.09166
KT7-1-2	3	0.090504	0.00148	0.08710	0.09391
KT7-2-1	3	0.090504	0.00148	0.08710	0.09391
KT7-2-2	3	0.089153	0.00148	0.08575	0.09256

Std Error uses a pooled estimate of error variance

Exhibit A-3. Statistical Evaluation of the ICP Calibration Effects from the KT07 Batch 1 Results by Oxide. (continued)

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=PF, Oxide=B2O3 (wt%), Targeted=7.777



Oneway Anova
Summary of Fit

Rsquare	0.612286
Adj Rsquare	0.466894
Root Mean Square Error	0.227302
Mean of Response	7.768009
Observations (or Sum Wgts)	12

Analysis of Variance

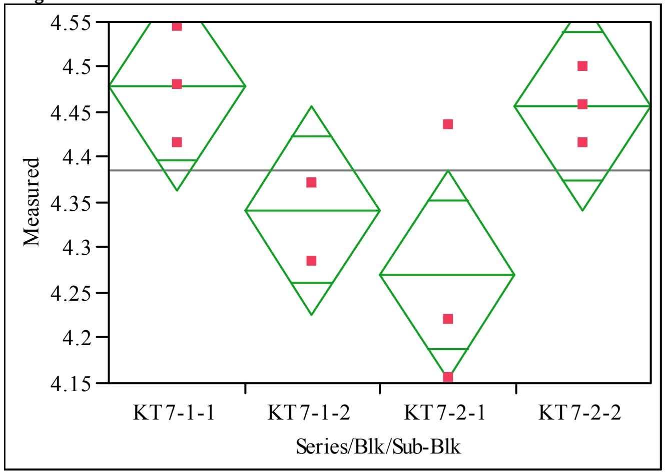
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.6527366	0.217579	4.2113	0.0461
Error	8	0.4133279	0.051666		
C. Total	11	1.0660645			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	8.13561	0.13123	7.8330	8.4382
KT7-1-2	3	7.55603	0.13123	7.2534	7.8587
KT7-2-1	3	7.57750	0.13123	7.2749	7.8801
KT7-2-2	3	7.80289	0.13123	7.5003	8.1055

Std Error uses a pooled estimate of error variance

Oneway Analysis of Measured By Series/Blk/Sub-Blk Series=KT7, Prep Method=PF, Oxide=Li2O (wt%), Targeted=4.429



Oneway Anova
Summary of Fit

Rsquare	0.591041
Adj Rsquare	0.437681
Root Mean Square Error	0.086563
Mean of Response	4.386534
Observations (or Sum Wgts)	12

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Series/Blk/Sub-Blk	3	0.08663547	0.028878	3.8540	0.0564
Error	8	0.05994572	0.007493		
C. Total	11	0.14658119			

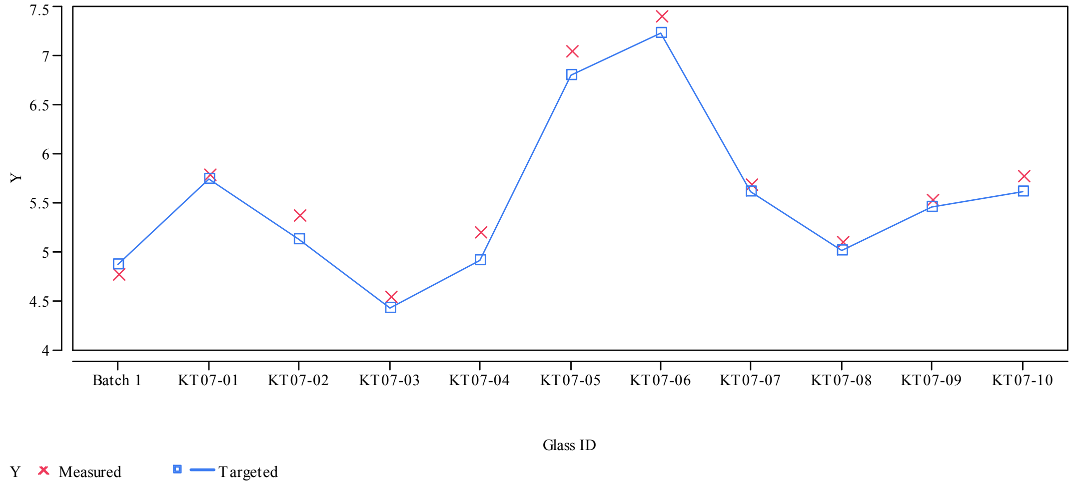
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
KT7-1-1	3	4.47803	0.04998	4.3628	4.5933
KT7-1-2	3	4.34168	0.04998	4.2264	4.4569
KT7-2-1	3	4.26992	0.04998	4.1547	4.3852
KT7-2-2	3	4.45650	0.04998	4.3413	4.5718

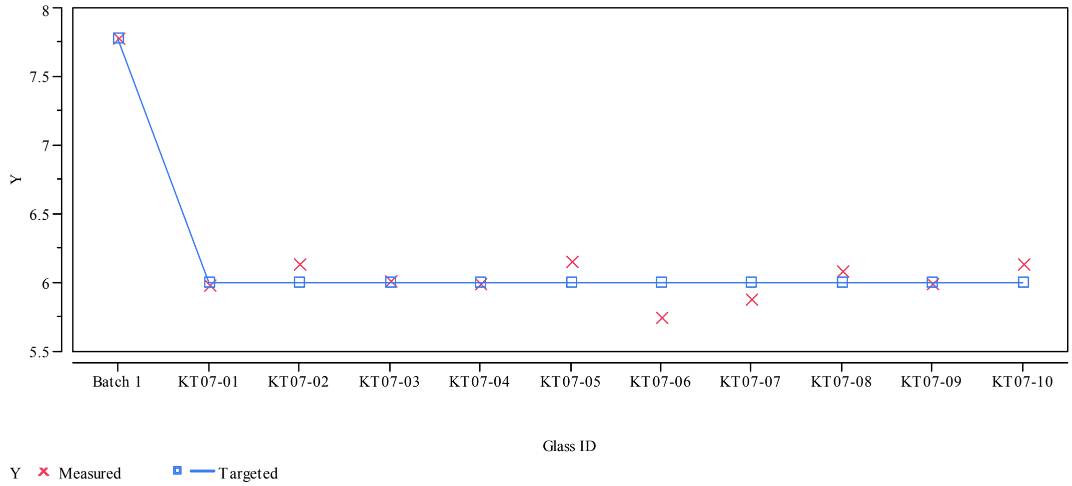
Std Error uses a pooled estimate of error variance

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

Oxide=Al2O3 (wt%)



Oxide=B2O3 (wt%)



Oxide=BaO (wt%)

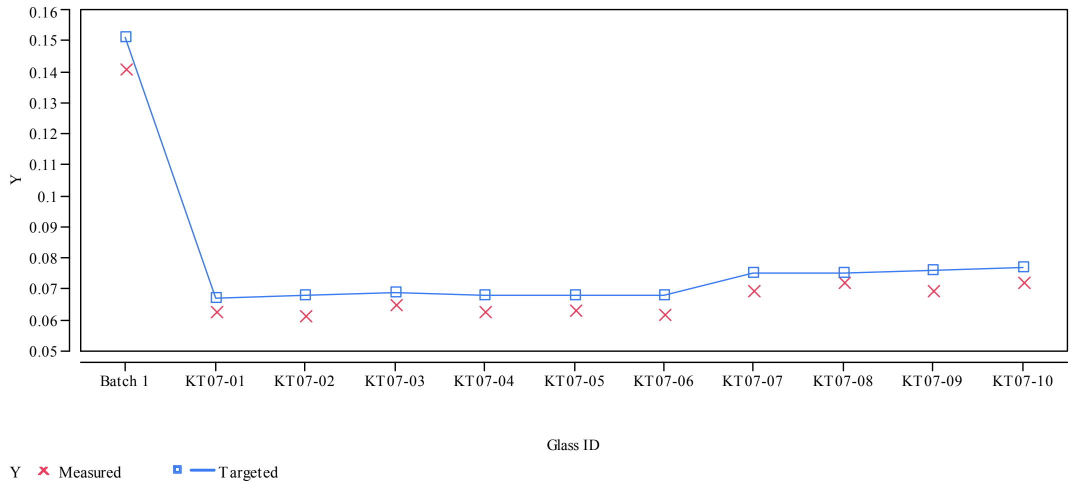
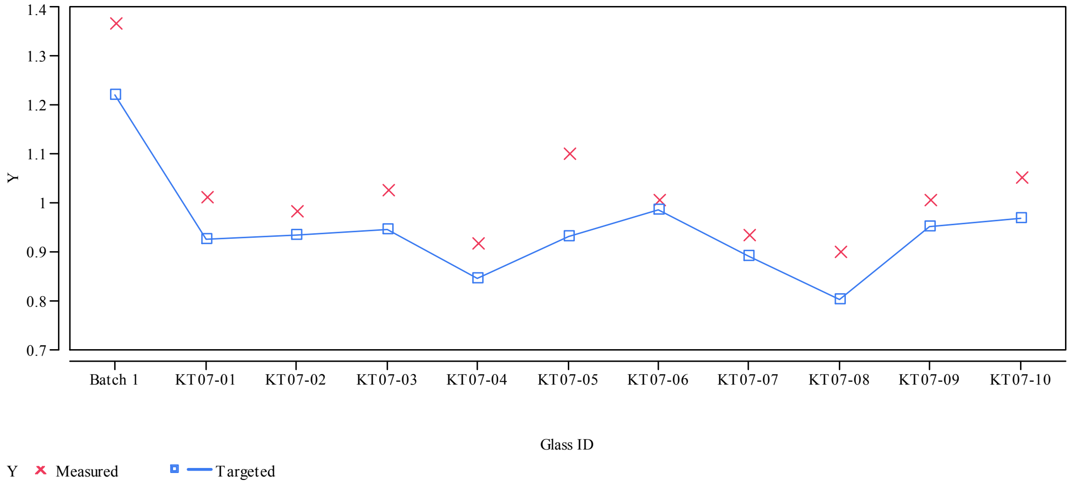
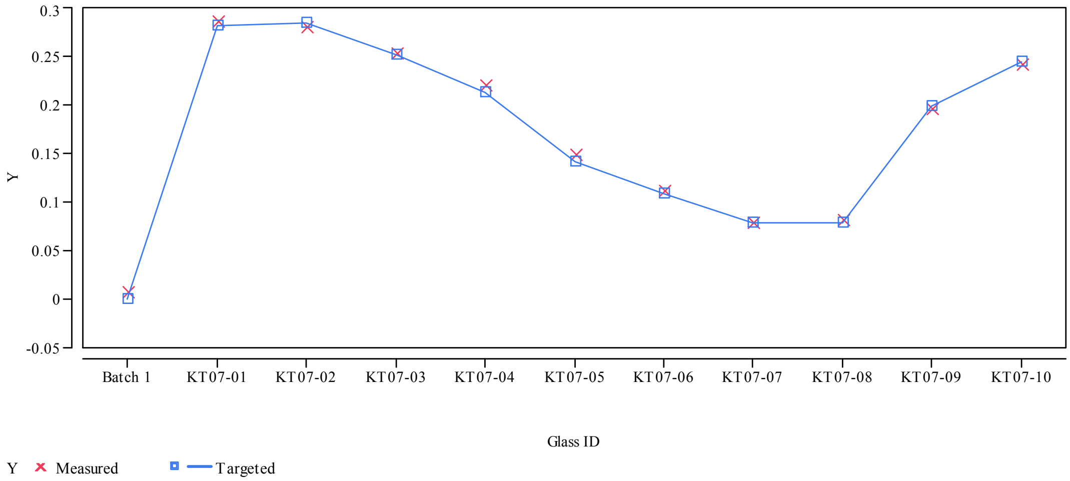


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=CaO (wt%)



Oxide=Ce2O3 (wt%)



Oxide=Cr2O3 (wt%)

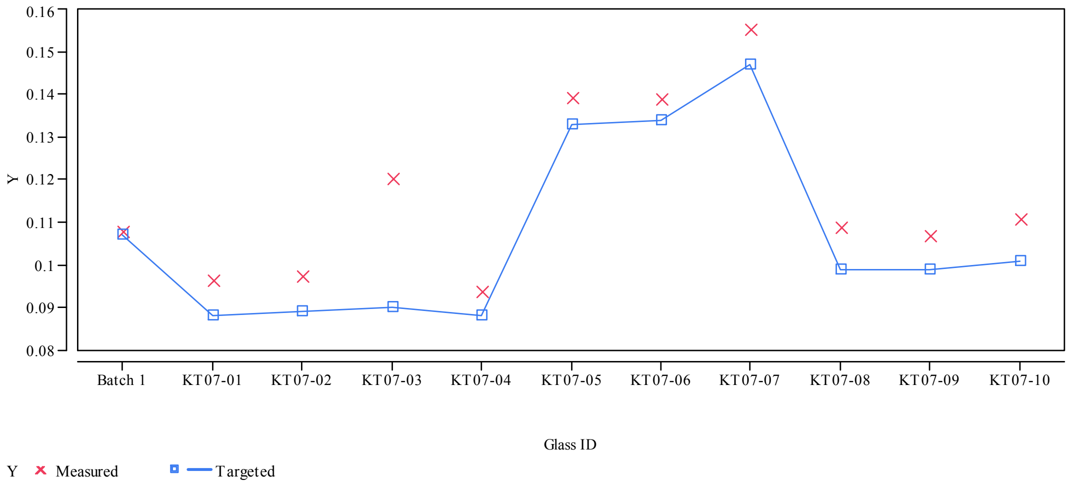
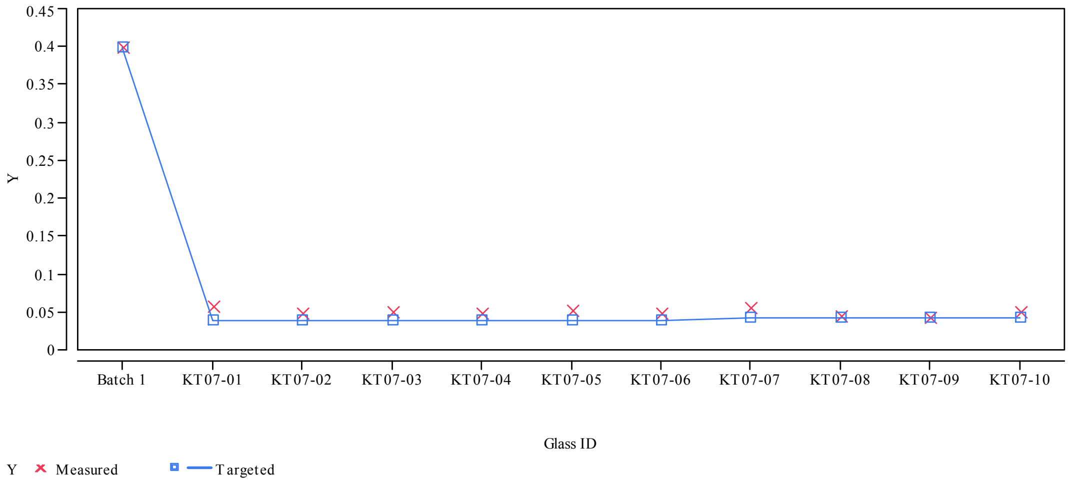
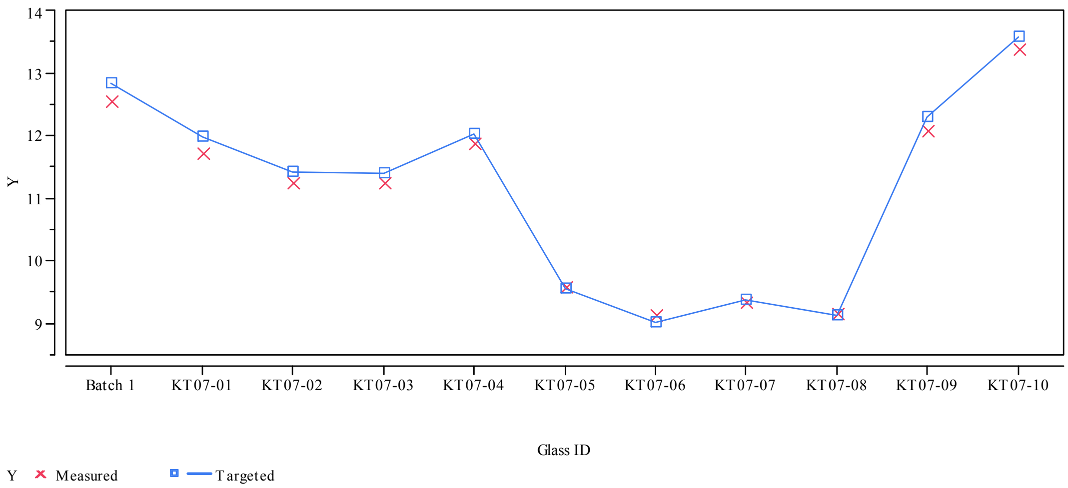


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=CuO (wt%)



Oxide=Fe2O3 (wt%)



Oxide=K2O (wt%)

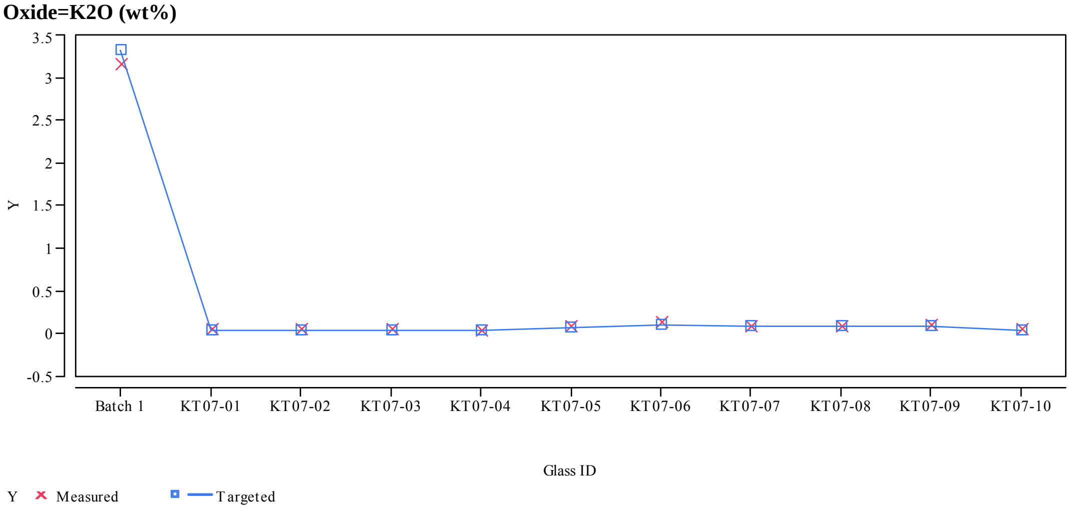
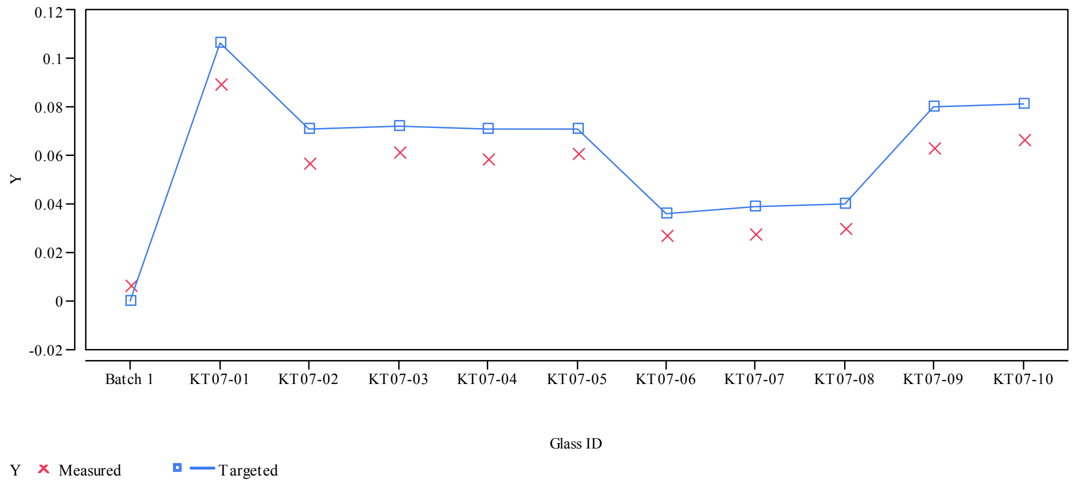
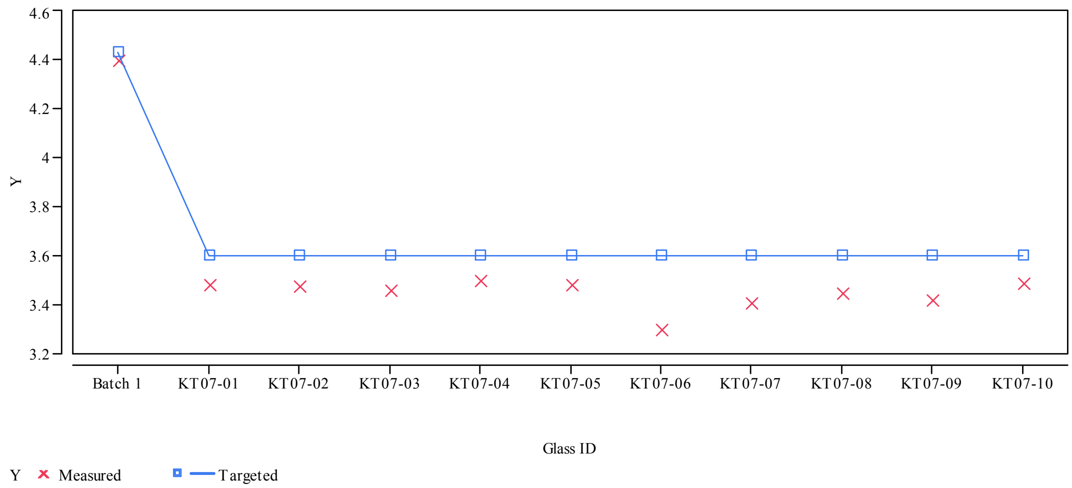


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=La2O3 (wt%)



Oxide=Li2O (wt%)



Oxide=MgO (wt%)

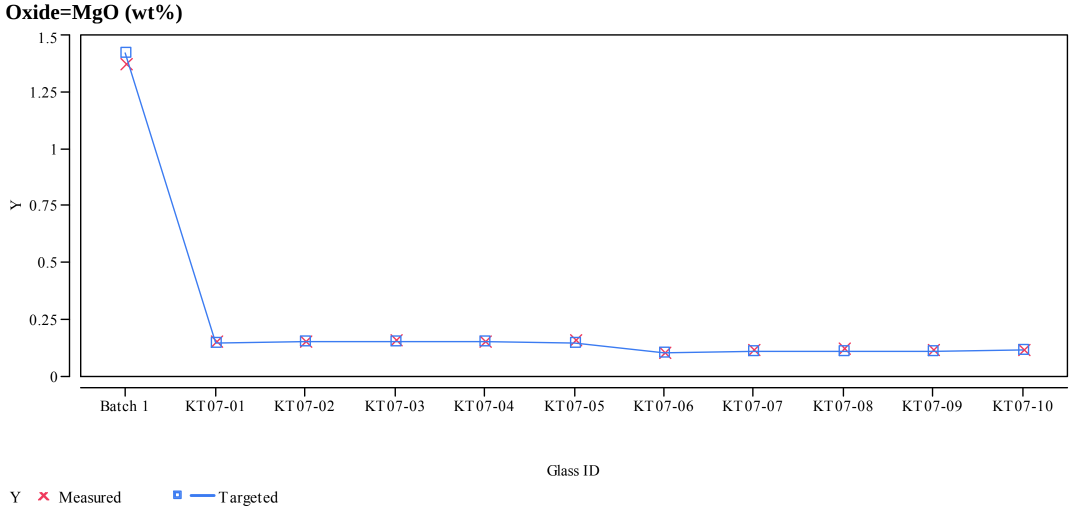
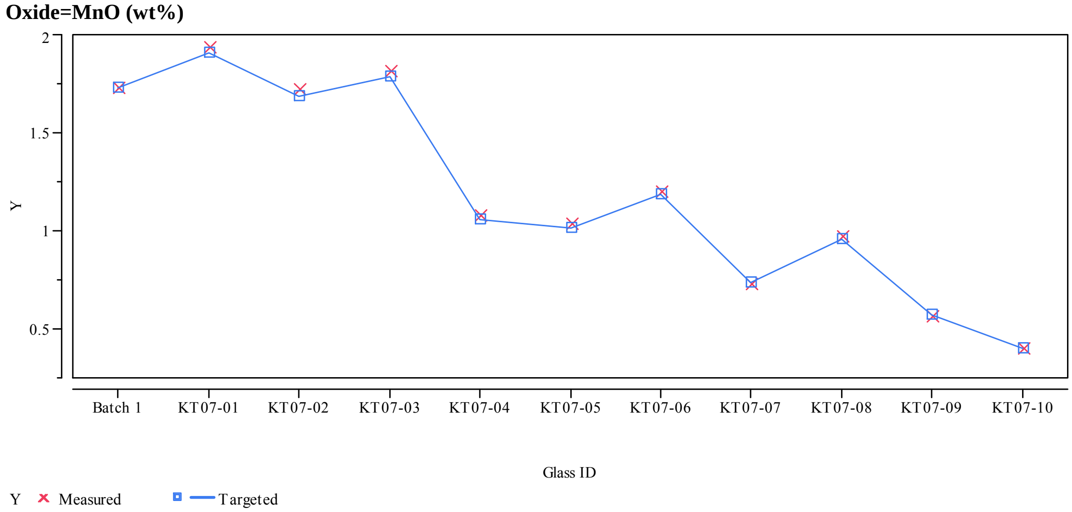
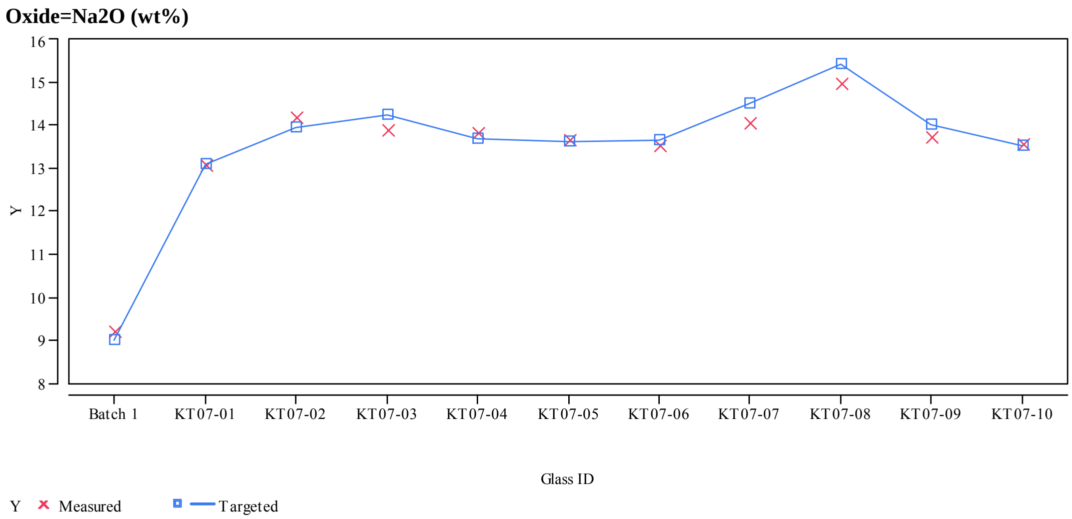


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)





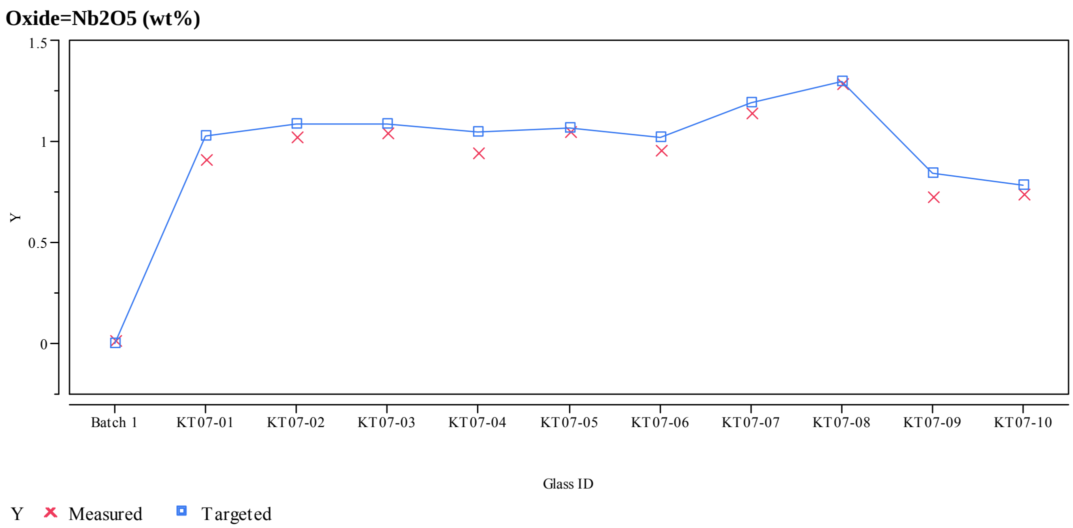
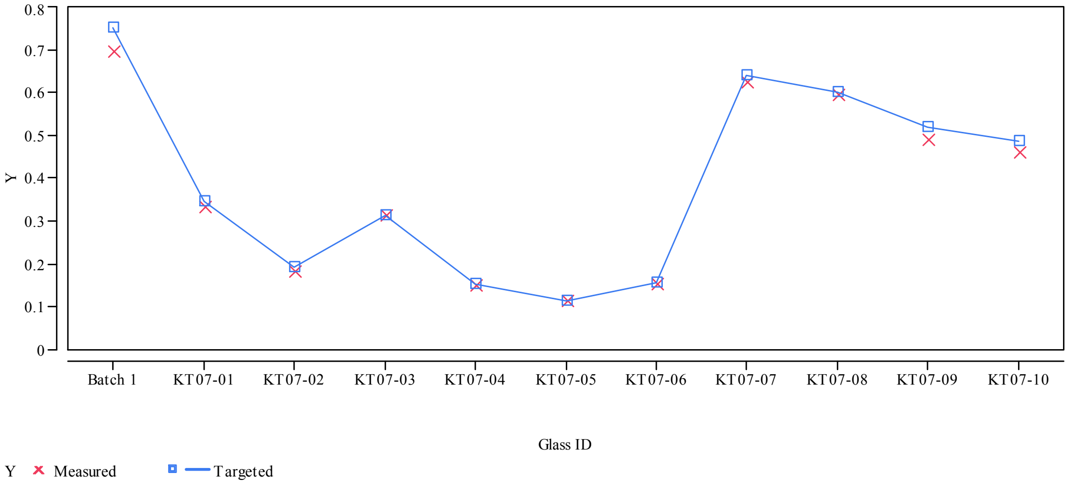
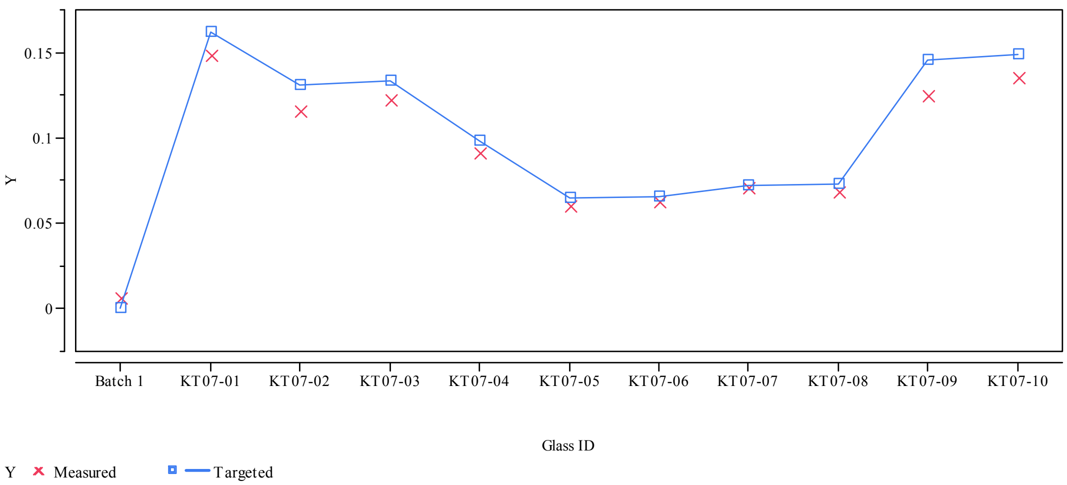


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=NiO (wt%)



Oxide=PbO (wt%)



Oxide=SiO2 (wt%)

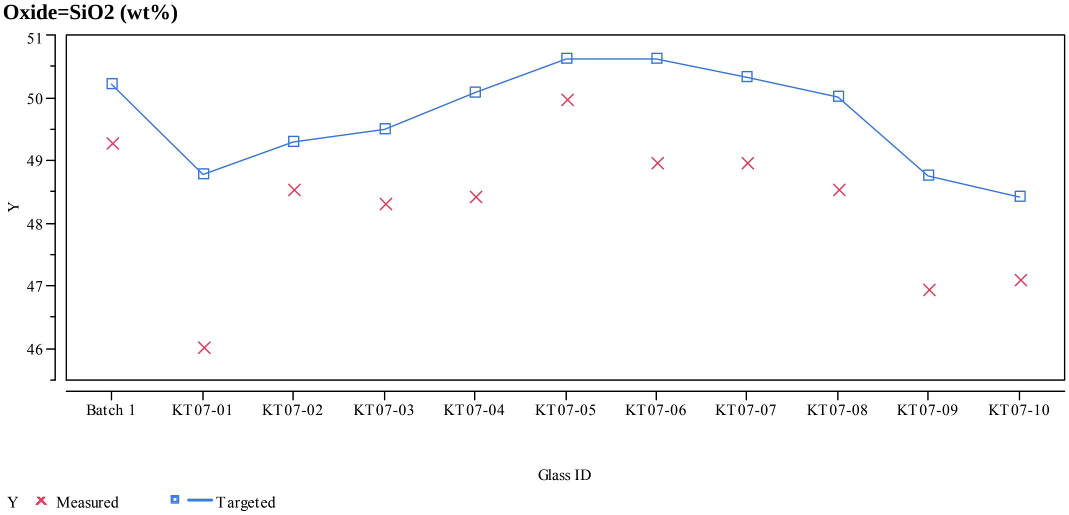
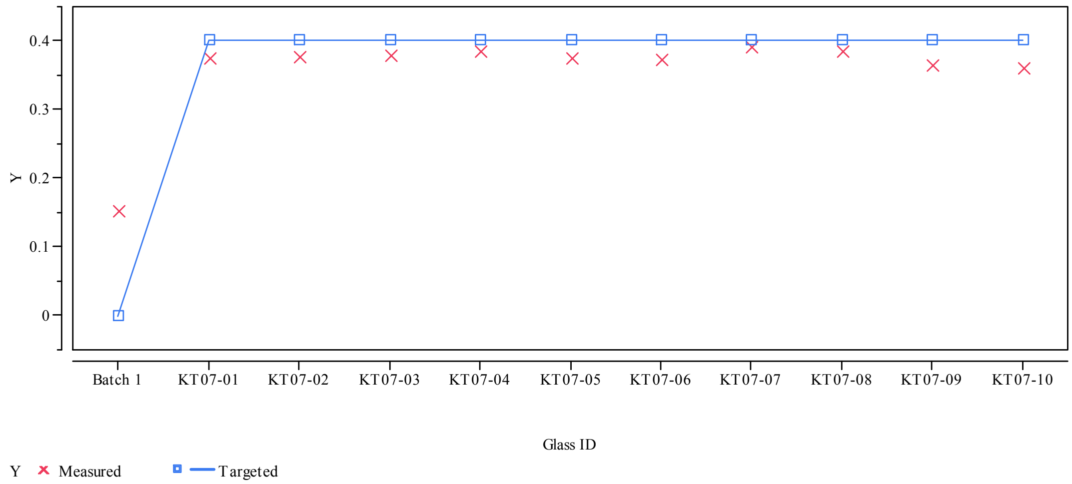
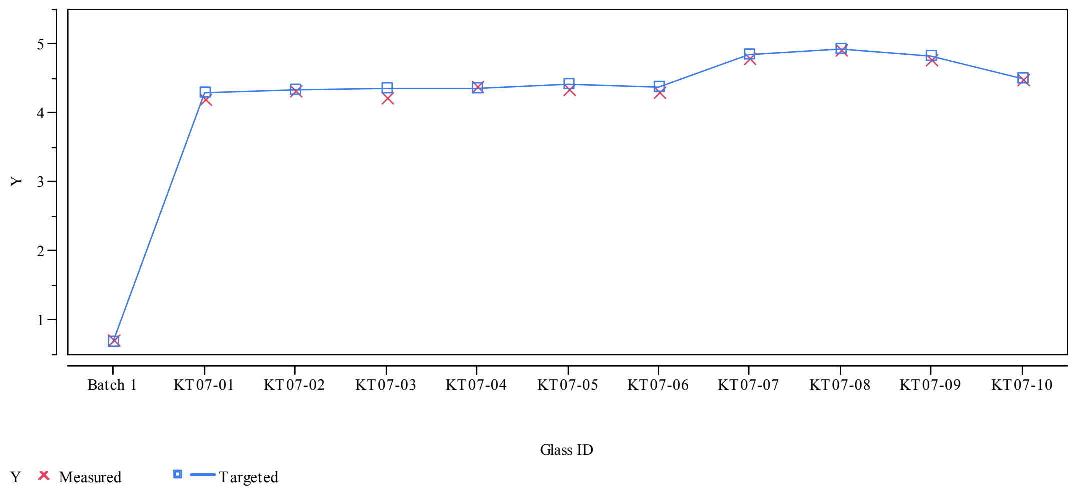


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=SO4 (wt%)



Oxide=TiO2 (wt%)



Oxide=ZnO (wt%)

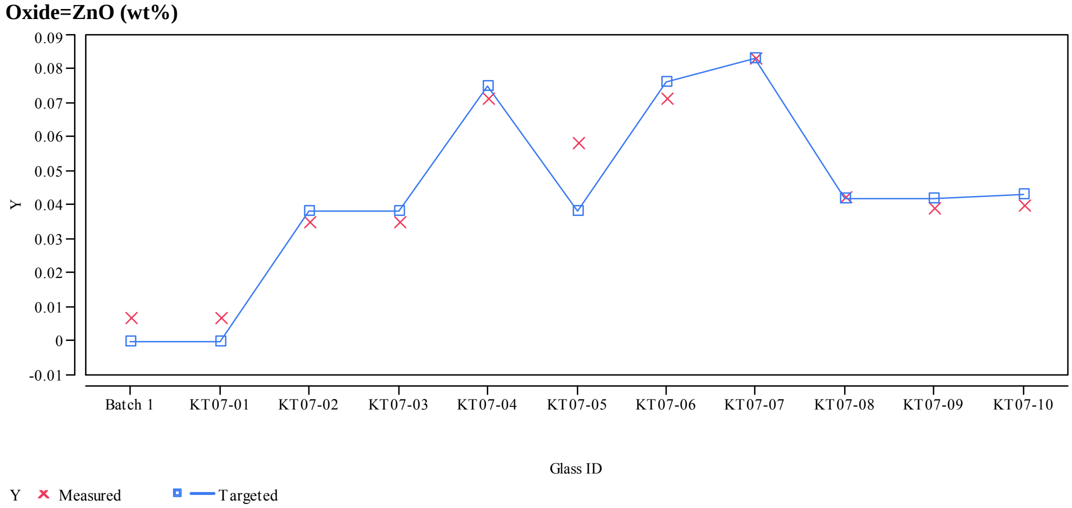
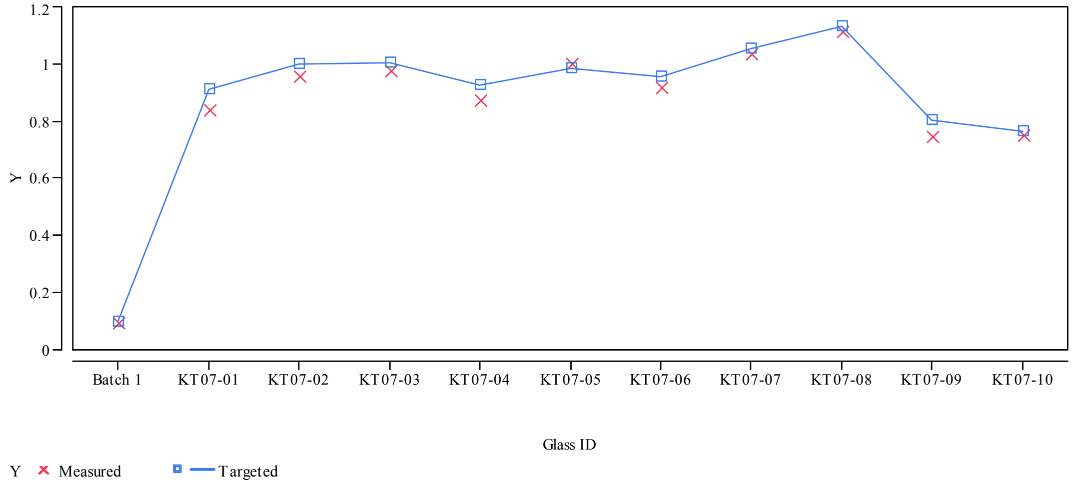
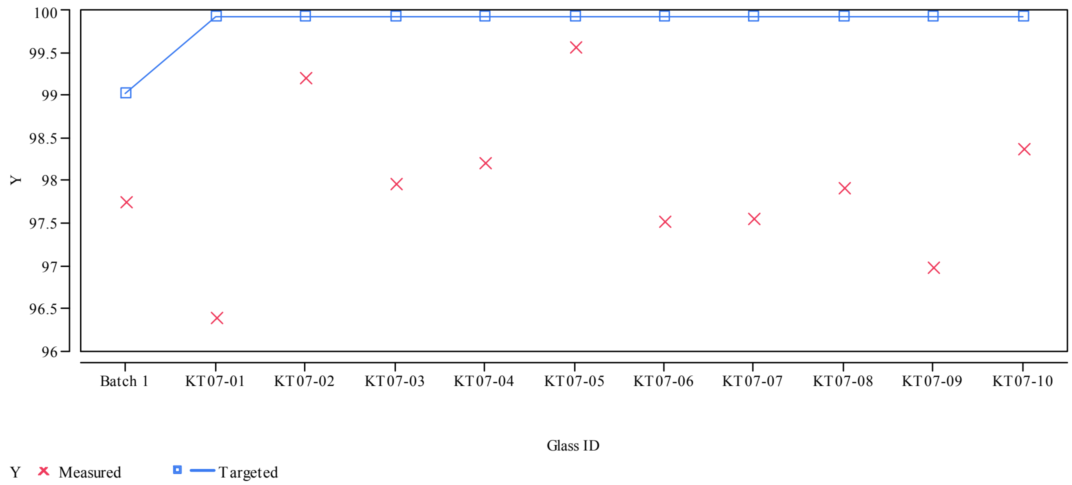


Exhibit A-4. Plots of Measured versus Targeted Concentrations by Glass ID by Oxide. (continued)

Oxide=ZrO2 (wt%)



Oxide= Sum of Oxides



Appendix B. Data Supporting the PCT Measurements of the KT07-Series Glasses

Table B-1. PCT Measurement Data for the KT07 Glasses from PSAL, As Received (ar) and Parts per Million (ppm).

Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
Soln Std	ref	1	1	std-11	21.6	10.2	83.1	49.9	21.60	10.20	83.10	49.90
KT07-01	quenched	1	2	h33	6.79	7.04	36.8	56.4	11.32	11.73	61.33	94.00
KT07-03	ccc	1	3	h10	7.35	7.25	44.1	60.2	12.25	12.08	73.50	100.34
KT07-05	ccc	1	4	h39	5.61	6.13	32.8	54.0	9.35	10.22	54.67	90.00
KT07-04	ccc	1	5	h06	6.75	6.90	38.2	58.8	11.25	11.50	63.67	98.00
KT07-03	quenched	1	6	h08	7.34	7.20	46.6	60.1	12.23	12.00	77.67	100.17
KT07-08	quenched	1	7	h16	6.99	6.94	55.1	65.5	11.65	11.57	91.84	109.17
KT07-09	ccc	1	8	h36	6.67	6.85	40.2	57.8	11.12	11.42	67.00	96.34
KT07-10	ccc	1	9	h02	7.23	7.54	40.3	62.1	12.05	12.57	67.17	103.50
EA	ref	1	10	h52	34.6	11.3	95.5	52.9	576.67	188.33	1591.67	881.67
KT07-06	ccc	1	11	h42	5.77	6.05	32.6	53.8	9.62	10.08	54.33	89.67
KT07-07	quenched	1	12	h49	6.53	6.63	45.4	61.9	10.88	11.05	75.67	103.17
KT07-04	quenched	1	13	h13	6.67	7.01	40.5	58.8	11.12	11.68	67.50	98.00
Soln Std	ref	1	14	std-12	21.2	10.5	85.5	50.7	21.20	10.50	85.50	50.70
KT07-09	quenched	1	15	h60	7.79	7.51	46.4	63.1	12.98	12.52	77.33	105.17
ARM-1	ref	1	16	h01	10.9	8.50	22.0	35.8	18.17	14.17	36.67	59.67
KT07-06	quenched	1	17	h57	6.12	7.11	39.3	57.0	10.20	11.85	65.50	95.00
KT07-02	quenched	1	18	h47	7.18	7.37	44.3	60.5	11.97	12.28	73.83	100.84
KT07-10	quenched	1	19	h14	7.29	7.62	42.4	61.4	12.15	12.70	70.67	102.34
KT07-07	ccc	1	20	h66	6.16	6.41	40.7	58.1	10.27	10.68	67.83	96.84
blank	ref	1	21	h31	0.554	<1.00	0.331	0.123	0.92	0.83	0.55	0.21
KT07-05	quenched	1	22	h62	5.72	6.49	36.2	56.7	9.53	10.82	60.33	94.50
KT07-08	ccc	1	23	h20	7.01	7.34	52.3	66.3	11.68	12.23	87.17	110.50
KT07-02	ccc	1	24	h28	6.96	7.08	40.5	57.0	11.60	11.80	67.50	95.00
KT07-01	ccc	1	25	h18	6.97	7.28	36.9	56.8	11.62	12.13	61.50	94.67
Soln Std	ref	1	26	std-13	21.0	10.6	86.7	51.2	21.00	10.60	86.70	51.20
Soln Std	ref	2	1	std-21	20.1	10.1	85.1	49.1	20.10	10.10	85.10	49.10
KT07-06	quenched	2	2	h03	5.07	5.90	33.2	51.7	8.45	9.83	55.33	86.17
KT07-06	ccc	2	3	h26	4.92	5.94	32.1	53.3	8.20	9.90	53.50	88.84
KT07-08	quenched	2	4	h43	6.44	6.98	56.9	64.9	10.73	11.63	94.84	108.17
KT07-02	quenched	2	5	h61	6.11	6.85	41.8	56.7	10.18	11.42	69.67	94.50
KT07-03	ccc	2	6	h68	6.50	7.00	43.1	58.1	10.83	11.67	71.83	96.84
KT07-01	ccc	2	7	h58	6.09	6.91	35.9	54.9	10.15	11.52	59.83	91.50
KT07-08	ccc	2	8	h41	6.16	6.90	50.2	63.0	10.27	11.50	83.67	105.00
KT07-04	quenched	2	9	h53	5.88	6.75	40.2	57.4	9.80	11.25	67.00	95.67
KT07-05	ccc	2	10	h23	4.85	6.02	33.0	53.1	8.08	10.03	55.00	88.50
KT07-05	quenched	2	11	h59	4.78	6.05	34.1	52.9	7.97	10.08	56.83	88.17
KT07-07	quenched	2	12	h30	5.65	6.48	44.6	60.1	9.42	10.80	74.33	100.17
KT07-01	quenched	2	13	h64	5.70	6.89	35.8	54.6	9.50	11.48	59.67	91.00
Soln Std	ref	2	14	std-22	19.6	10.1	84.6	49.3	19.60	10.10	84.60	49.30
KT07-04	ccc	2	15	h67	6.31	6.66	37.8	56.8	10.52	11.10	63.00	94.67
KT07-09	quenched	2	16	h17	6.72	7.22	45.9	60.9	11.20	12.03	76.50	101.50
KT07-10	quenched	2	17	h05	6.59	7.39	42.2	60.5	10.98	12.32	70.33	100.84
KT07-02	ccc	2	18	h54	6.00	6.61	38.7	54.1	10.00	11.02	64.50	90.17
EA	ref	2	19	h09	31.0	10.4	88.6	49.2	516.67	173.33	1476.67	820.00
KT07-09	ccc	2	20	h48	6.31	7.00	42.0	59.5	10.52	11.67	70.00	99.17
KT07-07	ccc	2	21	h44	5.33	6.11	39.4	55.8	8.88	10.18	65.67	93.00
ARM-1	ref	2	22	h22	9.88	8.22	21.5	35.1	16.47	13.70	35.83	58.50
KT07-10	ccc	2	23	h27	6.17	7.12	38.6	57.8	10.28	11.87	64.33	96.34
KT07-03	quenched	2	24	h34	6.49	7.13	46.8	59.8	10.82	11.88	78.00	99.67
Soln Std	ref	2	25	std-23	19.7	10.1	85.1	49.9	19.70	10.10	85.10	49.90
Soln Std	ref	3	1	std-31	20.7	9.9	83.1	48.9	20.70	9.90	83.10	48.90
KT07-01	quenched	3	2	h32	6.40	6.99	37.1	55.7	10.67	11.65	61.83	92.84
KT07-04	quenched	3	3	h29	6.25	6.94	41.0	60.0	10.42	11.57	68.33	100.00
KT07-09	quenched	3	4	h24	6.23	7.12	45.2	61.0	10.38	11.87	75.33	101.67
KT07-02	ccc	3	5	h15	6.20	7.00	41.0	57.0	10.33	11.67	68.33	95.00
KT07-02	quenched	3	6	h19	6.04	7.06	43.6	59.1	10.07	11.77	72.67	98.50
KT07-06	quenched	3	7	h63	4.45	5.96	34.0	53.8	7.42	9.93	56.67	89.67
KT07-01	ccc	3	8	h35	5.77	6.86	35.6	55.6	9.62	11.43	59.33	92.67

Table B-1. PCT Measurement Data for the KT07 Glasses from PSAL, As Received (ar) and Parts per Million (ppm). (continued)

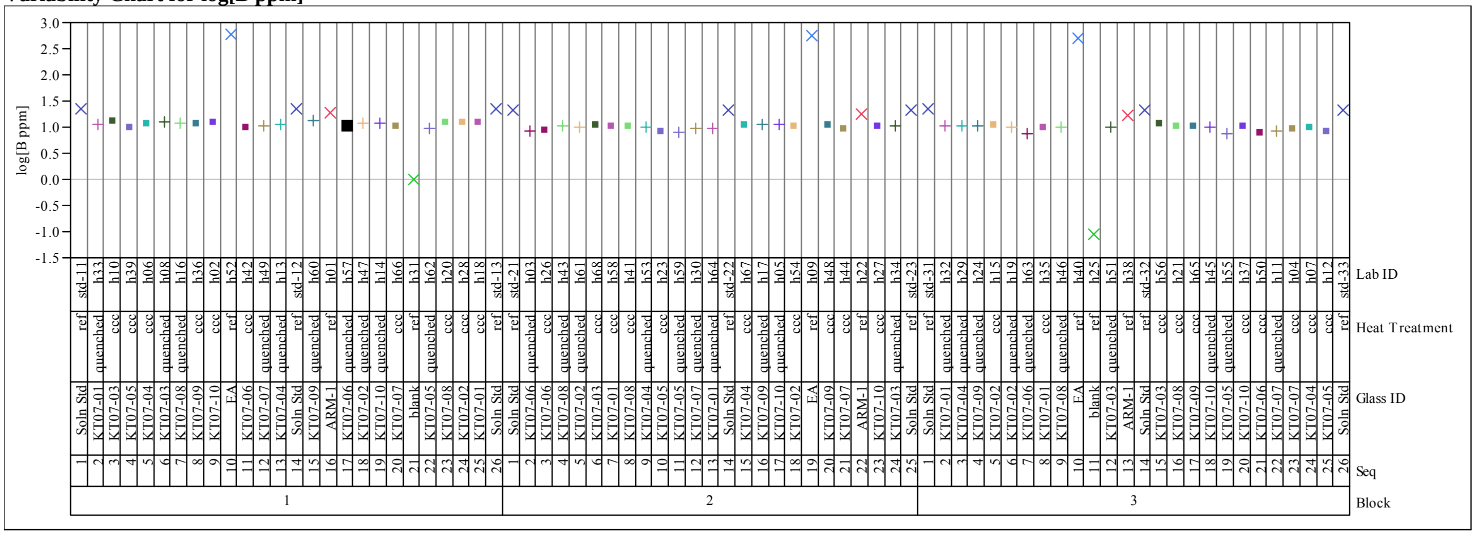
Glass ID	Heat Treatment	Block	Seq	Lab ID	B ar	Li ar	Na ar	Si ar	B (ppm)	Li (ppm)	Na (ppm)	Si (ppm)
KT07-08	quenched	3	9	h46	5.99	6.90	56.9	64.6	9.98	11.50	94.84	107.67
EA	ref	3	10	h40	28.8	9.80	82.4	46.8	480.00	163.33	1373.34	780.00
blank	ref	3	11	h25	<0.100	<1.00	<0.100	0.129	0.08	0.83	0.08	0.22
KT07-03	quenched	3	12	h51	6.17	6.89	45.5	58.1	10.28	11.48	75.83	96.84
ARM-1	ref	3	13	h38	9.55	8.05	20.7	34.4	15.92	13.42	34.50	57.33
Soln Std	ref	3	14	std-32	19.8	9.95	83.5	49.0	19.80	9.95	83.50	49.00
KT07-03	ccc	3	15	h56	6.76	7.19	44.2	60.7	11.27	11.98	73.67	101.17
KT07-08	ccc	3	16	h21	5.89	6.80	49.7	62.5	9.82	11.33	82.83	104.17
KT07-09	ccc	3	17	h65	5.94	6.96	41.9	59.1	9.90	11.60	69.83	98.50
KT07-10	quenched	3	18	h45	5.89	7.01	39.7	57.3	9.82	11.68	66.17	95.50
KT07-05	quenched	3	19	h55	4.60	6.16	35.1	54.9	7.67	10.27	58.50	91.50
KT07-10	ccc	3	20	h37	5.83	7.03	38.2	58.9	9.72	11.72	63.67	98.17
KT07-06	ccc	3	21	h50	4.53	6.00	33.0	54.3	7.55	10.00	55.00	90.50
KT07-07	quenched	3	22	h11	5.15	6.28	43.8	58.9	8.58	10.47	73.00	98.17
KT07-07	ccc	3	23	h04	5.24	6.43	41.9	58.7	8.73	10.72	69.83	97.84
KT07-04	ccc	3	24	h07	5.54	6.75	38.1	57.7	9.23	11.25	63.50	96.17
KT07-05	ccc	3	25	h12	4.71	6.27	34.6	56.5	7.85	10.45	57.67	94.17
Soln Std	ref	3	26	std-33	19.8	10.1	85.8	50.3	19.80	10.10	85.80	50.30

Table B-2. Normalized PCT Responses for the KT07-Series Glasses.

Glass ID	Heat Treatment	Comp View	log NL B (g/L)]	log NL [Li(g/L)]	log NL [Na (g/L)]	log NL [Si (g/L)]	NL B(g/L)	NL Li (g/L)	NL Na (g/L)	NL Si (g/L)
ARM	ref	reference	-0.3193	-0.2343	-0.3036	-0.5701	0.479	0.583	0.497	0.269
EA	ref	reference	1.1732	0.9459	1.0740	0.5595	14.901	8.829	11.858	3.627
KT07-01	ccc	targeted	-0.2520	-0.1553	-0.2079	-0.3897	0.560	0.699	0.620	0.408
KT07-02	ccc	targeted	-0.2440	-0.1629	-0.1904	-0.3923	0.570	0.687	0.645	0.405
KT07-03	ccc	targeted	-0.2120	-0.1473	-0.1602	-0.3668	0.614	0.712	0.691	0.430
KT07-04	ccc	targeted	-0.2574	-0.1708	-0.2041	-0.3860	0.553	0.675	0.625	0.411
KT07-05	ccc	targeted	-0.3458	-0.2132	-0.2585	-0.4157	0.451	0.612	0.551	0.384
KT07-06	ccc	targeted	-0.3453	-0.2234	-0.2707	-0.4214	0.452	0.598	0.536	0.379
KT07-07	ccc	targeted	-0.3032	-0.2009	-0.2010	-0.3899	0.498	0.630	0.630	0.407
KT07-08	ccc	targeted	-0.2466	-0.1556	-0.1311	-0.3413	0.567	0.699	0.739	0.456
KT07-09	ccc	targeted	-0.2491	-0.1602	-0.1787	-0.3666	0.564	0.692	0.663	0.430
KT07-10	ccc	targeted	-0.2434	-0.1424	-0.1876	-0.3579	0.571	0.721	0.649	0.439
KT07-01	quenched	targeted	-0.2504	-0.1579	-0.2027	-0.3913	0.562	0.695	0.627	0.406
KT07-02	quenched	targeted	-0.2406	-0.1507	-0.1573	-0.3716	0.575	0.707	0.696	0.425
KT07-03	quenched	targeted	-0.2256	-0.1518	-0.1361	-0.3692	0.595	0.705	0.731	0.427
KT07-04	quenched	targeted	-0.2519	-0.1625	-0.1761	-0.3788	0.560	0.688	0.667	0.418
KT07-05	quenched	targeted	-0.3485	-0.2068	-0.2374	-0.4134	0.448	0.621	0.579	0.386
KT07-06	quenched	targeted	-0.3717	-0.2283	-0.2571	-0.4300	0.425	0.591	0.553	0.372
KT07-07	quenched	targeted	-0.2888	-0.1910	-0.1608	-0.3695	0.514	0.644	0.691	0.427
KT07-08	quenched	targeted	-0.2381	-0.1600	-0.0858	-0.3340	0.578	0.692	0.821	0.463
KT07-09	quenched	targeted	-0.2106	-0.1391	-0.1341	-0.3460	0.616	0.726	0.734	0.451
KT07-10	quenched	targeted	-0.2311	-0.1359	-0.1618	-0.3569	0.587	0.731	0.689	0.440
KT07-01	ccc	measured	-0.2501	-0.1397	-0.2050	-0.3643	0.562	0.725	0.624	0.432
KT07-02	ccc	measured	-0.2531	-0.1465	-0.1966	-0.3854	0.558	0.714	0.636	0.412
KT07-03	ccc	measured	-0.2119	-0.1289	-0.1485	-0.3561	0.614	0.743	0.710	0.440
KT07-04	ccc	measured	-0.2561	-0.1578	-0.2078	-0.3711	0.554	0.695	0.620	0.426
KT07-05	ccc	measured	-0.3560	-0.1975	-0.2582	-0.4099	0.441	0.635	0.552	0.389
KT07-06	ccc	measured	-0.3261	-0.1849	-0.2655	-0.4067	0.472	0.653	0.543	0.392
KT07-07	ccc	measured	-0.2936	-0.1764	-0.1861	-0.3777	0.509	0.666	0.652	0.419
KT07-08	ccc	measured	-0.2517	-0.1359	-0.1173	-0.3281	0.560	0.731	0.763	0.470
KT07-09	ccc	measured	-0.2478	-0.1370	-0.1676	-0.3497	0.565	0.729	0.680	0.447
KT07-10	ccc	measured	-0.2519	-0.1281	-0.1883	-0.3455	0.560	0.745	0.648	0.451
KT07-01	quenched	measured	-0.2485	-0.1422	-0.1999	-0.3658	0.564	0.721	0.631	0.431
KT07-02	quenched	measured	-0.2497	-0.1343	-0.1635	-0.3647	0.563	0.734	0.686	0.432
KT07-03	quenched	measured	-0.2255	-0.1334	-0.1244	-0.3585	0.595	0.736	0.751	0.438
KT07-04	quenched	measured	-0.2506	-0.1495	-0.1798	-0.3639	0.562	0.709	0.661	0.433
KT07-05	quenched	measured	-0.3588	-0.1911	-0.2371	-0.4076	0.438	0.644	0.579	0.391
KT07-06	quenched	measured	-0.3525	-0.1898	-0.2519	-0.4154	0.444	0.646	0.560	0.384
KT07-07	quenched	measured	-0.2792	-0.1665	-0.1459	-0.3573	0.526	0.682	0.715	0.439
KT07-08	quenched	measured	-0.2432	-0.1402	-0.0720	-0.3208	0.571	0.724	0.847	0.478
KT07-09	quenched	measured	-0.2093	-0.1160	-0.1230	-0.3291	0.618	0.766	0.753	0.469
KT07-10	quenched	measured	-0.2397	-0.1216	-0.1625	-0.3445	0.576	0.756	0.688	0.452

Exhibit B-1. KT07 PCT Measurements (as Common Logarithms) in Analytical Sequence by Element.

Variability Chart for log[B ppm]



Variability Chart for log[Li ppm]

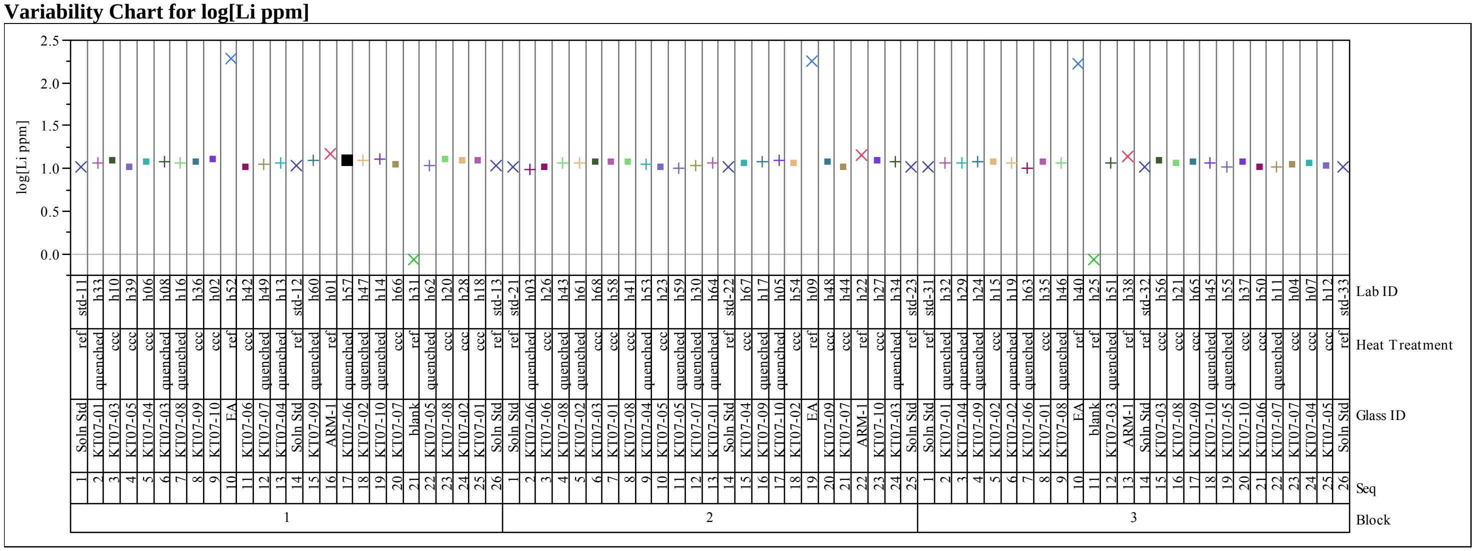
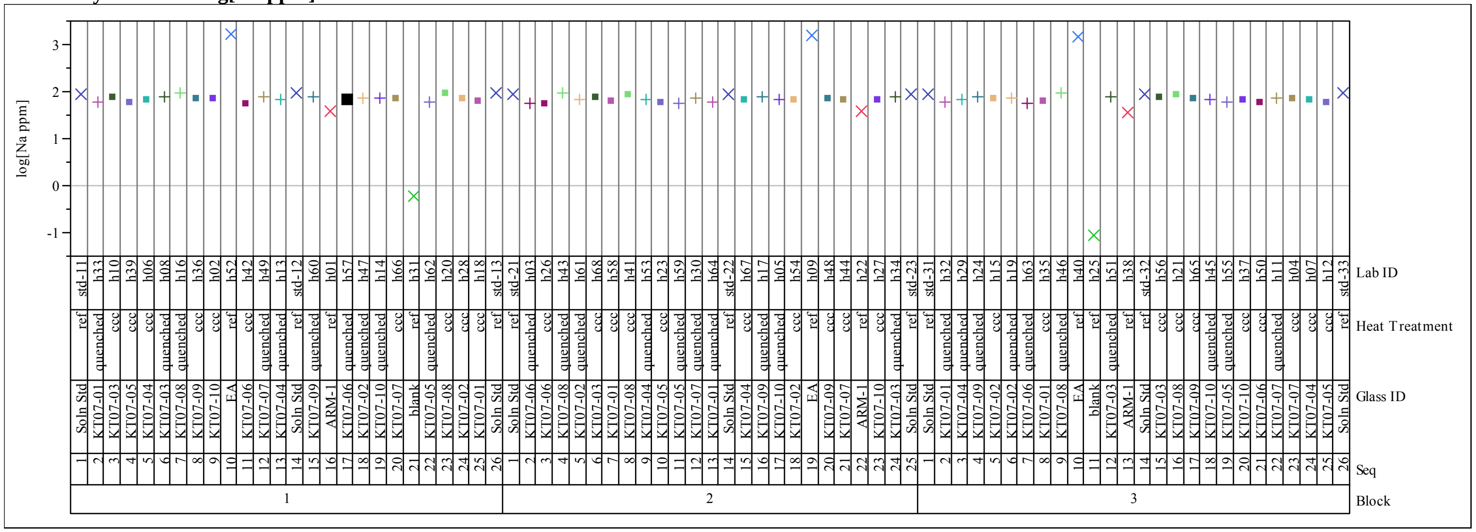


Exhibit B-1. KT07 PCT Measurements (as Common Logarithms) in Analytical Sequence by Element. (continued)

Variability Chart for log[Na ppm]



Variability Chart for log[Si ppm]

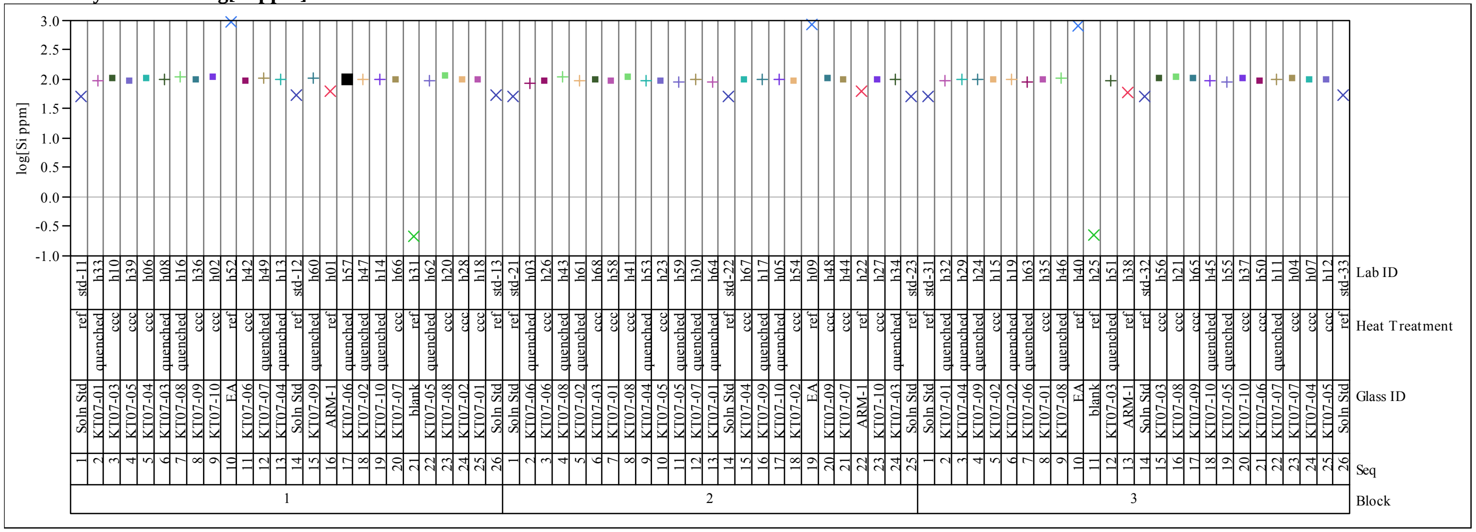
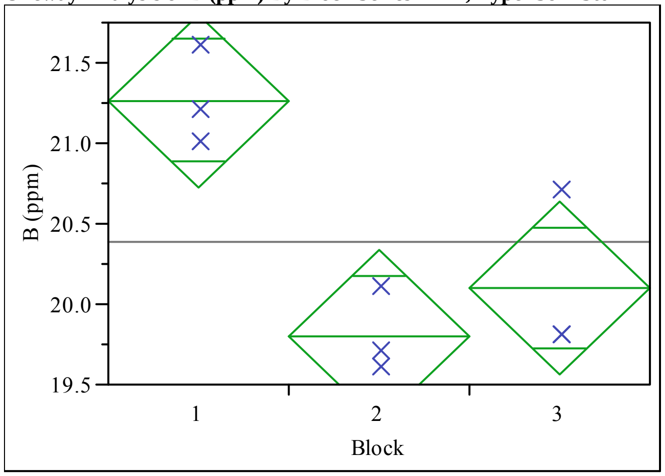


Exhibit B-2. Statistical Evaluation of the ICP-AES Calibration Effects from the Multi-Element Standard Solution Results by Oxide.

Oneway Analysis of B (ppm) By Block Series=KT7, Type=Soln Std



Summary of Fit

Rsquare	0.806067
Adj Rsquare	0.741422
Root Mean Square Error	0.380058
Mean of Response	20.38889
Observations (or Sum Wgts)	9

Analysis of Variance

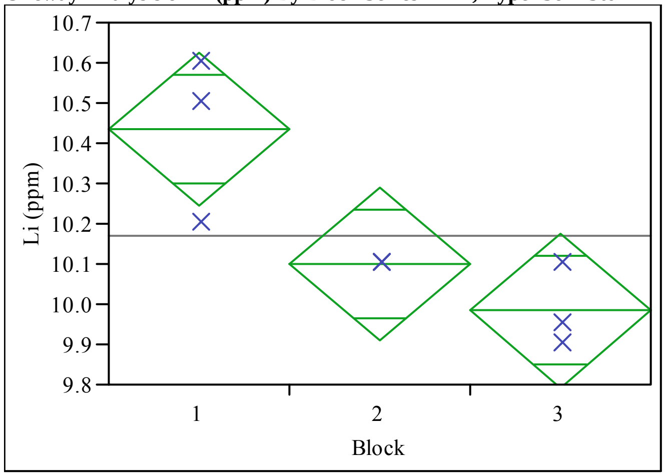
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	3.6022222	1.80111	12.4692	0.0073
Error	6	0.8666667	0.14444		
C. Total	8	4.4688889			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	21.2667	0.21943	20.730	21.804
2	3	19.8000	0.21943	19.263	20.337
3	3	20.1000	0.21943	19.563	20.637

Std Error uses a pooled estimate of error variance

Oneway Analysis of Li (ppm) By Block Series=KT7, Type=Soln Std



Summary of Fit

Rsquare	0.751276
Adj Rsquare	0.668367
Root Mean Square Error	0.134371
Mean of Response	10.17222
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	0.32722222	0.163611	9.0615	0.0154
Error	6	0.10833333	0.018056		
C. Total	8	0.43555556			

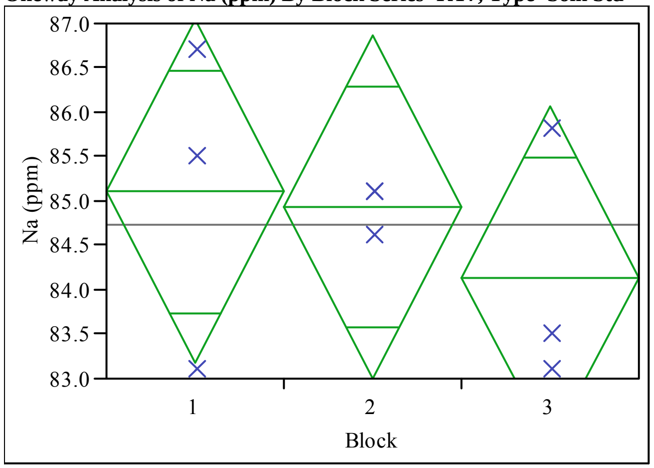
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	10.4333	0.07758	10.244	10.623
2	3	10.1000	0.07758	9.910	10.290
3	3	9.9833	0.07758	9.794	10.173

Std Error uses a pooled estimate of error variance

Exhibit B-2. Statistical Evaluation of the ICP-AES Calibration Effects from the Multi-Element Standard Solution Results by Oxide. (continued)

Oneway Analysis of Na (ppm) By Block Series=KT7, Type=Soln Std



Summary of Fit

Rsquare	0.125807
Adj Rsquare	-0.16559
Root Mean Square Error	1.362188
Mean of Response	84.72222
Observations (or Sum Wgts)	9

Analysis of Variance

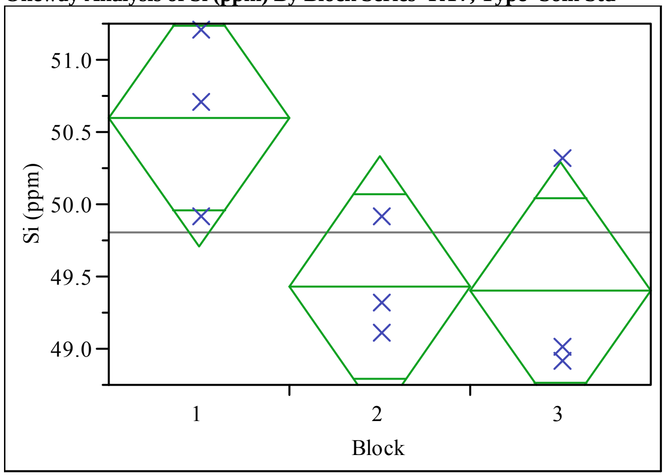
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	1.602222	0.80111	0.4317	0.6681
Error	6	11.133333	1.85556		
C. Total	8	12.735556			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	85.1000	0.78646	83.176	87.024
2	3	84.9333	0.78646	83.009	86.858
3	3	84.1333	0.78646	82.209	86.058

Std Error uses a pooled estimate of error variance

Oneway Analysis of Si (ppm) By Block Series=KT7, Type=Soln Std



Summary of Fit

Rsquare	0.535912
Adj Rsquare	0.381215
Root Mean Square Error	0.635959
Mean of Response	49.81111
Observations (or Sum Wgts)	9

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Block	2	2.8022222	1.40111	3.4643	0.1000
Error	6	2.4266667	0.40444		
C. Total	8	5.2288889			

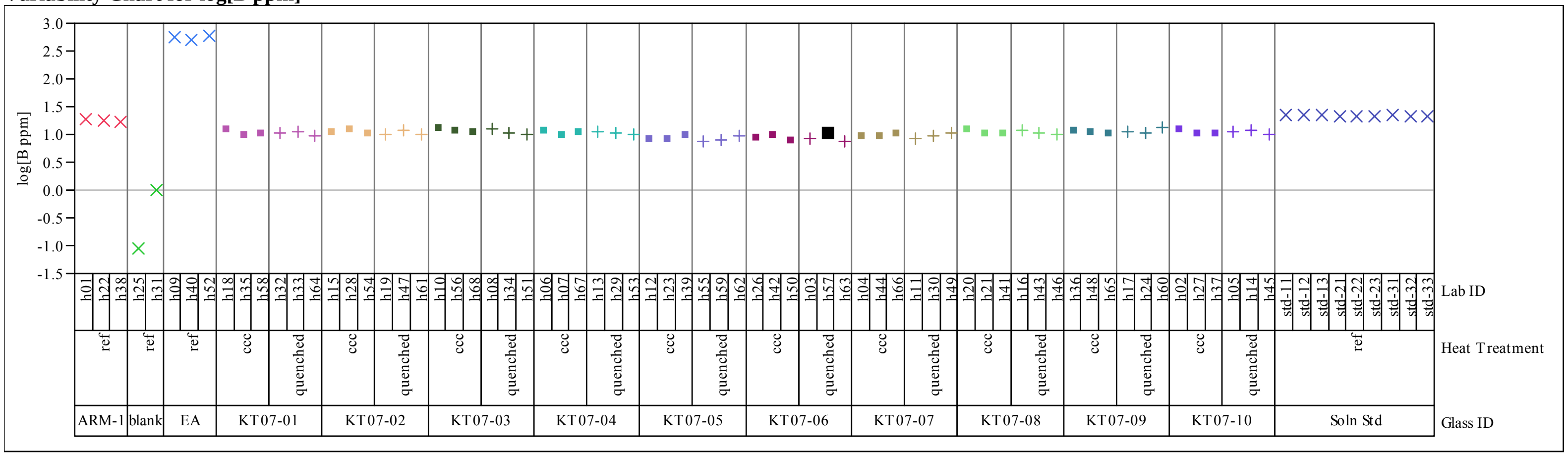
Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	3	50.6000	0.36717	49.702	51.498
2	3	49.4333	0.36717	48.535	50.332
3	3	49.4000	0.36717	48.502	50.298

Std Error uses a pooled estimate of error variance

Exhibit B-3. KT07 PCT Results (as Common Logarithms) Grouped by Glass ID and Heat Treatment.

Variability Chart for log[B ppm]



Variability Chart for log[Li ppm]

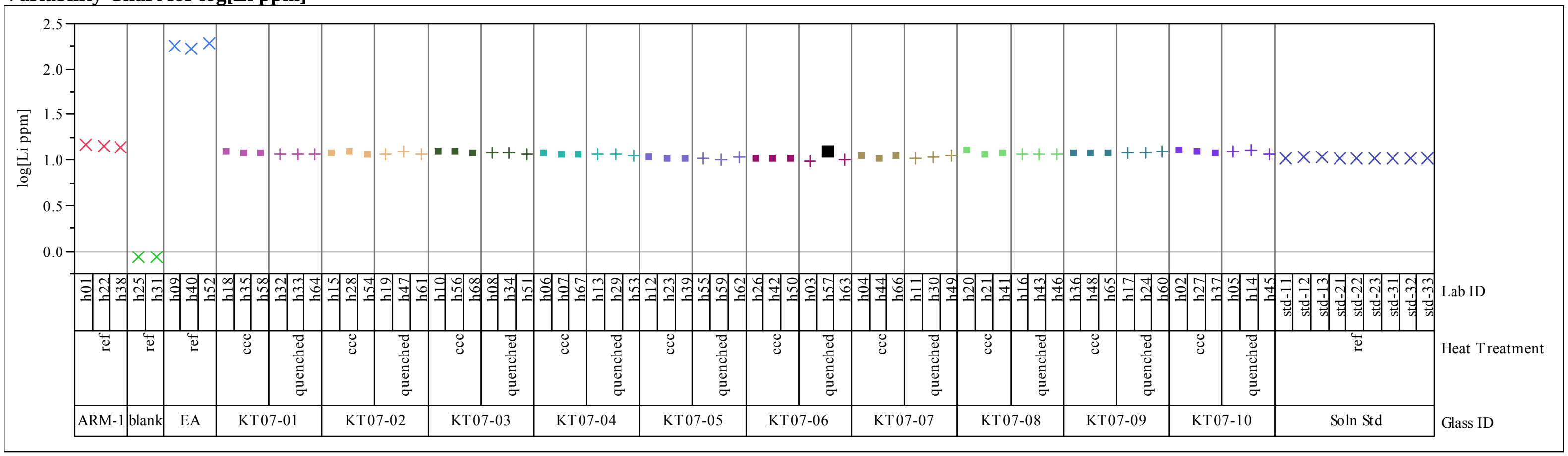
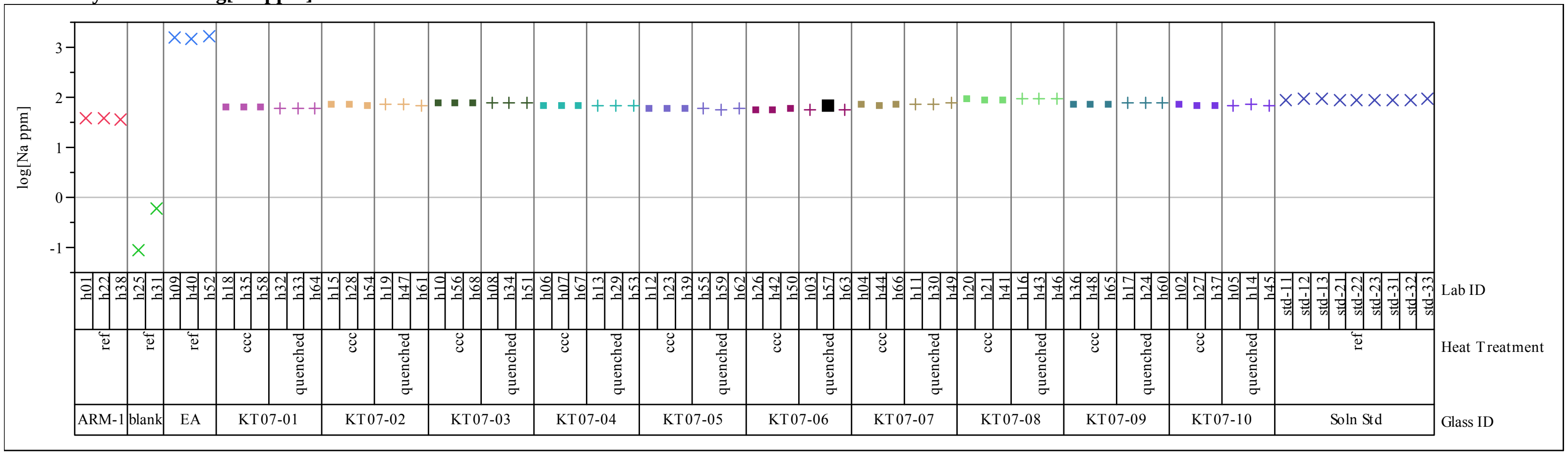


Exhibit B-3. KT07 PCT Results (as Common Logarithms) Grouped by Glass ID and Heat Treatment. (continued)

Variability Chart for log[Na ppm]



Variability Chart for log[Si ppm]

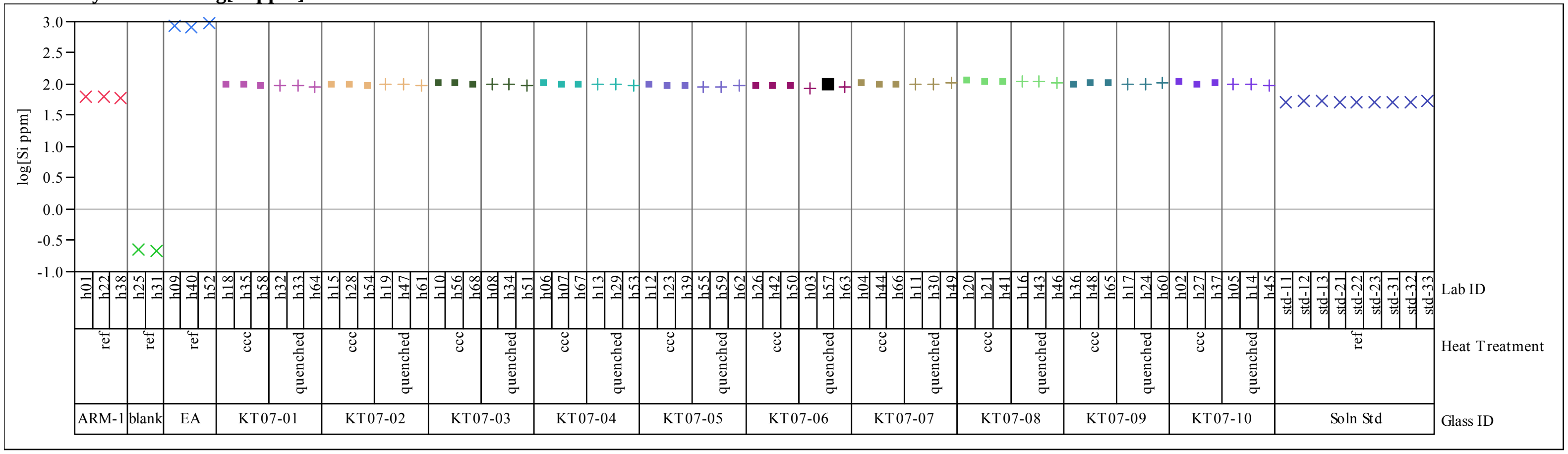


Exhibit B-4. Correlations among the Normalized PCT Results for the KT07-Series Glasses (as common logarithms).

(Over All Comp Views and Heat Treatments)

Multivariate Correlations:

	log NL[B (g/L)]	log NL[Li(g/L)]	log NL[Na (g/L)]	log NL[Si (g/L)]
log NL[B (g/L)]	1.0000	0.9954	0.9874	0.9787
log NL[Li(g/L)]	0.9954	1.0000	0.9855	0.9855
log NL[Na (g/L)]	0.9874	0.9855	1.0000	0.9885
log NL[Si (g/L)]	0.9787	0.9855	0.9885	1.0000

Scatterplot Matrix

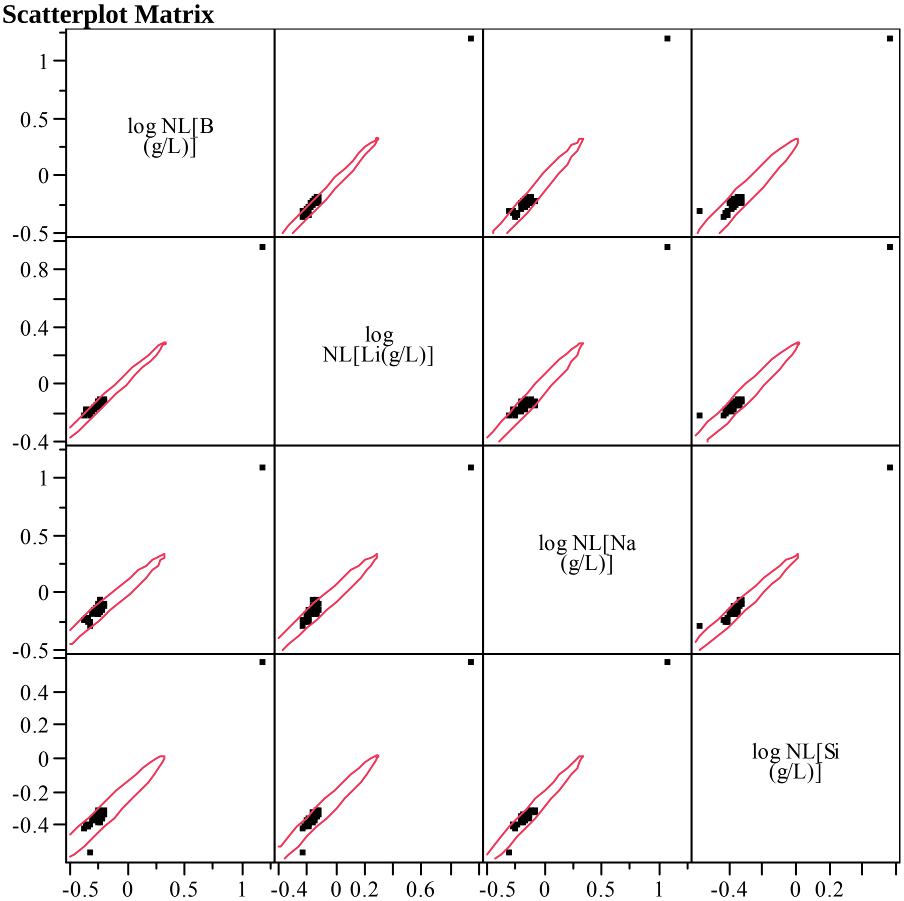
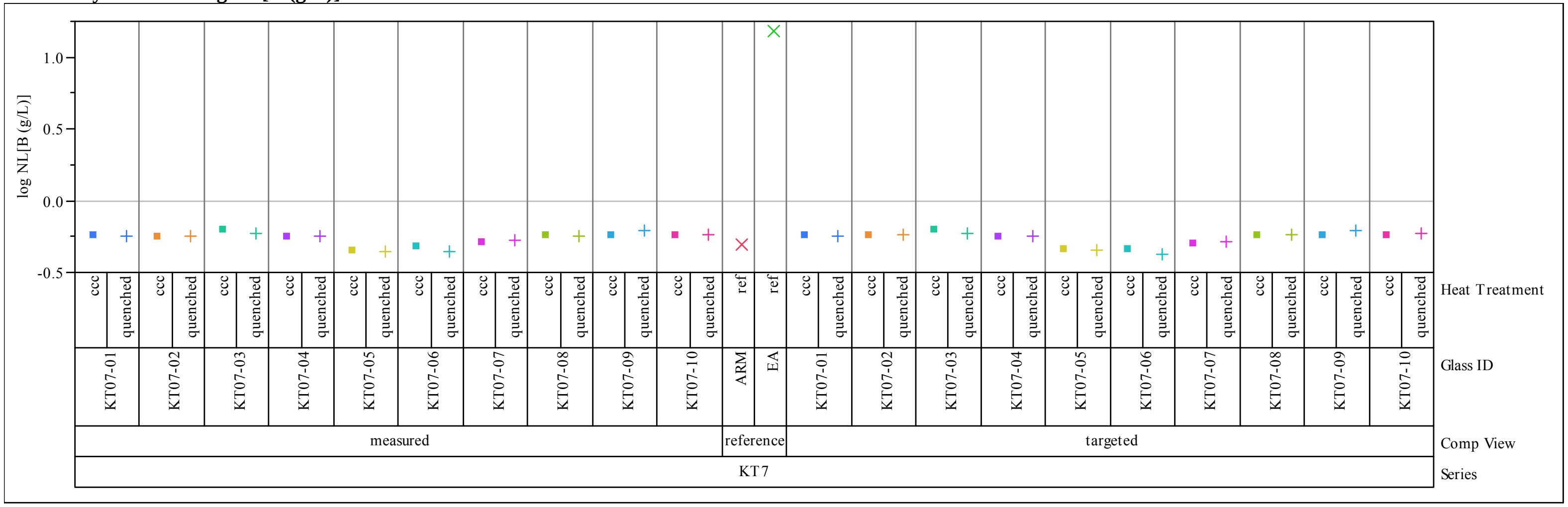


Exhibit B-5. Normalized PCT Response by Compositional View and Heat Treatment for the KT7-Series Glasses.

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



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

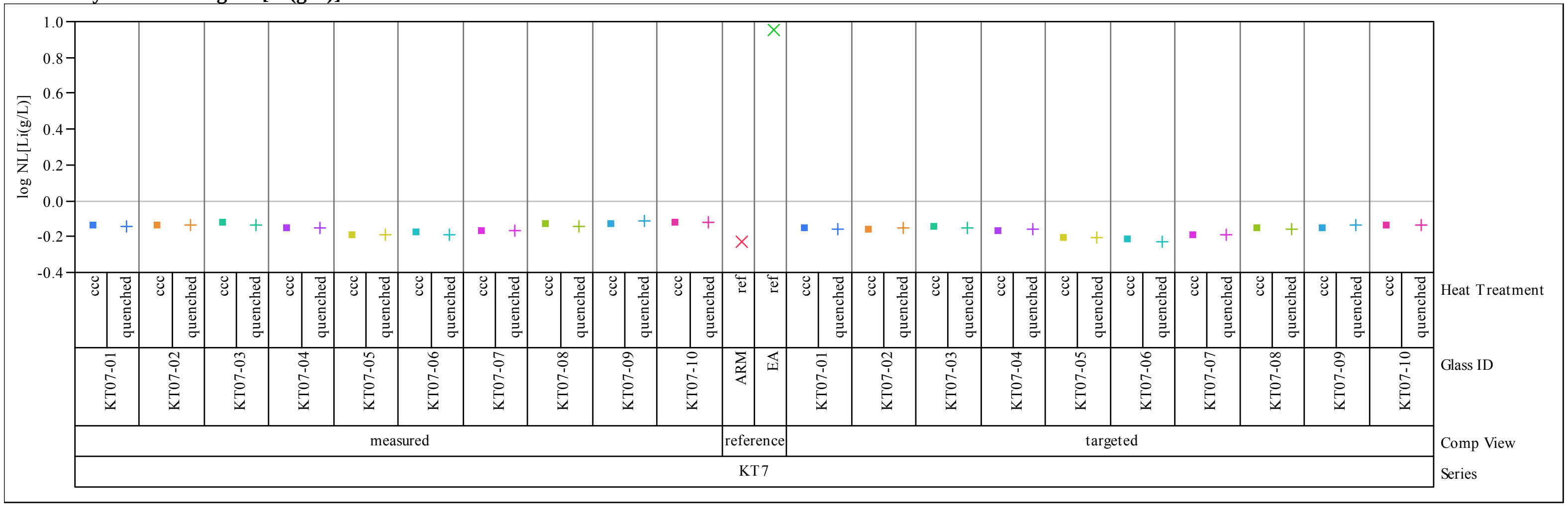
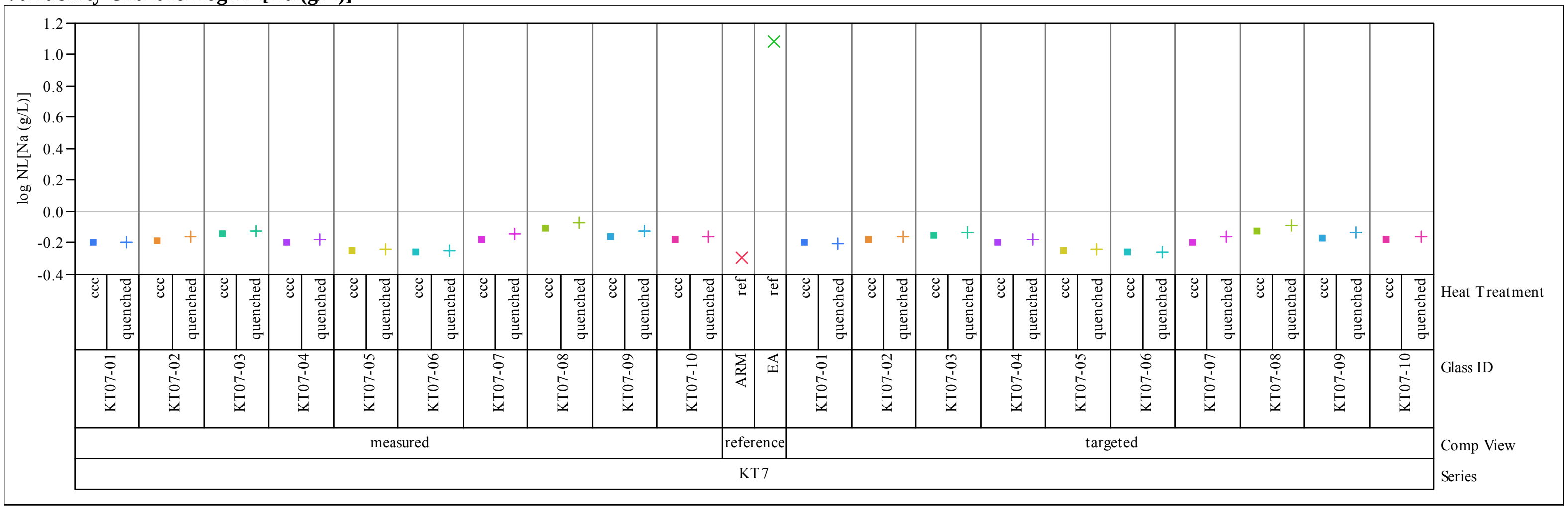


Exhibit B-5. Normalized PCT Response by Compositional View and Heat Treatment for the KT7-Series Glasses. (continued)

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



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

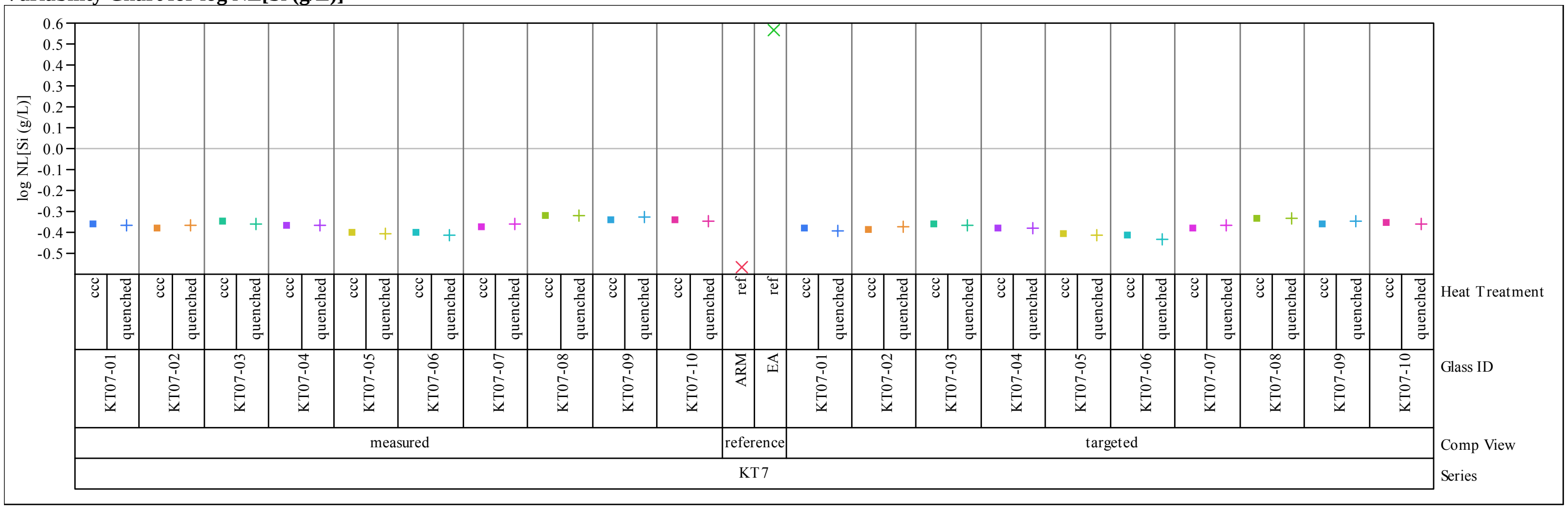
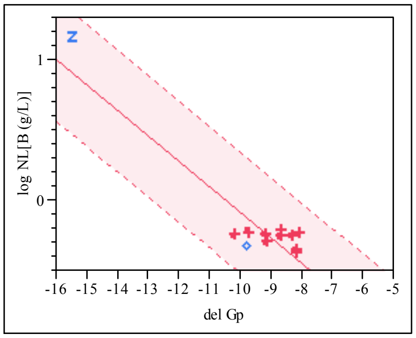


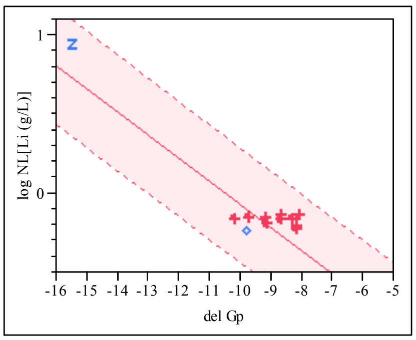
Exhibit B-6. PCT Measurements versus Durability Model Predictions for the KT07 Series Glasses.

Based Upon Targeted Compositions

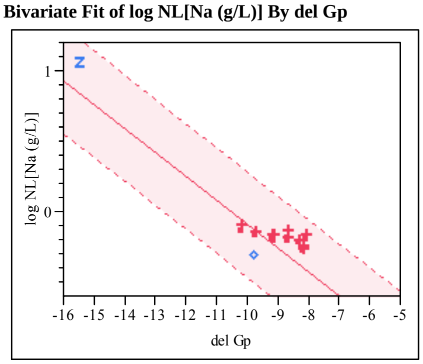
Bivariate Fit of log NL[B (g/L)] By del Gp



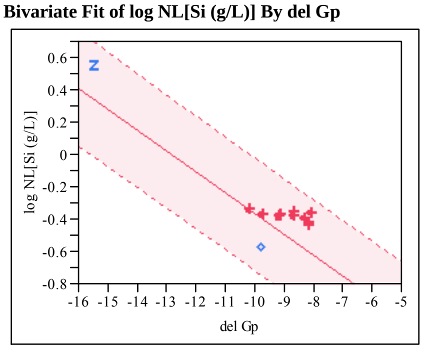
Bivariate Fit of log NL[Li (g/L)] By del Gp



Bivariate Fit of log NL[Na (g/L)] By del Gp

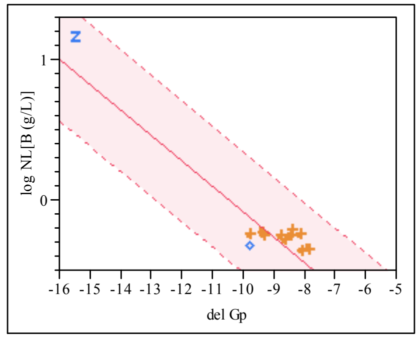


Bivariate Fit of log NL[Si (g/L)] By del Gp

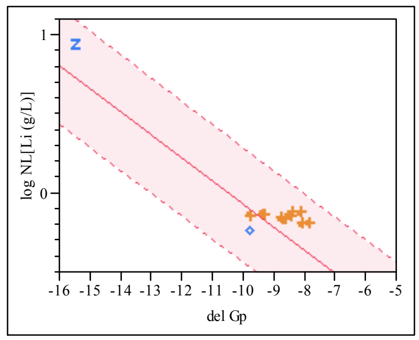


Based Upon Measured Compositions

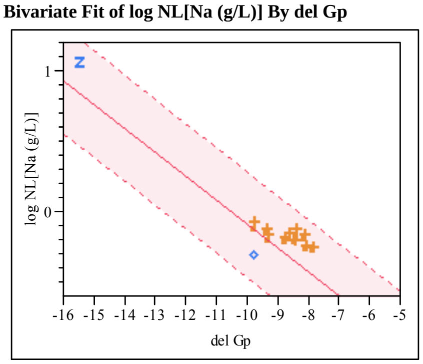
Bivariate Fit of log NL[B (g/L)] By del Gp



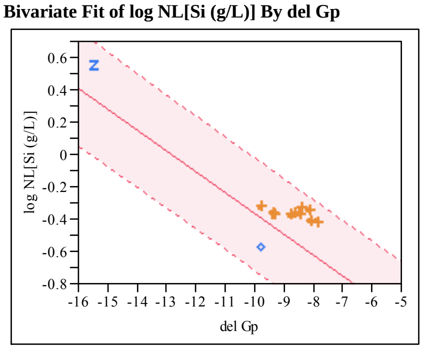
Bivariate Fit of log NL[Li (g/L)] By del Gp



Bivariate Fit of log NL[Na (g/L)] By del Gp



Bivariate Fit of log NL[Si (g/L)] By del Gp



Appendix C. Results from Fitting Fulcher Equations to the Viscosity Measurements for the KT07 Glasses

Exhibit C-1. Results of Fitting Fulcher Equations to the KT07-Series Viscosity Data.

Nonlinear Fit Glass ID=KT07-01

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

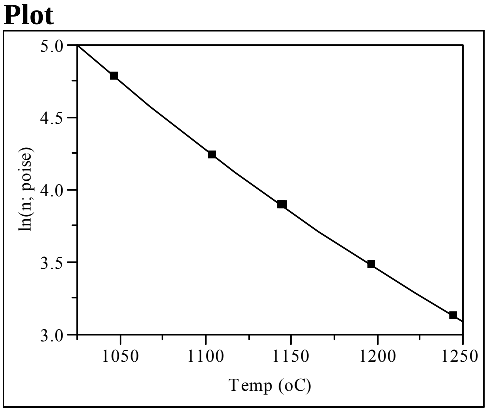
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	1.199189e-10	1e-15
Relative Gradient	3.6711775e-9	0.000001
Gradient	1.9492114e-9	0.000001

Parameter	Current Value
C	22.989680509
B	10461.315663
A	-5.442289307

SSE 0.0001100897
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	22.989680509	64.1049	192.315
B	10461.315663	3212.47	9637.41
A	-5.442289307	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0001100897	4	2.7522e-5	0.0052462

Parameter	Estimate	ApproxStdErr
C	22.989680509	71.7219884
B	10461.315663	1348.50448
A	-5.442289307	0.60484506

Solved By:
Analytic NR

Nonlinear Fit Glass ID=KT07-02

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

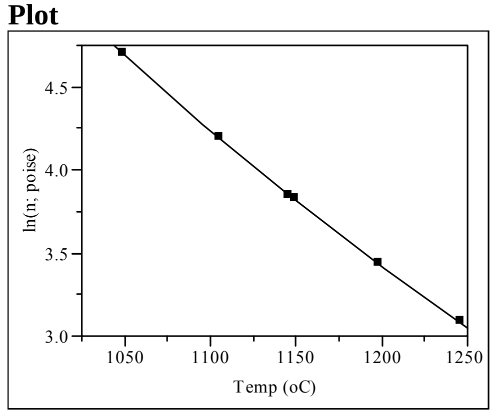
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	3.343225e-10	1e-15
Relative Gradient	5.5029582e-9	0.000001
Gradient	2.6085191e-9	0.000001

Parameter	Current Value
C	-229.179006
B	15457.226998
A	-7.396801818

SSE 0.0002054836
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	-229.179006	64.1049	192.315
B	15457.226998	3212.47	9637.41
A	-7.396801818	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0002054836	4	5.1371e-5	0.0071673

Parameter	Estimate	ApproxStdErr
C	-229.179006	151.430856
B	15457.226998	3421.88244
A	-7.396801818	1.24916718

Solved By:
Analytic NR

Exhibit C-1. Results of Fitting Fulcher Equations to the KT07-Series Viscosity Data. (continued)

Nonlinear Fit Glass ID=KT07-03

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

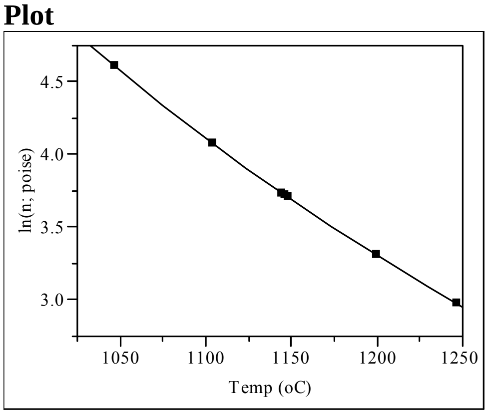
Criterion	Current	Stop Limit
Iteration	3	60
Obj Change	7.8337699e-7	1e-15
Relative Gradient	1.6341665e-7	0.000001
Gradient	1.425265e-7	0.000001

Parameter	Current Value
C	96.731193476
B	8944.4356246
A	-4.80757161

SSE 0.0000385246
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	96.731193476	64.1049	192.315
B	8944.4356246	3212.47	9637.41
A	-4.80757161	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0000385246	4	9.6312e-6	0.0031034

Parameter	Estimate	ApproxStdErr
C	96.731193476	37.2589966
B	8944.4356246	641.352714
A	-4.80757161	0.30792186

Solved By:
Analytic NR

Nonlinear Fit Glass ID=KT07-04

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

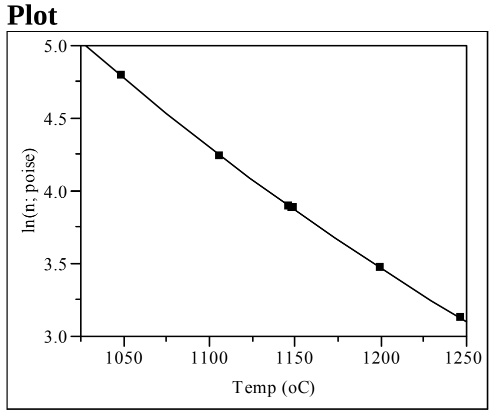
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	9.206737e-11	1e-15
Relative Gradient	1.1545811e-8	0.000001
Gradient	4.7559316e-9	0.000001

Parameter	Current Value
C	32.230800768
B	10364.980453
A	-5.413526705

SSE 0.0002496349
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	32.230800768	64.1049	192.315
B	10364.980453	3212.47	9637.41
A	-5.413526705	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0002496349	4	0.0000624	0.0078999

Parameter	Estimate	ApproxStdErr
C	32.230800768	106.922362
B	10364.980453	2004.77222
A	-5.413526705	0.90499194

Solved By:
Analytic NR

Exhibit C-1. Results of Fitting Fulcher Equations to the KT07-Series Viscosity Data. (continued)

Nonlinear Fit Glass ID=KT07-05
Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

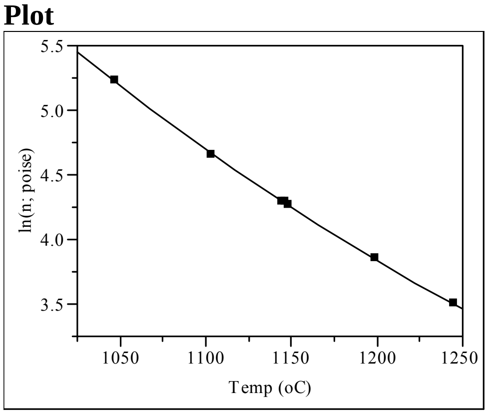
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	7.224503e-13	1e-15
Relative Gradient	4.5855139e-9	0.000001
Gradient	4.609586e-10	0.000001

Parameter	Current Value
C	87.885721819
B	9628.5255857
A	-4.823094076

SSE 0.0004258557
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	87.885721819	64.1049	192.315
B	9628.5255857	3212.47	9637.41
A	-4.823094076	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0004258557	4	0.0001065	0.0103181

Parameter	Estimate	ApproxStdErr
C	87.885721819	121.820911
B	9628.5255857	2239.5498
A	-4.823094076	1.06681483

Solved By:
Analytic NR

Nonlinear Fit Glass ID=KT07-06
Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

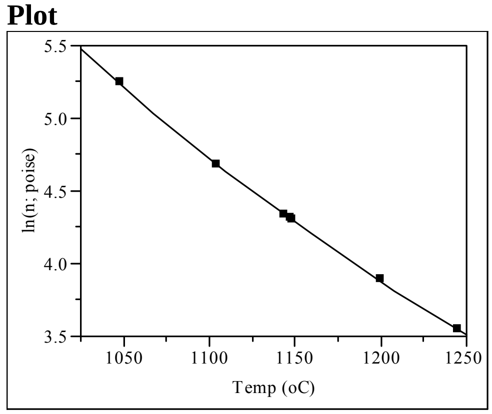
Criterion	Current	Stop Limit
Iteration	3	60
Obj Change	1.8627015e-6	1e-15
Relative Gradient	7.2077969e-7	0.000001
Gradient	6.7801548e-7	0.000001

Parameter	Current Value
C	95.986442999
B	9386.7617581
A	-4.626976313

SSE 0.000127233
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	95.986442999	64.1049	192.315
B	9386.7617581	3212.47	9637.41
A	-4.626976313	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.000127233	4	0.0000318	0.0056399

Parameter	Estimate	ApproxStdErr
C	95.986442999	66.2777451
B	9386.7617581	1196.97561
A	-4.626976313	0.57454696

Solved By:
Analytic NR

Exhibit C-1. Results of Fitting Fulcher Equations to the KT07-Series Viscosity Data. (continued)

Nonlinear Fit Glass ID=KT07-07

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

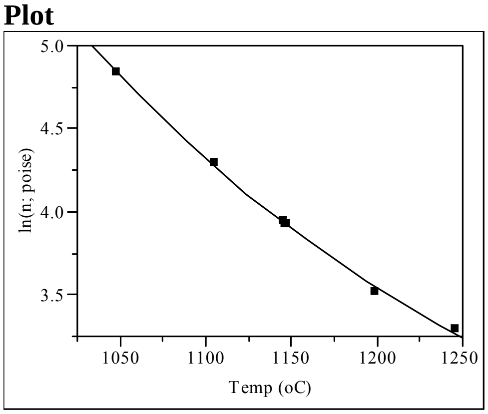
Criterion	Current	Stop Limit
Iteration	7	60
Obj Change	2.523508e-8	1e-15
Relative Gradient	5.9239464e-7	0.000001
Gradient	8.0318905e-8	0.000001

Parameter	Current Value
C	543.25252537
B	2828.8464675
A	-0.766864772

SSE 0.0024741221
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	543.25252537	64.1049	192.315
B	2828.8464675	3212.47	9637.41
A	-0.766864772	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0024741221	4	0.0006185	0.0248703

Parameter	Estimate	ApproxStdErr
C	543.25252537	101.698934
B	2828.8464675	984.168434
A	-0.766864772	0.83608447

Solved By:
Analytic NR

Nonlinear Fit Glass ID=KT07-08

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

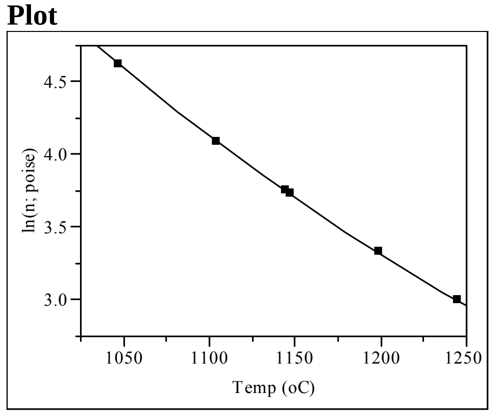
Criterion	Current	Stop Limit
Iteration	3	60
Obj Change	1.317744e-6	1e-15
Relative Gradient	4.3829036e-7	0.000001
Gradient	4.1031131e-7	0.000001

Parameter	Current Value
C	92.479254111
B	9041.1329061
A	-4.851777369

SSE 0.0000485002
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	92.479254111	64.1049	192.315
B	9041.1329061	3212.47	9637.41
A	-4.851777369	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0000485002	4	1.2125e-5	0.0034821

Parameter	Estimate	ApproxStdErr
C	92.479254111	42.8428428
B	9041.1329061	742.764436
A	-4.851777369	0.35534565

Solved By:
Analytic NR

Exhibit C-1. Results of Fitting Fulcher Equations to the KT07-Series Viscosity Data. (continued)

Nonlinear Fit Glass ID=KT07-09

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

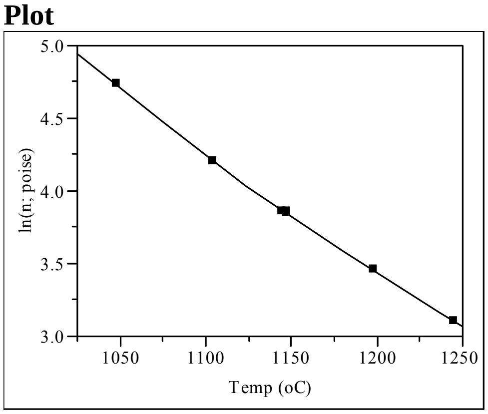
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	5.500331e-10	1e-15
Relative Gradient	1.664391e-8	0.000001
Gradient	8.6990446e-9	0.000001

Parameter	Current Value
C	-42.14374189
B	11519.043478
A	-5.844337455

SSE 0.0002787014
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	-42.14374189	64.1049	192.315
B	11519.043478	3212.47	9637.41
A	-5.844337455	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0002787014	4	6.9675e-5	0.0083472

Parameter	Estimate	ApproxStdErr
C	-42.14374189	130.866562
B	11519.043478	2557.25808
A	-5.844337455	1.08281789

Solved By:
Analytic NR

Nonlinear Fit Glass ID=KT07-10

Response: ln(n; poise), Predictor: ln(n; VTF)

Control Panel

Converged in Gradient

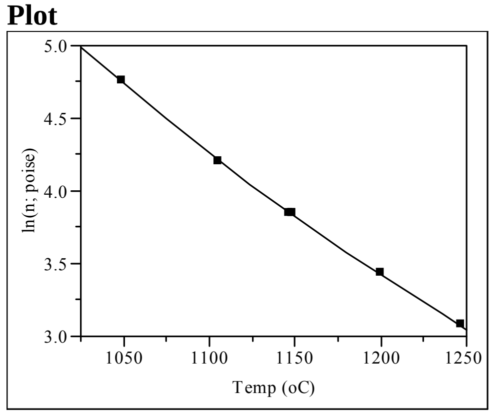
Criterion	Current	Stop Limit
Iteration	4	60
Obj Change	1.9957769e-9	1e-15
Relative Gradient	2.9278828e-8	0.000001
Gradient	2.0310013e-8	0.000001

Parameter	Current Value
C	-35.7936051
B	11735.6524
A	-6.077489781

SSE 0.0003736379
N 7

Edit Alpha 0.050
Convergence Criterion 0.00001
Goal SSE for CL
.

Plot



Parameter	Estimate	Low	High
C	-35.7936051	64.1049	192.315
B	11735.6524	3212.47	9637.41
A	-6.077489781	-5.8424	-1.9475

Solution

SSE	DFE	MSE	RMSE
0.0003736379	4	0.0000934	0.0096649

Parameter	Estimate	ApproxStdErr
C	-35.7936051	145.213064
B	11735.6524	2904.02826
A	-6.077489781	1.23516379

Solved By:
Analytic NR

Exhibit C-2. Plot of Predicted versus Measured Viscosity Values for the KT07-Series Glasses with 95% Confidence Intervals (CI).

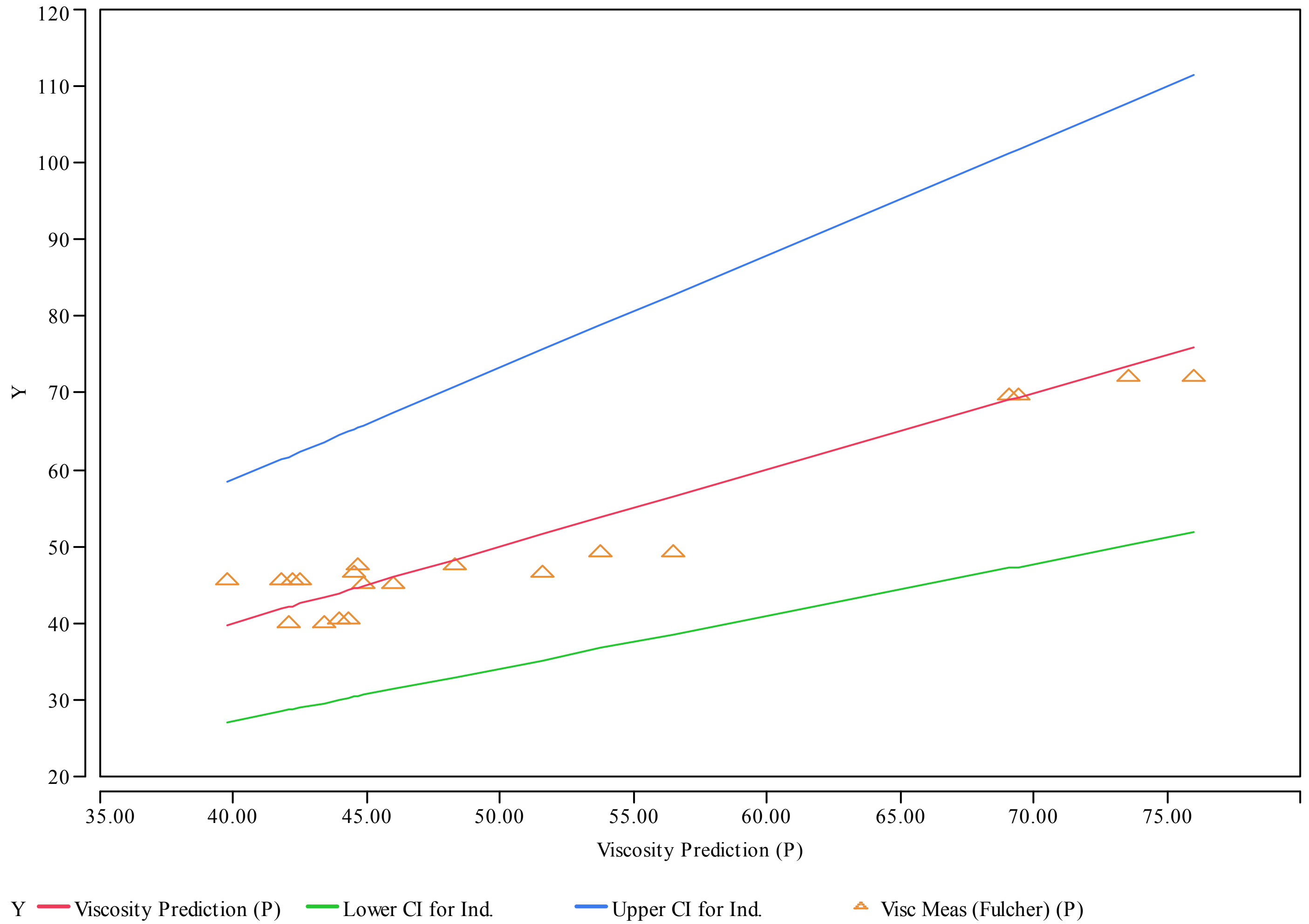


Table C-1. Predicted and Measured Viscosity Values for the KT07-Series Glasses with Confidence Intervals (CI).

Glass ID	Compositional View	Viscosity Model Prediction (P)	Lower CI for Precition (P).	Upper CI for Prediction (P)	Measured Viscosity (Fulcher) (P)	Predictable?
KT07-01	targeted	51.59	35.19	75.62	46.53	yes
KT07-02	targeted	45.99	31.37	67.43	45.18	yes
KT07-03	targeted	42.09	28.70	61.72	39.83	yes
KT07-04	targeted	48.32	32.96	70.83	47.44	yes
KT07-05	targeted	69.08	47.14	101.24	69.57	yes
KT07-06	targeted	73.57	50.20	107.82	72.15	yes
KT07-07	targeted	53.79	36.70	78.85	49.18	yes
KT07-08	targeted	43.94	29.97	64.44	40.35	yes
KT07-09	targeted	42.51	28.99	62.33	45.52	yes
KT07-10	targeted	42.24	28.81	61.95	45.58	yes
KT07-01	measured	44.54	30.38	65.30	46.53	yes
KT07-02	measured	44.87	30.60	65.79	45.18	yes
KT07-03	measured	43.37	29.58	63.59	39.83	yes
KT07-04	measured	44.68	30.47	65.51	47.44	yes
KT07-05	measured	69.41	47.36	101.72	69.57	yes
KT07-06	measured	76.00	51.86	111.38	72.15	yes
KT07-07	measured	56.51	38.55	82.82	49.18	yes
KT07-08	measured	44.34	30.24	65.02	40.35	yes
KT07-09	measured	41.80	28.50	61.30	45.52	yes
KT07-10	measured	39.79	27.13	58.36	45.58	yes

Distribution:

J. W. Amoroso, 999-W
C. J. Bannochie, 773-42A
A. B. Barnes, 999-W
A. L. Billings, 999-W
J. M. Bricker, 704-27S
M. A. Broome, 704-29S
C. L. Crawford, 773-42A
D. A. Crowley, 773-43A
R. E. Edwards, 766-H
T. B. Edwards, 999-W
T. L. Fellinger, 704-26S
S. D. Fink, 773-A
K. M. Fox, 999-W
B. J. Giddings, 786-5A
J. M. Gillam, 766-H
B. A. Hamm, 766-H
C. C. Herman, 999-W
D. T. Herman, 735-11A
R. N. Hinds, 704-S
E. W. Holtzscheiter, 704-15S
T. H. Huff, 766-H
J. F. Iaukea, 704-30S
P. R. Jackson, 703-46A
C. M. Jantzen, 773-A
F. C. Johnson, 999-W
D. C. Koopman, 999-W
D. D. Larsen, 766-H
P. L. Lee, 703-41A
S. L. Marra, 773-A
D. H. Miller, 999-W
J. E. Occhipinti, 704-S
D. K. Peeler, 999-W
F. M. Pennebaker, 773-42A
J. W. Ray, 704-S
M. A. Rios-Armstrong, 766-H
H. B. Shah, 766-H
D. C. Sherburne, 704-S
A. V. Staub, 704-27S
M. E. Stone, 999-W
J. P. Vaughan, 773-41A